BATTERY STORAGE
KEY ENABLER FOR LARGE-SCALE GRID INTEGRATION OF RENEWABLES


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Dr. Matthias Vetter

Fraunhofer Institute for Solar Energy Systems ISE

B2G Roundtable – Chile

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AGENDA

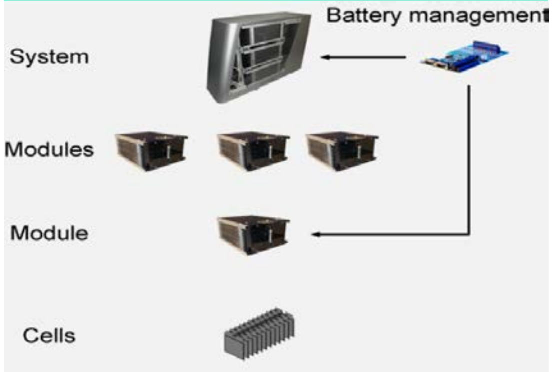
- Introduction to battery research, development and services at Fraunhofer ISE
- Stationary battery storage – Mission, market developments and market segments
- The role of battery storage towards highest shares of renewables
  - Isolated mini-grids
  - Active distribution grids
  - Commercial & industrial applications
- Conclusions

Department Electrical Energy Storage
Overview – Research, Development and Services

Battery Cell Technology
materials, architecture, production

- Development and characterization of materials and battery cells
- Development of process technologies
- Aqueous systems for stationary energy storage
- Lithium ion battery cells
- Solid state battery cells
- Technical and economical analysis
- Life cycle analysis

Battery Engineering
from cells to systems



- Cell formation
- Cell and system characterization
- Ageing and performance scrutiny
- System design and engineering
- Thermal management
- Battery management
- Algorithms for state estimation and life time prediction
- Optimized charging and operating control strategies

Applied Storage Systems
system design, integration and quality assurance

- Realization of lighthouse projects
- Business case development
- Consulting during complete life cycle of storage projects
- System modelling, analysis and optimized system design
- Simulation based storage sizing
- Energy management systems
- Technical due diligence: Site inspection, testing and monitoring

TestLab Batteries
electrical, thermal, mechanical testing

- Ageing: calendric and cyclic
- Safety: components and systems including functional safety
- Reliability: consideration of operating conditions and system behavior with aged components
- Performance: efficiency and effectiveness
- End-of-line quality control for cell production

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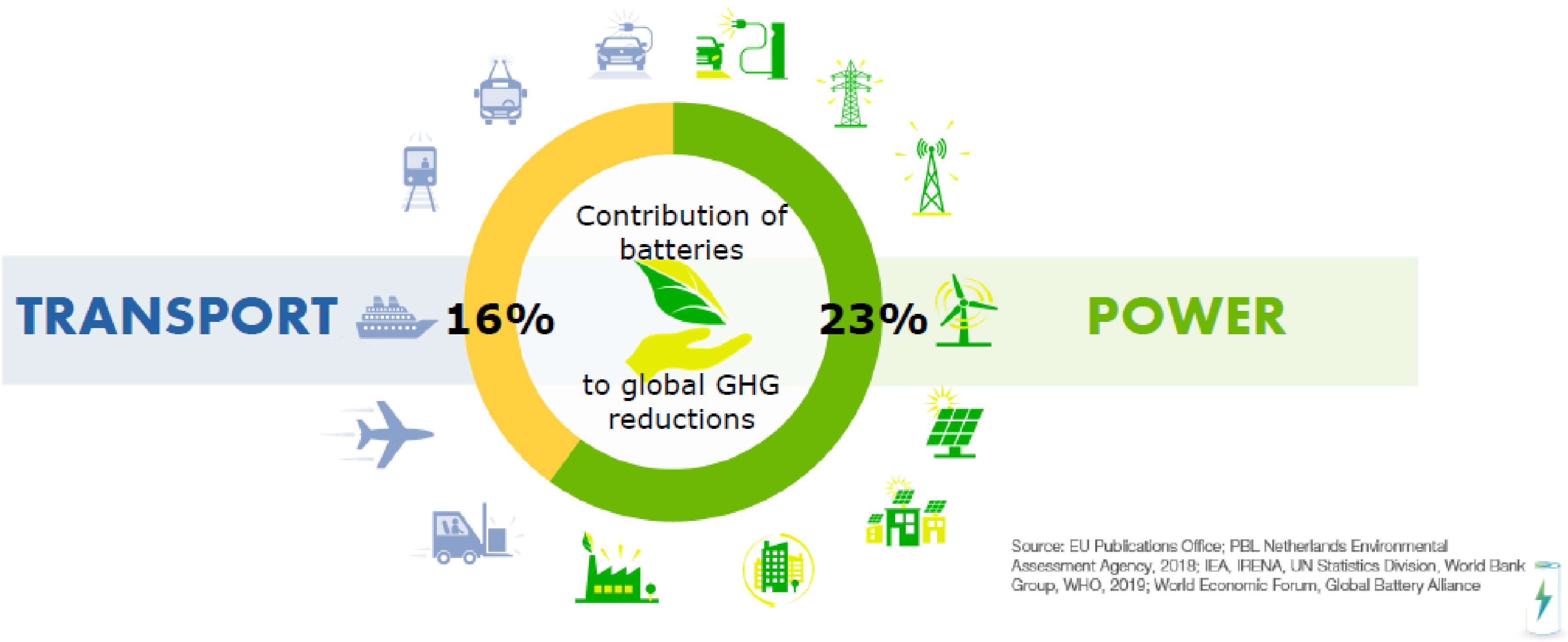
Stationary battery storage – Mission

Batteries Europe: Strategic Research Agenda – Extract

BATTERIES EUROPE
EUROPEAN TECHNOLOGY
AND INNOVATION PLATFORM

« Everything we can electrify will be electrified »



Source: E. Sheridan: Batteries Europe, European Technology and Innovation Platform – Overview of Strategic Research Agenda, Batteries Europe Webinar, 28th of October 2020.

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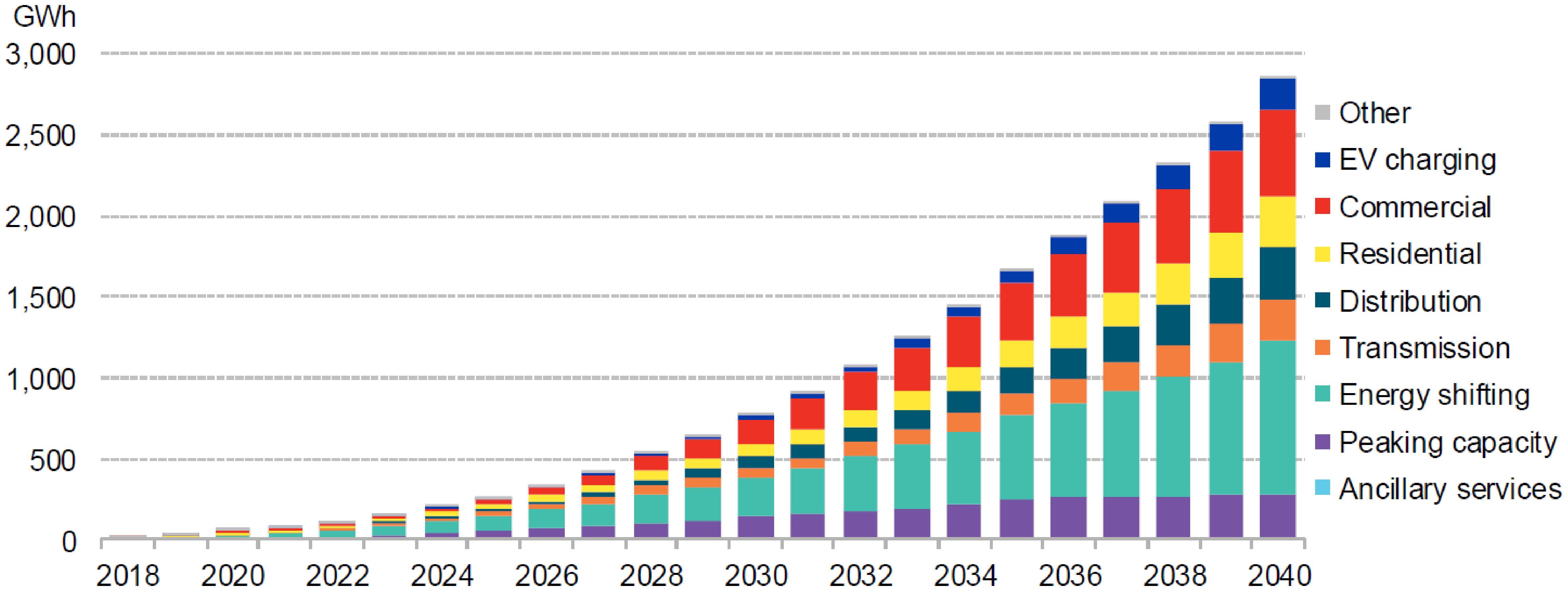
Stationary battery storage – Market developments
Prognosis for global cumulative deployments



