The value of solar forecasting

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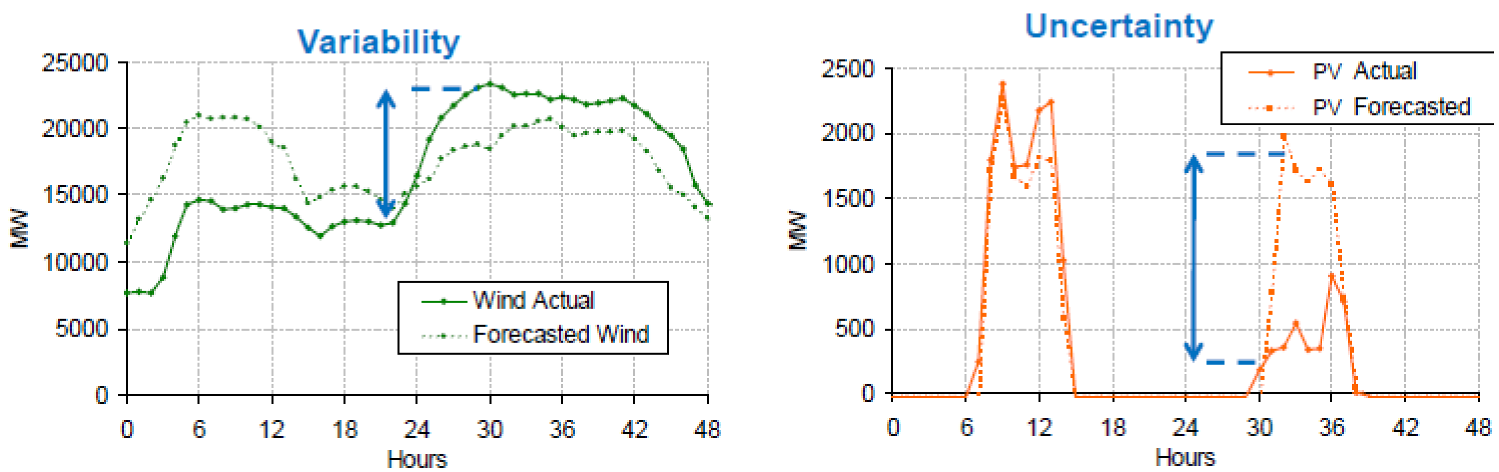
Motivation for this session

Why solar forecasting

- Variability vs Uncertainty (Ela et al., 2013)



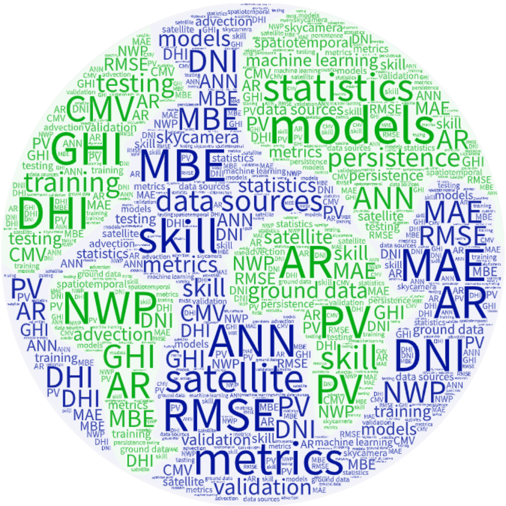
- High PV-penetration study in Arizona (USA)
  - Uncertainty is responsible for **2/3 of PV-driven imbalance**

**Figure from original reference*

Motivation for this talk

Why solar forecasting value

- 2015-2020: PhD on solar forecasting
  - Read about tons of models, metrics, data sources, etc.



- But what about **applications**? And **added value**?
  - Scattered references and barely discussed in literature reviews

