

ESTIMATING ECONOMIC VALUES FOR A SUSTAINABLE ENERGY  
SUPPLY: A CASE STUDY IN NORTHERN CYPRUS

by

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## **Abstract**

Stated preference techniques are widely used to evaluate an individual's preferences in the context of environmental economics. The aim of this thesis is to explore the use of different stated preference methods to estimate willingness to pay (WTP) for micro-generation solar systems. The case study setting is North Cyprus. Households' preferences and choices for generating electricity on their premises were assessed using contingent valuation (CV) and choice experiments (CEs).

CV was employed to estimate individuals' WTP for micro-generation solar technology, and also willingness to accept (WTA) compensation for loss of amenity and feed-in tariff. The data comprised a survey of 369 individuals through the face-to-face interviews. The survey was split between two separate CV experiments, one using open-ended questions, and the other in the double-bounded format. A Becker-DeGroot-Marschak (BDM) incentive compatible experimental approach was adopted with a cheap-talk to reduce strategic behaviour and hypothetical biases.

Additionally, a CE survey of 205 respondents was carried out to evaluate the attributes that influence respondents' choices in the adoption of micro-generation solar panels. The attributes comprised a government subsidy, feed-in tariff, investment cost, energy savings, and the space required for installation. Respondents were asked to choose their most preferred alternative from two hypothetical scenarios of attributes and the status quo (do nothing).

One of the important findings of this thesis is the significance of the suggested experimental approach, which enabled the convergence of WTA/WTP values. The contribution of this thesis relies on the use of BDM with CV, as well as the CE, to value

preferences for micro-generation solar panel adoption. This is the first application of the BDM and CE methods to evaluate solar technology in Northern Cyprus.

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## **Acronym**

AIC      Akaike Information Criterion

ASC	Alternative Specific Constant
AR	Accept-Reject
BDM	Becker-DeGroot-Marschak
BIM	Building Information Modelling
BIPV	Building Integrated Photovoltaic
CBI	Component Based Integration
CBA	Cost-Benefit Analysis
CM	Choice Modelling
CE	Choice Experiment
CL	Conditional Logit
CV	Contingent Valuation
C	Compensation
CSSM	Crystalline Silicon Solar Modules
CBS	Crystal-Based Silicon
CDF	Cumulative Distribution Function
E	Equivalent
DF	Degrees of Freedom
DC	Discrete Choice
DB	Double-Bounded

EU	European Union
HEV	Heteroskedastic Extreme Value
H	Hour
IID	Independently Identically Distributed
IIA	Independence of Irrelevant Alternatives
KWH	Kilo Watt Hour
LCM	Latent Class Model
LL	Log-Likelihood
LBM	Lower Bound Mean
MLE	Maximum Likelihood Estimation
MSLE	Maximum Simulated Likelihood Estimator
MXL	Mixed Logit
MNL	Multinomial Logit
MWH	Mega Watt Hour
NOAA	National Oceanic and Atmospheric Administration
PV	Photovoltaic
Pr	Probability
RUM	Random Utility Maximisation
RPL	Random Parameter Logit

RP	Revealed Preference
RES	Renewable Energy Sources
RE	Renewable Energy
SP	Stated Preference
SAS	Statistical Analysis Software
SQ	Status Quo
SB	Single-Bounded
TEV	Total Economic Value
FIT	Feed-in Tariff
TL	Turkish Lira
UBM	Upper Bound Mean
Var	Variance
WTP	Willingness to Pay
WTA	Willingness to Accept

# Chapter 1. Introduction

## 1.1 Environmental economic valuation

An appraisal of the economic value of the environment has a subject of concern within the field of economics. Economists develop theories of human behaviour and examine the impact of individual's behaviour and decisions on demand and supply. The use values of resources in the market place can be inferred from observing individuals' revealed preferences. However, not all resources are in use or placed on the market, for instance there is no market for a clean and unpolluted environment.

To evaluate the non-market values, individuals' choice process and stated preferences can be assessed through hypothetical settings. Economic analysis explores how society's choices and preferences underlie utility maximisation and rationality. The standard economic theory suggests that individuals should respond to a survey in such a way as to maximise their expected welfare. The preference responses by a rational person to a hypothetical question can be influenced by strategic incentives and the mechanism's design.

Benefits and costs are the elements of determining preferences, such as an individual's willingness to obtain a benefit for a given price as opposed to when a person is willing to forego something in return for compensation. If money is used as a standard to measure welfare, the measure of benefit is willingness to pay (WTP) to secure that benefit, or willingness to accept (WTA) compensation to forego the same.

Consumer demand and producer supply can be traced to WTP and WTA for a good, and consumer surplus and producer surplus are the components of welfare measurement. This

can be fed into the cost-benefit analysis (CBA) to appraise the welfare economics for a particular plan.

In addition to analysing welfare from the perceptions of consumer and producer surplus, policy implication can be inferred. A multidimensional policy results in simultaneous transformation of environmental services. The aggregate policy is the summation of independent values, as each value independently has a single impact on multidimensional policy, thus any valuation of policy is unique.

## **1.2 Sustainable development**

Recently, there has been growing recognition across the world of the need to balance economic growth and environmental concern. Barbier et al. (1990) argued for an economic explanation of sustainability and suggested a modified structure of CBA by integrating the sustainability objective into the basic CBA. Consideration of future generations' benefits or compensations by the current generation was the initial departure point from the conventional CBA. This compensation was defined as the prevention of declining capital values for the next generation by the present generation.

This is mainly concerned with the issue of depletable externalities: the depletion of natural resources. However, some believe that the depletion of natural capital such as oil can be compensated by investment in other capital resources such as man-made equipments and skills. Overall, Munda (1997) identified that the main conflict between economic theory and the environment arises from the allocation of resources using efficiency criteria without adequate consideration of ethical and ecological issues.

## **1.3 Energy economics**

Energy economics refers to the supply of and demand for power in societies. Electricity generation and consumption can be considered one of the driving factors of both gross

domestic product (GDP) and welfare. The industrial revolution and urbanisation has led to technology development and standard of living improvements. This evolution has brought about hastened population growth across the world, and a consequent larger demand for energy has led to the acceleration of the exploitation of energy sources and ultimately the threat of the depletion of natural resources.

Over the years, increasing reliance on fossil fuels and oil has raised global concern to preserve energy or natural resources and this has in turn led to the consideration of lower carbon technology. The notion of sustainable development and maintaining environmental resources for future generations, in conjunction with the elimination of pollution and urban decay, has shed light on the exploitation of renewable energy sources (RES). Accordingly, environmental concern from a local or micro-policy perspective connects to macro-policy global agencies such as the World Bank and the United Nations. In the light of the abovementioned issues, Jamasb et al. (2008, p.4613) suggest that the essential aspect of technology research and development (R&D) is through a combination of “learning-by-research” and “learning-by doing processes”, with the use of policy to pursue a sustainable technology. Overall, if politically there is the will to implement a sustainable and effective technology policy, this will also help to achieve economic competitiveness.

To tackle barriers to the progress towards a sustainable technology, government intervention is essential to place incentives in terms of the rewards or penalties which will lead individuals toward making rational decisions and choices. Financial incentives have recently been the subject of debate amongst energy policy planners and economists. Supporters believe that national governments and international policy should organise a fair financing scheme to avoid the risks of existing energy policies and adjust to a sustainable path for prosperity and expansion. On the other hand, opponents argue that a

financing scheme prevents a welfare-optimal energy supply. Drechsler et al. (2012) showed that the presence of a feed-in tariff (FIT) accompanied by optimal welfare would be difficult to achieve in West Saxony, Germany. A lower set of FITs may not result in the expansion of energy production, whereas a higher set of FITs may decrease social welfare.

### **1.3.1 *Renewable energy***

Renewable energy sources (RES) refers to natural resources such as sun, rain, wind, waves, and tides, with the potential of exploitation for power generation. However, non-renewable energies (i.e. gas, fossil fuel and oil) have been the major sources of the trade market, and recently the notion of RES exploitation has spread across the globe relevant to the countries' climatic conditions and the natural resource potentials. Renewable energy (RE) can be an alternative source of power generation as it can positively impact the welfare of a society by supplementing the sources of power generation. The diversity of sources of energy supply expands the scope and choice of energy alternatives, shifting from unconditional demand to conditional demand. This multiplicity creates a distinction between end use (i.e. people desires for room temperature, light, and transportation) and energy demand (i.e. demand for heating, electricity, and fuel).

Lund (2009) defined RES as unlimited sources of energy supply in preference to nuclear and fossil fuels. Lund suggested that shifting from traditional non-renewable sources of energy to RES can be achieved through the alteration of demand for technologies in association with energy savings and conservation or storage technology. In addition, the transition from a traditional system involves efficiency improvements in electric devices in the supply system by promoting combined heat and power <sup>1</sup>(CHP) units.

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<sup>1</sup> So called cogeneration puts waste heat into use again so that it is not released into the environment, and generates electricity and convenient heat and cool air simultaneously from the combustion of a fuel or a solar heat collector.

The determination for new technology efficiency makes undertaking a CBA and cost-effectiveness test a necessity (Jaffe et al., 2005) to facilitate the evaluation of external costs and benefits in the contexts of RE technologies (Diakoulaki et al., 2001; Bergmann et al., 2006; Willis, 2010; Bergmann and Hanley, 2012; Banfi et al., 2008). Price instability and high cost could impact the time of starting an investment. On the other hand, the notion of opportunity cost reflects the substitution effect on measuring the economic benefit and cost of a new product. The close substitute affects the benefits to decline by adding one alternative to the energy generators. New demand technology permits an analysis of substitution relationships based on the concept of an intrinsic activity group (Lancaster, 1971). Thus, the RE generators may not consider the normal substitution effect, and instead only allow efficiency substitution amongst the activities within the intrinsic group in order to minimise the cost. The social benefits of R&D must outweigh the social costs in terms of carbon dioxide emissions or energy efficiency (Parry, 2011).

### **1.3.2 *Solar energy***

The generation of electrical power from a solar source of energy is acknowledged as a new technology because it has been introduced since 1950, following which this technology has gradually improved and the number of satisfied consumers has increased.

A study on solar power for the Mediterranean region was carried out by the German Aerospace Centre (2005). This study reported that solar irradiance in the regions of Southern Europe (Portugal, Spain, Italy, Greece, Cyprus, Malta), Western Asia (Turkey, Iran, Iraq, Jordan, Israel, Lebanon, Syria), the Arabian Peninsula (Saudi Arabia, Yemen, Oman, United Arab Emirates, Kuwait, Qatar, Bahrain), and North Africa (Morocco, Algeria, Tunisia, Libya, Egypt) has considerably the largest proportion of RES with the potential of providing more than the total world electricity demand. The export of

electricity power would be a valuable source of economic growth in the region but the exploitation requires European Union (EU) technological and financial aids.

Overall, solar energy can be captured through micro-generation systems (photovoltaic) as well as large solar thermal power stations.

### **1.3.3 *Micro-generation technology***

Domestic micro-generation systems are in the form of micro-wind turbines, solar arrays or photovoltaics (PV), solar heating water systems, which are micro-combined. The micro-generation can be mounted as stand-alone systems with storage or a grid connection. The installation of possible micro-generation systems might be national grid-tied, micro-grids, or off-grid, which requires energy storage. Households can generate heat and electricity power locally by means of the RES. Due to the closeness to the point of use of the micro-generation system, less energy is wasted in transmission. The innovation of micro-generation technology offers the advantages of generating electricity power and heat to the households. Various micro-generations could be defined as a decentralised distribution or supply of energy for low carbon buildings (Allen et al., 2008a).

Substantially, the promotion of micro-generations' technology underpin reducing green house gas emission, "alleviation of fuel poverty", developing a sustainable energy system to make the carbon reduction possible, ability to diminish reliance on fossil fuels, and increasing energy security. (Allen et al., 2008b, p. 538). The UK Department of Energy and Climate Change defined fuel poverty as when the ratio of fuel cost to income is greater than 10%. It can be implied that households in fuel poverty may not be able to invest in micro-generation systems for their homes.

Demand for new technology has expanded the choice and also explains variations between households' WTP. Generally, micro-generator devices are expensive to purchase or install, and the economies of scale are said to be an effective means of cost reduction. The significance of increasing the amount of production, technical developments, or the efficiency of manufacture and the operational process are crucial (Allen et al., 2008b). The transition from low volume to mass-production lines will cause reduction in labour intensity and plant utilisation, and thus in manufacturing costs. Technology cost reduction has always been a major concern in boosting production, and forty years after the initial appraisal of the economics of fuel cells, academics and government agencies are still dependent on general estimates of system costs (Staffell and Green, 2012).

The promotion of a new technology linked to environmental issues may be tackled by a thoughtful policy and incentives. The installation of a micro-generation system by households, industrial CHP, and decentralised renewable generation sources require new regulations which will provide the incentives for innovation and the adoption of new technologies in the set of connections and networks (Jamassb and Pollitt, 2007).

To encourage investment in RE, financial support is necessary. These incentives may perhaps be granted as an economic opportunity to investors, although for the lower income households or those in fuel poverty, these benefits would be unattainable. The benefit for people with lower income from RE can be met through a low interest finance mechanism and the installation of RE micro-generator devices through a third party and networking (Allen et al., 2008a). This networking will cause a reduction of the risk involved in the investment, where the local energy organisation shares information within the community.

Overall, the development of a new technology for environmental purposes will be followed by new policies and incentives that should be thoughtful from the economists'

viewpoint. Because from the economist's point of view, these RE supporting policies such as subsidies or tax incentives and grants, are viewed as a heavy cost on both the economy and tax payers.

### **Grid-connected domestic systems**

A grid connection relies on two way flow. A micro-generator in a home or business is connected to the electricity network and allows the excess power generated to feed into the electricity grid to be sold to the utility. On other hand, electricity can be imported to the house or business through the network when the micro-generator is working inefficiently.

The feed-in tariff is a scheme that compensates an electricity producer for exporting electricity into the grid. In addition, it provides a guaranteed price for a specific period (15-20 years) for renewable electricity fed into the national grid. Conversely, network connections make the purchase of renewable electricity from the national grid possible. The instrument of expansion of RE, such as the feed-in tariff, has been applied in Southern Cyprus in a similar way to Germany and Spain, as approved by the Kyoto Protocol on 16th July 1999. The export price for the generated electricity from PV up to 20KW capacity in the residential sector into the grid is approved to be 22.5 Euro cent per kWh (NREAP, 2013).

### **Grid-connected power plants**

These systems produce a large quantity of electricity from the sun, wind and other RE sources in a single point. The size of these plants could vary from hundreds of kilowatts to several megawatts. Thus, energy projects for renewable energy production are mainly sited in remote areas due to the availability of land, and this may increase the potential for growth in rural economies (Bergman, et al, 2008).

#### **1.4 EU action plan in Northern Cyprus**

Cyprus' sustainable development strategy seeks to support sustainable energy production and consumption. The aim is to develop the utilisation of indigenous RES to contribute to the national electricity supply security and the sustainable development of the economy and society. According to EU Commission directive 2009/28/EC, the adoption of a national action plan is obligatory for each member state. Cyprus' target for the share of energy from renewable sources in terms of total consumption of energy was 2.9% until 2005, but recently the EU proposed a binding target of RES for road and transport of 10% and 13% for total use of energy, with a 5% reduction of greenhouse gas emissions by 2020. The objective is to develop plans for implementing projects on RES technologies in the sectors of electricity, heating/cooling and transport. In addition, the model of national energy policy also relies on the social dimension of energy savings. The energy policy underpinning these issues is, firstly, the security of the supply of energy via diversification of energy sources, increasing the country's energy self-sufficiency, and the maximisation of the efficiency of RES utilisation as a substitute to the imported sources. Secondly, there is the competitiveness and adoption of investment in the energy sector to maximise the benefit from the exploitation of the resources. The third intention of the policy is environmental protection and the pursuit of sustainable development schemes. Sustainable development can be ensured through the rational and efficient use of energy. The promotion of RES schemes for electricity generation supports a reduction in pollutant emissions (NREAP, 2013).

Cyprus has no local hydrocarbon energy sources and is almost fully reliant on imported non-renewable energy sources, such as fossil fuels, so the alternative of the utilisation of RES would be an advantage. Cyprus' plans for the exploitation of renewable sources of energy have prioritised solar energy and wind power over biomass, ocean and hydro

forms. Solar energy has the highest exploitation potential compared with other sources of RE in Cyprus. Average daily solar radiation varies from 2.3 to 7.2 kWh per square metre during winter and summer (IRENA2013 Assembly). However, despite this the complete benefit of deployment has not been obtained, over the past forty years, solar irradiance has only been exploited for the production of hot water. Despite non-renewable energies such as gas, fossil fuel and oil being the major sources, North Cyprus is reliant on imported fuels and its natural source of energy has been underutilised. Accordingly, the application of solar panels for electricity generation in North Cyprus is low, although the potential of utilisation is high. The exploitation of solar energy can mitigate the country and society's reliance on imported energy as well maximising benefit for the society. The government expects a significant contribution from the micro-generation strategy to the supply of energy at the point of consumption. This requires a thoughtful policy to induce the adoption of a new technology in the context of power generation and transmission. Therefore, the environmental externalities in terms of benefit and cost need to be taken into account and assessed. In the case of grid connected micro-generation solar panels, energy savings and investment expenditure could be the indicators of the benefit and cost.

### **1.5 Overview of the case study: Northern Cyprus**

The two techniques of stated preference (SP), namely contingent valuation (CV) and choice experiments (CE), were employed to evaluate preferences and choices in the adoption of micro-generation solar technology. The design of the SP studies was implemented through the process of pre-test studies to avoid the cognitive limitations of stating a preference which required adequate time and deliberation. SP techniques underlying the random utility model enabled the hypothetical survey settings; however, our concern was to reduce the hypothetical effect of the SP settings. Thus, the elicitation surveys were designed in attempt to elicit truthful responses close to real values

compliant with incentive compatibility. Three case studies were carried out in Northern Cyprus.

1. A CV approach was used to estimate WTA for losing amenity and WTP for micro-generation solar panels in the case of installation of 1kWh (8m<sup>2</sup>) solar panels in the household's property.
2. The WTA compensation for feed-in tariffs (FIT) and WTP for the integration of 4kWh solar power equipment into the building at the construction stage were estimated, using CV technique.
3. A CE approach was used to evaluate the influence of the attributes of the government's subsidy, feed-in tariff, investment cost, energy savings, and the space required for installation of the individual's preferences.

The sample population was selected based on random sampling. The target population of the study was households in Northern Cyprus, with adults aged above 18, who were aware of the expenditure of the household (as head of the household). Face-to-face interviews were used across all the surveys throughout the study.

The survey evaluations were designed in accordance with the incentive compatible format, to clarify the maximum WTP and minimum WTA terminologies. A gap between WTA and WTP values is often observed in the studies of preference evaluation. This disparity has been explained through different reasons, for instance consumers may behave strategically and overestimate WTA to gain more compensation, or it may arise from the hypothetical nature of the SP questions. In an attempt to reduce these effects and biases, we designed an experimental mechanism to pursue incentive compatibility as it underpins the elicitation of truthful responses. A Becker-DeGroot-Marschak (BDM) incentive compatible strategy along with cheap-talk was adopted to elicit truthful responses. Accordingly, the two case studies of CV experiments were designed by

incorporation of the BDM with cheap-talk in an attempt to reduce the behavioural anomalies and hypothetical bias. Moreover, applying the practice prior to the evaluation of micro-generation solar power assists respondents' understanding of the consequences of over and under bidding, and facilitates learning about exchanges for a realistic price. Throughout the survey, respondents were supported with the memory jogger hand-out to practise the potential consequences of under and over estimating the values. In addition, to circumvent the hypothetical effects, the micro-generation solar system was introduced to respondents through visual aids and hints.

Firstly, 105 responses were elicited through open-ended CV questions, and the survey was split between conventional and suggested experimental mechanism. The elicitation was carried out from 55 households using the experimental approach and 50 respondents answered the conventional CV questions, and no further clarification was provided for them. Both groups' preferences were evaluated through the same questions and each individual was required to state their minimum WTA compensation for losing amenity, and maximum WTP for installing 1kWh solar panel on their premises. The results of the experimental approach were compared with conventional CV, and the average WTA value was significantly influenced by the incentivised setting as its value sharply decreased to converge. Truthful responses and rational behaviour were brought to light using the experimental mechanism. Overall, the experimental approach enabled the convergence of WTA/WTP values; this convergence explicitly illustrates the impact of the suggested experimental mechanism.

Due to the significant results obtained from the experimental approach, the second study was also carried out using the same mechanism but this time the elicitation format was double-bounded CV. In this scenario, 264 individuals were asked to state their maximum WTP and minimum WTA compensation for a 4kwh solar power integrated into their

building at the stage of house construction. The responses to the WTA question were used for the estimation of the feed-in tariff. The expected maximum WTP, consumer surplus mean, was calculated and compared with the estimated cost for 4kWh integration of solar technology to the building during the construction. The results highlight the effect of the incentive compatible suggested experimental survey design.

The third case study was carried out using a CE survey of 205 respondents to evaluate the attributes that influence respondents' choice of micro-generation solar power. Respondents were asked to choose between two scenarios that were described by the attributes of government subsidy, feed-in tariff, investment cost, energy savings, space required and the status quo.

Discrete choice (DC) models were employed to estimate the choice probabilities between the discrete alternatives. The three models of conditional logit (CL), mixed logit (MXL) or random parameter logit (RPL), and latent class (LC) were used to estimate the significance of the factors on households' decisions and choices as well as WTP. The estimation of interaction terms was used to account for heterogeneity in preferences. Approximately 30% of the respondents revealed a weak tendency for the utilisation of this system while 69% of the sampled population of Turkish Cypriots expected to increase their utility.

Overall, involvement in new activities in our case is the adoption of a micro-generation solar system, which was more attractive to those with well-developed technologies characteristics or a higher level of education.

In particular, this thesis is innovative and makes an original contribution to knowledge by being the first to adopt a BDM and cheap-talk with a CV technique and a CE study to value choices for micro-generation solar power in Northern Cyprus.

## 1.6 Thesis outline

The chapters of this thesis are outlined as follows:

Chapter 2 considers the conceptual background relevant to non-market values and the valuation of the environmental goods and policy. This chapter outlines the theoretical framework for benefit and cost assessment through the identification of utility, random utility theory, and stated preference techniques (SP). The two approaches of SP are considered, namely, contingent valuation (CV) and choice experiments (CEs).

Chapter 3 presents the contingent valuation approach meant for the evaluation of preferences through different modes of elicitation. It provides an overview of types of validity tests. The two approaches of parametric and non-parametric for analysing the data are presented. To tackle hypothetical and strategic behaviour biases, various recommended mechanisms in the literature are considered.

Chapter 4 considers the conceptual and theoretical framework relevant to choice modelling and analysis. Different forms of discrete choice models designed to analyse an individual's choice are presented in this chapter.

Chapter 5 provides an overview of the development process behind the main surveys and essential experimental instruments that are employed prior to the main survey for the sake of clarity. This chapter presents the experiences and insights which were gained through different instruments, such as focus group studies, interviews and debriefing, and pilot surveys, to pace the stages and procedures for the implementation of the main survey. In addition, different links between policy and economic behaviour were perceived, leading towards policy analysis and implications. The trend of the study was to underpin individuals' intuitive understanding of the terminologies and attributes in both contingent valuation (CV) and choice experiment (CE) studies of stated preferences.

Chapter 6 examines households' WTA and WTP for solar technology equipment on their premises through both a novel experimental and conventional CV approach. This chapter compares the WTA/WTP ratio through the experimental and conventional settings. To design the experimental approach, a Becker-DeGroot-Marschak (BDM) incentive compatible mechanism was adopted with cheap-talk to reduce strategic behaviour and hypothetical bias.

Chapter 7 presents the results of a case study using double-bounded CV questions. This chapter uses the same experimental approach used in chapter 6. This chapter assesses an individual's WTA compensation for a feed-in tariff and WTP for micro-generation solar panels integrated into the building during the construction stage. It uses 3D images of the installed panels on the roof or window shade of the potential house to reduce the impact of hypothetical questions and also to familiarise respondents with the consequences of over and under bidding prior to evaluation.

Chapter 8 provides the results of the CE survey by assessing influential factors on an individual's choice of a micro-generation solar system. In addition, this chapter estimates individuals' WTP and presents the findings of the interaction between explanatory variables. Choice analysis was applied through discrete choice models, namely, the conditional logit model, the random parameter or mixed logit model, and the latent class model.

Chapter 9 summarises and discusses the results of the three case studies and finally concludes the thesis.

## Chapter 2. Non-Market Valuation

### 2.1 Introduction

A marketed good trades in the marketplace between buyers and sellers for a given price, whereas there is no actual marketplace for a non-market good. Notwithstanding this, the non-market good “contributes positively to human well-being and it has economic value” (Bateman et al., 2002, p. 1). Over the years, the assessment of non-use values has become a key element in the field of environmental economics (Adamowicz et al., 1995; Adamowicz et al., 1998). To date economists have suggested a number of methods to take account of non-market values within cost-benefit analysis<sup>2</sup> (CBA). This can be implemented through laboratory and experimental designed surveys. These techniques, known as stated preference (SP) techniques, refer to any hypothetically questioning technique for estimating respondents’ preferences.

This chapter reviews the conceptual frameworks with reference to non-market valuation. The sections of this chapter are outlined as follows. Section 2.2 classifies the strands and structure of the total economic value in terms of use and non-use values. Section 2.3 describes the fundamentals of microeconomics, and defines the concepts of demand and supply on the basis of preference relations. Section 2.4 describes economics welfare and consumer surplus. Section 2.5 reviews the evolutionary trend of consumer theory from the traditional to modern economy. Section 2.6 defines economic theory of choice by linking experimental data to psychometric and forecasts market demand. In section 2.7, neoclassical utility theory is reviewed and its limitations are discussed. Section 2.8 expresses random utility theory and shows how it predicts the probability of indirect

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<sup>2</sup> Costs and benefits are defined in terms of individuals’ preferences; people receive benefits whenever they receive something in return for which they are willing to give up something else that they value.

utility based on the distribution of unobservable attributes. Section 2.9 introduces a SP empirical technique for the estimation of non-market values. It provides the theoretical context for approaches to SP, namely contingent valuation (CV) and choice experiments (CE). Section 2.10 contrasts the SP method with the revealed preference (RP) technique pertinent to non-market valuation. Section 2.11 compares the two SP approaches of CE and CV. Section 2.12 summarises and concludes the chapter.

## 2.2 Total economic value

Total economic value (TEV) encompasses both non-use and use values. The use value or value in use is the utility derived from consumption of a good. The use value either arises from the actual use of the good, such as clean water consumption, or option value where an individual prefers to pay to preserve the current good or service as an option for future usage, such as preserving a forest (Bateman et al., 2002).

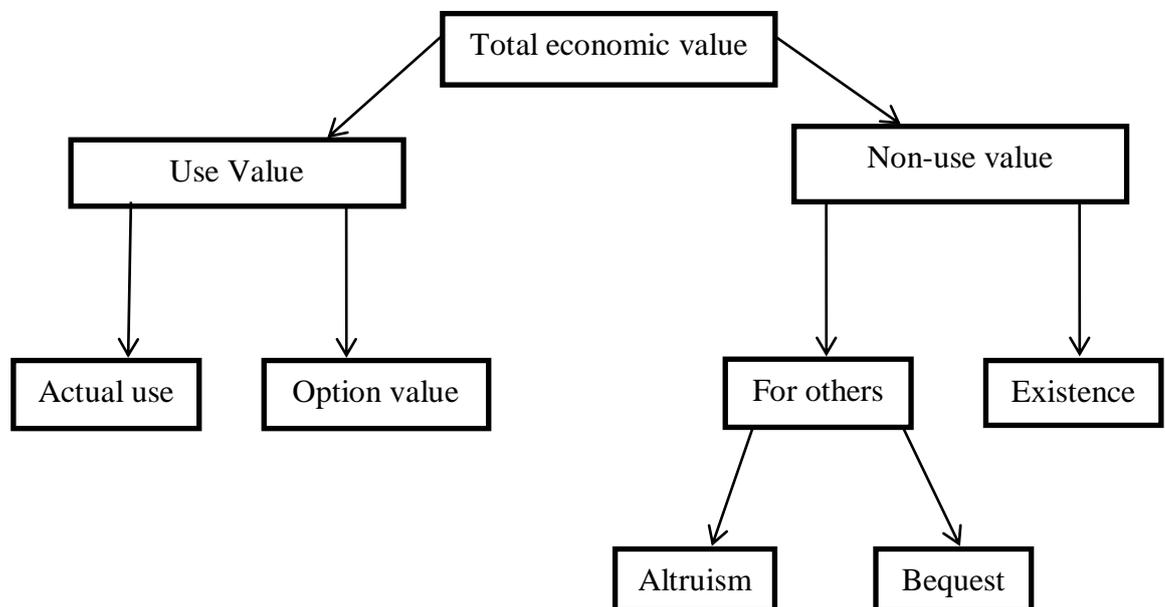


Figure 2.1 Total economic value

(Bateman et al., 2002, p. 29)

On the other hand, the non-use value refers to the individual's preferences for preserving the good, which exists but is not really used at the present time or is intended to be used in the future. The non-use value, also known as existence value, passive use value,

inherent value, bequest value, intrinsic value, or stewardship value, can be described based on the specific formulation of the individual's preference structure. The concept of existence value or passive use value was initially introduced by Krutilla (1967), who refers to the individuals' willingness to pay (WTP) for protecting environmental resources such as a national garden, with no personal intention of visiting the garden themselves or knowing whether their children will use it. Basically, the idea is that people's motives for the valuation of natural resources are sometimes irrelevant to the likelihood of using it. In the same way, if a person was willing to pay to save a national garden for the future generation, this is called bequest value (Krutilla, 1967). Altruistic value refers to the situation when a person is concerned with and is WTP to save the national garden so that others may use it in the present time. Figure 2.1 demonstrates the TEV classification into the use and non-use values (Bateman et al., 2002).

Principally, economic value measures the change in human well-being on the basis of the delivered good or service. The perception of well-being or welfare can be determined with the efficient allocation of benefits and costs of the assets based on individuals' preferences. There is a consistent link between preferences with WTP, and thus well-being can be measured from individuals' WTP. As such, TEV value refers to the net amount of total WTP, where the person chooses a change relevant to the current condition<sup>3</sup>, and willingness to accept (WTA), if the current situation is preferable to any decrease in the supply of a good or service.

Non-market valuation can explain changes in an individual's welfare from the use of alternative resources in the absence of competitive markets (Seller et al., 1985). The notion of an efficient allocation of resources underlies economic theory in which benefits exceed the costs. There are two ways of determining economic values: one way is to

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<sup>3</sup> Status quo (SQ), do nothing; retention with the existing or current condition.

observe an individual's behavioural valuation in response to a change in the actual market and use values, and from this behaviour the researcher can infer the value of a change. This technique is known as the revealed preference (RP) technique. The RP technique uses direct demand estimation in an actual market such as hedonic pricing<sup>4</sup> (labour market or property market), averting behaviour<sup>5</sup>, and market prices, which can be measured based on dose-response to the WTP question. RP analyses the preferences of a consumer over a bundle of goods under assumed budget constraints. This technique joins the demand model in observing behaviour through the utility function.

An alternative approach is when the researcher asks individuals directly hypothetical questions in which they state their values for the change; this technique is known as stated preference (SP). The non-use value can be only estimated by SP procedure, but use value can be estimated through both SP and RP.

With reference to the hypothetical questions in a quasi-market setting, the remainder of this chapter reviews the underlying theories and subsequently SP approaches.

### **2.3 Demand and Supply**

Market prices are determined by the interaction of demand and supply, and so predicting market effects under changed situations entails an understanding of supply and demand. Businesses in various circumstances can be expected to set their prices at marginal cost<sup>6</sup> or some fixed markup<sup>7</sup> over marginal cost, as well as based on the demand for their product and the impact of price deviations on product demand. In these situations, the

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<sup>4</sup> Job-related risks i.e. wage risk and property markets, disamenity effects i.e. noise.

<sup>5</sup> The expenditures required to prevent undesired effects.

<sup>6</sup> Marginal cost is a change in total cost from an additional unit of product.

<sup>7</sup> Fixed selling price, which is independent of demand.

observed prices can be evidenced and used to estimate the demand for products and price elasticities.

Generally, it is arbitrary to incorporate the supply side in the analysis, because demand can be determined without the inclusion of the supply side. Although the inclusion of supply improves the estimation of demand, under the pricing behaviour assumption, the estimation of demand without the supply side is usually preferable (Train, 2009). Although consumer demand and producer supply can be defined with WTP and WTA for a good, estimating consumer WTP is the foundation for developing monetary values of welfare. In other words, consumer surplus and producer surplus are the components of welfare measurement. The concepts of consumer demand and producer surplus can be used to analyse a variety of economic issues ranging from the welfare effects of monopoly to tariff policy. In addition to analysing welfare from the perceptions of consumer and producer surplus, policy implication can be inferred (Pearson, 2000).

**Therefore, the key research question of this thesis is estimating households' WTP, and thus the demand side is only included in the model.**

As shown in Figure 2.2, the horizontal axis measures the units of the good that can be bought and the vertical axis measures the price for each unit of the good. Each point on the demand curve represents the level of an individual's WTP or marginal unit, and the difference between total WTP and real expenditure is the consumer surplus. The marginal WTP is represented by the points on the demand curve and total WTP is the area under the Hicksian demand curve.<sup>8</sup> The grey area under the consumer demand curve is the consumer's surplus, when the marginal utility is assumed to be constant for consumers with any income level.

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<sup>8</sup> In microeconomics, consumer demand is over a bundle of goods that minimises their expenditure.

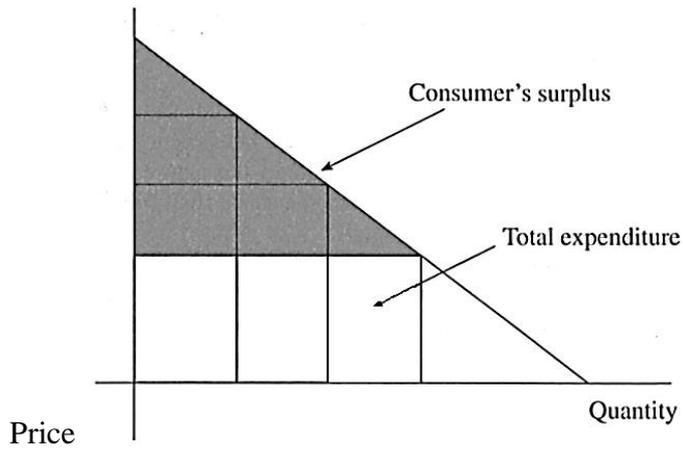


Figure 2.2 Demand curve and WTP

(Bateman et al, 2002, p. 23)

Thus, the net benefit to the consumer or consumer surplus can be calculated as follows:

$$\text{Total WTP} - \text{Market price} = \text{Consumer Surplus}$$

The underlying demand function is the individual's WTP and the demand elasticity can be measured from the individual's responses.

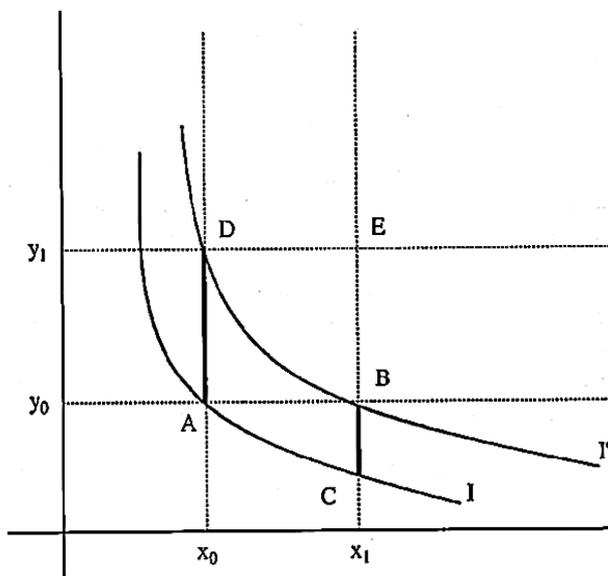


Figure 2.3 Indifference curves

(Bateman et al, 2002, p. 24)

Utility, also called welfare or well-being,<sup>9</sup> represents the ability of a good or service in terms of desire or satisfaction. Utility explains the satisfaction experienced by consumers and their preferences over a set of services or goods. To value the satisfaction and benefit of a good, economists developed utility measurement through the economic choice and preferences models.

The utility function for an individual is  $U(x, y)$  where  $x = (x_1 \dots x_m)$  is the vector of a private good and  $y = (y_1 \dots y_m)$  is the vector of the good's characteristics or a public good. Utility can be explained by an indifference curve<sup>10</sup> which is grounded on the preference assumption, and which represents the combination of goods that is regarded as acceptable to retain a given level of satisfaction or welfare by the consumer or society. In other words, preferences inferred from an individual's WTA and WTP evaluation and their association can be defined via indifference curve analysis.

Figure 2.3 demonstrates the preferences of an assumed individual. The vertical axis measures the individual's spending on private products ( $y$ ), in monetary units for a particular price. The horizontal axis measures the current quantity of a public good ( $x$ ). Each curve can be supposed as the equivalent to a level of utility, and as the indifference curves move up to the right, the welfare of an individual increases. The amount of utility or consumer satisfaction can be measured because, typically, utility diminishes when the quantity of a commodity obtained increases, and the cost of the product mirrors merely the latest unit of purchase and not the utility of all units. People's responses over WTP questions can reveal different values, due to the association between an individual's WTP for the good in question and his/her demand. Underlying consumer demand theory,

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<sup>9</sup> Welfare, well-being and utility refer to a specific aspect of an individual's life that can be stated in monetary value.

<sup>10</sup> In microeconomic theory, an indifference curve represents a different bundles of goods in which an individual is indifferent at any point on the curve; the individual has no preference for one bundle over the other as they obtain the same level of utility.

diminishing marginal rate of substitution, rests on the utility maximisation assumption. Individual utility and social utility can be constructed by the value of a utility function and a social welfare function, respectively.

In welfare economics, as shown in Figure 2.3, the WTP for the increase in the public good is equal to BC, which is also the equivalent loss when the loss of some private consumption would be exactly preferable to a reduction in the public good to  $x_0$ , since A and C are both on the same indifference curve. Similarly, WTA for the decrease in the public good is equal to DA, which is an equivalent gain when the additional sum of private consumption would be exactly preferable to an increase in the public good to  $x_1$ . Willig (1976) shows that the consumer's surplus via Marshallian<sup>11</sup> demand curves can be used to estimate the unobservable compensate and equivalent variations, which in turn measure the welfare impact of changes in prices on an individual.

Firstly, compensating variation (C) measures the consumers' maximum WTP for the quality improvement. This will be the amount that a household should forego from their income to obtain a new level  $q^1$ , to increase the level of convenience and satisfaction:

$$C = e(p^0, q^0, U^0) - e(p^0, q^1, U^0) \quad (2.1)$$

Let  $p$  denote the price, while  $e(.)$  is the expenditure function, and  $U$  signifies the utility function.

Then, the equivalent variation (E) measures the consumers' minimum WTA for no improvement in quality. As the Marshallian demand function comes from the utility

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<sup>11</sup> Alfred Marshall, one of the founders of economics, established the notions of supply and demand, marginal utility and costs of production.

maximisation problem, the Hicksian demand function<sup>12</sup> (compensated demand function) is related to the expenditure function. Consumer demand is for a bundle of goods that minimises their expenditure through supplying a fixed level of utility. This function is compensated for when the price of a good increases, utility is held constant, and expenditure or income adjusts to compensate:

$$E = e(p^0, q^0, U^1) - e(p^0, q^1, U^1) \quad (2.2)$$

As shown in Figure 2.3 the  $DA > BC$ , which reveals that the WTA is larger than WTP; that is to say, equivalent gain is larger than equivalent loss. Basically, this inequality appears on every occasion on which indifference curves are convex. Therefore, the ratio between WTA and WTP tends to be larger when the indifference curves become further convex, and the difference between  $x_0$  and  $x_1$  is greater. This can be articulated as the reduction of substitutability between private consumption and the public good (Hanemann, 1999).

Overall, utility or welfare varies from one person to another, however, neoclassical economic theory does not reveal the extent of an individual's wants  $q$  and the reasons for these, since, as Simon (1986, p. 213) stated, "neoclassical economics provides no theoretical basis for specifying the shape and content of the utility function".

## 2.5 Consumer theory

Consumer theory is a concept in microeconomics that relates preferences for the consumption of goods and services to the consumption of expenditures and ultimately to the consumer demand curves. Consumer theory is a way of analysing how consumers

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<sup>12</sup> One of the most influential economists of the twentieth century, the most well-known of his many contributions to economics was his declaration of consumer demand theory in microeconomics. The compensated demand function is named the Hicksian demand. In 1972, Hicks was awarded the Nobel Memorial Prize in economics for his original contributions to general equilibrium theory and welfare theory.

may achieve equilibrium between preferences and expenditures by maximising utility. Consumer theory investigates how consumers' choices are made based on some decision criteria such as utility maximisation through the balancing expenditures and preferences. Consumer preference is formed based on the desire or demand for a good, as well as the extent of bearing the cost according to the consumer's wealth.

Lancaster (1966) proposed that a good's characteristics determine consumer preferences, not only the good itself. A consumer preference for a good is not only for the good itself, as the attributes of the good distinguish that good to be the most preferred. Lancaster considered goods as inputs and their characteristics as outputs, because the product's characteristics distinguish them from each other. In addition, Louviere, et al. (2000) agreed that the characteristics of a good are the sources of consumer utility, not the good per se. Generally, "a good possesses more than one characteristic, and many characteristics will be shared by more than one good. Goods in combination may possess characteristics different from those pertaining to the goods separately" (Lancaster, 1966, p. 134).

Overall, conventional consumer theory is only applicable for simple markets, where consumers do not deal with a variety of choices. As a result of new technology and innovation, there has been a move from traditional to modern economies for the complex market. Consumers choose from a variety of choices and substitute their consumption with new and more efficient products on the market. Although the modern market provides consumers with an extensive choice of goods, some of these advanced and complicated products need to be provided with an itinerary of usage for consumers, which by definition is know how. Because of these extra services and the information needed for consumers, the producers may offer these products at a higher price. Hence, "specifying

proper price for the new commodities leads to an objective efficiency choice by the frontier, otherwise it would not be chosen by consumers” (Lancaster, 1966, p. 151).

On the other hand, the recently sustainable economy versus the modern economy has become a topic of debate. Jackson (2004) pointed out that sustainable consumption is derived from sustainable production, which does not occur in the present frame of economic consumption. Jackson (2004) believes that consumption should not be restricted to the models of utility maximisation and rational choice that underpin conventional or microeconomic theory. In other words, as a study by Evans and Jackson highlights, what is important is the socio-cultural theories of consumption rather than consumerism, which is characterised by a high volume of material consumption and accelerated environmental damage. In order to create sustainable consumption and prosperity, economic growth needs to be brought to a standstill, and changes need to be made to lifestyle (Evans and Jackson, 2005-2008).

## **2.6 Economic choices**

Economic choice theory enables the linkage of data from psychometrics and experiments to generate a forecast of market demand. To forecast the market demand for a new or existing product, the analysis of the product’s attributes and the target population’s characteristics are the function of the simulation. The success of forecasting observed behaviour facilitates a benchmark for stipulating the preference model and modelling the utility function (McFadden, 1986).

McFadden (1986, p. 275) stated that economists often view consumers as “optimising black box” producers of economic choices. The behaviour models can develop by accommodating the utility on “experience, information, and perception” (McFadden, 1980, p.15). As shown in Figure 2.4, the inputs to the black box were defined as “socioeconomic characteristics, market information, historical experience, and market

constraints” to reveal the outputs of “purchase decisions, consumption levels, and related market behaviour”. Economic choice theory is a method for modelling the black box; it is designed to provide a quantitative prediction through accurate statistical analysis. Naturally, preferences are expressed over various attributes of the good in accordance with consumer habits, past experience, and socio-demographic attributes. Individual preferences may be comprised of random components that underlie the perception variations and unobserved factors. The economic choice theory associates the random preference model with the possible responses under the structure of choice behaviour. Figure 2.4 presents a decision protocol that draws preferences into choices, and yields behavioural intentions to maximise preferences. The choice model is constructed based on psychometric data to predict consumer behaviour towards a new product’s attributes and to forecast market demand. “A natural approach for designing psychometric experiments is to mimic the consumer’s market decision by presenting hypothetical but realistic choice problems in the laboratory, incorporating psychometric scales for attitudes and perceptions” (McFadden, 1986, p. 277). The most important challenge for eliciting reliable responses from the laboratory method is a valid and well-designed study. The choice probability can be simulated as a function of the products’ attributes and the individual’s characteristics. The observed choice behaviour provides a measure for specifying the preference model and determining the utility function.

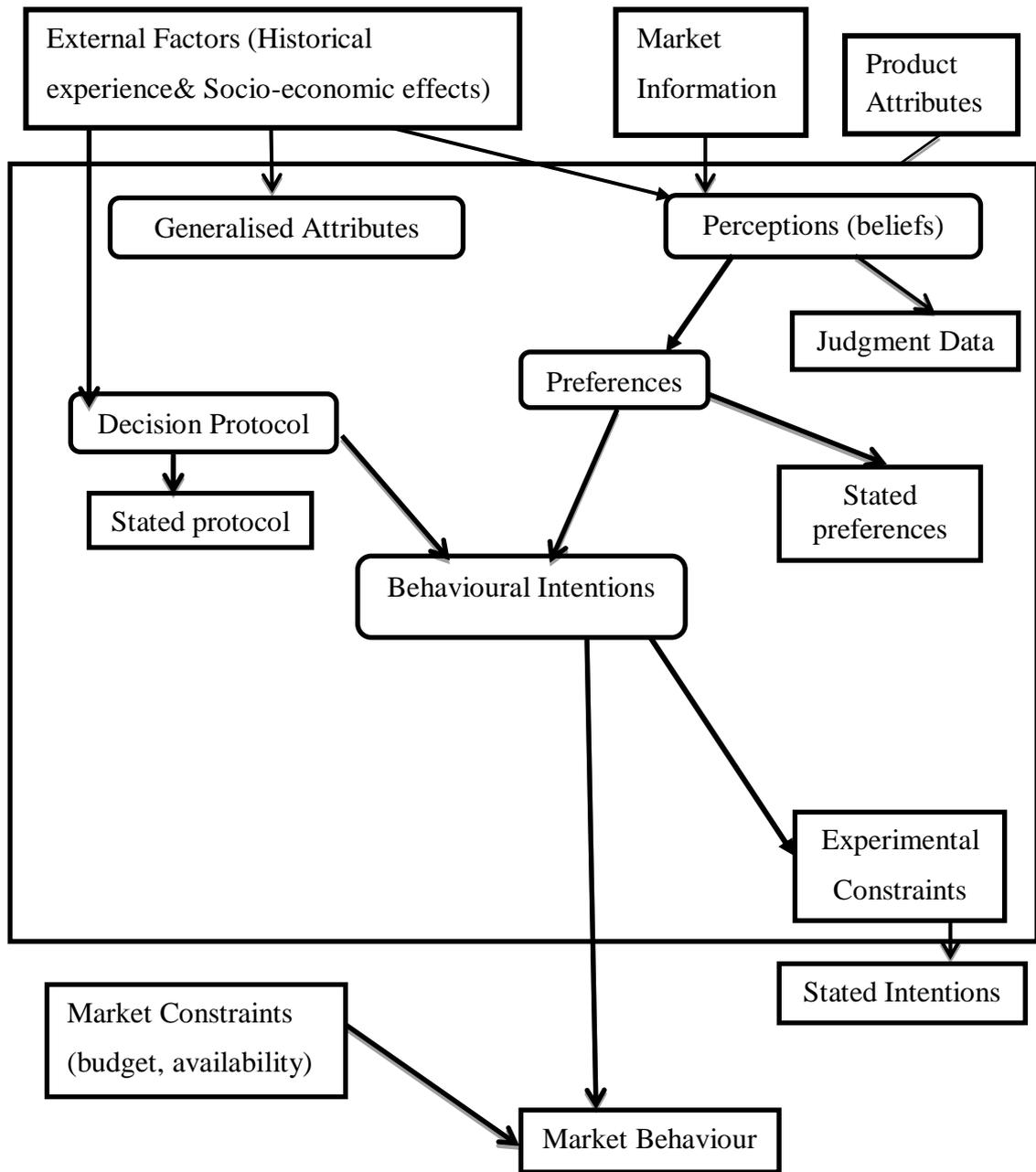


Figure 2.4 Path diagram for customer decision process, Black box

Source: McFadden (1986, p. 276)

## 2.7 Neo-classical theory and limitations

Neoclassical economic theory<sup>13</sup> is consistent with standard economic theory in that respondents should answer the survey questions in such a way as to maximise their expected welfare. It has been usually assumed that an individual's preferences have properties that are put forward in Hicksian consumer theory. Preferences over a bundle of goods are supposed to be complete,<sup>14</sup> transitive,<sup>15</sup> continuous<sup>16</sup> and convex,<sup>17</sup> with downward sloping indifference curves.<sup>18</sup> Convexity assumption prevents any kink around the indifference curve; as an individual obtains cumulative amounts of a good, marginal utility diminishes, which implies a smooth convex indifference function.

However, it has often been seen that surveys generate data in the fashion that is not consistent with the Hicksian model, and indifference curves exhibit a kink. This may be a signal of an unreliable survey instrument and strategic bias, or that the instrument is subject to the inconsistency of an individual's preferences with Hicksian theory assumption (Sugden, 1999b). There is a growing recognition that when rational agents respond to preference questions, strategic behaviour violates rationality and economic

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<sup>13</sup> Neoclassical theory refers to the maximisation of utility subject to the income constraints of individuals and of profits by cost constrained in accordance with rational choice theory. It is characterised by several assumptions common to many schools of thought, such as John Hicks'.

<sup>14</sup> Enables two bundles to be compared as better, worse, and indifferent; the latter can be responded to with a 'don't know' option.

<sup>15</sup> Internal consistency of an individual's preferences, consistency within preferences to make sure that a given bundle just fits into an indifference set. The solution from Marshallian and Hicksian demand function will differ when there is a price change, which can be shown by a Slutsky equation; for further definition, see Varian (1992).

<sup>16</sup> There is no gap on an indifference curve and preference is continuous, which implies that the utility function is continuous. This can be interpreted as being that if the consumption amount of one good is reduced, the amount of consumption of another good increases to compensate for the loss.

<sup>17</sup> An individual prefers averages to extremes; when he/she is indifferent to the two bundles of goods, then a linear combination of the two bundles is strongly preferred.

<sup>18</sup> Preferences are monotone if more of any good makes an individual strictly better off. Under the assumption of monotonicity, curves are downward sloping and indifference curves are convex.

maximisation. Carson and Groves (2011) “do not claim that neoclassical theory is not vulnerable to behavioural critique”. This anomaly can be explained by psychological theories.

### ***2.7.1 Psychological cognition***

The rational consumer has been explicitly explained by Hicks and Samuelson; moreover, Simon (1959) stated that the rational consumer in economics is a maximiser of utility. Rationality<sup>19</sup> is a multifaceted behavioural model; it can be described by “preferences, perceptions, and process”. “The most cognitive anomalies operate through errors in perception that arise from the way information is stored, retrieved, and processed, or through errors in process that lead to formulation of choice problems” (McFadden, 1999, p. 1). The concepts of perception, preference and process arise in both economic and psychological views of decision-making, although psychological and neoclassical economics have completely different assessments about the decision making process. The psychologists’ emphasis is on understanding the feature of the decisions; however, economists use information to draw the choice and then analyse the preferences and values as basic elements of the decision process, as presented in Figure 2.4 ‘black box’ (McFadden, 1999).

A number of empirical cases indicate that choices hinge on the status quo (SQ) and reference level, but indifference curves are drawn with no reference to the existing possessions. Tversky and Kahneman (1991) proposed the reference-dependent theory of consumer choice. This theory underpins the Kahneman and Tversky (1979) earlier choice model of prospect theory. Basically, the mutual notion of both studies is about people receiving decision options or a choice problem, as a gain or a loss relative to a reference

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<sup>19</sup> McFadden (1999, p.1) defined as sensible, planned, and consistent, is believed to govern most conduct in economic markets.

point. However, the standard economic models do not make any assumption about the association of preferences and the current belongings.

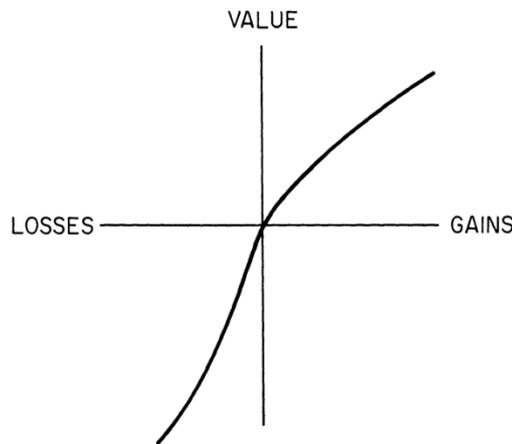


Figure 2.5 Value function

It is likely that preferences restricted to one reference point are not the same as preferences restricted to a different reference point. The two conditions of “diminishing sensitivity” and “loss aversion” and the incentives of value gains and loss were defined relative to a reference point by Tversky and Kahneman (1991). “Diminishing sensitivity”<sup>20</sup> indicates “marginal value decreases with the distance from the reference point”, and “loss aversion”, which embodies the psychological perception and indicates that “losses loom larger than corresponding gains” (Tversky and Kahneman, 1991, p. 1047-48). Preferences hinge on present entitlement, and can be relatively different on the basis of what is acquired and what is given up, even in the absence of transaction costs or income effects (Knetsch, 1989; Kahneman et al., 1990; Bateman et al., 1997; List, 2004). As shown in Figure 2.5, these properties shape an asymmetric S-shaped value function, concave above the reference point and convex below it, which is steeper in loss than gain. This implies a larger inclination in loss aversion. The loss aversion has an instant

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<sup>20</sup> Similar to the standard assumption, this is diminishing marginal utility.

consequence on endowment, which leads to the utility loss of relinquishing a valued good or service being larger than the utility gain for obtaining it. Thaler (1980) considered the endowment effect as an increased value of a good to an individual once a good is included in the individual's endowment. Kahneman et al. (1990) conducted a series of experiments from students in the classroom, to test the endowment effect. The study was carried out in such a way that one third of the students were given a \$5 mug, and were told "you can sell the mugs to other students that have not received any mug", at prices ranging from \$0.50 to \$9.50 with 50 cent intervals. Both groups of students (sellers and buyers) were confronted with the same decision problem, which was to choose the mug or the money. The seller had to choose either to retain the SQ, keeping the mug, or to sell it in exchange for cash. In this fashion, the mug would be valued as a gain by the buyer and as a loss by the seller. The results showed that there was a difference between values for the mug versus cash; this difference was reflected by the endowment effect. Moreover, this effect is an indicator of loss aversion, which is usually exposed to a larger bias or weighs considerably more than equivalent gain.

## **2.8 The random utility model**

Thurstone (1927) initially developed the idea of 'psychological stimuli' and Marschak (1960) interpreted the stimuli as utility, which is referred to as utility maximisation, or the so called random utility model. The random utility model task is to describe individual behaviour (Manski, 1977). The utility of a good is described as a function of a good's attributes by Lancaster (1966), as a good is initially evaluated based on its attributes and then might be chosen by individuals (McFadden, 1974; Train, 2003 ). Later, Thurstone's original theory of paired comparisons or pairs of choice alternatives was expanded to multiple comparisons by several authors (McFadden, 1974; McFadden, 1986; McFadden and Train, 2000).

Random utility suggests the presence of latent utility in an individual's behaviour, which is not observable to the researcher. The utility's randomness derives from the consumer's unobserved tastes and unobserved attributes of alternatives, and this model could be a basis for the estimation of an individual's choice according to the characteristics of a good as well as a random component. "The random component arises either from randomness in the preferences of the respondent or the researcher" (McFadden, 1980; Scarpa and Willis, 2010).

An individual's utility function can be specified in the form of equation 2.3.

$$U_{nj} = V_{nj} + \varepsilon_{nj} \quad (2.3)$$

Where  $U_{nj}$  is the utility that individual  $n$  obtains from alternative choice set  $j$ . Utility is comprised of a deterministic or systematic component  $V_{nj}$ , which comprises observable attributes explaining differences in individuals' choices, and a random error component  $\varepsilon_{nj}$ , containing all unknown factors that influence choices. The researcher only observes attributes of the chosen alternatives by respondent, and specifies a function  $V_{nj}$  relating these observed factors to the individual's utility. The selection of representative utility  $V_{nj}$  by the researcher is important for the identification of the error component and its distribution (Train, 2003).

Louviere et al. (2010) pointed out that the random utility model gives the advantage of a discrete choice (DC) experiment over conjoint analysis.<sup>21</sup> The random utility model explains how choice probabilities may react to the different choice options. It is strongly connected to the "random components whose properties play key roles in parameters estimates and welfare measures derived from discrete choice data collection. Random utility leads to families of probabilistic discrete choice models" that label how choice

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<sup>21</sup> Represents the systematic behaviour of ranking observed outcome mathematically, usually by using a complete factorial.

probabilities react to changes in choice possibilities or covariates signifying differences in individual decision makers. Thus, Equation 2.2, explains that:

$$P(i|C_n) = P[(V_{in} + \varepsilon_{in}) > \text{Max}(V_{jn} + \varepsilon_{jn})], \text{ for all } j \text{ option in choice set } C_n \quad (2.4)$$

(Max signifies maximum operator)

The probability that individual  $n$  chooses  $i$  from the choice set  $C_n$  equals the probability that systematic and random components of option  $i$  for individual  $n$  are larger than the systematic and random component of all other options competing with option  $i$  (Louviere et al., 2010, p.63).

