MORE-CONNECT
Development and advanced prefabrication of innovative, multifunctional building envelope elements for MOdular REtrofitting and CONNECTions (No. 633477)

D4.2 - Digitised tool for Modelling building and performance characteristics

MORE—
CONNECT

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1. Introduction

In the framework of the MORE-CONNECT project, a number of tools and methodologies have been developed in Work Package 3 that supports and accelerates the number of renovations in Europe by making the renovation process more user friendly and attractive for its (end) users. Specifically, the 'Tool to optimize the combined energy and materials performance of the alternative configurations in relation to local typologies' (D3.2 and D3.4) can support the decision making on renovation concepts, especially the optimization between operational energy, embodied energy, costs and the use of the available roof surface for energy production.
Work package 3 also contains a report on 'Platforms for (aesthetic) configurations and user/owner options within the basic elements configuration and within performance criteria' including a methodology for a morphological design approach for deep renovation.
This methodology is supported by a digitised tool for modelling building and performance characteristics, based on different renovation scenarios.
The tool is focused and organised with two different end users in mind. The first and most important target group is home owners, considering a renovation of their homes. The second target group consists of third party developers, concept developers and suppliers. Besides these two target groups, the tool is also mentioned to be used by the partners in the MORE-CONNECT project and beyond.

There are two user groups identified for which this tool is intended:

- Building users and owners

First of all, the tool, as developed in task 4.2, is dedicated to house owners, to support decision making for the renovation of their homes. Once there is an initial interest of a house owner for renovation, the tool is presented to house owners as it gives them an easy to use, attractive digitised tool making them understand actual potential energy saving and renewable generation potential on the site they will gain when considering certain renovation scenario.
Home owners can model, without a need of professional/expert guidance, different building renovation scenarios. For example, improvement of insulation of building envelope, improvement of Indoor Environmental Quality, by different ventilation strategies and systems, possible renewable energy generation on the site. In this way home owners get a first-hand experience and understanding about the estimated potential energy savings (compared to the current state) and needed investment connected with these renovation measures. Furthermore return of investment can be assessed if all data is available. By evaluating possible renewable integration, a user can evaluate how self-sufficient he can be in terms of energy generation on the site (solar).

- Third party developers, concept developers and suppliers

This target group can use this tool by adding their concepts and/or products, to show the consequences to their clients in terms of, for example, investment costs versus savings and added qualities.

A first objective of the tool is to get the public more aware about energy use and potential improved energy efficiency of buildings. Informing the public by giving a clear insight in potential savings can have a large impact on the reduction of energy consumption and CO2 emissions. in addition, the local potential of renewable energy production for home owners will drive the energy transition even further. Although there is a lot of information available in the EU there are not many end-user oriented. user friendly, non-to technical method of informing the general public about the necessary improvements to achieve higher energy efficiency in buildings and in nearly zero energy buildings following the requirements of the recast of the Energy Performance of Building Directive (2010/31/EU).

This report also explains briefly the development process, structure of the final tool (Excel tool), the products used in the database for the Dutch tool and possible modification of the tool according to the other countries legislation and manufacturer databases.

A second objective of the tool is to bridge the gap between an end-users wishes and understanding of the renovation process and sophisticated design process normally led by architects and engineers. With this tool, in combination with the tool in D3.2, it is possible to choose the most suitable optimal renovation scenarios (based on improved performance characteristics) with the end-users' approval and positive involvement which this in the end leads to the selection of a renovation configuration as input for task 4.2, the translation in BIM. It should be noted that the balance was sought between the accuracy and detailed calculation and user-friendliness. Also an inventory has been developed for the wishes of the end-user. These wishes can be translated into a program for seceding and producing the concept. The elements should be tooled to provide the optimal performance between reduction of energy demand and production of renewable energy, taking into account both the energy consequences as well as the material impacts the materials impacts as well. Important is the insulation level thickness and composition, in relation to the amount of energy production conversion devices, in terms of energy and material impacts, to comply with not only the energy efficiency strategies of the EU but as well, the resource efficiency strategy targets set by the EU.
On the constructive side a basic concept for the elements load bearing and connecting details will be developed in order to guarantee the performance of the system , constructively, but also energetically (air-tightness).

