

# Flexible Demand and Supply in Nordic Energy Markets

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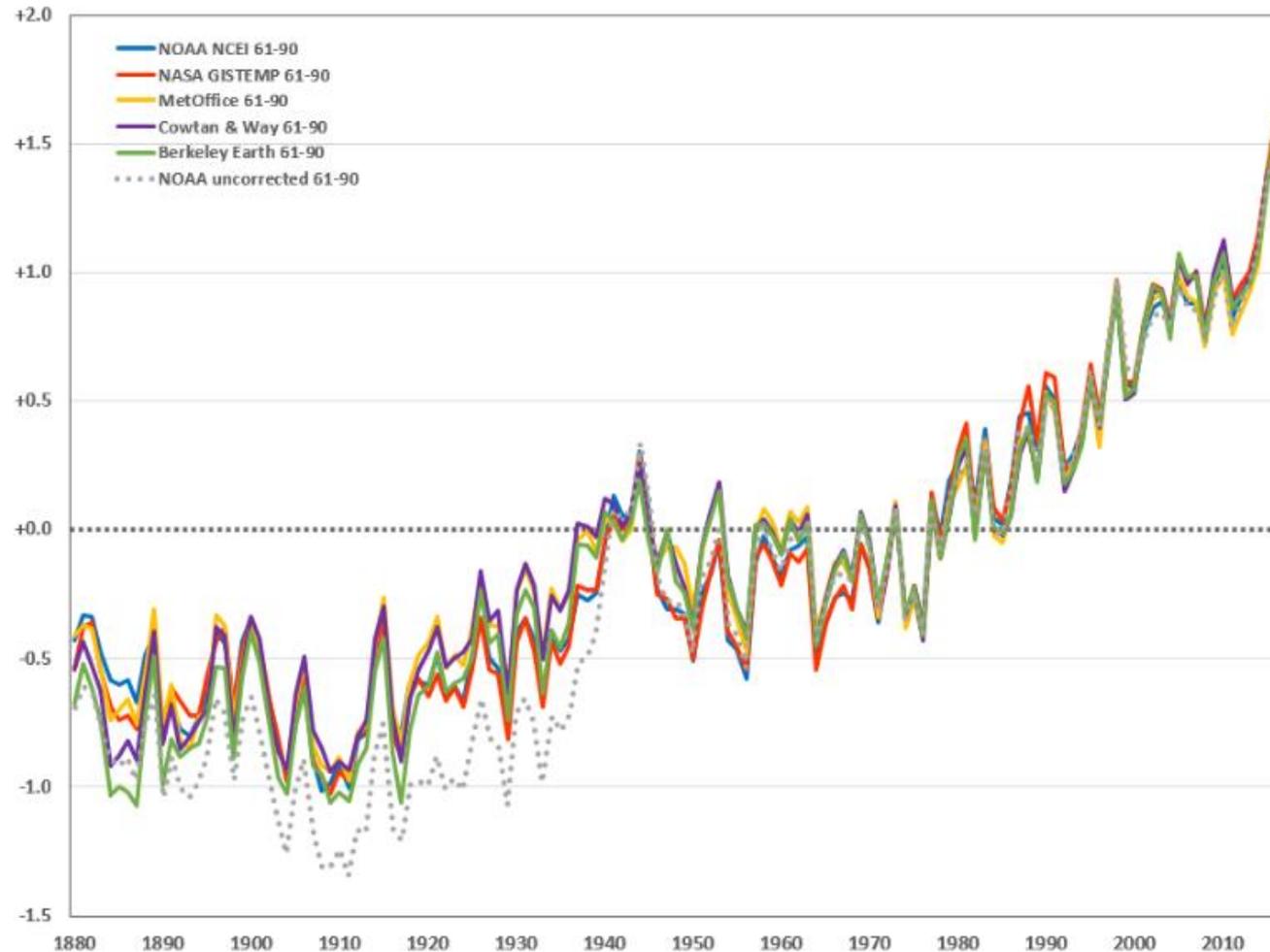
# Outline - Electricity market in transition

- WHY?
- HOW?
- ARE WE READY?

