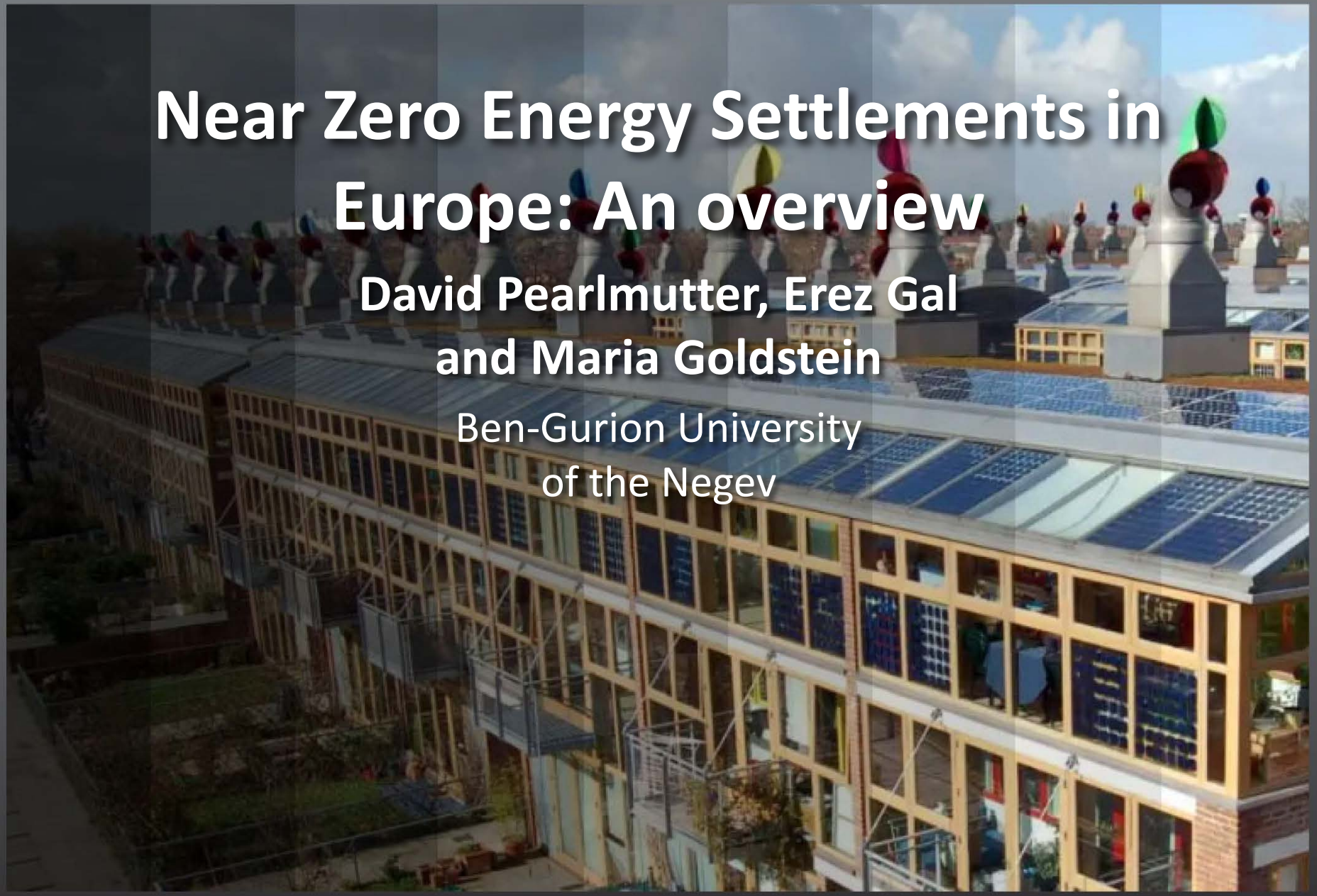


Near Zero Energy Settlements in Europe: An overview

David Pearlmutter, Erez Gal and Maria Goldstein

Ben-Gurion University of the Negev


FOSSIL FUEL CONSUMPTION
ZeroPlus
RENEWABLE PRODUCTION

ZERO-PLUS:

Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology

Work Package 1:

State of the Art on near Zero and Positive Energy Settlements

WP coordinators: David Pearlmutter, Erez Gal

WP Contributors: Maria Goldstein, Wolfgang Motzafi-Haller

Ben-Gurion University of the Negev, Israel

ZERO-PLUS:

Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology

Summary of current state of the art on NZE settlements in Europe

- **Objective**: Gain a deep understanding of the existing state of the art on near zero energy (NZE) settlements in different European countries, and their specific design.

- **Deliverable**: Report analyzing the literature on near zero energy residential settlements in Europe (Submitted: February 2016)

ZERO-PLUS:

Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology

- **Methodology**: a survey of academic and professional publications, as well as national and EU databases, on NZE buildings and settlements

- **Motivation:** Identifying *cost-optimal* solutions which take into account different climate zones and energy price scenarios

- **Application**: use flexible tools to derive cost-energy curves which represent the global cost vs. *net* primary energy demand of existing solutions (considering both energy conservation measures and renewable energy systems)

ZERO-PLUS:

Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION

HORIZON 2020

1. Introduction

- Energy use in the built environment
- Net zero: Buildings and settlements
- NZE at the settlement scale
- Investment in NZE settlements: costs and benefits

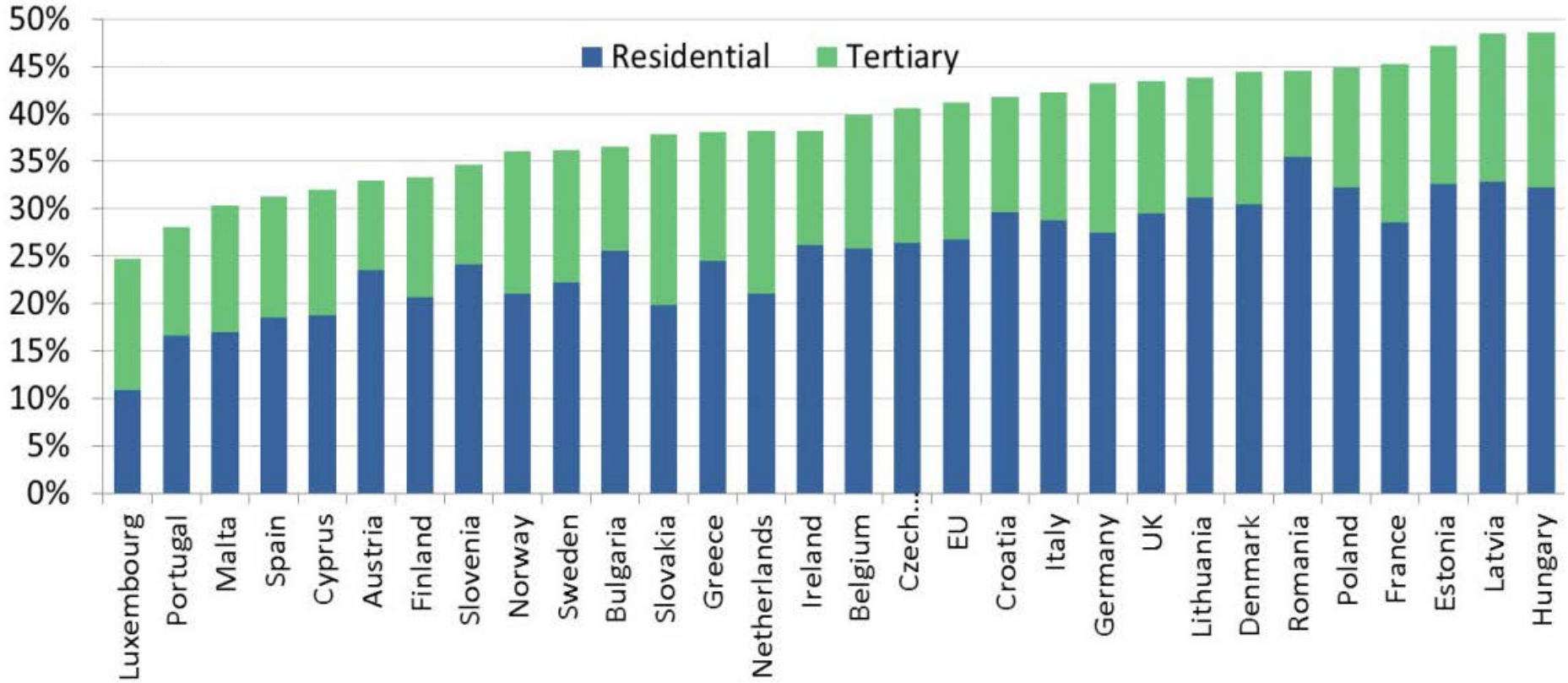
2. State of the art NZE technologies

- Energy conservation measures
- Renewable energy systems
- Space heating and cooling systems
- Energy management solutions

3. Case Studies & Lessons

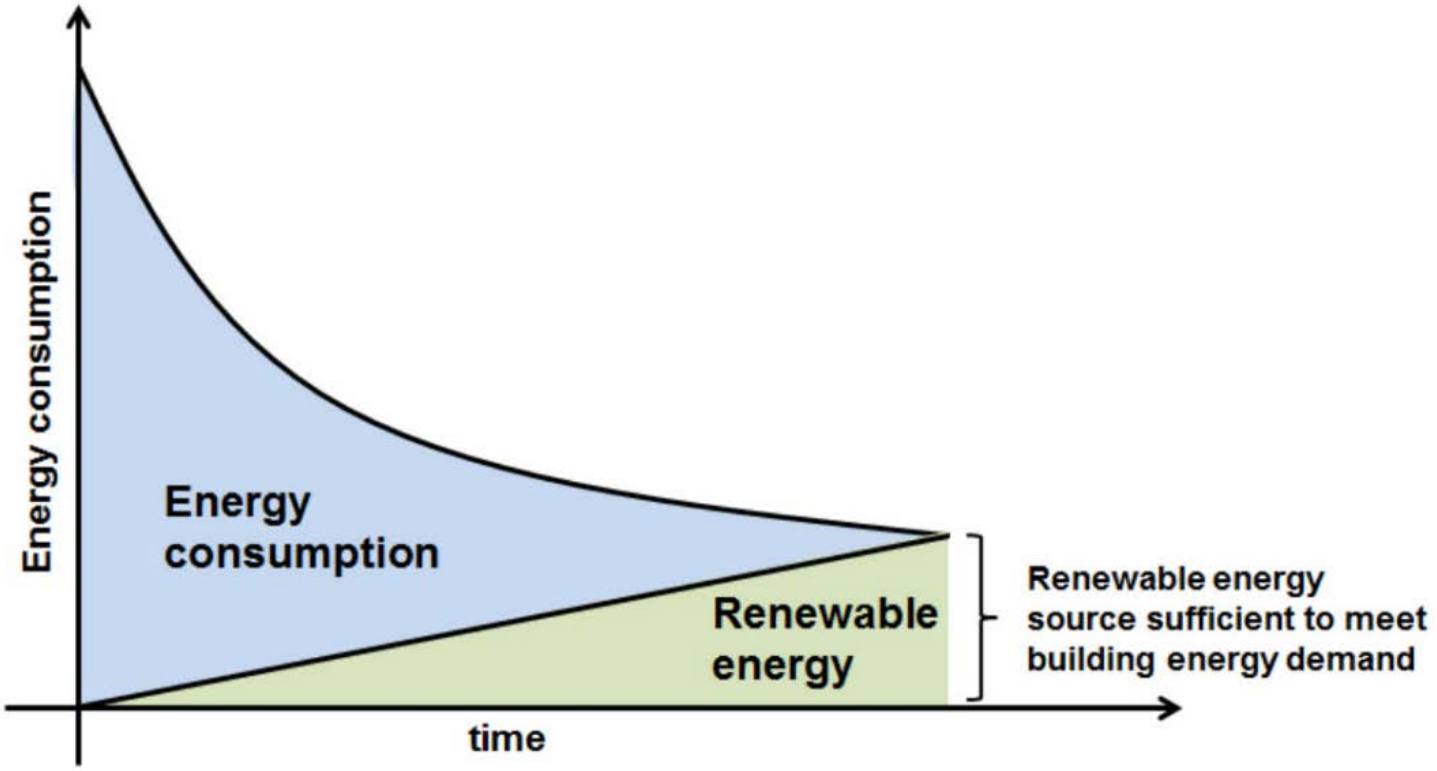
- NZE settlements in heating-dominated climates in Europe
- NZE settlements in cooling-dominated climates in Europe

