Bergische Universität Wuppertal
Bauphysik und Technische Gebäudeausrüstung
Prof. Dr.-Ing. Karsten Voss

Richtung Nullenergiehaus in der EU

Prof. Karsten Voss, M.Sc. Eike Musall
University Wuppertal
School of Architecture, Building Physics & Technical Services

Nullenergiegebäude

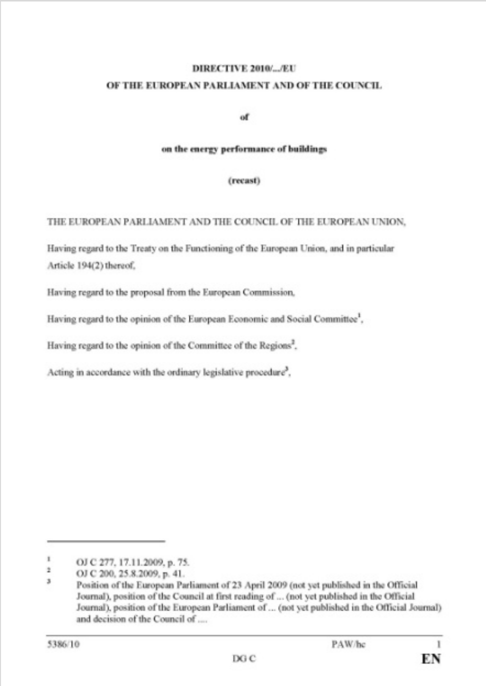
Content

- **Energy Policy Background**
- Paths towards
  Climate Neutral Buildings
- The International Framework
- Selected Examples
- Outlook

EPBD Recast 5/2010

Energy **P**erformance of

Buildings **D**irective, 2002



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

of

on the energy performance of buildings

(recast)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

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

Having regard to the proposal from the European Commission,

Having regard to the opinion of the European Economic and Social Committee[1],

Having regard to the opinion of the Committee of the Regions[2],

Acting in accordance with the ordinary legislative procedure[3],

1 OJ C 277, 17.11.2009, p. 75.
2 OJ C 200, 25.8.2009, p. 41.
3 Position of the European Parliament of 23 April 2009 (not yet published in the Official Journal), position of the Council at first reading of ... (not yet published in the Official Journal), position of the European Parliament of ... (not yet published in the Official Journal) and decision of the Council of ....

5386/10 PAW/hc 1
DG C EN

Article 2, Definitions:

Nearly zero-energy building means a building that has 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, including energy from renewable sources produced on-site or nearby.

Article 9, Nearly-Zero Energy Buildings

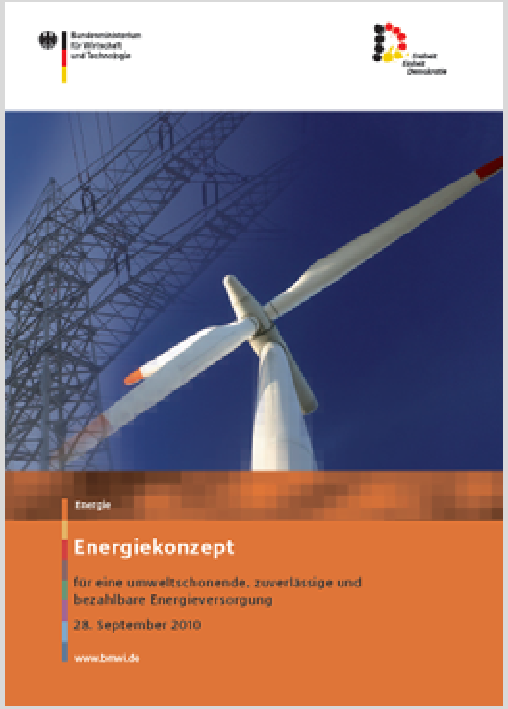
Member States shall ensure that:

- **by 31 December 2020, all new buildings are nearly zero-energy buildings**
- **after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy.**

Member States shall draw up national plans for increasing the number of nearly zero-energy buildings. These national plans may include targets differentiated according to the category of building.

Source:The Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, Official Journal of the European Union

German Energy Concept 9/2010



The central goal is a long term reduction of heating demands of existing buildings, in order to attain a **nearly climate-neutral stock of existing buildings by 2050**. Climate neutrality entails that buildings have very low energy demands and that remaining energy demands are predominantly covered by renewable energy sources .

The amendment of the Energy Savings Directive of 2012 introduces the concept of **“climate-neutral building” as standard for all new construction until 2020** on the basis of primary energy parameters. The **related renovation roadmap for existing buildings** set up in this amendment begins in 2020 and leads to a step-by-step target of **reducing primary energy demands by 80 percent until 2050.**

Maintaining **cost-efficiency** is required.

The federal government will assume a pioneering role in reducing energy consumption for its existing and future new construction stock.”

International Dimension

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UK

„The policy statement confirms the Government's intention for all new homes to be zero carbon by 2016 with a major progressive tightening of the energy efficiency building regulations - by 25 per cent in 2010 and by 44 per cent in 2013 - up to the zero carbon target in 2016"

[Department for Communities and Local Government: London, 07/2007]

Austria

"Vision 2050 on energy in buildings: The building stock of the year 2050 should be in total over the entire life cycle (involves the production and operation of the building) free of any carbon emissions

[http://www.e2050.at/pdf/energie_gebauede.pdf]

Netherlands

„In the Netherlands, the government and the construction sector aim at achieving energy neutral new construction in 2020"

[Chiel Boonstra, Trecodome]

USA

"The long-term strategic goal is to create technologies and design approaches that lead to marketable zero-energy houses by 2020 and to zero-energy commercial buildings by 2025."

[DOE's current construction technologies program]

Canada

„The Equilibrium House Initiative aims the community-scale demonstration of 1,500 Net Zero Energy Houses by 2010 and all new houses to be Net Zero by 2025“

[http://www.cmhc.ca]

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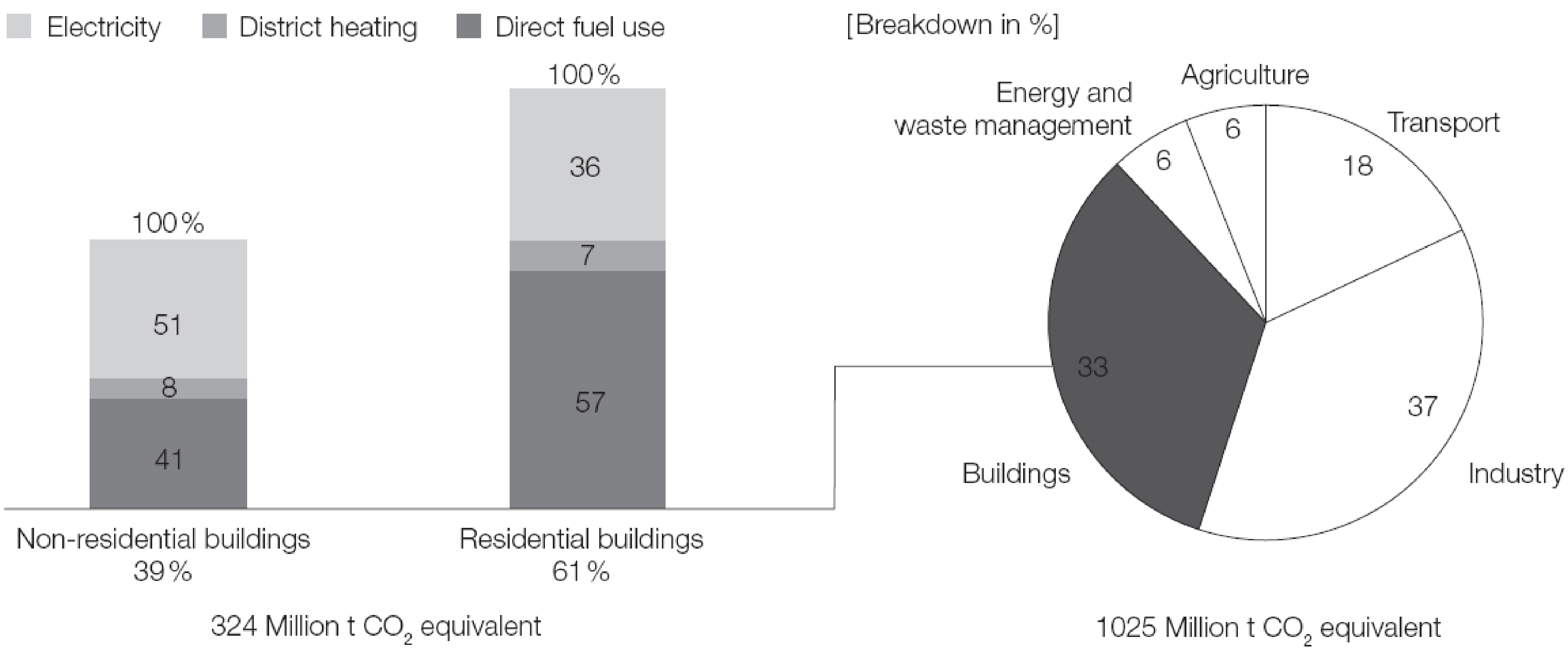
Climate Protection and Building Stock, Germany

About 1/3 of the total carbon emissions in Germany relate to the building stock. Half of the emissions are caused by on-site combustion processes, the other half is due to power and heating plants for grid energy supply.



