Modelling energy demand related to economic activities.

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- 20 researchers incl. 6 Ph.D.-students.
- Combine technical and economic research
- Focus on quantitative analysis/modelling within energy

Research areas:

1. Macro-economics, econometrics, and forecast models
2. System modelling, optimization, and simulation
3. Micro-economics, regulation, and policy analysis
4. Evaluation and integration of new energy technologies

My research: Macro-economics, econometrics, and forecast models

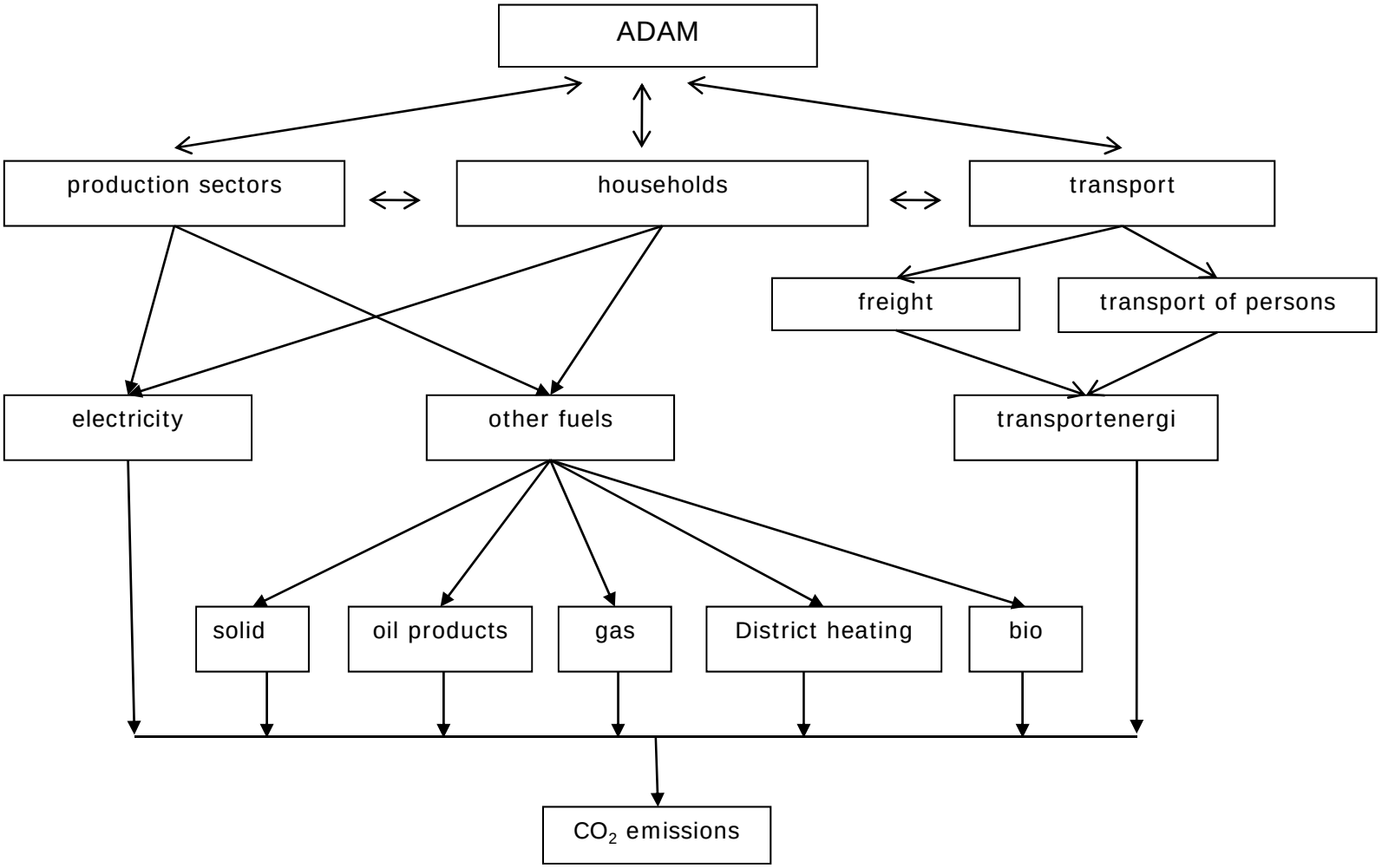
- Heading DSF-project ENSYMORA developing methods and models for Energy Systems Analysis (mainly including uncertainties into methods and models used for planning) (small 3 mio. Euro/23 man-years over 4 years)
- Participating in TopWaste and INCAP modelling waste generation/- handling and analysing flexible electricity consumption, respectively.
- Have developed the EMMA-model that will be the focus in this presentation.