The tool covers the following topics:

- Insulation
- Ventilation
- PV Panels (Photovoltaic)
- Collectors (Thermal Solar Panels)
- Heat pumps

These improvements will be the most common in the near future to achieve the high targets set by the EU and the ever-stricter laws to reduce CO_2 emissions. The main focus as stated above is to give home owners better understanding of the necessary energy improvement. With that in mind the tool will bridge the gap between the energy specialist and the general public. Although the calculations are as close as possible to the real world, to realise this bridge there is an unavoidable compromise between accuracy and user-friendliness. The user Is required to specify their personal housing situation. the results will show an estimated amount of energy that can be saved or sustainably produced as well as the potential financial benefits.
The second focus group are the partners of the project and interested businesses in the EU. For this group, the tool will form a base on which they can improve or build a version of their own. For instance, an insulation company can change the values according to their own product range. So that customers can get an insight in the potential savings with that specific type of insulation. Furthermore, the default values concerning the prices and available systems are designed to fit the Dutch market. So, for the tool to work in other member states of the EU these values will need to be adjusted depending on the market.

2. User manual

The tool is designed in such a way that anyone that is interested in improving the energy efficiency of their home won't be overwhelmed with calculations and technical definitions. The user will only have to deal with the first sheet called "MC2020". All the values and calculations are situated on the other sheets and run in the background.
To start, the user has to fill in the first table to specify the current housing situation called "Housing Situation". Within this table there are three subcategories: Current housing situation, Technical aspects and energy consumption shown in figure 1. On the left side of the table are the different categories to which the user needs to fill in the values on the right. The more accurate the user is with filling in the values the more accurate the results will be. In the default setting the values are 0 or the first choice of the dropdown menus.

HOUSING SITUATION	Current housing situation	
	Residents	1
	Type of house	Duplexwoning
	Construction year	1965 - 1974
	Country	Netherlands
	Providence	Limburg
	Technical Aspects	
	Desired indoor climate [ºC]	21
	Living area [m²]	0
	Ceiling height [m]	0
	Availaible roof surface [m²]	0
	Window surface [m²]	0
	Current type of wall insulation	Single wall
	Current type of window	Single glazing
	Current type of roof insulation	No insulation
	Heat distribution	Air distribution
	Current type ventilation	system A - natural air supply and exhaust
	Energy consumption	
	Electrical [kWh]	0
	Gas [m³]	0

FIGURE 1: SCREENSHOT OF THE FIRST TABLE OF THE EXCEL TOOL

Once the user has specified the current situation the next step will be to specify the new and improved situation. The table below is dedicated to heat loss which means it will feature insulation and ventilation (shown in figure 2).

HEAT LOSS	Transmission - insulation	
	New type of wall insulation	Single wall
	New type of glass	Single glazing
	New type of roof insulation	No insulation
	Cost of insulation investment [€]	0,00
	Ventilation	
	New type of ventilation	NO IMPROVEMENT
	Cost of ventilation investment [€]	0,00

FIGURE 2: SCREENSHOT OF THE SECOND TABLE OF THE EXCEL TOOL

The user can make an choice in the drop down menus. to give an example, in figure 1 the user can fill in the desired type of improved wall insulation. Depending on the specific housing situation the tool will give a potential energy and financial saving. If the user already has requested an offer and knows the investment cost to implement the change the user can include this to show the return of investment (ROI).

HEAT LOSS	Transmission - insulation	
	New type of wall insulation	Single wall
	New type of glass	Single glazing
	New type of roof insulation	ulation
	Cost of insulation investment [€]	,00
	New type of ventilation	NO IMPROVEMENT
	Cost of ventilation investment [€]	0,00

- Single wall
- Air cavity wall
- Insulated cavity wall (±60mm)
- Insulation according to bouwbesluit 2012
- Insulation according to BENG-norm

FIGURE 3: SCREENSHOT OF THE THIRD TABLE OF THE EXCEL TOOL

In the next table the user has the option to incorporate renewable energy production in the form of photovoltaic solar panels, heat pump or Collectors. for the photovoltaic panels as seen below the user has to specify four variables. and is able to – if known – specify the investment cost to show the ROI.