**Figure* created in wordart.com

A range of applications
The smart grid ecosystem

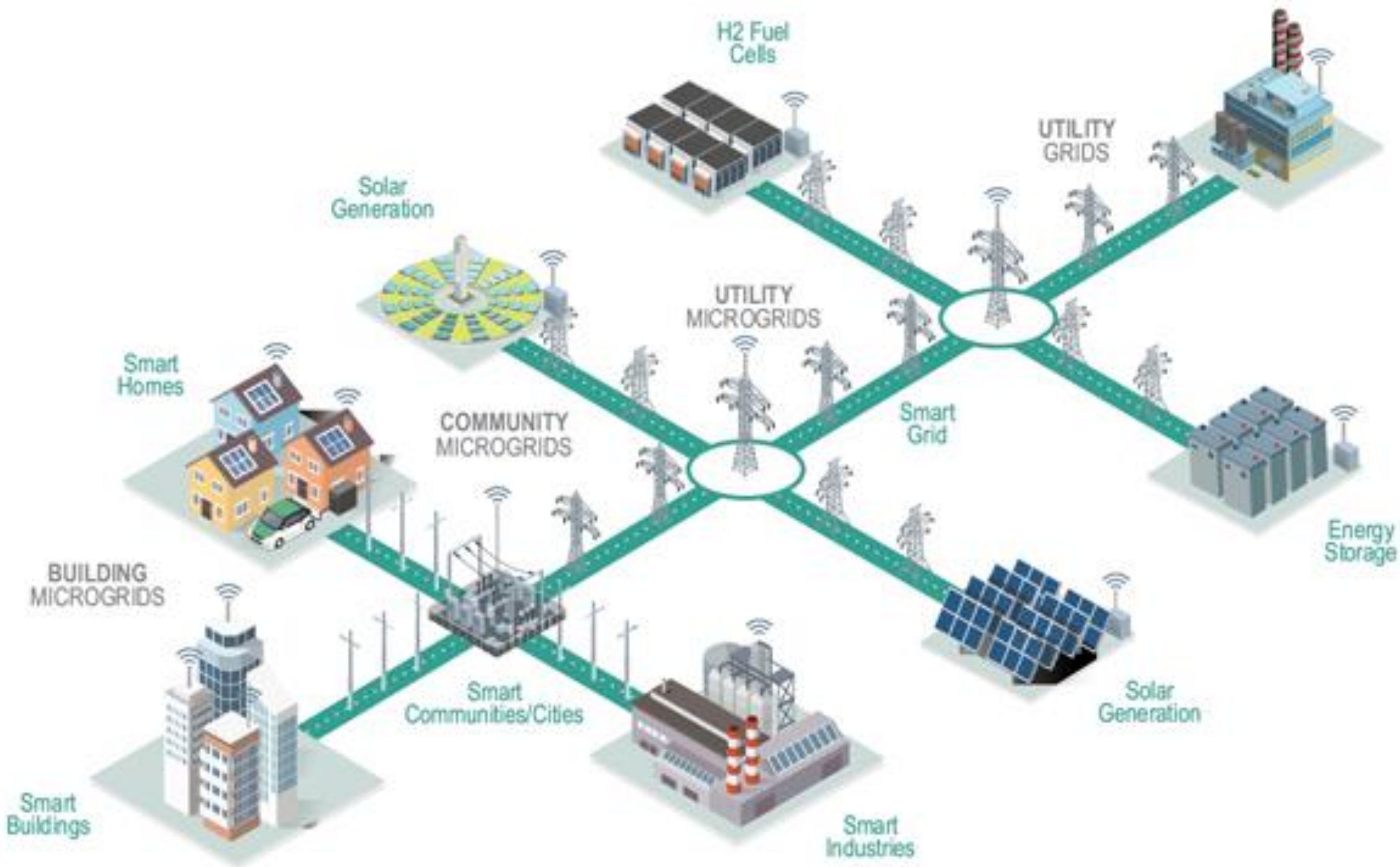


