29 May – 3 June
eceee 2017 Summer Study
on energy efficiency

Achieving University Campus Sustainability with Nearly Zero Energy Building Retrofits

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Motivation to implement energy efficiency programs in Universities (in Portugal)

ECONOMICS

- Shrinking budgets
- Rising energy costs (FITs, rise of electricity VAT from 6 to 23%)
- Strong commitment regarding an efficient public budget management

SUSTAINABILITY

- Increasing consciousness towards sustainability and energy optimization
- Demonstration sites of sustainable renovation integrated in buildings
- Shinning example for students/future generations

Context – Key Role of Buildings

- Buildings account for 40 % of total energy and over 60% of electricity consumption in the European Union
- The sector is expanding, which is bound to increase the demand for energy services
- Therefore, reduction of energy consumption and the use of energy from renewable sources in the buildings sector constitute important measures needed to reduce the EU's energy dependency and greenhouse gas emissions.

- Article 2 of the EPBD defines a **nearly zero-energy building**: a building with 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 produced on-site or nearby.

Legal framework – Buildings Energy Performance

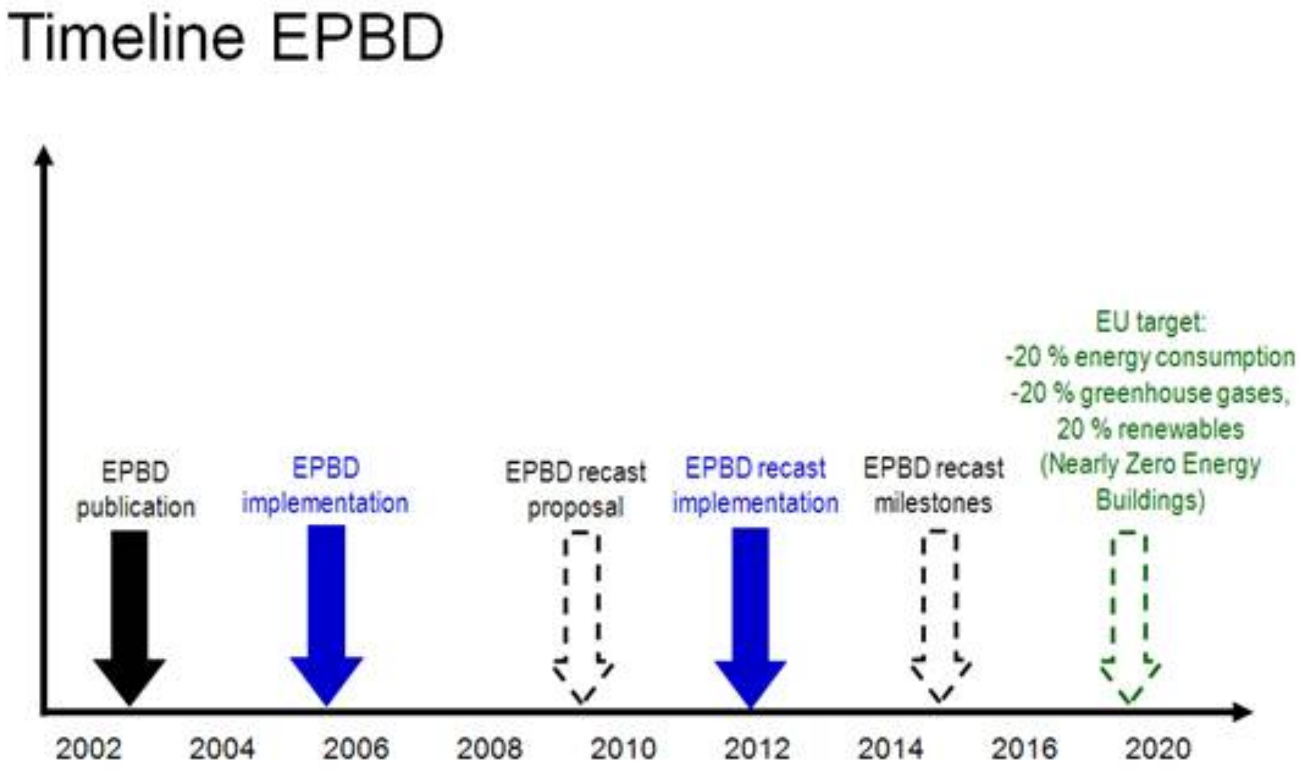
- **1992:** First building code in PT requiring minimum thermal performance (RCCTE)

Although the code was important at that time, its performance requirements were not very demanding and therefore, the building offers several opportunities for energy renovation improvements.

- **2002/91/EC : EPBD -** Energy Performance of Buildings Directive
- **2010:** RECAST of Energy Performance of Buildings Directive
- On **29 July 2016**, the European Commission released the Commission Recommendation (EU) 2016/1318 on guidelines for the promotion of **nearly zero-energy buildings** and best practices to ensure that, by 2020, all new buildings are nearly zero-energy buildings.