Energy consumption in the built environment



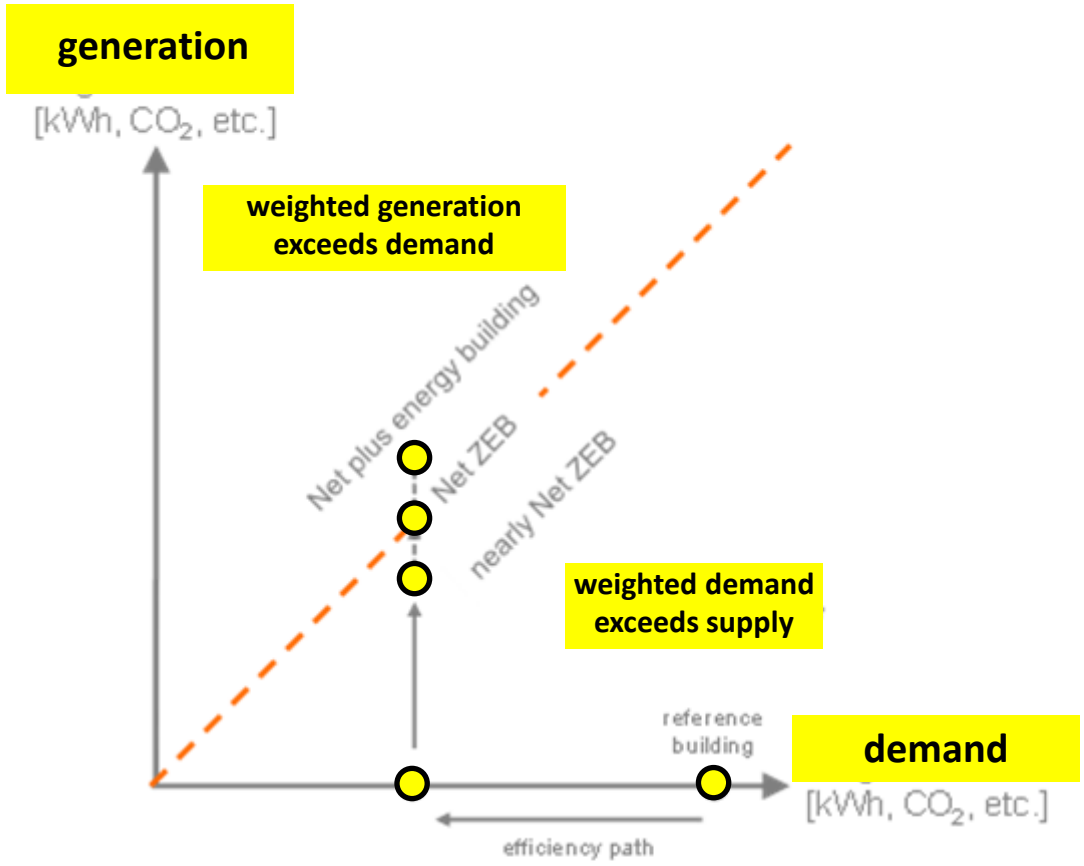
Share of buildings in final energy consumption (Odyssee-Mure, 2012).

Net zero buildings and settlements



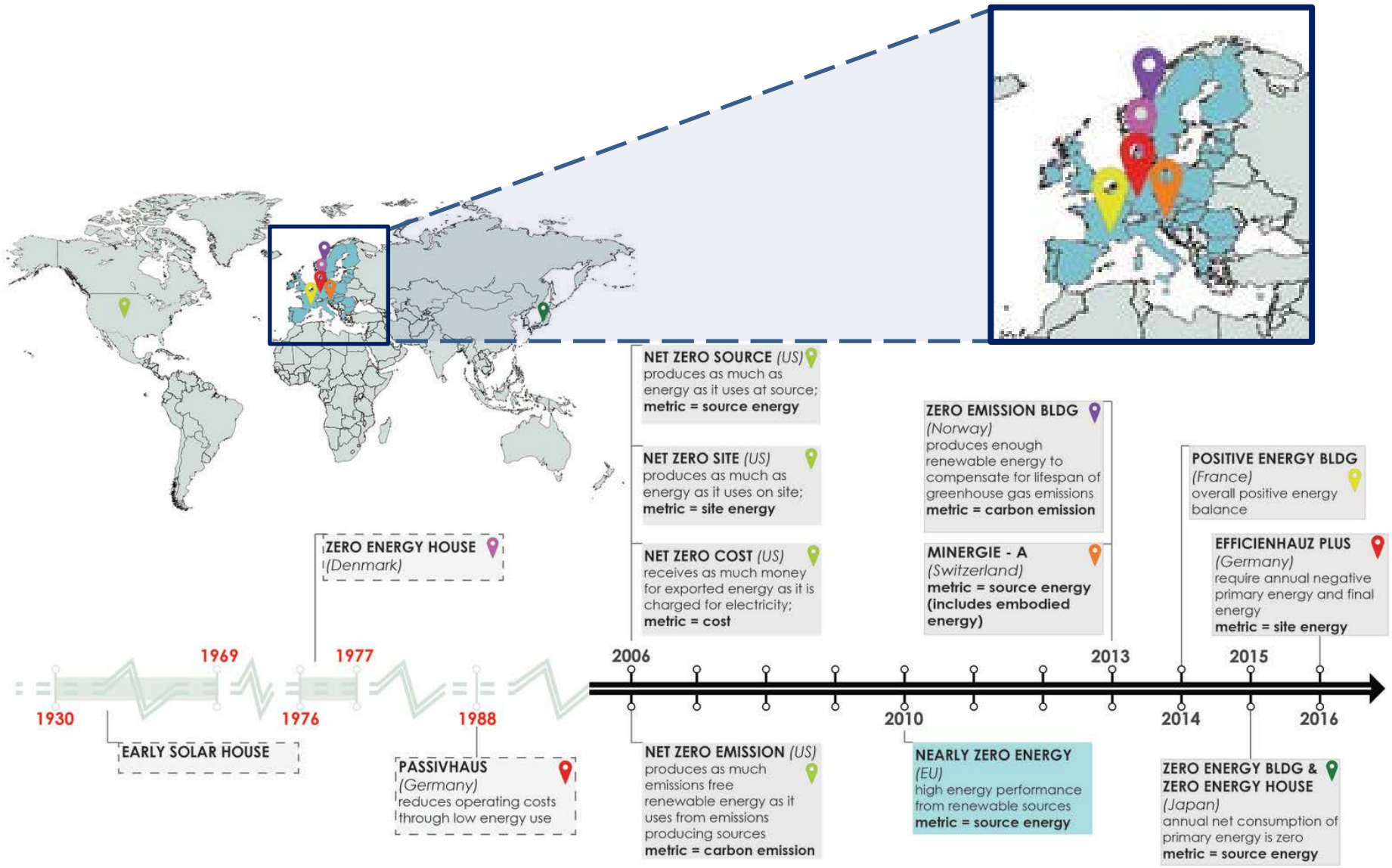
The net zero-energy building concept, by which energy consumption decreases over time and is eventually matched by an equivalent supply of energy from renewable sources (Bloom & Wheelock 2012).

Net zero buildings and settlements



Schematic depiction of the net zero energy building (ZEB) concept, also illustrating the concepts of "nearly" net-zero and "plus energy" buildings. These concepts may be applied at the settlement scale, potentially overcoming limitations inherent in the realization of net-zero at the individual building scale. (Source: Federation of European HVAC Associations)

Defining net-Zero

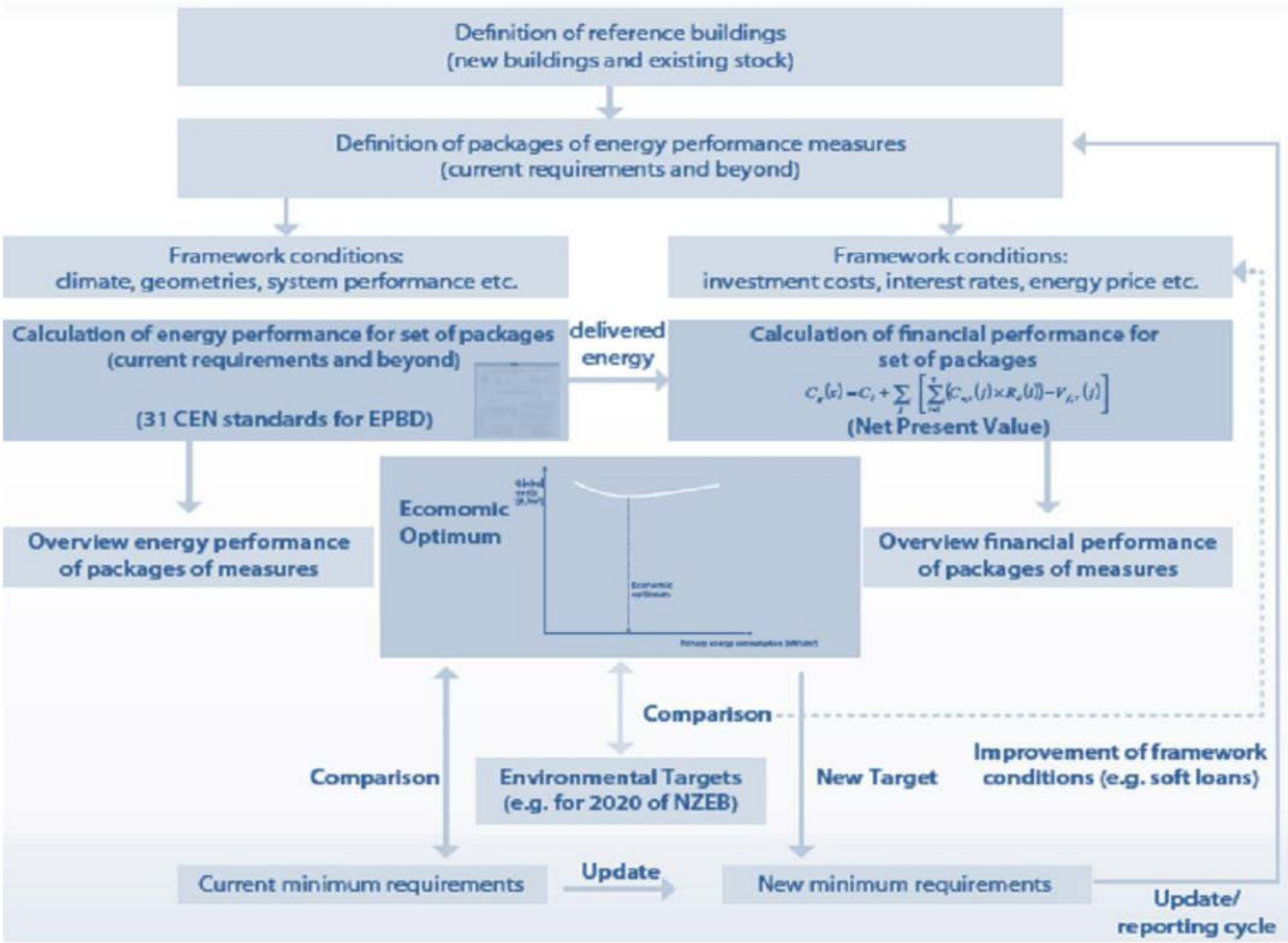


Ming Hu (2019) Net Zero Energy Building: Predicted and Unintended Consequences, Routledge.

NZE buildings and settlements

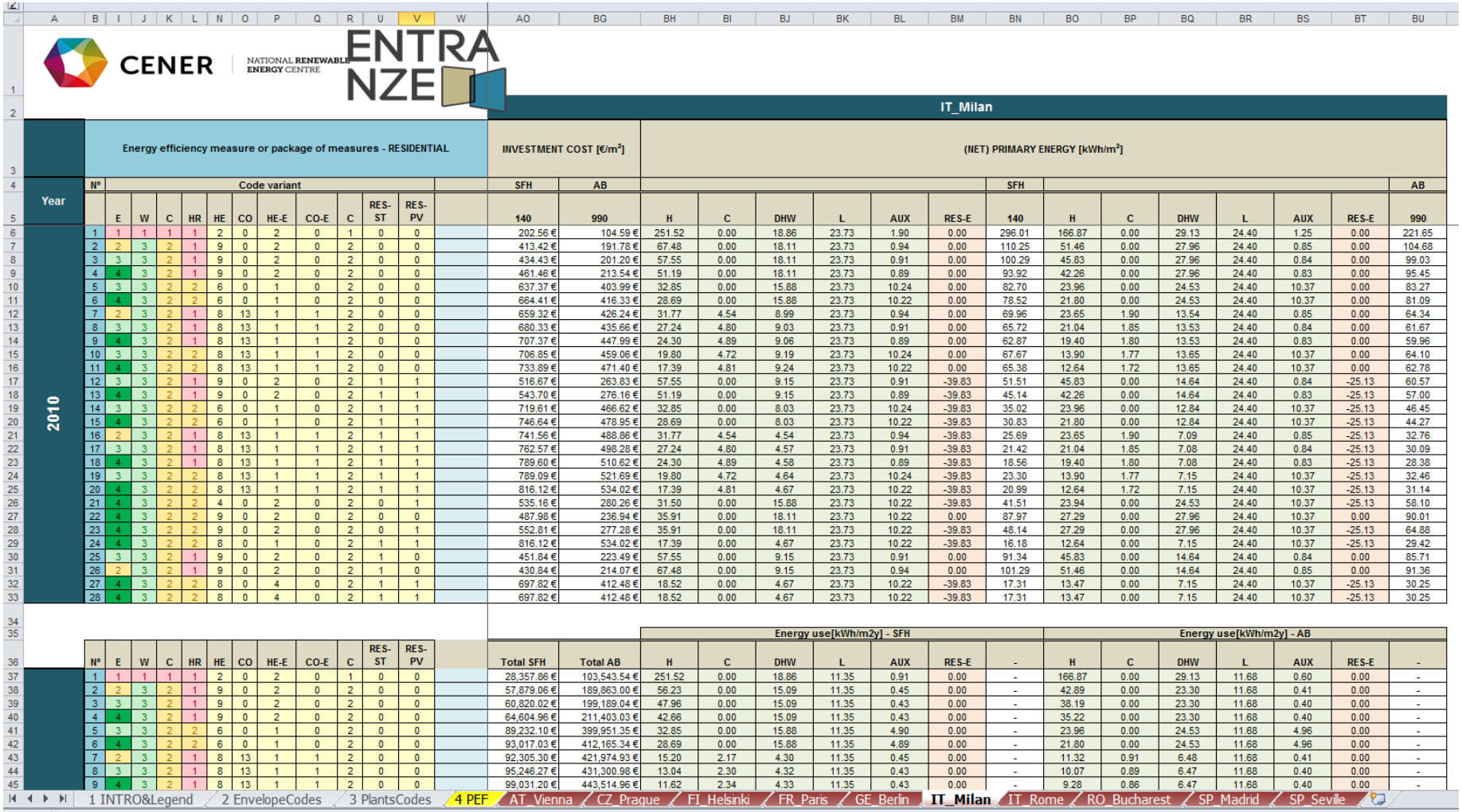
Map of net zero-energy building projects worldwide, including settlement-scale projects (www.enob.info/en/net-zero-energy-buildings/nullenergie-projekte-weltweit/)

