Tools for analyzing DR, DG and storage integration

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What are the tools we consider?

- All types of tools which can be used to analyze the power system (in the larger context energy system and the whole economy), are to some extent relevant in analyzing DR, DG and storage integration
- We have considered only high-level software tools, which can be used as an aid in planning or operation of DER (some hardware tools such as communication and meters are discussed in other parts of the report)
- We have broken down the tools into following classes
  - policy analysis
  - investment planning
  - network simulation
  - operation optimization
  - customer-level simulation
  - forecasting

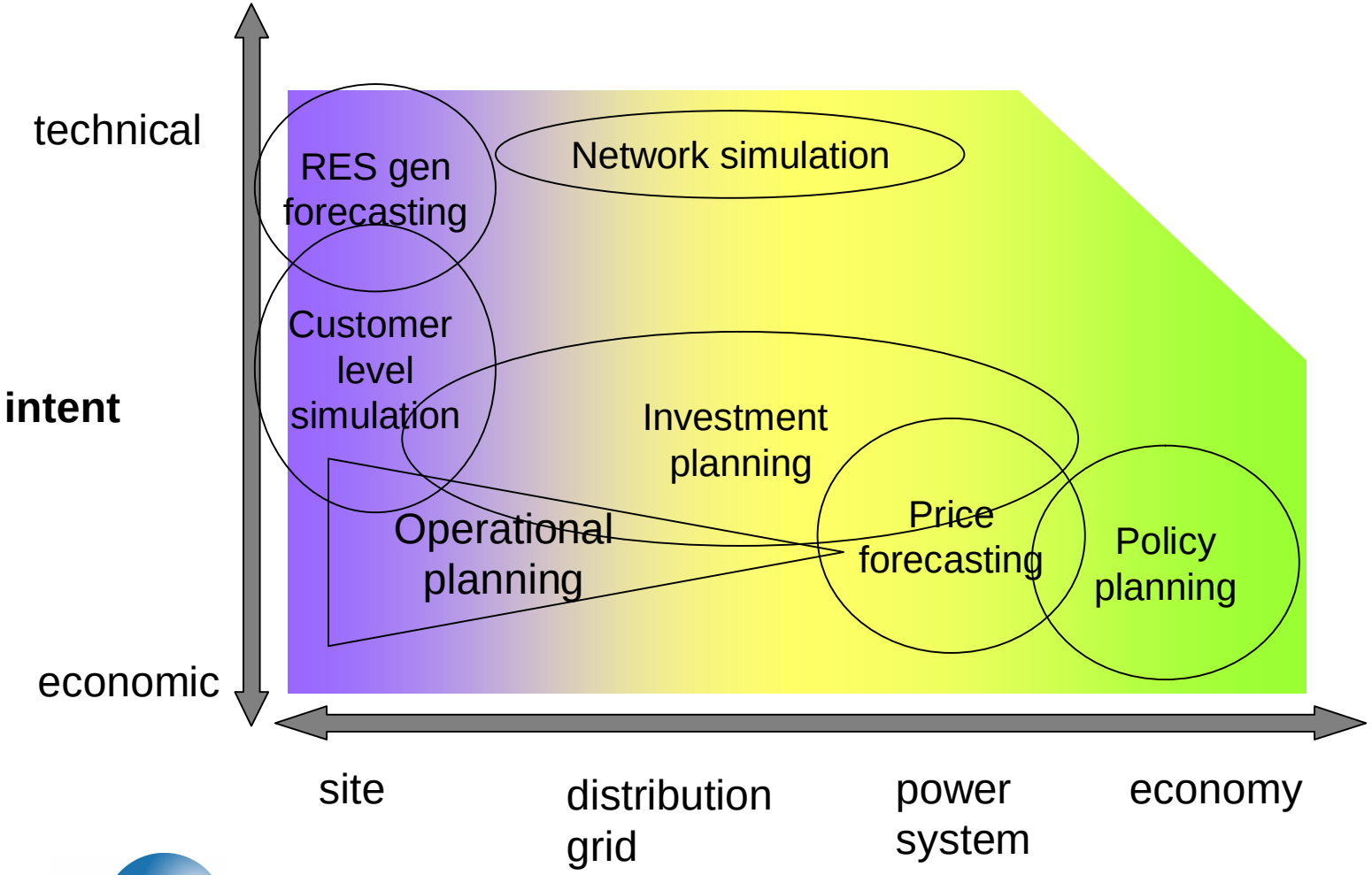
Examples of questions that the tools could answer