Different probabilistic DC models with different distribution assumptions can be derived from equation 2.4, such as non-independent, non-identically distributed normal random variates and independent, identically distributed (IID) Gumbel (Extreme value Type 1).<sup>22</sup> In this chapter we do not discuss about the distribution of error components further, as chapter 4 provides more explanation on this topic.

Returning to random utility theory, the assessment of a new product or service is only derived from the random utility model, as utility is specified as a function of attributes instead of demand for a good or service (Haab and McConnell, 2003). Moreover, the random utility model can measure welfare<sup>23</sup> based on a household's responses and behaviour for the quality change. In theory, the correct measure of welfare impact of an improvement of quality on the household are the compensation variation (C) and

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<sup>22</sup> McFadden assumed independently identically Gumbel (Extreme value Type 1) distribution for the error components because, in the case of more than two choice alternatives, the normal distribution is unable to take a closed form. The property of IID is discussed in chapter 4.

<sup>23</sup> The scale parameter does not affect the ratio of any two coefficients, since it cancels out the ratio. WTP and other measures of the marginal rate of substitution are not affected by the scale parameter (Train, 2009, p. 41).

equivalent variation (E), as shown in section 2.4, and also the measure of welfare via the random utility model can be expressed as follows:

First, utility maximisation is considered; compensation variation measures consumers' maximum WTP for an improvement in the quality of good or service  $q^1$  which can be expressed as:

$$V(p^0, q^0, Y) = V(p^0, q^1, Y - C) \quad (2.5)$$

In our case, it is the utilisation of solar technology in the residential sector. This will be the amount that a household should forego from his/her income to obtain a new level  $q^1$  of electricity service generated by micro-generation solar technology, to increase the household's convenience and satisfaction.

Second, expenditure minimisation is included by using equivalent variation to measure the minimum WTA for no improvement in quality  $q$ , or for inconvenience or amenity loss for having solar technology equipment on their premises. This is calculated as:

$$V = e(p^0 q^0, Y + E) = V(p^0, q^1, Y) \quad (2.6)$$

where  $V$  denotes the indirect utility function.

## 2.9 Stated Preference

The non-market valuation relies on the random utility model, and as stated earlier the non-market values can be estimated through the stated preference (SP) techniques. Whilst natural resources provide people's satisfaction or utility, certain aspects of these sources do not have a market price or monetary value because they are not directly sold. To date, the urge to place monetary values on passive use values has become essential. The use of SP has been approved as a significant and reliable technique for determining the imposed

damage cost onto the environment, by the National Oceanic and Atmospheric Administration (NOAA) Panel.

Due to the absence of an actual market for non-market values, the SP technique enables hypothetical setting surveys. The technique can be applied either by asking a respondent to state their preferences (WTP, WTA questions) or to choose their most preferred option over a bundle of goods. Alpizar et al. (2001) stated that non-market goods valuation methods are the key tools for the assessment of the costs and benefits of public projects. To estimate this value through SP, contingent valuation (CV) and choice modelling (CM) can be used, as both approaches have been extensively applied to estimate non-use values (Bateman et al., 2002). In addition, in the field of environmental economics both approaches are very well known (Kanninen, 2007). In the context of renewable energy (RE) evaluation, SP techniques have been applied to measure the choice as well as WTP for micro-generation technology (Scarpa and Willis, 2010). It can produce information concerning public preferences and economic efficiency (benefits and costs). Investment in an RE project with external costs and benefits requires the measurement of welfare; Bergmann et al. (2006) considered landscape quality, wildlife and air quality as external costs and employment and electricity price as external benefits to estimate welfare for people with both low and high incomes.

Generally, the apparent limitation of a SP survey is owing to the inconsistency of people's expression in the hypothetical survey and what they choose or decide and how they would act: "In fact, the respondents' idea might be influenced by factors that would not arise in the real choice situation such as their perception of what the interviewer expects or wants as answers" (Train, 2009, p. 153).

As classified in Table 2.1, there are four types of CM for the evaluation of respondents' preferences. The data produced from each type of the CM approach can provide different information regarding estimation of WTP and welfare changes (Hanley et al., 2001).

Table 2.1 Main choice modelling alternatives

<b>Approach</b>	<b>Respondent Task</b>
Choice experiments	Choose (usually) between two alternatives versus the status quo
Contingent ranking	Rank a series of alternatives
Contingent rating	Score alternative scenarios on a scale of 1-10
Paired comparisons	Score pairs of scenarios on similar scale

From: Bateman et al. (2002, p.250)

With any CM approach, typically each respondent is presented with a series of alternatives, and respondents are asked to put the choices in the order of contingent rating, contingent ranking, and paired comparison. The choice experiment (CE) technique is the most consistent approach with economic theory. Although contingent ranking can be consistent with economic theory, it has limitations such as generating unreliable and inconsistent choices across ranks. CE can be administered by asking respondents to select the most preferred alternative of two or more options. Adamowicz et al. (1998) stated the merit of the CE as the best option amongst other CM approaches in the evaluation of passive use. CE is an attribute- or component-based technique, and this technique is explained in more detail in subsection (2.9.2).

#### General survey modes

The major survey modes for SP are as follows:

- *Mail survey*: a questionnaire is sent to a sample of respondents by mail; respondents are required to complete the questions and send the questionnaire back to the researcher.
- *Telephone interviews*: the researcher contacts the respondent by telephone and asks individuals to answer the study questions on the phone.
- *Face- to-face interviews*: the researcher questions the sample respondents in person.

The steps for undertaking a SP survey are summarised in Figure 2.6.

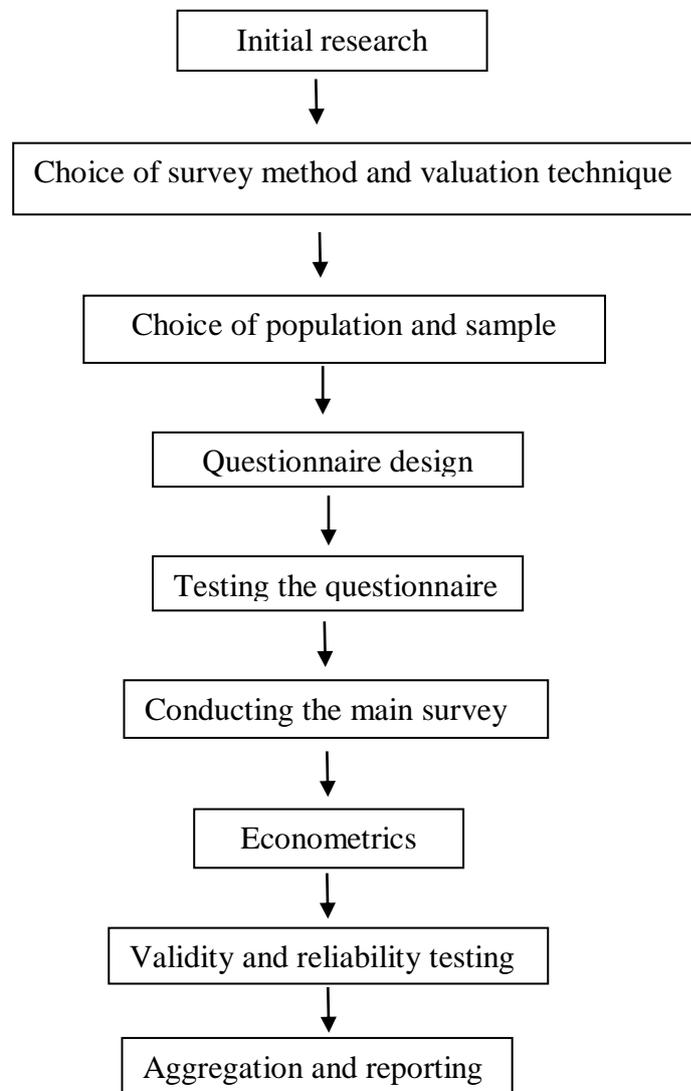


Figure 2.6 SP stages

(Pearce and Özdemiroglu, 2002, p. 28)

### ***2.9.1 Contingent valuation***

Contingent valuation (CV) as a kind of SP technique is well known for the evaluation of non-market values through the measurement of WTP and WTA underlying random utility theory. CV is widely used to measure passive use values, with no possibility of being evaluated in the actual market (Carson et al., 1999). Numerous studies have used CV to measure preferences for non-use values in the field of environmental economics (Seller et al., 1985; Whittington et al., 1990; McFadden, 1994; Carson, 1997; Alvarez-Farizo et al., 1999; Carson, 2000; Bateman et al., 2002; Haab and McConnell, 2002; Venkatachalam, 2004; Carson and Hanemann, 2005; Bateman and Willis, 1999). In addition, Haab and McConnell (2003) believe that the most widespread kind of SP for estimating WTP is the CV technique. CV is a survey-based method which is considered by scholars (Mitchell and Carson, 1989; Pearce and Markandya, 1989) as one of the most promising methods by which to place monetary values on environmental goods and services that are not tradable in the marketplace.

The theory of 'CV for non- market goods valuation' was initially suggested in the 1940s by Bowen as "social goods" and Wantrup as "collective, extra-market goods". In 1963, CV was applied by Davis to implement a survey on the evaluation of the outdoor recreation. The usage of the CV technique began to increase from the 1980s, and it was put into practice by the US government, Executive order 12291 statement, which urged that a cost and benefit analysis be undertaken for every important federal project. In 1989, the US Appellate court decision, *Ohio v. Department of Interior*, entailed the inclusion of passive use values for a reliable valuation of natural resource damages. This was followed by using the CV technique and placing monetary values on the damage caused by the Exxon Valdez oil spill in Prince William Sound. The NOAA appointed a blue ribbon panel chaired by Kenneth Arrow and Robert Solow to analyse the usage of CV in natural resource damage valuation actions (Carson and Hanemann, 2005). The result supports that

“CV studies can produce estimates reliable enough to be the starting point for a judicial or administrative determination of natural resource damages including passive use values” (Carson 1997, p.1,501).

In this respect, the CV technique was initially applied to address policy issues, and then the inclusion of passive-use values was ascribed. Now, CV is used ubiquitously by government agencies and the World Bank across the world. Moreover, the reliability of the CV method for estimating WTP in the case of developing countries was highlighted by Whittington et al., (1990, 1992). With this technique, analysts measure the monetary values of the change in the qualities of goods or amenities. The compensation measures the WTA for the amenity loss or minimum amount that an individual agreed for the loss, and the equivalent measure is the maximum WTP for the improvement (Hanemann, 1991). In the context of environmental assessment, the ratio of WTA/WTP is often explained as the ratio of accepting compensation for losing amenity over the relinquishing of some money to benefit from the obtained goods or services. It provides information on the distribution of WTP and WTA while holding the utility constant.

The reasons for distribution variations can be explained by covariates or individual characteristics, such as income and education levels, and other socio-demographic variables. To alternate the wording and the design of the survey's questions, different types of formats can be employed such as open-ended questions, a bidding game, a payment ladder, and closed-ended single or double-bounded dichotomous choice questions. In chapter 3, CV formats are explained in detail.

The wording of the open-ended and close-ended questions can be expressed as follows:

Open-ended (i.e. what is your maximum willingness to pay and minimum willingness to accept?)

Close ended (i.e. would you be willing to pay X amount or willing to accept X amount?)

What is more, some critical assessments have been contended by scholars (Kahneman and Knetsch, 1992; Hausman, 1993; Diamond and Hausman, 1994) on CV credibility, reliability and validity. Following the NOAA panel's argument on the reliability of CV evaluation, Hanemann (1994) argued that CV may not always be able to provide accurate outcomes in all circumstances, particularly in cost benefit analysis (CBA) and damage assessment. Note that in this chapter we do not discuss CV validity and experts' insights and their assessments. The next chapter provides more explanation about CV technique.

### **2.9.2 Choice experiments**

The choice experiments (CEs) application in environmental economics valuation is shaped subsequent to the use of the CV technique. Louviere et al. (2000) discussed Lancaster's (1966) consumer theory, which is that an individual's utility is a function of a good's characteristic. Louviere et al. (2000) assumed that an individual derives utility from the consumption of the services offered by goods based on his/her choice.

Experimental design is the foundation of any SP experiment that is embedded in consumer demand, consumer choice behaviour and random utility theories. Choice sets are "experimental" because some features of their composition in terms of choice diversity are controlled by the researcher (Carson et al., 1994, p.352). CE measures preferences by asking respondents to choose their most preferred product or service from a series of alternatives. It can be used to draw out an individual's preferences from a set of options. CE has the ability to forecast choice probability as a function of utility to facilitate inferences about consumer behaviour.

CE can have two forms of binary alternatives or more with multinomial alternatives. Respondents are required to make trade-offs between the two or more options, as well as a 'do nothing' or status quo (SQ) option, in order to increase the validity of the responses.

In fact, the inclusion of the SQ option in the choice set enables the measurement of welfare that is consistent with demand theory. Otherwise, it would be undesirable as respondents are being forced to choose one of the offered alternatives without the presence of the baseline condition. Respondents can choose the most preferred choice from the presented choice set that contains the common attributes and various attributes' levels so as to provide respondents with a diversity of choice (Johnson et al., 2007). CE provides welfare-consistent estimates for four reasons:

- they force the respondents to trade-off changes in attribute levels against the costs of making these changes.
- the respondents can opt for the status quo that is no increase in environmental quality at no extra cost to them.
- we can represent the econometric technique used in a way which is exactly parallel to the theory of rational, probabilistic choice.
- we can derive estimates of compensating and equivalent surplus from the 'output' of the technique (Bateman et al., 2002, p.251).

Furthermore, the main advantage of the CE is the arrangement of the choices, which covers variations in each attribute, enabling the valuation of the good or policy change from two or more alternatives. This increases the diversity of responses over various attributes and experiments as a function of the choice sets' composition (Train, 2009). To combine the levels of the attributes into a number of alternative environmental scenarios, statistical design needs to be applied. A fractional factorial design can be given in order to reduce the number of scenario combinations instead of a full factorial<sup>24</sup> design (Louviere et al., 2000). "This matters because estimates of consumer surplus or WTP can exhibit large differences between incorrect additive forms and correct non-additive

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<sup>24</sup> All possible treatment combinations are counted, as opposed to fractional factorial design.

specifications” (Louviere et al., 2010, p.60). A fractional factorial design is well-designed when it minimises the variance of the estimates or maximises the information in data matrix (Willis et al., 2011).

Generally, mitigation of multi-collinearity problems between attributes is another advantage of CE, where usually attributes’ levels are designed as orthogonal,<sup>25</sup> and are independent from each other.

## **2.10 SP versus RP**

Revealed preference (RP) data are based on an individual’s actual behaviour under existing circumstances in the real world, where respondents reveal their tastes and preferences by making choices in real conditions (Train, 2003). On the other hand, SP measures an individual’s preference and choice in a hypothetical setting, and thus it has the capability to evaluate both a new and old product with new attributes. However, RP reveals the actual choices so that the existing situation can be evaluated, and so basically it is unable to estimate the preferences for a new product (Train, 2003).

Earlier, we showed that the utility of any offered alternatives is comprised of a deterministic component that is known to the researcher, and also a random component reflecting impacts that are unknown to the researcher. The key assumption made is that the difference between hypothetical responses in the SP survey and observed real choices in the RP survey can be defined by a random term. Unlike RP, SP is able to evaluate the economic value of non-market resources such as environmental preservation or the impact of contamination. The lack of ability of the RP method to do this is because the non-use values tend not to leave some observable behavioural change that affects a price or quantity.

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<sup>25</sup> Variables have zero correlation with each other.

Adamowicz et al. (1998) highlighted the importance of passive use value measurement in environmental economics projects through the SP technique, whereas RP is impractical for the estimation of non-use values. In the case of non-use values where the good in question has a small number or for which there are no substitutes, this value can only be measured by SP techniques.

Nonetheless, both RP and SP techniques can be used to elicit use values (Bateman et al., 2002).

### **2.11 CV versus CE**

Several studies in the field of environmental economics have compared CE and CV studies to comment on these approaches' advantages and disadvantages in order to apply them in terms of their capabilities as relevant to the subject of study and research requirement (Hanley et al., 1998; Hynes et al., 2011).

Some of the basic differences between CE and CV approaches are:

- CV asks direct questions regarding their WTP; however, CE does not directly ask for monetary valuations, and instead asks a respondent to choose between alternatives.
- CV measures the total WTP for the good or service whereas CE measures WTP for the different attributes of a good or service.
- Respondents to the CV question give a single response while CE's respondents may give multiple answers.
- CE tends to understand the respondents' choices over the attributes of the scenarios, while CV focuses on a precise scenario and elicits the respondents' preferences toward that specific scenario. In other words, CE preference estimation is component-based, which is different from CV which measures the preferences as a whole.

- CE tends to improve the results through the examination of the attributes, the impact of the choice of functional form on welfare measures, and endowment effects; however, these effects are less likely to be measured with CV.
- In contrast to CV, CE measures the marginal value of changes in the attributes of the alternative, which can be viewed as an advantage to the analysts (Bateman et al., 2002).

Several studies have used both methods and compared and contrasted the results. Hynes et al. (2011) found distinct differences between CV and CE, arising from the potential of CE to estimate marginal WTP values for specific landscape attributes and also the total WTP for a specific landscape kind.

Adamowicz et al. (1995) compared the passive use values findings from the two approaches of CE and CV and, as a result, a richer report of the attribute trade-offs from respondents' choice and reduced variance of welfare values supported the higher capability of CE. However, no significant difference between their marginal utility variances and their error variances was observed.

Adamowicz et al. (1998, p.68) stated that, in the CE approach, utility contains attributes of the alternatives plus SQ, while in the CV model utility contains the "bid" and an intercept and so there are only two alternatives of "yes and no".

Moreover, CE is able to include only a limited number of attributes into the choice alternative, which subjectively are chosen by the researcher on the basis of pre-studies such as focus groups, experts' views, and relevant literature. Likewise, these attributes can also be specified in a CV survey, by showing real images of the agricultural landscape scenario to respondents (Willis and Garrod, 1993), and this may make CV a superior option over the CE technique. Under this assumption, Hynes et al. (2011)

suggested that CV can perform better than CE, particularly in the assessment of agri-environment policy packages or conserved landscapes as a whole, in terms of presenting the correct picture to respondents.

Nonetheless, CE and CV are both vital instruments for assessing non-market values, and the outcome of both techniques can be used in CBA (Alpizar et al., 2001). Adamowicz et al. (1998) suggest the exercise of CV and CE together and considered both as complementary and auxiliary approaches particularly in the environmental economics studies.

In sum, when the researcher or policy maker is interested in the estimation of the marginal WTP value for specific attributes to assist in the proposal of a policy scheme, then the CE shows more scope. On the other hand, CV is more applicable if the researcher is only concerned with launching a non-marketed environmental scheme which requires examining whether benefits outweigh costs.

## **2.12 Summary and conclusions**

This chapter provided an overview of the fundamental theories and conceptual framework for non-market valuation. The association of choices and preferences with the individual's behaviour and demand were discussed. The non-market valuation is more affected by the individual's behaviour or response errors that are not known to the researcher, compared with the marketed goods. Econometrics models such as the random utility model were introduced to address the individual's preferences with unobserved attributes, and also to investigate how choices are made to enable future market shares to be forecast (Hensher et al., 2005). The two techniques of preference evaluation, SP and RP, were contrasted. The SP technique underlying random utility theory and the two approaches of CV and CE were presented to estimate preferences and choice for non-use

values. The significances and weaknesses of each technique were discussed. Further explanation on CV and CM is provided in the subsequent chapters.

## **Chapter 3. The Contingent Valuation Method**

### **3.1 Introduction**

This chapter follows on from chapter 2, which defined the contingent valuation (CV) method as an eminent technique for the evaluation of non-market goods with economic application in health, infrastructure, transportation and environmental projects. Having defined CV in the previous chapter, this chapter moves onto the evaluation of preferences. This approach directly asks hypothetical preference questions from randomly sampled respondents to state their willingness to pay (WTP) to secure a gain and willingness to accept (WTA) compensation to tolerate a loss. This provides information on the distribution of WTP and WTA holding a utility constant.

Over the years, CV studies have commonly shown that WTA exceeds WTP for the same good in the same setting. There are a number of explanations with reference to overestimating WTA and underestimating WTP. It has been argued that this discrepancy may arise from moral or psychological theories of decision making, for instance reference-dependent preferences or the endowment effect (Sugden, 1999b). It has also been suggested that responses can be influenced by the modes of elicitation (Carson and Hanemann, 2005) which underpin obtaining reliable values close to the actual values.

This chapter begins by describing different formats of CV questions; these are defined in section 3.2. Section 3.3 discusses the contextual implications of CV validity. Section 3.4 describes different types of validity tests. Section 3.5 overviews the theoretical expectations resulting from the economic theory to which these can be sourced for

validity testing. In section 3.6, the limitations of CV and the potential biases are defined. Section 3.7 discusses the WTP and WTA gap with the economic and psychological justifications based on the literature and empirical studies. Section 3.8 discusses the use of experimental mechanisms to test WTA/WTP discrepancies. Section 3.9 describes the notion of the role of socio-demographic and individual characteristics in a CV study. Section 3.10 illustrates CV theoretical frameworks. Section 3.11 reviews the analysis of CV data through parametric methods. Section 3.12 shows how to derive estimates from the CV data using a non-parametric approach. Section 3.13 summarises and concludes the chapter.

### **3.2 Types of eliciting valuation formats**

Different elicitation formats may generate different WTP values. In the subsequent pages, the typical elicitation formats of CV are described.

The *open-ended* format is a direct mode of revealing respondents' values. Respondents can state their maximum WTP simply without any limitations and boundaries of low and high numbers. It is statistically easy to measure WTP and WTA with an open-ended format because answers to the survey questions produce a direct measure.

As a consequence of non-clue questions, the anchoring or starting point bias would be prevented; however, this might raise the unreliability of the responses, and increase non-response rates, outliers, and protest answers. Hoehn and Randall (1987) proposed that biased responses can be seen in open-ended questions compared with binary discrete choice (DC) questions, due to strategic behaviour by the respondents that may give very large values for WTP responses. Nonetheless, based on evidence from previous studies, Carson and Groves (2007) believe that the WTP values from binary DC were larger than those for open-ended questions due to the large portion of zero responses. Generally,

consumers buy ordinary goods at a given price and are never asked to pay for the maximum amount they could afford because it is not easy for consumers to place a monetary value on a good in question. If a researcher provides a respondent with information about the good itself and not the cost, this may cause ambiguity for the respondent because the price is not given and thus leads to a very high rate of zero response.

Overall, to overcome or minimize the adverse effects, mechanisms such as Becker-DeGroot-Marschak (1964) , and Vickrey (1961) auctions are used in the survey context to elicit WTP in an incentive compatible manner, to elicit truth-telling and truthful elicitation. The Becker-DeGroot-Marschak (BDM) mechanism with an open-ended format is said to be incentive compatible to elicit WTP truthful responses.

The BDM methodology involves formulating a bid. The bid value should be compared with a pre-determined random value. If the individual's bid is lower than the pre-determined value, the person receives nothing and pays nothing. But the individual will receive the item and pay when his/her bid value equals or more than preset amount. Another way to do this is to present an individual with a series of monetary values.

***The bidding game*** has an auction layout; a respondent is presented with several rounds of bids and the final bid is an open-ended WTP question. The iterative bidding game format uses an initial amount, and this is then iterated several times up or down from that initial amount in increments (Randall et al., 1974). For instance, if the respondent answers 'yes', the bidding repeats increasingly to reach the respondent's highest WTP. However, in the case of a 'no' response, the biddings' value iterates and keeps decreasing in amount until the respondent answers 'yes'. These iterations could facilitate incentives and lead the respondents to consider the preferences carefully.

Nonetheless, the problem of anchoring bias in which the respondents may be influenced by the starting point value is dominant in the bidding game format. Starting point bias is often reported in the iterated bidding survey, and the respondents' final evaluation is mainly influenced by the amount of bidding that they were primarily asked (Brookshire et al., 1976; Boyle et al., 1985).

Apart from the starting point bias, there are other weaknesses such as the outliers, whose WTP answers are implausibly large, and yea-saying, which rests on the respondents' social behaviour of avoiding saying 'no'. The bidding game cannot be applied in mail surveys or in the form of any self-completed questionnaires (Bateman et al., 2002).

***The payment card or ladder approach*** was first proposed by Mitchell and Carson (1989), with the tendency to improve the open-ended and bidding games formats. This approach provides the respondent with a visual aid comprising a number of monetary values with the aim of obtaining from the respondent an unbiased maximum WTP, and then the respondents are asked to choose a number from the categorical list of values.

***The close-ended approach*** is also called binary DC, referendum or dichotomous choice. It was first introduced by Bishop and Heberlein (1979) as an alternative to open-ended format.

In the CV surveys, the open-ended WTP or WTA question is defined as a "valuation task" while the binary preference question is defined as a "choice task" in which the respondent is presented with one or a number of values to choose from (Sugden, 1999b).

The strategic bias is said to be one of the reasons for obtaining different responses from open-ended versus binary DC surveys. The binary DC question avoids the problem of iterative bidding, in which a specific value is initially offered to the respondent and then iterated up or down from that value.

The estimation of the WTP and WTA values from close-ended questions requires statistical tools because of the binary DC question layout. Moreover, the referendum format enables probability of choice by linking and relating the explanatory variables to the respondent's choice as a conditional probability (Sellar et al., 1986).

Arrow et al. (1993) recommended the use of a referendum design because of the incentive compatibility nature of this format in various circumstances. Over the years, the incentive compatible nature of the binary DC format in the CV surveys has been acknowledged by scholars (Haab and McConnell, 1997; Carson and Groves, 2007). The assumption of incentive compatibility entails a strongly worded survey for the sake of respondents understanding the questions and responding accordingly. Carson and Groves (2007) proposed that the consequential<sup>26</sup> structure question is a condition that needs to be met to yield useful and correct information through an incentivised survey. If the survey consequences were understood by respondents as having an influence on actions, then the applicability of neoclassical theory could be deemed more evident. With binary DC, the incentive properties of the survey would assume a take-it-or-leave-it condition.

Close-ended questions can be presented to respondents in two formats of **single-bounded** and **double-bounded** approaches.

*The single-bounded dichotomous choice* provides respondents with a range of predetermined bid values in which each respondent is presented with a randomly selected single bid. The bidding prices are varied randomly across the sample population and a single binary DC can be offered with different random costs to individuals to observe the distribution of WTP and WTA values.

Bishop and Heberlein (1979) initially introduced the single-bounded format by showing that the empirical distribution of WTP and WTA values are obtainable. Each respondent makes a judgment over the specified price for the good in question and decides whether

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<sup>26</sup> When the participant of the survey thinks that the decision will be made upon his/her response.

to buy or not buy by answering 'yes' or 'no'. The response to the questions generates qualitative data in the form of a bound on their WTP for the change, with "a lower bound" for the 'yes' answer and an "upper bound" for the 'no' answer (Hanemann and Kanninen, 1999).

Moreover, the problems of starting point bias, non-response rate, and extremely large values can be mitigated with the single-dichotomous format of elicitation. However, the yea-saying problem which leads to the failure of actual WTP elicitation is dominant in the single-bounded dichotomous format. Due to the starting point vulnerability, adequate pre-surveys help to determine the variation of ranges of costs in the question (Carson and Groves, 2007).

*The double-bounded dichotomous approach* has similarities with the single-bounded format but it is statistically more efficient. The addition of the second question makes a larger amount of information available to the researcher. The respondent is asked to state his/her WTP for the first bid, and if s/he answers 'yes' then they will be asked the same question for a higher amount. If the respondent does not accept the first bid and rejects it then they will be asked the same question with a lower amount.

The double-bounded format was first proposed by Hanemann (1984) and then initially used by Carson and Steinberg (1990). Hanemann et al. (1991, p. 218) stated that the "double-bounded dichotomous choice CV model is asymptotically<sup>27</sup> more efficient than the single-bounded model," and also found that the WTP confidence interval was significantly minimised for the double-bounded data set. The double-bounded dichotomous choice has become a dominant approach in environmental valuation studies

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<sup>27</sup> The efficiencies and the relative efficiency of two procedures theoretically depend on the sample size available for the given procedure. An asymptotically efficient estimator tends to the theoretical limit as the sample size grows.

because of the capability to facilitate tighter confidence intervals of WTP distribution (Carson and Groves, 2007).

The double-bounded format eases the possibility of four levels of WTP responses from the lowest to the highest (Carson and Steinberg, 1990; Hanemann et al., 1991; McLeod and Bergland, 1999; Bateman et al., 2002) as follows:

1. Response is “no” and “no”
2. Response is “no” and “yes”
3. Response is “yes” and “no”
4. Response is “yes” and “yes”

Comparable to the iterative bidding game approach, single-bounded and double-bounded approaches suffer from the incidence of starting point bias (Boyle et al., 1985); however, there are differences between these two formats. In the bidding approach, the initial cost never deliberates to expose information about the good’s actual value, and the iterative stages from that amount are not usually large.

Following the notion of perfect correlation between WTP distributions from the first and second questions, Cameron and Quiggin (1994) examined the correlation of WTP distribution from the responses to the first versus the second question of dichotomous choice. The findings indicated that there is an imperfect correlation between the WTP distribution of the first and second questions. In addition, the estimation of WTP values from the first question was greater than the WTP values from the second question, implying a higher possibility of more negative responses to the second question.

Further than the prediction of imperfect correlation between the WTP values from the first and second questions, more precise assumptions about an individual’s beliefs are

brought to light, including “uncertainty surrounding<sup>28</sup> the second price”, where the individual is “willing to bargain over the price”<sup>29</sup>, “weighted average”<sup>30</sup>, and “the signal given by the second price”<sup>31</sup> (Carson and Groves, 2007, p.196). Eventually, on the basis of the robust empirical evidence, Carson and Groves (2007) postulated that the WTP estimates with a double-bounded format are smaller than with the single-bounded format.

Each of these formats has positive features and weaknesses that constitute the nature of the formats, which makes them distinct from each other. The selection of a format could be decided on the basis of the nature of the good in question, the mode of the survey and its costs, the target population’s characteristics, and the requirements of statistical analysis by the study.

Table 3.1 Elicitation formats: some stylised facts

<b>Open-ended</b>	Large number of zero responses, few small positive responses.
<b>Bidding game</b>	Final estimate shows dependence on starting point used.
<b>Payment card</b>	Weak dependence of estimate on amount used in the card.
<b>Single-bounded</b>	Estimates typically higher than other formats.

<sup>28</sup> This assumption is consistent with the theory of an individual’s risk aversion. It leads the distribution of mean and median WTP in the second question downward relative to the responses implied from the first question under the same preference condition.

<sup>29</sup> A ‘no’ answer to the first question would be generally followed by an offer of lower price in the second question; the individual optimal answer could be a ‘no’ again in hopes of being offered an even lower price. The same effect can be presumed with the yes answer to the original price (first offer). It is not surprising if a respondent answers ‘yes’ to the first question then answers ‘no’ to the second one, even if the WTP exceeds the second price. The effect of such behaviour would make the WTP distribution inferior and oblique by the second question; therefore, it shrinks the assessment of the mean and median of WTP.

<sup>30</sup> An individual believes that the actual cost would be an amount equal to the weighted average of the two prices. Under this assumption, the second question should be responded based on the weighted average. For an initial ‘no’ response, the weighted average of the first and second prices is larger than the second price. For an initial ‘yes’ response, the weighted average of the first and second prices would be smaller than the second price and alleviates the upward effect of price averaging (Carson and Groves, 2007).

<sup>31</sup> It can be implied that the quantity or quality of a good would change in accordance with the changed price.

<b>Double-bounded</b>	The two responses do not correspond to the same underlying WTP dichotomous choice distribution.
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Source: Bateman *et al.* (2002, p.142)

Overall, CV can estimate WTP and WTA via the above-mentioned formats in Table 3.1, and a review of their dissimilarities provides us with the opportunity to select an appropriate design based on our study features and constraints.

### 3.3 CV validity

One of the objectives of the Exxon Valdez argument was to determine the validity of the CV technique, particularly in passive use values' application. In 1993, a series of critical studies on CV technique was edited by Hausman (1993), and this was followed by the Blue Ribbon Panel. The panel was assembled by the National Oceanic and Atmospheric Administration (NOAA) to resolve the suspicions regarding CV estimation for non-use values, and guidelines<sup>32</sup> for CV practice were established. The judgment on the external validity of CV arose from experiments of "state-of-the-art CV"<sup>33</sup> (Arrow et al., 1993, p.9), which were used to compare CV to real behavioural WTP for goods which could be sold and bought in the market place. An over-estimation of WTP by CV estimation was observed, however, by Arrow et al. (1993), who pointed out that the problem is not associated with the CV method and must commonly occur with any method in the case of passive use valuation. Furthermore, Carson and Groves (2007) suggested that the problem of overriding rational responses arises from the use of hypothetical words in the survey.

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<sup>32</sup> The following guidelines need to be met with a good quality CV survey to assure the reliability and usefulness of the information. Conservative Design - Elicitation Format - Referendum Format - Personal Interview - Accurate Description of the Programme or Policy - Pre-testing of Photographs - Reminder of Substitute Commodities - Adequate Time Lapse from the Accident - Temporal Averaging - No-answer Option - Yes/No Follow-ups - Cross-Tabulations - Checks on Understanding and Acceptance. For further explanation see Haab and McConnell (2002, p.20) or Arrow et al. (1993, p.30-35).

<sup>33</sup> A comparison between the CV studies with the real behavioural WTP for the tradable goods.

The panel remarked on the following problems regarding the external validation of CV:

1. CV can yield values which may be inconsistent with rational choice<sup>34</sup>
2. Responses to a CV survey seem incredibly large
3. Budget constraints influence the respondents
4. There are difficulties with elicitation and providing sufficient information in the case of policy alternatives for which individuals may not be familiar with the policy issues.
5. Difficulties inherent with aggregation due to “extent of the market”<sup>35</sup>
6. The “warm glow”, a voluntary payment, whereby individuals either have a feeling to donate or pay nothing, and in that sense CV survey estimation is unreliable and it does not reveal the true WTP.

The panel suggested a means for validating and standardising the CV method such as a referendum format, real-life referenda, a payment mechanism (e.g. an increase in property taxes), and CV-like studies (Arrow et al., 1993). The comparison of CV-like studies with real-life or real-world referenda would be useful proof of the validity of the CV method.

### **3.4 Types of validity testing and inherent problems**

In response to the inherent problem with the design of CV studies, the NOAA Panel developed a list of guidelines for CV studies and stated that, “the burden of proof of reliability must rest on the survey designers. They must show through pre-testing or other experiments that their survey does not suffer from the problems that these guidelines are intended to avoid”. (Arrow et al., 1993, p.37)

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<sup>34</sup> For rationality, an individual seeks the most cost-effective good, and calculates the cost and benefit of the good before making a decision. Individual behaviour is grounded in microeconomic models. Individuals make a rational choice when they think the alternative outcomes and courses of action are the best choice..

<sup>35</sup> Representatives on behalf of a definable group limit the population that is suitable for the study, even though individuals outside this group may experience the same loss of passive and active use.

Validity problems grow from the presence of the bias in which the stated WTP and/or WTA values differ from the actual<sup>36</sup> or formulated<sup>37</sup> values. The validity of the specified payment or compensation mechanism should be established via pre-survey qualitative analysis, explicit survey responses and post-survey debriefing. Table 3.2 summarises types of validity testing.

The CV practitioner can appeal to simulated markets as a method for validating the research findings. In the case of simulated markets particularly, a range of techniques have been developed to design a survey in an incentive compatible manner, characterised by its truth-telling nature. Table 3.1 shows the types of validity testing explained by Bateman et al. (2002).

To examine content validity, three features need to be considered. First, the study design and execution of the survey should be implemented in such a way that sufficient quality data are collected and validity testing may be carried out. This can be done through surveys prior to the beginning of the main study (i.e. focus groups, piloting, and interviews). In addition, “within the confines of incentive compatibility and informational limits”, the objective of the study should be made clear during the survey to handle sufficient and accurate data for the subsequent programming process. Secondly, a good in question and its relevant features provides adequate and clear information regarding suggested changes versus status quo (do nothing), to allow respondents to make decisions easily. Respondents should be presented with adequate information without ambiguity in such a manner that they can easily make a decision. Thirdly, the content validity in terms of the identified amount of payment and compensation should be assessed through both pre-studies and post-survey debriefing. The assessment should inspect the

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<sup>36</sup> The WTP or WTA amount that an individual actually pays or accepts for changes.

<sup>37</sup> The WTP or WTA amount that an individual genuinely believes they would be ready to pay or accept for changes.

“appropriateness” of the welfare measure, the “acceptability” of the measure for property rights<sup>38</sup>, and the “credibility” of the consecutive numbers of the payment (i.e. lump sum, monthly, and yearly), which should be reliable and relevant to the attribute of the good in question (Bateman et al., 2002, p.308, 310).

In addition, convergent validity needs to be undertaken to assess the validity of a survey. This can be done by comparing measured values from different methods such as comparing CV with revealed preference (RP), and also by a comparison between the findings from the actual market with the simulated market CV study. Moreover, the expectation based validity assesses the theoretical expectations, including sequence, scope and embedding.

Table 3.2 Types of validity testing

Content/face validity	This assesses whether the CV study asked the right questions in a clear, understandable, sensible and appropriate manner, to obtain a valid estimate of the construct (say maximum WTP for a specific good) under investigation.
Construct validity	This examines whether the relationships between measures produced by a CV study and other measures are in accordance with expectations.
Convergent validity	Measures obtained from a given CV study are compared with some combination of: * results obtained from other valuation approaches such as the travel cost and hedonic pricing methods; * the findings of cross-study analyses or benefits transfer exercises); * and simulated markets such as those used in experimental tests
Expectation-based validity	Theoretical expectations derived from economic theory; and intuition and empirically driven expectations derived from prior intuition and regularities across prior studies.

Source: Bateman et al. (2002, p.304)

<sup>38</sup>Mitchell and Carson (1989) used property rights to circumvent a larger WTA compensation value compared with the WTP value for welfare projects, with the aim of comparing reductions with the increase in the current level of public goods.

Basically, the purpose of the CV is to elicit unbiased preferences. Typically, CV develops under the assumption that respondents have preferences consistent with standard economic theory and that they use these preferences to determine valuation. However, it has been seen that this consistency may not always be traced by standard economic theory (Sugden, 1999a; Sugden, 1999b). From the rational choice perspective, responses can be affected by inappropriate information such as a starting-point for the repeated bidding, and the elicitation of a higher value with binary choice versus open-ended question. Additional explanations of the hypothetical bias and the CV survey problem in eliciting preferences rests on the psychological theories of decision making, such as reference-dependent preferences.

Carson and Groves (2007) argued that serious attention should be paid to the incentive and informational properties of preference questions because of inherent difficulties with interpreting the behavioural anomaly. They argue that to address individuals' preferences towards different offers of products or policy services, a standard economic model has predictive power only under consequential<sup>39</sup> circumstances as opposed to inconsequential.<sup>40</sup> Carson and Groves (2007) demonstrated that a consequential survey offers incentives to respond in the direction which is predicted by the standard economic theory. A rational decision maker can take the incentive structure of a consequential survey into account along with the information delivered in the survey itself and views about the possibility of using that information. Thus, the possibility of truthfully gathering responses should not be dismissed. Truth-telling and utility maximisations are both concerns in the design of CV questions as underlying incentive compatible mechanisms. Incentive compatibility is one of the major applications of validity analysis.

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<sup>39</sup> The participant of the survey thinks that the decision would be made upon his/her response, and so s/he would care about the survey outcome.

<sup>40</sup> No changes or decisions would be made to the provision of the good in question upon the respondents' answer to the question.

### **3.5 Elicitation and response mode effect**

“A CV instrument is descriptive rather than explanatory, [and] seeks to find the average WTP for a specific environmental improvement”. (Arrow et al., 1993, p.18). The outcome of the CV survey may be at risk of the response effect, which emerges from the individual’s attitudes toward the survey and any wording difficulties. In the following subsections, response effects are defined.

#### **3.5.1 *The embedding effect***

The embedding effect is also called part-whole bias, the symbolic effect, and the disaggregation effect. The evaluation of WTP for a good may vary when the same good is valued either as part of an inclusive package or on its own regardless of its size. Mitchell and Carson (1981) documented the possibility of the embedding effect in a CV survey, and supposed that this effect is not inevitable. This inference was drawn based on the evidence from examination of WTP for improving water quality nationwide, which was only twice as large as the WTP for raising the water quality in the Monongahela River system in Pennsylvania. The embedding effect not only influences non-use values but also has an impact on use values. Randall and Hoehn (1996, p.379) showed that “incomplete<sup>41</sup> expenditure maximisation would lead a CV respondent to underestimate her true Hicksian compensating welfare measure”. Therefore, this would lead to underestimating values for WTP and overestimating values for WTA. Moreover, Hanemann (1991) indicated that the embedding effects are greater and more noticeable in policy goods than market goods. According to Kahneman and Knetsch (1992), embedding reduces the reliability of the CV technique and can suggest that CV is an unreliable technique due to the dissimilarity of the results in different assessments. Embedding raises the issues of assigning the proper level of embedding for policy

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<sup>41</sup> When the discretionary income is reduced and theory expects that the effects of embedding will be increased.

analysis. Embedding effects will occur once a respondent interprets the survey's question as this may differ from what the investigator means. This is not a specific case with the CV method, but there is a possibility that CV intensifies these effects. Embedding occurs in the economic valuation of private and public goods in either the stated preference or revealed preference methods. Overall, the miscommunication between the researcher and respondent could increase any embedding effect. By avoiding a poor study design and unclear survey instrument, the likelihood of improvement in the technique can be augmented.

### ***3.5.2 The scope effect***

Scope is one theoretical expectation following from economic theory, and is a debated point for validity testing. The quantity of a good grows or reduces, and a change in the scope of the good occurs (i.e. when the consideration of a project with 120 hectares preservation of wetland modifies to another project with 170 hectares protection of the same wetland). The scope test deals with perceiving changes in the WTP estimates as the quantity or quality of the good reduces or increases (Bateman et al., 2002). Carson et al. (1996, p.4) reported the findings from the summary of the first CV studies whose surveys adhered to the NOAA Panel guidelines, particularly the scope test. Generally speaking, a smaller WTP was found for smaller amounts of an environmental product or service to “meet the scope test of the burden of proof requirement”. The study concluded that the panel's guidelines and the protocol for CV study were an eminent set of construction, administration, and analysis, but these criteria regarding the validity test can possibly be reduced. The errors caused in the survey from scope bias are mainly seen to derive from sampling, survey design, and the implementation of the questionnaire. The scope effect can be tackled by using various visual aids to clarify the scenario to increase respondents' understanding about the question and the good itself (Bateman et al., 2004).

### 3.5.3 *The sequencing effect*

The sequencing effect is also called question order bias. In the case of policy and government resolutions, an independent valuation of the benefit assessment of the goods might be substantially large. The improvement in “cost benefit practice<sup>42</sup> limits alternatives to either one-shot, holistic evaluation or a sequenced approach” (Hoehn and Randall, 1989, p.550). Hoehn and Randall (1991) notified the probability of the overstatement of the benefits of policy changes, even for a quite small number of policy constituents with an independent valuation.

In the WTP survey, the order of questions can affect the respondent’s valuation. The survey design and administration in terms of sequences of questions should therefore be implemented in such a way that complete information is delivered to the respondents prior to the elicitation of their response.

Economic theory suggests that the specific values attained should be different along the sequence. The good presented at the top acquires larger stated values for WTP than the same good presented lower down in the sequence, and the economic justification for this discrepancy rests on the income and substitution effect. Normally, the divergence for a single good is substantial, and WTP and WTA sequences move conversely; thus, the “WTA for a good valued in any order in a sequence should be larger than WTP for a good valued first in a sequence” (Carson, 1997). In addition, Carson et al. (1998) showed that the effect arises in the WTA sequence through the limited number of substitute goods and income effects. Once the sequence develops, the later the good is valued in a sequence, the lower the value it obtains. Consistently, when normal goods are valued with Hicksian

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<sup>42</sup> The component valuations amount is single and the sequenced component valuations are different and would be selected in the sequence of valuation. For further detail see Hoehn and Randall (1989).

substitutes for each other, the value of that good gradually decreases when the later WTP is valued individually.

### **3.6 CV limitations**

Mitchell and Carson (1981) estimated the inherent benefits of water quality, such as the option and bequest value, by adopting a CV or WTP survey method. The research was developed through the pre-testing instruments and then extended to a larger scale. The data were analysed further than only determining the biases, but the extent and type of the biases, which were associated with WTP surveys, were estimated. Following this study, Mitchell and Carson (1989) identified the principal biases of the CV technique or WTP estimation as follows.

#### **3.6.1 *Strategic bias***

Strategic bias arises from the respondent's untrue stated WTP amount, that is, if the question is not answered truthfully. Untruthful answers can occur as a result of the unclear design and wording of the survey questions, or sometimes respondents intentionally show an implausible attitude toward the provision of the good in question. For instance, the respondent sometimes attempts to overestimate the value of the good in order to fulfil the agency's expectations, or the respondent may intentionally underestimate the good's value in order to influence the provision and cost. "The proposed solution to this perceived problem is to use an 'incentive compatible' elicitation procedure" (Bateman et al., 2002, p.380). Thus, the format and design of the survey is a key factor for preventing the strategic bias. Carson (2005) explained that insufficient information about environmental goods in CV questions leads to a large number of non-responses on the basis of psychological issues. Bateman et al. (2002) pointed out that the design of CV survey should facilitate the truth-telling mechanism and utility maximization correspondingly, as they are not always consistent. A survey should be

designed in such way as to encourage respondents to attend and answer truthfully. In the case of non-market goods, particularly unfamiliar or new goods, respondents' uncertainty may not lead them to express their true values.

### **3.6.2 *Hypothetical bias***

The CV elicitation can be biased due to the hypothetical nature of the question. Hypothetical bias can be defined as the difference between the estimated and the actual payment. Respondents usually do not state their true values under the hypothetical assumption and typically evaluate the cost and WTP question differently in the actual market. Hanemann (1985) pointed out that the hypothetical bias is the most serious problem of the CV approach, particularly in WTA or selling items' evaluation rather than WTP or purchasing goods' evaluation. Under the assumption that CV formats affect the pattern of responses, Hoehn and Randall (1987) found that the variation of responses was due to the insufficient information given to the respondents. Hoehn and Randall (1987) stated that "the routine market trade-offs are on prospect rather than experience," as people buy an ordinary product in the real market based on previous experiences and information in the market. However, in a conventional CV survey people have to make a decision on a hypothetically conditional or contingent market, based on assumptions and information provided in the question or the researcher's explanations. This is related to the hypothesis and assumed condition that is consistent with the term contingent in a CV survey. Cummings et al. (1995) compared the proportion of 'yes' answers to the specified amount for various private goods. They found that 'yes' answers in the real treatment are lower compared to the hypothetical treatment.

CV is more likely to apply to the policy changes which are generally seen as unfamiliar goods for the households. If this is the case, in addition to the problem of hypothetical condition or contingent market, individuals' lack of information concerning policy

choices exacerbates the bias of the CV outcome compared with the evaluation of an ordinary good in the real market. A condition closer to the real market or the greater familiarity of the respondents to the good in question lends support to truthful elicitation. Bjornstad et al. (1997) introduced a learning opportunity with the CV design in that the hypothetical choice was led by a real choice. As a result, a hypothetical bias was evidenced by comparing findings from the two conventional and learning CV designs, due to the significant differences between real and hypothetical valuation.

There are two ways to correct the hypothetical responses of the laboratory outcomes and to mitigate laboratory differences in wording and information. The two ways of mitigating hypothetical bias are: 1) “statistical calibration”, and 2) “instrument calibration”, which were recommended by Cummings et al. (1997, p.619). Overall, the burden of thinking and answering questions may be relieved psychologically by placing incentives that have an impact on the truthfulness of the responses (Bateman et al., 2002). Carson and Groves (2010) believe that the test of hypothetical bias lies in the properties of consequential against inconsequential questions in terms of the incentives respondents face in answering the question. The hypothetical bias arises from inappropriate experimental assessment such as inconsequential treatment or from voluntary contributions for purchasing new products. This voluntary contribution is so called free-riding, that is not incentive compatible and leads respondents to understate their valuation. However, with the consequential survey, respondents may think that the good will be available in the future and will then have an option to purchase the good later. This provides respondents with an incentive to overstate their valuation, which is consistent with neoclassical economic theory. “Neoclassical theory suggests the survey should overestimate the true WTP while actual contributions should underestimate true WTP” (Carson and Groves 2011, p.303).

Carson and Groves (2007) recommended avoiding usage of the term ‘hypothetical’ to reflect preference questions for consequential and inconsequential surveys in the application of economic theory. Carson and Groves (2011) suggest using cheap-talk in the survey to tackle the hypothetical bias. The term cheap-talk is used in game theory<sup>43</sup> to prevent the dominant strategy in that one has no incentive to lie in the game, the so called the equilibrium strategy. This strategy was explained as occurring when players share information consistently and on balance with incentives. Once an informed person says something about a problem to uninformed recipients, who then take actions based on their ideas and information provided. In particular, incentives persuade truthful revelation by a recipient when others are present (Farrell and Gibbons, 1989; Farrell and Rabin, 1996). The “talk signal is not costless to send, [and] the economic value of the signal need not be zero and can be calculated for each party as the difference in economic value of the outcomes achieved with and without its use” (Carson and Groves, 2011, p.304).

### ***3.6.3 Starting point bias or value cue bias***

The initial bidding amount that is specified by the interviewer may cause a biased response, called the starting point bias. The value cue bias occurs when a respondent explicitly or implicitly is influenced by one or a range of presented amounts of payment (WTP) from the elicitation format. This will arise when the individual’s WTP is correlated. In the case of iteration, if the respondent is willing to pay, the interviewer increases the bid to the maximum WTP, one level before a negative response. The negative response to the initial bid leads to downward bids until a positive response from the respondent is recorded. This would be implemented in a reverse manner for WTA

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<sup>43</sup>Hurwicz (1973) initially introduced ‘the game of mechanism design’ and was awarded a Nobel Prize in 2007. The theory of mechanism design supports ‘incentive compatibility’, which is derived from group choices and decisions in economic contexts.

evaluation. This bias is not only specific to the starting point bias, as there are other forms such as range bias, importance bias, and position bias. Boyle et al. (1985) explained that starting point bias may be related to the hypothetical or simulated market, as individuals are not familiar with how to place value on environmental amenities that are non-tradable in the market. Their study established a suspicion of the use of the iterative bidding mode for cost evaluation in the context of environmental amenities.

#### ***3.6.4 Part-whole bias***

The part-whole bias is a kind of scenario misspecification bias. This bias appears when the scenario of the survey is correct but it is not understandable for respondents. It would result in collecting incorrect answers, where the respondent's values are larger and broader or smaller and narrower than the researcher intended them to be. Mitchell and Carson (1989) stated that part-whole bias can arise from main deficiencies in the design of a survey instrument as well as the lack of ability of individuals to respond. Bateman et al. (1997) evidenced the existence of part-whole bias in the individual's preferences when elicited by the conventional CV method compared to an incentive compatible designed survey. However, based on the Hicksian consumer theory, Bateman et al. (1997) explained that this inconsistency may arise from individuals' preferences and valuations of goods and may not be associated with the CV technique. Furthermore, Bateman et al. (2002) defined part-whole bias as occurring when the respondent evaluates a good in the case of geographical, benefit, and policy instances with a larger or smaller unit than the experimenter intended to observe. The part-whole effect is similar to the concepts of scope and embedding effects, where the set of goods was valued independently, the sums may surpass the value of the same set of goods when valued totally.

### 3.7 WTA and WTP disparity

WTP and WTA are the two measures of economic values. Both of these measures are Hicksian consumer surplus measures presenting the paid or received price. Over the years, the CV method has been used to estimate WTP for gaining an increment of a good and WTA compensation for relinquishing the same unit of the good. A number of studies have been carried out to compare the findings of the hypothetical market with a real market. Thus far, apart from the field surveys, laboratory experiments for evaluation of preferences have become general practice (Knetsch and Sinden, 1984; Knetsch, 1989; Eisenberger and Weber, 1995).

Over the last three decades, a preference anomaly has often been observed in different field surveys, in that mean and median value of WTA exceeds WTP value in the same setting (Rowe et al., 1980; Viscusi et al., 1987). Bishop and Heberlein (1979) carried out a study on the valuation of goose hunting permits based on CV hypothetical measurement of willingness to sell. The stated values to the hypothetical willingness to sell were substantially overestimated, whereas the WTP question was answered more accurately and truthfully. Moreover, Knetsch and Sinden (1984) reported a large disparity between WTA and WTP due to underestimating the value of gains or overestimating the value of losses. Such behaviour was explained as irrational and one which would result in a lower level of well-being than a true utility-maximising manner.

Bateman et.al (2002) explained the five key elements with reference to the WTA/WTP gap that derives from a larger WTA values. Firstly, it is essential to know theoretically to what extent the gap can diverge. In many empirical surveys, environmental economists seek to gain money measures of welfare changes associated with the quantity changes (Mäler, 1974) imposed to the environmental amenities, not the price changes (Willig, 1976). Randall and Stoll (1980) found that the people's WTA and WTP for

modifications in environmental amenities should not diverge significantly except when there are odd income effects. However, underpinning quantity changes, Hanemann (1991) stated that WTA and WTP may be far apart. Hanemann showed that the WTA and WTP values are inconsistent and unequal and the magnitude of the gap would be large if subject to income and substitutability effects. Carson et al. (2001, p.184) clarified the positive connection between income and WTP for private goods. By categorising the environmental commodities as luxury goods, Carson et al. (2001) defined these goods by income elasticities of demand. The income elasticity of demand indicates demand increases as income increases where “the income elasticity of WTP looks at how WTP for a fixed quantity of the good changes as income increases”. Because luxury goods are not as necessary as normal goods, the income elasticity of WTP is likely to be smaller than the equivalent income elasticity of demand.

Secondly, there are sizable divergences due to behavioural reasons in contrast with neoclassical economic theory (Kahneman and Tversky, 1979). This has been explained through other studies with no intention of undermining Hanemann’s view that WTA/WTP discrepancy subject to income effect can be insignificant or trivial (Sugden, 1999b). Instead, divergence may develop from bargaining strategies, risk aversion, reference-dependence, and endowment effects. Several experiments have tried to categorise the two alternative explanations of strategic bias and reference-dependent preferences (Coursey et al., 1987; Kahneman et al., 1990; Shogren et al., 1994). Knetsch and Sinden (1984) used a psychological design<sup>44</sup> to control the divergence with the implication of independence from income effect. The study was formed by several groups of respondents from a common pool of individuals, with no systematic dissimilarity

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<sup>44</sup> Individuals were split at random into two groups. In one group, every individual was endowed with \$3 and offered a lottery ticket for \$3. In another group, individuals were endowed with a lottery ticket and then offered the opportunity to sell the ticket for \$3. Importantly, in each case, the participants were offered the same choice between the two options of \$3 and the lottery ticket.

between the groups. Furthermore, Kahneman et al. (1990) incorporated the endowment effect into utility theory<sup>45</sup> to examine bargaining strategy as an alternative explanation for the buying and selling discrepancy. The results show that the use of inducements in the experiment helped respondents to reveal true preferences. From the findings, Kahneman et al. (1990) concluded that endowment effects and loss aversion are the fundamental traits of preferences. Underpinning the substitution effect, some believe that the initial bidding governs the endowment effect. A number of studies have suggested the use of some experiments to control for these effects such as first-price auction, second-price auction, and *n*th-price auction, to eliminate the substitution and endowment effects. Shogren et al. (2000) suggested that the endowment effect can be evaded through repetitions of second-price, sealed bid or random *n*th-price auctions (Kolstad and Guzman, 1998; List, 2011). In addition to substitution and endowment theories, Kolstad and Guzman (1998) developed an auction equilibrium model to teach the bidders how to truly respond in return for spending effort and money. They showed that a divergence between WTA and WTP usually appears and it increases with a larger cost of gaining information. Moreover, the relation between behavioural critique and neoclassical theory can be inconsistent, and this problem arises from the divergence of the implicit preferences, responses to the choice, and corresponding questions (Carson and Groves, 2011). “Indeed, the failure of description” in respect of the nature of the information’s “framing effects” or incentive structure “elicitation effects” for truth-telling “poses a greater problem for the rational choice model” (Tversky et al., 1990, p.215). Changes to

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<sup>45</sup>A random allocation design was used to test for the incidence of endowment effect through the series of experiments involving real selling and buying of tokens and different consumption of goods. The sample study split randomly into two groups, where one group was endowed with a good and became potential sellers and the other group became potential buyers. Each individual traded induced-value tokens, which was redeemable for money. The market for prompted value token was used as a control condition to determine whether dissimilarities between the values of buyers and sellers in other markets could be reflected by transaction costs, misunderstandings, and strategies of bargaining.

the reference point or status quo often lead to reversals of preference (Tversky and Kahneman, 1991), underlying the assumption that losses usually have a greater impact or influence on the respondent's choice than gains.

Moreover, the results from studies of market goods by several authors (Coursey et al., 1987; Knetsch and Sinden, 1984; Shogren et al., 1994) have suggested that divergence can be eliminated by market experience. However, both Kahneman and Tversky (1979) and Shogren et al. (1994) made an opposing suggestion for non-market goods. On the basis of the findings from real trade markets for pins, sport cards and sports memorabilia, List (2003; 2004) explained the importance of market experience in leading the behaviour being consistent with neoclassical expectations. The field experiments and results suggest that market experience and the endowment effect are negatively associated. Further to the earlier field experiments, List (2011) indicated the great impact of market experience on eliminating the inconsistency of values and market anomalies.

