HAGFRÆÐISTOFNUN HÁSKÓLA ÍSLANDS

The Institute of Economic Studies
University of Iceland

Hagfræðistofnun Háskóla Íslands
Odda v/Sturlugötu
Sími: 525-4500/525-4553
Fax nr: 552-6806
Heimasíða: www.hag.hi.is
Tölvufang: ioes@hag.hi.is

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Energy Demand in Iceland

The Nordic Council of Ministers

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Formáli

Skýrslan sem hér birtist er unnin fyrir styrk frá orkumálanefnd Norðurlandaráðs. Hún greinir frá hluta af rannsóknum í orkumálum sem beinast að samspili orkuframleiðslu og orkunotkunar við aðra þætti samfélagsins. Þessar rannsóknir eru stundaðar í hópi sem nefnist Orka og samfélag. Innan hópsins hefur undanfarin þrjú ár verið ein rannsóknarstaða í hverju Norðurlandanna fimm. Nefnd aðallega skipuð hagfræðingum, sem hafa reynslu af rannsóknum í orkumálum og starfa við hagstofur, háskóla eða aðrar stofnanir, hefur verið leiðbeinandi í þessu starfi. Yfir þeirri nefnd situr orkumálanefndin. Hún stýrir einnig rannsóknum fimm annarra nefnda og hópa norrænna styrkþega, en þeir hópar stunda rannsóknir á verkfræðisviði, til dæmis við að finna úrbætur í mengunarmálum, betri orkunýtingu eða nýja orkugjafa.

Skýrslan er samin á ensku vegna þess að henni á að dreifa til allra Norðurlandanna og ef til vill kynna efni hennar víðar. Hún er samin af hagfræðingunum *Eystein Gjelsvik, Torgeir Johnsen, Hans Terje Mysen og Ásgeiri Valdimarssyni.* Eystein, Torgeir og Hans Terje störfuðu á Hagstofu Noregs í Osló þegar skýrslan var skrifuð, en Ásgeir á Hagfræðistofnun Háskóla Íslands.

Við viljum koma á framfæri þökkum til Orkustofnunar og Hitaveitu Reykjavíkur og fleiri fyrirtækja fyrir gott samstarf og skilning við að leggja til gögn í þessa vinnslu. Einnig þökkum við Norðurlandaráði fyrir að gera þessa rannsókn mögulega.

Hagfræðistofnun Háskóla Íslands

í desember 1994

Guðmundur Magnússon

forstöðumaður

ABSTRACT

This paper describes the development of energy consumption in Iceland and documents the structure and estimation of an energy demand model for Iceland. One purpose of constructing this model is to analyse effects on energy demand of various measures to reduce greenhouse gas emissions i.e. taxes on fossil fuels. With respect to total energy use the Icelandic market is approximately 1,4 percent of the total Nordic market. Iceland is located too far from the rest of the Nordic countries to make exports of electricity with the present state of technology profitable. Besides, the UK market is closer and offers better prospects.The energy demand model for Iceland is consequently not linked to the Nordic energy market model (Bye et al. (1994)). The estimation results suggest that reduced form models should be preferred to the models based on general cost and utility functions satisfying restrictions from microeconomic theory. This mirrors the lack of substitution possibilities that are characteristic for most energy use in Iceland. The simulations of the model show that Iceland will have no problems with reaching the target of stabilization of emissions of CO_2 in the year 2000 on a 1990 level mainly due to low economic growth forecasts. Implementation of the EC energy/carbon tax leads to emissions below the stabilisation target until the year 2010.

SAMMENDRAG

I dette notatet dokumenteres arbeidet med å opprette en energietterspørselsmodell for Island. Notatet inneholder en beskrivelse av den historiske utviklingen av energiforbruket på Island, en beskrivelse av modellens struktur og estimeringsresultater og til slutt resultater av simulering av modellen. Hovedhensikten med opprettelsen av modellen er å bli i stand til å analysere effekter på energietterspørsel av tiltak for å redusere utslipp av drivhusgasser dvs. først og fremst skattlegging av bruk av fossile brensler. Det islandske energiforbruket representerer om lag 1,4 prosent av det totale nordiske energiforbruket. Island er for langt unna de andre nordiske landene til at handel med elektrisitet kan være lønnsomt gitt dagens teknologi. En tilknytning til det britiske markedet som er nærmere virker mer lovende. Energietterspørselsmodellen for Island er derfor ikke tilknyttet den nordiske energimarkedsmodellen (Bye et al. (1994)). Estimeringsresultatene tyder på at redusert form modeller er å foretrekke framfor modeller basert på generelle kostnads- og nyttefunksjoner som er mer i samsvar med mikroøkonomisk teori. Dette reflekterer de begrensede substitusjonsmulighetene som kjennetegner energibruk på Island. Simuleringsresultatene viser at Island ikke vil ha noen problemer med å nå et mål om å stabilisere CO_2-utslippene på 1990-nivå i år 2000, noe som hovedsaklig skyldes lave vekstprognoser for islandsk økonomi. Implementering av EU's energi/karbon-skatt vil medføre utslipp under stabiliseringsgrensen fram til år 2010.

Contents

1. Introduction.

This paper describes the development of energy consumption in Iceland and documents the structure and estimation of an energy demand model for Iceland. The energy demand model for Iceland is part of a larger modelling project for all the Nordic countries, financed by The Nordic Council of Ministers. The Icelandic electricity market is 1,3% of the total for the Nordic countries (Nord (1987)). With respect to total energy use the Icelandic market is approximately 1,4% of the total Nordic market of close to 4,000 terajoules used per year (Nordel (1989)). The energy model for the Nordic countries will incorporate trade with electricity between Denmark, Finland, Norway and Sweden. Iceland is located too far from the rest of the Nordic countries to make exports of electricity with the present state of technology profitable. Besides, the UK market is closer and offers better prospects. The energy demand model for Iceland is therefore not linked to the rest of the Nordic countries. Our first target is to pinpoint the best statistical model for estimation of future demand in each market segment. The purpose of the selected model(s) is, amongst other things, to analyze effects on energy demand of various measures to reduce greenhouse gas emissions i.e. taxes on fossil fuels.

The outline of this paper consists of a brief description of the energy market in Iceland, and of the data sources. We proceed with a model description and report the results of econometric tests, arriving at the chosen model specifications for each of the sectors and energy commodities, a total of 13 demand functions. Most of the price and income elasticities were found significant and reasonable, but to a large extent we had to rely on reduced form models rather than models based on general cost and utility functions satisfying restrictions from microeconomic theory ("top down"-models). This mirrors the lack of substitution possibilities that are characteristic for most energy use in Iceland. Neither did data allow for the application of flexible functional forms in most sectors, or for alternative structural models such as discrete continuous choice models. In the last section, the model is simulated for the period 1990-2010 using the same exogenous assumptions as in the latest energy forecast from the energy research institute *Orkustofnun* and the National Economic Institute.

2. Development of Energy Markes in Iceland.

Iceland is an island in the North Atlantic Ocean. It is 103,000 km^2 in size and has a population of 260,000. Around sixty percent of the population (160,000 people) lives in and nearby the capital, Reykjavik. Around 60,000 people live in small towns around the coast. The remaining 40,000 inhabitants live in rural areas near the coast. The interior of the island is not habitable and has very little vegetation.

Electricity market

The demand for electricity was mostly for residential, commercial and small industry use in Iceland in 1960. Total demand was under 500 GWh per year. The load was very uneven with high peaks in wintertime and deep vallies in the summertime. There were no transmission lines between different parts of the country. The South-West, including the capital, Reykjavik, was the biggest single market but, in the West, North and East there were small power stations for each small village. In many areas the power stations were run on oil since waterpower was not available in all areas. In 1969 we had started the first large scale use of electricity in the aluminum smelter at Straumsvik, 25 km south of Reykjavik. It used 50-80 % more electricity than the rest of Iceland combined at first. In 1979 the second large user of electricity started operation, the Ferro-silicum plant in Hvalfjord, some 40 km north of Reykjavik. In 1982 those two plants consumed 2 TWh out of a total of 3 TWh electricity use in Iceland. In 1992 the general market has grown to 2 TWh a year, the plants use another 2 TWh a year, so total use is around 4 TWh a year. The plants have a stabilizing effect on the yearly load. The january sales amounted to 0,4 TWh in 1991 and the July low was 0,28 TWh.

Presently there is a national grid forming a circle around the island. All areas are interconnected and operational security in most areas is greatly improved. The market is of course dominated by the two plants that pay electricity price depending in part on the price of aluminum and ferro-silicum in world markets. Effort has been made to keep prices in the general market unaffected by large investments in hydro power

stations that serve the plants. These efforts have been fruitful most of the time; we believe, except in the high price period of 1982-1986. In the long run they have been successful.

Fuel market

The market for oil products had four main components in 1960. These were the fishing fleet, the Icelandic airlines, the car owners and residential house owners in areas were neither electricity nor geothermal heating was available. This market has grown in the first three sectors, but the fourth has diminished to very small use in remote areas only. Use has been shifted from oil heating to geothermal or electrical heating in most areas. This explains why total use of oil products has grown very little over the period despite considerable increase in the number of cars in Iceland and a bigger fishing fleet.

Geothermal heating market

The energy market in Iceland differes from other Nordic energy markets due to the utilization of a natural resource of hot water fit for house heating and other purposes. It is used extensively and provides around 75 percent of house heating. Thirty years ago, in 1960, hot water was only utilized up to a small degree. Even in the small townships around Reykjavik people had to heat their houses with imported oil. The Reykjavik area has rich supplies of hot water underground but, it requires large investments to harness these resources. It has, therefore, been done gradually over the last 50 years. Almost all houses in Reykjavik and surrounding townships are now heated with a domestic source of energy. Around sixty percent of the population of Iceland lives in this area.

The same process has been going on in several small towns in the North of Iceland and on the west coast. The main problem in about half of these cases is water shortage or long distance from the main drill holes to the town area. This leads to very high investment costs per ton of hot water sold. The district heating systems were financed with foreign loans in amounts that are indeed too high for small towns with 15 thousand inhabitants. This has resulted in higher prices charged by the new, expensive district heating companies. However, the local population served by them is only around 25,000 people or 10 percent of the total Icelandic population. The substitution of geothermal energy for oil kettle heating or electrical heating has been slow in these towns.

3. Energy use in Iceland

Figure 1 shows the development of total final energy consumption from 1972 to 1990 in Iceland. Use of oil products has been relatively stable in Iceland, while use of district heating and electricity have increased through the whole period.

Figure 1. Total final energy consumption in Iceland.