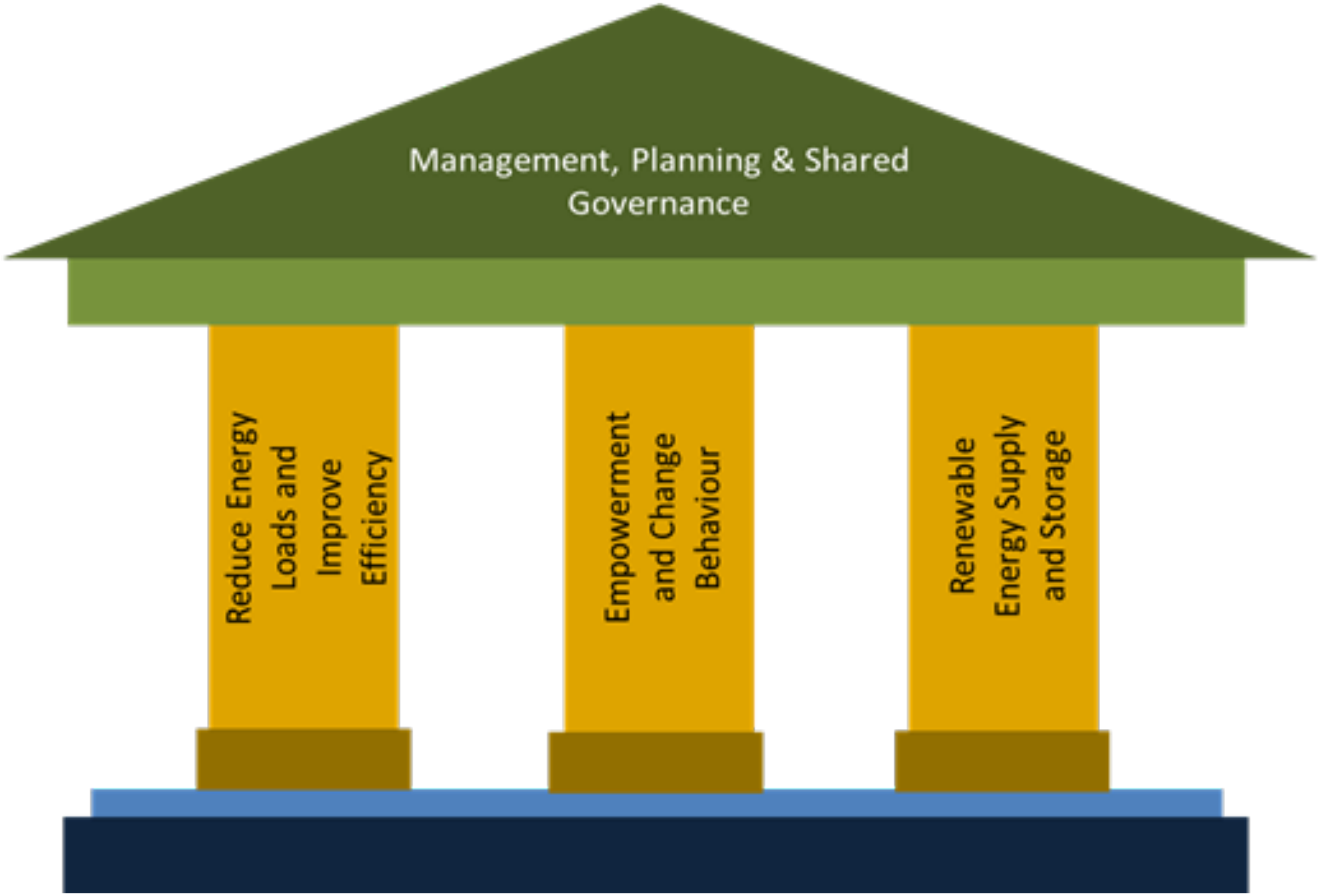
Timeline EPBD

By 31 December 2020, all new buildings are NZEB and after 31 December 2018, new buildings occupied and owned by public authorities are NZEB buildings. MS to draw up national plans for increasing the number of NZEBs buildings and shall develop policies and take measures to stimulate the transformation of buildings that are refurbished into NZEB buildings.



Nov2016: the Commission proposed to strengthen this crucial policy area beyond 2020 and asks for higher targets for **energy efficiency, renewables and CO2 emissions,** aiming for a 30% EU binding energy efficiency target for 2030.

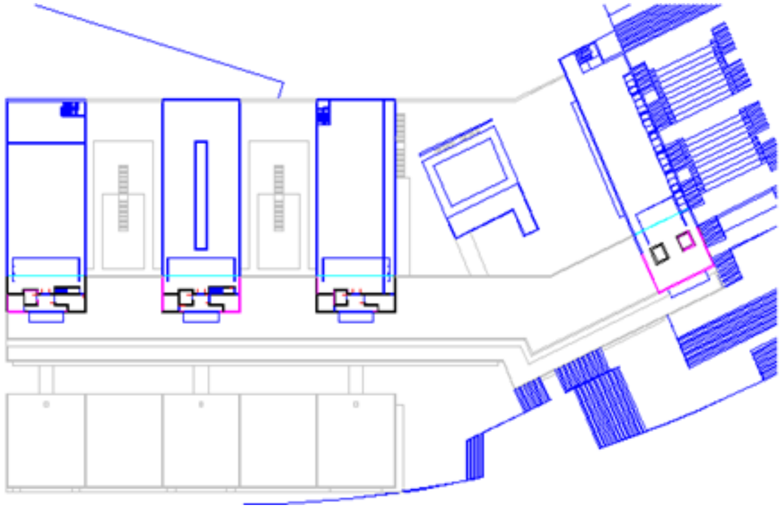
4 aspects of the systems approach

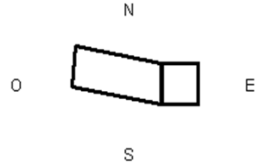


Energy renovation measures in the building

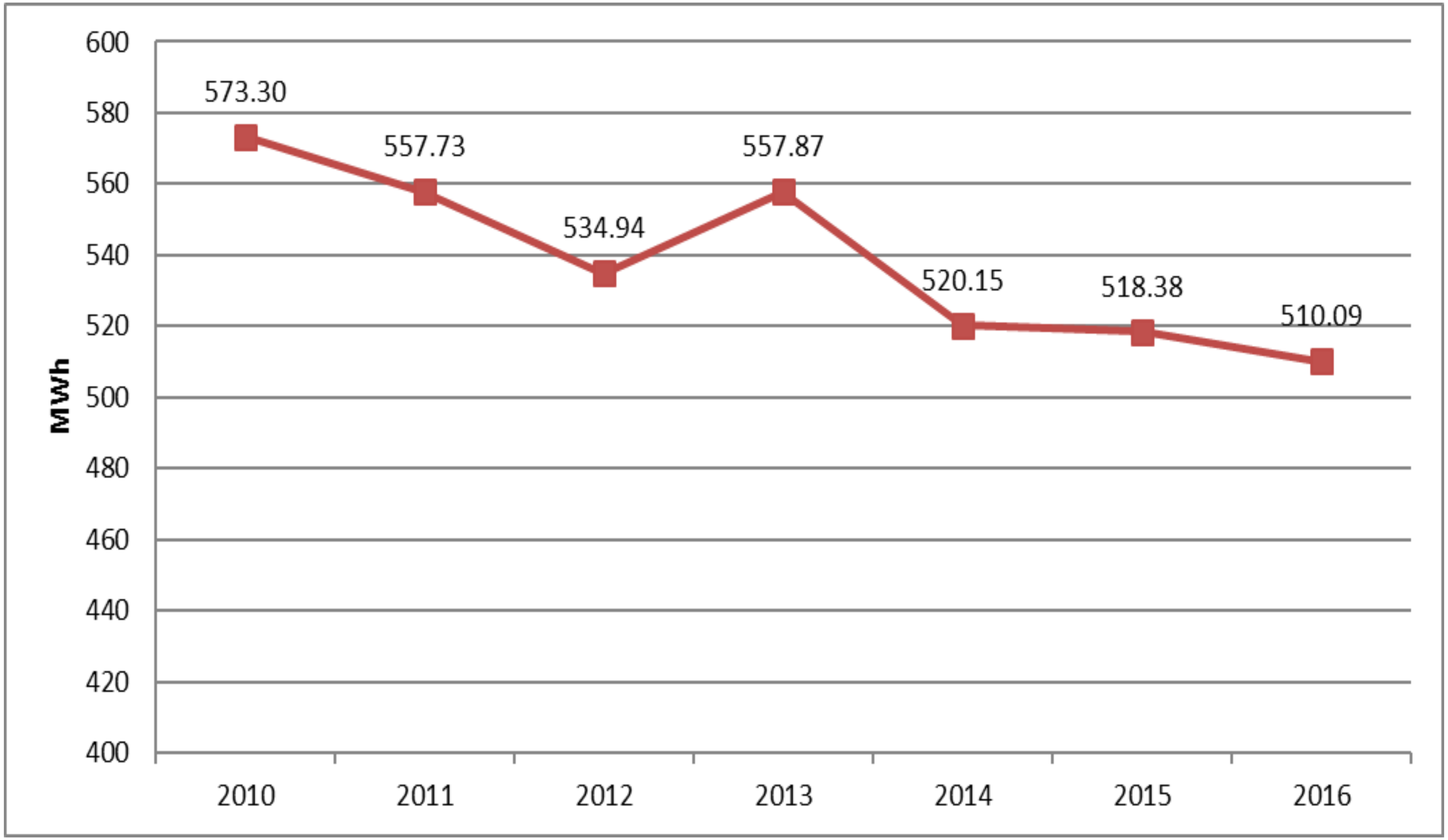
- Energy audits
- Energy management system
- Retrofit of lighting systems
- Occupancy sensors
- Power factor correction
- General improvements in electrical loads (Large scale replacement of CRTs, energy-efficient heat pumps, …)
- Installation of PV panels
- Installation of energy storage system

