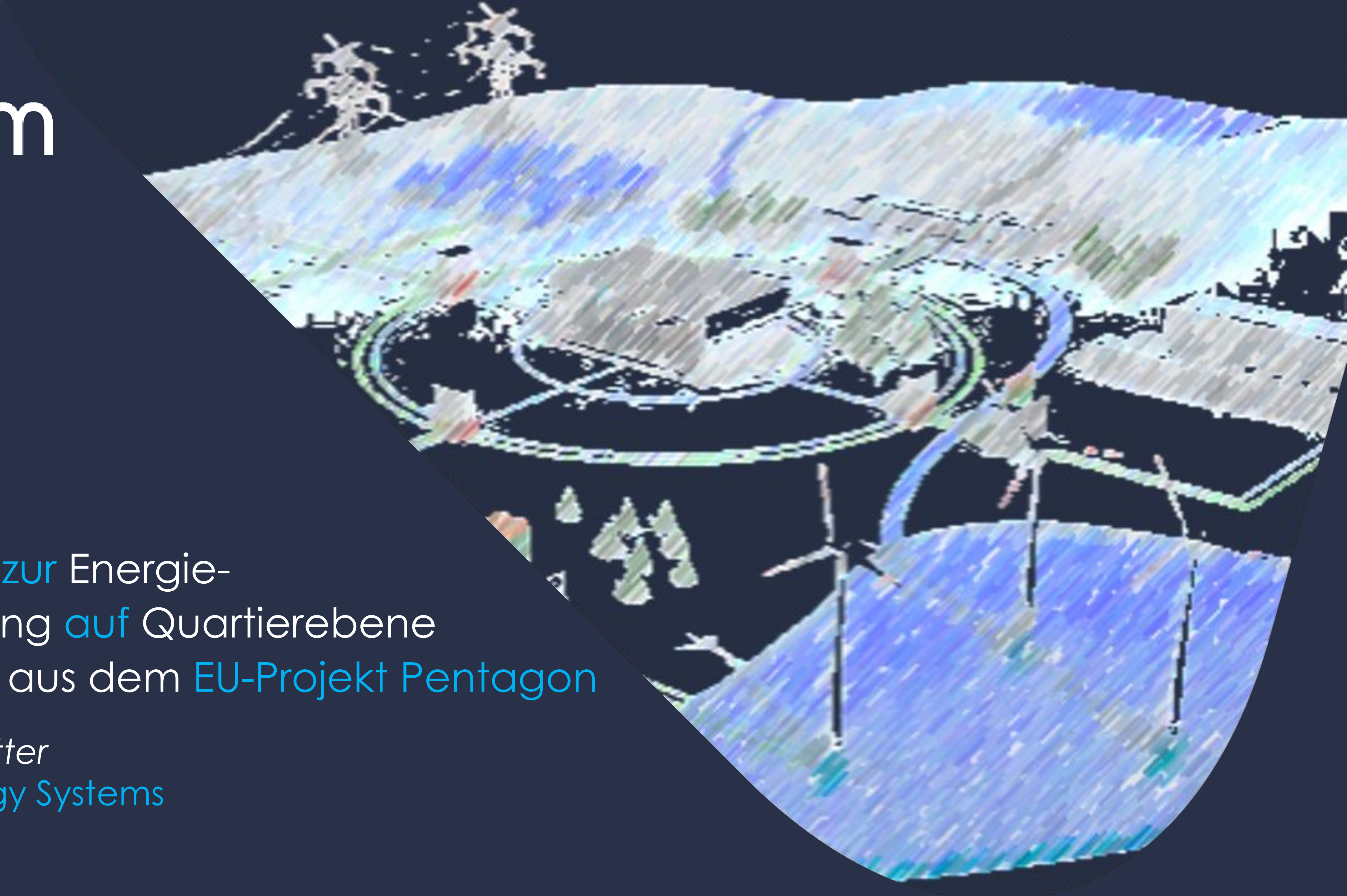
Strategien zur Energieumwandlung auf Quartierebene
Ergebnisse aus dem EU-Projekt Pentagon



Andreas Hutter
CSEM, Energy Systems

überblick

- **Einführung**: erneuerbare Energien auf dem Vormarsch – Fokus PV & P2G
- **PENTAGON**: Optimierung zur Energieumwandlung auf Quartierebene
- **Beispiel**: Evaluierung von P2G Technologien auf Quartierebene

CSEM a swiss private & public funded RTO

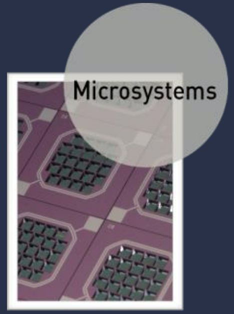
CSEM in numbers:

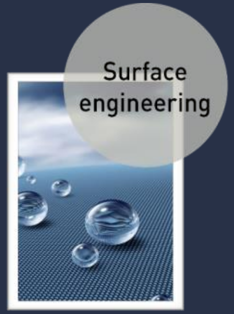
82.1	**500**	**200**	**200**	**76**
Turnover mio CHF	People	Industrial clients	Patent families	EU projects

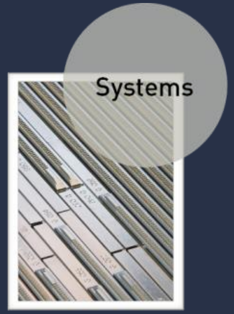
CSEM mission:

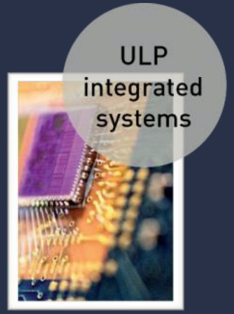
Development and transfer of world-class (micro-)technologies **to the industrial sector** – in Switzerland and EU – in order to reinforce its competitive advantage.

