

3<sup>RD</sup> INTERNATIONAL CONFERENCE ON  
**SMART ENERGY SYSTEMS AND  
4<sup>TH</sup> GENERATION DISTRICT HEATING**

COPENHAGEN, 12-13 SEPTEMBER 2017



**Towards a smart energy system approach in Europe – Enabling  
robust and cost-effective Renewable Energy investment strategies**

Wednesday 13 September 2017

Location: National Museum Denmark, Copenhagen

Brian Vad Mathiesen, Head of RE-INVEST



#SES4DH2017



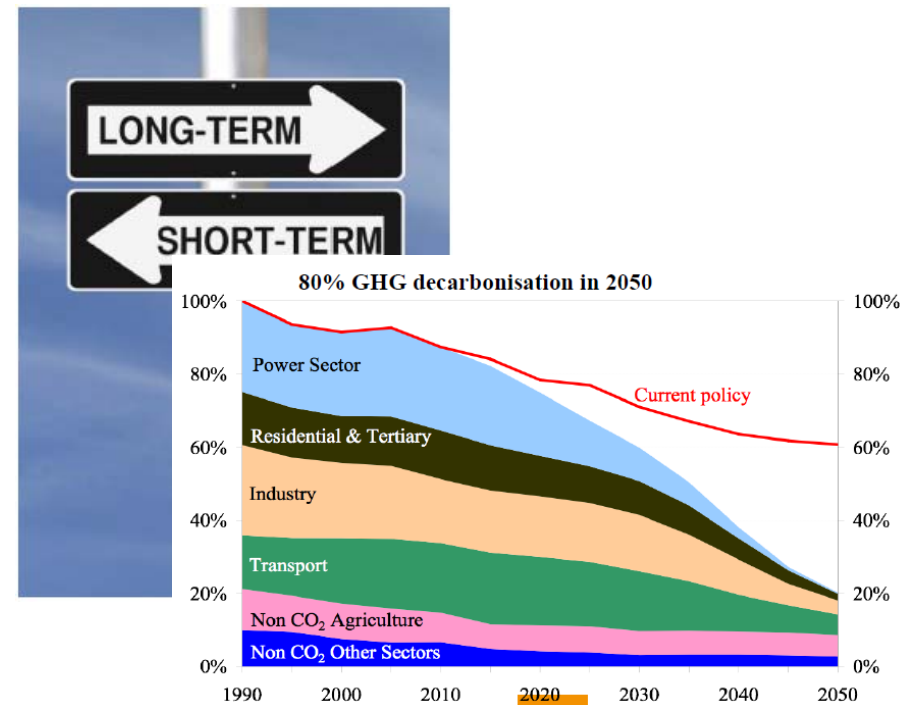
# Targets and challenges in Europe

## Long-term target (2011)

- 80-95% reduction of CO emissions in the energy sector

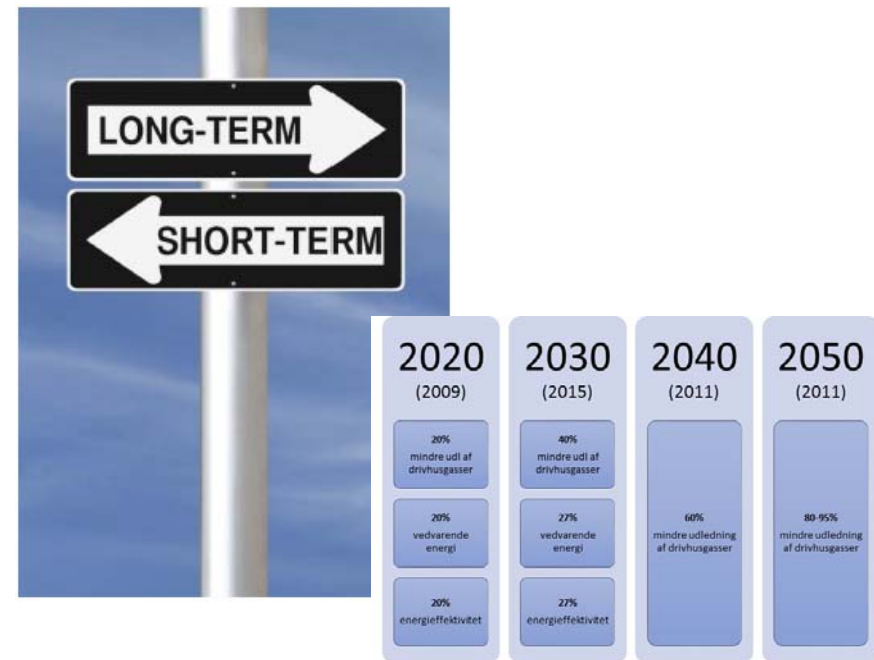
## Short term in the energy union (2015)

- Security of supply (el and gas)
- An integrated market
- Energy efficiency
- Lower CO<sub>2</sub> emissions
- Research and innovation
- New directives (RED, EPBD, ED etc.)



# Focuses in Europe

- Energy Savings
- More electricity in the energy system-
- More decentral production
- Gas in a transition
- Contribution from nuclear
- Reductions in energy imports and prices
- Much more Renewable Energy
- More investments – less costs for fuels
- Increasing electricity prices until 2030 – then reductions
- Large reductions in emissions is technically and economically possible.





