EN21 Final Energy Consumption Intensity

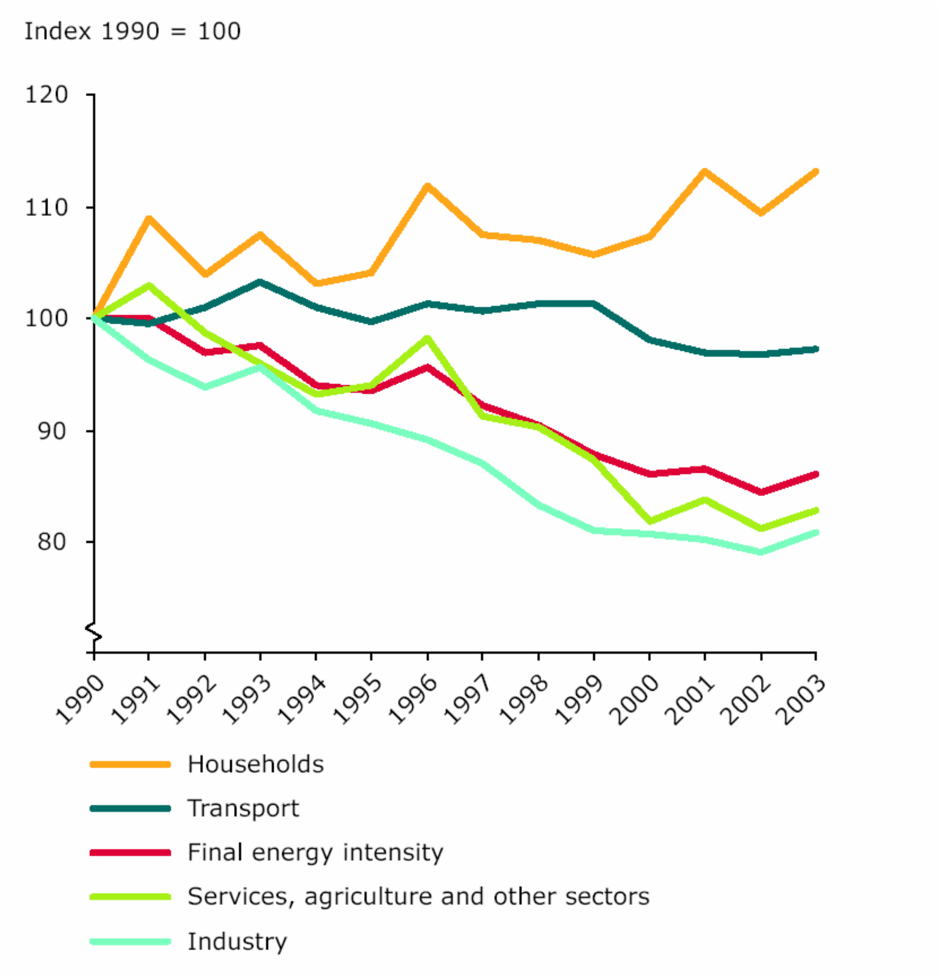
Key message

Economic growth has continued to require less additional final energy consumption within the EU-25 economy. However, this improvement was not sufficient to prevent total final energy consumption from rising. Decoupling was most successful in the industry sector as a result of technical improvements and structural changes, while private households consumed more energy per capita due to larger and more dwellings and more electrical appliances.

Rationale

Historically, economic growth has driven energy consumption in the end-use sectors of transport, industry and services, while household's final energy consumption is mainly influenced by population and the number of households. The indicator measures to what extent there is a decoupling between final energy consumption and these drivers, indicating one way of reducing the associated environmental pressures.

Fig. 1: Index of final energy intensity and energy intensity by sector, EU-25



Data Source: Eurostat, European Commission's Ameco database and National Technical University of Athens (Historic data), EEA (2005) for projection data.