The status and development of EMMA

EMMA: Energy and Environmental models for ADAM.

- An econometric model estimated on data for 1975 – 2010.
- Data: Energy balances and national account statistics (I/O-tables) from Statistics Denmark.
- Linked to ADAM – the model used for official forecasts of the economic development in Denmark (satellite to/integrated part of ADAM).
- Has been used for official analysis/forecasts by the Danish Energy Agency and the Danish TSO Energinet.dk for the last 15 years.
- The model is open source. That is, the model, data, simulation software, and some analysis may be downloaded from the homepage of the Danish Energy Agency. www.ens.dk
- The model is maintained/further developed in a collaboration between:
  - The Danish Energy Agency
  - The Danish TSO, Energinet.dk
  - The Technical University of Denmark (DTU)
  - T-T-analysis (developing the simulation software, also open source)

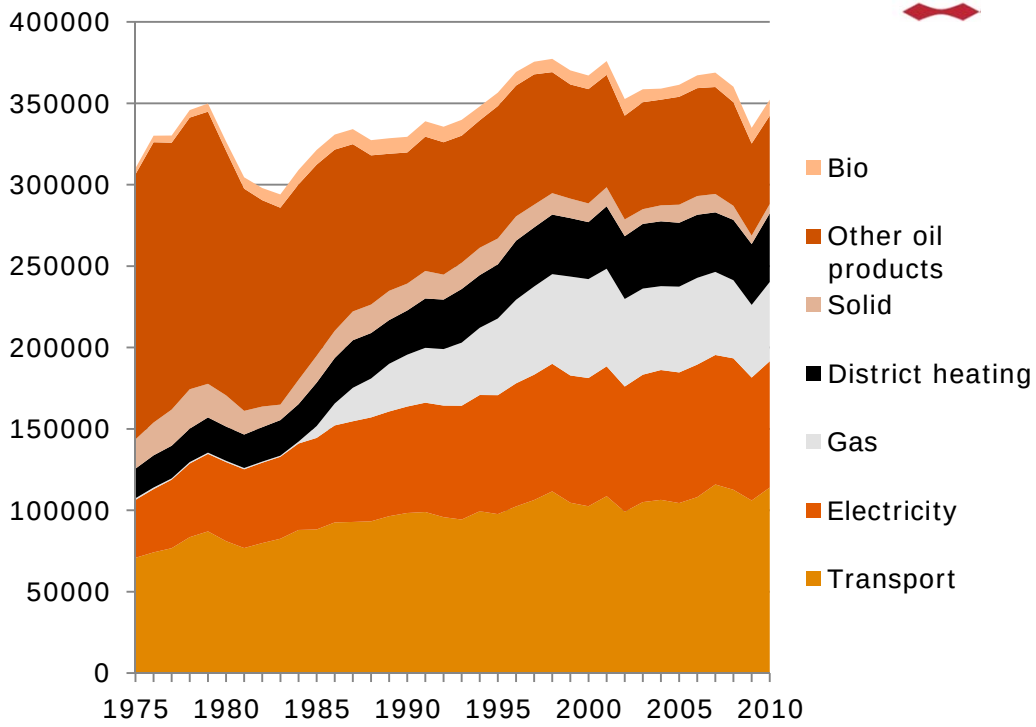
EMMA describes aggregated links between the economy, energy demand and energy related emissions.



Energy consumption by production sectors

Some general developments:

- The total energy consumption follows changes in production and prices.
- Considerable efficiency improvements.
- Structural changes, (we have exported nearly all energy intensive productions (decreasing energy consumption, but also employment
- Considerable substitution from oil to gas and electricity.