Building | Building Plant | Building Characteristics



Floors	9
Exterior Walls	Concrete with thermal isolation in the outside
Interior walls	Masonry of perforated brick with thermal isolating
Windows	Simple glass
Roof	Horizontal coverage with thermal isolation
Building orientation	
Flooring	Wood (rooms) and marble (halls)
Ceilings	Masonry of perforated brick
Total Building Surfaces *(total sq.m)*	10.000
Lighting	Mainly T8 lamps with conventional magnetic ballast
Lighting controls	Control of the lamps by the BMS in the halls and by motion sensor in the classrooms.
HVAC/heating	Yes, individual systems, unevenly distributed
HVAC/cooling	Yes, heat pumps in Amphitheaters and in some research laboratories
HVAC distribution	No
HVAC controls	No, manual individual control
BMS	Control of the lightings in the halls and in the corridors, and also the ventilation fans in the parking garage.
Sensors/actuators	Motion Sensors in some classrooms, toilets and in some corridors
Electricity	Grid (630 kVA)
Total electricity consumption per year *(KWh/year)*	518 380 (in 2015, the baseline year)
Other energy sources	No
Potable water	Yes
Water heating	No
Waste water	Yes
Other characteristics	

Electricity consumption per year



Energy efficiency of the existing loads

- Replacement **old inefficient lighting and ICT** equipment
- **Reduce the energy demand** by adjust the existing Building Management System (BMS) to the profile needs of the users
  - controlling the use of HVAC in classrooms
  - centrally controlled lighting in corridors, occupancy sensors installed in some less used areas, lighting in public areas
- **Shifting the HVAC loads** to match the night tariffs and reduce peak hours' consumption

Raising awareness to influence

- **Information** - a software tool was developed to show, online, the actual energy and water use within the building to occupants and visitors: TV screens in the main entrance hall of the building and in the cafeteria

Yearly Load Diagrams - 2009 Vs 2015

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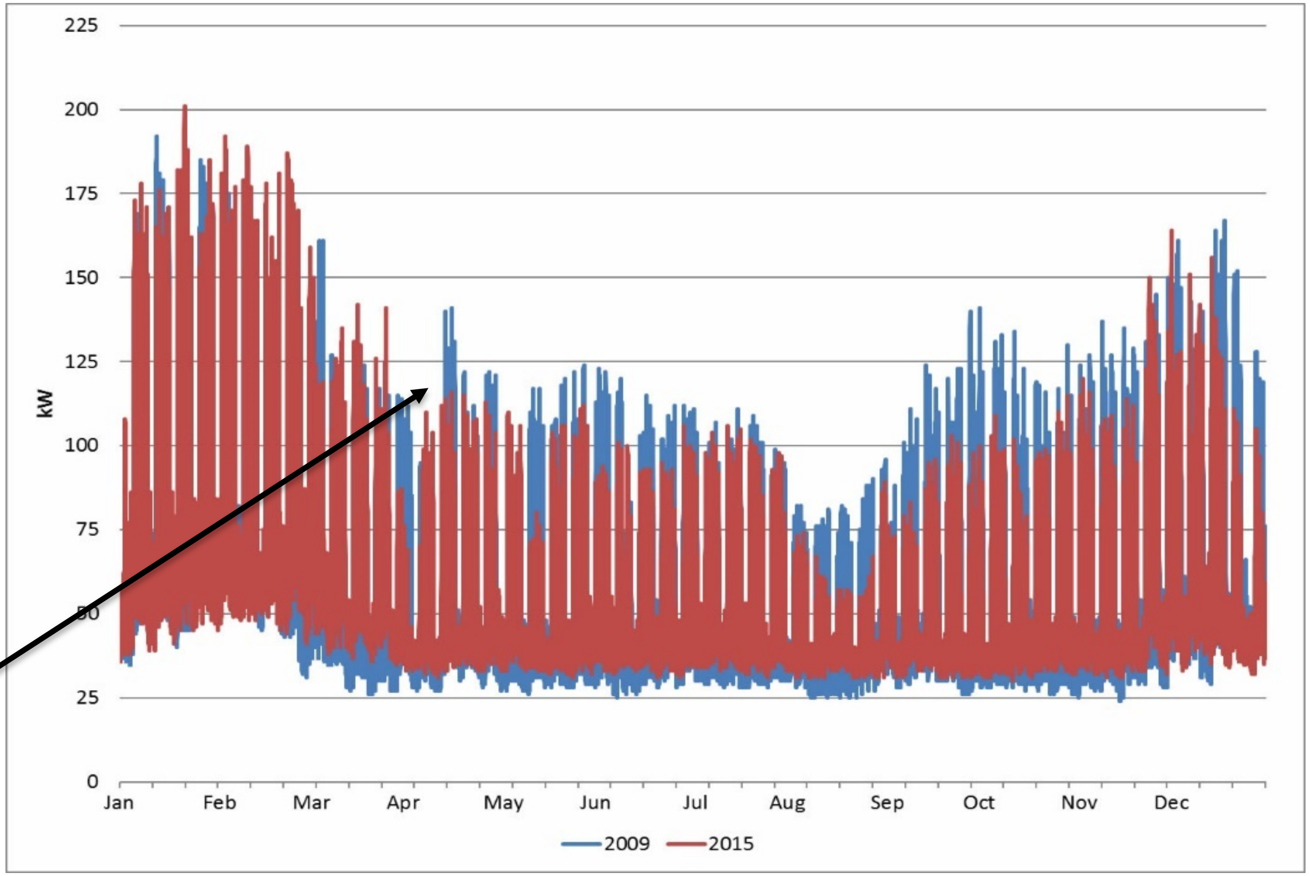
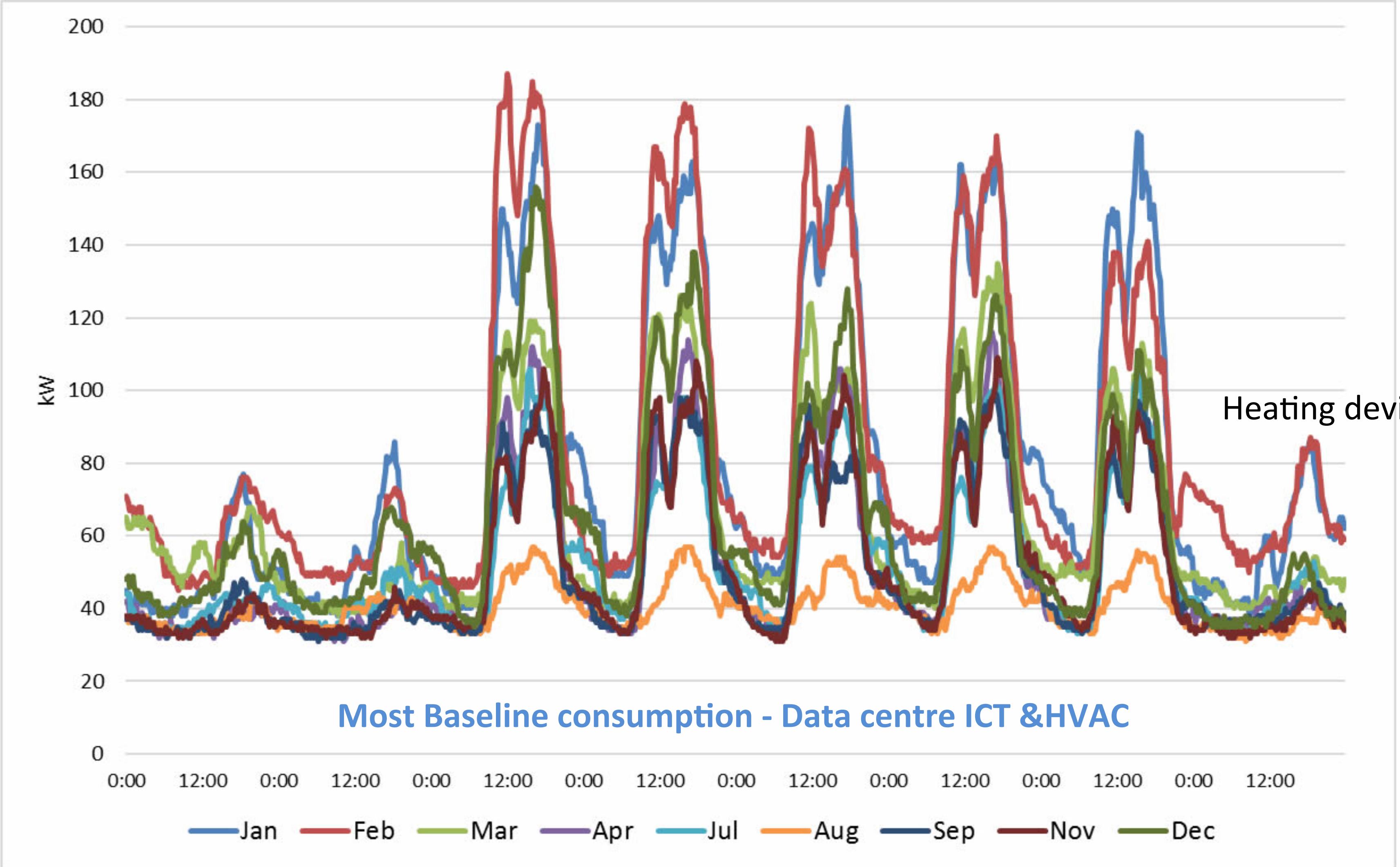


