On District Heating

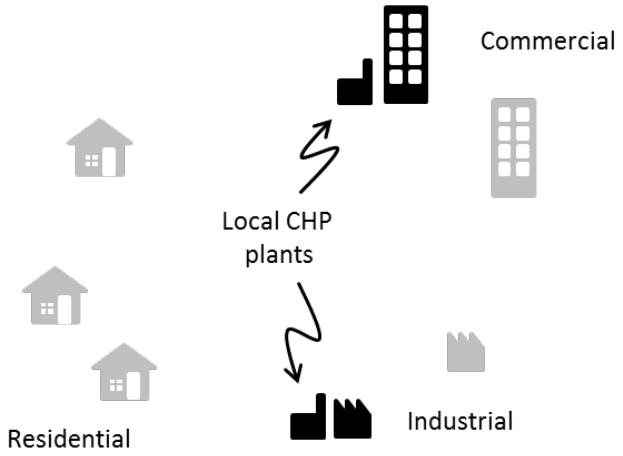
Case Study

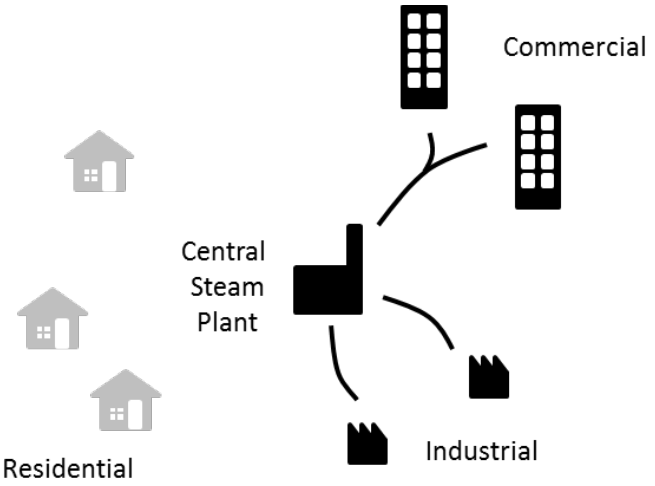
Jimmy Jia
jimmy@jimmyjia.com
Last Edit: April 14, 2019

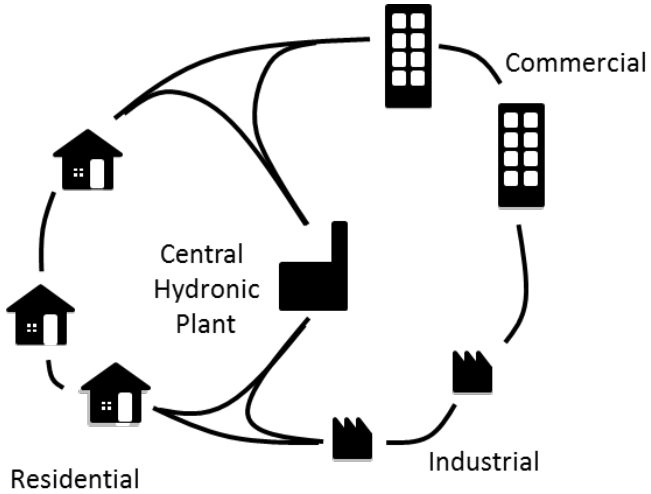
Centralized Heating

- Was a water engineer and invented a pump that could vary the pressure between households and fire hydrants
- If you can move water, why not move steam? This would allow heating to take advantage of economies of scale.
- Built the first centralized district heating utility in 1877. This was 5 years before Edison's Pearl Street Power Plant in Manhattan.

