Cost-Effective Options for Nearly Zero Energy Renovation of Municipal Buildings

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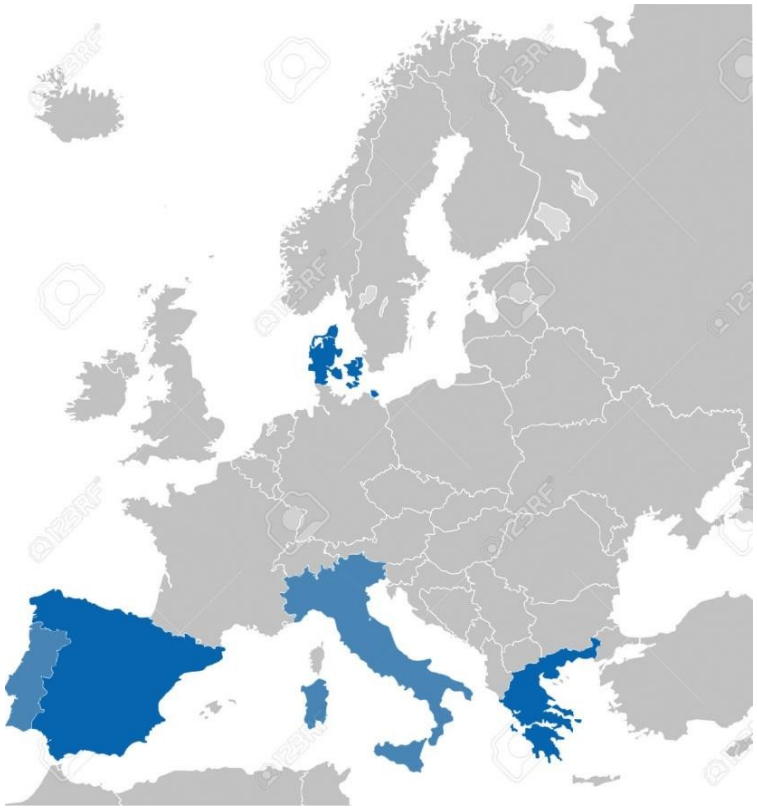
Context and Motivation

- The current energy situation in Southern European Countries is characterized by:
  - low energy efficiency,
  - energy saving investments have been impeded in the public sector due to the economic crisis.
- The latest European Energy Efficiency Directive demands strict energy efficiency measures for the public sector.
  - Many of the municipal buildings in Southern Europe require deep renovations to become nearly Zero Energy Buildings (nZEB).
  - Compliance to this directive is difficult for the public sector because the required investments are capital intensive and some interventions have long payback times.
- It is necessary to identify technical solutions and financing mechanisms suitable for nZEB deep renovations that meet the needs of the Municipalities and of the financing entities.

Project CERtuS

- **CERtuS** (Cost Efficient Options and Financing Mechanisms for nearly Zero Energy Renovation of Existing Buildings Stock)
  - **Programme:** Intelligent Energy Europe (IEE)
  - **Starting Date:** 01/03/2013
  - **End Date:** 28/02/2017
  - **Duration:** 36 months (3 years)
  - **Coordinator:** ENEA (IT)
  - **Municipalities:** Coimbra (PT), Messina (IT), Errenteria (ES), Alimos (GR)
  - **R&D:** ENEA (IT), ISR-UC (PT), Tecnalia (ES), EUDITI (GR), Aalborg University (DK)
  - **ESCOs:** ETVA VI.PE. (GR), ASSISTAL (IT), SINLOC (IT), INNOVA BIC (IT)



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Project CERtuS

- To prepare 12 representative nZEb renovation projects
- To adapt existing energy service models
- To work out financing schemes
- To provide means and examples
- To support replication by capacity building

Current Building Conditions

- Coimbra is the largest city in Centro Region of Portugal, with about 101,000 inhabitants in the urban area and 150,000 inhabitants in the area of the municipality.

