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Modeling Technology Wedges

for Low Energy and Low Carbon Strategies

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1 Introduction

Motivation

This paper is motivated by two questions:

- To what extent are energy systems different in various countries?
- What are the potentials for restructuring energy systems towards higher energy productivity and a lower carbon content?

We conduct this analysis for 18 European countries and in addition for Japan and the United States.

We attempt to distinguish between energy services as the only relevant indicator for welfare related conclusions and the resulting energy flows both for final (end use) energy and gross (untransformed) energy.

Methodology

The methodology used exhibits the following features:

- We employ a model based analysis that depicts the transformation and application technologies that finally generate energy services.
- We apply the concept of technology wedges, i.e. we show the impact over time of particular technologies applied with a certain intensity.
- The scenarios developed by this methodological approach are driven by envisaged economic activity, measured by forecasts for real gross domestic product (GDP), by the parameters that describe certain structural changes and by behavioural assumptions of companies and consumers.

Results

This modelling approach delivers a number of revealing results, as for example:

- A comparison of the current structure of energy demand as to sectors and energy types.
- A comparison of the current structure of energy supply as to energy sources.
- The impact of induced technological change on the demand for energy services as well as for final and gross energy flows.
- The impact of fuel switching by shifting to higher shares of renewable energy.

The paper does not cover the impact on CO_2 emissions since this would require a more detailed analysis of the technology options for the supply structure. As a consequence also the economic impacts of various technology strategies are not analyzed.

In total the technology scenario generated up to 2020 suggests that there is a wide span of technology options for reducing energy flows and their carbon content without losing the benefits of energy services and these options in most countries only need a shift of investment for conventional to advanced technologies.

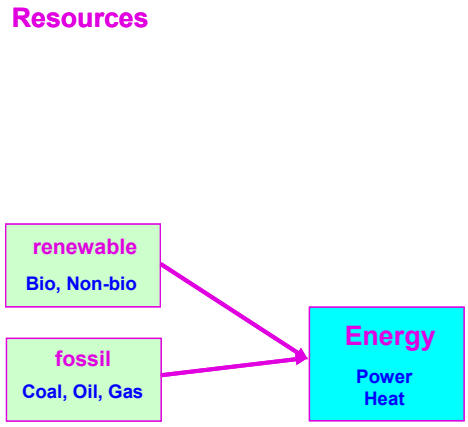
2 The Evolution of energy paradigms

Over the past decades a sequence of the energy paradigms has evolved that still requires attention and explanation in order to avoid guidelines for policy advice that have become outdated.

2.1 Stage 1: Focus on energetic resources

The first focus on energy was on the supply of energetic resources. This extremely narrow perspective unfortunately still dominated policy making whenever the main topic of energy policy focuses on security of supply. An additional issue is to what extent renewable resources should be used for substituting exhaustible energetic resources.

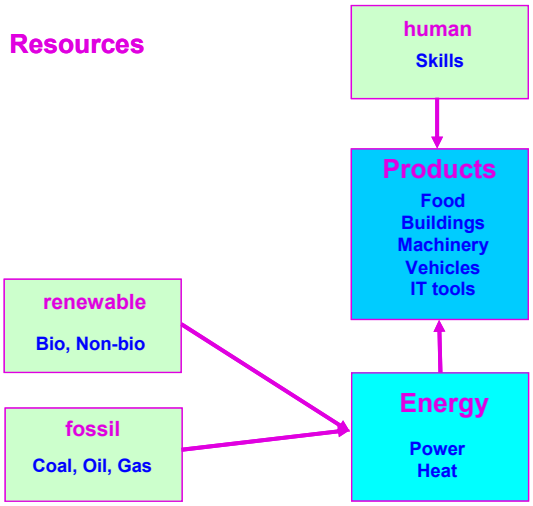
Figure 2.1: Focus on energetic resources



2.2 Stage 2: Focus on products

The next stage in the evolution of energy paradigm is dealing with energy as a production factor among others, as reproducible and human capital. Energy is considered as an input factor whose demand is mainly determined by product output, relative factor prices and mostly exogenous technological change.

Figure 2.2: Focus on products

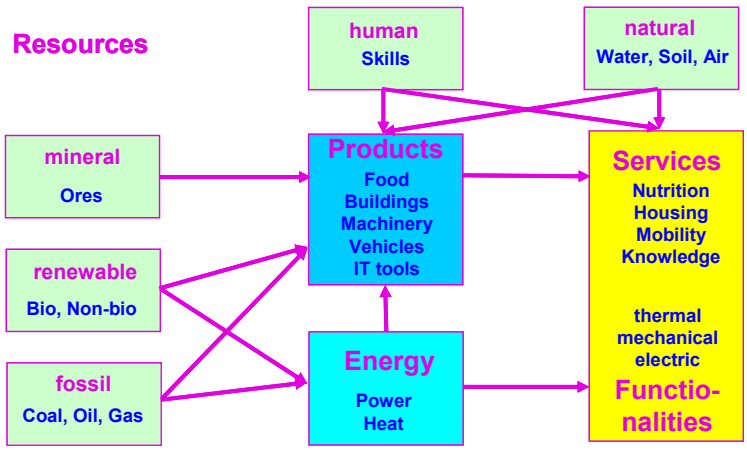


2.3 Stage 3: Focus on services and functionalities

A quantum leap is the next evolutionary step since it expands the understanding of energetic resources also to its alternative use as an input for producing materials as polymers from crude oil or paper from biomass. The new keywords are functionalities and services that can be obtained from an energetic resource. The still dominating use of oil is its energetic functionality. Major advances in materials science, however, compete for the material functionally of oil.

As a first implementation of this enhanced perspective of energetic resources the concept of energy services is emphasized in contrast to the flows of final and gross energy. Specific energy services, as mechanical for vehicles and thermal for buildings, can typically be produced with a wide range of energy intensities depending mainly on the amount and quality of capital employed, as the structure of vehicles and building.

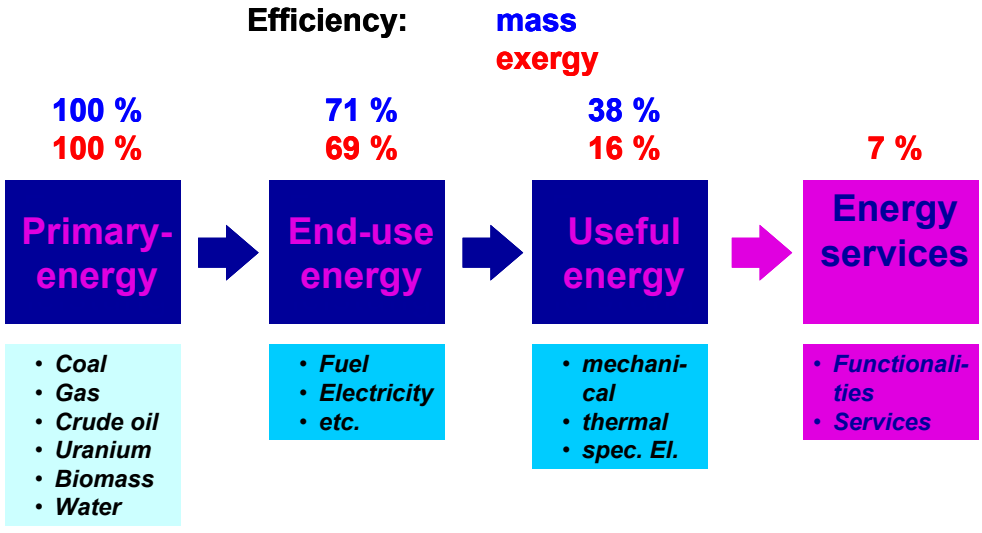
Figure 2.3: Focus on services and functionalities



2.4 From energy services to energy flows

This switch from energy flows to energy services has far reaching consequences in particular for the design of energy policy since it is the services and functionalities related to energy and not just energy flows that determine our well-being., Investment decisions need to check, therefore, also the option of improving the transformation and application technologies.

Figure 2.4: From energy services to energy flows



3 A comparative analysis of structures of energy systems

Based on a database generated from IEA Energy Balances we provide a thorough data analysis that sheds light on the specific differences of the energy systems of 20 industrialized countries.

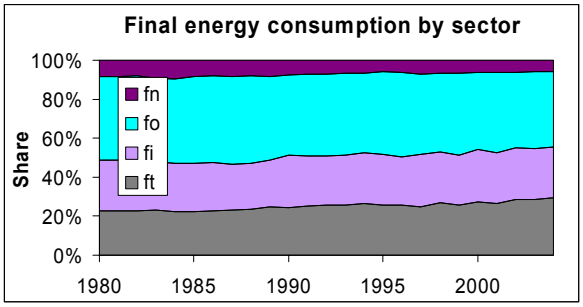
3.1 Structure of final energy demand

Final energy demand can be viewed both from the distribution by sectors and the distribution by energy types.

As Table 3.1 indicates the shares of transport (ft), industry (fi), other sectors (fo) as residential and commercial and non-energetic use (fn) reflect mainly the different intensities in transport and industry. For example Austria in comparison to the Czech Republic has a higher transport but lower industry share.

Figure 3.1: Final energy structure by sector in Austria and Czech Republic

Austria



Czech Republic

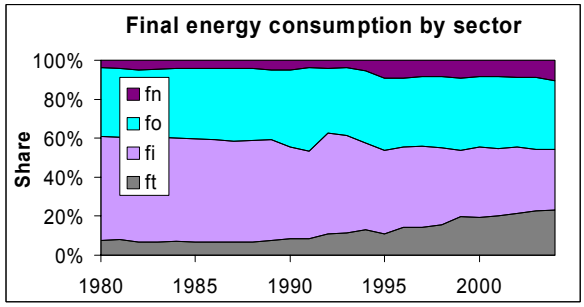


Table 3.1: Final energy structure by sector

	Final energy structure by sector Percentage shares 2004			
	Transport	Industry	Other	Non-en.
Austria	29,5	26,0	38,6	5,8
Belgium	25,3	26,9	36,2	11,5
Czech Republic	22,9	31,5	35,0	10,6
Denmark	33,7	18,8	45,7	1,8
Finland	18,1	46,3	31,9	3,7
France	30,2	21,5	39,9	8,4
Germany	25,6	21,0	43,1	10,2
Greece	38,0	18,9	38,9	4,2
Hungary	20,9	17,3	53,1	8,7
Italy	31,0	27,1	35,1	6,8
Netherlands	24,4	21,3	35,8	18,6
Poland	19,3	27,3	46,4	7,0
Portugal	34,9	27,0	26,6	11,4
Spain	37,8	28,6	25,1	8,5
Sweden	24,0	35,1	35,1	5,7
Switzerland	31,7	19,0	46,8	2,5
Slovakia	19,5	31,2	37,6	11,7
United Kingdom	33,5	20,0	39,5	7,0
Japan	26,6	28,9	32,4	12,1
United States	39,9	18,8	31,1	10,2

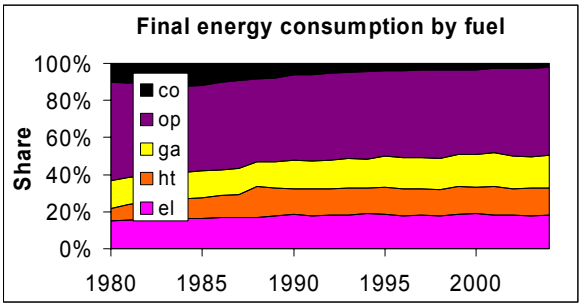
Differences in final energy demand as to energy types coal (co), oil products (op), gas (ga), heat (ht) and electricity (et) are visible from Table 3.2. These differences mainly reflect the distribution of heat which has very high shares in Finland (32,8%) Sweden (26,2%) and Denmark (20,3%). The corresponding shares are in Austria 14,6% and in the Czech Republic 12,8%. Obviously countries with low shares of heat show an unused potential for improving the overall efficiency of the energy system by increasing the use of cogeneration technologies.

Other remarkable differences result from the intensity of electricity use. These shares are on the average below 20 percent with exception of Sweden (31,4%), Finland (26,3%), Japan (23,5%) and Switzerland (22,0%), France (20,8%) and Greece (20,0%).

Austria in comparison to the Czech Republic shows higher shares of heat, electricity and oil products but a lower share of gas and almost no coal.

Figure 3.2: Final energy structure by energy type in Austria and Czech Republic

Austria



Czech Republic

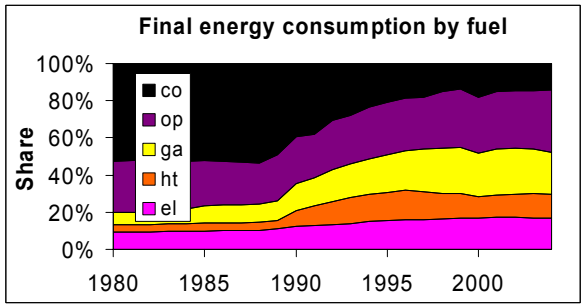


Table 3.2: Final energy structure by energy type

	Final energy structure by energy type Percentage shares 2004				
	Coal	Oil	Gas	Heat	Electricity
Austria	2,3	47,1	17,8	14,6	18,1
Belgium	3,8	50,7	26,2	2,5	16,8
Czech Republic	14,0	34,0	22,5	12,8	16,7
Denmark	1,7	48,9	11,0	20,3	18,2
Finland	3,9	33,6	3,4	32,8	26,3
France	2,0	51,4	19,7	6,2	20,8
Germany	3,6	45,9	24,8	8,1	17,5
Greece	2,6	69,7	2,8	5,0	20,0
Hungary	3,4	31,8	40,5	9,9	14,3
Italy	2,1	47,1	28,7	4,5	17,6
Netherlands	1,5	43,0	36,8	4,7	14,0
Poland	18,6	32,8	15,6	18,8	14,2
Portugal	0,4	62,7	6,0	12,9	18,0
Spain	1,6	59,4	16,3	3,6	19,2
Sweden	2,2	38,8	1,4	26,2	31,4
Switzerland	0,6	58,4	11,3	7,7	22,0
Slovakia	11,8	26,0	32,2	11,8	18,2
United Kingdom	1,9	47,2	31,3	1,8	17,9
Japan	7,6	59,9	7,5	1,5	23,5
United States	2,1	54,1	20,9	3,3	19,6

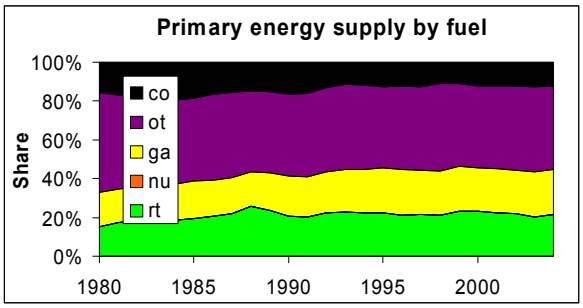
3.2 Structure of gross energy supply

Main differences as to the structure of gross energy result from the use of renewables and nuclear energy. Shares of renewables exceed 20 percent in Sweden (26,7%), Finland (23,5%) and Austria (21,2%). The corresponding high shares for nuclear power can be found in France (43,3%), Sweden (37,8%), Switzerland (26,1%), Slovakia (24,7%) and Belgium (21,1%).

The Czech Republic in comparison to Austria has a 15,5% share of nuclear energy, a high share of coal (47,4%), a lower share of gas (17,6%) and a much lower share of oil (15,5%).