Sectors in EMMA:

- 22 (3 energy sectors modelled exogenously)
- A sub-division of sectors in ADAM into sectors that are homogenous wrt. their energy consumption.

Theoretical considerations: What is demanded is energy services and this depends of production and prices. We model in efficiency-corrected units and efficiency changes depend of time.

General Characteristics:

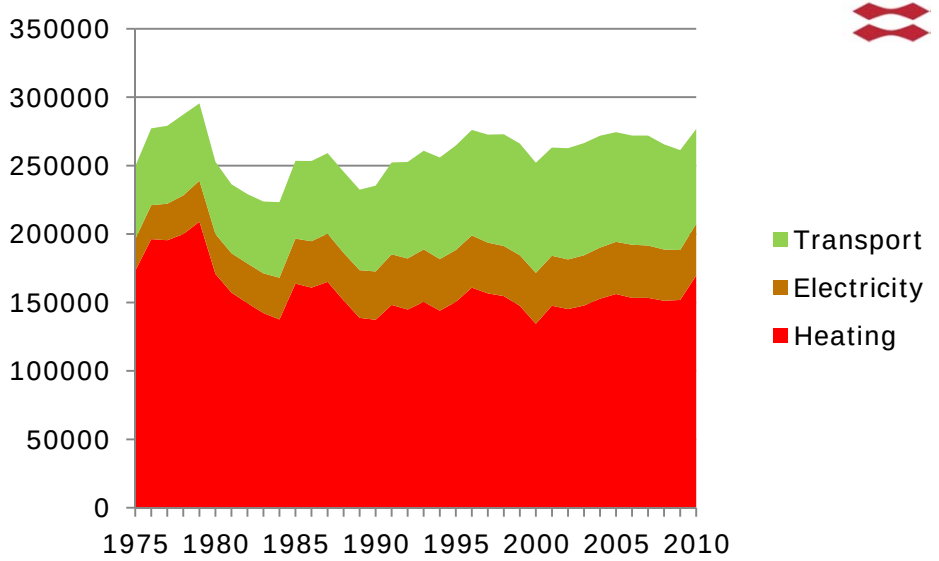
Constant return to scale $\delta E / \delta X = 1$. That is, production +1% ⇨ energy consumption +1%

Price are important. Both for the level of energy consumption and for substitution between fuels. Changes in efficiencies estimated on past data, but exogenous in projections.

Energy consumption by households

Households use energy for:

- Heating, decreased in 1980íes, fairly constant but slightly increasing since 2000
- Electricity, slightly increasing, but have decreased the last 5 years
- Transport, have increased considerably but decreased over the last years. A considerable change in the trend. (partly due to small energy-efficient cars)



Heating

Depends of the dwelling area, the price of heating, changes in heating efficiency (insulation) and climate (degree-days)

General characteristics:

The elasticity wrt. the dwelling area is 1. (dwelling area +1% ⇨ the demand for heating +1%).
(The dwelling area increases with ½ of the increase in investments in dwellings)

The elasticity wrt. climate (degree-days) is 1.

The long-term price-elasticity is -0.37 (price +1% ⇨ demand -0.37%)
the first-year elasticity is -0.15

Efficiency improvements are estimated to about 1% p.a.

Electricity consumption by households

We distinguish between:

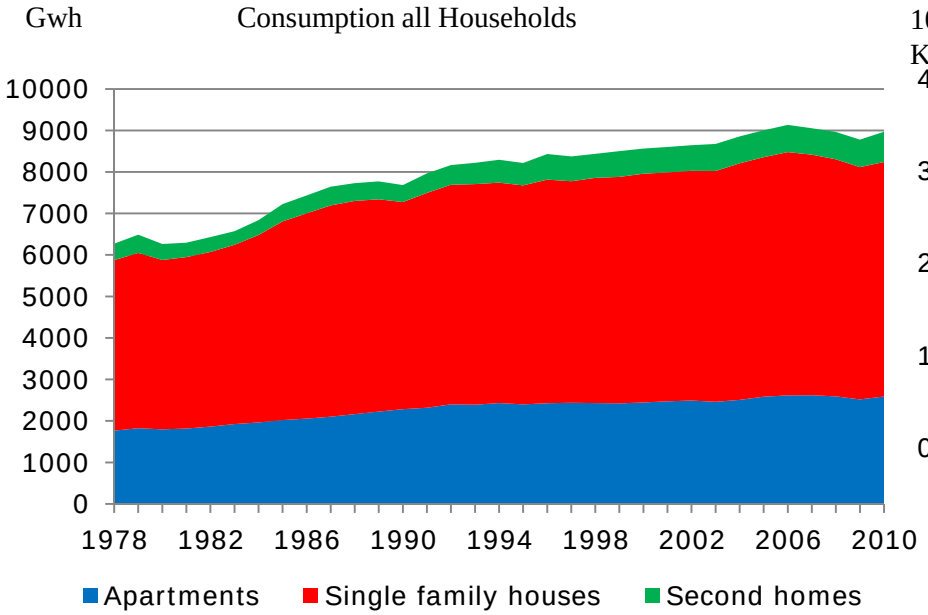
- Apartments in multifamily houses
- Single family houses
- Second homes

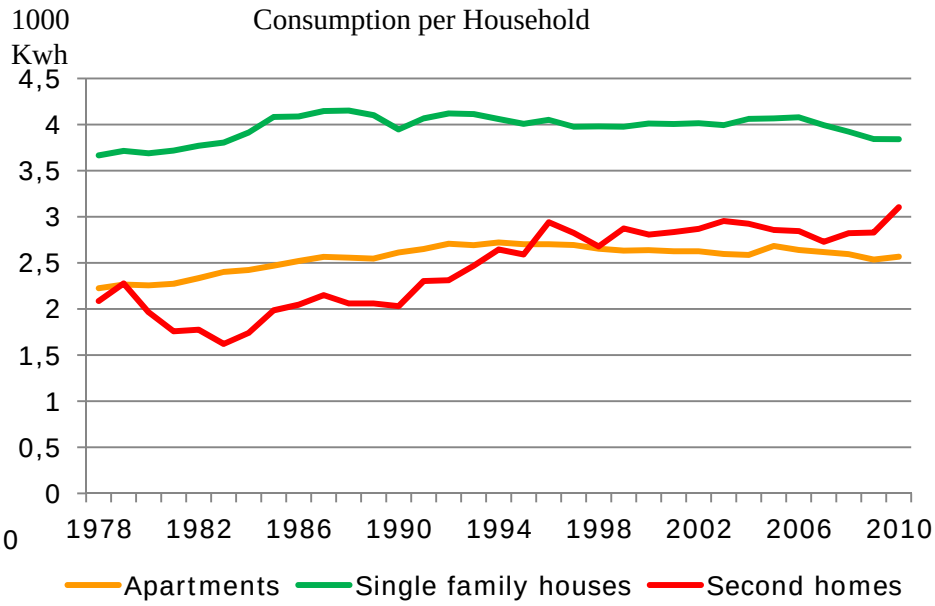
Looking at consumption, single family houses are larger than apartments and has a larger consumption per house. Second homes have a consumption close to apartments and is increasing.

Consumption depend of income and the price of electricity.

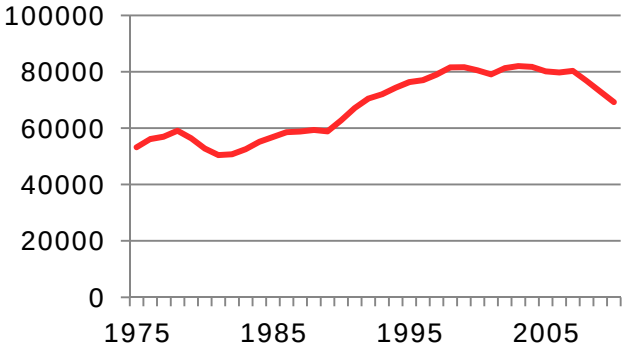
Estimated elasticities:

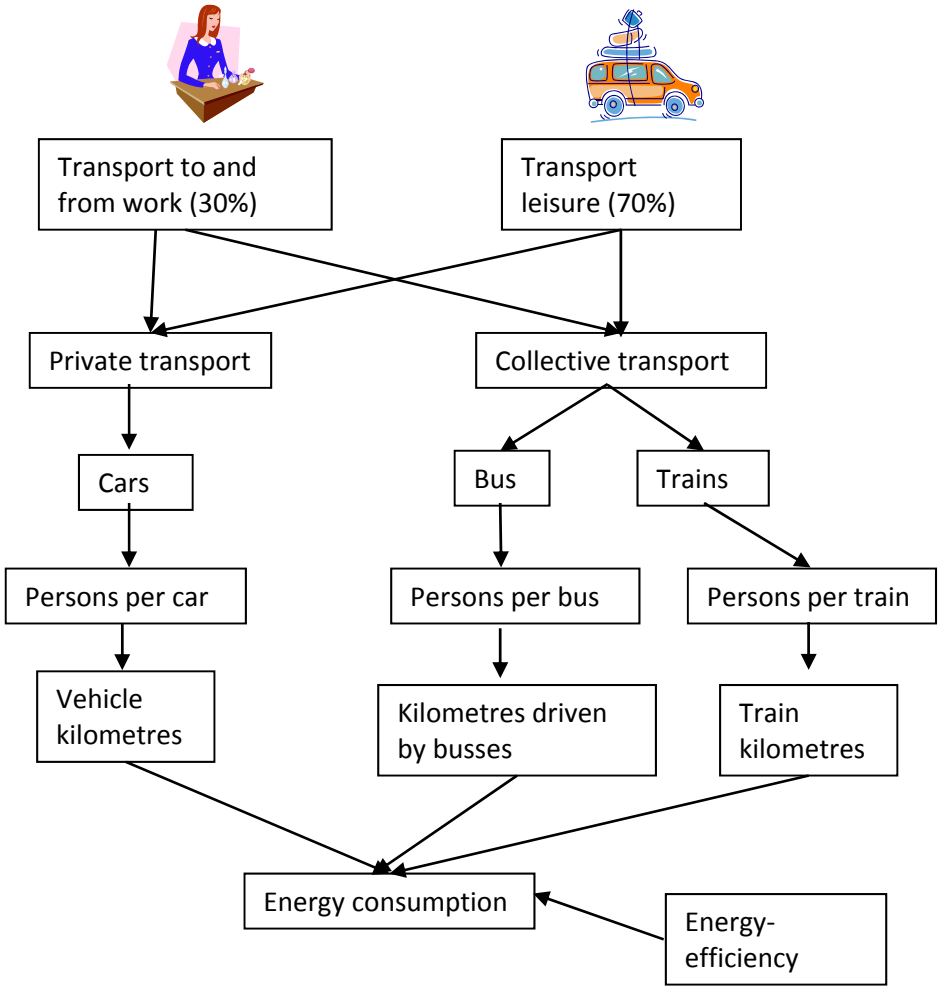
- The income-elasticity is 0.4 for both apartments and single family houses.
- The price-elasticity is -0.15 for single family houses and -0.09 for apartments.
- For second homes the income-elasticity is 1 and the price-elasticity 0.





Household transport consumption





We distinguish transport to and from work and transport for leisure purposes. Transport to and from work depend of the employment and is almost an identity. If you have a work you need the transport. Transport for leisure purposes depend of income (0.73) and the price of transport (-0.16).

Substitution between private and collective transport differs for transport to and from work and leisure. The price-elasticity largest for leisure.

The distribution of collective transport on busses, trains (the metro) is exogenous (depend of the given infrastructure)

Persons per car/bus/train is needed to come from person-kilometres to vehicle kilometres. Depend of income and prices.

The energy-efficiency (km/l) has a long-term price-elasticity of 0.7, the first year effect is 1/3. It takes time to replace vehicles.