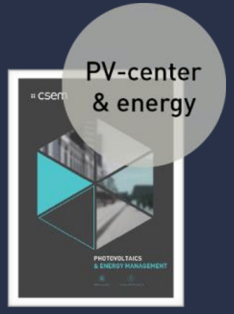
CSEM technology platforms to foster innovation:







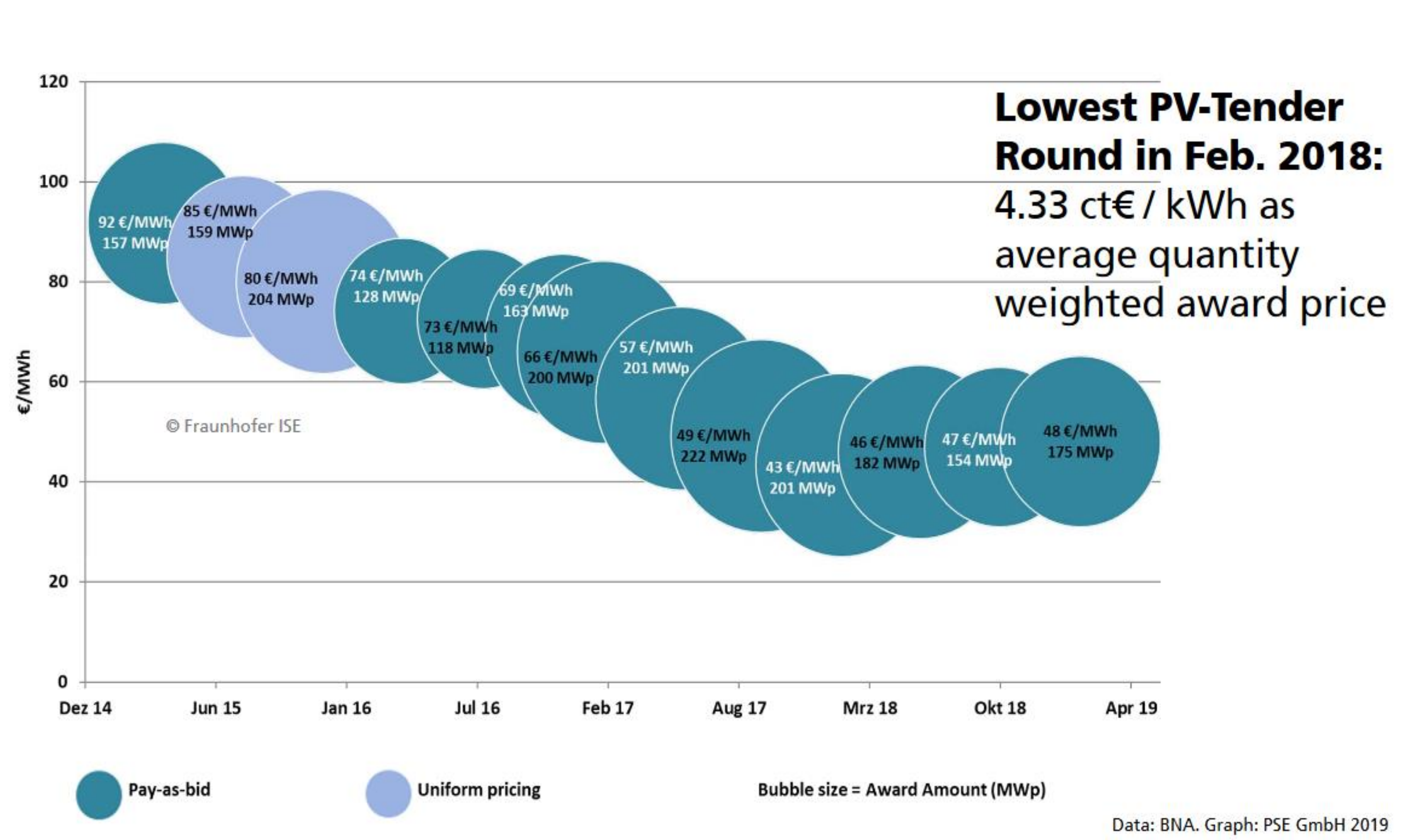




PV-Ausschreibung in Deutschland

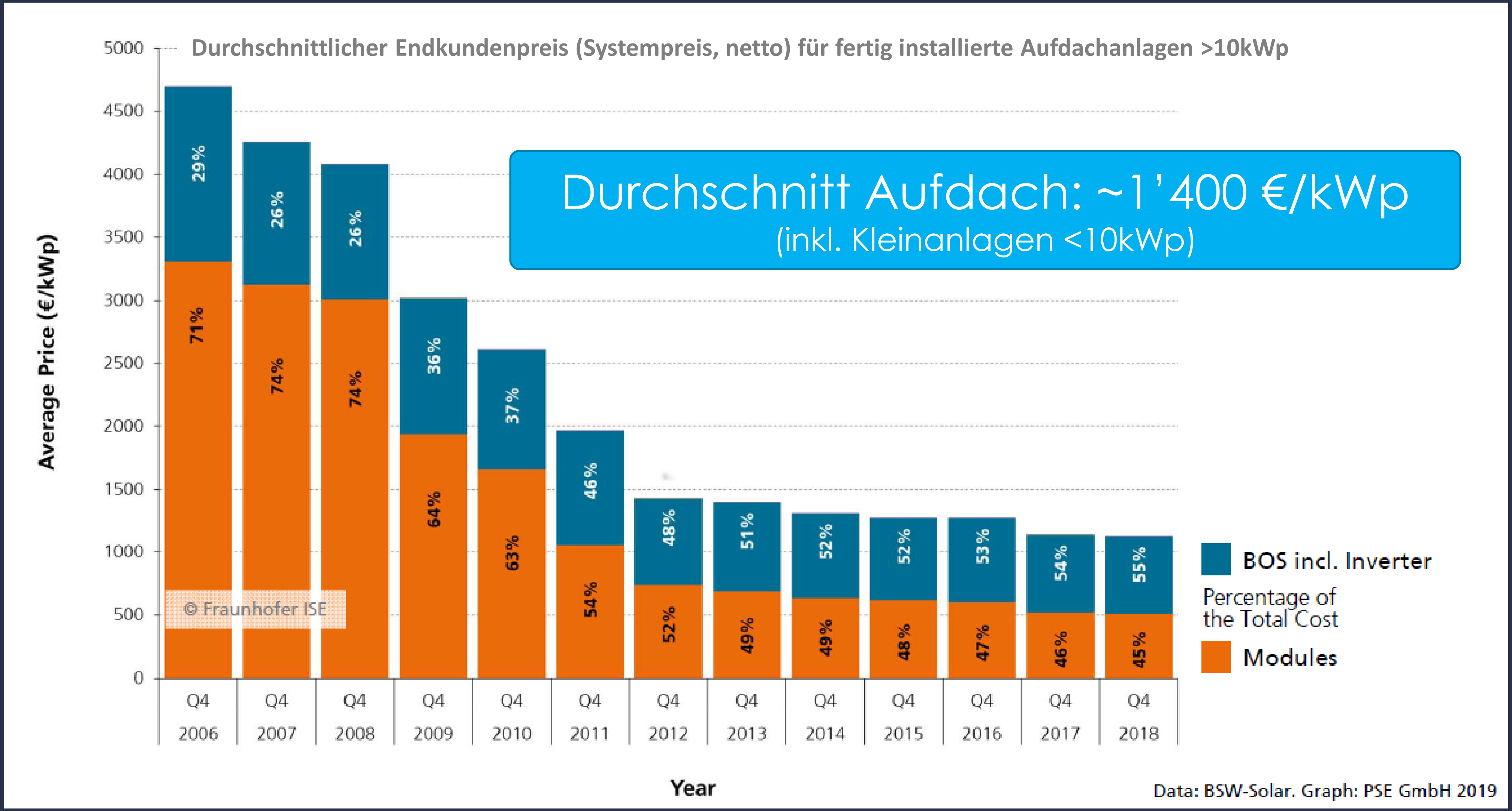
- **Deutschland**:
  Durchschnitt
  bei **4.6 €cts/kWh**

- In **sonnigen Region** werden die besten Preise im Bereich von **2-3 €cts/kWh** erzielt!