*Figure from Smart Energy Marketplace

Solar plant operators

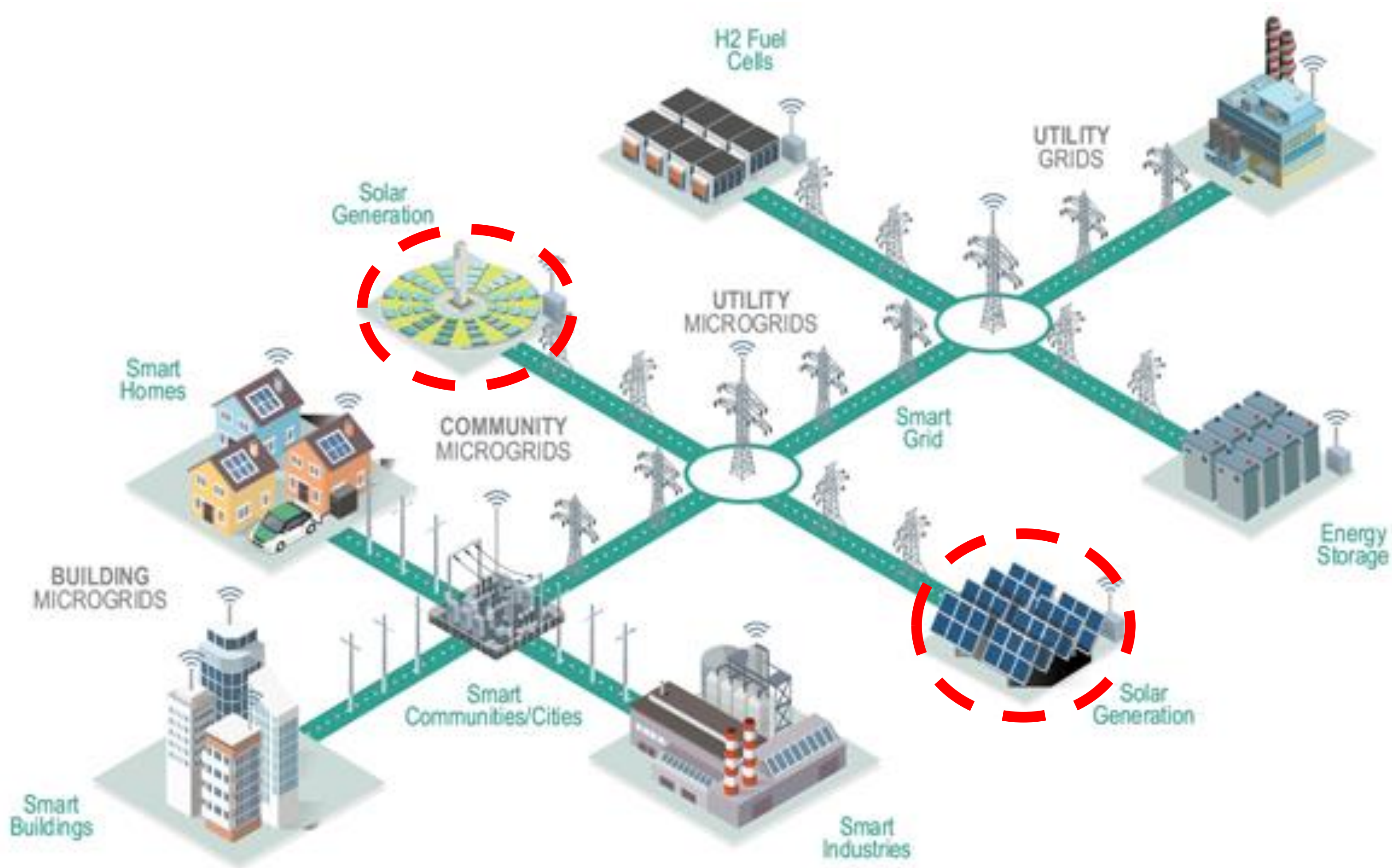
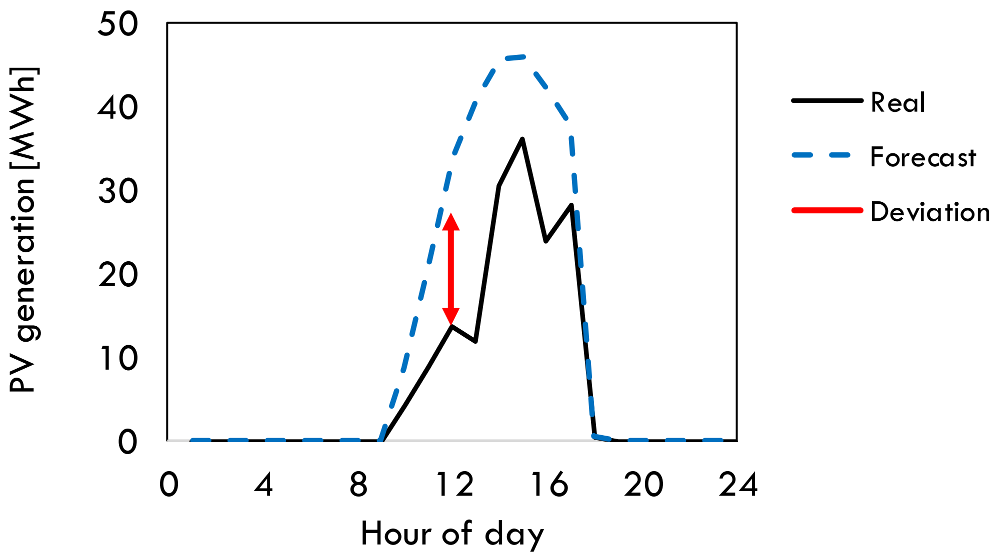