Thirdly, WTA/WTP differences exist in market transactions (Kahneman et al., 1990) and is not necessarily a CV survey problem. Horowitz and McConnell (2002) suggest that the ratio of WTA/WTP is nearly the same in both survey and actual transactions. Fourthly, the WTA/WTP discrepancy is not specifically allied with stated preference versus revealed preference techniques. Fifthly, in the case of the large divergence the WTA measure can have considerable implications. Horowitz and McConnell (2002) analysed 45 studies which had reported WTA and WTP values and found the mean WTA/WTP ratio was approximately seven; with a higher WTA/WTP ratio (10.4:1) for public and non-market goods, and a ratio of (2.9:1) for ordinary private goods, with the lowest ratio being for experiments involving forms of money.

Hanemann (1991) stated that the disparity can be diminished by the way in which questions are asked and the way survey is designed. Overall, the observed WTA/WTP

discrepancy not only needs to be reviewed by theoretical issues, but also needs to be inspected in terms of the survey design and content validity. In terms of validity, the discrepancy between WTA/WTP values may be overestimated as a result of a poor design, refusal of the expected WTA property rights, and unfamiliarity with the good in question. Therefore, the WTA/WTP discrepancy should be regarded as a theoretical problem and a content validity concern.

### **3.8 Experimental mechanisms to test CV validity particularly WTA/WTP gap**

Numerous studies have used CV to measure WTA and WTP for non-use and existence values in the field of environmental economics (Seller et al., 1985; Whittington et al., 1990; McFadden, 1994; Carson, 1997; Alvarez-Farizo et al., 1999; Bateman and Willis, 1999; Carson, 2000; Bateman et al., 2002; Haab and McConnell, 2002; Venkatachalam, 2004; Carson and Hanemann, 2005). Bishop et al. (1983) explained the discrepancy as an anomaly arising from people's unawareness of the value of environmental assets and non-market values in monetary terms. Haab and McConnell (2002) suggested that the proportion of the difference between WTA and WTP for private goods, such as pens and mugs, cannot be the same as public goods, and this notion challenges Haneman's assumption based on neoclassical theory. According to neoclassical theory, the income constraint limits the value of WTP. Unlike WTP, WTA is not constrained by income because consumers are able to demand greater monetary amounts. In conjunction with this, the substitution effect of goods was proposed by Hanemann (1991). However, in order to address the gap between WTA and WTP, uncovering other potential explanations based on the economics of choice has become a subject of study.

Rabin (1998) and other scholars have noted a gap between the individual's behaviour and psychological attitudes and neoclassical economic theory. Explanations for an individual's behaviour have been sought in the concepts of 'endowment effect' (Thaler,

1980) ,‘prospect theory’ (Kahneman and Tversky, 1979), ‘the loss aversion effect, reference point’ (Tversky and Kahneman, 1991), and ‘status quo bias’(Samuelson and Zeckhauser, 1988). It is generally accepted that consumers may behave strategically and overestimate WTA to gain more compensation or underestimate WTP to save money. Brookshire and Coursey (1987) argued that the gap would never be eliminated, whereas Carson and Groves (2007) claimed that incentive compatibility or ‘consequential’ questions may minimise the discrepancy. In survey instruments different systematic biases have been observed by CV practitioners. Sugden (1999b) suggested the use of a well-designed instrument to facilitate the minimisation of these biases to elicit true preferences in accordance with an incentive compatible mechanism. In attempting to weaken the endowment effect, Plott and Zeiler (2005) proposed the need to control subjects’ misconceptions. This effect can be controlled by using an incentive compatible elicitation mechanism to clarify the minimum WTA and maximum WTP terminologies. Bjornstad et al. (1997) proposed a teaching mechanism to simplify the CV technique, on the basis that the parametric and non-parametric results which suggested that the impact of “learning design” on eliminating of hypothetical bias is highly effective. In addition to teaching and clarification tools, assuring respondents’ confidentiality is an effective tool to control the subject’s misconceptions. Furthermore, research has identified the role of an incentive compatible survey design in eliciting truthful answers in which respondents must view their responses as an effective element over actions or decisions (Carson and Groves, 2007). The potential hypothetical bias can be controlled by clarifying for the respondents what is meant by a minimum WTA and maximum WTP. Indeed, the importance of a market-like environmental setting for a decreasing ratio was recommended nearly thirty years ago by (Brookshire and Coursey, 1987).

Various mechanisms exist to elicit truthful answers directly, such as take-it-or-leave it offers, Vickrey auctions, nth-price auctions, BDM, and stated preference methods, such

as contingent valuation, choice experiments, and conjoint analysis. Neil et al. (1994) designed open-ended CV questions and used two types of hypothetical and second-bid or Vickrey<sup>46</sup> auction surveys to evaluate the same good in question. In the Vickrey auction, individuals were asked to make the real payment for the good in question from their own pocket in order to generate true results. The values from both the hypothetical and Vickrey auctions were compared and the findings indicated that an open-ended hypothetical valuation is not always capable of providing unbiased true values. However, the Vickrey auction's WTP values were lower than the hypothetical ones, and the values were closer to the real economic values. This suggests that situating individuals in a real market setting supports the use of incentive compatibility in a survey to elicit truthful answers. Similarly, Berry et al. (2012) compared the BDM and take-it-or-leave<sup>47</sup> it values of WTP for clean drinking water technology in Northern Ghana. The take-it-or-leave-it survey results showed a higher WTP compared with the BDM. The gap was explained as a possibility of strategic behaviour and the anchoring effect.

List and Gallet (2001) addressed hypothetical bias by using meta-analysis on 29 experimental studies from the literature so as to find the significant parameters that distinguish between values obtained by actual and hypothetical settings. The results suggested that normally, in the hypothetical setting, individuals behave strategically and exaggerate threefold their WTA and WTP values on average preferences. List and Gallet (2001), based on field evidence, proposed that the gap reduces as respondents' familiarity with the process increases. Moreover, the design of the survey and experimental protocol affects the deviations of both the hypothetical and actual approach. Some of the CV

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<sup>46</sup>In a sealed-bid auction, the item will be obtained by the individual who bids the highest price, but the winner pays an amount equal to the second-highest bid.

<sup>47</sup>Take-it-or-leave-it is a conventional method which asks a respondent whether he/she is willing to pay or not; if yes, they will obtain the good, otherwise not.

limitations and bias can be handled in the sense that the question is clear to every participant with different socio-demographic backgrounds. In doing so, respondents need to be provided with an introductory section, a description of the good and the manner of payment for it, but not be overwhelmed with information (Carson et al., 2001).

According to ‘prospect theory’ (Kahneman and Tversky, 1979), numerous studies demonstrate that the reference point kinks on the indifference curve around the endowment effect (Kahneman et al., 1990; List, 2004). List (2003) studied the consequences of market experience on endowment effects to investigate the role of shopping experience in consumer behaviour. The results illustrate that endowment effects decrease as experiences increase. Furthermore, List (2004) identified the endowment effect as an opportunity cost for experienced consumers. Based on the literature, a market-like setting provides opportunities to learn and minimises the impact of endowment effects and property rights. As such, it is helpful to provide respondents with incentives and learning opportunities to experience trading and bidding strategies prior to seeing WTA and WTP questions, since people are more experienced in buying goods than selling items.

### **3.9 Socio-economic and attitudinal factors**

A CV study should take into account socio-demographic and economic characteristics, because individuals may express their attitudes associated to the good in question differently owing to their different socio-economic demographic characteristics. Bateman et al. (1998) pointed out that the inclusion of socio-economic and demographic questions, such as age, education level, job and income, in the survey questions is important in a CV survey. Whittington et al. (1992) evaluated the influence of the time required to think when answering CV questions, and found that people’s responses are substantially related with their demographic characteristics, particularly level of education.

In addition, the association between stated values and actual values can be hypothesised as a basic component of theoretical validity analysis. Arrow et al. (1993) suggested the practice of cross-tabulation to test whether people follow their stated values and behave as expected. These attitudes versus socio-economic or demographic indicators in several circumstances can be a primary element underpinning the stated values (Langford et al., 2000; Kontogianni et al., 2001). The classification of cultural groups with mutual and common attitudes helps economic theory to test a hypothesis associated with stated WTP. The sample representatives' WTP responses could be influenced by the diversity of respondents' demographic characteristics, which can be aggregated over the total population. Langford et al. (2000, p.702) used a mixed methodology of quantitative and qualitative analysis to investigate different "cultural solidarities" perceptions on a common issue.

### **3.10 Theoretical framework for CV**

According to Hanemann (1999), a consumer has preferences for different market goods whose consumption is represented by vector  $x$  and for non-market environmental amenities denoted by  $q$ . This preference is the consumer utility function  $u(x, q)$ . Subject to an individual's budget constraints and disposable income  $y$ , he/she makes a choice  $\max u(x, q)$ . Following standard economic theory, indirect utility function  $V(.)$  defines the maximum amount of utility people may use from their income  $Y$ . Let  $P$  and  $Q$  represent the prices of goods and the level of provision of the non-market good respectively. In this case, the individual indirect utility function would be

$$v(y, p, q) \tag{3.1}$$

If  $q$  is supposed to be 'good' by the individual, both  $u(x, q)$  and  $v(y, p, q)$  would increase in  $q$ . If  $q$  is supposed to be 'bad' by the individual, both  $u(x, q)$  and  $v(y, p, q)$  would

decrease in  $q$ . If the individual was indifferent to  $q$ , both  $u(x, q)$  and  $v(y, p, q)$  would both be independent of  $q$ .

To evaluate individuals' utility or well-being, changes in  $q$  ( $q_0$  to  $q_1$ ) need to be valued.

Therefore, if  $q$  changes from  $q_0$  to  $q_1$ , the consumer utility changes from  $u^0 \equiv v(p, q^0, y)$  to  $u^1 \equiv v(p, q^1, y)$ .

$u^1 > u^0$       When the changes are supposed to be an improvement by the individual.

$u^0 > u^1$       When the changes are deemed to be an inferior situation by the individual.

$u^1 = u^0$       When the individual is indifferent.

Hicks (1943) measured the adjusted value to the individual in monetary terms by compensation variation  $C$  and equivalent variation  $E$ , where the  $C$  measures individuals' maximum WTP to value the change and  $E$  measures the minimum WTA of the individuals to relinquish it.

$$v(p, q^1, y - C) = v(p, q^0, y) \quad \text{and} \quad v(p, q^1, y) = v(p, q^0, y + E)$$

$$C = C(q^0, q^1, p, y) \quad \text{and} \quad E = E(q^0, q^1, p, y)$$

Observes that

$$\text{Sign}(C) = \text{sign}(E) = \text{sign}(u^1 - u^0)$$

If the change is regarded as an improvement,  $C > 0$  and  $E > 0$ ,  $C$  measures the individuals' maximum WTP to secure the change while  $E$  measures their minimum WTA to forego it. If the change is regarded as being for the worse,  $C < 0$  and  $E < 0$ , in this case,  $C$  measures the individual's WTA to endure the change while  $E$  measures their WTP to avoid it. If they are indifferent to the change,

$$C = E = 0.$$

To emphasize the dependence of the compensating and equivalent variation on (i), the starting value of  $q$ , (ii) the terminal value of  $q$ , and (iii) the value of  $(p, y)$  at which the change in  $q$  occurs, we sometimes write them as functions:  $C = C(q^0, q^1, p, y)$  and

$E = E(q^0, q^1, p, y)$ . To simplify things, we will define the WTP function as:

$$WTP(q^0, q^1, p, y) = \begin{cases} C(q^0, q^1, p, y) & \text{if } C \geq 0, \\ -E(q^0, q^1, p, y) & \text{if } C \leq 0. \end{cases} \quad (3.2)$$

(Carson and Hanemann, 2005, p.845-6).

Where  $y = e(p, q, u)$  is the expenditure function equivalent to the direct utility function and indirect utility function. WTP and WTA can be evaluated using the expenditure ( $e$ ) representation as:

$$WTP = e(p, q^0, u^1) - e(p, q^1, u^1) \quad (3.3)$$

Economic theory predicts that as price falls, the number of consumers who are willing to buy the good will increase.

In contrast, economic theory predicts that as the price increases, the number of sellers increase. WTA measures the minimum amount that the potential vendor would accept to sell or forego it. The minimum WTA can be evaluated as:

$$WTA = e(p, q^0, u^0) - e(p, q^1, u^0) \quad (3.4)$$

### 3.11 Parametric models for CV

Parametric models aim to calculate WTP from the responses to the choice questions of the CV, and they can take the individual's characteristics into account. The association between WTP responses with an individual's characteristics facilitate information on the validity and reliability of the CV technique, and aid in extrapolating sample responses to

the overall population. In other words, models with the inclusion of covariates enable the expansion of a sample to a population. Additionally, it would be useful to incorporate the covariates for CV testing such as age, income, and other demographic effects that describe the individual's preferences. To estimate the covariates models, a sample mean needs to be adjusted to its relevant population, by assessing the likelihood of 'yes' as a function of exogenous variables. However, despite the advantages of the parametric models there is a weakness, which rests on the possibility of misspecification. If the estimated model differs from the real model, then the validity assumption will not be established.

According to Haab and McConnell (2002), the parametric model can be estimated by using the random utility model as a primary point.

The WTP can be defined for the linear random utility model when the deterministic part of the preference function is linear in income and covariates:

$$v_{ij}(y_i) = \alpha_i z_j + \beta(y_i) \quad (3.5)$$

Let  $z_j$  be an m-dimensional vector of variables related with individual  $j$  and  $\alpha_i$  is an m-dimensional vector of parameters. With the CV discrete responses (yes or no) and constant marginal utility of income  $y$  between the two stated values,  $\beta_1 = \beta_0$ , the utility becomes

$$v_{1j} - v_{0j} = \alpha z_j - \beta t_j \quad (3.6)$$

Where  $\alpha = \alpha_1 - \alpha_0$  and  $\alpha z_j = \sum_{k=1}^m \alpha_k z_{jk}$ . Through the deterministic part of the stated responses, the probability of answering 'yes', where the  $\varepsilon_j \equiv \varepsilon_{1j} - \varepsilon_{0j}$  would be

$$\Pr(\text{yes}_j) = \Pr(\alpha z_j - \beta t_j + \varepsilon_j > 0) \quad (3.7)$$

WTP can be calculated by solving equations (3.8) and (3.9):

$$\alpha_1 + \beta(y_j - WTP_j) + \varepsilon_{j1} = \alpha z_j + \beta y_j + \varepsilon_{j0} \quad (3.8)$$

WTP yields

$$WTP_j = \frac{\alpha z_j}{\beta} + \frac{\varepsilon_j}{\beta} \quad (3.9)$$

Due to the sources of randomness and the individual's different preferences, two measures of central tendency can be used over the preference distribution:

1. The mean or expectation of WTP with reference to preference uncertainty:

$$E_\varepsilon(WTP_j | \alpha, \beta, z_j) = \frac{\alpha z_j}{\beta} \quad (3.10)$$

According to Slutsky's theorem on consistency, the expected WTP can be estimated by substituting the normalised parameter:

$$E_\varepsilon(WTP_j | \alpha, \beta, z_j) = \left[ \frac{\alpha}{\beta} \right] z_j \quad (3.11)$$

2. The median or 50<sup>th</sup> percentile of the distribution relating to preference uncertainty.

Where the probability of utility is 0.5:

$$\Pr \left[ \alpha_1 z_j + \beta(y_j - Md_\varepsilon) + \varepsilon_{1j} > \alpha_0 z_j + \beta y_j + \varepsilon_{0j} \right] = 0.5 \quad (3.12)$$

$$= \Pr \left[ Md_\varepsilon(WTP) > \frac{\alpha z_j}{\beta} + \varepsilon_j / \beta \right] = 0.5 \quad \text{with setting the symmetric } \varepsilon \text{ equal to zero.}$$

Then 
$$Md_\varepsilon(WTP_j | \alpha, \beta, z_j) > \frac{\alpha z_j}{\beta} \quad (3.13)$$

Equation (3.14) shows the consistency for the median of WTP:

$$E_{\varepsilon}(WTP_j | \alpha, \beta, \bar{z}) = \left[ \frac{\alpha}{\beta} \right] \bar{z} \quad (3.14)$$

Different models can expect the marginal utility of individual responses; here, we explain the logit model in brief as a further explanation is given in Chapter 4. The logit model is based on exponential distribution where the error component is assumed to be logistically distributed with zero mean and unknown variance; then, the mean value is:

$$E_{\varepsilon}(WTP_j | \alpha, \beta, z_j) = y_j - y_j \frac{\left(\frac{\sigma}{\beta}\right)\pi}{\sin((\sigma\beta\sigma\pi))} \exp\left(-\frac{\alpha}{\beta} z_j\right) \quad (3.15)$$

and the WTP median can be calculated by setting an error equal to zero:

$$Md_{\varepsilon}(WTP_j | \alpha, \beta, z_j) = y_j - y_j \exp\left(-\frac{\alpha}{\beta} z_j\right) \quad (3.16)$$

Note that the median is the same for different distributions of the unobservable error (Haab and McConnell, 2002, p.39).

Parametric models are more suitable for model testing in respect of scope or price effect testing. However, if the intention of the study is basically to estimate WTP and not necessarily to reveal the effects of covariates, then the parametric model estimation is not a necessary task and distribution-free models can accomplish this sufficiently (Haab and McConnell, 1997). In the next section, we briefly review the non-parametric approach estimation for WTP.

### 3.12 Non-parametric

To measure WTP with the parametric approach, it is necessary to specify a distribution; however, there is a possibility of distribution misspecification (Bishop and Heberlein, 1979; Hanemann, 1984). To avoid the distribution inconsistency of the parametric approach, Turnbull (1976) suggested a distribution-free lower bound mean estimate. Furthermore, an alternative non-parametric approach was proposed by (Kriström, 1990)

for higher WTP estimation, which aimed to facilitate simple computation and avoid distributional misspecification robustly.

Both non-parametric models by Turnbull and Kriström were developed on the basis of responses to discrete choice CV. Each individual's response (the yes/no) to the offered prices needs to be recorded by the researcher, for instance,  $k$  different costs are presented to  $k$  different samples with each subsample  $i$  having  $n_i$  individuals. By assuming that  $L_i$  is the population of yes-answers to  $B_i$ , the proportion of yes-answers would be  $p_i = \frac{L_i}{n_i}$ . Let  $p_1$  be the proportion of yes-answer for the lowest bid, and  $p_k$  be the proportion for the highest bid; hence, the sequence of the proportion is typically specified as  $p = (p_1, p_2, \dots, p_k)$ . The monotonically non-increasing sequence of proportions can be derived to use a suitable instruction of interpolation such as linear interpolation, as a function of the probability of 'yes' is obtained in terms of the bid amount. The mean WTP is then approximated as the area under this curve. The Turnbull Lower Bound Mean (LBM) estimate is calculated following (Haab and McConnell, 1997; Vaughan and Rodriguez, 2001; Blaine et al., 2005). The Turnbull approach produces a non-negative estimation of WTP.

$$LBM(Turnbull) = p_1 B_1 + \sum_{i=2}^k p_i (B_i - B_{i-1}) \quad (3.17)$$

The variance of the LBM can be calculated as:

$$Var(LBM) = \sum_{i=1}^k \frac{(1-p_i)(B_i - B_{i-1})}{N} \quad (3.18)$$

Several problems in estimating WTP when using the CV referendum format or DC models can be circumvented through the distribution-free approach (Haab and McConnell, 1997). The estimation of the lower bound of WTP eliminates the problems encountered in the behaviour of random WTP in the tails of the distribution. The lower

bound represents the minimum expected WTP for all the distribution of WTP ranges from zero to infinity. Given the estimates of the distribution function, Turnbull uses the information that are contained in the responses. The estimate of mean or median WTP is derived from this minimal amount of information. The Turnbull estimates the point mass at a discrete number in which median WTP falls since the median can simply be described within a range. The price for which the distribution function passes 0.5 would be a lower bound and the next highest price represents the upper bound on the range of median WTP.

In addition to LBM, Upper Bound Mean (UBM) is an estimator of the mean WTP for non-parametric estimation. UBM is the tight or least upper bound. In the same fashion as the Turnbull LBM, Haab and McConnell (2003) indicate the UBM provides a discrete stepwise estimation to the cumulative distribution function from Yes and No answers at each bid level in a referendum CV. The coefficient of variation declines as the bid intervals move from lower toward upper bound (Vaughan and Rodriguez, 2001). The UBM can be calculated from equation

$$UBM = \sum_{i=1}^m p_i (B_{i+1} - B_i) \quad (3.19)$$

The non-parametric method provides a correct approach to estimate the survival function of WTP responses to estimate the mean and median of WTP. The survival function, unlike the continuous curve of the parametric design, is a step function.

### **3.13 Summary and conclusions**

This chapter provides a thorough explanation of CV in terms of reliability, validity, and credibility based on the environmental economics literature. Different formats of CV elicitation with the inherent advantages and disadvantages were reviewed. The elicitation and information effects, validity tests, theoretical framework were described. The two

approaches of parametric and non-parametric for analysing the data were presented. To tackle the hypothetical nature of CV questions and cope with different biases, various mechanisms and tools as suggested in the literature were reviewed. To pursue the goal of eliciting truthful responses, understanding the previous studies and scholars' recommendations is invaluable. This chapter compiles a necessary review of the CV literature and applies this to the empirical study in this thesis.

## Chapter 4. Choice Modelling

### 4.1 Introduction

The non-market value of the environmental cost and benefit can be assessed through individuals' choice process (Adamowicz *et al.*, 1995; Train, 1998; Rolfe *et al.*, 1999; Hanley *et al.*, 2001; Haab and McConnell, 2002; Louviere *et al.*, 2010). To date, Choice Modelling (CM) has been applied in the field of transportation, marketing, and environmental economics. Choice analysis seeks to understand individual's choice by measuring the factors that influence an individual's preference. The identified sources<sup>48</sup> of preferences can be generalised to many alternatives to compare and measure various combinations of the attributes across alternatives. The most common setting in the non-market valuation is based on the repeated choices from two hypothetical alternatives and status quo or do nothing option. The design of the experiment from different discrete alternatives in a choice set requires specification of the type of design and model to control the experiment size. The selection of the most desirable alternative by respondents rests on the level of attribute combinations. The chosen alternative supposes to provide the highest level of utility. Choice analysis describes the variability in behavioural responses from a sampled population of individuals through discrete choice (DC) models. The DC models explain choice probabilities between two or more discrete alternatives, for instance choosing between sources of energy supply. Moreover, DC model examines the situations where the potential results are discrete, it is the choice of 'which' in contrast to 'how much' in the quantitative models with a continuous variable. In the continuous situation, demand can be estimated through regression analysis where DC can be estimated through Logistic regression or Probit regression (Train, 2009). Different forms of DC models are: Binary Logit, Binary Probit, Multinomial Probit, Multinomial Logit,

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<sup>48</sup> Through pre-studies and literature reviews.

Conditional Logit, Nested Logit, Generalized Extreme Value Models, Mixed Logit, and Latent Class.

This chapter reviews the conceptual or theoretical framework underlying discrete choice modelling. The sections of the chapter proceed as follows. Section 4.2 gives a brief overview of the development of DC models. Section 4.3 reviews behavioural choice rule. Section 4.4 reviews the underlying economic theory and derivation of the CM. Section 4.5 describes the common properties of DC models. Section 4.6 illustrates how the maximum likelihood estimates a model. Section 4.7 explains how the DC models fit the data, reviews the model of goodness fit. Section 4.7 describes how the statistical significance of coefficient or parameters can be determined. Section 4.8 reviews the DC models, namely, 4.8.1 conditional logit (CL) model and its limitations, 4.8.2 panel data 4.8.3 mixed logit (MXL) model and its derivation, random parametric (RPL) estimation 4.8.4 latent class (LC) model, 4.8.5 willingness to pay (WTP).

## **4.2 Background to discrete choice**

To date, on account of decisions' process, different models and hypothesis have been developed to be assessed in the light of people's behaviour. The choice modelling (CM) on the basis of random utility theory (Thurstone, 1927) underpins individual's choice behaviour. McFadden (1974) linked the economic theory of demand and consumer choice into the measurement of choice behaviour by introducing conditional logit model. McFadden was awarded the (2000) Nobel Prize for developing the theoretical framework in economics and the technique for analysing the DC models.

## **4.3 Behavioural choice rule**

Discrete responses are the product of optimisation when utility is maximised for users and suppliers who aim to maximise benefits (McFadden and Train, 2000). As was mentioned in the previous chapter, in economics, rationality refers to maximiser who makes choices

to maximise utility. The standard model of the choice process is a theory of the rational choice when individuals' make choices or decisions in the way that maximises their utilities. The rational behaviour assumes that the choice of one alternative amongst others provides the highest utility for the decision maker. Louviere et al., (2000) stated that the traditional microeconomic theory of consumer behaviour underlies the DC models; as the rational choice and preference are the basics of the microeconomics. Thus, the DC models can be driven under the assumption of utility maximisation theory by assuming rational decisions to attain the highest utility.

The utility can be expressed as:

$$U_{nj} = V_{nj} + \varepsilon_{nj} \quad (4.1)$$

Where  $n$  is the decision maker for alternative  $j$ . The utility of individual has two components of deterministic component  $V_n$  so called representative utility and unobservable  $\varepsilon_n$  error component including all unknown factors and covariates describing differences in choice alternatives and in individuals' choices. Deterministic or systematic component includes observable attributes. Due to the unknown nature of the error  $\varepsilon_{nj}$  to the researcher, Marschak (1960) called the choice probabilities of utility maximisation as random utility maximisation (RUM). However, choice analysis treats both deterministic and random components as a great weight to the sources of variability in behavioural responses. The representative utility with a set of weights  $\beta_{1n}$  (coefficient or parameter) forms the relative influence of each attribute to the observed sources of relative utility in which can be different for each attribute. Under the assumptions of the linear model, the representative utility is formulated in equation 4.2. Each parameter is a single fix parameter

$$V_n = \beta_{0n} + \beta_{1n}(X_{1n}) + \dots \beta_{kn}(X_{kn}) \quad (4.2)$$

The parameter of  $\beta_{on}$  represents the alternative specific constant (ASC), denotes on average all unobserved sources of utility. ASC is not related to any of the observed and measured attributes.

On the other hand, the unobserved component  $\varepsilon_{nj}$  rests on the assumption that each individual's utility has a random component or parameter. Each random parameter has a mean and standard deviation which shapes the distribution of estimated values. The simplest distribution for each random component is assumed to be independently, identically distributed (IID). The IID distribution is also called Gumbel and type I extreme value. Basically, IID extreme value distribution is similar to the normal distribution, but it assigns a logistic distribution for the errors with fatter tails than the normal distribution. This is because to some extent IID extreme value distribution is more likely to assign additional behaviour parameter than the normal distribution (Train, 2003). Further details on this section subjects is provided in the subsequent sections, but before proceeding we review the derivation of the DC model.

#### **4.4 Derivation of discrete choice model**

An individual's choice for an alternative can merely be explained on the basis of the probability of being chosen. Logically, an alternative would be chosen when provides individuals with maximum utility. Decision maker compares the utility of alternatives and choose the one with the greatest utility.

According to McFadden (1974), the probability that decision maker  $n$  chooses alternative  $i$  is equal to the probability that the utility of  $i$  is greater than or equal to the utility associated with alternative  $j$  after evaluating every alternatives in the choice set

$$P = Prob(U_{ni} > U_{nj} \forall j \neq i) \quad (4.3)$$

For the researcher is equal to

$$= Prob(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj} \forall \neq i) \quad (4.4)$$

The probability of choosing an alternative is random, because the unobserved factors are considered to be as non-deterministic random factor with zero density<sup>49</sup>  $f(\varepsilon)0$  (Train, 2009).

The analyst's lack of full information limits the analysis to a modified behavioural choice rule which states that the information available to the analyst conditions the individual decision maker's utility maximisation rule to be a random utility maximisation rule. ( Hensher et al, p. 83)

Therefore,

$$= Prob(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj} \forall \neq i) \quad (4.5)$$

The probability of an individual selecting alternative  $i$  is equivalent to the probability that the difference in the unobserved variables of utility of alternative  $j$  compared to  $i$  is less than or equal to the difference in the observed variables of utility related with alternative  $i$  compared to alternative  $j$ , once every alternative in the choice set  $j = (1, \dots, i, \dots, J)$  were evaluated.

By assuming that  $V_{nj}$  is a linear utility function, then the distribution in DC analysis with type I extreme value is

$$prob(\varepsilon_j \leq \varepsilon) = \exp(-\exp - \varepsilon) \quad (4.6)$$

'exp' is shorthand for exponential function. Note that the use of exponential in the utility

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<sup>49</sup> To make a probabilistic statement of the decision maker's choice, the joint density of the random vector can be taken into account.

$\varepsilon'_n = (\varepsilon_{n1}, \dots, \varepsilon_{nj})$  or denoted as  $f(\varepsilon_n)$ .

function makes the possibility of deducing behavioural explanation from estimation of parameters.

In equation 4.6 all information are unobserved and randomly distributed across an unknown distribution.

Thus, if the information revealed in equation 4.5 is included in equation 4.6, then,

$$prob[\varepsilon_j \leq (\varepsilon_i + V_i - V_j)] \quad (4.7)$$

The utility expression for one alternative can be contrasted with another to define what alternatives are not chosen. From the type I extreme value distribution, the probability of choosing alternative  $i$  among  $j$  choices set is

$$Prob = \frac{\exp V_i}{\sum_{j=1}^J \exp V_j}; j = 1, \dots, i, \dots, J \quad i \neq j \quad (4.8)$$

Equation 4.8, logit probability expresses the likelihood of choosing alternative  $i$  out of set of  $j$  alternatives is equivalent to the ratio or exponential of the observed utility index for alternative  $i$  to sum of the exponentials of the observed utility indices for all  $j$  alternatives, including the  $i$ th alternative. The logit model is denoted as a closed-form model because it does not use additional estimation.

Different DC models rely on the specification of the unobserved portion of utility or unobserved density factor  $f(\varepsilon_n)$ . The conditional and nested logit models structured on the closed-form and unobserved factor is IID type I extreme value. However, IID assumption has not been followed in mixed logit model as it allows estimation of the errors correlation through simulation. These models are often used to forecast how people's choices change according to their different socio - demographic scale and

alternatives' attributes. In the remaining of this chapter, some of the DC models and their common properties are defined.

#### **4.5 Common properties of discrete choice models**

In general, the DC models aim to understand the behavioural process that makes the decision maker's choice. Accordingly, the DC's first task is to specify a behavioural model for the assumed distribution and then estimate parameters of that model in order to explain individual's choices among alternatives. According to Train, (2009) the common features that are characterised to any DC models are:

1) Presenting respondents with a set of alternatives to choose from, so called choice set.

Three features must be met within each choice set:

- *Exhaustive*, all possible alternatives must be incorporated in the choice sets.
- *Mutually exclusive*, decision maker must merely pick a single alternative, not more.
- *Finite*, the number of alternative must be countable and eventually be completed counted

2) "Only differences in utility matter, the absolute level of utility is irrelevant to both the decision maker's behaviour and researcher's model, and the scale of utility is arbitrary".

(Train, 2009, p. 19)

Choice probabilities always derive from utility maximisation behaviour and random utility model. The choice probability of an alternative can be determined by comparing the utility of the potential alternatives, which in fact decision makers choose the highest utility. Hence, choice probability hinges on the difference in utility, not the absolute level of utility, and this notion applies to the measure of welfare. Equation 4.9 explains that the choice probability depends on the utilities differences.

$$P_{ni} = Prob(U_{ni} > U_{nj} \forall j \neq i) = Prob(U_{ni} - U_{nj} > 0 \quad \forall j \neq i) \quad (4.9)$$

Under the assumption that only differences in utility matter, Train (2009) has made suggestions for identification and specification of the DC models.

**ASC**- captures the average effect on utility of all factors that are not included in the model, thus, they serve a similar function to the constant in a regression model, which also captures the average effect of all included factors.

$$V_{nj} = x'_{nj}\beta + k_j \forall j \quad (4.10)$$

where  $x_{nj}$  is a vector of variable that relates to alternative  $j$  as faced by decision maker  $n$ ,  $\beta$  are coefficients of these variables, and  $k_j$  is a constant that is specific to alternative  $j$ . (Train, 2009, p. 20)

Utility models with the same difference in constants are equal, therefore one of the constants should be normalised<sup>50</sup> to zero or some other number. There is no specific rule for choosing which constant being normalised, the one is normalised to zero, termed constant variance assumption, would be left out of the model and model remains with the same constant.

Under the IID assumption, covariances are set to zero or independent, and the unobserved components are identically distributed. In spite of non-zero mean of the extreme value, mean is irrelevant and the difference between the two random terms with the same mean has a zero value. Due to underlying assumption that utility is an ordinal<sup>51</sup> measure, the scale of utility should be normalised by exercising the variance of the error term for any IID in DC models (Ben-Akiva and Lerman, 1985; Train, 2003). Generally, one of the

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<sup>50</sup> Fix one of the constants to some number, the standard procedure is to zero

<sup>51</sup> It allows for rank order between alternatives, describes consumer preferences over the two goods.

variances randomly normalises to identify each variance relative to the others (Hensher et al. 2005). The error terms in standard logit model take the logistic distribution, the non-zero mean is making no difference, due to the assumption of absolute level of utility is trivial, and variance need to be normalised<sup>52</sup>. The normalisation of the variance is identified as a typical way of the scale utility. Logit model automatically normalises<sup>53</sup> the variance of the error term or the scale of utility as they are related to each other. For example, when the utility  $V_{nj}$  multiplies by  $Q$ , then the variance of  $\varepsilon_{nj}$  changes by  $Q^2$ , so the normalisation of both error term and scale of utility is equal. Moreover, Hensher et al. (2005) defined the scale of utility<sup>54</sup> or the scale of parameter as a base reference for comparing the relative levels between alternatives in the same choice set.

Furthermore, under the assumption of Heteroskedastic error distribution, the variance of the error terms would not be the same and equal for different segments of the population. For this reason, the overall scale of utility needs to be normalised through the variance of one segment and then the variance of each segment can be estimated relative to that segment.

There is an opposite relationship between scale and random component variance in terms of their size or proportion. Small random component variances would have larger estimated model parameters and vice versa. In words, all random utility based on choice models need to be compared on the basis of the differences in the random components (Train, 2003).

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<sup>52</sup> With IID condition, Hensher et al. (2005, p. 85) suggest the variance being normalised to 1.0 and this number is suggested to be  $\frac{\pi^2}{6}$  or  $\sqrt{1.6}$  by (Train, 2009, p. 24)

<sup>53</sup> Fixes one of the unknown variance and solves the other one that is unconstrained.

<sup>54</sup> Each of the coefficient is scaled to reflect the variance of unobserved portion of utility in logit model. Since the scale of utility is irrelevant to behaviour; utility can be divided by variance without changing behaviour. A larger variance in unobserved factors leads to smaller coefficients, even if the observed factors have the small effect on utility (Train, 2009, p. 40).

**Socio-economic and demographic information-** based on the ‘reasoned action’ theory, (Fishbein and Azjen, 1975) showed that decision maker’s attitude towards the survey questions is the function of socio-economic characteristics. In addition, Ben-Akiva and Lerman (1985) introduced a vector of socio- economic characteristics into the utilities for clarification of tastes variability across the segment of population in the model of choice behaviour;

$$U_{in} = U(Z_{in}, S_n) \quad (4.11)$$

$S_n$  denotes as a vector for characteristics of the decision maker  $n$ , such as income, age, and education.  $Z_{in}$  is a vector of the attribute values for alternative  $i$  as viewed by decision maker  $n$ . (Ben-Akiva and Lerman, 1985, p. 48). For instance, consumers with a higher income derive a higher utility, which explicitly describes the influence of the socio-demographic variables on utility differences. Different weights of the attributes from an individual to another person can highlight the idea of population segmentation which can be determined by socio-demographic characteristics of individuals or driven by respondents’ reactions to the different levels of attributes (Hensher et al. 2005). “However, attributes of the decision maker do not vary over alternatives; they can only enter the model if they are specified in ways that create differences in utility over alternatives”. The interaction of socio-demographic variables with the characteristics of the alternatives can be calculated without the normalisation of coefficients. “The socio-demographic variables affect the differences in utility through their interaction with the attributes of the alternatives” . (Train, 2009, p. 22)

3) Aggregation of individual decision maker. The DC is different from linear regression because the explanatory variables are not linear estimation of aggregation. The DC models do not only rely on the average probability of the responses, but also taking into account the average representative utility. Generally, the average representative utility

exaggerates the evaluation of probability for both low and high choices. There are two methods of aggregation:

- i. Sample enumeration. This way of aggregation simply sums or averages the choice probability of decision makers over their population. Each decision maker is attached with some weight; the same weight is associated with the similar person in the sample. The weighted sum of the individual probability estimates by

$$\hat{N}_i = \sum_n w_n p_{ni} \quad (4.12)$$

$\hat{N}_i$  denotes the weighted sum of the individual probabilities for alternative  $i$ . Similarly, the average derivative and elasticity can be calculated in the same fashion.

- ii. Segmentation of sample, in the case of small number of explanatory variables, the total number of decision makers have been segmented based on the level of explanatory variables. For example, different levels of households' numbers as it is given in the question and represented to respondents or decision makers. The aggregation of the outcome variables can be assessed by calculating choice probability of every segment and then accounting the weighted sum of the probability as shown in

$$\hat{N}_i = \sum_{s=1} w_s p_{si} \quad (4.13)$$

Where the  $p_{si}$  represents the probability that a decision maker in segment  $s$  chooses alternative  $i$ , and  $w_s$  is the number of decision makers in segment  $s$ .

4) Forecasting. To estimate future values, factors such as socio-economic variables need to be adjusted by the values of variables in the future time. Sample enumeration can adjust the sample of decision maker to the future, making changes to the value of the variables according to the future values. This can be done with the adjustment of every

individual's associated weight in the present time to the future number of decision makers. In the case of segmentation approach, the changes of decision makers' number mirror the changes of explanatory variables. However, in reality the creation of the segments is owing to the distinction of the explanatory variables value, this change may cause to move the decision maker from one segment to another.

5) Recalibration of constants, as discussed above ASC is often incorporated in the utility model to capture the average effect of unobserved variables. In addition, ASC adjustments can serve in forecasting to reflect the changes of unobserved factors overtime.

#### **4.6 Model estimation: maximum likelihood**

Maximum likelihood is the most common parametric estimator in econometrics. It aims to find the parameters that maximises the likelihood. Under the assumption of utility is a random function, the utility of an alternative can rely on the utility function likelihood that enables the construction of possible model of behaviour. The likelihood falls between numbers 0 and 1 through the information drawn from the random sample. Statistically, the maximum can be obtained from the likelihood function or the joint density of observations, which is specified from each sample of observation. The likelihood function provides all the observed information about the sample population and maximum likelihood estimation (MLE) is the function of the sample information that estimates the observed data with the greatest probability (Greene, 2010). The MLE assumes a number of expectations or moments in the entire distribution as opposed to the generalised method (Verbeek, 2008) . In general, MLE takes the variance and mean of the parameter to estimate the specific parametric value that increases the probability of the outcome.

According to Haab and McConnell (2002), "each individual population outcome is drawn from a population probability density function". Equation 4.14 is formulated by

assuming that the population distribution  $f(y_i|X_i\theta)$  are known and parameters' distributions  $\theta$  are unknown.

$$P(Y_N) = \prod_{y_i \in Y_N} f(y_i|X_i, \theta) \quad (4.14)$$

Where  $Y$  denotes the potential outcomes of the whole population from the random incidents, and  $y_i$  is the outcome of individual  $i$  is deduced from population probability density function  $f(y_i|X_i\theta)$ ,  $y_i$  is conditional on  $X_i$ , vector of individual characteristics, and  $\theta$  is an unobserved vector of parameter's distribution. This interpretation can be reversed.

Once, the population parameters are unknown and distribution parameters  $\theta$  are known, the unknown parameter vector is conditional on  $y_i$  and  $X_i$ .

Generally, likelihood function's task is choosing a value  $\theta$  that maximises  $L(\theta|Y_N, X)$

$$\hat{\theta} = \{\theta | \max L(\theta|Y_N, X)\},$$

For a known value  $\theta$  chooses the value  $\hat{\theta}$  to maximise the likelihood.

$$L(\theta|Y_N, X) = \prod_{y_i \in Y_N} f(y_i | X_i, \theta) \quad (4.15)$$

Independence of the observations in the likelihood function relaxes the natural logarithm maximisation.

Prior to proceeding, a brief definition of the Gradient and Hessian of likelihood function is provided. The gradient is the vector of first derivatives of the likelihood function. The gradient directs the steps to the maximum as a vector of first derivative, so at a global maximum, the gradient will be zero in relation to all parameters. The estimation procedure should be repeated until the maximum is reached. Therefore, the slope of the likelihood creates as a result of iteration or continuous steps for reaching the convergence point. The second derivative of the likelihood is the Hessian matrix that allows us to

know the degree of distance to the maximum step. Because of the concavity<sup>55</sup>, the Hessian takes negative sign. The definite negative sign ensures that the algorithm has perceived local maximum and positively shows the degree of curvature or magnitude of each step. Basically, Haab and McConnell (2002) summarised the general concept and procedure of MLE in six steps:

1. Select a value as a starting point.
2. Gradient vector and Hessian matrix assess the likelihood function.
3. “Update the parameter vector based on an updating rule”<sup>56</sup>.
4. Asses the log-likelihood function at the updated parameter value.
5. Increase the log-likelihood function value and progress to the next step, otherwise repeat the update procedure.
6. Halt the process “if the new parameter vector meets the convergence criteria, otherwise repeat from step 3”.

In addition, maximum likelihood of choice can be estimated through complete simulation rather than calculation of integral analytically. The notion of maximum likelihood simulation relies upon the fact of averaging the integration for all simulation approaches. Train (2003) explains simulation of choice probability based on averaging of integration over a density of unobservable variable,  $f(\varepsilon)$  denotes as density function. This probability can be shown with an indicator function of  $I[h(x, \varepsilon) = y]$  where  $x$  and  $y$  represent observable variable and outcome respectively. Note that when  $I[.] = 1$  the values of  $\varepsilon$  and  $x$  persuade the person to choose outcome  $y$ . In contrast, if  $I[.] = 0$  the values of  $\varepsilon$  and  $x$  persuade the individual to choose another outcome. The probability of choosing a

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<sup>55</sup> The concavity occurs when the Hessian is negative and convexity occurs when the Hessian is positive.

<sup>56</sup> Typically found by taking a Taylor-series approximation to the true parameter vector around the start values. Depending on the algorithm the updating rule may be a function of the likelihood gradient, the Hessian and a step length that determines the size of the adjustment made to the parameter. (Haab and McConnell 2002, p. 302)

certain outcome ( $y$ ) is an average of the indicator  $I(\cdot)$  over all likely values of  $\varepsilon$ , which can be approximated by taking several draws of  $\varepsilon$  from its distribution  $f$ . Train (2009), describes four steps of probability simulation as follows

1) Take a draw of  $\varepsilon$  from  $f(\varepsilon)$ . Label this draw  $\varepsilon_1$ , where the superscript denotes that it is the first draw.

2) Determine whether  $h(x, \varepsilon_1) = y$  with this value of  $\varepsilon$  unobserved value. If so, create  $I^1 = 1$ ; otherwise set  $I^1 = 0$ .

3) Repeat steps 1 and 2 several times, for a total of  $R$  draws. The indicator for each draw is labelled  $I^r$  for  $r = 1, \dots, R$ .

4) Calculates the average of the  $I^r$ 's. This average is the simulated probability:

$\check{P} = (y | x) = \frac{1}{R} \sum_{r=1}^R I^r$ . It is the proportion of times that the draws of the unobserved factors, when combined with the observed variables  $x$ , result in outcome  $y$ . (Train, 2009, p. 5)

#### 4.7 Goodness of fit of models

To measure how well the DC model statically fits the data, likelihood ratio index can be employed. The likelihood ratio index tests and compares the estimated model against its relevant base model. The log of the likelihood is easier to apply than the likelihood itself. The log likelihood (LL) takes the log from the summation of values, which produce negative (LL) values. The optimal result for the LL is being close to zero.

The LL ratio index is defined by McFadden as  $\rho = 1 - \frac{LL(\hat{\beta})}{LL(0)}$ , (4.16)

Where the  $LL(\hat{\beta})$  is the value of the log-likelihood function at the estimated parameters and the  $LL(0)$  is its value when the all parameters are zero. The maximum likelihood for estimated model occurs when the estimated model performs better than 'no model'. The comparison between estimated and zero parameters model would explain the probability

value, which it falls between 0 as the lowest and 1 to the highest. The likelihood of the equivalent models have  $\rho = 0$  and  $LL(0) = LL(\hat{\beta})$ , which the logarithm of zero is negative. However, the likelihood for the maximum performance is  $\rho = 1$ ,  $LL(\hat{\beta}) = 0$  as the zero logarithm is one. The log likelihood is always negative, with higher values (closer to zero) signifying a better fit.

#### 4.8 Statistical significance of coefficient estimates

The Wald-statistic determines the statistical significance of an explanatory variable. As shown in equation 4.17, Wald test estimates the significance of one value (null hypothesis) in that a set of parameters is equal to some values over the standard error of that parameter.

$$Wald = \frac{\beta_i}{standard\ error_i} \quad (4.17)$$

Then, the output of Wald-statistic should be compared with the critical Wald-value. Under the assumption of 95% confidence interval, the critical Wald-value is 1.96, if the Wald-test estimated output is larger than the critical Wald-value, the null hypothesis can be rejected and concluded that the coefficient is statistically significant. Conversely, if the given output from Wald-test is less than critical Wald-value, the hypothesis that the parameter is equal to zero can be rejected and inferred that the explanatory variable is not statistically significant. Alternatively, the chi-square test can be used with the log-ratio, under the same assumption of 95% confidence interval and 0.05 alpha. The larger  $p$ -value compared to the level of alpha indicates that the coefficient is not statistically significant and parameter is equal to zero. The analysis of Wald-test and  $p$ -value both provide the same results, when they both assigned to the same level of confidence (Hensher et al,

2005). Note that Wald test only estimates the constrained model while, both constrained and unconstrained models<sup>57</sup> can be treated with LL ratio test.

## 4.9 DC Models

Discrete choice models can be classified as binary choice (dichotomous) models and multinomial or polytomous choice models with three or more alternatives. Some of these multinomial models with and without correlation in unobserved variables are reviewed in the following sections.

### 4.9.1 Conditional logit model

The notion of understanding people's choice behaviour was developed by McFadden (1974) as an important concern in economics. The conditional logit (CL) model was developed as a technique for framing econometrics models of population choice behaviour from distributions of individual behavioural directions. Whereas, the conventional consumer analysis assumes that all consumers has a common choice behaviour. McFadden (1974) estimated the probability of choosing an alternative by individuals based on the attributes of the alternative and unknown parameters through the CL model. McFadden (1974) presented the CL model based on three axioms:

1. Independence of irrelevant alternatives (IIA), this notion was initially introduced by (Luce, 1959), which states that the probabilities of choosing one alternative over a second one should not be related to the third alternatives.

$$P(x|s, \{x, y\}) P(y|s, B) = P(y|s, \{x|s, B\}) \quad (4.18)$$

The equation 4.18 demonstrates the assumption of IIA,  $B$  denotes as all possible alternative sets,  $s$  as measured attributes, and  $x$  and  $y$  as members of  $B$ . Luce (1959)

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<sup>57</sup> Complex model can be constrained under the null hypothesis to a fewer parameters, where unconstrained model includes all parameters.

proved the reliability of the axiom in some choice experiments, despite its consistency with behaviour. However, it has limitations that are explained in the subsequent sections.

As shown in equation 4.19, when  $P(x | s, B)$  is positive indicates  $P(y | s, \{x | s, B\})$  and this status explains that the chances of  $y$  being chosen over  $x$  is in a multiple choice situation  $B$  is equivalent to the likelihood of a binary choice of choosing  $y$  over  $x$ .

$$\frac{P(y | s, \{x | s, B\})}{P(x | s, \{x, y\})} = \frac{P(y | s, B)}{P(x | s, B)} \quad (4.19)$$

Because a zero probability is hardly noticeable from a very small number, this may cause the detail of the selection not being precisely observable under the assumption of positivity.

2.  $P(x | s, B) > 0$ , positivity for all possible alternative sets  $B$  vector of measured attributes  $s$ , and  $x \in B$ .

Suppose that the choice set  $B$  comprises alternatives of  $x, y, z$  and  $p_{xy} = P(x | s \{x, y\})$ , express  $P_{xx} = \frac{1}{2}$  from equation 4.18.

$$P(y | s, B) = \frac{P_{xy}}{P_{xy}} P(x | s, B) \quad (4.20)$$

Also

$$1 = \sum_{y \in B} P(y | s, B) = \left( \sum_{y \in B} \frac{P_{yx}}{P_{xy}} \right) P(x | s, B) \quad (4.21)$$

Under the positivity axiom the multiple choice selection's probabilities can be expressed by binary odds

$$P(x | s, B) = \frac{1}{\sum_{y \in B} \left( \frac{P_{yx}}{P_{xy}} \right)} \quad (4.22)$$

Assuming that the  $x, y, z$  in equation 4.20, and multiplying yields the condition

$$\frac{P_{yx}}{P_{xy}} = \frac{p_{yz} / p_{zy}}{P_{xz} / P_{zx}} \quad (4.23)$$

Let  $z$  member of the alternative set  $B$ , taken as a benchmark, describing

$V(s, x, z) = \log (P_{xz} / P_{zx})$ , equation 4.22 can be written as

$$P(x | s, B) = \frac{e^{v(s,x,z)}}{\sum_{y \in B} e^{v(s,y,z)}} \quad (4.24)$$

Where  $s$  denotes “measured taste effect”,  $x$  represents “choice alternative effect”, and  $z$  explains “alternative set effect”. In an experiment with enough variation in measured attributes  $s$  and the alternative set  $B$ , and replications from respectively  $(s, B)$  pair, each one can usually classify each of these effects. Without replications, identification of the “alternative set effect” is impossible. The restriction should be known to separate the “choice alternative effect”. This can be assumed as follows.

3. Irrelevance of alternative set effect. The function  $V(s, x, z)$  defining the selection probabilities in equation 4.24 has the additively divisible form.

$$V(s, x, z) = v(s, x) - v(s, z) \quad (4.25)$$

Then,

$$P(x | s, B) = \frac{e^{V(s, x, z)}}{\sum_{y \in B} e^{V(s, y, z)}} \quad (4.26)$$

The function  $v$  can be interpreted as a “utility indicator” of representative tastes.

The following result justifies this terminology in terms of the behaviour of a population of consumers. (McFadden 1974, p. 110)

### ***Limitations of CLM***

The principle of IIA is that the likelihood of choosing between two alternatives is not related to the presence or absence of the third alternative. With reference to the characteristics of choice probabilities, Luce (1959) derived the logit formula from the IIA property. The property of IIA also holds in the CL model in which indicates that the third alternative even with a perfect substitution’s attribute does not have effect on the

probability of choosing between the other two alternatives (McFadden, 1974; Haab and McConnell, 2002; Train, 2003). However, the IIA assumption is found to be the main limitation of CL model when alternatives set contain choices that are close substitutes (McFadden, 1974).

In the case of binary choice, the probability of choosing each of the two alternatives would be 0.5, however, the existence of the third alternative can make changes to the probabilities' proportions. Therefore,

$$P(x |s, B) = e^{v(s,x)} / \sum_{y \in B} e^{v(s,y)} \quad (4.27)$$

To date, some studies have been carried out to clarify the implausibility of the IIA assumption. McFadden (1974) explained the concept of substitution in the case of choosing between car and bus as a transportation mode, and introduction of a new brand bus played the substitution role. Similarly, Train (2003) described the concept of substitution again in the example of modes of transportation. The probability of substitution was simplified by choosing between car and blue bus  $P_c / P_{bb} = 1$ , and introduced red bus as the third alternative,  $P_{rb} / P_{bb} = 1$ . Therefore, the probability of choosing one of those transportation alternatives would become  $P_{rb} = P_{bb} = P_c = \frac{1}{3}$  and also Train assumed the use of car remains  $P_c = \frac{1}{2}$  and the use of the red bus and the blue bus to be equal  $P_{rb} = P_{bb} = \frac{1}{4}$ .

Likewise, Haab and McConnell (2002) elucidated the relative probability of choosing between two sites of A and B when demand for site A= B= 0.50.

In addition to the alternatives A and B, site C was introduced as a perfect substitute for site B. Therefore,  $Pr (B) = Pr (C) = 0.25$ . Nevertheless, in the CL model with the IIA property, probability of choosing between alternatives of A and B remains 1:1. This is said to be a limitation for IIA axiom.

### ***Taste homogeneity***

An individual's taste may be varied on the basis of his/her unobserved variables as well as observed variables. Generally, heterogeneity is led by variations in individual's specific choice and preference. The economic analysis of heterogeneity helps to avoid a biased model also enables forecasting individual demand. Moreover, the inclusion of individual's characteristics can describe heterogeneity in choice for forecasting demand (Salomon and Ben-Akiva, 1983; Adamowicz *et al.*, 1997; Boxall and Adamowicz, 2002). The demographic parameters can be incorporated in the demand function directly or via the utility function. The standard logit model estimates the taste variations when the variations are driven by observed variables such as individuals' demographic variables. Under the assumption of IID, a standard logit model would be obtained by entering the two variables of representative utility and the individuals' characteristics. However, the assumption of homogenous characteristics and tastes of individuals restricts the estimation of heterogeneity in random utility model. This can be estimated through the interaction of individual's specific characteristics with various attributes of the alternatives in the choice set. Nevertheless, the random coefficient model or mixed logit model can accommodate both the observable and unobservable variables in the model. Overall, random coefficient model and latent class model are the two recognised approaches for specification of taste heterogeneity.

### ***4.9.2 Panel data***

A choice set involves with a series of choice questions, in which sequential offers are made to the respondent to state his/her most preferred alternative in each choice set. This repetition of the choices by different respondents generates panel data. The logit model can be employed to estimate the panel data, by assuming IID, which means that independent from unobserved factors over the repeated choices.

The utility that decision maker  $n$  obtains from alternative  $j$  in period

or choice situation  $t$  is  $U = V_{njt} + \varepsilon_{njt} \quad \forall j, t.$

If  $\varepsilon_{njt}$  is distributed extreme value, independent over  $n, j$ , and, importantly,

$t$ , then, using the same proof as the choice probabilities are  $P_{nit} = \frac{e^{V_{nit}}}{\sum_j e^{V_{njt}}}.$

Each choice situation with each decision maker becomes a separate observation.

If representative utility for each period is specified to depend only on variables for that period: for example,  $V_{njt} = \beta'x_{njt}$ , where  $x_{njt}$  is a vector of variables describing alternative  $j$  as faced by  $n$  in period  $t$ , then there is essentially no difference between logit model with panel data and with purely cross-sectional data. (Train, 2009, p. 51)

Adamowicz (1994) stated that the consumer's choice and decision for a product is significantly influenced by previous consumption habits. As such, Adamowicz (1994) defined the impact of current consumption habit on the future consumer's choice is by the use of 'rational dynamic model'. The identification of the representative utility in each choice situation can provide the experimenters with information about the dynamic feature of behaviour.

Train (2009) stated that consumers choose to change their consumption habits when a larger utility is obtainable from a new offered alternative. Where the representative utility  $V_{njt} = \alpha y_{nj(t-1)} + \beta'x_{njt}$ , can capture the people behaviour, then  $V_{njt} = 1$  if  $n$  chose  $j$  in period  $t$  and 0 otherwise. If  $\alpha > 0$  then, a higher utility would be obtained from the previously consumed product. If  $\alpha < 0$  then, a higher utility would not be obtained from the previously consumed product. Under the assumption of logit model, the previous periods' dependent variable can be entered as an explanatory variable; this insertion would not cause any inconsistency for the estimation. Due to the fact that, errors

are independent in the logit model, the lagged dependent variable is not correlated with the present error. The homogenous preferences for individuals have been defined as a key assumption by the standard logit models. The IID assumption limits the researcher's observation of uncorrelated errors and ignores the existence of dynamics in unobserved factors. Nevertheless, probit and the mixed logit approaches can overcome the limitations of the logit model by enabling the unobserved factors to be interacted over time.

#### ***4.9.3 Mixed logit model***

The mixed logit (MXL) also called random parameter or error component. Initially, the MXL model was used in 1980 by (Boyd and Mellman, 1980; Cardell and Dunbar, 1980) to model market share rather than individual choice for different attributes of automobiles, no variation in explanatory variables was applied. Moreover, the introduction of simulation made the MXL more prevalent. Furthermore, Train (2003) could utilise the full power of MXL simulation due to computer technology and science improvements. The limitations of standard logit can be handled by MXL. Overall, MXL avoids the three limitations of standard logit; random taste variations, unrestricted substitution patterns, and correlation in the unobserved factors over time. It allows the interactions of unobserved factors in the utility model unlike standard logit assumes IID type I for error components (Revelt and Train, 1998). Generally, the MXL model relaxes the homogenous assumption of IID in random errors under the assumption of heteroskedastic extreme value (HEV) (Ben-Akiva et al.).

#### ***Derivation of MXL model***

The MXL probability derives from utility maximising behaviour and approximates any random utility model. Each individual's behavioural pattern derives a specific choice probability, MXL can be derived under a mixture of choice probabilities of the behavioural specification (Train, 2009). The standard logit model describes the

probability of an individual's choice over all possible values of choices, whereas MXL model is the integral of the logit model to estimate the distribution of individual parameters (Revelt and Train, 1998). According to Train (2009), there are two sets of parameters in a MXL model. One is the parameters of  $\beta$  with the density of  $f(\beta)$  that enters in the logit model. The second set is the parameters that explain the density  $f(\beta)$ . The choice probability can then be expressed as

$$P_{ni} = \int L_{ni}(\beta) f(\beta) d\beta, \quad (4.28)$$

$L_{ni}(\beta)$  is the logit probability evaluated at parameters  $\beta$ , and  $f(\beta)$

is density function.

$$L_{ni}(\beta) = \frac{e^{V_{ni}(\beta)}}{\sum_{j=1}^J e^{V_{ni}(\beta)}} \quad V_{ni}(\beta) \text{ is the observed portion of the utility,}$$

which depends on the parameters  $\beta$ . If utility is linear in  $\beta$ , then

$$V_{ni}(\beta) = \beta' x_{ni}.$$

In this case, the mixed logit probability takes its usual form:

$$P_{ni} = \int \left( \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \right) f(\beta) d\beta. \quad (\text{Train, 2009, p. 135}) \quad (4.29)$$

In general, the difference between standard logit and MXL arises from the inclusion of density  $f(\beta)$  or mixing distribution in the MXL formula, which is a weighted average of the logit formula assessed at different values of  $\beta$ 's.