Investment in NZE settlements: costs & benefits



Methodology for calculating cost-optimal levels of minimum energy performance (Pietrobon et al. 2013)

Tools for cost optimization



CENER | NATIONAL RENEWABLE ENERGY CENTRE

ENTRA NZE

IT_Milan

Year	Nº	Code variant											INVESTMENT COST [€/m²]		(NET) PRIMARY ENERGY [kWh/m²]											
		E	W	C	HR	HE	CO	HE-E	CO-E	C	RES-ST	RES-PV	SFH 140	AB 990	SFH H	C	DHW	L	AUX	RES-E	140	H	C	DHW	L	AUX	RES-E	AB 990
2010	1	1	1	1	1	2	0	2	0	1	0	0	202.56 €	104.59 €	251.52	0.00	18.86	23.73	1.90	0.00	296.01	166.87	0.00	29.13	24.40	1.25	0.00	221.65
	2	2	3	2	1	9	0	2	0	2	0	0	413.42 €	191.78 €	67.48	0.00	18.11	23.73	0.94	0.00	110.25	51.46	0.00	27.96	24.40	0.85	0.00	104.68
	3	3	3	2	1	9	0	2	0	2	0	0	434.43 €	201.20 €	57.55	0.00	18.11	23.73	0.91	0.00	100.29	45.83	0.00	27.96	24.40	0.84	0.00	99.03
	4	4	3	2	1	9	0	2	0	2	0	0	461.46 €	213.54 €	51.19	0.00	18.11	23.73	0.89	0.00	93.92	42.26	0.00	27.96	24.40	0.83	0.00	95.45
	5	3	3	2	2	6	0	1	0	2	0	0	637.37 €	403.99 €	32.85	0.00	15.88	23.73	10.24	0.00	82.70	23.96	0.00	24.53	24.40	10.37	0.00	83.27
	6	4	3	2	2	6	0	1	0	2	0	0	664.41 €	416.33 €	28.69	0.00	15.88	23.73	10.22	0.00	78.52	21.80	0.00	24.53	24.40	10.37	0.00	81.09
	7	2	3	2	1	8	13	1	1	2	0	0	659.32 €	426.24 €	31.77	4.54	8.99	23.73	0.94	0.00	69.96	23.65	1.90	13.54	24.40	0.85	0.00	64.34
	8	3	3	2	1	8	13	1	1	2	0	0	680.33 €	435.66 €	27.24	4.80	9.03	23.73	0.91	0.00	65.72	21.04	1.85	13.53	24.40	0.84	0.00	61.67
	9	4	3	2	1	8	13	1	1	2	0	0	707.37 €	447.99 €	24.30	4.89	9.06	23.73	0.89	0.00	62.87	19.40	1.80	13.53	24.40	0.83	0.00	59.96
	10	3	3	2	2	8	13	1	1	2	0	0	706.85 €	459.06 €	19.80	4.72	9.19	23.73	10.24	0.00	67.67	13.90	1.77	13.65	24.40	10.37	0.00	64.10
	11	4	3	2	2	8	13	1	1	2	0	0	733.89 €	471.40 €	17.39	4.81	9.24	23.73	10.22	0.00	65.38	12.64	1.72	13.65	24.40	10.37	0.00	62.78
	12	3	3	2	1	9	0	2	0	2	1	1	516.67 €	263.83 €	57.55	0.00	9.15	23.73	0.91	-39.83	51.51	45.83	0.00	14.64	24.40	0.84	-25.13	60.57
	13	4	3	2	1	9	0	2	0	2	1	1	543.70 €	276.16 €	51.19	0.00	9.15	23.73	0.89	-39.83	45.14	42.26	0.00	14.64	24.40	0.83	-25.13	57.00
	14	3	3	2	2	6	0	1	0	2	1	1	719.61 €	466.62 €	32.85	0.00	8.03	23.73	10.24	-39.83	35.02	23.96	0.00	12.84	24.40	10.37	-25.13	46.45
	15	4	3	2	2	6	0	1	0	2	1	1	746.64 €	478.95 €	28.69	0.00	8.03	23.73	10.22	-39.83	30.83	21.80	0.00	12.84	24.40	10.37	-25.13	44.27
	16	2	3	2	1	8	13	1	1	2	1	1	741.56 €	488.86 €	31.77	4.54	4.54	23.73	0.94	-39.83	25.69	23.65	1.90	7.09	24.40	0.85	-25.13	32.76
	17	3	3	2	1	8	13	1	1	2	1	1	762.57 €	498.28 €	27.24	4.80	4.57	23.73	0.91	-39.83	21.42	21.04	1.85	7.08	24.40	0.84	-25.13	30.09
	18	4	3	2	1	8	13	1	1	2	1	1	789.60 €	510.62 €	24.30	4.89	4.58	23.73	0.89	-39.83	18.56	19.40	1.80	7.08	24.40	0.83	-25.13	28.38
	19	3	3	2	2	8	13	1	1	2	1	1	789.09 €	521.69 €	19.80	4.72	4.64	23.73	10.24	-39.83	23.30	13.90	1.77	7.15	24.40	10.37	-25.13	32.46
	20	4	3	2	2	8	13	1	1	2	1	1	816.12 €	534.02 €	17.39	4.81	4.67	23.73	10.22	-39.83	20.99	12.64	1.72	7.15	24.40	10.37	-25.13	31.14
	21	4	3	2	2	4	0	2	0	2	0	1	535.16 €	280.26 €	31.50	0.00	15.88	23.73	10.22	-39.83	41.51	23.94	0.00	24.53	24.40	10.37	-25.13	58.10
	22	4	3	2	2	9	0	2	0	2	0	0	487.98 €	236.94 €	35.91	0.00	18.11	23.73	10.22	0.00	87.97	27.29	0.00	27.96	24.40	10.37	0.00	90.01
	23	4	3	2	2	9	0	2	0	2	0	1	552.81 €	277.28 €	35.91	0.00	18.11	23.73	10.22	-39.83	48.14	27.29	0.00	27.96	24.40	10.37	-25.13	64.88
	24	4	3	2	2	8	0	1	0	2	1	1	816.12 €	534.02 €	17.39	0.00	4.67	23.73	10.22	-39.83	16.18	12.64	0.00	7.15	24.40	10.37	-25.13	29.42
	25	3	3	2	1	9	0	2	0	2	1	0	451.84 €	223.49 €	57.55	0.00	9.15	23.73	0.91	0.00	91.34	45.83	0.00	14.64	24.40	0.84	0.00	85.71
	26	2	3	2	1	9	0	2	0	2	1	0	430.84 €	214.07 €	67.48	0.00	9.15	23.73	0.94	0.00	101.29	51.46	0.00	14.64	24.40	0.85	0.00	91.36
	27	4	3	2	2	8	0	4	0	2	1	1	697.82 €	412.48 €	18.52	0.00	4.67	23.73	10.22	-39.83	17.31	13.47	0.00	7.15	24.40	10.37	-25.13	30.25
	28	4	3	2	2	8	0	4	0	2	1	1	697.82 €	412.48 €	18.52	0.00	4.67	23.73	10.22	-39.83	17.31	13.47	0.00	7.15	24.40	10.37	-25.13	30.25

															Energy use[kWh/m2y] - SFH							Energy use[kWh/m2y] - AB						
	Nº	E	W	C	HR	HE	CO	HE-E	CO-E	C	RES-ST	RES-PV	Total SFH	Total AB	H	C	DHW	L	AUX	RES-E	-	H	C	DHW	L	AUX	RES-E	-
	1	1	1	1	1	2	0	2	0	1	0	0	28,357.86 €	103,543.54 €	251.52	0.00	18.86	11.35	0.91	0.00	-	166.87	0.00	29.13	11.68	0.60	0.00	-
	2	2	3	2	1	9	0	2	0	2	0	0	57,879.06 €	189,863.00 €	56.23	0.00	15.09	11.35	0.45	0.00	-	42.89	0.00	23.30	11.68	0.41	0.00	-
	3	3	3	2	1	9	0	2	0	2	0	0	60,820.02 €	199,189.04 €	47.96	0.00	15.09	11.35	0.43	0.00	-	38.19	0.00	23.30	11.68	0.40	0.00	-
	4	4	3	2	1	9	0	2	0	2	0	0	64,604.96 €	211,403.03 €	42.66	0.00	15.09	11.35	0.43	0.00	-	35.22	0.00	23.30	11.68	0.40	0.00	-
	5	3	3	2	2	6	0	1	0	2	0	0	89,232.10 €	399,951.35 €	32.85	0.00	15.88	11.35	4.90	0.00	-	23.96	0.00	24.53	11.68	4.96	0.00	-
	6	4	3	2	2	6	0	1	0	2	0	0	93,017.03 €	412,165.34 €	28.69	0.00	15.88	11.35	4.89	0.00	-	21.80	0.00	24.53	11.68	4.96	0.00	-
	7	2	3	2	1	8	13	1	1	2	0	0	92,305.30 €	421,974.93 €	15.20	2.17	4.30	11.35	0.45	0.00	-	11.32	0.91	6.48	11.68	0.41	0.00	-
	8	3	3	2	1	8	13	1	1	2	0	0	95,246.27 €	431,300.98 €	13.04	2.30	4.32	11.35	0.43	0.00	-	10.07	0.89	6.47	11.68	0.40	0.00	-
	9	4	3	2	1	8	13	1	1	2	0	0	99,031.20 €	443,514.96 €	11.62	2.34	4.33	11.35	0.43	0.00	-	9.28	0.86	6.47	11.68	0.40	0.00	-

1 INTRO&Legend | 2 EnvelopeCodes | 3 PlantsCodes | 4 PEF | AT_Vienna | CZ_Prague | FI_Helsinki | FR_Paris | GE_Berlin | IT_Milan | IT_Rome | RO_Bucharest | SP_Madrid | SP_Seville

Ready

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ENTRA NZE

search

Policies to ENforce the TRAnsition to Nearly Zero Energy buildings in the EU-27

State of the art NZE technologies

Categories of measures and systems

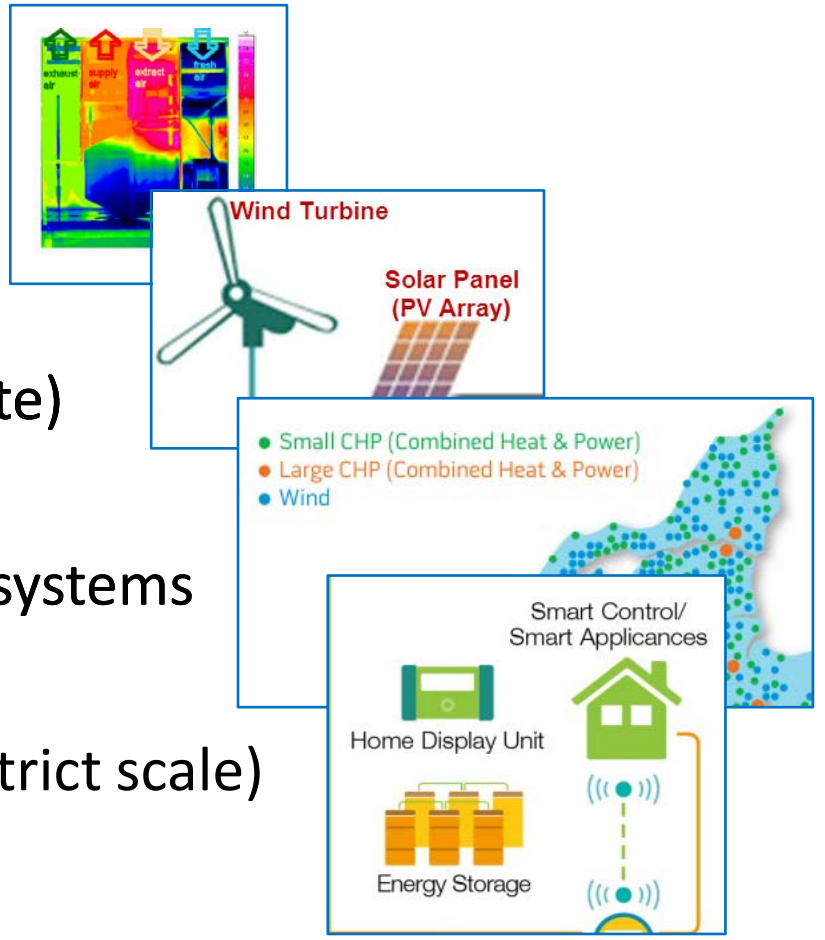
ZeroPlus Energy Technologies:

1) Energy conservation measures

2) Renewable energy systems (on-site)

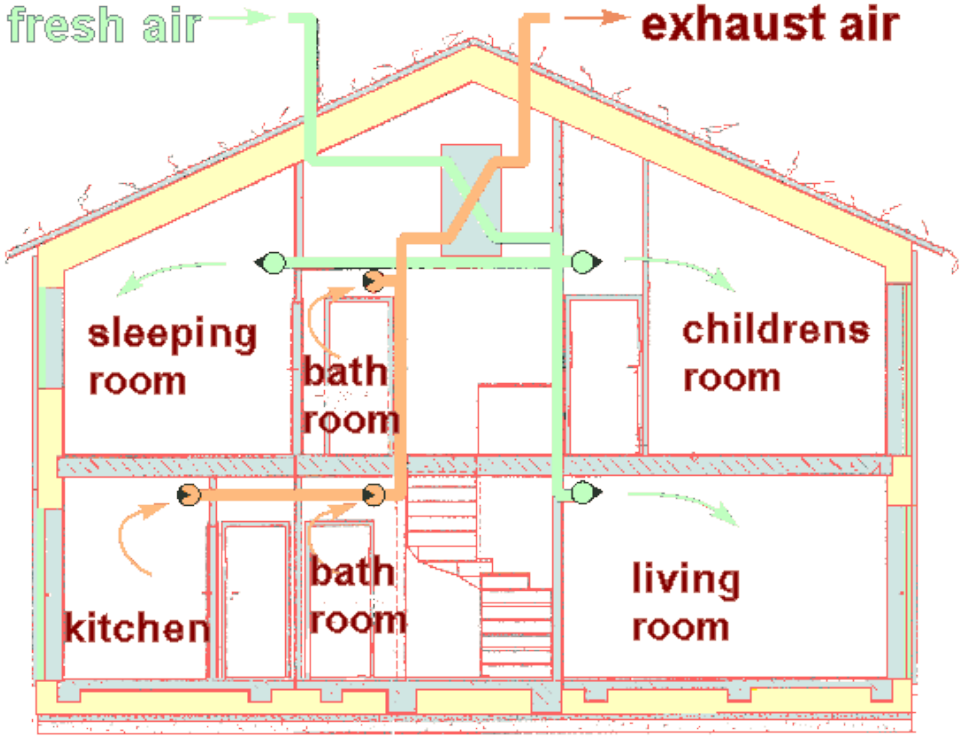
3) Efficient space heating & cooling systems

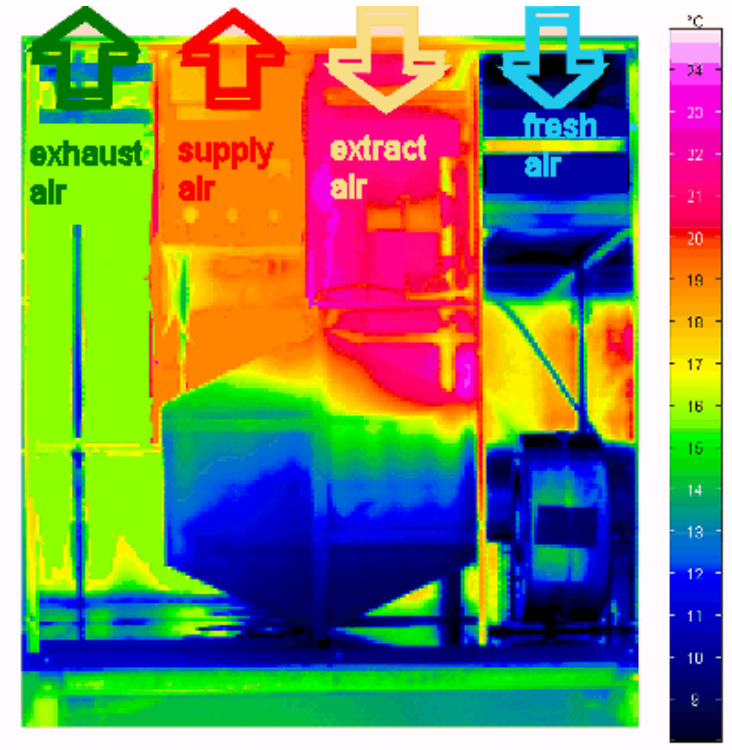
4) Energy management systems (district scale)



State of the art NZE technologies

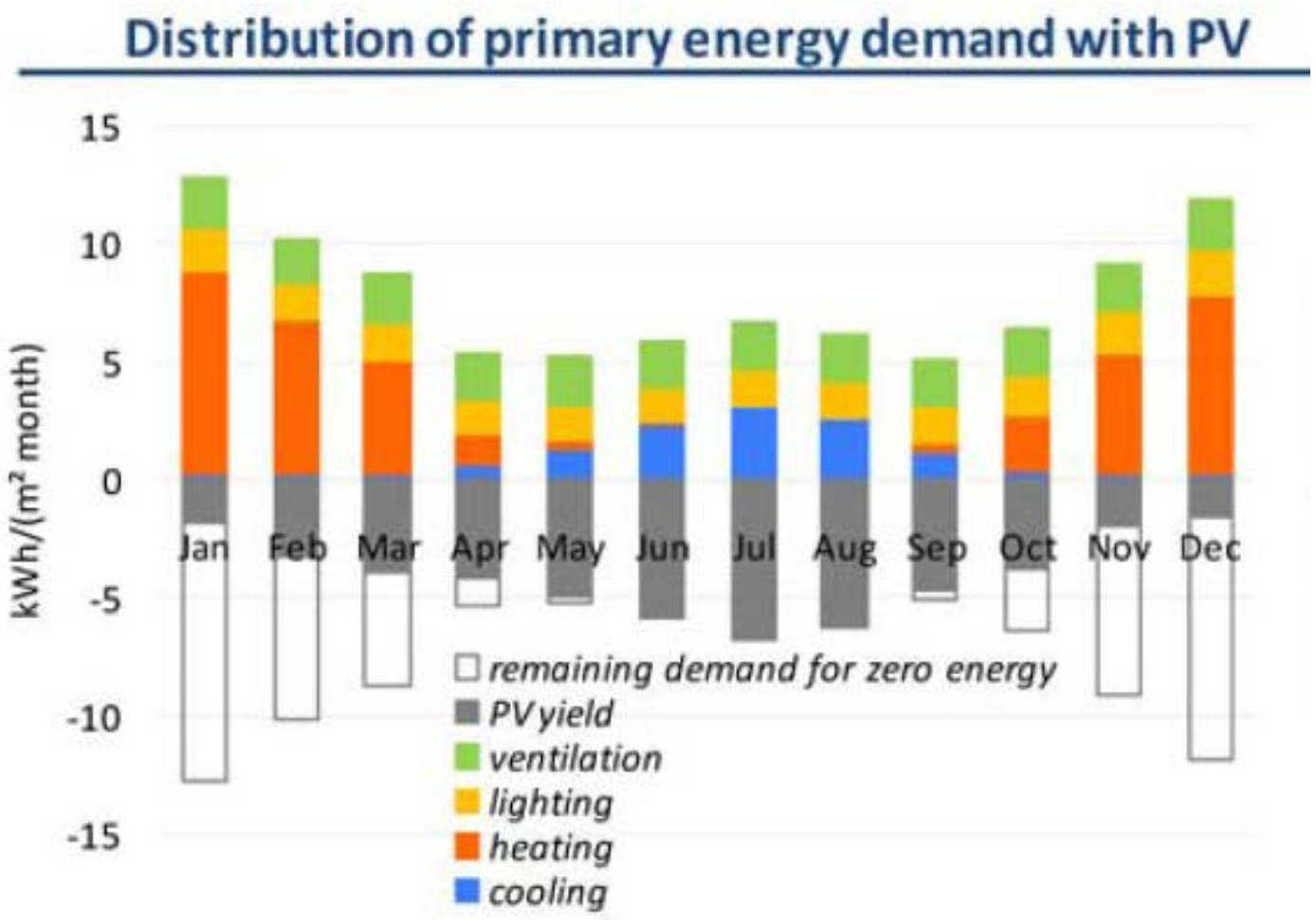
Energy conservation measures





Left: Principle of air distribution in the ventilation system. Right: Thermographic image of an opened counterflow heat recovery unit with 75% of the sensible heat recovery rate. The actual heat exchanger is a hexagon. (passipedia.com)

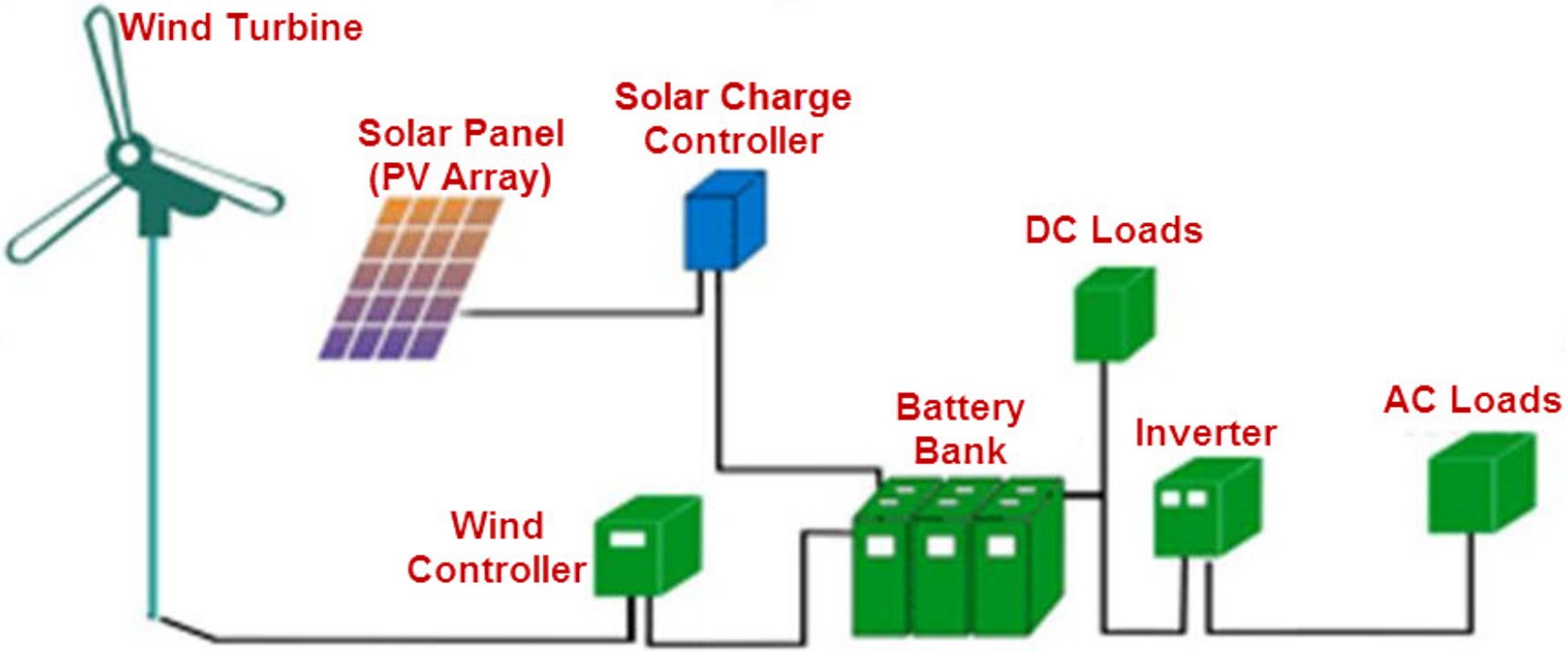
State of the art NZE technologies



Energy demand for an office building in Germany calculated with EnerCalc, reported by Karsten Voss, Eike Musall, and Markus Lichtmeß (2011) From Low-Energy to Net Zero-Energy Buildings: Status and Perspectives. Journal of Green Building. *Journal of Green Building* 6:46-57.

