Cost optimal analysis of PEBs

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Overview

- Objective and Introduction
- EXCESS project overview
- Demo buildings
- Cost optimal analysis - overview of method
- Results of Cost optimal analysis of EXCESS demos
  - Detailed analysis of Spanish pilot case
  - Sensitivity analysis
- Conclusion

Objective / Introduction

- European building stock is responsible for ~36% of CO_2 emissions in EU
- Around 90% of the buildings that exist today will still be standing in 2050

  => Strong need for renovation to decarbonize building sector
- New PEBs and renovation to PEB level is of highest importance
- Problem: High investment costs and long payback period for PEBs
- Target of the paper:
  - **Develop method to define cost-optimal technology packages of PEBs**
  - **Apply this method to two demo buildings of the EXCESS project**

The EXCESS project

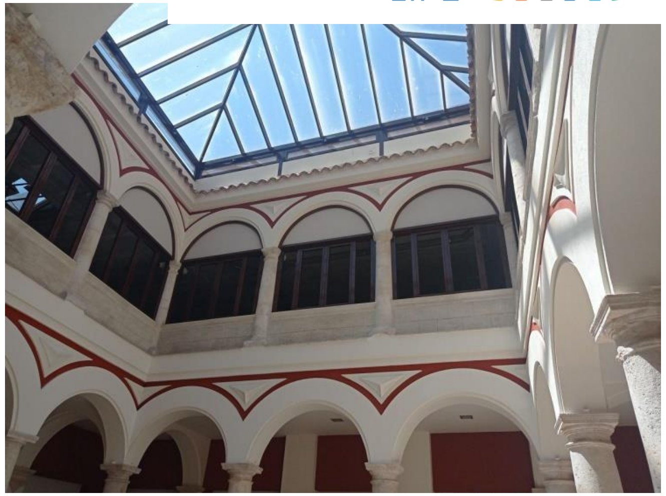
- EXCESS - FleXible user-CEntric Energy poSitive houseS
- EU Horizon2020 project with 21 partners from 8 countries, 2019-2024
- Main aim is to show how nZEBs can be transformed into PEBs
- Four demo sites in four different climate zones
- Focus on innovative technical solutions (deep boreholes for seasonal storage, PVT, multifunctional facade element, …)

EXCESS DEMO SITES

- *Demo Site Hasselt, Belgium*
- *Demo Site Granada, Spain*
- *Demo Site Helsinki, Finland*
- *Demo Site Graz, Austria*

EXCESS demo case Spain/Valladolid

- Historical palace from 16th century
- Located in the historical center of Valladolid
- Mediterrane climate
- Deep insulation without change of facade
- Change from gas to aerothermal heat pump (40kW) and floor heating
- PV (51.4kWP) with battery (30kWh)
- PVT for DHW (2.8kW)
- Building will achieve PEB-level after renovation

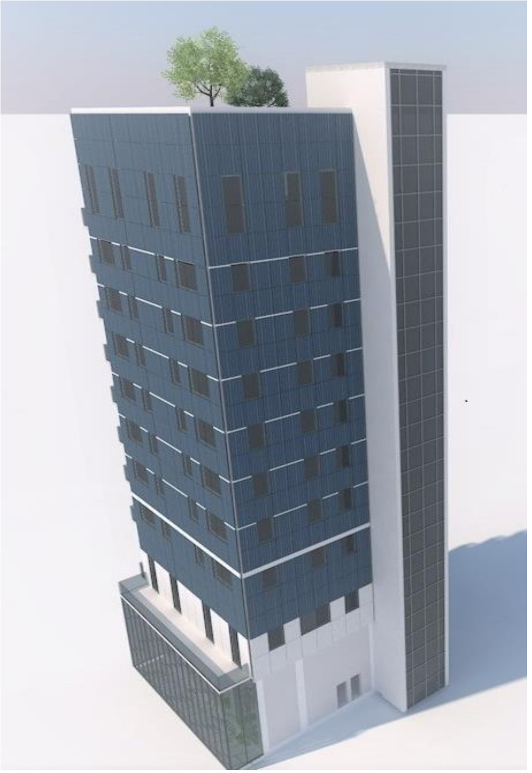


EXCESS demo case Helsinki/Finnland

- New building in Kalasatama district, city of Helsinki
- 8 floors, mixed-use building including residential apartments, commercial spaces and a restaurant
- Nordic climate
- ~600m deep boreholes, 79 kWp PVT for th e67 kW heatpump and recharging the bedrock ->seasonal storage
- 87 kWp building integrated PV
- PEB level cannot be achieved

