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Computer-aided supporting tool for LCA evaluation of energy efficiency of the buildings – assessment method and case studies

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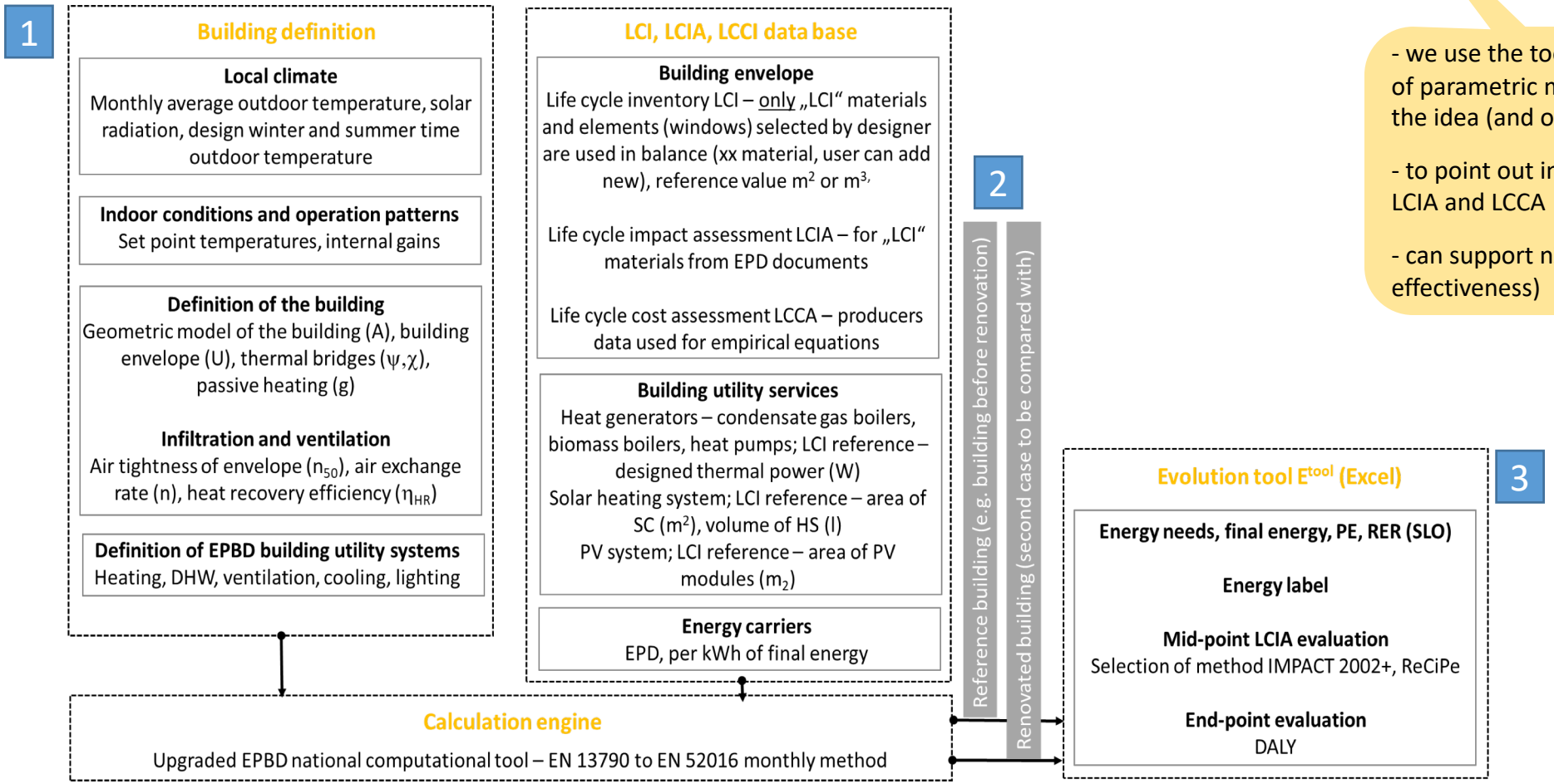
Modest attempt to bring LCA to students and engineering practice to promote the potential of the BIM.

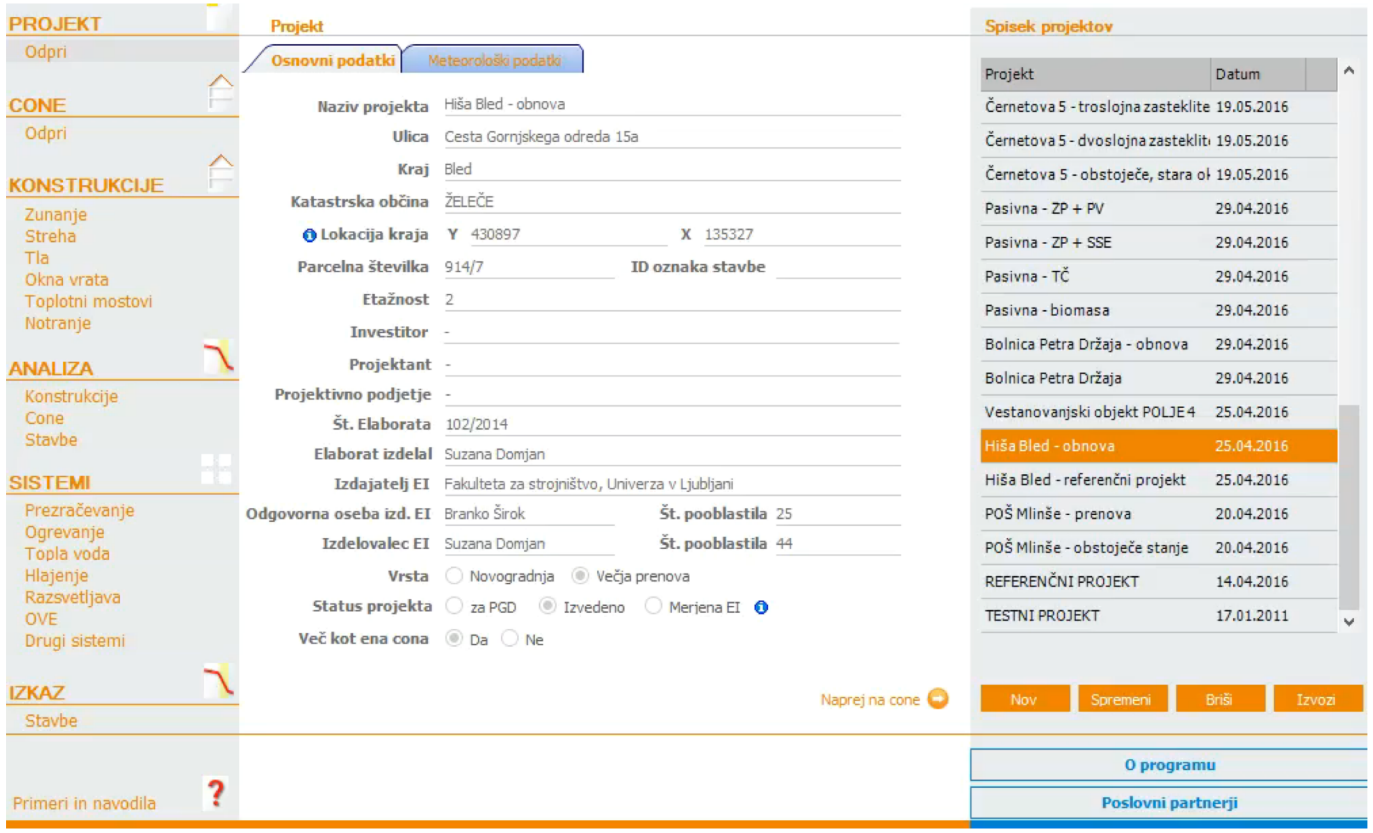
Computer tool (E^{tool}) for LCA assessment includes: LCE(energy)A, LCI(environment)A and LCC(cost)A indicators.