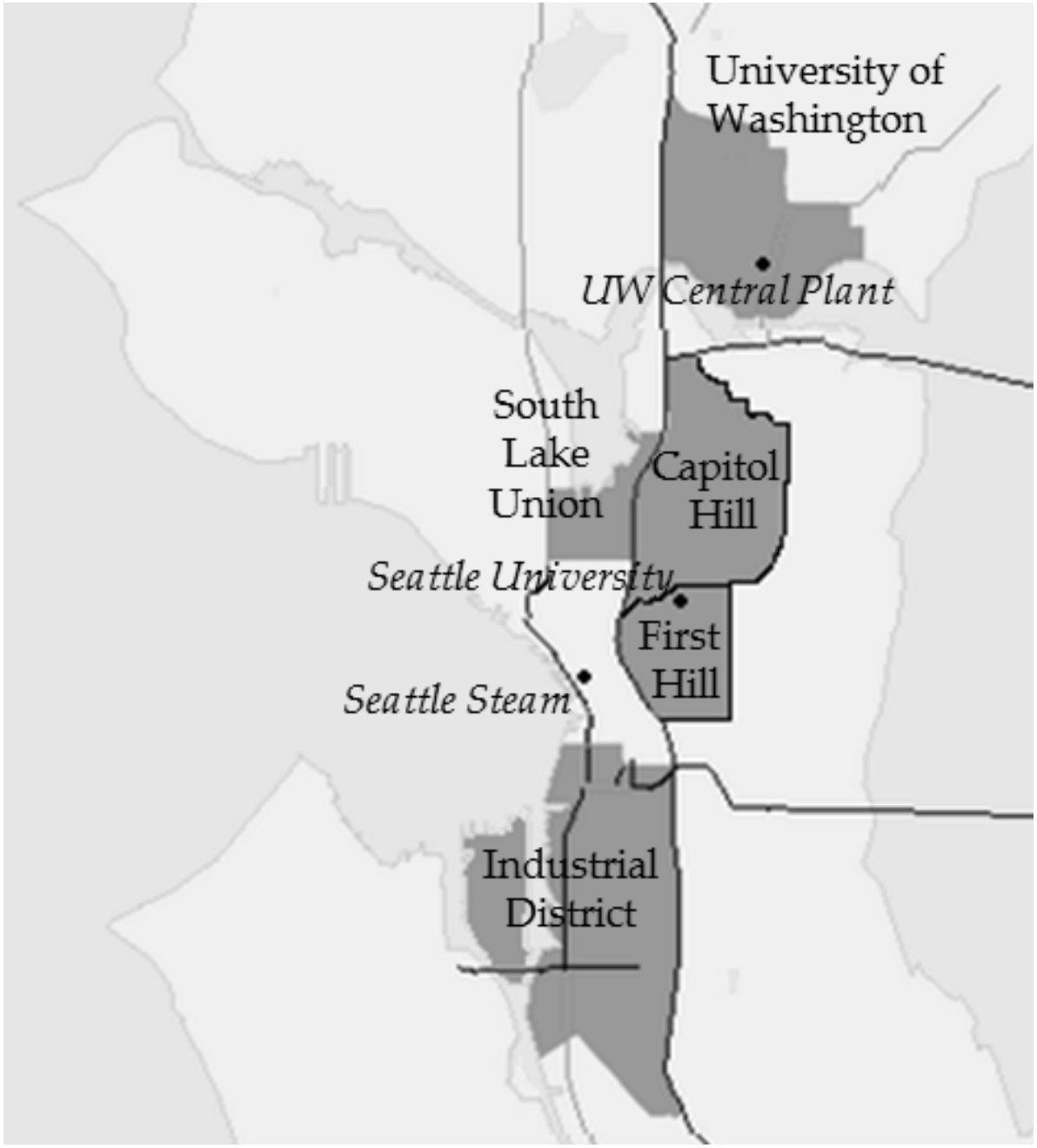
Birdsill Holley


Commercial
Local CHP
plants
Residential
Industrial


Commercial
Central
Steam
Plant
Residential
Industrial


Commercial
Central
Hydronic
Plant
Residential
Industrial

	Industrial District
First Hill	4
Capitol Hill	6
South Lake Union	6.5
University of Washington	8

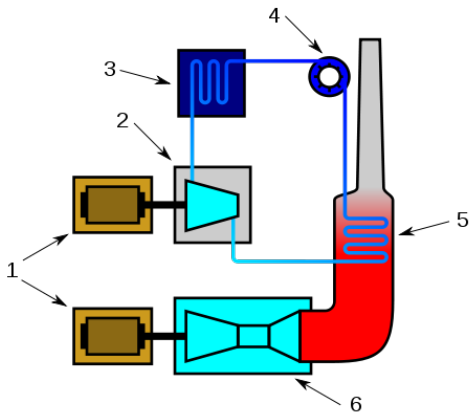


Combined Cycle / Cogeneration / CHP

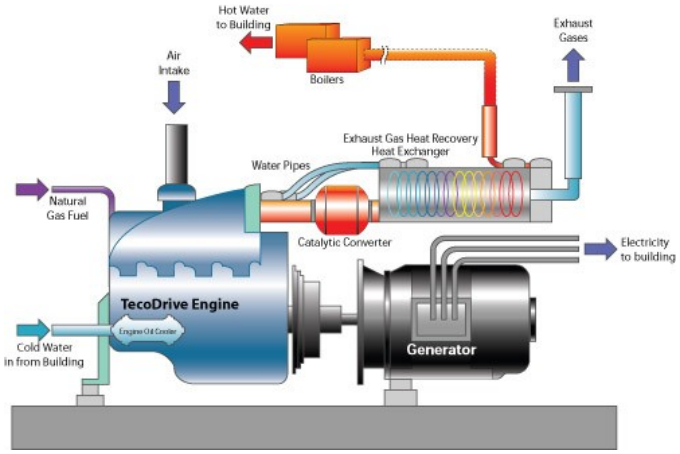
Using both the heat and electric energy from a combustion motor.

Combined Cycle:
Using waste heat from one process to preheat the next process

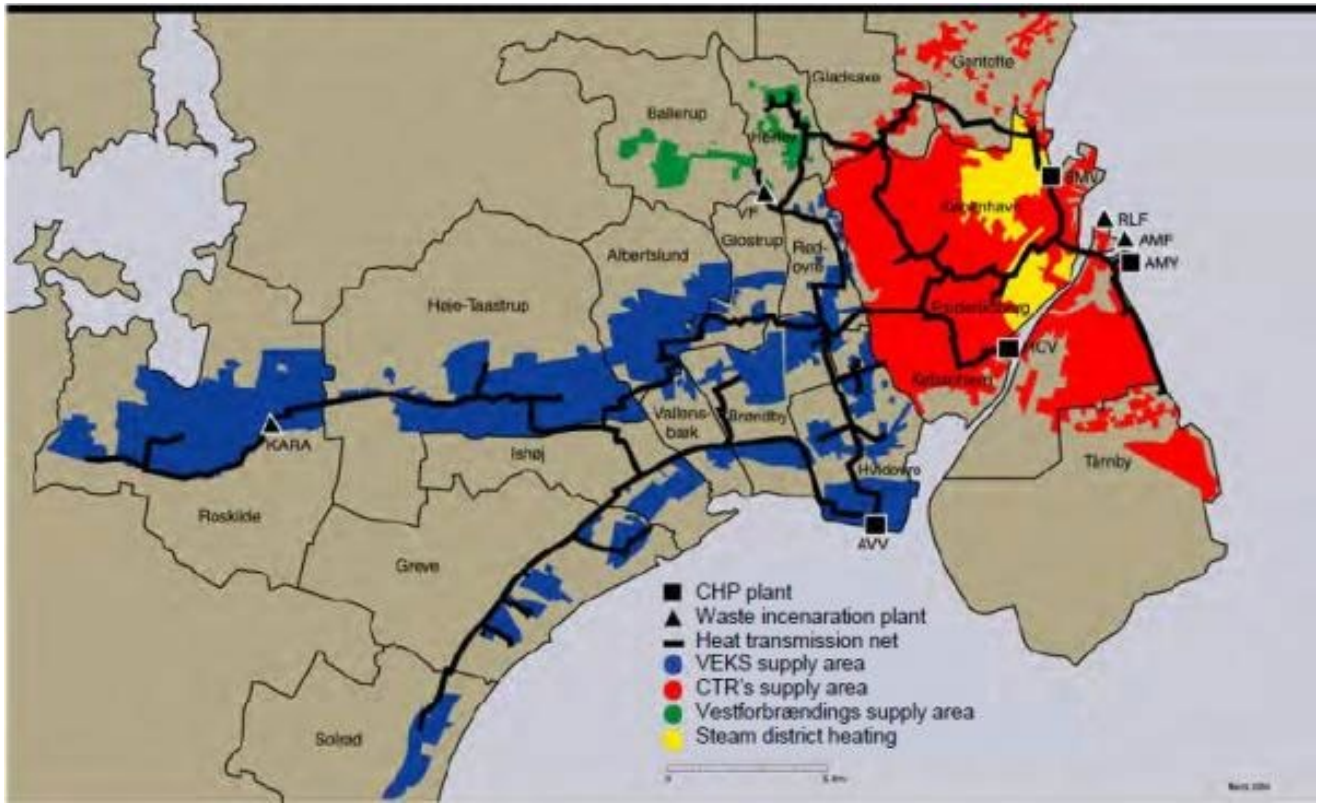
Co-generation and Combined Heat and Power (CHP)
Generating both electricity and heat for consumption.