- As a historic city, Coimbra holds an important cultural and architectural heritage. Part of the historic city centre, older University buildings and other urban structures are since June, 22nd 2013 inscribed on the World Heritage List of UNESCO.

- The selected buildings for CERtuS are
  - Town Hall
  - Municipal House of Culture
  - Elementary School of Solum

Elementary School of Solum

- The building was built in the 1950s and was converted into an Elementary School in the 1990s.
- The construction of refectory and a partial renovation of the building was done 10 years ago.
- The building is divided in 3 main areas: 2 blocks of classrooms and the refectory.

Floors	2
Area	1,650 m^2
Volume	6,270 m^3
Roof surface	900 m^2
Orientation	East–west Axis

Elementary School of Solum

- The lighting system is mainly constituted by fluorescent linear T8 lamps with electromagnetic ballast.
- The central heating of the refectory is ensure by a gas boiler.
- The 2 main blocks ensure the heating during the coldest days with oil-filled radiators.
- The building already has a small PV system (18 panels with a total power of 4.23 kW) and a 200-litre solar thermal system.

Electricity	23 MWh/year
Gas	17 MWh/year
Generation	6.1 MWh/year

Municipal House of Culture

- The Municipal House of Culture was built in 1991-1993.
- It has several cultural equipment, such as library, auditorium and art gallery, as well as several offices used by Municipality.
- The building has 80 employees and is visited by 17,500 users/year and has activities (Monday to Saturdays) between 9h00 and 19h00.

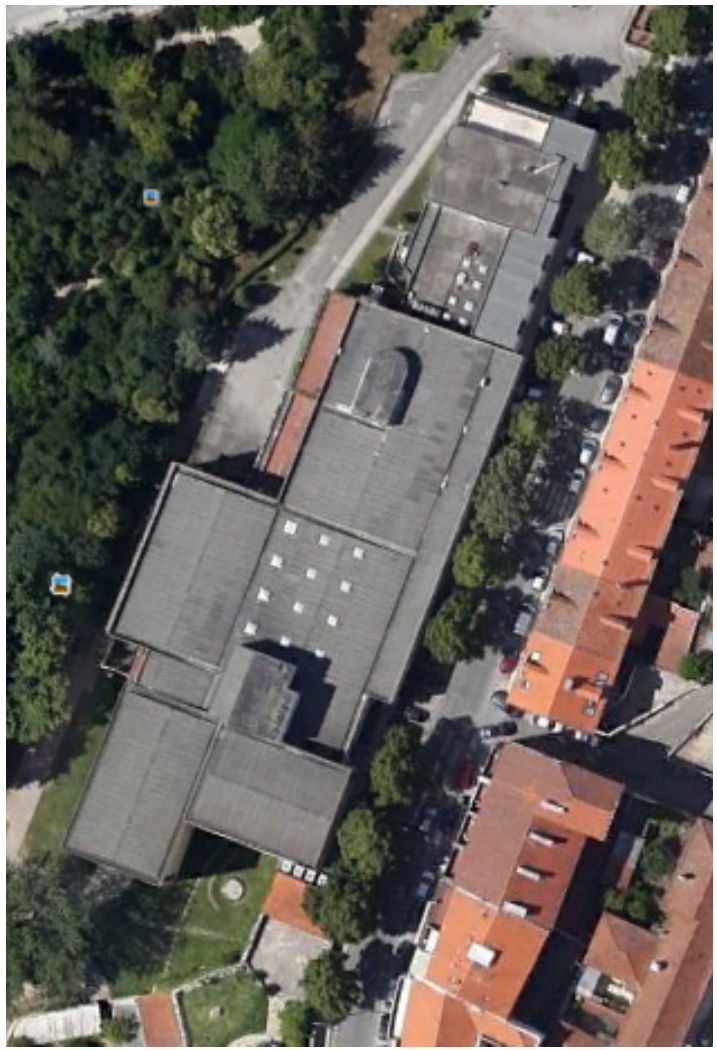
Floors	8
Area	13,200 m^2
Volume	39,900 m^3
Roof surface	2,60 m^2
Orientation	Southwest Axis

Municipal House of Culture

- The lighting is usually ensured by fluorescent lamps. Most of the rooms have a false roof in wood with small square holes, being the luminaries installed above the false roof.

