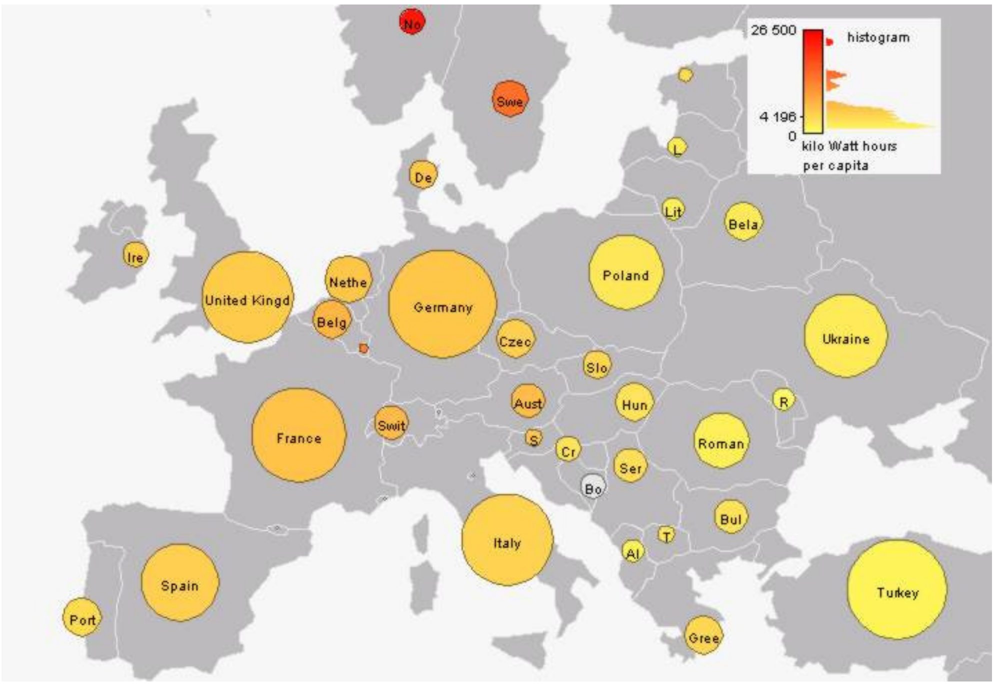

Energy Demands of European Buildings:

A Mapping of Available Data, Indicators and Models

Thesis for the Degree of Master of Science in Industrial Ecology

Eoin Ó Broin

Department of Energy and Environment
Division of Energy Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
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Eoin Ó Broin

Technical report no T2007-307
Department of Energy and Environment
Division of Energy Technology
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

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Abstract

This report has sought to undertake an investigation into data, indicators and models available for describing energy demand in Europe's buildings. The work has been carried out as part requirement of Work Package 4, Best Available Technology assessment (WP4), of the Pathways to a Sustainable European Energy System Project.

The first part of the report reviews pan-European sources of data on construction characteristics, energy end uses, installed energy-using apparatus, building envelope characteristics and energy carrier mixes for the European building stock.

The second part of the report investigates various approaches to the use of indicators for analysing and explaining the causes of energy use in the European building stock.

The third part of the report uses information from the first two parts of the report to undertake an analysis of energy use in Residential and Services Sector buildings of the EU 25 from 1990 to 2004.

The fourth and final part of the report discusses options available for forecasting energy use in the European building stock over the coming decades based on the expected improvements in energy and building construction technologies, and the influence of other non – technical factors.

Findings from the review of pan-European sources of data were aggregated for the entire building stock of each country, and also per dwelling type in the Residential Sector and per branch type in the Service Sector. These aggregations were subdivided into two data categories, focusing on either building design characteristics and energy end-use data or on energy-using apparatus installed, building thermal transmittance characteristics and energy carrier mix. The former category is considered to provide data for a top-down statistical analysis of building energy use, while the latter is useful in providing an itinerary of energy carriers and energy-using apparatus that can be substituted in efforts to reduce energy consumption and greenhouse gas emissions.

For the residential sector, it was possible to acquire sufficient data to undertake a time series or single-year analysis of trends in building energy use for five EU countries on a per-dwelling type, and for ten countries at an aggregated sectoral level. There was insufficient data available for undertaking a technology and energy carrier substitution exercise for any country.

For the service sector, it was possible to acquire sufficient data to undertake a single-year analysis of buildings energy use for five EU countries at a branch level, and for eleven countries at an aggregated sectoral level. For a technology and energy carrier substitution exercise, data was found to be available for three EU countries on a branch level and for four countries at an aggregated sectoral level.

There was insufficient data to describe any non–EU countries to the level desired.

Two exercises were performed to estimate missing data: one for heating systems installed in buildings, and another to estimate typical dwellings which represent the design characteristics of the stock as a whole.

The usefulness of indicators for the purposes of explaining why energy use is changing was explored and a set of indicators that could be used to display the various reasons why energy use is changing was proposed.

The analysis of energy use in buildings from 1990 to 2004 showed space heating and the fast-rising consumption of energy for water heating and electrical appliances to be significant for the residential sector. For the service sector, the large increases in electricity consumption over the same time period were highlighted. The analysis also attempted to highlight the influence of non-technical parameters such as population and economic growth on energy consumption in both the residential and service sectors.

The final chapter proposed a step-by-step approach to an analysis and forecasting exercise of future energy use in Europe's buildings that could be undertaken using data, indicators and models.

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First of all, I would like to thank my supervisor, Professor Filip Johnsson, for giving me the opportunity to carry out this work and for his advice, direction and support throughout.

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Units and abbreviations

Units

kWh	kilowatt-hour
GWh	gigawatt-hour
TWh	terawatt-hour
koe	kilo of oil equivalent
toe	tonne of oil equivalent
ktoe	kilo tonnes of oil equivalent
Mtoe	million tonnes of oil equivalent
kJ	Kilojoule (10^3 joule)
MJ	Megajoule (10^6 joule)
GJ	Gigajoule (10^9 joule)
TJ	Terajoule (10^{12} joule)
PJ	Petajoule (10^{15} joule)
EJ	Exajoule (10^{18} joule)
m^2	Square metre
Mm^2	Millions of square metres

Abbreviations

AGS	Alliance for Global Sustainability
BAT	Best available technology
BRE	Building Research Establishment, UK.
CFL	Compact fluorescent lamp
GH	Group heating
DC	District cooling
DG TREN	EU Directorate General for Transport and Energy
DH	District heating
DIW	Deutsche Institut für Wirtschaftsforschung
ECE	UN Economic Commission for Europe
ECH	Eurostat Energy Consumption in Households Study
ECSS	Eurostat Energy Consumption in the Service Sector Study
EEA	European Environmental Agency
EE&ESD	EU Energy Efficiency & Energy Service Directive, 2006/32/EC
EMEEES	IEE-funded project on the Evaluation and Monitoring for the EE&ESD
Energy C	Energy Charter Peerea Country Reports
Enper E	Enper Exist Project
Enper T	Enper Tubec Project
ENR Club	European Energy Network
EPA – ED	Energy Performance Assessment, Existing Dwellings Project
EPA – NR	Energy Performance Assessment, Non Residential Project
EPBD	EU Environmental Performance of Buildings Directive, 2002/91/EC
EU	European Union
EU 15	EU countries pre-2004
EU 25	EU countries post-2004
EU 27	EU countries post-2007
GDP	Gross domestic product
HR MFD	High-rise multi-family dwelling
HSEU	Housing Statistics of the European Union Report

HVAC	Heating, ventilation and air conditioning
IEA 30	Publication to mark IEA's 30th anniversary of foundation.
IEA EB	IEA Energy Balances
IEE	EU Intelligent Energy Europe branch of DG Tren
IEEA	EU Intelligent Energy Europe Agency (Same as IEE)
IEE SAVE	Portfolio of IEE funded projects focusing on energy efficiency
IIASA	International Institute for Applied Systems Analysis
IKARUS	Instrumente für Klimagasreduktionsstrategien Project
ICH	Individual central heating
ID	Index decomposition
LBNL	Lawrence Berkley National Laboratory
LMDI	Log Mean Divisia Index Decomposition
LR MFD	Low-rise multi-family dwelling
MFD	Multi-family dwelling
MURE	Measures for Rational Use of Energy Simulation Tool and Policy Database.
NA	Not available
NMC	New Member Countries of the EU
NACE	Statistical Classification of Economic Activities in the EU
OECD	Organisation for Economic Cooperation and Development
ODEX	Odyssee Energy Efficiency Index
PEEREA	Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects
RH	Room heating
SFD	Single-family dwelling
U-value	Thermal transmittance value
UNECE	United Nations Economic Committee for Europe
VAC	Ventilation and air conditioning
VLEEM	Very Long-Term Energy Environment Model
WP	Work package

Introduction

Energy is in the news in 2007. Concerns about climate change, security of energy supply and rising fuel and electricity prices have all ensured that the energy input needed for modern industrial society to function cannot be taken for granted. By convention, this energy input can be divided into that used for industry, for transport and for buildings*. Of these three sectors, buildings are the most heterogeneous. Although, in terms of their energy use patterns, industrial processes and transport are not significantly affected by weather, buildings are strongly affected because of their seasonal cooling and heating needs. Furthermore, the diverse habits, norms and income levels of building users add to this heterogeneity.

This report seeks to analyse energy use in Europe's buildings as part of Work Package 4 (WP4), of the Pathways to a Sustainable European Energy System Project (Johnsson & Rydén, 2006). Given the aforementioned heterogeneity, mapping, monitoring and addressing this energy usage is a tedious and detailed task. In order, however, to take advantage of the many opportunities to reduce energy use in buildings, so as to help combat climate change and reduce fossil fuel consumption, an attempt must be made at such an analysis.

Traditionally efforts to analyse energy use in buildings have been organised in a top-down manner by taking total amounts of fuels and electricity sold for use in buildings as an aggregated figure that reflected trends in energy demand in buildings. A more detailed breakdown, that could tell whether electricity sold had been used for lighting or for appliances, or how much of fuel sold had been used for space heating, would have involved expensive consumer surveying. Depending on their energy policy, such surveying may or may not have occurred in OECD countries.

Historically state energy policy has traditionally focused on ensuring the supply of energy, with demand being seen as little more than an addendum. One can speculate as to the reasons for this although, the assumption that a cheap and plentiful supply of energy was needed as a prerequisite for a strong growth economy would be important. A lack of detail regarding the various end uses and consumption patterns of energy means, however, that energy demand forecast modelling is limited in its accuracy, and thus energy policy formulation may be misguided. The Energy Efficiency Action Plan of the EU, for example, launched in 2006 as part of the implementation of the Energy Efficiency & Energy Service Directive (2006/32/EC), used the Primes (E3M Lab, Athens) demand model to quantify savings potentials (EU, 2006b). The Primes tool models demand in buildings in an aggregated way. Furthermore, it is well established that data for energy end use in buildings for most Eastern European countries is almost non-existent. Thus, at best, the savings potentials calculated for the EU plan is a guess.

Another demand forecasting model, MURE (MURE), has been used by the EU Directorate-General for Energy and Transport (DGTREN), to help establish the potential savings that could accrue from the EU Environmental Performance of Buildings Directive (EPBD). Although MURE is a very detailed model with regard to the types of energy end use and building characteristics that it seeks to use to model, it also suffers from the same lack of data availability. In the case of the EPBD, MURE was used only to calculate potentials for the EU 15, for which about ten countries, all of which are in Western Europe and members of the OECD, have an established energy end-use data collection system in place. Thus, if it is at all

* Agriculture and Fisheries are not included here given their comparative low energy us in Europe. Other primary sector activities such as mining and forestry are included with Industry.

possible, we wish to go at least as far as Primes and MURE-type forecasts allow for as many European countries as possible. An improvement would require more detailed energy end-use data and more sophisticated modelling tools.

The Pathways to a Sustainable European Energy System project is a five-year project with the overall aim of evaluating and suggesting robust pathways towards a sustainable energy system, with respect to environmental, technical, economic and social issues. The focus is on the non-transport energy system (power and heat) in the European setting. Evaluations will be based on a detailed description of the present energy system and will focus on how it can be developed in the future under a range of environmental, economic and infrastructural constraints. The project is part of an international cooperation, the Alliance for Global Sustainability (AGS), in which companies such as Ford, Du Pont and Vattenfall are involved in research collaborations together with MIT (Massachusetts Institute of Technology), ETH (Swiss Federal Institute of Technology, Zurich), Tokyo University and Chalmers University of Technology, Göteborg.

In order to address the research questions in an efficient way, the project is structured into ten work packages, addressing topics such as a description of the energy infrastructure, energy systems modelling, technology assessment of best available and future technologies, and international fuel markets. WP4 seeks to undertake a technology assessment of Best Available Technology on the demand side i.e. in the building and industrial sectors. The idea is to use the technology assessment to determine what demand scenarios in these sectors are likely to occur over the coming decades, and to match these demands to the design of the supply system that will be put in place. In keeping with the project methodology, the precursor to such a technology assessment is to characterise the existing building stock and set of industrial processes for the continent. For building stock, this means depicting building design, internal energy uses, energy using apparatus and energy carrier mixes. This data can then be used in conjunction with a data set of known best technologies to model various demand-side scenarios.

To get an idea of what kind of data is needed for building stock characterisation; we can take an energy data "wish-list" from 1977 which appeared in a UK Department of Energy Publication on Energy Elasticities (DOE, UK, 1977). The "wish list" consisted of:

- The quarterly consumption of each energy carrier.
- The quarterly expenditure on each energy carrier, and the nature of the tariff.
- The composition of the household and an indication of the time spent at home by it.
- The income of the household.
- A description of the household's stock of energy-using appliances.
- Recent purchases of appliances.
- The type of dwelling and degree of insulation.
- Recent purchases of insulation.
- Climatic variables of the household's locality.
- Ease of access to particular energy carriers.

This list seems ambitious for its time. It is still very valid today. It would now, however, be complemented by data for space heating, domestic hot water heating and cooking heating for each dwelling. One can speculate, however, that the authors were aware of the unlikelihood of obtaining such end–use data, and as such, sought to estimate thermal use of energy through a combination of energy carriers sold, domestic use patterns and climatic conditions. For many countries, such expert estimation is still the only source of end–use data, and is still common practise 30 years later. Although the working area of demand-side energy use monitoring is and has been developing since the first oil shock in 1973, this brief introduction to the issues gives an indication of the constraint that data availability has put on the level of analysis that can be undertaken.

This report begins by attempting to review what data relating to buildings exists for European countries (Chapter 1). Data sources analysed all have an EU or continent-wide focus: no national sources have been investigated. Time series data is preferred to 'snapshot' measurements. Following on from this data assessment, the report discusses the use of indicators to describe how and why energy is being used in various countries and across countries (Chapter 2). Raw data and indicators are then used to undertake a top down analysis of energy use in EU 25 buildings (Chapter 3). A methodology for tackling the pre-technology assessment phase of Work Package 4 of the Pathways Project is then proposed (Chapter 4). Finally, a number of appendices are included to cover certain topics in detail.

A number of international studies have been found that parallel somewhat the aims of this report, and will be referred to throughout the text where relevant. They are:

- The **Odyssee Indicators Project**, which has been compiling an energy end use database for all sectors for EU countries since 1980 (Odyssee Network, 2007).
- The **IEA Review of 30 Years of Energy Use** publication, which attempts to describe why energy end use has changed as it has in long-standing OECD countries (IEA, 2003).
- The **IPCC SRES**, which models global energy demand scenarios over the next three decades (IPCC, 2007).
- The recently established **LBNL Global Energy Database**, which seeks to build an energy end use database for all sectors for ten key regions throughout the world (LBNL, 2005).

Two further studies which may have some similarities, but which have not yet been investigated are:

- The **IIASA-endorsed Global Energy Assessment**, which seeks to provide a comprehensive solution based platform for global energy concerns (IIASA; 2005).
- The **VLEEM project** which, as its name indicates, seeks to model the global very-long-term energy environment (Enerdata, 2002).

In particular, an attempt will be made throughout Chapter 1 to establish the adequacy of the Odyssee database and assess the usability of its time-series data for the purposes of this project. This is due to the Odyssee being a dedicated energy end–use database.

As references are very topic-specific, they have been listed at the end of each chapter. It is also intended that the four chapters should be stand-alone modules that are, for the most part, independently coherent of the other chapters.

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1. Data

This chapter describes the type of raw data that is typically needed to begin an analysis of energy use in residential and service sector buildings across Europe. Its emphasis is on finding data that accounts for the variety of types of building and uses of energy that occur in these two sectors. The approach is based upon the energy indicators work pioneered by the following organisations; International Energy Studies Group of LBNL, the Fraunhofer institute, the IEA and the Odyssee Indicator Project (IEA, 1997). The information presented draws upon knowledge gained from a number of internationally focused databases and reports, which are wholly or partly dedicated to analysing building energy use in Europe. It may help the reader to look at these databases and reports in tandem with reading this chapter for a greater understanding of data availability. They are listed in Table 1.8.

Göransson (2006), carried out a first report to find sources of building energy use data which are currently available for Europe, and the categories of data that each source contained. Göransson's work describes the relevance of each source he found for the residential, service and industrial sectors. This chapter takes the work of Göransson as a point of departure and attempts to describe and analyse the actual data contained in the sources he details.

Work Package 1 of the Ecoheatcool report (Euro Heat and Power, 2006), assembled data for total floor space for both the residential and the service sectors for 32 European countries, and for the thermal energy needed for space heating and water heating for these same floor areas. It should be stated at the outset that the data for floor area and space heating practice collected in the report could be taken verbatim and used for the purposes of the project. This option will be discussed elsewhere in this report. The Ecoheatcool report, and communication with its lead author (Werner, 2008), proved to be a useful starting point in assessing the usefulness or quality[†] of data in some of the sources listed by Göransson. It also provided ideas for data acquisition from non-energy-related sources.

A report prepared by the Tyndall Centre for Climate Change Research in the UK, entitled "Modelling energy use in the global building stock: a pilot survey to identify available data sources" (Macmillan and Köhler, 2004), undertook work similar to that of Göransson (2006) although on a global scale and without seeking data on energy-using apparatus or building thermal characteristics. This report was useful to compare sources found with those of Göransson. It also contains what seems to be a thorough list of possible national data sources.

The EU IEE SAVE projects relating to energy efficiency in buildings, equipment and products were useful to show patterns that have occurred between the various funded projects with respect to where they each sourced data from. Some, which have been completed in the last few years, have proven to be useful in terms of providing new data. However, none of the 21 EU IEE SAVE projects listed as ongoing and relating to buildings in December 2006 (IEE, 2006), has provided additional sources of information to date. This is expected to change in the near future, as some of these projects publish results. In many cases, the lack of new data suggests some data "recycling" in projects, and that significant efforts to acquire new building energy use-related data have not been ongoing up until now.

This chapter steps through the data requirements for an analysis of energy use in European buildings, sequentially. This is done in an elementary manner. The aim of the chapter is that the reader should obtain a good grasp of the type of raw data needed for building energy use

[†] Quality as discussed further in this chapter makes no judgement with respect to the quality of any work carried out or of author competence. It merely reflects the usefulness of data for the purposes of the pathways project.

analysis and whether such data exists for each European country. In addition to this, knowledge of how data has been collected and further, an opinion on issues surrounding its "quality" should be obtained. The following sub themes are addressed:

1. Types of buildings
2. Types of building structural data needed
3. Types of energy use in buildings
4. Types of macro-economic data which influence energy use in buildings
5. Data variations between countries
6. International data sources
7. Data quality issues
8. Differences in data definitions
9. Gaps and limitations in data coverage
10. National data sources
11. Future developments

The overall long-term aim in undertaking an analysis of such information is that it will allow us to:

- Identify the various types of energy uses in buildings.
- Identify the technical parameters that can be varied and simulated to improve a building's energy performance.
- Compile a list of the devices and appliances that utilise energy within a building.
- Have sufficient data on the macro-economic parameters which indirectly influence building energy use.
- Obtain an appreciation of the potential scope for a European-wide building energy use analysis.

Findings are summarised at the end of the chapter. Conventions used in the analysis are standard SI units for building description data, and kilo tonnes of oil equivalent (ktoe) or gigawatt-hours (GWh) for energy data, given the use of these units by the IEA, Eurostat and the Odyssee project (Odyssee, 2006) in their energy balances. Data needed for a top down analysis of energy use in buildings is defined as:

- Construction characteristics, e.g. building floor size, age, and type
- Energy end uses, e.g. space heating, water heating, appliance electricity

while that for a bottom up analysis of energy use in buildings is defined as

- Installed energy-using apparatus, e.g. boilers, fridges, cookers
- Building envelope characteristics, e.g. façade u – values
- Energy carrier mixes, e.g. oil, coal, gas, electricity

Within installed energy using apparatus there is a division between heating devices and heating systems. The latter is defined as being any of central, group, district or room heating while the former refers to the device that supplies the heat.

1.1 Relevant buildings data required

1.1.1 Building types and construction

Table 1.1 describes the main categories of buildings types that will be examined in this work. The categories have been defined by the author under headings of ownership and type after a review of various relevant literatures. All the buildings covered are classified as being either residential sector or service sector buildings. The reason for this division is to reflect the diverse temporal usage patterns within these two sectors i.e. service sector buildings are mostly used between 09.00 and 17.00, while residential sector buildings are mostly used outside this time. A second reason is that the two sectors are divided by convention in general statistics. The buildings in these two sectors are then subdivided, as being either privately or publicly owned. Buildings that do not come under the residential or service sector categories, such as those in the industrial, agricultural, or transport sectors, are not included[‡]. Table 1.1 does not, however, reveal whether the owner of a building is its occupier or landlord.

The "Other" private residential sector category as shown in Table 1.1 can include dwellings on canal barges, in caravans or in trailers. Public residential sector buildings refer to dwellings owned by municipalities and offered to qualifying tenants at reduced rents. Such dwellings are often referred to as social housing. Although single and two-family dwellings in this category are rare, they do nevertheless occur.

Table 1.1 : Main building types in the residential and service sectors of the developed world, as defined by the author. Private buildings are those in private ownership, while public buildings refer to those under the control of municipalities, state or housing associations.

Residential sector		Service sector	
Private	**Public**	**Private**	**Public**
Single-family dwelling	Single-family dwelling	Education	Education
Two-family dwelling	Two-family dwelling	Healthcare	Healthcare
Terraced dwelling	Terraced dwelling	Retail	Military
Multi-family dwelling, low-rise	Multi-family dwelling, low-rise	Leisure	Leisure
Multi-family dwelling, high-rise	Multi-family dwelling, high-rise	Hotels	State and municipal
Holiday		Office	Street lighting
Other		Religious	National agencies
		Other	Other

For service sector buildings, the author defines 'leisure' as covering art and sports facilities under both private and public ownership, and defines state and municipal buildings as those used for state and municipal administration. The author includes street lighting, as it is both a publicly administered service sector activity and also uses energy on the property of the state agency responsible for the provision of the service of roads.

An alternative method of listing building types for the service sector would be to use the relevant *Nomenclature générale des activités économiques dans les communautés européennes* - Statistical Classification of Economic Activities in the EU (NACE) standard classification of Industrial activity. For example, the Eurostat report, Energy Consumption in the Service Sector (Eurostat, 2002), sought data for the following NACE classifications:

- Commerce – Nace 50-52
- Hotel and restaurants – Nace 55
- Offices and administration – Nace 60-67, 70-75, 99
- Health and social work – Nace 85

[‡] No sources have been sought or found for floor space dimensions or non process energy used in the industrial, agricultural or transport sectors such as that for heating, cooling and lighting.

- Education – Nace 80
- Other community social and personal service activities – Nace 90-93

Such an approach has the advantage of being easier to define for other practitioners and of facilitating comparisons with other similar studies.

Given the variety of activities that constitute the service sector, it is doubtful that a strict definition of the sector's buildings beyond the examples given in Table 1.1 and that of Eurostat (Eurostat, 2002) will be found. For the purposes of this report, we will allow data to dictate which categorisation is chosen.

Table 1.2 describes the relevant detail we are interested in for each of the building types listed in Table 1.1. Total floor area will allow us to describe the floor area that needs to be heated, cooled or illuminated within a region under examination. In doing so, we choose the square metre data category over the cubic metre. Cubic metres would more accurately describe the actual volume of space within a building needing an energy service. It is rare, however, for building volume data to be collected. Age distribution will allow us to estimate the theoretical thermal performance of the building stock by examining building thermal regulations for the various construction periods. It can also be possible to describe all buildings constructed prior to the introduction of building thermal regulations as having low quality insulation. It would not however be possible to infer building expected lifetime from the year of construction.

Table 1.2 : Basic data required for an energy analysis for any building type.

Total floor area in square metres
Number of buildings of each type
Age distribution of entire building stock

Assuming that we have a time series available, annual total stock is a satisfactory data category of stock change. However, other data available which can contribute to a better understanding of stock dynamics are:

- Number of newly built buildings every year.
- Number of buildings demolished every year.
- Number of buildings permanently occupied for most of the year[§].

This last data category makes a division between holiday homes and buildings that are used for most part of the year.

If we wish to describe the impact of a building's construction characteristics on its energy use, we would need data in addition to the above which describes the physical construction of the each building type. Table 1.3 lists the building insulation data required to calculate the thermal conductivity of a building envelope.

Table 1.3 : Building insulation data required to describe physical impact of building envelope on energy use.

Floor insulation material, type, thickness and thermal conductivity (U-value) in $W/m^2/K$
Roof insulation material, type, thickness and thermal conductivity (U-value) in $W/m^2/K$
Wall insulation material, type, thickness and thermal conductivity (U-value) in $W/m^2/K$
Window glazing type and thermal conductivity (U-value) in $W/m^2/K$

[§] An exact definition of a permanently occupied building has to date not been found although one can speculate that it means a building that is occupied for more than ten months a year.

1.1.2 Building energy use

For each of the building types outlined in Table 1.1 we are interested to know how much, and for what purpose, energy is used inside the four walls of the building, or on the property delineated by the building's deed of ownership. Total energy use for any building can be divided into energy from fuel for use as heat and that from electricity for simple heating and providing power to electronic devices. Both heat and power totals can be subdivided by particular energy end uses as is outlined in Table 1.4.

Table 1.4 : Specific energy end uses in any building. The temporal resolution needed for each end use for an energy analysis can vary from hourly measurements to annual consumption.

Total energy	
Fuel or energy carrier use	**Electric power use**
Space heating	Space heating
Hot water heating	Hot water heating
Cooking	Cooking
	VAC
	Lighting
	Appliances

Appliances are all the devices that utilise electricity directly to function, with the exception of lighting and air conditioning systems. The inclusion of some end uses under both fuel/ and electric power categories reflects the fact that a building may use fuels or electricity for heating purposes.

For each of the energy end uses in Table 1.4 we want to know what kind of apparatus has been used to supply the “energy service”, the age of the apparatus and its expected lifetime. We also want to know the particular types of fuels or energy carriers used by each apparatus. Fuels or energy carriers used, allow us to infer the conversion efficiencies of equipment and corresponding emissions. It can also allow us to know what apparatus or what fuels or energy carriers are substitutable for more sustainable alternatives. Table 1.5 exemplifies the requirements.

Table 1.5 : Examples of data on energy using apparatus in any building needed for an energy analysis.

Energy end use	Apparatus type	Apparatus age	Apparatus lifetime	Fuel/energy carrier	Conversion efficiency
Space heating	Condensing boiler	10	15	Gas	40 %
Hot water heating	Electric element	5	10	Electricity	85 %
Cooking	Gas oven	5	20	Gas	20 %
VAC	Fan	2	10	Electricity	40 %
Lighting*	Low-energy CFL	1	4	Electricity	25 %
Appliances*	TV	2	5	Electricity	100 %

*Number of devices per building needed.

Water heating may or may not be provided by a separate heating system. Further, if the building is part of a district heating network (DH), we are not concerned with what fuels are used to produce heat. This is because DH and district cooling (DC) heat production apparatus are part of the energy supply system and thus outside the remit of a building energy use study. Thus the system boundary with respect to losses in connection to heating systems is not addressed in this work.

1.1.3 Macro-economic data

Time series data on a country-by-country basis for the following macro-economic and social data are essential to our study. Ultimately, data such as this influence the dynamics of energy use in buildings.

- Population
- GDP
- Per-capita income
- Status of building user (Owner or tenant)
- Number of occupants
- Number of households
- Average household size
- Value added by service provided in the service sector
- Employees in each branch of service sector
- Number of service sector businesses
- Average service sector business size
- Taxes on fossil fuels
- Heat and electricity costs
- Fixed and variable costs of insulation and glazing materials in euro per square metre.
- Average investment cost for building energy-using apparatus in euro

The need for most of the items in the above list should be self-explanatory. Population, for example, will continue to rise, thus meaning that more people will be using energy. The rate of population increase is therefore important. Demographic trends in terms of household size influence dwelling size, while increasing employment in the service sector usually corresponds to increased energy use therein. The importance of the status of the building user stems from the split incentives conundrum: a short-term building tenant has no motivation to invest in energy efficiency technologies for a building in which he will only stay a few years, while at the same time the owner also has no incentive to invest if he does not pay the energy bills. An econometric analysis of the impact of both income and price elasticity of demand on energy use would require the economic data categories listed above.

The above data also helps to account for the differences that occur within countries or between countries due to respective macro-economic conditions and cultural traditions. For example, an increase in affluence in the residential sector generally leads to an increase in dwelling size although as mentioned in the previous paragraph a decrease in household size counteracts this effect somewhat. We may thus be able to infer trends in different countries by an examination of this data. There may also be variations in household habits within the same country (or same housing estate for that matter), in terms of, say, the number of times showers are taken, or indoor temperature norms. Such an example enters the realm of consumer behaviour and would require even greater detail of macro-economic data such as average times spent in the home by various types of people, e.g. homemakers, professionals, children etc. This goes beyond the scope of this report. A more tangible difference is the climatic variation within or between countries, which necessitates different amounts of heating. Accounting for these differences and ‘cleaning’ of data for comparison purposes is further discussed in Chapter 2 on indicators. A top down analysis of energy use in European Buildings is then conducted in Chapter 3 using macro economic data.

1.1.4 Geographic scope

The geographic scope of this report is to cover the European continent as far as data availability allows. For practical purposes, it excludes countries whose population is less than 1 000 000. The following countries are therefore not included:

- Cyprus
- Iceland
- Luxembourg
- Malta
- Montenegro

and

- Andorra
- Faroe Islands
- Lichtenstein
- Monaco
- San Marino
- Vatican

The lower list of countries has a population of less than 100 000. As such, all further references to EU 15, EU 25, EU 27 or NMC 10 exclude Cyprus, Luxembourg and Malta. Non–EU accession and EU accession countries are included where possible. Russia and Kazakhstan are included, given that part of their territory lies in Europe. We would, however, not expect to find data for either country disaggregated between their European and Asian parts. Armenia, Azerbaijan and Georgia are also included, although their being part of the European continent is disputed. Thus the Non–EU countries included are:

- Albania
- Belarus
- Bosnia
- Croatia
- Macedonia
- Moldova
- Norway
- Serbia
- Switzerland
- Ukraine
- Turkey
- Armenia
- Azerbaijan
- Georgia
- Kazakhstan
- Russia

For simplicity, Non–EU European countries are referred to as Non–EU countries.

1.1.5 Limitations

The data requirements outlined in the previous sections, from type of building to type of construction and energy end use, are the ideal data set for undertaking an analysis of energy use in buildings. Unfortunately, obtaining full and accurate data for each of the categories for all of the above European countries is not possible. There are a number of reasons for this. For a start there is a large disparity in the types of energy-related data collected by each country's respective statistics organisations. Even where data is collected, there is far more emphasis on data collected for the residential sector than for the service sector. Secondly, information such as investment costs for building apparatus and fixtures is not generally collected at all. Thirdly, in the case of heating equipment or electrical appliances, it would actually be impractical to collect stock and usage data for all the variety of brands of individual applications that exist.

In order to proceed, we therefore need to set some levels of aggregation or an acceptable minimum level of detail for each of our data requirement areas. However, this acceptable minimum has to be based on data availability, given that it is not intended to undertake any formal data collection. Beginning with buildings and based on an initial review of data availability for the types of buildings we wish to analyse, we divide the public and private residential categories into three sub categories;

- Single-family dwellings
- Low-rise multi-family dwellings
- High-rise multi-family dwellings

We do not therefore distinguish between public and privately owned dwellings. Furthermore for the various branches of the service sector, we attempt a categorisation that is as close as possible to the established NACE categorisation previously mentioned and thus do not distinguish between public and private service sector buildings either. More abstract service sector buildings such as churches are ignored and, as stated earlier, buildings that are designated as occurring in the industrial, agricultural, or transport sectors, are not included. The latter is a limitation in that there are obviously large non-process energy uses in industry for heating, cooling and lighting. The agricultural sector would also be significant in countries such as Spain and Holland, while every country would have numerous garages and petrol stations which use energy for heating, lighting and appliances.

A priority data category is to know the total building floor area in square meters for each country. Due to limitations in the availability of such data for the service sector, it is pertinent to collect data which can work as proxies for floor space, such as the number of employees in the service sector or value added per branch in the sector. These two categories are listed in Section 1.1.3 on macro-economic data. The number of buildings in the service sector is actually not so important, given the huge diversity in type of buildings that exist and because we are more interested in comparing energy use per square metre for the sector.

Data on building envelope characteristics may not be available on a Europe-wide scale, and thus we may have to rely on building thermal regulations to infer a single U-value for all buildings built within a certain period. We would therefore also seek to have a collection of European-wide Building Thermal Regulations in force. However, we may not be able to obtain any indication of the characteristics of buildings constructed before building thermal regulations were first enacted in Europe in the 1970s. In these cases, we may only be able to use age information to generalise on building envelope characteristics. There may be data on the characteristics of individual building envelope components available e.g. types of wall insulation, although this would only be for the components themselves, as they are newly placed on the market. These could be used to 'construct' a model house, although this approach would be time consuming and not realistic if we intend to look only at established international energy – use databases.

As much as possible we wish to obtain annual time series data per country for each of the energy end – uses outlined in Table 1.4**.** For space heating, however, we must consider that some heating is provided "free of charge" in every building by the:

- Occupants
- Electric appliances
- Lighting
- Insulation
- Cooking

The actual heat capacity of the internal structure of a building also plays a role in so far as the structure can store heat delivered for subsequent release when the ambient temperature cools. Quantifying such parameters is beyond the scope of this report. We can, however, assume that such internal dynamics add 4 ºC to a building's indoor temperature as per standard degree-day calculations. Thus heating degree-day data for each country under analysis is needed. It is also needed to enable comparisons of energy use between countries with different climates.

A further issue is that it would be more informative to show seasonal variations in energy end uses in buildings to show the influence of climate on energy use. This is especially true for heating and lighting but also indirectly for entertainment appliances, given that people spend a longer time indoors in winter. Such a level of disaggregation is also beyond the scope of this report. However, modelling needs may dictate that some such seasonal data is needed at a later stage of the project. If so, the data categories listed in Table 1.6 (MURE, 2000) could be an approach to parameterising general heating practice, although for now they will not be overtly sought.

Table 1.6 : Basic data on heating for any building. These data categories come from MURE simulation tool (MURE, 2000).

Average internal temperature of heated buildings, in ºC
Average external temperature during the periods when heating is used, in ºC
Average difference between the internal temperature and the ground temperature during the heating period in ºC
Average number of hours per day and days per year that heating is used
Frequency of maintenance of building equipment and structure
Types of equipment controls used

As indicated in Table 1.5, more data is needed on lighting and appliances given that they can occur in more than one incidence in buildings. In addition to this, appliances have a shorter lifetime and are used more sporadically than the other energy-using apparatus in a building Data similar to that in Table 1.6 which focuses on appliances, such as average hours of usage of a television or photocopiers per day, would be too detailed a level of aggregation for this report however. Thus we outline in Table 1.7 the level of aggregation for data for appliances and lighting.

Table 1.7 : Appliance-specific data required for energy analysis of any building. These data categories come from Odyssee Indicator Database (Odyssee, 2006).

Number (stock) of appliances of each type
Annual growth rates of stock
Average annual per-item consumption (kWh per year per appliance)

The idea would be to provide the data listed in Table 1.7 for all the building categories sought. Given the scope of this report, data for appliances should be narrowed down to a core set of large-impact appliances. A standard list of household appliances for which the data in Table 1.5 could be applied would be (Odyssee 2006, MURE 2000):

- Refrigerators
- Freezers
- Washing machines
- Dishwashers
- TV

With the increasing diffusion of electrical gadgets in the home, for example, electric tin openers, mixers, coffee machines and of IT devices (e.g. games consoles and satellite TV set-top boxes), other methods of categorisation have been suggested, such as from the Remodece project (Remodece, 2007):

- Large appliances
- Small appliances
- I.T. appliances

or from the Building Research Establishment (BRE Housing Centre, 2003):

Cold⇨	Refrigeration
Wet⇨	Washing machines, dryers and dishwashers
Brown⇨	DVD players and mobile phone chargers
Cooking⇨	Ovens, microwaves, kettles, toasters

The set chosen is ultimately dependant on the level of inter-country data available. Domestic appliance standard regulations in force across the continent could help with estimates of average electricity and so should also be sought.

In Table 1.5 we also seek data on heat-using apparatus and the energy carriers used to provide the heat. It is not possible to know from the international statistics what kinds of heating boilers or devices of any kind are installed in the building stock. What we do know, however, are the various energy carriers used across the building stock and sometimes also the energy carriers used per house type or per branch of the service sector or of energy carriers used per heating end use. At this point in time knowledge of the heat-providing apparatus installed can be acquired only through estimation based on energy carriers used.

An analysis of the energy embodied in the manufacture and transport of building materials and appliances i.e. the energy taken to produce and supply the materials and appliances, is beyond the scope of this report. The significance of embodied energy is that the energy taken to produce low-conductivity insulation or newer energy-efficient appliances may offset the energy savings accrued by the use of such materials and appliances.

For energy use in buildings, we exclude the use of micro-CHP plants or gas-fired clothes dryers as energy users in buildings, due to their low penetration in the stock or early stage of development.

The intention is to make a first pass of international data sources that exist to assemble a data set that would allow a basic characterisation of the European building stock and its energy use, and thus allow us to model a number of technical changes. It is expected that data availability for EU 15 countries will be good, but that the further east our search progresses the less data will be found.

1.2 International buildings data sources overview

This section lists the data sources examined in the search for data on building type, fittings, energy use and fuel mix. Questions regarding data usefulness and quality and data category definition are also addressed.

Data sources examined have ranged from those available from established energy statistic collection organisations such as Enerdata, Eurostat and the IEA, to other once-off projects relating to buildings.

For each of the sources described we list; title and publishing author, temporal resolution, purpose, which of residential and service sectors are covered, whether the data contained is official or not and whether it is harmonised or not. Sources are listed in alphabetical order. Further information on one of the data sources, the Odyssee Indicator Database, is provided in Appendix A given its comprehensive collection of energy end–use data for the EU.

A description of the exact data categories contained in each source is left to Section 1.3, while a description of the number of countries covered by each source is left to Section 1.4.

Official data is defined as that which emanates from a national statistics organisation or from international organisations such as the EU or the UN. Harmonised data is that which is comparable across countries due to it being defined in the same manner for each country.

In most cases stating whether data contained in a source is official and/or whether it is harmonised is as far as the study goes in attempting to address data quality issues. While in order to assess its quality it would be of interest to know the exact methodology used to collect each set of data - i.e. measurement, census, sample survey, estimation or recycled from other studies - the number of countries and data sources and categories examined would make such an undertaking difficult. Each statistic, and its underlying methodology, would have to be examined.

There are other reasons for not delving deeper. Intuitively one would assume that data that has been acquired by direct measurement would be considered to be of higher quality than that acquired by estimate. It is likely, however, that all data sets incorporate estimation (for non-response to survey, for example) and measurement to a greater or lesser degree[**]. It may also not be possible to measure particular parameters relating to energy end use. One well-known statistic, for example, that is not possible to measure on a national scale, is the number of miles driven by cars each year. This report does not go beyond an official/unofficial and harmonised/unharmonised categorisation of data.

Without a detailed knowledge of how data has been arrived at, it is also not possible to state that official data is of a higher quality than unofficial data. Unofficial data can often involve expert estimation (with university-led projects, for example) or sample survey (for EU IEE-funded projects, for example). It can also be acquired from questionnaires sent to participating national institutions or consultancies. Nonetheless, it is useful to distinguish between official and non-official data for the straightforward reason that official data has state endorsement and thus carries a degree of legitimacy that unofficial sources may not have.

It can be stated however, whether data is harmonised or not, if this is explicitly stated in an individual data source, or by an examination of data sources used for a data set. There is no single standard of methodology for inter-country harmonisation of data which applies to building or energy-related statistics. Nonetheless, the rules for harmonisation being applied

[**] The author is grateful to the Information Section of the Irish Central Statistics Office for clarification of some issues surrounding quality of data.

across countries from published sources such as the Enerdata, Eurostat or the IEA would be considered as satisfactory, given the need for these organisations to ensure comparability across countries in the data they published. Harmonisation is discussed in further detail in Section 1.2.2.

However, as previously mentioned, stating whether data is official or harmonised or not does not imply any judgement on the ability or quality of work of the source author: it merely reflects on the data itself under these two headings.

No sources have been found which include a margin of error analysis or test on data. The fact that data is available in the first place seems to be the overriding feature in the literature.

1.2.1 International buildings data sources description

Title of data source: Energy Consumption in Households (ECH) (Eurostat, 1999a)
Temporal resolution: Snapshot. One of either 1995 or 1996 or 1997 for each country
Purpose: Eurostat organised once-off project related to buildings
Sectors covered: Residential and service
Data type: Official, harmonised
Description: The ECH was a project initiated by Eurostat in order to quantify energy end uses in the residential sectors for the EU 15, for eight of the then ten EU accession countries and for three other Eastern European countries, and was published in report format. Data provided came from official national sources or from national organisations commissioned by Eurostat to undertake sufficiently detailed surveys. As such, the report would be classed as containing official data. Although somewhat dated now, this work is held in high regard in most quarters and it is sometimes lamented that it was not repeated.

Title of data source: Mitigation of Carbon Dioxide Emissions from the Building Stock, (Ecofys, 2004)
Temporal resolution: Snapshot for 1999
Purpose: Industry-funded project related to buildings
Sectors covered: Residential and Service
Data type: Unofficial, harmonised
Description: Ecofys is an energy consultancy that operates mainly in The Netherlands and in Germany. Its German office in Cologne has undertaken a number of studies on behalf of EURIMA, the European Insulation Manufacturers' Association, and EuroACE, the European Alliance of Companies for Energy Efficiency in Buildings, in which it has published floor space and U-value data for European service sector buildings. The data presented is calculated by expert estimation.

Title of data source: Ecoheatcool WP1, (Euro Heat & Power, 2006)
Temporal resolution: Snapshot for 2005
Purpose: Industry-funded project related to buildings
Sectors covered: Residential and service
Data type: Unofficial, unharmonised
Description: Ecoheatcool was a project conducted on behalf of Euro Heat and Power, the European District Heating Industry Association, and was published in a number of work packages between 2005 and 2006. As described in Section 1, Ecoheatcool Work Package 1 provides floor space data for both residential and service sector buildings for 32 European countries. The report used a combination of official data and estimates for its information.

Title of data source: Energy Consumption in the Service Sector (Eurostat, 2002)
Temporal resolution: Snapshot for one of either 1995 or 1996 or 1997 for each country
Purpose: Eurostat organised once-off project related to buildings

Sectors covered: Service
Data type: Official, harmonised
Description: This Eurostat-published report complements the ECH report, except that it only covers the EU 15 excluding Ireland and Luxembourg. It provides energy end use data for building heating and power needs for six NACE categories. The report had a similar data collection methodology to ECH and this, coupled with it being a Eurostat project, would make it official data.

Title of data source: El-tertiary, (El-tertiary, 2008)
Temporal resolution: Snapshot for 2008
Purpose: EU-funded once-off project related to buildings
Sectors covered: Service
Data type: Unofficial, harmonised
Description: An IEE-funded project that seeks to analyse electricity use in the tertiary (service) sector for twelve EU countries. The core of the project is in the empirical phase, where more than 100 buildings in the tertiary sector will be analysed with respect to their electricity consumption. The branches covered are office buildings, supermarkets, hotels, hospitals, schools and universities. At the time of publication of this report, no results have yet been published.

Title of data source: Energy Charter PEEREA Country Reports (Energy Charter Secretariat, 1998 to 2006)
Temporal resolution: Snapshot for one of any year between 1998 and 2006 for each country
Purpose: Report related to energy efficiency in buildings
Sectors covered: Residential and service
Data type: Official, unharmonised
Description: The Energy Charter is a legally binding treaty signed by 51 European governments. The Energy Charter secretariat publishes country reports periodically as part of its Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA). The reports themselves are compiled by national organisations mandated by their respective governments and as such would carry a virtual stamp of approval and be classed as official data. In general, however, these reports do not provide energy use information beyond what is already available from IEA energy balances. Where they do provide unique information, the main data of interest is building floor space in the service sector.

Title of data source: Enper Exist (Danish Building Research Institute, SBi, 2006)
Temporal resolution: Snapshot for various years
Purpose: EU-funded once-off project related to buildings
Sectors covered: Residential and service
Data type: Unofficial, unharmonised
Description: Enper Exist is an EU IEE-funded project that sought to investigate applying the EU Environmental Performance of Buildings Directive (EPBD) to improve the energy performance requirements of existing buildings. It contains no original data, but lists other data sources where building characteristic or energy use information can be obtained.

Title of data source: Enper Tubec (BRE Housing Centre, UK, 2003)
Temporal resolution: Snapshot for one of any year between 1998 and 2001 for each country
Purpose: EU-funded once-off project related to buildings
Sectors covered: Residential and service
Data Type: Unofficial, unharmonised
Description: An IEE-funded European collaboration of two separate projects, Enper and Tebuc, dealing with the development of the EPBD. Provides total floor area and total energy

use data for dwellings for EU 15, although this data is taken from the HSEU and from the Odyssee Project.

Title of data source: Energy Performance Assessment Existing Dwellings (National Observatory of Athens, 2003)
Temporal resolution: Snapshot for various years
Purpose: EU-funded once-off project related to buildings
Sectors covered: Residential
Data type: Unofficial, unharmonised
Description: EPA – ED is an EU IEE-funded European project which provides useful data on building characteristics, age distribution and installed heating systems for four countries; Austria, Denmark, Greece and The Netherlands.

Title of data source: Energy Performance Assessment Non Residential (National Observatory of Athens, 2006)
Temporal resolution: Snapshot for various years
Purpose: EU-funded once-off project related to buildings
Sectors covered: Service
Data type: Unofficial, unharmonised
Description: EPA – NR is a very useful IEE-funded project which surveys data availability for numbers of buildings, building characteristics, building apparatus installed and building energy end uses for all EU 25 countries. It shows explicitly the limitations in data availability for the service sector for many countries. Data collection has been organised by the project partners rather than by organisations in each individual country. This is reflected in the geographic coverage of the results.

Title of data source: Eurostat Online Energy Balances, 2007 (Eurostat, 2007a)
Temporal resolution: Time Series from 1990 to 2007
Purpose: Dedicated data collection and dissemination service
Sectors covered: Residential and service
Data type: Official, harmonised
Description: Eurostat is the official statistics organ of the EU. It has useful time-series macro-economic data and general energy-balance data for each member and accession country available free of charge on its web site. Eurostat data is classed as being "official" in the sense that it originally emanates from national statistics organisations and is then collected and presented by an international institution, of which national governments are part. Each year, Eurostat collaborates with the IEA and the UNECE to collect statistics from national statistics authorities using a set of five joint questionnaires (oil, coal, gas, electricity and renewables) and based on harmonised definitions, units and methodology. These questionnaires provide final consumption of energy and electricity data for both the residential and the service sectors. There should as such be a close, if not identical, alignment between the energy balances presented by all three organisations, although differences sometimes occur with regard to process conversion factors used in constructing the fuel balances and different conventions used for presenting final energy-balance data. In addition to this, although each organisation receives the same initial information back from national statistics organisations, the various parts of the questionnaires they query, the time it takes for them to receive clarification of queries back from national organisations and the respective publication times of the three organisations differ, causing differences in the data presented. However, the fuel balances presented by the UNECE (see below) appear to be identical to those of the IEA, such that real differences exist only between the IEA and Eurostat balances. Energy end use data is not requested or provided in the joint questionnaire. Eurostat states on

its web site that it harmonises data to make inter-country comparisons possible (Eurostat, 2007c).

Title of data source: Housing Statistics of the European Union (Swedish National Board of Housing, Building and Planning, 2004)
Temporal resolution: Periodic time series for 1980, 1990, 1995, 2000, 2002 and 2003
Purpose: EU funded periodic report relating to Housing Policy
Sectors covered: Residential
Data type: Official, unharmonised
Description: The HSEU project was initiated by the EU due to a desire to produce more data on housing than was being produced by Eurostat. The project is run bi-annually by one or more EU member country housing authorities. Its latest publication in 2005 resulted from collaboration between the Swedish National Board of Housing, Building and Planning (Boverket) and the Czech Ministry for Regional Development, and covered the new member states of the EU for the first time. The project collects data from national statistics organisations or government departments of EU countries. HSEU building stock data that is presented correlates with that of the UNECE for EU countries except for countries that define dwellings differently from the UNECE. The project is particularly useful in providing traceable data for housing stock, household sizes and dwelling tenure[††].

Title of data source: IEA Online Energy Balances (IEA, 2007)
Temporal resolution: Snapshot for 2004
Purpose: Dedicated data collection and dissemination service
Sectors covered: Residential and service
Data type: Official, harmonised
Description: The IEA is the energy affairs branch of the OECD. It publishes energy balance statistics for most of the world's countries on its website. As stated previously, it collaborates with Eurostat and the UNECE to collect its European country energy balances. Time-series data is available for a fee. Energy balances for both the residential and service sector are the only useful information provided.

Title of data source: Oil Crisis and Climate Change – 30 years of energy use in OECD Countries (IEA, 2003)
Temporal resolution: Time series 1980 to 1998
Purpose: Report related to energy demand in buildings
Sectors covered: Residential and service
Data type: Official and Unofficial, harmonised
Description: Oil Crisis and Climate was a report published to mark the 30th anniversary of the IEA. Unlike the general IEA statistics, which focus on energy supply, this report looks at how energy demand has developed over the thirty-year period in eleven OECD countries, eight of which are in Europe. For the residential and service sector, graphs are presented which show developments in building floor space area and in energy end uses. An updated edition of the report is due for publication this year by the IEA Energy Indicators department[‡‡].

Title of data source: Measures for Rational Use of Energy (MURE, 1995 & 2000)
Temporal resolution: Snapshot for 1995 (service sector) and 2000 (residential sector)

[††] At the time of this reports publication a subsequent edition of the Housing Statistics Report was received by the author from Federcasa in Italy.
[‡‡] At the time of this reports publication this follow up report has been published and is entitled "Energy Use in the New Millennium", (IEA, 2007).

Purpose: Simulation software with a default data set
Sectors covered: Residential and service
Data type: Unofficial, harmonised
Description: MURE is a detailed bottom-up energy demand simulation modelling tool with a default data set for the five sectors it covers – residential, service, industrial, transformation and transport. It uses data from the Odyssee database (year 2000 for residential sector, year 1995 for service sector) where possible. For the residential sector, the non Odyssee data that it uses is focused on building envelope characteristics and energy using apparatus. Data such as U - Values has been collected for Italy and then has been used in conjunction with some other studies such as the Ikarus Project (IKARUS, 1999) to derive values for other EU 15 countries. Costs of insulation technologies are given, although there is an almost identical data set for these values for the 15 countries. In other words, the cost of insulation installation is given to be the same in Sweden as in Portugal. For the service sector, the non-Odyssee data for each country does appear to be heterogeneous, although the methodology used to collect it is unknown. For residential sector building characteristics data, and for service sector energy end use data, MURE seems to be a useful source of data if no newer sources of the same data are found. In addition to this, MURE contains a database of all energy demand-related policies that have been published by the EU and by EU member states in the last decades. The MURE energy regulations database is grouped with Odyssee as one IEE-funded project, while the simulation tool is no longer funded by the IEE. However, a redevelopment of the simulation tool is currently being funded by EU DG TREN to allow it to review the Energy Efficiency Action Plans submitted by member's states as part of the EE&ESD. For more information on the MURE simulation tool, see Appendix F.

Title of data source: Odyssee Indicators Project (Odyssee Network, 2006)
Temporal resolution: Time series from 1980 to 2005
Purpose: Dedicated data collection and dissemination service
Sectors covered: Residential and service
Data type: Unofficial, harmonised
Description: The Odyssee indicators project is the only energy data collection organisation in Europe which focuses exclusively on the demand for energy. Its databases, which can be acquired for a fee, present raw data and indicators for energy end uses for the residential, service, industrial, transport and agricultural sectors. Countries covered are the EU 27 plus Norway, excluding Romania. It is expected that data for Croatia and Romania will be included soon. The project was started by the French Energy Agency Ademe. Data for the database is fed in by national organisations from each participating country. These organisations may or may not be public bodies. As such they may or may not utilise official data from national statistics organisations. Data submitted by member organisations may thus be simply rough estimates, as opposed to data produced by survey or measurement. The project does, however, harmonise data presented to make inter-country comparisons possible. For the purposes of this project, Odyssee seems particularly useful in that it presents time-series energy end use data for both the residential and the service sectors. The project is due to publish a quality rating for the sources from which its data originally emanates, and a quality rating of its own data, sometime in the future. The idea is that the quality checks should be performed by national teams. It can be assumed for now that the development of their quality rating is ongoing through cooperation with member organisations. As stated previously, Odyssee is grouped with the MURE regulations database for IEE funding. For more discussion on Odyssee, see Appendix A.

Title of data source: Remodece, (Remodece, 2008)
Temporal resolution: Snapshot for 2008

Purpose: EU-funded once-off project related to buildings
Sectors covered: Residential
Data type: Unofficial and harmonised
Description: Remodece is an IEE project that will evaluate the potential electricity savings in the residential sector in EU 27, and that can already be implemented by existing means, such as the use of very efficient appliances or the elimination or reduction of standby consumption. It is expected that when the project presents results in 2008, new data covering electricity consumption in domestic appliances will be included.

Title of data source: United Nations Economic Committee for Europe (UNECE, 2006 & 2007)
Temporal resolution: Periodic time series for 1993, 1997, 2001, and 2002
Purpose: Dedicated data collection and dissemination service
Sectors covered: Residential and service
Data type: Official, harmonised
Description: The UNECE is a branch of the UN, which in a sense mimics some of the work of the EU although for all European counties. One gets the impression that, as the EU increases the range of matters that it addresses, the UNECE reduces its involvement in EU countries and concentrates on economies in transition that are not yet members of the EU. Their geographical remit stretches from Portugal to Kyrgyzstan. As stated previously the UNECE collaborates with Eurostat and the IEA to collect European country energy balances. However, the energy balances data that is presented on its web site is exactly the same as that presented by the IEA. The organisation also undertakes its own housing survey and takes data from the HSEU where relevant. This publication is called the Bulletin of Housing Statistics for Europe and North America, and is published bi-annually**.** The advantage of the UNECE housing survey is that it covers all European countries. Its reports were originally published in print form but are now available only online. The organisation also publishes country reports entitled "UNECE Countries in Figures", which contain some of the macro-economic data we seek for the same set of countries. This data would be classed as being official.

Table 1.8 lists in alphabetical order abbreviations and web-based sources used in this report for describing the above data sources.

Table 1.8 : Summary of data sources and their respective reference points that have been reviewed to investigate data availability for energy use in European buildings.

ABBREVIATION	NAME	Available from
ECH	Energy Consumption in Households	http://epp.eurostat.ec.europa.eu
Ecofys	Mitigation of Carbon Dioxide Emissions from the Building Stock	http://www.ecofys.org
Ecoheatcool	Ecoheatcool WP1	http://www.ecoheatcool.org/
ECSS	Energy Consumption in the Service Sector	http://epp.eurostat.ec.europa.eu
El-tertiary	El-tertiary	http://www.eu.fhg.de/el-tertiary/
Energy C	Energy Charter PEEREA Country Reports	http://www.encharter.org/
Enper E	Enper Exist	http://www.enper-exist.com/
Enper T	Enper Tubec	http://www.enper.org/
EPA – ED	Energy Performance Assessment Existing Dwellings	http://www.epa-ed.org/
EPA – NR	Energy Performance Assessment Non-Residential	http://www.epa-nr.org/
Eurostat	Eurostat	http://epp.eurostat.ec.europa.eu
HSEU	Housing Statistics of the European Union	http://www.boverket.se/shopping/ShowItem.aspx?id=843&epslanguage=SV
IEA EB	IEA Energy Balances	http://www.iea.org/Textbase/stats/index.asp
IEA 30	Oil Crisis and Climate Change – 30 years of energy use in OECD Countries.	http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1260
MURE	Measures for Rational Use of Energy	http://www.MURE2.com/
Odyssee	Odyssee	http://www.odyssee-indicators.org/
Remodece	Remodece	http://www.isr.uc.pt/~remodece/
UNECE	United Nations Economic Committee for Europe Bulletin of Housing Statistics for Europe and North America and country reports.	http://www.unece.org/hlm/prgm/hsstat/welcome_hsstat.html

1.2.2 International buildings data sources harmonisation

A precursor to the harmonisation of data is knowledge of how the data categories have been defined. Individual countries can differ in how they do this. The HSEU report (Swedish National Board of Housing, Building and Planning, 2005) list the following categories relevant to this report for which alternative definitions exist for each country.