en.wikipedia.org/wiki/File:COGAS_diagram.svg



City of Copenhagen



- Serves 95% of all residences
- Has both district heating and cooling
- Includes CHP, waste-to-energy, hot water and steam systems.

Retail costs comparison:

DENMARK

- Cost of electricity: $0.38 per kWh.
- Cost of heat energy: $0.12 per kWh.
- Generally more energy efficient homes
- 3-5% of a household's monthly income.
- 8.4 tons of CO_2 per capita emitted

USA

- Cost of electric energy: $0.12 per kWh.
- No additional cost to heat.
- 3-5% of a household's monthly income.
- 18.5 tons of CO_2 per capita emitted

J. Jia and J. Crabtree., Driven By Demand: How Energy Gets its power. Cambridge University Press 2015

History of Danish Carbon Tax

- 1973 oil crises: price of fuel quadrupled. In Denmark, more than 90% of energy came from imported oil.
- 1979: Denmark passed its first heating supply law. Heat is considered a resource!
- 1990: Denmark adopted its “Energy 2000” plan, which called for a 20% reduction in CO2 emissions, relative to 1988 levels, by 2005
- 1992: One of the earliest countries to implement a carbon tax.

Denmark 1979: Heat supply act, article 1:

1. The objective of this Act is to promote the most socio-economic and environmentally friendly utilization of energy for heating buildings, supplying them with space heating and hot water and reduce the dependency of the energy system on oil.

2. In agreement with the objectives mentioned in subsection (1), the supply of heat shall be organized with a view to promoting the highest possible degree of cogeneration of heat and power.

How Carbon Taxes played into it

- There were 4 main goals of the carbon tax:
  - Reduce carbon emissions by 20%
  - Avoid temptation to maximize tax revenue for government coffers
  - Encourage businesses to invest in environmental innovation
  - Encourage households to change behaviors

- This is separate from the energy tax:
  - Levied regardless of where the energy is from.
  - A broad-based tax that generates revenue for the country.
  - Based on the ***energy content*** of the fuel

A fairly complicated tax structure

Type of energy use	Year/tax rate in DKK/tCO_2							
	1996	1997	1998	1999	2000	2005	2008	2015
Household	100	100	100	100	100	90	150	170
Space Heating	100	100	100	100	100	90	150	170
Light Process ***(No Agreement)***	50	60	70	80	90	90	150	170
Light Process ***(With Agreement)****	50	50	50	58	68	68	150	170
Heavy Process ***(No Agreement)***	5	10	15	20	25	25	150	170
Heavy Process ***(With Agreement)****	3	3	3	3	3	3	150	170

- Companies can reduce 25% of the tax if they enter into energy efficiency agreements with the Danish Energy Agency and report annually on projects. DEA can cancel the agreement if reports are not submitted and/or results are not achieved
- Heating was taxed separately!

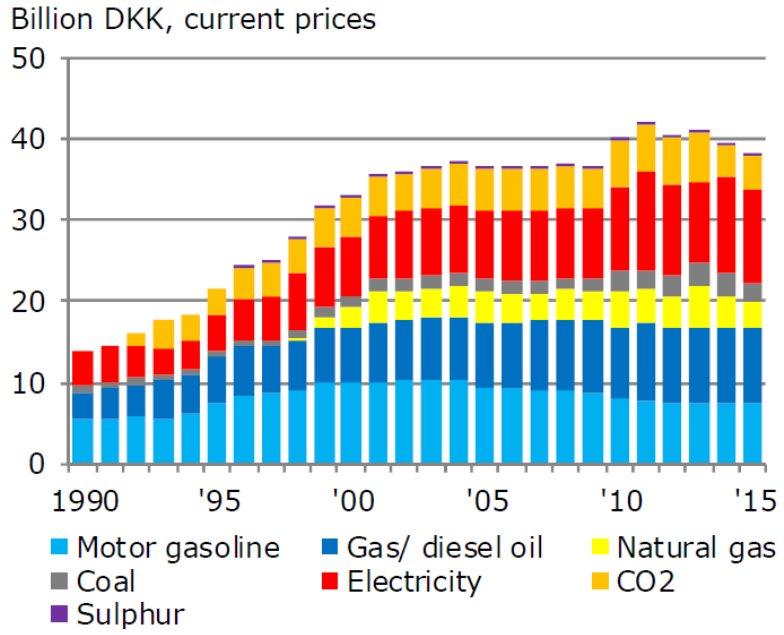
Revenues are spent on:

- 40% of tax revenue used for environmental subsidies

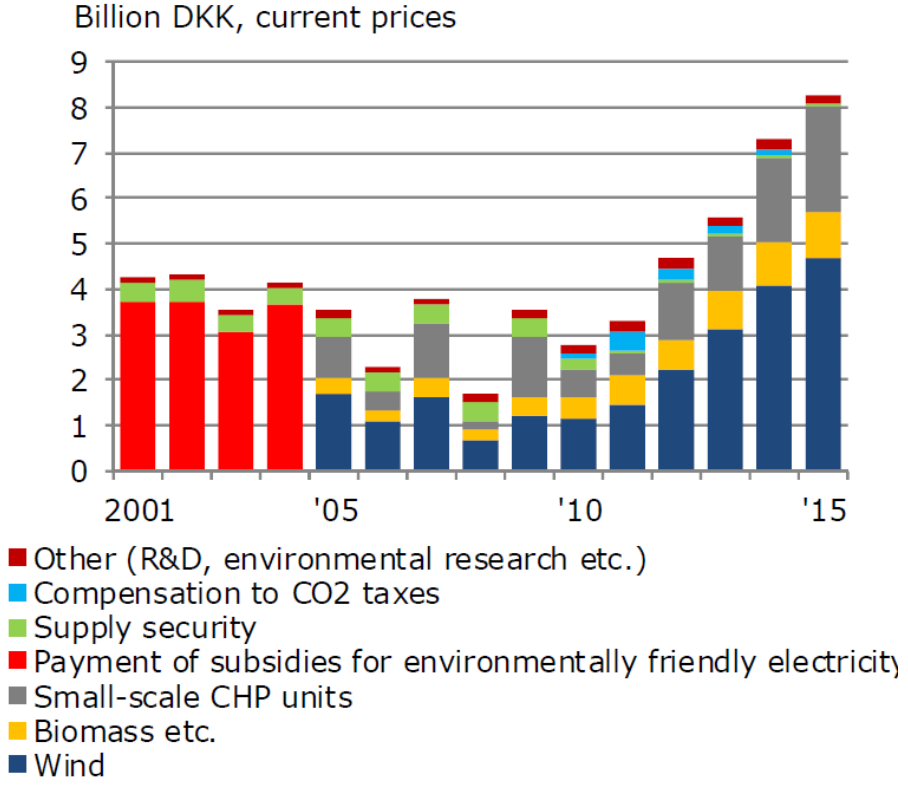
- 60% of tax is returned to industry
  - Grants to build co-generation facilities
  - Energy efficiency grants
  - Reduction of other tax burdens

Results:

Revenue from energy, CO_2 and sulphur taxes



Expenses for Public Service Obligations (PSO) in the electricity area

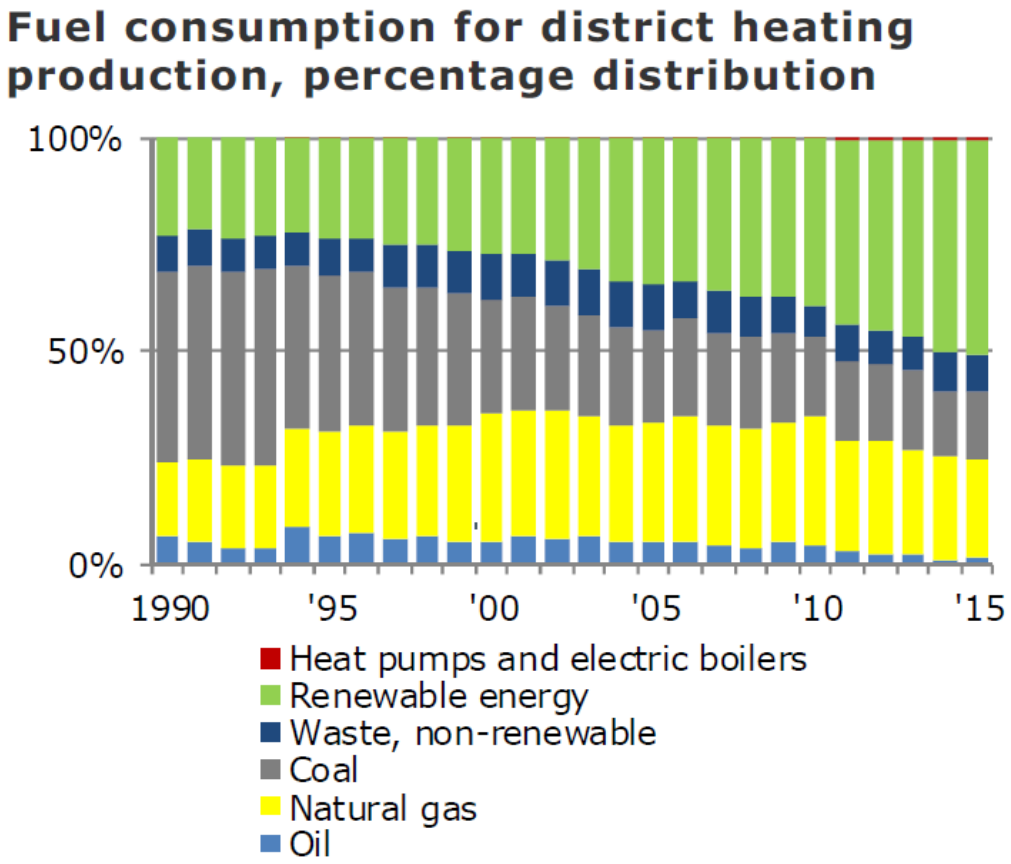


Several environmental taxes

Many investments in electricity

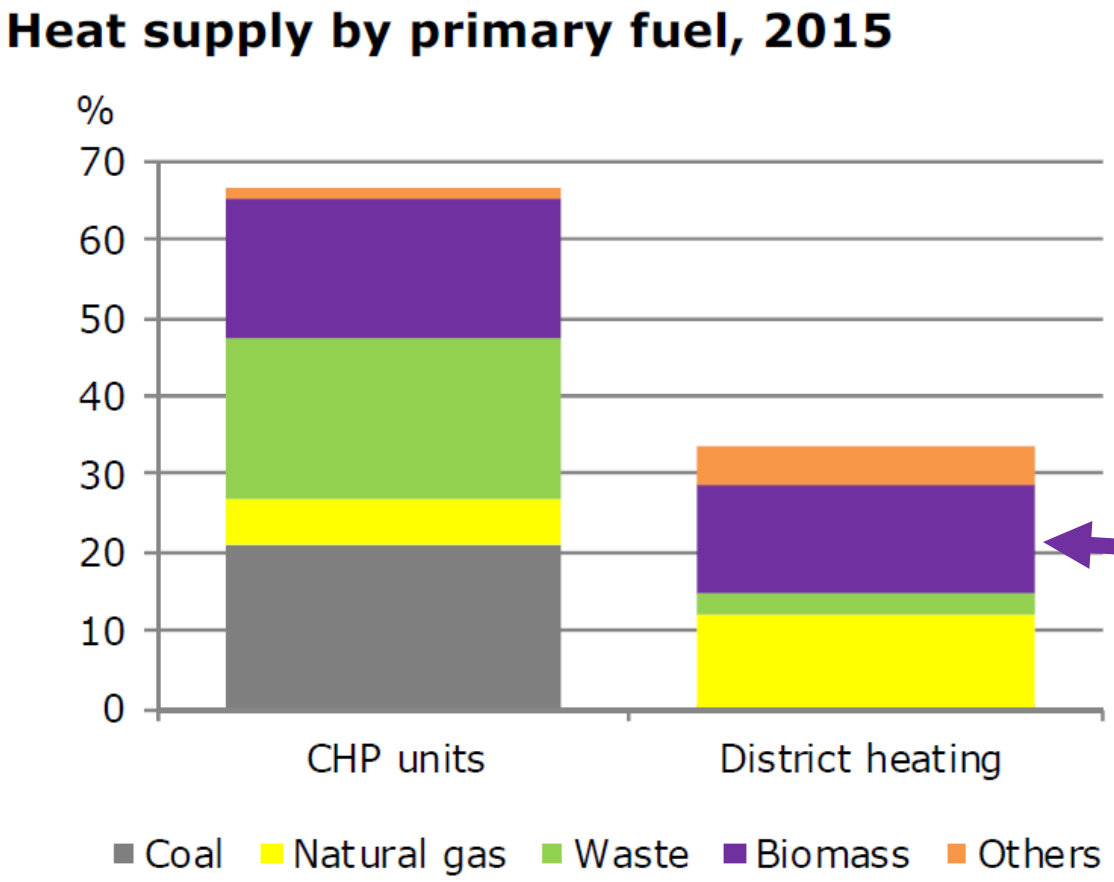
Effects of District Heating

- Fossil fuel share is below 50% (Coal: 15%) for heat production



Source: Energy Statistics 2015 Danish Energy Agency

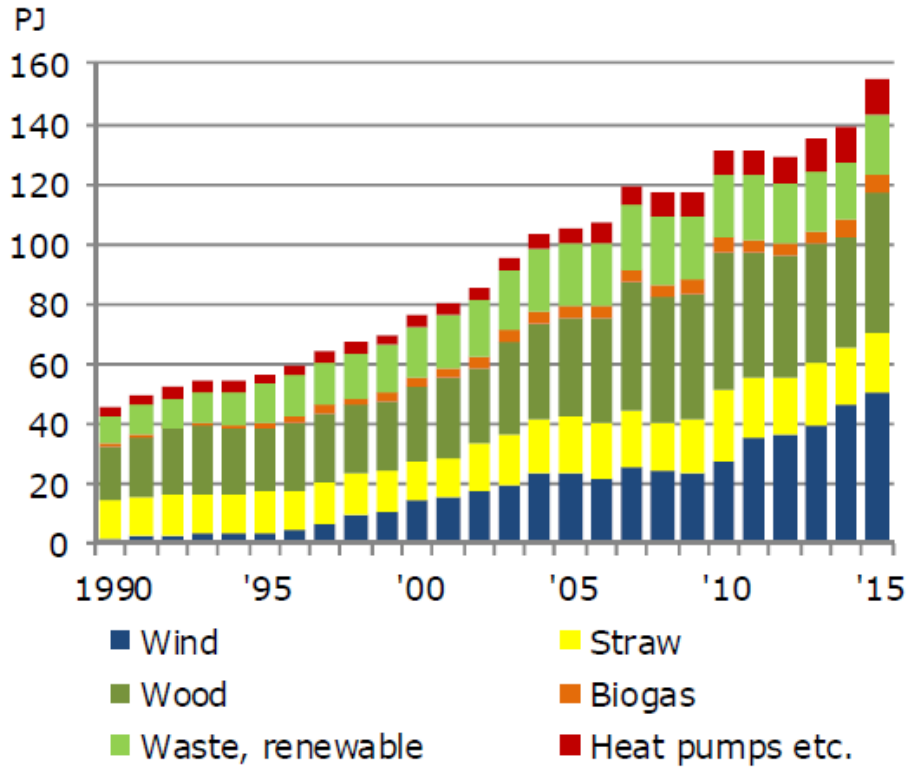
Fuel makeup of CHP and District Heating