- The building does not have a centralized HVAC system, being the HVAC ensured by several mono-split units. The exception to it, are the silos and the storage areas.

Electricity	488 MWh/year
Gas	0
Generation	0



Coimbra Town Hall

- The Town Hall was built after the demolition of part of the old Monastery of Santa Cruz, between 1876 and 1879, with some construction works developed until the beginning of century XX.
- The building is part of the property "University of Coimbra — Alta and Sofia" inscribed on the World Heritage List of UNESCO.
- The building is used as the Town Hall of the Municipality of Coimbra, being mainly constituted by offices and storage areas, has 220 employees and is visited by more than 25,000 users/year.

Floors	3+2
Area	5,900 m^2
Volume	40,600 m^3
Roof surface	2,000 m^2
Orientation	Axis of 10º

Coimbra Town Hall

- The existing lighting is ensured by several different types of lamps and luminaires, including fluorescent linear T8 and T5 lamps, several types of compact fluorescent lamps, incandescent lamps, halogen spots and projectors and metal halide lamps.
- The HVAC is ensured by 8 multi-split units and 21 mono-split units. Almost all the areas of permanent use have HVAC systems.

Electricity	305 MWh/year
Gas	0
Generation	0

Renovation Scheme

- Each renovation scheme was proposed according to the specific characteristics and conditions of the buildings and different scenarios were simulated in order to reach the optimum renovation design.

- Objectives
  - Maximize the use of renewable energy generation
  - Achieve a high impact with the use of a small group of technologies
  - Achieve a short payback time
- The selected renovation options are concentrated in three main areas:
  - Lighting
  - HVAC
  - Photovoltaic generation

Elementary School of Solum

- **Lighting**
  - Decrease on the installed power of about 4 kW
  - 5,730 kWh/year (57.9%) of savings

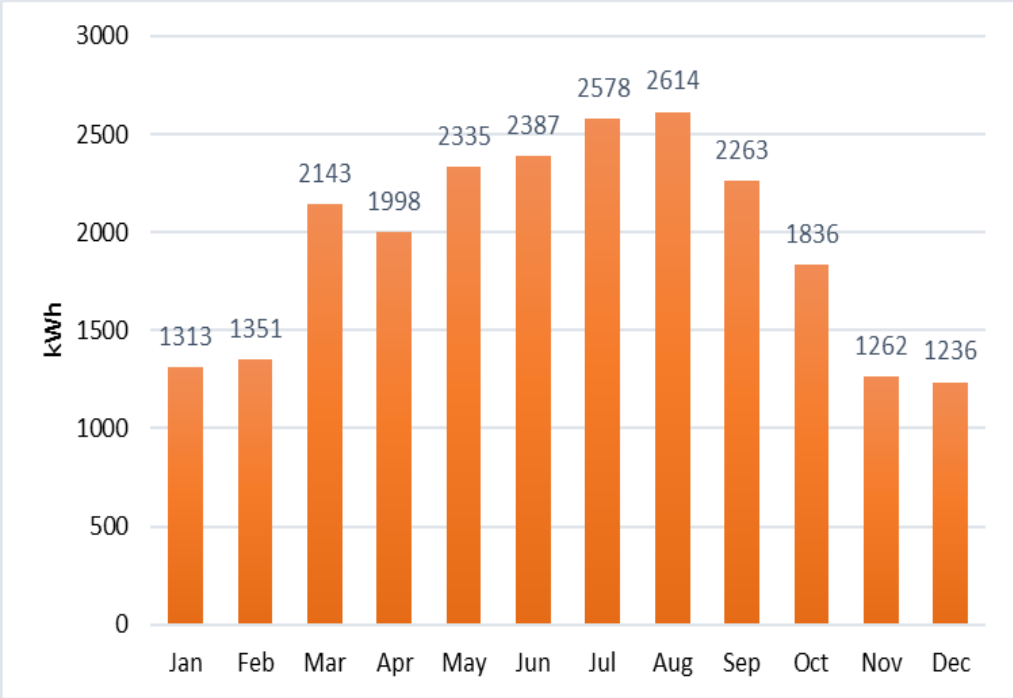
Actual			Renovation		
Lamp	**Q (n)**	**P (W)**	**Lamp**	**Q (n)**	**P (W)**
Fluorescent Linear T8 F150	4	270	LED Linear F150	4	85
Fluorescent Linear T8 F120	127	5,940	LED Linear F120	127	2,540
Fluorescent Linear T8 F60	12	280	LED Linear F60	12	120
Compact Fluorescent	28	500	LED Bulb	28	265
Emergency	4	50	LED Emergency	4	5
Total	**175**	**7,040**	**Total**	**175**	**3'025**

