Role of Flexible Consumers in a Future Renewable Power System

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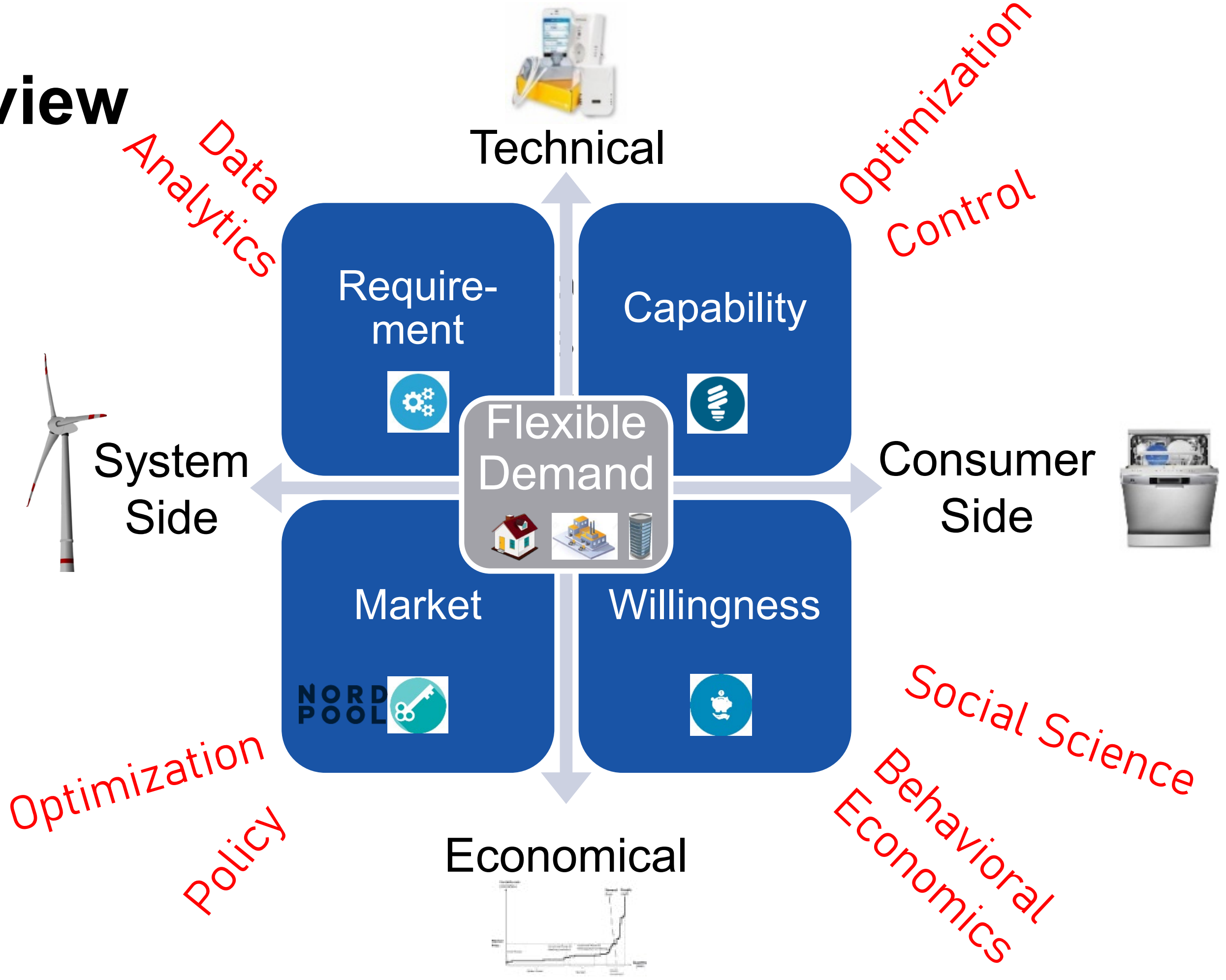
LINKÖPING UNIVERSITY

GRADUATE SCHOOL IN ENERGY SYSTEMS

Overview


Technical
Data Analytics
Optimization
Control
Require-ment
Capability
Flexible Demand
System Side
Consumer Side
Market
Willingness
NORD POOL
Optimization
Policy
Economical
Social Science
Behavioral Economics

Key questions:

1. Are consumers ***capable*** of being flexible ?

   Engineering

2. Is it ***profitable*** for consumers to provide flexibility ?

   Economics and Operations Research

3. Are consumers ***willing*** to be flexible ?

   Game Theory and Behavioral Economics

Overview

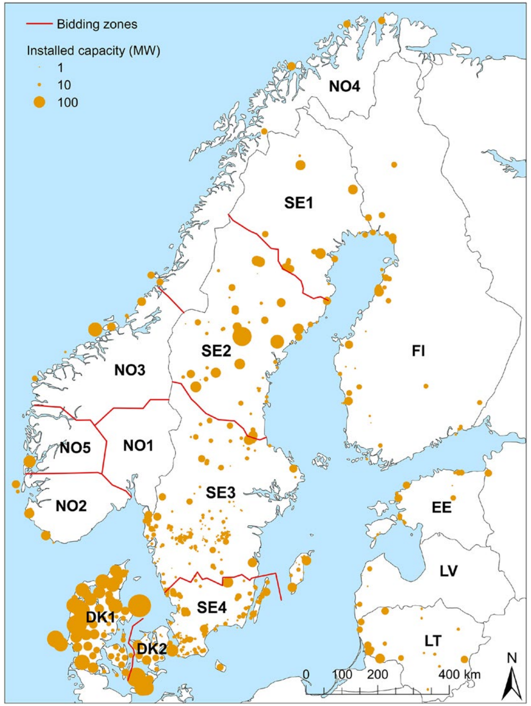
1. Motivation - Wind Power Forecasts

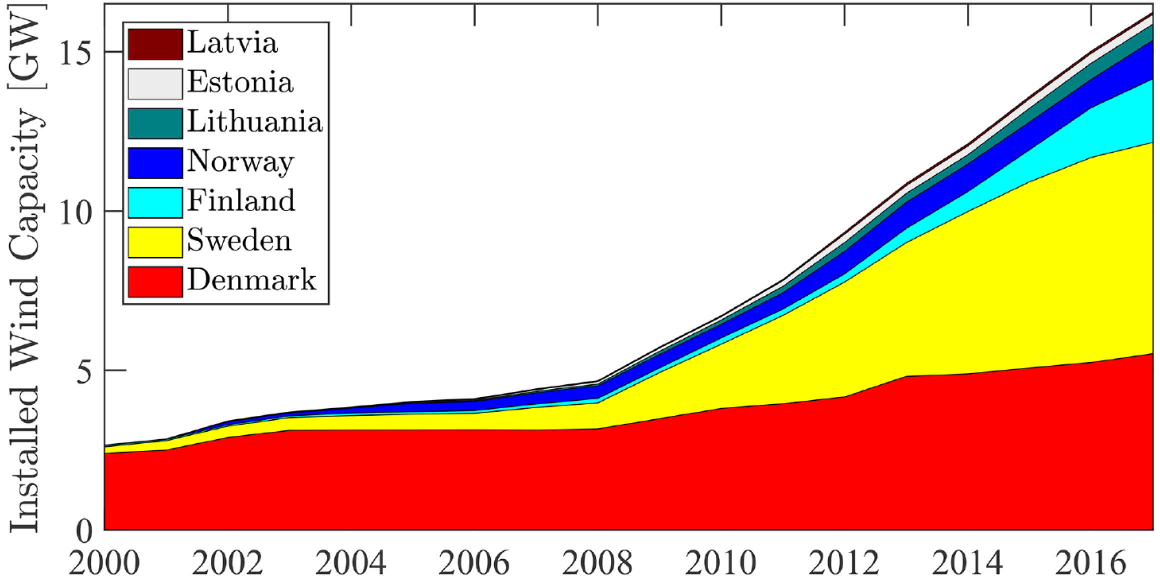
2. System Balance – An Analogy

3. Flexible Consumers – 3 examples

4. Recent Paper - Flexibility Gap

1. Wind Power Forecasts

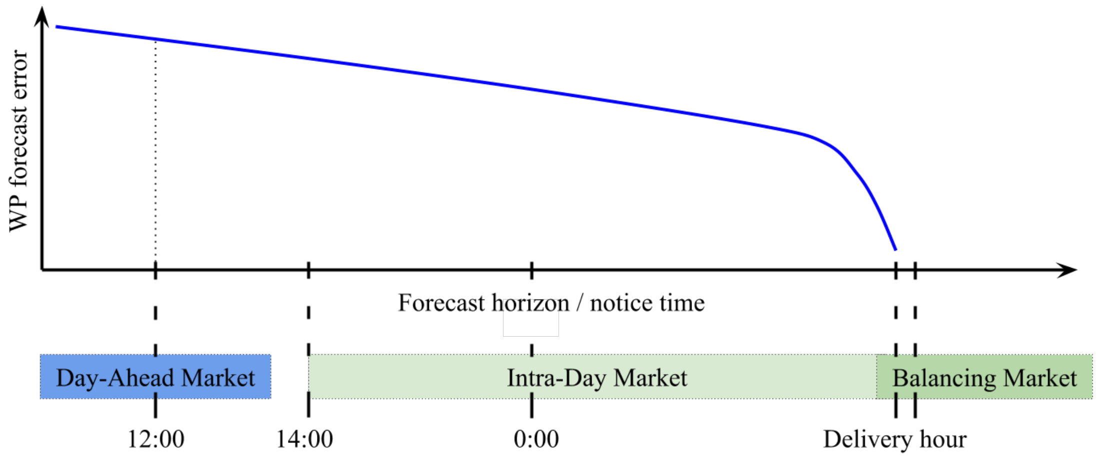


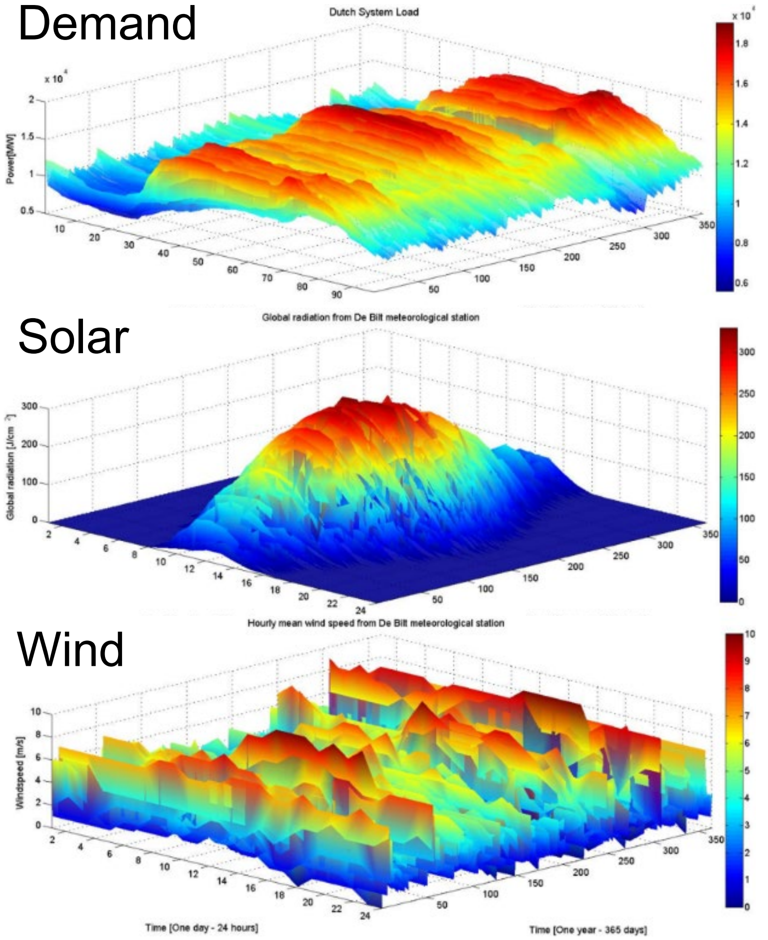


L. Herre *et al.*, "Exploring Wind Power Prognosis Data on Nord Pool: The Case of Sweden and Denmark," *IET Renewable Power Generation*, 2019.

