TUIASI

Co-funded by the Erasmus+ Programme of the European Union

MARUEEB

"GHEORGHE ASACHI" TECHNICAL UNIVERSITY OF IASI

Use of renewable energy to increase the energy efficiency in buildings

Introduction to the nZEB concept

Lecturer. Phd. Marius Balan

Yerevan, April 17-19

Romania in Europe

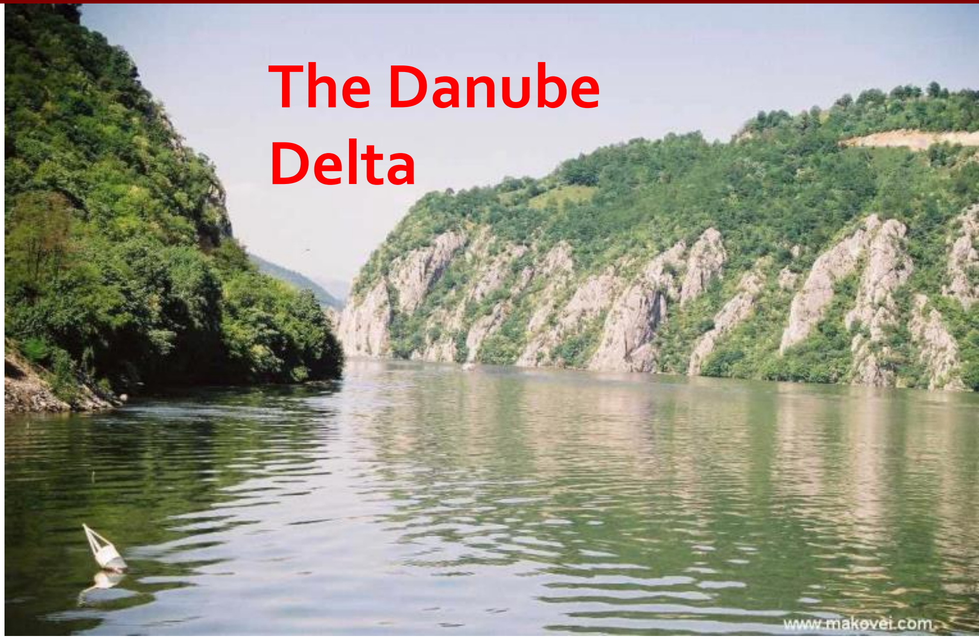
POPULATION

- 21 mil. inhabitants
- 73% live in urban areas
- another 8 mil Romanians live abroad

HILLS AND PLATEAUS (33%)

PLAINS (36%)


Black Sea

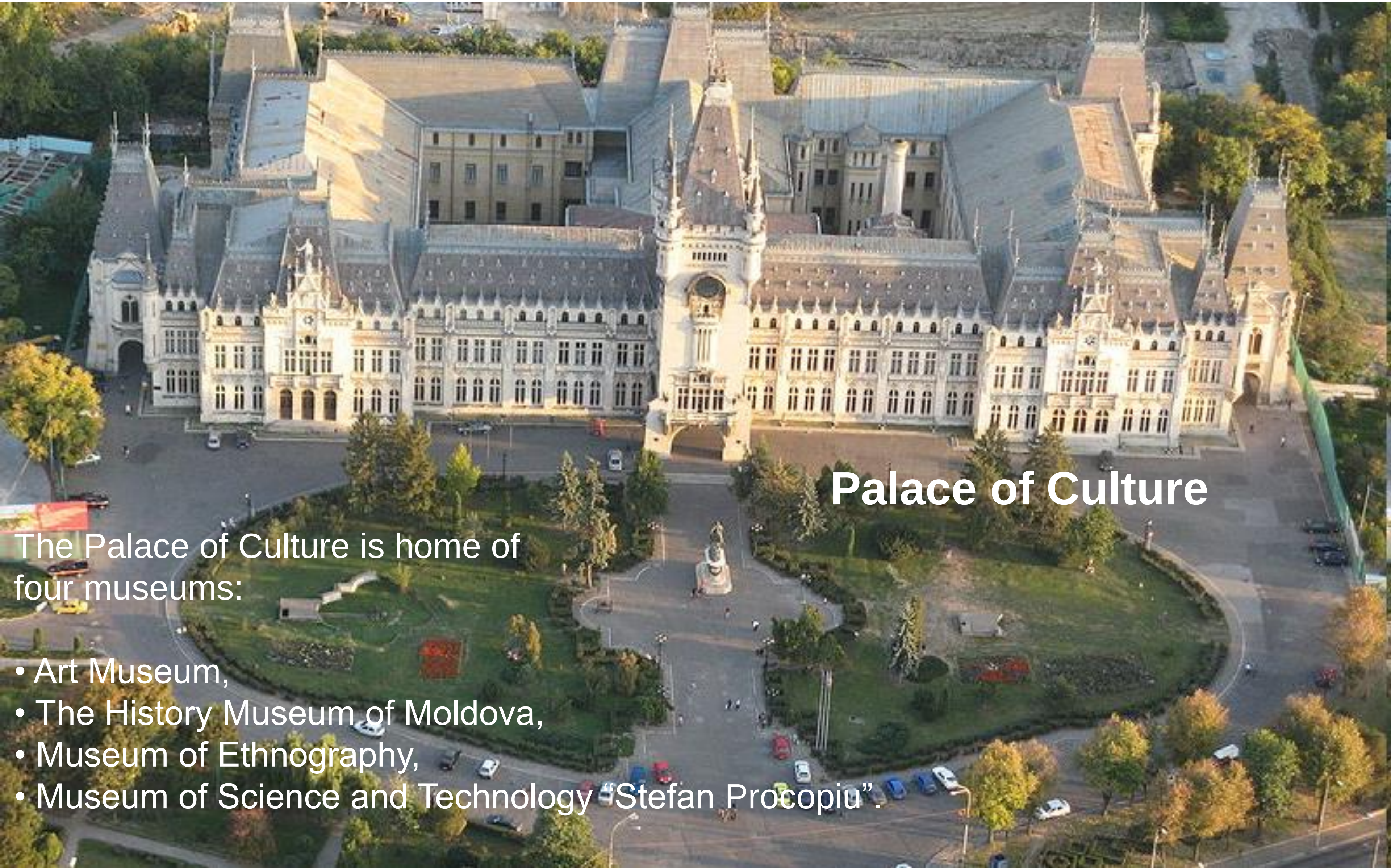

The Danube Delta
www.makovei.com


Rivers


Lakes

Iasi in Romania

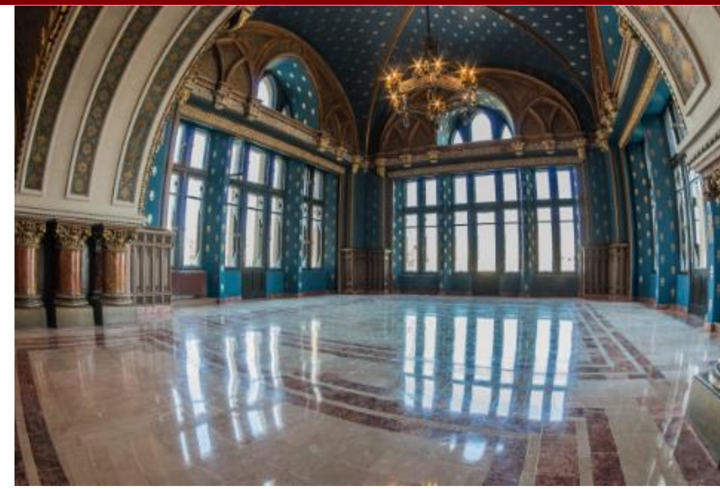
Co-funded by the Erasmus+ Programme of the European Union

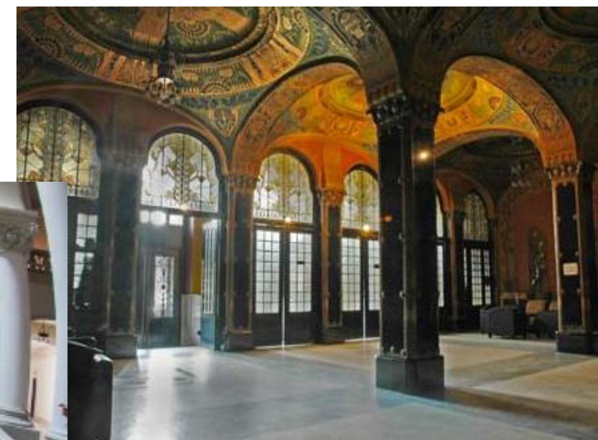


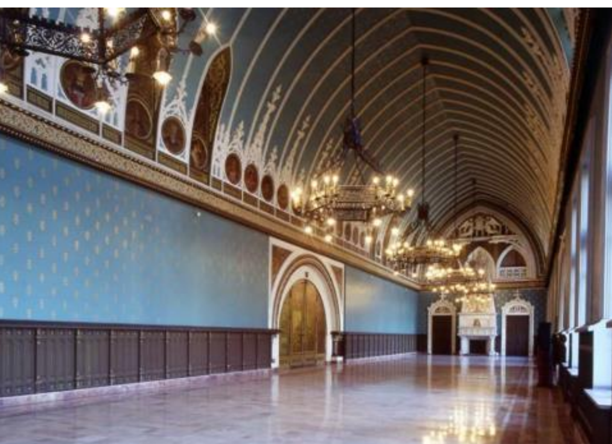
Palace of Culture

The Palace of Culture is home of four museums:

- Art Museum,
- The History Museum of Moldova,
- Museum of Ethnography,
- Museum of Science and Technology "Stefan Procopiu".







PALAS Business Center

“Gheorghe Asachi” Technical University of Iasi

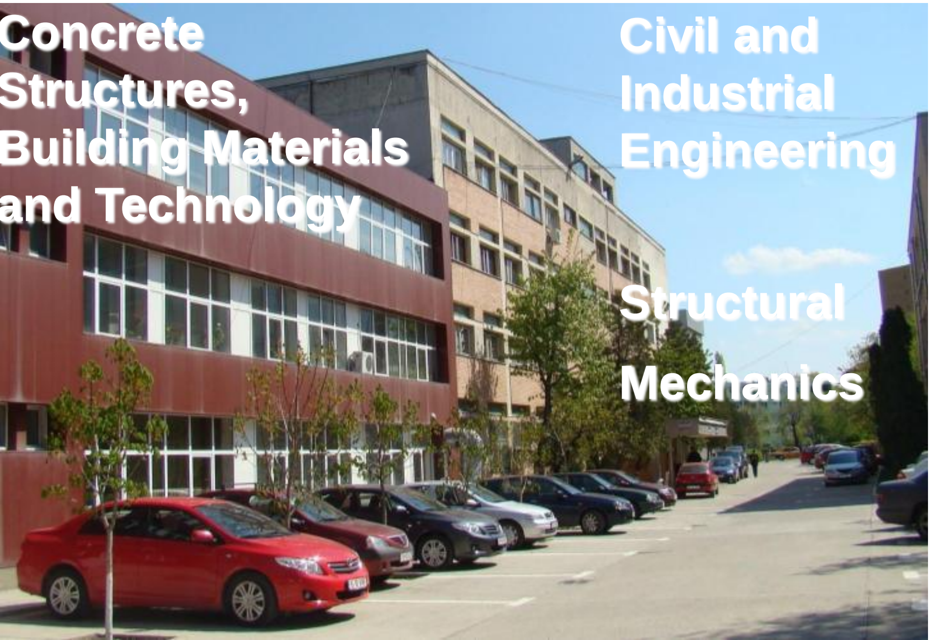
~ 14 000 students

~ 1000 teachers

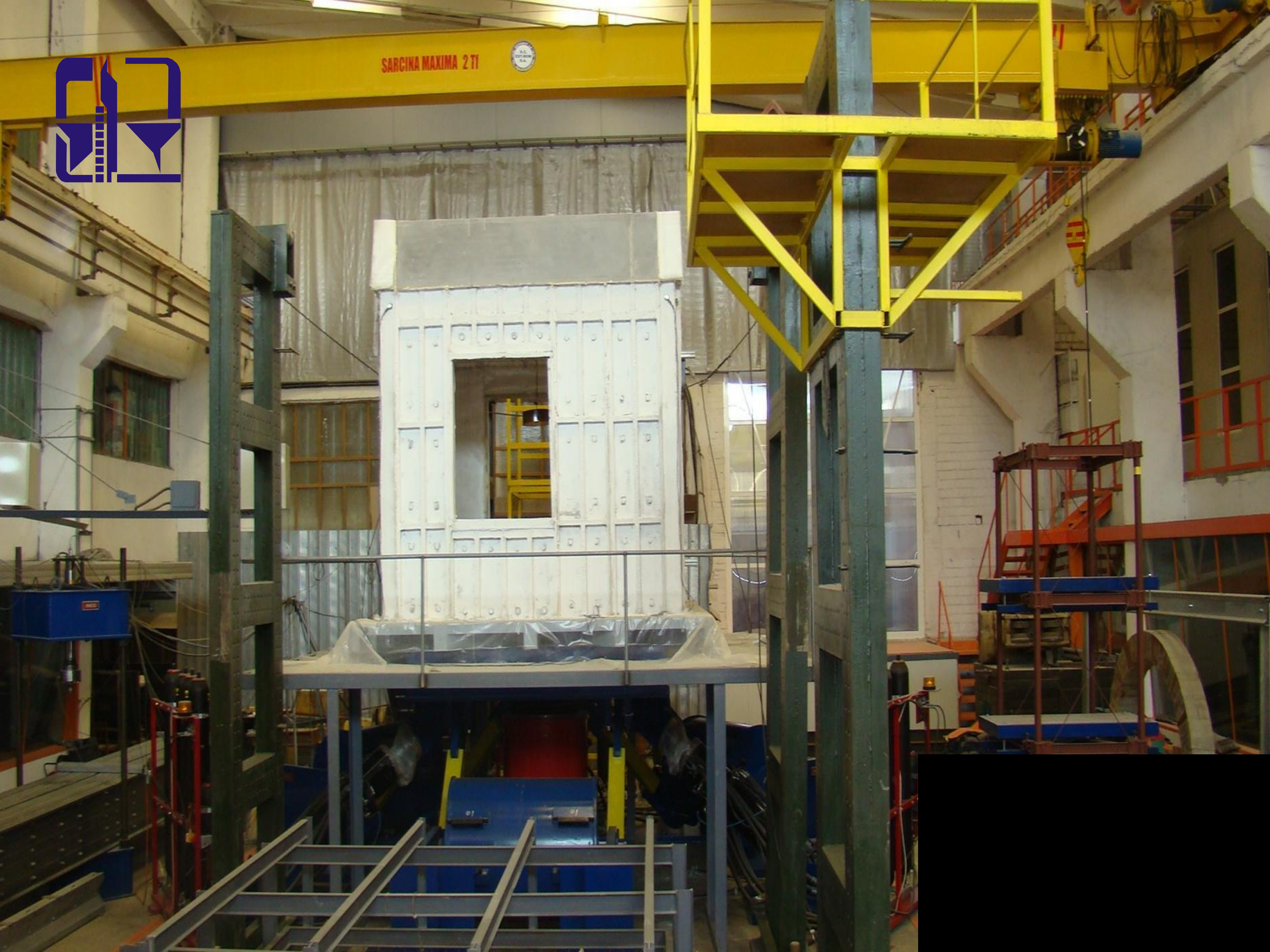
Faculty of Civil Engineering and Building Services Engineering


Civil Engineering


Transportation and Foundations
Engineering Graphics

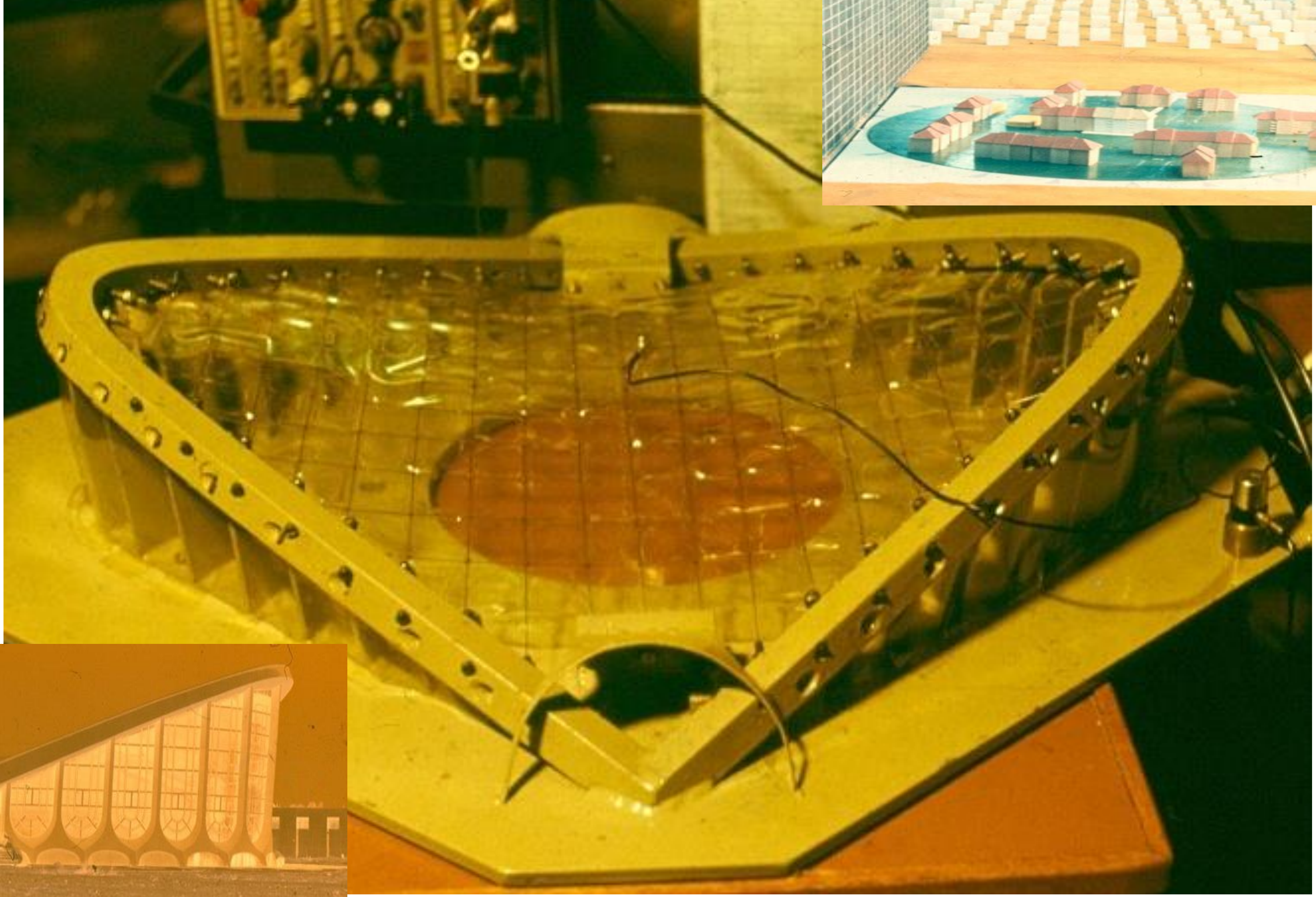

Concrete Structures, Building Materials and Technology
Civil and Industrial Engineering
Structural Mechanics


Building Services Engineering


SARCINA MAXIMA 2 Tf

Hall for road testing

Wind tunnel



TUIASI

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of the European Union

MARUEEB

- 1972-1973 – Foundation of the Department of Building Services at Mechanical Faculty of the Polytechnic Institute "Gheorghe Asachi" of Iaşi.
- 1977-1978 – The department move to the Faculty of Civil Engineering and Building Services,

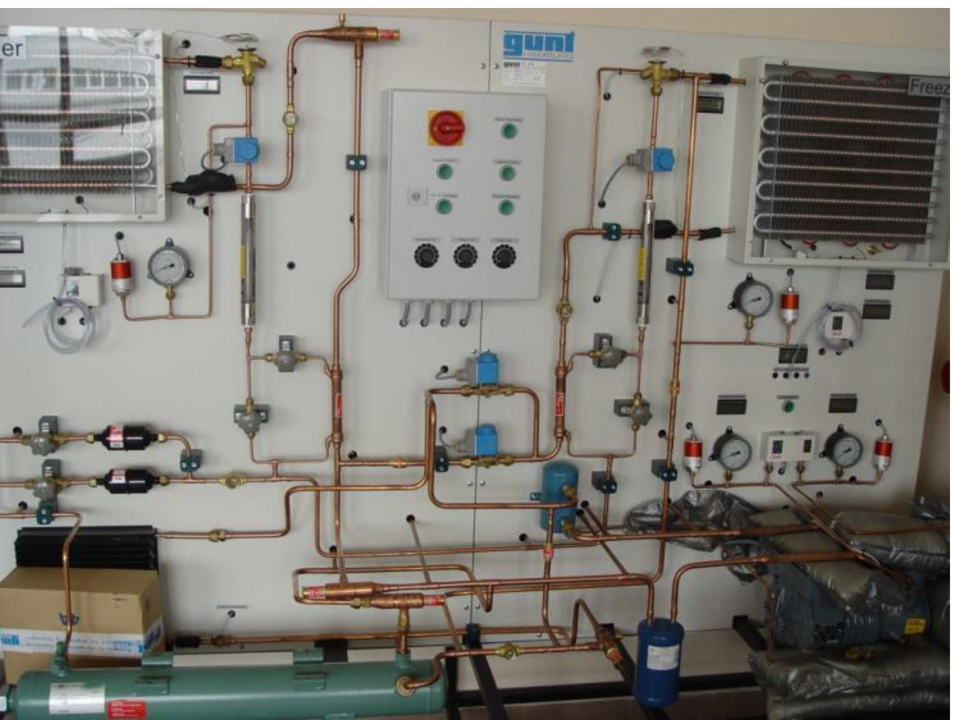
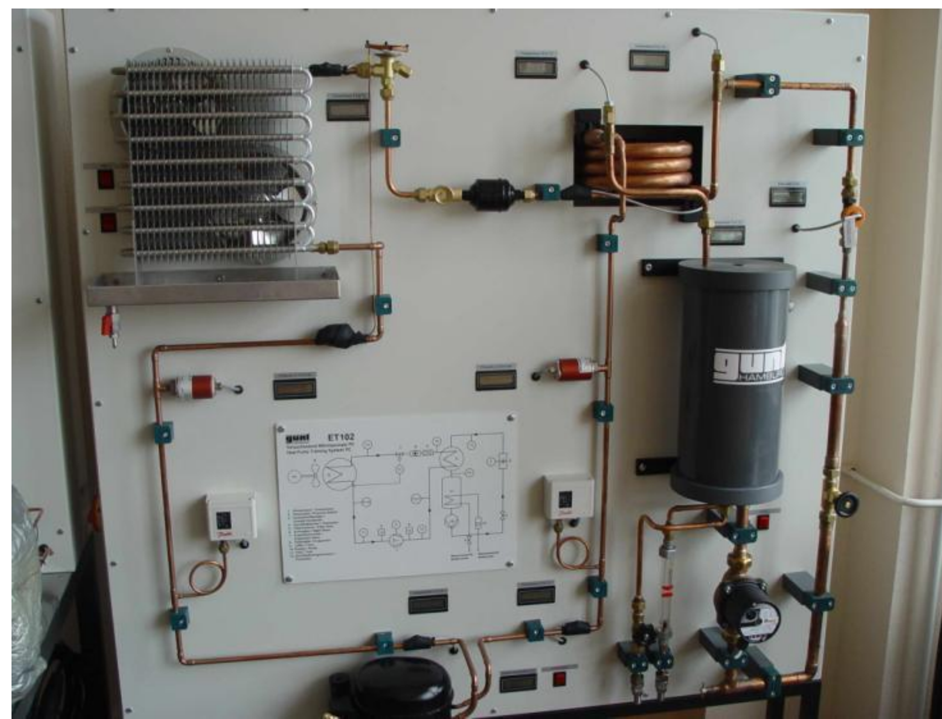
Building services laboratory

Laboratory of Ventilation and Air Conditioning


gunt


DACOFIL


gunt
HAMBURG

gunt
HAMBURG

gunt
HAMBURG
Freez

ET102
gunt
HAMBURG


gunt
HAMBURG

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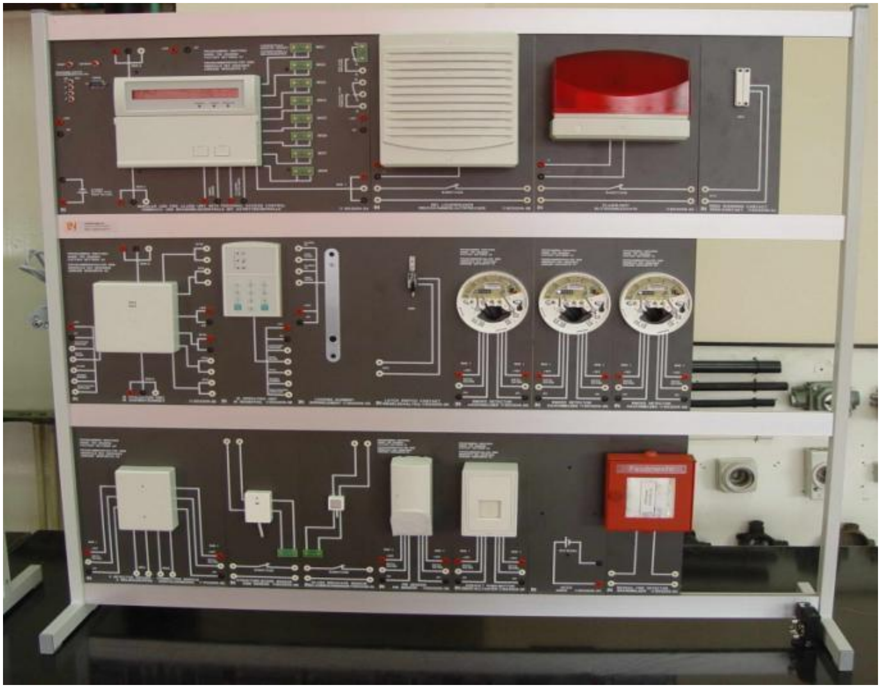
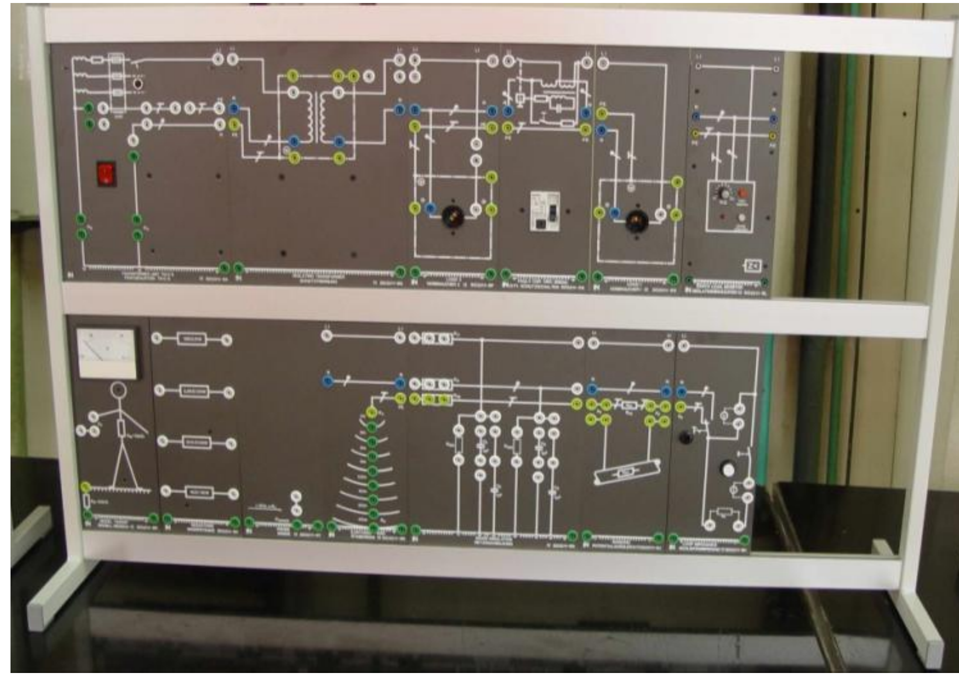
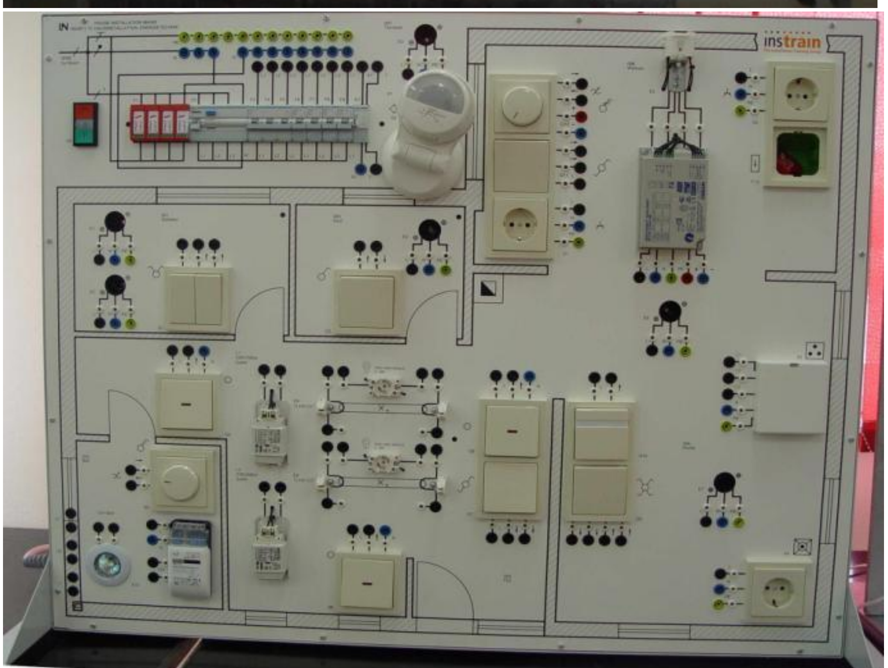
HAMBURG