Consists of three modules:

yet another ?

- we use the tool to show the advantages of parametric modelling and spreading the idea (and open questions) of LCA
- to point out interconnectivity of LCEA, LCIA and LCCA
- can support nZEB criteria's (cost effectiveness)





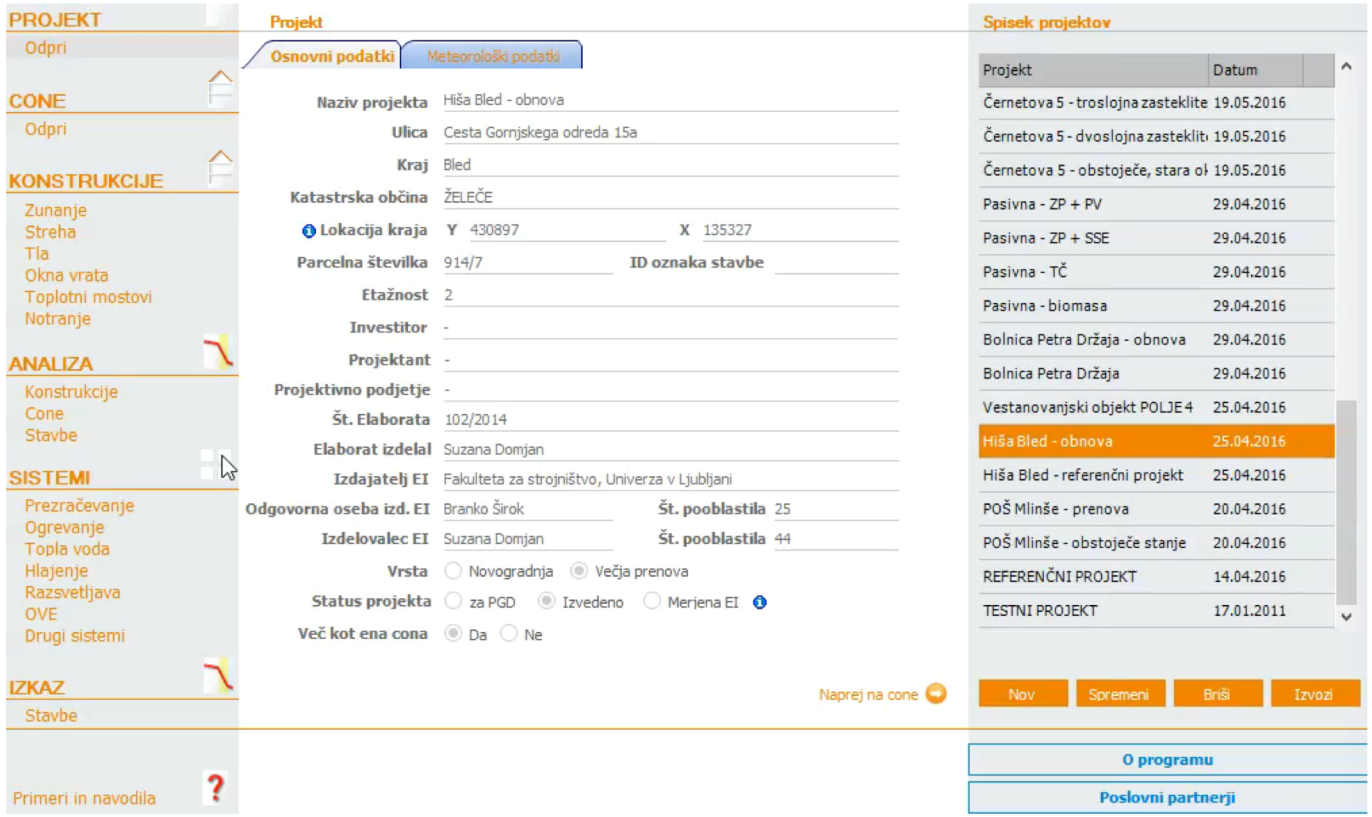
Reference (i.e. before renovation) and current building are evaluated at the same time.

1 Building description

Each building structures **can** consist one or more LCA layers.

Windows and doors **can** also be marked as LCA element.

Meanwhile LCEA will be performed for any building, only elements marked as „LCA“ will be taken into account in LCIA and LCCA.



1 Building description

Elements of building service systems can also be marked as „LCA“ elements.

