AALBORG UNIVERSITY

Smart energy system - combining EE & RE

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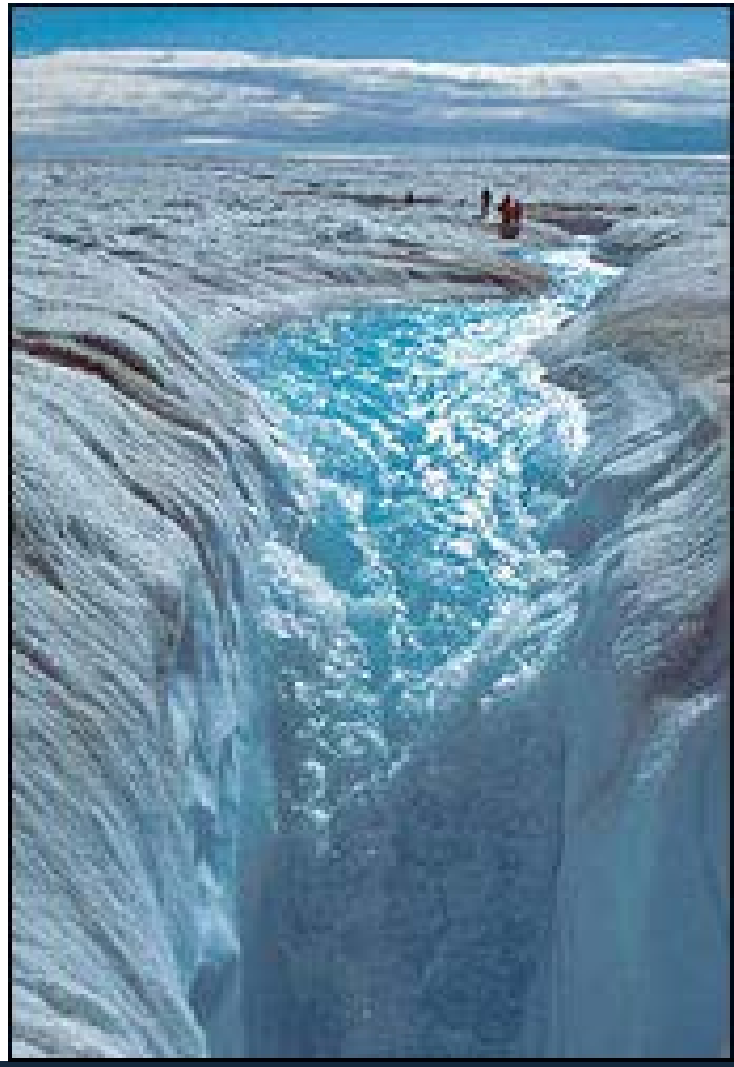
Climate change

- 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

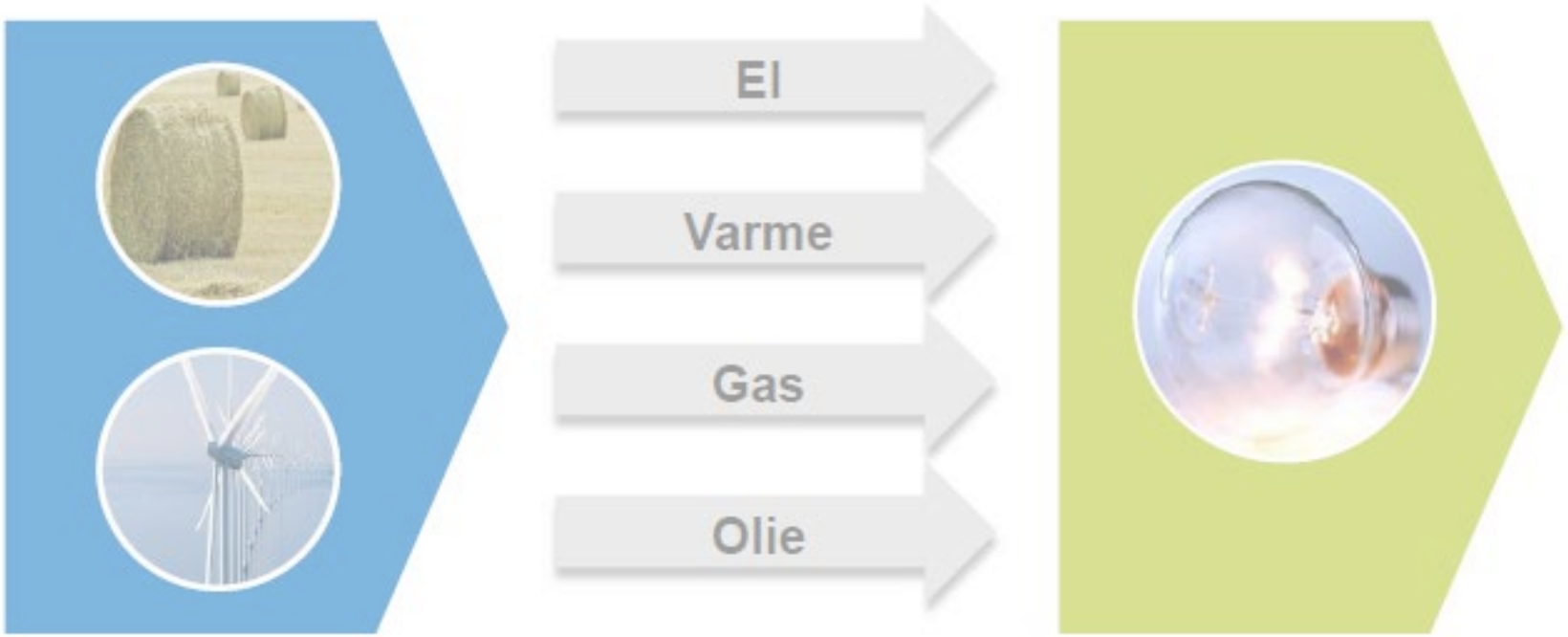
1) Smart grid + (infrastructure)
2) Smart technologies + (clean tech)
3) Smart people + (competences)
4) Smart governance (policy)