- Dwelling
- Dwelling: vacant
- Dwelling stock
- Equipment of dwellings
- Floor area: useful
- Household
- Housing census and/or housing condition survey
- Population on 1 January
- Population forecast
- Room
- Social housing association/organisation
- Social versus private rental dwelling

If we take as an example the definition of *floor area* from the UNECE and for three sample countries and compare the text for each, we find:

UNECE: Useful floor space is the floor space of dwellings measured inside the outer walls, excluding cellars, non-habitable attics and, in multi-dwelling houses, common spaces (Swedish National Board of Housing, Building and Planning, 2005).

Ireland: Floor area is defined as the floor space of dwellings measured inside the outer walls, excluding cellars, non-habitable attics and, in multi-dwelling houses, common spaces (Swedish National Board of Housing, Building and Planning, 2005).

Sweden: The useful floor space of a dwelling is defined as; the floor space bounded by the insides of walls, which enclose each apartment (Swedish National Board of Housing, Building and Planning, 2005).

Italy: The useful floor space is defined as the floor space of dwellings measured inside the outer walls, excluding passage thresholds and door and window bays (Swedish National Board of Housing, Building and Planning, 2005).

We can see that Ireland adopts the UNECE definition verbatim, while other countries have their own definitions. At the same time, the above definitions all more or less amount to the same thing and more reflect the types of dwellings in these countries rather than differences in definitions. However, if we compare the definition for a *dwelling* from the UNECE and two other countries, notable differences do appear.

UNECE: A dwelling is a room or suite of rooms and its accessories in a permanent building, or in a structurally separated part thereof, which, by the way that it has been built, rebuilt, converted, etc., is intended for private habitation. It should have a separate access to a street (direct or via a garden or grounds) or to a common space within the building (staircase, passage, gallery, etc.). Detached rooms for habitation that are clearly built, rebuilt, converted, etc., to be used as a part of the dwelling should be counted as part of the dwelling. (A dwelling may thus be constituted of separate buildings within the same enclosure, provided that they are clearly intended for habitation by the same private household, e.g. a room or rooms above a detached garage, occupied by servants or other members of the household.) (Swedish National Board of Housing, Building and Planning, 2005).

Austria: A dwelling is a (set of) room(s), including annexed rooms, which represents a closed unit and which includes as minimum standard a kitchen or a room with cooking facilities. Mobile dwellings, barracks, and dwellings without a kitchen are not considered dwellings (Swedish National Board of Housing, Building and Planning, 2005).

Belgium: A dwelling is a house or part of a house, a mobile dwelling (ship or caravan), or emergency dwelling (barracks, etc.) intended for occupation by a family and used as such (Swedish National Board of Housing, Building and Planning, 2005).

For the definition of a dwelling the important question is how the UNECE and the HSEU interact with the national statistics organisations, and if any harmonisation of data occurs after it has been received from member organisations. In private correspondence with the author (UNECE, 2007b) the UNECE states that it does not alter dwelling information sent to it by the countries. It says that the countries for their part are requested to provide an explanation should their definition and/or unit of measurement differ from what is indicated in the ECE housing questionnaire. UNECE consults the publication "Housing Statistics in the European Union" for some dwelling statistics that are not available on the replies from national statistical offices to its questionnaire. Thus it would appear that it is the UNECE data that is in fact harmonised, while that of the HSEU data is not. The proof that the HSEU data is not harmonised is that it lists the respective definitions for each country in its report.

Eurostat also harmonises data (Eurostat, 2007c), as does the Odyssee project. Both organisations take the same approach to harmonisation; namely, defining the data category in advance and then asking member organisations to submit data corresponding to the category definitions. Both organisations also check the data submitted and query submissions that seem to be out of range. Odyssee, in private correspondence with the author (Enerdata, 2007), states that “Enerdata does not modify any data sent by the countries, which have the responsibility for the data. We have the responsibility for the quality and comparability of the data. If we have a doubt of find a mistake we ask the countries to correct, we never correct ourselves”.

The above definition differences seem to be mostly a feature of building characteristics data. For information on the other definitions listed above, please see Appendix 1 of the HSEU (Swedish National Board of Housing, Building and Planning, 2005). From the point of view of this report, differences in definitions of dwelling stock and dwelling floor area need to be ironed out or harmonised in order to allow us to mix and match data from various sources so that we can cover as many countries as possible.

For energy consumption data the room for difference between sources is somewhat less given that PJ and tons of oil equivalent are the same the world over.

1.3 International buildings data sources in detail

This section lists the data categories included in each data source and the range of countries that each source attempts to cover. In all cases, a data source states that its remit covers a certain amount of countries. However, in nearly all cases sources do not achieve complete coverage for all countries. For example, Odyssee has many data categories available for all EU 25 countries plus Bulgaria and Norway, but in many cases it presents only data for a handful of these countries. This section does not reveal the actual data content of each source. It merely states the categories and countries that the source attempts to cover. This applies to buildings-related information and to the macro-economic information covered in Section 1.3.6. The actual data contained in sources is the subject of Section 1.4.

1.3.1 Building stock characteristics

The data requirement in Table 1.2 was to present information for each type of building in Table 1.1 for as many European countries as possible.

We refined our building type requirement in Section 1.1.5 to three types of dwellings and six service sector branches.

For the residential sector, Table 1.9 shows the availability of the required data from various sources. The actual data categories available from each source do not give an exact match for our requirements. For example, Odyssee gives only two categories for type of dwelling; single-family and multi-family.

Table 1.9 : Availability of building stock data for the European residential sector, from various sources.

	Dwelling type	Total area	Stock	Age distribution	Year
Odyssee	●	●	●		1980 to 2004
HSEU	●	*	●	●	1980, 1990, 1995, 2000, 2002, 2003
UNECE		*	●	●	1993. 1997, 2001, 2002
ECH	●	●	●	●	1995
EPA – ED	●		●	●	2003
Energy C		●	●		2000
Enper T		●	●		2003
Ecoheatcool		●	●		2005
IEA 30		●			1998
MURE	●		●	●	2000

*Time series data not available for this category

The age of the data available and its temporal resolution varies from source to source for all sources, as can be seen in the last column of Table 1.21. If the data categories are combined, and given the harmonisation issues discussed in Section 1.2.2, a complete time series or single year set of data categories for total floor area, building stock and building age distribution is available for all European countries, while data that distinguishes dwelling type is only available for EU 25. As stated, however, in the introduction to this section, these categories may be empty.

Specifically, the actual data categories available from each source are:

Odyssee – Number of permanently occupied single- and multi-family dwellings and average floor area in square metres (which needs to be multiplied by the number of dwellings to get total floor area) for EU 25 plus Norway and Bulgaria, but excluding Romania. The number of dwellings newly built every year since 1980 is also included.

HSEU – Number of single- and multi-family dwellings including the percentage of those that are high-rise, average floor area in square metres, and age distribution for EU 25. Number of dwellings demolished and newly built every year also included.

UNECE – Average floor area in square metres, stock of dwellings and age distribution for all European countries except Turkey and Bosnia. Number of dwellings demolished and newly built every year also included.

ECH **–** Number of houses and apartments, stock and age distribution for EU 25, Albania, Bulgaria and Romania. Total floor area for EU 15 and distribution of dwellings by size of heated area for other countries. Number of households owning farms also included, which could be used as an indication of how many farmhouses are located in each country.

EPA – ED – Number of single-family, attached, terrace and multi-family houses, stock and age distribution for four EU countries.

Energy Charter **–** Total floor area in square metres and stock of dwellings for all European countries except Serbia and Macedonia.[§§]

Enper Tebuc – Total floor area in square metres for EU 15.

Ecoheatcool – Total floor area in square metres for EU 27 plus Croatia, Turkey, Norway, Iceland and Switzerland.

IEA 30 Years Report – Total floor area in square metres for eight EU countries.

MURE – Number of single and multi-family dwellings and age distribution for EU 15.

For the service sector, Table 1.10 shows the availability of the required data from various sources.

[§§] At the time of publication of this work some Energy Charter Country Reviews, which had previously been available on the Energy Charter Website, were missing following a website overhaul. In private correspondence with the author (Energy Charter, 2007), they state that the reports will be put back up on the web.

Table 1.10 : Availability of building stock data for the European service sector from various sources.

	Building type	Total area	Stock	Age distribution	Year
Odyssee	●	●			1980 to 2004
Ecofys		●		●	2002
ECSS	●	●			2002
EPA – NR	●	●	●		2006
Energy C		●			2000
Ecoheatcool		●			2005
IEA 30		●			1998

Specifically, the actual data categories available from each source are:

Odyssee – A categorisation of buildings into those for administration, trading services, trade, education, hotel and restaurant, health and office branches, plus average floor area in square metres for each branch of the sector for EU 27 and Norway, excluding Romania.

Ecofys –Building floor area and age distribution estimated for the EU 15 as a whole.

ECSS – A categorisation of buildings into those for hotel and restaurants (Nace 55), health and social work (Nace 85), Education (Nace 80), other community social and personal Service activities (Nace 90-93), offices and administration (Nace 60-67, 70-75, 99) and commerce (Nace 50-52) for EU 15 excluding Ireland. Average floor area in square metres for each branch is also available but as fraction of a statistic for energy per square metre which thus must be divided by total energy use to get total floor area.

EPA – NR – A categorisation of buildings into various branches, building stock and floor areas for EU 25.

Energy Charter – Total floor area in square metres for all European countries, except Serbia and Macedonia.

Ecoheatcool – Total floor area in square metres for EU 27, plus Croatia, Turkey, Norway and Switzerland.

IEA 30 Years Report – Total floor area in square metres (as read from diagrams) for eight EU countries.

1.3.2 Building energy use

Table 1.4 outlined the data requirements for energy uses in the refined set of building types defined in Section 1.1.5. Table 1.11 shows the availability of the required data for the residential sector from various sources. Ventilation electricity is included in the appliances category.

Table 1.11 : Availability of energy use data for the European residential sector from various sources.

	Energy	Electricity	Heat	Space	Water	Appliances	Lighting	Year
Odyssee	●	●		●	●	●	●	1980 to 2004
IEA EB	●	●	●					2004
IEA 30	●	●		●	●	●		1998
ECH	●	●		●	●	●	●	1995
EPA – ED	●	●		●	●	●		2004
Energy C	●	●						2004
Eneper T	●							2004
Enper E	●							2006
Ecoheatcool	●	●						2005
Remodece		●						2008

Specifically, the actual countries for which the data categories are available are:

Odyssee – EU 27 plus Norway, excluding Romania.
IEA Energy Balances – All European countries.
IEA 30 Years – Eight EU countries.
ECH – EU 25, Albania, Bulgaria and Romania.
EPA – ED – Four EU countries.
Energy Charter – All European countries except Serbia and Macedonia.
Enper Tebuc – EU 15
Enper Exist – EU 25
Ecoheatcool – EU 27 plus Croatia, Turkey, Norway and Switzerland.
Remodece – EU 27

Odyssee is the only one of the above to sources to have energy end use data available per house type. MURE is not included in Table 1.11, as it takes energy use data directly from Odyssee.

Table 1.12 shows the availability of the required data for the service sector from various sources:

Table 1.12 : Availability of energy use data for the European service sector from various sources.

	Energy	Electricity	Heat	Space	Water	Appliances	Lighting	Year
Odyssee	●	●		●	●	●	●	1980 to 2004
IEA EB	●	●	●					2004
IEA 30	●	●						1998
ECSS	●	●		●	●	●	●	2002
EPA – NR	●	●	●	●	●	●		2006
Energy C	●	●						2004
Eneper T	●							2004
Enper E	●	●	●					2006
Ecoheatcool	●	●						2005
El Teritiery		●				●		2008
MURE	●	●		●	●	●	●	1995

Specifically, the actual countries for which the data categories are available are

Odyssee – EU 27, plus Norway excluding Romania.
IEA Energy Balances – All European countries.
IEA 30 Years – Eight EU countries.
ECSS – EU 15, minus Ireland
EPA – NR – EU 25
Energy Charter – All European countries except Serbia and Macedonia.

Enper Tebuc	– EU 15
Enper Exist	– EU 25
Ecoheatcool	– EU 27 plus Croatia, Turkey, Norway and Switzerland.
El Teritiery	– Twelve EU countries
MURE	– EU15

Odyssee, ECSS, EPA – NR and MURE provide energy end use data on a per-branch basis. In this case, the MURE data is a lot more thorough that that of Odyssee.

Heating degree-days data is available from Odyssee and from Eurostat. The Odyssee data comes from Eurostat. However, the Eurostat data for degree-days is not published on the Eurostat web site, but is contained in the publication, Panorama of Energy - Energy statistics to Support EU Policies and Solutions (Eurostat, 2007). Both sources contain long-term average degree-day data also. No degree-day data has been found for non–EU countries. The Eurostat publication is very comprehensive in terms of outlining how the degree-day figures have been calculated, e.g. whether the measurements have been taken from one sample point in a country, say the capital city, or whether population-weighted averages for each country have been used.

Data on indoor temperatures and heating norm averages have been found only in MURE, and are for the EU 15 residential sector for year 2000.

1.3.3 Building energy-using apparatus

All data found on types of heating devices installed comes from EPA – ED, which provides data for four EU countries for the residential sector, and EPA – NR which has data for the EU 25 service sector. However, an actual estimate of heating devices installed may be made via the fuel mix used. To do this we would have to use average useful heat provided by boilers, as opposed to their fuels used. Such estimation is discussed further in Appendix H. However, we would still not have data on boiler design, lifetimes or efficiencies. MURE as it happens contains data on the costs of new heating systems and their expected lifetimes which may help in estimating lifetimes for existing boilers[***].

ECH provides data on the fuel mixes used for each of space heating, water heating and cooking, which it uses to infer what types of equipment are installed. Odyssee presents data for the amount of energy used for cooking for EU 27 plus Norway, but excluding Romania.

For heating systems, Odyssee lists the numbers of dwellings with various systems installed, such as room heating or central heating. Odyssee and MURE list the numbers of dwellings with separate water heating systems as well, although the MURE data does not appear to come from Odyssee.

No data has been found for stock of cookers, light bulbs or VAC systems installed in the residential sector. This is significant, especially given the increasing consumption of electricity for lighting and VAC. This data is, however, available for the service sector from EPA NR.

For appliances, we require the following information:

- Number of appliances of each type (stock)
- Annual growth rates of stock

[***] At the time of publication of this report a study entitled, “Labelling and other measures for heating systems in dwellings FINAL TECHNICAL REPORT for SAVE II ACTION contract for DG for ENERGY and TRANSPORT”, (DG TREN, 2002) was found which contains a heating system stock model for Europe.

Table 1.13 lists the three sources which contain such data for the residential sector.

Table 1.13 : Availability of data on appliances in the European residential sector from various sources.

	Appliances	Year
ECH	●	1995
MURE	●	2000
Odyssee	●	1990 - 2004
Remodece	●	2008

Specifically, each source contains:

ECH – Percentage penetration of appliances for all countries covered, plus age of appliances for Eastern European countries covered

MURE – Number of appliances of each type (stock) and annual growth rates of stock for nine appliances

Odyssee – Stock for five main appliances for EU 25 plus Norway and Bulgaria, but excluding Romania

Remodece – Stock and average power consumption of appliances for EU 27. Not published yet

Table 1.14 lists the two sources which contain such data for the service sector.

Table 1.14 : Availability of data on appliances in the European service sector from various sources.

	Appliances	Year
El Teritiery	●	2008
EPA – NR	●	2008

Specifically, each source contains:

El Teritiery – Appliances stock for twelve EU countries. Not published yet

EPA – NR – Types of VAC and lighting installed for EU 25

Thus as of yet there is no information on the stock of appliances used in the service sector.

1.3.4 Building envelope characteristics

As specified in Table 1.3, we required:

- Floor insulation material type, thickness and thermal conductivity (U-value)
- Roof insulation material type, thickness and thermal conductivity (U-value)
- Wall insulation material type, thickness and thermal conductivity (U-value)
- Window glazing type and thermal conductivity (U-value)

for our refined set of building types.

For the residential sector Table 1.15 gives the availability of the required data from various sources. Specifically, the actual data categories available from each source are:

MURE – Thermal conductivity data for EU 15, plus generic data for new insulation types available

ECH **–** Categorisation of dwellings with/without insulation for EU 15

EPA – ED – Thermal conductivity data for four EU countries

Table 1.15 : Availability of building characteristics data for the European residential sector from various sources.

	Building envelope	Year
MURE	●	2000
ECH	●	Various
EPA – ED	●	2004

For the service sector, Table 1.16 shows the availability of the required data from various sources.

Table 1.16 : **Availability of building characteristics data for the European service sector from various sources.**

	Building envelope	Year
EPA – NR	●	Various
Ecofys	●	2004

Specifically, the actual data categories available from each source are:

EPA – NR – Building envelope U-values for offices, health care, education and hotels, plus a comprehensive description of existing thermal and appliance regulations for EU 25

Ecofys – U-values estimated for the EU 15, aggregated to three climatic zones

Interestingly, although MURE provides a comprehensive data set for building envelope, appliances and heating practice for the residential sector, its service sector module contains detailed data only for appliances. Its service sector model does contain a list of possible measures that would decrease heat or electricity consumption, but no data regarding their cost or conductivity (U-value). Odyssee does not contain this kind of data for either sector.

Other than from MURE, no sources for types of insulation material or thickness have been found.

A database of all existing EU and national policy regulations applying to building thermal and appliance regulations for EU 27 plus Norway, but excluding Romania, is available from the MURE online policy and measure database.

For the residential sector specifically, the MURE database case study entitled “A Comparison of Building Thermal Regulations in the European Union” (Eichhammer & Schlomann, 1998) includes the latest required U-value limits for EU 15.

EPA – NR and EPA – ED both provide a useful description of relevant regulations in force in the countries they respectively cover.

For both the residential and the service sector, the Energy Charter Peerea country reports provide a synopsis of regulations in place. Although the information presented would not be as detailed as that in the MURE or EPA – NR material, this is the only non–EU source of such data that has been found.

1.3.5 Building fuel mix

For the residential sector, Table 1.17 shows the availability of fuel mix data from various sources:

Table 1.17 : Availability of fuel mix data for the European residential sector from various sources.

	Fuel mix	per house type	per end – use	Year
Odyssee	●	●	●	1980 to 2004
IEA EB	●			2004
IEA 30	●		●	1998
ECH	●		●	2002
Energy C	●			2004
Ecoheatcool	●			2005
MURE	●	●	●	2000

Specifically, the actual data categories available from each source of Table 1.17 are:

Odyssee – Sector and end – use fuel mix for EU 27 including Norway, but excluding Romania. Sector fuel mix for space heating for single and multi-family dwellings for EU 15 including Norway.
IEA EB – Fuel mix for all European countries
IEA 30 – Sector fuel mix and sector fuel mix for space heating for eight EU countries
ECH – Sector and end use fuel mix for EU 27 including Albania, Bulgaria and Romania
Energy C – Sector fuel mix for all European countries except Serbia, Macedonia and Montenegro
Ecoheatcool – Sector fuel mix and fuel mix used for heating for EU 27, plus Croatia, Turkey, Norway and Switzerland.
MURE – Sector, end use and dwelling type fuel mix for EU 15.

For the service sector, Table 1.18 shows the availability of fuel mix data from various sources:

Table 1.18 : Availability of fuel mix data for the European service sector from various sources.

	Fuel mix	per branch	per end – use	Year
Odyssee	●			1980 to 2004
IEA EB	●			2004
IEA 30	●			1998
EPA - NR	●	●		Various
ECSS	●	●	●	2002
Energy C	●			2004
Ecoheatcool	●			2005
MURE	●	●		2000

Specifically, the actual data categories available from each source in Table 1.18 are:

Odyssee – Sector and fuel mix for EU 27, including Norway but excluding Romania.
IEA EB – Fuel mix for all European countries.
IEA 30 – Sector fuel mix for eight EU countries.
EPA – NR – Percentage of each fuel used in each branch for EU 25.
ECSS – Sector, branch and end use fuel mix for twelve EU countries.
Energy C – Sector fuel mix for all European countries except Serbia, Macedonia and Montenegro.
Ecoheatcool – Sector fuel mix for 32 European countries.
MURE – Sector and branch fuel mix for EU 15.

1.3.6 Macro-economic data

The data requirement outlined in Section 1.1.3 was to present data for each country in Europe for:

- Population
- GDP
- Income per capita
- Status of building user (Owner or tenant)
- Number of people housed
- Number of households
- Average household size
- Value added by service provided in the service sector
- Employees in each branch of the service sector
- Number of service sector businesses
- Average service sector size
- Taxes on fossil fuels
- Heat and electricity costs
- Fixed and variable costs of the insulation or glazing materials in euro per square metre
- Average investment for new building apparatus in euro

The Eurostat material provides all of the above categories for EU 27 plus Croatia, Norway and Turkey except:

- Average household size
- Fixed and variable costs of the insulation or glazing materials in euro per square metres
- Average investment for new building apparatus in euro

The Eurostat data does not have complete coverage for all countries in all instances, and can also be somewhat dated.

HSEU can provide the following data for EU 25:

- Population
- GDP
- Status of building user (owner or tenant)
- Number of people housed
- Number households
- Average household size

Odyssee can provide the following data for EU 27, plus Norway, excluding Romania:

- Population
- GDP
- Value added by service provided
- Employees in six branches of the service sector
- Number of households

The UNECE can provide the following data for all European countries

- Population
- GDP
- Status of building user (owner or tenant)
- Number of people housed
- Number of households
- Average household size

The Energy Charter country reports contain information on energy taxes. The information presented would not be as detailed as that of Eurostat. However, this is the only non–EU source of such data that has been found.

To summarise, the macro-economic data categories for which no sources have been found for the EU 27 plus Croatia, Norway and Turkey are:

- Fixed and variable costs of the insulation or glazing materials in euro per square metre
- Average investment for new building apparatus in euro

while for other European countries sources for the following have also not been found:

- Value added by service provided in the service sector
- Employees in each branch of the service sector
- Number of service sector businesses
- Average service sector size
- Taxes on fossil fuels
- Heat and electricity costs
- Fixed and variable costs of the insulation or glazing materials in euro per square metre
- Average investment for new building apparatus in euro

The UNECE also provide the following statistics which can be of use in the absence of some of the above:

- GDP of the service sector
- Employees in the service sector

No search for macro-economic data outside of the above sources has been undertaken, although it can be presumed that some large international institutions such as the World Bank may have more information. Heat and electricity costs in non–EU countries should be easily traceable, while costs for building envelope and building apparatus replacement may be available on a case-by-case basis from industry associations.

1.4 International building data sources compared

In this section we compare the data contained in the various sources that we outlined in Section 1.3 in an effort to choose the data that best satisfies our requirements. In doing so we must be conscious of whether data presented by one source is harmonised across the countries it covers. We also highlight the number of countries for which each source actually contains data. As stated in Section 1.3, although the data categories listed are contained in the sources outlined, not all sources have a complete data set for each category or for each country.

Section 1.4.4 summarises data on buildings that is available and suitable for use for a top-down analysis of energy use in buildings. Data on degree-days is included in Section 1.4.4 due to it being used in such top-down statistical analyses, but data on building regulations is left to Appendix H due to it being used for the estimation of U-value and appliance standards. Section 1.4.8 summarises data on buildings that is available and suitable for use for a bottom-up view of building technical details. Data on energy-using apparatus, fuel mixes and building envelope characteristics is included in Section 1.4.8. Section 1.4.9 examines macro-economic data availability from various sources. Finally, Section 1.4.10 summarises data needs and sources that provide for them.

1.4.1 Building stock characteristics

This section goes through building characteristic data availability for the residential and service sector source categories outlined in Section 1.3.1 and Section 1.3.4, and summarises findings in Section 1.4.1.4 and Section 1.4.1.9 respectively.

As stated in Section 1.1.5, it will not be possible to find data on all of the types of dwellings and buildings that we are interested in. No Europe-wide data is available that disaggregates the dwelling stock into these categories, apart from that of the EPA – ED, and that is only for four countries. The other three sources which disaggregate the dwelling stock; Odyssee, HSEU and ECH, simply divide it into single-family and multi-family dwellings. The HSEU does further divide multi-family between high-rise and low-rise by giving a percentage share of both types in the building stock, but does this for a single year only.

1.4.1.1 Residential sector total floor area

This data category is presented in one of two different formats by the various sources: either as total floor area for the entire stock, or as average floor area per dwelling. If it is presented as average floor area, it must obviously be multiplied by the total stock of dwellings to obtain total floor area. All sources except the Energy Charter and Enper Tubec use the latter method. Both data categories are adequate for our purposes. Table 1.19 presents data found for this data category for the 40 European countries we wish to analyse.

Starting from the right hand side of the table we will initially ignore both IEA 30 and ECH, as their data comes from between 1995 and 1998. We will also leave aside Ecoheatcool for the time being, as it is obvious from an examination of its data that it sources much of it from Odyssee, HSEU or UNECE. We will not divide the total floor space for the Energy Charter or Enper Tebuc by the stock of dwellings yet, until we ascertain if what we are looking for can be obtained from the first three listed sources. Although the Energy Charter reports were available for a lot more countries in 2006, the organisation appears to have removed all reports that were published prior to 2004 following a web site upgrade. In private correspondence with the author (Energy Charter, 2007), they state that the reports will be put back up on the web.

Examining Odyssee, HSEU and UNECE, it can immediately be seen that there are errors with the Odyssee data for Bulgaria and the UNECE data for Belgium, although the Belgium figure may in fact be for total floor area in millions of square metres. The data presented for Odyssee is all for 2003, whereas that for HSEU and the UNECE can be for 2000, 2001, 2002 or 2003 except where stated. For all countries bar Slovakia the data from the three sources are within 10 square metres of each other. These differences may be due to how a dwelling is defined or due to the data being from different years. Odyssee provides the only true time series with unbroken data back to 1995, although measurements for Belgium and Spain are totally absent. The only drawback with Odyssee is that we don’t know exactly what the source of the data is. HSEU lists sources explicitly, and the UNECE says in private correspondence with the author (UNECE, 2007b) that its data comes from either responses to the ECE housing questionnaire sent to the national statistical offices of the countries, or from official national publications.

Data for non – EU countries is scarce. It exists only for eight of the sixteen non – EU countries that we are interested in.

To conclude, both Odyssee and the UNECE present harmonised data and are most useful for our purposes. The advantage of the UNECE is that it is official data and covers more countries, while the advantage of Odyssee is that it has an unbroken time series from 1995 on.

Table 1.19 : Total floor area per country in square metres for European residential sector buildings from various sources. For both Energy Charter and Enper Tebuc, total floor area is given in thousands or millions of square metres. For the other sources listed, floor area is measured as average square metres per dwelling.

m^2	Odyssee	HSEU	UNECE	EnergyC	Enper T	Ecoheatcool	IEA 30	ECH
Austria	94	94	92		337 M	94		87
Belgium	na	§86	368		341 M	86		86
Bulgaria	6.56	Na	63			63		%H
Czech	79	76	84	273,800 k		76		%H
Denmark	109	109	109	300,731 k	271 M	109	108	108
Estonia	60	60	60			60		%H
Finland	78	77	76		187 M	77	76	78
France	90	90	90		2,526 M	90	88	86
Germany	85	90	90		3,211 M	90	84	78
Greece	82	83	na		371 M	82		82
Hungary	75	75	74			75		%H
Ireland	111	104	na		114 M	104		97
Italy	96	§90	na		2,260 M	90	98	na
Latvia	*60	55	57			55		%H
Lithuania	61	61	60			61		%H
Netherlands	104	98	Na		646 M	98		105
Poland	69	68	69			68		
Portugal	89	83	83		394 M	83		94
Romania			45					%H
Slovak R.	*83	56	56			92		%H
Slovenia	75	75	114			75		%H
Spain	na	90	na		1,598 M	90		95
Sweden	96	92	na		384 M	92	114	90
UK	88	87	87		2,129 M	87	84	85
Norway	114	na	na		207 M	107	124	
Switzerland			na	426,040k		89		
Croatia			na	136M		71		
Turkey			95			95		
Albania			na					% H
Belarus			50					
Bosnia			na					
Macedonia			¥72					
Moldova			61					
Serbia			na					
Ukraine			na					
Armenia			na					
Azerbaijan			na					
Georgia			96					
Kazakhstan			59					
Russia			na					

*na – not available, *2002, §1991, ¥1994, %H = distribution of dwellings by size of heated area.*

1.4.1.2 Residential sector number of buildings (stock)

Table 1.20 outlines data availability for stock in thousands.

Odyssee provides a time series from 1990 on for EU 15 data and from 1995 on for NMC 10 for all countries except Belgium, France, Ireland, Poland and Czech Republic. Odyssee also differentiates between the number of permanently occupied and total dwellings.

HSEU provides periodic time series stock data for 1990, 1995, 2000, 2001 and 2002 for EU 25 countries. UNECE provides periodic time series stock data (1993, 1997, 2001, and 2002) for all European countries, although with irregular information for Spain, Greece, Czech Republic and Belgium within the EU. All UNECE data presented in Table 1.18 is for 2001 or 2002 unless stated. EPA – ED provides stock for 2003 for Denmark, Greece, The Netherlands and Austria only. Energy Charter provides stock for the following countries: Sweden (2006), Denmark (2004), Czech Republic (2004), Romania (2006), and Switzerland (2006). EPA – ED gives approximations, while the Energy Charter data comes from national sources or from the UNECE. Ecoheatcool provides data for 32 of our 40 countries for 2005, although again is heavily reliant on the aforementioned sources. Enper Tebuc presents approximations for EU 15 plus Norway. ECH is not listed, given that there are newer sources available. Mure is also not listed as it obtains its stock data from Odyssee for year 2000.

In comparing the data from Odyssee, HSEU and UNECE a pattern emerges. Each entry in the column for HSEU or UNECE is either approximately equal to the data from Odyssee for total number of dwellings or for permanently occupied dwellings. The two exceptions are Belgium and Greece. Thus it would seem reasonable to accept data from any of these three sources provided it was quite clear whether the number referred to total or only permanently occupied dwellings. Some caveats remain. UNECE harmonises its stock data whereas the HSEU accepts each countries unique definition. Thus despite Table 1.20 making it seem obvious which data from HSEU and UNECE represents permanently occupied dwellings, this is not always stated explicitly in HSEU definitions and that we know from Section 1.1.5 that the UNECE definition of a dwelling covers both occupied and unoccupied dwellings.

If it exists, Odyssee data for permanently occupied dwellings is obtained from member organisations. Otherwise the number of households in the country is used as a proxy. Where they exist they are perhaps estimates made by national teams and as such may not have the same level of quality as Odyssee total stock, HSEU or UNECE data, which undoubtedly come from well established official sources. The difference Odyssee states in private correspondence with the author (Enerdata, 2007) that total stock is defined as permanently occupied dwellings plus week-end/summer house plus unoccupied dwellings. If the estimation methodology is the same for all sources, and this appears to be the case examining Table 1.20, than there should be no problems with Odyssee data for permanently occupied dwellings.

For total stock of dwellings two EU countries for which consistent data is hard to come by are Belgium and the Czech Republic. Since 1991, there is only one measurement of the entire Czech dwelling stock contained in Odyssee, and that is for 2001. The same figure is presented by the UNECE, while the figure for the HSEU is from 2000. However, the HSEU figure is obviously for permanently occupied dwellings. For Belgium, the figure presented by the HSEU for 2003 is 4820. The figure presented by the same organisation for 2002 is 4249. This would indicate that 600 000 houses were built in Belgium in 2002. This cannot be the case. For example, Spain is currently undergoing a boom in construction, has a population four times that of Belgium and still only managed to build 500 000 dwellings in 2006. The Odyssee permanently-occupied figure of 4362 for 2003 thus seems more realistic. The only UNECE figure presented for Belgium comes from 1993.

For non-accession countries the UNECE data is the only source available apart from information contained in one Energy Charter report for Switzerland. For Armenia, Ukraine and Russia and other countries of the former Soviet Union, the convention has been to present dwelling stock in millions of square metres.

Odyssee is the only unbroken time series of data available. As such use of its total data can be recommended, given that it is generally of the same order as that for the HSEU and UNECE. If missing data is to be supplemented by HSEU or UNECE we must bear in mind the aforementioned caveats. If we wish to cover non–EU countries, then it will be necessary to harmonise Odyssee and UNECE data or simply just to use UNECE data for all countries if a time series is not required again bearing in mind that the UNECE data seems to vacillate between that for total and permanently occupied dwellings.

Table 1.20 : Total stock of dwellings per country in thousands for European residential sector, from various sources.

'000	Odyssee PO*	Odyssee*	HSEU*	UNECE§	EPA – ED	Energy C.	EcoheatC.	Enper T.
Austria	3267	3766	3259	3284	3200		3280	3700
Belgium	4362		4820	3839¥			4820	4000
Bulgaria	2818	3697		3692			3692	
Czech	3904	4366§	3828¥	4366		3890	4366	
Denmark	2451	2778	2561	2540	2400	2759	2561	2500
Estonia	595	624	624	624			624	
Finland	2604	3070	2574§	2574			2574	2400
France	24,706		29495§	29495			29495	28700
Germany	35,910	39142	38158§	38925			38925	37000
Greece	3730	4192	5465§	5465	4300		5465	4700
Hungary	3743	4104	4134	4104			4134	
Ireland	1369		1554	1387			1554	1300
Italy	22068	27758	26526§				26526	25000
Latvia	901	967	967	958			967	
Lithuania	1292	1291	1292	1295			1292	
Netherlands	6663	6810	6811	6764	6500		6811	6600
Poland	12596		11764	11763			11764	
Portugal	3738	5398	5318	5225			5318	4700
Slovak R.	1680	1889	1665§	1725			1885	
Slovenia	756	791	778§	785			785	
Spain	14187	21973	14184§	20823			20947	18700
Sweden	4214	5000	4351	4329			4351	4300
UK	24595	25770	25617§	25617			25617	25000
Romania				8129		8129	8129	
Norway	2003	2001		1985			1985	1900
Switzerland				3638		3672	3638	
Croatia				1851			1852	
Turkey							16236	
Albania				785				
Belarus				216				
Bosnia								
Macedonia				597¥				
Moldova				1293				
Serbia				3151¥				
Ukraine				1026				
Armenia				67512				
Azerbaijan				99				
Georgia				98¥				
Kazakhstan				4580				
Russia				2818				

*2003, §2002 or 2001 or 2000, ¥ 2000 or pre-2000, po = permanently occupied

Alternatively we could use the Odyssee permanently-occupied material, for which there is a full data set for EU 25. Such a choice would be acceptable if we accept the current lack of transparency with respect to how Odyssee data is obtained. An apparent advantage is that Odyssee says, in private correspondence with the author (Enerdata, 2007), that energy use in the residential sector is better correlated to permanently occupied dwellings than with the entire stock of dwellings.

Data on new dwelling construction and demolition is available from UNECE and HSEU. Odyssee contains data on new build only.

1.4.1.3 Residential sector dwelling stock age distribution

Data presented from the HSEU and the UNECE show a close correlation for this category. Data from EPA – ED is only for four countries. Data from ECH and MURE is ignored due to more recent data for the same data category being available from the UNECE. Out of interest we show EPA – ED data in Figure 1.1. The data presented in Figure 1.1 for Greece and Holland does not conform to the same convention used to divide dwellings up as used for Austria and Denmark, or that used by the UNECE and HSEU, thus making comparisons difficult.

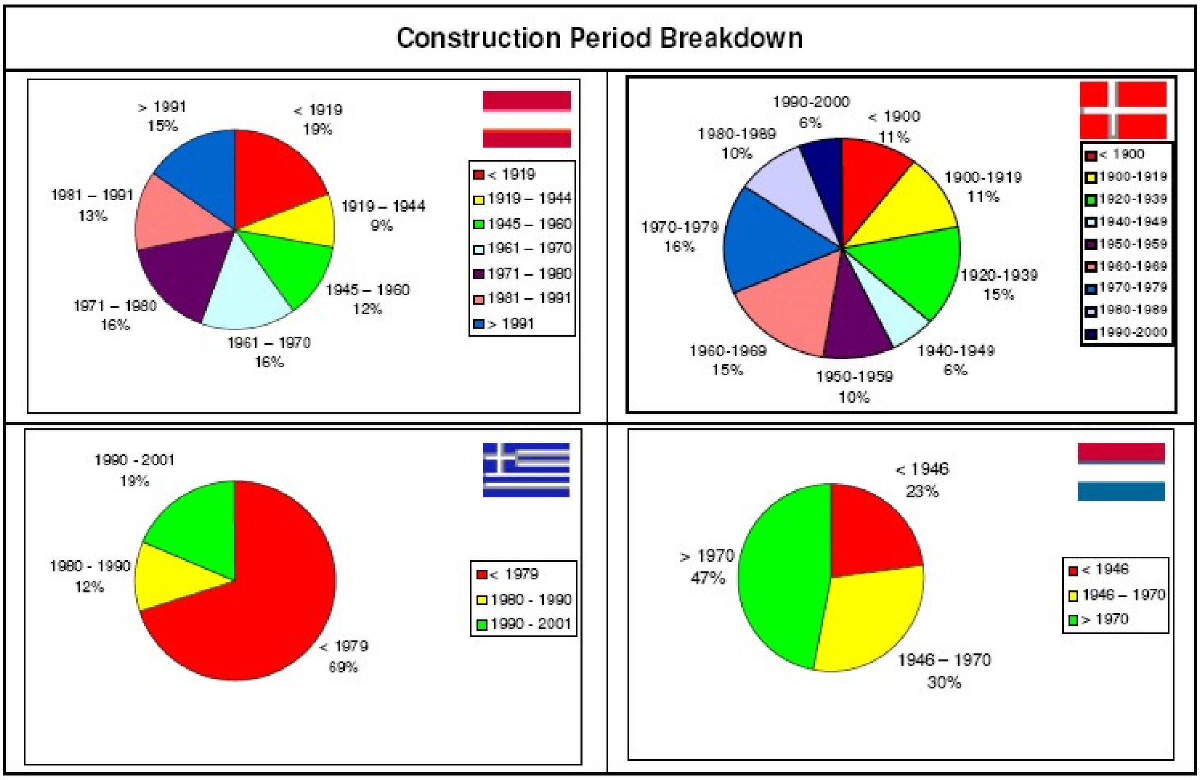

Figure 1.1 : Dwelling age distribution charts for Austria, Denmark, Greece and The Netherlands. This chart is taken from the EPA – ED report (National Observatory of Athens, 2003).

In Table 1.21 to Table 1.23 we present HSEU and UNECE age distribution data for a sample of three countries, in order to compare sources.

The difference in the age of the data from the HSEU and UNECE seems to be the obvious explanation for the differences between the two sources, especially since all construction periods have slightly less percentage of dwellings for HSEU than for UNECE, except the latest period which would be accounted for by the additions to stock in 2003. As such, it is reasonable to use HSEU, but only because it is slightly newer than that of the UNECE.

Table 1.21 : Percentage of dwelling stock per construction period of residential sector in Denmark as presented in HSEU (Swedish National Board of Housing, Building and Planning, 2005) and UNECE (UNECE, 2006).

Denmark	Construction period	HSEU 2002 %	UNECE 2001 %
	Before 1919	20.2	20.9
	1919 – 1945	16.9	17.8
	1946 – 1970	28.3	29.8
	1971 – 1980	17.6	16.4
	1981 – 1990	9.7	9.4
	After 1990	7.4	5.2

Table 1.22 : Percentage of dwelling stock per construction period of residential sector in Austria as presented in HSEU (Swedish National Board of Housing, Building and Planning, 2005) and UNECE (UNECE, 2006).

Austria	Construction period	HSEU 2002 %	UNECE 2001 %
	Before 1919	18.6	18.3
	1919 – 1945	8.1	8.4
	1946 – 1970	27.4	28.1
	1971 – 1980	15.9	16
	1981 – 1990	12.4	12.7
	After 1990	17.6	16.6

Table 1.23 : Percentage of dwelling stock per construction period of residential sector in The Netherlands as presented in HSEU (Swedish National Board of Housing, Building and Planning, 2005) and UNECE (UNECE, 2006).

Netherlands	Construction period	HSEU 2001 %	UNECE 1999 %
	Before 1919	7.1	8
	1919 – 1945	13.2	12.7
	1946 – 1970	30.9	31.8
	1971 – 1980	18.9	19.6
	1981 – 1990	29.8	16.5
	After 1990		11.4

HSEU has data collected in this decade for all EU 25 except Italy, whose data is from 1991. The UNECE presents no data for Italy. The UNECE covers all EU countries except Estonia, Italy, Spain, Sweden and the UK, and also does not cover the following non–EU countries; Switzerland, Croatia, Albania, Bosnia, Moldova, Armenia, Azerbaijan, Georgia, Kazakhstan, or Russia. As such, the HSEU covers more countries than the UNECE.

1.4.1.4 Summary of international data available for European residential sector building stock characteristics

Table 1.24 summarises data availability for a characterisation of EU residential sector building types and construction. Table 1.25 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. Numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final row of Table 1.24 and Table 1.25.

The field building stock growth rate we deem to be uncritical to our analysis, given that we already have a time series for the stock of buildings available. Data in time series based on different dwelling types is limited to eight countries, due to the Odyssee SFD/MFD split being available only for that many. Surprisingly, Odyssee can tell us how many single-family dwellings Italy has, but not how many multi-family dwellings, and thus that country is not included in our list.

If we accept data for a single year snapshot, we can cover 22 EU countries. Simply by using HSEU data we can know floor area, age and type of dwelling for all the EU countries we are interested in. If we wish to divide dwellings between low-rise and high-rise multi-family dwellings, we can cover fourteen EU countries. In time series, coverage that includes dwelling type is limited to eight countries. The same is true for harmonised data. As the HSEU data is official data, we cover 22 EU countries under that heading.

For non-EU countries, data is scarce. There are four countries for which we know floor space and age.

Table 1.24 : Summary of international data available for EU residential sector building types and construction.

EU	Time series	Snapshot	Harmonised	Official Data
Dwelling Stock	Odyssee (19) Odyssee PO (22) HSEU (22) UNECE (23)	Odyssee (19) Odyssee PO (22) HSEU (22) UNECE (23) Ecoheatcool (24)	Odyssee(19) Odyssee PO (22) UNECE (23)	HSEU (22) UNECE (23)
Floor area	Odyssee (21)	Odyssee (21) HSEU (22) UNECE (24) Ecoheatcool (24)	Odyssee(21) UNECE (24)	HSEU (22) UNECE (24)
Dwelling type	Odyssee permanently occupied SFD, and MFD (8)	HSEU SFD/MFD (22), LRMFD (22) HRMFD (14)	Odyssee (8)	HSEU SFD, LRMFD (22), HRMFD (14)
Dwelling age	Divide floor area according to UNECE breakdown (16), HSEU (22)	UNECE(16), HSEU (22)	UNECE(16), HSEU (22)	UNECE(16), HSEU (22)
Building growth rate	New build from Odyssee (22)	Demolish (20), New build from HSEU(22)	Odyssee(22) UNECE – time series new build (16), single year new build (3), time series demolish (11) single year demolish (4)	HSEU – new build rate (22) UNECE – time series new build (16), single year new build (3), time series demolish (11) single year demolish (4)
# Countries	Eight by dwelling type because of Odyssee SFD and MFD. 19 by sector	24 by sector or based on HSEU 22 by dwelling type or 14 if HRMFD/ LRMFD split desired	Eight by dwelling type because of Odyssee SFD and MFD. 19 by sector	24 by sector or based on HSEU 22 by dwelling type or 14 if HRMFD/ LRMFD split desired

Table 1.25 : Summary of international data available for non-EU residential sector building types and construction.

Non-EU	Time series or snapshot
Floor area	10 from UNECE, ECH & Energy Charter.
Dwelling type	1 from ECH
Dwelling age	UNECE age breakdown (5)
Building growth rate	UNECE new build time series (12), time series demolished (9)
# Countries	Floor space and age for (4) for sector.

1.4.1.5 Building types and construction in the service sector

In general, the level of data collection that has taken place for the service sector in Europe is significantly less than that for the residential sector. The main reason for this is that as housing is a social need, there is political will to monitor its development, while the same political motivation is absent for the service sector.

Our original idea defined in Section 1.1.5 was, where possible, to obtain the relevant building stock data for the following service sector branches:

- Commerce
- Hotel and restaurants
- Offices and administration
- Education
- Health and social work
- Other community social and personal service activities

As will be shown there are only a handful of European countries that can provide a time series or even single-year data for the whole service sector building stock or for individual branches.

We begin this section by looking at floor space data for the whole sector and for the branches listed above. Data for the actual number of buildings is of little use, given the diversity of building types in the sector. No complete data set on age distribution has been found either. EPA – NR does, on occasion, contain data for both stock and age categories, and is mentioned below. Data in the service sector for Eastern European non-EU countries is restricted to that found in Ecoheatcool and the Energy Charter.

1.4.1.6 Service sector floor area

Table 1.26 utilises Odyssee, EPA – NR, IEA 30, Ecoheatcool and the Energy Charter to display available data on total floor space of buildings. Odyssee data is from 2003. EPA – NR is for various years between 1997 and 2004. IEA 30 data is from 1998. Ecoheatcool's data is from 2005. Ecoheatcool provides the most comprehensive list and actually provides data for 32 European countries including Croatia and Turkey, although it provides only estimates for those whose value is not included in Table 1.26 (Euro Heat & Power, 2006)**.** The main issue with the Ecoheatcool data is that it is not harmonised, and is taken from a variety of sources. Its data is also for one year only. It is not possible to see from EPA – NR how the figures it presents for floor space are defined. This data is presented as responses to questionnaires sent to participating national organisations. However, each response includes references to the data sources used, so we can say that this data is transparent. As an EU funded project, and given that its data is traceable, it may contain better data than Odyssee. However, at the same time, it is probable that the countries that provide floor space data to Odyssee are those in which this kind of data is systematically collected and publicly available, and thus there should be no issues with the quality of Odyssee data. Furthermore Odyssee has time series data, whereas EPA – NR is only for one year. There are obvious discrepancies in the EPA – NR data as well. The floor space data presented for Spain and Slovenia are nearly equal. A closer examination of the EPA – NR reports for both countries reveals that according to data presented, non-residential buildings make up about 1/8 of the total building floor space in Spain, while they make up almost a third in Slovenia, although this latter total is only for buildings constructed after 1959**.** The figure for Spain is obviously too small, especially compared with that given for France, and compared to the residential/non-residential ratios for other countries.

Thus for time series and for harmonised data Odyssee is the only source. If single-year data is sufficient, all sources can be used to cover EU countries, although not all will be for the same year of measurement. However, this data will not be harmonised. Ultimately, the total floor area data category for the service sector may not be so useful, given the diversity of energy uses that exist in the sector between, say, hotels and offices.

Table 1.26 : Total floor area per country in thousands of square metres for European service sector buildings from various sources.

‘000m^2	Odyssee	EPA – NR	IEA 30	Ecoheatcool	Energy C
Austria					
Belgium					
Bulgaria					
Czech				100000	
Denmark	109890	310332	102,421	114000	103620
Estonia				2314	
Finland	89530	124159	86015	101000	
France	839260	814590	772495	861000	
Germany	*1789330	950000		1852000	
Greece				149000	
Hungary					
Ireland					
Italy			403233	453000	
Latvia					
Lithuania	*30100			14000	
Netherlands				183000	
Poland					
Portugal		81249		126000	
Slovak R.				81000	
Slovenia		20312		16000	
Spain		23200		341000	
Sweden	141700	118000	152290	161000	
UK	846620		744610	892000	
Norway	97860		69417		
Romania					
Switzerland				136000	142265
Croatia				33000	32000
Turkey				268000	

** not available in time series.*

1.4.1.7 Service sector floor area per branch

Table 1.27 presents Odyssee floor space data for various branches of the service sector for 2003. These are the same countries for which total floor space data is available from Odyssee and shown in Table 1.26.

Table 1.27 : Total floor area per branch and country in square metres for European service sector buildings from Odyssee (Odyssee, 2006).

Odyssee/ 2006/ ‘000m^2	Health	Education	Trade	Offices	Hotel & Rest.	Admin.
France	97	170	193	180	56	
Sweden	19	37	15	33	8	
UK	29	113	315	91	80	27
Denmark	4	19			6	
Finland	10	17	21			
Norway	11	17			4	
Germany*	60	169	490	263	344	112
Lithuania*		9			6	

** not available in time series.*

The branch data for Odyssee and EPA – NR has not been directly compared. A cursory examination has revealed inconsistent uniformity between the two sources.

Odyssee multi-branch data is available only for France, Sweden, the UK and Germany. It is also available for Finland, if we accept data for three branches as being sufficient. However, the data for Germany and Lithuania is not available in time series. EPA – NR is available on a multi-branch basis only for France, Sweden, Finland and Greece.

Table 1.28 shows the branches in countries for which floor space data is available from EPA – NR. The last column lists countries for which the total number of buildings for the sector as a whole is presented.

This data category, floor space of the service sector, is infamous for its absence from statistics, and as such we should not be surprised by the amount of data available. If it proves to be of any use, given the limitations in numbers of countries covered, either EPA – NR or Odyssee data is adequate for our purposes, with Odyssee having the time series advantage and EPA –NR having the transparency advantage.

Table 1.28 : Indication of floor area data per branch and country and stock of buildings data per country available for European service sector buildings from the EPA – NR report (National Observatory of Athens, 2006).

EPA – NR/ 2006	Health	Education	Trade	Offices	Hotel & Rest.	Admin.	*# Buildings*
France	●	●	●	●	●		
Sweden	●	●	●	●	●		●*
UK			●				●
Denmark		●		●	●		●
Finland	●	●	●	●			●
Norway							
Germany							●§
Spain	●						●¥
Estonia							●¥
Greece	●	●		●	●		●
Italy							●
Lithuania							●‡
Austria				●			●

**only for limited number of branches, §estimate, ¥far too low…, ‡ new buildings only*

As previously stated however, given the countries in which they are located, the organisations that supply Odyssee with service sector floor space data do in all likelihood supply good quality data, such that the Odyssee data should be as good a choice as that of EPA – NR.

1.4.1.8 Age distribution of building stock in the service sector

Detailed data for this category is scarce. EPA – NR presents data for Austria. EPA – NR also lists the amount of buildings built during certain periods for certain countries, for example new buildings in Belgium from 1988 to 1998. Ecofys presents floor area for EU 15 divided into old, recent and newly built floor area. This could be used in conjunction with the floor space data given in the previous two sections to provide a rough estimate of building age distribution. However, the Ecofys data is estimated based on the numbers of persons employed in the service sector (Ecofys, 2004).

1.4.1.9 Summary of international data available for European service sector building stock characteristics

Table 1.29 summarises data availability for a characterisation of EU service sector building types and construction. Table 1.30 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. Numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final row of Table 1.29 and Table 1.30.

We do not include building growth rate due to a lack of data and because a time series for building floor area is available. For a characterisation of the sector we have sufficient data for three to five countries dependant on whether we wish undertake a characterisation by branch in a time series or for a single year. If we do not need a per-branch characterisation, we have data for between five and eleven countries, again dependant on whether we need time-series data or whether a single year's data is sufficient. There is no official data available for this category.

As Table 1.30 shows, there is insufficient data for non-EU countries for us to perform any type of a stock characterisation.

Table 1.29 : Summary of international data available for European service sector building types and construction.

EU countries	Time series	Snapshot	Harmonised	Official data
Floor area total	Odyssee (5)	EPA – NR(8), Ecoheatcool (19)	Odyssee (5)	Not available
Floor area by branch	Odyssee (3)	EPA – NR(4) Odyssee (5)	Odyssee (3)	Not available
Building age	Ecofys estimates for EU 15	Ecofys estimates for EU 15	Ecofys estimates for EU 15	Not available
# Countries	Three by branch or five by sector.	Five by branch (two of EPA – NR and Odyssee do not overlap), eleven by sector (overlap of Ecoheatcool and Ecofys).	Three by branch or five by sector.	Not possible.

Table 1.30 : Summary of international data available for non-EU service sector building types and construction.

Non-EU	
Floor area total	Ecoheatcool (3)
Floor area by branch	Not available
Building age	Not available
# Countries	0

1.4.2 Building energy use

This section goes through total energy use, fuel use and energy end use data availability for both the residential and the service sectors, and summarises findings in Section 1.4.2.3 and Section 1.4.3 respectively. This section details the information contained in the source categories outlined in Section 1.3.2.

1.4.2.1 Total energy in the residential sector

The data presented by Odyssee, IEA and Eurostat for total energy use in the residential sector for 2004 are listed in Table 1.31 for comparison purposes.

There is a very close alignment between the data except for that for France, Germany, Italy, Spain and the UK. One could speculate from this that the differences between the other countries are significant but not obvious, due to the low quantities of energy involved. Against this, the data for another large country, Poland, is consistent through all three sources. In fact, the only figure which seems to be way off is the Odyssee amount listed for Germany. As such, if the reason behind this apparent anomaly were known, Odyssee data could be used. If coverage of more countries were needed, IEA data could be used. On this point, Odyssee states in private correspondence with the author (Enerdata, 2007), that the significant difference for the German data here is that the IEA and Eurostat include agriculture and small businesses in the service sector. However, this cannot be the only explanation, as in this instance it is only dwellings that all three organisations claim to measure.

Table 1.31 : Total energy consumption for the European residential sector compared, from the energy balances of Odyssee, IEA and Eurostat for 2004.

2004/ ktoe	Odyssee	IEA	Eurostat
Austria	6990	7051	6829
Belgium	9870	10080	10013
Bulgaria	2100	2085	2104
Czech	5770	5837	5840
Denmark	4330	4279	4264
Estonia	1160	996	1165
Finland	4930	5016	4987
France	47860	48520	41862
Germany	64820	76272	77018
Greece	5360	5441	5366
Hungary	6000	6032	6002
Ireland	2880	2816	2854
Italy	28760	30187	30052
Latvia	1440	1427	1426
Lithuania	1370	1368	1369
Netherlands	10220	10430	10430
Poland	17410	17640	17423
Portugal	3150	3217	3032
Romania		7875	7970
Slovak R.	2630	2666	2665
Slovenia	1240	1248	1237
Spain	16280	14684	14365
Sweden	7860	7152	7140
UK	45460	44852	43347
Norway	3840	3881	3875
Switzerland		6075	
Croatia		1892	1884
Turkey		17894	17186
Albania		352	
Belarus		5757	
Bosnia		612	
Macedonia		488	
Moldova		859	
Serbia		3359	
Ukraine		24265	
Armenia		152	
Azerbaijan		3359	
Georgia		1046	
Kazakhstan		507	
Russia		134749	

1.4.2.2 Energy end use in the residential sector

Table 1.11 highlighted the source options for energy use data. We reproduce again in Table 1.32 the columns dedicated to energy end use data. We begin by looking at data for thermal heating use for space, water and cooking. Of the four sources available, IEA 30 covers only seven EU countries plus Norway, and dates from 1998, while EPA – ED covers only four EU countries. ECH is over eight years old now, and for one year per country. Thus it would seem that in terms of residential sector heating end use data that Odyssee is “the only show in town”. The question remaining is more than the reliability of Odyssee data and also if it provides data for various end uses in which we are interested. Furthermore Odyssee is the only source to give data for space heating energy use disaggregated between single-family and multi-family dwellings.

Table 1.33 shows what Odyssee thermal energy end use data exists for EU 25. It also compares Odyssee data with that from the four EPA – ED countries. Although limited to four countries, EPA – ED provides a wealth of information in its reports for the four countries, such as energy use per house type and per period of construction. In fact, EPA – ED gives an ideal level of disaggregation for any analysis of where exactly energy is being used in dwellings. For EPA – ED data for Austria, Denmark and The Netherlands, we are given percentages of total sector energy per end use. The total energy use data that these percentages are based upon are from the national sources that EPA – ED used in its data compilation, and has not been investigated in this report. As the actual totals themselves are not given in EPA – ED, Eurostat energy balances for 2001 have been used to calculate energy end use from the EPA – ED percentages.

Table 1.32 : Energy end use data categories available for European residential sector from various sources.

