NREL
NATIONAL RENEWABLE ENERGY LABORATORY





Grid Services and Future System Values

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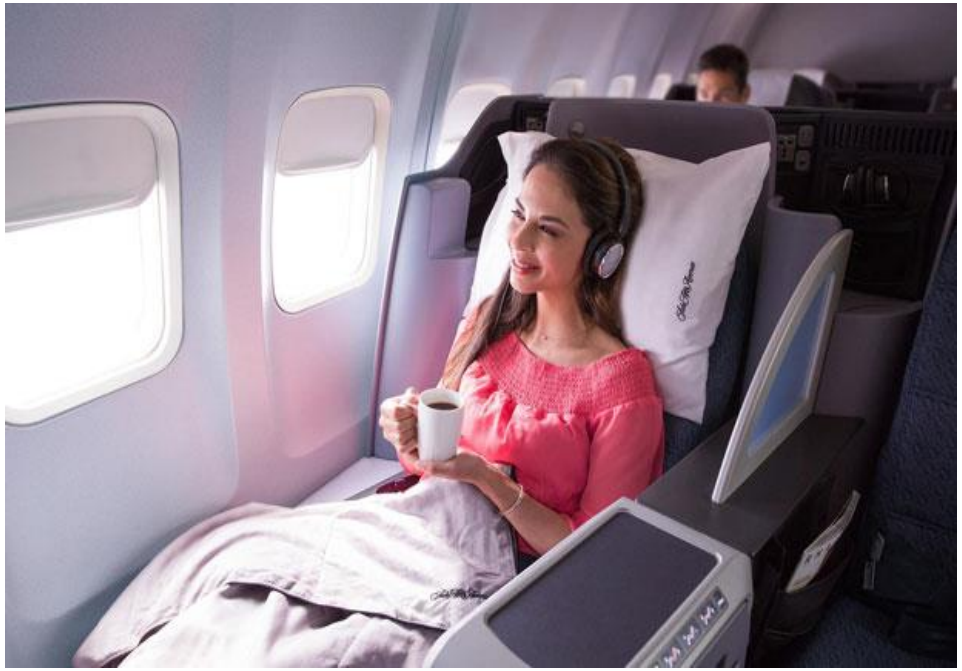
A Logical Outline

- Grid
- Services
- Future
- System
- Values

Grid - objective

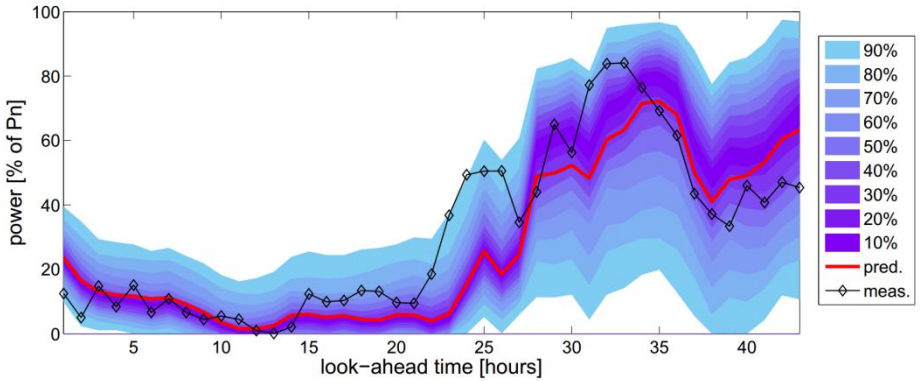
To maintain energy **supply demand balance** reliably in a wide **range of conditions** on a continuous basis across time and space and to do so in the **most economic way possible**.