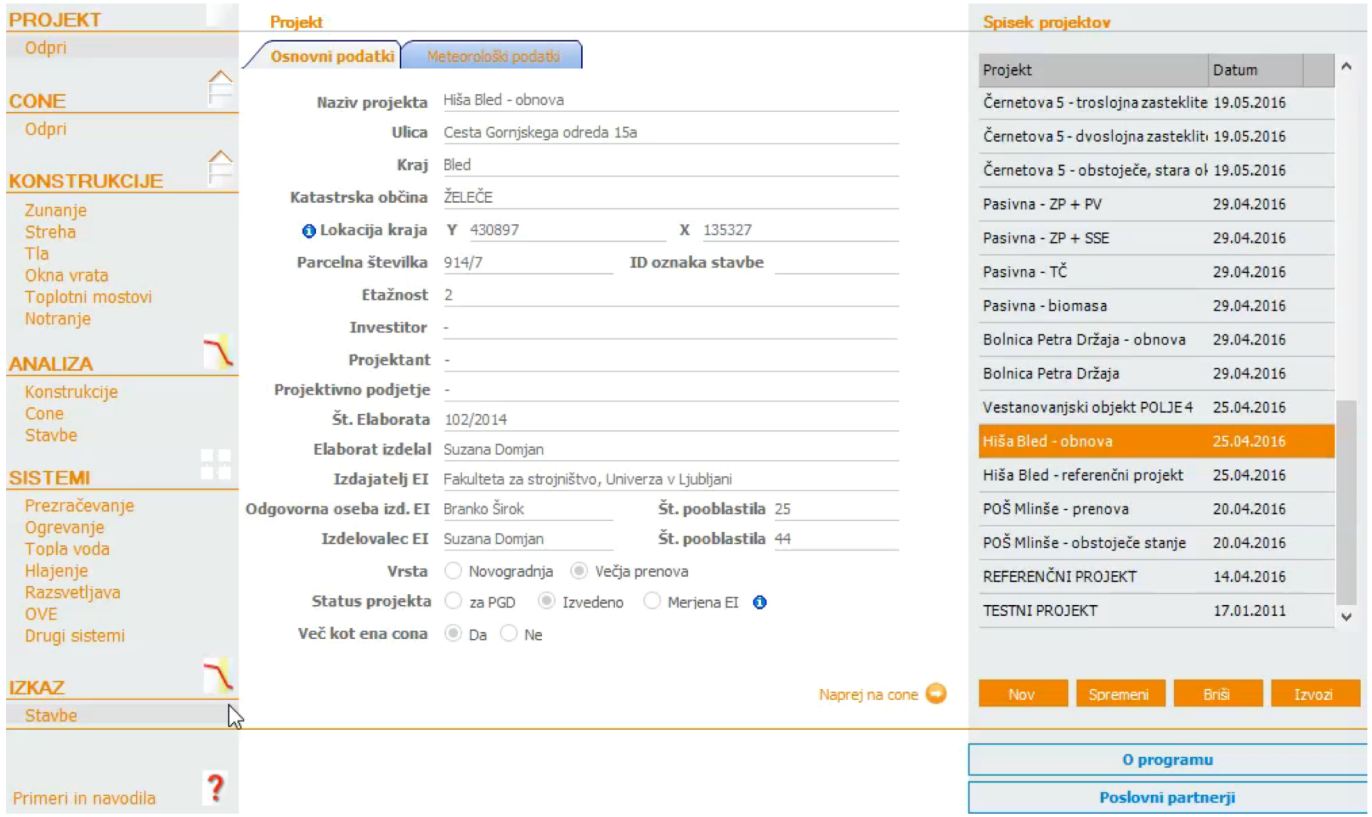
- biomass boilers,
- gas condensate boilers,
- oil boilers,
- HP (geosonde-W, S-W, W-W, A-W),
- SC (flat, vacuum) and
- PV (mono, poly, CdTe, CuInGaSe) and

- water heat storage.

Generic LCA data of energy carriers is used except for the electricity, for which local distributer can be selected

There is a large difference in Environment Product Data among distributors in SLO.

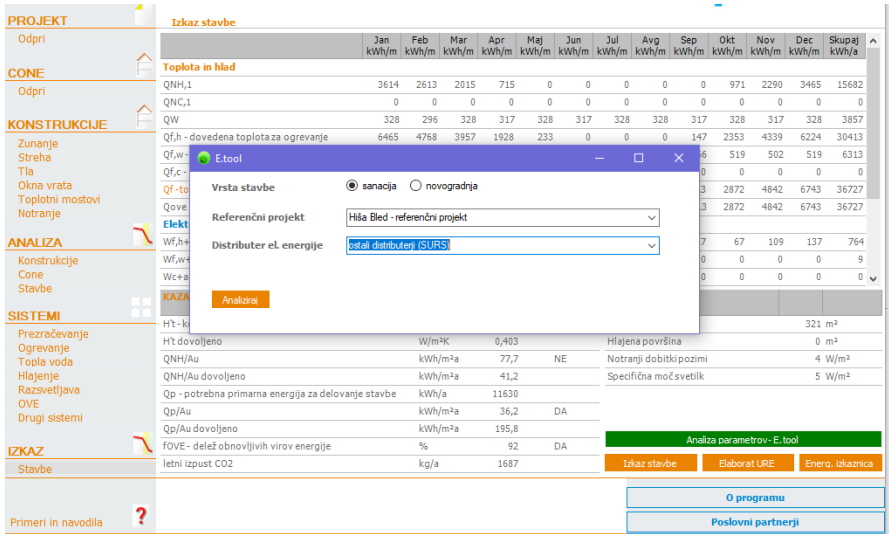
After the description of the building is completed, following will happened:



2 Using Taguchi matrix L50, the **energy needs** for heating $Q_{h,nd}$ and cooling $Q_{c,nd}$ ae determined in 50 loop simulations