NEW ENERGY	Solar Panels - electrical	
	Roof direction	East
	Roof gradient	50 + degrees - very steep
	Shading	No shadow
	Number of panels by roof surface	20
	Select solar panel	240
	Cost of solar panel investment [€]	0,00
	Solar Panels - thermal - domestic water	
	Type of bathroom	Shower
	Type of thermal solar installation	1 collector, 120L buffer
	Cost of solar panel investment [€]	0,00
	Heat Pump - thermal	
	Type of heatpump	
	Power of heatpump	
	COP heatpump	
	Cost of heatpump investment [€]	

FIGURE 4: SCREENSHOT OF THE FOURTH TABLE OF THE EXCEL TOOL

After all the desired improvements are filled In, the results will be and shown in the top right table. Meaning the energy and financial savings off all the five topics will be calculated. If the user has no interest in for example one or more of the topics, he/she can leave it blanc. The tool will only incorporate the specified variables. The end result will be a complete picture of the potential energy and finical savings.

3. The Tool

This chapter will further explain how the tool is built, which equations are used and how to change or implement desired values.

3.1 Heat losses

Heat losses can be limited by limiting both transmission losses and ventilation losses. Transmission losses can be limiting by adding and/or improving thermal insulation. Ventilation losses can be limited by better, more efficient ventilation systems, heat recovery, demand controlled ventilation and improving the air tightness..
After specifying the users housing situation, they can make the a selection of possible measures. The tolls offers following measures:

- Wall insulation
- Improved windows/glazing
- Roof insulation
- Ventilation systems

The topics Wall, Window and roof are calculated with the same equation explained below. The topic ventilation uses a slightly different equation but with the same principle in mind.

3.1.1 Transmission losses

Transmission loss is the heat transfer through the outer shell of a building. The higher the heat resistance the better the shell is in trapping the heat in the building. This can be expressed with the following equation (1) (E.Curfs, 2017)

$$= \tag{1}$$

Where:

Q = Transmission loss (W)
U = The overall heat transfer coefficient (W/(m²K))
A = Surface area where the heat transfer takes place (m²)
ΔT = Temperature difference between outside and inside

High heat resistance of a material or wall is determent by three factors. The first is the overall heat transfer coefficient of the material. The lower the U-value the better the building will be insulated. The overall heat temperature coefficient is expressed with the following equation:

$$U = \frac{1}{R} \tag{2}$$

Where:

U = The overall heat temperature coefficient (W/(m²K))
R = the heat resistance per unit of exposed area ((m²K)/W)

The R value is a measure of how well an object, per unit of its exposed area, resists conductive flow of heat. The greater the R-value, the greater the resistance, and so the better the thermal insulating properties of the object. R-value is used in describing effectiveness of insulation and in analysis of heat flow across assemblies (such as walls, roofs, and windows) under steady-state conditions.

$$R = \frac{t}{\lambda} \tag{3}$$

Where:

t = Thickness of the material (m)
Labda = thermal conductivity (W/mK)

3.1.2 Ventilation losses

The heat loss due to ventilation can be expressed with the following equation:

$$\Phi v = \rho * qv * fv * (\theta i - \theta e) \quad (4)$$

where

Φ_v = ventilation heat loss (W)
ρ = density of air (kg/m³)
fv = correction factor for higher incoming temperature than outside temperature (heat recovery)
q_v = air volume flow (m³/s)
θi = inside air temperature (°C)
θe = outside air temperature (°C)

To give a reliable outcome for the ventilation losses the losses will be calculated according to the specified living area. The amount of people or the different types of room will not be taken in consideration. This will only compromise the user-friendliness. (To give an example, usually the kitchen area requires a higher ventilation factor than a living room).