Services

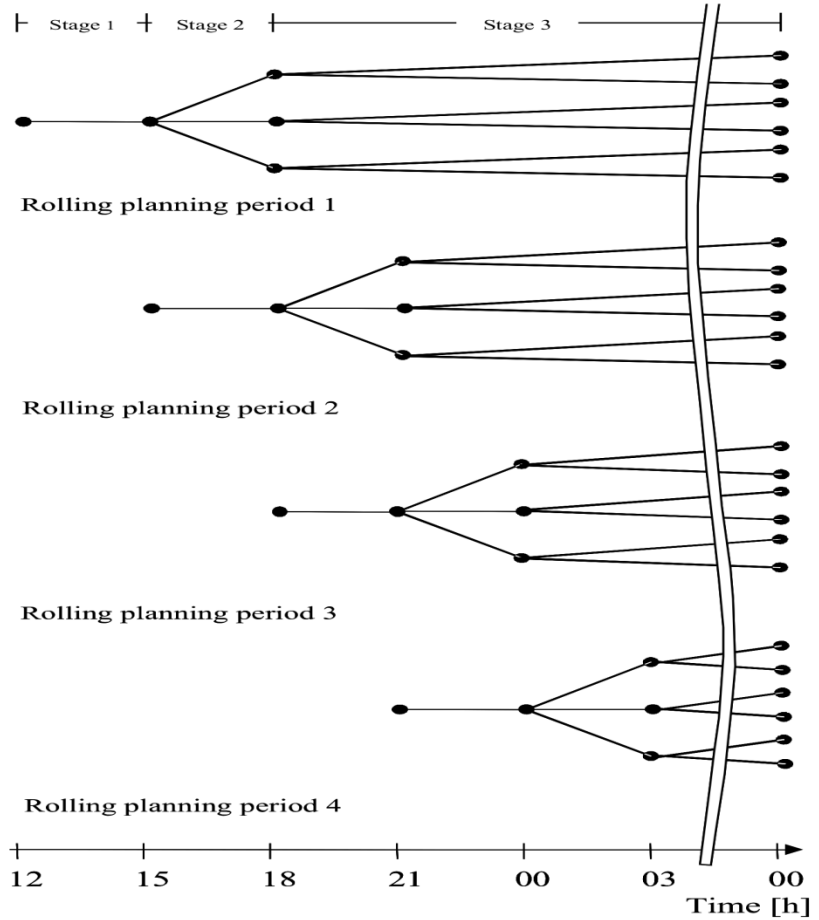


In economics, a **service** is a transaction in which no physical goods are transferred from the seller to the buyer. The benefits of such a service are held to be demonstrated by the buyer's willingness to make the exchange. Public services are those that society (nation state, fiscal union, region) as a whole pays for. Using resources, skill, ingenuity, and experience, service providers benefit service consumers. Service is intangible in nature.

Supply demand balance … wide range of conditions….economic



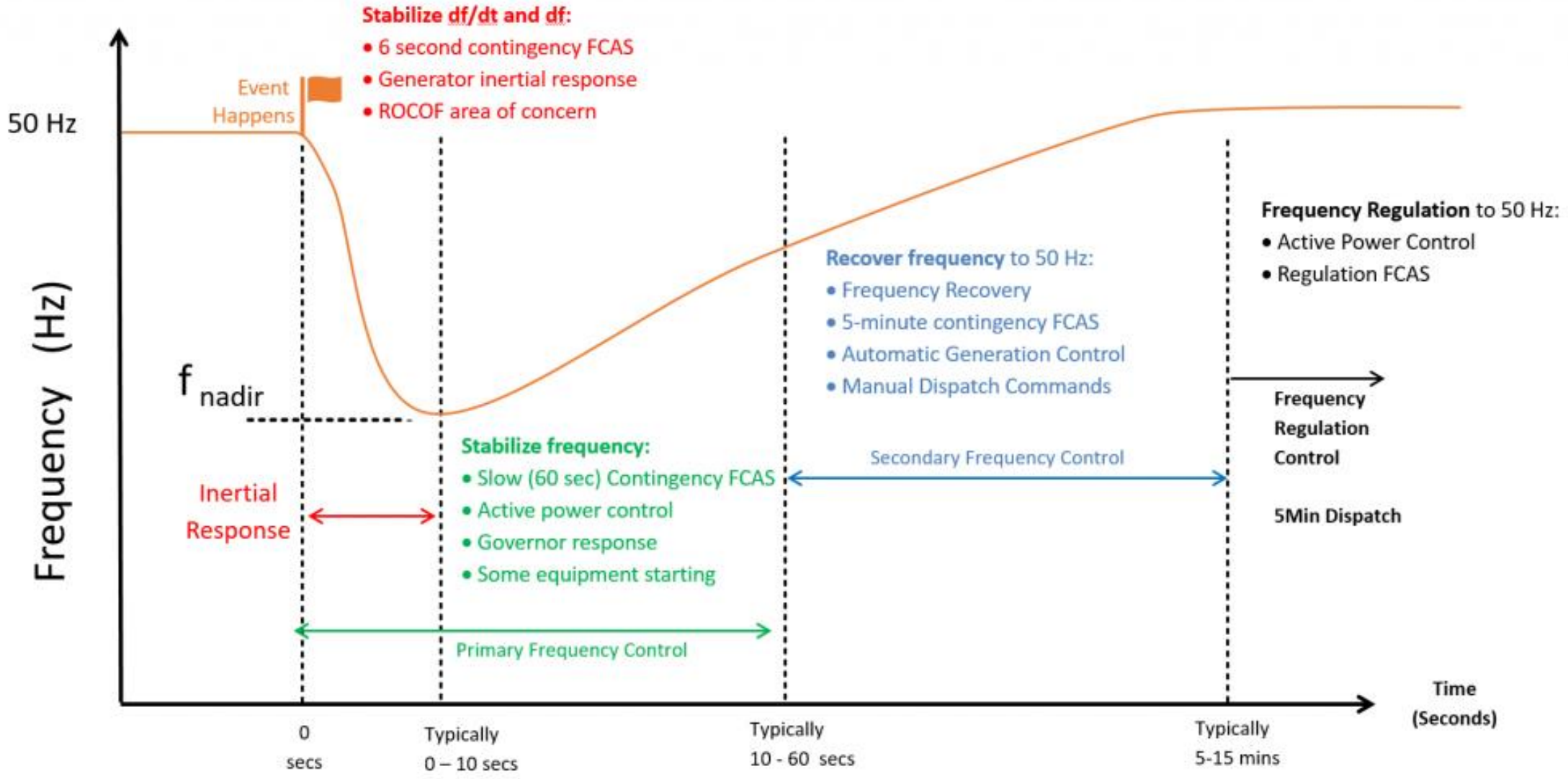
Pinson, P., Madsen, H, Nielsen, H., Papaefthymiou, G. and Klöckl, B., From probabilistic forecasts to statistical scenarios of short-term wind power production, Wind Energy, volume 12, issue 1, January 2009



