COMPUTER MANUAL SERIES No. 18

Model for Analysis of Energy Demand (MAED-2)

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Model for Analysis of Energy Demand (MAED-2)

User's Manual

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FOREWORD

The IAEA has been supporting its Member States in the area of energy planning for sustainable development. Development and dissemination of appropriate methodologies and their computer codes are important parts of this support. This manual has been produced to facilitate the use of the MAED model: Model for Analysis of Energy Demand.

The methodology of the MAED model was originally developed by. B. Chateau and B. Lapillonne of the Institute Economique et Juridique de l 'Energie (IEJE) of the University of Grenoble, France, and was presented as the MEDEE model. Since then the MEDEE model has been developed and adopted to be appropriate for modelling of various energy demand system. One such example is development of MEDEE-2 by B. Lapillonne for the needs of the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

The IAEA adopted MEDEE-2 model and incorporated important modifications to make it more suitable for application in the developing countries, and it was named as the MAED model. The first version of the MAED model was designed for the DOS based system, which was later on converted for the Windows system.

This manual presents the latest version of the MAED model. The most prominent feature of this version is its flexibility for representing structure of energy consumption. The model now allows country-specific representations of energy consumption patterns using the MAED methodology. The user can now disaggregate energy consumption according to the needs and/or data availability in her/his country. As such, MAED has now become a powerful tool for modelling widely diverse energy consumption patterns. This manual presents the model in details and provides guidelines for its application.

The IAEA officer responsible for this publication is Ahmed Irej Jalal of the Department of Nuclear Energy

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1 INTRODUCTION

1.1 Background information

The International Atomic Energy Agency (IAEA) has been assisting its Member States in the conduct of energy and electricity planning studies. The principal objectives of such studies are, in general, the evaluation of alternative paths/strategies for the development of energy and electricity sector to meet the future demand for energy and electricity in a given country (or a world region), and, in particular, an estimation of the role that nuclear power may play in meeting this demand. For this purpose, the IAEA has developed a set of energy models that provide a systematic framework for analyzing various issues covering social, economic, technical and environmental aspects of energy decisions. Among these models, the WASP computer program (Wien Automatic System Planning package) and a related methodology was the first model developed and introduced by the IAEA [1–6]. The WASP program is designed to find the economically optimal generation expansion policy for an electric power system within certain constraints specified by the user. Though extensively used, WASP handles only a part of the full spectrum of the analyses required for any meaningful energy studies. The other models in the IAEA's set of tools are: Model for Analysis of Energy Demand (MAED), Energy and Power Evaluation Program (ENPEP), Model for Energy Supply Systems and their General Environmental impacts (MESSAGE), Model for Financial Analysis of Electric Sector Expansion Plans (FINPLAN), and Simplified Approach for Estimating Impacts of Electricity Generation (SIMPACTS). This manual describes the MAED model.

The general approach to the MAED methodology was originally developed by Messrs. B. Chateau and B. Lapillonne (MEDEE: Modèle d'Evolution de la Demande d'Energie, Ref. 7) of the Institut Economique et Juridique de l'Energie (IEJE) of the University of Grenoble, France. In fact, MAED is closely related to a simplified version of this methodology, known as MEDEE-2 [8, 9], which was adapted by B. Lapillonne to the needs of the International Institute for Applied Systems Analysis (IIASA, Laxenburg, Austria) for carrying out studies on global energy assessment. While respecting the general structure of MEDEE-2, important modifications were introduced in MAED by the IAEA. They concern: the parameters required to be specified as input data; the equations used for calculating energy demand of some sectors; and the printed output produced by the programs.

More important, MAED includes some additional modules which may be used to convert first, the total annual electricity demand into the hourly electricity consumption expressed in terms of the load imposed on the electric power generating system in each hour of the year, and then into the so-called load duration curve of the power system, which is only a convenient representation of the load for the purpose of analyzing the expansion of the system. The additional modules above-mentioned have been developed based on well established methodologies and computer programs. In this respect, the module which calculates the hourly electric loads is based on a methodology developed by the Electricité de France (EDF), and the module used for calculating the load duration curves is based on a program (DURAT) which was originally developed for the UN-Economic Commission for Latin America (ECLA).

The first version of MAED model was developed for DOS based systems, and was distributed to over 40 countries [12]. In recent years majority of the users have shifted to Windows based PCs and are more conversant with Windows based applications. As such, the MAED software has been converted to EXCEL application. The EXCEL version not only permits working in a familiar and convenient environment but also make the model formulation completely transparent.

The earlier versions of the MAED model, both DOS and EXECL, were built on a pre-defined structure for the economic sectors as well as for the end-use energy consumption activities. There were six economic sectors, viz. Agriculture, Construction, Mining, Manufacturing, Service and Energy, for which energy demand was calculated rather at an aggregated level. The Manufacturing sector, however, was further sub-divided into four sub-sectors. Energy demand for Transport sector was disaggregated into passenger and freight categories but the transportation modes and fuel used by each mode were limited and predefined. There was a possibility for representing various types of households but they were all grouped at the country/region level. The Service sector was also represented at an aggregate level.

This predefined structure posed difficulties in modelling of energy consumption patterns in many developing countries. For example, the Agriculture sector comprises of combination of various types of economic activities such as cropping, livestock forming, fishing and forestry. Each of these sub-sectors has different energy consumption pattern and energy intensities. Using an average of diverse energy intensities to compute energy demand of the Agriculture sector was a problem for many developing countries. Similarly, energy consumption pattern and intensities in households vary across regions with in a developing country. Computation of energy demand for households by aggregating them at regions was also a problem.

In view of these difficulties, a new version of MAED has been developed that allows the user to expand the pre-defined energy demand structure according to the needs and/or data availability. This new version presents a flexible framework to disaggregate energy demand in each of the six economic sectors. Furthermore, the energy demand in the Households sector can now be further disaggregated into Rural and Urban groups and various end-use categories in each group of households. The Service sector has some additional end-use categories, while additional modes and fuels have been added for the Transport sector. In the new flexible framework, the users:

- can define up to ten sub-sectors in each of major sectors of the economy i.e from the Agriculture sector to the Service sector mentioned above,

- can define up to fifteen modes of transportation for each of the predefined intercity and Urban (intracity) passenger transportation and freight transportation,

- can specify up to eight fuels and assign them to each transportation mode as appropriate,

- can define up to ten types of dwellings in each of the two groups of Households i.e. Rural and Urban.

The model computes energy demand at the sub-sector level and activity level.

The principal objective of this manual is to document the technical aspects of the MAED model and the important assumptions behind the proposed modelling framework. This will help the users to understand the results of the model and to realize the limitations of the analysis carried out using these results. In addition, the Manual provides guidelines for developing a country/region specific model structure, and for using the model for projecting future energy needs.

1.2 Brief description of MAED model

MAED model evaluates future energy demand based on medium- to long-term scenarios of socio-economic, technological and demographic developments. The model relates systematically the specific energy demand for producing various goods and services identified in the model, to the corresponding social, economic and technological factors that affect this demand. Energy demand is disaggregated into a large number of end-use categories; each one corresponding to a given service or to the production of a certain good. The nature and level of the demand for goods and services are a function of several determining factors, including population growth, number of inhabitants per dwelling, number of electrical appliances used in households, peoples' mobility and preferences for transportation modes, national priorities for the development of certain industries or economic sectors, the evolution of the efficiency of certain types of equipment, market penetration of new technologies or energy forms etc. The expected future trends for these determining factors, which constitute "scenarios", are exogenously introduced.

An understanding of these determining factors permits the evaluation of the various categories of energy demand for each economic sector considered. The total energy demand for each end-use category is aggregated into four main "energy consumer" sectors: Industry (including Agriculture, Construction, Mining and Manufacturing), Transportation, Service and Household. The model provides a systematic accounting framework for evaluating the effect on energy demand of a change in economics or in the standard of living of the population.

The starting point for using the MAED model is construction of base year energy consumption patterns within the model. This requires compiling and reconciling necessary data from different sources, deriving and calculating various input parameters and adjusting them to establish a base year energy balance. This helps to calibrate the model to the specific situation of the country.

The next step is developing future scenarios, specific to a country's situation and objectives. The scenarios can be sub-divided into two sub-scenarios:

- one related to the socio-economic system describing the fundamental characteristics of the social and economic evolution of the country;

- the second related to the technological factors affecting the calculation of energy demand, for example, the efficiency and market penetration potential of each alternative energy form.

The key to plausible and useful scenarios is internal consistency of assumptions, especially for social, economic and technological evolution. A good understanding of the dynamic interplay among various driving forces or determining factors is necessary. The model output, i.e. future energy demand, is just a reflection of these scenario assumptions. The evaluation of output and the modification of initial assumptions is the basic process by which reasonable results are derived.

The model focuses exclusively on energy demand, and even more specifically on demand for specified energy services. When various energy forms, i.e. electricity, fossil fuels, etc., are competing for a given end-use category of energy demand, this demand is calculated first in terms of useful energy and then converted into final energy, taking into account market penetration and the efficiency of each alternative energy source, both specified as scenario parameters. Non-substitutable energy uses such as motor fuels for cars, electricity for specific uses (electrolysis, lighting etc.) are calculated directly in terms of final energy.

Demand for fossil fuels is therefore not broken down in terms of coal, gas or oil, because this energy supply mix largely depends on the technological possibilities of supply and relative prices of these fuels, aspects that are outside the scope of the MAED analysis. The substitution of fossil fuels by alternative “new” energy forms (i.e., solar, district heat etc.) is nevertheless estimated, due to the importance of the structural changes in energy demand that these energy forms may introduce in the future. Since these substitutions will be essentially determined by policy decisions, they are to be taken into account at the stage of formulating and writing the scenarios of development.

Special attention is given to the calculation of electricity demand, which is performed not only annually as for all other energy forms, but also on an hourly basis. These calculations in turn, can serve as input data for further analysis of the generating system using the WASP model. These calculations specifically determine the electric load imposed on the generating system, which will then permit WASP to select suitable generation technologies that match the variation in demand within a year or season.

The hourly load calculations are performed using various “modulation coefficients” which correlate changes in hourly electricity consumption with respect to average consumption. In determining hourly, daily and weekly electric load from the total annual electricity demand of the sector, the model takes into account:

(a) The trend of the average annual growth rate of electricity demand;

(b) The seasonal changes in electricity consumption (this variation may be reflected on a monthly or weekly basis, depending on available information);

(c) The changes in electricity consumption owing to the type of day being considered (i.e. working days, weekends, special holidays etc.);

(d) The hourly variation in electricity consumption during the given type of day considered.

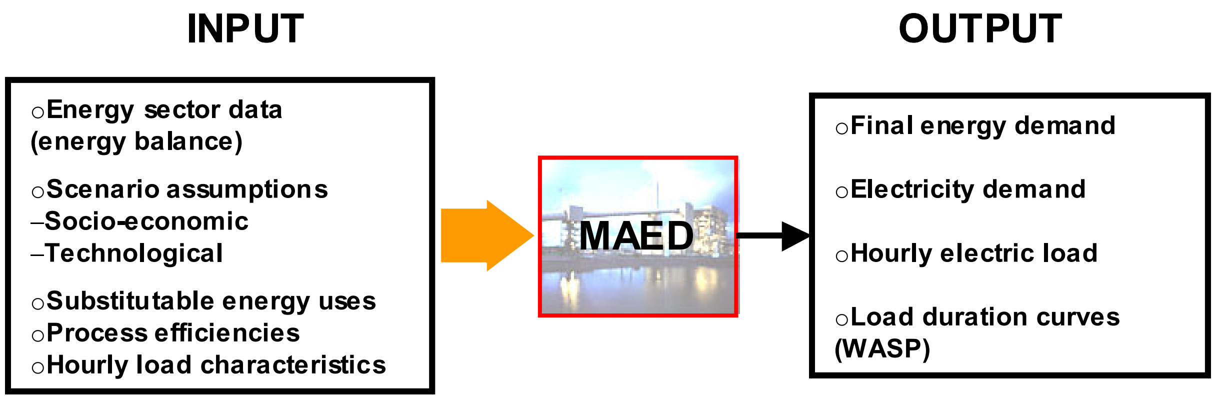

Figure 1.1. Main inputs and outputs of MAED.

1.3 Organization of MAED model

The MAED model software is provided in two EXCEL Workbooks (files): MAED_D and MAED_EL. The MAED_D workbook contains several EXCEL worksheets devoted to various sectors, sub-sectors and end-use activities included in the model. These worksheets also serve for inputting data and viewing results. This workbook is Module 1 (Energy Demand Calculations) of the MAED model. It processes information describing the social, economic and technological scenario of development and calculates the total energy demand for the desired years. The breakdown of this demand by energy form and by economic sector considered is also provided as part of the results of the analysis.

The 2nd workbook (MAED_EL) is Module 2 (Hourly Electric Power Demand) of the MAED model. It uses the total annual demand of electricity for each sector (calculated in MAED_D) to determine the total electric power demand for each hour of the year or, in other words, the hourly electric load, which is imposed on the power system under consideration. This workbook also contains several worksheets meant to provide additional input data, executing the module and viewing the results. Both worksheets have several Microsoft Visual Basic macros for performing certain functions, explained in the subsequent chapters, and executing the computations.

2 GENERAL DESCRIPTION OF MAED MODULE 1

ENERGY DEMAND ANALYSIS

2.1 Introduction

The Module 1 of MAED model (MAED_D) is a simulation model designed for evaluating the energy demand of a country or world region in the medium and long term. It belongs to the family of MEDEE models, which are based on the scenario approach. In the MAED/MEDEE approach a "scenario" is viewed as a consistent description of a possible long-term development pattern of a country, characterized mainly in terms of long-term direction of governmental socioeconomic policy. Following this approach, the planner can make assumptions about the possible evolution of the social, economic, and technological development pattern of a country that can be anticipated over the long term from current trends and governmental objectives. The consistency of the scenario is a very important consideration of the methodology in order to guarantee attainment of sound results. Such consistency is to be exercised by the planner while formulating possible scenarios of development.

In summary the MAED_D methodology comprises the following sequence of operations:

(1) disaggregation of the total energy demand of the country or region into a large number of end-use categories in a coherent manner;

(2) identification of the social, economic and technological parameters which affect each end-use category of the energy demand;

(3) establishing in mathematical terms the relationships which relate energy demand and the factors affecting this demand;

(4) developing (consistent) scenarios of social, economic and technological development for the given country;

(5) evaluation of the energy demand resulting from each scenario; and finally

(6) selection among all possible scenarios proposed, the "most probable" patterns of development for the country.

It should be noted that in the model, energy demand of the ultimate consumers is (as long as it is possible) always calculated in terms of the service performed ("useful" energy) as opposed to in terms of the amount of energy supplied ("final" energy). This differentiation between energy demand expressed in terms of useful and final energy permits a better study of the substitution between alternative energy forms, as well as an appraisal of the evolution of the technological improvements in the equipment and appliances used by the ultimate consumers.

Objectives of the methodology

The MAED_D model has been designed to reflect:

(a) The structural changes in the energy demand of a country in the medium and long term. This is done by means of a detailed analysis of the social, economic and technological characteristics of the given country. This approach takes especially into account the evolution of the social needs of the population, such as the demand for space heating, lighting, transportation, air conditioning, and this as a function of the distribution of population into urban and rural areas; the industrial policies of the country (development stressed on certain types of industries); and the country's policies concerning transportation, housing etc., as well as the technological development;

(b) The evolution of the potential markets of each form of final energy: electricity, fossil fuels (coal, gas, oil), solar etc.

In the model the substitution between alternative energy forms is not calculated automatically from the evolution of the price for each energy form and its corresponding coefficient of elasticity, but from an analysis made while formulating the possible scenarios of development. This could be considered as a drawback of MAED; however, one should bear in mind that in the actual economic context, characterized by continual changes of energy prices, the economists do not dispose of any proven technique, which would allow them to quantify the effect of changes in energy prices on energy demand. Besides, the considerable divergences between the results provided by many studies on price elasticity's of the demand have demonstrated that the traditional manner of conceiving elasticity's of the demand is no longer satisfactory.

Due to the reasons mentioned above, the MAED_D does not calculate the evolution of energy demand directly from the evolution of energy prices. For example, the demand for gasoline is not calculated from a hypothetical price; this price is simply taken into account implicitly while writing the scenarios of development and it serves as a reference for modulating the future evolution of the parameters involved, such as the car ownership ratio, average distance traveled by car each year etc. In this case, MAED_D simply calculates the demand for motor fuels (gasoline, diesel etc.) as a function of the socio-economic parameters specified by the scenario of development: number of automobiles, average distance driven by car etc. In other words, the prices of motor fuels are not explicitly taken into account; they simply affect the level at which the scenario developers situate the socio-economic parameters.

2.2 Energy demand calculations

The energy demand is calculated by the model MAED_D as a function of a scenario of possible development. This scenario covers two types of scenario elements (see Figure 2.1):

- One is related to the socio-economic system and describes the fundamental characteristics of the social and economic evolution of the country;
- The second is related to the technological factors, which should be taken into account in the calculation of energy demand, for example the efficiency of each alternative energy form and its penetration into its potential markets.

MAED_D calculates the total energy demand for each end-use category, aggregating the economic sectors into four main "energy consumer" sectors: Industry (including Agriculture, Construction, Mining and Manufacturing), Transportation, Service and Household. At the same time, it provides a systematic accounting framework for evaluating the effect on the energy demand of any change of economic nature or in the standard of living of the population.

When various energy forms, i.e. electricity, fossil fuels etc., are competing for a given end-use category of energy demand, this demand is calculated, first in terms of useful energy and then converted into final energy, taking into account the penetration into the given market and the efficiency of each alternative energy source, both specified as scenario parameters.

In the model, the demand for fossil fuels is not discerned in terms of coal, gas or oil, because this largely depends on the possibilities of supply and relative prices of these fuels, aspects that are out of the scope of the analysis carried out by the use of MAED. The substitution of fossil fuels by alternative "new" energy forms (i.e. solar, district heat etc.) is nevertheless estimated, due to the importance of the structural changes in energy demand that these energy forms may produce in the future. Since these substitutions will be essentially determined by political decisions, they are to be taken into account at the stage of formulating the scenarios of development.

Non-substitutable energy uses such as motor fuels for cars, electricity for specific uses (electrolysis, lighting etc.), are calculated directly in terms of final energy.

For each end-use category, the energy demand (useful or final) is related to a set of socio-economic and technological determining factors (macroeconomic parameters, physical quantities, etc.) whose evolution with time will determine the energy demand projections.

Six economic sectors are considered in MAED_D: Agriculture, Construction, Mining, Manufacturing, Service (including transport) and Energy. Agriculture, Construction, Mining, Manufacturing and Service sectors can be further subdivided into up to ten subsectors to allow grouping of the economic branches with similar energy intensities. Energy sector is used only to describe the GDP (Gross Domestic Product) formation. Its energy inputs, for conversions to other final energy forms, are not accounted for by the MAED model, which deals only with the final and useful energy demand projection.

The evolution of the structure of GDP formation is one of the driving factors of greater importance in the model. The GDP formation structure, expressed in terms of the share of the value added contribution to GDP by each sector, is specified directly as part of the scenario. Likewise, the shares of value added by each subsector in the total value added by each main economic sector are also specified directly as scenario elements.

As mentioned above, the energy demand is calculated separately for four major aggregated sectors: Industry, Transportation, Service and Household. The calculation of the energy demand of each of these sectors is performed in a similar manner. According to this procedure, the demand for each end-use category of energy is driven by one or several socio-economic and technological parameters, whose values are given as part of the scenarios.

2.2.1 Industry sector

In this aggregated sector are included the following economic sectors: Agriculture, Construction, Mining, and Manufacturing industries. Each main sector can be subdivided into a maximum of ten user-defined subsectors. This free split of sectors by subsectors allows for a high flexibility in reflecting the industry structure pattern of a particular country.

Generally speaking, the energy demand of each economic subsector is driven by the level of economic activity of the subsector evaluated in terms of its value added and the energy intensity of each energy form. The level of economic activity of each economic subsector is obtained from the data on total GDP and GDP structure, which are specified by the user as input.

For each sector the energy demand is calculated separately for three end-use categories: electricity for specific uses (lighting, motive power, electrolysis etc.); thermal uses (space and water heating, steam generation, furnace and direct heat); and motor fuels. Coke used in steel production and feedstock requirements for the petrochemical industry are calculated separately.

Of the end-use categories of energy demand considered, motor fuels and electricity for specific uses are non-substitutable forms. On the other hand, substitution possibilities exist for the thermal uses, in particular for the displacement of fossil fuels (mainly oil), especially in Manufacturing owing to the high level of concentration of these activities. As Agriculture, Construction, and Mining activities are generally much more decentralized, the opportunities for the substitution of fossil fuels in these sectors are also relatively small.

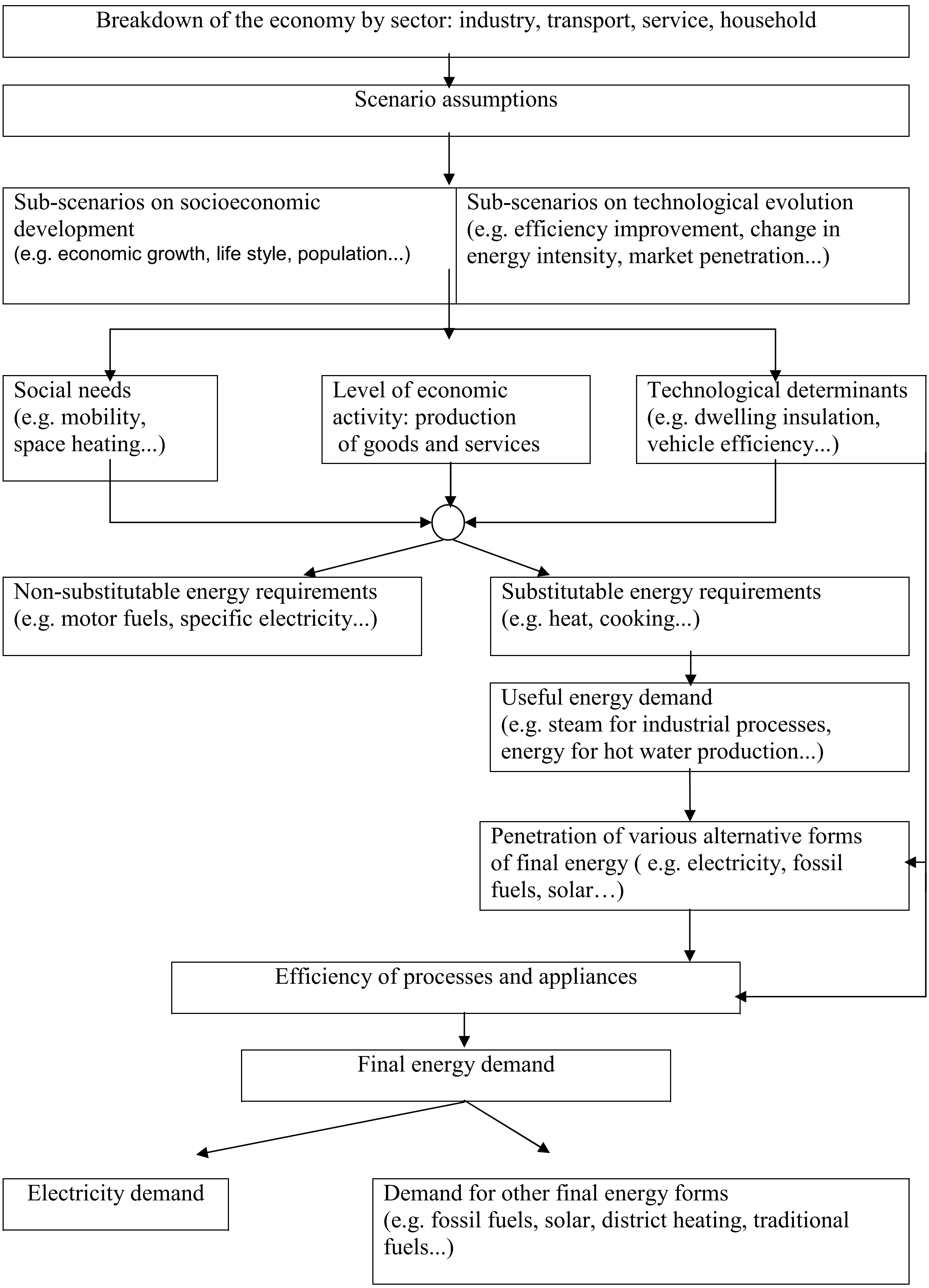

Figure 2.1. Scheme used to project useful and final energy demand in Module 1 of MAED.

Still, in particular situations, such opportunities may be large enough to warrant due consideration and MAED model allows for that.

In order to analyze the substitution process, the thermal energy demand in Manufacturing is broken down in three types of thermal processes: space and water heating; steam generation; and furnace and direct heat. For each Manufacturing sub sector, the scenario parameters must specify the breakdown of thermal uses into these thermal processes.

The energy intensities (i.e. the consumption of motor fuels, electricity and thermal energy per unit of value added) of each sub sector must be specified as scenario parameters due to the fact that these energy intensities are characteristics of each country and depend on the equipment used. For non-substitutable forms (i.e. electricity and motor fuels) energy intensities are specified in terms of final energy per unit of value added, and for substitutable forms (thermal uses) in terms of useful energy per unit of value added.

The thermal energy demand (for substitutable energy forms) is converted from useful into final energy by means of the scenario parameters related to the penetration into the potential market and the efficiency of each alternative energy form. For example, in order to take into account the evolution of the role played by new energy forms such as solar energy, both, the market penetration rate and the efficiency of the appliances (relative to that of the use of electricity with conventional technologies) must be specified as scenario parameters.

Table 2.1 summarizes the economic activities grouped in the Industry sector, as well as the various end-use categories of energy and the alternative energy forms considered.

Table 2.1. Activities, energy uses and alternative energy forms considered for the Industry sector in MAED-D

I. Activities		
• Agriculture		
• Construction		
• Mining		
• Manufacturing		
II. Energy uses		
• Specific uses of electricity (lighting, motive power, electrolysis etc		
• Motor fuels		
• Thermal uses*:	-space heating and hot water -steam generation -furnace and direct heat	
• Special treatment:	-coke use for pig iron steel-works -feedstock requirements in the petrochemical industry	

*Note: This breakdown applies to manufacturing only. In Agriculture, Construction and Mining, thermal uses are calculated globally at the level of each sector.

As already explained, the demand for fossil fuels is not broken down in terms of coal, oil and gas because the MAED model does not take into account the supply problems associated with these fuels.

III. Alternative energy forms by end-use category

Energy forms	Agriculture			Construction			Mining			Manufacturing				
												Thermal uses		
	SEL	MP	TU	SEL	MP	TU	SEL	MP	TU	SEL	MP	S/WH	SG	F/DH
Fossil fuels(coal, gas, oil)			X			X			X			X	X	X
Electricity	X		X	X		X	X		X	X		X	X	X
Motor fuels		X			X			X			X			
District heating												X	X	
Cogeneration												X	X	
Soft solar systems			X			X			X			X	X	
Traditional fuels			X			X			X			X	X	X
Modern biomass			X			X			X			X	X	X

Abbreviations: SEL: specific electricity uses; MP: motive power; TU: thermal uses; S/WH: space/water heating; SG: steam generation; F/DH: furnace/direct heat

2.2.2 Transportation sector

The energy demand of this sector is calculated directly in terms of final energy as a function of the total demand for transportation of passengers (passenger-kilometers) and freight (ton-kilometers), the breakdown of this demand by competing modes (car, bus, plane, truck, train etc.) and the specific energy needs and load factors of each mode. For transport of passengers, the distinction is made for urban (intracity) and intercity transport. The types and modes of transport considered in this sector are listed in Table 2.2.

The total demand for transport is calculated separately for freight and passengers according to macro-economic and life-style factors. In the case of freight transportation, the demand is calculated as a function of the GDP contribution (t-km/MU[1]) from the subsectors of Agriculture, Construction, Mining, Manufacturing and Service and from Energy sector.

On the other hand, the demand for transport of passengers is determined from total population, population living in large cities, and the average intercity and intracity distance traveled per person. The latter is considered to be a scenario variable since it is certainly dependent on disposable personal income and cost of travel, and also on consumer habits. Other scenario variables for intercity passenger transportation are: car ownership and average distance driven per car per year.

Following the same aim of flexibility as for the Industry sector, up to 15 transportation modes are allowed for freight and intracity passenger transportation. For intercity passenger transportation up to 5 types of cars (using different fuel types) and 10 types of public modes (using different fuel types and having different load factors) is permitted. Each transport mode is characterized by its specific fuel consumption (energy intensity). In addition, 8 different fuels are allowed in Transportation sector. Four of them are fixed: electricity, steam coal, diesel and gasoline, and four others are left at the user's choice.

Substantial improvements in specific fuel consumption of various modes of transport may be expected in the future. Such improvements may generally be deduced from past trends.

The load factors by mode of transport are highly dependent on the transport policy of the country and therefore must be specified as scenario parameters.

In addition to the above-mentioned transportation types, the energy consumption (motor fuels) of international and military transportation is calculated as a function of total GDP.

Table 2.2. Types and modes of transport considered for the Transportation sector in MAED_D

Transport type	Maximum number of transport modes	Maximum number of fuel used
Passenger (national level)		
- Intracity	15	8
- Intercity	5 car types 10 public modes	8
Freight (national level)	15	8
International, military and other	1 (aggregated transport type)	1 (aggregated fuel type - motor fuels)

---

[1] MU: monetary unit

2.2.3 Service sector

The scenario parameters and related equations which characterize the energy consumption in the Service sector are related to the economic level of activity of this sector (subsectorial value added and labor force in the sector).

The end-use categories considered for the Service sector are: space heating, other thermal uses (essentially water heating, cooking), air conditioning, specific uses of electricity (motive power for small motors, computers, lighting etc.) and motor fuels. A summary of end-use categories and alternative energy forms considered for the Service sector is given in Table 2.3.

The energy consumption for space heating and air conditioning is calculated on the basis of the specific space heating and cooling requirements (kWh/sqm/yr), while that for other thermal uses, specific uses of electricity and motor fuels is calculated as a function of the value added and energy intensity at the subsector level within Service sector.

When the demand of a given end-use category can be provided by various energy forms (space heating, other thermal uses and air conditioning), this is calculated in terms of useful energy. The final energy demand is then calculated from the penetration into the potential market and the efficiency of each energy form (relative to that of electricity for the same use) as specified in the scenario.

Table 2.3. Energy end-use categories and alternative energy forms distinguished in the Service sector in MAED_D

Energy forms	End-use category				
	SH	OTU	AC	AP	MP
Traditional fuels	X	X			
Modern biomass	X	X			
Electricity	X	X	X	X	
District heating	X	X			
Soft solar systems	X(1)	X(1)			
Fossil fuels (oil, gas, coal)	X	X	X		
Motor fuels (gasoline, diesel etc.)					X

(1) only for low-rise buildings.

Abbreviations: SH: space heating OTU: other thermal uses

AC: air conditioning AP: appliances

MP: motive power

2.2.4 Household sector

Although the energy demand in Household and Service sectors are calculated very similarly, the calculations are executed separately due to the fact that the scenario parameters and related equations which characterize their energy consumption are not the same: in the Household sector the determining factors are of demographic nature (population, number of dwellings etc.) whereas in the Service sector they are related to the economic level of activity of this sector.

A summary of end-use categories and alternative energy forms considered for the Household sector is given in Table 2.4. The categories of energy use considered in Household are: space heating, water heating, cooking, air conditioning and secondary appliances (refrigerators, lighting, washing machines etc.).

The calculations for the Household sector are performed taking into account the living conditions of the population, i.e. the place of residence (separate calculations for urban and rural areas), and type of residence (up to 10 different types of dwellings can be defined for both urban and rural areas). This permits a better representation of the proper needs of the individuals, of their living style, as well as a more appropriate definition of the potential markets for the alternative forms of final energy.

When the demand of a given end-use category can be provided by various energy forms (space heating, water heating, cooking and air conditioning), this is calculated in terms of useful energy and not in terms of final energy. The final energy demand is then calculated from the penetration into the potential market and the efficiency of each energy form (relative to that of electricity for the same use) as specified in the scenario.

The energy consumption for secondary appliances is calculated separately for electrified dwellings, for which the use of electric appliances is assumed, and for the non-electrified dwellings, for which alternative appliances using fossil fuels are considered (kerosene lighting, refrigerators on natural gas etc.).

Table 2.4. Energy end-use categories and alternative energy forms distinguished in the household sector in MAED_D

Energy forms	End-use category				
	SH	WH	CK	AC	AP
Traditional fuels	X	X	X		
Modern biomass	X	X	X		
Electricity	X	X	X	X	X
District heating	X	X			
Soft solar systems	X	X	X		
Fossil fuels (oil, gas, coal)	X	X	X	X	X

Abbreviations: SH: space heating WH: water heating CK: cooking
AC: air conditioning AP: appliances

2.3 Maximal capabilities of MAED_D program

Some references to the maximal capabilities of MAED_D program were already made in the previous sections describing the energy demand calculation for each model sector. Table 2.5 summarizes this information for the entire program.

Table 2.5. Maximal capabilities of the MAED_D program

Parameter	**Maximum allowance**
Reference years	15
Subsectors of Agriculture, Construction, Mining, Manufacturing and Service sectors	10
Freight transportation modes	15
Car types for intercity passenger transportation	5
Public modes for intercity passenger transportation	10
Intracity passenger transportation modes	15
Fuels used in Transportation sector	8
out of which fuels: fixed: electricity, steam coal, diesel and gasoline	4
user-specified fuels	4
Urban dwelling types	10
Rural dwelling types	10

3 EXECUTION OF MAED MODULE 1

3.1 Introduction

The MAED model operates under the Microsoft Excel software and can be readily installed on a PC operating in Windows 95, 98, 2000 or XP environment by transferring the files MAED_D and MAED_EL from a CD-ROM or from floppy diskettes to any selected directory (e.g. c:/programs/maed) on the user's computer. As pointed out earlier, MAED_D (Module 1) is meant for calculating and projecting final energy demand, while MAED_EL (Module 2) is intended for performing hourly electric power demand calculations and working out the load duration curves for specified periods of the year. This section provides an overview of the worksheets associated with the Excel workbook MAED_D and describes the execution of Module 1 (MAED_D). The corresponding aspects of Module 2 are covered in Chapter 7.

Table 3.1. List of worksheets in MS Excel workbook file MAED_D

Worksheet No.	Name of worksheet	Content of worksheet
i	MAED-WS	Title page of the workbook
ii	Notes	Colour code conventions
iii	Descr	Cover page (study and scenario description)
iv	TOC	Table of contents
v	Defs	Definition of the energy system
vi	Demogr-D	Demographic data
vii	GDP-D	GDP formation
viii	EnInt-D	Energy intensities for Industry sector (Agriculture, Construction, Mining and Manufacturing)
ix	UsEne-D	Useful energy demand calculation for Industry sector (Agriculture, Construction, Mining and Manufacturing)
x	ACMFac-D	Penetrations and efficiencies for thermal energy in Agriculture, Construction and Mining sectors
xi	FIN_ACM	Final energy demand calculation for Agriculture, Construction and Mining sectors
xii	ManFac1-D	Useful thermal energy demand by end-uses in Manufacturing sector
xiii	ManFac2-D	Penetrations and efficiencies for thermal energy in Manufacturing sector
xiv	FIN_Ind-D	Final energy demand calculation for Manufacturing sector
xv	FrTrp-D	Final energy demand calculation for Freight transportation subsector
xvi	PassIntra-D	Final energy demand calculation for Intracity (urban) passenger transportation subsector

Continues

Table 3.1. List of worksheets in MS Excel workbook file MAED_D (Continued)

xvii	PassInter-D	Final energy demand calculation for Intercity passenger transportation subsector.
xviii	Fin_Trp-D	Final energy demand calculation for Transportation sector
xix	US_HH_Ur-D	Useful energy demand calculation for Urban household subsector
xx	US_HH_Rr-D	Useful energy demand calculation for Rural household subsector
xxi	FIN_HH-D	Final energy demand calculation for Household sector
xxii	US_SS-D	Useful energy demand calculation for Service sector
xxiii	SS_Fac-D	Penetrations and efficiencies for Service sector
xxiv	FIN_SS-D	Final energy demand calculation for Service sector
xxv	Final-D	Total final energy demand by energy form and by sector (in energy unit specified in cell E50)
xxvi	Final Results (User Units)	Total final energy demand by energy form and by sector (in energy unit specified in cell L50)
xxvii	Convs	Energy unit conversion factor table

3.2 Description of MAED module 1 Excel worksheets

The MS Excel file MAED_D consists of 27 worksheets as listed in Table 3.1. Of these, 22 worksheets serve as spreadsheets for entering the input data and/or performing the model based calculations, while the others provide some general information (e.g. cover page, colour codes, conversion factors etc., used in various worksheets). Microsoft Visual Basic subroutines have been used in the Microsoft Excel environment to automatically generate the equations and tables of the model. A brief description of various worksheets follows.

(a) Worksheet "MAED-WS"

This worksheet contains the title page of the workbook file MAED_D, as shown in Figure 3.1.

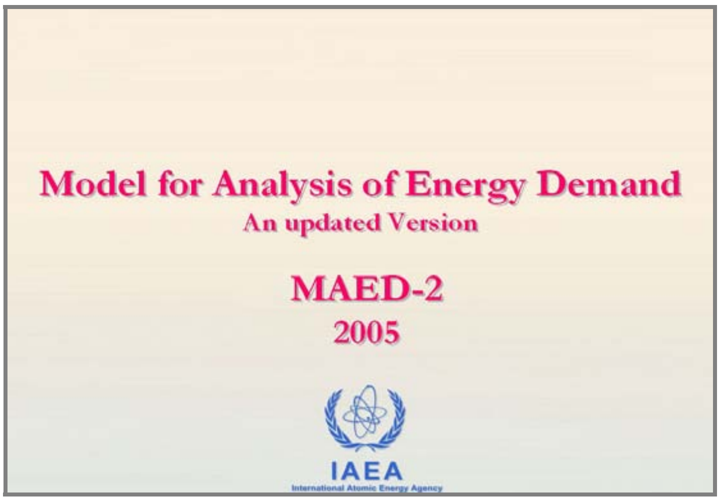

Figure 3.1. Snapshot of worksheet "MAED-WS".

(b) Worksheet "Notes"

A snapshot of the worksheet "Notes" is given in Figure 3.2. This worksheet contains information about the colour code conventions used in various worksheets for making a distinction between the types of information contained in various cells, what are the data that may be entered/changed in various data worksheets and to indicate whether the cells are locked or not:

- Light blue and blue: definition of names (column A of each worksheet) and units (column B of each worksheet) of model variables and reference years for energy demand calculations. These cells are locked.
- Orange and beige: calculated data. The respective cells are locked.
- White: input data. The only cells where the user is allowed to enter or change input data.
- Red: invalid value, locked cell.
- Mauve: error, locked cell.
- Black: unused cell in Defs worksheet.

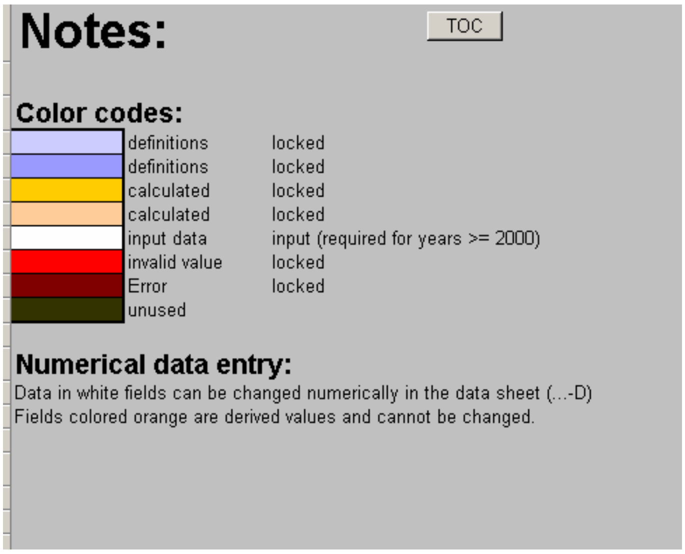

Figure 3.2. Snapshot of worksheet "Notes" in MAED_D.

(c) Worksheet "Descr"

As the various MAED_D worksheets have not any identification title for each scenario under study, this worksheet is intended to be a cover page for the output associated with a particular scenario. The user can include here the name, description and author(s) of the project (case study) as well as the name, description and date for a specific scenario. Figure 3.3 shows a snapshot of the worksheet.

(d) Worksheet "TOC"

As shown in Figure 3.4, this worksheet contains the table of contents of the workbook MAED_D. By clicking the various buttons available in this worksheet, the user can move to the corresponding worksheets of the workbook.

All the other worksheets in MAED_D have a button “TOC”; by clicking that button one can come directly into this worksheet.

Project/Scenario Description:	
Project name: Brief project description: Author(s):	Demonstration of MAED Model International Atomic Energy Agency Department of Nuclear Energy Planning and Economic Studies Section
Scenario name: Scenario number: Brief scenario description: Date:	MAED_D Demonstration Case The data used in this demonstration case correspond to a hypothetical scenario for a hypothetical country. They are there only for illustration purposes and will need to be replaced by actual country and scenario specific data by the user of the model. December 2004

Figure 3.3. Snapshot of worksheet "TOC" in MAED_D.

Table of Contents:

		Data sheets	Table nr.
1	Notes	Notes	
2	Description	Descr	
3	Definitions	Defs	
4	Demography	Demogr-D	1
5	GDP formation	GDP-D	2
6	Energy intensities	EnInt-D	3
7	Useful energy demand in Industry	UsEne-D	4
8	Factors for Agriculture, Construction and Mining	ACMFac-D	5
9	Final energy demand in Agriculture, Construction and Mining	FIN_ACM	6
10	Factors for useful thermal energy demand in Manufacturing	ManFac1-D	7
11	Factors for Manufacturing	ManFac2-D	8
12	Final energy demand in Industry	FIN_Ind-D	9
13	Freight transportation	FrTrp-D	10
14	Intracity passenger transportation	PassIntra-D	11
15	Intercity passenger transportation	PassInter-D	12
16	Final energy demand in Transportation	FIN_Trp-D	13
17	Useful energy demand in Urban Household sector	US_HH_Ur-D	14
18	Useful energy demand in Rural Household sector	US_HH_Rr-D	15
19	Final energy demand in Household sector	FIN_HH-D	16
20	Useful energy demand in Service sector	US_SS-D	17
21	Factors for Service sector	SS_Fac-D	18
22	Final energy demand in Service sector	FIN_SS-D	19
23	Total final energy demand	Final-D	20
24	Total final energy demand (in user-defined units)	Final_User-D	21
25	Conversion factors	Convs	

Figure 3.4. Snapshot of worksheet “TOC” in MAED_D.

(e) Worksheet “Defs”

This worksheet contains the information defining the energy system under study and the study horizon, namely(see Figure 3.8):

Number and list of the reference years of the study;

Base year (one of the reference years);

Number and names of sub sectors for Agriculture, Construction, Mining, Manufacturing and Service sectors;

Number of freight, passenger intracity and passenger intercity transportation modes;

Name and the fuel used by each transportation mode;

Names and numeric codes of the fuel used in the entire Transportation sector;

Natural units for energy intensities associated to each fuel and conversion factors from the natural units to kWh;

Number of types, and types of dwellings in urban and rural areas;

Monetary unit (MU) selected for the study and the units applicable to all variables of the model.

A detailed description of this worksheet will be given in a subsequent subsection.

(f) Data Entry and Handling Worksheets

The 21 worksheets listed under No. vi–xxvi in Table 3.1, serve as data worksheets for entering the input data into the model, for performing the model based calculations and for showing the model results. Each worksheet consists of one or more tables. The snapshot of a typical table taken from the worksheet "US_SS-D" is shown in Figure 3.5. As in Figure 3.5, the first column of each table lists brief descriptions of various input and derived parameters while the entries in the second column specify the corresponding units of measurement. The next several columns are meant for entering/changing the input data corresponding to different reference years or for recording the results of the calculations performed by the model. In line with the contents of the worksheet "Notes" (see Figure 3.2), the cells listing the parameter description, the units of measurement and the study reference years are colored blue and locked; those containing the input data are colored white; and those containing the values of the derived parameters of the model are colored in orange and locked. For more detailed information about the definition or role of a particular parameter, one could then refer to Section 4 (Tables 4.1 and 4.2) and Section 5 of this manual.

Table 17-1 Basic data for useful energy demand in Service sector

Item	Unit	2000	2005	2010	2015	2020	2025
Labour force in SS	[%]	45.000	46.000	47.000	48.000	49.000	50.000
Floor area per emp.	[sqm/cap]	8.000	8.400	8.800	9.200	9.600	10.000
Labour force in SS	[mill cap]	**1.689**	**2.059**	**2.536**	**3.139**	**3.888**	**4.800**
Floor area of SS	[mill sqm]	**13.512**	**17.300**	**22.320**	**28.878**	**37.320**	**48.001**

Figure 3.5. Snapshot of a typical table in data worksheets of MAED_D.

The data listed at present in Tables 1-21 of workbook MAED_D, covered by the 21 data worksheets correspond to a hypothetical scenario (Demonstration Case) for a hypothetical country. These data are only for illustration purposes and should not be considered as reference of typical values.

In the top right hand corner of each data worksheet is located a button named "TOC". Clicking this button moves one to the worksheet "TOC" (Table of contents). Likewise, one can come back to the same data worksheet by clicking the button named after that worksheet in "TOC".

(g) Worksheet "Convs"

This worksheet provides a handy set of conversion factors for converting from one type of energy unit to another type of energy unit, e.g. from TOE to kWh or vice-versa. Figure 3.6 shows the snapshot of a part of this worksheet.

Conversion factors:			name:	= MJ_CFG						
	to -->	example: 1MJ		9.48E-01	CFG					
from	CFG	MJ	TCE	cub m	btu	toe	boe	kWh	kwyr	kcal
CFG	1	1.055	3.6E-05	0.0283168	1000	2.52E-05	0.0001847	0.2930556	3.345E-05	251.9824209
MJ	0.9478673	1	3.412E-05	0.0268406	947.8673	2.388E-05	0.0001751	0.2777778	3.171E-05	238.8458966
TCE	27779.7156	29307.6	1	786.63395	27779716	0.7	5.131	8141	0.9293379	7000000
cubm	35.3146667	37.256973	0.0012712	1	35314.667	0.0008899	0.0065227	10.349159	0.0011814	8898.675215
btu	0.001	0.001055	3.6E-08	2.832E-05	1	2.52E-08	1.847E-07	0.0002931	3.345E-08	0.251982421
toe	39685.3081	41868	1.4285714	1123.7628	39685308	1	7.33	11630	1.3276256	10000000
boe	5414.09387	5711.869	0.1948938	153.31007	5414093.9	0.1364256	1	1586.6303	0.1811222	1364256.48
kWh	3.41232227	3.6	0.0001228	0.0966262	3412.3223	8.598E-05	0.0006303	1	0.0001142	859.8452279
kwyr	29891.9431	31536	1.0760349	846.44557	29891943	0.7532244	5.521135	8760	1	7532244.196
kcal	0.00396853	0.0041868	1.429E-07	0.0001124	3.9685308	0.0000001	7.33E-07	0.001163	1.328E-07	1

Figure 3.6. Snapshot of a part of worksheet "Convs".

3.3 Execution of MAED_D program

The major steps involved in the execution of the MAED_D program are:

Preparation of the necessary input data for each selected model reference year. The selected model reference years could be (a) a set of historical years, including some recent years or (b) the base year plus a set of future years for which energy demand is desired to be projected or (c) a combination of the above two sets.

Entering the input data into various worksheets of the module MAED_D.

Checking the model results by reviewing the values of the various derived variables in different worksheets of MAED_D, as well as the detailed information assembled in the worksheets "Final-D" and "Final Results (User Unit).

Reiteration of the model run after improving the input data, if necessary.

The option (a) of step (i) involving the use of MAED_D for reproducing the historical evolution of energy demand over a certain period, is intended mainly for the purpose of data validation and debugging. However, the implementation of this option is often not practicable in view of the difficulties experienced in gathering historical data and also because of the time constraints. The alternate approach generally used for executing the data validation and debugging phase is to use MAED_D to reconstruct the energy consumption pattern of the base year so as to conform, as closely as possible, to the available disaggregated information. This is done by appropriately adjusting the values of those input parameters of the model for which concrete information is lacking.

It may be emphasized here that the base year should be chosen as close as possible to the actual year in which the study is conducted; it should be a normal year (i.e. no abrupt changes in energy use or economic growth should be observed in this year e.g. due to some natural disaster); and the data availability in this year should not pose any serious problems compared to its neighbouring years. Great care should be exercised by the model user in the selection of the base year since it is a crucial year for the study as all future energy requirements are calculated by the program based on the energy structure established for this year and the changing scenario parameters from year to year.

3.3.1 Some preliminaries

Before proceeding with a new scenario analysis, copy the file MAED_D into a new folder and continue further work related to that scenario only in this new folder.