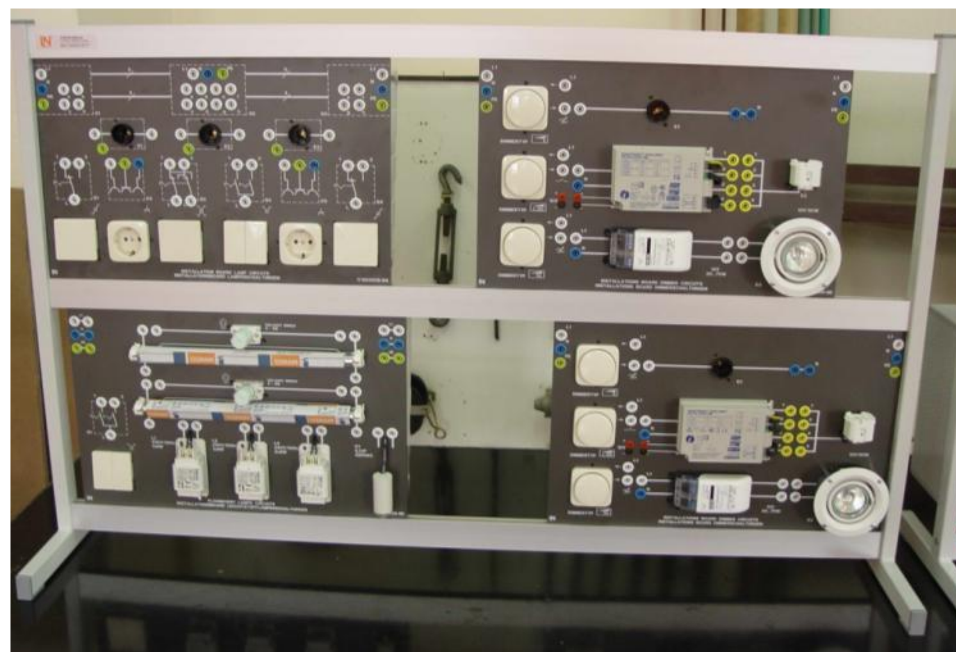


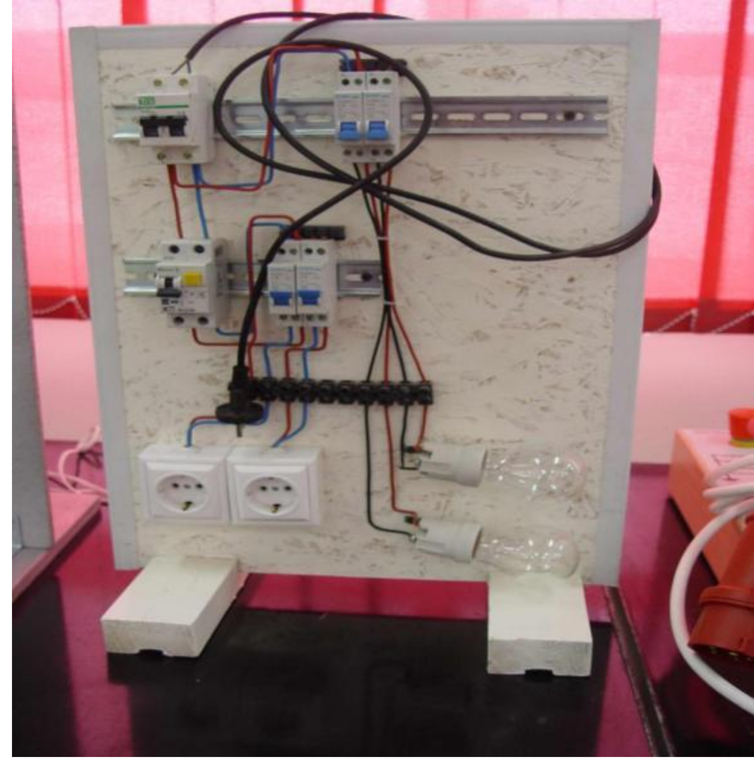
Experimental room for underfloor heating
PhD Thesis - Influence of the heating / cooling systems by radiation on indoor climate parameters. PhD student: Muscalu Ana Cristina, PhD supervisor: Prof. Mateescu Theodor

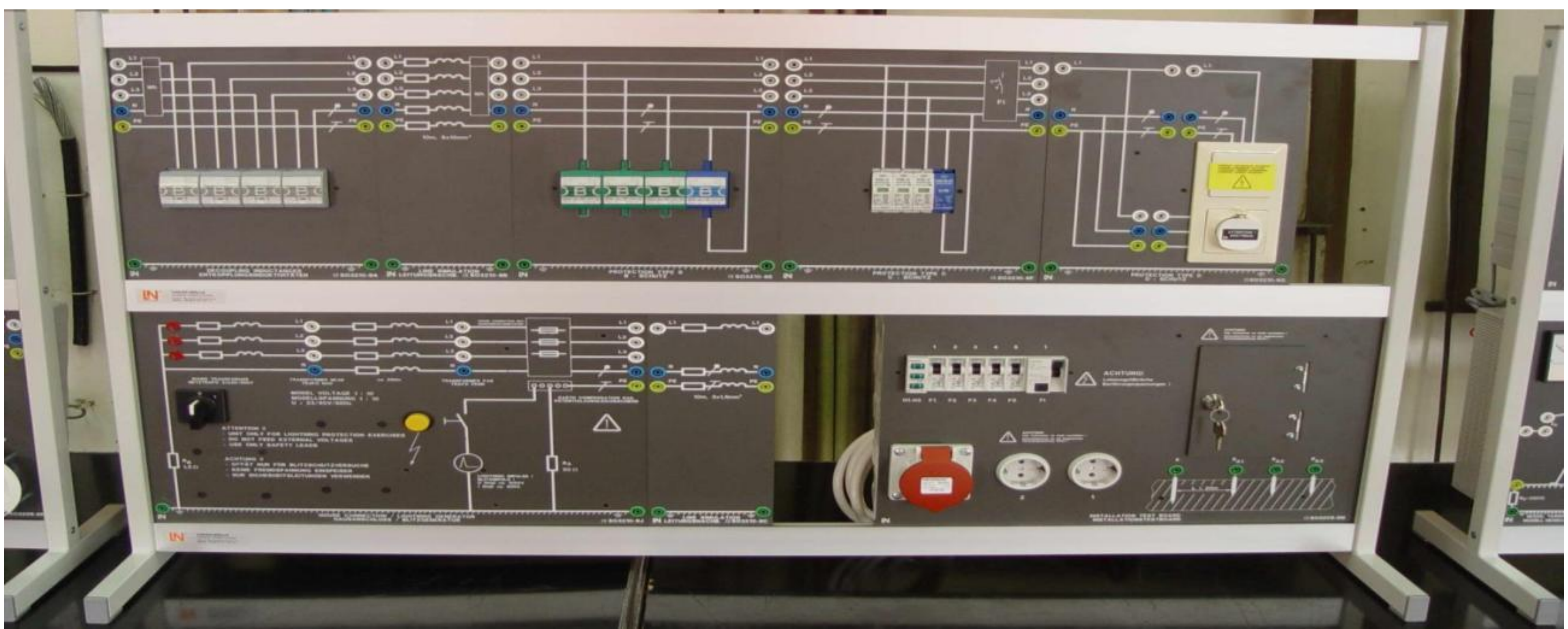





instrain







EDIȚIA a XXVII-a

ASOCIAȚIA INGINERILOR DE INSTALAȚII DIN ROMÂNIA
FILIALA MOLDOVA
Universitatea Tehnică „Gheorghe ASACHI" din Iași
Facultatea de Construcții și Instalații – Departamentul de Ingineria Instalațiilor
DAS Iași

CONFERINȚA

TEHNICO-ȘTIINȚIFICĂ
CU PARTICIPARE INTERNAȚIONALĂ

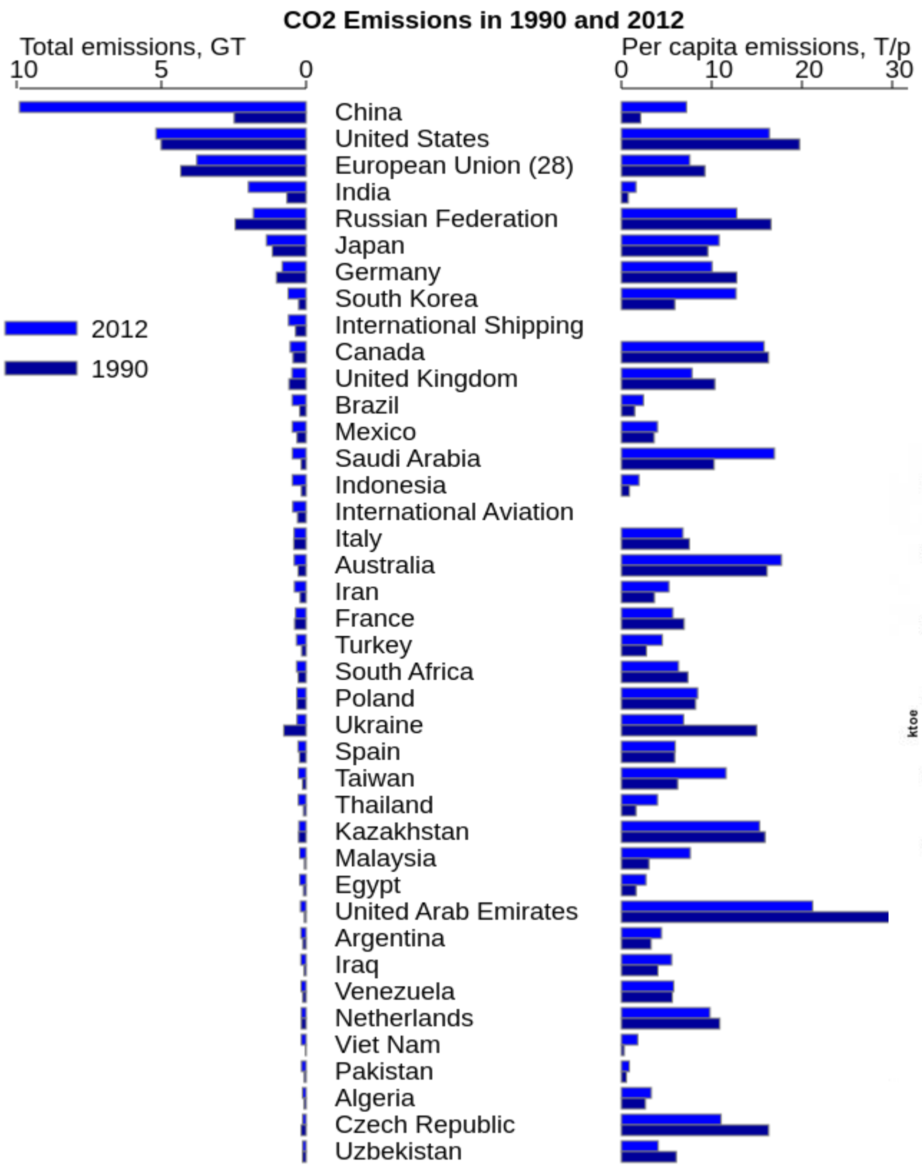
INSTALAȚII PENTRU CONSTRUCȚII ȘI ECONOMIA DE ENERGIE

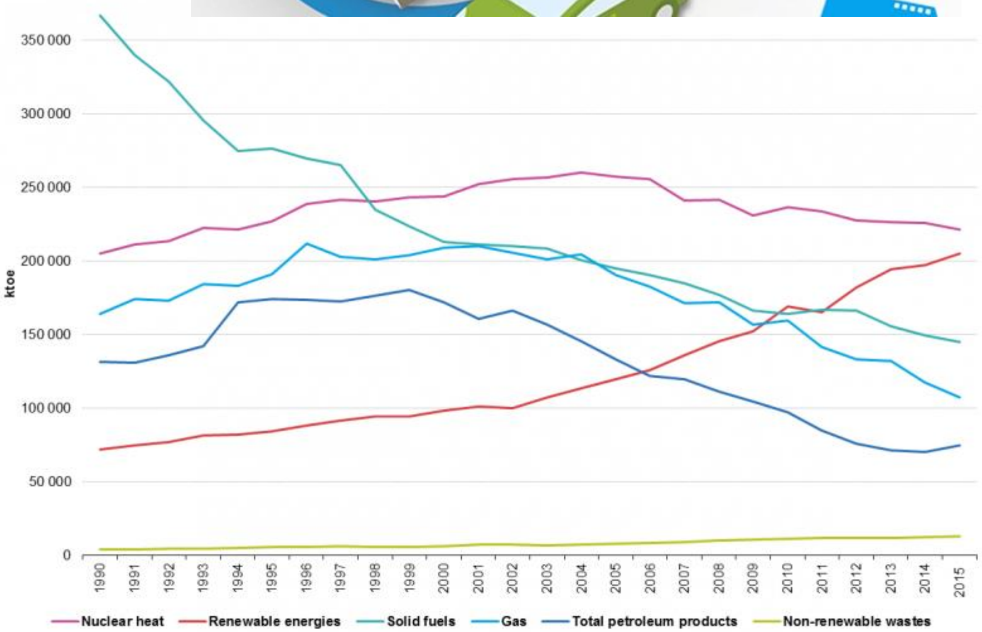
Deschiderea oficială a lucrărilor: Joi, 6 iulie, ora 9^{30}
AULA Universității Tehnice „GHEORGHE ASACHI" din Iași,
B-dul Carol I, Corp A

6-7 iulie 2017
IAȘI
ROMÂNIA

Introduction to the nZEB concept

Pollution from burning fossil fuels leads to an increase in greenhouse gases, acid rain, and the degradation of public health.


CO2 Emissions in 1990 and 2012
Total emissions, GT
10
5
0
Per capita emissions, T/p
0
10
20
30
2012
1990
China
United States
European Union (28)
India
Russian Federation
Japan
Germany
South Korea
International Shipping
Canada
United Kingdom
Brazil
Mexico
Saudi Arabia
Indonesia
International Aviation
Italy
Australia
Iran
France
Turkey
South Africa
Poland
Ukraine
Spain
Taiwan
Thailand
Kazakhstan
Malaysia
Egypt
United Arab Emirates
Argentina
Iraq
Venezuela
Netherlands
Viet Nam
Pakistan
Algeria
Czech Republic
Uzbekistan


350 000
300 000
250 000
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150 000
100 000
50 000
0
ktoe
1990
1991
1992
1993
1994
1995
1996
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2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Nuclear heat
Renewable energies
Solid fuels
Gas
Total petroleum products
Non-renewable wastes

Making the Change to Renewable Energy

- Solar
- Geothermal
- Wind

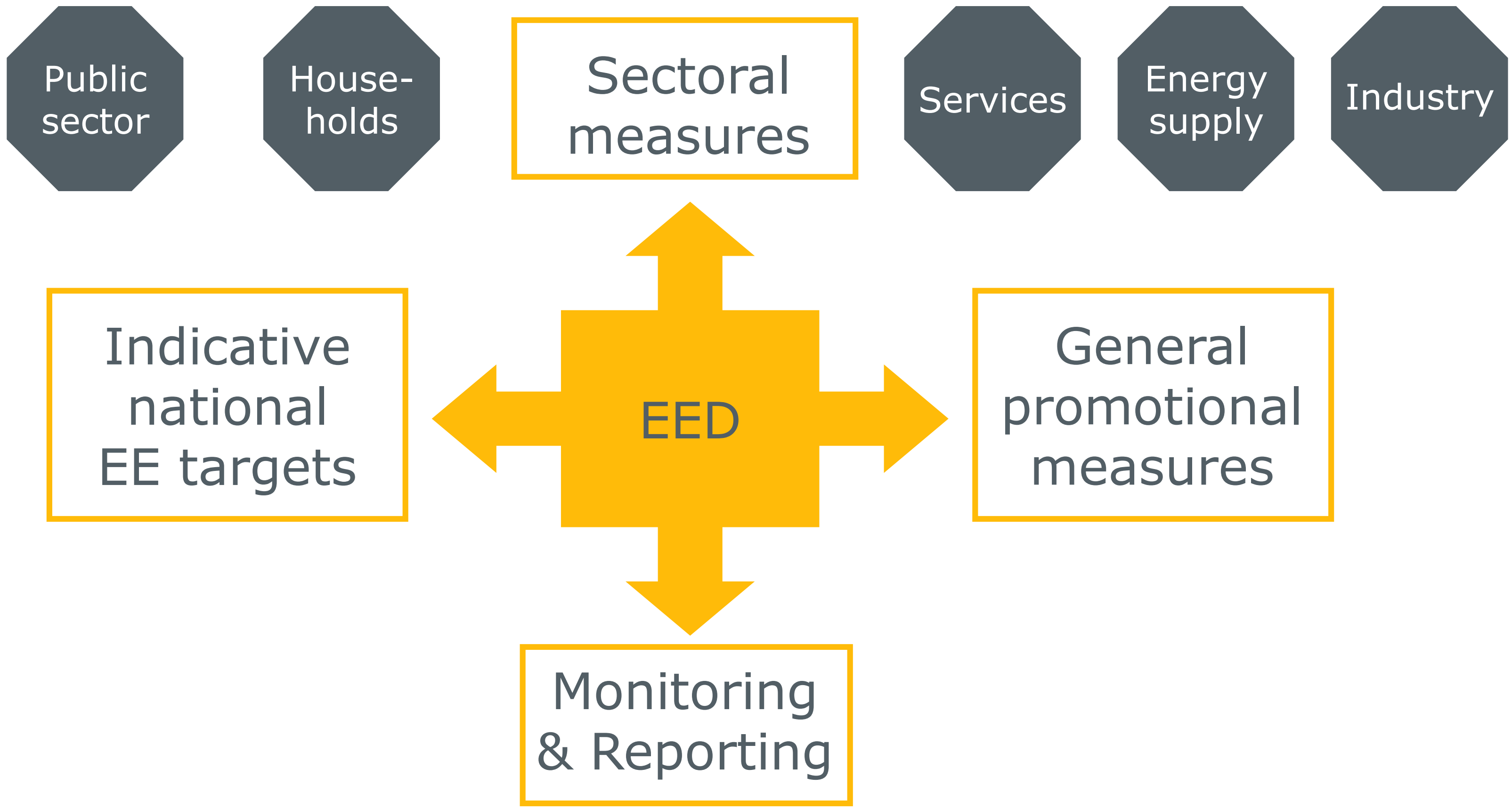
Why Sustainable Energy Matters

Detrimental environmental impacts

Energy efficiency policy–main instruments

- Energy Efficiency Directive
- Ecodesign Directive
- Energy Labelling Directive
- Energy Performance of Buildings Directive
- Energy Star programme for office equipment

Energy Efficiency Directive



Main elements of the EED

- Increased role of the public sector
- Energy efficiency obligation schemes or alternative approaches to be set by MS
- Accurate and frequent individual metering / billing
- Mandatory energy audits for large companies and promotion of audits for households and SMEs
- Heat and cooling demand plans
- Strong obligations for CHP
- Energy efficiency to be taken into account in setting network tariffs and regulations

TUIASI

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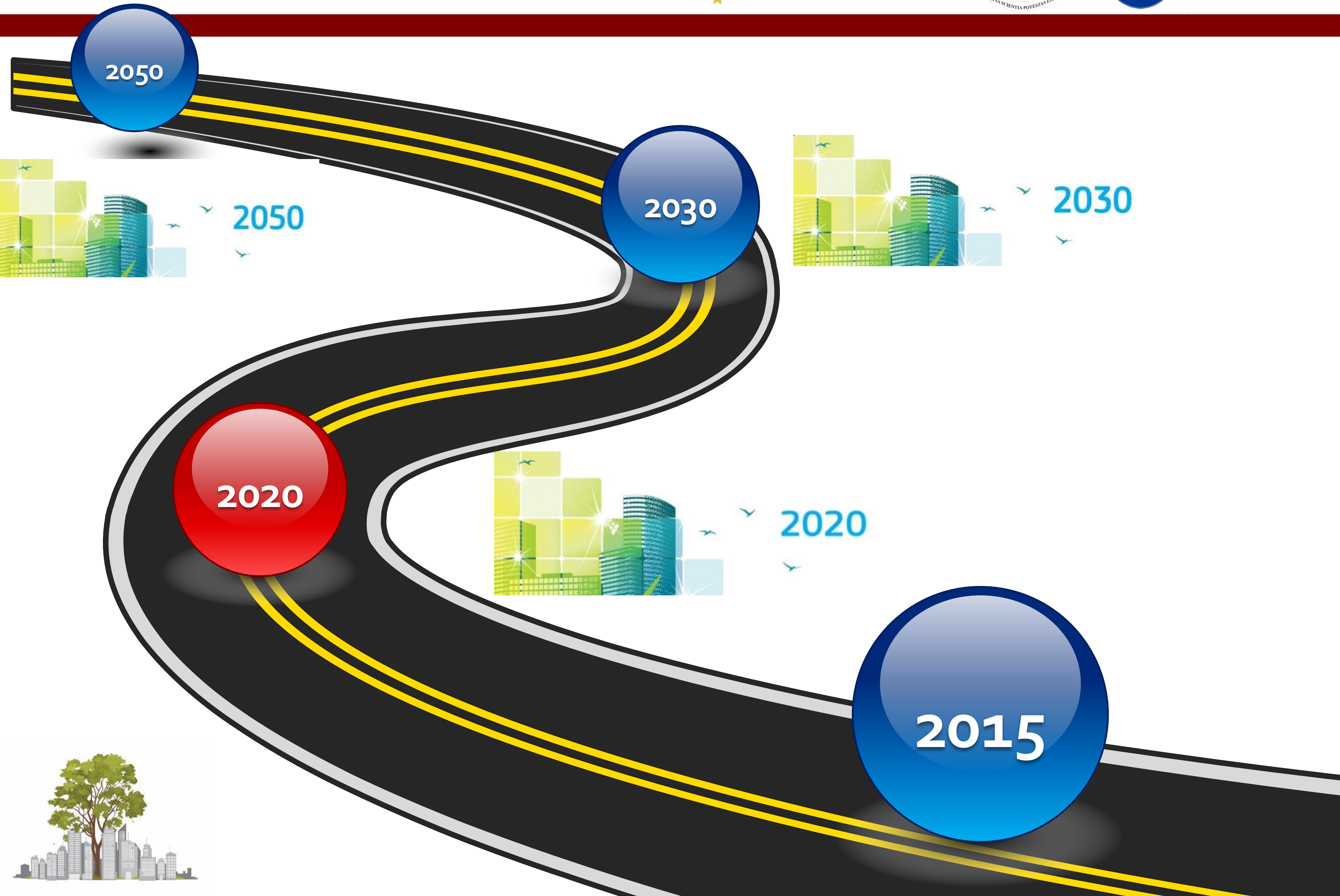
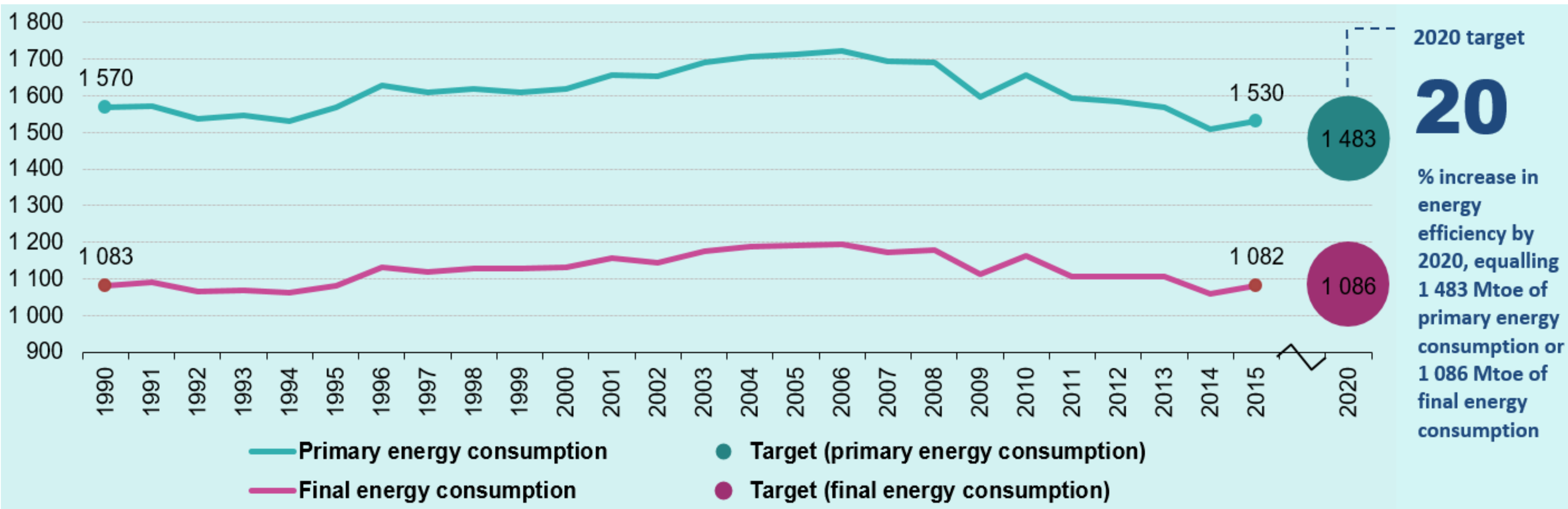
MARUEEB



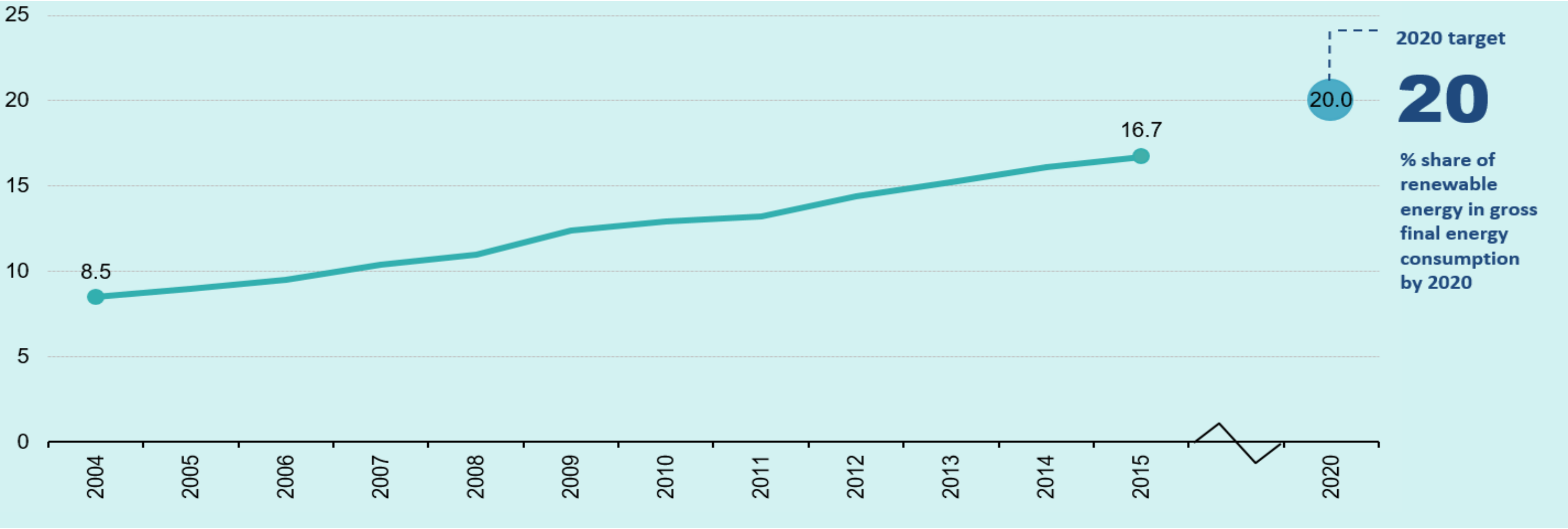
2020


2020

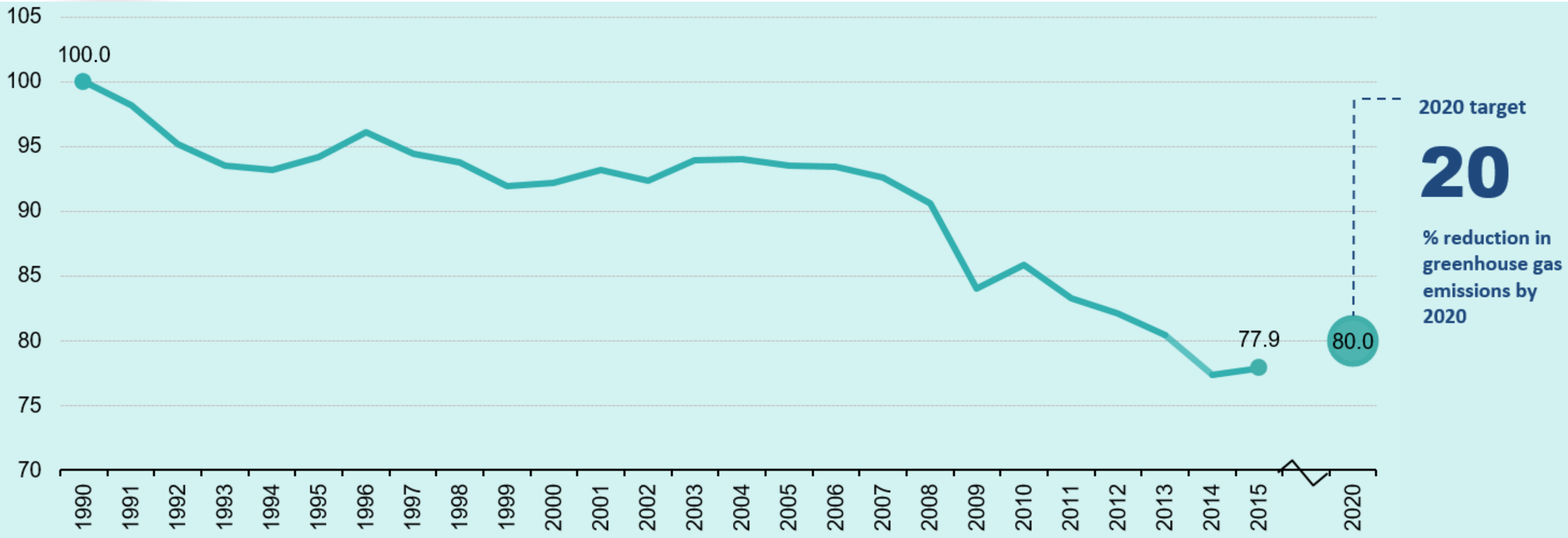

1 800
1 700
1 600
1 500
1 400
1 300
1 200
1 100
1 000
900
1 570
1 530
1 483
1 083
1 082
1 086
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2020
Primary energy consumption
Final energy consumption
Target (primary energy consumption)
Target (final energy consumption)
2020 target
20
% increase in energy efficiency by 2020, equalling 1 483 Mtoe of primary energy consumption or 1 086 Mtoe of final energy consumption

2020


2020

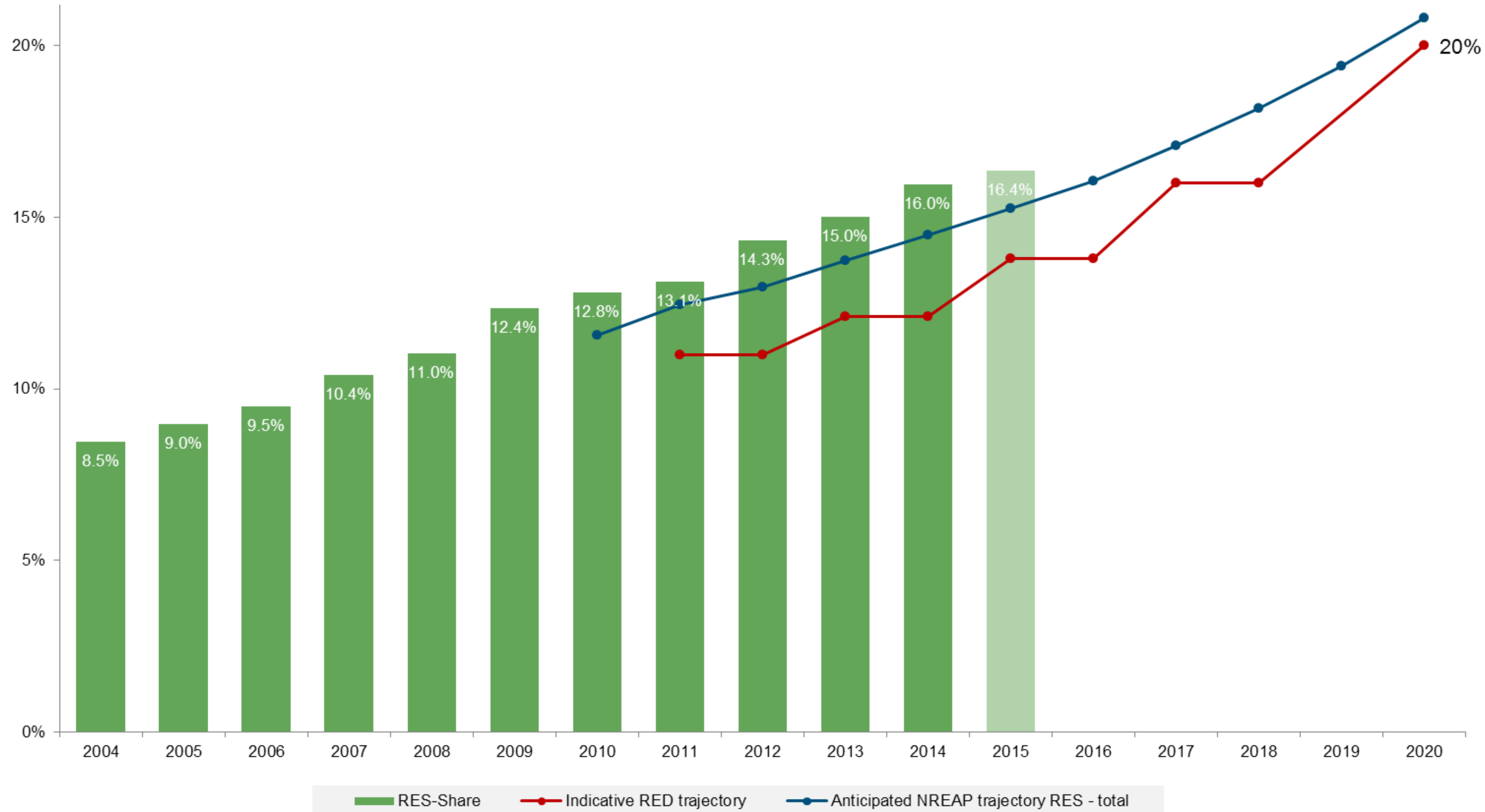

25
20
15
10
5
0
8.5
16.7
20.0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2020
2020 target
20
% share of renewable energy in gross final energy consumption by 2020

2020



Note: Total emissions, including international aviation and indirect CO_2, but excluding emissions from land use, land use change and forestry (LULUCF).