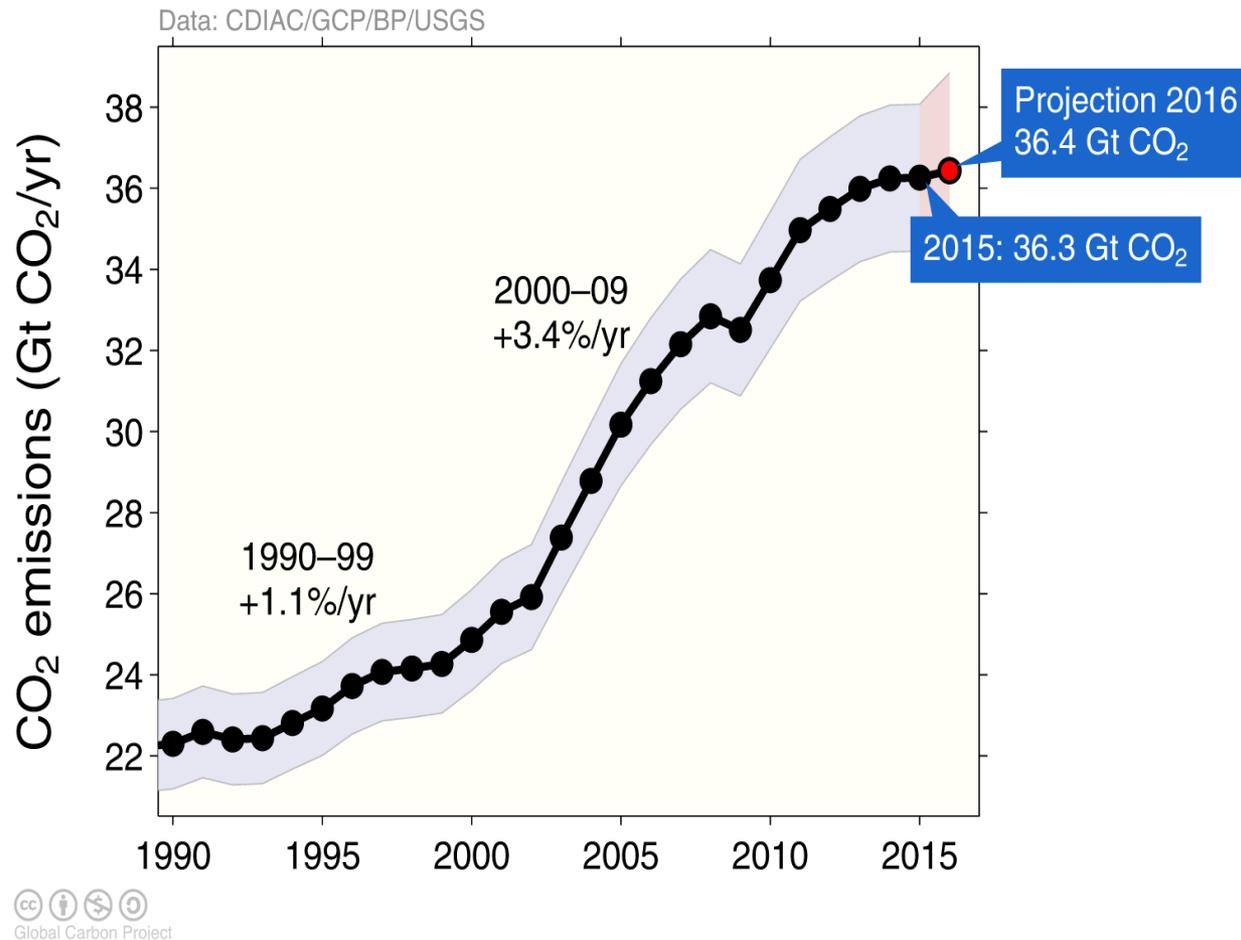
**WHY?**

# The Earth's average temperature

Several major datasets: Relative to a common 1961-90 base period

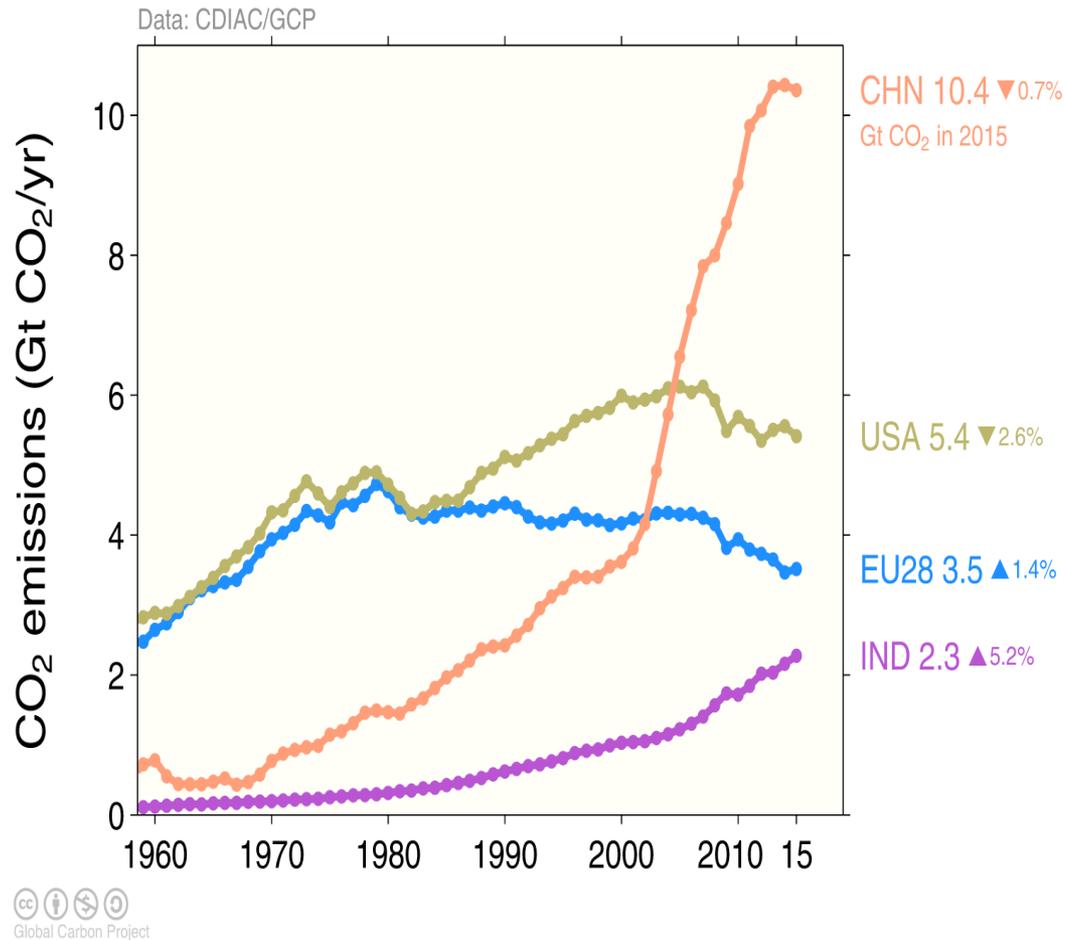


# Emissions from fossil fuel use and industry



# Top emitters: fossil fuels and industry (absolute)

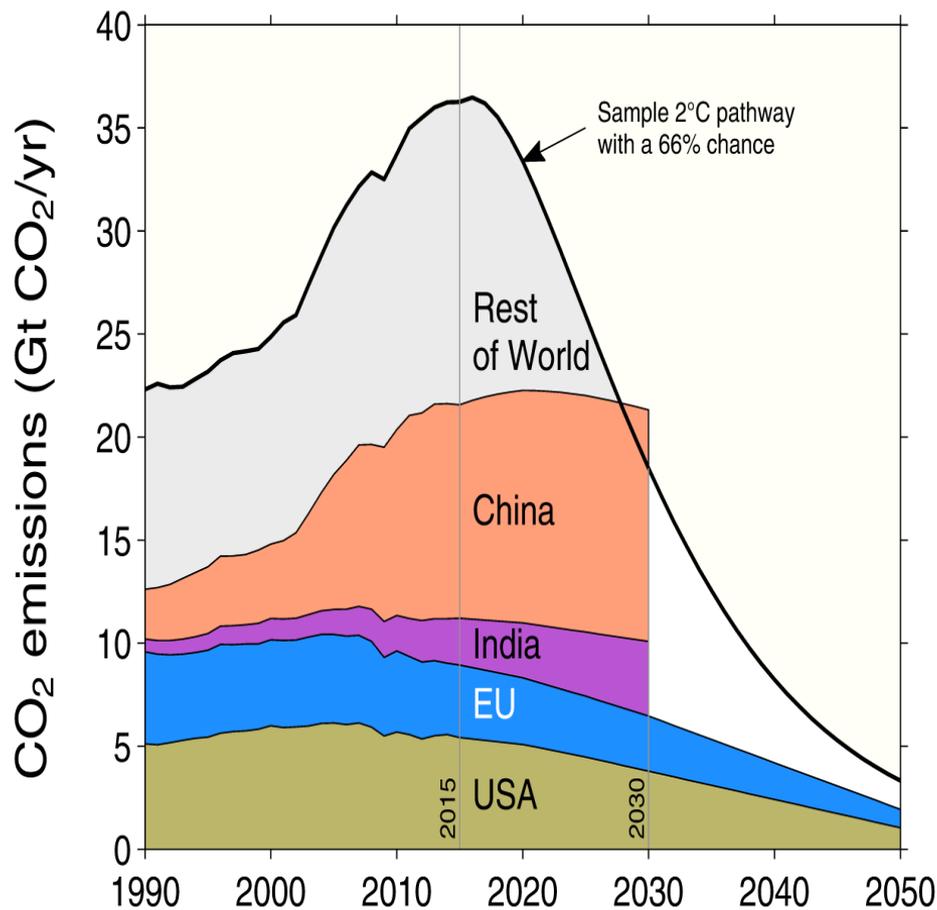
The top four emitters in 2015 covered 59% of global emissions