Source: BloombergNEF, 2019.

Stationary battery storage – Market segments

Services to various stakeholder groups

Where do you place it? (Provider)						
Consumer		Grid / Distribution				Bulk Generation
Low voltage		Medium Voltage			High Voltage	
Local		Regional / Municipal			National	
Residential	C&I	3rd Party	Utility	DSO*	TSO*	Utility

In this presentation: Focus on distribution level

- Isolated mini-grids
- Active distribution grids
- Commercial and industrial applications

Source: J. Wüllner et al.: Review of Stationary Energy Storage Systems – Applications, their Placement and Techno-Economic Potential, Springer, 2021.

(Beneficiary, Customer)	BESS Applications:	Where do you place it? (Provider)						
		Consumer		Grid / Distribution				Bulk Generation
		Low voltage		Medium Voltage			High Voltage	
	Operation level / Place	Local		Regional / Municipal			National	
	Operator	Residential	C&I	3rd Party	Utility	DSO*	TSO*	Utility
Generation support	Arbitrage			[9, 10]	[9]			[11]
	System Electric Supply capacity		[12]	[13]	[13]			[13]
	Support Conv. Generation							
	Seasonal Arbitrage							[14]
	Ancillary Services RES Support		[15–17]	[15–17]	[15–18]	[15–17]	[15–17]	[11,15–17,19]
	Capacity Firming							
	RES Curtailment Minimization			[20–22]	[20–23]			[21]
Transmission	*Transmission Grid upgrade deferral*						[24–26]	[24–26]
	Contingency Grid Support						[27]	[27]
	Transmission Support	[28]	[28]			[29]	[29, 30]	
	Angular Stability							
	Reactive Power Compensation							
	Cross Sectoral Storage	[31]	[31]	[31]	[32]			[32]
	Power Oscillation Damping (POD)							
Distribution	*Distribution Grid upgrade deferral*	[33, 34]	[33, 34]		[33–35]	[33–35]		
	Contingency Grid Support			[23]	[23, 29]	[29]		
	Dynamic Local Voltage Control			[18]	[18, 29]	[18, 29]		
	Intentional Islanding		[36]					
	Reactive Power Compensation		[33]	[37]	[23, 33, 37]	[33, 37]		
	Cross Sectoral Storage			[32]	[32]			
Ancillary Services	*Frequency Containment Reserve*	[28]	[10, 28, 38]	[28]	[39–44]	[45]	[30]	[11, 19, 43]
	Automatic Frequency Restoration Reserve	[12]			[43, 44]	[45]	[30]	[19, 43]
	Manual Frequency Restoration Reserve				[44]			[19]
	Replacement Reserve							
	Load Following					[46]		
	Frequency Stability (Weak grids)				[47]			
	Black Start				[27]			[27]
	Voltage Support	[12]			[18]	[46]	[30]	
	New Ancillary Services		[17, 48]	[17, 48]	[17, 44, 48]	[17, 48]	[17, 48]	[17, 43, 48]
EMS / Customer Services	*End-User Peak-Shaving*		[10, 38, 49, 50]	[10]		[46]		
	Time-of-use / energy cost Mgmt.	[51]	[51]					
	Energy Quality		[52, 53]	[52, 53]				
	Maximizing Self- Production / Self-Consumption	[28, 54–56]		[28, 55, 57, 58]	[54–56, 59]	[46]		
	Continuity of Energy Supply / UPS							
	Limitation of upstream disturbances (Distribution)					[46]		
	Compensation of reactive power		[52, 53, 60]	[52, 53]		[46]		

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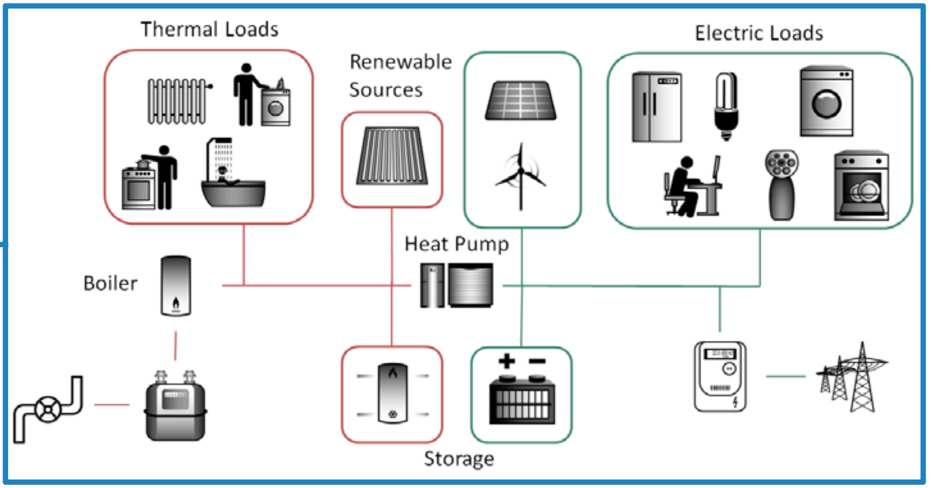
The role of battery storage towards highest shares of renewables

Isolated mini-grids – Examples of project React*

Targets:

- Energy consumption: **-10%**
- Renewable energy penetration: **+50%**
- Fossil fuel consumption: **-50%**
- Emissions: **-60%**
- Energy cost: **-60%**



*REACT: EU funded project "Renewable Energy for Self-Sustainable Island Communities. www.react2020.eu.