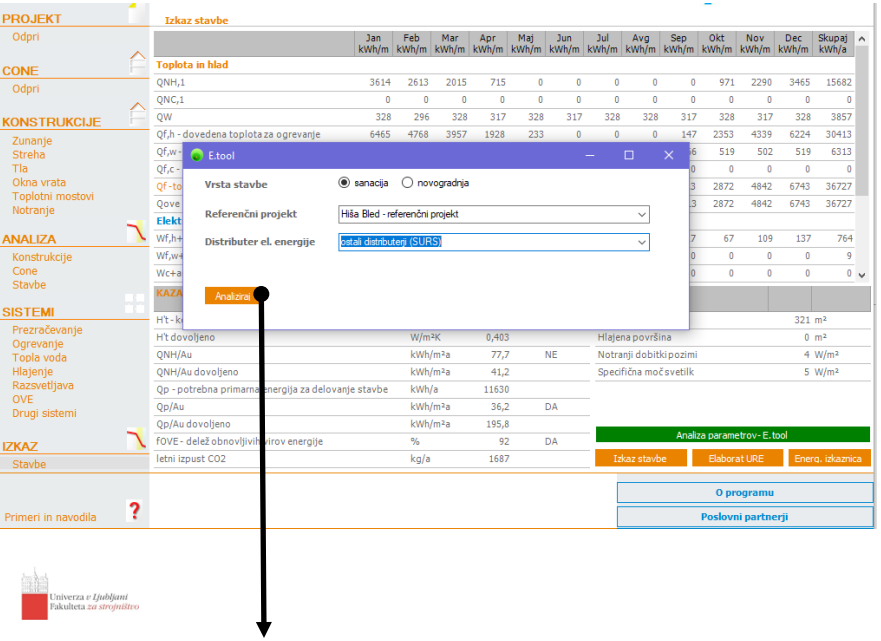
One of two Taguchi matrix: for new and renovated building can be selected; this one is for new buildings

Parameters (12)	Levels (5) – new buildings				
Degree days (DD Kday/y)	two levels (for reference and designed building)				
Thermal transmittance of walls structures (U W/m²K)	0.08 (2/7 U_{max})	0.14 (1/2 U_{max})	0.20 (5/7 U_{max})	0.24 (6/7 U_{max})	0.28 (U_{max})
Thermal transmittance of roof structures	0.07 (2/7 U_{max})	0.10	0.143	0.171	0.20 (U_{max})
Thermal tran. of structure in contact with ground	0.07 (2/7 U_{max})	0.10	0.143	0.171	0.20 (U_{max})
Thermal transmittance of windows and doors	0.46 (2/7 U_{max})	0.80	1.14	1.37	1.60 (U_{max})
Total solar transmittance of glazing (g)	0.65	0.55	0.45	0.35	0.25
Thermal bridge impact factor (ΔU W/m_2K)	0	0.03	0.06 (suggested)	0.08	0.10
Air tightness of envelope (n_{50} h^{-1})	0.6 (PHPP)	1.0	2.0 (n_{50} max)	2.5	3.5
Heat recovery of ventilation system (η_{hx} -)	0.40	0.65	0.85	0.90	0.95
Set point temperature for heating ($T_{i,h}$ °C))	18	19	20	22	24
Internal heat gains (W/m²)	0	2	4 (suggested)	6	8
Air exchange rate (n h^{-1})	0.38	0.5 (minimum)	0.8	1.0	1.2



Final energy demand per energy carriers is determined for both current and reference building, taking into account user defined data.

Embodied energy in LCA elements is determined.



2 Beside energy demand related data, following data are **exported to E^{tool}:**

Quantity of each **LCA material** are summarized and EPD data are exported to the next step of evaluation, weighted by m^3 or m^2. EPD data include basic indicators only (GWP, ODP, AP, EP, POCP, ADPE, ADPF (MJ)). Mostly from Ökobaudat, Environdec EPD Database, producer supplied data or research articles (for building services)

EPD Data for **LCA windows and door** are exported.

EPD data of **LCA building systems** are exported. Data are weighted by design heat load (kW,), area (m^2: SC, PV) and volume (HS). EPD data are determined by approximation polynomials:

$$ODP_{gen} = a_{0,gen} + a_{1,gen} \cdot P_{gen} + a_{2,gen} \cdot P_{gen}^2 \quad (kg\ CFC\ 11_{eq})$$

$$ODP_{sol} = 1.25 \cdot a_{1,sol} \cdot A_{sc} (kg\ CFC\ 11_{eq})$$

$$ODP_{hs} = a_{0,hs} + a_{1,hs} \cdot V_{hs} + a_{2,hs} \cdot V_{hs}^2 \quad (kg\ CFC\ 11_{eq})$$

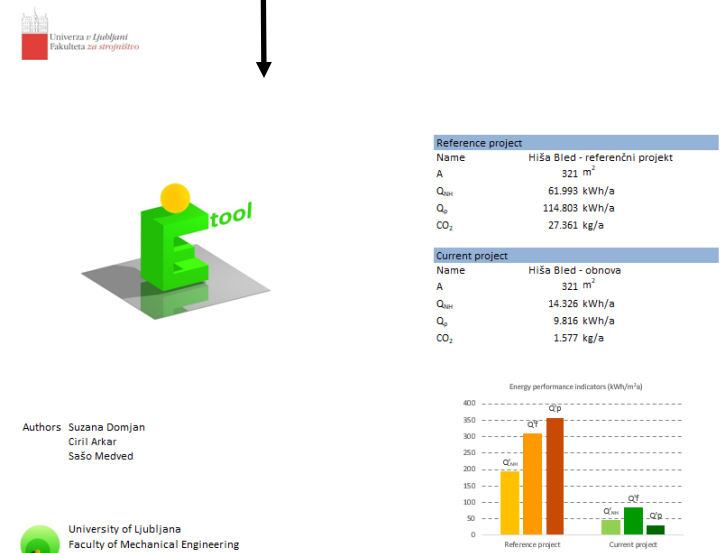
$$ODP_{pv} = a_{1,pv} \cdot A_{pv} \quad (kg\ CFC\ 11_{eq})$$

LCA EPD data of **energy carriers** based on defined building service systems are exported. (probably this will be the only data for reference project).