Source: [CDIAC](#); [Le Quéré et al 2016](#); [Global Carbon Budget 2016](#)

# The emission pledges of the top-4 emitters

The emission pledges from the US, EU, China, and India leave no room for other countries to emit in a 2°C emission budget (66% chance)

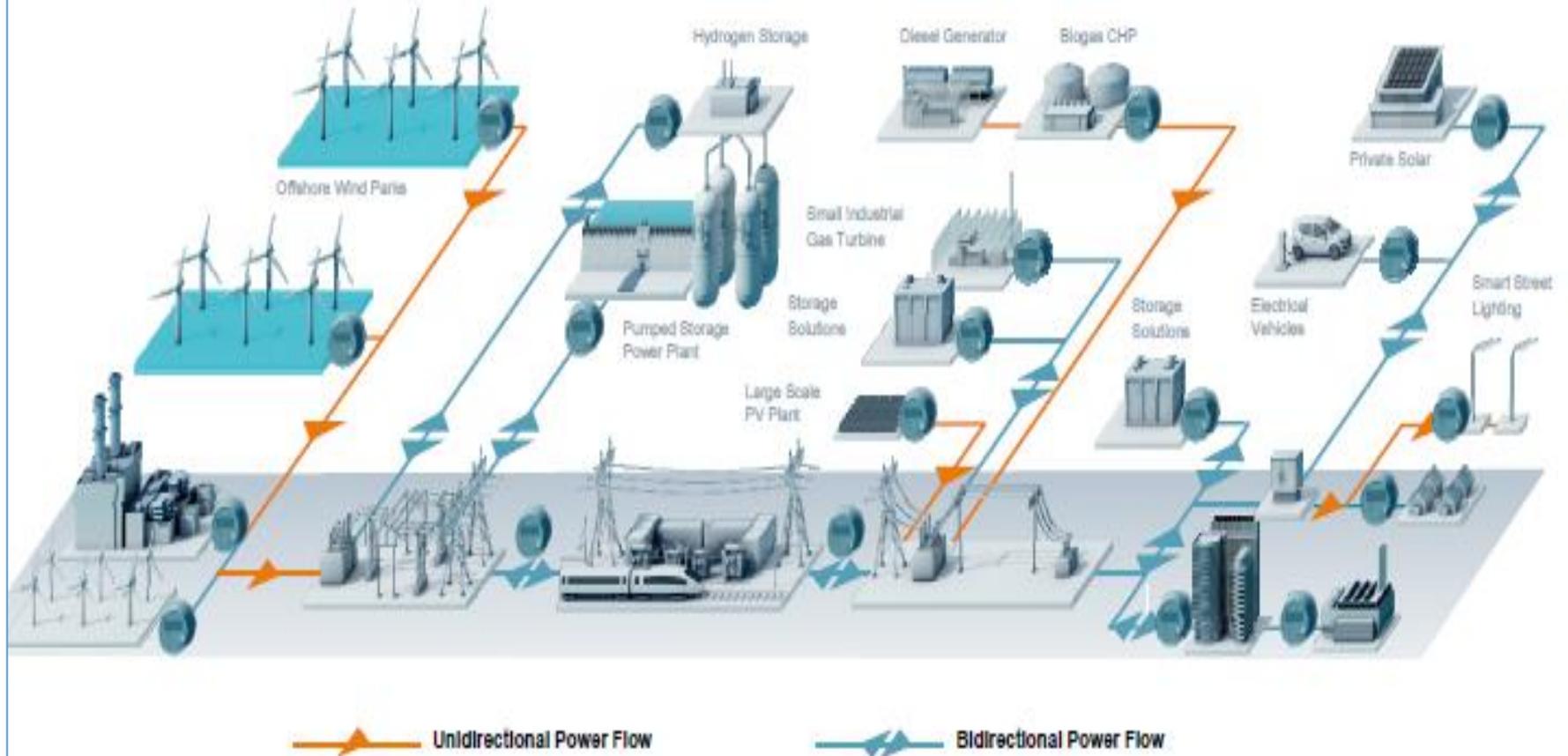


# Electricity market transition

From centralized, unidirectional grid...