maximum consumption values have generally decreased

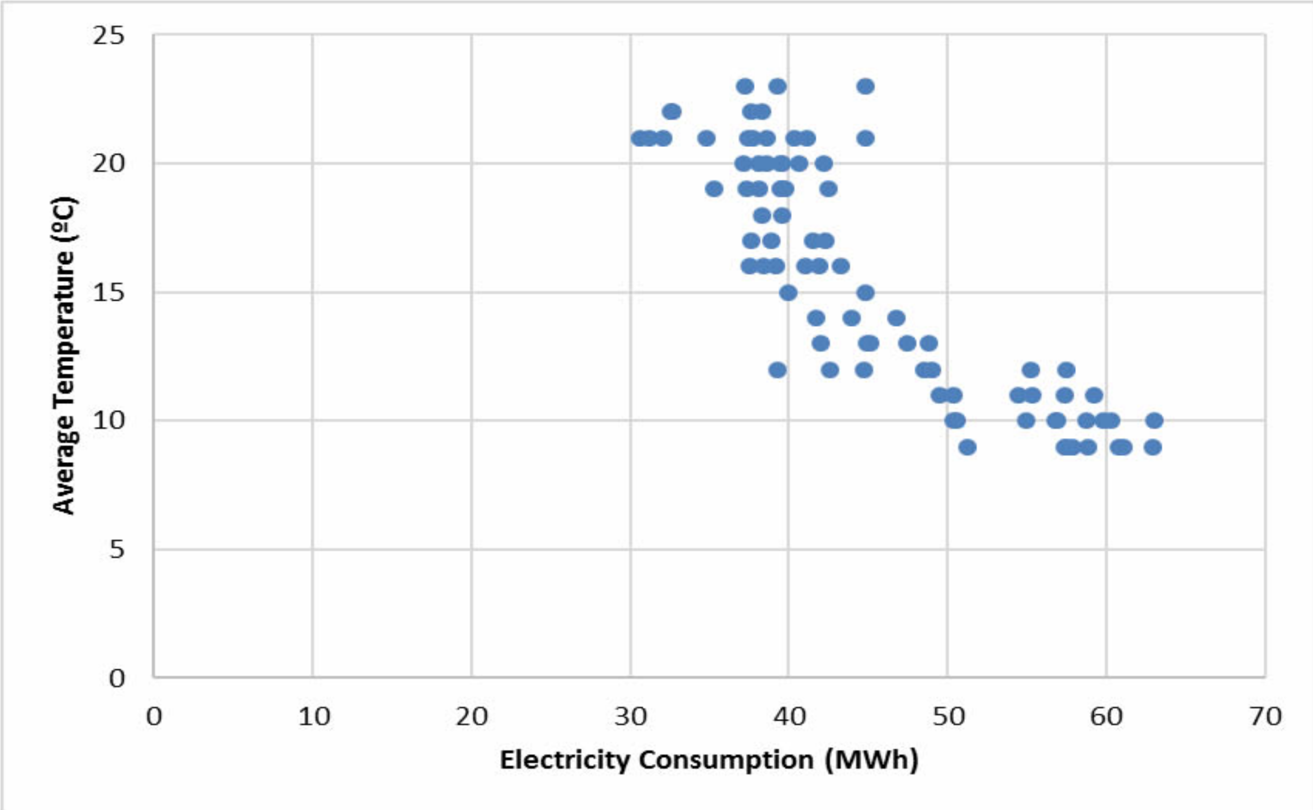
- Replacement of part of the Fluorescent T8 lamps and halogen lamps by LEDs in the amphitheatres and in some corridors,
- Large-scale replacement of CRT monitors and inefficient computers in classrooms and laboratories by more efficient equipment

Weekly Load Diagrams (several months 2015)



Electricity Consumption per Month, Over the Last Years, and Respective Average Temperatures

Negative correlation between the average temperature (independent variable) and the consumption (dependent variable)



Heating|Cooling
need action

Electricity Consumption per Month, Over the Last Years, and Respective Average Temperatures

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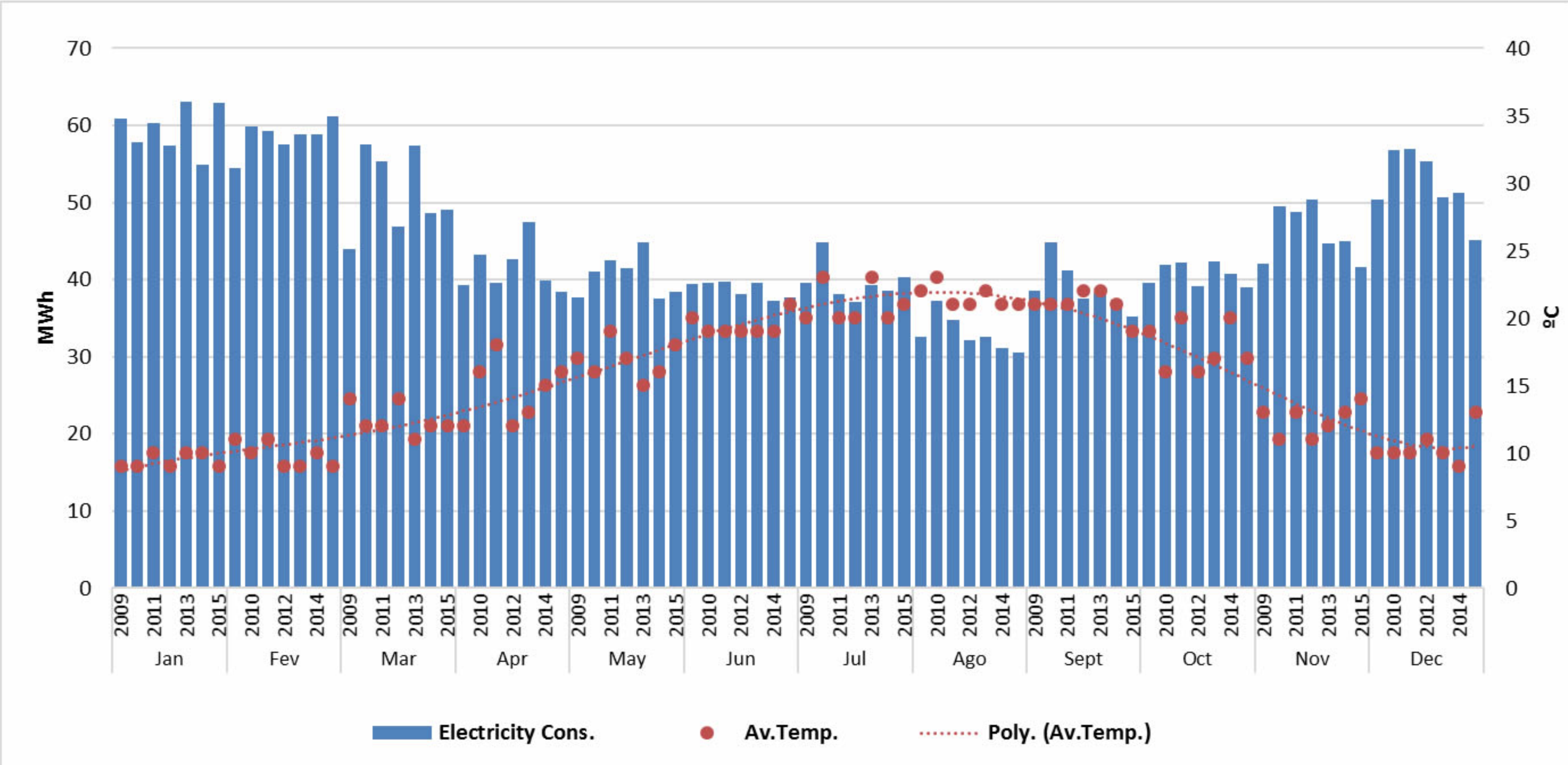


