Zero Energy Buildings, a Paradigm Shift.

Universidade de Coimbra

Energy for Sustainability Initiative (EfS)
Fall Doctoral Workshop

NAVITAS

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Paradigm Shift:

- Paradigm (from the greek parádeigma) a model, the representation of a pattern, something to serve as a general example or modell;
- In The Structure of Scientific Revolutions, Thomas Kuhn wrote that *"the successive transition from one paradigm to another via* ***revolution*** *is the usual developmental pattern of mature science“*;
- *“New paradigms then* ***ask new questions*** *of old data, move beyond the mere "puzzle-solving" of the previous paradigm,* ***change the rules*** *of the game and the "map"* ***directing new research****”*.

Energy Performance of Buildings Directive (EPBD) recast

2010/31/UE

18.6.2010 EN Official Journal of the European Union L 153/13

DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 19 May 2010

on the energy performance of buildings

(recast)

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Having regard to the Treaty on the Functioning of the European Union, and in particular Article 194(2) thereof,

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Whereas:

(1) Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings [4] has been amended [5]. Since further substantive amendments are to be made, it should be recast in the interests of clarity.

(2) An efficient, prudent, rational and sustainable utilisation of energy applies, inter alia, to oil products, natural gas and solid fuels, which are essential sources of energy, but also the leading sources of carbon dioxide emissions.

(3) Buildings account for 40 % of total energy consumption in the Union. The sector is expanding, which is bound to increase its energy consumption. Therefore, reduction of energy consumption and the use of energy from renewable sources in the buildings sector constitute important measures needed to reduce the Union's energy dependency and greenhouse gas emissions. Together with an increased use of energy from renewable sources, measures taken to reduce energy consumption in the Union would allow the Union to comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), and to honour both its long term commitment to maintain the global temperature rise below 2 °C, and its commitment to reduce, by 2020, overall greenhouse gas emissions by at least 20 % below 1990 levels, and by 30 % in the event of an international agreement being reached. Reduced energy consumption and an increased use of energy from renewable sources also have an important part to play in promoting security of energy supply, technological developments and in creating opportunities for employment and regional development, in particular in rural areas.

(4) Management of energy demand is an important tool enabling the Union to influence the global energy market and hence the security of energy supply in the medium and long term.

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(4) OJ L 1, 4.1.2003, p. 65.
(5) See Annex IV, Part A.
(6) OJ L 140, 5.6.2009, p. 136.
(7) OJ L 140, 5.6.2009, p. 16.

Planning for Federal Sustainability in the Next Decade

Executive Order 13693, 19 March 2015

15871

Federal Register
Vol. 80, No. 57
Wednesday, March 25, 2015

Presidential Documents

Title 3— **Executive Order 13693 of March 19, 2015**

The President **Planning for Federal Sustainability in the Next Decade**

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in order to maintain Federal leadership in sustainability and greenhouse gas emission reductions, it is hereby ordered as follows:

Section 1. *Policy.* Executive departments and agencies (agencies) have been among our Nation's leaders as the United States works to build a clean energy economy that will sustain our prosperity and the health of our people and our environment for generations to come. Federal leadership in energy, environmental water, fleet, buildings, and acquisition management will continue to drive national greenhouse gas reductions and support preparations for the impacts of climate change. Through a combination of more efficient Federal operations such as those outlined in this Executive Order (order), we have the opportunity to reduce agency direct greenhouse gas emissions by at least 40 percent over the next decade while at the same time fostering innovation, reducing spending, and strengthening the communities in which our Federal facilities operate.

It therefore continues to be the policy of the United States that agencies shall increase efficiency and improve their environmental performance. Improved environmental performance will help us protect our planet for future generations and save taxpayer dollars through avoided energy costs and increased efficiency, while also making Federal facilities more resilient. To improve environmental performance and Federal sustainability, priority should first be placed on reducing energy use and cost, then on finding renewable or alternative energy solutions. Pursuing clean sources of energy will improve energy and water security, while ensuring that Federal facilities will continue to meet mission requirements and lead by example. Employing this strategy for the next decade calls for expanded and updated Federal environmental performance goals with a clear overarching objective of reducing greenhouse gas emissions across Federal operations and the Federal supply chain.

Sec. 2. *Agency Greenhouse Gas Emission Reductions.* In implementing the policy set forth in section 1 of this order, the head of each agency shall, within 90 days of the date of this order, propose to the Chair of the Council on Environmental Quality (CEQ) and the Director of the Office of Management and Budget (OMB) percentage reduction targets for agency-wide reductions of scope 1 and 2 and scope 3 greenhouse gas emissions in absolute terms by the end of fiscal year 2025 relative to a fiscal year 2008 baseline. Where appropriate, the target shall exclude direct emissions from excluded vehicles and equipment and from electric power produced and sold commercially to other parties as the primary business of the agency. The proposed targets shall be subject to the review and approval of the Chair of CEQ in coordination with the Director of OMB under section 4(b) of this order.

Sec. 3. *Sustainability Goals for Agencies.* In implementing the policy set forth in section 1 of this order and to achieve the goals of section 2 of this order, the head of each agency shall, where life-cycle cost-effective, beginning in fiscal year 2016, unless otherwise specified:

(a) promote building energy conservation, efficiency, and management by:

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(a) promote building energy conservation, efficiency, and management by:

(o) "net-zero energy building" means a building that is designed, constructed, or renovated and operated such that the actual annual source energy consumption is balanced by on-site renewable energy;

(i) ensuring, beginning in fiscal year 2020 and thereafter, that all new construction of Federal buildings greater than 5,000 gross square feet that enters the planning process is designed to achieve energy net-zero and, where feasible, water or waste net-zero by fiscal year 2030;

(iii) identifying, as part of the planning requirements of section 14 of this order, a percentage of the agency's existing buildings above 5,000 gross square feet intended to be energy, waste, or water net-zero buildings by fiscal year 2025 and implementing actions that will allow those buildings to meet that target;

(i) reducing agency building energy intensity measured in British thermal units per gross square foot by 2.5 percent annually through the end of fiscal year 2025, relative to the baseline of the agency's building energy use in fiscal year 2015 and taking into account agency progress to date,

US Department Of Energy Common Definition for Zero Energy Buildings, September 2015

Zero Energy Building (ZEB)

An energy-efficient **building** where, on a **source energy** basis, the actual **annual delivered energy** is less than or equal to the on-site renewable **exported energy**.

On-site Renewable Energy: Includes any renewable energy collected and generated within the site boundary that is used for building energy and the excess renewable energy could be exported outside the site boundary. The renewable energy certificates (RECs) associated with the renewable energy must be retained or retired by the building owner/lessee to be claimed as renewable energy.[1]

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2. 'nearly zero-energy building' means a building that has a very high energy performance, as determined in accordance with Annex I. 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 9

Nearly zero-energy buildings

1. Member States shall ensure that:

(a) by 31 December 2020, all new buildings are nearly zero-energy buildings; and

(b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

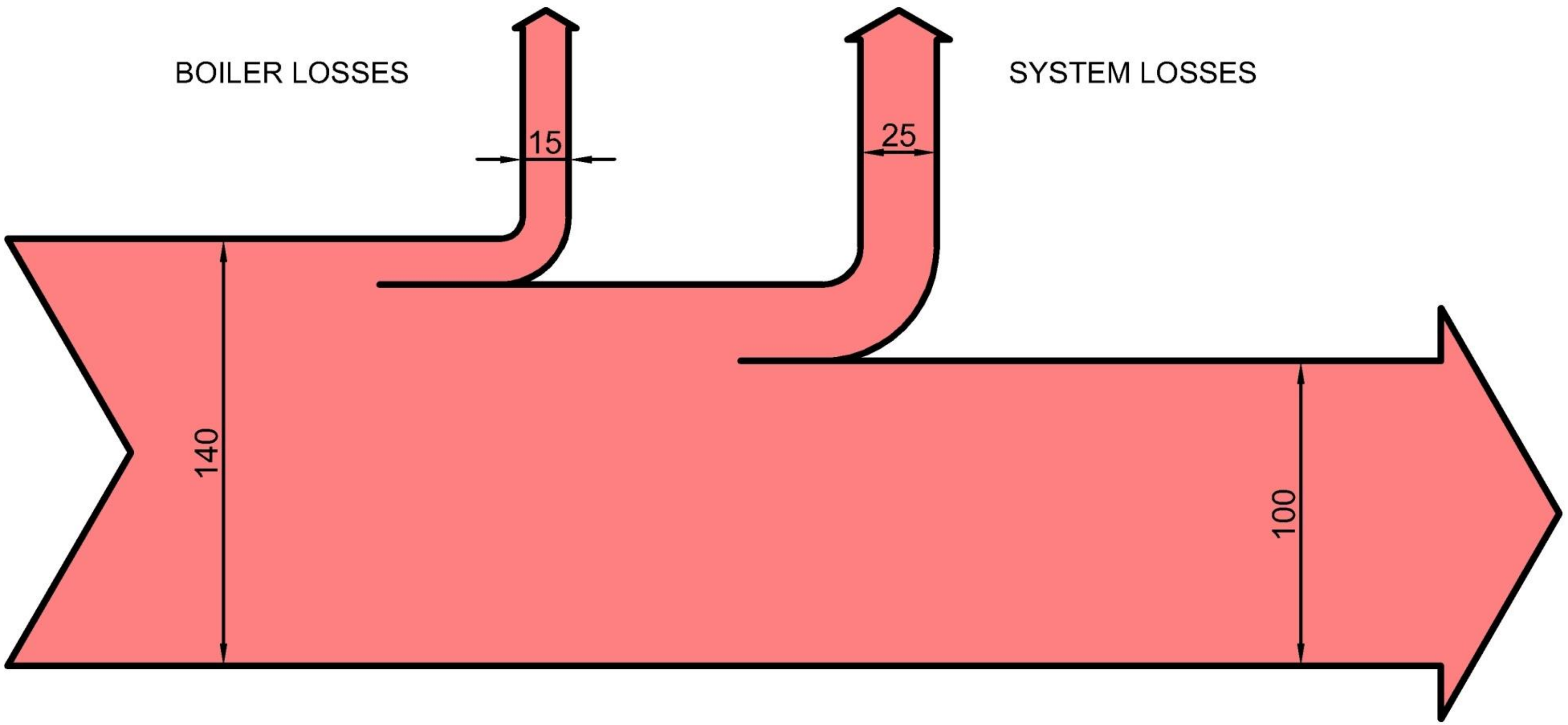
Countries shall define the meaning of:

- "Nearly zero";
- "Significant extent" of used energy that is covered by renewables;
- "on-site" renewable production;
- "nearby" renewable production.