## ...to distributed energy and bidirectional energy balancing



# Market Transition: challenges and opportunities

## Challenges

- Responding to variability
- Finding market based solutions
- Responding to information needs and generating communality

## Opportunities

- Increasing the efficiency and diversity of electricity system
- Creating new business opportunities
- Increasing welfare

# HOW?

## Flexible Demand and Flexible Supply As Enablers of Variable Energy Integration

Hannu Huuki, Santtu Karhinen, Maria Kopsakangas-Savolainen & Rauli Svento

# Background

- Wind power production is determined by weather
- Constant balance requirement in power grids
- Problems are arisen
  - Especially at high shares, challenging to integrate wind power into electricity system
  - Economic value of wind depends highly on correlation between demand and wind output
- Problem is very system-specific: how supply and demand react to wind power variation?

# Solving the problem in the Nordic power market context

## FLEXIBLE DEMAND

Real-time prices reflect the power system's condition  
– incentivize demand response

## FLEXIBLE SUPPLY

Nordic power market area has a lot of hydro power –  
consider it as a large-scale energy storage

# Real-Time Pricing (RTP)

There are three necessary conditions for active involvement of final consumers (Wolak 2017).

1. Customers must have the necessary technology to record their consumption on an hourly basis.
2. Second, they must receive actionable information that tells them when to alter their consumption.
3. Third, they must pay according to a price that provides an economic incentive consistent with actionable information to alter their consumption.

Automated response technologies are already available.

The technology shift eligible loads across the hours of a day to lower-cost times, reshaping the daily load curve of the households.

It can connect all small customers as a controllable power cloud and provides private households inbuilt flexibility to energy market.

(see BCDC energy and Cleworks/Clebox.)

# Nordic hydro power

Table 1. Nordic power production (Data: ENTSO\_E)

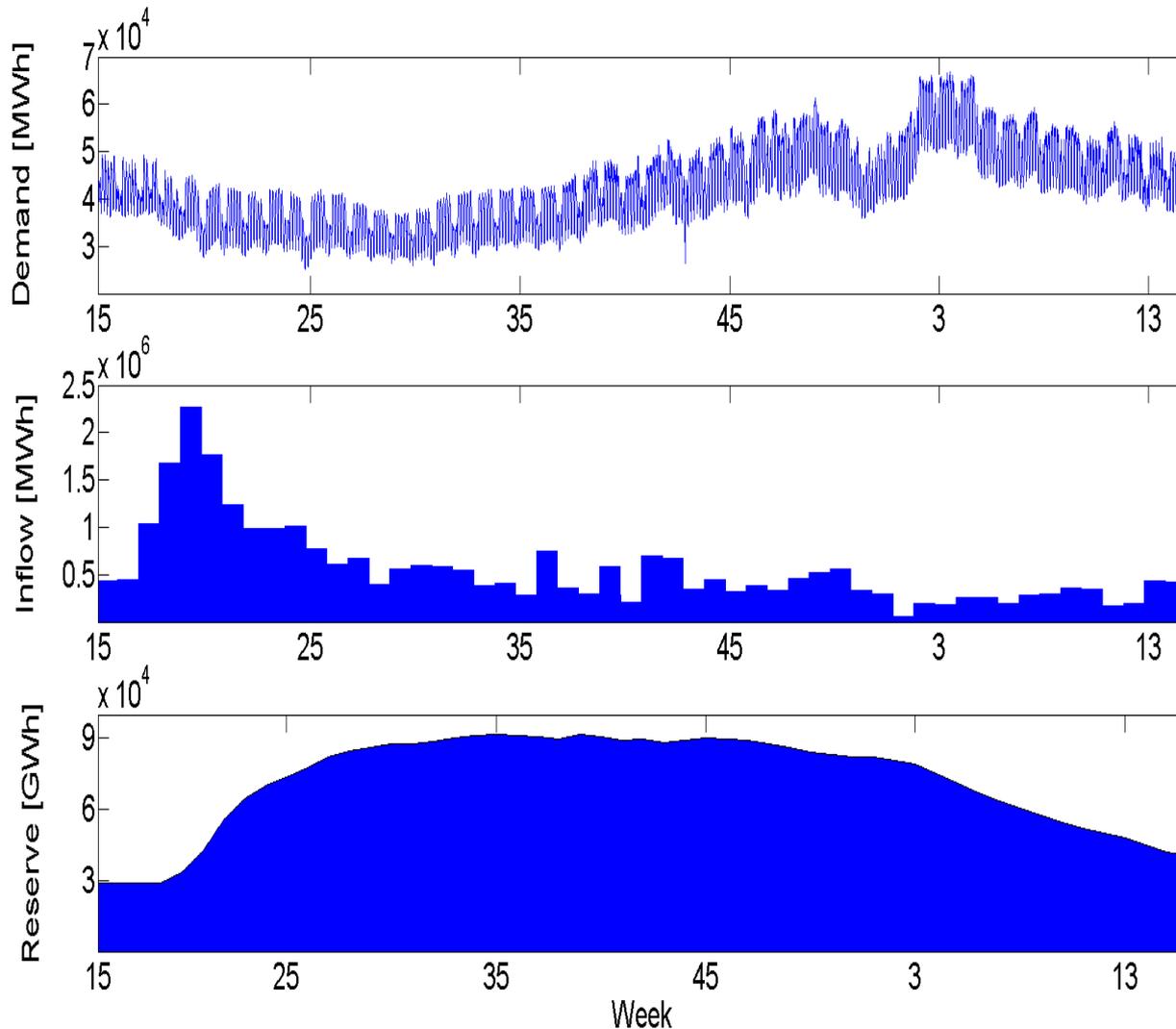
Production [GWh]	Nuclear	Fossil fuels	Renewables	Hydro	Other
Denmark	0	14603	15963	16	0
Finland	22654	16573	12146	13200	807
Norway	0	3469	2309	136630	0
Sweden	62176	3483	21317	64167	0
Total	84830	38128	51735	214013	807
Total [%]	21,8	9,8	13,3	55,0	0,1

