CROATIA´S RURAL AREAS – RENEWABLE ENERGY BASED ELECTRICITY GENERATION FOR ISOLATED GRIDS

by

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Several Western Balkan states face the consequences of the Yugoslavian war, which left hometowns with dilapidated electricity grid connections, a high average age of power plant capacities and low integration of renewable energy sources, grid bottlenecks and a lack of competition. In order to supply all households with electricity, UNDP Croatia did a research on decentralized supply systems based on renewable energy sources. Decentralized supply systems offer cheaper electricity connections and provide faster support to rural development. This paper proposes a developed methodology to financially compare isolated grid solutions that primarily use renewable energies to an extension of the public electricity network to small regions in Croatia. Isolated grid supply proves to be very often a preferable option. Furthermore, it points out the lack of a reliable evaluation of non-monetizable aspects and promotes a new interdisciplinary approach.

Key words: *rural electrification, renewable energy, isolated grids, social welfare, sustainable development, externalities*

Introduction

Although many people assume that most of the 1.3 billion people [1] on the globe without access to energy live in Africa and India, very few expect that there are thousands of families in the Balkans, which are not connected to the energy grid. The Yugoslav wars in the 1990s have let four million civilians displaced [2]. More than a million of displaced people have returned to their homes and reclaimed their property rights. Still thousands do not have access to the power grid. Their homes were connected to the grid before war, but the infrastructure has been destroyed. The income level of these families is already very often below the poverty level and resource prices continually rise. Necessary investments for a grid connection of these isolated locations are high and while small-scale agricultural production is the main source of livelihood for most of the families, fuel expenses (*e. g.* for powering diesel generators) are almost not bearable. This leads to a social marginalization and a lack of development of these areas.

Croatia's national electrification rate amounts to 99% [3] or 96.5% when considering a value estimated by a satellite detecting nighttime lighting [4]. Around 126 villages in Croatia, counting over 500 houses with mostly war returnees living there, are not connected to the public grid and, if there is an electricity grid connection at all, it is dilapidated [5]. Some of those villages have only a few inhabitants. Croatia's national electricity supplier estimates

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the costs for a grid connection of those villages to amount to EUR 6.7 million [6]. Furthermore, 79 islands and 525 islets have been recorded in the coastal sea of Croatia and 47 islands are inhabited all around the year [7, 8]. Especially for smaller inhabited islands, which do not have a connection to the public grid, an isolated grid may be the ideal solution to provide sporadic visitors (weekend houses, fishing houses, houses used during the wine and olive harvest) and permanent inhabitants with energy. Nevertheless, also on major islands, there are a number of gradually developing areas, which are not connected to the grid at all or face an insufficient connection. This causes periods of fluctuating voltage or even blackouts.

Croatia's power system was not supposed to guarantee self-sufficiency within former Yugoslavia. This explains why many former national network lines have become interconnections, with Bosnia and Herzegovina strongly affecting Croatia's power system [9]. Furthermore, Croatia's power plant capacities suffer from a high average age. Not only the replacement and enlargement of existing power plants in Croatia requires a shift towards renewable energies, but also the necessary reduction in greenhouse gases and the need to reduce future payment obligations under the Kyoto protocol or within future EU Emission Trading Scheme (ETS). Furthermore, Croatia's electricity market was opened in 2008 [10] and the national electricity supplier had a factual monopoly for a long time [3, 11]. Yet, the market is starting to face challenges like deregulation and a slowly increasing competition, which may exert a countervailing influence on electricity prices. Advantages of an isolated grid supply are the improvement of power quality, as well as the reduction of transmission losses and transmission line overloads. Furthermore, the use of local resources to supply remote regions with electricity reduces line construction costs and it is expected that the physical proximity of energy generation increases consumer awareness of efficient and judicious energy usage [12].

