

MAKING-CITY Webinar 3_PED Calculation Methods

29th September 2021

MAKING-CITY METHODOLOGY for
Calculation of Annual Energy Balance

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This project has received funding from the Horizon 2020 programme under grant agreement n°824418. The content of this presentation reflects only the author's view. The European Commission and INEA are not responsible for any use that may be made of the information it contains.

AGENDA

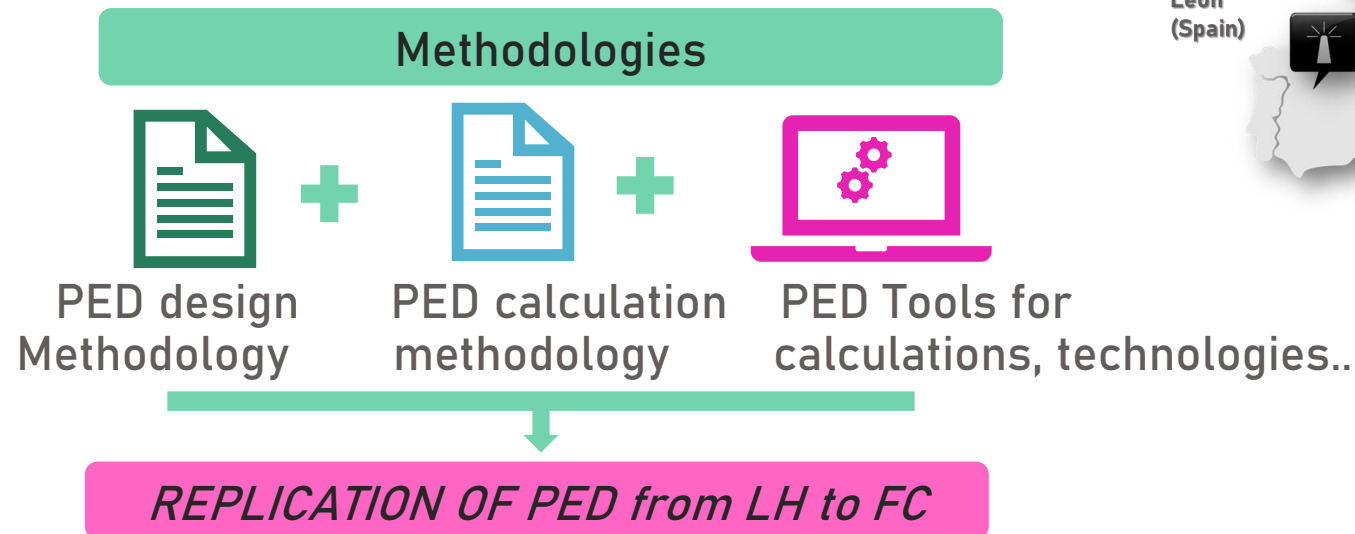
- ▶ Energy balance and calculation procedure for PEDs
 - ▶ Assumptions made by MAKING-CITY to perform the PED Energy Balance
 - ▶ Integrated tool for PED framework calculation –
- Future of PED Calculation Methodologies / What to consider next?



MAKING-CITY project

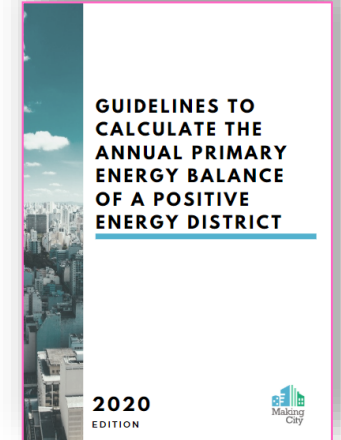
- ▶ addresses and demonstrates advanced procedures and methodologies based on the Positive Energy District (PED)

“A Positive Energy District is an urban area with clear boundaries, consisting on buildings of different typologies that actively manage the energy flow between them and the larger energy system to reach an **annual positive non-renewable primary energy balance**” i.e. more energy is produced than what is consumed within the district boundaries



Why an energy balance?

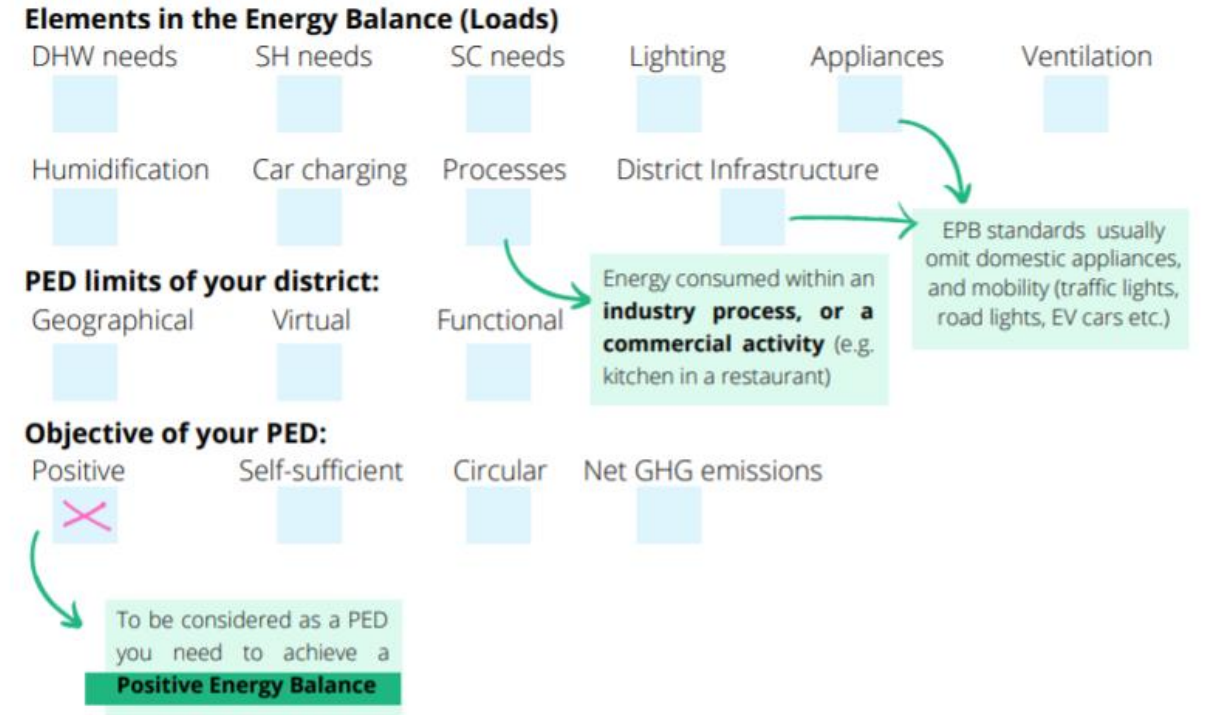
- ▶ different assumptions and approaches need to be followed when compared to a single building assessment.
- ▶ In order to make district energy balances comparable and standardized the evaluation of PED
- ▶ MAKING-CITY project developed a 8-step methodology to evaluate the district energy balance based on ISO 52000-1:2017 standard
- ▶ The energy balance is made in terms of non-renewable primary energy
- ▶ Allows to compare different energy carriers



1. Define the PED boundary

The boundary helps to identify:

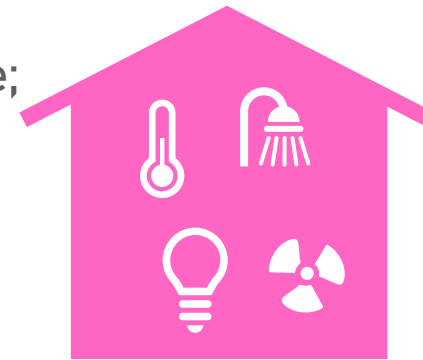
- ▶ The elements: such as the buildings to be included, loads, ..
- ▶ The energy Exchange between buildings and the larger energy system
- ▶ Boundary conditions (what is incoming energy – imported, and what is outgoing energy – exported)
- ▶ Can be geographical, functional or virtual



2. Calculate the energy needs

The different loads of the system (thermal and electric energy needs) are calculated using different tools or statistics

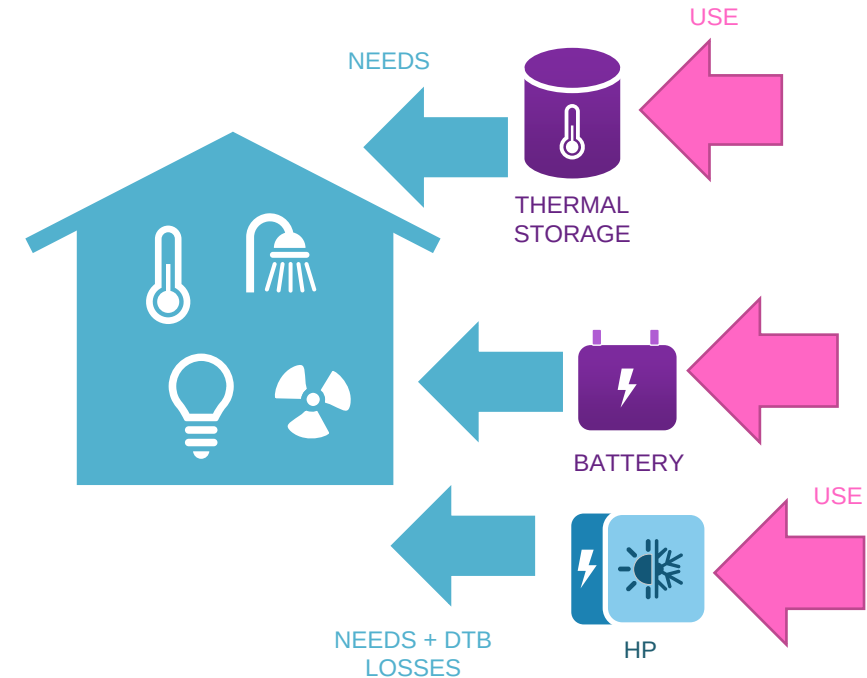
- ▶ Thermal energy needs is the amount of energy that a building needs to be maintained at a given temperature; also raise the cold network temperature to the desired temperature for domestic hot water (DHW) consumption
- ▶ Whereas electric energy needs are the energy to be delivered to cover the energy demand of lighting and ventilation of a building.