- Reservoir hydro power in Norway and Sweden
- Run-of-river hydro with some storage in Finland

# Research question

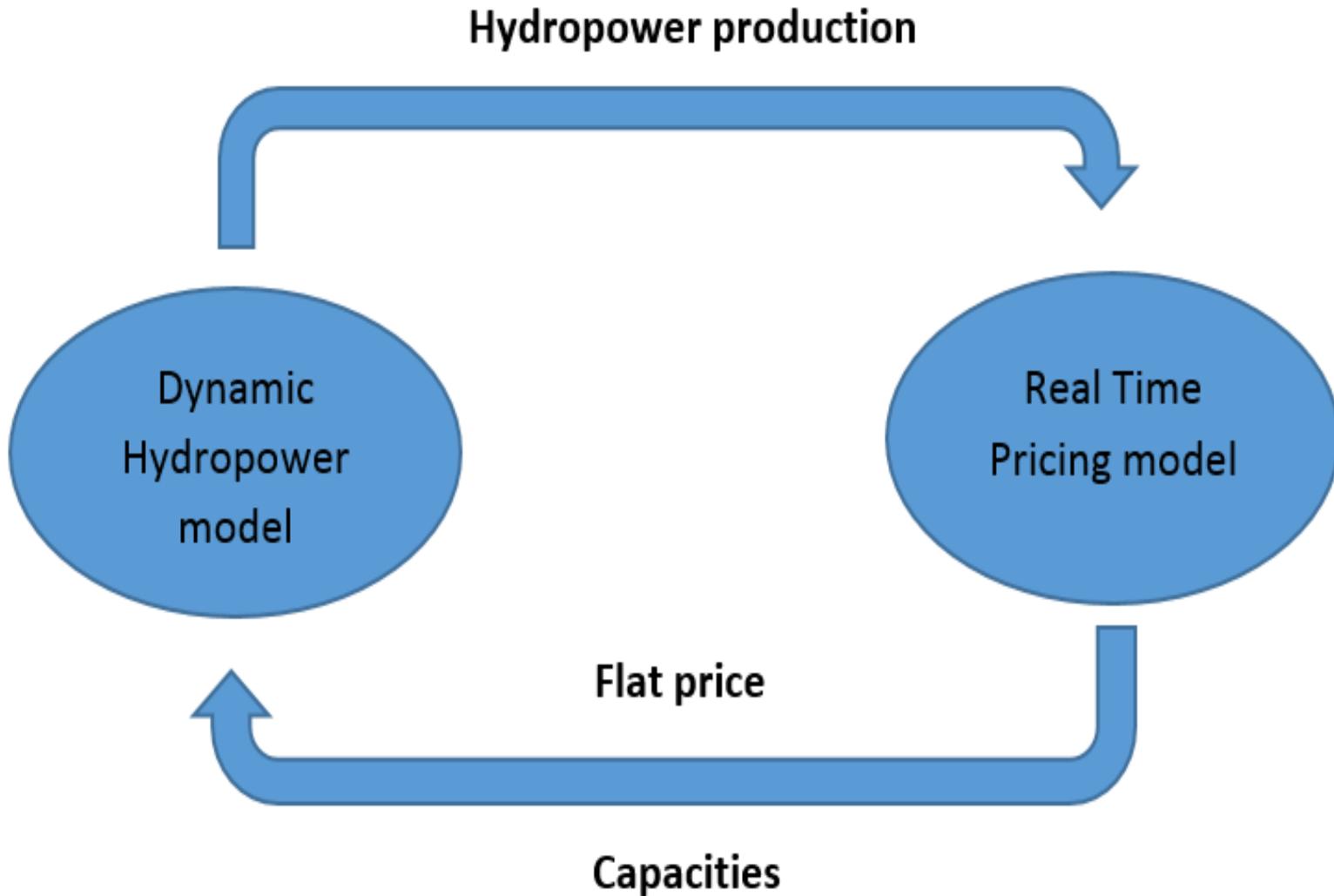
- How the integration of wind power (10%, 15%, 20% of demand) is made more efficient by dynamically optimizing hydro power production and with RTP customers (33.3%, 66.6%, 99.9% of all customers)?
- Results:
  - Thermal power capacity and its utilization rate
  - Customer billing costs
  - Total profits
  - CO2 emissions

