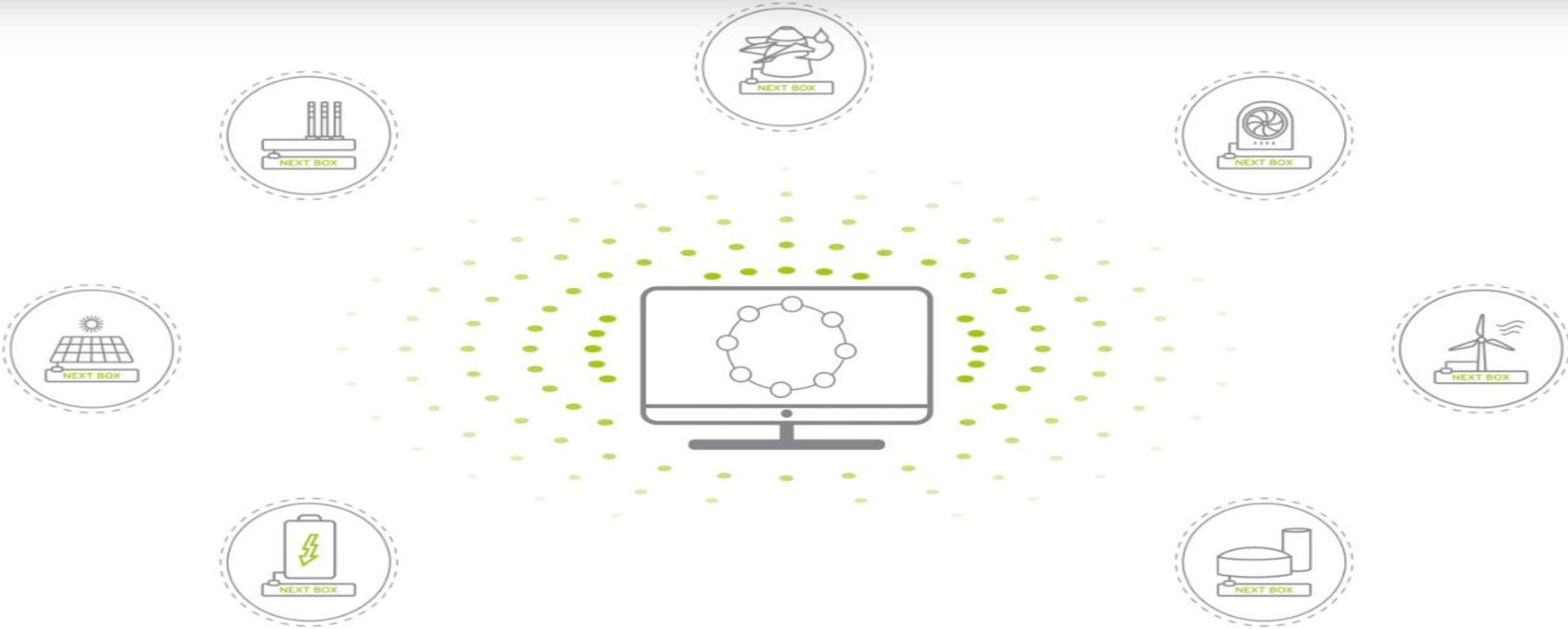

ECONOMIC EVALUATION OF ENERGY RESILIENCE IN A VIRTUAL POWER PLANT

Felipe Sabadini and Reinhard Madlener
RWTH Aachen School of Business and Economics

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PRESENTATION OUTLINE

DEFINITIONS

Resilience is “the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.”