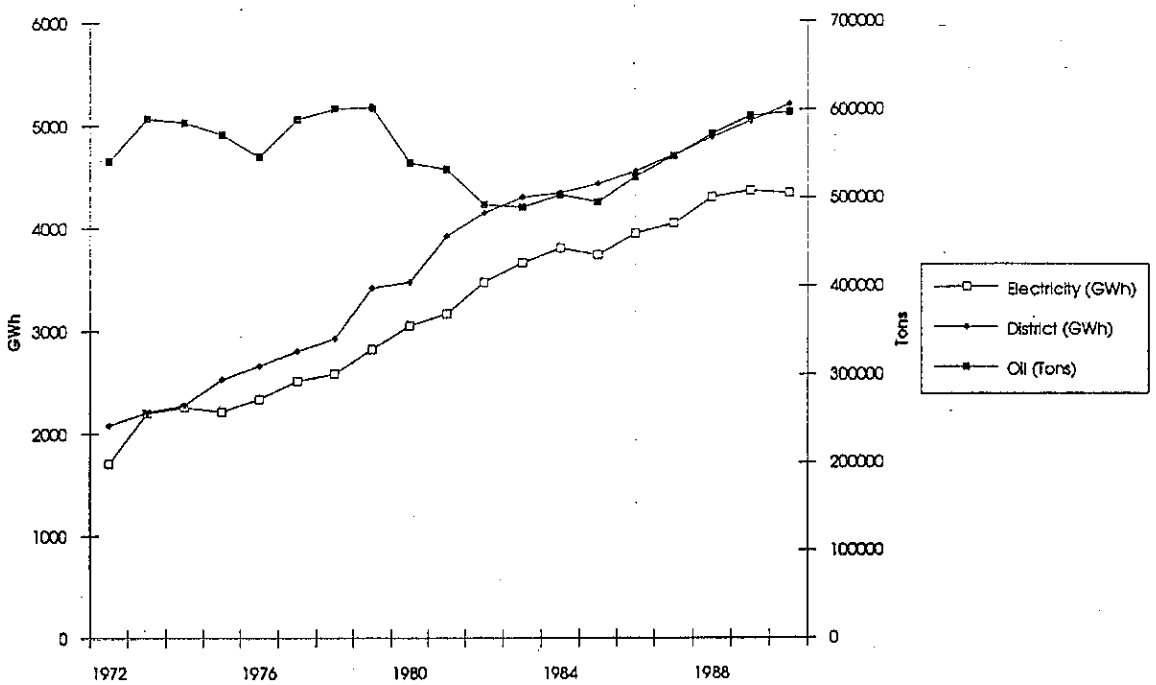


Figure 2 depicts the use of electricity in Iceland. General use consists of electricity use in households, small industry and services. The three large users of electricity, aluminum, alloy and fertilizer and cement accounts for the remaining electricity consumption in Iceland. The use of electricity in production of aluminum has been relatively stable since 1973. Production of alloy started in 1979 and electricity consumption grew rapidly the first years. Since 1985, consumption of electricity in production of alloy has levelled out. Consumption of electricity for general use has been growing steadily during the period.

Figure 2. Consumption of electricity.

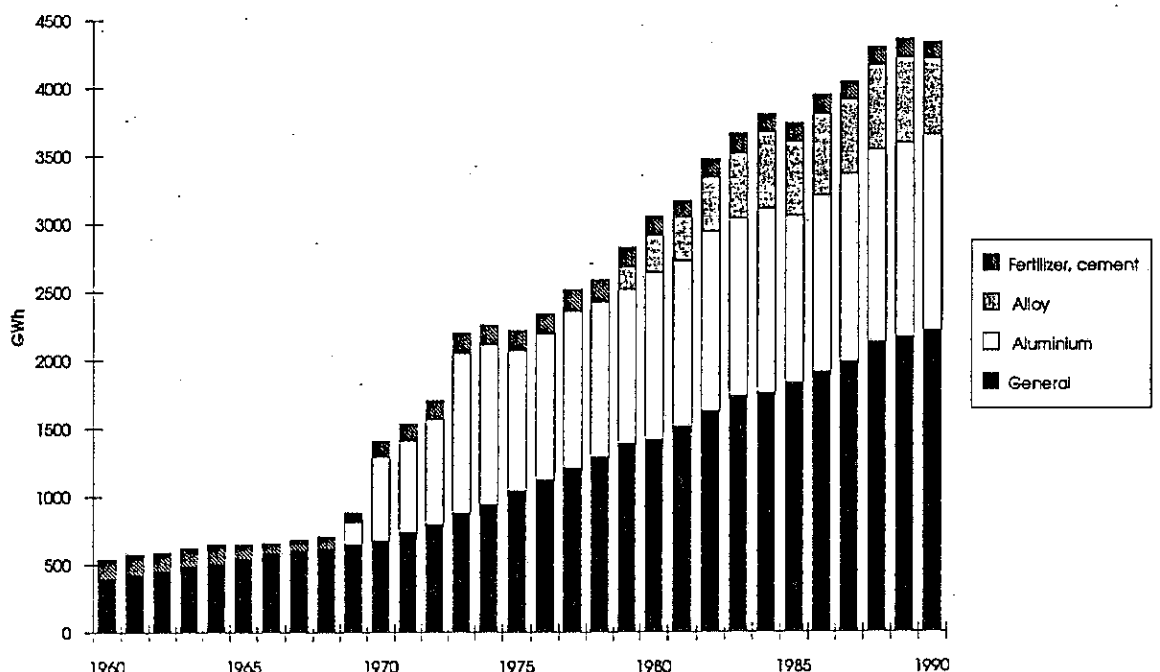


Figure 3 shows that aluminum, fertilizer and cement plants paid the same price until 1987, but from then on the price to fertilizer- and cement producers dropped below the price paid by producers of aluminum.

Figure 3. Electricity prices paid by large consumers.

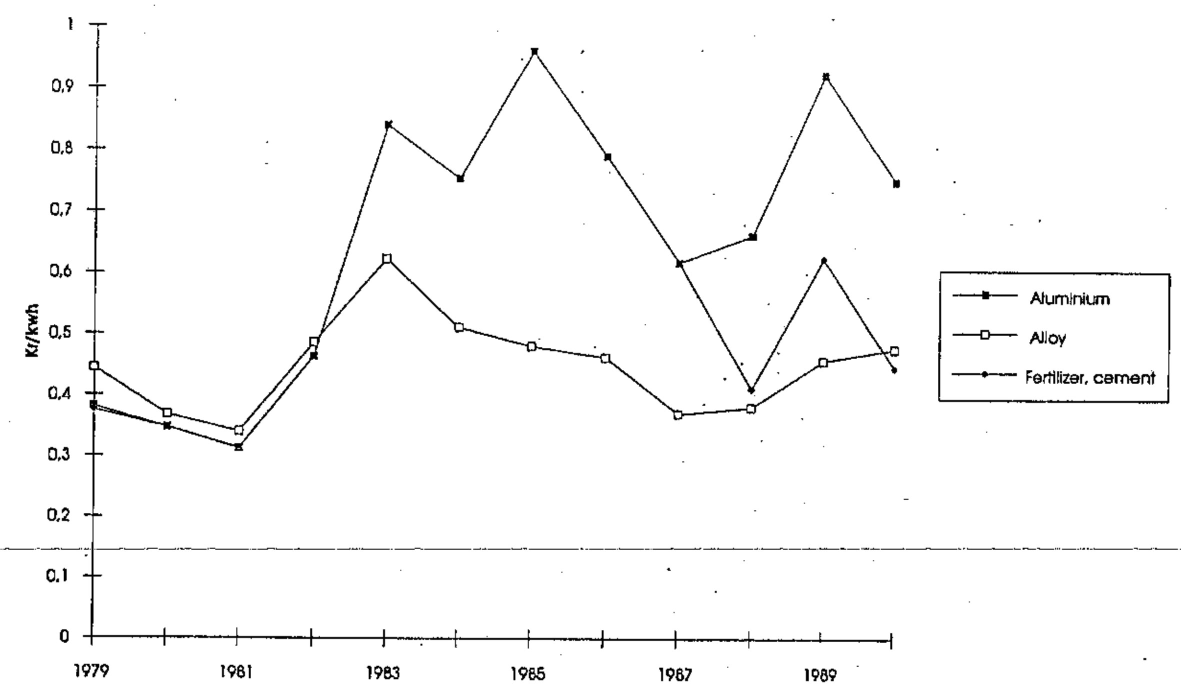


Figure 4 depicts the sale of oil products in Iceland for the period 1972-1990. The figure shows that diesel oil is the most important fuel. This is mainly due to use of diesel oil in the fishing fleet. Moreover, the volatile consumption by fisheries seem to explain most of the variation in total oil use. The variation in total oil use also seems related to the variations in the oil price. The use of oil products declined in 1979-80 when the prices of oil products increased, and total oil consumption has increased after the downward drift of oil prices in 1985-86. Thus, we expect to find negative price elasticities in most sectors. In 1990 the fishing fleet accounted for about 50 percent of total diesel oil use in Iceland. Use of diesel oil in fishing shows much greater volatility than use of diesel oil for other purposes. The reason for this is probably variations in the fish resources leading to chances in fishing regulations and the utilization of the fleet. Obviously, fuel demand depends also the stock of fishing boats. Sale of gasoline increased steadily during the period, while sale of jet fuel has been stable during the period. Sale of fuel oil to households shows a steady decline during the period.

Figure 4. Sale of oil products in Iceland.