Quelle: Fraunhofer ISE, Photovoltaics Report 2018

Anlagenpreise für PV Systeme, Deutschland 2018



Quelle: Fraunhofer ISE, Aktuelle Fakten zur Photovoltaik in Deutschland 2018

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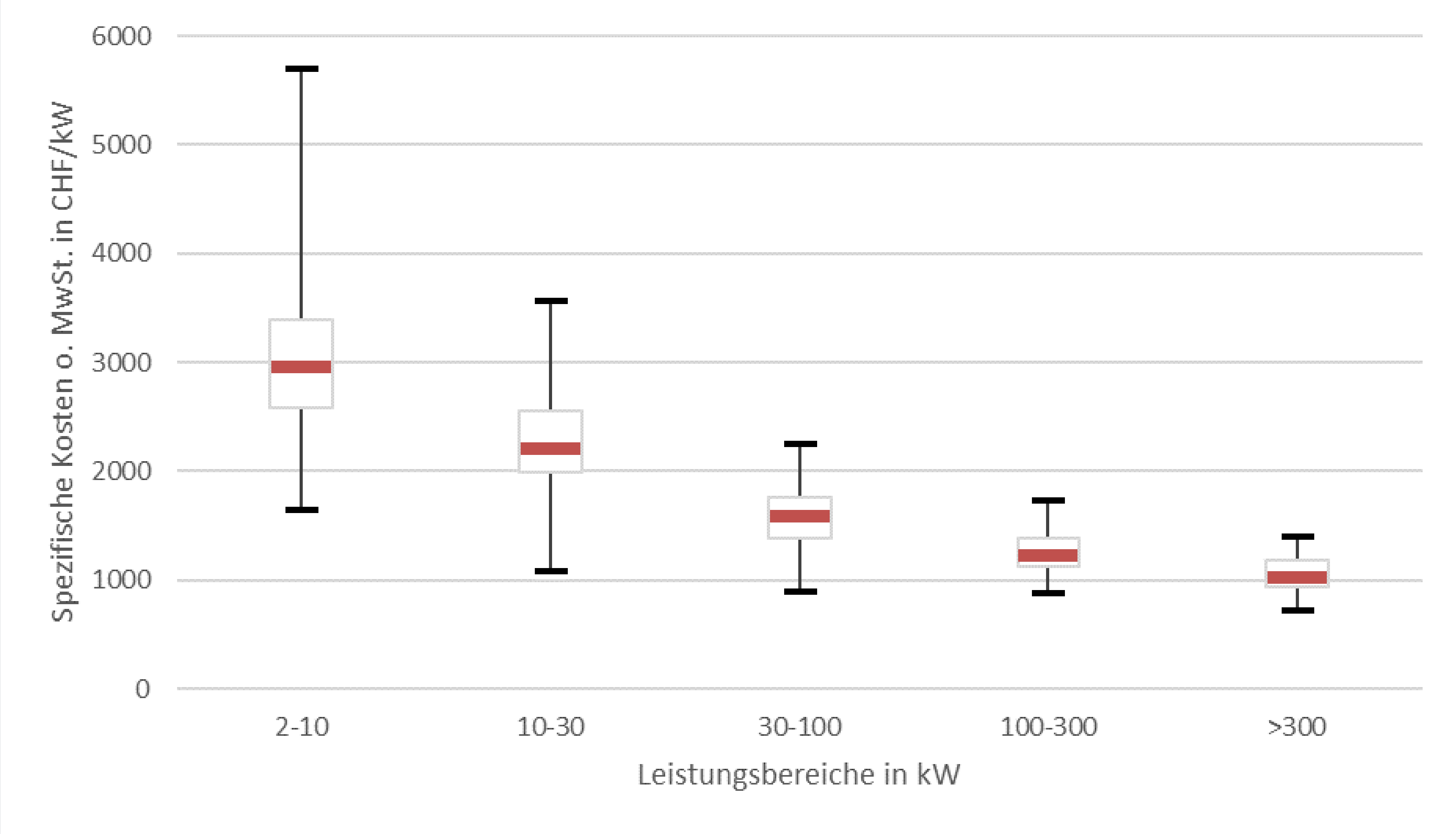
Installationskosten für PV System, Schweiz 2018



Quelle: SuisseEnergie & Planair, Observation du marché photovoltaïque 2018

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Solardacheignung und finanzielle Abschätzungen