	Space	Water	Appliances	Lights	Year
Odyssee	●	●	●	●	1980 to 2004
IEA EB					2004
IEA 30	●	●	●		1998
ECH	●	●	●	●	1995
EPA – ED	●	●	●		2004
Energy C					2004
Eneper T					2004
Enper E					2006
Ecoheatcool					2005
Remodece			●	●	2008

The data from Odyssee and EPA – ED for Austria in Table 1.33 show a good match. The EPA – ED data for Denmark provides different end use percentages depending on age and type of house. Again we see a reasonable match. However, the data for Greece is quite different between sources, so one would question the methodology used by the EPA – ED here. However, as one of the coordination teams of the EPA – ED project was a Greek university (National Observatory of Athens, 2003), one would expect reasonable quality data in that case. The space heating data for The Netherlands shows a good match, whereas that for water heating does not. Nevertheless, this is ok, because the EPA – NR data comes from 1997 and there has been a rise in energy consumption for water heating in The Netherlands over recent years (Odyssee, 2006). Overall, if accepting EPA – ED as a benchmark, we can be satisfied that for space and water heating Odyssee data is of the right order for at least three of the four countries covered. There is insufficient data available from EPA – ED for cooking to compare with that available from Odyssee.

No heating end use data is available for Belgium, Estonia, Ireland, Poland or Slovakia, apart from that in ECH. Table 1.33 shows that Odyssee provides data for space heating, water heating and cooking for eleven of the 24 EU countries we are interested in. If we ignore cooking, we come up to 14 countries. Of the data for these 14 countries we have, one problem is that some of it is certainly estimated. Statistics for energy used for water heating are not collected in Sweden, for example, yet Odyssee includes a value of 1570 ktoe for them.

Overall, the Odyssee data, while probably estimated in many cases, is the only data set available for thermal end – uses and, as such, should be a starting point for related work. Another consideration is that the Odyssee project has staked its reputation on providing comprehensive energy end use data. In addition to this, the project has continued to collect data for over ten years, and thus would have developed quite some experience with the matter.

Table 1.33 : Comparison of Odyssee (Odyssee, 2006) and EPA – ED (National Observatory of Athens, 2003) energy end – use data available for the European residential sector for space, water and cooking heating.

2003/ ktoe	Space heating		Water heating		Cooking	
	Odyssee	EPA – ED§	Odyssee	EPA – ED§	Odyssee	EPA – ED§
Austria†	5160	77.1 % = 5508	810	814 =11.4%	140	2.8 % = 200
Belgium						
Bulgaria	1590					
Czech						
Denmark¥	2920	54 to 71 % \ 2360 to 3103	710	8.5 to 16 % \ 372 to 699	60	na
Estonia						
Finland	2890		1240			
France	32590		3710		2580	
Germany	50590		7310		1620	
Greece‡	3940	61 % = 2665	240	10 % = 437	290	na
Hungary**	*5080		*790		*1080	
Ireland						
Italy	19750		2940		1510	
Latvia	*1150					
Lithuania	*1191		100		180	
Netherlands	6440	69 % = 6993	2010	16 % = 1622	490	na
Poland						
Portugal			50			
Slovak R.						
Slovenia	710		60			
Spain	6480		4040		1670	
Sweden	4880		1570		190	
UK	25850		10080		1210	

** Not available in Time Series, **1996, ‡ 2001, †2002, § % of purchased energy for EPA – ED, ¥ actual value dependant on type of dwelling and age, na = not available*

A second edition of the IEA 30 is due out this year, which should have data that could be useful for comparison purposes and perhaps cover more countries than the first edition did. No end use data is has been found for non-EU countries except Norway.

Space heating, water heating and cooking can also be done exclusively using electricity. Odyssee provides data for electricity use for these end uses for 15 EU countries. Odyssee also provides data on electricity use for appliances and lighting for the same 15 countries. Table 1.34 compares data from Odyssee and EPA – ED, again for these two data categories. As with the previous example, EPA – ED data is given as percentages of overall energy use, so Eurostat data for total energy use for the sector for 2001 has been used to calculate the actual quantity. In all cases except the amount given for lighting in Greece there are large differences between the two sources. The differences are so large in fact that they certainly warrant further examination before recommending the use of the Odyssee data. In defence of Odyssee, however, the EPA ED figures are taken from a graph and as such it is difficult to be sure of their detail.

Odyssee is the only source found with data for energy use for lighting. Of the EU 27, however, this is available only for Austria, France, Germany, The Netherlands, Spain, Sweden, Bulgaria and Slovenia. On the other hand, data is provided for electricity use for appliances and lighting. This is available for EU 15 except Belgium and Ireland, although only for Bulgaria, Lithuania and Slovenia of the NMC 12.

Table 1.34 : Comparison of Odyssee (Odyssee, 2006) and EPA – ED (National Observatory of Athens, 2003) energy end – use data available for the European residential sector for electrical appliances and lighting.

2001/ ktoe	Appliances		Lighting	
	Odyssee	**EPA – ED§**	**Odyssee**	**EPA – ED§**
Austria†	480	12 % (771)	130	2% (129)
Denmark	*670	17 % to 22 % (749 to 969)		2 % to 3 % (88 to 133)
Greece	*740	23 % (1077)		3 % (141)
Netherlands	1070	15 % (1581)	320	2 % (211)

* = figure is for appliances and lighting, *†2002, § % of purchased energy for EPA – ED*

No data has been found on electricity consumption for air conditioning.

Odyssee energy use per housing type is restricted to data on energy use for space heating in single-family and multi-family dwellings. This information is provided for six countries of the EU 15. No data has as such been found which compares data for other energy end uses such as water heating and appliances dependant on dwelling type. Differences in these energy uses across various dwelling types should not be significant, except perhaps that there would be more illuminated area in a house than in an apartment and perhaps more people too.

Despite the differences shown with the EPA – ED data, Odyssee energy end use data for both thermal and electric end uses should be our starting point for data for these categories. There are, as stated previously, a number of reasons for justifying this.

1.4.2.3 Summary of international data available for European residential sector energy use

Table 1.29 summarises data availability for an energy use analysis of EU residential sector buildings. Table 1.36 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. Numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final row of Table 1.35 and Table 1.36.

Table 1.35 : Summary of international data available for EU residential sector energy use.

EU	Time series	Snapshot	Harmonised	Official data
Total energy	Eurostat (27)	Eurostat (27)	Eurostat (27)	Eurostat (27)
Total energy per house type	Odyssee for space heating (6)	Odyssee for space heating (6)	Odyssee for space heating (6)	Not available
Energy thermal end – uses	Odyssee (14)	Odyssee (14)	Odyssee (14)	Not available
Energy electricity end – uses	Odyssee (15)	Odyssee (15)	Odyssee (15)	Not available
# Countries	Six per type of dwelling. Twelve per sector	Six per type of dwelling. Twelve per sector	Six per type of dwelling. Twelve per sector	Not possible

The limitation in this section is the energy end use data. This is available only for 13 EU countries. Data for the energy end use per type of dwelling is available for space heating for only six EU countries. If we want to have an analysis per dwelling type, we have to accept that it will cover only the space heating end use. A single-year view of energy use is restricted to dependency on the Odyssee energy end use data, and as such the result is the same. These findings must be qualified by the fact that there exists no data on VAC, and insufficient data on lighting, for them to be covered by an end use analysis. An official data analysis is also not possible due to there being no energy end use data of that grade.

As Table 1.36 shows, the lack of information on energy end use in non-EU countries precludes the possibility of an energy end – use analysis for these countries although the ECH report was not examined given its age.

Table 1.36 : Summary of international data available for non-EU residential sector energy use.

non-EU	
Total energy	IEA (16)
Total energy per house type	Not available
Energy end – use	Not available
Degree-days	Not available
# Countries	0

1.4.2.4 Total energy use in the service sector

Table 1.37 shows total fuel consumption for the service sector from the IEA, Eurostat and Odyssee energy balances.

Table 1.37 : Total energy consumption for the European service sector compared, for three sources from Odyssee, IEA and Eurostat energy balances for 2004.

2004/ ktoe	Odyssee	IEA	Eurostat
Austria	2910	3005	2795
Belgium	4080	4079	4036
Bulgaria	700	695	692
Czech	3560	3475	3560
Denmark	1800	1979	1977
Estonia	380	383	381
Finland	2770	1767	1789
France	21350	15518	25406
Germany	31330	24349	23496
Greece	*1660	1784	1774
Hungary	3450	3447	3446
Ireland	1710	1709	1630
Italy	14820	12452	12442
Latvia	630	638	636
Lithuania	550	552	552
Netherlands	8380	8300	7585
Poland	6020	6068	6019
Portugal	2150	1868	2020
Romania		1330	1418
Slovak R.	1480	1433	1439
Slovenia	630	310	282
Spain	8660	7771	7579
Sweden	4000	4561	4542
UK	17820	16794	17861
Norway	2390	2433	
Switzerland		3778	
Croatia		641	637
Turkey		3763	3763
Albania		165	
Belarus		1582	
Bosnia		97	
Macedonia		226	
Moldova		258	
Serbia		204	
Ukraine		2764	
Armenia		28	
Azerbaijan		198	
Georgia		216	
Kazakhstan		71	
Russia		20450	

= 2003

All IEA and Eurostat data is within 1000 Mtoe of each other, except that for France, Portugal and the UK. Odyssee data is within 1000 Mtoe of Eurostat data for all countries except France, Germany and Italy. The consistency shown in the data would make it seem reasonable either to choose Odyssee data for service sector fuel type purposes or to choose IEA data if coverage of non-EU countries is needed. However, the large differences in data presented from the three sources, especially for Germany and France, should be investigated before proceeding. If, as Odyssee states in private correspondence with the author (Enerdata, 2007), the IEA and Eurostat include agriculture and small business in the service sector this would not explain why, despite this, the Odyssee value for Germany is so much greater or why the value for France is smaller. The explanation may be that the differences are simply due to corrections and queries made by the IEA and Eurostat after the receipt of data. Interestingly, the amount of energy used in the service sector in Germany is greater than that used in Russia.

1.4.2.5 Total energy use per branch in the service sector

Odyssee provides total energy use in time series for six branches for eight of the EU 15 countries. However, the data is very erratic between the countries.

Table 1.38 : Countries for which total energy use data for at least three branches of the services sector is available from various sources.

	Odyssee	ECSS	MURE	EPA NR
Austria	●	●	●	●
Belgium		●	●	●
Bulgaria				
Czech				
Denmark	●	●	●	●
Estonia				
Finland		●		
France	●	●	●	●
Germany	●	●	●	
Greece		●		●
Hungary				
Ireland				
Italy		●	●	
Latvia				
Lithuania				
Netherlands	●		●	●
Poland				●
Portugal	●	●	●	●
Slovak R.				
Slovenia				
Spain	●	●	●	●
Sweden		●	●	●
UK	●	●	●	●

In some cases data is justfor three sequential years, while for others it is periodic. Only Denmark, France and Spain have a consistent long-term time series available for four branches or more. MURE provides information for 1995 for 15 EU countries for ten branches, although not all countries have complete coverage for every branch (see Table 1.42). Given the general lack of disaggregated data available for the service sector, we include the ECSS in our analysis despite its data being between ten and twelve years old. ECSS provide totals for six branches for twelve EU 15 countries, while EPA – NR provides data for fifteen EU countries from one up to ten branches per country. Such data is not available from Eurostat. Table 1.38 shows the countries for which data for three branches or more is available. Note that Poland is the only non–EU 15 country for which this kind of data has been found.

1.4.2.6 Energy end use in the service sector

Table 1.39, which is a section of Table 1.12, highlights sources which provide energy end use data for the service sector as a whole.

Table 1.39 : Availability of energy end – use data for the European service sector from various sources.

	Space	Water	Appliances	Lights	Year
Odyssee	●	●	●	●	1980 to 2004
IEA EB					2004
IEA 30					1998
ECSS	●	●	●	●	2002
EPA – NR	●	●	●		2006
MURE	●	●	●	●	1995
Energy C					2004
Eneper T					2004
Enper E					2006
Ecoheatcool					2005
El Teritiery			●		2008

Table 1.40 compares data from Odyssee, EPA – NR and ECSS for space and water heating. Both EPA – NR and ECSS present aggregated data for both end uses, while Odyssee provides end use data for space heating but no information for water heating. EPA – NR data is given either as a percentage or as an absolute figure. No attempt has been made to convert the percentages given into equivalent fuel amounts using national energy balances.

The most obvious feature of the data presented is the data gaps in the Odyssee data set. Data is available for only five EU countries. ECSS provides data for twelve of the 14 EU 15 countries we are interested in, although as stated previously, this data is between eight and twelve years old. It would, however, be classed as being official data. EPA – NR covers some countries additional to those that Odyssee covers**.** In some cases, for example with Belgium and Portugal, EPA – NR has used ECSS data. This is highlighted in Table 1.40.

Although the Odyssee space and water heating data involves estimates, it is available in time series up to 2004, and is harmonised and as such would appear to be the best choice for the limited data available for end uses in this sector. Data gaps could be complemented by data from EPA – NR and ECSS, if time series data are not necessary and bearing in mind the age of the ECSS data

EPA – NR is the only source found with data for energy end use data in the service sector for the ten NMC countries. As Table 1.40 shows, however, data is available only for Hungary, Latvia and Slovakia, and that for Slovakia is only for sports facilities. In addition to this, the only service sector branch information EPA – NR has is for energy use in offices in Slovakia, and for total education and healthcare in Poland.

Odyssee also provides data for electricity use for space heating for the sector as a whole for seven countries. If this were subtracted from total electricity use, one would have a figure for electricity for appliances and lighting for the sector if we assume that electricity for cooking and water heating is insignificant. However, air conditioning could make up a significant part of the non-space heating electricity use, which should be borne in mind. This space heating electricity use data category is available in time series for Denmark, Finland, France, Germany, and Sweden, with single-year values for The Netherlands and the UK.

Table 1.40 : Comparison of Odyssee, EPA – NR & ECSS data for heating in service sector for EU 27 from Odyssee (Odyssee, 2006), EPA NR (National Observatory of Athens, 2006) & ECSS (Eurostat, 2002).

ktoe/ 2004	Space heating	Space & water heating		
	Odyssee†	**ECSS**	**EPA – NR (%)**	**EPA – NR (ktoe)**
Austria		1708	59 %	
Belgium		**2488**		**§2489**
Bulgaria				
Czech				
Denmark	1090	1027	‡ na	‡ na
Estonia				
Finland	1160	1311		
France	11550	10692	63 %	
Germany	13030	17360		
Greece		828	70 %	
Hungary*			48.9%	14114
Ireland				
Italy		8988		
Latvia			☼77 %	
Lithuania				
Netherlands			47 %	
Poland				
Portugal		**367**	39.8 %	**§367**
Slovak R.			¥na	¥na
Slovenia				
Spain		301	☼ 43 %	
Sweden		1582	62.1 %	1577
UK	*10720	1548	64 %	13400

*2001, †breakdown by branch available, ‡per square metre available, §from ECSS, ¥ available for sports facilities, ☼ space heating only.

Odyssee contains no data for service sector energy end uses by branch. Such information is contained in ECSS, EPA – NR and in MURE. ECSS has data for eleven EU 15 countries, MURE contains patchy branch end use data for all EU 15 for most branches, while EPA – NR contains data for the twelve countries for which it provides sector-wide data in Table 1.40. One would like to think that EPA – NR data is preferable to the other two sources, given that its results were published in 2004. However an analysis of the data it sources shows that most of it comes from the late 1990s. Table 1.41 illustrates an example of data for space and water heating energy use for the education sector from the three sources. Thus it seems that ECSS may be the highest quality of the three sources, given that it being a Eurostat-endorsed report would make it official data. EPA – NR as an IEE-funded project should have involved a reasonable allocation of resources for data collection while the MURE data are probably in-house estimates. Nonetheless, given the similarities between most of the sources in this example, we could mix and match data from all three sources for our purposes.

For electricity use for appliances by branch, which are very important in the service sector when one considers the likes of office equipment, Odyssee provides total electricity use for six branches. This is available in time series for Denmark, France, Italy, Netherlands, Spain, and Sweden, with somewhat more patchy data for Germany, Portugal and the UK. No data which actually divides this electricity use into that for lighting or appliances or VAC per branch is available from Odyssee.

Table 1.41 : Data for space and water heating energy use in the education sector for EU 25 compared, for three sources MURE (MURE, 1995), EPA – NR (National Observatory of Athens, 2006) and ECSS (Eurostat, 2002).

ktoe	MURE (1995)	ECSS (2002)	EPA – NR (2006)
Austria	188	343	
Belgium	353	376	376
Denmark		185	
Finland		211	259
France	1488	1817	*1717
Germany	2300	2103	
Greece			*150
Ireland			
Italy	71	346	
Netherlands	318		194
Portugal		15	15
Spain	52	26	3
Sweden	360	329	*330
UK	1766		*1591 (1997) to *1931(2000)

* = *space heating only*

ECSS contains data for both electric appliances and lighting for six service sector branches for EU 15, except Ireland and The Netherlands. For its time, this is a good collection. EPA – NR has data for electric appliances and lighting's share of consumption for the eleven countries listed in the EPA – NR column of Table 1.40. EPA – NR also shows the type of lighting apparatus installed. This is covered in Section 1.4.5.5 on energy apparatus.

MURE provides very comprehensive data for appliance and lighting use in the service sector. The following ten branches of the sector are covered:

- Commercial offices
- Distribution & warehousing
- Education
- Government offices
- Health
- Hotel & catering
- Other sectors
- Public buildings
- Retail
- Sport & leisure

Within these ten branches, the electricity consumption and percentage of total energy use for the following end – uses is given:

- Cooking
- Lighting
- Motors - drives
- Office machinery
- Other
- Refrigeration
- Space heating and domestic hot water
- Ventilation and air conditioning

The data presented in MURE appears to be different for all countries. Table 1.42 lists the number of the above ten branches for which data is available in each country. The two right-hand columns of the table show total energy use and, as an example, the percentage of total electricity used for lighting for the education sector. Countries for which there is only information for one or two branches have no data for the education sector.

Table 1.42 : Example of appliance & energy end use data available by branch for education branch of service sector for EU 15 from MURE (MURE, 2005).

MURE/ 1995	# Branches	Education	
		Total energy, ktoe	**Lighting % of total**
Austria	9	251	12
Belgium	10	410	9
Denmark	7	176	0
Finland	1		
France	10	0	11
Germany	9	0	8
Greece	2		
Ireland	1		
Italy	10	128	16
Netherlands	10	484	12
Portugal	10	16	29
Spain	6	185	60
Sweden	10	500	12
UK	9	0	9

Looking at the figures presented, we can ask how it is that when there is no overall figure for energy use - i.e. for France, Germany and the UK - there is still data available for the contribution of lighting. The answer is that there is data available for total electricity use but not total energy use. Overall the MURE service sector energy end use data gives a very comprehensive depiction of energy use on a per-branch basis. The data dates from 1995 and thus may be of more use as a benchmark for comparison purposes than for its actual values.

EPA – NR and ECSS both provide data for air conditioning, which is an increasingly important electrical load in the service sector. EPA – NR also provides data on the actual installation types. This is covered in Section 1.4.5.5 on energy-using apparatus below. In Table 1.43 we compare data from both sources for air conditioning in offices. The table shows that for Belgium, Portugal and Sweden, the EPA – NR takes its data directly from ECSS. This is highlighted. There are large differences for the two other countries for which data exists, Greece and The Netherlands. The Greek data for EPA – NR should be accepted, given that the project coordinators were Greek and that the figure cited is more in line with that for Italy despite the fact that Italy has a far larger population. For total energy use in the service sector for air conditioning and cooling, EPA – NR has data for a total of eleven countries, of which only Slovakia is in Eastern Europe.

No service sector end – use data has been found for non-EU countries except Norway.

Table 1.43 : Comparison of data available for air conditioning and cooling electricity use in the service sector from ECSS (Eurostat, 2002) and EPA – NR (National Observatory of Athens, 2006).

GWh	ECSS	EPA – NR
Austria	632	
Belgium	**1123**	**1123**
Czech		
Denmark	581	
Estonia		
Finland	1103	
France	2700	
Germany	462	
Greece	81	4462
Hungary		
Ireland		
Italy	4833	
Latvia		
Lithuania		
Netherlands	1145	1833
Poland		
Portugal	**200**	**200**
Slovak R.		
Slovenia		
Spain	1253	
Sweden	**61**	**61**
UK	750	

1.4.3 Summary of international data available for European service sector energy use

Table 1.44 summarises data availability for an energy use analysis of EU service sector buildings. Table 1.45 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. The numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final rows of Table 1.44 and Table 1.45.

Time series energy end use data is available with a strict thermal/electrical split only for the sector as a whole, and not at all on a per-branch basis. Thus, strictly speaking, no time series analysis can be undertaken for any country. Using a combination of ECSS, MURE and EPA – NR, data is available for a single-year analysis of twelve EU countries. The actual year chosen depends on what combinations of data are used. Given that ECSS is official data, using it alone allows a twelve-country analysis. However, as stated previously, the data in ECSS is between eight and twelve years old.

Table 1.44 : Summary of international data available for EU service sector energy use.

EU	Time series	Snapshot	Harmonised	Official data
Total energy	Eurostat (24)	Eurostat (24)	IEA (40)	Eurostat (24)
Total energy per branch	Odyssee (3)	Mix and match from Odyssee, ECSS, MURE, EPA – NR (12)	Odyssee (3) ECSS(11)	ECSS (11)
Energy end use	Odyssee (four, and only for space heating)	Mix and match from Odyssee, ECSS, MURE, EPA – NR (14)	Odyssee (four, and only for space heating) ECSS(11)	ECSS(12)
Energy end use per branch	Odyssee (three, but thermal and electricity split only)	Mix and match from Odyssee, ECSS, MURE, EPA – NR (13)	Odyssee (three, but thermal and electricity split only) ECSS(11)	ECSS(12)
# Countries	Three per branch, four per sector.	12 by branch to 14 by sector.	11 by sector or branch.	11 by sector or 12 by branch.

Table 1.45 shows that no energy analysis of non-EU countries is possible**.**

Table 1.45 : Summary of international data available for non-EU service sector energy use.

Non-EU	Snapshot
Total energy	IEA (16)
Total energy per branch	Not available except for Norway
Energy end use	Not available
Energy end use per branch	Not available
# Countries	0

1.4.4 Summary of top–down data

We now seek to combine the summaries contained in Section 1.4.1 and Section 1.4.2 to produce lists of the countries and relevant data categories for which we have found useful data for a top-down statistical analysis of energy use in buildings. For both the residential and service sector, we show data available under two separate headings. First by house or branch type, and secondly for the entire stock of buildings in each sector.

In addition to this, we include details on degree-day data which can be used for climate correction of energy use statistics across both sectors

The methodology used in compiling the summary tables is to cross-reference countries using the aforementioned categorisation so as to finally list the countries for which a complete data set for a top-down statistical analysis exists. The judgement criterion is strict with regard to whether a country is included in the final set. The country must have a full data set for all significant categories in Section 1.4.1 and Section 1.4.2 . If, for example, the country is included in the building characteristics row but not in the energy end use row of the summary tables, then it is excluded from the final row.

The first two rows of Table 1.46 and Table 1.47 show the countries of the residential sector for which we have a complete set of building physical characteristics and energy end use data respectively. The final row cross-references the first two rows, to give a complete list of EU countries which we can describe using a top-down statistical analysis of the development of energy use in the entire stock. Table 1.49 and Table 1.50 do the same for the service sector.

Table 1.46 : Summary of EU countries for which relevant data on building characteristics and energy end – use is available for residential sector on a per-house type basis.

EU	Time series	Snapshot	Harmonised	Official data
Building characteristics per house type	Austria, Denmark, France, Germany, Greece, Ireland, Sweden, UK (1990 to 2002)	Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France , Germany, Greece , Hungary, Ireland , Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom	Austria, Denmark, France, Germany, Greece, Ireland, Sweden, UK	Austria, Belgium, Bulgaria , Czech Republic, Denmark, Estonia, Finland, France , Germany, Greece , Hungary, Ireland , Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom
Building energy end use	Austria, Denmark, France, Germany, Italy, UK (1990 to 2003)	Austria, Denmark, France, Germany, Italy, UK	Austria, Denmark, France, Germany, Italy, UK	Not available
Complete dataset available for	Austria, Denmark, France, Germany, UK (1990 to 2002)	Austria, Denmark, France, Germany, Italy, UK	Austria, Denmark, France, Germany, UK	Not possible

Looking at Table 1.46 and Table 1.47 which cover the residential sector, one can see that the number of countries for which a complete data set exists is limited. For building characteristics and energy end use data aggregated across the entire building stock, a complete data set is available for thirteen EU countries both in time series and for a single year. The reason that the same set of countries exists in time series, snapshot and harmonised data form is that the Odyssee database which provides data in time series is the source of much of the energy end use data. If we wish to divide the dwelling stock by house type, data exists for only five countries in time series, and six for a snapshot. It should be noted that only two NMC countries are listed in Table 1.46 and Table 1.47. This is primarily due to a lack of energy end use data for these countries.

The lack of availability of data for energy end uses means that no non-EU country makes any of the final lists. In fact, the most we can produce with respect to non-EU countries is dwelling floor area broken down by age for four countries for the residential sector as whole, as shown in Table 1.48.

Table 1.47 : Summary of the EU countries for which relevant data on building characteristics and energy end – use is available for residential sector on a sector-wide basis.

EU	Time series	Snapshot	Harmonised	Official data
Building characteristics per sector	Austria, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Slovakia, Slovenia, Sweden, United Kingdom (1990 - 2003)	Austria, Belgium, Bulgaria , Czech Republic, Denmark, Estonia, Finland, France , Germany, Greece , Hungary, Ireland , Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom	Austria, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Slovakia, Slovenia, Sweden, United Kingdom	Austria, Belgium, Bulgaria , Czech Republic, Denmark, Estonia, Finland, France , Germany, Greece , Hungary, Ireland , Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom
Building energy end use	Austria, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, , Spain, Sweden, UK, Lithuania, Slovenia* (1990 - 2004)	Austria, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Spain, Sweden, UK, Lithuania, *Slovenia	Austria, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Spain, Sweden, UK, Lithuania, *Slovenia	Not available
Complete dataset available for	Austria, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Sweden, UK, Lithuania, Slovenia* (1990 - 2004)	Austria, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Spain, Sweden, UK, Lithuania, Slovenia	Austria, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Sweden, UK, Lithuania, *Slovenia	Not possible

* = Lithuania and Slovenia from 1997 onwards only

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Table 1.48 : Summary of non-EU countries for which relevant data on building characteristics and energy end – use is available for residential sector on a sector-wide basis.

EU	Time series	Snapshot*	Harmonised	Official data
Building characteristics per sector	Not available	Belarus, FYR Macedonia, Norway, Turkey	Belarus, FYR Macedonia, Norway, Turkey	Belarus, FYR Macedonia, Norway, Turkey
Building energy end use	Not available	Not available	Not available	Not available
Complete dataset available for	Not possible	Not possible	Not possible	Not possible

To conclude, there are nine EU countries (Austria, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Sweden, and UK) for which data exists on dwelling characteristics and energy end use, and how trends with these two parameters have developed since 1990. These countries account for over 70 % of EU final energy use in the residential sector. Thus it should be possible to undertake a statistical top-down analysis of energy use in the residential sector building stock in these countries, Data exists for five countries (Austria, Denmark, France, Germany, and UK) for the same analysis on a dwelling-type basis.

For non-EU countries, the data available for the residential sector could be used for a basic top-down analysis involving total energy use per unit for floor area for Belarus, FYR Macedonia, Norway, and Turkey.

Looking at Table 1.49 and Table 1.50, which cover the service sector, one can see that the number of countries for which a complete data set exists is also limited. For a time series analysis of energy use trends on a branch-by-branch basis, a full data set exists only for France. For a snapshot we have data for five countries. For building characteristics and energy end use data, aggregated across the entire building stock, a complete data set is available for three EU countries in time series or for eleven for a single year. The “harmonised” and “Official data” columns list a complete data set for eleven countries for energy end use data. This is primarily due to the comprehensive coverage of the sector available in the ECSS. However, this data is now between nine and twelve years old, and so is not included in the snapshot category, even though it includes the same type of data. It should be noted that no NMC countries are listed in Table 1.49 and Table 1.50. This is due to both a lack of building characteristics and energy end use data available for these countries.

Table 1.49 : Summary of the EU countries for which relevant data is available on building characteristics and energy end – use for the service sector on a per-branch basis.

EU	Time series	Snapshot*	Harmonised	Official data
Building characteristics per branch	France, Sweden, UK (1994 to 2003)	Finland, France, Greece, Sweden, UK	France, Sweden, UK	Not available
Building energy end use	Denmark, France, (1986 to 2004)	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Portugal, Spain, Sweden, UK	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Portugal, Spain, Sweden.	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Portugal, Spain, Sweden.
Complete dataset available for	France (1994 to 2003)	Finland, France, Greece, Sweden, UK	France, Sweden	Not possible

A lack of data for building age and for energy end uses means that a full set of service sector top down analysis data is not possible for non-EU countries.

For a sector wide analysis, there are thirteen countries (Denmark, Finland, France, Germany, Greece, Italy, Lithuania, Netherlands, Portugal, Slovenia, Spain, Sweden, and UK) for which much data exists on building characteristics and energy end use. For time series analyses, such data is restricted to three countries. However, the data set is somewhat older than that for the residential sector, and is generally available only for single years. Data exists for five countries (Finland, France, Greece, Sweden, and UK) for the same analysis on a branch-type basis. Data for a per-branch time series analysis is available only for France.

Odyssee present time series data for degree-days for EU 25 plus Bulgaria and Norway from 1990. In private conversation with the author (Odyssee, 2007b), Odyssee says this data comes from Eurostat. Eurostat does not, however, publish degree-day data on its web site, so the exact source of the Odyssee data is unknown. The latest Eurostat degree-day data is available from a publication entitled Panorama of Energy - Energy Statistics to Support EU Policies and Solutions (Eurostat, 2007). The data available from both sources differs, as

Table 1.51 shows for three countries. The Eurostat data is available from 2000 to 2004, with a long-term average from 1980 to 2004 as well. As stated, Odyssee data is available from 1990 to 2004 for all countries, and from 1980 on for most EU 15 countries. Odyssee also provide a long-term average value for each year from 1990 to 2004. The Odyssee data is thus more comprehensive. However, until the reason for the differences between both sources is known, and depending upon requirements, Eurostat data is the better choice, given that it is official data.

Table 1.50 : Summary of the EU countries for which relevant data is available on building characteristics and energy end – use for the service sector on a sector-wide basis.

EU	Time series	Snapshot	Harmonised	Official data
Building characteristics per sector	Denmark, Finland, France, Sweden, UK, (1995 to 2003)	Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Portugal, Spain, Sweden, UK.	Denmark, Finland, France, Sweden, UK	Not Available
Building energy end – use	Denmark, Finland, France, Germany (1995 to 2003)	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Portugal, Spain, Sweden, UK	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Portugal, Spain, Sweden.	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Portugal, Spain, Sweden.
Complete dataset available for	Denmark, Finland, France (1995 to 2003)	Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Portugal, Spain, Sweden, UK	Denmark, Finland, France, Sweden	Not Possible

Table 1.51 : Comparison of degree-day data available from Eurostat (Eurostat, 2007c) and Odyssee (Odyssee, 2006) for 2004.

2004/ Degree-days	Eurostat	Odyssee
Germany	3186	3078
Spain	1915	2320
Sweden	5268	3420

1.4.5 Energy-using apparatus in buildings

This section goes through energy-using apparatus in buildings for both the residential and the service sectors, summarising the findings in Section 1.4.5.4 and Section 1.4.5.6 respectively. The point with this section is to highlight the apparatus that may be substitutable or may be used in a less energy-consuming way. This section details the information contained in the source categories outlined in Section 1.3.3.

1.4.5.1 Thermal equipment in the residential sector

As stated previously the only data source found that tells us about the types of heating devices installed in the residential sector is EPA – ED. Figure 1.2 presents heating devices and systems breakdown for the four countries that EPA – ED examines.

An examination of Figure 1.2 shows that the format in which the data is presented for each of the four countries differs, making it difficult to utilise the data.

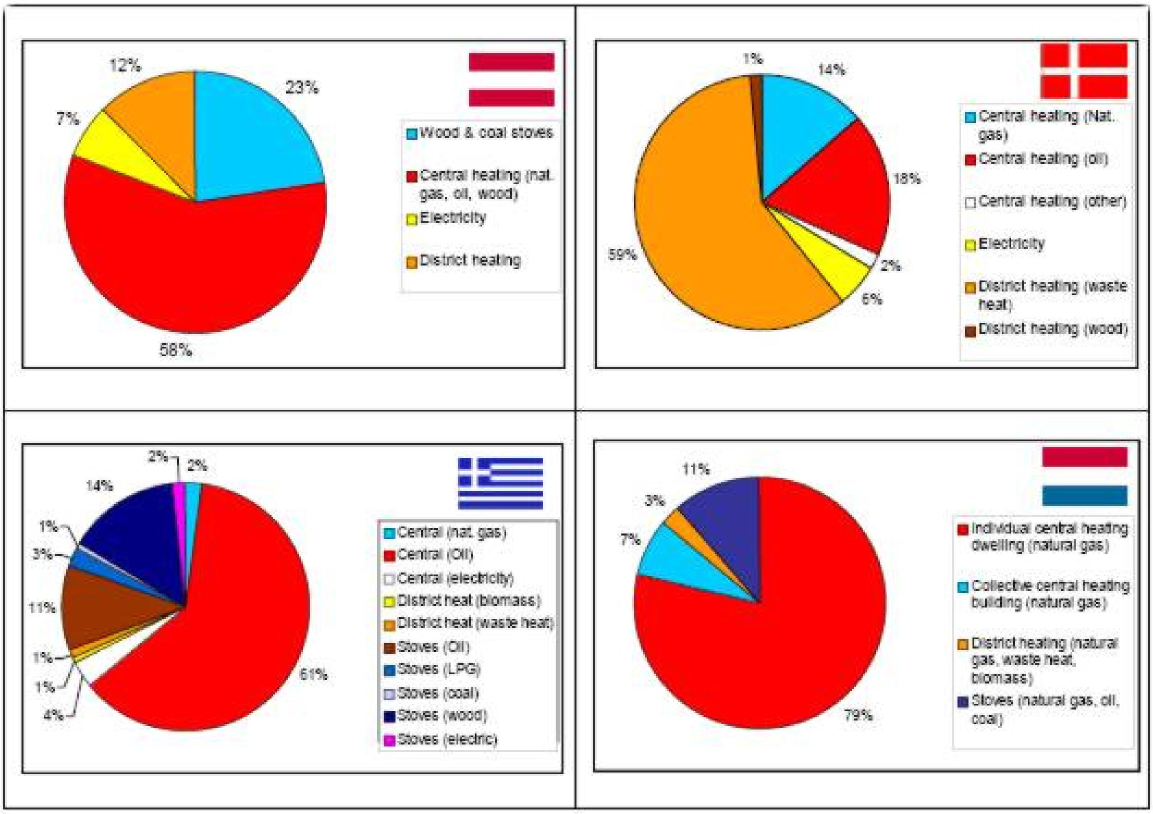

Figure 1.2 : Heating devices and systems installed in dwellings for four EU countries. This diagram comes from the EPA – ED report (National Observatory of Athens, 2003).

Odyssee provides the following data on installed heating systems, which can be important information given that anecdotally it is stated that energy for heating doubles in an average dwelling when central heating is installed.

- Stock of permanently occupied dwellings with group heating (GH)
- Stock of permanently occupied dwellings with individual central heating (ICH)
- Stock of permanently occupied dwellings with room heating (RH)

Both MURE and ECH contain data on the number of stand-alone water heating devices and combined water and space heating systems installed. Although the MURE data is newer, the ECH data would in all probability have had more resources devoted to its collection and thus be of higher quality. Odyssee has data for individual water heating devices in place for six EU 15 countries.

Thus it seems we have no useful information on space heating devices installed, but rather just on heating systems in place. No data has been found on cooking apparatus used, either.

No data has been found on the specific fuel mixes used for thermal equipment or the number of installations per dwelling type.

1.4.5.2 Building heating practise in the residential sector

This type of data is available on a national level from MURE only. In Table 1.52 we present some of the values available from MURE, but have no reference with which to judge their accuracy. There are less differences between countries in the data presented here than in Table 1.59, which shows MURE data for dwelling U-values for EU 15. It is hard to say if specific “data mining” was undertaken for each country. There will obviously be differences between countries in average external temperatures and daily working periods for equipment. Judging from the similarities in the data presented in Table 1.52 it is considered that the data are rough estimates. Again, however such data is our only inter-country starting point available for these categories.

Table 1.52 : Building heating Practise in the residential sector from MURE for three countries (MURE, 2000). Data are national averages.

MURE/ 2000	Parameter	Denmark	France	Portugal
Temperatures	**Internal temp**	18	18	18
	Average external temp.	3	7	10
	Diff. internal & ground temp	20	20	20
Working period for heating equip.	**Hours per day**	15	12	10
	Days per year	220	100	100
Average eff. of heating equip.	**Solid fuel**	0.72	0.48	0.55
	Oil	0.72	0.60	0.65
	Gas	0.78	0.78	0.70
	Electricity	0.97	0.95	0.95

1.4.5.3 Electrical equipment in the residential sector

This section covers electrically-powered equipment such as domestic appliances, lighting and VAC systems. For appliances, Odyssee provides data for stock, penetration in dwelling stock and average consumption per year. Consistent stock data is available for 16 EU countries. Stock penetration is not that critical to our report, as with a combination of stock and average annual power consumption we can obtain overall appliance end-use data. This last data category is actually classed as an Odyssee indicator, as opposed to general raw data, given that it is a function of the appliance power rating and its annual hours of use. For appliance-specific consumption, Odyssee has data for nine of the EU 15 but not for any NMC countries.

Table 1.53 presents data available from Odyssee and MURE for a sample of three countries. MURE provides data for all EU 15 countries, although some entries - for example the stock of freezers in The Netherlands - are left blank. For comparison purposes we have used Odyssee 2000 data even though Odyssee data is available up to 2004. There are similarities between both sources for the stock for washing machines and TVs, although not for refrigerators. We are only able to compare consumption data for The Netherlands. This shows consistencies for refrigerators and TV's but not for washing machines. This is inconclusive. Given that Odyssee data is available for time series, and partially covers NMC, we can recommend it be used. MURE does, however, provide data which is not available from Odyssee, namely:

- Annual growth rates (percentage annual increase in number of appliances)
- Average lifetime of the appliance
- Average investment cost for an average appliance in euro

If time series data were not needed, and given the slight similarities in data between Odyssee and MURE in Table 1.53 above, we could mix and match from both sources for our needs, bearing in mind that the MURE data is only currently available for the year 2000. Similar data may become available later this year, when the Remodece project presents results.

No further international data on appliance stock or the take-up of CFL light bulbs has been found. It should be noted that the formula for calculating the ODEX indicator (See Section

2.5) does not include lighting, due to the lack of data on the take-up of CFL light bulbs in Europe. No data has been found on types of ventilation or cooling systems installed.

Table 1.53 : Comparison of Odyssee & MURE data available for appliances in the residential sector for four countries from MURE (MURE, 2000) and Odyssee (Odyssee, 2006).

2000/ '000/kWh/yr	Country	Refrigerators		Freezer		Washing machine		TV	
		Stock	Consum.	Stock	Consum	Stock	Consum	Stock	Consum
MURE	Netherlands	11320	380	0	0	6530	130	11820	174
Odyssee	Netherlands	7607	395	3714	380	6532	231	11822	171
MURE	Spain	15490	837			13270	315	19900	0
Odyssee	Spain	12935	na	3679	na	12671	na	20988	na
MURE	Hungary								
Odyssee	Hungary	3745	na	2548	na	2278	na	4247	na
MURE	Poland								
Odyssee	Poland	13069	na	5373	na	9523	na	13271	na

na = not available Consum = electricity consumption in kWh/yr

No service sector energy apparatus data has been found for non-EU countries, except for Albania and Norway.

1.4.5.4 Summary of international data available for European residential sector energy-using equipment

Table 1.54 summarises data availability for energy-using equipment analysis of EU residential sector buildings. Table 1.55 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. The numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final rows of Table 1.54 and Table 1.55.

For EU countries the limitation with energy-using equipment is that no data exists for heating devices or for cooking, lighting or VAC systems. Thus we are restricted in terms of the technology substitution possibilities that we can investigate. Table 1.54 shows that due to the lack of data for key apparatus, a full data set is not available for any EU country except for the single-year data that EPA – ED provides. **Table 1.55** shows that the same is true for non-EU countries. The category building heating practice listed in Table 1.54 we deem to be uncritical for now.

Table 1.54 : Summary of international data available for EU residential sector energy using apparatus.

EU	Time series	Snapshot	Harmonised	Official data
Heating system	Odyssee (11)	Odyssee (11)	Odyssee (11)	Not available
Heating device	Not available	EPA – ED (4)	Not available	Not available
Building heating practise	Not available	MURE (EU 15).	Not available	Not available
Cooking devices	Not available	Not available	Not available	Not available
Appliances, lighting & VAC system installed	Odyssee appliances only (18)	Odyssee appliances only (18)	Odyssee appliances only (18)	Not available
# Countries	Not possible	Four by sector	Not possible	Not possible

Table 1.55 : Summary of international data available for non-EU residential sector energy-using apparatus.

non-EU	Time series
Heating system	ECH (2)
Heating devices	Not available
Building heating practice	Not available
Cooking device	Not available
Appliances, lighting & VAC	ECH (2)
# Countries	0

1.4.5.5 Heating, ventilation and lighting systems in the service sector

Odyssee service sector data does not contain any reference to heating systems installed, but EPA – NR does. As the EPA – NR results presented are responses to questionnaires, the data returned varies from country to country. Table 1.56 indicates the countries and service sector branches therein, for which indications of heating systems and other equipment installed can be found from EPA – NR.

Table 1.56 : Heating and other energy service systems installed in EU countries for four service sector branches (offices, education, health care and hotels) or for sector as a whole (National Observatory of Athens, 2006).

EPA – NR / 2006	Heating systems	Water heating	HVAC	Lighting
Austria	Offices, education, hotels	Offices, education, hotels	Offices, education, hotels	Offices, education, hotels
Belgium				
Bulgaria				
Czech				
Denmark				
Estonia	Health care			
Finland				
France				
Germany	Aggregated for whole sector	Aggregated for whole sector	Aggregated for whole sector	Aggregated for whole sector
Greece	All four branches	All four branches	All four branches	All four branches
Hungary	Aggregated for whole sector	Aggregated for whole sector		
Ireland				
Italy				
Latvia	All four branches			
Lithuania	Aggregated for whole sector	Aggregated for whole sector		Aggregated for whole sector
Netherlands	All four branches		Offices	
Poland	All four branches	All four branches	Offices, healthcare, hotels	All four branches
Portugal	Sports facilities		Sports facilities	
Slovak R.	Sports facilities	Sports facilities		Sports facilities
Slovenia				
Spain				
Sweden	All four branches	All four branches		
UK	Offices			

The data listed is only for offices, education, health care and hotels, which roughly corresponds to four of the NACE categories listed in Section 1.1.1, or for the sector aggregated as a whole.

Limited though the data in Table 1.56 is, it could be useful for estimation purposes. For examples of estimation see Appendix H.

No data has been found on the specific fuel mixes used for thermal apparatus.

No data has been found on the stock of appliances used in the service sector. As such we have no information on the penetration of, for example, office equipment.

No service sector energy apparatus data has been found for non-EU countries.

No data has been found for heating practice in the service sector.

1.4.5.6 Summary of international data available for European service sector energy-using apparatus.

Table 1.57 summarises data availability for energy-using apparatus analysis of EU service sector buildings, and Table 1.58 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. The numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final row of Table 1.57 and Table 1.58.

As the data available from EPA – NR is available only for a single year, this is the only type of analysis possible. Due to the lack of data on heating devices, a full data set is not possible for any country. Table 1.58 shows that the same is true for non-EU countries.

Table 1.57 : Summary of international data available for EU service sector energy-using apparatus.

EU	Time series	Snapshot	Harmonised	Official data
Heating system	Not available	EPA – NR (9)	Not available	Not available
Heating device	Not available	Not available	Not available	Not available
Appliances, lighting & VAC system installed	Not available	EPA – NR (4)	Not available	Not available
Appliances, lighting & VAC system installed per branch	Not available	EPA – NR (3)	Not available	Not available
# Countries	Not possible	Not possible	Not possible	Not possible

Table 1.58 : Summary of international data available for non-EU service sector energy-using apparatus.

non-EU	
Heating System	Not available
Heating Devices	Not available
Appliances, Lighting & VAC	Not available
Building Heating Practise	Not available
# Countries	0

1.4.6 Building envelope characteristics

This section goes through building envelope characteristics for both the residential and the service sectors, and summarises findings in Section 1.4.6.2 and Section 1.4.6.4 respectively. The point with this section is to highlight the U-values that may be improved. This section details the information contained in the source categories outlined in Section 1.3.4.

1.4.6.1 Residential sector dwelling envelope characteristics

Data for this category is available only from MURE, ECH and EPA – ED[†††]. MURE provides a complete data set for both single and multi-family dwellings for the categories outlined in Table 1.3 for old, recent and newly built dwellings for EU 15. Table 1.59 gives an example of the MURE data for new single-family and multi-family dwellings. EPA – ED provides some related data for four countries, such as diffusion rates for various building envelope technologies; for example, double glazing or air tightness. ECH lists the numbers of dwellings with insulation for EU 15 in 1998.

ECH also gives the percentage of the entire dwelling stock for EU 27 plus Albania that has one of the following characteristics:

- No insulation
- Loft/roof insulation
- Cavity wall insulation
- Floor insulation
- Double glazing

However, no attempt has been made to utilise this ECH data, given that it would involve estimating insulation thicknesses.

Table 1.59 : Inter-country comparison of building characteristics data for EU 15 for new dwellings from MURE (MURE, 2000).

MURE/ 2000/ U-values	Conductivity (W/m^2) in single-family dwelling	Conductivity (W/m^2) in multi-family dwelling
Austria	0.43	0.55
Belgium	0.92	1.37
Denmark	0.31	0.42
Finland	1.63	1.99
France	0.6	1.02
Germany	0.42	0.55
Greece	0.86	1.03
Ireland	0.68	1.81
Italy	0.90	1.09
Netherlands	0.67	0.79
Portugal	1.17	1.55
Spain	0.69	0.96
Sweden	0.44	0.89
UK	0.93	0.99
Norway	0.37	0.53

[†††] At the time of this reports publication a list of U-value regulations in force in a selection of regions across Europe was received from EURIMA the insulation manufacturers association.

Although both the MURE and the ECH data are over five years old, they are useful in the sense that most of the houses they describe are still in existence.

MURE also provides thermal conductivity data for a number of types of insulation that can be used to replace that currently in use. The only possible issue with this data is that for most countries and most categories the same values are presented. Table 1.60 lists data relevant to external panels for wall insulation. While the panels could, for example, be of the same brand in each country, it is doubtful if costs would be the same in each country. One gets the impression from the data presented that a lot of it has been estimated, although with some exceptions where data was available. This pattern is repeated for most other building insulation information available from MURE. For now, however, this is the only data available of this type. To improve on this situation it would be necessary to undertake further research into sources of this type of data or wait for the next version of MURE to appear.

Table 1.60 : Inter-country comparison of building characteristics data for EU 15 for one example of new insulation materials from MURE (MURE, 2000).

MURE/ 2000/ External panels – wall insulation	Conductivity (W/m^2)	Default thickness (cm)	Variable cost (€/cm)	Installation cost (€/m^2)
Austria	4.2	8	30.95	1.22
Belgium	4.2	8	30.95	1.22
Denmark	4.2	8	30.95	1.22
Finland	4.2	10	30.95	1.22
France	4.2	8	30.95	1.22
Germany	4.2	8	30.95	1.22
Greece	0.05	4	30.95	1.22
Ireland	4.2	8	30.95	1.22
Italy	4.2	6	30.95	1.22
Netherlands	4.2	8	30.95	1.22
Portugal	4.2	4	30.95	1.22
Spain	0.49	5	4.73	1.34
Sweden	4.2	10	30.95	1.22
UK	4.2	8	30.95	1.22
Norway	0.22	20	0	0

1.4.6.2 Summary of international data available for European residential sector dwelling envelope characteristics

Table 1.61 summarises data availability for building envelope characteristics for the EU residential sector buildings, and Table 1.62 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. The numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final rows of Table 1.61 and Table 1.62.

For building envelope characteristics U-value data is only available for the EU 15 from MURE and then only for a single year. As Table 1.62 shows no data is available for non-EU countries.

Table 1.61 : Summary of international data available for EU residential sector dwelling envelope characteristics.

EU	Time series	Snapshot	Harmonised	Official data
Building envelope	Not available	MURE U-values for old, recent, and new dwellings (14).	MURE U-values for old, recent, and new dwellings (14).	Not available
# Countries	Not possible	14 by sector	14 by sector	Not possible

Table 1.62 : Summary of international data available for non-EU residential sector dwelling envelope characteristics.

non-EU	Time series
Building envelope	0
# Countries	0

1.4.6.3 Service sector building envelope characteristics

Data for this category is available from EPA – NR and Ecofys. As stated in Section 1.3.4, the MURE service sector module has no database of U-values such as those in the MURE residential module, while Odyssee also provides no U-value data for either sector. EPA – NR provides data for

- Wall U-value
- Roof U-value
- Glazing U-value

for the whole service sector and where available for four branches (offices, health care, education & hotels).

Table 1.63 : Inter-country comparison of building characteristics data available for EU 25 for service sector from EPA – NR for the sector as a whole or for four branches (offices, health care, education, hotels) (National Observatory of Athens, 2006)

EPA – NR/ 2006	U-values for walls, roofs and glazing.
Austria	Average for four branches for all three building envelope components
Belgium	Average for sector for all three building envelope components
Czech	Average for sector for all three building envelope components
Denmark	Average for four branches for all three building envelope components
Estonia	Average for sector for all three building envelope components
Finland	Average for sector for all three building envelope components
France	
Germany	Average for sector for all three building envelope components
Greece	Average for four branches for all three building envelope components
Hungary	
Ireland	Average for sector for all three building envelope components
Italy	
Latvia	Average for sector for all three building envelope components
Lithuania	
Netherlands	Average for sector for all three building envelope components
Poland	Average for sector for all three building envelope components
Portugal	Average for sector for all three building envelope components plus for sports facilities
Slovak R.	Average for sector for all three building envelope components plus for sports facilities
Slovenia	Average for sector for all three building envelope components
Spain	Average for sector for all three building envelope components
Sweden	Average for sector for all three building envelope components
UK	Average for sector for all three building envelope components plus for offices

Most of the data presented seem to be an average for the sector for each of the three building envelope components, although some are estimates. This is explicitly stated in the report for Denmark with the line "All numbers are rough estimates!" under the table describing their data. Table 1.63 summarises data available from EPA – NR.

Ecofys provide different U-values for old, recently constructed and new buildings across Europe, divided into three climatic zones. They also have U-values for those buildings that have been retrofitted. The data presented are "roughly established" and obviously not as detailed as the EPA – NR data, which is on a country-by-country basis (Ecofys, 2004).

No data at all has been found on types of insulation or glazing materials or their respective thicknesses for the service sector.

1.4.6.4 Summary of international data available for European service sector dwelling envelope characteristics

Table 1.64 summarises data availability for building envelope characteristics for the EU service sector buildings, and Table 1.65 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. The numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final rows of Table 1.64 and Table 1.65.

U-value data for building envelope characteristics is available from EPA – NR and Ecofys only for a single year. This is a reasonable level of coverage, given the usual problems with sourcing data for the service sector. As Table 1.65 shows, no data is available for non-EU countries.

Table 1.64 : Summary of international data available for EU service sector dwelling envelope characteristics.

EU	Time series	Snapshot	Harmonised	Official data
Building envelope	Not available	EPA – NR(18) plus estimates from Ecofys for EU 15	Ecofys for EU 15	Not available
# Countries	Not possible	18 by sector	15 by sector	Not possible

Table 1.65 : Summary of international data available for non-EU service sector dwelling envelope characteristics.

Non-EU	
Building envelope	Not available
# Countries	Not possible

1.4.7 Building fuel mix

This section goes through the fuels used for both the residential and the service sectors, and summarises findings in Section 1.4.7.2 and Section 1.4.7.6 respectively. The point with this section is to highlight the fuels that may be substitutable or may be used in a less consuming way. This section details the information contained in the source categories outlined in Section 1.3.5.

1.4.7.1 Residential sector fuel mix for thermal and electrical equipment

As listed in Table 1.11, the fuel mix in total energy consumption in the residential sector is available from many sources. Given that the IEA energy balances present this information, it would seem pertinent to use their data, given their established reputation. However, their publicly accessible data is available only for 2004. Eurostat's fuel mix data is available from its web site, and dates from 1990 to 2004. Sources other than those mentioned in **Table 1.11**, will not be discussed given that none would provide information that is not already included in IEA energy balances. Table 1.66 compares data for 2004 from three sources for five countries. As previously noted, both the IEA and Eurostat collect their data from the same questionnaire that they send to national statistics organisations.

In Table 1.66, we can see a close if not exact correlation between IEA and Eurostat data in many instances. Some Odyssee data is also similar. There are, however, large differences in some of the data presented by Odyssee, which would need to be examined. The figures given for coal consumption for Germany, Greece and the UK by Odyssee are clearly out of line with the other two sources. The data from Odyssee for petroleum products and combustibles in Sweden, and that for heat consumed in Germany, would also give cause for concern. The figure for combustibles for Sweden seems particularly strange, given that Odyssee lists this category as being wood products only, while for the IEA and Eurostat it is for combustibles, renewables and waste. Eurostat data is available in time series, despite it being a somewhat tedious task to access, and as such would seem to be the best option of the three presented for fuel type data, including total electricity use. The fact that the Eurostat and IEA data comes from the same questionnaire bolsters the authenticity of the Eurostat data. Differences arise between the two organisations due to the timing and query factors outlined in the description of Eurostat in Section 1.2. The only problem with Eurostat data is the time taken to access it through the Eurostat internet portal. If similar time series data for non accession countries was required, this could be purchased from the IEA.

Table 1.66 : Fuel mix for the residential sector in five countries, compared from the energy balances of Odyssee, IEA and Eurostat for 2004.

2004/ktoe	2004	Coal	Petroleum products	Gas	Combustibles/ renewables	Electricity	Heat
Germany	**IEA EB**	570	17620	28375	4585	12073	12664
	Odyssee	1170	17340	25560	4870	12040	3850
	Eurostat	691	17247	28375	4921	12071	13713
Greece	**IEA EB**	3	3103	35	702	1449	43
	Odyssee	40	3030	40	810	1450	na
	Eurostat	3	3028	35	808	1449	43
Portugal	**IEA EB**	0	787	181	1158	1069	9
	Odyssee	0	740	180	1160	1070	na
	Eurostat	0	602	181	1171	1069	9
Sweden	**IEA EB**	0	509	70	572	3558	2439
	Odyssee	0	860	70	980	3670	2270
	Eurostat	0	497	70	576	3558	2440
UK	**IEA EB**	1030	2941	30668	226	9935	52
	Odyssee	1310	3030	30680	520	9930	na
	Eurostat	1030	2886	30667	226	8164	363

Odyssee also has fuel mix per house type, but only for space heating and only consistently for six countries. Odyssee even divides energy fuel mix for heating between single and multi-family dwellings for EU 15, but only for Austria, Denmark, France, Germany, Italy, Sweden and the UK.

For fuel mix cross-referenced with thermal energy end use i.e. the fuel mix for space heating, water heating and cooking, Odyssee has data for twelve countries. Eleven are from EU 15 (no data for Belgium, Ireland or Portugal), while Lithuania is the only NMC country. Odyssee contains data for Slovenia and Bulgaria for fuel mix for space heating, but not for water heating or cooking. ECH also contains the same category of data. It provides consistent data on fuel mix for all EU 15 countries except Italy, and sporadic information for NMC 12 countries plus Albania and Norway. For this category the choice is thus between a time series from Odyssee or single year data (one of 1996 to 1998) from ECH at the level of detail outlined.

1.4.7.2 Summary of international data available for fuel mix for thermal and electrical equipment in the European residential sector

Table 1.67 summarises data availability for fuel mix for the EU residential sector buildings. Table 1.68 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. The numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final rows of Table 1.67 and Table 1.68.

For fuel mix, Table 1.67 and Table 1.68 shows that we are limited by the number of European countries for which we know fuel mix per end use or fuel mix per house type.

Table 1.67 : Summary of international data available for EU residential sector fuel mix.