Set the security level of Excel program to medium (Tools/Macro/Security/Medium)[2]. With this setting, when the file MAED_D will be opened, a dialogue box will appear on the monitor screen (see Figures 3.7 a, b) asking the user if the Microsoft Visual Basic macros present in the workbook should be enabled. Click the "Yes" or the "Enable Macros" button as the macros provided in the worksheet are necessary for the proper operation of the program.

The program MAED_D includes many internal checks for consistency of input data. For example, if the user tries to exceed the maximal capabilities of the model, a warning message will be written on the monitor screen. Sometimes, a cell corresponding to a derived variable may be colored in red (error according to the color codes), telling the user that the value of an upstream variable is not appropriate (for example, a percentage outside the interval 0-100). Nevertheless, the user must take care himself about the general consistency of the input data and of the results of the model.

Figure 3.7a. Snapshots of the dialogue box asking about the enabling of the Macros.

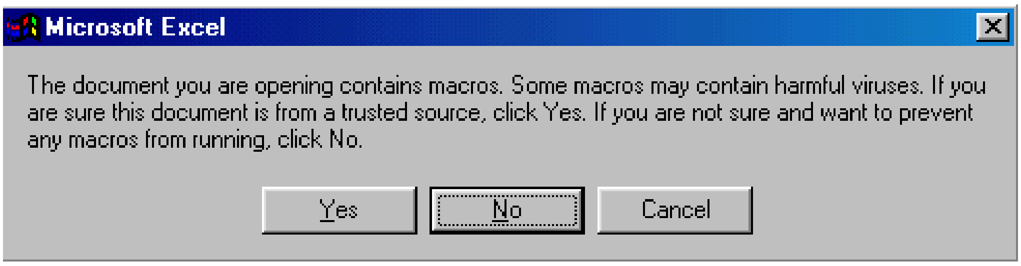

Figure 3.7b. Snapshot of the dialogue box after selection of Enable Macros button.

3.3.2 Entering of input data and progressive review of model results

MAED_D has some 250 input parameters whose symbolic names; definitions and units are described in Table 4.1. The user is required to collect and compile the input data

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[2] For low security level setting the computer is not protected from potentially unsafe macros while for high security level the MAED_D macros might be automatically disabled.

corresponding to all these parameters, for each selected reference year, and enter them in the appropriate data worksheets of the file MAED_D. However, before entering these data, the user should enter the scenario description in worksheet “Descr” and set the model according to the economy structure and the energy and electricity consumption pattern of the country/region under study in worksheet “Defs”.

3.3.3 Worksheet “Defs”

As mentioned in section 3.2(e), this worksheet contains several fields, which may be changed by the user to define the specific environment of a particular study. The fields with white background color are for the user to enter/modify input data (Figure 3.8).

The following categories of input data are specified in this worksheet:

Reference years for the study:

- Number of reference years (cell B6)
- Sequential list of the model years for which energy demand will be projected (cells B8:P8)
- Base year (one of the reference years) in cell B7.The most recent year for which all population, economy and energy data are available.

The reference years include at least one historical year called (called base year) and some future years for which energy demands are projected. It is preferable that the user includes more than one historical years; in which case the most recent historical year will be the base year. The program gives grey color to the background of all data fields for historical years.

To start with, the program shows "No.of Ref. Years" as 6 and 2000 as the base year as well as the first reference year (i.e. only one historical year). In row 8, the program shows 5 fields with white background color for the user to enter projection years. To add two more historical years, the user should enter " No.of Ref. Years" 8. If 2002 is the most recent historical year, then the user should enter 2002 as the base year and start the reference years from 2000 onwards.

Structure of the economic sector:

- Number of subsectors for Agriculture sector (cell B19)
- Names of subsectors of Agriculture sector (cells B20:B29)
- Number of subsectors for Construction sector (cell C19)
- Names of subsectors of Construction sector (cells C20:C29)
- Number of subsectors for Mining sector (cell D19)
- Names of subsectors of Mining sector (cells D20:D29)
- Number of subsectors for Manufacturing sector (cell E19)
- Names of subsectors of Manufacturing sector (cells E20:E29)
- Number of subsectors for Service sector (cell F19)
- Names of subsectors of Service sector (cells F20:F29)

The Energy sector is not split into sub sectors. It is used only to describe the GDP formation. Energy demand for the energy sector is for conversion of one energy form in to another for example oil-refining industry. Since these are conversion losses, the MAED model does not consider them in projection of final and useful energy demand.

For the other sectors the user can change the number of sub sectors and define their names in the appropriate cells.

Structure of the Transportation sector:

- Number of freight transportation modes (cell J17)
- Name of freight transportation modes (cells I19:I33)
- Fuel codes of freight transportation modes (cells J19:J33)
- Number of intercity passenger transportation modes (cell L17)
- Name of intercity passenger transportation modes: air plane, as public mode (cell K19), 5 types of cars (cells K20:K24) and 9 other types of public modes (cells K25:K33)
- Fuel codes of intercity passenger transportation modes (cells L19:L33)
- Number of intracity passenger transportation modes (cell N17)
- Name of intracity passenger transportation modes (cells M19:M33)
- Fuel codes of intracity passenger transportation modes (cells N19:N33)

For freight and intracity passenger transportation subsectors the user can change the number of transport modes and then define their names and fuel used by each mode in the above-mentioned cells.

For intra-city, the program differentiates between private and public modes for passenger transportation. After the first pre-defined mode of "Air plane", following five cells are reserved for defining private modes. These cells have green background color. The program assumes that there is at least one private mode of passenger transportation in these fields. When the users enter any number greater than 2 in the field for "Mode Nr.", the program skips these green cells to go to the first cell for defining the public mode of transportation. However, if there is more than one private mode of transportations for passengers, the user should enter the fuel code for that mode in the first green field and its name in the adjacent field. For deleting any mode, the user should first make the fuel code "0" and then delete the mode name. The user can either continue with entering private modes or can increase the "Mode Nr." The program take her /him to the cell for public modes.

Fuels types used in the entire Transportation sector:

- Names of fuels (cells J38:J45); the first four fuels: electricity, steam coal, diesel oil and gasoline are fixed; the user can add up to four country-specific new fuels.
- Natural units for energy intensities associated to each fuel when used for freight transportation (cells L38:L45). For example, kilogram of coal equivalent (kgce) for steam coal, litre for diesel oil, gasoline, jet fuel, alcohol etc.
- Conversion factors from the natural units (kgce, litre etc.) to kWh when the fuel is used for freight transportation (cells M38:M45)

- Natural units for energy intensities associated to each fuel when used for passenger transportation (cells N38:N45). For example, kilogram of coal equivalent (kgce) for steam coal, litre for diesel oil, gasoline, jet fuel, alcohol etc.

- Conversion factors from the natural units (kgce, litre etc.) to kWh when the fuel is used for passenger transportation (cells O38:O45)

The user can change only the natural energy unit (numerator) but not the denominator (100 t-km for freight transportation, and 100 km and 1000 seat-km for passenger transportation) of the energy intensity of the use of the respective fuel, because they are built-in in the equations of the model. After changing the natural unit, the corresponding conversion factor from the respective natural unit (kgce, litre etc.) to kWh must be also changed accordingly.

In the Demonstration case the conversion factors are calculated with the formula expressions using the heat content (kcal/kg) and density (kg/litre) of various motor fuels included in worksheet “Convs”. The user can adjust the content of the respective cells of worksheet “Convs” according to the characteristics of fuels used in the country under study and use the same type of formula expressions or enter directly the appropriate conversion factors.

Structure of the Household sector:

- Number of types of urban dwellings (cell B35)

- Types of urban dwellings (cells B37:B46)

- Number of types of rural dwellings (cell D35)

- Types of rural dwellings (cells D37:D46)

The user can change the number of urban/rural dwelling types and define their names in the appropriate cells.

Units of the model variables and conversion factors:

- Symbolic name of the selected monetary unit for the study (US$, EUR, local currency etc.) in cell A50.

- Unit for GDP (cell B50); default unit: billion US$.

- Unit for Population and Dwelling numbers (cell C50); default magnitude: million.

- Energy unit (specified in cell E50, default: GWyr (or GWa)) in which energy demand results will be shown in Tables 4, 6 to 7, 9 to 17, 19 to 20 of MAED_D. As the energy unit for the internal calculations of the model is TWh, the conversion factor from TWh to this unit should be indicated in cell N50 either as a number or as a formula using the appropriate conversion factor from worksheet “Convs”.

- User-specified energy unit (cell L50) in which the model final results will be shown in worksheet “Final results (User unit)”. The default energy unit in which energy demand results are shown in other tables of MAED_D is that indicated in cell E50, but the user can ask also the final results in worksheet “Final results (User unit)” in another preferred energy unit. The conversion factor from the unit from cell E50 to the user-specified energy unit (cell L50) for worksheet “Final results (User unit)” should be input in cell M50 either as a number or as a formula using the appropriate conversion factor from worksheet “Convs”.

In row 50 of the worksheet “Defs” there are also some other units applicable to various variables of the model that will be shown in column B of Tables 1 to 20. Some of them must be consistent with the user-specified monetary unit. Therefore, if the user changes the monetary unit from the default one (US$) to other unit (for example, EUR) some of these units must be modified accordingly (for example, change the unit for energy intensity from kWh/US$ to kWh/EUR).

Changes in the magnitude of different units must be made cautiously because some default ratios are built-in in the equations of the model. Some examples are the following:

- The ratio between the GDP (default magnitude: billion) and population (default magnitude: million) figures must be 1000.

- The energy intensities for freight transportation (cells L38:L45) are all expressed in some natural energy unit (litre, kgce etc) per 100 t-km. The user can change the natural energy unit (numerator) and the corresponding conversion factors to kWh (cells M38:M45) but not the denominator (100 t-km).

- The main parts of energy intensities for passenger transportation are expressed in some natural energy unit (litre, kgce etc) per 100 km. The only exception is the fuel for air planes for which the energy intensity is expressed in some natural unit per 1000 seat-km. Again, the user can change the natural energy unit (numerator) and the corresponding conversion factors to kWh (cells O38:O45) but not the denominator (100 km and 1000 seat-km).

On the top of worksheet “Defs” (Figure 3.8) there are three buttons with the following respective functions:

button “**Construct the model structure**”: automatic re-construction of the model structure after each change in relevant data of worksheet “Defs”: number of reference years, number of subsectors of Agriculture, Construction, Mining, Manufacturing or Service sectors; number of transportation modes or fuel used in Transportation sector; number of urban or rural household types.

button “**Adjust column width**”: adjust the column width according to the magnitude of numbers in each column;

button “**Clear input data**”: delete all input data of the case.

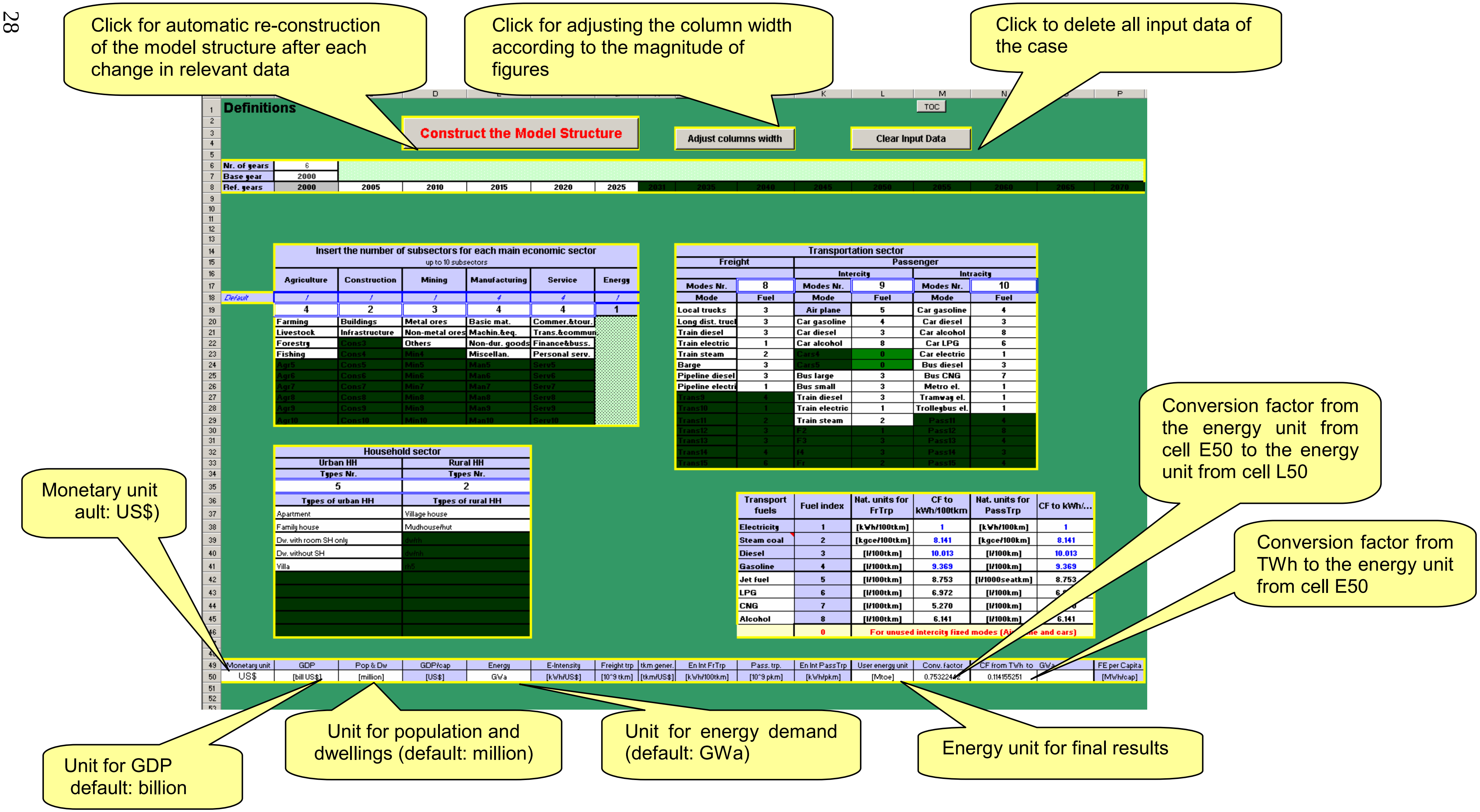
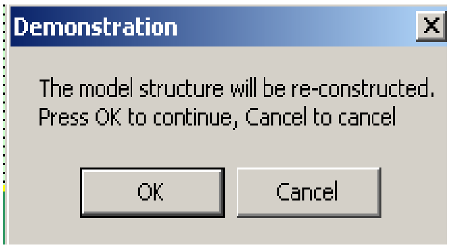


Figure 3.8. Snapshot of worksheet "Defs" in MAED_D.

After changing any input data in worksheet “Defs” the user should press the button “Construct the Working Area”. The following message is displayed:



If the **Cancel** button is pressed, the reconstruction of the model structure stops and the control is transferred back to worksheet Defs.

If the user presses the **OK** button, the tables in the sheets affected by the above-mentioned changes will be rearranged and the respective equations will be recalculated according to the new values of modified parameters: number of reference years, number of economic/energy subsectors, of transportation modes or of dwelling types.

Some change will affect only a few numbers of sectors and model’s parameters; other will affect the majority of sectors. The user may be interested in keeping the maximum volume of useful old data for unaffected parameters and sectors or to delete all old data for the modified sectors/subsectors and keep only a minimum volume of old data for unaffected parameters in the non-modified sectors/subsectors. To do so he/she will answer with Yes or No the following new message:

If the answer is **Yes**, the old valid data are kept as shown in Table 3.2 for the most frequent system changes. For **No**, all old input data for the changed sector(s) are deleted.

At the end of this procedure all Excel tables will be automatically reconfigured and energy demand will be recalculated according to the latest input data.

If for some input data or calculated variables the column width is not large enough and the program shows the ##### symbols in the respective cells, the user should press the button “**Adjust column width**” to enlarge the respective columns and to get the actual figures in those cells.

The button “Clear Input Data” will be used to delete all input data of an existing case.

The input data of this worksheet are internally checked and warning/error messages are displayed if some data are beyond the model capabilities or they don’t observe the model constraints.

Table 3.2. Option "Keep valid data from old structure" when the economic/energy system changes in MAED_D program

No.	Change in data	What MAED_D do in each case: Delete	Keep
1	Change the number of subsectors of AGR sector	- VA by subsector of AGR (Table 2) - EI by subsector of AGR (Table 3) - Penetrations for AGR (Table 5-1) - Coefficients for AGR in Table 10-1 (FT)	- All demography, MAN, intracity & intercity PT, HH and SER data - VA by subsector for all other sectors (Table 2) - Average efficiencies for ACM (Tables 5-5 to 5-7) - EI for other sectors: CON, MIN, MAN (Table 3) - Penetrations for CON (Table 5-2) and MIN (Table 5-3) - Modal split of FT (Table 10-3) - EI for FT (Table 10-4)
2	Change the number of subsectors of CON sector	Similarly as for AGR	Similarly as for AGR
3	Change the number of subsectors of MIN sector	Similarly as for AGR	Similarly as for AGR
4	Change the number of subsectors of MAN sector	- VA by subsector of MAN (Table 2) - EI by subsector of MAN (Table 3) - Share of useful thermal energy of MAN subsectors by thermal process category (Table 7) - Penetrations for MAN (Table 8-1) - Coefficients for MAN in Table 10-1 (FT)	- All demography, ACM, intracity & intercity PT, HH and SER data - VA by subsector for all other sectors (Table 2) - Efficiencies for MAN (Table 8-2) - Modal split of FT (Table 10-3) - EI for FT (Table 10-4)
5	Change the number of subsectors of SER sector	- VA by subsector of SER (Table 2) - Coefficients for SER in Table 10-1 (FT) - EI for SER (Tables 17-4 to 17-6) - Penetrations into Other thermal uses in SER (Table 18-2)	- All demography, ACM, MAN, intracity & intercity PT and HH data - VA by subsector for all other sectors (Table 2) - Modal split of FT (Table 10-3) - EI for FT (Table 10-4) - Basic data for SER (Table 17-1) - Factors for SER (Table 17-2) - Penetrations and efficiencies for SER, except penetrations into Other thermal uses (Tables 18-1, 18-3, 18-4 and 18-5)

Continues

Table 3.2. Option “Keep valid data from old structure” when the economic/energy system changes in MAED_D program (Continued)

No.	Change in data	What MAED_D do in each case:	
		Delete	**Keep**
6	Change the number of FT modes or the fuel code of a FT mode	- Modal split of FT (Table 10-3) - EI of FT modes (Table 10-4)	- All demography, GDP, ACM, MAN, intracity & intercity PT, HH and SER data - Generation of freight-kilometres (Table 10-1) data
7	Change the number of intercity PT modes. Same number of car types (only number of public modes changes).	- LF of public intercity PT modes (Table 12-3) - Split of p-km by public intercity PT mode (Table 12-7) - EI of public intercity PT modes (Table 12-9)	- All demography, GDP, ACM, MAN, FT & intracity PT, HH and SER data - General intercity PT data (Tables 12-1 and 12-2) - LF of car types in intercity PT (Table 12-3) - Split of p-km by car type (Table 12-5) - EI of car types in intercity PT (Table 12-9)
8	Change the number of intercity PT modes and the number of car types. Same number of public modes.	- LF of car types in intercity PT (Table 12-3) - Split of p-km by car type (Table 12-5) - EI of car types in intercity PT (Table 12-9)	- All demography, GDP, ACM, MAN, FT & intracity PT, HH and SER data - General intercity PT data (Tables 12-1 and 12-2) - LF of public intercity PT modes (Table 12-3) - Split of p-km by public PT mode (Table 12-7) - EI of public intercity PT modes (Table 12-9)
9	Change both the number of intercity car types and public modes. (case 9 = case 7 + case 8)	- LF for all intercity PT modes (Table 12-3) - Split of p-km by car type (Table 12-5) - Modal split of p-km by public mode (Table 12-7) - EI of all intercity PT modes (Table 12-9)	- All demography, GDP, ACM, MAN, FT & intracity PT, HH and SER data - General intercity PT data (Tables 12-1 and 12-2)

Continues

Table 3.2 Option “Keep valid data from old structure” when the economic/energy system changes in MAED_D program (Continued)

No.	Change in data	What MAED_D do in each case:	
		Delete	**Keep**
10	Change the fuel code of a car type in intercity PT. (same delete/keep as for item 8)	- LF of car types in intercity PT (Tables 12-3) - Split of p-km by car type (Table 12-5) - EI of car types in intercity PT (Table 12-9)	- All demography, GDP, ACM, MAN, FT & intracity PT, HH and SER data - General intercity PT data (Tables 12-1 and 12-2) - LF of public intercity PT modes (Tables 12-3) - Split of p-km by public PT mode (Tables 12-7) - EI of public intercity PT modes (Table 12-9)
11	Change the fuel code of a public intercity PT mode. (same delete/keep as for item 7)	- LF of public intercity PT mode (Table 12-3) - Split of p-km by public intercity PT mode (Table 12-7) - EI of public intercity PT modes (Table 12-9)	- All demography, GDP, ACM, MAN, FT & intracity PT, HH and SER data - General intercity PT data (Tables 12-1 and 12-2) - LF of car types in intercity PT (Tables 12-3) - Split of p-km by car type (Tables 12-5) - EI of car types in intercity PT (Table 12-9)
12	Change the number of intracity PT modes or the fuel code of an intracity PT mode	- LF of intracity PT modes (Table 11-2) - Modal split of intracity PT (Table 11-3) - EI of intracity PT modes (Table 11-5)	- All demography, GDP, ACM, MAN, FT & intercity PT, HH and SER data - General intracity PT data (Tables 11-1)

Continues

Table 3.2 Option “Keep valid data from old structure” when the economic/energy system changes in MAED_D program (Continued)

No.	Change in data	What MAED_D do in each case:	
		Delete	**Keep**
13	Change the number of urban HH types	- All dwelling factors for SH and AC (Table 14-2) - Penetrations into SH (Table 14-5)	- All demography, GDP, ACM, MAN, FT & PT, rural HH and SER data - Basic data for urban HH (Table 14-1) - All dwelling factors for CK, HW and AP (Table 14-3) - All efficiencies for urban HH (Tables 14-6, 14-8, 14-10 and 14-12) - Penetrations into HW (Table 14-7) and CK (Table 14-9) and AC (Table 14-11)
14	Change the number of rural HH types	Similarly as for urban HH	Similarly as for urban HH

Abbreviations:

AGR: Agriculture CON: Construction MIN: Mining ACM: Agriculture, Construction and Mining

MAN: Manufacturing SER: Service FT: Freight transport PT: Passenger transport

HH: Household GDP: Gross domestic product VA: Value added EI: Energy intensity

LF: Load factor SH: Space heating HW: Hot water CK: Cooking

AP: Appliances AC: Air conditioning

3.3.4 Worksheet “Demogr-D” (Table 1)

This worksheet is intended for handling the demographic data: population and households, living areas and labor force. It covers 7 input parameters and 5 derived parameters (see Figure 3.9). The data contained in this worksheet are required for calculating the values of the derived parameters in various other worksheets distributed throughout the workbook file MAED_D. Before entering a new set of input data into the white cells of this worksheet, the existing data corresponding to the Demonstration Case scenario may be erased, either all in one go using the button “Clear the working area” in worksheet “Defs” or row by row or one cell at a time, as felt convenient by the user.

Table 1 Demography

Item	Unit	2000	2005	2010	2015	2020	2025
Population*	[million]	19.150	21.666	24.275	26.934	29.591	32.194
Pop. gr. rate*	[%p.a.]	na**	2.500	2.300	2.100	1.900	1.700
Urban pop.	[%]	41.500	42.000	43.000	44.000	45.000	45.000
Capita/hh	[cap]	6.000	5.900	5.700	5.400	5.000	4.500
Households	[million]	1.325	1.542	1.831	2.195	2.663	3.219
Rural pop.	[%]	58.500	58.000	57.000	56.000	55.000	55.000
Capita/hh	[cap]	7.000	6.800	6.600	6.300	5.900	5.400
Households	[million]	1.600	1.848	2.097	2.394	2.759	3.279
Potential lf	[%]	49.000	49.200	49.400	49.550	49.650	49.700
Participating lf	[%]	40.000	42.000	45.000	49.000	54.000	60.000
Active lf	[million]	3.753	4.477	5.396	6.539	7.934	9.600
Share of lc. pop.	[%]	22.000	23.000	24.000	25.000	26.000	27.000
Pop. inside lc	[million]	4.213	4.983	5.826	6.733	7.694	8.692
*one of the time series should be entered, the other calculated:							
C4*(1+D5/100)^(D3-C3)			(Population)				
((D4/C4)^(1/(D3-C3))-1)*100			(Population growth rate)				
** na - not applicable							

Figure 3.9. Snapshot of Table 1 of worksheet "Demogr-D".

If it is desired to enter the input data into the cells of a particular row using a formula expression, one needs to pay a little extra attention. This aspect may be clarified to some extent by considering the case of the two parameters: Population (variable name: PO) and Population growth rate (variable name: POGR) in the table shown in Figure 3.9. Here, as explained in the footnote of the table, only one of the two time series should be entered numerically and the other calculated using the relevant formula from the two expressions listed in cells A18 and A19. Please note that, irrespective of whether the formula expression is being used in row 4 or row 5, the values of PO and POGR for the first model reference year cannot be calculated using that expression. The values of both these variables for this year will have to be given numerically. This will not necessarily be the case each time some formula expression is used to enter data for some input variable. The purpose of the above remarks is simply to emphasize that special vigil is necessary whenever data entry in a row is to be made through the use of a formula rather than numerically.

If the user wants to use the same formula in a particular row as has been used in the Demonstration Case, there is no need to delete the contents of that row and re-enter the same formula expression again at the time of entering the input data. If, however, it is desired to use a different formula expression in that row or to enter the corresponding data numerically, the contents of that row may be readily deleted along with those of the rows with numerical data only, before starting the entry of new input data.

In Table 1 of the Demonstration Case (Figure 3.9), the input data for POGR has been provided numerically, while that for PO has been worked out through the use of the formula expression.

As one progresses entering the input data, one starts getting the values worked out properly for those derived variables for which all necessary data have been entered. Once the process of input data entry is complete, all the cells corresponding to the derived variables in the table will display the properly worked out data for those variables. At this stage the user should carefully check the values of the derived variables if they look reasonable; if they do not, he will need to check the corresponding input data and make the necessary corrections/adjustments. The MAED_D program makes some internal checks of input data and of derived variables and provides some error/warning messages but they are not exhaustive. Additional checks by the user of the derived variables are necessary.

Much of the general discussion covered above concerning the entry of the input data and review of the values of the derived variables will equally apply to the other data worksheets of MAED_D.

3.3.5 Worksheet "GDP-D" (Table 2)

This worksheet deals with the formation of Gross Domestic Product (GDP). It consists of a maximum of 9 tables labeled as Tables 2-1 to 2-9.

The first table, Table 2-1 (see Figure 3.10), is essentially an input table where the new scenario data are to be inserted for the parameters dealing with GDP (or GDP growth rate) and the structure of GDP formation. The parameters in rows 8 (GDP/cap) and 14 (share of Energy sector in the GDP formation) are derived parameters and accordingly, the cells belonging to these rows are coloured orange and locked. The parameter "Energy" (representing share of Energy sector in the GDP formation), which appears in row 14, is an input parameter (as defined by the variable: PYEN in Section 4, Table 4.1) but its value is not required to be entered into the data worksheet by the user. This parameter represents the balance of the share of GDP formation after the corresponding shares of all other sectors (Agriculture, Construction, Mining, Manufacturing and Service) have been taken out. It is therefore treated as a "remainder" by the program and its values are worked out automatically. This is why the corresponding row (row 14) is coloured orange and locked.

As in the previous data worksheet, two input parameters of this table, i.e. GDP and GDP growth rate may also be interlinked through a formula expression. In that case the user has to provide the input time series for only one of the parameters and the program automatically calculates the other one.

Tables 2-2 to 2-6 are meant to include the structure of value added formation by subsectors of the main sectors Agriculture, Construction, Mining, Manufacturing and Service. They will have a variable number of rows depending of the number of subsectors of the respective main sector. If the main sector is not split into subsectors, the corresponding table is missing because the share of the value added for the main sector was already given in Table 2-1. The same situation of the value added shares calculated as remainder apply also to the final rows of these tables, if the main sector has at least two subsectors. The user will come across similar situations in some other data worksheets of MAED_D as well.

Table 2-7 comprises data on various derived variables representing the monetary values for the value added by subsector and sector, calculated on the basis of the information on the total GDP and its percentage structure by sectors and subsectors provided in the previous tables. The final row of this table shows the calculated values of total GDP, which, as a check, must be identical with the input data entered/calculated in Table 2-1 (row 6). These data, together with the data in Table 2-1 are used by the program in calculating the values of the derived variables in several other worksheets of MAED_D.

Table 2-8 shows the calculated per capita monetary values for total GDP and for sector value added by the main sectors Agriculture, Construction, Mining, Manufacturing, Service and Energy.

The final table of the worksheet (Table 2-9) gives the growth rates for the value added by sector and subsector as well as for total GDP and GDP per capita. These growth rates are shown only for the second reference year onward, the first year serving only as reference for calculating the growth rates for the second year. The Tables 2-7, 2-8 and 2-9 are shown in Figure 3.11.

3.3.6 Worksheets for industry sector (Tables 3 to 9)

In MAED_D seven worksheets, namely “EnInt-D”, “UsEne-D”, “ACMFac-D”, “FIN_ACM”, “ManFac1-D”, “ManFac2-D” and “FIN_Ind-D”, are used to cover the energy demand analysis of the Industry sector, which is a composite sector, comprising four major economic sectors: Agriculture, Construction, Mining and Manufacturing. The term “ACM” has some times been used in the above worksheets, and will also be used in this Manual to refer to the combination of Agriculture, Construction and Mining sectors.

(a) Worksheet “EnInt-D” (Table 3)

The worksheet “EnInt-D” covers Table 3 of MAED Module 1. It comprises three sub-tables, intended for entering the input data on energy intensities of Agriculture, Construction, Mining and Manufacturing sectors with respect to motor fuels (Table 3-1), specific uses of electricity (Table 3-2) and thermal uses (Table 3-3). The energy intensities are expressed in terms of final energy per monetary unit for motor fuels and specific uses of electricity and in terms of useful energy per monetary unit for thermal uses. They are entered at subsector level and the model calculates the weighted average energy intensities at the main sector level. Figure 3.12 shows a snapshot of Table 3-1 of this worksheet.

GDP formation

Table 2-1 Total GDP and GDP structure by main economic sectors

Item	Unit	2000	2005	2010	2015	2020	2025
GDP*	[bill US$]	33.550	42.819	54.131	67.780	84.063	103.263
GDP gr. rate*	[%]	na	5.000	4.800	4.600	4.400	4.200
GDP/cap	US$	1752.0	1976.3	2229.9	2516.6	2840.8	3207.6
Agriculture	[%]	24.500	23.500	21.500	19.400	17.400	15.500
Construction	[%]	2.300	2.300	2.300	2.300	2.300	2.200
Mining	[%]	5.500	5.300	5.100	4.800	4.300	3.800
Manufacturing	[%]	13.000	14.000	15.200	16.100	16.800	16.900
Service	[%]	49.000	49.000	50.000	51.800	54.200	57.300
Energy	[%]	5.700	5.900	5.900	5.600	5.000	4.300

*One of the time series should be entered, the other calculated:
C6*(1+D7/100)^(D5-C5) *(GDP)*
((D6/C6)^(1/(D5-C5))-1)*100 *(GDP growth rate)*

Table 2-2 Distribution of GDP by subsectors of Agriculture

Item	Unit	2000	2005	2010	2015	2020	2025
Farming	[%]	55.000	53.000	50.500	48.000	46.000	44.000
Livestock	[%]	25.000	26.500	28.000	29.500	30.500	32.000
Forestry	[%]	15.500	15.000	15.000	15.000	15.000	15.000
Fishing	[%]	4.500	5.500	6.500	7.500	8.500	9.000

Table 2-3 Distribution of GDP by subsectors of Construction

Item	Unit	2000	2005	2010	2015	2020	2025
Buildings	[%]	20.000	21.000	22.000	23.000	24.000	25.000
Infrastructure	[%]	80.000	79.000	78.000	77.000	76.000	75.000

Table 2-4 Distribution of GDP by subsectors of Mining

Item	Unit	2000	2005	2010	2015	2020	2025
Metal ores	[%]	35.000	35.000	35.000	35.000	35.000	35.000
Non-metal ores	[%]	40.000	40.000	40.000	40.000	40.000	40.000
Others	[%]	25.000	25.000	25.000	25.000	25.000	25.000

Table 2-5 Distribution of GDP by subsectors of Manufacturing

Item	Unit	2000	2005	2010	2015	2020	2025
Basic mat.	[%]	25.000	24.000	23.000	22.000	21.000	20.000
Machin.&eq.	[%]	10.000	13.000	16.000	19.000	21.000	23.000
Non-dur. goods	[%]	60.000	58.000	56.000	54.000	53.000	52.000
Miscellan.	[%]	5.000	5.000	5.000	5.000	5.000	5.000

Table 2-6 Distribution of GDP by subsectors of Service

Item	Unit	2000	2005	2010	2015	2020	2025
Commer.& tour.	[%]	13.000	15.000	16.500	18.000	19.000	19.500
Public admins.	[%]	32.500	33.000	33.500	34.000	34.500	35.000
Finance&buss.	[%]	6.000	6.500	7.000	7.500	8.100	9.000
Persn. serv. & others	[%]	48.500	45.500	43.000	40.500	38.400	36.500

Figure 3.10. Snapshot of Tables 2-1 to 2-6 (input data) of worksheet "GDP-D".

Table 2-7 GDP formation by sector/subsector (absolute values)

Item	Unit	2000	2005	2010	2015	2020	2025
Agriculture	[bill US$]	8.220	10.063	11.638	13.149	14.627	16.006
Farming	[bill US$]	4.521	5.333	5.877	6.312	6.728	7.043
Livestock	[bill US$]	2.055	2.667	3.259	3.879	4.461	5.122
Forestry	[bill US$]	1.274	1.509	1.746	1.972	2.194	2.401
Fishing	[bill US$]	0.370	0.553	0.756	0.986	1.243	1.441
Construction	[bill US$]	0.772	0.985	1.245	1.559	1.933	2.272
Buildings	[bill US$]	0.154	0.207	0.274	0.359	0.464	0.568
Infrastructure	[bill US$]	0.617	0.778	0.971	1.200	1.469	1.704
Mining	[bill US$]	1.845	2.269	2.761	3.253	3.615	3.924
Metal ores	[bill US$]	0.646	0.794	0.966	1.139	1.265	1.373
Non-metal ores	[bill US$]	0.738	0.908	1.104	1.301	1.446	1.570
Others	[bill US$]	0.461	0.567	0.690	0.813	0.904	0.981
Manufacturing	[bill US$]	4.362	5.995	8.228	10.913	14.123	17.451
Basic mat	[bill US$]	1.090	1.439	1.892	2.401	2.966	3.490
Machin.&eq.	[bill US$]	0.436	0.779	1.316	2.073	2.966	4.014
Non-dur. goods	[bill US$]	2.617	3.477	4.608	5.893	7.485	9.075
Miscellan.	[bill US$]	0.218	0.300	0.411	0.546	0.706	0.873
Service	[bill US$]	16.440	20.981	27.065	35.110	45.562	59.170
Commer.& tour.	[bill US$]	2.137	3.147	4.466	6.320	8.657	11.538
Public admins.	[bill US$]	5.343	6.924	9.067	11.937	15.719	20.709
Finance&buss.	[bill US$]	0.986	1.364	1.895	2.633	3.691	5.325
Persn. serv. & others	[bill US$]	7.973	9.547	11.638	14.220	17.496	21.597
Energy	[bill US$]	1.912	2.526	3.194	3.796	4.203	4.440
Total GDP	[bill US$]	33.550	42.819	54.131	67.780	84.063	103.263

Table 2-8 GDP formation by sector (per capita):

item	Unit	2000	2005	2010	2015	2020	2025
GDP/cap	US$	1751.958	1976.291	2229.868	2516.569	2840.799	3207.556
Agriculture	US$	429.230	464.428	479.422	488.214	494.299	497.171
Construction	US$	40.295	45.455	51.287	57.881	65.338	70.566
Mining	US$	96.358	104.743	113.723	120.795	122.154	121.887
Manufacturing	US$	227.755	276.681	338.940	405.168	477.254	542.077
Service	US$	858.460	968.383	1114.934	1303.583	1539.713	1837.930
Energy	US$	99.862	116.601	131.562	140.928	142.040	137.925

Table 2-9 GDP formation by sector/subsector (growth rates):

Item	Unit	2000	2005	2010	2015	2020	2025
Agriculture	[%]		4.129	2.952	2.472	2.153	1.818
Farming	[%]		3.360	1.962	1.437	1.287	0.917
Livestock	[%]		5.349	4.092	3.547	2.836	2.800
Forestry	[%]		3.448	2.952	2.472	2.153	1.818
Fishing	[%]		8.393	6.450	5.447	4.742	2.989
Construction	[%]		5.000	4.800	4.600	4.400	3.278
Buildings	[%]		6.030	5.780	5.534	5.292	4.124
Infrastructure	[%]		4.736	4.533	4.330	4.127	3.005
Mining	[%]		4.225	3.997	3.339	2.128	1.655
Metal ores	[%]		4.225	3.997	3.339	2.128	1.655
Non-metal ores	[%]		4.225	3.997	3.339	2.128	1.655
Others	[%]		4.225	3.997	3.339	2.128	1.655
Manufacturing	[%]		6.568	6.538	5.810	5.292	4.324
Basic mat	[%]		5.701	5.635	4.874	4.317	3.311
Machin.&eq.	[%]		12.309	11.055	9.510	7.421	6.239
Non-dur. goods	[%]		5.848	5.793	5.044	4.900	3.927
Miscellan.	[%]		6.568	6.538	5.810	5.292	4.324
Service	[%]		5.000	5.224	5.343	5.350	5.366
Commer.& tour.	[%]		8.049	7.249	7.192	6.495	5.914
Public admins.	[%]		5.321	5.541	5.655	5.658	5.669
Finance&buss.	[%]		6.694	6.796	6.806	6.984	7.609
Persn. serv. & others	[%]		3.668	4.042	4.088	4.234	4.302
Energy	[%]		5.727	4.800	3.514	2.060	1.104
Total GDP	[%]		5.000	4.800	4.600	4.400	4.200
GDP/cap	[%]		2.439	2.444	2.449	2.453	2.458

Figure 3.11. Snapshot of Tables 2-7 to 2-9 (calculated data) of worksheet "GDP-D".

Energy intensities for Industry							
Table 3-1 Energy intensities of Motor fuels							
Item	**Unit**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Agriculture	**[kWh/US$]**	**0.972**	**0.872**	**0.798**	**0.725**	**0.668**	**0.611**
Farming	[kWh/US$]	1.500	1.400	1.350	1.300	1.250	1.200
Livestock	[kWh/US$]	0.000	0.000	0.000	0.000	0.000	0.000
Forestry	[kWh/US$]	0.800	0.700	0.600	0.500	0.450	0.400
Fishing	[kWh/US$]	0.500	0.450	0.400	0.350	0.300	0.250
Construction	**[kWh/US$]**	**0.580**	**0.574**	**0.568**	**0.562**	**0.556**	**0.550**
Buildings	[kWh/US$]	0.100	0.100	0.100	0.100	0.100	0.100
Infrastructure	[kWh/US$]	0.700	0.700	0.700	0.700	0.700	0.700
Mining	**[kWh/US$]**	**0.210**	**0.210**	**0.210**	**0.210**	**0.210**	**0.210**
Metal ores	[kWh/US$]	0.300	0.300	0.300	0.300	0.300	0.300
Non-metal ores	[kWh/US$]	0.200	0.200	0.200	0.200	0.200	0.200
Others	[kWh/US$]	0.100	0.100	0.100	0.100	0.100	0.100
Manufacturing	**[kWh/US$]**	**0.122**	**0.121**	**0.120**	**0.119**	**0.119**	**0.118**
Basic mat.	[kWh/US$]	0.150	0.150	0.150	0.150	0.150	0.150
Machin.&eq.	[kWh/US$]	0.100	0.100	0.100	0.100	0.100	0.100
Non-dur. goods	[kWh/US$]	0.120	0.120	0.120	0.120	0.120	0.120
Miscellan.	[kWh/US$]	0.050	0.050	0.050	0.050	0.050	0.050

Figure 3.12. Snapshot of Table 3-1 of worksheet "EnInt-D".

(b) Worksheet "UsEne-D" (Table 4)

This worksheet contains only model-calculated data on the useful energy demand of motor fuels (Table 4-1), specific uses of electricity (Table 4-2) and thermal uses (Table 4-3) in the Agriculture, Construction, Mining and Manufacturing sectors. Table 4-4 summarizes the useful energy demand for the entire aggregated sector of Industry. Figure 3.13 shows a snapshot of Table 4-1.

It should be mentioned that the energy demand for motor fuels and specific uses of electricity are, in fact, calculated directly in terms of final energy because no substitution is allowed for these particular energy uses and sectors. The only energy use for which the energy demand is calculated in terms of useful energy is that of thermal uses. To convert the useful energy demand for thermal uses in Agriculture, Construction, Mining and Manufacturing sectors to final energy, additional information is necessary on the penetrations of various energy carriers into this market and on the efficiencies of their use. The respective input data will be provided in the next worksheets.

Useful energy demand in Industry							
Table 4-1 Useful energy demand for Motor fuels							
Item	**Unit**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Agriculture	**GWa**	**0.912**	**1.001**	**1.060**	**1.089**	**1.115**	**1.115**
Farming	GWa	0.774	0.852	0.906	0.937	0.960	0.965
Livestock	GWa	0.000	0.000	0.000	0.000	0.000	0.000
Forestry	GWa	0.116	0.121	0.120	0.113	0.113	0.110
Fishing	GWa	0.021	0.028	0.035	0.039	0.043	0.041
Construction	**GWa**	**0.051**	**0.065**	**0.081**	**0.100**	**0.123**	**0.143**
Buildings	GWa	0.002	0.002	0.003	0.004	0.005	0.006
Infrastructure	GWa	0.049	0.062	0.078	0.096	0.117	0.136
Mining	**GWa**	**0.044**	**0.054**	**0.066**	**0.078**	**0.087**	**0.094**
Metal ores	GWa	0.022	0.027	0.033	0.039	0.043	0.047
Non-metal ores	GWa	0.017	0.021	0.025	0.030	0.033	0.036
Others	GWa	0.005	0.006	0.008	0.009	0.010	0.011
Manufacturing	**GWa**	**0.061**	**0.083**	**0.113**	**0.149**	**0.191**	**0.235**
Basic mat.	GWa	0.019	0.025	0.032	0.041	0.051	0.060
Machin.&eq.	GWa	0.005	0.009	0.015	0.024	0.034	0.046
Non-dur. goods	GWa	0.036	0.048	0.063	0.081	0.103	0.124
Miscellan.	GWa	0.001	0.002	0.002	0.003	0.004	0.005
Total	**GWa**	**1.068**	**1.203**	**1.320**	**1.415**	**1.516**	**1.587**

Figure 3.13. Snapshot of Table 4-1 of worksheet "UsEne-D".

(c) Worksheet "ACMFac-D" (Table 5)

Tables 5-1 to 5-3 are meant for entering the input data on penetration of different energy carriers (traditional fuels, modern biomass, electricity, soft solar and fossil fuels) into the useful thermal energy markets of Agriculture, Construction and Mining sectors (see Figure 3.14). Table 5-4 provides the model-calculated values of the weighted average penetration of the above five energy carriers into the combined useful thermal energy market of ACM. (For the details of these and all other calculations performed by MAED_D, the user should refer to Section 5 of this manual). The weighted average penetration have only an informative role because when converting useful to final thermal energy demand the sector specific penetrations from Tables 5-1 to 5-3 are used.

The next three tables are used to indicate the average efficiency of traditional fuels (Table 5-5), modern biomass (Table 5-6) and fossil fuels (Table 5-7) when used for thermal uses in Agriculture, Construction and Mining sectors (see Figure 3.15). It should be mentioned that all the efficiencies in MAED_D model are expressed in relative terms versus the efficiency of electricity for the same end-use.

Penetration of energy carriers into useful thermal energy for Agriculture, Construction and Mining

Table 5-1 Penetration of energy carriers into useful thermal energy for Agriculture

Agriculture	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	12.00	11.00	10.00	9.00	8.00	7.00
Modern biomass	[%]	2.00	4.50	7.00	9.50	12.00	15.00
Electricity	[%]	1.00	2.00	3.50	5.00	6.50	8.00
Solar	[%]	0.00	1.00	2.00	3.00	4.00	5.00
Fossil fuels	[%]	85.00	81.50	77.50	73.50	69.50	65.00

Table 5-2 Penetration of energy carriers into useful thermal energy for Construction

Construction	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	5.00	4.50	4.00	3.50	3.00	2.00
Modern biomass	[%]	1.00	1.50	2.00	3.00	4.00	5.00
Electricity	[%]	0.00	0.00	0.00	0.00	0.00	0.00
Solar	[%]	0.00	0.00	0.00	0.00	0.00	0.00
Fossil fuels	[%]	94.00	94.00	94.00	93.50	93.00	93.00

Table 5-3 Penetration of energy carriers into useful thermal energy for Mining

Mining	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	5.00	4.50	4.00	3.50	3.00	2.00
Modern biomass	[%]	1.00	1.50	2.00	3.00	4.00	5.00
Electricity	[%]	0.00	0.00	0.00	0.00	0.00	0.00
Solar	[%]	0.00	0.00	0.00	0.00	0.00	0.00
Fossil fuels	[%]	94.00	94.00	94.00	93.50	93.00	93.00

Figure 3.14. Snapshot of Tables 5-1 to 5-3 (penetrations) of worksheet "ACMFac-D".

Table 5-5 Average efficiency of traditional fuels in thermal uses in Agriculture, Construction and Mining

item	Unit	2000	2005	2010	2015	2020	2025
Agriculture	[%]	25.00	27.00	29.00	31.00	33.00	35.00
Construction	[%]	30.00	32.00	34.00	38.00	38.00	40.00
Mining	[%]	30.00	32.00	34.00	36.00	38.00	40.00

Table 5-6 Average efficiency of modern biomass in thermal uses in Agriculture, Construction and Mining

item	Unit	2000	2005	2010	2015	2020	2025
Agriculture	[%]	30.00	32.00	34.00	38.00	38.00	40.00
Construction	[%]	33.00	33.50	34.00	36.00	38.00	40.00
Mining	[%]	33.00	33.50	34.00	36.00	38.00	40.00

Table 5-7 Average efficiency of fossil fuels in thermal uses in Agriculture, Construction and Mining

item	Unit	2000	2005	2010	2015	2020	2025
Agriculture	[%]	40.00	42.00	44.00	46.00	48.00	50.00
Construction	[%]	40.00	42.00	44.00	46.00	48.00	50.00
Mining	[%]	40.00	42.00	44.00	46.00	48.00	50.00

Figure 3.15. Snapshot of Tables 5-5 to 5-7 (efficiencies) of worksheet "ACMFac-D".

(d) Worksheet "FIN_ACM-D" (Table 6)

This worksheet contains only model-calculated data on the final energy demand for different energy carriers (traditional fuels, modern biomass, electricity, soft solar, fossil fuels and motor fuels) in Agriculture (Tables 6-1 to 6-3), Construction (Tables 6-4 to 6-6), Mining (Tables 6-7 to 6-9) and aggregated ACM (Tables 6-10 to 6-12). For each sector the final energy demand for each energy carrier is expressed in absolute terms (default unit: GWa), as share of total final energy demand of the sector (%) and as energy intensity (kWh/MU). Figure 3.16 shows the content of Tables 6-1 to 6-3 relating to the final energy demand in Agriculture sector.