By assuming that, there are two sets of parameters in MXL model, if parameter  $\beta$  has a normal distribution then density  $f(\beta)$  would be explained by mean and covariance of parameter  $\beta$ . Train (2009) denotes  $\theta$  as the parameter that explains density  $f$  of  $\beta$ .

The MXL probabilities as a function of  $\theta$  is

$$P_{ni} = \int L_{ni}(\beta) f(\beta | \theta) d\beta, \quad (4.30)$$

### *Random parameter specifications of the MXL model*

In addition to the information attained from the  $\theta$  function, the individual's taste information can be obtained from  $\beta$ s of each sampled decision maker. The MXL model can be derived from utility maximisation behaviour with different techniques, but recently the random coefficient or random parameter has become the most applicable derivation for the MXL model. Random parameter is the specification of the MXL model which does not assume parameters are fixed over the decision makers like standard logit model. MXL or the random parameter logit (RPL) model can be explained under the assumption of unconditional choice probability, where the probability's density is made by the random component (Train, 2009). In particular, MXL relaxes the restriction of IID on unobserved factors. Nevertheless, a less restrictive model on behavioural assumptions is likely to receive the sources of preference heterogeneity from systematic and random components. Different distributions have been used in empirical studies in the economics literature for estimation of the parameters' distribution, such as normal or lognormal, triangular and uniform, truncated normal. This variation for distribution selection indicates that the researcher is free to choose a distribution for the coefficients in that the distribution provides satisfactory results for the researcher.

Generally, the inclusion of observed attributes of the decision maker can increase the taste variations. Bhat (2000) specified lognormal distribution for coefficients subject to observed and unobserved variables of decision makers' characteristics. The unobserved factors or error components are found to be equivalent with the random coefficient specification. Alternatively, fixed coefficients can be used in MXL by embodying the error components in which the correlations among alternatives can be predicted. Moreover, the correlations over alternatives in terms of their observed or unobserved variables leads to the 'substitution patterns'. The 'substitution patterns' approach through

the use of error components was examined by Revelt and Train, (1998) and Brownstone and Train, (1999), though with different aims, the former being taste form while prediction was the intention of the latter study. The mutual concern of the study was in the use of random parameters instead of error components. However, both techniques capture variance and correlations in unobserved variables.

Estimation of the MXL model

According to Train (2009), simulation is an appropriate method for estimation of the MXL model. McFadden and Train (2000) demonstrated that any random utility model can be estimated by a MXL model

$$U_{nj} = \beta'_n x_{nj} + \varepsilon_{nj} \quad (4.31)$$

By assuming that the coefficient  $\beta_n$  are distributed with density  $f(\beta | \theta)$ , where  $\theta$  represents parameter distribution with mean and covariance of  $\beta$ , with the specified functional form  $f(\cdot)$ , the parameters  $\theta$  can be estimated where the choice probabilities are

$$P_{ni} = \int L_{ni}(\beta) f(\beta | \theta) d\beta, \quad (4.32)$$

Where

$$L_{ni}(\beta) = \frac{e^{\beta' x_{ni}(\beta)}}{\sum_{j=1}^J e^{\beta' x_{nj}(\beta)}} \quad (4.33)$$

Following the simulation's steps described by Train (2009, p. 144) probabilities can be estimated for any given value of  $\theta$ :

1. Draw a value of  $\beta$  from  $f(\beta | \theta)$ , Label it  $\beta^r$  with the superscript  $r = 1$  referring to the first draw.
2. Calculate the logit formula  $L_{ni}(\beta^r)$  with this draw
3. Repeat the steps many times and average the results

The average simulated probability is

$$\check{P}_{ni} = \frac{1}{R} \sum_{r=1}^R L_{ni}(\beta^r) \quad (4.34)$$

R represents the number of draws, which has a reverse direction to its variance. R allows us to approximate the log likelihood function from  $\check{P}_{ni}$ .

$\check{P}_{ni}$  is an unbiased estimator of  $P_{ni}$ .  $\check{P}_{ni}$  is smooth (twice differentiable) in the parameters  $\theta$  and the variables  $x$ , which facilitates the numerical search for the maximum likelihood function also the calculation of elasticity.

The summation of  $\check{P}_{ni}$  to one over alternatives would support the prediction. Entering the simulated probabilities to the log likelihood function would give the simulated log

likelihood as 
$$SLL = \sum_{n=1}^N \sum_{j=1}^J d_{nj} \ln \check{P}_{nj}, \quad (4.35)$$

$d_{nj} = 1$  occurs when the  $n$  chooses  $j$  and if not choosing  $j$ , it would be equal to zero.

The maximum simulated likelihood estimator (MSLE) is the value of  $\theta$  that maximises SLL. Usually, different draws are taken for each observation. This procedure maintains independence over decision makers of simulated probabilities that enter SLL. The simulated mixed logit probability can be related to accept-reject (AR)<sup>58</sup> methods of simulation. For any random utility model, an AR simulator can be constructed through the steps addressed by mixed logit estimation. (Train, 2009, p. 145)

#### 4.9.4 *Latent class model*

In addition to the RPL model, the latent class model (LCM) also relaxes the IIA assumption, examines preference heterogeneity and correlations between the alternatives and choice situations. Greene and Hensher (2003) found that the MXL and LC models are quite comparable since both achieve a significant variety of information about choice

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<sup>58</sup> A type of drawing from a density in simulation is Accept-Reject (AR) for Truncated Multivariate densities, for more explanation see (Train 2009, p.209).

behaviour from panel or repeated data. LC models heterogeneity with a semi-parametric specification while MXL does the same with fully parametric measurement. LCM classifies and segments the individuals' choices and preferences based on their choices; however, the RPL model accounts for heterogeneity by allowing parameters to vary randomly across respondents. It addresses the characteristics of the choice structure, which is the objective of the research in choice theory. The initiation of the LC model dates back to (1968) by Lazarsfeld and Henry, once the variables were framed in discrete form as opposed to continuous form in factor analysis<sup>59</sup>. McFadden (1986) documented the outlook of practicing latent variables in understanding choice behaviour. McFadden presented an image of economic choice theory to forecast market share for a new product by integrating information from product's attributes and demographic characteristics. Note that the unobserved attributes make variations on latent heterogeneity, despite the fact that the latent classes or segments are constructed via a combination of the observed components of variables (Hagenaars and McCutcheon, 2002). Basically, the analyst perceives that individual's behaviour depends on observable and latent heterogeneity that vary with unobservable factors (Greene and Hensher, 2003). This heterogeneity can be signified by categorising individuals into a set of classes but the researcher does not know the particular allocation of individuals into the classes (Boxall and Adamowicz, 2002).

Under the assumption of the homogeneity of individual's characteristics over the choice sets, heterogeneity is not detectable in the random utility model, but the interaction of individual's specific characteristics with the attributes of different choices can ease this constraint (Adamowicz et al., 1997). Underlying individual's different attitudes and

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<sup>59</sup> A statistical technique, explains observed variability with the mutual variations to unobserved latent variables.

“The factor analysis approach involves analysis of the interrelationships between attitudinal indicators and statistical procedure that transforms the correlated indicators into a smaller group of uncorrelated (latent) variables called principal components or factors”. (Daly *et al.*, 2012, p. 269)

preferences, Hess and Beharry (2012) showed that latent attitudinal variable can describe the answers to the choice questions as well as to the attitudinal questions. The empirical study was carried out based on the hypothesis that unobserved attitudes have an effect on policy interventions. The inclusion of latent variables in the model of choice helped to improve the model fit and increase the understandings of the behavioural variations, considerably in the WTP patterns.

#### **4.9.5 Willingness to pay**

Hensher et al. (2005) indicate that the estimation of WTP is a common practice in the application of DC models. It is not unusual to measure WTP for non-monetary goods as WTP has a key application in environmental economics. The measurement of WTP derives from the behavioural responses if the individual is willing to relinquish some amount of money for acquiring a good with some labelled benefits.

The ratio of two parameters simply calculates WTP in the linear model, all other things being equal. One of the parameters must be in a monetary unit such as cost or price, in order to obtain the monetary value. In addition, when WTP involves the distribution of individual's parameters, the random parameter is the derivation of WTP and it estimated from the ratio of the random parameters. To estimate the WTP based on the random parameters; information should be taken from the distribution that is to say, mean and standard deviation.

#### **4.10 Summary and Conclusions**

This chapter provides an overview on CM conceptual framework and DC analysis. The derivation of the choice probability in the DC models, namely random utility model and utility maximisation were described.

The CM types were expressed in the form of the binary and multinomial models in which could be used under the homogeneity or heterogeneity assumptions. Under the homogeneity assumption, the IID type I extreme value distribution of the error components are assumed to be fixed, and wherein the error component of utility derives based on independently identically distribution. However, this restriction can be relaxed under HEV assumption. DC models such as MXL or RPL, LC adopts HEV, thus, the sources of utility would be both observables and unobservable characteristics of individuals and alternatives and their interactions. In contrast, standard logit model with IID distribution assumes fix or identical distribution for unobservable attributes of alternatives and individuals.

On the whole, this chapter provides relevant contextual theories and econometrics tools in which to be used in empirical estimation and choice analysis of this thesis.

## Chapter 5. Methodology

### 5.1 Introduction

Over the past few decades, economists have developed their understanding of public attitudes' towards environmental criteria and non-use value. Because non-use value is unobservable in the market, a direct survey based on the stated preference (SP) method can be used for this purpose. The SP technique has been developed based on the utility function, and asks individuals hypothetical questions. It measures preferences for the good in question by asking respondents about willingness to pay (WTP) to secure a gain and willingness to accept (WTA) to tolerate a loss, and addresses the factors from which they can be derived. SP can be categorised into contingent valuation and choice modelling methods. The former seeks measures of WTP via a direct question, for example "what are you willing to pay?" or "are you willing to pay £X?" The latter evaluates peoples' preferences through ranking, rating alternatives, or selecting the most preferred scenario and WTP, and thus seeks the conditional factors or attributes which derive WTP. The design of the SP studies must be implemented through the process of pre-test studies, which require adequate time and deliberation.

We used the contingent valuation (CV) technique to examine the preferences and desires of the sampled population for adopting micro-generation solar panel or Photovoltaic (PV) system. In addition, a choice experiment (CE) approach was used to value the different attributes that influence individuals' preferences. To address the survey questions, we referred to the available literature and pre-test surveys to avoid the cognitive limitations of stating a preference. Thus, truthful responses and rational behaviour were brought to light. The sample population was selected based on random sampling. The target population of the study was households in Northern Cyprus, with adults aged above 18,

who were aware of the expenditure of the household (head of the household). Face to face interviews were used across all the surveys throughout the study, because of its superior advantages compared with other modes such as mail and telephone survey. These advantages of face to face interviewing are, as (Bateman *et al.* 2002, p. 106). report “high flexibility as complex questionnaire structures are possible”, “potential for extensive use of visual and demonstration aids, high response rates of 70% plus great sample control” , and enabling investigation, explanation, and management of the collection of a larger quantity of data. In this chapter, we review the progression of the design of the final layout and the tools used in the CV and CE surveys. This chapter’s sections are as follows. Section 5.2 briefly describes ethics approval process. Section 5.3 outlines pre-test studies including focus groups, interviews and pilot surveys. Section 5.4 explains the design of the choice experiment, including the process of the initial choice set design to the final setting through the pilot surveys and revision of the questions. Section 5.5 describes the experimental design using contingent valuation, and the pilot study for willingness to accept of the households near the 1MW solar park in Serhatkoy, which was used to test the experimental approach’s impact on preferences. Section 5.6 summarises and concludes the chapter.

## **5.2 Ethics approval process**

As part of Newcastle University compliance processes, all university projects including student research must undergo an appropriate ethical review prior to initiation of their survey. Thus, all postgraduate research students must complete at least a preliminary ethical review<sup>60</sup> (see Appendix A.3) in order to progress with their projects and studies. Accordingly, this project through the Newcastle University research ethical

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<sup>60</sup> But depends on the outcome, students may have to complete a full ethical review form.

guidance<sup>61</sup> gained an ethical approval and permission to develop a robust and ethically-considerate project.

### **5.3 Pre-test studies**

The significance and need for a well-designed questionnaire for contingent valuation and choice modelling has been highlighted by several authors (Carson et al., 2001; Bateman et al., 2002; Pearce and Özdemiroglu, 2002). To avoid any bias that threatens the credibility and validity of SP, the questions must be structured clearly, comprehensibly and simply prior to the survey administration. In the non-market valuation setting, focus groups can be applied to test the draft questionnaire to gain insights about methodological issues. Furthermore, the credibility and validity of the SP results require adequate piloting and revision of the questionnaire. In what follows, we explain the pre-test studies that were used in this study.

#### **5.3.1 Focus groups**

Social scientists recommend the use of focus group as a complement to other techniques in the multi-method research approaches, even if a hypothesis should be tested by quantitative research (Goss, 1996). Particularly, in the context of environmental valuation with reference to the policy assessments, adoption of qualitative approaches such as focus group is suggested by a number of scholars (e.g. Powe et al., 2005). A focus group is a type of qualitative study, but not a substitute for the main survey, as it precedes the design of the SP questions. Basically, the focus group is used to recruit a non-random sample of population to discuss the subject of study; however, in the main survey, the respondents are chosen randomly (Bateman et al., 2002). The information gathered via focus group can only be used to identify the significant attributes required for the design of the survey

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<sup>61</sup> Designed for students aids (see Appendix A.3)

questions. Conducting focus group discussions is one of the first steps in the design of the CE questions.

Therefore, the focus group study was carried out in three sessions in April, 2011. A total of twenty people participated and were divided into three focus groups consisting of six to seven individuals. The participants were selected from those who were responsible for the household expenses, regardless of their gender, but aged above 35. They were invited from five districts: Nicosia, Famagusta, Karpaz, Kyrenia and Lefke/Guzelyurt.

Three discussion sessions were held on different days at a known location in Famagusta, in the Eastern Mediterranean University in the Mechanical Engineering department. The room was equipped with a round table and more than ten seats. Prior to the discussion, the participants were provided with a brief introduction about renewable energy (RE) issues by showing pictures on PowerPoint slides( see Appendix A.1), while they were served refreshments and cookies. I played the moderator role and an assistant helped me to record the meeting and by taking notes. The assistant also translated the parts of the meeting which were not in English. In the first group, 90% of the discussion was in English and the remaining 10% in Turkish. The second group's discussion was equally split between English and Turkish. The last group discussion took place only in Turkish. Each session took about an hour and we tried not to make it very long, as Bateman et al. (2002) suggested that a long discussion leads to inefficiency.

Table 5.1 Focus groups

	<b>Participants</b>	<b>Female</b>	<b>Male</b>	<b>Degree</b>
<b>Group one</b>	7	4	3	Master and PhD
<b>Group two</b>	7	3	4	School and University
<b>Group three</b>	6	2	4	School degree

**Focus group discussion questions are listed as follows:**

*1. Would you prefer to generate your own electricity via micro-generation system or would you rather be connected to large power plants through the network?*

*After comparing different sources of energy and energy technologies including solar, wind and the existing system, the participants were asked to state their most preferred renewable energy source and technology.*

*2. Which of the explained technology would you prefer the most?*

*3. Would you install a micro-generation solar system into your house?*

*4. What would you ask the architect if you were to build a new house? Would you want to build an energy efficient house?*

*5. How much more would you be willing to pay for electricity production from renewable energy?*

Each question was launched in the discussion in sequence, and then the participants' feedback was taken. The detail of the issues in the discussions is provided in Appendix A. Briefly, in the next paragraph some of the notions expressed by the participants are re-stated.

Overall, the majority of the participants agreed with the micro-generation system. Some of the comments were as follows:

- *“Using a micro-generation system would allow the sale of excess electricity to the grid”.*
- *“Maintenance costs and servicing is important, especially in Cyprus where there is a lack of expert technicians and professionals who can make repairs. It would*

*be an advantageous, if long term, service accompanied with the system's installation”.*

The potential of RE utilisation in Cyprus was mentioned, such as that of wind and solar energies, and these were the main points of discussion:

- *If energy can be stored in the battery, electricity will not be disconnected when there is no wind and sun available, and therefore in this condition definitely we should utilise the sun and wind energy.*

Some of the participants believed that Cyprus has a higher potential for solar energy utilisation than wind power. However, those who lived in more remote elevated areas were inclined to adopt wind turbines too.

Obstacles to the installation of a micro-generation system in their houses were addressed, such as cost and maintenance:

- *The government needs to lend its support. We cannot do it on our own.*
- *I would check the price first. Second, I would check to see whether it is practical or not. To find out whether it is used by the majority of people or if we are the first ones to use it. Is it safe to use it? Not only should the consumer know all about these issues, but technicians and the company should also be conscious and well-informed enough in order to deliver the service.*

Their standards for the construction of a new house were discussed in terms of insulation and the energy efficiency for the building, as well as the integration of a PV system in the building.

- *I considered insulation while I was building my house but these things are really expensive, and the price would be lower if it was commonly used.*

- *I would ask for an energy efficient house with the integration of the solar system at the design stage.*

From the group discussion, it was inferred that cost was a decisive issue to substitute existing sources of energy for RE. Commonly, cost and maintenance were mentioned throughout the discussion sessions. In general, most participants were willing to pay an extra cost for electricity of 10% to 20% annually.

Some common issues that were frequently mentioned by participants were the lack of maintenance and service, cost and higher expenses, and lack of knowledge or consciousness about RE technologies and how to take advantage of these. Generally, the level of education and income were not the driving factors in people's willingness to adopt the products of RE technology. In fact, the cost and convenience of a new product or service were noticed by most of the focus groups' participants. Overall, the discussants were concerned to have energy efficient houses in terms of construction design, plus the installation of a micro-generation system in their houses. The need to formulate a policy concerning energy issues and create an energy agenda by the government was expressed in the focus groups as households may not have sufficient knowledge and capability to perform it on their own.

Participants raised questions about the initial cost of the installation of micro-generation systems (micro-wind-PV), their efficiency and reliability, and whether they were guaranteed and serviced after purchase. Hence, it was concluded that, before designing the CE questions, we needed to obtain a reliable answer to these issues by interviewing micro-generation suppliers.

### ***5.3.2 Interview with the micro-generation company suppliers***

In addition to the focus group studies which were conducted to gain a better understanding of the position of RE in North Cyprus amongst the general population, three suppliers (agents) of different brands (Chinese, German and Austrian) were visited in December, 2011. The oldest company was established around four years ago and the other two companies were fairly new. The director of one of the companies, explained that four years ago interest in these systems had been close to zero, and people were passive recipients. However, the increase in the price of electricity by thirty three percent, the reduction in the price of PV installation (less than half compared to two years ago), and the increase in the efficiency of photovoltaic systems and general awareness of them had prompted a 70% increase in enquiries about possible installations over the past year.

The interview was comprised of eight questions that elicited the following responses from the company supplier:

1. What is the price of PV for households with and without tracking?

1 kWh 2,500 €, and with a tracking device 3,500 €

1 kWh PV requiring four batteries, 1,200 €. Battery life 12 years and minimum storage time is 6 hours.

2. What is the price of a micro-wind turbine which installs on the roof?

1 kWh 2,000 €

3. How efficient are PV with tracking in Cyprus?

PV performance is approximately 15%-20%, and this performance can be increased up to 40% by adding a tracking device to the system.

Even though summer days are longer than winter ones, PV performance drops up to 50% in very hot weather (during July and August). Likewise, the efficiency of PV can decrease when the panels are exposed to dust.

4. What is the current PV installation position?

Although people are enthusiastic about solar energy utilisation and PV systems, only five percent of the households had installed a photovoltaic system in their houses. In the form of businesses, restaurants were the main users in remote areas to have installed PV where there was no electricity. This was because people were waiting for the feed-in tariff (FIT) to be legislated.

5. What would be PV and Wind turbine maintenance costs?

Micro-generation product warranty is 10 years.

Performance guarantee: 12 years at 90%, and 30 years at 80%.

Generally, micro-generation technologies do not require significant maintenance. 3% of the initial cost can be considered as maintenance cost. Cleaning PV panels is necessary especially in dusty climates, and this cleaning can be considered a maintenance cost.

6. Why should wind or solar technology be preferred in Cyprus?

Micro wind technology is more economical compared to PV in terms of initial cost. However, since wind speed is variable in Cyprus, it is considered an alternative by energy company dealers. The first priority is assumed to utilise solar energy in Cyprus.

7. What are the installation problems?

Because most Cypriot homes have water storage and heating devices already stored on their roof, there is insufficient space to install solar panels. On average, two tonne reserve tanks are mounted in each household due to the water shortage in Cyprus. One recent project has been to bring water from Turkey which could pave the way for dismantling these tanks and provide more space for PV installation.

8. Will Cypriot architects need to be educated about PV systems and the use of essential criteria while they are designing a building?

Networking between PV suppliers and architects is necessary. Houses should be designed in such a way as to accommodate the panels efficiently. In addition, architects need to be educated about PV installation systems in order to use their creativity for designing a building or retrofitting an existed building, for instance, installing photovoltaic windows.

### **5.3.3 Pilot study**

General questionnaire

The study began with describing the purpose of the study for each respondent, and where the result of this investigation would be used. To assure the respondents of their privacy, they were not required to record their names on the questionnaires, and had no obligation to answer the income level question. An introduction to the study was given to each respondent as outlined below:

*‘Your answers to the following question will be used in a PhD thesis which aims to examine Cypriot willingness to pay for the use of renewable technology. It will take the form of a series of questions about your current source of energy consumption and your willingness to pay for the production of electricity from renewable energy sources.*

*This project assumes that renewable energy laws will be enacted and EU legislations will be followed in North Cyprus. I would be pleased if you keep these conditions in your mind while completing this form. Thank you for agreeing to take part in this interview'.*

Subsequently, a set of ten questions was structured to ascertain people's behaviour towards RE sources and energy consumption scales, covering six main aims. First, the questions sought to investigate people's opinions regarding the contribution of RE to tackling the growth in demand for energy. Second, the survey aimed at understanding the level of awareness about micro-generation technology and the possibility or desire to have it installed, subject to space availability and interest. Third, the survey investigated views on adopting renewable sources of energy as a primary or supplementary source of power generation. Fourth, the questions sought to understand the level of concern for energy savings, and efficient use of energy. The fifth aim was to assess beliefs about exposure to environmental hazards, the need to preserve nature, and carbon dioxide emissions. Finally, we evaluated the standpoint on bequest value in their consumption lifestyle, or their outlook on future generations' demand for energy and natural resources. The complete questionnaire plus socio demographic questions are attached in Appendix B.

The questionnaire was supplemented with the choice experiment questions (choice sets). However, the general questions were only used during the pilot surveys and excluded in the main survey for saving participants' time. In the following section (5.4), the process of developing the design of the ultimate choice sets for the main survey through three pilot studies is explained.

## 5.4 Choice experiment design

The choice experiment (CE) modelling technique is widely used in the field of environmental economics, based on consumer demand theory (Lancaster, 1966) and random utility (McFadden, 1974; Manski, 1977), which in turn defines goods based on characteristics not consumption value. The CE usually contains two or more alternatives plus the status quo (do nothing), and 4-5 attributes with different levels. To design a CE survey, the attributes of the alternatives need to be identified on the basis of the literature, the focus group discussions, and interviews with individuals.

### 5.4.1 *Pilot study of the CE main survey*

The process of developing the choice scenarios from the pilot study to the final revision for the main survey is now explained. Experimental choice design was applied using SAS software to create choice sets with randomly assigned attribute levels across all the CE surveys, from the first pilot to the main survey. The CE fractional factorial was designed to minimise standard error and maximise the information in the data matrix. Therefore, D-efficiency<sup>62</sup>, as a promising design (Ferrini and Scarpa, 2007) was used to maximise the elicitation of the design. This produced 72 alternative choice bundles. By pairing each choice alternative, 36 choice sets were generated, each comprising the two produced scenarios and the status quo. The presence of the status quo provided respondents with the chance to choose their existing energy system against micro-generation technology.

In SP research, respondents can either be asked to (1) choose between two or more alternatives, without the inclusion of the status quo (SQ) or a “Don’t know” or “None of the above”; or (2) choose between two or more alternatives, with the inclusion of the SQ or a “Don’t know” or “None of the above”.

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<sup>62</sup> Statistically efficient design, enhance the amount of information obtained from a design in which maximises the determinant of the variance-covariance matrix.

In other words this can be done in two ways: 1) Forced choice, when respondents may know their utility would be reduced relative to the SQ, but they feel compelled to respond the question. 2) Non-response option such as “Do not know” or a “None of the above” choice, when only an alternative with a value higher than the SQ would have to be chosen by respondents.

Boyle and Özdemir (2009) believe that the potential of distortion or bias can be arisen from both results. If the researcher wishes to gain information of respondents trade-offs between various attributes then the inclusion of the SQ is irrelevant. The inclusion of the SQ or “Don’t know” or “none of the above” options may simply make it easier for the respondent to avoid thinking about the trade-offs between attributes, and opt for an easy answer. Thus, the inclusion of the SQ or “Don’t know” or “none of the above” options may reduce the number of observations or choices with trade-offs, and result in a substantial number of SQ or “Don’t know” or “none of the above” responses. This will reduce the amount of information to model, and may necessitate the need for a larger sample size. Moreover, there is some evidence to suggest that the inclusion of “Don’t know” or “none of the above” options does not affect WTP estimates (Krosnick et al., 2002).

However, the decision not to include an SQ option in every choice question may be considered somewhat contentious. The main arguments in favour of including an SQ option in every choice situation are that it avoids ‘forced choice’ as people can simply opt out; it mimics a real-world market setting, wherein everyone is free not to buy; and it provides a helpful reference point against which respondents can compare the offered alternatives. The SQ, or “Don’t know” or “none of the above” options can be included or omitted, i.e. there is not absolute “right approach”.

*Conducting the First Pilot*

Each choice card included two alternative scenarios of RE sources of solar panels and a wind turbine, and one scenario of the status quo (maintain current source of energy). The four attributes of TYPE-COST-SIZE-ENERGY SAVING were included, which had been deliberated on in the focus group discussions. The attribute of TYPE was assigned three levels: photovoltaic, photovoltaic with tracking system, and micro-wind turbine. SIZE was also given three levels: 1000kWh, 2000kWh, and 3000kWh. Six levels of COST were defined, with the average cost the equivalent to the market price, two upper levels, and three lower than average. Similarly, the ENERGY SAVING factor was presented as six levels, based on interviews and investigating the average monthly electricity bills of a typical family of four (prices were in Turkish lira). The presented attributes in the choice sets signified the underlying factors which were conferred in the focus group discussions. Table 5.2 demonstrates an example choice set for the first pilot survey.

Table 5.2 First pilot choice card

<b>01</b>	<b>Alternative 1</b>	<b>Alternative 2</b>
<b>Type</b>	Micro-wind turbine	Photovoltaic
<b>Size (kWh)</b>	1000	2000
<b>Initial Cost (TL)</b>	9000	10000
<b>Energy saving annually (TL)</b>	800	1200
<b>Choice</b>		

I would choose neither of the alternatives and retain the current energy source

The survey evaluation was carried out by providing the respondents with the general questions (see Appendix B) followed by presenting nine choice cards in sequence to the

randomly chosen householders, who were aged above 18. Each respondent was asked to choose which of the two alternative scenarios was the most desirable, and then answer the demographic questions. The nine choice cards presented to each individual were dissimilar in levels of attributes. Repeated choices by individuals from sets of alternatives disclose the trade-offs respondents are willing to make between the attributes and the two alternatives. In total, 28 individuals were questioned face to face from various areas of Northern Cyprus.

During the data collection, it was apparent that the *SIZE* attribute was unknown to the respondents despite being given verbal clarification about each of the terms and attributes. Further explanations on each alternative (solar panels or micro-wind turbines) in terms of efficiency and dimensions of space therefore needed to be incorporated, as it was not easy for everyone to comprehend the mathematical and engineering details.

#### Revising the design

To achieve greater simplicity, the choice set design was modified. The combination of attribute levels was revised so that three factors had three levels, and two factors had six levels. In addition, *SIZE* was replaced by an *APPEARANCE* and *CAPACITY FACTOR*. The three levels of low visual, medium visual, and high visual were assigned to the *APPEARANCE* attribute for both alternatives. Likewise, the *CAPACITY FACTOR* had three levels for the photovoltaic system (15%-20%-25%) and three levels (20%-25%-30%) for the micro-wind turbine. The larger defined *CAPACITY FACTOR* for micro-wind turbines compared with the photovoltaic system rests on the evidence from the technical experiments, and is not a randomly assigned number. Additionally, a follow up question was added to the end of the questionnaire to check whether the respondents found the questions easy or difficult.

#### *Conducting the Second Pilot*

The second pilot was conducted with 20 individuals via face to face interview. Similar to the first pilot, the general questionnaire was given to each respondent and then he/she was presented with nine choice cards one after another, followed by a set of demographic questions. Table 5.3 shows an example of the second stage design choice sets for the second pilot survey.

Table 5.3 Second pilot choice card

<b>01</b>	<b>Alternative 1</b>	<b>Alternative 2</b>
<b>Type</b>	Photovoltaic	Photovoltaic +track
<b>Capacity factor, annually</b>	20%	25%
<b>Appearance</b>	Medium visual	High visual
<b>Initial Cost (TL)</b>	8000	11000
<b>Energy saving annually (TL)</b>	800	1500
<b>Choice</b>		

I would choose neither of the alternatives and retain the current energy source

During the data collection for the second pilot, we noted that the choice cards were received with less ambiguity by the respondents. This confirmed the improvement in the design and combination of the choice set, compared with the first version. Thus, due to the higher transparency and clarity, and we were required to give less clarification of the attributes.

However, the respondents predominantly noted that they found the questions difficult rather than easy. In addition, the results from the economic analysis of the collected data showed that a photovoltaic system with tracking had not drawn the respondents' attention sufficiently. In other words, it was neglected, indicating that there was a lack of

awareness of the new technology which would influence the choice or decision making. It may be that people in Northern Cyprus lack experience of photovoltaic systems, as it is a very new technology for generating electricity. With this in mind, it was essential to add an explanation regarding photovoltaic know-how for systems with and without tracking systems. Accordingly, a memory jogger including visual aids was prepared so as to elucidate the function of the tracking system. In the protocol, the advantages were explained of the greater efficiency, capacity factor, and space saving, for the photovoltaic system with tracking (see Appendix C).

In the meantime, financial incentive regulations for investing<sup>63</sup> in solar energy had been approved by the Northern Cyprus government. It was stated that 25% of the installation cost would be funded through government subsidy to the investors, and also the electricity generated from solar energy could be sold to the grid with a feed-in tariff of 0.25 Euro per kWh. Therefore, this new regulation was revised in the introduction of the protocol manuscript and questionnaire ( see Appendix F), in the following form:

Previous statement:

*“Please assume that renewable energy laws are being enacted and EU legislations are being followed in North Cyprus”.*

Replacement statement:

*“I would be pleased if you could keep these conditions in mind while completing this form (25% subsidy for installation of PV, feed-in tariff of 0.25 Euro (=0.60TL)<sup>64</sup>”.*

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<sup>63</sup>The new regulations were approved by the time of the main survey conduction in 2012.

<sup>64</sup> It was the currency rate at the time of survey conduction.

Consequently, we decided to include policy incentives in the choice set to measure the optimal level of subsidy and feed-in tariff (FIT). Note that, henceforth, the Euro was used across all surveys instead of Turkish lira. SUBSIDY was included in the choice sets by subtracting it from the initial cost of investment. In addition, FIT was incorporated as an attribute with three levels of 0.25 TL=0.10 Euro – 0.50 TL=0.25 Euro and 0.90TL=0.40 Euro in the choice sets. Additionally, based on the experiment, 7.1m<sup>2</sup> is the required area for a 1kWp photovoltaic system. Simultaneously, the terminologies were revised for further simplicity, such that the APPEARANCE and CAPACITY FACTORS were replaced by REQUIRED AREA AND SPACE in the choice set. Three levels were assigned to the SPACE REQUIRED attribute for solar panels and micro-wind turbines, respectively, in the order as follows:

Adjusted set    7m<sup>2</sup>; 1kWp   -  15m<sup>2</sup>; 2kWp   -  25m<sup>2</sup>; 3kWp

Previous set    1m<sup>2</sup>; 1kWp   -  2m<sup>2</sup>; 2kWp   -  3m<sup>2</sup>; 3kWp

#### *Conducting the Third Pilot*

Consequently, there was a need to test the validity of the design of the adjusted choice set.

Table 5.4 depicts an example of the third reviewed choice cards.

Table 5.4 Third pilot choice card

<b>01</b>	<b>Alternative 1</b>	<b>Alternative 2</b>
<b>Type</b>	Photovoltaic	Photovoltaic + tracking system
<b>Feed-in tariff€</b>	0.60	0.80
<b>Space required</b>	15m <sup>2</sup> ; 2kWp	25m <sup>2</sup> ; 3kWp
<b>Initial investment cost€+ subsidy</b>	6500	11000
<b>Energy saving€ (annual)</b>	800	1500

I would choose neither of the alternatives and retain the current energy source

The third pilot survey was carried out with 20 people via face to face interview. It began with an explanation of the technique and mechanism of the PV plus tracking system, using visual aids as support. For the ease of the respondents and to avoid fatigue, the six choice cards were presented to each respondent, rather than the nine in the previous surveys. Identical to the earlier pilots, this survey concluded with a request to complete the socio-demographic questionnaire.

The results revealed that the respondents held the same view about the PV tracking system as in the earlier piloting, despite further exposition via visual aids on the subject of the tracking system device. This essentially created the need for an investigation through small group or individual interview to discover the reasons for the reluctance towards the tracking system and micro-wind turbine. It was felt that the advantages of saving energy and space, which are inherent to the tracking system, would not outweigh the initial cost or the cost for professional repair and advice in the case of fault. In addition, some believed that the micro wind turbine would not be an attractive alternative due to noise nuisance, obstruction of views, and the greater availability of the sun. Generally, Cypriots

are more aware of solar panel systems for water heating as these have been installed on the roof of the majority of buildings over the past forty years.

Hence, the information gathered from the debriefing and from individuals' insights fed into the design of the next choice set. This time the focus of the study was only on micro-generation solar energy based on people's views and government-approved regulations for solar energy. These regulations created the need to reconsider the project from the policy standpoint, and so in what follows we looked at individual preferences for micro-generation solar technology in relation to the existing sources of energy (e.g. fuel, oil). In addition, we aimed to evaluate the optimal level of financial incentives, such as via subsidy and feed-in tariff. The results of these estimations might be reflected in adjustments to government regulations should more households need to be enticed to install micro-generation solar energy on the roof, balcony or garden of their houses.

The assumption of COST as an attribute enabled the estimation of willingness to pay. The SPACE REQUIRED and SAVING ENERGY attributes allowed the assessment of the potential limitations and level of advantage to the micro-generation solar system from the householders' perspective. Overall, the most and least frequently considered attributes were included in the choice set to estimate the willingness to pay for micro-generation solar panels. In Chapter 8, the choice experiment main survey and the results are explained. Table 5.4 illustrates an example of the main survey's choice set for the micro-generation solar system. The diversity of attribute levels made two different generic scenarios of A and B.

Table 5.5 Main survey choice card

Micro-generation solar panel		
01	Alternative 1	Alternative 2
Subsidy	40%	10%
Feed in tariff €	0.30	0.20
Space required	8m <sup>2</sup> ; 1kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	4000	14000
Energy saving €/Annual	1200	3600
<b>Choice</b>		
<input type="checkbox"/> I would choose neither of the alternatives and retain the current energy source		

Additionally, a follow up question was added to the questionnaire to rank the choice attributes, namely, SUBSIDY, FIT, SPACE, COST, and SAVING. The 36 generated choice cards which were used in the main survey are attached in Appendix F.

### 5.5 Experimental mechanism for the CV survey

Contingent valuation (CV) is a widely used survey-based technique in the field of environmental economics. The conventional CV approach can be administered to respondents in different ways, such as via open-ended questions, a payment ladder, or closed-ended single and double bounded dichotomous choice questions. An open-ended question directly asks the respondent *what is the maximum amount you would be willing to pay for Z*. The closed-ended single bounded dichotomous choice asks *would you be willing to pay X for Z, yes or no*; double-bounded dichotomous choice question would you be willing to pay X for Z, yes or no; if yes would you be willing to pay X+a for Z, if no would you be willing to pay X-a for Z. The underlying demand function is the individual's WTP, and the demand elasticity can be measured from the individual's responses. Despite the popularity of CV questions in evaluating non-market goods, this

method inherently has hypothetical and strategic behaviour bias. Therefore, the survey design needs to overcome these limitations to elicit truthful values of responses. Because WTA compensation tends to generate larger responses, a well designed CV survey can deal with irrational behaviour and reduce overstated WTA values. Following studies by Eisenberger and Weber (1995), Plott and Zeiler (2005) and Chilton et al. (2012), we also assessed the WTP and WTA via two settings of conventional and experimental surveys from different respondents. The experimental setting was based on the fundamental assumption of incentive compatibility using Becker-DeGroot-Marschak (BDM) to prevent individuals' strategically behaviour (Becker *et al.*, 1964). This helps respondents to have a better understanding about minimum WTA and maximum WTP concepts. Particularly, the experimental approach aims to elicit the truthful minimum WTA and maximum WTP responses, which requires beginning with the respondents' familiarity with the terminologies prior to asking the main questions. In addition, the inclusion of the further clarification so called cheap-talk in the survey helps to circumvent the hypothetical bias (Carson and Groves, 2011).

Traditionally, individuals would be asked their maximum WTP and minimum WTA, regardless of intuitive understanding of the terminologies. Therefore, to help respondents have a better understanding about minimum WTA and maximum WTP concepts and the potential consequences of over- and under-stating, an experimental survey in accordance with the incentive compatibility was designed and examined.

To do so, a protocol was prepared. The protocol included the two concerns of this study: firstly, familiarising respondents with the concepts of minimum WTA and maximum WTP and the consequences of untruthful responses; and secondly, asking respondents to state their minimum WTA and maximum WTP for the installation of micro-generation

solar panels on their premises. Finally, they were asked to complete a socio-demographic form.

### **5.5.1** *Experimental approach*

The content of the protocol was supplemented by visual aids, to aid memory and assist the respondents with the questions. The protocol consisted of two sections on WTA and WTP, and the minimum WTA concept was first introduced and practised. Between five to twelve respondents participated in each group session and the participants were incentivised by the opportunity to enter a prize draw for a prize of €10. The practice procedure started with an introductory session on the study's subject and brief information was given to them about micro-generation solar technology for the residential sector.

The group discussion began by introducing them to the term 'reserve price' as a substitute for the term minimum WTA. Based on (Chilton et al., 2012) respondents are usually more comfortable with 'reserve price' as a term, and these participants were familiarised with the term by discussing the process of selling (600m<sup>2</sup>) land in an auction. The reserve price was explained as the lowest fixed price (floor price), at which the land could be offered at the auction sale. This was followed by introducing the term 'external sealed bid', and also to simplify the meaning of minimum WTA. Respondents were divided into two groups and asked to discuss a 'reserve price,' i.e. the minimum price they would accept for a teddy (which had been given to them beforehand). Then, the reserve price was compared with a predetermined sealed bid in a second price auction mechanism. After comparing the respondents' answers and the sealed bids, the question of 'why it is always best to be truthful' was discussed. In particular, the experimenter should clarify the possibility of the undesirable consequences of over- or under-stating, i.e. in the case of over-bidding, there is a danger that the vendor keeps the item rather than sells it.

Similarly, this is the case of under-bidding when the item sells for less than it is worth. Respondents were given a 'memory jogger' to summarise the key concepts, and their answers were recorded in response books.

The subsequent valuation survey was based on individual answers, so it was important that respondents had some experience of deciding their own WTA for an item. Participants were given two tokens for entry to a prize draw. In each of two rounds, participants recorded their 'reserve price' or minimum willingness to accept, for selling the token and foregoing entry into the draw. Their reserve price was compared with a sealed bid in an envelope (100 bids ranging from (€1 to €10), which had already been randomly selected from a visible box at the front of the room. If their reserve price was lower than, or equal to, this sealed bid they would sell the token, and receive a higher or equivalent sealed bid, but if the reserve price was higher, s/he would not sell the token and be put into the draw.

In the process of WTP, contributors were given €2 to spend, €1 in each round, to buy two tickets for entry to a prize draw for €10. In each round, participants' maximum willingness to pay was recorded in order to buy a token to enter into a new prize draw. Then, after participants were presented with a box of chocolates and told that it would be sold, they were asked how much they were willing to pay for it. In other words, the respondents were asked to bid their maximum willingness to pay for the box of chocolates. Before respondents had revealed their maximum WTP amount for the box of chocolates, they were sufficiently familiarised with the potential consequences of over- or under-bidding. In the case of under-bidding when the offered price for the item is less than it is worth, there is a danger of the item not being sold to the buyer, and the vendor decides not to sell for the offered value. Based on the predetermined value or sealed bid price, the respondent's maximum WTP was evaluated. Each respondent had a memory

jogger in his/her hand throughout the practice in the form of their response books. (For further detail, see Appendix D).

### *5.5.2 Pilot study using mechanism with CV format*

Based on experience, householders are usually more experienced in buying rather than selling. Consistently, the result of empirical studies mirrors the fact that people's minimum WTA and maximum WTP are usually unequal, as WTA usually takes a larger value. WTA is the minimum amount that an individual is willing to accept for foregoing with a good, whereas WTP is the maximum amount that an individual is willing to pay to procure a good.

Numerous studies have used CV questions in the field of environmental economics and encountered the gap between WTA/WTP (Horowitz and McConnell, 2000). This discrepancy and inequality between WTA/WTP has become the subject of study. Thus far, the empirical methods such as Vickery auctions, BDM and other methods have been proposed in an attempt to avoid this difficulty. Due to the underlying assumption that people are unaccustomed and inexperienced at selling their items, the difficulty can be more inherent with WTA valuation than WTP. This problem can be tackled by raising awareness and knowledge in terms of the possible consequences of strategic of overstating and understating values. In the case of overstating WTA, the seller may lose the customer. Likewise, understating the WTP amount may leave the purchaser with no good.

In this research, we used the teaching mechanism to evaluate an individual's WTA a 1.2 MW solar park nearby. This mechanism was designed on the basis of studies by Plott and Zeiler (2005) and Chilton et al. (2012). The key element was to test and pilot the impact of the mechanism for eliciting the minimum willingness to accept truthful responses, which begin with familiarising respondents with the term minimum WTA. To do so, a

protocol was adopted for piloting, including a memory jogger following Chilton et al. (2012), as shown in Figure 5.1. The sample population were the householders living near a 1.2 MW solar park. In total, 100 respondents comprised the sample population from the Serhatkoy area (pictures from solar park and area are attached in Appendix D). The 50-person sample was interviewed individually. In this fashion, respondents were not provided with any clarification on minimum WTA terminology prior to asking the key question. On the other hand, the opportunity to clarify terminologies was provided in the experimental survey, involving 50 respondents in groups of five to twelve. These group discussions took place in a traditional local coffee shop in the village in the vicinity of Serhatkoy, where mainly men gather to drink coffee or tea during the day.

Before starting evaluation of the solar park, we ensured that the respondents were sufficiently practised and experienced at truthful bidding. Then, the respondents' evaluation of the solar park was carried out using the below cheap-talk script:

*The process of the discussion that we went through was implemented with the intention of eliciting your truthful responses. We tried to clarify what will be the consequences of overestimating a value to incentivise you to state an amount close to your actual valuation.*

Then, following the aforementioned experimental procedure, we asked individual's minimum WTA for the amenity loss caused by the erected solar park in the neighbourhood of Serhatkoy:

*You live near a 1.2 MW Solar Park. This Solar Park may cause inconvenience for people who live nearby such as:*

- Visual effect –changes to the view
- Loss of space –land use.

In spite of these inconveniences and the disamenity caused,

*What would be your minimum WTA (reserve price) compensation for the inconveniences caused by a 1.2 MW solar park?*

***Processing the valuation***

The respondents' reserve price was compared with the sealed price which had been set before by the government and solar company. Factors such as the cost of land, the cost of operation, and the cost of construction influenced the sealed price or pre-set amount. Three scenarios could have potentially arisen on comparison of the respondents' reserve price and the sealed bid price. Firstly, if the respondents' reserve price was more than the pre-set amount, they would not be compensated. This refers to those who disagreed with the existence of the nearby solar park, and who preferred to keep space and the view. Secondly, if the respondents' reserve price was equal to the pre-set amount, they would receive a compensation amount equal to the pre-set amount for the loss of amenity caused by living near to a solar park. Thirdly, if the respondents' reserve price was less than the pre-set amount, they would receive a compensation amount more than their reserve price, equal to the pre-set amount for the loss of amenity caused by living near to a solar park.

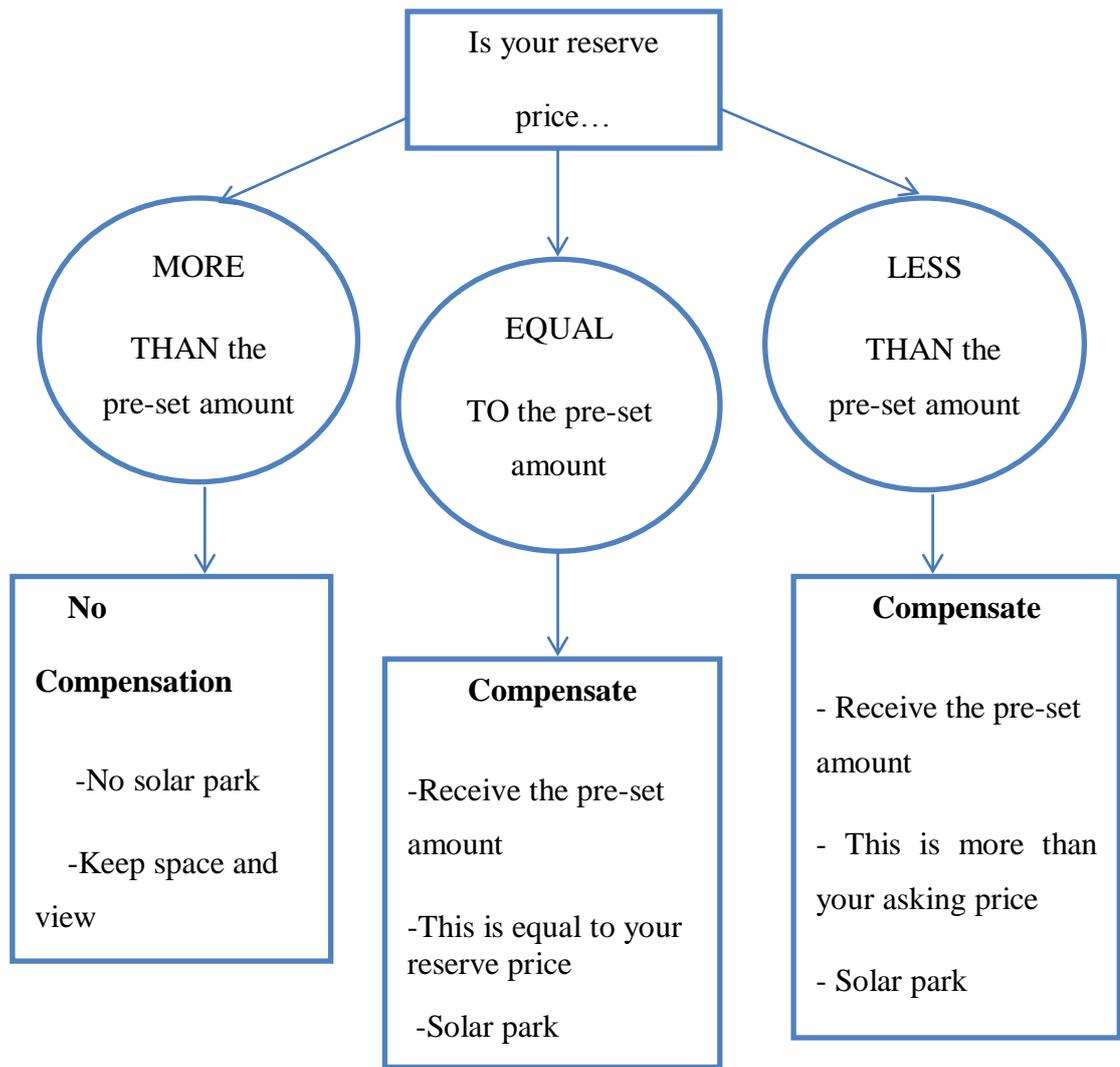


Figure 5.1 Memory jogger for the solar park WTA evaluation

The key points:

1. Once you have given your reserve price to the solar company or government, the rules determine whether you will be compensated or not.
2. If you receive any money, you receive the PRESET AMOUNT, not your reserve price.
3. There's NO POINT OVERSTATING what you'd accept.
  - No compensation at the price you think is low.

There's no point understating what you'd pay.

- Amenity is lost when you prefer the solar park and are compensated at the price you would like to accept.

Along these lines, the structure of the solar park valuation questions was coordinated with questions in the earlier learning experiment. The supplier's (government or private company) unknown price worked as the sealed bid in earlier rounds, and the same consequences of over- and under-bidding was applied. Each respondent was provided with a memory jogger during the course of the experiment, and they were directed to determine their reserve price, being aware of the consequences of over- and under-estimating. In the last part, respondents were required to fill in a demographics questionnaire. The sequence of the WTA evaluation based on teaching and experiment are delineated in Table 5.6.

Table 5.6 Experimental design: Optimal WTA Responses

<b>Stage</b>	<b>Purpose</b>
<p>1. (Hypothetical): Selling a piece of land</p> <p>Discussion</p>	<p>To introduce the idea of a pre-set selling amount (reserve price), respondents' true values, the dangers of over/underbidding, second price auction rules</p>
<p>2. (Hypothetical): Selling a Teddy</p> <p>Discussion</p>	<p>To reinforce the idea of the pre-set selling amount (reserve price), true values, the dangers of over/underbidding, second price auction rules; to introduce and demonstrate the role of the (secret) sealed bid within the second price auction</p>
<p>3. (Real): Selling a draw entry ticket</p> <p>Experiment</p>	<p>Experience of selling and using the mechanism, elicitation of minimum WTA values in an incentivised context</p>
<p>4. (Hypothetical): Solar park valuation, WTA</p> <p>Survey</p>	<p>Elicitation of monetary values from respondents who have an understanding/intuition of the economic meaning of minimum WTA</p>

## **5.6 Summary and conclusions**

This chapter explains the commencement of the empirical and experimental test of my thesis research to the end. This involved the use of direct survey stated preference techniques underpinning the utility function for the evaluation of non-use value in the context of environmental economics. This chapter explains the experiences and insights which were gained through different instruments such as focus group studies, interviews and debriefing, and pilot surveys to pace the stages and procedures of progression towards completion. These instruments brought light to the concentration of the study on micro-generation solar panels. In addition, different links between policy and economic behaviour were perceived, leading towards policy analysis and implications.

Through the study, essential experimental devices were employed prior to the main survey for the sake of clarity. The trend of the study was the underpinning of individuals' intuitive understanding of the terminologies and attributes in both CV and CE studies of stated preferences. This intuitive understanding rests on the incentive compatible mechanism, when participants reveal their responses truthfully to the questions asked. Overall, this chapter explains the development process behind the main surveys (Chapters 6-7-8) to achieve the outcome by means of empirical methods and economic analysis.

## **Chapter 6. Overstating WTA and Understating WTP and the Role of Incentives**

### **6.1 Introduction**

This chapter examines and compares households' willingness to accept (WTA)/willingness to pay (WTP) ratio for solar technology equipment on their premises through both a novel experimental approach and conventional techniques. In so doing, we tested the role of an incentive-compatible survey design on the WTA/WTP ratio.

Cyprus has 300 days of sunny weather per year and there is therefore a high potential for solar energy utilisation above other renewable energy (RE) sources, in particular micro-generation solar panels. The government is attempting to raise people awareness about the benefits of energy efficiency, diversification of sources of energy and being less dependent on imported fossil fuels. This can be done by changing people's behaviour towards energy production and consumption, primarily by the use of incentives. Moreover, the individuals' behaviour toward this technology and policy can be measured by eliciting people's WTA and WTP for micro-generation solar panels. Contingent valuation (CV) a well-known stated preference (SP) technique is often applied to estimate non-market values. However, this method can be subject to some inherent hypothetical and strategically behaviour biases. Carson et al. (2001) suggested the role of survey design to overcome the CV limitations in order to elicit truthfully values of responses. Because WTA compensation tends to generate larger protest responses, Hanley and Shogren, (2005) provide suggestions on how well CV format should be designed and WTA scenario be structured to deal with irrational behaviour and reduce overstated WTA values. Due to the fact that, the rational choice is the underlying element in cost-benefit analysis (CBA), behavioural economics is interconnected with environmental

policy. This chapter explores the role of the survey's design and data elicitation by comparing the results generated both with and without the provision of the experimental setting.

The sections of this chapter are as follows. Section 6.2 refers to the relevant literature on preference evaluation in the context of micro-generation technology. Section 6.3 describes the methodology that was used to carry out the survey. Subsection 6.3.1 elucidates the experimental approach that was applied to cope with the problems of SP hypothetical bias and respondents' strategic behaviour. A Becker-DeGroot-Marschak (BDM)<sup>65</sup> incentive compatible experimental study was adopted to induce truth-telling to cope with some of the behavioural anomalies that can potentially affect the use of CV in estimating the benefit of environmental policies. BDM elicits an individual's true maximum WTP (Becker et al., 1964). In addition, the inclusion of the further clarification so called cheap-talk<sup>66</sup> in the survey helps to refute the hypothetical bias. Subsection 6.3.2 explains the experimental approach, including the key questions for micro-generation solar system. Section 6.4 identifies the population targeted for sampling. Section 6.5 presents the results of the two approaches and compares the findings. Section 6.6 compares and contrasts the findings with studies that have been previously reported in the environmental economics literature. Section 6.7 summarises and concludes the chapter.

## **6.2 Background on micro-generation solar systems**

The high capital cost of micro-generation solar technology is a barrier to accelerating the distribution and supply of the technology. However, consumers can be influenced by

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<sup>65</sup> The BDM acts similar to a second price auction. It asks a respondent to state his/her willingness to pay for the item in question, and then a price is randomly drawn from distribution. If the respondent's stated amount is equal to, or larger than, the random price, he or she obtains the item, but if the stated amount is less than the randomly drawn price, no payment is required and nothing is obtained.

<sup>66</sup> It has the ability to influence the respondent's opinion about the good in question when respondents do not have dominant strategies (Carson and Groves, 2011).

financial incentives to install them on their premises. Previous studies have suggested the viability of grid connected micro-generation solar systems in the residential sector. Scarpa and Willis (2010) suggested that, in the UK, government grants would need to be increased to attract more households to install micro-generation systems and offset the higher cost of the RE micro-generation systems. However, their results showed that despite households' enthusiasm for investing and their WTP for micro-generation systems, the benefits households received from micro-generation were not sufficiently large to cover the capital cost of micro-generation energy technologies. Claudy et al. (2011) reviewed the Irish's WTP for micro-generation technologies, and found that their WTP was considerably lower than the actual market prices. The main obstacle was said to be the initial cost of purchasing or installation, but they also suggested more market based finance options for consumers such as leasing and 'fee for service.' An alternative to leasing and fee for service might be the network connection. Grid connection has a number of advantages over the stand-alone or off-grid system and may enhance the number of investors. It offers both reliability and financial benefits for consumers and an unfailing connection to electricity would be guaranteed. Any excess generated electricity can be exported and sold to the grid and electricity outages can be prevented by importing when there is no sun. In addition, it saves the extra cost of installing batteries. However, although the need for financial incentives to induce consumers has been recognised by governments and policy makers, the economic cost and burden of lending support should not be neglected. A CBA based on individuals' responses provides an insight into the extent of the incentives required. The demand elasticity for government financial support can be measured by using the SP methods.

### 6.3 The survey method

CV technique was used to evaluate the WTP and WTA values. CV is a widely used direct survey approach in the field of environmental economics. With this technique, analysts measure the monetary values of changes in the qualities of goods or amenities. The compensation measures the WTA for the amenity loss or minimum amount that an individual is willing to accept for the loss, and the equivalent measure is the WTP measures the maximum amount of the individual's willingness to pay for an environmental gain (Hanemann, 1991). The difference between WTA and WTP values is a focus of economic analysis; the discrepancy between WTA and WTP values has been reported by a number of studies in the literature. But the requirement of larger sum to compensate than the WTP amount has been frequently reported by the researchers (Knetsch and Sinden, 1984). In the context of environmental assessment, the ratio of WTA/WTP is often explained as the ratio of accepting compensation for losing amenity over the relinquishing of some money to benefit from the obtained goods or services. The underlying demand function is the individual's WTP and the demand elasticity can be measured from the individual's responses. In addition, policy implications may be drawn to regulate the extent of the subsidies and other types of financial incentives (Berry et al., 2012). The conventional CV approach can be administered to respondents in different ways, such as via open-ended questions, a payment ladder, or closed-ended single and double-bounded dichotomous choice questions. An open-ended question asks respondent directly about the maximum amount they would be willing to pay for Z. Each CV elicitation's format has its own features (as explained in Chapter 3) that distinguish one from the other, but all can be used effectively under certain circumstances. For instance, despite the assumption that the closed-ended referenda format is more incentive compatible than open-ended in the hypothetical study (Arrow et al., 1993; Carson and Groves, 2007), lower WTP was evidenced with the open-ended questions (Kriström,

1993; Brown et al., 1996). Additionally, a lower hypothetical bias was found in hypothetical rather than actual WTP settings (Balistreri et al., 2001; List and Gallet, 2001). This implies that the lower WTP can be perceived due to the larger non-response proportions in an open-ended format. In addition, sometimes respondents with a lower propensity to meet the expense of the good in question may overstate their WTP in an open-ended question. Carson and Groves, (2007, p.203) stated that “it is impossible to formulate a simple open-ended matching question that is both informationally and strategically equivalent to an incentive compatible binary discrete choice question in a survey context”, unless the respondents are provided either with a specific price or a device that chooses the cost independent of the individual’s answer. In this manner, unneeded information is not included from the responses to the open-ended questions. Moreover, the use of BDM with the open-ended format is said to facilitate the incentive compatibility of the survey setting (Becker et al., 1964; Sugden, 1999b; Carson and Groves, 2007). With this technique, individuals have the incentive to state their maximum WTP. “This incentive is supposedly robust in the sense that truth-telling is a dominant strategy and therefore independent of risk attitudes and even of whether the individual is an expected utility maximiser” (Horowitz, 2006, p.7).