3. Calculate the energy use

The loads of the system are satisfied by energy systems.. If you take into account the losses of storage and distribution systems, then you are calculating the energy use (usually, the useful output of the energy systems).

- ▶ Thermal energy use is the energy input into the heating, cooling or hot water distribution systems (radiators, storage, heat exchangers, etc.) to satisfy the energy needs for heating, cooling or hot water respectively. It can also be identified as the useful energy output from the thermal generation systems (e.g. solar thermal collectors, boilers, thermal output from CHP, etc.).
- ▶ Electric energy use is the electricity directly consumed by loads (Ventilation, lighting) or systems (e.g. heat pumps) to supply the needs (heating, cooling, ventilation, lighting and domestic hot water).



4. Calculate the on-site production

The useful energy (output) from renewable energy sources is calculated:

	PV	PVT (el/th)	Solar thermal	Geothermal	Biomass(el/th)	Waste Heat
Building 1						
Building 2						
....						
Building n						

*useful outputs to be use to cover total thermal and electric energy uses

Total Energy from RES (electric) =

Total Energy from RES (thermal) =

With the useful outputs calculated, the remaining energy to be covered (or the surplus energy to be exported) is calculated:

Remaining (Thermal) = Total Thermal Use - Total RES Thermal =
(Surplus if negative, remaining to be covered by external sources if positive)

Remaining (Electric) = Total Electric Use - Total RES Electric =
(Surplus if negative, remaining to be covered by external sources if positive)



1. Define the PED boundary



2. Calculate the energy needs



3. Calculate the energy use



4. Calculate the on-site generation



5. Estimate the energy delivered



6. Calculate the primary energy



7. Calculate the energy balance



8. Perform a Sankey Diagram

5. Estimate the energy delivered

- ▶ The energy delivered is known as the energy supplied to the PED (thermal and electricity) that is produced outside the district boundaries.
- ▶ Usually comes from thermal, gas or electric grids and feeds the energy systems available on-site the district.

Delivered energy from fossil fuels:

	Remaining Energy (kWh)	efficiency	Delivered Energy kWh
Natural gas =		/	
Oil =		/	
Other fuels =		/	

Delivered energy from external grids (still any remaining energy not covered?):

District heating =		=	
Grid =		=	

Delivered energy from Renewable Energies (Biomass, biogas...etc.)

Biomass boiler =	Thermal	/		=	
Biogas turbine =		/		=	
Biomass CHP =	Thermal	/		=	
	Electric	/			



6 + 7 : Calculate primary energy and the balance

Primary Energy Imported(+):

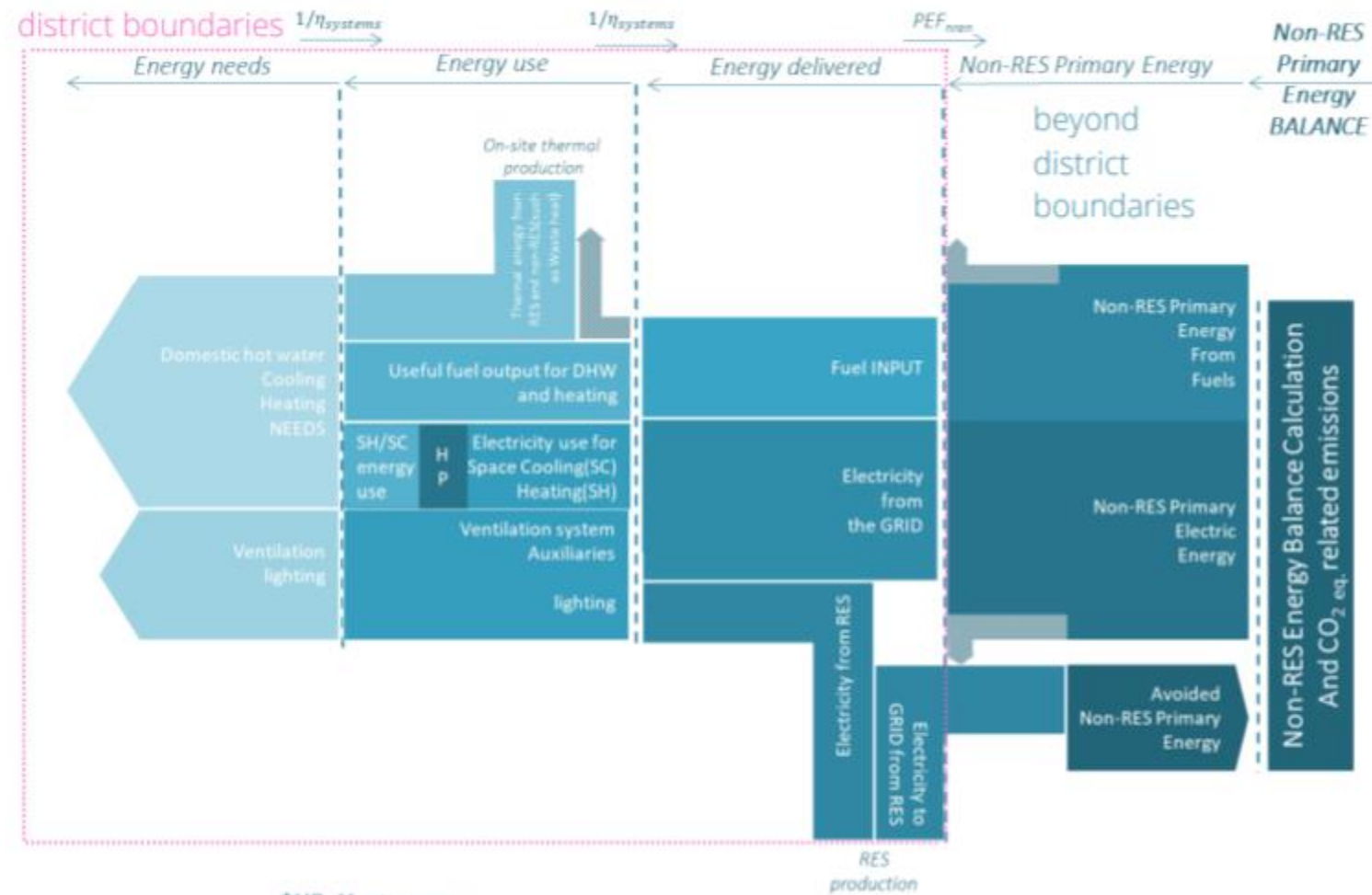
	Delivered Energy (kWh)		PEF _{nren}		kWh
Natural gas =		x		=	+
Grid =		x		=	+
Biomass =		x		=	+
Other fuels =		x		=	+
District heating =		x		=	+

Primary Energy Exported(-):

	Delivered Energy (kWh)		PEF _{nren}		kWh
Surplus El. Energy =		x		=	-
Surplus Th. Energy =		x		=	-
Surplus fuel Energy =		x		=	-
Non-Renewable Primary Energy Balance =					