EXCESS demo case Austria/Graz

- Former feed production silo in former industrial area of Graz
- Continental climate
- Renovation to an area with mixed uses including offices, sport facilities and restaurants
- Renovation with highly insulated prefabricated multifunctional façade elements (component activation, insulation, BiPV)
  - 88kWp building integrated PV
- Cascadic heat pump system for heating and cooling
- Building energy management system

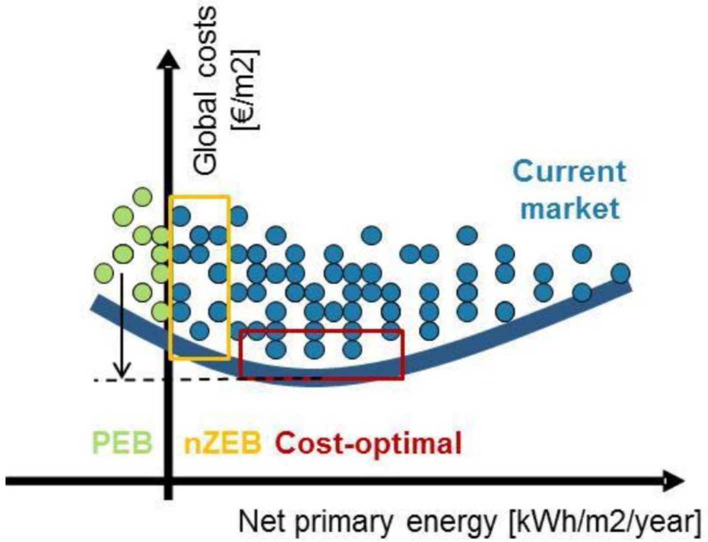


EXCESS demo case Belgium/Hasselt

- Social housing complex in Hasselt
- Demo building includes four apartment with 20 dwellings
- Oceanic/Coastal climate
- Change to multisource geothermal heat pump
- 44kWp PV for renewable electricity
- 44kWp PVT panels for electricity, heatpump and recharge of bedrock
- Small wind turbine on the roof (5kWe)
- Building energy management system
- PEB level may be achieved after renovation

Cost-optimal analysis method and approach

- Method based on cost-optimal framework acc. (EU) No 244/2012 – supplementing guideline to EPBD
  - Guideline defines a framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements
- Comparison of global costs (as NPV) and net primary energy demand (cost/energy curves)
- Approach in EXCESS project
  - Definition of technology packages
  - Cost/energy curves for several technology packages of pilots
  - Identification of cost-optimal technical solutions and technology packages for pilot cases



Cost-optimal analysis method

- Global costs include
  - Investment costs
  - Replacement cost (if expected technology lifetime is lower than the calculation period)
  - Residual value (if expected technology lifetime is higher than the calculation period)
  - Maintenance and operation cost for complete calculation period
  - Energy cost and revenues from RES feed-in for complete calculation period
  - All values as NPV (discount factor 3%)
- Net primary energy demand includes
  - Annual energy demand for heating, cooling, air-conditioning, DHW and lighting
  - Annual electricity production from RES
  - Energy demand/production in terms of primary energy
- Calculation parameter
  - Calculation period: 30 years (according cost-optimal framework EU No 244/2012)
  - Discount factor: 3%