3.2 Renewable energy

The user has the possibility to apply renewable energy production. The tool gives an insight in these topics:

- Photovoltaic panels
- Thermal Solar Collectors

3.2.1 Photovoltaic panels

Photovoltaic panels produce electricity, in the most ideal situation the installed system can offset the total consumption of the house. The amount of solar panels will depend on specified electricity use or the available roof surface. If the roof surface will not support this amount of panels the tool will show the maximum amount of panels that fit on the roof.
The tool is developed for the Netherlands. So to calculate the energy production possible with solar panels empirical data from the Netherlands is used. To calculate the production the following equation is used (5):

$$E = A * Wp * fp\ (* fg * fs * fd) \quad (5)$$

E = yearly energy production (kWh)
A = Amount of solar panels
Wp = the nominal output of the module under standard test conditions (W)
f_p = empirical factor depending on the amount of radiation hitting the panels (Wp/kwh conversion) (p= providence)
f_g = factor depending on which slope the panels face the sun (g= gradient)
f_s = factor depending on the amount of shadow that is casted over the panels (s=shadow)
f_d = factor depending on the orientation of the roof or panels (d=direction)

The factor f_p is empirical, meaning it is derived for real world data (SolarCare, 2017). The factor is a conversion form Wp to kWh depending on the location in the Netherlands. This gives the possibility to use the total Wp of the system and calculate the possible yearly production in kilowatt-hours. The illustration bellow shows the f_p factor of the Netherlands.

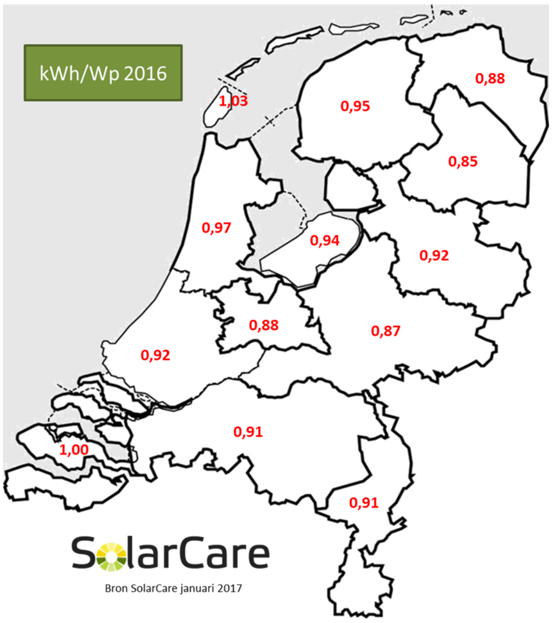

FIGURE 5: MAP FROM SOLARCARE SHOWING THE KWH/WP 2016 PER PROVIDENCE IN THE NETHERLANDS

The factor f_g is the gradient factor. This means the angle the panels have in respect to horizontal. A slope of 0° corresponds to horizontal and a slope of 90° corresponds to vertical. The optimal slope for fixed systems is 30° to 35°. the table below shows the options users can choose on the left and the corresponding values on the right. These values are derived from the table of Hespul (appendix A)

Gradient	
50 + degrees - very steep	0,93
40 degrees - steep	1
30 degrees - conventional	1
20 degrees - low slope	0,98
0-10 degrees - flat roof	0,9

TABEL 1: VALUES USED TO CALCULATE PV-PANEL PRODUCTION DERIVED FROM THE TABLE OF HESPUL

The factor f_s is determent by the amount of shadow over the system. the more shadow the more production loss will occur. As shown in the table below the user can choose between four options form 'No shadow' to 'High amount of shadow' depending on the situation.

Shadow	
No shadow	1
Small amount of shadow	0,9
Medium amount of shadow	0,8
High amount of shadow	0,65

TABEL 2: SHADOW FACTOR USED TO CALCULATE THE PRODUCTION OF PV-PANELS

The factor f_d is the orientation factor. The sun comes up in the east and sets in the west. For an optimal production the panels need to be oriented towards the south. Iff the panels are facing an north direction the radiation off the sun will hit the panel at an angel and there will be a greater inefficiently. The user can choose six directions with the corresponding factors.