8. Perform a sankey diagram



1. Define the PED boundary

2. Calculate the energy needs

3. Calculate the energy use

4. Calculate the on-site generation

5. Estimate the energy delivered

6. Calculate the primary energy

7. Calculate the energy balance

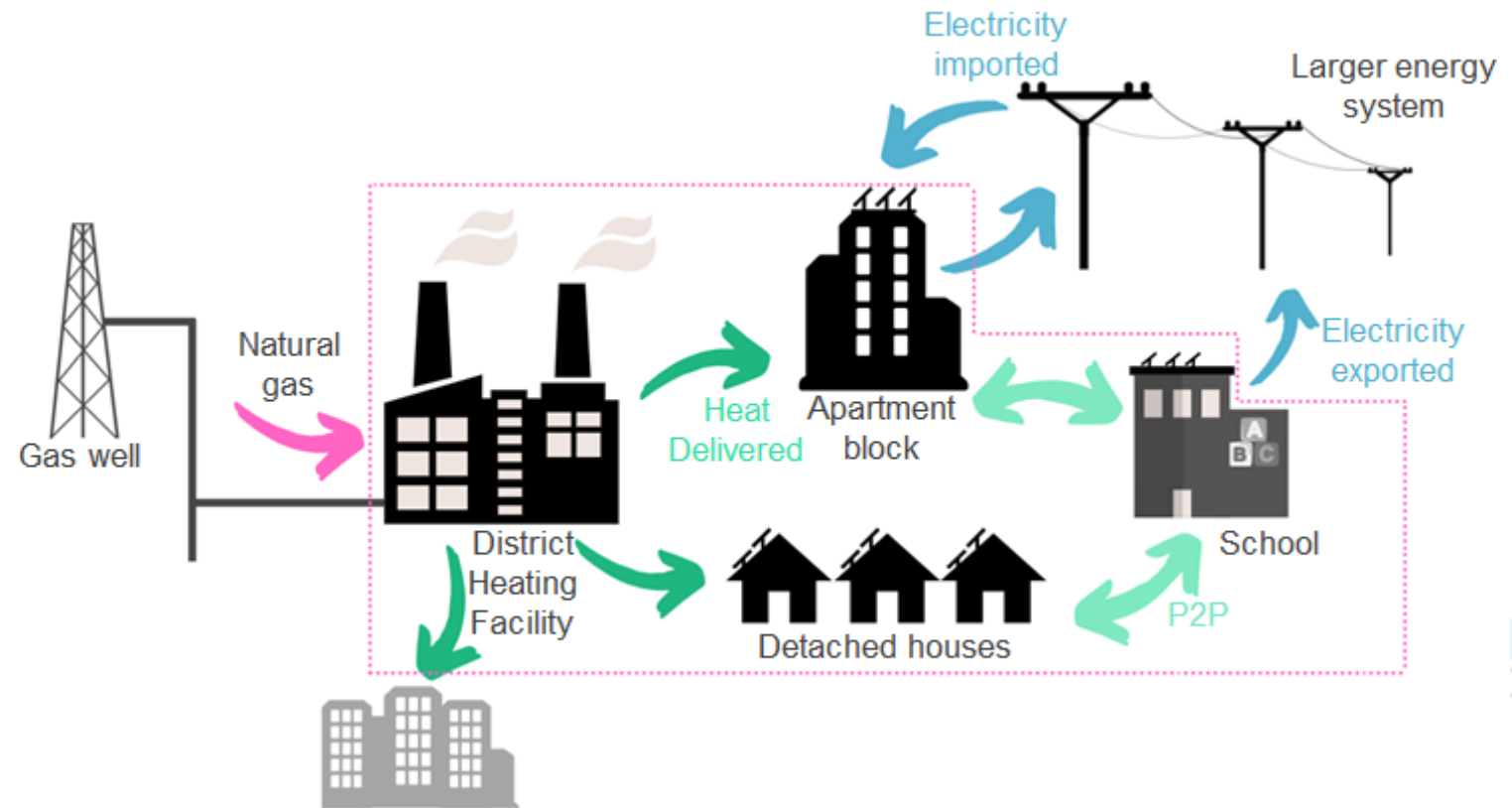
8. Perform a Sankey Diagram

Assumptions made by MAKING-CITY to perform the PED Energy Balance

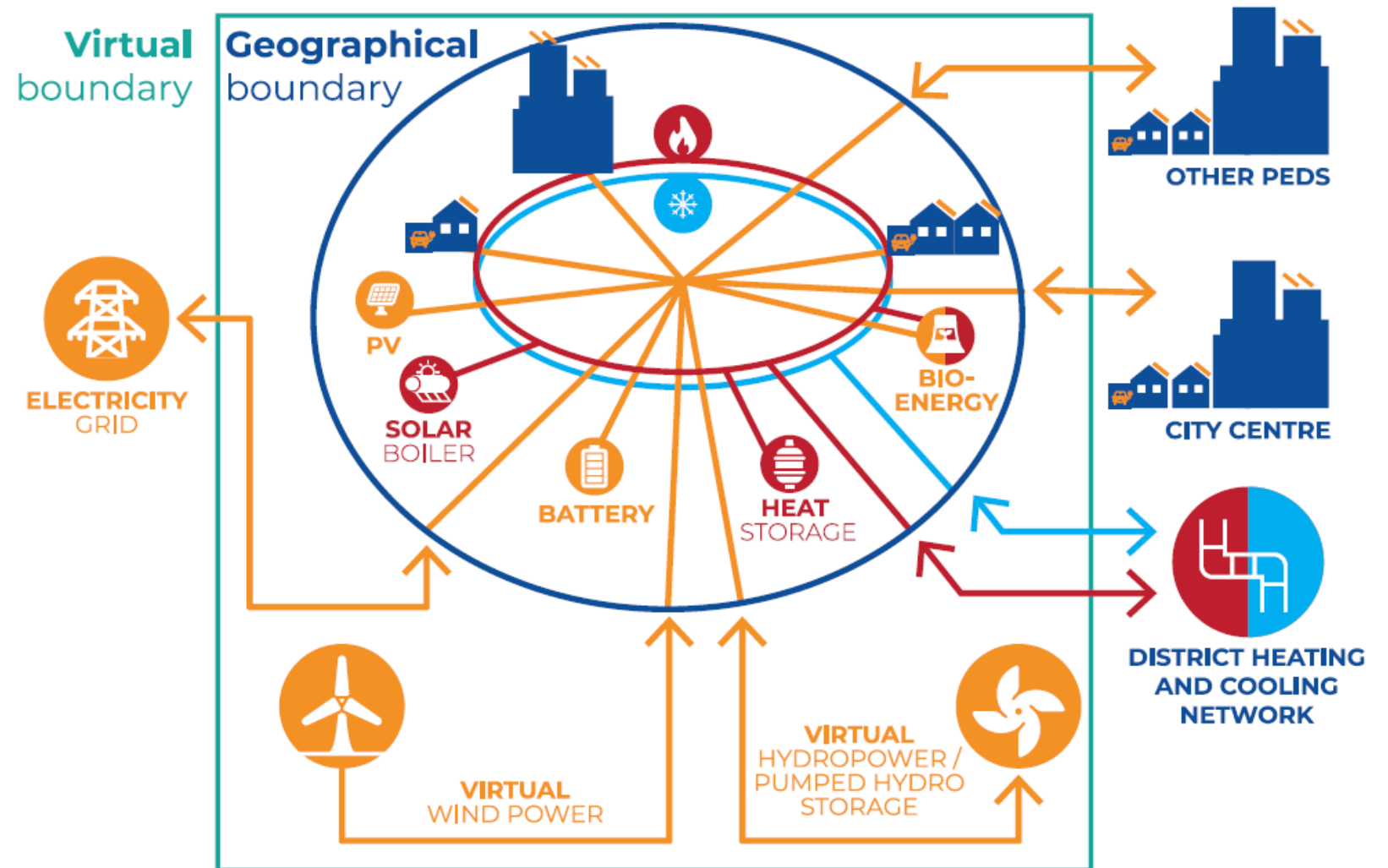
- ▶ Boundaries of the PED
- ▶ Appliances for calculation of electrical needs
- ▶ How to consider RES produced on-site and outside in the calculation of the Energy Used
- ▶ How to consider the Waste Heat in the Primary Energy Balance (PEB)
- ▶ Energy Surplus

Boundaries of the PED

Geographical and continuous
Not autonomous – Interacts with the Grid



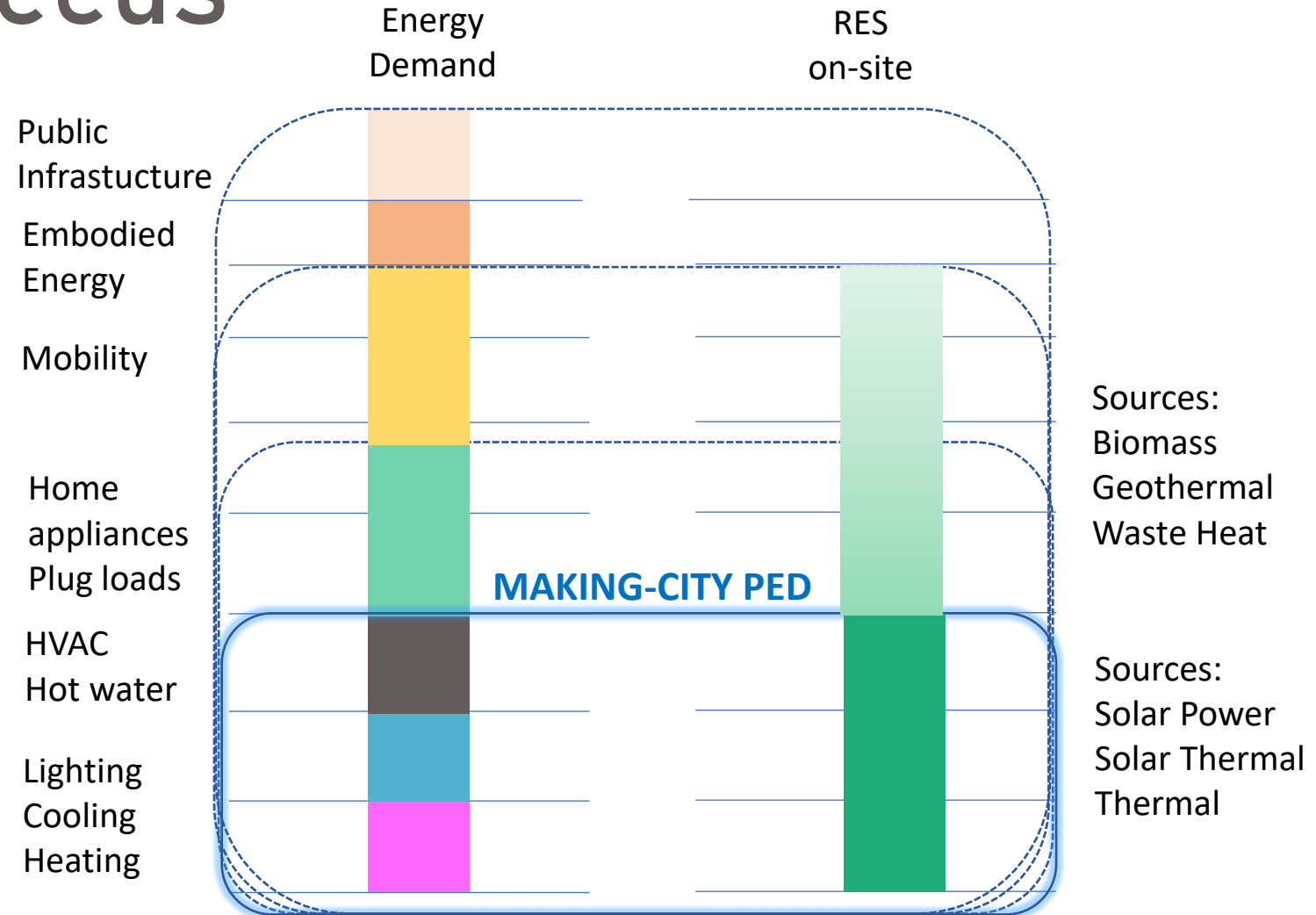
Boundaries of the PED



PED Solution Booklet, 2020

Appliances for calculation of electrical needs

MAKING-CITY follows the European Directive “Guidelines 2012/C 115/01” (European Commission, 2012), where the appliances are not considered for the electric energy needs calculation



Appliances for calculation of electrical needs

- ▶ Electric energy use, identified as the **useful energy output from the electric generation systems**, only considers the electric energy uses in the EPB standard. Thus, the electricity used within the district boundaries for **domestic appliances, mobility and infrastructure** (traffic lights, road lights, EV cars etc.) are neglected.

How to consider RES produced on-site and outside in the calculation of the Energy Used

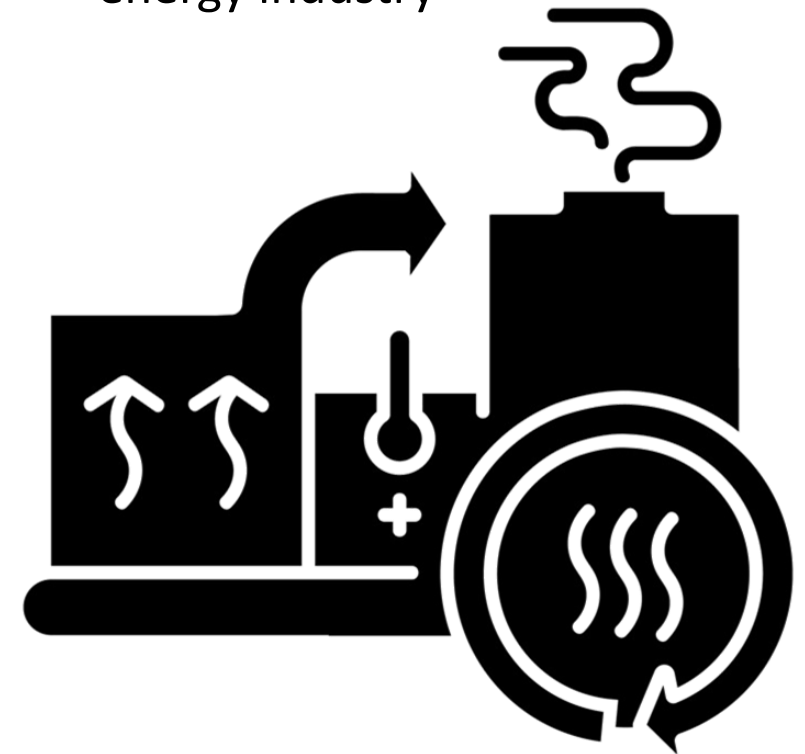
- ▶ RES produced on-site is used in the internal balance of the district to reduce directly the energy demand of it, so no primary energy factor (PEF) will be included at this step of the calculation. In case of RES would come from outside the district boundaries, the corresponding PEF would be included in the energy balance as would be done for any other import of energy.