Types and Quantity of Lamps Considered in the Lighting Renovation – Phase 1

Actual			*Renovation*		
Lamp	***Quantity***	***Power (W)***	***Lamp***	***Quantity***	***Power (W)***
Fluorescent Linear T8 F120	60	2,590	LED Linear F120	36	130
Compact Fluorescent	30	940	LED Spots	20	70
Halogen Spot	72	10,800	LED Spots	72	1,440
Total	**162**	**14,330**	**Total**	**128**	**1,640**

Reduction on the electricity consumption of 27,1 MWh/y (90% savings)

Lamps + Luminaires

Lighting Renovation

Types and Quantity of Lamps Considered in the Lighting Renovation – Phase 2

Space	Actual			Renovation		
	Lamp	Quantity	Power (W)	Lamp	Quantity	Power (W)
Classrooms	Fluorescent Linear T8 F120	30	1,300	LED Linear F120	30	600
	Fluorescent Linear T8 F150	168	11,690	LED Linear F150	168	4,030
Corridors	CFL13	40	620	LED SPOT	40	140
	HP Sodium Projectors	8	2,400	LED Projector	8	640
	Fluorescent Linear T8 F120	24	1,040	LED Linear F120	24	480
Admi. Services	Fluorescent Linear T8 F120	44	1900	LED Linear F120	44	880
	Fluorescent Linear T8 F150	4	280	LED Linear F150	4	100
Cafeteria	Fluorescent Linear T8 F120	20	860	LED Linear F120	20	400
	CFL13	28	440	LED Spot	28	100
Prof. Offices	Fluorescent Linear T8 F120	288	12,440	LED Linear F120	288	5,760
R&D Labs	Fluorescent Linear T8 F120	84	3,630	LED Linear F120	84	1,680
	Fluorescent Linear T8 F150	152	10,580	LED Linear F150	152	3,650
Teaching Labs	Fluorescent Linear T8 F120	40	1,730	LED Linear F120	40	800
	Fluorescent Linear T8 F150	368	25,610	LED Linear F150	368	8,830
Other offices	Fluorescent Linear T8 F120	24	1,040	LED Linear F120	24	480
	Fluorescent Linear T8 F150	100	6,960	LED Linear F150	100	2,400
	Total	**1422**	**82,520**	**Total**	**1422**	**30,970**

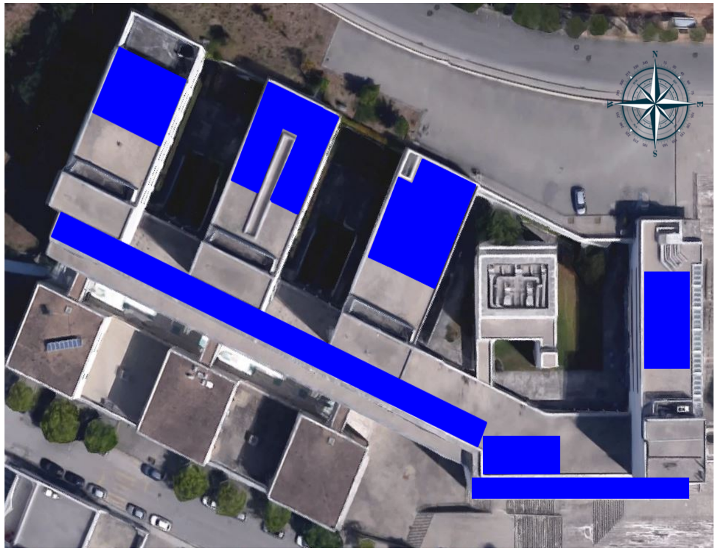
Reduction on the electricity consumption of 76,6 MWh/y (63% savings)