# The Vision in RE-INVEST

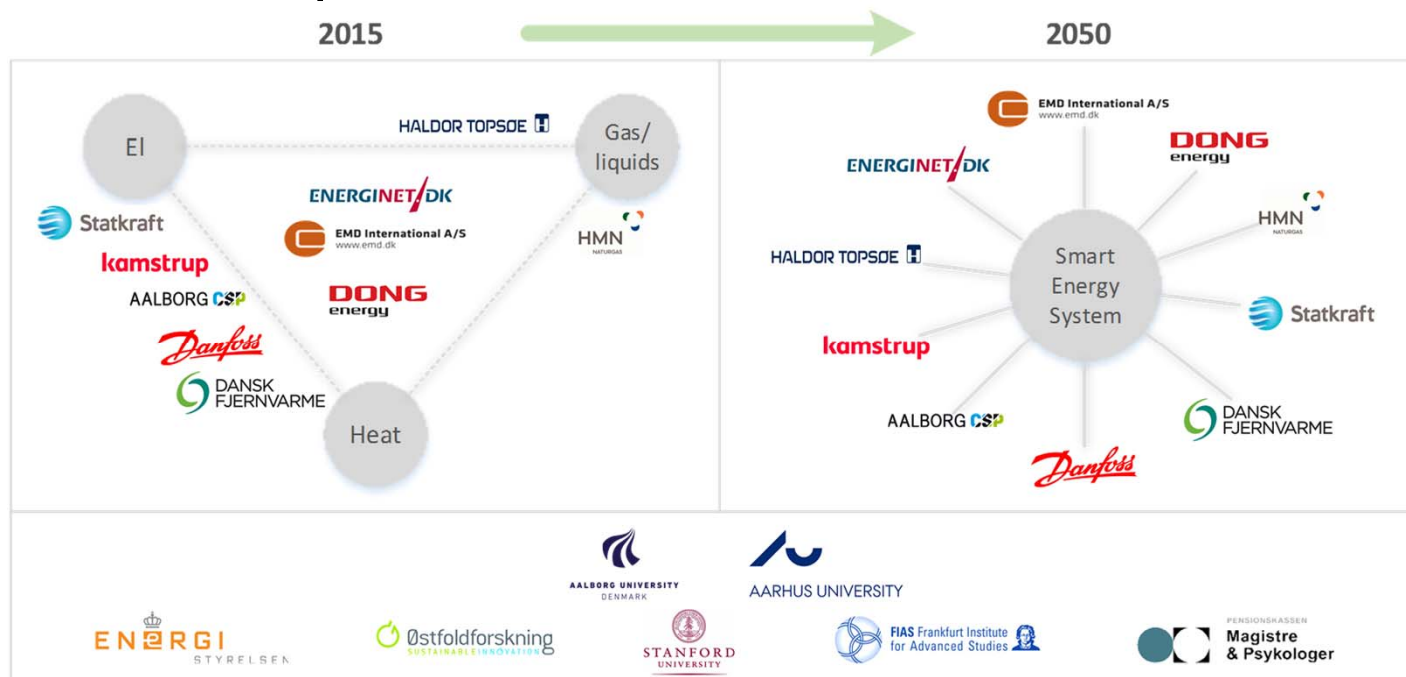
**The vision of RE-Invest** is to overcome the described **silos-thinking** that characterizes traditional energy sectors, by using a **two dimensional interconnectivity approach** as well as existing and new energy infrastructures.

The aim of this is dual:

- 1) to further develop the Smart Energy System concept and *identify synergies* in low-cost storages across sectors on one side and international electricity and gas transmission on the other side
- 2) to *support expanding markets* in Denmark and Europe for Danish industries and enable the industrial partners in RE-Invest to be early adaptors of trends in integrated energy markets, thus having cutting edge R&D for key technologies in future sustainable energy systems for value creation.



# Academics working with the private and public sector – a Partnership





### Energy System Challenges and opportunities

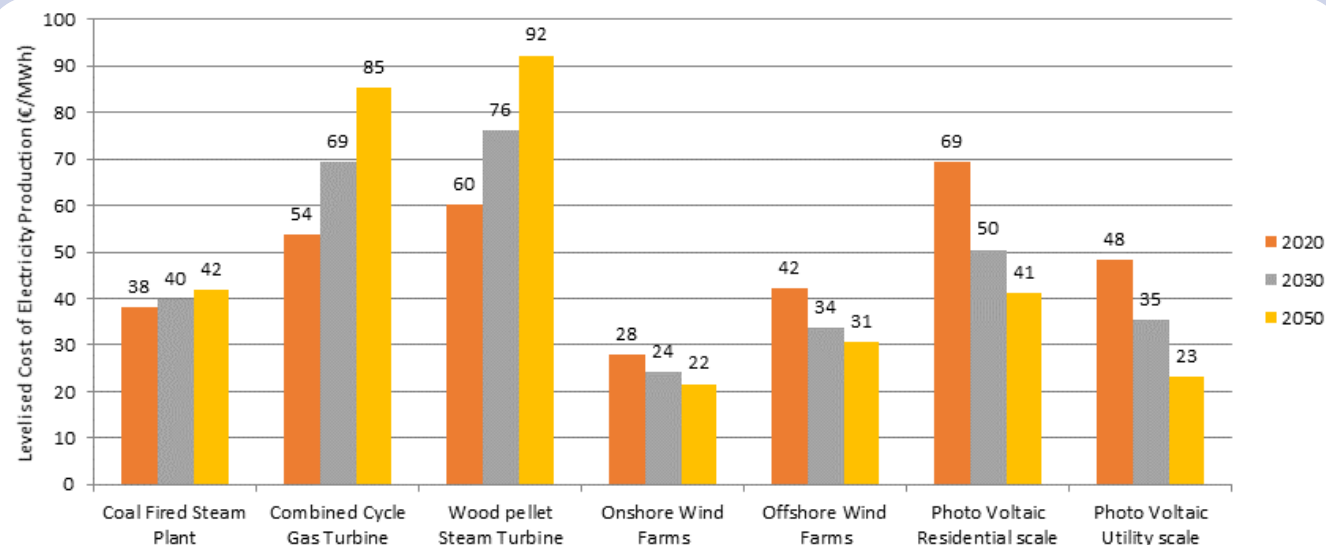
- Lower and lower Renewable Energy investment costs (Electricity especially)
- Batteries are falling in price
- Electricity prices are falling (sign of system design failure) and cannot merit investments in new capacity
- Power plants for back-up is closing down (lower operation hours)

### Questions and strategic decisions

- How should we use and balance (energy storage) more electricity from renewable energy?
- How should we re-design the energy system and how much renewable energy is needed?



(sources: EnergyPLAN cost database)