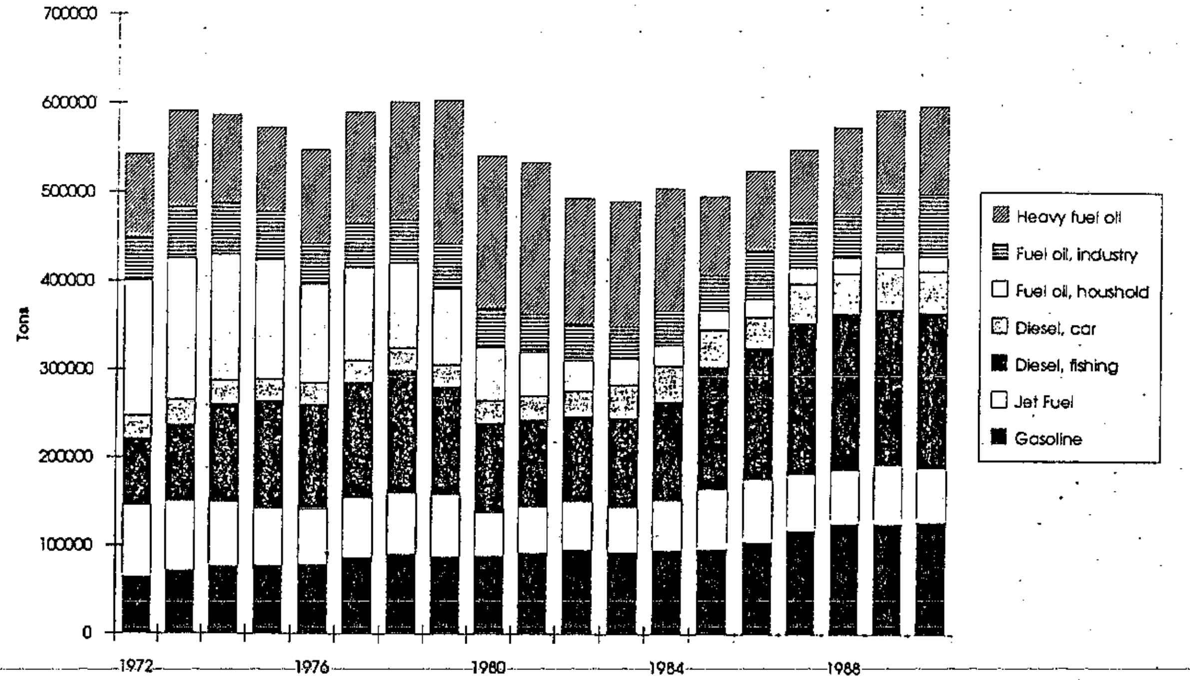
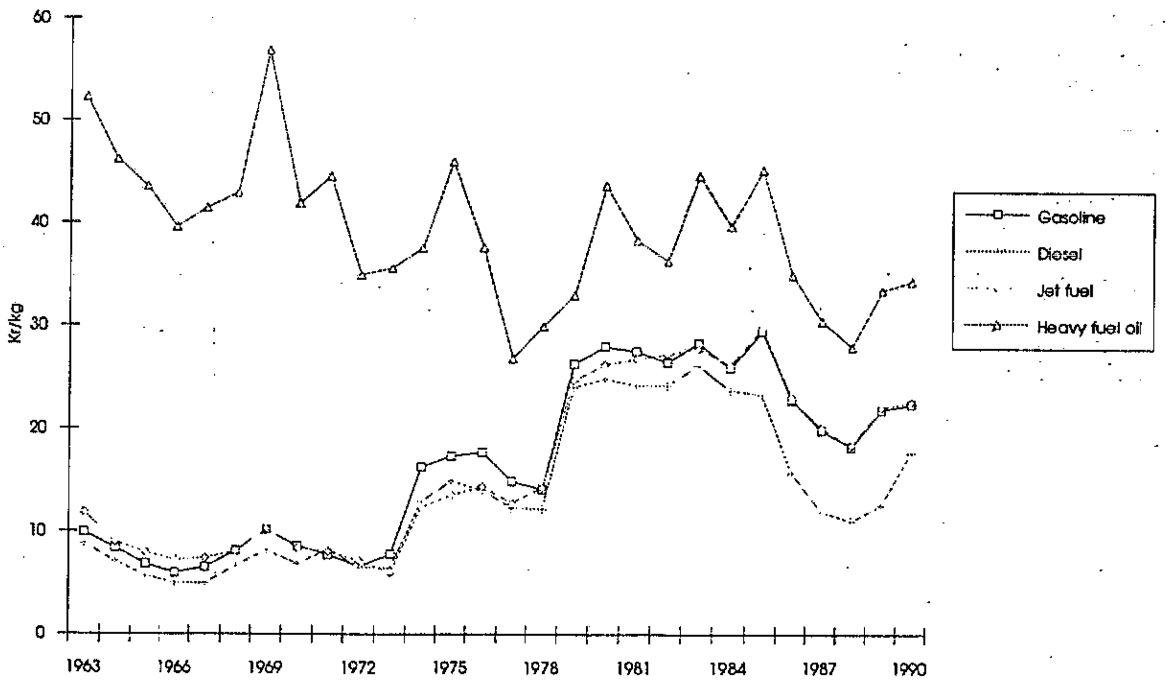


Figure 5 depicts the price development of some fuels in the period 1963 1984. The prices are CIF-prices because we have not been able to find a time series of fuel prices including all taxes and margins.

Figure 5. Fuel prices in Iceland, 1990 Isl Kr/kg.



The figure shows that prices on most fuels (except heavy fuel oil) were stable until 1973 (Yom Kippur war). After 1974 the prices remained relatively stable until 1979 when the first Gulf war caused another jump upwards in fuel prices.

Use of district heating has increased steadily since 1960 along with the development of district heating systems and seemingly unaffected by the price as depicted in figure 7.

Figure 6. Use of district heating in Iceland.

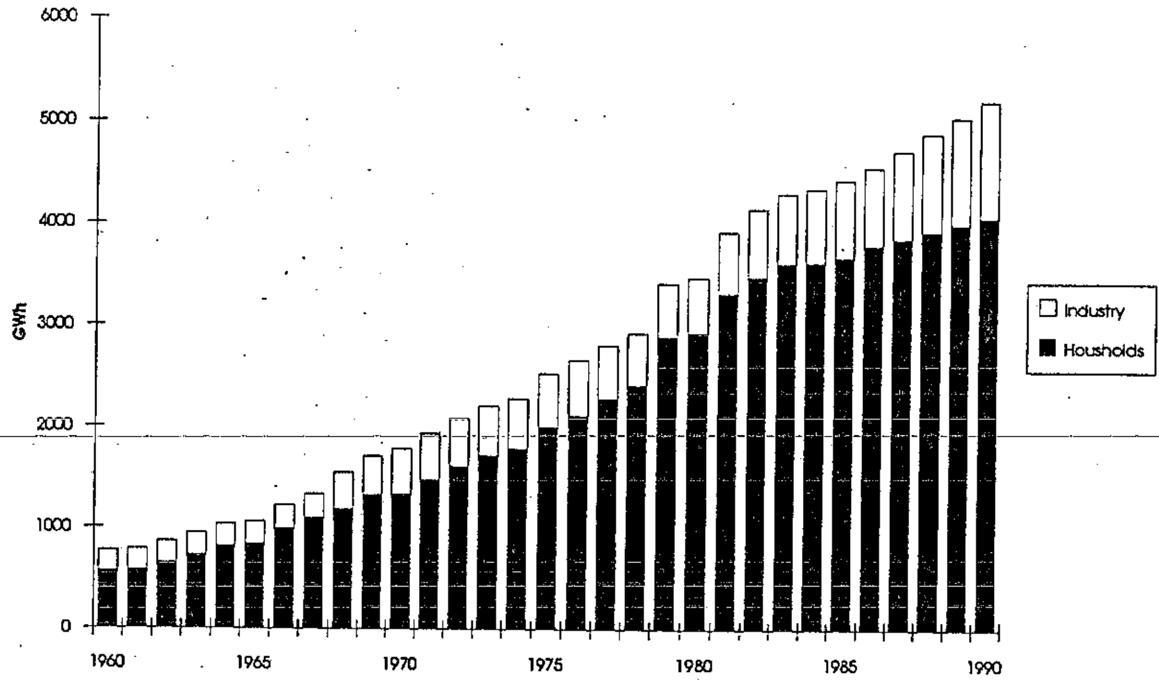
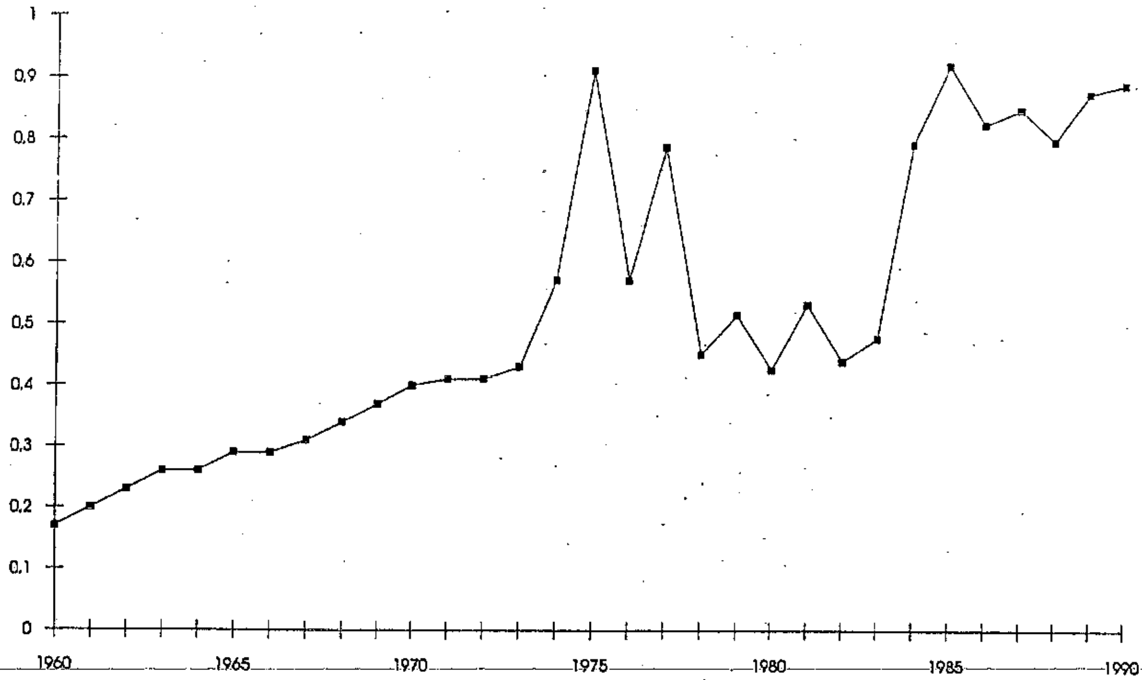


Figure 7. Price of district heating in the Reykjavik area. Kr/kwh.



4. Energy demand functions. Basic model concept

When factor demand functions (for a given output) are derived from restricted cost functions, a change in one of the prices will generally affect demand for all factors. Several functional forms are available that incorporate all these effects. Estimation of these flexible functional forms requires data of good quality and long time series because of the high number of parameters that must be estimated. Assuming weak separability between energy and other inputs, more data efficient functional forms can be applied, such as CES or Cobb-Douglas functions. However, substitution between energy commodities in a significant scale is possible in the household and small (in the meaning small scale energy use) industry sector only. In these sectors, a CES technology were tested. For the other sectors, we have only estimated reduced form demand functions for Iceland. Estimation of reduced form equations of this type can be justified as long as no change in structural parameters occurs.