= 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**



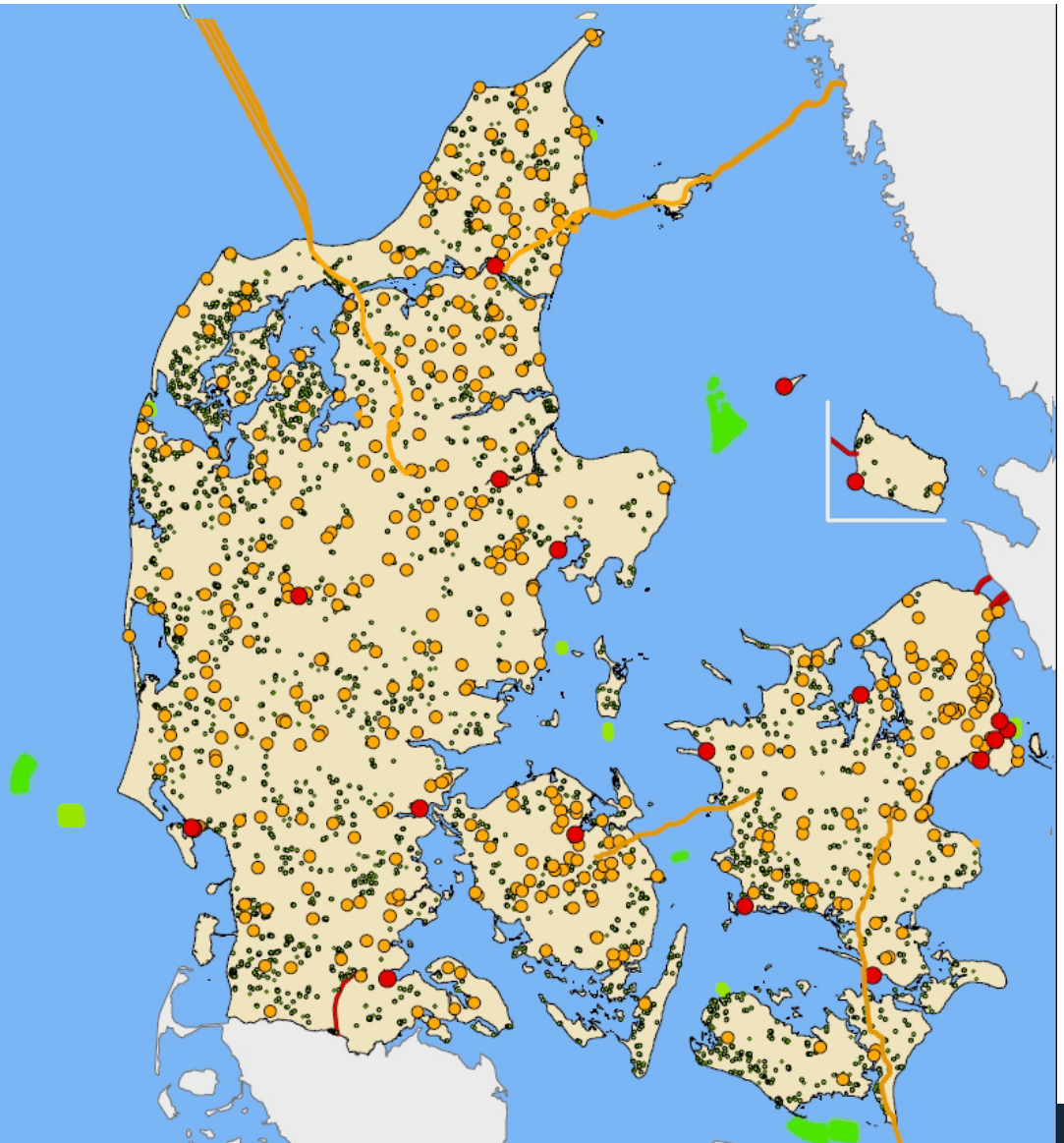
From central to distributed energy system

1985

Centralt kraftvarmeværk	Central CHP
Decentralt kraftvarmeværk	Local CHP
Vindmølle	Wind
Havvindmølle	Off-shore wind
Udlandsforbindelse (vekselstrøm)	AC Interconnection
Udlandsforbindelse (jævnstrøm)	DC interconnection

Maps: Danish Energy

From central to distributed energy system



2013

Centralt kraftvarmeværk	Central CHP
Decentralt kraftvarmeværk	Local CHP
Vindmølle	Wind
Havvindmølle	Off-shore wind
Udlandsforbindelse (vekselstrøm)	AC Interconnection
Udlandsforbindelse (jævnstrøm)	DC interconnection

Maps: Danish Energy

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

Source:
Energy Strategy 2050
Danish Government, 2011.