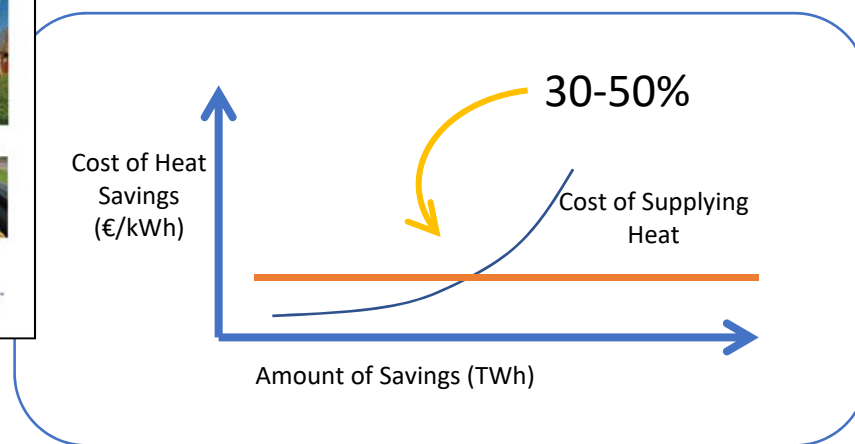
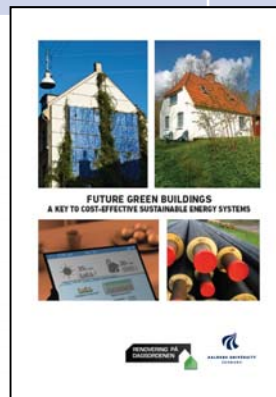
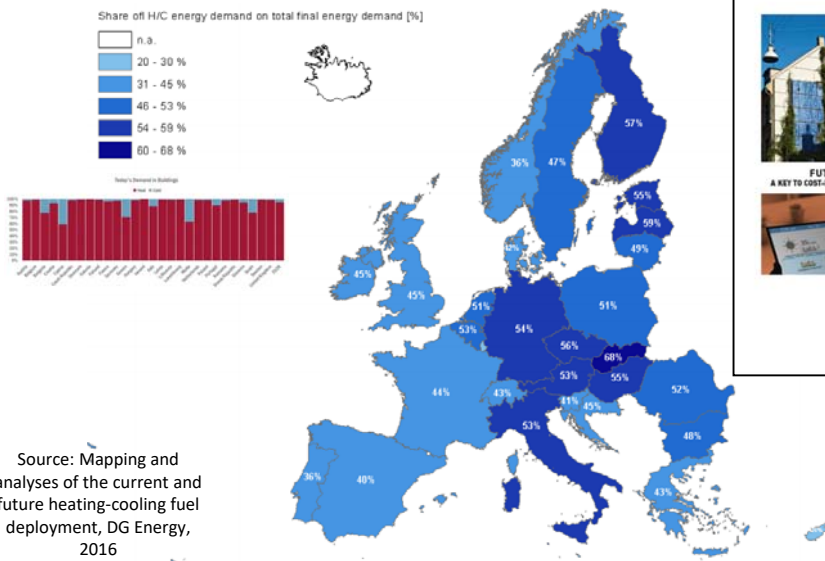


### Energy System Challenges and opportunities

- Electricity demands the smallest of the demands
- Both transport & heating/cooling demands larger
- Electricity grids are much more expensive than thermal grids/gas grids (pr. capacity)
- Energy storages have different costs in different sectors and different scales

### Questions and strategic decisions

- What are the role of the grids in the future
- How can energy storage be used across sectors to transform all demands to renewable energy cost-effectively?
- How important are energy savings in the future and what is the balance between electricity or heat savings compared to renewable energy?



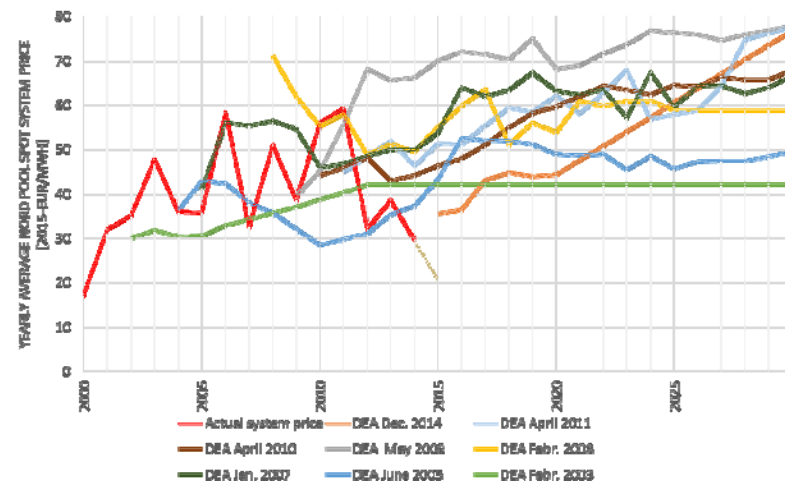


Energy System Challenges and opportunities

- Bio-refinery technology is developing rapidly but bioenergy is a limited resource and can have adverse effects outside the energy sector
- Transport sector technologies are emerging fast
- New technologies may develop
- The international energy context is uncertain

Questions and strategic decisions

- What technologies are key for the transport sector?
- What is the role of bioenergy in future energy systems?
- How can key Danish strength help on an international level and what investments are robust in an uncertain future?



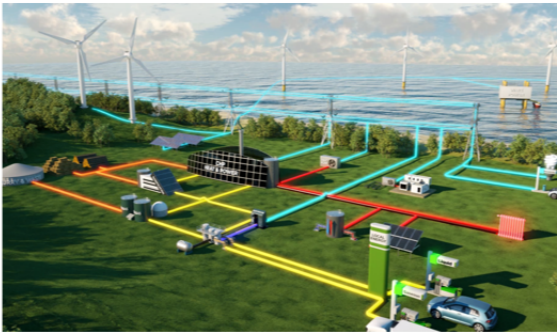




The Danish Society of Engineers, IDA  
a modern professional association for  
technical and science professionals

