DECISION SUPPORT TOOL FOR SUSTAINABLE RENOVATION PROJECTS IN THE DUTCH HOUSING CORPORATIONS

Davide Garufi[1]; Bauke de Vries[1].

1: Department of Built Environment, Eindhoven University of Technology, Eindhoven, The Netherlands

ABSTRACT

In Europe, the Energy Performance of Buildings Directive is a driving force for member states to develop and strengthen energy performance regulations for new and existing buildings. In the Netherlands, 33% of dwellings (2.4 million) are owned by social housing corporations (SHC), and 86% of them do not yet conform to the European 2009/28/EC which states that all the existing houses have to reach at least energy label B by 2020. If the actual retrofitting trend will not significantly increase, the Dutch SHCs will not comply with the European Commission requirements. Due to a lack of information and ambiguity about the performance of such systems, the decision-makers in companies whose core competence is not strictly energy efficiency related, face challenges in selecting the most appropriate sets of measures for their projects. Hence, there is a need for a quick and reliable tool, able to provide accurate predictions energy savings to the users as well as environmental impact and financial feasibility of energy retrofitting projects. This paper describes the challenges and relative solutions of a decision support tool (DST) at house and district level, developed together with the employees of a SHC, so coherent with the company strategy and parameters. This leads to the development of a methodology in which the performance of insulation scenarios is pre-calculated using an energy performance certificate (EPC) software, while low-resolution models **(**LRM) were built for assessing the potential of renewable energy technologies (RET) and financial consequences. As a result, the DST has been already successfully applied in a project of the SHC in Eindhoven. The lessons learned from the design and the implementation of the system have the potential to be applied in other European countries.

Keywords: decision support tool, social housing, energy retrofit, strategic tool.

INTRODUCTION

In recent years the social housing corporations in Europe have been submitting and realizing many retrofitting projects. In the Netherlands, various initiatives are currently being undertaken to improve the energy efficiency of the existing building stock, for example in the cities of Roosendaal in 2010 or in Kerkrade in 2011. Their goal was to explore the financial and energy bill consequences when insulating terraced houses until passivhaus standards and RETs for gas consumption for domestic hot water (DHW) and room heating (RH).

Nomenclature

ASHP	Air Source Heat Pump	*HL Menu*	House Level Menukaart	*PVs*	Photovoltaic panels
DHW	Domestic Hot Water	*IC s*	Investment costs	*RETs*	Renewable Energy Technologies
EI	Energy Index	*IRR*	Investment Rate of Return	*RH*	Room Heating
EL	Energy Label	*IS s*	Insulation Scenarios	*SHC*	Social Housing corporation
ESMs	Energy Saving Measures	*LRM*	Low Resolution Model	*SL Menu*	Strategy Level Menukaart
GSHP	Ground Source Heat Pump	*NL Menu*	Neighborhood Level Menukaart	*STC*	Solar Thermal Collector

The combination of these solutions resulted to be remarkable since the gas demand reduction of more than the half and a small increase (around 10%) of electricity consumption after monitoring. On the other hand, overheating in summer season was experienced by the users and the high retrofitting costs, around €100.000,00 [1] per house, are undesirable for SHC standards. One of the methods to make the process from design to construction of energy retrofitting projects more effective in terms of involved resources and expected results, is the use of a decision support tool (DST). There have been made different DSTs for studies in the sustainable redevelopment of individual objects as the studies of Rosenfeld and Shohet [2] and Alanne [3]. These models support the choice for retrofitting actions in individual dwellings, based on a techno-economic comparison, but not implementing sustainable energy technologies at neighbourhood level. The lack of information in energy retrofitting within the SHCs can be minimised through the DST described in this paper so that to fill this gap.

SYSTEM REQUIREMENTS

In order to reduce the above mentioned weaknesses of the available DSTs, the tool kit was developed together with the target group called "end-users", composed by real estate advisors and project leaders of the company Woonbedrijf, the biggest SHC in the region of North-Brabant, the Netherlands. Five meetings have been scheduled to define the system requirements, preferred inputs and outputs from the DST called *Menukaart*, the word "menu" in Dutch language. In *Figure 1* the main system requirements are presented.

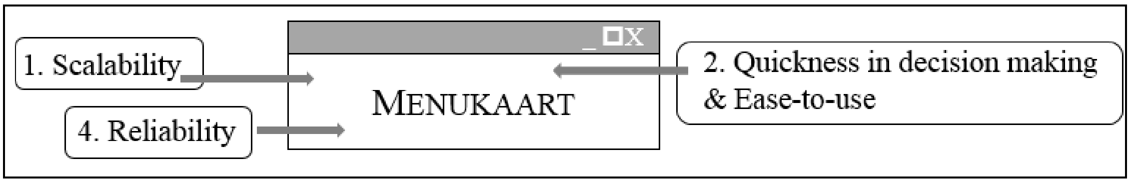

Figure 1: System requirements from the Social Housing Corporation's users.