Services of general public interest are services that answer basic social needs and meet the fundamental rights of the citizens. These services do not only include the supply with fresh water, access to transport, communication and health care but also the supply with energy. Therefore, the electrification of remote regions should be considered as a part of public service obligations. It is important to create preconditions for rural development in Croatia. People who live from remote regions as their daily source of income (*e.g.* wine yards or pastureland) and who do not have access to the electricity grid, face enormous financial expenses to run a diesel generator in order to generate the amount of electricity needed. These expenses are very often disproportionately high in relation to the monthly income of the customers and they, therefore, are a threat to financial security and the settlers' subsistence. An investment into the rural infrastructure can help to slow down rural migration in Croatia [13] and to enable settlers to lead a normal life. Also, concerns of security of supply and essential services should be taken into account when arguing for the electrification of remote regions. The extension of the public grid is not only a matter of costs, but also a matter of time, considering the assumed high potential of remote regions to be supplied and the long decision-making processes for public grid roll-out plans. In addition, aspects of national economic output and the labor market may be considered in a national social welfare comparison. One may also argue that an increased demand of renewable energies would lead to an increase of national production and prosperity of national small and medium sized enterprises.

Literature review – social welfare

The developed Excel-model is based on empirically determined data. The definition of social welfare and social welfare functions are analyzed on the basis of selected literature, such as Kleinwefers [14], Endres [15], Stiglitz [16], Schaltegger [17], and Frey [18]. The dictionary assigns terms like happiness, health, good fortune and prosperity to "welfare" [19]. This displays the broad range of the term and squares with the fact that a final definition of the concept has not been found [15]. Social welfare may be measured by comparing different forms of distribution and individual situations as a function of their utility and social welfare. This can be defined as the total amount of willingness to pay [15].

There are different approaches to define social welfare. Basically, discussions about measuring social welfare have been developed using primarily an economic approach. The public discussion was largely characterized by an increasing attention towards non-economic aspects within the last years [15]. Also, the United Nations recently affirmed the need for a new economic paradigm, including social and environmental aspects [20]. While GDP refers to national economic aspects, the state of well-being is influenced by more dimensions, including material living standards, health, education, personal activities, social connections and relationships, environmental conditions, political voice and governance, insecurity of economic or physical nature, *etc.* [16]. These dimensions cannot be easily converted into monetary units or are even impossible to monetize.

In 2000, Schaltegger [17] defined a function of social welfare, which represents a trade-off between the economic and environmental dimension. Schaltegger argues that his analysis takes into account society as a whole. Therefore, the following section may be seen as a definition of social welfare at a global level. According to Schaltegger social welfare increases as quality of life rises. This results from an improved state of the natural environment and an increasing amount of available economic assets, defined as the aggregate output. In turn, the aggregate output increases within a given period t, when the overall economic input and the negative environmental impact rise. This can be explained by the fact that the production of an asset causes environmental impacts, such as pollution, or simply reduces the amount of available natural resources. Further, Schaltegger takes account of the environment's capacity of regeneration and argues that, when demanding a sustainable development, a strategy of an environmental impact smaller or equal to the environment´s capacity of regeneration should be chosen Naturally, sustainable development implies that social welfare has to remain constant or will increase [15]. Schaltegger's approach to social welfare maximization describes a trade-off between the economic and the environmental dimension. He visualizes a 1:1 relation between these two dimensions. When considering the definition of the natural environment [17] it is obvious that, from a national point of view, a 1:1 trade-off between the economic and the environmental dimension is not appropriate. A country bears its own costs arising from climate protection measures, yet, it benefits from every effort made all around the globe [15]. Negative environmental impacts may not only have an effect within the country's borders, but in the entire world. National welfare maximization as such would not necessarily result in a maximization of global welfare, if all national welfare levels were added up [15]. Due to an insufficient adaption of common goals and global agreements as well as insufficient know-how concerning the potential monetization, countries act in conformity with their own benefit and external costs, which incur when the amount of social costs exceeds the amount of private costs. This triggers misallocation [21]. A welfare analysis conducted at national level would therefore differ from an analysis at global level.