Note: Final energy intensities between sectors, and also the total final energy intensity, are not comparable, because the normalising variables are not the same. The indicator serves to highlight the evolution in energy intensity within each sector. The denominators for the total, household, transport, industry (excl. construction) and services (incl. agriculture) sector energy intensities are, respectively; GDP, population, GDP, Gross Value added in industry (excl. construction), and Gross Value Added in Services (incl. agriculture). EEA baseline projections are consistent with European Commission (2004). The Low-Carbon-Energy Pathway (LCEP) scenario assumes that ambitious future greenhouse gas emission reduction targets will be reached and thus assumes a CO_2 permit price of EUR 30 per t CO_2 and EUR 65 per t CO_2 in 2020 and 2030, respectively.

1. Indicator assessment

Over the period 1990 to 2003 the total gross domestic product (GDP) of the EU-25 grew at an annual average rate of 2.0 % and final energy consumption by 0.8 %. This led to a decrease in final energy consumption intensity at an average annual rate of –1.2 %. However, this trend has appeared to slow in recent years and final energy intensity actually increased by 1.8 % from 2002 to 2003. Improvements in final energy intensity are, in general terms, influenced both by structural changes of the economy such as a shift from industry towards services and within industry to less energy-intensive industries, and improvements in the technical efficiency of appliances or processes or better insulation. Decomposition analysis suggests that in the EU-15, structural changes in economy contributed significantly to the decrease in overall energy intensity during the first part of the 1990s. This has dropped with energy efficiency becoming responsible for a higher share of intensity improvements. However, a slow-down in energy efficiency improvements from the late 1990s onwards has led to a similar slowing in the rate of decline of final energy intensity (Enerdata et al, 2003; ADEME, 2005).

The drivers and the pace of final energy intensity improvement are significantly different between the new Member States and the pre-2004 EU-15 (-3.7 % and -0.8 % on average per year, respectively, over the period 1990 to 2003). In the EU-15 during the early 1990s, a combination of low growth in GDP, continued low fossil fuel prices (see EN31) and a general low priority for energy saving in most Member States contributed to a slowing down of the reduction in final energy consumption intensity. During this period much of the reduction came from the aforementioned structural changes in the economy, particularly a shift towards services[1], with few proactive energy efficiency efforts (see EN17). Since then energy-efficiency improvements became more important in reducing final energy intensity (ADEME, 2005). Final energy consumption intensity differs widely across countries. In the new Member States it is still around 1.4 times higher than in the EU-15[2], although there is a converging trend. The main factors leading to improvements in energy intensity of the New Member States were structural changes of the national economies and a rise in energy prices.

Examining trends in final energy consumption intensity by sector for the EU-25 suggests that both the industry and services sectors have seen substantial improvements in their energy intensity over the past decade. The energy intensity of the household sector (final energy consumption of the household sector per capita) has actually worsened and the transport sector shows only a very limited decoupling of transport energy consumption from economic growth.

The energy intensity of the industry sector fell steadily between 1990 and 1999 but slowed down afterwards and eventually increased between 2002 and 2003. The average annual decrease over the period 1990-2003 was 1.6 %, although industry final energy consumption declined far more slowly. Hence this improvement was mainly due to a rise in value added within the sector during the 1990s and almost stagnation since then, coupled to relatively static final energy consumption. In the EU-15 the improvement has been induced by a wide range of factors reflecting structural changes in specific countries - shifts towards high value added, but less energy intensive industries, changes in energy intensive industries - and some general improvement in the use of energy. For example, production of goods such as electronic equipment requires less energy per unit of value added than more traditional products such as cars (IEA, 2004), and the production of primary metals needs 11 times more energy per unit of value added than the production of machinery or equipment (ADEME, 2005). The analysis of energy intensity is complex and the decrease in energy intensity can only partly be explained by structural changes. It is also the result of improvements in energy efficiency, influenced by technological innovation. Recently published results indicate that most manufacturing industries (except textiles) experienced increasing energy efficiency between 1990 and 2002 in the EU-15, influenced by improved production processes and innovative technologies (ADEME, 2005). In the new Member States the economic restructuring of the early 1990s led to a substantial initial decline in both the energy consumption and output of heavy industry. Since 1995, industrial production has started to recover, while energy consumption continues in a downward trend, with the overall result that final energy has declined much more rapidly than in the EU-15. The largest shift to less energy intensive branches of industries between 1996 and 2001 was observed in Hungary and Slovakia (Lapillonne 2004).