Quelle: Kosten und Potenziale zur Vermeidung von Treibhausgasen in Deutschland – Sektorbericht Gebäude, McKinsey, 2007

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NET ZEB

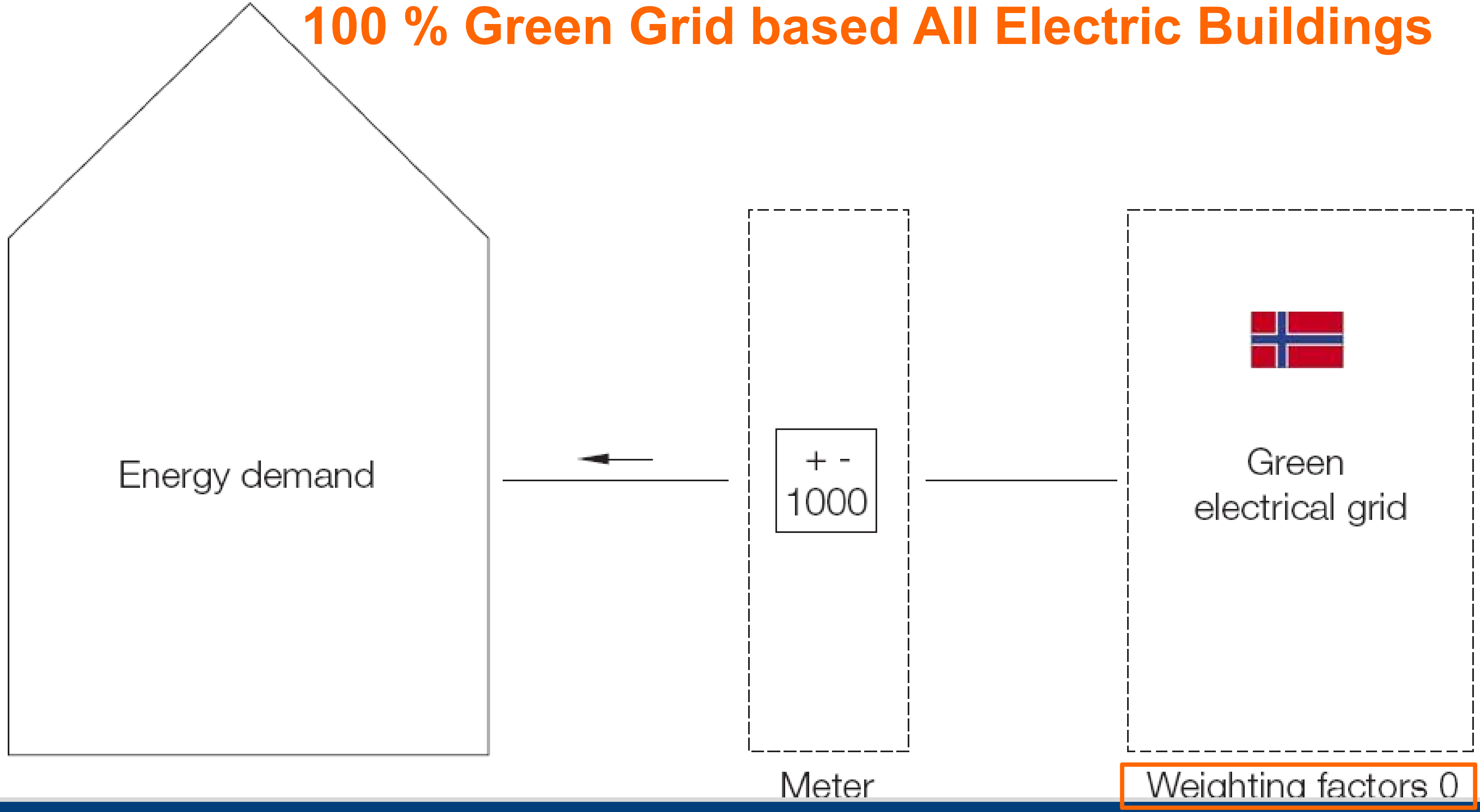
Energy Autonomous Buildings

The Self-Sufficient Solar House Freiburg, DE 1992
Picture: triolog, Freiburg

The New Monte Rosa Hut, Zermatt, CH, 2009
Picture: T. Amrosetti, Zürich, Lausanne

Paths towards Climate Neutral Building I: Green Power

100 % Green Grid based All Electric Buildings



Grids of the Future

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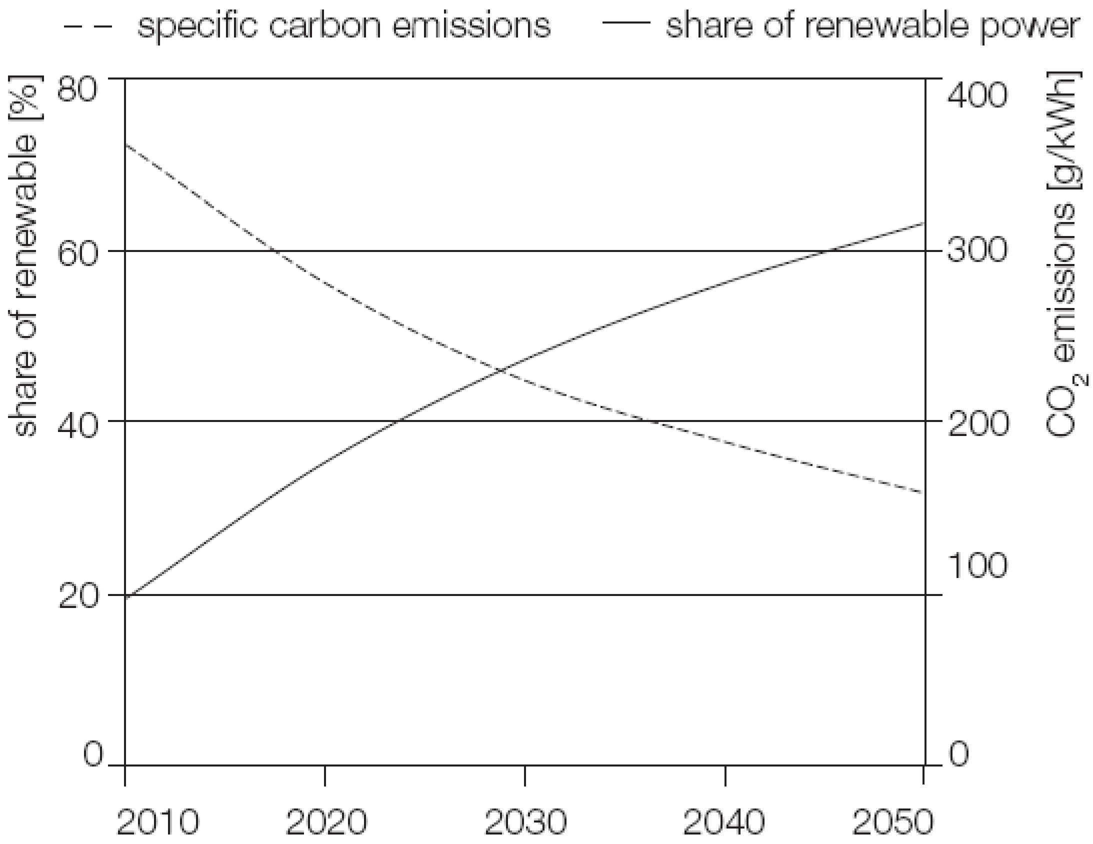
Green scenario for the development of the **European electricity grid until 2050** with rising share of renewables (local and regional level), limited demand (high efficiency) and thereby decreasing specific emissions (EMPS modelling).

The share of renewable power in Germany is currently comparable to the average EU mix by about 18%. Switzerland reaches about 56% and Norway 96%, both mainly hydro power based.



Graabak, Ingeborg; Feilberg, Nicolai: CO_2-Emissions in Different Scenarios of Electricity Generation in Europe, SINTEF report TRA 7058, 2011.

A Green Power System is a Limited Resource

Green power already has its market. The full substitution of nuclear power drastically increases the needs.

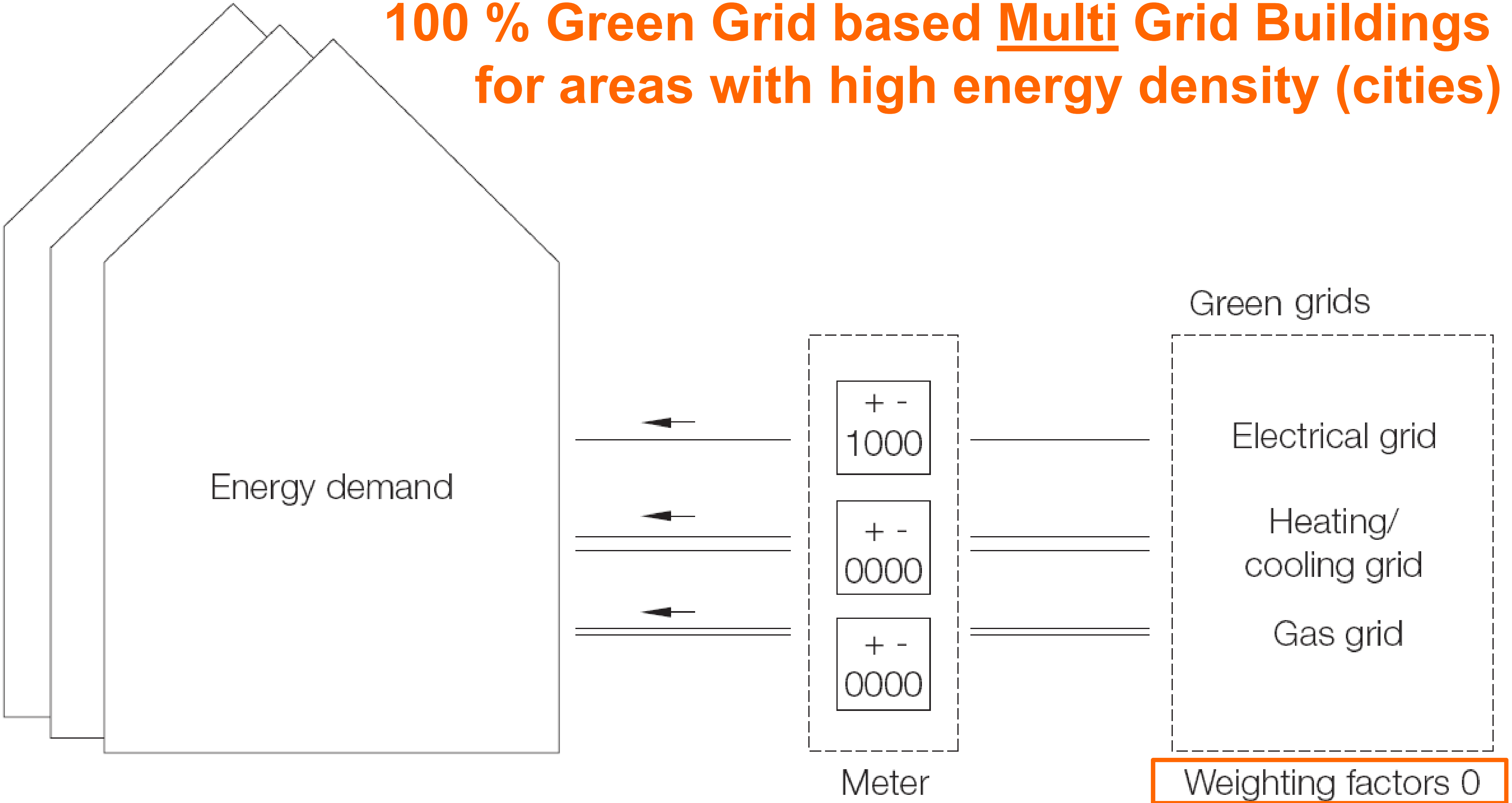
Limitations are:

- limited available and acceptable locations for power generation from renewables
- limited storage capacity to fit the fluctuating generation from hydro, wind and sun to the fluctuating demands
- comparably high costs (compared to efficiency actions)
- rising power demands due to extended communication technology, space cooling, electricity use for heating and the future introduction of electric mobility.