Below the system requirements definitions are presented:

1. The system must be applicable to all the building complexes with same archetype (terraced houses 1945-1965). It is supposed to combine the data from the background calculations and the variable inputs through a user-friendly interface.
2. The ISs and RETs options provided should be linked to a financial model in line with the company rates. Check boxes and buttons can be part of the system and, to guide the steps to take, some comments and input limitations have to be implemented.
3. Consistence of the embedded LRMs with the national Dutch regulations or broadly recognised institutions is highly desirable. The characteristics of the location, weather data as well as the specific geometry of the archetype are essential prerequisites.

The systems outputs, according to the end-users, have to include the energy index (EI) and the energy label (EL) before and after renovation. The actual energy consumption of the dwellings often differs from the EPC values, which are strictly related to the building performances but, they do not take into account among others, the contribution of the electric appliances [4]. The DST provides the users with a quick way to estimate more accurate scenarios, since the annual energy bills of the tenants, as available data in the company, can be easily implemented in the model. The results of the insulation scenarios (IS), a selection of energy saving measures (ESM) and RET are asked to be converted in terms of environmental, energy savings and financial impacts. Moreover, a key output for the end-users is the financial contribution to the project from the tenant, i.e. the increment of the monthly rent.

METHOD

A step by step procedure was built so that to define each input-output stage during the decision making process, as usually done in energy planning [5].

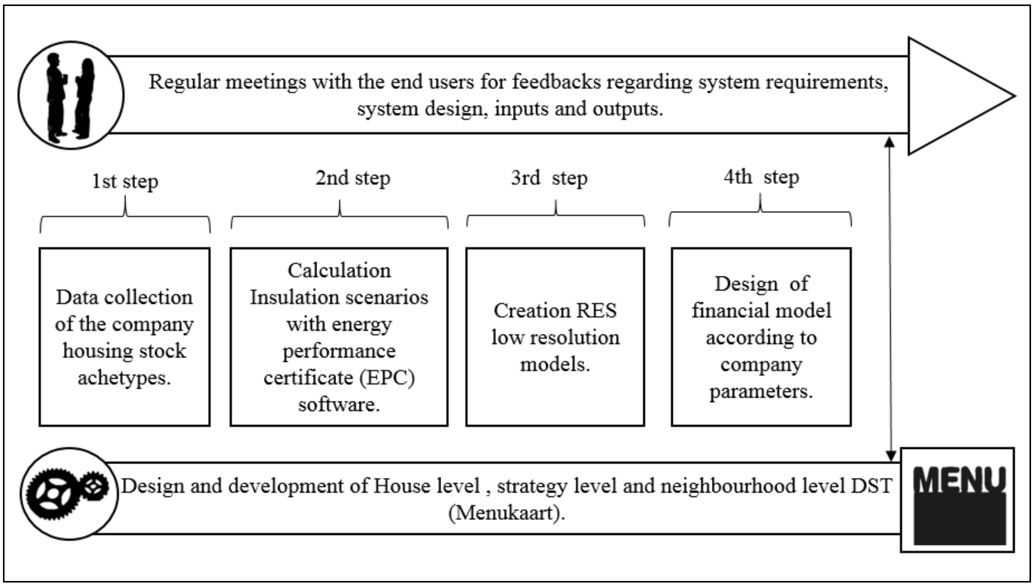

Figure 2: The steps taken in the research methodology are shown.

Since the company's housing stock is very diverse, in the 1st step of the research a data collection about the geometry, components construction and heating systems currently installed has been performed. A sample of 440 terraced houses distributed in two different complexes, sub-units of neighbourhoods, located in the city of Eindhoven was chosen coherently with the strategic plans of renovation projects of Woonbedrijf. To explore the different options of energy reduction based on insulating the houses, as a 2nd step, eight ISs have been calculated with the Dutch EPC software *Vabi Assets Energie 4.3*. In *Table 1* the actual situation of an average terraced house, the scenarios, the increasing thermal properties of the components, the ventilation and heating systems are indicated. The further four IS configurations are called ''No floor'' scenarios, in which the same measures have been applied, and the floor insulation have been excluded. The latter ISs have been selected to deal with situations in which the foundations of the houses are not accessible or their construction layers could contain toxic materials such as asbestos.

