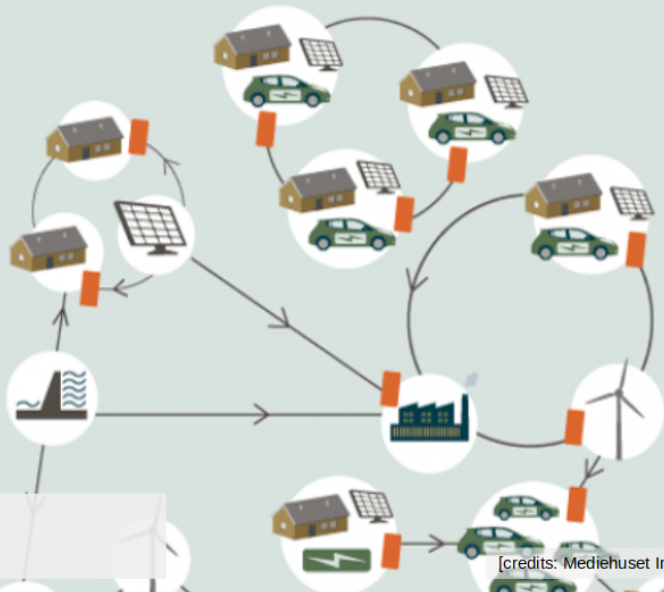


Module 1 – Fundamentals of Electricity Markets

1.4 Current challenges with renewables in electricity markets

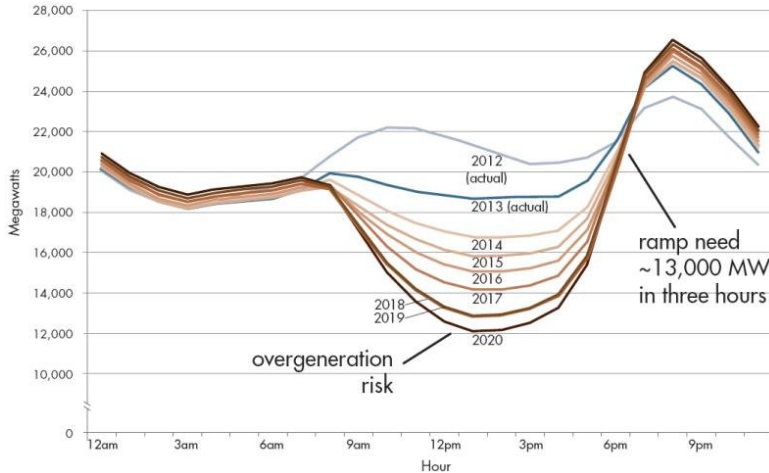


Pierre Pinson
Technical University of Denmark

[credits: Mediehuset Ingeniøren]

Renewable energy generation affects system operation

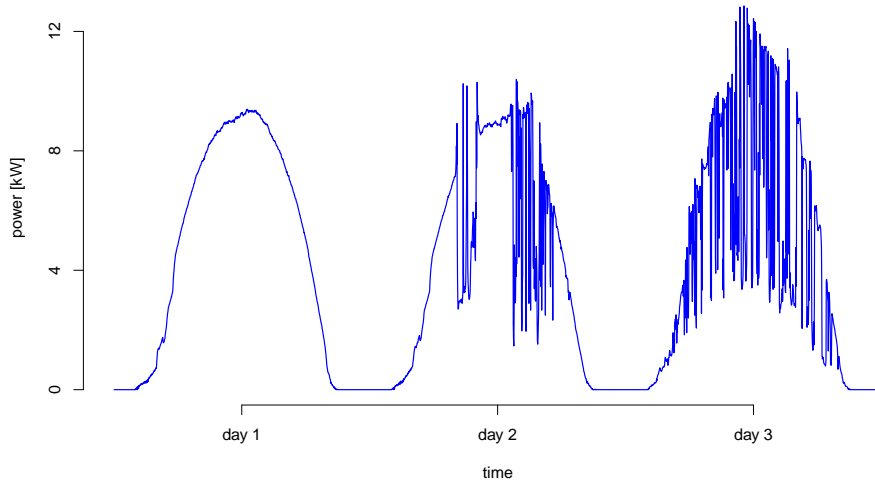
The example of the California ISO's "duck curve"



[source: California ISO. Fast Facts. What the duck curve tells us about managing a green grid.
www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf]

Renewable energy generation is variable and non-dispatchable

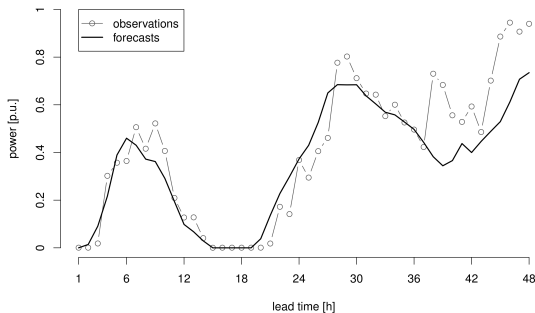
Example power generation from rooftop solar panels for 3 consecutive days in September 2018 in Australia



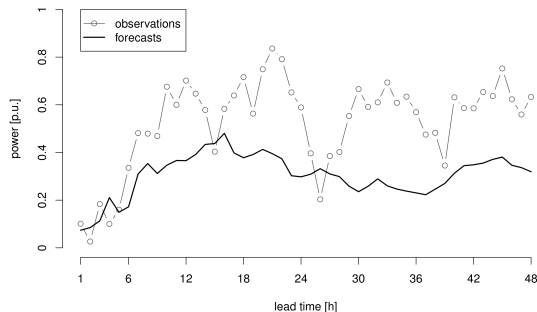
[data source: University of Queensland, St Lucia campus, Prentice building. solar.uq.edu.au]