- what are the effects on
  - network losses and congestion
  - power quality
  - existing power plants
  - electricity price
  - emissions
  - supporting logistics (e.g. gas network)
- how profitable is DER to different stakeholders
  - effects of different market rules
- how DR, DG and storages, together with smart grid technology, could be used instead of network reinforcements
- once DER is installed, how it should be operated
- what kind of support schemes could be used to promote DER integration
- is market price likely to support DER investments in near future

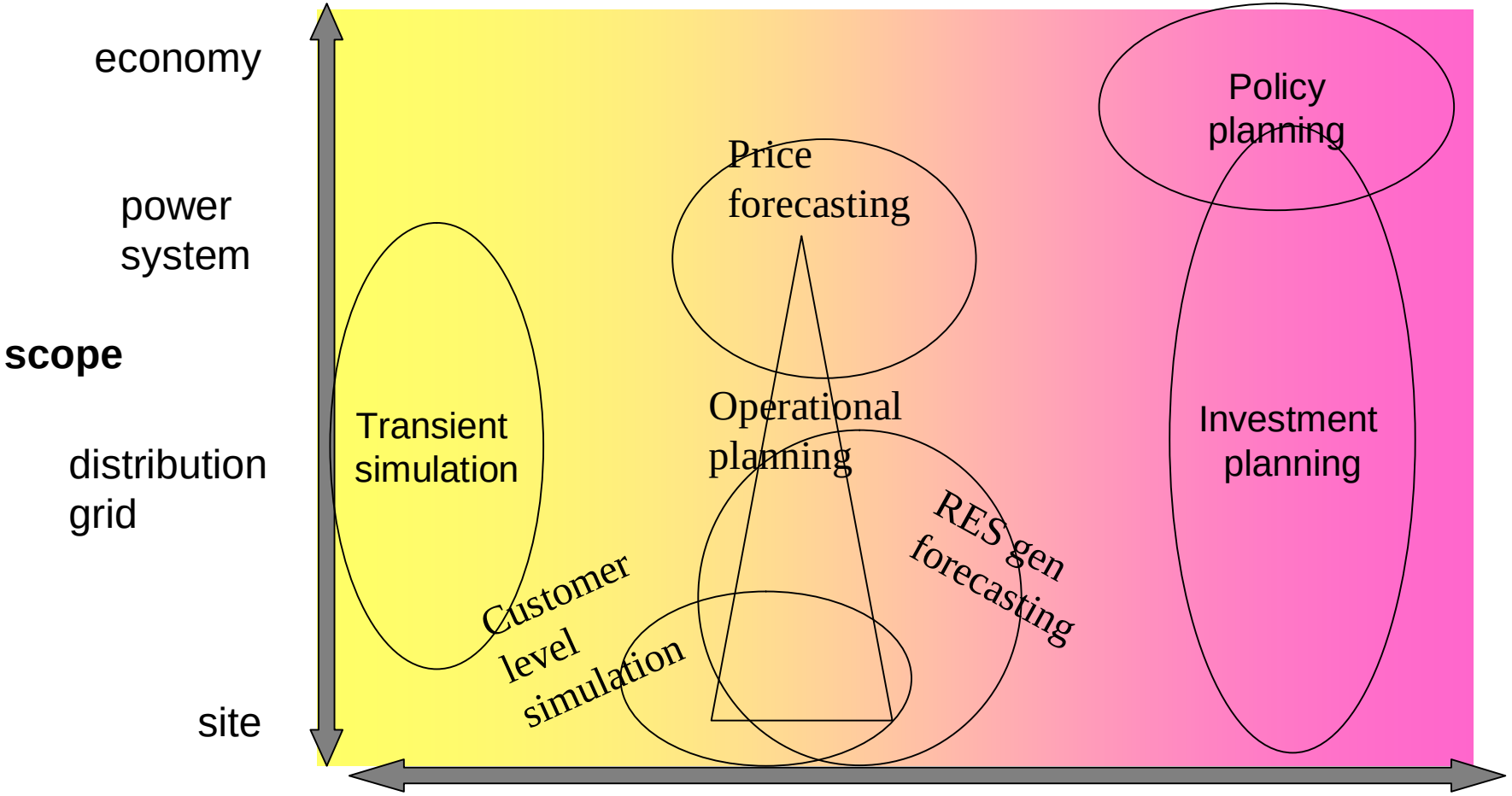
Drawbacks of the tools

- Using the tools requires expertise and often experience in how certain situation should be modeled
- Input data is often not available, for example about market prices
- Results can be specific to the case under study and cannot be generalized
- Results concerning distant future are only suggestive, with large error margins
- Some tools are expensive