(EN 15603, to be published)

Domestic Hot Water (DHW) Example.

Existing DHW system serving showers in a gymnasium, using a gas boiler to produce DHW



PRIMARY ENERGY (PE)

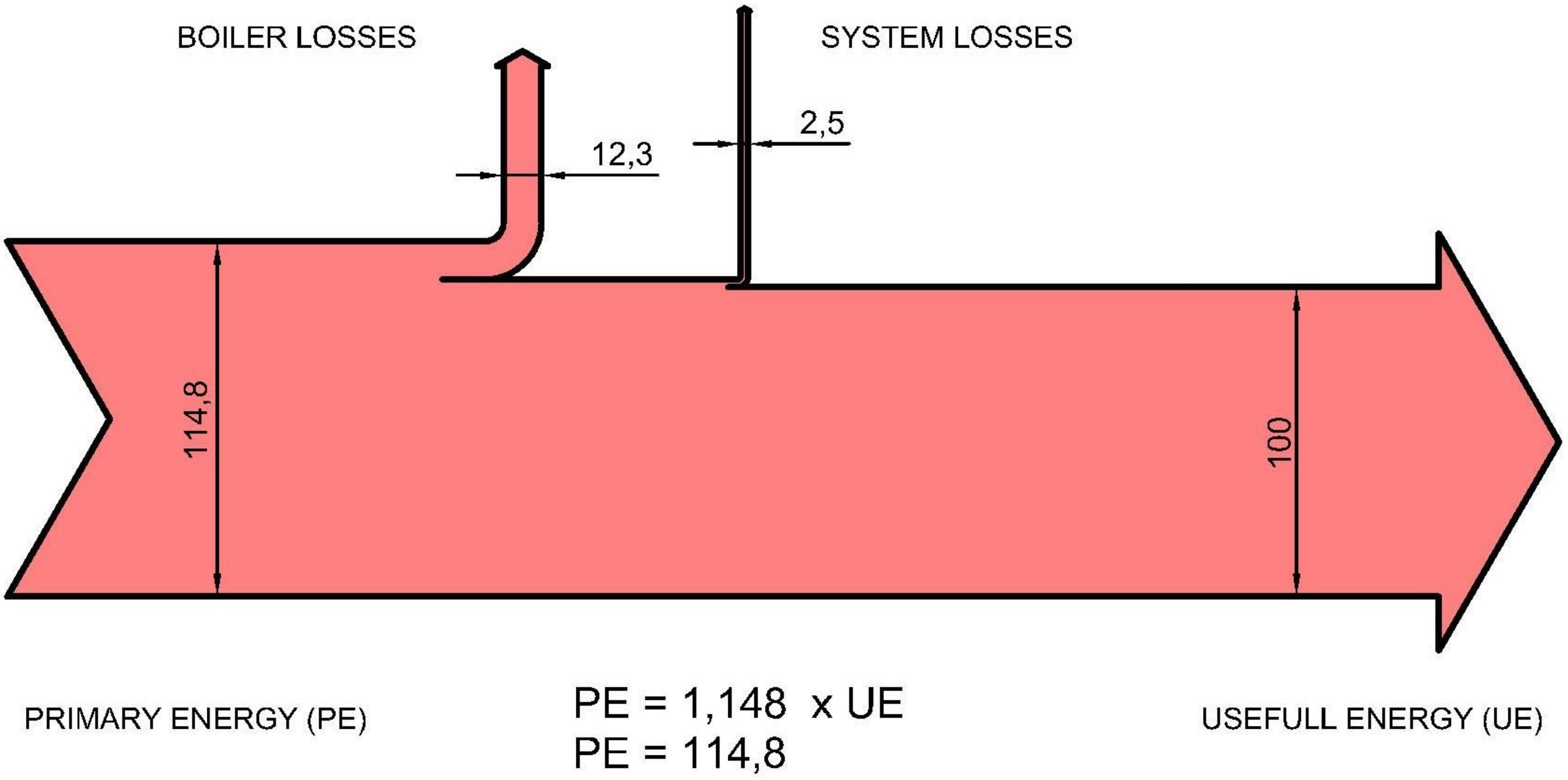
PE = 1,4 x UE
PE = 140

USEFULL ENERGY (UE)

Domestic Hot Water (DHW) Example.

Step1 - Minimize system losses:

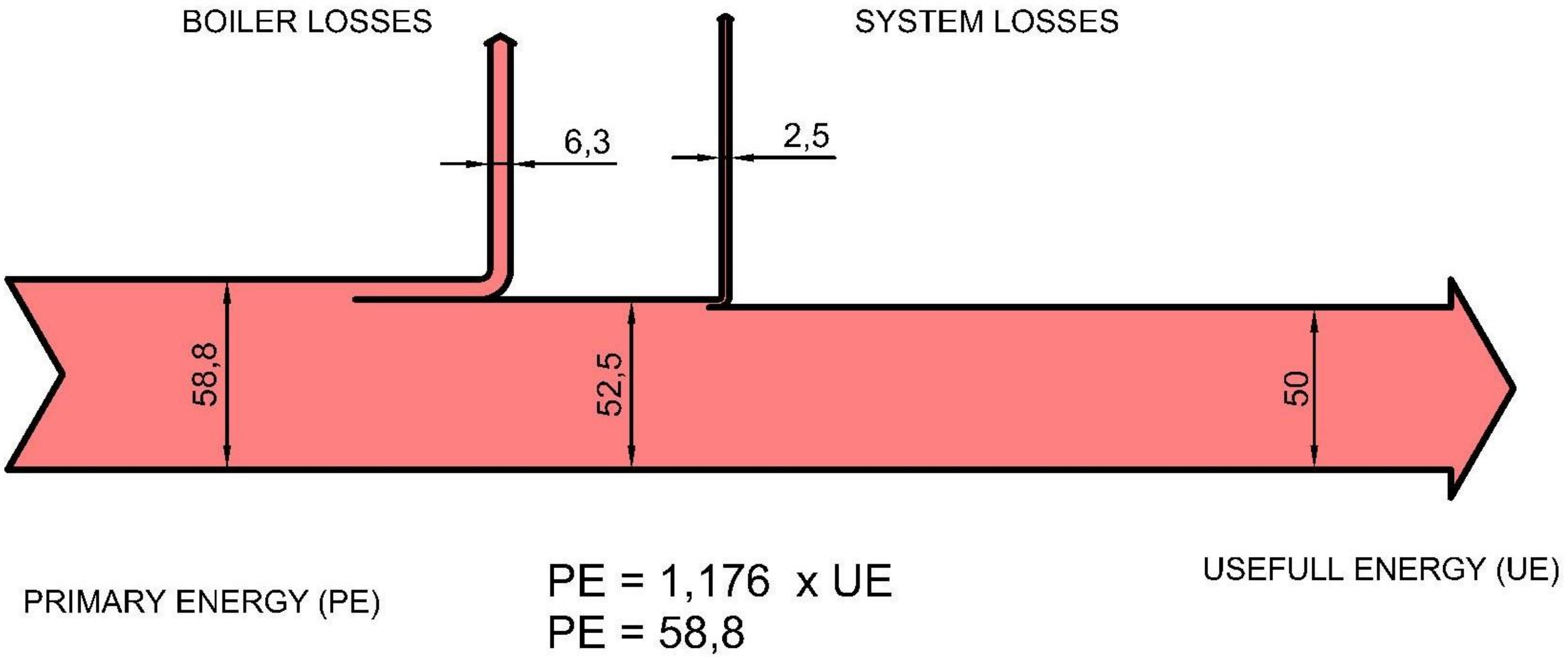
- Benefit system piping and components insulation;
- Balance and minimize return water flow;
- Implement a non-thermal strategy to fight Legionella.