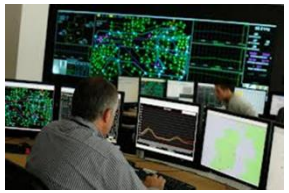
Meibom, P., Barth, R., Hasche, B., Brand, H., Weber, C. and O´Malley, M.J., "Stochastic optimisation model to study the operational impacts of high wind penetrations in Ireland", *IEEE Transactions on Power Systems*, Vol. 26, pp. 1367 - 1379, 2011.

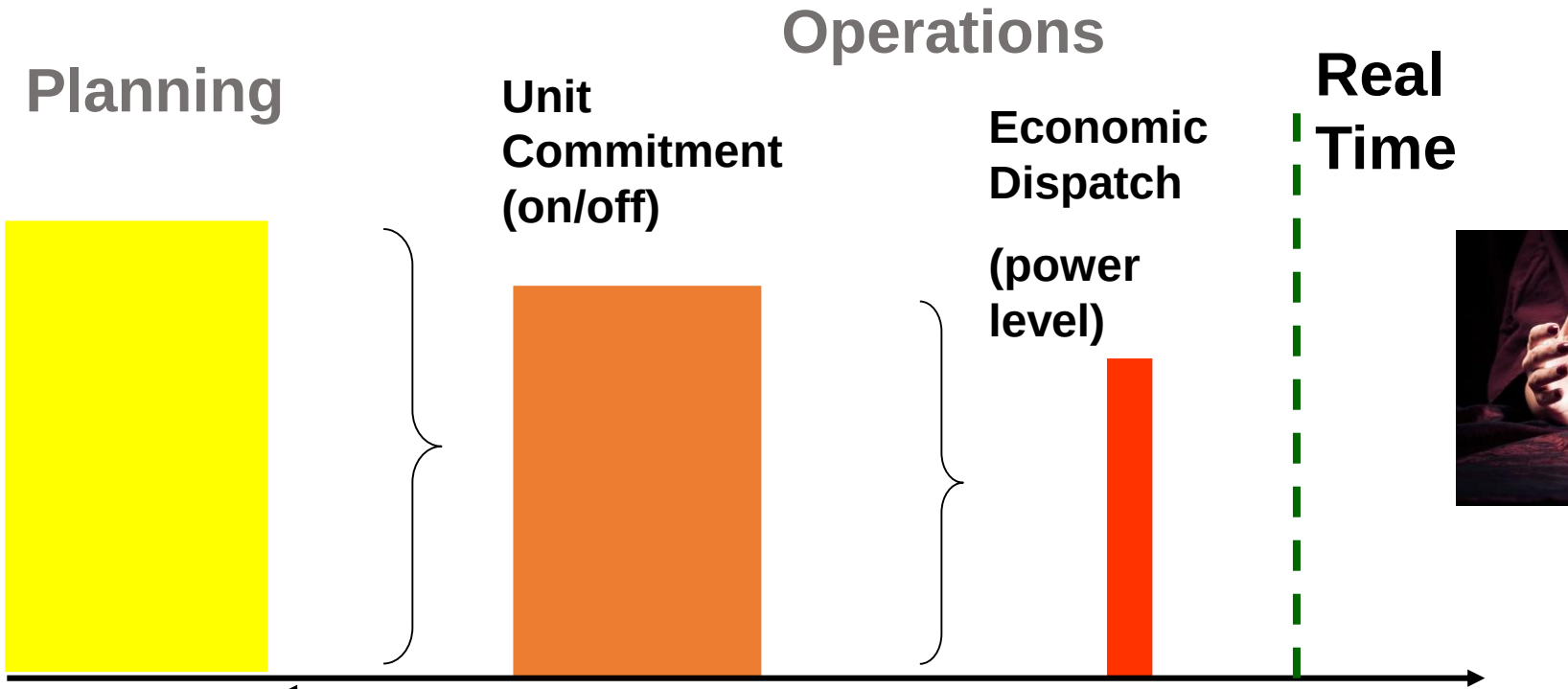
How do we deal with contingencies ?