Sonnendach

- Auswertung via sonnendach.ch, Beispielgebäude

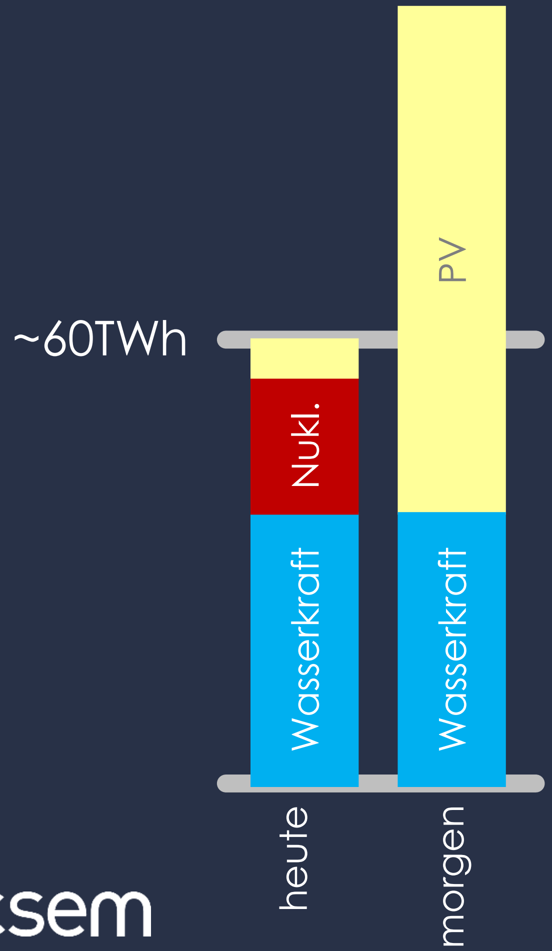
Erfolgsrechnung der Photovoltaikanlage

Investitionskosten	CHF (-)	45000	
Kleine Einmalvergütung KLEIV	CHF	12'800	
Steuereinsparung	CHF	6'208	
Einsparung Eigenverbrauch	CHF	121'711	→ 25 Rp/kWh ↓
Ertrag Einspeisung	CHF	89'540	→ 11 Rp/kWh ↓
Betriebsaufwand	CHF (-)	15'653	
Gewinn / Verlust (-)	**CHF**	**169'606**	
Mittlere Rendite		7.0 %	
Amortisationsdauer		4 Jahre	

Potential für die Schweiz

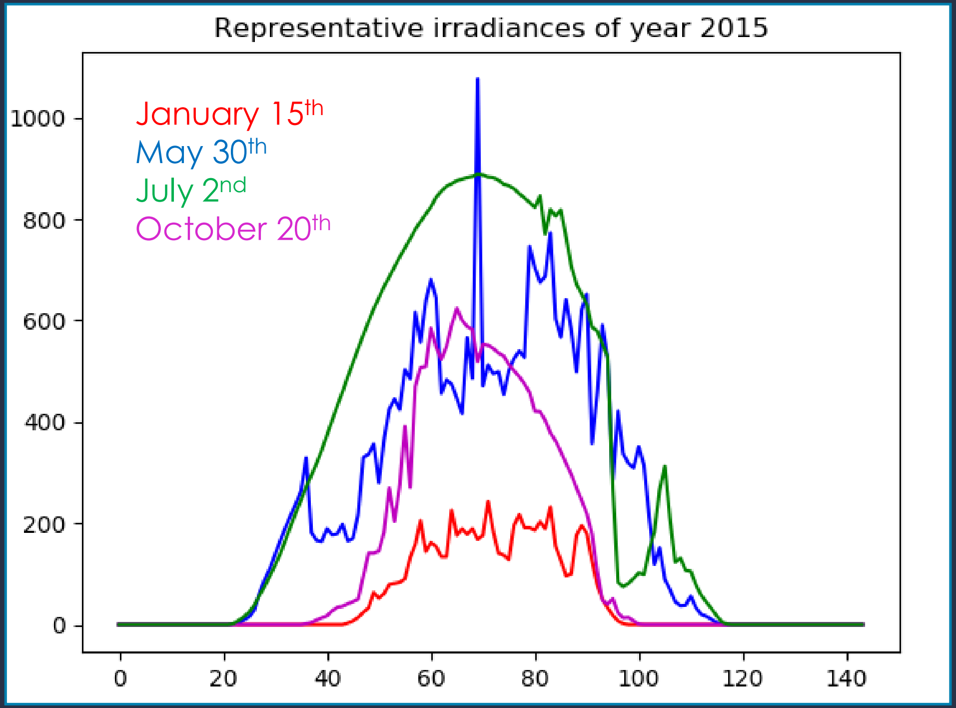
Solarstrom CH: **50 TWh** von Dächern und **17 TWh** von Fassaden

saisonale Speicherung & Energieumwandlung



7.2 kW_p

Datum	PV Prod.
15.01.2015	7.5 kWh
30.05.2015	35.3 kWh
02.07.2015	49.2 kWh
20.10.2015	20.5 kWh



Quelle: BFE, https://www.admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-74641.html

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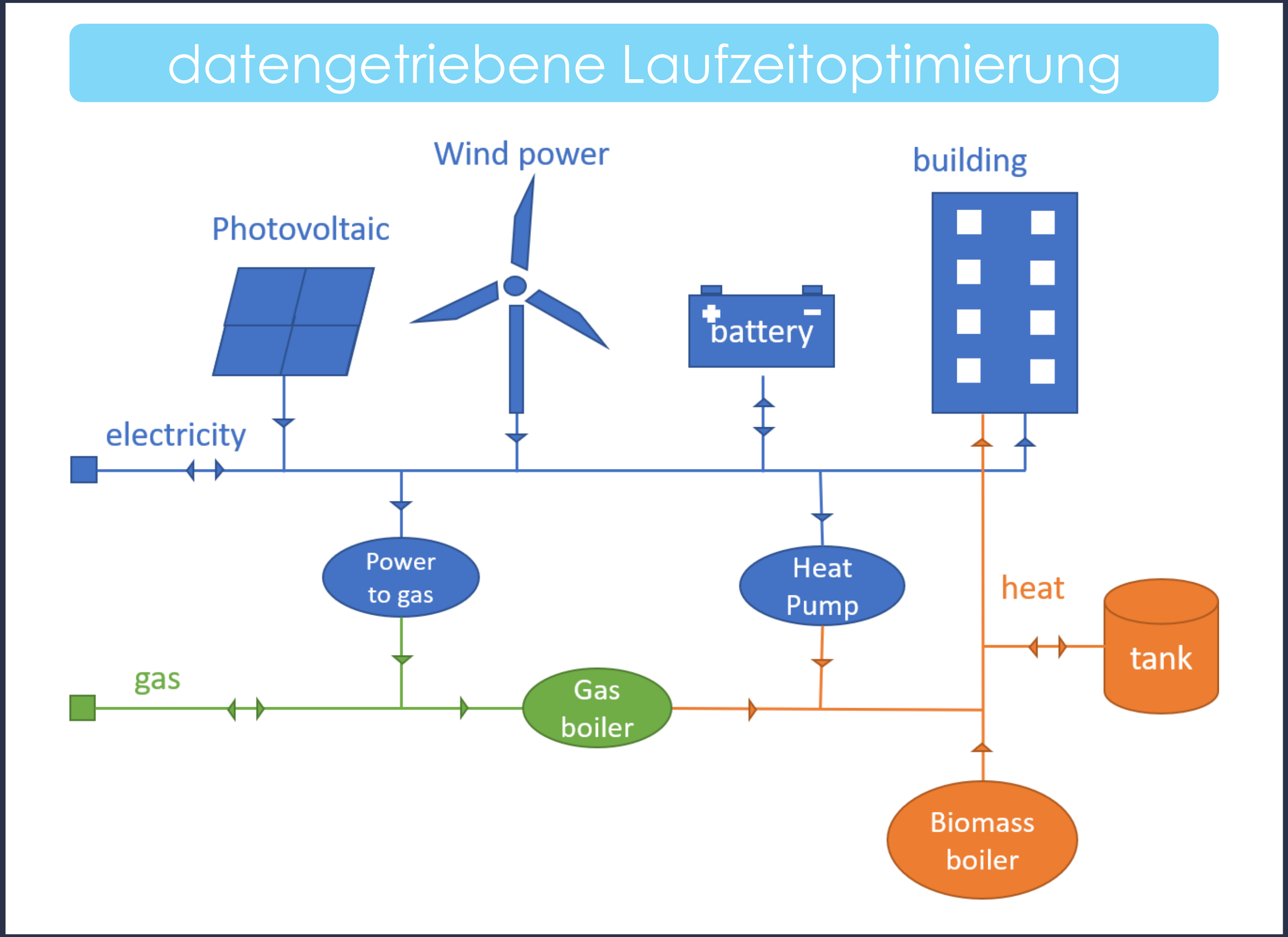
Optimierte Sektorkopplung für Gas-, Elektrizitäts- und Fernwärmenetze