**Figure from Smart Energy Marketplace*

Market bidding

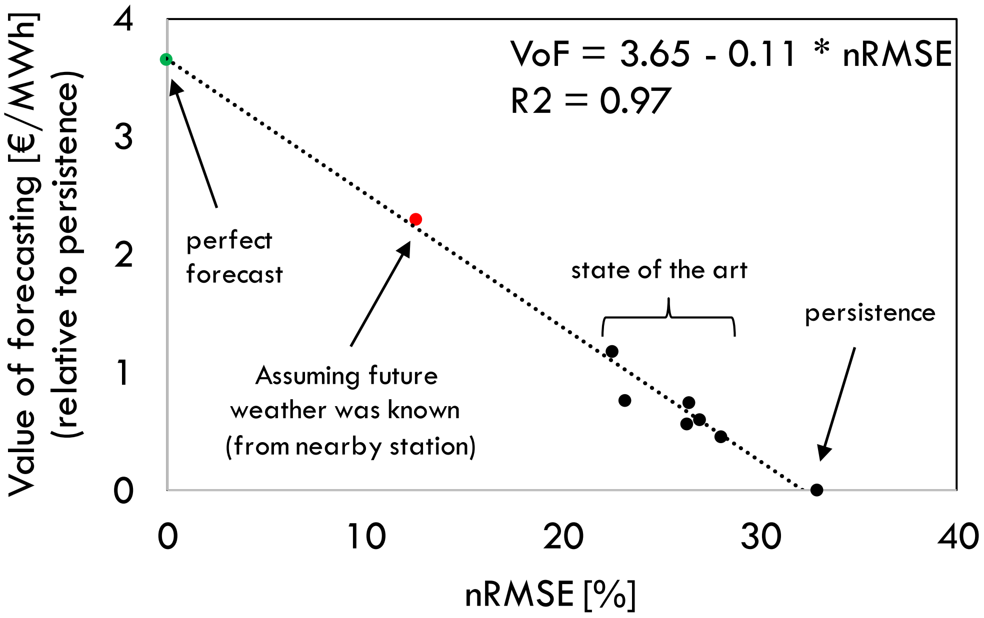
Utility-scale PV, CPV and CSP

- Plant operators forecast their generation + bid selling price
  - Penalties applied to forecast deviations
  - Forecast horizon & penalty mechanism depend on given market