- **HVAC**
  - Replacement of the gas boiler by a heat pump with COP 3.6
  - 11.9 MWh/year (70.8%) of energy savings

Elementary School of Solum

- **PV Generation**
  - PV panels oriented to south, but keeping the orientation of the building (azimuth of -15º)
  - Installation of 72 PV panels (16.92 kWp)
  - Total generation of about 23 MWh/year

Number of PV modules	In series 18 modules In parallel 4 strings
Unit Nominal Power	235 Wp
Total Power	4.23 kWp
Total area	Module 117 m² Cell 43.2 m²
Generated Energy	23.32 MWh/year
Specific Generation	1,378 kWh/kWp/year



Municipal House of Culture

- **Lighting**
  - Decrease on the installed power of about 42 kW
  - 101 MWh/year (60.6%) of savings

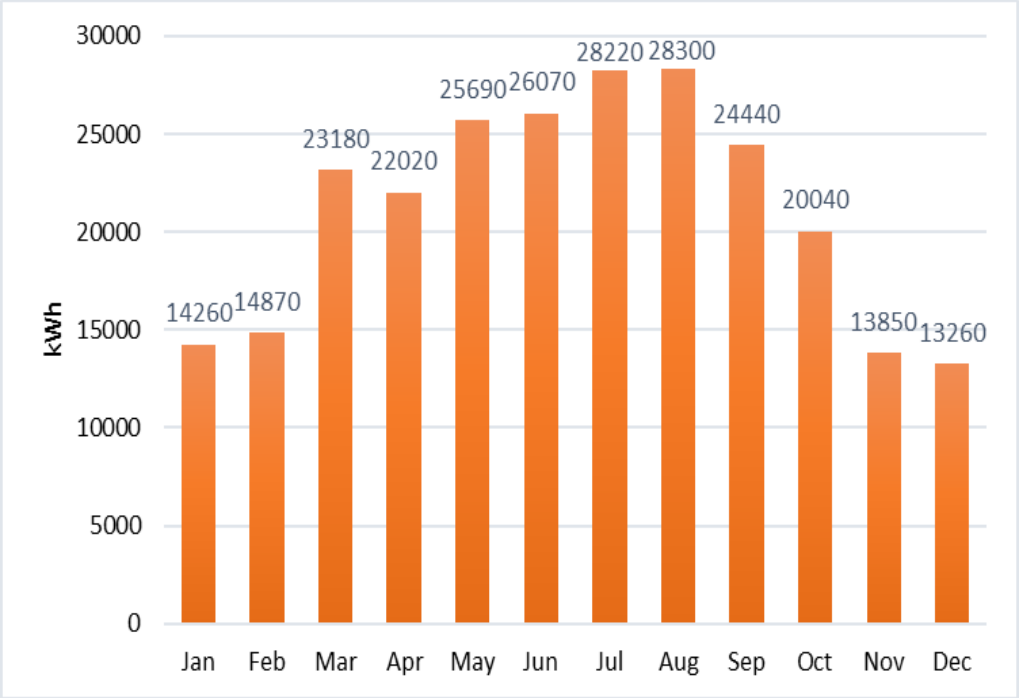
Actual			Renovation		
Lamp	**Q (n)**	**P (W)**	**Lamp**	**Q (n)**	**P (W)**
Fluorescent Linear T8 F150	312	21,090	LED Linear F150	312	7,490
Fluorescent Linear T8 F120	803	37,580	LED Linear F120	803	16,060
Fluorescent Linear T8 F60	9	210	LED Linear F60	17	170
Fluorescent Linear T5 F60	8	140			
Halogen Projector	24	7,200	LED Projector	24	2,400
Halogen Spot	5	250			
LED Spot	12	70	LED Spot	17	95
Incandescent	23	1,380			
Compact Fluorescent	70	1,260	LED Bulb	93	885
Total	**1,266**	**69,180**	**Total**	**1,266**	**27,100**