Roof direction	
East	0,93
South-East	0,93
South	1
South-West	1
West	0,77
North	0,72

TABEL 3: DIRECTION OF THE ROOF

3.2.2 Thermal Solar Collectors

Thermal Solar Collectors collect the infrared radiation from the sun. this radiation, also known as heat, is transfer to a hot water tank so I can be used as domestic water later on. This system can reduce the amount of natural gas or electricity used to heat up domestic water.

Solar Panels - thermal - domestic water	
Type of thermal solar installation	NO IMPROVEMENT
Type of bathroom	Shower + bath
Cost of collector investment [€]	0,00

After choosing the number of residents the tool automatically adjusts itself for type of thermal collectors. In this situation, there is selected that there will be 4 residents housing.

RENEWABLE ENERGY	Solar Panels - electrical	
	Roof direction	South
	Roof gradient	20 degrees - low slope
	Shading	No shadow
	Number of panels by roof surface	25
	Select solar panel	NO IMPROVEMENT
	Cost of solar panel investment [€]	0,00
	Solar Panels - thermal - domestic water	
	Type of thermal solar installation	NO IMPROVEMENT NO IMPROVEMENT 3 collectors, 200L buffer 3 collectors, 300L buffer
	Type of bathroom	
	Cost of collector investment [€]	
	Type of heatpump	no heatpump
	Power of heatpump	no heatpump
	COP heatpump	0
	Cost of heatpump investment [€]	0,00

The Type of bathroom can be chosen as next.

RENEWABLE ENERGY	Solar Panels - electrical	
	Roof direction	South
	Roof gradient	20 degrees - low slope
	Shading	No shadow
	Number of panels by roof surface	25
	Select solar panel	NO IMPROVEMENT
	Cost of solar panel investment [€]	0,00
	Solar Panels - thermal - domestic water	
	Type of thermal solar installation	3 collectors, 200L buffer
	Type of bathroom	Shower + bath Shower Shower + bath Rainshower + bath
	Cost of collector investment [€]	
	Type of heatpump	no heatpump
	Power of heatpump	no heatpump
	COP heatpump	0
	Cost of heatpump investment [€]	0,00

The calculation for the Collectors are made with 5 parameters. These are:

- Roof Gradient – flat or slope
- Roof direction – as chosen in Solar Panels – electric
- Residents – as chosen in first menu
- Type installation – as described above
- Type bathroom – as described above

The value of gas savings is determined on information by the manufacturer HR Solar.

Residents	Bathroom	Gradient	Direction	Installation	M3
1	sh	flat	x	1+120	74
1	sh	flat	x	2+120	82
1	sh	slope	e	1+120	58
1	sh	slope	e	2+120	65
1	sh	slope	se	1+120	68
1	sh	slope	se	2+120	75
1	sh	slope	s	1+120	74
1	sh	slope	s	2+120	82
1	sh	slope	sw	1+120	71
1	sh	slope	sw	2+120	79
1	sh	slope	w	1+120	61
1	sh	slope	w	2+120	67
1	sh	slope	n	1+120	42
1	sh	slope	n	2+120	47
1	bt	flat	x	1+120	95
1	bt	flat	x	2+120	109

**this is just a small part of the total table*

3.3 Heat pumps

Heat pumps are an ever-emerging technology used to replace traditional, coal and gas burning, heating systems. A heat pump extracts heat out of its surroundings and stores it in a hot water tank. That hot water is then in turn used to heat up the house. the system only uses electricity and no natural gas or coal. If the electricity is renewably sourced the whole system doesn't use any CO_2. The tool lets the user choose systems ranging from 4,4 kW till 16 kW. after the user made a choice the tool incorporates the additional electricity used in the end results, and more importantly, the natural gas saved by the system is also visible in the results.
For renovation often air/water heat pumps are used (as these are easy to install), However also water/water heat pumps in combination with ground collectors are used.

