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Case study: Mediterranean Demo of Cultural-E

Results and outcomes from the design process and the simulation-aided activities of the PEB Italian Demonstration Building

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Cooperativa di Abitazione Modena
Ing. Andrea Prampolini

Demo Cases

Demo case
Oceanic climate

Demo case
Continental climate

Demo case
Sub-Arctic climate

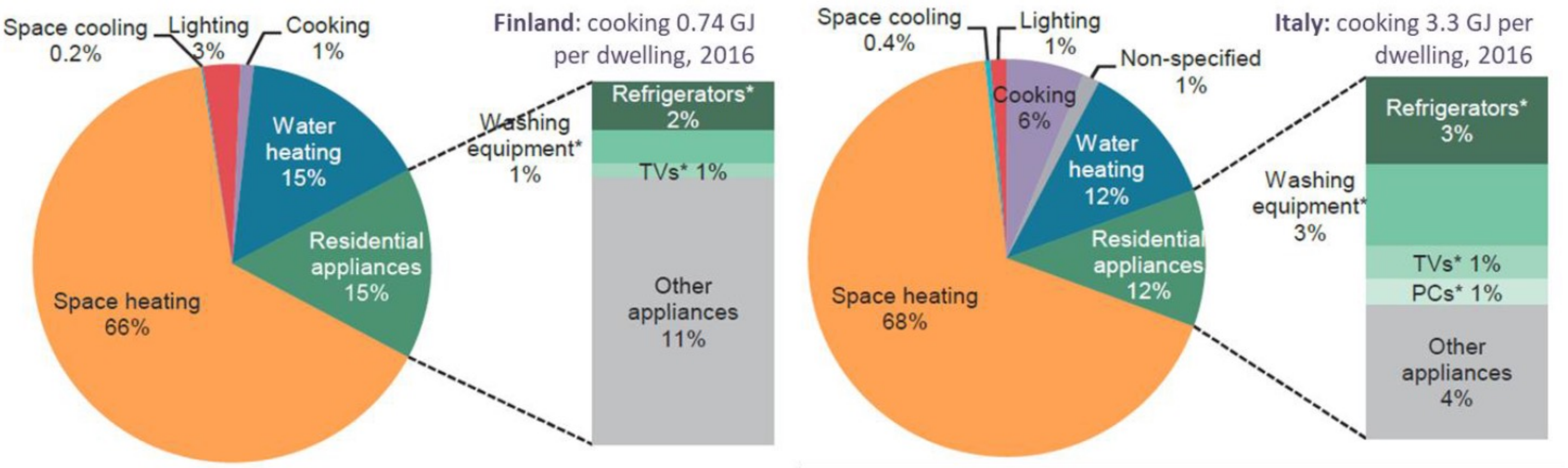
Demo case
Mediterranean climate

Climatic context: temperature, weather, latitude

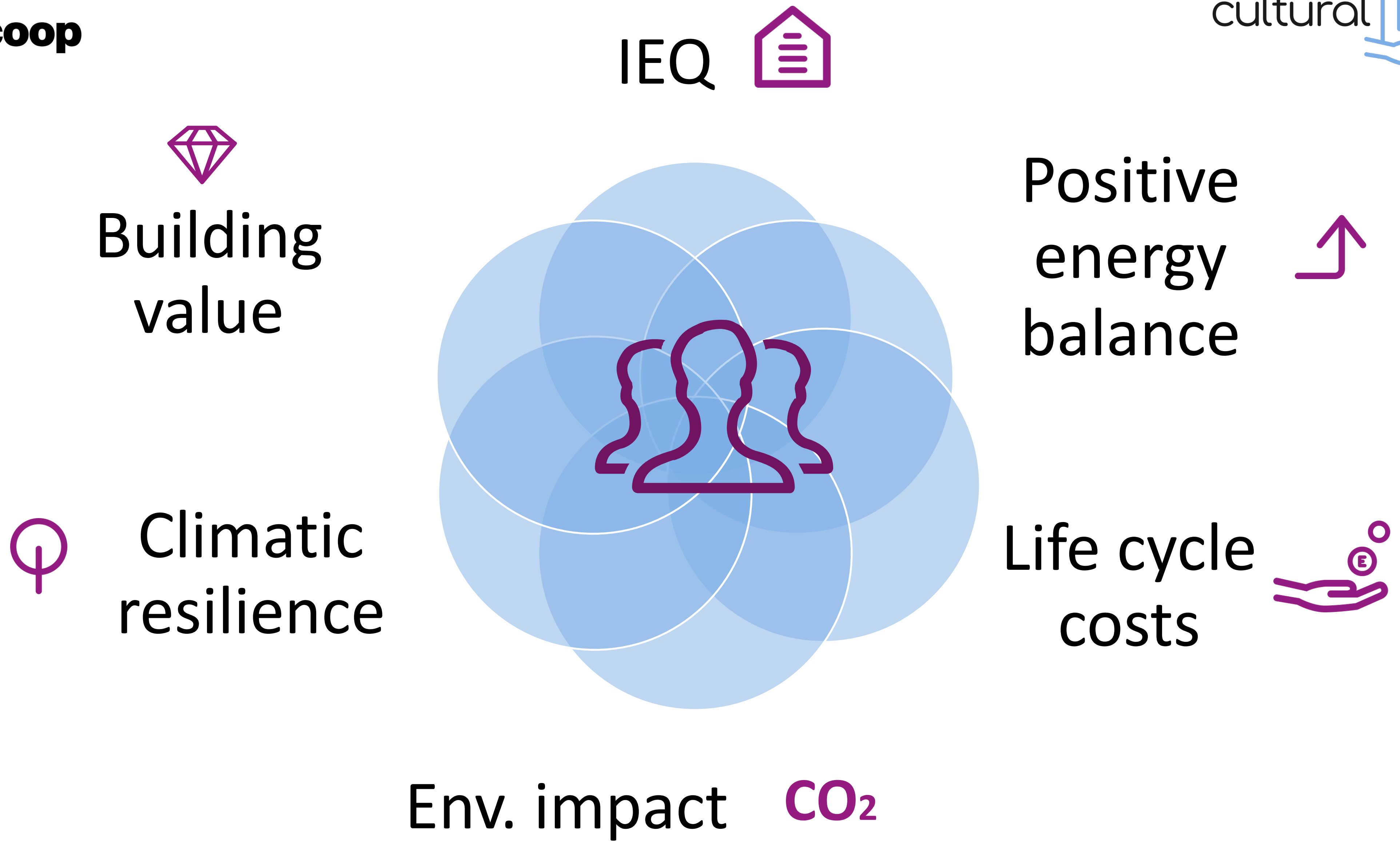
Cultural context: user behaviour, habits, preferences

Considered along the design process to boost value and optimize costs for PEB

User habits, preferences and expectations



Residential energy consumption by end-use according to 2018 IEA energy efficiency indicators highlights


IEQ
Building value
Positive energy balance
Climatic resilience
Life cycle costs
Env. impact
CO_2

Italian Demo Case – Castenaso (BO)

Pilot A includes 7 apartments – 4 floors, pilot B includes 6 apartments – 3 floors. Avg 75-110 m2.

Garage at ground level. Garden.