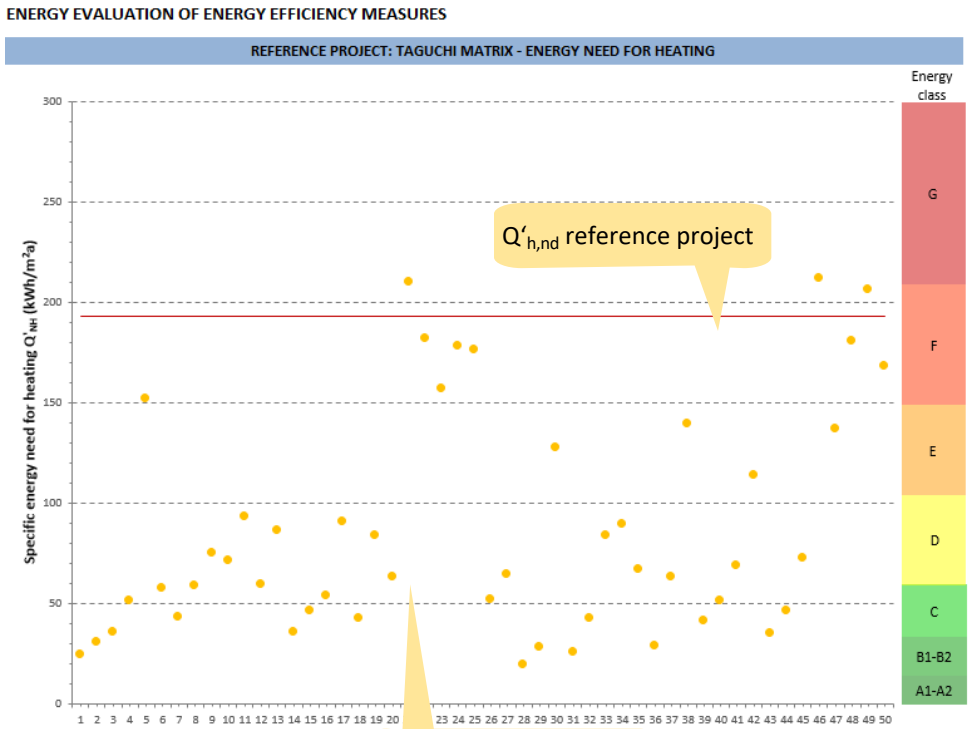
LCC data are exported for „LCA“ elements based on market cost of energy caries or approximation models for LCA elements.

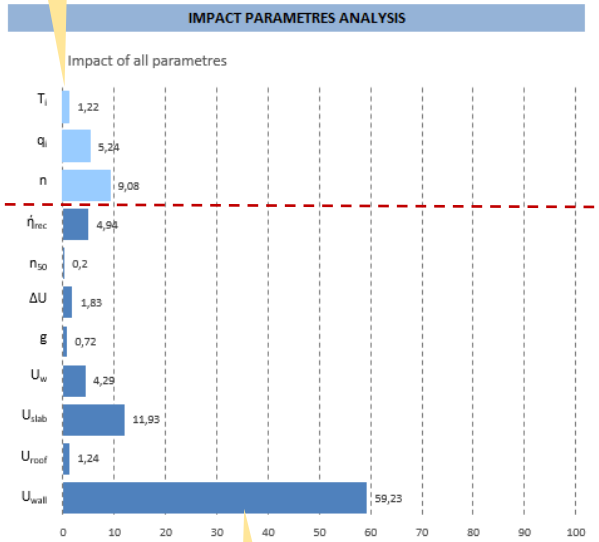
Heat generator - wood chips				
kW		**a2,gen**	**a1,gen**	**a0,gen**
GWP	kg eq CO2	0,028	1,272	1566,316
ODP	kg eq CFC11	2,74E-13	1,24E-11	6,42E-08
AP	kg eq SO2	1,03E-04	4,67E-03	7,161
EP	kg eq (PO4)3-	9,27E-06	4,18E-04	0,601
POCP	kg eq eten	1,45E-05	6,64E-04	0,768
ADPE	kg Sb	2,33E-09	7,37E-08	0,054
ADPF	MJ	0,319	14,443	18151

Heat generator - kondens.				
kW		**a2,gen**	**a1,gen**	**a0,gen**
GWP	kg eq CO2	0,0035	10,166	618,4
ODP	kg eq CFC11	-1,00E-13	6,00E-10	6,00E-08
AP	kg eq SO2	5,00E-06	4,86E-02	3,6074
EP	kg eq (PO4)3-	6,00E-07	4,00E-03	0,2837
POCP	kg eq eten	1,00E-06	4,10E-03	0,2605
ADPE	kg Sb	9,00E-07	1,60E-03	0,0835
ADPF	MJ	4,33E-02	1,25E+02	7548,7



this is how occupant behaviour influence the energy demand for heating (i.e. the way how the buildings is ventilated has highest impact on energy demand for heating