Figure 3.3: Gross energy structure by energy type in Austria and Czech Republic

Austria



Czech Republic

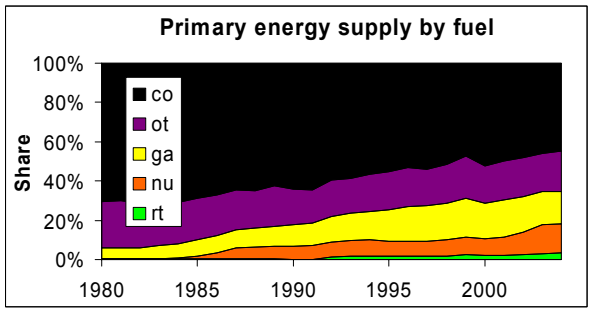


Table 3.3: Gross energy structure by energy type

	Gross energy structure by energy type Percentage shares 2004				
	Coal	Oil	Gas	Nuclear	Renwables
Austria	11,9	44,2	22,8	0,0	21,2
Belgium	9,9	41,7	25,0	21,1	2,3
Czech Republic	47,4	15,6	17,6	15,5	3,8
Denmark	22,0	39,9	23,4	0,0	14,8
Finland	19,6	31,3	10,3	15,4	23,5
France	5,2	30,2	14,9	43,3	6,4
Germany	24,7	35,9	22,6	12,5	4,3
Greece	29,6	57,9	7,3	0,0	5,2
Hungary	13,0	28,5	43,4	11,6	3,6
Italy	8,8	48,5	35,0	0,0	7,7
Netherlands	10,4	41,6	44,0	1,2	2,8
Poland	59,6	22,1	13,1	0,0	5,3
Portugal	12,4	61,0	12,2	0,0	14,4
Spain	14,8	49,5	17,7	11,7	6,3
Sweden	5,5	28,3	1,7	37,8	26,7
Switzerland	0,5	45,8	10,0	26,1	17,6
Slovakia	24,9	15,9	30,2	24,7	4,2
United Kingdom	16,0	36,3	37,3	8,9	1,6
Japan	21,8	47,8	13,2	13,8	3,4
United States	23,4	40,8	22,1	9,1	4,5

4 Energy and economic activity

To what extent energy demand is driven by economic activity is revealed by GDP energy elasticities, a measure that indicates the percentage reaction of energy with respect to a one percent increase of gross domestic product (GDP).

4.1 Gross domestic product trends

We use OECD Economic Outlook as data source for calculating the trend values for real GDP growth rates by smoothing the actual rates of changes by an exponential weighted filter. In Table 4.1 we list the results we obtained by this procedure. This table is also informative as to the changes of GDP trend values over the past 15 years. Austria for example maintained a rather stable but moderate GDP growth rate after a hike around 2000 whereas the Czech Republic exhibits a declining but still fairly high GDP growth.

Table 4.1: GDP trends

	Gross domestic product trend Percent p.a.			
	1990	1995	2000	2004
Austria	2,2	2,2	2,5	2,2
Belgium	2,1	1,9	2,3	2,0
Czech Republic	3,1	3,3	2,6	2,8
Denmark	1,4	1,8	2,3	1,8
Finland	3,2	1,8	2,9	2,7
France	2,2	1,8	2,2	2,0
Germany	2,2	2,2	2,5	2,2
Greece	2,2	2,2	2,5	2,2
Hungary	3,1	2,2	3,0	3,4
Italy	2,3	1,9	2,0	1,6
Netherlands	2,1	2,1	2,8	2,1
Poland	3,1	3,0	3,9	3,7
Portugal	3,0	2,5	3,1	2,3
Spain	2,2	2,2	2,5	2,2
Sweden	2,1	1,7	2,4	2,3
Switzerland	2,3	1,4	1,7	1,4
Slovakia	3,1	3,6	3,6	3,9
United Kingdom	2,1	2,1	2,6	2,5
Japan	3,7	2,8	2,1	1,8
United States	3,0	2,8	3,4	3,0

4.2 Final energy elasticities by energy type

In Tables 4.1 and 4.2 we report GDP elasticities both for non-electric and electric energy with a number of very revealing results.

In general these elasticities are rather low (not exceeding 0,5) or even negative which indicates a pronounced tendency of decoupling non-electricity energy demand from economic activity. This is true for most countries analyzed with the exception of Austria (0,9), Greece (1,0), Italy (0,9), Portugal (1,4) and Spain (1,5). There is also evidence of an increase of these elasticities over recent years.

GDP elasticities for electricity in general are higher with most countries tending to values of one but rather low values in Denmark (0,6), Sweden (0,5) Germany (0,5) and Italy (0,3).

Table 4.1: Final non-electric energy GDP elasticities

	Final non-electric energy GDP elasticity			
	1990	1995	2000	2004
Austria	-0,1	0,2	0,4	0,9
Belgium	-0,6	0,0	0,5	0,2
Czech Republic	-0,4	-0,8	-0,8	-0,2
Denmark	-1,9	-0,4	-0,3	-0,1
Finland	0,0	-0,1	0,1	0,4
France	-0,4	-0,1	0,1	0,1
Germany	-0,5	-0,3	-0,3	0,0
Greece	1,2	0,8	0,9	1,0
Hungary	-0,3	-0,8	-0,4	0,0
Italy	0,2	0,3	0,4	0,9
Netherlands	-0,4	0,0	0,2	0,4
Poland	-0,8	-0,3	-0,5	-0,2
Portugal	1,7	1,6	1,4	1,4
Spain	0,7	1,0	1,2	1,5
Sweden	-1,5	-0,5	-0,3	-0,1
Switzerland	0,4	0,5	0,4	0,5
Slovakia	0,4	-0,6	-0,3	-0,2
United Kingdom	-0,2	0,0	0,1	0,1
Japan	0,5	0,7	0,7	0,5
United States	-0,3	0,0	0,3	0,3

Table 4.2: Final electric energy GDP elasticities

	Final electric energy GDP elasticity			
	1990	1995	2000	2004
Austria	1,2	1,0	0,9	1,1
Belgium	1,2	1,5	1,2	1,1
Czech Republic	0,8	0,6	0,5	0,6
Denmark	1,8	1,1	0,7	0,7
Finland	1,5	2,1	1,1	1,1
France	1,6	1,7	1,2	1,2
Germany	0,6	0,4	0,5	0,5
Greece	1,7	1,7	1,7	1,8
Hungary	0,7	0,2	0,3	0,3
Italy	1,2	1,3	1,4	1,6
Netherlands	1,0	1,1	1,0	1,1
Poland	0,4	0,1	0,2	0,2
Portugal	1,7	1,9	1,7	2,1
Spain	1,6	1,4	1,7	2,1
Sweden	1,6	1,4	0,7	0,5
Switzerland	1,3	1,5	1,1	1,3
Slovakia	0,9	0,4	0,3	0,4
United Kingdom	0,4	0,5	0,6	0,5
Japan	1,0	1,2	1,3	1,1
United States	0,9	1,0	0,8	0,7

4.3 Final energy elasticities by sectors

We calculated GDP elasticities also for the sectors transport, industry and other sectors. These estimates serve for calculating the business-as-usual projections in the model simulations.

All of these estimates are time-varying, that means they also reveal variations of the dependency between economic activity and the respective energy demand.

As to the transport sector results which are listed in Table 4.3, we notice the striking increase for Austria (from 0,2 to 1,5) and a similar and even higher increase for the Czech Republic (from 0,1 to 2,0). Other countries show reverse trends as Germany (from 1,0 to 0,3) and Switzerland (from 1,6 to 0,99:

As to the industry sector we obtain rather mixed results as can be seen in Table 4.4. Only a few countries exhibit higher GDP elasticities like Austria (from 0,0 to 0,8) and Spain (from 0,0 to 1,4) whereas the majority of countries seems to be able to increase industrial production without additional energy inputs.

As to the other sectors, which encompass residential and commercial use of energy, there seems to be a tendency for increasing the relationship between energy use and economic activity but countries as Denmark (from -2,0 to -0,3) and Sweden (from -1,6 to -0,4) still demonstrate a decoupling also in this sector.

Table 4.3: Final transport sector energy GDP elasticities

	Final transport sector energy GDP elasticity			
	1990	1995	2000	2004
Austria	0,2	0,6	0,9	1,5
Belgium	1,0	1,0	0,9	1,0
Czech Republic	0,1	0,2	1,9	2,0
Denmark	0,3	0,7	0,5	0,8
Finland	1,0	1,0	0,5	0,7
France	1,1	1,2	1,0	0,7
Germany	1,0	0,8	0,6	0,3
Greece	1,8	1,4	1,1	1,2
Hungary	-0,1	-0,5	0,4	0,7
Italy	1,2	1,3	1,0	1,2
Netherlands	0,9	1,2	1,0	1,1
Poland	-0,8	-0,2	0,2	0,6
Portugal	1,2	1,7	1,6	1,9
Spain	1,3	1,3	1,4	1,7
Sweden	0,6	0,8	0,5	0,5
Switzerland	1,6	1,6	1,5	0,9
Slovakia	-0,1	0,1	0,2	1,0
United Kingdom	1,3	1,0	0,8	0,6
Japan	0,8	1,1	1,1	0,8
United States	0,3	0,5	0,5	0,5

Table 4.4: Final industry sector energy GDP elasticities

	Final industry sector energy GDP elasticity			
	1990	1995	2000	2004
Austria	0,0	0,2	0,6	0,8
Belgium	-0,5	-0,3	0,6	-0,1
Czech Republic	-0,7	-1,1	-1,4	-1,0
Denmark	-1,6	-0,2	-0,2	-0,2
Finland	1,9	2,3	1,3	1,3
France	-1,2	-0,7	-0,3	0,1
Germany	-1,1	-1,3	-0,7	-0,5
Greece	0,1	0,1	0,4	-0,1
Hungary	-0,6	-2,2	-1,2	-0,8
Italy	-0,4	-0,2	0,5	0,5
Netherlands	-0,6	-0,3	0,2	0,5
Poland	-1,0	-0,7	-0,7	-0,6
Portugal	1,1	1,0	1,1	0,7
Spain	0,0	0,1	0,9	1,4
Sweden	-0,4	0,1	0,3	0,1
Switzerland	-0,2	0,3	0,7	0,8
Slovakia	-0,6	-1,3	-0,9	-0,5
United Kingdom	-1,6	-1,0	-0,4	-0,2
Japan	0,3	0,3	0,2	0,2
United States	-1,0	-0,8	0,2	-0,1

Table 4.5: Final other sectors energy GDP elasticities

	Final other sectors energy GDP elasticity			
	1990	1995	2000	2004
Austria	0,3	0,6	0,3	0,7
Belgium	-1,1	0,0	-0,1	0,3
Czech Republic	0,2	-0,4	-0,5	-0,1
Denmark	-2,0	-0,6	-0,5	-0,3
Finland	-0,8	-0,8	-0,3	0,0
France	-0,1	0,1	0,2	0,4
Germany	-0,5	-0,3	-0,3	0,3
Greece	1,8	1,4	1,6	1,9
Hungary	0,3	0,2	0,0	0,3
Italy	0,5	0,6	0,6	1,6
Netherlands	-0,7	0,0	0,0	0,1
Poland	-0,4	0,1	-0,3	-0,1
Portugal	2,2	2,1	1,5	1,9
Spain	1,7	1,7	1,6	2,0
Sweden	-1,6	-0,5	-0,5	-0,4
Switzerland	0,4	0,5	0,0	0,7
Slovakia	1,5	0,3	0,2	-0,2
United Kingdom	-0,2	0,1	0,2	0,2
Japan	1,1	1,3	1,5	1,1
United States	-0,1	0,2	0,3	0,4

5 Scenarios of technology wedges

Based on the structural analysis we have obtained and on the elasticity parameters estimated for the relationship between economic activity and energy demand we develop scenarios for energy projections up to 2020 by applying the methodology of technology wedges. This methodology identifies technology options and simulates the impact of these options given the implementation of a particular technology with a specified intensity.

5.1 Methodology of the technology wedges scenarios

For developing the scenarios we proceeded in two steps.

In step 1 we produced a business-as-usual projection up to 2020 by extending the demand for final energy by sectors based on the latest available estimates for GDP growth and the corresponding energy elasticities. No changes were made as to the application and transformation technologies for obtaining the corresponding projections for gross energy flows.

In step 2 we introduced three basic options for technology wages:

- A reduction of energy services of 1,3 percent per year in transport and of 1,0 percent in the remaining sectors which reflects the potential for reducing redundancy and structural improvements
- An increase in final energy productivity of 1,0 percent per year in all sectors which takes into account the potential for switching to improved application technologies in vehicles, buildings and machines.
- An improvement of the transformation efficiency of 1,0 percent per year in the conversion of gross energy to final energy by taking into account the new technology option for cogeneration of electricity and heat.

Corresponding to these three technology options we obtain three technology wedges

- A service wedge that reflects the elimination of redundant services
- An application wedge that reflects the implementation of application technologies with a higher energy productivity
- A transformation wedge that indicates the impact of higher transformation efficiency by switching to advanced transformation technologies.

As basic results of these technology assumptions we obtain

- final energy flows indicating the effect of the service and application technology wedge
- gross energy flows that in addition exhibit the effect of the transformation wedge

In addition we show how an increase of renewables to levels suggested by EU policies reduces the requirements for the remaining non-renewable energy flows.

Country details are reported in the country results of section 6. In the sequel we summarize the overall simulation results.

5.2 Final energy technology wedges

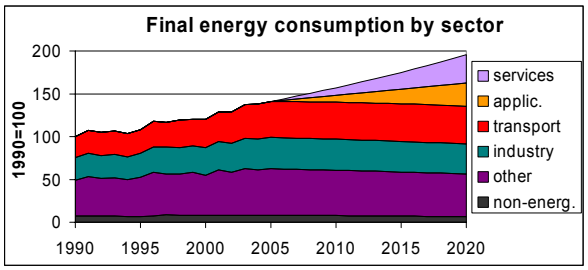
The impacts of the suggested technology wedges on final energy are listed in Table 5.1. All energy flows are expressed as indices with value 100 in base year 1990. We realize that the results differ widely across a country which is mainly due to the different reaction of energy flows with respect to GDP activity.

Most countries seem to be able to lower in 2020 their final energy flows well below 1990 levels. The notable exceptions are Spain (204), Portugal (162), Greece (154) and Austria (136).

The projections vary vastly for Austria compared to the Czech Republic. Under business-as-usual projections Austria would almost double final energy demand by 2020 over 1990 whereas the Czech Republic would exceed only modestly the 1990 levels. The service and application wedges would still see Austria 36% above 1990 whereas the Czech Republic 29% below the 1990 energy flows.

Figure 5.1: Final energy scenarios for Austria and Czech Republic

Austria



Czech Republic

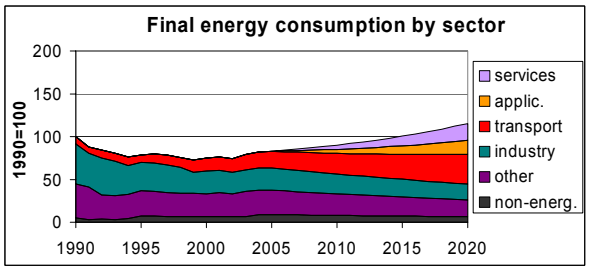


Table 5.1: Final energy scenarios

	Final energy scenarios Index (1990=100)			
	2000	2004	2010	2020
Austria	120,1	138,1	140,1	135,6
Belgium	127,3	124,3	116,7	99,4
Czech Republic	74,5	81,8	80,5	78,9
Denmark	108,6	112,6	101,8	81,3
Finland	109,0	119,6	120,9	119,5
France	114,1	117,1	109,4	92,1
Germany	97,4	101,8	93,0	75,8
Greece	126,1	138,6	146,2	153,7
Hungary	82,4	91,1	87,2	76,9
Italy	112,1	123,1	120,5	109,8
Netherlands	116,1	123,4	119,1	106,5
Poland	94,3	97,8	89,8	73,9
Portugal	144,5	152,4	159,1	161,9
Spain	142,5	165,6	182,7	203,5
Sweden	109,9	111,1	100,8	81,5
Switzerland	107,9	111,8	106,9	93,6
Slovakia	70,9	71,9	64,2	52,2
United Kingdom	110,8	112,6	104,5	87,0
Japan	115,1	115,9	112,9	102,6
United States	119,8	122,5	117,1	102,6

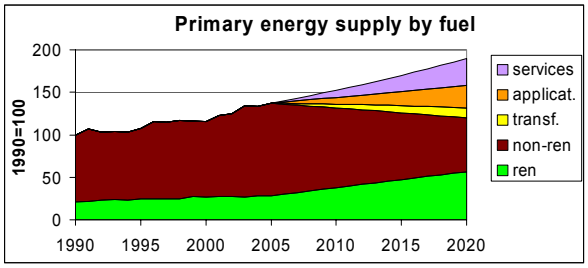
5.3 Gross energy technology wedges

The results for gross energy depict as indicated in Table 5.2 similar patterns but in addition show the transformation wedges generated by improved transformation technologies. The general impression is that most countries should be able to keep their gross energy requirements well below 1990 levels if they also invest into advanced transformation technologies. If in addition a reasonable amount of switching to renewables is initiated this would mean a potential for reducing CO_2 emissions by 2020 substantially under 1990 levels.