Tools characterized with scope-intent matrix



Tools characterized with scope-time matrix



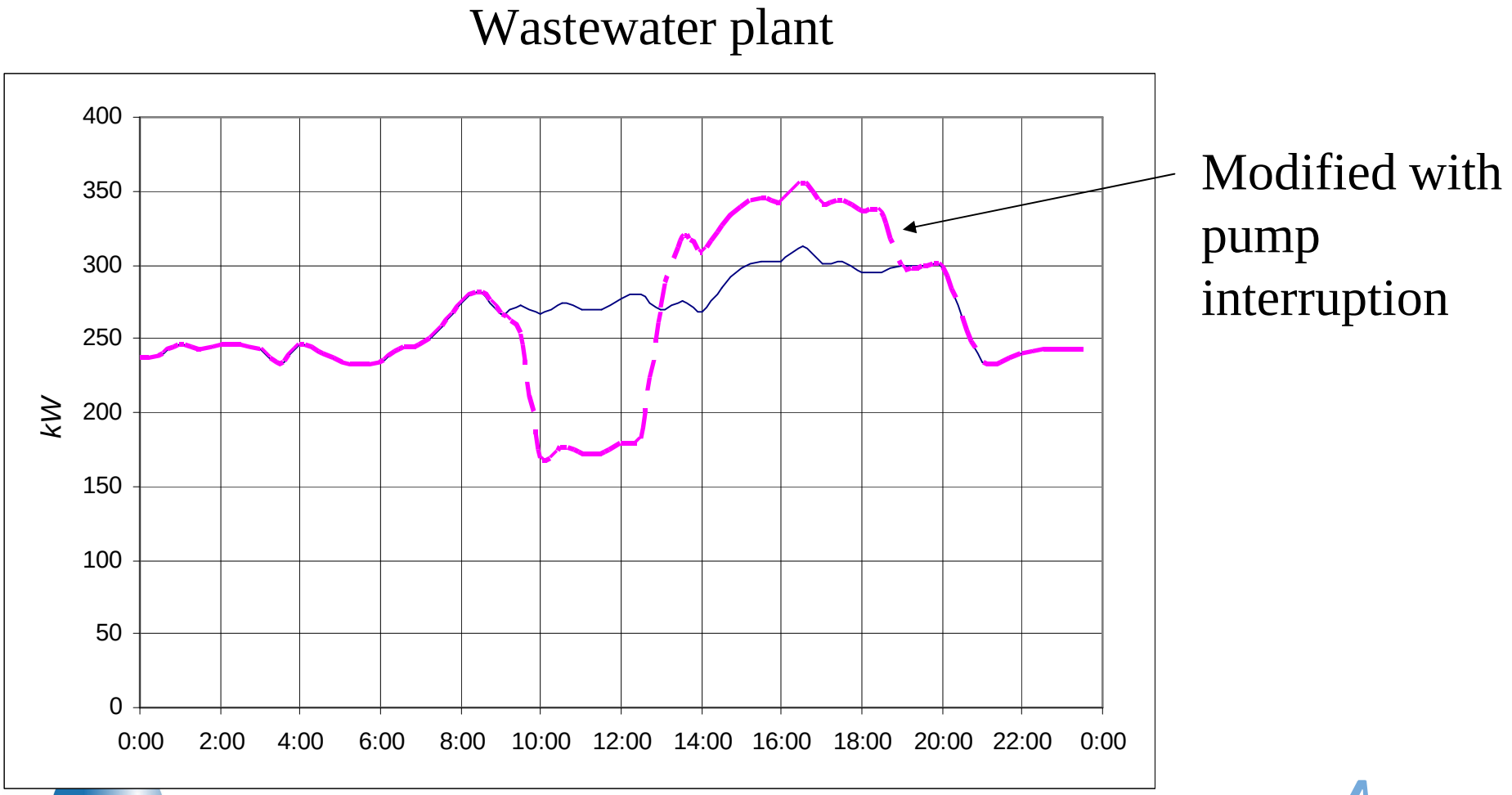
Policy planning tools

- The tools look ahead years or decades, work with aggregated variables on macro level and do also economic analysis
- Besides the power system these tools can also include models of energy use (industrial sectors), fuels production (e.g. biofuels), and even all sectors of the economy
- The tools can give partial answer to the question ”what kind of support schemes (e.g. tax reductions) would be needed to promote certain production form (e.g. biogas plants) and what are the effects to different economic sectors and consumer sectors”
- Normally the tools do not consider the network as constraint. Therefore they neglect one benefit or DR and DG.
- In our opinion the results have large error margins.

Customer-level simulation tools

- The tools simulate customers' internal processes: buildings or industrial processes
- As result we get *forecasts* about heat/cooling demand and available demand response
  - Heat/cooling demand is needed in planning CHP operation
- Building simulation tools are plenty and widespread
- Industrial processes vary more than buildings and models have to be customized more