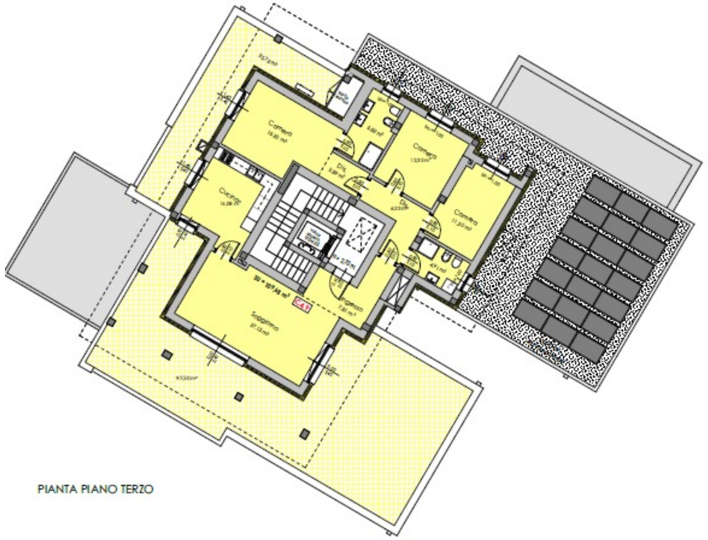
The apartments are made in different sizes for the middle class, dedicated to singles, families, and the elderly.

Building B

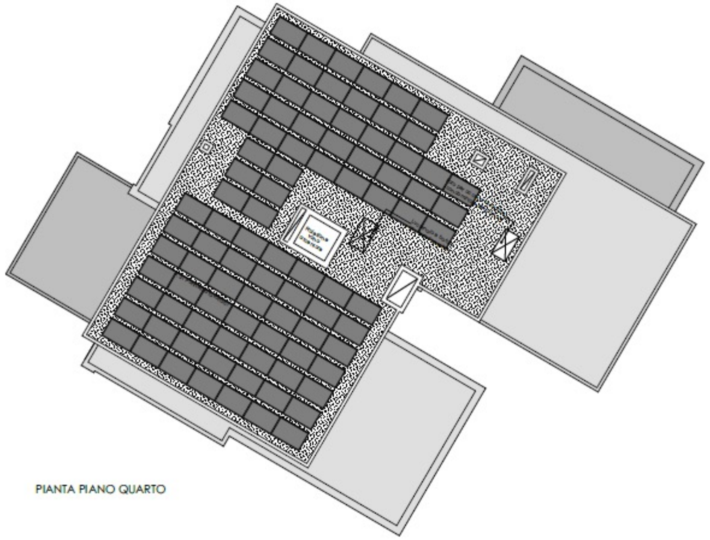
Building A

PIANTA PIANO PRIMO

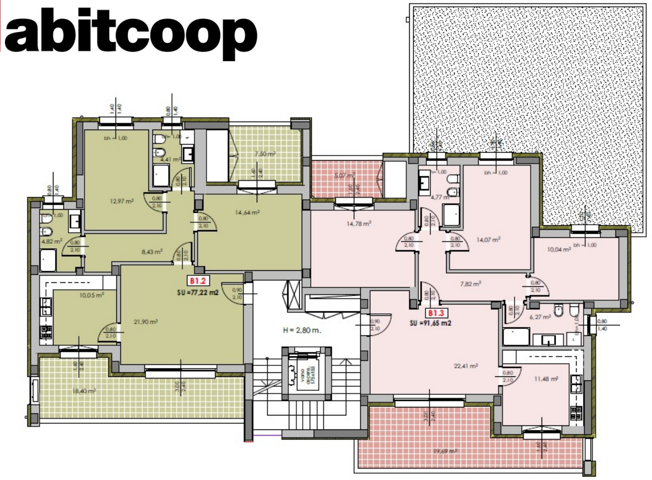
PIANTA PIANO SECONDO



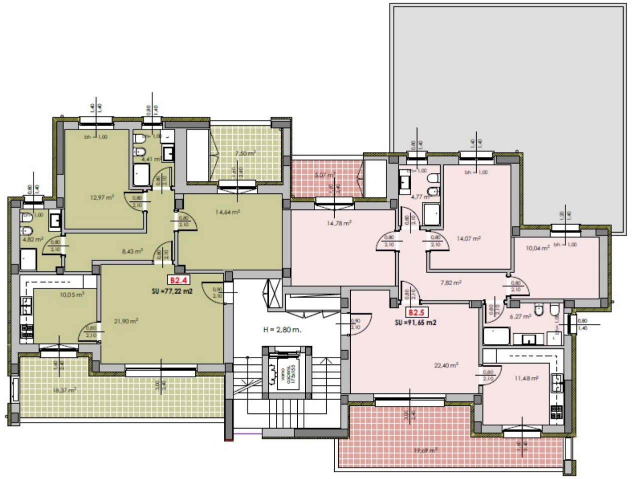
PIANTA PIANO TERZO



PIANTA PIANO QUARTO



PIANTA PIANO PRIMO



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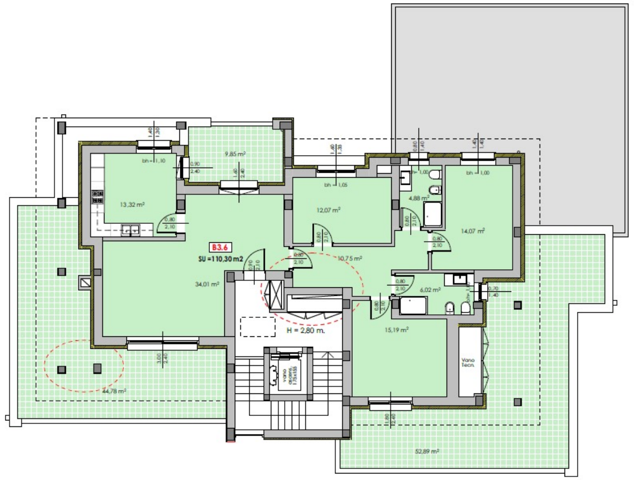
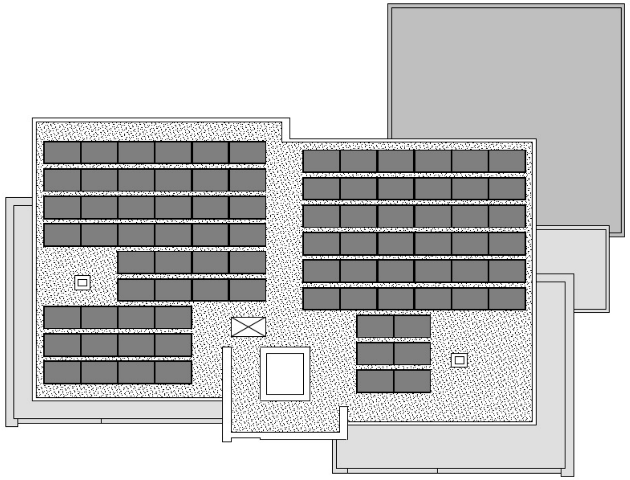


PIANTA PIANO TERZO



PIANTA PIANO QUARTO

Building C - Reference building (nZEB)

Certifications: Casaclima class A, regional certification A4

Innovative technologies

ACTIVE WINDOW

EURO FINESTRA

PACKED HEAT PUMP SYSTEM

ventive

naturally intelligent ventilation

SMART AIR MOVEMENT

VORTICE

HOUSE MANAGEMENT SYSTEM

advanticsys

- Building envelope: insulation layers, windows
- Heating : UFH, PHP
- Cooling : air cooling, PHP
- DHW : PHP
- Controlled ventilation : based on T/H/CO2 room sensors
- Lighting : LED
- Energy production : PV (6 kWp), BESS (6 kWh)
- Monitoring and control : cloud-backed HMS
- Other key aspect : solar shading systems