The results for Austria and the Czech Republic reveal that Austria would by 2020 still have gross energy requirements that are 20 percent above 1990 whereas the Czech Republic could be 36 percent below 1990. Major differences are in the respective shares of renewables because of the major differences in historical patterns.

Figure 5.2: Gross energy scenarios for Austria and Czech Republic

Austria



Czech Republic

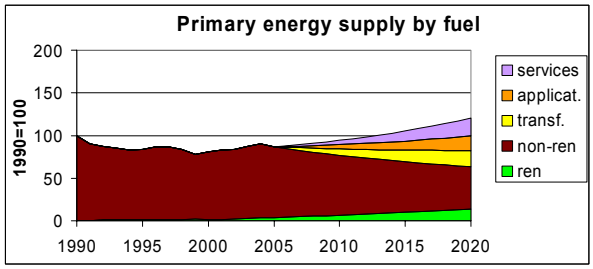


Table 5.2: Gross energy scenarios

	Gross energy scenarios Index (1990=100)			
	2000	2004	2010	2020
Austria	115,5	133,9	131,7	119,7
Belgium	121,5	119,6	109,1	87,3
Czech Republic	80,8	90,3	76,6	63,6
Denmark	104,8	107,2	94,9	69,2
Finland	113,1	127,9	118,8	107,1
France	112,6	120,8	102,3	78,7
Germany	96,5	97,6	88,9	68,1
Greece	125,1	138,1	137,0	131,4
Hungary	85,7	91,5	84,4	68,0
Italy	116,9	124,7	116,8	97,3
Netherlands	114,7	123,7	112,6	91,9
Poland	89,0	91,1	80,5	58,9
Portugal	142,9	152,7	151,8	141,0
Spain	137,4	155,9	168,7	171,5
Sweden	102,8	112,7	92,7	68,3
Switzerland	103,0	109,1	99,9	82,1
Slovakia	80,4	83,5	69,3	51,5
United Kingdom	109,8	109,9	98,8	75,1
Japan	118,6	119,6	109,9	91,2
United States	119,7	120,7	110,4	88,3

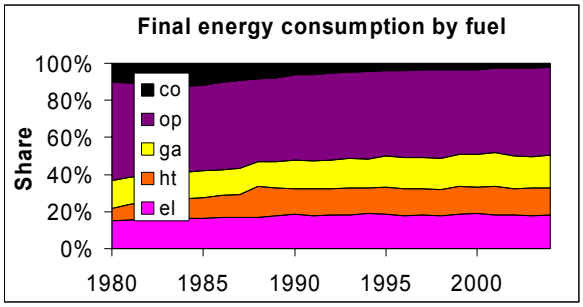
6 Country results

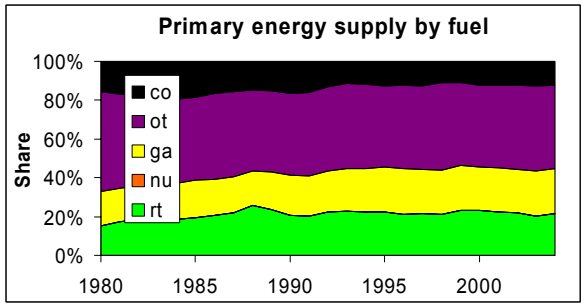
We report for the following countries structural indicators of their energy system together with the technology wedges scenarios:

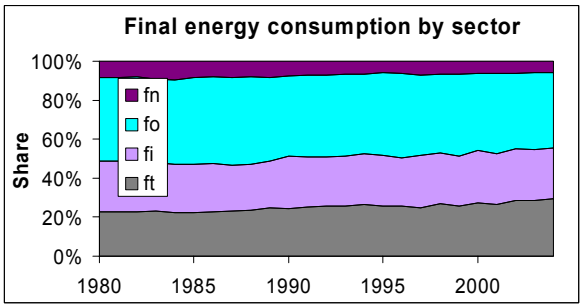
- Austria
- Belgium
- Czech Republic
- Denmark
- Finland
- France
- Germany
- Greece
- Hungary
- Italy
- Netherlands
- Poland
- Portugal
- Spain
- Sweden
- Switzerland
- Slovakia
- United Kingdom
- Japan
- United States