Biomass and other renewables exempt from the Carbon Tax

Innovation: Integration of Renewable Energy

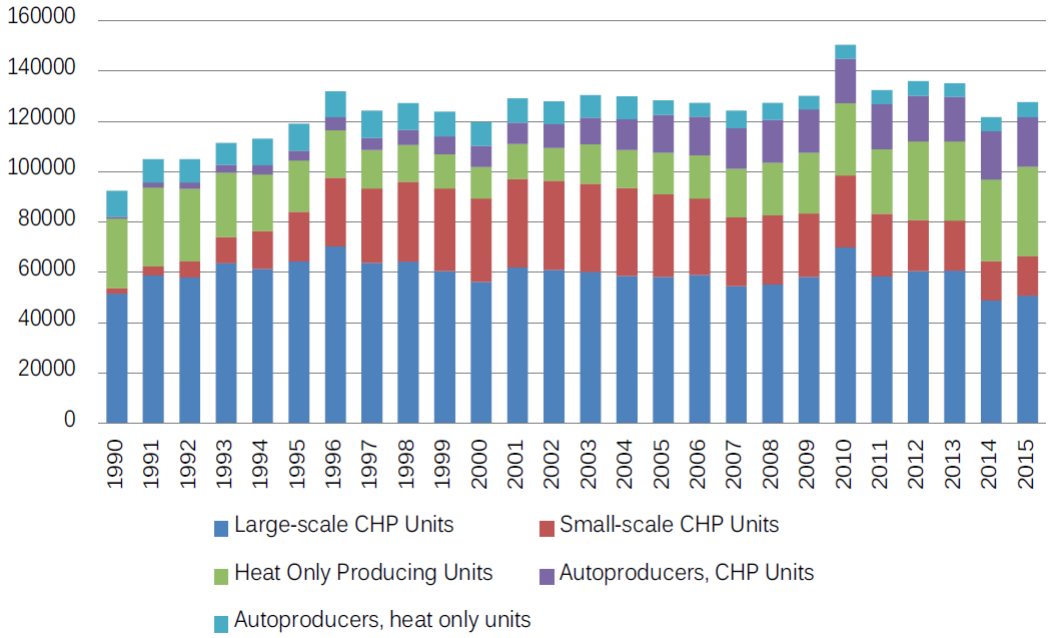
Production of renewable energy by energy product



- Remember: Denmark has ***two options*** for transporting energy:
  - Electric transmission
  - Hot water pipes!

Innovation: Customer's role

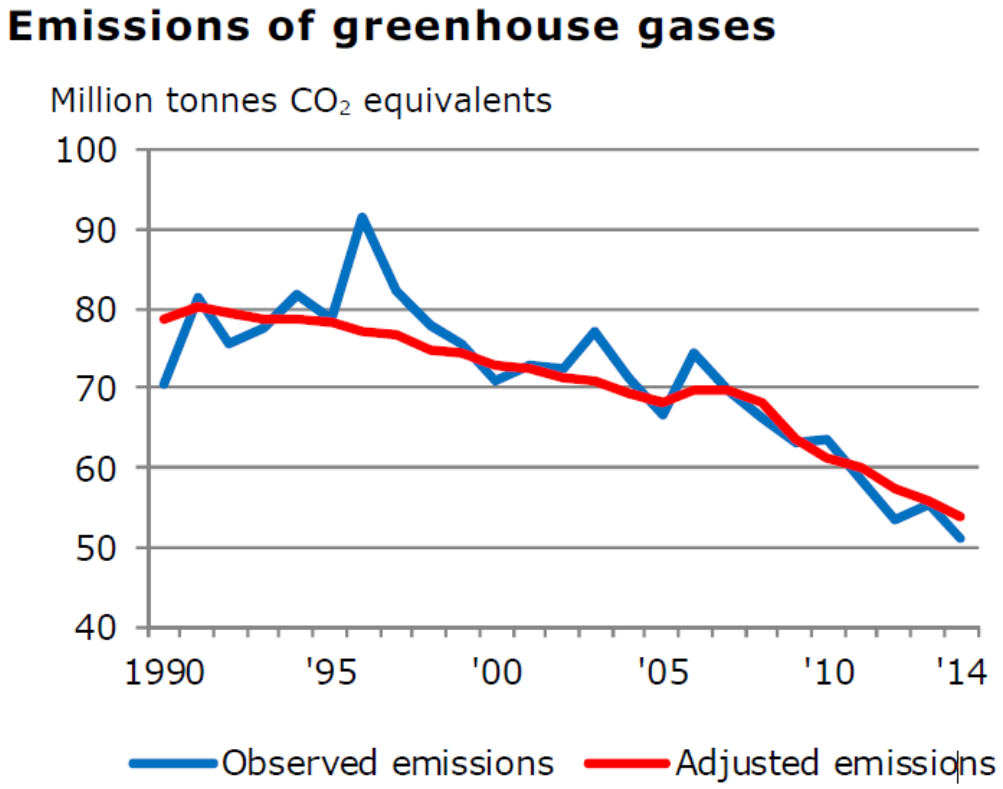
Figure 1: DH production by type of production plant



Production from industrial customers

- Industry can produce waste and 'sell' waste heat back into the thermal system!