Lösung zur effizienten Kopplung von Energieerzeugern und -verbrauchern mit Verschiebungspotential auf unterschiedlichen Zeithorizonten für Komponenten von

- elektrischen,
- thermischen und
- Gasnetzwerken

sowie dazugehörigen Speichern.



EC project PENTAGON, *Unlocking local flexibility at district level*, grant agreement no. 731125, Dec. 2016 to Nov. 2019

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Modelle und Parameter

Basierend auf *mixed-integer* linearen Modellen (MILP), welche die Hauptmerkmale erfassen:

- einfache Modellkonfiguration
- einschließlich variabler Tarife
- leicht erweiterbar

Optimization name	Type	Symbol	Description
energyType	configuration	-	Energy type of the consumer (electrical or heating)
isSheddable	configuration	-	Boolean value
loadSheddingPriceProfile	sensor	$f^{shedding}(\tau)$	The price of shedding the load profile
forecastedActivePowerProfile	sensor	$P^{forecast}(\tau)$	Forecasted power profile provided by PENTAGON forecasting framework
powerConsumptionProfile	actuator	$P_{BL}(\tau)$	Optimized power consumption of the consumer

E … electric network H … heat network G … gas network

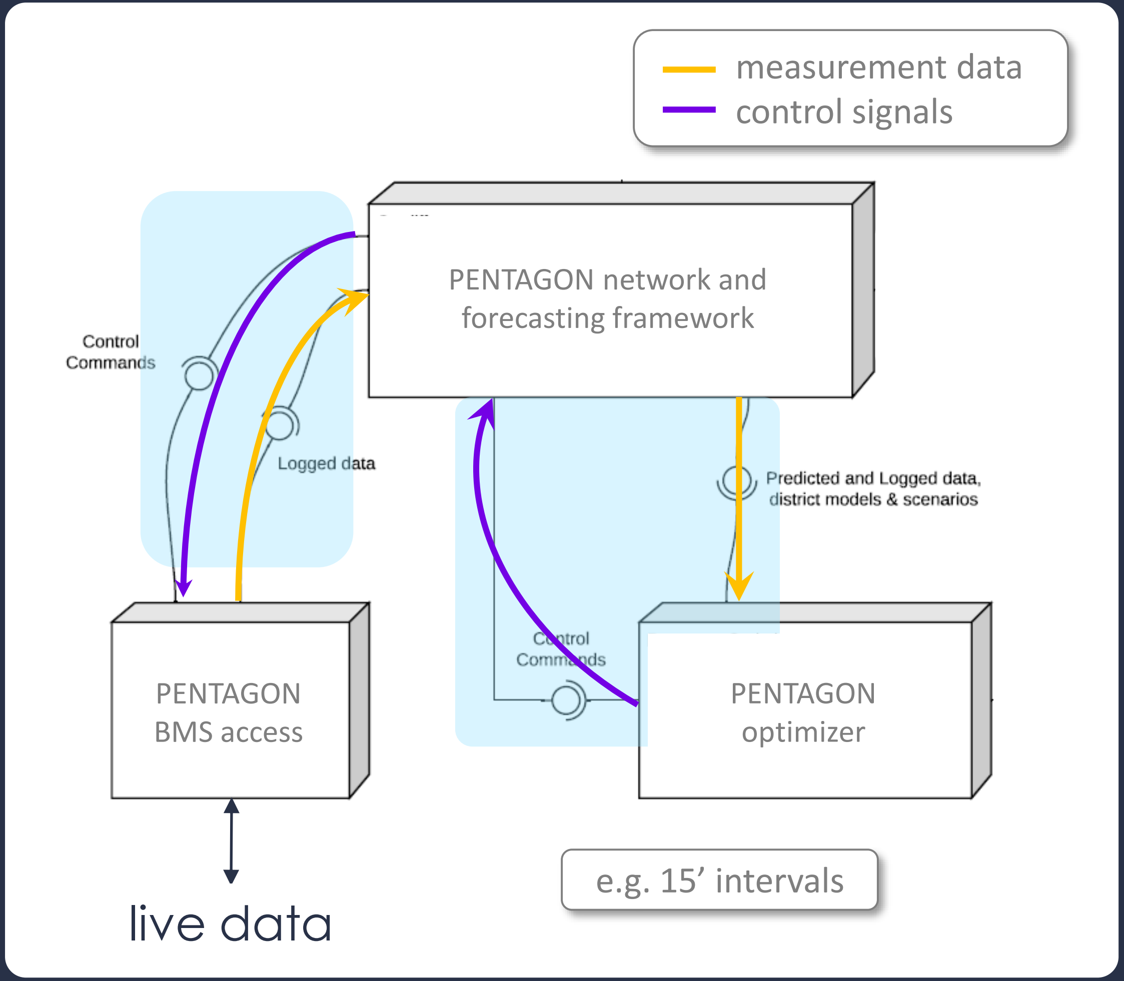
Component	Network	Level	Model
Baseline Load (BL)	E | H	Building/District	Consumer
Photo-voltaic (PV)	E	Building/District	Renewable generator
Solar thermal	H	Building/District	Renewable generator
Wind turbines	E	District	Renewable generator
Electrical utility | Gas utility	G | E	District	External tie
Power-to-Gas (P2G)	E,G	District	Converter
Heat-pump (Power-to-Heat, P2H)	E,H	Building/District	Converter
Gas boiler (GB)	G,H	Building/District	Converter
Electrical boiler (EB)	E,H	Building	Converter
Biomass boiler (BB)	H	District	Generator
Gas CHP	E,H,G	District	Cogenerator
Electric battery	E	Building/District	Battery energy storage system
Water tank (Pool, thermal storage)	H	Building/District	Thermal storage
Space heating (SH)	H	Building	Thermal storage