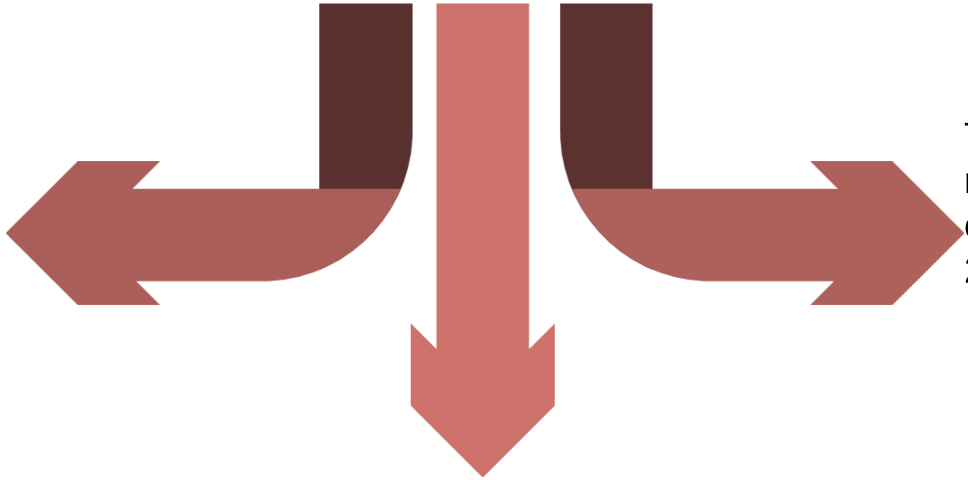
A **Virtual Power Plant** is a network of decentralized, with power generating units such as wind farms, solar parks, and Combined Heat and Power (CHP) units, as well as flexible power consumers and storage systems. The objective of a Virtual Power Plant is to optimize the grid by smartly distributing the power generated by the individual units during periods of peak load

The **value of lost load** (VoLL) is a monetary indicator expressing the costs associated with an interruption of electricity supply

1. MOTIVATION

In 2011, the German federal government changed the national energy policy radically

Shutdown of 8 existing nuclear power plants, decommissioning of the remaining 9 until 2022.

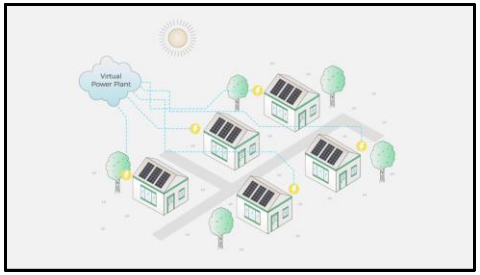


To reach a 60% share of renewables in gross final energy consumption until 2050

The increasing penetration of distributed energy resources (DER) reshapes the grid design deeply

Transmission congestion, voltage, and frequency instabilities

1. MOTIVATION



One element of this new grid structure is the virtual power plant (VPP)

- Combines a variety of DER and operates them as a unified resource on the energy markets
- Individual DER will benefit from VPP market intelligence to optimize their position and maximize revenue opportunities
- Can optimize the entire system, and deliver much greater value, without the need for large capital investments in infrastructure and operate with renewable sources

2. RESEARCH QUESTION

This work focuses on a household operation through a VPP that partially employ solar photovoltaics (PV) and battery energy storage systems (BESS) in its portfolio

What is the economic value of energy resilience?

- Does the resilience interfere in the final project's profit?
- Tries to deliver another way to do an economic assessment of VPP
- Takes the VoLL (Value of Lost Load) and applies it to real-world situations as an input information investment

3. METHODOLOGY

- Data / Exemplary case: Generation and consumption for a 3-person household in the city of Stuttgart, Germany

- The profitability calculations of the various investment options follow the approach proposed in Johann and Madlener (2014); the evaluation is based on the NPV criterion given by:

$$NPV = -I_0 + \sum_{t=0}^{T} \frac{CF_t}{(1+i)^t}$$

- The Net Present Value (NPV) is considered the theoretically most reliable tool since it correctly measures shareholder value creation