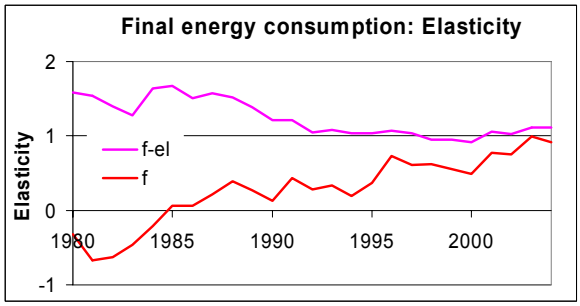
Austria

Structural indicators

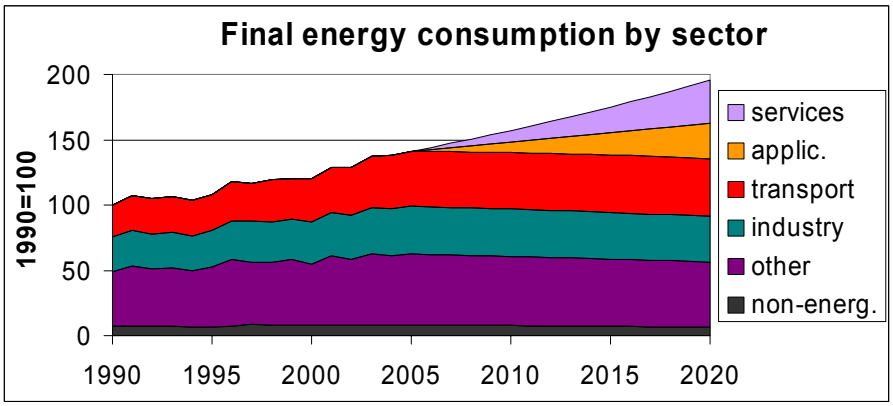


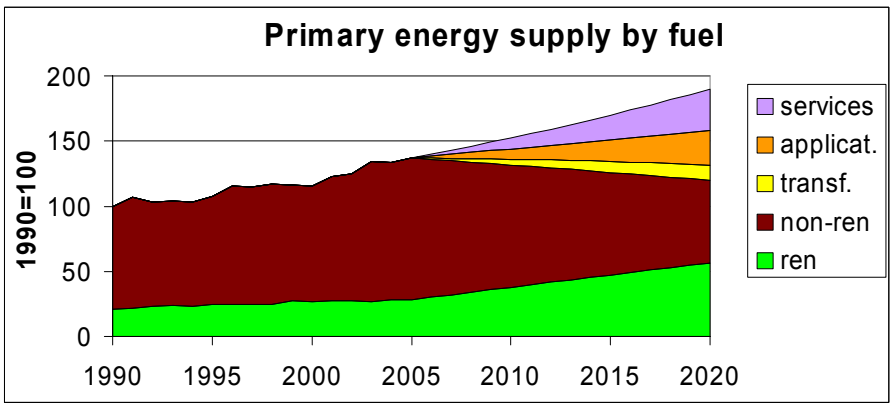






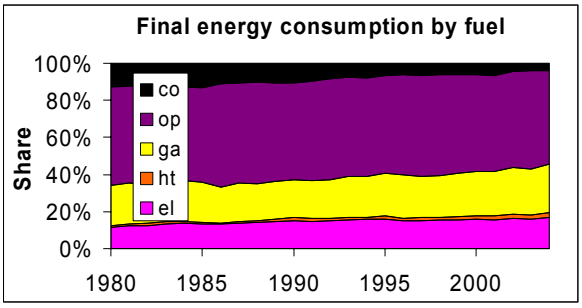
Technology wedges scenario

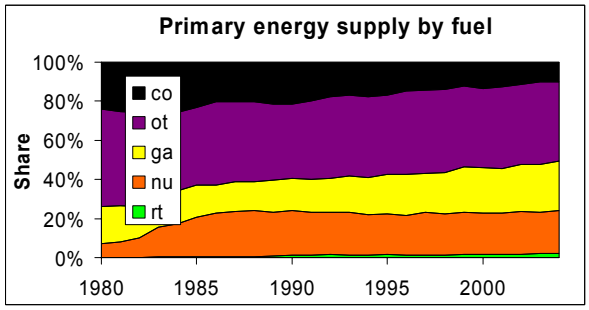


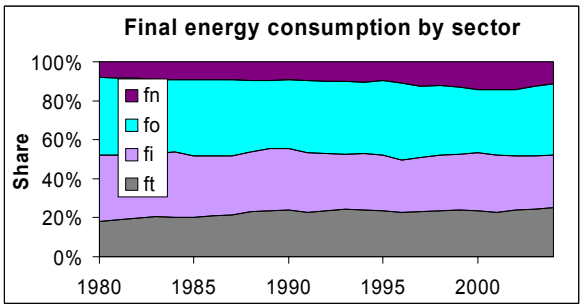


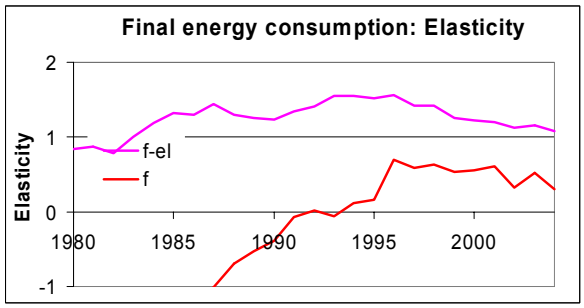
Belgium

Structural indicators

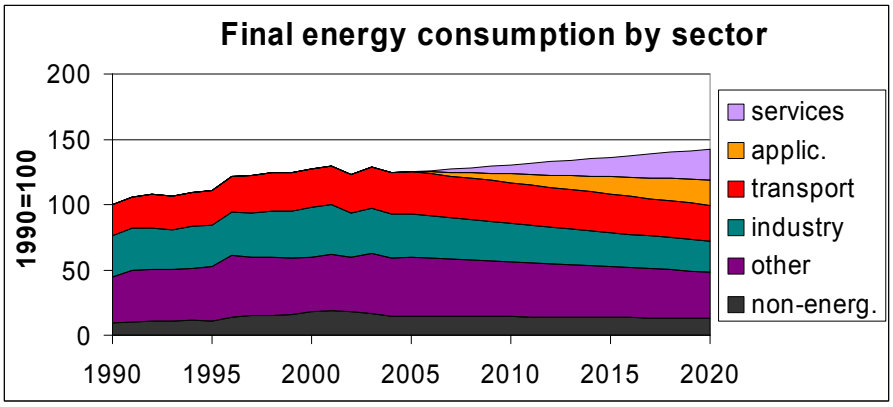


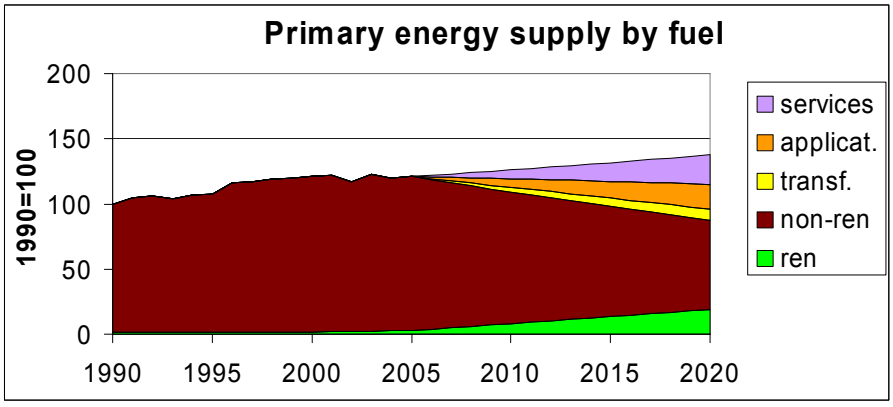






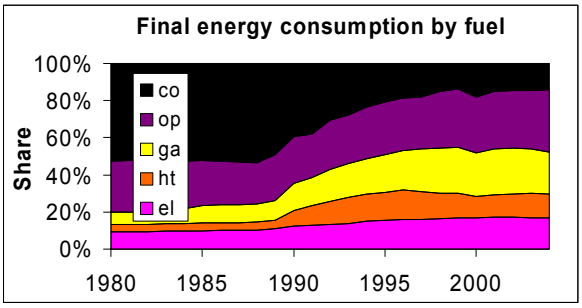
Technology wedges scenario

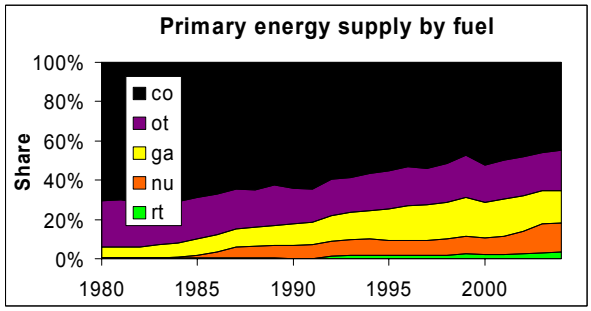


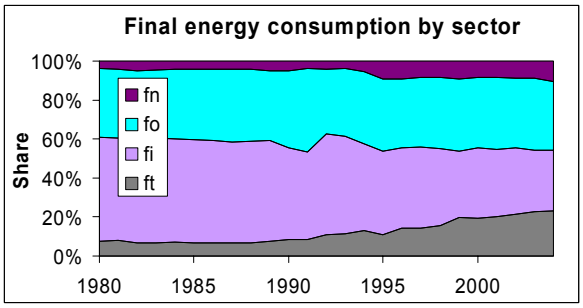


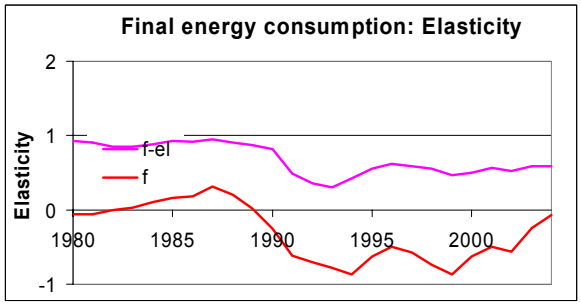
Czech Republic

Structural indicators

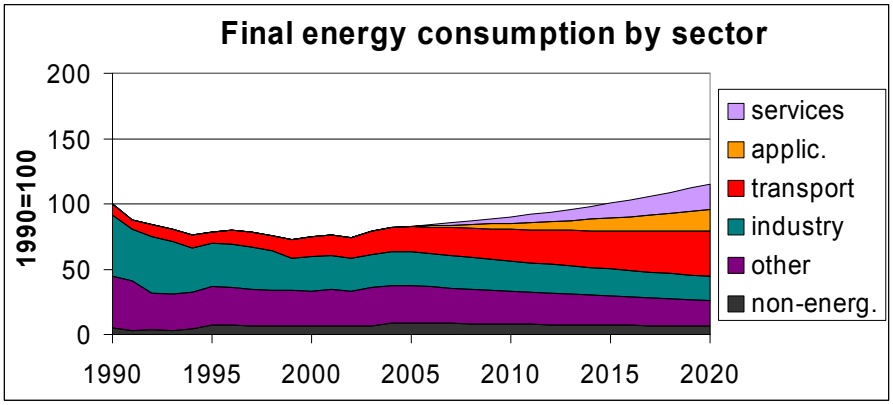


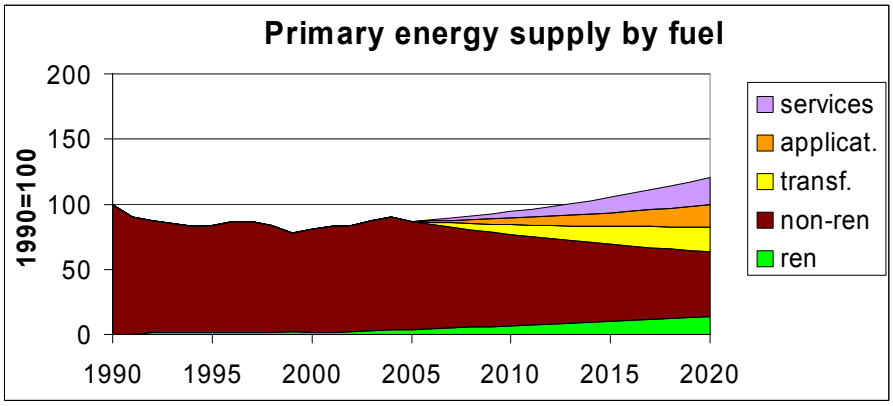






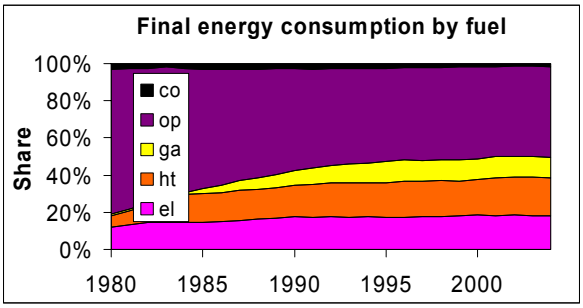
Technology wedges scenario

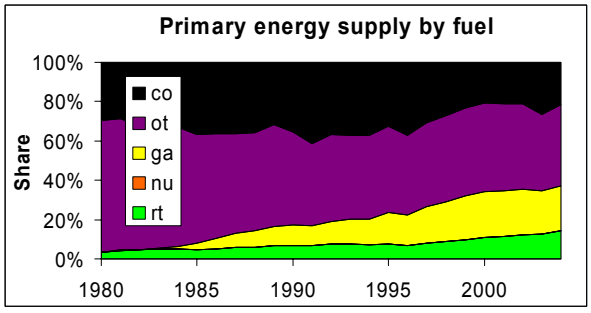


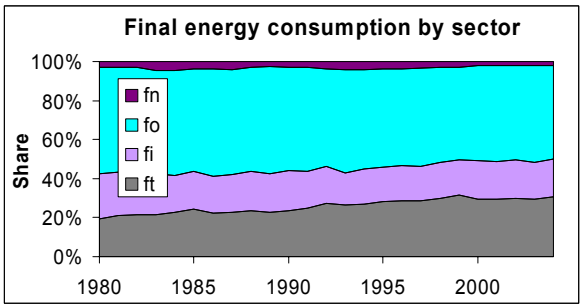


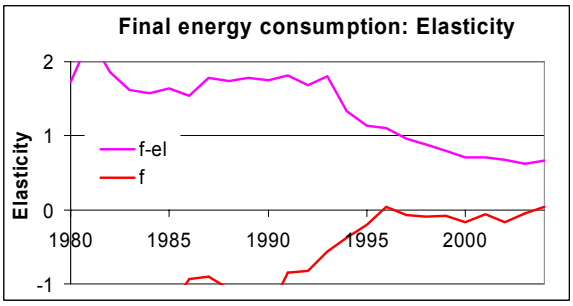
Denmark

Structural indicators

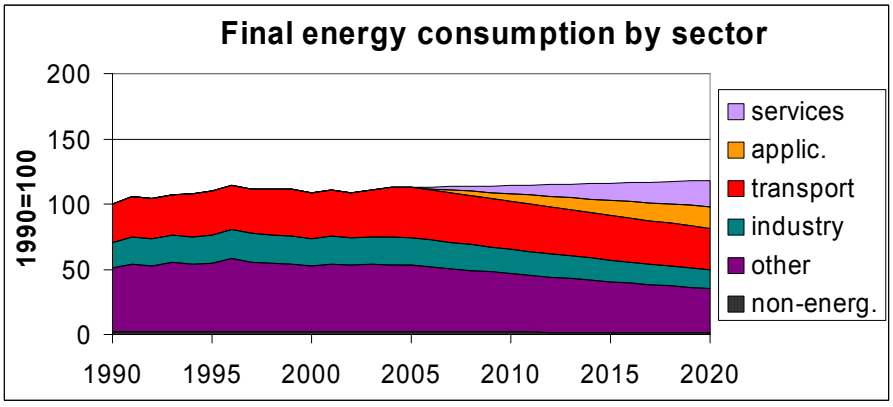


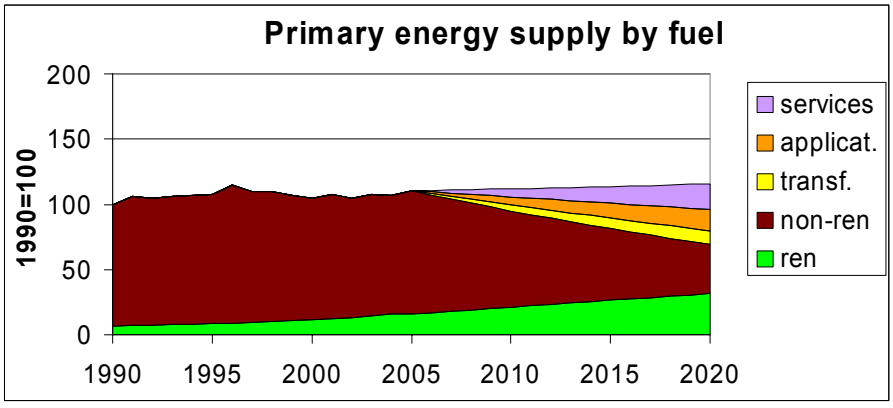






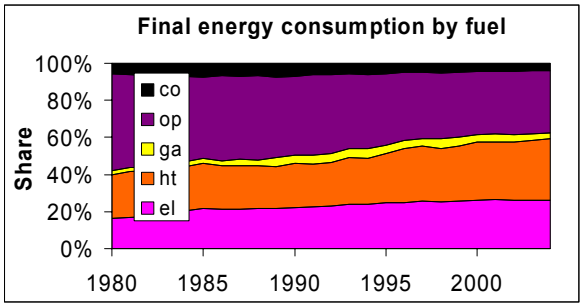
Technology wedges scenario

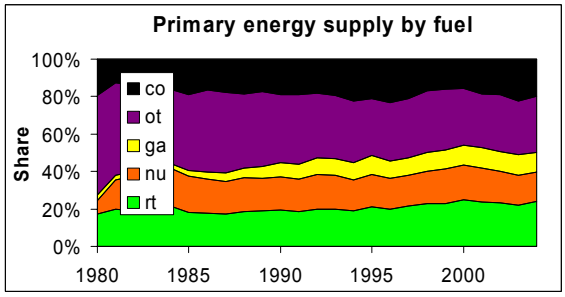