Scenarios	Rc Value	Floor	Roof	Façade	Doors	Glazing	Ventilation system	Heating System
Actual	[m².K/W]	0.15	0.22	0.36	Not insulated	Single or double	Natural	High efficiency gas boiler
1 Reasonable	[m².K/W]	2.4	2.6	1.6	Insulated	Double + wooden frame	Mechanical	High efficiency gas boiler
2 Good	[m².K/W]	3.6	4	3.7	Insulated	Double + wooden frame	Mechanical	High efficiency gas boiler
3 Excellent	[m².K/W]	8.7	8	8.3	Insulated	Triple wooden frame	Heat recovery	High efficiency gas boiler
4 Excellent+Triple	[m².K/W]	8.7	8	8.3	Insulated	Triple wooden frame	Heat recovery	High efficiency gas boiler

Table 1: Overview of the selected insulation scenarios.

After getting the outputs in terms of yearly gas consumption depending on the insulation scenarios, the 3rd step has been to define low resolution models (LRM) for a selection of RETs: PVs for electricity conversion, flat plate solar collectors (SC) for DHW , air source and ground source heat pump (ASHP) and (GSHP) for RH and DHW. The assumptions within the LRMs for RETs are: house orientation 45° southwest, tilt angle of the roof of 20°, a low temperature radiator system 45°C /35°C for room heating distribution, constant occupancy of two inhabitants per house. A selection of ESMs is included in the DST: heat recovery shower plate for reducing DHW consumption, electric stoves for cooking, stand-by killers for minimizing the electricity from appliances, smart meter and app for higher awareness which leads to a lower energy consumption [6]. Then, RET implementation was provided to be integrated in the buildings, to exploit the local available resources so that to achieve a high sustainability level [7]. An extra model was built for the estimation of thermal energy storage at neighbourhood level. With the support of the financial department of the company the 4th step, the financial LRM was built. In order to connect the mentioned steps to the needs of the users group, three different menus have been designed. All the LRMs for RETs have been validated with the results from broadly used softwares showing between 2% and 9% difference in outputs.

DATA SOURCES AND SYSTEM DESIGN

The geometry data of the component surfaces, actual energy bills and financial parameters are provided by the company. The LRM for EI and EL as well as ASHP, GSHP electricity consumption and Aquifer Thermal Energy Storage (ATES) are conforming to the NEderlandse Norm (NEN) 7120, Dutch legislation for calculating the energy performance in buildings. The energy conversion LRM was built in accordance with the guideline provided by the Sustainable Energy Authority of Ireland [8]. One option for the installation of flat plate SC has been calculated on the basis of the ESTIF standards [9]. Moreover, the prices estimation for the chosen insulation materials, the selected technologies and the ESMs is provided by Dutch national price lists for buildings [10]. Below the design per Menukaart is described and in the figures the required inputs per step and outputs are displayed. The menus will be accessed from the system Home page. In the *SL Menu* the user is invited to go through five steps (see *Figure 3*). The system shows the top three on 39 background combinations per selected strategy goal. Minimizing the energy bill for the tenant and the CO_2 production of the housing stock are the priorities two strategic scenarios called *Min* CO_2 and *Min Bill* were designed. Two further scenarios called *No Heat pump_Min Bill* and *No heatpump_Min* CO_2 were included since the deployement of heat pumps is not included in the commonly in SHCs renovation projects. The fifth and sixth strategic options called *ALL Electric_Min Bill* and *ALL Electric_Min* CO_2 provide the user with the option of avoiding the consumption of natural gas. No financial consequences are shown.

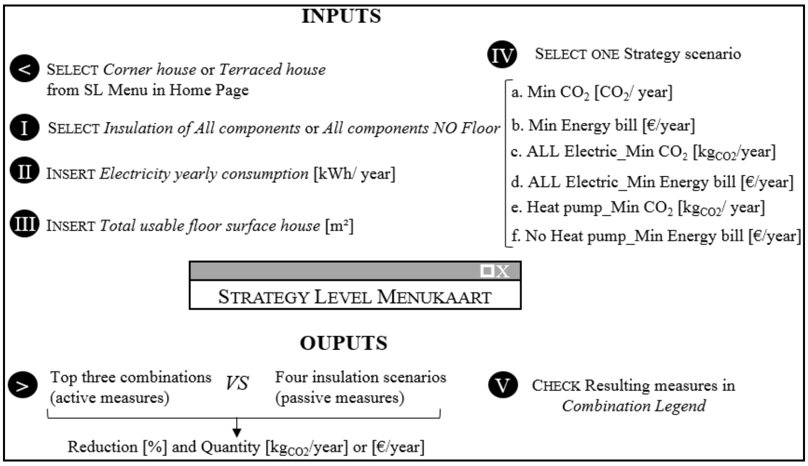

Figure 3: The steps involved in the SL Menu in Roman numerals are indicated.

While in the *SL Menu* average values are in the background data, in nine steps of the *HL Menu* the user can insert the specific geometry inputs per complex. Personalized combinations of ISs, ESMs and RETs can be chosen and the energy, environmental and financial consequences presented as outputs (see *Figure 4*).