The service sector has a relatively low level of final energy consumption intensity. Energy intensity declined by 1.4 % per year on average, largely due to a significant improvement between 1996 and 2000, although there was some fluctuation in energy intensity over this period. This was due to the value added of the sector growing at a faster average annual rate than final energy consumption, 2.3 % compared with 0.9 % respectively. The rate of reduction in intensity was over three times faster for the new Member States than for the EU-15, although the overall EU-25 trend is dominated by the EU-15. A wide range of drivers impact on services final energy intensity, although the impact of each is difficult to quantify. These include: improvements in energy efficiency, counteracted by an increased use of information and communication technology in offices; change in the average office or floor space per unit of added value, and changes in climatic conditions, but improvements in insulation. In addition, much of the energy consumption in the service sector is not directly related to the level of economic output as a large proportion is 'information based', in contrast to a physical increase in the output of cement, cars etc. It is rather dependent on the physical size of the sector (number of people employed, floor area of buildings) and can be considered as a

[1] Creating one unit of GDP in the services sector requires around 1/8 of the energy that would be needed to create one unit of GDP in the manufacturing sector (EU-15 average);

[2] GDP calculated in Power Purchasing Standards (PPS) to equalise the purchasing power of different currencies; around 3 times higher with GDP expressed in constant prices.

fixed cost for much of the sector (which does not imply that there is no important reduction potential in e.g. reducing energy for space heating or electrical appliances). However, the sector's economic output is sensitive to economic growth cycles (following the overall economy's pattern of investment and divestment/disinvestment) and consumer spending. Fluctuations in energy intensity may therefore reflect the cyclical nature of the economy, and also year-on-year fluctuations in climatic conditions which can contribute significantly to energy intensity trends as they affect building requirements for space heating.

The final energy consumption intensity of the household sector increased slightly over the period 1990-2003 (by 1.0 % on average per year), with average annual population growth of 0.3 % and final household energy consumption growing by 1.3 % per annum. However, the household sector's energy intensity is linked closely with climatic conditions, as the major part of the energy is used for space heating[3]. Hence the rate of change in energy intensity varies greatly year on year due to fluctuations in final energy consumption (see EN16). Household energy consumption actually grew by 3.8 % from 2002 to 2003 (leading to a 3.4 % rise in energy intensity over the same period) due largely to a colder winter than the previous year. In general, the lack of improvement in energy intensity is due to increasing living standards and lifestyle changes, leading to larger numbers of households, lower occupancy levels (more square metres of living space per person) and increased use of household appliances (air conditioning, refrigerators, freezers, TVs, etc.) as well as the rise of new small appliances. These have outweighed the improvements in the efficiency of large electrical appliances such as refrigerators, TVs etc, which were supported by the introduction of energy efficiency labels and standards (IEA, 2005). Building energy efficiency standards have also been tightened in recent years but because the rate of turnover in the housing stock is slow the effect of these improvements will be seen over the longer term. New policies such as the EU Directive (2002/91/EC) on the energy performance of buildings and the Directive (2005/32/EC) on the eco-design of products may go some way to improving the overall level of efficiency.

Decoupling of transport energy consumption from economic growth has almost not occurred – the average annual decrease in energy intensity remained small at -0.2 % annually. This was due to the rapid growth in road transport, which led to a rapid increase in energy consumption despite some improvements in fuel efficiencies of cars. Transport growth was influenced by various developments. In many regions growing settlement and urban sprawl resulted in longer distances, infrastructure improvements made transport cheaper and faster, and rising disposable incomes changed many people's lifestyle with more demands for travelling and private cars. Furthermore, the development of the internal market has resulted in increased freight transport as companies exploit the production cost advantages of different regions.