State of the art NZE technologies

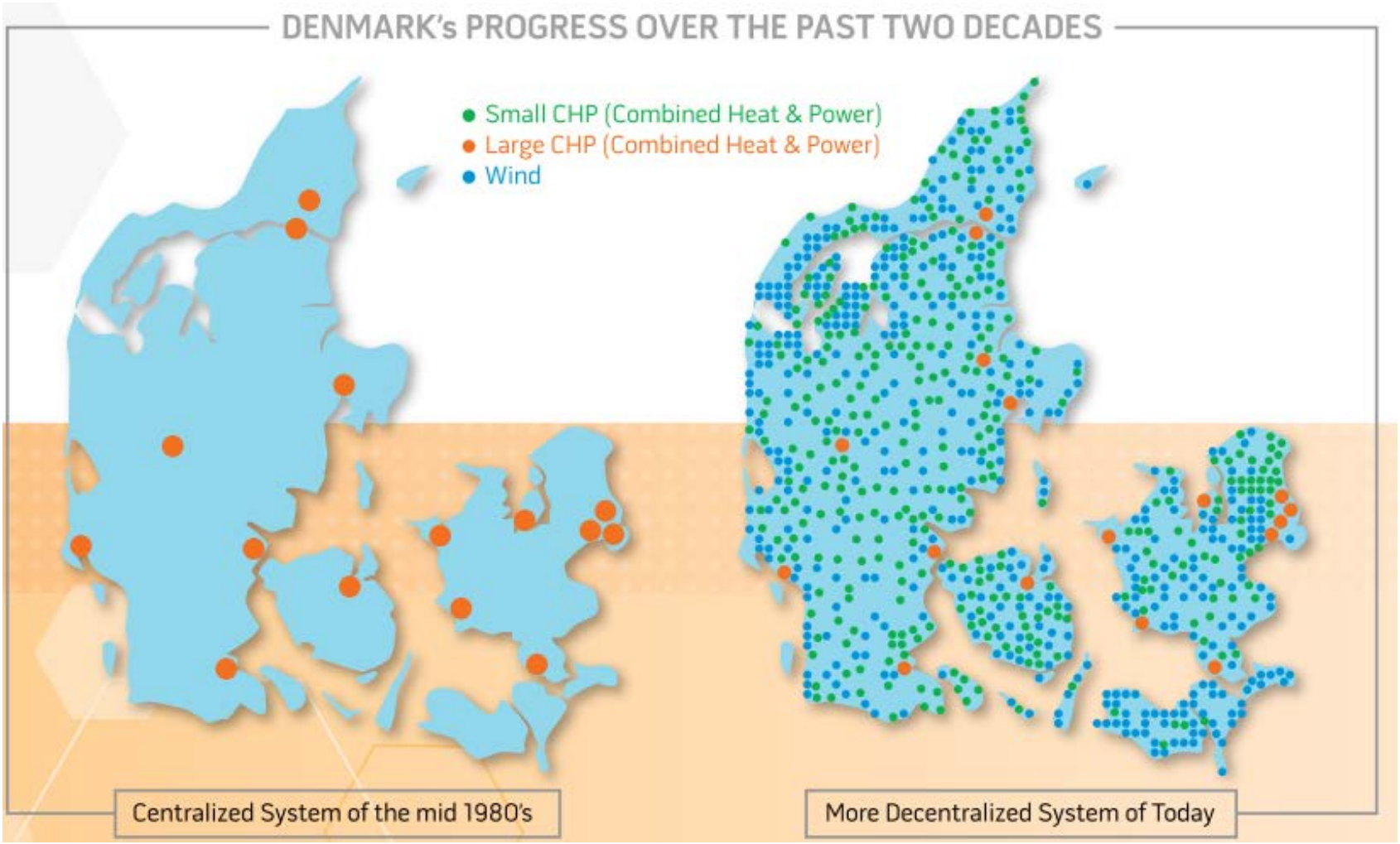
Renewable energy systems



Solar-Wind Hybrid power system block diagram. (efxkits.com)

State of the art NZE technologies

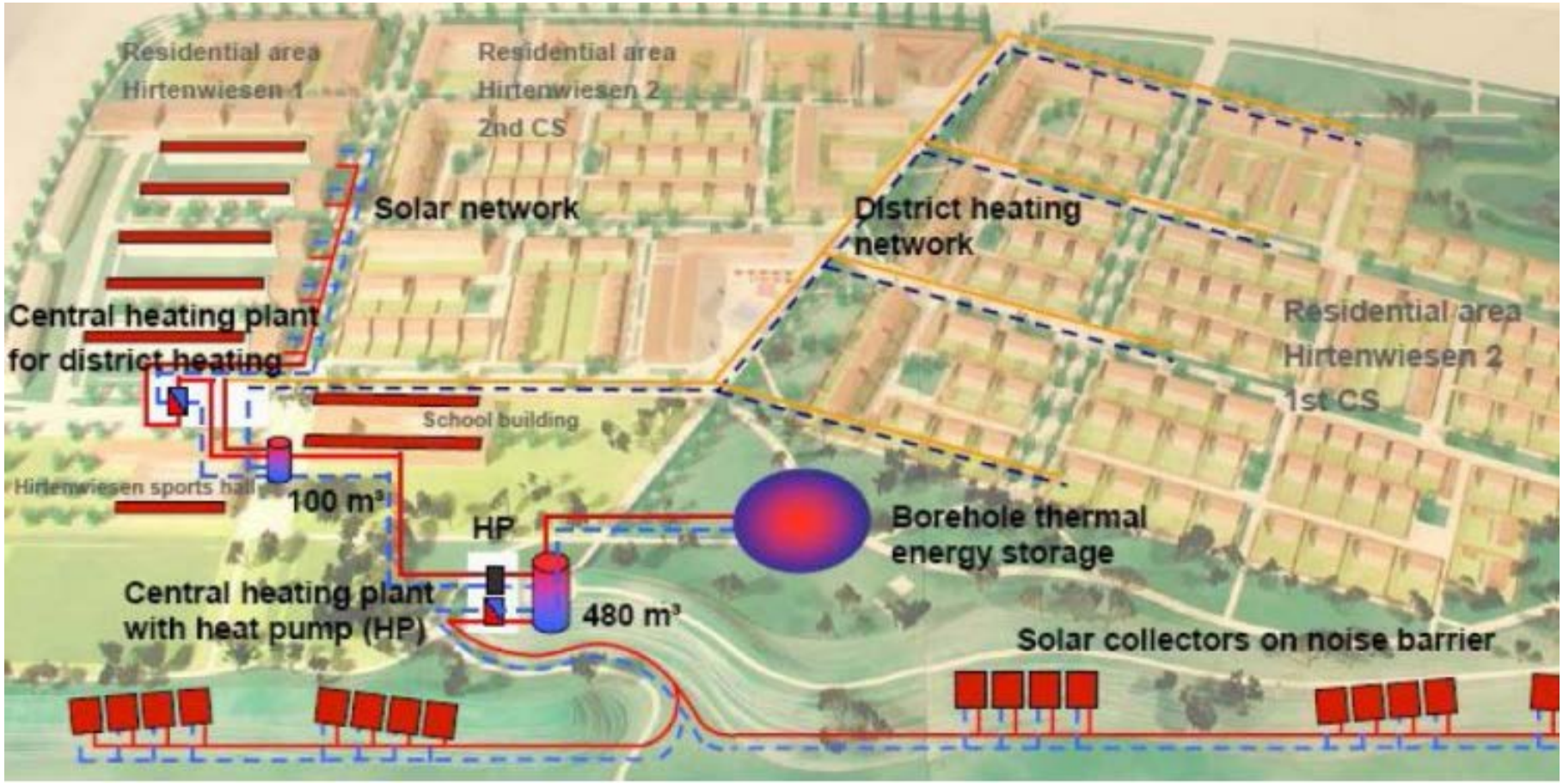
Space heating and cooling systems



CHP network development progress in Denmark (USDOE, 2010)

State of the art NZE technologies

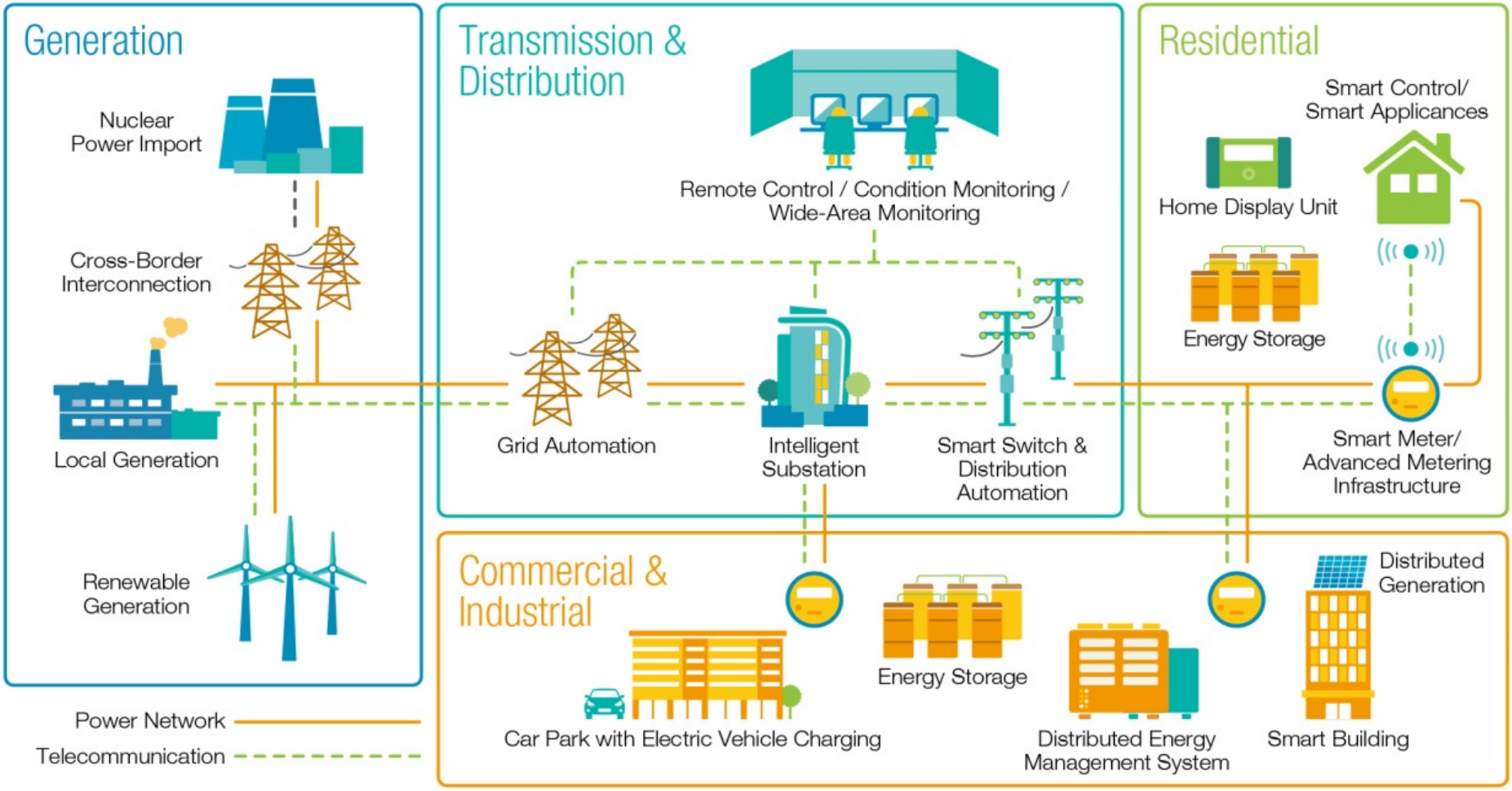
Settlement-scale heating and cooling



Solar powered micro network Crailsheim, Germany (Schmidt et al. 2013)

State of the art NZE technologies

Energy management solutions



Conceptual diagram of global smart grid components (clp.com.hk)

NZE settlements: Case studies

Schlierberg – Freiburg, Germany

Weiz-Gleisdorf – Weiz, Austria

St. Pierre – Reunion, France

Kleehäuser – Freiburg, Germany

BedZED – London, UK

Loccioni – Rosora Ancona, Italy

COLD CLIMATE

WARM CLIMATE

All information is taken from a report of the International Energy Agency (IEA) Task 40/Annex 52,"Towards Net Zero Energy Solar Buildings: A review of 30 Net ZEBs case studies worldwide." (Garde & Donn 2014)

NZE settlements: Case studies

Case 1: Solar settlement in Schlierberg

Completion Date: **2006**

Building type: **Residential terrace houses**

Location: **Freiburg, Germany**

Climate: **Cold** (T_{avg} = 11.6°C)

Solar radiation = **1100** kWh/m²a

Site Context: **Urban edge, 2-5 storey buildings** with narrow lanes between, street widths of 20-40m