Don´t waste green power in inefficient buildings but increase the activities towards a (European) interconnected, smart power system to share generation and storage options for efficient, smart consumers!

Paths towards Climate Neutral Building II: Green Grids

100 % Green Grid based Multi Grid Buildings for areas with high energy density (cities)



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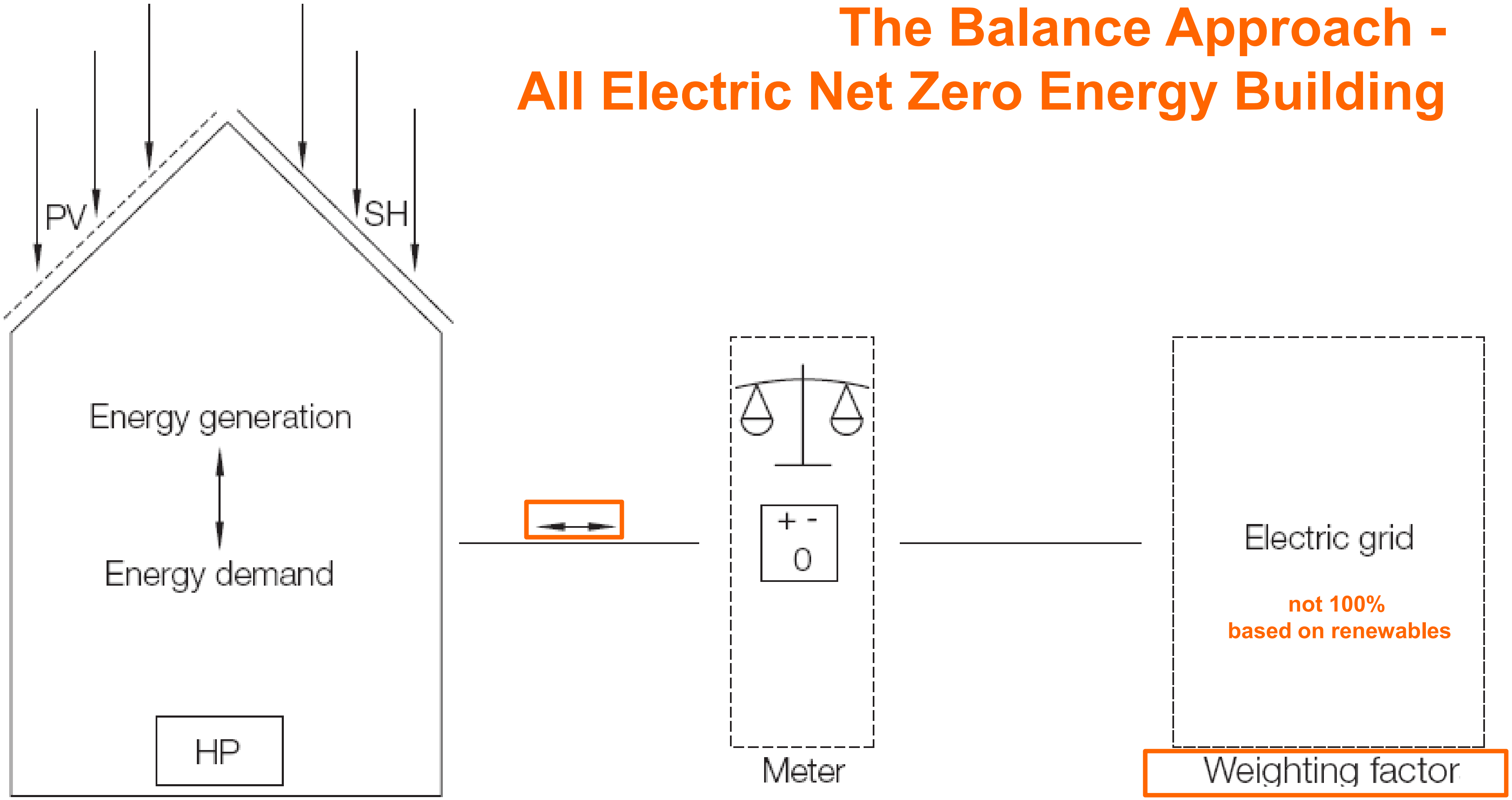
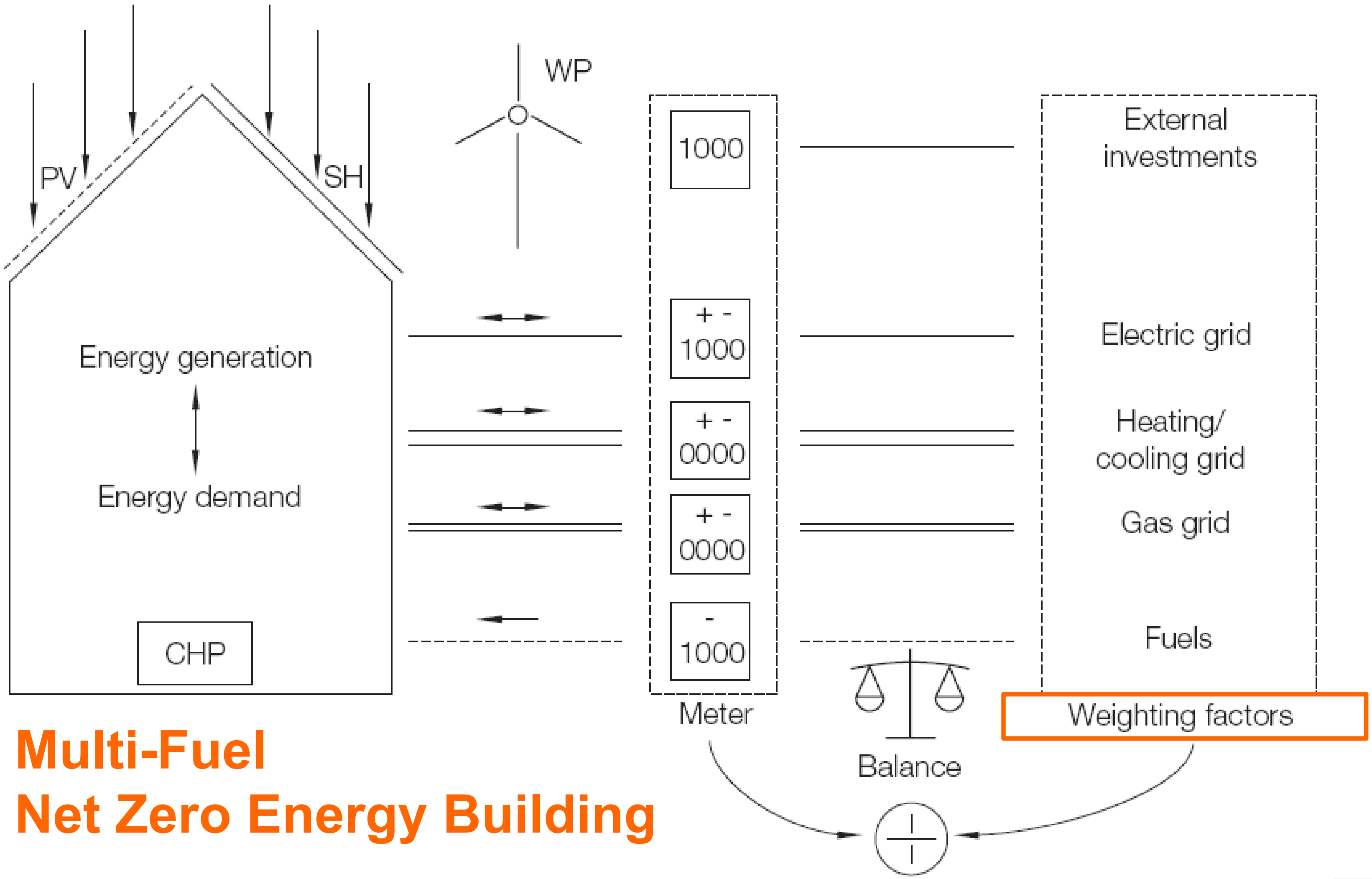
Paths towards Climate Neutral Building III

The Balance Approach - All Electric Net Zero Energy Building



Paths towards Climate Neutral Building IV



Multi-Fuel
Net Zero Energy Building

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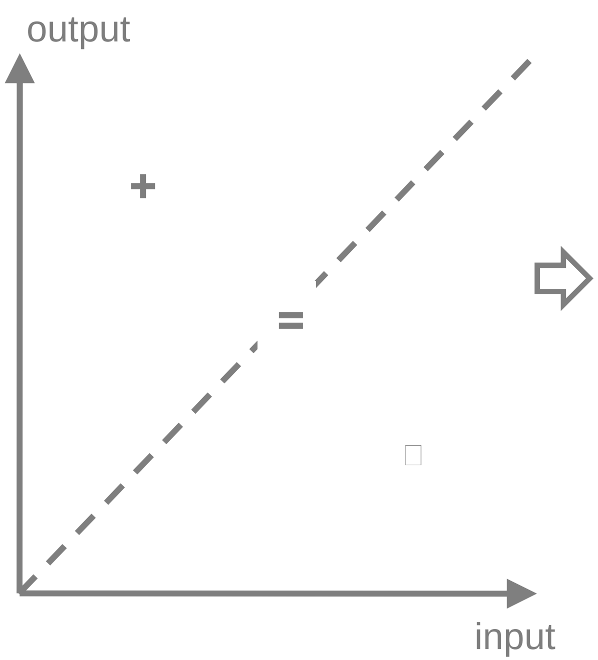
The Net ZEB Definition Framework is based on 3 Items