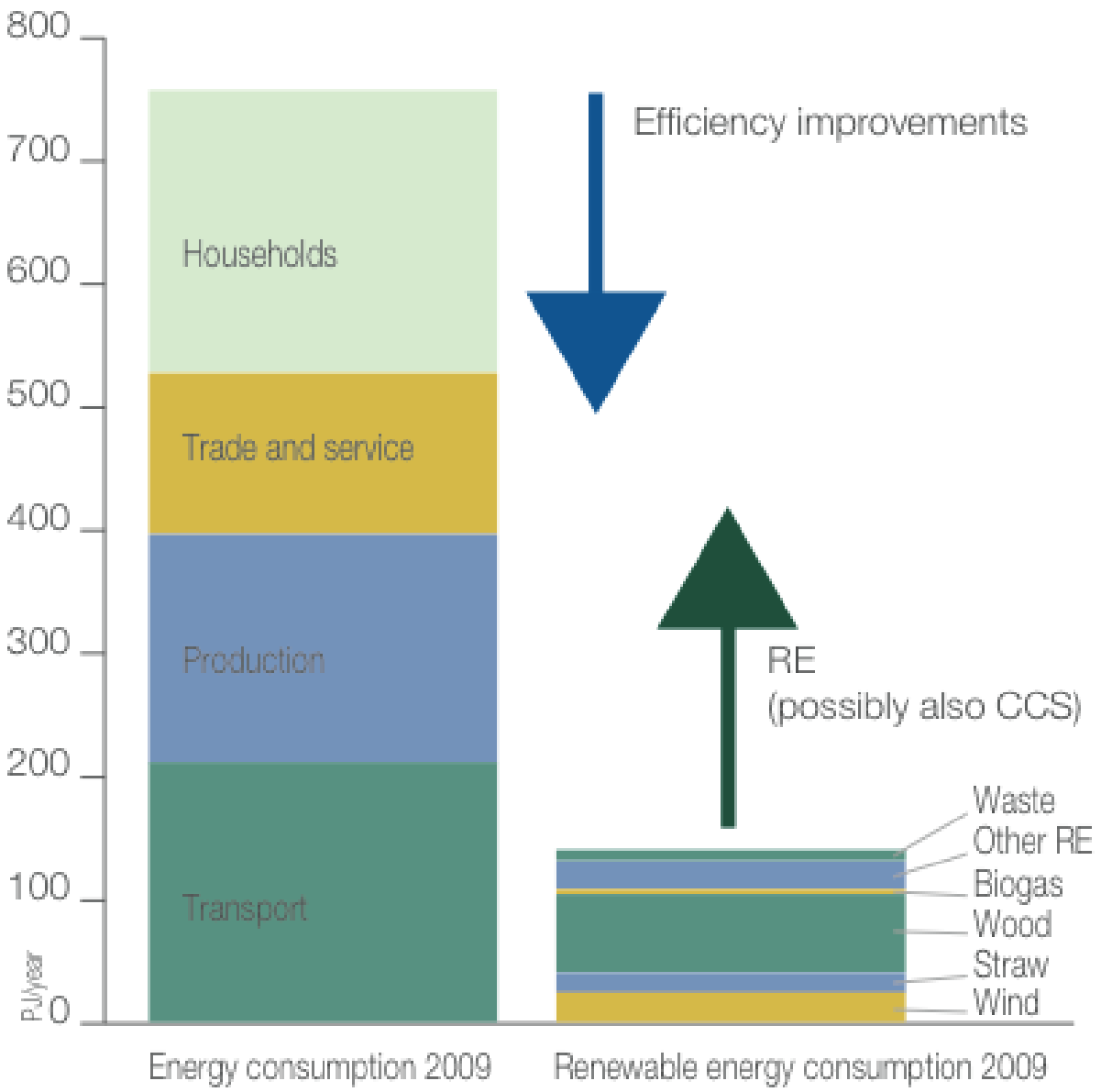
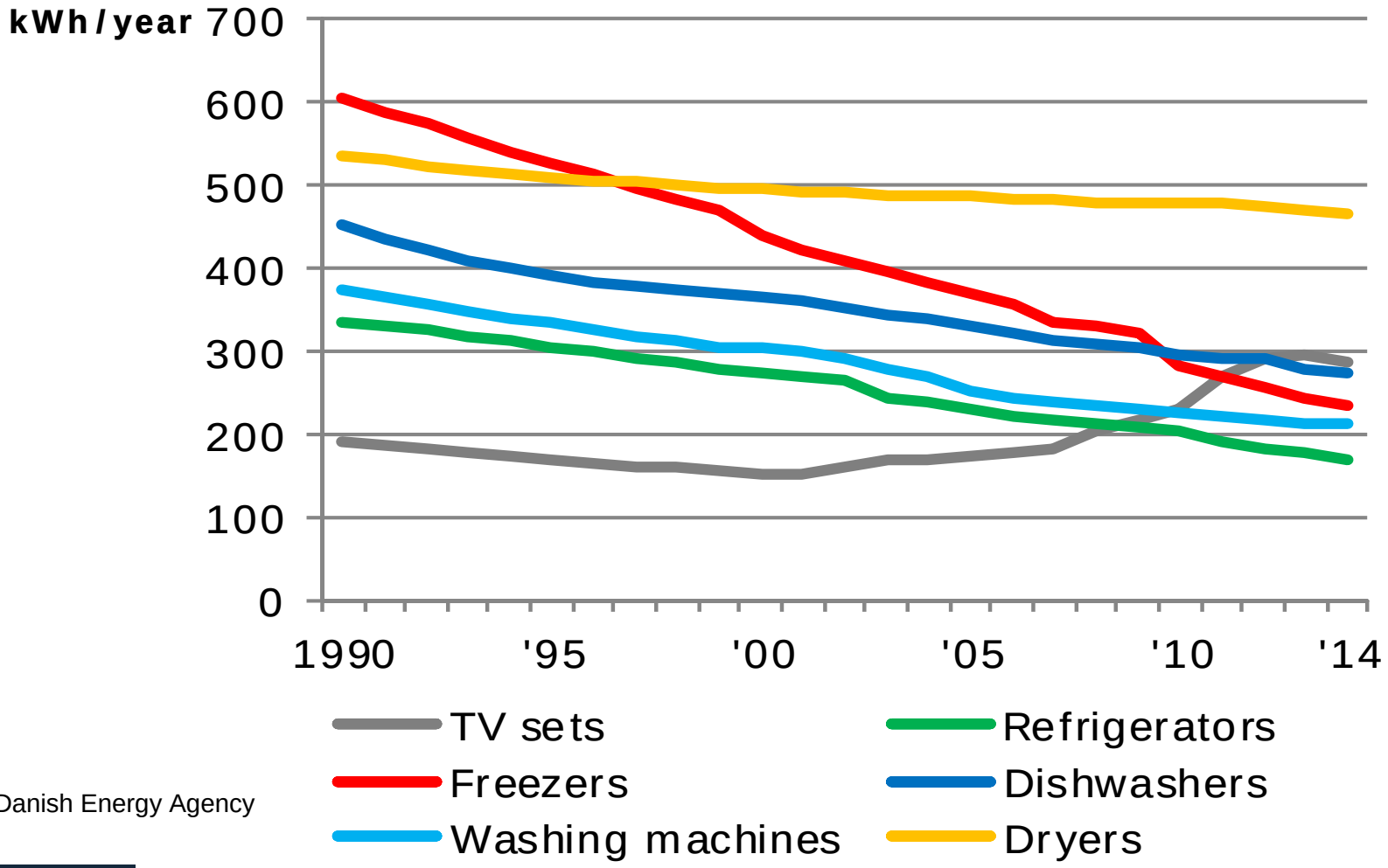