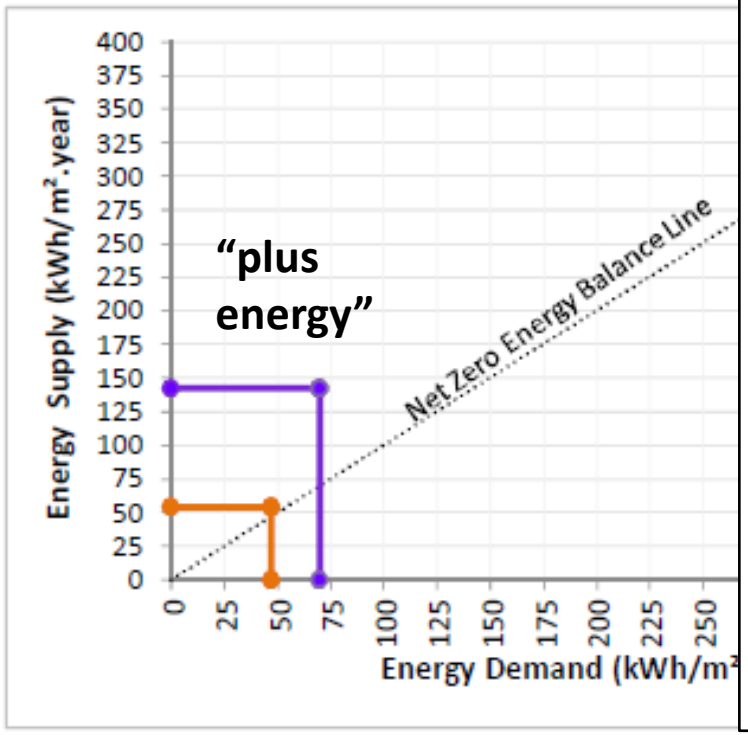
Net Floor Area: **7890 m²**; S/V = 0.56 m²/m³

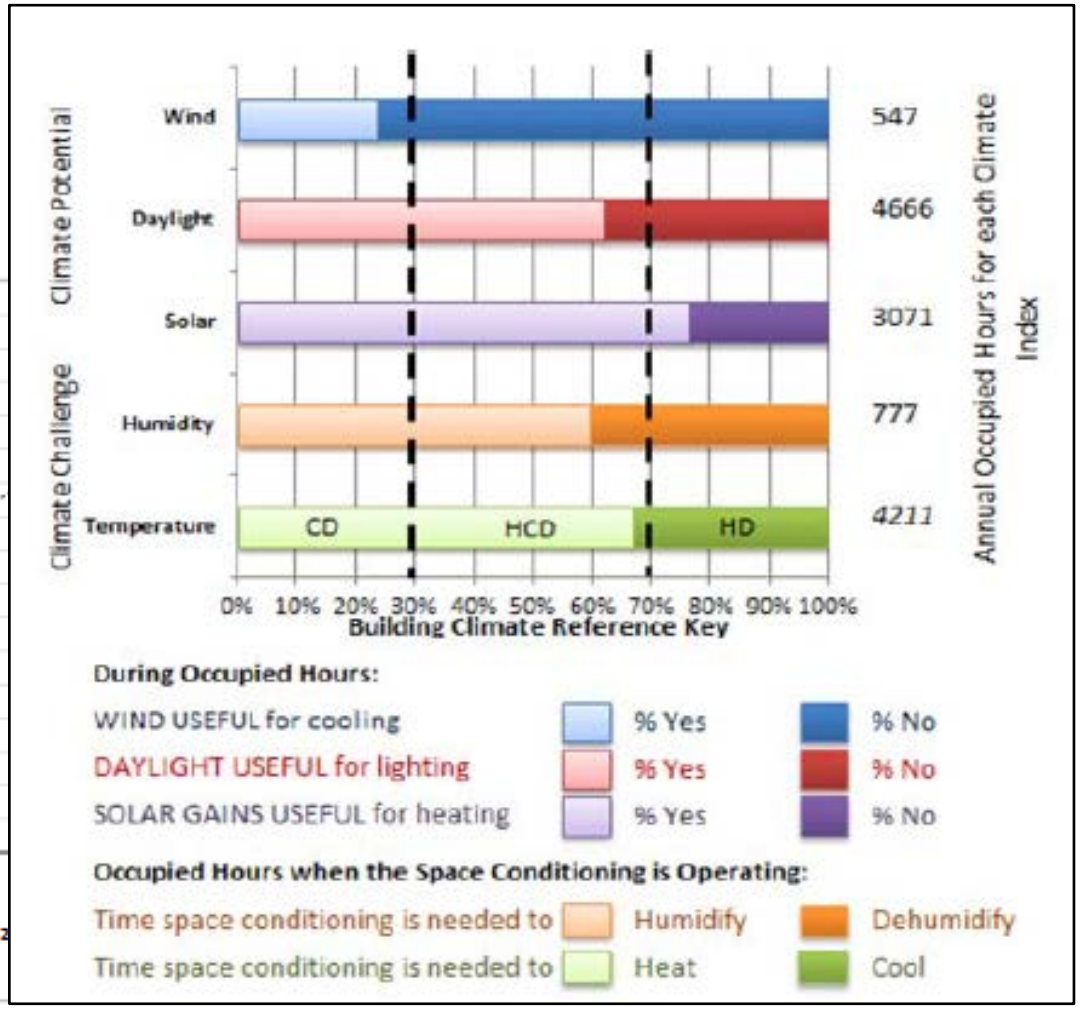
Occupancy: **46.4 m² / person**; (170 dwellers)

Cost: **1940€ / m²** (net, 2006)

NZE settlements: Case studies

Case 1: Solar settlement in Schlierberg





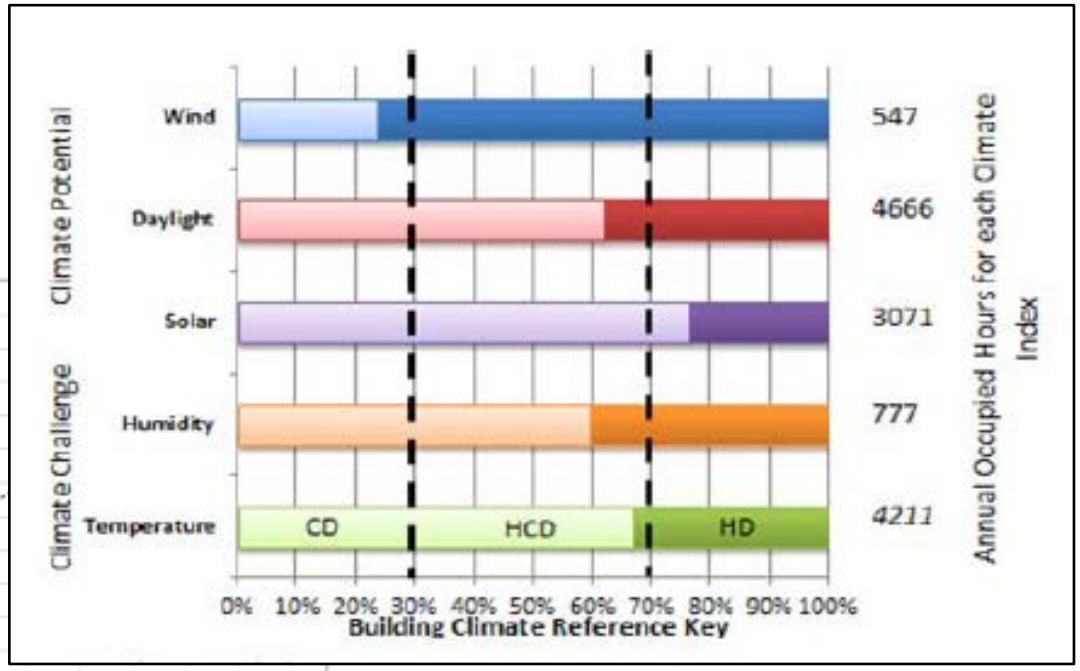
Energy Generated/Energy Consumed - Primary

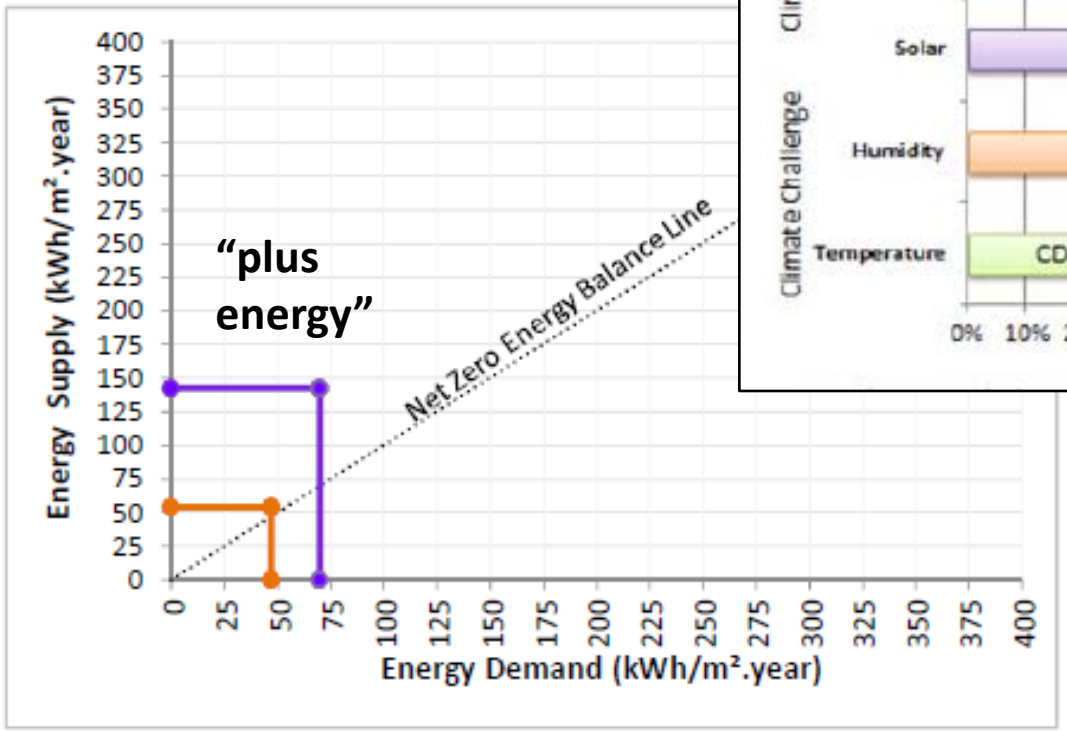
Energy Generated/Energy Consumed - Final

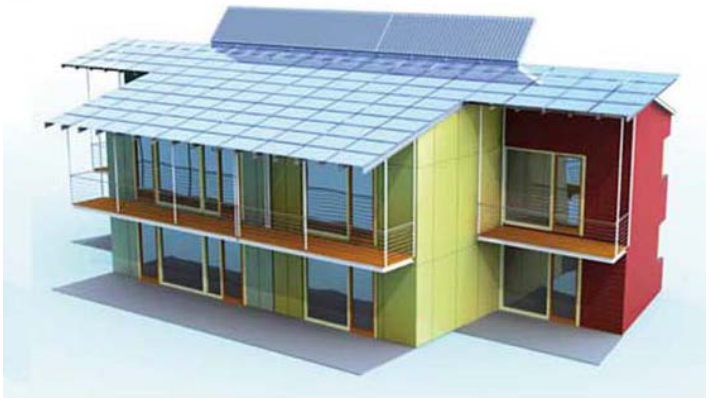
NZE settlements: Case studies

Case 1: Solar settlement in Schlierberg

- **Purchase price: 2,700 - 3,300 €/m²**
- **Super-insulation, roof-integrated PV (purchased separately)**
- **District CHP (gas + wood chips)**







NZE settlements: Case studies

Case 2: Kleehäuser

Completion Date: **2006**

Building type: **Residential**

Location: **Freiburg, Germany**

Climate: **Cold** (T_{avg} = 11.6°C)

Solar radiation = **1100** kWh/m²a

Site Context: **Suburban, two buildings** (3 and 5 storeys)