many grid services are designed to deal with this type of uncertainity



Future - forecasting





Inertia market & salt

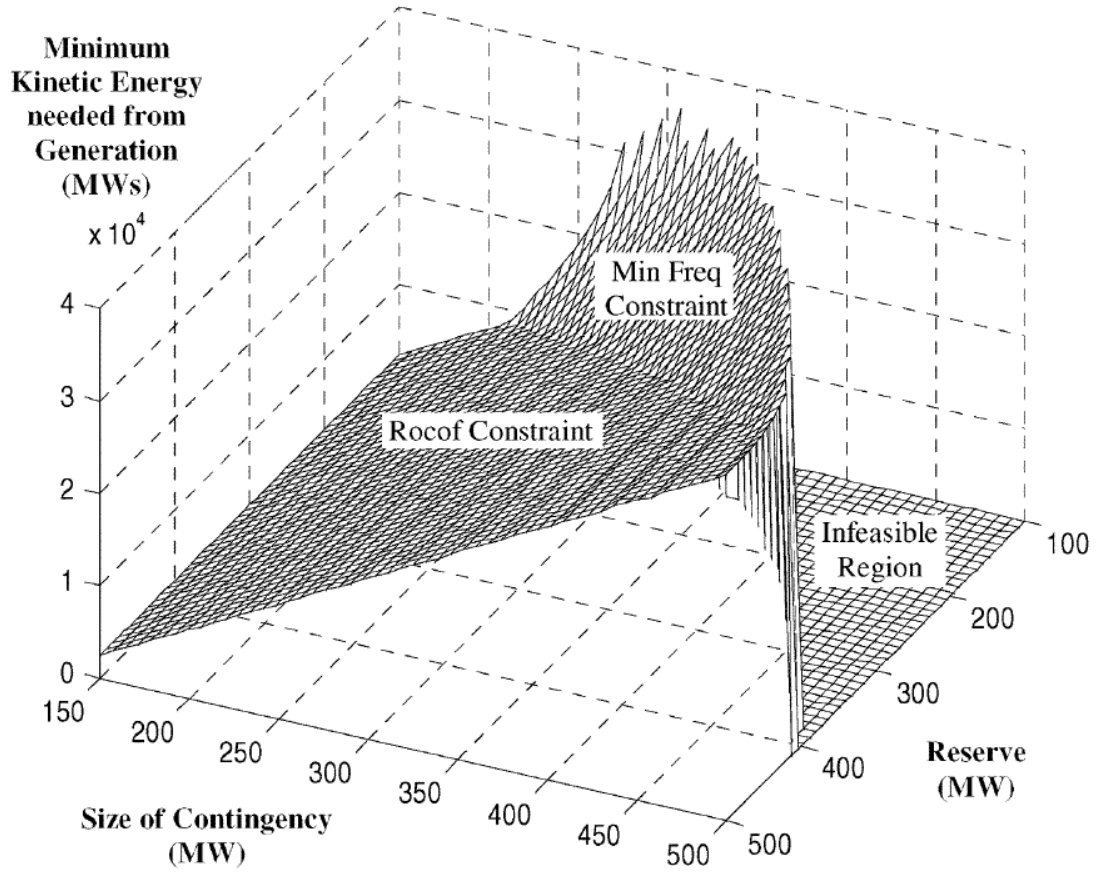
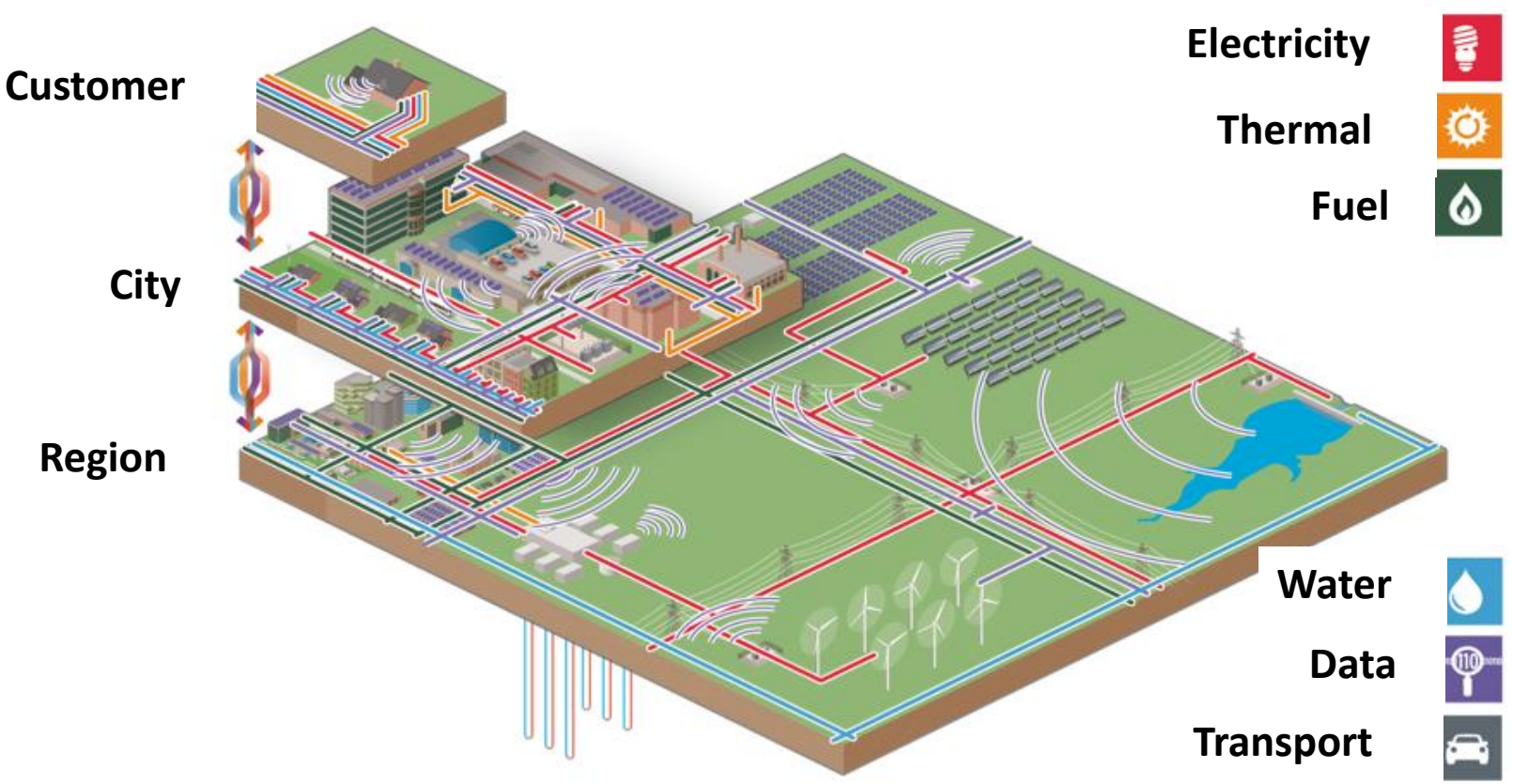


Fig. 6. Illustration of the frequency-based constraints.