Renewable energy generation has limited predictability

Example wind power forecasts for an onshore wind farm in Northern Jutland, Denmark



Forecast issued on 23 December 2003, 12:00
(a good one)

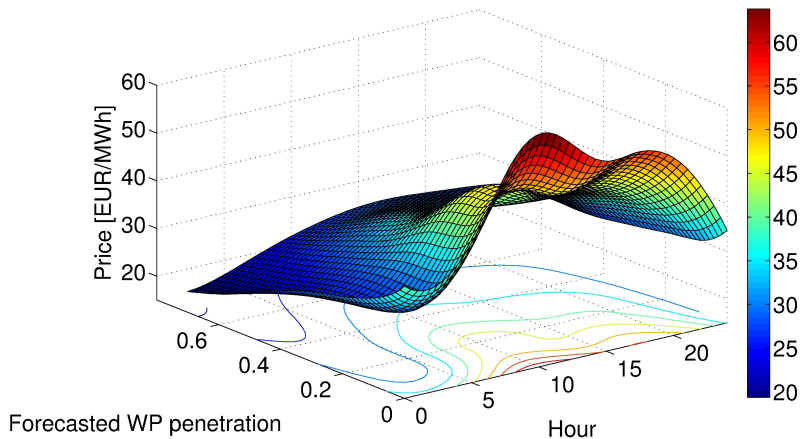


Forecast issued on 16 November 2001 (18:00)
(a not-so-good one)

The economic impact of renewable energy

Wind and solar energy induce a downward pressure on market prices

Example impact of forecasted wind power penetration on day-ahead prices (Nord Pool, Western Denmark, 2007)



[source: Jónsson T, Pinson P, Madsen H (2010). On the market impact of wind energy forecasts. *Energy Economics* 32: 313–320 ([pdf](#))]

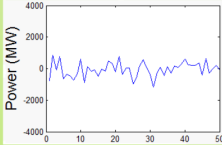
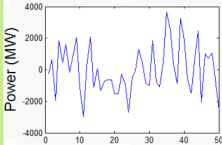



Flexibility is to be seen as the ability to adapt to variable and possibly unforeseen changes in operating conditions

Flexibility may originate from

- *generation units* e.g. gas-fired power plants
- the *power system* itself e.g. transmission, interconnections and storage
- the *demand side* e.g. demand response and its integration in electricity markets
- from an *integrated energy system* view, e.g. heat and gas energy systems



Example installation for demand response in the EcoGrid project experiments on Bornholm [source: ecogrid.dk]

	Before	Future
Imbalance	 Demand	 Demand + Wind
Source providers	 Traditional generators	 Traditional + wind
Cost Distribution	Demand	Demand + Wind 

- Should renewables (and demand) pay for the power fluctuations they induce?
- What is an optimal market design (and offering strategies) if renewables are to provide system services?

- **The narrative fallacy:**
Do we really believe we can offer renewables deterministically with lead times of 12-36 hours ahead?
- Why not adapting market designs to reveal and accommodate the true cost of renewables' uncertainty?

probabilistic
offers

evaluation
of offers

coupled day-
ahead and real-
time markets

Dispatch under uncertainty



Some open questions to consider

Some open questions to consider

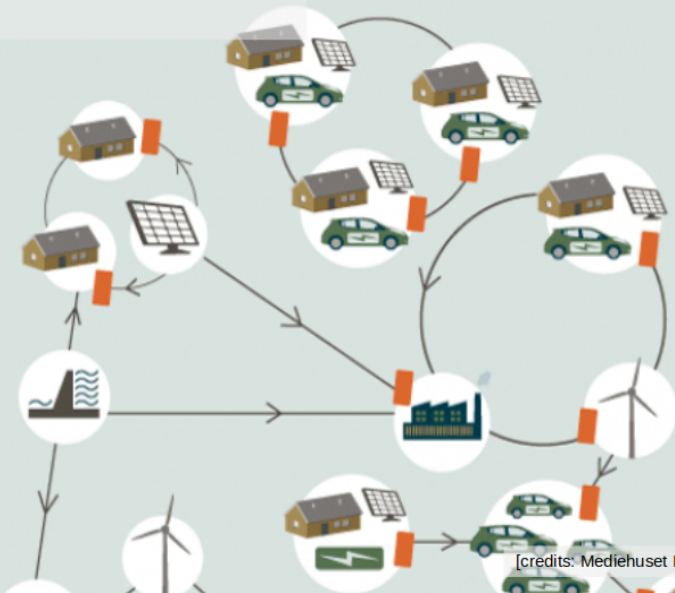
- ① Can we continuously integrate more and more renewable energy generation through existing electricity markets?

Some open questions to consider

- 1 Can we continuously integrate more and more renewable energy generation through existing electricity markets?
- 2 What would electricity markets look like for power systems with 100% renewable energy generation?

- 1 Can we continuously integrate more and more renewable energy generation through existing electricity markets?
- 2 What would electricity markets look like for power systems with 100% renewable energy generation?
- 3 What will be the impact of potential game-changers on the way e.g. storage and peer-to-peer electricity markets?

Use the self-assessment quizz to check your understanding!



[credits: Mediehuset Ingeniøren]