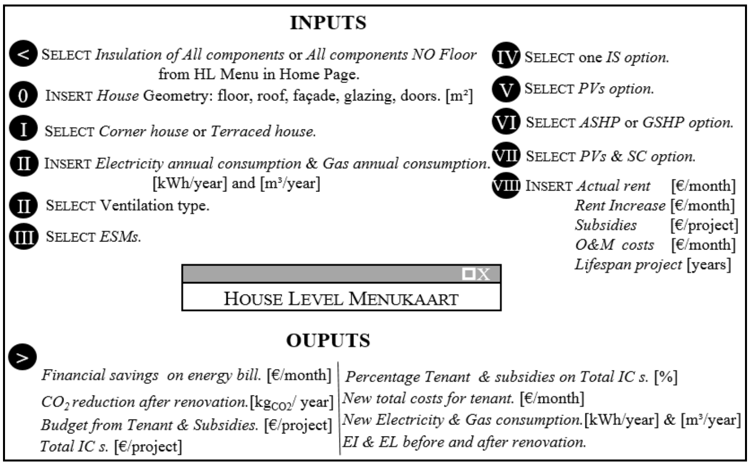

Figure 4: The steps involved in the HL Menu in Roman numerals are indicated.

The *NL Menu* (see *Figure 5*) offers to the user an estimation of the total investment and operational cost for ATES applicable in large scale projects which involve terraced houses and non-residential buildings in two steps: the number of houses, the annual heating and cooling demand of the buildings.

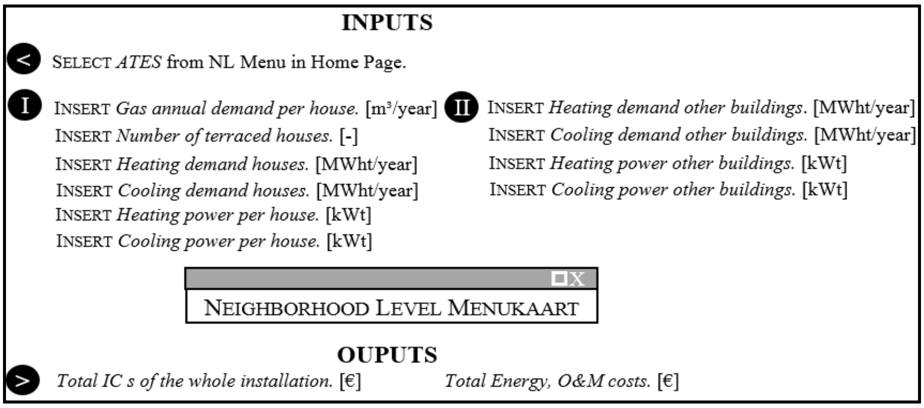

Figure 5: The steps involved in the NL Menu in Roman numerals are indicated.

CONCLUSION

System implementation: case study HL Menu

The DST for retrofitting projects in Dutch SHCs has been implemented in Microsoft Excel to guarantee the accessibility from all the employees of the company and avoid extra licence costs for the company. To have an overview of the possible results of a deep renovation of a corner terraced house in *Table 3* a summary of the choices made (in *italic*) is presented. The DST designed has been easily and successfully applied to all complexes with the same archetype, so the design requirements have been satisfied. The DST is still under development for other archetypes in the housing stock that one kind find in a housing corporation.

Steps	*Insulation ALL components*			
0 &1	Façade [m^2]	Roof [m^2]	Windows [m^2]	Doors [m^2]
	90	*43*	*15*	*4*
	Usable floor area [m^2]	*Corner House*		
	70			
2	Electricity consumption [kWh/year]	Gas consumption [m^3/year]	*Mechanical Ventilation*	
	3000	*1700*		
3	*Stand-by killers*	*Smart meter & Smart app*	*Heat recovery shower plate*	*Electric cooking*
4, 5,6 & 7	*Scenario 2_Good*	*ASHP_RH & DHW*	*18PVs + 1SC*	
8	Lifespan [years]	Actual Rent [€/month]	Rental increase [€/month]	
	25	*€ 450,00*	*€ 70,00*	
	Subsidies [€/project]	Maintenace costs [€/month]	Operating costs [€/month]	
	€ 2.000,00	*€ 100,00*	*€ 100,00*	
Results				
Financial savings on bill [€/month]	New Electricity consumption [kWh/year]	New Gas consumption [m^3/year]	New total costs for tenant [€/month]	Total *IC s* [€/project]
€ 120,00	*1247*	*152*	*€ 520,00*	*€ 23.500,00*
Tenant & subsidies	Tenant & subsidies [%] on *IC s*	CO2 reduction [%]	EL before	New EL
€ 15.326,00	*65%*	*78%*	*D*	*A++*

Table 2: HL Menu case study for a corner terraced house deep retrofitting.

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