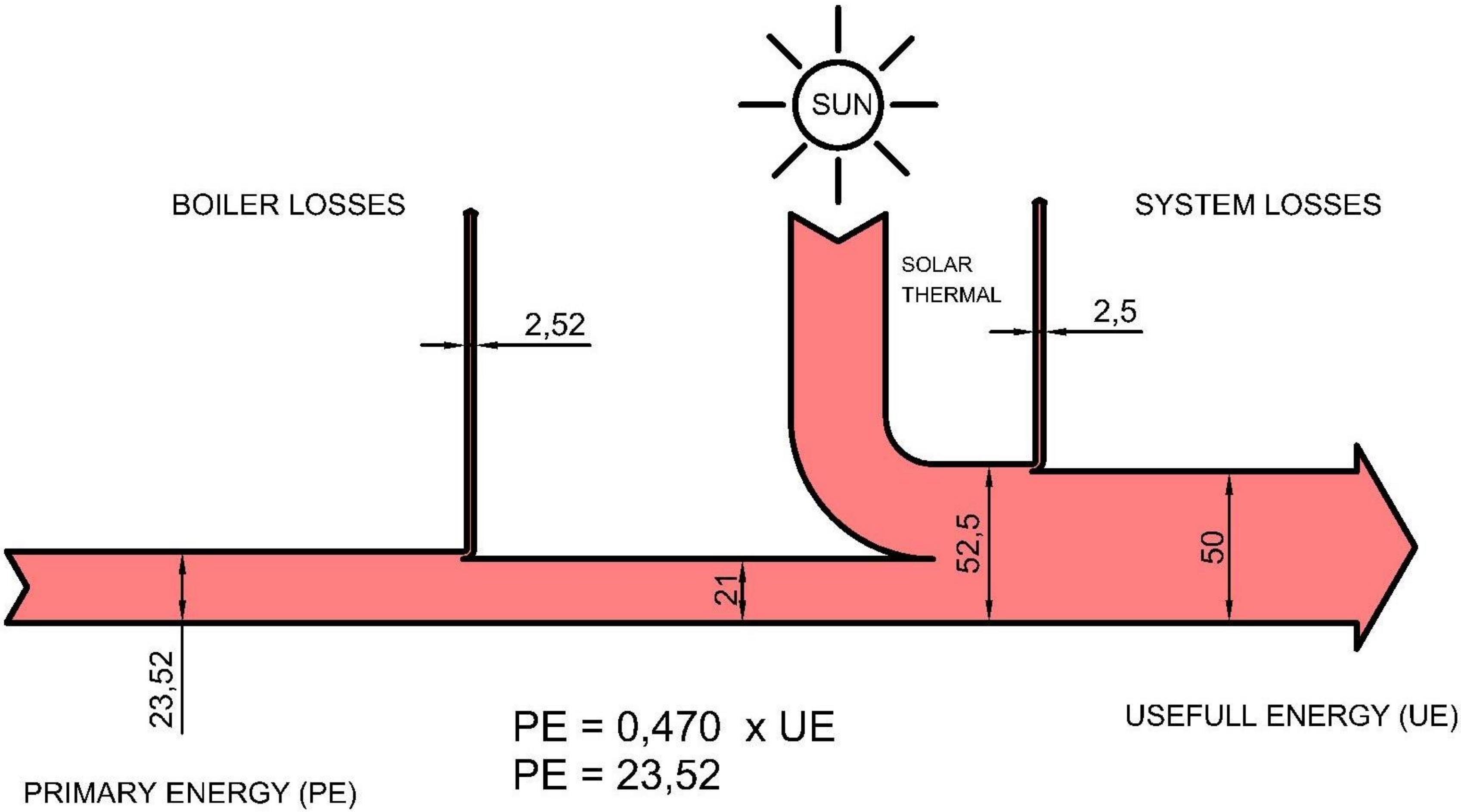
Domestic Hot Water (DHW) Example.

Step2 - Minimize final user requirements:

- Change existing shower heads, of 12 liter/m, by high efficiency shower heads using only 6 liter/m.

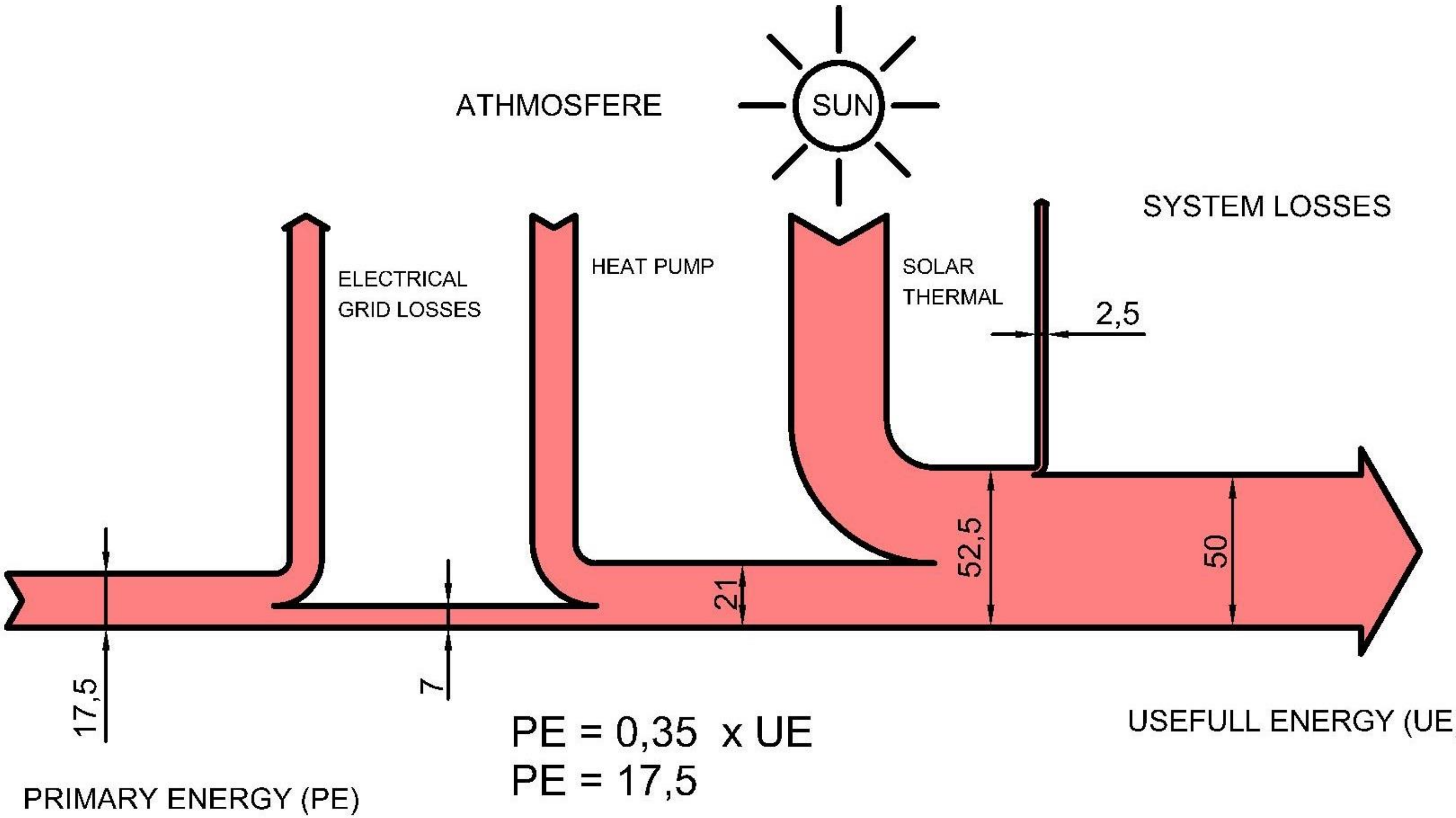


Domestic Hot Water (DHW) Example.
Step3 – Solar thermal.



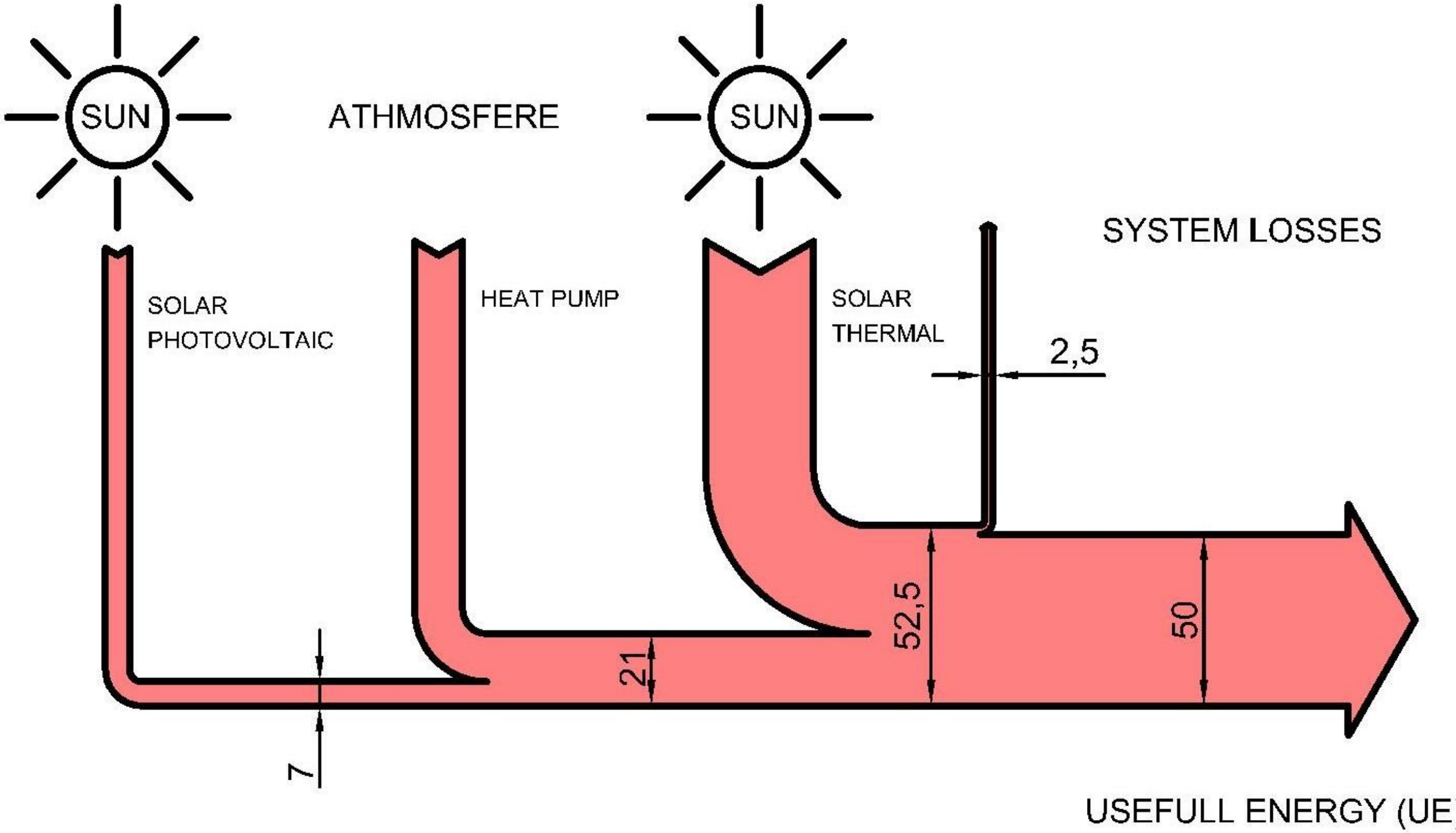
Domestic Hot Water (DHW) Example.