Example of customer modeling: Technical University of Valencia industrial process model



Network simulation (or power system simulation) tools

- Are suitable for load flow calculation and/or transient analysis, depending on tool
  - load-flow calculation provides voltage profiles for all nodes and loading of network components
  - in transient analysis voltage and current are monitored as function of time in different nodes e.g. after load switching or generator start-up
- Components such as power lines, relays, appliances, transformers and generators can be included
  - These can be modeled with varying accuracy
- Feedback loops can be often included, e.g. automatic voltage regulators or power system stabilizers (PSS) for generators

How network simulation tools can be used in context of DR, DG & storage integration?

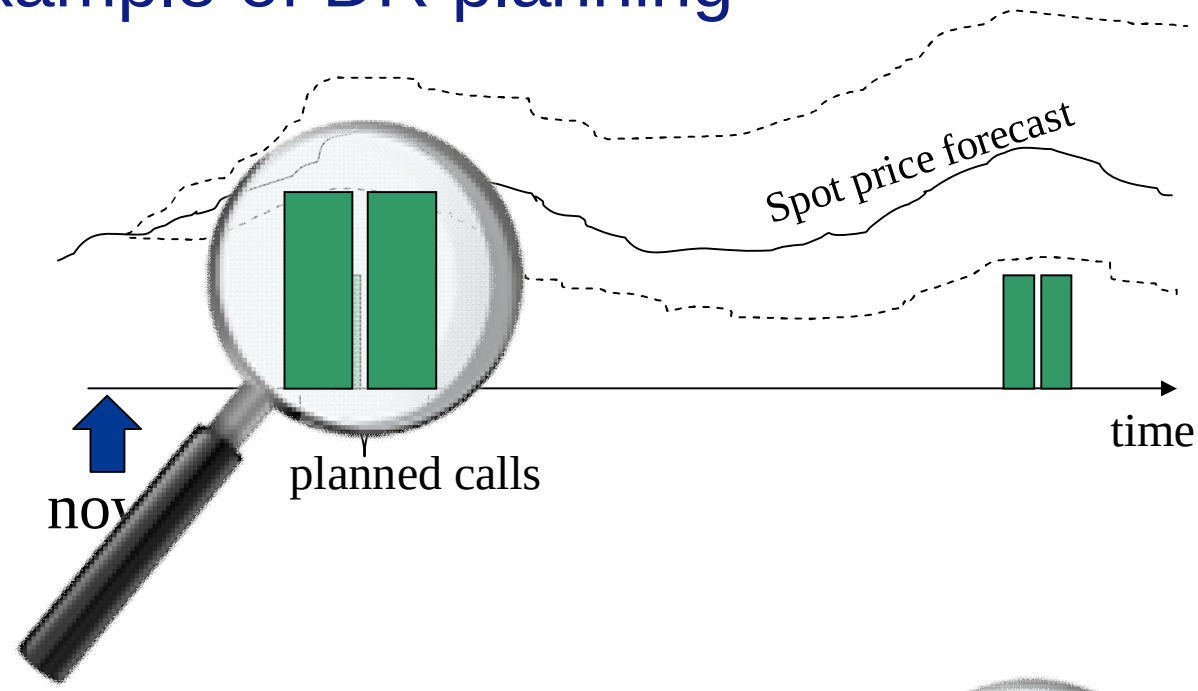
- Power quality:
  - Simulation of voltage flicker in case of load reduction and DG start-up
  - Simulation of harmonic waves and their suppression in case of load curtailment
- Planning of DG and storage installation (location, type, size)
  - Economics of installation cannot be handled with just network installation tools
- Calculation of network losses