# Model data



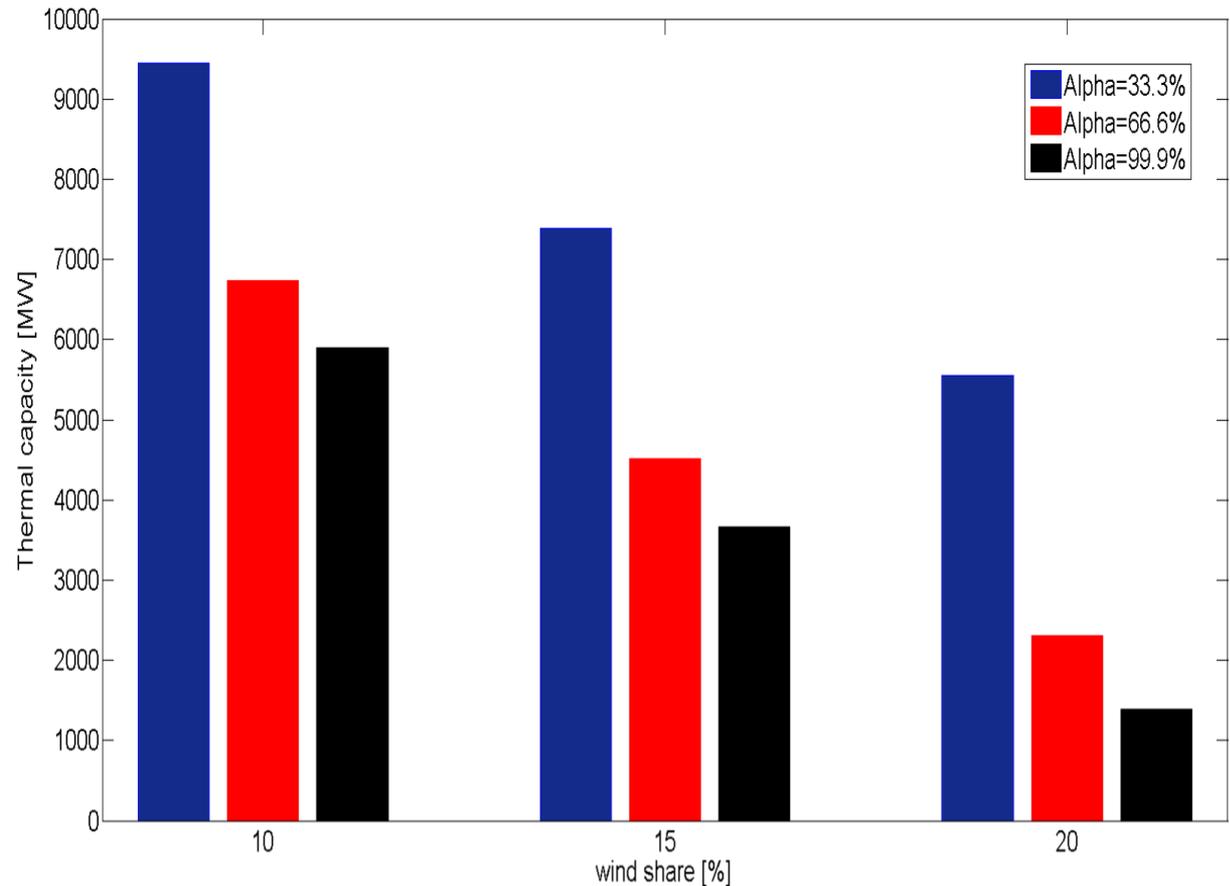
- Hydro is modelled as a reservoir hydro able to store energy
- Hydro reservoir is allocated over the hydrological year (starting from Spring inflow peak)

# Model iteration



# Results: Thermal power capacity

- Higher share of wind power reduces thermal capacity
- Higher RTP-share leads to lower thermal capacity



# Results: Profits and CO2 emissions

	10 % wind			15 % wind			20 % wind		
<b>RTP share</b>	33.3	66.6	99.9	33.3	66.6	99.9	33.3	66.6	99.9
	%	%	%	%	%	%	%	%	%
<b>Billing €/MWh</b>	62.2	65.0	65.7	59.7	63.7	64.8	56.7	61.8	63.6
<b>Total profits €/MWh</b>	21.6	25.6	26.6	19.6	24.9	26.4	17.0	23.6	25.8
<b>Emissions CO<sub>2</sub>/MWh</b>	15.9	14.3	13.9	11.3	8.87	8.16	7.56	4.14	2.89

**ARE WE READY?**

## Wolak (2017)

- Customer choice is a crucial driver of the adoption of new technologies in the electricity sector.
- Efficient pricing without market participants having the freedom to respond to these economic signals will not produce the intended economic benefits to consumers.

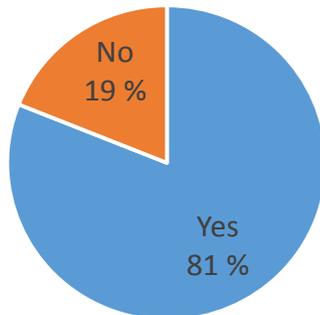
# Households' willingness to offer flexibility to the energy market with the help of flexible energy usage and dynamic contracts

Enni Ruokamo, Maria Kopsakangas-Savolainen, Teemu Meriläinen and Rauli Svento



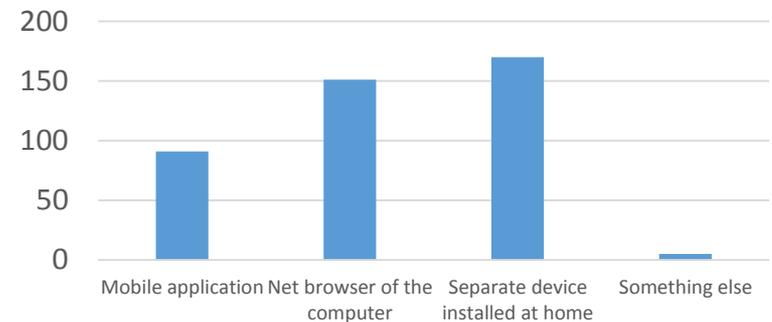
# Following information

Would you be interested in following your electricity consumption with some device and/or service if you had the opportunity and if it...



If willing ...