Step4 – Heat pump.



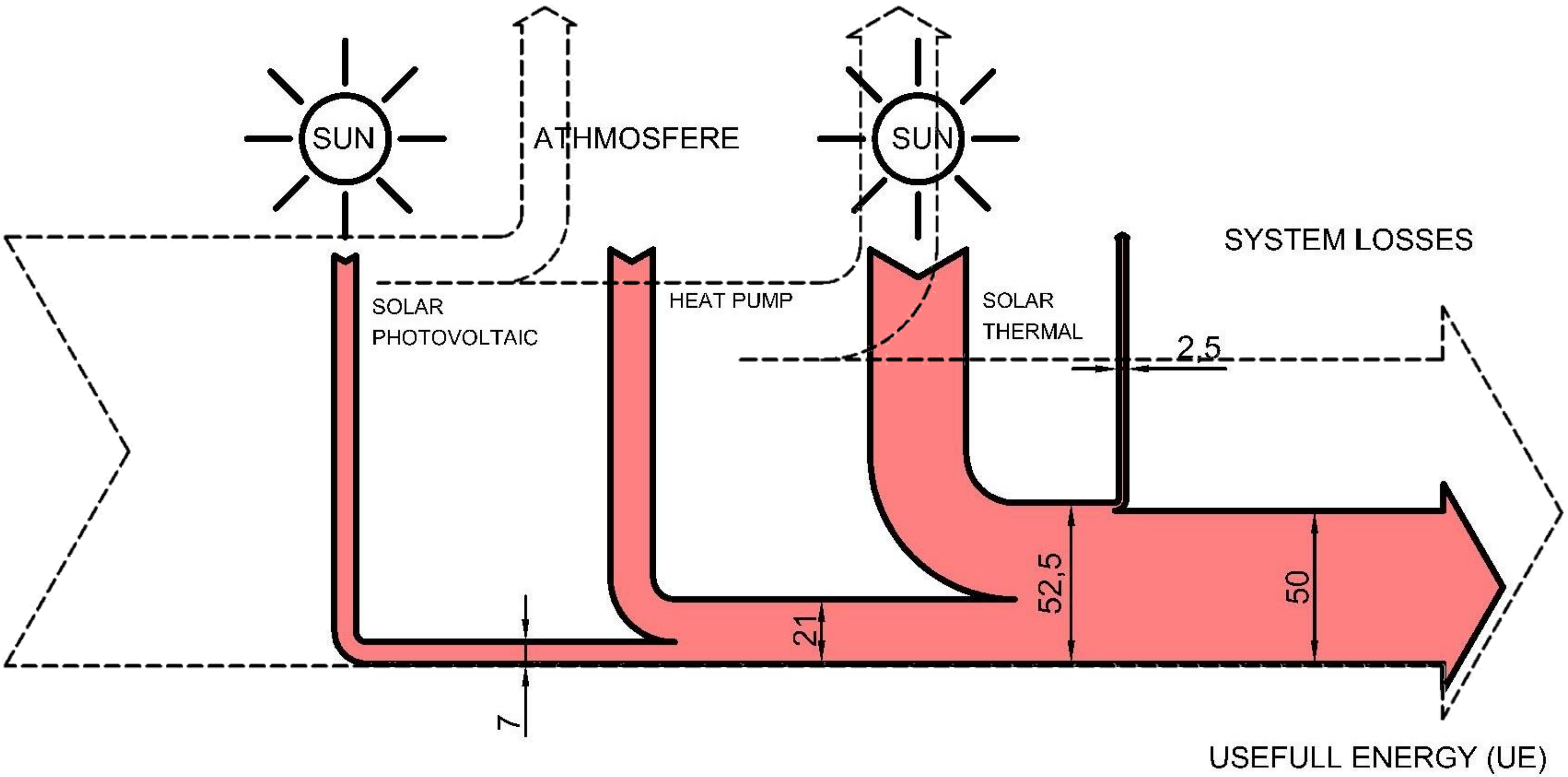
Domestic Hot Water (DHW) Example.

Step5 – Solar PhotoVoltaic.



PE = 0

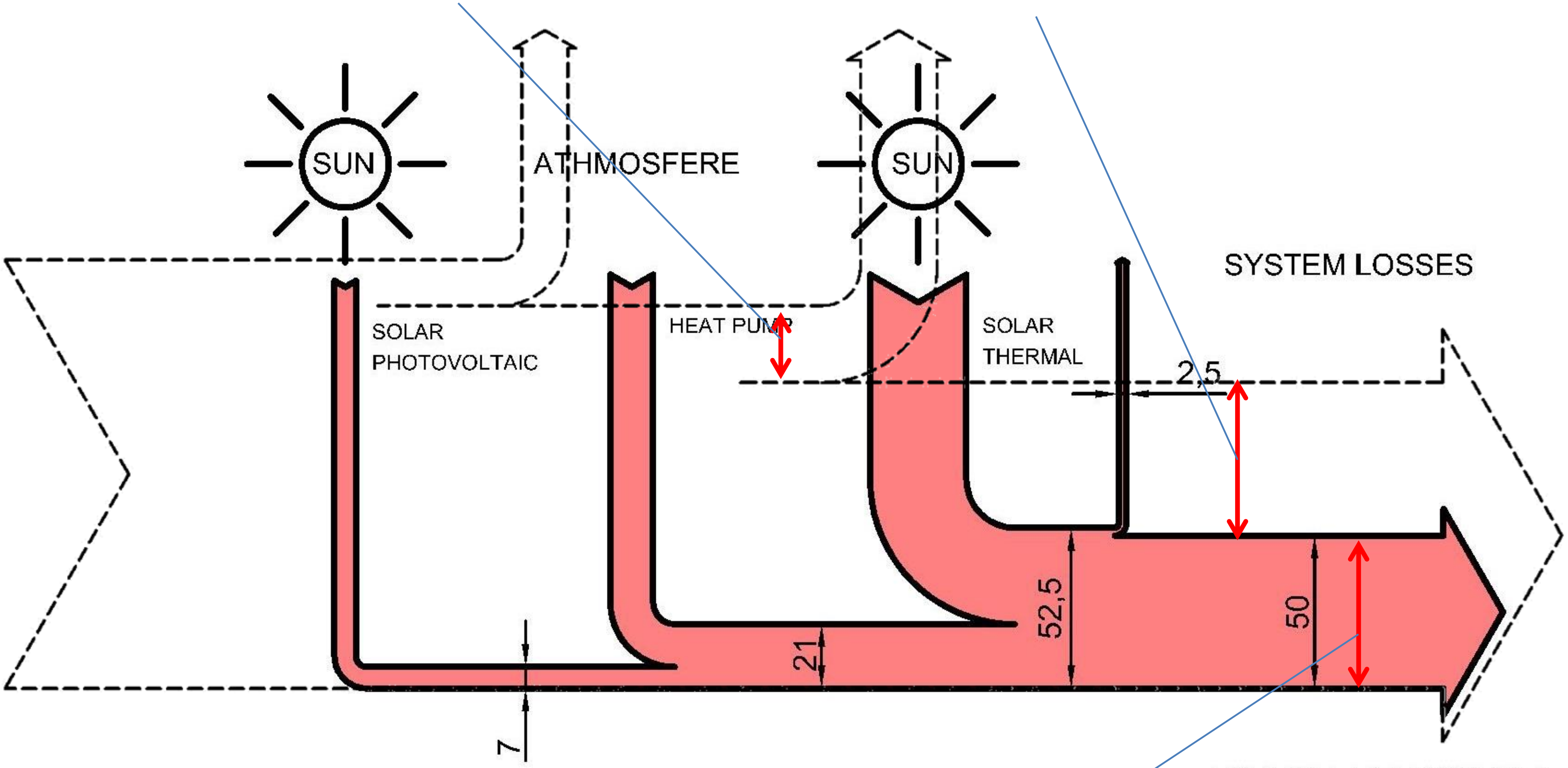
Domestic Hot Water (DHW) Example.



PE = 0

Domestic Hot Water (DHW) Example.