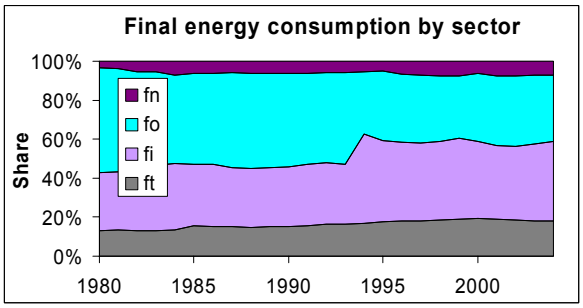


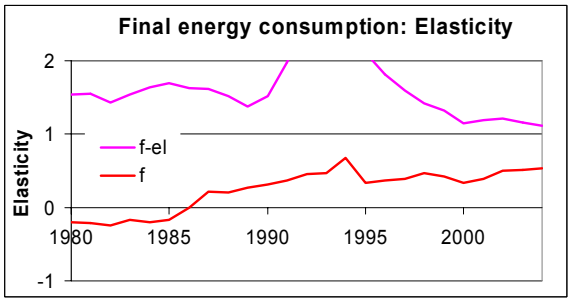
Finland

Structural indicators

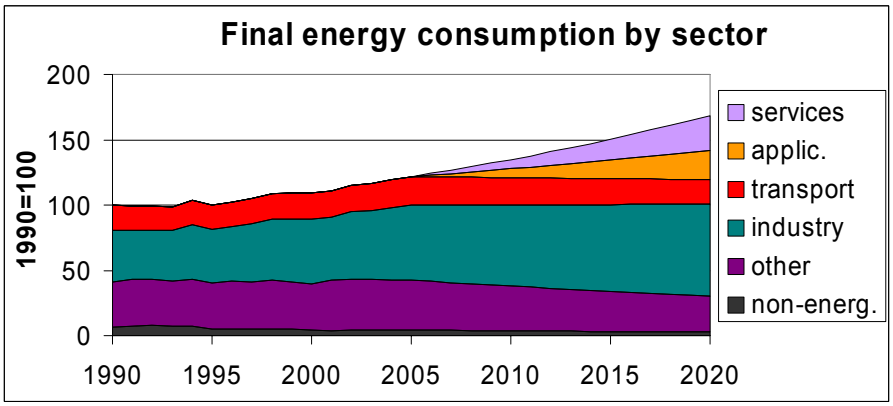


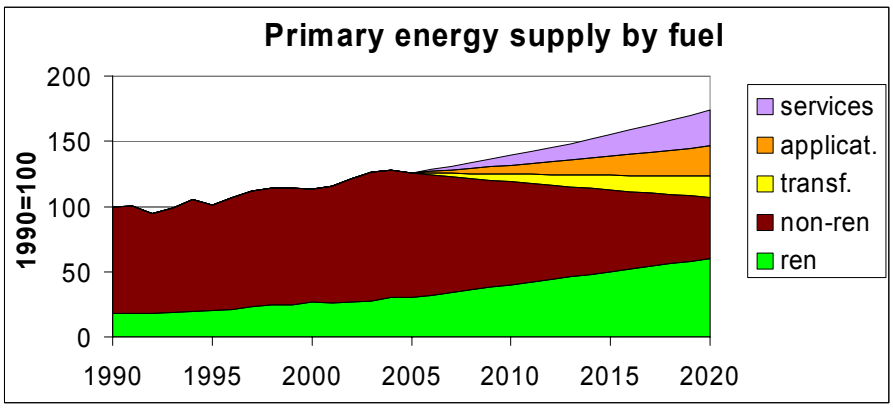






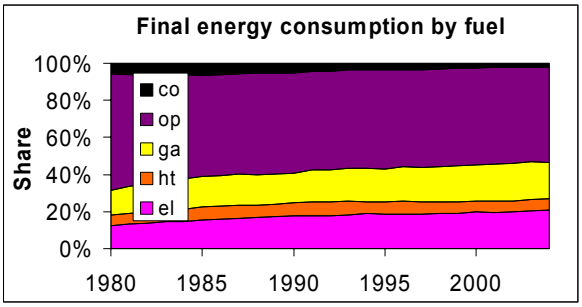
Technology wedges scenario

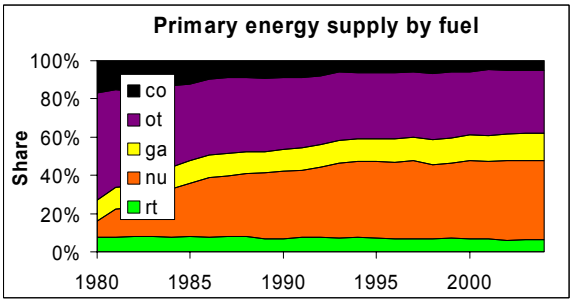


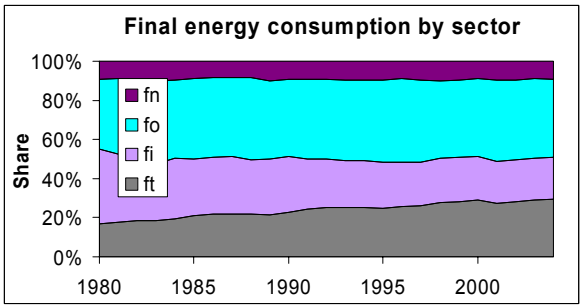


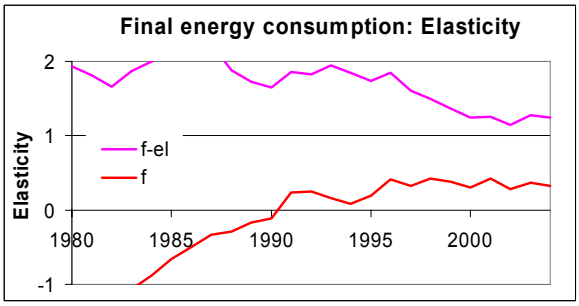
France

Structural indicators

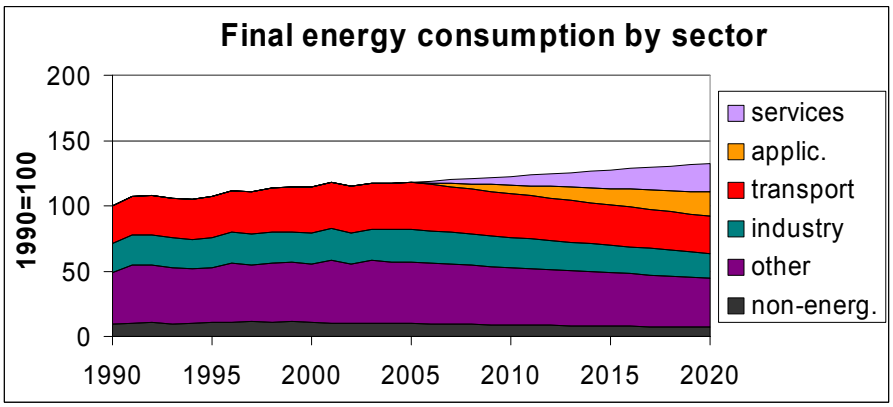


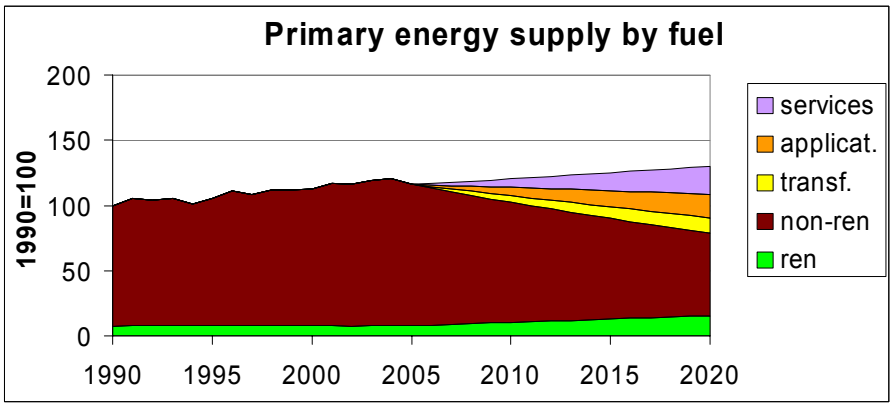






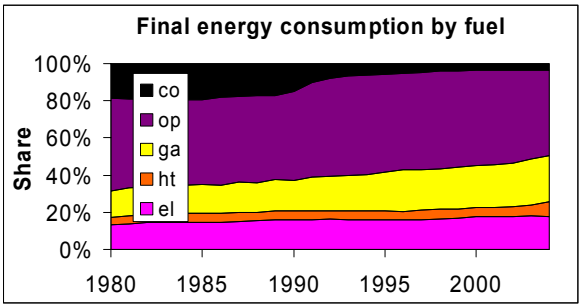
Technology wedges scenario

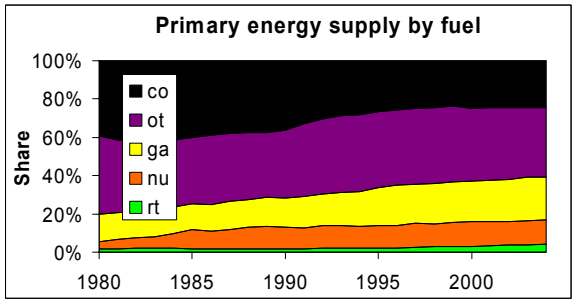


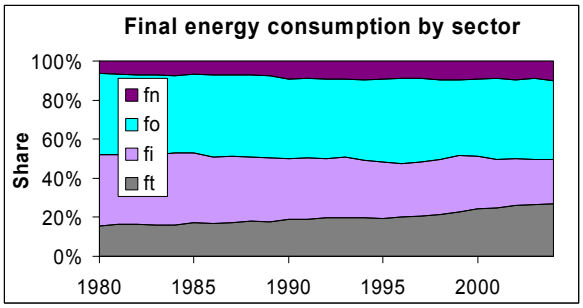


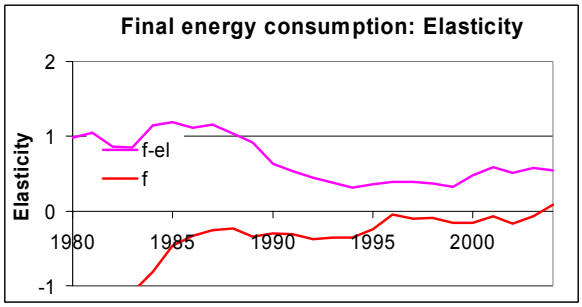
Germany

Structural indicators

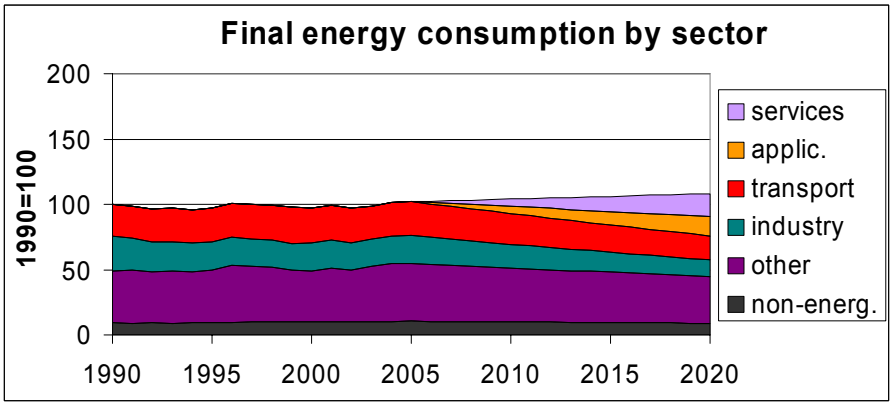


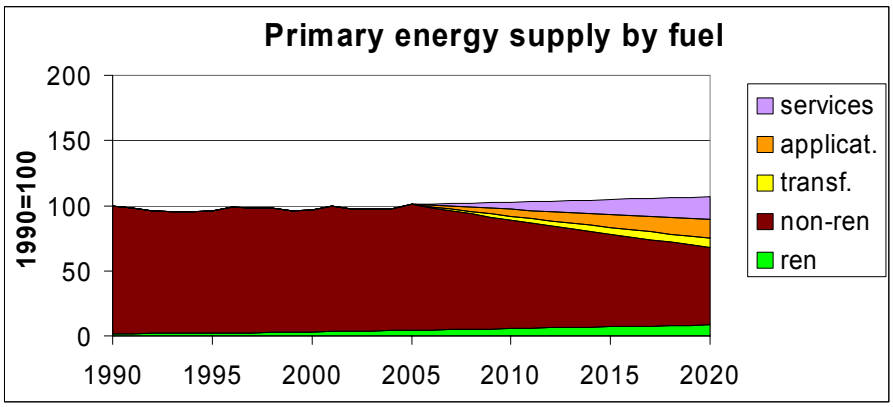






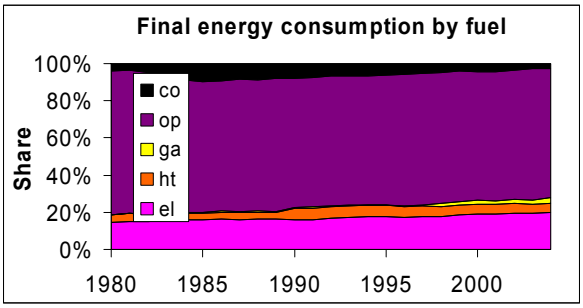
Technology wedges scenario

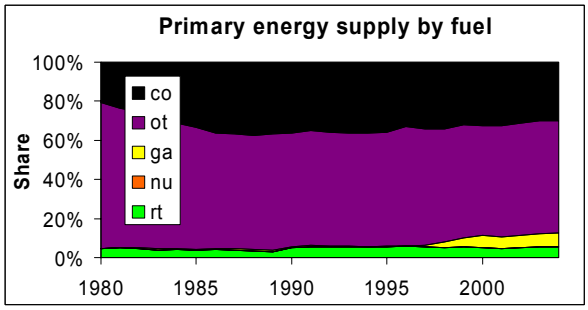


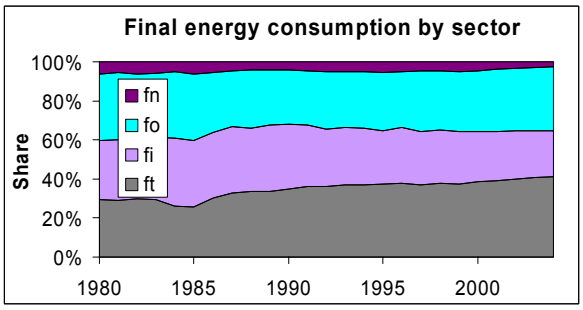


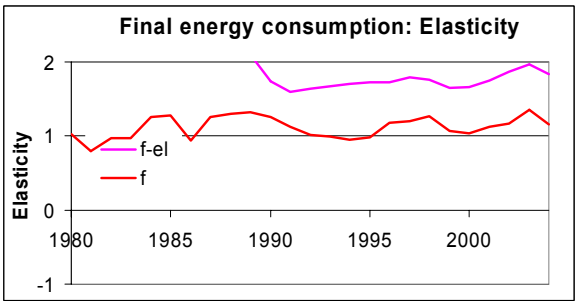
Greece

Structural indicators

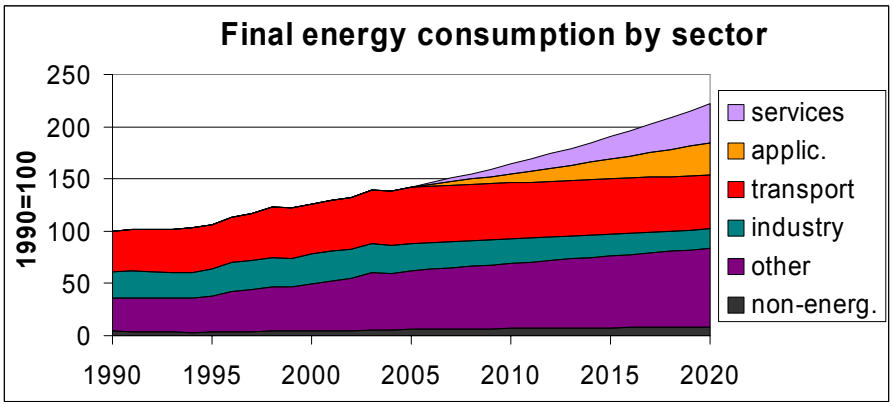


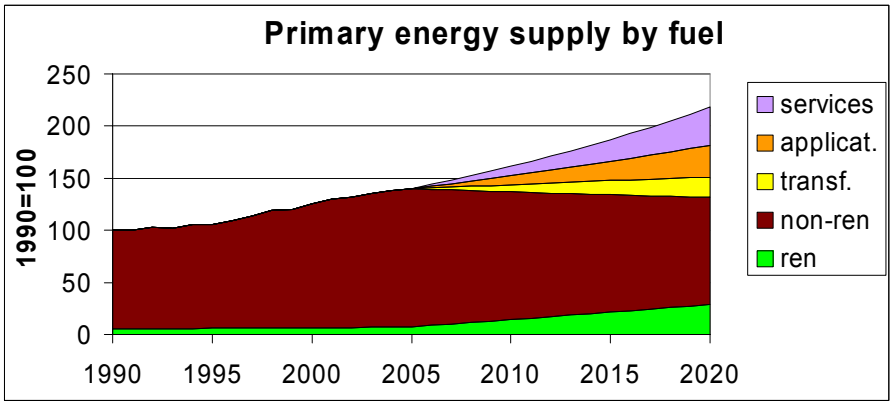






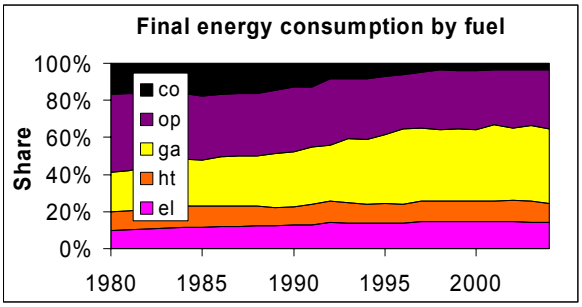
Technology wedges scenario

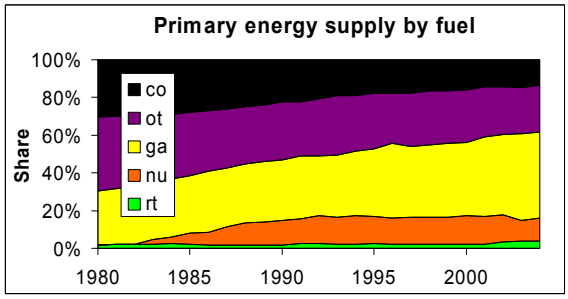