The considerations set out above illustrate an economic approach extended by an environmental dimension and it seems that important aspects influencing social welfare have not been taken into account in the model. The Stiglitz Commission worked out a definition of indicators influencing social welfare in 2009 [16]. The initiative defined three major pillars. As such, it extends the discussion to further aspects. The first pillar deals with economic aspects, indicated by classical GDP values*, emphasizing the position of households and considering aspects of distributive justice. The second pillar deals with the quality of life, considering health, education, political voice and governance, social connections, personal activities, personal and economic insecurity and environmental conditions. The third pillar deals with the dimension of sustainable development and the environment, which emphasizes a prospective dimension of future generations and sustainability. As may be expected, it is hardly possible to measure these values, due to uncertainties concerning future values, technologies, resources, *etc.* [16]. The broad range of dimensions influencing social welfare is obvious and it seems hardly possible to argue that the existing list of aspects, as set out in the Stiglitz Commission, will not be extended in future. The fact that it is unknown if the list of considered aspects is exhaustive and the difficulty to limit them to monetary units visualizes the complexity of measuring social welfare. Numerous aspects would have to be measured in terms of subjective perception besides objective measurement alone. In turn, people's preferences can be channeled through national politics, awareness raising, regulations, internalization of external costs or simply by influencing the customer's demand with a change in the products offered [17]. Therefore, the complexity of introducing a thorough and final definition of social welfare, which is able to compare different strategies, has to be underlined. It is obvious that existing welfare functions do not allow for a thorough comparison of social welfare at a sufficient quantitative level and that future research will be needed.

Social aspects as the third pillar of sustainability, besides economic and environmental aspects, are hardly mentioned by Schaltegger when talking about social welfare. They include requirements of inter and intra-generational distributive justice, the supply of basic needs and an equitable and universal access to resources. The first World Happiness Report was edited by the Earth Institute of Columbia [22]. Economics of happiness was also discussed by Frey, *et al.*, who state that environmental degradation negatively affects happiness and instance approaches of measuring the value of public goods. The authors describe the Life-Satisfaction Approach, which estimates the marginal utility of a public good by correlating it with the reported subjective well being, as being suited for the evaluation from a macroeconomic point of view, but claim that it is difficult to measure specific public goods [18]. A future investigation of the citizens' values and perceptions regarding social and environmental aspects could help to establish a ranking system. For example, a survey of perceptions, public attitude and knowledge about renewable energy sources which was conducted in the cities of Zagreb and Rijeka in 2003, signals that the citizens of Croatia attach a great importance to environmental aspects and fear health risks caused by fossil fuels and particularly nuclear power [23].

The difficulties of estimating social and environmental aspects in econometric terms lie in the fact that life satisfaction and utility are subjective variables [1].

Data and methods

The paper focuses on the development of an Excel-model**, which compares alternatives of supply. It uses empirically determined load profiles for model regions. The model

* The impression might have been conveyed that, by using the GDP as a reference value, a national approach was chosen in the underlying analysis of the Stiglitz Commission. Yet in contrast, the underlying paper attempted to interpret the function of Schaltegger from a global point of view, when defining the aggregate output instead of a national product or GDP. Schaltegger himself does not provide a clear definition.

** The Excel-model is available on request (sonjamariaprotic@gmail.com).

is extended by further information and uses different scenarios. The development of the model includes the following steps:

- summary of background information about available electricity infrastructure (utilities, grid),
- provide information of distance and costs of grid construction projects,
- develop the model comparing the possibilities of supply,
- design model regions and provide price information,
- extend the model and compare various regions, and
- based on the results, discuss social welfare as a possibility to compare alternatives of supply.

Electricity infrastructure and utilities in Croatia

The state-owned national utility is the only company responsible for electricity distribution in Croatia [11]. Together with its subsidiaries the group operates the power system and is in charge of interstate electricity transmission, delivery of electricity to the customers, maintenance, replacement and the development of the supraregional transmission and the local distribution networks. The distribution system operator (DSO) being responsible for the local distribution provides more than two million customers with electricity and operates a network length of 134,122 km [24]. The 4-year-average of the construction costs for current construction projects of new facilities amounts to approximately 11 M€ [6], while the 4-year-average of the annual depreciation costs accounts for approximately 100 M€, [6, 24-27]. Comparing these two amounts, it becomes obvious that the company faces major expenses for the maintenance of the distribution network. The latter is due to the network's age and the continuous need for improvement [9].