Market bidding
A PV example

- As an example, (Antonanzas et al., 2017)
  - 1.86 MW PV plant in Spain



<u>Forecast can increase margins by up to 3.65 €/MWh</u>

**Figure adapted from original reference*

Grid operators

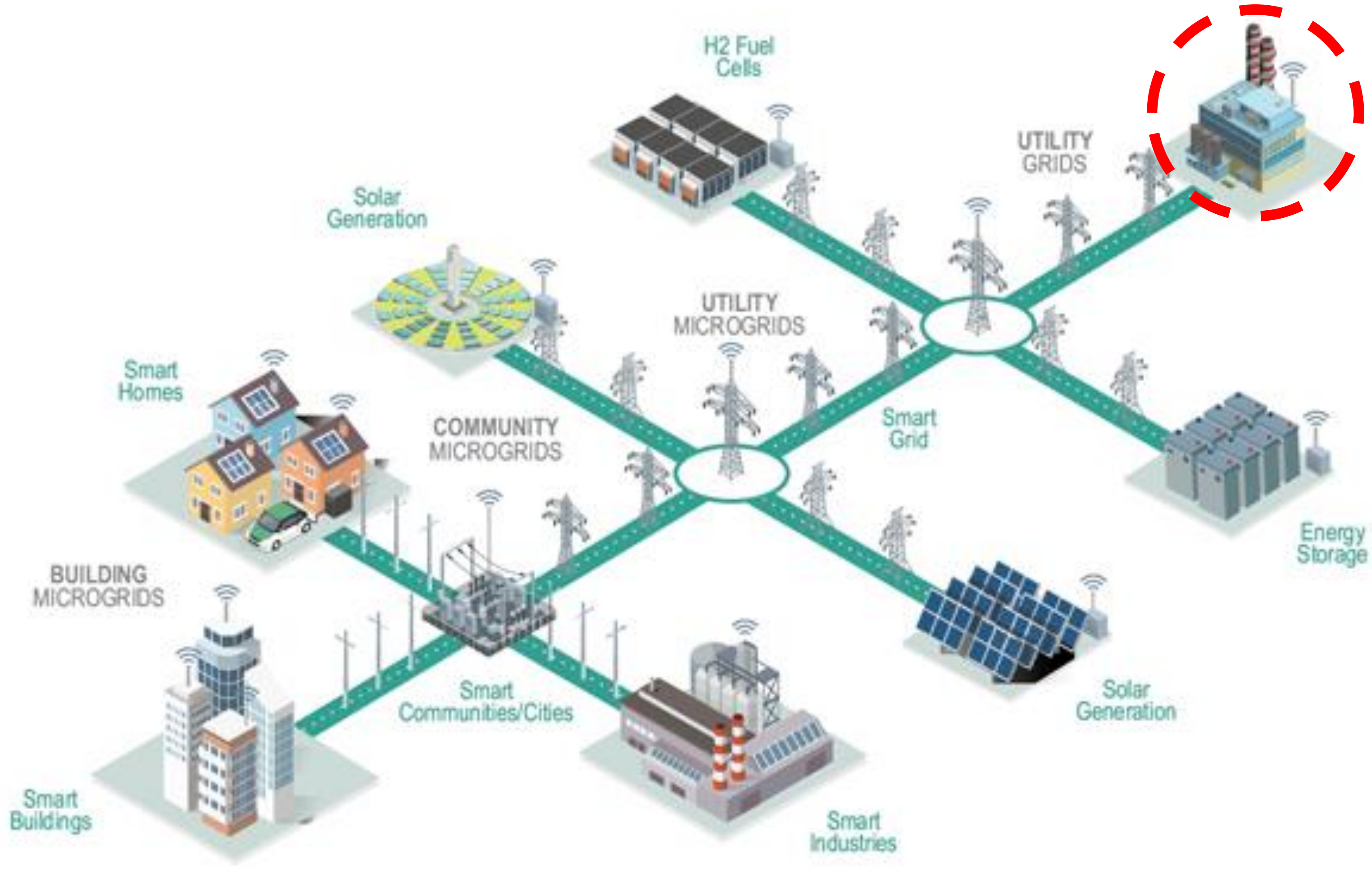
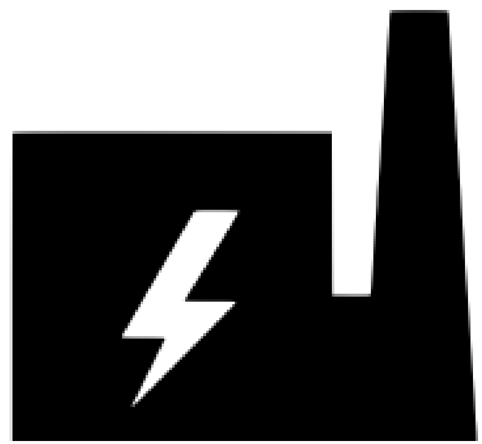