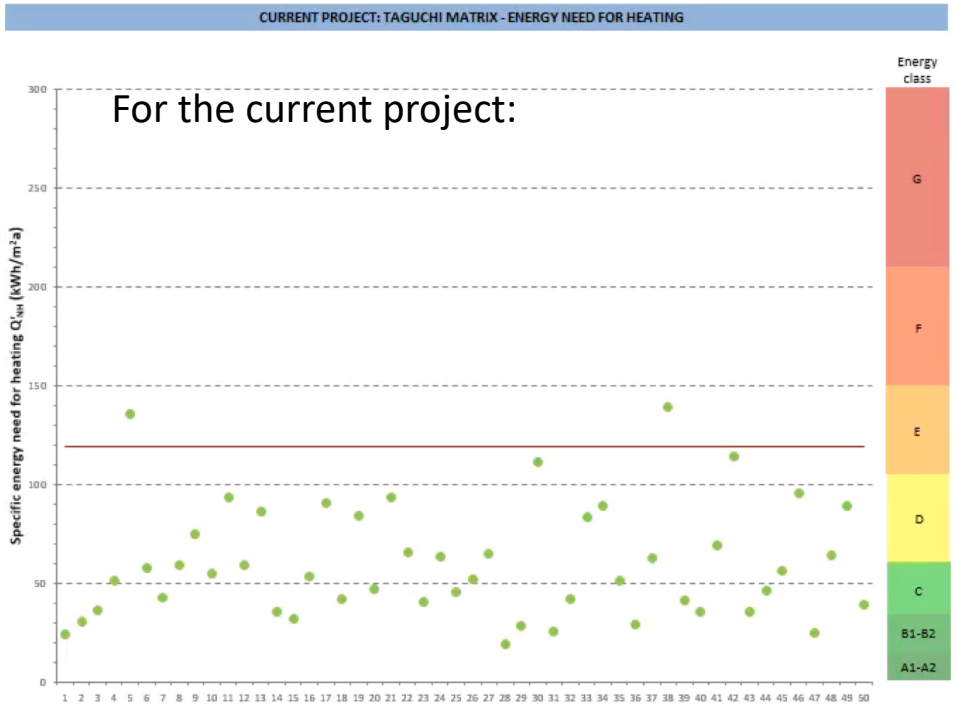


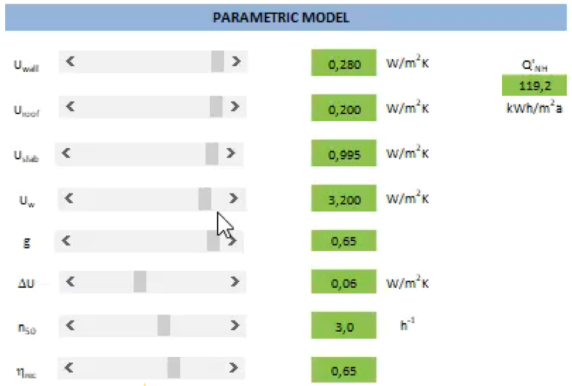


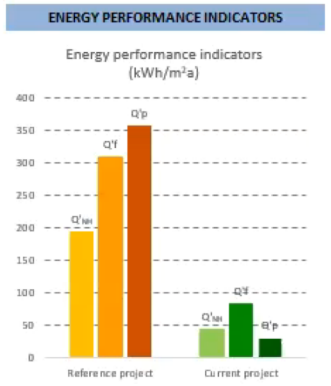
3 Following results are available in E[tool]: for the reference building:

- range of energy needs $Q_{h,nd}$ and $Q_{c,nd}$ is shown according to values defined in Taguchi matrix; designer can evaluate **to what extend** energy efficiency of the building could be improved.

- statistically evaluated impacts of individual influence parameter is shown; designer can evaluate what **measures to take first** for particular building.







influence parameters included in approximation model (k=12)

3 Following results are available in E^tool: for the current building:

Based on Taguchi matrix **approximation model** of energy needs $Q_{h,nd}$ and $Q_{c,nd}$ of current building are produced for parametric analyse in form:

$$Q'_{h,nd} = b_0 + \sum_{i=1}^{12}\left(b_{1,i} \cdot k_i + b_{2,i} \cdot k_1^2\right) \text{ (kWh/m²a)}$$

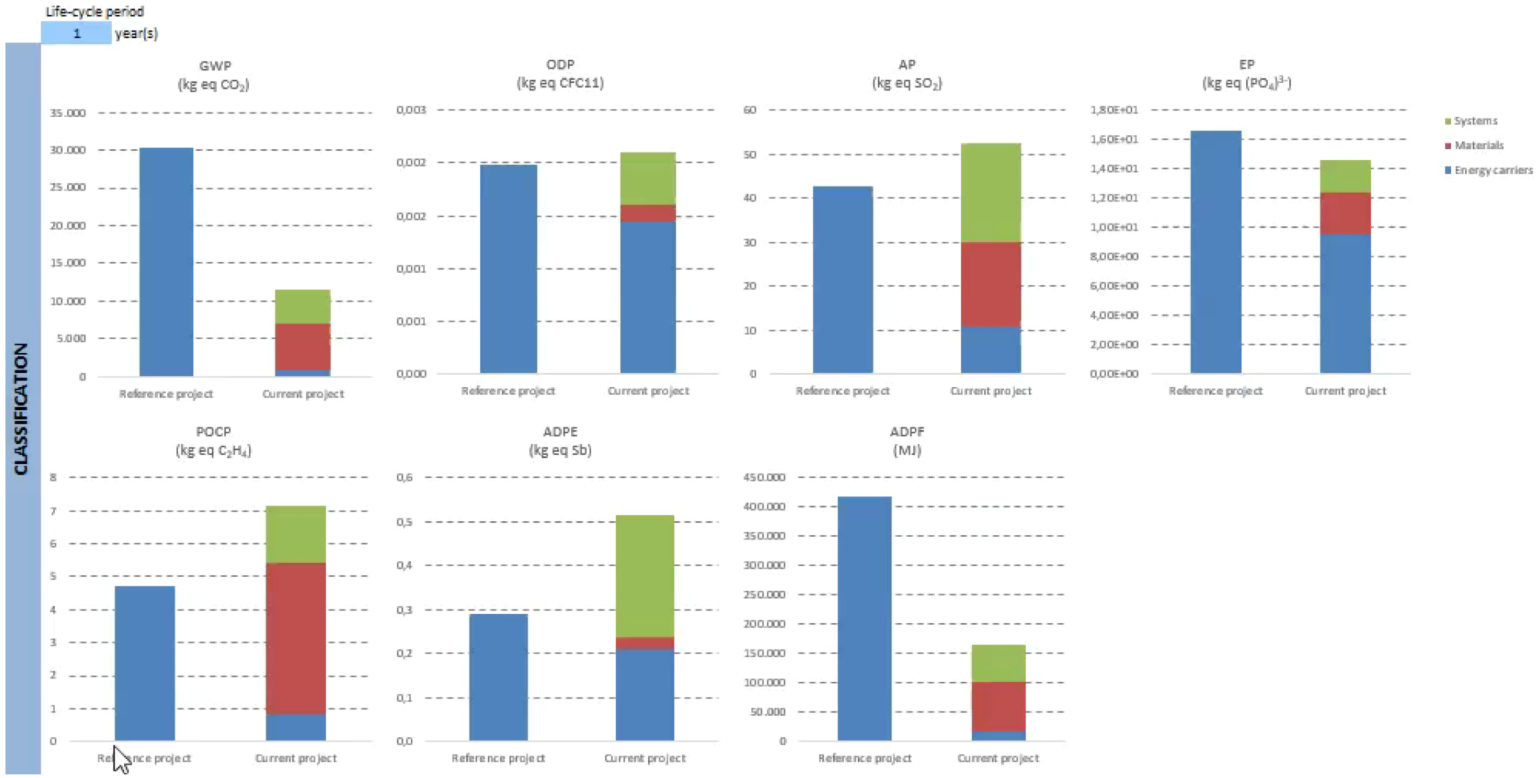
3 As part of the LCEA following results for reference and current project are shown:

- **primary energy** demand

- **final energy use** per energy carriers

- **CO_2 and GW** gas emissions resulting from energy use, built-in „LCA“ materials and „LCA“ building service elements

- **embodied energy of „LCA“ components** is compared with energy savings in selected time range.