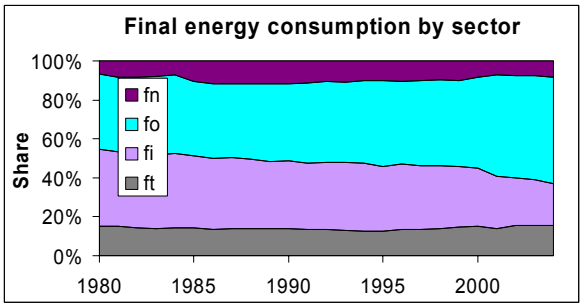


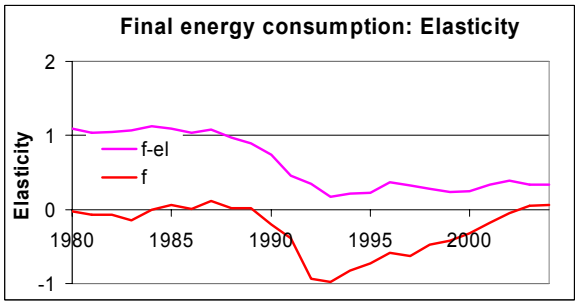
Hungary

Structural indicators

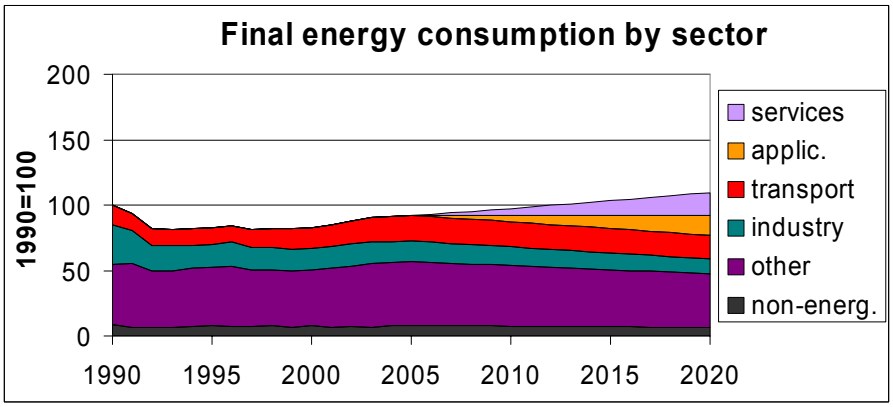


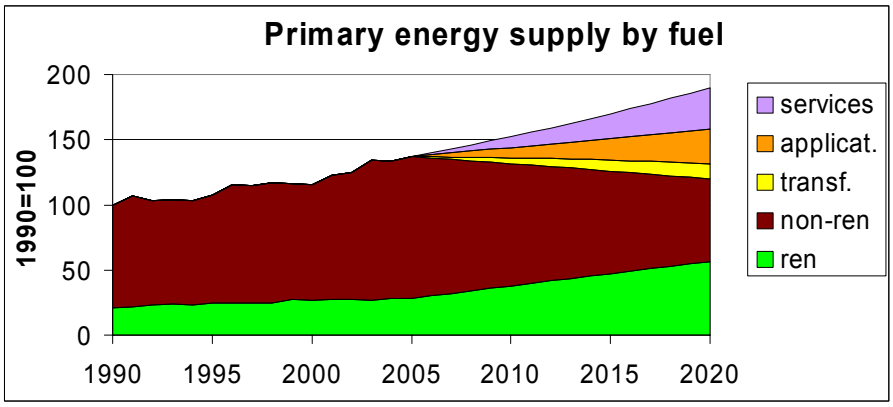






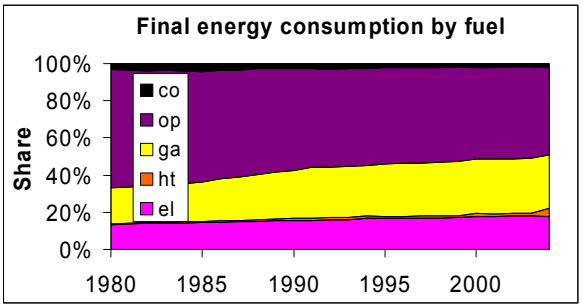
Technology wedges scenario

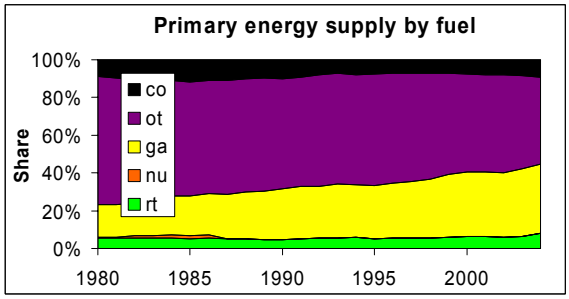


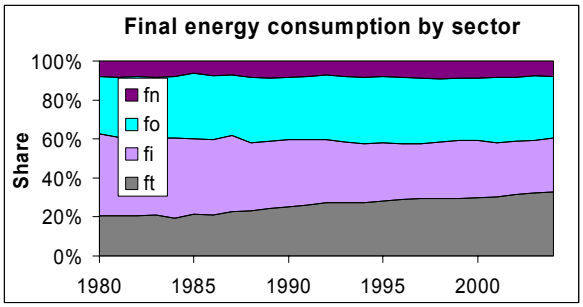


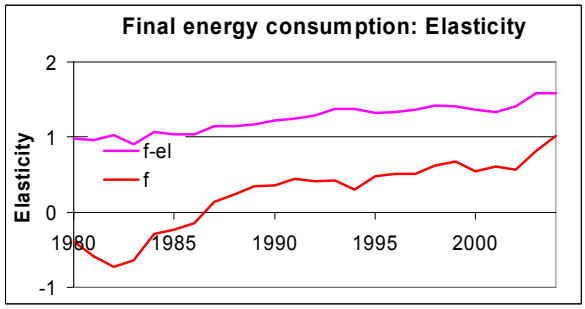
Italy

Structural indicators

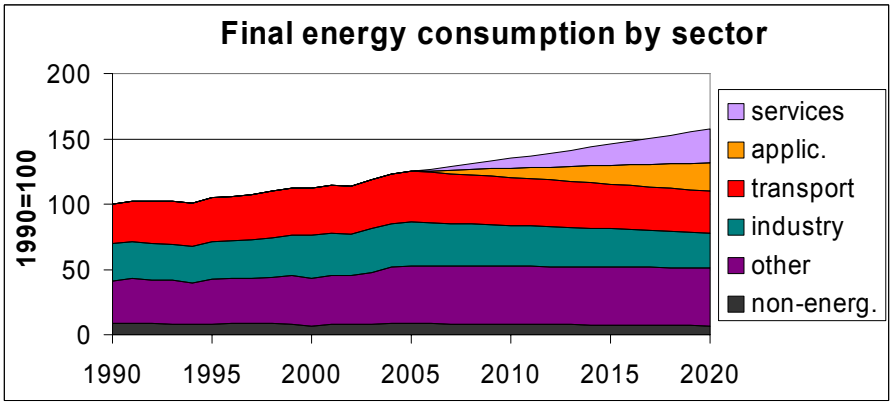


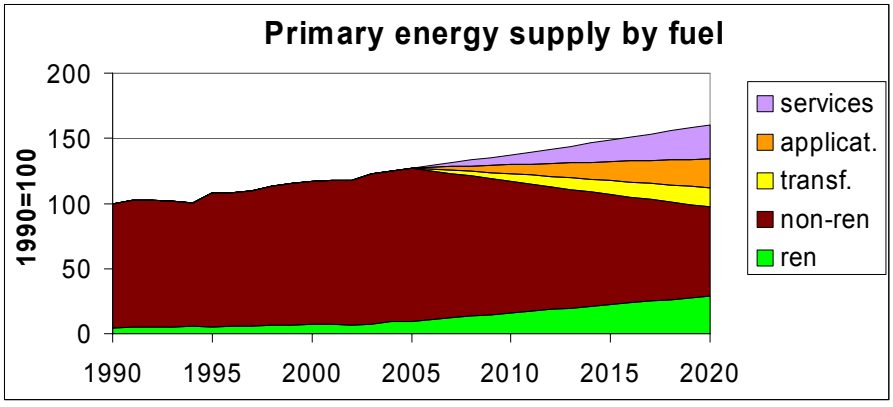






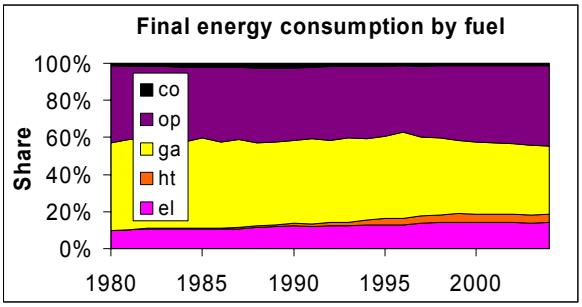
Technology wedges scenario

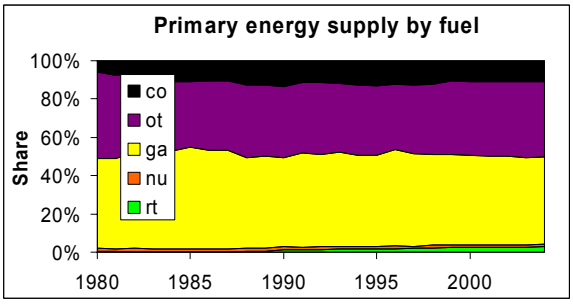


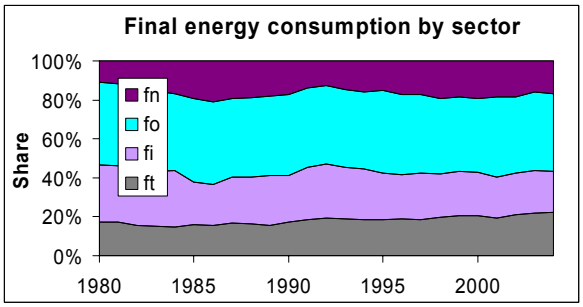


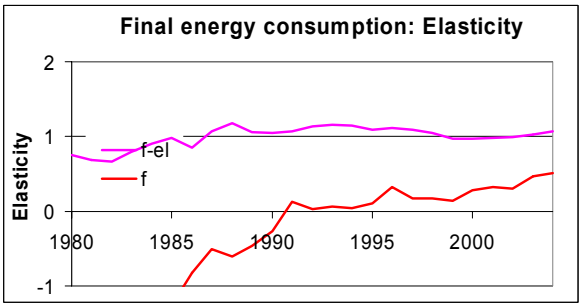
Netherlands

Structural indicators

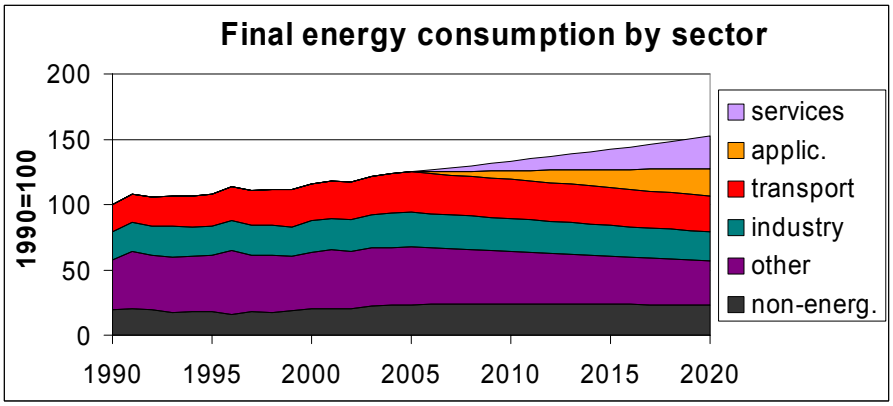


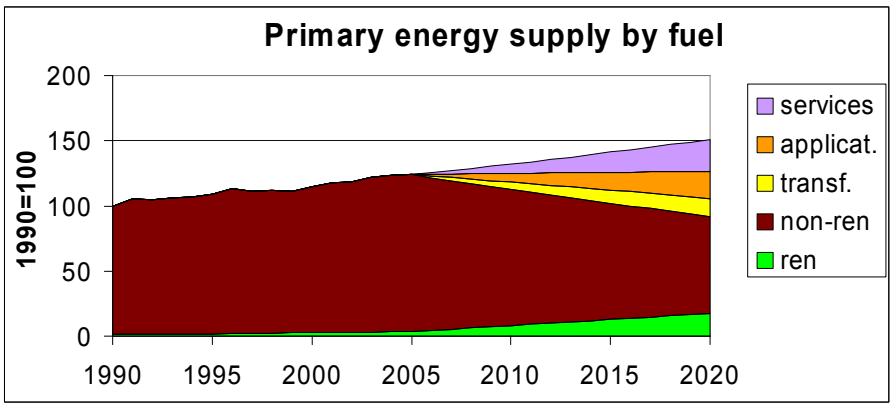






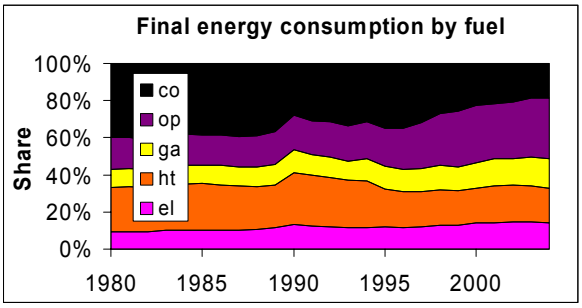
Technology wedges scenario

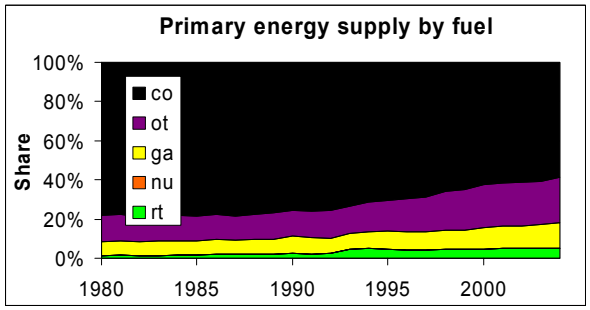


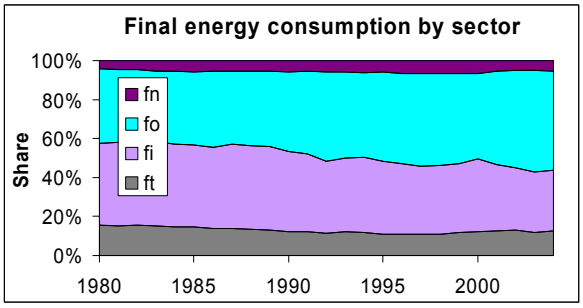


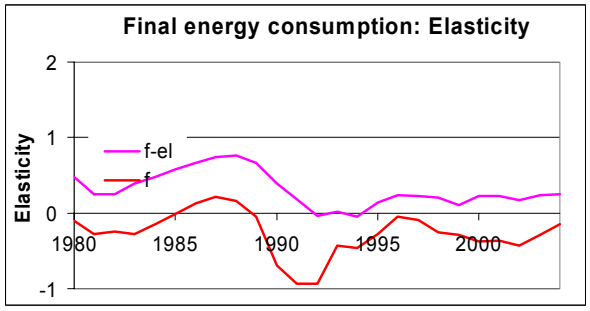
Poland

Structural indicators

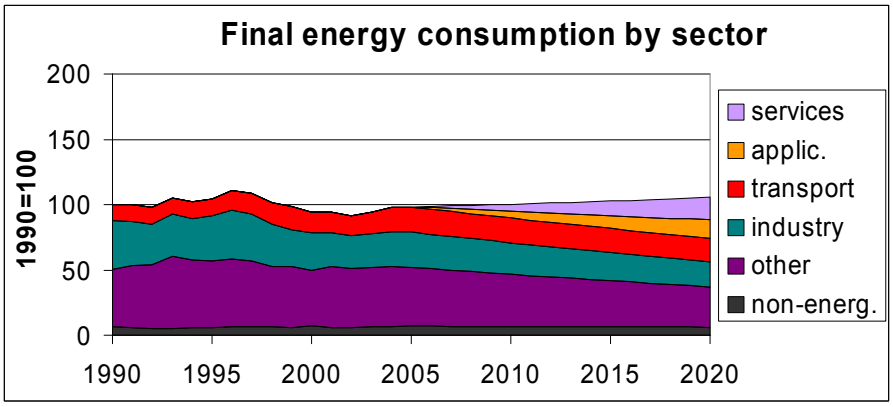


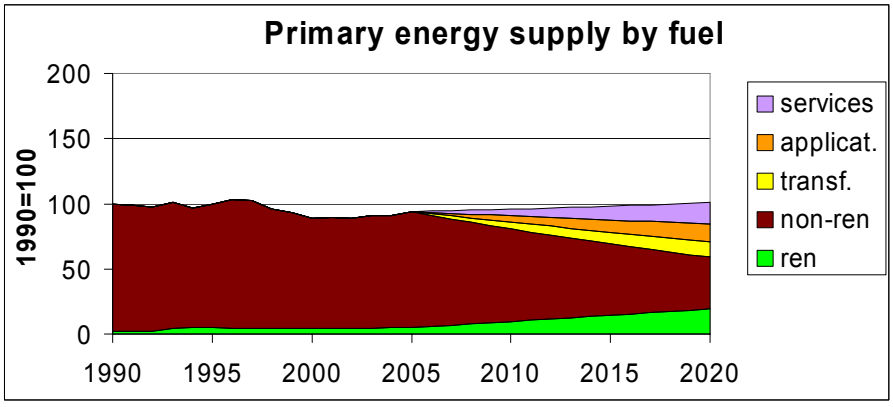






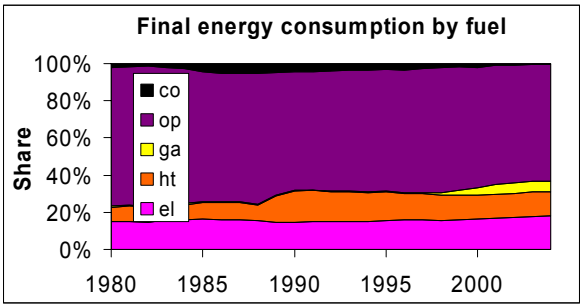
Technology wedges scenario