LEDs -> 130 lm/W

Renewable Energy Generation

- PV panels with 270 Wp each, 732 panels

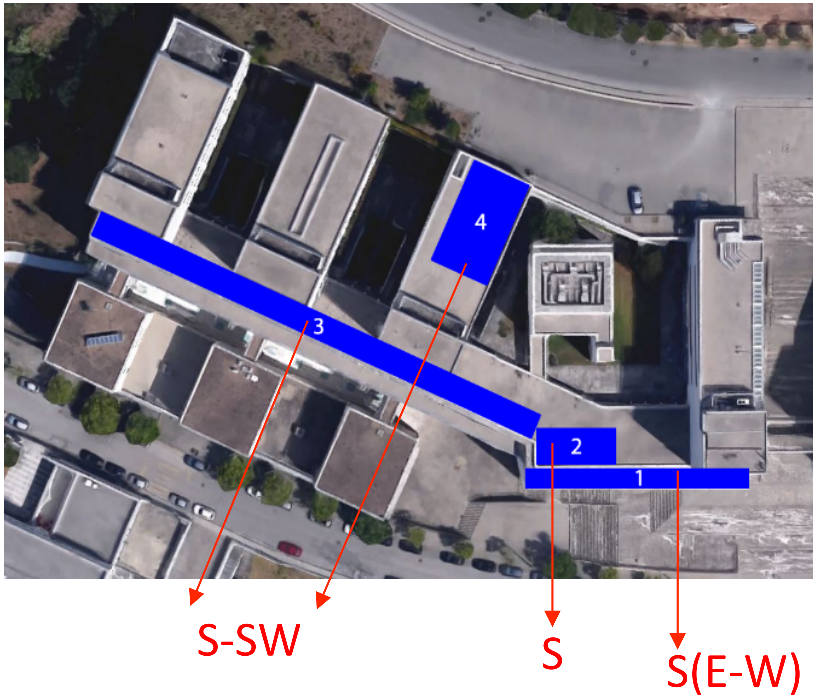
  => Installed power of 197.64 kWp



Energy generation 282 MWh, representing 54.4% of the actual energy consumption

- PV panels with 270 Wp each, 392 panels

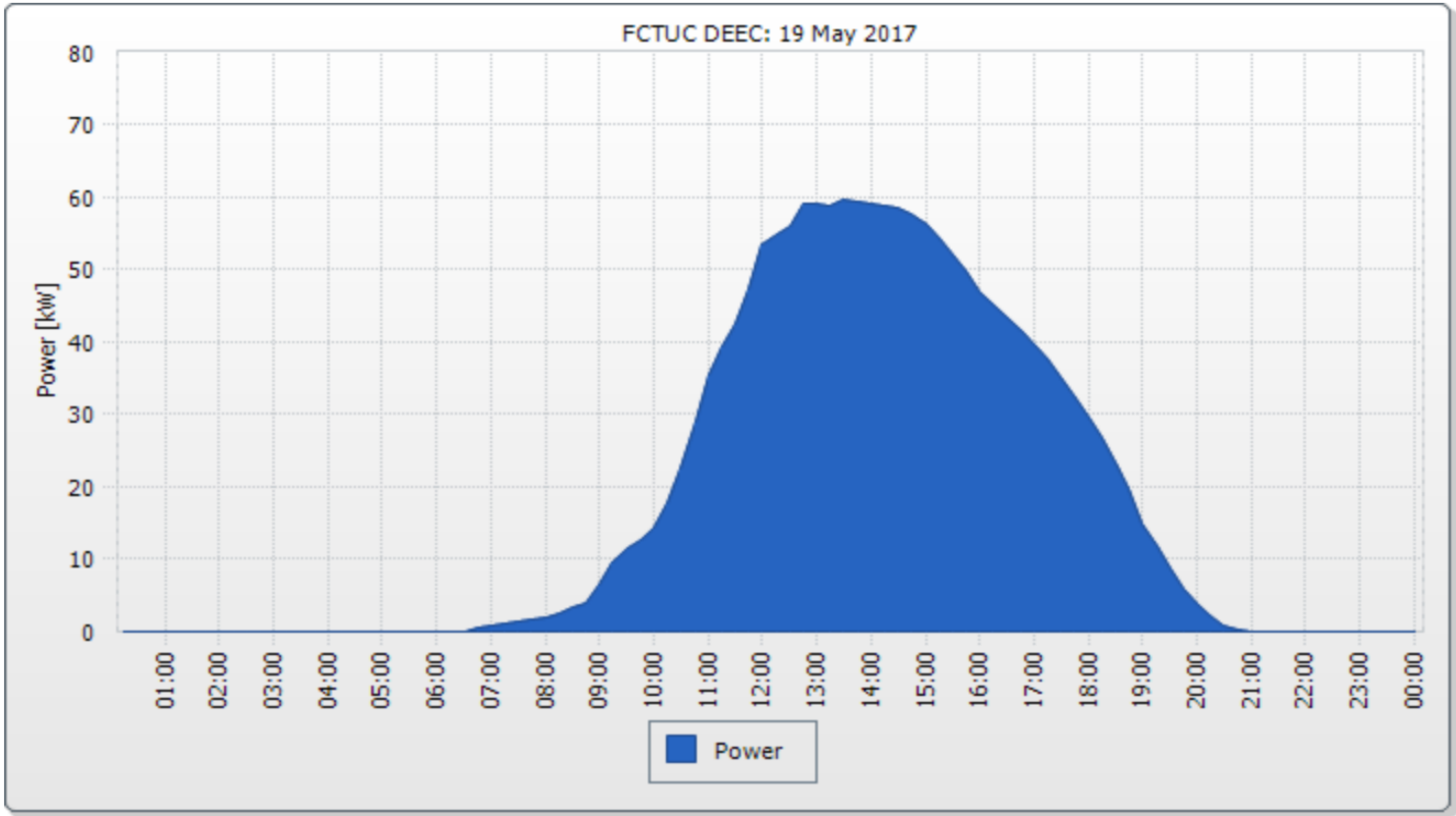
  => Installed power of 105.84 kWp



Energy generation 152.6 MWh, representing 36.8% of the actual energy consumption

Renewable Energy Generation

Renewable Energy Generation



Technical data of the designed PV system

Total number of PV modules	392
Peak power	105.84 kWp
Number of PV inverters	5
AC active power	92.00 kW
Active power ratio	86.9%
Annual energy yield	152.61 MWh
Energy usability factor	99.6%
Performance ratio	88%
Spec. energy yield	1442 kWh/kWp
Battery Capacity	100 kWh

„Constraints“ for local electricity generation

Despite the higher consumption in the building during the hours of higher generation, the building has a **low consumption** during **weekends** and during July and August (undergrad students summer vacations), leading to generation surplus.

From the economic point-of-view, this is a problem since the **price paid by the consumed energy** is much higher than the price **received by the energy injected into the grid**.

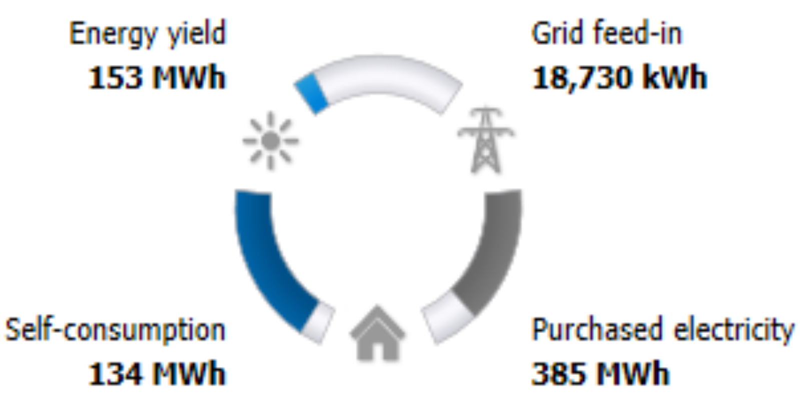
With the new Portuguese regulation to self-consumption of locally generated electricity, the energy injected into grid is paid only with a price of 90% of the monthly average price of the Portuguese spot electricity market and the average price paid during 2016 was only 0.03546 €/kWh.

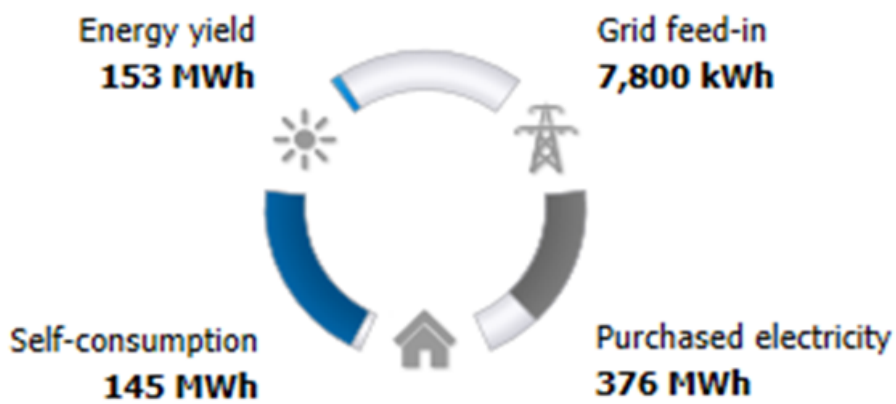
Tariffs (Including VAT) for the Energy Consumption and Energy Injected into the Grid

Consumption from the Grid				***Injection into the Grid***
Peak	***Half-Peak***	***Normal Off-Peak***	***Super Off-Peak***	
0.2746 €/kWh	0.1315 €/kWh	0.0969 €/kWh	0.0956 €/kWh	-0.03546 €/kWh

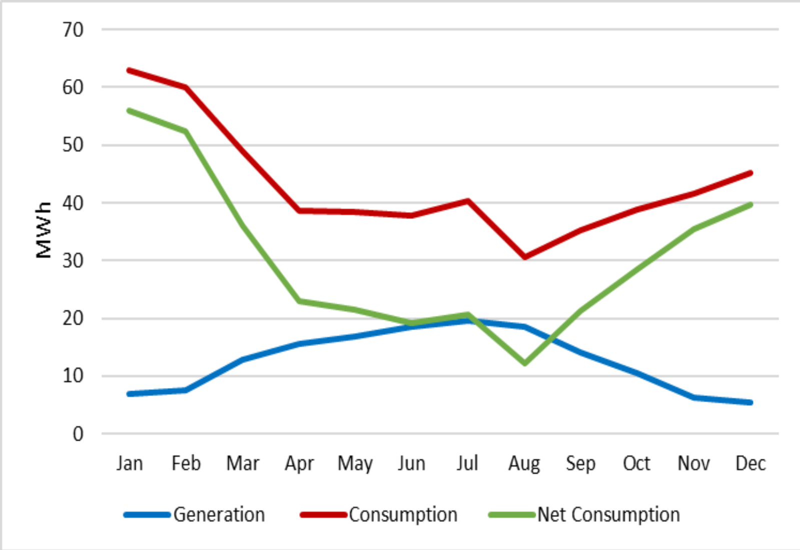
Distribution of PV Energy without and with Energy Storage