Our energy demand model is the partial adjustment model. With this model we can estimate both short- and long term demand elasticities. The difference between short term and long term elasticities is usually connected with adjustments of the capital equipment due to changes in relative prices. We assume that the optimal consumption of energy commodity i, Q^*_i, depends on income, prices and a trend factor for technical change. If we specify the demand function with constant elasticities the optimal consumption is given by:

$$Q_i^* = AP_i^{\beta_1} Y_i^{\beta_2} e^{\beta_3 t} \quad (1)$$

The demand function (with constant elasticities) for a energy commodity is written this way:

$$Q_t{}^* = AP_i^{\beta 1}Y_i^{\beta 2}e^{\beta 3t}$$

$Q_t{}^*$	=	optimal consumption of the energy commodity in relevant units (GWh, etc)
A	=	a constant
P_i	=	price of electricity, oil, geothermic heat, etc.
β_1	=	exponential coefficient
Y_i	=	an income index for the user group
β_2	=	exponential coefficient
e	=	root for natural log
β_3	=	exponential coefficient
t	=	trend parameter

We are going to use a partial adjustment model that relies on an adjustment process. It means that the users initial use of the energy commodity is not optimal and he takes steps toward a more optimal position in relation to the price of the commodity, his income and a trend factor. The adjustment process is described as:

$$\left[\frac{Q_t}{Q_{t-1}}\right] = \left[\frac{Q_t^*}{Q_{t-1}}\right]^{1-\theta} \qquad (2)$$

Here θ is a coefficient where $0 < \theta < 1$. It expresses the speed of adjustment, the smaller the θ, the faster is the adjustment, i.e. Q_t approaches Q_t^* as θ approaches zero.

We want to express the demand function in terms of Q_t instead of Q_t^*. This is possible by using equation (2). It can be written this way:

$$\frac{Q_t}{Q_{t-1}} = \frac{(Q_t^*)^{1-\theta}}{Q_{t-1}(Q_{t-1})^{-\theta}} \qquad (2a)$$

Rearranging and cancelling gives:

$$Q_t Q_{t-1}^{-\theta} = (Q_t^*)^{1-\theta} \qquad (2b)$$

Now put equation (1) in the power of $(1-\theta)$:

$$(Q_t^*)^{1-\theta} = A^{(1-\theta)} P_i^{\beta_1(1-\theta)} Y_i^{\beta_2(1-\theta)} e^{\beta_3 t(1-\theta)} \qquad (1b)$$

and substitute the left side of eq. (2b) for $(Q_t{}^*)^{1-\theta}$ and move $(Q_{t-1})^{-\theta}$ to the right side.

Now we have equation (3) which expresses the users present demand as a function of the use in preceding period in the power of θ, the price of the commodity in the power of $\beta_1(1-\theta)$, his income in the power of $\beta_2(1-\theta)$ plus a trend factor expressed in natural log exponential form in the power of $\beta_3(1-\theta)t$.

Combining equation (1) and (2) gives:

$$Q_t = A^{1-\theta} Q_{t-1}^{\theta} P_t^{\beta_1(1-\theta)} Y_t^{\beta_2(1-\theta)} e^{\beta_3(1-\theta)t} \quad (3)$$

Taking natural logs of equation (3) gives:

$$q_t = \alpha(1-\theta) + \theta q_{t-1} + \beta_1(1-\theta)p_t + \beta_2(1-\theta)y_t + \beta_3(1-\theta)t \quad (4)$$

where small letters are the logs of the corresponding capital letters. Since equation (4) is double logarithmic, the coefficients represent elasticities. The short run price elasticity from equation (4) is $\beta_1(1-\Theta)$ and the long term price elasticity is β_1 as can be seen from equation (1). If the estimated equation is of the form:

$$q_t = a_0 + a_1 p_t + a_2 y_t + a_3 t + a_4 q_{t-1} \quad (5)$$

we will have that the short run price elasticity is a_1, and the short run income elasticity is a_2. The corresponding long term elasticities can be calculated as $a_1/(1-a_4)$ and $a_2/(1-a_4)$ where a_4 is the adjustment parameter. The parameter a_3 is the proportionate rate of change in Q per unit of change in t.

In the energy intensive industries aluminum, alloy, and fertilizer energy use is dominated by processes that require energy inputs in a fixed proportion to output. Thus, simple input-output functions are usually assumed (Mysen (1993)). However, some energy use are independent of the processes, and there might be choices between different input-output mixes as well as technical progress and learning effects. Also, input efficiency may depend on capacity utilization. Thus, we tested both linear and loglinear functions. The results confirmed our expectation that energy prices are insignificant, and the linear and loglinear functions seem to have equivalent econometric properties (neither is a better choice).

The linear model is shown in equation (6)

$$Q_t = \alpha + \beta_1 Y + \beta_2 P + \beta_3 t + \beta_4 Q_{t-1} \quad (6)$$

In the linear case the parameters are interpreted as derivatives.

Even though input of energy and output is determined simultaneously and endogenously, we treat output as an exogenous variable, as our ambition is restricted to a partial equilibrium model in energy demand. The output data has been deflated by sector specific price indices in order to obtain volume series.

5. Estimated energy demand functions

5.1. Demand for electricity, stationary consumption.

As outlined above, our hypothesis is that for a specific technology like production of aluminum, demand for electricity is closely linked to output. Estimation results for production of metal in Norway suggests that there are small substitution possibilities between input factors in the metal producing industries. We therefore expect to find a positive relation between use of electricity and output and a non significant parameter for the price of electricity. Table 5.1 shows the model specifications that survived the tests (best results) of the log-linear model.

Table 5.1. Estimation results for electricity demand. Log-linear-model. t-values in parenthesis.

	a_1 p_t	a_2 y	a_3 t	a_4 q_{t-1}	R^2(adj)	DW
Aluminum		0,75 (6,40)		0,28 (2,30)	0,90	2,0
Alloy		1,1 (19,2)	-0.02 (-3,30)		0,99	1,6
Fertilizer		0,35 (2,10)		0,31 (1,40)	0,39	1,8
Households and small industry		0,21 (3,03)		0,83 (16,2)	0,99	1,72

Large industries

The price parameter of electricity a_t was insignificant and got the "wrong" sign in all estimations and was excluded. The results in table 5.1. shows the estimations where $a_1 = 0$. The production variable was significant for all sectors, and the value of a_2 was lowest in production of fertilizer and cement (0.35) and highest in production of alloy (1,1). In production of aluminum the short term production elasticity was 0.75.

The trend variable was significant only in production of alloy, where it got a negative sign, indicating an autonomous energy saving trend, linked to investments in training and management.

The management of the alloy plant has reported on a succesful rationalization process, resulting in lower production costs per ton of alloy.

As regards the aluminum plant some investment has been made in pollution control equipment. This does not show up in increased productivity, of course. The aluminum plant has been run with the same technology from the start of production. There is not much incentive or room for profitable improvements in technology based on the existing plant.

The fertilizer (and cement) industry consists of one fertilizer plant and one cement factory. These are the only plants in Iceland in this industry. The low R^2 is explained by the inhomogenous structure of this sector. Since this sector is based on an aggregate of two industries it is not surprising that R^2 is low. Disaggregated data were not available. The fertilizer plant supplies the agriculture where swings depend on weather conditions as well as the income of farmers. The cement plant is a supplier to the building industry.

A note on the Durbin-Watson statistic

When there are one or more lagged endogenous variables present the DW statistic is no longer reliable. Instead one should use the Durbin-h statistic. It is designed for large samples of data but can be used for small sampes also. The formula for the Durbin -h statistic is written this way:

$$h = \left(1-\frac{DW}{2}\right)\sqrt{\frac{T}{1-T[Var(a_4)]}}$$

It is only applied to the parameter (a_4) of the lagged endogenous variable (q_{t-1}). To find the appropriate Durbin-h statistic we can apply this formula to the results of the log-linear model for aluminium demand in table 5.1:

$$h = \left(1-\frac{2,0}{2}\right)\sqrt{\frac{12}{1-12[0,015]}}$$

We see right away that the outcome is h = 0 because the first brackets equal zero. Since zero is obviously lower than the critical t-value for T=12 is 1.745 at the 5 percent level we cannot reject the null hypothesis of no serial correlation in the case of the demand of the aluminium producers for electricity.

Next we apply the Durbin-h statistic to the a_4 of the fertilizer factory's demand for electricity. Then the outcome is h = 0,54 and we again cannot reject the null hypothesis of no serial correlation in the case of the demand of the fertilizer producers for electricity. The h statistic for households and small industry is 0,49 and again the null hypothesis cannot be rejected.

Economic swings depend on the swings in the fishing industry which is the main industry in Iceland. In fact, the whole economy depend on income from fishing and fish processing. Fish products share of total export is over 75 percent. The residual 10 percent consists of aluminum, alloy and other industrial products.

Households and small industry

The data for electricity consumption in households and small industry are lumped together, leaving no option for disaggregated analysis. We estimated a demand function for households and small industry combined, using the log-linear model. Also for households and small industries the price and trend got the "wrong" sign and was not ststistically significant. None of these results were surprising, as electricity small scale consumption is mainly used for lighting and appliances, with no energy substitutes. Investments in appliances are long term income dependent, thus consumption of electricity in households is a luxury good with positive Engel elasticity. The effects are similar in the service industries because electricity expenditure is a small share of operating costs in most firms. After the second oil crisis in 1979-82 there was some government stimulation of electricty saving. Long term loans were offered by the Housing Administration in Iceland. Some improvement were made in rural areas and small towns where electricity or fuel were used for heating. In Reykjavik and other towns with geothermal heating the savings made from improvements of housing were too small to pay off loan and interests because of the low price of a ton of hot water.

Table 5.2 shows the results for the linear model for large industries.

Table 5.2. Estimation results for large industries in Iceland. Linear-model. t-values in parenthesis. Estimation period 1974-1989.

Industry	a_1 p	a_2 y	a_3 t	a_4 q_{t-1}	R^2(adj)	DW
Aluminum		0,65 (6,0)		0,27 (2,1)	0,90	2,0
Alloy		0,61 (10,2)	-9,9 (-1,80)		0,99	1,6
Fertilizer		0,13 (1,96)		0,35 (1,60)	0,39	1,8

As for the log-linear models we get the best fit for alloy where R^2 is 0.99. The significant explanatory variables are the same for both models. The trend variable is significant for alloy only. The interpretation of a_1 in the linear model is the short term input-output coefficient.

Both the log-linear and the linear models gives a reasonably good fit for aluminum and alloy. Demand for electricity in the aggregate sector fertilizer and cement is, however, not very well explained by either model, R^2 is only 0.39.

R^2 is the same for both models, but one can not compare R^2 directly when estimating two different functional forms. We have therefore re-computed R^2 in the log-linear model by taking exponential of the fitted values and then compared with R^2 from the linear model. The differences between the R^2's were marginal. The log-linear and linear models therefore seem to fit equally well. We have chosen the log-linear model for implementation in the demand model mainly because the parameters have a straightforward interpretation as elasticities.[1]

[1]The loglinear model is strictly concave in output when $a_1<1$, and convex otherwise. Thus, for aluminum the process (energy use) is short term decreasing to scale but long term almost constant. Alloy is both short and long term weakly increasing to scale. The fertilizer is short term strongly decreasing, and long term almost constant, but the short term concavity depends on the scale, reflecting that some fraction of energy use are production independent (lighting etc). None of the specifications contradicts the simple input-output hypothesis of constant

5.2. Demand for oil products in transportation and heating.

Table 5.3 shows the results from the estimations for oil products. We have excluded the prices of alternative fuels from the set of dependent variables, because almost all oil products follow the same price development. Attempts to estimating cross price elasticities between oil products thus lead to multicollinearity. The main effects of multicollinearity are large sampling variances of the estimated coefficients and great sensitivity of estimated coefficients to small data changes.