The EU 20-20-20 targets by 2020

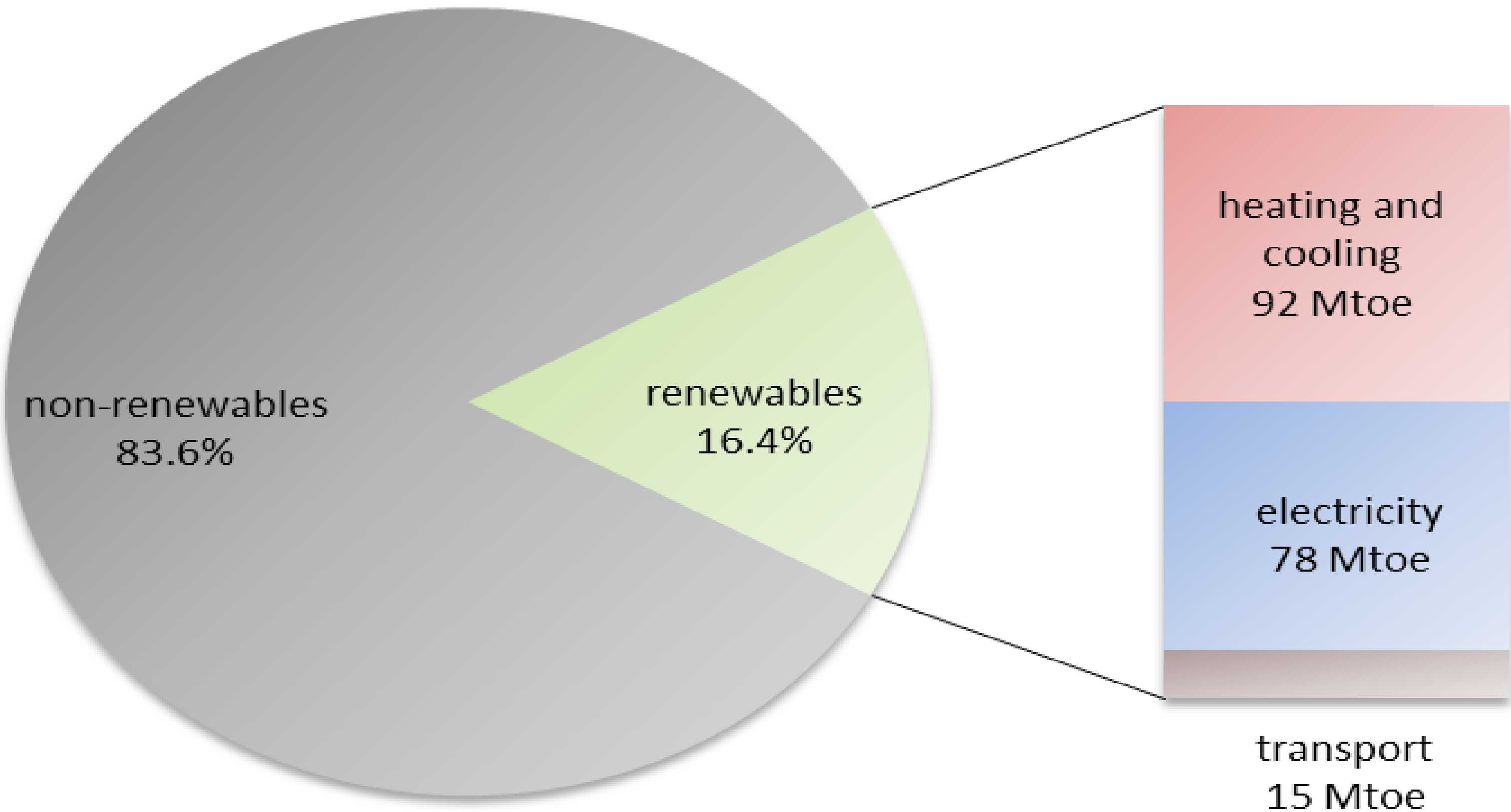


	Share of energy from renewable sources in gross final consumption of energy, 2005 (S_{2005})	Target for share of energy from renewable sources in gross final consumption of energy, 2020 (S_{2020})
Belgium	2,2 %	13 %
Bulgaria	9,4 %	16 %
Czech Republic	6,1 %	13 %
Denmark	17,0 %	30 %
Germany	5,8 %	18 %
Estonia	18,0 %	25 %
Ireland	3,1 %	16 %
Greece	6,9 %	18 %
Spain	8,7 %	20 %
France	10,3 %	23 %
Italy	5,2 %	17 %
Cyprus	2,9 %	13 %
Latvia	32,6 %	40 %
Lithuania	15,0 %	23 %
Luxembourg	0,9 %	11 %
Hungary	4,3 %	13 %
Malta	0,0 %	10 %
Netherlands	2,4 %	14 %
Austria	23,3 %	34 %
Poland	7,2 %	15 %
Portugal	20,5 %	31 %
Romania	17,8 %	24 %
Slovenia	16,0 %	25 %
Slovak Republic	6,7 %	14 %
Finland	28,5 %	38 %
Sweden	39,8 %	49 %
United Kingdom	1,3 %	15 %

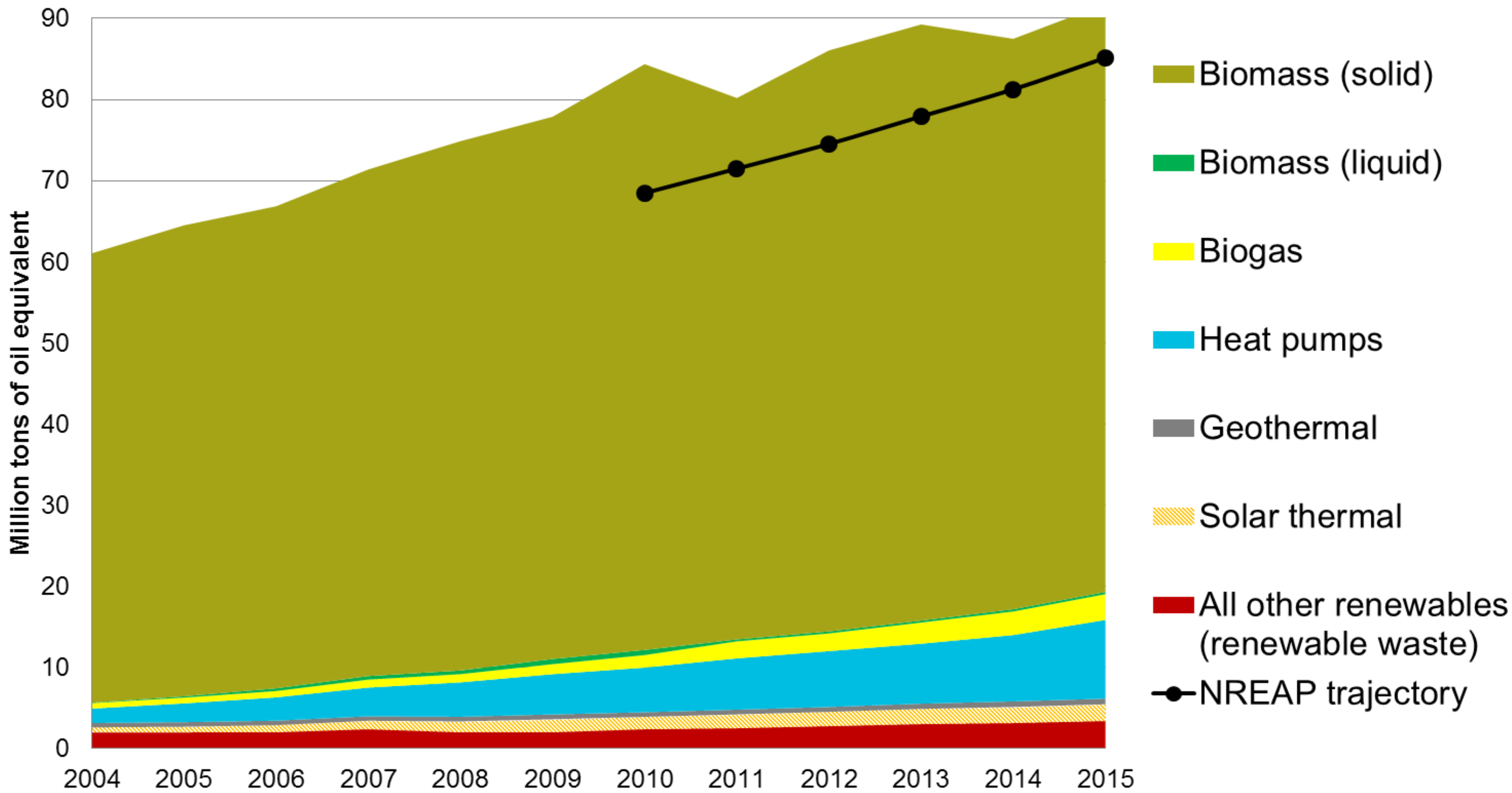
The EU 20-20-20 targets by 2020

Final Energy Consumption in the EU28 in 2015

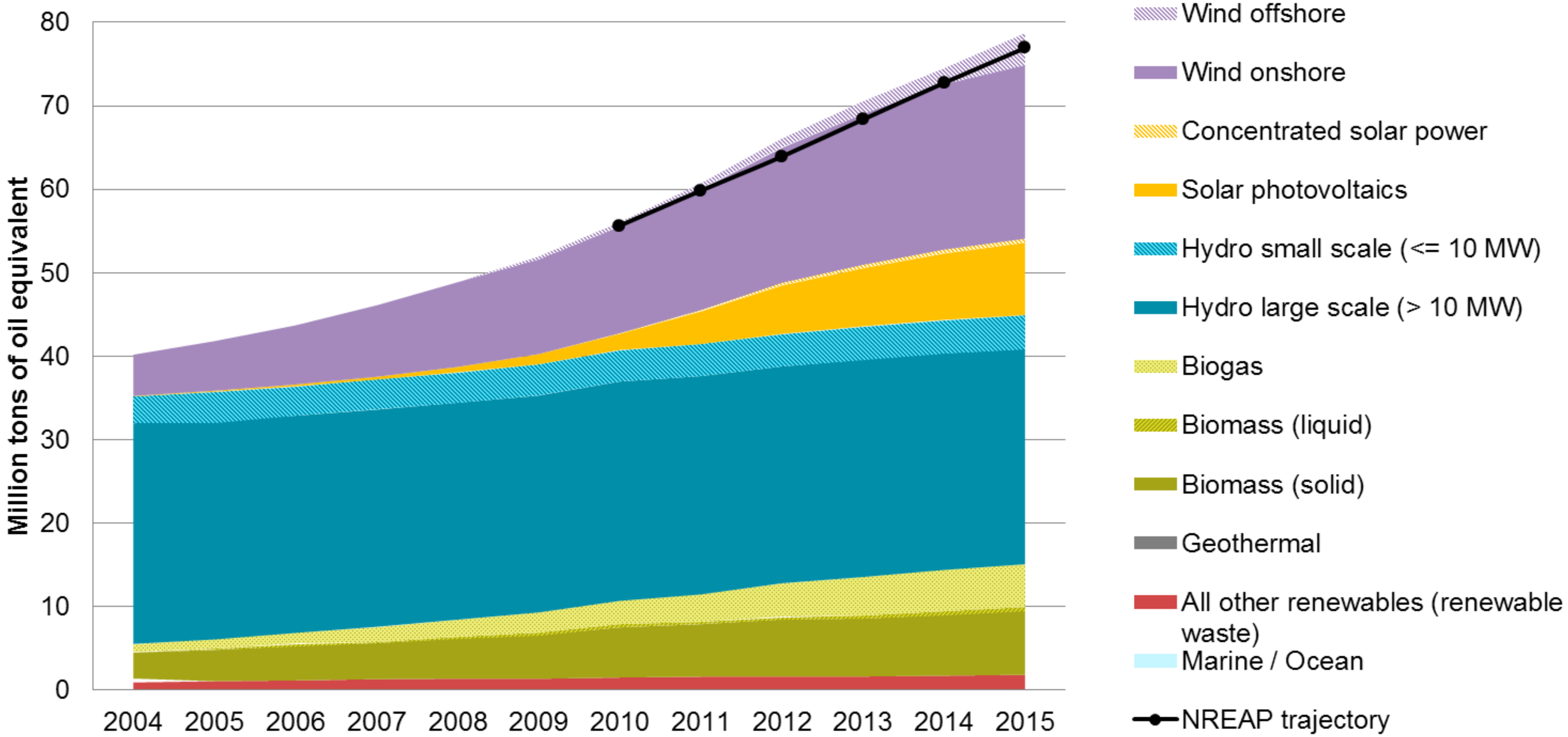
based on Öko-Institute proxies, statistical transferts and mult. counting excluded in Mtoe



Heating and Cooling



Electricity

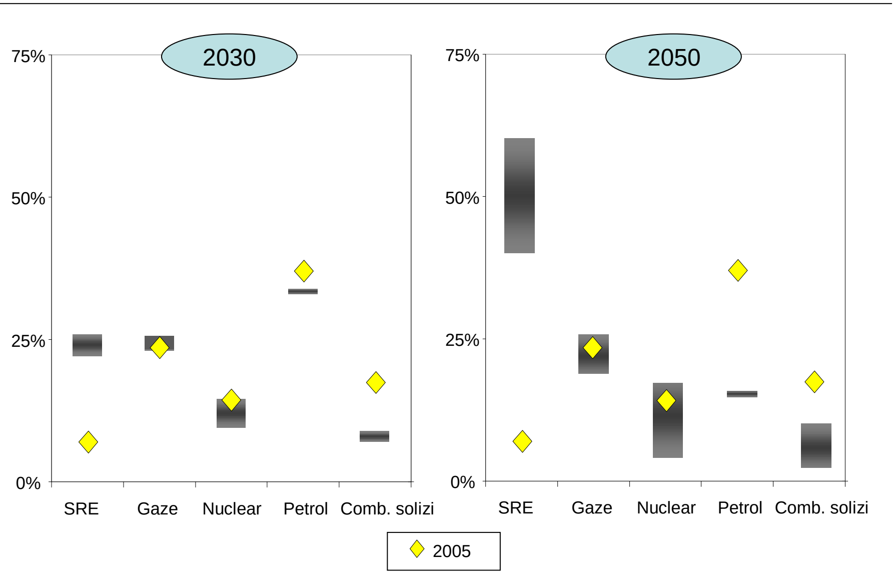


Energy & Climate Strategy 2030

- *EE – 30%*
- *RES – 27%*
- *GHG – 40%*

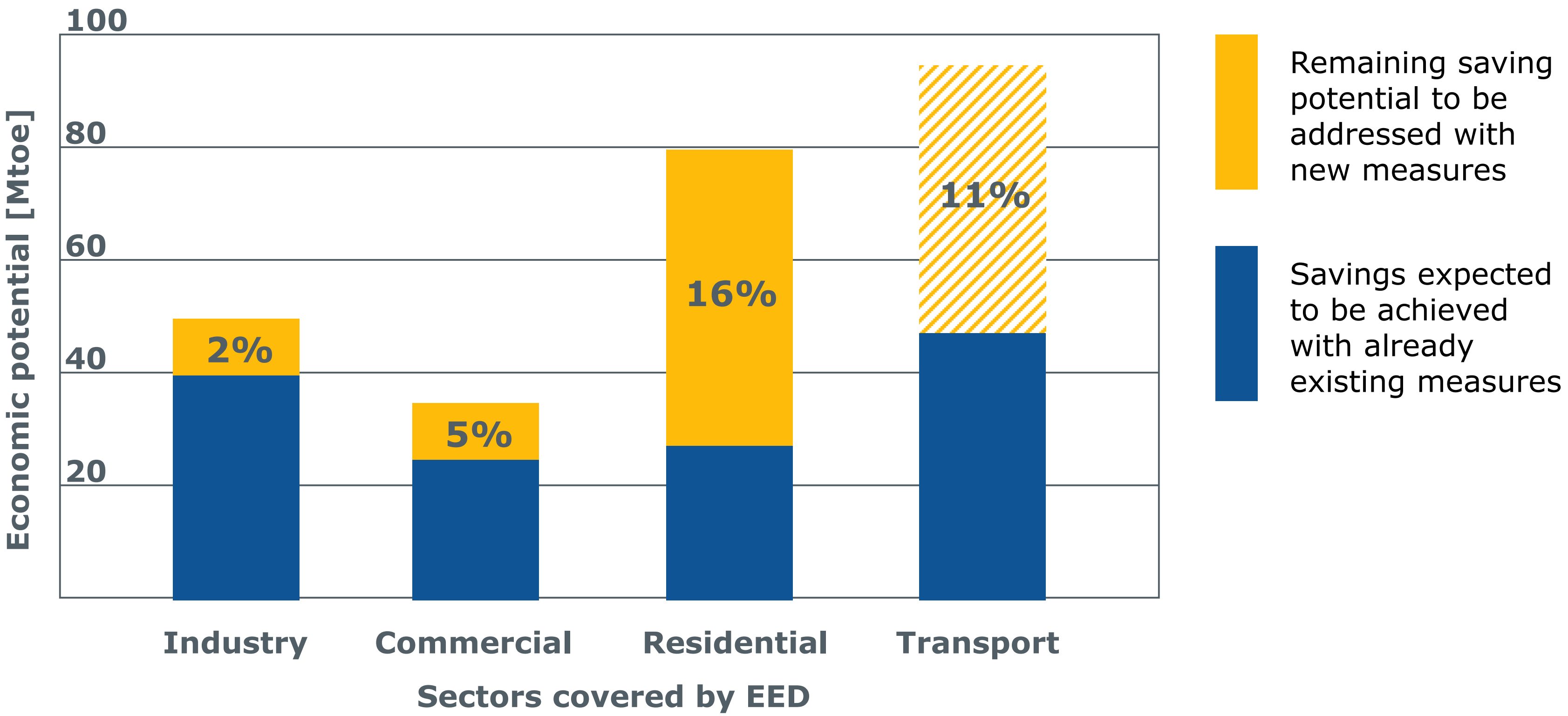
Energy policy beyond 2020

"Energy Roadmap 2050"



- Published in December 2011
- Reducing greenhouse gas emissions to 80-95% below 1990 levels by 2050
- Explore EU decarbonisation objective while ensuring security of supply and competitiveness
- Give more certainty to governments and investors
- Energy efficiency is a 'no-regrets' option
- Well-functioning energy markets are key

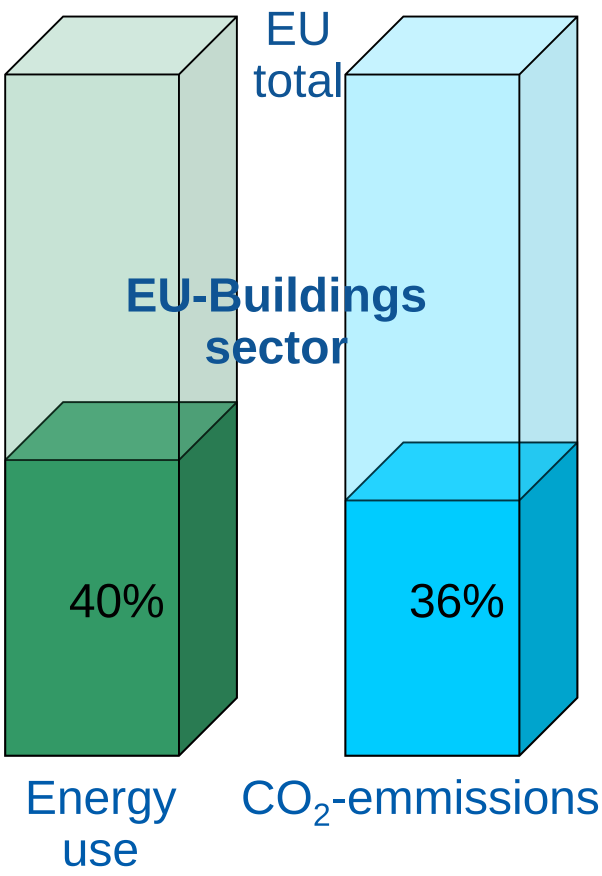
Despite untapped savings potentials across all major sectors



Ecodesign Directive

- **Examples of some adopted implementing measures:**
- **Total (333 TWh) → savings correspond approx. to the electricity consumption of the UK**

Product	Estimated savings (annual by 2020)
Standby	35 TWh
Simple set-top boxes	6 TWh
Street & Office lighting	38 TWh
External power supplies	9 TWh
Domestic lighting	37 TWh
Electric motors	135 TWh
Circulators	23 TWh
Freezers/refrigerators	6 TWh
Televisions	43 TWh
Total	**333 TWh**



Energy Performance of buildings


West
70
nZEB
full speed
Night stop
EXIT ONLY
Back

EPBD recast

Article 2.2

*'**nearly zero-energy building**' means a building that has a **very high energy performance**, [...]. The nearly zero or very low amount of energy required should be covered to a very **significant extent by energy from renewable sources**, including energy from renewable sources produced on-site or nearby*

Article 2.4

*'**energy performance of a building**' means the calculated or measured amount of energy needed to meet the energy demand associated with a **typical use of the building**, which includes, **energy used for heating, cooling, ventilation, hot water and lighting***

Article 2.14

***'cost-optimal level' means the energy performance level which leads to the lowest cost during the estimated economic lifecycle** [...]*

Article 4.1

***Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels**. [...].*

EPBD recast introduced the nZEB and cost-optimal concepts

nZEB

>> energy performances

≈0 energy needs

≈100% of energy needs renewable energy

Co-funded by the Erasmus+ Programme of the European Union

What does nZEB mean?

nZEB

Zero Energy

Which "energy"?

Balance between the renewable energy produced on-site and the building's energy uses **(LOAD/GENERATION balance)**

SITE Energy

PRIMARY Energy

Balance between the renewable energy produced/bought and the building's energy uses **(IMPORT/EXPORT balance)**

Balance between the **incomes** due to renewable energy production and the building's energy **costs**

Energy **COST**

Energy **EMISSIONS**

Balance between the **emissions** credits gained by producing renewable (zero emissions) energy and the CO_2 emissions related the building's energy

The road to Nearly Zero-Energy Buildings

Why "Passive House"

- *clear concept and standard*

The concept vs the standard

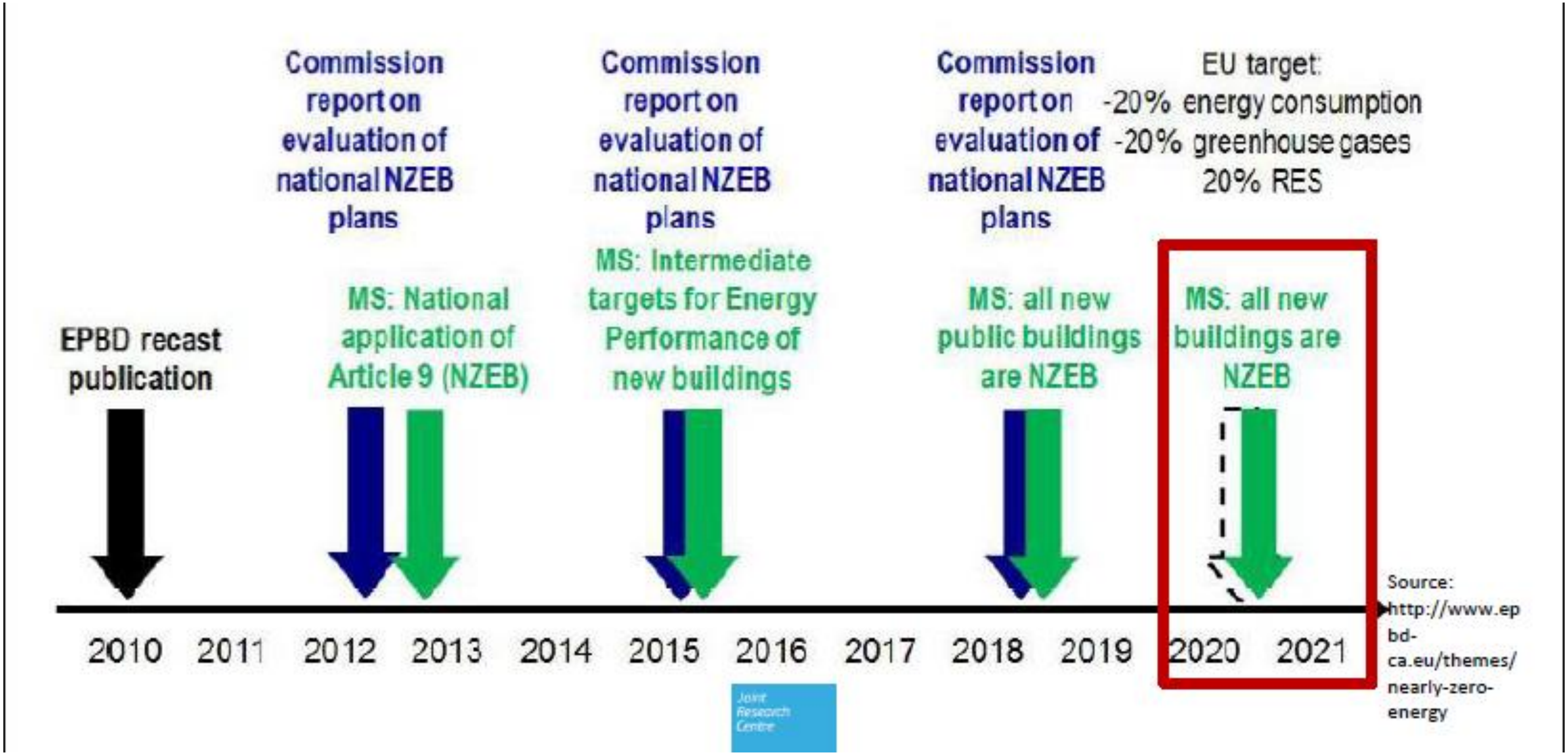
- *universal principles*

The living comfort

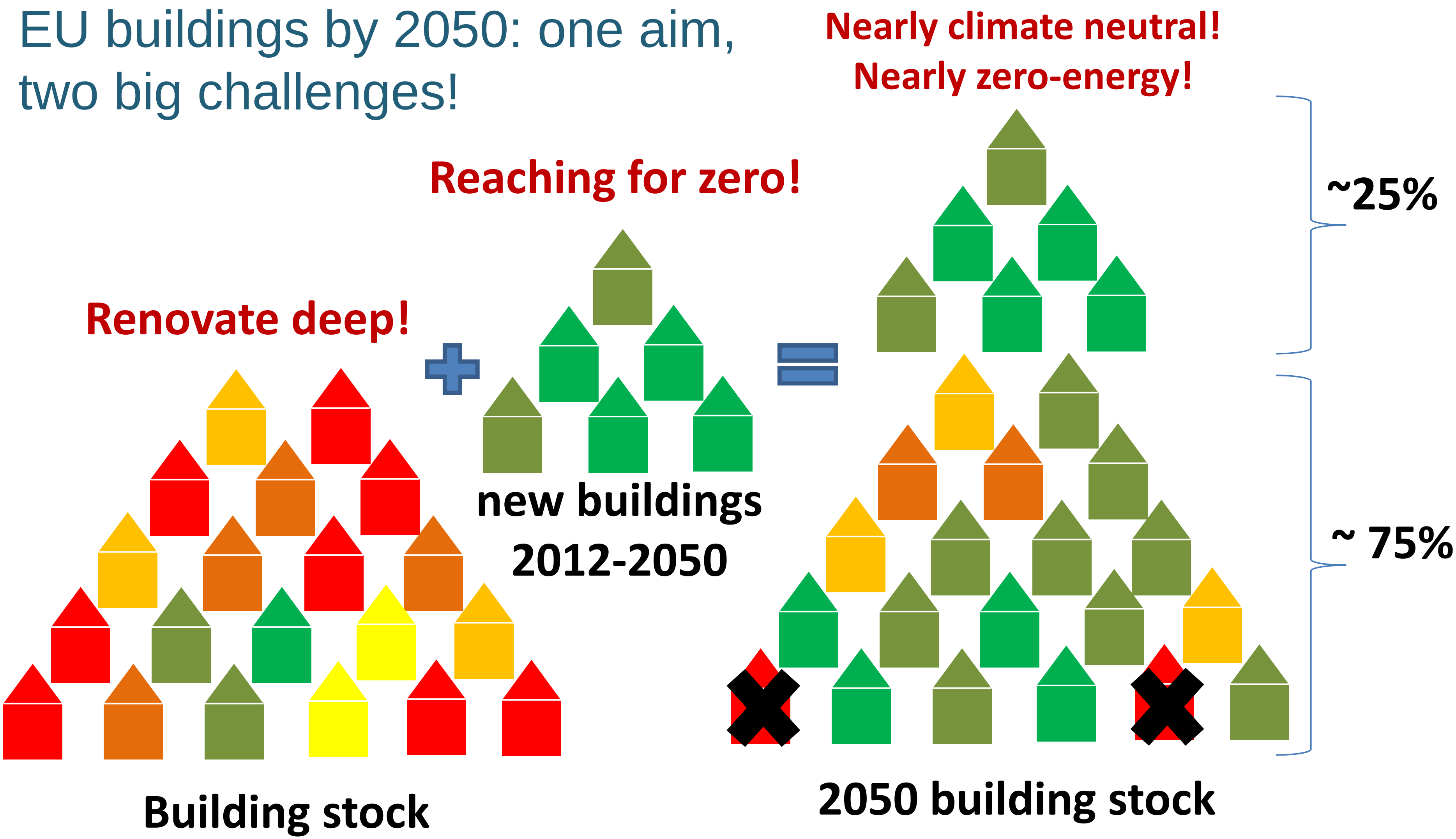
- *new approach*

Policy contest

EPBD2002/91/EC,EPBDRecast2010/31/EU,EED2012/27/EU,RED2009/28/EC



EU buildings by 2050: one aim, two big challenges!