Konzept

Model-basierte prädiktive Steuerung
basierend auf

- Integration von Echtzeitdaten
- datengetriebener Vorhersagen
- wirtschaftliche Optimierung
- quasi Echtzeit Steuerung
- Simulation als Entwicklungsoption

optimierter Echtzeit-Betrieb
von gekoppelten Netzwerken



BMS … building managment system

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Maestro: A Python library for multi-carrier energy district optimal control design*†

Tomasz T. Gorecki and William Martin‡

December 2, 2019

Abstract

This paper introduces the *Maestro* library. This library for Python focuses on the design of predictive controllers for small to medium-scale energy networks. It allows non-expert users to describe multi-carrier (electricity, heat, gas) energy networks with a range of energy production, conversion, and storage component classes; together with consumption patterns. Based on this description a predictive controller can be synthesized and tested in simulation. This controller manages the dispatch of energy in the network, making sure that the demands are met, while minimizing the total energy cost. Alternative objectives can be specified. The library uses a mixed-integer linear modelling framework to describe the network and can be used in stand-alone based on standardized input files or as part of the larger energy network control platform PENTAGON.

1 Introduction

The shift from centralized energy generation in few large plants to a more and more decentralized generation infrastructure with a growing penetration of intermittent renewables challenges the management logic of the grid in all its aspects: communication, data management, control [1, 2]. With the emergence of micro-grids and self-consumption communities, it is expected that local grid control strategies will play an important role in the management of the future power grids. In addition, with the electrification of transport, the increasing penetration of heat pump to serve heating and cooling needs and the emergence of new technology such as power-to-gas systems and fuel cells, power, gas and local heat energy grids are becoming more interconnected. This provides additional opportunities to improve the

*This project has received funding from the European Unions Horizon 2020 research and innovation programme under grant agreement No 731125

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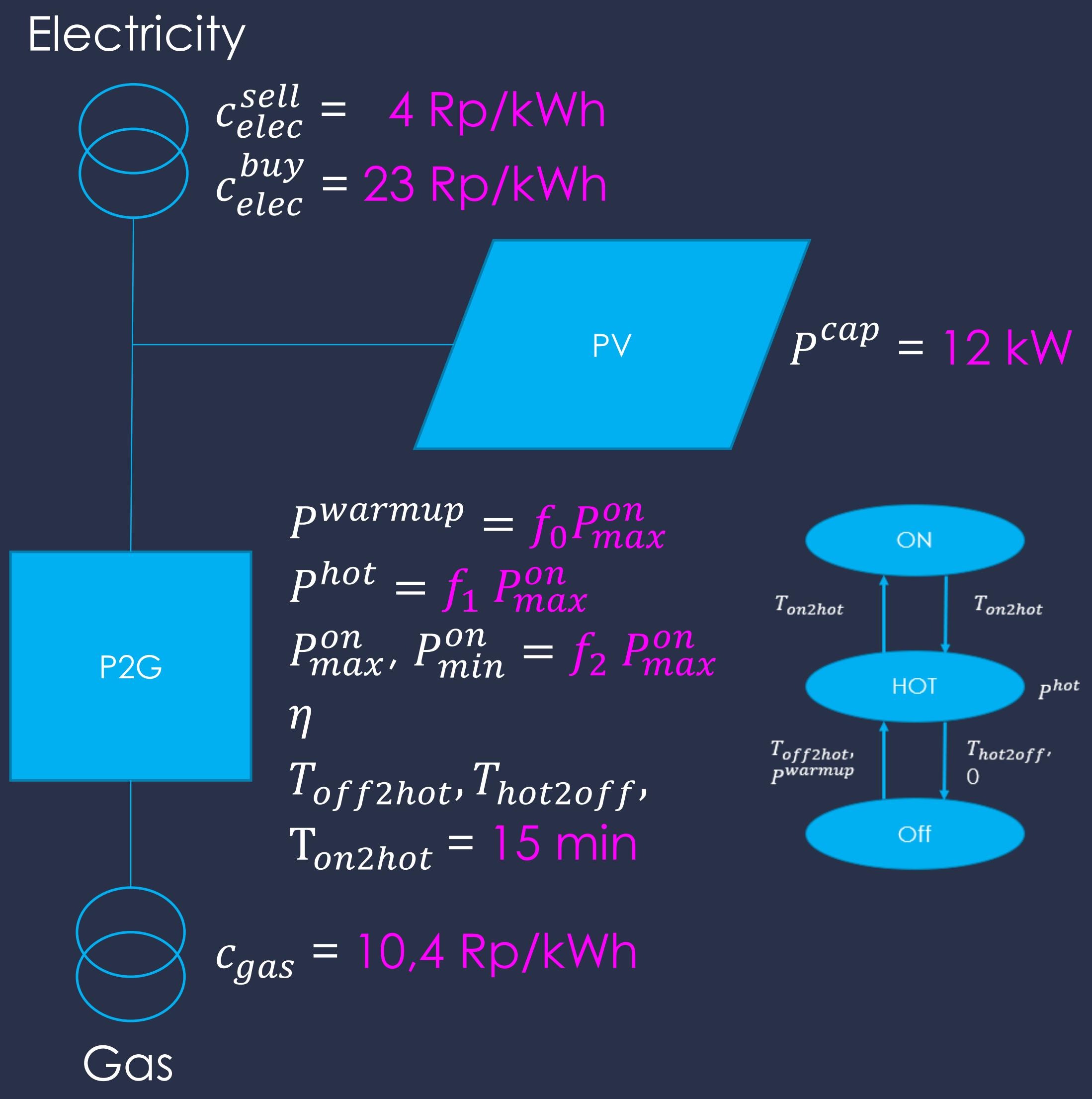
Ein einfaches Beispiel – Dimensionierung & Technologievergleich



c_{gas}

if $\eta c_{gas} P_{PV} \geq c_{elec}^{sell} P_{min}^{on}$
→ **produce gas with P_{PV}**

if $P_{excess} < P_{min}^{on}$ &
$\eta c_{gas} P_{min}^{on} \leq c_{elec}^{buy} (P_{min}^{on} - P_{PV})$
→ **produce gas at P_{min}^{on}**