3 As part of the LCIA EPD indicators are compared for reference and current building.

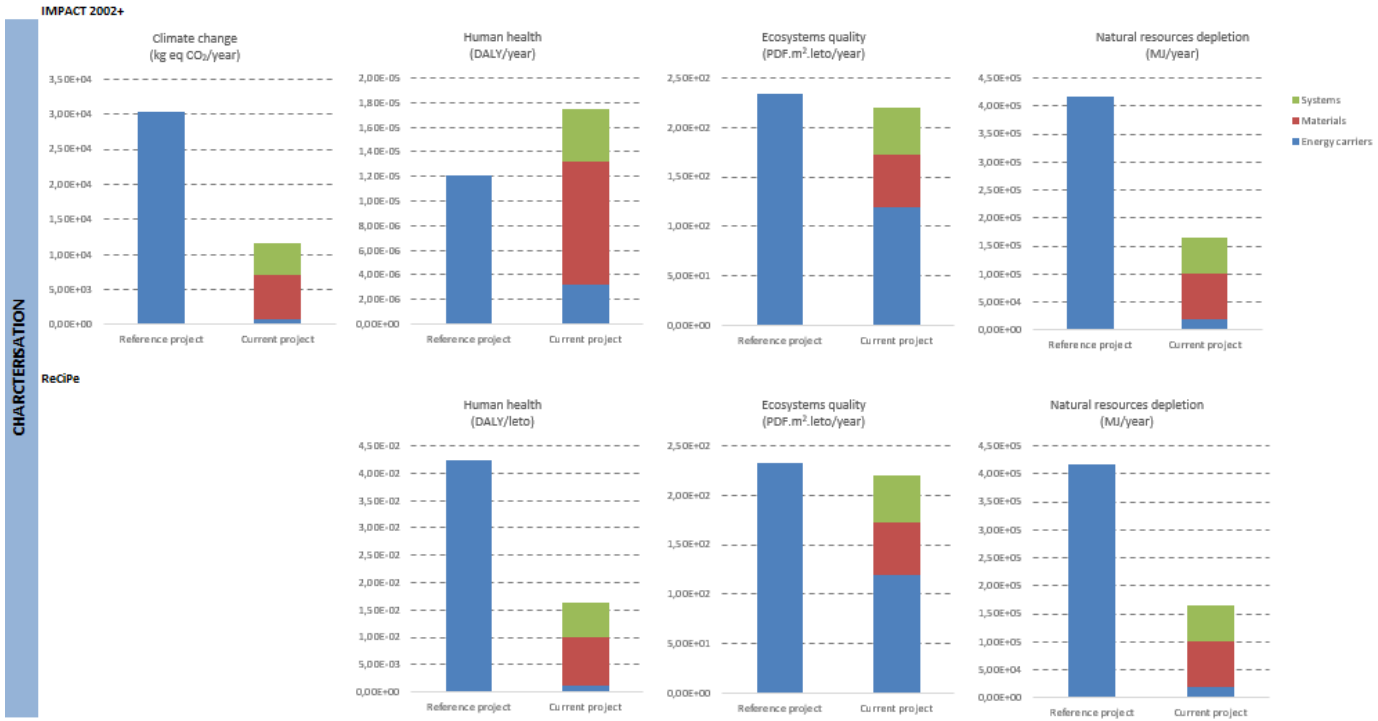
For the current building EPD indicators which are the results of energy demand, built-in „LCA“ materials and „LCA“ building service materials are show separately.

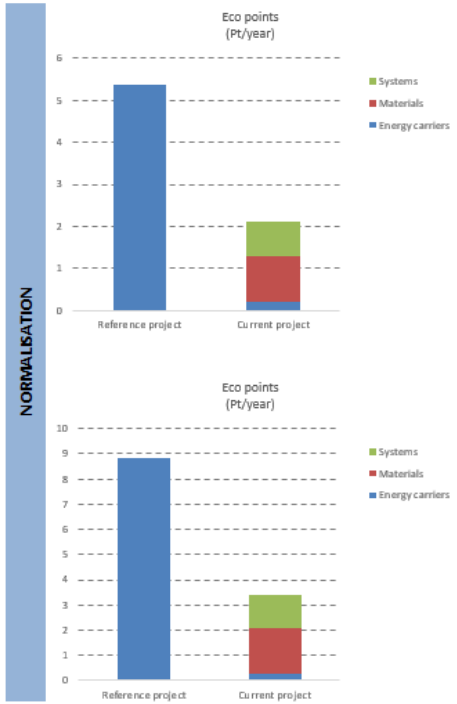
Designer can see which EPD indicator is **most critical** and indicates whether the selection of „LCA“ materials or elements **should be modified**.

3 Damage categories included in IMPACT 2002+ are analysed:

- by normalization phase

- by grouping and weighting





End-point single score environmental impact can be evaluated by Eco Points per year (PT/y).