... with what device/service would you be interested in following your household's electricity consumption?  
(N=308)

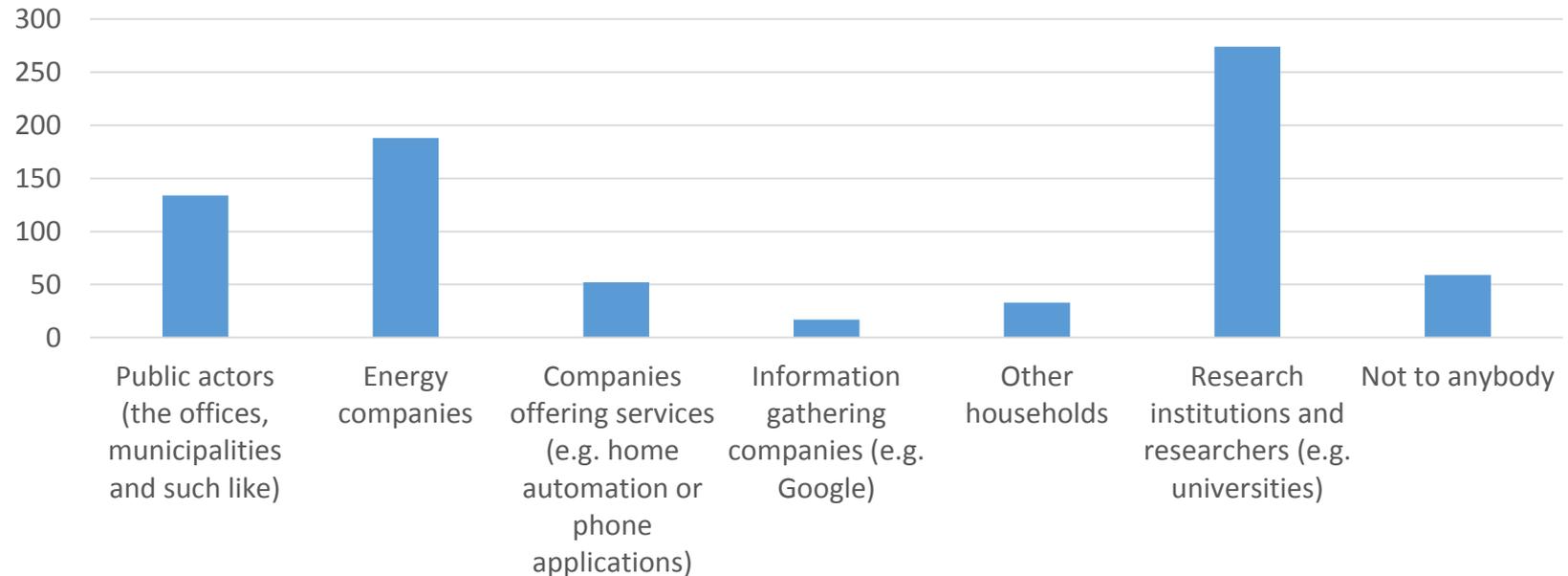


How much would you be willing to pay at maximum (as a single payment) for a separate device which is installed in home and gives detailed information about your electricity consumption (for example device-specific consumption)? (N=170)

**On average 47,5€**

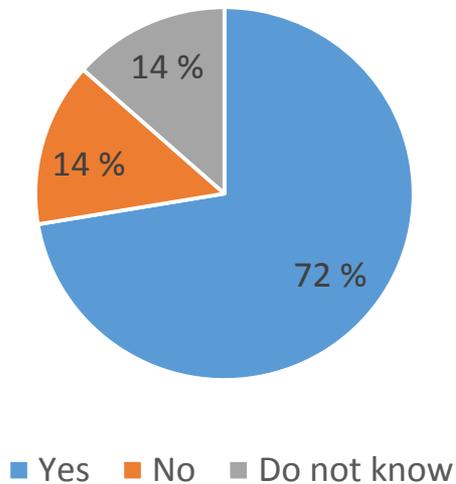
# Sharing information

To what of the following actors would you be ready to share information about your electricity/energy consumption? (N=380)

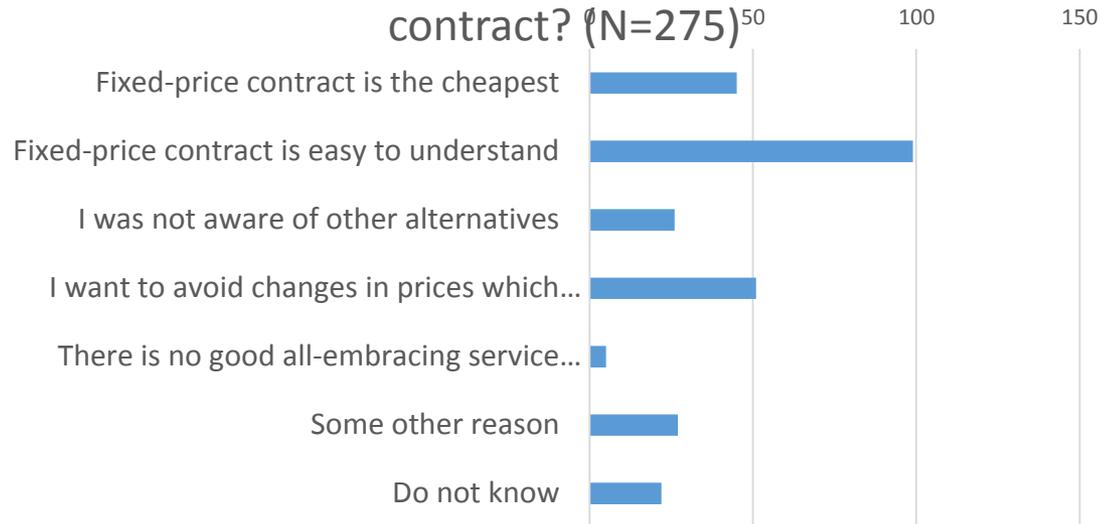


# Existing contracts

Do you have a fixed-price contract? (N=380)