EXCESS demo Valladolid – scenarios and technology packages

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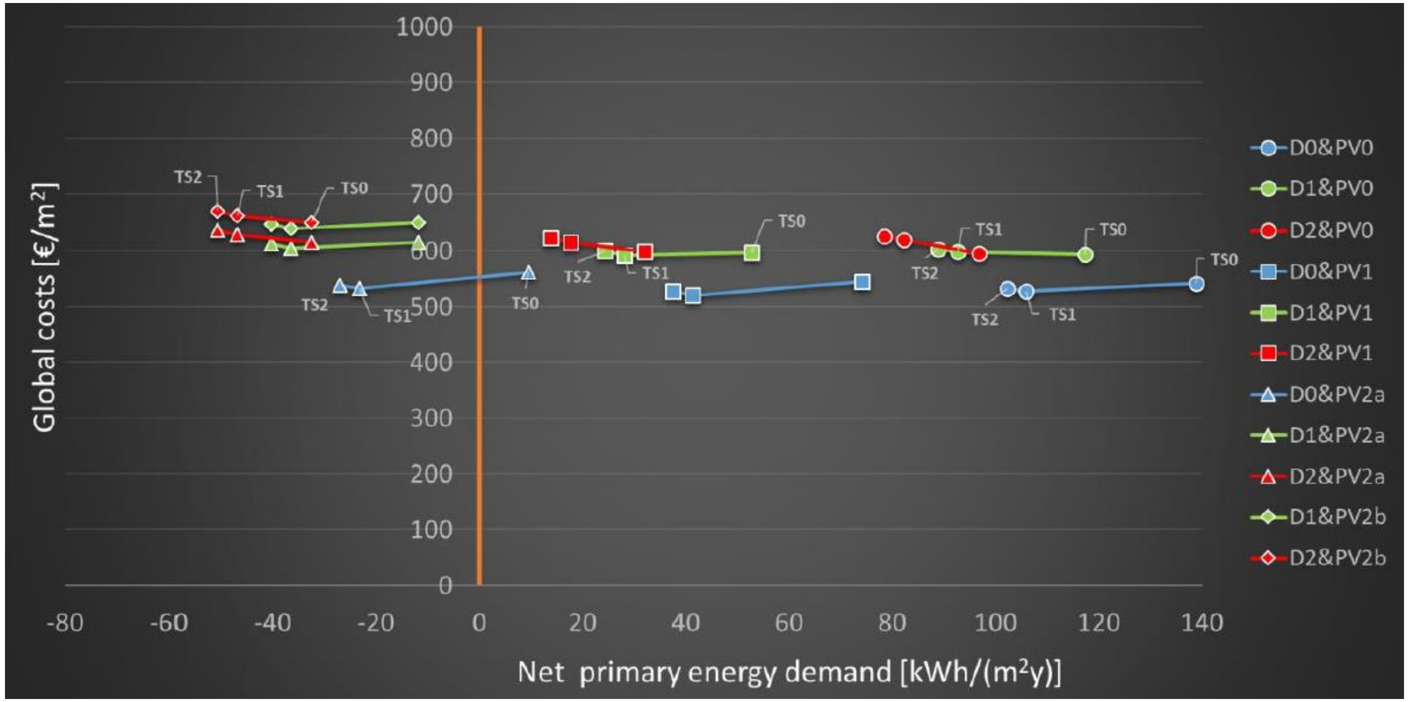
- Scenarios for building elements (envelope, thermal system, PV, BEMS) defined
- Scenarios are combined to 42 technology packages and cost-optimal framework applied

	Scenario	Description	Investment costs [€]	Investment costs per unit [€/(m² or kW or kWh)]	Expected technology lifetime [y]
Building envelope	D0	Baseline Spanish regulation envelope; U-value of envelope [W/(m²K)]: walls 0.41, roof 0.35, floor 0.65, windows 1.8	143 700	131 €/m²	50
	D1	High efficiency envelope; U-value of envelope [W/(m²K)]: walls 0.13, roof 0.1, floor 0.27, windows 0.87	269 100	247 €/m²	50
	D2	High efficiency envelope D1 plus heat recovery unit **(EXCESS scenario)**	318 600	292 €/m²	50
Thermal system	TS0	Gas heating with boiler and solar thermal for DHW	78, 300	348 €/kW	15
	TS1	Aerothermal heat pump (40 kW) with floor heating	156 200	3905 €/kW	20
	TS2	Aerothermal heat pump (40kW) with PVT (2.8kW) for DHW **(EXCESS scenario)**	164 600	3905 €/kW HP 3000 €/kWp PVT	20
PV facility	PV0	no PV	0	0 €/kWp	n.a.
	PV1a	22.75 kWp (70 panels each 375Wp), no storage	48 000	2110 €/kWp	25
	PV2a	51.38 kWp (70 panels each 375Wp), no storage	95 900	1866 €/kWp	25
	PV2b	51.38 kWp (70 panels a 375Wp), 30kWh battery energy storage **(EXCESS scenario)**	149 900	1866 €/kWp PV 1800 €/kWh bat.	25
Building management system	CS0	Baseline monitoring - control for heaters	4 100	n.a.	30
	CS1	Standard monitoring - control for space heating/cooling floor	15 000	n.a.	30
	CS2	Advanced Building Energy Management System **(EXCESS scenario)**	58 500	n.a.	30