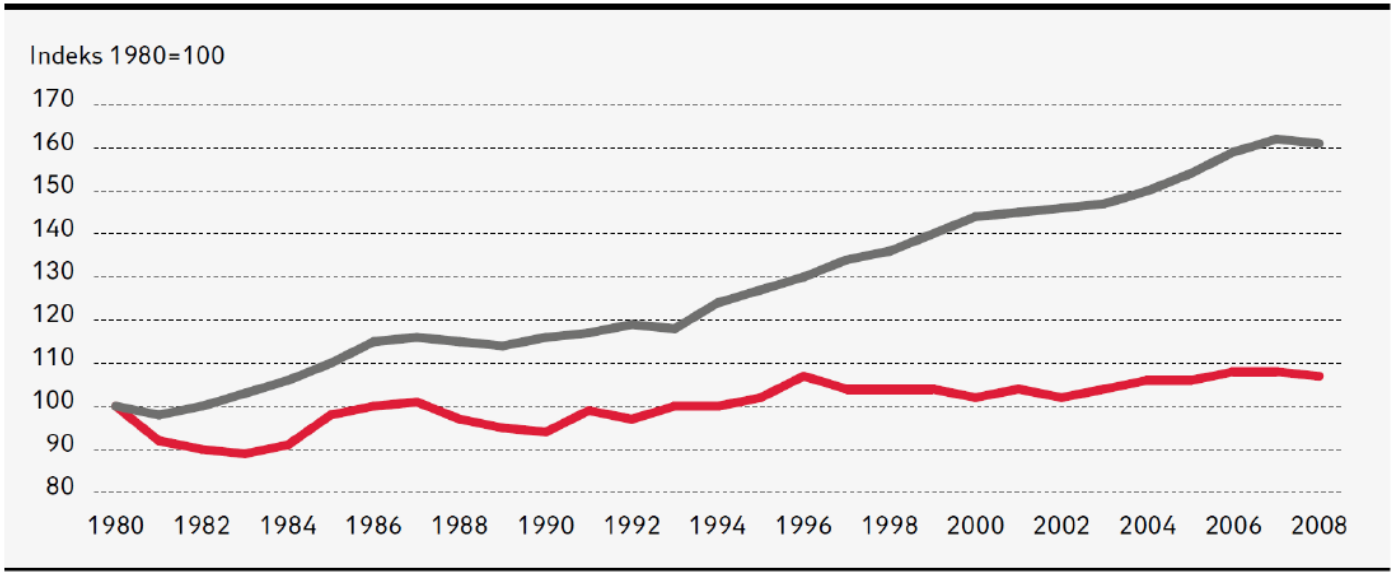
Carbon Effect of Denmark



Source: Energy Statistics 2015
Danish Energy Agency

Effect on the Economy

The development in GDP (black) and energy consumption (red)