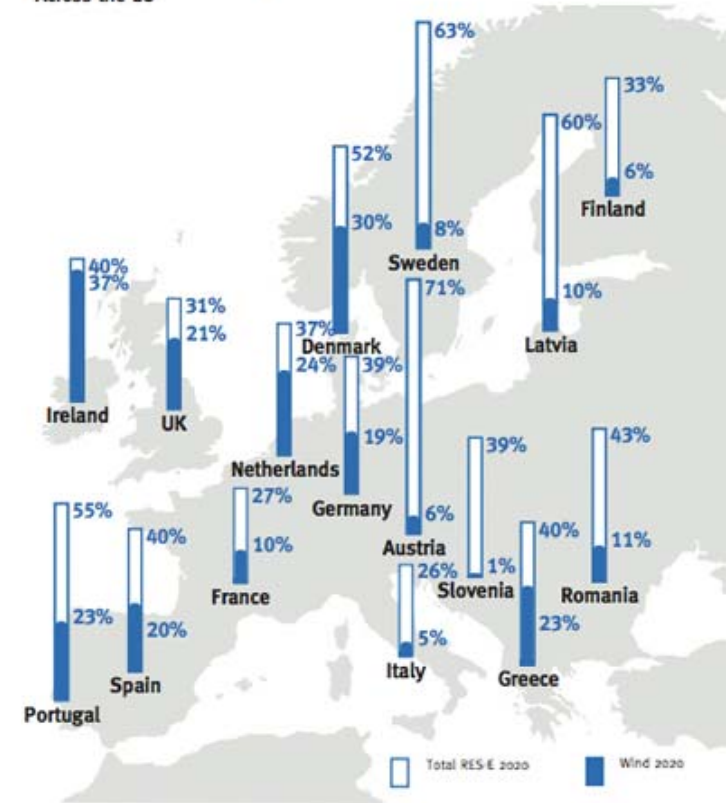
## IDA's Energy Vision 2050

A smart energy system strategy for 100% renewable Denmark



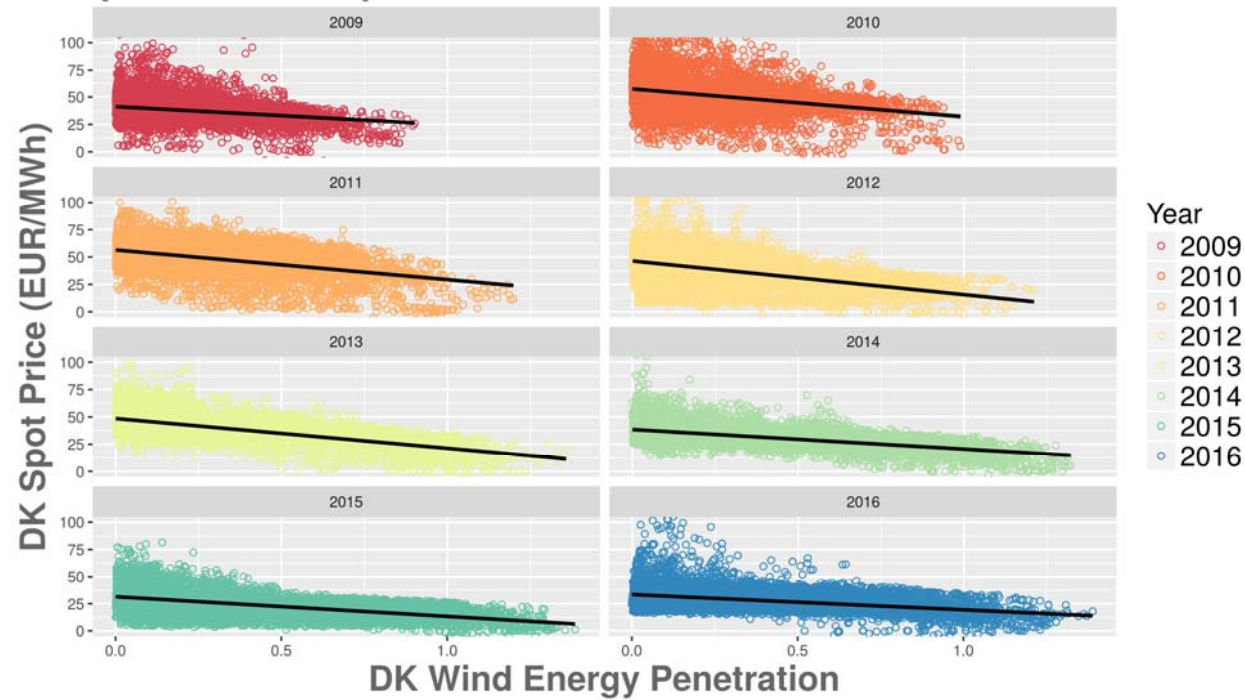
The European Union is a world leader in the deployment of renewable energy.