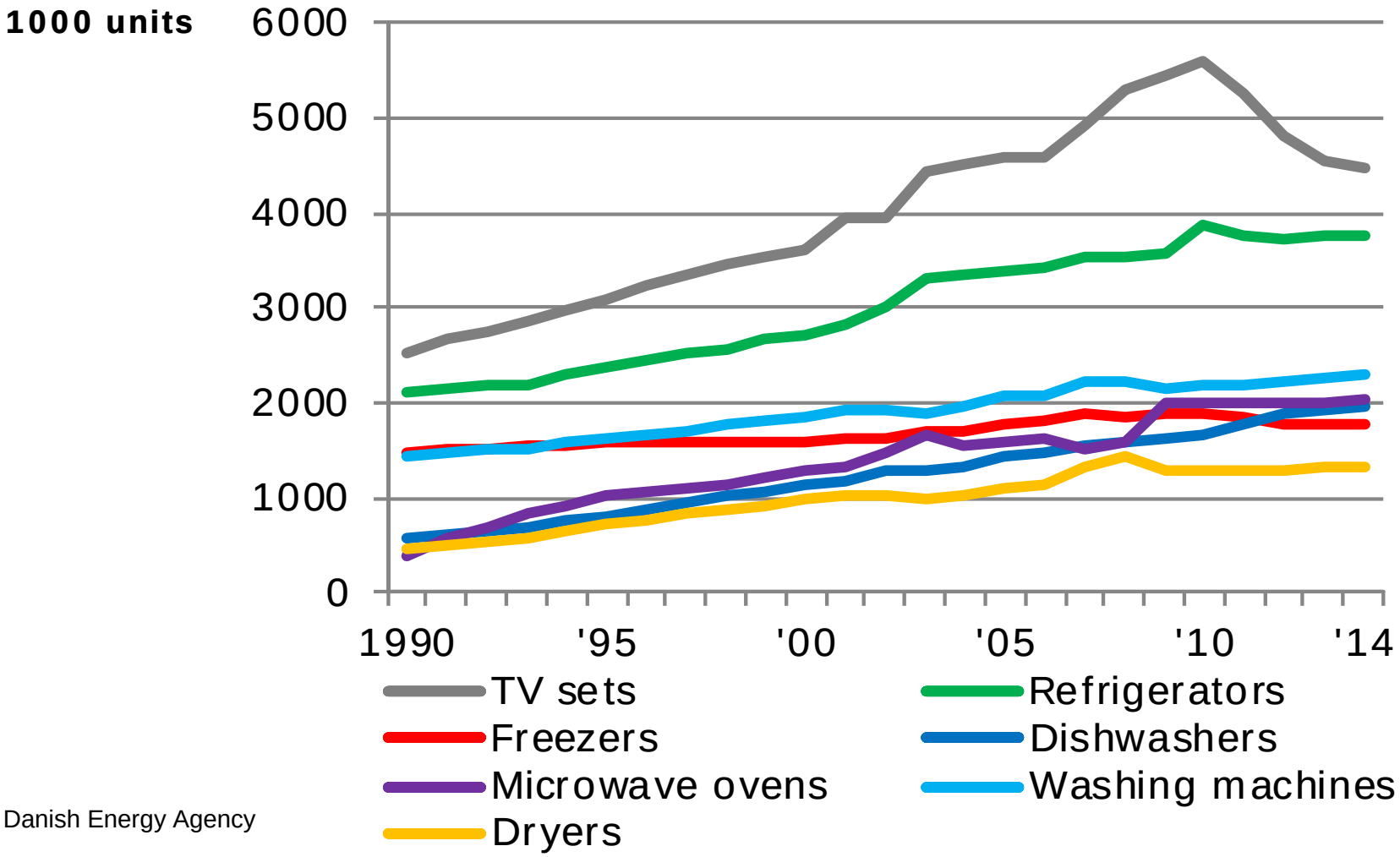
Figure 2.1. Energy consumption and renewable energy 2009. Source: Danish Energy Agency