Transport consumed just under a third of final energy consumption in 2003 (see EN16) and is predicted to keep growing to 2010, at an average annual rate of about 1.5 %, according to baseline projections (EEA, 2005). Nevertheless, projections predict important future reductions of transport energy intensity (between 0.9 % and 1.7 % p.a. in 2010 and 2030, respectively), largely due to reductions in fuel consumption by new cars and trucks as a result of the voluntary commitment of the European, Japanese and Korean car manufacturers on improved specific fuel efficiency of new passenger cars (see European Commission, 2005 for progress achieved so far). Industrial energy intensity is expected to continue falling with the improvement driven by structural changes towards less energy intensive manufacturing processes but also by the exploitation of energy saving options (European Commission, 2004). In the services sector final energy intensity is expected to improve considerably over the next three decades, although energy consumption is expected to grow due to the increasing use of information and communication technology. Trends in this sector are important in view of the growing significance of services in terms of value added to the economy. The services sector is projected to increase its productivity through specialisation towards higher value added products, and also reduce intensity via changes in the fuel mix and the adoption of improved technologies, as well as some energy uses approaching saturation. The potential for future improvement in the household sector remains substantial, but nevertheless, baseline projections for the EU-25 suggest that the growth rate of energy intensity in the household sector will rise, although the rate of increase will decline out to 2030. Energy demand for heating purposes is expected to increase slowly, whereas the need for energy for electric appliances and air conditioning is predicted to grow considerably faster over the next 30 years (European Commission, 2004). Construction techniques and equipment for more energy efficient buildings have evolved rapidly in recent years, but take considerable time to penetrate throughout the building stock.

Overall projections to 2030 for the EU-25 suggest that energy use per person is increasing. This is linked to increasing wealth (GDP per capita). However, the rate of energy consumption increase is expected to be slower than the rate of GDP increase, leading to an overall decrease in final energy intensity out to 2030, with the rate of decrease accelerating in subsequent years. Nevertheless, further actions are needed to improve awareness about energy efficiency and stimulate the uptake of energy efficient technologies if the EU is to make substantial improvements in energy intensity over the longer term. Following

[3] The share of energy used for space heating varies with the outside temperature between years and countries. ADEME (2005) estimates it as being around 70 % in the EU-15.

significant improvements in energy intensity during the past decade, driven by economic restructuring, the energy intensities of the new Member States are projected to improve at rates well above the EU-25 average up to 2030. However, the average energy intensity of these countries is still expected to be significantly worse than the EU-15 even in 2030 (by around a factor of two). A scenario that assumes the introduction of a carbon permit price suggests the energy intensity of the household increasing at a slower rate than the baseline, and the overall final energy intensity, and all other sector intensities decreasing more rapidly (EEA, 2005, LCEP scenario). The most important relative reductions in the final energy intensity in households indicate that this sector has a large potential for further efficiency measures.

2. Indicator rationale

2.1 Environmental context

Energy production and use is a source of many environmental pressures, including emissions of greenhouse gases (see EN01 and EN02), ozone precursors (see EN05) acidifying substances (see EN06) and particulate emissions (see EN07), the build up of solid wastes (see EN13) and discharges to the aquatic environment (see EN14). One way of reducing energy-related pressures on the environment is to use less energy. This may result from reducing the demand for energy-related activities (e.g. for warmth, passenger or freight transport), or by using energy in a more efficient way (thereby using less energy per unit of demand), or a combination of the two.

The level of consumption has historically been driven by economic growth, the value added of different economic sectors and population. This indicator identifies the extent, if any, of any decoupling between final energy consumption and these drivers in the main economic sectors. The differentiation between sectors allows a more detailed analysis of the effect of structural changes (e.g. the shift away from energy intensive industry) within these sectors and to identify those with a particular need for further action.