1. Wind Power Forecasts

- Intermittent Renewables
- Uncertain forecasts





1. Wind Power Forecasts

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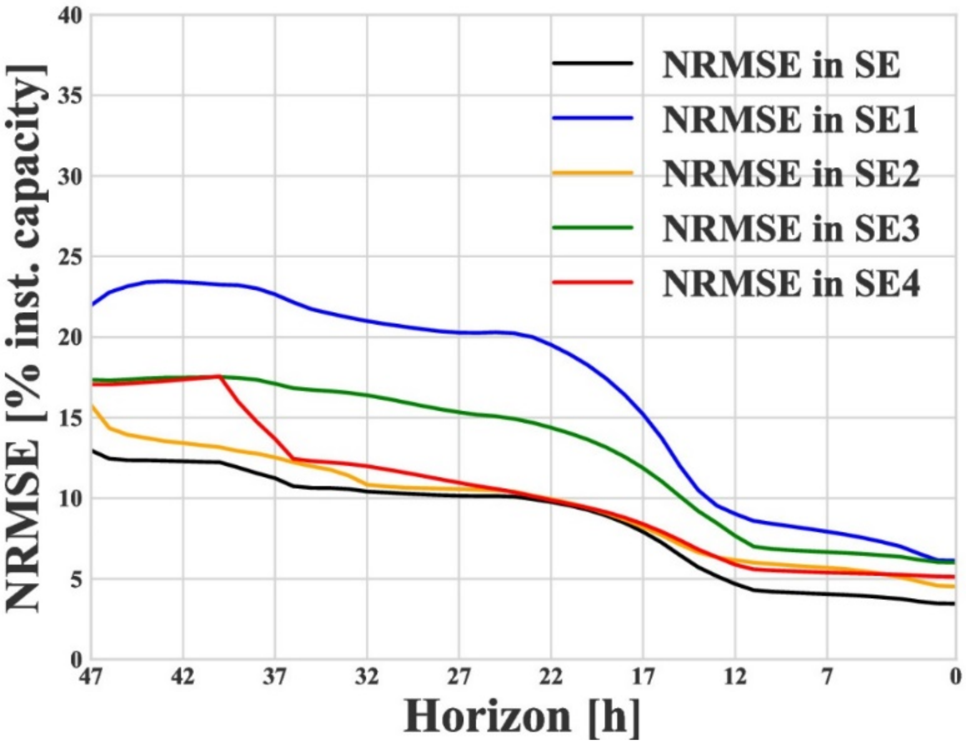


L. Herre *et al.*, "Exploring Wind Power Prognosis Data on Nord Pool: The Case of Sweden and Denmark," *IET Renewable Power Generation*, 2019.