A non-connected customer who wants to be connected to the public grid must file a request to the distribution company to have the grid extended to their area. If the distribution system operator approves, the expansion plan will be incorporated into a three-year development and construction plan to be submitted to the Croatian Energy Regulatory Agency, which either approves or rejects the plan [10]. Besides the slow decision-making processes and long delays by the operator, technical and economic criteria determine a distribution company's interest in extending the electricity grid and, consequently, in enabling new customers to be provided with energy. The grid operator has to fulfill statutory obligations concerning investments in maintenance, infrastructure development and security of supply. A common concept of evaluating the economic benefit of a project is the Method of Discounted Cash Flows (DCF Analysis). A positive net present value backs an approval of the investment. The national electricity supplier uses the profitability index describing the ratio between the expected annual benefit from the project and the annuity of its expected costs for evaluating the transmission system plan. These economic evaluation methods illustrate how economic benefits influence the prioritization of certain projects. As a result of the positive correlation between the costs for construction and distance [28, 29], the construction of new facilities might prove economically more advantageous if they are supposed to supply more customers at shorter distances than vice versa. Furthermore, plans for the construction of new facilities also depend on the political interest and political pressure, which is exerted on the company. The national electricity supplier has remained a state-owned company, even after Croatia's accession to the European Union. The latter pursues a policy that pushes the company's privatization. Yet, the majority of the company's shares will remain in the ownership of the Republic

Croatia [30]. Therefore, politics is to continue to exert an especially strong influence on the company's decisions.

Distance and costs of grid construction projects

Construction costs include equipment costs and installation costs for overhead lines, underground cables, pylons such as switching and transformer stations. The DSO estimates the average construction costs to be as follows (personal information according to the DSO) [6]:
- overhead low-voltage lines and wooden pylons: 24,120 €/km,
- overhead low-voltage lines and concrete pylons: 29,282 €/km,
- underground middle-voltage (10/20 kV) cable: 46,585 €/km,
- pole transformer (up to 250 kVA): 13,310 EUR/km, and
- transformer station (up to 1,000 kVA): 53,240 €/km.

Real construction costs depend on the circumstances of the individual case, as the terrain, the conditions of the ground, *etc*. Also maintenance costs, even if not examined in greater detail, logically rise as the distance increases. Transmission and distribution losses generally vary from about 5% to 20% [12]. The DSO's electricity losses amounted up to 8.74% in 2010, whereby the last years were marked by a slightly declining trend [24]. The estimated average loss is between 1% and 1.5% per 100 km in distance [28, 31].

The model comparing the possibilities of supply

This paper came up with a methodology to financially compare isolated grid solutions that primarily use renewable energies to an extension of the public electricity network to small regions. The model exclusively considers monetizable criteria and it is, therefore, limited to an economic and, to a certain degree, an environmental dimension. In the financial comparison of the implementation of an isolated grid and the extension of the public utility grid, initial investment costs and operation and maintenance costs are considered. They are compared over a 30-year life-cycle and described as the Present Value of the costs. The model includes different scenarios of price developments and inflation, as well as transmission losses and efficiency losses of the system components, such as photovoltaic modules, batteries, *etc*. Table 1 shows the scenarios, which may be chosen in the calculation of the model. Submarine cables are included to demonstrate their high investment costs with regard to their share of electricity supply for remote islands in Croatia. As their costs highly diverge due to construction conditions, they are included as a very rough estimate only. By assuming a correlation between two model regions, the analysis can be conducted for any potential small region. The model is easy to use and easy to understand. It illustrates the topic on a simple way, which increases the likelihood of its use. By drawing conclusions from the model, the paper also analyzes social welfare in terms of supply solutions.