How to consider the Waste Heat in the PEB?



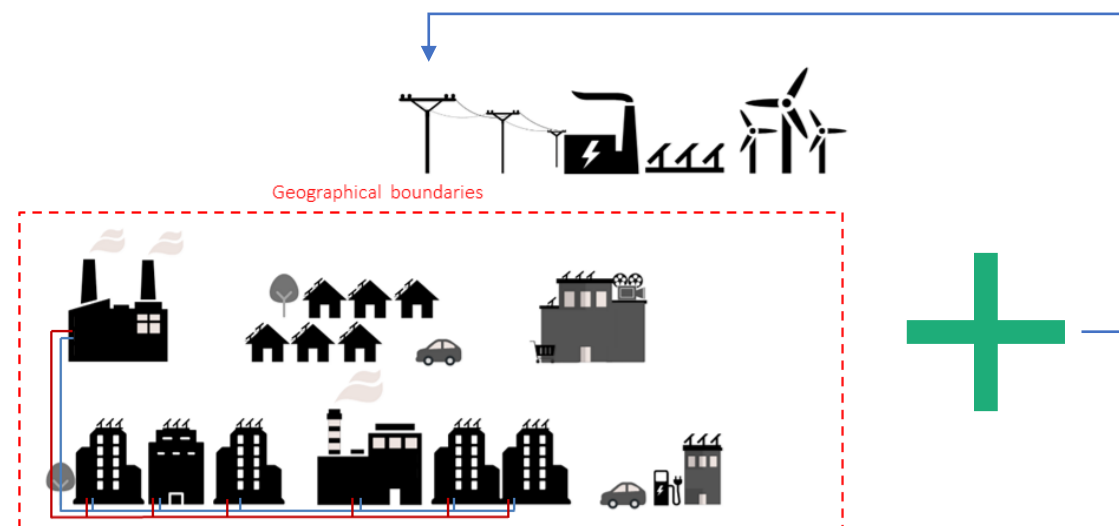
Waste heat from HVAC systems, sewage systems .etc.

Waste heat from intensive energy industry



Energy Surplus

- ▶ Energy surplus produced in the PED is exported outside the district boundaries. This is the main value of the PEB and gives a quantitative consideration in the effectivity of the PED.
- ▶ for MAKING-CITY procedure only a **surplus of RES** can be considered.



TOOLS for PED calculation

- ▶ BEST Tables
- ▶ MAKINGCITY
- ▶ GIS Based tool – Hourly energy balances
- ▶ Detailed system modelling

BEST Table – Simplified Annual Balance

Building Energy Specification Table (BEST)											
Description of elements/solutions for Positive Energy Block/District											
Overview table for SCC1											
version 2.0											
Publication date: 30 October 2017											
As stated in the Scope: " <i>Integrated innovative solutions for Positive Energy Blocks/Districts will be developed and tested and performance-monitored in the Lighthouse Cities</i> ". As Primary Energy Factors used for energy balance calculations differ substantially depending on the framework, for this call and in this BEST table you are only asked to report on proposed measures, the estimated energy need, RES produced locally and energy flows within and through test site boundaries. This overview shall help to assess the ambition of the project and will facilitate comparison between proposals.											
						Local Climate					
Project:						January average outside temperature °C					
City:						August average outside temperature °C					
District:						Average global horizontal radiation kWh/m2/y					
						Annual heating degree days °Cd/y					
						Annual cooling degree days °Cd/y					
Important: Energy efficiency first! Self consumption (if possible) over grid export ! Connect building and build on synergies !											
net energy need for											
	new, retrofitted	year of construction/ retrofit	use type	floor area [m2]	Space heating, cooling, and air conditioning [kWh/m2/y] [kWh/y]	Hot water [kWh/y]	Lighting [kWh/m2/y] [kWh/y]	Appliances [kWh/m2/y] [kWh/y]	sub-total net energy need [kWh/y]		
Building 1											
Building 2											
Building 3											
Building 4											
Building 5											
...											
Add rows if needed. Add lines for every additional building/area/location										Total net energy need [kWh/y]	
Local RES (within the boundaries of the project district)											
	Photovoltaic [kWp] [kWh/y]	Solar Thermal [kWh/y]	Biomass [kWh/y]	other [kWh/y]	other [kWh/y]	Add rows if needed					
Building/Location 1											
Building/Location 2											
Building/Location 3											
Building/Location 4											
Building/Location 5											
...											
Add lines for buildings/locations if needed										Total local RES [kWh/y]	
										% of total net energy need covered by local RES:	%
Energy in/out through district boundaries											
Please provide also energy flow chart											
	in				out (if applicable)						
Electricity [kWh/y]											
Gas [kWh/y]											
Biomass [kWh/y]											
other [kWh/y]											
Add lines for buildings/locations if needed										Total incoming [kWh/y]	
										% of total net energy need covered by resources coming from outside district boundaries:	%

MAKINGCITY – Simplified Annual Balance

+ clarifying boundaries, energy services included, use ISO 52000 terminology,

1. Elements considered in the Energy Balance

Buildings (residential)

Heating	Cooling	DHW	Lighting	Appliances	Ventilation	Humidification	car charging (at the buildings)	Other:	Specify
YES	YES	YES	YES	NO	YES	YES	NO		

Public buildings, private enterprises & Industry

Heating	Cooling	DHW	Lighting	Appliances	Ventilation	Humidification	car charging point (at the buildings)	Processes & others	Other:	Specify
YES	YES	NO	YES	NO	YES	YES	NO	YES		

Public services and infrastructures

Lighting	Water	Food	Wastewater	Waste	Other:	Specify
NO	NO	NO	NO	NO		

Mobility

Private	Public	Cars passing through	Refueling visitors	Other:	Specify
NO	THE ELEMENT	NO	NO		

2. PED limits of your district

Geographic

3. Objectives of your PED

Self-sufficient	Positive	Net emissions	Circular	Other:
NO	YES	NO	NO	Specify

4. Positive Energy Balance is achieved in terms of:

Non-renewable Primary Energy



MAKINGCITY – Simplified Annual Balance

+ clarify boundaries, energy services included, use ISO 52000 terminology,

ENERGY NEEDS

THERMAL ENERGY NEEDS

		Units (m2 or people)		kWh/unit		GWh (divide by 10^6)
buildings	DHW needs	4,20E+07	x	47	=	1974
	SH needs		x		=	0
	SC needs		x		=	0
Industry 1	DHW needs		x		=	0
	SH needs	1	x	5000000	=	5
	SC needs		x		=	0
Industry 2	DHW needs		x		=	0
	SH needs		x		=	0
	SC needs		x		=	0
Utility	DHW needs		x		=	0
	SH needs	100000	x	10	=	1
	SC needs		x		=	0
Total Thermal Energy Needs						= 1980

ELECTRIC ENERGY NEEDS

		Units (m2 or people)		kWh/unit		GWh (divide by 10^6)
buildings	Lighting	4,20E+07	x	31,4	=	1318,8
	Ventilation		x		=	0
	Other (e.g. Process)	1	x	5000000	=	5
Industry 1	Lighting		x		=	0
	Ventilation		x		=	0
	Other (e.g. Process)	1	x	50000000	=	50
Industry 2	Lighting		x		=	0
	Ventilation		x		=	0
	Other (e.g. Process)	1	x	50000000	=	50
Utility	Lighting	100000	x	30	=	3
	Ventilation		x		=	0
	Other (e.g. Process)		x		=	0
Total Electric Energy Needs						= 1376,8



ENERGY USE

THERMAL ENERGY USE

		Energy needs		Efficiency of the emitter+distribution losses		GWh (divide by 10^6)
buildings	DHW use	1,97E+03	/	100,00%	=	1,97E+03
	SH use	0	/		=	0,00E+00
	SC use	0	/		=	0,00E+00
Industry 1	DHW use	0	/		=	0,00E+00
	SH use	5	/	1,00	=	5,00E+00
	SC use	0	/		=	0,00E+00
Industry 2	DHW use	0	/		=	0,00E+00
	SH use	0	/		=	0,00E+00
	SC use	0	/		=	0,00E+00
Utility	DHW use	0	/		=	0,00E+00
	SH use	1	/	1,00	=	1,00E+00
	SC use	0	/		=	0,00E+00
Total Thermal Energy use						= 1980