Eficiência energética **Alteração de requisitos**



Renováveis

PE = 0

ROADMAP

1.º Changing/Reducing traditional requirements

↓

2.º Energy Efficiency

↓

3.º Renewables

↓

4.º Energy monitoring

1.º Changing/Reducing traditional requirements

i. Thermal comfort;

ii. Indoor Air Quality;

iii. Lighting;

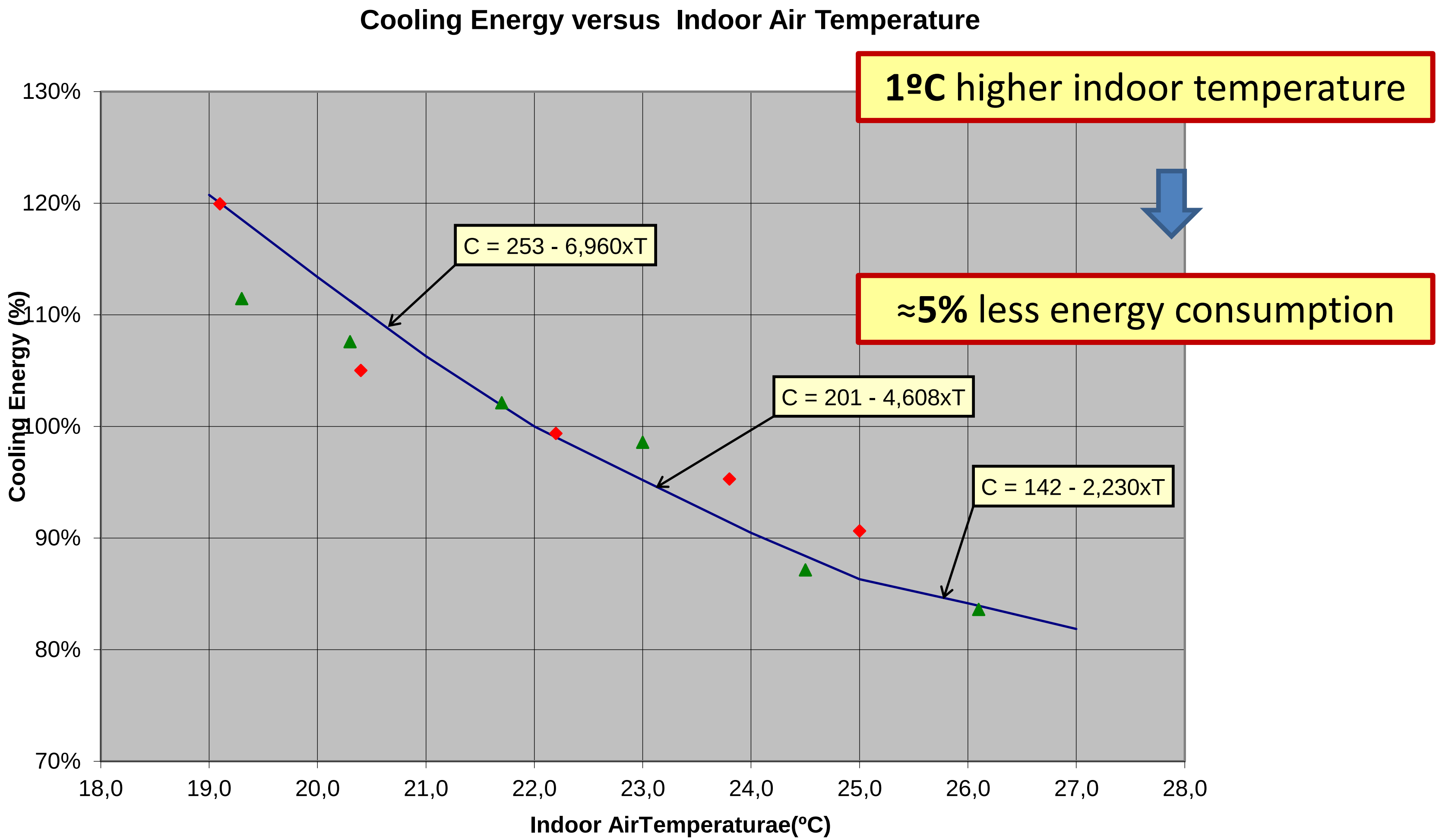
iv. Office equipment loads;

v. Energy Flexibility.

1.º Changing/Reducing traditional requirements

i. Thermal comfort;

Results from measurements in two actual buildings.



1.º Changing/Reducing traditional requirements

i. Thermal comfort;

Adaptative Comfort criteria must be adopted whenever possible !

ISO 7730:2005(E)

10 Adaptation

In determining the acceptable range of operative temperature according to this International Standard, a clothing insulation value that corresponds to the local clothing habits and climate shall be used.

In warm or cold environments, there can often be an influence due to adaptation. Apart from clothing, other forms of adaptation, such as body posture and decreased activity, which are difficult to quantify, can result in the acceptance of higher indoor temperatures. People used to working and living in warm climates can more easily accept and maintain a higher work performance in hot environments than those living in colder climates (see ISO 7933 and ISO 7243).

Extended acceptable environments may be applied for occupant-controlled, naturally conditioned, spaces in warm climate regions or during warm periods, where the thermal conditions of the space are regulated primarily by the occupants through the opening and closing of windows. Field experiments have shown that occupants of such buildings could accept higher temperatures than those predicted by the PMV. In such cases, the thermal conditions may be designed for higher PMV values than those given in Clause 6 and Annex A.

1.º Changing/Reducing traditional requirements

i. Thermal comfort;

Adaptative Comfort criteria must be adopted whenever possible !

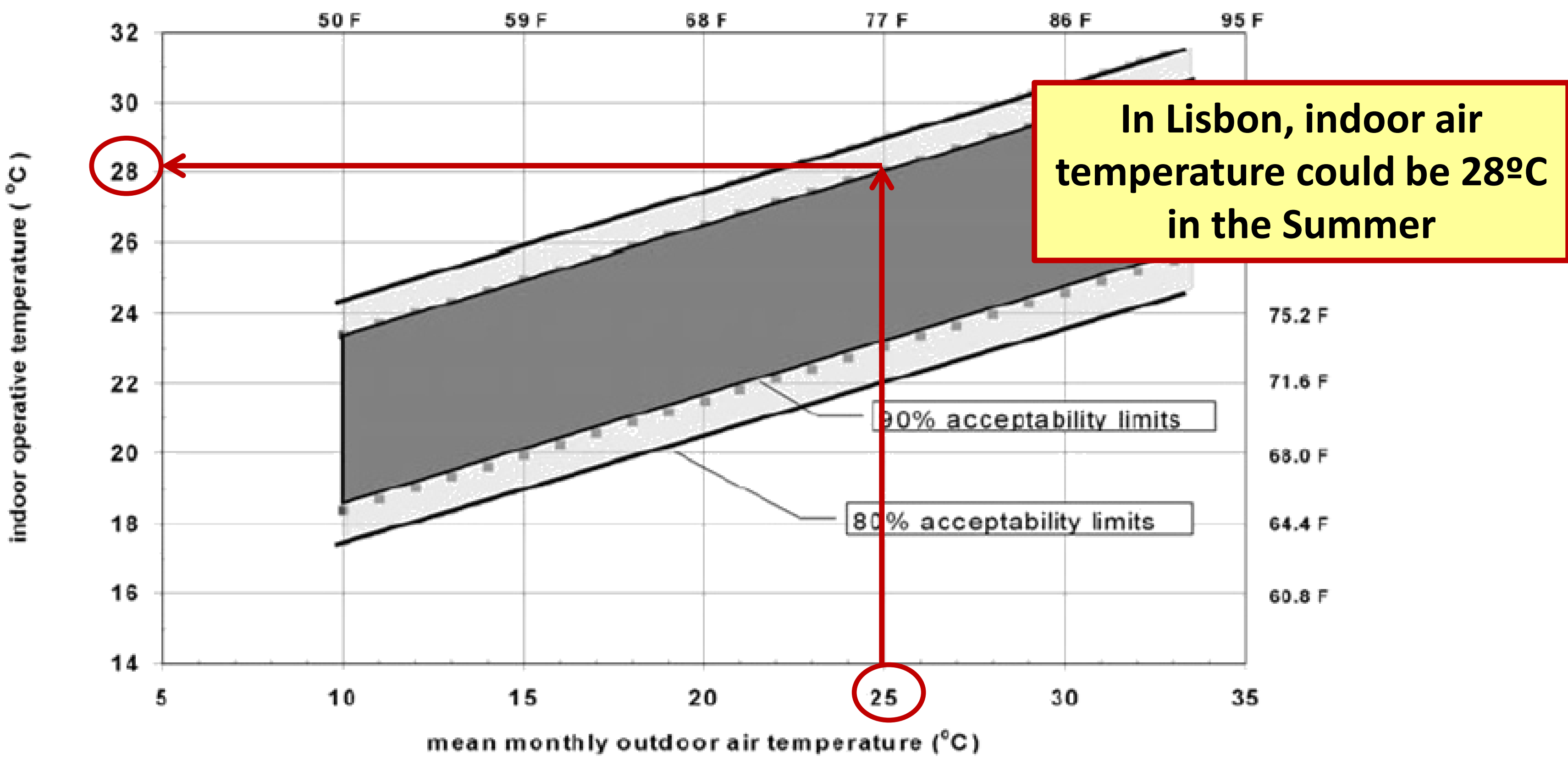


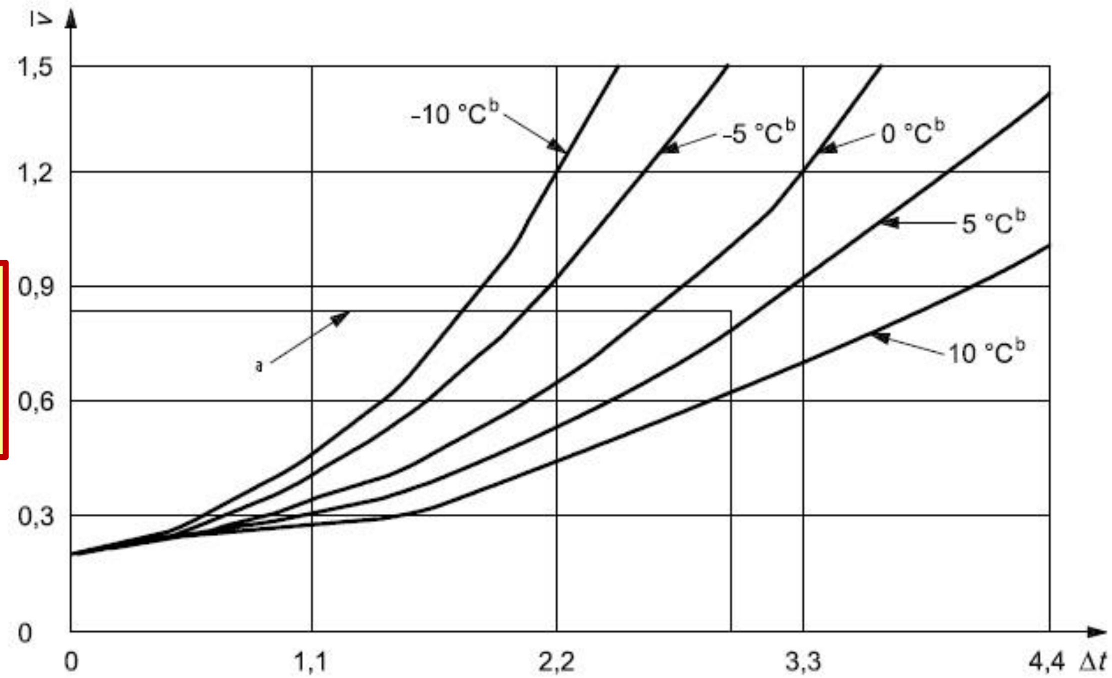
Figure 5.3 **Acceptable operative temperature ranges for naturally conditioned spaces.**

1.º Changing/Reducing traditional requirements

i. Thermal comfort;

ISO 7730 – Annex G – Air Velocity

Higher indoor air temperatures can be compensated with higher indoor air velocities



For light primarily sedentary activity, Δt should be < 3 °C and $\bar{v}$ < 0,82 m/s.