bridge HORIZON 2020
REACT Renewable Energy for Self-Sustainable Island Communities
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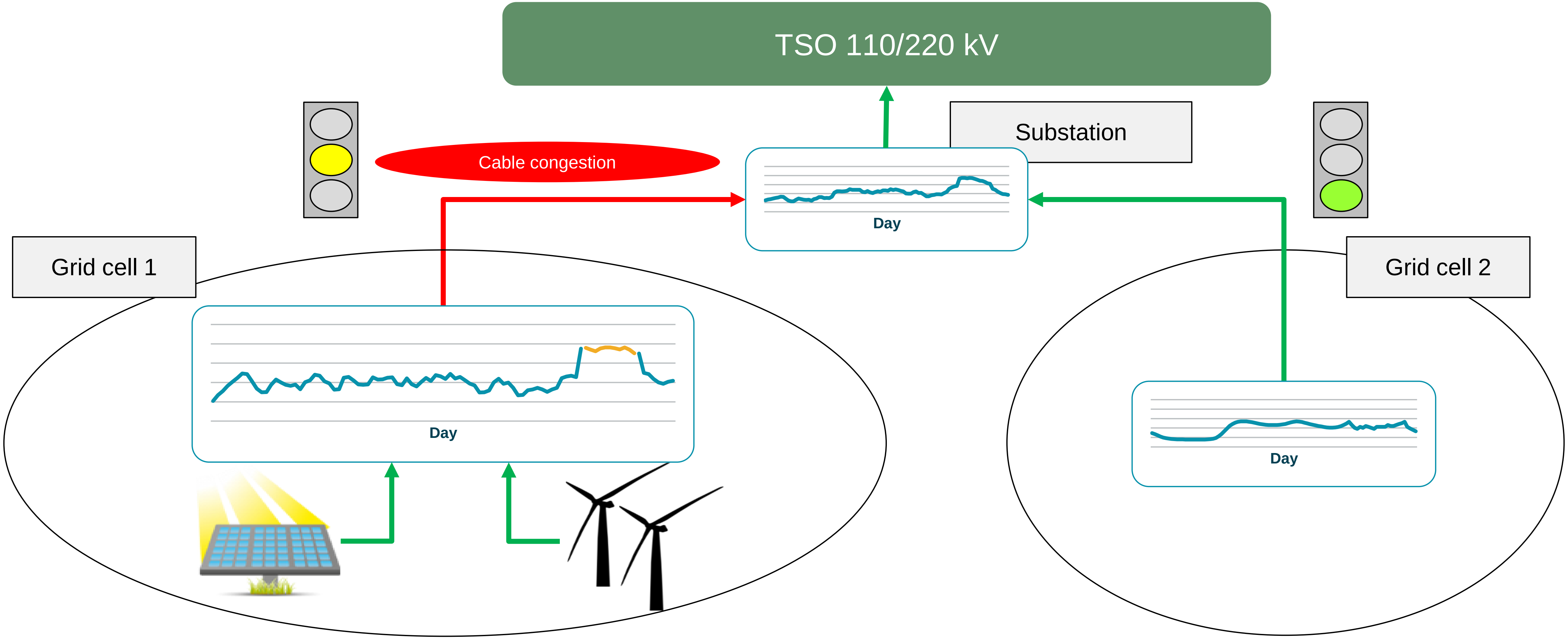
Active distribution grids – Example: Grid overload in grid cell 1



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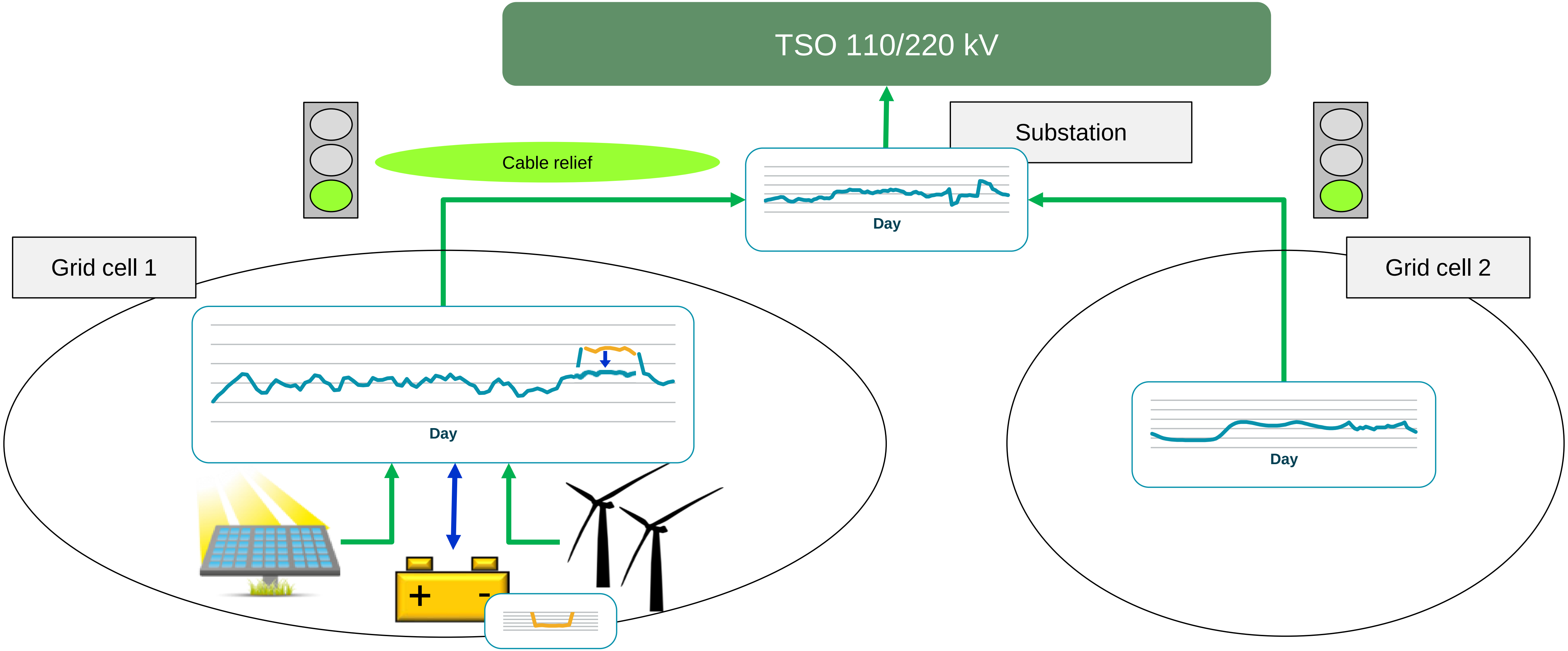
Active distribution grids – Example: Grid relief via usage of battery in grid cell 1



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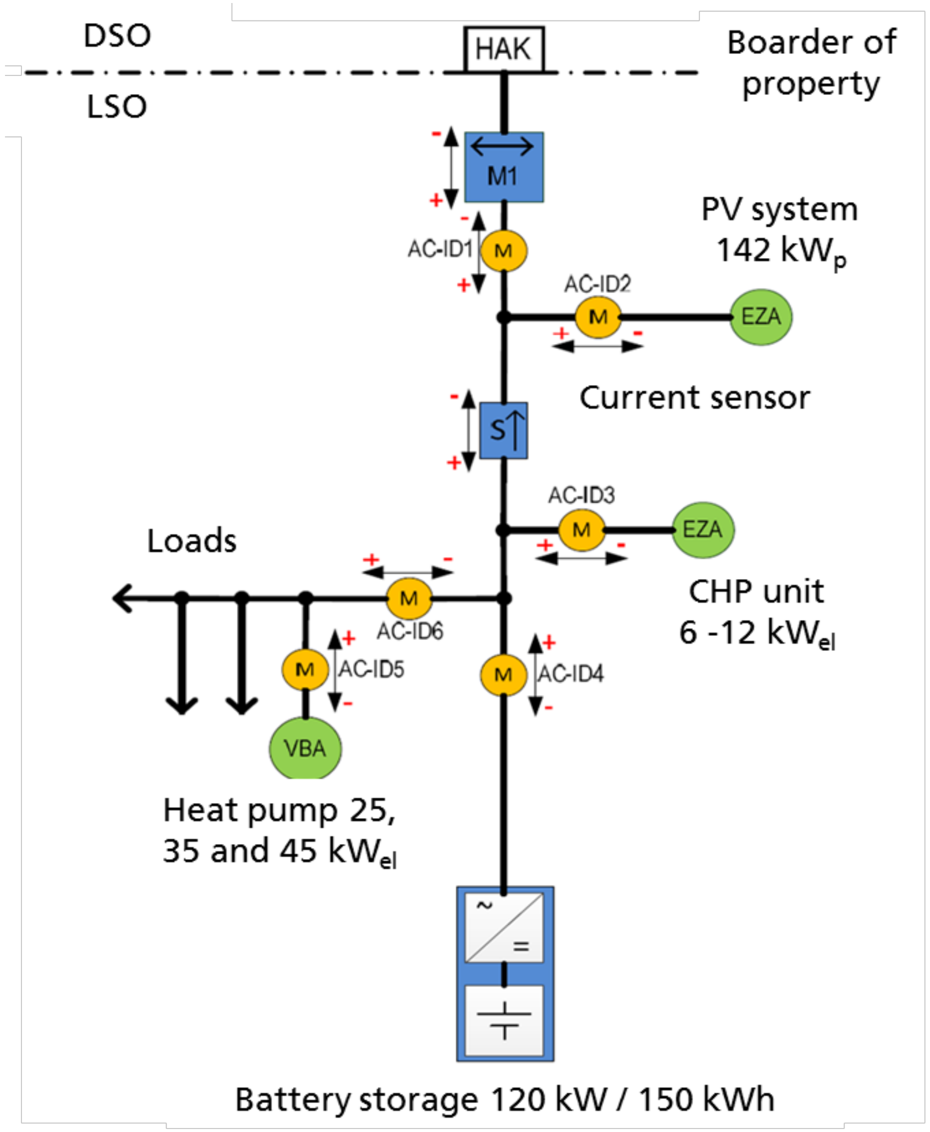
Active distribution grids – Example: Smart district "Weinsberg"

