

# Positive Energy Districts

Green. Building. Solutions. Summerschool 2020

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Research group Sustainable buildings and cities



Gefördert von



**Stadt  
Wien**

Wirtschaft, Arbeit  
und Statistik

KoIPEQ – Stadt Wien Kompetenzteam für lebenswerte Plusenergiequartiere

# POSITIVE ENERGY DISTRICTS (PEDs)

## 🏠 **PART 1** What is a „Positive Energy Districts“?

- ▶ Goals
- ▶ Examples
- ▶ Definitions

## 🏠 **PART 2** Why and how the PED is connected to our societal **climate goals**

- ▶ Connect Top-Down and Bottom-Up goals quantitatively
- ▶ Measure flexibility and support for carbon neutrality
- ▶ Examples

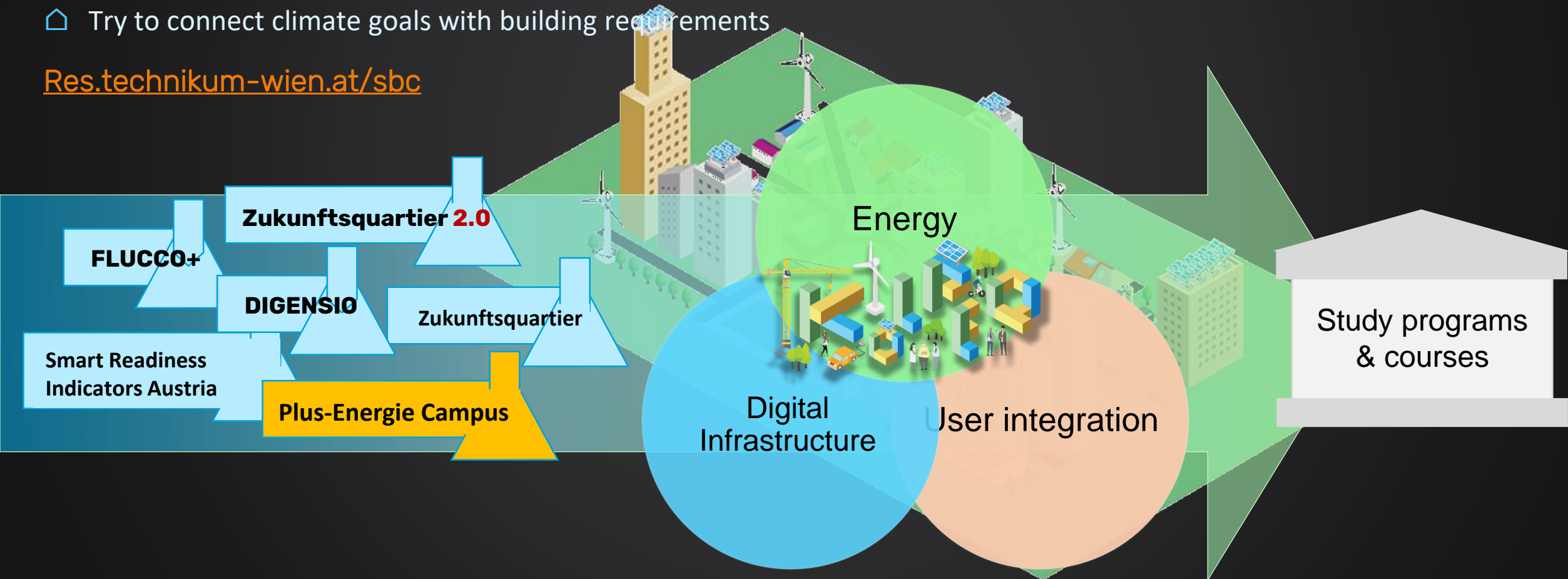
# Tell me about yourself: What is your background?

Top

# What I do @ Sustainable buildings and cities research group

- 🏠 Research “ [Livable Positive Energy Districts \(KolPEQ\)](#)”
- 🏠 Try to connect climate goals with building requirements

[Res.technikum-wien.at/sbc](https://res.technikum-wien.at/sbc)



# What we do @ Sustainable buildings and cities research group

[Res.technikum-wien.at/sbc](http://Res.technikum-wien.at/sbc)

Work **transdisciplinarily and put the user in the spotlight**

**Holistic, multidisciplinary assessments** (techn., ener., ecol., econ., Usability, Gender/Diversity)

Develop **Simulation & Visualization** methods

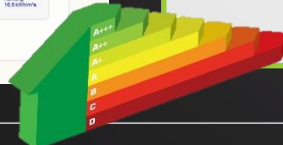
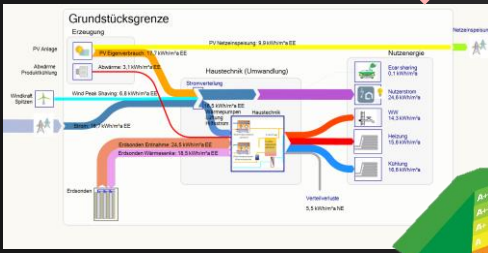
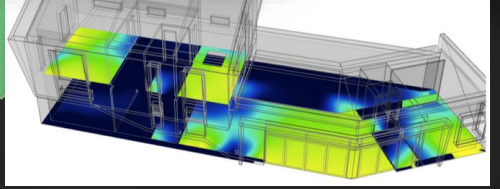
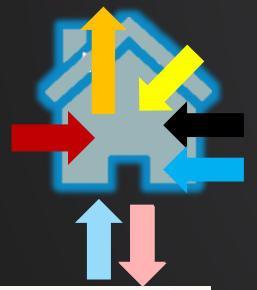
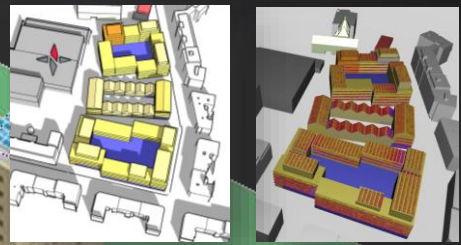
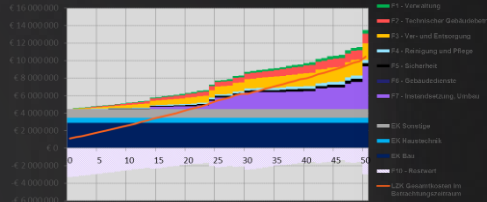
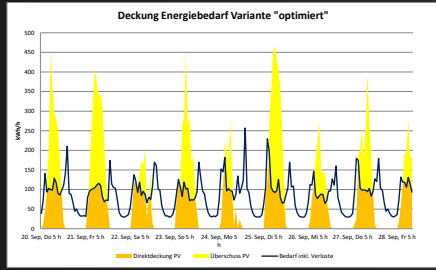
Research **Positive Energy Districts and energy autonomous Cities**

**Energy flexible Building concepts**

Research and develop **Positive Energy Buildings (NZEB)** concepts

**Highly energy efficient Building concepts**

**Modelling and simulation of and Thermal Comfort**



# What do you associate with a positive energy district?

energy  
efficiency

# EU Goal: 100 Positive Energy Districts by 2025

## The Strategic Energy Technology (SET) Plan 3.2

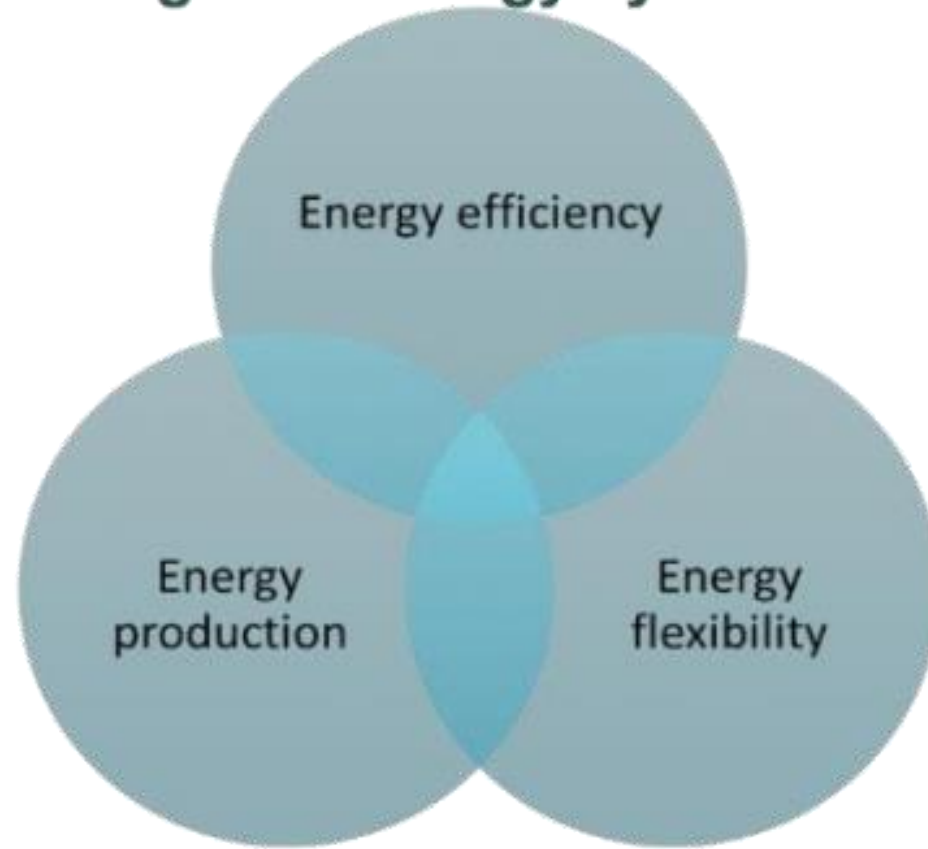
Europe to become a global role model in integrated, innovative solutions for the planning, deployment, and replication of **Positive Energy Districts**



## The Joint Programming Initiative (JPI) Urban Europe



## PED Framework: Functions of PED/PENs in the regional energy system



### Target:

Optimisation of the three functions of PEDs (energy efficiency, energy flexibility and energy production) towards climate neutrality and energy surplus by taking into account the guiding principles

### Guiding principles:

- Quality of life
- Inclusiveness
- Sustainability

### Enablers:

- Political vision and governance framework
- Active involvement of problem owners and citizens
- Integration of energy and urban planning
- ICT and data management



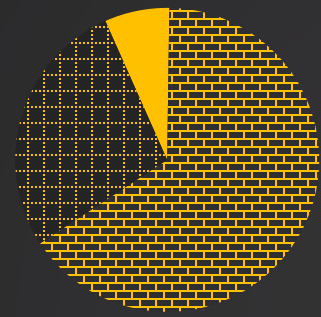


# PEDs in Europe:

🏠 2 In Operation

🏠 19 In Implementation

🏠 8 In Planning

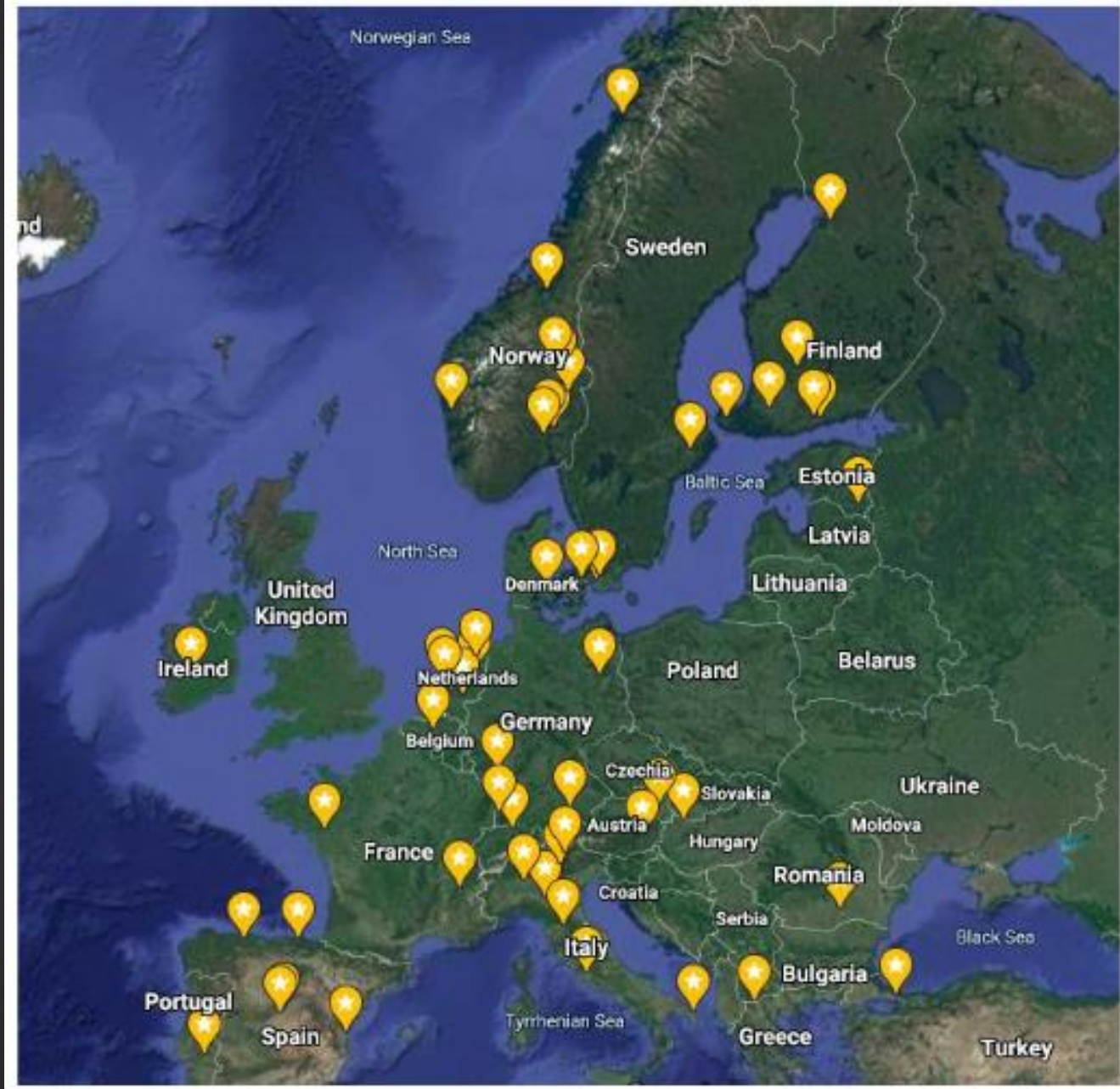
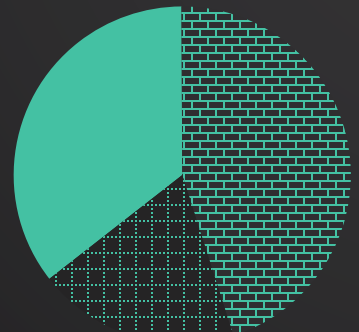


# TOWARDS PEDs, but not actual PEDs:

🏠 11 In Operation

🏠 14 In Implementation

🏠 6 In Planning



(JPU Urban Europe, 2020)

# Example PED: Smart Energy Åland (JPU Urban Europe, 2020)

**City** Åland Island, Sweden

**Project name** Smart Energy Åland - A society scale demo of an energy system running on re

**Project start – end** 2014 - 2019

**Project website** <https://flexens.com/the-demo/>

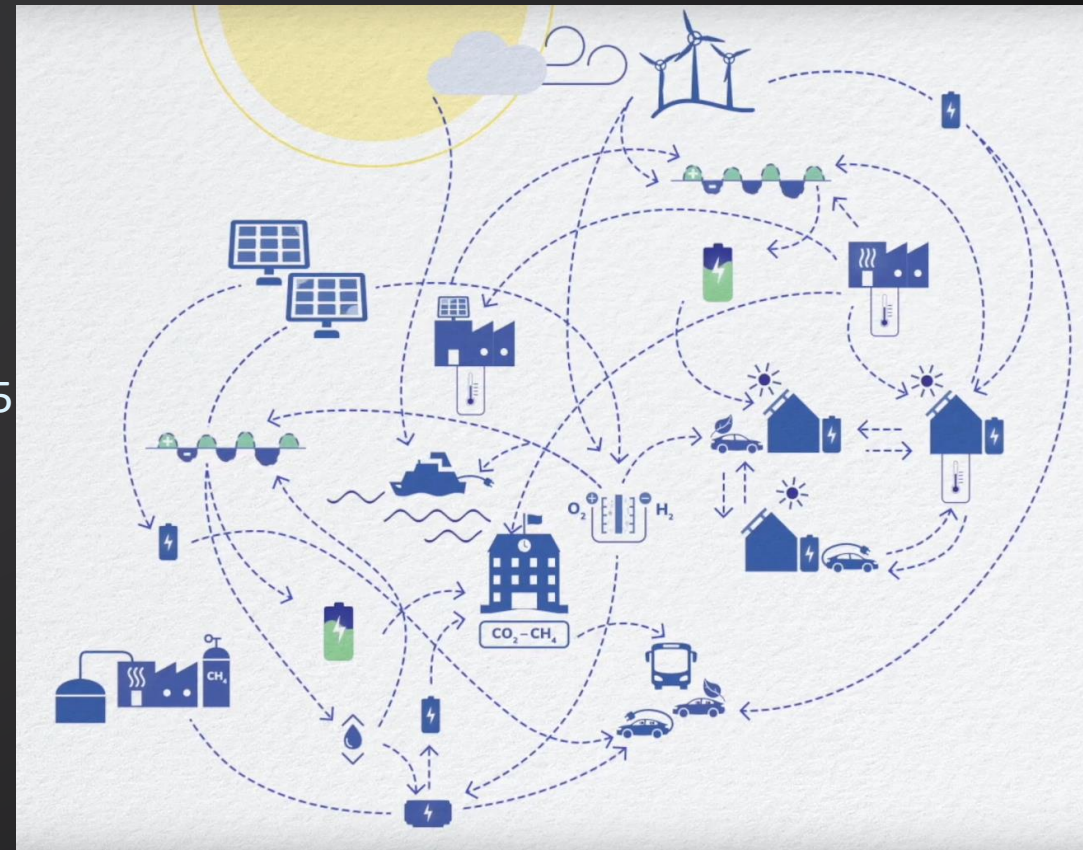
**Size of project area** Åland Islands, Area: 13,300 km<sub>2</sub>, Population: 30,000