otherwise, sell electricity

$\frac{c_{elec}^{sell}}{\eta}$

no power2gas,
sell all excess

0

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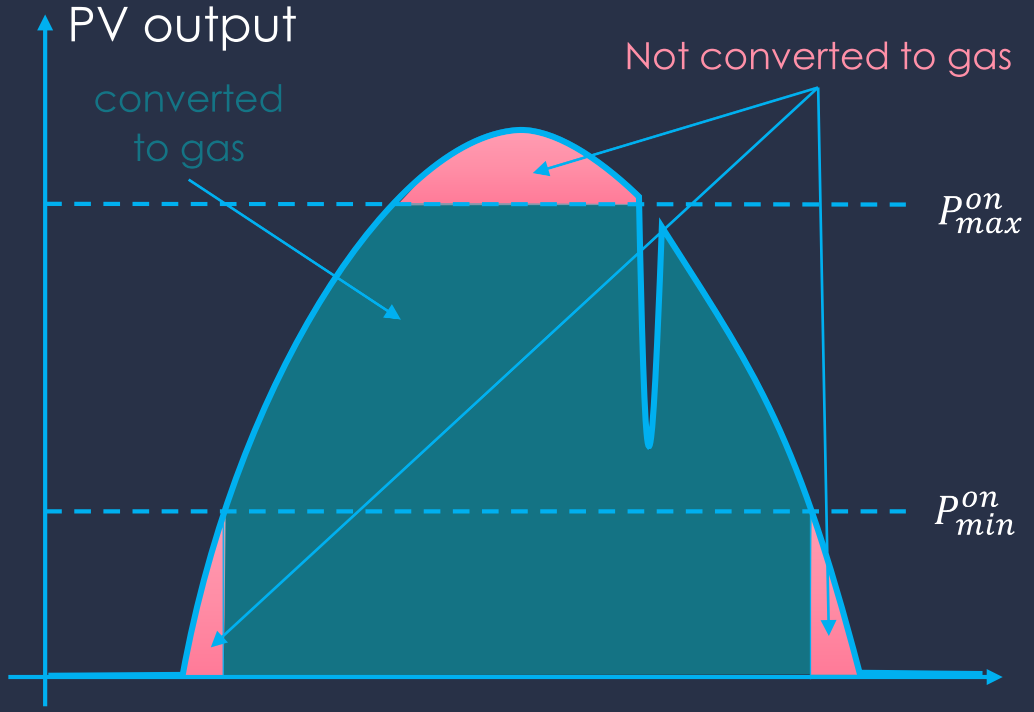
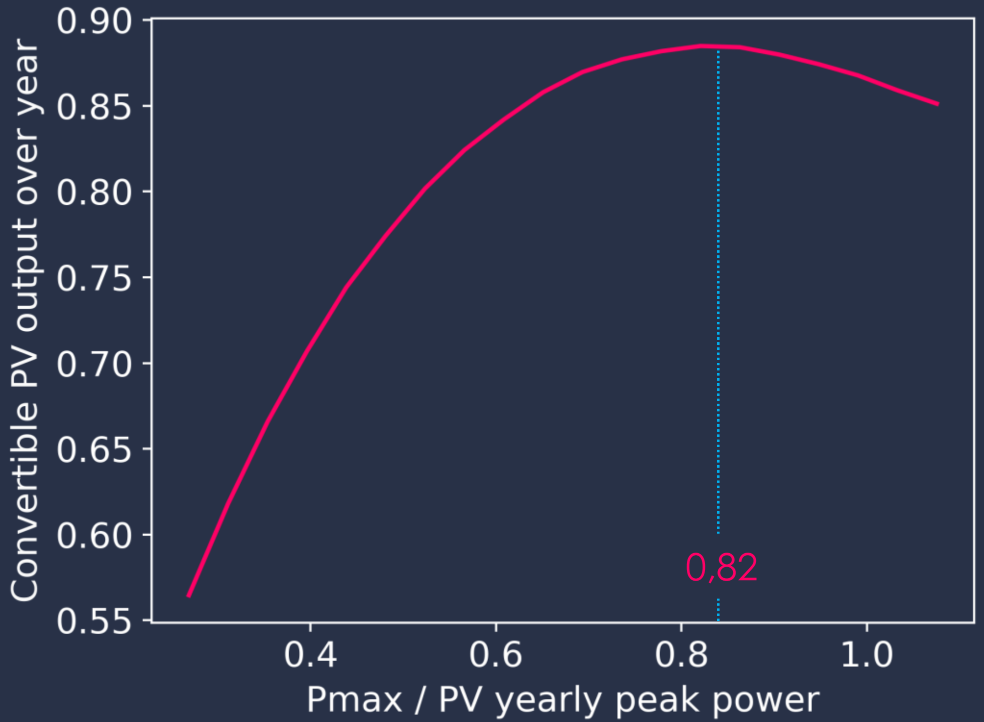
Dimensionierung



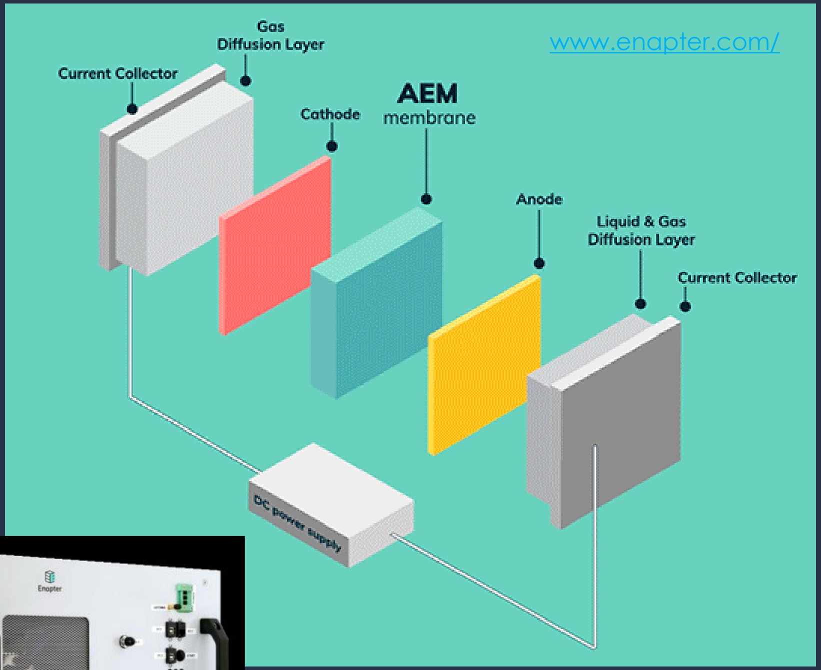
Beispiel $P_{min}^{on} = 0.2 P_{max}^{on}$