EU	Time series	Snapshot	Harmonised	Official data
Fuel mix in total energy	Eurostat(24)	Eurostat(27)	Eurostat(27)	Eurostat(27)
Fuel mix per house type	Odyssee for space heating (6)	Odyssee for space heating (6)	Odyssee for space heating (6)	Not available
Fuel mix for energy thermal end – uses	Odyssee (12)	Odyssee (12)	Odyssee (12)	Not available
# Countries	6 to 12 depending on analysis sought	6 to 12, depending on analysis sought	6 to 12, depending on analysis sought	Not Possible

Table 1.68 : Summary of international data available for EU residential sector fuel mix.

Non-EU	Time series
Fuel mix in total energy	16
Fuel mix per house type	Not available
Fuel mix for energy thermal end – uses	Not available
# Countries	0 to 16, depending on analysis sought

1.4.7.3 Fuel mix for thermal and electrical equipment in the service sector

No comparison has been made of the fuel balance mix presented by Eurostat, the IEA or Odyssee for the service sector. Without undertaking any investigation, we can take as the default option to choose the same source for fuel mix as was chosen for the residential sector, as described in Section 1.4.7.1.

1.4.7.4 Service sector - fuel mix per branch

Odyssee does not provide fuel mix per branch, except to disaggregate electricity and thermal use of fuel for six countries. ECSS provides fuel mix per branch for twelve EU 15 countries. MURE does the same for ten branches for EU 15. Table 1.42 shows the number of branches for which MURE has data in each country. ECSS data should be chosen in preference to

MURE, given that it would be classed as official data. EPA – NR does not cover this category of data.

1.4.7.5 Service Sector fuel mix by end use

ECSS provide fuel mix by end use for the same twelve EU 15 countries for which it has data on fuel mix per branch. EPA – NR does not cover this category of data.

1.4.7.6 Summary of international data available for fuel mix for European service sector - thermal and electrical equipment

Table 1.69 summarises data availability for fuel mix for the EU service sector buildings. Table 1.70 does the same for non-EU countries. Data is divided into columns dependant on its temporal resolution, whether it is harmonised between countries and on whether it is official. Section 1.2 describes how official and harmonised data are defined. The numbers of countries covered for each category are in brackets. The idea with the summary is to show the number of European countries for which data is available under the different headings listed. Results are shown in the final rows of Table 1.69 and Table 1.70.

For fuel mix, Table 1.69 and Table 1.70 show that we are limited by the number of European countries for which we know fuel mix per end use or fuel mix per house type.

Table 1.69 : Summary of international data available for EU service sector fuel mix.

EU	Time series	Snapshot	Harmonised	Official data
Fuel mix in total energy	Eurostat(24)	Eurostat(27)	Eurostat(27)	Eurostat(27)
Fuel mix per branch	Not available	ECSS (12)	ECSS (12)	ECSS (12)
Fuel mix for energy thermal end – uses	Not available	ECSS (12)	ECSS (12)	ECSS (12)
# Countries	0 to 24, depending on analysis sought	12 to 27, depending on analysis sought	12 to 24, depending on analysis sought	12 to 27, depending on analysis sought

Table 1.70 : Summary of international data available for non-EU service sector fuel mix.

non-EU	
Fuel mix in total energy	IEA (16)
Fuel mix per branch	Not available
Fuel mix for energy thermal end – uses	Not available
# Countries	0 to 16, depending on analysis sought

1.4.8 Summary of bottom – up data

We now seek to combine the summaries contained in Section 1.4.5, Section 1.4.6 and Section 1.4.7 to produce lists of the countries and relevant data categories for which we have found useful data for providing a list of fuels and energy using apparatus that can be substituted in efforts to reduce energy consumption and greenhouse gas emissions. For both the residential and service sector we show data available under two separate headings. First by house or branch type, and secondly for the entire stock of buildings in each sector.

The methodology used in compiling the summary tables is to cross-reference countries using the aforementioned categorisation so as finally to list the countries for which a complete data set for a top-down statistical analysis exists. The judgement criterion is strict with regard to whether a country is included in the final set. The country must have a full data set for all significant categories in Section 1.4.5, Section 1.4.6 and Section 1.4.7. If, for example, the country is included in the building envelope characteristics row but not in the fuel mix row of the summary tables, then it is excluded from the final row.

The first two rows of Table 1.71 show the countries for which we have a complete set of data for energy-using apparatus, building envelope characteristics and fuel mix in the residential sector. The final row cross-references the first three rows to give a complete list of EU countries for which we can focus on what is substitutable in technology and fuel terms. Table 1.72 does the same thing for the service sector in the EU.

Looking at Table 1.71, which covers the residential sector, we can see that there are no countries for which a complete data set exists.

No data has been found on heating devices installed except for the four EU countries covered by EPA – ED. However, we do know what types of heating systems - i.e. central heating or room heating - are installed in dwellings across the EU. The only data available on electricity-using equipment is for electrical appliances, there being no data available on lighting or VAC installations. Data on U-values is available for a single year for fourteen countries. These are EU 15 countries. No U-value data has been found for any other European countries, except that from ECH which contains no dimensions with regard to insulation thickness installed. Data on fuel mix is obviously available for all European countries on an aggregated level for each sector. On a per-house type basis, it is available for six countries, but only for the space heating data that the Odyssee database provides.

We are thus limited in the components or apparatus that we can categorise as being substitutable. The lack of data available on energy-using apparatus suggests that estimation or individual country information may be the only solution available for now if we wish to have a comprehensive set of installed technology we can substitute (See Appendix H on estimation).

Table 1.71 : Summary of the EU countries for which relevant data on energy-using equipment, building envelope characteristics and fuel mix is available for the residential sector on both a sector-wide and a per-house type basis.

EU	Time series	Snapshot	Harmonised	Official data
Building thermal energy-using apparatus	Not available	Austria, Denmark, Greece, The Netherlands	Not available	Not available
Building electricity-using apparatus	Not available	Not available.	Not available	Not available
Building envelope characteristics	Not available	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom	Not available
Fuel mix	24 EU countries	24 EU countries	24 EU countries	24 EU countries
Fuel mix per branch and end use	Austria, Denmark, France, Germany, Italy, UK.	Austria, Denmark, France, Germany, Italy, UK.	Austria, Denmark, France, Germany, Italy, UK.	Austria, Denmark, France, Germany, Italy, UK.
Complete data set available for	Not possible	Not possible	Not possible	Not possible

It should be noted that no NMC EU countries are listed in Table 1.71. No U-value data has been found for these countries for the Residential Sector.

There is insufficient data in any category for non-EU countries.

To conclude, there exist no European countries for which a complete set of data from the residential sector covering energy-using apparatus, building envelope characteristics and fuel mix is available. However, if we ignore the absence of data on lighting and VAC, we do obtain a full set of data for a single year for Austria, Denmark, Greece, The Netherlands. In simple terms, Table 1.71 shows the data available for which substitution could be undertaken.

Looking at Table 1.72, which covers the service sector, one can see that the amount of countries for which a complete data set exists is limited.

Data on energy-using apparatus is limited to coverage of a handful of countries in snapshot. It is available for Austria, Germany, Greece and Poland, aggregated to sectoral level, and is also available for the first three of these countries on a branch-level basis. Building U-value data is available for eighteen EU countries. For fuel mix, again there is complete coverage of European countries for the sector as a whole, and for twelve countries on a branch basis, using data from the ECSS.

Table 1.72 : Summary of the EU countries for which relevant data on energy-using apparatus, building envelope characteristics and fuel mix is available for the service sector on both a sector-wide and a per-house type basis.

EU	Time series	Snapshot	Harmonised	Official data
Building thermal energy-using apparatus	Not available	Austria, Germany, Greece, (Poland)	Not available	Not available
Building electricity-using apparatus	Not available	Austria, Germany, Greece, (Poland)	Not available	Not available
Building envelope characteristics	Not available	Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Ireland, Latvia, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom	Not available
Fuel mix	24 EU countries	24 EU countries	24 EU countries	24 EU countries
Fuel mix per branch and end use	Not available	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Portugal, Spain, Sweden ,UK (1995 to 1998) (cess)	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Portugal, Spain, Sweden ,UK	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Portugal, Spain, Sweden ,UK
Complete data set available for	Not possible	Austria, Germany, Greece, (Poland).	Not possible	Not possible

The possibilities for technology substitution simulation in the service sector is thus just as limited as for the residential sector, except that there are actually some countries for which we have a full set of data for countries for the service sector aggregated as a whole.

There is also no data available for non-EU countries, apart from data for U-values and fuel mix for Norway.

1.4.9 Summary of macro-economic data

This section goes through macro economic data availability and summarises findings in Section 1.4.9.1. This section details the information contained in the source categories outlined in Section 1.3.6.

Most of the macro-economic data set needed is available from a combination of Eurostat, the HSEU, the UNECE and Odyssee. All four provide data for population. Eurostat provides data for GDP and GDP per-capita, while Odyssee and the UNECE provide data only for GDP, and HSEU provides only GDP per-capita.

Data from Eurostat is available by navigation through from the Eurostat homepage. The exact path to the data required is outlined for each category below, as it is difficult to find without a working knowledge of the Eurostat folder system. In general, Eurostat provides data for the EU 27 plus Croatia, Norway and Turkey.

The exact data available from Eurostat is outlined as follows:

- Population for EU 27 to 2006

Path to data from Eurostat web site: Data → Population and social conditions → Population → Demography → Demography - National data → Population → Population by sex and age on 1. January of each year

- GDP and GDP per capita for EU 27 to 2006, plus forecast for 2007 and 2008

Path to data from Eurostat web site: Data → Economy & Finance → National accounts (including GDP) → Annual national accounts → GDP and main aggregates → GDP and main components - Current prices

- Income per capita for 12 of the EU 15 to 2001

Path to data from Eurostat web site: Data → Population and social conditions → Living conditions and welfare → Income and living conditions → Income distribution and monetary poverty → Distribution of income → Distribution of income by quintiles

- Mean and median income by age and gender for EU 25 to 2005

Path to data from Eurostat web site: Data → Population and social conditions → Living conditions and welfare → Income and living conditions → Income distribution and monetary poverty → Distribution of income → Mean and median income by age and gender

When presenting statistics for individual branches of the service sector, Eurostat provides information only for:

NACE G: Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
NACE H: Hotels and restaurants
NACE K: Real estate, renting and business activities

We thus cannot obtain data from Eurostat based on the Nace classifications for the service sector that we outlined in Section 1.1.1. The following service sector-related categories (which apply only to the NACE G, H and K) are listed as being available on the Eurostat web site. However, only the first of the three listed here contains data, and that is only for 18 EU countries in 2006.

- Employees in each branch of service sector
- Value added by service provided (production value)
- Number of service businesses & average service size.

Path to data from Eurostat web site: Data → Industry, trade and service → Service →Annual enterprise statistics on service → Annual enterprise statistics on service detailed activity breakdown → Preliminary results on all enterprises (NACE Rev.1 C-K) - main indicators

For taxes, Eurostat now provides the following data up to 2004 for EU 25:

- Total environmental tax revenues as a share of GDP

Path to data from Eurostat web site: Tables → Long-term indicators → Environment and energy → Environment → Environmental protection expenditure and environmental tax revenues → Total environmental tax revenues as a share of GDP

- A breakdown of energy taxes in place for EU 27 is available from the Eurostat publications (Eurostat, 2007d). This publication includes energy prices for electricity, gas and petroleum for EU 27 up to 2006
- Energy prices are available also for a number of European cities from 1985.

Path to data from Eurostat web site: Data → Energy → Energy statistics - prices

Additional data which is available from Eurostat which may prove to be useful is:

- Average gross annual earnings in industry and service for EU 27, available sporadically up to 2005

Path to data from Eurostat web site: Data → Economy and finance → Main economic indicators →Economy overview → Long-term indicators → Prices, wages and labour costs → Wages and labour costs → Average gross annual earnings in industry and service

- Household and NPISH final consumption expenditure for EU 27 up to 2006, with a forecast for 2007 and 2008

Path to data from Eurostat web site: Data → Economy & Finance → National accounts (including GDP) → Annual national accounts → GDP and main aggregates → GDP and main components - Current prices

- GDP per capita in PPS for EU 27 up to 2006 with a forecast for 2007 and 2008

Path to data from Eurostat web site: Data → Main economic indicators → Economy - Structural indicators →General economic background → GDP per capita in PPS

- Number of individuals living in private households for EU 15 up to 2001

Path to data from Eurostat web site: Data → Population and social conditions → Living conditions and welfare → Income and living conditions → Non-monetary poverty and social exclusion → Households and living conditions

The following data categories are available from Eurostat up to 1999 for EU 15.

- Household characteristics by employment status of the reference person
- Household characteristics by number of active persons

- Household characteristics by type of household
- Household characteristics by age of the reference person
- Household characteristics by urbanisation degree
- Household characteristics by main source of income

Path to data from Eurostat web site: Data → Population and social conditions → Living conditions and welfare → Consumption expenditure of private households → Household characteristics

The following data is displayed up to 1991 or earlier from Eurostat. It is assumed that the reason that the data collection was discontinued was due to the advent of the HSEU.

- Number of dwellings by type of living quarters (Source: Census - Round 90-91)
- Occupied conventional dwellings by tenure status
- Rooms per dwelling/person and persons per dwelling by tenure status
- Occupied conventional dwellings by date of construction
- Occupied conventional dwellings by principal amenities

Path to data from Eurostat web site: Data → Population and social conditions → Living conditions and welfare → Income and living conditions → Non-monetary poverty and social exclusion → Housing

HSEU can provide periodic time series data for EU 25 for:

- Tenure of houses
- Number households
- Average household size

Odyssee can provide time series data for EU 27 plus Norway excluding Romania:

- Fuel and electricity costs
- Value added by service provided
- Employees in five branches of the service sector
- Number of households

UNECE provides periodic time-series data for the following for all the European countries we are interested in.

- Population
- GDP
- Status of building user (owner or tenant)
- Number of people housed
- Number of households
- Average household size

Population, GDP and per-capita income are contained in UNECE's Countries in Figures publication, while the rest in the list are in its Bulletin of Housing Statistics for Europe and North America. Although per-capita income is not given in the Countries in Figures publication, Final Consumption Expenditure, which is related, is given.

1.4.9.1 Summary of international data available for European macro-economic data

Table 1.73 summarises data availability for relevant European macro-economic data. No judgement is made on quality or harmonisation of data. The table simply lists data availability from the four sources listed. The idea of the summary is to show the number of European countries for which data is available under the different headings listed. The non-EU countries covered by UNECE are those listed in Section 1.1.4.

Table 1.73 : Summary of international data available for relevant European macroeconomic categories.

	Eurostat	HSEU	Odyssee	UNECE	#Countries EU	#Countries non-EU
Population	EU 27 plus 3 (2006)	EU 25 (2004)	EU 27 excluding Romania	16 non-EU countries	27	16
GDP	EU 27 plus 3 (2006)		EU 25 (2004)		27	
GDP/ capita		EU 25 (2006)		16 non-EU countries	25	16
Income per capita	EU 12 (2001)				12	
Status of building user (owner or tenant)		EU 25 (2003)		8 non-EU countries	25	8
Number of people housed	EU 15 (2001)	Indirectly		8 non-EU countries	15	6
Number of households	EU 15 (1991)	EU 25 (2000) – scant up to 2003	EU 27 excluding Romania and Greece (2004)	8 non-EU countries	22	8
Average household size		EU 25 (2000) – scant up to 2003		8 non-EU countries	25	8
Value added by service provided in service sector	Listed, though contains no information		EU 25 (2004)		25	1
Employees in each branch of service sector	EU 18 (2006) for three branches		EU 27 excluding Austria, Slovenia and Romania for five branches to 2004.		21	1
Number of service sector businesses	Listed, though contains no information					
Average service sector size						
Taxes on fossil fuels	EU 27 (2007)				27	
Heat and electricity costs	EU 27 (2006) for electricity		EU 27 excluding Bulgaria, Latvia, Lithuania, Romania (electricity), 18 EU countries sporadically for fuel.		18	
Fixed and variable costs of the insulation or glazing materials in €/m2						
Average investment for new building equipment in euro						
Private consumption of households			EU 25 (2004)		25	1
Private per capita consumption of households			EU 25 (2004)		25	1

1.4.10 Summary of data needs and sources

No organisation seems to collect energy end use data for either the residential or the service sector for non-EU countries. Table 1.74 summarises the most comprehensive sources of data available as described throughout the chapter. What the table does not reveal is that if time-series data are needed the Odyssee database is the only consistent source for many categories and especially for energy end use data. Despite the sources and quality of Odyssee data remaining somewhat ambiguous, the fact that it is a dedicated energy end use database, and has worked diligently to reinforce its reputation among the various international institutions involved with energy demand questions, such as Eurostat and the IEA, lends to its credibility.

Table 1.74 : Summery of data requirements and availability for European residential and service sectors.

Parameter	Residential	Service
Building type	Data exists to split the stock on a single-family/multi-family house basis from HSEU or Odyssee only	Six branches used by Odyssee plus any further NACE categories needed
Total floor area in square metres	Odyssee (un-sourced), HSEU (sourced), or UNECE (sourced)	EPA – NR (sector or branch) or Odyssee (branch) or Ecoheatcool (sector). Data scarce
Stock of buildings	Odyssee or UNECE raw data (harmonised)	EPA – NR but probably not needed. Data scarce
Age distribution	HSEU or UNECE	No data
Fuels used	Eurostat	Eurostat
Heating system	Four countries from EPA – ED. Estimate by derivation from fuel balances	EPA – NR for four countries. Possibly estimate by derivation from fuel balances
Building tenure	HSEU	No data
Building envelope	MURE	EPA – NR, Ecofys (aggregated for EU – 15)
Building appliances	Odyssee and MURE	MURE and EPA – NR
Building heating practice	MURE	No data
Building total energy use	Eurostat	Eurostat
Building energy end use	Odyssee	Odyssee, EPA – NR, MURE, ECSS
Building electricity end use	Odyssee	Odyssee, EPA – NR, MURE, ECSS
Building thermal and appliance policies	MURE, EPA – ED	MURE, EPA – NR
Macro-economic data	Eurostat/Odyssee/HSEU/UNECE	

.

The HSEU publication also has specific uses in relation to dividing the stock of dwellings between single and multi-family, for dwelling tenure and for dwelling age. For non-EU countries, the UNECE dwelling statistics are useful. Both the HSEU and UNECE have some periodic time-series data available, which may also be useful for some types of forecasting analyses. If time-series data are not needed, the options are then broadened. In the service sector, the EPA – NR report is very significant. The Ecoheatcool report is also significant for the service sector in terms of static year data on building floor areas. Between them these two reports provide data on floor area, building envelope characteristics and some end uses. No organisation seems to collect energy end use data for either the residential or service sector for non-EU countries

1.5 National data sources

There are data sources available on a national basis for many countries. These sources often provide very good information for building energy use. Data for building design characteristics has not, however, been found from national sources except for the UK. No investigation of the possible data available from national sources has been undertaken. However, the following national sources, outlined in Table 1.75 and Table 1.76, are mentioned given the exceptional detail of the data they provide.

Table 1.75 : Comparison of data availability for residential sector in Europe from three national sources.

	Source – Residential sector	Type	Design	Energy end use	Floor space
Denmark	www.statistikbanken.dk	●	Age		●
Sweden	www.scb.se / www.energimyndigheten.se	●	Age	● (STEM)	●
France	Ademe, Les Chiffres Cles du Batiment	●	Age	●	●
UK	Domestic Energy Fact file	●	U-values	●	●
	DTI Tables from BRE			●	●

Table 1.76 : Comparison of data availability for service sector in Europe from three national sources.

	Source – Service sector	Branch	Design	Energy end use	Floor space
Denmark	www.statistikbanken.dk	●	Age		●
Sweden	www.scb.se / www. energimyndigheten.se	●	Age	● (STEM)	●
France	Ademe, Les Chiffres Cles du Bâtiment	●	Age	●	●
UK	Non-domestic Building Energy Fact file*	?	?	?	?
	DTI Tables from BRE			●	●

** This publication must be purchased and as such its contents are unknown*

1.6 Future developments in data availability

Further sources that may come to hand in the near future have been mentioned throughout the text. To summarise they are:

IEA 30: A second edition of the IEA 30 book is due to be published in mid-2007. This publication would contain energy end use and floor space data for the residential sector and possibly for the service sector too. However, availability will be limited to long-time member countries of the IEA.

Remodece: This IEE-funded project will contain end use data for electricity use in the residential sector for EU 27.

El Teritiery: This IEE-funded project will contain end use data for electricity use in the service sector for a number of EU countries.

Eurostat: As part of its obligations under the Energy Service Directive for enhanced monitoring of energy efficiency trends, Eurostat may seek to us national census data for collecting energy end use data for the residential sector from 2009 and onwards.

1.7 Conclusion

This chapter began in Section 1.1 by describing the types of buildings for which this report is interested in sourcing data, and then continued by describing the physical characteristics, energy uses and energy-using apparatus relevant to the same types of buildings. Section 1.3 followed by describing the international data sources that have been used to find data and the data categories that each source contained. The issue of data harmonisation across sources and data quality was also described. Section 1.4 compared data found across international data sources and summarised the findings. Finally, data available from some national sources, and some possible future developments in data availability, were discussed.

Overall, there are ten countries (Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Spain, Sweden, and UK – see Table 1.47 and Table 1.50) for which a single-year top-down statistical analysis of energy using trends can be performed for both the residential and the service sector. Information on how to undertake such an analysis is described in Chapter 2, Chapter 3 and Appendix C. As regards data on energy-using apparatus, building envelope characteristics and fuel mixes for which a single-year bottom – up simulation can be undertaken, a complete data set is not possible for the residential sector and exists for only four countries (Austria, Germany, Greece, and Poland) for the services sector. The limiting data in this latter category are knowledge of heating, lighting or ventilation devices installed. Information on how to undertake such an analysis can be found in Chapter 4 and Appendix F.

Further investigations could be to concentrate on missing data to see what individual country data can be used to fill the current gaps. The usefulness of direct contact with energy agencies or statistical organisations in countries with low data availability has to be measured against the fact that many of these countries are already members of the Odyssee network and thus should have made public, through Odyssee, all of the data that they have. For non-Odyssee members (this now amounts to all non-EU countries except Norway and Croatia), direct contact with energy agencies or statistical organisations would be useful to gauge the possibilities of energy end use data being available in these countries.

Further work would certainly be to see if gaps in data availability could be filled through the use of estimation. Such estimates may be needed for countries from Eastern European and newly developed Western European countries that have not traditionally collected the type of data necessary for detailed demand-side analysis. An obvious estimation methodology would be if data is not available for one country to use that of a neighbouring or similar country as a basis for an estimate. Another estimation method would be an examination of country's building thermal regulations to know what the theoretical thermal characteristics of new buildings are. A further example would be that there is certainly enough data available to attempt to calculate some average U-values for different EU 25 countries, or for the EU as a whole. However, there is not sufficient data to say anything about U-values in individual branches or house types. Appendix H provides an example of estimating heating devices installed in dwellings by examining fuel mixes.

Other work could be to perform energy analysis exercises that attempt to compare results obtained by using different data sets. Such exercises would add to the assessment of data quality. In addition to this, it would be useful to carry out some exercises starting with Odyssee data but then substituting data from other sources to see the effects, and attempting to deduce assumptions or limitations with the various data sets. The outcomes of such exercises could perhaps be submitted for peer review to attempt to obtain a consensus on best available data.

In terms of the discourse surrounding “quality of data”, the publication of the Odyssee data quality ratings in the near future will significantly enhance knowledge with regard to these questions.

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2. Energy indicators

Indicators have been used in many fields of knowledge for many years. An economist measures the state of the economy by examining indicators such as the economic growth rate, the unemployment rate and the international balance of payments. A social scientist may examine statistics relating to the infant mortality rate, the adult literacy rate or the suicide rate, to assess a human development index. A doctor can evaluate a patient's health using a handful of numbers: blood pressure, pulse rate, weight-to-height ratio, cholesterol level and so on. By watching how these numbers change over time, the doctor can advise the patient whether his or her health is improving or deteriorating and proceed to give medical counsel (IEA, 1997). The common thread with these examples is that indicators are used to help an analyst to ascertain the state of some macro-economic or other societal or technical category which may or may not be possible to measure directly. Obviously, the economy or human health, are such categories that cannot be measured directly. However, the measurement of different aspects within either allows analysts to make an educated assessment of their condition.

An area which is of interest to our report, and where indicators can be useful, is the environment. The use of indicators to help monitor the state of the environment has its origins in the Local Agenda 21 (LA21) (UNEP, 1992) initiative that was conceived at the UN Environmental Programme (UNEP) Earth Summit in Rio in 1992. LA21 encouraged municipalities, the world over, to organise local study groups to come up with a set of indicators that could be used to monitor people's conception of their surrounding environment. The idea was twofold: first, to formulate a means for localities to assess the degradation or improvement of their environment as they perceived it, such as, for example, in terms of the number of smog-free days per year, the number of corncrakes heard in the spring or the number of window flower boxes located in apartment blocks, and second, that the set of indicators used would develop over time as people developed a greater awareness of what aspects of their environment were important.

The tenth anniversary conference of the Earth Summit, the World Summit on Sustainable Development, in Johannesburg in 2002 (WSSD), provided the impetus to develop indicators that focus on energy, although not following the "bottom-up" LA21 approach. This initiative arose following acknowledgement at the summit that access to energy service was a key requirement for achieving the Millennium Development Goals and alleviating global poverty. Thus the Energy Indicators for Sustainable Development Project (EISD) (IAEA, 2005) was coordinated by the International Atomic Energy Agency (IAEA), and involved collaboration with the International Energy Agency (IEA), Eurostat, the EU European Energy Agency (EEA) and the United Nations Department of Economic and Social Affairs (UNDESA), and led to the publication of a set of energy indicators for sustainable development in April 2005.

The reason that these organisations were invited to participate in the process of developing EISD was that, since the 1990s, they had been involved in the production or promotion of energy indicators (IAEA, 2005). To this list of pioneering energy indicators organisations should also be added the Odyssee Indicators Project (Bosseboeuf et al., 1997). The reasons for Odyssee not being asked to participate in developing the EISD were perhaps either because Odyssee doesn't explicitly focus on sustainability (Abdalla, 2005) or that it worked closely with the EU Directorate for Energy and Transport, whereas the EU was involved with the EISD through their Directorate for the Environment.

The approach to energy indicators advocated by both the Odyssee project and the IEA looks in particular at the root causes of increases in energy use in the developed world/OECD countries. As it happens, the EISD indicators are focused on the impact of energy on economic, environmental and social issues, in particular in the developing world, and so are in fact too broad in scope for the purposes of this project. The approach pioneered by the IEA and Odyssee does, on the other hand, provide the detail needed to know why energy use in Europe is changing, and so the substantial part of this work will be based on their recommendations. Both organisations have held a number of related workshops over the last number of years aimed at national energy agencies and government departments of energy in IEA/OECD and EU member countries, and have published a number of papers as well. Perhaps the most seminal was an important work by Schipper (IEA, 1997).

The aim of this chapter is to provide a thorough background to the IEA and Odyssee approach for utilising energy indicators and to suggest particular indicators that may be useful for the purposes of this project. To do this, the following topics relating to the use of indicators are covered:

1. Historical background - energy/GDP
2. Top-down indicators
3. Index decomposition
4. Bottom-up indicators
5. Combined top-down/bottom-up indicators
6. Use of indicators for policy implementation
7. Comparative indicators for inter-country analysis
8. Example lists of indicators
9. Use of indicators for energy analysis in buildings
10. Data requirements for energy indicators

2.1 Historical background – energy intensity

In recent decades, energy analysts have been concerned with how demand grows. The overriding drivers of demand are hundreds of millions of households and car drivers, millions of truckers and hundreds of thousands of building operators, farmers and factory managers (IEA, 1997). Thus the lifestyles, choices and apparatus efficiencies used by these players determine energy demand. Historically, however, the focus of causes for increased energy use has been solely on economic development, thus excluding detail on actual end users. Up until the 1970s, the understanding was that as economic activity increased so too does energy use or, put another way, the economy could not improve without increased access to, and use of, energy resources. There was in fact an observed linear coupling between growth of both GDP and energy use. The data category energy/GDP was said to depict the energy intensity of the economy[‡‡‡] - the unit of energy needed to produce a unit of GDP. However, from 1973 on, increases in GDP became decoupled from energy use and the two curves diverged. This was primarily due to energy efficiency measures taken to reduce energy intensity of the economy and reliance on imported oil. In addition to this, the increased cost of energy meant that the structure of the economy in the western world shifted towards less energy-intensive industry (Marlay, 1984).

From this point on, analysts discovered that while energy use grows with economic growth in nearly every region, the coupling varies from sector to sector, from country to country and from period to period. Many factors contribute to this: income, energy prices, technological progress, energy efficiency programmes, structural changes (changes in the mix of materials, goods and service produced) and profound changes in the levels of mobility (IEA, 1997). As such, energy use/GDP or energy intensity was no longer sufficient to describe whether the

[‡‡‡] Not to be confused with energy efficiency. We want efficiency to go up and intensity to go down.

shifts in energy use were due to improvements in energy efficiency or to shifts in economic structure.

So what parameters are necessary to show why energy demand is changing? We have stated in the previous paragraph that the following parameters have affected and continue to affect energy use:

- income
- energy prices
- technological progress
- energy efficiency programs
- structural changes (in the mix of materials, goods and service produced)
- profound changes in the levels of mobility

To this list we can also add population change. We also have also stated that the fundamental questions for analysts are “Why is the energy use increasing?” Obviously the answer lies in a combination of the influences of the above parameters. All of these parameters are, however, continually developing. The overriding influence, price, has been historically important with a high price of electricity since the 1970s (Marlay, 1984). Price stagnation however occurred in the 1990’s but increased again this decade showing that the effects of price have varied. Thus the relative importance of the various factors also keeps changing (IEA, 1997). In addition there are also regional differences, such as structural differences, in the influence of each parameter. Nevertheless, indicators are needed in order to distinguish and detect the partial influences of each parameter and thus answer the fundamental question. Depending on their type, these indicators may include aspects of the above list.

2.2 Top-down indicators

Energy intensity as an indicator is obviously insufficient to help with determining the energy use dynamics described. To do this will require a set of indicators which could include energy/GDP. Just as there are limitations with the energy/GDP indicator, there are limitations with all individual indicators and, as such, a set is needed to perform meaningful analysis of the causes of energy use change. In fact, there is no one indicator which can accurately account for all of the above parameters. To begin a description of how indicators can be utilised for our aims, we start by distinguishing between top-down and bottom-up indicators.

Energy intensity is a top-down indicator. It takes two macro-economic or aggregate values from existing national and international statistics sources, namely total energy use in an economy and total GDP (without essentially caring how these two figures were calculated, as long as they are official data), and uses them to give an overview indicator of energy trends in the economy. A strict bottom-up approach, on the other hand, would count and continue to count the individual uses of all applications and service that use electricity or fuel, to build up the total amount of energy consumed. It is easy to see which of the two approaches is easier to organise. As it happens, there are many options in between these two levels of disaggregation, which allow a combination of bottom-up and top-down indicators. The indicator pyramid in Figure 2.1 offers a useful explanation of options.

In the indicator pyramid (IEA, 1997), the first two levels from the “top down” can clearly be classed as top-down. Macro-economic data for energy use from national level down to branch (subsectoral) level is used to calculate energy intensities of the respective levels of the economy and society. The third level looks at energy use per application and as such is classed between the obviously top-down nature of the first two levels and the bottom-up nature of the bottom level. In looking at energy use per application we could, for example, look at the total energy use for lighting on a national level, sectoral, or per capita level. As such, we would look at energy use for lighting but would not look at energy use per individual light bulb. This is what distinguishes the third level from the last level. The lumens of light per watt from a light bulb are of course the process efficiency of lighting in just the same way as any standard industrial process, so belong in the bottom level.

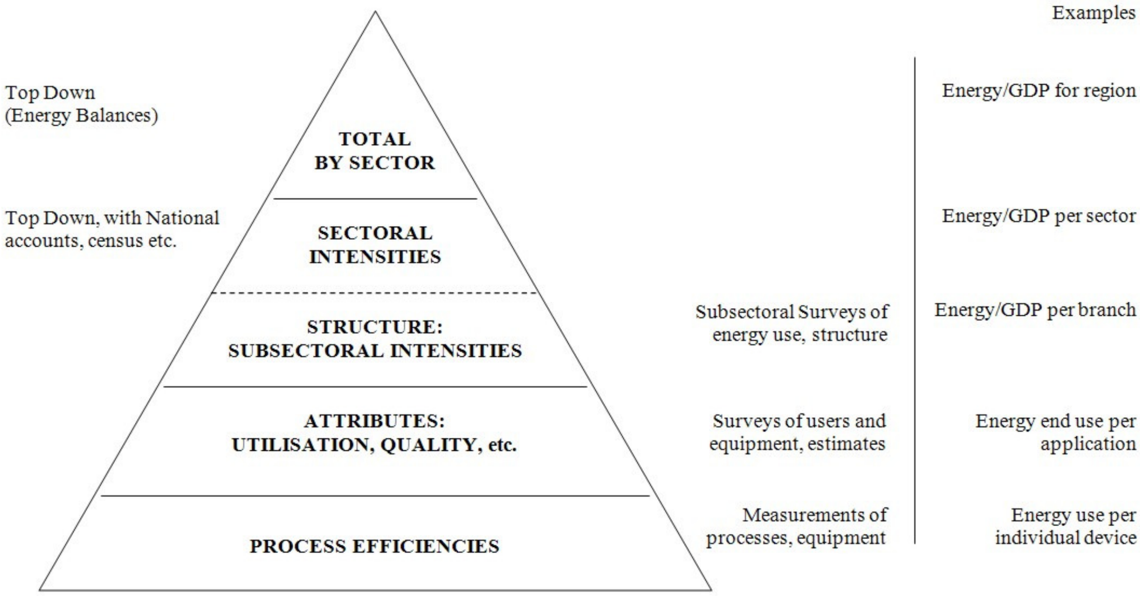

Figure 2.1 : Indicators pyramid. This diagram is taken from the IEA Indicators Manual (IEA, 1997)

As it happens, the closer to the final level reached, the closer one gets to an engineer's concept of energy efficiency, while the closer to the top one goes the closer to an economic or social rating of energy efficiency. Consumers have a lot more control over Level 3 than over Level 4, as they dictate overall purchasing patterns, while the actual energy efficiency of a process is left to the manufacturing company. The reason for the pyramid shape is due to the level of detail needed – little at the top, much at the bottom. Obviously one use of indicators is to avoid the need to collect the amount of data needed for a "true" bottom-up approach.

At every level of the pyramid, the actual sectoral structure determines the weighting of the indicator (IEA, 1997). For example, even if the intensity of agriculture was higher than that of industry, it would in all likelihood not be as important, given its size and thus overall consumption relative to that of the industrial sector.

2.3 Index decomposition

As has been repeatedly stated, energy/GDP is, and has been for the last 35 years, an insufficient indicator to explain exactly why energy use is changing. Granted, the examples given for the indicators pyramid above use energy/GDP, although this is as much for explanatory purposes as for anything else. The indicator does not, as we have explained, show the partial influences of the relevant parameters. Another top-down approach which implicitly seeks to display these influences as well as energy intensities, and which has been proposed as an alternative to energy/GDP, is index decomposition (ID) (Ang and Zhang, 2000). ID has also been named the **STRINT** approach (**str**ucture & **int**ensity) (Haas and Schipper, 1998), given that, as stated, it implicitly attempts to show both structural and intensity effects.

This approach attempts to decompose a time series trend for overall energy use in an economy/country or sector into the various influences of changes in activity, structure and intensity trends. Activity is defined as being the driver or overriding goal of the sector and as such is value added for the industrial and service sector, is people housed for the residential sector, and has been said to be GDP for the transport sector (IEA, 2003). Structure is the share of the various branches of each sector in overall sector consumption, while intensity is the efficiency of the individual branches. An interesting feature of ID is that it disentangles the parameter that engineers have most influence over, energy efficiency, from the parameter that consumer behaviour has most influence over, structure. Ultimately, rather than having a single number value for the intensity of the economy, ID produces three numbers which between then show the varying influences.

As a top-down indicator, ID has obvious advantages over energy/GDP. It can be calculated at the same levels of the pyramid as energy/GDP, and thus offers a more complete picture at these macro-economic levels. A disadvantage is that intensity and structure are not entirely independent as intensity decreases, structure can increase due to the rebound effect. Thus we would not be able to state how much of the increase in structural energy use was due to the rebound effect, as opposed to general business developments. Analysing rebound effects using indicators is dealt with elsewhere. A further disadvantage is that calculations are more complicated than with energy/GDP. Ultimately, however, ID allows us a more revealing macro-economic view of energy use than the more traditional indicator. For further discussion on the theory and methodology behind ID, please refer to Appendix E.

2.4 Bottom up indicators

Whereas energy/GDP or energy/per capita or energy/household can all be considered top-down, and allow us to look at energy use “from a distance”, the main indicators classed as bottom-up are of the energy use/activity or energy use/output type. Despite the fact that they are still aggregated data categories, they allow a closer look at how and why energy is actually being utilised. They associate an activity, output or service provided (distance travelled, steel produced) or some other parameter (size of house heated, ownership of refrigerators) (IEA, 1997) with every energy use, thus revealing the fundamental purposes behind energy consumption. These types of “revealing” indicators occur essentially on the third level of the above pyramid.

Bottom-up indicators also occur on the fourth level of the indicator, but are rarer. The structural effects at this level are revealed by the summation of all process efficiencies and respective running times. This level of disaggregation is undertaken for electrical appliances, although even so there are aggregations involved. For example, one would not be expected to record the process efficiency of every type of refrigerator brand on the market, but rather attempt to state the average efficiency for all refrigerator brands and thus how overall energy use for refrigeration is progressing. In general, indicators built from the bottom up in its truest sense are impractical on temporal and data collection grounds.

The advantage of bottom-up indicators is that they allow us to measure the impact of policies, taxes and technologies that affect small components of energy demand in a way that top-down analysis cannot. Most policies affect specific end uses. Top-down analysis is also unable to distinguish between changes that occur spontaneously and those that occur because of legislation. This is also difficult for bottom-up indicators to do, but has a better chance of success with a set of indicators (IEA, 1997).

A disadvantage with a bottom-up approach is that it is prone to the variances in use patterns between consumers of the same energy using service – e.g. number of showers per day or the patterns of use. This issue is distinct from the rebound effect. The monitoring of this issue goes beyond the scope of indicators. A further disadvantage is that of accounting for how policy measures effect fuel poverty. A bottom-up indicator may, for example, reveal that energy use for a certain service has been reduced for the population as a whole, but not how this has impacted on the standard of living of less well-off people.

2.5 Combined top-down/bottom-up indicators

An indicator which has come to the fore in the last year and combines top-down and bottom-up indicators is the Odyssee Energy Efficiency Index (ODEX). In actual fact, the ODEX uses bottom-up indicators to produce a top-down or aggregated result. The ODEX is particularly interesting as it has been explicitly recommended by the EU Energy Efficiency and Energy Service Directive (2006/32/EC), as a method for individual countries to calculate their overall progress with achieving energy efficiency. By aggregating, by means of an index, bottom-up unit efficiency for the industrial, transport, and household sectors, the ODEX produces a national efficiency index which is "cleaned" of structural and other factors which have nothing to do with energy efficiency. As such, a national ODEX may or may not be similar in vector to an energy/GDP indicator, although we can be sure that it is a more precise reflection of energy efficiency. The calculation of the ODEX as published by the Odyssee network does not include an efficiency indicator for lighting and excludes the service sector entirely, both due to a general lack of data at the European level. For lighting, the problem is in accounting for the take-up of CFL light bulbs.

The motivation for ODEX endeavouring to exclude structural and other non-technical effects is not that these effects are considered unimportant. It is more to help separate effects (just as ID does) although also perhaps as energy policy has up until now mostly focused on efficiency too. As it happens, ODEX calculations for some countries show a decrease in energy efficiency, which is generally considered to be impossible due to the fact those technological improvements are permanent/irreversible (Haas & Schipper, 1998). As such, Odyssee recommends that for such results, the best/lowest values recorded for energy efficiency is used, and that the decreases be attributed to structural effects which have not been cleaned from the results. An example given is that with higher indoor temperature norms the household space heating indicator, energy per square metre, could indeed be getting worse. This has given rise to the "Technical ODEX" to differentiate from results produced by the standard ODEX calculation. For more information on the methodology of the ODEX, see Odyssee Network (Odyssee, 2007).

2.6 Use of indicators for policy implementation

Energy policy, and in fact any social policy as it happens, needs indicators to know how successful it has been. In fact, one can say that in order to achieve proper assessment of policy effectiveness, each policy must have at least one indicator associated with it. The "location" of the indicator on the pyramid depends on the scope of the policy. A policy focusing on minimum standards for electrical appliances would take an indicator from the third or fourth level, while a cross-cutting policy such as a fuel tax would take an indicator from the first two levels. An indicator can provide one of the benchmark measures of success. Obviously, overall energy use or CO_2 emissions reductions in an economy, or in a sector's energy use, is another measure of success. Given that the success of individual measures or policies may be offset by increases in energy use elsewhere in the economy however, indicators can show the success of targeted policies and measures. The same ideas are true for forecasting studies of energy use. Thus regardless of what technical changes are suggested, indicators will be needed to monitor their progress.

This type of policy monitoring through indicators already occurs. The EU or individual states, for example, set up targets/goals as policy. Policy targets could be in the form of percentage energy saved per year, percentage absolute values, percentage energy/ CO_2 saving. A popular

EU expression arising is "distance to target". Ultimately, the motivation is to monitor and evaluate existing policy and thus have better planning (Odyssee Network, 2006).

Specifically, policy innovation or technical measure change aims at fostering a specific action from a consumer group i.e. householders, car drivers or farmers, to modify their equipment, technologies and possibly behaviours. Indicators focus on monitoring these changes (Odyssee Network, 2006). Results can be used by energy experts, government, and international organisations wanting to improve energy planning (Odyssee Network, 2006). Thus while policy goals are to reduce overall energy use in an economy (which can be read with top-down indicators) the focus of policy is usually on a selection of end uses (which can be evaluated with bottom-up indicators) to meet these top-down goals. Bottom-up indicators are thus nearly more important to capture actual policy progress.

The level of detail and the specific indicators chosen depends on the aim of the policy. The Odyssee indicators project describes four types (Odyssee Network, 2005):

- Descriptive
- Explanatory
- Comparison
- Diffusion

Descriptive indicators show trends in energy efficiency or carbon dioxide emissions as basic intensities or emissions/unit. They are constructed from national statistics such as GDP and population. They present trends as an index or as an annual growth rate. Examples would be kWh/€ or tonnes CO_2/€. These are top down indicators.

Explanatory indicators involve more in depth calculations than do descriptive. They can show a disaggregation of intensity and structural effects. They can be built on estimates or surveys if data is not available. They present trends as change in unit consumption or consumption trends climate-corrected. Explanatory indicators include ID and the ODEX index of progress. Examples would be litres fuel per 100 km driven, toe/tonne cement, kWh/refrigerator or toe per square metre for space heating. These are bottom-up indicators.

Comparative indicators are used for inter-country comparisons, and can be adjusted to account for institutional differences such as climate, affluence or industry mix. They can also be used to assign benchmarks or targets with which to compare performance.

Diffusion indicators track the penetration of an appliance, a label, a renewable fuel etc.

As can be seen, all four are - with the exception of international comparative indicators - some function of activity at varying levels within the indicator pyramid. One could associate the descriptive indicators with top-down first or second level indicators, while the explanatory indicators would be formulated at Level 3. The comparative indicators can actually compare functions within the pyramid to benchmarks, or external to the pyramid if the pyramid represents a country, while the diffusion indicators are structural components that are built from the bottom level of the pyramid.

The following example from the transport sector helps explain an approach to deciding which indicators are appropriate for effective analysis. Experts have not always measured consumption per se for each end use i.e. total fuel use per vehicle class, but have carefully and scientifically added up the number of users, consumption per user and fuel for each end use to approximately match the supply-side data (IEA, 2007).Thus we begin by breaking overall fuel use in the sector into parameters which can show the various influences.

- km/vehicle
- total number of vehicles of class

- litres/km

The first indicator is related to activity – transport per vehicle – and is also explanatory as it looks at the unit consumption per vehicle. The second indicator relates structure and diffusion by showing the number of users and share of a vehicle in a class in the total fleet, while the last is an indicator of intensity and is also explanatory and looks at unit consumption in a more comparable way. By multiplying all three together, we can estimate the amount of fuel used per vehicle class. Thus we have multiplied three bottom-up indicators together to obtain a top-down aggregated indicator. If we do the same thing for each vehicle class, we can know how much fuel is being used in the transport sector. We may already know this from looking at national statistics of fuels imported or sold. However, and this is the important part, without the above three indicators, we would not know why fuel use is changing[§§§]. Using the above analysis, policy-makers could choose to focus attention on vehicle tax, on fuel prices, on fuel economy or on public transport etc. In fact, a package of policy measures would often be necessary (as is a package of indicators) to capture the above issues and also to prevent rebound effects within the sector. For example as cars become more efficient less fuel is needed but the money saved by the driver may be spent on a larger car. Class effects may also be taken into consideration. For example if roads were tolled according to car design wealthier people would just pay the toll as the free time is worth more to them than the cost. If this was considered to be problematic there would have to be seriously punitive measures on big cars to prevent wealthier people not "doing what everyone else is doing…"

2.7 Comparative indicators for inter-country analysis

Our analysis to date has been within the boundaries of one indicator triangle. However, for any European-wide analysis, we will want to compare between countries, which means in effect different indicator triangles with different mixes.

In their indicators manual the IEA (1997), state that the fundamental reasons for international comparisons of energy use are learning and cooperation including international competitiveness. For example, if the USA wants to know how drivers react to high petrol prices, they can look to Europe. Furthermore, there is the inherent international nature of the energy market, of economic markets, of ecological problems and of carbon dioxide emissions which, for the purposes of international treaties, need inter-country comparisons. However, there are significant structural differences between countries which complicate comparisons[****]. Population size and economic activity are two of the biggest differences between countries. Across the countries of Europe there are obvious differences between climate and resultant energy load profiles, geographical differences across large countries, levels of insulation, levels of home ownership, energy resources available, housing densities, service sector structure and affluence. Murtinshaw et al (2001), estimates that these irreducible factors account for up to 75 % of energy use across IEA countries. As such, comparing energy use per square metre cannot always be a useful comparison, but perhaps

[§§§] As it happens, the statistic km/vehicle is at best an estimate itself, as national statistics do not attempt to collect this data.

[****] Climate treaty negotiations in particular are tough because of great differences in structures between national economies (IEA, 2007). In fact one could speculate when looking at the differences in industrial structure between say Australia and say Sweden that the approach of the Kyoto negotiations to date has been a waste of time in that there is no way that Australia will sign up as long as its economy and thus the standard of living of its citizens relies on the use of coal. Thus to compare "like with like" between countries we need normalisation of energy data by population, GDP, value added, climate etc.

more importantly it is important to attempt to separate" hard wired" factors from inter country comparisons.

Looking at some of these irreducible factors we see that, for example, Finland's 30-year average for degree days is 4878, whereas Portugal's is 1278. Clearly, there will be a greater energy requirement for space heating per meter squared per year in Finland than in Portugal. However, levels of insulation and thermal isolation would be higher in Finland than in Portugal, thus reducing the difference in energy needed for space heating. A further difference between Finland and Portugal is the fuel mix used to provide energy for these sectors. Both countries have a high dependency on oil compared to their use of coal or gas. Despite this, Portugal produces most of its electricity from coal and gas, whereas Finland produces most of its from nuclear energy. Due to the difference in utility mix, carbon dioxide emissions from the residential or service sectors in Finland will be lower on a per square metre basis than for Portugal, regardless of whether a comparable level of energy services are being provided. The conversion efficiency of various fuels would also distort end use indicators for space heating, showing greater energy use where coal was involved as opposed to natural gas.

To remove the impact of utility mix on the space heating indicator, a measure is taken of useful energy per meter squared. Useful energy is the actual exergy extracted from the fuel and applied to an energy service within a building. It is calculated using standard conversion efficiency factors for various fuels. There is however no agreement in the literature as to how to remove the influence of varying levels of insulation. The usual method is to ignore insulation levels and simply to adjust to a constant European climate, that being to weight fuel use according to the amount of heating degree days in a particular country to remove difference in fuel use that are attributable to different weather patterns. Werner (2005) proposes that adjusting in proportion to the square root of degree days does in fact take account of insulation differences. A further difference that would need to be eliminated would be diversity in GDP levels. Levels of affluence are important, as they dictate increasing trends in levels of comfort sought. Differences in GDP can however be accommodated, but differences in heating practices or equipment usage norms are difficult to remove.

In the service sector, differences between the mix and type of business can be eliminated from inter-country indicators by taking a European-wide average structure and using this as the basis of calculating intensity indicators. In doing so, the energy intensity indicator (energy/GDP) which we had effectively discarded can be reintroduced if we choose to use it as energy/[constant European GDP], which allows us to compare progress in this sector. Against this, (Blok, 2001), states that value added is not very well related to energy use, although he is probably referring exclusively to the industrial sector.

A more detailed inter country comparison approach is the Mine/Your approach (Murtinshaw et al, 2001). In this method, one country's GDP, structural, value added and activity parameters are replaced by another's to allow direct comparison of both countries' energy intensity progress. For example, it is commonly known that Japan, with nearly the same GDP/capita as the USA, uses considerably less energy/GDP than does the USA. The implication is that Japan is more energy-efficient then the USA. However, if USA intensity is measured using Japanese structural components, the differences are significantly less, which shows that it is inaccurate to state that energy efficiency is worse in the USA than in Japan. For the full worked example, see (IEA 1997, box 2.1, Chapter 2.1 and annex to Chapter 2.)

2.8 Example lists of indicators

Various organisations have promoted lists of recommended indicators. For a full list of sets reviewed, see Appendix D. Below, two short sets are listed, one from the IEA and another from Eurostat. The IEA's simplified list is what it considers the bare minimum for work with the residential and service sector, and is described in its Indicators Manual (IEA, 1997). The Eurostat list is known as the "Eurostat Priority list of Indicators" and dates from 2000 (Eurostat, 2003). One of its uses was for the Eurostat publication, Energy Efficiency Indicators – Data 1990-1999 (Eurostat, 2002). The zero indicators, A0, B0… etc. are the first choice indicators for the priority list, while the A1, A2, B1… etc. list are alternate indicators for situations and countries where data is insufficient to calculate the zero list. The data for each example chart is for EU 25 or EU 15 where data is limited.

The Odyssee project does not publish a recommended short list, but rather includes time series data for a set of 50 indicators of energy use trends for their member countries for analysts to choose from. As it happens, the energy/GDP indicator has never really gone away, despite the limitations associated with its use.

IEA simplified list of indicators (IEA, 1997)

The IEA list covers the residential and service sector. Its idea is to highlight trends in the various end uses of energy for both sectors. The following list is of its four residential sector indicators. Figure 2.2 shows the same indicators constructed.

- space heating energy use/square metre/degree-day
- square metres of household space
- estimated electricity use/appliance for major appliances, both current and new
- market saturation of major appliances

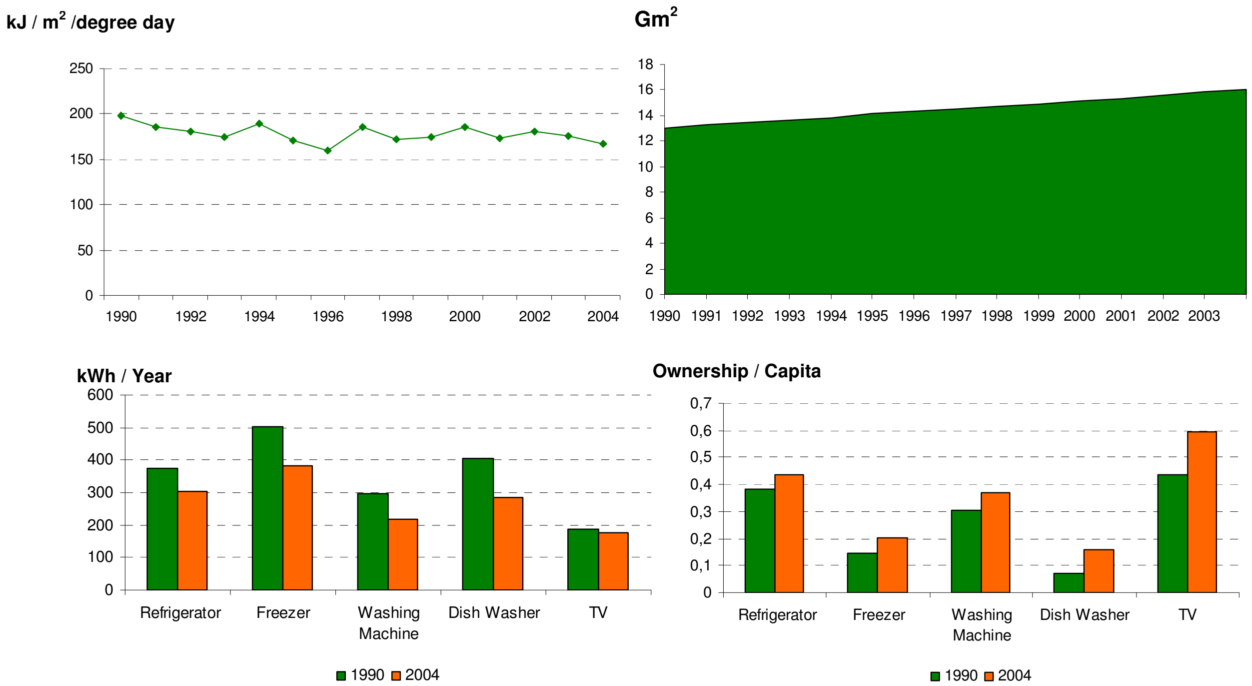

Figure 2.2 : The IEA simplified list of indicators for the residential sector. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

The top two indicators in Figure 2.2 relate to space heating, while the bottom two relate to appliances. Thus water heating and lighting are not directly referred to, although the idea may be that space heating and appliances are the end uses that both technical and lifestyle changes influence.

The following list is of the three IEA service sector indicators. Figure 2.3 shows the first and third indicator constructed. No data is available to allow the construction of the second indicator.

- Heat use /square metre floor space
- Non-heating electricity use/square metre floor space
- Total floor space (GDP or value added as a proxy for floor space)

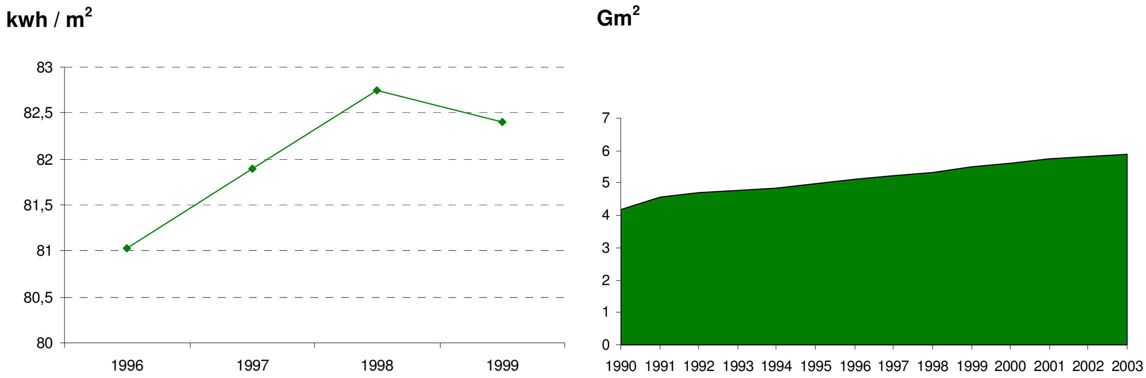

Figure 2.3 : The IEA simplified list of indicators for the service sector. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

The IEA approach to the Service Sector is to again look at trends in space heating and energy use of appliances.

EUROSTAT priority indicators (Eurostat, 2003)

The Eurostat list covers macro-economic indicators as well as the residential and service sector. As already stated, it provides an alternative list of indicators.

The following list is of the three Eurostat macro-economic indicators and their three respective alternates. Figure 2.4 shows the three priority indicators constructed.

A0. Final energy intensity at constant GDP structure with climatic correction (kgoe/EC90)
B0. Gross inland consumption intensity (kgoe/EC90)
C0. Ratio of final to primary energy consumption

A1. Final energy intensity with climatic correction (kgoe/EC90)
A2. Final energy intensity at constant GDP structure (kgoe/EC90)
A3. Final energy intensity (kgoe/EC90)

The Eurostat macro-economic indicators seek to look at the grand old man of energy indicators, namely energy intensity, and also to look at the intensity of primary fuel consumption using the Eurostat-coined statistic, Gross Inland Consumption, and also the efficiency of its conversion to final energy available for delivery.