The main Goal of the project for 2030 is to:

- Reduce carbon dioxide emissions by at least 60% compared to 2005.
- Increase the proportion of renewable energy to at least 60%.
- Increase the proportion of locally produced renewable electricity to at least 60%.
- Reduce emissions from road traffic by at least 50% compared to 2005

Unique features

- **Energy Autonomous**
- **Full society scale**
- **Adopting future EU regulation**
- **Location in the tempered climate zone**
- **A platform supporting open innovation**



# Example PED: Carquefou (Nantes), France Fleuriaye West (JPU Urban Europe, 2020)



**City** Carquefou (which is one of the 24 cites of Nantes Metropole), France  
**Project name** Fleuraye west  
**Project start – end** 1995 – 2022  
**Project website** [www.quartierlafleuriaye.fr](http://www.quartierlafleuriaye.fr)  
**Size of project area** 37 ha - Fleuriaye West project  
**Building structure** Newly built  Existing neighbourhood  Mixed

## Unique features

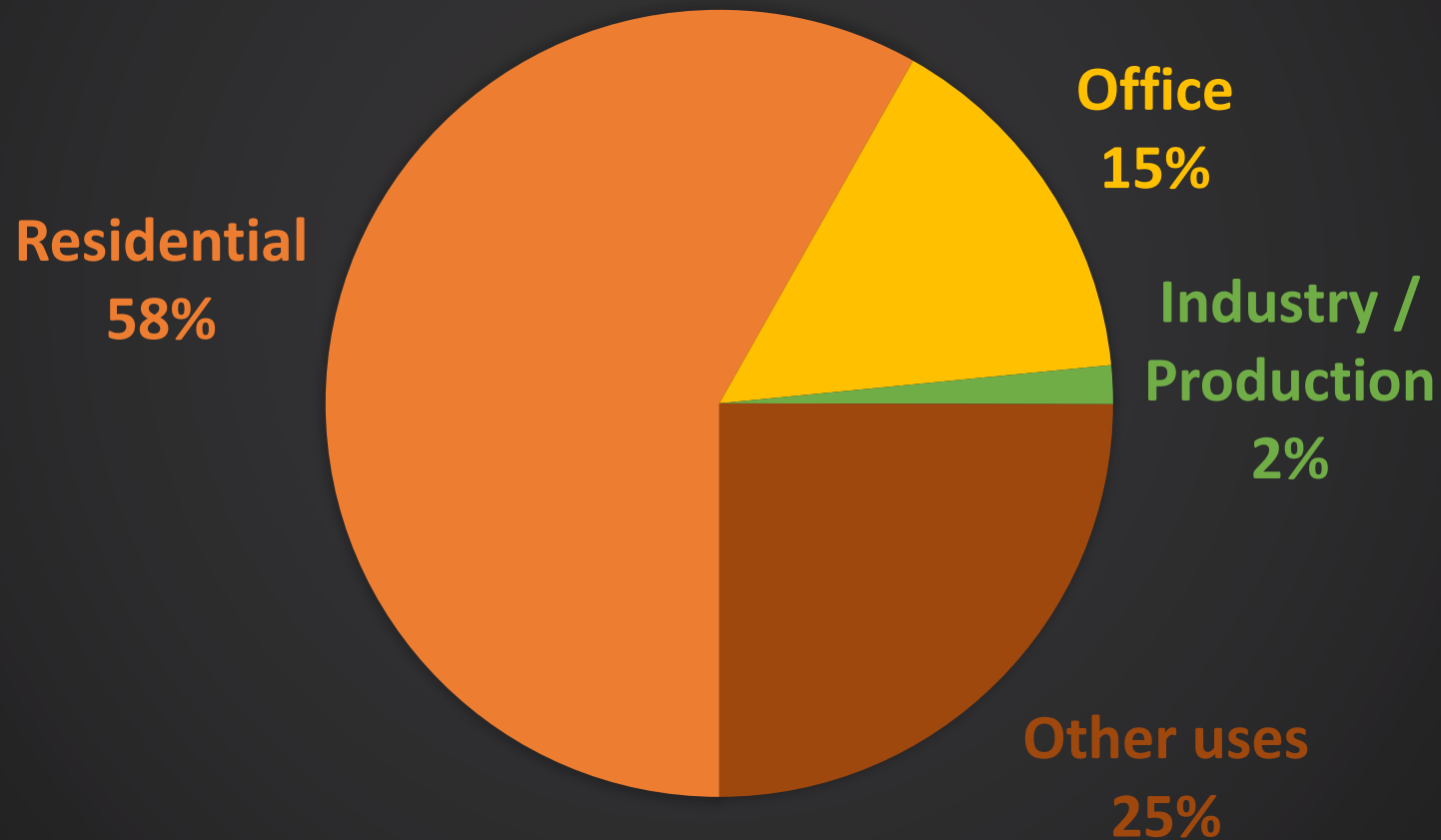
- **100% Renewable Energy Supply (Annual Balance)**
- **100% Passive House Standard**
- **Soft Mobility**
- **Materials for circular economy**



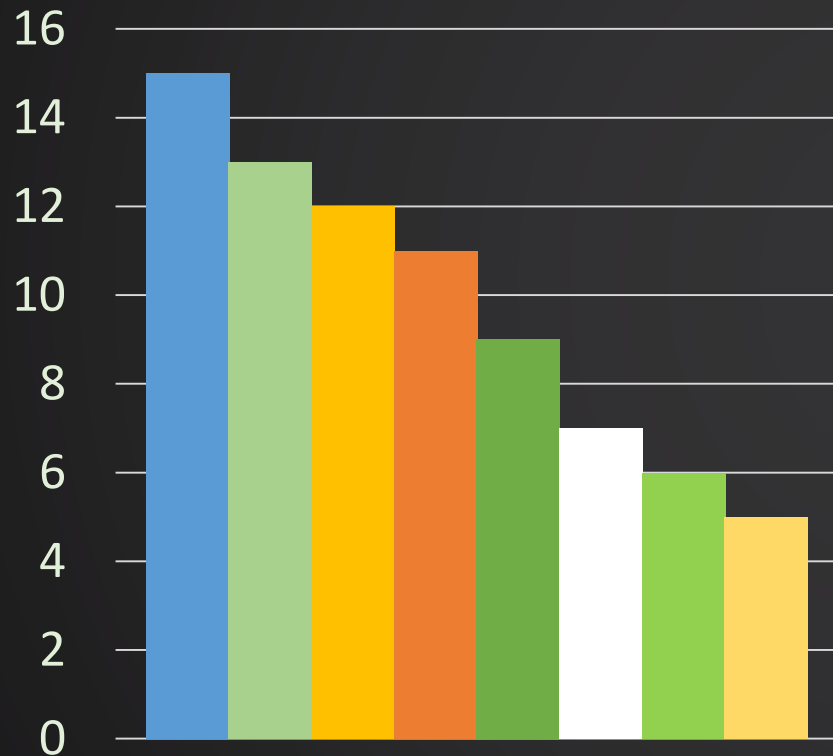
L'extension ouest du quartier de La Fleuriaye (à gauche) vient parachever un bassin de vie de 102 ha avec une mixité harmonieuse de fonctions.



# PED Projects – Average distribution of space use

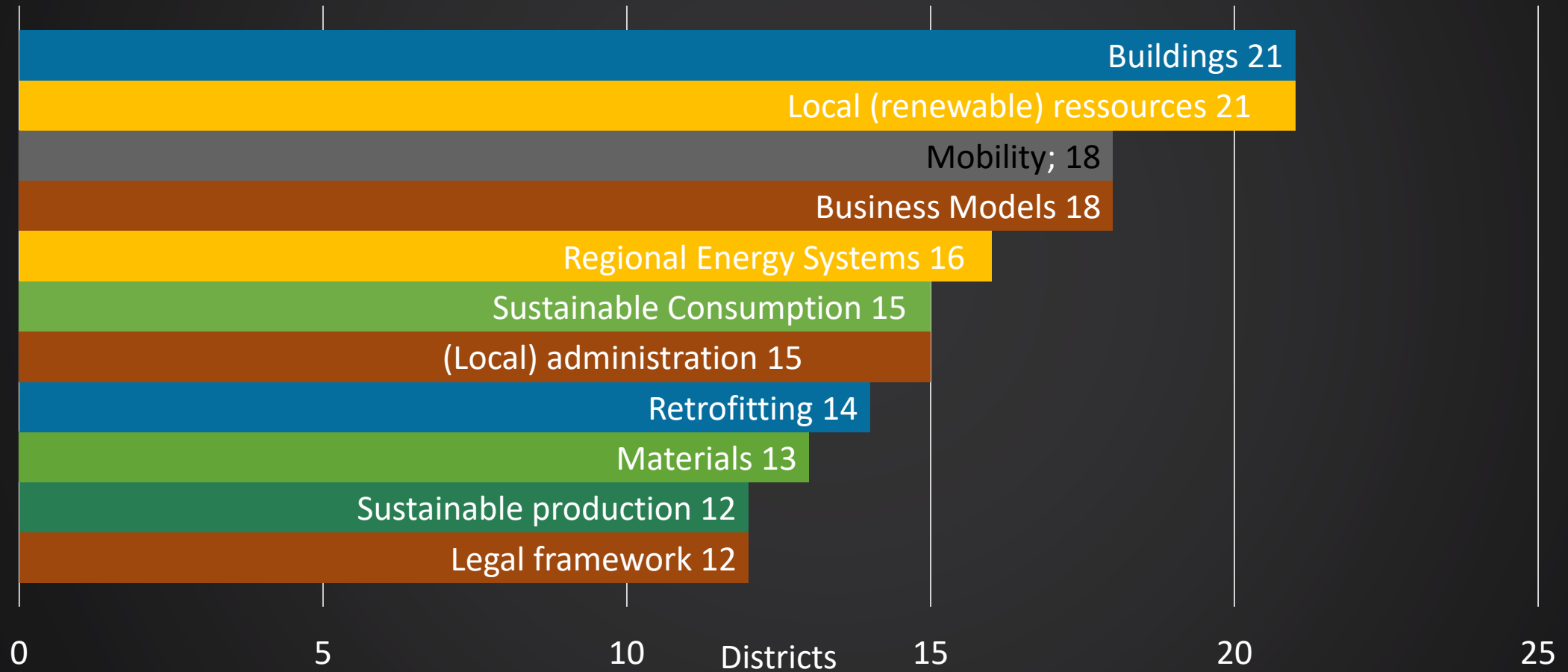


# PED Project goals and ambitions



- (Energy efficiency)
- (sustainable neighbourhoods)
- (Positive Energy)
- (social aspects / affordability)
- (climate neutral)
- (Zero-emission)
- (Carbon-free)
- (Energy neutral)

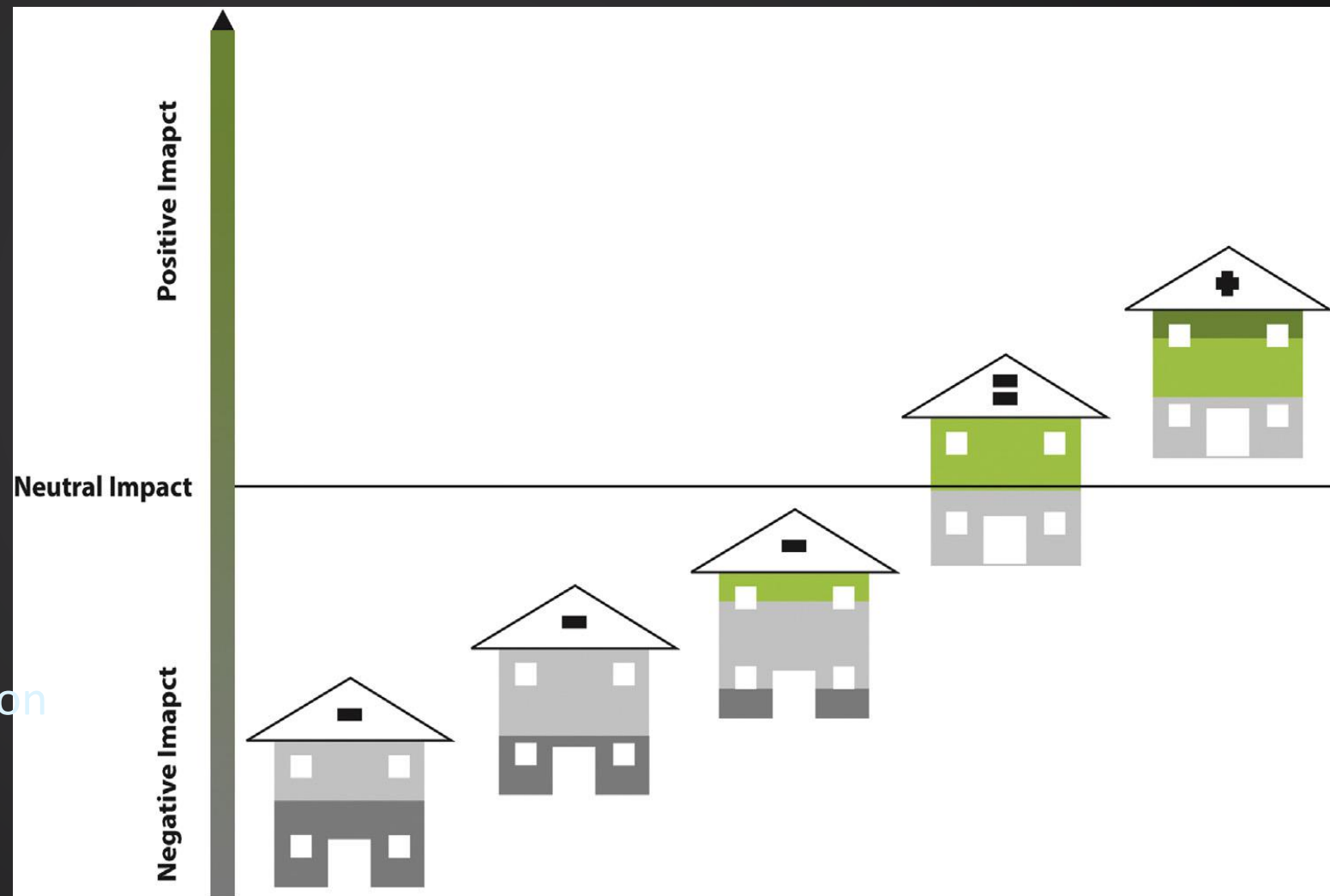
# PED Projects – Areas of activity and focus



# Multiple aspects and dimensions of improvement

- 🏠 Carbon Footprint
- 🏠 Ecology
- 🏠 Energy
- 🏠 Economy
- 🏠 Livelihood
- 🏠 Comfort
- 🏠 Social equality and participation
- 🏠 Aesthetics and cityscape
- 🏠 ...