- **HVAC**
  - 9 Systems of temperature and humidity with an EER of 2.43, COP of 2.97 and a total power of 301 kW replaced by systems with EER of 5.2 and COP of 5.74.
  - Mono-split systems with heat pumps with a total power of 239 kW replaced by systems with average EER of 6.7 and COP of 4.1.
  - 118 MWh/year (61.3%) of energy savings.

Municipal House of Culture

- **PV Generation**
  - PV panels oriented to south, but keeping the orientation of the building (azimuth of 20º)
  - Installation of 770 PV panels (181 kWp)
  - Total generation of about 254.2 MWh/year

Number of PV modules	In series 22 modules In parallel 35 strings
Unit Nominal Power	235 Wp
Total Power	181 kWp
Total area	Module 1,248 m² Cell 462 m²
Generated Energy	254.2 MWh/year
Specific Generation	1,405 kWh/kWp/year



Coimbra Town Hall

- **Lighting**
  - Decrease on the installed power of about 34 kW
  - 49 MWh/year (57%) of savings

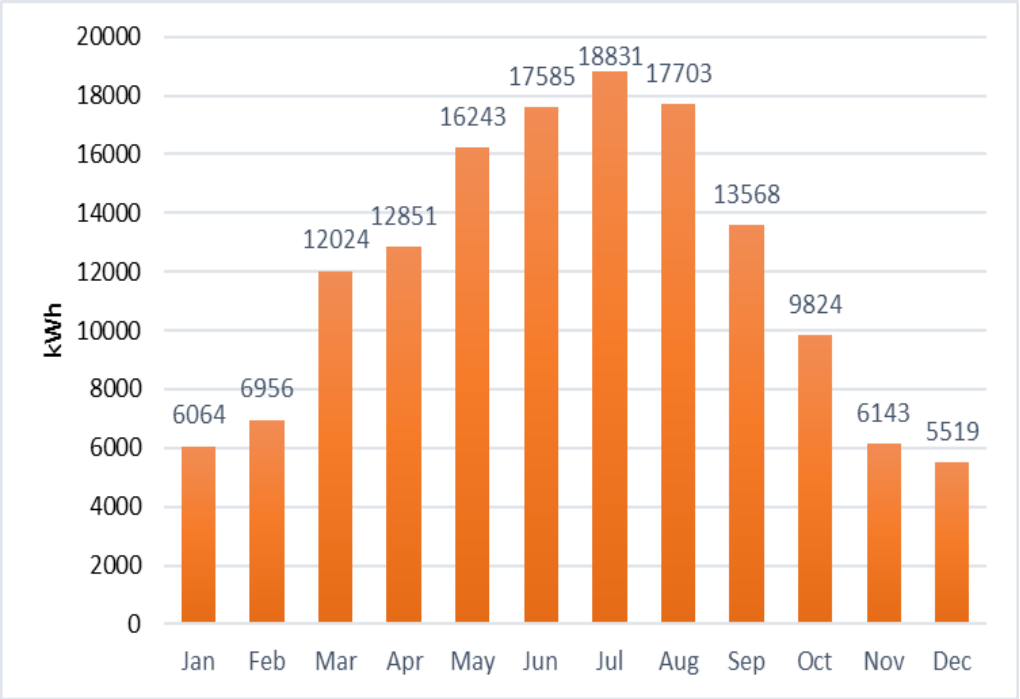
Actual			Renovation		
Lamp	Q (n)	P (W)	Lamp	Q (n)	P (W)
Compact Fluorescent E27	139	2,500	LED E27	173	1,640
Incandescent	34	2,040			
Compact Fluorescent E14	156	1,400	LED E14	156	470
Compact Fluorescent 2G11	182	4,910	LED 2G11	182	3,280
Fluorescent Linear T8 F30	6	70	LED Linear F30	6	40
Fluorescent Linear T8 F60	69	1,620	LED Linear F60	69	690
Fluorescent Linear T8 F120	242	11,330	LED Linear F120	262	5,240
Fluorescent Linear T5 F120	20	600			
Fluorescent Linear T8 F150	195	13,200	LED Linear F150	251	6,020
Fluorescent Linear T5 F150	56	3,130			
Halogen Spot	4	200	LED Spot	4	20
Halogen Projector	22	5,500	LED Projector	22	2,200
Halogen Projector	18	9,000	LED Projector	18	3,600
Metal Halide	10	2,500	LED Projector	10	800
Total	**1,153**	**58,000**	**Total**	**1,153**	**24,000**