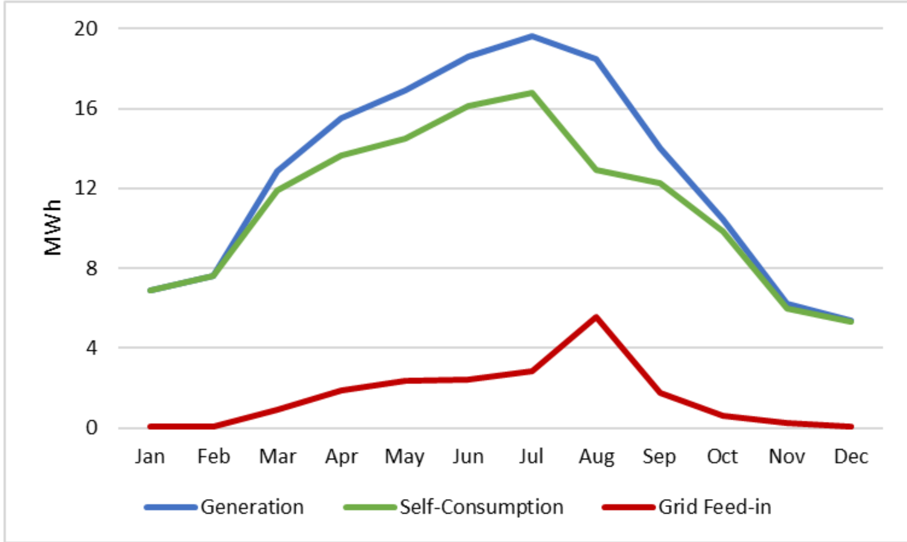
Distribution of PV generation (between self-consumption and grid feed-in), as well as the impact on the purchased energy considering scenarios **without** and **with** energy storage





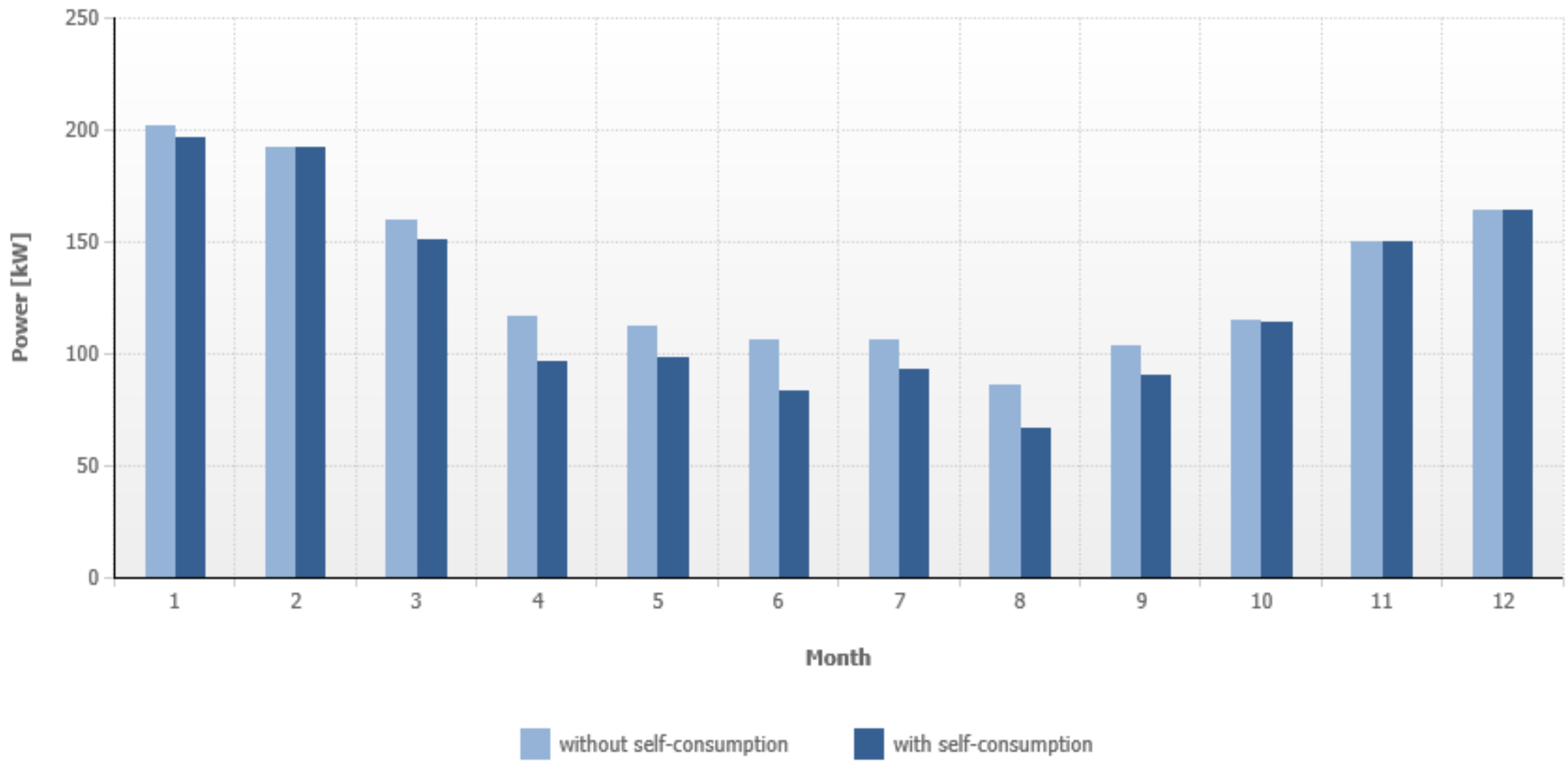
Yearly variation of the energy generation and consumption, as well as the net-energy consumption