(Attia, 2016)

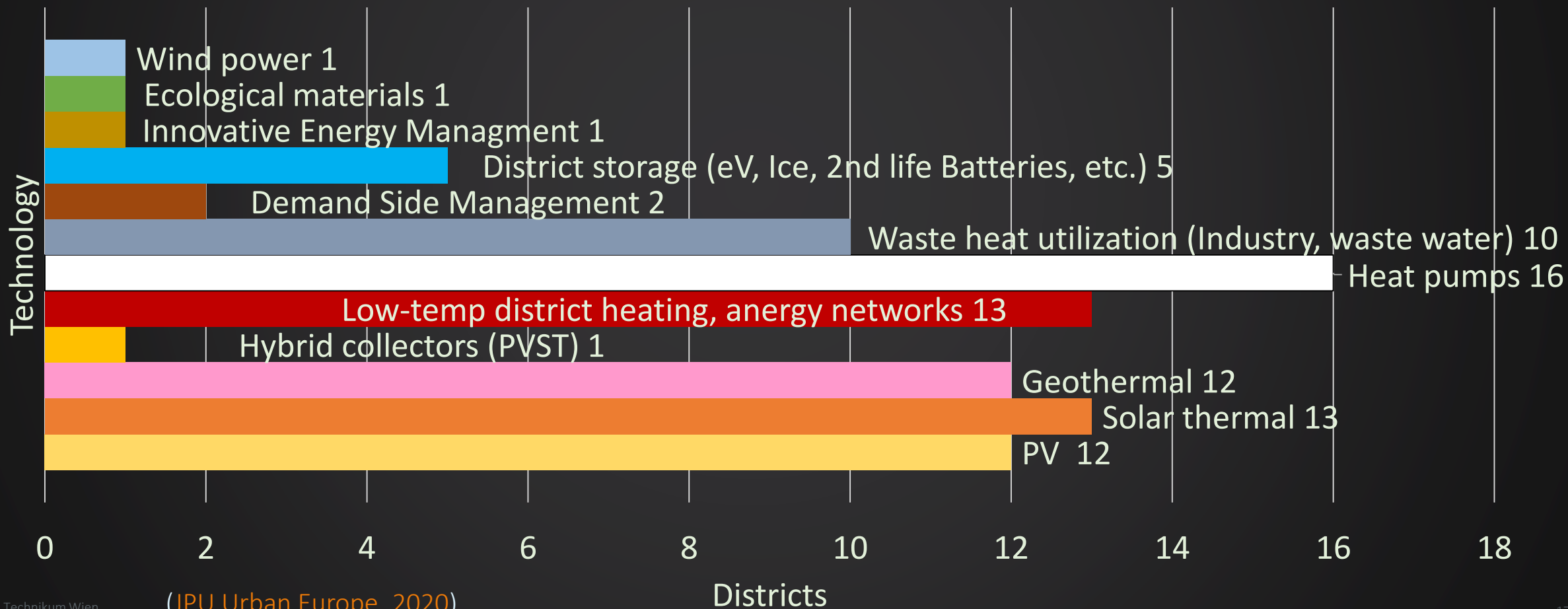


## **PEDs are a story-telling device:**

“Positive Energy Districts” aim to push further in sustainable and low-emission building, offer higher quality of life and enable a carbon-free society



# Utilized technologies in PED projects



# The Three Pillars of a Positive Energy District

And common measures

## Utilization of local renewables

- **Solar:** Thermal , PV
- **Heatpumps** w/ ambient heat (ground, water, air)
- Local **waste heat** from cooling, waste water and processes

## Energy Efficiency

- **Thermal hull:** passive house
- **HVAC:** Low-temp heating, heat recovery ventilation
- **Demand:** eff. Lighting, appliances

## PED

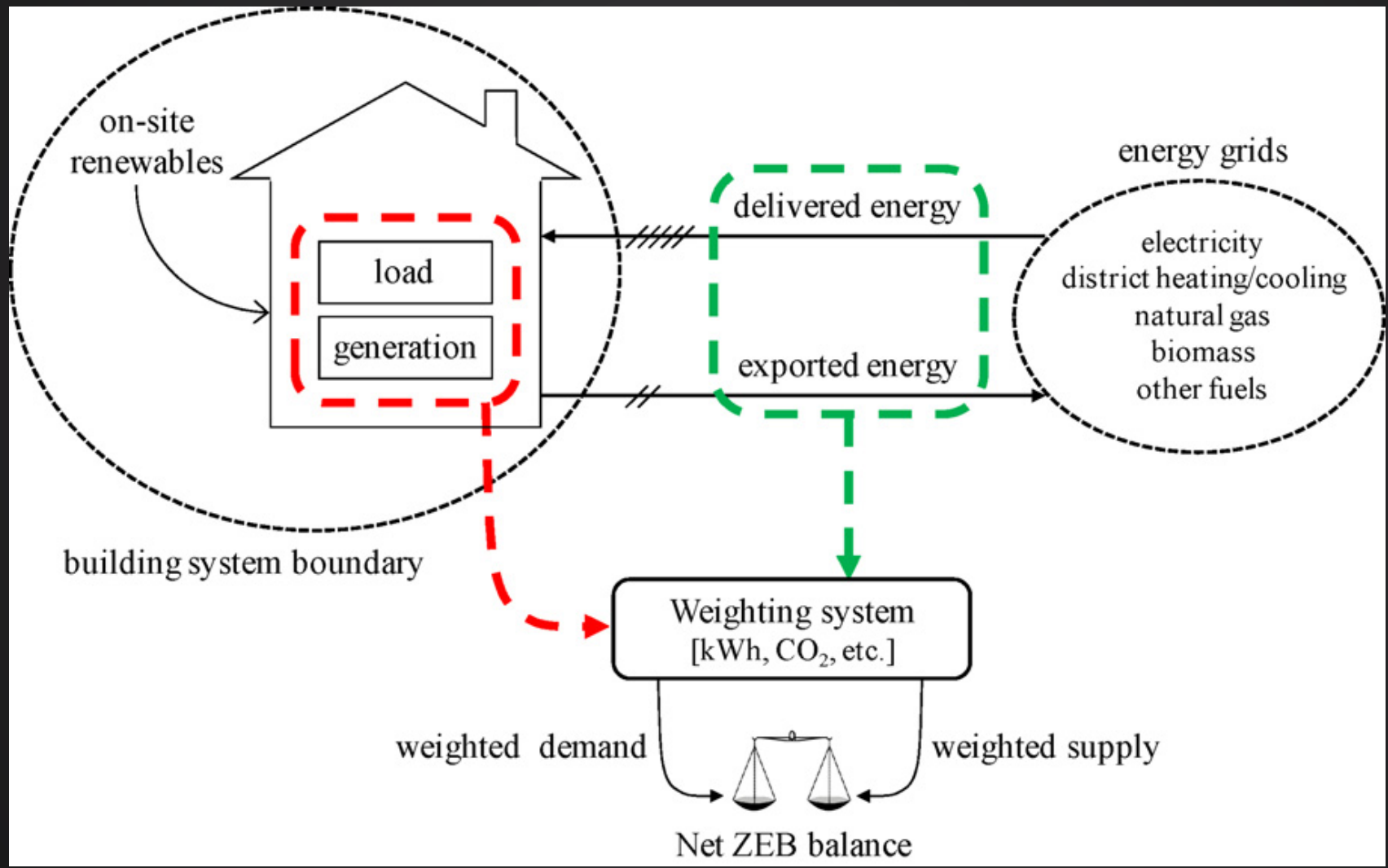
## Energy Flexibility

- **Thermal storage:** Buffer tank, **TABS**, boreholes
- **Electric storage:** DSM, (batteries, e-cars)
- **USER flexibility** service fluctuations

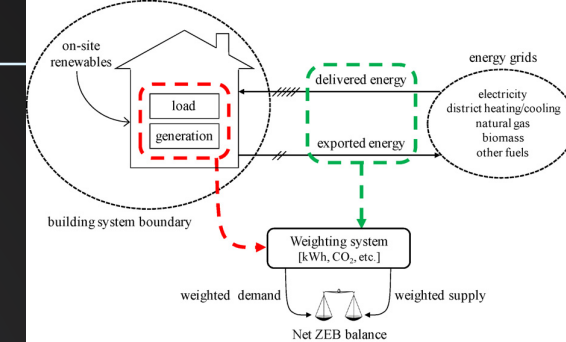
So when can you call your project a  
“Positive Energy District”?

The tricky trade of defining a  
**consistent framework of system  
boundaries and indicators**

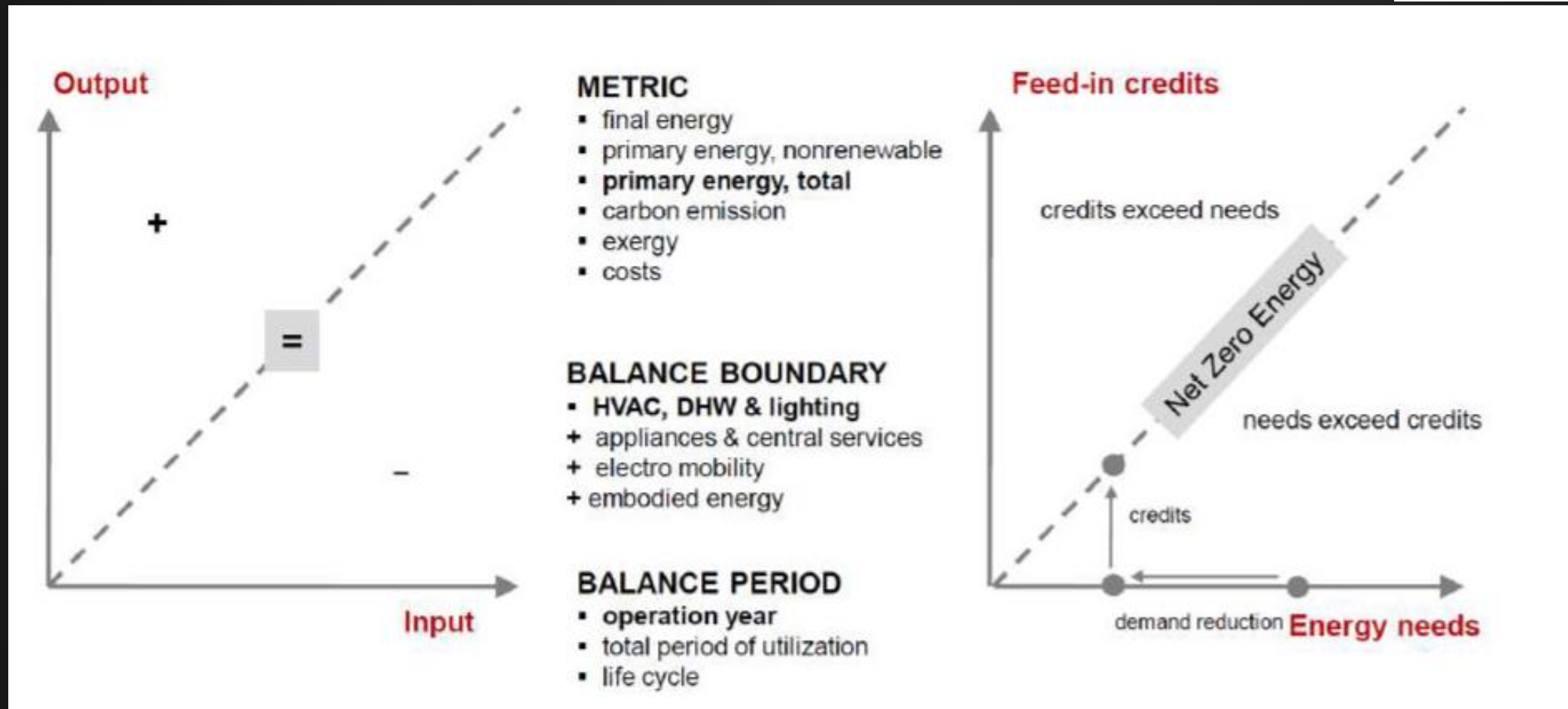
# PED System anatomy



(Sartori et al., 2012)



# Basic principle: Balancing inputs and outputs



# Quick check, are you familiar with the metrics?

Final Energy

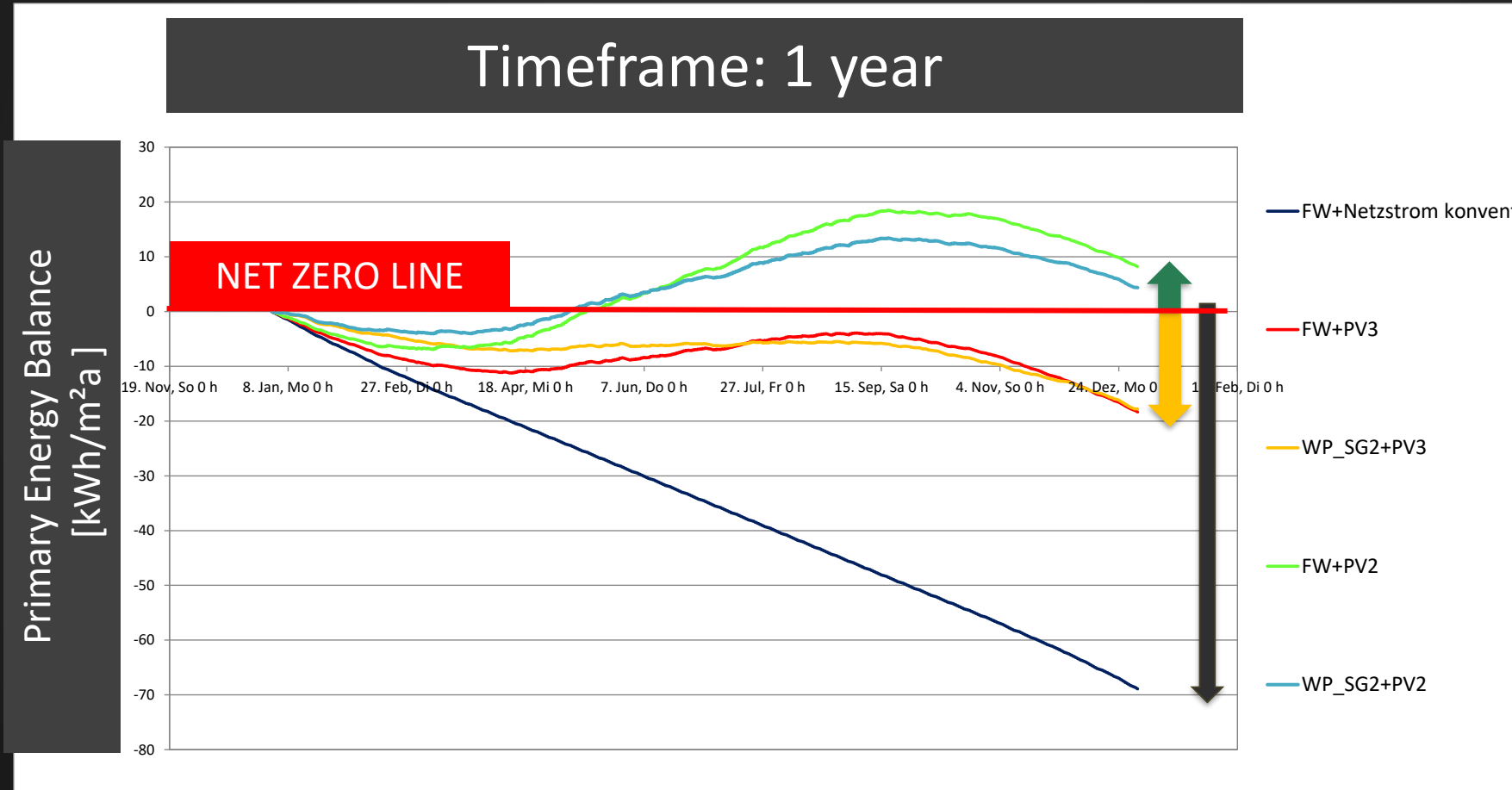
Primary Energy, Non Renewable

Primary Energy, Total

Exergy

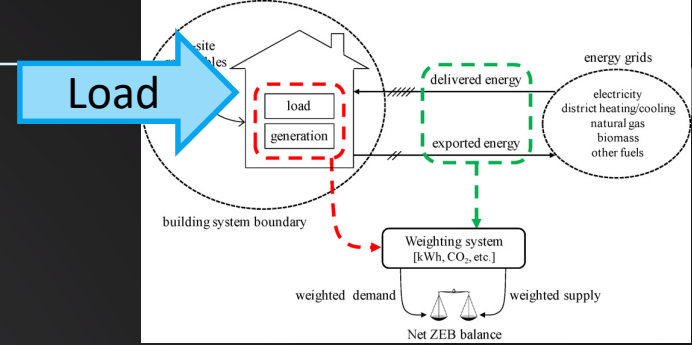
Carbon emission (equivalents)

# Basic principle: Balancing inputs and outputs

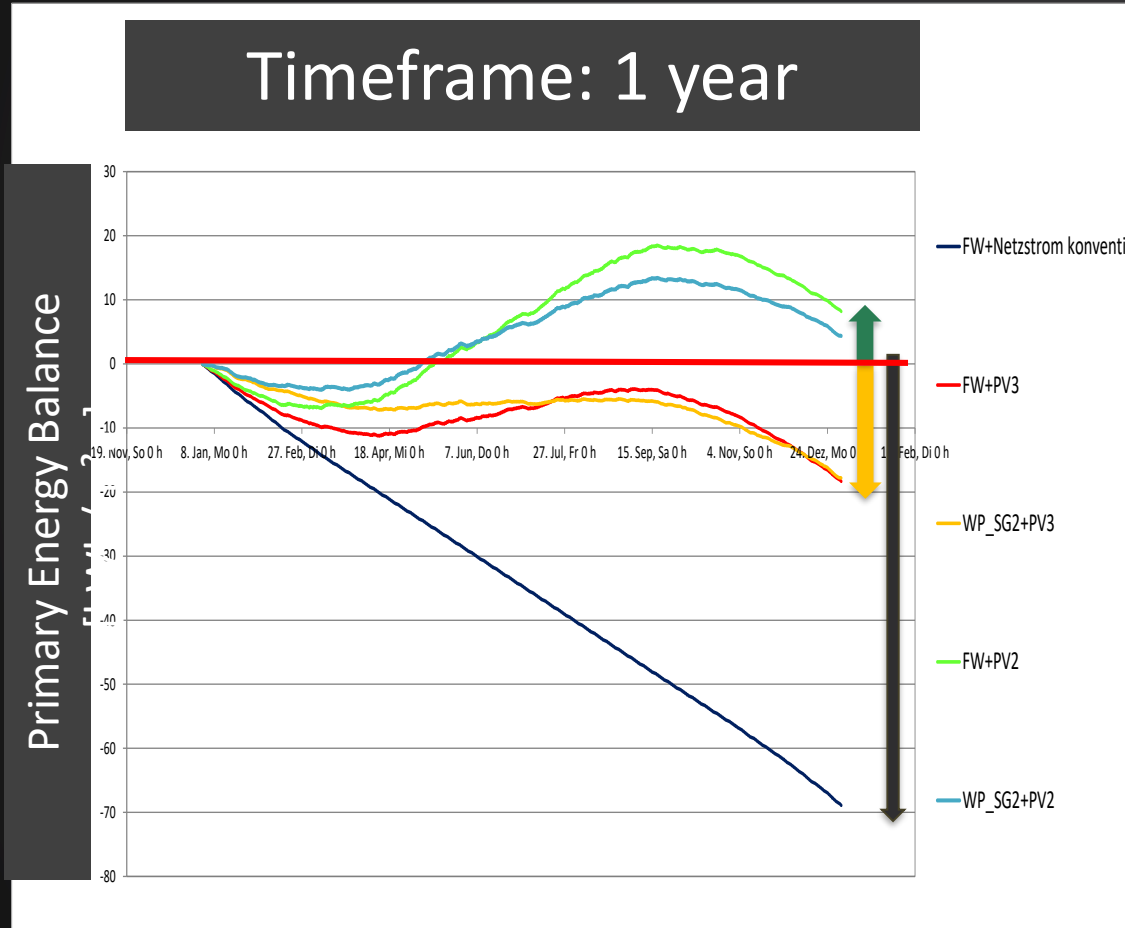


(Sartori et al., 2012)