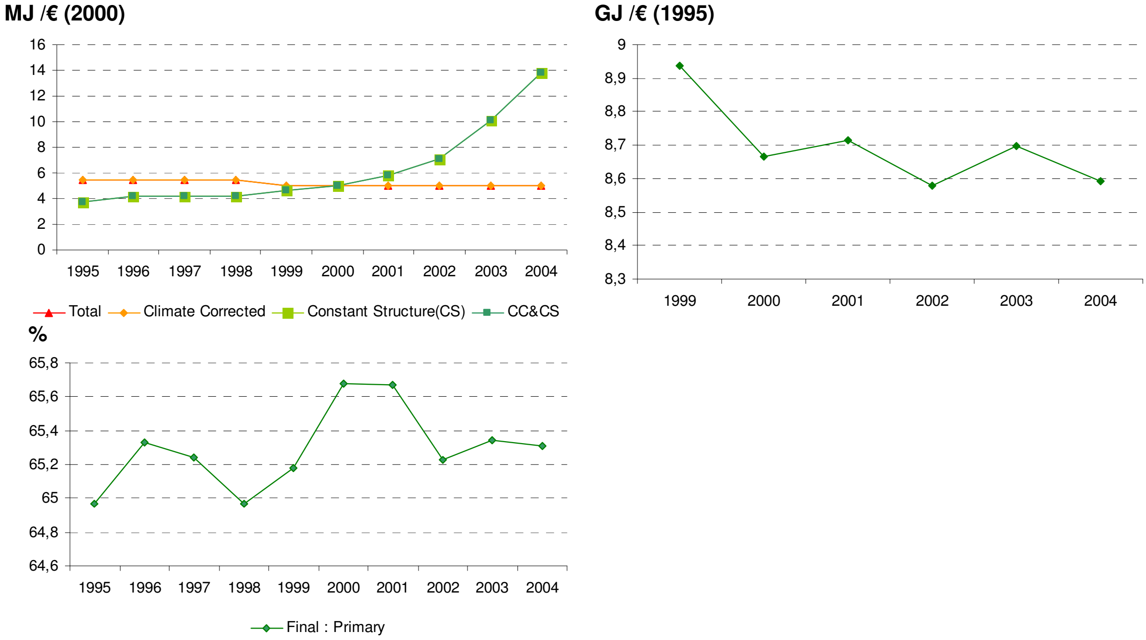

Figure 2.4 : The EUROSTAT priority macro-economic indicators. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006) and from Eurostat Annual Energy Statistics (Eurostat, 2004).

The following list is of the two Eurostat residential sector indicators and the single alternate which refers to space heating. Figure 2.5 shows the two priority indicators constructed.

A0. Unit consumption per square metre for space heating with temperature correction (toe/m²)
B0. Unit consumption per equivalent dwelling for lighting and electrical appliances (kWh)

A1. Unit consumption per equivalent dwelling with temperature correction (toe)

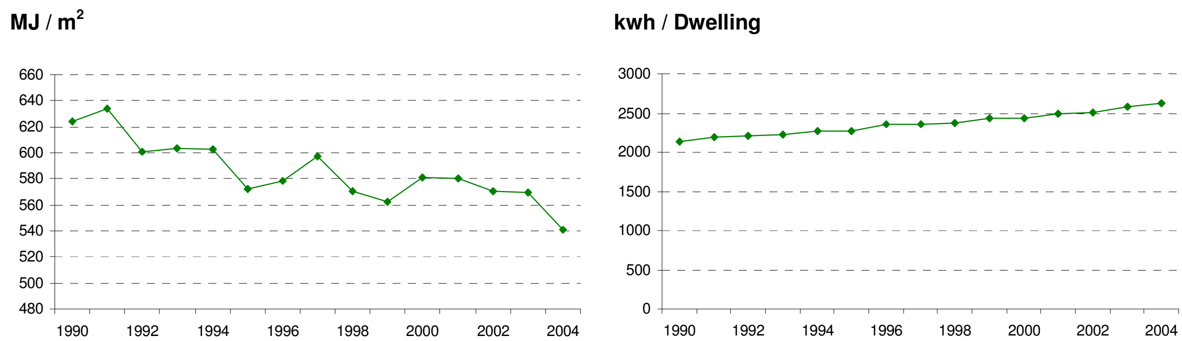

Figure 2.5 : The EUROSTAT priority residential sector indicators. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

Once again, the approach to the residential sector used by Eurostat is to look at trends in space heating and energy use of appliances, although it also includes electricity use for lighting.

The following list is of the four Eurostat service sector indicators and the two alternates that refer to space heating and electricity consumption. Figure 2.6 shows the priority indicators A0, C0 and D0 constructed. No data is available for either indicator B0 or B1.

A0. Energy intensity of the sector, temperature-corrected (kgoe/EC90)
B0. Unit consumption of service sector for space heating per m² with temperature correction (toe/m²)
C0. Unit consumption of electricity (excluding electricity for space heating) of the service sector per m² (kWh/m²)

D0. Electricity intensity (kWh/EC90)

B1. Unit consumption of service sector for space heating per person employed with temperature correction (toe/per.)
C1. Unit consumption of electricity (excluding electricity for space heating) of the service sector per person employed (kWh/per.)

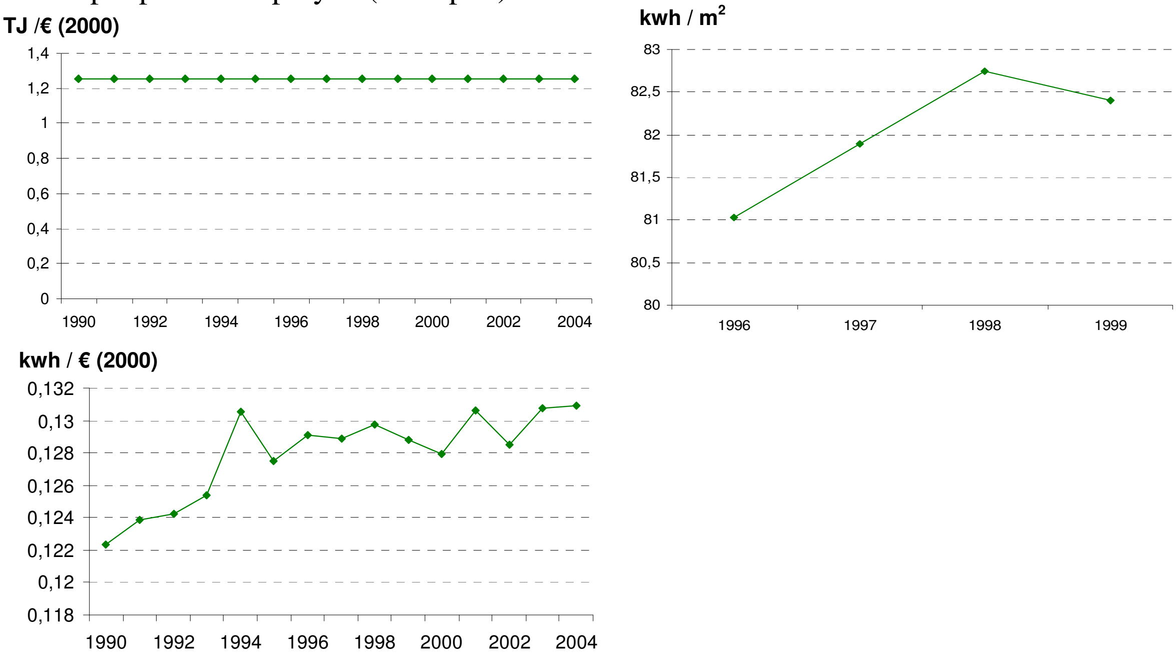

Figure 2.6 : The EUROSTAT priority service sector indicators. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

The approach to the service sector used by Eurostat emphasises the importance of energy intensity, whether of all energy consumed or of electricity use only. This is due to the production value of the sector and its coupling to energy use trends being so important. Space heating and electricity use are also highlighted.

The EU Commission is due to present a shortlist of 14 structural indicators to be covered in the statistical annex to its 2006 Annual Progress Report to the European Council. Perhaps aptly, indicator number 13 is:

- Energy intensity of the economy (as defined in the Eurostat B0 Macro-economic Indicator above)

This is the only energy related indicator included in the list although number 12 relates to Greenhouse Gas Emissions.

2.9 Use of indicators for energy analysis in buildings

A common precursor to presentation of indicators is to present general raw data information for the country under study. The following list is typical. Although the data here are not strictly indicators in their own right, they do offer important indications of the drivers of energy use.

General energy balance statistics:

- Share of total energy consumption per sector
- Share of total electricity consumption per sector
- Total energy consumption per sector

- Total electricity consumption per sector
- Fuel mixes per sector
- Total energy consumption per branch per sector
- Fuel mix per branch per sector

General building stock statistics:

- Building codes per sector
- U-values (average or specific) of buildings per sector
- Stock of buildings per sector
- Type of building per sector
- Year of construction of building per sector
- Floor space of buildings (average or total) per sector
- Installed heating systems mix per sector
- Share of buildings with central heating per sector
- Age of installed heating systems per sector
- Stock electrical appliances per sector

Drivers of energy use:

- Private consumption in Euros
- GDP in Euros
- Electricity price in Euros
- Fuel prices in Euros
- Population housed for the residential sector
- Share of population employed in the service sector
- Population employed for the service sector
- Share of value added in the service sector
- Value added for the service sector

Analytical:

- Trends in any of above since 1970
- Absolute value comparisons between countries for any of the above
- Corrected value comparisons between countries for any of the above

In the residential and service sectors, which are the focus of this report, there are many bottom-up indicators which can be used. The Odyssee Project lists over 30 such indicators relating to energy use in the household sector and over 20 for the Service Sector.

We already know the specific areas that energy is used for within a building:

- Space heating
- Water heating
- Cooking
- Lighting
- Electrical appliances
- Air Conditioning

If we take the intensity, structure, activity disaggregation approach (Schipper et al., 2001) to the residential sector in order to find the same factors of overall energy use as for the transport example above, we get:

Space heating energy = energy/m^2 * floor area/per capita * population

Water heating energy	=	energy/capita	* person/household	* population
Cooking energy	=	energy/capita	* person/household	* population
Lighting energy	=	electricity/m^2	* floor area/per capita	* population
Electrical appliances	=	electricity/appliance	* Ownership/per capita	* population
Air Conditioning	=	electricity/ appliance	* Ownership/per capita	* population
Total service	=	energy/value added	* value added	

We thus now have a complete set of indicators which are a basis for telling us what the influence of the various components of energy use in the sector. We can in turn use this as a basis for developing our own set of indicators. We can use ID to relate these different components to energy use development for each branch in order to quantify their relevant influence.

Although such a disaggregation of energy end uses can explain to us whether the cause of change is intensity, structural or activity-related, we would need further indicators to know why each of these individual parameters is changing. The above can tell us, for example, that intensity is decreasing, but not why. Likewise, the above can tell us that floor area is increasing and the impact of this on overall energy use, but not why. To know this we would need to relate floor size change to external parameters such as income or price change and intensity to technical development and energy price trends. If this knowledge is needed for policy development we suggest the following indicators:

- Dwelling floor area/per capita versus change in income
- Appliance ownership/per capita versus change in income
- Penetration of CFL lighting versus change in income
- Penetration of A-label appliances versus change in income
- Penetration of ventilation versus change in income

- Dwelling floor area/per capita versus change in cost price
- Appliance ownership/per capita versus change in cost price
- Penetration of CFL lighting versus change in cost price
- Penetration of A-label appliances versus change in cost price
- Penetration of ventilation versus change in cost price

- energy/m^2 for space heating versus change in income and price
- energy/capita Water heating versus change in income and price
- energy/capita Cooking energy versus change in income and price
- electricity/m^2 Lighting versus change in income and price
- electricity/year /appliance versus change in income and price
- electricity/year Ventilation versus change in income and price

- Global long-term trends for persons per household

If necessary, ID and the aforementioned ODEX can give a good account of progress with energy efficiency progress for the sector branches, which can thus dictate whether more interventions are needed to improve efficiency without actually knowing what types of for example space, water or cooking heating technologies, are in use. Thus combining all of the indicators mentioned in this section until now can tell us "why energy use is changing". For a more elaborate example of the types of indicators which attempt to do this and to account for the root causes of increased energy use, see Chapter 4 and 5 of (Odyssee network, 2006).

To boot, if we are concerned with both sectors' fuel mix, for the purposes of carbon dioxide emissions, fuel security of supply or energy conversion efficiency, we would also add to our list the following indicators and statistics:

- Useful energy for thermal energy purposes per square metre.
- Delivered energy for thermal energy purposes per square metre.
- Fuel mix trends (not an indicator by the authors definition, but useful)
- Heating system installed

If we are keen to examine space heating energy use across the building stock, we would also add:

- Space heating by year of construction and type of building
- U-values by year of construction and type of building
- Building thermal standards as specified by national and international policy
- Proportion of central heating versus room heating
- Dwelling tenure (who is paying the energy bill)

It should be noted that dividing energy trends by building tenure is much talked about, but seldom carried out in the statistics. It is important in terms of the split incentives to reduce energy use in buildings.

We could also make a similar distinction between efficiency of newer electrical appliances. With new appliance efficiency standards, we need to measure efficiency of what is sold and measure consumption patterns in households to allow results to be seen (IEA, 1997).

- electricity/new appliances

The buildings in the service sector actually differ from the residential service in terms of load profile, mix of needs, types of buildings and policies *in situ* (Krackler et al., 1999). A further practical difference is that data availability is very limited compared to what is available for the residential sector due to it not being a priority area for policy makers. Floor space data is particularly rare for European countries. Value added or employee numbers are as such used as proxies for floor space in the following manner:

- Energy/ value added
- Energy/ employee
- Electricity/ value added
- Electricity/ employee
- Electricity intensity (kWh/€)

Krackler et al. (1998), actually state that heating, lighting, and cooling levels are driven primarily by commercial floor area, whereas energy use for water heating, office equipment, and some electric appliances depends more strongly on the number of service sector employees. Thus the absence of floor area data does not rule out all possibilities for use of indicators in this sector.

Energy use per square metre is the intensity indicator used above for space heating, while electricity per square metre is used for lighting. We could use these same indicators as indicators of overall intensity in the residential sector as well. The advantage of using the square metre data category is obvious; it makes more sense to compare cost of accommodation per square metre for Tokyo, Paris, L.A. and Singapore then the cost of a dwelling (Schipper and Hass, 1997). It is, however, also useful to look at energy use per dwelling and energy use per household. These indicators allow an insight into the effect on energy use of the twinned effects of increasing dwelling and decreasing household sizes.

Although household sizes are decreasing, house sizes are not decreasing at the same rate, which can mean that people are heating a bigger space and thus using more energy per person to do so. The following four indicators would help to describe these trends.

- Consumption/dwelling
- Consumption/household
- Dwelling size
- Household size

The main or overriding driver of energy use in the residential sector is population, while for the service sector it is added value (EEA, 2002). As these parameters will continue to rise indefinitely, the point with keeping track of them is more their decoupling from energy use than their individual trends.

There are of course the aforementioned variances in weather patterns between countries and between seasons in the same country, and of course in GDP and climate, which cause differences in these individual components between countries. To account for these differences it is necessary to adjust indicators for constant weather, constant European climate, constant European service sector structure, or constant GDP. For more information in this see Appendix B. The idea is to add a weighting to the energy use of each country to iron out structural differences. For example, even thought Norway and Moldova have the same population, their respective energy uses cannot be compared unless the differences in their respective GDP, climate and service sector structure are accounted for.

From the perspective of inter–country energy use analysis, the important thing is to go through the above indicators to find the problem ones, to quantify some distance to target benchmarks, to model some changes in the above parameter mix and then to monitor indicator response to technical policy change. The ODEX and ID can then be used in tandem with the above raw statistics to show general aggregate trends.

2.10 Data requirements for energy indicators

The IEA recommends that data series from the 1970s should be used to show the full impacts of the oil shocks, and also to show the influence of demographics, recessions, prices, the evolution of basic industrial processes, lighting and I.T. The IEA also recommends that data used must be within ±5 % accuracy. Otherwise, the differences will be bigger than the changes which occur naturally from year to year (IEA, 1997).

The source of the raw data for building indicators for a European-wide energy use analysis would start with the Odyssee project. The IEA actually welcomed the arrival of the Odyssee project for the contribution it would make to data supply (IEA, 1997). For more discussions on this matter, see Chapter 1 on data in this report. At the same time, the raw data for the indicator calculation process can actually be skipped altogether with the Odyssee Indicator Database data, as they actually contain a large calculated time series set of macro-economic, residential and service sector indicators, many of which are suitable for the purposes of this project.

2.11 Conclusion

This chapter began by listing the following factors which affect energy use:

- income
- energy prices
- technological progress
- energy efficiency programs
- structural changes (in the mix of materials, goods and services produced/provided)
- profound changes in the levels of mobility
- population

We described the role of top-down and bottom-up indicators in analysing the aggregate and individual importance of these parameters, before producing a broad set of general indicators that should be used as part of a first characterisation of the European building stock in order to find the main causes of energy use increase.

Using the indicators described throughout the chapter, we could undertake the following step-by-step analysis for energy use in buildings

- Describe the types of buildings, their ages and their energy end uses
- Use the ODEX to account for national efficiency improvement progress in the residential sector
- Use ID to account for structural and activity effects in the residential sector and activity effects in the service sector
- Disaggregate energy end uses in both the residential and service sectors into revealing indicators which can depict the end use trends in both sectors to tell us "why energy use is changing", and also tell us the impact of targeted policies. The Eurostat priority indicator list and IEA short indicator list can be useful as an initial survey to find obvious causes
- Use the methodology outlined in Section 2.9, to focus on the relevant energy end uses and structural effects that are highlighted in the IEA and Eurostat Indicator analyses (see previous point) to be worth focusing on in terms of their susceptibility to technical change

An indicator-based analysis is attempted in Chapter 3, although not precisely following this step-by-step approach.

Some limitations with the use of indicators are that:

- they are completely dependent on data availability and on quality of data. Furthermore, the more detailed the indicators are, the more time and resources need to be devoted to their calculation

- they cannot detect quality issues. For example, we could have an A-rated washing machine that doesn't wash clothes very well (IEA, 1997)

- they cannot detect changes in indoor temperature norms due to this statistic not being collected

- while pointing out the main causes of increasing energy use, trends say nothing about the potential for reversing such trends, unless they are accompanied by an analysis which seeks to describe developments

Nonetheless, the IEA Indicators Manual (IEA, 1997) states that bottom-up indicators can account for 75 % to 80 % of final energy use, and are thus obviously a useful and necessary component of effective energy use analysis. Put simply - to detect change, you need good indicators.

Further work would be to carry out an exercise based on the proposal in Section 2.9, using a set of indicators to "encircle" the various causes of energy use in order that their full impact is captured. This would test the robustness of the proposal. To develop the knowledge on the subject of indicators and their use further, it would be necessary to delve deeper into the Odyssee Network approach to indicators and to develop ID methodology to incorporate more explanatory parameters.

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3. EU building stock characterisation

This section describes demand-side energy trends in the EU 25 from 1990 to 2004. Its aim is to account for energy use in buildings, with the focus being on the residential and service sectors. By the end of the section, the reader should have an idea about the various technical and non-technical influences that affect energy use in buildings and, in particular, trends and developments between 1990 and 2004.

3.1 Introduction

This analysis aggregates all EU 25 countries to one unit to describe their energy use trends, i.e. it does not account for trends in individual countries. The exercise is thus somewhat academic, given the variety in terms of economy and climate and political will to reduce energy use that exists across the EU countries. In other words, trends and policy measures that are true for one country may not be true for another. In fact, the EU Energy End Use Efficiency and Energy Service Directive (2006/32/EC) specifically requires individual countries to produce action plans as to how they intend to make energy savings according to their own particular set of circumstances. The directive thus acknowledges diversity between countries by not enforcing any prescriptive measures across the EU. Nonetheless, the exercise is still useful in terms of highlighting general trends. One important statistic worth bearing in mind is that eight countries (Belgium, France, Germany, Italy, Netherlands, Poland, Spain and the United Kingdom) account for 80 % of final energy consumption and over 80% of carbon dioxide emissions in the EU 25. Thus trends for the EU 25 reflect in a large part trends across these eight countries. The EU 15 countries themselves account for 88 % of final energy consumption.

We begin our analysis by examining final energy use across all sectors of the economy. Figure 3.1 shows final energy consumption for EU 25 for two time periods divided between the industry, transport and other (residential, services, agriculture and fisheries) sectors. The largest increase in consumption has been in the transport sector, while that for the other sector is also increasing.

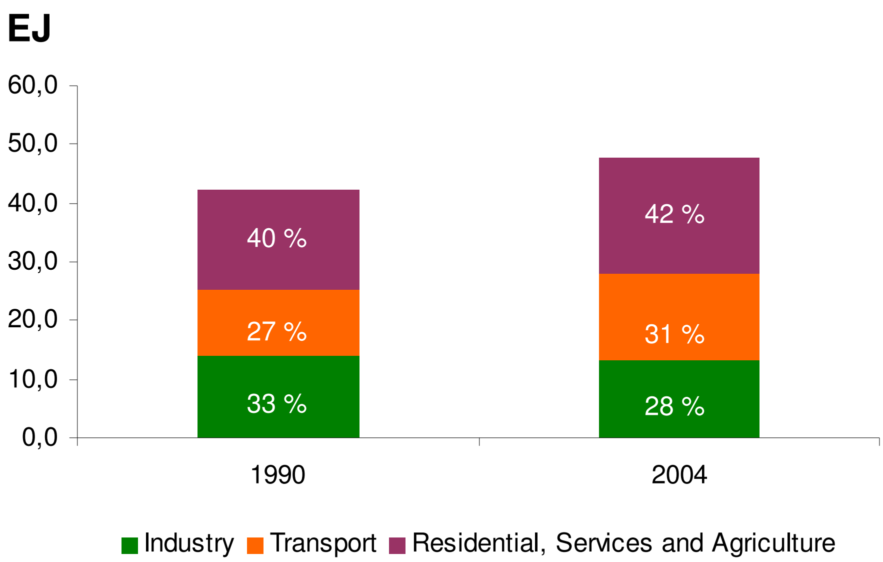

Figure 3.1 : Final energy consumption in EU 25 in 1990 and 2004. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

Figure 3.2 lists the primary energy consumption fuel mix for the EU 25. Figure 3.3 then shows the conversion efficiency from primary fuel to the final energy supply shown in Figure 3.1. Figure 3.2 and Figure 3.3 tell us that there has been no overall reduction in the use of fossil fuels or significant improvements in conversion efficiencies from 1990 to 2004. Efficiency gains in conversion processes have been offset by converted fuels (e.g. electricity, refined petroleum products) taking a larger share of final energy consumption (EEA, 2002). Figure 3.20 and Figure 3.28 clearly show this increase in electricity use in the residential and service sectors. Thus given the increased consumption of converted fuels and the predominantly fossil fuel-based mix in the primary energy supply, we can only assume that the increase in total final energy consumption shown in Figure 3.1 is a negative development in terms of the goals of curbing climate change and ensuring fuel security of supply in Europe. We can also assume that energy efficiency policy measures have not had enough of an impact to prevent a rise in primary energy consumption.

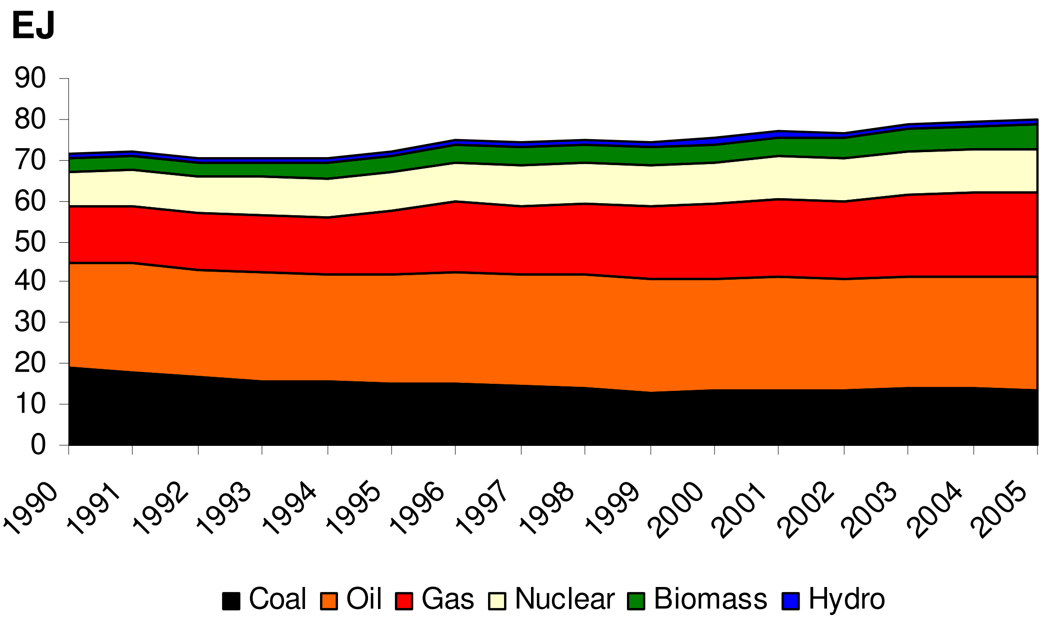

Figure 3.2 : Primary Energy Consumption in EU 25 from 1990 to 2005 (Eurostat calls this Gross inland consumption). Chart constructed using data from the Eurostat Online Database (Eurostat, 2007).

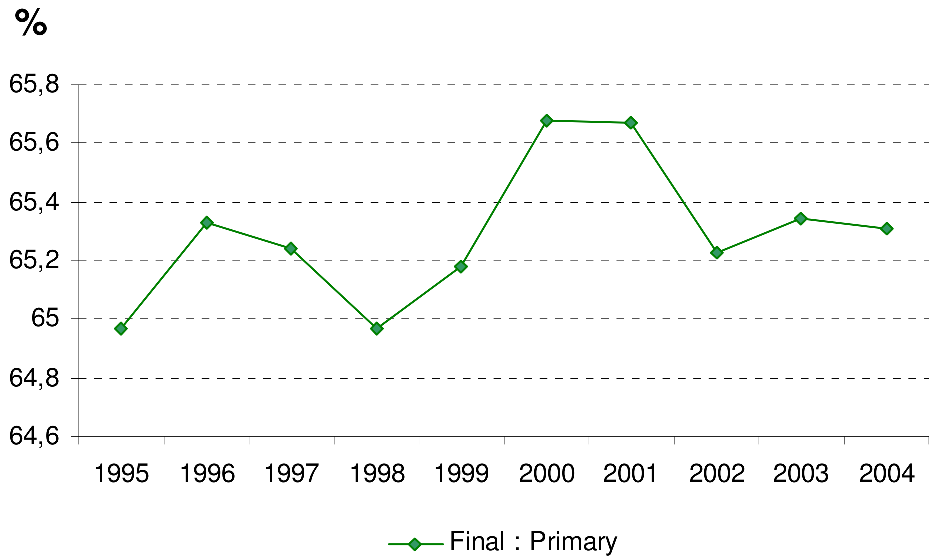

Figure 3.3 : Ratio of final to primary energy consumption for EU 25 from 1995 to 2004 (Eurostat Macro priority indicator C0). Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

Traditionally, increases in final energy consumption are inevitable due to both economic and population growth. Increased economic growth leads to an increase in demand for goods and services, which in turn leads to more employment and greater affluence. Increased production of goods and services generally requires increased energy input. Increased affluence usually leads to higher living standards which usually increase per-capita energy use. In fact, anecdotally it is very uncommon to find a region of high economic growth that does not have some corresponding growth in energy use. Figure 3.4 shows the increasing trends in value added in the service sector and in GDP per capita in EU 25 from 1995 to 2004. Value added in monetary terms is the measure with most use for quantifying the volume changes in output for the diverse types of goods or services produced in the industrial and service sector, while the development of GDP per capita is a general indicator of trends in consumer affluence. The graph shows a steady increase in both indicators over the period. There has, however, been a shift in most European countries to a more service-based economy. This is the result of the flight of traditional manufacturing industry to the Far East and attempts to exploit the technical expertise found in Europe to produce goods and services higher up the value chain. Despite this development, value added in the industrial and agricultural sectors has continued to rise across EU 25 countries, although agriculture seems to have just kept pace with inflationary growth over the last number of years. Thus overall we can say that there is indeed increased economic growth and affluence in Europe between 1990 and 2004.

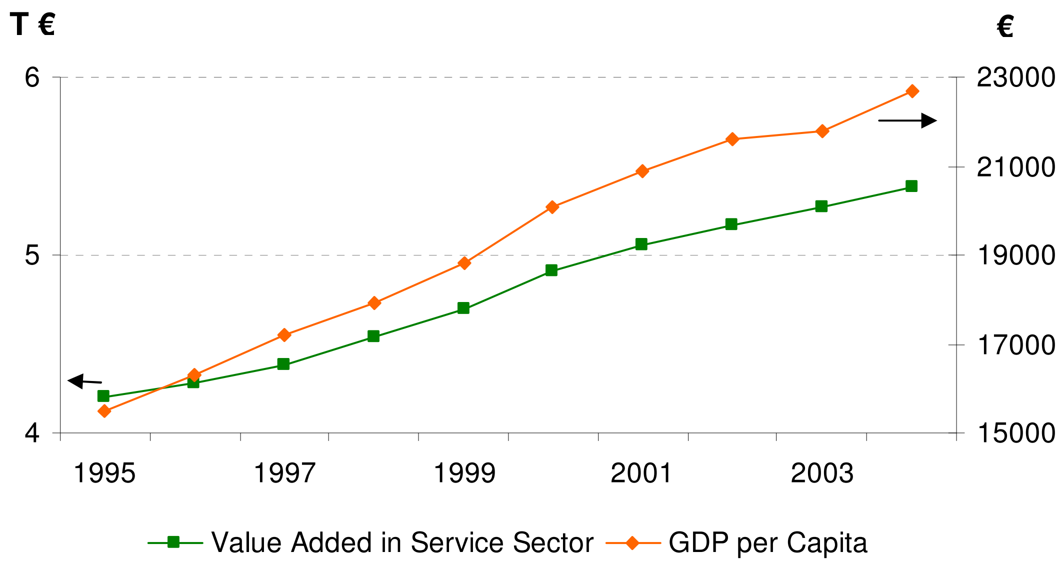

Figure 3.4 : Value added in the service sector and GDP per capita in EU 25 from 1995 to 2004. Chart constructed using value added data from the Odyssee Indicators Database (Enerdata, 2006) and GDP data from the Eurostat Online Database (Eurostat, 2007).

Although higher standards of living are usually associated with falling birth rates, they also lead to increased inward migration and greater life expectancy. This can lead to population growth. Increased population inevitably means more dwellings are needed. Decreasing household size, which is also associated with increasing affluence, increases the number of dwellings needed even further. Figure 3.5 below shows the average number of persons per household over recent decades for the EU 25 and for two other countries which have the highest and lowest average number of persons per household in the EU 25 respectively. The data show that household size is decreasing in line with modern trends.

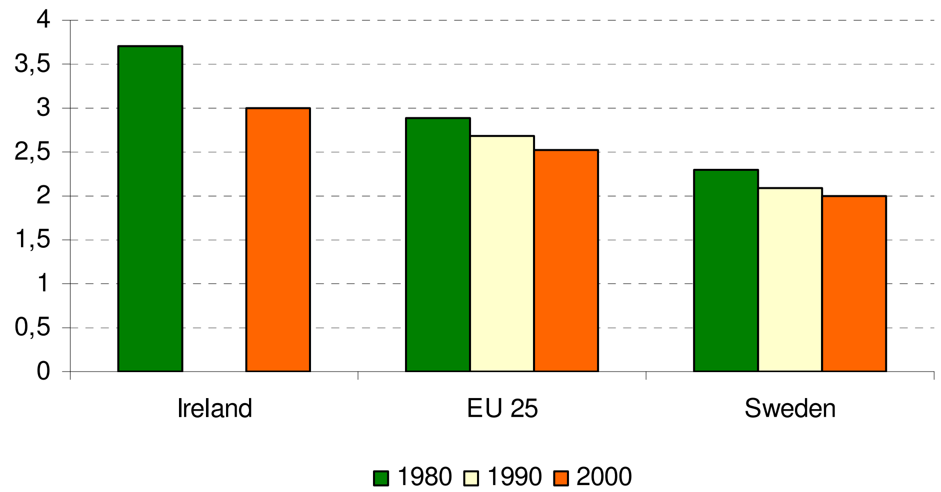

Figure 3.5 : Average number of persons per household in Ireland (highest average), EU 25 and Sweden (lowest average) in 1980, 1990 and 2000. Chart constructed using data from the Housing Statistics of the European Union (Swedish National Board of Housing, Building and Planning, 2005).

Figure 3.6 shows that, from 1990 to 2004, population in the EU 25 has increased by over 20 million, while the stock of dwellings has increased by over 30 million, from bases of 438 million and 172 million respectively.

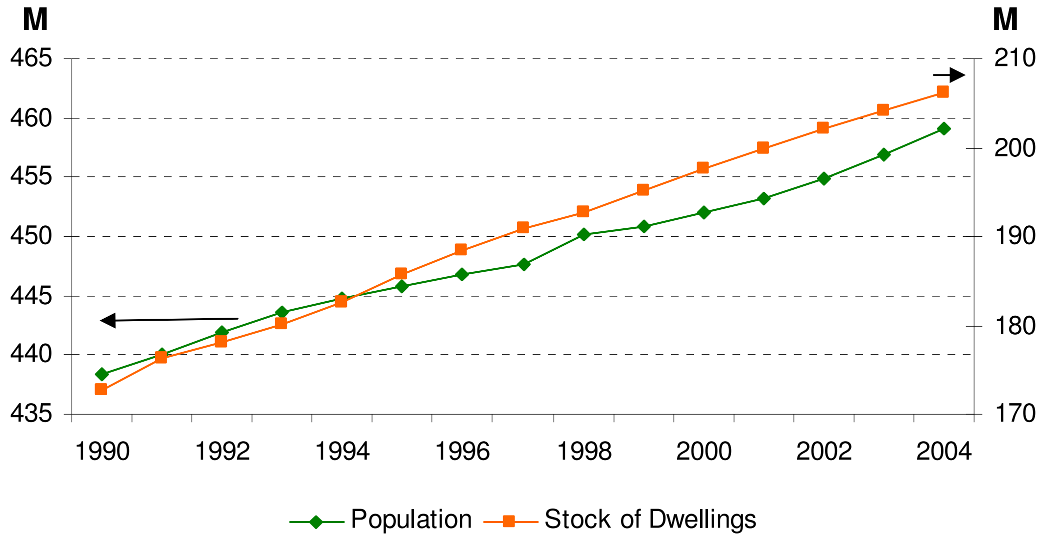

Figure 3.6 : EU 25 Population (lhs Y-axis) and dwelling stock (rhs -Y-axis) from 1990 to 2004. Chart constructed using population data from the Eurostat Online Database (Eurostat, 2007) and stock of dwellings data from the Odyssee Indicators Database (Enerdata, 2006).

Population increase coupled with increased standard of living means that not only is the number of dwellings increasing, but the size of the average dwelling is also increasing. Figure 3.7 shows the increase in the size of an average dwelling across the continent over four time periods. In every country, except Sweden and Greece, dwelling areas are increasing. Although the smaller average household size shown in Figure 3.5 mean that, in theory, smaller dwellings should be needed, in fact the increased affluence offsets this as households are choosing to have larger dwellings or are opting for single-family dwellings as opposed to living in multi-family dwellings (Ademe, 2005). More dwellings and larger dwellings mean an increase in the amount of floor area that needs to be heated, cooled and illuminated.

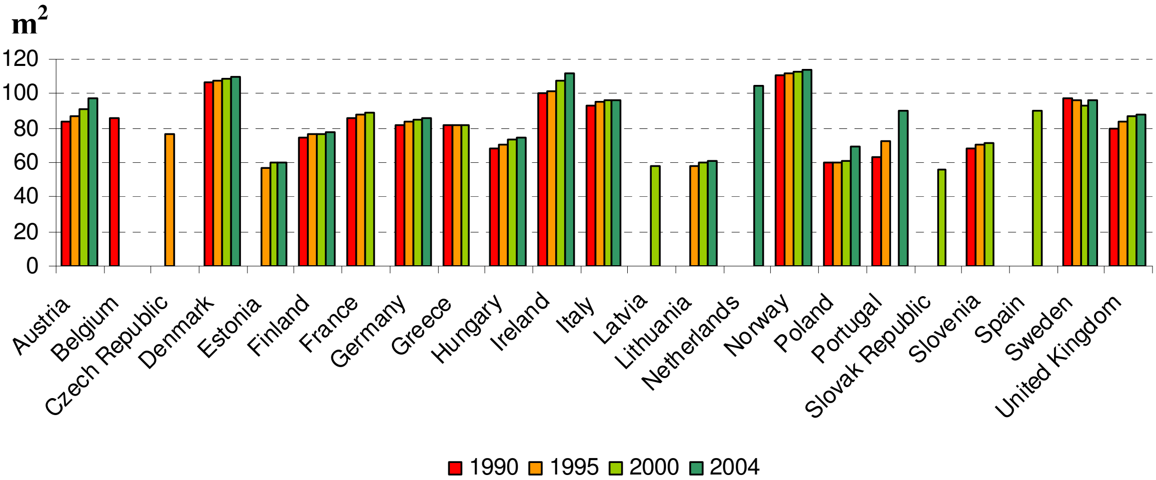

Figure 3.7 : Average dwelling floor space size in EU 22 over four time periods. Chart constructed using data from the Housing Statistics of the European Union (Swedish National Board of Housing, Building and Planning, 2005).

Figure 3.8 gives a breakdown of the entire dwelling stock between single-family and multi-family dwellings. There is insufficient data to show how this ratio has developed over time. However, from the little data that is available it is clear that from country to country there is variation in whether there are more single-family than multi-family dwellings being built or not. In France, for example, there are more single-family than multi-family dwellings being built. In Sweden, the numbers of both are about equal, while in the Czech Republic more multi-family dwellings are being built (Swedish National Board of Housing, Building and Planning, 2005). Overall, however, there is a trend towards a greater proportion of single-family dwellings (Ademe, 2005).

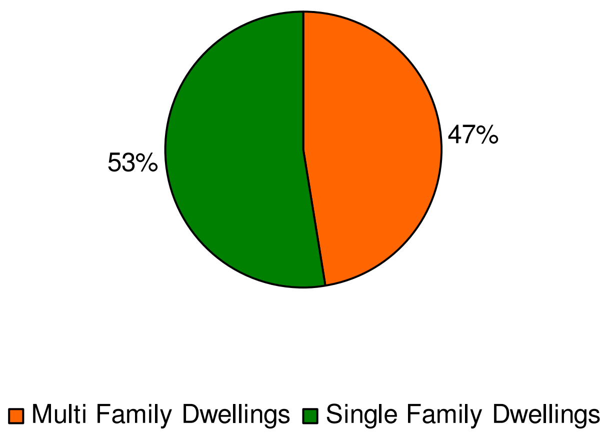

Figure 3.8 : Stock of dwellings in EU 25 in 2004, divided by type. Chart constructed using data from the Housing Statistics of the European Union (Swedish National Board of Housing, Building and Planning, 2005).

The same types of floor space trends are true in the industrial and service sectors. Business obviously needs larger floor space to cope with increasing demand for goods and services. Figure 3.9 shows the trends in total floor space area in both the residential and service sectors from 1990 to 2004 for the EU 15. Data is not available for service sector floor size for the NMC 10 countries. Interestingly, while there is constantly three times more floor space in the residential sector than in the service sector, the residential sector uses only twice as much energy as the service sector.

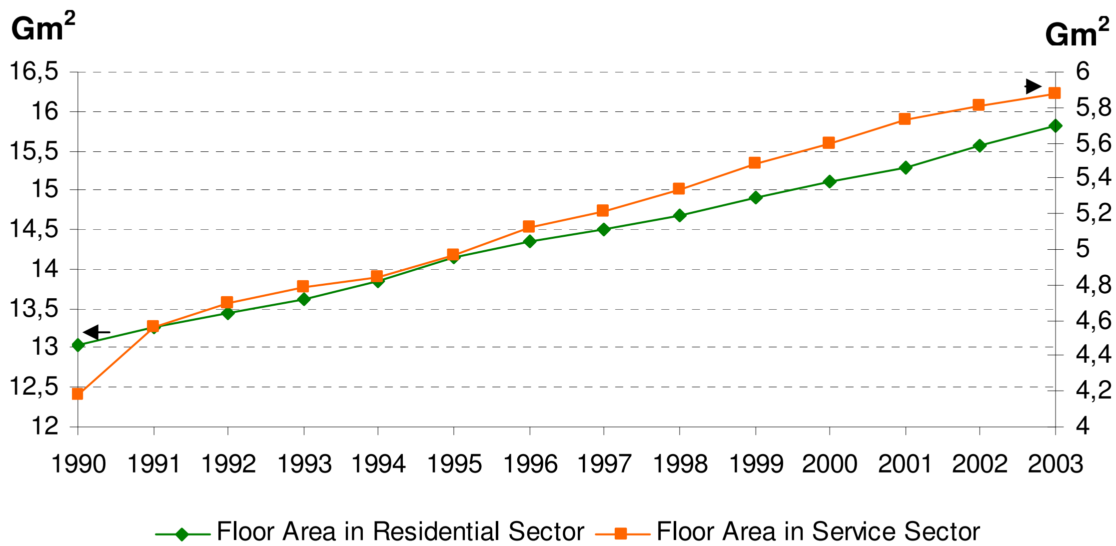

Figure 3.9 : EU 15 Floor Area in residential sector (lhs Y-axis) and service sector (rhs Y-axis) from 1990 to 2003. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

We have hypothesized that increased affluence and population growth leads to an increase in floor area across sectors which lead to an increase in energy needed for space heating, cooling and illumination. It also undoubtedly leads to an increase in energy use for personal transport and domestic appliances. This is especially true in the European context, given the existing and the desired standard of living. Figure 3.6 shows the increased ownership rates of some domestic appliances for 1990 and 2004. Thus the number of energy-using appliances per person is increasing, while population increase is increasing the total amount of energy using appliances even further. It is also true that due to economic globalisation the price of energy-using appliances is decreasing, thus allowing greater affordability to households regardless of their economic circumstances. Technological progress - e.g. the advent of mobile communications and home entertainment applications - are also increasing the variety of energy-using appliances that are part and parcel of everyday life in the developed world. Furthermore, the spate of heat waves and higher than usual summer temperatures has caused a dramatic increase in the purchase and use of air conditioning in the southern half of Europe in recent years. We thus have five separate parameters which are increasing the amount of energy-using appliances used in the EU 25.

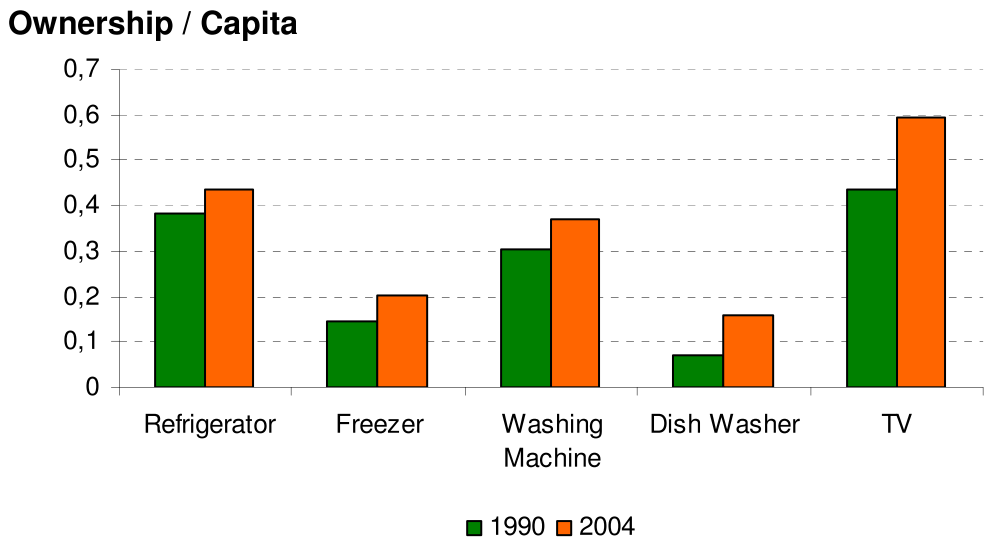

Figure 3.10 : Penetration of appliances in population in EU 25 in Residential Sector in 1990 and 2004. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

Figure 3.1 shows us that the absolute demand for energy is increasing in the EU 25, while Figure 3.2 shows that most of this demand is being met by the consumption of fossil fuels. Figure 3.4 to Figure 3.10 then allowed us to speculate that economic and population growth in the region is the underlying cause. However, even if this assumption is true, we cannot get away from the fact that population and economic growth will continue to increase and thus that overall energy use and the demand for energy will continue to rise. The market economy is predicated on economic growth, and while there may be cyclical economic recessions and booms the trend has to continue upwards. It always has. The increasing world population over coming decades cannot but contribute to an increasing population in Europe despite falling population in some of the former planned economies such as Ukraine and Russia. In addition to this, the disparity in GDP per capita between the NMC 10 countries of the EU 27 and the Northern European members which is masked by aggregated statistics such as those in Figure 3.4, can only lead to those countries striving to continue their economic development to reach and maintain an acceptable standard of living. Lars Josefsson, CEO of Vattenfall, says in his book *The Future in Our Hands* (Vattenfall, 2006) that poor countries of the world should be allowed to reach a certain level of prosperity. One can hardly imagine that the citizens of those countries will have it any other way.

Thus if our tackling climate change and security of supply goals are to be met, growth in energy use must in fact be decoupled from economic and population growth, or at least until such time as the bulk of energy supply comes from renewables.

It is useful to look at trends in the actual amount of energy needed to provide economic growth per unit of value added for the industrial or service sector or an average standard of living per member of the population to get a view of a region's progress with reducing energy consumption. These two data categories are calculated as energy per unit of value added and energy per capita respectively. They are known as sector-specific energy intensity indicators, as they depict the energy intensity of sectoral activity. The EEA (EEA, 2002) defines four drivers of activity for the industrial, transport, residential and service sectors (all related to economic or population trends), and then choose four corresponding energy intensity indicators, as listed in Table 3.1, to analyse energy consumption trends therein. Its use of these indicators is to measure progress with whether growth in activity in these sectors has been decoupled from energy consumption. They then postulate that the energy intensity indicators for each sector must be decreasing faster than the driver is increasing in order for decoupling to occur.

Table 3.1: Sectoral growth drivers. Information for table taken from Energy and Environment in the European Union (EEA, 2002).

Sector	**Driver**	**Energy intensity indicator**
Industry	Value added	Energy demand/value added
Transport	GDP	Energy demand/GDP
Residential	Population	Energy demand/ Capita
Service	Value added	Energy demand/value added

Figure 3.11 shows how decoupling, as defined by the EEA (EEA, 2002), progressed between 1990 and 1999. The figure shows that the industrial sector is the only sector in which actual decoupling has happened. In the services sector, energy intensity is not decreasing fast enough, while in the residential sector intensity is actually increasing.

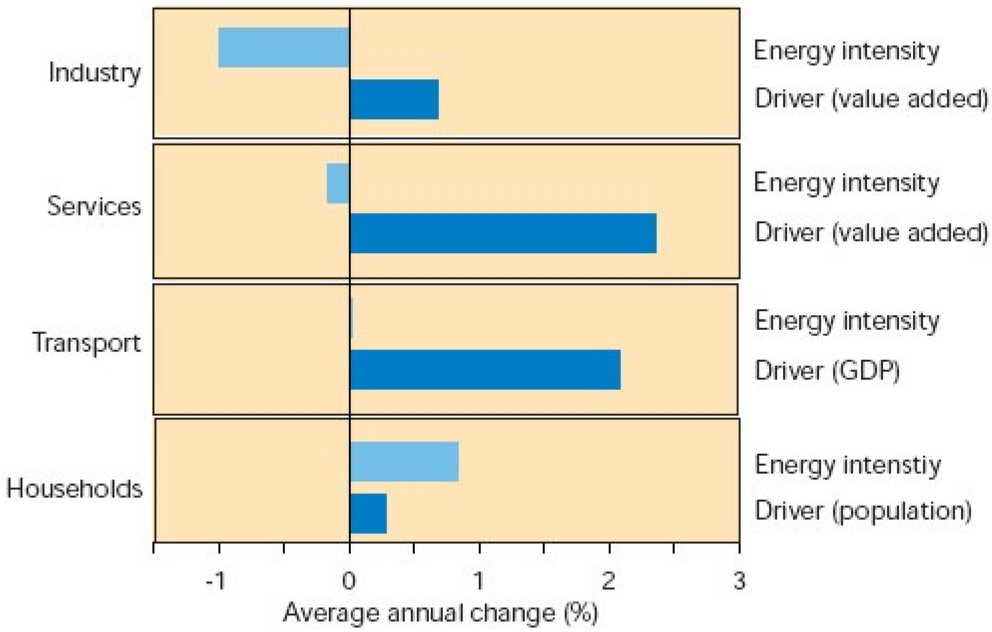

Figure 3.11 : Annual change in sectoral energy intensities and related drivers, 1990 to 1999. Chart taken from Energy and Environment in the European Union (EEA, 2002).

Figure 3.12 shows the absolute increases in energy intensity in the residential sector between 1990 and 2004. This corresponds to the data for the residential sector in Figure 3.11, except that the time resolution in Figure 3.12 is for five additional years until 2004. Even removing the effect of very cold winters and warm summers (climate correction) does not diminish the fact that more energy per capita is being used in the residential sector.

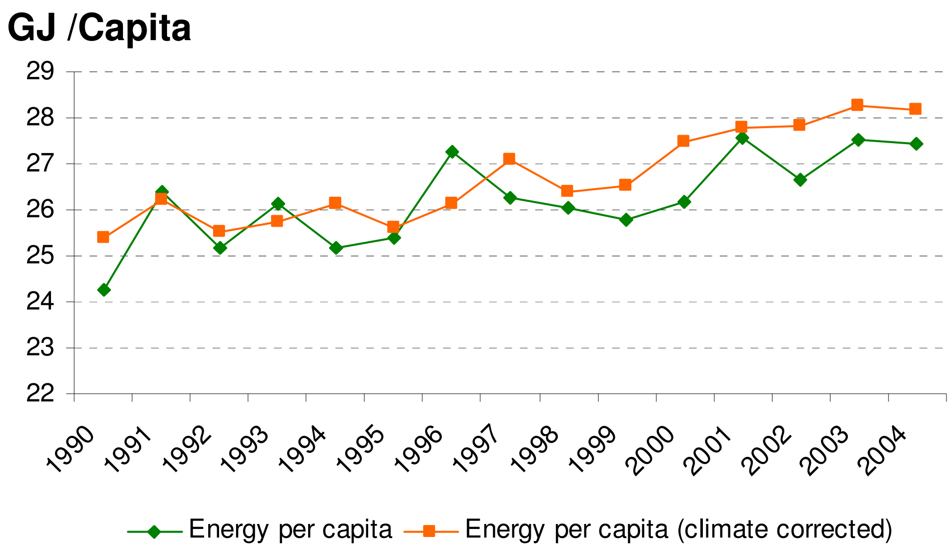

Figure 3.12 : Energy intensity of the residential sector in EU 25 from 1990 to 2004. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

Figure 3.13 confirms the slight decrease in intensity in the service sector but at the same time confirms the corresponding near 50 % increase in output in the sector over the period. Annually, value added has increased by 7.5 % between 1990 and 2004, while efficiency improvements have managed only 4 % per year over the same period. Thus the energy efficiency improvements are not occurring quickly enough to offset the general increase in output. Comparing the service sector data from the EEA in Figure 3.11 with the data from

Figure 3.13, our findings are both positive and negative. The negative part is that the absolute increases are greater, but the positive part is that energy efficiency is improving at half the rate of value added compared to the order of magnitude difference in the two indicators in the EEA graph. However, as we do not know what data the EEA used, we cannot say why such a large difference in findings exists.

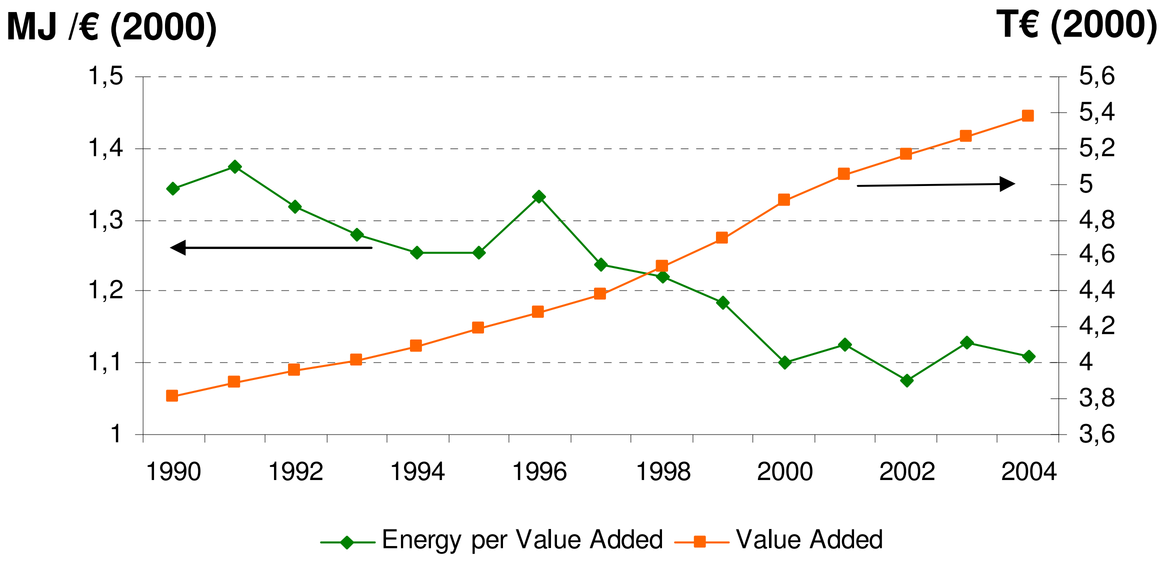

Figure 3.13 : Energy intensity and value added of service sector for EU 25 from 1990 to 2004. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

If we accept the EEA approach to measuring decoupling, we can see that for the sectors we are interested in, the service and residential sectors, that quite some change must occur in the consumption trends in these sectors. We already know from Figure 3.1.that absolute energy use in these sectors is increasing. Now we know that one of the causes is that energy use per capita is increasing, and that energy per value added is not decreasing quickly enough.

The only way that increasing energy use can be decoupled from increased growth is through further technical progress, and/or a switch by individuals and businesses away from activities that require energy input. We can guarantee that, through improvements in energy conversion efficiencies, technical progress will occur, and that this will decrease the amount of energy needed across all sectors. However, we cannot guarantee that consumers will choose activities that require little or no external energy input, such as cycling instead of driving, or playing chess instead of computer games. Thus we are more dependent on technical improvements in efficiency than on lifestyle changes.

Government and municipal policy measures have attempted to influence technical efficiency and consumer energy use patterns across the European Union since the first oil crisis, and in particular since climate change became headline news. Some technical improvements have occurred regardless of policy intervention, and are known as autonomous technical improvements. Others, however, are a direct result of policy measures. If there have been attempts in individual countries to focus on energy consumption patterns and effect lifestyle change they should presumably have been tackled through policy measures that impose an increased cost on the use of energy.

Prices for both fuel and electricity have certainly evolved between 1990 and 2004. These increases are due to a variety of reasons including scarcity of supply, increased demand in particular from China, increased fuel taxes, disruption to supply caused by the various Gulf Wars and deregulation of the electricity market in some EU countries. However, without a very detailed breakdown of the trends in final energy consumption, we cannot speculate as to whether the changing fuel prices have had an effect on final energy consumption of if energy demand is becoming more or less elastic to price changes.

Nevertheless, we can in general terms attempt to separate the effects of population and economic growth, technical progress and consumer behaviour on energy use. The aim is to be more definitive about the magnitudes of the various causes of increased energy use and thus get an idea for their importance. The approach we adopt to separating the respective causes of increased energy use is that of Index Decomposition (ID) (See Appendix E). This method breaks the total change in energy use over a period of time into the effects of activity, structure and intensity, such that

$E_t = A_t * S_t * I_t$

For the purposes of this report we will only break energy use into the influences of those three parameters, as defined in the IEA Indicators Manual (IEA, 1997). The advantage of the IEA ID approach is that it allows us in very general terms to make a strict distinction between technical and non-technical parameters effecting energy use. Activity in the residential sector is related by the IEA to population, given that population reflects the number of people that need to be housed. It relates structure in the residential sector to a combination of floor space per capita, persons per household, and per-capita ownership of appliances (IEA, 2003). Thus structure can help show the impacts of non-technical effects such as economic growth[††††] on energy consumption rates. Intensity in the residential sector is a combination of the energy per unit of floor area, per-capita energy or energy per appliance for the energy end uses of space heating, water heating, cooking and electrical appliances, and thus can show improvements with technical efficiency of energy-using applications.