Challenges

Limited Heating and Cooling capacity
→ Need to avoid peaks
→ Need to overlap air movement and cooling

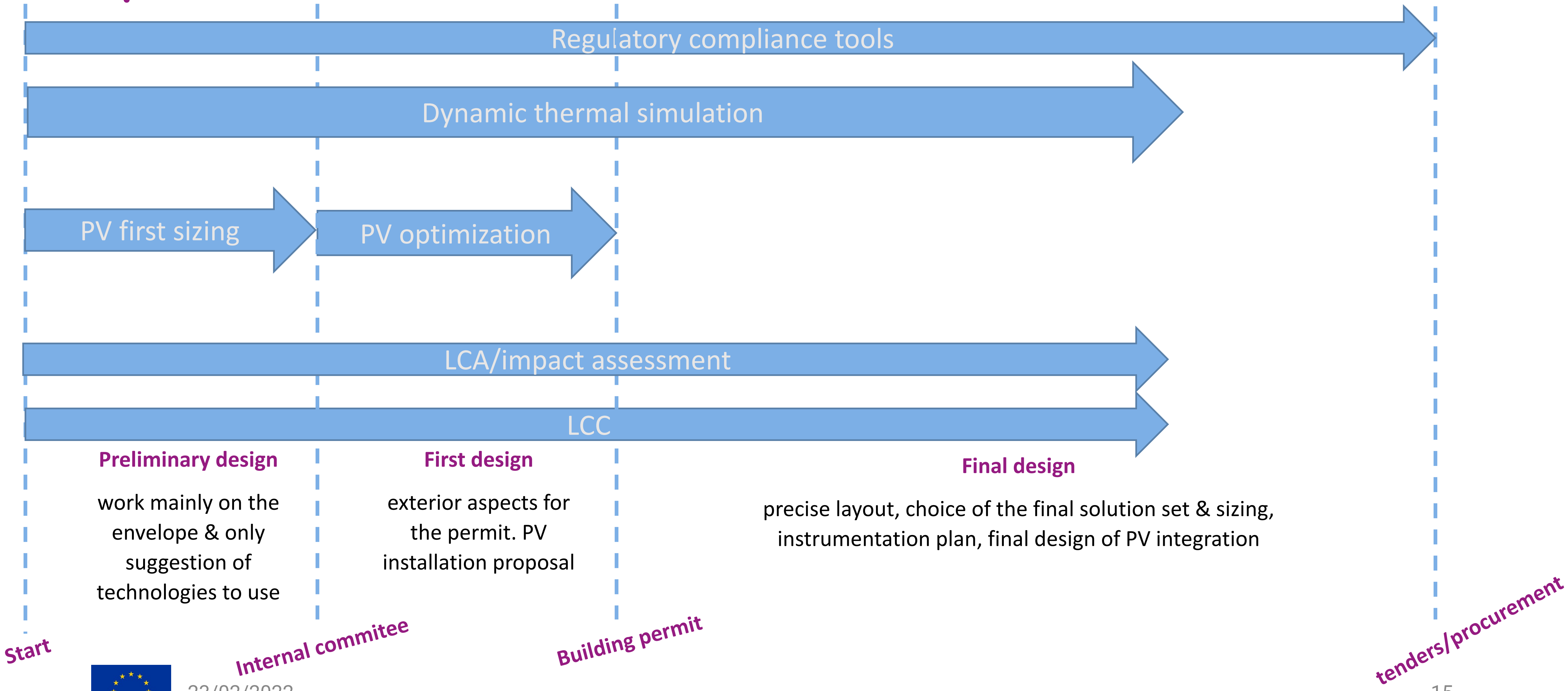
Advanced control logics
→ Need to consider user occupancy/behaviour
→ to manage electric and thermal storages (energy flexibility)

Limited resources for energy production (i.e. roof area)
→ Need to reduce energy consumption

Timeline

4/21: Building permit request
8/21: Final design
9/21: Economic assessment
9/21: Start building process
2/23: Delivery
3/23: Start monitoring

Simulation-aided design process



Preliminary design
Parametric inputs

ITALIAN DEMO PRELIMINARY SIMULATIONS – Parametric inputs

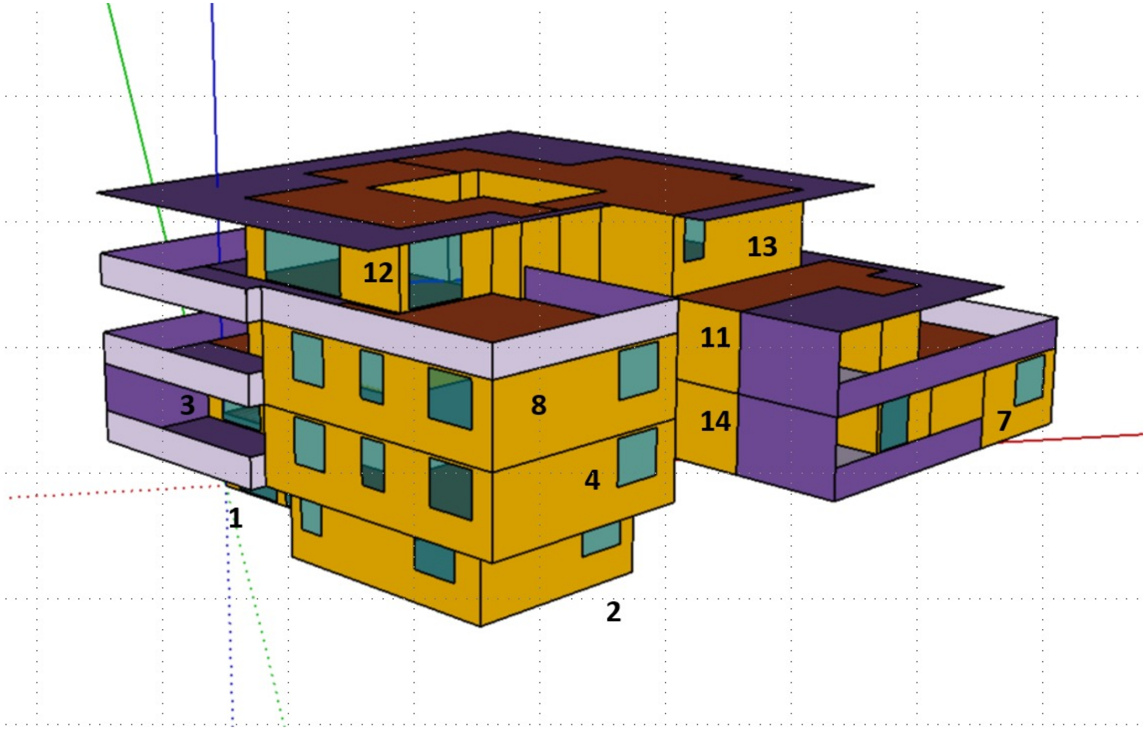
- SET POINT HEATING: 20°C (fixed)
- SET POINT COOLING: 26°C (fixed)
- MECHANICAL VENTILATION 0.5 ACH (fixed) with 70% heat recovery (summar and winter)
- INFILTRATION 0.15 ACH (fixed)
- WINDOW (U_frame=0.8 W/m²K):
  - Double glazing U=1 W/m²K, g=51%
  - Triple glazing U=0.5 W/m²K, g=48%
- SHADING SYSTEM: Absent
- SHADING SYSTEM: Basic Control