Source: Danish Energy Agency and Danish Statistical Department

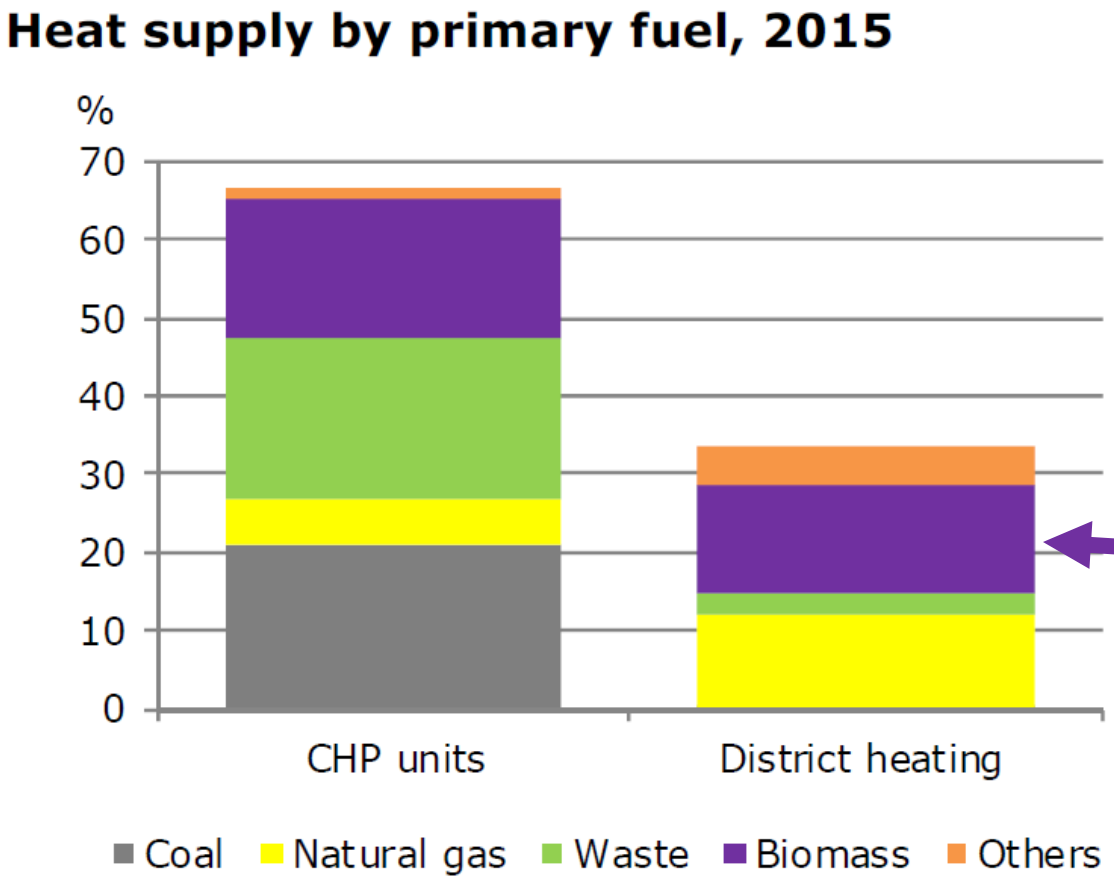
GDP

~60% increase

Energy

~10% increase

Fuel makeup of CHP and District Heating



Biomass and other renewables exempt from the Carbon Tax

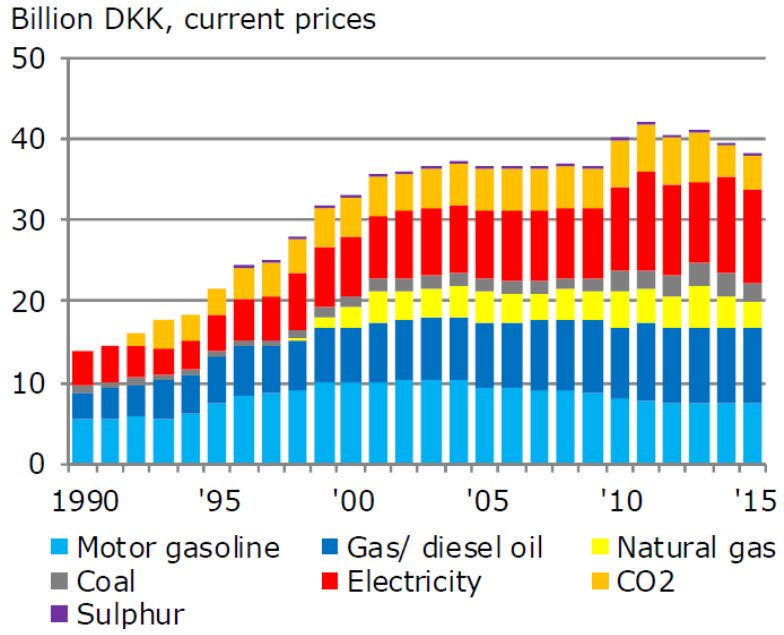
Innovation: Energy Storage in Hot Water

Two 5-million gallon tanks

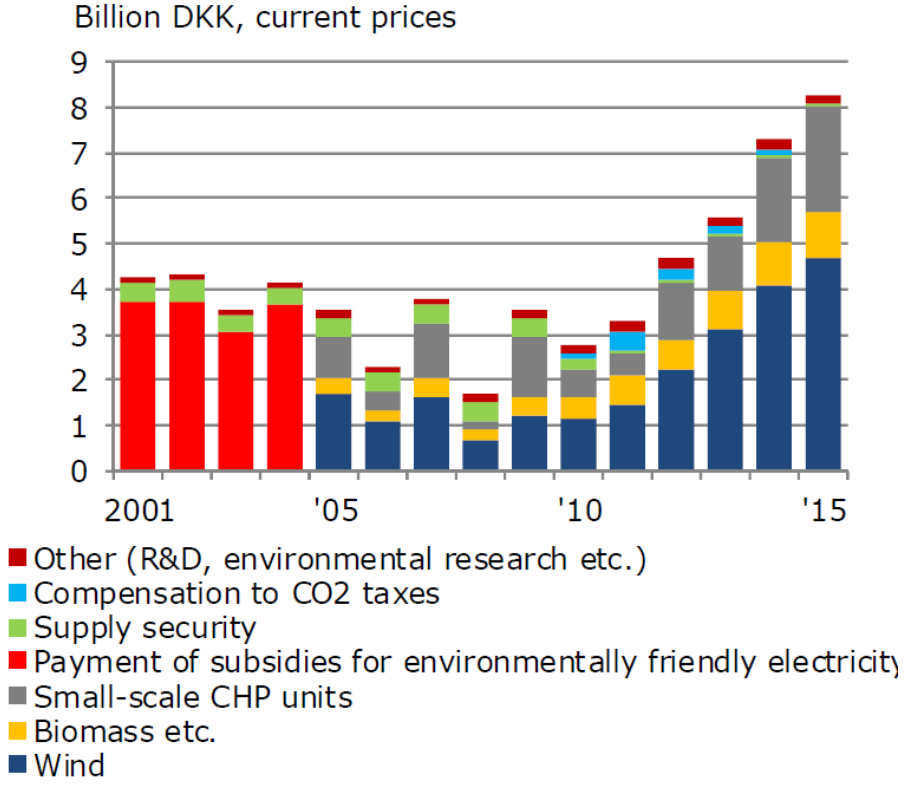
- A pit containing 52.8 million gallons of water
- 5 degree change in water temperature equals 1 GWH of stored energy!

Results:

Revenue from energy, CO_2 and sulphur taxes



Expenses for Public Service Obligations (PSO) in the electricity area

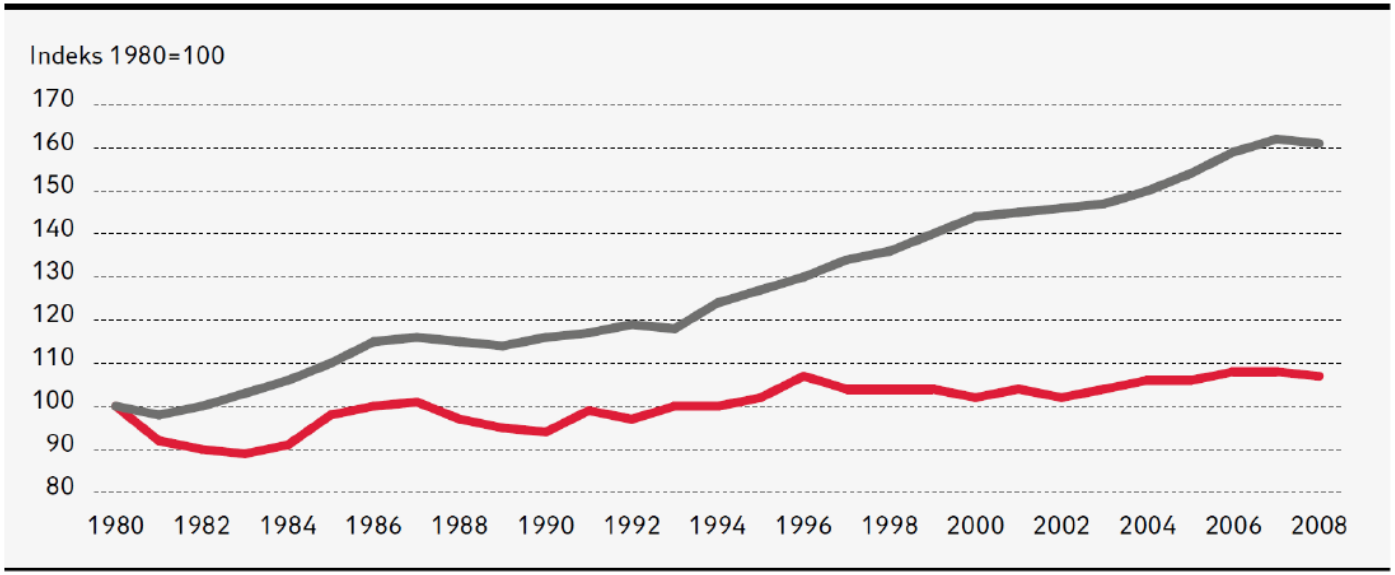


Several environmental taxes

Many investments in electricity

Effect on the Economy

The development in GDP (black) and energy consumption (red)



Source: Danish Energy Agency and Danish Statistical Department

GDP

~60% increase

Energy

~10% increase

Q&A