Envelope	Thermal system	PV facility	Building management system	Gas demand [kWh/(m²y)]	Electricity demand (incl. plug loads) [kWh/(m²y)]	Electricity demand w/o plug loads) [kWh/(m²y)]	Electricity production [kWh/(m²y)]	Net Primary Energy demand wo plug loads [kWh/(m²y)]	Global costs wo plug loads [€/m²]
D0	TS0	PV0	CS0	77	36	22	0	139	637
D1	TS0	PV0	CS0	60	36	22	0	117	671
D2	TS0	PV0	CS0	42	36	22	0	97	669
D0	TS1	PV0	CS1	0	64	50	0	106	587
D1	TS1	PV0	CS1	0	58	44	0	93	649
D2	TS1	PV0	CS1	0	53	39	0	82	679
D0	TS2	PV0	CS1	0	63	49	0	102	582
D1	TS2	PV0	CS1	0	56	42	0	89	644
D2	TS2	PV0	CS1	0	51	37	0	78	674
D0	TS0	PV1a	CS0	77	36	22	31	74	650
D1	TS0	PV1a	CS0	60	36	22	31	53	684
D2	TS0	PV1a	CS0	42	36	22	31	32	682
D0	TS1	PV1a	CS1	0	64	50	31	41	587
D1	TS1	PV1a	CS1	0	58	44	31	28	651
D2	TS1	PV1a	CS1	0	53	39	31	18	682
D0	TS2	PV1a	CS1	0	63	49	31	38	584
D1	TS2	PV1a	CS1	0	56	42	31	24	648
D2	TS2	PV1a	CS1	0	51	37	31	14	679
D0	TS0	PV2a	CS0	77	36	22	62	10	680
D1	TS0	PV2a	CS0	60	36	22	62	-12	713
D2	TS0	PV2a	CS0	42	36	22	62	-32	711
D0	TS1	PV2a	CS1	0	64	50	62	-23	609
D1	TS1	PV2a	CS1	0	58	44	62	-37	673
D2	TS1	PV2a	CS1	0	53	39	62	-47	706
D0	TS2	PV2a	CS1	0	63	49	62	-27	606
D1	TS2	PV2a	CS1	0	56	42	62	-40	672
D2	TS2	PV2a	CS1	0	51	37	62	-51	704
D0	TS0	PV2b	CS0	77	36	22	62	10	711
D1	TS0	PV2b	CS0	60	36	22	62	-12	745
D2	TS0	PV2b	CS0	42	36	22	62	-32	742
D0	TS1	PV2b	CS1	0	64	50	62	-23	641
D1	TS1	PV2b	CS1	0	58	44	62	-37	706
D2	TS1	PV2b	CS1	0	53	39	62	-47	737
D0	TS2	PV2b	CS1	0	63	49	62	-27	639
D1	TS2	PV2b	CS1	0	56	42	62	-40	704
D2	TS2	PV2b	CS1	0	51	37	62	-51	736
D1	TS1	PV2b	CS2	0	56	42	62	-40	717
D2	TS1	PV2b	CS2	0	52	38	62	-50	749
D1	TS1	PV2b	CS2	0	55	41	62	-44	715

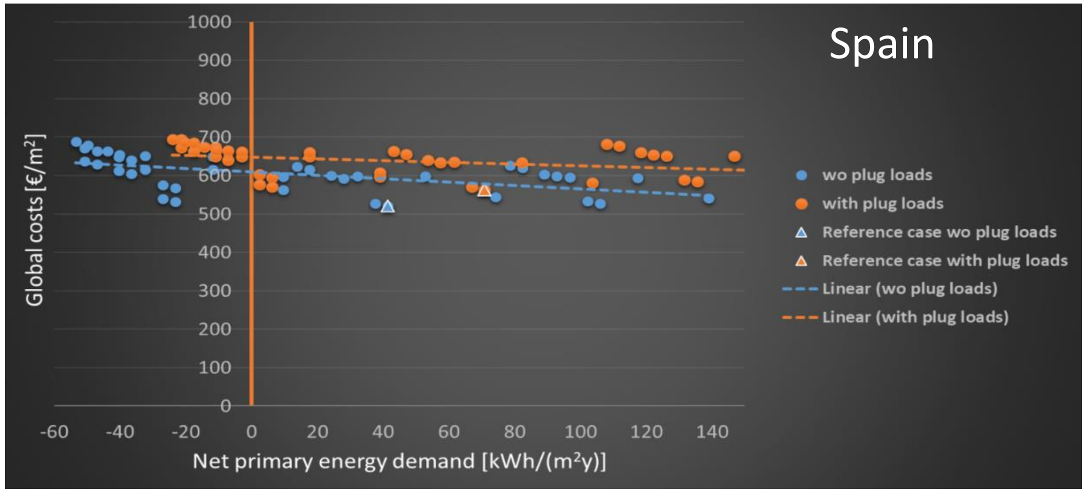
EXCESS demo Valladolid – results of cost optimal analysis