2. Balance: Production = Consumption

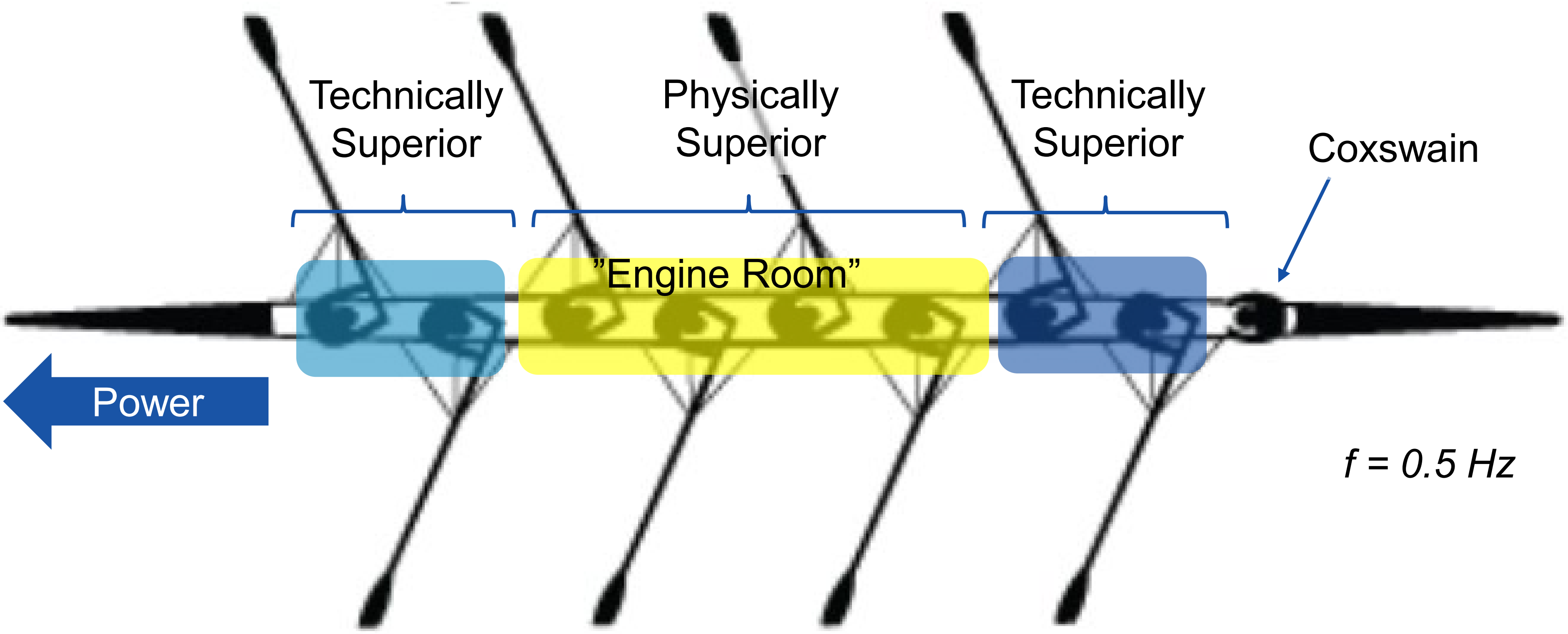
2. Keeping the balance - An Analogy

Normal Operation

No Inertia

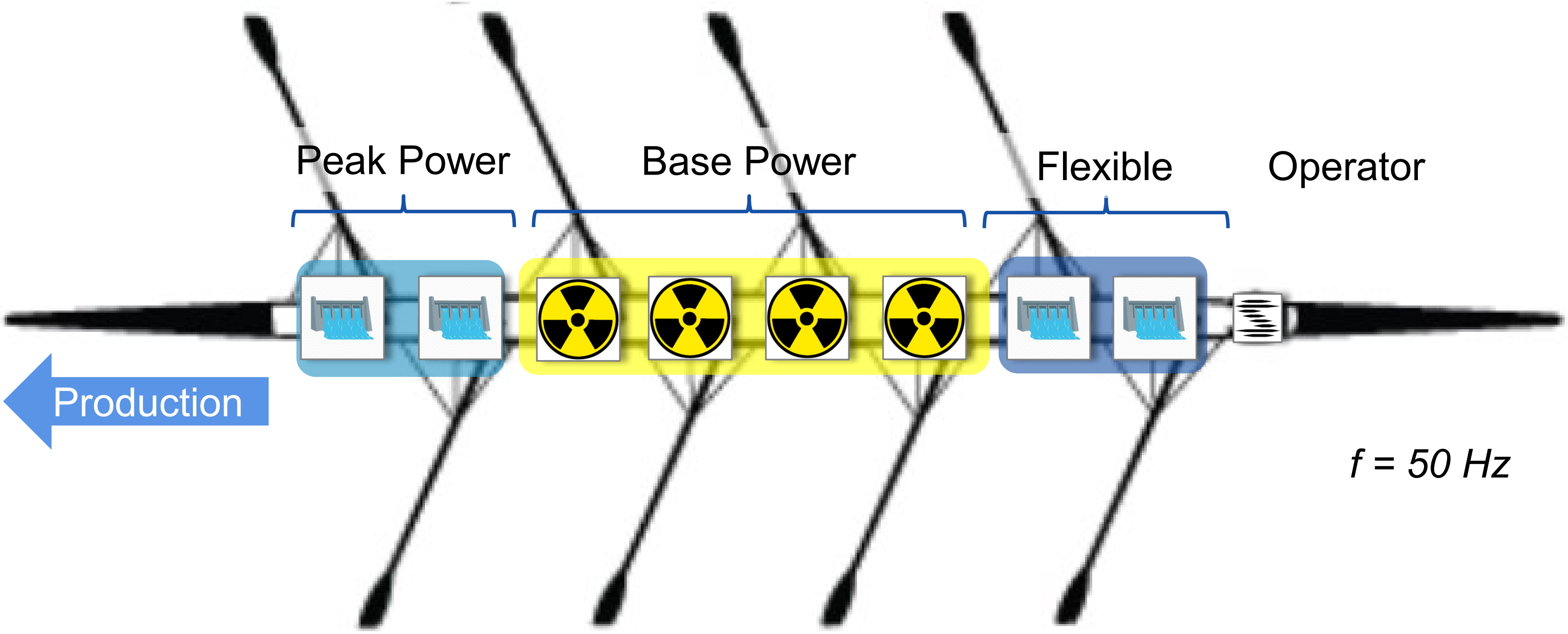
Blackout

2. Rowing Boat

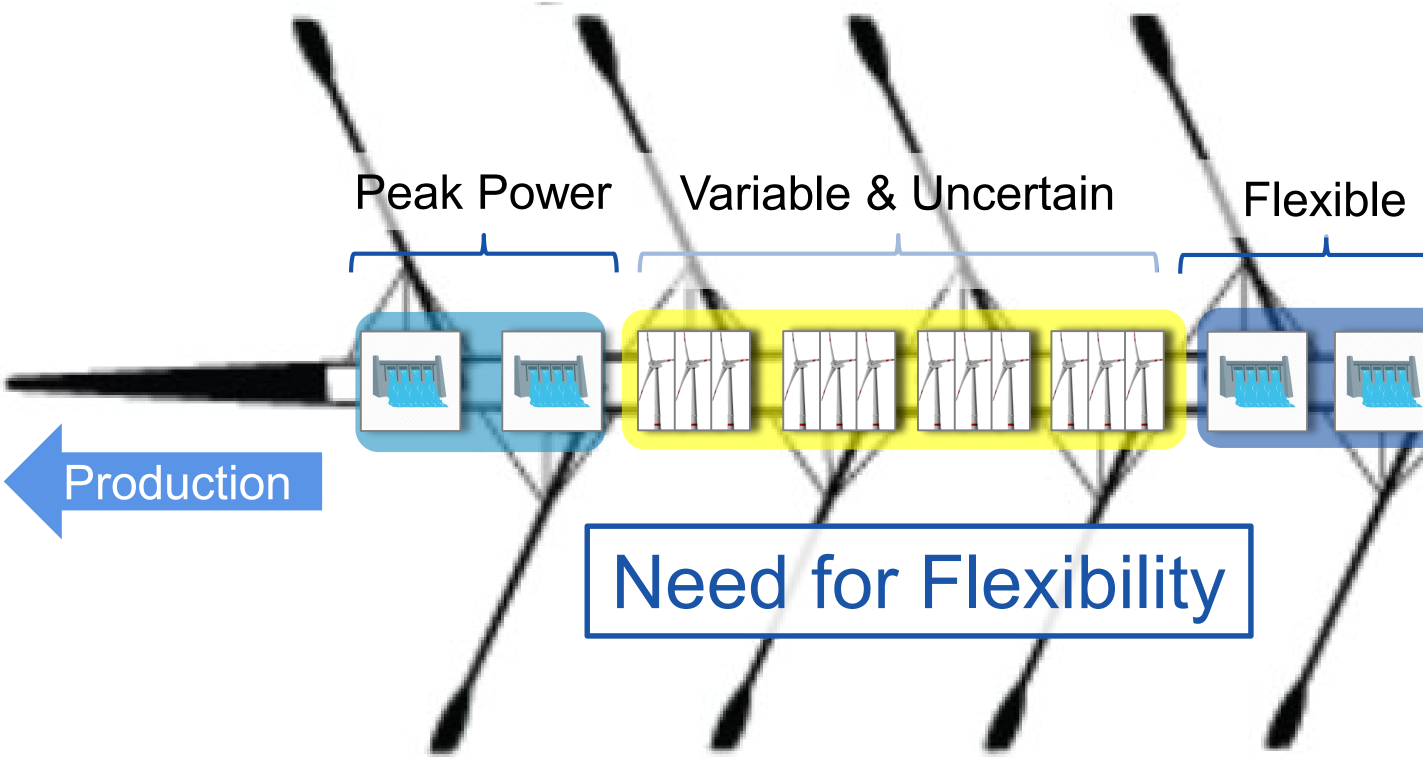


f = 0.5 Hz

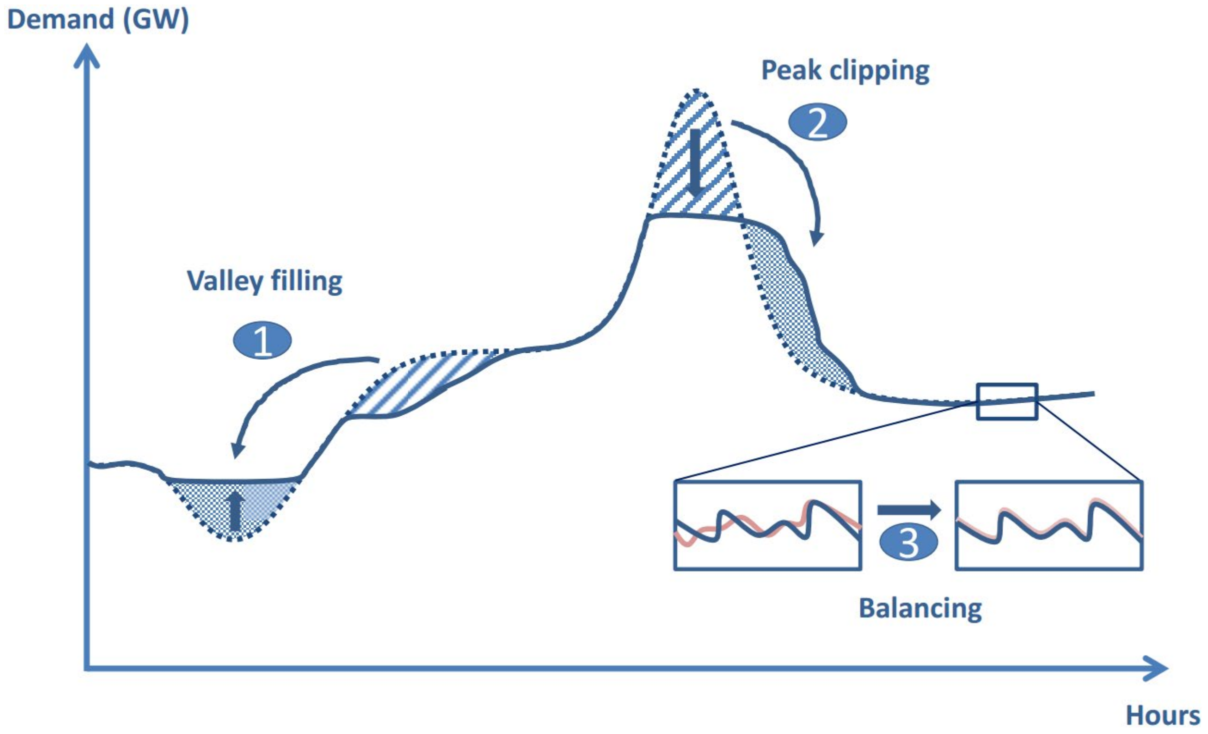
2. Sweden Today



2. Sweden Target



3. Flexible Consumers



Energy Flexibility

1. Valley filling
2. Peak Shaving
- Energy Efficiency

Power Flexibility

3. Balancing: FCR-N/-D
- Strategic Reserve

3. Flexible Consumers

Electric Heating/Cooling

7.4 GW Flexibility

in Sweden

Electric Vehicles

Cost savings:

50% (NO)   50-100% (SE)

Pulp and Paper Mill

15% of SE el. consumption

Cost savings: 2.3-7.4%

Recent Paper: Flexibility Gap

Table 1: Parameters impacting the responsiveness of consumers [53]

	More Responsive	Less Responsive
Price Exposure	Volatile RTP	Flat Rate
Cost [% O&M]	High	Low
Equipment	Auto DR	Manual
Normal Load	High	Low
Load urgency	(Time-) critical	Deferrable
Lead Time	??	??

Flexibility Now or Later - Impact of Market Timing on Social Welfare of Flexible Consumers

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Abstract

Power systems with large shares of renewable energy generation require flexibility from both producers and consumers. Demand side management enables flexible electricity consumers to participate in system services that contribute to enhanced integration of renewable energy sources. The specific market timing, pricing scheme and demand response program decide in which way consumers receive and react to incentives. Aside from pricing, several other parameters were found to greatly influence consumer response. Here, the impact of *lead time* on the flexibility of consumers is investigated and its impact on social welfare is estimated. The price elasticity of consumers can vary in different ways depending on the lead time. Consequently, the time when the price is broadcast would impact the response and the social welfare. We summarize projects and literature on consumer elasticity and conduct a simulation study, where the aggregated demand is updated with statistically improved forecasts at several instances. The results show the importance of lead time for demand side management. We find that the difference between stated and measured elasticity results in a demand *flexibility gap* and quantify this in terms of social welfare. We conclude that lead time should be considered in electricity market design, e.g., in consecutive ahead markets in order to tap the full potential of flexibility from the demand side.