3 As part of the LCCA simple return period and cash flow diagram is presented for the current building. Parametric analysis can be performed according to:

- the yearly **energy carries increase cost rate**

- investment **discount rate**

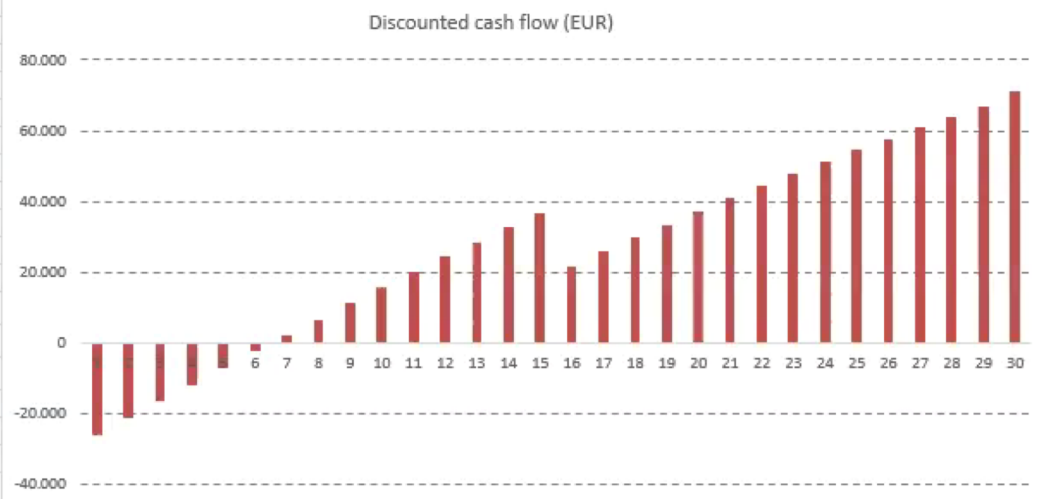
- yearly **maintenance cost**

- **CO_2 emissions global (environmental) cost** (as defined in Commission delegated regulation (EU) No. 244/2012)

COSTS EVALUATION OF ENERGY EFFICIENCY MEASURES - LCCA

SIMPLE PAYBACK PERIOD

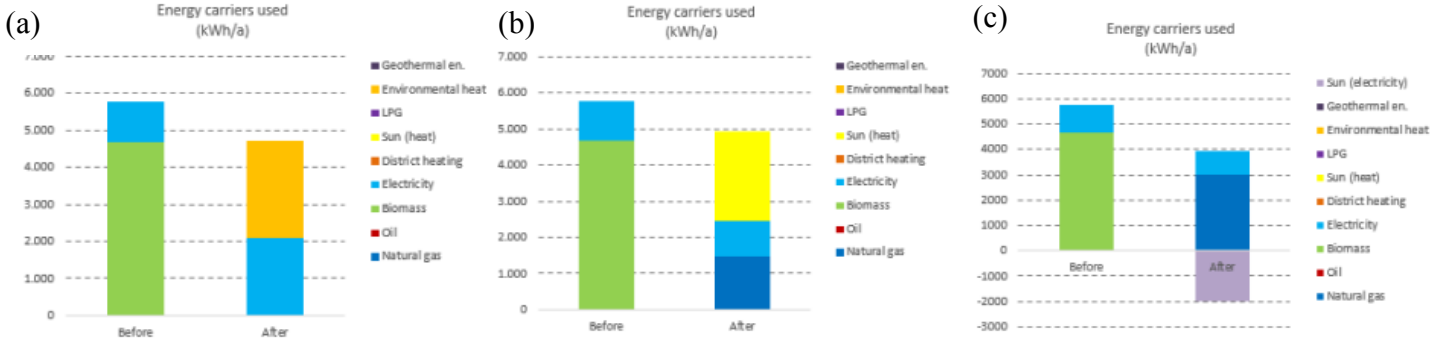
Simple payback period	investment costs		30.401	EUR	
	yearly costs of energy carriers (before)		8.369	EUR/year	
	yearly costs of energy carriers (after)		1.886	EUR/year	
	yearly energy savings		6.483	EUR/year	
	simple payback time		4,69	year(s)	
Discounted cash flow	discount factor of energy carriers pri	e	0,03		
	discount factor of investment	d	0,03		
	investment costs	c_i	-30.401	EUR	
	yearly energy savings	P_e	6.483	EUR/year	
	yearly maintainance costs	c_a	-1.520	EUR/year	5%
	life-cycle of the measure	n	30	year(s)	



The LCA for following cases are shown in the paper:

- renovation of the municipality hospital

- single family passive house



pellet boiler with HS (reference object) is compared to (a) A-W HP with HS, (b) NG condensing boiler + solar heating system (7.5 m^2) and (c) NG condensing boiler + 1.75 kW_p PV

- renovation of the multi-family building

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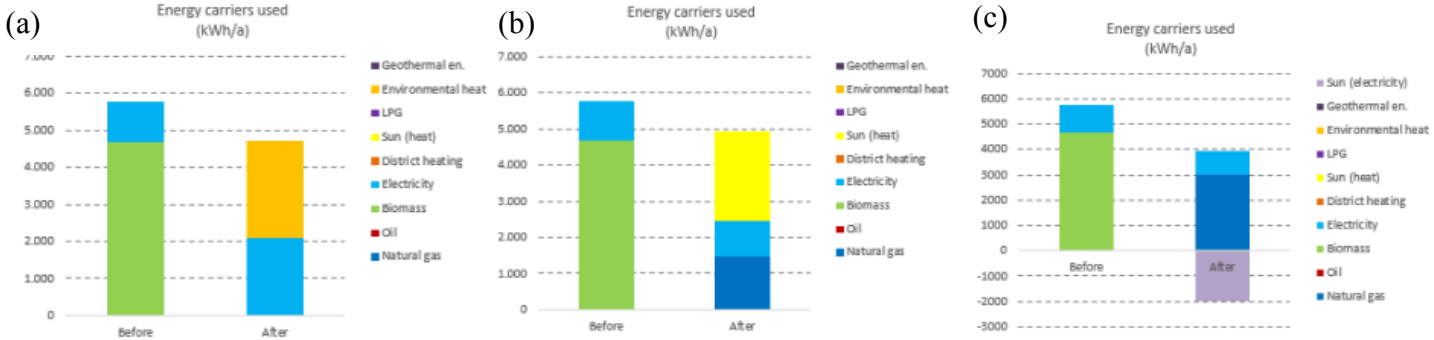

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Thank you for your attention