Net Floor Area: **2520 m²**; S/V = 0.4 m²/m³

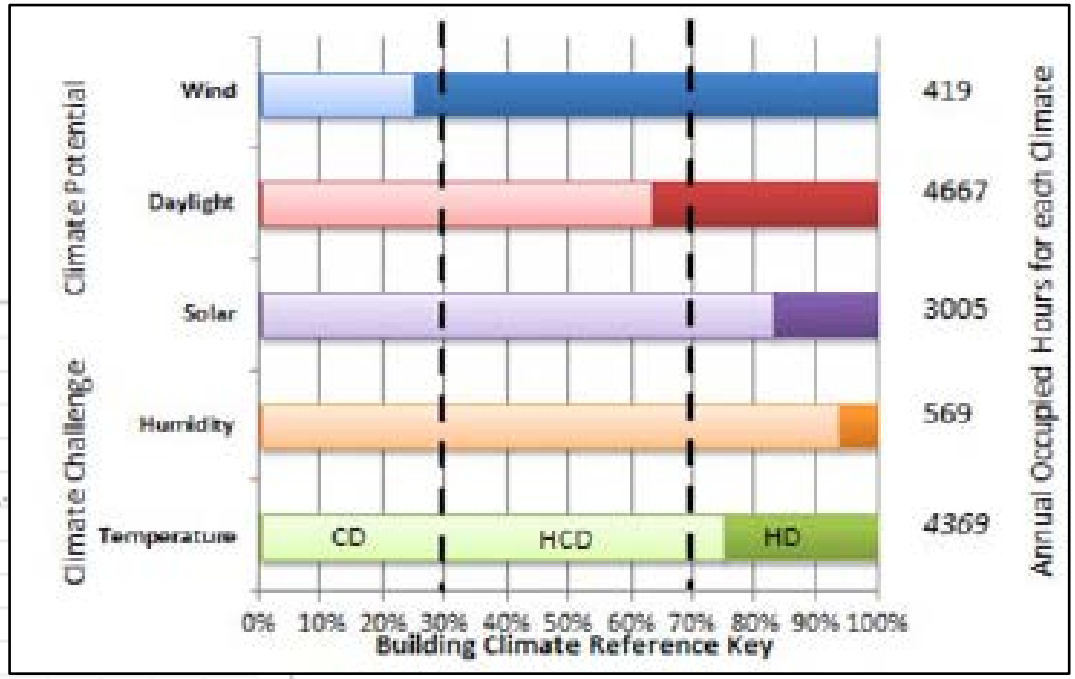
Occupancy: **33 m² per person** (25 units/~75 dwellers)

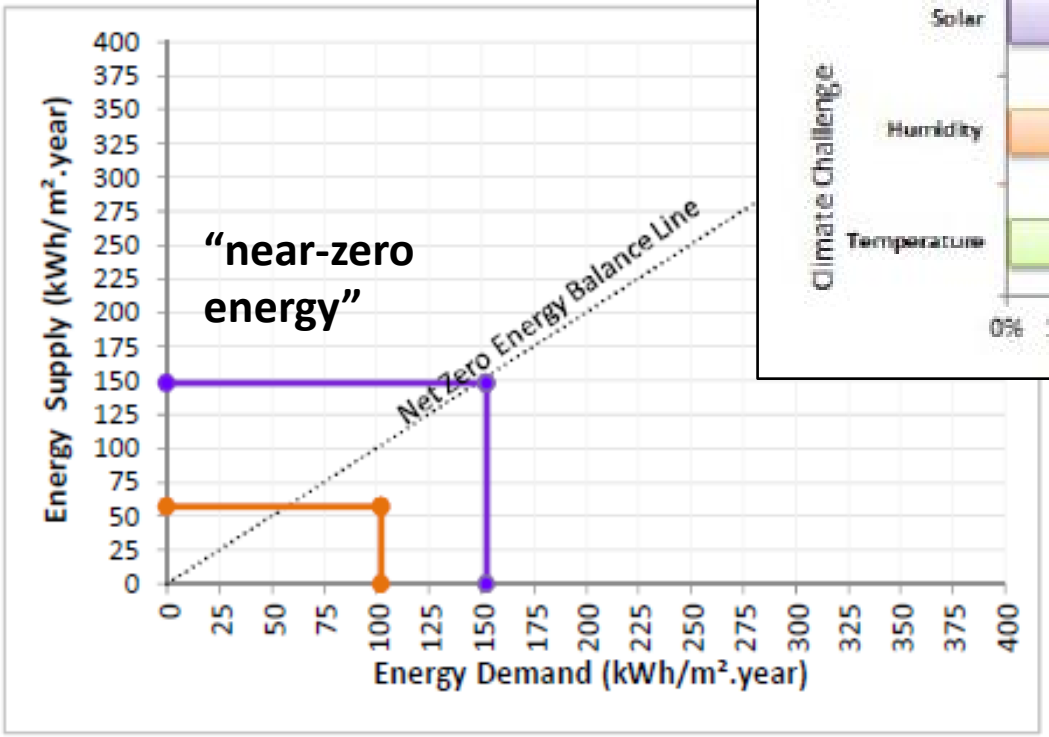
Cost: **1154€ / m²** (net, 2006)

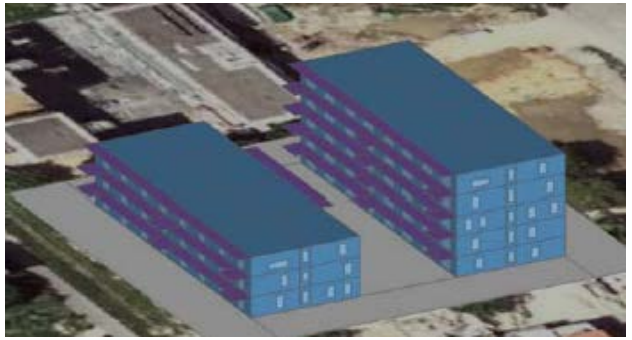
NZE settlements: Case studies

Case 2: Kleehäuser

- **Community purchased share in off-site wind turbine as energy offset**
- **Car-free community: ride-sharing + convenient public transportation**







Flat roofs covered with solar PV

NZE settlements: Case studies

Case 3: ENERPOS University Complex in St. Pierre

Completion Date: **2009**

Building type: **Offices & classrooms**

Location: **Reunion Island, France**

Climate: **Warm** (T_{avg} = 25°C)

Solar radiation = **1929** kWh/m²a

Site Context: **Suburban**, 2-storey courtyard arrangement

Net Floor Area: **781 m²**, S/V 0.32 m²/m³

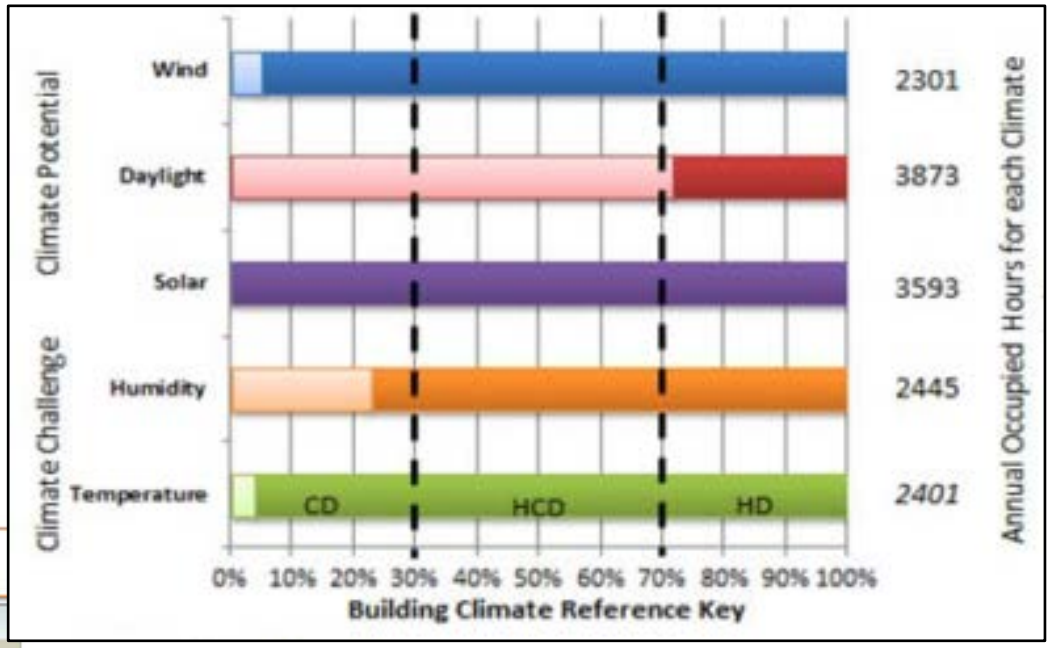
Occupancy: **4.6 m² / person**; (170 Persons)

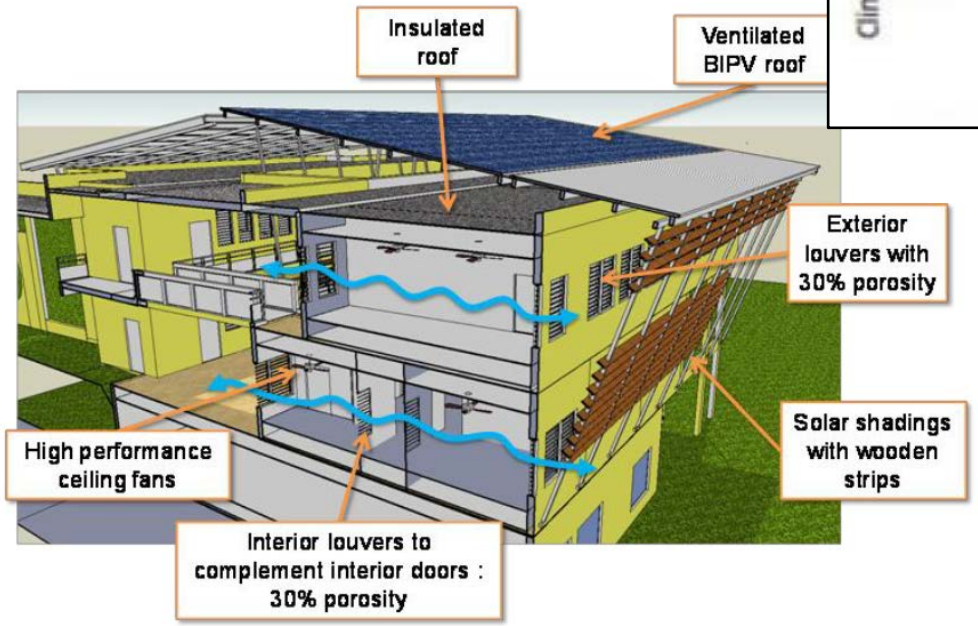
Cost: **1664€ / m²** (net, 2009)

NZE settlements: Case studies

Case 3: ENERPOS University Complex in St. Pierre

- **Energy efficiency 5-times higher than standard office building due to shading & ventilation**
- **All-electric demand covered by 350 m² roof-integrated PV system**



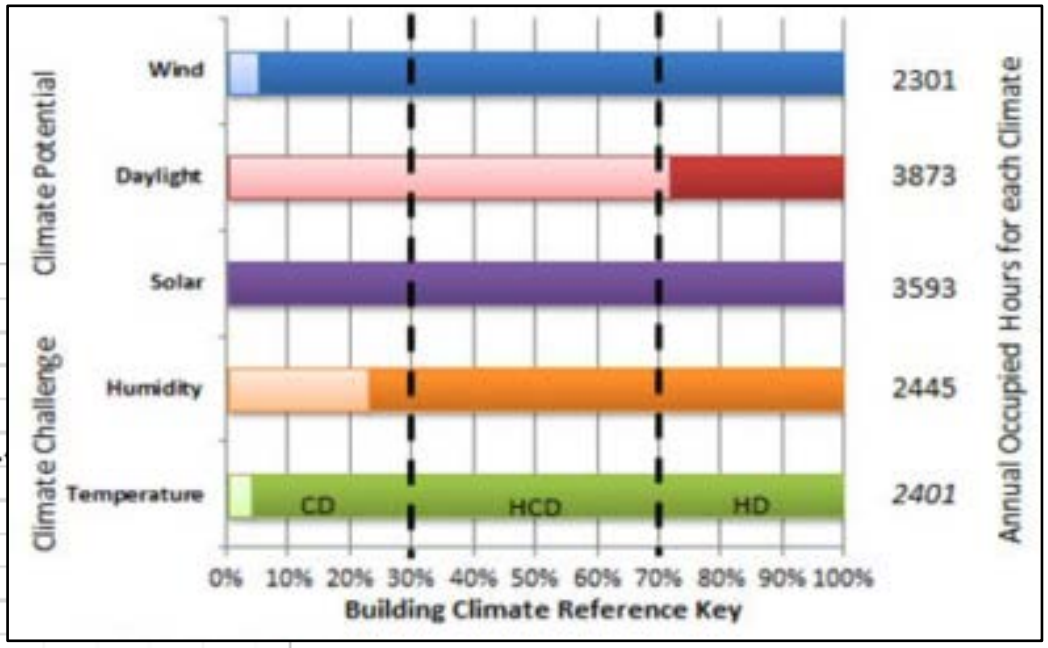


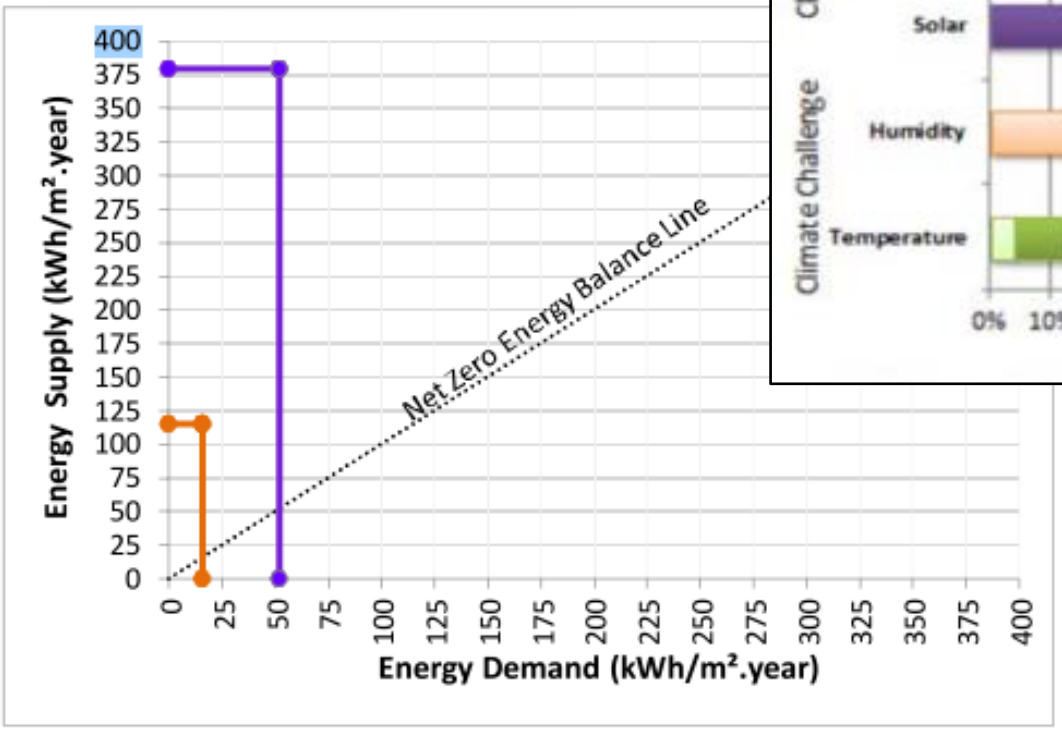
- **Internal website and large screens display data on renewable energy produced and consumed, with resulting carbon savings – raising occupants' awareness of energy-related behavior.**