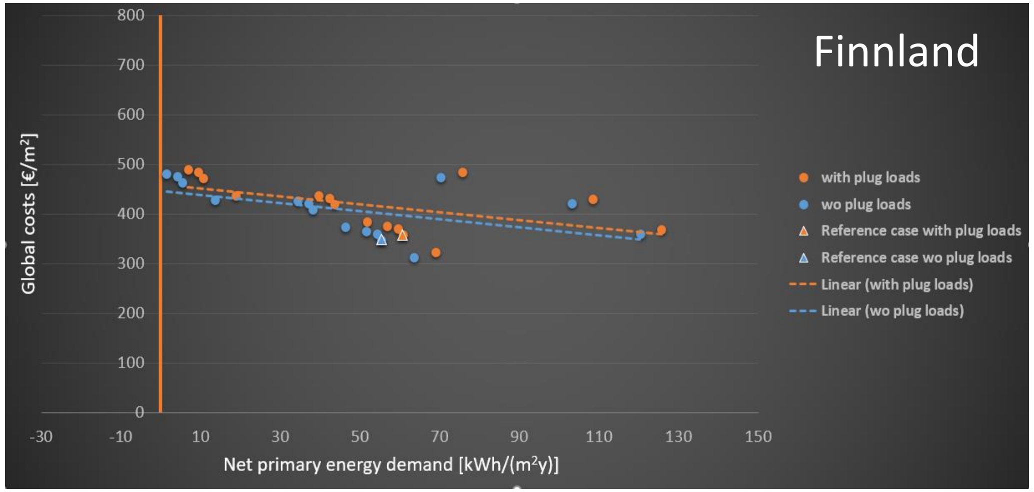
- Analysis of heating system

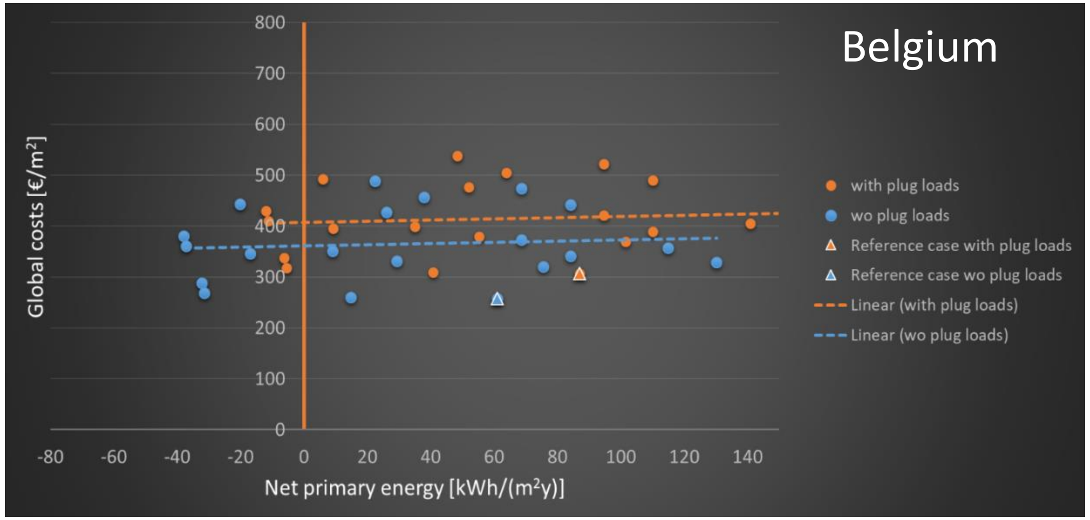


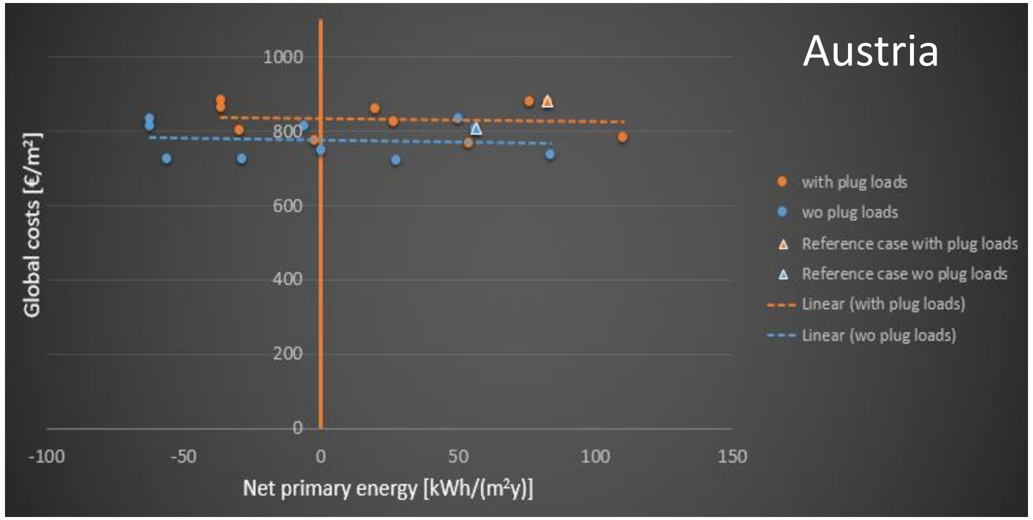
- TS0: Business as usual (gas heating system)
- TS1: Aerothermal heatpump
- TS2: Aerothermal heatpump + PVT (DHW)
- Change from TS0 to TS1
  - reduces net primary energy and global costs (for envelop D0 and D1)
  - Reduces net primary energy but increases global costs (for envelop D2)
  - => Cost effectiveness depends on quality of envelope
- Change from TS1 to TS2
  - Increases global costs => PVT not cost effective
- TS1 cost-optimal heating system scenario