Relative decoupling occurs when energy consumption grows, but more slowly than the underlying driver. Absolute decoupling occurs when energy consumption is stable or falls while the driver grows. From an environmental point of view, however, overall impacts depend on the total amount of energy consumption and the fuels used to produce the energy.

2.2 Policy context

The indicator shows how the energy intensity of the EU and its various economic sectors has evolved and assesses progress in decoupling economic growth from energy consumption. Changes in final energy consumption intensity can result from deliberate measures to improve energy efficiency or from indirect structural, socio-economic, climatic and technological factors that influence energy demand.

For the EU-15, the European Commission proposed, and the Council supported, an EU indicative target of reducing final energy intensity by 1 % per year, above ‘that which would have otherwise been attained’ during the period 1998-2010 (see Energy Efficiency in the European Community – Towards a Strategy for the Rational Use of Energy, COM(98) 246 final and Council Resolution 98/C 394/01 on energy efficiency in the European Community). This target is considered to assist the EU in meeting the Kyoto commitments for the reduction of greenhouse gas emissions under the United Nations Framework Convention on Climate Change (UNFCCC).

There are a number of important community policies that have been devoted to improving energy efficiency, or that will lead to significant improvements in the energy intensity of end-use sectors. For example, the recently agreed Directive 2006/32/EC on energy end-use efficiency and energy services aims at boosting the cost-effective and efficient use of energy in the Union. It sets an overall national indicative energy savings target of 9 % to be adopted and aimed to be achieved by Member States nine years after implementation of the directive.

Other specific policies include Directive 2005/32/EC on the eco-design of Energy-using Products, such as electrical and electronic devices or heating equipment and will help to improve end-use efficiency across all sectors using these products. The Directive establishing a scheme for greenhouse gas emission allowance trading within the Community (2003/87/EC), which is intended to contribute to the European Union fulfilling its commitments under the Kyoto Protocol, is also likely to contribute to reduced energy intensity. With the aim of limiting CO_2 emissions from large industrial sources, the Directive establishes a cap-and-trade system covering combustion installations over 20 MW, as well as specific industrial processes (oil refining, cement production, iron and steel manufacture, glass and ceramics, and paper and pulp production). In addition to encouraging improved generation efficiency and fuel switching in the energy production sector, it will also encourage improved end-use energy efficiency within the industrial sector (as many companies both produce and consume their own heat and power) and cleaner processes in the other sectors directly covered. In the transport sector, a voluntary commitment of the European, Japanese and Korean car manufacturers aims at reducing the fuel efficiency of new passenger cars to 140g CO_2/km in 2008 for the European and 2009 for the Japanese and Korean manufacturers (European Commission, 2005).

The EU's Sixth Environment Action Plan (COM(2001)31 final) calls for a decoupling of economic growth and the demand for transport with the aim of reducing environmental impacts, and the EU's recent Green Paper on energy efficiency (COM(2005)265 final) also aims to expand the debate, particularly on the demand side, of energy policy. Primarily in relation to the three key areas of economic competitiveness, environmental protection (including the EU's Kyoto obligations) and energy security – and hence aims to lead to improved efficiency and reduced energy intensity.

References

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Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC

Directive 2005/32/EC (amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC) on the eco-design of Energy-using Products

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Meta data

<u>Technical information</u>

1. Data source:
   Total final energy consumption and final energy consumption by sector, Gross domestic product, Gross Value Added for Industry: Eurostat (historical data)
   http://europa.eu.int/comm/eurostat/
   GDP growth rates used for the estimation of missing GDP data from Eurostat: European Commission Ameco database.
   Gross Value Added (GVA) for Service Agriculture and Other sector – National Technical University of Athens (NTUA) as used for projections in EEA (2005) and European Commission (2003 and 2004).
   Projection data: European Environment Agency (2005) – baseline projections are consistent with European Commission (2004)