NZE settlements: Case studies

Case 3: ENERPOS University Complex in St. Pierre

- **Distinctly "plus energy" building**





- **Cost: 1664€ / m²**

  (net, 2009)

NZE settlements: Case studies

Case 4: Leaf House in Loccioni

Completion Date: **2008**

Building type: **Residential**

Location: **Rosora Ancona, Italy**

Climate: **Warm/Cold** (T_{avg} = 13.2°C)

Solar radiation = **1302** kWh/m²a

Site Context: **Urban edge, 4-6 apartments**

Net Floor Area: **477 m²**, S/V 0.48 m²/m³

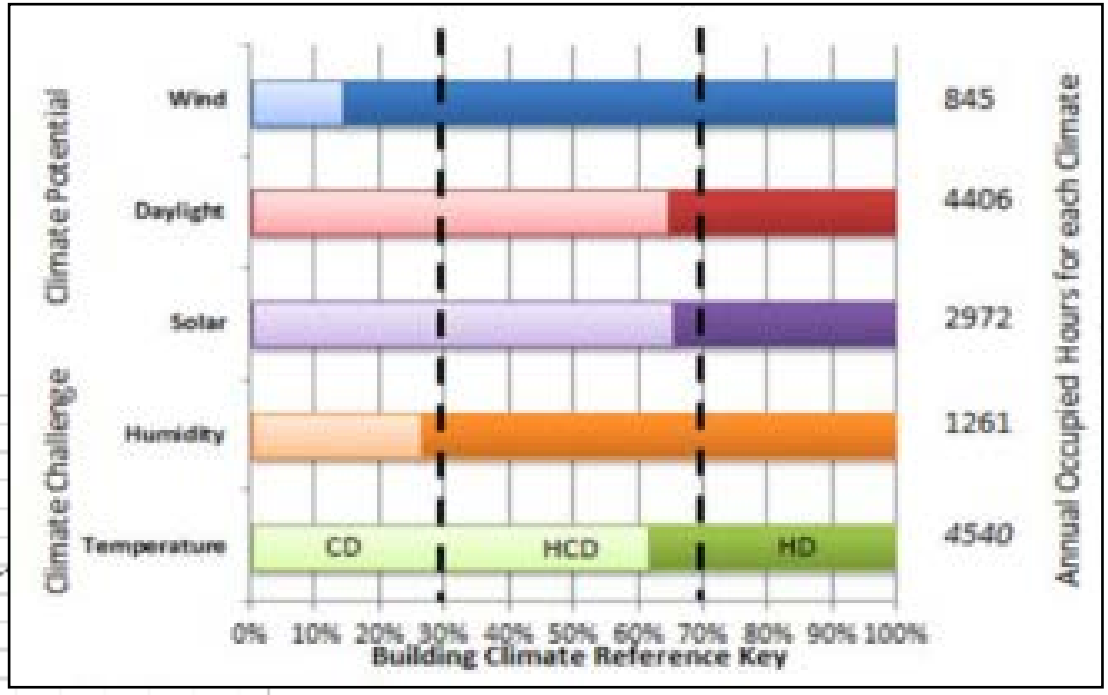
Occupancy: **40 m² / person**

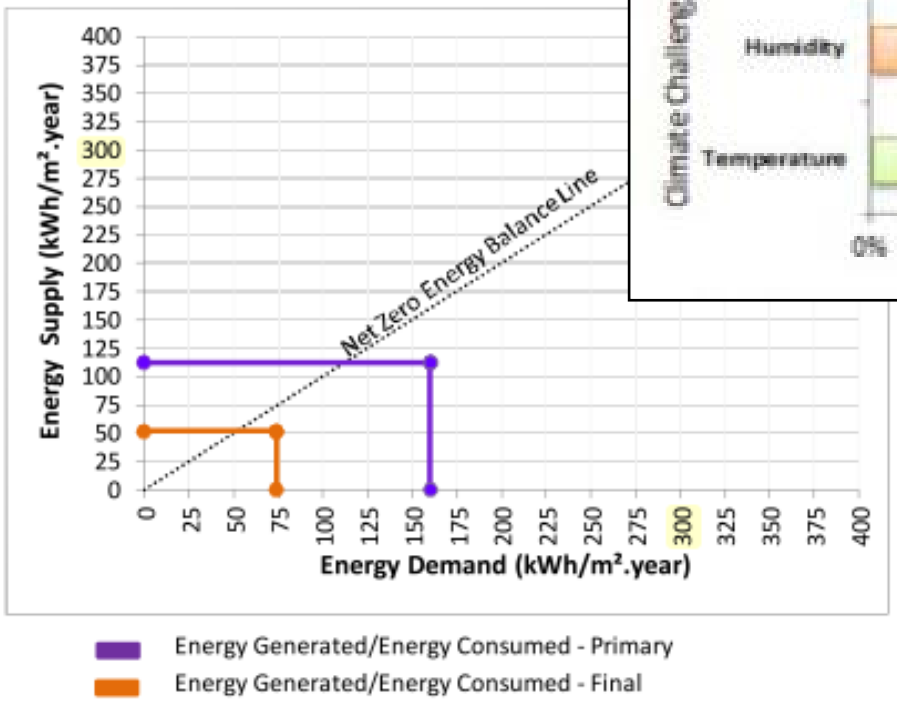
Cost: **US$943 / m²** (net 2008, compared to US$704 /m² for typical similar building

NZE settlements: Case studies

Case 4: Leaf House in Loccioni

- **Pilot carbon neutral building for testing sustainable technologies**
- **Advanced monitoring system with 1,200 installed sensors**





- **Geothermal heat pump with 80% heat recovery is powered by rooftop PV, but its performance was overestimated**

NZE settlements: Case studies

	Kleehäuser	Schlierberg	Weiz-Gleisdorf	BedZED	ENERPOS	Leaf House
Year of construction	2006	2006	2006	2002	2009	2008
Country	Germany	Germany	Austria	UK	France	Italy
Function	Residential	Residential	Residential	Mixed use	University	Residential
Climate	Heating dominated	Heating dominated	Heating dominated	Heating dominated	Cooling dominated	Heating/ cooling
U-value of building envelope (W/m^2K)	0.2	n/a	0.2	0.2	2.9	n/a
Net Floor Area	2520 m^2	7890 m^2	~2180 m^2	8850 m^2	781 m^2	477 m^2
S / V (m^2/m^3)	0.4	0.56	0.56	0.48	0.32	n/a
CHP	Natural gas	Wood chips + natural gas	No All electric	Natural gas, wood chips	No All electric	No geothermal
Primary energy demand (kWh/m^2a)	152	70	120	82 (final)	52	160
PV area m^2	202	3205	520	777	360	150
PV power (kWp)	23	404	5x22 = 110	108	50	20
PV yield (kWh/m^2a)	26.5	55	53.8	12.2 (Wp/m^2)	70	167
Price per (net) m^2	1154€	1940€	1420€	1580€	1664€	943 US$

Comparative summary of case study parameters

State of the art on NZE settlements

WHAT HAVE WE LEARNED?

A variety of creative efforts are being made to achieve the net-zero goal, and these efforts demonstrate both:

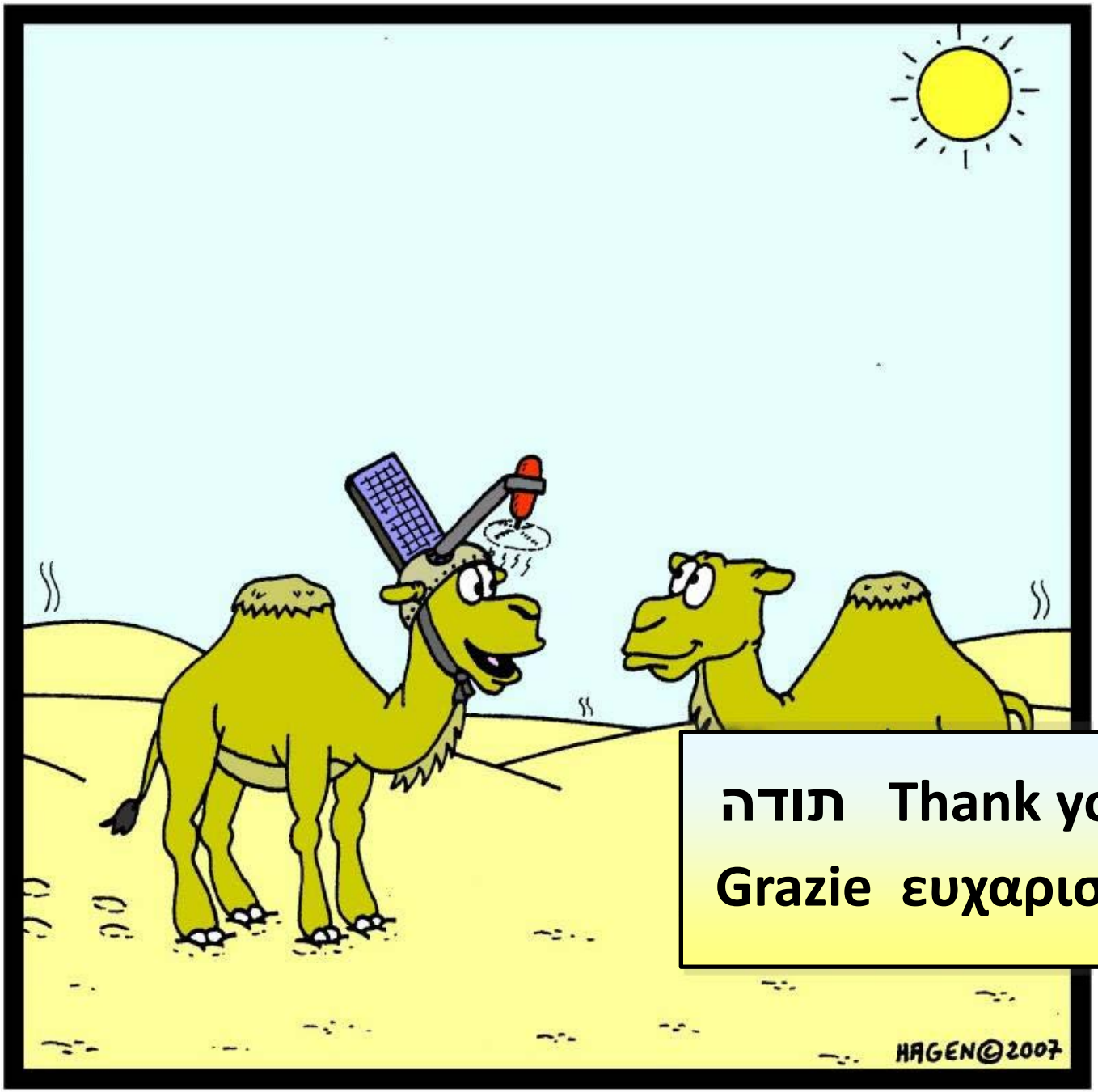
- the **enormous potential** that exists for lowering the net energy and carbon footprint of the built environment, and
- the **significant challenges** that remain to achieve the NZE objective in a **cost-effective manner**.

State of the art on NZE settlements

WHAT HAVE WE LEARNED?

The case studies highlight the great importance of attacking the NZE challenge at the **settlement level**:

- In some cases the NZE target is reached by supplementing on-site strategies with **off-site** renewable energy production
- In other cases, on-site production is able to meet the **average demand of the community** even though individual dwellings may be energy-negative.


תודה Thank you!
Grazie ευχαριστώ
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