In addition, to control the hypothetical problem of an SP survey, a number of studies suggested the use of cheap-talk to minimise the hypothetical bias effect either in open-ended or closed-ended formats (Farrell and Rabin, 1996; Cummings and Taylor, 1999; List, 2001; Brown et al., 2003; Aadland and Caplan, 2006; Carlsson et al., 2011; Carson and Groves, 2011). With an open-ended question, the cheap-talk script resulted in a decrease in the quantity of respondents stating a zero WTP and an increase in the WTP (Carlsson et al., 2011); therefore, hypothetical bias can be circumvented with the use of cheap-talk. Carson and Groves (2011) state that cheap-talk is not a costless technique for non-market valuation if it influences the actions of players in the game. Therefore, the

economic value of the difference with and without its use needs to be calculated. The term cheap-talk is used in game theory<sup>67</sup> in an attempt to prevent the dominant strategy in such a way that one has no incentives to lie in the game, which is the so called equilibrium strategy. This strategy occurs when players share information consistently and on balance with incentives.

To accomplish a survey with the objective of gathering truthful responses, it is essential for the survey to be designed in accordance with the incentive compatibility format, owing to the high possibility of an individual's over-stating or under-stating the value of the good in question in so called strategic behaviour. This may happen when respondents think that a decision will be made based on their evaluation, and their answers may contribute to delivering the good at a lower price. To avert or minimise some of the limitations of the CV method, an incentivised mechanism can be incorporated prior to asking the key questions. For instance, an incentive compatible survey can be implemented through the following instruments: a voting system, price auction, lottery auction, games, prize draw, and the selling and buying of items. The information revealed by the respondents' answers would be the outcome of incentive strategies and the explicit information about the question itself to the respondent.

Following studies (Eisenberger and Weber, 1995) and (Plott and Zeiler, 2005; Chilton et al., 2012), this study also evaluates the WTP and WTA via two structures of conventional and experimental surveys from different respondents. Traditionally, individuals were asked their maximum WTP and minimum WTA, regardless of intuitive understanding of the terminologies. Therefore, to help respondents have a better understanding about

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<sup>67</sup> As its name implies costless way of signalling, Hurwicz (1973) introduced the theory of mechanism design supports 'incentive compatibility' which is derived from group choices and decisions in economic contexts.

minimum WTA and maximum WTP concepts and the potential consequences of over- and under-stating, an experimental survey in accordance with the incentive compatibility was designed and implemented. In addition, to control for order effects and allow for a between and within subject evaluation, the study was carried out with two groups of respondents with and without the experimental approach. The respondents of one group were individually asked to respond to the open-ended questions without the use of clarification and experimental values. They were required to state their minimum WTA and maximum WTP for solar technology equipment. The other survey was elicited with the same open-ended question but prior to that we used the experimental approach. Prior to eliciting values for the solar technology intervention, we administered the BDM practice with familiar goods and then cheap-talk (see Appendix H) was used before asking the main question. However, it is worth noting that the micro-generation solar equipment elicitation is not itself incentive compatible, as even if individuals believe that their decisions potentially have consequences, the conditions for incentive compatible elicitation will not be met. Micro-generation solar panels can be categorised as a new product and people are unfamiliar with this innovation (Carson and Groves, 2007).

Furthermore, the results of these two settings were compared in order to determine the role of the incentivised mechanism. Particularly, the experimental approach aims to elicit the truthful minimum WTA and maximum WTP responses, which requires beginning with the respondents' familiarity with the terminologies prior to asking the main questions. The conventional approach was considered as a control group for the experimental study in order to compare the gap.

The protocol includes two concerns of this study; firstly, familiarising respondents with the concepts of minimum WTA and maximum WTP and the consequences of untruthful responses; and secondly, asking respondents to state their minimum WTA and maximum

WTP for installation of 1kWp micro-generation solar panels on their premises. Finally, they were asked to complete a socio-demographic form.

### **6.3.1 *Experimental approach***

The content of the protocol was supplemented by visual aids (for further detail see Appendix C), to aid memory and assist the respondents with the questions. The protocol consisted of two sections on WTA and WTP, and the minimum WTA concept was first introduced and practised. Because, the pre- survey made it apparent for us that respondents are more sensitive to minimum WTA terminology compared with maximum WTP. Thus, the elicitation was carried out firstly by asking WTA question from all the respondents instead of splitting the sample, to increase the respondents' ability to respond. Then, all the respondents maximum WTP was evaluated. Generally, when a respondent is faced with a multiple choices in a long survey, fatigue effects can be observed.

Between five to twelve respondents participated in each group session and the participants were incentivised by the opportunity to enter a prize draw for a prize of €10. The practice procedure started with an introductory session on the study's subject and brief information was given to them about micro-generation solar technology for the residential sector. Following the procedure which is explained in chapter 5, the participants were divided into two groups to discuss the term 'reserve price' hypothetically and in reality with the aim to become familiar with the terms minimum WTA, maximum WTP and the consequences of over-bidding and underbidding. The micro-generation evaluation started using the cheap-talk script (see Appendix H). Then, each respondent was given a 'memory jogger', summary of the key concepts, and their answers were recorded in response books.

A complete description of the instrument is attached in Appendix H.

### **6.3.2 *Micro-generation solar technology evaluation***

At this stage, respondents should be sufficiently practised and experienced for truthful bidding in order to start solar technology evaluation questions. Again, respondents were supported by the memory jogger hand-out throughout the micro-generation solar system evaluation. The participants were requested to assume that we were a government or private company offering to install micro-generation solar panels in their properties. An area of 8m<sup>2</sup> was considered for the installation of 1kWp solar panels, including a space allowance for maintenance. We told the respondents ‘you will be losing the amenity for a specific period (15years). They were then asked to consider, in spite of these inconveniences, *their minimum willingness to accept compensation*.

Then, after the respondents had answered the first question, we asked them again to assume that a government or private company had offered to install 1kWp micro-generation solar panels in an area of 8m<sup>2</sup> in their property. Again, they were *asked to reveal their maximum willingness to pay*.

Throughout the evaluation, the respondents were supported with memory joggers and were given sufficient explanations and opportunities to ask questions from the moderator (see Appendix H). Finally, participants were given a demographics questionnaire to fill in, and then the session finished with the prize draw. The demographic questionnaire is attached in Appendix B.

## **6.4 Study sample**

The target population of this study was drawn from a residential sector in Northern Cyprus. The survey was conducted in urban areas including Nicosia, Famagusta and Kyrenia as well as rural regions including Karpaz and Iskele, Guzelyurt and Lefke. In total, 105 respondents comprised the sample of this study, and they were the decision makers for the household’s expenditure, regardless of their gender. All the participants

were aged above 18 with a mean age of 45. The sample population for the conventional CV study was 50 respondents, who were interviewed individually. In this fashion, respondents were not provided with any clarification on terminologies of maximum WTP and minimum WTA prior to asking the key question. On the other hand, the opportunity to clarify terminologies was provided in the experimental survey, and this study was conducted with 55 respondents in groups of five to twelve. During the data collection in the experimental setting, images and photos were provided; some of them are attached in Appendix G. In what follows, we present and compare the results of the conventional and experimental approaches.

## 6.5 Results

In order to compare the WTA/WTP divergences, the WTA/WTP ratios of the conventional and experimental approaches were calculated separately. Table 6.1 shows the outcome of the conventional approach, where the mean WTA was €15,418 and the mean WTP was €4,392. The WTA/WTP ratio was approximately 3.5:1.

Table 6.1 Conventional approach

N	Variable	Mean	Standard Deviation	Minimum	Maximum
50	WTA	15,418.85	26,821.11	2,800	170,000
50	WTP	4,392.95	9,053.47	700	60,000
	Ratio	3.50990	2.9625		

Values in Euros, 2013 prices

In addition, to explore the disparity when the highest bids are removed, a sensitivity analysis was carried out (Bateman et al., 1995). Table 6.2 shows the results of truncation analysis for conventional approach. The top 5% of values were trimmed, which resulted

in top values of 50K and 30K. Therefore, the mean ratio decreased from 3.50:1 to 1.343:1.

Table 6.2 Truncation analysis for conventional approach

N	Variable	Mean	Standard Deviation	Minimum	Maximum
46	WTA	10737.36	18756.02	2,800	50,000
46	WTP	7992.1	20655.72	700	30,000
	Ratio	1.343	0.9080		

Values in Euros, 2013 prices

The result of the experimental mechanism is provided in Table 6.3. This result explicitly illustrates the function of the experimental mechanism in that the WTA and WTP values have converged. A significant reduction in WTA values generated a mean value of €6,390. Therefore, the WTA/WTP converged at 1.08:1. Subsequently, the standard deviation values for WTA and WTP from the experimental mechanism were more consistent and had a lower obtained ratio.

Table 6.3 Experimental mechanism

N	Variable	Mean	Standard Deviation	Minimum	Maximum
55	WTA	6,390.11	5,196.85	1,700	35,000
55	WTP	5,913.77	3,222.76	2,600	18,000
	Ratio	1.080715	1.612		

Values in Euros, 2013 prices

Furthermore, to test the gap between WTA/WTP, a sensitivity analysis for the experimental approach was also used. The results are reported in Table 6.4. Similar to the conventional approach, the top 5% of WTA and WTP values were trimmed, which resulted in top values of 15 K and 40K. Therefore, the mean ratio decreased from 1.08:1

to 0.385:1. The sensitivity analysis results for conventional and experimental data indicate the presence of the extreme bids, however the reduction in truncated mean values from conventional data was higher, and the discrepancy decreased substantially.

Table 6.4 Truncation analysis for experimental approach

N	Variable	Mean	Standard Deviation	Minimum	Maximum
51	WTA	5862.48	4767.75	17,00	15,000
51	WTP	15207	7612.1	2600	40,000
	Ratio	0.385	0.626		

Values in Euros, 2013 prices

As reported in Table 6.5, participants' WTP increased from 4,392 to 5,913 Euros, with a  $WTP_E/WTP_C$  ratio equal to 1.34, when they were provided with an intuitive understanding of the terminologies.

Table 6.5 Means of WTPs

Variable	Mean	Standard Deviation
Experimental-maximum WTP	5,913.77	3,222.76
Conventional-maximum WTP	4,392.95	9,053.47
Ratio	1.34619	0.3559

Values in Euros, 2013 prices

Similarly, as shown in Table 6.6, respondents' WTA decreased from 15,418.85 to 6,390 Euros with 0.414  $WTA_E/WTA_C$  ratio.

Additionally, the T test was used to compute the difference between  $WTA_E-WTA_C$  and  $WTP_E-WTP_C$ , and the results are presented in Table 6.7. The statistically significant  $WTA_E-WTA_C$  with the mean value = -9,028 at the 0.05 level explains that the  $WTA_E$  is

smaller than the  $WTA_C$ . The statistically significant WTAs t value = -2.28 was larger than WTPs t value= 1.16, and this shows a statistically larger discrepancy between  $WTA_E$ - $WTA_C$  than  $WTP_E$ - $WTP_C$  values.

Overall, the results from Tables of 6.5, 6.6, and 6.7 indicate the effect of the experimental setting in the survey.

Table 6.6 Means of WTAs

Variable	Mean	Standard Deviation
Experimental-minimum WTA	6,390.11	5,196.85
Conventional-minimum WTA	15,418.85	26,821.11
Ratio	0.41443	0.19375

Values in Euros, 2013 prices

Nevertheless, it is worthy to note that the  $WTA_E$  value was considerably influenced by the impact of experimental setting compared with the  $WTP_E$  value. The significant reduction in  $WTA_E$  values via experimental setting implies that there is a greater need for clarification on WTA term compared with WTP. In other words, it is more important to tackle the elicitation of truthful responses from WTA questions than from WTP questions.

Table 6.7 TTEST

Variables difference	Mean	t Value	Pr >  t
$WTA_E$ - $WTA_C$	-9,028.74	-2.28	0.0268
$WTP_E$ - $WTP_C$	1520.82	1.16	0.2533

Values in Euros, 2013 prices

In addition, we used the T test to measure the difference between  $WTA_E$ - $WTP_E$  and  $WTA_C$ - $WTP_C$ . As reported in Table 6.8, the t value of conventional setting was 4.19

whereas the experimental t value = 0.81. Thus, we can conclude the significance and effect of the experimental approach in this study.

Table 6.8 TTEST

Variables difference	Mean	t Value	Pr >  t
WTA <sub>E</sub> -WTP <sub>E</sub>	476.34	0.81	0.4197
WTA <sub>C</sub> -WTP <sub>C</sub>	11,025.9	4.19	0.0001

Values in Euros, 2013 prices

As a result, the experimental approach showed a lower ratio (WTA/WTP) than has previously been reported in the environmental economics literature. The average WTA value was significantly influenced by the incentivised setting and its value sharply decreased, whereas the average value of WTP was not substantially greater than in conventional studies.

## 6.6 Discussion

We tested the role of incentives on individuals' overestimating WTA and underestimating WTP for micro-generation solar panels. The discrepancies between WTA and WTP valuations are recognised as an obvious problem in the CV surveys; however, the true preferences can be elicited through an incentivised mechanism. The incentive-compatible mechanism provides respondents with an adequate understanding and does not encourage strategic biases (Sugden, 1999b). Note that in this work, these biases which give rise to the discrepancy were ascertained through the truncation analysis. Respectively, the reduced discrepancy between the conventional and experimental mechanisms agrees with the literature. The suggested novel experimental approach allowed the convergence of WTA and WTP, when the respondents were sufficiently incentivised to respond. The average discrepancy based on the 45 studies on WTA/WTP ratio was found to be (10.4:1) for public and non-market goods, and a ratio of 2.9:1 for ordinary private goods

(Horowitz and McConnell, 2000). Correspondingly, the conventional setting with an average 3.5:1 ratio is consistent with the average ratio in the literature. Nevertheless, this ratio substantially decreased to 1.08:1 in the experimental or incentivised setting. Consequently, this finding agrees with the hypothesis that the incentivised setting would perform better than the conventional setting in terms of strategic and hypothetical biases prevention. In addition, the perceived larger sum to compensate in the conventional setting corroborates previous studies (Knetsch and Sinden, 1984).

Moreover, the findings agree with studies by (Scarpa and Willis, 2010; Claudy et al., 2011) on WTP for micro-generation in that households are willing to pay for micro-generation systems, but the benefit households receive from micro-generation are not sufficiently large to cover the capital cost of micro-generation energy technologies. The prerequisites of financial incentives to encourage people were advised. However, the findings of the suggested novel experimental setting indicate a higher support from respondents for covering the capital costs of micro-generation solar technology. This was achieved when individuals had a better understanding about the WTA and WTP questions, the consequences of overestimating and underestimating, and the good in question (micro-generation solar technology) then they could reveal the truthful answers. The limitations of the study are the cost of data collection and lack of respondents' awareness about the micro-generation solar technology as well as its cost of installation. The next case is explained in the next chapter, using CV closed-ended questions instead.

## **6.7 Summary and conclusions**

This chapter assesses the households' acceptance and preferences for the installation of micro-generation solar panels in a residential sector. Therefore, the individuals' WTA loss of amenity and WTP for installation of 1kWp solar panel was tested. The survey was implemented via conventional and incentivised settings. The discrepancy between WTA

and WTP within each setting and between the settings was compared. The most obvious findings are: (1) the WTA is statistically different to WTP in the conventional setting, whereas it is equivalent in the experimental setting; (2) a smaller value of WTA for compensation and larger WTP are observed in the incentivised setting compared with the conventional setting.

From the findings, it can be concluded that, firstly, the conventional method is suspect in deriving truthful WTA and WTP responses. Secondly, the experimental setting's results suggest that policy makers should base their plan on lower financial incentives to increase the solar power installed capacity on the island.

## Chapter 7. WTA and WTP estimation for BIPV

### 7.1 Introduction

This chapter examines people's preferences for a Built in Photovoltaic<sup>68</sup> (BIPV) renewable energy (RE) system integrated into housing construction. The methodology incorporates Building Information Modelling (BIM), as a real-time design and economic assessment tool for BIPV choices. This serves to benefit both the construction companies and potential house owners in their decision-making. It uses a contingent valuation (CV) method to estimate the willingness to pay (WTP) and the willingness to accept (WTA) compensation. This chapter also adopts the same experimental CV approach with a Becker-DeGroot-Marschak (BDM) mechanism and cheap-talk, suggested in the previous chapter. However, the CV questions are designed based on the closed-ended dichotomous format.

The sections of this chapter are outlined as follows. Section 7.2 discusses some of the existing literature in the context of RE and economics as a basis for our study. Section 7.3 briefly defines the study problem and how it can be resolved. Section 7.4 describes component based photovoltaic (PV) integration to the building, using the virtual platform of BIM technology. Section 7.5 explains the objectives of the study through the five levels. Section 7.6 portrays a novel methodology framework that was developed to give a better understanding of both the construction companies and potential house owners to accomplish the objectives through the five stages. Section 7.7 describes the case study, a housing estate designed by Tanyel Construction Company in Famagusta, North Cyprus. Section 7.8 classifies the sampled study population and data collection. Section 7.9

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<sup>68</sup> A photovoltaic system uses solar panels composed of a number of solar cells to supply usable solar power.

represents the results of the WTA and WTP analysis. Parametric and non-parametric approaches are used to estimate WTP. Section 7.10 discusses the results of the study concerning households' attitudes towards BIPV. It compares the estimated preferences values with the initially expected values. Section 7.11 concludes and reviews the chapter.

## **7.2 Theoretical background**

The residential sector is heterogeneous in its energy consumption pattern, because it is influenced by many factors. The level of awareness in an individual of the need and the methods of conservation of energy, the nature of the building(s) and their characteristics are some of the factors. Residential buildings are considered a huge and dynamic energy sink (Swan and Ugursal, 2009), as they consume a great deal of electricity for cooling and heating systems and for electrical appliances. For instance, in the UK, 34% of energy fed into consumption by the residential sector is mainly for space heating. The UK government attempts to reduce this consumption by modifying the building regulations and providing financial aids and advice to the households on the measurement of energy saving or the efficiency of the building insulation (Ward, 2008).

However, the importance of energy conservation cannot be overstated. Parameters influencing energy conservation include the materials used during the construction process and the nature of the construction, geographic and climatic factors, and also the financial status of the individual(s) occupying the building. Studies have been undertaken with the intention of developing new and practical methods and tools for energy conservation and optimisation within building spaces. Pless et al. (2007) highlighted certain parameters which should be considered early in the design process, such as set points of temperature and humidity, maximum U-values of windows and night setback, and any other variables with potential impact on energy demand and consumption. Moreover, pre-construction energy cost modelling becomes very important because it is a

major tool for forecasting energy costs, especially in the lifecycle operation of a prospective building (Liu et al., 2011).

Alternatively, RE increases the scope of the sources for the energy supply as well as saving the non-renewable energy sources. Solar energy is amongst one of the renewable energy sources (RES) with a great potential of deployment in the residential sector. Zhai et al. (2007) believe that BIPV in residential housing is a fast growing technology. A number of studies on BIPV technology have been carried out in the context of developing countries with a high potential of solar radiation. Haw et al. (2009) assessed the responses of Kuala Lumpur's residents for the integration of a photovoltaic system into their buildings. In spite of the great potential of solar energy in Malaysia and households' promising responses for adopting BIPV, the system is yet to penetrate into the local market. In many countries across the world, the advantages of solar energy have not been fully harnessed. Eiffert (2003) stated that the technology would be accepted as cost effective if the payback period of investing in a BIPV system does not exceed its life cycle period. Furthermore, to increase the potential of the PV market in residential housing, James et al. (2011) proposed the importance of module cost reduction, the increase of consumer interest in solar energy, and government support through policy schemes. The studies of Scarpa and Willis (2010) examined British households' and Claudy et al. (2011) examined Irish households' WTP for RE micro-generation. Both studies found the high investment cost as a main obstacle; therefore, government financial incentives and supports would be required to increase the dissemination of solar technology in the residential sector. Moreover, Willis et al. (2011) stated that the provision of a feed-in tariff and subsidy can support and promote the uptake of RE on a small scale for the households, since currently the payback period for investing in a PV system is not very encouraging.

In addition, applying PV after the structure has been built would incur more costs and sometimes leaves the building with a less pleasing appearance. The cost effectiveness of the system determines the willingness of people to invest in BIPV systems. Exhaustive studies have been carried out to investigate public perceptions on BIPV application. However, fewer studies have considered solar technology as a part of the overall building in residential housing design (Haw et al., 2009; Malagueta et al., 2013; Makrides et al., 2010; Celiktas et al., 2009; Shi et al., 2013). Effective integration of solar systems in housing design has a higher potential for effective application if the system is integrated during the design of the house (Johnston, 2007).

Households are one of the major targets for developing BIPVs with a view to producing electricity for their own usage and also to selling the excess generated electricity to the grid. Despite the advantages provided by BIPV for households to generate their own electricity independently, the reliability of generating electricity in terms of power outages during winter and night times is a discouraging factor in addition to the high cost. These problems can be tackled by connecting to the national grid.

### **7.3 Method**

The potential users are able to build an ideological experience of what to expect if they accept the PV system in their housing design. Therefore, different questions may come to the potential household's mind about a BIPV system, before making a decision. A virtual platform and 3D images can help to address some of these ambiguities. The design of a 3D image through BIM software makes the possibility of a good level of experience and also provides them with factual information for deciding on their WTP. The economic concept of demand and preference is fundamental to the estimation of a consumer's WTP and WTA. Exploring the consumer's demand elasticity for utilisation and purchasing the product is essential for utility estimation. In addition, new product development can be

managed by understanding the people's preferences. To do so, stated preference (SP) techniques can be used to estimate WTP for the good in question. Since the value of BIPV is not separately observed in the market, it can be measured through hypothetical SP techniques.

There is a general tendency for people to not respond truthfully in a hypothetical study, unless certain incentive measures are adopted (Carson and Groves, 2007). In this study, a framework for appraising the household's maximum WTP for the integration of PV into the building at the initial design stage has been proposed. In addition, we assess households' minimum WTA compensation for the sale of electricity, generated by the integration of PV design in the building, to the national grid. A case study was carried out in rural and urban areas of Northern Cyprus to elaborate the framework.

#### **7.4 Component based PV integration**

Using the virtual platform of BIM<sup>69</sup> technology, building elements can be broken down into components. The components can be designed as singular parts and then assembled to form a whole system of components.

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<sup>69</sup> Building Information Modelling (BIM) is an approach to design and construction, which provides a systematic way of solving problems. Through this medium, construction companies and potential house users can outline their objectives in key areas before the actual construction of a building. Such objectives include energy efficiency, on-site renewable energy, grid-supplied renewable energy (Barista et al., 2008). BIM provides a comprehensively advanced way of studying building structures from the conceptual stage to the construction period and the eventual lifecycle of the building. The most important part of the BIM system is the "I", which stands for several layers of INFORMATION. The information that is fed into the virtual application determines the outcome of the final model. There are several softwares for BIM applications. They include Revit, Archicad, Autocad, Navisworks, ECOTECT (Azhar et al, 2011; Kymmell, 2008; Crawley et al, 2008). From the illustration above, using the BIM technology, the project can be realised on a virtual platform and studied from "part" to "whole" before the actual construction of the project. BIM provides a platform for sustainable design through a virtual platform for promoting "observability". This is very important because it could stimulate the rate of adoption of that design. Applications of BIM technology cover both simple to complex projects. Examples as cited by Middling (URL 1) include the Adelaide Oval Stadium in South Australia (with 30% time savings in architectural design), Maze Stadium in Northern Ireland (which utilised Revit, Robot and Navisworks BIM softwares) with 15% time savings, Royal Welsh College of Music and Drama, with zero redesign required during construction. Using BIM for project delivery can substantially reduce the duration of the

The first consideration in the application of PV technologies in residential housing design is the “CONSUMER” or “USER”. It is important to keep the installation within the financial capabilities of the user. Thus, the financial capability of the user determines which system is most suitable in terms of the surface area to be covered with PV and the choice of module, technology and efficiency. Component Based Integration of PV technology (CBI) is a technological approach that is gradually gaining ground in today’s constructions. It provides an added advantage of reduction in cost if the PV systems are integrated during the design and construction stages of houses. As a result, thin film photovoltaic technologies have been introduced into housing design and can be used as wall claddings or placed between window panes as solar collectors. According to Rahoma (2008), high efficiency equates to high cost and vice versa, as is the case with crystalline silicon solar modules (CSSM) (Rahoma, 2008). PV produced from Crystal-Based Silicon (CBS) is presently considered as the best. It offers up to 20% efficiency, but at a high cost (Swanson, 2007).

### **7.5 Study objectives**

The study objectives include five levels of analysis (Figure 7.1). These analyses are coined into an acronym AICWF (Awareness, Importance, Challenges, WTP, and Framework).

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project, eliminate errors and also reduce the costs of a project. It provides the opportunity to test the “buildability” (Middling, URL1) of a project before implementation. According to Kymmell (2008), this goes a long way to enhance the quality of the project and its performance during its lifecycle or usage period. Adopting this strategy can also prove its expedience in testing BIPVs before the on-ground installation of the system. That way, maximum functionality and efficiency of the system can be determined and errors eliminated without incurring additional cost or losses with the BIPVs. Another very important reason for introducing BIM in BIPV is that it helps the contractors and potential house owner(s) during the decision making process, to have a better understanding of what the final outcome of the project would be.

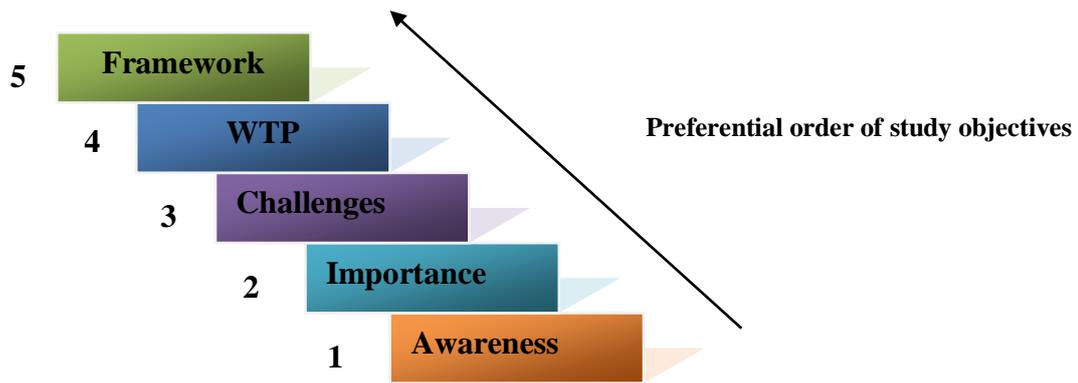


Figure 7.1 Study objectives

The first line of action assesses the general knowledge level and awareness of contractors and potential house owners about BIPV. There is a need to educate people on the application of solar collectors in buildings as components. The possibility of doing this without distorting the facade aesthetics of the building is the main objective for creating this awareness. It further analyses the importance of introducing BIPV in residential houses. Apart from the PV system being a more efficient source of energy, if connected to the grid, the excess could be sold to the grid and thus create another source of income. Integrating BIPV during residential housing design and construction stages eliminates certain challenges such as additional cost, time and labour. After establishing the first three objectives, a yardstick is formed for assessing the willingness of both the contractors and potential house owners to invest in this system based on their perceptions and preferences. The decision to do so lies firmly in the payback period of investing in the system. Finally, the study sought to develop a generic framework that is strategic for the effective application of BIPV during the design of residential houses.

## 7.6 Framework

A novel methodology was developed to help both the construction companies and potential house owners understand the possibilities that abound for PV integrated into their homes at the design stage. The proposed framework is depicted in Figure 7.2.

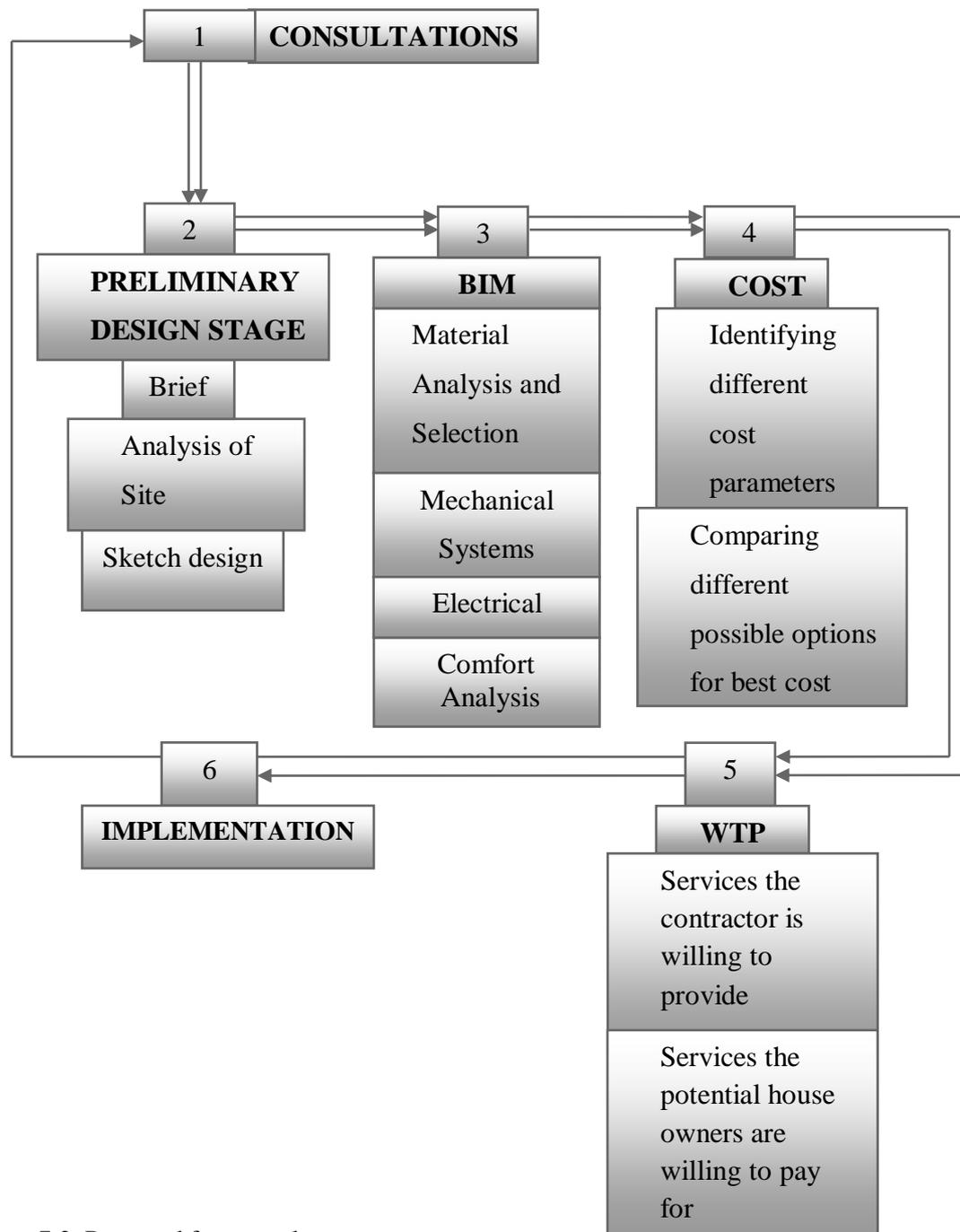


Figure 7.2 Proposed framework

### *Stage 1*

The first step was to source relevant information that would meet the needs of the client. The general information gathered included external and internal climate conditions, spatial requirements, and safety. Data collected for non-graphical components during the BIM modelling were gathered through interviews and consultations. Examples of non-graphical components include the most preferred materials and colour schemes. The data will serve as input parameters for the BIM to predict possible outcomes. The outcomes are real-time in nature, meaning they can accommodate changes based on the client preferences.

### *Stage 2*

The second stage, which was the design stage, involves a process of translating the various pieces of information gathered into a series of preliminary sketches. Once the ideas were put down in sketch forms, a process of scrutiny was initiated in order to work out the best possible design solution suitable for the study.

### *Stage 3*

In this step, the model was considered in depth in terms of the non-geometrical aspect of the structure contained in the information borne within. At this stage, solar collectors were integrated into various building components and tested to see their performance in a virtual platform. The component based design is usually technology intensive and, if integrated at the design stage, the solar collectors can be applied to facades and other elements of the building without destroying the aesthetic appeal of that building. The 3D model (Figure 7.3) of the building was used as an example for the house owners to elicit the possibilities that abound as a more environmentally friendly solution in the integration of PV systems in residential houses, from the design stage. The preferred design solution

was tested with virtual application simulations using BIM software (ARCHICAD) in order to test the feasibility of integrating a solar system in the design before implementation, the reason being that if this solution were successful, once the attention of the intended users could be captured and they became involved, then policy implementation concerning PV systems integration in housing design of residences becomes easier.

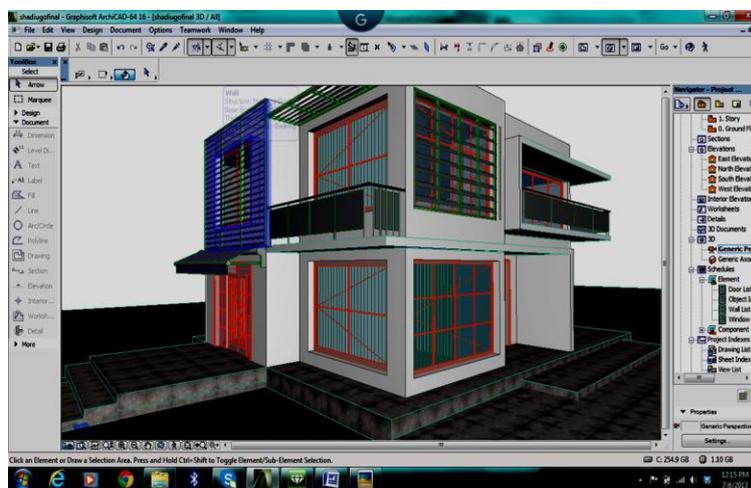


Figure 7.3 Simulation screen of the structure using BIM software

#### *Stage 4*

The cost of the implementation and the market value of the project for PV integrated into the residential house design determine its feasibility. These cost parameters include the cost of materials, labour, professional fees, solar system components and the general construction cost amongst others. The cost includes the services that the Construction Company is willing to include in a house based on the request of potential house owners.

### *Stage 5*

The WTP measurement in this study can fulfil the lack of information for the supplier and user; in this case, they are the construction company and the household respectively. Agents' responses can be used to forecast the value of BIPV for consumers and modelling demand function. By measuring the people's demand elasticity and preferences for BIPV, policy implications may also be drawn. The direct survey, which originates in the SP method, can be used to measure the WTP and estimate a preference structure from which WTP can be derived. The CV questions can ask respondents directly the value of the good(s) in question. In this context, a house could be sold as a bundle of attributes. Developers do not know how much purchasers value each attribute of the house e.g. the value of a fourth bedroom, the installation of BIPV and so on. Consumers' demand for BIPV is likely to depend on the cost of the BIPV system, and the value of the energy it produces. Both of these can be measured with SP techniques such as CV.

In CV, WTP is evaluated using the expenditure ( $e$ ) representation:

$$WTP = e(p, Q_0, U) - e(p^*, Q_1, U)$$

Where  $Q_0$  is the good without BIPV and  $Q_1$  is the good with BIPV;  $p$  is the price of the good without the BIPV attribute, and  $p^*$  a price vector of the good with the BIPV attribute. By allowing the price ( $p^*$ ) of the good or attribute to vary across customers, the demand or marginal valuation curve for BIPV can be estimated. By observing the number of customers who are willing to pay price  $p^*$  for the attribute, the demand for the attribute can be mapped, holding utility ( $U$ ) constant. Economic theory predicts that as price falls, the number of consumers who are willing to buy the good will increase. WTP measures the maximum amount ( $p^*$ ) that can be taken away from a consumer in exchange for BIPV, leaving his or her utility constant.

As discussed earlier, CV questions can be administered to respondents in different ways, as an open-ended question, a payment ladder, a closed-ended single-bounded (SB) dichotomous choice question or a closed-ended double-bounded (DB) dichotomous choice question. However, Carson and Groves (2007) have argued that only SB dichotomous choice questions are incentive compatible, producing truthful answers.

The use of energy in the home will depend upon the characteristics of the family, such as their use of electrical appliances, and the times of the day these are used in the house. Households where members are absent during the day, due to work and other commitments, may value BIPV energy less than households who use BIPV energy throughout the day when BIPV power output is greatest. One way of trying to measure the value of BIPV energy is to estimate the minimum that households would be willing to accept to sell any surplus energy into the national grid.

CV studies comparing WTP for a unit increase with WTA compensation for a unit decrease have shown that WTA values are typically many times greater than WTP amounts. There are many reasons for this disparity between WTA and WTP. A possible explanation for this might be that consumers behave strategically and overestimate WTA to gain more compensation. Unlike WTP, WTA is not constrained by income, so consumers are able to demand greater monetary amounts.

To carry out a survey in order to assess people's preferences, an incentivised mechanism can be incorporated prior to asking the key questions. The information revealed by the respondents' answers would be the outcome of incentive strategies and the explicit information about the question itself to the respondent. For instance, an incentive compatible survey can be implemented through the following instruments: a voting system, a price auction, a lottery auction, games, drawing a prize, or selling and buying items. The experimenter, prior to the evaluation of the subject of interest, can present

items such as a mug, chocolate, a pen or other mundane goods to the respondents and ask them to bid for a realistic price. This assumption can be practised through two scenarios: (1) if the respondent is assumed to be the owner of the good and a potential seller, (2) when the respondent is assumed to be the potential buyer or consumer of the good. Because the majority of households do not have experience in selling, it would be an effective opportunity for them to experience bidding strategies and to understand the meaning of the term minimum WTA. The goal of the practice is to clarify the minimum WTA terminology, and the possible consequences of over-estimating WTA, in which case the good is not sold nor compensation generated. Similarly, the maximum WTP terminology can be practised when a respondent is assumed to be a consumer and is asked to state his/her maximum WTP for the presented good, such as a box of chocolates. Under-estimating the WTP value may cause the mug not to be sold by the vendor. The majority of the households have shopping experience for everyday goods, but the potential consequences of underbidding are often not acknowledged. Accordingly, applying the practice prior to the evaluation of BIPV aids respondents' understanding of the consequences of over and under bidding, and facilitates learning about exchanges for a realistic price. This experimental mechanism was adopted to familiarise respondents with the economic terminologies in the study. Minimum WTA and maximum WTP concepts were simplified by using memory joggers as a survey practice, while the protocol was supplemented with other clarification aids for the respondents.

### ***Stage 6***

The process of Stages 1-5 continues until a reasonable level of compromise is reached. This includes the building's design, materials, services and the quantity of electricity the house owner is willing to generate and/or sell to the grid. Implementation also considers

the policies of the government and strategies that could be used in maximising these policies.

To examine the willingness of people to pay for BIPV, a survey was carried out using a methodology which covers both the architectural and economic aspects of household energy consumption for a new residential estate design. The applicability of the BIPV was tested using the concept of maximum WTP to evaluate the demand for implementation.

### **7.7 Case study**

The case study setting is a housing estate designed by Tanyel Construction Company in North Cyprus. It consists of five different residential design options. The site plan was organised to maximise the solar potential available through architectural solutions and technological innovations for solar energy. The architectural solutions include the proper orientation of the longer side of the building, distribution of living spaces on plan and the positioning of openings for proper lighting and ventilation. As shown in Figure 7.4, the technological innovations in solar energy include the use of a triple glazing<sup>70</sup> system for very large windows, adopting windows with solar collectors embedded between the panes.

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<sup>70</sup> It improves the thermal condition of the buildings' interior spaces.

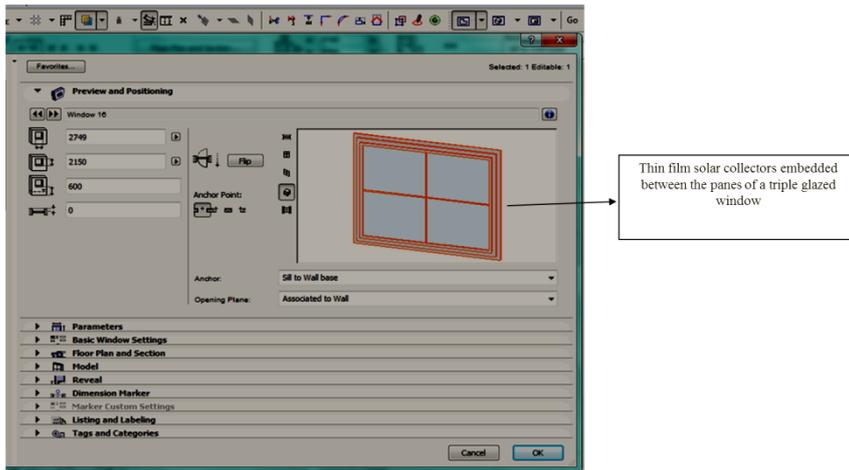


Figure 7.4 Integration of solar collectors in window panes

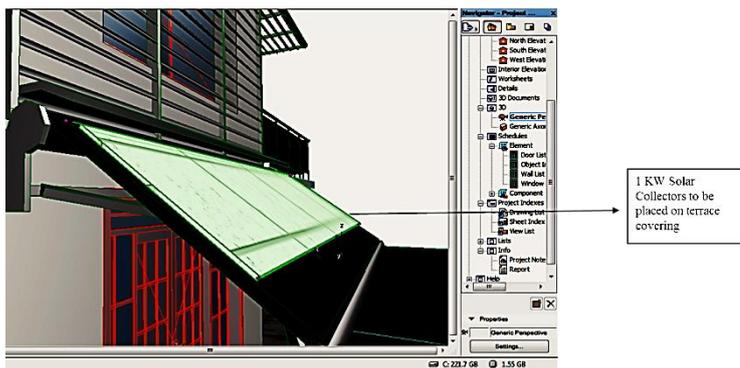


Figure 7.5 PV integration into the shading device

In Figure 7.5, the solar collectors are also integrated into the shading devices. This integration process was adopted in such a way as to retain the aesthetics.



Figure 7.6 Solar collector integrated as shading

One of the houses from the residential estate designed by the Tanyel Construction Company was used as a case study. The house area measured 140m<sup>2</sup> with a 4kW solar system grid connected, inclined at an angle of 35° and placed in the southward direction on the flat roofed house. This had an area of 21m<sup>2</sup> covered with solar panels with space allowance for maintenance. As shown in Figure 7.6, an area of 19m<sup>2</sup> comprised of solar collectors was integrated in shading devices. The total purchasing cost of the panels and installation, if integrated at the design stage, is estimated at 6,000 Euros with incentives of a 25% subsidy approved by the North Cyprus government in the year 2012. The payback period was estimated to be three years (Atikol et al., 2013), when the excess was sold at the feed-in tariff of 0.25 Euro per kWh.

### **7.8 Study sample**

The sample of the study consisted of 264 head householders, aged above 18 with a mean age of 50, regardless of their gender. The survey was carried out from individuals in the group of five to twelve participants, and began by a brief introduction on the survey purpose and an opportunity for entry into the prize draw for 10 Euros (30TL). Prior to the

evaluation of BIPV, respondents were informed about the meaning of minimum WTA and maximum WTP, in order to clarify the terminologies and potential consequences of over and under bidding. The applied instrument has been tested in other studies (Bjornstad et al., 1997; Plott and Zeiler 2005; Chilton et al., 2012). Participants, with the help of a facilitator, practised a series of bidding interactions for goods which were presented to them, such as a Teddy bear or a box of chocolates. In this way, group discussion took place in a market-like setting. In addition, they were provided with information regarding micro-generation solar technology and Northern Cyprus' government policy issues regarding RE. Prior to BIPV evaluation, the participants were practised selling or buying familiar items for the potential consequences of over bidding and under bidding. In this way, they were taught that inaccurate bidding actions might lead them to lose opportunities for exchanging a good or service. Respondents were also given opportunities to ask questions, and provided with memory jogger hand outs, images and sufficient information about BIPV. Once we ensured that the respondents had sufficiently understood the terminologies of minimum WTA and maximum WTP, the cheap-talk script was used (see Appendix H). Then, evaluation of the integration of a PV system at the construction level was implemented as follows:

*Presumably, you have decided to buy a house from the Tanyel Construction Company, which is not built yet. Your prospective house will be built for you on the basis of your requirements and choices amongst the options that are presented and visualised through 3D images to you. One of those options is the integration of a PV system into the building at the construction level. The integration of a 4kWp solar system to the house would provide the possibility of exporting or selling the generated electricity to the grid. If you are considering BIPV:*

- 1. What is the minimum amount you would be willing to accept to sell the excess electricity generated by your solar panels (PV) to the grid?*

Following the WTA question, the WTP question with the specified amount was presented to them such as:

2. *Would you be willing to pay 2000 Euro extra for the integration of 4kWh solar power equipment into your property at the construction level for your own usage?*

The questions were designed in the closed-ended referendum dichotomous format. The WTP questions were presented with different levels of 2000, 4000, 6000, 8000, 10,000, 12,000, 18,000 across individuals (see Appendix I). If an individual answered 'yes' to the first bid value of WTP then he/she was presented to a higher level of bid, and if an individual WTP response was 'no' to the first bid then he/she was offered a lower level of bid.

Then, participants were required to complete information on their demographic profiles in the questionnaire, and the session finished with the prize draw, which was initially introduced as an incentive instrument.

## **7.9 Results**

### **7.9.1 WTA analysis**

The responses to the question of minimum WTA are depicted in Figure 7.7. The histogram demonstrates the frequency of the stated minimum WTA amount by respondents in Euros.

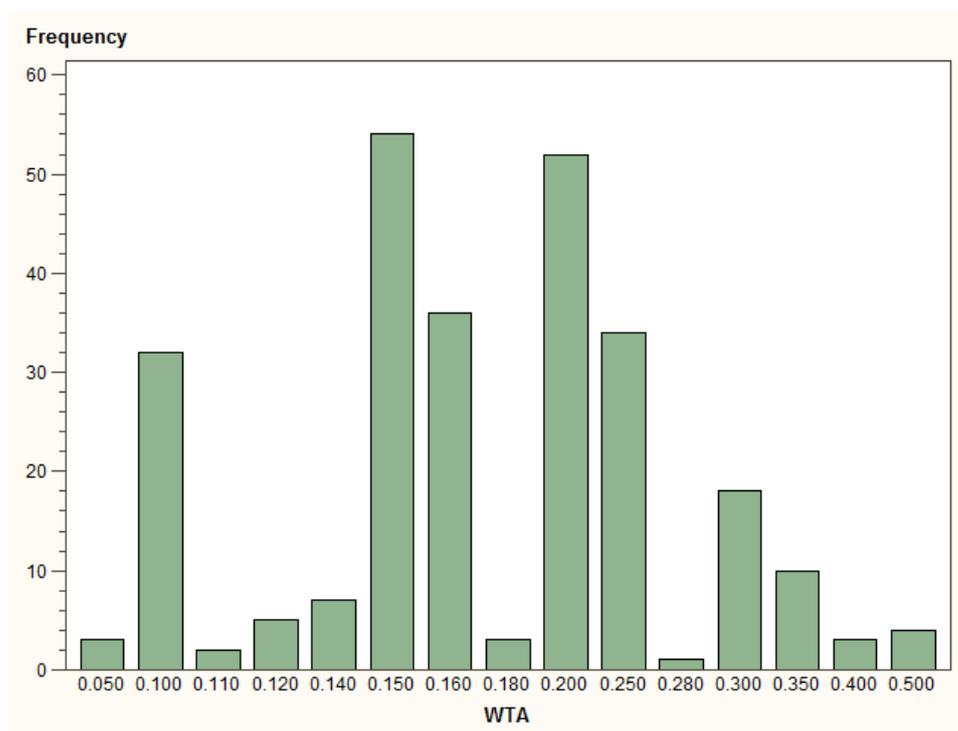


Figure 7.7 Frequency of respondents' willingness to accept

As reported in Table 7.1, the arithmetic WTA mean is approximated as 19.2 cent Euros/kWh. The lower bound and upper bound mean at the 1% level were 18 and 20 cent Euros respectively.

Table 7.1 WTA value

Mean	Confidence interval 99%	
	Lower bound mean	Upper bound mean
0.1925	0.183	0.202

Values in Euros, 2013 prices

The maximum amount of 50 cent Euro and the minimum amount of 5 cent Euro/kWh compensation was required by four and three persons respectively. The most frequently

required amount of compensation was 15 cent Euro/kWh, and the 20 cent Euros/kWh was the second most required amount. At the time of the study, the price of purchasing electricity from the network was 16 cent Euro/kWh in North Cyprus<sup>71</sup>. This implies that the price of selling electricity to the grid can be compared to the price of purchasing electricity from the grid.

In addition, a Tobit regression model was used to provide a parametric estimate, as it recognises that the dependent variable is not continuous, but is bounded at zero WTA. The Tobit model describes the effect of each independent variable  $x_n$  on the dependent variable WTA.

As shown in Table 7.2, the Tobit model relates WTA values to the observable variables, which were assumed to influence the dependent variable value.

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<sup>71</sup> In November 2013, a sudden 25% increase in the electricity tariff modified the price of 1kWh electricity from 16 to approximately 21 cent euro. Note that at the time of the data collection, the tariff was 16 cent euro and had not yet been increased.

Table 7.2 Tobit model

<i>Dependent variable WTA</i>					
Parameter	N	Mean	Standard Deviation	Minimum	Maximum
WTA	264	0.192538	0.078396	0.05	0.50
<i>Independent variables (Demographics)</i>					
Parameter	DF	Coefficient	Standard Error	t Value	Approx.
					Pr >  t
Intercept	1	0.183816***	0.016981	10.82	<.0001
Rural area	1	0.029798**	0.014233	2.09	0.0363
Unemployed	1	0.028508**	0.014740	1.93	0.0531
Advance degrees	1	-0.048505***	0.011252	-4.31	<.0001
Note: ***, **, * ==> Significance at 1%, 5%, 10% level					

Consistent to the non-parametric estimator, the WTA mean from the Tobit model was also 19.2cent Euros/kWh. The dummy coded variables are urban/rural areas, employed-unemployed, and education. The rural area variable including Guzelyurt, Karpaz, and Iskele is statistically significant with a  $p$  value=0.03 at the 5% level. In addition, the variable of unemployed is statistically significant at the 5% level. Education is statistically significant and as the level of education increases people are more willing to accept a lower amount of compensation.

## 7.9.2 WTP analysis

### *Double-bounded CV model for WTP study*

The conventional CV dichotomous single-bounded (SB) question asks the respondent whether he/she would pay some specified amount for a good in question. Respondents' answers are in the binary form 'no' or 'yes', which can be coded as (0, 1).

The double-bounded (DB) dichotomous format includes the first bid with a follow-up question. The initial bids of this survey that are articulated in section 7.8 are listed in Table 7.3. The six levels of values were varied randomly across each 44 respondents. This produced a total number of 264 observations.

Table 7.3 Initial bidding values

First Bid €	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2000	44	16.67	44	16.67
4000	44	16.67	88	33.33
6000	44	16.67	132	50.00
8000	44	16.67	176	66.67
10000	44	16.67	220	83.33
12000	44	16.67	264	100.00

Values in Euros, 2013 prices

The DB format increased information limits as a result of adding a follow-up question, and Table 7.4 shows the DB values in addition to the SB prices.

This approach was administered so that the experimenter initially asked for a value from an individual, and if he/she responded 'yes' to the initial amount then they were asked the same question with a greater value, and if the individual answered 'no' to the initial price, then they would be offered a lower bidding value. In this fashion, the four possible pairs

of WTP responses generated from the lowest to the highest were ‘no and no’, ‘no and yes’, ‘yes and no’, ‘yes and yes’.

Table 7.4 Initial bids and follow-up bid

First & Second Bids €	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1000	19	7.20	19	7.20
2000	21	7.95	40	15.15
3000	37	14.02	77	29.17
4000	20	7.58	97	36.74
5000	27	10.23	124	46.97
6000	56	21.21	180	68.18
9000	29	10.98	209	79.17
12000	26	9.85	235	89.02
15000	17	6.44	252	95.45
18000	12	4.55	264	100.00

Values in Euros, 2013 prices

The non-parametric and parametric econometrics models can both be applied to estimate WTP. In the subsequent section, we present the results of WTP with parametric and non-parametric approaches.

### **The parametric approach**

A single bounded (SB) dichotomous choice (DC) has been argued to be the only incentive compatible CV method (Carson and Groves, 2007 ), but numerous studies have shown that double bounded (DB) DC CV produces more “conservative estimates” of WTP (Cameron and Quiggin, 1994, Alberini et al., 1997, Barton, 2002). Hence, while the SB DC estimates should be used, it was thought interesting to produce DB DC estimates too

by way of comparison, to see if there was much difference between the two set of estimates.

With the use of parametric analysis, we compared the SB and DB formats because the DB analysis did not fit the function. This might have been because we had set quite a number of costs for evaluation. Each respondent were asked one of the six predetermined values of the cost followed by a higher or lower level of cost, depends on the respondent's answer to the first bid. The combination of first and second bids produced ten different bidding values as shown in Table 7.4.

The comparison between the stated WTP values of the first and the second question were carried out under the assumption that the responses to the SB and DB are related to the individual's latent WTP value and unobserved resources (Carson and Steinberg, 1990; Hanemann *et al.*, 1991). Underlying an empirical proof, there is an imperfect correlation between WTP distributions, because larger WTP values are estimated from the first question than the second (Cameron and Quiggin, 1994). This can be implied as the possibility of more negative responses or 'no' answers to the second question compared with the first. Additionally, Cameron and Quiggin (1994) hypothesised that the difference between the first and second WTP question evaluation may be driven from strategic behaviour. Furthermore, Carson and Groves (2007) assumed that the imperfect correlations between responses to the two questions arise from implicit signals of the second price. This situation can influence respondents' beliefs in terms of uncertainty and may lead them to a risk adverse reaction and willingness to bargain over the price. Parameters of mean and median WTP for the risk adverse people will be shrinking in the second question, even though with the same preferences.

Following Carson and Groves (2007, p.196), we adopt the same hypothesis that "WTP estimates from a double-bounded format to be smaller than those from a single-bounded".

Hence, to test this assumption in our study, we statistically compared the SB and DB formats as shown in Table 7.5. The mean and median of the second WTP question was smaller than the first bid value. Equally, the standard deviation results showed a consistency with the mean and median where the first WTP bid was valued with a smaller deviation compared with the second WTP question.

Table 7.5 Non-parametric

Variable n=264	Mean	Median	Standard deviation
First WTP value	7000.00	7000	3,422.14
Second WTP value	6,693.18	6000	4,542.22

Tables 7.6 and 7.7 present the likelihood ratio test for the two formats of DB and SB. The LL function of the estimated model can be compared to the base model in order to test the significance of the model. According to Hensher (2005, p.330), the LL ratio test can be calculated as:

$$-2(LL_{base\ model} - ) \sim \chi^2_{(number\ of\ new\ paramtrs\ estimated\ in\ the\ estimated\ model)}$$

By comparing the obtained -2LL value to the critical value of chi-square statistic, the superiority or inferiority of the estimated model against the base model can be determined. If the value of the -2LL exceeds the critical chi-square statistic, the null hypothesis can be rejected. This denotes that the estimated model is no better than the base model. If the -2LL value is smaller than critical chi-square value, then the alternative hypothesis can be rejected.

Table 7.6 DB (second bid)

Testing Global Null Hypothesis: $BETA=0$			
Test	Chi-Square	DF	Pr > Chi Sq
Likelihood Ratio	20.3323	1	<.0001
Score	21.3564	1	<.0001
Wald	19.5053	1	<.0001

The results show that the -2LL ratio SB and DB with one degree of freedom are both larger than the 3.84 Chi-square Critical value, and this implies that the null hypothesis can be rejected, as the estimated model is better than the base model. However, the SB -2LL =11.1278 is smaller than DB -2LL =20.3323. The Chi-square test suggests that the SB model is statistically better than the DB model.

Table 7.7 SB (first bid)

Testing Global Null Hypothesis: $BETA=0$			
Test	Chi-Square	DF	Pr > Chi Sq
Likelihood Ratio	11.1278	1	0.0009
Score	10.9922	1	0.0009
Wald	10.7215	1	0.0011

Moreover, we used the maximum likelihood estimates (MLE) to approximate the probability of utility. The probability of people saying ‘yes’ for the integration of micro-generation solar panels to the houses at the design stage is related to the probability that they derive less utility from other goods. When respondents answer dichotomous choice CV questions, a utility difference model can be formulated that relates the probability of a

‘yes’ to the utility difference amongst improved and unimproved building designs (Hanemann, 1984).