Doherty, R., Lalor, G. and O'Malley, M.J., "Frequency Control in Competitive Electricity Market Dispatch", *IEEE Transactions on Power Systems*", Vol. 20, pp. 1588 - 1596, 2005.

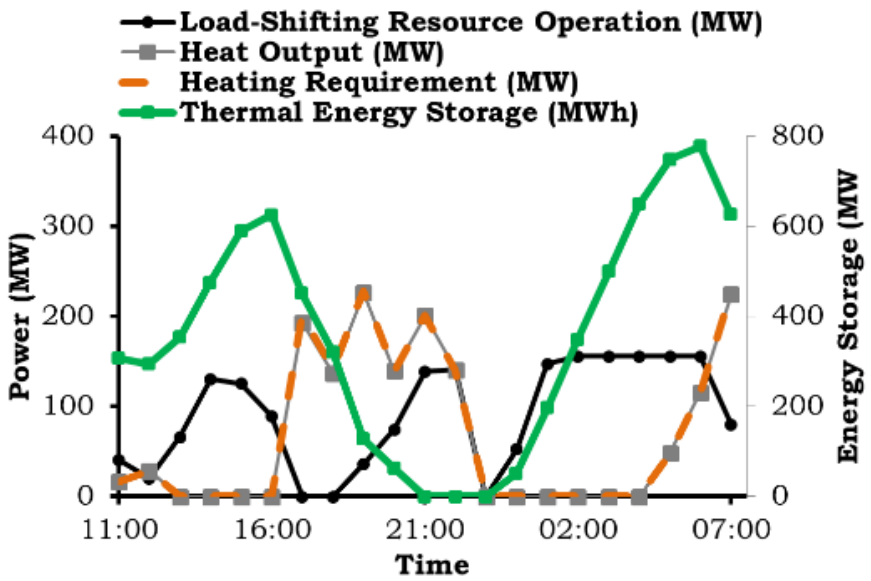
System

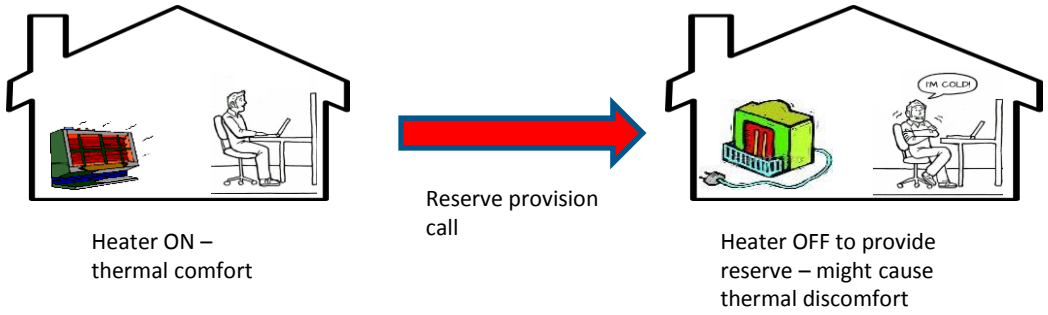


Energy system integration is the process of coordinating the operation and planning of energy systems across multiple pathways and/or geographical scales to deliver reliable, cost-effective energy services with minimal impact on the environment.

O'Malley, M.J., Kroposki, B., Hannegan, B., Madsen, H., Andersson, M., D'haeseleer, W., McGranaghan, M., Dent, C., Strbac, G., Baskaran, S. and Rinker, M., "Energy System Integration Defining and Describing the Value Proposition", NREL Technical Report NREL/TP-5D00-66616, June 2016.

Then we electrify heat





S. Nolan, O Neu, M O'Malley. `Capacity value estimation of a load-shifting resource using a coupled building and power system model", Applied Energy, Vol. 192, pp. 71 – 82, 2017.

What is value ?