BASIC PRINCIPLE



SPECIFICATIONS

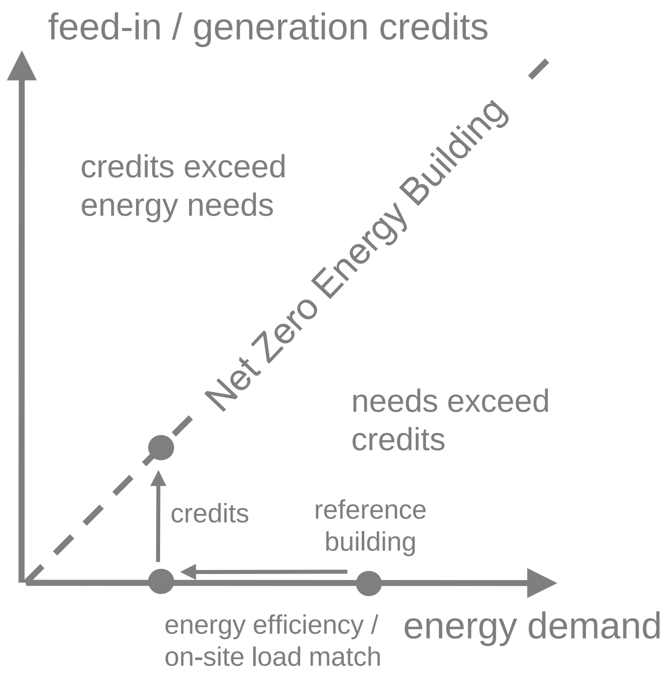
1. INDICATOR / METRIC
- site energy
- **primary energy, non renew.**
- primary energy, total
- equiv. Carbon emissions
- energy costs

2. BALANCE BOUNDARY
- **HVAC, DHW & lighting**

\+ **equipment & central services**
\+ electric mobility
\+ building material & construction
\+ external investments

3. BALANCE PERIOD
- **year**
- total time of utilization
- life-cycle

EXAMPLE



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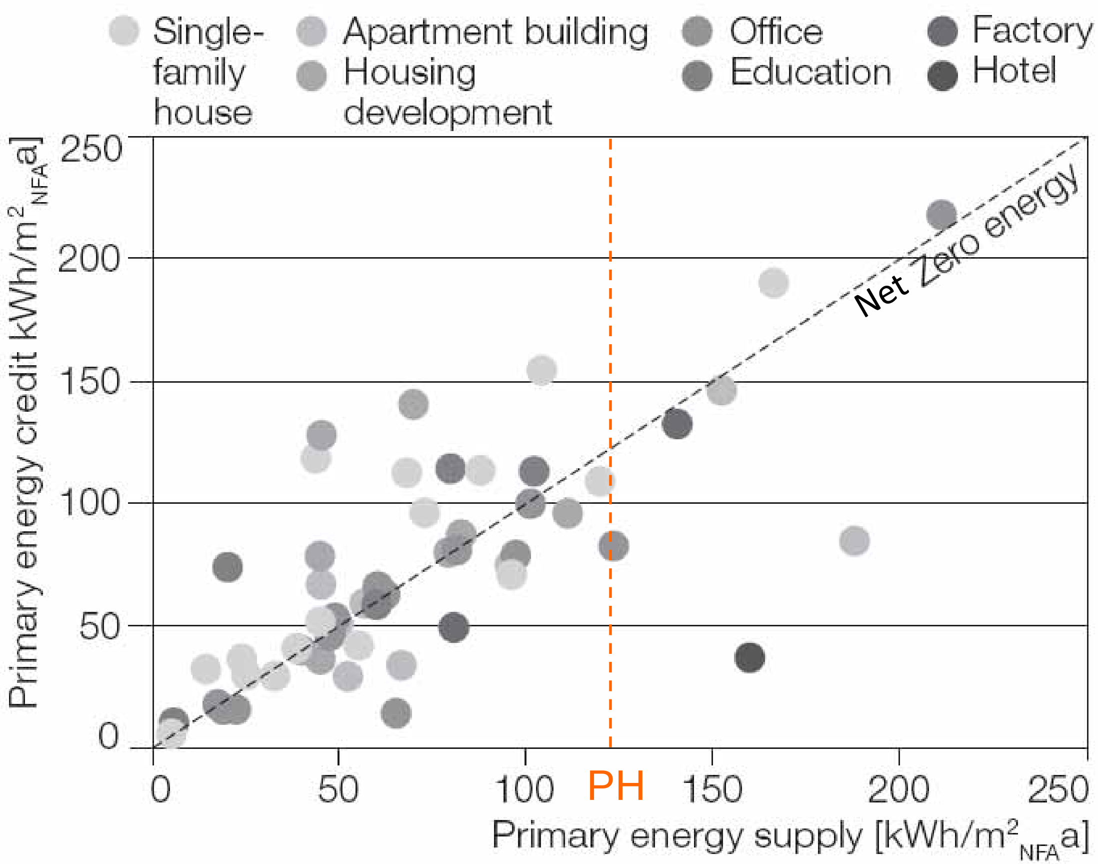
Monitoring Results

Total primary energy consumption versus primary energy credits based on monitoring results for consumption and on-site generation.

- user related loads included
- primary energy factors according to location



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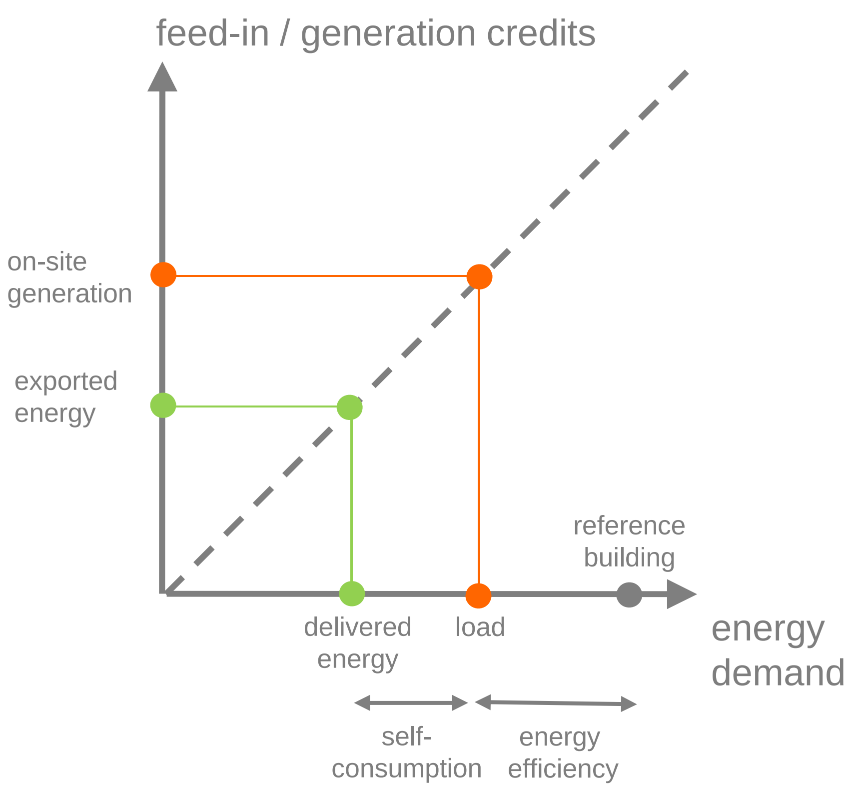
Two Balance Types:
Generation versus Load or Export versus Delivered?



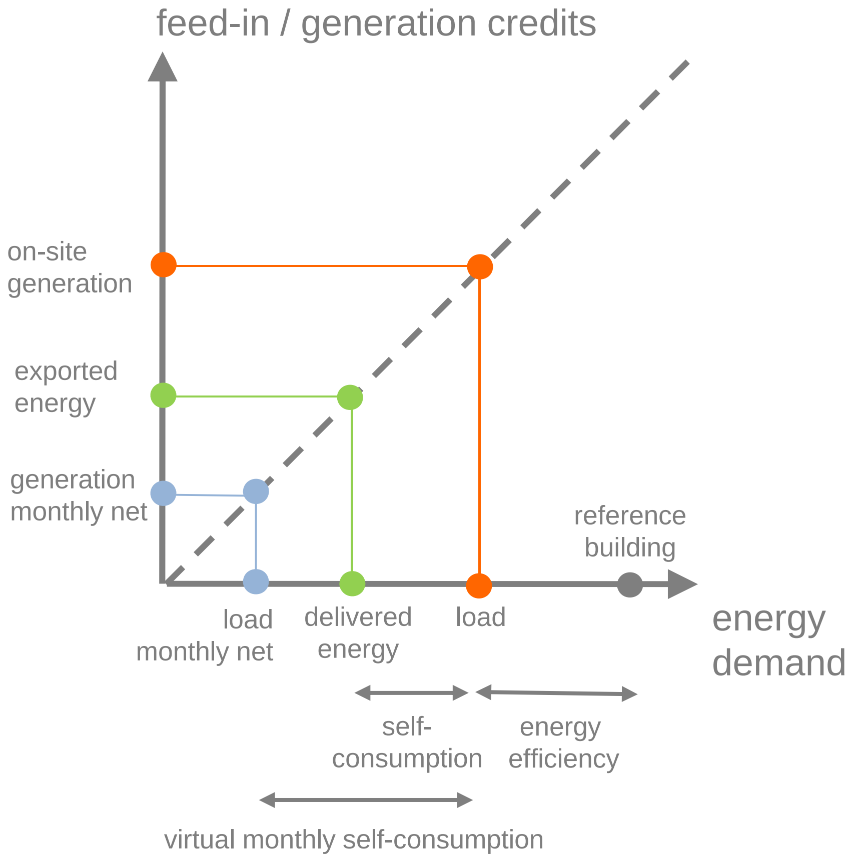
Planning: Generation/Load

- **Independent** calculation of on-site energy generation (PV, CHP,...) and building total energy demand

Operation: Export/Delivered

- Monitoring of net energy flow at the point of grid interaction considering **internal load match.**

Simplified combined Approach: Monthly Balance (Virtual Load Match)



Planning: Generation/Load

- **Independent** calculation of on-site energy generation (PV, CHP,...) and building total energy demand