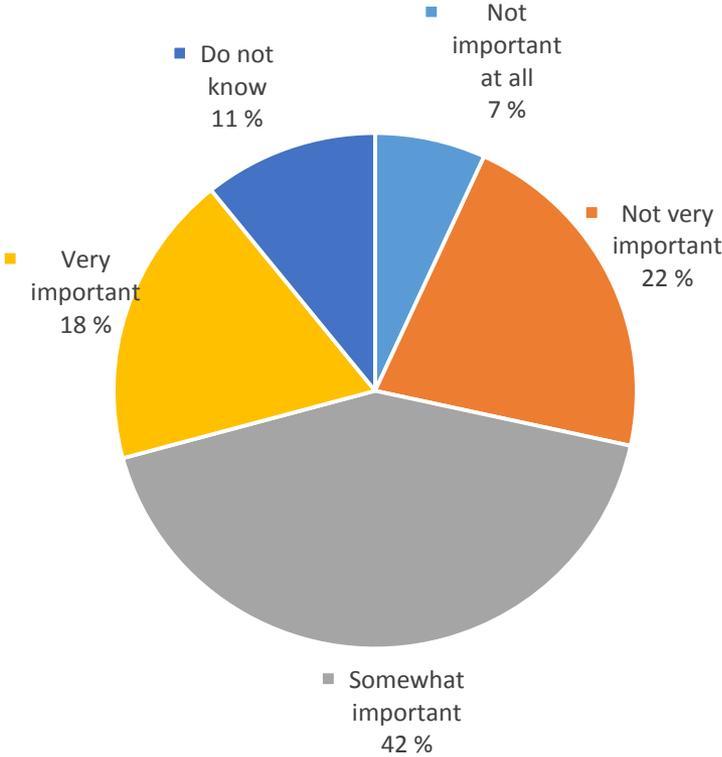


What of the following alternatives describes the best the reason for choosing the fixed-price contract? (N=275)<sup>50</sup>

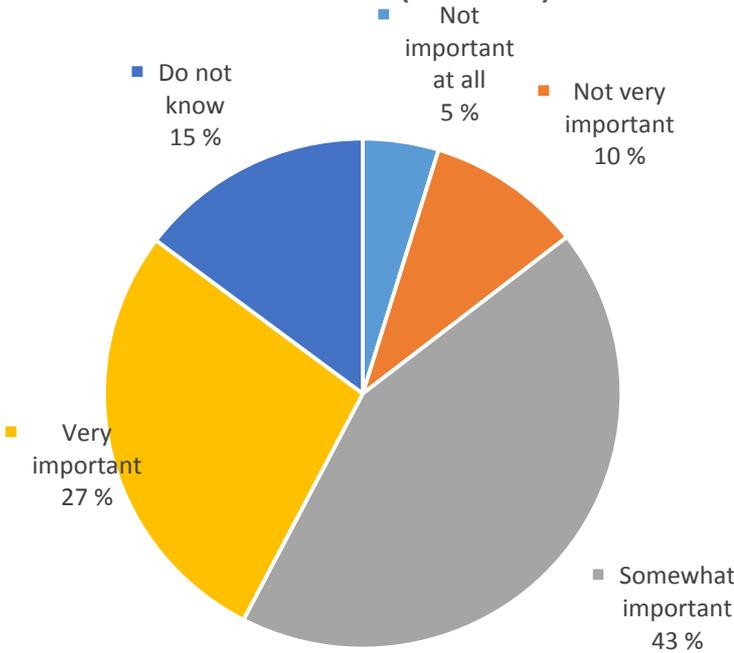


# Opinions about contracts

How important it is for you that RTP contract is also an alternative in the electricity sales contracts? (N=380)

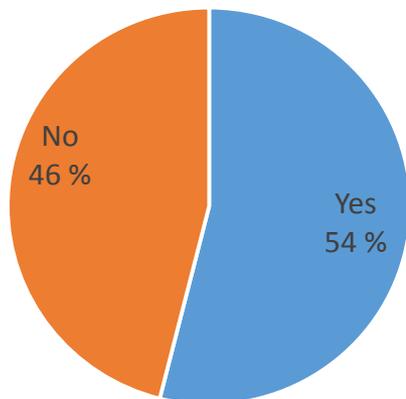


How important it is for you that a power-based pricing contract would be available in the electricity distribution contracts? (N=380)



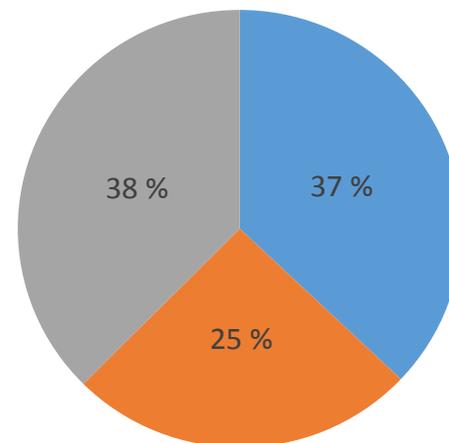
# Remote control of electricity usage

Are you ready to get a contract that includes remote control of the electricity usage (the consumption is postponed out of the peak hours of the energy demand, if necessary,)? (N=380)



If willing ...

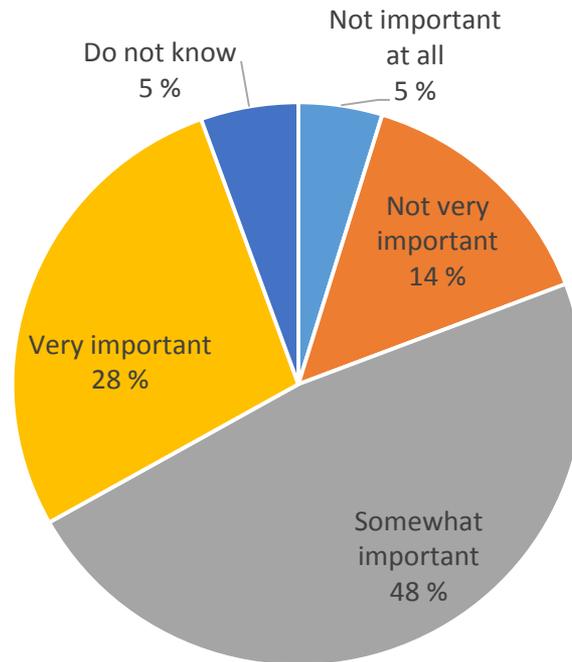
...to what kind of remote control would you be ready to participate? (N=205)



■ My electricity usage can be automatically adjusted during the times agreed in the contract.

# Demand response and emissions

How important do you think that the flexibility offered by households is in reducing the carbon dioxide emissions of energy market? (N=380)



# Literature

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