### 2020 Renewable Electricity Targets Across the EU



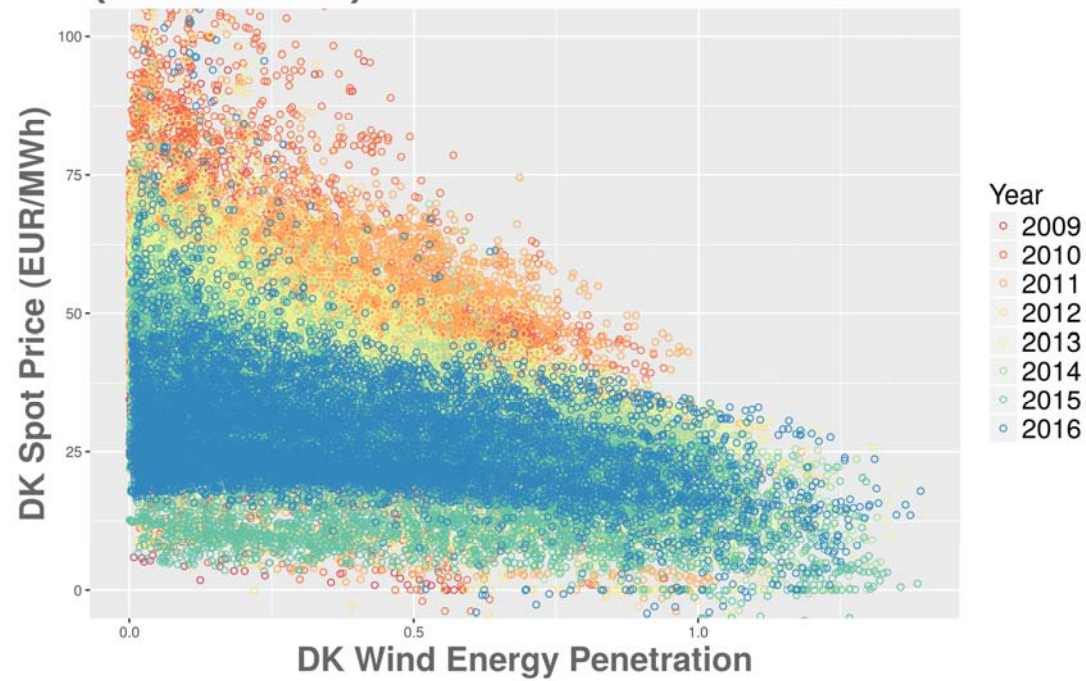


## Danish Elspot Price by Danish Wind Power Penetration (2009-2016)



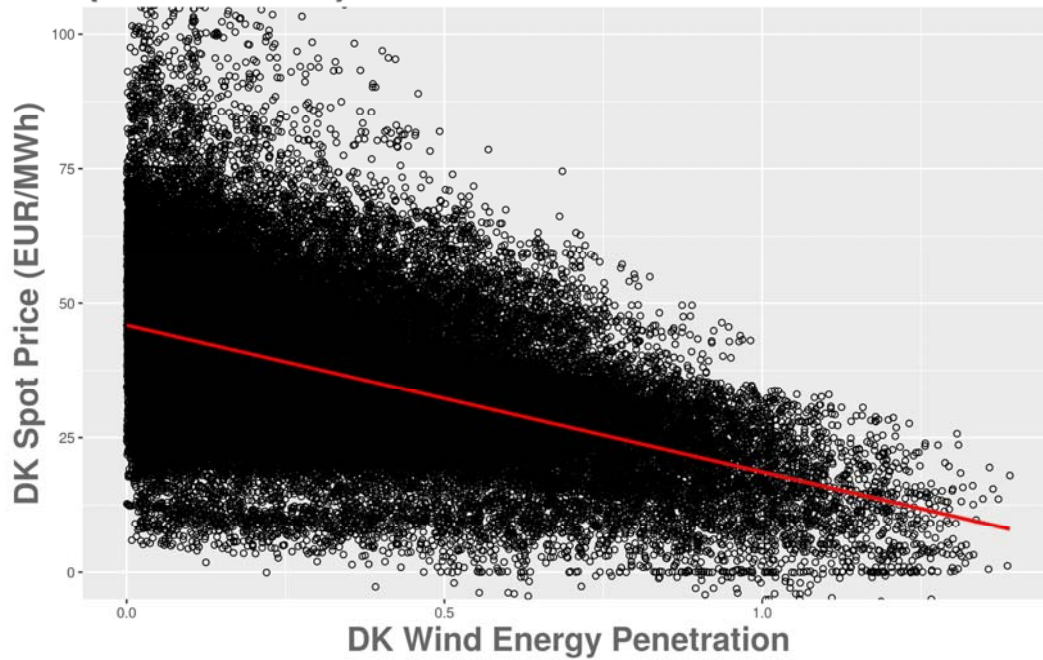


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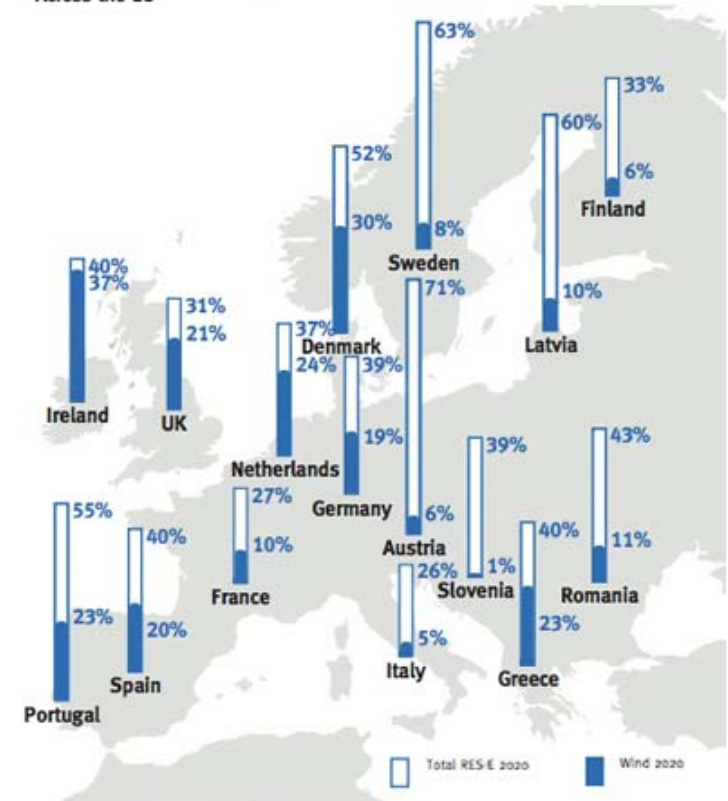


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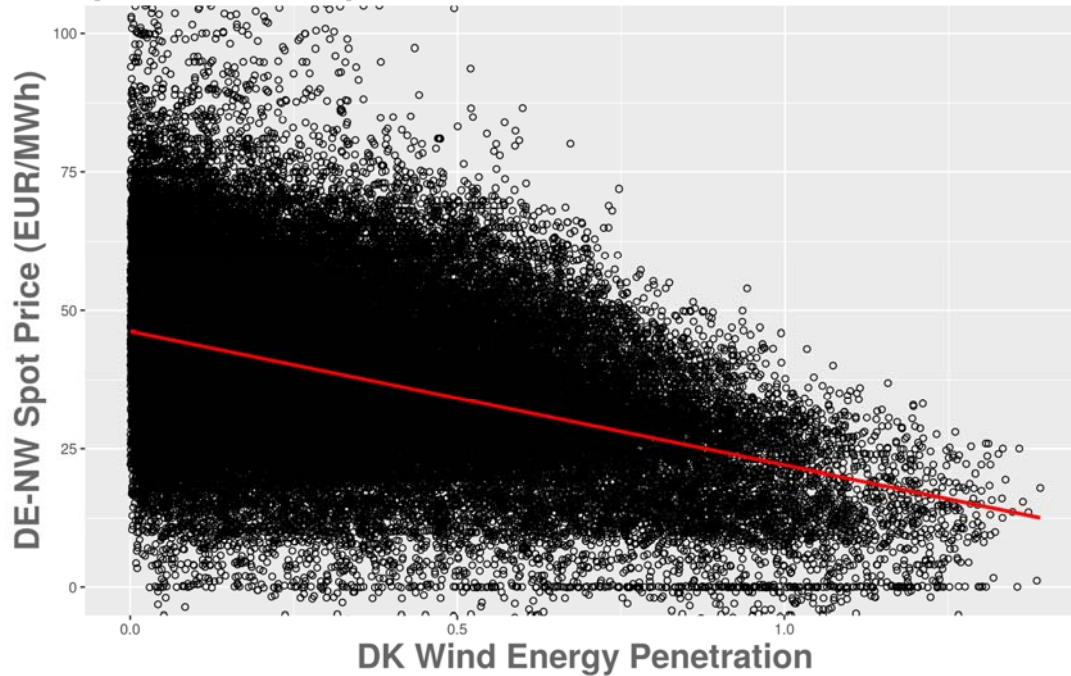
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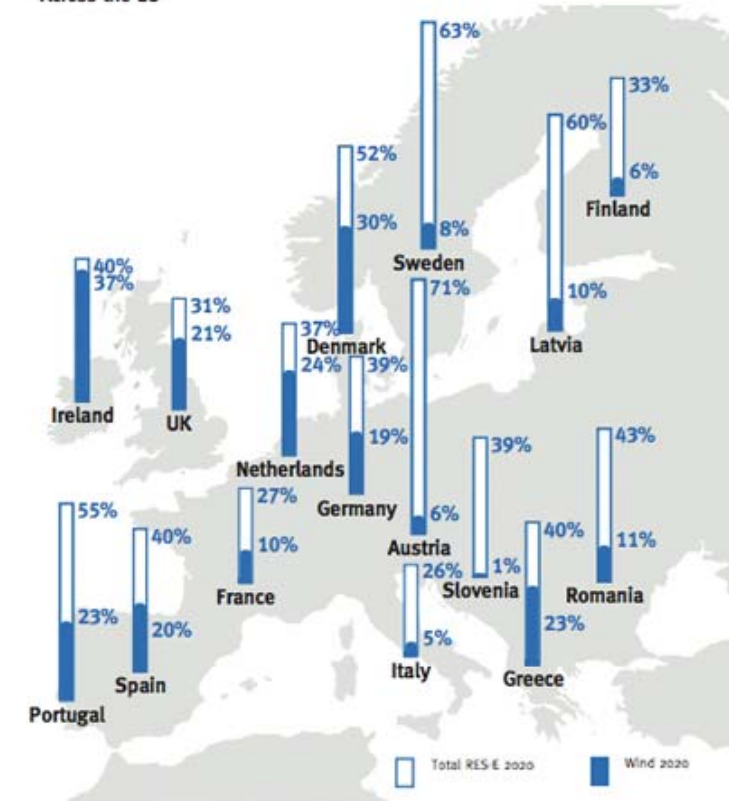