Final energy demand in Agriculture, Construction and Mining

Table 6-1 Total final energy demand in Agriculture (absolute)

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	0.037	0.038	0.037	0.034	0.030	0.026
Modern biomass	GWa	0.005	0.013	0.022	0.029	0.039	0.049
Electricity	GWa	0.167	0.300	0.504	0.734	0.982	1.248
Solar	GWa	0.000	0.001	0.002	0.003	0.005	0.007
Fossil fuels	GWa	0.165	0.182	0.186	0.186	0.180	0.171
Motor fuels	GWa	0.912	1.001	1.060	1.089	1.115	1.115
Total AGR	GWa	**1.287**	**1.536**	**1.811**	**2.075**	**2.352**	**2.618**

Table 6-2 Total final energy demand in Agriculture (shares)

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	**2.904**	**2.487**	**2.016**	**1.628**	**1.283**	**1.008**
Modern biomass	[%]	**0.403**	**0.858**	**1.204**	**1.402**	**1.672**	**1.890**
Electricity	[%]	**13.013**	**19.543**	**27.831**	**35.378**	**41.743**	**47.687**
Solar	[%]	**0.000**	**0.061**	**0.117**	**0.168**	**0.212**	**0.252**
Fossil fuels	[%]	**12.858**	**11.846**	**10.299**	**8.959**	**7.665**	**6.551**
Motor fuels	[%]	**70.822**	**65.203**	**58.534**	**52.465**	**47.426**	**42.612**

Table 6-3 Total final energy demand per value added in Agriculture

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[kWh/US$]	0.040	0.033	0.027	0.023	0.018	0.014
Modern biomass	[kWh/US$]	0.006	0.011	0.016	0.019	0.024	0.027
Electricity	[kWh/US$]	0.179	0.261	0.379	0.489	0.588	0.683
Solar	[kWh/US$]	0.000	0.001	0.002	0.002	0.003	0.004
Fossil fuels	[kWh/US$]	0.176	0.158	0.140	0.124	0.108	0.094
Motor fuels	[kWh/US$]	0.972	0.872	0.798	0.725	0.668	0.611
Total AGR	[kWh/US$]	**1.372**	**1.337**	**1.363**	**1.382**	**1.409**	**1.433**

Figure 3.16. Snapshot of Tables 6-1 to 6-3 (Agriculture) of worksheet "FIN-ACM".

(e) Worksheet "ManFac1-D" (Table 7)

This worksheet contains both input data fields and model-calculated data. The input data required to be entered refer to the shares of different thermal processes (steam generation, furnace/direct heat, space & water heating) in useful thermal energy demand of each sub sector of Manufacturing sector (Figure 3.17).

The model calculates the useful energy demand for steam generation, furnace/direct heat and space & water heating for the Manufacturing subsectors and for the entire sector, which is shown in the next sub-tables of the worksheet (Figure 3.18). The number of these sub-tables depends on the number of subsectors of Manufacturing sector.

(f) Worksheet "ManFac2-D" (Table 8)

In Table 8-1 of this worksheet the user enters the penetrations of different energy carriers (electricity, heat pumps, district heat, cogeneration, soft solar, traditional fuels, and modern biomass) into their respective applicable heat markets (steam generation, furnace/direct heat, space & water heating) associated with the useful thermal energy demand of the

Manufacturing sector. Given their nature, some energy carriers (heat pumps, district heat, cogeneration, soft solar) are not applicable for the furnace/direct heat market. The model puts the same penetration data in a systematic format (Table 8-5) and the aggregated penetrations of each energy form into the useful thermal energy demand of the entire Manufacturing sector are calculated (Table 8-3).

Table 8-2 contains input data related to the efficiencies of different energy carriers when used for thermal uses in Manufacturing sector and other factors: coefficient of performance (COP) of heat pumps, solar share, heat to electricity ratio of cogeneration systems and biomass share in cogeneration systems (see Section 4, Table 4.1 for the definition of these variables). The last three rows of this table show the calculated values of the average efficiencies of the three types of fuels (fossil fuels, traditional fuels and modern biomass) used for providing useful thermal energy to Manufacturing industries (see Figure 3.19).

Table 8-4 includes coefficients of equations used for projecting the quantities of steel production and feedstock requirements for the petrochemical industry, shown in the last two rows of the table, and some parameters used to derive the coke demand for non-electric steel production (see Figure 3.20).

Factors for Manufacturing

Shares of useful thermal energy demand in Manufacturing

Table 7-1

Basic mat.	Unit	2000	2005	2010	2015	2020	2025
Steam generation	[%]	15.000	15.000	15.000	15.000	15.000	15.000
Furnace/direct heat	[%]	80.000	80.000	80.000	80.000	80.000	80.000
Space& water heating	[%]	5.000	5.000	5.000	5.000	5.000	5.000

Table 7-2

Machin.&eq.	Unit	2000	2005	2010	2015	2020	2025
Steam generation	[%]	15.000	15.000	15.000	15.000	15.000	15.000
Furnace/direct heat	[%]	70.000	70.000	70.000	70.000	70.000	70.000
Space& water heating	[%]	15.000	15.000	15.000	15.000	15.000	15.000

Table 7-3

Non-dur.goods	Unit	2000	2005	2010	2015	2020	2025
Steam generation	[%]	70.000	70.000	70.000	70.000	70.000	70.000
Furnace/direct heat	[%]	15.000	15.000	15.000	15.000	15.000	15.000
Space& water heating	[%]	15.000	15.000	15.000	15.000	15.000	15.000

Table 7-4

Miscellan.	Unit	2000	2005	2010	2015	2020	2025
Steam generation	[%]	20.000	20.000	20.000	20.000	20.000	20.000
Furnace/direct heat	[%]	60.000	60.000	60.000	60.000	60.000	60.000
Space& water heating	[%]	20.000	20.000	20.000	20.000	20.000	20.000

Figure 3.17. Snapshot of input data tables of worksheet "ManFac1-D".

Useful thermal energy demand in Manufacturing

Table 7-5

Basic mat.	Unit	2000	2005	2010	2015	2020	2025
Steam generation	GWa	0.075	0.094	0.117	0.140	0.163	0.179
Furnace/direct heat	GWa	0.398	0.499	0.622	0.745	0.867	0.956
Space&water heating	GWa	0.025	0.031	0.039	0.047	0.054	0.060
Total	GWa	**0.498**	**0.624**	**0.778**	**0.932**	**1.083**	**1.195**

Table 7-6

Machin.&eq.	Unit	2000	2005	2010	2015	2020	2025
Steam generation	GWa	0.002	0.003	0.005	0.007	0.010	0.012
Furnace/direct heat	GWa	0.008	0.014	0.022	0.033	0.045	0.058
Space&water heating	GWa	0.002	0.003	0.005	0.007	0.010	0.012
Total	GWa	**0.012**	**0.020**	**0.032**	**0.047**	**0.064**	**0.082**

Table 7-7

Non-dur. goods	Unit	2000	2005	2010	2015	2020	2025
Steam generation	GWa	0.418	0.472	0.515	0.565	0.598	0.653
Furnace/direct heat	GWa	0.090	0.101	0.110	0.121	0.128	0.140
Space&water heating	GWa	0.090	0.101	0.110	0.121	0.128	0.140
Total	GWa	**0.597**	**0.675**	**0.736**	**0.807**	**0.854**	**0.932**

Table 7-8

Miscellan.	Unit	2000	2005	2010	2015	2020	2025
Steam generation	GWa	0.001	0.001	0.001	0.002	0.002	0.002
Furnace/direct heat	GWa	0.002	0.003	0.004	0.005	0.006	0.007
Space&water heating	GWa	0.001	0.001	0.001	0.002	0.002	0.002
Total	GWa	**0.004**	**0.005**	**0.007**	**0.008**	**0.010**	**0.011**

Table 7-9

Total MAN	Unit	2000	2005	2010	2015	2020	2025
Steam generation	GWa	0.495	0.570	0.638	0.714	0.772	0.846
Furnace/direct heat	GWa	0.499	0.617	0.759	0.905	1.046	1.160
Space&water heating	GWa	0.117	0.136	0.155	0.176	0.194	0.214
Total MAN	GWa	**1.111**	**1.324**	**1.552**	**1.794**	**2.012**	**2.221**

Figure 3.18. Snapshot of calculated data of worksheet.

Table 8-1 Penetration of energy carriers into useful thermal energy demand in Manufacturing							
Energy carriers	Unit	2000	2005	2010	2015	2020	2025
Electricity, steam gen.	[%]	2.000	2.000	2.000	2.000	2.000	2.000
Electricity, furn./dir. heat	[%]	7.000	8.000	9.000	10.000	12.000	14.000
Electricity, sp./w heating	[%]	2.000	3.000	4.000	6.000	8.000	10.000
Of which:							
Heat pumps, steam gen.	[%]	0.000	0.000	0.000	0.000	0.000	0.000
Heat pumps, sp./w heating	[%]	20.000	30.000	40.000	50.000	65.000	80.000
District heat, steam gen.	[%]	10.000	11.000	12.000	13.000	14.500	16.000
District heat, sp./w heating	[%]	12.000	13.000	14.000	15.000	16.000	17.000
Cogeneration, steam gen.	[%]	14.000	15.000	16.000	17.000	18.000	19.000
Cogeneration, sp./w heating	[%]	9.000	10.000	11.000	12.000	13.000	14.000
Solar, steam gen.	[%]	0.000	0.000	0.000	0.000	0.000	0.000
Solar, sp./w heating	[%]	1.000	2.000	3.000	4.000	5.000	6.000
Trad. F., steam gen.	[%]	5.000	4.500	4.000	3.500	3.000	2.000
Trad. F., furn./dir. heat	[%]	3.000	2.600	2.200	1.800	1.400	1.000
Trad. F., sp./w heating	[%]	5.000	4.500	4.000	3.500	3.000	2.000
Mod. Bio., steam gen.	[%]	2.000	3.000	4.000	6.000	8.000	10.000
Mod. Bio., furn./dir. heat	[%]	2.000	3.000	4.000	6.000	8.000	10.000
Mod. Bio., sp./w heating	[%]	2.000	3.000	4.000	6.000	8.000	10.000

Table 8-2 Efficiencies, ratios etc.							
Factors	Unit	2000	2005	2010	2015	2020	2025
COP of heat pumps	[ratio]	2.500	3.000	3.500	4.000	4.500	5.000
Solar share	[%]	40.000	40.000	40.000	40.000	40.000	40.000
Eff. of cogeneration	[%]	70.000	72.000	74.000	76.000	78.000	80.000
Heat/electricity ratio	[ratio]	3.000	3.000	3.000	3.000	3.000	3.000
Biomass share in CoGen	[%]	4.000	6.000	8.000	10.000	12.500	15.000
Eff. of Fossil F., steam gen.	[%]	70.000	71.000	72.000	73.000	74.000	75.000
Eff. of Fossil F., furn./dir. heat	[%]	60.000	61.000	62.000	63.000	64.000	65.000
Eff. of Fossil F., sp./w heating	[%]	60.000	61.000	62.000	63.000	64.000	65.000
Eff. of Trad. F., steam gen.	[%]	30.000	32.000	34.000	36.000	38.000	40.000
Eff. of Trad. F., furn./dir. heat	[%]	30.000	32.000	34.000	36.000	38.000	40.000
Eff. of Trad. F., sp./w heating	[%]	25.000	27.000	29.000	31.000	33.000	35.000
Eff. of Mod. Bio., steam gen.	[%]	40.000	42.000	44.000	46.000	48.000	50.000
Eff. of Mod. Bio., furn./dir. heat	[%]	40.000	42.000	44.000	46.000	48.000	50.000
Eff. of Mod. Bio., sp./w heating	[%]	35.000	37.000	39.000	41.000	43.000	45.000
Eff. of Fossil F., average	[%]	63.535	64.364	65.154	65.996	66.837	67.792
Eff. of Trad. F., average	[%]	29.249	31.257	33.264	35.260	37.247	39.268
Eff. of Mod. Bio., average	[%]	39.407	41.423	43.442	45.455	47.468	49.470

Figure 3.19. Snapshot of Tables 8-1 and 8-2 of worksheet "ManFac2-D".

Table 8-4 Factors for pig iron production and feedstock:							
Factors	Unit	2000	2005	2010	2015	2020	2025
Steel production (const)	[Mt]	-1.460	-1.460	-1.460	-1.460	-1.460	-1.460
Steel production (var)	[Mt/VAMan(1)]	1.910	1.910	1.910	1.910	1.910	1.910
Steel in non-elec furn.	[%]	100.000	90.000	80.000	70.000	60.000	50.000
Spec. cons. of pig iron	[%]	80.000	80.000	80.000	80.000	80.000	80.000
Coke usage	[kg/ton]	750.000	540.000	530.000	520.000	510.000	500.000
Feedstock prod. (const)	[Mt]	0.010	0.010	0.010	0.010	0.010	0.010
Feedstock prod. (var)	[Mt/VAMan(1)]	0.600	0.600	0.600	0.600	0.600	0.600
Steel production	[Mt]	0.623	1.288	2.155	3.125	4.205	5.206
Feedstock production	[Mt]	0.664	0.873	1.145	1.450	1.789	2.104

Figure 3.20 Snapshot of Tables 8-4 of worksheet "ManFac2-D"

(g) Worksheet "FIN_Ind-D" (Table 9)

This worksheet includes only model-calculated data on the final energy demand for different energy carriers (traditional fuels, modern biomass, electricity, district heat, soft solar, fossil fuels, motor fuels, coke and feedstock) in Manufacturing (Tables 9-1 to 9-3) as shown in Figure 3.21 and in the entire aggregated sector of Industry (Tables 9-4 to 9-6) as illustrated in Figure 3.22. For each sector the final energy demand for each energy carrier is expressed in absolute terms (default unit: GWa), as share of total final energy demand of the sector (%) and as energy intensity (kWh/MU).

Final energy demand in Manufacturing

Table 9-1 Total final energy demand in Manufacturing (absolute)

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	0.156	0.153	0.146	0.135	0.117	0.084
Modern biomass	GWa	0.665	1.197	1.861	2.736	3.848	5.219
Electricity	GWa	0.380	0.519	0.711	0.944	1.234	1.492
District heat	GWa	0.064	0.080	0.098	0.119	0.143	0.172
Solar	GWa	0.000	0.001	0.002	0.003	0.004	0.005
Fossil fuels	GWa	1.488	1.711	1.940	2.133	2.250	2.332
Motor fuels	GWa	0.061	0.083	0.113	0.149	0.191	0.235
Coke	GWa	0.347	0.465	0.679	0.846	0.957	0.968
Feedstock	GWa	0.882	1.159	1.521	1.926	2.376	2.794
Total MAN	GWa	4.043	5.370	7.070	8.990	11.119	13.300

Table 9-2 Total final energy demand in Manufacturing (shares)

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	3.855	2.850	2.059	1.496	1.053	0.628
Modern biomass	[%]	16.454	22.295	26.323	30.437	34.604	39.243
Electricity	[%]	9.407	9.667	10.057	10.498	11.098	11.220
District heat	[%]	1.573	1.498	1.391	1.326	1.286	1.292
Solar	[%]	0.012	0.020	0.026	0.031	0.035	0.039
Fossil fuels	[%]	36.796	31.871	27.433	23.731	20.236	17.532
Motor fuels	[%]	1.502	1.543	1.597	1.653	1.720	1.766
Coke	[%]	8.587	8.666	9.606	9.408	8.603	7.276
Feedstock	[%]	21.812	21.589	21.508	21.419	21.366	21.004

Table 9-3 Total final energy demand per value added in Manufacturing

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[kWh/US$]	0.313	0.224	0.155	0.108	0.073	0.042
Modern biomass	[kWh/US$]	1.336	1.749	1.981	2.197	2.387	2.620
Electricity	[kWh/US$]	0.764	0.759	0.757	0.758	0.765	0.749
District heat	[kWh/US$]	0.128	0.118	0.105	0.096	0.089	0.086
Solar	[kWh/US$]	0.001	0.002	0.002	0.002	0.002	0.003
Fossil fuels	[kWh/US$]	2.988	2.501	2.065	1.713	1.396	1.170
Motor fuels	[kWh/US$]	0.122	0.121	0.120	0.119	0.119	0.118
Coke	[kWh/US$]	0.697	0.680	0.723	0.679	0.593	0.486
Feedstock	[kWh/US$]	1.771	1.694	1.619	1.546	1.474	1.402
Total MAN	[kWh/US$]	8.120	7.847	7.528	7.217	6.897	6.676

Figure 3.21. Snapshot of Tables 9-1 to 9-3 of worksheet "FIN_Ind-D".

Final energy demand in Industry

Table 9-4 Total final energy demand in Industry (absolute)

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	0.197	0.195	0.187	0.173	0.151	0.113
Modern biomass	GWa	0.671	1.212	1.885	2.769	3.893	5.276
Electricity	GWa	0.571	0.847	1.249	1.719	2.261	2.791
District heat	GWa	0.064	0.080	0.098	0.119	0.143	0.172
Solar	GWa	0.000	0.002	0.004	0.006	0.009	0.012
Fossil fuels	GWa	1.710	1.961	2.206	2.411	2.532	2.613
Motor fuels	GWa	1.068	1.203	1.320	1.415	1.516	1.587
Coke	GWa	0.347	0.465	0.679	0.846	0.957	0.968
Feedstock	GWa	0.882	1.159	1.521	1.926	2.376	2.794
Total IND	GWa	5.510	7.126	9.149	11.384	13.837	16.324

Table 9-5 Total final energy demand in Industry (shares)

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	3.581	2.743	2.039	1.516	1.094	0.692
Modern biomass	[%]	12.181	17.004	20.605	24.326	28.131	32.321
Electricity	[%]	10.356	11.892	13.656	15.097	16.343	17.095
District heat	[%]	1.154	1.128	1.075	1.047	1.033	1.053
Solar	[%]	0.009	0.028	0.044	0.055	0.064	0.072
Fossil fuels	[%]	31.038	27.521	24.112	21.180	18.297	16.005
Motor fuels	[%]	19.377	16.884	14.424	12.432	10.956	9.722
Coke	[%]	6.301	6.531	7.424	7.430	6.913	5.928
Feedstock	[%]	16.004	16.269	16.622	16.916	17.169	17.113

Table 9-6 Total final energy demand per value added in Industry

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[kWh/US$]	0.114	0.089	0.068	0.052	0.039	0.025
Modern biomass	[kWh/US$]	0.387	0.550	0.692	0.840	0.994	1.166
Electricity	[kWh/US$]	0.329	0.384	0.458	0.521	0.578	0.616
District heat	[kWh/US$]	0.037	0.036	0.036	0.036	0.037	0.038
Solar	[kWh/US$]	0.000	0.001	0.001	0.002	0.002	0.003
Fossil fuels	[kWh/US$]	0.986	0.890	0.810	0.731	0.647	0.577
Motor fuels	[kWh/US$]	0.615	0.546	0.484	0.429	0.387	0.351
Coke	[kWh/US$]	0.200	0.211	0.249	0.257	0.244	0.214
Feedstock	[kWh/US$]	0.508	0.526	0.558	0.584	0.607	0.617
Total IND	[kWh/US$]	3.176	3.233	3.357	3.454	3.534	3.606

Figure 3.22. Snapshot of Tables 9-4 to 9-6- of worksheet "FIN_Ind-D".

3.3.7 Worksheets for transportation sector (Tables 10 to 13)

The energy demand analysis of the Transportation sector is covered by four worksheets: “FrTrp-D”, meant for entering the input data related to freight transportation and also for showing the results of the model-based calculations for this transportation subsector; “PassIntra-D”, serving the same purpose but for the intracity (urban) passenger transportation subsector; “PassInter-D” for intercity passenger transportation subsector; and “FIN_Trp-D”, which summarizes the overall energy demand analysis results for the entire Transportation sector.

(a) Worksheet "FrTrp-D" (Table 10)

As illustrated in Figure 3.23, the input data requirements of this worksheet include coefficients of various terms of the formula adopted for calculating total freight transport activity (Table 10-1); modal split of freight transportation (Table 10-3); and energy intensities (in natural units) of the respective modes of freight transportation (Table 10-4).

Freight transportation

Table 10-1 Generation of freight-kilometers

Item	Unit	2000	2005	2010	2015	2020	2025
Farming	[tkm/US$]	0.816	0.816	0.816	0.816	0.816	0.816
Livestock	[tkm/US$]	0.000	0.000	0.000	0.000	0.000	0.000
Forestry	[tkm/US$]	0.816	0.816	0.816	0.816	0.816	0.816
Fishing	[tkm/US$]	0.816	0.816	0.816	0.816	0.816	0.816
Buildings	[tkm/US$]	0.000	0.000	0.000	0.000	0.000	0.000
Infrastructure	[tkm/US$]	0.000	0.000	0.000	0.000	0.000	0.000
Metal ores	[tkm/US$]	0.800	0.800	0.800	0.800	0.800	0.800
Non-metal ores	[tkm/US$]	0.800	0.800	0.800	0.800	0.800	0.800
Others	[tkm/US$]	0.800	0.800	0.800	0.800	0.800	0.800
Basic mat.	[tkm/US$]	1.500	1.500	1.500	1.500	1.500	1.500
Machin.&eq.	[tkm/US$]	0.500	0.500	0.500	0.500	0.500	0.500
Non-dur. goods	[tkm/US$]	0.800	0.800	0.800	0.800	0.800	0.800
Miscellan.	[tkm/US$]	1.000	1.000	1.000	1.000	1.000	1.000
Commer.& tour.	[tkm/US$]	0.500	0.500	0.500	0.500	0.500	0.500
Public admins.	[tkm/US$]	0.500	0.500	0.500	0.500	0.500	0.500
Finance&buss.	[tkm/US$]	0.000	0.000	0.000	0.000	0.000	0.000
Persn. serv. & others	[tkm/US$]	0.000	0.000	0.000	0.000	0.000	0.000
Energy	[tkm/US$]	0.400	0.400	0.400	0.400	0.400	0.400
Base value	[10^9 tkm]	43.800	43.800	43.800	43.800	43.800	43.800

Table 10-2 Total freight-kilometers

Item	Unit	2000	2005	2010	2015	2020	2025
Freight-km	[10^9 tkm]	58.977	63.326	68.484	74.512	81.482	89.095

Table 10-3 Modal split of freight transportation

Item	Unit	2000	2005	2010	2015	2020	2025
Local trucks	[%]	20.000	21.000	22.000	23.000	24.000	25.000
Long dist. trucks	[%]	25.000	24.000	23.000	22.000	21.000	20.000
Train diesel	[%]	30.000	28.000	26.000	24.000	22.000	20.000
Train electric	[%]	10.000	12.000	14.000	16.000	18.000	20.000
Train steam	[%]	5.000	4.000	3.000	2.000	1.000	0.000
Barge	[%]	3.000	3.200	3.400	3.600	3.800	4.000
Pipeline (diesel)	[%]	4.000	4.400	4.800	5.200	5.600	6.000
Pipeline (electric)	[%]	3.000	3.400	3.800	4.200	4.600	5.000

Table 10-4 Energy intensity of freight transportation (natural units)

Item	Unit	2000	2005	2010	2015	2020	2025
Local trucks	[l/100t km]	11.500	11.500	11.400	11.300	11.200	11.100
Long dist. trucks	[l/100t km]	9.250	9.250	9.200	9.100	9.000	8.900
Train diesel	[l/100t km]	2.310	2.300	2.290	2.280	2.270	2.260
Train electric	[kWh/100t km]	6.500	6.500	6.400	6.300	6.200	6.100
Train steam	[kgce/100t km]	13.150	13.150	13.150	13.150	13.150	13.150
Barge	[l/100t km]	2.300	2.300	2.290	2.280	2.270	2.250
Pipeline (diesel)	[l/100t km]	0.800	0.800	0.800	0.800	0.800	0.800
Pipeline (electric)	[kWh/100t km]	6.050	6.050	6.050	6.050	6.050	6.050

Figure 3.23. Snapshot of input data tables of worksheet "FrTrp-D".

The freight transportation modes are those specified by the user in worksheet "Defs". The model-based calculated data stored in this worksheet comprise total freight transportation activity, expressed in 10^9 ton-kilometers (Table 10-2); energy intensities of freight transportation modes expressed in a common energy unit - kWh/100t-km (Table 10-5); and energy consumption of freight transportation sub sector by mode of transportation (Table 10-6) as well as by fuel type (Table 10-7) and by fuel group type: electricity, steam coal and motor fuels (Table 10-8). The size of Table 10 depends on the number of subsectors selected by the user for Agriculture, Construction, Mining, Manufacturing and Service sectors, on the number of freight transportation modes and on the number of fuels used by these transportation modes. Figure 3.24 shows a snapshot of calculated data tables of this worksheet.

Table 10-5 Energy intensity of freight transportation (energy units)

Item	Unit	2000	2005	2010	2015	2020	2025
Local trucks	[kWh/100t km]	115.154	115.154	114.153	113.152	112.150	111.149
Long dist.trucks	[kWh/100t km]	92.624	92.624	92.124	91.122	90.121	89.120
Train diesel	[kWh/100t km]	23.131	23.031	22.931	22.831	22.730	22.630
Train electric	[kWh/100t km]	6.500	6.500	6.400	6.300	6.200	6.100
Train steam	[kWh/100t km]	107.054	107.054	107.054	107.054	107.054	107.054
Barge	[kWh/100t km]	23.031	23.031	22.931	22.831	22.730	22.530
Pipeline (diesel)	[kWh/100t km]	8.011	8.011	8.011	8.011	8.011	8.011
Pipeline (electric)	[kWh/100t km]	6.050	6.050	6.050	6.050	6.050	6.050

Table 10-6 Energy consumption of freight transportation (by mode)

Item	Unit	2000	2005	2010	2015	2020	2025
Local trucks	GWa	1.551	1.748	1.963	2.214	2.504	2.826
Long dist.trucks	GWa	1.559	1.607	1.656	1.705	1.760	1.813
Train diesel	GWa	0.467	0.466	0.466	0.466	0.465	0.460
Train electric	GWa	0.044	0.056	0.070	0.086	0.104	0.124
Train steam	GWa	0.360	0.310	0.251	0.182	0.100	0.000
Barge	GWa	0.047	0.053	0.061	0.070	0.080	0.092
Pipeline (diesel)	GWa	0.022	0.025	0.030	0.035	0.042	0.049
Pipeline (electric)	GWa	0.012	0.015	0.018	0.022	0.026	0.031
Total	GWa	4.061	4.281	4.516	4.780	5.080	5.395

Table 10-7 Energy consumption of freight transportation (by fuel)

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.056	0.071	0.088	0.107	0.130	0.155
Steam coal	GWa	0.360	0.310	0.251	0.182	0.100	0.000
Diesel	GWa	3.645	3.900	4.177	4.490	4.851	5.240
Total	GWa	4.061	4.281	4.516	4.780	5.080	5.395

Table 10-8 Energy consumption of freight transportation (by fuel group)

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.056	0.071	0.088	0.107	0.130	0.155
Steam coal	GWa	0.360	0.310	0.251	0.182	0.100	0.000
Motor fuels	GWa	3.645	3.900	4.177	4.490	4.851	5.240
Total	GWa	4.061	4.281	4.516	4.780	5.080	5.395

Figure 3.24. Snapshot of calculated data tables of worksheet "FrTrp-D".

(b) Worksheet "PassIntra-D" (Table 11)

The input data required to be entered into this worksheet covers the intracity (urban) passenger travel. The first input data is the intracity distance traveled per urban person per day (Table 11-1), which, together with the population living in large cities from "Demogr-D" worksheet, is used for deriving the urban travel activity, expressed in 10^9 passenger-kilometers (Table 11-4). The other input data include load factors (Table 11-2) of the urban passenger transportation modes selected by the user in worksheet "Defs", modal split of the urban travel activity (Table 11-3) and the energy intensities (in natural units) of various transportation modes of urban travel (Table 11-5). The corresponding data calculated by the model for intracity travel and stored in this worksheet, include the travel activity levels (10^9 passenger-km) by different modes of transportation (Table 11-4); energy intensities of these modes expressed in kWh/p-km (Table 11-6); and energy consumption of intracity passenger transportation subsector by mode (Table 11-7), by fuel type (Table 11-8) and by fuel group type: electricity and motor fuels (Table 11-9). The size of Table 11 depends on the number of intracity passenger transportation modes selected by the user in worksheet "Defs" and on the number of fuels used by these transportation modes. Figure 3.25 shows a snapshot of input data tables of this worksheet while the calculated data are presented in Figure 3.26.

Intracity passenger transportation

Table 11-1 Distance travelled

Item	Unit	2000	2005	2010	2015	2020	2025
Dist. intracity	km/prsn/day	3.300	3.500	4.000	4.500	5.000	6.000

Table 11-2 Load factors

Item	Unit	2000	2005	2010	2015	2020	2025
Car gasoline	[prsn/Car gasoline]	2.000	2.000	2.000	2.000	2.000	2.000
Car diesel	[prsn/Car diesel]	2.000	2.000	2.000	2.000	2.000	2.000
Car alcohol	[prsn/Car alcohol]	2.000	2.000	2.000	2.000	2.000	2.000
Car LPG	[prsn/Car LPG]	2.000	2.000	2.000	2.000	2.000	2.000
Car electric	[prsn/Car electric]	2.000	2.000	2.000	2.000	2.000	2.000
Bus diesel	[prsn/Bus diesel]	60.000	60.000	55.000	50.000	45.000	40.000
Bus CNG	[prsn/Bus CNG]	60.000	58.000	55.000	50.000	45.000	40.000
Metro el.	[prsn/Metro el.]	500.000	480.000	460.000	440.000	420.000	400.000
Tramway el.	[prsn/Tramway el.]	100.000	96.000	92.000	88.000	84.000	80.000
Trolleybus el.	[prsn/Trolleybus el.]	60.000	58.000	55.000	50.000	45.000	40.000

Table 11-3 Modal split of intracity passenger transportation

Item	Unit	2000	2005	2010	2015	2020	2025
Car gasoline	[%]	6.000	6.500	7.000	8.000	9.000	10.000
Car diesel	[%]	1.000	1.500	2.000	3.000	4.000	5.000
Car alcohol	[%]	0.000	0.000	1.000	2.000	3.000	5.000
Car LPG	[%]	1.000	2.000	3.000	4.000	5.000	6.000
Car electric	[%]	0.000	0.000	0.000	1.000	2.000	4.000
Bus diesel	[%]	75.000	75.000	70.000	60.000	50.000	40.000
Bus CNG	[%]	1.000	2.000	3.000	4.000	5.000	5.000
Metro el.	[%]	0.000	0.000	0.000	3.000	6.000	10.000
Tramway el.	[%]	0.000	0.000	3.000	5.000	7.000	10.000
Trolleybus el.	[%]	16.000	13.000	11.000	10.000	9.000	5.000

Table 11-5 Energy intensity of intracity passenger transportation (natural units)

Item	Unit	2000	2005	2010	2015	2020	2025
Car gasoline	[l/100km]	11.000	10.900	10.800	10.700	10.600	10.500
Car diesel	[l/100km]	10.000	9.900	9.800	9.700	9.600	9.500
Car alcohol	[l/100km]	16.000	15.900	15.800	15.700	15.600	15.500
Car LPG	[l/100km]	14.000	13.900	13.800	13.700	13.600	13.500
Car electric	[kWh/100km]	30.000	29.800	29.600	29.400	29.200	29.000
Bus diesel	[l/100km]	35.000	34.800	34.600	34.400	34.200	34.000
Bus CNG	[l/100km]	45.000	44.700	44.400	44.100	43.800	43.500
Metro el.	[kWh/100km]	800.000	790.000	780.000	770.000	760.000	750.000
Tramway el.	[kWh/100km]	500.000	495.000	490.000	485.000	480.000	475.000
Trolleybus el.	[kWh/100km]	300.000	295.000	290.000	285.000	280.000	275.000

Figure 3.25. Snapshot of input data tables of worksheet "PassIntra-D".

Table 11-4 Intracity passenger transportation by mode

Item	Unit	2000	2005	2010	2015	2020	2025
Total	[10^9 pkm]	5.075	6.366	8.506	11.060	14.041	19.038
Car gasoline	[10^9 pkm]	0.304	0.414	0.595	0.885	1.264	1.904
Car diesel	[10^9 pkm]	0.051	0.095	0.170	0.332	0.562	0.952
Car alcohol	[10^9 pkm]	0.000	0.000	0.085	0.221	0.421	0.952
Car LPG	[10^9 pkm]	0.051	0.127	0.255	0.442	0.702	1.142
Car electric	[10^9 pkm]	0.000	0.000	0.000	0.111	0.281	0.761
Bus diesel	[10^9 pkm]	3.806	4.775	5.954	6.636	7.021	7.614
Bus CNG	[10^9 pkm]	0.051	0.127	0.255	0.442	0.702	0.952
Metro el.	[10^9 pkm]	0.000	0.000	0.000	0.332	0.842	1.904
Tramway el.	[10^9 pkm]	0.000	0.000	0.255	0.553	0.983	1.904
Trolleybus el.	[10^9 pkm]	0.812	0.828	0.936	1.106	1.264	0.952

Table 11-6 Energy intensity of intracity passenger transportation (energy units)

Item	Unit	2000	2005	2010	2015	2020	2025
Car gasoline	[kWh/pkm]	0.515	0.511	0.506	0.501	0.497	0.492
Car diesel	[kWh/pkm]	0.501	0.496	0.491	0.486	0.481	0.476
Car alcohol	[kWh/pkm]	0.491	0.488	0.485	0.482	0.479	0.476
Car LPG	[kWh/pkm]	0.488	0.485	0.481	0.478	0.474	0.471
Car electric	[kWh/pkm]	0.150	0.149	0.148	0.147	0.146	0.145
Bus diesel	[kWh/pkm]	0.058	0.058	0.063	0.069	0.076	0.085
Bus CNG	[kWh/pkm]	0.040	0.041	0.043	0.046	0.051	0.057
Metro el.	[kWh/pkm]	0.016	0.016	0.017	0.018	0.018	0.019
Tramway el.	[kWh/pkm]	0.050	0.052	0.053	0.055	0.057	0.059
Trolleybus el.	[kWh/pkm]	0.050	0.051	0.053	0.057	0.062	0.069

Table 11-7 Energy consumption of intracity passenger transportation (by mode)

Item	Unit	2000	2005	2010	2015	2020	2025
Car gasoline	GWa	0.018	0.024	0.034	0.051	0.072	0.107
Car diesel	GWa	0.003	0.005	0.010	0.018	0.031	0.052
Car alcohol	GWa	0.000	0.000	0.005	0.012	0.023	0.052
Car LPG	GWa	0.003	0.007	0.014	0.024	0.038	0.061
Car electric	GWa	0.000	0.000	0.000	0.002	0.005	0.013
Bus diesel	GWa	0.025	0.032	0.043	0.052	0.061	0.074
Bus CNG	GWa	0.000	0.001	0.001	0.002	0.004	0.006
Metro el.	GWa	0.000	0.000	0.000	0.001	0.002	0.004
Tramway el.	GWa	0.000	0.000	0.002	0.003	0.006	0.013
Trolleybus el.	GWa	0.005	0.005	0.006	0.007	0.009	0.007
Total	GWa	0.054	0.074	0.114	0.173	0.250	0.389

Table 11-8 Energy consumption of intracity passenger transportation (by fuel)

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.005	0.005	0.007	0.013	0.022	0.037
Diesel	GWa	0.028	0.037	0.052	0.071	0.092	0.126
Gasoline	GWa	0.018	0.024	0.034	0.051	0.072	0.107
LPG	GWa	0.003	0.007	0.014	0.024	0.038	0.061
CNG	GWa	0.000	0.001	0.001	0.002	0.004	0.006
Alcohol	GWa	0.000	0.000	0.005	0.012	0.023	0.052
Total	GWa	0.054	0.074	0.114	0.173	0.250	0.389

Table 11-9 Energy consumption of intracity passenger transportation (by fuel group)

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.005	0.005	0.007	0.013	0.022	0.037
Steam coal (na)	GWa	0.000	0.000	0.000	0.000	0.000	0.000
Motor fuels	GWa	0.049	0.069	0.107	0.160	0.229	0.352
Total	GWa	0.054	0.074	0.114	0.173	0.250	0.389

Figure 3.26. Snapshot of calculated data tables of worksheet "PassIntra-D".

(c) Worksheet "PassInter-D" (Table 12)

This worksheet covers the intercity passenger travel as well as the international and military transportation. The first input data is the intercity distance traveled per person per year (Table 12-1), which, together with the total population from "Demogr-D" worksheet, is used for deriving the intercity travel activity level (10^9 passenger-kilometers). Secondly, car ownership ratio (ratio of population to total number of cars) and the average intercity distance driven per car per year are entered (Table 12-2). Based on the previous information the model calculates the intercity travel activity performed with cars; the remaining intercity passenger travel activity is assumed to be performed with public transportation modes (Table 12-4). The other input data for this Transportation subsector refer to the load factors of intercity transportation modes (Table 12-3), split (%) by car types of intercity travel activity performed by car (Table 12-5), modal split of public intercity passenger transportation (Table 12-7), and energy intensities of various modes of transport, expressed in natural units (Table 12-9).

The additional data calculated by the model for intercity travel and stored in this worksheet include the travel activity levels (10^9 passenger-km) by car type (Table 12-6) and by public mode type (Table 12-8); energy intensities of these modes expressed in kWh/p-km (Table 12-10); and energy consumption of intercity passenger transportation by mode (Table 12-11), by fuel type (Table 12-12) and by fuel group: electricity, steam coal and motor fuels (Table 12-13).

Regarding the international and military transportation, the user has to enter into this worksheet the values of two input coefficients relating the corresponding motor fuel consumption to the total GDP. The model then calculates directly the energy consumption for this type of transportation activity and stores it in the cells meant for this derived variable (Table 12-14).

In the end this worksheet provides the results of the model-based calculations for the passenger (intercity and intracity) and international & military transportation subsectors (Table 12-15), giving total final energy demand for these activities split by fuel group: electricity, steam coal and motor fuels.

The size of Table 12 depends on the number of intercity passenger transportation modes selected by the user in worksheet "Defs" and on the number of fuels used by these transportation modes. A snapshot of input data tables of this worksheet is shown in Figure 3.27 while calculated data tables are illustrated in Figure 3.28.

(d) Worksheet "FIN_Trp-D" (Table 13)

Finally, the worksheet "FIN_Trp-D" sums up the results of all transportation activities and provides information on (i) total final energy demand of Transportation sector by fuel type (Table 13-1), fuel group type: electricity, steam coal and motor fuels (Table 13-3) and subsector: freight, passenger intracity, passenger intercity, and international & military (Table 13-5) (ii) corresponding percentage shares in the total transportation energy of each fuel type (Table 13-2), fuel group type (Table 13-4) and subsector (Table 13-6). Figure 3.29 shows the content of the entire worksheet "FIN_Trp-D".

3.3.8 Worksheets for household sector (Tables 14 to 16)

The energy demand analysis of the Household sector is covered by three worksheets: "US_HH_Ur-D", meant for entering the input data for urban dwellings and also for showing the results of the model-based calculations for the useful energy demand of this Household subsector; "US_HH_Rr-D", serving the same purpose but for the rural dwellings; and "FIN_HH-D", which summarizes the overall energy demand analysis results for the Household sector. As already mentioned in Section 2, the categories of energy use considered in the Household sector are: space heating, water heating, cooking, air conditioning and secondary appliances (refrigerators, lighting, washing machines etc.). The energy demand for water heating, cooking and secondary appliances is calculated based on average specific energy consumptions for all dwellings of the Household subsector (urban or rural) while for space heating and air conditioning the energy demand is calculated separately for the dwelling types defined by the user in worksheet “Defs” for each subsector.

Intercity passenger transportation

Table 12-1 Distance travelled

Item	Unit	2000	2005	2010	2015	2020	2025
Dist.intercity	[km/prsn/yr]	1500.000	1700.000	2000.000	2400.000	2900.000	3300.000
Total	[10^9 pkm]	28.725	36.833	48.551	64.641	85.815	106.239

Table 12-2 Factors for intercity passenger transport by car

Item	Unit	2000	2005	2010	2015	2020	2025
Car ownership	[person/car]	50.000	45.000	40.000	35.000	30.000	20.000
Car-kilometers	[km/car/yr]	5000.000	5500.000	6000.000	6500.000	7000.000	8000.000

Table 12-3 Load factors

Item	Unit	2000	2005	2010	2015	2020	2025
Air plane	[%occupied]	70.000	70.000	70.000	70.000	70.000	70.000
Cars	[prsn/car]	3.000	3.000	3.000	3.000	3.000	3.000
Bus large	[prsn/Bus large]	45.000	43.000	40.000	37.000	35.000	35.000
Bus small	[prsn/Bus small]	15.000	15.000	15.000	15.000	15.000	15.000
Train diesel	[prsn/Train diesel]	500.000	500.000	500.000	500.000	500.000	500.000
Train electric	[prsn/Train electric]	800.000	800.000	800.000	800.000	800.000	800.000
Train steam	[prsn/Train steam]	200.000	200.000	200.000	200.000	200.000	200.000

Table 12-5 Modal split of cars intercity passenger transportation

Item	Unit	2000	2005	2010	2015	2020	2025
Car gasoline	[%]	60.000	60.000	58.000	56.000	53.000	50.000
Car diesel	[%]	40.000	40.000	40.000	40.000	40.000	40.000
Car alcohol	[%]	0.000	0.000	2.000	4.000	7.000	10.000

Table 12-7 Modal split of public intercity passenger transportation

Item	Unit	2000	2005	2010	2015	2020	2025
Air plane	[%]	5.000	6.000	7.000	8.000	9.000	10.000
Bus large	[%]	35.000	34.000	33.000	32.000	31.000	31.000
Bus small	[%]	30.000	31.000	32.000	33.000	34.000	34.000
Train diesel	[%]	15.000	13.000	11.000	9.000	8.000	7.000
Train electric	[%]	10.000	12.000	14.000	16.000	17.000	18.000
Train steam	[%]	5.000	4.000	3.000	2.000	1.000	0.000

Table 12-9 Energy intensity of intercity passenger transportation (natural units)

Item	Unit	2000	2005	2010	2015	2020	2025
Air plane	[l/1000seatkm]	87.500	85.000	82.500	82.000	77.500	75.000
Car gasoline	[l/100km]	9.500	8.000	8.000	8.000	8.000	8.000
Car diesel	[l/100km]	9.000	7.000	7.000	7.000	7.000	7.000
Car alcohol	[l/100km]	11.000	11.000	11.000	11.000	11.000	11.000
Bus large	[l/100km]	30.000	30.000	30.000	30.000	30.000	30.000
Bus small	[l/100km]	25.000	25.000	25.000	25.000	25.000	25.000
Train diesel	[l/100km]	250.000	250.000	250.000	250.000	250.000	250.000
Train electric	[kWh/100km]	650.000	650.000	650.000	650.000	650.000	650.000
Train steam	[kgce/100km]	1315.000	1315.000	1315.000	1315.000	1315.000	1315.000

Table 12-14 Energy consumption of international and military transportation

Item	Unit	2000	2005	2010	2015	2020	2025
Constant	GWa	0.010	0.010	0.010	0.010	0.010	0.010
Variable	[kWh/US$]	0.030	0.030	0.030	0.030	0.030	0.030
Total	GWa	0.125	0.157	0.195	0.242	0.298	0.364

Figure 3.27. Snapshot of input data tables of worksheet "PassInter-D".

Table 12-4 Modal split of intercity passenger transportation

Item	Unit	2000	2005	2010	2015	2020	2025
Cars	[10^9 pkm]	5.745	7.944	10.924	15.006	20.714	38.632
Public	[10^9 pkm]	22.980	28.889	37.627	49.635	65.101	67.607

Table 12-6 Cars intercity passenger transportation by car type

Item	Unit	2000	2005	2010	2015	2020	2025
Car gasoline	[10^9 pkm]	3.447	4.767	6.336	8.403	10.978	19.316
Car diesel	[10^9 pkm]	2.298	3.178	4.370	6.002	8.286	15.453
Car alcohol	[10^9 pkm]	0.000	0.000	0.218	0.600	1.450	3.863

Table 12-8 Public intercity passenger transportation by mode

Item	Unit	2000	2005	2010	2015	2020	2025
Air plane	[10^9 pkm]	1.149	1.733	2.634	3.971	5.859	6.761
Bus large	[10^9 pkm]	8.043	9.822	12.417	15.883	20.181	20.958
Bus small	[10^9 pkm]	6.894	8.955	12.041	16.379	22.134	22.986
Train diesel	[10^9 pkm]	3.447	3.756	4.139	4.467	5.208	4.732
Train electric	[10^9 pkm]	2.298	3.467	5.268	7.942	11.067	12.169
Train steam	[10^9 pkm]	1.149	1.156	1.129	0.993	0.651	0.000

Table 12-10 Energy intensity of intercity passenger transportation (energy units)

Item	Unit	2000	2005	2010	2015	2020	2025
Air plane	[kWh/pkm]	1.094	1.063	1.032	1.025	0.969	0.938
Car gasoline	[kWh/pkm]	0.297	0.250	0.250	0.250	0.250	0.250
Car diesel	[kWh/pkm]	0.300	0.234	0.234	0.234	0.234	0.234
Car alcohol	[kWh/pkm]	0.225	0.225	0.225	0.225	0.225	0.225
Bus large	[kWh/pkm]	0.067	0.070	0.075	0.081	0.086	0.086
Bus small	[kWh/pkm]	0.167	0.167	0.167	0.167	0.167	0.167
Train diesel	[kWh/pkm]	0.050	0.050	0.050	0.050	0.050	0.050
Train electric	[kWh/pkm]	0.008	0.008	0.008	0.008	0.008	0.008
Train steam	[kWh/pkm]	0.535	0.535	0.535	0.535	0.535	0.535

Table 12-11 Energy consumption of intercity passenger transportation (by mode)

Item	Unit	2000	2005	2010	2015	2020	2025
Air plane	GWa	0.144	0.210	0.310	0.465	0.648	0.724
Car gasoline	GWa	0.117	0.136	0.181	0.240	0.313	0.551
Car diesel	GWa	0.079	0.085	0.117	0.160	0.221	0.412
Car alcohol	GWa	0.000	0.000	0.006	0.015	0.037	0.099
Bus large	GWa	0.061	0.078	0.106	0.147	0.198	0.205
Bus small	GWa	0.131	0.171	0.229	0.312	0.422	0.438
Train diesel	GWa	0.020	0.021	0.024	0.026	0.030	0.027
Train electric	GWa	0.002	0.003	0.005	0.007	0.010	0.011
Train steam	GWa	0.070	0.071	0.069	0.061	0.040	0.000
Total	GWa	0.624	0.775	1.046	1.433	1.919	2.468

Table 12-12 Energy consumption of intercity passenger transportation (by fuel)

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.002	0.003	0.005	0.007	0.010	0.011
Steam coal	GWa	0.070	0.071	0.069	0.061	0.040	0.000
Diesel	GWa	0.291	0.355	0.476	0.645	0.870	1.082
Gasoline	GWa	0.117	0.136	0.181	0.240	0.313	0.551
Jet fuel	GWa	0.144	0.210	0.310	0.465	0.648	0.724
Alcohol	GWa	0.000	0.000	0.006	0.015	0.037	0.099
Total	GWa	0.624	0.775	1.046	1.433	1.919	2.468

Table 12-13 Energy consumption of intercity passenger transportation intercity (by fuel group)

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.002	0.003	0.005	0.007	0.010	0.011
Steam coal	GWa	0.070	0.071	0.069	0.061	0.040	0.000
Motor fuels	GWa	0.551	0.701	0.973	1.365	1.869	2.456
Total	GWa	0.624	0.775	1.046	1.433	1.919	2.468

Table 12-15 Energy consumption of intra + inter passenger + international & military transportation (by fuel group)

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.007	0.008	0.012	0.021	0.032	0.048
Steam coal	GWa	0.070	0.071	0.069	0.061	0.040	0.000
Motor fuels	GWa	0.726	0.927	1.275	1.767	2.395	3.172
Total	GWa	0.803	1.005	1.356	1.848	2.467	3.220

Figure 3.28. Snapshot of calculated data tables of worksheet "PassInter-D".

(a) Worksheet "US_HH_Ur-D" (Table 14)

First, the number of urban dwellings is taken from worksheet "Demogr-D" where it was calculated based on the input data related to the share of urban population and urban household size. Then, the user is required to provide the following general input data which have impact on the energy demand for space heating in urban dwellings (Table 14-1):

- fraction (%) of urban dwellings situated in areas where space heating is required;
- degree-days (days^{0}C) for urban dwellings (see Section 4, Table 4.1 for the definition of this variable).

Table 14-2 includes input data referring to space heating and air conditioning by type of dwelling, namely:

- fraction (%) of urban dwellings by type (relative to the total number of urban dwellings situated in areas where space heating is required);
- average size (sqm) of dwellings by type;
- specific heat loss rate (Wh/sqm/^{0}C/h) by dwelling type;
- share (%) of urban dwellings with air conditioning, by type (relative to the total number of urban dwellings of the same type);
- specific cooling requirements (kWh/dw/yr) by dwelling type.

Table 14-3 contains the average specific energy consumptions and other factors required for calculation of useful energy demand for cooking, hot water and secondary appliances, namely:

- specific useful energy consumption for cooking per urban dwelling and per year (kWh/dw/yr);
- share (%) of urban dwellings with hot water facilities;
- specific useful energy consumption for water heating per person in urban dwellings (kWh/cap/yr);
- specific final electricity consumption per electrified urban dwelling and per year (kWh/dw/yr) for electric appliances (other end-uses than space heating, hot water, cooking and air conditioning);
- share (%) of electrified urban dwellings (electricity penetration for appliances);
- specific fossil fuel consumption per urban dwelling and per year (kWh/dw/yr, final energy) for non-electric appliances (other end-uses than space heating, hot water, cooking and air conditioning), mainly lighting, but also non-electric refrigerators etc.

The previous input data tables for the Demonstration case are shown in Figure 3.30.