Operation: Export/Delivered

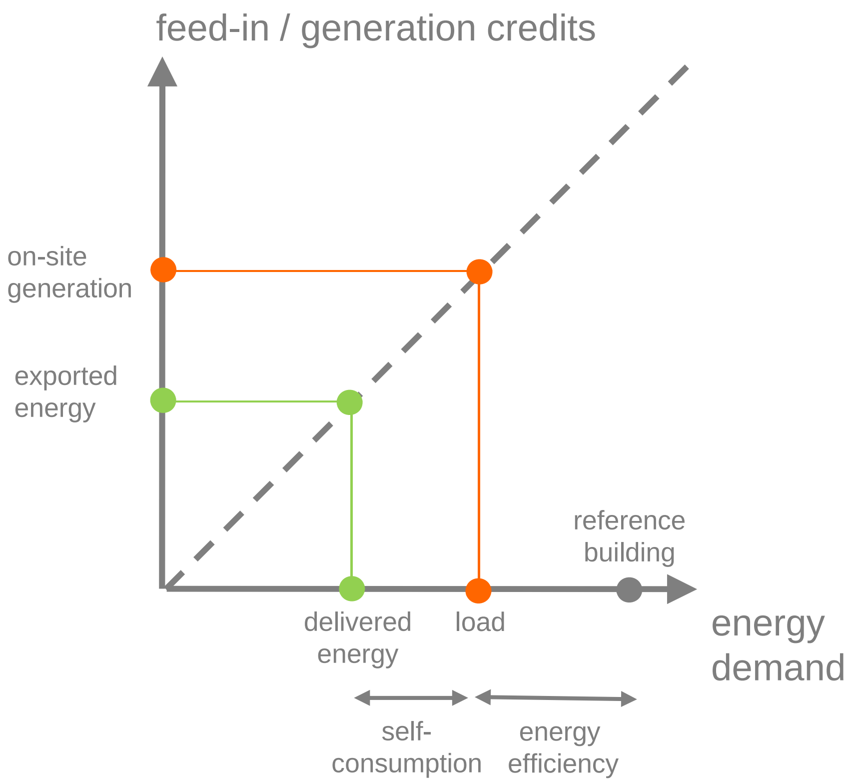
- monitoring of net energy flow at the point of grid interaction considering **internal load match.**

Compromise: "Virtual" Load Match

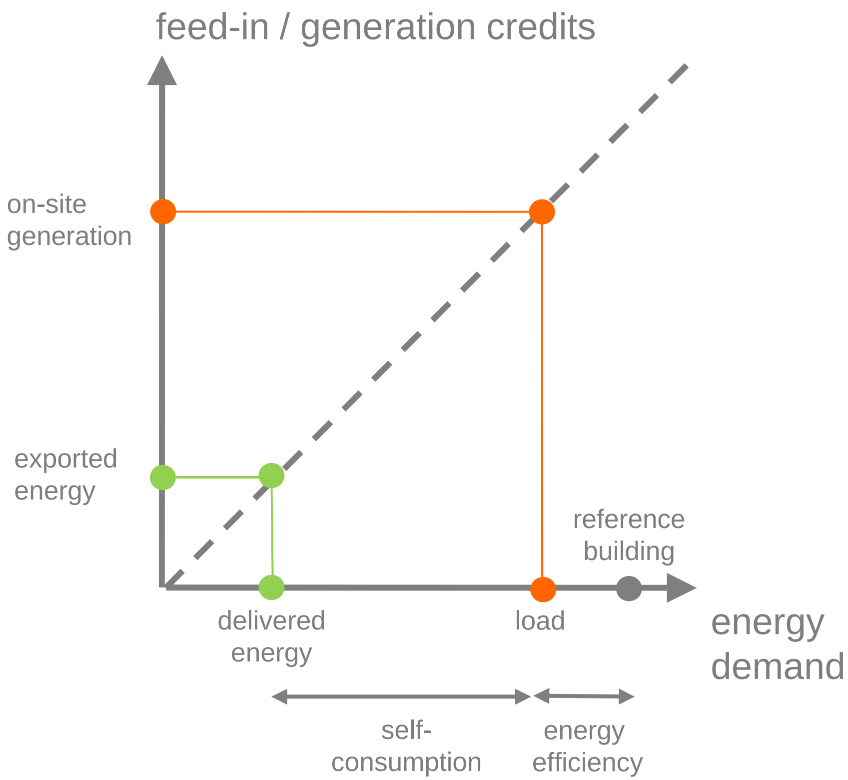
- Independent calculation of on-site energy generation and demand plus **monthly based balance**.

100% Annual Balanced but different Performance

Moderate Efficient and Load Match



Low Efficient but High Load Match



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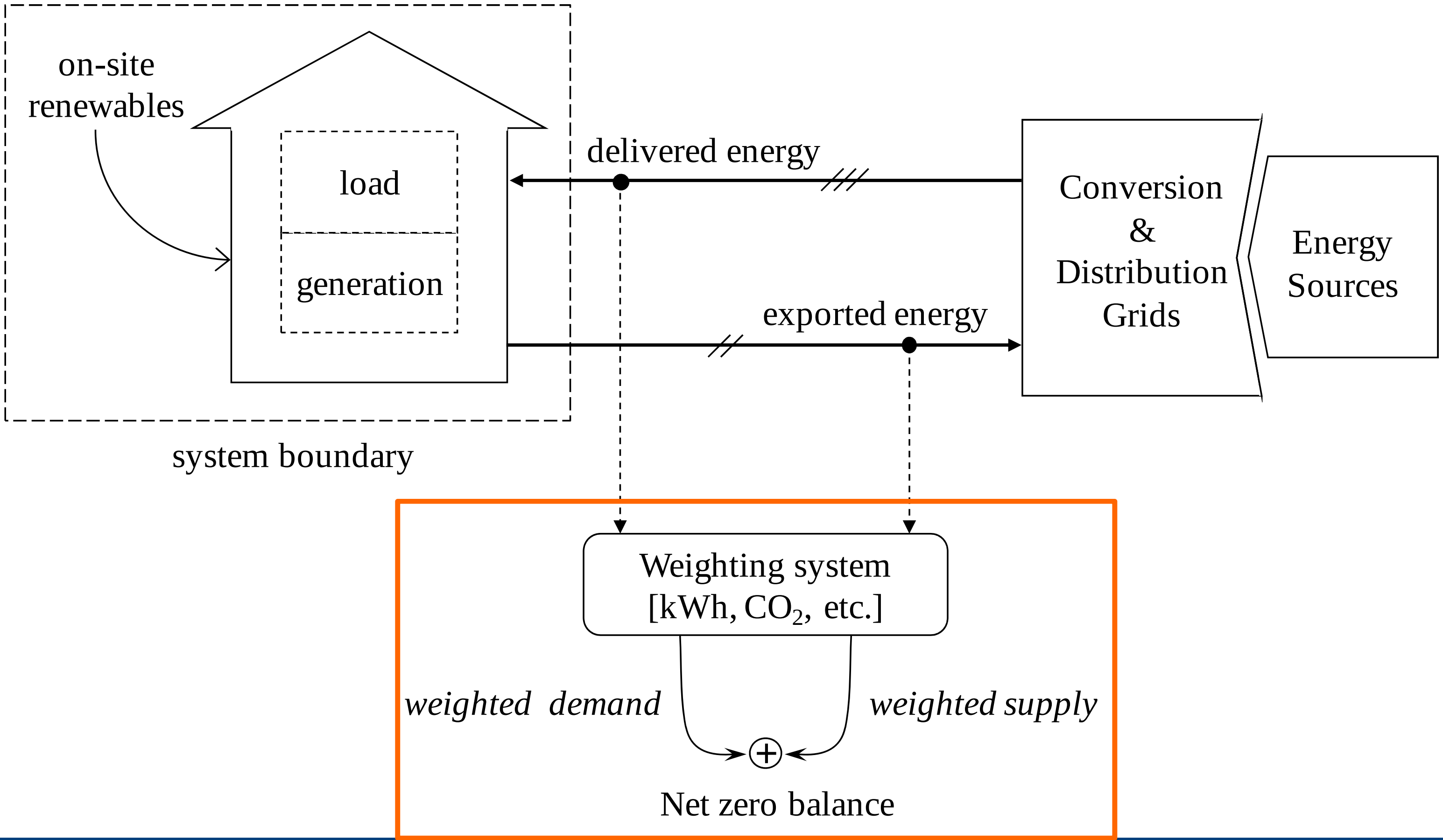
Market and Energy Policy Influences - Weighting Factors, Weighting Symmetry, Tariffs, ...



Market and Energy Policy Influences - Examples I
Weighting Factor System

Weighting Factors

The Swiss energy code system EnDK weights combustion of timer with a primary energy factor of 0.7, although the non renewable primary energy factor is in the range of 0.05). Background are the limited resources from sustainable foresting compared to the non-limited resources like solar energy. This results in higher calculated primary energy needs and larger credits needed to fulfil the balance.

Weighting Symmetry

The new 2011 governmental demonstration program for net energy plus buildings in Germany applies asymmetric primary energy factors for electricity:

- grid electricity utilization: 2.4
- feed-in electricity: 2.8

The strategy leads to higher credits achieved compared to symmetric weighting.