Table 1. Possible scenarios to be chosen in each category

Category	Scenario 1	Scenario 2	Scenario 3	Scenario 4
€/t CO_2 – increase/decrease (per year)	3.3%	8.0%	11.5%	
Electricity [€/kWh] – increase/decrease (per year)	1%	2%	3%	
Diesel: €/l – increase/decrease (per year)	1%	2%	3%	
Inflation per year [%]	2%	3%		
Interest rate per year [%]	2%	3%		

Kind of cables which connect the model region with the public grid:
- Scenario 1 – overhead low-voltage lines – wooden pylons,
- Scenario 2 – overhead low-voltage lines – concrete pylons,
- Scenario 3 – underground middle-voltage cable (10/20 kV), and
- Scenario 4 – submarine cable.

Designing model regions and testing the model

Two model regions have been designed. In the following, the design of one model region (Region 2) will be portrayed. Calculations of the costs to be incurred as a result of an isolated grid supply and the connection of the region to the existing electricity grid will be compared. To create representative model regions for Croatia, the following steps were taken:
- assume an average household in Croatia (number of persons),
- assume a representative electricity demand/profile for an average household in Croatia,
- assume that the model regions are located in an area of Croatia, with an approximate national average of wind and solar potential, and
- create two model regions, which are likely to be established in a rural area.

Model region 2

Location: County Sibenik-Knin.

Project comprises: 1 private house heating water with electricity: three persons, all around the year; 1 private house not heating water with electricity: three persons, all around the year; 3 weekend houses not heating water with electricity: three persons each, visiting two days a week in summer. 1 agricultural family business: a high load requirement has to be met at noon, when the milk cooling equipment operates; 1 small marina: the marina is open in July and August; 2 small restaurants: the restaurants are open in the evening only.

Social-economic background: Private customers, an agricultural family business and small enterprises.

Location: Suitable for photovoltaic modules and wind turbines.

Purchasing behavior: The purchasing behavior of the entrepreneurs was designed as an approximation to real life and is based on the model of the purchasing behavior of a real agricultural family business, a real marina and a real restaurant [32]. The untypical type of load profile of the marina shows a significant increase during daytime in the summer months.

Electricity loads were shifted towards daytime and summer, when electricity generation by PV is higher. As a result, the demand curve may be flattened and optimized according to the level of electricity generation. Storage capacity may be reduced and an over-dimensioning of the solar modules prevented. Shifting the loads to daytime and summer season leads to a higher solar fraction in the energy mix being used. Consequently, the supply by the back-up generator can be reduced. In addition, using a time-dependent control to charge the battery can increase the share of renewable energies. The chosen state of charge should ensure a reliable supply at nighttime with minimum battery charging through the back-up generator, while the charging process may be shifted to a period of time offering a high renewable energy capacity [33]. Model Region 2 has a yearly electricity consumption of 21,208.04 kWh.

Establishing an isolated grid. An isolated grid meeting the requirements of the load profile for the model region was designed in accordance with the software HOMER, assuming an ideal angle of PV array, the intensity of irradiation and the wind conditions of the county Sibenik-Knin. The isolated grid system is based on a 7 kW PV-array, a 6 kW wind turbine and a 15 kW diesel back-up generator. Prices of the system are based on accurate offers by Croatian companies (EnergyPlus: http://www.energyplus.hr; Sunato d.o.o.: http://www.sunato.hr). The investment costs for the establishment of the exemplary isolated grid amount to € 76,497.13.

Comparing the possibilities of supply. The Present Value for the isolated grid is portrayed over a 30-year life cycle, which amounts to € 168,074.02. The scenario to be considered is a representative assumption of a moderate annual increase in CO_2 prices (8%), electricity prices (2%) and diesel prices (2%), and a slight annual increase in inflation (2%) and interest rates (2%). The Present Value of the isolated grid includes investment costs and operational expenses. Investment costs are € 76,497.13 in the first year and an additional € 81,551.02 dedicated to replacements within these 30 years. Operational expenses contain fuel costs for the diesel generator, CO_2 costs and maintenance costs as a percentage of total investment. To meet equal Present Values in the mentioned scenario, the distance between the model region and the existing grid has to be 2.53 km when using overhead low-voltage lines (wooden pylons), 2.10 km when using overhead low-voltage lines (concrete pylons) and 1.21 km when using an underground middle-voltage cable (10/20 kV). Any increase in distance would lead to a preference for an isolated grid supply for the potential region. This is due to the fact that the line connection expenses grow with increasing distance between the potential region and the existing electricity grid. While the expenses for the isolated grids are stable and hardly depend on the extent of remoteness.