ELECTRIC ENERGY USE

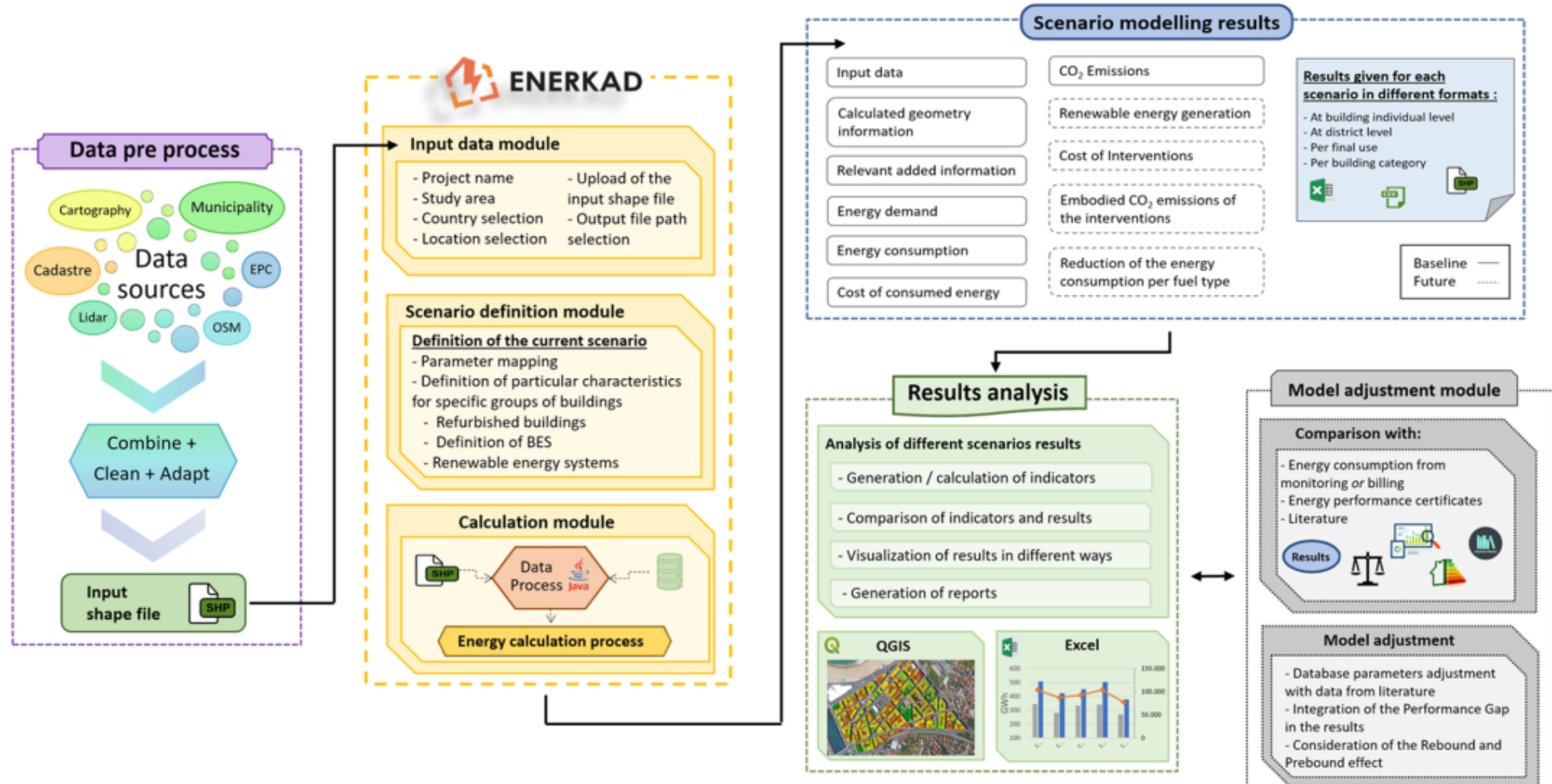
		Energy needs		Efficiency of the emitter		GWh (divide by 10^6)
buildings	SH electric use	0,00E+00	/	3	=	0,00E+00
	SC electric use		/		=	0,00E+00
	DHW electric use		/		=	0,00E+00
buildings	Lighting needs (usually losses)	1318,8	/	1	=	1,32E+03
	Ventilation needs (usually losses)	0	/	1	=	0,00E+00
	Other (process)	5	/	1	=	5,00E+00
Industry 1	SH electric use		/	1	=	0,00E+00
	SC electric use		/		=	0,00E+00
	DHW electric use		/		=	0,00E+00
Industry 2	SH electric use		/	1	=	0,00E+00
	SC electric use		/		=	0,00E+00
	DHW electric use		/		=	0,00E+00
Industry 2	Lighting needs (usually losses)	0	/	1	=	0,00E+00
	Ventilation needs (usually losses)	0	/	1	=	0,00E+00
	Other (process)	50	/	1	=	5,00E+01
Utility	SH electric use		/	1	=	0,00E+00
	SC electric use		/		=	0,00E+00
	DHW electric use		/		=	0,00E+00
Utility	Lighting needs (usually losses)	3	/	1	=	3,00E+00
	Ventilation needs (usually losses)	0	/	1	=	0,00E+00
	Other (process)		/		=	0,00E+00
Total Electric energy use						= 1376,8

MAKINGCITY – Simplified Annual Balance

+ clarify boundaries, energy services included, use ISO 52000 terminology,

SUMMARY									
SYSTEMS		DELIVERED ENERGY				FACTORS		PRIMARY ENERGY	
RES THERMAL GENERATION SYSTEMS		DELIVERED ENERGY FROM OUTSIDE BOUNDARIES				PEFnren		PRIMARY ENERGY BALANCE in non-renewable primary energy terms	
	1841,428571								2358,467971
Geothermal	0	ON-site energy source							
Solar Thermal	0	ON-site energy source							
Biomass_heat	647,6190476	CHP_biomass	1000	x	0,05	=		50	
Waste heat	0	Waste heat	0	x	0,00	=			
Biomass_peat_heat	777,1428571	CHP_peat (bioma	1200	x	1,05	=		1260	
PVT_th	0	ON-site energy source							
Biomass_firewood_th	416,6666667	fuelwood (small-	500	x	0,03	=		15,75	
RES ELECTRIC GENERATION SYSTEMS	805,7142857	electr_grid nation	561	x	1,46	=		818,4893994	
Biomass_el	257,1428571	(CHP input allocated already to heat)							
Biomass_peat_el	308,5714286	(CHP input allocated already to heat)							
PVT_el	0	ON-site energy source							
Other	0	ON-site energy source							
PV	0	ON-site energy source							
wind/hydro	240	ON-site energy source							
NON-RES GENERATION SYSTEMS ON-SITE									
Gas boiler	0	national gas netw	0	x	1,03	=		0	
other fuels (oil)	194	DH_national av.	-82	x	1,03	=		-84,47142857	
Other fuels (fossil CHP; electricity)	10	oil	250	x	1,03	=		257,5	
Other fuels (fossil CHP; thermal)	26	CHP_fossil	40	x	1,03	=		41,2	
Total Electricity on-site (from non-RES)	10								
Total thermal on-site (from non-RES)	221								
Remaining energy?	YES								

GIS Based tool – Hourly energy balances



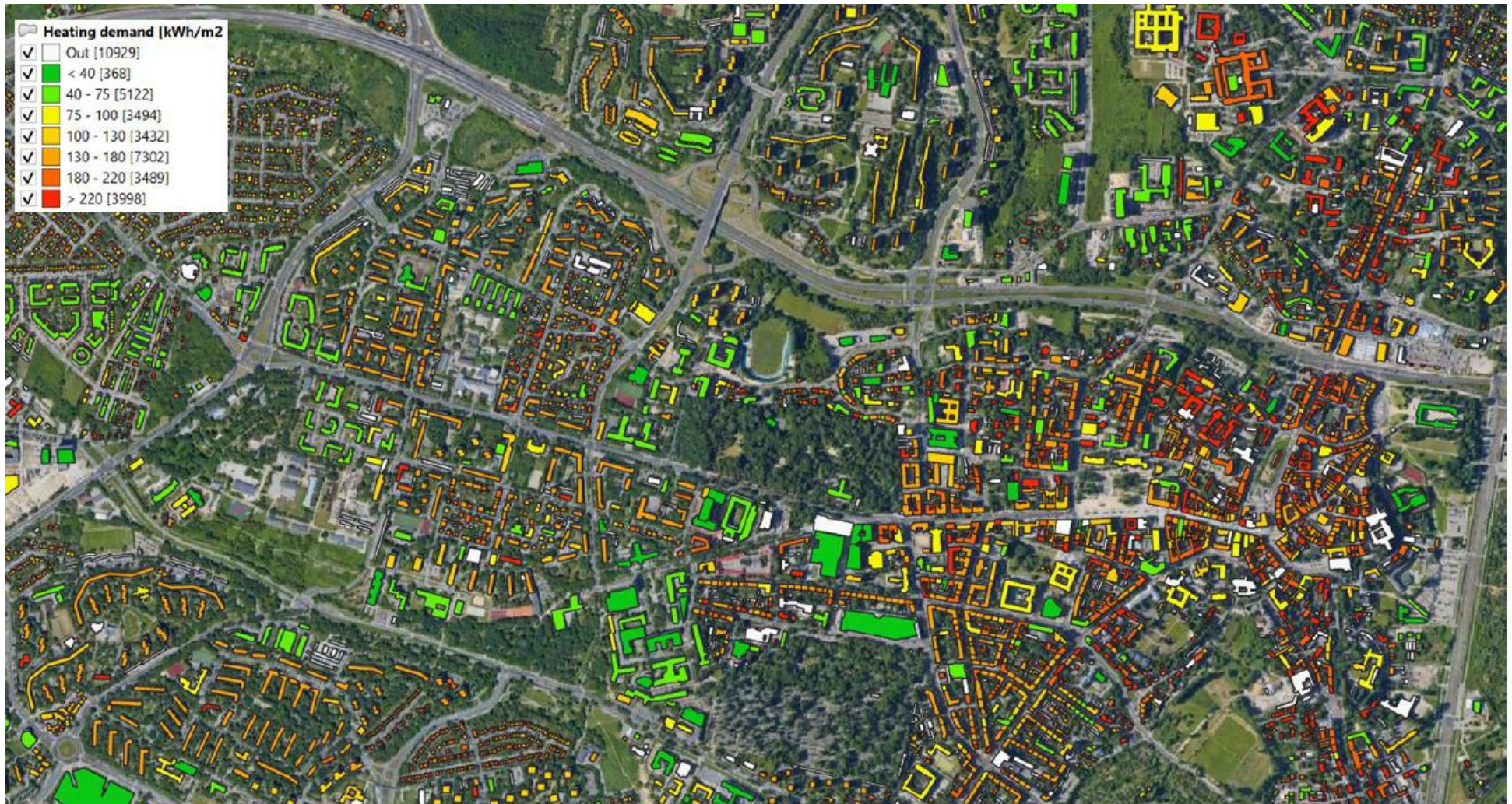


Figure 47: Modelling results, heat demand of the buildings in the city of Lublin (kWh/m²).



Figure 54: Modelling results, heat demand of the buildings in the city of Vidin (kWh/m²).



Figure 50: Modelling results, heat demand of the buildings in the city of Trenčín (kWh/m²).