Keywords: lead time, price elasticity, flexible consumers, demand response, wind power integration, electricity market design

1. Introduction

The increasing share of intermittent renewable energy generation challenges the conventional power system operation. Uncertainties extend beyond demand forecasting and outages also towards renewable production forecasting. While renewable energy generation forecasts are continuously improving, there remains an inherent probabilistic forecast error. In addition, forecasting errors depend on numerical weather predictions that improve with shorter forecast horizons. Therefore, the forecast horizon of renewable generation and the *lead time* of balancing reserves are important factors for power system balancing.

There exist several means to balance the power system on different time scales. In addition to conventional strategies of controlling the supply side and storage technologies, demand side management (DSM) has been suggested [1, 2] as an efficient option to involve the demand side in balancing services. Around the world, many demand response (DR) projects have been implemented in pilot projects and for commercial use. Commercial programs mainly involve large industrial consumers [1]. However, in some countries residential consumers can choose to receive hourly DA spot market prices, e.g., in Sweden and Norway [3].

Accurate information regarding the uncertainty of wind power forecasts is key to efficient and cost-effective integration of wind power. Reference [4] presents a methodology for producing probabilistic wind power forecast scenarios on a rolling horizon in order to investigate how the uncertainty in wind forecasts affect the operation of power systems. The review in [5] provides models employed to integrate renewable energy sources in the generation expansion planning. A new wind offering strategy is proposed in [6] in which a wind power producer employs DR to cope with the power production uncertainty and market violations.

Fig. 1 shows the typical qualitative development of wind power forecast errors, as reported in [7]. The improvement behaves approximately linear on a long forecast horizon and shows significant improvement for short forecast horizons. In addition, the time frame of current electricity markets is illustrated Fig. 1. Since the day-ahead (DA) market typically closes at 12:00, the forecast horizon for wind power production on the following day lies between 12 and 35 h. The use of such long forecast horizons for DA planning can result in significant power imbalances in real time operation. These imbalances can be balanced in the intra-day (ID) and balancing markets by flexible units.

DR is viewed as a practical and relatively low-cost solution to increasing penetration of intermittent renewable generation in bulk electric power systems. Reference [8] examines the optimal installed capacity allocation of renewable resources in conjunction with DR. The authors find that the inter-hourly DR magnitude is much less helpful in promoting additional renewables than intra-hourly demand elasticity. Reference [9] proposes a probabilistic unit commitment problem with incentive-

Preprint submitted to Applied Energy *February 25, 2020*

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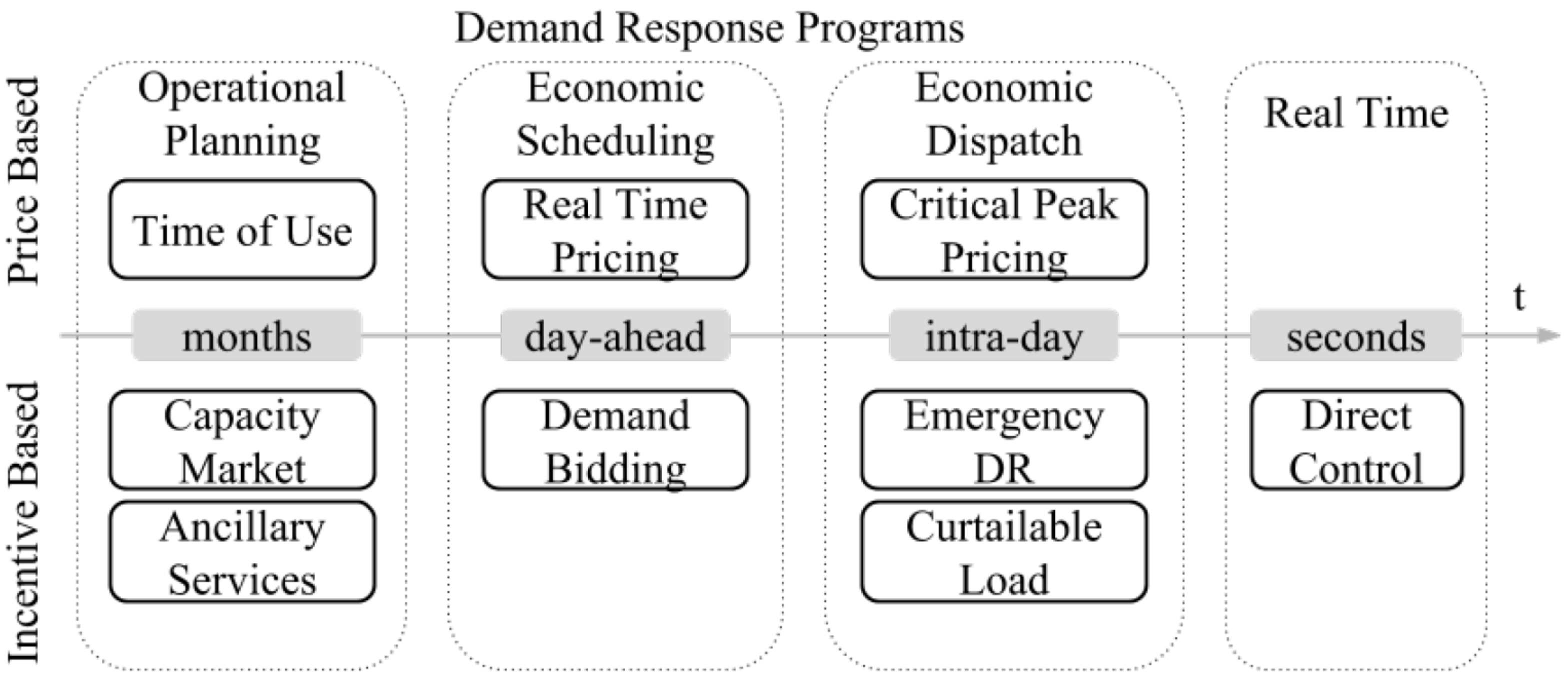
Demand Response Programs and Market Timing



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Definition: Lead Time Window