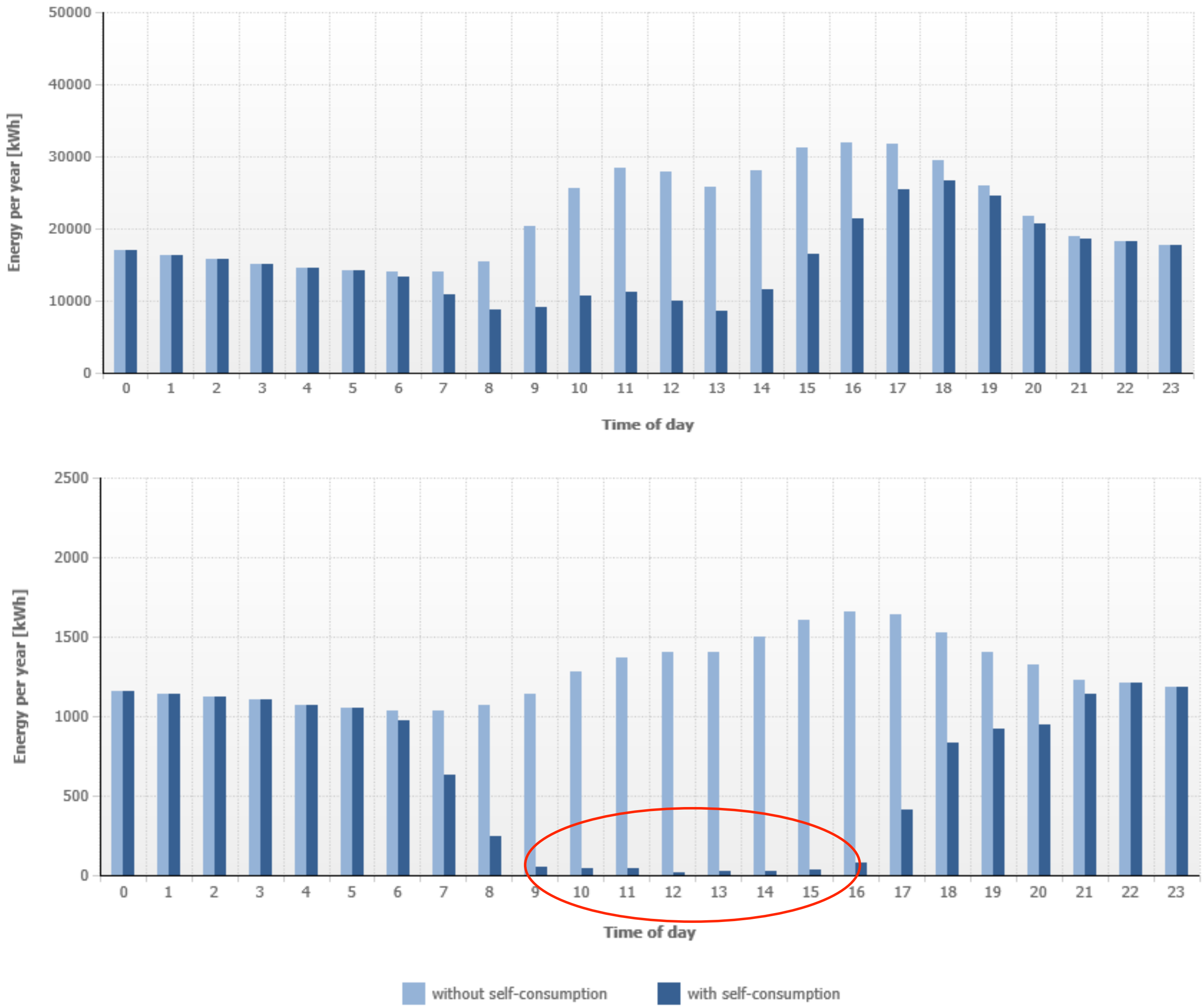
- In Winter months almost all the generation is used for self-consumption
- In Summer a high share of the energy has to be injected into the grid
  - ↑ of solar radiation ; ↓ of consumption
  - injection of generated energy into the grid concentrated during weekends

Maximum Load in each Month with and without self-consumption



Lower maximum load, but also a higher impact on its reduction due to self-consumption during Summer

Daily average variation of the consumed energy with and without self-consumption



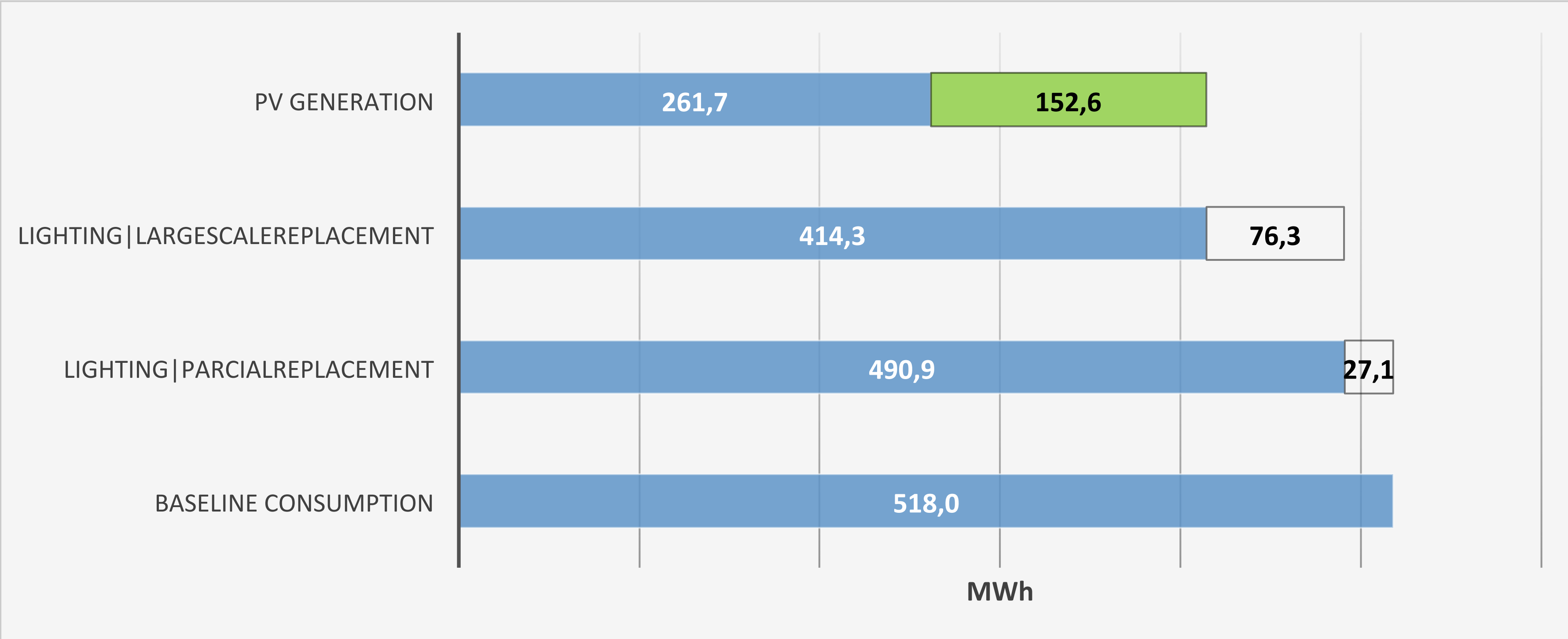
Yearly

August

Daily average variation of the consumed energy with and without self-consumption

- In August, due to self-consumption the average energy consumption, between 9h and 16h is almost zero.
- It can be noticed from the daily average variation that most of the impact of the generated energy on the purchased energy occurs between 8h and 20h.
- The self-consumption ensures a reduction of 27.4% on the annual purchased electricity.
- Considering only the electricity purchased between 8h and 20h the reduction of the annual purchased electricity is 40.5%.

Energy Balance |
Consumption, Savings and Generation



Scenario	*Consumption (MWh/Year)*	*Savings (MWh/Year)*	*Generation (MWh/Year)*	*Net-Cons. (MWh/Year)*
BaselineConsumption	518	-	-	518
Lighting|ParcialReplacement	490,9	27,1	-	490,9
Lighting|LargeScaleReplacement	441,4	76,3	-	441,4
PV Generation	-	-	152,6	365,4
Total	**414,3**	**103,4**	**152,6**	**261,7**

Results: final energy and CO2 emissions savings

Scenario	*Final Energy (MWh/Year)*	*Specific Energy ($kWh/m^2 Year$)*	*CO_2 Emissions (kg CO_2 /Year)*
Baseline	518	51.8	72,5
Retrofit	262	26.2	36,6
Savings	**256** **49.5%**	**25.6** **49.5%**	**35,8** **49.5%**

- The tangible improvement measures ensure 49.5% savings, decreasing the energy density of the building to only **26.2 kWh/m^2 year**
- A conversion factor from electricity to CO_2 emissions of 140 g CO_2/kWh

Mix of Strategies running in parallel

- Tackle behaviour
- Innovative systems to reduce energy consumption
- In site production and storage
- smart monitoring, automation and control

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Thank you!

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