nZEB: One EU requirement national implementation rules

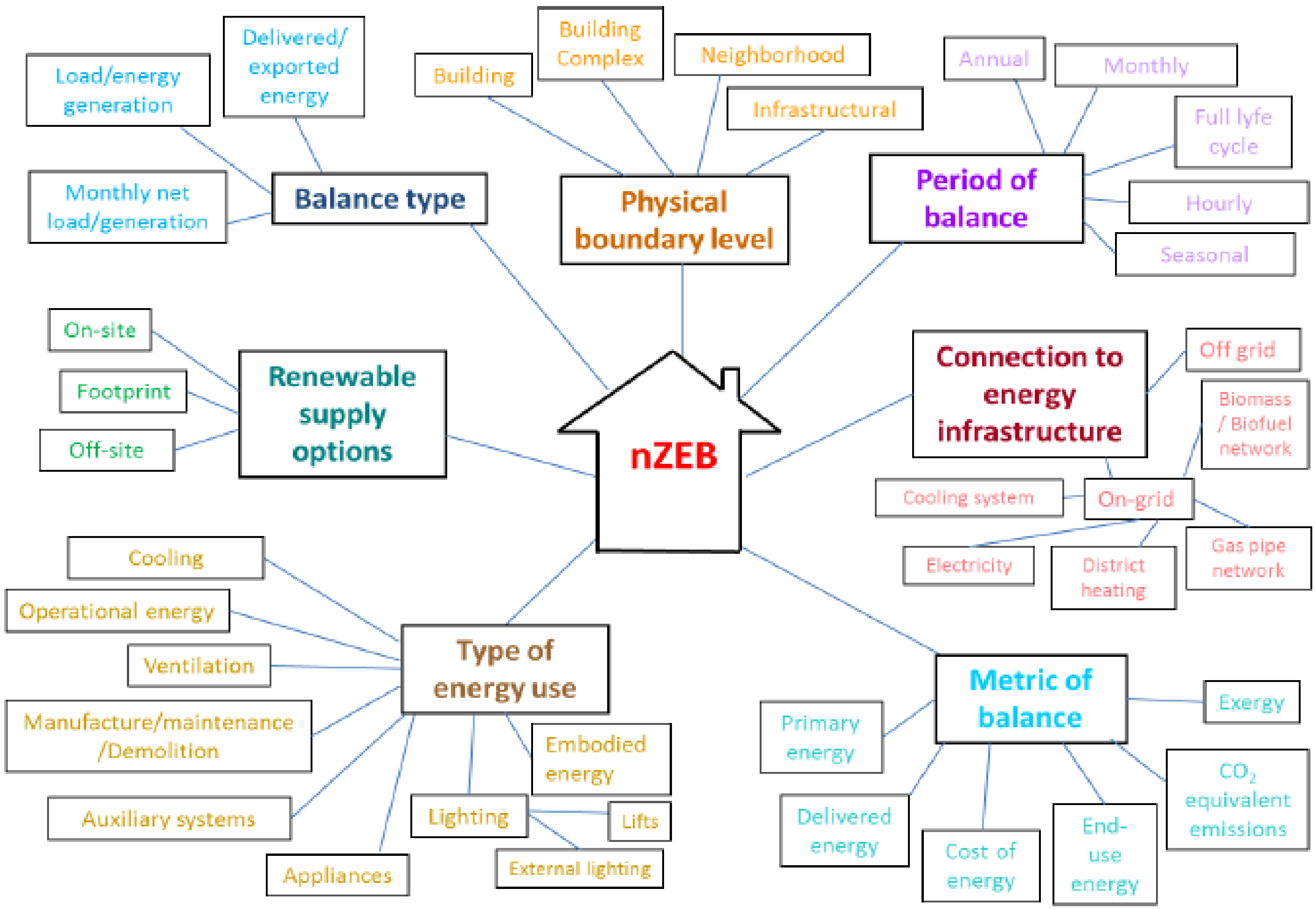
‘nearly zero-energy building’ […] has a **very high energy performance**. The **nearly zero or very low amount of energy required (for HVAC, DHW, aux. equip. and lighting)** should be covered to **a very significant extent by energy from renewable sources, including on-site or nearby RES.** (EPBD)

recast EPBD: Nearly Zero-Energy Buildings

- by 31 December 2020, all new buildings
- after 31 December 2018, new buildings occupied and owned by public authorities

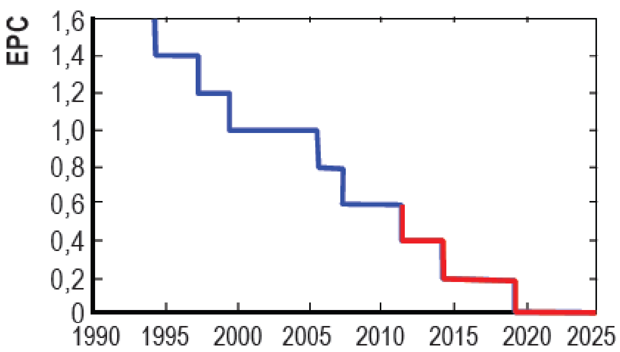
- National definition for nZEB
- National plans for nZEB (including public buildings retrofit towards nZEB levels)
- Support measures & overcoming barriers

Main arguments around NZEBs to be establised

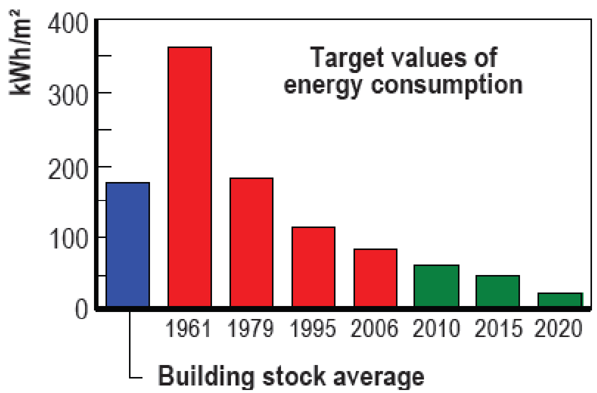


Some guys already started: Roadmap towards nZEB

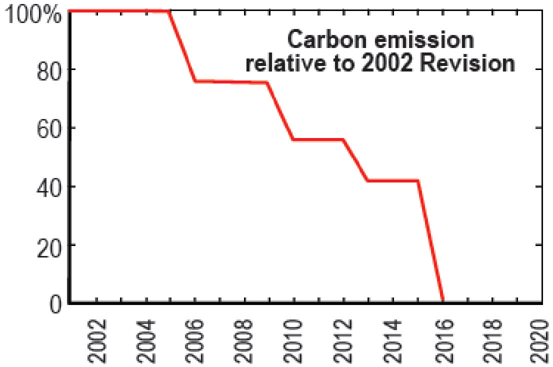
The Netherlands



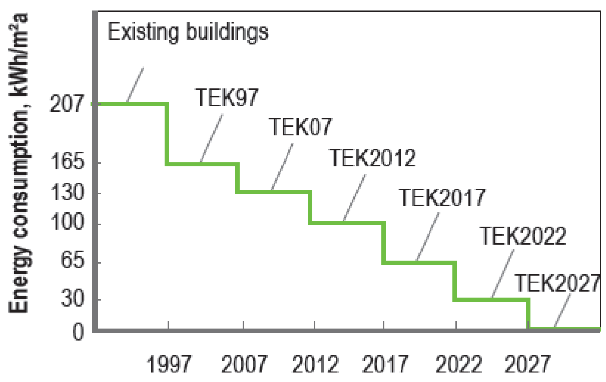
Denmark



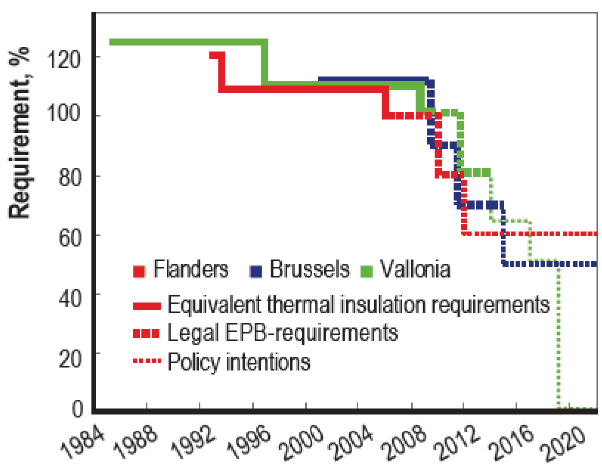
United Kingdom



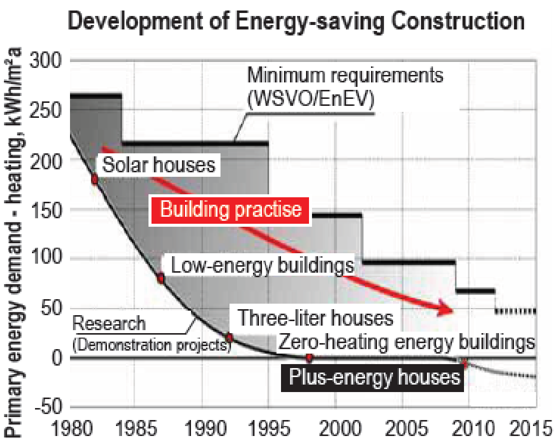
Norway



Belgium

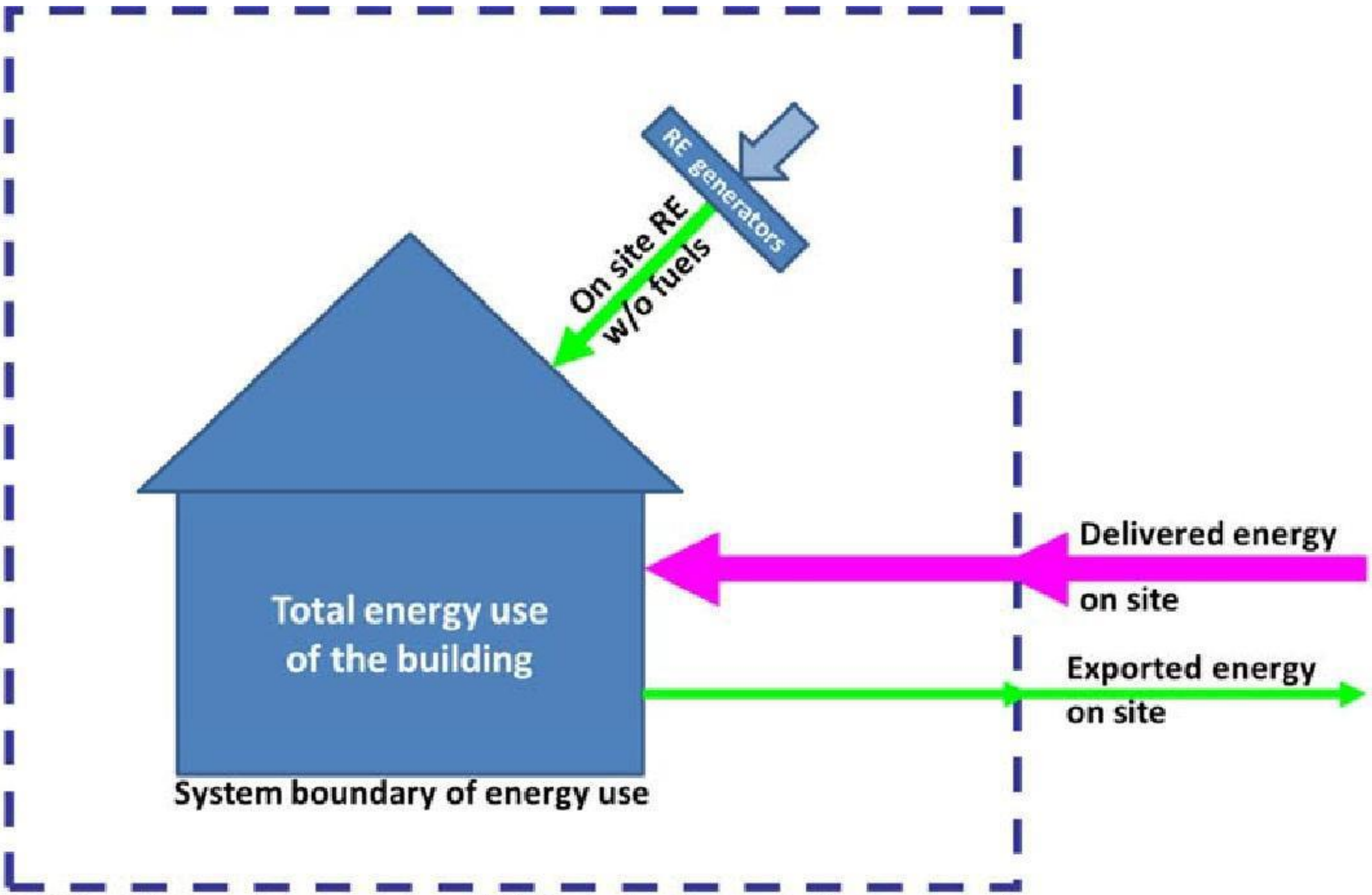


Germany



Source: REHVA

NZEB level of energy performance	Mediterranean Zone 1: Catania (others: Athens, Larnaca, Luga, Seville, Palermo)	Oceanic Zone 4: Paris (others: Amsterdam, Berlin, Brussels, Copenhagen, Dublin, London, Macon, Nancy, Prague, Warszawa)	Continental Zone 3: Budapest (others: Bratislava, Ljubljana, Milan, Vienna)	Nordic Zone 5: Stockholm (Helsinki, Riga, Stockholm, Gdansk, Tovarene)
	Offices kWh/(m2/y)			
net primary energy	20-30	40-55	40-55	55-70
primary energy use	80-90	85-100	85-100	85-100
on-site RES sources	60	45	45	30
	New single family house kWh/(m2/y)			
net primary energy	0-15	15-30	20-40	40-65
primary energy use	50-65	50-65	50-70	65-90
on-site RES sources	50	35	30	25



Building site = system boundary of delivered and exported energy on site

$$E = \frac{f_{DH} \cdot Q_{DH} + f_{DC} \cdot Q_{DC} + \sum_i f_{fuel} \cdot Q_{fuel} + f_{el} \cdot W_{el}}{A_{net}}$$

E the total energy use of the building weighted by coefficients calculated for purchased energy in buildings of its net heated area per year, [(kWh/(m^2a));

Q_{DH} the total annually consumed district heating energy, (kWh/a);

Q_{DC} the total annually consumed district cooling, (kWh/a);

Q_{fuel} the total annually consumed energy in the form of fuels, (kWh/a);

W_{el} the annual electricity consumption, which takes into account the reduced consumption due to 'free energy' from on-site renewables as long as it is used for standardized electricity use within the building. (kWh/a);

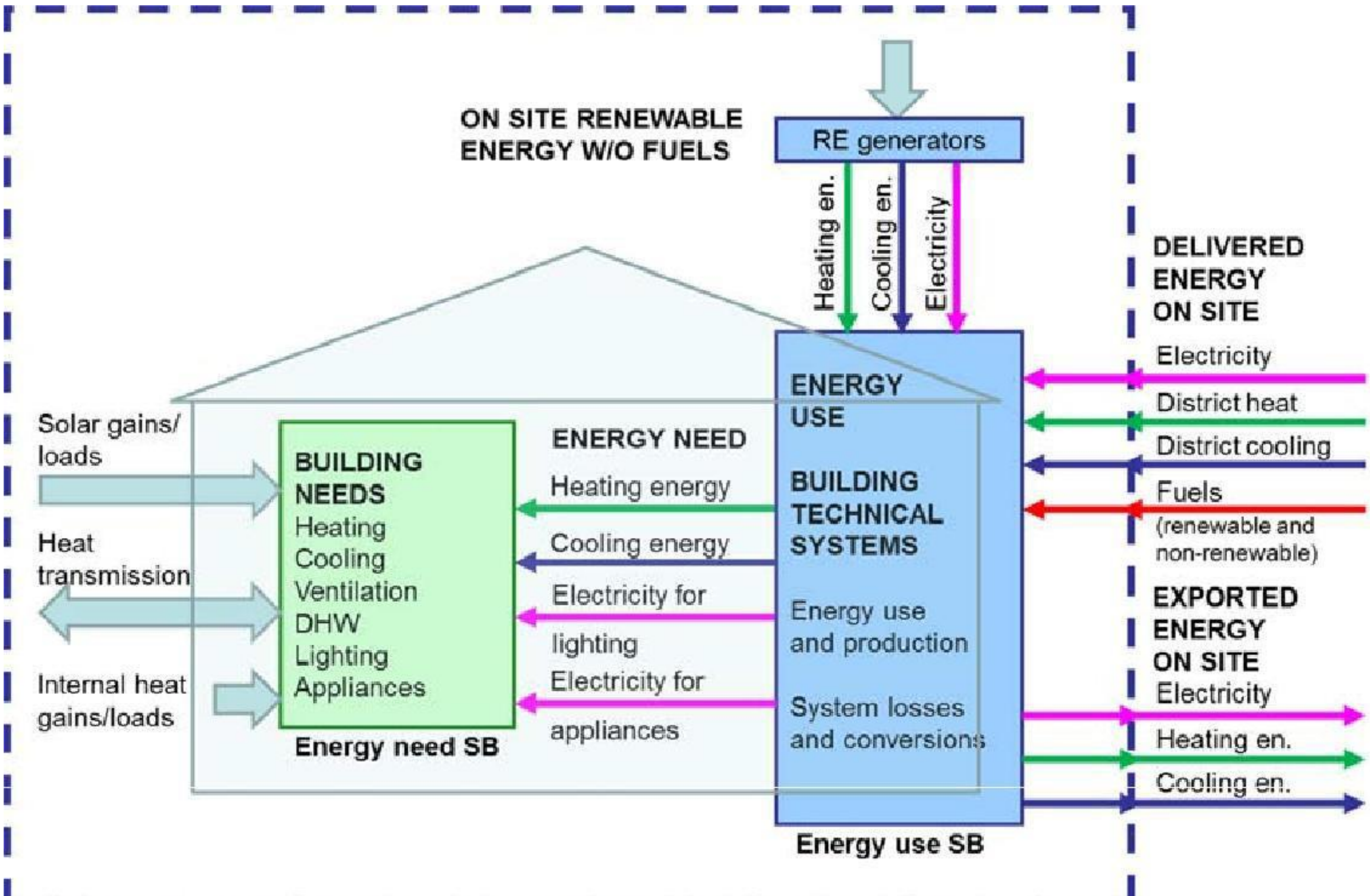
f_{DH} the primary energy form factor for district heating;

f_{DC} the primary energy form factor for district cooling;

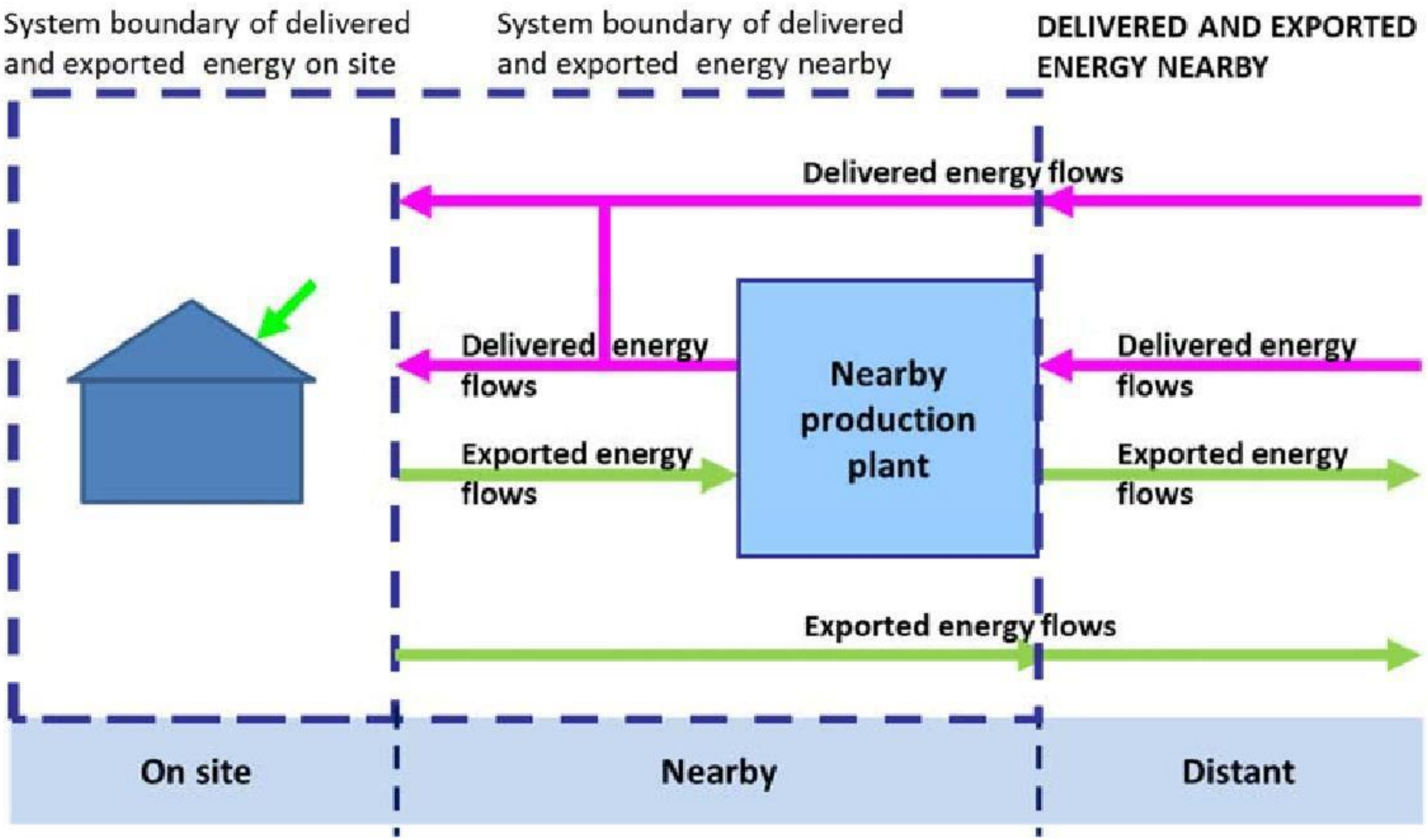
f_{fuel} the primary energy form factor of a given fuel type;

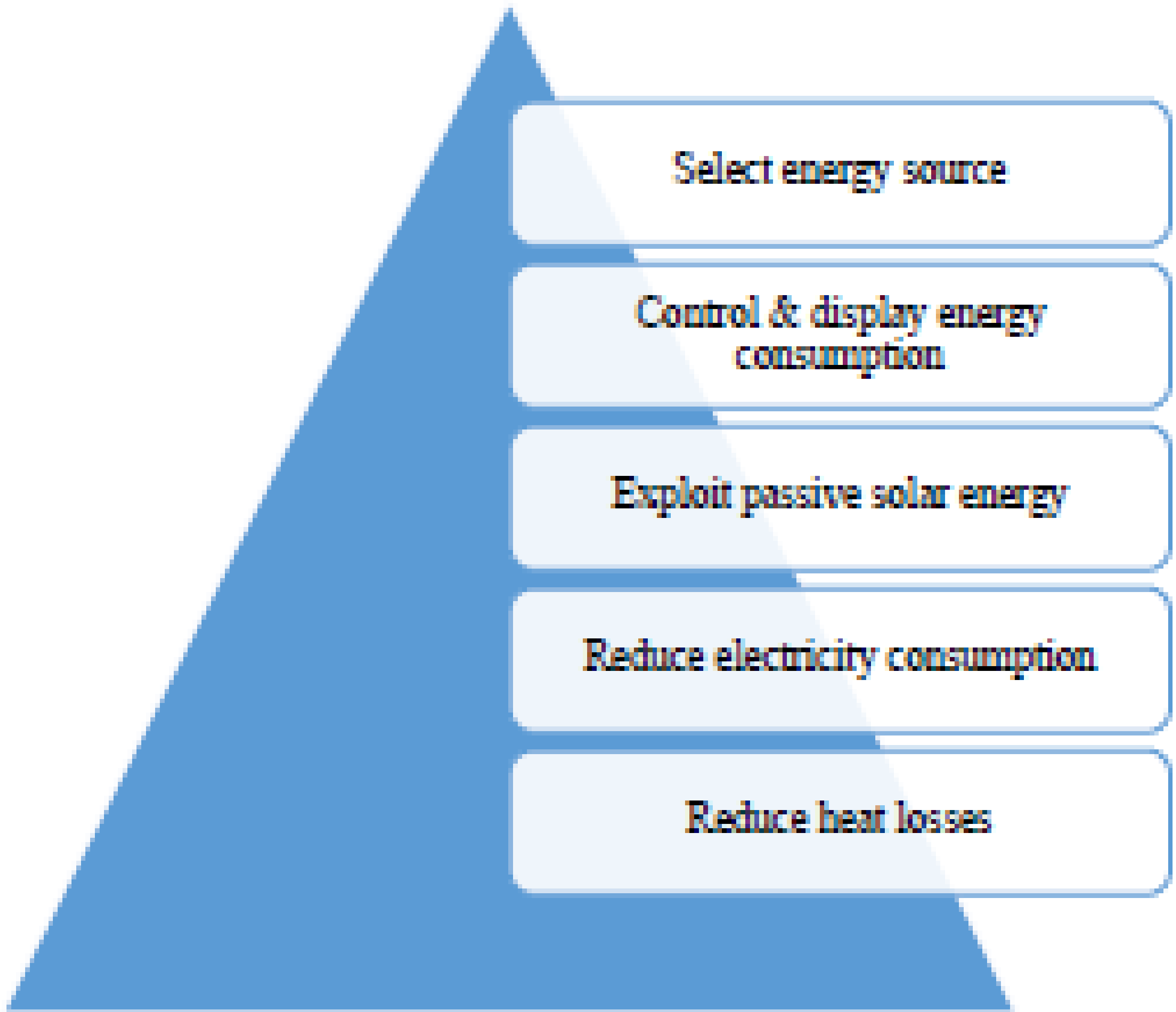
f_{el} the primary energy form factor for electricity;

A_{net} the net heated area of the building, (m^2).