Optimization criteria:

Minimization of grid dependency –

Physically not only accumulated



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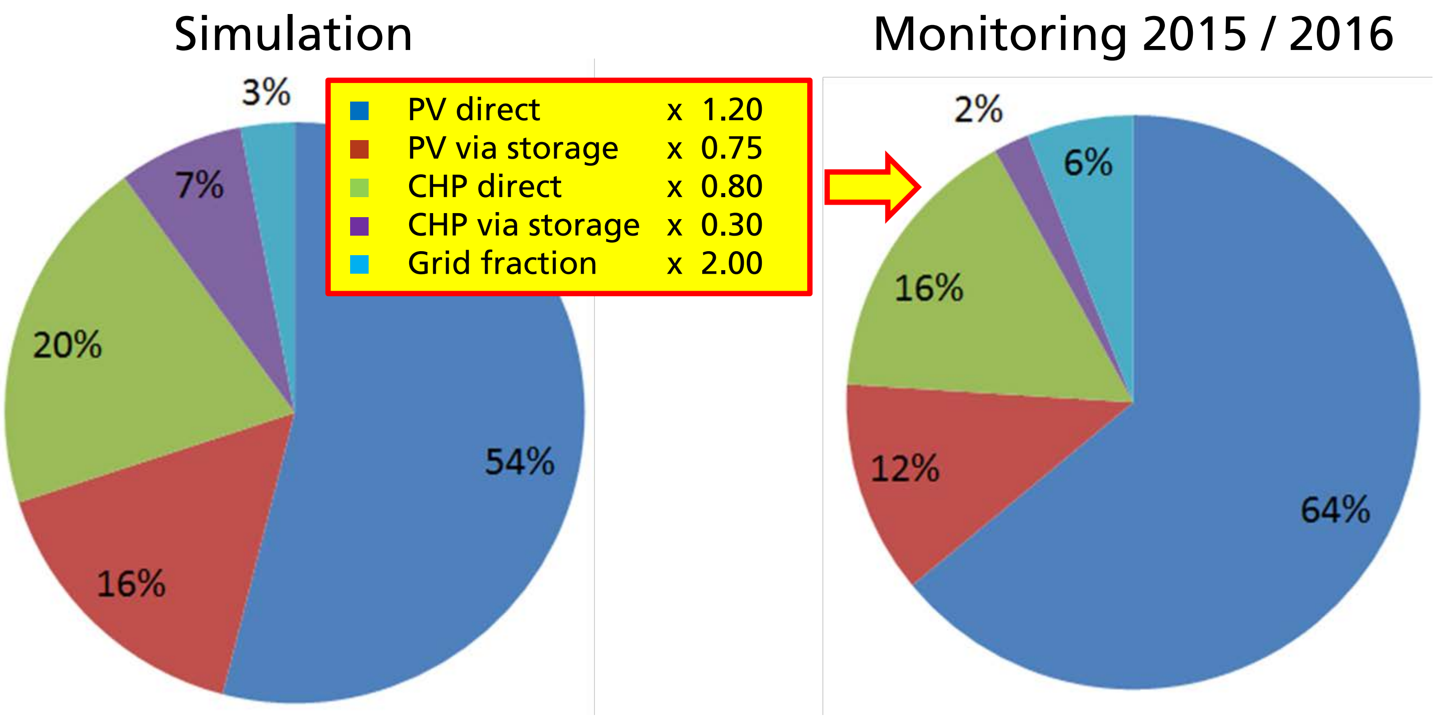
The role of battery storage towards highest shares of renewables
Active distribution grids – Example: Smart district “Weinsberg”

Accumulated annual electrical energy quantities



Reasons for differences:

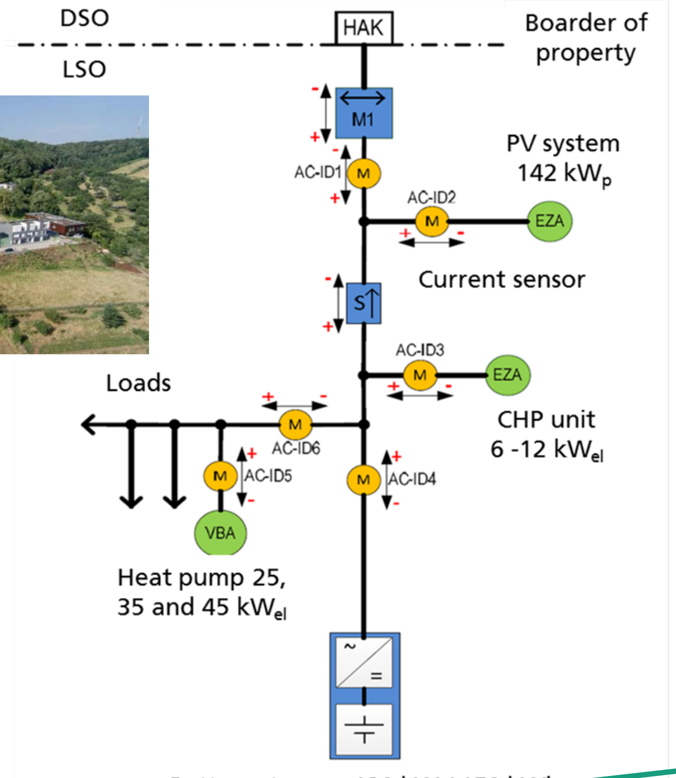
- Problems with air conditioning → To high temperatures in operation room → Shut-down of CHP unit and battery inverter
- Necessary maintenance interval of CHP unit in winter (!)
- End-users do not behave 100 % as predicted (!)