*Figure from Smart Energy Marketplace

Unit commitment and dispatch

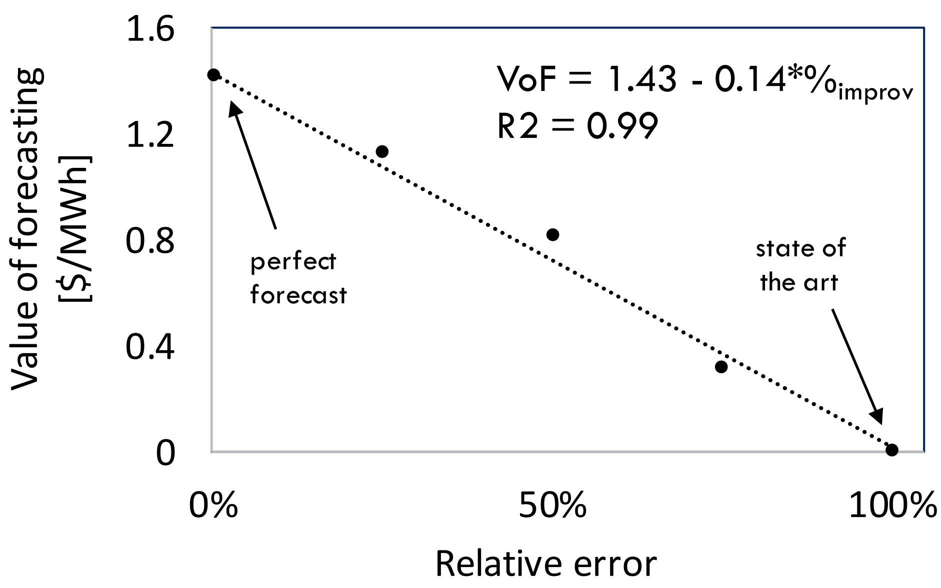
Power grids of various sizes

- Grid operators must deal with solar uncertainty
  - To do so they use:
    - ramping of operating generators (↓efficiency)
    - dispatch operating reserves (↑costs)
    - curtailment (↑costs)



Unit commitment and dispatch
A system operator example

- As an example, (Martinez-Anido et al., 2016)
  - 100+ TWh/y grid in USA (**18% PV**, biomass, coal, gas, hydro, nuclear)



<u>Forecast can reduce costs by 1.43 $/MWh</u>

**Figure adapted from original reference*

RENEWABLE ENERGY WORLD

Grab the low-hanging fruit: use solar forecasting before storage to stabilize the grid
Steven E. Letendre, October 2014

Other applications

- Solar plant operators
  - Storage & curtailment scheduling for ramp-rate compliance (Cires et al., 2019)
  - Thermal control of CSP plants (Nouri et al., 2020)
- Grid operation
  - Coping with extreme events, e.g. solar eclipse (Killinger et al., 2016)
- Prosumer
  - Load scheduling to ↑self-consumption (Masa-Bote et al., 2014)
  - Storage scheduling to ↑self-consumption (Moshövel et al., 2016)

Solar Eclipse
A few numbers

2015
2 hours
(38 GWp)

~ -20 GWh

14 GW dip

25 GW surge

700 MW/min

energytransition.org (2015)

Final remarks

- Broad range of applications (techno-economic benefit)
  - difficult to compare results due to ≠ contexts and regulations
- Synergies between forecasting and generator/storage/load scheduling
- ↑behind-the-meter PV: focus shifts to net-load (Haupt et al., 2017)
- Cost of forecasting should be considered, e.g. (Cires et al., 2019)

Final remarks

Thanks for listening!

Questions? Remarks?