Table 5.3. Estimation results for gasoline demand in Iceland. Log-linear model. t-values in parenthesis.

	α_1 p	α_2 y	α_3 t	α_4 q_{t-1}	access	R^2(adj)	DW
Gasoline	-0,13 (-6,59)	0,39 (5,57)		0,65 (8,79)		0,99	1,97
Diesel oil	-0,05 (-0,63)	0,36 (1,76)		0,74 (4,47)		0,87	2,10
Jet fuel	-0,20 (-2,41)	1,47 (3,88)	-0,05 (-3,41)			0,85	2,75
Diesel oil in the fishing fleet	-0,12 (-1,59)	0,02 (0,16)		0,82 (5,93)		0,81	1,25
Fuel oil households	-0,16 (-2,25)			0,91 (15,21)	-0,36 (-0,96)	0,99	2,86
Fuel oil industry		0,54 (1,45)	-0,06 (-3,68)			0,87	2,22
Heavy fuel oil	-0,25 (-1,23)	0,40 (0,79)		0,55 (1,46)		0,75	1,74

Gasoline

The estimation period for gasoline and diesel oil demand is 1973-90. Both of these products are mainly used in road transportation. We chose not to use the structural model applied to the other Nordic countries (Johnsen, (1993)), as sufficient data were not easily available. For gasoline demand all variables except the trend variable are significant and are of reasonable magnitude. The short run price elasticity is -0,13 and the short run income elasticity is 0,39. The corresponding long run elasticities are -0,37 and 1,11. Bacon et al. (1990) reports an average long run price elasticity for 16 West-European countries of -0,91 and an average long run income elasticity of 1,26. Even if the price elasticity in Iceland is lower than the average many other countries also experience price elasticities in this range. R^2 is very high in the estimated equation and the Durbin-Watson statistic is close to 2, indicating low auto-correlation..

returns to scale, and as the analysis in this section points out, either model is econometrically equivalent.

Diesel oil

The regression for diesel oil demand in road transport did not perform as well as the regression for gasoline. The price variable is not significant, but since it got the right sign and we are interested in analyzing the effects of taxes on fossil fuels we have chosen to include it in the model. The short run price elasticity is -0,05 and the short run income elasticity is 0,36. The corresponding long run elasticities are -0,19 and 1,38. Bacon et al. (1990) reports an average long term price elasticity for diesel oil for 16 West European countries of -0,14 and an average long term income elasticity of 1,68. Since our elasticities are so close to these estimates we feel comfortable with using them even if they are not significant. The long run price elasticity for diesel oil is lower than the price elasticity for gasoline. One reason for this might be that diesel oil is used in scheduled transport, i.e. buses, that drives the same distance whether the price of diesel oil goes up or down.

Jet fuel

The estimation period for jet fuel is 1973-84. The regression for jet fuel gave a non-significant and negative sign for the lagged dependent variable and has therefore been left out. The remaining variables are all significant on a five percent level. Since the lagged dependent variable is not included the estimated parameters can be interpreted as long run elasticities.

Diesel oil in fishing

The estimation period for demand for diesel oil in the fishing fleet is 1973 1990. The income variable is not significant, but we have chosen to include it in the model. If we keep the price variable and the lagged endogenous variable only, forecasts of fuel use in the fishing fleet will decline even if activity in the fishing sector increases. The short run price elasticity is -0,12 and the income elasticity is 0,02. The corresponding long term elasticities are -0,66 and 0,13. The relatively poor results for this equation, confirms our hyphotesis of a weak correlation between income (the volume of catch) and fuel demand as described in section 4. A more sophisticated model based on better data would be preferable.

A low income elasticity in this sector can be defended by the following argument: Fishing in Iceland is regulated by quotas and if catches are good each boat may need less days at sea in order to fill quotas. Energy use might therefore be relatively low in periods with good catches and therefore tend to produce a low income elasticity in this sector. As income is correlated with quotas we get a positive, but low income elasticity.

Fuel oil in households

Fuel oil, district heating and electricity are all substitutes in the demand for space heating. Thus, we tested a top down model with weak separability in these energy commodities, see section 6.4. Since the tests turned out negatively, we report the reduced form regression here. The estimation period for fuel oil demand in households is 1973-90. Since we believe that the introduction of district heating is a major factor behind the fall in oil consumption for households we have also included the access variable for district heating. If the access to district heating has an influence on consumption of oil we expect a negative sign for this variable. The results show that the price variable and consumption in the previous period are significant. The access variable is not significant, but gets the right sign. An attempt to estimate the function without the access variable gave a long run price elasticity of -5,0 which is unreasonably large. Since there are strong reasons to believe that access to district heating is important for determining consumption of oil we have chosen to include the access variable even if it is not significant. The short run price elasticity is -0,16 and the long run price elasticity is -1,77.

Fuel oil in industry

The estimation period for fuel oil in industry is 1973-84. The price variable and the lagged dependent got the wrong sign and were left out. The income variable is significant only on the 18 percent level.

Heavy fuel oil in industry and shipping

The estimation period for heavy fuel oil is 1973-90. The parameters reported for heavy fuel oil in table 6.3 are not statistically significant, but since this regression produces reasonable magnitudes for both short and long term elasticities we have implemented these parameters in the model. Relying on statistically significant variables only, we would end up with a regression in income and the trend variable. The size of the long term income elasticity would then be 2,7 which we consider unrealistically high. The short run price elasticity with the chosen equation is -0,25 and the short run income elasticity is 0,40. The corresponding long run elasticities are -0,55 and 0,89.

5.3. Demand for district heating in households and small industry.

Testing a top down approach using a CES cost function was our starting point. This approach was used in Mysen (1993) for the four other Nordic countries. For Iceland we were interested in investigating the substitution possibilities between district heating on one hand and electricity and oil respectively on the other hand. A term measuring the effect of the availability of district heating, using the percent of households with access to the network, was included. These estimations did not yield satisfying results, that is, no significant substitution could be detected. The same rather disappointing results were obtained in tests of Denmark, Sweden and Finland (Haug (1992)). The explanation is that consumers are not offered a free choice whenever district heating is supplied. Consumers are either confronted with *fait a complie* as heating systems are already built into the house, or strong incentives that are not reflected in the price of heating. Also, the price of heating was imperfectly measured as outlined in section 4. Models that explicitly take the investment decision in heating systems into account, have a better chance of success, but they are data demanding. For a recent application of a discrete choice model on Norwegian data, see Nesbakken and Strøm (1993).

Consequently, we used a bottom up specification for estimating demand for district heating in the household sector. The results are given in table 5.3. These estimations suggested that demand for district heating is a function of own price (negative impact), access to district heating (positive impact) and time (positive impact).

Table 5.4. Estimation results for demand for district heating in households and industry. t-values in parenthesis.

Model	p	y	t	q_{t-1}	acc	R^2(adj)	DW
Household	-0,07 (-3,58)		0,47 (8,56)		1,31 (9,48)	0,98	0,90
Industry		1,59 (2,90)			1,49 (1,47)	0,80	0,67

Table 5.5 gives an overview of the short and long run price and income elasticities that are used in the model.

Table 5.5. Price and income elasticities of energy demand in Iceland.

	Short run price elasticity	Long run price elasticity	Short run income elasticity	Long run income elasticity
Electricity				
Aluminum			0,75	1,04
Alloy			1,10	1,10
Fertilizer and cement*			0,35	0,51
Households			0,21	1,24
Oil products				
Gasoline	-0,13	-0,37	0,39	1,11
Diesel oil*	-0,05	-0,19	0,36	1,38
Jet fuel	-0,20	-0,20	1,47	1,47
Diesel oil in the fishing fleet*	-0,12	-0,67	0,02	0,11
Fuel oil in households	-0,16	-1,77		
Fuel oil in industry*			0,54	0,54
Heavy fuel oil*	-0,25	-0,56	0,89	0,89
District heating				
Households	-0,07	-0,07		
Industry*			1,59	1,59

* Elasticities based on regressions where not all variables are significant on a 10 percent level

6. Simulation of the model

6.1 The reference scenario

The key exogenous variables are based on forecasts from the National Economic Institute, Orkustofnun (1992), and the Energy Technology System Analysis Program (ETSAP). The reference scenario should not be interpreted as an official energy demand forecast, but rather as a business as usual scenario serving as a reference point for policy scenarios.

Table 6.1. Growth rates of activity variables.

	Average annual growth rate 1990-2000	Average annual growth rate 2000-2010
GDP	0,8	2,1
Fishing	3,0	0
Air transport	1,5	1,0
Aluminum	0	0
Alloy	0	0
Fertilizer and cement	0	0

The projections for GDP growth rates is taken from Orkustofnun (1992), and the activity variables for fishing and air-transport from the National Economic Institute. The average growth rate for GDP and fishing between 1990 and 2000 is positive, but for the first years the growth rate is negative. As shown in figure 6.3 the consumption of oil products therefore falls during the first years. Since we assume full capacity utilization and no new capacity for the three large users of electricity the growth rate for the activity variables in these sectors are zero.

There are plans for a new aluminum plant in Iceland, and this will lead to both direct and indirect increases in electricity demand. The direct shift is of a such magnitude that it would lead to an increase of electricity consumption of 2700 GWh from 1997. This requires investment in new hydro power plants. An analysis of this project is given in Orkustofnun (1992). In line with this study, we exclude this project from our reference scenario.