Key

Δt temperature rise above 26 °C

$\bar{v}$ mean air velocity, m/s

a Limits for light, primarily sedentary, activity.

b $(\bar{t}_r - t_a)$, °C (t_a, air temperature, °C; $\bar{t}_r$, mean radiant temperature, °C).

Figure G.1 — Air velocity required to offset increased temperature

1.º Changing/Reducing traditional requirements

i. Thermal comfort;

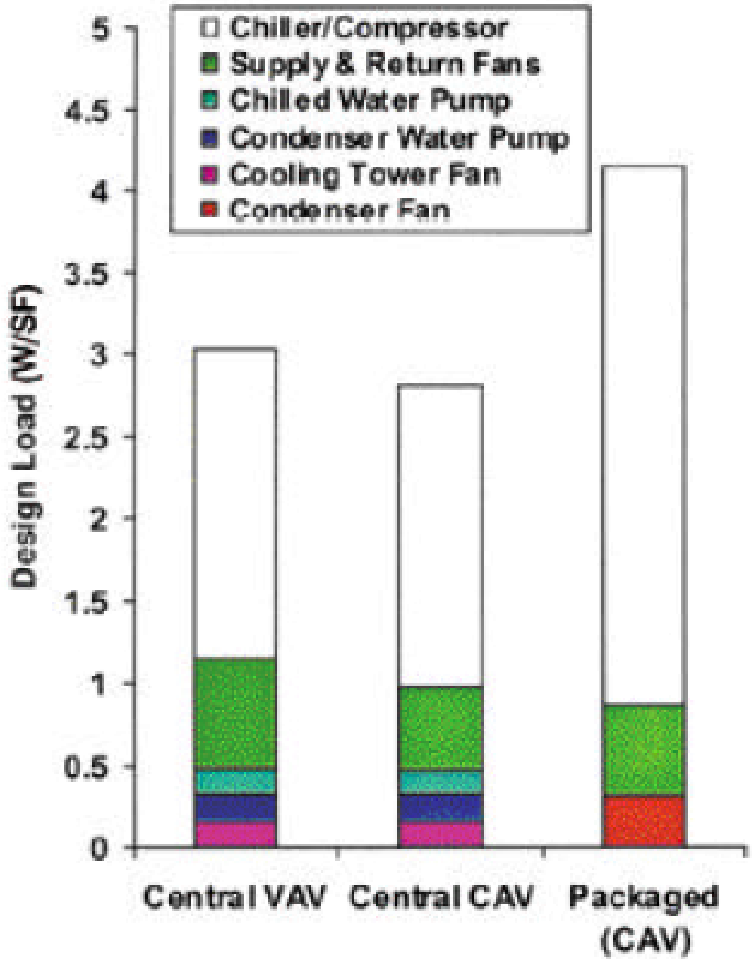
Changing Requirements:

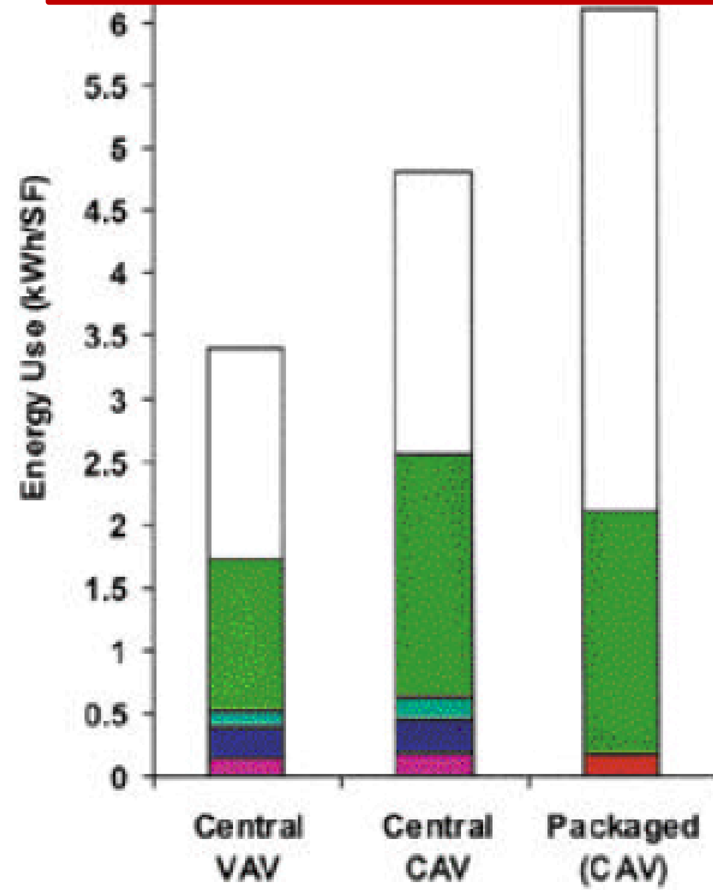
- Adaptative comfort criteria;
- Natural ventilation;
- Occupant control of the indoor environment (whenever possible);
- Use of higher air velocities in the Summer;
- Flexible dress code;
- Flexible use of indoor space;
- Flexible work schedules.

1.º Changing/Reducing traditional requirements

ii. Indoor Air Quality;

In the majority of HVAC systems, **fans&pumps use more energy than water chillers**





Research from the USA Department of Energy (DOE).

1.º Changing/Reducing traditional requirements

ii. Indoor Air Quality;

Ventilation requirements

For adapted occupants

ASHRAE 62.1

num	description	symbol	value	units	formula/source
1	floor área	A	6,0	m2	
2	num of people	NP	1	-	
3	**ventilation airflow**	**V**	**4,3**	**l/s**	EN15251 : 2007 (Rp x NP + Ra x A)
4	airflow per person	Rp	2,5	l / s.p	EN 15251 - categoria 2
5	airflow per floor área	Ra	0,30	l / s.m2	EN 15251 - categoria 2 ; low polluting

For unadapted visitors

EN 15251

num	description	symbol	value	units	formula/source
1	floor área	A	6,0	m2	
2	num of people	NP	1	-	
3	**ventilation airflow**	**V**	**11,2**	**l/s**	EN15251 : 2007 (Rp x NP + Ra x A)
4	airflow per person	Rp	7,0	l / s.p	EN 15251 - categoria 2
5	airflow per floor área	Ra	0,70	l / s.m2	EN 15251 - categoria 2 ; low polluting

Portugal law

num	description	symbol	value	units	formula/source
1	floor área	A	6,0	m2	
2	num of people	NP	1	-	
3	**ventilation airflow**	**V**	**8,3**	**l/s**	RECS : Max [(Rp x NP) ; (Ra x A)]
4	airflow per person	Rp	6,7	l / s.p	RECS, tabela I.04
5	airflow per floor área	Ra	1,4	l / s.m2	RECS, tabela I.05

1.º Changing/Reducing traditional requirements

ii. Indoor Air Quality;

Ventilation requirements

Portugal law (former)