Figure 42: Modelling results, energy consumption for heating + DHW in the city of León (kWh/m²).

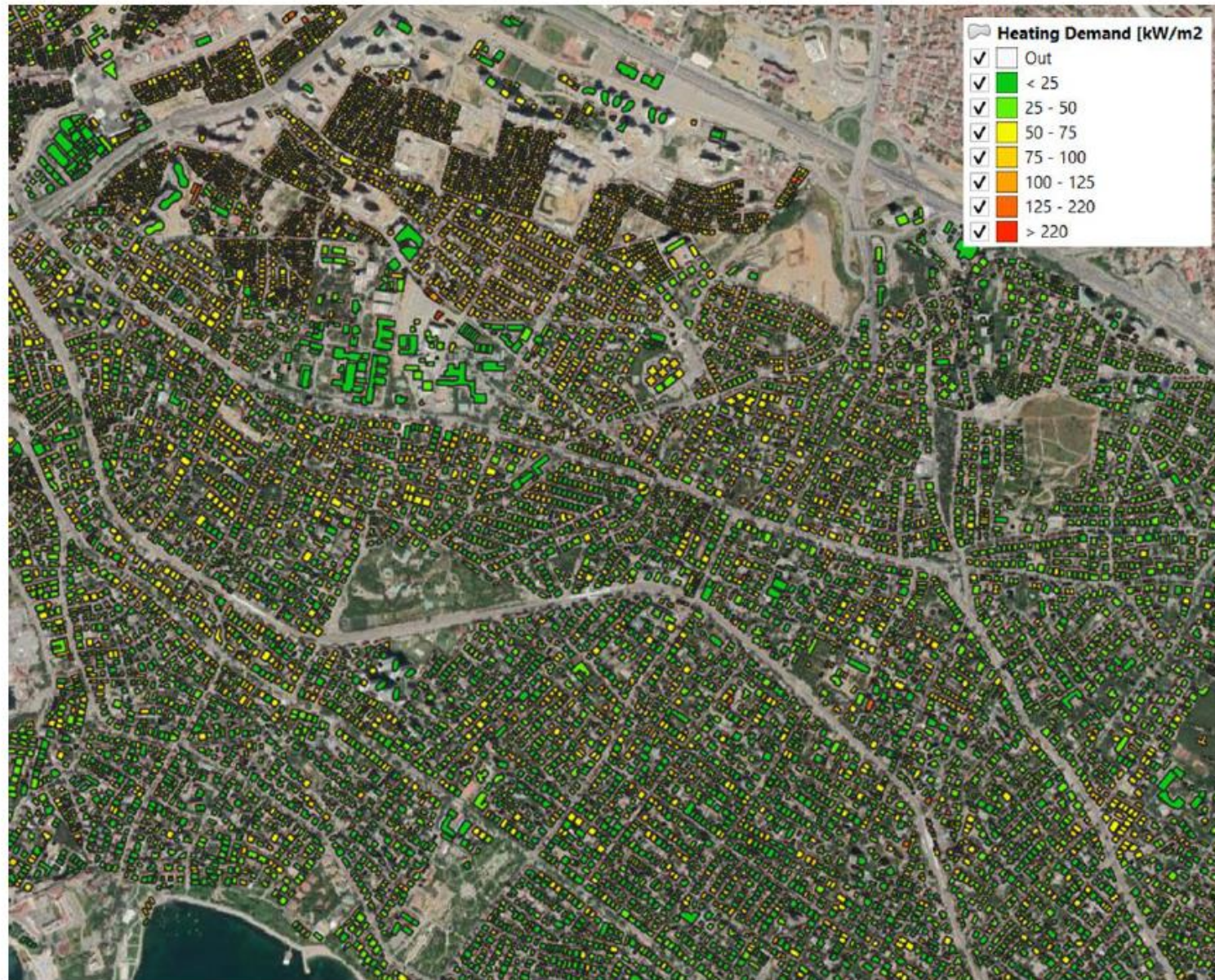


Figure 35: Modelling results, heat demand of the buildings in the city of Kadiköy (kWh/m²).

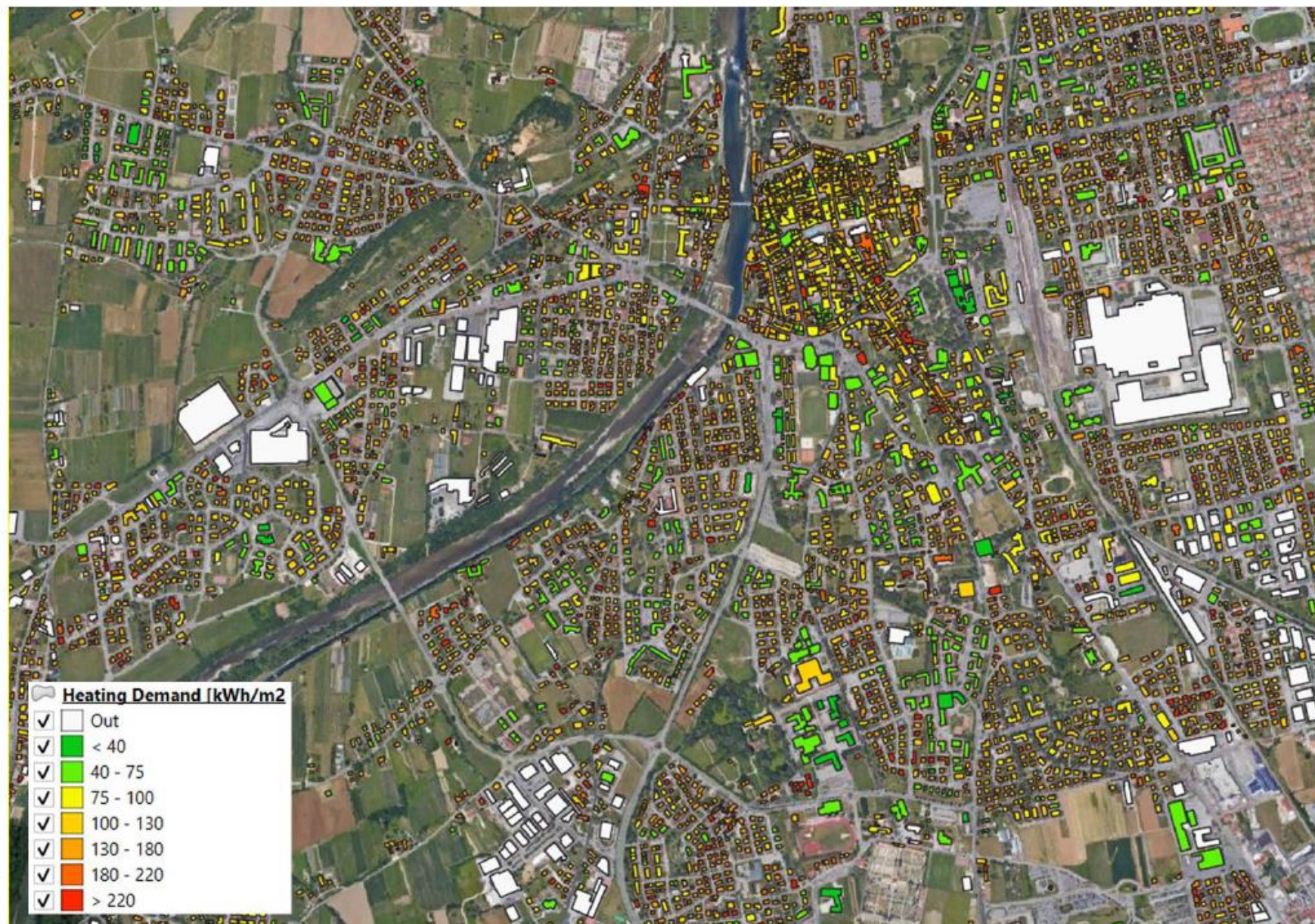
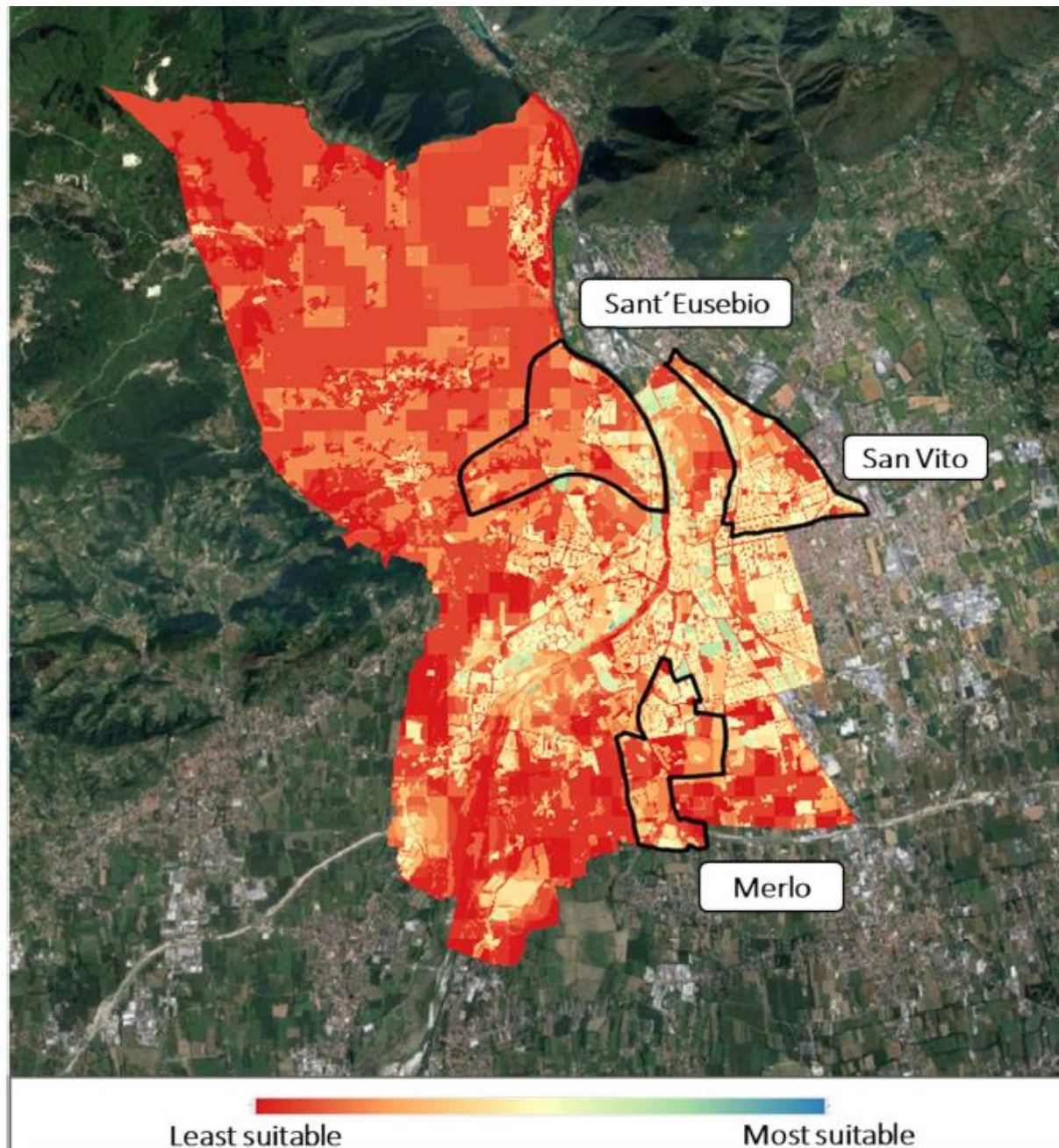
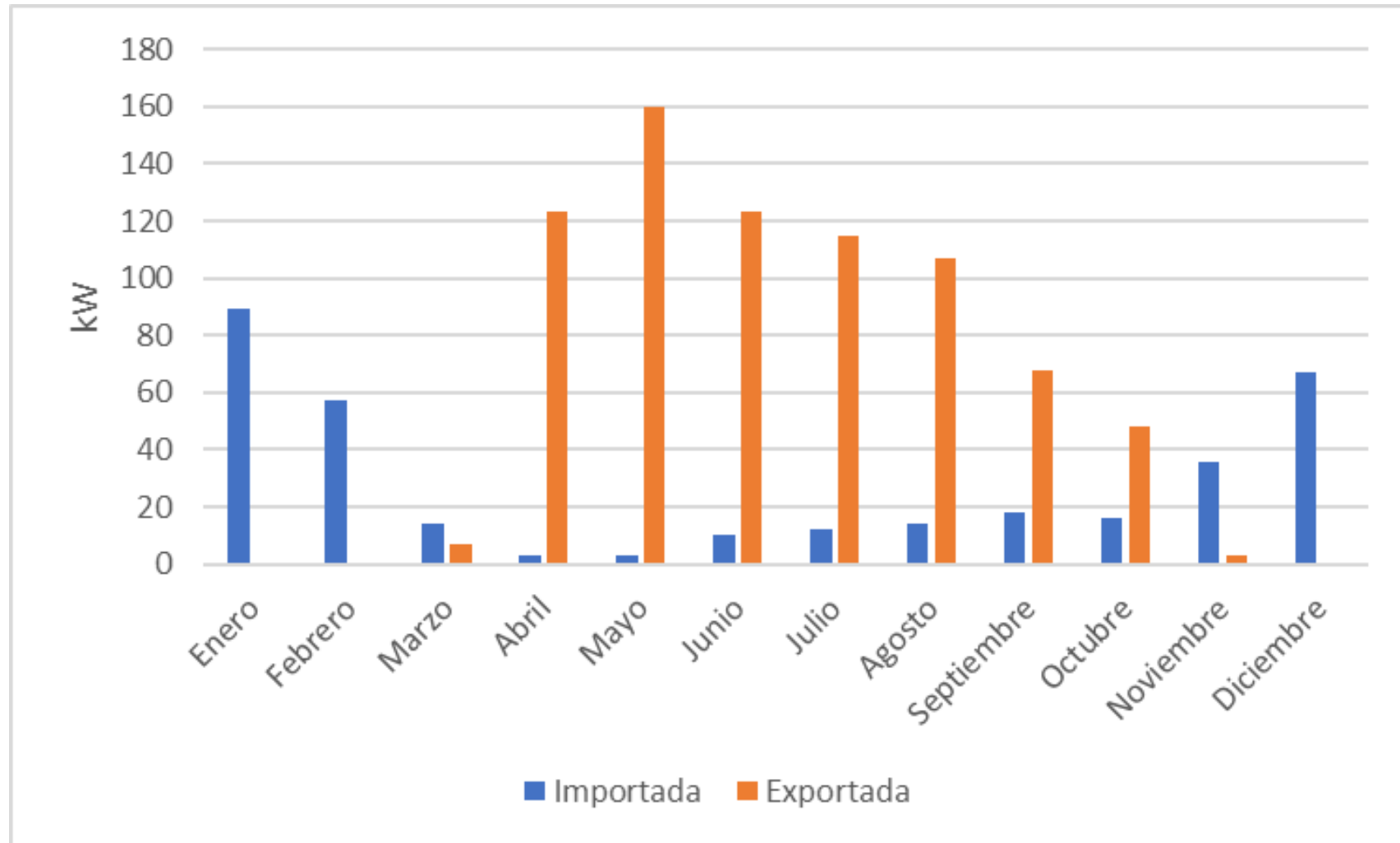