Table 6.2. Growth rates of exogenous prices

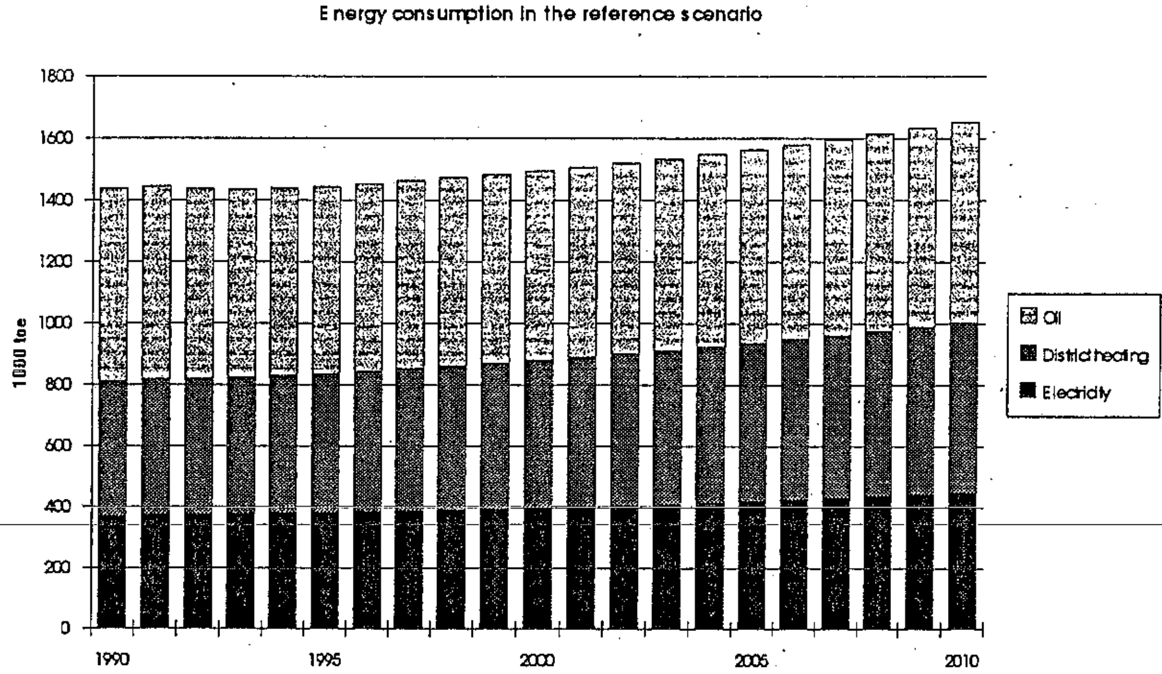
	Average annual growth rate 1990-2000	Average annual growth rate 1990-2000
CIF-price of all oil products	2,14	1,84
Electricity	-	-
District heating	0	0

The forecasts of CIF-prices for oil products are taken from ETSAP (1991). The price of electricity was not significant for any of the regressions and consequently we have not made any projections for the electricity price either. The price of district heating is not assumed to rise further. The trend variable is assumed to grow by one percent every year. Access to district heating remains at the same level.

Figure 8 shows the resulting forecasts of consumption of oil, electricity and district heating. Total final energy consumption in the reference scenario will rise from 1400 thousand toe in 1990 to about 1600 thousand toe in year 2010. This implies an average annual growth rate of energy consumption of 0,7 percent

during the period. Consumption of electricity and district heating grows much faster than consumption of oil products. The average annual growth rates for electricity is 1,0, for district heating 1,1 and for oil products only 0,2 percent.

Figure 8. Projected energy use in the reference scenario for Island



We have compared our results for electricity consumption with forecasts in Orkustofnun (1992). In Orkuspá we find three alternative scenarios for electricity consumption, giving a low, medium and high estimate of future electricity consumption in Iceland. The low alternative gives an estimate of 4400 GWh, the medium alternative 4900 GWH and the high alternative 8600 GWH in year 2010. Our simulations gives an electricity consumption of 5280 GWh in 2010, which is 7 percent above the medium forecast from Orkustofnun.

One reason for the low growth of oil products is that GDP is assumed to grow very moderately during the first half of the forecast period. The demand for diesel oil in fishing grows slowly due to low income forecasts and a low income elasticity. Since this demand component is a major share of the total oil consumption, it explains the low total growth rate. The development of use of oil products in the fishing fleet is uncertain (see section 5.2).

Fuel oil for heating purposes has to a large extent been replaced by district heating and electricity. We have assumed that access to district heating does not increase over the period so the increase is due to more intensive use of installed capacity.

6.2 The carbon/energy tax scenario

On May 13 1992 the European Commission proposed a plan to stabilize CO_2-emissions in the Community by the year 2000 at 1990 levels. The measures introduced in the plan are both fiscal and non-fiscal, but in this paper we focus on the fiscal measures. The fiscal measure consist of a tax based partly on an energy

component and partly on a carbon component. A $3 per barrel tax would be introduced in 1993 with an additional $1 per barrel per year until year 2000.

In this paper we look at the effects on energy consumption in Iceland of introducing the tax measure suggested by the European Commission.

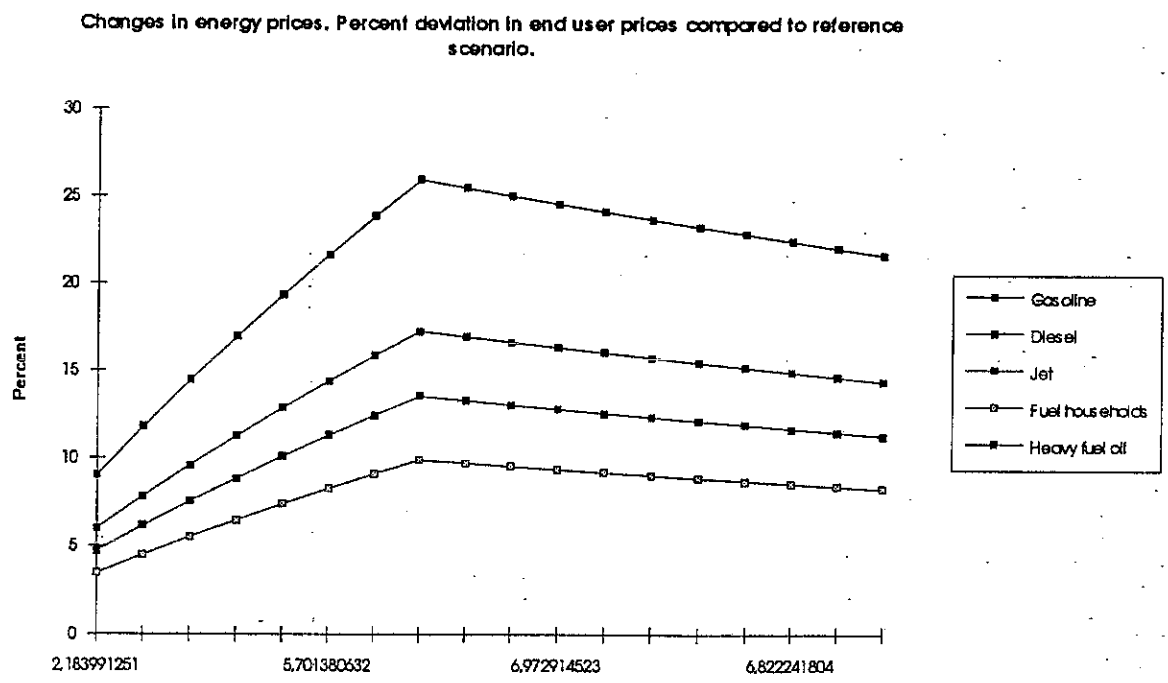
We take our estimate of the combined carbon/energy tax from Birkelund et al. (1993) table 4.1. whith a carbon/energy tax for oil products of $68 per toe in year 2000, measured in 1988 prices. Transforming this to Icelandic kroner measured in 1990 prices gives a combined carbon/energy tax of 4028 Icelandic kroner per toe.

The tax is superimposed on the existing tax structure in the model. The effect on end user prices therefore depend on the level of CIF-prices, margins, VAT and other taxes. Figure 9 shows the percent increase in end-user prices as a result of the introduction of the carbon/energy tax.

The figure shows that the introduction of the tax has greatest impact on the price of fuel oil for households. The reason for this is that the CIF-price of fuel oil is low and households do not pay VAT for heating purposes. The impact on the price of gasoline is small because gasoline taxes are already high.

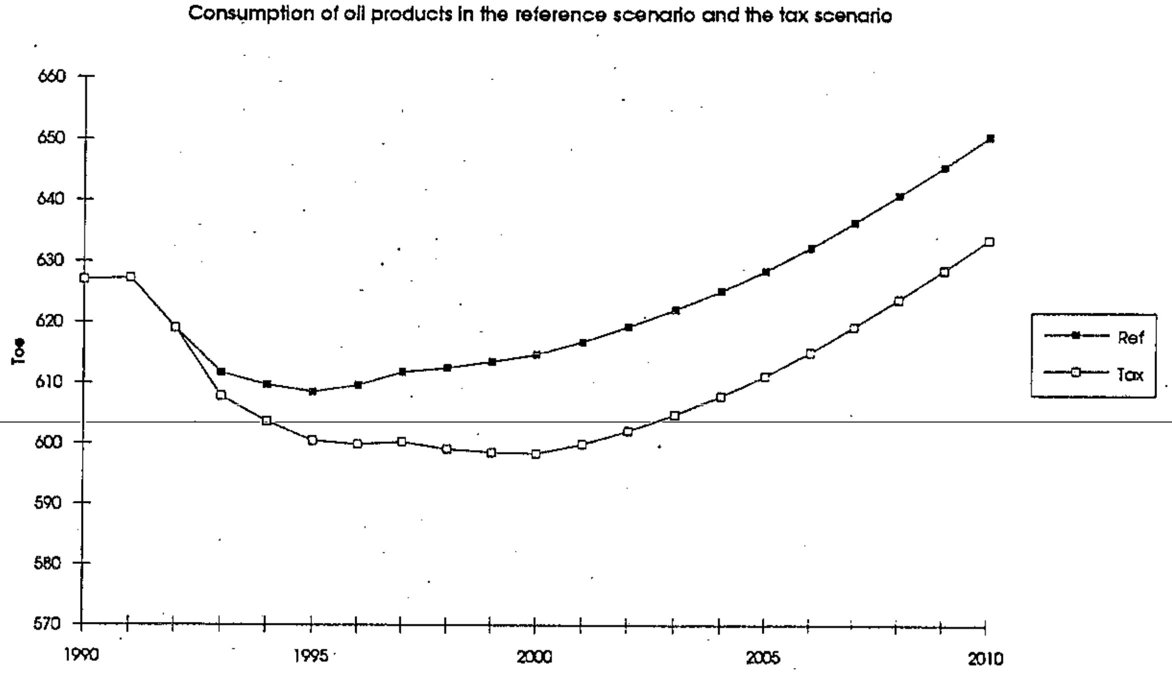
The figure also shows that since the CIF-prices are rising and the tax level stays constant after year 2000 the relative increase in the end user prices declines after year 2000.

Figure 9. Percent deviation in end user prices compared to the reference scenario.



Since all electricity in Iceland is produced by hydropower the carbon/energy tax will have no effect on electricity prices[2]. Since we assume that no substitution possibilities between oil and electricity exists the increased price of oil products will not lead to substitution towards electricity or district heating. The only effect will be to reduce consumption of fossil fuels. In figure 10 we depict the effect of the tax on consumption of oil products.

Figure 10. Consumption of oil products in the reference scenario and the tax scenario.



Consumption of oil products declines in the first years both in the reference scenario and the tax scenario due to high increases in the CIF-price and negative or low GDP-growth in the first years. As GDP growth increases the fall in consumption levels off and with lower growth of oil prices from 2000, consumption of oil products picks up a steady growth. The CO_2-tax is introduced in 1993 and consumption of oil products in the tax scenario is reduced compared to the reference scenario until year 2000. After year 2000 the tax is kept constant and consumption increases in line with the reference path.