Table 2: lead time window and price sensitivity of DR programs

DR program	TOU	DB, RTP	CPP
lead time	Static	Day-ahead	Intra-day
mean	108 h	36 h	12 h
window	168 ... 48 h	48 ... 24 h	24 ... 1 h

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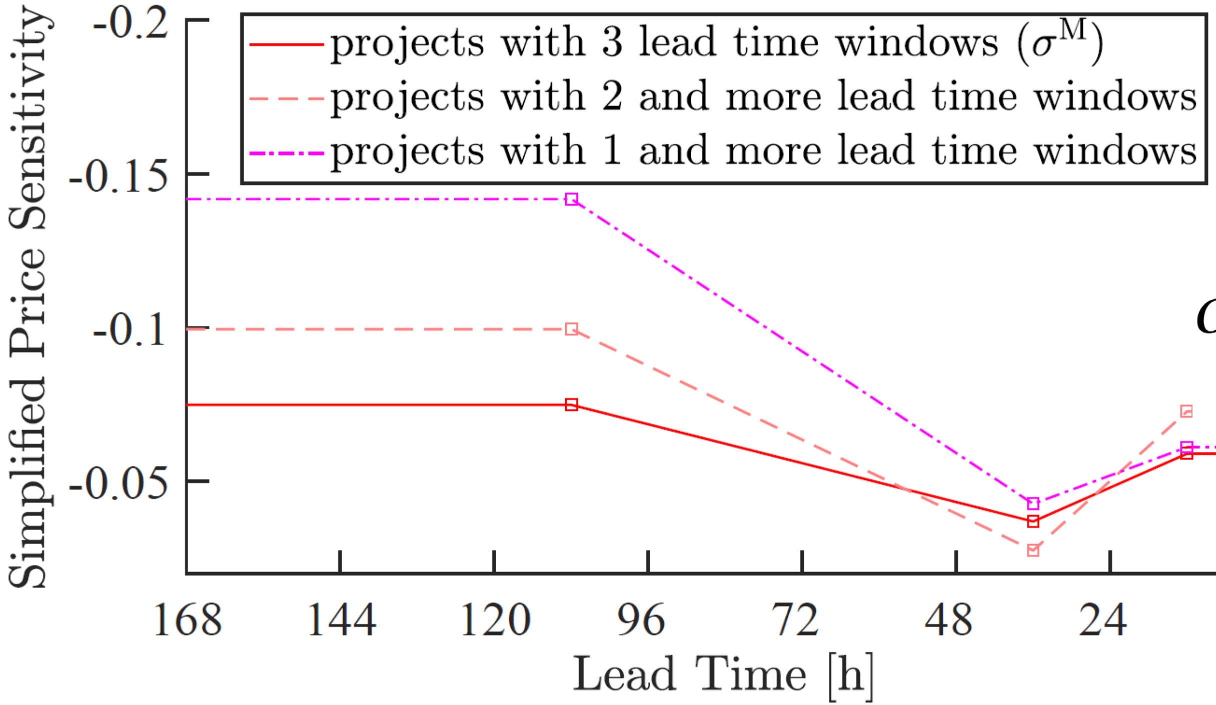
Stated Sensitivity: Pilot Project Review



$$\sigma_w = \frac{PAI_w}{\frac{P_w - C_w}{C_w}}$$

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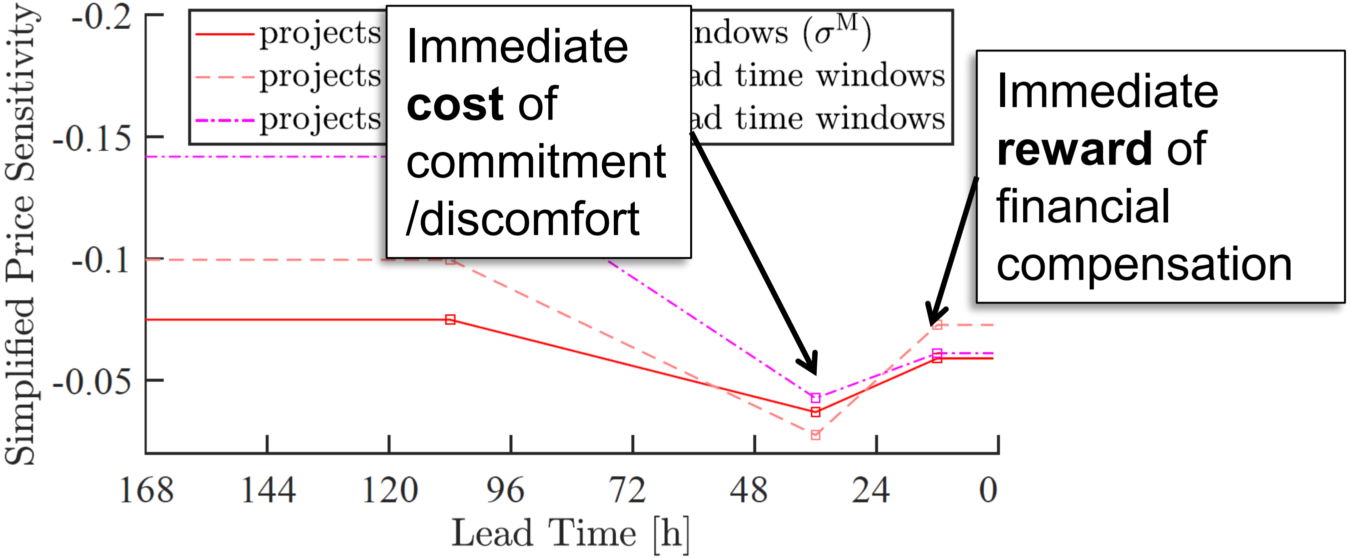
Possible Explanation

- When ***costs** are immediate*, you tend to ***procrastinate***; if you are aware you will procrastinate in the future, that makes you perceive it as more costly to procrastinate now.
- When ***rewards** are immediate*, you tend to ***preproperate***; if you are aware you will preproperate in the future, that makes you perceive it as less costly to preproperate now.