Using the model for projections

Input:

- A projection of the economic development (an official forecast with the ADAM-model)
- Projections of energy prices (the world marked price on oil, domestic electricity prices and energy taxes)
- Exogenous energy-efficiencies (policy goals for energy savings)

The latest forecast of electricity consumption by Energinet.dk

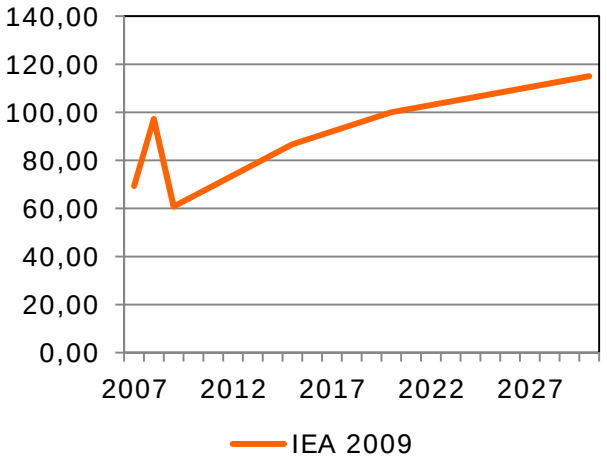
økonomisk redegørelse august 2011		2000-2010	2011	2012	2013-15	2015-20	2020-30	2030-35
		Annual change in percent						
GDP	fy	0.6	2.3	1.3	2.2	1.9	1.5	1.5
Private consumption	fcp	1.5	2.0	1.0	2.3	2.2	1.5	1.5
Consumer prices	pcp	1.8	2.6	1.9	1.7	1.8	2.0	2.0
		1000 persons, level						
Employment	q	2751	2753	2757	2755	2851	2852	2852
Un-employment	ul	114	105	107	122	121	121	121

Assumes a fairly large economic growth (has later been revised and reduced)

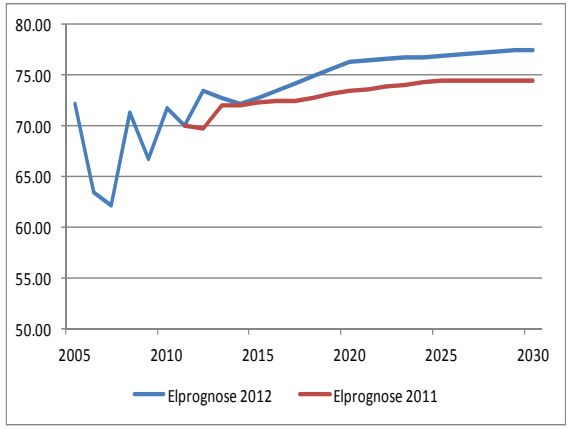
	2000-2010	2011	2012	2013-15	2015-2020	2020-2025	2025-2030
	Annual change in percent						
Agriculture	1.23	2.49	2.48	0.29	0.59	0.97	1.07
Industry	-0.10	5.83	2.42	0.65	0.74	1.37	1.40
Building and constr	-1.24	4.45	1.53	1.20	3.45	1.56	1.53
Private services	2.38	3.50	2.58	1.27	2.98	1.50	1.50
Public services	1.75	-0.22	0.36	0.31	0.66	1.50	1.50

Large increase in building and construction and private services.
Moderate increases in industry and public services

Oil price



Electricity price



Oil prices continue to increase.
Very moderate increase in the electricity price after 2020

Energy efficiencies and new categories of consumption

Efficiency improvements included: Potentials with a four year pay back time.
Implies annual savings of 1.45%, 0.3% included via estimated trends, 1.15% has to be new initiatives (policy on energy savings)

New electricity consuming technologies:
Electrical vehicles: 70.000 by 2020, 300.000 by 2030, each consuming 2.2 MWh/year
Individual heat pumps: 180.000 by 2020, 450.000 by 2030, each consuming 6 MWh/year