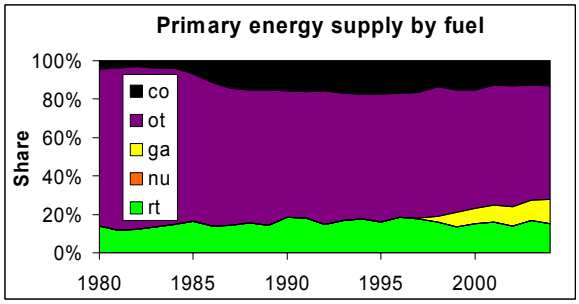


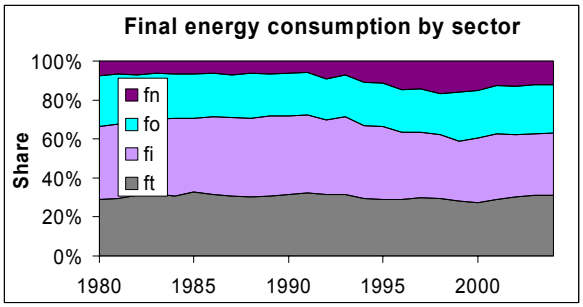


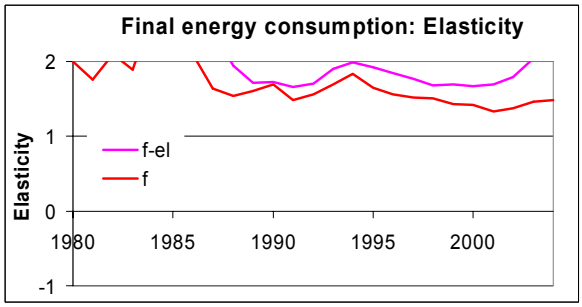
Portugal

Structural indicators

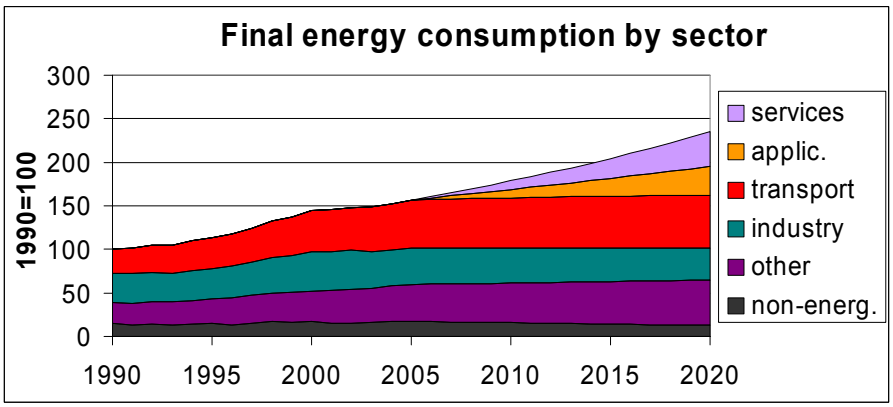


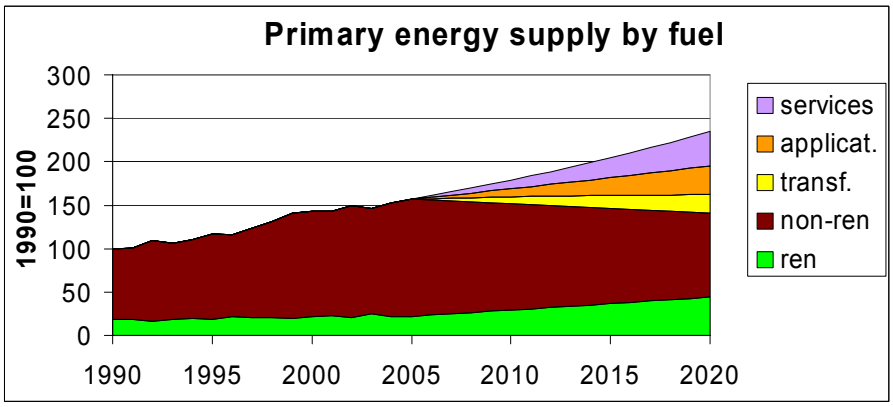






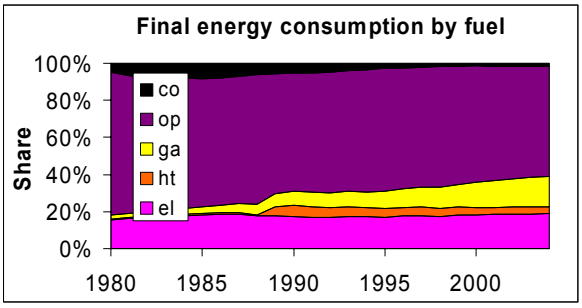
Technology wedges scenario

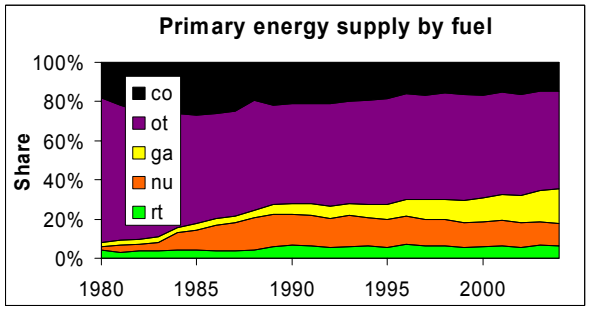


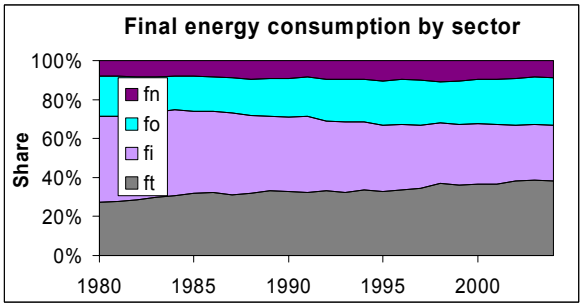


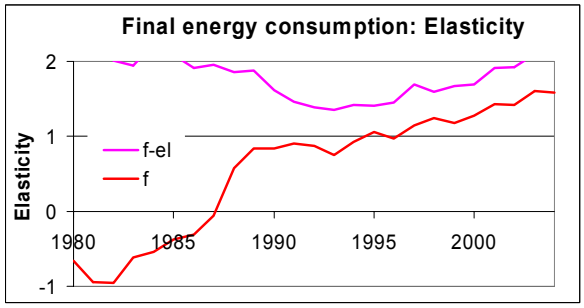
Spain

Structural indicators

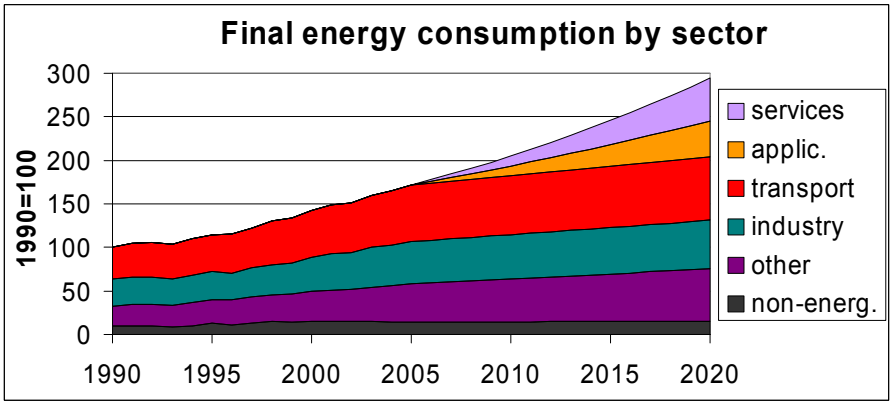


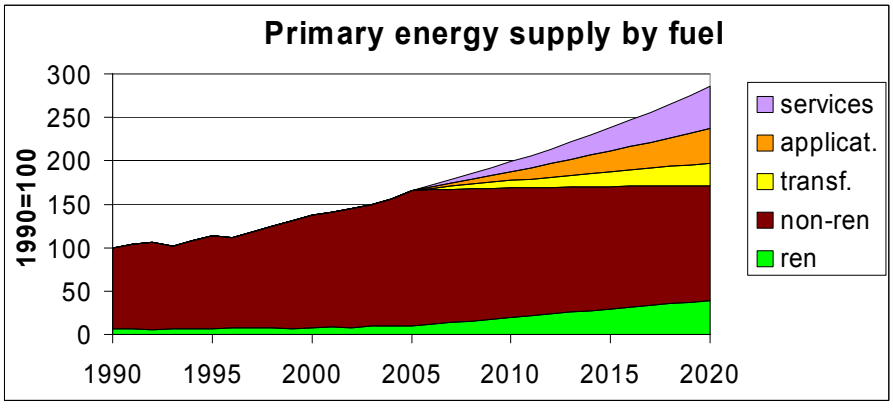






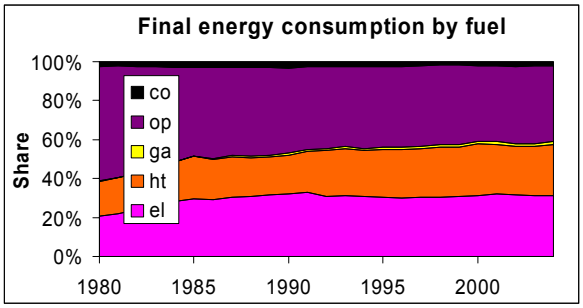
Technology wedges scenario

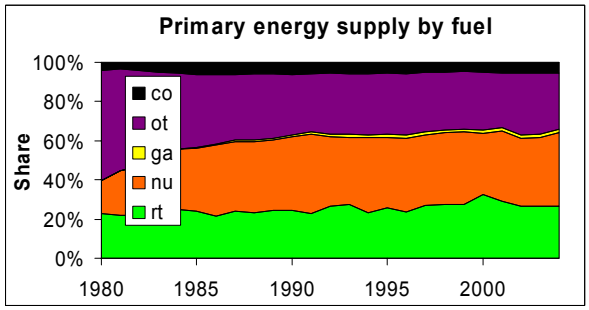


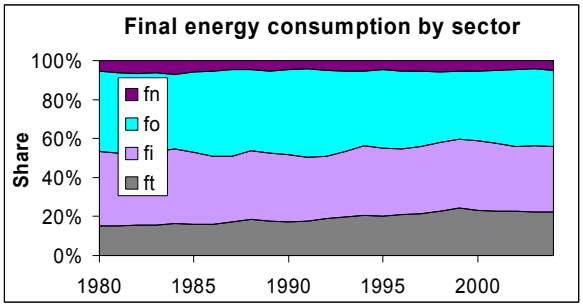


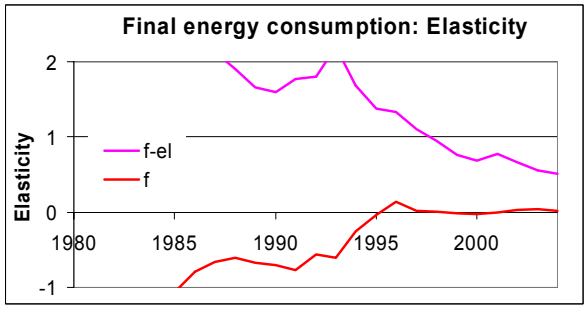
Sweden

Structural indicators

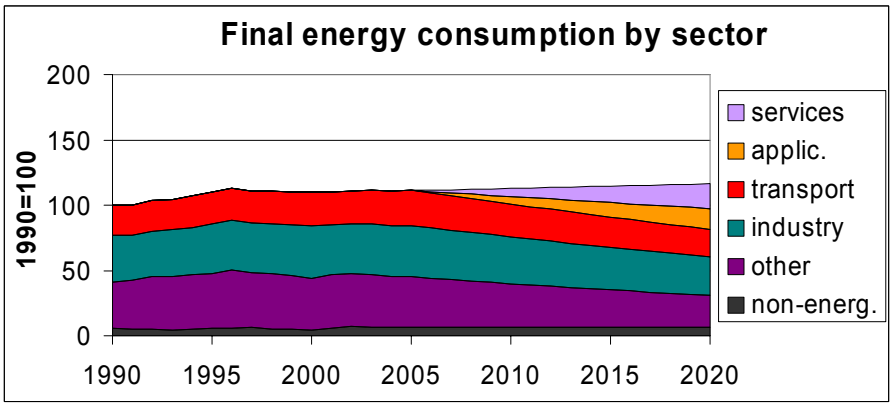


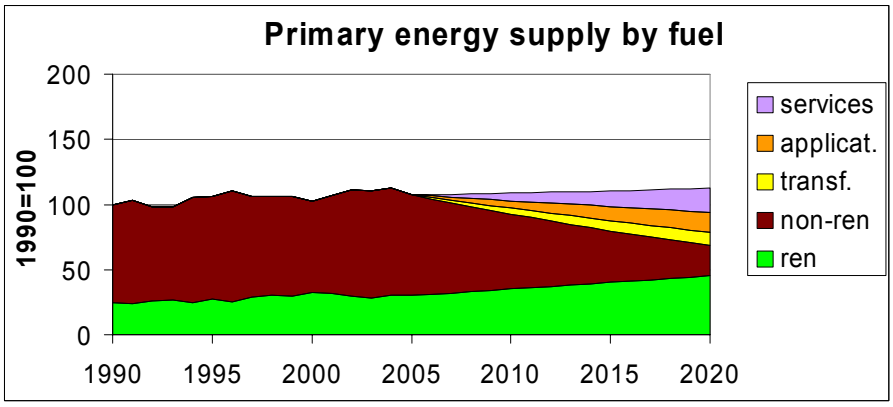






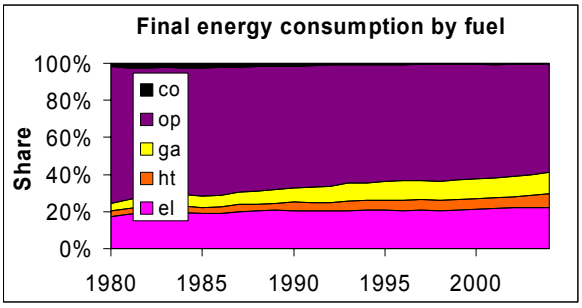
Technology wedges scenario

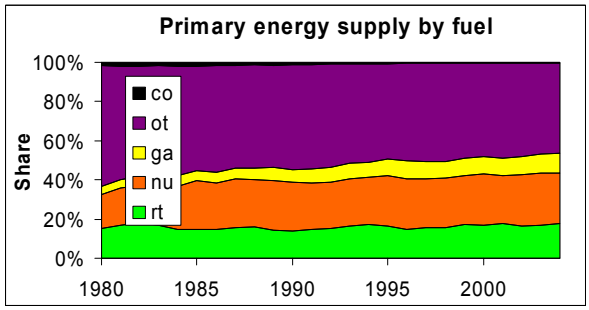


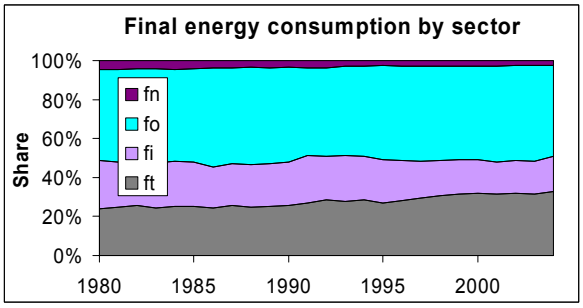


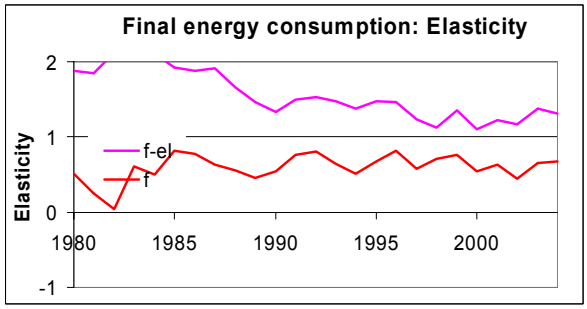
Switzerland

Structural indicators

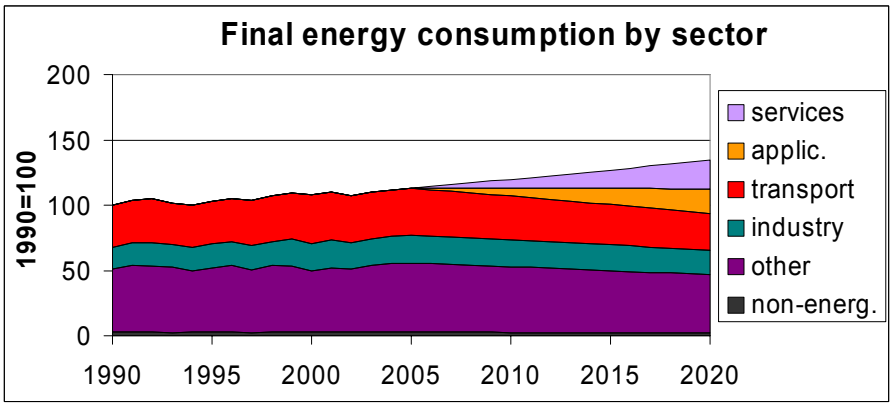


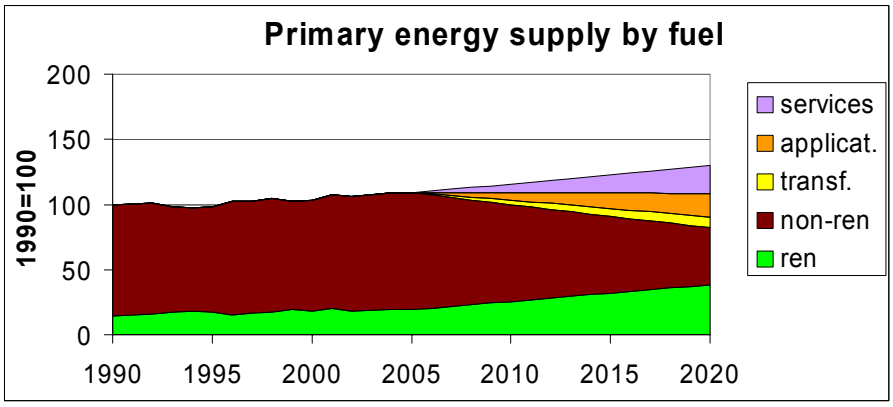






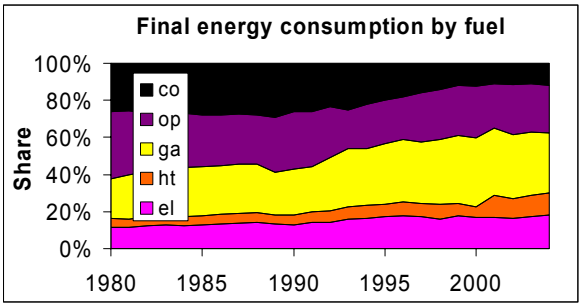
Technology wedges scenario