The role of battery storage towards highest shares of renewables

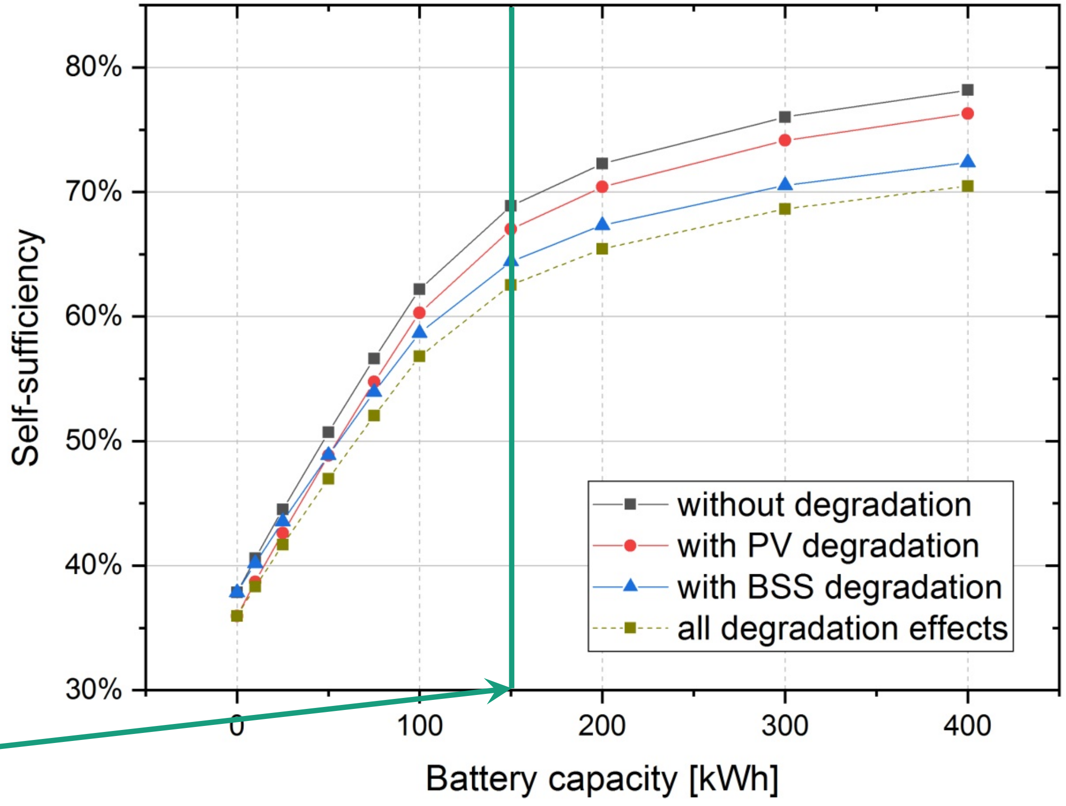
Active distribution grids – Example: Smart district “Weinsberg”

- Simulation based analyses: Influence of aging on effectiveness

System concept of district power supply



Reduction of self-sufficiency over time



Source: L. Millet et al.: Extensive analysis of photovoltaic battery self-consumption: Evaluation through an innovative district case-study; Applied Physics Reviews, 2019.

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The role of battery storage towards highest shares of renewables
Active distribution grids – Example: Smart district “Weinsberg”

- Simulation based analyses: Influence of aging on effectiveness

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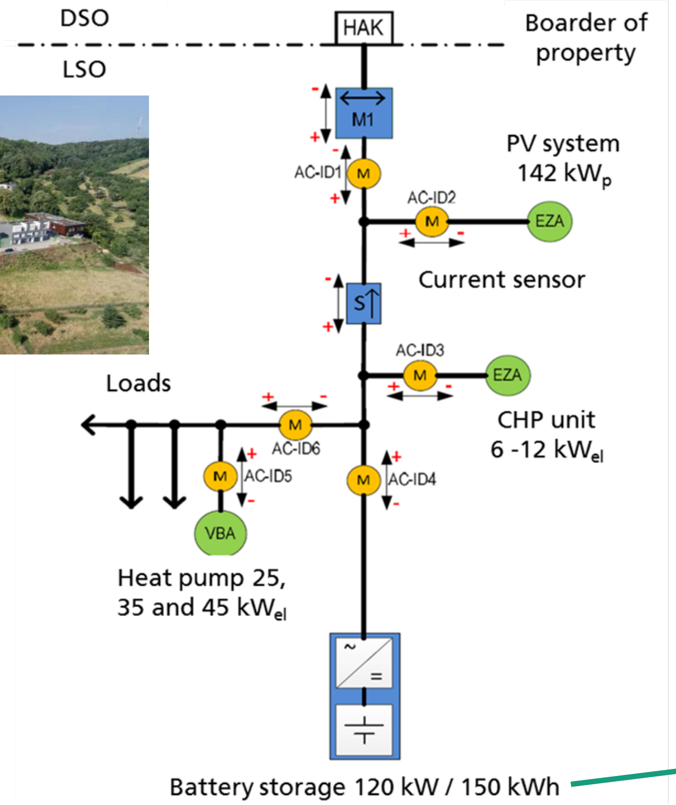
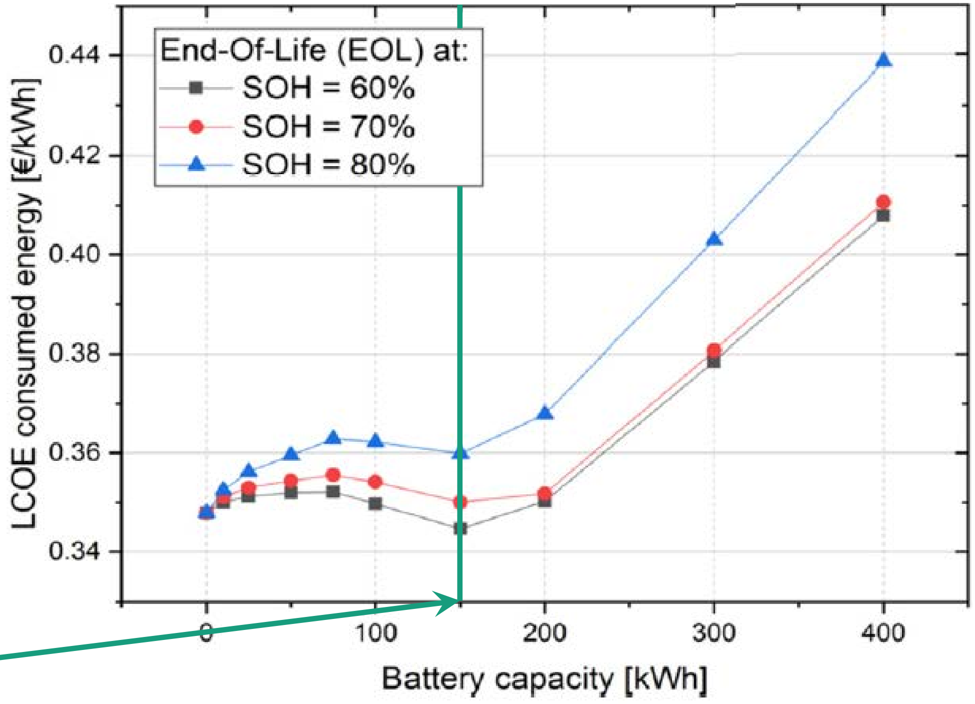


Levelized cost of consumed electrical energy for varying end-of-life criteria



Source: L. Millet et al.: Extensive analysis of photovoltaic battery self-consumption: Evaluation through an innovative district case-study; Applied Physics Reviews, 2019.