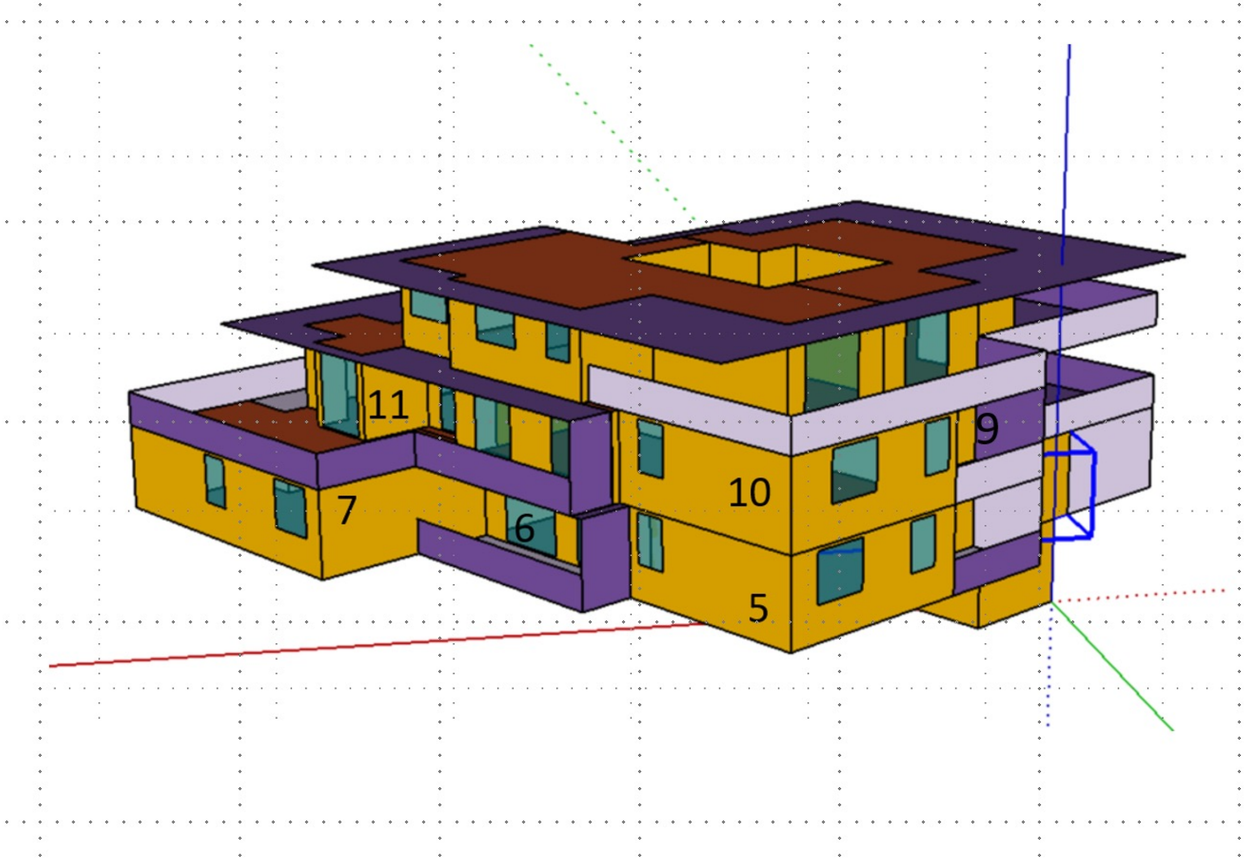
  (Shading factor 80%)
  - CLOSED with radiation >140 W/m²
  - OPEN with radiation <120 W/m²
- SHADING SYSTEM: Advanced Control

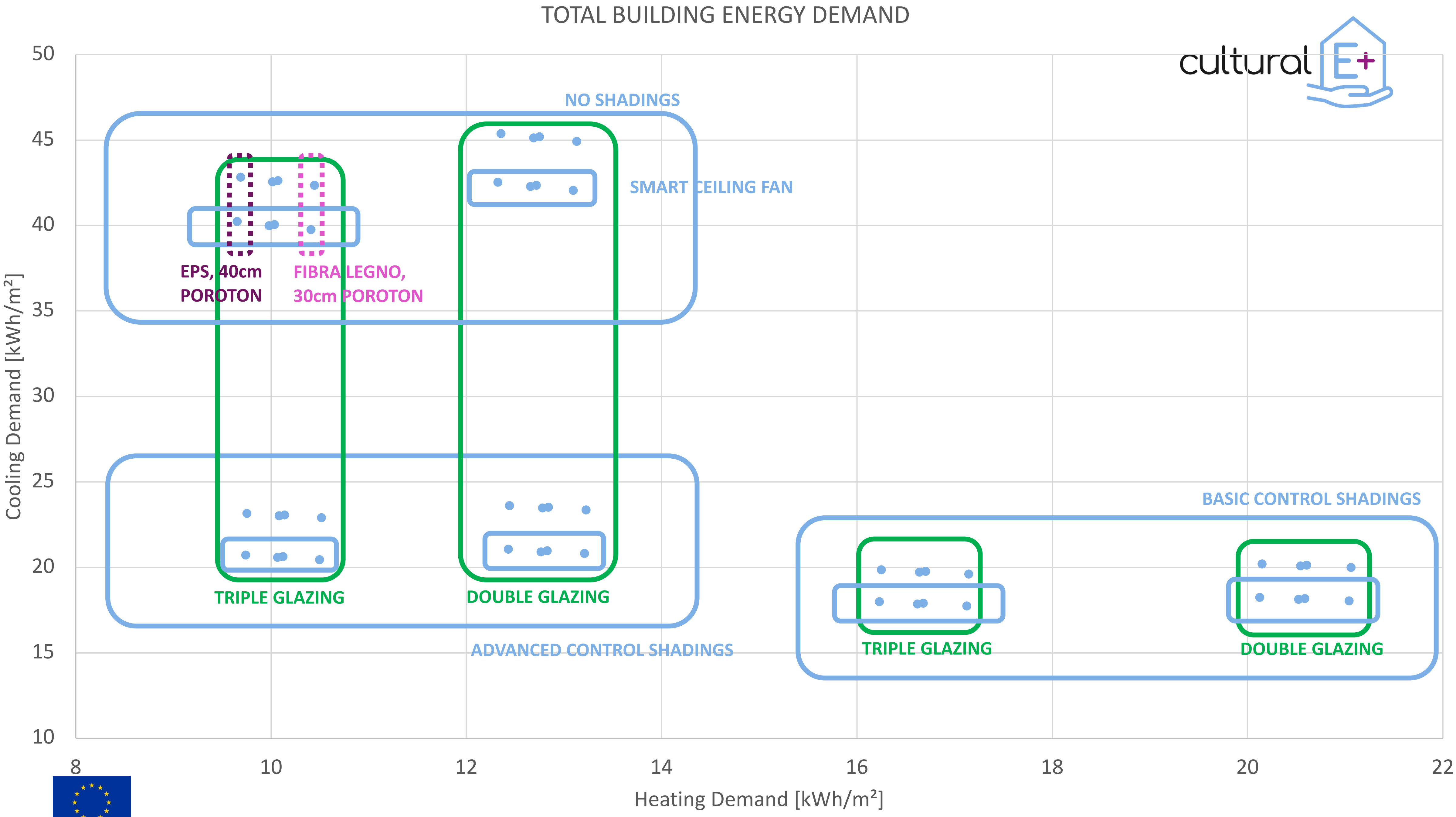
  (Shading factor 80%)