Building site boundary = system boundary of delivered and exported energy on site


System boundary of delivered and exported energy on site
System boundary of delivered and exported energy nearby
DELIVERED AND EXPORTED ENERGY NEARBY
Delivered energy flows
Delivered energy flows
Nearby production plant
Delivered energy flows
Exported energy flows
Exported energy flows
Exported energy flows
On site
Nearby
Distant


Select energy source
Control & display energy consumption
Exploit passive solar energy
Reduce electricity consumption
Reduce heat losses

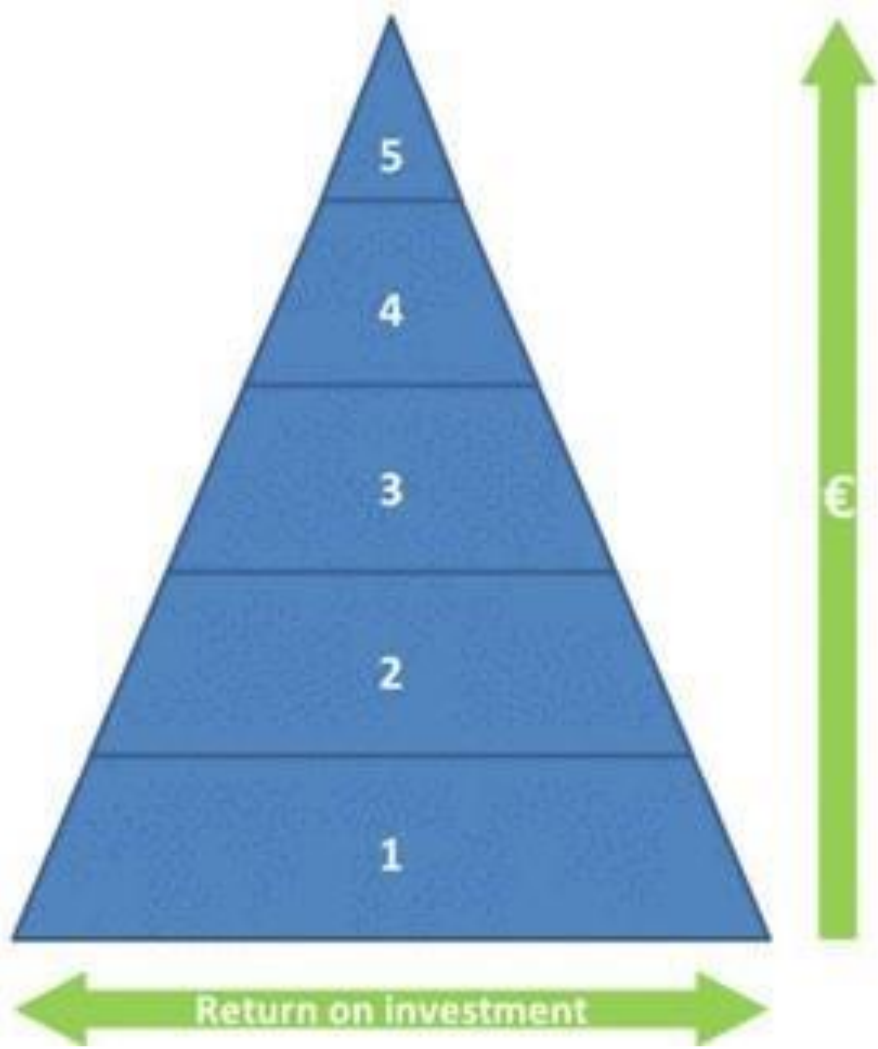
5 On site renewables
photovoltaic, solar thermal, free cooling

4 Energy supply
district heating & cooling, heat pumps

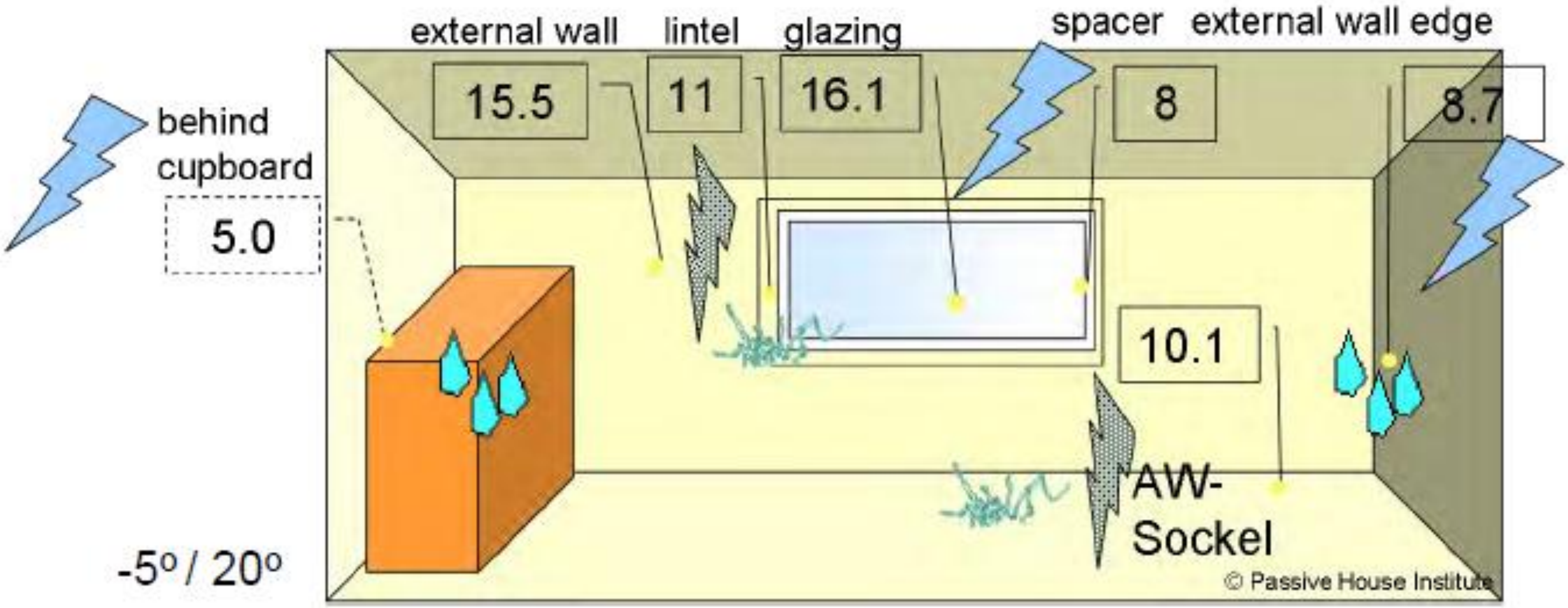
3 Efficient technical systems
ventilation, AC, heating, lighting, controls

2 Facade design
thermal, light transmission, shading

1 Mass & form
orientation, shape & fabric

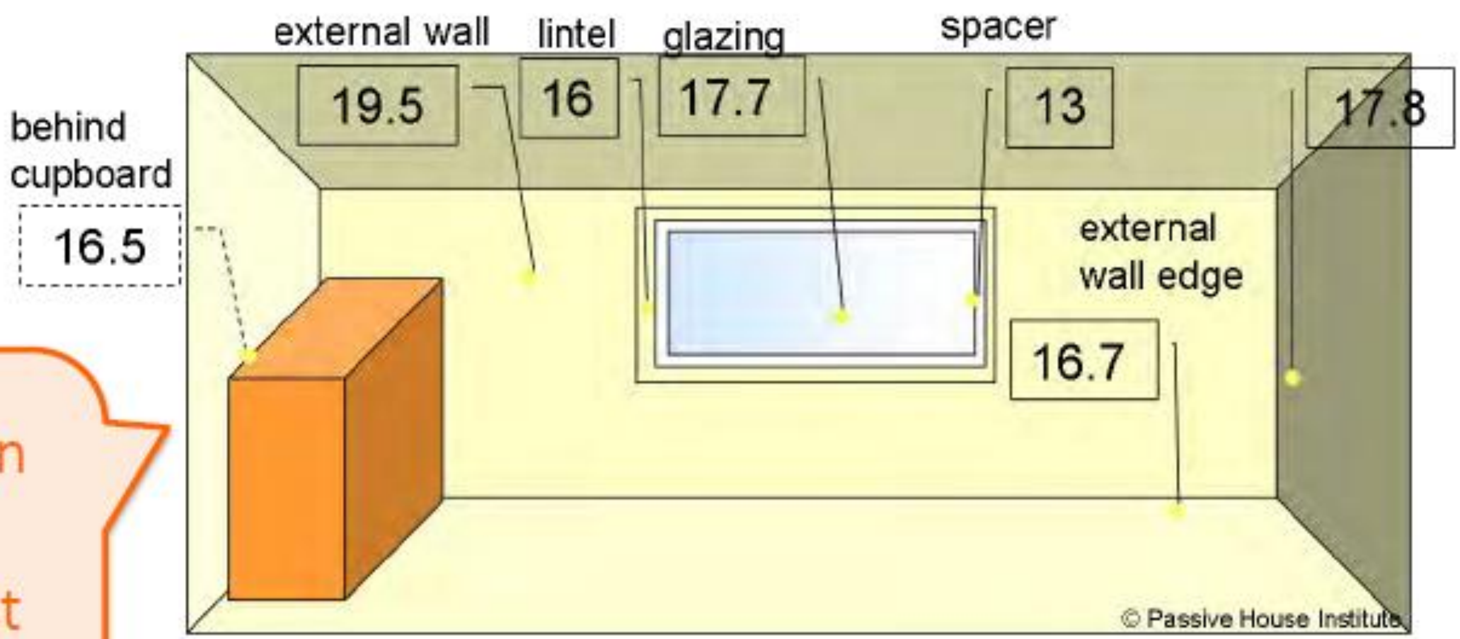


Houses, in which we live



- T° of critical surfaces – about 9°C
- Critical areas around furniture, windows, corners
- To avoid mold – relative indoor humidity < 38%

Passive Houses



Emphasis on **comfort** but not just **energy**

- T^0 of critical surfaces – > 16^{0}C
- No risk for mold even behind furniture
- To avoid mold – relative indoor humidity < 62%

Basic advantages of Passive Houses

- Building with a healthy lifestyle comfort
- Building with the lowest cost of energy
- Building with easy operation and maintenance
- Building without a separate heating system

THE PASSIVE HOUSE CONCEPT

Design and construction principles

Physical characteristics of buildings

1. Optimal solar gains
2. Superinsulation
3. High quality windows and doors
4. High air tightness
5. Minimal thermal bridges
6. Ventilation with heat recovery

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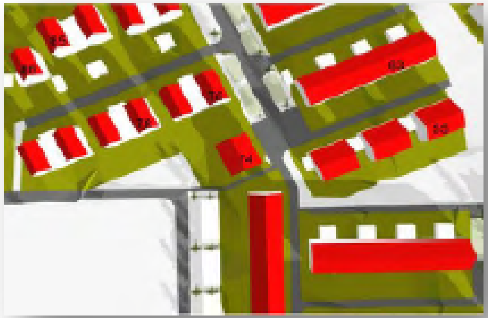
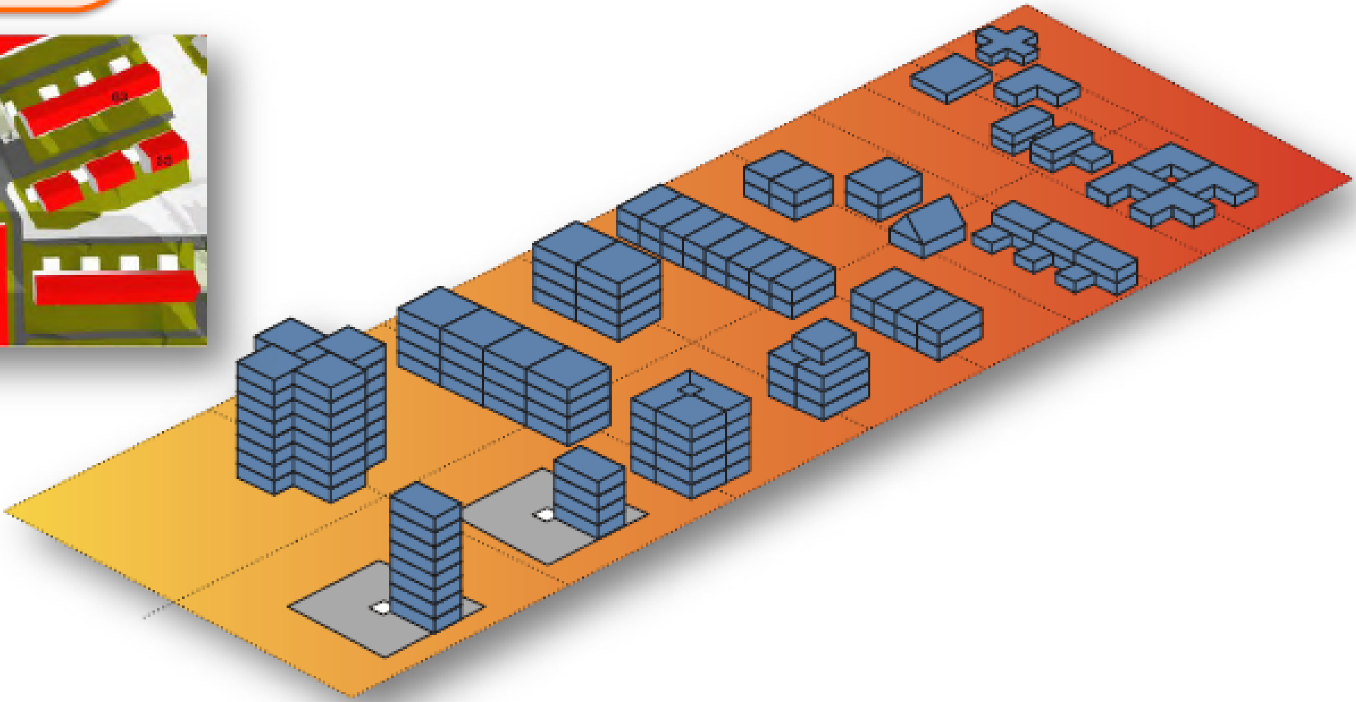
Territorial
planning
Architectural
design

THE PASSIVE HOUSE CONCEPT

1. Optimal solar gains





Architectural and structural design
Finishing works

THE PASSIVE HOUSE CONCEPT

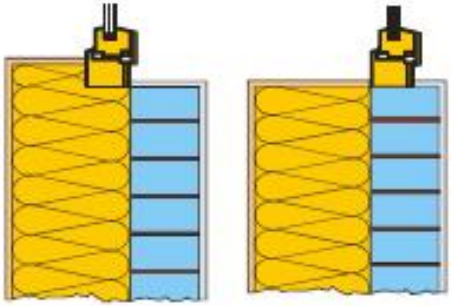
2. Superinsulation

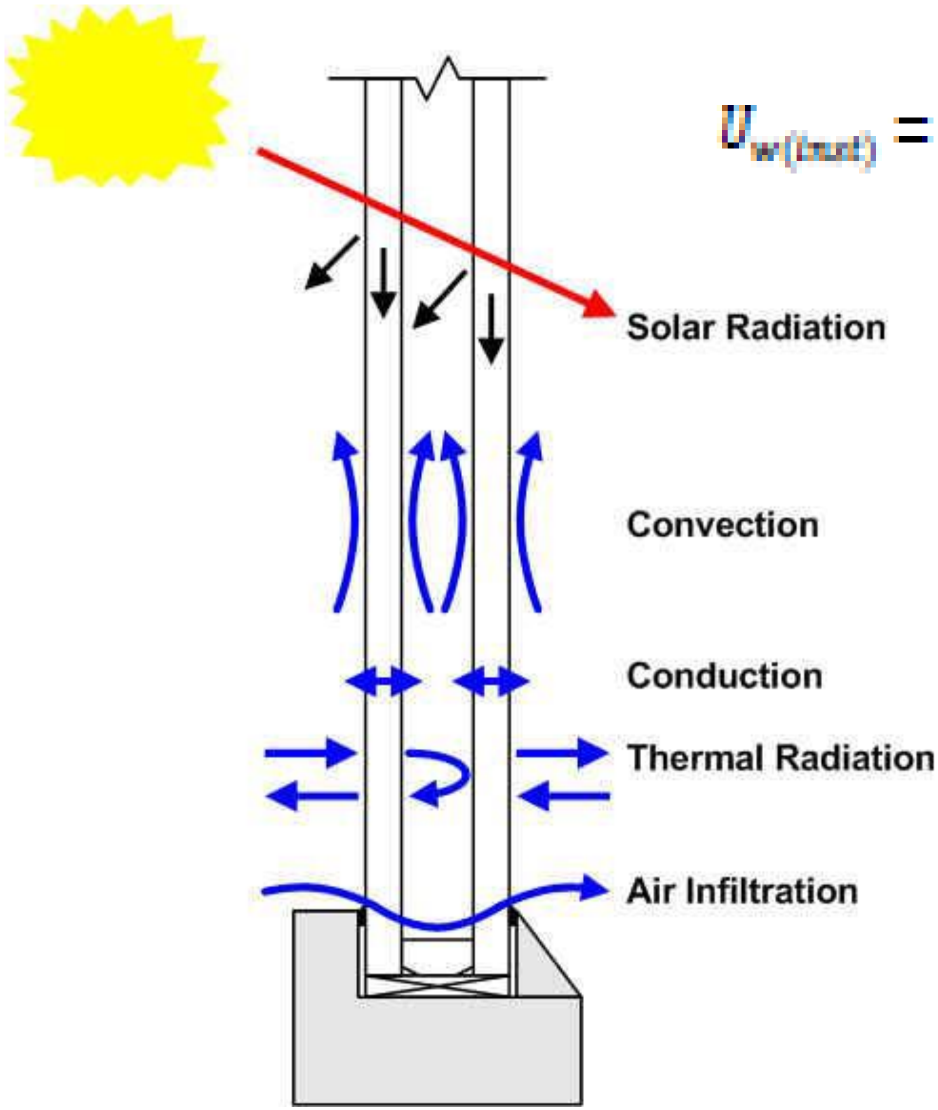

U=0.08
U=0.85
U=0.10
U=0.09

Architectural design
Quality of components and assembling

THE PASSIVE HOUSE CONCEPT

3. High quality windows and doors





$$U_{w(inst)} = \frac{A_g \cdot U_g + A_f \cdot U_f + l_g \cdot \Psi_g + (l_{inst} \cdot \Psi_{inst})}{A_g + A_f}$$

where:

U_w the whole window U-value, (W/m2K);

U_g the U-value of the glazing, (W/m2K);

U_f the U-value of the frame, (W/m2K);

A_g the area of the glazing, (m2);

A_f the area of the frame, (m2);

l_g the length of the glazing perimeter, (m);

l_{inst} the length of the installed frame perimeter, (m);

$U_{w(inst)}$ is the installed window U-value when the additional term ($l_{inst} \cdot \Psi inst$) is included, (W/m2K);

Ψg the additional two-dimensional heat flow or linear thermal bridge occurring between the glazing edge and the frame, (W/(m K);

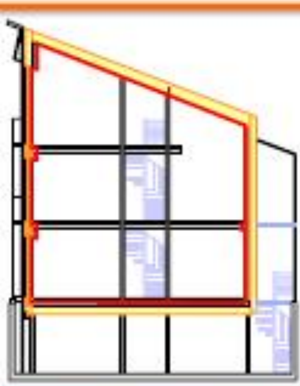
$\Psi inst$ not a material-specific parameter but depends on the way the window

is installed at the junction with the wall. Since the head, cell and jam psi- values can all be different (depending on the specific window installation and profile), $\Psi inst$ is taken to be the average value.

Architectural design
Quality of construction work

THE PASSIVE HOUSE CONCEPT

4. High air tightness



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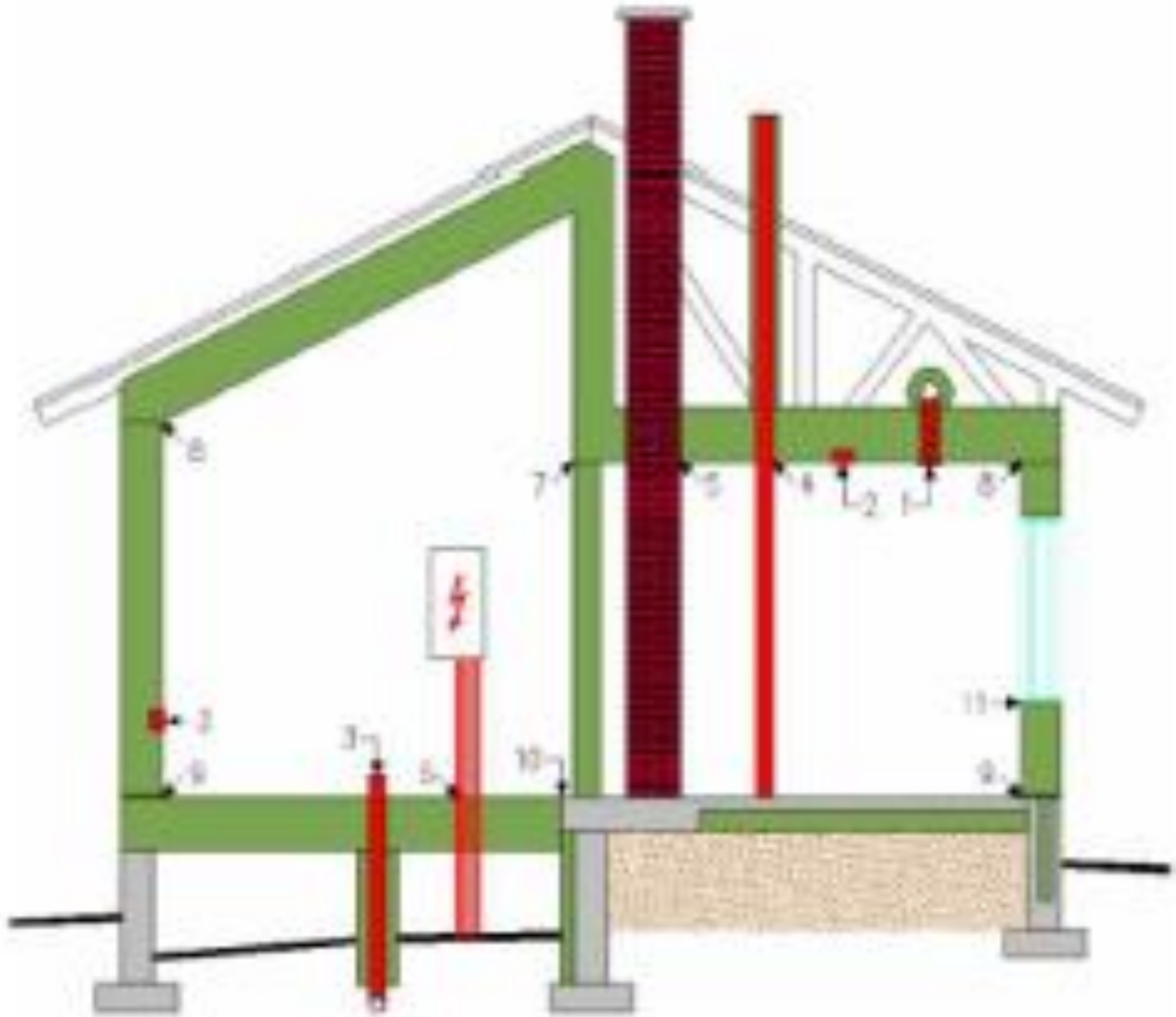
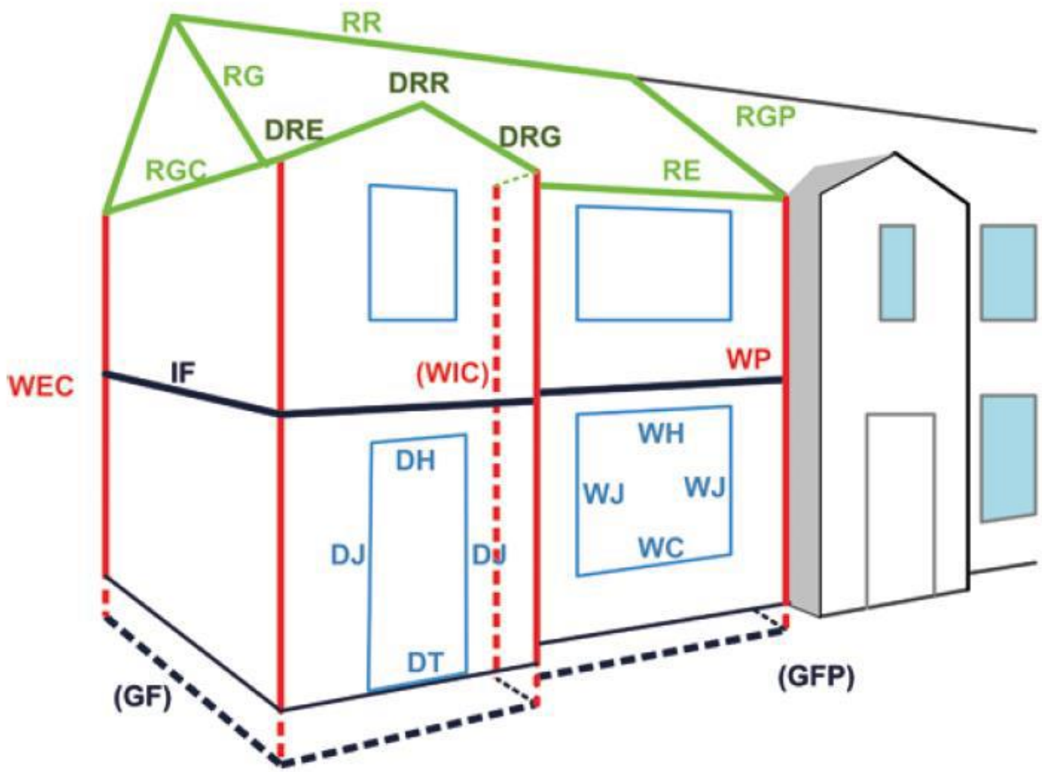


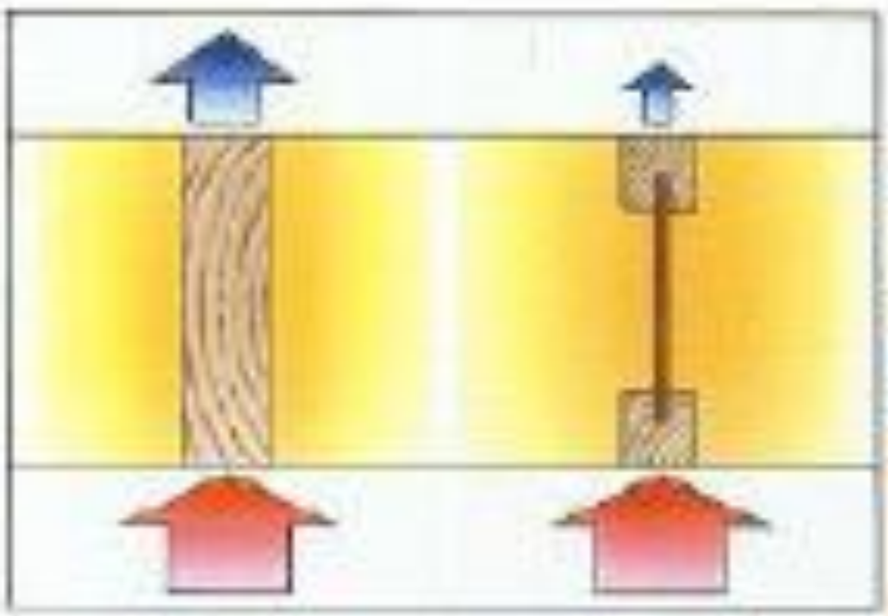
Architectural and structural design
Construction works

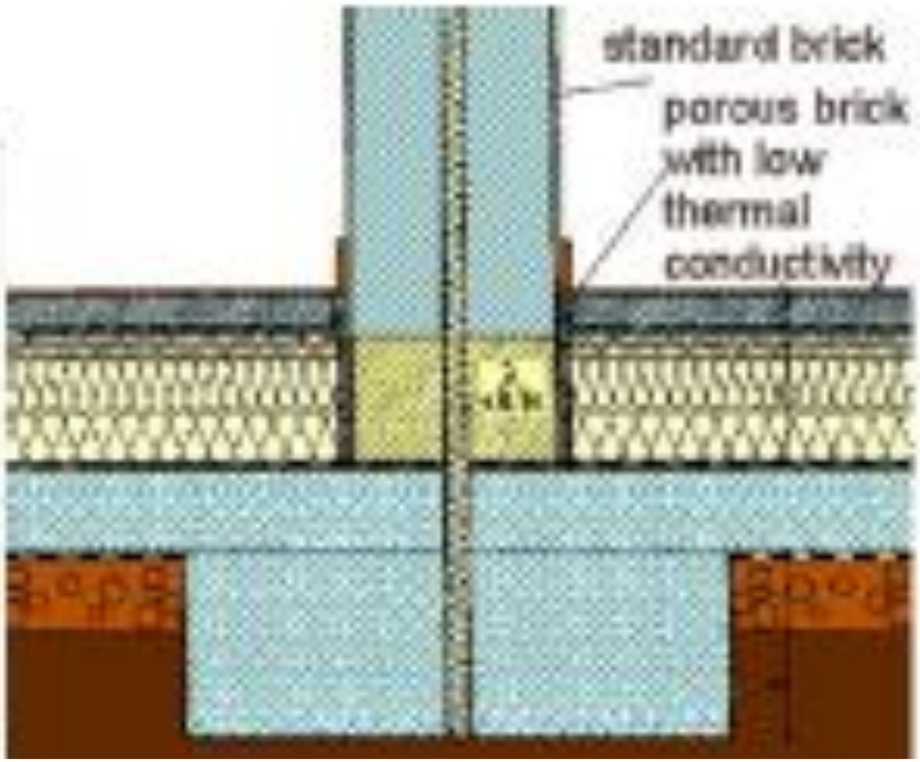
THE PASSIVE HOUSE CONCEPT

5. Minimal thermal bridges



- WIC: wall internal corner
- WEC: wall external corner
- WP: wall to party wall
- RGC: roof gable ceiling (verge)
- RG: roof gable
- RE: roof eaves
- RGP: roof to party wall
- RR: roof ridge
- DRE: dormer roof eaves
- DRG: dormer roof gable
- DRR: dormer roof ridge
- WH/DH: window/door to wall at head
- WJ/DJ: window/door to wall at jamb
- WC: window to wall at cill
- DT: door threshold
- IF: intermediate floor to wall
- GF: ground floor to wall
- GFP: ground floor to party wall

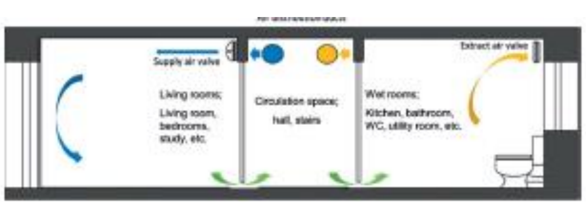



standard brick
porous brick with low thermal conductivity

HVAC design
Quality of assembling

THE PASSIVE HOUSE CONCEPT

6. Ventilation with heat recovery



THE PASSIVE HOUSE CONCEPT

Design and construction

The critical importance of the **design** and the quality of **construction work** need special care

Physical characteristics of building

1. Optimal solar gains
2. Superinsulation
3. High quality windows and doors
4. High air tightness
5. Minimal thermal bridges
6. Ventilation with heat recovery

ADDITIONAL REQUIREMENTS TO NZEB

Societal and political requirements

- 7. Cost optimality (effectiveness)
- 8. Prevailing use of RES
- 9. Minimal CO_2 emissions

EPBD

Integrated design

ADDITIONAL REQUIREMENTS TO nZEB

7. Cost-effectiveness

Architectural and technological design

ADDITIONAL REQUIREMENTS TO nZEB

8. Prevailing use of RES

Integrated design

ADDITIONAL REQUIREMENTS TO nZEB

9. Minimal CO_2 emissions

"Solar" buildings (80-ies)

"3-liter" buildings (90-ies)

"Carbon-free" buildings (United Kingdom)

"Green" building – with a minimal environmental footprint

NEARLY ZERO-ENERGY BUILDING CONCEPT

Physical characteristics of buildings

1. Optimal solar gains
2. Superinsulation
3. High quality windows and doors
4. High air tightness
5. Minimal thermal bridges
6. Ventilation with heat recovery