Table 7.8 Maximum likelihood estimates (SB)

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > Chi Sq
Intercept	1	0.8572***	0.2904	8.7120	0.0032
WTPbid1	1	-0.00012***	0.000037	10.7215	0.0011

Note: \*\*\*, \*\*, \* ==> Significance at 1%, 5%, 10% levels

A logit model with a logistic distribution through the procedure of MLE was used to analyse the maximum WTP observations. The mean consumer surplus is calculated from the result of MLE through logistic regression equation (Loomis, 1988).

$$\text{Log}(\text{Prob Yes} / 1 - \text{Prob Yes}) = a + \text{price} \quad (7.1)$$

The expected mean maximum WTP is the integral of this function, or the probability of paying price  $X$  multiplied by price  $X$  and summed over all prices. The mean consumer surplus derived from Table 7.8 is 6,881.8Euros.

WTP is the area under the cumulative distribution function ( $g(\$BID)$ ) between zero and infinity:

$$WTP = \int_0^{\infty} [1 - g(BID)] dBID \text{ when } WTP > 0$$

To calculate the mean WTP, the formula for the mean of a non-negative<sup>72</sup> random variable is used (Hanemann, 1989).

$$\text{Mean WTP} = 1/B_1 \times (\ln(1 + \exp(B_0 + (B_i (Z_i))))$$

Where  $B_i$  is the vector of the coefficients which is associated with the attitude and demographic variables and  $Z_i$  is a vector of sample means of the associated independent variables and  $B_1$  is the coefficient on BID.

$$\text{Mean WTP} = 1/0.00012 \ln(1 + \exp(0.8572))$$

$$\text{Mean WTP} = \text{€}6881.8$$

### **The non-parametric analysis**

The non-parametric approach estimates the distribution of WTP without any distribution assumption. Turnbull (1976) proposes a distribution free lower bound mean estimate in order to evade the distribution misspecification problem.<sup>73</sup>

As shown in Table 7.9, individuals' responses to the offered amounts of 2000, 4000, 6000, 8000, 10,000, 12,000 Euros were recorded as yes and no answers. The empirical distribution of WTP does not monotonically decrease as the bidding price increases.

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<sup>72</sup> Sometimes the researcher logically believes that WTP is non-negative, but models for unrestricted WTP present negative expected WTP. This may happen when the number of responses of 'no' to the low bid questions is large; in that case the estimate of expected WTP will be negative

<sup>73</sup> This problem arises when a single- or double-bounded bidding design does not answer to a specific WTP interval. To specify the problem constructing the relation between WTP bid intervals and their responses, or the self-consistency algorithm, is essential to ensure monotonic convergence in order to yield the maximum likelihood function. Nevertheless, the parametric model is unable to specify an appropriate model for completed data with a large combination of components.

Table 7.9 Proportion of Yes and No responses

N	Bid price €	Yes	Number offered	Yes Proportion	No proportion	Yes %
264						
1	2000	26	44	0.591	0.409	59%
2	4000	24	44	0.545	0.455	54%
3	6000	27	44	0.614	0.386	61%
4	8000	25	44	0.568	0.432	57%
5	10000	20	44	0.455	0.545	45%
6	12000	11	44	0.250	0.750	25%

The responses to 6000 and 8000 Euros violate the monotonicity assumption of the distribution; therefore, the data were pooled across the 4000 and 6000 responses to smooth the distribution following the reviewed steps of the Turnbull calculation by Haab and McConnell (2003).

Table 7.10 Proportion of Yes answers after pooling

N	Bid price €	Yes	Number offered	Yes proportion	No proportion	Yes %
264						
1	2000	26	44	0.591	0.409	59%
2	4000	51	88	0.580	0.420	58%
3	8000	25	44	0.568	0.432	57%
4	10,000	20	44	0.455	0.545	45%
5	12000	11	44	0.250	0.750	25%
		0	0	0		

As reported in Table 7.10, as the price of BIPV increases, the proportion of respondents answering ‘no’ increases and the proportion answering ‘yes’ decreases. Because the

respondents only answer 'yes' or no to the pre-specified values, only the interval of actual WTP can be observed. Therefore, the Turnbull Lower Bound Mean is used to approximate the lower bound of each interval (Haab and McConnell, 2002).

The results of Table 7.10 have been used to calculate the Turnbull lower bound mean (LBM) from equation 7.2 below:

$$LBM (Turnbull) = p_1 B_1 + \sum_{i=2}^m p_i (B_i - B_{i-1}) \quad (7.2)$$

$$\begin{aligned} LBM (Turnbull) &= 0.59 * 2000 + 0.58 * (6000-2000) + \dots + 0.25 * (12000-10000) \\ &= \text{€ } 6,045.5 \end{aligned}$$

Figure 7.8 plots the estimated probabilities at each successive WTP value, and the probability of surviving or WTP decreases as the bidding value increases. The graph shows consistency with Hicksian demand function, since as price increases, utility and demand decrease.

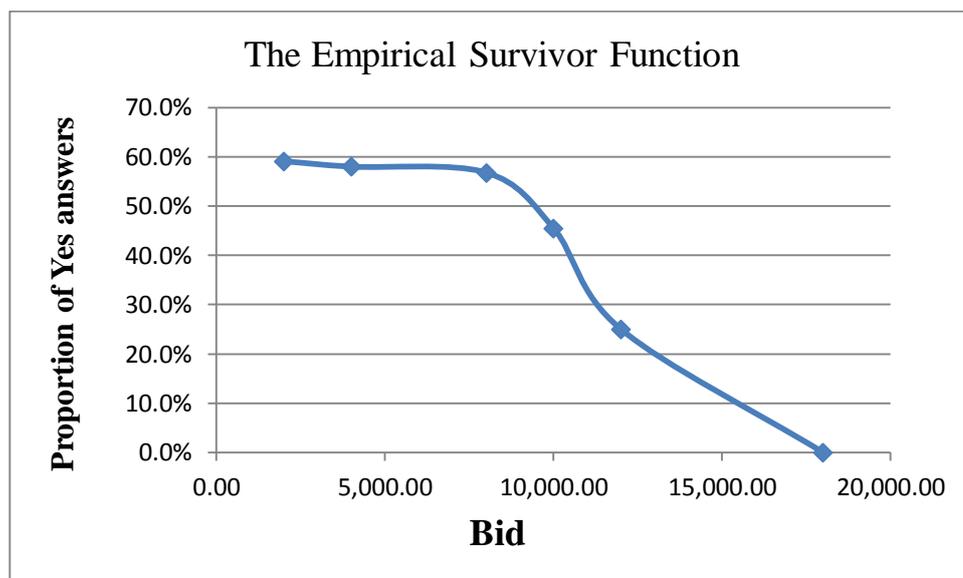


Figure 7.8 Survivor function for WTP

In addition, the median point of WTP can be calculated from the range of values estimated by Turnbull. The lower bound on the range of median WTP falls where the distribution of values passes 0.50, and the upper bound of the median WTP is the subsequent highest price. The median WTP is calculated as follows:

$$\text{Median WTP} = 10000 + [(50\% - 52\%) (12000 - 10000)] / (32\% - 52\%) = \text{€}9,167$$

The lower bound variance is calculated from equation 7.3; the lower bound mean and variance for each price are demonstrated in Table 7.11, and for simplicity the WTP bid values were divided by 1000.

$$\text{Var} (LBM) = \sum_{i=1}^m \frac{p_i (1-p_i)(B_i - B_{i-1})^2}{N} \quad (7.3)$$

$$\text{Variance } V (E_{LB} (WTP)) = [0.59(1-0.59) (2000-0)^2 + 0.58(1-0.58) (6000-2000)^2 + \dots + 0.25 (1-0.25) (12000-10000)^2] / 264 = 28.7$$

Subsequently, standard deviation is:

$$\text{Standard Deviation (LBM)} = (28.7)^{1/2} = \text{€}5.35$$

Table 7.11 Lower bound mean and variance calculation

N	Bid price Thousands €	Cumulative Number of No Responses	CDF (NO)	CDF	LBM $p_i (B_i - B_{i-1})$	V (lower bound) $[p_i * (1 - p_i) * (B_i - B_{i-1})^2] / N$
264	0	0	0.0%	100.0%		
1	2	18	41.0%	59.0%	1180	0.967
2	6	37	42.0%	58.0%	2320	3.89
3	8	19	43.2%	56.8%	1136	0.981
4	10	24	44.5%	45.5%	910	0.991
5	12	31	75.0%	25.0%	500	0.75
Total					6.046	7.58/264=0.0287

The upper bound mean (UBM) on WTP can be estimated by using a similar procedure as the lower bound mean, as the upper bound mean shows a larger value compared with the lower bound mean. The UBM = 6,909 Euros was calculated using formula 7.4. The UBM value is greater than LBM= 6,045.5 Euros.

$$UBM = \sum_{i=1}^m p_i (B_{i+1} - B_i) \quad (7.4)$$

$$UBM = (2000-0)*100\% + (6-2)*59\% + \dots (12000-10000)* 25\% = \text{€}6,909$$

### 7.10 Households' attitude towards BIPV

The empirical results indicate that the proposed methodology was successful in providing an intuitive understanding of BIPV and the terminologies in question. The introduction of BIM in BIPV helped the contractors and potential house owner(s) during the decision making process to have a better understanding of the final outcome of the project in terms of respondents' preferences. On average, individuals are willing to pay the estimated cost

of 6000 Euros including a 25% subsidy, for installation of a 4kWp solar system. The WTP upper bound mean and WTP consumer surplus were found to be more than the estimated cost of 6000 Euros, and the WTA for compensation was lower than the 25 cent Euros scheduled feed-in tariff by the North Cyprus government. The results indicate that Turkish Cypriots were willing to support government policy, and this could be done with lower financial incentives. The collaboration of homeowners in integrating solar power equipment into their houses at the design stage would make a contribution to the reduction of CO<sub>2</sub> emissions over a long period of time in the lifecycle of buildings. Overall, to reach the goal of maintaining environmental stability and sustainable development, it could be very helpful to approach the issue of energy conservation from a micro scale and then expand the scale of application of solar power once its benefits have been demonstrated. The results indicate that the capital cost of solar energy utilisation is not instrumental in choice, and a lower feed-in tariff could be acceptable. Despite Turkish Cypriots' general tendency for lower financial incentives, this condition may not be applicable or observed in other countries. We found that the capital cost of solar technology is not so dominant in North Cyprus; however, it could be a discouraging factor for other countries to invest in PV technology.

### **7.11 Summary and conclusions**

This chapter estimates preferences for the integration of a PV system into the household's properties at the construction stage. A CV technique with binary discrete choice questions was used to estimate an individual's WTP. The data comprised 264 individuals as a sample population of North Cyprus. The case study was a housing estate designed by the Tanyel Construction Company in Famagusta. The site plan was organised to maximise the solar potential available through architectural solutions and technological innovations for solar energy. Using one of the houses from the residential (140m<sup>2</sup> in area) estate

design by the Tanyel Construction Company, a 4kWh solar system was connected to grid, inclined at an angle of  $35^{\circ}$  and placed in the southward direction on the flat roofed house. The total purchasing cost of the panels and installation, if integrated at the design stage, was estimated to be 6000 Euros including a 25% government subsidy approved in the year 2012.

Evaluation of WTP was carried out with the DB format of CV. However, as the second bid data did not fit the function, we compared the SB and DB through the parametric approach to evidence the assumption of higher incentive compatibility and of SB format. Additionally, the nature of incentive compatibility through the usage of BDM and cheap-talk (hints) in the CV binary questions allowed us to use parametric and non-parametric calculations. Furthermore, a non-parametric approach was used to estimate and plot the survivor function of WTP responses. Overall, the empirical results indicate that the proposed methodology could successfully facilitate an intuitive understanding on BIPV and the terminologies in questions.

## **Chapter 8. Choice Experiments Analysis**

### **8.1 Introduction**

An individual's willingness to accept (WTA) and willingness to pay (WTP) were tested using the Contingent Valuation (CV) procedure to uncover the extent of households' acceptance of compensation and propensity to purchase a micro-generation solar system. In addition to that, information can be quantified about the factors that influence an individual's preference and choice. The objective of this chapter is to assess people's choice behaviour toward micro-generation solar technology on the basis of the micro-generation attributes or components. Sections of this chapter are outlined as follows. Section 8.2 reviews the discrete choice models and their specification for analysing a survey of 205 individuals. It uses the models of conditional logit, mixed logit and latent class models with the indirect utility function application. The analysis of the data was executed through NLOGIT. Section 8.3 compares the estimated models' results, including interaction results. Section 8.4 discusses the respondents' choice concerning micro-generation solar technology and determines the linkage of the individual's behaviour and policy factors. Section 8.5 summarises the results and draws conclusions.

### **8.2 Choice experiments**

One of the most used survey methods, particularly for non-market valuation in environmental economics projects, is the choice experiment (CE) (Scarpa and Rose, 2008). The CE sets choices in the form of qualitative choices or discrete choices (DC) and asks respondents to choose over a bundle of alternatives. With this technique, respondents make trade-offs between the levels of attributes and their WTP and WTA can also be estimated from the trade-offs that they make. A change in the attributes' levels or marginal effects of attributes yields information on the individual's level of preferences.

In addition, the CE enables an evaluation of policy alternatives (Bergmann, et al. 2008). In this chapter, we examined the impact of the reflected attributes with their levels that are most likely to influence the households' decision to adopt micro-generation solar technology in their lifestyle. These influential factors were deliberated through different instruments, such as focus groups discussion, pilot surveys, supplier interviews, and literature on design (the detail of the process of identification and refinement of the attributes and attributes levels is described in the methodology chapter).

Subsequently, the dominant and influential elements of people's decisions were: the installation cost of solar panels, financial incentives in terms of subsidy, the feed-in tariff, the space requirement for panel installation, and energy saving. Moreover, the levels of attributes were assigned as part of the experimental process. Table 8.1 shows the specified attributes with the assigned levels as follows: a subsidy with three levels, a feed-in tariff with four levels, the space required with four levels, the initial investment cost with six levels, and energy saving with six levels.

Table 8.1 Levels of attributes

<b>Attributes</b>	<b>Attribute levels</b>
Subsidy	10%, 25%, 40%
Feed-in tariff	0.10, 0.20, 0.30
Space required	8m <sup>2</sup> ; 1kWp 16m <sup>2</sup> ; 2kWp 25m <sup>2</sup> ; 3kWp 40m <sup>2</sup> ; 4kWp
Initial investment cost	4000, 6000, 8000, 10000, 12000,14000
Energy saving (Annual)	800,1200,1500, 2000, 3000, 3600

The experimental design was developed with a D-efficient orthogonal fractional factorial through statistically independent attributes (Hensher et al., 2005). The CE fractional factorial design minimises standard error and maximises the information in the data matrix. For this reason, the D-efficiency as a promising design was used to minimise the utility coefficients (Ferrini and Scarpa, 2007). This produced 72 alternative choice bundles and by pairing each choice alternative 36 choice sets were generated. The combination of attribute levels made two unlabelled scenarios of A and B with a generic title, the micro-generation solar panel. To each pair of the hypothetical alternatives, a status quo (SQ) alternative was added. The presence of the SQ (do nothing) provided respondents with the chance of choosing the current source of energy generation against micro-generation solar technology, if neither of the hypothetical scenarios increased their utility. Holmes and Adamowicz (2003) stated that the SQ alternative would be effective in the development of welfare, when individuals are given a chance to select neither of the two presented alternatives. This option allows respondents to make decisions freely and place their choices over one of the alternatives or the SQ (Carson et al., 1994).

Table 8.2 Choice card

Micro-generation solar panel		
01	Scenario A	Scenario B
Subsidy	25%	40%
Feed in tariff	€ 0.30	€ 0.40
Space required	15m <sup>2</sup> ; 2kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost	€ 7000	€ 11000
Energy Saving Annual	€ 800	€ 1500

I would choose neither of the alternatives and retain with the current energy source

Table 8.2 is an example of a generated generic choice card designed through the SAS.

Note that the currency used in the survey was the Euro.

The data were collected through personal interviews. Every respondent was presented with six choice cards in sequence. To prevent the hypothetical effect, cheap-talk regarding the micro-generation solar technology and its attributes was included through the usage of images, visual aids, and hints. This was followed by a demographic section in the questionnaire. Each respondent was asked to choose one scenario or alternative that was the most desirable from his/her viewpoint. The complete choice set questionnaire is attached in Appendix F.

From the 205 respondents' answers, 3,690 number observations were generated. The variable of choice was coded as {0, 1, 0} to indicate which of the three scenarios of A, B, and SQ was chosen.

A few protest bids were observed<sup>74</sup>, but they were not many. As a result of debriefing, we found that the main reason for not taking part in the survey interview was the lack of familiarity of people and their ignorance about micro-generation solar technology.

### **8.3 Econometrics models of choice and their specifications**

The objective of using econometrics models is to understand how the utility function is correlated with preference estimation. We tested people's choice behaviour towards the utilisation of micro-generation solar technology compared to the current source of energy. Choice modelling (CM) was used to analyse the choice responses. The theories on random utility and DC models that were discussed in the previous chapters were applied in this chapter to measure the respondents' choices. The discrete choice models of conditional logit (CL), mixed logit (MXL) or random parameter logit (RPL), and latent

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<sup>74</sup> They are not included because did not have a willingness to pay.

class (LC) models, were applied to analyse individuals' choices for scenarios A, B or SQ. In addition, WTP was estimated from the CL and RPL models. The CL estimates individuals' preferences and their choices for the same need based on the variation of the attributes in each alternative. In addition to the options' characteristics, the individual's characteristics were included through the RPL model to determine any inherent heterogeneity. Moreover, an LC model was used to investigate further different preferences of households by testing observed variables in association with unobserved variables within the segmentations. The LC model is mainly similar to RPL except for the identification of the distribution for the parameters of preferences (Czajkowski et al., 2014).

### **8.3.1 The Conditional logit model**

“The basic random utility consistent model for analysing CE data is the conditional logit” (Scarpa et al., 2005, p.253); regarding statistical analysis of the data, conditional logit (CL) is the best model in accordance with random utility theory (Scarpa and Rose, 2008). The CL model examines the differences between the scenario characteristics or the levels of attributes, and measures the unknown or unobserved parameters. Therefore, we begin with the basic random utility model:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (8.1)$$

The utility of  $j$  alternative for individual  $i$  was expressed as systematic  $V_{ij}$  and random components  $\varepsilon_{ij}$ .

Then, equation 8.2 expresses the probability that alternative  $j$  is chosen over all  $J$  alternatives by individual  $i$  where  $X_{ij}$  is the vector of alternative  $j$  attributes. According to Haab and McConnell (2002), the variation of the alternatives' or scenarios' attributes would affect the probability of making a choice. In the CL model, the individual's characteristics do not vary over alternatives that face the individual, while the

independent variables of a good's characteristics vary across both observations and alternatives. The CL model assumes the disturbance term is independent from irrelevant alternatives (IIA) across the individual's choices. Therefore, the cumulative distribution function (CDF) is:  $F(\varepsilon) = \exp(-\exp(-\varepsilon))$

$$Pr_i(j) = \frac{e^{X_{ij} \beta}}{\sum_{k=1}^J e^{X_{ik} \beta}} \quad (8.2)$$

Under the assumption of IIA, choosing one alternative over another is irrelevant to the absence or presence of the third alternative (McFadden, 1974).

As formulated in equation 8.3, the CL model calculates the difference between each alternative's characteristics to estimate the probability of unknown parameters only when the attributes vary.

$$Pr_i(j) = \frac{e^{X_{ij} \beta}}{\sum_{k=1}^J e^{X_{ik} \beta}} = \frac{1}{\sum_{k=1}^J e^{(X_{ik} - X_{ij}) \beta}} \quad (8.3)$$

McFadden (1974) stated that the CL model estimates the expected utilities  $\eta_{ij}$  on account of the  $\eta_{ij} = Z_j \gamma$  alternatives' characteristics.  $z_j$  denotes the vector of characteristics of the  $j$ -th alternative. The CL is equivalent to the log-linear model since the major effect of the response is characterised by covariates  $z_j$ . Indeed, the CL model accommodates variables  $Z$  that vary across choices or observations, whereas the Multinomial logit (MNL) model assumes covariates  $X$ s vary only over individuals or cases and not across choices. Therefore, the choice probability can be expressed as:

$$Pr(Y_{ij} = j) = \frac{\exp(Z_{ij} \gamma)}{\sum_{j=1}^J \exp(Z_{ij} \gamma)} \quad (8.4)$$

According to Scarpa et al. (2005), equation 8.5 is the conventional CL model, where the  $\lambda$  is the scale parameter of the unobserved stochastic component.

$$P_i(j) = \frac{\exp(\lambda V_j)}{\sum_k \exp(\lambda V_k)}, \quad k = sq, c_1, c_2 \quad (8.5)$$

The CL model can be applied to link the conditional probability of making a choice over the specified explanatory variables when utility across scenarios and choices is assumed to be independent. This model estimates the impact of the specific variables on the probability of choosing a specific alternative.

Accordingly, we used the CL model to evaluate the probability of choosing micro-generation solar panels by households, and also to estimate the impact of the attributes' variables on the basis of the conditional demand.

The total collected data from 205 respondents yielded 1,230 choice sets and 3,690 numbers of cases, estimated in NLOGIT5.0. We assumed that in the CL model each individual's random utility related to choosing alternative  $j$  was a linear function of its features, namely subsidy, FIT, space, cost, and energy saving. Therefore, the underlying utility function form was as follows:

$$U_{ij} = \beta_{subsidy} \cdot subsidy + \beta_{FIT} \cdot FIT + \beta_{space} \cdot space + \beta_{cost} \cdot cost + \beta_{saving} \cdot saving + \varepsilon_{ij}$$

The results of the basic CL choice model as a primary point of analysing the CE data is reported in Table 8.3. The parameters of COST (capital cost) and SPACE (space requirement) were statistically significant and negative, and the coefficients of FIT (the feed-in tariff), SUBS (the subsidy), SAVE (saving energy) were significant and positive. Note that parameter<sup>75</sup> FITC as presented in Table 8.3 is the FIT parameter multiplied by 10, and also the COSTK and SAVEK are the division of the COST and SAVE parameters by 1000, and only SUBS is shown as a percentage.

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<sup>75</sup>Hereafter, SUBS denotes subsidy, FITC represents Feed-in tariff or FIT, COSTK and SAVEK signify cost and saving parameters.

All the explanatory variables included in the model took the correct signs; the negative sign of the parameters COSTK and SPACE are correct as expected. The parameters of SUBS, FITC, SPACE, COSTK and SAVEK were found to have a small standard error and were highly significant at the 1% level.

Overall, the basic CL model was statistically significant with the goodness-of-fit of Pseudo-  $R^2 = 0.3510$ , which was above average. A Pseudo  $R^2 = 0.12$  is often regarded as an acceptable goodness-of-fit (Brefle and Rowe, 2002).

Furthermore, the alternative specific constant (ASC) was found to be negative but insignificant, for this reason, it was not included in Table 8.3. If it had been significant, this would have implied that the hypothetical changes were expected to increase the utility. Depending on the value of the ASC added to the utilities, choice probability may vary. As explained in Chapter 4, ASC captures the average influence on utility of all elements excluded from the model. It represents the impact of unobserved factors on choice decisions associated with the particular estimated alternatives (Hensher et al., 2005). The majority of the studies in environmental economics based on survey designs include ASC (Scarpa et al., 2005); the inclusion of the ASC in the model indicates a zero mean for the error term.

Table 8.3 indicates the WTP estimation with the CL model. The WTP for each attribute was calculated by dividing the coefficient of attributes with the coefficient of the COST attribute.

Table 8.3 Basic CL model and WTP estimation

Attributes				<u>WTP</u>		
	Coefficient	St.err.	<i>p</i> -values		St.err.	<i>p</i> -values
SUBS	0.76412***	0.04496	0.0000	2.75848***	0.15980	0.0000
FITC	0.37750***	0.05800	0.0000	1.36278***	0.20911	0.0000
SPACE	-0.01934***	0.00454	0.0000	-0.06980***	0.01714	0.0000
SAVEK	0.74417***	0.06589	0.0000	2.68645***	0.23000	0.0000
COSTK	-0.27701***	0.01732	0.0000			

Note: \*\*\*, \*\*, \* → Significance at 1%, 5%, 10% level. N=205

The result shows that people are willing to pay 2.7 Euro more for each one percent of increase in subsidy, and they are willing to pay 0.13 Euro more for each 10 cent Euros FIT. The negative sign of WTP for SPACE indicates that people are willing to pay 70 Euros less for the loss of each 1m<sup>2</sup> space. In addition, people were willing to pay 2,700 Euros for each extra 1000 Euros of annual energy saving.

In the next table, we show the results from the CL model with the interaction terms. This model introduces the heterogeneity in the preferences through the interaction of socio-economic and other attributes in the model. The three variables of CITY, INCOME, EDUCATION were coded as dummy variables and they were used to estimate the interactions. Three factors were coded as dummy variables, including: ‘rural area (IRCITYD) and urban city (UCITYD)’, ‘high income (INCHD)’, and ‘higher level of education (HIGHD)’.

Table 8.4 presents the basic CL model with interactions. The variable IRCITYD (urban large cities) generated by the interaction between UCITYD and SPACE. The IRCITYD was statistically significant at 5% level but negative. In addition, the interaction between

high income and subsidy (IINCHD = high income \* SUBS), generated IINCHD and it was significant at 1% level.

Table 8.4 Basic CL model with interaction terms

Choice	Coefficient	Standard Error	z	Prob.  z >Z*
Subsidy	0.69359***	0.05052	13.73	0.0000
FIT	0.38803***	0.06125	6.34	0.0000
SPACE	-0.01533***	0.00495	-3.10	0.0020
Cost	-0.27942***	0.01740	-16.06	0.0000
SAVE	0.75067***	0.06610	11.36	0.0000
IRCITYD	-0.01636**	0.00707	-2.31	0.0207
IINCHD	0.18644***	0.06079	3.07	0.0022

Note: \*\*\*, \*\*, \* → Significance at 1%, 5%, 10% level. N=205

Table 8.5 reports the CL model with interaction terms and WTP estimation. In this table variable UCITYD (urban large cities) is included. Then, the IUCITYD variable was generated by the interaction between UCITYD and SPACE. The IUCITYD coefficient was statistically insignificant but positive.

Table 8.5 The CL model with interaction terms and the WTP estimation

Attributes				<u>WTP</u>		
	Coefficient	St.err.	p-values		St.err.	p-values
SUBS	0.71450***	0.05135	0.0000	2.55041***	0.17792	0.0000
FIT	0.27335***	0.06500	0.0000	0.97573***	0.22979	0.0000
SPACE	-0.02719***	0.00698	0.0001	-0.09705***	0.02574	0.0002
SAVE	0.75540***	0.6656	0.0000	2.69639***	0.22998	0.0000
COST	-0.28015***	0.01754	0.0000			
IUCITYD	0.00989	0.00724	0.1719	0.03531	0.02592	0.1731
IINCHD	0.15415**	0.06143	0.121	0.55023**	0.22080	0.0127
IHIGHD	2.61370***	0.70482	0.0002	9.32957***	2.56018	0.0003

Note: \*\*\*, \*\*, \* ==> Significance at 1%, 5%, 10% level. N=205

Parallel to the previous result, IINCHD parameter was statistically significant at the 5% level. The estimation of WTP for IINCHD was 0.55. This indicates that people with a higher level of income were willing to pay 0.55 Euro more than lower income people for each one percent of increase in subsidy. In addition, IHIGHD is the parameter produced from the interaction of HIGHD (higher level of education) with FIT (IHIGHD = high degree \* FIT). The IHIGHD was statistically significant at the 1% level with the 9.3 WTP. This reveals that educated people were willing to pay 93 cent Euro more than the lower or non-degree people for each 10 cent Euro FIT. Overall, the model is statistically significant with an acceptable goodness-of-fit, Pseudo R2 = 0.3656.

### 8.3.2 The Mixed logit model

The mixed logit (MXL) model with a specification of the random coefficients or parameters can be used to model the unobserved heterogeneity across individuals in their

sensitivity to observed exogenous variables. The MXL model is the integration of logit model:

$$P(j) = \frac{\exp(X'_{ij} \beta)}{\sum_{k=1}^J \exp(X'_{ik} \beta)}, \text{ with the mixing distribution of } f(\varepsilon_{ij}|\gamma). \quad (8.6)$$

Let  $X'_{ij}$  denote an exogenous attribute and  $\beta$  is the vector of the individual's attributes that differ across individuals.

The standard logit model calculates the probability of choosing alternative  $j$  by assuming independent, identical distribution (IID) type I Gumbel distribution for error  $\varepsilon$ , where the probability of choosing alternative  $j$  is conditional on the given  $\varepsilon$ . Under the IID extreme value assumption, the probability that a person chooses an alternative is the standard logit (Revelt and Train, 1998).

However, MXL or the random parameter relaxes the restriction of the IIA assumption, by allowing heterogeneity in preferences or tastes to be accommodated in the model (Revelt and Train, 1998; McFadden and Train, 2000; Hensher and Greene, 2003). The random distribution of marginal utility accommodates taste heterogeneity across individuals (Hess, 2010). Once a sampled individual ( $i = 1, \dots, I$ ) chooses an alternative over  $J$  alternatives in each choice situation  $t$ , this can be expressed as:

$$U_{jti} = \beta'_i x_{jti} + \varepsilon_{jti} \quad (8.7)$$

The explanatory variables of alternative  $j$ , socio-economic characteristics  $q$ , and the decision on choice situation  $t$ , are all labelled in vector of  $x_{jti}$ . The unobserved components of  $\beta_i$  and  $\varepsilon_{jti}$  to the researcher are the random parameters of the model (Greene et al., 2005). Under the assumption that individual  $i$  selects an alternative over other alternatives in choice situation  $t$  to gain the maximum utility, the probability is conditional on  $\beta_i$ , and then:

$$L(\beta_i) = \frac{e^{\beta_i' x_{jti}}}{\sum_j \beta_i' x_{jti}} \quad (8.8)$$

*Mixed multinomial logit estimate*

MXL model analysis is similar to the CL model but it also transforms the individual's characteristics into the alternative-specific variables, which is a supplementary task to the CL model. The choice probability is conditional on the vector of coefficients  $\beta_i$ , the randomly distributed individual-specific value with density function  $f(\beta_i | \theta)$ , where  $\theta$  is the true parameter of the distribution.

The random parameter logit (RPL) model relaxes the limitation of fixed coefficients in the standard logit model by allowing coefficients to vary randomly over individuals. The MXL model allows the error components in different choice situations from a specified individual to be correlated. In other words, it reduces the logit model's restriction on IIA property, and allows for heterogeneity in preferences. The generalisation of logit by avoiding the IIA property was estimated in one study of anglers' choice of site for fishing (Train, 1998). The use of RPL allowed the variation of observed variables over respondents. This variation implies that the unobserved utility related to any alternative is automatically correlated over time for every chooser. Each individual  $i$  obtains utility  $U_{ijt}$  from alternative  $j$  in choice situation  $t$  as:

$$U_{ijt} = \beta_i x_{ijt} + \varepsilon_{ijt} \quad (8.9)$$

$\beta_i = b + \gamma_i$  then the utility can be defined as:

$$U_{ijt} = bX_{ijt} + \gamma_i X_{ijt} + \varepsilon_{ijt} \quad (8.10)$$

Where  $\beta_i$  is comprised of  $b$  population mean and  $\gamma_i$  is the random term, which is the distribution or deviation of the individual's taste from the population mean.

We used the RPL model to analyse the individual's choice to adopt a micro-generation solar system. In this analysis, a normal distribution was applied because normal distribution typically applies to the MXL logit model (Hess, 2010).

$$\text{Normal distribution: } \beta_{\text{attribute mean}} + \sigma_{\text{attribute standard deviation}} * N$$

Table 8.6 reports the results from the RPL model for the same 205 data, which yielded 1,230 observations and 3,690 cases. The number of iterations increased from 6 to 23; this increase indicates that the RPL is a more complex model than the CL model.

In addition, the Pseudo  $R^2 = 0.5154$  shows a better fit of the data than the CL model.

The random parameters in the utility functions were estimated by requesting standard Halton<sup>76</sup> sequences, as reported in the first section of the Table 8.6. All estimated random parameters were highly significant at the 1% level. The negative sign of the parameters SPACE and COST are correct, as was expected, which indicates the adverse impact of these factors on the household's decision and choice. These results conform to the CL model findings.

In the second part of Table 8.6, non-random parameters in utility functions were used to capture those heterogeneity aspects which were not perceived by random parameter distribution. Non-random is a distribution that does not take the common distributions of normal, log normal, uniform, or triangular form in random parameters.

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<sup>76</sup> Sequences generate points that are deterministic with low discrepancy.

Table 8.6 Random parameters logit model

Choice	Coefficient	Standard Error	Z	Prob.  z >Z*
<i>Random parameters in utility functions</i>				
FITC	0.52270***	0.10356	5.05	0.0000
SUBS	1.08737***	0.09291	11.70	0.0000
SPACE	-0.02979***	0.00698	-4.27	0.0000
SAVEK	1.10588***	0.12580	8.79	0.0000
<i>Non-random parameters in utility functions</i>				
ASC	-1.18773***	0.43442	-2.73	0.0063
COSTK	-0.42959***	0.03326	-12.91	0.0000
<i>Derived standard deviation of parameters</i>				
NsFITC	0.41443***	0.11934	3.47	0.0005
NsSUBS	0.51209***	0.09269	5.53	0.0000
NsSPACE	0.04390**	0.01130	3.89	0.0001
NsSAVEK	0.78998***	0.12395	6.37	0.0000

Note: \*\*\*, \*\*, \* ==> Significance at 1%, 5%, 10% level.

Generally, fixed or non-random distribution is a practical analysis when a statistically significant parameter with an insignificant standard deviation in terms of heterogeneity around the mean is included in the model. As shown in Table 8.6, ASC and COSTK were included as non-random parameters. Both of the parameters took correct signs and were significant at the 1% level. Thus, the negative sign of ASC can be interpreted as an expected change that may cause an increase in utility. In addition, the high cost of investment would be a challenge for the households and might negatively impact their choice.

In the third part of Table 8.6, random parameters are estimated for derived standard deviations with the normal distribution. They were all statistically significant. This suggests “the existence of heterogeneity in the parameter estimates over the sampled

population around the mean”. The estimation of respondents with various individual specific parameters can be different from estimation of the sampled population mean parameter (Hensher et al., 2005, p.633).

Table 8.7 summarises the implied values or WTP estimation results from RPL model and Figure 8.1 demonstrates the Kernel density estimators for the empirical estimates. The results suggest that on average people were willing to pay 2.5 Euro more for each one percent increase in subsidy and they were willing to pay 12cent Euro more for each 10 cent Euro FIT. In addition, individuals were willing to pay 2600 Euro for each extra 1000 Euro saving annually.

Table 8.7 WTP estimates across sample from the RPL model

<b>Kernel Function</b>	<b>Logistic</b>			
Observations	205			
Points plotted	205			
<b>WTP for</b>	<b><i>SUBS</i></b>	<b><i>FITC</i></b>	<b><i>SPACE</i></b>	<b><i>SAVEK</i></b>
Bandwidth	0.228060	0.132587	0.015201	0.349699
Mean	-2.552718	-1.225271	0.068589	-2.607624
Standard Deviation	0.734781	0.427178	0.048975	1.126685
Skewness	0.383980	0.692565	0.148962	0.403759
Kurtosis-3 (excess)	-0.051477	0.250218	0.196556	0.007520
Chi2 normality test	0.353735	1.189404	0.080610	0.389059
Minimum	-4.396939	-2.054436	-0.076297	-5.812667
Maximum	-0.536135	0.177366	0.213153	0.454549

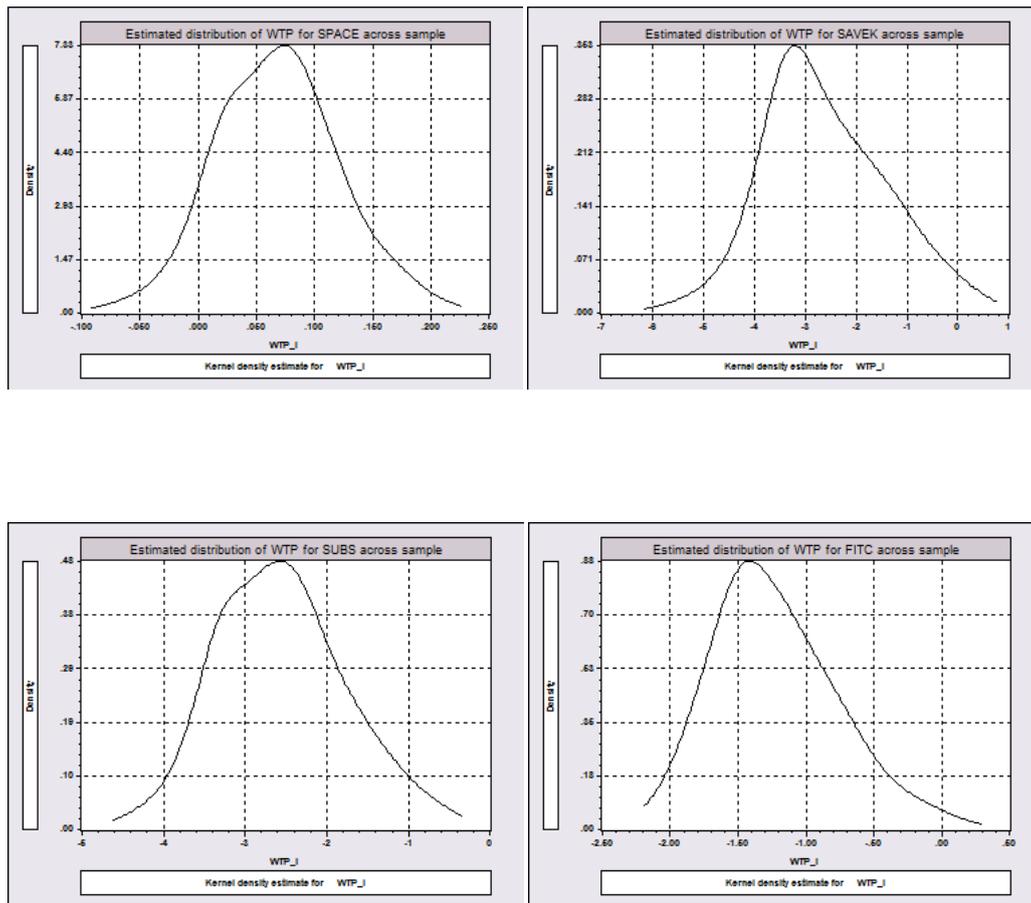


Figure 8.1 Kernel Density Estimator for WTP for RPL model

Thus far, the RPL model with the normal distribution suggested the presence of heterogeneity in the parameter estimates where the parameters randomly varied across individuals. To address the existing sources of heterogeneity, the individual’s socio-demographic characteristics can be incorporated into the model (Boxall and Adamowicz, 2002). “The interaction terms obtained by interacting random parameters with other covariates in effect decompose any heterogeneity observed within the random parameter, offering an explanation as to why that heterogeneity may exist” (Hensher et al., 2005, p.655).

The remainder of this chapter primarily uncovers some of the sources of preference heterogeneity and unobserved variables through the RPL and LC models with interaction terms.

Table 8.8 reports the results of the RPL model with the interaction terms. The parameters of FITC, SUBS, SPACE, and SAVEK were treated as random parameters and estimated by requesting standard Halton sequences. All the estimated random parameters were significant with the approximate zero  $p$  values at 1% level. With non-random distribution, the negative and significant ASC and COSTK with significant standard error were also observed. Likewise, these results also agree with the earlier findings from the basic RPL model.

Table 8.8 RPL with interaction terms

Choice	Coefficient	Standard Error	z	Prob. $ z  > Z^*$
<b>Random parameters in utility functions</b>				
<b>FITC</b>	0.31439***	0.12066	2.61	0.0092
<b>SUBS</b>	0.97059***	0.9630	10.08	0.0000
<b>SPACE</b>	-0.03241***	0.01227	-2.64	0.0082
<b>SAVEK</b>	1.05661***	0.11825	8.94	0.0000
<b>Non-random parameters in utility functions</b>				
<b>ASC</b>	-1.24665***	0.46670	-2.67	0.0076
<b>COSTK</b>	-0.41785***	0.03176	-13.16	0.0000
<b>IUCITYD</b>	0.0287	0.01356	0.21	0.8322
<b>IINCHD</b>	0.17618	0.11331	1.55	0.1200
<b>IHIGHD</b>	3.90157***	1.42354	2.74	0.0061
<b>Derived standard deviation of parameters</b>				
<b>NsFITC</b>	0.39671**	0.16798	2.36	0.0182
<b>NsSUBS</b>	0.48080***	0.08341	5.76	0.0000
<b>NsSPACE</b>	0.3593***	0.01354	2.65	0.0080
<b>NsSAVEK</b>	0.68757***	0.13925	4.94	0.0000

Note: \*\*\*, \*\*, \* ==> Significance at 1%, 5%, 10% level. N=205

Additionally, the interaction terms of IUCITYD ( $IUCITYD = UCITYD * SPACE$ ), IINCHD ( $IINCHD = \text{high income} * SUBS$ ), and IHIGHD ( $IHIGHD = \text{high degree} * FIT$ ) were included in the non-random parameters in the utility functions model. The statistically insignificant IUCITYD coefficient with a positive sign and the significant IHIGHD were consistent with the results from the CL model with interaction terms. This may suggest that the SPACE factor may not have a significant role in the choice of the decision makers from cities compared to the rural areas residents. One possible explanation could be that city residents have no extra spaces to leave for other usage that could be thought of as an opportunity cost. Overall, the model is statistically significant, with 13 degrees of freedom,<sup>77</sup> where the Pseudo R<sup>2</sup> value was 0.5102, which represents an excellent model fit in comparison with the CL model.

As shown in Table 8.9, WTP from the RPL model with interaction terms is estimated. On average, the high income people were willing to pay 2.3 Euro more than lower income for each one percent increase in subsidy. In addition, people with a higher level of education were willing to pay 0.07 Euro more for each 10 cent Euro increase in FIT. The citizens of urban areas on average were willing to pay 0.07 Euro more for each one square meter space than the rural areas' citizens. Furthermore, individuals with higher income were willing to pay 2500 Euro for each extra 1000 Euro saving annually.

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<sup>77</sup> Degree of freedom is equivalent to the difference in the number of parameters assessed for the two models.

Table 8.9 Kernel Density Estimator for WTP with interactions

<b>Kernel Function</b>	<b>Logistic</b>			
Observations	205			
Points plotted	205			
<b>WTP for</b>	<b><i>SUBS</i></b>	<b><i>FITC</i></b>	<b><i>SPACE</i></b>	<b><i>SAVEK</i></b>
Bandwidth	0.220573	0.130475	0.11888	0.297955
Mean	-2.353292	-0.775710	0.076683	-2.552359
Standard Deviation	0.710657	0.420373	0.038302	0.9599972
Skewness	0.383980	0.896109	0.097281	0.304952
Kurtosis-3 (excess)	-0.165864	0.606427	1.079223	0.006596
Chi2 normality test	0.186389	2.179502	0.856397	0.221947
Minimum	-4.414878	-1.571435	-0.062881	-5.485757
Maximum	-0.267400	0.597582	0.201070	0.004203

### 8.3.3 *The Latent class model*

The principal attraction of using the Latent class (LC) model rests on the classification of choice behaviours. The heterogeneity parameters across individuals are similar to the RPL model, but with a discrete distribution or set of classes. This heterogeneity can be signified by categorising individuals into a set of fixed classes based on their choices. Estimates consist of the classes with specific parameters, and a set of probabilities which define the classes. The analyst perceives that the individual's choice arises from observable and unobservable factors, and the unobserved attributes make variations on latent heterogeneity. Each class is made by observed behaviour and the good's characteristics (Swait, 1994), but the researcher does not know the particular setting of individuals into the classes (Boxall and Adamowicz, 2002). The posterior probability provides the best information available for estimating which individual is in which class.

The LC technique seeks a suitable specification by computing the maximum likelihood estimation (MLE), and then reporting the number of classes and the Akaike information criterion (AIC). Thus, the number of the segments of the latent model can be determined with the help of statistical criterion such as AIC or can be imposed by the investigator (Boxall and Adamowicz, 2002). According to NLOGIT 5 documentation, the number of classes can be specified from two to five, and an optimal model could have three classes. However, there is no assumption to direct us to the best number of classes. In the case of specification of numerous classes, some parameters will be estimated imprecisely with enormous standard errors, or after estimation, the approximate asymptotic covariance matrix will not be positive (Greene and Hensher, 2013). The NLOGIT firstly requires a conventional one class model and the Poisson model yields good starting values for the LC estimator. As noted before, class membership was not observed by the researcher, so the unconditional class probabilities can be specified through the multinomial (MNL) procedure. The segmentations or classes insert into the underlying random utility model:

$$U_{ijt} = \beta_c' X_{ijt} + \varepsilon_{ijt} \quad (8.11)$$

Where C represents the class specific parameter vector.

Conditional probability for the observed sequence of choice for person  $i$  is:

$$P_{ji}|c = \prod_{m=1}^{T_i} P_{jim}|c$$

Where  $P_{jn}|c$  signifies the conditional probabilities, and  $T_i$  denotes the number of choice situations for person  $i$ , which can vary by individual as the individual's choices are independent from one situation to another within the class. The expected value of unconditional probability for the sequence of choices can be calculated from:

$$P_{ji} = \sum_{c=1}^C \pi_{ic} \prod_{m=1}^{T_i} P_{jim} | c = \sum_{c=1}^C \text{Prob}(\text{class} = c) \text{Prob}(\text{choices} | c)$$

We examined the association of observed variables to unobserved variables by classifying individuals into the three classes based on their choices. In addition, the potential strategic behaviour and heterogeneity came into view because the outcomes of the CL and MXL analysis were statistically significant and a positive attitude towards the uptake of micro-generation solar system was perceived.

Table 8.10 reports the results of the LC model with three classes and 72 iterations. Each class had the same variables. Overall, the model was significant as Pseudo R<sup>2</sup> equals 0.5257, which is a quite good fit with 20 degrees of freedom.

Class one as shown in Table 8.10 is comprised of approximately 59% of the respondents' population. The significant parameters imply that all explanatory variables have a significant role on households' decisions for the choice. This group could include people who were willing to procure and install micro-generation solar equipment on their premises

The second class of the LC model is embraced by 11% of the sampled population. In this class, the ASC was negative and insignificant, so the hypothetical changes were expected to increase the utility. This sampled population can be categorised as those who preferred the uptake of solar technology to produce electricity on their own than other sources of energy. On the basis of the insignificant FIT, this group may primarily be concerned with the initial investment cost to some extent, and did not see FIT as a great financial support.

The third class was comprised of approximately 30% of the respondent population. This group showed a negative attitude as the ASC was found significant. This class, similar to the second class, might have preferred reimbursement for the initial cost of purchase and installation of solar equipment than FIT.

Table 8.10 Latent class logit model with three classes

Choice	Coefficient	Standard Error	z	Prob.  z >Z*
Utility parameters in latent class -->> 1				
ASC	0.86474	0.67873	1.27	0.2026
SUBS	1.62735***	0.24431	6.66	0.0000
FITC	1.32891***	0.24097	5.51	0.0000
SPACE	-0.02553**	0.01090	-2.34	0.0192
COSTK	-0.66101***	0.11297	-5.85	0.0000
SAVEK	1.58471***	0.22804	6.95	0.0000
Utility parameters in latent class -->> 2				
ASC	-11.7927	8.16600	-1.44	0.1487
SUBS	8.35488**	4.18431	2.00	0.0459
FITC	-4.32417	3.21940	-1.34	0.1792
SPACE	-0.62134**	0.29956	-2.07	0.0381
COSTK	-2.66584**	1.32599	-2.01	0.0444
SAVEK	8.00702**	3.85136	2.08	0.0376
Utility parameters in latent class -->> 3				
ASC	-1.98365***	0.51662	-3.84	0.0001
SUBS	.41736***	0.07310	5.71	0.0000
FITC	-0.22167*	0.12858	-1.72	0.0847
SPACE	-0.00880	0.00714	-1.23	0.2176
COSTK	-0.18391***	0.03146	-5.85	0.0000
SAVEK	0.28791***	0.10993	2.62	0.0088
Estimated latent class probabilities				
PrbCls -1	0.59188***	0.05273	11.22	0.0000
PrbCls- 2	0.11080***	0.02931	3.78	0.0002
PrbCls- 3	0.29732***	0.04936	6.02	0.0000

Note: \*\*\*, \*\*, \* ==> Significance at 1%, 5%, 10% level. N=205

To explore the sources of the heterogeneity, parameters can be interacted with other attributes and explanatory variables. Table 8.11 reports analysis of the LC model with the interaction terms to detect heterogeneity in different choice situations. This class included the interacted parameters of IUCITYD, IINCHD, and IHIGHD in the model, which are generated from the interaction of:

IINCHD= INCHD \*SUBS

IRCITYD= RCITYD \*SPACE    IUCITYD=UCITYD\*SPACE

IHIGHD= HIGHD\*FIT

As reported in Table 8.11, the interaction between the parameters and other attributes or variables in the first class was all statistically insignificant and negative. In addition, ASC was statistically significant. This class might not have been willing to pay for the micro-generation solar system. The results imply that this class constituted 27% of the sampled population. It is associated with a lower level of income, as the respondents resided in rural areas not in the cities, and had a lower level of education. In addition, they may have been concerned about the losing space and amenity. Alternatively, if they lived in the villages, the opportunity cost and using their extra spaces for other purposes were considered.

Table 8.11 Latent class model with interaction terms

<b>Choice</b>	<b>Coefficient</b>	<b>Standard Error</b>	<b>Prob. z</b>	<b> z &gt;Z*</b>
<b>Utility parameters in latent class --&gt;&gt; 1</b>				
<b>ASC</b>	-4.34947***	1.06672	-4.08	0.0000
<b>SUBS</b>	0.38860***	0.10301	3.77	0.0002
<b>FITC</b>	-0.03741***	0.19423	-0.19	0.8473
<b>SPACE</b>	-0.01133	0.01579	-0.72	0.4733
<b>COSTK</b>	-0.20801***	0.4446	-4.68	0.0000
<b>SAVEK</b>	0.42410***	0.17538	2.42	0.0156
<b>IUCITYD</b>	-0.00569	0.01801	-0.32	0.7522
<b>IINCHD</b>	-0.17668	0.15457	-1.14	0.2530
<b>IHIGHD</b>	-3.45650	2.81717	-1.23	0.2198
<b>Utility parameters in latent class --&gt;&gt; 2</b>				
<b>ASC</b>	0.78385	0.56911	1.38	0.1684
<b>SUBS</b>	1.25002***	0.13651	9.16	0.0000
<b>FITC</b>	0.62994***	0.15769	3.99	0.0001
<b>SPACE</b>	-0.03671***	0.1272	-2.89	0.0039
<b>COSTK</b>	-0.50379***	0.05072	-9.93	0.0000
<b>SAVEK</b>	1.10644***	0.14093	7.85	0.0000
<b>IUCITYD</b>	0.00438	0.01320	0.33	0.7403
<b>IINCHD</b>	0.21552	0.13379	1.61	0.1072
<b>IHIGHD</b>	7.19592***	1.86442	3.86	0.0001
<b>Utility parameters in latent class --&gt;&gt; 3</b>				
<b>ASC</b>	-4.26365*	2.25514	-1.89	0.0587
<b>SUBS</b>	1.42333***	0.54058	2.63	0.0085
<b>FITC</b>	-2.32381***	0.88988	-2.61	0.0090
<b>SPACE</b>	-0.22758	0.28798	-0.79	0.4294

<b>COSTK</b>	-0.498651***	0.16911	-2.95	0.0032
<b>SAVEK</b>	-0.62223	0.56593	-1.10	0.2716
<b>IUCITYD</b>	0.10141	0.28928	0.35	0.7259
<b>IINCHD</b>	1.23964**	0.59143	2.10	0.0361
<b>IHIGHD</b>	20.5221***	7.67240	2.67	0.0075
Estimated latent class probabilities				
<b>PrbCls -1</b>	0.26967***	0.07415	3.64	0.0003
<b>PrbCls- 2</b>	0.68518***	0.07511	9.12	0.0000
<b>PrbCls- 3</b>	0.04515***	0.01579	2.86	0.0042

Note: \*\*\*, \*\*, \* ==> Significance at 1%, 5%, 10% level. N=205

The second class was embraced by approximately 69% of the sampled population, which was above the average. This class was comprised of those who were more educated on the basis of the significant and positive interaction between variables of education and FIT. They believed that the utilisation of the micro-generation solar technology would increase their utility. For this class the uptake of PV is driven by rational factors: as people become more educated they are more likely to adopt PV, also this class is economically rational: as subsidy increases uptake increases, and as price declines uptake increases. The income effect is almost significant at the 10% level, which also indicates that as people become wealthier they will more adopt micro-generation solar technology. Thus for policy, the largest market section is responsive to policy instruments such as subsidy, FIT, and price. But other instruments such as higher education, and income growth, will be more long term in their effects.

The third class only represented the 0.045 quota of the sampled population. This class believed that the utility would not increase with the hypothetical changes because of the negative and significant ASC in the model. This class was comprised of people who were educated and had a higher income but may not have thought of installing a micro-generation solar system on their properties as an alternative choice for generating energy.

#### **8.4 Comparisons of CL, MXL, LC models with interaction results**

Horowitz (1983) proposed the use of the likelihood ratio index to compare and choose between the alternative models. Train (1998) suggested that the results between a logit and RPL differ based on specific situation; despite the lack of certainty which the model estimates reliably, the estimation of likelihood ratio is necessary for comparison of the models.

The Log-likelihood (LL) function of the estimated model can be compared to the base model in order to test the significance of the model. According to Hensher et al. (2005, p.330),

the LL ratio test can be calculated as:

$$-2(LL_{base\ model} - ) \sim \chi^2_{(number\ of\ new\ parametrs\ estimated\ in\ the\ estimated\ model)}$$

By comparing the obtained -2LL value to the critical value of the chi-square statistic with degrees of freedom, the superiority or inferiority of the estimated model against the base model can be determined. If the value of the -2LL exceeds the critical chi-square value, (significant at  $\rho = 0.000 < \alpha = 0.05$  usual level of acceptance), the null hypothesis can be rejected [that is the estimated model is no better than the base model]. If the -2LL value is smaller than critical chi-square value, then we can reject the alternative hypothesis. The NLOGIT executes the LL ratio-test automatically.

Table 8.12 presents the comparison results of the models: basic CL, RPL or MXL, and LC as well as interaction terms.

Table 8.12 Log-likelihood ratio test for model selection

<b>Model Compared</b>	<b>LL</b>	<b>D.F.</b>	<b>D.F. difference</b>	<b>-2LL Function</b>	<b>Chi Critical (5% sig.)</b>
<b>CL</b>	-716.94400	5			
<b>CL with interactions</b>	-700.86042	8	3		7.815
<b>RPL</b>	-668.68087	10	2		
<b>CL vs. RPL</b>			5	48.26313	11.070
<b>RPL with interactions</b>	-649.35396	13	4		
<b>CL vs. RPL with interactions</b>			5	38.99099	9.488
<b>RPL without interaction vs. RPL with interactions</b>			3	19.32691	7.815
<b>CL vs. MXL with interactions</b>			1		3.841
<b>LC</b>	-640.89132	20			
<b>LC with interactions</b>	-618.63778	29			
<b>LC without interaction vs. LC with interactions</b>			9	22.25354	16.919
<b>RPL vs. LC</b>			10	27.78955	18.307
<b>RPL vs. LC with interactions</b>			16	43.23165	26.296

As shown in Table 8.12, the models with interactions are statistically closer to zero than without interactions models and also have larger -2LL function at the 5% level than Chi-

square critical value. The null hypothesis can be rejected in that the estimated model is no better than the base model.

As an alternative index to the likelihood ratio, Ben-Akiva and Swait (1986) argued that Akaike Information Criterion (AIC) is an applicable criterion for choosing the model.

Table 8.13 Akaike information criterion

Basic CL model	Inf.Cr.AIC = 1443.9	AIC/N = 1.174
CL with interaction terms	Inf.Cr.AIC = 1417.7	AIC/N = 1.153
Random parameters logit model with 10 df	Inf.Cr.AIC = 1357.4	AIC/N = 1.104
Random parameter logit model with 13 df	Inf.Cr.AIC = 1324.7	AIC/N = 1.077
Latent class model	Inf.Cr.AIC = 1321.8	AIC/N = 1.075
Latent class model with interactions	Inf.Cr.AIC = 1295.3	AIC/N = 1.053

Table 8.13 reports the results of AIC. The LC model with interaction terms performed the best and smallest AIC compared with the other models. The result from the AIC test was consistent with the LL ratio test, and it compiles the effect of interaction terms in the model to obtain a smaller AIC.

### **8.5 Respondents' behaviour and policy implications**

Commonly, across the analysis of CL, RPL, and LC with and without interaction terms, the parameters of COST (capital cost) and SPACE (space requirement) were found to be statistically significant but negative. The negative signs are correct and were expected as the consumer's behaviour accords with the choice of minimum expenditure and saving space. In addition, the parameters of SUBSIDY, FIT, AND SAVING ENERGY were found to have a small standard error and were significant throughout the analysis with the examined models. This suggests that all explanatory variables play important roles in

households' decisions for the choice and procurement of micro-generation solar equipment on their premises. This can be implied as a proof for the choice of the explanatory variables in this survey.

In addition, the provision of financial incentives in terms of FIT and SUBSIDY, both were found to be significant across the estimation with the CL, RPL, LC models but in the LC models the FIT took the negative sign. In addition, the WTP results showed that people were willing to pay 2.7 Euro more for each one percent of increase in subsidy and they were willing to pay 0.13 Euro more for each 10 cent Euro FIT. In addition, people were willing to pay 2,700 for each extra 1000 saving annually.