  If INTERNAL Temperature >24°C e T_mean_24h>15°C
  - CLOSED with radiation >140 W/m²
  - OPEN with radiation <120 W/m²
- SMART CEILING FAN
  - Present (allows cooling set point +1.8°C), only day-zones (with big zones 2 have been used)
  - Absent
- WALL CHARACTERISTICS:
  - 30cm o 40cm insulation
  - Insulation type: wood fibre or EPS

1+2= APT1
3+4= APT2
5+6= APT3
7+14= APT4
8+9= APT5
10+11=6
12+13=7







TOTAL BUILDING ENERGY DEMAND
Cooling Demand [kWh/m²]
Heating Demand [kWh/m²]
50
45
40
35
30
25
20
15
10
8
10
12
14
16
18
20
22
NO SHADINGS
SMART CEILING FAN
EPS, 40cm
POROTON
FIBRA LEGNO,
30cm POROTON
TRIPLE GLAZING
DOUBLE GLAZING
ADVANCED CONTROL SHADINGS
BASIC CONTROL SHADINGS
TRIPLE GLAZING
DOUBLE GLAZING

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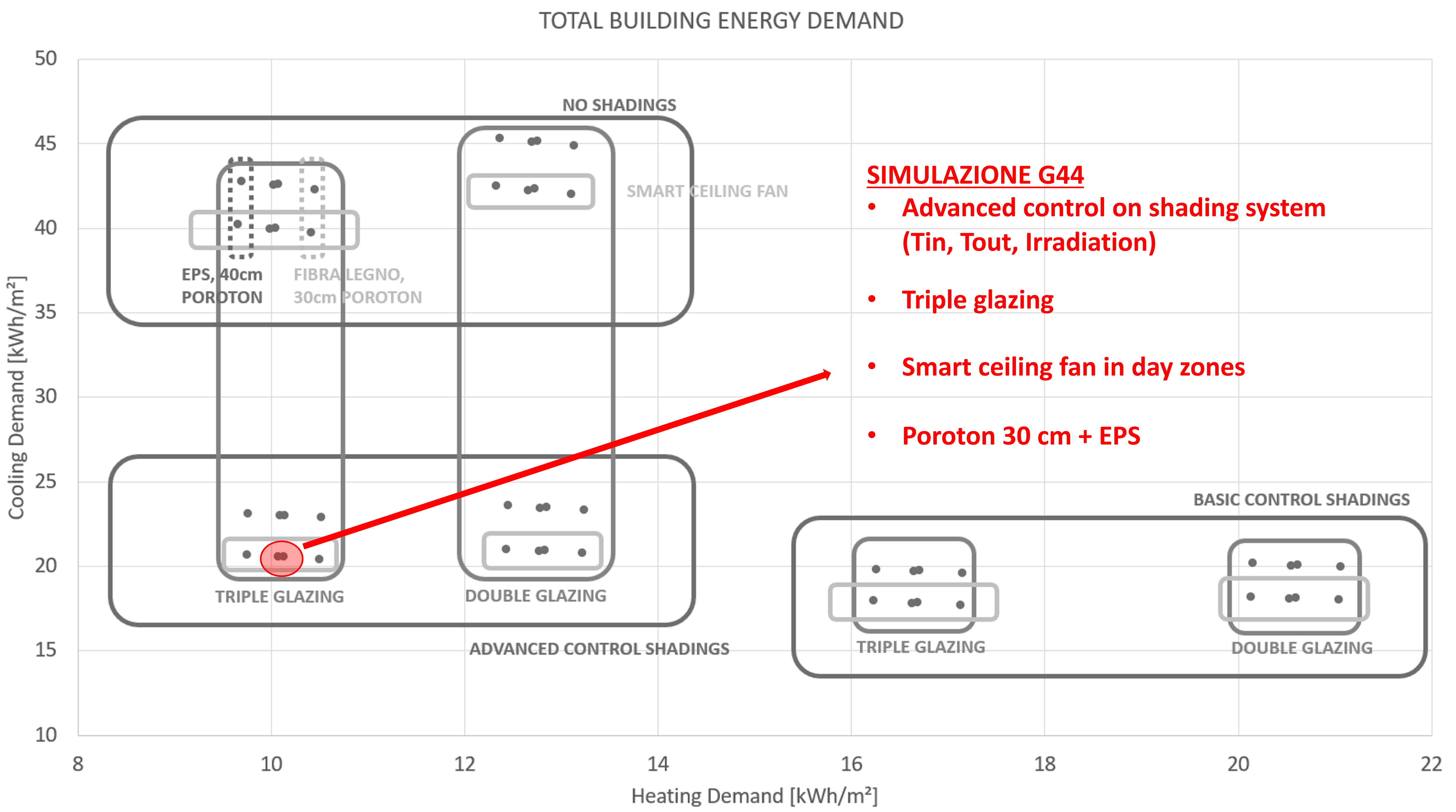
TOTAL BUILDING ENERGY DEMAND
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50
45
40
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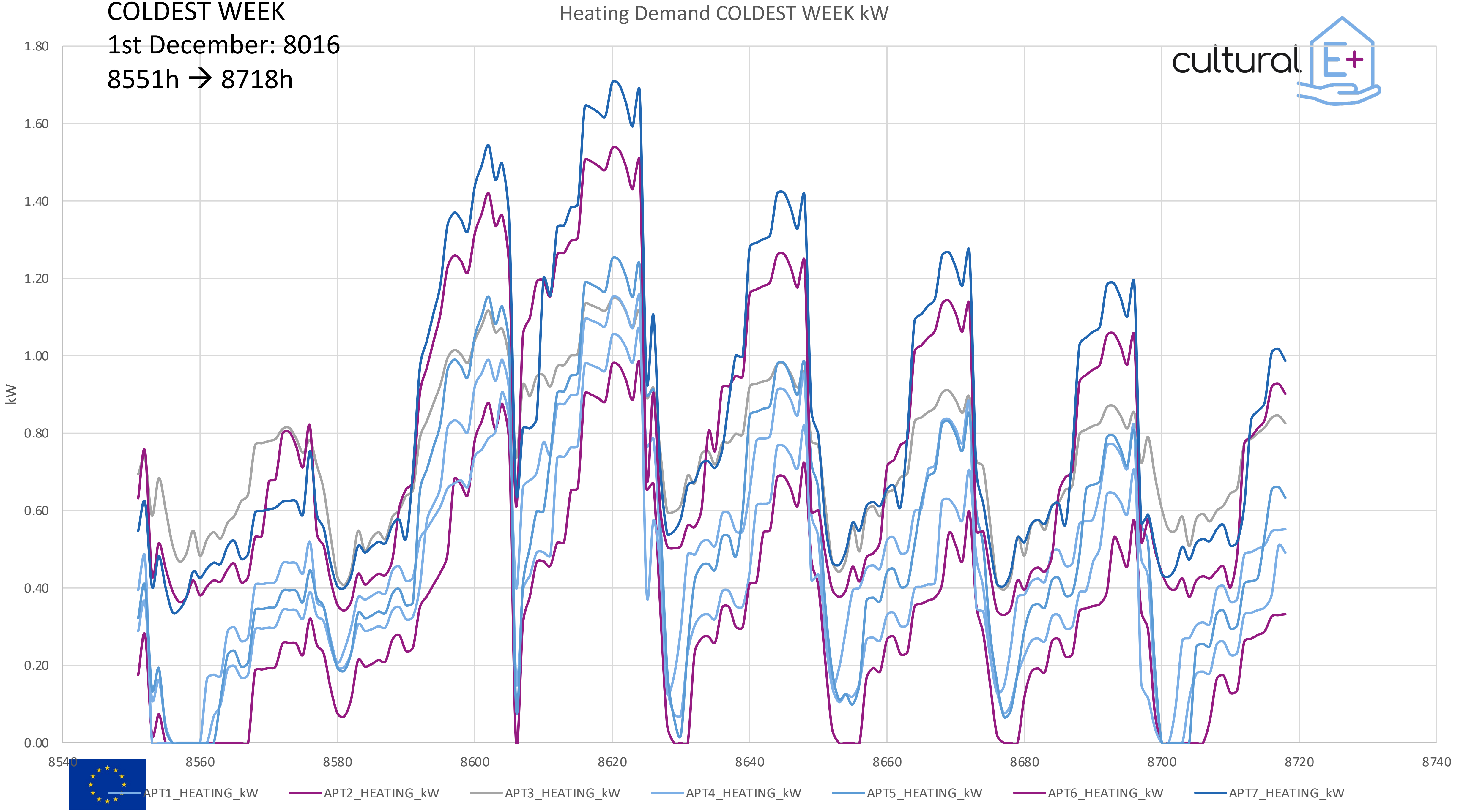
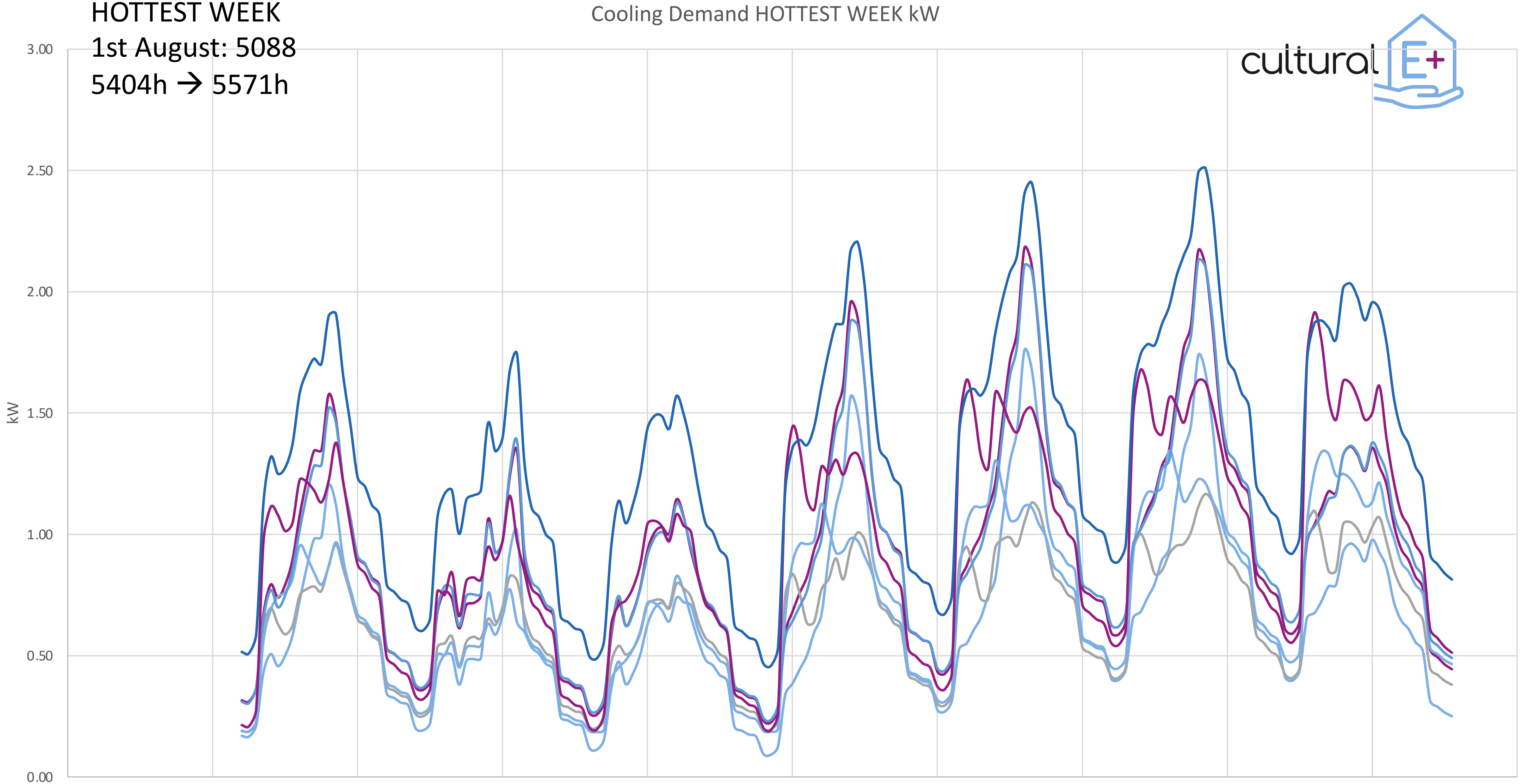
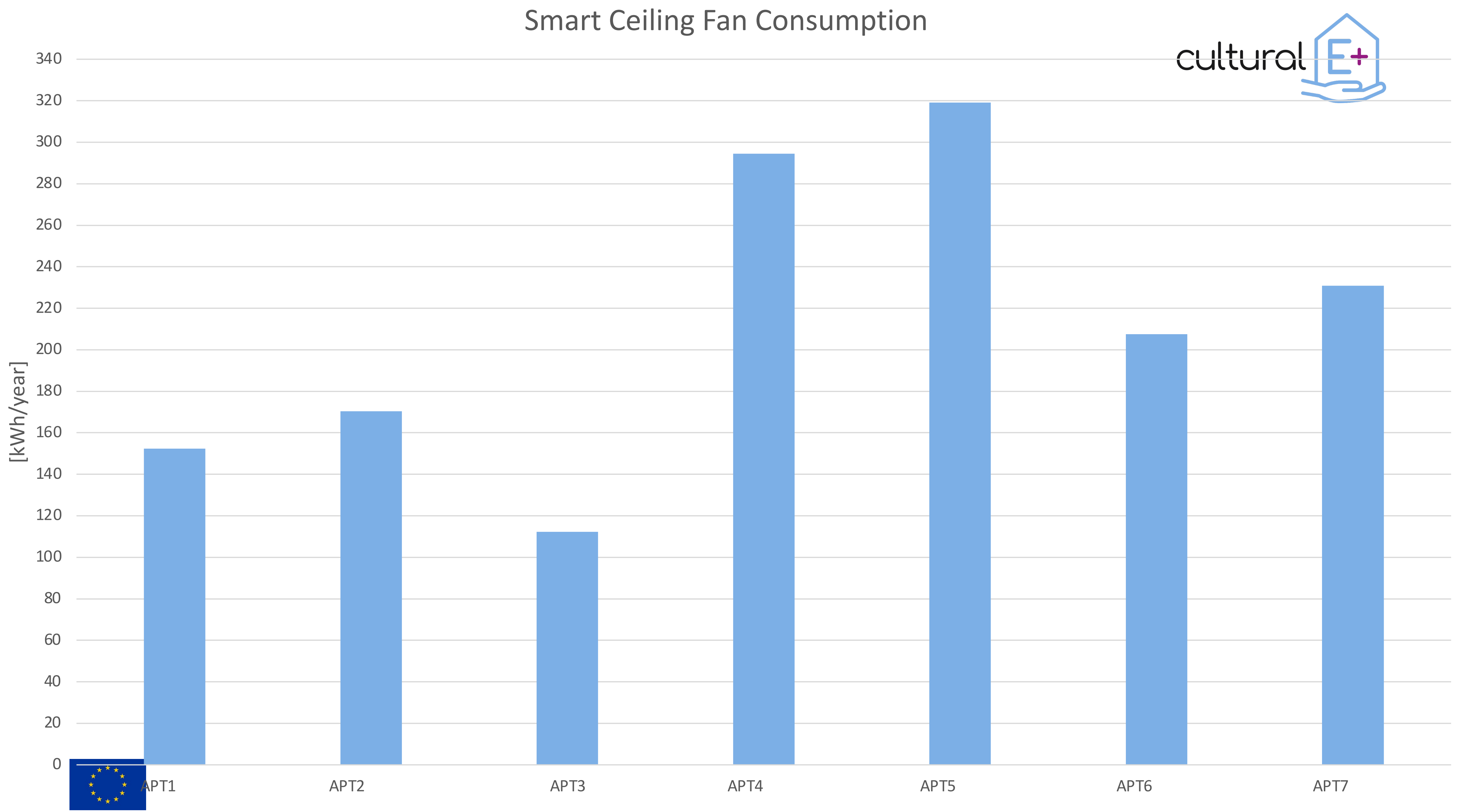
30
25
20
15
10
8
10
12
14
16
18
20
22
NO SHADINGS
SMART CEILING FAN
EPS, 40cm POROTON
FIBRA LEGNO, 30cm POROTON
TRIPLE GLAZING
DOUBLE GLAZING
ADVANCED CONTROL SHADINGS
BASIC CONTROL SHADINGS
TRIPLE GLAZING
DOUBLE GLAZING
SIMULAZIONE G44
• Advanced control on shading system (Tin, Tout, Irradiation)
• Triple glazing
• Smart ceiling fan in day zones
• Poroton 30 cm + EPS