The effect of the tax increase on consumption of different oil products is shown in table 6.3.

[2]The EC-tax proposal includes an energy tax (50 %) on large scale hydropower. But as mentioned above a tax on hydropower will have no impact on demand for neither electricity nor fossil fuels in the model.

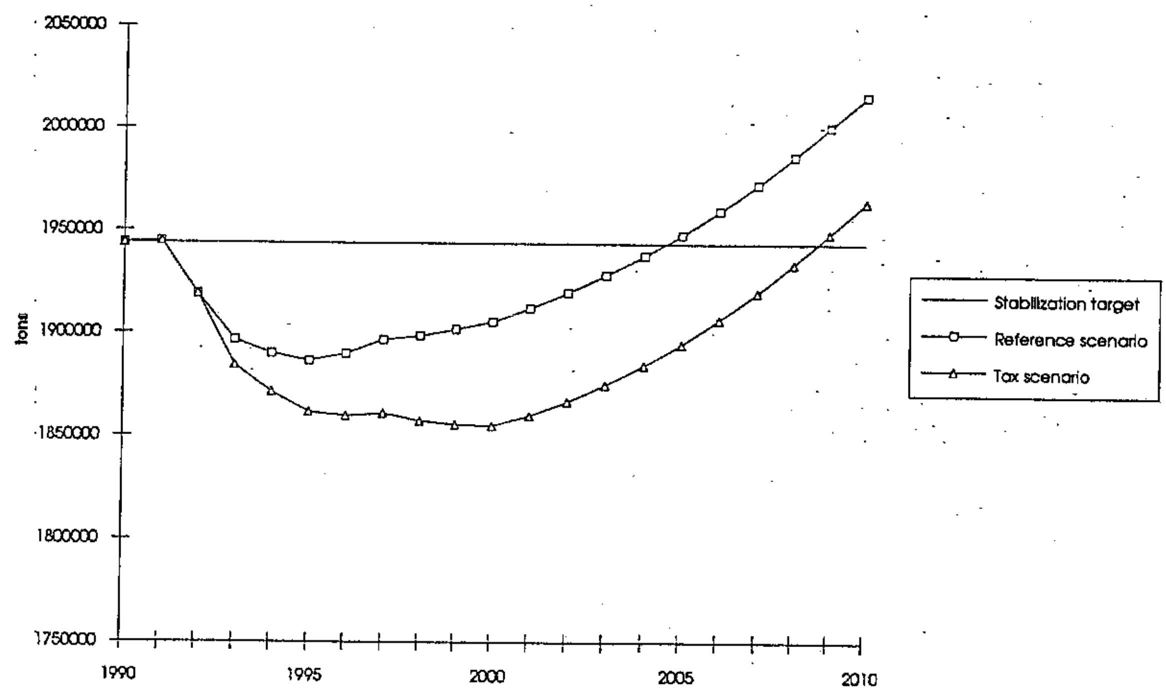
Table 6.3 Percent deviation from reference scenario in year 2010.

Gasoline	-2,4
Diesel oil	-2,5
Jet fuel	-2,2
Diesel oil in the fishing fleet	-2,3
Fuel oil in households	-25,0
Heavy fuel oil	-4,2
Total oil products	-2,6

Consumption of fuel oil in households experiences the largest reduction compared to the reference scenario. This is due to a large long run price elasticity and a large percentage increase in the end user price of fuel oil for households. Most other fuels are reduced between 2,2 and 2,6 percent compared to the reference scenario. Heavy fuel oil is reduced by 4,2 percent due to a high price elasticity.

The development of emissions of CO_2 in the reference and tax scenario is shown in figure 11. The figure shows that even in the reference case the emissions of CO_2 are lower in year 2000 than in 1990. Emissions of CO_2 are declining during the first years due to negative or low GDP growth and high growth in real prices.

Figure 11. Emissions of CO_2 from oil products in Iceland.



Emissions will however rise above the stabilization target around year 2005. In the tax scenario emissions are well below the stabilization target until year 2010. However, much of this development depend on the development of oil use in the fishing fleet. This is among the most uncertain elements in the forecasts of oil use in Iceland.

It should be noted that this analysis only takes into account oil products. Iceland does use some coal in aluminum production and production of non-metallic minerals, but since we assume that capacity remains the same we also assume that use of coal is constant.

7. Conclusions.

The simulations with the energy demand model for Iceland show that Iceland will have no problems with reaching the target of stabilization of emissions of CO_2 in year 2000 on a 1990 level. Even in the reference scenario this target is achieved because of low (negative) economic growth forecasts during the first part of the period. Increased growth in the period 2000-2010 leads to an increase in emissions and by year 2005 the emissions of CO_2 will be above the stabilization target and continue to grow. In the energy/carbon tax scenario the emissions will be below the stabilization target until year 2010.

This rather optimistic picture can be changed if the growth rate of GDP increases faster during the first part of the period. The use of oil products in the fishing fleet is also difficult to forecast due to changes in the fish stock.

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Appendix 1. Data.

The data used for the estimation has been collected from various sources. Data on electricity consumption are taken from the statistical journal "ORKUMAL", which was published annually by the National Energy Authority of Iceland (NEA) between 1963 and 1985. Tables 1.3 and 2.1 are used. To obtain end use data we subtract transmission losses from bulk sales; 5 percent of sales to the aluminum smelter; 7 percent of sales to the fertilizer plant and 10 percent of sales to Keflavik airport. Sales to the airport are included in retail sales because of the small-scale nature of the use there. Converting to 110 volts and distributing the electricity is done by the airport[3]. Consumption data for 1986-1990 is taken from the brochure "Electricity in Iceland", editions 1985-1990, published by the Association of Icelandic Electric Utilities in Iceland.

Electricity prices are taken from "ORKUMAL" tables 4.1 and 4.2.(Orkumal (1965-85)). The prices to retail users is that of Reykjavik Municipal Electric Works.

The data on hot water consumption was supplied by Mr. Olafur Palsson at the National Energy Authority in Iceland. It is mostly drawn from an unpublished report written by the Afl engineering consultants in 1987. The report is in turn based on data collected by the National Energy Authority. Data for recent years is obtained from the NEA (O.Palsson).

The price of hot water is represented by the marginal price per ton charged by Reykjavik Municipal District Heating (RMDH). The main source is again the National Energy Authority and "ORKUMAL" except for the period 1980-1990. Data for this period was obtained directly from RMDH (Jónsson (1992)). The price per ton is converted to price per kWh using a diagram on page 14 in 1990's annual report of Reykjavik Municipal District Heating. The diagram shows annual amount of water pumped from the hot water wells of the company. Two scales are used simultaneously one giving tons and the other GWh. One ton of hot water is estimated to contain 50 kWh of energy.

The data on oil consumption is drawn from "ORKUMAL" table 7.4.

Data on oil prices is taken from "ORKUMAL" table 7.1 and the data on gasoline is drawn from the same source and from monthly price sheets for 1979-1992 supplied by Olíufélagið hf. in Iceland.

[3]It is an international airport combined with a NATO airforce base. The base has an american population of 1-3 thousand people. Its demand for electricity is therefore, similar to the demand faced by electricity distributors in small towns in Iceland.