2. Description of data / Indicator definition:
   Final energy consumption covers energy supplied to the final consumer for all energy uses. It is calculated as the sum of final energy consumption of all sectors. These are disaggregated to cover industry, transport, households, services and agriculture.
   Total final energy intensity is defined as total final energy consumption (consumption of transformed energy such as electricity, publicly supplied heat, refined oil products, coke, etc, and the direct use of primary fuels such as gas or renewables, e.g. solar heat or biomass)

divided by gross domestic product (GDP) at constant (1995) prices. The GDP figures are taken at constant prices to avoid the impact of inflation, base year 1995 (ESA95). Comparisons of intensity in specific years are however made using GDP in purchasing power standards.

- Household energy intensity is defined as household final energy consumption divided by population.
- Transport energy intensity is defined as transport final energy consumption divided by GDP at constant (1995) prices.
- Industry energy intensity is defined as industry final energy consumption divided by industry Gross Value Added at constant (1995) prices. This excludes final energy consumption and gross value added from construction.
- Services energy intensity is defined as services final energy consumption divided by services Gross Value Added at constant (1995) prices. Services includes agriculture and other sectors, and this is aggregation is consistent with that used in the projections.

Units:
Final energy consumption is measured in 1000 tonnes of oil equivalent (ktoe) and GDP in million Euro at 1995 market prices. Energy intensity is measured in tonnes of oil equivalent per million Euro (GDP or GVA), except in the case of household energy intensity which is measured in tonnes of oil equivalent per 1000 people.
The PRIMES model was used by the EEA to analyse possible future developments of the European energy sector, including a baseline scenario without a permit price and the low carbon energy pathway (LCEP) scenario. It describes the least-cost response of the EU-25 energy system to the introduction of a carbon permit price that rises to EUR 65/t CO_2-equivalent by 2030.

3. Geographical coverage:
The Agency had 31 member countries at the time of writing of this fact sheet. These are the 25 European Union Member States and Bulgaria, Romania and Turkey, plus Iceland, Norway and Liechtenstein. On 1 April 2006, Switzerland joined the EEA, bringing its number of member countries to 32.
No energy data available for Switzerland and Liechtenstein. No projection data are available for Iceland, Liechtenstein.

4. Temporal coverage:1990-2003, projections to 2030 in 5 year intervals.

5. Methodology and frequency of data collection:
Data collected annually.
Eurostat definitions for energy statistics http://forum.europa.eu.int/irc/dsis/coded/info/data/coded/en/Theme9.htm
Eurostat metadata for energy statistics http://europa.eu.int/estatref/info/sdds/en/sirene/energy_base.htm

6. Methodology of data manipulation:
The coding (used in the Eurostat New Cronos database) and specific components of the indicators are:
   - Total final energy intensity: final energy consumption 101700 divided by GDP - Constant (1995) prices.
   - Household energy intensity: Final energy consumption households 102010 divided by PJAN Population by sex and age on 1. January of each year.
   - Transport energy intensity: Final energy consumption transport 101900 divided by B1GM GDP and main components - Constant (1995) prices.
   - Industry energy intensity: (Final energy consumption industry 101800) minus (Final energy consumption – other non-classified industries – 'Construction' – 101850) divided by (nace c_d_e Total industry GVA - excluding construction).
   - Services, agriculture and other energy intensity: (Final energy consumption Households/Services/Agriculture and Others 102000) minus (Final energy consumption households 102010) divided by (Services, agriculture and other sectors GVA provided by NTUA).