BMVBS Bekanntmachung, 18.8.2011

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Weighting Factors aplied in European Countries

			Europe		Austria	Denmark	Finland		Germany[7]		Italy	Norway		Spain		Sweden		Switzerland	
			EN 15603 2008	PHPP 2007	Gemis Version 4.5[3]	BR 2010 2010	BC 2012 2011	Gemis 2011	DIN V 18599/1 2007	GEMIS Version 4.5	UNI-TS -11300/4 draft 9/2009	NS 3700 2009	ZEB centre[10] 2010-2050	I.D.A.E. 2010	CAL-ENER 2009	aver-age[12] 2008	pol. factors[13] 2008	SIA 2031 2009	EnDK 2009
Electrical grid	PEI n.r.	kWh_p/kWh_s	3,14[1]	2,70	1,3[4]		1,70		2,60	2,61	2.18[8]							2,53	2,00
	PEI total	kWh_p/kWh_s	3,31[1]		1,91	2,50[5]	1,70		3,00	2,96				2,28	2,60	1,50	2,50	2,97	
	CO_2 eq.	g/kWhs	617,00[1]	680,00	389,00		329,62	331,00		633,00	531[9]	395	132	350[11]	649			154,00	
Natural gas	PEI n.r.	kWh_p/kWh_s	1,36	1,10	1,12		1,00		1,10	1,12	1,00							1,10	1,00
	PEI total	kWh_p/kWh_s	1,36		1,12	1,00	1,00		1,10	1,12				1,07	1,10			1,15	
	CO_2 eq.	g/kWhs	277,00	250,00	268,00		202[6]	315,00		244,00		211		251[11]	204,00			241,00	–
Heating oil	PEI n.r.	kWh_p/kWh_s	1,35	1,10	1,11		1,00		1,10	1,11	1,00							1,15	1,00
	PEI total	kWh_p/kWh_s	1,35		1,13	1,00	1,00		1,10	1,11				1,12	1,08	1,20	1,20	1,24	
	CO_2 eq.	g/kWh_s	330,00	310,00	302,00		279[6]	381,00		302,00		284		342[11]	287,00			295,00	
Timber	PEI n.r.	kWh_p/kWh_s	0,09[2]	0,20	0,01		0,50		0,20	0,01	0,00							0,05	0,70
	PEI total	kWh_p/kWh_s	1,09[2]		1,01	1,00	0,50		1,20	1,01				1,25		1,20	1,20	1,06	
	CO_2 eq.	g/kWh_s	14**	50,00	6,00		32,40	17,00		6,00		14		0,00	0,00			11,00	
Wood pellets	PEI n.r.	kWh_p/kWh_s			0,14		0,50		0,20	0,14	0,00							0,30	0,70
	PEI total	kWh_p/kWh_s			1,16	1,00	0,50		1,20	1,16					0,00	1,20	1,20	1,22	
	CO_2 eq.	g/kWhs			41,00			19,00		41,00		14						36,00	
Disctrict heating	PEI n.r.	kWh_p/kWh_s		0,80	0,76				0,70	0,76	system specific							0,81[14]	0,60
70% CHP	PEI total	kWh_p/kWh_s			0,77	1,00*	0,70		0,70	0,77						0,90	1,00	0,8[14]	
(fossil)	CO_2 eq.	g/kWh_s		240,00	219,00			230,00		219,00		231						162[14]	

n.r.: non renewable

[1] Electricity according to UCTE Mix 1996, CO_2-values for 2009: 432 g/kWh_e

[2] Wood, general

[3] Data from Environment Agency Austria

[4] 60 % hydro power in Austrias power production, but 50 % when considering imported power

[5] 2015 requirements use 0,8; 2020 requirements use 0,6 for district heating and 1,8 for electricity

[6] based on Motiva report, 2004

[7] The normative primary energy factors for the national building code are given with DIN V 18599, emission data are not listed; if emission data are applied the most common source is GEMIS

[8] original source: AEEG – Autorità per l'energia elettrica e il gas – Aggiornamento del fattore di conversione 2008

[9] Ministero dell'ambiente e della tutela del territorio e del mare

[10] EU mix scenario for nearly carbon-free grid towards 2050 (in line with IPCC 450 ppm scenario): average 2010–2050

[11] carbon emissions only

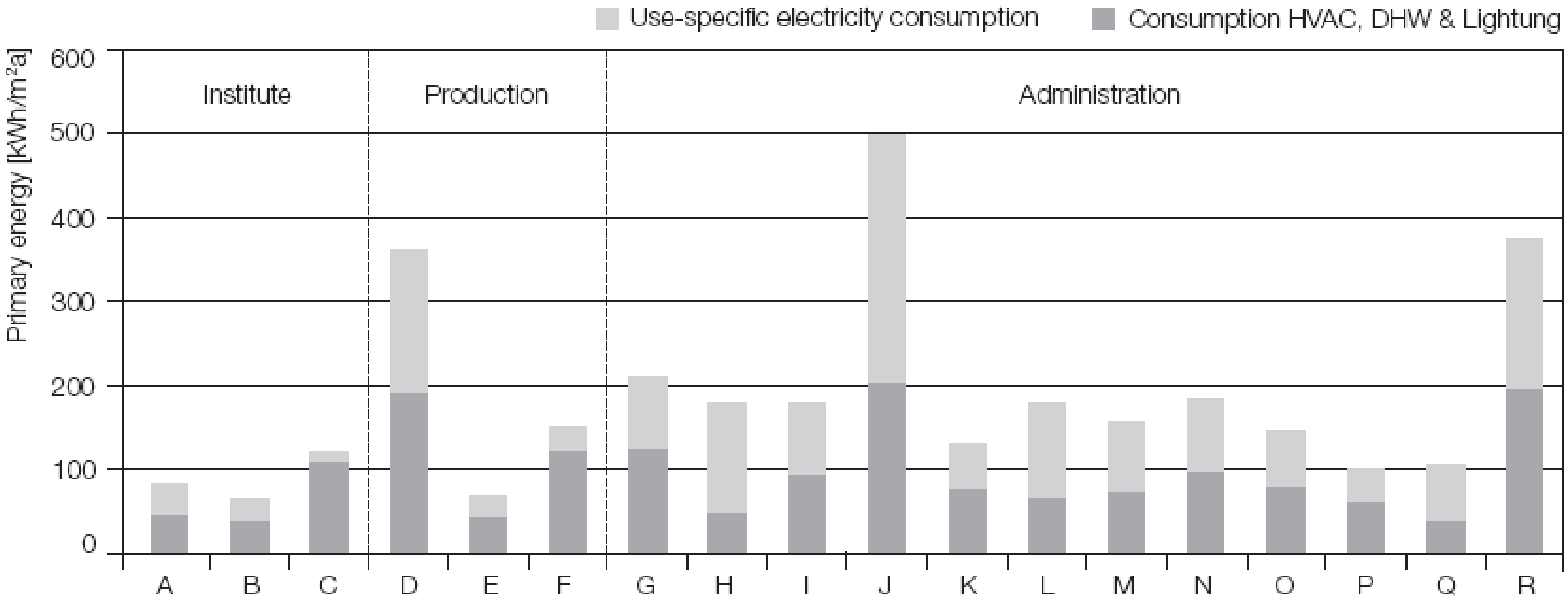
[12] calculated according to EN15316. For electricity, calculations are based on Nordic electricity mix

[13] Pol. Factors are PEI promoted to/by the government as they believe that increased use of electricity means more fossil fuel use in condensing power plants.

[14] based on waste combustion

Market and Energy Policy Influences - Examples II:
Balance Boundary Definition

Monitored primary energy use in energy efficient non-residential demonstration buildings in Germany. Use-specific consumption makes up 60% of total primary energy use on average.



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SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

SHC TASK 40 - ECBCS ANNEX 52

- What's New
- Objectives
- Subtasks
- Events
- Case Studies
- Task Highlights
- Task Participants
- Meetings / Events
- Publications / Outcomes
- Related Sites
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SHC Home > ECBCS Home >

Towards Net Zero Energy Solar Buildings

OVERVIEW

Energy use in buildings worldwide accounts for over 40% of primary energy use and 24% of greenhouse gas emissions . Energy use and emissions include both direct, on-site use of fossil fuels as well as indirect use from electricity , district heating/cooling systems and embodied energy in construction materials.

NET ZEB
TASK 40 /ANNEX 52

Given the global challenges related to climate change and resource shortages, much more is

Task/Annex Information

Duration

October 1, 2008 -- .September 30, 2013

Operating Agent

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Task 40 Annex 52	**Towards Net Zero Energy Solar Buildings (NZEBs)**			**Operating Agent:** Mark Riley, Canada **Time frame:** 1.10.08 - 30.9.2013	
Objective	The objective of the task is joint international research to advance NZEBs to practical reality in the marketplace by developing a common understanding and methodology, guidelines, tools and typical solutions sets and a source book that would be the basis of national demonstrations that would support broader industry adoption.				
Scope	The scope includes existing and new buildings (residential and non-residential, clusters of buildings and small settlements for the different climates (cold, moderate and hot) of participating countries. The work focuses on an analysis of existing examples and the development of optimized, whole building solutions that will be the basis of advanced, practical demonstrations, with exemplary architecture, that aim to equalize their small remaining annual energy needs by building integrated heat or power generation in combination with the interaction with utility structures.				
Subtasks	**A** Analysis, Methodologies & Large-Scale Implications	**B** Energy Efficiency and Energy Supply Simulation & Tools	**C** Advance Building Design & Engineering **C1** Non-Residential	**C2** Residential	**D** Dissemination
Lead country/STL Co-Lead	Germany: Karsten Voss	USA: Paul Torcellini Canada: Andreas Athienitis	NZ: Michael Donn France: François Garde	Sweden: Maria Wall NL: Chiel Boonstra	All: Task Steering Committee
Subtask Objectives	To develop an international definition and understanding of NZEBs based on a common methodology that considers large-scale implications, credit systems for grid interaction (heat, cool, power) and relevant ISO/CEN standards.	To identify and investigate key measurements and technologies, to simulate impacts on buildings and to produce a suite of NZEB tools and database to support industry adoption.	To develop whole building net-zero solutions sets for cold, moderate and hot climates with exemplary architecture that would be the basis for national demonstration projects; to document NZEB design options in terms of market and design acceptance and lifecycle energy and CO2 implications; and to develop guidelines and tools for industry adoption of integrated designs and concepts		To support knowledge transfer and market adoption of NZEBs on a national and international level
Means	The review and analysis of existing NZEBs definitions (site / source energy, exergy, emissions, costs, etc.) with respect to the demand, the supply, the grid interaction and the mismatch.	A technology focused review of existing NZEB concepts for cold, moderate and hot climates and identification of technological improvements considering sustainability, economy and future prospects.	Documenting and analyzing existing NZEBs, benchmarking with near NZEBs and other very low energy buildings (new and existing) and undertaking lifecycle assessment and optimization studies with respect to material/resource use and technologies for participating countries.		Establishing an NZEB web page, within the IEA SHCP framework, and an NZEB database that can be expanded and updated with the latest projects and experiences.
	Analysis of the energy, emission and energy cost balance for existing NZEBs and near zero buildings.	Investigation of advanced building integrated passive (incl. shading), active solar system concepts and cogeneration technologies (micro CHP) for warm, moderate and cold climates.	Development of integrated architectural and NZEB engineering solutions, including shading systems for control of solar gains, in close cooperation with builders, planners, manufacturers and clients that would lead to the development of pratical, national demonstration projects.		Producing a NZEB source book including example buildings from all investigated building types and climates.
	A study on the grid interaction (power/heat/cool) and analysis of the time dependent energy mismatch.	Investigation of advanced storage (heat,cool electricity) and integration with utility grids as well as advanced controls and load management technologies.	Developing typical NZEB solution sets with respect to building types and cold, moderate and warm climates and to document design options in terms of market and design acceptance and lifecycle energy and CO2 implications		Establishing an education network for student competitions, summer schools, contributions to the Solar Decathlon and similar activities.
	The development of a harmonized NZEB methodology and definition based on experience from existing approaches and relevant CEN/ISO standards	Detailed simulations of these innovative technologies in connection with building energy loads, solar gain control, energy storage, controls and utility grids.	With Subtask B, develop NZEB projects that integrate engineering solutions and exemplary architecture - in close cooperation with architects, builders, planners, manufacturers, clients and utilities – as the basis for national demonstrations projects.		Workshops, architectural competitions and articles and features in magazines to stimulate market adoption.
	The development of a monitoring and verification concept for checking the annual balance in practice (energy, emissions, costs).	The development of simplified NZEB tools or interfaces (e.g. spreadsheet or web-based method) linked to a national / international database of building archetypes and technologies.	With Subtask B, develop tools, guidelines and case studies for architects, engineers, manufacturers and clients to support the market adoption of practical, integrated NZEB concepts.		The transfer of task outputs to national policy groups, industry associations, utilities, academia and funding programmes.
Results	Harmonized methodology, definition and monitoring and verification guide (report)	Overview of market available and near market components and systems for different building types and climates.	Best practices, case studies, design guidelines, tools and knowledge for the task sourcebook and database and other dissemination materials.		NZEB source book covering the methodology, technologies, tools, case studies and demonstration projects.
	Studies of sector and national potential including impacts on grids (report).	A suite of NZEB tools including a data base and user manuals.	Solution sets and designs for national demonstration projects.		NZEB web page and database, papers, special issues of industry magazines.
Dissemination	Dissemination is organised as a shared responibility of all subtasks				