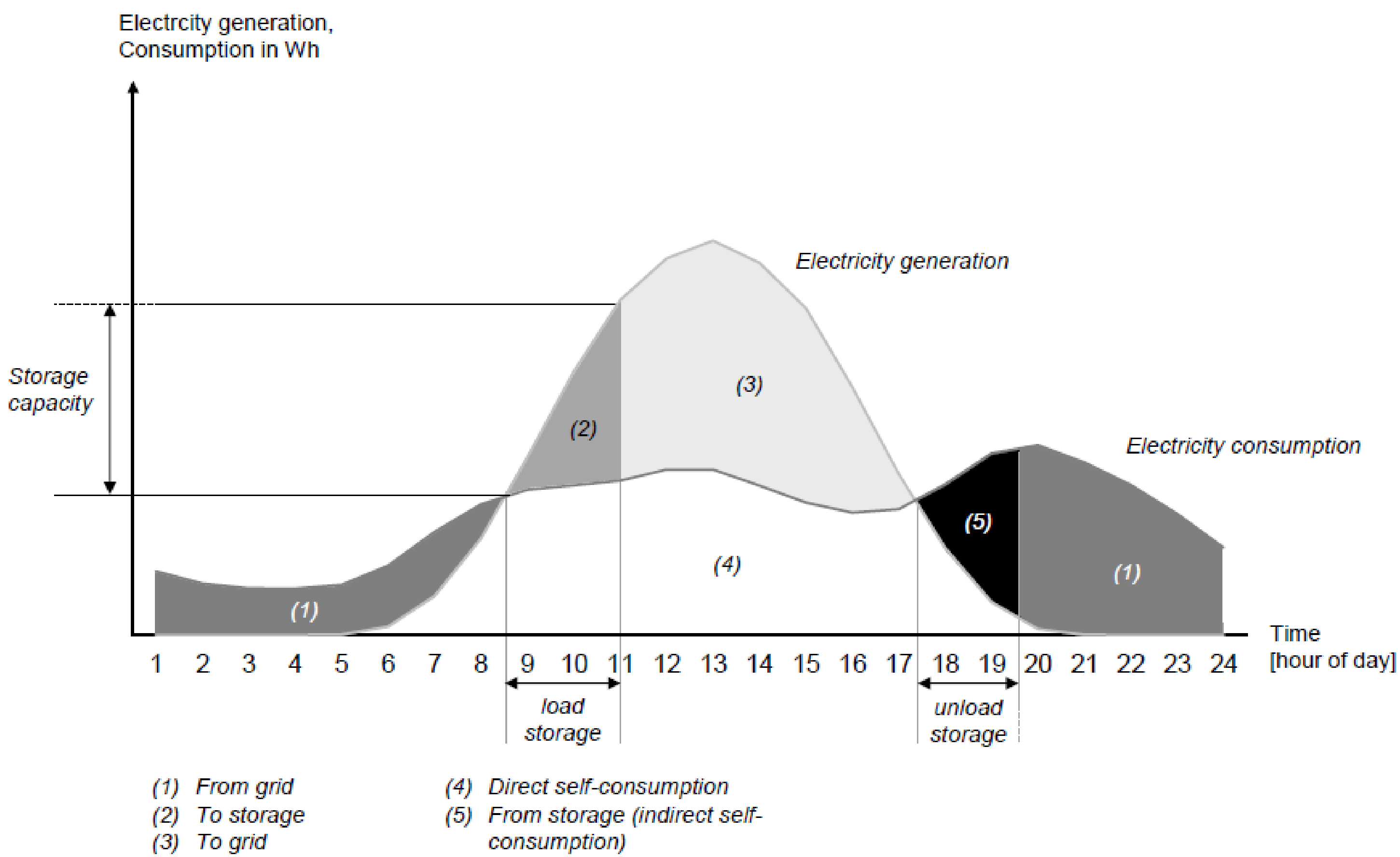
- It is a well-known method for valuing an investment project and is determined by calculating the costs (neg. cash flows) and benefits (pos. cash flows) for each period of investment and discount-ting its future value