## North-western Germany Elspot Price by Danish Wind Power Penetration (2009-2016)



The European Union is a world leader in the deployment of renewable energy.

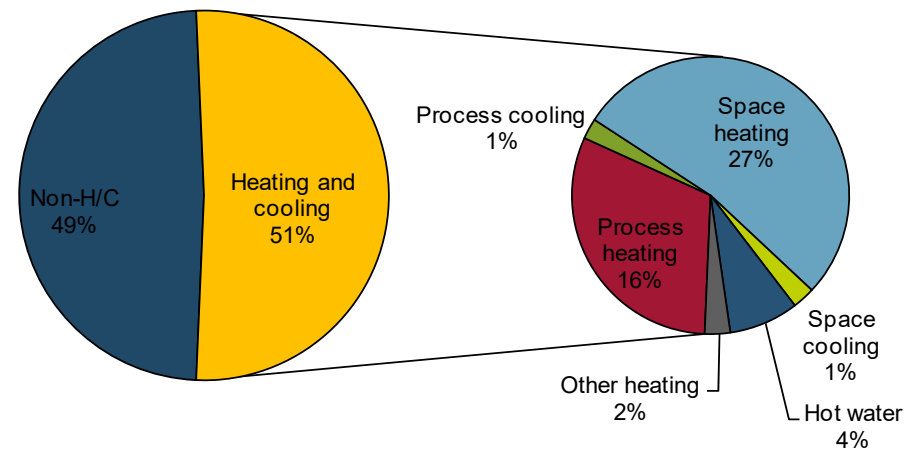
2020 Renewable Electricity Targets Across the EU





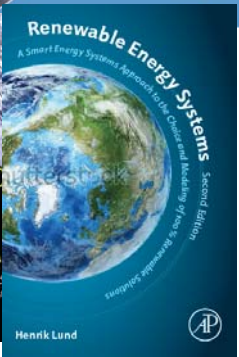
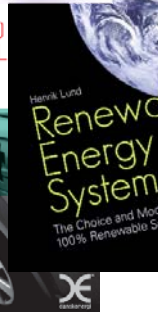
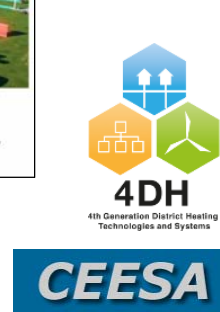
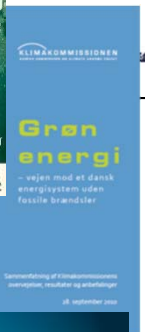
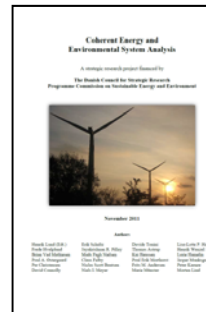
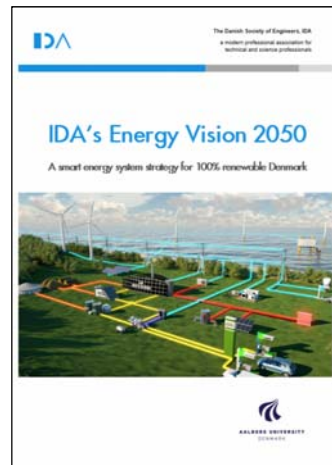
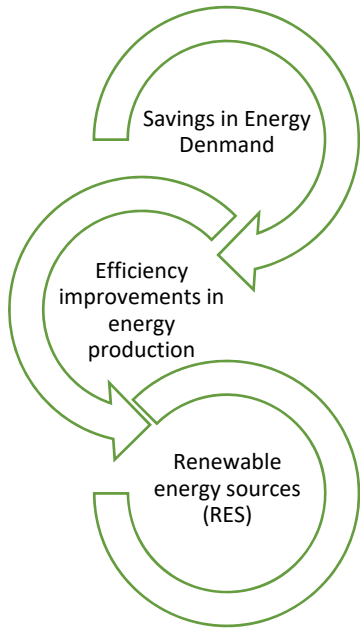
# Activate the entire energy system

- Total final energy in 2015 (EU28)
- H&C about 50%
- Demands and resources in 2050?