Prefab HVAC platforms with air-water heat pumps

Prefab HVAC platforms with water-water heat pumps

For example, in the Netherlands, heat pumps in combination with (large surfaces of) PV are a standard option in the so called NOM (zero-on-the-meter) renovation concepts.

References

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Appendix

Oost — Zuid — West

Hellingshoek

	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	
0	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	0
5	88	88	89	89	89	90	90	90	91	91	91	91	91	91	91	91	91	92	92	92	91	91	91	91	91	91	91	91	90	90	90	91	91	91	90	89	89	5
10	89	90	91	91	91	92	92	93	94	94	94	95	95	95	95	95	95	96	96	96	95	95	95	95	95	95	94	94	94	93	93	93	92	91	91	90	90	10
15	88	89	90	91	92	93	93	94	95	95	95	96	96	96	97	97	97	97	97	97	97	97	97	96	96	96	95	95	95	94	94	93	92	91	91	90	89	15
20	87	88	89	90	91	92	93	94	95	96	96	97	97	97	98	98	98	98	98	98	98	98	98	97	97	97	96	96	96	95	94	93	92	91	90	89	88	20
25	87	88	89	90	91	92	93	94	95	96	97	98	98	99	99	99	99	99	99	99	99	99	99	98	97	97	97	96	96	95	94	93	92	91	89	88	87	25
30	86	87	88	89	90	92	93	94	95	96	97	98	98	98	99	99	99	100	100	100	100	100	100	99	98	98	97	96	96	95	94	93	91	90	89	87	86	30
35	84	85	87	88	89	91	92	93	95	96	97	98	98	98	99	99	99	100	100	100	100	100	100	99	98	98	97	96	95	94	93	92	90	89	88	86	85	35
40	82	83	85	86	87	89	90	92	94	95	96	97	97	98	99	99	99	100	100	100	99	99	99	98	98	98	97	96	95	93	92	91	89	88	87	85	84	40
45	80	82	84	85	86	88	89	91	93	94	95	96	96	97	98	98	98	99	99	99	98	98	98	97	97	96	95	95	93	92	91	89	88	87	85	84	82	45
50	78	80	82	84	85	87	88	89	91	92	93	94	95	95	96	96	96	97	97	97	97	97	97	96	96	95	94	93	92	90	89	88	86	85	84	82	80	50
55	76	78	80	82	83	85	86	87	89	90	91	92	93	94	94	94	95	95	95	95	95	95	94	94	93	92	91	90	89	88	86	85	83	82	80	78	78	55
60	74	76	78	79	81	83	84	85	86	87	88	89	90	90	91	91	92	93	93	93	93	93	93	92	92	91	90	89	88	87	86	85	83	81	80	78	76	60
65	72	74	76	77	78	80	81	82	84	85	86	87	88	88	89	89	89	90	90	90	90	90	90	89	89	88	87	87	85	84	83	82	80	79	77	75	73	65
70	69	71	73	74	75	77	78	79	81	82	83	84	85	85	86	86	86	87	87	87	87	87	87	86	86	86	85	84	83	81	80	79	77	76	74	72	70	70
75	66	68	70	71	72	74	75	76	78	79	80	81	81	82	83	83	83	84	84	84	84	84	84	83	83	82	81	81	79	78	77	76	74	73	71	69	68	75
80	63	65	67	68	69	71	72	73	74	75	76	77	77	78	79	79	79	80	80	80	80	80	80	79	79	79	78	77	76	75	74	73	71	69	68	66	65	80
85	60	61	63	64	65	67	68	69	70	71	72	73	73	74	75	75	75	76	76	76	76	76	76	75	75	75	74	73	72	71	70	68	67	66	64	63	62	85
90	56	57	59	60	61	63	64	65	66	67	68	69	69	70	71	71	71	71	71	71	71	71	71	71	71	71	70	69	68	66	65	64	63	62	61	59	58	90
	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	

De Tabel van Hespul