COLDEST WEEK
1st December: 8016
8551h → 8718h



HOTTEST WEEK
1st August: 5088
5404h → 5571h




Smart Ceiling Fan Consumption
[kWh/year]
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
APT1
APT2
APT3
APT4
APT5
APT6
APT7
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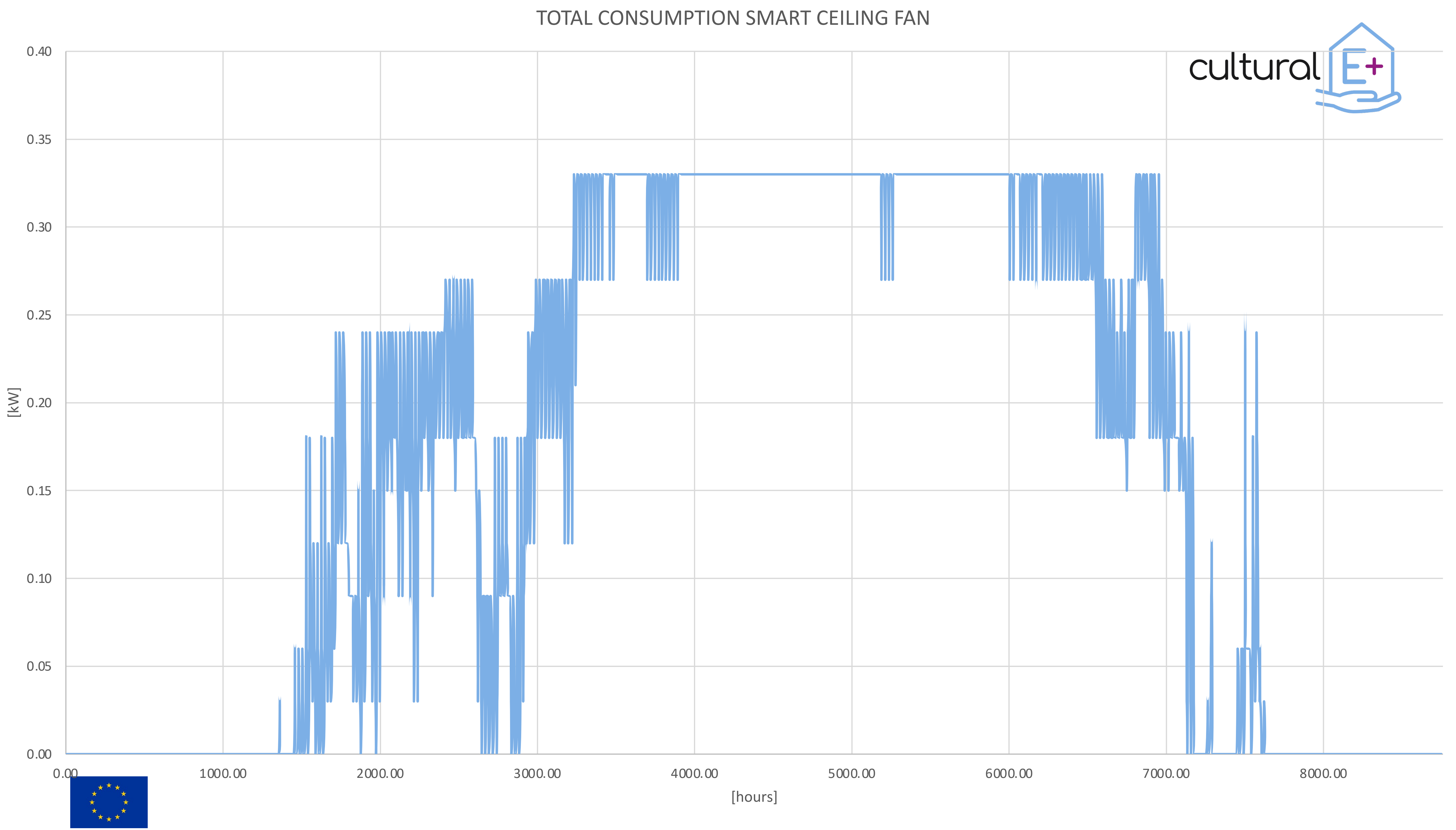
TOTAL CONSUMPTION SMART CEILING FAN
[kW]
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
1000.00
2000.00
3000.00
4000.00
5000.00
6000.00
7000.00
8000.00
[hours]
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ZONA:	*7*	***P3 - APP. A7***

	Mese:	***Luglio***

Ora di massimo carico della zona:	***18***

Carichi termici nell'ora di massimo carico della zona:

N.	Descrizione	Q_{Irr} [W]	Q_{Tr} [W]	Q_v [W]	Q_c [W]	$Q_{gl,sen}$ [W]	$Q_{gl,lat}$ [W]	Q_{gl} [W]
1	*SOGGIORNO*	*493*	*451*	*853*	*717*	*1819*	*694*	*2514*
2	*CUCINA*	*323*	*192*	*377*	*273*	*881*	*284*	*1165*
5	*LETTO SINGOLO 1*	*42*	*86*	*315*	*250*	*444*	*249*	*693*
6	*LETTO SINGOLO 2*	*42*	*63*	*330*	*256*	*434*	*258*	*691*
8	*LETTO MATRIMONIALE*	*329*	*145*	*447*	*433*	*960*	*394*	*1354*
	Totali	*1230*	*937*	*2321*	*1930*	*4539*	*1878*	*6417*