# STATE-OF-THE-ART-KNOWLEDGE ON 100% RENEWABLE ENERGY IN 2050





# Smart Energy Systems





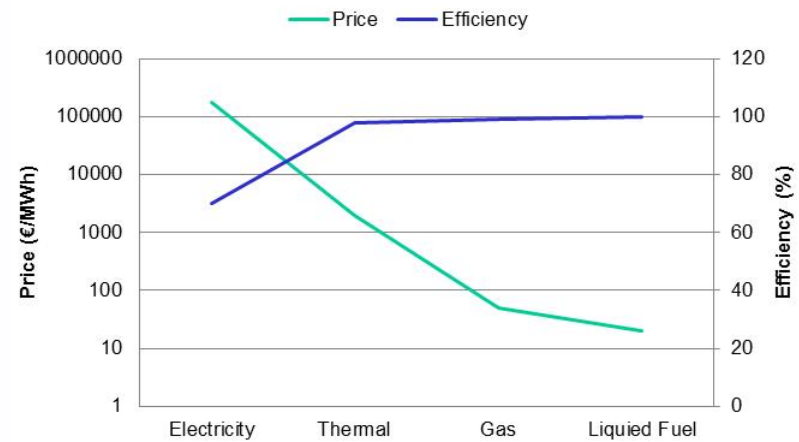


**Pump Hydro Storage**  
175 €/kWh

(Source: Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits. Electric Power Research Institute, 2010)



**Energy storage: Price and Efficiency**



**Thermal Storage**  
1-4 €/kWh

(Source: Danish Technology Catalogue, 2012)



**Oil Tank**  
0.02 €/kWh

(Source: Dahl KH, Oil tanking Copenhagen A/S, 2013: Oil Storage Tank. 2013)



**Natural Gas Underground Storage**  
0.05 €/kWh

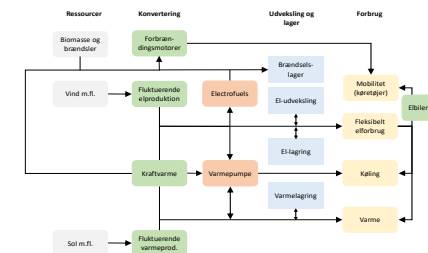
(Source: Current State Of and Issues Concerning Underground Natural Gas Storage. Federal Energy Regulatory Commission, 2004)





# How should storage be used in the long term?

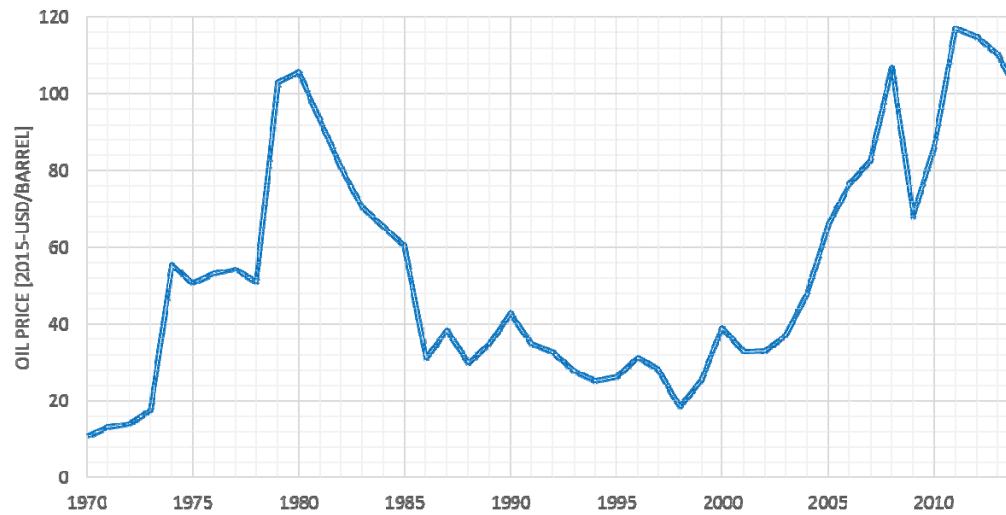
- Three crucial grids in Smart Energy Systems,
  - Smart electricity grids, Smart thermal grids, Smart gas grids
- High capacity electrolyses (Power-to-gas)
- More district heating and district cooling
- Large and small-scale heat pumps (Power-to-heat)
- CHP, solar thermal, etc.
- Electricity storage in transport (batteries and electrofuels)
- Production of green gasses and synthetic fuels





