Smart energy system
- combining EE & RE

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Climate change

- Change in global average temperature: 12 of the warmest years have been in the past 13 years (since 1850)
- Melting glaciers
- Ice at Artic and Antartic is melting
- Warming up of sea (hurricanes)
- More extreme weather
- Raise of sea level
- Loss of species /biodiversity
- Lack of clean water in some countries
- Health problems

Global warming is caused by burning of fossil fuels = Green House Gas emissions
Sandy was here!
Climate adaptation

versus

Climate mitigation
Point of departure

1) Smart grid + (infrastructure)
2) Smart technologies + (clean tech)
3) Smart people + (competences)
4) Smart governance (policy)

= Smart energy system (smart communities)

How to image a transition towards a smart energy system?
The linear energy system of the industrial society

Production

Distribution

Consumption

El
Varme
Gas
Olie
From central to distributed energy system

Maps: Danish Energy
From central to distributed energy system

Maps: Danish Energy

2013
Changes in infrastructures

• From linear (supply to demand) towards interactive (smart gridS)
• From few central plants to plenty decentral and distributed units

Challenges:
• The siloes – sector integration
• Coordination and communication
More Efficiency and More Renewables


Figure 2.1. Energy consumption and renewable energy consumption 2009. Source: Danish Energy Agency.
Electricity consumption of household appliances

Danish Energy Agency

kWh/year

1990  '95  '00  '05  '10  '14

TV sets  Refrigerators  Freezers  Dishwashers  Washing machines  Dryers
Household electrical appliances

1000 units

Danish Energy Agency
Development of Vestas turbines

<table>
<thead>
<tr>
<th>Product/Rotor diameter (m)</th>
<th>V15</th>
<th>V17</th>
<th>V19</th>
<th>V20</th>
<th>V25</th>
<th>V27</th>
<th>V39</th>
<th>V44</th>
<th>V47</th>
<th>V52</th>
<th>V66</th>
<th>V80</th>
<th>V90</th>
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<tbody>
<tr>
<td>Capacity (kW)</td>
<td>55</td>
<td>75</td>
<td>90</td>
<td>100</td>
<td>200</td>
<td>225</td>
<td>500</td>
<td>600</td>
<td>660</td>
<td>850</td>
<td>1750</td>
<td>2000</td>
<td>3000</td>
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<tr>
<td>MWh/year</td>
<td>217</td>
<td>265</td>
<td>301</td>
<td>346</td>
<td>481</td>
<td>647</td>
<td>1304</td>
<td>1581</td>
<td>1947</td>
<td>2530</td>
<td>4705</td>
<td>6768</td>
<td>–</td>
</tr>
</tbody>
</table>
Changes in technologies

- From fossil based system towards renewables
- From inefficient products to energy savings and clean technologies

Challenges:
- Fluctuation – energy storage
- Rebound effect – efficient, but more products
- Energy efficiency versus resource and system efficiency
Riisager & the T vind wind turbines

SYMBOL: The T vind wind turbine, erected by farmers in the 1970s, became a symbol of the result of ordinary people’s campaigns against nuclear power and centralised energy supply. Here it is in its new 'park' designed by the architect Jan Ottesen.

Photo: Dipl.-Wirt. Holstbro
Social Movements against and for different technologies

OOA – Oplysning om Atomkraft

OVE – Oplysning om Vedvarende Energi
Danish export of energy technology

Exports of energy technology and equipment

Share of Denmark's total exports (Right axis)

Danish Energy Agency, 2015
People matter

- Renewables / scaling-up – learning-by-doing
- Local entrepreneurs and ownership
- Vestas and Bonus/Siemens WP was originally manufacturers of equipment to farmers
- Employment and (rural) community benefits

Challenges:
- Change in competences
- Smart/intelligent – user benefits?
- Keep local ownership
Windpower capacity and its share of Danish electricity supply

- **Wind power offshore capacity, MW**
- **Wind power onshore capacity, MW**
- **Wind power's share of domestic electricity supply, %**

![Graph showing the increase in wind power capacity and its share of electricity supply from 1990 to 2014.](image-url)
Policy matters

- Broad public support
- All political parties (-1) behind agreement
- EE + RE is important to the Danish economy
- EU policies + International agreements

Challenges:
- Keep up momentum
- Financing via energy ”tax” or public taxes
- Electrification of new sectors eg. transport
Energy system of the Internet society

1) Demand side becomes also production
   • Energy+ houses (passive houses / ZNE buildings)
   • Electric vehicles (use and produce electricity)
   • Energy efficient products and technologies
   • From consumers to prosumers

2) Renewable energy sources
   • Sun, wind, wave, tidal, biogas, biomass, etc. (several thousands)
   • CHP – combined heat and power (several hundreds) on RE
   • Waste incineration (to power and heat/cooling)

3) From Distribution to Integrated Smart Grids
   • An ”Intelligent” System – adjust energy use to energy production
   • Dynamic prices – depending on peak hours, etc.
   • The two-way energy system of the “internet age”
Smart energy system = Integration

Smart technologies
Energy harvesting, renewable energy sources
Active buildings, plus-energy-buildings
Polygeneration
Energy storage (power to gas, etc.)
Resource-efficient products (eco-design)

Smart infrastructures
Smart energy grids
E-Mobility and integration into grid
Heating and cooling networks
Intelligent energy management, load transfers, demand side management

Hans Günther Schwarz, 2012
Smart Cities = Bringing in People

**Smart people**
New competences on new technologies
Active experimentation and learning
Feed-back interfaces to users
Integrative simulation and monitoring tools

**Smart governance**
Local participation
Living labs
1:1 demonstrations models
Quadruple helix collaboration (Citizens, Industry, Government and Universities)
Interactive innovation processes
Sustainable business models
CO2 emissions from energy consumption

Danish Energy Agency, 2015
CO₂ emissions in end-use of energy

Million tonnes CO₂

Climate-adjusted

Danish Energy Agency, 2015
Energy consumption for heating in dwellings

Climate adjusted

Index 1990=100

- Heated floor space
- Final energy consumption
- Final energy consumption per m²

Danish Energy Agency, 2015