Final energy demand in Transportation sector

Table 13-1 Final energy demand in Transportation sector (by fuel)

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.063	0.079	0.100	0.128	0.162	0.203
Steam coal	GWa	0.431	0.380	0.320	0.243	0.139	0.000
Diesel	GWa	3.964	4.292	4.705	5.206	5.813	6.448
Gasoline	GWa	0.135	0.160	0.215	0.290	0.385	0.658
Jet fuel	GWa	0.144	0.210	0.310	0.465	0.648	0.724
LPG	GWa	0.003	0.007	0.014	0.024	0.038	0.061
CNG	GWa	0.000	0.001	0.001	0.002	0.004	0.006
Alcohol	GWa	0.000	0.000	0.010	0.028	0.060	0.151
MF for Int'l & milit.	GWa	0.125	0.157	0.195	0.242	0.298	0.364
Total	GWa	4.864	5.286	5.872	6.628	7.548	8.615

Table 13-2 Share of fuels in Transportation sector

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	[%]	1.290	1.500	1.705	1.930	2.143	2.359
Steam coal	[%]	8.853	7.191	5.451	3.663	1.846	0.000
Diesel	[%]	81.507	81.195	80.136	78.545	77.021	74.846
Gasoline	[%]	2.769	3.028	3.663	4.380	5.098	7.636
Jet fuel	[%]	2.951	3.978	5.282	7.012	8.588	8.401
LPG	[%]	0.058	0.133	0.239	0.364	0.503	0.712
CNG	[%]	0.005	0.011	0.021	0.035	0.054	0.072
Alcohol	[%]	0.000	0.000	0.176	0.416	0.799	1.753
MF for Int'l & milit.	[%]	2.568	2.963	3.327	3.653	3.947	4.221

Table 13-3 Final energy demand in Transportation sector (by fuel group)

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.063	0.079	0.100	0.128	0.162	0.203
Steam coal	GWa	0.431	0.380	0.320	0.243	0.139	0.000
Motor fuel	GWa	4.370	4.827	5.452	6.257	7.246	8.412
Total	GWa	4.864	5.286	5.872	6.628	7.548	8.615

Table 13-4 Share of fuel groups in Transportation sector

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	[%]	1.290	1.500	1.705	1.930	2.143	2.359
Steam coal	[%]	8.853	7.191	5.451	3.663	1.846	0.000
Motor fuel	[%]	89.857	91.309	92.845	94.407	96.010	97.641

Table 13-5 Final energy demand in Transportation sector (by subsector)

Item	Unit	2000	2005	2010	2015	2020	2025
Freight	GWa	4.061	4.281	4.516	4.780	5.080	5.395
Pass_intracity	GWa	0.054	0.074	0.114	0.173	0.250	0.389
Pass_intercity	GWa	0.624	0.775	1.046	1.433	1.919	2.468
Int'l & military	GWa	0.125	0.157	0.195	0.242	0.298	0.364
Total	GWa	4.864	5.286	5.872	6.628	7.548	8.615

Table 13-6 Shares of final energy demand of Transportation subsectors

Item	Unit	2000	2005	2010	2015	2020	2025
Freight	[%]	83.500	80.979	76.912	72.118	67.313	62.620
Pass_intracity	[%]	1.108	1.393	1.940	2.611	3.318	4.514
Pass_intercity	[%]	12.824	14.665	17.821	21.618	25.422	28.645
Int'l & military	[%]	2.568	2.963	3.327	3.653	3.947	4.221

Figure 3.29. Snapshot of worksheet "FIN_Trp-D".

Useful energy demand in Urban Household sector

Table 14-1 Basic data for useful energy demand in Urban Household sector

Item	Unit	2000	2005	2010	2015	2020	2025
Dwellings	[million]	1.325	1.542	1.831	2.195	2.663	3.219
Share of dw. requiring SH	[%]	100.000	100.000	100.000	100.000	100.000	100.000
Degree-days	[days°C]	1500.000	1500.000	1500.000	1500.000	1500.000	1500.000

Tables 14-2 Dwelling factors for space heating and air conditioning, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Share of Apartment	[%]	30.000	30.000	30.000	30.000	30.000	30.000
Share of Family house	[%]	13.000	14.000	16.000	18.000	19.000	20.000
Share of Dw. with room SH only	[%]	45.000	43.000	40.000	37.000	34.000	33.000
Share of Dw. without SH	[%]	8.000	8.000	8.000	8.000	8.000	8.000
Share of Villa	[%]	4.000	5.000	6.000	7.000	9.000	9.000
Dw. size. Apartment	[sqm]	80.000	80.000	80.000	80.000	80.000	80.000
Dw. size. Family house	[sqm]	120.000	120.000	120.000	120.000	120.000	120.000
Dw. size. Dw. with room SH only	[sqm]	60.000	60.000	60.000	60.000	60.000	60.000
Dw. size. Dw. without SH	[sqm]	50.000	50.000	50.000	50.000	50.000	50.000
Dw. size. Villa	[sqm]	200.000	200.000	200.000	200.000	200.000	200.000
Area h. Apartment	[%]	100.000	100.000	100.000	100.000	100.000	100.000
Area h. Family house	[%]	80.000	80.000	80.000	80.000	80.000	80.000
Area h. Dw. with room SH only	[%]	40.000	40.000	40.000	40.000	40.000	40.000
Area h. Dw. without SH	[%]	0.000	0.000	0.000	0.000	0.000	0.000
Area h. Villa	[%]	80.000	80.000	80.000	80.000	80.000	80.000
H. los. R. Apartment	[Wh/sqm/°C/h]	4.000	4.000	4.000	4.000	4.000	4.000
H. los. R. Family house	[Wh/sqm/°C/h]	4.500	4.500	4.500	4.500	4.500	4.500
H. los. R. Dw. with room SH only	[Wh/sqm/°C/h]	3.500	3.500	3.500	3.500	3.500	3.500
H. los. R. Dw. without SH	[Wh/sqm/°C/h]	3.500	3.500	3.500	3.500	3.500	3.500
H. los. R. Villa	[Wh/sqm/°C/h]	4.500	4.500	4.500	4.500	4.500	4.500
Dw. AC. Apartment	[%]	5.000	7.000	9.000	11.000	13.000	15.000
Dw. AC. Family house	[%]	7.000	8.000	9.000	11.000	13.000	15.000
Dw. AC. Dw. with room SH only	[%]	5.000	5.500	6.000	6.500	7.000	8.000
Dw. AC. Dw. without SH	[%]	0.000	0.000	0.000	0.000	0.000	0.000
Dw. AC. Villa	[%]	100.000	100.000	100.000	100.000	100.000	100.000
Spc. req. AC. Apartment	[kWh/dw/yr]	2500.000	2500.000	2500.000	2500.000	2500.000	2500.000
Spc. req. AC. Family house	[kWh/dw/yr]	3500.000	3500.000	3500.000	3500.000	3500.000	3500.000
Spc. req. AC. Dw. with room SH only	[kWh/dw/yr]	2000.000	2000.000	2000.000	2000.000	2000.000	2000.000
Spc. req. AC. Dw. without SH	[kWh/dw/yr]	0.000	0.000	0.000	0.000	0.000	0.000
Spc. req. AC. Villa	[kWh/dw/yr]	6000.000	6000.000	6000.000	6000.000	6000.000	6000.000

Table 14-3 Dwelling factors for cooking, hot water and appliances, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Cooking	[kWh/dw/yr]	930.000	915.000	900.000	850.000	800.000	750.000
Dw with hot water	[%]	40.000	45.000	50.000	55.000	60.000	70.000
HW per cap	[kWh/cap/yr]	350.000	400.000	450.000	500.000	600.000	700.000
Electr. cons. for appliances	[kWh/dw/yr]	900.000	1100.000	1300.000	1500.000	1750.000	2000.000
Electr. penetration	[%]	85.000	90.000	95.000	98.000	100.000	100.000
FF for lighting	[kWh/dw/yr]	100.000	100.000	100.000	100.000	100.000	100.000

Figure 3.30. Snapshot of Tables 14-1 to 14-3 of worksheet "US HH Ur-D".

Based on the previous information, the useful energy demand for all end-use categories: space heating, water heating, cooking, air conditioning, and secondary appliances (electric and non-electric) is calculated (Table 14-4) as illustrated in Figure 3.31.

Table 14-4 Calculation of useful energy demand in Urban Household sector

Item	Unit	2000	2005	2010	2015	2020	2025
Space heating	GWa	1.191	1.449	1.821	2.302	2.971	3.637
Water heating	GWa	0.127	0.187	0.268	0.372	0.547	0.810
Cooking	GWa	0.141	0.161	0.188	0.213	0.243	0.276
Air conditioning	GWa	0.054	0.077	0.110	0.155	0.235	0.298
Elec. for appliances	GWa	0.116	0.174	0.258	0.368	0.532	0.735
FF for lighting	GWa	0.002	0.002	0.001	0.001	0.000	0.000
Total	GWa	1.630	2.050	2.646	3.411	4.528	5.756

Figure 3.31. Snapshot of Table 14-3 of worksheet "US HH Ur-D".

Table 14-5 Penetration of energy forms into space heating, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	5.000	4.500	4.000	3.000	2.000	1.000
Modern biomass	[%]	2.000	2.500	3.000	3.500	4.000	5.000
Electricity	[%]	5.000	6.000	7.000	8.000	9.000	10.000
(thereof: heat pump)	[%]	1.000	2.000	3.000	4.000	5.000	6.000
District heat	[%]	0.000	0.000	0.000	3.000	5.000	8.000
Soft solar	[%]	0.000	0.000	0.000	1.000	2.000	4.000
Fossil fuels	[%]	88.0	87.0	86.0	81.5	78.0	72.0

Table 14-6 Efficiencies and other factors for space heating, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Eff. Trad. fuels	[%]	15.000	16.000	17.000	18.000	19.000	20.000
Eff. Mod. biomass	[%]	25.000	26.000	27.000	28.000	29.000	30.000
Eff. Fossil fuels	[%]	60.000	61.000	62.000	63.000	64.000	65.000
COP heat pumps	[ratio]	2.500	2.750	3.000	3.500	4.000	4.500
Solar share	[%]	40.000	40.000	40.000	40.000	40.000	40.000

Table 14-7 Penetration of energy forms into water heating, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	5.000	4.500	4.000	3.000	2.000	1.000
Modern biomass	[%]	2.000	2.500	3.000	3.500	4.000	5.000
Electricity	[%]	5.000	6.000	7.000	8.000	9.000	10.000
(thereof: heat pump)	[%]	1.000	2.000	3.000	4.000	5.000	6.000
District heat	[%]	0.000	0.000	0.000	3.000	5.000	8.000
Soft solar	[%]	0.000	0.000	0.000	1.000	2.000	4.000
Fossil fuels	[%]	88.0	87.0	86.0	81.5	78.0	72.0

Table 14-8 Efficiencies and other factors for water heating, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Eff. Trad. fuels	[%]	15.000	16.000	17.000	18.000	19.000	20.000
Eff. Mod. biomass	[%]	25.000	26.000	27.000	28.000	29.000	30.000
Eff. Fossil fuels	[%]	60.000	61.000	62.000	63.000	64.000	65.000
COP heat pumps	[ratio]	2.500	2.750	3.000	3.500	4.000	4.500
Solar share	[%]	40.000	40.000	40.000	40.000	40.000	40.000

Table 14-9 Penetration of energy forms into cooking, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	10.000	9.000	8.000	7.000	5.000	3.000
Modern biomass	[%]	5.000	6.000	7.000	8.000	9.000	10.000
Electricity	[%]	5.000	6.000	7.000	8.000	9.000	10.000
Soft solar	[%]	0.000	0.000	0.000	1.000	2.000	3.000
Fossil fuels	[%]	80.0	79.0	78.0	76.0	75.0	74.0

Table 14-10 Efficiencies and other factors for cooking, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Eff. Trad. fuels	[%]	12.000	12.500	13.000	13.500	14.000	14.000
Eff. Mod. biomass	[%]	20.000	21.000	22.000	23.000	24.000	25.000
Eff. Fossil fuels	[%]	50.000	51.000	52.000	53.000	54.000	55.000
Solar share	[%]	40.000	40.000	40.000	40.000	40.000	40.000

Table 14-11 Penetration into air conditioning by technology, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	[%]	95.000	93.000	90.000	87.000	84.000	80.000
Non-electric	[%]	5.00	7.00	10.00	13.00	16.00	20.00

Table 14-12 Efficiencies for air conditioning, Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
COP electric AC	[ratio]	2.500	2.600	2.700	2.800	2.900	3.000
COP non-electric AC	[ratio]	2.500	2.600	2.700	2.800	2.900	3.000

Figure 3.32. Snapshot of input data tables of worksheet "US_HH_Ur-D".

The other tables of the worksheet are meant to allow entering of the following input data (Figure 3.32):

- penetration of different energy carriers (traditional fuels, modern biomass, electricity, heat pumps, district heating, soft solar and fossil fuels) into the markets of space heating (Table 14-5), water heating (Table 14-7), cooking (Table 14-9) and air conditioning (Table 14-11) of the Urban Household subsector;

- data such as efficiencies / coefficients of performance (COP) of different energy carriers when used in the Urban Household subsector for the previously-mentioned applications: space heating (Table 14-6), water heating (Table 14-8), cooking (Table 14-10) and air conditioning (Table 14-12). For the detailed definitions of these variables the user should refer to Section 4, Tables 4.1 and 4.2.

The previous input data and the model-calculated data on useful energy demand stored in this worksheet are used in worksheet "FIN_HH-D" to work out the final energy demand of the Household sector.

(b) Worksheet "US_HH_Rr-D" (Table 15)

This worksheet has the same functions and structure as the previous one (US_HH_Ur-D) but it deals with rural dwellings.

(c) Worksheet "FIN_HH-D" (Table 16)

The worksheet "FIN_HH-D" converts the previously calculated useful energy demand to final energy demand by type of end-use (space heating, water heating, cooking, air conditioning and appliances) and by type of energy carrier (traditional fuels, modern biomass, electricity, district heating, soft solar and fossil fuels), for urban dwellings (Tables 16-1 to 16-6), rural dwellings (Tables 16-7 to 16-12), and sums up the results for the two subsectors as final energy demand of the entire Household sector (Tables 16-13 to 16-18). Figure 3.33 illustrates the final energy results for urban Household sub sector.

Final energy demand in Household sector

Urban

Table 16-1 Urban Household, space heating

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	0.397	0.408	0.428	0.384	0.313	0.182
Modern biomass	GWa	0.095	0.139	0.202	0.288	0.410	0.606
Electricity	GWa	0.059	0.086	0.125	0.179	0.257	0.347
District heat	GWa	0.000	0.000	0.000	0.069	0.149	0.291
Soft solar	GWa	0.000	0.000	0.000	0.009	0.024	0.058
Fossil fuels	GWa	1.746	2.067	2.525	3.000	3.676	4.163
Total	GWa	2.298	2.699	3.281	3.928	4.829	5.647

Table 16-2 Urban Household, water heating

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	0.042	0.053	0.063	0.062	0.058	0.041
Modern biomass	GWa	0.010	0.018	0.030	0.047	0.075	0.135
Electricity	GWa	0.006	0.011	0.018	0.029	0.047	0.077
District heat	GWa	0.000	0.000	0.000	0.011	0.027	0.065
Soft solar	GWa	0.000	0.000	0.000	0.001	0.004	0.013
Fossil fuels	GWa	0.186	0.267	0.372	0.485	0.677	0.928
Total	GWa	0.245	0.348	0.483	0.635	0.889	1.258

Table 16-3 Urban Household, cooking

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	0.117	0.116	0.116	0.110	0.087	0.059
Modern biomass	GWa	0.035	0.046	0.060	0.074	0.091	0.110
Electricity	GWa	0.703	0.967	1.317	1.704	2.189	2.756
Soft solar	GWa	0.000	0.000	0.000	0.001	0.002	0.003
Fossil fuels	GWa	0.225	0.250	0.282	0.308	0.343	0.380
Total	GWa	1.080	1.378	1.775	2.197	2.712	3.309

Table 16-4 Urban Household, air conditioning

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.020	0.028	0.037	0.048	0.068	0.079
Non-electric	GWa	0.001	0.002	0.004	0.007	0.013	0.020
Total	GWa	0.021	0.030	0.041	0.055	0.081	0.099

Table 16-5 Urban Household, appliances

Item	Unit	2000	2005	2010	2015	2020	2025
Elec. for appliances	GWa	0.116	0.174	0.258	0.368	0.532	0.735
FF for lighting	GWa	0.002	0.002	0.001	0.001	0.000	0.000
Total	GWa	0.118	0.176	0.259	0.369	0.532	0.735

Table 16-6 Total final energy demand in Urban Household

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	0.556	0.576	0.607	0.556	0.457	0.281
Modern biomass	GWa	0.141	0.203	0.292	0.408	0.576	0.852
Electricity	GWa	0.905	1.265	1.755	2.328	3.094	3.995
District heat	GWa	0.000	0.000	0.000	0.080	0.176	0.356
Soft solar	GWa	0.000	0.000	0.000	0.012	0.030	0.074
Fossil fuels	GWa	2.161	2.587	3.185	3.800	4.710	5.491
Total	GWa	3.763	4.632	5.839	7.184	9.043	11.049

Figure 3.33. Snapshot of Tables 16-1 to 16-6 of worksheet "FIN_HH-D".

3.3.9 Worksheets for service sector (Tables 17 to 19)

The energy demand analysis of the Service sector is covered by three worksheets: "US_SS-D", meant for entering those input data which allow the model to calculate the useful energy demand for space heating, air conditioning, motor fuels, electricity specific uses and other thermal uses (excluding space heating); "SS_Fac-D", serving for entering the penetration of different energy carriers into the various useful energy markets of the sector (space heating, other thermal uses and air conditioning); and "FIN_SS-D", which converts the previously calculated useful energy demand to final energy demand by type of end-use (thermal uses, air conditioning and electricity specific uses) and by type of energy carrier (traditional fuels, modern biomass, electricity, district heating, soft solar, fossil fuels and motor fuels). As already mentioned in Section 2, the categories of energy use considered in the Service sector are: space heating, air conditioning, motor fuels, electricity specific uses and other thermal uses (water heating and cooking). The energy demand for space heating and air conditioning is calculated based on specific space heating and cooling requirements (kWh/sqm/yr) while the energy demand for motor fuels, electricity specific uses and other thermal uses (water heating and cooking) is calculated through value added and energy intensity at Service sub sector level.

(a) Worksheet "US_SS-D" (Table 17)

The input data required to be entered into this worksheet are the following (see Figure 3.34):

- share (%) of Service sector in the total labour force and average floor area per employee (sqm/cap) in Table 17-1;
- share (%) of floor area requiring space heating and what of that (%) is actually heated, specific space heat requirements (kWh/sqm/yr), share (%) of air-conditioned floor area and specific cooling requirements (kWh/sqm/yr) in Table 17-2;
- energy intensities for motor fuels (Table 17-4), specific uses of electricity (Table 17-5) and other thermal uses, except space heating (Table 17-6).

The model-calculated data are:

- labour force (million employees) and floor area (million sqm) in Service sector (Table 17-1);
- useful energy demand for space heating and air conditioning (Table 17-3), motor fuels (Table 17-7), specific uses of electricity (Table 17-8), and other thermal uses (Table 17-9);
- total useful energy demand for the entire Service sector (Table 17-10).

Figure 3.35 shows the model-calculated data included in Tables 17-3 and Tables 17-7 to 17-10.

Useful energy demand in Service sector

Table 17-1 Basic data for useful energy demand in Service sector

Item	Unit	2000	2005	2010	2015	2020	2025
Labour force in SS	[%]	45.000	46.000	47.000	48.000	49.000	50.000
Floor area per emp.	[sqm/cap]	8.000	8.400	8.800	9.200	9.600	10.000
Labour force in SS	[mill cap]	1.689	2.059	2.536	3.139	3.888	4.800
Floor area of SS	[mill sqm]	13.512	17.300	22.320	28.878	37.320	48.001

Table 17-2 Factors for space heating and air conditioning

Item	Unit	2000	2005	2010	2015	2020	2025
Share of area req. SH	[%]	100.000	100.000	100.000	100.000	100.000	100.000
Area actually heated	[%]	50.000	55.000	60.000	65.000	70.000	75.000
Specific SH req.	[kWh/sqm/yr]	60.000	58.000	56.000	54.000	52.000	50.000
Air cond. floor area	[%]	10.000	15.000	20.000	25.000	30.000	40.000
Specific cooling req.	[kWh/sqm/yr]	50.000	50.000	50.000	50.000	50.000	50.000

Energy intensities for end-uses other than space heating and air conditioning

Table 17-4 Energy intensities of Motor fuels

Item	Unit	2000	2005	2010	2015	2020	2025
Service	[kWh/US$]	0.169	0.175	0.180	0.184	0.187	0.189
Commer.& tour.	[kWh/US$]	0.400	0.400	0.400	0.400	0.400	0.400
Public admins.	[kWh/US$]	0.200	0.200	0.200	0.200	0.200	0.200
Finance&buss.	[kWh/US$]	0.050	0.050	0.050	0.050	0.050	0.050
Persn. serv. & others	[kWh/US$]	0.100	0.100	0.100	0.100	0.100	0.100

Table 17-5 Energy intensities of Electricity specific uses

Item	Unit	2000	2005	2010	2015	2020	2025
Service	[kWh/US$]	1.086	1.086	1.085	1.085	1.085	1.086
Commer.& tour.	[kWh/US$]	1.070	1.070	1.070	1.070	1.070	1.070
Public admins.	[kWh/US$]	1.050	1.050	1.050	1.050	1.050	1.050
Finance&buss.	[kWh/US$]	1.200	1.200	1.200	1.200	1.200	1.200
Persn. serv. & others	[kWh/US$]	1.100	1.100	1.100	1.100	1.100	1.100

Table 17-6 Energy intensities of Other thermal uses

Item	Unit	2000	2005	2010	2015	2020	2025
Service	[kWh/US$]	0.123	0.127	0.130	0.132	0.134	0.135
Commer.& tour.	[kWh/US$]	0.300	0.300	0.300	0.300	0.300	0.300
Public admins.	[kWh/US$]	0.100	0.100	0.100	0.100	0.100	0.100
Finance&buss.	[kWh/US$]	0.050	0.050	0.050	0.050	0.050	0.050
Persn. serv. & others	[kWh/US$]	0.100	0.100	0.100	0.100	0.100	0.100

Figure 3.34. Snapshot of input data tables of worksheet "US SS-D".

(b) Worksheet "SS_Fac-D" (Table 18)

In this worksheet the user should enter the following input data:

- penetrations of different energy carriers (traditional fuels, modern biomass, electricity, heat pumps, district heat, soft solar and fossil fuels) into the space heating market (Table 18-1);
- penetrations of different energy carriers into the market of other thermal uses: hot water and cooking (Table 18-2);
- efficiencies of various fuels, coefficient of performance of heat pumps and other factors related to all thermal uses (space heating, hot water and cooking) in Service sector (Table 18-3);
- penetration of electric and non-electric equipment in the market of air conditioning (Table 18-4);
- coefficients of performance of electric and non-electric air conditioning equipment (Table 18-5).

A snapshot of this worksheet is shown in Figure 3.36.

Table 17-3 Useful energy demand for space heating and air conditioning

Item	Unit	2000	2005	2010	2015	2020	2025
Total area heated	[mill sqm]	6.756	9.515	13.392	18.771	26.124	36.001
Space heating	GWa	0.046	0.063	0.086	0.116	0.155	0.205
Air conditioning	GWa	0.008	0.015	0.025	0.041	0.064	0.110

Useful energy demand for end-uses other than space heating and air conditioning

Table 17-7 Useful energy demand of Motor fuels

Item	Unit	2000	2005	2010	2015	2020	2025
Service	GWa	0.316	0.419	0.555	0.738	0.975	1.277
Commer.& tour.	GWa	0.098	0.144	0.204	0.289	0.395	0.527
Public admins.	GWa	0.122	0.158	0.207	0.273	0.359	0.473
Finance&buss.	GWa	0.006	0.008	0.011	0.015	0.021	0.030
Persn. serv. & others	GWa	0.091	0.109	0.133	0.162	0.200	0.247

Table 17-8 Useful energy demand of Electricity specific uses

Item	Unit	2000	2005	2010	2015	2020	2025
Service	GWa	2.038	2.600	3.353	4.349	5.644	7.333
Commer.& tour.	GWa	0.261	0.384	0.545	0.772	1.057	1.409
Public admins.	GWa	0.640	0.830	1.087	1.431	1.884	2.482
Finance&buss.	GWa	0.135	0.187	0.260	0.361	0.506	0.729
Persn. serv. & others	GWa	1.001	1.199	1.461	1.786	2.197	2.712

Table 17-9 Useful energy demand of Other thermal uses

Item	Unit	2000	2005	2010	2015	2020	2025
Service	GWa	0.231	0.304	0.400	0.530	0.697	0.908
Commer.& tour.	GWa	0.073	0.108	0.153	0.216	0.296	0.395
Public admins.	GWa	0.061	0.079	0.104	0.136	0.179	0.236
Finance&buss.	GWa	0.006	0.008	0.011	0.015	0.021	0.030
Persn. serv. & others	GWa	0.091	0.109	0.133	0.162	0.200	0.247

Table 17-10 Total useful energy demand in Service sector

Item	Unit	2000	2005	2010	2015	2020	2025
Space heating	GWa	0.046	0.063	0.086	0.116	0.155	0.205
Air conditioning	GWa	0.008	0.015	0.025	0.041	0.064	0.110
Motor fuels	GWa	0.316	0.419	0.555	0.738	0.975	1.277
Electricity spec. uses	GWa	2.038	2.600	3.353	4.349	5.644	7.333
Other thermal uses	GWa	0.231	0.304	0.400	0.530	0.697	0.908
Total	GWa	2.639	3.400	4.419	5.775	7.535	9.833

Figure 3.35. Snapshot of calculated data tables of worksheet "US SS-D".

Penetration of energy carriers into useful energy demand, and efficiencies in Service sector

Table 18-1 Penetration of energy forms into Space heating

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	25.000	23.000	21.000	19.000	17.000	15.000
Modern biomass	[%]	2.000	3.000	4.000	6.000	8.000	10.000
Electricity	[%]	8.000	10.000	12.000	14.000	16.000	18.000
(thereof: heat pump)	[%]	10.000	12.000	14.000	16.000	18.000	20.000
District heat	[%]	0.000	0.000	5.000	7.000	10.000	12.000
Soft solar	[%]	0.000	1.000	3.000	5.000	7.000	9.000
Fossil fuels	[%]	65.00	63.00	55.00	49.00	42.00	36.00

Table 18-2 Penetration of energy forms into Other thermal uses

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[%]	25.000	23.000	21.000	19.000	17.000	15.000
Modern biomass	[%]	2.000	3.000	4.000	6.000	8.000	10.000
Electricity	[%]	8.000	10.000	12.000	14.000	16.000	18.000
District heat	[%]	0.000	0.000	5.000	7.000	10.000	12.000
Soft solar	[%]	0.000	1.000	3.000	5.000	7.000	9.000
Fossil fuels	[%]	65.00	63.00	55.00	49.00	42.00	36.00

Table 18-3 Efficiencies and other factors for Thermal uses

Item	Unit	2000	2005	2010	2015	2020	2025
Eff. Trad. fuels	[%]	15.000	16.000	17.000	18.000	19.000	20.000
Eff. Mod. biomass	[%]	25.000	26.000	27.000	28.000	29.000	30.000
Eff. Fossil fuels	[%]	60.000	61.000	62.000	63.000	64.000	65.000
COP heat pumps	[ratio]	2.500	2.750	3.000	3.500	4.000	4.500
Low rise buildings	[%]	70.000	65.000	60.000	55.000	50.000	50.000
Solar share	[%]	40.000	40.000	40.000	40.000	40.000	40.000

Table 18-4 Penetration of energy forms into Air conditioning

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	[%]	90.000	86.000	82.000	78.000	74.000	70.000
Non-electric	[%]	10.00	14.00	18.00	22.00	26.00	30.00

Table 18-5 Efficiencies for Air conditioning

Item	Unit	2000	2005	2010	2015	2020	2025
COP of electric AC	[ratio]	2.500	2.600	2.700	2.800	2.900	3.000
COP of non-electric AC	[ratio]	2.500	2.600	2.700	2.800	2.900	3.000

Figure 3.36. Snapshot worksheet "SS_Fac-D".

(c) Worksheet "FIN_SS-D" (Table 19)

This worksheet calculates and shows the final energy demand of the Service sector by end-uses: thermal uses, air conditioning and specific uses of electricity and by energy form: traditional fuels, modern biomass, electricity, district heat, soft solar, fossil fuels and motor fuels (Figure 3.37).

Final energy demand in Service sector

Table 19-1 Final energy demand for Thermal uses

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	0.462	0.527	0.600	0.682	0.762	0.835
Modern biomass	GWa	0.022	0.042	0.072	0.138	0.235	0.371
Electricity	GWa	0.022	0.036	0.057	0.089	0.133	0.195
District heat	GWa	0.000	0.000	0.024	0.045	0.085	0.134
Soft solar	GWa	0.000	0.001	0.003	0.007	0.012	0.020
Fossil fuels	GWa	0.300	0.381	0.439	0.519	0.587	0.663
Total	GWa	0.806	0.987	1.196	1.480	1.814	2.219

Table 19-2 Final energy demand for Air conditioning

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	0.003	0.005	0.008	0.011	0.016	0.026
Non-electric	GWa	0.000	0.001	0.002	0.003	0.006	0.011
Total	GWa	0.003	0.006	0.009	0.015	0.022	0.037

Table19-3 Final energy demand for Electricity specific uses

Item	Unit	2000	2005	2010	2015	2020	2025
Electricity	GWa	2.038	2.600	3.353	4.349	5.644	7.333

Table 19-4 Total final energy demand in Service sector (by energy forms)

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	0.462	0.527	0.600	0.682	0.762	0.835
Modern biomass	GWa	0.022	0.042	0.072	0.138	0.235	0.371
Electricity	GWa	2.062	2.641	3.418	4.449	5.793	7.553
District heat	GWa	0.000	0.000	0.024	0.045	0.085	0.134
Soft solar	GWa	0.000	0.001	0.003	0.007	0.012	0.020
Fossil fuels	GWa	0.301	0.382	0.441	0.522	0.593	0.674
Motor fuels	GWa	0.316	0.419	0.555	0.738	0.975	1.277
Total	GWa	3.163	4.012	5.114	6.582	8.455	10.865

Figure 3.37. Snapshot of worksheet "FIN SS-D".

3.3.10 Worksheets Showing the Final Results of MAED_D Model (Tables 20 and 21)

The final results of the energy demand analysis for the entire system under study are shown in both energy unit specified by the user in cells E50 and L50 of worksheet “Defs”.

(a) Worksheet “Final-D” (Table 20)

This worksheet calculates and stores the final set of results of final energy demand analysis worked out by MAED_D in the energy unit specified by the user in cell E50 of worksheet “Defs” (default: GWa). It consists of 12 tables. The first table (Table 20-1) gives the total final energy demand and its break-up into various energy forms (traditional fuels, modern biomass. electricity, district heat, soft solar, fossil fuels, motor fuels, coke & steam coal, and feedstock). The next table (Table 20-2) shows the values of final energy demand per capita (MWh/cap) and final energy demand per monetary unit of GDP (kWh/US$). The third table (Table 20-3) reports on the values of total final energy demand by sector. The sectors considered here are: Industry, which is split further into Manufacturing and ACM (Agriculture, Construction and Mining), Transportation (split further into freight and passenger subsectors), Household and Service. The final energy demand of each of the nine energy forms contained in Table 20-1 is then disaggregated in Tables 20-4 to 20-12 by the sectors mentioned for Table 20-3. Figure 3.38 illustrates the content of Tables 20-1 to 20-4. Tables 20-5 to 20-12 are similar to Table 20-4 but are related to other energy forms.

Total final energy demand

Table 20-1 Final energy demand by energy form

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	GWa	7.912	7.992	7.987	7.898	7.756	6.765
Modern biomass	GWa	0.910	1.647	2.622	3.913	5.587	7.775
Electricity	GWa	3.822	5.216	7.103	9.605	12.803	16.765
District heat	GWa	0.064	0.080	0.123	0.245	0.404	0.661
Soft solar	GWa	0.000	0.003	0.008	0.027	0.055	0.112
Fossil fuels	GWa	5.234	6.236	7.392	8.584	10.045	11.786
Motor fuels	GWa	5.754	6.449	7.326	8.411	9.737	11.275
Coke & steam coal	GWa	0.778	0.846	0.999	1.089	1.096	0.968
Feedstock	GWa	0.882	1.159	1.521	1.926	2.376	2.794
Total	GWa	25.356	29.627	35.081	41.696	49.858	58.901

Table 20-2 Final energy demand per capita and per GDP

Item	Unit	2000	2005	2010	2015	2020	2025
FE per capita	[MWh/cap]	11.599	11.979	12.659	13.561	14.760	16.027
FE per GDP	[kWh/US$]	6.620	6.061	5.677	5.389	5.196	4.997

Table 20-3 Final energy demand by sector

Item	Unit	2000	2005	2010	2015	2020	2025
Industry	GWa	5.510	7.126	9.149	11.384	13.837	16.324
Manufacturing	GWa	4.043	5.370	7.070	8.990	11.119	13.300
ACM	GWa	1.467	1.756	2.078	2.393	2.718	3.024
Transportation	GWa	4.864	5.286	5.872	6.628	7.548	8.615
Freig.transp.	GWa	4.061	4.281	4.516	4.780	5.080	5.395
Pass.transp.	GWa	0.803	1.005	1.356	1.848	2.467	3.220
Household	GWa	11.819	13.203	14.947	17.102	20.018	23.097
Service	GWa	3.163	4.012	5.114	6.582	8.455	10.865
Total	GWa	25.356	29.627	35.081	41.696	49.858	58.901

Table 20-4 Traditional fuels by sector

Item	Unit	2000	2005	2010	2015	2020	2025
Industry	GWa	0.197	0.195	0.187	0.173	0.151	0.113
Manufacturing	GWa	0.156	0.153	0.146	0.135	0.117	0.084
ACM	GWa	0.041	0.042	0.041	0.038	0.034	0.029
Transportation	GWa	0.000	0.000	0.000	0.000	0.000	0.000
Freig.transp.	GWa	0.000	0.000	0.000	0.000	0.000	0.000
Pass.transp.	GWa	0.000	0.000	0.000	0.000	0.000	0.000
Household	GWa	7.253	7.269	7.201	7.044	6.843	5.816
Service	GWa	0.462	0.527	0.600	0.682	0.762	0.835
Total	GWa	7.912	7.992	7.987	7.898	7.756	6.765

Figure 3.38. Snapshot of Tables 20-1 to 20-4 of worksheet "Final-D".

(b) Worksheet “Final Results (User Unit)” (Table 21)

This worksheet just converts the final results from worksheet “Final-D” from the energy unit specified in cell E50 to the energy unit chosen by the user in cell L50 of the worksheet “Defs”. It has the same structure as the worksheet “Final-D” (Figure 3.39).

Total final energy demand (User unit)

Table 21-1 Final energy demand by energy form

Item	Unit	2000	2005	2010	2015	2020	2025
Traditional fuels	[Mtoe]	5.960	6.020	6.016	5.949	5.842	5.095
Modern biomass	[Mtoe]	0.685	1.240	1.975	2.947	4.208	5.857
Electricity	[Mtoe]	2.879	3.929	5.350	7.234	9.643	12.628
District heat	[Mtoe]	0.048	0.061	0.092	0.184	0.304	0.498
Soft solar	[Mtoe]	0.000	0.002	0.006	0.020	0.041	0.085
Fossil fuels	[Mtoe]	3.942	4.697	5.568	6.465	7.566	8.878
Motor fuels	[Mtoe]	4.334	4.857	5.518	6.335	7.334	8.493
Coke & steam coal	[Mtoe]	0.586	0.637	0.753	0.820	0.825	0.729
Feedstock	[Mtoe]	0.664	0.873	1.145	1.450	1.789	2.104
Total	[Mtoe]	19.099	22.316	26.424	31.407	37.554	44.366

Table 21-2 Final energy demand per capita and per GDP

Item	Unit	2000	2005	2010	2015	2020	2025
FE per capita	[MWh/cap]	11.599	11.979	12.659	13.561	14.760	16.027
FE per GDP	[kWh/US$]	6.620	6.061	5.677	5.389	5.196	4.997

Table 21-3 Final energy demand by sector

Item	Unit	2000	2005	2010	2015	2020	2025
Industry	[Mtoe]	4.150	5.368	6.891	8.575	10.423	12.296
Manufacturing	[Mtoe]	3.045	4.045	5.326	6.772	8.375	10.018
ACM	[Mtoe]	1.105	1.323	1.565	1.803	2.047	2.278
Transportation	[Mtoe]	3.663	3.982	4.423	4.992	5.685	6.489
Freig. transp.	[Mtoe]	3.059	3.224	3.402	3.600	3.827	4.063
Pass. transp.	[Mtoe]	0.604	0.757	1.021	1.392	1.858	2.426
Household	[Mtoe]	8.902	9.945	11.259	12.882	15.078	17.397
Service	[Mtoe]	2.383	3.022	3.852	4.958	6.369	8.184
Total	[Mtoe]	19.099	22.316	26.424	31.407	37.554	44.366

Table 21-4 Traditional fuels by sector

Item	Unit	2000	2005	2010	2015	2020	2025
Industry	[Mtoe]	0.149	0.147	0.140	0.130	0.114	0.085
Manufacturing	[Mtoe]	0.117	0.115	0.110	0.101	0.088	0.063
ACM	[Mtoe]	0.031	0.032	0.031	0.029	0.026	0.022
Transportation	[Mtoe]	0.000	0.000	0.000	0.000	0.000	0.000
Freig. transp.	[Mtoe]	0.000	0.000	0.000	0.000	0.000	0.000
Pass. transp.	[Mtoe]	0.000	0.000	0.000	0.000	0.000	0.000
Household	[Mtoe]	5.463	5.475	5.424	5.306	5.154	4.381
Service	[Mtoe]	0.348	0.397	0.452	0.513	0.574	0.629
Total	[Mtoe]	5.960	6.020	6.016	5.949	5.842	5.095

Figure 3.39. Snapshot of Tables 21-1 to 21-4 of worksheet "Final results (User unit)".

Once the analysis of a particular scenario has been completed through the application of MAED_D, the user should carefully review the whole set of results, once again, in addition to the review of the particular results contained in various worksheets that the user would have been doing throughout the exercise. During the reconstruction of base year energy consumption patterns within the model the user should compare after each run of the program the final energy consumption by energy form and by sector calculated by MAED_D with the final energy consumption from the final energy balance of the country/region for the base year. If any difference persists, further adjustments of input data and additional runs of the program are necessary. The printout of the entire Demonstration Case is shown in Appendix 1 for illustration purposes. Each table/sub-table presents the selected values for every year which has been analyzed and chosen for printing to facilitate the comparison between years. The project (case study) and scenario description, as specified in worksheet “Descr”, is included as a cover page, in order to permit a quick identification of the printout. This identification is rather convenient particularly when several scenarios of development have to be investigated for the same case study.

If a thorough study of the report and its comparison with the reports of other scenarios of the same case study (if available) brings to light some weaknesses in any parts of the results, the user should carefully review both, the corresponding input data and the relevant scenario assumptions, make necessary changes and rerun the model MAED_D. This process of reiteration should be continued until the user feels satisfied with the results of the scenario being investigated

4 INPUT AND DERIVED VARIABLES OF MAED MODULE 1

4.1 Introduction

In order to be able to operate a mathematical model properly and to appreciate fully the significance of its output results, one needs to know: (i) the exact definitions of its input and output parameters (variables), and (ii) the way each output parameter is worked out by the model using the input data provided by the user. This section provides information on the first of the above two aspects concerning the Module 1 of MAED model; the second aspect is covered in Section 5.

4.2 Input variables

Table 4.1 provides a list of the input variables of MAED_D, together with their definitions. Also included in this table are a few variables for which input values are not required to be entered by the user; the model assumes their values as the balance left after deducting from the whole the values of certain other input variables (please refer to Section 3.3.2.3). Each variable of MAED_D is assigned a symbolic name. The first column of Table 4.1 lists the symbolic names of the input variables; the second column contains their definitions; the third column spells out the corresponding units of measurement; and the last column provides additional comments, if required to clarify the significance of a particular variable.

The variables in Table 4.1 are arranged in 6 different groups: Demography, GDP formation, Industry, Transportation, Household and Service. Some of the groups have been split into two or more subgroups in order to facilitate the user in locating the position of a particular parameter of interest within the table. For example, the parameters corresponding to the Transportation group have been split into three subgroups: (i) Freight transportation, (ii) Intracity passenger transportation, and (iii) Intercity passenger transportation. The correspondence of each group/subgroup in Table 4.1 with the input parameters covered in various tables of the EXCEL worksheets of MAED_D has also been shown under the heading of each group/subgroup.

4.3 Derived variables

Table 4.2 provides information about the derived/output variables of MAED_D. Of the variables listed in this table, all but 13 appear in various tables contained in the EXCEL worksheets of MAED_D. The 13 additional variables are interim derived variables i.e. they appear only in some intermediate steps of the calculations described in Section 5 but their values are not readily available in the worksheets of MAED_D; they have been underlined in Table 4.2 as well as in Section 5 in order to facilitate their easy identification.

As against four columns in Table 4.1, Table 4.2 has only three columns: the first column lists the symbolic names of the derived variables, the second column gives their units of measurement, while the third column provides explanatory notes to define these variables.

The variables listed in Table 4.2 have been arranged in groups and subgroups essentially according their correspondence with the derived parameters included in various tables of the EXCEL worksheets of MAED_D. It should be noted that the units indicated in this table for the variables representing energy values are GWa, which correspond to the default energy unit of the model. However, as discussed in Sections 3.3.2.1 and 5.2, the user can readily arrange to have the model's output results worked out and displayed in some other energy unit by providing the name of that unit and the corresponding value of the conversion factor in the worksheet "Defs" of MAED_D.

Table 4.1a List and Definition of input variables of module MAED_D of MAED Model

VARIABLE	DEFINITION	UNIT	COMMENT
DEFINITIONS: (see worksheet “Defs” of MAED_D.xls)			
NRY	Number of reference years for the case study.	-	Max. 25
RY(I)	Reference years for the case study. I=1,……,NRY	-	
NSAGR	Number of subsectors of Agriculture sector.	-	Max. 10
NSCON	Number of subsectors of Construction sector.	-	Max. 10
NSMIN	Number of subsectors of Mining sector.	-	Max. 10
NSMAN	Number of subsectors of Manufacturing sector.	-	Max. 10
NSSER	Number of subsectors of Service sector.	-	Max. 10
NMFT	Number of freight transportation modes.	-	Max. 15
NMIT	Number of intercity passenger transportation modes.	-	Max. 15
NCTIT	Number of car types in intercity passenger transportation.	-	Max. 5
NMUT	Number of intracity (urban) passenger transportation modes.	-	Max. 15
NTF	Number of fuels used in Transportation sector.		Max. 8
NUDT	Number of urban dwelling types.	-	Max. 10
NRDT	Number of rural dwelling types.	-	Max. 10

Table 4.1b List and definition of input variables of demography

DEMOGRAPHY: (see worksheet “Demogr-D” of MAED_D.xls)			
PO	Total population.	milion persons	May be calculated by the program, if annual growth rate is entered.
POGR	Average annual growth rate of population between the previous and current model years.	% p.a.	May be calculated by the program, if total population is entered.
PURB	Share of urban population.	%	According to UN definition.
CAPUH	Average household size in urban areas.	persons/ household	The term household is used in the sense "persons living together in one dwelling".
CAPRH	Average household size in rural areas.	persons/ household	The term household is used in the sense "persons living together in one dwelling".
PLF	Share of population of age 15 - 64 in the total population (potential labour force).	%	
PARTLF	Share of potential labour force actually working.	%	
POPLC	Share of population living in large cities.	%	Variable used to determine the approximate potential market for intracity mass transportation.

Table 4.1c List and definition of input variables of GDP formation

GDP FORMATION: (see worksheet "GDP-D" of MAED_D.xls)			
Y	Total GDP.	billion MU	MU stands for monetary units of base year.
YGR	Average annual growth rate of GDP between the previous and current model years.	% p.a.	
PYAGR PYCON PYMIN PYMAN PYSER PYEN	Distribution of GDP formation by kind of economic activity. Sectors considered are: Agriculture (AGR), Construction (CON), Mining (MIN), Manufacturing (MAN), Service (SER) and Energy (EN).	%	The sum of these variables must be 100. Therefore, direct input is provided only for the first five of them, while the share for the last one (PYEN) is calculated by the program as the remainder.
PVAAG(I)	Distribution of Agriculture (AGR) sector value added by subsectors. I=1,…..,NSAGR	%	The sum of these variables must be 100. Therefore, direct input is provided only for the first (NSAGR-1) subsectors, while the program calculates the share for the last one as the remainder.
PVACO(I)	Distribution of Construction (CON) sector value added by subsectors. I=1,…..,NSCON	%	The sum of these variables must be 100. Therefore, direct input is provided only for the first (NSCON-1) subsectors, while the program calculates the share for the last one as the remainder.
PVAMI(I)	Distribution of Mining (MIN) sector value added by subsectors. I=1,…..,NSMIN	%	The sum of these variables must be 100. Therefore, direct input is provided only for the first (NSMIN-1) subsectors, while the program calculates the share for the last one as the remainder.
PVAMA(I)	Distribution of Manufacturing (MAN) sector value added by subsectors. I=1,…..,NSMAN	%	The sum of these variables must be 100. Therefore, direct input is provided only for the first (NSMAN-1) subsectors, while the program calculates the share for the last one as the remainder.
PVASE(I)	Distribution of Service (SER) sector value added by subsectors. I=1,…..,NSSER	%	The sum of these variables must be 100. Therefore, direct input is provided only for the first (NSSER-1) subsectors, while the program calculates the share for the last one as the remainder.

Table 4.1d List and definition of input variables of energy intensities in industry

INDUSTRY:			
ENERGY INTENSITIES IN INDUSTRY (AGRICULTURE, CONSTRUCTION, MINING AND MANUFACTURING): (see worksheet "EnInt-D" of MAED_D.xls)			
EI.MF.AG(I)	Specific motor fuel consumption per monetary unit of value added (energy intensity) of subsector I of Agriculture sector. I=1,…..,NSAGR	kWh/MU	Expressed in terms of final energy per MU.
EI.MF.CO(I)	Specific motor fuel consumption per monetary unit of value added (energy intensity) of subsector I of Construction sector. I=1,…..,NSCON	kWh/MU	Expressed in terms of final energy per MU.
EI.MF.MI(I)	Specific motor fuel consumption per monetary unit of value added (energy intensity) of subsector I of Mining sector. I=1,…..,NSMIN	kWh/MU	Expressed in terms of final energy per MU.
EI.MF.MA(I)	Specific motor fuel consumption per monetary unit of value added (energy intensity) of subsector I of Manufacturing sector. I=1,…..,NSMAN	kWh/MU	Expressed in terms of final energy per MU.
EI.ELS.AG(I)	Specific electricity consumption (for specific uses) per monetary unit of value added (energy intensity) of subsector I of Agriculture sector. I=1,…..,NSAGR	kWh/MU	Expressed in terms of final energy per MU.
EI.ELS.CO(I)	Specific electricity consumption (for specific uses) per monetary unit of value added (energy intensity) of subsector I of Construction sector. I=1,…..,NSCON	kWh/MU	Expressed in terms of final energy per MU.
EI.ELS.MI(I)	Specific electricity consumption (for specific uses) per monetary unit of value added (energy intensity) of subsector I of Mining sector. I=1,…..,NSMIN	kWh/MU	Expressed in terms of final energy per MU.
EI.ELS.MA(I)	Specific electricity consumption (for specific uses) per monetary unit of value added (energy intensity) of subsector I of Manufacturing sector. I=1,…..,NSMAN	kWh/MU	Expressed in terms of final energy per MU.
EI.TU.AG(I)	Specific useful energy consumption for thermal uses per monetary unit of value added (energy intensity) of Subsector I of Agriculture sector. I=1,…..,NSAGR	kWh/MU	
EI.TU.CO(I)	Specific useful energy consumption for thermal uses per monetary unit of value added (energy intensity) of Subsector I of Construction sector. I=1,…..,NSCON	kWh/MU	
EI.TU.MI(I)	Specific useful energy consumption for thermal uses per monetary unit of value added (energy intensity) of Subsector I of Mining sector. I=1,…..,NSMIN	kWh/MU	
EI.TU.MA(I)	Specific useful energy consumption for thermal uses per monetary unit of value added (energy intensity) of Subsector I of Manufacturing sector. I=1,…..,NSMAN	kWh/MU	

TABLE4.1e List and definition of input variables of penetration of energy carriers into useful thermal energy demand of agriculture, construction and mining (acm):

PENETRATION OF ENERGY CARRIERS INTO USEFUL THERMAL ENERGY DEMAND OF AGRICULTURE, CONSTRUCTION AND MINING (ACM): (see Tables 5-1 to 5-3 in worksheet "ACMFac-D" of MAED_D.xls)			
TFPAGR MBPAGR ELPAGR SSPAGR FFPAGR TFPCON MBPCON ELPCON SSPCON FFPCON TFPMIN MBPMIN ELPMIN SSPMIN FFPMIN	Penetration of energy carrier I into the useful thermal energy demand market of economic sector J. Energy carriers: (I=1) Traditional fuels (TF) (I=2) Modern biomass (MB) (I=3) Electricity (EL) (I=4) Soft solar (SS) (I=5) Fossil fuels (FF) Sectors: (J=1) Agriculture (AGR) (J=2) Construction (CON) (J=3) Mining (MIN)	%	The sum of energy carrier penetrations for each sector must be 100. Therefore, direct input is provided only for the first four energy carriers, while the penetration for the last one (Fossil fuels) is calculated by the program as the remainder.