Electricity consumption of household appliances



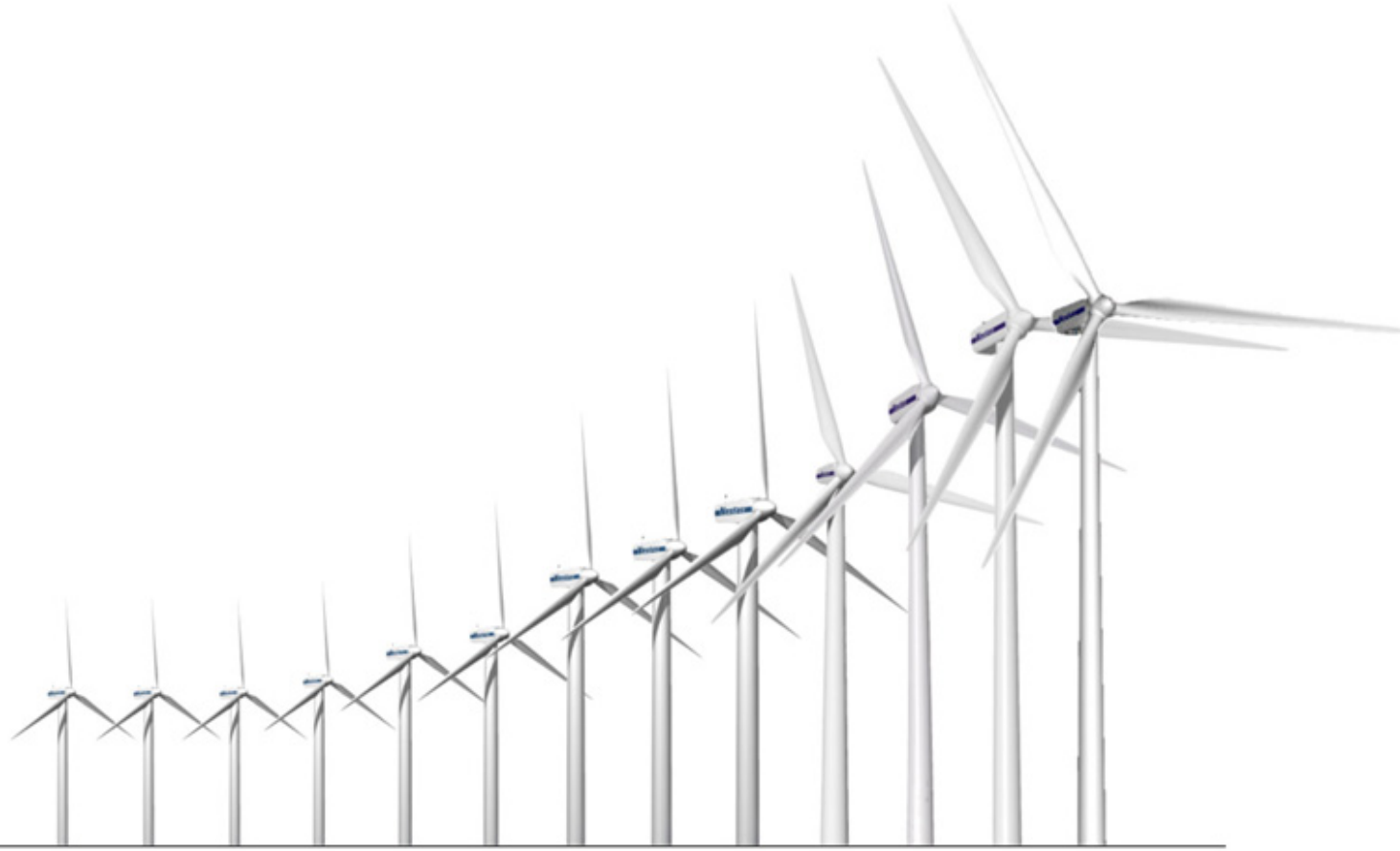
Danish Energy Agency

Household electrical appliances



Danish Energy Agency

Development of Vestas turbines



Product/Rotor diameter (m)	V15	V17	V19	V20	V25	V27	V39	V44	V47	V52	V66	V80	V90
Year of installation	1981	1984	1986	1987	1988	1989	1991	1995	1997	2000	1999	2000	2002
Capacity (kW)	55	75	90	100	200	225	500	600	660	850	1750	2000	3000
MWh/year	217	265	301	346	481	647	1304	1581	1947	2530	4705	6768	–