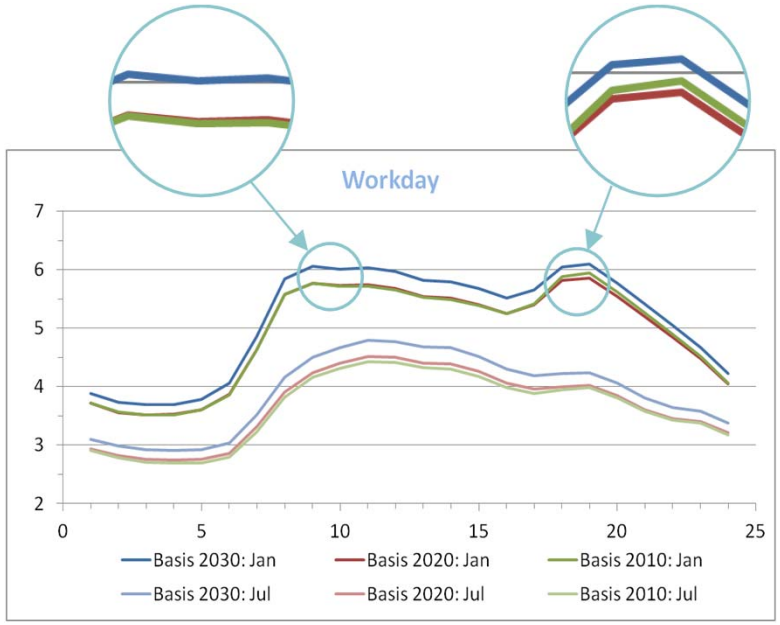
The aggregated forecast

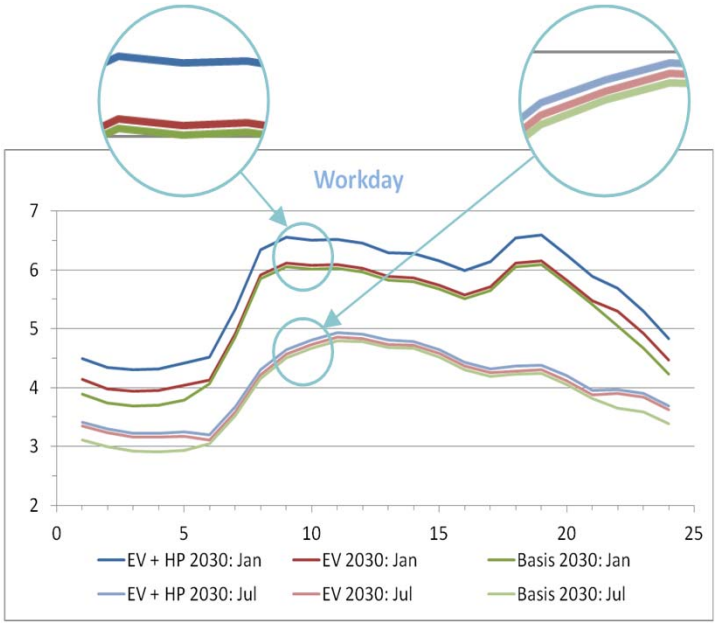
	GWh			Change	
	2010	2020	2030	2010-2020	2010-2030
Households	10257	10239	10398	0.9983	1.0138
Agriculture	1988	1966	1897	0.9888	0.9542
Industry	7193	7241	7134	1.0067	0.9918
Private services	9495	10543	11197	1.1104	1.1793
Public services	2977	2700	2669	0.9071	0.8967
Total	31909	32689	33295	1.0244	1.0434
Electrical vehicles	1	152	701		
Individual heat pumps	90	1072	2705		
Total	32000	33913	36701	1.0587	1.1469

Very moderate increase in consumption by existing consumers.
Consumption in private services is expected to increase, other sectors almost constant.
Public services is expected to decrease consumption by 10%.
Total electricity consumption is expected to increase mainly due to individual heat pumps.

The hourly electricity consumption.

Besides the annual electricity consumption Energinet.dk needs the hourly consumption profile.
From hourly electricity meters we have statistics on the hourly electricity consumption by categories of customers. Profiles are very different for different categories of customers. Therefore, to convert the annual consumption to hourly consumption we use profiles for categories and weight these by their share of the annual consumption.





For existing categories of customers the aggregated profile increase more at day-time than in the evening (due to increase in private services and constant consumption by households).
New categories of consumption:

- Electrical vehicles mainly contribute to consumption at nights.
- Individual heat pumps mainly contribute to consumption in winter where consumption is already very high. Increasing the need for peak-capacity.

Thank you for your attention