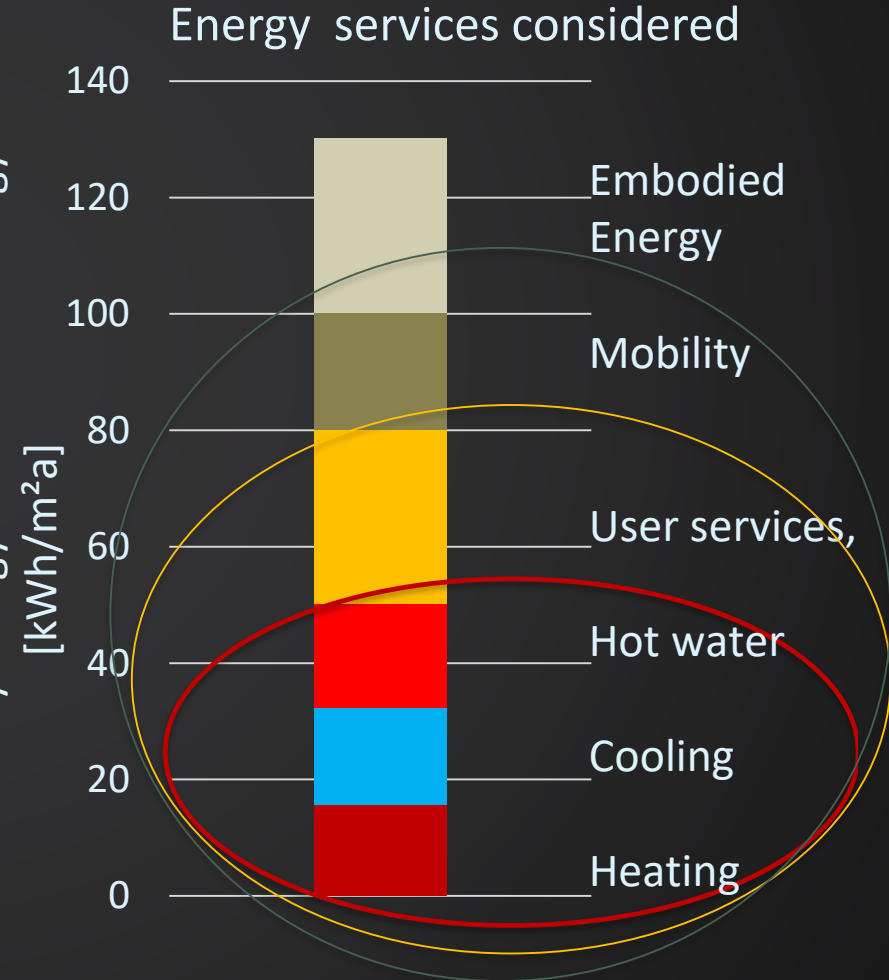




# Boundaries of included energy services



Primary Energy demand for energy services [kWh/m²a]



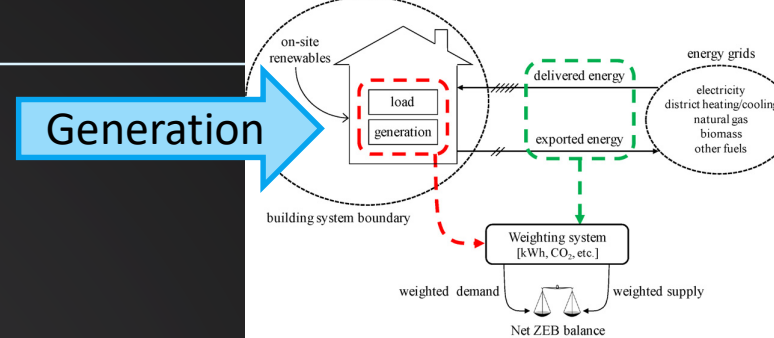
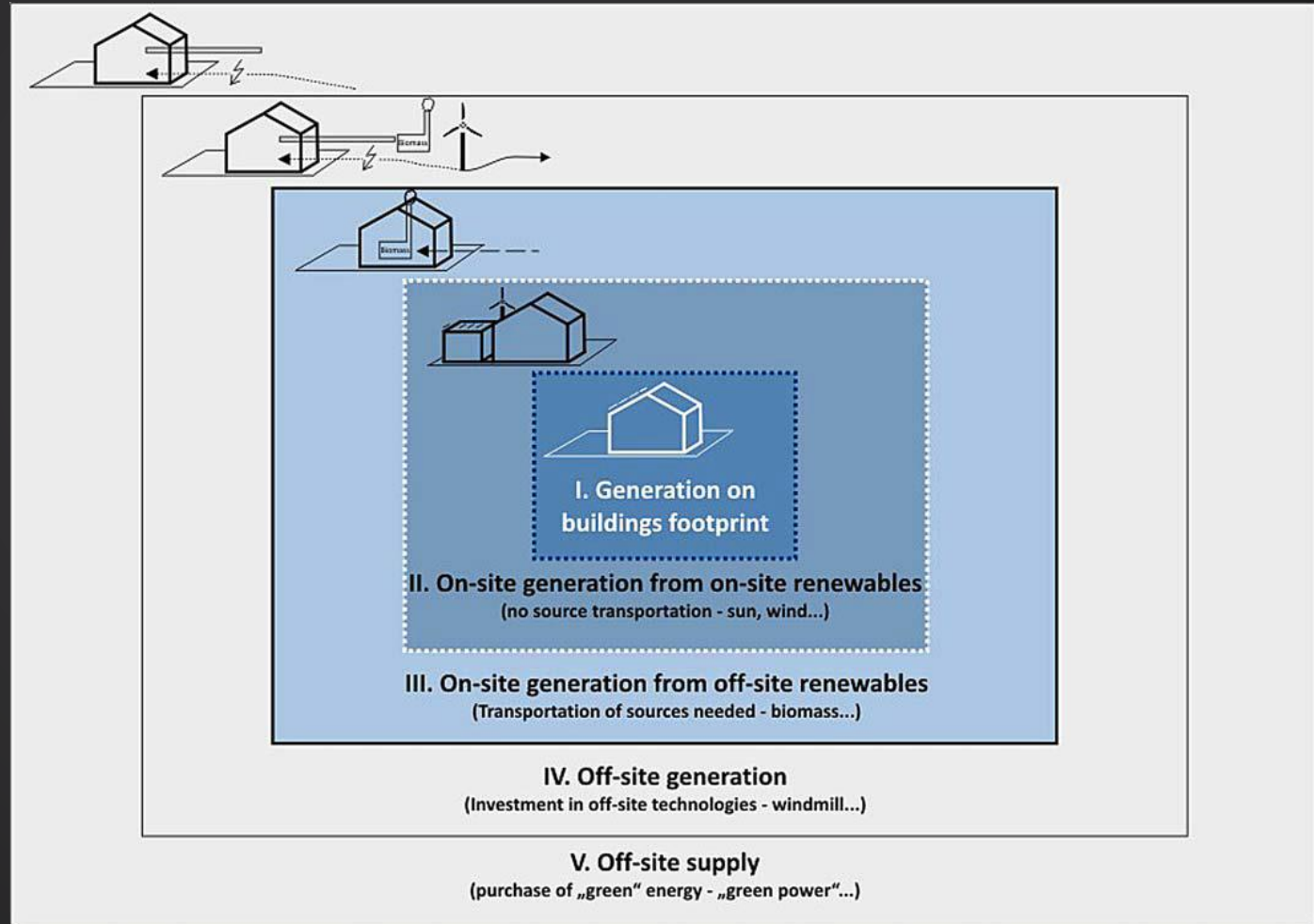
# Spatial boundaries of balanceable Renewable Energy Sources

- ▶ Implicit connection between energy use intensity and land use intensity

## 🏠 Less RES onsite

- ▶ More Land for energy somewhere else

(Marszal et al., 2011)

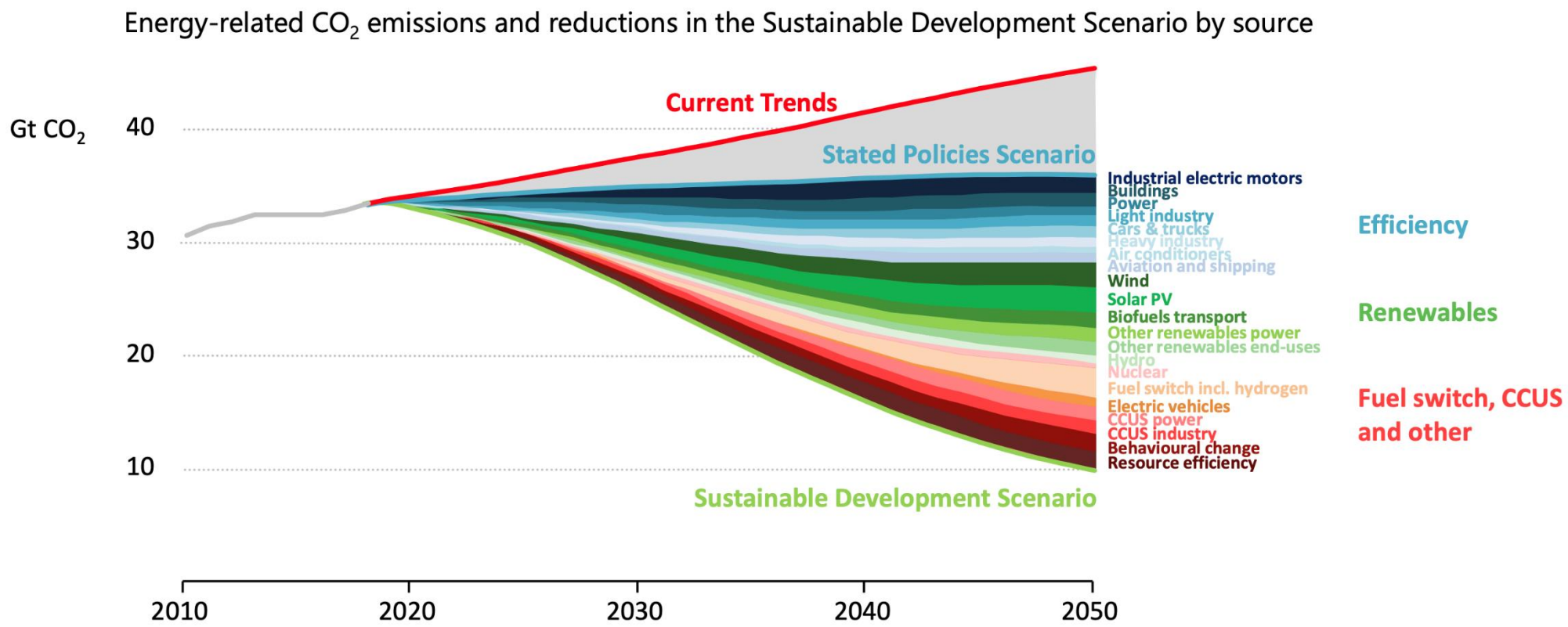


PED as a  
well-defined benchmark:

Measuring its contribution to a climate-neutral  
and carbon-free society

# IEA World Energy outlook: Sustainable development scenarios

## No single or simple solutions to reach sustainable energy goals



A host of policies and technologies will be needed across every sector to keep climate targets within reach, and further technology innovation will be essential to aid the pursuit of a 1.5°C stabilisation

Can we derive from this curve how much energy and emissions are **allowed** /necessary for a PED?

What happens if we apply an annual primary energy balance?

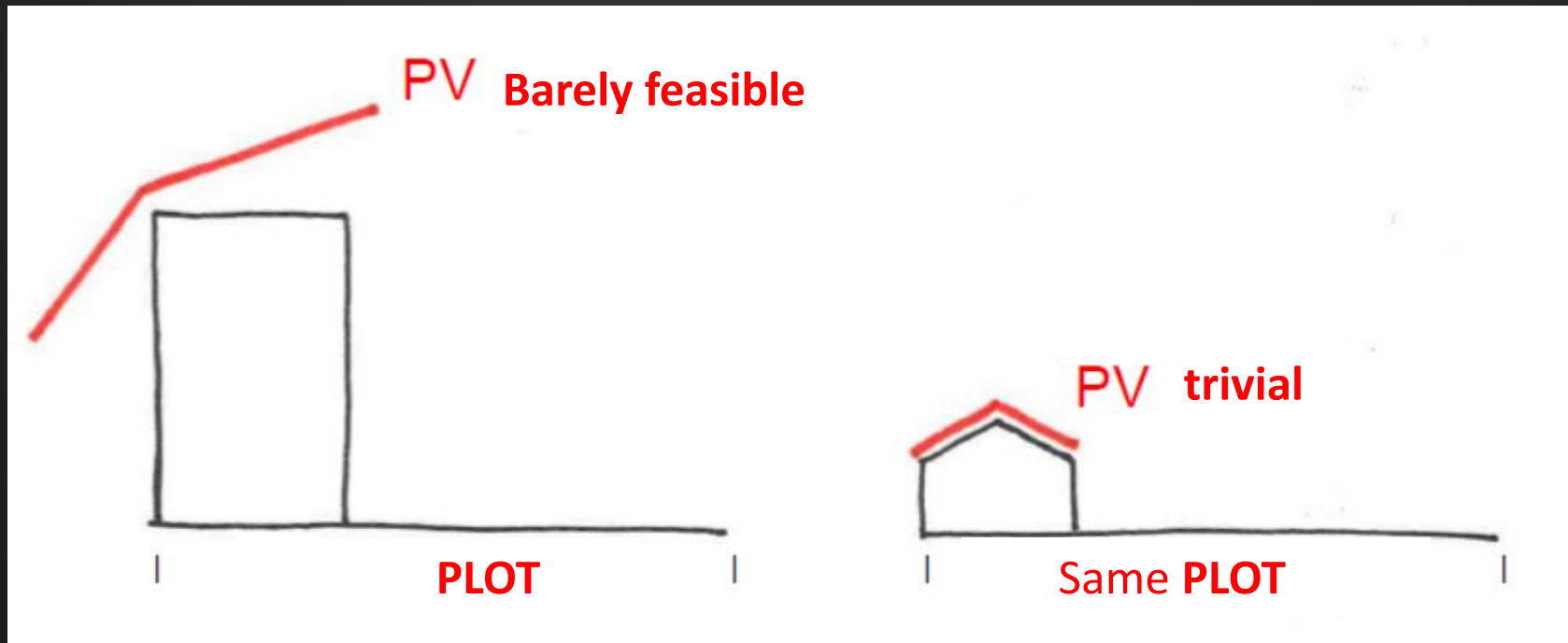
Where do we account for the embodied energy of the building materials? Someone else needs to do it...

How will this lead to zero emissions, if we don't have the energy when it is required?

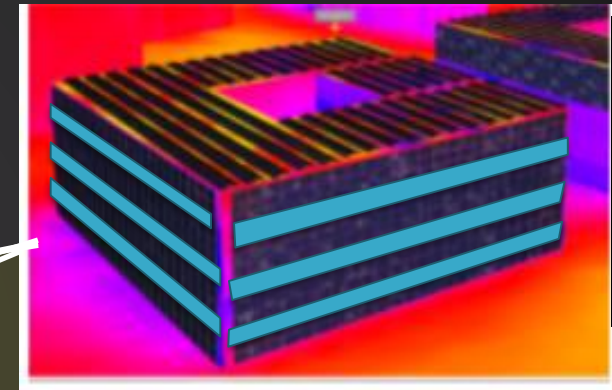
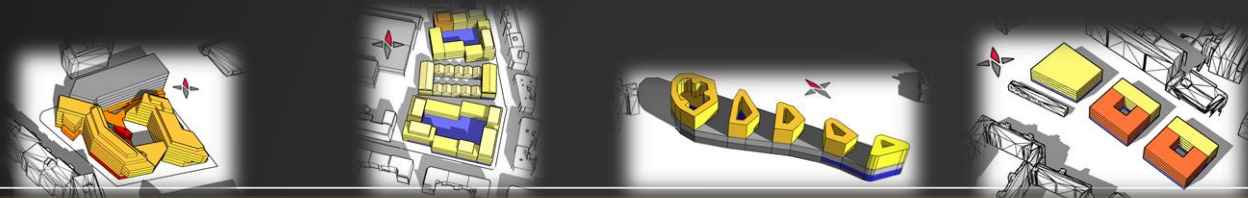
# Local supply depending on floor area?

🏠 The bigger the building, the bigger the supply?