Activity in the service sector is defined by the IEA as value added in order to have a measure of economic growth for the sector and, less explicitly, the general buoyancy of the economy and population growth. There is no structural component in the service sector as compared to the residential sector given the lack of data available for the sector and the fact that a shift in the structure of the sector from, say, banking to administration, does not have a significant impact on energy use. Intensity for the service sector is the amount of energy needed for unit of value added. Figure 3.14 shows a LMDI (Ang, 2000) index decomposition for the residential sector for the period 1990 to 2000. The service sector will be covered after the residential sector.

[††††] Competition, which is associated with economic growth, can also encourage energy efficiency due to businesses endeavouring to cut overhead costs. Increased affluence also allows consumers to purchase the highest standard electrical appliances. Thus economic growth has a technical effect on overall efficiency. This is however not considered for the purpose of this exercise.

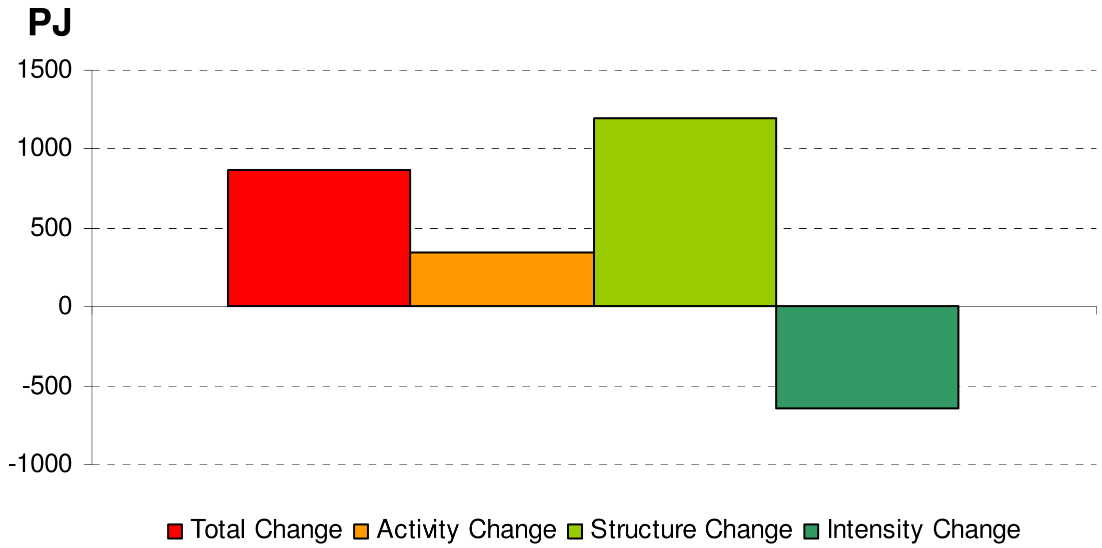

Figure 3.14 : Period-wise ID of residential sector energy use in EU 25 from 1990 to 2000. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006) and Log Mean Divisia Index method (Ang, 2000).

3.2 Residential sector

For the residential sector, the increase in consumption of 0,9 EJ over the period is thus a combination of increased activity (population), a shift in the structural make-up of the sector (both non-technical effects), and a reduction in intensity caused by increasing efficiencies. The structural effect is the largest contribution parameter and is offsetting the intensity improvements and the inevitable population growth. Figure 3.15 shows the trends in two of the structural effects, floor area per capita and persons per household, while Figure 3.10 has already shown an increased ownership rate for certain electric appliances. The diagram shows that floor area per capita is increasing by 4 % per year, while household size is falling by 5.5 % every year. Even with this knowledge in mind, one wonders if there is really any likelihood of change or even if we would want change in societal lifestyle choices such as how large one's dwelling is, whether one lives collectively or not, or whether one should own lots of electrical appliances or not.

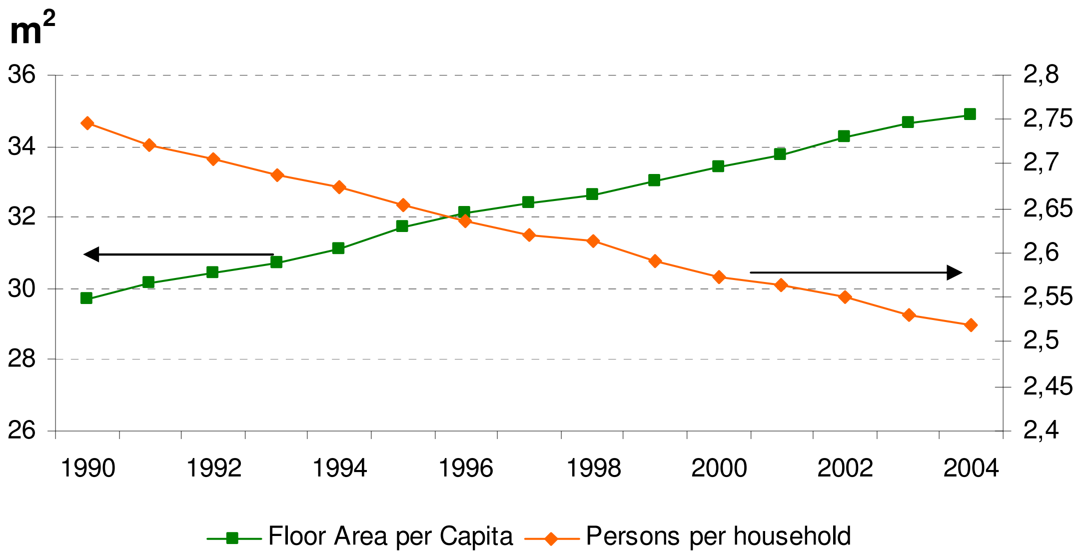

Figure 3.15 : Two of the residential sector indicators of structural change for EU 25 from 1990 to 2004. Chart constructed from floor area and dwelling data from the Odyssee Indicators Database (Enerdata, 2006) and population data from the Eurostat Online Database (Eurostat, 2007).

Can energy intensity in the residential sector fall more quickly than it currently is doing, and thus help offset the activity and structural-related increases and the move towards the EEA-defined decoupling goals? The ODEX (Ademe, 2006) provides an indicator of progress with energy efficiency for individual sectors, or for the economy as a whole, that can help answer this question.

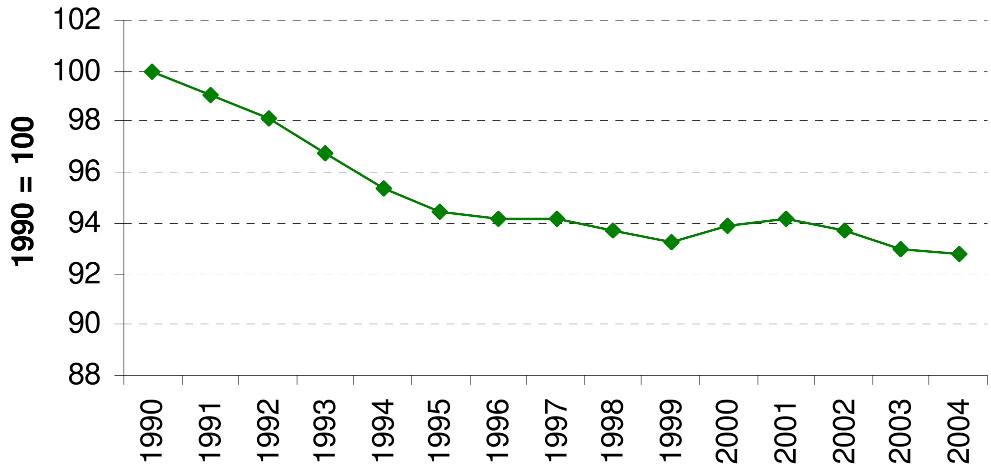

Figure 3.16 : ODEX for residential sector for EU 25 from 1990 to 2004. Chart constructed using data and methodology from the Odyssee Indicators Database (Enerdata, 2006).

Figure 3.16 shows the ODEX calculated for the residential sector for EU 25 from 1990 to 2004. The graph shows steady progress, with improved efficiency in the sector from 1990 1995, but that progress levelled off after that.

Box 3.1

Professor Reinhard Haas (Haas, 1997) has produced the diagram in Figure 3.17 to account for the various influences on energy consumption that occur in the residential sector. His analysis combines the role of the economic and policy effects that we have previously described, and highlights the structural and intensity effects used in index decomposition. He does not, however, include population growth (activity change) as an effect, perhaps, given the inevitable trajectory of population and also it lying outside the scope of policy recommendations. The diagram is useful as a check list of influences to methodically examine and assess their partial contribution to consumption trends. Professor Haas's view seems to centre more on the individual in terms of their attitude and income, and its influence on their behaviour, rather than on the impact of the economy as a whole on consumption.

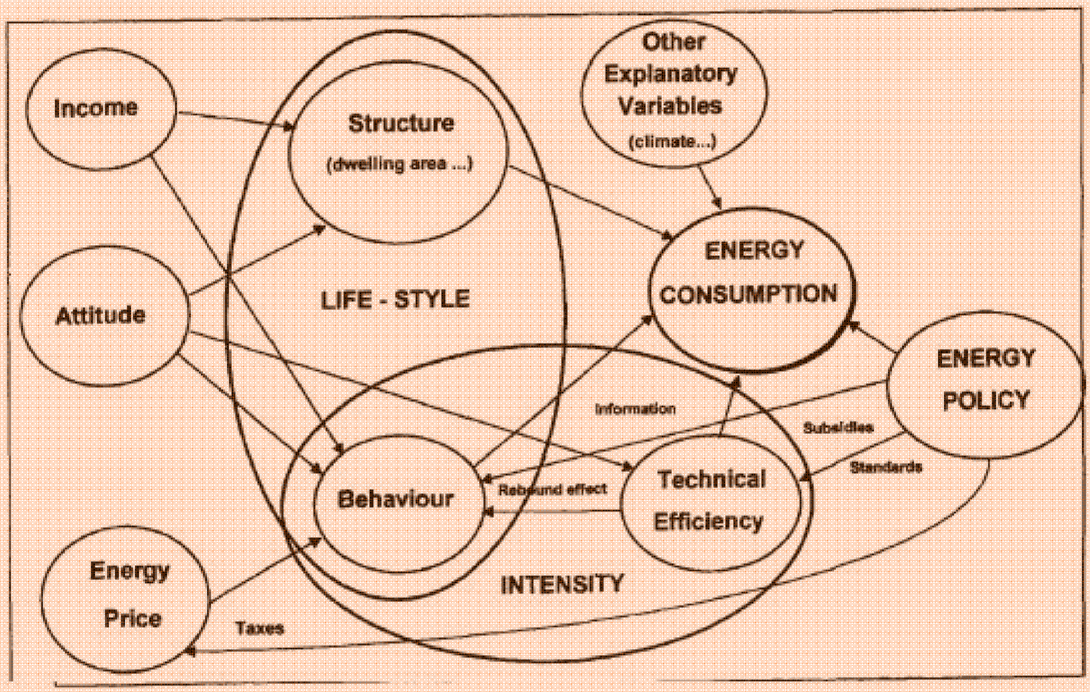

Figure 3.17 : A basic scheme of definitions and interactions in the residential sector. Chart taken from Energy Efficiency Indicators in the Residential Sector - What do we Know and What has to be Ensured? (Haas, 1997).

The Odyssee Network (Ademe, 2005) proves how the shape of the residential sector ODEX is due to improved space heating efficiency between 1990 to 1995, followed by a subsequent trend reversal, while over the entire time period the efficiency of electrical appliances has improved. Looking at energy use for space and water heating in detail in Figure 3.18, we can see a decrease in energy for space heating per square metre and an increase in energy use per capita for water heating. The decrease between 1990 and 2003 is only 5 %, but with no improvement between 1999 and 2003. This is despite the reasonable improvement in efficiency shown in Figure 3.14, and has undoubtedly been offset by higher indoor temperatures and increased installation of central heating in southern Europe and in Ireland. The increase in energy for water heating is due to a desire for increased levels of comfort in the population (Ademe, 2005), as undoubtedly water heating would also have benefited from the improved heating technologies, given that some dwellings combine space and water heating in the same systems.

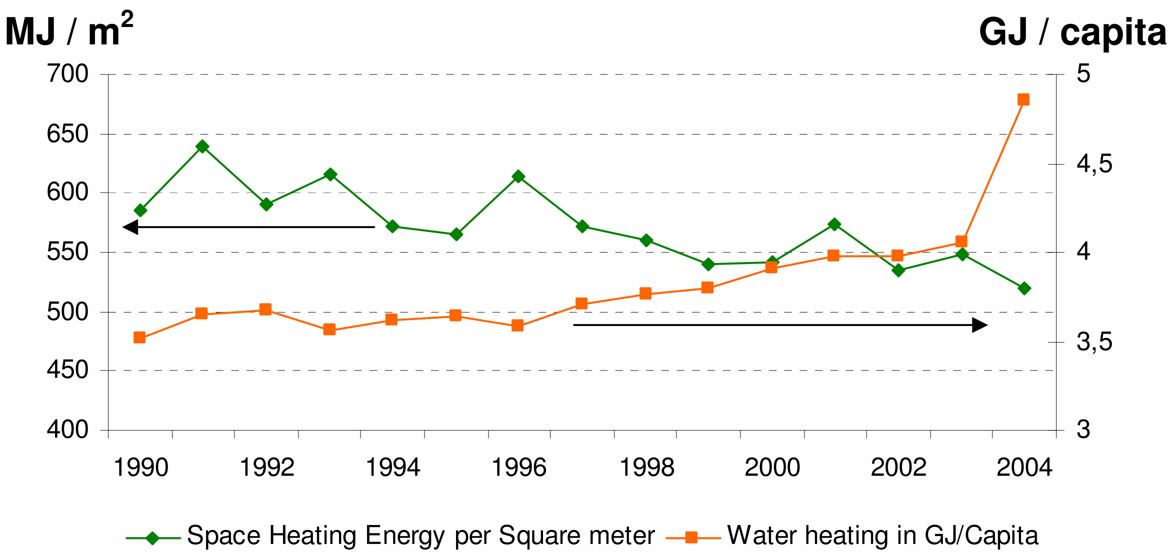

Figure 3.18 : Two of the residential sector indicators of intensity change for EU 25 from 1990 to 2004. Chart constructed from space and water heating and floor area data from the Odyssee Indicators Database (Enerdata, 2006) and population data from the Eurostat Online Database (Eurostat, 2007).

Figure 3.19 shows that there has been an absolute increase in demand for all energy end uses except for cooking in the residential sector over the 1990 to 2004 time frame.

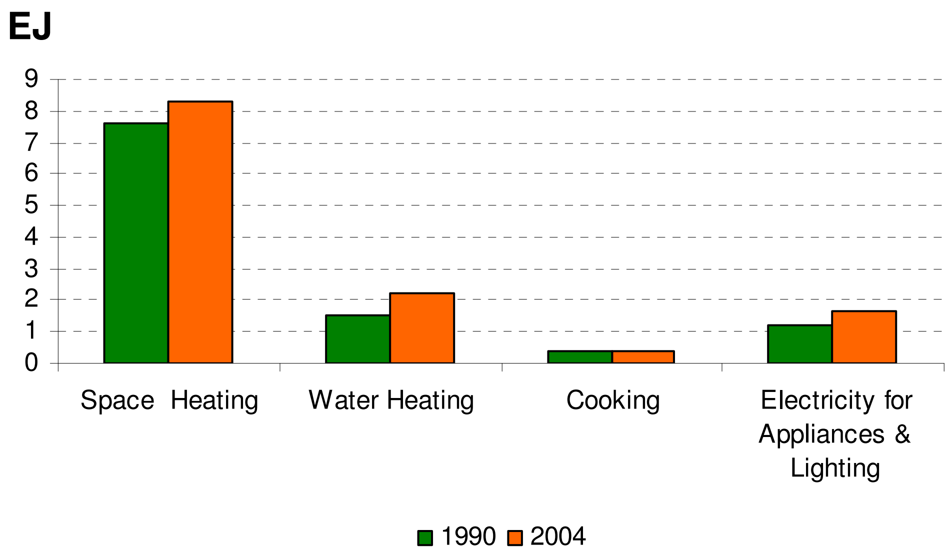

Figure 3.19 : Energy end – use in the residential sector in EU 25 for 1990 and 2004. Chart constructed from data from the Odyssee Indicators Database (Enerdata, 2006).

The increase in space heating energy use has been accounted for previously, while the increase in energy for water heating is quite dramatic, given its proportion of total energy use as compared to space heating. The increase in uses of electricity is particularly significant given the amount of primary energy needed to provide the electricity. However, data is not available that can allow us to account for the various end uses of electricity and in particular the expansion of air conditioning and cooling systems across Southern Europe.

Figure 3.20 shows that electricity use has increased by from 19% to 22% in the Residential sector. The figure also shows that the vast majority of the increase in final energy consumption in the residential sector has been through the consumption of natural gas. Given that natural gas is used only for heating, we can speculate that this increase has occurred due to increased use of space and water heating borne about by the desire for increased comfort levels and increased dwelling sizes and increased adoption of central heating**.**

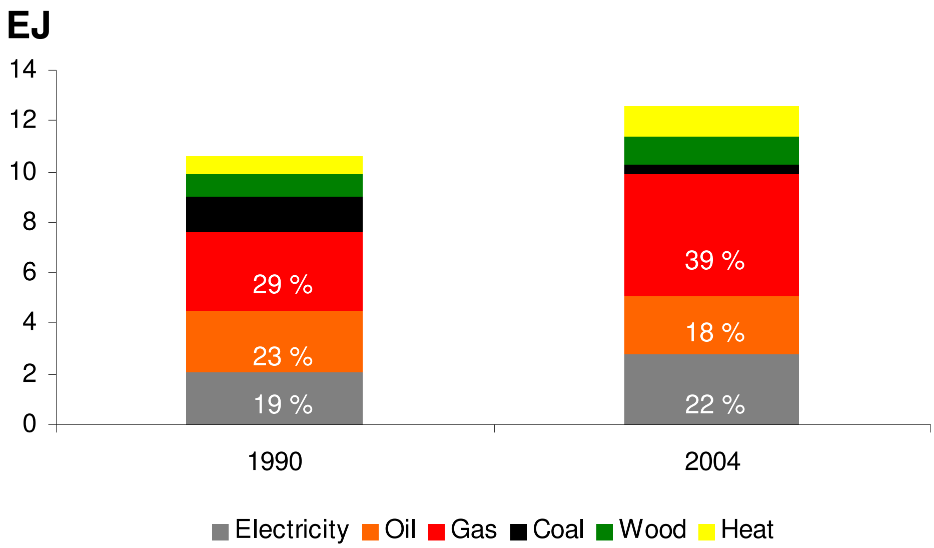

Figure 3.20 : Fuel mix in the residential sector in EU 25 from 1990 to 2004. Chart constructed from data from the Odyssee Indicators Database (Enerdata, 2006).

Have we thus explained the increase in energy use arising from structural effects? We have stated that larger and more numerous dwellings, installation of central heating, higher indoor temperature norms, increased consumption of hot water and increased ownership of appliances are the causes. Figure 3.14 has shown that these structural effects are increasing more rapidly than energy intensity is decreasing. Thus the EEA measure of decoupling is not being met.

If further proof is needed, we can use the data in Figure 3.21 to undertake a simple calculation to investigate if space heating energy per square metre is decreasing more rapidly than floor area per capita is rising, given the proportion of residential sector energy use accounted for by space heating.

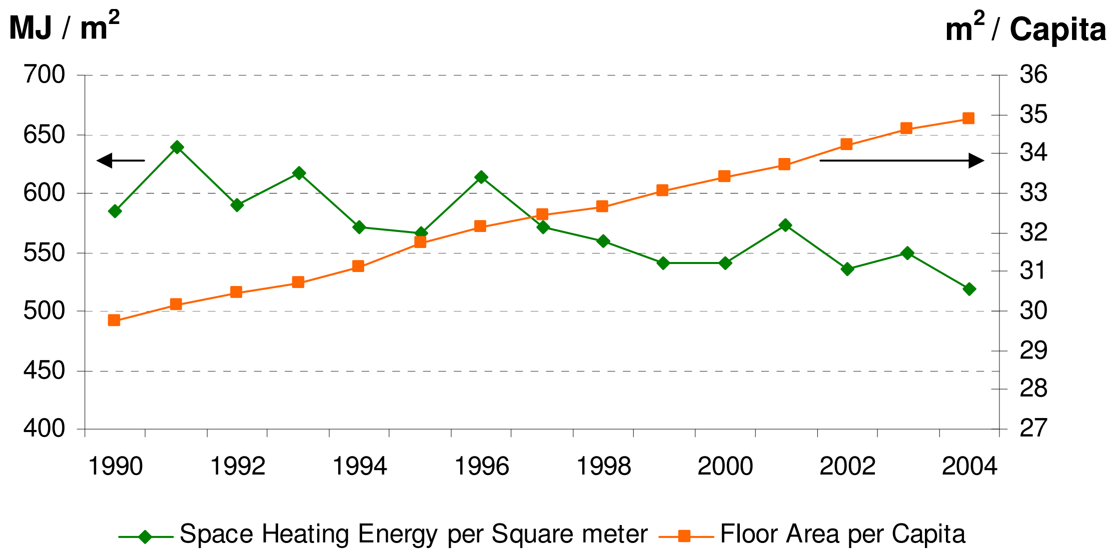

Figure 3.21 : Indicators of space heating for the residential sector in EU 25 from 1990 to 2004. Chart constructed from space heating and floor area data from the Odyssee Indicators Database (Enerdata, 2006) and population data from the Eurostat Online Database (Eurostat, 2007).

Year: *energy/m^2 x m^2/ capita = energy/ capita*
1990: 590 MJ X 30 = 17.7 GJ
2004: 520 MJ X 35 = 18.2 GJ

This calculation shows that the reduction in space heating energy use per square metre is not happening quickly enough to offset increased floor sizes. If we included population in this equation, the differences would be even larger. Thus, given the inevitable population increase, the decrease in energy intensity of space heating needed due to larger dwellings is not happening quickly enough. However, this calculation cannot account for the separate influences of increased temperature norms, adoption of central heating, or changing space heating energy consumption per capita on energy use per square metre. We can thus only assume that a combination of all three effects is responsible for the trends.

A similar calculation examining water heating using data from Figure 3.22 reveals the same pattern, although if we exclude the anomalous high consumption data for 2004 the increase is only 7% per household for the fifteen-year period. In any case, the results are somewhat meaningless, as although we have shown that households and individuals are using more energy for hot water (which we already know from Figure 3.19), and we know that falling household sizes are inevitable, we cannot say which of the absolute increase in hot water use per capita or insufficient progress in improving efficiencies in the heating of water is responsible.

Year: *energy/capita x persons/household = energy/ household*
1990: 3.50 GJ X 2.750 = 9.625 GJ
2003: 4.05 GJ X 2.540 = 10.30 GJ
2004: 4.80 GJ X 2.525 = 12.12 GJ

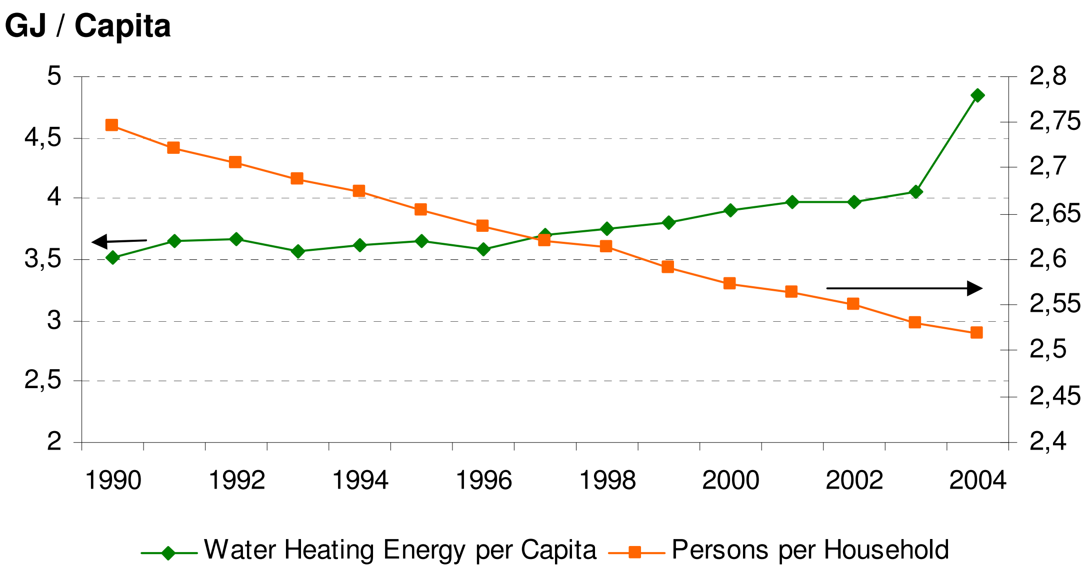

Figure 3.22 : Indicators of water heating for the residential sector in EU 25 from 1990 to 2004. Chart constructed from water heating data from the Odyssee Indicators Database (Enerdata, 2006) and population data from the Eurostat Online Database (Eurostat, 2007).

For information, Figure 3.23 shows the cumulative savings that occurred in the residential sector due to the improvements in energy efficiency. The calculation uses a corollary of the ODEX to show energy not used. The dashed line shows the increase of roughly 2 EJ that has occurred nonetheless. (Note that the 0.9 EJ increase shown in Figure 3.15 is for the period 1990 to 1999, while the 2 EJ increase shown in Figure 3.23 is for 1990 to 2004.)

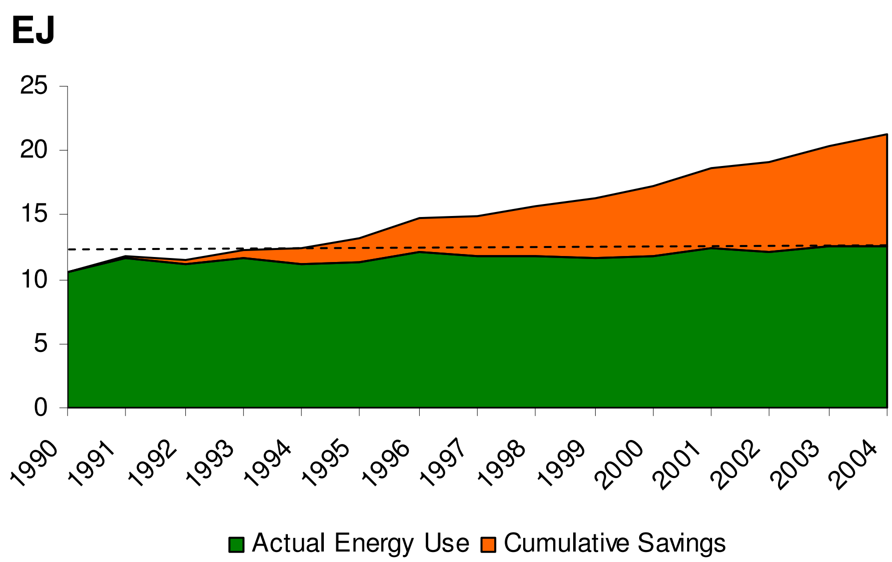

Figure 3.23 : Energy savings accruing due to efficiency improvements in the residential sector in EU 25 from 1990 to 2004. Chart constructed using corollary of ODEX formula (Enerdata, 2006).

3.3 Service sector

Figure 3.24 shows a LMDI (Ang, 2000) index decomposition for the EU 25 service sector for the period 1990 to 2000. The increase in consumption of 0,25 EJ over the period is a combination of increased activity (output measured as value added) and a reduction in energy intensity caused by increasing efficiencies. For this period, both effects are of equal importance. The increase of 0,25 EJ amounts to an average increase in energy consumption of 8.25% per year between 1990 and 1999.

Figure 3.13 however showed that output was increasing at twice the rate of energy efficiency (this also contradicts the EEA decoupling diagram in Figure 3.11), and that efficiency improvements in the service sector have levelled off between 2000 and 2004. This may explain the fact that in our ID analysis for 1990 to 1999 efficiency kept pace with rising output, while for the period from 1990 to 2004 covered by Figure 3.13 there is a 1:2 ratio between efficiency pace and rising output respectively. Unfortunately, a lack of data prevents us from calculating an ODEX for the service sector which would give an indication of the energy efficiency trends aggregated across the various end uses in the sector.

Thus, despite the dramatic rise in output in the sector over the period 1990 to 2004, we can speculate that significant improvements were made in energy efficiency of production between 1990 and 1999 but have remained static from then until 2004.

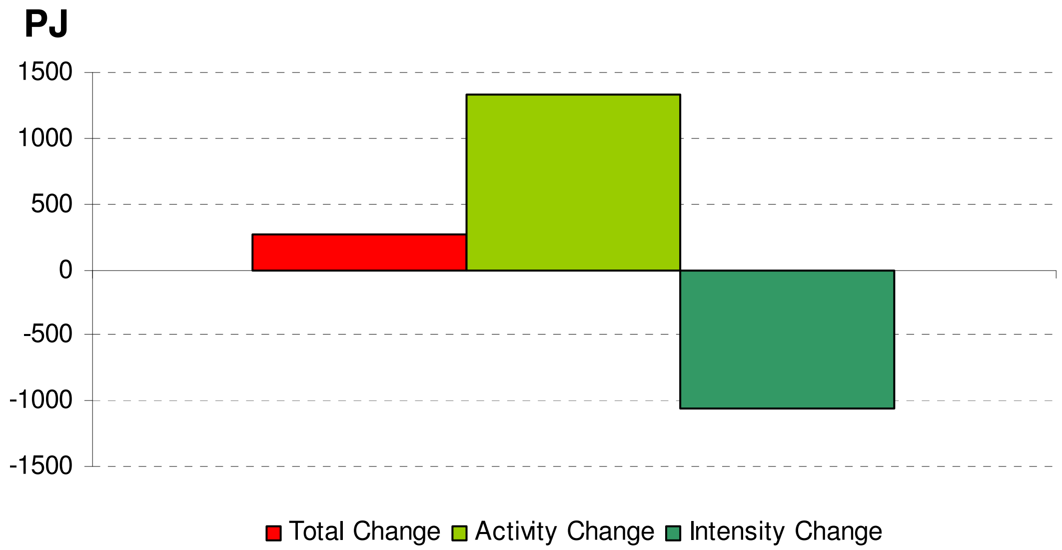

Figure 3.24 : Period-wise LMDI ID of service sector energy use in EU 25 from 1990 to 2000. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006) and Log Mean Divisia Index method (Ang, 2000).

It would be of interest to examine the various applications of energy use in the service sector in the same way as Figure 3.19 does for the residential sector. Unfortunately, there is not sufficient detailed end-use data available for the sector to give an estimation as to where or how energy is being used therein, and how it is related to increased output or efficiency. However, we could speculate that the overall increased use of electricity consumption would be very significant in the service sector, given the importance of lighting and office equipment therein. The sector fuel mixes in Figure 3.20 and Figure 3.28 show that electricity use now accounts for 41 % of final energy consumption in the service sector, as opposed to 22 % in the residential sector. The total use of heating energy carriers (coal, oil, gas, wood and heat) in the sector has not changed at all over the period. Thus, as the redrawn sector fuel mix in Figure 3.29 shows, the entire 0,5 EJ increase in final energy consumption from 1990 to 2004 can be attributed to increased electricity consumption. The implications this has for primary energy supply are enormous. At the same time, this is not entirely true. There has been a change in the entire fuel mix, but for the sake of emphasising and highlighting the significance of electricity use in the sector the argument can be made. This electricity use is obviously for appliances, lighting and air conditioning, but could also be for space and water heating by immersion and resistance heaters.

We could speculate that the total fuel use for heating has remained static due to efficiency improvements, given that there has been an increase in floor area, in value added and in employees in the sector. However, we certainly know that more heating is being used, simply due to the fact that the heating fuel mix now incorporates a greater proportion of natural gas and that this fuel has a higher heating capacity than the coal and oil it has replaced.

We do have some further information we can utilise to help our service sector analysis. Figure 3.25, Figure 3.26 and Figure 3.27 show the change in floor area, in value added and in the number of employees respectively on a per branch basis for the service sector for 1990 and 2004. These diagrams show us how economic activity is changing in the sector, and can be used as proxy indicators of how energy use may be reacting to these changes. The regions shown in the diagrams reflect data availability. As mentioned earlier, the point about it being unlikely that these sorts of indicators can increase in a developed economy without a parallel increase in energy use is important to keep in mind. The absolute values of all three indicators have risen. At the same time there has been very little change over the time period in the contributions of each respective branch to overall totals for any of floor area, value added or numbers of employees except that administrations employee less people and generate less product while the, “Other” branches employs 2 % less people and generates 2 % more product with the same floor area.

Unfortunately, however, the data in Figure 3.25, Figure 3.26 and Figure 3.27 is not available for all EU 25 countries, and so does not paint a full picture of trends across the EU. At the same time, the countries covered for employees and value added do, as mentioned previously, account for over 88 % of EU 25 energy use, so the diagrams are not in vain either.

Figure 3.25, Figure 3.26 and Figure 3.27 do not tell us if the same rises are true for energy use across all branches and allow us only to speculate that practices have not changed in any one branch over the time period. It is certain that space heating and lighting are of paramount importance in the five branches we list; Trade, Education, Hotel & Restaurants, Health and Administration, while the use of electrical appliances would obviously be significant in the trade sector. Air conditioning would, in addition to this, be an increasing feature of all branches, especially across southern Europe.

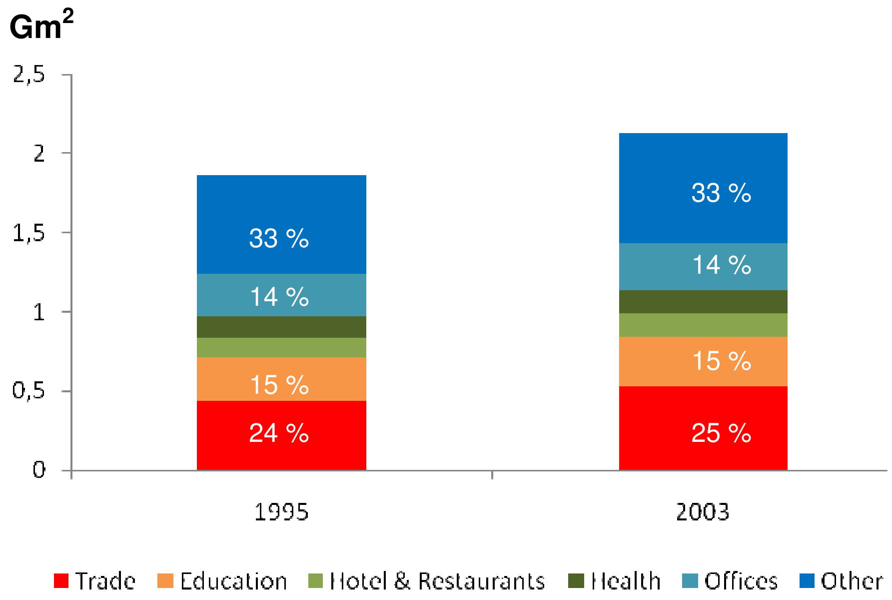

Figure 3.25 : Floor area by branch in the service sector for France, Sweden & UK in Gm^2 from 1995 to 2003. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

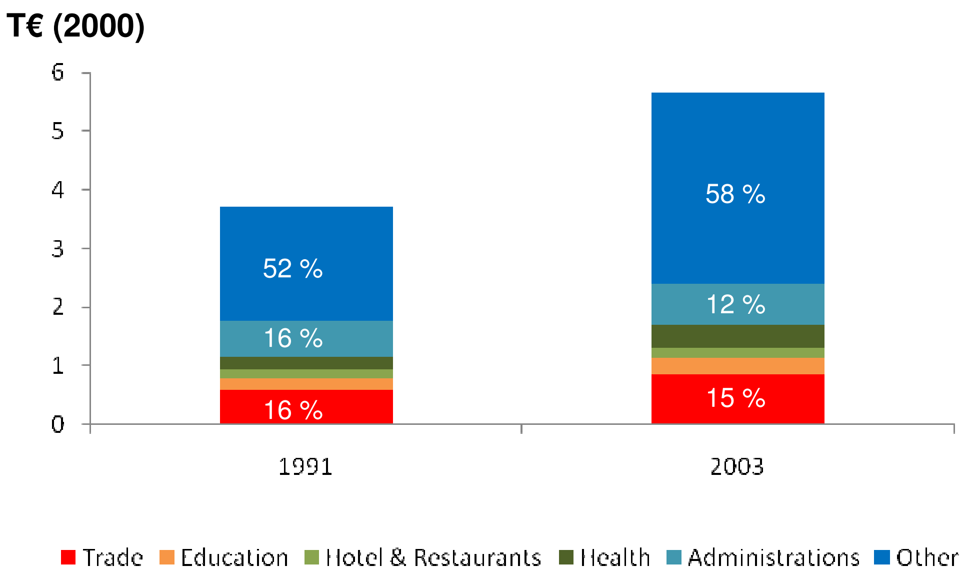

Figure 3.26 : Value added by branch in the service sector in EU 15 for 1991 and 2003. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

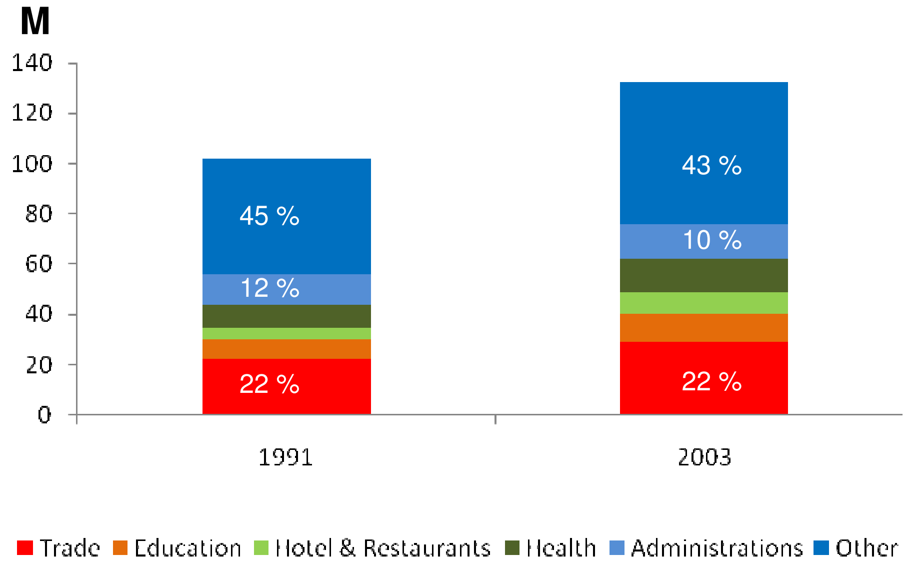

Figure 3.27 : Employees by branch in the service sector in EU 15 for 1991 and 2003. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

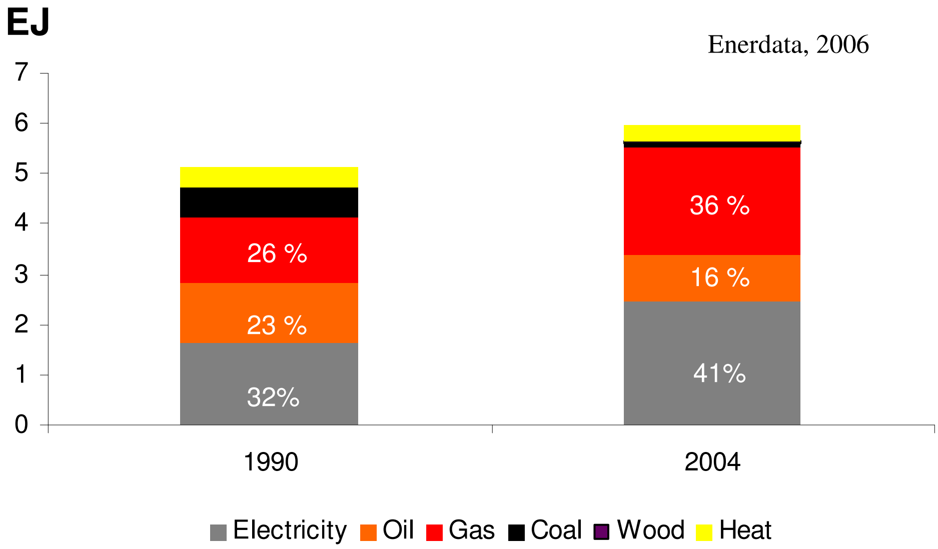

Figure 3.28 : Fuel mix in the service sector in EU 25 from 1990 to 2004. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

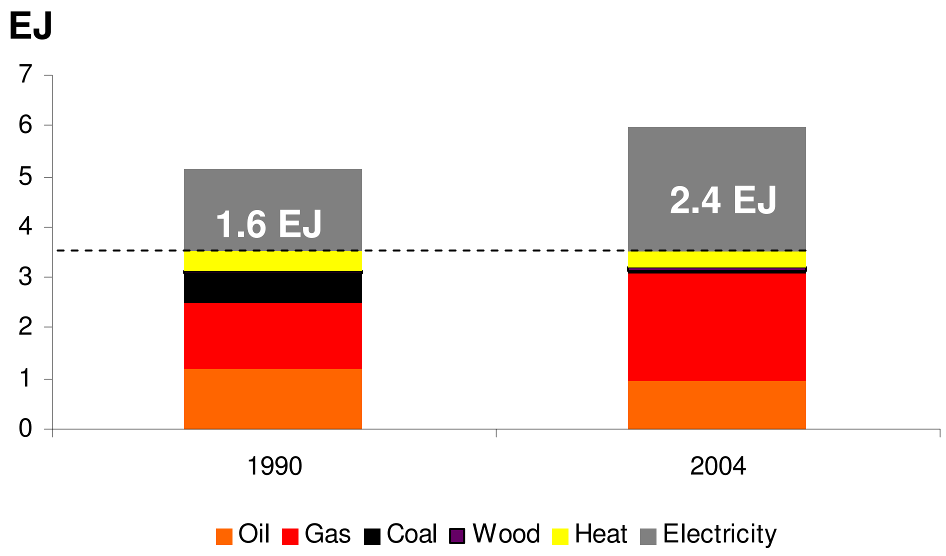

Figure 3.29 : Fuel mix in the service sector in EU 25 from 1990 to 2004. Significantly, practically the entire increase in energy use can be attributed to electricity use. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

Unfortunately, we have no insight into where the energy efficiency improvements from 1990 to 1999 took place in the sector, or if any of the branches contributed more to this. However, we can see from the fuel mixes that final energy consumption for space heating, perhaps for water heating and for electricity use are increasing.

3.4 Conclusion

We have shown that the cumulative effects of economic and population growth and increasing affluence have led to a greater building floor area in the EU 25, and that this means that more energy is needed for space heating and illumination. The EEA decoupling diagram has shown us that improvements in energy efficiency are not happening quickly enough to offset these structural changes. ID has allowed us to compare the magnitude of the technical and structural (non-technical) effects on energy consumption, and has also shown us that improvements in energy efficiency are not happening quickly enough to offset the population, economic and structurally related increases.

For the residential sector, the ODEX has shown us that improvements in energy efficiency have actually levelled off since 1995 and that this is for the most part due to the efficiency of space heating (which accounts for over two-thirds of final energy use in the residential sector, although this proportion has fallen from 71 % in 1990 to 66 % in 2004), not improving from 1995 on. In tandem with this, there has been an increasing per-capita use of hot water and an increasing per-capita ownership of electricity-dependent appliances in the residential sector. These developments may account for the increasing energy use per capita shown in Figure 3.11, the EEA decoupling graph.

For the service sector, we have shown that for the countries of the EU 15 that output (value added) and the total number of employees is increasing, although there has been no significant change in the proportions of these two indicators accounted for by each branch of the sector. Our Index Decomposition for the sector showed that for the period 1990 to 1999 energy efficiency increases matched the increases in value added. We further showed that energy efficiency has not increased since then. A lack of data has prevented us from examining the various end uses of energy in the sector. We do, however, know from the sector fuel mix that electricity consumption has increased by 50 % over the period, and that there has been a significant shift towards natural gas for heating needs and away from coal, oil and biomass.

The overall conclusion from this analysis is that, given the inevitability of economic and population growth and increasing affluence, there needs to be more action on energy efficiency. For the residential sector, the need is to reduce energy use for space heating, water heating and electrical devices, primarily in order to attempt to offset the non-technical related increases in energy use and to meet our stated goals. In the service sector, it seems that the increasing heating needs that have surely accompanied the increases in output and numbers of employees have been accounted for by a switch to natural gas. Thus, if the sector continues to grow, absolute use of energy for heating will increase as the possibilities for switching to natural gas decrease. The huge increase in electricity use in the sector would for now seem to be the most pressing issue to tackle.

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4. Demand-side analysis for buildings

As stated in the Introduction, the Pathways Project has divided its work into ten packages. Work Package 4 (WP4) of the project is concerned with energy demand. The actual approach adopted by WP4 is to assess Best Available Technology (BAT) which, in our case, is BAT that could be used in buildings, in an effort to describe various pathways to sustainability that demand in buildings may take. Thus, we are very interested in the potential influence of said BAT on demand in buildings. We are also interested in the other non-technical drivers of demand in order to enable us to assess all of the influences on demand in buildings. The link to the energy supply questions that the Pathways Project is seeking to answer is that in order to assess the stationary energy supply system that will exist or be needed over coming decades we need to know what the energy demand on the system will be. Any influences, however, that the supply system has on demand, such as in the case that there would be abundant cheap electricity, are beyond the scope of this report. As such, we set the boundaries for our demand analysis strictly around buildings and how demand therein develops in response to known technical, economic and societal phenomena. Box 3.1 in Section 3.2 gives a good overview of the various technical and non–technical influences on demand.

4.1 Technology assessment and simulation

The first step of WP4 is to perform a technology assessment of technologies that are thought to contribute to energy efficiency in the stationary sectors. Technology assessment is implicit in the MURE simulation tool (MURE, 2000). MURE contains a database of BAT for the year 2000 that can be applied in order to reduce consumption in all sectors. It thus could be a starting point for an updated BAT list. MURE is a bottom-up simulation approach to modelling in its strictest sense, and models the change that occurs in unit energy consumption of an appliance or other energy end use due to technical efficiency improvements or equipment replacement, and then aggregates results for the entire stock of a sector. There is, however, no optimisation, minimisation, saturation limits of market for energy-using apparatus, influence of GDP increase, influence of income or comfort level increase, technology price fluctuations, fuel price fluctuations, or learning incorporated in this model. For this, other modelling approaches are needed. MURE can thus be called a static parameter model whose results give us a sector-wide technological assessment but without the influence of non–technical demand drivers. However, the results of simulations of changes that occur from the widespread introduction of BAT are useful in helping to indicate what the best-case scenario potentials are. Practically, MURE allows us to take the following measures within residential sector buildings:

- Improve building thermal transmittance standards
- Switch to biomass, heat pumps or district heating for heat
- Improve unit energy consumption of electrical appliances
- Improve boilers (according to EU Boiler Directive, 92/42/EEC)
- Switch from coal or oil heating to more efficient gas heating

For a corresponding list of MURE service sector measures, see Appendix F. For each of the above measures, the modeller is allowed to set the penetration rate of BAT or a lower standard technology in the stock of buildings. This itself is quite a difficult task and requires a portfolio of relevant assumptions. The designers of MURE in fact state that the idea behind the simulation tool is to parameterise energy policies to assess their impact. Thus we can say that all parameterisation of all policies boils down to knowledge concerning the implementation of one or more of the above. We can also state that MURE can model economic or other non–technical cross-cutting influences if, and only if, one can make assumptions on what impact such policy would have on the above measures. Not an easy task! Furthermore, any technical changes proposed on the basis of simulation results must be cognisant of existing policies in place and the likelihood of additional policy measures being accepted.

To complement MURE, the LEAP (Stockholm Environmental Institute) modelling tool can provide a complementary tool, to incorporate the non-technical demand drivers that would allow us obtain an overall picture of demand in buildings. LEAP pertains to produce scenarios based on comprehensive accounting of how energy is consumed, based on a range of alternative assumptions concerning parameters such as population, economic development, technology, price and so on. The model is currently being used for the LBNL global assessment, which incorporates a technically detailed bottom-up approach in parallel with a simulation of the development of the aforementioned parameters (LBNL, 2006). LEAP would not be as technically detailed as MURE, and so would not allow us dispense with the need for MURE.

Although this report has not set out to gather assumptions from the literature that can be useful for forecasting exercises, the following list is an example of how the existing body of knowledge for Europe can be used to enhance accuracy and help build scenarios for Pathways demand-side modelling.

- Appliance electricity use to grow by 25 % from 2000 – 2020 (de Almeida et al, 2006)
- By 2020, 10 % of total appliance electricity consumption in the OECD could be for standby functionality, which is currently unregulated in OECD countries (de Almeida et al, 2006)
- The number of televisions will keep rising to 2015; this increase is due to the growth in second or third TV sets. (de Almeida et al, 2006)
- Appliances for recording audio-visual data (video VCR recorders, DVD recorders) have become common in households in the past few years. It can be expected that the stock of DVD players will increase tenfold in the next ten years, and that a rapid displacement of conventional video VCR recorders will take place. (de Almeida et al, 2006)
- Refrigeration needs special attention because of the litany of problems that occur with it, such as insulation degrading or getting wet, coolant leaking, door seals failing or the thermostat or controller failing. Despite these, the appliance may continue to operate (i.e. make noise and keep food cool) for years, as people do not realise there is a problem. (HEEP, 2006)[‡‡‡‡]
- Ownership of appliances does not appear to be influenced by dwelling occupancy levels. It is more a function of personal life stage, income and building tenure (HEEP, 2006)
- Indoor temperature is a function of location (climate), the decade of construction and ventilation installed (HEEP, 2006)
- 60 % of the year 2050's building stock in the UK has already been built (Johnston et al, 2005)

[‡‡‡‡] Note that the HEEP study was carried out in New Zealand and while the country would have a relatively affluent standard of living it would not have come as far as the EU in updating minimum standards for electrical appliances.

- Buildings built since 1990 in EU15 represent 16 % overall heating consumption (Haas & Schipper, 1998)
- A large changeover from gas fired central heating to heat pumps is necessary to reduce carbon dioxide emissions from buildings (Johnston et al, 2005)
- Comparison of space heating use in Central and Eastern Europe today show levels close to those in the U.S., Denmark and other European countries in the early 1970s, suggesting that significant reductions in heating needs can be made, while increasing comfort and reducing cost (Schipper, 1995)
- A change from room heating to central heating increases energy use for space heating by 50 % (Odyssee, 2006)
- In the medium to long term, the role of lifestyle factors should be less because of market saturation for some equipment (e.g. central heating, large electrical appliances), a slowdown in the average size of dwellings (reinforced by decreasing size of households and increased cost of housing) and the increasing impact of new efficient dwellings and appliances on existing stock (Odyssee, 2006)
- Predicting stock growth function is difficult because of lack of data for demolition of stock. Nonetheless it is estimated that some 1 to 2 % of existing European buildings are replaced each year (Enper Tebuc, 2003)
- Findings of IPCC's third instalment of its fourth climate change assessment report (IPCC, 2007), released on Friday 11th May 2007, as listed in Table 4.1, which focuses on measures to mitigate climate change. Note that the table draws on a very comprehensive review of the knowledge of what is and what is not thought to be effective

Table 4.1 : Selected sectoral policies, measures and instruments that have shown to be environmentally effective in the respective sector in at least a number of national cases. This table is taken from the IPCC's third instalment of its fourth climate change assessment report (IPCC, 2007).

Sector	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Buildings	Appliance standards and labelling	Periodic revision of standards needed
	Building codes and certification	Attractive for new buildings. Enforcement can be difficult
	Demand-side management programmes	Need for regulations so that utilities may profit
	Public sector leadership programmes, including procurement	Government purchasing can expand demand for energy efficient products
	Incentives for energy Service companies (ESCO's)	Success factor: Access to third party financing

Table 4.1 can be described as a policy assessment which could complement our technical assessment and knowledge of non–technical drivers of consumption. The relevant EU and national policies in place that encourage the diffusion of BAT and reduction in energy use will also need to be known in order to incorporate their future influence on demand.

An entire paper which would help with assumptions is “Residential energy demand in OECD-countries and the role of irreversible efficiency improvements” (Reinhard Haas and Lee Schipper, 1998). In their study, which analysed energy use in OECD countries from the early 1970s to the 1990s, they concluded that price elasticity had not been the same for rising and falling prices. For falling prices, elasticity was close to zero, implying a low rebound effect within the residential sector. The background to these findings was the increased energy prices due to the oil shocks of 1973 and 1981 and the subsequent drop and stagnation of energy prices from the mid-eighties on.

Coupled to this, they found the importance of income elasticities to be declining due to saturation of technologies. Space heating, water heating and cooking technologies had reached near-saturation levels in OECD countries. Energy use for TVs and ventilation was increasing, but at the same time it was not thought that IT and home entertainment would be particularly demanding.

Thus they pointed out that the use of conventional economic theory for energy use forecasting would be wrong due to over-reliance on price and income policy to effect change. Almost bizarrely, they stated that increased income actually encourages home improvement and renovation, which can lead to the adoption of more efficient technologies. In addition to this, they said that as newly built homes always used less energy than the existing stock, but given that the existing stock will be important for many decades to come, it was important to focus efforts on measures aimed at the existing building stock. To reinforce this point that the existing stock is important, they said that with population slowing and shrinking of family size, new housing starts would be less important than in the past.

A further issue they touched was that retirees are at home more often, so their energy use is somewhat higher than that of younger energy users. An ageing population can lead to increased residential sector energy use, although this can be somewhat offset by the absence from home of the non-retirees.

Ten years after the publication of the Haas and Schipper paper, perhaps we can say that their speculation that IT and home entertainment would not be too important was underestimated. The view that saturation had been achieved in OECD countries has been overtaken by the admission of many Eastern European countries to the OECD, and which are some way off saturation of advanced home heating and appliance technologies. This is primarily due to the long tradition of, and continued, energy price subsidisation in these countries[§§§§]. Income has also continued to rise, although the rate of new home-building, existing home renovation and efficiency improvements in electrical appliances has not reversed energy use growth in the residential sector. At the same time, their views on the importance of the existing building stock or of the particular dynamics of price and income elasticity are very correct.

Hass and Schipper also stated that the rebound effect was close to zero in reaction to reduced prices. Another paper published around the same time (Haas et al, 1997) showed that the rebound effect for space heating energy use was 15 % to 30 % due to building retrofit. Ten years later, the rebound effect due to increased income in terms of increased comfort levels in the home are significant enough for the proposed Version 2 of the MURE simulation tool to state that it will endeavour to account for rebound effects by using indicators from the Odyssee Database (Odyssee, 2006). A member of the consortium that is redesigning the MURE simulation tool, wrote in private correspondence to the author (Mure, 2007) that, partially, the Odyssee indicators separate comfort and rebound effects such as the demand for

[§§§§] A perhaps extreme example of this is that in Turkmenistan all household heating fuel and electricity are free.

increased heated floor areas, the trend towards larger cars, the higher equipment rates with appliances, penetration of central heating in homes, trend towards single-family houses etc. Some comfort and rebound effects are, however, not directly separable in the Odyssee database, and need additional calculation and modelling: for example, the increased internal temperatures in homes and the longer heating periods can only be separated through additional estimates because there are no detailed statistics available for this. The same for the larger size of refrigerators, which partially compensates for the technical improvement. Also difficult to separate are rebound effects, such as for larger televisions. In all these cases, additional estimates are necessary to separate these issues in a modelling exercise. Nevertheless, the indicators provide the set of boundaries in which these estimates may evolve.

Thus, for the purposes of assessing demand trends, we may be able to input specifications of BAT plus relevant assumptions from the literature to the MURE simulation tool and then to account for the non technical effects using LEAP.