Cost-optimal analysis of EXCESS demos



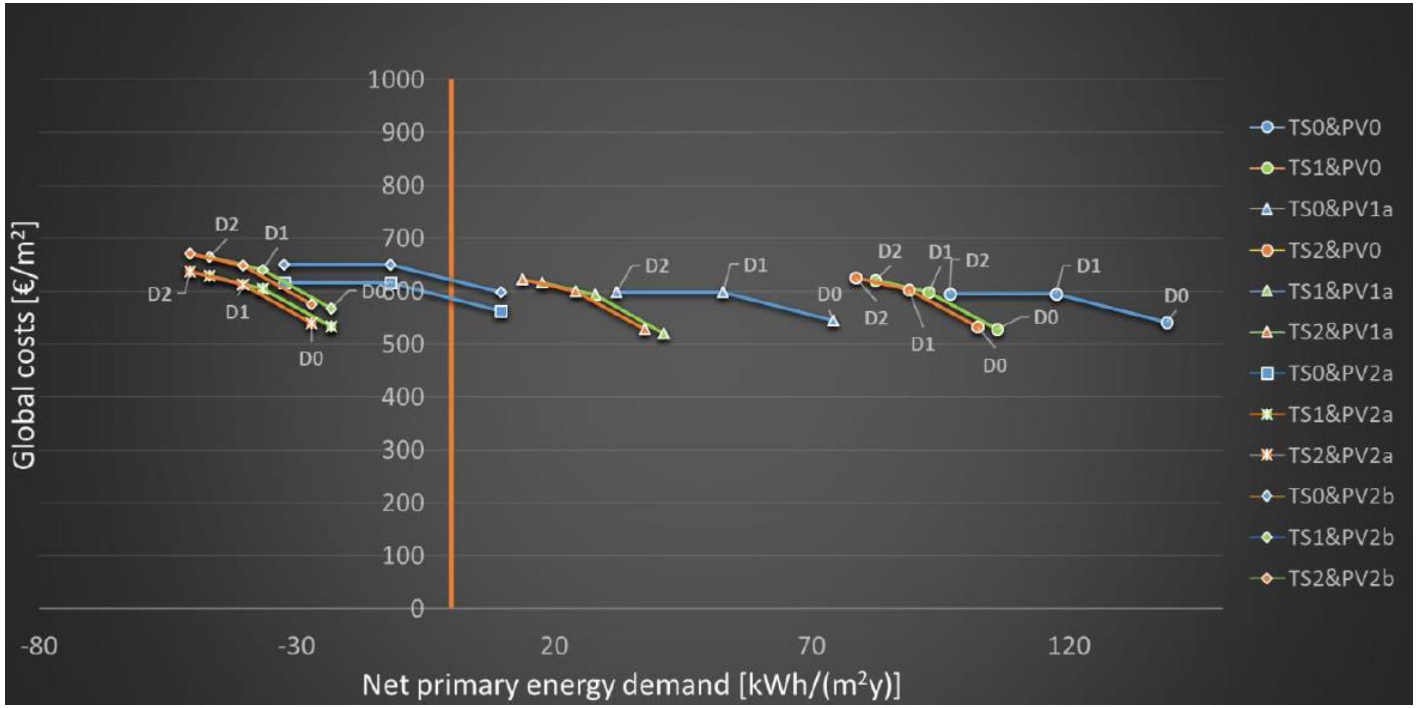






EXCESS demo Valladolid – results of cost optimal analysis

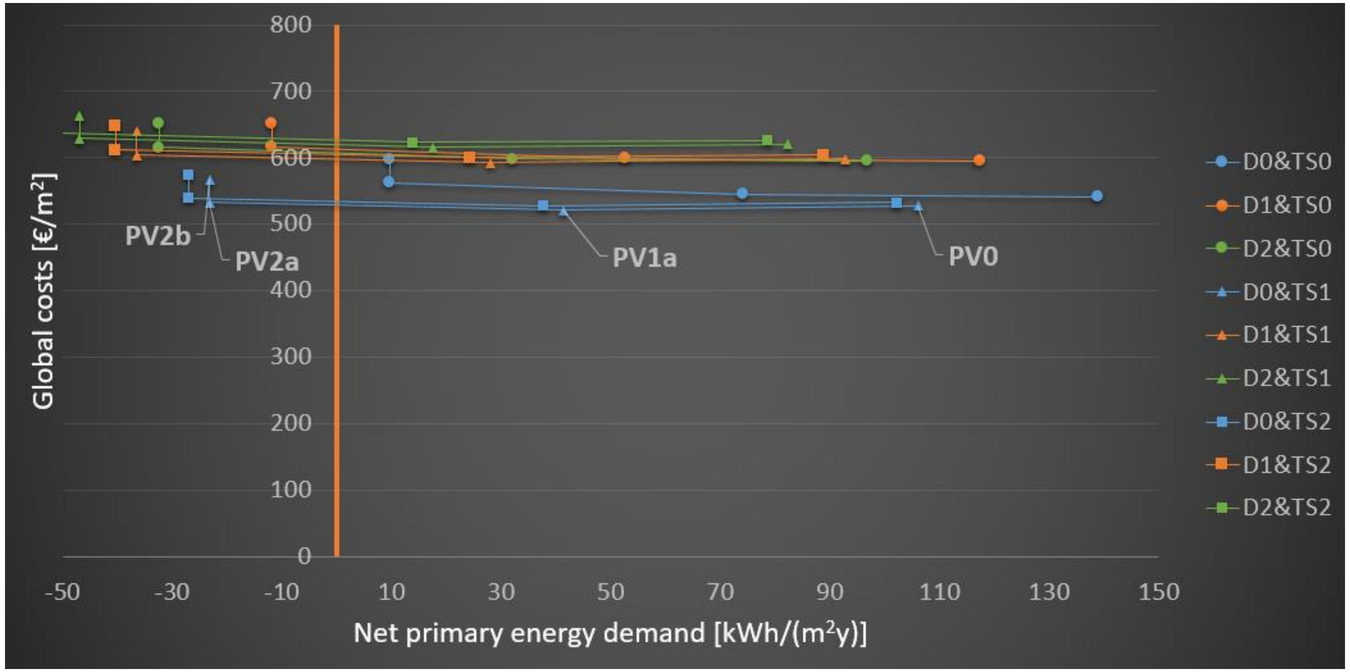
- Analysis of envelope



- D0: Baseline Spanish regulation envelope
- D1: Envelope high efficiency
- D2: Envelope high efficiency + heat recovery
- Change from D0 to D1 to D2
  - reduces net primary energy but increases global costs
  - => D0 is cost efficient technology in Spanish pilot case