Table 4.1f List and definition of input variables of efficiencies of fuels for thermal uses in agriculture, construction and mining (ACM)

AVERAGE EFICIENCIES OF FUELS FOR THERMAL USES IN AGRICULTURE, CONSTRUCTION AND MINING (ACM): (see Tables 5-5 to 5-7 in worksheet "ACMFac-D" of MAED_D.xls)			
TFEAGR TFECON TFEMIN MBEAGR MBECON MBEMIN FFEAGR FFECON FFEMIN	Average efficiency of the use of fuel I for thermal processes in the economic sector J, relative to the efficiency of electricity. *Fuels*: (I=1) Traditional fuels (TF) (I=2) Modern biomass (MB) (I=3) Fossil fuels (FF) *Sectors*: (J=1) Agriculture (AGR) (J=2) Construction (CON) (J=3) Mining (MIN)	%	

Table 4.1g List and definition of input variables of shares of useful thermal energy demand in manufacturing

SHARES OF USEFUL THERMAL ENERGY DEMAND IN MANUFACTURING: (see worksheet "ManFac1-D" of MAED_D.xls)			
PUSIND (I,J)	Share of thermal process category J in the useful thermal energy demand of Subsector I of Manufacturing sector. I=1,….,NSMAN; *Thermal processes*: (J=1) Steam generation (STM) (J=2) Furnace/direct heat (FUR) (J=3) Space/water heating (SWH)	%	The sum of shares for the same subsector must be 100. Therefore, direct input is provided only for the first two process categories, while the share for the last process category (Space/water heating) is calculated by the program as the remainder.
PENETRATION OF ENERGY CARRIERS INTO USEFUL THERMAL ENERGY DEMAND OF MANUFACTURING: (see Table 8-1 in worksheet "ManFac2-D" of MAED_D.xls)			
ELPMAN(J) ELP.STM.MAN ELP.FUR.MAN ELP.SWH.MAN	Penetration of electricity into the market J of useful thermal energy demand in Manufacturing industries. *Thermal processes*: (J=1) Steam generation (STM) (J=2) Furnace/direct heat (FUR) (J=3) Space/water heating (SWH)	%	Including heat pump contribution for Steam generation and Space/water heating.
HPP.STM.MAN HPP.SWH.MAN	Contribution of heat pumps to Steam generation and Space/water heating uses in Manufacturing industries.	%	As fraction of electricity penetration in the respective markets.
DHP.STM.MAN DHP.SWH.MAN	District heat penetration for Steam generation and Space/water heating uses in Manufacturing industries.	%	
CGP.STM.MAN CGP.SWH.MAN	Share of the Manufacturing demand for Steam and Space/water heating which is supplied by Fossil fuels and Modern biomass, but with cogeneration of electricity.	%	
SSP.STM.MAN SSP.SWH.MAN	Solar penetration for Steam generation and Space/water heating in Manufacturing.	%	
TFPMAN(J) TFP.STM.MAN TFP.FUR.MAN TFP.SWH.MAN	Penetration of Traditional fuels on the various markets of the useful thermal energy demand in Manufacturing industries. *Thermal processes*: (J=1) Steam generation (STM) (J=2) Furnace/direct heat (FUR) (J=3) Space/water heating (SWH)	%	
MBPMAN(J) MBP.STM.MAN MBP.FUR.MAN MBP.SWH.MAN	Penetration of Modern biomass on the various markets of the useful thermal energy demand in Manufacturing industries. *Thermal processes*: (J=1) Steam generation (STM) (J=2) Furnace/direct heat (FUR) (J=3) Space/water heating (SWH)	%	

Table 4.1h List and definition of input variables of efficiencies and other ratios for useful thermal energy demand in manufacturing

EFFICIENCIES AND OTHER RATIOS FOR USEFUL THERMAL ENERGY DEMAND IN MANUFACTURING: (see Table 8-2 in worksheet “ManFac2-D” of MAED_D.xls)			
HPEMAN	Coefficient of performance of (electric) heat pumps in Manufacturing industries.	ratio	Thermal energy extracted per unit of electric energy input.
FIDS	Approximate share of useful thermal energy demand of Manufacturing industries that can be met by solar installations.	%	Note: (100 – FIDS) determines the backup requirements.
EFFCOG	System efficiency of cogeneration.	%	(Heat + electricity) output / Heat content of fuels used
HELRAT	Ratio heat/electricity in output of cogeneration systems.	ratio	kWh steam / kWh electricity
MBSCOG	Share of Modern biomass in the fuel used in cogeneration systems (Fossil fuels and Modern biomass).	%	
FFEMAN(J) FFE.STM.MAN FFE.FUR.MAN FFE.SWH.MAN	Average efficiency of Fossil fuel use for thermal process J in Manufacturing industries, relative to the efficiency of electricity. *Thermal processes*: (J=1) Steam generation (STM) (J=2) Furnace/direct heat (FUR) (J=3) Space/water heating (SWH)	%	
TFEMAN(J) TFE.STM.MAN TFE.FUR.MAN TFE.SWH.MAN	Average efficiency of Traditional fuel use for thermal process J in Manufacturing industries, relative to the efficiency of electricity. *Thermal processes*: (J=1) Steam generation (STM) (J=2) Furnace/direct heat (FUR) (J=3) Space/water heating (SWH)	%	
MBEMAN(J) MBE.STM.MAN MBE.FUR.MAN MBE.SWH.MAN	Average efficiency of Modern biomass use for thermal process J in Manufacturing industries, relative to the efficiency of electricity. *Thermal processes*: (J=1) Steam generation (STM) (J=2) Furnace/direct heat (FUR) (J=3) Space/water heating (SWH)	%	

Table 4.1i List and definition of input variables of steel production and feed stock consumption

STEEL PRODUCTION AND FEEDSTOCK CONSUMPTION: (see Table 8-4 in worksheet "ManFac2-D" of MAED_D.xls)			
CPST(1) CPST(2)	Constants used to project the amount of steel production.	See comment	First constant expressed in million tons of steel; the second in tons of steel per thousand MU of value added by the first Manufacturing subsector. For seek of consistency, the steel-making industry must be considered, from both energy consumption and value added viewpoints, in the first Manufacturing subsector.
BOF	Share of steel produced in non-electric furnaces.	%	For seek of consistency, the electricity requirements for electric steel-making must be reflected in the electricity intensity for specific uses of the first Manufacturing subsector.
IRONST	Specific consumption of pig iron in non-electric steel works.	%	Tons of pig iron per ton of non-electric steel produced; the residual is assumed to be scrap.
EICOK	Coke input in blast furnaces per unit output of pig iron.	kg/ton	
CFEED(1) CFEED(2)	Constants used to project the feedstock requirements of the petrochemical industry.	See comment	First constant expressed in million tons of feedstock; the second in tons of feedstock per thousand MU of value added by the first Manufacturing subsector. For seek of consistency, the petrochemical industry must be considered, from both energy consumption and value added viewpoints, in the first Manufacturing subsector.

Table 4.1j List and definition of input variables of freight transportation

TRANSPORTATION:			
FREIGHT TRANSPORTATION: (see worksheets “FrTrp-D” and “Defs” in MAED_D.xls)			
CTKFT(I)	Coefficients of variable terms in the equation used for projecting total freight transportation. I = 1, 2, 3, ……,NS	tkm/MU	NS = NSAGR + NSCON + NSMIN + NSMAN + NSSER + 1 tkm = ton-kilometer
CKFT	Constant term in the equation used for projecting total freight transportation.	10^9 tkm	
SFTM(I)	Share of transportation mode I in the total demand for freight transportation. I=1,……,NMFT	%	The sum of these shares must be 100. Therefore, direct input is provided only for the first (NMFT-1) transportation modes, while the share for the last one is calculated by the program as the remainder.
EIFTM(I)	Energy intensity (specific energy consumption) of freight transportation mode I. I=1,……,NMFT	See comment	Measured in the natural units indicated by the user in worksheet Defs. The user can choose only the numerator of the energy intensity unit, e.g. liter of motor fuel, kgce of steam coal etc. The denominator (100t-km) is built-in in the equations of the model.
FCFT(I)	Fuel code of freight transportation mode I. I=1,……,NMFT	-	Code numbers from 1 to 8, as defined in cells K38 ÷ K45 of worksheet “Defs”. Same fuel code number may apply for several freight transportation modes.
CFFT(I)	Conversion factor from the user-specified natural unit of specific fuel consumption to kWh/100tkm of a freight transportation mode using the fuel I. I=1,……,NTF		Specified by the user in cells M38 ÷ M45 of worksheet “Defs”.

Table 4.1k List and definition of input variables of intracity passenger transportation

INTRACITY PASSENGER TRANSPORTATION: (see worksheets “PassIntra-D” and “Defs” of MAED_D.xls)			
DU	Average intracity (in urban areas) distance travelled per person per day.	km/pers./day	Applies only to the population living in large cities.
LFUTM(I)	Average load factor of intracity (urban) passenger transportation mode I. I=1,……..,NMUT	person/ transportation mode	
SUTM(I)	Share of transportation mode I in the total demand for intracity (urban) passenger transportation. I=1,……..,NMUT	%	The sum of these shares must be 100. Therefore, direct input is provided only for the first (NMUT-1) transportation modes, while the share for the last one is calculated by the program as the remainder.
EIUTM(I)	Energy intensity (specific energy consumption) of transportation mode I in intracity (urban) travel. I=1,……..NMUT	See comment	Measured in the natural units indicated by the user in worksheet Defs. The user can choose only the numerator of the energy intensity unit, e.g. liter of motor fuel etc. The denominator (100 km) is built-in in the equations of the model.
FCUT(I)	Fuel code of intracity (urban) transportation mode I. I=1,……,NMUT	-	Code numbers from 1 to 8, as defined in cells K38 ÷ K45 of worksheet “Defs”. Same fuel code number may apply for several urban transportation modes. Steam coal is not a valid fuel for urban transportation.
CFPT(I)	Conversion factor from the user specified natural unit of specific fuel consumption to kWh/pkm of a passenger transportation mode using the fuel I. I=1,……,NTF		Specified by the user in cells O38 ÷ O45 of worksheet “Defs”.

Table 4.11 List and definition of input variables of intercity passenger transportation

INTERCITY PASSENGER TRANSPORTATION: (see worksheets "PassInter-D" and "Defs" of MAED_D.xls)			
DI	Average intercity distance travelled per person per year.	km/pers./yr	Applies to total population.
CO	Inverse of car ownership ratio.	persons/car	Ratio of population to total number of cars.
DIC	Average intercity distance driven per car per year.	km/car/yr	Note: The assumption on DIC, together with the average distance driven in urban areas travel as implied by assumptions on PO, POPLC, DU, share of cars in urban passenger transportation and average load factor of cars in urban travel, should match the total average distance driven per car per year.
LFITM(I)	Average load factor of intercity transportation mode I. I=1,……..,NMIT LFITM(I) = LFCIT for I = 2, 3, 4, 5 and 6 (cars)	person/ transp. mode (see comment)	For planes the unit is "% seats occupied". The different types of cars are assumed to have the same average load factor (LFCIT) in intercity travel.
SITC(I)	Share of car type I in the intercity passenger travel by car. I=1,……..,NCTIT	%	The sum of these shares must be 100. Therefore, direct input is provided only for the first (NCTIT-1) car types, while the share for the last one is calculated by the program as the remainder.
SITM(I)	Share of public transportation mode I in the intercity passenger travel by public modes (excluding travel by car). I=1,……..,NMIT-NCTIT	%	The sum of these shares must be 100. Therefore, direct input is provided only for the first (NMIT–NCTIT-1) transportation modes, while the share for the last one is calculated by the program as the remainder.
EIITM(I)	Energy intensity (specific energy consumption) of transportation mode I in intercity travel. I=1,……..,NMIT	See comment	Measured in the natural units indicated by the user in worksheet Defs. The user can choose only the numerator of the energy intensity unit, e.g. liter of motor fuel, kgce of steam coal etc. The denominator (1000 seat-km for planes and 100 km for other modes) is built-in in the equations of the model.
FCIT(I)	Fuel code of intercity transportation mode I. I=1,……,NMIT	-	Code numbers from 1 to 8, as defined in cells K38 ÷ K45 of worksheet "Defs". Same fuel code number may apply for several intercity transportation modes.
CMFMIS(1) CMFMIS(2)	Constants used to project the total motor fuel demand for international and military (miscellaneous) transportation.	See comments	First constant expressed in the energy unit specified by the user in cell E50 of worksheet "Defs"; the second in kWh/MU of GDP.

Table4.1m List and definition of input variables of urban households

HOUSEHOLD:			
URBAN HOUSEHOLDS: (see worksheet "US_HH_Ur–D" of MAED_D.xls)			
UDWSH	Fraction of urban dwellings in areas where space heating is required.	%	Relative to the total number of urban dwellings.
UDD	Degree–days for urban dwellings.	degree–day	The definition used here is: (a) based on Celcius degrees with a threshold of 18^0C; (b) based on monthly average temperature; and (c) averaged over regions (weighted by urban population) which require space heating.
UDW(I)	Fraction of urban dwellings per type. I=1,……,NUDT	%	Relative to the total number of urban dwellings situated in areas where space heating is required. The sum of these fractions must be 100. Therefore, direct input is provided only for the first (NUDT-1) dwelling types, while the share for the last type is calculated by the program as the remainder.
UDWS(I)	Average size of urban dwellings by type. I=1,……,NUDT	sqm/dw	Measured in terms of floor area.
UAREAH(I)	Fraction of floor area that is actually heated in urban areas, by dwelling type. I=1,……,NUDT	%	Relative to the average dwelling size UDWS(I).
UK(I)	Specific heat loss rate by urban dwelling type. I=1,……,NUDT	See comments	Wh / sqm / degree Celcius / hour
UDWAC(I)	Share of urban dwellings with air conditioning, by dwelling type. I=1,……,NUDT	%	Relative to total number of urban dwellings of the respective type.
UACDW(I)	Specific cooling requirements by urban dwelling type. I=1,……,NUDT	kWh/dw/yr	
CKUDW	Specific energy consumption for cooking in urban dwellings (in useful energy terms).	kWh/dw/yr	
UDWHW	Share of urban dwellings with hot water facilities.	%	Relative to total number of urban dwellings.
UHWCAP	Specific energy consumption for water heating per person in urban dwellings (useful energy).	kWh/pers./yr	
ELAPUDW	Specific electricity consumption (final energy) per urban dwelling for electric appliances (other end-uses than space and water heating, cooking and air conditioning).	kWh/dw/yr	Refers to households in electrified urban localities (see variable ELPU).
ELPU	Electricity penetration for appliances in urban households.	%	This variable can be interpreted as the fraction of total urban dwellings that are electrified (i.e. the electrification rate of urban households).

Continues

Table 4.1m List and definition of input variables of urban household (Continued)

FFLTUDW	Specific fossil fuel consumption (final energy) per urban dwelling for lighting and non-electric appliances (other end-uses than space and water heating, cooking and air conditioning).	kWh/dw/yr	Refers to households in non-electrified urban localities (see variable ELPU) and to end-uses as: fossil fuel lighting, refrigerators using natural gas etc.
TFP.UH.SH MBP.UH.SH ELP.UH.SH HPP.UH.SH DHP.UH.SH SSP.UH.SH FFP.UH.SH	Penetration of various energy forms into space heating (SH) in urban households (UH): *Energy forms*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Electricity, conventional (EL) (4) Heat pumps (HP) (5) District heat (DH) (6) Soft solar (SS) (7) Fossil fuels (FF)	%	Contribution of heat pumps to electric space heating (HPP.UH.SH) is a fraction of electricity penetration in the respective market. The sum of energy form penetrations (excluding heat pumps) must be 100. Therefore, direct input is provided only for the first (n-1) energy forms, while the penetration for the last one (Fossil fuels) is calculated by the program as the remainder.
TFE.UH.SH MBE.UH.SH FFE.UH.SH	Efficiency of various fuels use, relative to that of electricity use, for space heating (SH) in urban households (UH): *Fuels*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Fossil fuels (FF)	%	
HPE.UH.SH	Coefficient of performance (COP) of (electric) heat pumps for space heating (SH) in urban households (UH).	ratio (see comment)	Thermal energy extracted / electrical energy input.
FDS.UH.SH	Approximate share of space heating (SH) demand in urban households (UH) that can be met with solar installations.	%	The rest of the demand will have to be met by a backup system.
TFP.UH.HW MBP.UH.HW ELP.UH.HW HPP.UH.HW DHP.UH.HW SSP.UH.HW FFP.UH.HW	Penetration of various energy forms into water heating (HW) in urban households (UH): *Energy forms:* (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Electricity, conventional (EL) (4) Heat pumps (HP) (5) District heat (DH) (6) Soft solar (SS) (7) Fossil fuels (FF)	%	Contribution of heat pumps to electric water heating (HPP.UH.HW) is a fraction of electricity penetration in the respective market. The sum of energy form penetrations (excluding heat pumps) must be 100. Therefore, direct input is provided only for the first (n-1) energy forms, while the penetration for the last one (Fossil fuels) is calculated by the program as the remainder.

Continues

Table 4.1m List and definition of input variables of urban household (Continued)

TFE.UH.HW MBE.UH.HW FFE.UH.HW	Efficiency of various fuels use, relative to that of electricity use, for water heating (HW) in urban households (UH): *Fuels*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Fossil fuels (FF)	%	
HPE.UH.HW	Coefficient of performance (COP) of (electric) heat pumps for water heating (HW) in urban households (UH).	ratio (see comment)	Thermal energy extracted / electrical energy input.
FDS.UH.HW	Approximate share of water heating (HW) demand in urban households (UH) that can be met with solar installations.	%	The rest of the demand will have to be met by a backup system.
TFP.UH.CK MBP.UH.CK ELP.UH.CK SSP.UH.CK FFP.UH. CK	Penetration of various energy forms into cooking (CK) in urban households (UH): *Energy forms*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Electricity, conventional (EL) (4) Soft solar (SS) (5) Fossil fuels (FF)	%	The sum of energy form penetrations must be 100. Therefore, direct input is provided only for the first (n-1) energy forms, while the penetration for the last one (Fossil fuels) is calculated by the program as the remainder.
TFE.UH.CK MBE.UH.CK FFE.UH.CK	Efficiency of various fuels use, relative to that of electricity use, for cooking (CK) in urban households (UH): *Fuels*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Fossil fuels (FF)	%	
FDS.UH.CK	Approximate share of cooking (CK) demand in urban households (UH) that can be met with solar installations.	%	The rest of the demand will have to be met by a backup system.
ELP.UH.AC	Share of air conditioning (AC) demand of urban households (UH) that can be met with electricity.	%	The rest of the demand for air conditioning is assumed to be met with non-electric (fossil fuel) chillers [FFP.UH.AC].
ELE.UH.AC	Coefficient of performance (COP) of electric air conditioning (AC) in urban households (UH).	ratio (see comment)	Thermal energy extracted / electrical energy input.
FFE.UH.AC	Coefficient of performance (COP) of non-electric air conditioning (AC) in urban households (UH).	ratio (see comment)	Thermal energy extracted / energy input.

Continues

Table 4.1n List and Definition of Input Variables of Rural Households

RURAL HOUSEHOLDS: (see worksheet “US_HH_Rr–D” of MAED_D.xls)			
RDWSH	Fraction of rural dwellings in areas where space heating is required.	%	Relative to the total number of rural dwellings.
RDD	Degree–days for rural dwellings.	degree–day	The definition used here is: (a) based on Celcius degrees with a threshold of 18^0C; (b) based on monthly average temperature; and (c) averaged over regions (weighted by rural population) which require space heating.
RDW(I)	Fraction of rural dwellings per type. I=1,……,NRDT	%	Relative to the total number of rural dwellings situated in areas where space heating is required. The sum of these fractions must be 100. Therefore, direct input is provided only for the first (NRDT-1) dwelling types, while the share for the last type is calculated by the program as the remainder.
RDWS(I)	Average size of rural dwellings by type. I=1,……,NRDT	sqm/dw	Measured in terms of floor area.
RAREAH(I)	Fraction of floor area that is actually heated in rural dwellings, by dwelling type. I=1,……,NRDT	%	Relative to the average dwelling size RDWS(I).
RK(I)	Specific heat loss rate by rural dwelling type. I=1,……,NRDT	See comment	Wh / sqm / degree Celcius / hour
RDWAC(I)	Share of rural dwellings with air conditioning, by dwelling type. I=1,……,NRDT	%	Relative to total number of rural dwellings of the respective type.
RACDW(I)	Specific cooling requirements by rural dwelling type. I=1,……,NRDT	kWh/dw/yr	
CKRDW	Specific energy consumption for cooking in rural dwellings (in useful energy terms).	kWh/dw/yr	
RDWHW	Share of rural dwellings with hot water facilities.	%	Relative to total number of rural dwellings.
RHWCAP	Specific energy consumption for water heating per person in rural dwellings (useful energy).	kWh/pers./yr	
ELAPRDW	Specific electricity consumption (final energy) per rural dwelling for electric appliances (other end-uses than space and water heating, cooking and air conditioning).	kWh/dw/yr	Refers to households in electrified rural localities (see variable ELPR).

Continues

Table 4.1n List and definition of input variables of rural households (Continued)

ELPR	Electricity penetration for appliances in rural households.	%	This variable can be interpreted as the fraction of total number of rural dwellings that are electrified (i.e. the electrification rate of rural households)
FFLTRDW	Specific fossil fuel consumption (final energy) per rural dwelling for lighting and non-electric appliances (other end-uses than space and water heating, cooking and air conditioning).	kWh/dw/yr	Refers to households in non-electrified rural localities (see variable ELPR) and to end-uses as: fossil fuel lighting, refrigerators using natural gas etc.
TFP.RH.SH MBP.RH.SH ELP.RH.SH HPP.RH.SH DHP.RH.SH SSP.RH.SH FFP.RH.SH	Penetration of various energy forms into space heating (SH) in rural households (RH): *Energy forms*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Electricity, conventional (EL) (4) Heat pumps (HP) (5) District heat (DH) (6) Soft solar (SS) (7) Fossil fuels (FF)	%	Contribution of heat pumps to electric space heating (HPP.RH.SH) is a fraction of electricity penetration in the respective market. The sum of energy form penetrations (excluding heat pumps) must be 100. Therefore, direct input is provided only for the first (n-1) energy forms, while the penetration for the last one (Fossil fuels) is calculated by the program as the remainder.
TFE.RH.SH MBE.RH.SH FFE.RH.SH	Efficiency of various fuels use, relative to that of electricity use, for space heating (SH) in rural households (RH): *Fuels*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Fossil fuels (FF)	%	
HPE.RH.SH	Coefficient of performance (COP) of (electric) heat pumps for space heating (SH) in rural households (RH).	ratio (see comment)	Thermal energy extracted / electrical energy input.
FDS.RH.SH	Approximate share of space heating (SH) demand in rural households (RH) that can be met with solar installations.	%	The rest of the demand will have to be met by a backup system.
TFP.RH.HW MBP.RH.HW ELP.RH.HW HPP.RH.HW DHP.RH.HW SSP.RH.HW FFP.RH.HW	Penetration of various energy forms into water heating (HW) in rural households (RH): *Energy forms*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Electricity, conventional (EL) (4) Heat pumps (HP) (5) District heat (DH) (6) Soft solar (SS) (7) Fossil fuels (FF)	%	Contribution of heat pumps to electric water heating (HPP.RH.HW) is a fraction of electricity penetration in the respective market. The sum of energy form penetrations (excluding heat pumps) must be 100. Therefore, direct input is provided only for the first (n-1) energy forms, while the penetration for the last one (Fossil fuels) is calculated by the program as the remainder.

Continues

Table 4.1n List and Definition of Input Variables of Rural Households (continued)

TFE.RH.HW MBE.RH.HW FFE.RH.HW	Efficiency of various fuels use, relative to that of electricity use, for water heating (HW) in rural households (RH): *Fuels*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Fossil fuels (FF)	%	
HPE.RH.HW	Coefficient of performance (COP) of (electric) heat pumps for water heating (HW) in rural households (RH).	ratio (see comment)	Thermal energy extracted / electrical energy input.
FDS.RH.HW	Approximate share of water heating (HW) demand in rural households (RH) that can be met with solar installations.	%	The rest of the demand will have to be met by a backup system.
TFP.RH.CK MBP.RH.CK ELP.RH.CK SSP.RH.CK FFP.RH. CK	Penetration of various energy forms into cooking (CK) in rural households (RH): *Energy forms*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Electricity, conventional (EL) (4) Soft solar (SS) (5) Fossil fuels (FF)	%	The sum of energy form penetrations must be 100. Therefore, direct input is provided only for the first (n-1) energy forms, while the penetration for the last one (Fossil fuels) is calculated by the program as the remainder.
TFE.RH.CK MBE.RH.CK FFE.RH.CK	Efficiency of various fuels use, relative to that of electricity use, for cooking (CK) in rural households (RH): *Fuels*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Fossil fuels (FF)	%	
FDS.RH.CK	Approximate share of cooking (CK) demand in rural households (RH) that can be met with solar installations.	%	The rest of the demand will have to be met by a backup system.
ELP.RH.AC	Share of air conditioning (AC) demand of rural households (RH) that can be met with electricity.	%	The rest of the demand for air conditioning is assumed to be met with non-electric (fossil fuel) chillers [FFP.RH.AC].
ELE.RH.AC	Coefficient of performance (COP) of electric air conditioning (AC) in rural households (RH).	ratio (see comment)	Thermal energy extracted / electrical energy input.
FFE.RH.AC	Coefficient of performance (COP) of non-electric air conditioning (AC) in rural households (RH).	ratio (see comment)	Thermal energy extracted / energy input.

Table 4.1o List and definition of input variables of service sector

SERVICE: (see worksheets “US_SS–D” and “SS_Fac-D” in MAED_D.xls)			
PLSER	Share of Service sector in the total active labour force.	%	
AREAL	Average floor area per employee in Service sector.	sqm / employee	
ARSH	Share of Service sector floor area requiring space heating.	%	Relative to total floor area of Service sector.
AREAH	Share of the Service sector floor area requiring space heating that is actually heated.	%	Relative to Service sector floor area requiring space heating.
SSHR	Specific space heat requirements of Service sector buildings (useful energy).	kWh/sqm/yr	
AREAAC	Share of air-conditioned Service sector floor area.	%	Relative to total floor area of Service sector.
SACR	Specific cooling requirements in the Service sector (useful energy).	kWh/sqm/yr	
EI.MF.SE(I)	Energy intensity of motor fuel use in subsector I of Service sector (final energy). I=1,…….,NSSER	kWh/MU	
EI.ELS.SE(I)	Energy intensity of electricity specific uses in subsector I of Service sector (final energy). I=1,…….,NSSER	kWh/MU	
EI.OTU.SE(I)	Energy intensity of other thermal uses (except space heating) in subsector I of Service sector (useful energy). I=1,…….,NSSER	kWh/MU	

Continues

Table 4.1o List and definition of input variables of service sector (Continued)

TFP.SER.SH MBP.SER.SH ELP.SER.SH HPP.SER.SH DHP.SER.SH SSP.SER.SH FFP.SER.SH	Penetration of various energy forms into space heating (SH) in Service sector: *Energy forms:* (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Electricity, conventional (EL) (4) Heat pumps (HP) (5) District heat (DH) (6) Soft solar (SS) (7) Fossil fuels (FF)	%	Contribution of heat pumps to electric space heating (HPP.SER.SH) is a fraction of electricity penetration in the respective market. The sum of energy form penetrations (excluding heat pumps) must be 100. Therefore, direct input is provided only for the first (n-1) energy forms, while the penetration for the last one (Fossil fuels) is calculated by the program as the remainder.
TFP.SER.OTU MBP.SER.OTU ELP.SER.OTU DHP.SER.OTU SSP.SER.OTU FFP.SER.OTU	Penetration of various energy forms into other thermal uses (OTU) in Service sector (except space heating): *Energy forms*: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Electricity, conventional (EL) (4) District heat (DH) (5) Soft solar (SS) (6) Fossil fuels (FF)	%	The sum of energy form penetrations must be 100. Therefore, direct input is provided only for the first (n-1) energy forms, while the penetration for the last one (Fossil fuels) is calculated by the program as the remainder.
TFE.SER.TU MBE.SER.TU FFE.SER.TU	Efficiency of various fuels use, relative to that of electricity use, for thermal uses (TU) in Service sector: Fuels: (1) Traditional fuels (TF) (2) Modern biomass (MB) (3) Fossil fuels (FF)	%	Thermal uses (TU) include: space heating (SH) and other thermal uses (OTU).
HPE.SER.SH	Coefficient of performance (COP) of (electric) heat pumps in space heating (SH) in Service sector.	ratio (see comment)	Thermal energy extracted / electrical energy input.
PLB	Share of low-rise buildings in the total Service sector floor area.	%	Generally, up to 3 stores high buildings are considered as low-rise buildings.
FDS.SER.TU	Approximate share of thermal uses (TU) in the Service sector that can be met by solar installations.	%	Thermal uses (TU) include: space heating (SH) and other thermal uses (OTU). The rest of the demand will have to be met by a backup system.
ELP.SER.AC	Share of air conditioning (AC) that can be met with electricity.	%	The rest of the demand for air conditioning is assumed to be met by non-electric (fossil fuel) chillers [FFP.SER.AC].
ELE.SER.AC	Coefficient of performance (COP) of electric air conditioning in the Service sector.	ratio (see comment)	Thermal energy extracted / electrical energy input.
FFE.SER.AC	Coefficient of performance (COP) of non-electric air conditioning in the Service sector.	ratio (see comment)	Thermal energy extracted / energy input.

Table 4.2a List and Definition of Derived Variables of Demography

(Note: Variables which are used for calculations in Section 5 but not shown in the EXCEL worksheet tables of MAED_D, have been underlined for easy identification.)

VARIABLE	UNIT	EXPLANATION
INCR	years	Time interval between the current and the last previous model years.
DEMOGRAPHY: (see worksheet "Demogr-D" of MAED_D.xls)		
UHH	10^6 dw	Number of urban households.
PRUR	%	Share of rural population.
RHH	10^6 dw	Number of rural households.
ALF	10^6 persons	Active labour force.
POLC	10^6 persons	Total population living in large cities (where mass transportation is feasible).

Table 4.2b List and Definition of GDP Formation

GDP FORMATION: (see worksheet GDP-D of MAED_D.xls)		
YAGR	10^9 MU	GDP contribution, Agriculture sector.
YAG(I)	10^9 MU	GDP contribution, Subsector I of Agriculture sector. I = 1........NSAGR
YCON	10^9 MU	GDP contribution, Construction sector.
YCO(I)	10^9 MU	GDP contribution, subsector I of Construction sector. I = 1........NSCON
YMIN	10^9 MU	GDP contribution, Mining sector.
YMI(I)	10^9 MU	GDP contribution, Subsector I of Mining sector. I = 1........NSMIN
YMAN	10^9 MU	GDP contribution, Manufacturing sector.
YMA(I)	10^9 MU	GDP contribution, subsector I of Manufacturing sector. I = 1........NSMAN
YSER	10^9 MU	GDP contribution, Service sector.
YSE(I)	10^9 MU	GDP contribution, subsector I of Service sector. I=1........NSSER
YEN	10^9 MU	GDP contribution, Energy sector (electricity/gas/water).
Y.CAP	MU/cap	Per capita total GDP.
YAGR.CAP	MU/cap	Per capita GDP contribution, Agriculture sector.
YCON.CAP	MU/cap	Per capita GDP contribution, Construction sector.
YMIN.CAP	MU/cap	Per capita GDP contribution, Mining sector.
YMAN.CAP	MU/cap	Per capita GDP contribution, Manufacturing sector.
YSER.CAP	MU/cap	Per capita GDP contribution, Service sector.

Continues

Table 4.2b List and definition of GDP formation (Continued)

YEN.CAP	MU/cap	Per capita GDP contribution, Energy sector.
YAGR.GR	%	GDP growth rate, Agriculture sector.
YAG.GR(I)	%	GDP growth rate, subsector I of Agriculture sector. I=1,……,NSAGR
YCON.GR	%	GDP growth rate, Construction sector.
YCO.GR(I)	%	GDP growth rate, subsector I of Construction sector. I=1,……,NSCON
YMIN.GR	%	GDP growth rate, Mining sector.
YMI.GR(I)	%	GDP growth rate, Subsector I of Mining sector. I=1,……,NSMIN
YMAN.GR	%	GDP growth rate, Manufacturing sector.
YMA.GR(I)	%	GDP growth rate, Subsector I of Manufacturing sector. I=1,……,NSMAN
YSER.GR	%	GDP growth rate, Service sector.
YSE.GR(I)	%	GDP growth rate, subsector I of Service sector. I=1,……,NSSER
YEN.GR	%	GDP growth rate, Energy sector.
Y.GR	%	GDP growth rate.
Y.CAP.GR	%	Per capita GDP growth rate.

Table 4.2c List and definition of derived variables of energy intensities in industry

INDUSTRY:		
ENERGY INTENSITIES IN INDUSTRY (AGRICULTURE, CONSTRUCTION, MINING AND MANUFACTURING): (see worksheet "EnInt-D" of MAED_D.xls)		
EI.MF.AGR	kWh/MU	Specific motor fuel consumption per monetary unit of value added (energy intensity) of Agriculture sector.
EI.MF.CON	kWh/MU	Specific motor fuel consumption per monetary unit of value added (energy intensity) of Construction sector.
EI.MF.MIN	kWh/MU	Specific motor fuel consumption per monetary unit of value added (energy intensity) of Mining sector.
EI.MF.MAN	kWh/MU	Specific motor fuel consumption per monetary unit of value added (energy intensity) of Manufacturing sector.
EI.ELS.AGR	kWh/MU	Specific electricity consumption (for specific uses) per monetary unit of value added (energy intensity) of Agriculture sector.
EI.ELS.CON	kWh/MU	Specific electricity consumption (for specific uses) per monetary unit of value added (energy intensity) of Construction sector.
EI.ELS.MIN	kWh/MU	Specific electricity consumption (for specific uses) per monetary unit of value added (energy intensity) of Mining sector.
EI.ELS.MAN	kWh/MU	Specific electricity consumption (for specific uses) per monetary unit of value added (energy intensity) of Manufacturing sector.
EI.TU.AGR	kWh/MU	Specific useful energy demand for thermal uses per monetary unit of value added (energy intensity) of Agriculture sector.
EI.TU.CON	kWh/MU	Specific useful energy demand for thermal uses per monetary unit of value added (energy intensity) of Construction sector.
EI.TU.MIN	kWh/MU	Specific useful energy demand for thermal uses per monetary unit of value added (energy intensity) of Mining sector.
EI.TU.MAN	kWh/MU	Specific useful energy demand for thermal uses per monetary unit of value added (energy intensity) of Manufacturing sector.

Table 4.2d List and definition of derived variables of useful energy demand in industry (agriculture, construction, mining and manufacturing)

USEFUL ENERGY DEMAND IN INDUSTRY (AGRICULTURE, CONSTRUCTION, MINING AND MANUFACTURING): (see worksheet "UsEne-D" of MAED_D.xls)		
US.MF.AGR	GWa	Useful energy demand for motor fuels, Agriculture sector.
US.MF.AG(I)	GWa	Useful energy demand for motor fuels, subsector I of Agriculture sector. I=1,……,NSAGR
US.MF.CON	GWa	Useful energy demand for motor fuels, Construction sector.
US.MF.CO(I)	GWa	Useful energy demand for motor fuels, Subsector I of Construction sector. I=1,……,NSCON
US.MF.MIN	GWa	Useful energy demand for motor fuels, Mining sector.
US.MF.MI(I)	GWa	Useful energy demand for motor fuels, subsector I of Mining sector. I=1,……,NSMIN
US.MF.MAN	GWa	Useful energy demand for motor fuels, Manufacturing sector.
US.MF.MA(I)	GWa	Useful energy demand for motor fuels, subsector I of Manufacturing sector. I=1,……,NSMAN
US.MF.IND	GWa	Useful energy demand for motor fuels, Industry aggregated sector.
US.ELS.AGR	GWa	Useful energy demand for electricity (specific uses), Agriculture sector.
US.ELS.AG(I)	GWa	Useful energy demand for electricity (specific uses), subsector I of Agriculture sector. I=1,……,NSAGR
US.ELS.CON	GWa	Useful energy demand for electricity (specific uses), Construction sector.
US.ELS.CO(I)	GWa	Useful energy demand for electricity (specific uses), subsector I of Construction sector. I=1,……,NSCON
US.ELS.MIN	GWa	Useful energy demand for electricity (specific uses), Mining sector.
US.ELS.MI(I)	GWa	Useful energy demand for electricity (specific uses), subsector I of Mining sector. I=1,……,NSMIN
US.ELS.MAN	GWa	Useful energy demand for electricity (specific uses), Manufacturing sector.
US.ELS.MA(I)	GWa	Useful energy demand for electricity (specific uses), subsector I of Manufacturing sector. I= 1……,NSMAN
US.ELS.IND	GWa	Useful energy demand for electricity (specific uses), Industry aggregated sector.
US.TU.AGR	GWa	Useful energy demand for thermal uses, Agriculture sector.
US.TU.AG(I)	GWa	Useful energy demand for thermal uses, subsector I of Agriculture sector. I=1,……,NSAGR
US.TU.CON	GWa	Useful energy demand for thermal uses, Construction sector.
US.TU.CO(I)	GWa	Useful energy demand for thermal uses, subsector I of Construction sector. I=1,……,NSCON

USEFUL ENERGY DEMAND IN INDUSTRY (AGRICULTURE, CONSTRUCTION, MINING AND MANUFACTURING): (see worksheet "UsEne-D" of MAED_D.xls)		
US.TU.MIN	GWa	Useful energy demand for thermal uses, Mining sector.
US.TU.MI(I)	GWa	Useful energy demand for thermal uses, subsector I of Mining sector. I=1,……,NSMIN
US.TU.ACM	GWa	Useful energy demand for thermal uses, Agriculture + Construction + Mining sectors.
US.TU.MAN	GWa	Useful energy demand for thermal uses, Manufacturing sector.
US.TU.MA(I)	GWa	Useful energy demand for thermal uses, subsector I of Manufacturing sector. I=1,……,NSMAN
US.TU.IND	GWa	Useful energy demand for thermal uses, Industry aggregated sector.

Table 4.2e List and definition of derived variables of useful and final energy demand

PENETRATION OF ENERGY CARRIERS INTO USEFUL THERMAL ENERGY OF AGRICULTURE, CONSTRUCTION AND MINING (ACM): (see Table 5-4 in worksheet "ACMFac-D" of MAED_D.xls) (They are not used in the new version of the program. They can be removed!)		
TFPACM	%	Weighted average penetration of traditional fuels into the market of useful thermal energy demand of (Agriculture + Construction +
MBPACM	%	Weighted average penetration of modern biomass into the market of useful thermal energy demand of (Agriculture + Construction +
ELPACM	%	Weighted average penetration of electricity into the market of useful thermal energy demand of (Agriculture + Construction +
SSPACM	%	Weighted average penetration of solar systems into the market of useful thermal energy demand of (Agriculture + Construction +
FFPACM	%	Weighted average penetration of fossil fuels into the market of useful thermal energy demand of (Agriculture + Construction +
FINAL ENERGY DEMAND IN AGRICULTURE, CONSTRUCTION AND MINING: (see worksheet "FIN_ACM" of MAED_D.xls)		
TFAGR	GWa	Traditional fuel demand, Agriculture sector.
MBAGR	GWa	Modern biomass demand, Agriculture sector.
ELHAGR	GWa	Electricity demand for thermal uses, Agriculture sector.
ELAGR	GWa	Total electricity demand, Agriculture sector.
SSAGR	GWa	Useful thermal energy demand replaced by soft solar systems, Agriculture sector.
FFAGR	GWa	Fossil fuel demand, Agriculture sector.
MFAGR	GWa	Motor fuel demand, Agriculture sector.
FINAGR	GWa	Final energy demand, Agriculture sector.
TFAGR.S	%	Share of traditional fuels in final energy demand, Agriculture sector.
MBAGR.S	%	Share of modern biomass in final energy demand, Agriculture sector.
ELAGR.S	%	Share of electricity in final energy demand, Agriculture sector.
SSAGR.S	%	Share of soft solar in final energy demand, Agriculture sector.
FFAGR.S	%	Share of fossil fuels in final energy demand, Agriculture sector.
MFAGR.S	%	Share of motor fuels in final energy demand, Agriculture sector.
EI.TF.AGR	kWh/MU	Traditional fuel demand per value added (energy intensity), Agriculture sector.
EI.MB.AGR	kWh/MU	Modern biomass demand per value added (energy intensity), Agriculture sector.
EI.EL.AGR	kWh/MU	Electricity demand per value added (energy intensity), Agriculture sector.
EI.SS.AGR	kWh/MU	Soft solar demand per value added (energy intensity), Agriculture sector.
EI.FF.AGR	kWh/MU	Fossil fuel demand per value added (energy intensity), Agriculture sector.

Continues

Table 4.2e List and definition of derived variables of useful and final energy demand (Continued)

EI.F.AGR	kWh/MU	Motor fuel demand per value added (energy intensity), Agriculture sector.
EI.FIN.AGR	kWh/MU	Final energy demand per value added (energy intensity), Agriculture sector.
TFCON	GWa	Traditional fuel demand, Construction sector.
MBCON	GWa	Modern biomass demand, Construction sector.
ELHCON	GWa	Electricity demand for thermal uses, Construction sector.
ELCON	GWa	Electricity demand, Construction sector.
SSCON	GWa	Useful thermal energy demand replaced by soft solar systems, Construction sector.
FFCON	GWa	Fossil fuel demand, Construction sector.
MFCON	GWa	Motor fuel demand, Construction sector.
FINCON	GWa	Final energy demand, Construction sector.
TFCON.S	%	Share of traditional fuels in final energy demand, Construction sector.
MBCON.S	%	Share of modern biomass in final energy demand, Construction sector.
ELCON.S	%	Share of electricity in final energy demand, Construction sector.
SSCON.S	%	Share of soft solar in final energy demand, Construction sector.
FFCON.S	%	Share of fossil fuels in final energy demand, Construction sector.
MFCON.S	%	Share of motor fuels in final energy demand, Construction sector.
EI.TF.CON	kWh/MU	Traditional fuel demand per value added (energy intensity), Construction sector.
EI.MB.CON	kWh/MU	Modern biomass demand per value added (energy intensity), Construction sector.
EI.EL.CON	kWh/MU	Electricity demand per value added (energy intensity), Construction sector.
EI.SS.CON	kWh/MU	Soft solar demand per value added (energy intensity), Construction sector.
EI.FF.CON	kWh/MU	Fossil fuel demand per value added (energy intensity), Construction sector.
EI.MF.CON	kWh/MU	Motor fuel demand per value added (energy intensity), Construction sector.
EI.FIN.CON	kWh/MU	Final energy demand per value added (energy intensity), Construction sector.
TFMIN	GWa	Traditional fuel demand, Mining sector.
MBMIN	GWa	Modern biomass demand, Mining sector.

Continues

Table 4.2e List and definition of derived variables of useful and final energy demand (Continued)

ELHMIN	GWa	Electricity demand for thermal uses, Mining sector.
ELMIN	GWa	Electricity demand, Mining sector.
SSMIN	GWa	Useful thermal energy demand replaced by soft solar systems, Mining sector.
FFMIN	GWa	Fossil fuel demand, Mining sector.
MFMIN	GWa	Motor fuel demand, Mining sector.
FINMIN	GWa	Final energy demand, Mining sector.
TFMIN.S	%	Share of traditional fuels in final energy demand, Mining sector.
MBMIN.S	%	Share of modern biomass in final energy demand, Mining sector.
ELMIN.S	%	Share of electricity in final energy demand, Mining sector.
SSMIN.S	%	Share of soft solar in final energy demand, Mining sector.
FFMIN.S	%	Share of fossil fuels in final energy demand, Mining sector.
MFMIN.S	%	Share of motor fuels in final energy demand, Mining sector.
EI.TF.MIN	kWh/MU	Traditional fuel demand per value added (energy intensity), Mining sector.
EI.MB.MIN	kWh/MU	Modern biomass demand per value added (energy intensity), Mining sector.
EI.EL.MIN	kWh/MU	Electricity demand per value added (energy intensity), Mining sector.
EI.SS.MIN	kWh/MU	Soft solar demand per value added (energy intensity), Mining sector.
EI.FF.MIN	kWh/MU	Fossil fuel demand per value added (energy intensity), Mining sector.
EI.MF.MIN	kWh/MU	Motor fuel demand per value added (energy intensity), Mining sector.
EI.FIN.MIN	kWh/MU	Final energy demand per value added (energy intensity), Mining sector.
TFACM	GWa	Traditional fuel demand, Agriculture + Construction + Mining sectors.
MBACM	GWa	Modern biomass demand, Agriculture + Construction + Mining sectors.
ELSACM	GWa	Electricity demand for specific uses, Agriculture + Construction + Mining sectors.

Continues

Table 4.2e List and definition of derived variables of useful and final energy demand (Continued)

ELHACM	GWa	Electricity demand for thermal uses, Agriculture + Construction + Mining sectors.
ELACM	GWa	Total electricity demand, Agriculture + Construction + Mining sectors.
SSACM	GWa	Useful thermal energy demand replaced by soft solar systems, Agriculture + Construction + Mining sectors.
FFACM	GWa	Fossil fuel demand, Agriculture + Construction + Mining sectors.
MFACM	GWa	Motor fuel demand, Agriculture + Construction + Mining sectors.
FINACM	GWa	Final energy demand, Agriculture + Construction + Mining sectors.
TFACM.S	%	Share of traditional fuels in final energy demand, Agriculture + Construction + Mining sectors.
MBACM.S	%	Share of modern biomass in final energy demand, Agriculture + Construction + Mining sectors.
ELACM.S	%	Share of electricity in final energy demand, Agriculture + Construction + Mining sectors.
SSACM.S	%	Share of soft solar in final energy demand, Agriculture + Construction + Mining sectors.
FFACM.S	%	Share of fossil fuels in final energy demand, Agriculture + Construction + Mining sectors.
MFACM.S	%	Share of motor fuels in final energy demand, Agriculture + Construction + Mining sectors.
EI.TF.ACM	kWh/MU	Traditional fuel demand per value added (energy intensity), Agriculture + Construction + Mining sectors.
EI.MB.ACM	kWh/MU	Modern biomass demand per value added (energy intensity), Agriculture + Construction + Mining sectors.
EI.EL.ACM	kWh/MU	Electricity demand per value added (energy intensity), Agriculture + Construction + Mining sectors.
EI.SS.ACM	kWh/MU	Soft solar demand per value added (energy intensity), Agriculture + Construction + Mining sectors.
EI.FF.ACM	kWh/MU	Fossil fuel demand per value added (energy intensity), Agriculture + Construction + Mining sectors.
EI.MF.ACM	kWh/MU	Motor fuel demand per value added (energy intensity), Agriculture + Construction + Mining sectors.
EI.FIN.ACM	kWh/MU	Final energy demand per value added (energy intensity), Agriculture + Construction + Mining sectors.