4.2 Energy use reduction targets

Another approach to strategising how to model an appropriate diffusion of BAT that is based on the lateral thinking concept (de Bono, 1967) is to set targets for reductions in energy use in buildings and then seek to put together the set of BAT and policies that would allow these targets to be met. The following existing relevant targets are a useful starting point:

- EEA Targets
- EU Energy Policy Targets
- IPCC SRES

EEA targets
(EEA, 2002) state that the linkage between the growth and the energy consumption of a sector can be broken only if the rate of reduction of its energy intensity at least equals its rate of growth. Table 3.1 names the sectoral drivers and the corresponding definitions of energy intensity, while Figure 3.11 shows progress with both corresponding components for each sector. It is clear that, for the residential and service sector, intensity is not decreasing more rapidly than the sectoral driver. In fact, for the residential sector, energy intensity is on the "wrong" trajectory. If we accept this EEA statement as a definition of sustainability, then we can definitely use it as an overall target for our modelling to aim for.

EU energy policy
The EE&ESD seeks a 1 % overall reduction in energy use per year between 2008 and 2017, thus leading to a 9 % reduction by the year 2017. However, the targets are not sector-specific, and thus may be difficult to quantify for buildings unless individual country implementation plans do just this. The Energy Efficiency Action Plan (EEAP) of the EU, (COM(2006)545 final) which was published as a follow-up to the EE&ESD, seeks a reduction in energy use of 27 % in the residential sector and of 30 % in the service sector by 2020. These two targets seem ideal for incorporation into Pathways aims. The projections undertaken by the EU to assess that there were such potential savings available in these sectors was carried out using the Primes modelling tool. It would be interesting to get a closer look at the assumptions on which the Primes work was based. It should also be noted that Primes does not have the same level of technical detail as MURE.

IPCC SRES
Although no review of targets or assumptions is contained within the IPCC SRES, it would be another obvious forecast which Pathways could make use of.

Pathways targets
Pathways could of course set its own target, based on review of literature including targets for the rebound effect based on same type of review.

4.3 Summary

In this chapter we have discussed the combination of modelling tools, forecast assumptions and energy use reduction targets to map out pathways to reduced energy use in buildings. In terms of assumptions, a difficulty arises in estimating what percentage of building stock chooses to adopt a BAT, and over what timescale the same BAT diffuses through the stock. This kind of information can be obtained using econometric analysis of the profitability of BAT investments for building owners, and also through an analysis of existing or past policy measures that have attempted to incentivise the diffusion of BAT. However, this report has not investigated an approach to either of these analyses. Indicators, as discussed in Chapter 2, can identify for us the historical causes of energy end use change, but can also in theory reveal what the impact has been of policy measures aimed at constraining energy use or diffusing BAT, thus adding even more information to our list of assumptions above. Although Chapter 3 did in fact perform an indicator-based analysis which can tell us why energy use patterns have developed as they have across the EU, it generally did not give us an indication as to which actual energy-using apparatus was involved or which policy measures had an impact. Ideally, we should be able to distinguish through indicators and technology assessment what the "low hanging fruit" such as a ban on incandescent light bulbs would be, as opposed to costly measures which may not be so productive. Our use of indicators has not produced this information yet.

Overall, an outline approach for a Pathways demand-side requirement for buildings can be summarised as to:

- Characterise the building stock using existing data, estimates or by using average building parameterisation (See Appendix H)
- Use indicators to identify the causes of energy use increase in the stock
- Set targets as benchmark targets or caps on energy use increase
- Undertake a bottom-up modelling simulation of BAT, using MURE to provide a range of technology change-based scenarios plus a range of technology-based scenarios that achieve defined targets
- Undertake a literature review to find the assumptions about energy use prospects that exist in the body of knowledge
- Undertake econometric modelling with LEAP that incorporates the influences of both technical and non-technical parameters to provide a selection of those that achieve defined targets

Needless to say, all of the above are restricted by the availability of data. The general limitation with the above is that, to date, we have not managed to undertake a policy assessment using indicators. Thus, and as mentioned, knowing the patterns of diffusion of BAT would be difficult to estimate. Using the lateral thinking approach of setting targets and then choosing the portfolio of polices, measures and BAT to achieve this, may be the preferred option as a modelling strategy.

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Conclusion

This report began by reviewing pan-European sources of data on construction characteristics, energy end – uses, installed energy using apparatus, building envelope characteristics and fuel mixes for the European Building Stock.

It then discussed and described various approaches to the use of indicators for analysing and explaining the causes of energy use in the European Building Stock.

A top down analysis of energy use in buildings in the Residential and Services sectors of the EU 25 from 1990 to 2004 was then carried out.

Finally the report discussed options available for forecasting energy use in Europe's buildings over the coming decades based on the expected improvements in energy using and building construction technologies and the influence of other non – technical factors.

The appendices that accompany this report add further detail to the data, indicator and modelling options discussed throughout the report.

The first result from the data analysis conducted in Chapter 1 is that a thorough review of the data contained in pan-European sources has been conducted. The review has revealed that there are ten countries for which a single year top down statistical analyses of energy use in Europe's building stock can be performed. These countries account for over 70 % of final energy consumption in the EU. The number of countries in Europe for which a bottom up analyses of the energy using apparatus, building envelope characteristics and fuel mixes in buildings is however significantly less for both the residential and service sector. It can be concluded that inconsistencies in the type of energy demand information collected by national statistical organisations means that analysts must trawl through various EU project reports to find relevant data. The one exception to this is the Odyssee Project which is a dedicated energy demand statistics and indicators database. As such the project is a useful starting point for the data needed for energy use analysis although more for a statistical than a bottom up analysis.

Chapter 2 proposed a set of indicators to use in an analysis of past trends in building energy use that can reveal the reasons for energy use change. The chapter also proposed the use of specific indicators for examining the impacts of structural and efficiency effects on sectoral energy use.

Results from the analysis of energy use in buildings from 1990 to 2004 performed in Chapter 3 showed the significance of space heating and the quickly rising consumption of energy for water heating and electrical appliances in the Residential Sector. For the Service Sector the large increases in electricity consumption over the same time period were highlighted. The analysis also attempted to highlight the influence of non technical parameters such as population and economic growth on energy consumption in buildings.

Chapter 4 discussed possible methodologies for modelling energy use trends in the European building stock over the coming decades. The chapter specified models, forecasting assumptions and energy reduction targets that could be used as an overall strategy for determining demand side dynamics in buildings over coming decades.

The overall aim of this report was to contribute to WP4 of the Pathways Project. Only time will tell how far the project is right now, from having best available data, and a best available approach to demand side scenario modelling for Europe.

Appendix A Odyssee indicators database

The Odyssee indicators database is a database that contains both raw data and calculated indicators relating to energy use in all major economic sectors for EU 27 countries plus Norway and Croatia. Data for the database is fed in by national organisations from each participating country. Until now the project has been funded on a framework to framework basis by the EU IEE programme. Funding covers the cost of bi annual network meetings and some of the costs of the administration of the database which is undertaken by Enerdata in France. Figure A.1 shows database coverage across the continent. For a history of the project see Appendix 1 of (Bosseboeuf et al, 1997).

Figure A.1 : Odyssee EU 27 plus Croatia and Norway.

The Odyssee database is primarily used to allow member organisations to compare their own countries energy efficiency progress with that of other member countries and to develop more sophisticated methods for monitoring energy use in buildings. The emphasis on monitoring means that Odyssee is primarily renowned for its indicators. The database does however also contain the raw data necessary to build the same indicators. The main strength of Odyssee is that it presents harmonised time series data and indicators for member countries. This has obvious advantages for inter country comparisons and pan European forecasting work. Its raw data is harmonised in terms of how each data category is defined while its indicators are harmonised and normalised in terms of physical differences between countries such as climate, demography and economy.

Known users of the database are (Bossebeauf, 2006):

- IEEA : (EMEEES)
- DG TREN : (EMOS database)
- DG ENV: (Climate change task force, list of carbon dioxide indicators)
- DG RECH : (JRC Ispra (SRS data base) and IPTS)
- EUROSTAT : (List of energy efficiency indicators)

- EEA: (Term project)
- IEA: (EE indicators)
- ENR Club
- Turkey, Tunisia
- PRIMES Model

The main weakness of the database, as discussed in the Chapter 1 on data, is that the exact source and quality of the data therein is unknown. It is known where the data came from in terms of which organisation submitted it to the database. What is not known however is how member organisations arrived at their respective data. Coupled to this is the fact that the database is not seen as being a compilation of official data in the same way as data from the IEA or Eurostat is. Some of the data submitted is bound to be official data, in the sense that it has emanated from an organ of member organisations states or from the EU. There is no way however of knowing this from looking at the database. Its advantages over the IEA and Eurostat as an energy data compilation service are that it goes beyond standard sectoral fuel balances to divide sectoral energy use into its specific end – uses such as space heating. Table A.1 summarises advantages and disadvantages associated with the database.

Table A.1 : Summary of advantages and disadvantages associated with the Odyssee Indicators Database.

Advantages	**Disadvantages**
Ease of use	Non official data.
Time series data	Frequently same data available from national sources.
Established reputation	Estimates used
Approachable staff	Transparency problem.
Harmonised data	
EU wide coverage	
Unique service for Europe	
Coordination approach around member organisations.	
Ready to use pre calculated indicators	

For a full discussion on the actual data contained in the Odyssee database that is relevant to buildings see Section 1.4.1 and Section 1.4.2. Table A.2 and Table A.3 give some indication of data relevant for Pathways that the database contains. Of late the network is perhaps most famous for inventing the ODEX indicator (see Section 2.5). It is listed in Annex 4 of the EE&ESD as an indicator to use for countries to monitor efficiency improvements.

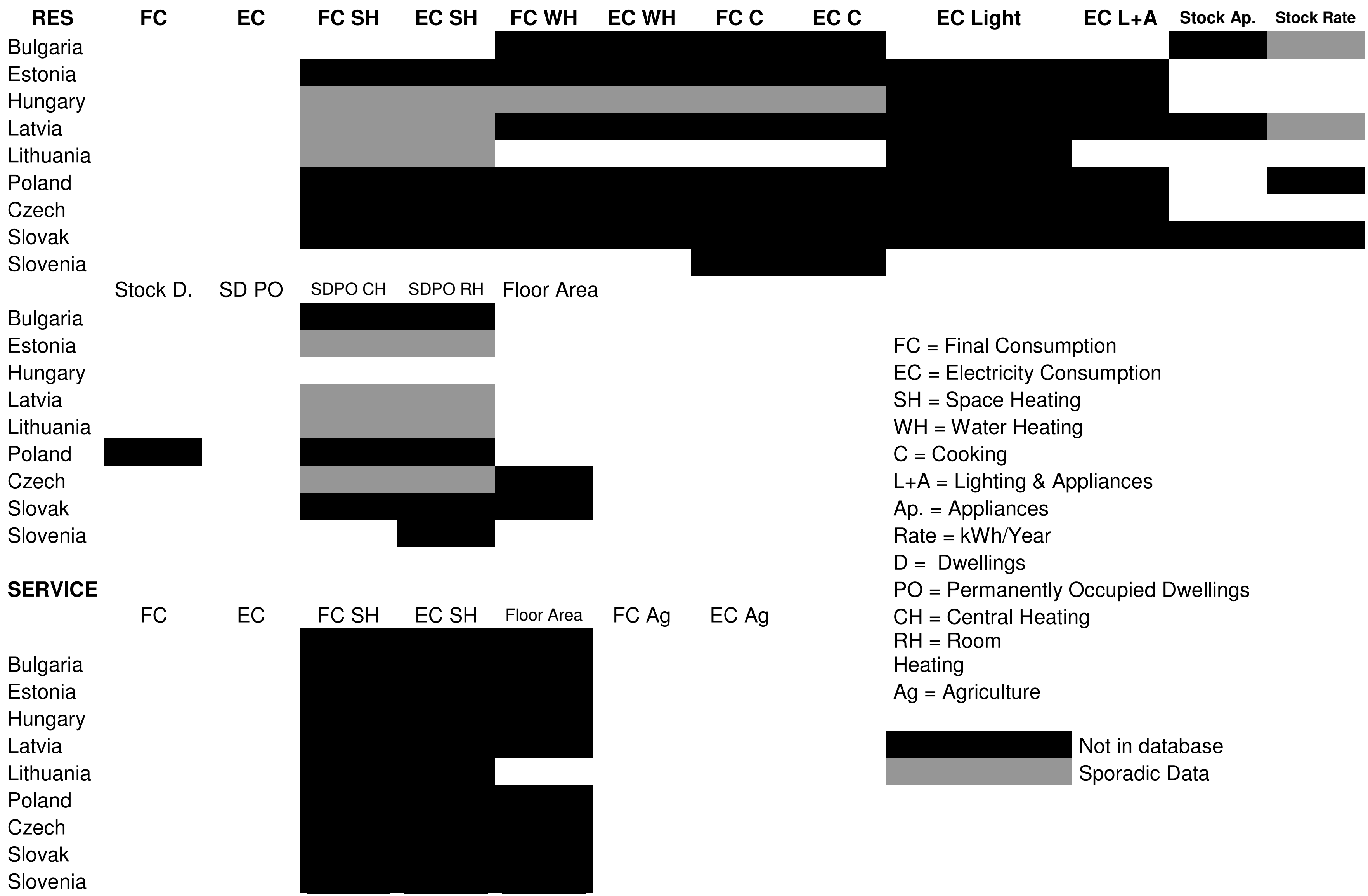

Table A.2 : NMC 10 data missing from Odyssee database. Information compiled in 2007 from Odyssee Indicator Database (Enerdata, 2006).

Table A.3 : EU 15 data missing from Odyssee database. Information compiled in 2007 from Odyssee Indicator Database (Enerdata, 2006).

RES

FC SH	EC SH	FC WH	EC WH	FC C	EC C	EC LA	EC L	Stock D	SD PO	SDPO CH	SBPO RH	Floor Area	Stock Ap.
Ireland	Ireland	Ireland	Ireland	Ireland	Ireland	Ireland	Ireland	Ireland		Belgium	Belgium	Belgium	Belgium
Portugal	Portugal	Belgium	Belgium	Belgium	Belgium	Belgium	Belgium	Belgium		Finland	Finland	Spain	Finland
Belgium				Finland	Finland	Norway	Norway	France		Norway	Spain		Norway
							Denmark			Spain	Portugal		
							Finland			Portugal			
							Greece						
							Italy						
							Portugal						
							UK						

SERVICE

FC SH	EC SH	Floor Area
Austria	Austria	Austria
Belgium	Belgium	Belgium
Greece	Greece	Greece
Ireland	Ireland	Ireland
Italy	Italy	Italy
Netherlands	Netherlands	Netherlands
Portugal	Portugal	Portugal
Spain	Spain	Spain
Sweden		
UK		

FC = Final Consumption
EC = Electricity Consumption
SH = SpaceHeating
WH = WaterHeating
C = Cooking
L+A = Lighting & Appliances
Ap. = Appliances
Rate = kWh/Year
D = Dwellings
PO = Permanently Occupied Dwellings
CH =CentralHeating
RH = Room Heating

References to Appendix A:

Bosseboeuf, D., Lapilionne, B., Château, B., (1997). Cross-country comparison on energy efficiency indicators: the on-going European effort towards a common methodology, Energy Policy

Bosseboeuf, D., (2006). Presentation to Odyssee network meeting in Brussels in December 2006

Appendix B Degree day rectification

Degree day rectification is used to remove the effect of varying weather patterns from energy use statistics. The idea is that if the variety in winter and summer temperatures that occur over any given number of years are removed that one will have a better idea of how energy use trends are developing. The rectification is most useful for space heating and cooling statistics given how these vary with weather patterns.

A 30 year average for degree days is used for individual countries to remove the influence of exceptionally cold winters or hot summers on energy use data. Data for this data category is listed in the Odyssee database as degree days of reference. It has been said by people involved in Odyssee however that the thirty year average is quickly becoming obsolete due to the exceptionally warm winters over the last ten years. A second issue is that evidence suggests that in warmer winter's people do not turn down their heat as much as they "theoretically" should.

An indicator for inter country comparison which takes account of degree-day difference between countries would have to adjust energy figures to an inter country average i.e. scale up or down the space heating figures to an average of the space heating data between countries (Schipper et al., 2001). The actual methodology for this approach is to first list the amount of energy used per country but then to divide by the countries respective total degree days for each respective year to produce an energy per degree-day indicator. If building numbers or building floor spaces are included this can be called:

Unit consumption (per square metre or dwelling) for space heating per degree-day

A more complex methodology for inter country comparison in Europe which uses the thirty year average is given by the Odyssee network as follows:

- Unit consumption (per square metre or dwelling) scaled to the average European climate. cutocsurce= (toccfreschc/(surlog*nbrlpr)*(djref.ueur/djref)+(toccfrescc-toccfreschc)/(surlog*nbrlpr))*1000000 [koe/m2]
- cutoclogce=toccfresce/nbrlpr*1000

toccf = total final energy consumption
toccfresce = energy consumption for households
toccfrescc = energy consumption of households with climatic corrections
toccfreschc = energy consumption of households for space heating with climate corrections

surlog = average size of dwellings in square metres.
nbrlpr = number of permanently occupied buildings
djref = degree days of reference.
djref.ueur = refers to the degree of reference of the whole EU as reference.

cutocsurce = unit consumption of dwellings per square metre scaled to European climate
cutoclogce = unit consumption of dwellings scaled to European climate

When analysing energy use trends for one country in isolation it is also useful to remove the effects of climate. The DIW (Deutsche Institut für Wirtschaftsforschung) produced a methodology for this one country rectification for Eurostat in 1998, and this approach has now been recommended by Eurostat (DIW, 1998). It involves two separate formulas. One for countries that have annual space heating energy consumption data available and one for those that do not. The variable definitions outlined above apply.

Formula 1 (Countries without specific space heating data):

- Climate corrected household energy consumption = Household Energy consumption / (1-(fraction of space heating in overall consumption*0,9)*(1- (dd/dd_ref)))

Formula 2 (Countries with specific space heating data):

- Space heating consumption with climatic corrections = Space heating consumption/ (1 - (0,9 * (1 - dd/dd_ref)))

No methodology has of yet been agreed to differentiate between levels of thermal insulation between countries although one is suggested by Professor Sven Werner (Ecoheatcool, 2005).

These formulas are used only to bring consistency to time series data on amount of energy used for space heating. Results can be presented for space heating only or for total energy use which obviously includes space heating. Formulae presented come from the Odyssee Indicators Definition Manual (Odyssee Network).

References to Appendix B:

Deutsche Institut für Wirtschaftsforschung (1998). The Determination of a Common Method for the Climatic Correction of Energy Consumption data in the EU. Report carried out for Eurostat

Odyssee Network. Definition of Energy Efficiency Indicators in ODYSSEE data base

Euro Heat and Power, (2005). Ecoheatcool Work Package 1

Schipper, L., Unander, F., Murtinshaw, S. and Ting, M. (2001). “Indicators of energy use and carbon emissions: Explaining the energy economy link”, Annual Review Of Energy And The Environment 26, pp49-81.

Appendix C Use of Raw Data for Residential Sector

This appendix is an addendum to Chapter 1 and Chapter 2 and outlines how raw data can be used to construct indicators. As it happens the Odyssee database contains many of these same indicators ready calculated for EU 27 countries and for the Union as a whole. Sources listed below refer to pan-European sources and not to individual country sources and may not have a complete data set for each country.

Dwelling Characteristics Data

Stock of Dwellings
Available from: Odyssee, HSEU, UNECE.
Reasons to collect:

- To combine with age distribution to obtain **distribution in stock**
- To combine with population to produce **persons per dwelling**
- To combine with total energy to give **energy/dwelling**
- To combine with total space energy to give **space energy/dwelling**
- To combine with total water energy to give **water energy/dwelling**
- To combine with total cooking energy to give **cooking energy/dwelling**
- To combine with total lighting energy to give **lighting energy/dwelling**

Limitation: Definitions of what constitutes a holiday home or permanently occupied dwellings may vary between countries and sources.

Vacant Dwellings in Stock
Available from: HSEU.
Reason to collect:

- To measure number of people housed and hence **an activity** component of index decomposition

Age distribution of dwellings
Available from: HSEU, UNECE.
Reason to collect:

- To combine with building thermal regulations to **categorise building thermal performance**

Dwellings demolished or otherwise removed from the housing stock
Available from: HSEU, UNECE.
Reason to collect:

- To combine with rate of new build to graph **stock growth rate**

Stock Growth Trends plus building permits
Available from: Need to be put together from HSEU, Odyssee, and UNECE.
Reason to collect:

- For **stock growth rate**

Occupied Stock by tenure
Available from: HSEU.
Reason to collect:

- For distribution of **responsibility for dwelling renovation**

Average useful floor area per dwelling
Available from: Odyssee, HSEU, UNECE, Ecoheatcool.
Reason to collect:

- For **unit comparisons per square metre**

Floor Area Dwellings in square metre categorised by size ranges.
Available from: HSEU, Odyssee.
Reason to collect:

- Useful for looking at **spread of stock**. Possibly combine with family size spread for more **accurate trend analysis**

Total Floor Area of Dwellings
Available from: Must be calculated using stock of dwellings and average dwelling size.
Reasons to collect:

- For combining with population to get **floor space in m^2/capita** or for combining with stock of dwellings to get **floor space in m^2/dwelling**
- To combine with total energy use to obtain **energy/m^2**
- To combine with total energy use to obtain **space energy/m^2**
- To combine with total electricity use to obtain **electricity use/m^2**

Average Number of persons per occupied dwelling
Available from: Must be calculated using stock of dwellings and population.
Reason to collect:

- For combining with dwelling size to see **dwelling space/capita**

Number Households (Number of families)
Available from: HSEU.
Reason to collect:

- to divide by total energy to get **energy use/household** (may not be used)
- to divide by space heating energy to get **space heating energy use/household**
- to divide by water heating energy to get **water heating energy use/household**
- to divide by cooking energy to get **cooking energy use/household**
- to divide by appliances electricity to get **appliance electricity use/household**
- to divide by air conditioning electricity energy to get **air conditioning energy use/household**

Persons per household
Available from: HSEU, Odyssee.
Reason to collect:

- Combine with total floor area of dwellings to see **trends in household size versus dwellings size**

Distribution (%) Household Size i.e. % one person households, % two person etc.
Available from: HSEU.
Reason to collect:

- Could be useful if correlated with **house sizes/household size**

Dwelling Area per capita in square metres
Available from: Must be calculated using total floor area and population.
Reason to collect:

- For **growth trend in dwelling area per capita in m^2**

Definition of Floor Area
Available from: HSEU.
Reason to collect:

- For **cleaning differences between countries**

Definition of a Dwelling
Available from: HSEU.
Reason to collect:

- For **cleaning differences in definition between countries**

Definition of Household
Available from: HSEU.
Reason to collect:

- For **cleaning differences in definition between countries**

U Values
Available from: MURE
Reason to collect:

- To know **insulation levels**

Dwelling energy consumption data

Final Energy Consumption Dwellings
Available from: Eurostat, IEA, Odyssee.
Reason to collect: To combine with dwelling characteristics data and conversion efficiencies to calculate:

- **sector total**
- **energy/household**
- **energy /dwelling**
- **energy /capita**
- **energy /m^2**
- **useful energy/household**
- **useful energy /dwelling**
- **useful energy /capita**
- **useful energy /m^2**
- **useful energy /m$^{2/}$degree day**
- **useful energy /m$^{2/}$ climate corrected**
- **useful energy /m$^{2/}$ scaled to European climate**

Space heating
Available from: Odyssee.
Reason to collect: To combine with dwelling characteristics data and conversion efficiencies to calculate:

- **sector total**
- **space heating energy/household**
- **space heating energy /dwelling**
- **space heating energy /capita**
- **space heating energy /m^2**
- **useful space heating energy/household**
- **useful space heating energy /dwelling**
- **useful space heating energy /capita**
- **useful space heating energy /m^2**
- **useful space heating energy /m$^{2/}$degree day**
- **useful space heating energy /m$^{2/}$ climate corrected**
- **useful space heating energy /m$^{2/}$ scaled to European climate**

Water Heating
Available from: Odyssee.
Reason to collect: To combine with dwelling characteristics data and conversion efficiencies to calculate:

- **sector total**
- **water heating energy/household**
- **water heating energy /dwelling**
- **water heating energy /capita**
- **useful water heating energy/household**
- **useful water heating energy /dwelling**
- **useful water heating energy /capita**

Cooking
Available from: Odyssee.
Reason to collect: To combine with dwelling characteristics data and conversion efficiencies to calculate:

- **sector total**
- **cooking heating energy/household**
- **cooking heating energy /dwelling**
- **cooking heating energy /capita**
- **useful cooking heating energy/household**
- **useful cooking heating energy /dwelling**
- **useful cooking heating energy /capita**

Final Electricity Consumption Residential Sector
Available from: Eurostat, IEA, Odyssee.
Reason to collect: To combine with dwelling characteristics data to calculate:

- **sector total**
- **energy/household**
- **energy /dwelling**
- **energy /capita**
- **energy /m^2**
- **consumption/ heating**
- **consumption/space heating**
- **consumption/water heating**
- **consumption/cooking**
- **consumption/lighting**
- **consumption/appliances**
- **consumption/VAC**

Lighting
Available from: Odyssee.
Reason to collect: To combine with dwelling characteristics data to calculate:

- **sector total**
- **lighting energy /household**
- **lighting energy /dwelling**
- **lighting energy /capita**

- **lighting energy /m²**

VAC
Available from: No Sources found

Macro-economic data

Population
Available from: Eurostat, Odyssee.
Reasons to collect:

- to combine with total energy for **energy/capita**
- to combine space heating energy to get **space heating energy use/capita**
- to combine with water heating energy to get **water heating energy use/capita**
- to combine with cooking energy to get **cooking energy use /capita**
- to combine with appliances electricity to get **appliance electricity use /capita**
- to combine with air conditioning electricity energy to get **air conditioning energy use /capita**

GDP
Available from: Eurostat, Odyssee.
Reason to collect:

- to combine with total energy for **energy/GDP (energy intensity)**

Appendix D Indicator Sets

This appendix simply lists a number of indicator sets advocated or used by various institutions involved in the field of energy end – use trend analysis. References to all sets are provided at the end of the appendix. Those listed are:

1. **IEA simplified list of indicators, 1997**
2. **IEA Indicators manual, 1997**
3. **Eurostat priority indicators, 2003**
4. **Eurostat publication, actual indicators publication, 2002**
5. **Odyssee network publication, 2006**
6. **Odyssee indicators in Odyssee database, 2006**
7. **Odyssee indicator based study of Danish Buildings, 2000**
8. **UK DTI indicators 2006**
9. **Sustainable Energy Ireland Residential Sector publication 2005**
10. **LBNL developing country indicators for GED project, 2006**

IEA simplified list of indicators, 1997

Residential Sector:

- space heating energy use/square metre/degree day
- square metres of household space
- estimated electricity use/appliance for major appliances both in stock and new
- saturation of major appliances

Service Sector:

- Heat use /square metre floor space
- Non heating electricity use/square metre floor space
- Total floor space (GDP or value added s a proxy for floor space)

IEA indicators manual, 1997

The following indicators were used in the examples presented in the manual for how to analyse energy use in buildings.

Residential Sector:

- Residential end – use heating adjusted to 2700 dd
- Residential fuel use by type of fuel
- Space heating by year of construction and fuel type
- Space heating by CH/RH & SFD/MFD
- Useful energy for space heating per dwelling
- Useful space heating energy use/m^2
- Useful energy space heating per m^2 per dd
- Electricity end – use per capita/fuel type
- Delivered residential electricity use per capita
- Bottom up data on appliances
- Reduction in energy intensity of new appliances
- Top down disaggregation by ID
- Inter country comparisons

- Personal consumption expenditure/ household energy use
- Household light fuel oil price, gas price, electricity price
- Carbon dioxide emissions per country

Service Sector:
- Basic list of minimum for both sectors

Accompanying driving factors of energy use:
Residential Sector:
- Personal consumption and house area
- Personal consumption and energy use
- Personal consumption and electricity for appliances/lighting
- Fuel and electricity for heating V's price
- Electricity for lighting and appliance V's price

Service Sector:
- Floor area and GDP

Eurostat priority indicators, 2003

Macro-economic:
A0. Final energy intensity at constant GDP structure with climatic correction (kgoe/EC90)
B0. Gross inland consumption intensity (kgoe/EC90)
C0. Ratio of final to primary energy consumption

Residential Sector:
A0. Unit consumption per m^2 for space heating with temperature correction (toe/m^2)
B0. Unit consumption per equivalent dwelling for lighting and electrical appliances (kWh)

Service Sector:
A0. Energy intensity of the sector, temperature- corrected (kgoe/EC90)
B0. Unit consumption of service sector for space heating per m^2 with temperature correction (toe/m^2)
C0. Unit consumption of electricity (excluding electricity for space heating) of the service sector per m^2 (kWh/m^2)
D0. Electricity intensity (kWh/EC90)

Alternates to be used where data lacking for zero list:

Macro-economic:
A1. Final energy intensity with climatic correction (kgoe/EC90)
A2. Final energy intensity at constant GDP structure (kgoe/EC90)
A3. Final energy intensity (kgoe/EC90)

Residential Sector:
A1. Unit consumption per equivalent dwelling with temperature correction (toe)

Service Sector:
B1. Unit consumption of service sector for space heating per person employed with temperature correction (toe/per.)
C1. Unit consumption of electricity (excluding electricity for space heating) of the Service Sector per person employed (kWh/per.)

Eurostat energy efficiency indicators publication, 2002

Macro-economic:

- Energy intensity
- Eurostat agreement to use same indicators as IEA

Residential Sector:
- Unit per m^2
- Unit per dwelling
- Unit light & electric appliances

Service Sector:
- Energy intensity
- Electrical intensity
- Unit space heating/m^2
- Unit space heating/employee
- Unit electricity/m^2
- Unit electricity/person employed

Odyssee network publication, 2005

The following indicators were used in the examples presented for how to analyse energy use in buildings.

Residential Sector:
- Total consumption by end – use 1990 & 2002
- Changes in average consumption per dwelling in the EU-15 1990-1996, 1996-2000, 2000-2002, 1990-2002
- Unit Consumption, energy price and income in the EU-15 1990-1996, 1996-2000, 2000-2002, 1990-2002
- Unit consumption per dwelling (adjusted to EU – 15 climate) 1990 & 2002
- Drivers of the variation in heating consumption pre dwelling in the EU-15 – variation, diffusion of central heating, size effect, efficiency improvement
- Heating requirement per square metre in the EU-15
- % central heating
- Consumption per household for electrical appliances in the EU-15
- Electricity consumption for electrical appliances and household income
- Household electricity consumption by type of appliance – large, small & appliance
- Variation of the consumption per dwelling for large appliances in the EU-15 – variation, increased equipment ownership & energy efficient efficiency progress
- Progression of Class A labels in the EU-15 in the sales of new appliances – refrigerators, freezers, cold appliances & washing machines
- Market share of A labels in selected EU-15 countries (2003) – cold appliances & washing machines
- Energy efficiency improvements for households in the EU-15 – overall, heating & large electrical appliances
- Energy-efficiency improvements in the household sector (1990-2002)
- Drivers of energy consumption per household in the EU-15 (1990-2002) – consumption per dwelling, more appliances, larger homes, behaviour, others & improved efficiency
- Variations in carbon dioxide emissions from households in the EU-15 – total variations, quantity effect (more dwellings), carbon dioxide savings (energy substitutions) and carbon dioxide savings (energy savings)

Service Sector:

- Growth in activity and labour productivity in the EU-15 service sector – value added, surfaces, employees & labour productivity
- Service Sector final consumption by sub-sector (EU-15, 2001) – 7 branches
- Fuel substitution in the EU-15 service sector. 1990, 2000 & 2002 – fuel mix
- Service sector intensity and EU-15 unit consumption trends – toe/employee, koe/€1995, MWh/MEuro1995, kWh/employee
- Impact of the business cycle in the EU-15 service sector – change in service sector value added, change in end use energy intensity & change in unit consumption per employee
- Energy intensity/ unit consumption indices in the service sector – unit consumption per employee, unit consumption per m^2, energy intensity
- Service sector electricity intensity in the EU-15 – countries with saturating versus still growing electricity intensities
- Unit consumption per employee in some service sectors (2001) – 6 sectors.
- Annual decreases in unit consumption of fuels per square metre
- Carbon dioxide -emission variations for the EU-15 Service Sector (Mt CO_2)

Odyssee indicators in Odyssee database, 2006

Macro-economic:

- Primary energy intensity
- Primary energy intensity with climatic corrections
- Primary energy intensity at purchasing power parities
- Ratio final/primary energy intensities
- Final energy intensity
- Final energy intensity with climatic corrections
- Final energy intensity at constant structure
- Final energy intensity at constant structure (with climatic correction
- Final energy intensity at reference climate (EU average)
- Final energy intensity at adjusted economic structure
- Final energy intensity adjusted for industry & economic structure & climate
- Final energy intensity at purchasing power parities
- Energy efficiency index of final consumers
- Energy efficiency index of transport
- Energy efficiency index of households
- Final energy efficiency of manufacturing
- Carbon dioxide emissions of final consumers per capita
- Carbon dioxide emissions of final consumers per capita (with climatic correction)
- Carbon dioxide intensity of final consumers
- Carbon dioxide intensity of final consumers (with climatic correction)
- Total carbon dioxide emissions per capita
- Total emissions per capita (with climatic correction)
- Total carbon dioxide intensity

Residential Sector:

- Unit consumption per dwelling with climate corrections
- Unit consumption of electricity per dwelling
- Unit consumption per m^2 with climatic corrections
- Unit consumption per dwelling scaled to EU average climate
- Unit consumption per m^2 scaled to EU average climate
- Energy efficiency index for households

- Unit consumption per dwelling for space heating with climate corrections
- Unit consumption per m^2 for space heating with climate corrections
- Unit consumption in useful energy for space heating with climatic corrections
- Unit consumption in useful energy per m^2 for space heating with climatic corrections
- Index of unit consumption per dwelling for space heating with climatic corrections
- Index of unit consumption per m^2 space heating with climatic corrections
- Index of unit consumption (per m^2) in useful energy for space heating (climatic corrections)
- Unit consumption of space heating scaled to European EU climate
- Unit consumption in useful energy for space heating per degree day
- Unit consumption in useful energy per m^2 for space heating per degree day
- Specific consumption of new multi-family dwellings
- Specific consumption of new single-family dwellings
- Unit consumption of hot water per dwelling
- Unit consumption of hot water per capita
- Unit consumption per dwelling for cooking
- Unit consumption per dwelling for lighting and electrical appliances
- Unit consumption per dwelling for lighting
- Specific consumption of refrigerators
- Specific consumption of freezers
- Specific consumption of Washing Machines
- Specific Consumption of Dish Washers
- Specific Consumption of TV
- Specific Consumption of Dryers
- Carbon Dioxide Emissions per dwelling
- Carbon Dioxide Emissions per dwelling with climate corrections
- Carbon Dioxide Emissions of space heating per dwelling
- Carbon Dioxide emissions of space heating with climate corrections
- Total Carbon Dioxide emissions per dwelling with climate correction (incl. electricity)
- Total Carbon Dioxide emission of space hearting with climate correction (incl. electricity)

Service Sector:

- Electricity intensity of Service Sector (with climatic correction)
- Electricity intensity of Service Sector
- Unit consumption of Service Sector per employee with climatic corrections
- Unit consumption of electricity per employee of Service Sector
- Unit consumption of Service Sector per m^2 (climate corrected)
- Unit consumption of electricity in Service per m^2
- Unit consumption of administrations
- Unit consumption of electricity in administrations
- Unit consumption of trade (wholesale and retail)
- Unit consumption of electricity in trade (wholesale and retail)
- Unit consumption of hotels, restaurants
- Unit consumption of electricity in hotels, restaurants
- Unit consumption of health and social action sector
- Unit consumption of electricity in health and social action sector
- Unit consumption of education, research
- Unit consumption of electricity in education, research
- Unit consumption of offices

- Unit consumption of electricity in offices
- Energy intensity of agriculture
- CO^2 intensity of Service (with climatic correction)
- Carbon Dioxide emissions of Service per employee (with climatic correction)
- Carbon Dioxide intensity of agriculture

Odyssee indicator based study of Danish Buildings, 2000

The following indicators were used in the examples presented for how to analyse energy use in buildings.

Residential Sector:

- Total Energy, Total Electricity
- Fuel Mix
- Number dwellings, m^2, growth
- Index: Unit Consumption/dwelling, unit electricity/dwelling
- Index: Unit consumption/space heating /electricity appliances and lighting
- (main influences: share sfd/mfd, dwelling size, building code, fuels)
- SFD V's MFD
- SFD size, mfd size, total of the two 1980, 1990, 1999
- Building codes
- Heating system installed
- toe: Unit consumption final & useful, space heating/dwelling
- toe**:** Final & useful/m^2 for space heating
- Variation in energy consumption to space heating in households due to energy consumption.
- Private consumption versus electricity consumption
- kWh unit consumption electric, lighting & appliances
- Penetration of appliances
- Specific consumption/appliance
- Specific consumption of various types of freezers
- Share of refrigerators and freezers by label/class

Service Sector:

- Growth in m^2 of floor area because it actually = heated area.
- Energy/m^2, value added and employee
- Total energy, total electricity, total energy climate adjusted.
- Intensity total, intensity by branch
- Unit consumption energy/electricity per employee
- Energy savings accrued

UK DTI indicators, 2006

Macro-economic:

- E6.12 Domestic electricity prices in the EU and G7
- E11.1 The energy ratio
- E11.2 Final energy consumption by sector

Residential Sector:

- E5.11 Household energy use per person in OECD countries and Russia
- E5.12 Household energy consumption per person in G8 countries
- E11.13 Domestic energy consumption
- E11.14 Domestic energy consumption by final use

- E11.15 SAP rating of housing stock
- E11.16 Ownership of central heating by type
- E11.17 Thermal efficiency of housing stock
- E11.18 Specific energy consumption for households
- E11.19 Ownership and depth of loft insulation
- E11.20 Electricity consumption by household domestic appliance by
- broad type
- E11.21 Percentage of households owning refrigeration appliances
- E11.22 Percentage of households owning domestic washing and
- drying appliances
- E11.23 Energy efficiency of new cold appliances

Service Sector:
- E11.24 Service sector energy consumption and output
- E11.25 Final energy use and value added by public administration
- E11.26 Final energy use and value added by commercial and other service

Sustainable Energy Ireland publication, 2005

Residential Sector:
- Energy intensity (res energy consumption v household disposable income)
- Space cooling
- Number of dwellings
- Household income
- Dwelling type
- New build
- Average household size
- Occupancy
- Floor area
- Period of construction
- Tenure
- Location
- Central heating
- Fuel prices and expenditure on energy
- Fuel poverty
- Internal and external temperature
- Penetration of electrical appliances
- Improvements in energy efficiency

Three step approach defined by SEI to using above list:
- Describe stock and energy use
- Graph energy intensity and unit consumption
- Undertake international comparisons of energy and electricity consumption/dwelling

LBNL developing country indicators for GED project, 2006.

Macro-economic:
- Population

Residential Sector:
- Energy demand in the residential buildings sector
- Number of persons per household (family)
- Average floor area per household in m^2

- Average energy intensity in the residential sector in $MJ/m^2/year$
- Energy type
- Locale type (urban, rural)
- Housing type (detached home, multi-family unit, other home)
- Space heating energy intensity in residential buildings in MJ/m^2-year
- Space cooling energy intensity in residential buildings in Mj/m^2-year
- Type of appliance or end-use device
- Penetration of appliance or device
- Average energy intensity of appliance
- Average cooking and water heating energy use per household
- Average lighting energy use per household
- Residual household energy use

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Appendix E Index Decomposition

Given a time series or a period wise, set of aggregate energy consumption data for an economic sector, such as, manufacturing, transport, service or residential, one may wish to decompose this aggregate energy consumption data to depict the partial temporal influences of factors such as energy efficiency, changes in structure from heavy industry to light consumer goods, changes in product output levels or changes in fuel mix. For individual sectors, say transport, one may wish, for example, to know the impact on overall energy use of an increase in miles driven per vehicle or increased efficiency of engines. Two methodologies have been proposed in the literature for carrying out such decomposition or disaggregation of aggregate energy consumption data: Index Decomposition (ID) (Ang et al., 2000) and input–output decomposition (IOD) (Rose and Casler, 1996). Both approaches use known economic statistical tools to achieve their desired results.

This appendix will only deal with ID as no investigation has been made into the workings of IOD. ID decomposes changes in aggregate energy use over a defined time period. The raw data that ID uses to assess the various impacts on consumption such as sector output or process energy intensity are themselves incomparable in absolute terms and thus ID uses indices to calculate the contributions of various impacting factors on energy use trends. For example the impacts industrial output and energy intensity would be measured in euro and joules per euro respectively which are two incomparable units. A simple index begins with a base year reference index value of 100. Subsequent years indices are lesser or greater than 100 depending on whether the indexed data increased or decreased and are plotted to show developments after the base year. A start point such as the base year is necessary for all other years to refer to. The trends sought must be with respect to some start point. For ID base year aggregate energy use would equate to 100 and trends in years thereafter would be relative to 100. Graphically, ID depicts decomposed influencing factors or parameters on the same index scale. The percentage or absolute contributions of various parameters to overall energy use change can then be measured to quantify the energy savings or increased energy use they led to.

To illustrate the idea behind ID we can take the industrial sector as an example. We decompose overall industrial sector energy use over time as the effects of activity, structure and intensity such that:

$$E_i = \Sigma A_i * S_{i,j} * I_{i,j} \quad (1)$$

where $\mathbf{E}_i$ represents overall energy use in industry (i), **A** represents overall sector activity, i.e. production output, **S** represents the share of each subsector (j) in same output and **I** represents the energy intensity ($I_{i,j} = E_i/S_{i,j}$) of same subsectors. As stated previously the parameters under examination are dissimilar in unit terms. $\mathbf{E}_i$ in actual fact represents energy change and can be expressed as a differential sum say $E_i = E_i2000$ minus E_i1995 or as an index $E_i = E_i2000/ E_i1995$. **A**, **S**, and **I** then either give the sum, or the product, of the change in **E**i respectively such that they can rewrite (1) as

$$\Delta E_{agg} = \Delta E_{pdn} + \Delta E_{str} + \Delta E_{int} + \Delta E_{rsd} \quad (2)$$

$$RE_{agg} = RE_{pdn} RE_{Str} RE_{int} RE_{rsd} \quad (3)$$

Where $\Delta E_{agg} = E_t - E_0$ and $RE_{agg} = E_t/E_0$. **R** denotes ratio and **RSD** a residual value which denotes that after the calculation of the individual parameters, their sum or their product is not equal to the original total. equation (2) is additive decomposition while equation (3) is known as multiplicative decomposition. The same formulae can be used for all sectors. We don’t usually attempt to decompose a single year’s energy use into the effects of various parameters but rather the change in total energy use over a period of time. The ID approach has been named the STRINT (Haas and Schipper, 1998) due to the interest being for the most part on the interplay between structure and intensity and their combined impact on energy use, EASI (Schipper et al., 2001), of CASIF by (Schipper et al., 2001), where a fourth parameter, fuel mix, is included in order to calculate the impact of the various parameters on carbon emissions. The approach has also been compared to the IPAT formula (Ehrlich and Holdren, 1972), of Impact = Population * Affluence * Technology. We will return to these similarities further in the text. In theory total change can be broken into any number of explanatory parameters provided a consistent controlling function is used. In this appendix however activity, structure and intensity are the only explaining parameters used.

Overall energy use for any sector is generally available from a country's energy balance data which can be obtained from the IEA statistics web site. Production output is measured as value added to output products. This data is generally available from national statistics organisations or Eurostat. Value added is used rather than turnover to eliminate overlapping or double counting between sectors. The inputs to one sector may have been purchased from another and so on. The NACE classification of Industrial sub sectors is adequate when choosing a particular list of sub sectors (branches) within industry. We thus define the components to help calculate (2) and (3) as:

E_i = total industrial (i) sector energy consumption

PDN = P_i= total industrial production[*****] (4)

STR = $S_{i,j}$ = production share of branch j in sector i (= $P_{i,j}/P_i$) (5)

INT = $I_{i,j}$ = energy intensity for branch j of sector i (= $E_{i,j}/P_{i,j}$) (6)

PDN, STR and **INT** can all be calculated from the aforementioned national energy use and value added data for each of the NACE level 1 branches.

Background to ID

Various methods of carrying out Energy use ID with varying degrees of complexity exist. The issue at hand is what formula to use to define the various components on the right hand side of equations (2) and (3). All proposals seek to use data such as that described in the previous paragraph as inputs to disaggregate energy use. All methodologies have their origins in the discourse over how to construct an economic price index which raged from the middle of the 19th century to the 1920s. The concept behind ID is thus a version of the application of economic index numbers to the study of contributions of price and quantity levels to changes in aggregate commodity consumption. Price and quantity are not directly comparable thus necessitating the use of an index.

A standard price index combines quantities of goods sold and their respective prices over a number of years to produce a one number index for each year that depicts consumer purchasing patterns and price trends. Some of the goods are weighted to convey their priority on a general shopping list. For example a certain amount of consumer expenditure will be on food, fuel and clothing whereas there might not be any expenditure on periodicals or holidays. Most price indexes are normalized to a value of 100 in the base year(s), to indicate the percentage level of the price index in each year relative to the base year. So a price-index value of 110 for a given year means that the price index is 10 percent higher in that year than the base year. Various mathematicians such as Laspayres, Paasche, Marshall, Edgeworth and

[*****] In the literature the convention is often to use the letter Y to denote Production.

Divisia proposed alternative methods for constructing a price index. They sought to provide an index that would be capable of providing the information sought and be mathematically consistent at the same time. To this day no one formula has been agreed for constructing a price index.

Perhaps all of the problems with mathematical consistency were captured in Irving Fishers seminal work "The Making of Index Numbers" (Fisher, 1922). Fisher's book described 134 different formulae for constructing a single number index and included "Fishers ideal index". Fisher presupposed in the introduction to his book that most of the questions relating to constructing indices had by his time been resolved stating, "I think we may be confident that the end is being reached of the long controversy over the proper formula of an index number". Francois Divisia's publication of the Divisia Index three years later introduced the idea of using logarithms to construct indices which heretofore had not been suggested. However between Fishers ideas and the Divisia index most of the choices surrounding how to construct an index had been covered.

The consistency problems that Fisher thrashed out revolved around questions such as how to take the average of a set of prices and quantities within a single year, how the weighting should be calculated and if the various years indices should be calculated with respect to the previous year in the series (a chained index) or to the first (base) year in the series. An example of a weighting problem would be that the a weighting given to expenditure on fixed line phone calls in 1995 would no longer be valid in 2000 given the advent of mobile phones whereas it would be difficult to accordingly adjust an index which ran from 1995 to 2005. The Laspayres and Paasche approaches actually advocate base year or target year reference for weights respectively and as such the Laspayres index systematically overstates inflation, while the Paasche index understates it[†††††], because the indices do not account for the fact that consumers react to price changes by changing the quantities they buy. Divisia's index sought to address this problem by having moving weight references. Prior to Divisia all systems were bilateral (Balk, 2000) i.e. with a base or target year as reference.

Fisher further stipulated that all approaches were developments of six methods for taking the average of a set of data: the arithmetic, harmonic, geodata category, median, mode or aggregative average. The developments of these six approaches stepped through possibilities with alternate weight reference years, "chaining years" and "crossing" years (Fisher, 1924). Fisher also proposed tests for identifying desirable properties of an index. Three of these tests are relevant to ID methodology namely the time reversal test, the circular test and factor reversal test (Ang and Zhang, 2000, p.1167). The circular test seeks that the chosen index is immune from the path of data between the base and target year while the factor reversal text implies that no residual remains after the influence of each parameter has been calculated. A tall order for energy ID!

A different analogy as to what the ID of energy use seeks to achieve is that with the supply of money in an economy. The supply of money is made up of cash, coins, deposits and credit card limits (m0 +m1 + m2 + Credit card limits) [‡‡‡‡‡] . An index of the supply of money itself amalgamates these four sets of data into a one number index that represent all money for each time period. To compare with energy supply it is as if we have an index for the supply of money (the sectoral energy balance) but don't know how much of it comprises of cash, notes,

[†††††] Definition from http://www.reference.com

[‡‡‡‡‡] The advent of Credit cards in society has meant that the calculation of the supply of money is no longer an exact science given that one can never know if credit cards will be utilised to their limits and whether their limits can really be classed as a supply of money.

deposits and credit card limits. Variations of the Laspayres, Paasche, Marshall, Edgeworth and Divisia formulae for constructing indices have been proposed in the literature for disaggregating the overall figure. Essentially the various approaches compose a linear or differential formula which relates the activity, structure and intensity components of energy use to overall energy use. This appendix will only describe in detail the Laspayres and Divisia approaches as they have been the most commonly used since papers on energy decomposition were first published in the 1980s. Ang (Ang, 1995) gives a very good account of early developments with ID.

Laspayres ID

The Laspayres approach to ID takes as its start point the principle feature of the Laspayres index, which is that all parameters are referenced from the base year of the study being undertaken[§§§§§]. Laspayres ID uses this operating principle to allow each of the three parameters (Activity, Structure and Intensity), to change one at a time while keeping the other two at base year values. As such, to calculate the change in energy use over a time period that is attributable to for example activity, both the structure and intensity components are held at their base year values while the activity component is allowed to change. In other words we multiply the activity level for each successive year by the base level values for structure and intensity to measure the influence that activity has on overall consumption using the definitions from (4), (5) and (6) and the value added and intensity data outlined previously. The same methodology is then repeated in turn for the structure and intensity components. This approach gives a separate value for each of A, S and I for their contribution to overall energy change for each year. However with the Laspayres approach, the sum or product of the contributions of these three parameters does not add up to overall energy use, resulting in the aforementioned residual. In the literature these residuals are sometimes referred to as a quantity which portrays the interaction between the three components while others see them more as a disadvantage or nuisance factor of the Laspayres approach. One can say for sure however that a large residual means a lot of change in energy use remains left unexplained (Ang et al, 1997). For a mathematical explanation as to why a residual occurs after decomposition see (Blok, 2001).

To illustrate with a numerical example we take the following data for a fictive industrial sector with two branches B1 and B2 and data for two years 0 and t. Formulas (4), (5) and (6) apply. The units of the data are considered equal for the purposes of our calculations as we want to see their relative influences on aggregate change.

Table E.1 : Industry sector energy use and output (measured as value added) for two branches. Data comes from Ang & Lee (1994).

Sector	E_0	P_0	S_0	I_0	E_t	P_t	S_t	I_t
B1	60	10	0.2	6.0	80	20	0.25	4.0
B2	40	40	0.8	1.0	48	60	0.75	0.8
Total	100	50	1.0	2.0	128	80	1.0	1.6

Additive decomposition (2) has appeared significantly more often in the literature than the multiplicative (3). In fact one could speculate that multiplicative decomposition did not take off. As such we will undertake an additive decomposition in our example. For relevant

[§§§§§] The Paasche index uses target year to reference weights while the Marshall Edgeworth Index takes an arithmetic average of the base and target year. The formulae are the same as for Laspayres except that the reference year is different.

examples of the multiplicative decomposition see (Howarth et al., 1991) and (Hass, 1997) while a good explanation is found in (Ang & Zhang, 2000, page 1157).

The Laspayres formulas for the partial influences of activity, structure and intensity are (Park, 1991):

$\Delta E_{pdn} = \Sigma_i P_t S_{i,0} I_{i,0} - E_0$ (7)

$\Delta E_{str} = \Sigma_i P_0 S_{i,t} I_{i,0} - E_0$ (8)

$\Delta E_{int} = \Sigma_i P_0 S_{i,0} I_{i,t} - E_0$ (9)

If we rewrite (7) using the definitions outlined in equations (4) to (6) we get

$\Delta E_{pdn} = \Sigma_i (P_t * P_{i,j} / P_i * E_{i,j} / P_{i,j}) - E_0$ (10)

This formula is in fact in the same form as the IPAT formula previously mentioned whereby we similarly write:

Impact (energy use) = capita * gdp/capita * energy/gdp (11)

except that the activity is population rather than production and the structure is gdp/capita rather than value added per branch. One could say thus that EASI is a particular application of the IPAT formula which focuses on energy consumption although also incorporates economic statistical tools for its actual calculation. We can also see clearly in (10) and (11) that the three parameters cancel when multiplied together so as to be equal to the original aggregate energy sum.

Liu (Liu et al, 1992) citing (Hankinson & Rhys, 1983) rewrite equations (7), (8) and (9) to give the following Laspayres formulae for A, S and I:

$\Delta E_{pdn} = I_0 (P_t - P_0)$ (12)

$\Delta E_{str} = \Sigma P_{i.t} I_{i,0} - P_t I_0$ (13)

$\Delta E_{int} = E_t - \Sigma P_{i.t} I_{i,0}$ (14)

Their purpose is to eliminate superfluous parameters from the equations. For example for activity the change in overall production has been allowed to change but weighted by the base year intensity. Production multiplied by intensity gives energy use. In this formula there is no structure effect as we only interested in the influence of production on the sector as a whole.

As previously mentioned, for each of formula (7) – (9), one of production, structure or intensity is allowed develop over time while the other two are held at base year values. As

$\Sigma_i Y_0 S_{i,0} I_{i,0} = E_0$

E_0 must be subtracted in each formula to obtain the actual change between E_0 and E_t due to each parameter.

Calculating each in turn, using the definitions from (4), (5) and (6) and the data from Table E.1, we obtain:

$\Delta E_{pdn} = 80*((0.2 *6.0)+(0.8*1.0)) - 100 = 60$

$\Delta E_{str} = 50*((0.25 *6.0)+(0.75*1.0)) - 100 = 12.5$

$\Delta E_{int} = 50*((0.2 *4.0)+(0.8*0.8)) - 100 = -28$

We know from Table E.1 that the change in energy use over time is:

$E_t - E_0 = 28$

However the addition of the three calculated terms is:

$\Delta E_{pdn} + \Delta E_{str} + \Delta E_{int} = 60 + 12.5 + (-28) = 44,5$.

Thus there is a residual of 16,5. Nonetheless we can plot our findings Figure E.1.

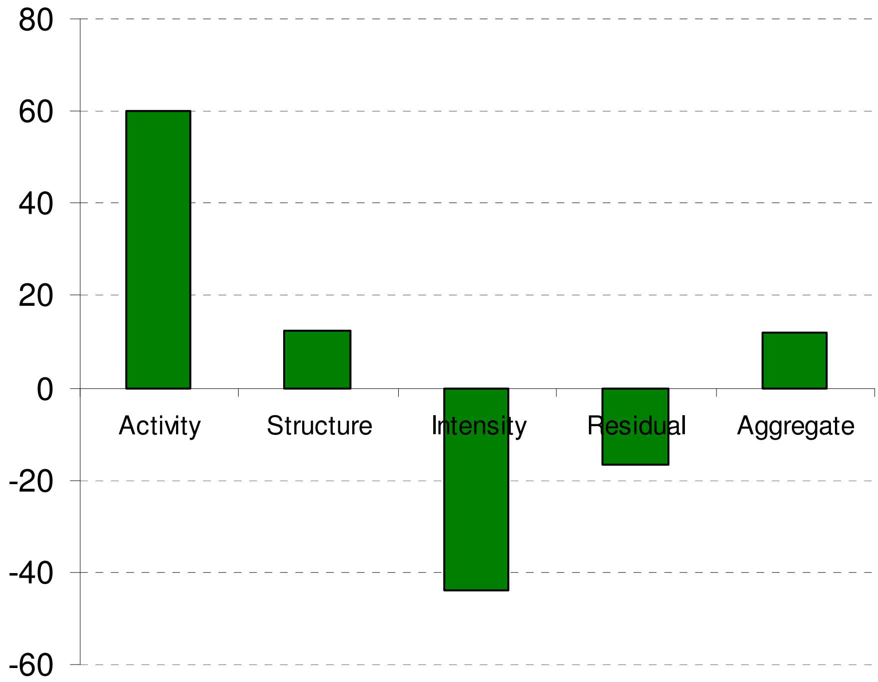

Figure E.1 : Results from Laspayres Decomposition example. Y axis is absolute change in energy use between time 0 and time t caused by each parameter. Aggregate is the sum of the other four parameters or the total change. Chart constructed using data from Table E.1.

Looking at Figure E.1 we can see that for our dataset that the increase in activity (production) was by far the biggest influencing factor on the overall increased energy use. The change in structure (share of production per branch) also contributed towards a minor increase. Energy efficiency improved which meant intensity (energy per branch output) fell by 28 units. The residual which as previously be stated be interpreted as an interaction term between the three parameter or as an error in the Laspayres method also resulted in a decrease in energy use. If it is, as is more often than not stated, that the residual is in fact a weakness of the approach it is rather large. Our overall interpretation of the results is that although energy efficiency increased (decreased intensity) the reductions in energy use that this contributed to were offset by increased volume of production and a slight shift towards more energy intensive production(structural shift).