<u>I have some extra slides just in case ☺</u>

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Extra slides

(Con/Pro)sumers

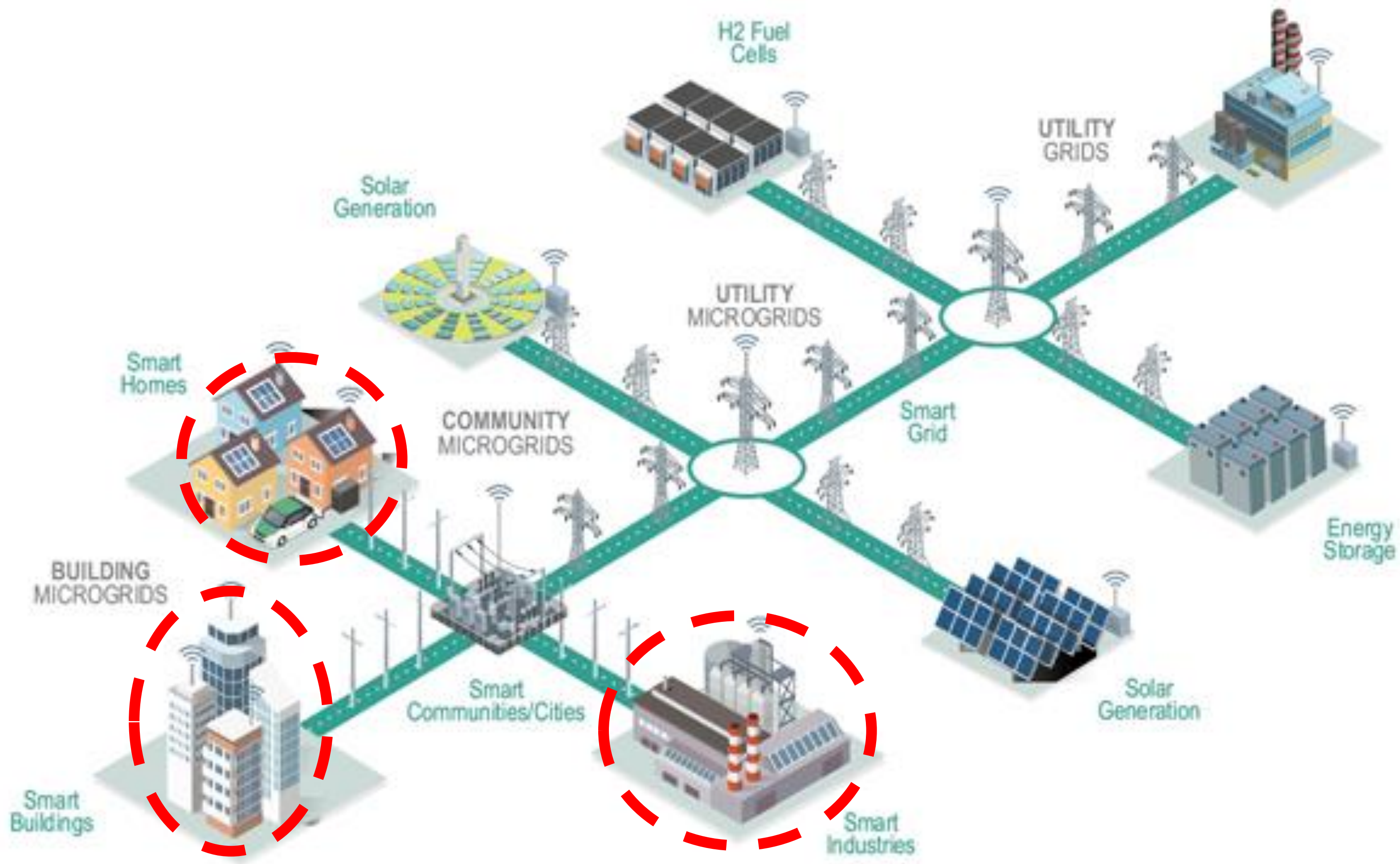
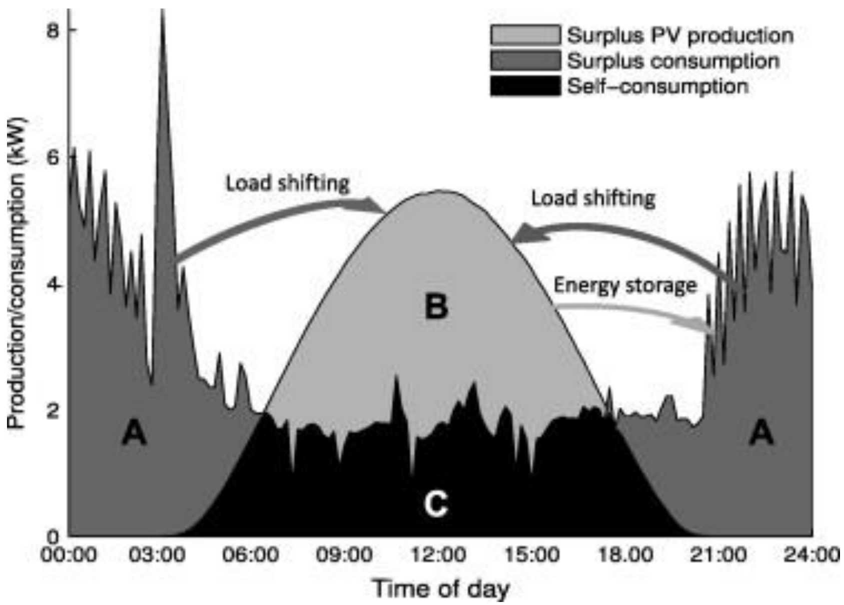


**Figure from Smart Energy Marketplace*

Self-consumption
And some "spices"

- Storage and demand side management
  - Maximizing self-consumption and/or complying with feed-in limits
  - coordination based on load and PV forecasts