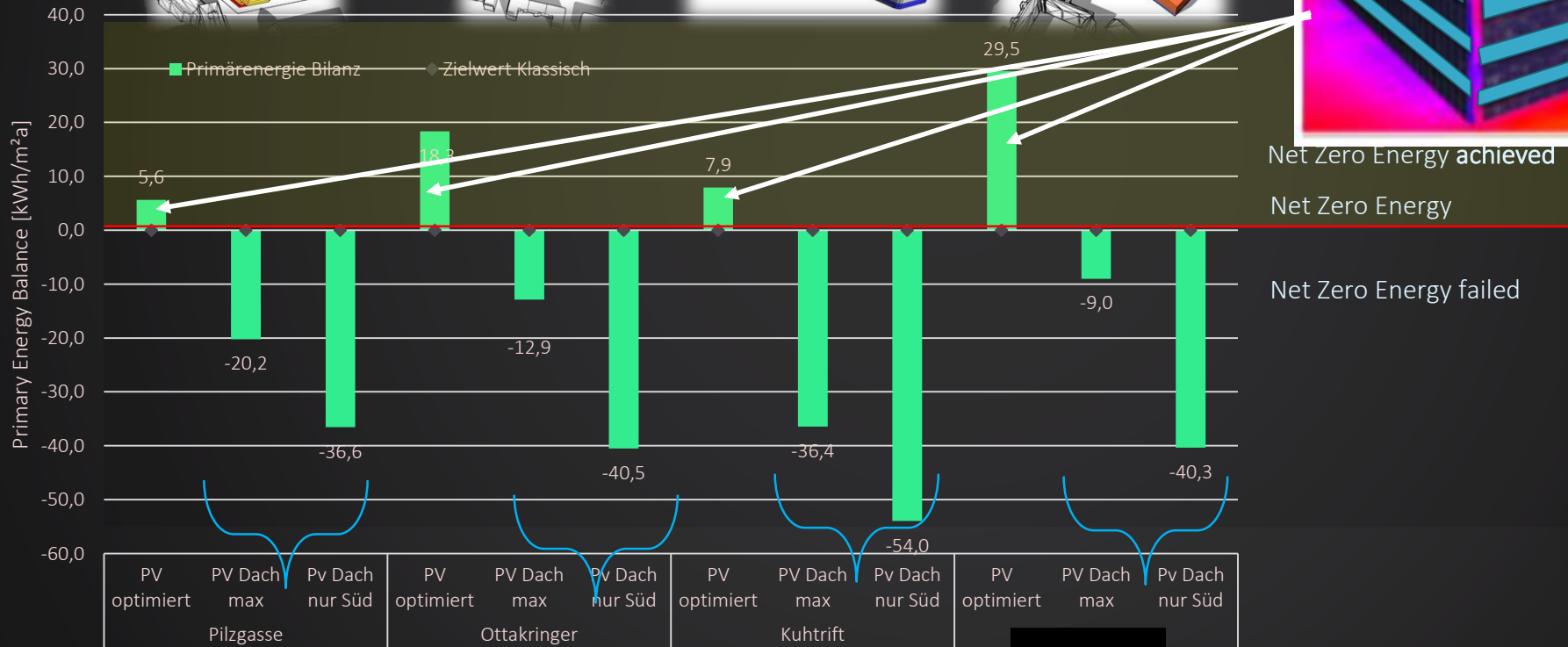
## ▶ Disadvantages compact districts that use land sparingly



# „Classic“ Net zero energy balance remains unfeasible for dense urban projects



Entire building Envelope needs to be **Photovoltaic**



Net Zero Energy achieved

Net Zero Energy

Net Zero Energy failed

Feasibility of moderate PV utilization (50 – 100% of roof surfaces)

# The goal of PED system definition frameworks

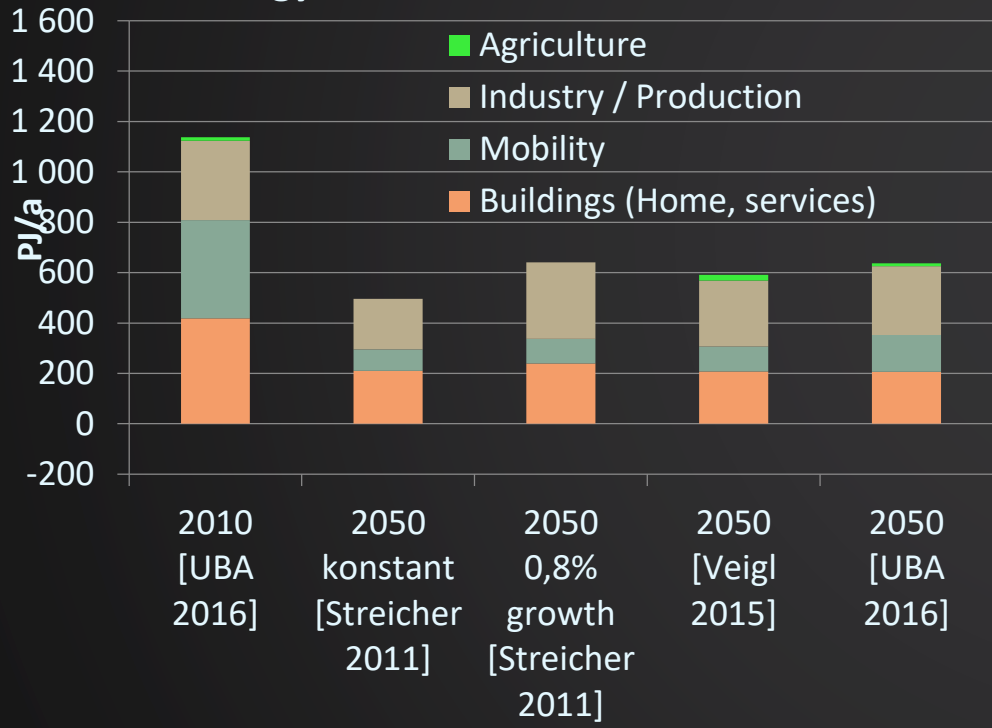
## The Purpose of PEDs

- ✓ **Connecting the global/national climate goals** of a carbon neutral energy system 2050 with the **local energy goals of a district**
  
- ✓ ~~„what is desirable?“~~ => „what is necessary?“  
Sustainable energy concepts for districts, that will work in a future carbon free energy system 2050
  
- ✓ Categorical imperative (Kant):
  - *„‘Positive energy districts’ must adhere to ,positive’ rules which, if applied to the entire building sector, would suffice in a carbon free energy system.“*

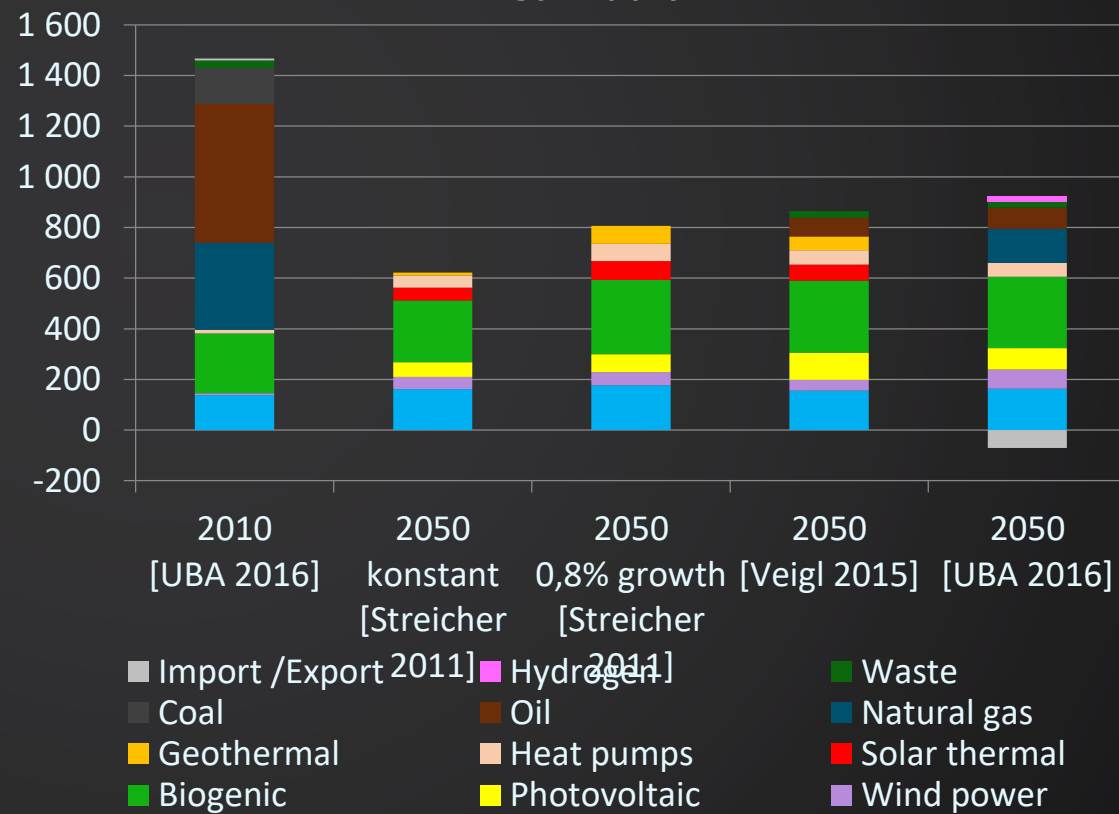


# Connect Top-Down Renewable energy system 2050

Final energy demand Austria 2050



Gross domestic energy supply Austria 2050



(Schneider, et al. 2020)

# Austria in ~~2050~~ 2040 is 100 % renewable



100 % Renewable Energy in Austria (2050)

Central power plants

Decentral, local energy supply systems

# Austria in ~~2050~~ 2040 is 100 % renewable



100 % Renewable Energy in Austria (2050)

Central power plants

Cover industry,  
production and public  
transport

Surplus can be allocated  
per person



„Central surplus credit for PEDs  
including private mobility“

Decentral, local energy supply systems

# Austria in ~~2050~~ 2040 is 100 % renewable



100 % Renewable Energy in Austria (2050)

Central power plants

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Cover industry,  
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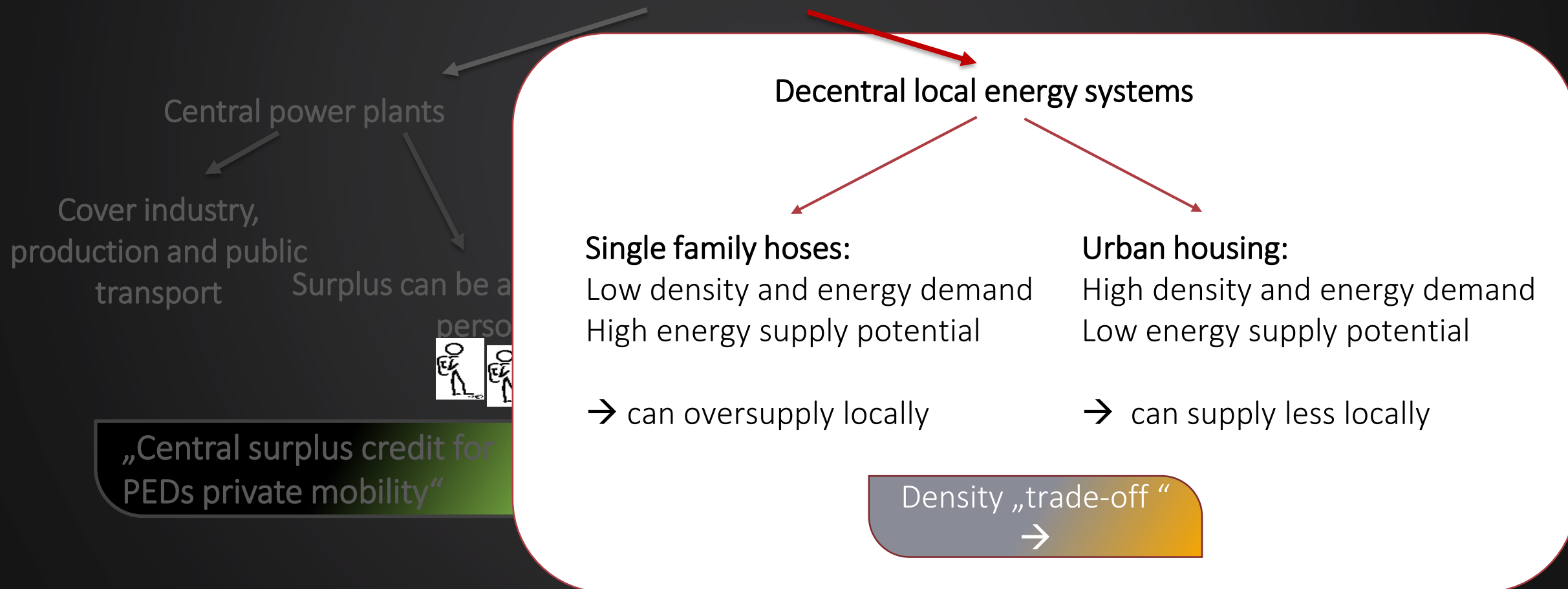


„Central surplus credit for  
PEDs private mobility“

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100 % Renewable Energy in Austria (2050)



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100 % Renewable Energy in Austria (2050)

Central power plants

Decentral, local energy supply systems

Cover industry,  
production and public  
transport

Surplus can be allocated per  
person



„Central surplus credit for  
PEDs private mobility“

Single family houses:

Low density and energy  
demand

High energy supply potential

→ can oversupply locally

Urban housing:

High density and energy  
demand

Low energy supply potential

→ can supply less locally

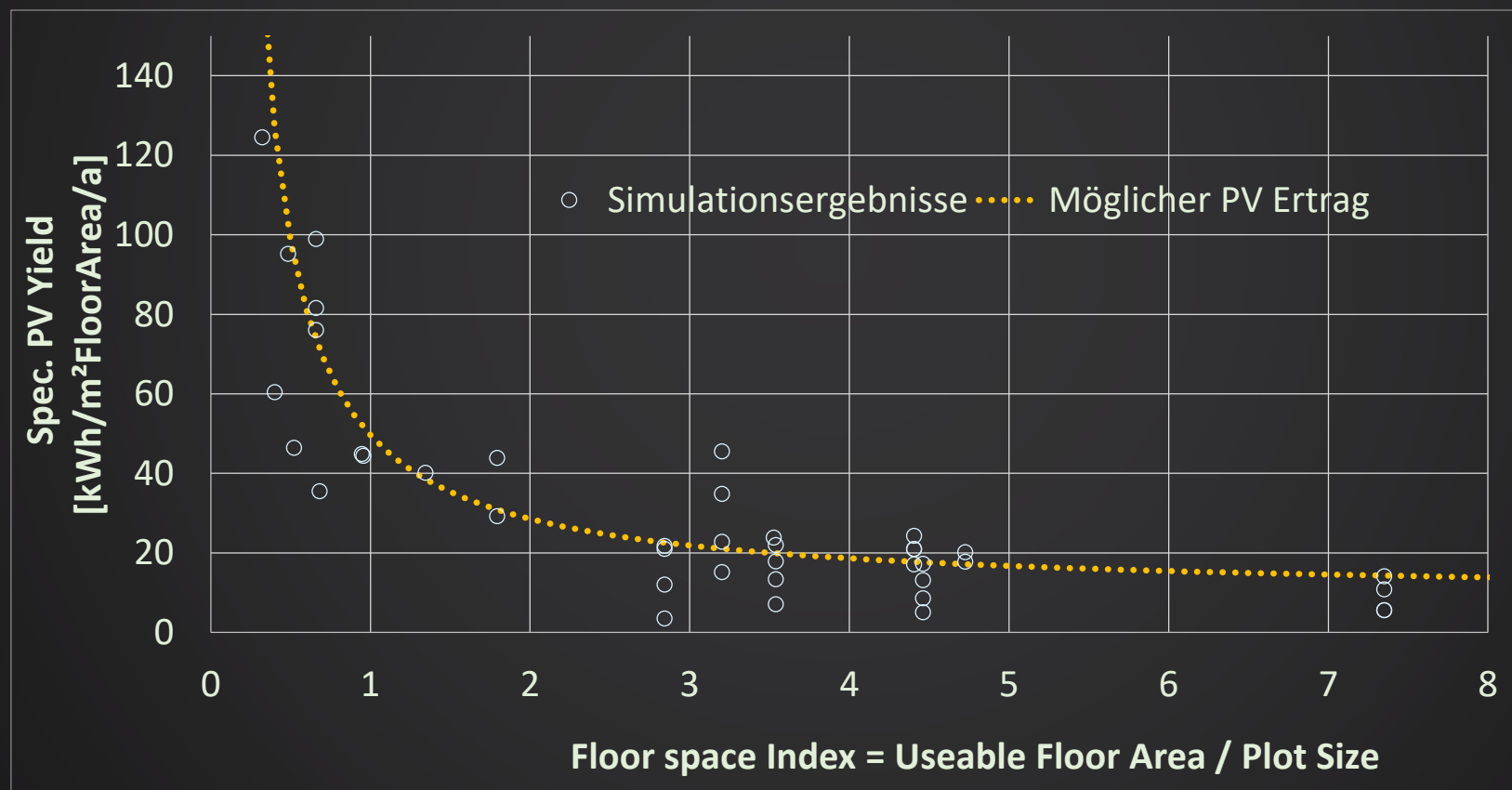
Density „trade-off “



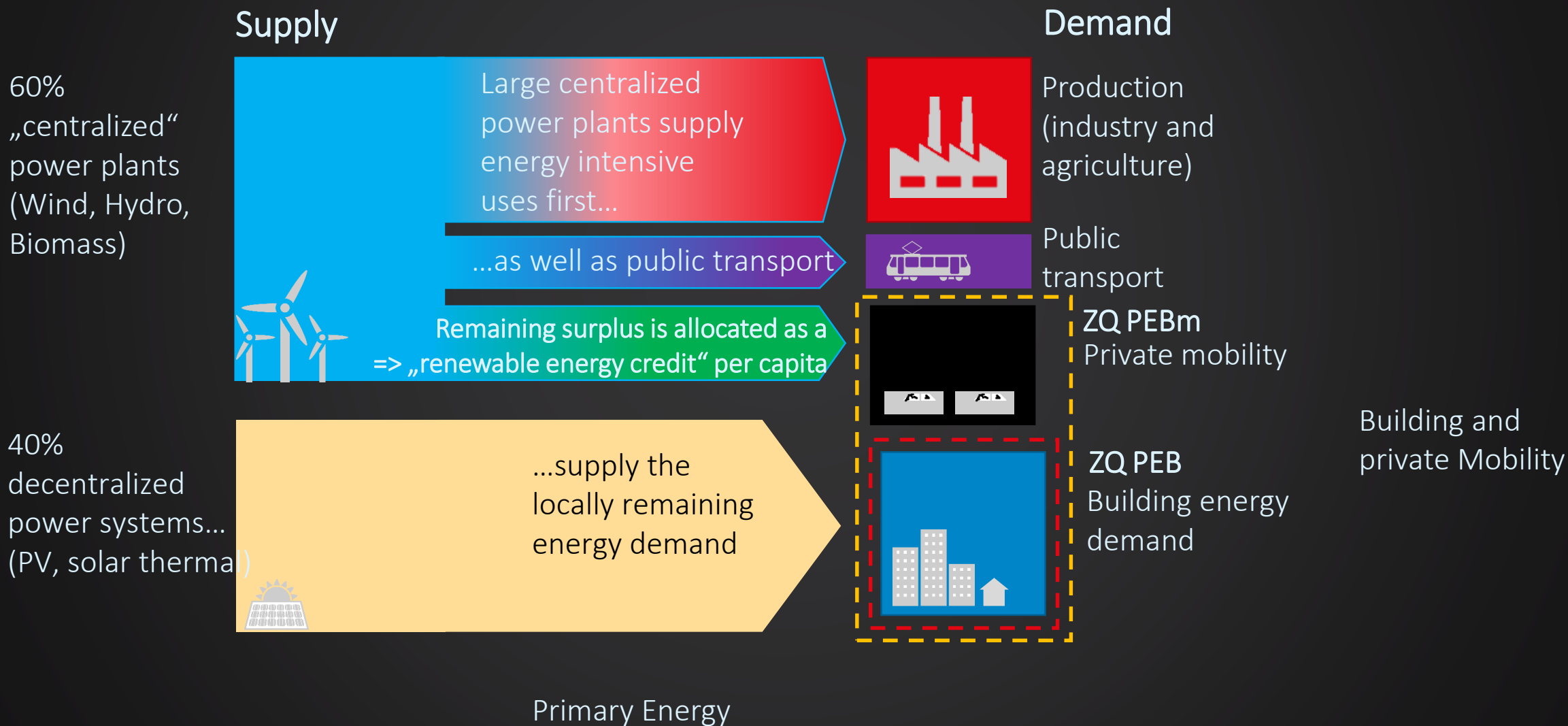
# District density:

## The most important predictor of a district's energy balance

🏠 Solar potential scales with plot size

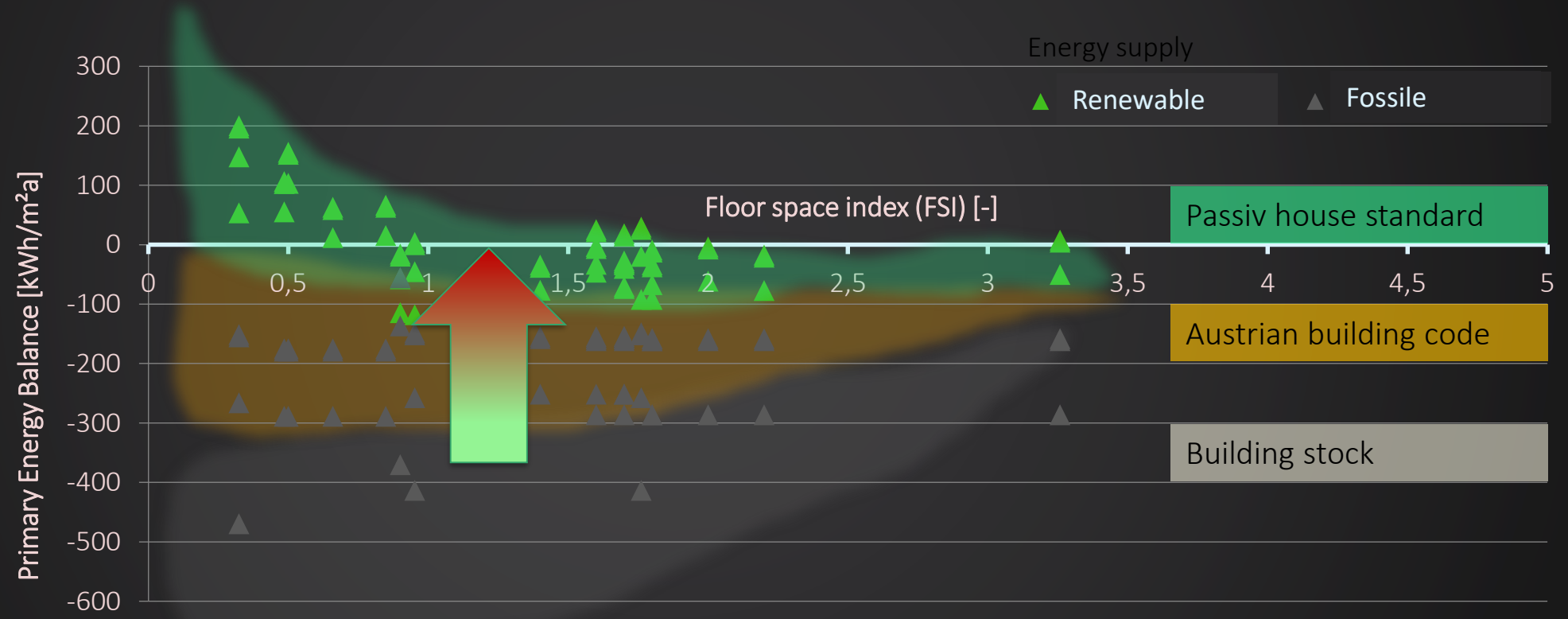


# Attempting to combine top-down and bottom-up targets





# District density: The most important predictor of a district's energy balance



Detached single family housing      Row housing      Block housing

Source: Building typology variations from SC Microquartiere

Amendment of common „positive energy“

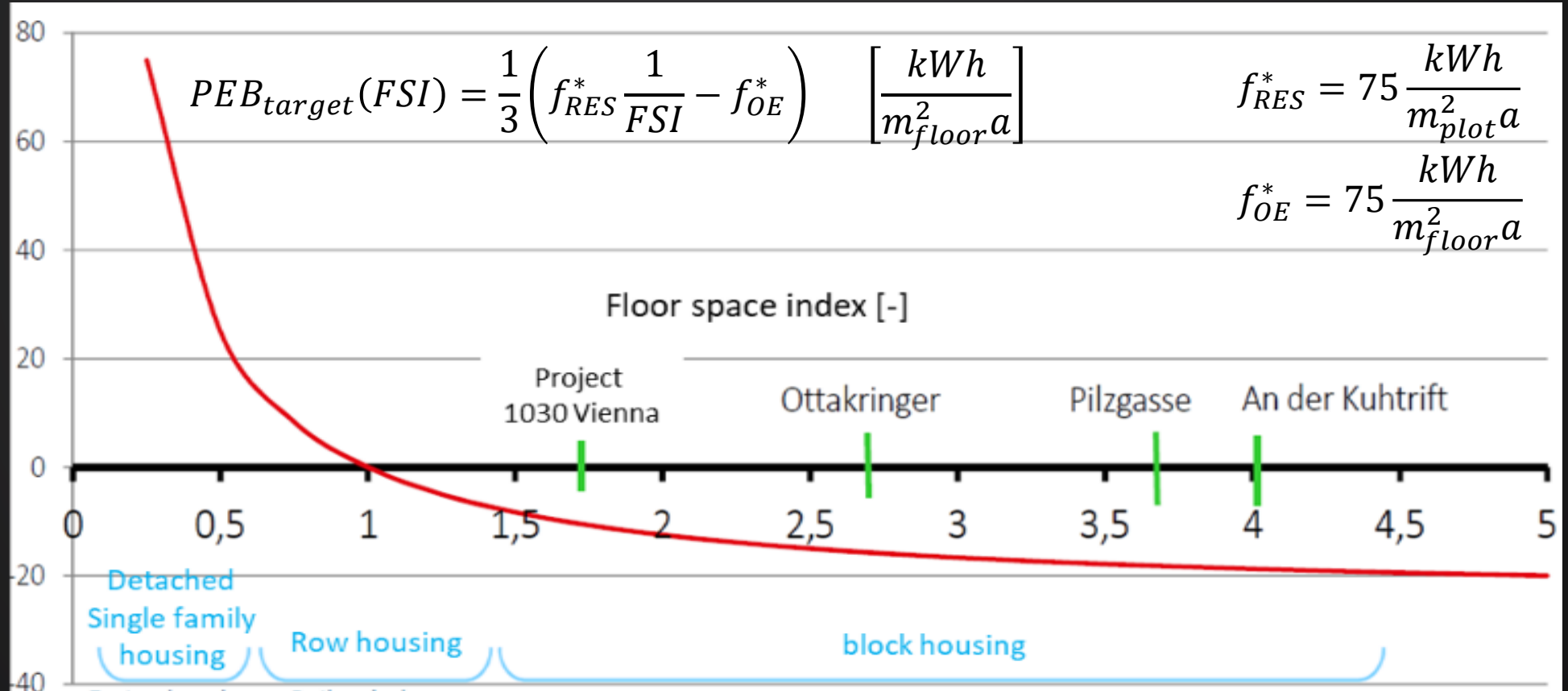
# Balancing Target depends on Density:

🏠 Primary Energy Balance (PEB) as a function of the floor space index

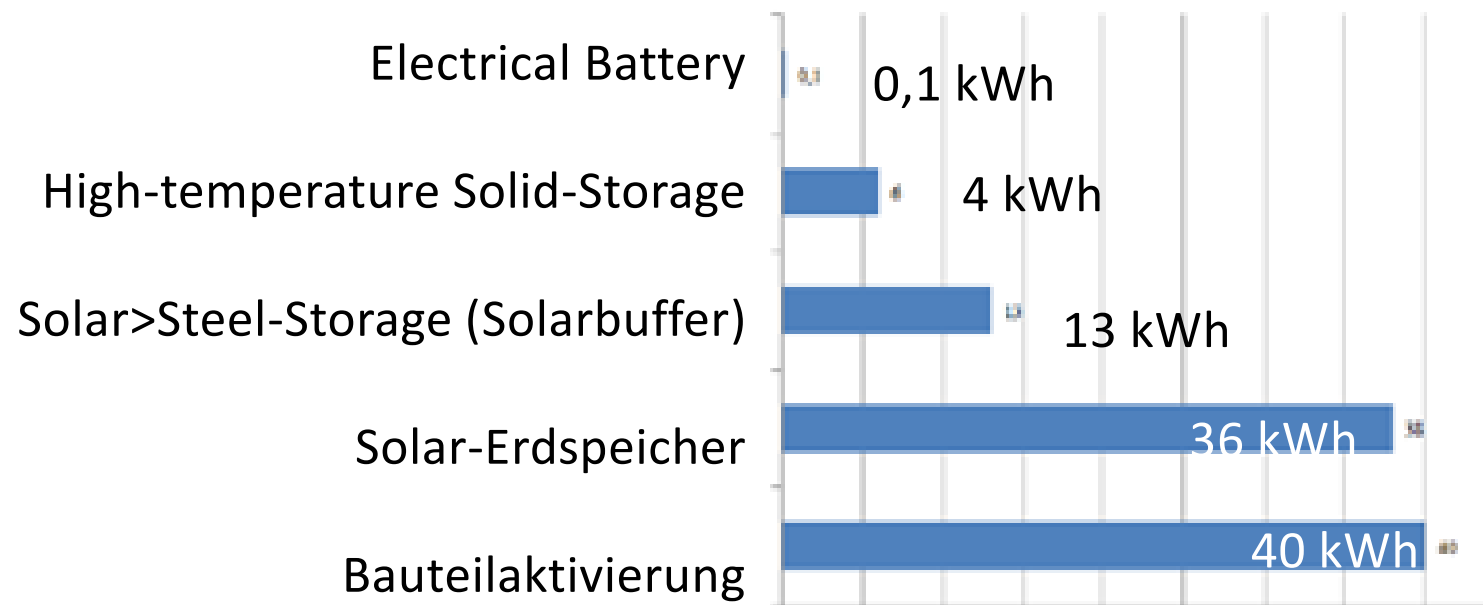
$$PEB = f_{RES}^* A_{plot} - f_{OE}^* A_{floor}$$

Primary Energy Balance [kWh/m²a]

Primary energy balance [kWh/m²a]

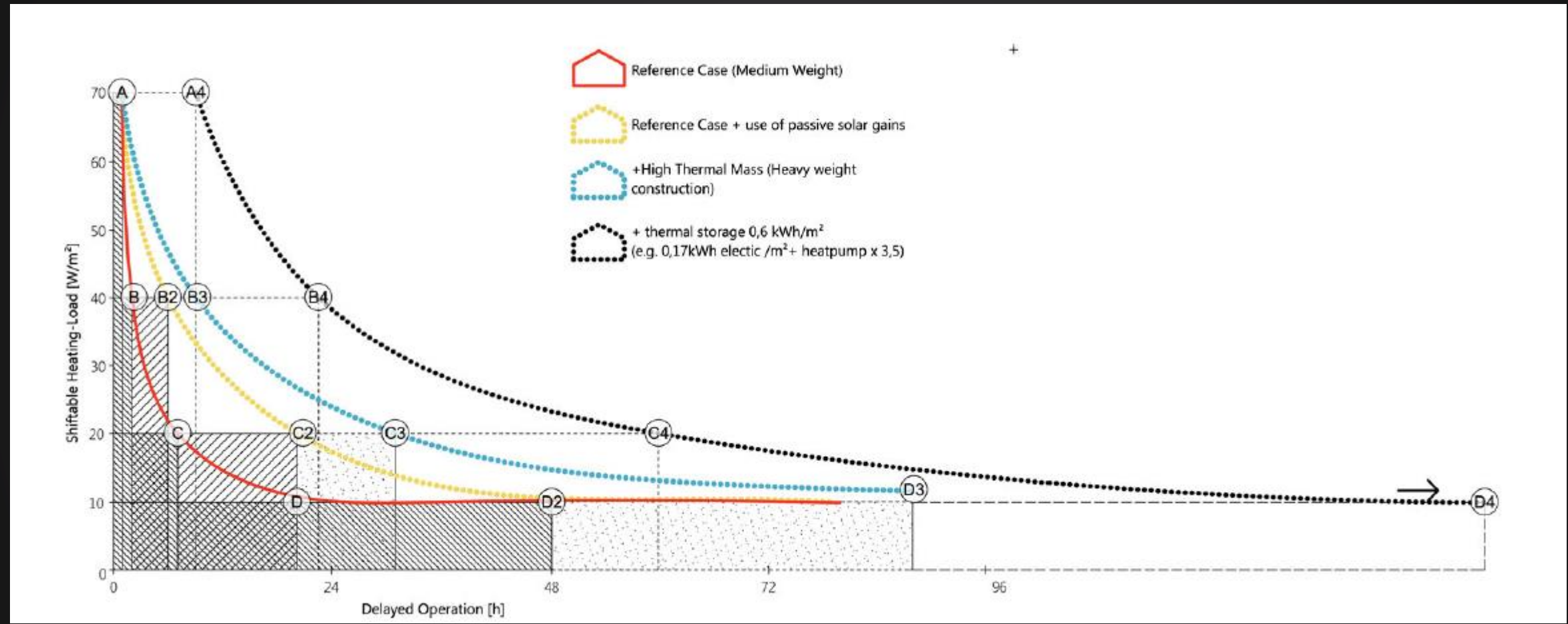


# 100€ of Storage gets you (2017):



(Fechner, Thebavol Qualifizierung 2017)

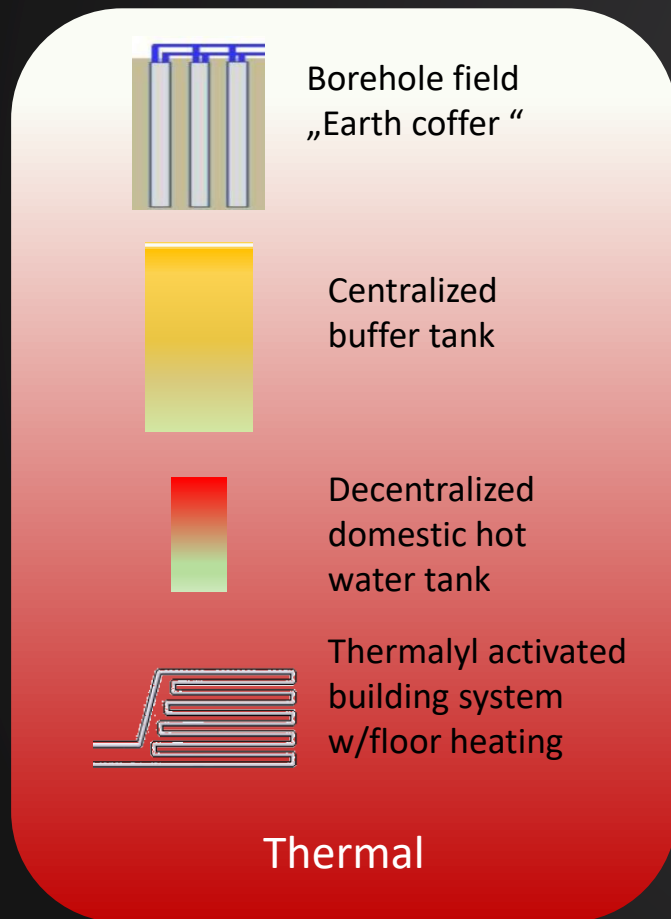
# Thermal Energy Flexibility depends on thermal hull quality!