maximaler jährlicher P2G-Ertrag mit P_{max}^{on} = 82% P_{PV}^{max}

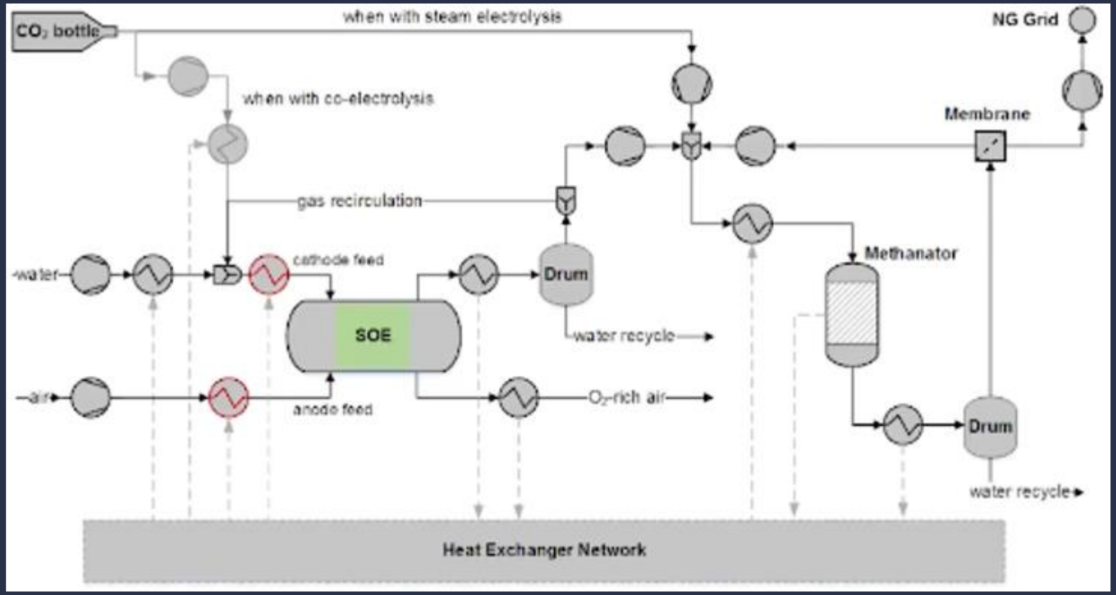
Technologievergleich

Anion Exchange Membrane (AEM) electrolysis



kommerziell

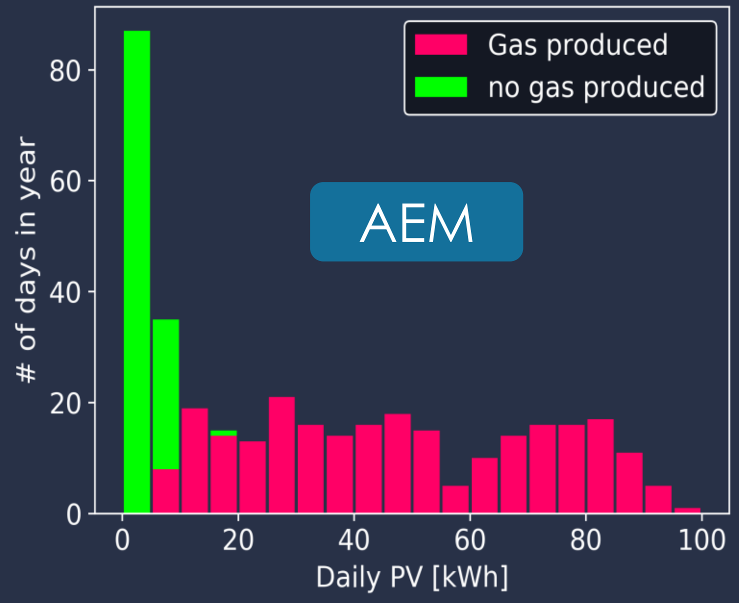
Solid Oxid Electrolysis (SOE) the PENTAGON approach

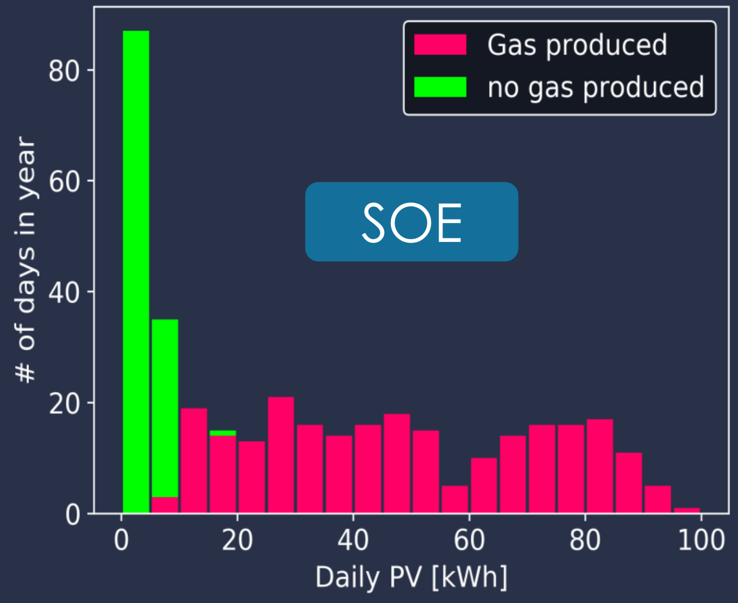


noch in Entwicklung

Technologievergleich - Resultate

Param.	AEM	SOE
P_{max}^{on}	9.2 kW	
P_{min}^{on}	$0.2P_{max}^{on}$	$0.2P_{max}^{on}$
P^{warmup}	0	$0.1P_{max}^{on}$
P^{hot}	0	$0.01P_{max}^{on}$
η	58%	70%
$T_{off2hot}$	3 min.	2 h
$T_{hot2off}$	3 min.	1 h





Case	Revenue [CHF/y]	Increase [%]	SC ratio [%]	Gas [MWh]
No P2G	491	n.a.	0	0
P2G - AEM	707	45.3	89.8	6.4
P2G - SOE	808	64.7	89.7	7.4

Potential der SOE Technologie bestätigt

P2G für Kleinanlagen noch nicht rentable

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Thank you for your attention

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