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World Wide Net ZEB Data Base

http://www.enob.info/de/nullenergie-plusenergie-klimaneutrale-gebaeude-im-stromnetz-20/nullenergiegebaeude-karte-internationaler-projekte/

comparable building typology · special typology (hotel, hospital, sports hall,...) · educational building · office building · small residential building · settlement (building group, row houses) · appartment building (block of flats) · Others

list edited by Eike Musall, Bergische Universität Wuppertal (emusall@uni-wuppertal.de). list will be updated continuously, locations used for reference only. Sometimes they simply refer to a general location (city / country), but not to the exact address

Publications


FROM LOW-ENERGY TO NET ZERO-ENERGY BUILDINGS: STATUS AND PERSPECTIVES

Karsten Voss, Eike Musall and Markus Lichtmeß

- Voss, Karsten et. al.: *Load Matching and Grid Interaction of Net Zero Energy Buildings*, Proceedings of the EuroSun Conference, Graz, 2010
- Voss, K., Musall, E., Lichtmeß, M.: *From Low-Energy to Net Zero Energy Buildings*, Journal of Green Building, Vol. 6, Nr. 1, p. 46-57, 2011
- Heinze, M., Voss, K.: *Goal Zero Energy Building – Exemplary Experience based on a Solar Estate*, Journal of Green Building, Vol. 4, Nr. 4, p. 1-8, 2009
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- Salom, J., et al.: *Understanding Net Zero Energy Buildings - evaluation of load matching and grid interaction indicators*, Proceedings of IPBSA, Sydney, 2011
- Sartori, I., Napolitano, A., Voss, K.,: *Net Zero Energy Buildings – A consistent definition framework*, Energy & Buildings, under review

Content

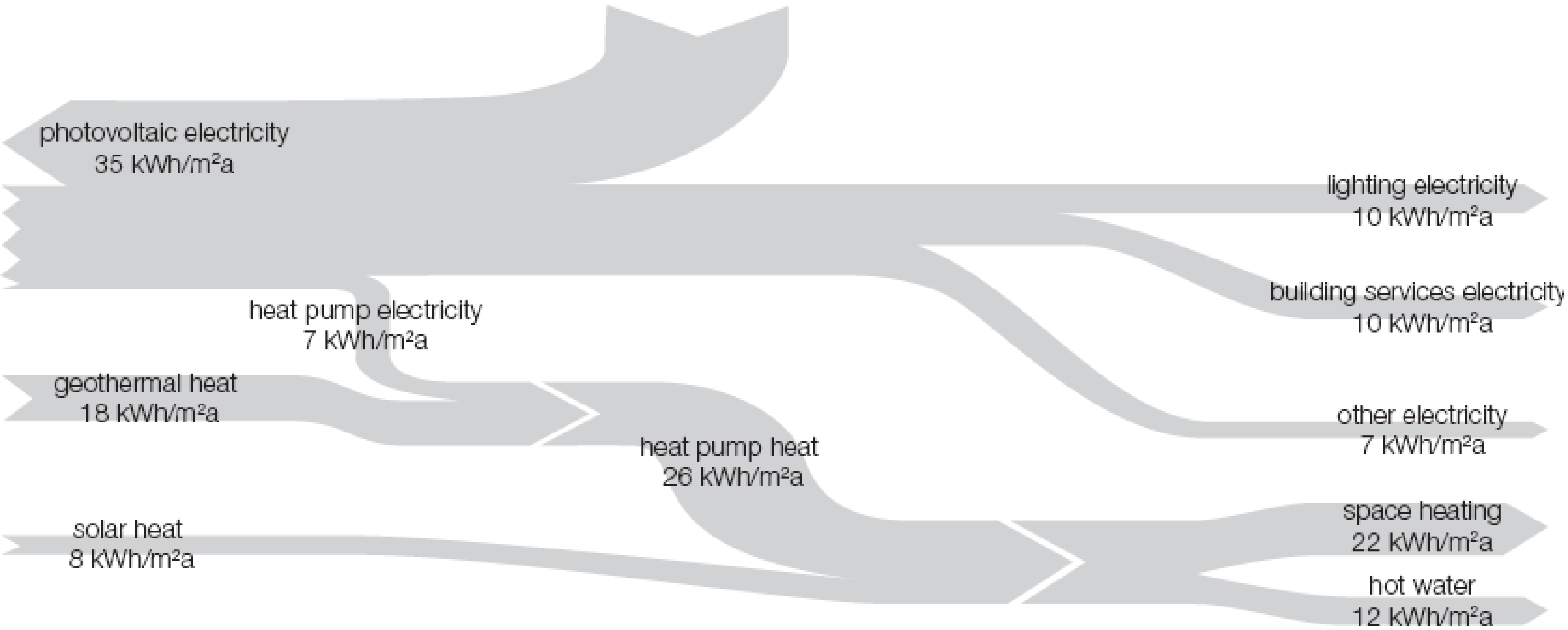
- Energy Policy Background
- Paths towards Climate Neutral Buildings
- The International Framework
- **Selected Examples**
- Outlook

Day Care Centre, Mohnheim, Germany, 2009

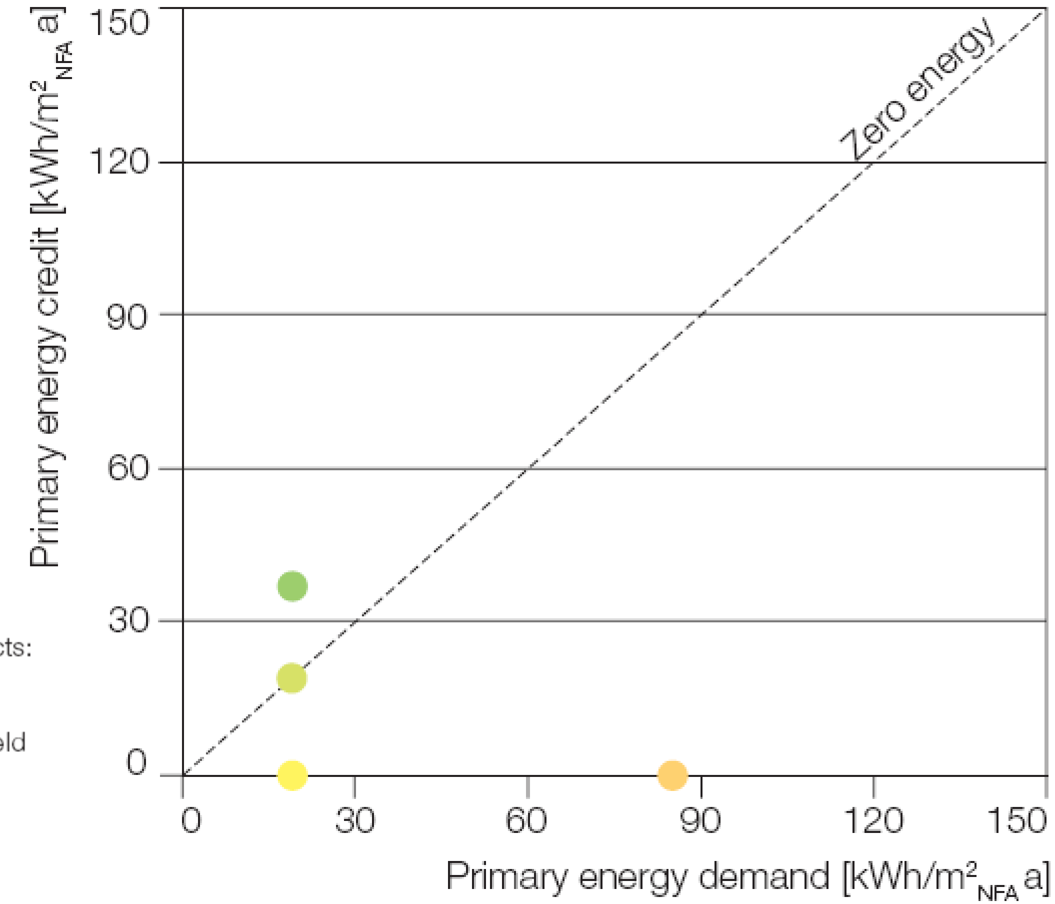
Picture: A. Schröder, Stuttgart

Client: Bayer Real Estate, Leverkusen
Architect: tr.architekten, Cologne
Energy consultant: IPJ Ingenieurbüro P. Jung, Cologne
Building services: E+W Ingenieurgesellschaft, Leichlingen
Monitoring: Bayer MaterialScience, Leverkusen
Primary stakeholders: client and architect