Moreover, education was found to be a crucial factor in Turkish Cypriot decisions and choices. The interaction between the variables of higher level of income with subsidy reveals that as the level of income increases, households showed a higher consent and WTP for a lower subsidy. The WTP of people with higher level of income was found to be 0.55 Euro more than people with the lower income for each one per cent of increase in subsidy. In addition, educated people were WTP 93 cent Euro more than lower or non-degree people for each 10 cent Euro FIT. In addition, the results of WTP from the RPL model suggest that on average people were willing to pay 2.5 Euro more for each one per cent of increase in subsidy and they were willing to pay 0.12 Euro more for each 10 cent Euro FIT. Moreover, they were willing to pay 2600 Euro for each extra 1000 Euro saving annually.

Furthermore, people were willing to pay 70 Euro less for the loss of each 1m<sup>2</sup> space. The interaction between SPACE with CITIES and also SPACE and RURAL AREAS were tested. The latter was found to be negatively significant at the 5% level. The negative sign indicates that people living in rural areas (remote areas or villages) were less likely to devote spaces for the potential micro-generation solar panel installations. On the other

hand, the former was found to be positive but insignificant. This suggests that those who lived in cities, unlike rural areas, considered the space as a significant factor. A possible explanation for an individual's behaviour towards the space factor may be rooted in Turkish Cypriot culture's belief in holding property rights. This variance may be the consequence of the loss aversion or endowment effects on people's behaviour. Even though spaces are limited in the urban areas compared to rural areas where people live in the apartments, their choices may not have been influenced by the space factor. Moreover, the enthusiasm of urban residents for the choice of solar technology alternative for generating their own electricity may outweigh the problem of space limitation. City households may perhaps have been inclined to install solar panels on their houses according to their vacant spaces where the panels can be fitted no matter how large or small the space would be. Another possible explanation could be that the urban areas in North Cyprus have still kept the traditional patterns in terms of industrialisation, and even in the cities the limitations of space for the Turkish Cypriot have not yet become a common problem.

Moreover, one potential conclusion can be drawn, which is that those who resided in the cities may not have been characterised by loss aversion, endowment effects and property rights as much as people from villages were. However, the space limitation may not have been relevant and a major concern in rural areas of Northern Cyprus, as people could be loss averse and possibly thought of the opportunity cost and use their exposed areas for other purposes, such as agriculture. The WTP of city residents were 0.07 Euro less than residents from rural areas for each 1 m<sup>2</sup> space loss for installation of solar equipment on the premises. The city residents' lower WTP could have been because of space limitation and higher prices of properties in the cities.

Overall, the ASC parameter was perceived negatively insignificant by 69% of the sampled population, suggesting that the hypothetical changes were expected to increase the utility. The results of the LC model with interactions indicate that approximately 69% of the respondents showed strong preferences for utilisation of solar panel equipment on their premises. On the other hand, approximately 30% of the respondents revealed a weak tendency for utilisation of this system. Hence, the model predicts no expected increase in utility by approximately 30% of the sampled population.

## **8.6 Summary and conclusions**

Data were collected from 205 respondents in a CE format in order to evaluate attributes that impact the respondents' choice and preferences for the purchase and installation of micro-generation solar equipment on their properties. The five attributes with the assigned levels were deliberated through pre-studies and the literature. They were defined as Subsidy with three levels, FIT with three levels, Space required with four levels, Initial investment Cost with six levels, and Energy Saving with six levels. To evaluate how these factors impact on people's decisions, each respondent was presented with six choice cards in sequence followed by socio-demographic questions. The analysis started with a simple descriptive mean value. Then, the three models of CL, MXL or RPL, and LC were used to estimate the significance of the factors on household decisions and choices, as well as WTP. The estimation of interaction terms enabled us to account for heterogeneity in preferences. Both the MXL and LC offered alternative techniques of capturing unobserved heterogeneity and other potential sources of variability in unobserved sources of utility. Both models have distinct intrinsic value, and neither has superiority over the other. The LC model has a feature of being a "semi-parametric specification, which frees the analyst from possibly strong or unwarranted distributional assumption about individual heterogeneity, whereas MXL is fully parametric and is sufficiently flexible to

provide the modeller with a tremendous range within which to specify individual unobserved heterogeneity” (Greene and Hensher, 2003, p.697).

Overall, we found that the hypothetical changes were expected to increase the utility by approximately 69% of the sampled population of Turkish Cypriot. This 69% of the sampled population can compensate a large part the expected cost.

## **Chapter 9. Conclusions**

### **9.1 Introduction**

Benefits and costs are the elements of preference assessment. If money is used as a standard to measure utility, the measure of benefit is willingness to pay (WTP) to secure that benefit, and willingness to accept (WTA) compensation to forego the same benefit. Basically, the elicitation of an individual's preferences generates values that can be used to evaluate the utility from a hypothetical change.

The empirical analysis of this thesis was developed on the basis of household preference values for the utilisation of solar technology to generate electricity on their premises. It used Northern Cyprus as a case study, where the sustainable development strategy seeks to support sustainable energy production and consumption. According to European Union Commission directive 2009/28/EC, the adoption of a national action plan is obligatory for each member state. Thus, the goal of the country is to develop the utilisation of indigenous renewable energy sources (RES) to contribute to national electricity supply security and the sustainable development of the economy and society.

To measure utility or people's satisfaction with the utilisation of natural resources, indicators of cost and benefit should be transformed into monetary terms. However, certain aspects of these sources do not have a market price or monetary value because they are not directly sold. Due to the absence of an actual market for non-market values, stated preference (SP) techniques underlying the random utility model enable the hypothetical setting of the survey. The SP techniques can be applied either by asking respondents to state their preferences (WTP, WTA questions) or choose their most preferred option over a bundle of goods. This thesis aimed to explore the use of different SP techniques to estimate households' preferences for adopting micro-generation solar

technology on their premises. Accordingly, the two approaches of the SP technique, namely, contingent valuation (CV) and choice experiments (CEs), were used in the empirical analysis of this thesis.

## **9.2 Summary of the approaches**

Contingent valuation (CV) questions were administered to respondents in two ways. One was administered through the mode of open-ended questions, comprised of 105 data items from face-to-face interviews with individuals; however, this study was built based on the initial 100 collected data items from the pilot survey. Another case study was administered with the use of a double-bounded format, which was comprised of 264 data items from face-to-face interviews with individuals.

To elicit truthful responses, an experimental approach was designed using a Becker-DeGroot-Marschak (DBM) incentive compatible strategy, along with cheap-talk. Accordingly, the two case studies of CV experiments were designed by the incorporation of the BDM with cheap-talk in an attempt to reduce the behavioural anomalies and hypothetical bias. This research clearly brings new knowledge to the field of SP valuation method. The use of the BDM and cheap-talk jointly facilitate an incentivised mechanism to cope with strategic and hypothetical bias of SP.

In the subsequent sections, the two CV case studies are explained in brief, and the detailed explanations are provided in Chapters 6 and 7.

In addition, an individual's evaluation based on the CE technique is summarised in the next section, and a thorough explanation is provided in Chapter 8.

The three surveys were conducted in urban areas, Nicosia, Famagusta and Kyrenia, as well as rural regions, Karpaz and Iskele, Guzelyurt. The samples of these studies were the head of the household, regardless of gender. All the participants were over 18. Note that this research commenced in the year 2011, when the cost of installation of micro-

generation solar equipment was higher than today. As capital costs of solar technology decline<sup>78</sup>, and with technical innovation in PV technology, this suggests a reduction in supply price leading to more demand which could be reinforced with demand side policy instruments. However, the market value's drop has not affected the exploitation of the results, because the outcome has already been presented to the government's policy makers and influenced their decisions and set of laws.

### **9.2.1 Case study one**

This survey evaluated individuals' WTAs and WTPs using CV open-ended questions. It compares the results via two structures of conventional survey and the suggested experimental (novel) approach. To control for order effects and allow for a between and within subject evaluation, the study was carried out with two groups of respondents, with and without the experimental approach. Moreover, the conventional technique was considered as a control group for the experimental approach in order to compare the gap between WTA/WTP. In total, 105 individual heads of household comprised the sample of this study, generating 55 data items for the experimental mechanism and 50 for the conventional study. The respondents of the conventional study were individually asked to state their maximum WTP and minimum WTA, regardless of intuitive understanding of the terminologies without the use of clarification and practice.

On the other hand, the experimental approach was elicited with the same open-ended questions but through the experimental mechanism as mentioned in the previous section. Particularly, the experimental approach aimed to elicit the truthful minimum WTA and maximum WTP responses, which required initially practising the respondents' familiarity with the terminologies prior to asking the main questions. Following the procedure

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<sup>78</sup> The "renewable energy costs expected to drop 40% in next few years" in Computer World, (IRENA report, 2015 and LAZARD's levelised cost of energy analysis in Sept 2014).

described in Chapters 5 and 6, and in Appendix D, we asked the participants to assume that we were a government or private company offering to install micro-generation solar panels on their properties. An area of 8m<sup>2</sup> was considered for installation of 1kWp solar panels. Each respondent was told ‘you will be losing amenity for a specific period (15 years). They were then asked to consider, in spite of these inconveniences, *their minimum willingness to accept compensation*. Then, after the respondents had answered the first question, they were asked: presumably the government or a private company has offered to install 1kWp micro-generation solar panel in an area of 8m<sup>2</sup> in your property. *What would be your maximum willingness to pay?*

Furthermore, the results from conventional and experimental settings were compared in order to determine the role of the experimental or incentivised mechanism. As a result, the experimental approach showed a lower ratio (WTA/WTP) than has previously been reported in the environmental economics literature. The average WTA value was significantly influenced by the incentivised setting and its value sharply decreased to converge. The 3.5:1 ratio was observed from the conventional setting which is consistent with the average ratio in the literature; however, this ratio substantially decreased from 3.5:1 to 1.08:1 in the experimental or incentivised setting. Consequently, this finding agreed with the hypothesis that the incentivised setting would perform better than the conventional setting to circumvent the strategically and hypothetically biases.

The most obvious findings were: (1) the WTA was statistically different to WTP in the conventional setting, whereas it was equivalent in the experimental setting; (2) a smaller value of WTA for compensation and larger WTP were observed in the incentivised setting compared with the conventional setting.

### **9.2.2 Case study two**

This study used one of the houses from the Tanyel residential site in North Cyprus as a case study. The house area was measured at 140m<sup>2</sup> with a 4kWh grid connected and integrated solar system to the building. 6000 Euros was the estimated total purchasing cost of the panels and installation, when the system is integrated at the design stage, and 6000 Euro was the cost including the incentives of 25% subsidy approved by the Northern Cyprus government in the year 2012. The payback period was estimated to be three years, with the feed-in tariff rate at 0.25 Euro per kWh (Atikol et al., 2013). The sample of the study consisted of 264 individual heads of household. Due to the effectiveness of the novel experimental approach, it was also used in this survey. Following the procedure explained in Chapters 5 and 7, and in Appendix D, respondents were familiarised with the minimum WTA and maximum WTP terminologies and taught about the consequences of overbidding and underbidding, and in addition they were presented with 3D images of the house. Then they were asked to state the minimum amount that they would be willing to accept to sell the generated solar power to the grid. After this, respondents were asked the WTP question randomly across individuals at different levels of (2000, 4000, 6000, 8000, 10,000, 12000, 18000 Euros) for the integration of 4kWh solar technology.

The WTP questions were presented. The questions were designed in the close-ended referendum dichotomous format. The 6000 Euro estimated cost was not revealed to the respondent and used as a sealed bid and compared with the stated WTP values by the respondents. The responses to the WTA question were used for the estimation of feed-in tariff. WTA mean was approximated as 19.2 cent Euros/kWh. The lower bound and upper bound mean at the 1% level were 18 and 20 cent Euros respectively.

The non-parametric and parametric econometrics models were both applied for estimating WTP. We compared the values from single-bounded (SB) and double-bounded (DB) WTP analysis as the DB analysis did not fit the function, because we had set quite a number of costs for evaluation. The combination of first and second bids produced ten (ranging from 1000 to 18000). The comparison between WTP values of the first and the second question was carried out under the assumption that the responses to the single-bounded and DB were related to the individual's latent WTP value and unobserved resource (Carson and Steinberg, 1990; Hanemann et al., 1991). Following Carson and Groves (2007), we compared the SB and DB values of WTP and the results agreed with the assumption of SB WTP values being larger than WTP DB values.

The expected maximum WTP consumer surplus mean was calculated and found to be 6,882 Euro, which is greater than the 6000 Euro estimated cost for 4kWh integration of solar technology to the building during the construction. The results highlight the effect of the incentive compatible suggested experimental survey design. In addition, the results imply that on average people's WTP is greater than the estimated cost, this would be an indicator for policy makers to base their plan on lower financial incentives.

### **9.2.3 Case study three**

A CE survey of 205 respondents was carried out to evaluate the attributes that influence households' choices in the adoption of micro-generation solar panels. The trade-offs between explanatory variables or attributes and their levels were assessed, and individuals' choices and preferences were estimated from the trade-offs that they made. The five trade-offs' attributes<sup>79</sup> or sources of preferences were comprised of a government subsidy, a feed-in tariff, investment cost, energy savings, and the space

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<sup>79</sup> These attributes were deliberated through different instruments, such as focus groups discussion, pilot surveys, supplier's interviews, and literature to design (the detail of the process of identification and refinement of the attributes and attributes levels are described in the methodology chapter).

required for installation. The identified sources of preferences were generalised to many alternatives to compare and measure various combinations of the attributes across alternatives. The combinations of the attributes (with the use of a computer package) across alternatives yielded two unlabelled scenarios of A and B with a generic title, a micro-generation solar panel. To each pair of the hypothetical alternatives, a status quo (SQ) alternative was added. Each respondent was given six choice cards, producing 3,690 cases, and they were provided with the support of further clarification about the micro-generation solar system, visual aids, and hints to reduce the hypothetical bias.

Discrete choice (DC) models were employed to expect the choice probabilities between the discrete alternatives. The three models of conditional logit (CL), mixed logit (MXL) or random parameter logit (RPL), and latent class (LC) were used to estimate the significance of the factors on households' decisions and choices as well as WTP. The estimation of interaction terms was used to account for heterogeneity in preferences.

The WTP results from CL model showed that people were willing to pay 2.7 Euro more for each one percent of increase in subsidy and they were willing to pay 13 cent Euro more for each 10 cent Euro FIT. In addition, people were willing to pay 2,700 for each extra 1000 saving annually.

Education was found to be a crucial factor in Turkish Cypriot decision and choice. The interaction between the variables of higher level of income with subsidy revealed that as the level of income increases, households showed more consent and WTP for a lower subsidy. The WTP of people with a higher level of income was found to be 0.55 Euro more than people with the lower income for each one percent of increase in subsidy. In addition, educated people were willing to pay 93 cent Euro more than lower or non-degree people for each 10 cent Euro FIT. Moreover, the results of WTP from RPL model suggested that people were willing to pay 2.5 Euro more for each one percent of increase

in subsidy and they were willing to pay 12 cent Euro more for each 10 cent Euro FIT. Moreover, they were willing to pay 2600 Euro for each extra 1000 saving annually. Furthermore, the LC model showed that the hypothetical changes were expected to increase the utility by approximately 69% of the sampled population. The uptake of micro-generation solar system for 69% of the sampled population is driven by rational factors: as people become more educated they are more likely to adopt PV, as price declines uptake increases, and as people become wealthier they will more adopt micro-generation solar technology.

### **9.3 Future study and limitations**

The limitations of the study were the cost of data collection and the lack of respondents' awareness about the micro-generation technology. The cost of data collection limited the collection of a larger set of data.

Universally, playing games has become an attractive hobby in the course of everyday life, whatever the age of the person. Future study could be carried out using a CV survey with the same experimental setting in a computer game layout, to evaluate an individual's WTA and WTP. This requires that the game design be consistent with the incentive compatibility in order to maintain the structure of the experimental study. Similarly, the suggested experimental approach can be carried out in the case of other developing countries with the potential of renewable energy source (RES) exploitation in residential buildings. However, specific features of the country, such as available energy sources, government policies, and the country's international obligations, need to be taken into account for the experimental design with a game layout. This also helps the spread of the RE technology which can increase people's awareness and familiarisation. Furthermore, a future study could be carried out to evaluate individuals' WTA and individuals' WTP

separately by splitting the sample respondents into two groups. This approach can help to minimise the fatigue and order effects.

What is more, the development of Northern Cyprus is being rapidly shaped by population growth and increasing demand for housing. To meet this housing demand, contractors are resorting to high rise buildings. Currently, a study is being carried out to investigate the potentials and preferences of integrating PV into apartment buildings.

#### **9.4 Summary and conclusions**

The most apparent finding of this thesis is the significance of the novel experimental approach, which enabled the convergence of WTA/WTP ratio values. The incorporation of BDM and cheap-talk into the design of the CV survey helped to tackle the hypothetical and strategic behaviour biases. Specifically, it should be emphasised that this first use of such an innovative mechanism represents the originality of this study's contribution to knowledge.

Moreover, the results suggest that policy makers should base their plan on lower financial incentives to increase the solar power installed capacity in Northern Cyprus. The outcome of the study has already contributed to the application of the economy and policy of Northern Cyprus towards a sustainable development scheme. Accordingly, adjustments regarding incentives have been made by the government. Currently, feed-in tariffs and subsidy schemes are abolished and a net metering policy is adopted instead.

Furthermore, the results of this study could be useful for similar islands that are dependent on importing non-renewable sources of energy.

## **Appendix A. Focus group**

### **A.1 Introduction**

I'm here to co-ordinate the meeting but mostly I'll leave it to you to have your say. Every one is invited today lives in North Cyprus, but may from zones and cities.

We are considering to carry out a survey on renewable energy in North Cyprus, to evaluate people's preferences and choice of energy's source for electricity generation. In addition, to examine to what extent individual's are willingness to pay for electricity generated via renewableable.

The initial step of undertaking the study is to understand the factors that are important in people's choice and utilisation of energy's sources. Therefore, your comments and insights are important to outset the study. We would like to hear your opinions concerning the Solar, Wind power electricity generation. Hope you would allow us to record the meeting, and you would not be bothered. The reason of recording is to recap the session later. Although the comments and discussions will be written out, recording would help us to listen to your notes and opinions afterwards. The report may includes individual comments but they will be anonymous within the report. We would appreciated it if only one person speaks at a time, this gives us a chance to hear everyone's view and opinion. The session may take between 1-1.30 hours. we can start by going round the group asking everyone to say their thoughts about the most preferred mode of electricity production and consumption.

**Wind, Solar, Hydropower, Gas?**

## Solar Thermal Power plants



## Major Wind power plant



**Micro generation or Major Power Plant ?**

## Photovoltaic's



Stand-alone Photovoltaic system with tracking system and battery

## Micro Wind Turbine



### **A.2 Discussion questions are listed as follows**

- 1. Would you prefer to generate your own electricity via micro-generation system or would you rather be connected to large power plants through the network?*
- 2. Which of each solar, wind and the existing system, would you prefer the most?*
- 3. Would you install a micro generation solar system into your house?*
- 4. What would you ask the architect if you were supposed to build a new house?  
Would you want to build an energy efficient house?*
- 5. How much more would you be willing to pay for electricity production from renewable energy?*

### **The answers to the discussion questions:**

In response to the first question the micro-generation system was the primary comment, and the majority of respondents' preferences to the large power producers, if the demand grows indeed. The main concern was the availability of maintenance and service. The majority of Participants' preferred source of renewable energy was solar energy, as 90%

of Cypriots produce their hot water by solar panels. However, minority of them were agreed with micro wind turbine too.

Some of the other comments and concerns were as follows:

- “Using a micro-generation system would allow selling excess electricity to the grid”.
- “Maintenance costs and servicing is important, especially in Cyprus with the lack of expert technicians and professionals in repairing. It would be an advantageous, if long term service accompanied with the system’s installation”.
- “We should make use of the sun in Cyprus but the government should contribute too. For example, the government should subsidize at least 50% of the cost involved”.
- “Maintenance cost discourages households from adopting renewable energy”.
- “At the moment demand is low, but higher demand will cause reduction of maintenance cost and also will guarantee the availability of service”.
- One of the participant remarked that availability of space to install the solar panels should be considered. She said: “It’s a kind of dreaming and wasting money; this micro-generation technology might not be successful”.
- Most respondents found solar technology attractive but they thought the high cost is a discouraging factor.
- “Although my neighbour installed it, he wasn’t pleased. Storage batteries are very expensive and they break down frequently”.
- “The cost is really high, and the supplier charges a service fee for installation and maintenance”.
- “People might not know about this operation system. Educating them is important. Solar energy is the best renewable energy source in Cyprus, particularly, micro-

generation system for the households. Though it has been used rarely due to lack of awareness of infinite solar energy and existed RE technology. Therefore the government policy is a crucial issue”.

- “Solar energy utilization is very logical in Cyprus and would lead to pollution reduction.”
- If energy can be stored in the battery, electricity won't be disconnected when there is no wind and sun available, and therefore in this condition definitely we should utilise the sun and wind energy.
- Current sources of energy are depleting which makes it essential that we use renewable energy sources.
- Taking into account the fact that, 8-9 months of the year is sunny in Cyprus, I would prefer solar energy to other alternatives.
- This system was installed in Cayirova village. One housewife believed that people seem to be happy with the solar panels system.
- The cost is approximately 20000 pounds. It would be worth it, if there were guarantee of a good service. There should be an on call service.
- People should not simply choose the cheapest option, but rather look for a long term solution.
- Exemption from paying taxes would also help.
- The government needs to lend its support. We cannot do it on our own.
- Certainly, that's an excellent idea, and then we will not pay for electricity to the government.
- I have got a plot where there is no electricity. It costs 25000 pounds to connect it to the grid. If I could get a credit from the bank, I would consider a renewable energy.

- I would go for a central electricity system. If I built a house, I would make use of solar energy. But the solar energy system is expensive. If it is a deserted or uninhabited area and I have no other choice I would be obliged to do it. Otherwise, I would prefer central city network. But the government should encourage households.
- If this system is installed in one house in my village, undoubtedly others will be interested to have it as well.
- To what extent we will need solar energy system if we have got insulation in the house.
- I would check the price first. Second, I would check to see whether it is practical or not. Last but not least, if it is widely used or not. I mean, if it can be repaired easily. Another thing is to find out whether it is used by the majority of people or are we the first ones to use it. Is it safe to use it? Not only should the consumer know all about these, but technicians and the company should also be conscious and well-informed enough in order to deliver the service.
- I would ask the architect to make use of the sun by capturing the sun rays if I built a house.
- I would ask for a building that is well insulated to keep the house cool in the summer and warm in the winter.
- I would ask for an energy efficient house with the integration of the solar system at the design stage.
- I considered insulation while I was building my house but these things are really expensive, and the price would be lower if it was commonly used.
- I would prefer to decrease the house size and eliminate luxury items so as to have an efficient house.

In general, most of the participants stated that they are willing to pay “between” 10% to 20% extra.

- “Thinking of advantages in the long run I would pay up to 20%-50%. It may sound luxurious but I would.”
- Income of people should be calculated, and find an average in order to find out how much extra people can afford to pay for it.
- Government must encourage people to install this system by reducing the tax, and people get advantage of tax reduction.

### **A.3 University guidance and toolkit for research ethics**

Typically, every project is distinctive due to its own unique aim. Thus, each form (e.g. consent, information, or debriefing) needs to be tailored to the specification of the project and its intended participants, but a complicated language must be prevented. In the cases of working with human participants, researchers should inform participants of their entitlement to refuse to contribute or withdraw from the investigation at any time and no matter what the reason would be. The participants should not be forced to take part in the research.

Adult research participants, however, may be given proper monetary reimbursement for their time and costs involved. Occasionally, it makes sense to use techniques such as a free prize draw or vouchers, to persuade survey responses. Respondents must not be required to do anything other than agree to participate or return a questionnaire to be eligible to a free prize draw, for instance: respondent must not spend any money.

Researchers should assure participants about the security of their personal records such as, medical, genetic, financial, personnel, criminal information.

**The preliminary application form for the approval of this research is presented in the next pages.**

## Application for Approval of Research Project and Supervisory Team

**Mehrshad Radmehr**

### Ethical Issues - and where to get further guidance

(i) Does your research involve NHS PATIENTS OR STAFF, their tissue, organs or data?

Yes  No

If YES your project will require additional review by a [NHS Research Ethics Committee](#).

You will also require separate Trust Research & Development Department (R&D) approval from each NHS Organisation involved in the study ([Newcastle upon Tyne NHS Foundation Trust](#)).

When making your application to these bodies, please provide a copy of this project approval form (once it has been approved) as it will act as your independent peer review.

(ii) If the answer to question (i) is **NO**, does your research involve other HUMAN SUBJECTS?

Yes  No

If YES, please answer questions 1-10 below. If your answer to any of these questions is YES you will need to obtain separate University ethical approval. Discuss your plans to address the ethical issues raised by your proposal with your supervisory team and submit them to your School or Institute's Research Ethics Coordinator using the [University Research Ethics application form](#).

**YES NO**

- Does the study involve participants who are particularly vulnerable or  
1 unable to give informed consent? (e.g. children, people with learning  
disabilities, your own students)
- Will the study require the co-operation of a gatekeeper for initial access to  
2 the groups or individuals to be recruited? (e.g. students at school, members  
of a self-help group, residents of a nursing home)
- Will it be necessary for participants to take part in the study without their  
3 knowledge and consent at times? (e.g. covert observation of people in non-  
public places)
- 4 Will the study involve discussion of sensitive topics? (e.g. sexual activity,  
pornography or drug use)
- 5 Are drugs, placebos or other substances (e.g. food substances, vitamins) to  
be administered to the study participants or will the study involve invasive,  
intrusive or potentially harmful procedures of any kind?
- 6 Is pain or more than mild discomfort likely to result from the study?
- 7 Could the study induce psychological stress or anxiety or cause harm or  
negative consequences beyond the risks encountered in normal life?
- 8 Will the study involve prolonged or repetitive testing?
- 9 Will financial inducements (other than reasonable expenses and  
compensation for time) be offered to participants?
- 10 Does the research involve any other actions that you feel may be regarded as  
unethical or illegal – please specify these elsewhere on the form?

(iii) Does your research involve working with LIVE VERTEBRATE ANIMALS?

Yes  No

If **YES**, you and your supervisory team should discuss your proposed project with the Director of the Centre for Comparative Biology who will be able to advise on seeking specific approval.

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## Appendix B. Pilot Survey



Good morning/afternoon/evening. Your answers to the following question will be used in a PhD thesis which aims to examine Cypriot willingness to pay for the use of renewable technology. It will take the form of a series of questions about your current source of energy consumption and your willingness to pay for the production of electricity from renewable energy sources.

This project assumes that renewable energy laws will be enacted and EU legislations will be followed in North Cyprus. I would be pleased if you keep these conditions in your mind while completing this form. Thank you for agreeing to take part in this interview.

## B.1 Background

**A1.** Do you have a solar water heating system in your house? 1. Yes 2. No

**A2.** Please circle the number that presents how you are satisfied with your existing solar water heating system.

<i>1. Strongly satisfied</i>	<i>2. Satisfied</i>	<i>3. Neither satisfied nor dissatisfied</i>	<i>4. Dissatisfied</i>	<i>5. Strongly dissatisfied</i>
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**A3.** Do you have an electrical heating system at home? 1. Yes 2. No

**A4.** How much is your house's monthly electricity bill on average? (Turkish Lira, TL)

1. 50 -100 TL	2. 100-200 TL	3. 200-300TL	4. 300 -400TL	5. More than 400 TL
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**A5.** How many months a year your house is occupied?

1. 1-3months      2. 3-6months      3. 6-9 months      4. 9-12 months

**A6.** Do you have a flat roof or balcony, garden?

Yes

No

**A7.** Please circle the number that indicates how you feel about the statements below.

	<i>Strongly Agree</i>	<i>Agree</i>	<i>Neither Agree nor Disagree</i>	<i>Disagree</i>	<i>Strongly Disagree</i>
a. Renewable energy technologies	1	2	3	4	5

are able to solve the energy problem that the world is facing now.					
b. Renewable energy technologies have reached the level to produce economically feasible energy.	1	2	3	4	5
c. Renewable energy technologies are playing a crucial role in preventing environmental pollution.	1	2	3	4	5

**A8.** Please, indicate how you are familiar with the micro-generation (Wind and Solar) technology.

	<i>1.Never heard</i>	<i>2.Heard</i>	<i>3.Quote</i>
a. Wind turbine			
b. Solar panel			

<b>A9.</b> What is your view of this technology for power generation within next 10 years?		
a. Could it be primary source of power generation?	<i>agree</i>	<i>disagree</i>
b. Could it be supplementary source of power generation?	<i>agree</i>	<i>disagree</i>

<b>A10.</b> Please indicate to what extents do you agree or disagree.					
	<i>Strongly Agree</i>	<i>Agree</i>	<i>Neither Agree nor</i>	<i>Disagree</i>	<i>Strongly Disagree</i>

			<i>Disagree</i>		
a. We need to worry much about the environment because future generations will be less able to deal with these problems.	1	2	3	4	5
b. I am very concerned about environmental issues.	1	2	3	4	5
c. I believe that environmental claims are exaggerated	1	2	3	4	5
d. Solar panels are economically feasible in residential use.	1	2	3	4	5
e. Would you prefer to make your existed house energy efficient?	1	2	3	4	5

## B.2 Demographic questions

B1. Sex	1. Female			2. Male		
B2. Age	1 18-27	2 28-37	3 38-47	4 48-60	5 more than 60	
B3. Education	1 Primary School	2 Secondary School	3 High School	4 University (2 Years)	5 University (4 Years)	6 Advanced Degree
B4. Employment	1 Unemployed	2 Retired	3 Student	4 Self-employed	5 Employed	
B5. Monthly Household Income (TL) (Salary + Interests +	1 less than	2 1500-3000	3 3000-4500	4 4500-6000	5 6000-7500	6 more than

Rental income)	1500					7500
B6. City	1. Nicosia	2. Famagusta	3. Kyrenia	4. Morphou	5. Trikomo	
B7. Marriage Status	1. Single		2. Married		3. Divorced/Widow	

## Appendix C. Micro-generation solar panel

### The benefits of solar Photovoltaic (PV) electricity

- **Lowers carbon emissions.**
- **Lower fuel bills:** electricity bills could be reduced.
- **can export electricity back to the grid:** if system is producing more electricity than needed, or at times during the day when householder is not at home, someone else can use it – by either exporting by a private wire or to the grid (feed in tariff)\*
- **energy storage options:** if a home is not connected to the grid, excess electricity can be stored in batteries



Figure C.7 An area of 120m<sup>2</sup> covered with photovoltaic panels

As shown in Figure C.7, 120m<sup>2</sup> photovoltaic panels (Polycrystalline) have been installed on the roof of the house. Each panel (1 sqm) is 1 kwh with the efficiency (capacity factor) 15%-25%.  $1 \times 15\% = 150 \text{ Wh}$ .

$150 \text{ Wh} \times 120 = 1800 \text{ Wh}$  or 1.8kWh

A low energy concrete house consumes 30-40kWh/m<sup>2</sup> annually. A house in size 120m<sup>2</sup> then,

$30\text{-}40 \text{ kWh/m}^2 \times 120 \text{ m}^2 = 3600 - 4800 \text{ kWh/yr}$

Cost for 1m<sup>2</sup> solar panel (1kwh with the capacity factor 0.15-0.22) is about 2500Euro.

If we consider on average 18% capacity factor, the requirement of number of panels to cover 120 m<sup>2</sup> can be calculated as follows:

$120 \text{ Wh} * ? = 3600 \text{ kWh}$  answer is **30** \* 120 = 3600 30 number of panels(30m<sup>2</sup>)

$120 \text{ Wh} * ? = 4800 \text{ kWh}$  answer is **40** \* 120 = 4800 40 number of panels(40m<sup>2</sup>)

At the moment, each panel cost is 2500Euro in Cyprus. But as the number of purchased panels increase, price will drop to even less than 2000Euro. So, if we consider 2000 Euro on average for purchasing and installing 30 panels,  $30 * 2000 \text{ Euro} = 60,000 \text{ euro}$

60,000Euro will be the cost of installing PV for generating electricity in a 120m<sup>2</sup> building. The system will be fully guaranteed for 20 years, no need to pay electricity bills, and no maintenance cost.



Figure C. 8 PV Two systems in the same neighbourhood in Frenaros, Cyprus

The system is fitted onto the building as a replacement roof, avoiding the need for tiles and also includes the building's water heating panels (Figure C.8).



Figure C. 9 A system of 7.56 kWh in the garden of a house in Vrysoulles, Cyprus



Figure C.10 Solar panels placed in a curtain wall type aluminium frame

Figure C.10 shows the 36 solar panels have covered a total area of  $60\text{m}^2$ . A system of 6.4 kWh that replaces the roof on the extension of this house in Sotira, Cyprus. The 36 panels with a total surface area of  $60\text{m}^2$  are placed in an aluminum curtain wall type frame, making the fitting of a ceiling on the underside of the roof very simple.

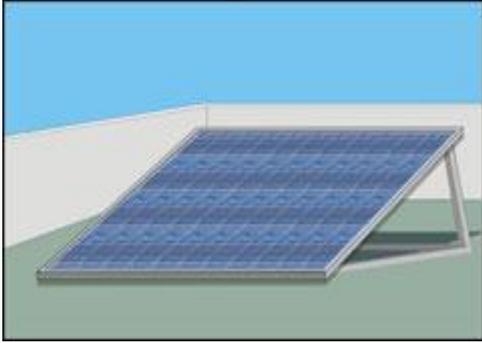


Figure C.1 Panels fitted onto a flat roof

Panels fitted onto a flat roof or terrace is fitted into a strong solid frame at the optimum angle of 30 degrees (Slope) and Azimuth 0 degree.

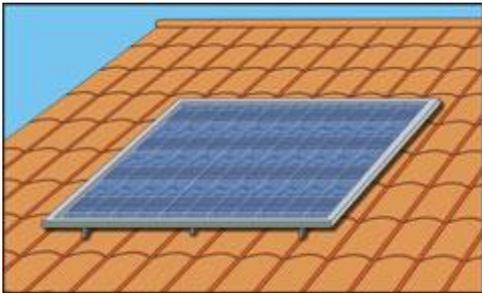


Figure C.2 Panels fitted onto an existing tiled roof

This solution allows you a quick and safe method of fitting solar panels in cases where the existing roof is covered in tiles.

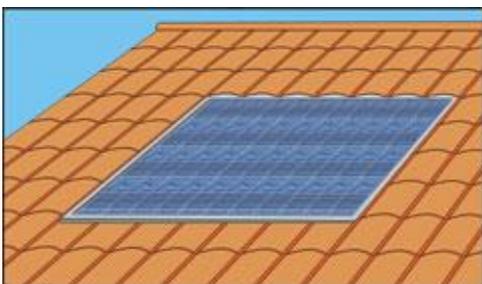


Figure C.3 Panels fitted as part of a new tiled roof

Solar panels can be embodied within the roof surface in a tried solution with guaranteed insulation. This results in a smooth roof surface, since the panels do not extrude from the areas that are tiled.



Figure C.4 Panels fitted in a tiled roof

In cases of requiring the entire roof surface to be covered in solar panels, these can be combined with windows and water heating panels with the same appearance for an impressive smooth, modern surface which adds to the design of your building.



Figure C.5 Panels fitted as covers and canopies

Solar cells incorporated into covers or canopies above entrances and windows protect against rain and provide shading. With an ideal angle of between 30- 45 degrees these can add to the total electricity produced as well as add to the design of the building, giving it a unique appearance.

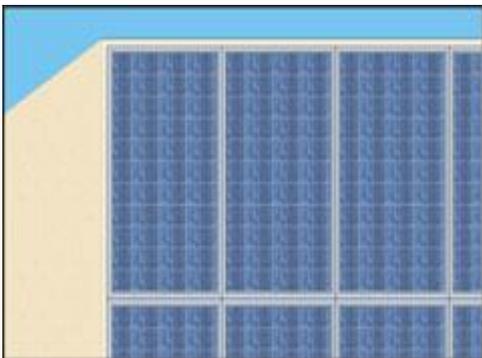


Figure C.6 Panels fitted vertically on a facade Figure

Glass fronts for modern buildings are ever more popular. Photovoltaic panels can be fitted in place of traditional glass panels in more or less the same way, using the entire surface for producing energy.

## PV Trackers Benefits

PV solar panels maximise solar energy and megawatt hours when directly facing the sun.

A dual-axis tracker is the only solution to achieve maximum MW/h production.

Trackers add cost and maintenance to the system - if they add 25% to the cost, and improve the output by 25%, the same performance can be obtained by making the system 25% larger. Larger system needs more space though, which can be saved by installing PV tracker.

15%-25% performance of Solar panels can be increased up to **65%** in the full tracking system although in the East and West system can be increased up to 40% by providing tracking device (Figure C.11). In that case another 1000Euro will be added to the cost. For example; 1kWh PV with tracking system (East and West) will become 3500Euro. Therefore,

$15\% + 40\% = 55\%$  factor capacity for PVT

Almost  $55\% * 1\text{kWh} = 500\text{ Wh}$  efficiency, so PVT system is about 3 times efficient than PV.

As explained  $120\text{m}^2$  consumes 3600-4800Kwh/yr

$500\text{Wh} * ? = 3600\text{ kWh}$        $7 * 500 = 3600\text{ kWh}$

$500\text{Wh} * ? = 4800\text{ kWh}$        $10 * 500 = 4800\text{ kWh}$

We calculate the maximum numbers  $10 * 2000\text{Euro} = 20,000\text{euro}$

$10 * 1000\text{euro}(\text{tracking device cost}) = 10,000\text{Euro}$

$10,000 + 20,000 = 30,000\text{Euro}$  total cost

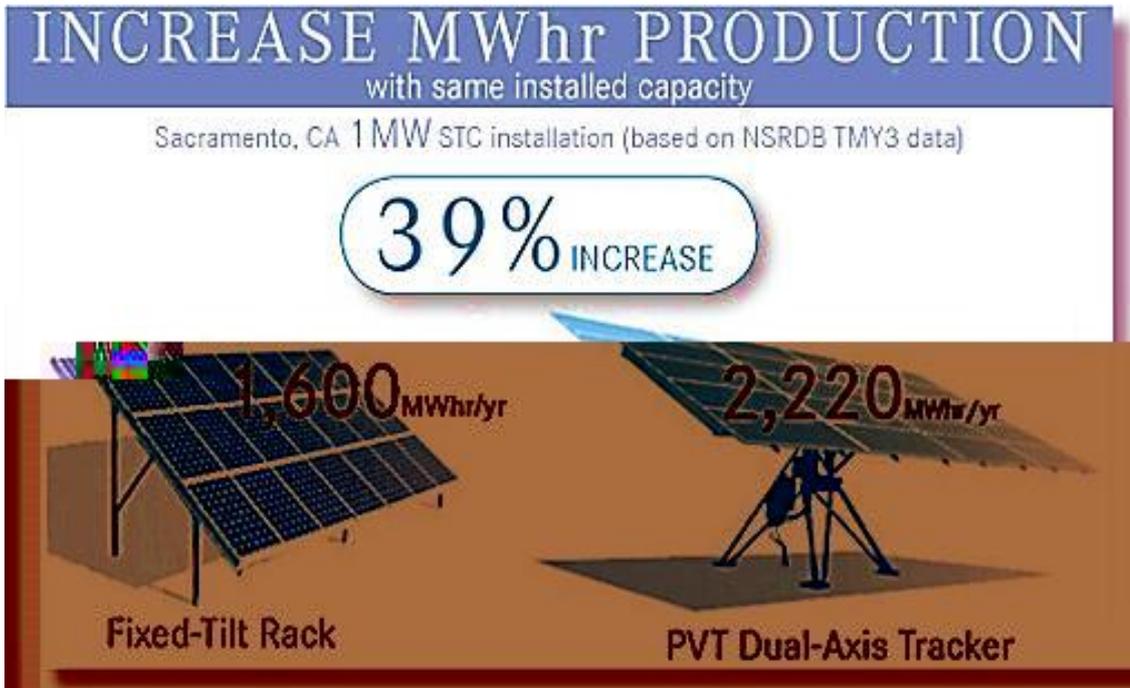


Figure C. 11 PV trackers



Figure C. 12 PV with tracking system

PV with tracking system cost will be almost half of the cost of photovoltaic without tracking system for the generation of equal energy, because of higher efficiency or capacity factor. In addition, space will be saved.



Figure C.13 PV with tracking system

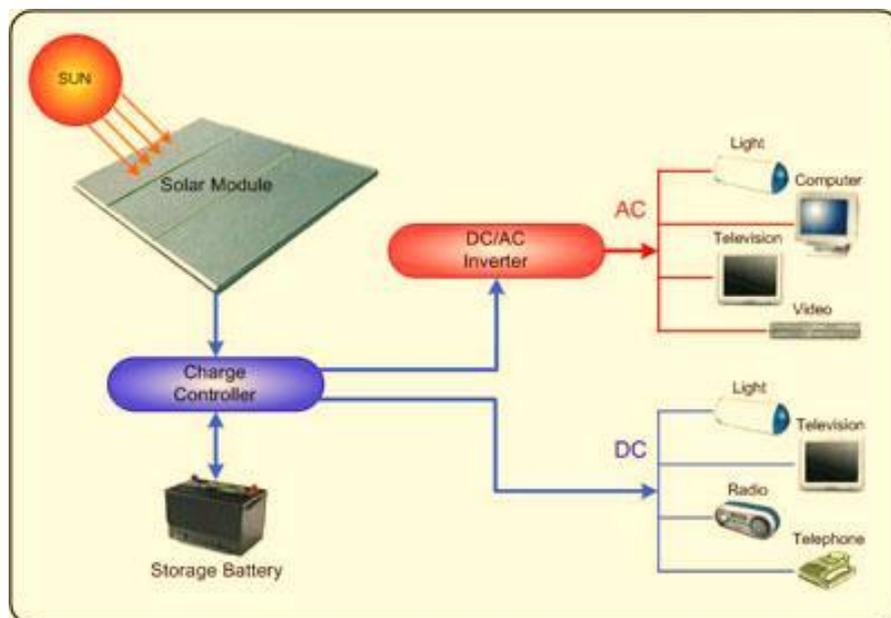


Figure C.14 PV system with battery storage

## **Micro and small wind turbines**

Micro and small wind turbines generate renewable electricity from wind (FigureC.15). Rotor blades are aerodynamically engineered to take optimal power and then turn a turbine to generate electricity. The power of a wind turbine increases exponentially in a relation to the speed of the wind and the diameter of the blades. This makes larger turbines with higher wind speeds more cost effective e.g. the energy payback for larger turbines in windy places is multiplied but good wind speeds at the micro level, can also generate considerable energy.

There are two types of domestic-sized micro-wind turbine:

**Mast mounted:** these are free standing and are erected in a suitably exposed position.

**Roof mounted:** these are smaller than mast mounted systems and can be installed on the roof of a home.

If a micro wind turbine eligible for feed in tariff\* is connected to the grid in a location with high wind speeds, consumers can sell generated electricity to an electricity supply company, and earn an added export tariff. If a wind turbine is not connected to the Grid, surplus electricity can be stored in a battery. The issue of existing wind has to be taken into consideration, as well as amenity issues in terms of noise and visual amenity.



Figure C.15 Micro-Wind Turbine

Cost for 1 kWh micro-wind turbine is about 2000 Euro, In average a building energy consumption is about 30-40 kWh/yr per 1 square metre, If we consider 25% in average;

$$1\text{kWh} * 25\% = 250 \text{ Wh efficiency}$$

Again we consider a 120m<sup>2</sup> building with annual energy consumption of 3600-4800kWh/yr

$$250\text{Wh} * ? = 3600 \text{ answer is almost 14}$$

$$250\text{Wh} * ? = 4800 \text{ answer is almost 20}$$

A number of 14- 20 micro-wind turbine will be needed to meet the building energy demand.

At the moment a 1 kWh micro-wind turbine cost is 2000Euro in Cyprus and mentioned before, the cost will be discounted by purchasing higher quantities.

$$14-20 * 2000 = \text{price will be 28,000Euro to 40,000 depends on the numbers}$$



Figure C.16 Micro-Wind Turbine and PV system

**\*The Feed-in Tariffs (FITs)** scheme was introduced in 1st April 2010, under powers in the Energy Act 2008. This is currently the primary mechanism to support deployment of large-scale renewable electricity generation – and the Renewable Heat Incentive (RHI) which supports generation of heat from renewable sources at all scales. There are three financial benefits from FITs:

Generation tariff – the electricity supplier of your choice will pay you for each unit (kilowatt) of electricity you generate

Export tariff – if you generate electricity that you don't use yourself, you can export it back to the grid. You will be paid for exporting electricity as an additional payment (on top of the generation tariff)

Energy bill savings – you will not have to import as much electricity from your supplier because a proportion of what you use you will have generated yourself, you will see this impact on your electricity bill.

## **Appendix D. Using Teaching Experimental Mechanism**

### **D.1 Minimum Willingness to Accept**

This technique is based on an incentivised experiment for helping respondents to have a better understanding about minimum willingness to accept (WTA) concept. This technique helps respondents to have a better understanding about minimum willingness to accept (WTA) concept and maximum willingness to pay (WTP). People are usually more experienced in buying rather than selling. This makes awareness about possible consequences of strategic over and understatement necessary. In order to elicit the truthful minimum WTA responses, familiarising respondents with the term minimum WTA is helpful.

Experimental mechanism can be carried out firstly to teach the survey's respondents, what is meant by a minimum willingness to accept and potential consequences of over and understating. Then solar energy evaluation can be discussed, once the experimenter becomes quite sure about respondents' intuition of minimum WTA concept. This would be followed by a subsequent hypothetical minimum WTA valuation for losing amenity values caused by photovoltaic installation in your property for others' usage. Furthermore, maximum WTP would be examined in order to be compared with minimum WTA response for measuring the magnitude of gap between them. Sometimes the discrepancy between MWTA and MWTP occur on the basis of respondents' misinterpretation of what is actually meant by MWTA.

At the end, demographic questions should be distributed among the respondents.

The content of the protocol is supplemented by the use of visual aids, aide memories and questions to assist the respondents.

## **Method**

A number of five to twelve respondents should contribute in each group session; participants are treated by the opportunity of entering a draw for a prize of 30 lira as an incentive. Each discussion session will begin with introducing them to the term 'reserve price' as a substitute for the term minimum WTA. Based on other studies, respondents are usually more comfortable with 'reserve price' term. The term familiarised by discussing the process of selling a piece of land (600m<sup>2</sup>) in an auction. The reserve price can be explained as the lowest fixed price (floor price), at which the land can be offered at the auction sale.

This will followed by introducing 'external sealed bid' term, also for simplifying the meaning of minimum WTA. Respondents should be divided into two groups and ask to discuss a 'reserve price'. i.e. the minimum they would accept to sell a teddy (which is given to them previously). Then reserve price compares with a predetermined sealed bid in a second price auction mechanism.

After comparing between the respondents' answers and sealed bids, the question of 'why it is always best to be truthful' can be discussed. In particular, the experimenter should clarify the possibility of undesirable consequences of over-or-under stating i.e. in the case of over bidding, there is a danger that the vendor keeps the item rather than sells it. (If the sealed bid being between the vendor's 'true value' and inflated stated reserve price). Similarly, in the case of under-bidding when the item sells for less than it's worth (if the sealed bid lies above the very conservative reserve price but below the vendor's 'true value').

Respondents should be given a ‘memory jogger’ summarising the key concepts, and their answers recorded in response books. The figure D1 shows the memory jogger for minimum WTA.

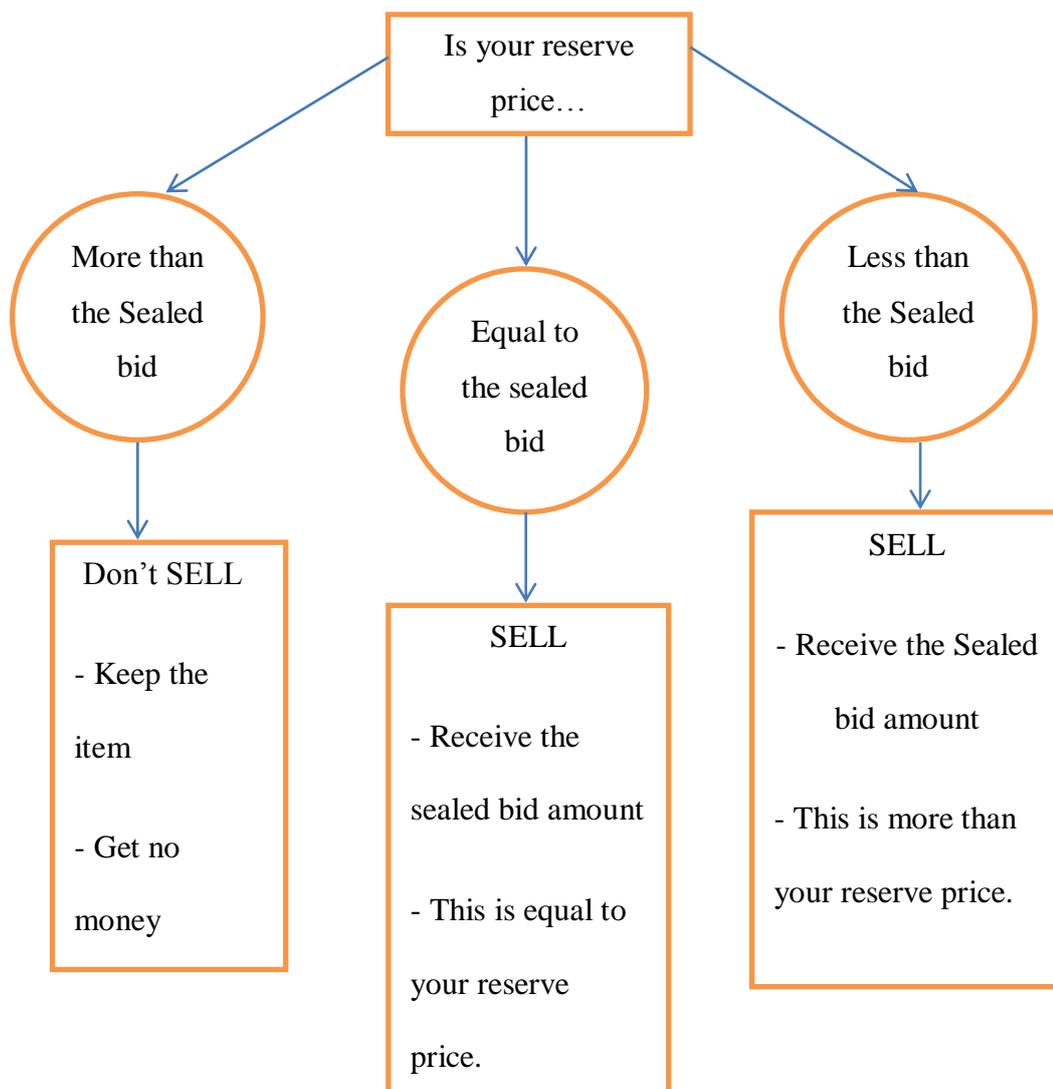


Figure D1. WTA Memory jogger, bidding process

The Key points:

Once you have recorded your reserve price, the RULES OF THE GAME DETERMINE if you sell or not. You cannot choose.

If you sell, you receive the SEALED BID AMOUNT, not your reserve price.

There's NO POINT UNDERSTATING what you'd accept

HAVE TO SELL at the price you think is too low

There's NO POINT UNDERSTATING what you'd accept

CANNOT SELL at a price you'd like to accept

Subsequent valuation survey is based on individual answers, so it is important that respondents have some experience of deciding their own WTA for an item. Participants will be given two tokens for entering to a prize draw. In each of the two rounds, participants record their 'reserve price' or minimum willingness to accept, for selling the token and forego entry into the draw. Their reserve price should be compared with a sealed bid in an envelope (100 bids ranging from 1lira to 10lira), which is randomly selected from a visible box at the front of the room. If their reserve price is lower than or equal to this sealed bid they will sell the token, and receive higher or equivalent sealed bid. But, if the reserve price is higher, s/he will not sell the token and it should put into the draw.

### **Micro-generation solar panel evaluation**

Once experimenter ensured that respondents are sufficiently practised and experienced about truthful bidding, then, experimenter can draw attention to the following statement

*Presumable you have a house or a piece of land. Government or private company has offered you to install photovoltaic system in your property to produce electricity. You will be losing the amenity for a specific period (15 years), not for your self-usage but also for others' usage. In spite of these inconveniences, what would be your answer to the following question:*

*We would like to install micro-generation system in your property, what is your minimum willingness to accept?*

The respondents' reserve price should be compared with the compensation amount which has been set before by the government and solar company (but is not released to the seller). The value of land and amenity loss had been incorporated in the sealed price or pre-set amount. After comparison between respondents' reserve price and sealed bid price, three scenarios can be arisen.

Firstly, if the respondents' reserve price is more than the pre-set amount, they will not compensate. This refers to those who disagree with the existence of photovoltaic in their own property for others' usage, and who preferred to keep space and the view.

Secondly, if the respondents' reserve price is equal to the pre-set amount, they will receive a compensation amount for their amenity loss caused by the installed photovoltaic system in their property.

Thirdly, if the respondents' reserve price is less than the pre-set amount, they will receive a compensation amount more than their reserve price, equal to the pre-set amount for the loss of amenity caused by photovoltaic installed in their property.

In this manner, the structure of the solar energy valuation questions exactly harmonised with the questions in the former learning experiment in the beginning of the session. The supplier (government or private company) undisclosed price operated as the sealed bid in the earlier rounds, and the same consequences of over and under-bidding is applied.

Respondents should have the memory jogger in their hands throughout the examination and become experienced sufficiently of how to determine their reserve price, and being aware of the consequences of over and underestimating. The graph D2 shows the memory

jogger which is designed for evaluation of micro-generation solar panel. It summarises the key concepts, and their answers will be recorded in response book.

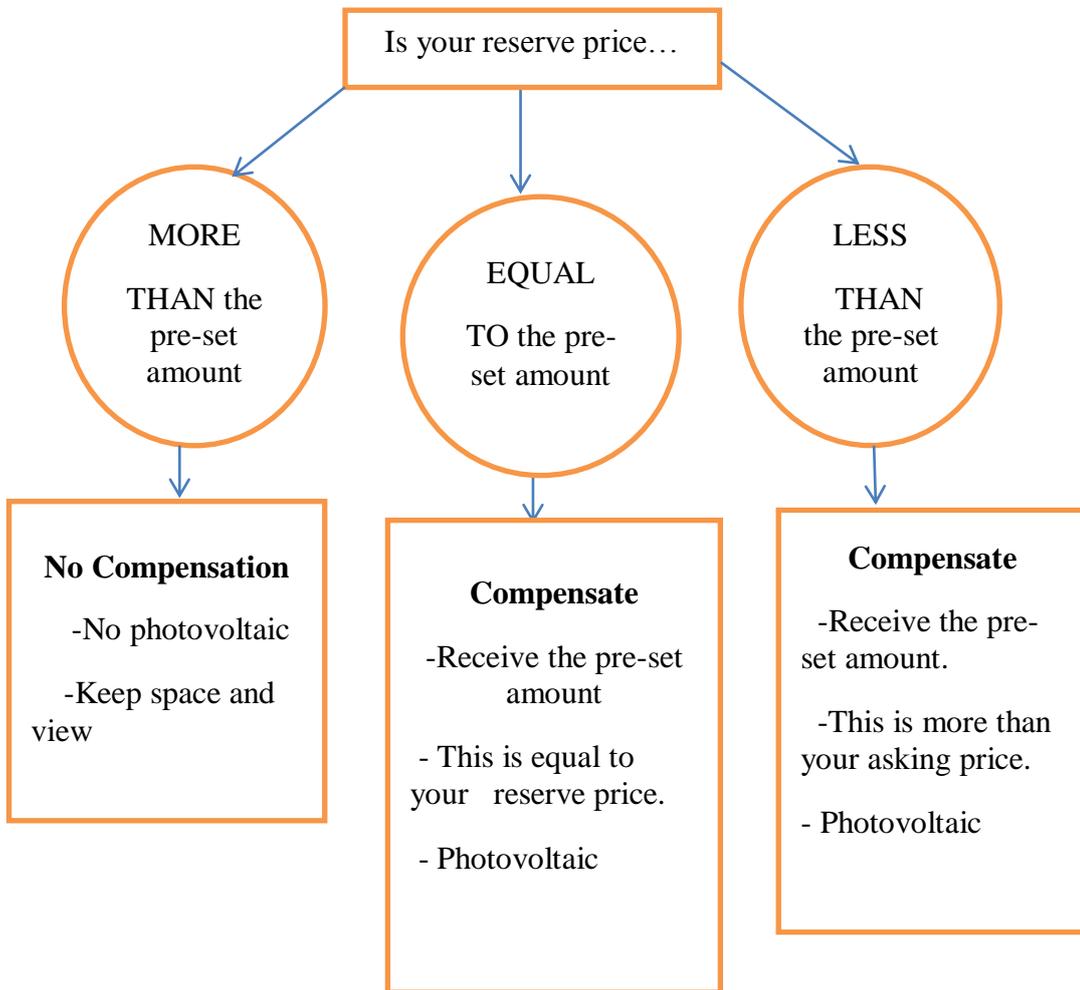


Figure D2. WTA Memory jogger, micro-generation solar energy evaluation

The key points:

4. Once you have told your reserve price to solar company or government, the rules determine whether you get compensated or not.
5. If you receive any money, you receive the PRESET AMOUNT, not your reserve price.
6. There's NO POINT OVERSTATING what you'd accept.
  - No compensation at price you think is low.

There's no point understating what you'd pay.

- Lose amenity when you prefer to get compensated and photovoltaic system at the price you would like to accept.