Societal and political requirements to buildings

7. Cost effectiveness
8. Prevailing use of RES
9. Minimal CO_2 emissions



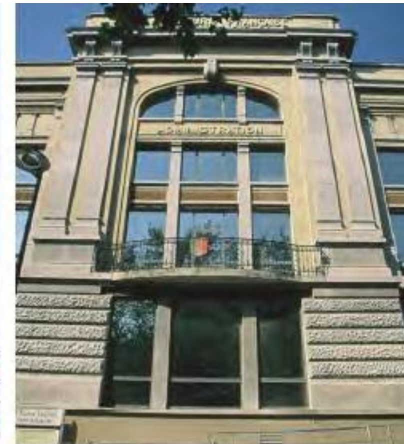


Passive House standard
15 kWh/m^2.a





Raiffeisen



Structure of the study and methodological approach

Study case : Romania

Actual practice in construction

Economic situation
Technology costs

Existing policy framework

Simulation of technical solutions for improving the energy performance of new buildings as comparing to actual practice:

Defining Reference buildings

- Single family homes
- Multi family buildings
- Office buildings

Technical analysis of solutions (primary energy, CO_2, RES share)

Financial and economic analysis of the solutions

Optimized solutions for specific national context

Proposed nZEB Definitions

Proposing policy implementation roadmaps by 2020

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	Walls	Roof	Floor	Windows	Global requirement
Residential (requirement)	0.56 W/m²K	0.20 W/m²K	0.35 W/m²K (floors above unheated basement 0.22 W/m²K (floors, no basement) 0.21 W/m²K (floors of heated basements)	1.30 W/m²K	Global thermal transmittance coefficient, G (W/m³K).
Residential (typical building)	0.56 W/m²K	0.20 W/m²K	0.22 W/m²K	1.30 W/m²K	
Office building (requirement)	Depending on climatic region and thermal inertia, U=0.56…0.67 W/m²K	Depending on climatic region, U=0.22…0.29 W/m²K	Depending on climatic region and thermal inertia, U=0.34…0.50 W/m²K	2.0 W/m²K	Global thermal transmittance coefficient, G (W/m³K).
Office building (typical building)	0.60 W/m²K	0.25 W/m²K	0.35 W/m²K	1.30 W/m²K	

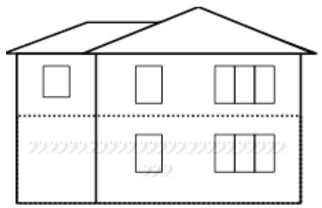
Actual practice in construction

To analyse the impact of different nZEB options, three reference buildings have been defined, based on current construction practices in Romania:

- **Detached single-family houses (SFH)**
- **Multi-family houses (MFH)**
- **Office buildings**

Reference buildings for new constructions

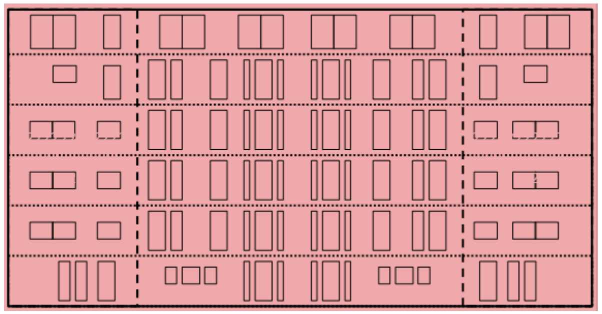
Single family homes



Parameter	Value/Description
Number of conditioned floors	2
Net floor area	99.7 m^2
Room height	2.5 m
U-walls	0.56 $W/(m^2K)$
U-roof	0.35 $W/(m^2K)$
U-floor	0.52 $W/(m^2K)$
U-windows, frame fraction	1.30 $W/(m^2K)$; 30%
Window fraction (window/wall-ratio)	12% (no windows on North facade)
Shading	None
Air tightness	Moderate
Thermal bridges	Yes
Heating system	Gas boiler (set point: 20°C), Heating efficiency: 0.9
DHW system	Same as for heating, DHW efficiency: 0.9
Ventilation system	Natural/window ventilation (0.5 1/h)
Cooling system	Split system (set point: 26°C), SEER: 2.75
Internal gains	5 W/m^2
Installed lighting power	18 W/m^2
Automatic lighting control	No

Reference buildings for new constructions

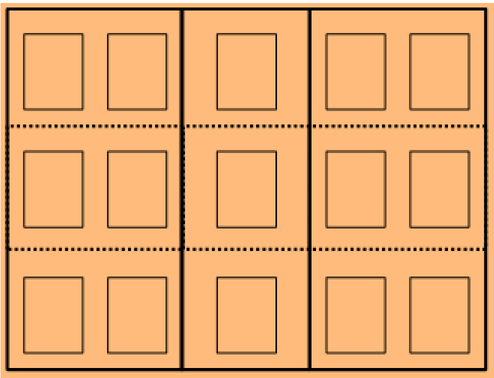
Multi family buildings



Parameter	Value/Description
Number of conditioned floors	6
Net floor area	2 870 m^2
Room height	2.73 m
U-walls	0.6 $W/(m^2K)$
U-roof	0.24 $W/(m^2K)$
U-floor	0.60 $W/(m^2K)$
U-windows, frame fraction	1.30 $W/(m^2K)$, 30%
Window fraction (window/wall-ratio)	23%
Shading	None
Air tightness	Moderate
Thermal bridges	Yes
Heating system	Gas boiler (set point: 20°C), Heating efficiency: 0.9
DHW system	Same as for heating, DHW efficiency: 0.9
Ventilation system	Natural/window ventilation (0.5 1/h)
Cooling system	Split system (set point: 26°C), SEER: 2.75
Internal gains[illegible]	5 W/m^2
Installed lighting power[illegible]	18 W/m^2
Automatic lighting control	No

Reference buildings for new constructions

Office buildings



Parameter	Value/Description
Number of conditioned floors	3-5
Net floor area	2 817 m²
Room height	3.30 m
U-walls	0.61 W/(m²K)
U-roof	0.33 W/(m²K)
U-floor	0.64 W/(m²K)
U-windows, frame fraction	1.30 W/(m²K), 15%
Window fraction (window/wall-ratio)	55% (East side without glazing)
Shading	None
Air tightness	Moderate
Thermal bridges	Yes
Heating system	Gas boiler, fan coils (set point: 20°C), Heating efficiency: 0.9
DHW system	Same as for heating, DHW efficiency: 0.9
Ventilation system	Mechanical ventilation, (0.46...2.72 1/h, zone dependent)
Ventilation rates during system operating time (6 am till 6 pm)	Office spaces: 1.36 1/h
	Conference rooms: 2.72 1/h
	Other rooms: 0.46 1/h
Cooling system	Central chiller, fan coils, (set point: 26°C), SEER: 2.7
Internal gains[**]	3.5 W/m²
Person density in office areas (considered as an additional internal load)	0 am - 8 am and 6 pm - 0 am: no persons
	8 am - 12 am and 2 pm - 6 pm: 1 person/15 m²
	12 am - 2 pm: 1 Person/30 m²
Installed lighting power[**]	10 W/m²
Automatic lighting control	No

nZEB solutions for single-family house (SFH)

Variants	U-Value Opaque Shell	U-Value Window	Heat Recovery Ratio	Solar Collector for DHW	Brief Description
V0	U-Wall: 0.56 W/m².K U-Roof: 0.35 W/m².K U-Floor: 0.52 W/m².K	1.3 W/m².K	0%	No	Reference
V1	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.36 W/m².K	1.0 W/m².K	0%	No	Improved building shell
V2	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.36 W/m².K	1.0 W/m².K	0%	Yes	Improved building shell + solar collectors
V3	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.36 W/m².K	1.0 W/m².K	80%	No	Improved building shell + mech. ventilation with heat recovery
V4	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.36 W/m².K	0.80 W/m².K	90%	No	Passive house standard[12]
V5	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.36 W/m².K	0.80 W/m².K	90%	Yes	Passive house standard + solar collectors

nZEB solutions for multi-family house (MFH)

Variants	U-value Opaque Shell	U-Value Window	Heat Recovery Ratio	Solar Collector for DHW	Brief Description
V0	U-Wall: 0.60 W/m².K U-Roof: 0.24 W/m².K U-Floor: 0.60 W/m².K	1.3 W/m².K	0%	No	Reference
V1	U-Wall: 0.20 W/m².K U-Roof: 0.15 W/m².K U-Floor: 0.40 W/m².K	1.0 W/m².K	0%	No	Improved building shell
V2	U-Wall: 0.60 W/m².K U-Roof: 0.24 W/m².K U-Floor: 0.60 W/m².K	1.3 W/m².K	80%	No	Mech. ventilation with heat recovery
V3	U-Wall: 0.20 W/m².K U-Roof: 0.15 W/m².K U-Floor: 0.40 W/m².K	1.0 W/m².K	80%	No	Improved building shell + mech. ventilation with heat recovery
V4	U-Wall: 0.20 W/m².K U-Roof: 0.15 W/m².K U-Floor: 0.40 W/m².K	1.0 W/m².K	80%	Yes	Improved building shell + mech. ventilation with heat recovery + solar collectors

Variants	U-value Opaque Shell	U-Value Window	Heat Recovery Rate	External shading	Window Share	Light system	Solar Collector for DHW	Brief Description
V0	U-Wall: 0.61 W/m².K U-Roof: 0.33 W/m².K U-Floor: 0.64 W/m².K	1.3 W/m².K	0%	None	55%	Manual control	No	Reference
V1	U-Wall: 0.61 W/m².K U-Roof: 0.33 W/m².K U-Floor: 0.64 W/m².K	1.3 W/m².K	80%	None	55%	Manual control	No	Mech. ventilation with heat recovery
V2	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.23 W/m².K	1.0 W/m².K	80%	Automatic	55%	Manual control	No	Mech. ventilation with heat recovery + improved building shell + external shading
V3	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.23 W/m².K	1.0 W/m².K	80%	Automatic	36%	Manual control	No	Mech. ventilation with heat recovery + improved building shell + external shading + reduced window share
V4	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.23 W/m².K	1.0 W/m².K	80%	Automatic	36%	Automatic controlled lighting	No	Mech. ventilation with heat recovery + improved building shell + external shading + reduced window share + automatic lighting control
V5	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.23 W/m².K	1.0 W/m².K	80%	Automatic	36%	Automatic controlled lighting	Yes	Mech. ventilation with heat recovery + improved building shell + external shading + reduced window share + automatic lighting control + improved cooling: efficient high temperature concrete activation

nZEB solutions for office buildings

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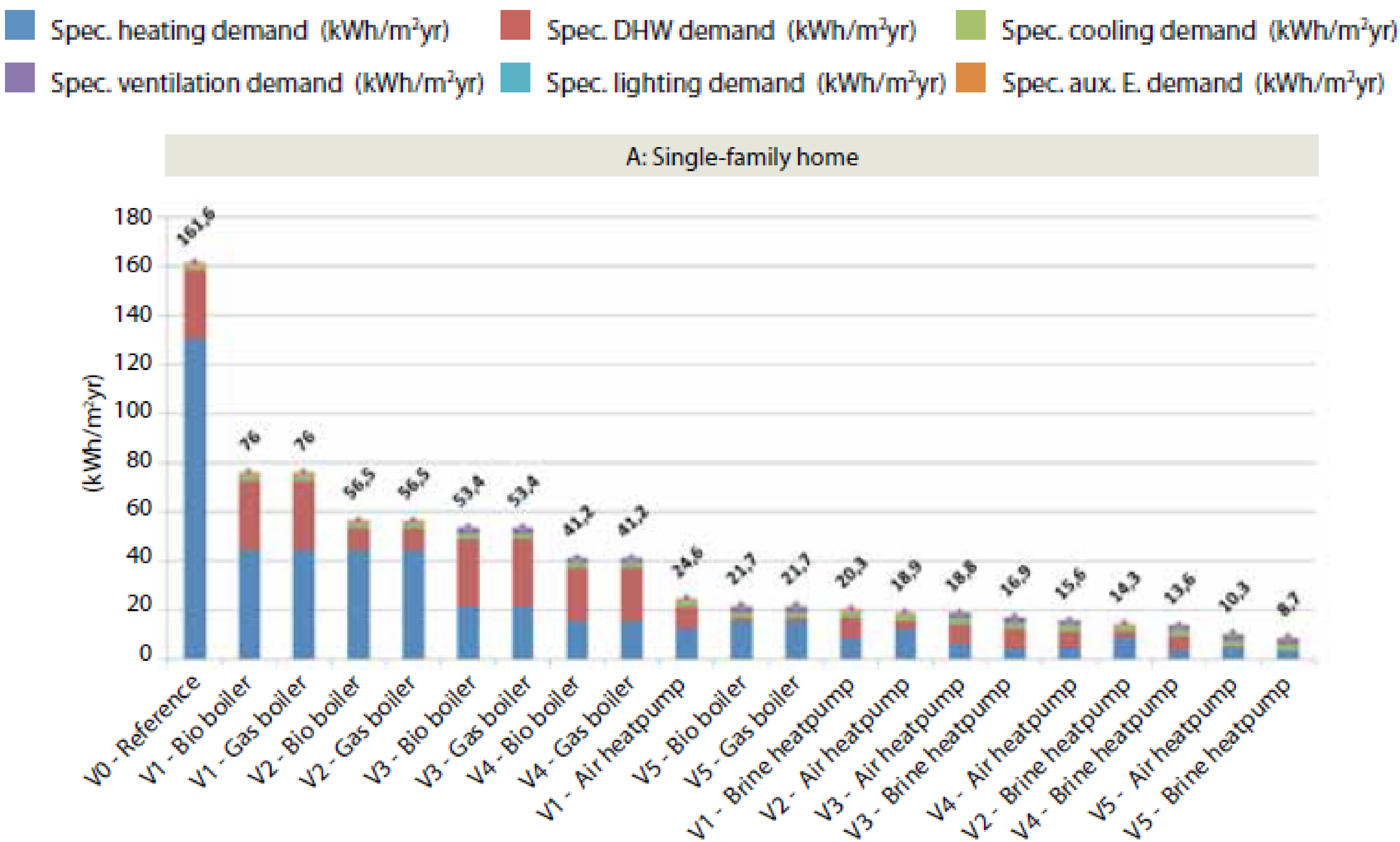
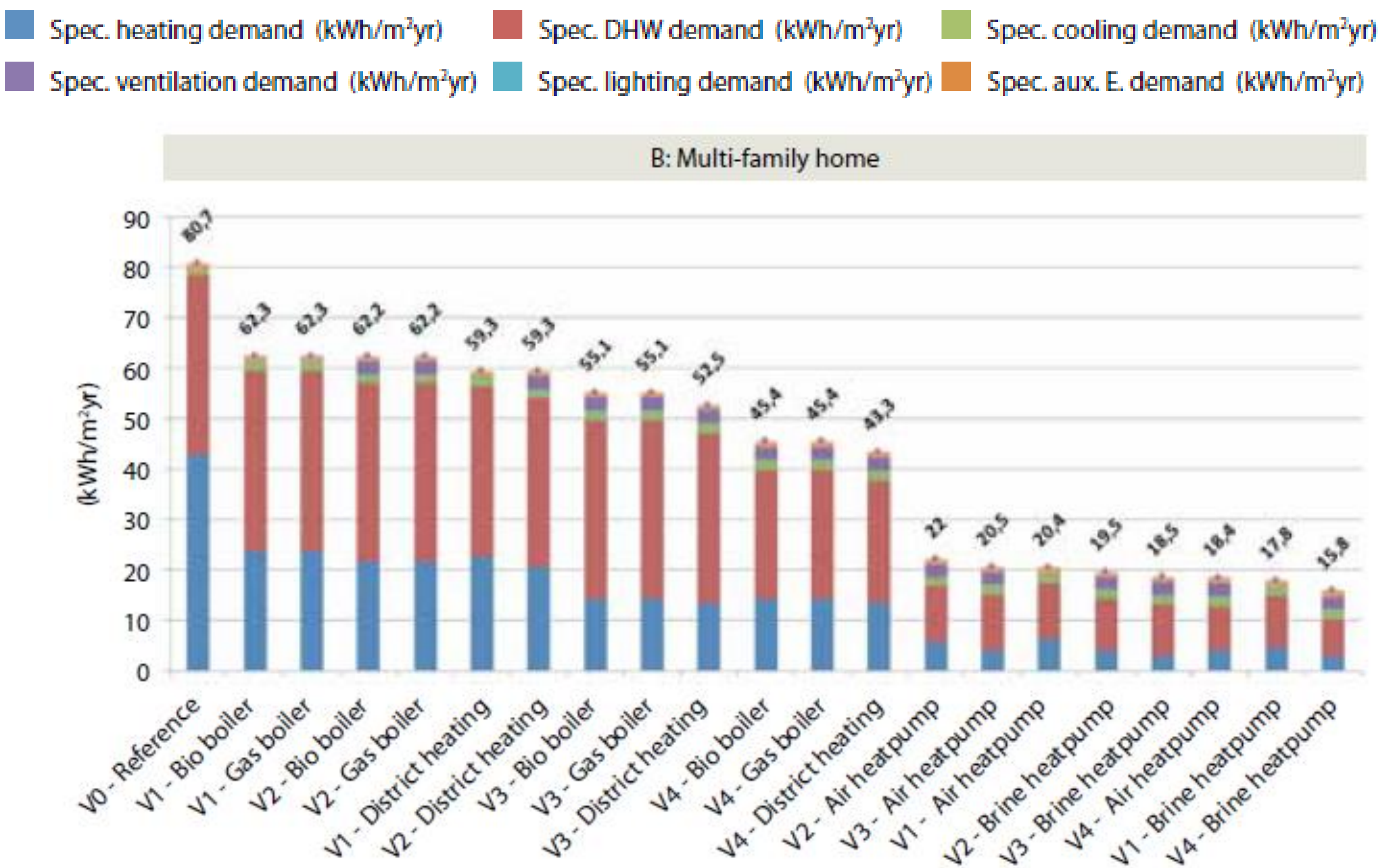
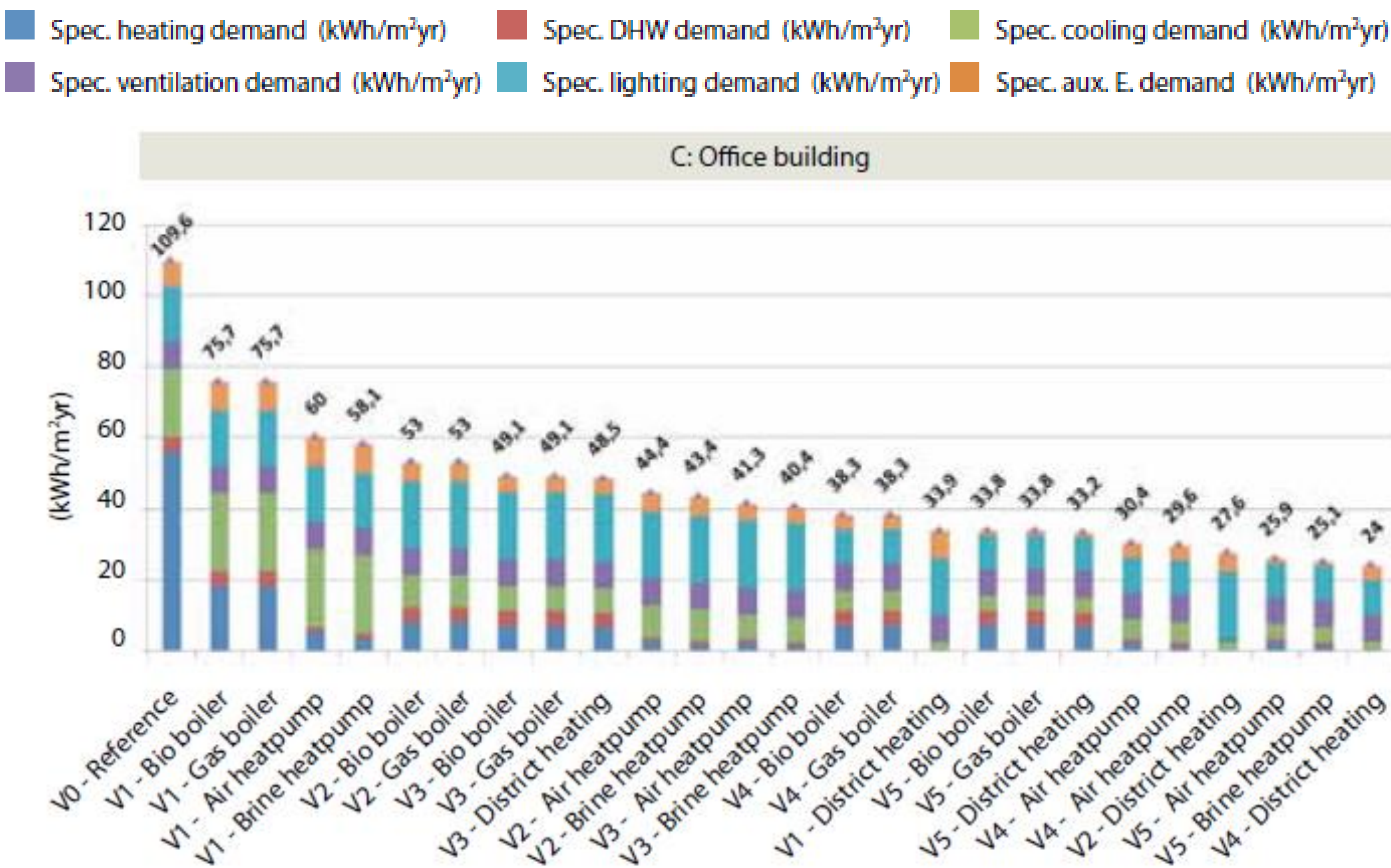
final energy demand for SFH, MFH and offices by building services



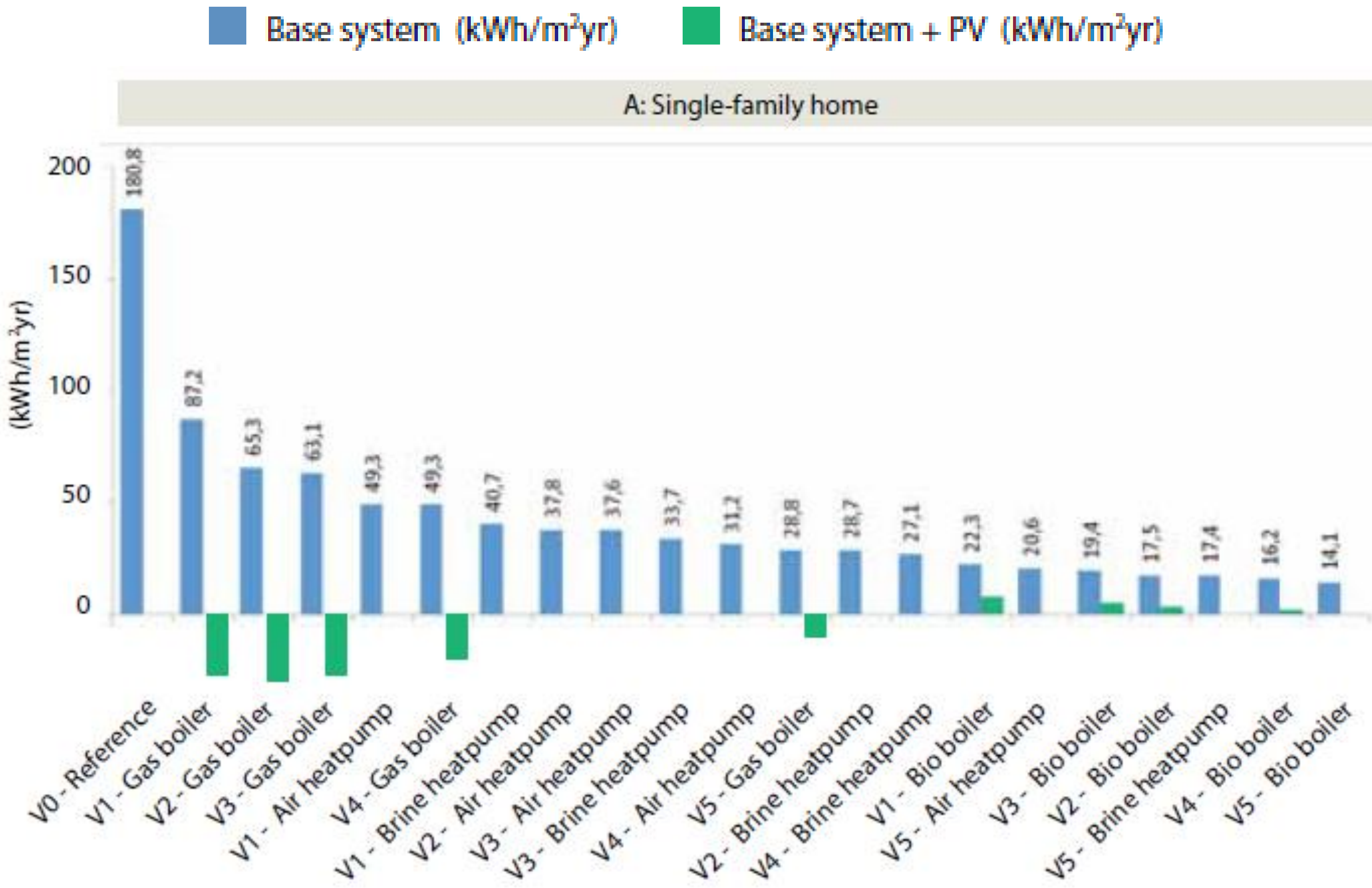
final energy demand for SFH, MFH and offices by building services



final energy demand for SFH, MFH and offices by building services



primary energy demand for SFH, MFH and offices



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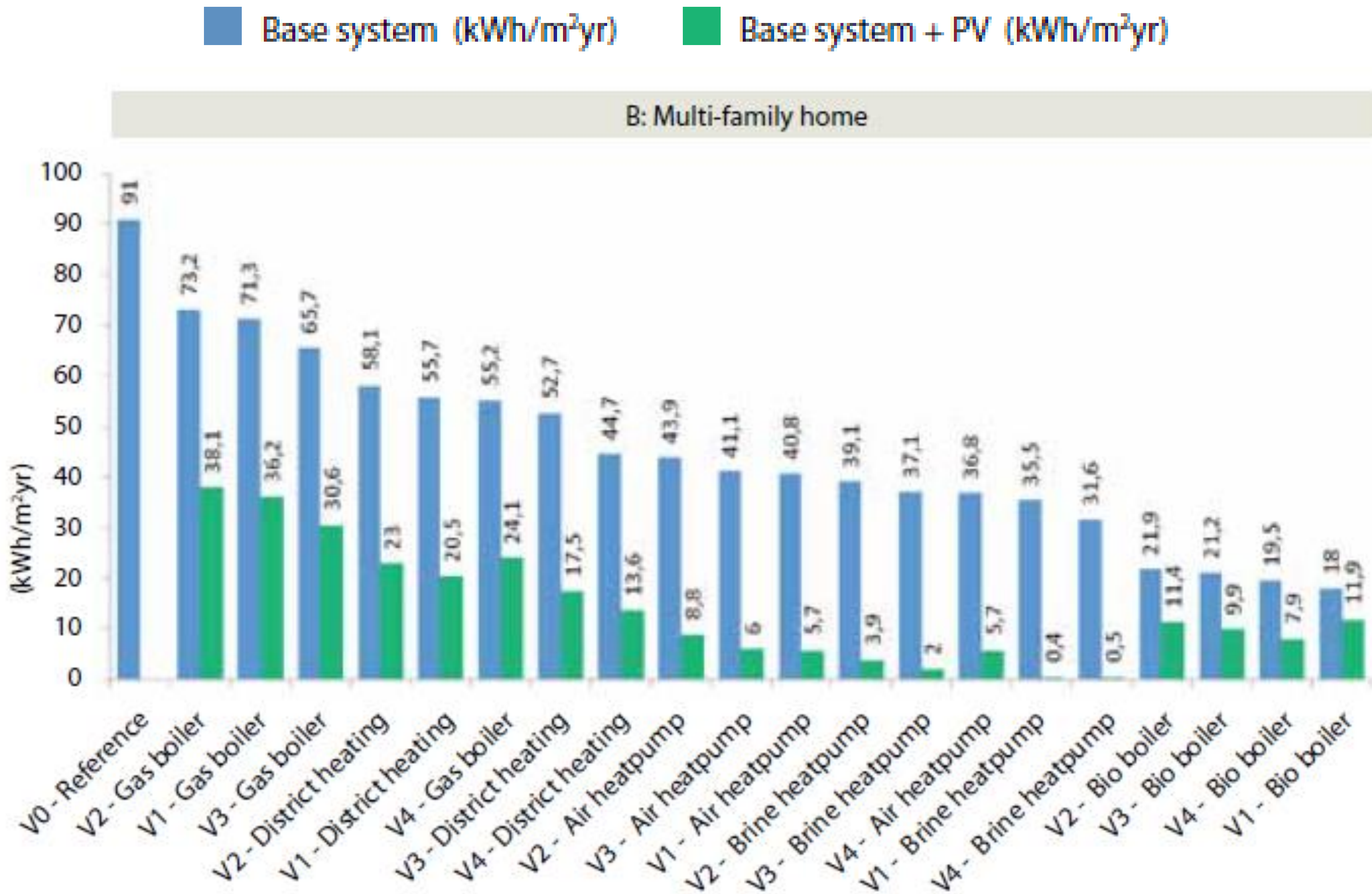
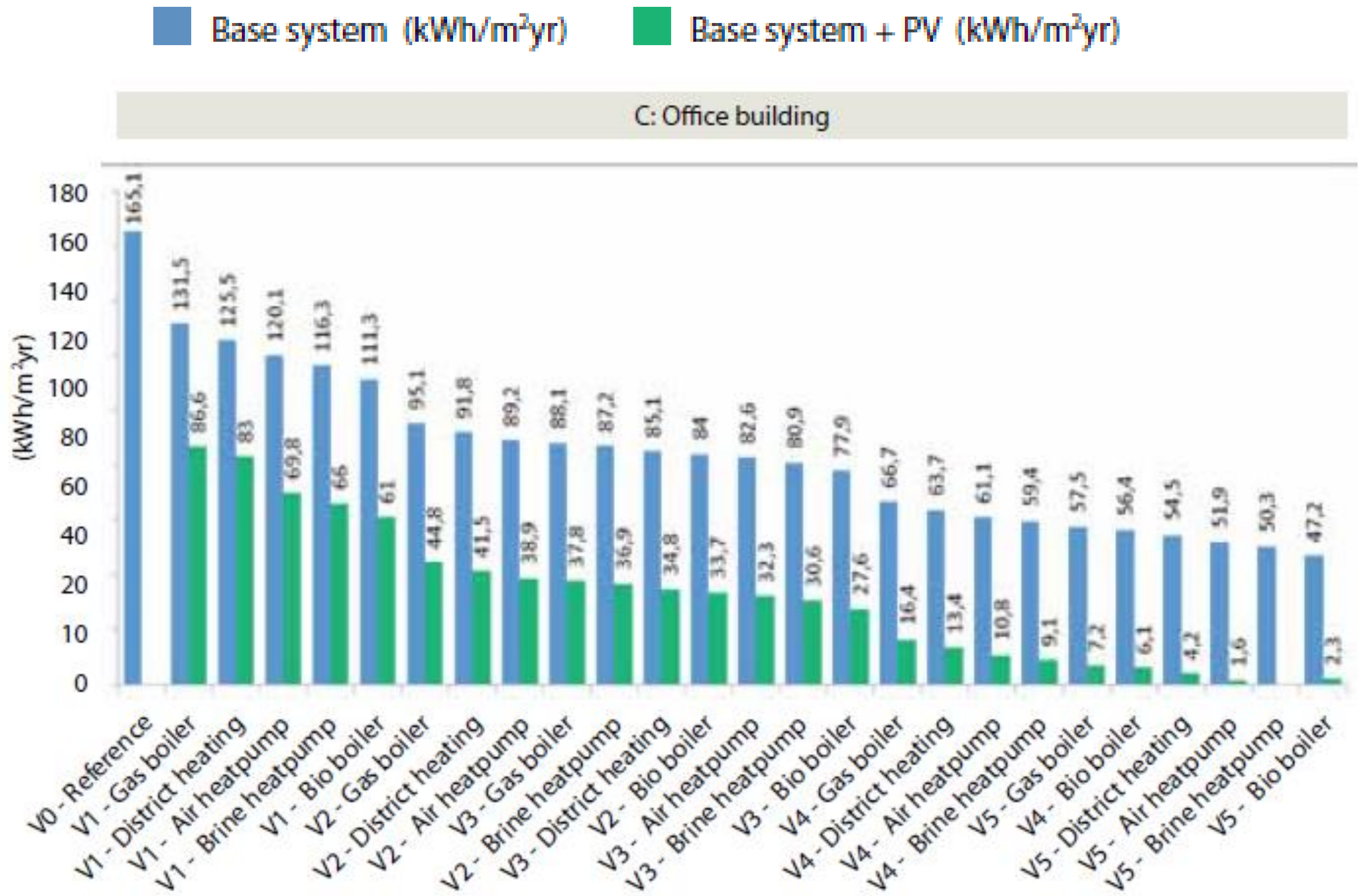
MARUEEB