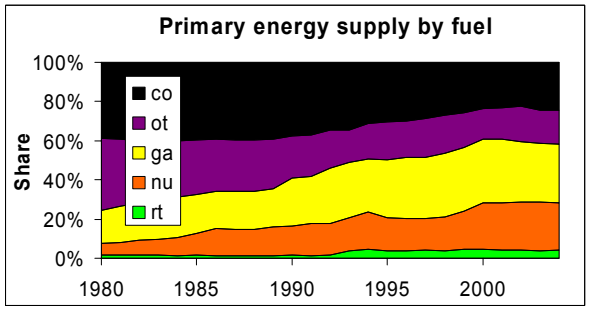


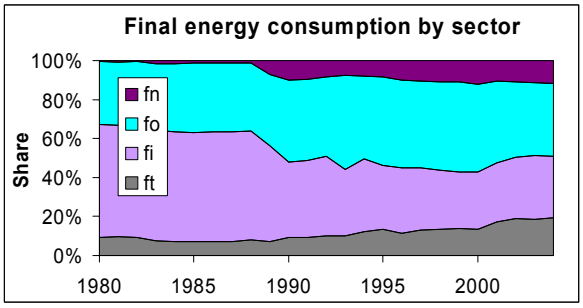


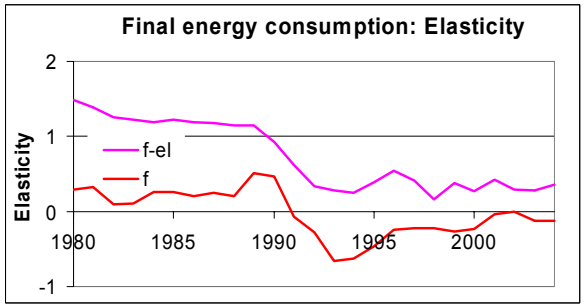
Slovakia

Structural indicators

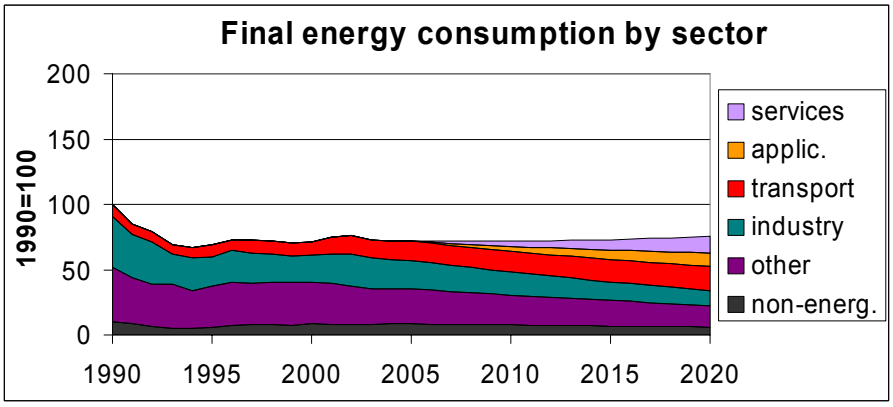


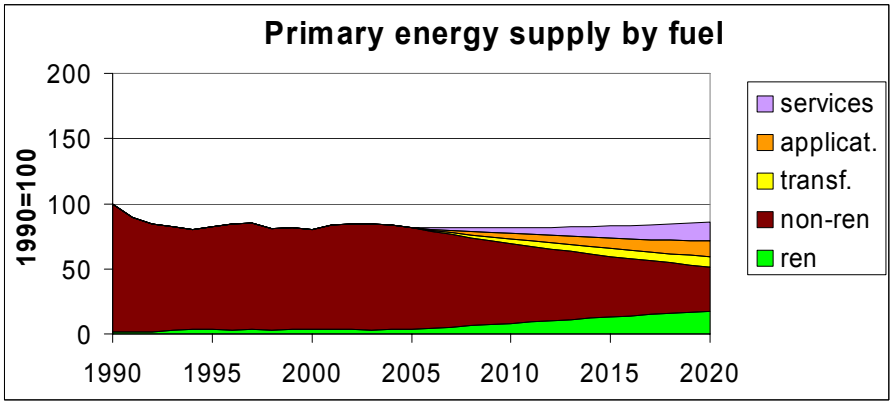






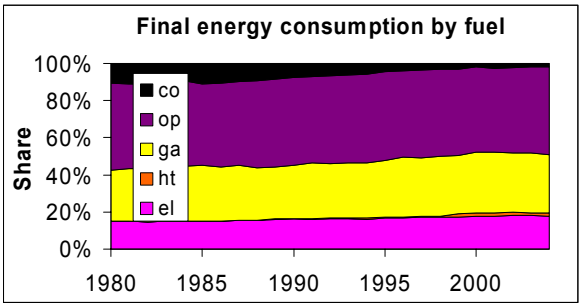
Technology wedges scenario

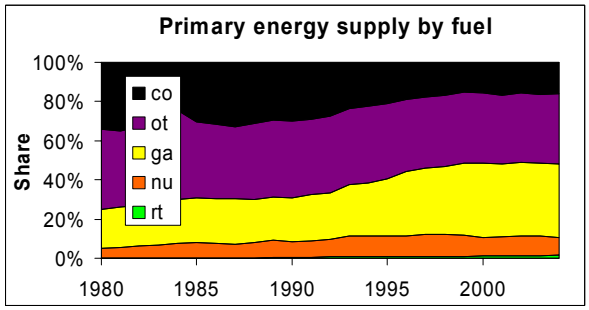


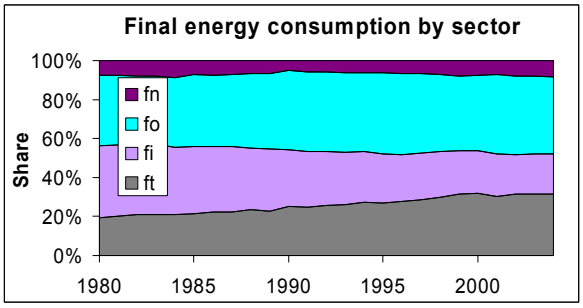


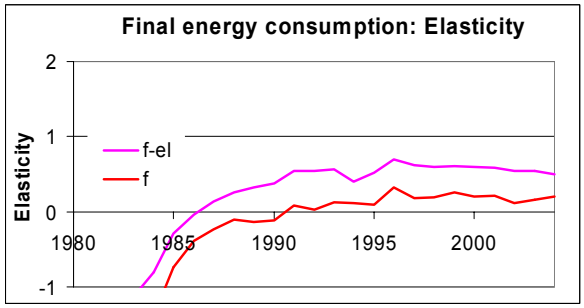
United Kingdom

Structural indicators

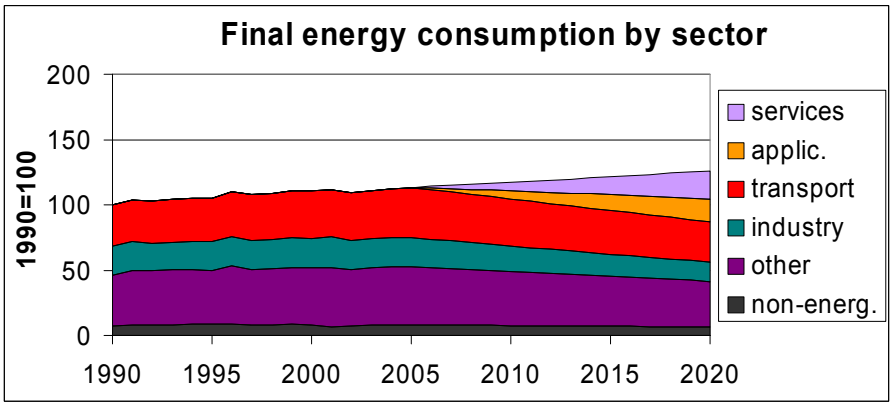


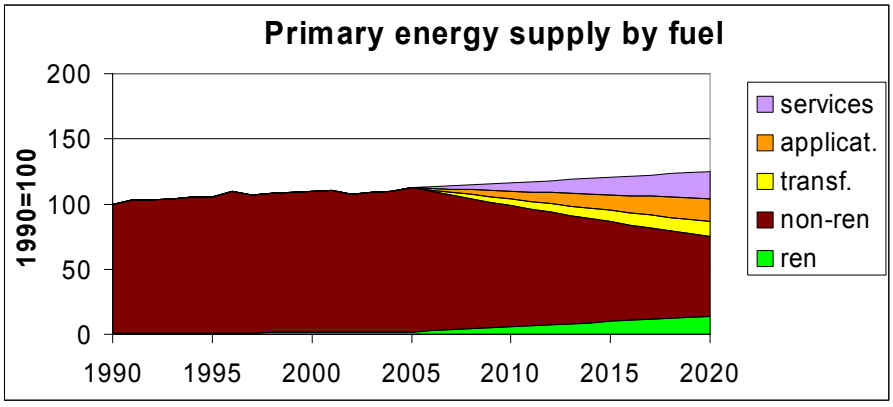






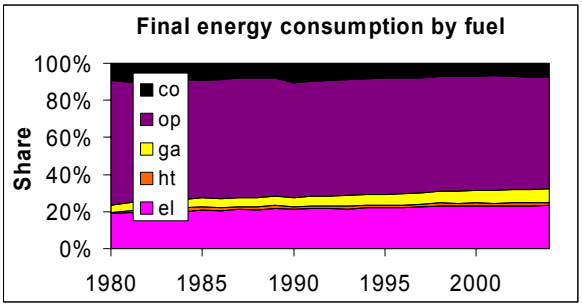
Technology wedges scenario

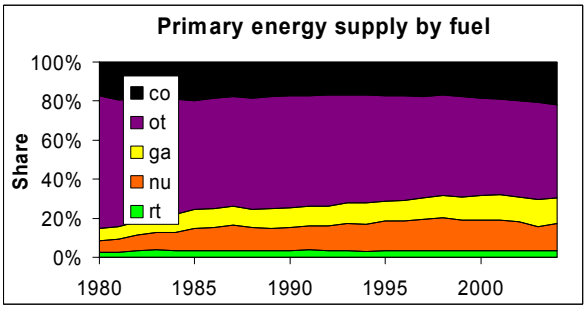


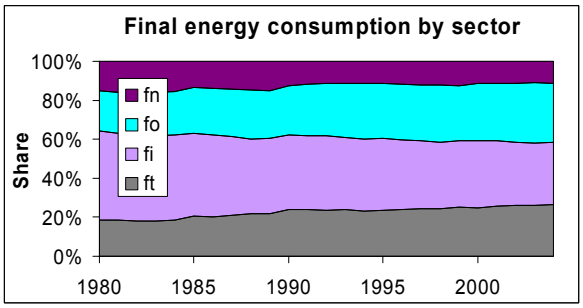


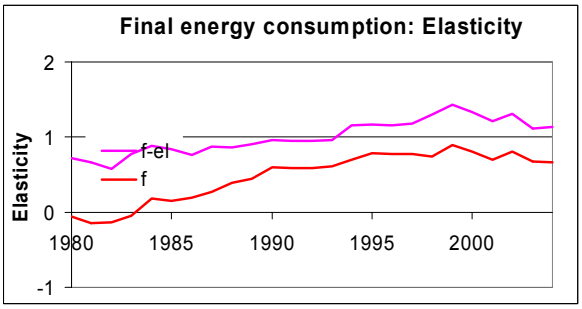
Japan

Structural indicators

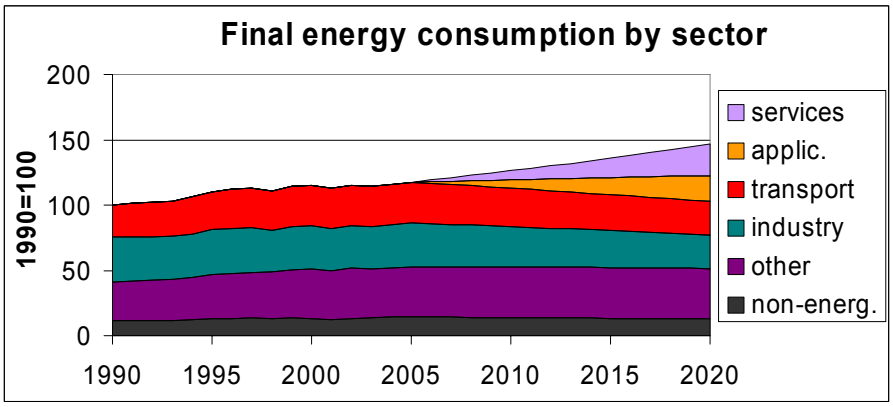


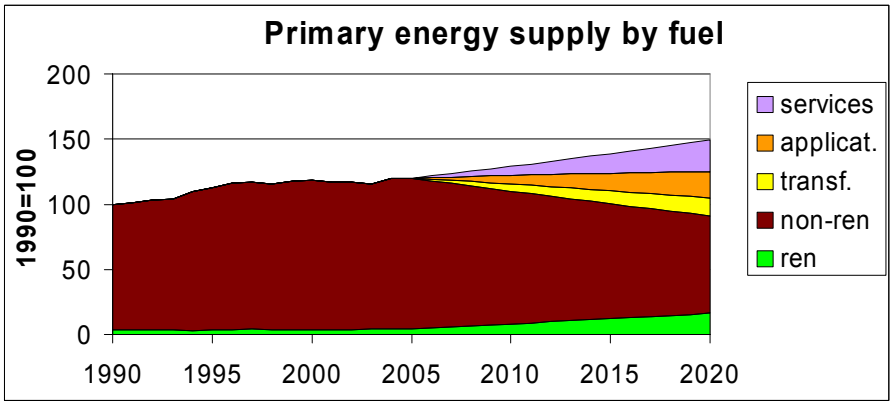






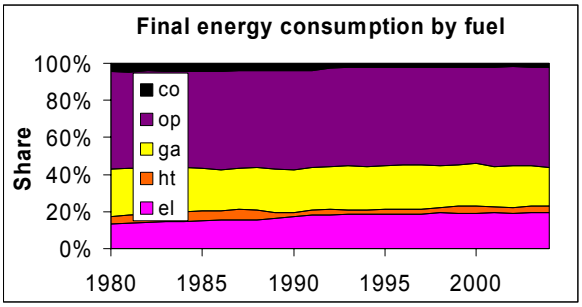
Technology wedges scenario

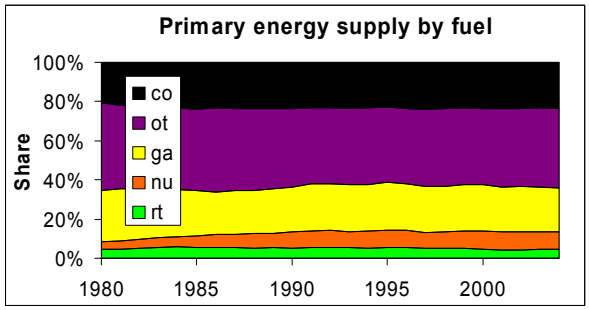


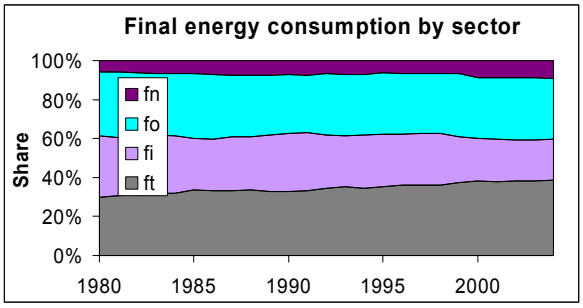


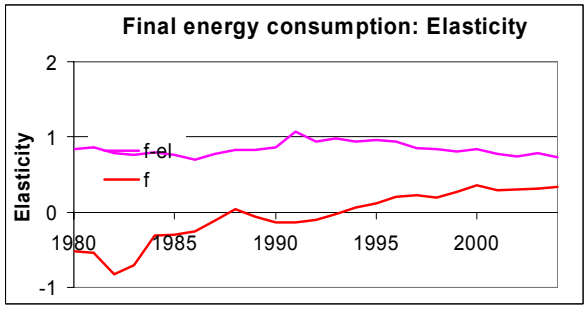
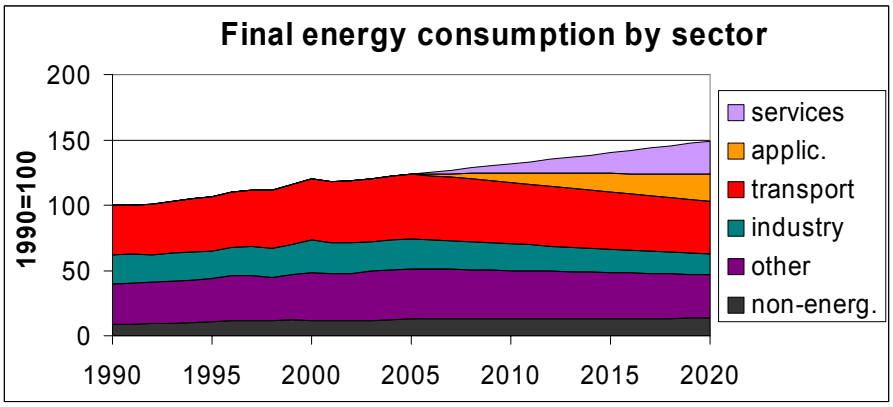
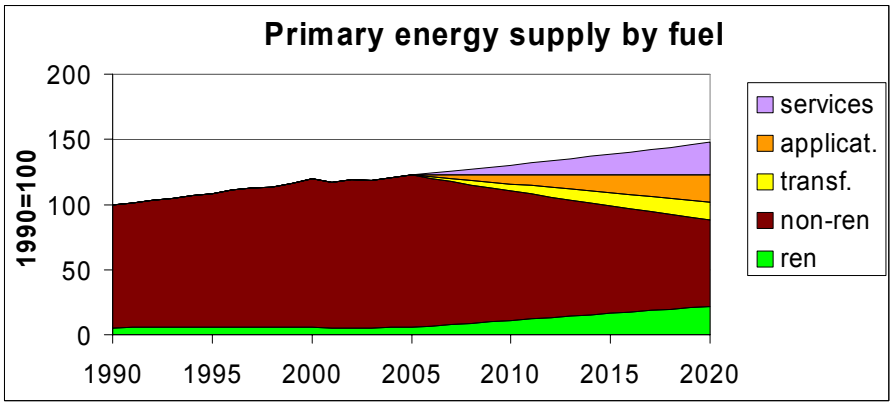
United States

Structural indicators









Technology wedges scenario