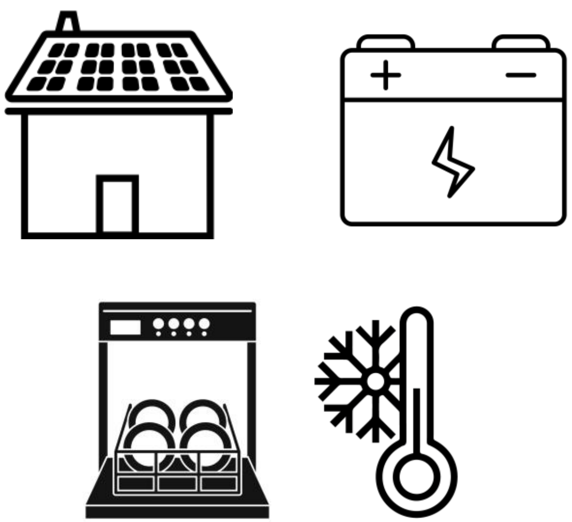
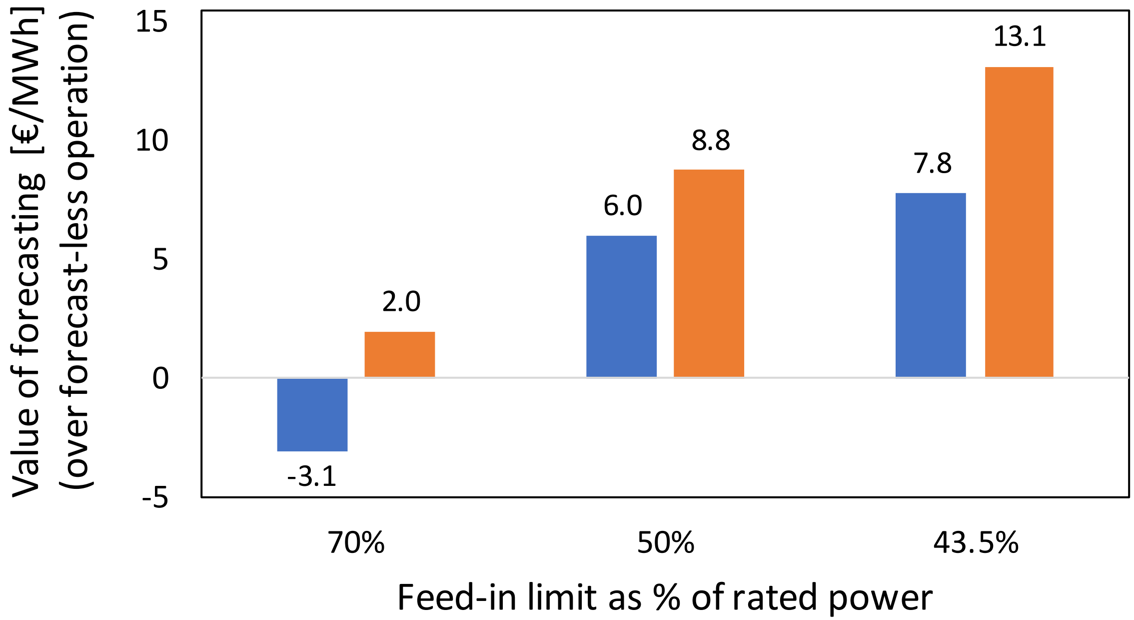


*Figure from (Luthander et al., 2015)

Storage scheduling
A prosumer example

- As an example, (Moshövel et al., 2016)
  - Household in Germany, PV + storage with feed-in limit



<u>Forecast can reduce costs by up to 2-13 €/MWh</u>

**Figure created based on data from original reference*

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References

References (1/2)
Alphabetical order

- (Antonanzas et al., 2017), The value of solar forecasting for photovoltaics in the Spanish electricity market, Solar Energy
- (Cires et al., 2019), The potential of forecasting in reducing the LCOE in PV plants under ramp-rate restrictions, Energy
- (Ela et al., 2013), Impacts of variability and uncertainty in solar photovoltaic generation at multiple timescales, NREL Report
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- (Letendre, 2014), Grab the low-hanging fruit: use solar forecasting before storage to stabilize the grid, Renewable Energy World

References (2/2)
Alphabetical order

- (Luthander et al., 2015), Photovoltaic self-consumption in buildings: A review, Applied Energy
- (Martinez-Anido et al., 2016), The value of day-ahead solar power forecasting improvement, Solar Energy
- (Masa-Bote et al., 2014), Improving photovoltaics grid integration through short time forecasting and self-consumption, Applied Energy
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