- **HVAC**
  - 8 multi-split systems with 211 kW replaced by systems with average EER of 5.2 and COP of 5.7.
  - 21 mono-split systems with 62 kW replaced by systems with average EER of 8.1 and COP of 4.7.
  - 57 MWh/year (62.6%) of energy savings.

Coimbra Town Hall

- **PV Generation**
  - Due to the protection rules, the use of traditional PV panels was not considered
  - 2,102 m^2 of thin film solar tiles (126.1 kWp)
  - Total generation of about 143.3MWh/year

Total Power	126.1 kWp
Total area	2,102 m²
Generated Energy	143.3 MWh/year
Specific Generation	1,336 kWh/kWp/year



Impact Assessement

- The impact of each renovation scheme was assessed in terms of :
  - Energy savings
  - Net-energy consumption
  - Contribution of renewable generation
  - Specific energy consumption
  - Primary energy
  - CO_2 emissions

- The main objectives were to achieve:
  - 75-80% reduction on the net energy consumption
  - 50-90% of the consumption ensured by renewable generation in the building.

Elementary School of Solum

- 42.1% of energy savings
- 96.2% of RES
- 97.4% reduction on the net-energy consumption

Scenario	Consumption (kWh/Year)	Savings (kWh/Year)	Generation (kWh/Year)	Net-Cons. (kWh/Year)
Before Renovation	41,850	-	6,100	35,750
Lighting Renovation	36,120	5,730	6,100	30,020
HVAC Renovation	29,975	11,875	6,100	23,875
PV Installation	-	-	23,315	18,535
Total Renovation	**24,245**	**17,605**	**23,315**	**930**

Scenario	Final Energy (kWh/Year)	Specific Ener. (kWh/m²Year)	Prim. Energy (kWh/Year)	CO_2 Emissions (kgCO_2 /Year)
Electricity – Bef.	18,975	11.47	47,440	2,655
Gas - Before	16,775	10.14	16,775	3,390
Total - Before	35,750	21.61	64,215	6,045
Electricity – Af.	930	0.56	2,320	130
Gas - After	0	0	0	0
Total - After	930	0.56	2,320	130
Savings	**34,820**	**21.05**	**61,895**	**5,915**

- 96.4% savings in primary energy
- 97.8% savings in CO_2 emissions
- 0.56 kWh/m² of specific energy

Municipal House of Culture

- 45.1% of energy savings
- 95% of RES
- 97.2% reduction on the net-energy consumption