Extending the model for a range of various regions

Assuming a linear correlation between the two model regions, which have been designed in the full version of this paper, the model has been extended and, as a consequence, it provides an estimate for comparing the Present Values of any potential region. The correlation assumes that a model region with an electricity demand between Region 1 and Region 2 will have proportional expenses based on the underlying assumptions of the Excel-model. After entering the annual consumption of a model region in kilowatt-hours, the model calculations provide a target search comparing the isolated grid and the public grid solution. The result is the distance in kilometers that separates the region from the existing public grid to meet equal Present Values of the isolated grid supply and the extension of the public grid. According to the model, any increase in distance would lead to the preference for an isolated grid supply for the potential region under the same conditions. Figure 1 illustrates the graph of equal Present Values for the same scenario as described above, with a preference for monetizable costs for the isolated grid supply for all regions above the graph. The Present Values of the grid connection include investment costs for the grid and transformer stations, as well as operational expenses. Operational expenses contain expenses for purchasing electricity, CO_2 costs, expenses for radioactive waste disposal and maintenance costs as a percentage of total investment.

For example, when supplying a region with a yearly electricity consumption of 15 MWh it is economically preferable to establish an isolated grid than to extend the existing grid using underground middle voltage lines, if the distance between the potential region and the existing grid is more than 0.7 km (see fig. 1, A). When using overhead low voltage lines with concrete pylons, the decisive distance amounts 1.4 km (see fig. 1, B). When using overhead low voltage lines with wooden pylons, the decisive distance amounts approximately 1.8 km (see fig. 1, C).

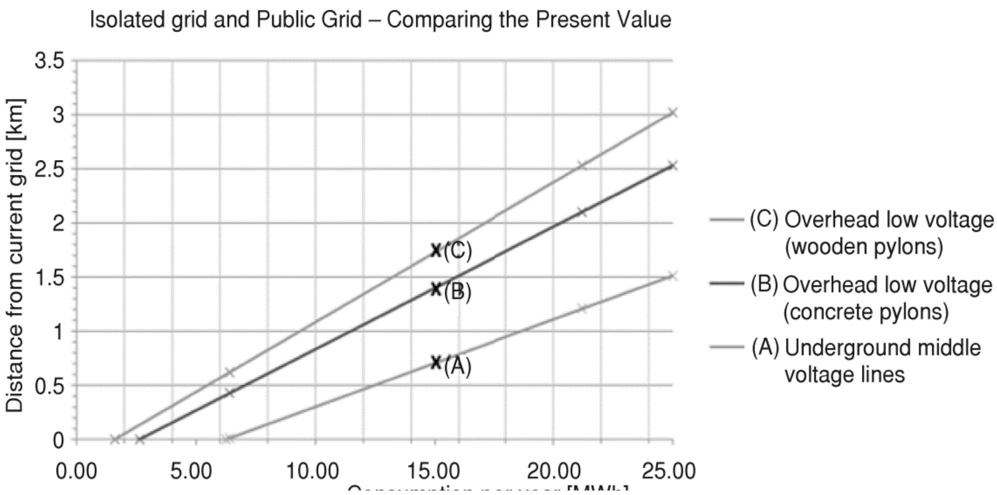

Figure 1. Present values for supply alternatives (source: own illustration)