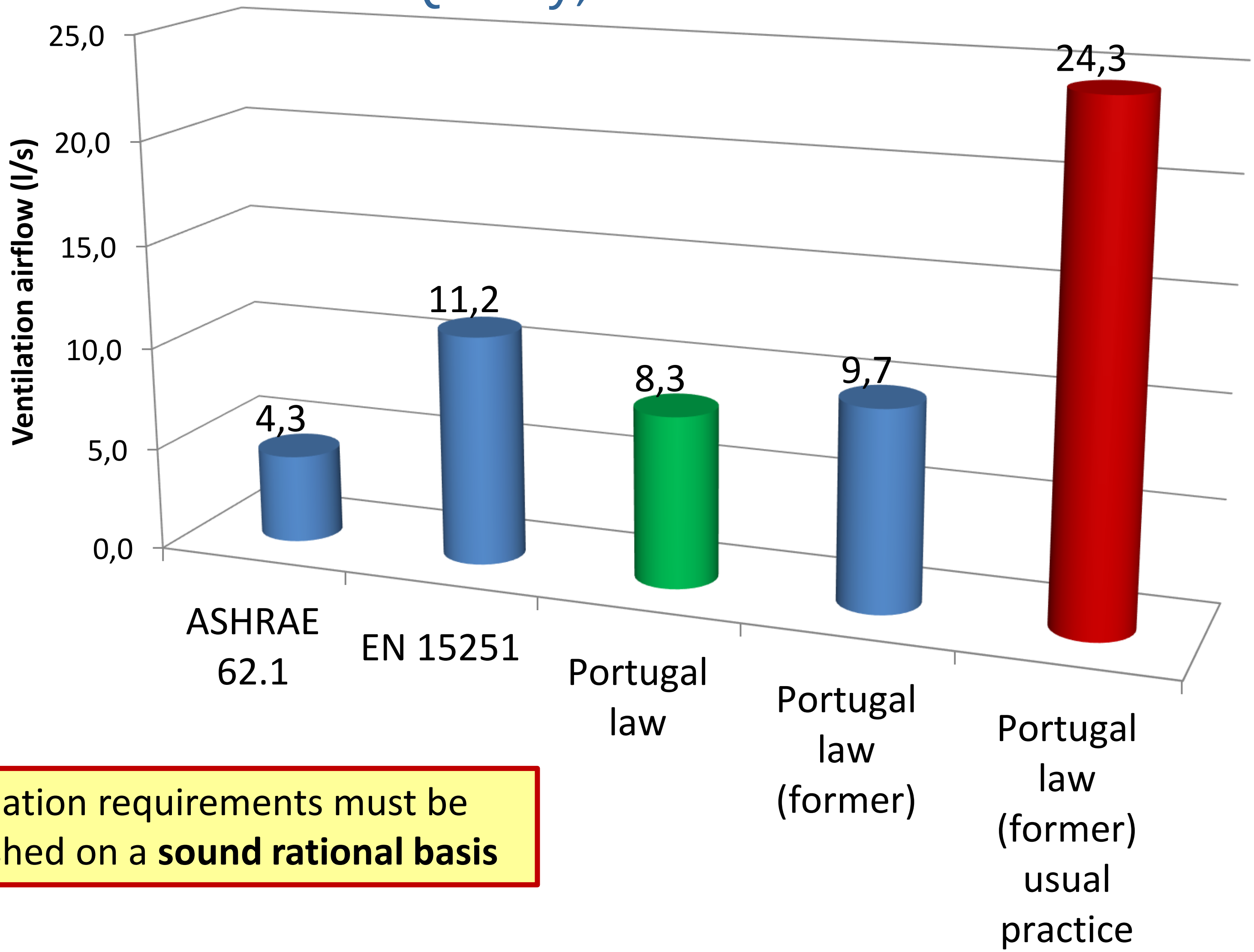
num	description	symbol	value	units	formula/source
1	floor área	A	6,0	m2	
2	num of people	NP	1	-	
3	**ventilation airflow**	**V**	**9,7**	**l/s**	RSECE : Max [(Rp x NP) ; (Ra x A)]
4	airflow per person	Rp	9,7	l / s.p	RSECE, table I.04
5	airflow per floor área	Ra	1,4	l / s.m2	RSECE, table I.05

Portugal law (former) usual practice

num	descrição	symbol	value	units	formula/source
1	floor área	A	6,0	m2	
2	num of people	NP	1	-	
3	**ventilation airflow**	**V**	**24,3**	**l/s**	RSECE : Max [(Rp x NP) ; (Ra x A)]
4	airflow per person	Rp	9,7	l / s.p	RSECE, tabela I.04
5	airflow per floor área	Ra	1,4	l / s.m2	RSECE, tabela I.05
6	ventilation "efficiency"	Ev	0,6	-	frequently used value
7	non ecological materials	mat	1,5	-	RSECE
8	**final coeficient**	**K**	**2,50**	**-**	mat / Ev

1.º Changing/Reducing traditional requirements

ii. Indoor Air Quality;



Ventilation requirements must be established on a **sound rational basis**

1.º Changing/Reducing traditional requirements

ii. Indoor Air Quality;

Air cleaning, (filters):

- Air filters introduce a significant pressure drop in the air stream and, therefore require significant amounts of energy to operate;
- Energy used in fans also increases the energy used in chillers since it is fully degraded to heat that must be cooled by the air conditioning system;
- In the last years, driven by IAQ criteria, the number of filters and its cleaning efficency/pressure drop has greatly increased;
- **Criteria for rational application of air filters must be developed.**

1.º Changing/Reducing traditional requirements

ii. Indoor Air Quality;

Changing Requirements:

- Review of ventilation airflow criteria;
- Review of filter application criteria;
- Conciliate requirements for mechanical ventilation with those for natural ventilation.

1.º Changing/Reducing traditional requirements

iii. Lighting&Equipemt;

Changing Requirements:

- Lower required general lighting level, using task lighting;
- Lower IT energy consumption at the building level, adopting cloud computing, moving IT energy to high efficiency DataCenters with heat recovery;

Reducing energy use in lighting&equipment also reduces energy use in HVAC since all this energy is degraded to heat that must be removed by the HVAC system.

1.º Changing/Reducing traditional requirements

v. Energy Flexibility;

Energy use Flexibility is desirable due to the variable output of renewable sources. Buildings and its technical systems should idealy be designed to allow this flexibility.

Energy storage is the easiest way to adress the issue of Building energy flexibility but other options can be considered:

- Allow for a broader range of accepted indoor environment requirements in limited time periods;
- Create monetary benefits for those who allow the grid manager to temporarily unload specific electrical loads in the building;
- Allow for flexible work time;
- Other…

2.º Energy Efficiency

i. Integrated Building Design;

ii. Passive solutions optimization;

iii. Active systems optimization;

iv. Efficient technology.

2.º Energy Efficiency

i. Integrated Building Design;

Integrated design is an approach that considers the design process as well as the physical solutions with the overall goal to optimize buildings as whole systems throughout the lifecycle.

In the early design phases, the opportunities to positively influence building performance are great, while cost and disruptions associated with design changes are very small.

UE MaTriD project,
Market Transformation Towards Nearly Zero Energy Buildings Through Widespread use of Integrated Energy Design

2.º Energy Efficiency

i. Integrated Building Design;

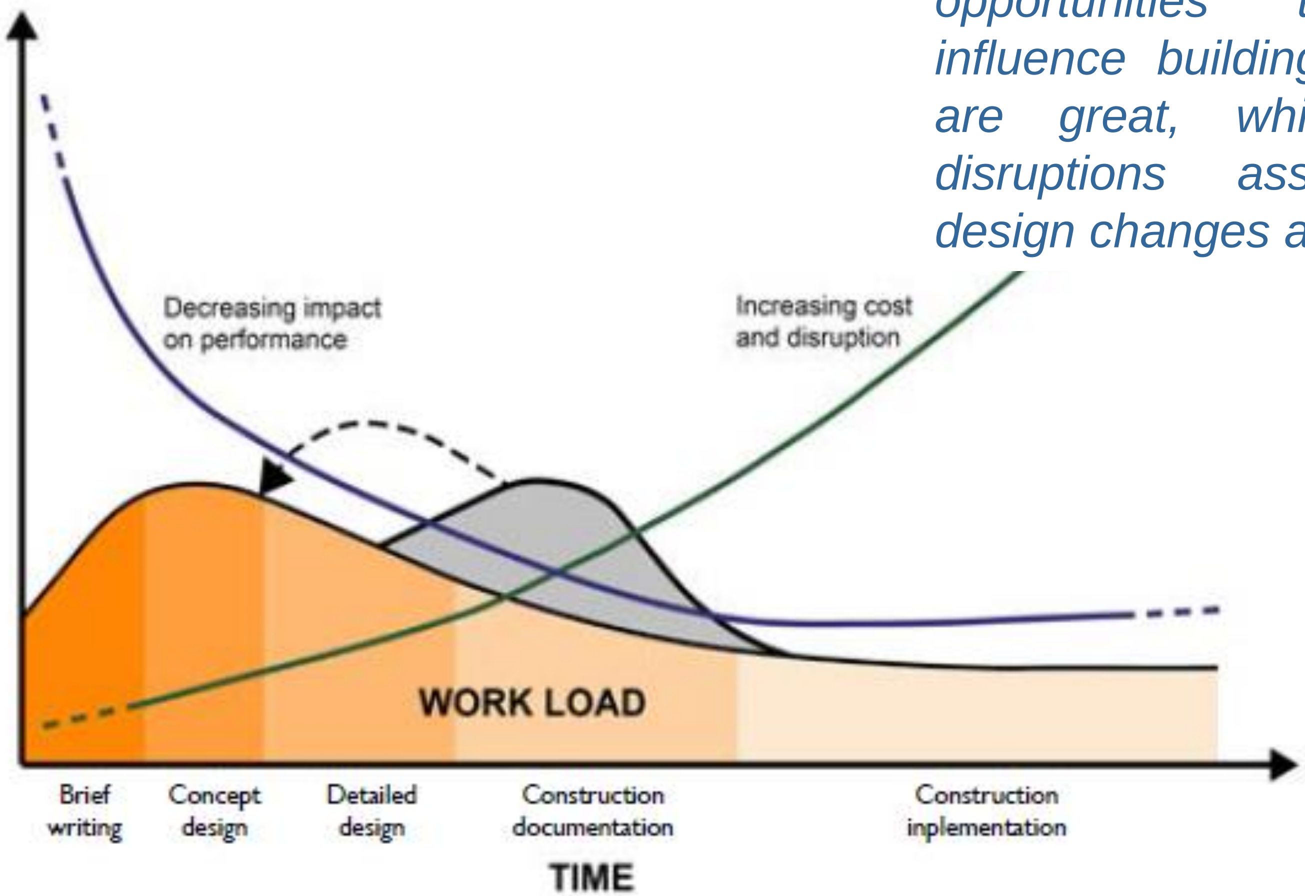
- *Collaboration within the integrated mutlidisciplinary Building Design Team;*
- *Discussion and evaluation of multiple alternative design concepts;*
- *Clear goal setting;*
- *Building performance assessed in a lifecycle perspective;*
- *Systematic monitoring;*
- *First optimize passive solutions;*
- *In an integrated design process, high indoor comfort and low energy consumption should be achieved through passive design measures;*
- *As few efficient technical systems as possible.*

UE MaTriD project,
Market Transformation Towards Nearly Zero Energy Buildings Through Widespread use of Integrated Energy Design

2.º Energy Efficiency

i. Integrated Building Design;

In the early design phases, the opportunities to positively influence building performance are great, while cost and disruptions associated with design changes are very small.