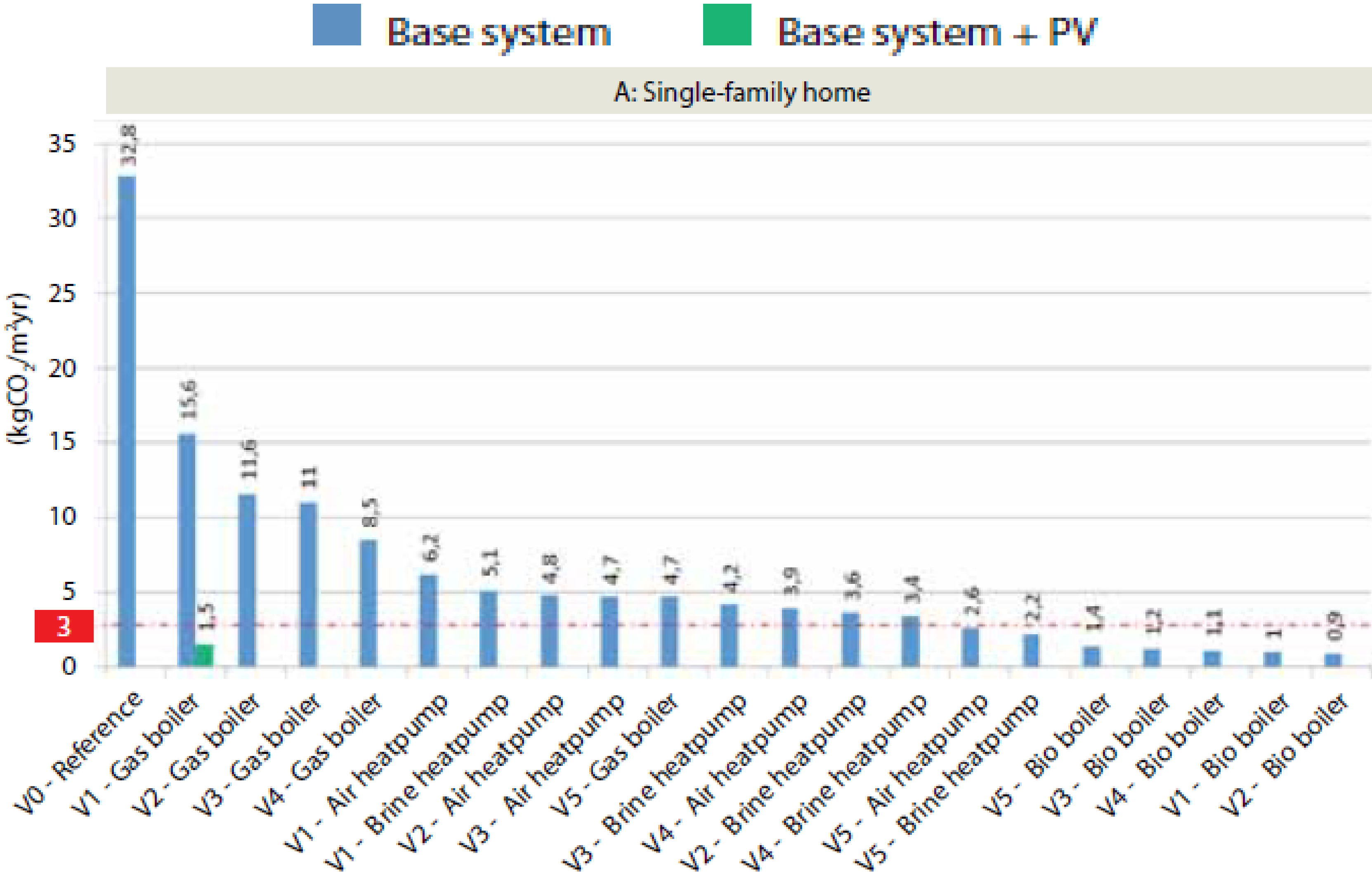
primary energy demand for SFH, MFH and offices



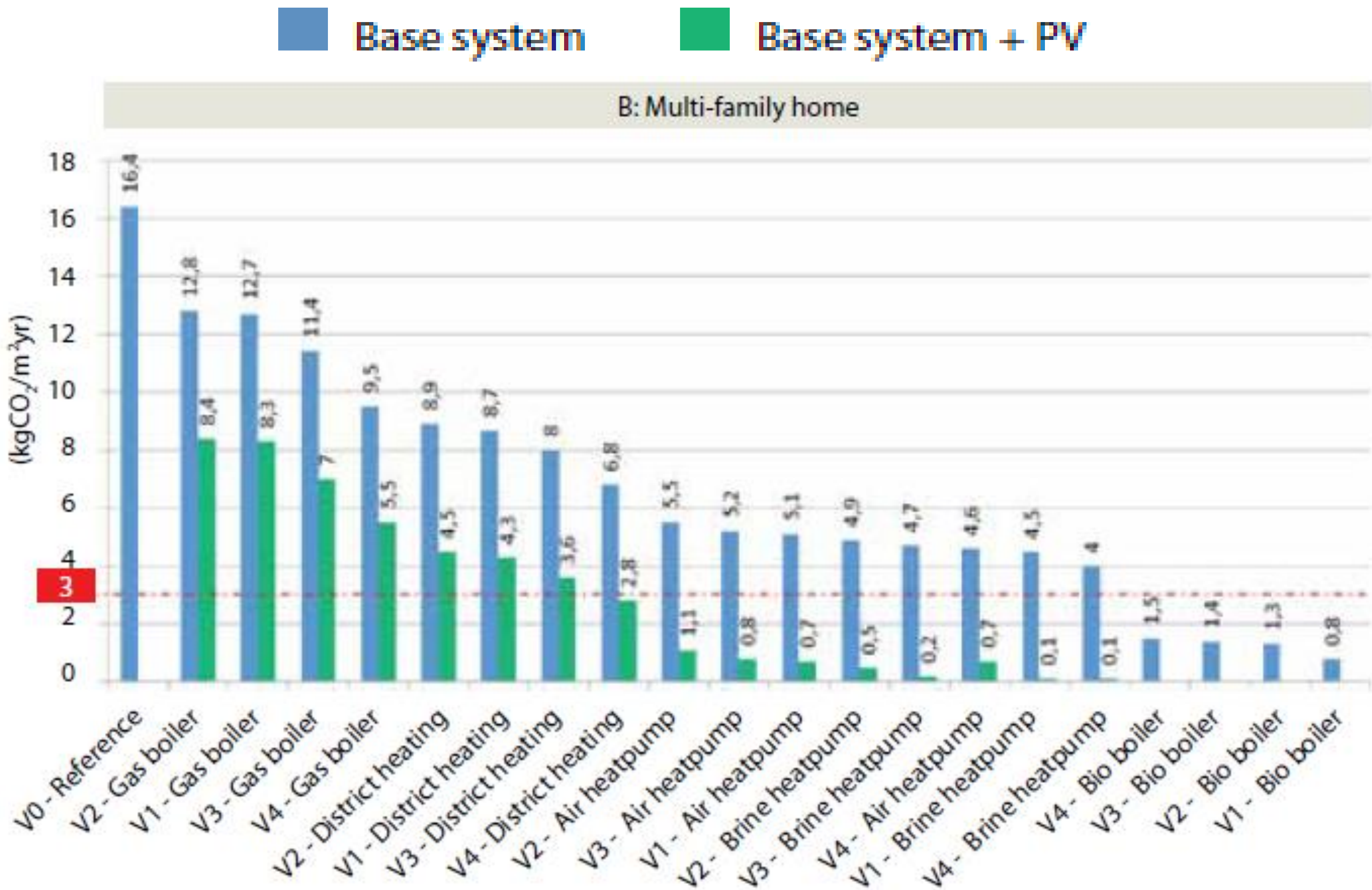
primary energy demand for SFH, MFH and offices



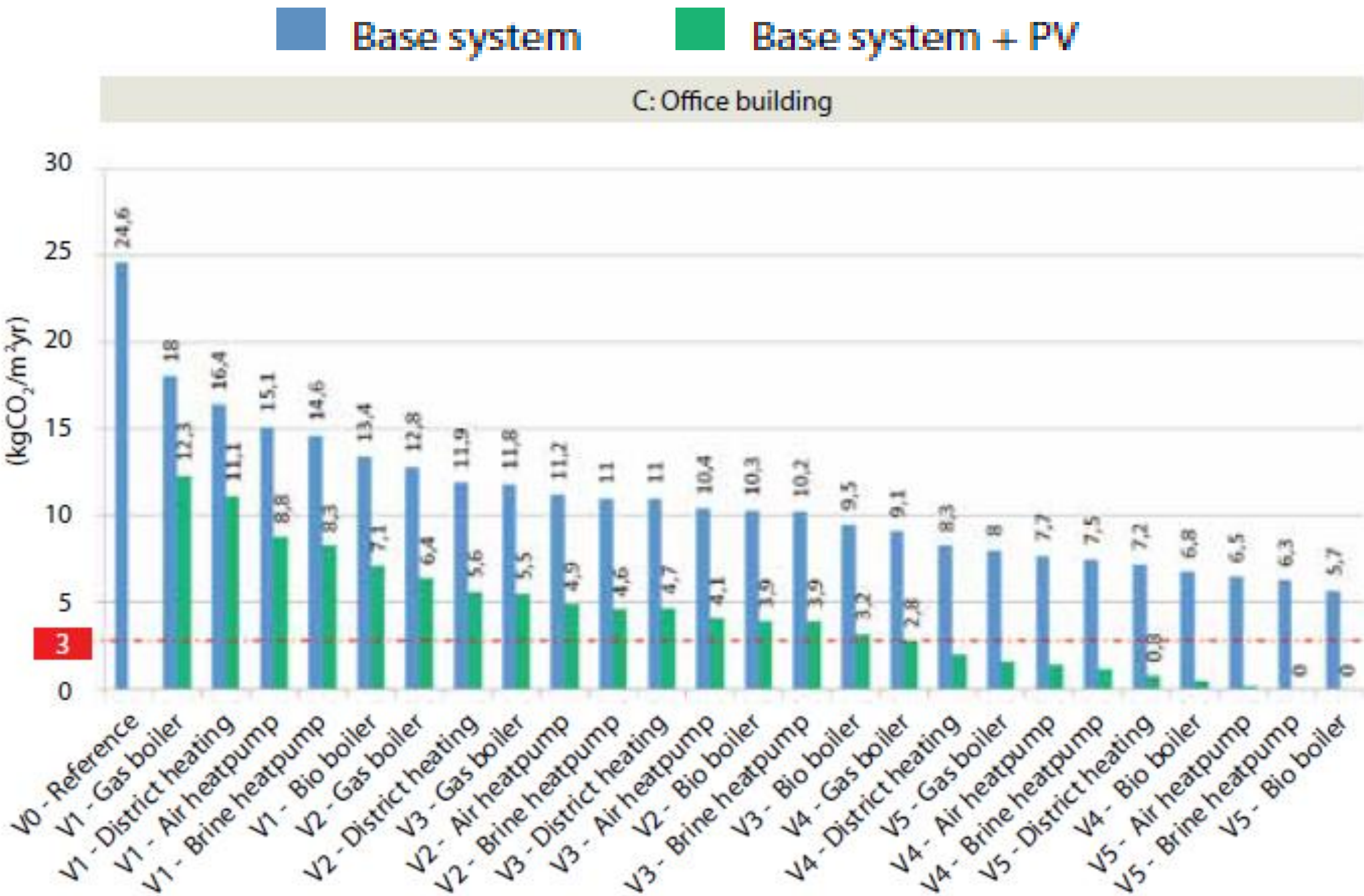
Associated CO_2 emissions for SFH, MFH and offices



Associated CO_2 emissions for SFH, MFH and offices



Associated CO_2 emissions for SFH, MFH and offices



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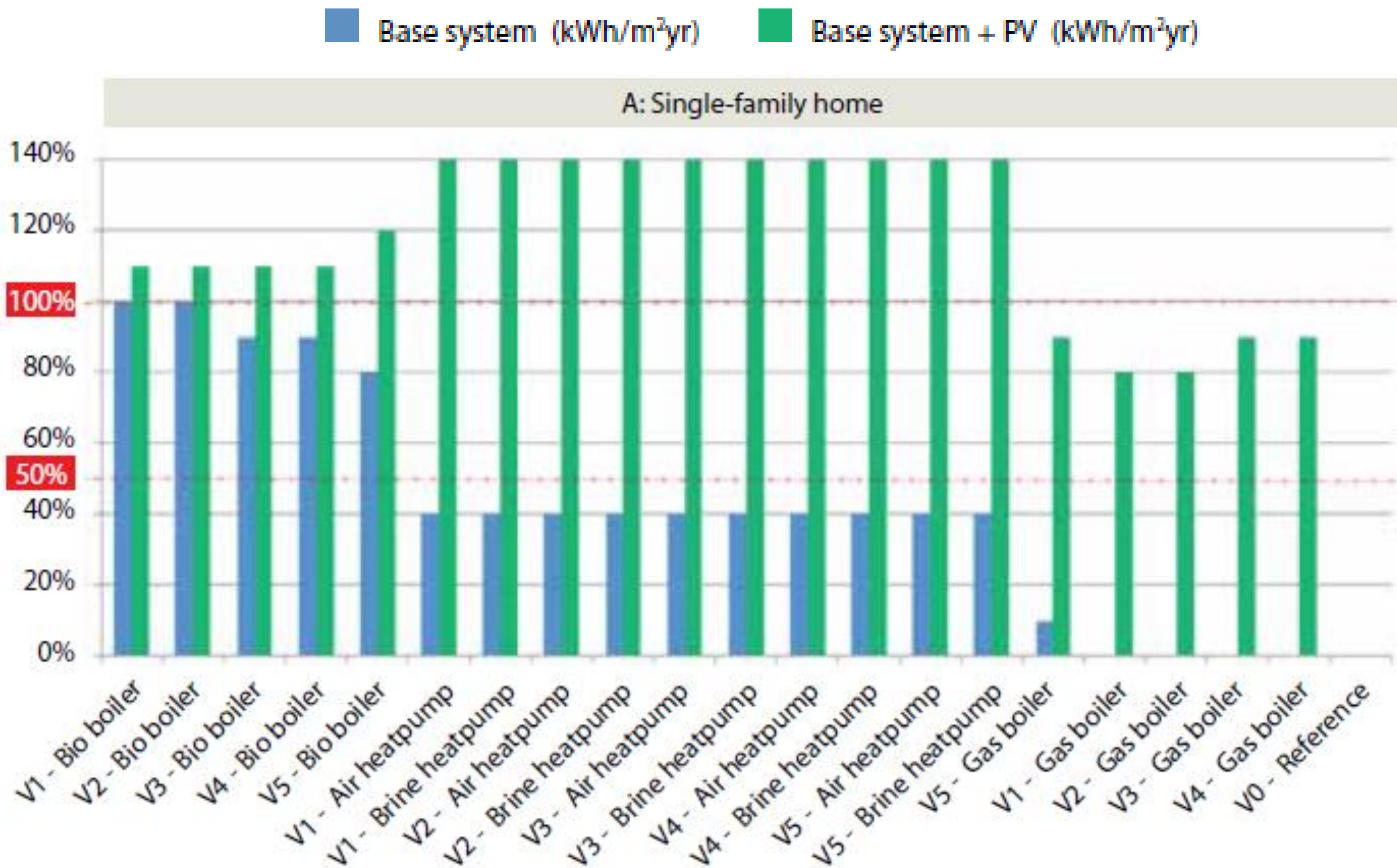
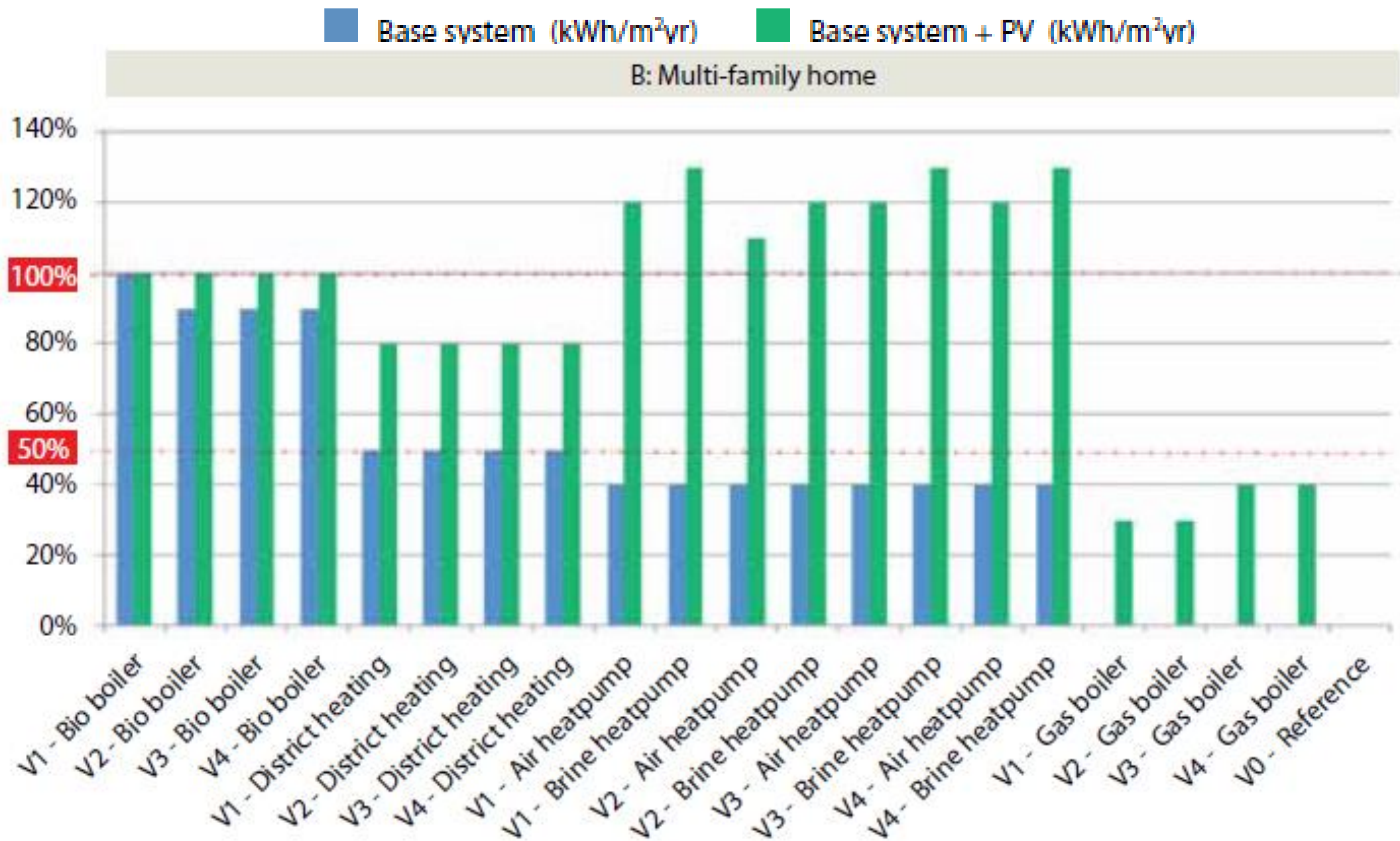
MARUEEB

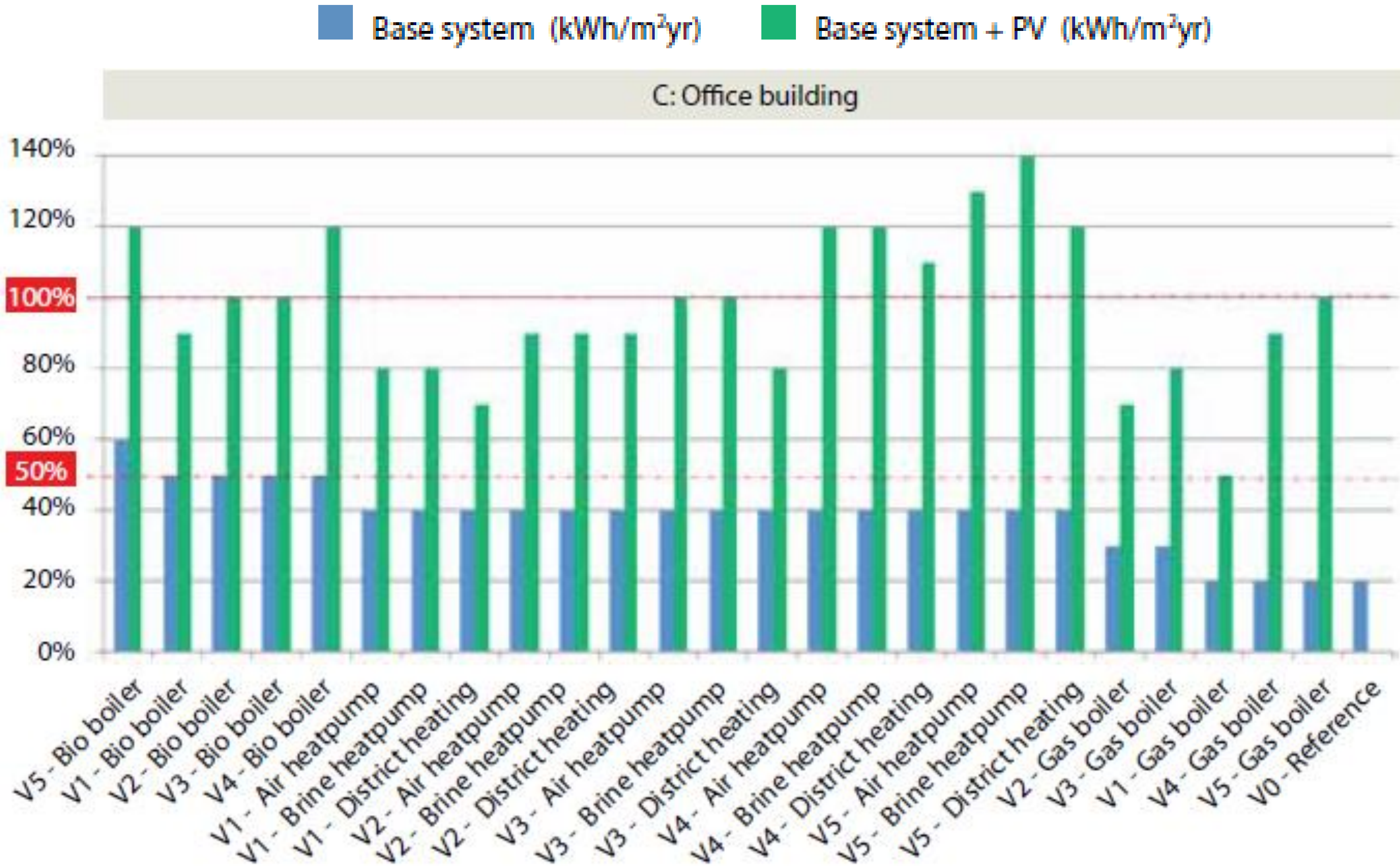
Renewable energy share for SFH, MFH and offices



Renewable energy share for SFH, MFH and offices



Renewable energy share for SFH, MFH and offices



Financial analysis of the nZEB solutions

Basic assumptions

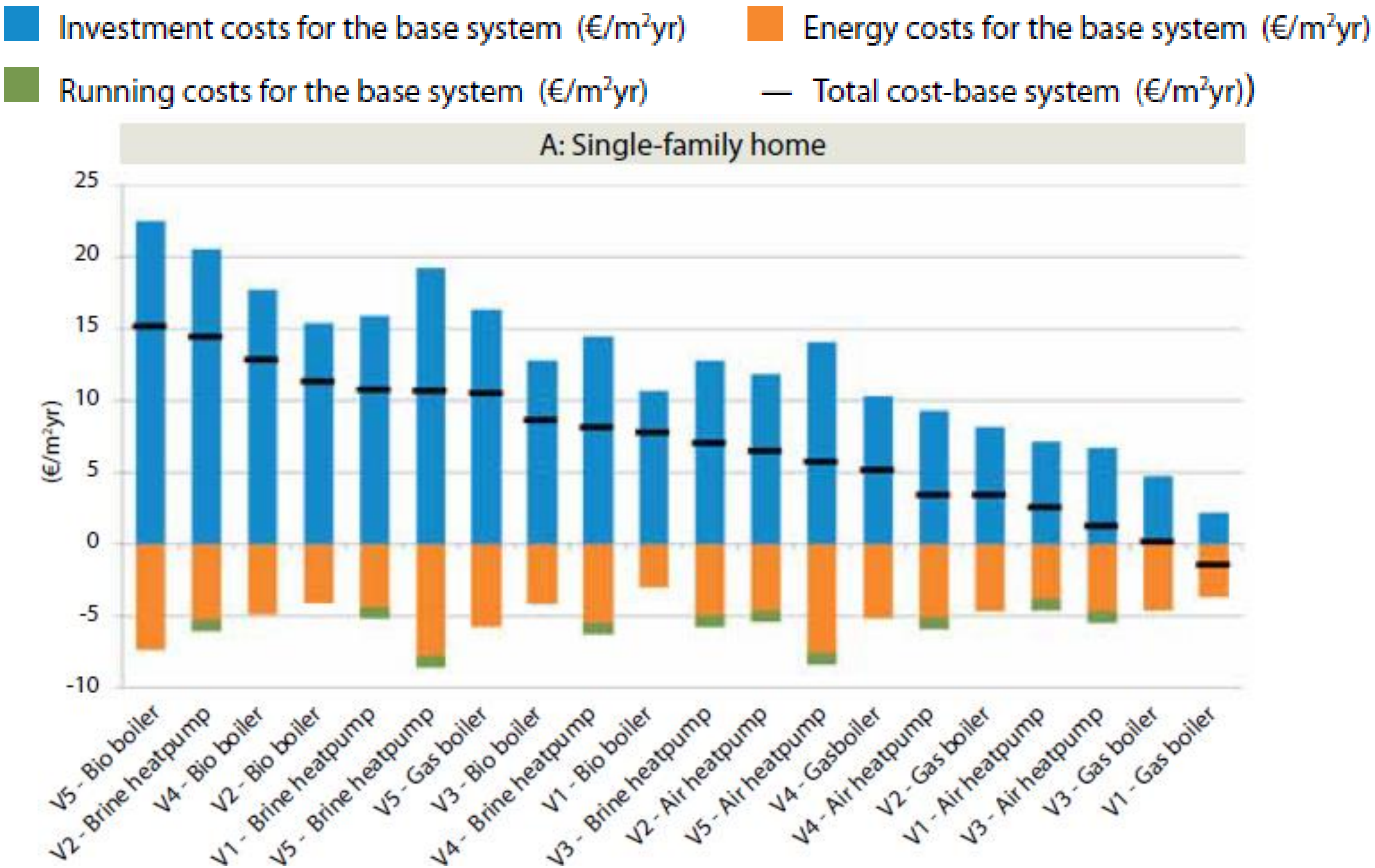
Assumed energy prices for private households (average 2011-2040)			
	Energy price average	Yearly price increase 2011 to 2020	Yearly price increase 2021 to 2040
Gas [€/kWh]	0.044	6.0 %	1.5 %
Conventional electricity [€/kWh]	0.154	5.5 %	1.5 %
Feed-in electricity [€/kWh]	0.154	5.5 %	1.5 %
District heat (50% RES) [€/kWh]	0.023	6.0 %	1.5 %
Wood pellets [€/kWh]	0.054	1.5 %	1.5 %
Assumed energy prices for offices/industry (average 2011-2040)			
	Energy price average	Yearly price increase 2011 to 2020	Yearly price increase 2021 to 2040
Gas [€/kWh]	0.046	6.0 %	1.5 %
Conventional electricity [€/kWh]	0.198	5.5 %	1.5 %
Feed-in electricity [€/kWh]	0.198	5.5 %	1.5 %
District heat (50% RES) [€/kWh]	0.023	6.0 %	1.5 %
Wood pellets [€/kWh]	0.054	1.5 %	1.5 %

Component	SFH	MFH	Office	Unit
Additional costs triple glazing	15	15	15	€/m² glazing
Additional costs PH windows	187	-	-	€/m² glazing
Additional costs automatic external shading	-	-	65	€/m² shading
Additional costs heat recovery	21	26	-	€/(m³/h)
Additional costs improved heat recovery	31.5	-	11	€/(m³/h)
Additional costs air tight construction	289	537	537	€
Additional costs automatic lighting control	-	-	7.5	€/m²
Additional costs floor heating	11	11	-	€/m²
Additional costs 1 cm roof insulation	0.51	0.51	0.51	€/m²
Additional costs 1 cm wall insulation	0.47	0.47	0.47	€/m²
Additional costs 1 cm floor insulation	1.13	1.13	1.13	€/m²
Additional costs high efficient cooling system	-	-	909	€/kW
Spec. costs PV system	2 400	1 700	1 700	€/kWp
Spec. costs solar hot water system	1 098	735	-	€/m² collector