(Weiß et al., 2018)

# Development and simulation of grid supportive energy management

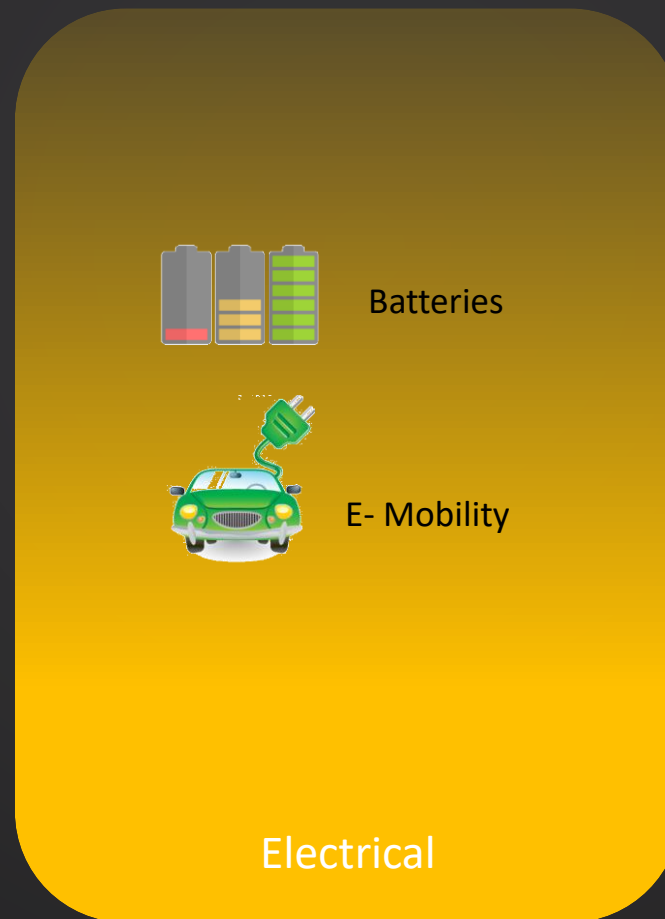
🏠 Storage capabilities provided by components:



This panel illustrates thermal storage capabilities. It features four icons: a borehole field, a centralized buffer tank, a decentralized domestic hot water tank, and a thermally activated building system with floor heating. The background is a vertical gradient from light yellow at the top to dark red at the bottom.

- Borehole field „Earth coffer“
- Centralized buffer tank
- Decentralized domestic hot water tank
- Thermally activated building system w/floor heating

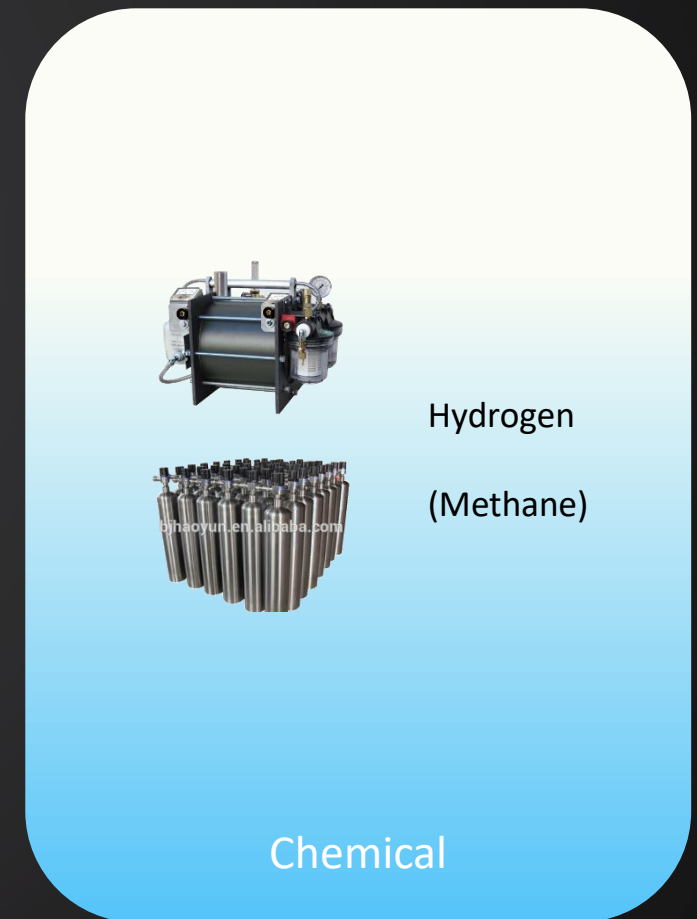
Thermal



This panel illustrates electrical storage capabilities. It features two icons: a set of batteries and an electric car with a charging cable. The background is a vertical gradient from light yellow at the top to dark yellow at the bottom.

- Batteries
- E- Mobility

Electrical



This panel illustrates chemical storage capabilities. It features two icons: a hydrogen compressor and a cluster of gas cylinders. The background is a vertical gradient from light yellow at the top to light blue at the bottom.

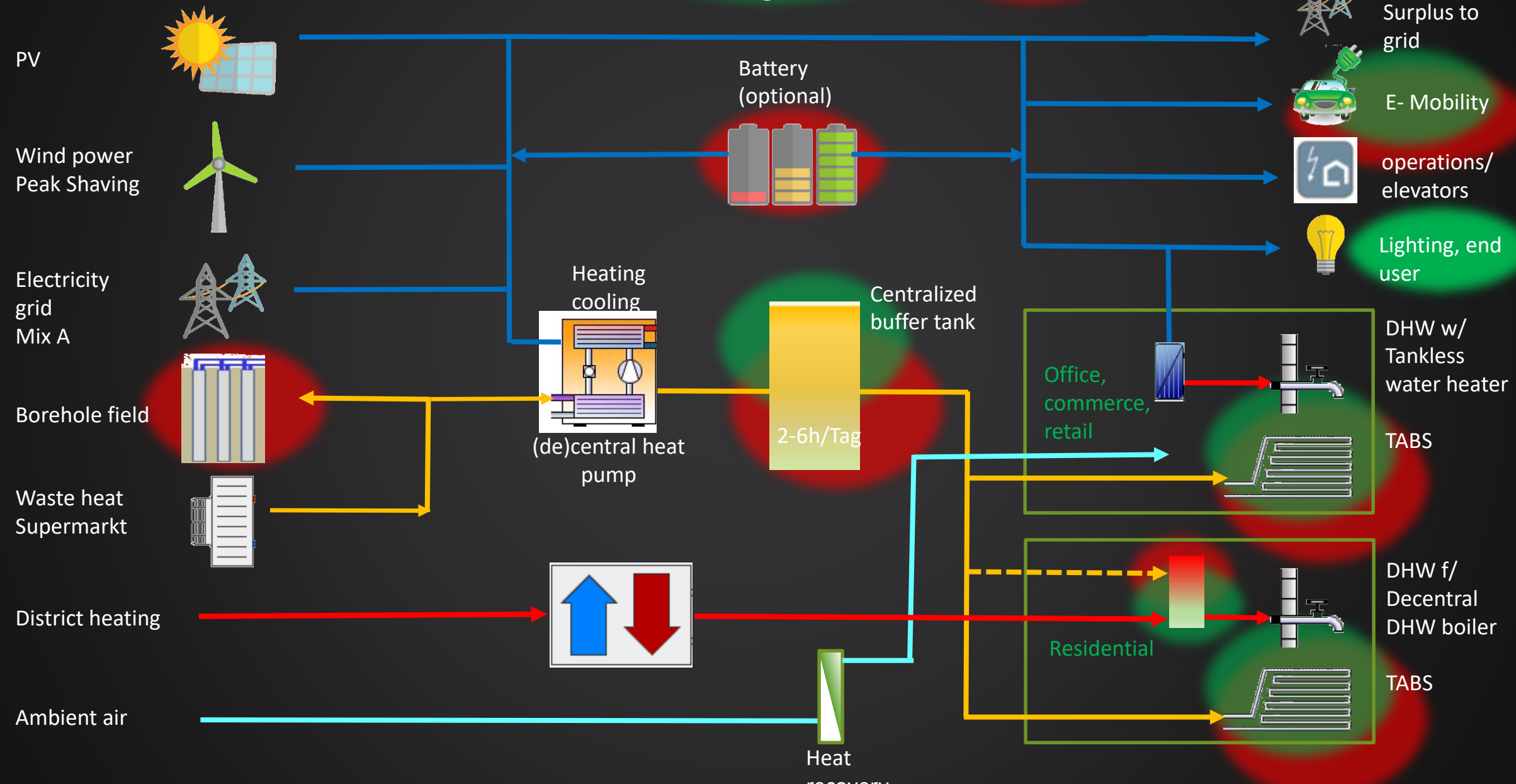
- Hydrogen
- (Methane)

Chemical

# Example energy concept

Demand side Management

Storage



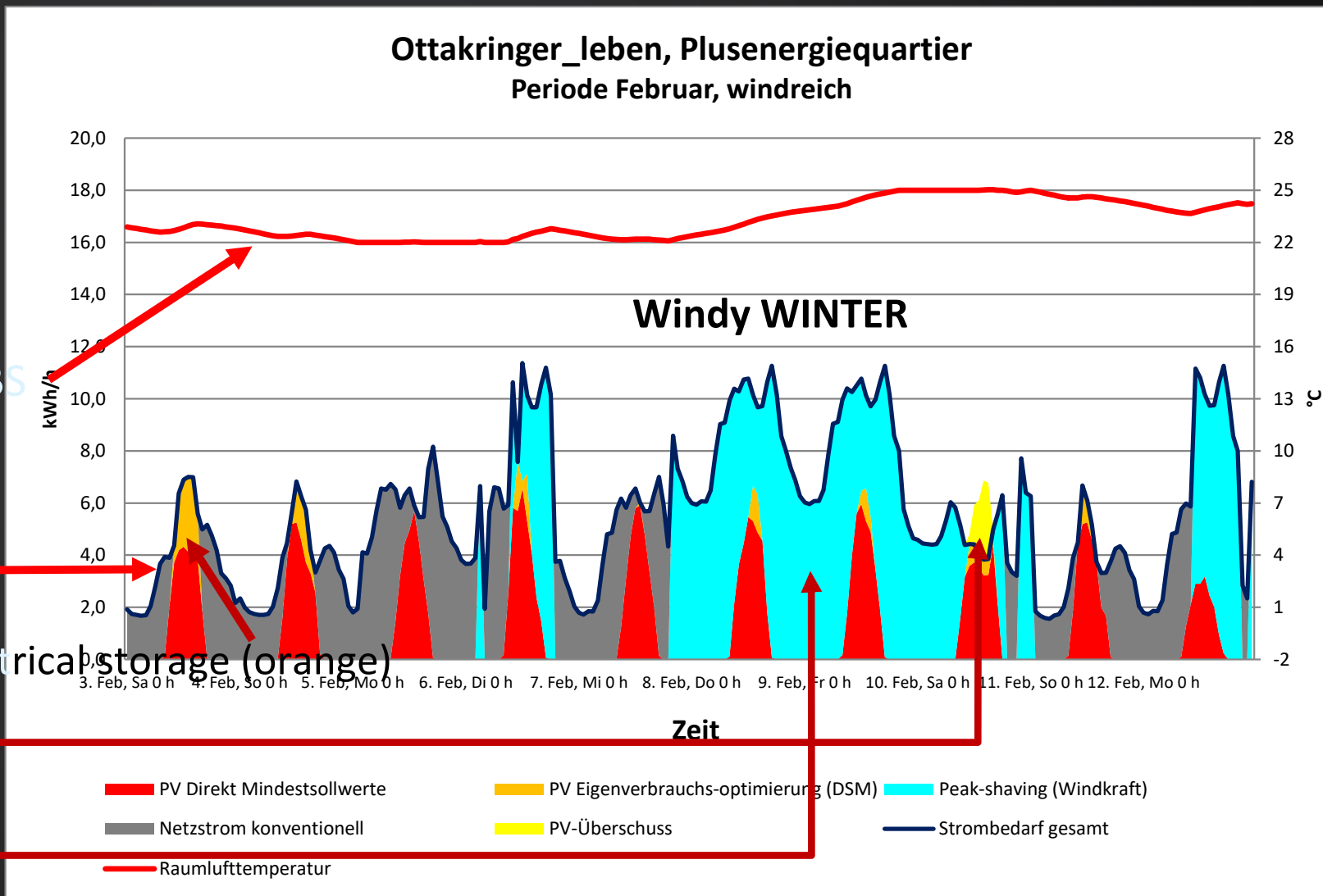
# Direct utilization of otherwise unuseable RES power peaks (DSM)

## 🏠 USER FLEXIBILITY:

- ▶ Max. 25°C in winter
- ▶ Min. 23°C in summer
- ▶ Over-Heating/cooling of TABS

## 🏠 RES sources

- ▶ PV Direct use (red)
- ▶ PV Loading of thermal and electrical storage (orange)
- ▶ PV Grid infeed (yellow)
- ▶ Wind peak shaving (cyan)

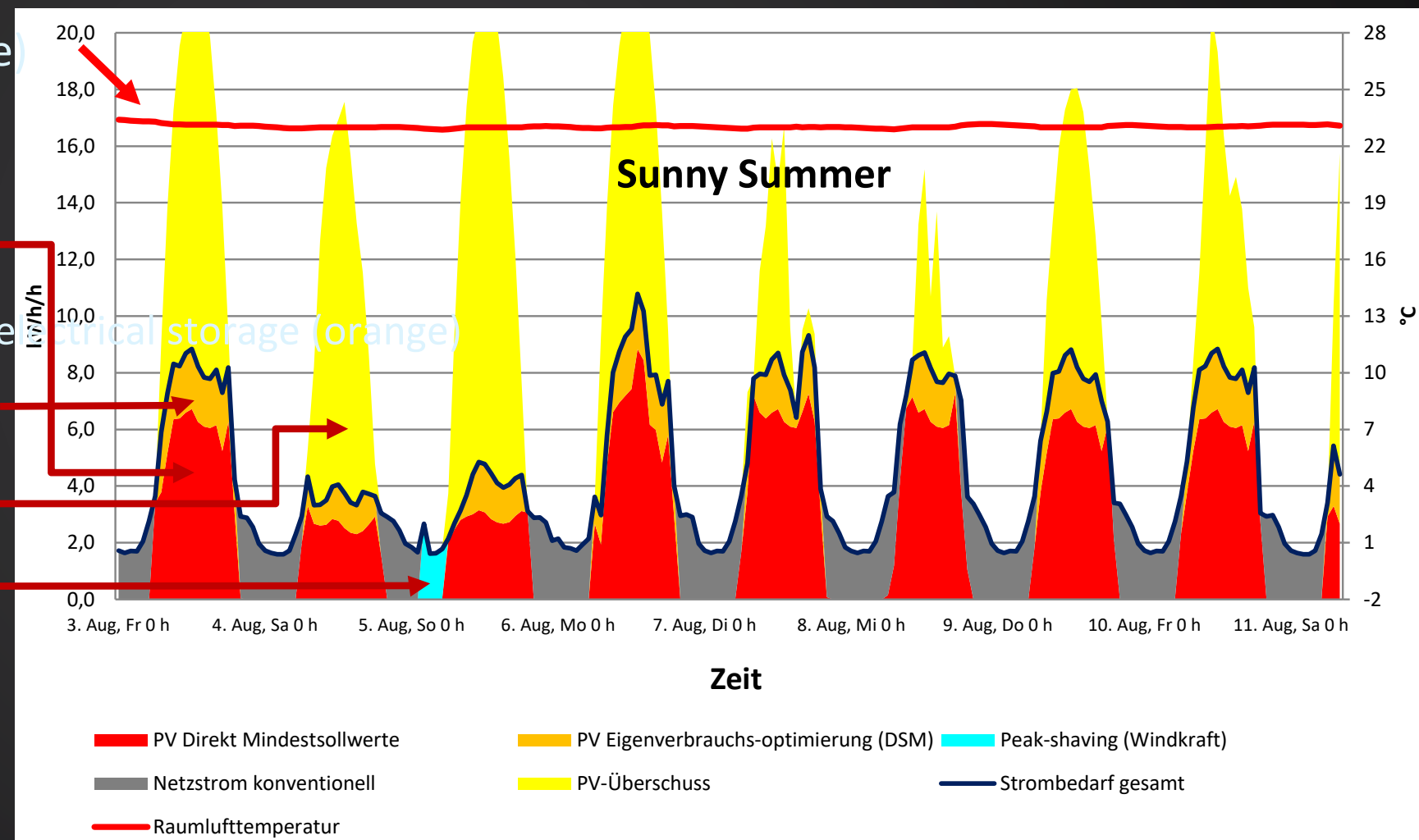


# Direct utilization of otherwise unuseable RES power peaks (DSM)

🏠 Room temp (thermal storage)

🏠 RES DSM

- ▶ PV Direct use (red)
- ▶ PV Loading of thermal and electrical storage (orange)
- ▶ PV Grid infeed (yellow)
- ▶ Wind peak shaving (cyan)





Zukunftsquartier approach

# Direct utilization of otherwise unuseable RES power peaks (DSM)

Reduction of required grid electricity

and surplus infeed of 30-70%

(but overall slightly higher energy demand)