Value decrease

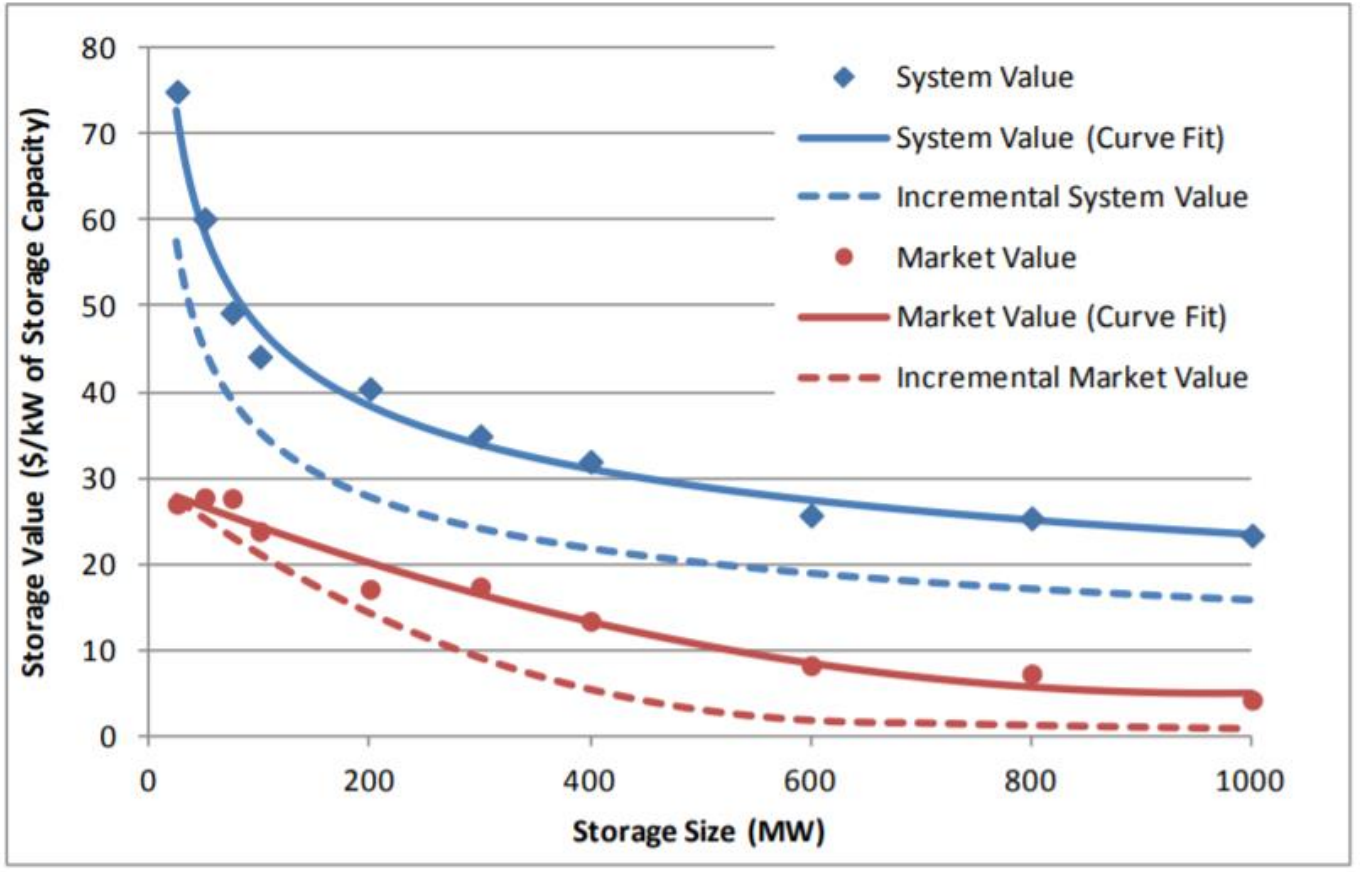
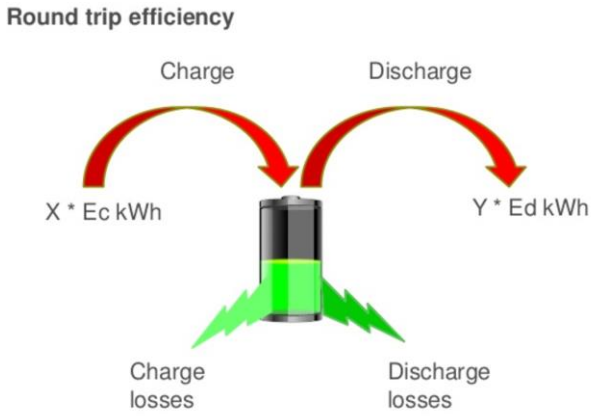