Result overview

The results show that the establishment of an isolated grid in a remote region is expected to be an economically preferable option if the results of the created Excel-model indicate so. Isolated grid supply proves to be very often a preferable option even in the case of short distances between the potential region and the existing grid. The use of underground-middle voltage cables and rough terrain for the extension of the public grid support the advantages of isolated grids. Nevertheless, the developed model cannot portray social welfare and is limited to a consideration of monetizable criteria. If environmental and social aspects could be monetized, it might be expected that preference is more likely to be given to the isolated supply than to the extension of the public grid. This statement can be defended when presenting the advantages of renewable energies and an independent supply as described in the paper. The discussion shows that decisions should take account of numerous fields of research and consider all aspects, which are being considered in interdisciplinary research in social welfare, such as economic, social, environmental, political and psychological ones. Therefore, existing methods of measuring social welfare should be revised. Additionally, account should be taken of national requirements regarding social welfare maximization such as externalities at national level.

Discussion

The costs and the utility of the supply possibilities have been described in order to compare the possibilities of electricity supply portrayed in this paper. In the Excel-model, costs have been included as far as possible and have been measured as objectively as possible. The developed methodology showed that isolated grid supply proves to be very often an economically preferable option even in the case of very short distances between the potential region and the existing grid. Anyhow, implementation in practice still lacks behind.

As argued above, the definition of social welfare is broad and the list of considered criteria is hardly an exhaustive one. Even though they are important and worthwhile to be considered in a national welfare comparison, the monetization of these aspects is simply not possible to an appropriate degree. These unquantifiable costs include, for instance, health risks or psychological costs occurring from nuclear energy generation nearby, the dependence on energy supply and, as a consequence, on national and international political and economic circumstances or aspects of life satisfaction connected to social relationships. The comparison considers the economic dimensions of the supply possibilities only, while environmental aspects are considered to a limited extend and social aspects, influencing the well-being and quality of life are not included at all. As for now, social welfare can't be expressed in numbers. When considering non-monetary costs, which haven't been part of the conducted comparison of the supply alternative's Present Values, the preference given to a supply possibility, should be revised. If environmental and social aspects, as a health burden or a psychological burden connected to issues of supply security and dependence, could be monetized, it might be expected that preference is more likely to be given to the isolated grid supply than to the extension of the public grid.

With regard to social welfare and the measurement of social welfare, it would be favorable to revise the above-discussed welfare function of Schaltegger and to display the indifference curves as a function depending on three pillars. These three pillars include the state of the natural environment, the amount of economic assets and additional social aspects and thus represent the three pillars of sustainability. The relation of the trade-off between the three dimensions depends on the allocation and monetization of externalities. The criteria named by the Stiglitz Commission need to be introduced into these three pillars of sustainability. Referring to the evaluation of social welfare by choosing a supply alternative, no final conclusion can be drawn. Yet, it may be assumed that an isolated grid solution would improve social welfare in situations favoring isolated grid supply when considering monetizable costs. The establishment of an isolated grid for a specific region is expected to depend on public preferences, values and awareness. The preference for an isolated grid can be assumed to be higher, the greater the value attached to environmental and social aspects is. Therefore, the principal challenge is not to design an isolated system that is affordable, but to conceive, measure and consider all its dimensions that influence social welfare and, thus, conceiving a solution to existing problems and shortages that may serve as an unbiased preferable option when attempting to supply certain remote regions in Croatia.

Conclusions

Several conclusions are drawn. The establishment of an isolated grid in a remote region is expected to be an economically preferable option if the results of the created Excel-model indicate that the autonomous supply alternative would be a preferential option. Isolated grid supply proves to be very often a preferable option even in the case of short distances between the potential region and the existing grid. The model cannot portray social welfare and is limited to a consideration of monetizable criteria. It is evident that further efforts are needed to improve the methods of monetization and allocation of externalities. Decisions for supporting isolated grid solutions should include numerous fields of research, considering economic, social, environmental, political and psychological aspects and, thus, an interdisciplinary approach ought to be used.

Presented analysis suggests a possible extension of the known indicators of social welfare by further aspects, also named in the Report of the Stiglitz Commission. Subsequently, an analysis regarding the three pillars of sustainability, including economic, environmental and social aspects, is recommended.

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