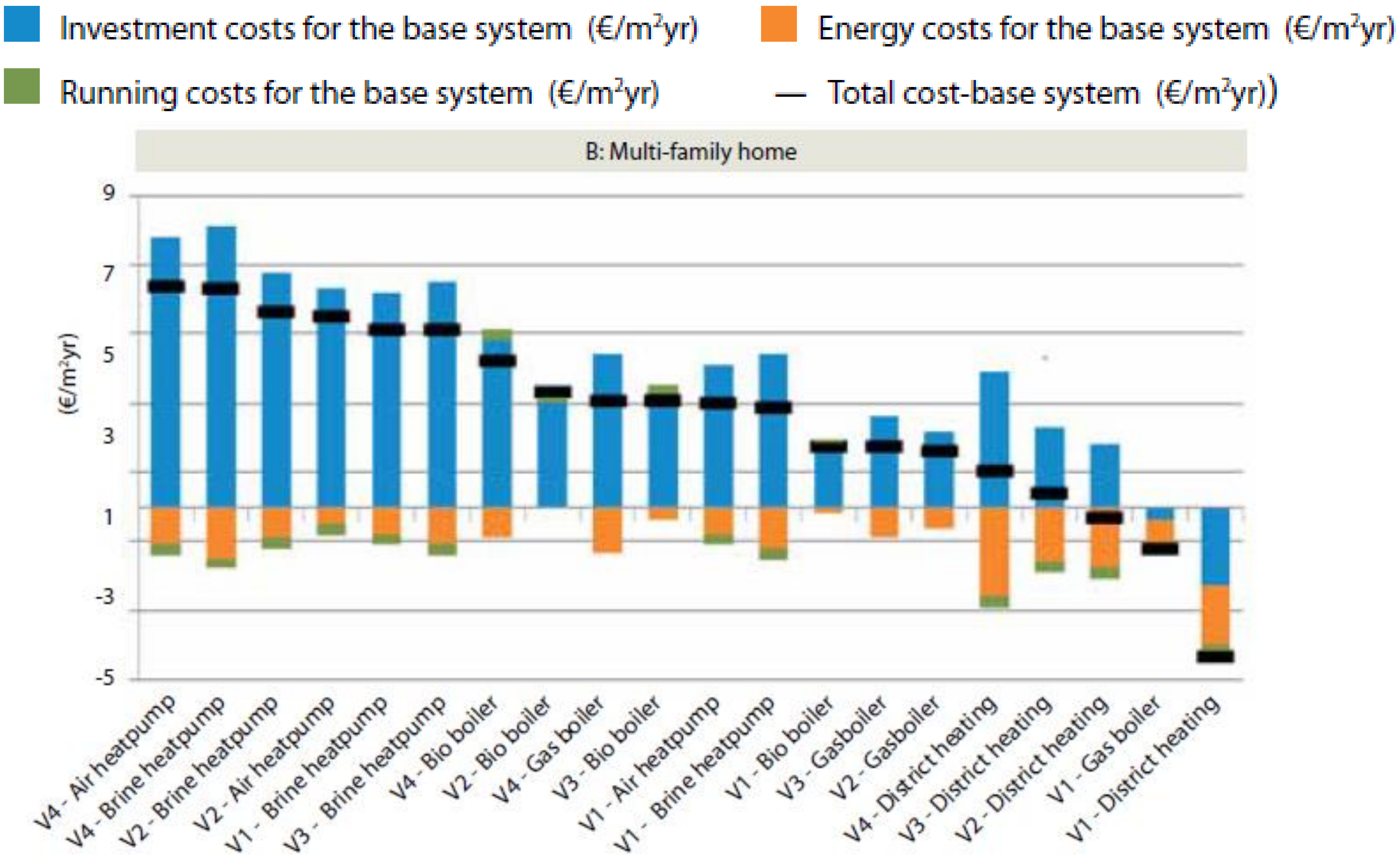
Technology	Subsidy
Heat pump system	€1 850
Solar thermal system	€1 390
Wood pellet boiler	€1 390

Heating system incl. exhaust system [prices €]	SFH (4...9 kW)	MFH (80...130 kW)	OFFICE (100...170 kW)
Gas boiler [€]	3 510	6 970 – 16 690	13 750 – 20 000
Air heat pump [€]	4 280 – 7 360	53 810 – 90 150	67 420 – 115 700
Brine heat pump [€]	8 090 – 13 920	61 940 – 103 770	77 610 – 133 180
Pellet boiler [€]	9 280	19 100 – 37 000	34 930 – 53 070

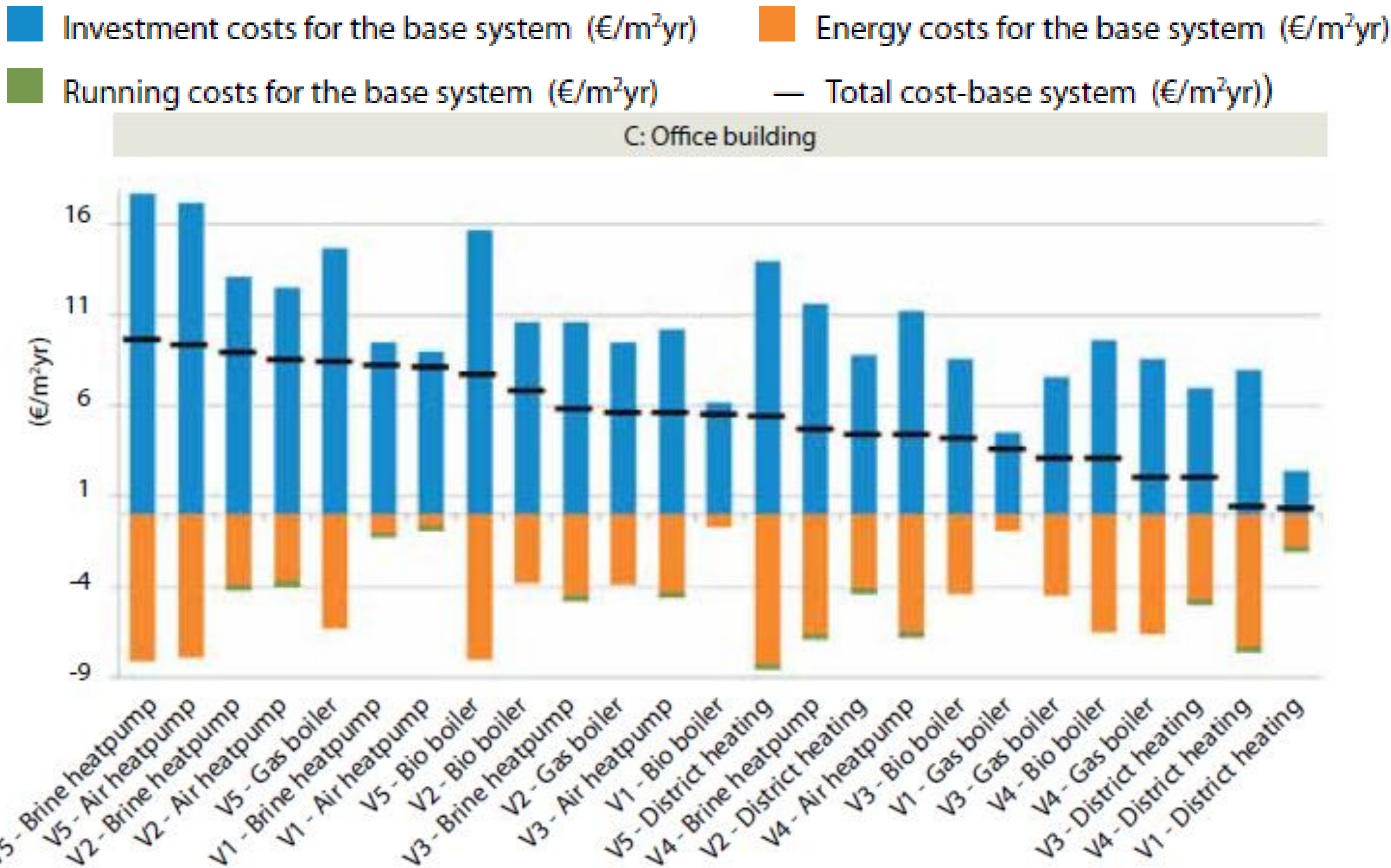
Annualised costs of nZEB solutions without CO_2 compensation



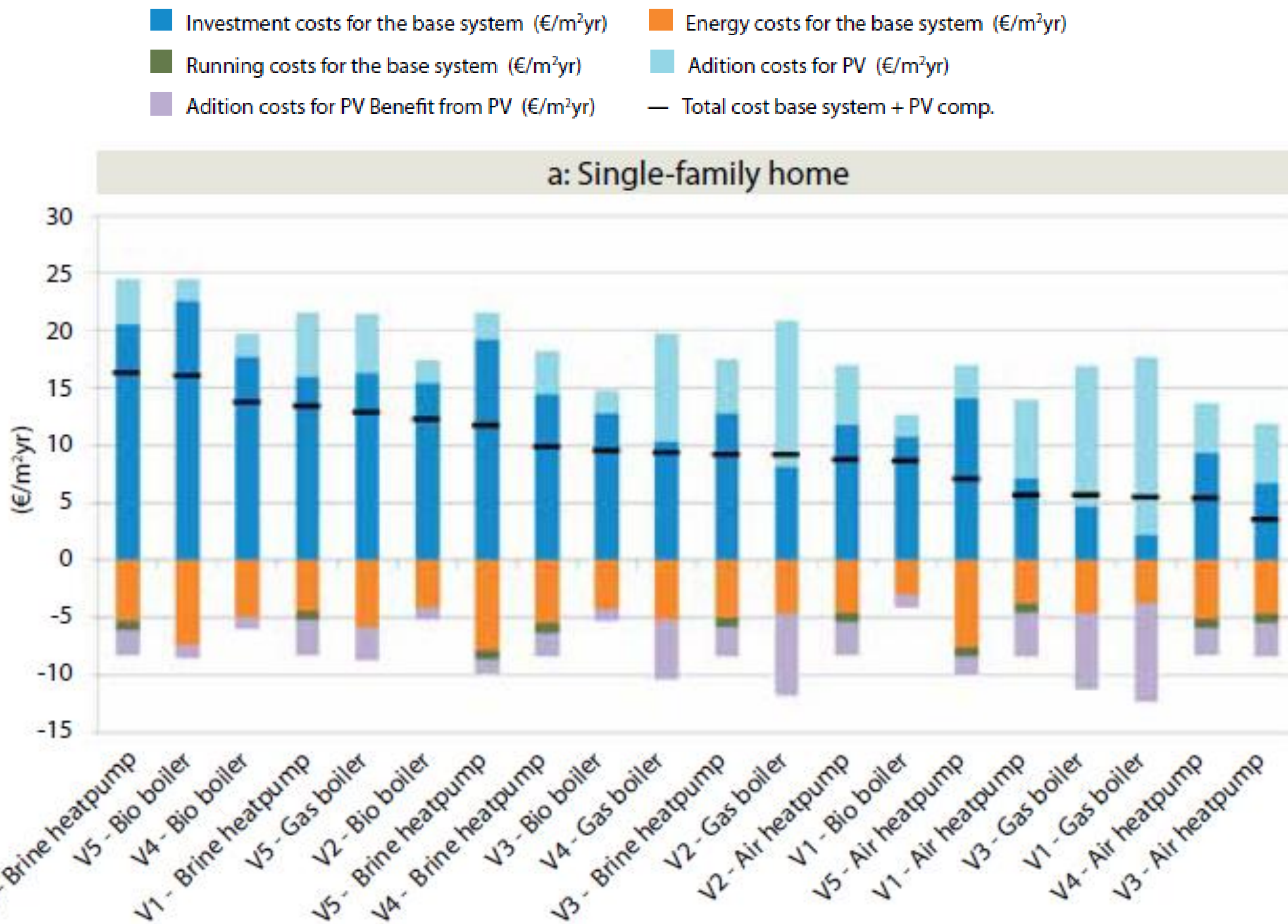
Annualised costs of nZEB solutions without CO_2 compensation



Annualised costs of nZEB solutions without CO_2 compensation

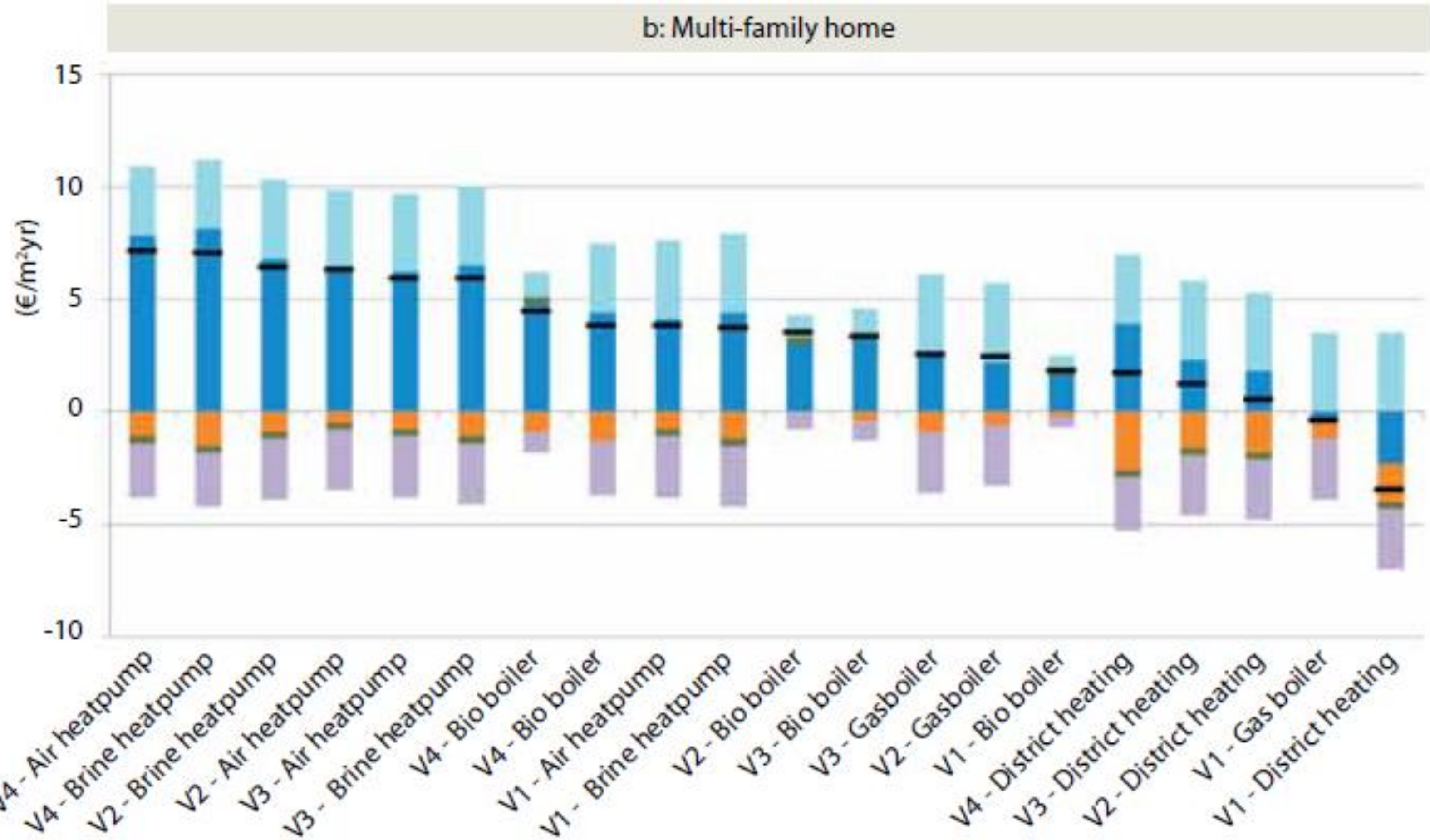


Annualised costs of nZEB solutions with CO_2 compensation

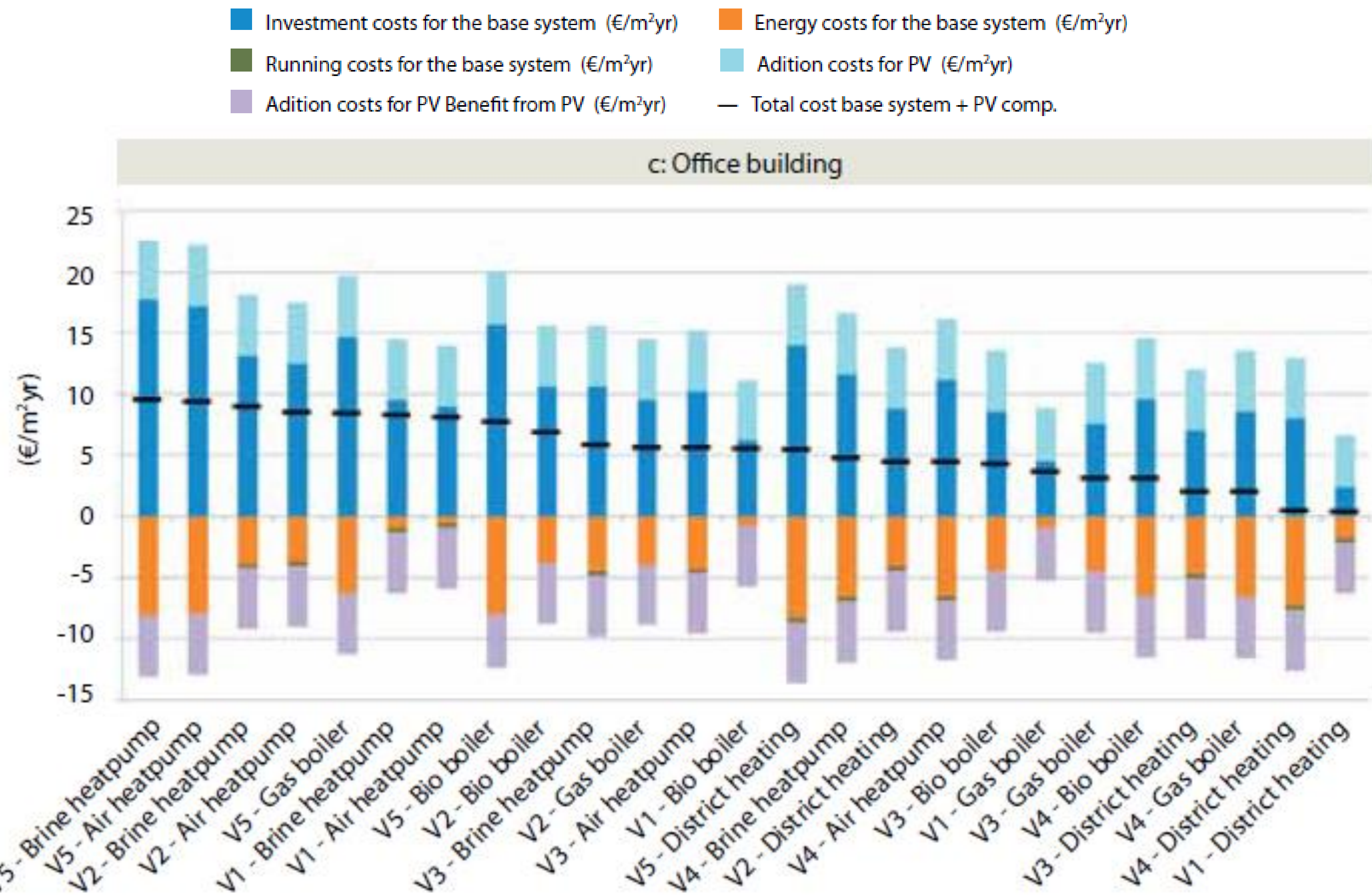


Annualised costs of nZEB solutions with CO_2 compensation

Investment costs for the base system (€/m²yr)
Energy costs for the base system (€/m²yr)
Running costs for the base system (€/m²yr)
Adition costs for PV (€/m²yr)
Adition costs for PV Benefit from PV (€/m²yr)
— Total cost base system + PV comp.



Annualised costs of nZEB solutions with CO_2 compensation



Overview of the results for the single-family building

Variants	Final specific demand [kWh/m²/yr]	Without CO_2 compensation: Primary energy demand [kWh/m²/yr]	Without CO_2 compensation: CO_2 emissions [$kgCO_2/m^2/yr$]	Without CO_2 compensation: Renewable share [%]	Without CO_2 compensation: Total additional annualised costs Euro/m²/yr]	With CO_2 compensation (by additional PV): Primary energy demand* [kWh/m²/yr]	With CO_2 compensation (by additional PV): CO_2 emissions [$kgCO_2/m^2/yr$]	With CO_2 compensation (by additional PV): Renewable share [%]	With CO_2 compensation (by additional PV): Total additional annualised costs [Euro/m²/yr]
V0 - Reference	161.6	180.8	32.8	0	0	n.a.	n.a.	n.a.	0
V1 - Air heatpump	24.6	49.3	6.2	40%	2.5	0	0	140%	5.7
V1 - Brine heatpump	20.3	40.7	5.1	40%	10.7	0	0	140%	13.2
V1 - Bio boiler	76	22.3	1	100%	7.7	7.9	0	110%	8.6
V1 - Gas boiler	76	87.2	15.6	0	-1.5	-24.2	1,5	80%	5.4
V2 - Air heatpump	18.9	37.8	4.8	40%	6.4	0	0	140%	8.7
V2 - Brine heatpump	14.3	28.7	3.6	40%	14.4	0	0	140%	16.2
V2 - Bio boiler	56.5	17.5	0.9	100%	11.3	3.1	0	110%	12.1
V2 - Gas boiler	56.5	65.3	11.6	0	3.4	-26.8	0	80%	9.2
V3 - Air heatpump	18.8	37.6	4.7	40%	1.2	0	0	140%	3.6
V3 - Brine heatpump	16.9	33.7	4.2	40%	7	0	0	140%	9.2
V3 - Bio boiler	53.4	19.4	1.2	90%	8.6	5	0	110%	9.5
V3 - Gas boiler	53.4	63.1	11	0	0.1	-24.4	0	90%	5.5
V4 - Air heatpump	15.6	31.2	3.9	40%	3.4	0	0	140%	5.3
V4 - Brine heatpump	13.6	27.1	3.4	40%	8.1	0	0	140%	9.9
V4 - Bio boiler	41.2	16.2	1.1	90%	12.8	1.8	0	110%	13.8
V4 - Gas boiler	41.2	49.3	8.5	0	5.1	-18.6	0	90%	9.3
V5 - Air heatpump	10.3	20.6	2.6	40%	5.7	0	0	140%	7
V5 - Brine heatpump	8.7	17.4	2.2	40%	10.6	0	0	140%	11.7
V5 - Bio boiler	21.7	14.1	1.4	80%	15.1	-0.3	0	120%	16
V5 - Gas boiler	21.7	28.8	4.7	10%	10.5	-8.2	0	90%	12.8
	<40	<40	<4	>50	<5	<40	<4	>50	<5
	40<x<60	40<x<70	4<x<7	30<x<50	5<x<10	40<x<70	4<x<7	30<x<50	5<x<10
	>60	>70	>7	<30	>10	>70	>7	<30	>10

Overview of the results for the multi-family building

Variants	Final specific demand [kWh/m²/yr]	Without CO_2 compensation: Primary energy demand [kWh/m²/yr]	CO_2 emissions [kgCO_2/m²/yr]	Renewable share [%]	Total additional annualised costs Euro/m²/yr]	With CO_2 compensation (by additional PV): Primary energy demand* [kWh/m²/yr]	CO_2 emissions [kgCO_2/m²/yr]	Renewable share [%]	Total additional annualised costs [Euro/m²/yr]
V0 - Reference	80.7	91	16.4	0	0	n.a.	n.a.	n.a.	0
V1 - Air heatpump	20.4	40.8	5.1	40%	3	5.7	0.7	120%	3.8
V1 - Brine heatpump	17.8	35.5	4.5	40%	2.9	0.4	0.1	130%	3.7
V1 - Bio boiler	62.3	18	0.8	100%	1.7	11.9	0	100%	1.8
V1 - Gas boiler	62.3	71.3	12.7	0	-1.2	36.2	8.3	30%	-0.5
V1 - District heating	59.3	55.7	8.7	50%	-4.3	20.5	4.3	80%	-3.5
V2 - Air heatpump	22	43.9	5.5	40%	5.5	8.8	1.1	110%	6.3
V2 - Brine heatpump	19.5	39.1	4.9	40%	5.6	3.9	0.5	120%	6.4
V2 - Bio boiler	62.2	21.9	1.3	90%	3.3	11.4	0	100%	3.5
V2 - Gas boiler	62.2	73.2	12.8	0	1.6	38.1	8.4	30%	2.4
V2 - District heating	59.3	58.1	8.9	50%	-0.3	23	4.5	80%	0.6
V3 - Air heatpump	20.5	41.1	5.2	40%	5.1	6	0.8	120%	5.9
V3 - Brine heatpump	18.5	37.1	4.7	40%	5.1	2	0.2	130%	6
V3 - Bio boiler	55.1	21.2	1.4	90%	3.1	9.9	0	100%	3.4
V3 - Gas boiler	55.1	65.7	11.4	0	1.7	30.6	7	40%	2.5
V3 - District heating	52.5	52.7	8	50%	0.4	17.5	3.6	80%	1.2
V4 - Air heatpump	18.4	36.8	4.6	40%	6.4	5.7	0.7	120%	7.1
V4 - Brine heatpump	15.8	31.6	4	40%	6.3	0.5	0.1	130%	7.1
V4 - Bio boiler	45.4	19.5	1.5	90%	4.2	7.9	0	100%	4.5
V4 - Gas boiler	45.4	55.2	9.5	0	3.1	24.1	5.5	40%	3.8
V4 - District heating	43.3	44.7	6.8	50%	1	13.6	2.8	80%	1.7

	<40	<40	<4	>50	<5	<40	<4	>50	<5
	40<x<60	40<x<70	4<x<7	30<x<50	5<x<10	40<x<70	4<x<7	30<x<50	5<x<10
	>60	>70	>7	<30	>10	>70	>7	<30	>10

Variants	Final specific demand [kWh/m²/yr]	Without CO_2 compensation: Primary energy demand [kWh/m²/yr]	Without CO_2 compensation: CO_2 emissions [$kgCO_2$/m²/yr]	Without CO_2 compensation: Renewable share [%]	Without CO_2 compensation: Total additional annualised costs Euro/m²/yr]	With CO_2 compensation (by additional PV): Primary energy demand* [kWh/m²/yr]	With CO_2 compensation (by additional PV): CO_2 emissions [$kgCO_2$/m²/yr]	With CO_2 compensation (by additional PV): Renewable share [%]	With CO_2 compensation (by additional PV): Total additional annualised costs [Euro/m²/yr]
V0 - Reference	109.6	165.1	24.6	20%	0	n.a.	n.a.	n.a.	0
V1 - Air heatpump	60	120.1	15.1	40%	8.1	69.8	8.8	80%	8.1
V1 - Brine heatpump	58.1	116.3	14.6	40%	8.2	66	8.3	80%	8.2
V1 - Bio boiler	75.7	111.3	13.4	50%	5.5	61	7.1	90%	5.5
V1 - Gas boiler	75.7	131.5	18	20%	3.6	86.6	12.3	50%	3.5
V1 - District heating	33.9	125.5	16.4	40%	0.3	83	11.1	70%	0.3
V2 - Air heatpump	44.4	89.2	11.2	40%	8.5	38.9	4.9	90%	8.6
V2 - Brine heatpump	43.4	87.2	11	40%	8.9	36.9	4.6	90%	8.9
V2 - Bio boiler	53	84	10.3	50%	6.8	33.7	3.9	100%	6.8
V2 - Gas boiler	53	95.1	12.8	30%	5.6	44.8	6.4	70%	5.6
V2 - District heating	27.6	91.8	11.9	40%	4.4	41.5	5.6	90%	4.4
V3 - Air heatpump	41.3	82.6	10.4	40%	5.6	32.3	4.1	100%	5.5
V3 - Brine heatpump	40.4	80.9	10.2	40%	5.8	30.6	3.9	100%	5.9
V3 - Bio boiler	49.1	77.9	9.5	50%	4.2	27.6	3.2	100%	4.2
V3 - Gas boiler	49.1	88.1	11.8	30%	3.1	37.8	5.5	80%	3.1
V3 - District heating	48.5	85.1	11	40%	2	34.8	4.7	80%	2
V4 - Air heatpump	30.4	61.1	7.7	40%	4.4	10.8	1.4	120%	4.4
V4 - Brine heatpump	29.6	59.4	7.5	40%	4.7	9.1	1.2	120%	4.7
V4 - Bio boiler	38.3	56.4	6.8	50%	3.1	6.1	0.5	120%	3.1
V4 - Gas boiler	38.3	66.7	9.1	20%	2	16.4	2.8	90%	2
V4 - District heating	24	63.7	8.3	40%	0.4	13.4	2	110%	0.3
V5 - Air heatpump	25.9	51.9	6.5	40%	9.3	1.6	0.2	130%	9.3
V5 - Brine heatpump	25.1	50.3	6.3	40%	9.6	0	0	140%	9.6
V5 - Bio boiler	33.8	47.2	5.7	60%	7.7	2.3	0	120%	7.7
V5 - Gas boiler	33.8	57.5	8	20%	8.4	7.2	1.6	100%	8.3
V5 - District heating	33.2	54.5	7.2	40%	5.4	4.2	0.8	120%	5.5
	<40	<40	<4	>50	<5	<40	<4	>50	<5
	40<x<60	40<x<70	4<x<7	30<x<50	5<x<10	40<x<70	4<x<7	30<x<50	5<x<10
	>60	>70	>7	<30	>10	>70	>7	<30	>10

Overview of the results for the office building

Proposed nZEB definitions for Romania

Building type	Minimum requirements	Year		
		2016	2019	2020
Single-family buildings	Primary energy [$kWh/m^2/yr$]	100		30-50
	Renewable share [%]	>20		>40
	CO_2 emissions [$kgCO_2/m^2/yr$]	<10		<3-7
Multi-family buildings	Primary energy [$kWh/m^2/yr$]	70		30-50
	Renewable share [%]	>20		>40
	CO_2 emissions [$kgCO_2/m^2/yr$]	<10		<3-7
Office buildings	Primary energy [$kWh/m^2/yr$]	100		40-60
	Renewable share [%]	>20		>40
	CO_2 emissions [$kgCO_2/m^2/yr$]	<13		<5-8
Public office buildings	Primary energy [$kWh/m^2/yr$]	100	40-60	
	Renewable share [%]	>20	>50	
	CO_2 emissions [$kgCO_2/m^2/yr$]	<13	<5	

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Thank you!