Figure 4-7. Storage operational value as a function of size for an energy-only device

Denholm, P., Jorgenson, J., Hummon, M., Palchak, D., Kirby, B., Ma, O. and O'Malley, M.J., "The Impact of Wind and Solar on the Value of Energy Storage", National Renewable Energy Laboratory, Technical Paper NREL/TP -6A20-60568, November, 2013. http://www.nrel.gov/docs/fy14osti/60568.pdf



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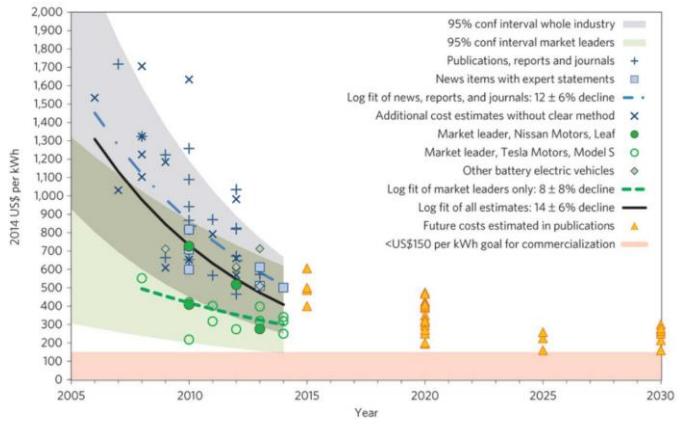
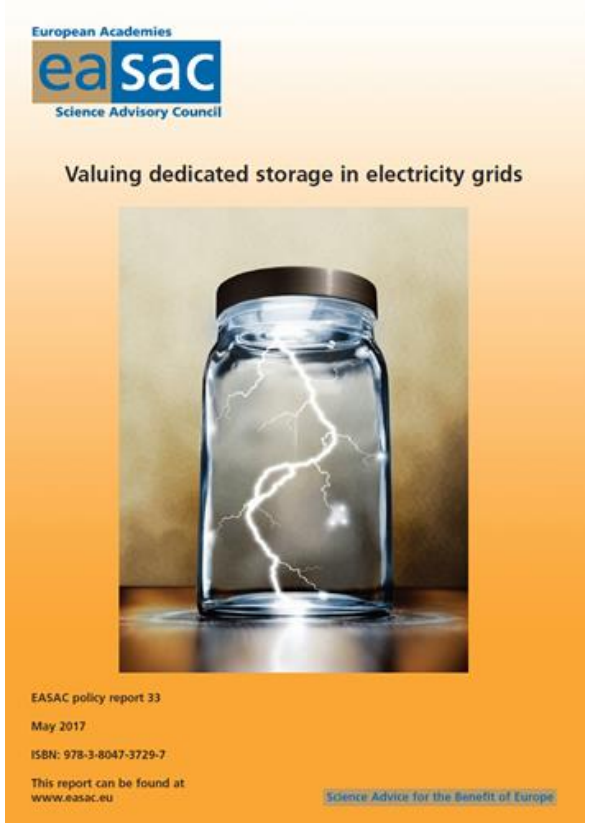


Source: Nature Climate Change 5, 329–332 (2015)

Graph 1. The cost evolution of vehicle batteries.



Conclusions: what should be done to ensure that storage is used effectively?

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1) Electricity **market design** should deliver price signals (locational and temporal) which encourage investments in cost-efficient **flexibility options** on both transmission and distribution grids.

2) Electricity market design should not create barriers to the deployment of potentially valuable systems and technologies **(including storage**).

3) Electricity market design should address PV plus battery systems on **distribution grids**.

Conclusions

- We need to **understand** what we are talking about
- Define and agree the **objective**, levels of **reliability** and the **boundaries**
- If it can **competitively** contribute to the objective it has value
- **It** is **generic**, its value may be **limited** and it may have **no value**
- There is **no single best answer** – we just need one that is **good enough**

Acknowledgements

- Your patience with my rant

- My fellow panelist ☺