Energy Flow Diagram (Monitoring Results)



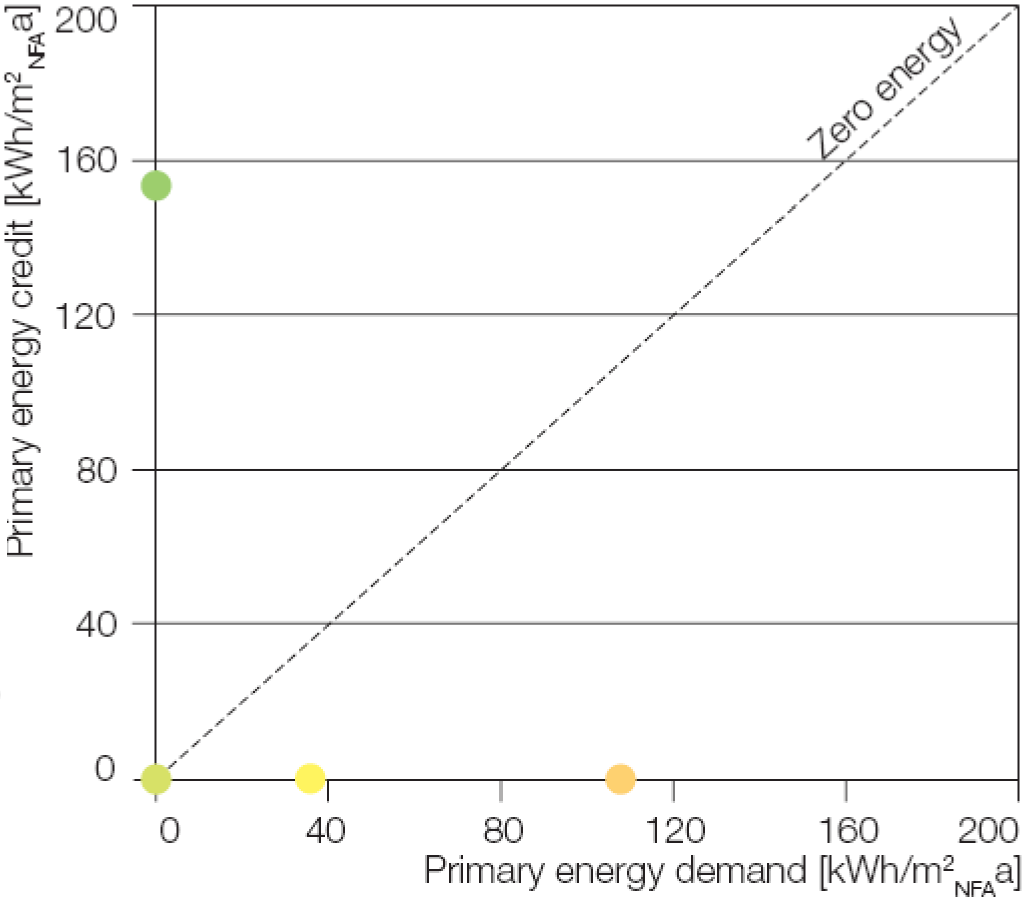
Net Zero Energy Performance (Monthly Balance Method)



The Net-ZEB-18 Standard comprises the following aspects:

- annual total primary energy consumption for all loads (80 kWh/m²a)
- self-demand covered by monthly creditable energy yield (62 kWh/m²a)
- residual consumption balance by monthly surplus
- annual energy surplus, public grid feed-in (18 kWh/m²)

Net Zero Energy Performance (Monthly Balance Method)



The very large solar yield covers total consumption each month; also, a very large surplus is generated. Clearly, user consumption is the dominant factor, and its monthly compensation is due to consistent year-long solar intake and absence of space heating or hot water demand.

- metered annual total primary energy consumption (106 kWh/m²a)
- building-specific primary energy consumption (36 kWh/m²a)
- seasonal compensation of total consumption via creditable monthly energy yield (106 kWh/m²a). Coverage of residual energy consumption is not required.
- annual energy surplus, grid feed-in (154 kWh/m²)

primary energy factor for electricity (3.3), specific to La Réunion

Office Building Refurbishment, Zeist, Netherlands, 2006

Bauherr: WWF – World Wide Fund for Nature, Zeist
Architekt: RAU architects, Amsterdam
Energieplaner: DGMR, Drachten
Technische Gebäudeausrüstung: Arup, Amsterdam
Monitoring : Arup, Amsterdam
Hauptakteure: Architekt und Bauherr

School Refurbishment, Wolfurt, Austria, 2007

Picture: R. Doerler

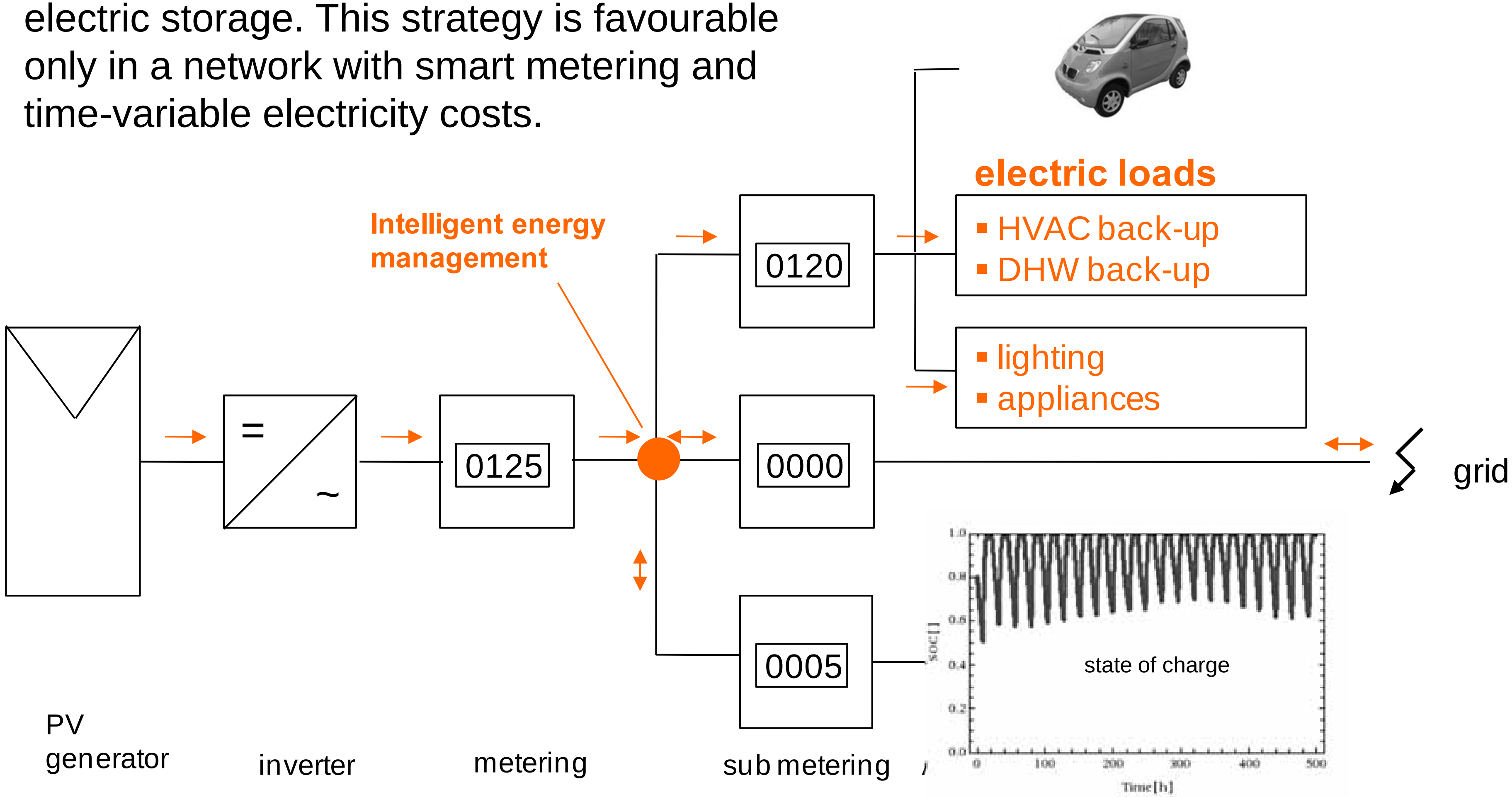
Experimental Building:
Team Wuppertal Solar Decathlon Home 2010, Madrid

sd europe
SOLAR DECATHLON
ESPAÑA 2010

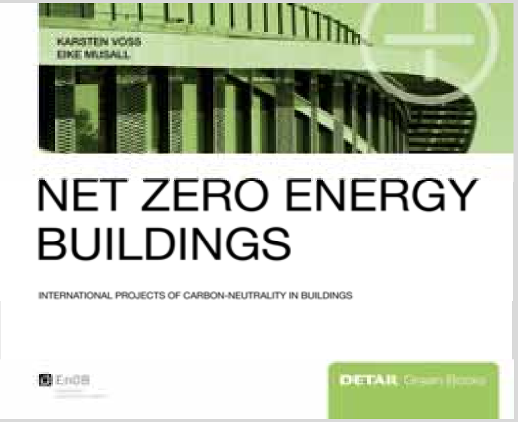
Photo: P. Keil

Improved Load Matching by Small Electric Storage

Load matching can be improved by **small** electric storage. This strategy is favourable only in a network with smart metering and time-variable electricity costs.



Outlook



Zero Energy/Carbon Energy Infrastructure

Increasing the fraction of renewables in the energy infrastructure improves the options for cost effective Net ZEBs for new and existing buildings.

Integrated Thermal and Electricity Management

Net ZEBs create the need for an integrated power and thermal energy management to optimize load matching and grid interaction. Smart metering, small batteries in the building and electric vehicles are future options for an integrated energy management to be researched.

Micro Cogeneration in Buildings (CHP)

Intelligent controlled, building integrated CHP operated with biomass for existing buildings.

Life Cycle Assessment

All Net ZEB solution sets must be analysed on life-cycle energy/carbon/cost level to judge about the appropriate measures on the building and the grid site.