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

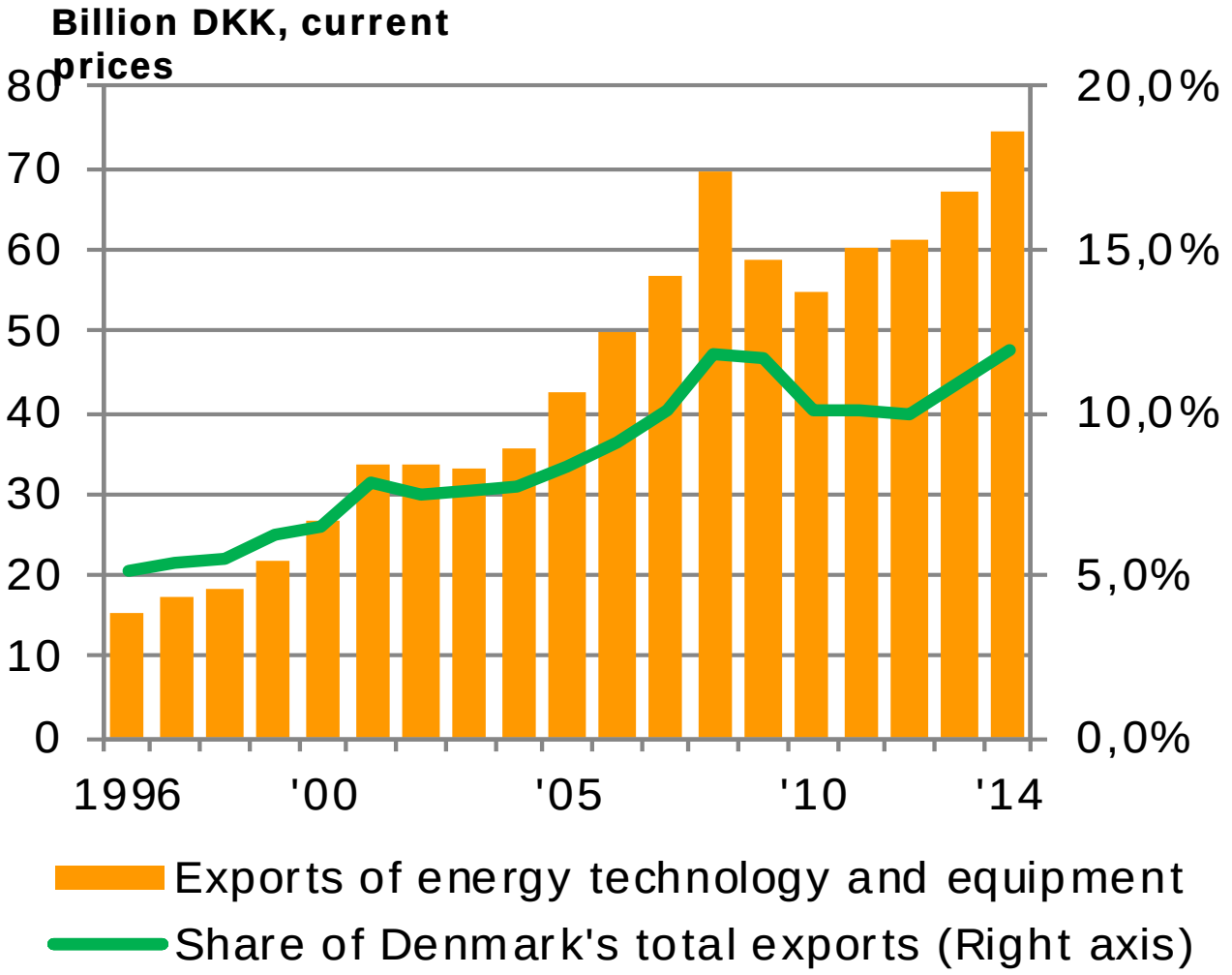
Riisager & the Tvind wind turbines

Social Movements *against and for* different technologies

OOA – Oplysning om Atomkraft

OVE – Oplysning om Vedvarende Energi

Danish export of energy technology



Danish Energy Agency, 2015