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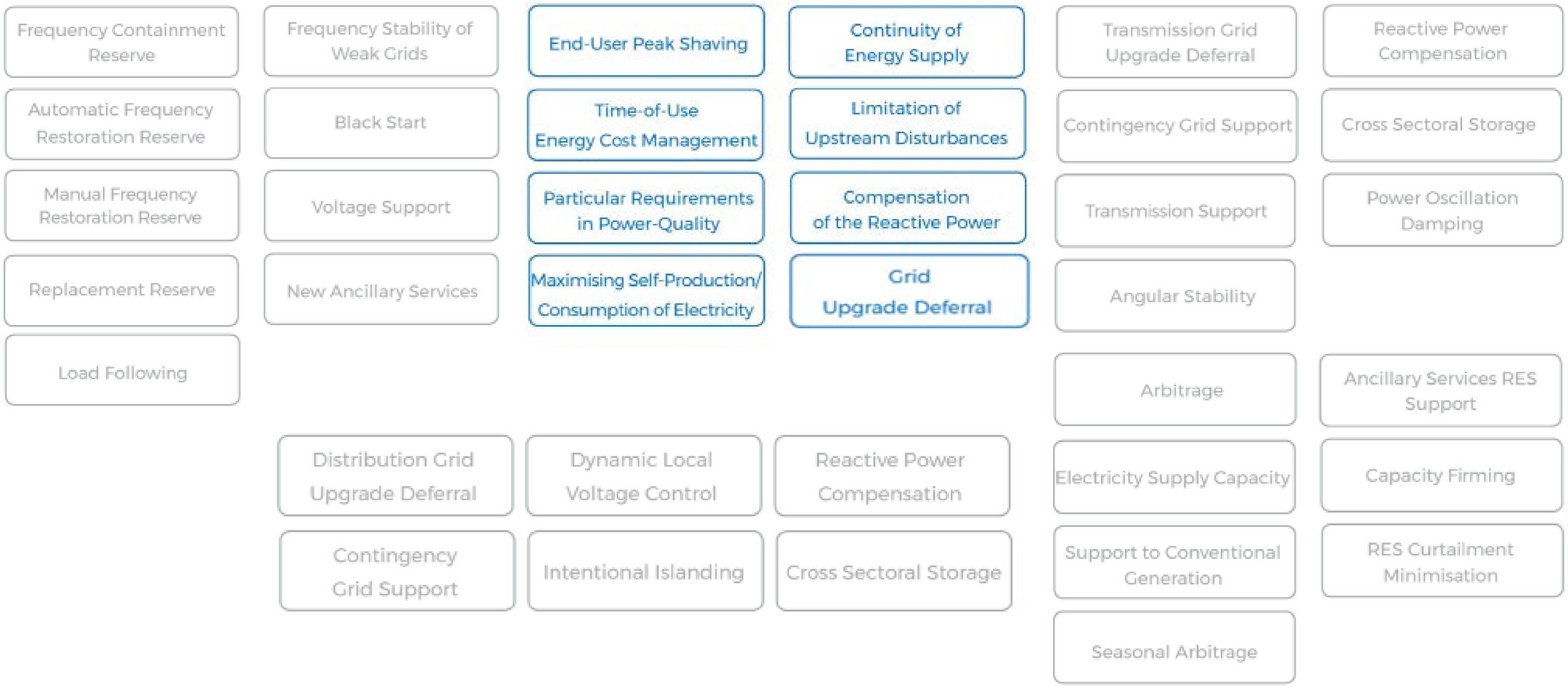
Commercial and industrial applications – Most important revenue streams

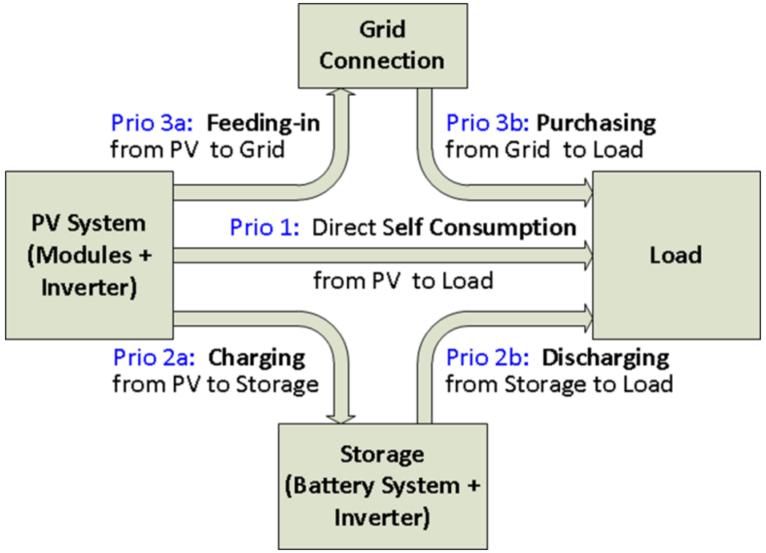


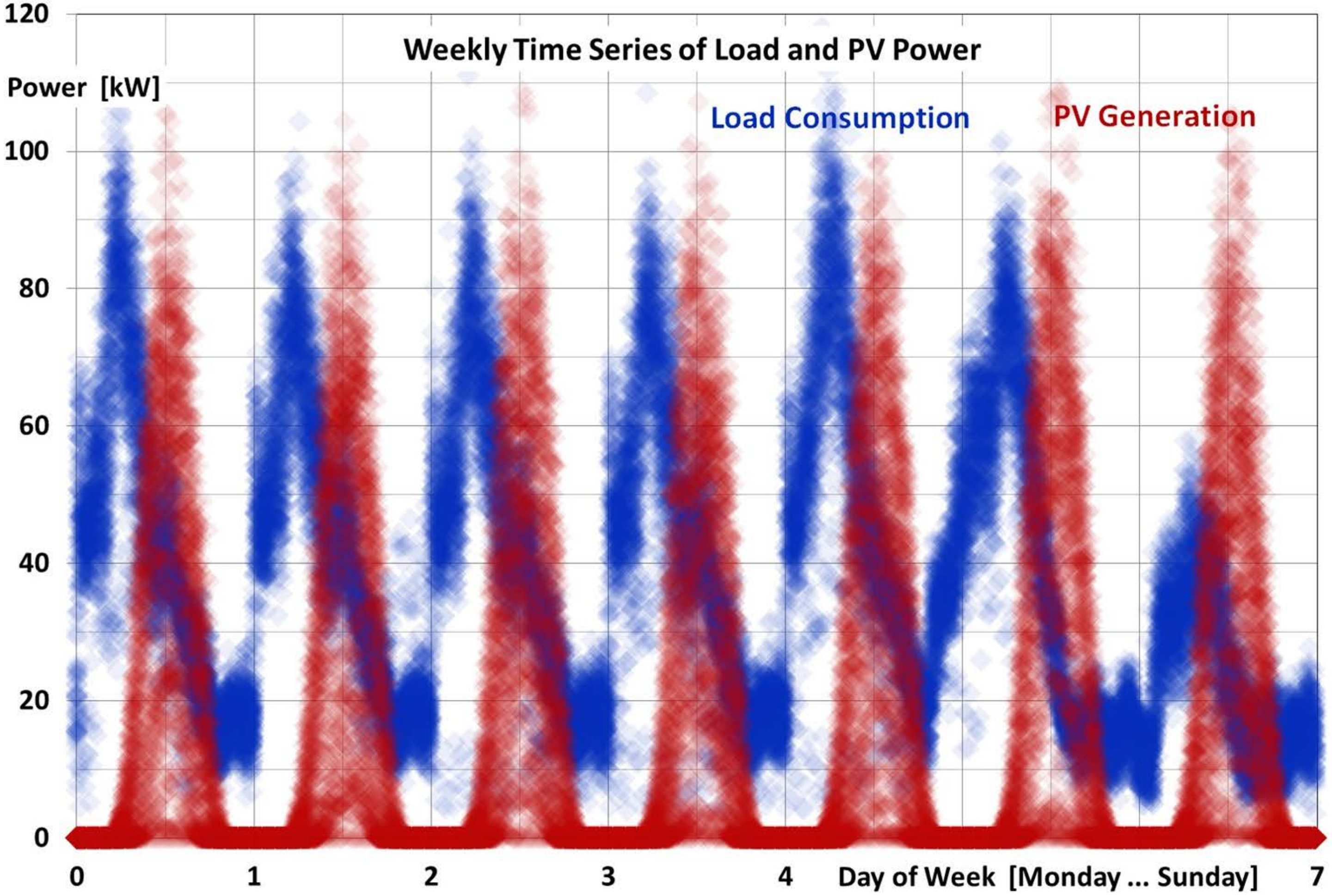
Source: EASE Energy Storage Applications Summary, Brussels, June 2020.