Table 4.2f List and definition of derived variables of useful thermal energy demand in manufacturing

USEFUL THERMAL ENERGY DEMAND IN MANUFACTURING: (see worksheet "ManFac1-D" of MAED_D.xls)		
USMAN(I,J)	GWa	Useful thermal energy demand of subsector I of Manufacturing sector for demand category J. I=1,…..,NSMAN; Demand categories: (J = 1) Steam generation (STM) (J = 2) Furnace/direct heat (FUR) (J = 3) Space/water heating (SWH)
USMA(I)	GWa	Useful thermal energy demand of subsector I of Manufacturing sector. I=1,…..,NSMAN
USMAN(1) US.STM.MAN	GWa	Useful thermal energy demand of Manufacturing sector for Steam generation (STM).
USMAN(2) US.FUR.MAN	GWa	Useful thermal energy demand of Manufacturing sector for Furnace/direct heat (FUR).
USMAN(3) US.SWH.MAN	GWa	Useful thermal energy demand of Manufacturing sector for Space/water heating (SWH).
USMAN(4)	GWa	Total useful thermal energy demand of Manufacturing sector.
PENETRATIONS AND EFFICIENCIES FOR USEFUL THERMAL ENERGY DEMAND OF MANUFACTURING (see worksheet "ManFac2" of MAED_D.xls)		
PMEL(J)	%	Share of electricity (conventional) in USMAN(J). Demand categories: (J = 1) Steam generation (STM) (J = 2) Furnace/direct heat (FUR) (J = 3) Space/water heating (SWH)
PMEL(4)	%	Weighted average penetration of electricity (conventional) into the market of useful thermal energy demand of Manufacturing industries.
PMHP(J)	%	Share of electricity (heat pump) in USMAN(J). Demand categories: (J = 1) Steam generation (STM) (J = 2) Furnace/direct heat (FUR) (J = 3) Space/water heating (SWH)

Continues

Table 4.2f List and definition of derived variables of useful thermal energy demand in manufacturing (Continued)

PMHP(4)	%	Weighted average penetration of electricity (heat pump) into the market of useful thermal energy demand of Manufacturing industries.
PMDH(J)	%	Share of district heat in USMAN(J). Demand categories: (J = 1) Steam generation (STM) (J = 2) Furnace/direct heat (FUR) (J = 3) Space/water heating (SWH)
PMDH(4)	%	Weighted average penetration of district heat into the market of useful thermal energy demand of Manufacturing industries.
PMSS(J)	%	Share of solar systems in USMAN(J). Demand categories: (J = 1) Steam generation (STM) (J = 2) Furnace/direct heat (FUR) (J = 3) Space/water heating (SWH)
PMSS(4)	%	Weighted average penetration of solar systems into the market of useful thermal energy demand of Manufacturing industries.
PMCG(J)	%	Share of on-site cogeneration in USMAN(J). Demand categories: (J = 1) Steam generation (STM) (J = 2) Furnace/direct heat (FUR) (J = 3) Space/water heating (SWH)
PMCG(4)	%	Weighted average penetration of on-site cogeneration into the market of useful thermal energy demand of Manufacturing industries.
PMTF(J)	%	Share of traditional fuels in USMAN(J). Demand categories: (J = 1) Steam generation (STM) (J = 2) Furnace/direct heat (FUR) (J = 3) Space/water heating (SWH)
PMTF(4)	%	Weighted average penetration of traditional fuels into the market of useful thermal energy demand of Manufacturing industries.
PMMB(J)	%	Share of modern biomass in USMAN(J). Demand categories: (J = 1) Steam generation (STM) (J = 2) Furnace/direct heat (FUR) (J = 3) Space/water heating (SWH)

Continues

Table 4.2f List and definition of derived variables of useful thermal energy demand in manufacturing (Continued)

PMMB(4)	%	Weighted average penetration of modern biomass into the market of useful thermal energy demand of Manufacturing industries.
PMFF(J)	%	Share of fossil fuels in USMAN(J). Demand categories: (J = 1) Steam generation (STM) (J = 2) Furnace/direct heat (FUR) (J = 3) Space/water heating (SWH)
PMFF(4)	%	Weighted average penetration of fossil fuels into the market of useful thermal energy demand of Manufacturing industries.
FFEMAN(4)	%	Average efficiency of fossil fuel use in thermal processes in Manufacturing sector, relative to the efficiency of electricity.
TFEMAN(4)	%	Average efficiency of traditional fuel use in thermal processes in Manufacturing sector, relative to the efficiency of electricity.
MBEMAN(4)	%	Average efficiency of modern biomass use in thermal processes in Manufacturing sector, relative to the efficiency of electricity.
PSTEEL	10^6 tons	Total steel production.
PFEED	10^6 tons	Total feedstock consumption (i.e. use of energy sources as raw materials)

Table 4.2g List and definition of derived variables of final energy demand in manufacturing

FINAL ENERGY DEMAND IN MANUFACTURING (see Tables 9-1 to 9-3 in worksheet "FIN_Ind-D" of MAED_D.xls)		
TFMAN	GWa	Thermal use of traditional fuels in Manufacturing.
COGSTH	GWa	Useful thermal energy demand of Manufacturing that is provided with cogeneration of electricity.
MBMAN	GWa	Thermal use of modern biomass in Manufacturing.
ELHMAN	GWa	Thermal use of electricity in Manufacturing.
ELSMAN	GWa	Electricity demand for specific uses in Manufacturing.
ELMAN	GWa	Electricity demand in Manufacturing.
DHMAN	GWa	District heat demand in Manufacturing.
SSMAN	GWa	Useful thermal energy demand replaced by soft solar systems in Manufacturing.
FFMAN	GWa	Thermal use of fossil fuels in Manufacturing.
MFMAN	GWa	Motor fuel demand in Manufacturing.
COKE	GWa	Coke demand for pig iron production.
FEED	GWa	Total feedstock consumption, expressed in internal energy units of the module.
FINMAN	GWa	Final energy demand in Manufacturing.
TFMAN.S	%	Share of traditional fuels in final energy, Manufacturing.
MBMAN.S	%	Share of modern biomass in final energy, Manufacturing.
ELMAN.S	%	Share of electricity in final energy, Manufacturing.
DHMAN.S	%	Share of district heat in final energy, Manufacturing.
SOLMAN.S	%	Share of soft solar in final energy, Manufacturing.
FFMAN.S	%	Share of fossil fuels in final energy, Manufacturing.
MFMAN.S	%	Share of motor fuels in final energy, Manufacturing.
COKEMAN.S	%	Share of coke in final energy, Manufacturing.
FEEDMAN.S	%	Share of feedstock in final energy, Manufacturing.
EI.TF.MAN	kWh/MU	Traditional fuel demand per value added, Manufacturing.
EI.MB.MAN	kWh/MU	Modern biomass demand per value added, Manufacturing.
EI.EL.MAN	kWh/MU	Electricity demand per value added, Manufacturing.
EI.DH.MAN	kWh/MU	District heat demand per value added, Manufacturing.
EI.SS.MAN	kWh/MU	Soft solar demand per value added, Manufacturing.
EI.FF.MAN	kWh/MU	Fossil fuel demand per value added, Manufacturing.
EI.MF.MAN	kWh/MU	Motor fuel demand per value added, Manufacturing.
EI.COKE.MAN	kWh/MU	Coke demand per value added, Manufacturing.
EI.FEED.MAN	kWh/MU	Feedstock demand per value added, Manufacturing.
EI.FIN.MAN	kWh/MU	Final energy demand per value added, Manufacturing.

Table 4.2h List and definition of derived variables of final energy demand in industry (Manufacturing + ACM)

FINAL ENERGY DEMAND IN INDUSTRY (MANUFACTURING + ACM): (see Tables 9-4 to 9-6 in worksheet "FIN_Ind-D" of MAED_D.xls)		
TFIND	GWa	Thermal use of traditional fuels in Industry.
MBIND	GWa	Thermal use of modern biomass in Industry.
ELSIND	GWa	Electricity demand for specific uses, Industry.
ELHIND	GWa	Electricity demand for thermal uses, Industry.
ELIND	GWa	Electricity demand in Industry.
DHIND	GWa	District heat demand in Industry.
SSIND	GWa	Useful thermal energy demand replaced by soft solar systems in Industry.
FFIND	GWa	Thermal use of fossil fuels in Industry.
MFIND	GWa	Motor fuel demand in Industry.
FININD	GWa	Final energy demand in Industry.
TFIND.S	%	Share of traditional fuels in final energy, Industry.
MBIND.S	%	Share of modern biomass in final energy, Industry.
ELIND.S	%	Share of electricity in final energy, Industry.
DHIND.S	%	Share of district heat in final energy, Industry.
SSIND.S	%	Share of soft solar in final energy, Industry.
FFIND.S	%	Share of fossil fuels in final energy, Industry.
MFIND.S	%	Share of motor fuels in final energy, Industry.
COKEIND.S	%	Share of coke in final energy, Industry.
FEEDIND.S	%	Share of feedstock in final energy, Industry.
EI.TF.IND	kWh/MU	Traditional fuel demand per value added, Industry.
EI.MB.IND	kWh/MU	Modern biomass demand per value added, Industry.
EI.EL.IND	kWh/MU	Electricity demand per value added, Industry.
EI.DH.IND	kWh/MU	District heat demand per value added, Industry.
EI.SS.IND	kWh/MU	Soft solar demand per value added, Industry.
EI.FF.IND	kWh/MU	Fossil fuel demand per value added, Industry.
EI.MF.IND	kWh/MU	Motor fuel demand per value added, Industry.
EI.COKE.IND	kWh/MU	Coke demand per value added, Industry.
EI.FEED.IND	kWh/MU	Feedstock demand per value added, Industry.
EI.FIN.IND	kWh/MU	Final energy demand per value added, Industry.

Table 4.2i List and definition of derived variables of freight transportation

TRANSPORTATION:		
FREIGHT TRANSPORTATION: (see worksheet "FrTrp-D" of MAED_D.xls)		
TKFT	10^9 tkm	Total ton-kilometers for freight transportation (domestic).
TKFTM(I)	10^9 tkm	Ton-kilometers by freight transportation mode. I=1,……..,NMFT
FTMEI(I)	kWh/100tkm	Energy intensity of freight transportation mode I. I=1,……..,NMFT
ECFTM(I)	GWa	Energy consumption of freight transportation mode I. I=1,……..,NMFT
TELFT	GWa	Total electricity consumption of freight transportation.
TSCFT	GWa	Total steam coal consumption of freight transportation.
TDIFT	GWa	Total diesel oil consumption of freight transportation.
TGAFT	GWa	Total gasoline consumption of freight transportation.
TF5FT	GWa	Total consumption of fuel number 5 in freight transportation.
TF6FT	GWa	Total consumption of fuel number 6 in freight transportation.
TF7FT	GWa	Total consumption of fuel number 7 in freight transportation.
TF8FT	GWa	Total consumption of fuel number 8 in freight transportation.
ECFTF(I)	GWa	Energy consumption in freight transportation by fuel type I. I=1,……..,NTF
TMFFT	GWa	Total motor fuel consumption for freight transportation.
TENFT	GWa	Total energy consumption for freight transportation.

Table 4.2j List and definition of derived variables of intracity (urban) passenger transportation

INTRACITY (URBAN) PASSENGER TRANSPORTATION: (see worksheet "PassIntra-D" of MAED_D.xls)		
PKU	$10^9$9 pkm	Total passenger-kilometers, intracity (urban) traffic.
PKUTM(I)	10^9 tkm	Passenger-kilometers by urban transportation mode. I=1,……..,NMUT
UTMEI(I)	kWh/pkm	Energy intensity of urban transportation mode I. I=1,……..,NMUT
ECUTM(I)	GWa	Energy consumption of urban transportation mode I. I=1,……..,NMUT
TELUT	GWa	Total electricity consumption, urban passenger traffic.
TDIUT	GWa	Total diesel oil consumption, urban passenger traffic.
TGAUT	GWa	Total gasoline consumption, urban passenger traffic.
TF5UT	GWa	Total consumption of fuel number 5, urban passenger traffic.
TF6UT	GWa	Total consumption of fuel number 6, urban passenger traffic.
TF7UT	GWa	Total consumption of fuel number 7, urban passenger traffic.
TF8UT	GWa	Total consumption of fuel number 8, urban passenger traffic.
ECUTF(I)	GWa	Energy consumption in urban transportation by fuel type I. I=1,……..,NTF
TMFUT	GWa	Total motor fuel consumption, urban passenger traffic.
TENUT	GWa	Total energy consumption, urban passenger traffic.

Table 4.2k List and definition of derived variables of intercity passenger transportation

INTERCITY PASSENGER TRANSPORTATION: (see worksheet “PassInter-D” of MAED_D.xls)		
PKI	10^9 pkm	Total passenger-kilometers, intercity traffic.
PKIC	10^9 pkm	Passenger-kilometers by car, intercity traffic.
PKIP	10^9 pkm	Passenger-kilometers by public transportation, intercity traffic.
PKICT(I)	10^9 pkm	Passenger-kilometers by car type I, intercity traffic. I=1,….,NCTIT
PKIPM(I)	10^9 pkm	Passenger-kilometers by public transportation mode I, intercity traffic. I=1,….,(NMIT-NCTIT)
ITMEI(I)	kWh/pkm	Energy intensity of intercity transportation mode I. I=1,……..,NMIT
ECITM(I)	GWa	Energy consumption of intercity transportation mode I. I=1,……..,NMIT
TELIT	GWa	Total electricity consumption, intercity passenger transportation.
TSCIT	GWa	Total steam coal consumption, intercity passenger transportation.
TDIIT	GWa	Total diesel oil consumption, intercity passenger transportation.
TGAIT	GWa	Total gasoline consumption, intercity passenger transportation.
TF5IT	GWa	Total consumption of fuel number 5, intercity passenger transportation.
TF6IT	GWa	Total consumption of fuel number 6, intercity passenger transportation.
TF7IT	GWa	Total consumption of fuel number 7, intercity passenger transportation.
TF8IT	GWa	Total consumption of fuel number 8, intercity passenger transportation.
ECITF(I)	GWa	Energy consumption in intercity transportation by fuel type I. I=1,……..,NFT
TMFIT	GWa	Total motor fuel consumption, intercity passenger transportation.
TENIT	GWa	Total energy consumption, intercity passenger transportation.
TMFMIS	GWa	Fuel consumption, international and military (miscellaneous) transportation.
TELPT	GWa	Total electricity consumption for passenger transportation.
TSCPT	GWa	Total steam coal consumption for passenger transportation.
TMFPT	GWa	Total motor fuel consumption for passenger (including international and military) transportation.
TENPT	GWa	Total energy consumption for passenger transportation.

Table 4.21 List and definition of derived variables of final energy demand in transportation

FINAL ENERGY DEMAND IN TRANSPORTATION: (see worksheet FIN_Trp-D of MAED_d.xls)		
TELTR	GWa	Total electricity consumption for transportation.
TSCTR	GWa	Total steam coal consumption for transportation.
TDITR	GWa	Total diesel oil consumption for transportation.
TGATR	GWa	Total gasoline consumption for transportation.
TF5TR	GWa	Total consumption of fuel no. 5 for transportation.
TF6TR	GWa	Total consumption of fuel no. 6 for transportation.
TF7TR	GWa	Total consumption of fuel no. 7 for transportation.
TF8TR	GWa	Total consumption of fuel no. 8 for transportation.
ECTRF(I)	GWa	Total energy consumption for transportation, by fuel type I (including international and military transportation). I=1,……..,(NTF+1)
FINTR	GWa	Final energy consumption for transportation.
ECTRF.S(I)	%	Share of fuel type I (including international and military transportation) in final energy consumption for transportation. I=1,……..,(NTF+1)
TMFTR	GWa	Total motor fuel consumption for transportation.
TELTR.S	%	Share of electricity in total final energy consumption for transportation.
TSCTR.S	%	Share of steam coal in total final energy consumption for transportation.
TMFTR.S	%	Share of motor fuel in total final energy consumption for transportation.
TENFT.S	%	Share of energy consumption for freight transportation in total final energy consumption for transportation.
TENUT.S	%	Share of energy consumption for urban passenger transportation in total final energy consumption for transportation.
TENIT.S	%	Share of energy consumption for intercity passenger transportation in total final energy consumption for transportation.
TMFMIS.S	%	Share of energy consumption for international and military transportation in total final energy consumption for transportation.

Table 4.2m List and definition of derived variables of useful energy demand in urban household

HOUSEHOLD:		
USEFUL ENERGY DEMAND IN URBAN HOUSEHOLD: (see worksheet "US_HH_Ur-D" of MAED_D.xls)		
TUDW	10^6 dw	Total stock of urban dwellings (assumed to be equal to the number of urban households).
SHUHT(**I**)	GWa	Useful energy demand for space heating in urban dwellings of type **I**. **I**=1,…..,NUDT
SHUH	GWa	Useful energy demand for space heating, urban households.
HWUH	GWa	Useful energy demand for water heating, urban households.
CKUH	GWa	Useful energy demand for cooking, urban households.
ACUHT(**I**)	GWa	Useful energy demand for air conditioning in urban dwellings of type **I**. **I**=1,…..,NUDT
ACUH	GWa	Useful energy demand for air conditioning, urban households.
ELAPUH	GWa	Electricity consumption for specific uses in electrified urban dwellings (i.e. for purposes other than space and water heating, cooking and air conditioning).
FFLTUH	GWa	Fossil fuel consumption for lighting and non-electric appliances (for example, refrigerators using natural gas) in non-electrified urban dwellings.
USUH	GWa	Total useful energy demand in urban households.
USEFUL ENERGY DEMAND IN RURAL HOUSEHOLD: (see worksheet "US_HH_Rr-D" of MAED_D.xls)		
TRDW	10^6 dw	Total stock of rural dwellings (assumed to be equal to the number of rural households).
SHRHT(**I**)	GWa	Useful energy demand for space heating in rural dwellings of type **I**. **I**=1,…..,NRDT
SHRH	GWa	Useful energy demand for space heating, rural households.
HWRH	GWa	Useful energy demand for water heating, rural households.
CKRH	GWa	Useful energy demand for cooking, rural households.
ACRHT(**I**)	GWa	Useful energy demand for air conditioning in rural dwellings of type **I**. **I**=1,…..,NRDT
ACRH	GWa	Useful energy demand for air conditioning, rural households.
ELAPRH	GWa	Electricity consumption for specific uses in electrified rural dwellings (i.e. for purposes other than space and water heating, cooking and air conditioning).
FFLTRH	GWa	Fossil fuel consumption for lighting and non-electric appliances (for example, refrigerators using natural gas) in non-electrified rural dwellings.
USRH	GWa	Total useful energy demand in rural households.

Table 4.2n List and definition of derived variables of final energy demand in urban household

FINAL ENERGY DEMAND IN URBAN HOUSEHOLD: (see Tables 16.1 ÷ 16.6 in worksheet "FIN_HH-D" of MAED_D.xls)		
TF.UH.SH	GWa	Traditional fuel demand for space heating in urban households.
MB.UH.SH	GWa	Modern biomass demand for space heating in urban households.
EL.UH.SH	GWa	Electricity demand for space heating in urban households.
DH.UH.SH	GWa	District heat demand for space heating in urban households.
SS.UH.SH	GWa	Soft solar demand for space heating in urban households.
FF.UH.SH	GWa	Fossil fuel demand for space heating in urban households.
FIN.UH.SH	GWa	Final energy demand for space heating in urban households.
TF.UH.HW	GWa	Traditional fuel demand for water heating in urban households.
MB.UH.HW	GWa	Modern biomass demand for water heating in urban households.
EL.UH.HW	GWa	Electricity demand for water heating in urban households.
DH.UH.HW	GWa	District heat demand for water heating in urban households.
SS.UH.HW	GWa	Soft solar demand for water heating in urban households.
FF.UH.HW	GWa	Fossil fuel demand for water heating in urban households.
FIN.UH.HW	GWa	Final energy demand for water heating in urban households.
TF.UH.CK	GWa	Traditional fuel demand for cooking in urban households.
MB.UH.CK	GWa	Modern biomass demand for cooking in urban households.
EL.UH.CK	GWa	Electricity demand for cooking in urban households.
SS.UH.CK	GWa	Soft solar demand for cooking in urban households.
FF.UH.CK	GWa	Fossil fuel demand for cooking in urban households.
FIN.UH.CK	GWa	Final energy demand for cooking in urban households.
EL.UH.AC	GWa	Electricity demand for air conditioning in urban households.
FF.UH.AC	GWa	Fossil fuel demand for air conditioning in urban households.
FIN.UH.AC	GWa	Final energy demand for air conditioning in urban households.
EL.UH.AP	GWa	Electricity demand for specific uses in electrified urban dwellings (i.e. for purposes other than space and water heating, cooking and air conditioning).
FF.UH.AP	GWa	Fossil fuel demand for lighting and non-electric appliances (for example, refrigerators using natural gas) in non-electrified urban dwellings.
FIN.UH.AP	GWa	Final energy demand for appliances and lighting in urban households.
TFUH	GWa	Traditional fuel demand in urban households.
MBUH	GWa	Modern biomass demand in urban households.
ELUH	GWa	Electricity demand in urban households.
DHUH	GWa	District heat demand in urban households.
SSUH	GWa	Soft solar demand in urban households.
FFUH	GWa	Fossil fuel demand in urban households.
FINUH	GWa	Final energy demand in urban households.

Table 4.2o List and definition of derived variables of final energy demand in rural household

FINAL ENERGY DEMAND IN RURAL HOUSEHOLD: (see Tables 16.7 ÷ 16.12 in worksheet “FIN_HH-D” of MAED_D.xls)		
TF.RH.SH	GWa	Traditional fuel demand for space heating in rural households.
MB.RH.SH	GWa	Modern biomass demand for space heating in rural households.
EL.RH.SH	GWa	Electricity demand for space heating in rural households.
DH.RH.SH	GWa	District heat demand for space heating in rural households.
SS.RH.SH	GWa	Soft solar demand for space heating in rural households.
FF.RH.SH	GWa	Fossil fuel demand for space heating in rural households.
FIN.RH.SH	GWa	Final energy demand for space heating in rural households.
TF.RH.HW	GWa	Traditional fuel demand for water heating in rural households.
MB.RH.HW	GWa	Modern biomass demand for water heating in rural households.
EL.RH.HW	GWa	Electricity demand for water heating in rural households.
DH.RH.HW	GWa	District heat demand for water heating in rural households.
SS.RH.HW	GWa	Soft solar demand for water heating in rural households.
FF.RH.HW	GWa	Fossil fuel demand for water heating in rural households.
FIN.RH.HW	GWa	Final energy demand for water heating in rural households.
TF.RH.CK	GWa	Traditional fuel demand for cooking in rural households.
MB.RH.CK	GWa	Modern biomass demand for cooking in rural households.
EL.RH.CK	GWa	Electricity demand for cooking in rural households.
SS.RH.CK	GWa	Soft solar demand for cooking in rural households.
FF.RH.CK	GWa	Fossil fuel demand for cooking in rural households.
FIN.RH.CK	GWa	Final energy demand for cooking in rural households.
EL.RH.AC	GWa	Electricity demand for air conditioning in rural households.
FF.RH.AC	GWa	Fossil fuel demand for air conditioning in rural households.
FIN.RH.AC	GWa	Final energy demand for air conditioning in rural households.
EL.RH.AP	GWa	Electricity demand for specific uses in electrified rural dwellings (i.e. for purposes other than space and water heating, cooking and air conditioning).
FF.RH.AP	GWa	Fossil fuel demand for lighting and non-electric appliances in non-electrified rural dwellings.
FIN.RH.AP	GWa	Final energy demand for appliances and lighting in rural households.
TFRH	GWa	Traditional fuel demand in rural households.
MBRH	GWa	Modern biomass demand in rural households.
ELRH	GWa	Electricity demand in rural households.
DHRH	GWa	District heat demand in rural households.
SSRH	GWa	Soft solar demand in rural households.
FFRH	GWa	Fossil fuel demand in rural households.
FINRH	GWa	Final energy demand in rural households.

Table 4.2p List and definition of derived variables of final energy demand in household sector

FINAL ENERGY DEMAND IN HOUSEHOLD SECTOR: (see Tables 16.13 ÷ 16.18 in worksheet "FIN_HH-D" of MAED_D.xls)		
TF.HH.SH	GWa	Traditional fuel demand for space heating in Household.
MB.HH.SH	GWa	Modern biomass demand for space heating in Household.
EL.HH.SH	GWa	Electricity demand for space heating in Household.
DH.HH.SH	GWa	District heat demand for space heating in Household.
SS.HH.SH	GWa	Soft solar demand for space heating in Household.
FF.HH.SH	GWa	Fossil fuel demand for space heating in Household.
FIN.HH.SH	GWa	Final energy demand for space heating in Household.
TF.HH.HW	GWa	Traditional fuel demand for water heating in Household.
MB.HH.HW	GWa	Modern biomass demand for water heating in Household.
EL.HH.HW	GWa	Electricity demand for water heating in Household.
DH.HH.HW	GWa	District heat demand for water heating in Household.
SS.HH.HW	GWa	Soft solar demand for water heating in Household.
FF.HH.HW	GWa	Fossil fuel demand for water heating in Household.
FIN.HH.HW	GWa	Final energy demand for water heating in Household.
TF.HH.CK	GWa	Traditional fuel demand for cooking in Household.
MB.HH.CK	GWa	Modern biomass demand for cooking in Household.
EL.HH.CK	GWa	Electricity demand for cooking in Household.
SS.HH.CK	GWa	Soft solar demand for cooking in Household.
FF.HH.CK	GWa	Fossil fuel demand for cooking in Household.
FIN.HH.CK	GWa	Final energy demand for cooking in Household.
EL.HH.AC	GWa	Electricity demand for air conditioning in Household.
FF.HH.AC	GWa	Fossil fuel demand for air conditioning in Household.
FIN.HH.AC	GWa	Final energy demand for air conditioning in Household.
EL.HH.AP	GWa	Electricity demand for specific uses in electrified dwellings (i.e. for purposes other than space and water heating, cooking and air conditioning).
FF.HH.AP	GWa	Fossil fuel demand for lighting and non-electric appliances in non-electrified dwellings.
FIN.HH.AP	GWa	Final energy demand for appliances and lighting in Household.
TFHH	GWa	Traditional fuel demand in Household.
MBHH	GWa	Modern biomass demand in Household.
ELHH	GWa	Electricity demand in Household.
DHHH	GWa	District heat demand in Household.
SSHH	GWa	Soft solar demand in Household.
FFHH	GWa	Fossil fuel (substitutable) demand in Household.
FINHH	GWa	Final energy demand in Household.

Table 4.2q List and definition of derived variables of useful energy demand in service sector

SERVICE:		
USEFUL ENERGY DEMAND IN SERVICE: (see worksheet "US_SS-D" of MAED_D.xls)		
LSER	10^6 empl	Number of employees in Service sector.
TAREA	10^6 sqm	Total Service sector floor area.
TARSH	10^6 sqm	Total Service sector floor area where space heating is required.
US.SH.SER	GWa	Useful energy demand for space heating in Service sector.
US.AC.SER	GWa	Useful energy demand for air conditioning in the Service sector.
EI.MF.SER	kWh/MU	Energy intensity of motor fuel use in Service sector.
EI.ELS.SER	kWh/MU	Energy intensity of electricity specific uses in Service sector.
EI.OTU.SER	kWh/MU	Energy intensity of other thermal uses (except space heating) in Service sector.
US.MF.SE(I)	GWa	Energy demand for motor fuels in subsector **I** of Service sector. I=1,….,NSSER
US.MF.SER	GWa	Energy demand for motor fuels in Service sector.
MFSER		
US.ELS.SE(I)	GWa	Electricity demand for specific uses in subsector **I** of Service sector. I=1,…….,NSSER
US.ELS.SER	GWa	Electricity demand for specific uses in Service sector.
ELSSER		
US.OTU.SE(I)	GWa	Useful energy demand for other thermal uses (except space heating) in subsector **I** of Service sector. I=1,….,NSSER
US.OTU.SER	GWa	Useful energy demand for other thermal uses (except space heating) in Service sector.
US.SER	GWa	Total useful energy demand in Service sector.

Table 4.2r List and definition of derived variables of final energy demand in service sector

FINAL ENERGY DEMAND IN SERVICE: (see worksheet "FIN_SS-D" of MAED_D.xls)		
TF.TU.SER	GWa	Traditional fuel demand for thermal uses in Service sector.
MB.TU.SER	GWa	Modern biomass demand for thermal uses in Service sector.
EL.TU.SER	GWa	Electricity demand for thermal uses in Service sector.
DH.TU.SER	GWa	District heat demand for thermal uses in Service sector.
SS.TU.SER	GWa	Soft solar demand for thermal uses in Service sector.
FF.TU.SER	GWa	Fossil fuel demand for thermal uses in Service sector.
FIN.TU.SER	GWa	Final energy demand for thermal uses in Service sector.
EL.AC.SER	GWa	Electricity demand for air conditioning in Service sector.
FF.AC.SER	GWa	Fossil fuel demand for air conditioning in Service sector.
FIN.AC.SER	GWa	Final energy demand for air conditioning in Service sector.
TFSER	GWa	Traditional fuel demand in Service sector.
MBSER	GWa	Modern biomass demand in Service sector.
ELSER	GWa	Electricity demand in Service sector.
DHSER	GWa	District heat demand in Service sector.
SSSER	GWa	Soft solar demand in Service sector.
FFSER	GWa	Fossil fuel (substitutable) demand in Service sector.
FINSER	GWa	Final energy demand in Service sector.

Table 4.2 s List and definition of derived variables of total final energy demand for the country/region

TOTAL FINAL ENERGY DEMAND FOR THE COUNTRY/REGION: (see worksheet “FINAL-D” of MAED_D.xls)		
TF	GWa	Grand total, thermal use of traditional fuels.
MB	GWa	Grand total, thermal use of modern biomass.
ELTU	GWa	Grand total, thermal use of electricity.
ELNTU	GWa	Grand total, non-thermal use of electricity.
ELEC	GWa	Grand total, electricity demand.
DH	GWa	Grand total, district heat demand.
SS	GWa	Grand total, solar energy demand.
FF	GWa	Grand total, thermal use of fossil fuels.
MF	GWa	Grand total, motor fuel demand.
COALSP	GWa	Grand total, specific uses of coal.
TFEED	GWa	Grand total, feedstock demand.
FINEN	GWa	Grand total, final energy demand.
FINEN.CAP	MWh/cap	Per capita total final energy demand.
EI.FIN.GDP	kWh/MU	Energy intensity of final energy use (i.e. final energy consumption per monetary unit of GDP).

5 PRINCIPAL EQUATIONS USED IN THE MAED MODULE 1

5.1 Introduction

This section provides a logical sequence of the calculations performed by the module MAED_D.xls. Some of these equations are trivial but they may help to clarify how the various scenario parameters affect the results as well as in understanding the MAED_D module. This will also facilitate the process of introducing changes in a future program version.

In the description which follows, the input variables have been written in bold letters in order to facilitate their distinction from the derived variables used by the program. Furthermore, an underline below a derived parameter indicates that its value is not explicitly listed in the Tables of MAED_D.xls worksheets. In order to keep this description as compact as possible, the definitions of various variables given in Section 4 of the manual are generally not repeated after the related equations. Besides, it is believed that in most cases the meaning of the variables is often clear by context, as it is illustrated in a few examples.

5.2 Energy units

As the energy intensities for the various energy uses in Agriculture, Construction, Mining, Manufacturing and Service sectors are expressed in kWh/MU, the specific energy consumption in Household sector are expressed in kWh/dw/yr or kWh/cap/yr and in Service sector in kWh/sqm/yr, the straightforward internal energy unit of the MAED_D model is **Terawatt-hours** (TWh = 10^9 kWh). All the equations of the model include also a conversion factor from TWh to the energy unit specified by the user in cell E50 of the workshhet “Defs”. As such, the energy consumption/demand can be also expressed in all worksheets of the model in this unit. The corresponding conversion factor (CF1) from TWh to the unit specified in cell E50 must be indicated in cell N50 of workshhet “Defs”. Grand totals of final energy demand for the country/region under study, expressed in that unit are listed in worksheet “Final-D”. To have the same grand totals converted to another user-desired energy unit (Mtce, Mtoe, PJ etc.), this new energy unit must be specified by the user in cells L50 and the corresponding conversion factor from the energy unit from cell E50 to the new energy unit in cell M50. The energy demands expressed in this last energy unit are shown in worksheet “Final Results (User Units)”. A comprehensive set of conversion factors for this purpose is provided in a separate worksheet “Convs” of the MAED_D.xls file.

5.3 Demographic calculations

In MAED_D.xls (see worksheet “Demogr-D”) the evolution of population as a function of time is defined exogenously as a scenario parameter. This can be done in two ways: either one can specify the population size PO for each model year or, alternatively, one can give the population figure only for the first reference year and provide values of the average annual growth rate of population, POGR (in % per annum), between all successive model years. In the former case, MAED_D.xls may be used to calculate POGR and, in the latter case, PO through the relations:

$$\mathbf{POGR} = \{ (\mathbf{PO} / \mathbf{PO}(-1))^{(1/\mathrm{INCR})} - 1 \} * 100$$

or

$$\mathbf{PO} = \mathbf{PO}(-1) * (1 + (\mathbf{POGR} / 100))^{\mathrm{INCR}}$$

where: **PO** and **PO(-1)** represent the size of the population in the current and the last previous model years respectively, **POGR** is the growth rate of population between the two model years, and

INCR is the number of years between the current and the last previous model years.

Some other demographic parameters, namely the share of urban population **(PURB),** the average household size in urban areas **(CAPUH)** and in rural areas **(CAPRH)**, the share of population of age 15-64 in the total population (potential labour force, **PLF**), the share of potential labour force actually working **(PARTLF)** and the fraction of the total population living in large cities **(POPLC)** are also defined exogenously in the model. From these are derived the following parameters which are used in the energy demand calculations of the Transportation, Household and Service sectors:

- Number of urban households (10^6)

UHH = **PO** ∗ **(PURB** / 100) / **CAPUH**

- Share of rural population (%)

PRUR = 100 **- PURB**

- Number of rural households (10^6)

RHH = **PO** ∗ (1 **- PURB** / 100) / **CAPRH**

- Large cities population (10^6)

POLC = **PO** ∗ (**POPLC** / 100)

- Total active labour force (10^6)

ALF = **PO** ∗ (**PLF** / 100) ∗ (**PARTLF** / 100)

5.4 Macroeconomic calculations

Like the population evolution, the growth of GDP (Gross Domestic Product, Y) is also defined exogenously as a scenario parameter and is specified in the same two ways, namely either in terms of the values of Y (in constant currency units of the base year or some other reference year) for each model year or by specifying the GDP value only for the first reference year together with the values of the average annual growth rate of GDP, **YGR** (in % per annum) between all successive model years. MAED_D.xls (see worksheet "GDP-D") then calculates YGR in the former case and Y in the latter case, according to the relations:

$$\mathbf{YGR} = \{ (\mathbf{Y} / \mathbf{Y}(-1))^{(1/\mathrm{INCR})} - 1 \} * 100$$

and

$$\mathbf{Y} = \mathbf{Y}(-1) * (1 + (\mathbf{YGR} / 100))^{\mathrm{INCR}}$$

where: **Y** and **Y**(-1) represent the values of the GDP in the current and the last previous model years respectively, and **YGR** is the growth rate of GDP between the two model years. Again, INCR represents the number of years between the current and the last previous model years.

The changes in the structural composition of GDP by main sectors, as well as the changes in the structural compositions of main sector value added by sub sectors, over the projection period are also exogenously defined by the user as a part of the scenario. From these scenario input parameters the module calculates, for each model year, first the GDP formation by economic sector, and then the value added by sub sectors of each sector in the following manner:

GDP (**Y**) formation by economic sector and subsector (10^9 monetary units, MU):

YAGR = **Y** ∗ (**PYAGR** / 100) (AGRiculture)

YCON = **Y** ∗ (**PYCON** / 100) (CONstruction)

YMIN = **Y** ∗ (**PYMIN** / 100) (MINing)

YMAN = **Y** ∗ (**PYMAN** / 100) (MANufacturing)

YSER = **Y** ∗ (**PYSER** / 100) (SERvice)

YEN = **Y** ∗ (**PYEN** / 100) (ENergy)

where: **PYAGR, PYCON, PYMIN, PYMAN, PYSER and PYEN** are the % shares of GDP contributed by the respective economic sectors, as specified in worksheet “GDP-D”.

The values added (VA) of the subsectors of Agriculture, Construction, Mining, Manufacturing and Service are:

YAG(I) = YAGR ∗ (PVAAG(I) / 100) I=1,…..,NSAGR (AGRiculture)

YCO(I) = YCON ∗ (PVACO(I) / 100) I=1,…..,NSCON (CONstruction)

YMI(I) = YMIN ∗ (PVAMI(I) / 100) I=1,…..,NSMIN (MINing)

YMA(I) = YMAN ∗ (PVAMA(I) / 100) I=1,…..,NSMAN (MANufacturing)

YSE(I) = YSER ∗ (PVASE(I) / 100) I=1,…..,NSSER (SERvice)

where: **PVAAG(I), PVACO(I), PVAMI(I), PVAMA(I)** and **PVASE(I)** are the % shares of value added of subsector I (as specified in worksheet “GDP-D”) in the respective value added of the main economic sector, and **NSAGR**, **NSCON**, **NSMIN**, **NSMAN** and **NSSER** are the number of subsectors in each of the main economic sector.

Total GDP per capita (MU/CAP):

$$\mathbf{Y.CAP} = \mathbf{Y / PO * 1000}$$

Economic sector value added per capita (MU/CAP):

$$\mathbf{YAGR.CAP} = \mathrm{YAGR} / \mathbf{PO} * 1000 \qquad \text{(AGRiculture)}$$

$$\mathbf{YCON.CAP} = \mathrm{YCON} / \mathbf{PO} * 1000 \qquad \text{(CONstruction)}$$

$$\mathbf{YMIN.CAP} = \mathrm{YMIN} / \mathbf{PO} * 1000 \qquad \text{(MINing)}$$

$$\mathbf{YMAN.CAP} = \mathrm{YMAN} / \mathbf{PO} * 1000 \qquad \text{(MANufacturing)}$$

$$\mathbf{YSER.CAP} = \mathrm{YSER} / \mathbf{PO} * 1000 \qquad \text{(SERvice)}$$

$$\mathbf{YEN.CAP} = \mathrm{YEN} / \mathbf{PO} * 1000 \qquad \text{(ENergy)}$$

Growth rates of sector/subsector value added, total GDP and per capita GDP (%):

$$\mathrm{YAGR.GR} = \{ (\mathrm{YAGR} / \mathrm{YAGR(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \text{(AGRiculture)}$$

$$\mathrm{YAG.GR(I)} = \{ (\mathrm{YAG(I)} / \mathrm{YAG(I)(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \mathrm{I}=1,\ldots,\mathbf{NSAGR}$$

$$\mathrm{YCON.GR} = \{ (\mathrm{YCON} / \mathrm{YCON(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \text{(CONstruction)}$$

$$\mathrm{YCO.GR(I)} = \{ (\mathrm{YCO(I)} / \mathrm{YCO(I)(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \mathrm{I}=1,\ldots,\mathbf{NSCON}$$

$$\mathrm{YMIN.GR} = \{ (\mathrm{YMIN} / \mathrm{YMIN(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \text{(MINing)}$$

$$\mathrm{YMI.GR(I)} = \{ (\mathrm{YMI(I)} / \mathrm{YMI(I)(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \mathrm{I}=1,\ldots,\mathbf{NSMIN}$$

$$\mathrm{YMAN.GR} = \{ (\mathrm{YMAN} / \mathrm{YMAN(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \text{(MANufacturing)}$$

$$\mathrm{YMA.GR(I)} = \{ (\mathrm{YMA(I)} / \mathrm{YMA(I)(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \mathrm{I}=1,\ldots,\mathbf{NSMAN}$$

$$\mathrm{YSER.GR} = \{ (\mathrm{YSER} / \mathrm{YSER(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \text{(SERvice)}$$

$$\mathrm{YSE.GR(I)} = \{ (\mathrm{YSE(I)} / \mathrm{YSE(I)(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \mathrm{I}=1,\ldots,\mathbf{NSSER}$$

$$\mathrm{YEN.GR} = \{ (\mathrm{YEN} / \mathrm{YEN(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \text{(ENergy)}$$

$$\mathrm{Y.GR} = \{ (\mathrm{Y} / \mathrm{Y(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \text{(Total GDP)}$$

$$\mathrm{Y.CAP.GR} = \{ (\mathrm{Y.CAP} / \mathrm{Y.CAP(-1)})^{(1/\mathrm{INCR})} - 1 \} * 100 \qquad \text{(Per capita GDP)}$$

The previous equations are similar to those described earlier in relation with the variables **POGR** and **YGR**.

5.5 Energy demand calculations

5.5.1 Industry sector

(a) Average energy intensities in Agriculture, Construction, Mining and Manufacturing (see worksheet “EnInt-D” of MAED_D.xls)

<u>Energy intensities of Motor Fuels (MF) use</u>:

$$\text{EI.MF.AGR} = \sum_{I=1}^{NSAGR} \mathbf{(EI.MF.AG(I) * PVAAG(I)\ )} / 100 \qquad \text{(AGRiculture)}$$

$$\text{EI.MF.CON} = \sum_{I=1}^{NSCON} \mathbf{(EI.MF.CO(I) * PVACO(I)\ )} / 100 \qquad \text{(CONstruction)}$$

$$\text{EI.MF.MIN} = \sum_{I=1}^{NSMIN} \mathbf{(EI.MF.MI(I) * PVAMI(I)\ ) /} 100 \qquad \text{(MINing)}$$

$$\text{EI.MF.MAN} = \sum_{I=1}^{NSMAN} \mathbf{(EI.MF.MA(I) * PVAMA(I)\ )} / 100 \qquad \text{(MANufacturing)}$$

<u>Energy intensities of ELectricity, Specific uses (ELS):</u>

$$\text{EI.ELS.AGR} = \sum_{I=1}^{NSAGR} (\ \mathbf{EI.ELS.AG(I) * PVAAG(I)\ ) /} 100 \qquad \text{(AGRiculture)}$$

$$\text{EI.ELS.CON} = \sum_{I=1}^{NSCON} \mathbf{(\ EI.ELS.CO(I) * PVACO(I)\ ) /} 100 \qquad \text{(CONstruction)}$$

$$\text{EI.ELS.MIN} = \sum_{I=1}^{NSMIN} \mathbf{(\ EI.ELS.MI(I) * PVAMI(I)\ )} / 100 \qquad \text{(MINing)}$$

$$\text{EI.ELS.MAN} = \sum_{I=1}^{NSMAN} \mathbf{(\ EI.ELS.MA(I) * PVAMA(I)\ )} / 100 \qquad \text{(MANufacturing)}$$

Energy intensities of Thermal Uses (TU):

$$\text{EI.TU.AGR} = \sum_{I=1}^{NSAGR} (\ \text{EI.TU.AG(I)} * \text{PVAAG(I)}\ ) / 100 \qquad \text{(AGRiculture)}$$

$$\text{EI.TU.CON} = \sum_{I=1}^{NSCON} \mathbf{(\ EI.TU.CO(I) * PVACO(I)\ ) /} 100 \qquad \text{(CONstruction)}$$

$$\text{EI.TU.MIN} = \sum_{I=1}^{NSMIN} \mathbf{(\ EI.TU.MI(I) * PVAMI(I)\ ) /} 100 \qquad \text{(MINing)}$$

$$\text{EI.TU.MAN} = \sum_{I=1}^{NSMAN} \mathbf{(\ EI.TU.MA(I) * PVAMA(I)\ ) /} 100 \qquad \text{(MANufacturing)}$$

(b) Energy demand of agriculture, construction and mining (ACM)

The demand for motor fuels and for specific uses of electricity (such as lighting, motive power and electrolysis) is calculated directly in terms of final energy. However, the demand for thermal energy is first calculated in terms of useful energy and then converted to final energy based on scenario assumptions about the penetration of alternative energy sources (traditional fuels, modern biomass, electricity, soft solar and fossil fuels) into this demand market and their efficiencies (relative to the use of electricity with conventional technologies).

(b.1) Energy demand for motor fuels, electricity (specific uses) and thermal uses
(see worksheets "UsEne-D" and "FIN_ACM" of MAED_D.xls)

<u>Final energy demand for Motor Fuels (MF):</u>

$$\text{US.MF.AG(I)} = \textbf{EI.MF.AG(I)} * \text{YAG(I)} * \textbf{CF1} \qquad \text{I=1,…..,}\textbf{NSAGR} \text{ (AGR subsector I)}$$

$$\text{MFAGR} = \text{US.MF.AGR}$$

$$= \sum_{I=1}^{NSAGR} \text{US.MF.AG(I)}$$

$$= \sum_{I=1}^{NSAGR} (\ \textbf{EI.MF.AG(I)} * \text{YAG(I)}\ ) * \textbf{CF1} \qquad \text{(AGR)}$$

$$\text{US.MF.CO(I)} = \textbf{EI.MF.CO(I)} * \text{YCO(I)} * \textbf{CF1} \qquad \text{I=1,…..,}\textbf{NSCON} \text{ (CON subsector I)}$$

$$\text{MFCON} = \text{US.MF.CON}$$

$$= \sum_{I=1}^{NSCON} \text{US.MF.CO(I)}$$

$$= \sum_{I=1}^{NSCON} (\ \textbf{EI.MF.CO(I)} * \text{YCO(I)}\ ) * \textbf{CF1} \qquad \text{(CON)}$$

$$\text{US.MF.MI(I)} = \textbf{EI.MF.MI(I)} * \text{YAG(I)} * \textbf{CF1} \qquad \text{I=1,…..,}\textbf{NSMIN} \text{ (MIN subsector I)}$$

$$\text{MFMIN} = \text{US.MF.MIN}$$

$$= \sum_{I=1}^{NSMIN} \text{US.MF.MI(I)}$$

$$= \sum_{I=1}^{NSMIN} (\ \textbf{EI.MF.MI(I)} * \text{YMI(I)}\ ) * \textbf{CF1} \qquad \text{(MIN)}$$

$$\text{MFACM} = \text{MFAGR} + \text{MFCON} + \text{MFMIN} \qquad \text{(ACM)}$$

Final energy demand for ELectricity for Specific uses (ELS):

$$US.ELS.AG(I) = \mathbf{EI.ELS.AG(I)} * YAG(I) * \mathbf{CF1} \qquad I=1,\ldots,\mathbf{NSAGR} \text{ (AGR subsector I)}$$

$$ELSAGR = US.ELS.AGR$$

$$= \sum_{I=1}^{NSAGR} US.ELS.AG(I)$$

$$= \sum_{I=1}^{NSAGR} (\mathbf{EI.ELS.AG(I)} * YAG(I)) * \mathbf{CF1} \qquad \text{(AGR)}$$

$$US.ELS.CO(I) = \mathbf{EI.ELS.CO(I)} * YCO(I) * \mathbf{CF1} \qquad I=1,\ldots,\mathbf{NSCON} \text{ (CON subsector I)}$$

$$ELSCON = US.\ ELS.CON$$

$$= \sum_{I=1}^{NSCON} US.ELS.CO(I)$$

$$= \sum_{I=1}^{NSCON} (\mathbf{EI.\ ELS.CO(I)} * YCO(I)) * \mathbf{CF1} \qquad \text{(CON)}$$

$$US.ELS.MI(I) = \mathbf{EI.ELS.MI(I)} * YMI(I) * \mathbf{CF1} \qquad I=1,\ldots,\mathbf{NSMIN} \text{ (MIN subsector I)}$$

$$ELSMIN = US.ELS.MIN$$

$$= \sum_{I=1}^{NSMIN} US.ELS.MI(I)$$

$$= \sum_{I=1}^{NSMIN} (\mathbf{EI.\ ELS.MI(I)} * YMI(I)) * \mathbf{CF1} \qquad \text{(MIN)}$$

$$ELSACM = ELSAGR + ELSCON + ELSMIN \qquad \text{(ACM)}$$

Useful energy demand for Thermal Uses (TU):

$$US.TU.AG(I) = \mathbf{EI.TU.AG(I)} * YAG(I) * \mathbf{CF1} \qquad I=1,\ldots,\mathbf{NSAGR} \text{ (AGR subsector I)}$$

$$US.TU.AGR = \sum_{I=1}^{NSAGR} US.TU.AG(I)$$

$$= \sum_{I=1}^{NSAGR} \mathbf{EI.TU.AG(I)} * YAG(I)) * \mathbf{CF1} \qquad \text{(AGR)}$$

$$US.TU.CO(I) = \mathbf{EI.TU.CO(I)} * YCO(I) * \mathbf{CF1} \qquad I=1,\ldots,\mathbf{NSCON} \text{ (CON subsector I)}$$

$$US.TU.CON = \sum_{I=1}^{NSCON} US.TU.CO(I)$$

$$= \sum_{I=1}^{NSCON} (\mathbf{EI.TU.CO(I)} * YCO(I)) * \mathbf{CF1} \qquad \text{(CON)}$$

$$US.TU.MI(I) = \mathbf{EI.TU.MI(I)} * YMI(I) * \mathbf{CF1} \qquad I=1,\ldots,\mathbf{NSMIN} \text{ (MIN subsector I)}$$

$$\text{US.TU.MIN} = \sum_{I=1}^{NSMIN} \text{US.TU.MI(I)}$$

$$= \sum_{I=1}^{NSMIN} (\ \mathbf{EI.TU.MI(I)} * \text{YMI(I)}\ ) * \mathbf{CF1} \qquad \text{(MIN)}$$

$$\text{US.TU.ACM} = \text{US.TU.AGR} + \text{US.TU.CON} + \text{US.TU.MIN} \qquad \text{(ACM)}$$

In the previous equations, **CF1** is the conversion factor from TWh, internal energy unit of the model, to the energy unit specified in cell E50 of worksheet "Defs".