3. METHODOLOGY

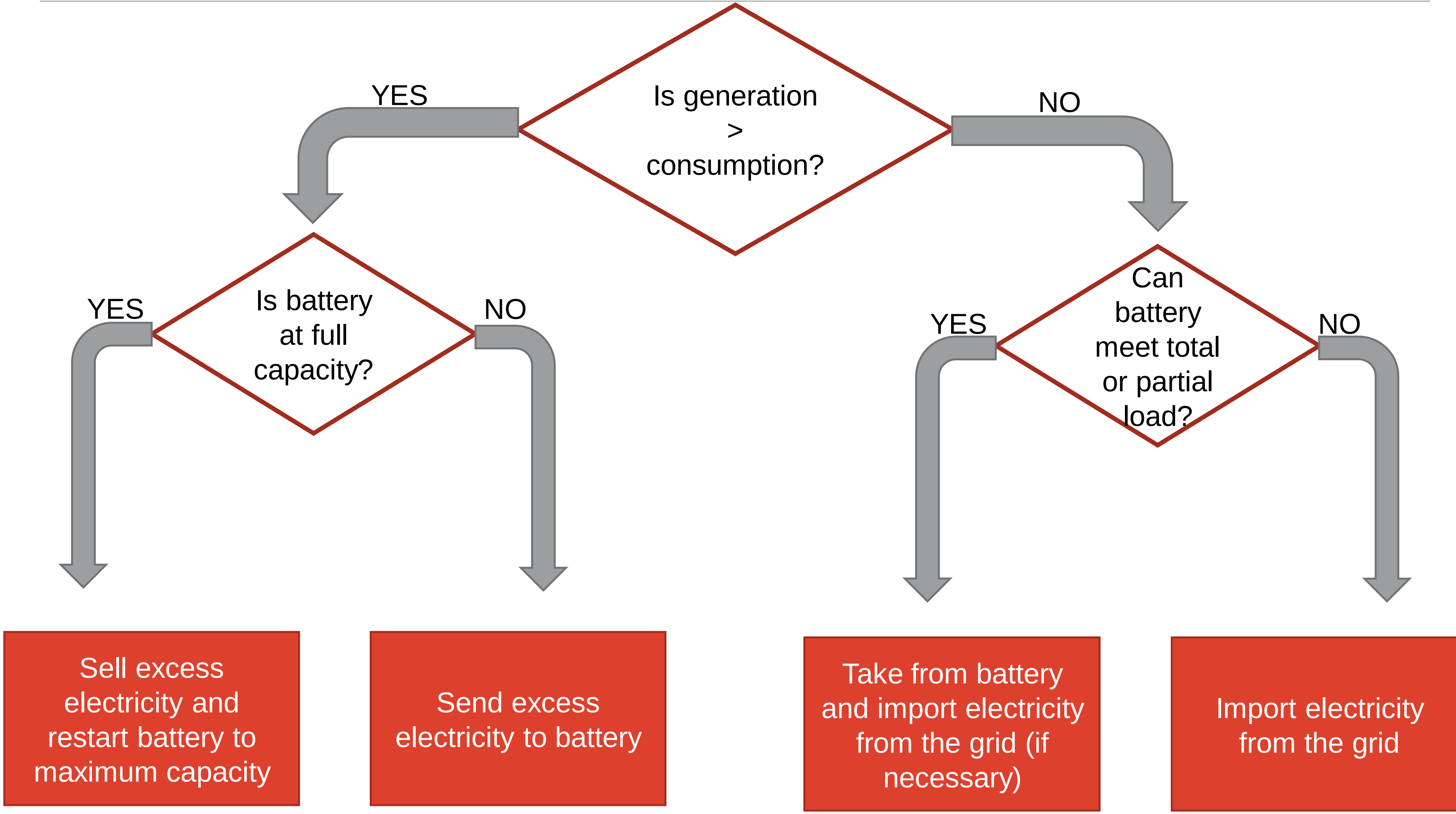
- The approach of the first scenario is to find the economic return of households equipped with PV panels and Battery Energy Storage Systems (BESS) connected to the grid.

- In the second scenario, where a blackout occurs, it assesses how households not affected by grid disruption can profit from surviving the blackout, using energy generation from their own.

■ LOGIC OF PV AND BATTERY



3. METHODOLOGY



3. METHODOLOGY

- Johann and Madlener (2014) showed that it is preferable to consume as much self-produced PV electricity as possible, irrespective of the location and household size

- An energy storage device enables the share of self-consumption to be increased (by up to 20%)

- Location matters greatly and payback time is reduced in southern Germany

- With increasing installed capacity the share of self-consumption declines, while the NPV rises, since with more self-generated electricity less costly power from the grid is needed

3. METHODOLOGY

- In Vonsien and Madlener (2018) study is proved that the variance of the battery size shows a smaller impact on the battery lifetime.

- On the one hand, a smaller battery reduces the option of higher self-consumption, whereas, on the other hand, an excessively large battery has not only higher costs but is also oversized with respect to the limited load demand of an average German household

- Pooling concept is profitable, although a 12KWh battery is required (V2G)

3. METHODOLOGY

- By finding an economic value for the resilience this study increment discussion about renewable energy and its structures, showing that a system can be more viable than before

Category	Price	Source
PV cost	1000–1400 €/kWp	Fraunhofer (2019)
Battery cost	250–800 €/kWh	(Cristoph et al.)
Inverter	0.17 EUR/Wp	Fraunhofer (2019) & Annual reports of SMA AG
Operations and maintenance cost PV	0.17 EUR/Wp	(Peters et al. 2011)
Engineering, procurement and construction	8% of PV system cost	(Peters et al. 2011)
Annual interest Discount rate	3.5%	(Hoppmann et al. 2014)
Project lifetime	12 years	Up to battery lifetime
Buying electricity tariff	0.2987 €/kWp	Statista
Savings from using own electricity	0.2987 €/kWp	Statista
Selling electricity remuneration	0.4489 €/kWp	EEG (2012)
Value of Lost Load	16€/hour	References in Table 1