The role of battery storage towards highest shares of renewables
Commercial and industrial applications – Example: Bakery production line

Case study:
- Consumption: 335 MWh/a
- Max. power: 118 kW

PV reference system:
- Size: 150 kWp
- Production: 135 MWh





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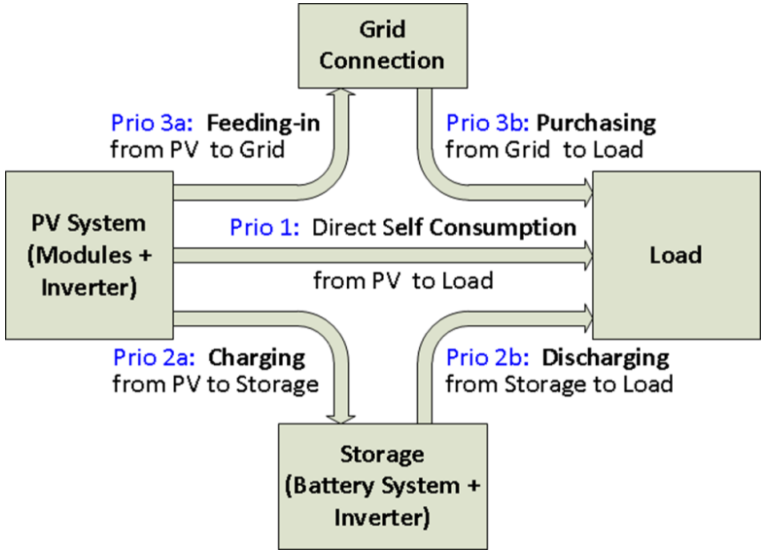
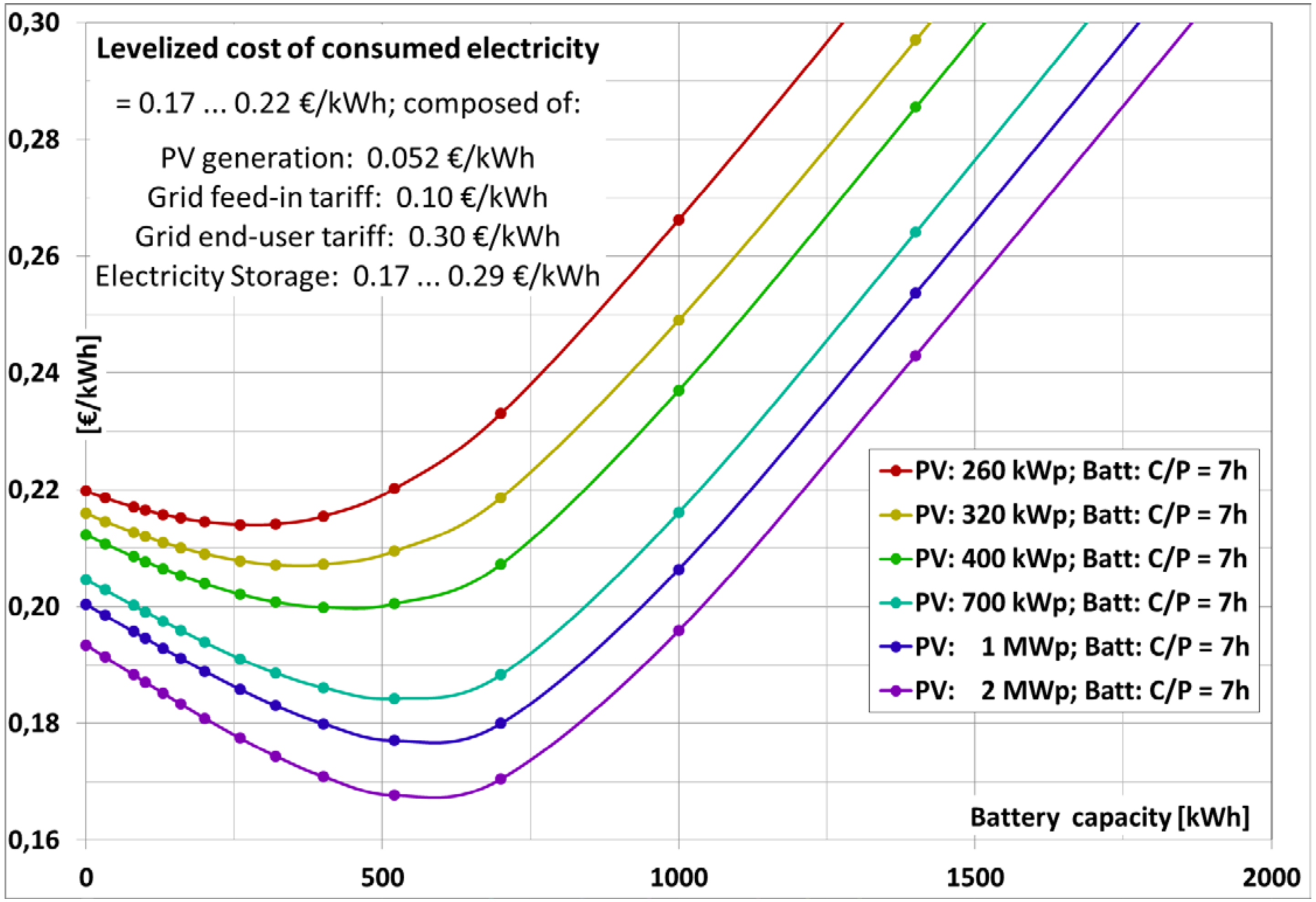
Commercial and industrial applications – Example: Bakery production line

Levelized cost of consumed electricity





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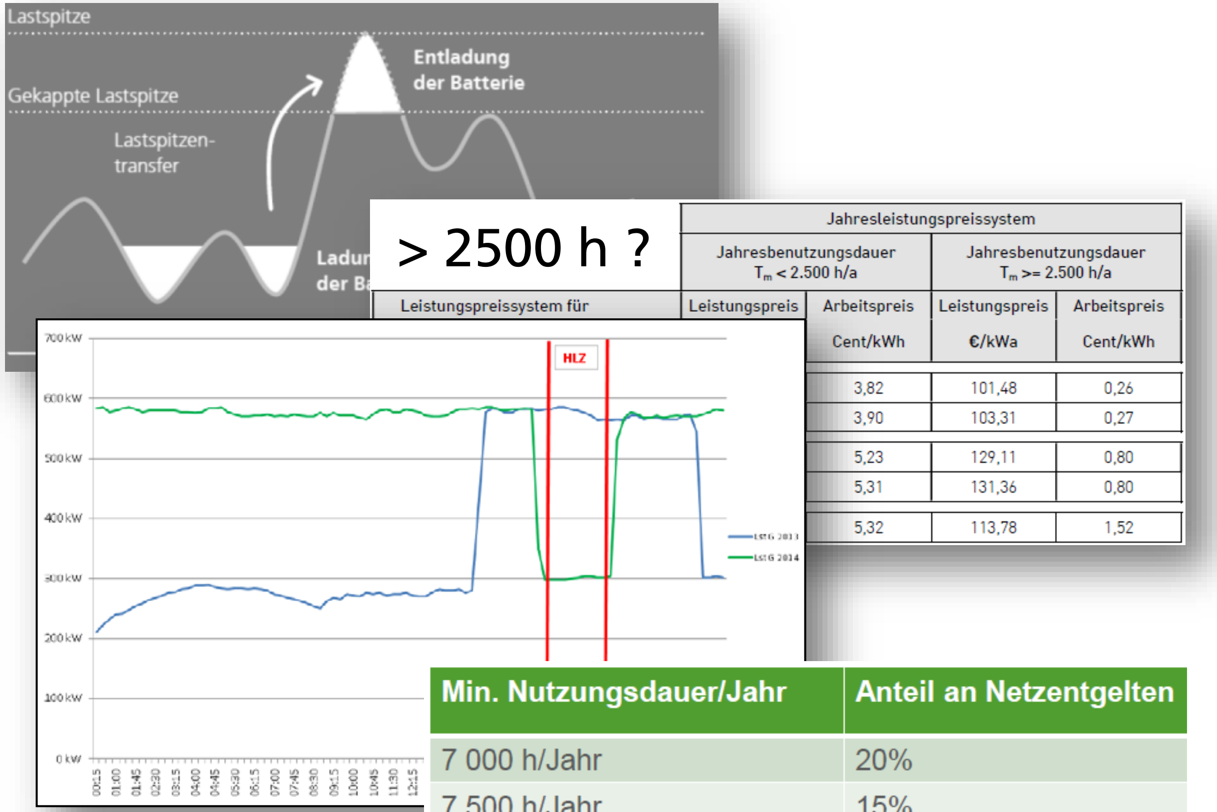
Commercial and industrial applications – Reduction of grid charges