UE MaTriD project,
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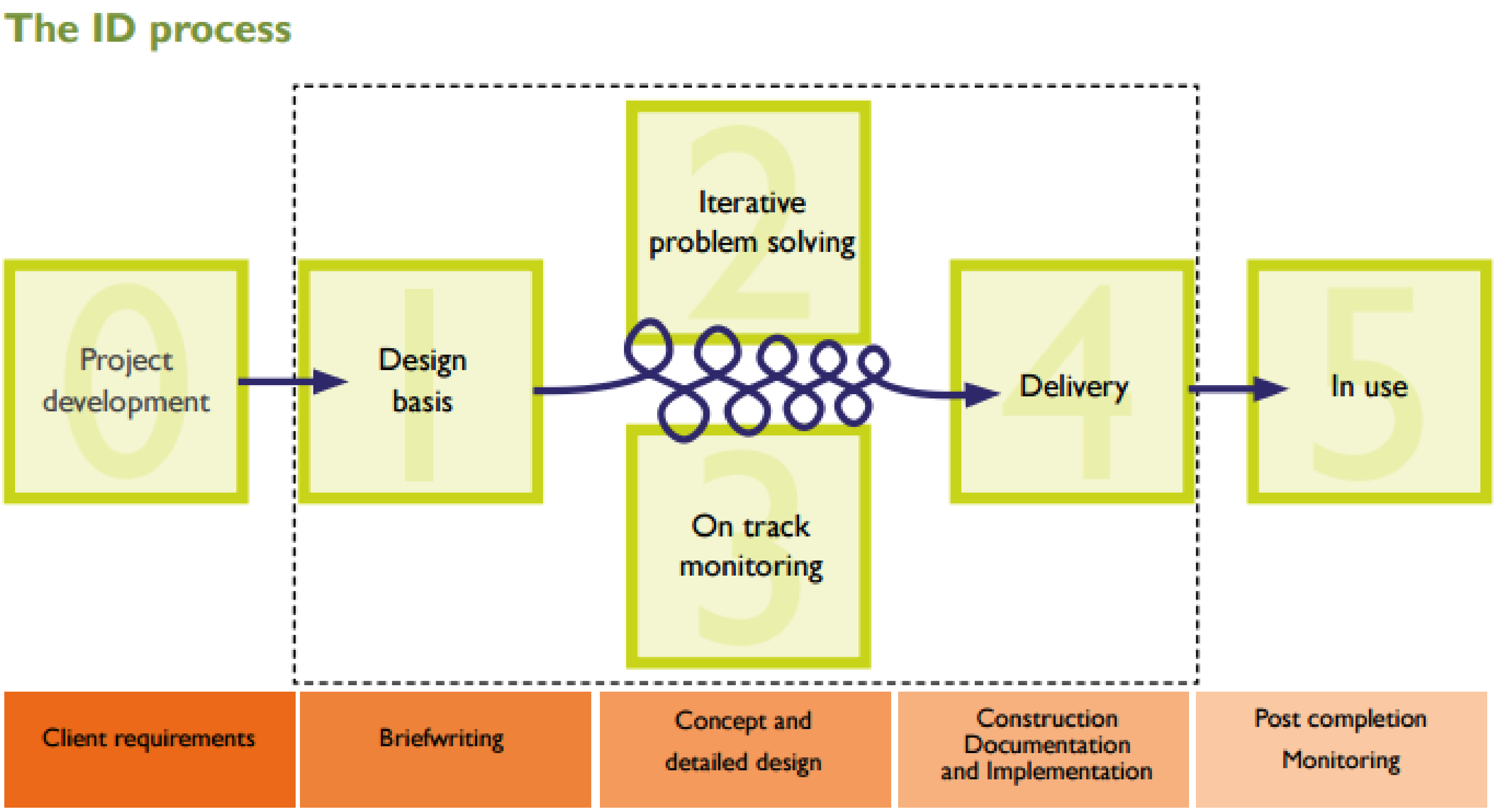
2.º Energy Efficiency

i. Integrated Building Design;



UE MaTriD project,
Market Transformation Towards Nearly Zero Energy Buildings Through Widespread use of Integrated Energy Design

3.º Renewables

On-site:

- *Building Integrated PhotoVoltaics (BIPV);*
- *Heat pumps;*
- *Solar thermal;*
- *Shallow Geothermal.*

Off-site or nearby:

- *Wind;*
- *Hydro;*
- *Solar;*
- *Biomass;*
- *Geothermall;*
- *Other (waves, etc).*

3.º Renewables

Building Integrated PhotoVoltaics

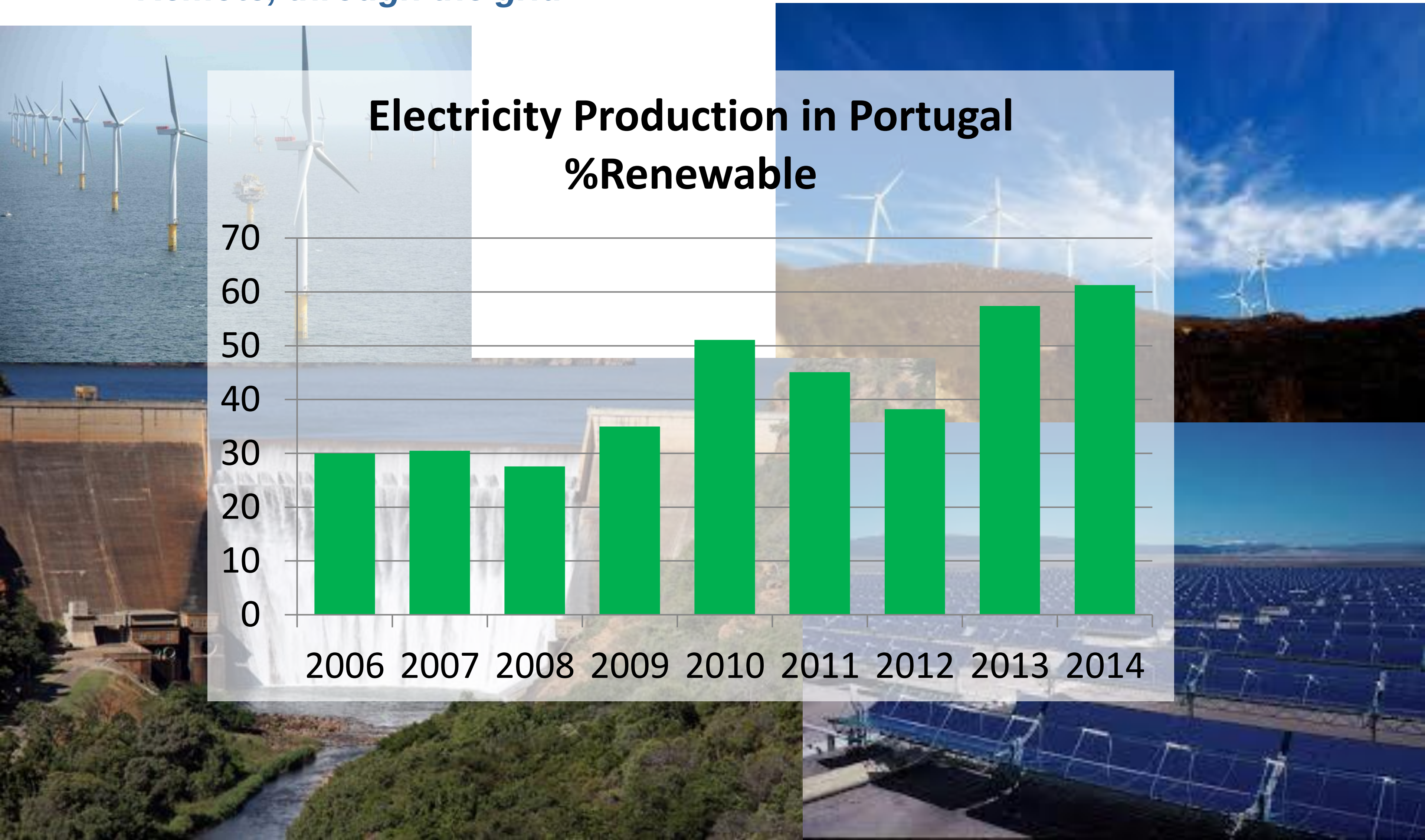
Cortesy of SAPA

3.º Renewables

Remote, through the grid

3.º Renewables

Remote, through the grid



4.º Energy monitoring

	Monitoring Strategy	*Use of monitoring information*	*Typicasl economy(%)*
1	**Instaling energy counters data aquisition software**	**Consumption registration**	**0%**
2	**Strategy1, plus alocation of energy costs per department/sector**	**Monthly retports for each department/sector**	**2% – 5%**
3	**Startegy2, plus analysis and fine tunnig of system soperation**	**Startegy2, plus revison and fine tuning of schedules, setpoints, operating creiteri,a etc.**	**5% - 15%**
4	**Strategy3, plus continuos monitoring and commissioning**	**Strategy3, plus continuos fine tuning and systems commissioning**	**15% – 45%**

USA Department Of Energy FEMP Fact Sheet

4.º Energy monitoring

European Project iSERV (concluded in 2014):

*As a result of continuous monitoring of 330 buildings the project reached an average energy consumption reduction of **9%** and a maximum of **33%**.*

*This reduction was achieved with measures with **no cost or low cost**, achieving payback periods of investment of less than one year.*

(www.iservcmb.info)

4.º Energy monitoring

Continuos monitoring:

- Global and parcial energy counters;
- Counter remotely read using webserver and webpage;
- Online data register and reading;
- Graphical treatment of data and alarming;
- Remote continuous analysis;
- Identification, diagnosis, and quick correction of consumption anomalies;
- System operation optimization based on aquired knowledge from energy monitoring.

Good luck for the NZEB challenge!