Table E.2 : Values for presentation of results from Figure E.1.

PARAMETER	ABSOLUTE VALUE	% Change = /E_0	Index Number = %+1
Aggregate time 0	100		1
Δ Aggregate	28	0.28	1.28
Aggregate time t	128	1.28	
Δ Activity Share	60	0.6	1.6
Δ Structure Share	12.5	0.125	1.125
Δ Intensity Share	-44	-0.44	0.56
Residual	-16.5	-0.165	0.835

The above approach decomposes the overall energy consumption data category into three distinct parameters. As such the results can be expressed in absolute values of energy, as a percentage change or as an index change. Percentage and index changes are usually easier to graph than absolute change as can be seen above the value 60 for activity dominates the graph.

Figure E.2 presents the same data as in Table E.2 but indexed to base year energy use equal to 100 for ease of interpretation.

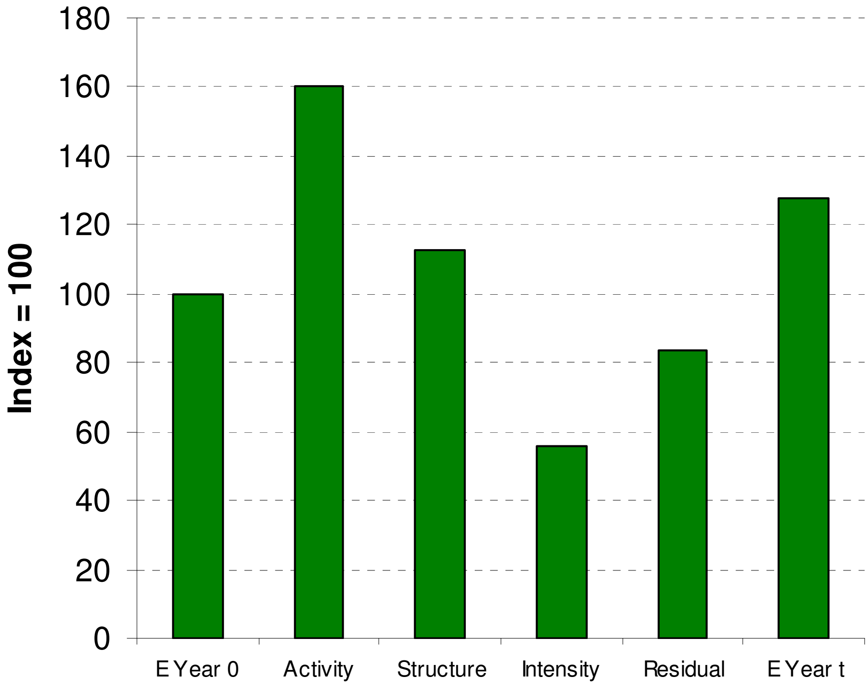

Figure E.2 : Laspayres Decomposition example presented in Index Base 100 form. Y axis is the change in energy use relative to 100 caused by each parameter. Chart constructed using data from Table E.1.

IEA (1997, Appendix 1) and Ang and Zhang (2000, p 1158), outline how percentage change whether over entire period or per year is used to present data.

Rather than calculate the factors influencing change in total energy use we could have sought the change in overall energy intensity for the sector over time and decomposed this into the impact of change in structure and intensity. To do this we could have taken either the additive change, $I_t - I_0$ or the index change in overall intensity, I_t/I_0 as our start points. Overall sector production (activity), is not needed to calculate the change in intensity of the sector as this change is defined as a ratio of total industrial energy consumption to total Industrial production (ang,1995, p 1084) . In other words the activity parameter is included in the definition of aggregate intensity. Such a definition of energy intensity is actually the same as general energy/gdp provided value added is used as the data category for production in the calculation. Such an intensity focused approach would use the following formulae:

$$\Delta I_{agg} = \Delta I_{str} + \Delta I_{int} + \Delta I_{rsd} \quad (15)$$

$$RI_{agg} = RI_{Str} RI_{int} RI_{rsd} \quad (16)$$

where $\Delta I_{agg} = I_t - I_0$ and $RI_{agg} = I_t/I_0$, R denotes ratio and RSD residual as before. This approach can produce easier interpretation of results as the industrial production parameter is neglected. For example in quickly growing developing countries the growth in industrial production can be extremely rapid and dwarf structure and intensity. This would not help if the impact of change in structure on intensity is the desired parameter to view. Energy intensity is in fact often a more used indicator or benchmark of progress and as such its attributing factors can on occasion be more interesting than those affecting overall energy use. On the other hand the energy consumption approach as outlined in the example given in Figure E.1 is very easy to understand for the non specialist. Ang & Zhang (2000) gives a good account of both energy intensity approaches formulated in (10) and (11).

Additive Laspayres Energy Consumption has been used and promoted in the literature by IEA/LBNL in their work on indicators over the last decade. They present their results using average percentage change per year on the Y Axis (IEA 1997).

General comments in the literature about the Laspayres approach are that it is good when data is scarce (Boyd et al., 1988) and it is easiest with discrete data (Schipper et al 2001).

An important point is that ID can be undertaken over successive years or for separated years. The latter approach is known as period wise decomposition. The example given using the data from Table E.1 could have been for a period wise or time series pair of years. It should also be noted however that with either a time series or period wise approach that data changes within one year not reflected (Ang, 1995, p 1092).

As previously stated the fundamental of the Laspayres approach is to use the base year references. We could of course take E_t or an average energy consumption between E_0 and E_t as our reference year but then this would not be Laspayres decomposition. The former would be Paasche decomposition while the latter which would involve slightly adding to the complexity of our formula would be Marshall – Edgeworth. Such option leads us on to the second approach we will discuss in this appendix, namely the Divisia approach.

Divisia ID

The Divisia method of ID introduces the use logarithms to the decomposition formulae. It also attempts to address the limitations of the Laspayres method with regard to having a fixed base year reference. In doing this it seeks to calculate growth rates for the three different parameters of activity, structure and intensity over time. This results in the exponential of a weighted sum of growth rates where the weights are each parameters share of energy in the aggregate (Torvanger, 1991).

In the simple average Divisia method the growth rate of energy use is expressed as the sum of the growth rates of the activity, structure and intensity parameters. The decomposition of overall energy use is carried out by multiplying these growth rates by total energy consumption and then taking the integration with respect to time. In a sense a growth index for each parameter is calculated and then weighted by the energy use over the period. The term "simple average" is used because the real changes in energy consumption are taken as the average of the consumption levels at the base and target year. The average is used as we don't know the path the energy use actually takes between data points. The growth rate of each individual parameter is thus given a logarithmic function over the period such that for example[******]:

Growth rate in production = $d \ln P_t / dt$

[******] The reason as to why a logarithmic growth function is selected has not been investigated. Divisia's original paper (in French) or the work or Balk (Balk, 2000) or Hulten (cited in Balk) may explain.

Figure E.3 illustrates the point. We can have production (P) and energy use (x) for year 0 and the same two parameters for year one, however we know not the path that these two dependent parameters will take over the time period.

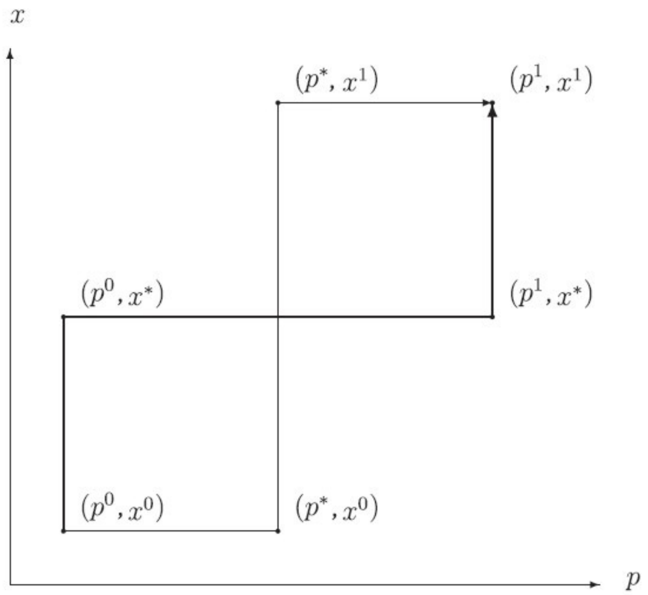

Figure E.3 : Path dependency of decomposition. This diagram is taken from Balk (Balk, 2000).

The equations for the simple average Divisia method (liu et al., 1992, page 164) derived in Boyd et al (1988), are as follows:

Change in Activity = $0.5(E_0 + E_t) \ln (P_t/P_0)$ (17)

Change in Structure = $0.5\Sigma(E_{j,0} + Ej,t) \ln(S_{j,t}/S_{j,0})$ (18)

Change in Intensity = $0.5\Sigma(E_{j,0} + E_{j,t}) \ln(I_{j,t}/I_{j,0})$ (19)

In the above formulae we obviously have the logarithmic growth of the parameter (Activity, Structure or Intensity) weighted by the average energy use for the parameter. These formulae differ from the additive Laspayres formulae described above although the data needed to compute them does not. Boyd et al (1988) state that over short periods of time the simple average Divisia method is a good approximation to the integral for the given parameter. This method is currently used by the Odyssee Project (Bosseboeuf et al, 1996). The author has also heard that it has recently been recommended by Eurostat. It may be that they have chosen this methodology to incorporate the moving reference year and to make the calculations as straightforward as possible for practitioners, without any undue loss of quality.

Liu (Liu et al., 1992) take Divisia decomposition a step beyond the simple average method by the introduction of a smoothing constant (α, β, γ) as follows:

Change in Activity = $[E_0 + \alpha (E_0 - E_t)] \ln (P_t/P_0)$ (20)

Change in Structure = $\Sigma[E_{j,0} + \beta j (Ej,t - E_{j,0}) \ln(S_{j,t}/S_{j,0})$ (21)

Change in Intensity = $\Sigma[E_{j,0} + \gamma j(E_{j,t}- E_{j,0}) \ln(I_{j,t}/I_{j,0})$ (22)

Rather than take the weight of the energy use change as 0.5 as before we introduce the smoothing constant, which is a value between 0 and 1, which allows the user to set the specific weight of energy use over the period. If we isolate the weight part of the formula as follows:

weight = $[E_0 - \alpha (Et - E0)]$ (23)

we can see that all that is happening is that we add to base year energy use E_0, the fraction of energy use change we deem appropriate for the analysis we are undertaking. The problem is that setting the value of alpha is completely arbitrary. The freedom to choose any value however allows us to eliminate the residual term completely and thus actually correctly attribute the actual level of energy use, although this depends on one's view of what the residual term actually is.

To get a sense of alphas role and taking a hypothetical example where E0 = 10 and Et = 5 for formula (23), if we set alpha = 0 the weight will be equal to 10 and as such all changes will be related to the base year. If on the other hand alpha is = 1 the weight will be 15 and as such all changes will be calculated relative to the target year. Choosing alpha as 0 or 1 thus reverts the formula to a Laspayres type or Paasche type approach although now using the logarithmic growth function. In general alpha is chosen as zero for historical analysis, as 1 for forecasting and arbitrarily if the goal is to minimise or eliminate the residual term.

In the above equations (20) to (22) beta and gamma have the same role as alpha although without necessarily the same value. The three formulae are collectively referred to in the literature as Parametric Divisia Method 1 (PDM1). For their derivation see (Liu et al., 1992). The same paper also describes another variation named Parametric Divisia Method 2(PDM2) which also introduces the smoothing constant and a third approach called the adaptive weighting Divisia method (AWDM) which excludes the need for a smoothing constant. AWDM does so by equating the formula for the three parameters of PDM 1 to their respective counterparts in PDM2. This allows specific formula to be developed to produce correct values for alpha, beta and gamma to remove the arbitrariness of their origin. The disadvantage with AWDM however, is that it increases the complexity of the formulae. Again one is referred to (liu et al, 1992) for the detail.

The latter three approaches, PDM1, PDM2 and AWDM, take as their start point the development that if the instantaneous value of E_t for any time t is equal to:

$E_t = A_t * S_t * I_t$

differentiation and subsequent integration of both sides with respect to time produces

$$(\Delta E_{tot})_{0,t} = \int_{0,t} [At'*St*It]dt + \int_{0,t}[At*St'*It]dt + \int_{0,t}[At*St*It']dt \qquad (24)$$

which although producing a growth function for each of the three parameters, runs into the aforementioned path problem in that we don't have discrete data for the variables in the equation between times 0 or time T. We cannot as such compute the integral since exact data does not exist. There are an infinite number of possibilities. In fact the classical Divisia index (Divisia, 1926) assumes that data are available at every moment of time t, where t ranges over a closed interval instead of only at discrete points in time (liu et al., 1992) This is what leads to the introduction of the smoothing constant as a rectifying measure. For a discussion on which of the aforementioned methodologies to select see Ang & Lee (1994). To give one example of their thoughts on the matter they state that generally PDM1 is preferred if growth levels of the parameters are thought to be logarithmic whereas PDM2 is better if they are thought to be linear.

The latest development in the refinement of the Divisia index for ID has been the introduction of the Logarithmic Mean Divisia Index (LMDI ID) Method (Ang and Choi, 1997). This is based on the Tornqvist price index (Tornqvist, 1985) which provides best approximation of the classical Divisia index since it employs all available information (Balk, 2000). This approach takes a step back to before the development of the PDM and AWDM methods to attempt a refinement of the simple Divisia method. The goals are to satisfy Fischer's consistency rules, produce formulae that are simple to compute and to eliminate the residual. Their approach takes as a start point that the Simple Average Divisia index, formula (17):

0.5(E0 + Et) (ln Yt/Y0)

has become the most popularly used decomposition method practised by practitioners and as such they rename it the conventional Divisia Method. However they state that this index has two drawbacks namely a residual and an inability to compute zero values that occur in the data set. To solve these two problems they replace the arithmetic mean weight function

$0.5(E_0 + E_t)$

or

$0.5(x + y)$

by a logarithmic function:

$L(x,y) = (y - x)/\ln(y/x)$ (25)

where both x and y are positive numbers and x is not equal to y but L(0,0) = 0. Thus L (E_t,E_0) is equal to:

$(E_t - E_0)/\ln(E_t/E_0)$

Ang and Choi (Ang and Choi, 1997) use their approach to decompose the change in energy intensity of industry and as such is an alternative approach to those outlined in formulas (15) and (16) above.

Ang et al (1998) takes this work a step further to allow the decomposition of change in total energy use for a sector using formulae (26) – (28) below.

Substituting L (E_t,E_0) into equations (17) to (19) produces the refined Divisia Index formula that can be used for ID of total energy use in a sector as follows:

Change in Activity = $[(E_t - E_0)/\ln(E_t/E_0)]\ \ln(P_t/P_0)$ (26)

Change in Structure = $\Sigma[(E_{j,t} - Ej,_0)/\ \ln(E_{j,t} / Ej,_0)]\ \ln(S_{j,t}/S_{j,0})$ (27)

Change in Intensity = $\Sigma[(E_{j,t} - Ej,_0)/\ \ln(E_{j,t} / Ej,_0)]\ \ln(I_{j,t}/I_{j,0})$ (28)

Ang et al (1998) thus seem to have produced the most refined decomposition approach to date which eliminates the residual term, removes the problem of zero values (important given the presence of the log function), satisfy Fishers index rules and are not as complicated as the PDM or AWDM approaches. For a description and discussion on Fishers tests see (Ang & Zhang, 2000, Page 1167).

We now return to the data set given in Table E.1 to attempt an LMDI ID. We know that the aggregate change in energy use between times zero and t is 28. Using formulae (26) to (28) we get:

Change in Activity = $[(E_t - E_0)/\ln(E_t/E_0)]\ \ln(P_t/P_0)$
=[(128 - 100)/ln(128/100] ln (80/50)
= 53.3

Change in Structure = $\Sigma[(E_{j,t} - Ej,_0)/\ \ln(E_{j,t} / Ej,_0)]\ \ln(S_{j,t}/S_{j,0})$
= [(80-50)ln(80/50)* ln(.25/.2)] + [(48-40)ln(48/40)* ln(0.75/0.8)]
= 12.7

Change in Intensity = $\Sigma[(E_{j,t} - Ej,_0)/\ \ln(E_{j,t} / Ej,_0)]\ \ln(I_{j,t}/I_{j,0})$
= [(80-50)ln(80/50) * ln(4/6)] + [(48-40)ln(48/40) * ln(0.8/1)]
= -37.9

Total Change = 53.3 + 12.7 + (-37.9) = 28.1

We have thus decomposed the change in energy use of 28 into the effects of activity, structure and intensity and have left no residual. Figure E.4 displays this graphically.

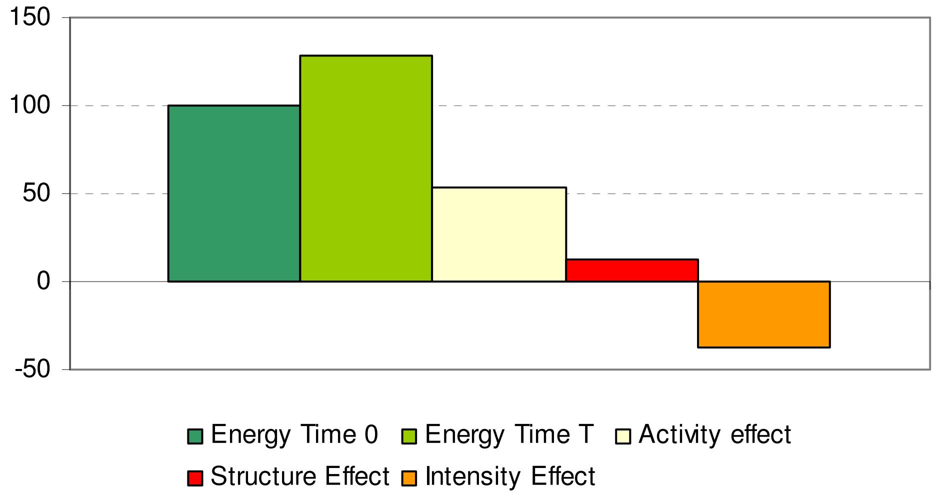

Figure E.4 : Period wise LMDI ID of energy consumption. Arbitrary units used on Y - Axis. Note zero residual. Chart constructed using data from Table E.1 (Enerdata, 2006).

The results of the decomposition show that the decrease in energy intensity was not enough to offset the increase due to activity and the slight increase due to structure. These results are of the same order as those shown in Figure E.1 and Figure E.2 for the Laspayres ID. The absolute values of the three parameters are different however. In the Laspayres approach they are 60, 12.5 and -44 for activity, structure and intensity respectively while in the LMDI approach they are 53.3, 12.7 and -37.9. The difference is that there is no residual effect now.

Thus on this basis LMDI ID would seem to be the best all round approach to use. This judgement must however be weighed against the fact that Eurostat and thus the EU recommend the simple or conventional Divisia method.

ID for Residential and Service Sectors

The vast majority of the literature focuses on the Industrial sector. In fact of the 124 studies listed by Ang & Zhang (2000) only a handful could be said to look at the residential and service sectors. The reoccurring authors working with the residential and service sectors however are Schipper, Hass and Howarth. It turns out that adapting the above methodologies to disaggregation for these sectors is unfortunately not as straightforward as we would wish. The problems for both sectors are however different. For the residential sector the first problem is that activity is hard to define. There is no output. Schipper defines it as the activity of housing or sheltering people. He thus straightforwardly equates population to activity. Structure he further postulates is the mix of energy used for energy end – uses such as space heating, water heating, cooking, lighting, ventilation and electrical appliances. Calculating the share of activity (population) engaged in each structural branch is also problematic as all people are involved in all branches. Intensity harbours the same problem although can be classed as the process efficiency of the structural parameters.

The issues with the service sector are twofold. First structure is not so important in the sense that a shift from a large financial sector to a large hotel and restaurant sector does not affect energy use to the same degree as similar shifts in the industrial sector. This implies that for

Service Sector decomposition we only need look at activity and intensity effects. Secondly and more importantly the level of data available for the service sector is scant making any theoretical approaches difficult to implement.

The IEA (1997 and 2004) both describe their views on approaches to decomposition using these aforementioned parameters. The IEA have however promoted the use of the Laspayres methodology of ID and as such it is to make the data available fit the Laspayres approach that they formulate their methodology. Table E.3 describes how they factorise both the residential and service sectors by branch activity and intensity.

Table E.3 : Residential & Building Sector factors of Energy Use (IEA, 2003).

Sector (i) **Sub sector (j)**	**Activity (A)**	**Structure (Sj)**	**Intensity (Ij = Ej/Aj))**
Household			
Space Heating	Population	Floor Area/Capita	Heat/Floor Area
Water Heating	“	Person/Household	Energy/Capita
Cooking	“	Person/Household	Energy/Capita
Lighting	“	Floor Area/ Capita	Electricity/Floor Area
Appliances	“	Ownership/Capita	Energy/Appliance
Service			
Total Service	Value Added	(not defined)	Energy/Value Added

Note: Structural factor for Water Heating & Cooking is actually:

Household(√(Person/ Household))[††††††]

Thus the corresponding energy/capita intensity factor needs to be adjusted to account for this.

As it happens however such a factorisation of aggregate consumption patterns is not method specific. The only goal with a factorisation is that the factors capture the various parameters and influences we want to look at. Population could be replaced by the number of households. Then we would have structure for space heating as floor area/household and so on.

The following example attempts to decompose residential sector energy use in France between 1990 and 2000 using LMDI ID. Only two structural branches, space heating and water heating are used for ease of display. Table E.4 provides data for the example. Each value in Table E.4 has been calculated using the factors in Table E.3. Then formulae (26) to (28) are written specific to the example as follows:

A_total = [(Et sector – Eo sector)ln(Et sector – Eo sector)] ln[population_t/population_o]

S_space = [(Et b_heat – Eo b_heat)ln(Et b_heat – Eo B_heat)] ln[floor_area/capita_t/fapc_o]

S_water = [(Et b_water – Eo b_water)ln(Et b_water– Eo B_water)] ln[person_h_t/person_h_0]

I_space = [(Et b_heat – Eo b_heat)ln(Et b_heat – Eo B_heat)] ln[heat_fa_t/heat_fa_0]

I_water = [(Et b_water – Eo b_water)ln(Et b_water– Eo B_water)] ln[energy/capita_t/ energy/capita_0]

The results are:

[††††††] Howarth et al., (1993) “The Structure and intensity of Energy Use: Trends in Five OECD Nations”, The Energy Journal, Vol, 14, No. 2.

Change due to Activity = 56919474.11

Change due to Structure = 142612728.4

Change due to Intensity = -91924241.47

The sum of these three parameters is then: 56919474.11 + 142612728.4 + (-91924241.47) = 107607961

We already know from Table E.4 that the change in energy use from 1990 to 2000 is equal to = 1424349360 – 1316748600 = 107600760

Thus using LMDI ID in conjunction with the IEA recommended factors we have obtained a near perfect decomposition of total energy use change for a Residential Sector example.

Table E.4 : Calculated decomposition factors for Space heating and Water heating branches for France. Data for calculations taken from the Odyssee Indicators Database (Enerdata, 2006).

France		**1990**		
Sector	**E_0 (Gj)**	**A_0**	**S_0**	**I_0**
Heat	1180258920	56709000	32.61474983	0.6381331
Water	136489680	56709000	35031168.41	6.871E-08
Total	1316748600	56709000		

France		**2000**		
Sector	**E_t (Gj)**	**A_t**	**S_t**	**I_t**
Heat	1258970760	59115000	36.3333	0.586155696
Water	165378600	59115000	3.77E+07	7.42414E-08
Total	1424349360	59115000		

Figure E.5 and Figure E.6, present results graphically. Figure E.5 shows the absolute change in energy use for the sector between 1990 and 2000 and the varying influences of activity, structure and intensity change. Figure E.6 shows the percentage contribution of each of the three parameters to overall change.

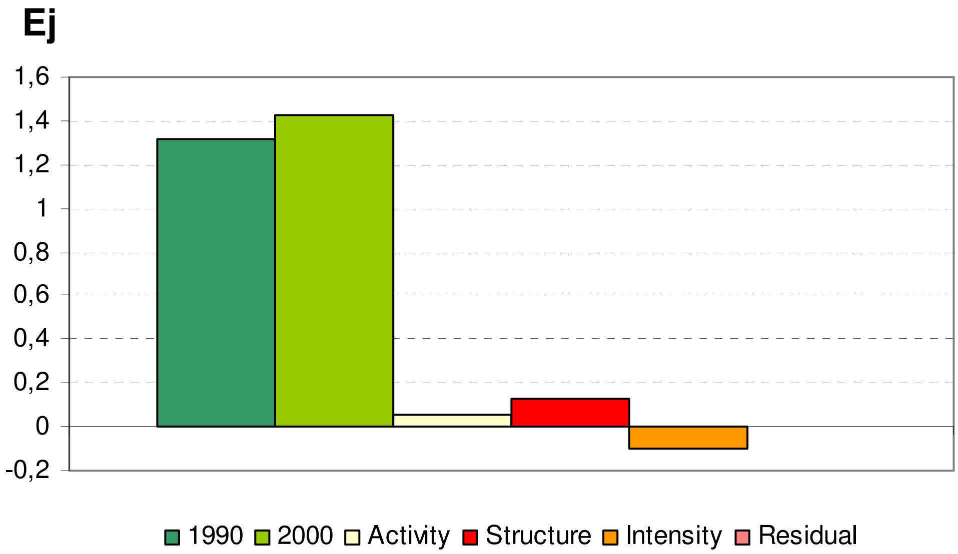

Figure E.5 : Period wise Log Mean Divisia Decomposition of Residential Sector Space and Water Heating for France 1990 - 2000. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

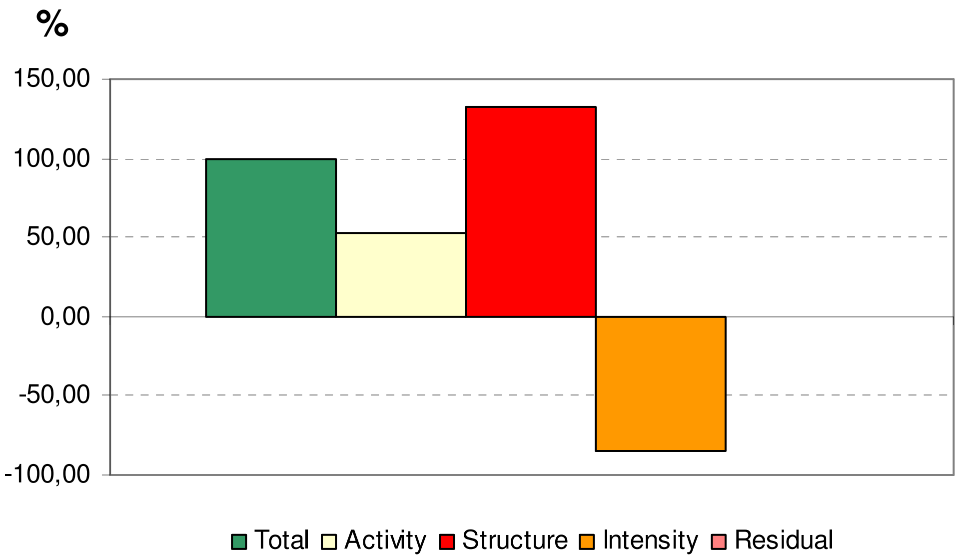

Figure E.6 : Period wise percentage change via Log Mean Divisia Decomposition of Residential Sector Space and Water Heating for France 1990 - 2000. Chart constructed using data from the Odyssee Indicators Database (Enerdata, 2006).

We have thus now shown that it is possible to use LMDI ID for decomposing energy end use in the residential and service sectors.

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Tornqvist, L., Vartia, P., and Vartia, Y. O., (1985). *How should relative changes be measured?* The American Statistician, 39

Torvanger, A., (1991). *Manufacturing sector Carbon Dioxide emissions in nine OECD countries, 1973-87. A Divisia index decomposition to changes in fuel mix, emission* *coefficients, industry structure, energy intensities and international structure*. Energy Economics, July

Appendix F MURE Simulation Tool

MURE is a detailed bottom up energy demand simulation model which holds some promise for undertaking detailed bottom up simulations in buildings for the Pathways Project. Such simulations would be of the combined effects of changes in thermal characteristics and installed energy using apparatus in buildings on energy use in buildings. MURE has separate modules for the industrial, transport, residential and service sectors. Both the residential and service sector modules have a three level hierarchical approach to how to implement measures and view their impact. This appendix describes both modules beginning with the residential sector module.

MURE Residential Sector Module

Level 1 of the residential sector module contains building and appliance stock data. This default data set is from 2000 and has been sourced primarily from the Odyssee database. This dataset can be updated manually.

Level 2 of the residential sector module contains U-values, power loads and fuel requirements for the data set defined in level 1 but in addition to this also contains household and energy growth forecast rates and a set of technical measures and associated costs that can be taken to reduce energy use in the stock. All information in level 2 can be updated manually. Additional user defined measures can be input manually at this level also.

Level 3 of the residential sector module is where a package of energy saving measures is constructed for the entire stock or part thereof of buildings for one country. Measures can be within one or more of the nine areas listed:

- Space heating (insulation interventions)
- Heating control devices
- Limit of the internal heating temperature
- Equipment replacement/maintenance
- Fuel substitution
- New technologies (and renewables)
- Local energy supply (distributed energy generation like PV and cogeneration)
- Sanitary water heating (this set of interventions is not yet implemented in MURE)
- Appliances

Some of the nine intervention areas have many sub choices - which can all be changed at the same time. For details see the next section and the MURE Households Module Tutorial (MURE, 2000). One can change as many of the sub measures within the nine measure categories as desired, then save and simulate all changes, and then look at the overall gain and cost results for this suggested *package of measures*. One cannot choose a different start and end date for each measure or intervention area. Each measure in the package selected must start and finish at the same year respectively. For each measure chosen in each of the nine categories the user must exogenously input the proportion of the building stock that the measure will apply to, the length of time the measure will run for and the temporal rate at which the measure will penetrate in the stock.

Figure F.1 shows the actions that are necessary at each level and lists the exogenous inputs needed. From the figure it is obvious that the first two levels are for scenario set up and the third for assembling a particular package of measures from the portfolio of measures contained in level 2. Thus if one accepts the default data for building stock and technical intervention portfolio in MURE, one only works at the third level where the calculations take place.

Results from a simulation of a selected package of measures are, the gain (this is what MURE calls the energy savings) and associated investment costs. The gain is the reduction in the energy consumption trend that MURE calculates relative to a baseline scenario. The baseline scenario is calculated by MURE taking into consideration the household and electricity consumption growth rates for one country at a time.

MURE Residential Sector Module Intervention areas

This Section details the nine intervention areas possible in Level three of the MURE simulation package.

1 *Space heating (insulation interventions)*

The options in this category are presented as a matrix each for single and multi-family houses. Ground, roof, walls, and windows are across the top axis while old, intermediate and new houses down the side axis. So, for example, one can choose to change the insulation of the ground for all old single-family houses.

For ground insulation there is only one choice listed - extrados beneath the floor. Thus the choice is either no intervention in the floor or extrados. The default situation is no intervention which leaves the floor U-value at 0.88. Choosing extrados lowers the floor U-value to 0.31. Another example would be to change the insulation in the walls of new houses. The choices are to include external insulating plaster, or injection in the cavity walls, or external panels, or internal panels. Each of these four options would have a different price and U-values associated. One can also set one's own measure and associated U-value and cost. To do this however one must leave the matrix and go back to level 2 to set up the measure in the appropriate list.

2 *Heating control devices*

The only choice in this category is to exogenously input the percentage energy savings that would accrue from use of improved or new heating control devices.

3 *Limit of the internal heating temperature*

The choices are to manipulate the average internal temperature, the average working time in hours per day and the average working time in days per year. The average outside temperature is set in level 2 of MURE.

4 *Equipment replacement/maintenance*

The options are to replace or maintain the boilers be they solid fuel, oil or gas boilers. There are no specifications as to the type of equipment to change to; just the facility to input estimated general percentage energy reduction improvements due to replacement or maintenance.

5 *Fuel substitution*

The options are to swap between the solid fuel, oil, gas and electric heating systems.

6 *New technologies (and renewables)*

The options are to substitute any of the solid fuel, oil, gas or electric heating systems with any of the following options listed:

- District Heating
- Heat Pumps
- Electric Night Storage
- Solar and heat pumps
- Solar and non renewable Schemes
- Biomass

The efficiency of the new equipment is set in level 2. Additional technologies can be included.

7 Local energy supply (distributed energy generation like PV and cogeneration)

The options are to introduce one of the following on a sectoral level and to state the penetration in the stock:

- PHV
- Fuel Cells
- CHP

Default values for the efficiencies and costs of a range of the above types of measures can be set in level 2.

8 Sanitary water heating

Not working in MURE but probably replaces gas or electric schemes as with new technologies above.

9 Appliances

For one or more of the following nine electrical appliances, one selects the appliance and then MURE calculates the quantity of the appliance stock that was replaced by BAT and the subsequent energy savings that accrued. The BAT is set in level 2 of MURE.

- Refrigerators
- Freezers
- Washing Machines
- Dishwashers
- Clothes Dryers
- Cookers
- Televisions
- Kettles
- Lighting

LEVEL 1

- Dwelling data for stock, type, age & fuel consumption mix.
- Appliance data for stock & average fuel consumption.

LEVEL 2

- Dwelling, electricity use and Primary fuel supply growth forecast set – (Energy Demand Trend)
- U Values for dwelling stock.
- Appliance BAT and growth forecast.
- Costs.
- Heating systems & internal temperature.

LEVEL 3 Start year Target year		**Unit Consumption & cost year 0**	**Unit Consumption & cost year t**	**% Stock Involved**	**Penetration Rate**	**Total Gain & Cost**
1. Space Heating (insulation)	Ground	**Set in level 2**	**Calculated By MURE**	**?**	**?**	**Toe & €**
	Roof					
	Walls					
	Windows					
2. Heating Control Devices	Improved	**Set in level 2**	**Calculated By MURE**	**?**	**?**	
	New					
3. Limit internal Temp/ Heating Period	**...**	**Set in level 2**	**Calculated By MURE**	**?**	**?**	
4 – 9 ...	**...**	**...**	**...**	**...**	**...**	

Figure F.1 : MURE three level Residential Sector policy scenario model for one country.

Gain Calculations:
Improved insulation: Based on ratio between new U – Values & old U – Values (Faberi & Eichhammer, 2005).

Improved Appliances: Based on findings or E Grids project (Faberi & Eichhammer, 2005).

MURE Service Sector Module

MURE has a somewhat different approach for measures in the service sector. Again there are three levels although the second level is not involved in the forecast simulation.

Level 1 of the service sector module is where energy fuel balances and technology/intervention measure improvement potentials are set.

Level 3 of the service sector module is for assembling a package of measures and calculating its effect on end – use of energy. There is no limit to the number of sub measures that can be included in a package although each package can only apply to one branch. Thus scenarios/ packages of measures are assembled and run on a per branch basis.

For each of the following branches, for EU 15:

- Commercial Offices
- Distribution & Warehousing
- Education
- Government Offices
- Health
- Hotel & Catering
- Other Sectors
- Public Buildings
- Retail
- Sport & Leisure

MURE allows one to state what gain is possible from improvements in any of the following process efficiencies:

Electrical Measures:

- Lighting:
    - Auto - manual control
    - High n lamps
    - Time control
    - Zoning control

- Motor Drives:
    - High rpm motors
    - Variable speed drives

- Office Machinery:
    - Auto - manual control

- Refrigeration:
    - Cooling load analysis
    - Floating pressure head control
    - Insulation
    - Maintenance issues
    - Optimum delta T
    - Scheduling

- Space Heating / Domestic hot water heating
    - Auto - manual control

  - Insulation

Thermal Measures:

- Space Heating /Domestic hot water Heating
  - Auto - Manual control
  - Insulation

No user defined measures can be pre-defined in level 1. For the default measures listed, one either accepts or manipulates the default values given for penetration percentages in the building stock of the particular branch under study, and the percentage of energy savings that this would lead to. Thus there is no work with U-values, types of equipment efficiencies, fuel substitution etc. In fact insulation is considered to be a process like the rest of the measures for which the default savings and penetration percentages must be accepted or redefined.

Figure F.2 outlines the MURE hierarchical approach for the service sector. Again the timeframe of the package must be input exogenously and the simulations run on a country by country basis. Level 1 is for scenario set up and the third for assembling a particular package of measures from the portfolio of measures contained in level 2.

Results from a simulation of the selected package of measures are the gain (this is what MURE calls the energy savings) and associated investment costs. The gain is the reduction in the energy consumption trend that MURE calculates relative to a baseline although for the service sector module it is not obvious how this gain is calculated.

LEVEL 1

- Branch data for fuel mix, number employees and value added.
- End use process data of penetration and savings potential by process improvement.

LEVEL 2

- List of branches, energy service needs and technologies used.

Branch	LEVEL 3	End Use	Measure	% Savings by process improvement	% Penetration in Stock	Energy Savings
Commercial offices ...	Electric	Lighting ...	Auto - Manual control	Set by MURE	Set by MURE	KToe
			High n lamps			
			Time Control			
			Zoning Control			
	Thermal	Space Heating - Warm water ...	Auto - Manual control			
			Insulation			

Figure F.2 : MURE three level Service Sector policy scenario model for one country.

Exogenous or Endogenous inputs:

- % Savings by process improvement
- % Penetration in Stock

General Methodology:

- User chooses package of measures related to energy end-uses.
- MURE calculates energy savings accruing.

References to Appendix F:

Faberi. F., and Eichhammer, W., (2005). Evaluation of Policies and Measures in the Residential Sector of the EU-15 in Odyssee, Energy Efficiency Monitoring in the EU 15

MURE, (2000). MURE Households Module Tutorial - http://www.isis-it.com/mure/download.htm

Appendix G Related Papers

This appendix lists publications which have not been read at the time of publication of this report but which would further contribute to the knowledge as part of further work.

Energy use in buildings

Buildings and climate change - Status, Challenges and Opportunities. UNEP, 2007

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Retrofitting of social housing, 12 innovative projects for an energy-intelligent Europe, IEE

Empirical assessment of the Hellenic non-Residential building stock, energy consumption, emissions and potential energy savings, Gaglia et al, Energy Conversion & Management, 2007

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The efficiency of energy use in the USSR - an international perspective, Caron & Schipper. Energy, 1991

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Rapport till energimyndigheten 2006-06-15. Profu

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Electricity use in buildings

Cool appliances, Policy Strategies for Energy Efficient Homes, IEA, 2003

Implementing Agreement on Demand Side Management Technologies and Programmes, INDEEP. IEA, 2004

Demand-side management. End-use metering campaign in 400 households of the European Community Assessment of the Potential Electricity Savings. Eureco, 2007

Demand-Side Management: Experimental Study of highly efficient Electrical Appliances in Household Use. Ecodrome 1998

Electricity demand management. An experimental investigation of cooking appliances, domestic cold appliances and clothes dryers in 100 households. Ecuel, 1999

Changes in Electricity Demand in the United States from the 1970s to 2003. Marvin J. Horowitz. The Energy Journal, Vol. 28, No. 3

Energy Policy

Energy Efficiency Policies and Measures in Ireland SEI, 2006

Directive of the European parliament and of the council on the energy performance of buildings. 2001

Green paper on energy efficiency or doing more with less. EU, 2005

Taking the lead. Post 2012 climate targets for the north. Wuppertal, 2005

Environmental taxes in the European economy 1995-2003, Eurostat, 2006

UNFCCC country reports

Index decomposition

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Appendix H Data Estimation

This appendix provides two examples of how estimation can be used to provide data which is otherwise unavailable. It then discusses availability of data on building and appliance regulations. Such regulations data is useful for estimating building U-values and appliance standards of equipment stock in place.

Heating Systems

For both the residential and service sector, quantities of a particular heating system installed is a function of three variables; fuel used, central heating diffusion and amount of district heating.

Taking the proportions of various fuels that make up total fuel use for the residential sector as per Eurostat energy balances we can speculate that the amounts of particular fuels used reflect the proportion of dwellings using that fuel in their heating systems. We must however use the proportions of useful energy provided by each fuel given that, for example, if equal amounts of fuel and natural gas are used this reflects there being more natural gas boilers given gas's greater efficiency. Our findings will only be approximations however, given that:

- Some of the natural gas in the fuel balances is certainly used for cooking.
- Although some of the electricity use listed in the fuel balances is for "dry system" storage heating and heat pumps, most of it is obviously for appliances and lighting.
- Regarding the correlation between the figures given by the IEA for heat and district heating, the IEA Energy Statistics Division states in private communication to the author (IEA, 2007), "Regarding heat consumed in the Residential Sector, it refers to heat sold (when reported) which for the most part should be from district heating, but it can also include direct use. Please note that in a number of countries, the heat sold is reported under the "non-specified" category, as they cannot always provide the breakdown of consumption." The same thing would be true for Odyssee and Eurostat heat data.

Despite this we can still attempt to approximate the amount of houses using a solid, gas, oil or renewable fired heating device to warm their house and perhaps suggest that most of the rest are heated by electricity.

Table H.1 lists the percentage proportions of various fuels used in three sample countries based on Eurostat energy balances. These proportions are fractions of the fuel data figures presented in Table 1.66 for each respective country.

Table H.1: Proportions of total fuel used for Residential Sector for three EU countries (Eurostat, 2007).

Eurostat/ 2004/ %	% Solid Fuel	% Oil	% Gas	% Renewables	% Other
Germany	.75	23	37	6	33
Greece	0.055	57	.65	13	30
UK	2	7	68	.5	22.5

Now however we must resize these fuel contributions based on the useful energy they embody. We use the conversion factors listed in Table H.2 (Euro Heat & Power, 2006):

Table H.2 : General conversion efficiencies for building heating equipment fuels (Euro Heat & Power, 2006).

Ecoheatcool/ 2005/ %	% Solid Fuel	% Oil	% Gas	% Renewables	% Other
Res/Services Sector	64	78	85	64	100

We also divide the "other" category between heat and electricity based on the same Eurostat statistics and thus produce the proportions listed in Table H.3.

Table H.3 : Proportions of heating systems in stock derived from amounts of various types of fuels used in Residential Sector in three EU countries.

Eurostat/ 2004/ %	% Solid Fuel	% Oil	% Gas	% Renewables	% Heat	% Electricity
Germany	0.7	20.1	36.0	4.7	20.5	18.0
Greece	0.0	53.6	0.7	11.7	1.0	32.9
UK	1.8	6.0	69.2	0.4	1.0	21.7

According to this approach 36 % of German and 69 % of UK dwellings use gas fired central heating. The accuracy of this table cannot be relied upon however, as the energy used for appliances and lighting is included in the electricity category, and so distorts our attempt to use the fuel used data category as a proxy for type of heating system installed.

Odyssee provides a data category for total electricity use for appliances and lighting for the Residential Sector. If we subtract this figure from the Eurostat balances for energy use and then re-examine the remaining proportions of fuels used we obtain the data presented in Table H.4. Our calculations show gas central heating to account for 82.7 % of heating in UK dwellings. Anecdotally this sounds correct. (Schipper et al, 2001) state that over 80 % of UK homes are heated by gas. The figure of 22.5 % for heat listed for Germany is higher however nearly twice as high as the estimated coverage of district heating there (Euro Heat & Power, 2005). This point warrants further investigation.

Applying this data to our data for Odyssee permanently occupied stock (Table 1.20) gives the amounts of heating systems installed in thousands in each of our sample countries as outlined in Table H.5.

Table H.4 : Proportions of heating systems in Residential Sector stock derived from amounts of various types of fuels used in Residential Sector (minus electricity use for appliances and lighting) in three EU countries.

Eurostat/ 2004/ %	Solid Fuel	Oil	Gas	Renewables	Heat	Electricity
Germany	0.7	22.5	40.3	5.3	22.9	8.2
Greece	0.1	66.7	0.8	14.6	1.2	16.6
UK	2.1	7.1	82.7	0.5	1.2	6.5

Table H.5 : Estimated numbers dwellings in thousands heated by each fuel type for Residential Sector in three EU countries. Results infer amount of houses heated by each fuel type.

2004 / '000	Odyssee PO*	Solid Fuel	Oil	Gas	Renewables	Heat	Electricity
Germany	35910	251	8080	14472	1903	8223	2945
Greece	3731	4	2529	30	554	46	629
UK	24595	517	1746	20340	123	295	1599

** = Permanently Occupied dwellings*

We still do not have a clear picture, however, of questions such as how the gas fired heating devices are divided between condensing and non condensing boilers. The same problem applies to renewables in terms of what types of renewables are in question. As such additional sources of information which focus on heating equipment are required to complete data for heating devices especially if we are concerned with the proportion of "old technology" boilers in the dwelling stock. The Odyssee "electricity use for appliances and light" data category, which is essential for calculating the above estimation of types of heating systems in place, is available for EU 15 except Belgium and Ireland although only for Lithuania, Norway and Slovenia of the NMC.

Our above calculations have also not distinguished between houses that have central heating and those without. We could speculate however that the proportion of dwellings we calculated as using solid fuel, which only amount to a few hundred thousand houses in each country, are those without central heating. They may also be additional numbers of dwellings using renewables for individual room heating. Odyssee provides the following relevant data:

- Stock of permanently occupied dwellings with Group heating (GH)
- Stock of permanently occupied dwellings with Individual Central Heating (ICH)
- Stock of permanently occupied dwellings with Room Heating (RH)

The data available in the latter two categories is only consistently available for eleven of the EU 15 countries and for Hungary of the NMC 10. Table H.6 presents data for the three ample EU 15 countries. In no case does the number of dwellings we calculated to be burning solid fuels plus the amount using renewables (see Table H.5) add up to the numbers presented in Table H.6 for room heating. Thus the usefulness of the data in Table H.6 is unclear and the accuracy of Table I.5 questionable.

Table H.6 : Stock of dwellings for three EU countries with collective, central or room heating (Odyssee, 2006).

Odyssee/2004/'000	PO	GH	ICH	RH
Germany	35910	29446	2873	3591
Greece	3731	1642	821	1268
UK	24595	0	22628	1967

PO = Permanently Occupied Dwellings

For Greece, for example we calculate 558000 dwellings using solid fuel plus renewable fuels for heating versus 1268000 dwellings using room heating and for the UK we calculate 640000 dwellings using solid fuel and renewables for heating versus 1967000 using room heating. We can ask if it is possible that large numbers of the dwellings without central heating use primitive "plug in" electric heaters or "gas bottle" heaters for room heating and thus make up the difference. Regardless, we have no correlation between the amounts of houses listed as being without central heating and those we calculated as burning solid and renewable fuel.

There is correlation between the numbers of dwellings calculated to be using oil and gas fuels with those listed as having individual central heating but only for the UK. We calculate the UK to have 22086000 dwellings with gas and oil and it has 22626000 houses listed as having central heating which indicates that our approach to estimating the number of heating devices has in this case been correct or maybe by pure chance? Things are not so clear for Greece or Germany given the number of dwellings which are heated by collective heating systems there. Overall I suggest that Table H.4 and Table H.5 do provide some approximation of type of heating system installed but the stated limitations must be borne in mind.

Paramaterising BAT Buildings

Section 1.1.1 outlined the following types of dwellings as being of interest to our report:

- Single-family Dwelling
- Two Family Dwelling
- Terraced Dwelling
- Multi-family Dwelling low rise
- Multi-family Dwelling high rise
- Holiday

We were further interested in the ages of the buildings and their U Values for each category. Data limitations however mean that we cannot achieve this level of disaggregated data for the stock. An alternative approach is to parameterise one or two dwelling types which represent the stock as a whole. The EP Label Project (EP Label, 2006) attempts this. They build a benchmark building by constructing a model building from the bottom up. All energy using apparatus and insulation is BAT. They then estimate the average amount of energy used by the BAT building for a year by multiplying process efficiencies for heating, lighting and appliances by average usage times. Figure H.1 exemplifies. They also parameterise a median and low standard energy performance building model with the same bottom up approach. The idea is to then to compare these three model dwellings with known data for building end – use consumption to calibrate the models with actual known usage patterns and thus to have a couple of parameterised buildings which represent the stock as a whole and one that represents the best case scenario (BCS) for improvements in building energy performance. This approach is of course very dependent on relevant data on BAT and energy use patterns being available. Anecdotally however the EP Label project managed to collect a sufficient amount of data to do this for only one country, the UK.

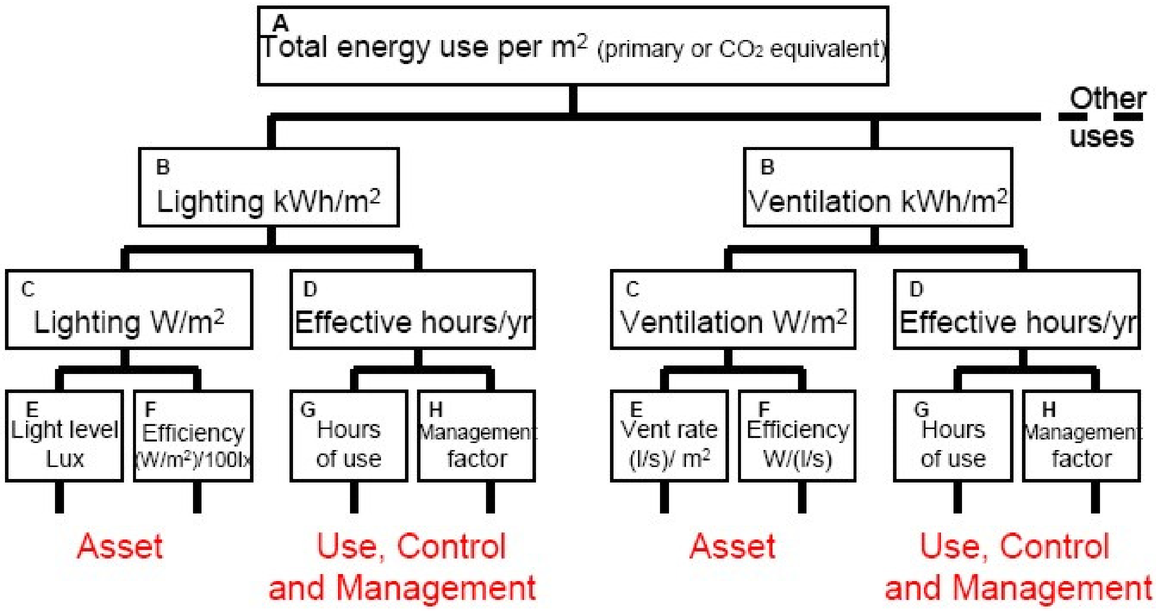

Figure H.1 : The tree diagram description of a building's annual energy use. Chart taken from EP Label (2006).

Johnston et al (2005) attempted another version of the parameterised building which is not so data dependent. They model two dwelling types. One as an average of pre 1996 building thermal regulations and another as a post 1996 equivalent. The first is representative of the pre 1996 stock of dwellings and the other the post 1996. They state that the impact of dwelling type on energy use is small in comparison with the impact of thermal characteristics of the building fabric and system efficiencies. Therefore, they continue, what is important in the long-term is the average performance of a wall, a roof, a space heating system and a lighting system rather than the individual differences in geometry, thermal performance and energy use of the various individual dwelling types.

For the purposes of the pathway project it is certainly one option with respect to building stock that is worth exploring.

Relevant Building Regulations

As stated in Section 1.2 MURE has an online database of existing national and EU policies applying to building thermal and appliance regulations for EU 27 plus Norway excluding

Romania. The MURE simulation tool also has a similar database but only for EU 15. This simulation tool database does not however seem to have been updated since 2000. Figure H.2 shows how the MURE online database presents policy information for a sample EU policy. A detailed description of policies presented is also downloadable for each of those listed online. The simulation tool presents data in a similar manner however also includes a diagram of the stakeholders and technologies the policy impacts upon. Key information presented in the policy descriptions of relevance for a building energy analysis is:

- Policy start and finish date and technologies affected.
- Minimum building thermal conductivity standards
- Minimum standards for appliances

Measure Code	EU23
Country	European Union
Title	Public Awareness Campaign for an Energy Sustainable Europe
Reference	Campaign for Take Off, 1999-2003 Sharing Skills and Achievements. June 2004
Status	Ongoing
Issuing Date	6/2003
Starting Date	8/2004
Ending Year	2006
Qualitative Impact	High
European Measure	No
Impact Evaluation	No
Subsector	
Types	37) Information/Education - Information campaigns (by energy agencies, energy suppliers etc)
Technologies	Appliances, Fuel substitution, Future stock : insulation and other tec., Heating control devices, New technologies
Actors	associations, central government, energy agencies, financial institutions, industries, local government, utilities
Target Audience	general public, researchers
Applications	collective, individual, public
Keywords	Demand Side Management, Pilot/Demonstration Project, Subsidy for research, Training/teaching materials

Figure H.2 : Example of a national energy policy description from MURE online database. (MURE, 2007).

The MURE database case study entitled "A Comparison of building thermal regulations in the European Union" (Eichhammer & Schlomann, 1998) includes latest regulation U-value limits for EU 15.

EPA – ED provides policy descriptions as outlined in Figure H.3 for Austria. These are useful, however, are only available for four countries. The Energy Charter Peerea country reports provide a general synopsis of types of regulations in place and government targets for reductions in energy use and emissions.

Overall the MURE regulations online database is the most comprehensive available. It is in fact dedicated to this task and as such we can assume it offers the most comprehensive relevant policy collection.

The Energy Charter Peerea country reports are useful for information on regulations in non-EU countries.

Existing policies regarding reduction of energy use in existing dwellings

List the **most relevant** policies that exist in your country that stimulate the reduction of energy use in existing dwellings, like financial (e.g. subsidies or tax-reductions) or communicational (e.g. promotional activities) instruments.

Code	Full name of Energy Policy Mechanism	Year of first version	Organisation responsible for mechanism	Short description of mechanism	References
A-P1	Vereinbarung zwischen dem Bund und den Ländern gemäß Art. 15aB-VG über die Einsparung von Energie (Agreement between the federal government and the provinces according to Art. 15a constitutional law about the saving of energy)	1995	Bund-Bundesländer-kooperation	In Austria, the provinces have a strong position when it comes to enacting laws. They are in charge of the building sector, and this is why there are different regulations in Austria that target at buildings, energy efficiency and renewable energy. To make sure that the provinces co-ordinate themselves, there is the instrument of "agreement between the federal government and the provinces". To deal with energy, the agreement about "the saving of energy" was implemented.	Website: http://www.ris.bka.gv.at
A-P2	Althaussanierungsförderung der Wohnbauförderung (subsidy for energy saving renovation) Different versions in the 9 Austrian provinces. Subsidy regulations focus on reduction of transmission losses, efficiency of heating installations (hot water and space heating), choice of energy carrier, choice of building material for renovation.	Different versions in 9 provinces	One institute per province, associated with the state government, in many cases energy agencies	Financial instrument that stimulates private housing owners and housing companies to improve the energy efficiency of their house. Subsidised measures include improvement of the envelope of the house, application of active solar. The application of high efficient domestic equipment is subsidised for both new and existing new dwellings. In Austria there are a lot of programmes aiming at improving energy efficiency by granting subsidies for suitable measures in renovation and new construction. They have usually been designed as a contribution towards investment costs or as a loan with subsidised reduced interest rates. In 1997 the subsidies granted in the context with the construction of new buildings amounted to 1.88 billion € in total, although not all of this amount related to energy efficiency. But in many cases the extent of the financial support depended upon the extent to which certain efficiency criteria were met. Incidentally, subsidies granted in for refurbishments in the housing sector amounted to 0.55 billion € in 1997. Roughly 1/6 of that amount referred to energy relevant investment.	Website: http://www.eva.wsr.ac.at/ (Austrian Energy Agency, gives an overview about all subsidies of the provinces) Energy Efficiency and CO_2 Emissions in Austria. Report published by E.V.A., the Austrian Energy Agency. Project manager and author: Robert Freund. Vienna, March 2002
A-P3	Forschungsprogramm "Nachhaltig Wirtschaften", Subprogramm "Haus der Zukunft" (The Austrian Program of Technologies for Sustainable Development, Subprogram "Building of Tomorrow")	1999	Federal Ministry for Transport, Innovation and Technology	The Austrian Program on Technologies for Sustainable Development is a five-year research and technology program. It has been developed by the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT). It initiates and supports trend setting research and development projects and the implementation of exemplary pilot projects. Subprogram "Building of Tomorrow": The "Building of Tomorrow" makes use of the two most important developments in solar and energy efficient building: the passive house and the low energy solar building method. For the purposes of the "Building of Tomorrow" subprogram, these energy centred innovations are expanded to take	Website: http://www.hausderzukunft.at

Figure H.3 : Example of a national energy policy description from EPA – ED (National Observatory of Athens, 2003).

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National Observatory of Athens, (2003). EPA – ED