## **D.2 Maximum Willingness to Pay**

Maximum willingness to pay (WTP) can be measured through an incentivised experiment. This method helps respondents to have a clear understanding about maximum WTP concept and potential consequences of over and under stating. Certainly people are more experienced in buying rather than selling. Bidding for a good at a sale or auction is already acknowledged to them. In spite of that, a brief clarification for WTP concept will be practised before beginning evaluation of micro-generation solar system (photovoltaic). Specifically, the experimenter should clarify the possibility of undesirable consequences of over-or-under stating i.e. in the case of under bidding; the buyer will not spend enough money to cover the cost of the item, so she/he will miss the chance of obtaining the good.

The procedure of the approach is in this way, after experimenter ensures about respondents' intuition of maximum WTP concept, then micro-generation solar panel evaluation would be discussed. This would be followed by a subsequent hypothetical maximum WTP valuation for purchasing photovoltaic system.

Towards the end, respondents would be required to fill the demographics questionnaire and the session will finish by the prize draw from the incentivised learning round.

The content of the protocol is supplemented by the use of visual aids, aide memories and questions to assist the respondents.

## **Method**

The survey continues with the same participants from the WTA evaluation for the WTP evaluation. The session will continue by entering to a prize draw for 30lira. Participants will be given 2lira and told that they can spend 1 lira in each round to buy two tokens which can be used to gain entry to a prize draw. In each round, participants' maximum willingness to pay will be recorded in order to buy a token to enter into a new prize draw, for 30 lira again.

Subsequently, experimenter will show a box of chocolate to the participants and tell them we want to sell this box of chocolates, how much are you willing to pay for this box of chocolates? In other words, respondents will be asked to bid their maximum WTP for the box of chocolate. Though, respondents before revealing their maximum WTP amount for the box of chocolates should be absolutely being acquainted with the consequences of over and under bidding. In the case of under-bidding when the offered price for the item is less than it is worth, there is a danger of the item not being sold to the buyer and vendor decides not to sell for the offered price.

Based on the predetermined value or sealed bid price, respondents maximum WTP will be evaluated. Respondents will be supported by 'memory joggers' throughout the practice, 'memory jogger' summarising the key concepts, and their answers will be recorded in response books.

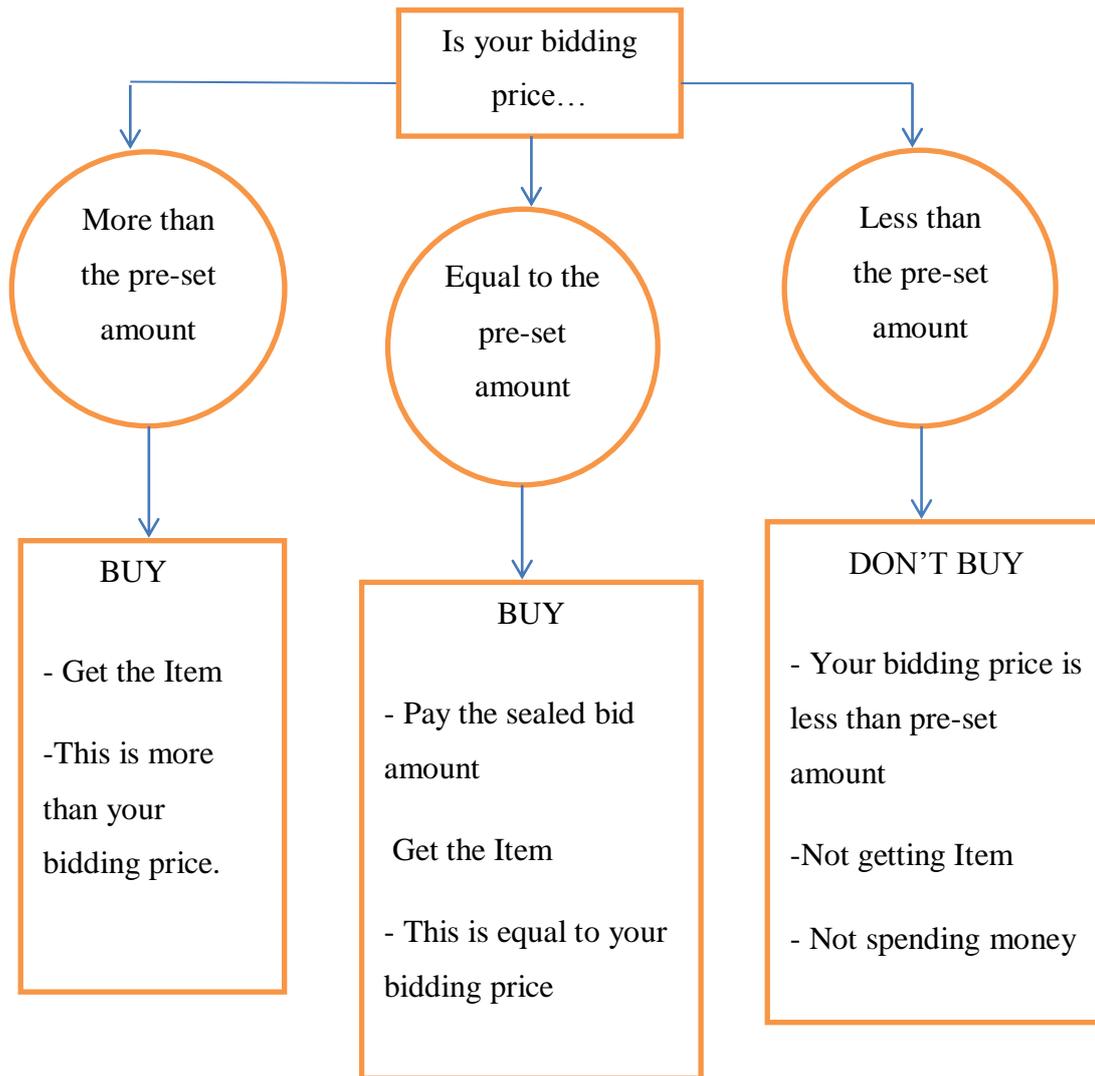


Figure D3. WTP Memory jogger

The Key points:

1. Once you have recorded your bidding price, the **RULES OF THE GAME DETERMINE** whether you will obtain or not. You cannot choose.
2. If you buy, you pay the **SEALED BID AMOUNT**, not your bidding price.
3. There's **NO POINT UNDERSTATING** what you'd pay
  - **HAVE TO BUY** photovoltaic at the price you think is too high

There's **NO POINT UNDERSTATING** what you'd pay

- CANNOT BUY at a price you'd like to pay

### **Micro-generation solar panel evaluation**

To start evaluation of micro-generation solar panel, we should make sure that respondents are sufficiently practised and experienced of truthful bidding and supported by memory jogger hand-out from beginning towards the end of the survey. When these conditions are met then we ask respondents,

*Presumably you have a house or a piece of land. Government or private company has offered you to install photovoltaic system in your property for your own usage, following statement:*

***We would like to install micro-generation system in your property for your own usage, what is your maximum willingness to pay?***

To evaluate the respondent's values, their biddings price should be compared with the pre-set amount which had been set before by government or solar company (but will not be released to the seller). The cost of each solar panel (1m<sup>2</sup> or 1kWh with efficiency of 15%-20%) incorporated in sealed bid price. After comparison between respondents' bidding price and sealed bid price, three scenarios will arise.

Firstly, if respondents' bidding price is more than pre-set amount, they will obtain photovoltaic system installed in their property for their own usage. But, they are willing to pay more than it's worth.

Secondly, when respondents' bidding price is equal to the pre-set amount, they will get photovoltaic installed in their property for their own usage. They just pay amount equivalent to the value of micro-generation solar panel.

Thirdly, if respondents' bidding price is less than the pre-set amount, the photovoltaic system will not be obtained and installed in their property, because the money they are willing to pay is less than the value of the micro-generation solar panel, and it doesn't cover the cost of that. In this fashion, the procedures of the solar energy evaluation questions exactly conform to the prior learning experiment setting. The supplier (government or private company) undisclosed price works as the sealed bid in earlier rounds, and the same consequences of over and under-bidding will apply. Respondents should have the memory jogger in their hands and experienced sufficiently of how to determine their reserve price, and being aware of the consequences of over and underestimating. In the last part, respondents will be required to fill the demographics questionnaire (Table D.1). At the end, the session will be finished by the prize draw from the incentivised learning round.

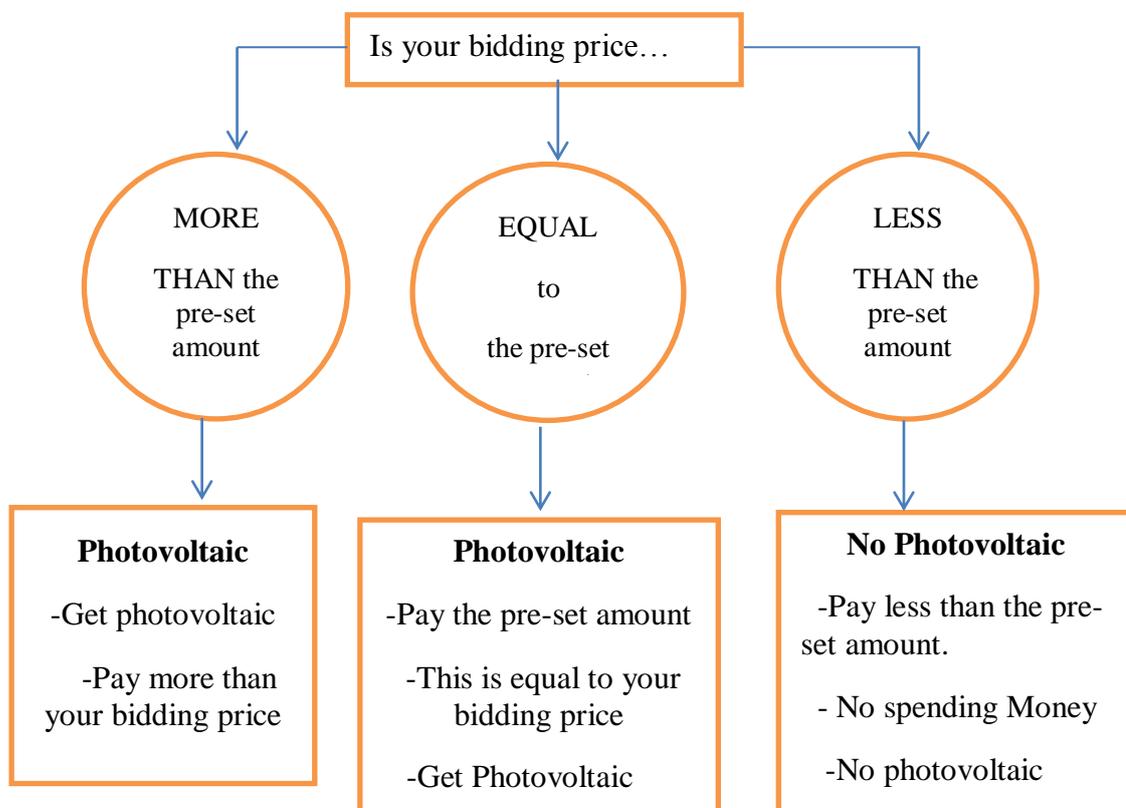


Figure D.4. WTP Memory jogger, solar energy evaluation

The key points:

7. Once you have given your bidding price to the solar company or government, the rules determine whether you will get photovoltaic or not.
8. If you pay any money, you pay the PRESET AMOUNT, not your bidding price.
9. There's NO POINT OVERSTATING what you'd pay.
  - No photovoltaic at the price you think is high.

There's no point understating what you'd pay.

- CANNOT BUY photovoltaic at a price you'd like to pay

### D.3 Socio-demographic questions

Table D.1 Demographic questions

C1. Sex	1. Female			2. Male		
C2. Age	1 18-27	2 28-37	3 38-47	4 48-60	5 more than 60	
C3. Education	1 Primary School	2 Secondary School	3 High School	4 University (2 Years)	5 University (4 Years)	6 Advanced Degree
C4. Employment	1 Unemployed	2 Retired	3 Student	4 Self-employed	5 Employed	
C5. Monthly Household Income (TL) (Salary + Interests + Rental)	1 less than 1500	2 1500-3000	3 3000-4500	4 4500-6000	5 6000-7500	6 more than 7500

income)						
C6. City	1. Nicosia	2. Famagusta	3. Kyrenia	4. Morphou	5. Trikomo	
C7. Marriage Status	1. Single		2. Married		3. Divorced/Widow	

Tables D.2 summarises the experimental mechanism and instruments used to clarify minimum WTA terms respectively.

Table D.2 summary of minimum WTA clarification

1. (Hypothetical): Selling a Teddy Discussion	To reinforce the idea of the pre-set selling amount (reserve price), true values, the dangers of over/underbidding, second price auction rules; to introduce and demonstrate the role of the (secret) sealed bid within the second price auction
2. (Real): Selling a Draw entry ticket Experiment	Experience of selling and using the mechanism, elicitation of minimum WTA values in an incentivised context
3. (Hypothetical): Solar park valuation, WTA Survey	Elicitation of monetary values from respondents who have an understanding/intuition of the economic meaning of minimum WTA

Table D.3 summarises the experimental mechanism and instruments used to clarify maximum WTP.

Table D.3 summary of maximum WTP clarification

<b>Stage</b>	<b>Purpose</b>
5. (Hypothetical): Selling a piece of land  Discussion	To introduce the idea of a pre-set selling amount (reserve price), respondents' true values, the dangers of over/underbidding, second price auction rules
6. (Hypothetical): Selling a Teddy  Discussion	To reinforce the idea of the pre-set selling amount (reserve price), true values, the dangers of over/underbidding, second price auction rules; to introduce and demonstrate the role of the (secret) sealed bid within the second price auction
7. (Real): Selling a Draw entry ticket  Experiment	Experience of selling and using the mechanism, elicitation of minimum WTA values in an incentivised context
8. (Hypothetical): Solar park valuation, WTA  Survey	Elicitation of monetary values from respondents who have an understanding/intuition of the economic meaning of minimum WTA

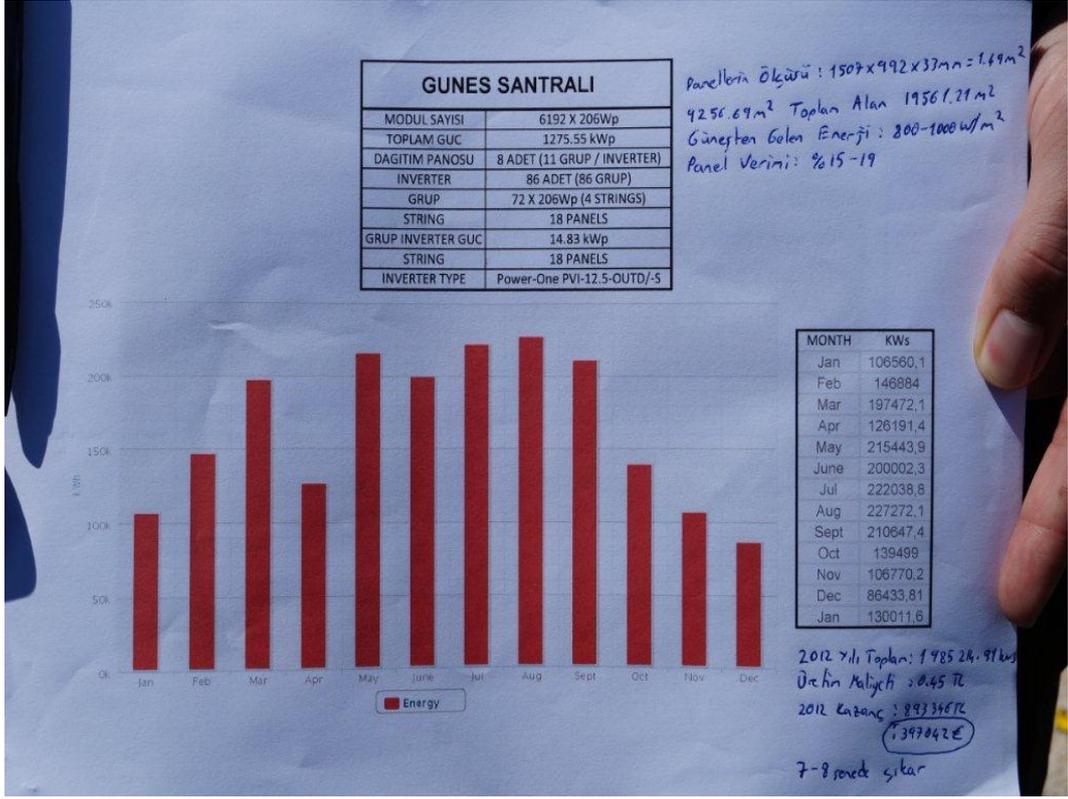
## **Appendix E. Solar Park (1.2MW) in Serhatkoy**

A solar park with capacity of 1.2 MW has been active since 2011 in Serhatkoy which has been funded by European Union. In the Middle East, it is one of the biggest solar generations in its kind (Ozerdem and Biricik, 2013).

The solar park and the view of the village from where the solar generator is located is shown in the following photos.









This Project is Financed by  
The **European Union**

**Name of Project:**

Development and Restructuring of the  
Energy Infrastructure  
Solar Power Plant



Contract 2009/218-787

**Contracting Authority:**  
European Commission

**Beneficiaries:**  
KIB-TEK

**Contract Price:**  
3,770.823 EURO

**European Grant:**  
3,770.823 EURO

**Contract:**  
Consortium of  
ANELTECH and  
Enerqos S.p.a



**Contract Period:**  
Start of the Works: 09 March 2010  
End of the Works: 14 April 2011

## Appendix F. Choice Experiment (CE) main survey



Good morning/afternoon/evening. ‘Your answers to the following question will be used in a PhD thesis which aims to examine Cypriot willingness to pay for the use of renewable technology. It will take the form of a series of questions about your current source of energy consumption and your willingness to pay for the production of electricity from renewable energy sources. “I would be pleased if you could keep these conditions in mind while completing this form (25% subsidy for installation of PV, feed-in tariff of 0.25 Euro (=0.60TL))”.

I would like you to consider a scenario in which you could supplement your existing system with an additional system. Would you add one of these alternative systems to your existing system, or would you prefer to retain your existing system “as is”?

Please assume that solar panels will be fully guaranteed for 10 years, and this means that if any repairs and replacement parts are required, these would be freely provided by the company supplier. I would be pleased if you could keep these conditions in your mind while completing this form. Thank you for agreeing to take part in this interview’.

### **A. Choice questions**

Assume your current energy system is working adequately; I would like you to consider a scenario in which you could supplement your existing system with an additional system. Would you add one of these alternative systems to your existing system; or whether you would prefer to retain your existing system “as is”.

Please assume that micro-generation solar panels system will be fully guaranteed for 10 years, this means that if any repairs and replacement parts are required, it would be provided for free by the company supplier.

01	Scenario A	Scenario B
Subsidy	40%	10%
Feed in tariff €	0.30	0.20
Space required	8m <sup>2</sup> ; 1kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	4000	14000
Energy saving €	1200	3600
<i>Choice</i>		

“As is” Would you still wish to retain access to electricity network?

**\*There is no right or wrong answer. You must make a decision as to which of the two alternatives, if any, is the best for you, or whether you would prefer to keep your current heating and electricity system “as is”**

## B. Choice cards

### Micro-generation solar panel

01	Alternative 1	Alternative 2
Subsidy	40%	10%
Feed in tariff €	0.30	0.20
Space required	8m <sup>2</sup> ; 1kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	4000	14000
Energy saving €/Annual	1200	3600
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

### Micro-generation solar panel

02	Alternative 1	Alternative 2
Subsidy	40%	10%
Feed in tariff €	0.20	0.20
Space required	8m <sup>2</sup> ; 1kWp	25m <sup>2</sup> ; 2kWp
Initial investment Cost€	14000	8000
Energy saving € /Annual	1500	2000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

03	Alternative 1	Alternative 2
Subsidy	10%	40%
Feed in tariff €	0.40	0.30
Space required	40m <sup>2</sup> ; 4kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	14000	10000
Energy saving €/ Annual	800	3000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

04	Alternative 1	Alternative 2
Subsidy	10%	25%
Feed in tariff €	0.30	0.40
Space required	40m <sup>2</sup> ; 4kWp	8m <sup>2</sup> ; 1kWp
Initial investment Cost€	8000	10000
Energy saving €/ Annual	800	3600
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

05	Alternative 1	Alternative 2
Subsidy	40%	10%
Feed in tariff €	0.40	0.20
Space required	40m <sup>2</sup> ; 4kWp	8m <sup>2</sup> ; 1kWp
Initial investment Cost€	6000	8000
Energy saving € /Annual	800	2000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

06	Alternative 1	Alternative 2
Subsidy	40%	25%
Feed in tariff €	0.40	0.30
Space required	8m <sup>2</sup> ; 1kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	4000	14000
Energy saving € /Annual	1200	3000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

### C. Demographic Part

C1. Sex	1. Female			2. Male		
C2. Age	1 18-27	2 28-37	3 38-47	4 48-60	5 more than 60	
C3. Education	1 Primary School	2 Secondary School	3 High School	4 University (2 Years)	5 University (4 Years)	6 Advanced Degree
C4. Employment	1 Unemployed		2 Retired	3 Student	4 Self-employed	5 Employed
C5. Monthly Household Income (TL) (Salary + Interests + Rental income)	1 less than 1500	2 1500-3000	3 3000-4500	4 4500-6000	5 6000-7500	6 more than 7500
C6. City	1. Nicosia	2. Famagusta	3. Kyrenia	4. Morphou	5. Triкомо	
C7. Marriage Status	1. Single		2. Married		3. Divorced/Widow	

C8. Please indicate number of people in the house including you.						
1. One	2. Two	3. Three	4. Four	5. Five	6. Six or more	

C9. How did you find answering choice questions?

1. Easy
2. Difficult

C10. Which of the alternatives' factors you have considered most?

- |                            |    |
|----------------------------|----|
| 1. Subsidy                 | 1. |
| 2. Feed in tariff          | 2. |
| 3. Space required          | 3. |
| 4. Initial investment Cost | 4. |
| 5. Energy saving           | 5. |

The following cards present choice bundles of 7 to 36. Each 6 choice card was presented to each respondent with the abovementioned layout (including part A, B, C).

Micro-generation solar panel

07	Alternative 1	Alternative 2
Subsidy	40%	25%
Feed in tariff €	0.30	0.20
Space required	40m <sup>2</sup> ; 4kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	10000	6000
Energy saving €/Annual	3000	1500
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

08	Alternative 1	Alternative 2
Subsidy	40%	25%
Feed in tariff €	0.40	0.30
Space required	8m <sup>2</sup> ; 1kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	8000	6000
Energy saving € / Annual	1500	1200
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

09	Alternative 1	Alternative 2
Subsidy	25%	10%
Feed in tariff €	0.40	0.20
Space required	25m <sup>2</sup> ; 3kWp	40m <sup>2</sup> ; 4kWp
Initial investment Cost€	8000	14000
Energy saving €/ Annual	3000	3600
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

10	Alternative 1	Alternative 2
Subsidy	40%	10%
Feed in tariff €	0.40	0.30
Space required	16m <sup>2</sup> ; 2kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost€	6000	4000
Energy saving € /Annual	800	1500
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

### Micro-generation solar panel

11	Alternative 1	Alternative 2
Subsidy	25%	10%
Feed in tariff €	0.30	0.20
Space required	40m <sup>2</sup> ; 4kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	14000	10000
Energy saving €/ Annual	3000	1500
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

### Micro-generation solar panel

12	Alternative 1	Alternative 2
Subsidy	10%	40%
Feed in tariff €	0.30	0.40
Space required	8m <sup>2</sup> ; 1kWp	40m <sup>2</sup> ; 4kWp
Initial investment Cost€	4000	10000
Energy saving € /Annual	1500	2000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

13	Alternative 1	Alternative 2
Subsidy	10%	40%
Feed in tariff €	0.30	0.20
Space required	40m <sup>2</sup> ; 4kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost€	8000	14000
Energy saving € /Annual	800	1200
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

14	Alternative 1	Alternative 2
Subsidy	10%	25%
Feed in tariff €	0.40	0.20
Space required	25m <sup>2</sup> ; 3kWp	40m <sup>2</sup> ; 4kWp
Initial investment Cost€	4000	6000
Energy saving € /Annual	3600	1500
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

15	Alternative 1	Alternative 2
Subsidy	10%	25%
Feed in tariff €	0.30	0.20
Space required	25m <sup>2</sup> ; 3kWp	40m <sup>2</sup> ; 4kWp
Initial investment Cost€	8000	4000
Energy saving €/Annual	800	2000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

16	Alternative 1	Alternative 2
Subsidy	40%	25%
Feed in tariff €	0.20	0.40
Space required	16m <sup>2</sup> ; 2kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost€	4000	10000
Energy saving €/Annual	3000	3600
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

17	Alternative 1	Alternative 2
Subsidy	10%	25%
Feed in tariff €	0.40	0.20
Space required	16m <sup>2</sup> ; 2kWp	8m <sup>2</sup> ; 1kWp
Initial investment Cost€	12000	10000
Energy saving €/Annual	1200	800
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

18	Alternative 1	Alternative 2
Subsidy	25%	40%
Feed in tariff €	0.30	0.20
Space required	16m <sup>2</sup> ; 2kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost €	6000	12000
Energy saving €/Annual	1200	800
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

19	Alternative 1	Alternative 2
Subsidy	40%	25%
Feed in tariff €	0.20	0.40
Space required	25m <sup>2</sup> ; 3kWp	8m <sup>2</sup> ; 1kWp
Initial investment Cost €	6000	14000
Energy saving €/Annual	3600	2000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

20	Alternative 1	Alternative 2
Subsidy	25%	40%
Feed in tariff €	0.20	0.30
Space required	40m <sup>2</sup> ; 4kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost €	8000	12000
Energy saving € /Annual	1200	2000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

21	Alternative 1	Alternative 2
Subsidy	10%	40%
Feed in tariff €	0.20	0.30
Space required	8m <sup>2</sup> ; 1kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost €	12000	8000
Energy saving €/Annual	3000	3600
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

22	Alternative 1	Alternative 2
Subsidy	25%	10%
Feed in tariff €	0.30	0.40
Space required	8m <sup>2</sup> ; 1kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost €	4000	6000
Energy saving € /Annual	800	3000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

23	Alternative 1	Alternative 2
Subsidy	40%	25%
Feed in tariff €	0.40	0.30
Space required	16m <sup>2</sup> ; 2kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost€	10000	12000
Energy saving € /Annual	2000	3600
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

24	Alternative 1	Alternative 2
Subsidy	40%	25%
Feed in tariff €	0.40	0.30
Space required	25m <sup>2</sup> ; 3kWp	8m <sup>2</sup> ; 3kWp
Initial investment Cost€	8000	10000
Energy saving € /Annual	1500	800
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

25	Alternative 1	Alternative 2
Subsidy	40%	10%
Feed in tariff €	0.20	0.40
Space required	25m <sup>2</sup> ; 3kWp	40m <sup>2</sup> ; 4kWp
Initial investment Cost€	12000	4000
Energy saving € /Annual	800	3600
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

26	Alternative 1	Alternative 2
Subsidy	25%	10%
Feed in tariff €	0.30	0.20
Space required	25m <sup>2</sup> ; 3kWp	8m <sup>2</sup> ; 1kWp
Initial investment Cost€	4000	12000
Energy saving € / Annual	800	3000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

27	Alternative 1	Alternative 2
Subsidy	25%	10%
Feed in tariff €	0.20	0.30
Space required	16m <sup>2</sup> ; 2kWp	8m <sup>2</sup> ; 1kWp
Initial investment Cost€	4000	10000
Energy saving € /Annual	2000	1200
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

28	Alternative 1	Alternative 2
Subsidy	25%	40%
Feed in tariff €	0.40	0.30
Space required	8m <sup>2</sup> ; 1kWp	40m <sup>2</sup> ; 4kWp
Initial investment Cost€	8000	10000
Energy saving € /Annual	3000	2000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

### Micro-generation solar panel

29	Alternative 1	Alternative 2
Subsidy	10%	40%
Feed in tariff €	0.40	0.30
Space required	40m <sup>2</sup> ; 4kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost€	12000	14000
Energy saving € /Annual	1200	1500
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

### Micro-generation solar panel

30	Alternative 1	Alternative 2
Subsidy	10%	25%
Feed in tariff €	0.30	0.40
Space required	8m <sup>2</sup> ; 1kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	6000	12000
Energy saving € /Annual	2000	1500
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

31	Alternative 1	Alternative 2
Subsidy	10%	40%
Feed in tariff €	0.30	0.20
Space required	8m <sup>2</sup> ; 1kWp	40m <sup>2</sup> ; 4kWp
Initial investment Cost€	6000	4000
Energy saving € /Annual	2000	3000
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

32	Alternative 1	Alternative 2
Subsidy	40%	10%
Feed in tariff €	0.30	0.20
Space required	40m <sup>2</sup> ; 4kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	8000	14000
Energy saving € /Annual	3600	800
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

33	Alternative 1	Alternative 2
Subsidy	25%	40%
Feed in tariff €	0.40	0.20
Space required	40m <sup>2</sup> ; 4kWp	25m <sup>2</sup> ; 3kWp
Initial investment Cost€	12000	14000
Energy saving € /Annual	1500	1200
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

34	Alternative 1	Alternative 2
Subsidy	10%	25%
Feed in tariff €	0.40	0.20
Space required	25m <sup>2</sup> ; 3kWp	16m <sup>2</sup> ; 2kWp
Initial investment Cost€	12000	12000
Energy saving € /Annual	3000	1200
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

35	Alternative 1	Alternative 2
Subsidy	10%	40%
Feed in tariff €	0.30	0.40
Space required	25m <sup>2</sup> ; 3kWp	8m <sup>2</sup> ; 1kWp
Initial investment Cost€	10000	6000
Energy saving € /Annual	1200	3600
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

Micro-generation solar panel

36	Alternative 1	Alternative 2
Subsidy	25%	10%
Feed in tariff €	0.30	0.20
Space required	8m <sup>2</sup> ; 1kWp	40m <sup>2</sup> ; 4kWp
Initial investment Cost€	12000	10000
Energy saving € /Annual	3600	1500
<b>Choice</b>		

I would choose neither of the alternatives and retain with the current energy source

## Appendix G. Experimental survey photos

The following pictures are taken from some of the participants in the experimental groups setting survey. These groups of 5-12 of individuals were gathered in one location such as a house or office or coffee-shop. The survey took place from December to February 2012.











## **Appendix H. Instrument for preference evaluation**

### **Mechanism**

#### **H.1 Minimum Willingness to Accept to get micro-generation system installed in your property.**

This technique is based on an incentivised experiment for helping respondents to have a better understanding about minimum willingness to accept (WTA) concept. People usually are more experienced in buying rather than selling. This makes awareness about possible consequences of strategic over and understatement necessary. In order to elicit the truthful minimum WTA responses, familiarising respondents with the term maximum WTA is helpful.

In this survey, experimental mechanism is carried out firstly to teach the survey's respondents, what is meant by a minimum WTA and potential consequences of overstating. Once the experimenter becomes quite sure about respondents' intuition of minimum WTA concept, then solar energy evaluation can be discussed. This would be followed by a subsequent hypothetical minimum WTA valuation for losing amenity values caused by photovoltaic installation in your property for others' usage. At the end, demographic questions should be distributed among the respondents.

The content of the protocol is supplemented by the use of visual aids, aide memories and questions to assist the respondents.

Method-

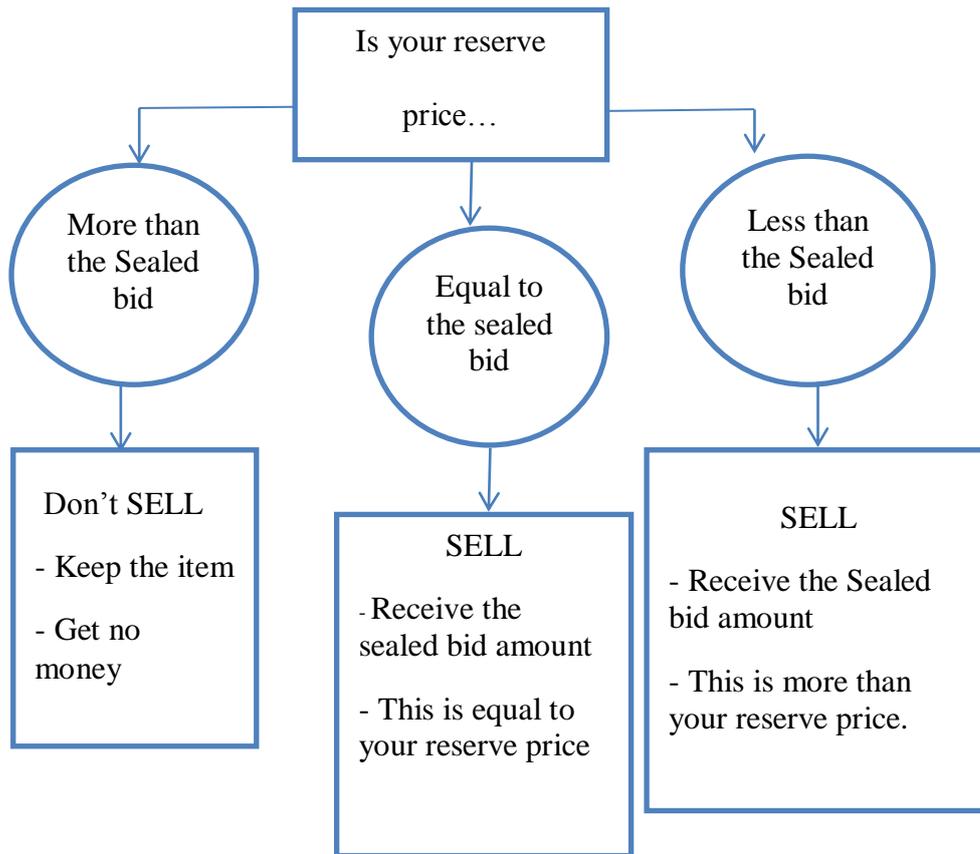
A number of five to twelve respondents should contribute in each group session; participants are treated by the opportunity of entering a draw for a prize of 30 lira (€10).

The group discussion begin with introducing the term 'reserve price' as a substitute for the term 'minimum WTA' to them. Based on other studies, respondents are usually more comfortable with 'reserve price' term. The term familiarised by discussing the process of selling a piece of land (600m<sup>2</sup>) in an auction. The reserve price is explained as the lowest fixed price (floor price), at which the land can be offered at the auction sale.

This will be followed by introducing 'external sealed bid' term, also for simplifying the meaning of MWTA. Respondents are divided into two groups and asked to discuss a 'reserve price'. i.e. the minimum they would accept to sell a Teddy (which has been given to them previously). Then reserve price is compared with a predetermined sealed bid in a second price auction mechanism.

After comparison between the respondents' answers and sealed bids, the question of 'why it is always best to be truthful' is discussed. In particular, the experimenter should clarify the possibility of undesirable consequences of over-or-under stating i.e. in the case of over bidding, there is a danger that the vendor keeps the item rather than sells it. (If the sealed bid being between the vendor's 'true value' and inflated stated reserve price). Similarly, in the case of under-bidding when the item sells for less than it's worth (if the sealed bid lies above the very conservative reserve price but below the vendor's 'true value'). Respondents should be given a 'memory jogger' (Figure H.1) summarising the key concepts, and their answers recorded in response books.

The bidding process:



FigureH.1 Memory Jogger for teaching experiment WTA

The Key points:

Once you have recorded your reserve price, the **RULES OF THE GAME DETERMINE** if you sell or not. You cannot choose.

If you sell, you receive the **SEALED BID AMOUNT**, not your reserve price.

There's **NO POINT UNDERSTATING** what you'd accept

**HAVE TO SELL** at a price you think is too low

There's **NO POINT UNDERSTATING** what you'd accept

**CANNOT SELL** at a price you'd like to accept

Subsequent valuation survey is based on individual answers, so it is important that respondents have some experience of deciding their own WTA for an item. Participants are given two tokens for entering to a prize draw. In each of two rounds, participants need to record their 'reserve price' or minimum WTA, for selling the token and forego entry into the draw. Their reserve price should be compared with a sealed bid in an envelope (100 bids ranging from 1lira to 10lira), which is already randomly selected from a visible box at the front of the room. If their reserve price was lower than or equal to this sealed bid they would sell the token, and receive higher or equivalent sealed bid. But, if the reserve price was higher, s/he would not sell the token and it should put into the draw.

### **Micro-generation solar technology evaluation**

To start this part, we should ensure that respondents are sufficiently practised and experienced of truthful bidding and also should be supported by memory jogger hand-out (Figure H.2).

After discussing the reserve price and familiarising respondents with what is meant by minimum WTA, using BDM mechanism, the study was then carried out using the below cheap-talk script before asking respondents' minimum WTA for the amenity caused by solar technology.

*The process of the discussion that we went through was implemented with the intention of eliciting your truthful responses to the payment question. We tried to clarify what will be the consequences of overestimating a value to incentivise you to state a willingness to accept amount close to your actual value.*

Then, we can ask respondents; presumably, you have a house or a piece of land and government or private company offers you to install photovoltaic system in your

property. You will be losing amenity for a specific period. In spite of these inconveniences, what would be your answer to them when you are asked;

**We would like to install micro-generation system in your property, what is your minimum willingness to accept?**

The respondents' reserve price should be compared with the compensation amount which has been set before by government and solar company (but is not released to the seller).

Note that the value of the land and amenity loss are constituted the sealed price or pre-set amount. After comparison between respondents' reserve price and sealed bid price, three scenarios can be arisen.

Firstly, if respondents' reserve price is more than pre-set amount, they will not get compensated. This refers to those who disagree with the existence of photovoltaic in their own property for others' usage, and keeping space and view is much more preferred.

Secondly, when respondents' reserve price is equal to the pre-set amount, they will receive compensation amount for their amenity loss caused by the installed photovoltaic system in their property.

Thirdly, if respondents' reserve price is less than the pre-set amount, they will receive compensation amount more than their reserve price for losing amenity as photovoltaic system will be installed in their property.

In this way, the structure of the solar energy valuation questions is exactly matched with the questions in the earlier learning experiment. The supplier (government or private company) unknown price worked as the sealed bid in the earlier rounds, and the same consequences of over and under-bidding are applied.

Respondents should have the memory jogger (see Figure H.2) in their hands throughout the examination and become experienced sufficiently of how to determine their reserve

price, and being aware of the consequences of over and underestimating. In the last part, respondents are required to fill the demographics questionnaire. At the end, the session finishes by the prize draw from the incentivised learning round.

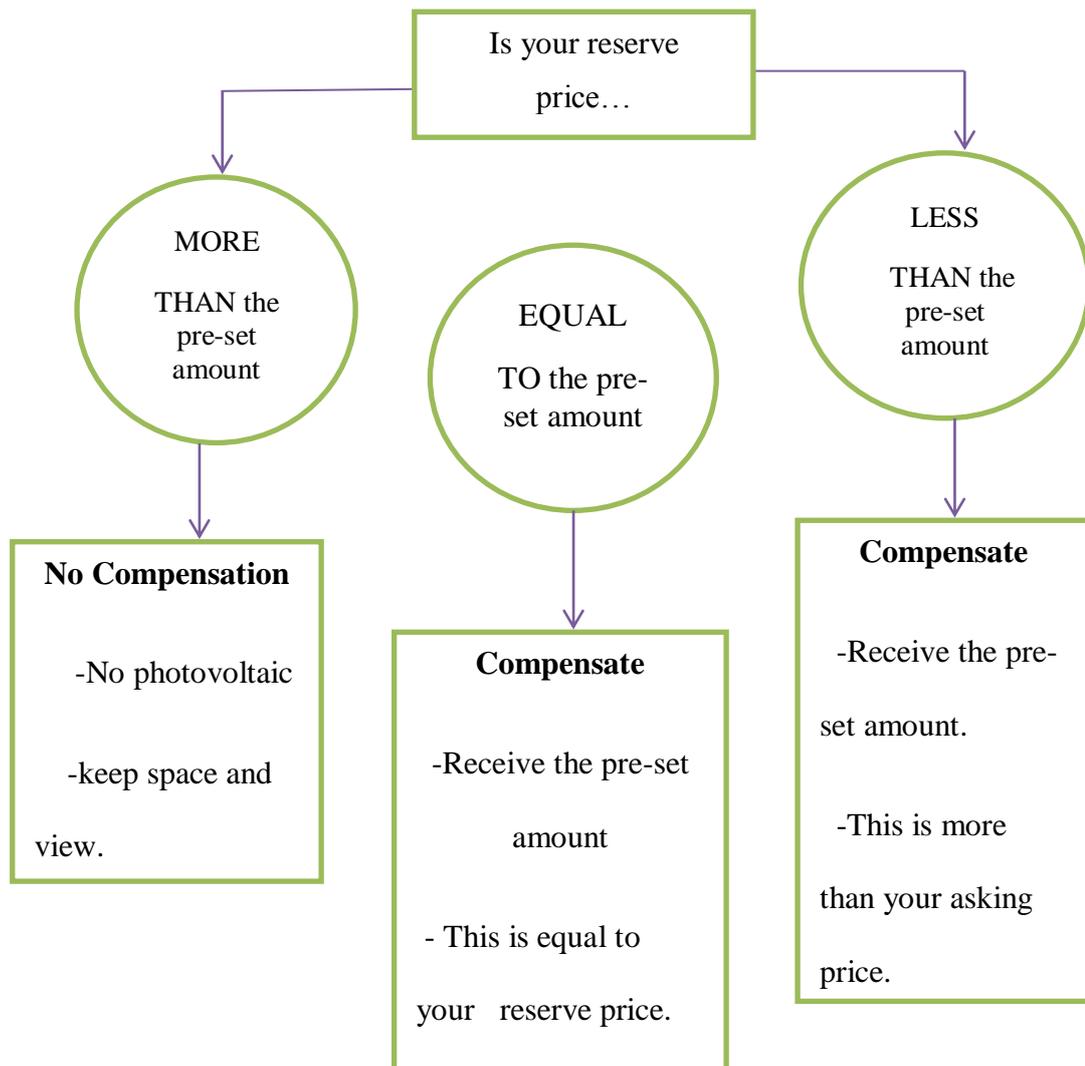


Figure H.2 Memory Jogger, minimum WTA

The key points:

Once you have told your reserve price to solar company or government, the rules determine whether you get compensated or not.

If you receive any money, you receive the PRESET AMOUNT, not your reserve price.

There's NO POINT OVERSTATING what you'd accept.

- No compensation at price you think is low.

There's no point understating what you'd pay.

- Lose amenity when you prefer to get compensated and photovoltaic system at the price you would like to accept.

## **H.2 Evaluation of maximum willingness to pay of property owner for micro-generation solar panel (photovoltaic).**

Maximum willingness to pay (WTP) can be measured through an incentivised experiment. This method helps respondents to have a clear understanding about maximum WTP concept and potential consequences of over and under stating. Particularly, aims to elicit the truthful responses in which requires to begin with familiarising respondents with the term of maximum WTP. Certainly people are more experienced in buying rather than selling, bidding for a good at a sale or auction is already acknowledged to them. In spite of that a brief clarification for WTP concept should be practised before beginning evaluation of micro-generation solar system (photovoltaic). Specifically, the experimenter should clarify the possibility of undesirable consequences of over-or-under stating i.e. in the case of under bidding; the buyer will not spend enough money to cover the cost of the item, so she/he will miss the chance of obtaining the good.

The procedure of the approach is in this way:

After experimenter ensures about respondents' intuition of maximum WTP concept, then micro-generation solar panel evaluation would be discussed. This would be followed by a subsequent hypothetical maximum WTP valuation for purchasing photovoltaic system. At the end, demographic questions will be distributed amongst the respondents.

The content of the protocol is supplemented by the use of visual aids, aide memories and assisting with the respondents' questions.

## **Method**

A group of five to twelve respondents needs to participate in each session. Session will be started by entering to a prize draw for 30lira (€10). Participants should be given 2lira and told that they can spend 1 lira in each round to buy two tokens which can be used to gain entry to a prize draw. In each round, participants' maximum WTP will be recorded in order to buy a token to enter into a new prize draw, for 30 lira (€10) again.

Subsequently, experimenter will show a box of chocolate to the participants and tell them we want to sell this box of chocolates, how much are you willing to pay for this box of chocolates? In other words, respondents should be asked to bid their maximum willingness to pay for the box of chocolate. Note that respondents before revealing their maximum WTP amount for the box of chocolates should be absolutely being acquainted with the consequences of over and under bidding. In the case of under-bidding when the offered price for the item is less than it is worth, there is a danger of not the item being sold to the buyer and vendor decides not to sell for the offered price. Based on the predetermined value or sealed bid price, respondents' maximum WTP will be evaluated. Respondents should be supported by 'memory joggers' throughout the practice, 'memory jogger' summarises the key concepts (Figure H.3), and their answers should be recorded in response books.

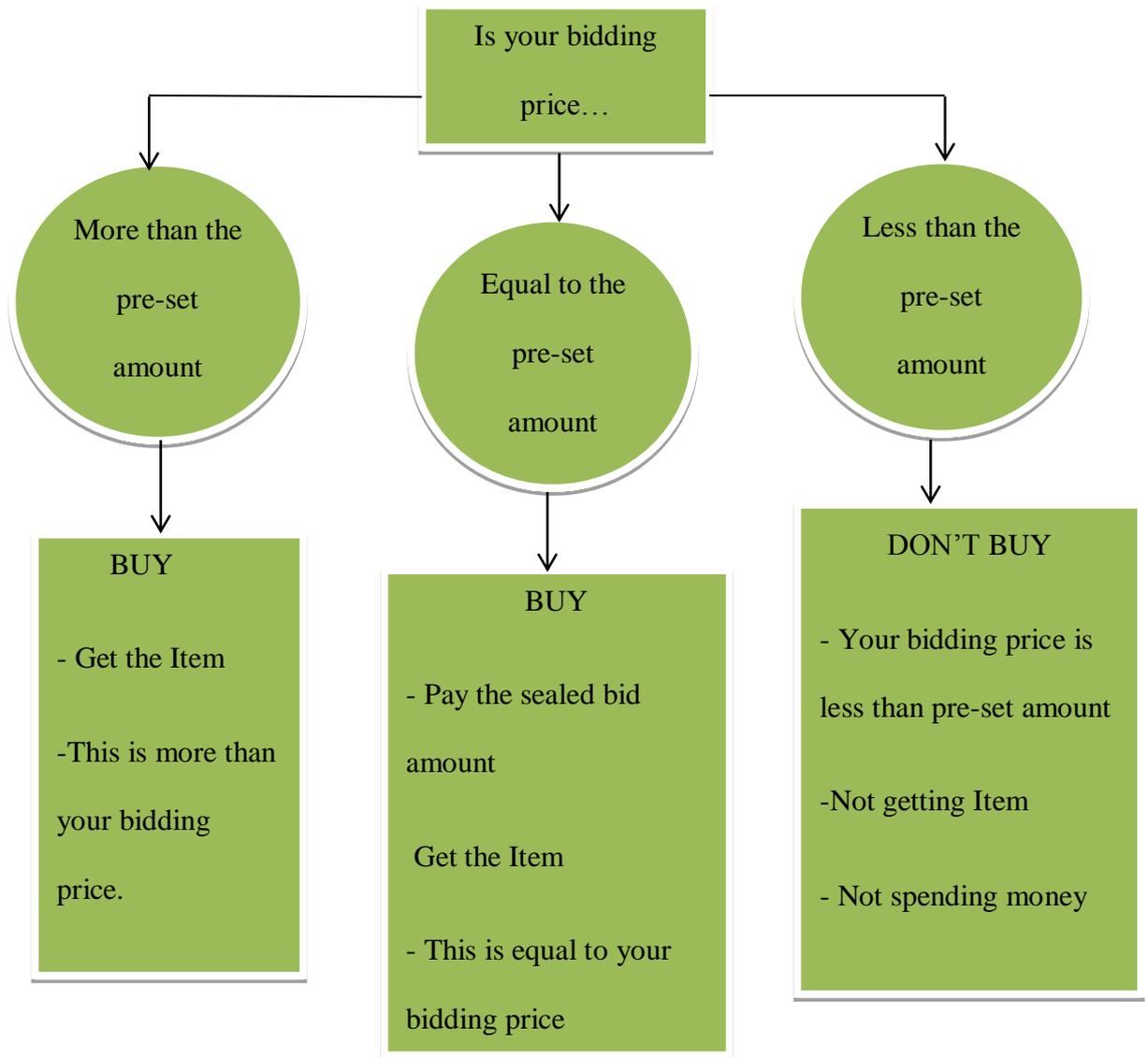


Figure H.3 Memory Jogger for teaching experiment WTP

The Key points:

4. Once you have recorded your bidding price, the **RULES OF THE GAME DETERMINE** if you buy or not. You cannot choose.
5. If you buy, you pay the **SEALED BID AMOUNT**, not your bidding price.
6. There's **NO POINT UNDERSTATING** what you'd pay
  - **HAVE TO BUY** photovoltaic at a price you think is too high

There's NO POINT UNDERSTATING what you'd pay

- CANNOT BUY at a price you'd like to pay

### **Photovoltaic evaluation**

Prior to proceeding micro-generation system evaluation, it is necessary to ensure that respondents are sufficiently practised and experienced to bid a value truthfully, using BDM mechanism. Then, the study would be accomplished using the below cheap-talk script before asking respondents' maximum WTP for solar technology.

*The process of the discussion that we went through was implemented with the intention of eliciting your truthful responses to the payment question. We tried to clarify what will be the consequences of underestimating the values to incentivise you to state a willingness to pay amount close to your actual payments.*

Presumably, you have a house or a piece of land. Government or private company has offered you to install photovoltaic system in your property and you would be asked:

***We would like to install micro-generation system in your property, what is your maximum willingness to pay?***

To evaluate the respondents stated values, their biddings price should be compared with the pre-set amount which had been set before by government or solar company (but will not be released to the seller). The cost of each solar panel (1m<sup>2</sup> or 1kWh with efficiency of 15%-20%) incorporated in sealed bid price. After comparison between respondents' bidding price and sealed bid price, three scenarios will arise.

Firstly, if respondents' bidding price is more than pre-set amount, they will obtain photovoltaic system installed in their property for their own usage. But, they are willing to pay more than it's worth.

Secondly, when respondents' bidding price is equal to the pre-set amount, the photovoltaic system will be installed in their property for their own usage. They just pay amount equivalent to the value of micro-generation solar panel.

Thirdly, if respondents' bidding price is less than the pre-set amount, the photovoltaic system will not be installed in their property, because the money they are willing to pay is less than the value of the micro-generation solar panel, and it doesn't cover the cost of that.

In this fashion, the procedures of the solar energy evaluation questions exactly conform to the prior learning experiment setting. The supplier (government or private company) undisclosed price works as the sealed bid in earlier rounds, and the same consequences of over and under-bidding will apply.

Respondents should have the memory jogger (Figure H.4) in their hands and experienced sufficiently of how to determine their reserve price, and being aware of the consequences of over and underestimating.

In the last part, respondents will be required to fill the demographics questionnaire. At the end, the session will be finished by the prize draw from the incentivised learning round.

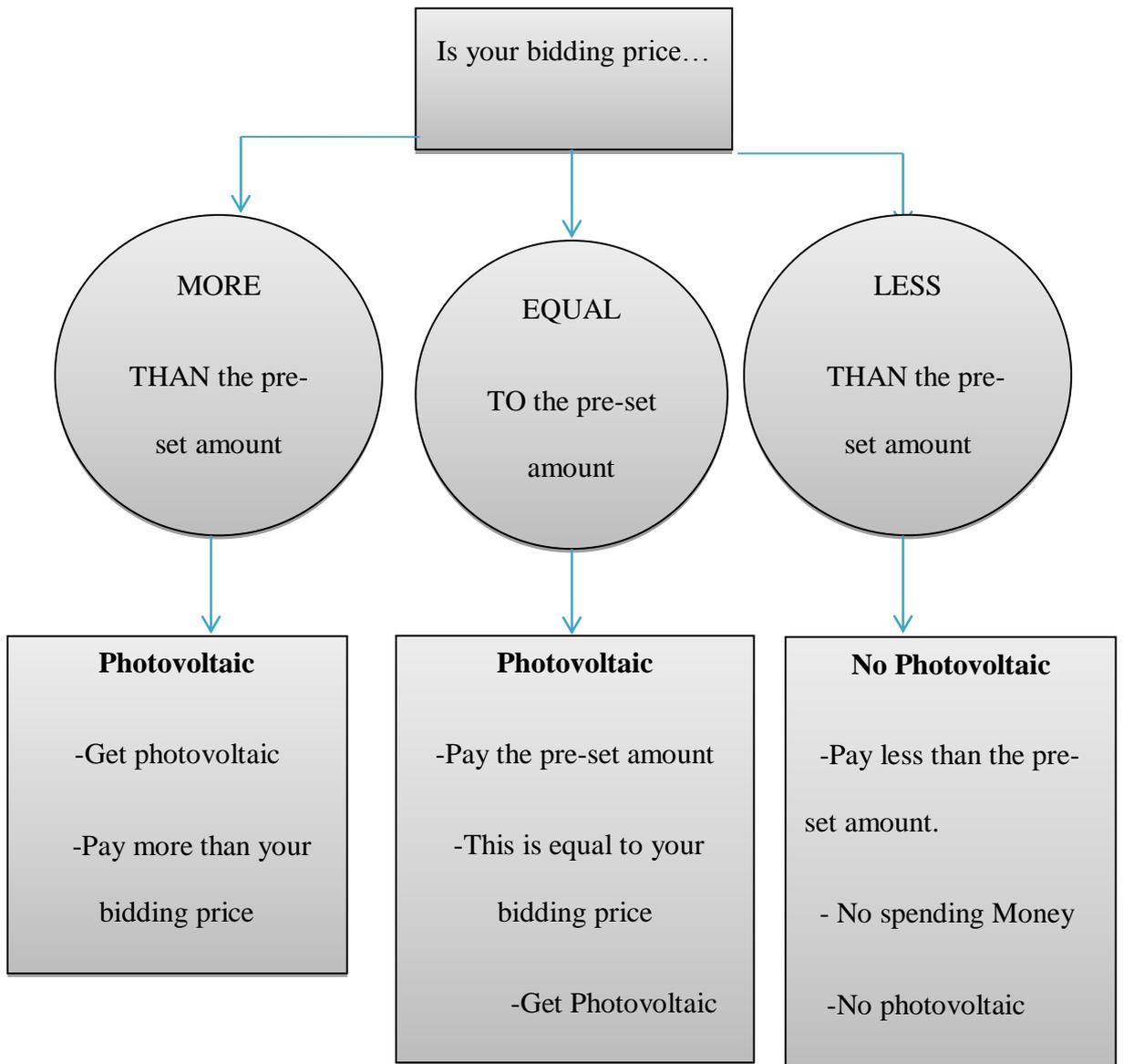


Figure H.4 Memory Jogger for solar energy utilisation valuation

The key points:

10. Once you have told your bidding price to solar company or government, the rules determine whether you get photovoltaic or not.
11. If you pay any money, you pay the PRE-SET AMOUNT, not your bidding price.
12. There's NO POINT OVERSTATING what you'd pay.
  - No photovoltaic at price you think is high.

There's no point understating what you'd pay.

- CANNOT BUY photovoltaic at a price you'd like to pay

Table H.1 summarises the experimental mechanism and instruments used to clarify maximum WTP term.

Table H.1 summary of maximum WTP clarification

<p>9. (Real): Buying a Draw entry ticket,  Experiment</p>	<p>Experience of buying and using the mechanism, elicitation of maximum WTP values in an incentivised context.</p>
<p>10. (Hypothetical): Buying a box of chocolates  Discussion</p>	<p>To reinforce the idea of the bid amount for buying (bidding price), true values, the dangers of over/underbidding, second price auction rules; to introduce and demonstrate the role of the (secret) sealed bid within the second price auction.</p>
<p>11. (Hypothetical): Micro-generation Solar panel valuation, WTP  Survey</p>	<p>Elicitation of monetary values from respondents who have an understanding/intuition of the economic meaning of maximum WTP.</p>

## Appendix I. CV questions for BIPV evaluation



Good morning/afternoon/evening. ‘Your answers to the following question will be used in a PhD thesis, which aims to examine Cypriot willingness to pay for the use of micro-generation solar technology. I would like you to consider a scenario in which you could supplement your existing system with an additional system. Please assume that solar panels will be fully guaranteed for 10 years, and this means that if any repairs and replacement parts are required, these would be freely provided by the company supplier. Presumably, you have decided to buy a house from Tanyel Construction Company which is not built yet. Your prospective house will be built for you on the basis of your requirements and choices amongst the options that are presented and visualised through 3 D images to you. One of those options is the integration of PV system to the building at the construction level. The integration of 4kWp PV system to the house would provide the possibility of exporting or selling the generated electricity to the grid; If you are considering BIPV;

1. What is the minimum amount you would be willing to accept to sell the excess electricity generated by your solar panels (PV) to the grid?
2. Would you be willing to pay 2000 Euro extra for the integration of 4kWh micro-generation solar equipment (PV) to your property at the construction level for your own usage?

3. Demographic questions

Sex	1. Female			2. Male		
Age	1 18-27	2 28-37	3 38-47	4 48-60	5 more than 60	
Education	1 Primary School	2 Secondary School	3 High School	4 University (2 Years)	5 University (4 Years)	6 Advanced Degree
Employment	1 Unemployed		2 Retired	3 Student	4 Self-employed	
	5 Employed					
Monthly Household Income (TL) (Salary + Interests + Rental income)	1 less than 1500	2 1500-3000	3 3000-4500	4 4500-6000	5 6000-7500	6 more than 7500
City	1. Nicosia	2. Famagusta	3. Kyrenia	4. Morphou	5. Trikomo	
Marriage Status	1. Single		2. Married		3. Divorced/Widow	

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