It should be noted that value added in industry during 1990-94 was not available from Eurostat. Estimates for that period are based on data from the National Technical University of Athens (as used for projections in EEA (2005) and European Commission (2004)) using gross value added in 1995 from Eurostat as the reference value.
Average annual rate of growth calculated using: [(last year / base year) ^ (1 / number of years) –1]*100
Data on GDP in New Cronos is expressed in market 1995 prices. The projection data also expresses GDP in constant prices, but this time at 2000 levels. The projected GDP data has therefore been converted from 2000 constant prices (GDP2000) to 1995 constant prices for year x using:

$$GDP1995\ (x) = [GDP_{current\ prices}(1995)/GDP_{2000}\ (1995)] * GDP_{2000}\ (X)$$

Some estimates have been necessary in order to compute the EU-25 GDP index in 1990. For some EU-25 member states Eurostat data was not available for a particular year. The European Commission's annual macroeconomic database (Ameco) was therefore used as an additional data source. GDP for the missing year is estimated on the basis of the annual growth rate from Ameco, the rate which is applied to the latest available GDP from Eurostat. This method was used for the Czech Republic (1990-94), Hungary (1990), Poland (1990-94), Malta (1991-1998) and for Germany (1990). For some other countries and particular years, however, GDP was not available from Eurostat or from Ameco. With the purpose of estimating the EU-25, a number of assumptions were made. For Estonia, GDP in 1990-92 is assumed constant and takes the value observed in 1993. For Slovakia, GDP in 1990-91 takes the value of 1992. For Malta, GDP in 1990 is assumed to be equal to GDP in 1991. These assumptions do not distort the trend observed for the EU-25's GDP, since the latter three countries represent about 0.3-0.4 % of the EU-25's GDP.

Qualitative information

7. Strength and weaknesses (at data level)
Data gap procedure needed, as highlighted in section 6.
Data have been traditionally compiled by Eurostat through the annual Joint Questionnaires, shared by Eurostat and the International

Energy Agency, following a well established and harmonised methodology. Methodological information on the annual Joint Questionnaires and data compilation can be found in Eurostat's web page for metadata on energy statistics.
http://europa.eu.int/estatref/info/sdds/en/sirene/energy_sm1.htm
Gross domestic product (GDP) is the central aggregate of National Accounts. Some estimates have been necessary using the procedure described in 6. Methodological information related to GDP can be found at http://europa.eu.int/estatref/info/sdds/en/aggs/aggs_base.htm
Gross Value Added data from the NTUA has been used for the Services, agriculture and other sectors as well as to gap-fill for the industry sector prior to 1995 to ensure completeness (due to gaps in Eurostat data) and also to ensure consistency with the projection data.

8. Reliability, accuracy, robustness, uncertainty (at data level):
Indicator uncertainty (historic data)
The sectoral breakdown of final energy consumption includes industry, transport, households, services, agriculture, fisheries and other sectors. To be consistent with projection data, the indicator aggregates agriculture, fisheries and other sectors together with the services sector. The inclusion of agriculture and fisheries together with the services sector is however questionable given their divergent trends. Because the main focus of the indicator is on trends, energy intensity is presented as an index. It should be noted that the final energy intensities between sectors, and also the total final energy intensity, are not directly comparable, because as described above, the definitions of energy intensity within each sector not identical. The indicator serves to highlight the evolution in energy intensity within each sector.
Scenario analysis always includes many uncertainties and the results should thus be interpreted with care.
   - uncertainties related to future socioeconomic developments (e.g. GDP) and human choices;
   - uncertainties in the underlying statistical and empirical data (e.g. on future technology costs and performance);
   - uncertainties in the choice of indicators (representativeness);
   - uncertainties in the dynamic behaviour of systems and its translation into models;
   - uncertainties in future fuel costs and the impact on low carbon technologies.

The LCEP scenario uses relatively optimistic assumptions on economic growth, compared with other scenarios. The same level of carbon prices as in the LCEP scenario would lead to higher CO_2 emission reduction when simulated with other models (e.g. TIMER), which may partly result from the fact, that carbon capture and storage was not included in the PRIMES LCEP scenario.

9. Overall scoring – historic data (1 = no major problems, 3 = major reservations):
   Relevance: 1
   Accuracy: 1
   Comparability over time: 2
   Comparability over space: 2