Appendix 2. The energy demand model for Iceland

```
access island
use 1980 1990

parameter a0alu -0.411544  a1alu 0.75528  a3alu 0.287346
parameter a0oy  -0.894874  a1oy  1.08126  a2oy -0.0201282
parameter a0sem  1.33248  a1sem 0.350671  a3sem 0.315871
parameter a0gas  -0.52012  a1gas -0.126075  a2gas 0.394678 a3gas 0.652286
parameter a0dies -1.62792  a1dies -0.047078  a2dies 0.360402 a3dies 0.740177
parameter a0jet  -1.14347  a1jet -0.202995 a2jet 1.47296  a3jet -0.0520921
parameter a0fish  9.29987 a1fish -0.128181  a2fish 0.0242792 a3fish 0.82182
parameter a0ohou  0.803528 a1ohou -0.213571  a3ohou 0.969228
parameter a0oind 5.35394 a1oind 0.537861 a2oind -0.0631162
parameter a0hind 1.1954 a1hind 0.401026  a2hind -0.250315 a3hind 0.556545
parameter a0alm -1.30546 a1alm 0.207254  a2alm 0.831938
parameter a0dhind -18.3302 a1dhind 1.58716 a2dhind 1.46765
parameter a0dhhou 2.68347 a1dhhou -0.0727144 a2dhhou 0.0253011
parameter a3dhhou 1.10730


use 1990 2010

! Data til prislikninger. kr/kg oe

! tigas = skatter og toll
! tavggas = Marginer og distribusjonskostnader

read tigas tavggas
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4
34  10.4;
replace  tigas tavggas


! CO2 skatter i avgiftsalternativet
```

```
! *****************************************************************
! * Beregningen av co2 skattene bygger paa arbeidet som er utfort    *
! * av Birkelund, Aaserud og Gjelsvik dokumentert i Discussion Paper *
! * nr 81. SSB. Tabell 4.1 gir her en oversikt over karbon/energi-   *
! * skatter per toe i aar 2000 maalt i 1988 US$. For oljeprodukter er *
! * denne skatten 68 US$ per toe. Valutakursen mellom Islandske kroner*
! * og dollar var i 1988 iflg. Nordisk Statistisk AArbok 46,28 og    *
! * dette gir en kombinert karbon/energi skatt paa 3147 Islandske    *
! * 1988 kroner. Dette belopet er saa multiplisert med BNP deflatoren *
! * for aa faa belopet i 1990 kroner. 3147*1,28 = 4028,16 Islandske  *
! * 1990 kroner per toe. Siden vi maaler prisene i kr/kg. olje-      *
! * ekvivalent har vi delt dette beløpet med 1000. Dette gir en co2- *
! * avgift paa 4,02816 Islandske 1990 kroner per kg oljeekvivalent i *
! * aar 2000. Avgiften blir introdusert gradvis fra 1993 og saa      *
! * trappet opp fram til aar 2000. Etter aar 2000 er den holdt konstant*
! *****************************************************************


read tco2gas tco2fuel tco2jet tco2dies tco2heavy
    0       0       0       0        0
    0       0       0       0        0
    0       0       0       0        0
    1.208   1.208   1.208   1.208    1.208
    1.611   1.611   1.611   1.611    1.611
    2.014   2.014   2.014   2.014    2.014
    2.417   2.417   2.417   2.417    2.417
    2.819   2.819   2.819   2.819    2.819
    3.223   3.223   3.223   3.223    3.223
    3.625   3.625   3.625   3.625    3.625
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028
    4.028   4.028   4.028   4.028    4.028;
replace tco2gas  tco2fuel  tco2jet  tco2dies tco2heavy


parameter VATGAS 0.245
parameter VATDIES 0
parameter VATFHOU  0
parameter VATJET 0
parameter vatheavy 0


keep vatgas
keep vatdies
keep vatfhou
```

```
keep vatjet
keep vatheavy

! Kalibrering for å få CIF-bensinprisen til å stemme med data fra National
! Economic Institute


use 1990 1990

pgasoline = 54.64 -(tigas + tavggas)
print pgasoline


endpgas = (pgasoline +TIGAS + TAVGGAS )*(1+VATGAS)
lendpgas = ln(endpgas)
endpdies = (pdistillate )*(1+VATDIES)
lendpdies = ln(endpdies)
endpfuelh = (pfuelh )*(1+VATFHOU)
lendpfuelh = ln(endpfuelh)
endpjet = (pjet )*(1+VATJET)
lpjet = ln(endpjet)


use 1990 1990
! Kalibrering
parameter basalu = laluminium/(a0alu + a1alu*lyaluminium + a3alu*laluminium(-1))
parameter basoy =  lalloy/(a0oy  + a1oy*lyalloy       + a2oy*t)
parameter basement = lsement/(a0sem + a1sem*lysement     + a3sem*lsement(-1))
parameter basegas = lgasoline/( a0gas + a1gas*lendpgas  + a2gas*lgdp1990 &
+ a3gas*lgasoline(-1))
parameter basedies = ldieselcar/( a0dies + a1dies*lendpdies  + a2dies*lgdp1990 &
+ a3dies*ldieselcar(-1))
p basedies
parameter basetotav = ltotav/( a0jet + a1jet*lpjet + a2jet*ltransport + a3jet*t)
parameter basefish = ldieselfishing/(a0fish + a1fish*lendpdies + &
a2fish*lfisk + a3fish*ldieselfishing(-1))
parameter baseohou = ldieselhouse/(a0ohou + a1ohou*lendpfuelh+a3ohou*ldieselhouse(-1))
parameter baseoth = ldieselother/(a0oind + a1oind*lgdp1990 + a2oind*t)
parameter baseheavy = lheavyfuel/(a0hind + a1hind*lgdp1990 + &
a2hind*lpresidual + a3hind*lheavyfuel(-1))
parameter basealm = lalm/(a0alm + a1alm*lgdp1990 + a2alm*lalm(-1))
parameter baseinddh = lndh/(a0dhind + a1dhind*lgdp1990 + a2dhind*lndhacc)
parameter basehousdh = lndhha/(a0dhhou + a1dhhou*lnpdhd + a2dhhou*t + &
a3dhhou*lndhacc)


keep basalu basoy basement basegas basedies basetotav basefish
keep baseohou baseoth baseheavy basealm baseinddh basehousdh


! Forecast of exogenous variables
on dynamic
on revise
```

```
! Forecast of GDP

use 1991 1991
lgdp1990 = ln(1)+lgdp1990(-1)
use 1992 1992
lgdp1990 = ln(0.97)+lgdp1990(-1)
use 1993 1993
lgdp1990 = ln(1)+lgdp1990(-1)
use 1994 1994
lgdp1990 = ln(1.01)+lgdp1990(-1)
use 1995 1995
lgdp1990 = ln(1.01)+lgdp1990(-1)
use 1996 1996
lgdp1990 = ln(1.02)+lgdp1990(-1)
use 1997 1997
lgdp1990 = ln(1.019)+lgdp1990(-1)
use 1998 1998
lgdp1990 = ln(1.019)+lgdp1990(-1)
use 1999 1999
lgdp1990 = ln(1.019)+lgdp1990(-1)
use 2000 2000
lgdp1990 = ln(1.018)+lgdp1990(-1)
use 2001 2005
lgdp1990 = ln(1.02)+lgdp1990(-1)
use 2006 2010
lgdp1990 = ln(1.022)+lgdp1990(-1)

use 1991 1991
lfisk = ln(1.10) + lfisk(-1)
use 1992 1992
lfisk = ln(0.95) + lfisk(-1)
use 1993 1993
lfisk = ln(1.04) + lfisk(-1)
use 1994 1994
lfisk = ln(1.03) + lfisk(-1)
use 1995 1995
lfisk = ln(1.04) + lfisk(-1)
use 1996 1996
lfisk = ln(1.08) + lfisk(-1)
use 1997 1997
lfisk = ln(1.08) + lfisk(-1)
use 1998 2010
lfisk = ln(1) + lfisk(-1)

! Forecast of transport

use 1991 1991
ltransport = ln(1.01) + ltransport(-1)
use 1992 1992
ltransport = ln(1) + ltransport(-1)
use 1993 1993
ltransport = ln(0.99) + ltransport(-1)
use 1994 1994
ltransport = ln(1.03) + ltransport(-1)
use 1995 1995
```

```
ltransport = ln(1.03) + ltransport(-1)
use 1996 1996
ltransport = ln(1.03) + ltransport(-1)
use 1997 1997
ltransport = ln(1.03) + ltransport(-1)
use 1998 2010
ltransport = ln(1.01) + ltransport(-1)

use 1990 2010
z = exp(ltransport)
print z


use 1991 2000
pgasoline = 1.0214*pgasoline(-1)
pdistillate = 1.0214*pdistillate(-1)
pjet =    1.0214*pjet(-1)
presidual = 1.0214*presidual(-1)
pfuelh = 1.0214*pfuelh(-1)

use 2001 2010

pgasoline = 1.0184*pgasoline(-1)
pdistillate = 1.0184*pdistillate(-1)
pjet =    1.0184*pjet(-1)
presidual = 1.0184*presidual(-1)
pfuelh = 1.0184*pfuelh(-1)


! Forecast of exogenous variables

use 1991 2010

lysement     = ln(1)+lysement(-1)
lyalloy      = ln(1)+lyalloy(-1)
lyaluminium = ln(1)+lyaluminium(-1)
t          = 1.01*t(-1)
lndhacc = ln(1.0)+lndhacc(-1)
lnpdhd = ln(1.0)+ lnpdhd(-1)

off dynamic
off revise


use 1960 1990
print dhha dhoc pdhd


use 1990 2010


! *****************************************
! * Energiettersporselsmodell for Island    *
! *****************************************
```

```
equation eq1 laluminium = basalu*(a0alu + a1alu*lyaluminium + &
a3alu*laluminium(-1))
equation eq2 lalloy  = basoy*(a0oy  + a1oy*lyalloy       + a2oy*t)
equation eq3 lsement  = basement*(a0sem + a1sem*lysement + &
a3sem*lsement(-1))
equation eq4 aluminium  = exp(laluminium)
equation eq5  alloy      = exp(lalloy)
equation eq6 sement    = exp(lsement)
equation eq7 lgasoline  = basegas*(a0gas + a1gas*lendpgas  + a2gas*lgdp1990 &
+ a3gas*lgasoline(-1))
equation eq8 gasoline   = exp(lgasoline)
equation eq9 ldieselcar= basedies*(a0dies + a1dies*lendpdies  + a2dies*lgdp1990 &
+ a3dies*ldieselcar(-1))
equation eq10 dieselcar = exp(ldieselcar)
equation eq11 ltotav     = basetotav*(a0jet + a1jet*lpjet + &
a2jet*ltransport + a3jet*t)
equation eq12 totav      =  exp(ltotav)
equation eq13 ldieselfishing =  basefish*(a0fish + a1fish*lendpdies + &
a2fish*lfisk + a3fish*ldieselfishing)
equation eq14 dieselfishing = exp(ldieselfishing)
equation eq15 ldieselhouse = baseohou*(a0ohou + a1ohou*lendpfuelh + a3ohou*ldieselhouse(-1))
equation eq16 dieselhouse = exp(ldieselhouse)
equation eq17 ldieselother = baseoth*(a0oind + a1oind*lgdp1990 + a2oind*t)
equation eq18 dieselother = exp(ldieselother)
equation eq19 lheavyfuel = baseheavy*(a0hind + a1hind*lgdp1990 + &
a2hind*lpresidual + a3hind*lheavyfuel(-1))
equation eq20 heavyfuel = exp(lheavyfuel)
equation eq21 lalm = a0alm + a1alm*lgdp1990 + a2alm*lalm(-1)
equation eq22 alm = exp(lalm)
equation eq23 lndh = baseinddh*(a0dhind + a1dhind*lgdp1990 +a2dhind*lndhacc)
equation eq24 dhoc = exp(lndh)
equation eq25 lndhha = basehousdh*(a0dhhou + a1dhhou*lnpdhd + a2dhhou*t + &
a3dhhou*lndhacc)
equation eq26 dhha = exp(lndhha)


! ************************************
! * Pris likninger                  *
! ************************************


equation eq27  endpgas = (pgasoline + TIGAS + TAVGGAS )*(1+VATGAS)
equation eq28 lendpgas = ln(endpgas)
equation eq29 endpdies = (pdistillate )*(1+VATDIES)
equation eq30 lendpdies = ln(endpdies)
equation eq31 endpfuelh = (pfuelh )*(1+VATFHOU)
equation eq32 lendpfuelh = ln(endpfuelh)
equation eq33 endpjet = (pjet)*(1+VATJET)
equation eq34 lpjet = ln(endpjet)
equation eq35 endpresidual = (presidual)*(1+vatheavy)
equation eq36 lpresidual = ln(endpresidual)

group eqs eq*
```

```
group vars laluminium aluminium lalloy alloy lsement sement lgasoline &
gasoline ldieselcar dieselcar ltotav totav ldieselfishing dieselfishing &
ldieselhouse dieselhouse  ldieselother dieselother lheavyfuel heavyfuel &
lalm alm lndh dhoc endpgas lendpgas endpdies lendpdies lndhha dhha &
endpfuelh lendpfuelh endpjet lpjet endpresidual lpresidual

use 1990 2010

on group
build eqs vars zzz
superf mdl ^eqord
forecast(tag=fit)mdl
dot vars
compare   fit^: :
end

fit^oilcons = fit^gasoline + fit^dieselcar + fit^totav + fit^dieselfishing &
+ fit^dieselhouse + fit^dieselother + fit^heavyfuel

fit^elcons = fit^aluminium + fit^alloy + fit^sement + fit^alm

fit^dhcons = fit^dhoc + fit^dhha


print fit^oilcons fit^elcons fit^dhcons
print fit^gasoline fit^dieselcar fit^totav fit^dieselfishing
print fit^dieselhouse fit^dieselother fit^heavyfuel
print fit^aluminium fit^alloy fit^sement fit^alm
print fit^dhoc fit^dhha

gdp = exp(lgdp1990)
fisk = exp(lfisk)
print gdp fisk

use 1960 1990

oilcons = gasoline + dieselcar + totav + dieselfishing &
+ dieselhouse + dieselother + heavyfuel

elcons = aluminium + alloy + sement + alm

dhcons = dhoc + dhha

print oilcons elcons dhcons
```