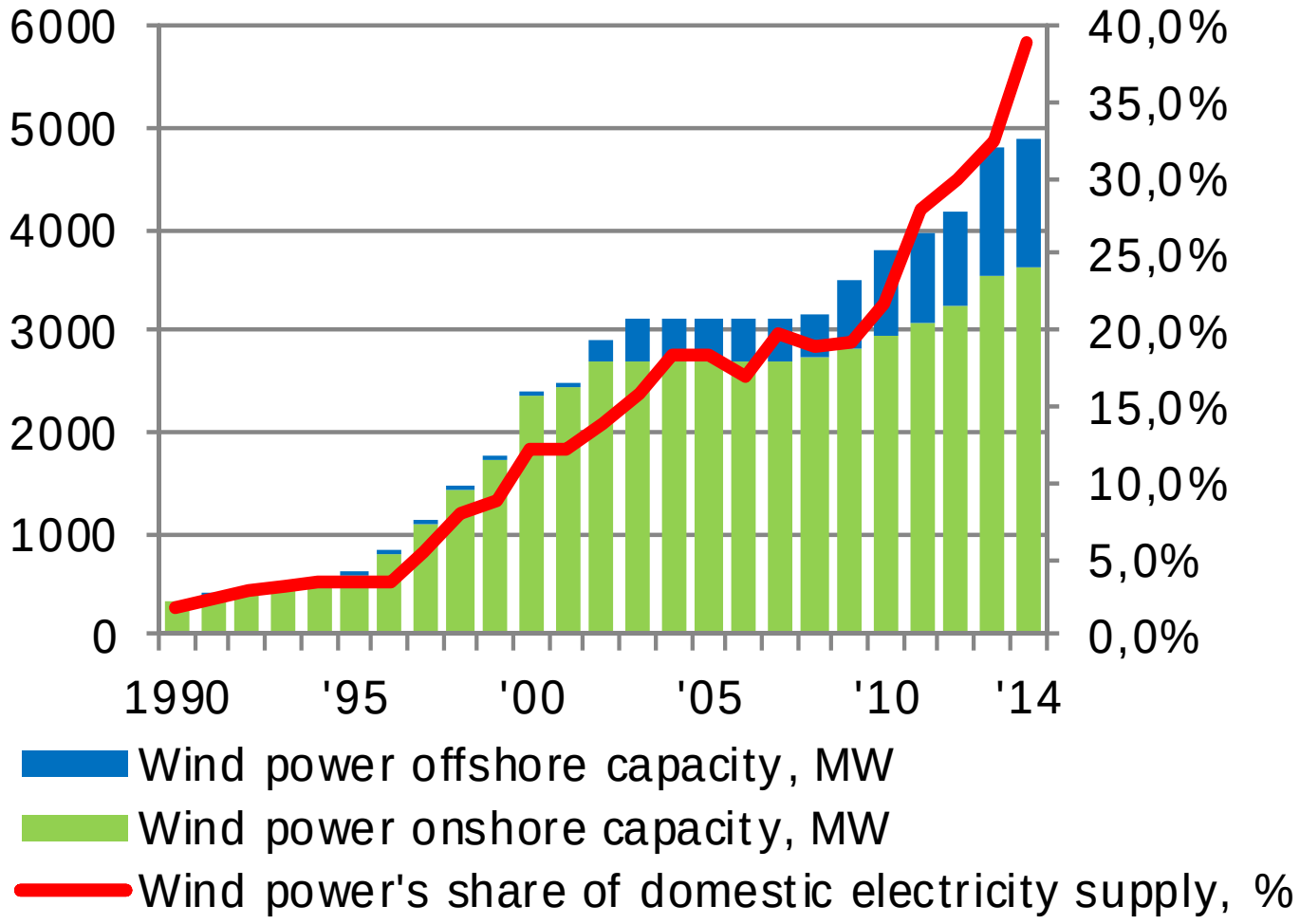
People matter

- 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 electricitv supply



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

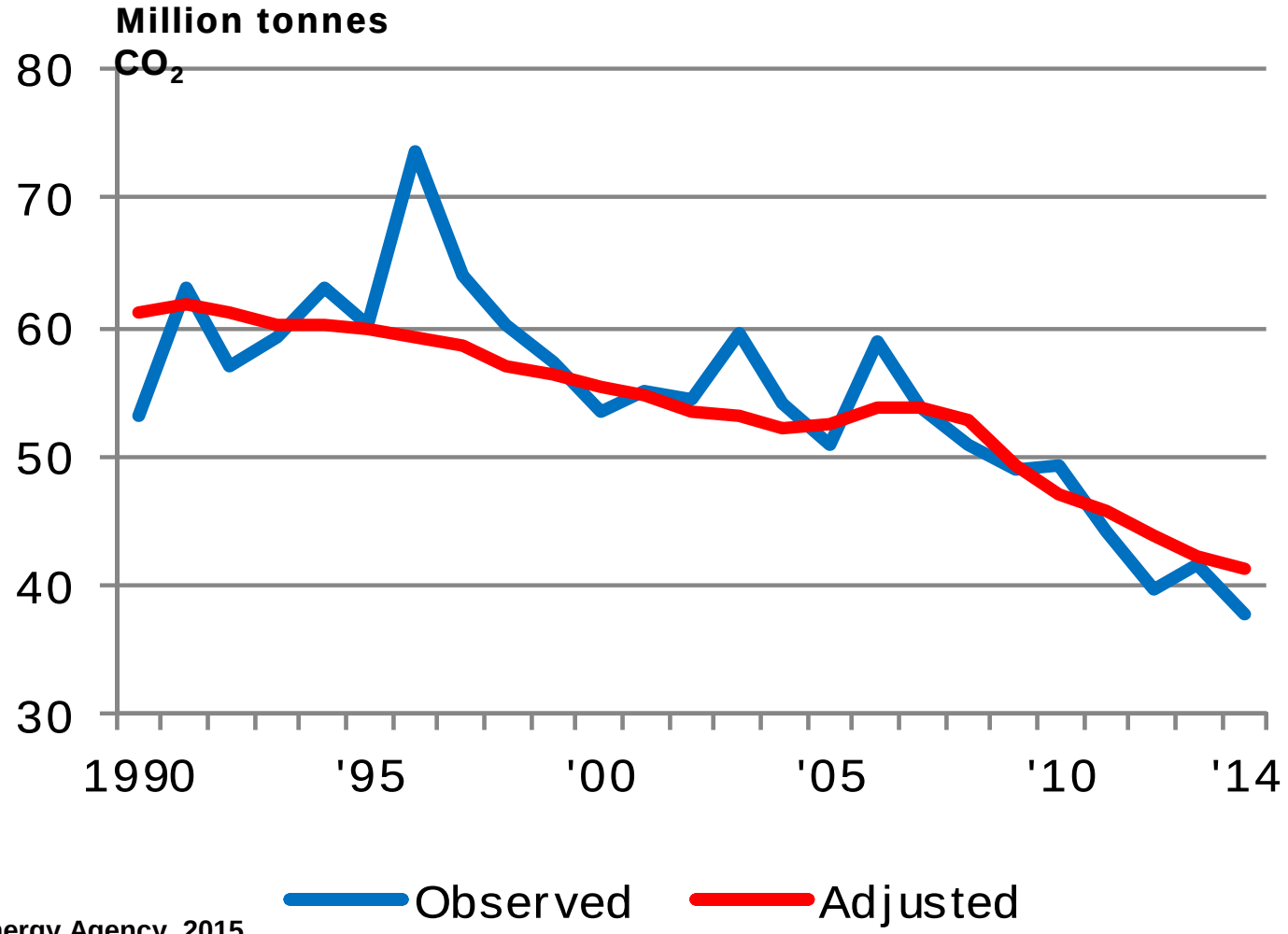
1:1 demonstrations models

Quadruple helix collaboration (Citizens, Industry, Government and Universities)