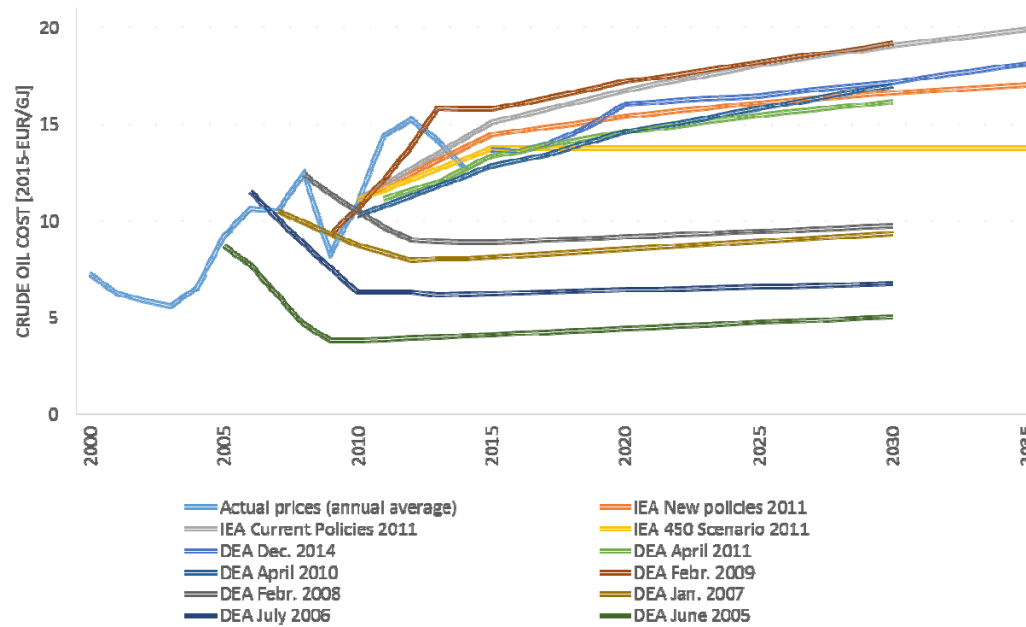
# World oil prices

Yearly Brent crude oil price





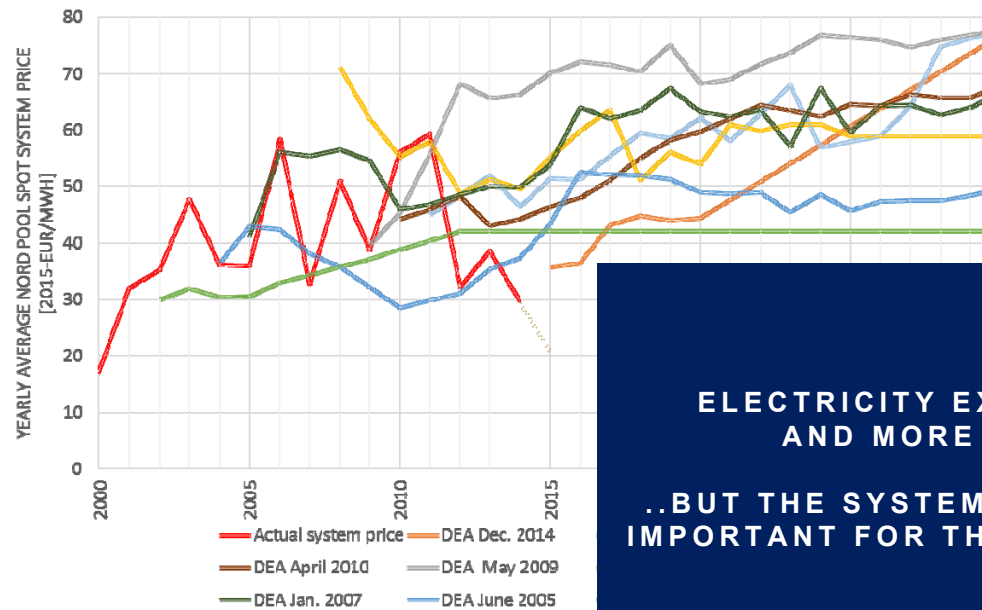
# Oil price projections?







# Electricity prices in Denmark

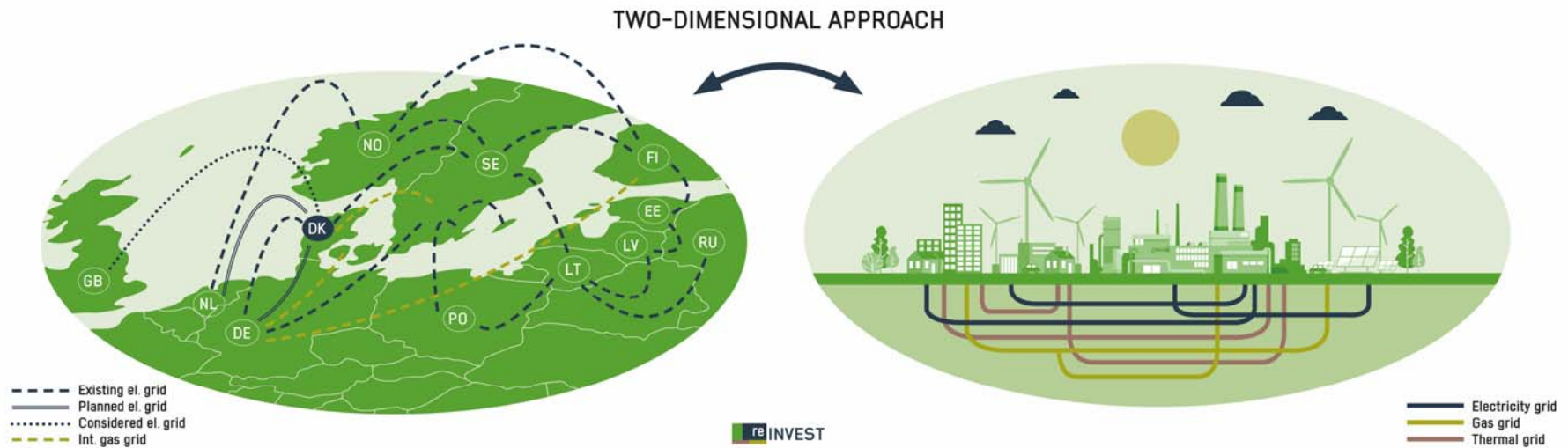


**ELECTRICITY EXCHANGE IS MORE AND MORE IMPORTANT...**

**..BUT THE SYSTEM RE-DESIGN IS MORE IMPORTANT FOR THE ECONOMY OVERALL**



# Why the two-dimensional approach?





# Coherent 2050 analyses

- 100% is possible technically and feasible
- Future need to focus on transmission between the sectors instead of only between countries
- A flexible system is robust with regards to costs and biomass consumption. It uses storages intelligently
- It provides more jobs and lower health costs than fossil fuel systems

## IDA's Energy Vision 2050

A smart energy system strategy for 100% renewable Denmark

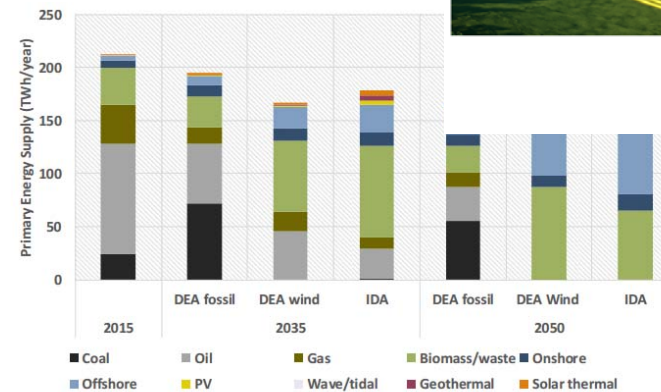


Figure 3: Primary Energy supply in 2035 and 2050 in the IDA Energy Vision, in 2015 and in the DEEA scenarios





## Recommendations from the Heating and Cooling conference in February 2017:

- EU 2030 targets and Energy Union policies should



### Heating/cooling in the building:

- Policy should enable to identify synergies with neighbors (old and new houses)
- Separate production and savings in energy requirements in regulation
- Have high energy saving ambitions but balance with sustainable supply

### Re-think the system design:

- New infrastructure investments support should include thermal grid across Europe
- Need for integrated markets and unbundling (e.g. NordPOOL and integrated heat markets)
- Need for new energy system design to exploit costs-effective synergies
- More cross-sector approach in the Energy Union



# Recommendations from the Heating and Cooling conference in February 2017:

- EU 2030 targets and Energy Union policies should



## SMART ENERGY EUROPE

From a Heat Roadmap  
To an Energy System Roadmap

The flowchart, titled "Smart Energy System", illustrates the integration of different energy sources and storage technologies. It is divided into "Resources" and "Conversion" sections. Resources include Biomass/Fuels, Wind etc., and Solar etc. Conversion includes Combustion Engines, Fuel Storage, Electrofuels, Power Exchange, Electricity Storage, and Thermal Storage. The system also shows outputs for Mobility, Electric Vehicles, Flexible Electricity, Cooling, and Heating. A central "Heat Pump" connects the conversion and storage stages.

For  
European Commission

By  
Aalborg University  
David Connolly  
Brian Vad Mathiesen  
Henrik Lund  
July 2015



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Energi System Analyse Model

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