Scenario	Consumption (kWh/Year)	Savings (kWh/Year)	Generation (kWh/Year)	Net-Cons. (kWh/Year)
Before Renovation	487,230	-	-	487,230
Lighting Renovation	386,070	101,160	-	386,070
HVAC Renovation	368,840	118,390	-	368,840
PV Installation	-	-	254,200	233,030
Total Renovation	**267,680**	**219,550**	**254,200**	**13,480**

Scenario	Final Energy (kWh/Year)	Specific Ener. (kWh/m²Year)	Prim. Energy (kWh/Year)	CO_2 Emissions (kgCO_2 /Year)
Before	487,230	49.4	1,218,070	68,160
Renovation	13,480	1.4	33,700	1,890
Savings	**473,750**	**48.0**	**1,184,370**	**66,270**

- 97.2% savings in primary energy
- 97.2% savings in CO_2 emissions
- 1.4 kWh/m² of specific energy

Coimbra Town Hall

- 34.2% of energy savings
- 72.1% of RES
- 81.8% reduction on the net-energy consumption

Scenario	Consumption (kWh/Year)	Savings (kWh/Year)	Generation (kWh/Year)	Net-Cons. (kWh/Year)
Before Renovation	305,100	-	-	305,100
Lighting Renovation	256,190	48,910	-	256,190
HVAC Renovation	247,730	57,370	-	247,730
PV Installation	-	-	143,310	161,790
Total Renovation	**198,820**	**106,280**	**143,310**	**55,510**

Scenario	Final Energy (kWh/Year)	Specific Ener. (kWh/m²Year)	Prim. Energy (kWh/Year)	CO_2 Emissions (kgCO_2 /Year)
Before	305,100	51.9	762,770	42,680
Renovation	55,510	9.4	138,770	7,765
Savings	**249,590**	**42,4**	**624,000**	**34,915**

- 81.8% savings in primary energy
- 81.8% savings in CO_2 emissions
- 9.4 kWh/m² of specific energy

Investment and Savings

Building	Investment €	Investment €/m²	Savings €/Year	Payback Years
Elementary School of Solum	31,469	19.12	5,082	6.2
Municipal House of Culture	338,274	26.6	53,081	6.0
Coimbra Town Hall	632,068	107.5	34,880	17

- To the financial scheme, an Energy Performance Contract of “shared savings” was chosen with 5% annual remuneration for the Municipality.

- Duration of the EPC
  - Elementary School of Solum - 15 years
  - Municipal House of Culture - 15 years
  - Coimbra Town Hall - 25 years

Investment and Savings

- Given the selected renovation schemes and the characteristic of the projects, an ESCO involvement is possible at current market conditions, but it needs a mix of financial sources, in particular the use of subsidised funds.

Building	Equity	Senior Debt	VAT Facilities	Subsidised
Elementary School of Solum	33.1%	53.3%	13.6%	0%
Municipal House of Culture	25.6%	59.8%	14.6%	0%
Coimbra Town Hall	9.9%	37.2%	3.5%	49.4%

ESCO Investment

- With the proposed financial structure, an ESCO intervention is possible and the remuneration of the invested capital is adequate for the two first buildings.
- For the Town Hall, an ESCO intervention at market conditions is sustainable, but with a lower profit.

Building	Equity Payback Year	ESCO IRR %	Equity NPV €
Elementary School of Solum	13.5	8.0	1054
Municipal House of Culture	12.5	9.06	23946
Coimbra Town Hall	18	7.5	5806

Conclusions

- The selected options (lighting, HVAC and PV) for the renovation design were able to ensure a high impact:
  - 81.8 – 97.2% of net energy savings
  - 72.1 – 96.4% of renewable generation
  - 0.56 – 9.4 kWh/m^2 of specific energy

- The designed options are cost-effective and an ESCO intervention is possible with enough remuneration of the invested capital.
  - ESCO interventions at market conditions in nearly zero energy renovations of public buildings are possible.

- The renovation projects and financial structure can be easily used as examples and adapted for other Municipalities.

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