Doing It Now or Later

O'Donoughe and Rabin, "Doing It Now or Later", 1999



Measured Response: Survey Data

- 400 respondents
- Mälarenergi (DSO) customers

Table 5: price sensitivity obtained from the survey

Lead Time	24 h	6 h	2 h	1 h
Elasticity	-0.0462	-0.0670	-0.0576	-0.1272

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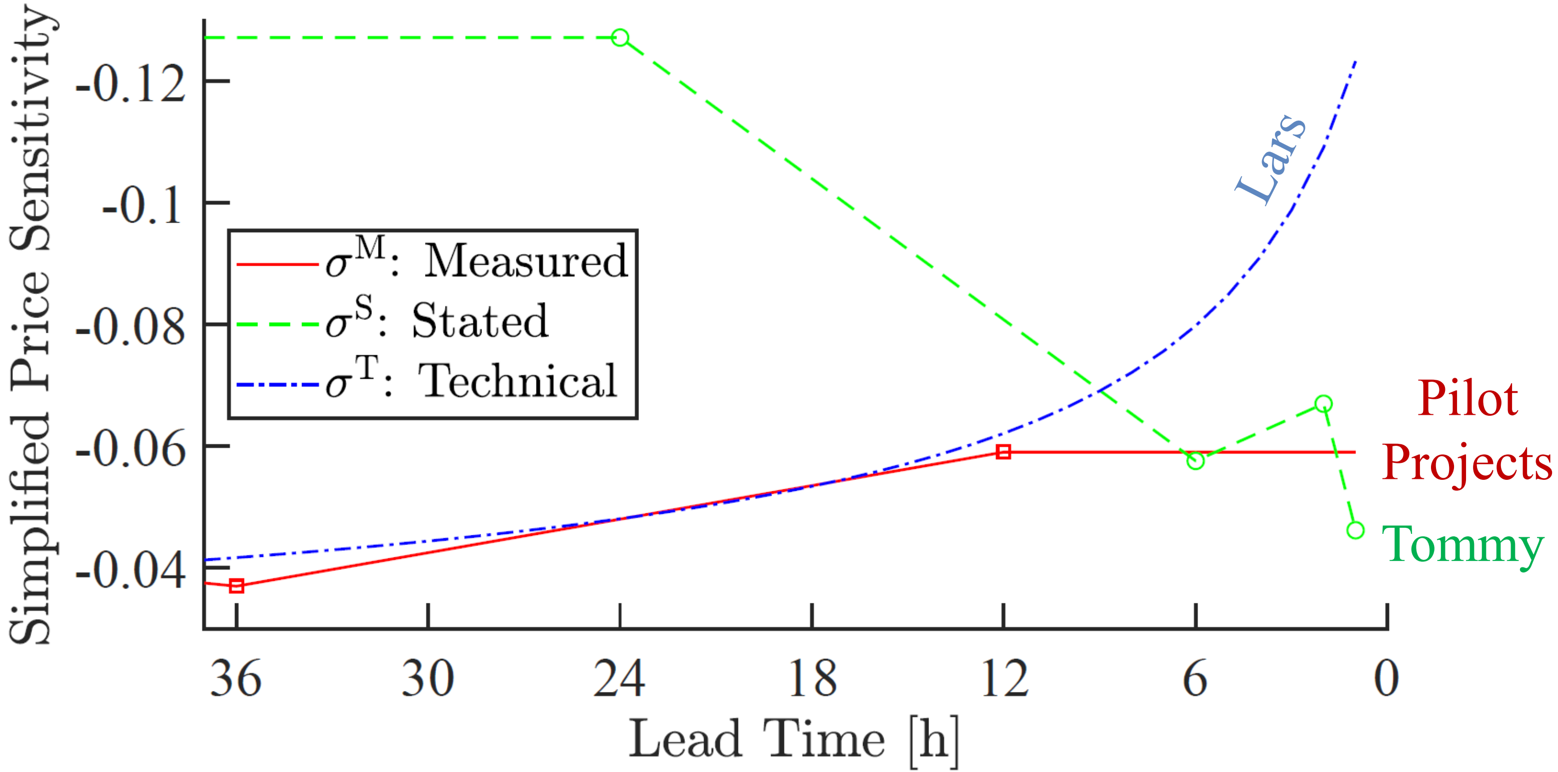
Stated and Measured Price Sensitivity



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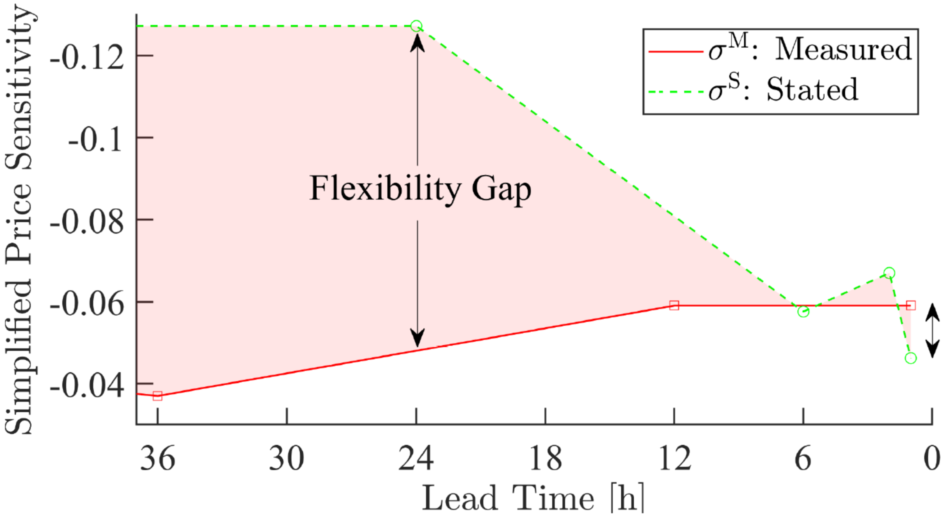
Questions and Discussion



- What is the reason for the difference between **stated** and **measured** price sensitivity?
- How will this difference affect consumers in practise?
- How is consumer flexibility used today?
- How does the uncertainty in price sensitivity affect energy companies?

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