Planning tools for DER operation

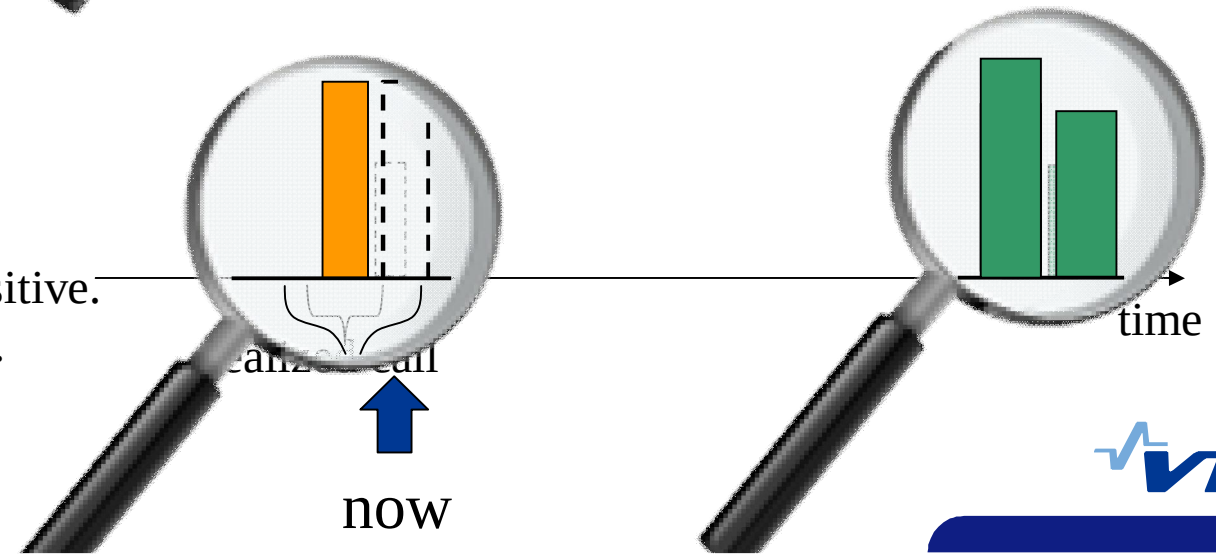
- These tools take the point of view of DER aggregator and try to operate DER with maximum profitability, recognizing any operational limits of generation, load reduction or storage use
- These tools normally take a more economic view, while taking account technical constraints such as maximum daily operation period
- This optimization is done against (forecast) electricity and gas prices, and with forecast load and other quantities
- Besides benefiting the aggregator, the optimization can also help others by lowering electricity price and making easier for intermittent power to be injected into the system, and in some cases by reducing network congestion
- We broke down these tools into following classes:
  - for operational use
  - for assessment use

Example of DR planning

1. Schedule of calls
is made for next 1-2 days



2. The second
call was cancelled
because power imbalance
turned out to be highly positive.
Schedule was recalculated.



Forecasting tools

- Are used to create inputs for other tools
- Can be used to forecast intermittent power generation, load and electricity prices
  - For example dispatch orders to DG or DR largely depend on these
- Different target variables:
  - There are numerous tools for wind power forecasting
    - normally these take numerical weather forecasts and current power as input
  - Different prices can be forecasted: spot price, imbalance prices, locational marginal price, transmission charges (depending on country)
    - Short-run forecast $\leq$ 1 day, long-run $\geq$ 1 year

Summary

- There are a lot different tools which can be useful in analyzing DR, DG and storage integration
- These tools each have their own characteristics and clear division into groups cannot be made
- The tools require quite a lot of effort to be used efficiently, therefore there are large economies of scale
- A list of available tools will be presented in our report
  - Suggestions from country experts and stakeholders?