(b.2) Average penetration of alternative energy forms into useful thermal energy for ACM (%):(see Table 5-4 of worksheet "ACMFac-D" in MAED_D.xls)

In Tables 5-1 to 5-3 of worksheet "ACMFac-D" the particular penetrations of different energy carriers (traditional fuels, modern biomass, electricity, solar and fossil fuels) into the useful thermal energy demand market of each sector (Agriculture, Construction and Mining) are entered. Based on these sector related penetrations and on the share of each sector in the total market of useful thermal energy demand of the three sectors, the weighted average penetration of each energy carrier into the market is calculated (Table 5-4) as follows:

Traditional fuels (TF):

$$\begin{aligned}\text{TFPACM} = {} & \mathbf{TFPAGR} * \mathbf{EI.TU.AGR} * \text{YAGR} \\ & + \mathbf{TFPCON} * \mathbf{EI.TU.CON} * \text{YCON} \\ & + \mathbf{TFPMIN} * \mathbf{EI.TU.MIN} * \text{YMIN}\ ) \\ & /\ (\ \mathbf{EI.TU.AGR} * \text{YAGR} + \mathbf{EI.TU.CON} * \text{YCON} \\ & + \mathbf{EI.TU.MIN} * \text{YMIN}\ ) \\ = {} & (\ \mathbf{TFPAGR} * \text{US.TU.AGR} + \mathbf{TFPCON} * \text{US.TU.CON} \\ & + \mathbf{TFPMIN} * \text{US.TU.MIN}\ )/\ \text{US.TU.ACM}\end{aligned}$$

Modern biomass (MB):

$$\begin{aligned}\text{MBPACM} = {} & (\mathbf{MBPAGR} * \mathbf{EI.TU.AGR} * \text{YAGR} + \mathbf{MBPCON} * \mathbf{EI.TU.CON} * \text{YCON} \\ & +\mathbf{MBPMIN} * \mathbf{EI.TU.MIN} * \text{YMIN}\ )\ / \\ & (\mathbf{EI.TU.AGR} * \text{YAGR} + \mathbf{EI.TU.CON} * \text{YCON} + \mathbf{EI.TU.MIN} * \text{YMIN}\ ) \\ = {} & (\ \mathbf{MBPAGR} * \text{US.TU.AGR} + \mathbf{MBPCON} * \text{US.TU.CON} \\ & + \mathbf{MBPMIN} * \text{US.TU.MIN}\ )\ /\ \text{US.TU.ACM}\end{aligned}$$

Electricity (EL-conventional):

$$\begin{aligned}\text{ELPACM} = {} & (\ \mathbf{ELPAGR} * \mathbf{EI.TU.AGR} * \text{YAGR} \\ & + \mathbf{ELPCON} * \mathbf{EI.TU.CON} * \text{YCON} \\ & + \mathbf{ELPMIN} * \mathbf{EI.TU.MIN} * \text{YMIN}\ )\ / \\ & (\ \mathbf{EI.TU.AGR} * \text{YAGR} + \mathbf{EI.TU.CON} * \text{YCON} + \mathbf{EI.TU.MIN} * \text{YMIN}\ ) \\ = {} & (\mathbf{ELPAGR} * \text{US.TU.AGR} + \mathbf{ELPCON} * \text{US.TU.CON} \\ & + \mathbf{ELPMIN} * \text{US.TU.MIN}\ )\ /\ \text{US.TU.ACM}\end{aligned}$$

Soft solar systems (SS):

$$\begin{aligned}\text{SSPACM} = {} & (\ \mathbf{SSPAGR} * \mathbf{EI.TU.AGR} * \text{YAGR} + \mathbf{SSPCON} * \mathbf{EI.TU.CON} * \text{YCON} \\ & + \mathbf{SSPMIN} * \mathbf{EI.TU.MIN} * \text{YMIN}\ )\ / \\ & (\ \mathbf{EI.TU.AGR} * \text{YAGR} + \mathbf{EI.TU.CON} * \text{YCON} + \mathbf{EI.TU.MIN} * \text{YMIN}\ ) \\ = {} & (\ \mathbf{SSPAGR} * \text{US.TU.AGR} + \mathbf{SSPCON} * \text{US.TU.CON} \\ & + \mathbf{SSPMIN} * \text{US.TU.MIN}\ )\ /\ \text{US.TU.ACM}\end{aligned}$$

Fossil fuels (FF):

FFPACM = (**FFPAGR** ∗ **EI.TU.AGR** ∗ YAGR + **FFPCON** ∗ **EI.TU.CON** ∗ YCON
+ **FFPMIN** ∗ **EI.TU.MIN** ∗ YMIN)
/ (**EI.TU.AGR** ∗ YAGR + **EI.TU.CON** ∗ YCON + **EI.TU.MIN** ∗ YMIN)

= (**FFPAGR** ∗ US.TU.AGR + **FFPCON** ∗ US.TU.CON
+ **FFPMIN** ∗ US.TU.MIN) / US.TU.ACM

(b.3) Conversion of useful energy demand for thermal uses to final energy demand in ACM (see worksheet "FIN_ACM" in MAED_D.xls)

Agriculture (AGR):

TFAGR	=	US.TU.AGR ∗ (**TFPAGR** / 100) / (**TFEAGR** /100 **)**	(traditional fuels)
MBAGR	=	US.TU.AGR ∗ (**MBPAGR** / 100) / (**MBEAGR** /100)	(modern biomass)
ELHAGR	=	US.TU.AGR ∗ (**ELPAGR** / 100)	(electricity for thermal uses)
SSAGR	=	US.TU.AGR ∗ (**SSPAGR** / 100)	(soft solar)
FFAGR	=	US.TU.AGR ∗ (**FFPAGR** / 100) / (**FFEAGR** /100)	(fossil fuels)

Construction (CON):

TFCON	=	US.TU.CON ∗ (**TFPCON** / 100) / (**TFECON** /100)	(traditional fuels)
MBCON	=	US.TU.CON ∗ (**MBPCON** / 100) / (**MBECON** /100)	(modern biomass)
ELHCON	=	US.TU.CON ∗ (**ELPCON** / 100)	(electricity for thermal uses)
SSCON	=	US.TU.CON ∗ (**SSPCON** / 100)	(soft solar)
FFCON	=	US.TU.CON ∗ (**FFPCON** / 100) / (**FFECON** /100)	(fossil fuels)

Mining (MIN):

TFMIN	=	US.TU.MIN ∗ (**TFPMIN** / 100) / (**TFEMIN** /100)	(traditional fuels)
MBMIN	=	US.TU.MIN ∗ (**MBPMIN** / 100) / (**MBEMIN** /100)	(modern biomass)
ELHMIN	=	US.TU.MIN ∗ (**ELPMIN** / 100)	(electricity for thermal uses)
SSMIN	=	US.TU.MIN ∗ (**SSPMIN** / 100)	(soft solar)
FFMIN	=	US.TU.MIN ∗ (**FFPMIN** / 100) / (**FFEMIN** /100)	(fossil fuels)

(b.4) Final energy demand of Agriculture (AGR)
(see worksheet "FIN_ACM" in MAED_D.xls)

ELAGR	=	ELSAGR + ELHAGR	(electricity, total)
FINAGR	=	MFAGR + ELAGR + TFAGR + MBAGR + SSAGR + FFAGR	(total final energy)

Energy form shares in Agriculture total final energy demand (%):

TFAGR.S	=	TFAGR / FINAGR ∗ 100	(traditional fuels)
MBAGR.S	=	MBAGR / FINAGR ∗ 100	(modern biomass)
ELAGR.S	=	ELAGR / FINAGR ∗ 100	(electricity)
SSAGR.S	=	SSAGR / FINAGR ∗ 100	(soft solar)
FFAGR.S	=	FFAGR / FINAGR ∗ 100	(fossil fuels)
MFAGR.S	=	MFAGR / FINAGR ∗ 100	(motor fuels)

Final energy demand per value added (energy intensity) in Agriculture (kWh/MU):

EI.TF.AGR	=	(TFAGR / YAGR) / **CF1**	(traditional fuels)
EI.MB.AGR	=	(MBAGR / YAGR) / **CF1**	(modern biomass)
EI.EL.AGR	=	(ELAGR / YAGR) / **CF1**	(electricity)
EI.SS.AGR	=	(SSAGR / YAGR) / **CF1**	(soft solar)
EI.FF.AGR	=	(FFAGR / YAGR) / **CF1**	(fossil fuels)
EI.MF.AGR	=	(MFAGR / YAGR) / **CF1**	(motor fuels)
EI.FIN.AGR	=	(FINAGR / YAGR) / **CF1**	(total final energy)

(b.5) Final energy demand of Construction (CON)
(see worksheet "FIN_ACM" in MAED_D.xls)

ELCON	=	ELSCON + ELHCON	(total electricity)
FINCON	=	MFCON + ELCON + TFCON + MBCON + SSCON + FFCON	(total final energy)

Energy form shares in Construction total final energy demand (%):

TFCON.S	=	TFCON / FINCON ∗ 100	(traditional fuels)
MBCON.S	=	MBCON / FINCON ∗ 100	(modern biomass)

ELCON.S	=	ELCON / FINCON ∗ 100	(electricity)
SSCON.S	=	SSCON / FINCON ∗ 100	(soft solar)
FFCON.S	=	FFCON / FINCON ∗ 100	(fossil fuels)
MFCON.S	=	MFCON / FINCON ∗ 100	(motor fuels)

<u>Final energy demand per value added (energy intensity) in Construction (kWh/MU):</u>

EI.TF.CON	=	(TFCON / YCON) / **CF1**	(traditional fuels)
EI.MB.CON	=	(MBCON / YCON) / **CF1**	(modern biomass)
EI.EL.CON	=	(ELCON / YCON) / **CF1**	(electricity)
EI.SS.CON	=	(SSCON / YCON) / **CF1**	(soft solar)
EI.FF.CON	=	(FFCON / YCON) / **CF1**	(fossil fuels)
EI.MF.CON	=	(MFCON / YCON) / **CF1**	(motor fuels)
EI.FIN.CON	=	(FINCON / YCON) / **CF1**	(total final energy)

(b.6) Final energy demand of Mining (MIN)
(see worksheet “FIN_ACM” in MAED_D.xls)

ELMIN	=	ELSMIN + ELHMIN	(electricity, total)
FINMIN	=	MFMIN + ELMIN + TFMIN + MBMIN + SSMIN + FFMIN	(total final energy)

<u>Energy form shares in Mining total final energy demand (%):</u>

TFMIN.S	=	TFMIN / FINMIN ∗ 100	(traditional fuels)
MBMIN.S	=	MBMIN / FINMIN ∗ 100	(modern biomass)
ELMIN.S	=	ELMIN / FINMIN ∗ 100	(electricity)
SSMIN.S	=	SSMIN / FINMIN ∗ 100	(soft solar)
FFMIN.S	=	FFMIN / FINMIN ∗ 100	(fossil fuels)
MFMIN.S	=	MFMIN / FINMIN ∗ 100	(motor fuels)

<u>Final energy demand per value added (energy intensity) in Mining (kWh/MU):</u>

EI.TF.MIN	=	(TFMIN / YMIN) / **CF1**	(traditional fuels)
EI.MB.MIN	=	(MBMIN / YMIN) / **CF1**	(modern biomass)
EI.EL.MIN	=	(ELMIN / YMIN) / **CF1**	(electricity)

EI.SS.MIN	=	(SSMIN / YMIN) / **CF1**	(soft solar)
EI.FF.MIN	=	(FFMIN / YMIN) / **CF1**	(fossil fuels)
EI.MF.MIN	=	(MFMIN / YMIN) / **CF1**	(motor fuels)
EI.FIN.MIN	=	(FINMIN / YMIN) / **CF1**	(total final energy)

(b.7) Final energy demand of agriculture, construction and mining (ACM)
(see worksheet "FIN_ACM" in MAED_D.xls)

Total final energy demand by energy form

TFACM	=	TFAGR + TFCON + TFMIN	(traditional fuels)
MBACM	=	MBAGR + MBCON + MBMIN	(modern biomass)
ELSACM	=	ELSAGR + ELSCON + ELSMIN	(electricity for specific uses)
ELHACM	=	ELHAGR + ELHCON + ELHMIN	(electricity for thermal uses)
ELACM	=	ELSACM + ELHACM	
	=	ELAGR + ELCON + ELMIN	(electricity, total)
SSACM	=	SSAGR + SSCON + SSMIN	(soft solar)
FFACM	=	FFAGR + FFCON + FFMIN	(fossil fuels)
MFACM	=	MFAGR + MFCON + MFMIN	(motor fuels)
FINACM	=	MFACM + ELACM + TFACM + MBACM + SSACM + FFACM	
	=	FINAGR + FINCON + FINMIN	(total final energy)

Energy form shares in ACM total final energy demand (%):

TFACM.S	=	TFACM / FINACM ∗ 100	(traditional fuels)
MBACM.S	=	MBACM / FINACM ∗ 100	(modern biomass)
ELACM.S	=	ELACM / FINACM ∗ 100	(electricity)
SSACM.S	=	SSACM / FINACM ∗ 100	(soft solar)
FFACM.S	=	FFACM / FINACM ∗ 100	(fossil fuels)
MFACM.	=	MFACM / FINACM ∗ 100	(motor fuels)

Final energy demand per value added (energy intensity) in ACM (kWh/MU):

EI.TF.ACM	=	(TFACM / YACM) / **CF1**	(traditional fuels)

EI.MB.ACM = (MBACM / YACM) / **CF1** (modern biomass)

EI.EL.ACM = (ELACM / YACM) / **CF1** (electricity)

EI.SS.ACM = (SSACM / YACM) / **CF1** (soft solar)

EI.FF.ACM = (FFACM / YACM) / **CF1** (fossil fuels)

EI.MF.ACM = (MFACM / YACM) / **CF1** (motor fuels)

EI.FIN.ACM = (FINACM / YACM) / **CF1** (total final energy)

(c) Energy demand of manufacturing (MAN)

The energy demand of Manufacturing sector is calculated in a similar manner as for ACM sectors: the demand for motor fuels and for specific uses of electricity (such as lighting, motive power and electrolysis) are calculated directly in terms of final energy. The demand for thermal energy is first calculated in terms of useful energy and then converted to final energy based on scenario assumptions about the penetration of alternative energy sources: traditional fuels, modern biomass, electricity (conventional and heat pumps), district heat, on-site cogeneration, soft solar and fossil fuels into this demand market and their efficiencies (relative to the use of electricity with conventional technologies).

(c.1) Final energy demand for motor fuels, electricity (specific uses) and useful energy demand for thermal uses
(see worksheet "UsEne-D" and "FIN_Ind-D" of MAED_D.xls)

<u>Manufacturing subsector I</u>:

US.MF.MA(I) = **EI.MF.MA(I)** ∗ YMA(I) ∗ **CF1** I=1,…..,**NSMAN** (MF)

US.ELS.MA(I)= **EI.ELS.MA(I)** ∗ YMA(I) ∗ **CF1** I=1,…..,**NSMAN** (ELS)

US.TU.MA(I) = **EI.TU.MA(I)** ∗ YMA(I) ∗ **CF1** I=1,…..,**NSMAN** (TU)

<u>Manufacturing sector</u>:

MFMAN = US.MF.MAN

$$= \sum_{I=1}^{NSMAN} \text{US.MF.MA(I)}$$

$$= \sum_{I=1}^{NSMAN} (\,\textbf{EI.MF.MA(I)} * \text{YMA(I)}\,) * \textbf{CF1} \qquad \text{(MF)}$$

$$ELSMAN = US.ELS.MAN$$

$$= \sum_{I=1}^{NSMAN} US.ELS.MA(I)$$

$$= \sum_{I=1}^{NSMAN} (\mathbf{EI.ELS.MA(I)} * YMA(I)) * \mathbf{CF1} \qquad \text{(ELS)}$$

$$US.TU.MAN = \sum_{I=1}^{NSMAN} US.TU.MA(I)$$

$$= \sum_{I=1}^{NSMAN} (\mathbf{EI.TU.MA(I)} * YMA(I)) * \mathbf{CF1} \qquad \text{(TU)}$$

In order to convert the useful thermal energy demand of the Manufacturing sector into final energy one needs to take into account the scenario specified assumptions about the penetration of alternative energy sources into their respective potential markets and their efficiencies. These potential markets are very broadly defined by three thermal processes (demand categories), namely:

- steam generation;
- furnace/direct heat (but excluding electrolysis and iron ore reduction by coke which are accounted for as specific uses);
- space and water heating

Useful thermal energy demand (US) by subsector and by type of use:
(see worksheet "ManFac1-D" of MAED_D.xls)

$$USMAN(I,1) = \mathbf{EI.TU.MA(I)} * YMA(I) * (\mathbf{PUSIND(I,1)} / 100) * \mathbf{CF1} \qquad \text{(For subsector I;}$$

$$= US.TU.MA(I) * (\mathbf{PUSIND(I,1)} / 100) * \mathbf{CF1} \qquad \text{steam generation)}$$

$$USMAN(I,2) = \mathbf{EI.TU.MA(I)} * YMA(I) * (\mathbf{PUSIND(I,2)} / 100) * \mathbf{CF1}$$

$$= US.TU.MA(I) * (\mathbf{PUSIND(I,2)} / 100) * \mathbf{CF1} \qquad \text{(furnace/direct heat)}$$

$$USMAN(I,3) = \mathbf{EI.TU.MA(I)} * YMA(I) * (\mathbf{PUSIND(I,3)} / 100) * \mathbf{CF1}$$

$$= US.TU.MA(I) * (\mathbf{PUSIND(I,3)} / 100) * \mathbf{CF1} \qquad \text{(space/water heating)}$$

or, in general:

$$USMAN(I,J) = \mathbf{EI.TU.MA(I)} * YMA(I) * (\mathbf{PUSIND(I,J)} / 100) * \mathbf{CF1}$$

$$= US.TU.MA(I) * (\mathbf{PUSIND(I,J)} / 100) * \mathbf{CF1}$$

where: Manufacturing subsectors: I=1,…..,**NSMAN**, and

Thermal processes:	(J=1) Steam generation (STM)
	(J=2) Furnace/direct heat (FUR)
	(J=3) Space/water heating (SWH)

In the previous equations, **CF1** is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet "Defs".

Useful thermal energy demand (US) of Manufacturing by type of application:
(see worksheet "ManFac1-D" of MAED_D.xls)

US.STM.MAN = USMAN(1)

$$= \sum_{I=1}^{NSMAN} \text{USMAN(I,1)} \qquad \text{(steam generation)}$$

US.FUR.MAN = USMAN(2)

$$= \sum_{I=1}^{NSMAN} \text{USMAN(I,2)} \qquad \text{(furnace/direct heat)}$$

US.SWH.MAN = USMAN(3)

$$= \sum_{I=1}^{NSMAN} \text{USMAN(I,3)} \qquad \text{(space/water heating)}$$

Useful thermal energy demand (US) by subsector of Manufacturing:

USMA(I) = USMAN(I,1) + USMAN(I,2) + USMAN(I,3) I=1,…..,**NSMAN**

Total useful thermal energy demand in Manufacturing:

USMAN(4) = US.STM.MAN + US.FUR.MAN + US.SWH.MAN

$$= \sum_{I=1}^{3} \text{USMAN(I)}$$

$$= \sum_{I=1}^{NSMAN} \text{USMA(I)}$$

(c.2) Penetration in market (PM) of alternative energy forms (%)
(see Tables 8-5 and 8-3 in worksheet "ManFac2-D" of MAED_D.xls)

Electricity (EL-conventional):

PMEL(1) = **ELPMAN(1)** ∗ (1 – (**HPP.STM.MAN** / 100)) (steam generation)

PMEL(2) = **ELPMAN(2)** (furnace/direct heat)

PMEL(3) = **ELPMAN(3)** ∗ (1 – (**HPP.SWH.MAN** / 100)) (space/water heating)

PMEL(4) = (PMEL(1) ∗ USMAN(1) + PMEL(2) ∗ USMAN(2) + PMEL(3) ∗ USMAN(3)) / USMAN(4) (total useful thermal)

<u>Electricity (HP-heat pump):</u>

PMHP(1) = **ELPMAN(1)** ∗ (**HPP.STM.MAN** / 100) (steam generation)

PMHP(2) = 0 (furnace/direct heat)

PMHP(3) = **ELPMAN(3)** ∗ (**HPP.SWH.MAN** / 100) (space and water heating)

PMHP(4) = (PMHP(1) ∗ USMAN(1) + PMHP(2) ∗ USMAN(2) + PMHP(3) ∗ USMAN(3)) / USMAN(4) (total useful thermal)

<u>District heat (DH):</u>

PMDH(1) = **DHP.STM.MAN** (steam generation)

PMDH(2) = 0 (furnace/direct heat)

PMDH(3) = **DHP.SWH.MAN** (space/water heating)

PMDH(4) = (PMDH(1) ∗ USMAN(1) + PMDH(2) ∗ USMAN(2) + PMDH(3) ∗ USMAN(3)) / USMAN(4) (total useful thermal)

<u>Soft solar systems (SS):</u>

PMSS(1) = **SSP.STM.MAN** ∗ (**FIDS** / 100) (steam generation)

PMSS(2) = 0 (furnace/direct heat)

PMSS(3) = **SSP.SWH.MAN** ∗ (**FIDS** / 100) (space/water heating)

PMSS(4) = (PMSS(1) ∗ USMAN(1) + PMSS(2) ∗ USMAN(2) + PMSS(3) ∗ USMAN(3)) / USMAN(4) (total useful thermal)

<u>Cogeneration (within industrial plants) as opposed to cogeneration in central power plants (CG):</u>

PMCG(1) = **CGP.STM.MAN** (steam generation)

PMCG(2)	=	0	(furnace/direct heat)
PMCG(3)	=	**CGP.SWH.MAN**	(space/water heating)
PMCG(4)	=	(PMCG(1) ∗ USMAN(1) + PMCG(2) ∗ USMAN(2) + PMCG(3) ∗ USMAN(3)) / USMAN(4)	(total useful thermal)

<u>Traditional fuels (TF):</u>

PMTF(1)	=	**TFPMAN(1)**	(steam generation)
PMTF(2)	=	**TFPMAN(2)**	(furnace/direct heat)
PMTF(3)	=	**TFPMAN(3)**	(space/water heating)
PMTF(4)	=	(PMTF(1) ∗ USMAN(1) + PMTF(2) ∗ USMAN(2) + PMTF(3) ∗ USMAN(3)) / USMAN(4)	(total useful thermal)

<u>Modern biomass (MB):</u>

PMMB(1)	=	**MBPMAN(1)**	(steam generation)
PMMB(2)	=	**MBPMAN(2)**	(furnace/direct heat)
PMMB(3)	=	**MBPMAN(3)**	(space/water heating)
PMMB(4)	=	(PMMB(1) ∗ USMAN(1) + PMMB(2) ∗ USMAN(2) + PMMB(3) ∗ USMAN(3)) / USMAN(4)	(total useful thermal)

<u>Fossil fuels (FF) (remainder):</u>

PMFF(1)	=	100 – (PMEL(1) + PMHP(1) + PMDH(1) + PMSS(1) + PMCG(1) + PMTF(1) + PMMB(1))	(steam generation)
PMFF(2)	=	100 – (PMEL(2) + PMHP(2) + PMDH(2) + PMSS(2) + PMCG(2) + PMTF(2) + PMMB(2))	(furnace/direct heat)
PMFF(3)	=	100 – (PMEL(3) + PMHP(3) + PMDH(3) + PMSS(3) + PMCG(3) + PMTF(3) + PMMB(3))	(space/water heating)
PMFF(4)	=	(PMFF(1) ∗ USMAN(1) + PMFF(2) ∗ USMAN(2) + PMFF(3) ∗ USMAN(3)) / USMAN(4)	(total useful thermal)

(c.3) Average efficiencies of fossil fuels, traditional fuels and modern biomass for thermal processes (%, relative to electricity):
(see Table 8-2 in worksheet "Man_Fac2-D" of MAED_D.xls)

Fossil fuels (FF):

FFEMAN(4) = USMAN(4) ∗ PMFF(4) / [USMAN(1) ∗ PMFF(1) / **FFEMAN(1)**
+ USMAN(2) ∗ PMFF(2) / **FFEMAN(2)**
+ USMAN(3) ∗ PMFF(3) / **FFEMAN(3)]**

Traditional fuels (TF):

If

PMTF(4) = 0,

then

TFEMAN(4) = (TFEMAN(1) + TFEMAN(2) + TFEMAN(3)) / 3

Otherwise

TFEMAN(4) = USMAN(4) ∗ PMTF(4) / [USMAN(1) ∗ PMTF(1) / **TFEMAN(1)**
+ USMAN(2) ∗ PMTF(2) / **TFEMAN(2)**
+ USMAN(3) ∗ PMTF(3) / **TFEMAN(3)**]

Modern biomass (MB):

If

PMMB(4) = 0,

then

MBEMAN(4) = (MBEMAN(1) + MBEMAN(2) + MBEMAN(3)) / 3

Otherwise

MBEMAN(4) = USMAN(4) ∗ PMMF(4) / [USMAN(1) ∗ PMMF(1) / **MBEMAN(1)**
+ USMAN(2) ∗ PMMF(2) / **MBEMAN(2)**
+ USMAN(3) ∗ PMMF(3) / **MBEMAN(3)]**

(c.4) Conversion of useful thermal energy to final energy demand
(see worksheet "FIN_Ind-D" of MAED_D.xls)

Cogeneration (CG):

COGSTH = USMAN(4) ∗ (PMCG(4) / 100)

Modern biomass (MB):

MBMAN = USMAN(4) ∗ PMMB (4) / MBEMAN(4) + COGSTH
∗ (1 + 1 / **HELRAT**) / (**EFFCOG** / 100) ∗ (**MBSCOG** / 100)

= USMAN(4) ∗ PMMB(4) / MBEMAN(4) +
(USMAN(4) ∗ [PMCG(4) / 100]) ∗ (1 + 1 / **HELRAT**)
/ (**EFFCOG** / 100) ∗ (**MBSCOG** / 100)

Fossil fuels (FF):

FFMAN = USMAN(4) ∗ PMFF(4) / FFEMAN(4) + COGSTH
∗ (1 + 1 / **HELRAT**) / (**EFFCOG** / 100) ∗ (1 – [**MBSCOG** / 100])

= USMAN(4) ∗ PMFF(4) / FFEMAN(4) + { USMAN(4) ∗ PMCG(4) / 100 } ∗ (1 + 1 / **HELRAT**) / (**EFFCOG** / 100) ∗ (1 – (**MBSCOG** / 100))

<u>Electricity for thermal uses (ELH):</u>

ELHMAN = USMAN(4) ∗ (PMEL(4) + PMHP(4) / **HPEMAN**) / 100 - COGSTH / **HELRAT**

= USMAN(4) ∗ (PMEL(4) + PMHP(4) / **HPEMAN**) / 100 - (USMAN(4) ∗ (PMCG(4) / 100)) / **HELRAT**

<u>Traditional fuels (TF):</u>

TFMAN = USMAN(4) ∗ PMTF(4) / TFEMAN(4)

<u>District heating (DH):</u>

DHMAN = USMAN(4) ∗ (PMDH(4) / 100)

<u>Soft solar systems (SS):</u>

SSMAN = USMAN(4) ∗ (PMSS(4) / 100)

(c.5) Coke use for pig iron production:

(see Table 8-4 in worksheet “Man_Fac2-D” of MAED_D.xls)

PSTEEL = **CPST(1)** + **CPST(2)** ∗ YMA(1)

COKE = PSTEEL ∗ (**BOF** /100) ∗ (**IRONST** / 100) ∗ (**EICOK** / 1000) ∗ CF2 ∗ **CF1**

where: CF2 is the conversion factor from Mtce to TWh, and CF1 is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet “Defs”.

(c.6) Feedstock requirements:

(see Table 8-4 in worksheet “Man_Fac2-D” of MAED_D.xls)

PFEED = **CFEED(1)** + **CFEED(2)** ∗ YMA(1)

FEED = PFEED ∗ CF3 ∗ **CF1**

where: CF3 is the conversion factor from Mtoe to TWh, and CF1 is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet “Defs”.

Note: As the number of subsectors of the Manufacturing sector is a user-defined variable varying from 1 to 10, the steel production and feedstock requirements of the petrochemical industry are calculated in the model as a function of the value added by the first Manufacturing subsector. Therefore, if Manufacturing sector is split in several subsectors, for seek of consistency the steel-making industry and petrochemical industry must be considered, from both energy consumption and value added viewpoints, in the first Manufacturing subsector.

(c.7) Final energy demand of Manufacturing:

(see worksheet "FIN_Ind-D" of MAED_D.xls)

Total final energy demand by energy form

In addition to the final energy demands for traditional fuels (TFMAN), modern biomass (MBMAN), district heat (DHMAN), solar (SSMAN), fossil fuels (FFMAN), motor fuels (MFMAN), coke (COKE) and feedstock (FEED), previously calculated, the total final energy demand for electricity and final energy demand for the entire Manufacturing sector are also determined:

ELMAN	=	ELSMAN + ELHMAN	
	=	ELSMAN + USMAN(4) ∗ (PMEL(4) + PMHP(4) / **HPEMAN**) / 100 - { USMAN(4) ∗ (PMCG(4) / 100) } / **HELRAT**	(electricity)
FINMAN	=	MFMAN + ELMAN + TFMAN + MBMAN + DHMAN + SSMAN + FFMAN + COKE + FEED	(total final energy)

Energy form shares in Manufacturing total final energy demand (%):

TFMAN.S	=	TFMAN / FINMAN ∗ 100	(traditional fuels)
MBMAN.S	=	MBMAN / FINMAN ∗ 100	(modern biomass)
ELMAN.S	=	ELMAN / FINMAN ∗ 100	(electricity)
DHMAN.S	=	DHMAN / FINMAN ∗ 100	(district heat)
SSMAN.S	=	SSMAN / FINMAN ∗ 100	(soft solar)
FFMAN.S	=	FFMAN / FINMAN ∗ 100	(fossil fuels)
MFMAN.S	=	MFMAN / FINMAN ∗ 100	(motor fuels)
COKEMAN.S	=	COKE / FINMAN ∗ 100	(coke)
FEEDMAN.S	=	FEED / FINMAN ∗ 100	(feedstock)

Final energy demand per value added (energy intensity) in Manufacturing (kWh/MU):

EI.TF.MAN	=	(FMAN / YMAN) / **CF1**	(traditional fuels)
EI.MB.MAN	=	(MBMAN / YMAN) / **CF1**	(modern biomass)
EI.EL.MAN	=	(ELMAN / YMAN) / **CF1**	(electricity)
EI.DH.MAN	=	(DHMAN / YMAN) / **CF1**	(district heat)
EI.SS.MAN	=	(SSMAN / YMAN) / **CF1**	(soft solar)
EI.FF.MAN	=	(FFMAN / YMAN) / **CF1**	(fossil fuels)
EI.MF.MAN	=	(MFMAN / YMAN) / **CF1**	(motor fuels)

EI.COKE.MAN=		(COKE / YMAN) / **CF1**	(coke)
EI.FEED.MAN =		(FEED / YMAN) / **CF1**	(feedstock)
EI.FIN.MAN	=	(FINMAN / YMAN) / **CF1**	(total final energy)

(d) Industry sector totals
(see worksheets "US_Ene-D" and "FIN_Ind-D" in MAED_D.xls)

<u>Total final energy demand by energy form</u>

TFIND	=	TFACM + TFMAN	(traditional fuels)
MBIND	=	MBACM + MBMAN	(modern biomass)
ELSIND	=	ELSACM + ELSMAN	(electricity for specific uses)
ELHIND	=	ELHACM + ELHMAN	(electricity for thermal uses)
ELIND	=	ELACM + ELMAN	
	=	ELSIND + ELHIND	(electricity, total)
DHIND	=	DHMAN	(district heat)
SSIND	=	SSACM + SSMAN	(soft solar)
FFIND	=	FFACM + FFMAN	(fossil fuels)
MFIND	=	MFACM + MFMAN	(motor fuels)
FININD	=	TFIND + MBIND + ELIND + DHMAN + SSIND + FFIND + MFIND + COKE + FEED	(total final energy)

<u>Energy form shares in Industry total final energy demand (%):</u>

TFIND.S	=	TFIND / FININD ∗ 100	(traditional fuels)
MBIND.S	=	MBIND / FININD ∗ 100	(modern biomass)
ELIND.S	=	ELIND / FININD ∗ 100	(electricity)
DHIND.S	=	DHIND / FININD ∗ 100	(district heat)
SSIND.S	=	SSIND / FININD ∗ 100	(soft solar)
FFIND.S	=	FFIND / FININD ∗ 100	(fossil fuels)
MFIND.S	=	MFIND / FININD ∗ 100	(motor fuels)
COKEIND.S	=	COKE / FININD ∗ 100	(coke)
FEEDIND.S	=	FEED / FININD ∗ 100	(feedstock)

Final energy demand per value added (energy intensity) in Industry (kWh/MU):

EI.TF.IND	=	(TFIND / (YAGR + YCON + YMIN + YMAN)) / **CF1**	(traditional fuels)
EI.MB.IND	=	MBIND / (YAGR + YCON + YMIN + YMAN) / **CF1**	(modern biomass)
EI.EL.IND	=	(ELIND / (YAGR + YCON + YMIN + YMAN)) / **CF1**	(electricity)
EI.DH.IND	=	(DHIND / (YAGR + YCON + YMIN + YMAN)) / **CF1**	(district heat)
EI.SS.IND	=	(SSIND / (YAGR + YCON + YMIN + YMAN)) / **CF1**	(soft solar)
EI.FF.IND	=	(FFIND / (YAGR + YCON + YMIN + YMAN)) / **CF1**	(fossil fuels)
EI.MF.IND	=	(MFIND / (YAGR + YCON + YMIN + YMAN)) / **CF1**	(motor fuels)
EI.COKE.IND	=	(COKE / (YAGR + YCON + YMIN + YMAN)) / **CF1**	(coke)
EI.FEED.IND	=	(FEED / (YAGR + YCON + YMIN + YMAN)) / **CF1**	(feedstock)
EI.FIN.IND	=	(FININD / (YAGR + YCON + YMIN + YMAN)) / **CF1**	(total final energy)

5.5.2 Transportation Sector

(a) Freight transportation (FT):
(see worksheet "FrTrp-D" of MAED_D.xls)

Total ton-kilometers (10^9 t-km):

$$\begin{aligned} \text{TKFT} = {} & \mathbf{CKFT} + \sum_{I=1}^{NSAGR} (\, \mathbf{CTKFT(I)} * \text{YAG(I)} \,) \\ & + \sum_{I=1}^{NSCON} (\, \mathbf{CTKFT(NSAGR+I)} * \text{YCO(I)} \,) \\ & + \sum_{I=1}^{NSMIN} (\, \mathbf{CTKFT(NSAGR+NSCON+I)} * \text{YMI(I)} \,) \\ & + \sum_{I=1}^{NSMAN} (\, \mathbf{CTKFT(NSAGR+NSCON+NSMIN+I)} * \text{YMA(I)} \,) \\ & + \sum_{I=1}^{NSSER} (\, \mathbf{CTKFT(NSAGR+NSCON+NSMIN+NSMAN+I)} * \text{YSE(I)} \,) \\ & + \text{CTKFT(NSAGR+NSCON+NSMIN+NSMAN+NSSER+1)} * \text{YEN} \end{aligned}$$

Distribution by transportation mode (10^9 t-km):

TKFTM(I) = TKFT ∗ (**SFTM(I)** / 100) I = 1,…….,**NMFT**

Energy intensity in units of kWh / 100 ton-kilometers:

Each freight transportation mode has assigned a fuel code number and a specific energy consumption (energy intensity) expressed in a natural unit chosen by the user. Each fuel has assigned a conversion factor from the natural unit for the energy intensity to kWh per 100 ton-kilometers. The following equation converts the energy intensity of freight transportation mode I from selected natural unit per 100 ton-kilometers to kWh/100tkm, taking into consideration the fuel used by each particular transportation mode.

FTMEI(I) = **EIFTM(I) ∗ CFFT(FCFT(I))** I = 1,…….,**NMFT**

Energy consumption by mode:

ECFTM(I) = TKFTM(I) ∗ FTMEI(I) / 100 ∗ **CF1**

= TKFT ∗ (**SFTM(I)** / 100) ∗ FTMEI(I) / 100 ∗ **CF1** I = 1,…….,**NMFT**

where: **CF1** is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet “Defs”.

Energy consumption by fuel

Summing up only the FT modes using electricity:

ECFTF(1) = TELFT

$$= \sum_{I=1;(FCFT(I)=1)}^{NMFT} \text{ECFTM(I)}$$

Summing up only the FT modes using steam coal:

ECFTF(2) = TSCFT

$$= \sum_{I=1;(FCFT(I)=2)}^{NMFT} \text{ECFTM(I)}$$

Summing up only the FT modes using diesel oil)

ECFTF(3) = TDIFT

$$= \sum_{I=1;(FCFT(I)=3)}^{NMFT} \text{ECFTM(I)}$$

Summing up only the FT modes using gasoline:

ECFTF(4) = TGAFT

$$= \sum_{I=1;(FCFT(I)=4)}^{NMFT} \text{ECFTM(I)}$$

Summing up only the FT modes using fuel no. 5:

$$\text{ECFTF}(5) = \text{TF5FT} = \sum_{I=1;(FCFT(I)=5)}^{NMFT} \text{ECFTM}(I)$$

Summing up only the FT modes using fuel no. 6:

$$\text{ECFTF}(6) = \text{TF6FT} = \sum_{I=1;(FCFT(I)=6)}^{NMFT} \text{ECFTM}(I)$$

Summing up only the FT modes using fuel no. 7:

$$\text{ECFTF}(7) = \text{TF7FT} = \sum_{I=1;(FCFT(I)=7)}^{NMFT} \text{ECFTM}(I)$$

Summing up only the FT modes using fuel no. 8:

$$\text{ECFTF}(8) = \text{TF8FT} = \sum_{I=1;(FCFT(I)=8)}^{NMFT} \text{ECFTM}(I)$$

or, in general (total energy consumption of FT modes using fuel no. J):

$$\text{ECFTF}(J) = \sum_{I=1;(FCFT(I)=J)}^{NMFT} \text{ECFTM}(I) \qquad J = 1, .,\mathbf{NTF}$$

$$\text{TMFFT} = \text{TDIFT} + \text{TGAFT} + \text{TF5FT} + \text{TF6FT} + \text{TF7FT} + \text{TF8FT} = \sum_{J=3}^{NTF} \text{ECFTF}(J) \qquad \text{(total motor fuels)}$$

<u>Total final energy demand of freight transportation subsector</u>:

$$\text{TENFT} = \sum_{I=1}^{NMFT} \text{ECFTM}(I) = \sum_{J=1}^{NTF} \text{ECFTF}(J) = \text{TELFT} + \text{TSCFT} + \text{TMFFT}$$

(b) Passenger transportation

(b.1) Passenger, urban (or intracity)

(see worksheet "PassIntra-D" of MAED_D.xls)

Total passenger-kilometers, urban (intracity) traffic (10^9 p-km):

PKU	=	(**DU** ∗ 365) ∗ (POLC / 1000)	
	=	(**DU** ∗ 365) ∗ (**POPLC** / 100) ∗ (**PO** / 1000)	(urban transport demand)

Distribution by transportation mode (10^9 p-km):

PKUTM(I)	=	PKU ∗ (**SUTM(I)** / 100)	I = 1,…….,**NMUT**

Energy intensity in units of kWh / passenger-kilometer:

Each passenger intracity transportation mode has assigned a fuel code number and a specific energy consumption (energy intensity) expressed in a natural unit chosen by the user per 100 kilometers. Each fuel has assigned a conversion factor from the natural unit for the energy intensity to kWh per passenger-kilometer. The following equation converts the energy intensity of urban transportation mode I from selected natural unit per 100 kilometers to kWh/pkm, taking into consideration the fuel used by and the load factor of each particular transportation mode.

UTMEI(I)	=	**EIUTM(I)** ∗ **CFPT(FCUT(I))** / 100 / **LFUTM(I)**	I = 1,….,**NMUT**

Energy consumption by mode:

ECUTM(I)	=	PKUTM(I) ∗ UTMEI(I) ∗ **CF1**	I = 1,…….,**NMUT**

where: **CF1** is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet "Defs".

Energy consumption by fuel

Summing up only the urban PT modes using electricity:

$$\mathrm{ECUTF(1)} = \mathrm{TELUT} = \sum_{I=1;(FCUT(I)=1)}^{NMUT} \mathrm{ECUTM(I)}$$

Steam coal is not a valid fuel for urban PT in MAED_D model:

$$\mathrm{ECUTF(2)} = \mathrm{TSCUT} = 0$$

Summing up only the transportation modes using diesel oil:

$$\mathrm{ECUTF(3)} = \mathrm{TDIUT} = \sum_{I=1;(FCUT(I)=3)}^{NMUT} \mathrm{ECUTM(I)}$$

Summing up only the urban PT modes using gasoline:

$$ECUTF(4) = TGAUT = \sum_{I=1;(FCUT(I)=4)}^{NMUT} ECUTM(I)$$

Summing up only the urban PT modes using fuel no. 5:

$$ECUTF(5) = TF5UT = \sum_{I=1;(FCUT(I)=5)}^{NMUT} ECUTM(I)$$

Summing up only the urban PT modes using fuel no. 6:

$$ECUTF(6) = TF6UT = \sum_{I=1;(FCUT(I)=6)}^{NMUT} ECUTM(I)$$

Summing up only the urban PT modes using fuel no. 7:

$$ECUTF(7) = TF7UT = \sum_{I=1;(FCUT(I)=7)}^{NMUT} ECUTM(I)$$

Summing up only the urban PT modes using fuel no. 8:

$$ECUTF(8) = TF8UT = \sum_{I=1;(FCUT(I)=8)}^{NMUT} ECUTM(I)$$

or, in general (total energy consumption of urban transportation modes using fuel no. J):

$$ECUTF(J) = \sum_{I=1;(FCUT(I)=J)}^{NMUT} ECUTM(I) \qquad J = 1,\ldots,\mathbf{NTF}$$

$$TMFUT = TDIUT + TGAUT + TF5UT + TF6UT + TF7UT + TF8UT = \sum_{J=3}^{NTF} ECUTF(J) \qquad \text{(total motor fuels)}$$

<u>Total final energy demand of urban (intracity) transportation subsector</u>:

$$TENUT = \sum_{I=1}^{NMUT} ECUTM(I) = \sum_{J=1}^{NTF} ECUTF(J) = TELUT + TMFUT$$

(b.2) Passenger, intercity

(see worksheet "PassInter-D" of MAED_D.xls)

Total passenger-kilometers, intercity traffic (10^9 p-km):

PKI	=	**PO** ∗ **DI** / 1000	

Out of which:

PKIC	=	(**PO** / **CO**) ∗ **DIC** ∗ **LFCIT** / 1000	(by car)
PKIP	=	PKI – PKIC	(by public modes)

Distribution by car type (10^9 p-km):

PKICT(I)	=	PKIC ∗ (**SITC(I)** / 100)	I=1,… ,**NCTIT**

Distribution by public transportation mode (10^9 p-km):

PKIPM(I)	=	PKIP ∗ (**SITM(I)** / 100)	I=1,….,**NMIT - NCTIT**

Energy intensity in units of kWh / passenger-kilometer:

Each passenger intercity transportation mode has assigned a fuel code number and a specific energy consumption (energy intensity) expressed in a natural unit chosen by the user per 100 kilometers (except air planes, for which the energy intensity is expressed in natural units per 1000 seat-kilometers). Each fuel has assigned a conversion factor from the natural unit for the energy intensity to kWh per passenger-kilometers. The following equations convert the energy intensity of intercity transportation mode I from selected natural unit per 100 kilometers (or 1000 seat-kilometers, in the case of air planes) to kWh/pkm, taking into consideration the fuel used by and the load factor of each particular transportation mode.

ITMEI(1)	=	**EIITM(1)** / 1000 ∗ **CFPT(FCIT(1))** / (**LFITM(1)** / 100)	(air plane)
ITMEI(I)	=	**EIITM(I)** / 100 ∗ **CFPT(FCIT(I))** / **LFITM(I)**	I = 2,….,**NMIT** (other modes)

Energy consumption by mode:

ECITM(I)	=	PKITM(I) ∗ ITMEI(I) ∗ **CF1**	I = 1,…….,**NMIT**

where: **CF1** is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet "Defs".

Energy consumption by fuel:

Summing up only the intercity PT modes using electricity:

ECITF(1) = TELIT

$$= \sum_{I=1;(FCIT(I)=1)}^{NMIT} \text{ECITM(I)}$$

Summing up only the intercity PT modes using steam coal:

$$\mathrm{ECITF(2)} = \mathrm{TSCIT}$$

$$= \sum_{I=1;(FCIT(I)=2)}^{NMIT} \mathrm{ECITM(I)}$$

Summing up only the intercity PT modes using diesel:

$$\mathrm{ECITF(3)} = \mathrm{TDIIT}$$

$$= \sum_{I=1;(FCIT(I)=3)}^{NMIT} \mathrm{ECITM(I)}$$

Summing up only the intercity PT modes using gasoline:

$$\mathrm{ECITF(4)} = \mathrm{TGAIT}$$

$$= \sum_{I=1;(FCIT(I)=4)}^{NMIT} \mathrm{ECITM(I)}$$

Summing up only the intercity PT modes using fuel no. 5:

$$\mathrm{ECITF(5)} = \mathrm{TF5IT}$$

$$= \sum_{I=1;(FCIT(I)=5)}^{NMIT} \mathrm{ECITM(I)}$$

Summing up only the intercity PT modes using fuel no. 6:

$$\mathrm{ECITF(6)} = \mathrm{TF6IT}$$

$$= \sum_{I=1;(FCIT(I)=6)}^{NMIT} \mathrm{ECITM(I)}$$

Summing up only the intercity PT modes using fuel no. 7:

$$\mathrm{ECITF(7)} = \mathrm{TF7IT}$$

$$= \sum_{I=1;(FCIT(I)=7)}^{NMIT} \mathrm{ECITM(I)}$$

Summing up only the intercity PT modes using fuel no. 8:

$$\mathrm{ECITF(8)} = \mathrm{TF8IT}$$

$$= \sum_{I=1;(FCIT(I)=8)}^{NMIT} \mathrm{ECITM(I)}$$

or, in general total energy consumption of intercity PT modes using fuel no. J:

$$ECITF(J) = \sum_{I=1;(FCIT(I)=J)}^{NMIT} ECITM(I) \qquad J = 1,\ldots,\mathbf{NTF}$$

$$TMFIT = TDIIT + TGAIT + TF5IT + TF6IT + TF7IT + TF8IT$$

$$= \sum_{J=3}^{NTF} ECITF(J) \qquad \text{(total motor fuels)}$$

Total final energy demand of intercity passenger transportation sub-sector:

$$TENIT = \sum_{I=1}^{NMIT} ECITM(I)$$

$$= \sum_{J=1}^{NTF} ECITF(J)$$

$$= TELIT + TSCIT + TMFIT$$

(b.3) International and military transportation (Miscellaneous), demand for motor fuels

$$TMFMIS = CMFMIS(1) + CMFMIS(2) * Y * CF1$$

where: **CF1** is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet "Defs".

(b.4) Passenger (including International and military) transportation totals

$$TELPT = TELUT + TELIT \qquad \text{(electricity)}$$

$$TSCPT = TSCIT \qquad \text{(steam coal)}$$

$$TMFPT = TMFUT + TMFIT + TMFMIS \qquad \text{(motor fuels)}$$

$$TENPT = TELPT + TSCPT + TMFPT \qquad \text{(total final energy)}$$

(c) Transportation sector totals
(see worksheet "FIN_Trp-D" of MAED_D.xls)

Final energy demand by fuel:

$$\begin{aligned} ECTRF(1) &= TELTR \\ &= TELFT + TELUT + TELIT \\ &= TELFT + TELPT \qquad \text{(electricity)} \end{aligned}$$

$$\begin{aligned} ECTRF(2) &= TSCTR \\ &= TSCFT + TSCIT \\ &= TSCFT + TSCPT \qquad \text{(steam coal)} \end{aligned}$$

Note: Steam coal is not a valid fuel for urban passenger transportation in MAED_D model

$$ECTRF(3) = TDITR = TDIFT + TDIUT + TDIIT \quad \text{(diesel oil)}$$

$$ECTRF(4) = TGATR = TGAFT + TGAUT + TGAIT \quad \text{(gasoline)}$$

$$ECTRF(5) = TF5TR = TF5FT + TF5UT + TF5IT \quad \text{(fuel no. 5)}$$

$$ECTRF(6) = TF6TR = TF6FT + TF6UT + TF6IT \quad \text{(fuel no. 6)}$$

$$ECTRF(7) = TF7TR = TF7FT + TF7UT + TF7IT \quad \text{(fuel no. 7)}$$

$$ECTRF(8) = TF8TR = TF8FT + TF8UT + TF8IT \quad \text{(fuel no. 8)}$$

or, in general:

$$ECTRF(J) = ECFTF(J) + ECUTF(J) + ECITF(J) \quad J=1,\ldots\ldots,\mathbf{NTF}$$

Motor fuels for international and military transportation:

$$ECTRF(NTF+1) = TMFMIS$$

$$FINTR = \sum_{J=1}^{NTF+1} ECTRF(J) \quad \text{(total final energy)}$$

Fuel shares in Transportation sector totals (%):

$$ECTRF.S(J) = ECTRF(J) / FINTR * 100 \quad J=1,\ldots\ldots,\mathbf{NTF}+1$$

Final energy demand by fuel group:

The demands for electricity (TELTR) and steam coal (TSCTR) are those previously calculated, while the total demand for motor fuels is:

$$TMFTR = \sum_{J=3}^{NTF+1} ECTRF(J)$$

Fuel group shares in Transportation sector totals (%):

$$TELTR.S = TELTR / FINTR * 100 \quad \text{(electricity)}$$

$$TSCTR.S = TSCTR / FINTR * 100 \quad \text{(steam coal)}$$

$$TMFTR.S = TMFTR / FINTR * 100 \quad \text{(motor fuels)}$$

Sub sector shares in Transportation sector totals (%):

$$TENFT.S = TENFT / FINTR * 100 \quad \text{(freight)}$$

$$TENUT.S = TENUT / FINTR * 100 \quad \text{(passenger, urban)}$$

TENIT.S = TENIT / FINTR ∗ 100 (passenger, intercity)

TMFMIS.S = TMFMIS / FINTR ∗ 100 (international and military)

5.5.3 Household Sector

(a) Urban households

(a.1) Total number of urban dwellings (10^6)

The number of urban dwellings is assumed to be equal to the number of urban households calculated in section 5.3 (Demographic Calculations).