Interactive innovation processes

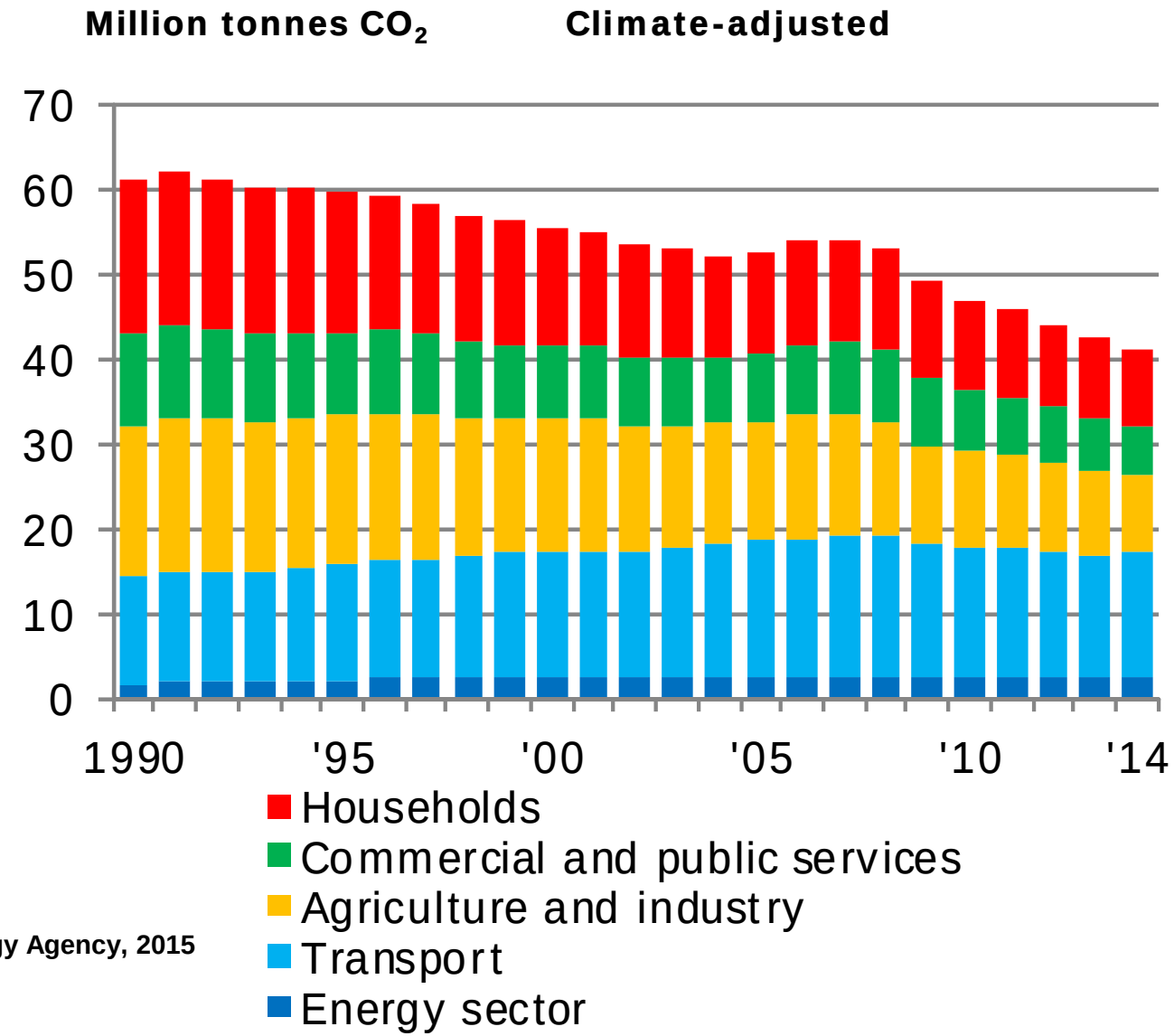
Sustainable business models

CO2 emissions from energy consumption



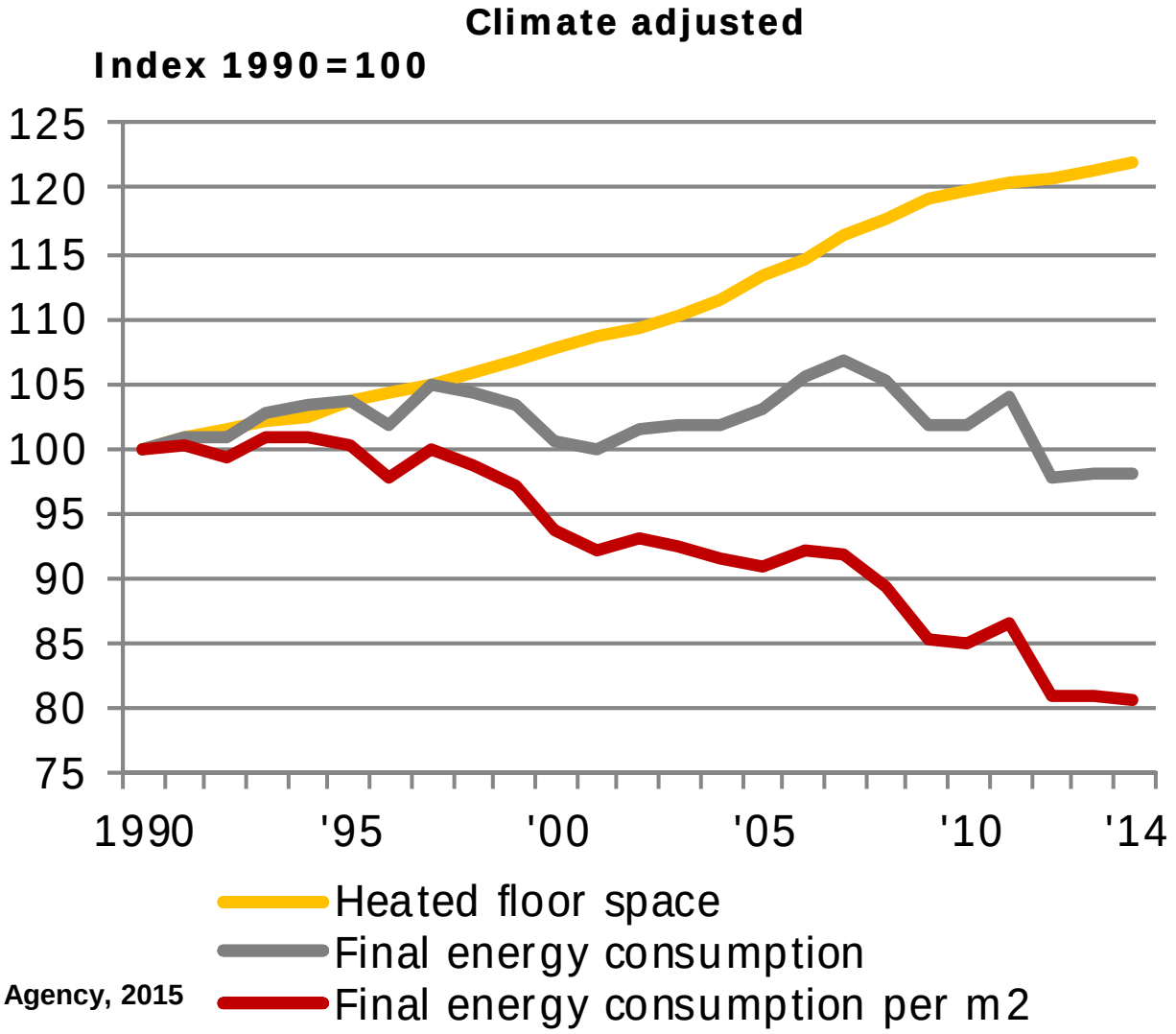
Danish Energy Agency, 2015

CO_2 emissions in end-use of energy



Danish Energy Agency, 2015

Energy consumption for heating in dwellings



Danish Energy Agency, 2015