EXCESS demo Valladolid – results of cost optimal analysis

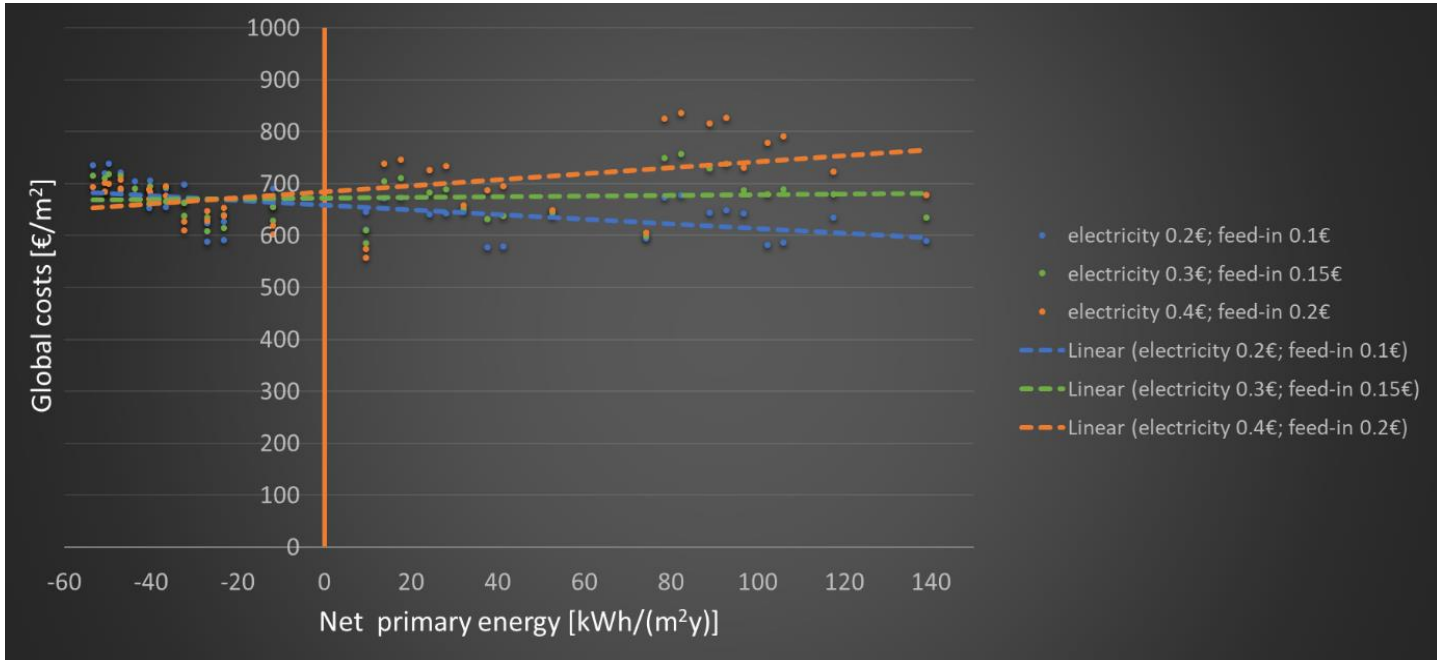
- Analysis of PV system



- PV0: no PV system
- PV1: 22.75 kWp PV, no storage
- PV2a: 51.38 kWp PV, no storage
- PV2b: 51.38 kWp PV, 30kWh battery storage
- Change from PV0 to PV1 to PV2a
  - reduces net primary energy without increase of global costs => cost efficient
- Change from PV2a to PV2b
  - No influence on net primary energy but increase of global costs => not cost efficient
- PV2a is cost efficient scenario

EXCESS demo Valladolid – results of cost optimal analysis

- Sensitivity analysis



- High influence of electricity cost
- Slope of linear trendline decreases for electricity prices of 0.3€ and feed-in tariffs of 0.2€
- Electricity prices of 0.4€ turns almost all analysed PEB technologies into cost-efficient technologies that reduce global costs

Cost savings not yet sufficiently considered

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- Revenues from demand response unclear
- Non-intrusivness can lead to cost savings
- Mounting costs can be reduced with better trained companies
- Serial renovation with prefabricated facades needs optimized production processes offsite and onsite
- Cost need to consider future needs, eg more cooling needs
- Materials such as for BIPV can have also other purpuses

Main Conclusions

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- Not all PEB technologies reduce global costs with current energy prices and a 30 years calculation period => subsidies, grants, other support needed to upscale PEBs
- Non intrusiveness of some technolgies
- Results very sensitive to calculation parameters (elec. prices, discount rate, calc. period)
- PV and change of heating system (from gas to heatpump) are cost-optimal
- PVT, BiPV, Co-generation unit and envelop improvement are often not cost-optimal if only energy demand/generation is considered

Main Conclusions

- Shape of building is a crucial parameter as PEB can be only achieved cost-efficient if there is enough area for renewables
- Even if technologies are not cost-optimal, they can be enabling technologies or provide additional benefits that were not considered in the analysis
- Focus should be on technological systems and an not on individual technologies
- Current PEB definition exhibits shortcomings => PEB possible just with PV if enough area is available

Thank you for your attention

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