Figure 30: Modelling results, heat demand of the buildings in the city of Bassano (kWh/m²).

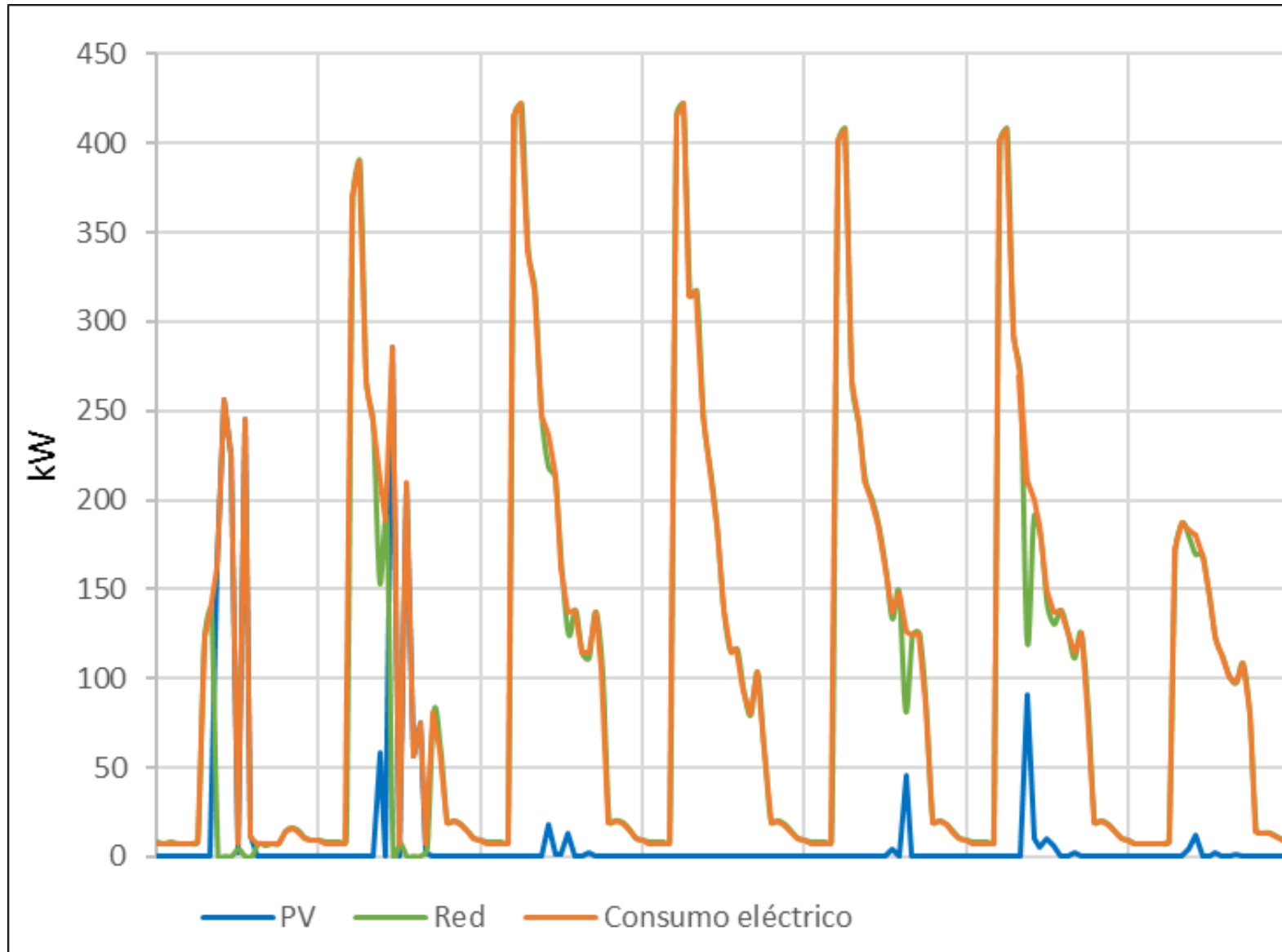




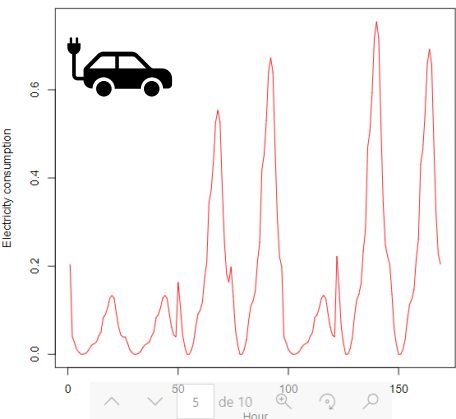
Sample District – Monthly Energy Balance