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- Five days and hourly slots were randomly selected
- The system could meet its requirements in a total of 37 h/year

REVENUE COMES FROM

The **self-consumed electricity**, multiplied with the retail electricity price and

The **electricity sold**, multiplied with the wholesale electricity price

The gains are taken from **recovered Value of Lost Load** in a resilience scenario

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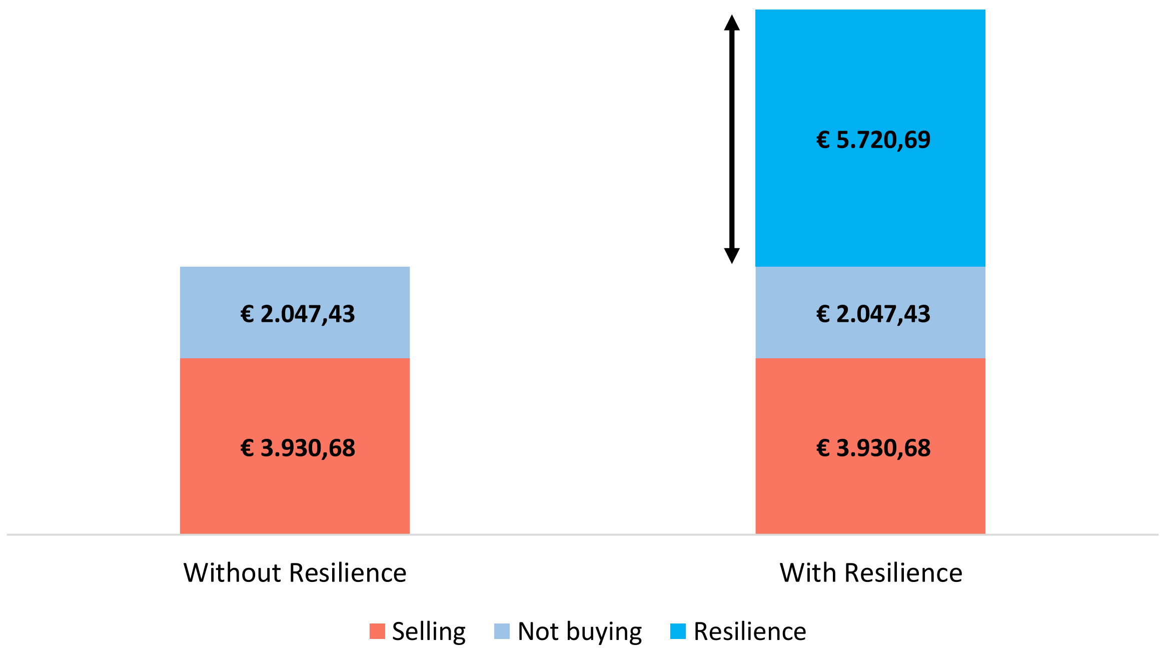
4. RESULTS

- When the scenario does not include resiliency the NPV is € 5,978 and the internal rate of return (IRR) is 5.3%
- These results are compatible with previous analysis in the German market
- When the scenario includes the resiliency approach we can see an increase in the economic indicators. The NPV rises to € 11,698 and the internal rate of return (IRR) rises to 9.8%



Our research question…

01 …does resiliency affect the final project's profit?

Yes, positively (increasing both NPV and IRR)

02 …leads to approach that tries to deliver a novel way of economic assessment to VPP

With VPP optimization a household can be included in the German energy market

03 …takes the VoLL (Value of Lost Load) and applies it to real-world situations as a kind of investment in additional input information

The VoLL was a strategic input to identify another source of revenue

5. CONCLUSION (work in progress; cont.)

1. The work in this paper presented a novel method for incorporating the value of resilience provided by solar PV and BESS into a techno-economic model

2. The results show that accounting for the value of resilience in electricity supply has a significant impact on the financial project of PV and BESS

3. We could also measure the costs and benefits that a household would have if decided to participate in the energy market operating with a VPP

4. In the future, with decreasing costs of PV and BESS, and increasing dependency of renewable energy sources to generate energy, more discussions of grid resilience will appear

Contact

Institute for Future Energy Consumer Needs and Behavior (FCN
E.ON Energy Research Center
Mathieustraße 10
52074 Aachen, Germany

Felipe Sabadini
T +49 241 80 49 820
Felipe.Sabadini@eonerc.rwth-aachen.de

http://www.eonerc.rwth-aachen.de/FCN

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