Legenda simboli

Q_{Irr}	Carico dovuto all'irraggiamento
Q_{Tr}	Carico dovuto alla trasmissione
Q_v	Carico dovuto alla ventilazione
Q_c	Carichi interni
$Q_{gl,sen}$	Carico sensibile globale
$Q_{gl,lat}$	Carico latente globale
Q_{gl}	Carico globale

5.2.3.5.4. ***BALANCE 4 - ENERGY BALANCE FOR ZONES (NTYPE 904)***

The system boundary for this energy balance includes the inside surface node of all surfaces of a zone. Due to this also all radiative heat fluxes appear in this balance. This is different from the balance shown in Section 5.4.1.1 which could only treat the Convective Heat Flux to the Air Node. However the system boundary doesn't include the inside of a wall so the energy of an active layer as well as the stored energy of walls is not part of this balance but of the detailed balance for surfaces (see 5.2.3.5.6). If NType 904 was selected in the output manager, this balance will be printed for all zones in one file (called ENERGY_ZONES.BAL).

B4_QBAL =- B4_DQAIRdt + B4_QHEAT - B4_QCOOL + B4_QINF
+ B4_QVENT + B4_QCOUP + B4_QTRANS
+ B4_QGINT + B4_QWGAIN + B4_QSOL
+ B4_QSOLAIR [kJ/hr] Eq. 5.2.3-4

Balance:

B4_QBAL	energy balance for one zone should be always close to 0. In order to save time the matrix of Type 56 is not inverted all the time, but only if the error is less than a certain tolerance. Due to this fact the energy balance of the zone isn't always 0.
B4_DQAIRdt	change of internal energy of zone (calculated with capacitance of air +additional capacitance which might be added in TRNBuild)
B4_QHEAT	power of ideal heating (convective+radiative)
B4_QCOOL	power of ideal cooling
B4_QINF	infiltration gains
B4_QVENT	ventilation gains
B4_QCOUP	coupling gains
B4_QTRANS	transmission into the surface from inner surface node (might be stored in the wall, going to a slab cooling or directly transmitted)
B4_QGINT	internal gains (convective+radiative)
B4_QWGAIN	wall gains
B4_QSOL	absorbed solar gains on all inside surfaces of zones (NOTE: This gain isn't equal to Balance 1, because the absorbed solar gains of the inside surface of all windows are taken into account. These absorbed gains may go inside or outside. For Balance 1, the absorbed gains on the inside and outside node going inside are used.)
B4_QSOLAIR	convective energy gain of zone due transmitted solar radiation through external windows which is transformed immediately into a con. heat flow to internal air.

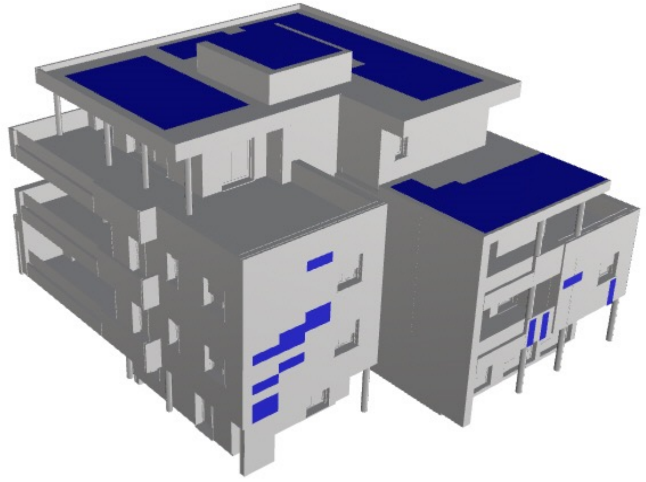
BILANCIO DA G44, picco massimo COOLING:

TIME [HR]	T_outdoor °C	12+13_B4_QHEAT- [W]	12+13_B4_QCOOL+ [W]	12+13_B4_QINF+ [W]	12+13_B4_QVENT+ [W]	12+13_B4_QTRANS+ [W]	12+13_B4_QGINT+ [W]	12+13_B4_QSOL+ [W]
5536.00	38.39	0.00	2561.67	201.53	177.81	-405.17	491.89	2095.56

PV system design process

1) Optimization of PV and battery for the whole building (energy sharing)
   - **Both roof and façade available** for PV installation, **PV modules (16.5% efficiency) coplanar** to the building surface
   - Hourly profiles of electric consumption for h&c, appliances and common areas lighting from **Eurac available data**
   - Target function: **payback of investment** by 15 years considering a fixed rate of interest
   - Cost of electricity: 0.18 €/kWh for consumer, 0.05 €/kWh for provider
   - Cost of PV system: 1500 €/kWp on roof, 2200 €/kWp on façade

PV capacity [kWp]	31
capacity of electric storage [kWh]	3.9
self-consumption [%]	60
self-sufficiency [%]	40
annual cumulative balance production/consumption	0.70



PV system design process

2) Optimization of PV and battery for each apartment and for the whole building (energy sharing)

- **Roof only available** for PV installation, **PV modules (16.5% efficiency) coplanar** to the building surface
- Hourly profiles of electric consumption for h&c **provided by energy simulations**, appliances and individual lighting from **Load Profile Generator (LPG)**
- Target function: **maximum NPV** at 25th years
- Cost of electricity: 0.2082 €/kWh for consumer, 0 €/kWh for provider
- Cost of PV system: 1200 €/kWp

	Flat 1	Flat 2	Flat 3	Flat 4	Flat 5	Flat 6	Flat 7	All flats NO en. sharing	All flats en. sharing
PV capacity [kWp]	7.1	8.4	6.6	6.4	5.8	6.1	9.9	50.2	33.3
Battery capacity [kWh]	0	0	0	0	0	0	0	0	0
Self-consumption [%]	32	35	33	35	43	43	42	40	56
Self-sufficiency [%]	36	39	37	39	47	47	46	44	39

PV system design process

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3) Simulation of PV and battery for each apartment

- **Fixed PV capacity at 6 kWp per apartment**
- **Same input as step 2** but **PV modules (17.9% efficiency) tilted on roof (7°)**
- **Simulation of four different battery capacities: 0, 3.3, 6.5, 9.8 kWh** (ref: LG Chem RESU)

WITH 0 kWh of battery	Flat 1	Flat 2	Flat 3	Flat 4	Flat 5	Flat 6	Flat 7
Self-consumption [%]	30	39	31	31	35	36	54
Self-sufficiency [%]	34	37	36	39	51	51	42

WITH 3.3 kWh of battery	Flat 1	Flat 2	Flat 3	Flat 4	Flat 5	Flat 6	Flat 7
Self-consumption [%]	43	52	44	44	47	49	66
Self-sufficiency [%]	48	49	51	55	70	68	52

WITH 6.5 kWh of battery	Flat 1	Flat 2	Flat 3	Flat 4	Flat 5	Flat 6	Flat 7
Self-consumption [%]	52	62	52	53	54	55	74
Self-sufficiency [%]	58	58	61	68	79	78	58

WITH 9.8 kWh of battery	Flat 1	Flat 2	Flat 3	Flat 4	Flat 5	Flat 6	Flat 7
Self-consumption [%]	58	68	58	59	55	57	80
Self-sufficiency [%]	64	64	67	74	81	79	62

Thank you for your attention!

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