- Goal: Reduction of demand / grid charges (Netzentgelte) (StromNEV §19) in Germany
- 4 Options:
  - Performance price: Shaving occasional peak loads in 15 minutes intervals
  - Performance price classification: Increase of full-load hours over 2500 h
  - Atypical grid usage: Reduction of power consumption during high load hours
  - Energy intensive consumer: > 10 GWh/a and min. 7000 full-load hours



Min. Nutzungsdauer/Jahr	Anteil an Netzentgelten
7 000 h/Jahr	20%
7 500 h/Jahr	15%
8 000 h/Jahr	10%

Sources:
- R. Schuster: Reduzierte Netzentgelte durch Batteriespeicher, ees Forum, München, 2019.
- Netzzugangsentgelte Strom, Preisblatt, bnNETZE GmbH, 2020.
- Faktenpapier Atypische Netznutzung, DIHK, 2015.

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The role of battery storage towards highest shares of renewables

Commercial and industrial applications – What's next ? → Revenue stacking

Battery storage:
- Increased PV self-consumption
- Peak shaving
- Backup power
- Flexible BEV / PHEV charging
- Grid services

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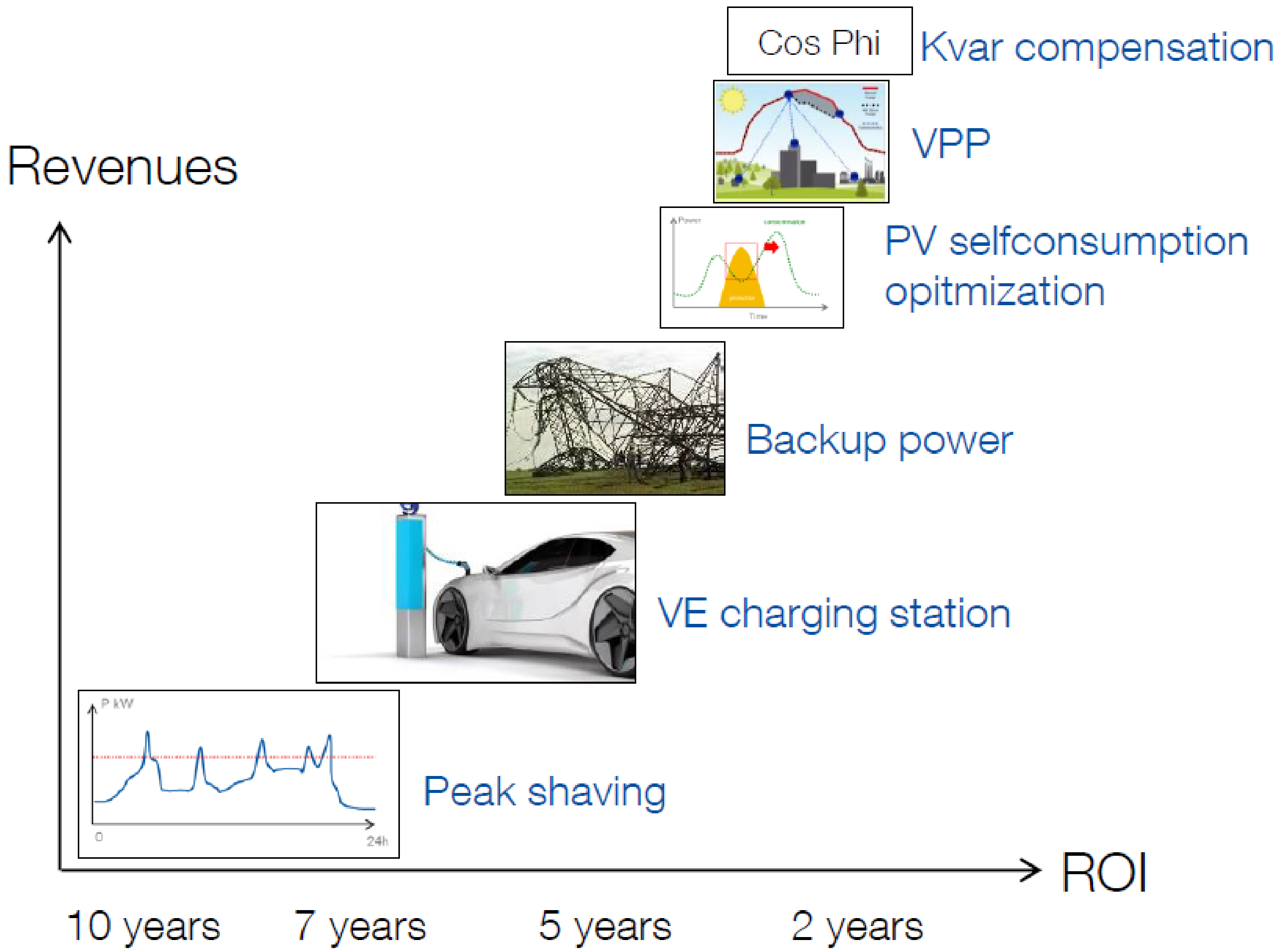
The role of battery storage towards highest shares of renewables
Commercial and industrial applications – What's next ? → Revenue stacking

- Storage technologies
  - Still potential for improvement of technical parameters
  - Still potential for cost reduction
  - But: Products are ready to use
- Regulatory framework
  - Is not adapted in many countries
  - Germany as an example: Storage is still not defined as a fourth element of the power supply
  - Result: "Complicated" structure of fees and taxes
  - Good news: There is progress



Source: C. Carpentier: How do Energy storage solutions help C&I customers to save Money? ees Forum, Munich, 2019.

Conclusions

- Large-scale system integration of fluctuating renewable energies require storage
  - Technically → Reliability of power supply
  - Economically → Business models in post feed-in tariff times
  - Accelerated market growth for stationary storage can be expected !
  - But: Regulatory framework is still lagging behind in many countries !
- Advanced battery technologies
  - Scalable from several kWh up to GWh
  - Provide services to various stakeholder groups: Behind-the-meter and front-of-the-meter
  - But: Lack of long-term field experiences
  - Appropriate quality assurance measures are key for risk mitigation

Thanks for your attention !!!

Dr. Matthias Vetter
Department "Electrical Energy Storage"

www.ise.fraunhofer.de

matthias.vetter@ise.fraunhofer.de

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