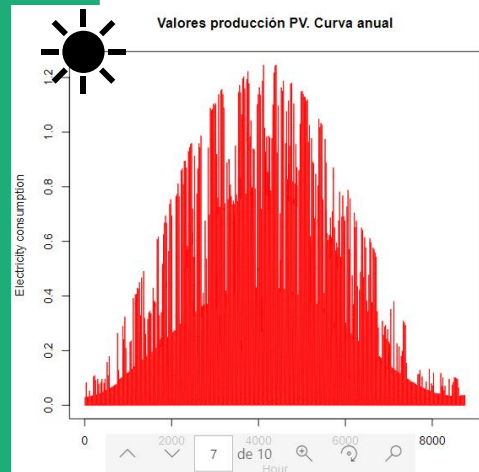
Sample District – Hourly Energy Balance



Valores de consumo del EV.hora 3000 a 3168

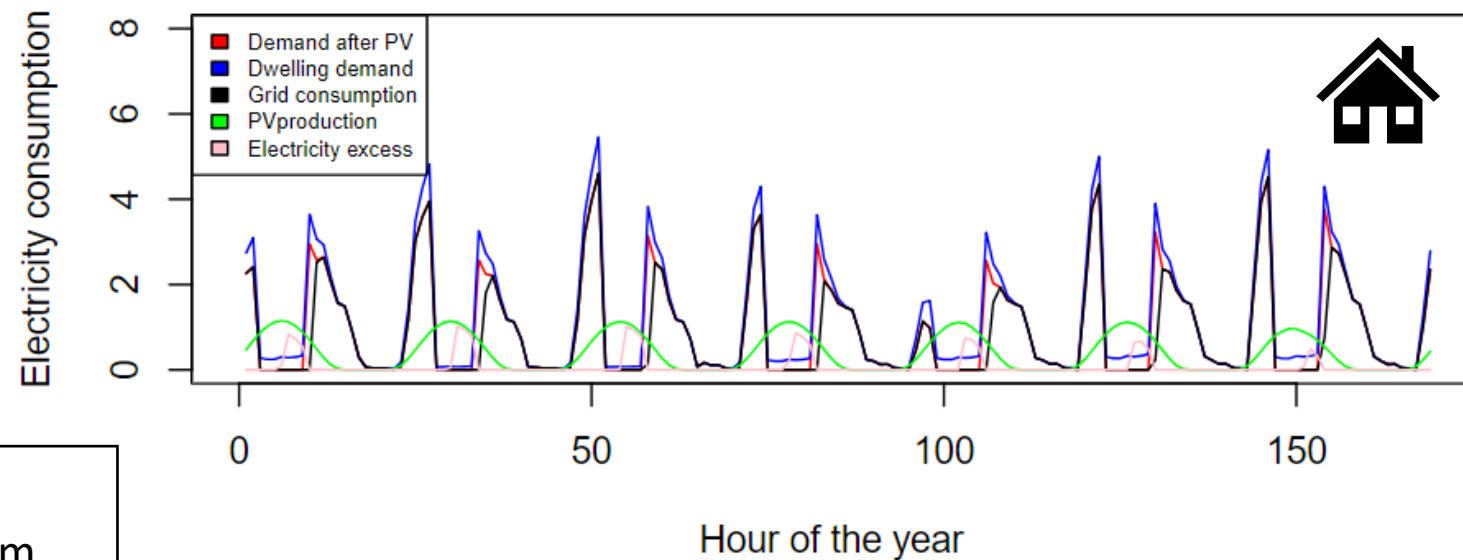


Valores producción PV. Curva anual

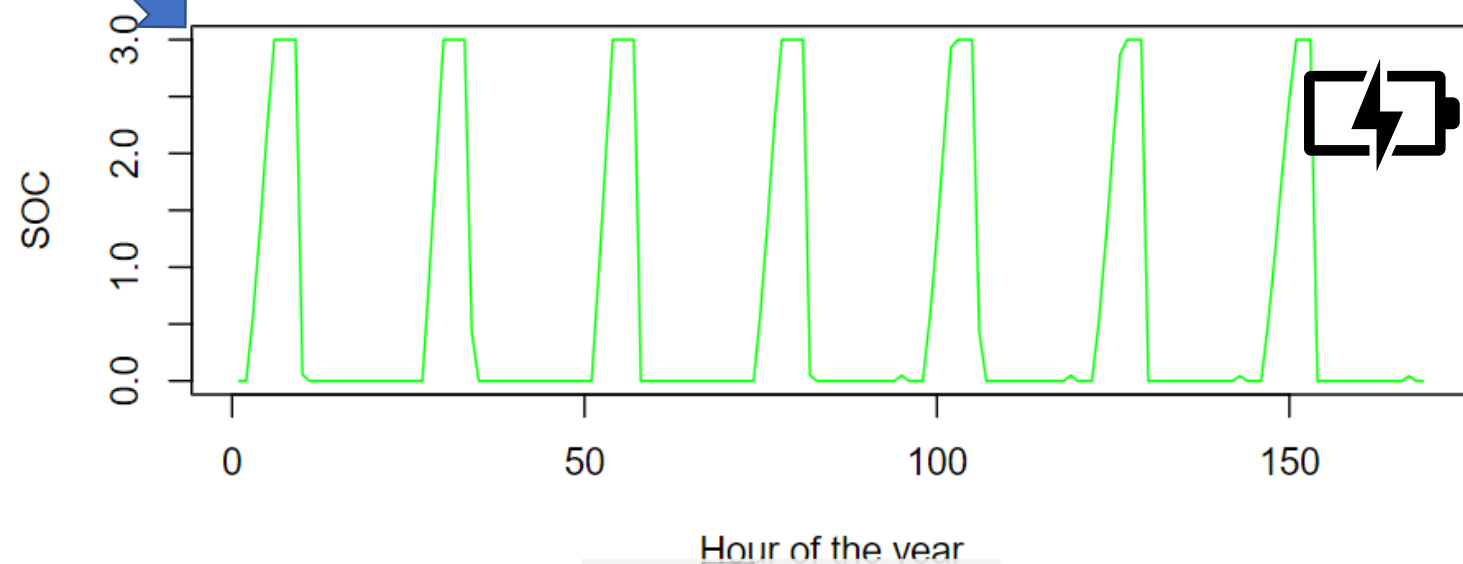


Energy system
management

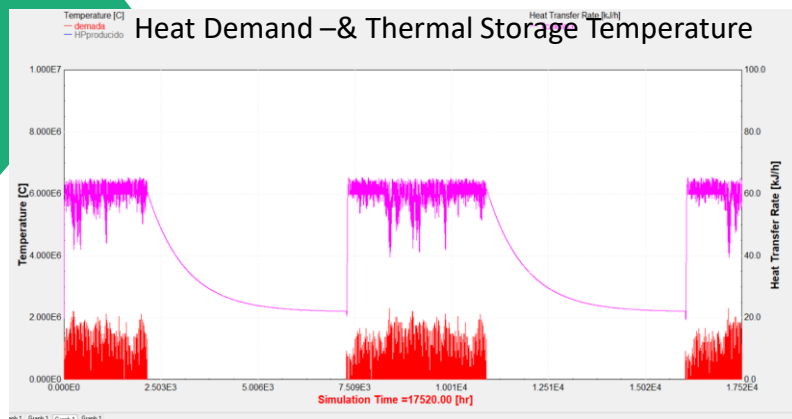
Hourly energy balance – Hour 5000 - 5168



State of Charge of the battery (3kWh)

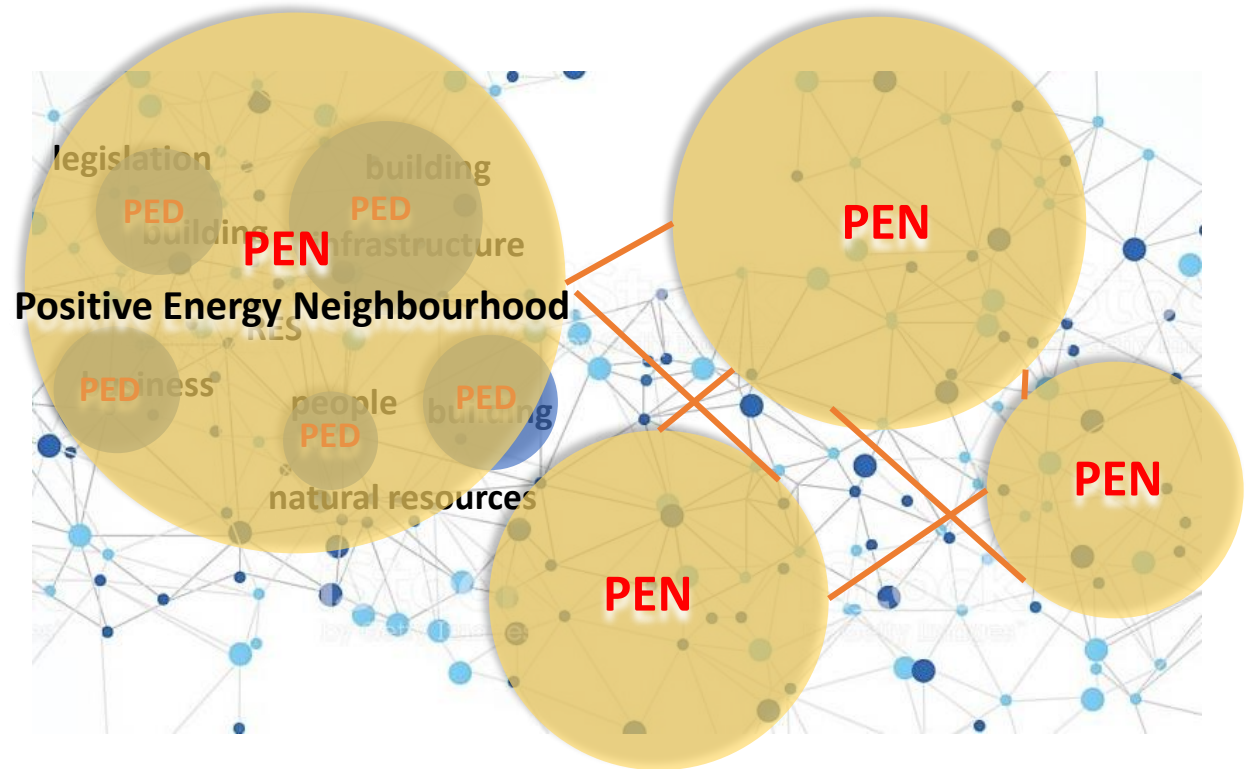


Heat Demand –& Thermal Storage Temperature



Future of PED Calculation Methodologies

- Dynamic Characteristic of PED Framework – Changes in calculation methods
 - Mobility, Public Infrastructure, Embodied Energy, Water, Food, etc.
- Connection of Districts to a wider perspective
 - Neighborhood, City, Region?
 - How to evaluate, add new PED analytical components?



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Thank you

Get in touch for more information!



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