Wind overproduction in winter

▶ NOT wind power itself

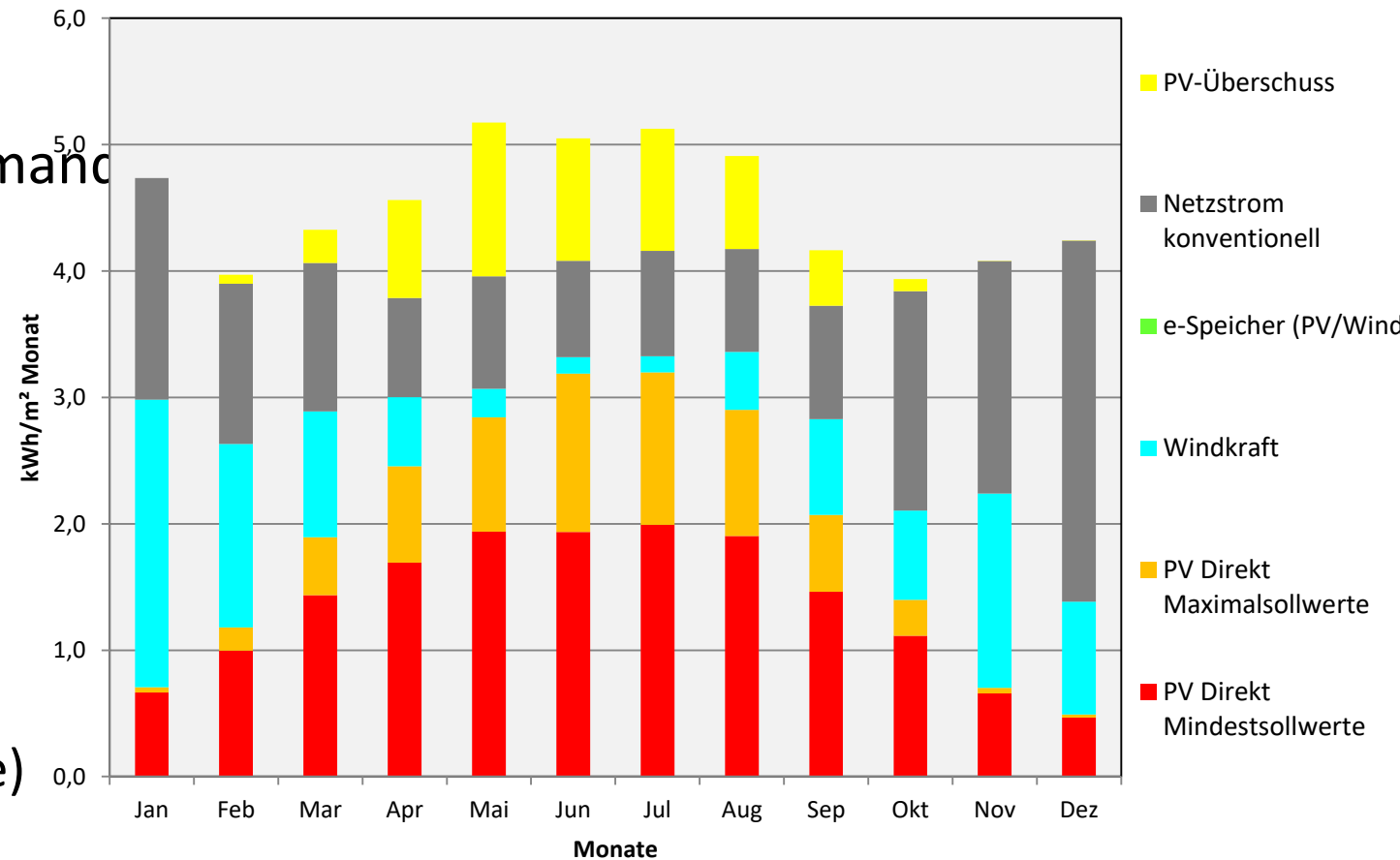
PV in Summer

▶ Direct utilization

▶ Utilization of thermal storage (orange)

## Supply of energy end use

Monatsbilanz



# Projects

Zukunftsquartier  
**Exploration** project

## Zukunfts Quartier

Duration: 12 months (07/18 – 06/19)

Funding:  Bundesministerium  
Verkehr, Innovation  
und Technologie

Partners:



Zukunftsquartier 2.0  
**Demonstration**

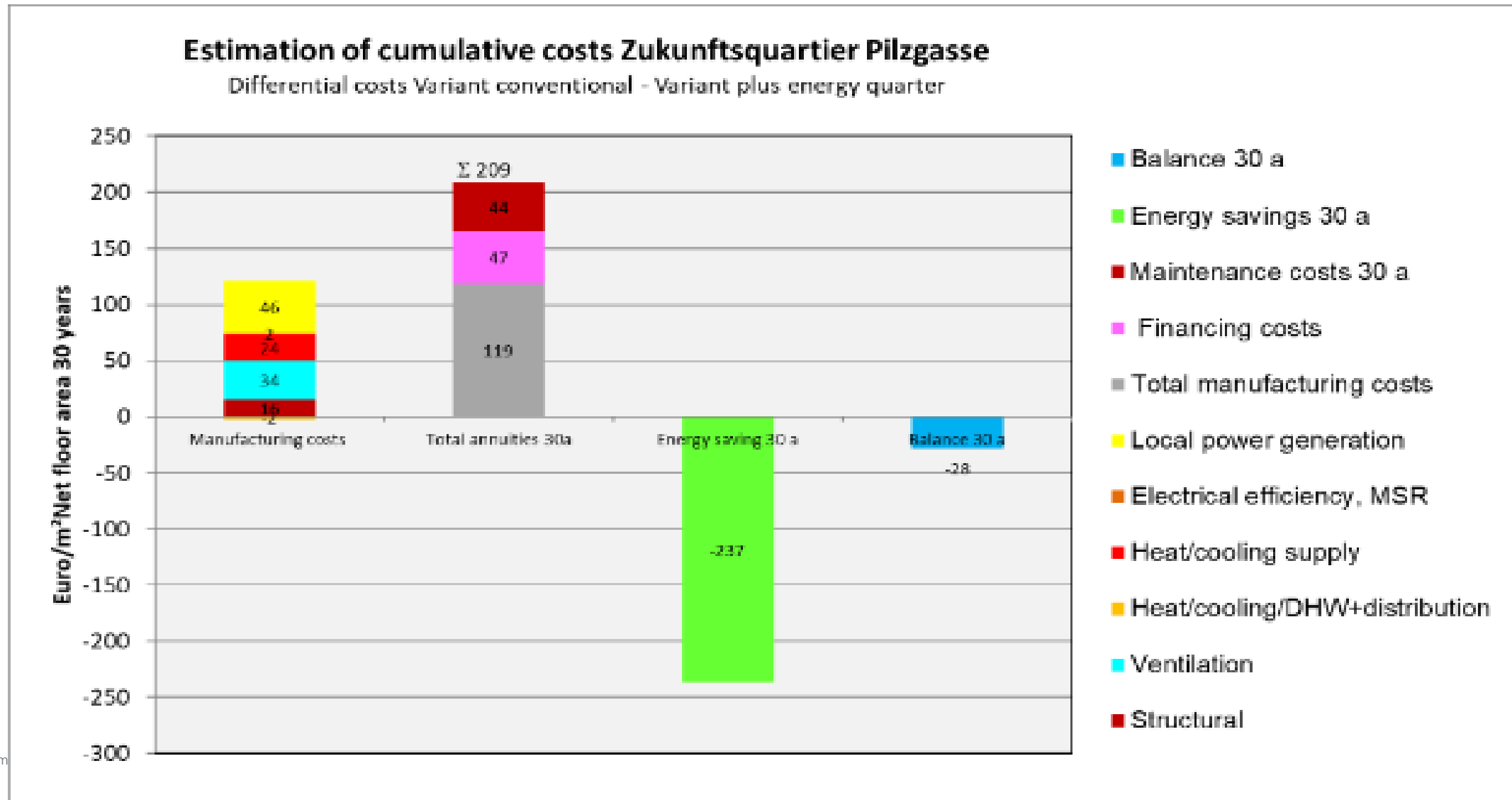
Duration: 36 months (09/19 – 08/21)

Funding:  Bundesministerium  
Verkehr, Innovation  
und Technologie

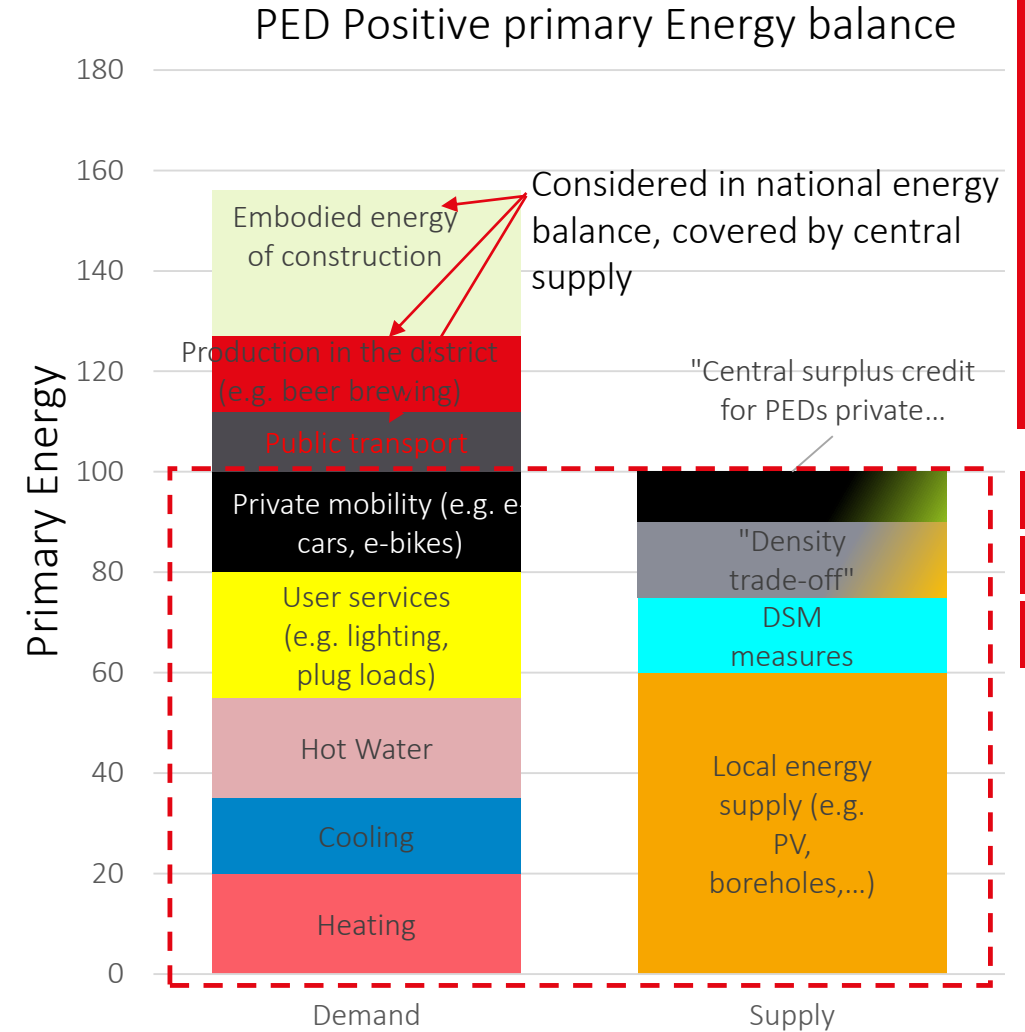
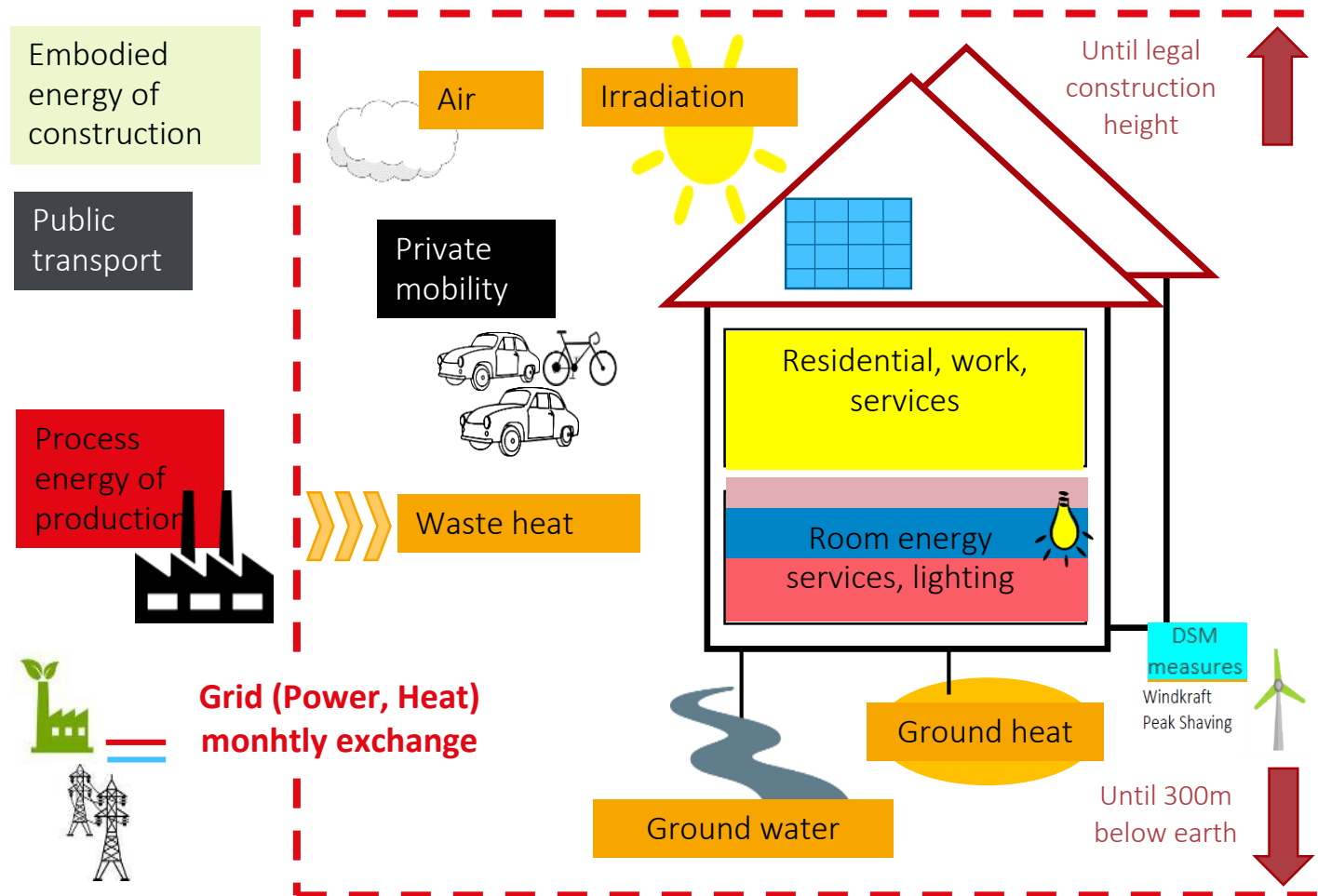
Partners:



# Differential life cycle costs o/ 30 years are positive!



# PED System boundary and primary energy balance connected to the climate scenario

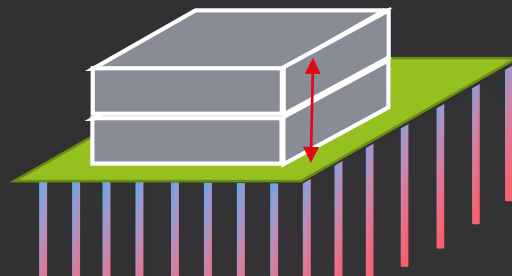
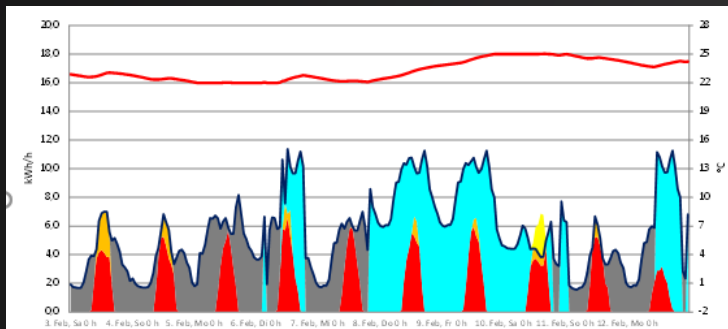


Considered in local positive primary energy balance

Amendments

3  
2  
1

# Conclusion I: Three keys to useful PED KPIs



## „Subsidiarity“

PEDs use DSM to include more RES than momentarily necessary (e.g. by preheating utilizing curtailed wind power peaks)

## „Density trade-off“ by FSI

Districts with low energy density and high potential have to compensate for districts with high density and low potential

## „Central surplus credit for PEDs private mobility“

Allocated per person

# Conclusion II: PED Enablers

## 🏠 Energy Efficiency is always first!

- ▶ High **energy efficiency** of thermal hull and HVAC system is a **critical requirement** for an urban PED. Mind the **Rebound!**

🏠 The use of solar energy (mostly PV) has to be **integrated in the planning process from the very beginning**. This way, possible conflicting goals (greening, terraces, HVAC towers, etc.) can be addressed proactively.

🏠 **Energy Flexibility:** The use of local resources groundwater and geothermal energy for heating and cooling is required. Regeneration must be taken into account. Ambient air should only be used if no other potential can be used.

🏠 The optimal use of different storage facilities and user elasticity (borehole storage, buffer storage, battery storage, building mass, load shift) is crucial for maximizing self-consumption and thus for economic efficiency.

- ▶ PV's own consumption rates of 60% and 70% can be achieved. The PV surpluses can largely be absorbed by the process energy requirements of businesses and future e-mobility.

# Impulse questions

- 🏠 How can mobility issues be taken into account in PED/PEN implementation?
  - ▶ Are the approaches of countries like Switzerland, Austria also suitable for your country?
  - ▶ Which adaptations have to be made?
- 🏠 What are the different (national) methodologies for calculating the carbon emissions of a PED? (e.g. using annual averages or hourly resolution and/or considering the emissions of the marginal power plant)
- 🏠 How can questions of sustainability (e.g. the UN SDGs) and of liveability be embedded into the PED/PEN concept?

# Presentation feedback

When survey is active, respond at [Pollev.com/simons007](https://Pollev.com/simons007)

**0 surveys done**

 **0 surveys underway**



# Literature

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# Thank you for your attention!

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## Further Information

[Project Zukunftsquartier](#)

[Projekt Zukunftsquartier 2.0](#)

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