TUDW = UHH

= **PO** ∗ (**PURB** / 100) / **CAPUH**

(a.2) Useful energy demand for different categories of end-use

(see Table 14.4 in worksheet "US_HH_Ur-D" of MAED_D.xls)

Space heating (SH):

SHUHT(I) = TUDW ∗ (**UDWSH** / 100) ∗ { (**UDW(I)** / 100) ∗ **UDWS(I)** ∗ (**UAREAH(I)** / 100) ∗ **UK(I)** } ∗ **UDD** ∗ 24 / 1000000 ∗ **CF1** I=1,…..,**NUDT** (urban dwelling type I)

$$SHUH = \sum_{I=1}^{NUDT} SHUHT(I)$$ (total urban dwellings)

Hot water (HW):

HWUH = TUDW ∗ **CAPUH** ∗ (**UDWHW** / 100) ∗ **UHWCAP** ∗ (**CF1** / 1000)

Cooking (CK):

CKUH = TUDW ∗ **CKUDW** ∗ (**CF1** / 1000)

Air conditioning (AC):

ACUHT(I) = TUDW ∗ { (**UDW(I)** / 100) ∗ (**UDWAC(I)** / 100) ∗ **UACDW(I)** }∗ (**CF1** / 1000) I=1,…..,**NUDT** (urban dwelling type I)

$$ACUH = \sum_{I=1}^{NUDT} ACUHT(I)$$ (total urban dwellings)

Specific electricity uses (appliances) - final energy (AP):

$$\mathrm{ELAPUH} = \mathrm{TUDW} * (\mathbf{ELPU} / 100) * \mathbf{ELAPUDW} * (\mathbf{CF1} / 1000)$$

Fossil fuels for lighting in non-electrified dwellings - final energy (LT):

$$\mathrm{FFLTUH} = \mathrm{TUDW} * (1 - \mathbf{ELPU} / 100) * \mathbf{FFLTUDW} * (\mathbf{CF1} / 1000)$$

Subtotal, Urban households:

$$\mathrm{USUH} = \mathrm{SHUH + HWUH + CKUH + ACUH + ELAPUH + FFLTUH}$$

In the previous equations, **CF1** is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet “Defs”.

(a.3) Conversion of useful energy to final energy demand in Urban households
(see Tables 16.1 to 16.6 in worksheet “FIN_HH-D” of MAED_D.xls)

Space heating (SH):

$$\mathrm{TF.UH.SH} = \mathrm{SHUH} * (\mathbf{TFP.UH.SH} / 100) / (\mathbf{TFE.UH.SH} / 100) \qquad \text{(traditional fuels)}$$

$$\mathrm{MB.UH.SH} = \mathrm{SHUH} * (\mathbf{MBP.UH.SH} / 100) / (\mathbf{MBE.UH.SH} / 100) \qquad \text{(modern biomass)}$$

$$\mathrm{EL.UH.SH} = \mathrm{SHUH} * (\mathbf{ELP.UH.SH} / 100) * (1 - (\mathbf{HPP.UH.SH} / 100) * (1 - 1 / \mathbf{HPE.UH.SH})) \qquad \text{(electricity)}$$

$$\mathrm{DH.UH.SH} = \mathrm{SHUH} * (\mathbf{DHP.UH.SH} / 100) \qquad \text{(district heat)}$$

$$\mathrm{SS.UH.SH} = \mathrm{SHUH} * (\mathbf{SSP.UH.SH} / 100) * (\mathbf{FDS.UH.SH} / 100) \qquad \text{(soft solar)}$$

$$\mathrm{FF.UH.SH} = \mathrm{SHUH} * \{ (\mathbf{FFP.UH.SH} / 100) + (\mathbf{SSP.UH.SH} / 100) * (1 - \mathbf{FDS.UH.SH} / 100) \} / (\mathbf{FFE.UH.SH} / 100) \qquad \text{(fossil fuels)}$$

$$\mathrm{FIN.UH.SH} = \mathrm{TF.UH.SH + MB.UH.SH + EL.UH.SH + DH.UH.SH + SS.UH.SH + FF.UH.SH} \qquad \text{(total)}$$

Hot water (HW):

$$\mathrm{TF.UH.HW} = \mathrm{HWUH} * (\mathbf{TFP.UH.HW} / 100) / (\mathbf{TFE.UH.HW} / 100) \qquad \text{(traditional fuels)}$$

$$\mathrm{MB.UH.HW} = \mathrm{HWUH} * (\mathbf{MBP.UH.HW} / 100) / (\mathbf{MBE.UH.HW} / 100) \qquad \text{(modern biomass)}$$

$$\mathrm{EL.UH.HW} = \mathrm{HWUH} * (\mathbf{ELP.UH.HW} / 100) * (1 - (\mathbf{HPP.UH.HW} / 100) * (1 - 1 / \mathbf{HPE.UH.HW})) \qquad \text{(electricity)}$$

$$\mathrm{DH.UH.HW} = \mathrm{HWUH} * (\mathbf{DHP.UH.HW} / 100) \qquad \text{(district heat)}$$

SS.UH.HW = HWUH ∗ (**SSP.UH.HW** / 100)
∗ (**FDS.UH.HW** / 100) (soft solar)

FF.UH.HW = HWUH ∗ { (**FFP.UH.HW** / 100)
+ (**SSP.UH.HW** / 100)
∗ (1 - **FDS.UH.HW** / 100) }/ (**FFE.UH.HW** / 100) (fossil fuels)

FIN.UH.HW = TF.UH.HW + MB.UH.HW + EL.UH.HW
+ DH.UH.HW + SS.UH.HW + FF.UH.HW (total)

<u>Cooking (CK):</u>

TF.UH.CK = CKUH ∗ (**TFP.UH.CK** / 100)
/ (**TFE.UH.CK** / 100) (traditional fuels)

MB.UH.CK = CKUH ∗ (**MBP.UH.CK** / 100)
/ (**MBE.UH.CK** / 100) (modern biomass)

EL.UH.CK = CKUH ∗ (**ELP.UH.CK** / 100) (electricity)

SS.UH.CK = CKUH ∗ (**SSP.UH.CK** / 100)
∗ (**FDS.UH.CK** / 100) (soft solar)

FF.UH.CK = CKUH ∗ { (**FFP.UH.CK** / 100)
+ (**SSP.UH.CK** / 100)
∗ (1 - **FDS.UH.CK** / 100) }/ (**FFE.UH.CK** / 100) (fossil fuels)

FIN.UH.CK = TF.UH.CK + MB.UH CK + EL.UH.CK
+ SS.UH.CK + FF.UH.CK (total)

<u>Air conditioning (AC):</u>

EL.UH.AC = ACUH ∗ (**ELP.UH.AC** / 100) / **ELE.UH.AC** (electricity)

FF.UH.AC = ACUH ∗ (**FFP.UH.AC** / 100) / **FFE.UH.AC** (fossil fuels)

FIN.UH.AC = EL.UH.AC + FF.UH.AC (total)

<u>Appliances and lighting</u>:

EL.UH.AP = ELAPUH (electricity)

FF.UH.AP = FFLTUH (fossil fuels)

FIN.UH.AP = EL.UH.AP + FF.UH.LT (total)

(a.4) Total final energy in Urban Household

TFUH = TF.UH.SH + TF.UH.HW + TF.UH.CK (traditional fuels)

MBUH = MB.UH.SH + MB.UH.HW + MB.UH.CK (modern biomass)

ELUH = EL.UH.SH + EL.UH.HW + EL.UH.CK + EL.UH.AC
+ ELAPUH (electricity)

DHUH = DH.UH.SH + DH.UH.HW (district heat)

SSUH = SS.UH.SH + SS.UH.HW + SS.UH.CK (soft solar)

FFUH = FF.UH.SH + FF.UH.HW + FF.UH.CK + FF.UH.AC + FFLTUH (fossil fuels)

FINUH = TFUH + MBUH + ELUH + DHUH + SSUH + FFUH (total final energy)

(b) Rural households

(b.1) Total number of rural dwellings (10^6)

The number of rural dwellings is assumed to be equal to the number of rural households calculated in section 5.3 (Demographic Calculations).

TRDW = RHH

= **PO** ∗ (**PRUR** / 100) / **CAPRH**

(b.2) Useful energy demand for different categories of end-use
(see Table 15.4 in worksheet "US_HH_Rr-D" of MAED_D.xls)

Space heating (SH):

SHRHT(I) = TRDW ∗ (**RDWSH** / 100) ∗ { (**RDW(I)** / 100) ∗ **RDWS(I)**

∗ (**RAREAH(I)** / 100) ∗ **RK(I)** }∗ **RDD** ∗ 24 / 1000000 ∗ **CF1**

I=1,…..,**NRDT** (rural dwelling type I)

$$SHRH = \sum_{I=1}^{NRDT} SHRHT(I)$$ (total rural dwellings)

Hot water (HW):

HWRH = TRDW ∗ **CAPRH** ∗ (**RDWHW** / 100) ∗ **RHWCAP** ∗ (**CF1** / 1000)

Cooking (CK):

CKRH = TRDW ∗ **CKRDW** ∗ (**CF1** / 1000)

Air conditioning (AC):

ACRHT(I) = TRDW ∗ { (**RDW(I)** / 100) ∗ (**RDWAC(I)** / 100) ∗ **RACDW(I)** } ∗ (**CF1** / 1000)

I=1,…..,**NRDT** (rural dwelling type I)

ACRH $= \sum_{I=1}^{NRDT}$ ACRHT(I) (total rural dwellings)

Electricity specific uses (appliances) - final energy (AP):

ELAPRH = TRDW ∗ (**ELPR** / 100) ∗ **ELAPRDW** ∗ (**CF1** / 1000)

Fossil fuels for lighting in non-electrified dwellings - final energy (LT):

FFLTRH = TRDW ∗ (1 - **ELPR** / 100) ∗ **FFLTRDW** ∗ (**CF1** / 1000)

Subtotal, Rural households:

USRH = SHRH + HWRH + CKRH + ACRH + ELAPRH + FFLTRH

In the previous equations, **CF1** is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet "Defs".

(b.3) Conversion of useful energy to final energy demand in Rural households

(see Tables 16.7 ÷ 16.12 in worksheet "FIN_HH-D" of MAED_D.xls)

Space heating (SH):

TF.RH.SH = SHRH ∗ (**TFP.RH.SH** / 100) / (**TFE.RH.SH** / 100) (traditional fuels)

MB.RH.SH = SHRH ∗ (**MBP.RH.SH** / 100) / (**MBE.RH.SH** / 100) (modern biomass)

EL.RH.SH = SHRH ∗ (**ELP.RH.SH** / 100)
∗ (1 – (**HPP.RH.SH** / 100) ∗ (1 - 1 / **HPE.RH.SH**)) (electricity)

DH.RH.SH = SHRH ∗ (**DHP.RH.SH** / 100) (district heat)

SS.RH.SH = SHRH ∗ (**SSP.RH.SH** / 100) ∗ (**FDS.RH.SH** / 100) (soft solar)

FF.RH.SH = SHRH ∗ { (**FFP.RH.SH** / 100) + (**SSP.RH.SH** / 100)
∗ (1 - **FDS.RH.SH** / 100) } / (**FFE.RH.SH** / 100) (fossil fuels)

FIN.RH.SH = TF.RH.SH + MB.RH.SH + EL.RH.SH + DH.RH.SH
+ SS.RH.SH + FF.RH.SH (total)

Hot water (HW):

TF.RH.HW = HWRH ∗ (**TFP.RH.HW** / 100)
/ (**TFE.RH.HW** / 100) (traditional fuels)

MB.RH.HW = HWRH ∗ (**MBP.RH.HW** / 100)
/ (**MBE.RH.HW** / 100) (modern biomass)

EL.RH.HW = HWRH ∗ (**ELP.RH.HW** / 100) ∗
(1 – (**HPP.RH.HW** / 100) ∗ (1 - 1 / **HPE.RH.HW**)) (electricity)

DH.RH.HW = HWRH ∗ (**DHP.RH.HW** / 100) (district heat)

SS.RH.HW = HWRH ∗ (**SSP.RH.HW** / 100)
∗ (**FDS.RH.HW** / 100) (soft solar)

FF.RH.HW = HWRH ∗ { (**FFP.RH.HW** / 100) + (**SSP.RH.HW** / 100)
∗ (1 - **FDS.RH.HW** / 100) }
/ (**FFE.RH.HW** / 100) (fossil fuels)

FIN.RH.HW = TF.RH.HW + MB.RH.HW + EL.RH.HW
+ DH.RH.HW + SS.RH.HW + FF.RH.HW (total)

<u>Cooking (CK):</u>

TF.RH.CK = CKUH ∗ (**TFP.RH.CK** / 100) / (**TFE.RH.CK** / 100) (traditional fuels)

MB.RH.CK = CKUH ∗ (**MBP.RH.CK** / 100) / (**MBE.RH.CK** / 100) (modern biomass)

EL.RH.CK = CKUH ∗ (**ELP.RH.CK** / 100) (electricity)

SS.RH.CK = CKUH ∗ (**SSP.RH.CK** / 100) ∗ (**FDS.RH.CK** / 100) (soft solar)

FF.RH.CK = CKUH ∗ { (**FFP.RH.CK** / 100) + (**SSP.RH.CK** / 100)
∗ (1 - **FDS.RH.CK** / 100) } / (**FFE.RH.CK** / 100) (fossil fuels)

FIN.RH.CK = TF.RH.CK + MB.RH CK + EL.RH.CK + SS.RH.CK
+ FF.RH.CK (total)

<u>Air conditioning (AC):</u>

EL.RH.AC = ACRH ∗ (**ELP.RH.AC** / 100) / **ELE.RH.AC** (electricity)

FF.RH.AC = ACRH ∗ (**FFP.RH.AC** / 100) / **FFE.RH.AC** (fossil fuels)

FIN.RH.AC = EL.RH.AC + FF.RH.AC (total)

<u>Appliances and lighting:</u>

EL.RH.AP = ELAPRH (electricity)

FF.RH.AP = FFLTRH (fossil fuels)

FIN.RH.AP = EL.RH.AP + FF.RH.LT (total)

(b.4) Total final energy in Rural Household

TFRH = TF.RH.SH + TF.RH.HW + TF.RH.CK (traditional fuels)

MBRH = MB.RH.SH + MB.RH.HW + MB.RH.CK (modern biomass)

ELRH = EL.RH.SH + EL.RH.HW + EL.RH.CK
+ EL.RH.AC + ELAPRH (electricity)

DHRH = DH.RH.SH + DH.RH.HW (district heat)

SSRH	=	SS.RH.SH + SS.RH.HW + SS.RH.CK	(soft solar)
FFRH	=	FF.RH.SH + FF.RH.HW + FF.RH.CK	
		+ FF.RH.AC + FFLTRH	(fossil fuels)
FINRH	=	TFRH + MBRH + ELRH + DHRH + SSRH + FFRH	(total final energy)

(c) Final energy demand of Household sector (urban + rural)
(see Tables 16.13 to 16.18 in worksheet "FIN_HH-D" of MAED_D.xls)

Space heating (SH):

TF.HH.SH	=	TF.UH.SH + TF.RH.SH	(traditional fuels)
MB.HH.SH	=	MB.UH.SH + MB.RH.SH	(modern biomass)
EL.HH.SH	=	EL.UH.SH + EL.RH.SH	(electricity)
DH.HH.SH	=	DH.UH.SH + DH.RH.SH	(district heat)
SS.HH.SH	=	SS.UH.SH + SS.RH.SH	(soft solar)
FF.HH.SH	=	FF.UH.SH + FF.RH.SH	(fossil fuels)
FIN.HH.SH	=	TF.HH.SH + MB.HH.SH + EL.HH.SH + DH.HH.SH	
		+ SS.HH.SH + FF.HH.SH	
	=	FIN.UH.SH + FIN.RH.SH	(total)

Hot water (HW):

TF.HH.HW	=	TF.UH.HW + TF.RH.HW	(traditional fuels)
MB.HH.HW	=	MB.UH.HW + MB.RH.HW	(modern biomass)
EL.HH.HW	=	EL.UH.HW + EL.RH.HW	(electricity)
DH.HH.HW	=	DH.UH.HW + DH.RH.HW	(district heat)
SS.HH.HW	=	SS.UH.HW + SS.RH.HW	(soft solar)
FF.HH.HW	=	FF.UH.HW + FF.RH.HW	(fossil fuels)
FIN.HH.HW	=	TF.HH.HW + MB.HH.HW + EL.HH.HW + DH.HH.HW	
		+ SS.HH.HW + FF.HH.HW	
	=	FIN.UH.HW + FIN.RH.HW	(total)

Cooking (CK):

TF.HH.CK	=	TF.UH.CK + TF.RH.CK	(traditional fuels)
MB.HH.CK	=	MB.UH.CK + MB.RH.CK	(modern biomass)
EL.HH.CK	=	EL.UH.CK + EL.RH.CK	(electricity)

SS.HH.CK	=	SS.UH.CK + SS.RH.CK	(soft solar)
FF.HH.CK	=	FF.UH.CK + FF.RH.CK	(fossil fuels)
FIN.HH.CK	=	TF.HH.CK + MB.HH.CK + EL.HH.CK + SS.HH.CK + FF.HH.CK	
	=	FIN.UH.CK + FIN.RH.CK	(total)

Air conditioning (AC):

EL.HH.AC	=	EL.UH.AC + EL.RH.AC	(electricity)
FF.HH.AC	=	FF.UH.AC + FF.RH.AC	(fossil fuels)
FIN.HH.AC	=	EL.HH.AC + FF.HH.AC	
	=	FIN.UH.AC + FIN.RH.AC	(total)

Appliances and lighting:

EL.HH.AP	=	EL.UH.AP + EL.RH.AP	(electricity)
FF.HH.AP	=	FF.UH.LT + FF.RH.LT	(fossil fuels)
FIN.HH.AP	=	EL.HH.AP + EL.HH.AP	
	=	FIN.UH.AP + FIN.RH.AP	(total)

Total final energy in Household sector:

TFHH	=	TF.HH.SH + TF.HH.HW + TF.HH.CK	
	=	TFUH + TFRH	(traditional fuels)
MBHH	=	MB.HH.SH + MB.HH.HW + MB.HH.CK	
	=	MBUH + MBRH	(modern biomass)
ELHH	=	EL.HH.SH + EL.HH.HW + EL.HH.CK + EL.HH.AC + ELAPHH	
	=	ELUH + ELRH	(electricity)
DHHH	=	DH.HH.SH + DH.HH.HW	
	=	DHUH+ DHRH	(district heat)
SSHH	=	SS.HH.SH + SS.HH.HW + SS.HH.CK	
	=	SSUH + SSRH	(soft solar)
FFHH	=	FF.HH.SH + FF.HH.HW + FF.HH.CK + FF.HH.AC + FFLTHH	
	=	FFUH + FFRH	(fossil fuels)

FINHH = TFHH + MBHH + ELHH + DHHH + SSHH + FFHH
= FINUH + FINRH (total final energy)

5.5.4 *Service sector*

(a) Service sector labor force (10^6) and floor area (10^6 sq.m)
(see Table 17-1 of worksheet "US_SS-D" of MAED_D.xls)

LSER = ALF ∗ (**PLSER** / 100) (labour force)

TAREA = LSER ∗ **AREAL** (floor area)

(b) Useful energy demand for different categories of end-use
(see Tables 17-3 and 17-7 to 17-10 of worksheet "US_SS-D" of MAED_D.xls)

Space heating (SH):

TARSH = TAREA ∗ (**ARSH** / 100) ∗ (**AREAH** / 100) (floor area where SH) is required)

US.SH.SER = TARSH ∗ **SSHR** ∗ (**CF1** / 1000)

Air conditioning (AC):

US.AC.SER = TAREA ∗ (**AREAAC** / 100) ∗ **SACR** ∗ (**CF1** / 1000)

Motor fuels (MF):

US.MF.SE(I) = **EI.MF.SE(I)** ∗ YSE(I) ∗ **CF1** I=1,…..,**NSSER** (subsector I)

MFSER = US.MF.SER

$$= \sum_{I=1}^{NSSER} \text{US.MF.SE(I)}$$

$$= \sum_{I=1}^{NSSER} (\ \mathbf{EI.MF.SE(I)} * \text{YSE(I)}\ ) * \mathbf{CF1}$$ (entire sector)

Electricity for specific uses (ELS):

US.ELS.SE(I) = **EI.ELS.SE(I)** ∗ YSE(I) ∗ **CF1** I=1,…..,**NSSER** (subsector I)

ELSSER = US.ELS.SER

$$= \sum_{I=1}^{NSSER} \text{US.ELS.SE(I)}$$

$$= \sum_{I=1}^{NSSER} (\ \mathbf{EI.ELS.SE(I)} * \text{YSE(I)}\ ) * \mathbf{CF1}$$ (entire sector)

Other thermal uses (OTU):

$$\text{US.OTU.SE(I)} = \textbf{EI.OTU.SE(I)} * \text{YSE(I)} * \textbf{CF1} \qquad \text{I=1,..,}\textbf{NSSER} \text{ (subsector I)}$$

$$\text{US.OTU.SER} = \sum_{I=1}^{NSSER} \text{US.OTU.SE(I)}$$

$$= \sum_{I=1}^{NSSER} (\textbf{EI.OTU.SE(I)} * \text{YSE(I)}) * \textbf{CF1} \qquad \text{(entire sector)}$$

Total useful energy:

$$\text{US.SER} = \text{US.SH.SER} + \text{US.AC.SER} + \text{MFSER} + \text{ELSSER} + \text{US.OTU.SER}$$

In the previous equations, **CF1** is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet "Defs".

(c) Conversion of useful thermal to final energy demand

Space heating and other thermal uses:

$$\text{TF.SER.TU} = \{ \text{US.SH.SER} * (\textbf{TFP.SER.SH} / 100) + \text{US.OTU.SER} * (\textbf{TFP.SER.OUT} / 100) \} / (\textbf{TFE.SER.TU} / 100) \qquad \text{(traditional fuels)}$$

$$\text{MB.SER.TU} = \{ \text{US.SH.SER} * (\textbf{MBP.SER.SH} / 100) + \text{US.OTU.SER} * (\textbf{MBP.SER.OUT} / 100) \} / (\textbf{MBE.SER.TU} / 100) \qquad \text{(modern biomass)}$$

$$\text{EL.SER.TU} = \text{US.SH.SER} * (\textbf{ELP.SER.SH} / 100) * \{ 1 - (\textbf{HHP.SER.SH} / 100) * (1 - (1 / \textbf{HPE.SER.SH})) \} + \text{US.OTU.SER} * (\textbf{ELP.SER.OTU} / 100) \qquad \text{(electricity)}$$

$$\text{DH.SER.TU} = \text{US.SH.SER} * (\textbf{DHP.SER.SH} / 100) + \text{US.OTU.SER} * (\textbf{DHP.SER.OUT} / 100) \qquad \text{(district heat)}$$

$$\text{SS.SER.TU} = \{ \text{US.SH.SER} * (\textbf{SSP.SER.SH} / 100) + \text{US.OTU.SER} * (\textbf{SSP.SER.OUT} / 100) \} * (\textbf{FDS.SER.TU} / 100) * (\textbf{PLB} / 100) \qquad \text{(soft solar)}$$

$$\text{FF.SER.TU} = \text{US.SH.SER} * \{ (\textbf{FFP.SER.SH} / 100) + (\textbf{SSP.SER.SH} / 100) * (1 - (\textbf{FDS.SER.TU} / 100)) * (\textbf{PLB / 100}) \} / (\textbf{FFE.SER.TU} / 100) + \text{US.OTU.SER} * \{ (\textbf{FFP.SER.OTU} / 100) + (\textbf{SSP.SER.OTU} / 100) * (1 - (\textbf{FDS.SER.TU} / 100)) * (\textbf{PLB} / 100) \} / (\textbf{FFE.SER.TU} / 100) \qquad \text{(fossil fuels)}$$

$$\text{FIN.SER.TU} = \text{TF.SER.TU} + \text{MB.SER.TU} + \text{EL.SER.TU} + \text{DH.SER.TU} + \text{SS.SER.TU} + \text{FF.SER.TU} \qquad \text{(total)}$$

Air conditioning:

EL.SER.AC	=	US.AC.SER ∗ (**ELP.SER.AC** / 100) / **ELE.SER.AC**	(electricity)
FF.SER.AC	=	US.AC.SER ∗ (**FFP.SER.AC** / 100) / **FFE.SER.AC**	(fossil fuels)
FIN.SER.AC	=	EL.SER.AC + FF.SER.AC	(total)

(d) Total final energy in Service sector

TFSER	=	TF.SER.TU	(traditional fuels)
MBSER	=	MB.SER.TU	(modern biomass)
ELSER	=	ELSSER + EL.SER.TU + EL.SER.AC	(electricity)
DHSER	=	DH.SER.TU	(district heat)
SSSER	=	SS.SER.TU	(soft solar)
FFSER	=	FF.SER.TU + FF.SER.AC	(fossil fuels)
FINSER	=	MFSER + TFSER + MBSER + ELSER + DHSER + SSSER + FFSER	(total)

5.5.5 Grand totals of final energy demand for the country

Once all final energy demand calculations by sector have been completed, the program proceeds to calculate grand totals for the country as the addition of the sectoral demands. The results of these calculations, expressed in the energy unit specified in cell E50 of worksheet "Defs", are shown in worksheet "Final-D" of MAED_D.xls.

Demand by energy form:

TF	=	TFIND + TFHH + TFSER	(traditional fuels)
MB	=	MBIND + MBHH + MBSER	(modern biomass)
ELTU	=	ELHIND + EL.HH.SH + EL.HH.HW + EL.HH.CK + EL.SER.TU	(electricity for thermal uses)
ELNTU	=	ELSIND + TELTR+ EL.HH.AC + ELAPHH + ELSSER + EL.SER.AC	(electricity for non-thermal uses)
ELEC	=	ELIND + TELTR + ELHH + ELSER	
	=	ELTU + ELNTU	(total electricity)
DH	=	DHIND + DHHH + DHSER	(district heat)
SS	=	SSIND + SSHH + SSSER	(soft solar)
FF	=	FFIND + FFHH + FFSER	(fossil fuels)

MF	=	MFIND + TMFTR + MFSER	(motor fuel)
Coalsp	=	COKE + TSCTR	(coal, specific)
TFEED	=	FEED	(feedstock)
FINEN	=	TF + MB + ELEC + DH + SS + FF + MF + COALSP + TFEED	(total final energy)

Final energy per capita (MWh/cap):

FINEN.CAP = (FINEN / **PO**) / **CF1**

Final energy intensity i.e. final energy per monetary unit of GDP (kWh/MU):

EI.FIN.GDP = (FINEN / **Y**) / **CF1**

where: **CF1** is the conversion factor from TWh to the energy unit specified in cell E50 of worksheet “Defs”.

Several different aggregations of the individual energy demands by form and by sector are performed by the program in order to present the output tables with the results of the run. As these aggregations do not involve any new calculations, they are not presented here.

In order to convert the grand totals of final energy demand for the country from the energy unit specified in cell E50 of worksheet “Defs” to another energy unit the user have to indicate the new unit and the corresponding conversion factor in cells L50 and M50 of worksheet “Defs”. The grand totals of final energy demand from worksheet “Final-D”, converted to the new energy unit, will be shown in worksheet “Final Results (User Unit)”.

6 GENERAL DESCRIPTION OF MAED MODULE 2

HOURLY ELECTRIC POWER DEMAND CALCULATIONS

6.1 Introduction

The second Module of MAED has been developed to convert the annual electricity demand for each economic sector (considered for demand projection in Module 1) to the hourly electricity demand during the year. This Module considers four economic sectors, namely Industry, Transport, Household and Service and six clients for each of these sectors for calculation of hourly electricity demand.

Various modulation factors are used to calculate the hourly demand from the annual electricity demand. These factors characterize the changes in the electricity consumption with respect to the average electricity consumption during a year, week or a day. This module converts the total annual electricity demand of a sector to the electricity load of the sector in a giver hour, day and week of the year by taking into account the following factors:

(i) The trend of the average growth rate of the electricity demand during the year;

(ii) The changes in the level of electricity consumption owing to the various seasons of the year (this variation is reflected on a weekly basis in this Module);

(iii) The changes in the level of electricity consumption owing to the type of day being considered (i.e. working days, weekends, special holidays etc.);

(iv) The hourly variation of electricity consumption during a particular type of day.

The trend of average growth rate of electricity demand is already known from the results of Module 1. The variation of electricity load of a given sector by hour, day and week is characterized by three sets of modulation coefficients that are defined for 24 hours in a day, by type of days in a week and for each week in a year. The product of all of these coefficients, along with the coefficients for the average growth rate of electricity demand, multiplied by the average electricity demand of a particular sector result in the electric load of that sector in a particular hour. Knowing all these coefficients for a particular year allows us to calculate the chronological hourly electricity load for 8760 hours of that year.

Similar calculations are repeated for each sector of the economy (Industry, Transport, Household and Service) and the loads for same hour in all sectors are aggregated together to produce the hourly load values of the total load imposed on the power system in a particular year. The graphical representation of these hourly loads in decreasing order produces the well-known hourly load duration curve for the electric power system.

The modulation coefficients used for these calculations are obtained from statistical analysis based on the past operating experience for the power system under consideration.

This section of the User's Manual describes various worksheets of the Microsoft Excel workbook file <**MAED_El.xls**> designed for MAED Module 2 calculations, procedure for execution of this Module and theoretical approach used for these calculations.

6.2 Description of MAED module 2 Excel worksheets

A separate workbook file has been designed to prepare input data, calculation of the hourly loads and presentation of the model results of Module 2. This Microsoft Excel file is named as

<**MAED_El.xls**> and is present in the same directory where the other MAED file, for Module 1, <**MAED_D.xls**> is located.

The Microsoft Excel workbook file consists of 20 worksheets. Some of these worksheets provide general information related to the terminology and color codes used in the worksheets, while the other worksheets are used to prepare input data and to display the results of the model in numerical as well as graphical form. Microsoft Visual Basic subroutines have been used in the Microsoft Excel environment for validation of input data, calculation and presentation of the model results. Names of various worksheets present in the Microsoft Excel Workbook file <**MAED_El.xls**> used for calculations related to Module 2 of MAED are given in Table 6.1.

Table 6.1: List of Worksheets in Microsoft Excel Workbook file <MAED_El.xls>

Worksheet No.	Name of worksheet	Content of worksheet
i	MAED_EL	Title page of the workbook
ii	Notes	Colour code conventions
iii	Descr	Short description of the module
iv	TOC	Table of contents
v	Calendar	Calendar of the reference years
vi	FinEle	Final electricity demand
vii	SecEle	Secondary electricity demand
viii	Ldfac(1)	Load modulation coefficients for Industry
ix	Ldfac(2)	Load modulation coefficients for Transport
x	Ldfac(3)	Load modulation coefficients for Household
xi	Ldfac(4)	Load modulation coefficients for Service
xii	Check	Check modulation coefficient correctness
xiii	LDC	Load duration curves in numerical form
xiv	LDC-G	Load duration curves in graphical form
xv	ChrtLdc	Chronological load data
xvi	SvFac(1)	Save load modulation coefficients for Industry
xvii	SvFac(2)	Save load modulation coefficients for Transport
xviii	SvFac(3)	Save load modulation coefficients for Household
xix	SvFac(4)	Save load modulation coefficients for Service
xx	temp	Temporarily stored data during program execution

The description of each of these worksheets is given in the following paragraphs.

(i) Worksheet "MAED_EL"

This is the title worksheet, which shows the title of the workbook file. Figure 6.1 gives the snapshot of this worksheet.

Figure 6.1. Snapshot of worksheet "MAED_EL.

(ii) Worksheet "Notes"

This worksheet contains notes about the color convention used in various worksheets and some general comments about data entry. Figure 6.2 shows the snapshot of this worksheet

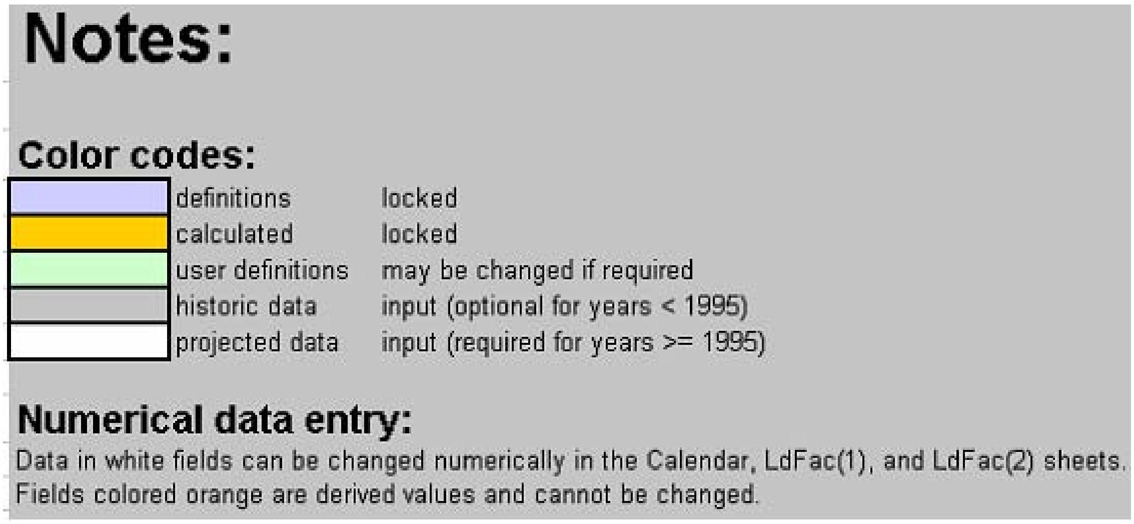
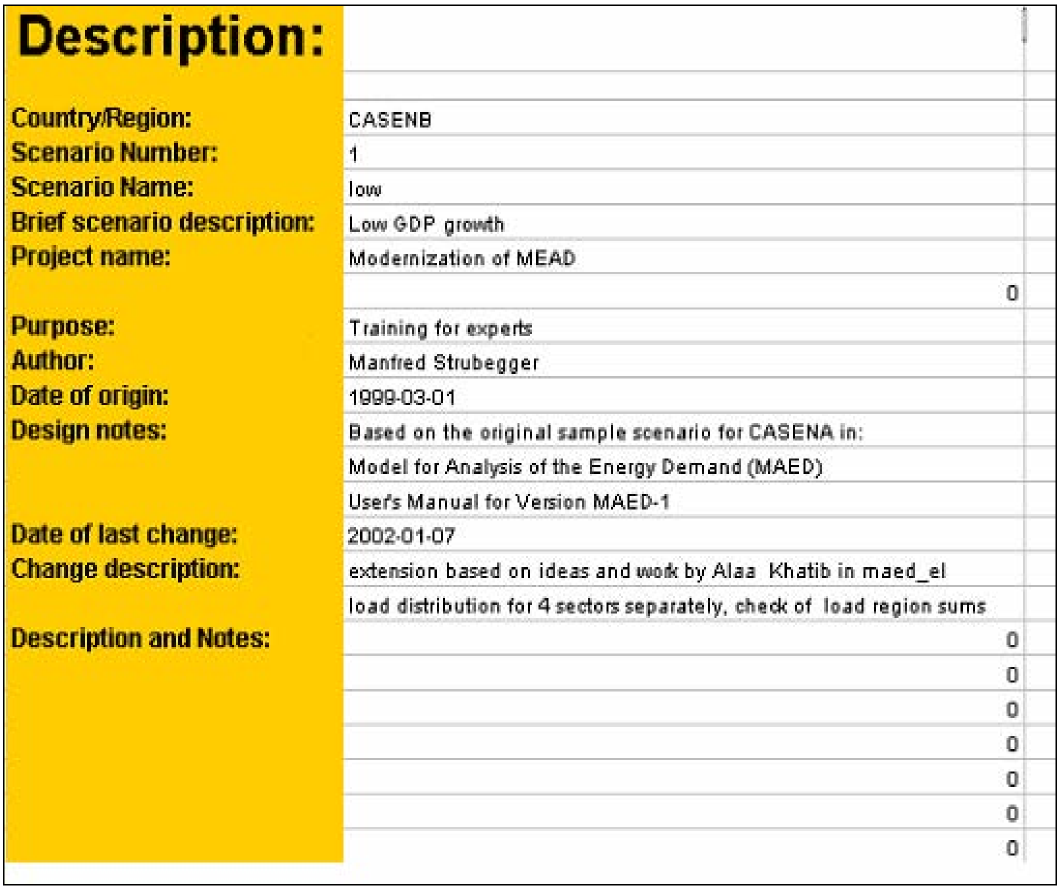


Figure 6. 2. Snapshot of worksheet "Notes".

(iii) Worksheet "Descr"

This worksheet provides general description of the electricity demand projection scenario and some other information about the workbook file. A snapshot of this worksheet is shown in Figure 6.3.



Description:	
Country/Region:	CASENB
Scenario Number:	1
Scenario Name:	low
Brief scenario description:	Low GDP growth
Project name:	Modernization of MEAD
	0
Purpose:	Training for experts
Author:	Manfred Strubegger
Date of origin:	1999-03-01
Design notes:	Based on the original sample scenario for CASENA in:
	Model for Analysis of the Energy Demand (MAED)
	User's Manual for Version MAED-1
Date of last change:	2002-01-07
Change description:	extension based on ideas and work by Alaa Khatib in maed_el
	load distribution for 4 sectors separately, check of load region sums
Description and Notes:	0
	0
	0
	0
	0
	0
	0
	0

Figure 6.3. Snapshot of worksheet "Descr".

(iv) Worksheet "TOC"

Table of contents of the overall workbook is given in this worksheet. A view of this worksheet is shown in Figure 6.4. The user can move to various worksheets by clicking the respective buttons available in this worksheet. Most of the worksheets also have a TOC button that can be clicked to move back to "TOC" worksheet.

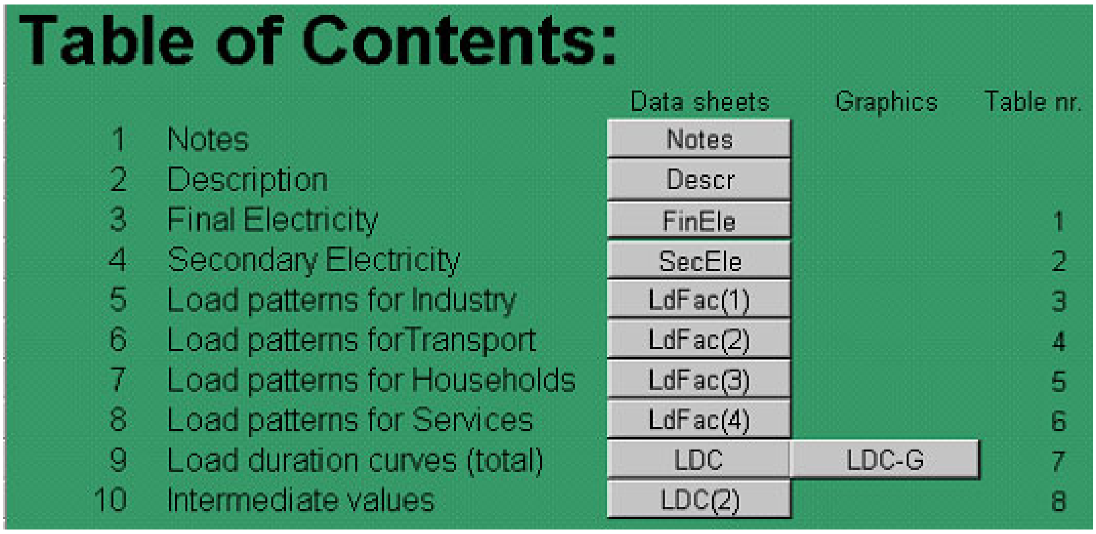


Table of Contents:

		Data sheets	Graphics	Table nr.
1	Notes	Notes		
2	Description	Descr		
3	Final Electricity	FinEle		1
4	Secondary Electricity	SecEle		2
5	Load patterns for Industry	LdFac(1)		3
6	Load patterns forTransport	LdFac(2)		4
7	Load patterns for Households	LdFac(3)		5
8	Load patterns for Services	LdFac(4)		6
9	Load duration curves (total)	LDC	LDC-G	7
10	Intermediate values	LDC(2)		8

Figure 6.4. A view of worksheet "TOC".

(v) Worksheet "Calendar"

This worksheet contains information related to the annual official holidays, duration of the four seasons (winter, spring, summer and autumn) in terms of their starting and ending dates used for the study, starting and ending dates of special season during each year and definitions of normal and typical weekdays. Figures 6.5, 6.6 and 6.7 show the snapshots of different parts of this worksheet.

Holidays:

Year	Description	every week	single days
1970	free	Fri	1-Jan
	special		
1975	free	Fri	
	special	0	
1980	free	Fri	
	special	0	
1985	free	Fri	
	special	0	
1990	free	Fri	
	special	0	
1995	free	Fri	
	special	0	
2000	free	Fri	
	special	0	
2005	free	Fri	
	special	0	
2010	free	Fri	
	special	0	

Figure 6.5. Definition of holidays in worksheet "Calendar ".

(vi) Worksheet "FinEle"

This worksheet consists of total and sector-wise electricity demand along with the sectoral shares and growth rates for the base year as well as those for the future years worked out by Module 1 of MAED (Microsoft Excel file **<maed_d.xls>).** Figure 6.8 shows the total and sectoral final electricity demand during the study period.

Seasons (starting days):

season	1970	1975	1980	1985	1990	1995	2000	2005	2010
winter	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan	1-Jan
spring	21-Mar	21-Mar	21-Mar	21-Mar	21-Mar	21-Mar	21-Mar	21-Mar	21-Mar
summer	21-Jun	21-Jun	21-Jun	21-Jun	21-Jun	21-Jun	21-Jun	21-Jun	21-Jun
autumn	23-Sep	23-Sep	23-Sep	23-Sep	23-Sep	23-Sep	23-Sep	23-Sep	23-Sep
winter	22-Dec	22-Dec	22-Dec	22-Dec	22-Dec	22-Dec	22-Dec	22-Dec	22-Dec
	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec	31-Dec

Special Season: **Ramadan**

season	1970	1975	1980	1985	1990	1995	2000	2005	2010
start	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan	9-Jan
end	20-Jan	20-Jan	20-Jan	20-Jan	20-Jan	20-Jan	20-Jan	20-Jan	20-Jan

Figure 6.6. Duration of different seasons and starting & ending dates in worksheet "Calendar".

Days:

Definition of normal weekdays:

	1	2	3	4	5	6	7
all	Sat	Sun	Mon	Tue	Wed	Thu	Fri

Definition of typical weekdays:

	1	2	3	4	5	6	7
reduced	Sat	Sun	Mon	Tue	Wed	Thu	Fri

Figure 6.7. Definition of normal and special weekdays in worksheet "Calendar".

Table 1: Electricity Demand during the Year (CASENB/low):									
Table 1a: Final Electricity Consumption (from MAED-1):									
	unit	1970	1975	1980	1985	1990	1995	2000	2005
Industry	GWa	0.55	0.81	1.39	2.07	2.87	3.52	4.07	4.75
Transport	GWa	0.00	0.00	0.03	0.05	0.08	0.11	0.17	0.23
Households	GWa	0.16	0.27	0.46	0.66	0.99	1.35	2.01	2.62
Services	GWa	0.11	0.18	0.31	0.44	0.63	0.86	1.11	1.42
Total	GWa	0.83	1.26	2.20	3.22	4.56	5.84	7.38	9.02

Figure 6-8. Total and sectoral final electricity demand in worksheet "FinEle".

Figures 6.9 and 6.10 show sections of this worksheet giving the shares and growth rates of different clients in the industrial sector. Similar tables are also present in the worksheet for transport, households and services sectors. At the end of the worksheet, the aggregated electricity demand for Industry & transport and Households & services sector are also given. This section of the worksheet is shown in Figure 6.11. Two graphs are also present in the worksheet to show the evolution of electricity demand over the study period and its growth rates by sector shown in Figures 6.12 and 6.13.

Table 1a1a: Share of industrial clients:									
	unit	1970	1975	1980	1985	1990	1995	2000	2005
ind1	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Figure 6-9. Shares of industrial clients in worksheet "FinEle".

Table 1a1b: Growth rates of industrial clients:									
	unit	1970	1975	1980	1985	1990	1995	2000	2005
ind1	[%p.a.]	8.22	8.22	11.39	8.24	6.74	4.19	2.96	3.10
	[%p.a.]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	[%p.a.]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	[%p.a.]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	[%p.a.]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	[%p.a.]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	[%p.a.]	8.22	8.22	11.39	8.24	6.74	4.19	2.96	3.10

Figure 6-10. Growth rates of industrial clients in worksheet "FinEle".

Table 1b: Total growth rates:

	unit	1970	1975	1980	1985	1990	1995	2000	2005
Ind+Trp	[%p.a.]	9.31	8.38	11.58	8.27	6.79	4.28	3.18	3.22
Hh+Service	[%p.a.]	9.50	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total	[%p.a.]	9.32	8.96	11.51	7.98	7.18	5.06	4.79	4.11

Figure 6-11. Total sectoral growth rates in worksheet "FinEle".

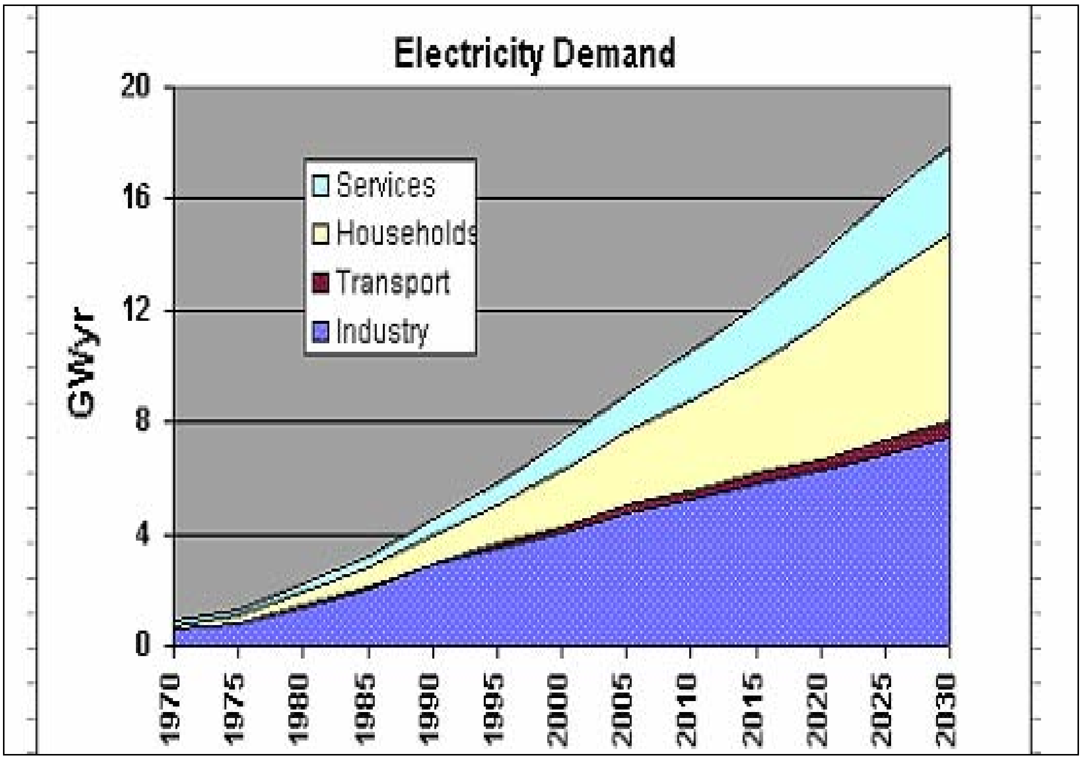


Figure 6.12. Graph of evolution of electricity demand in worksheet "FinEle".

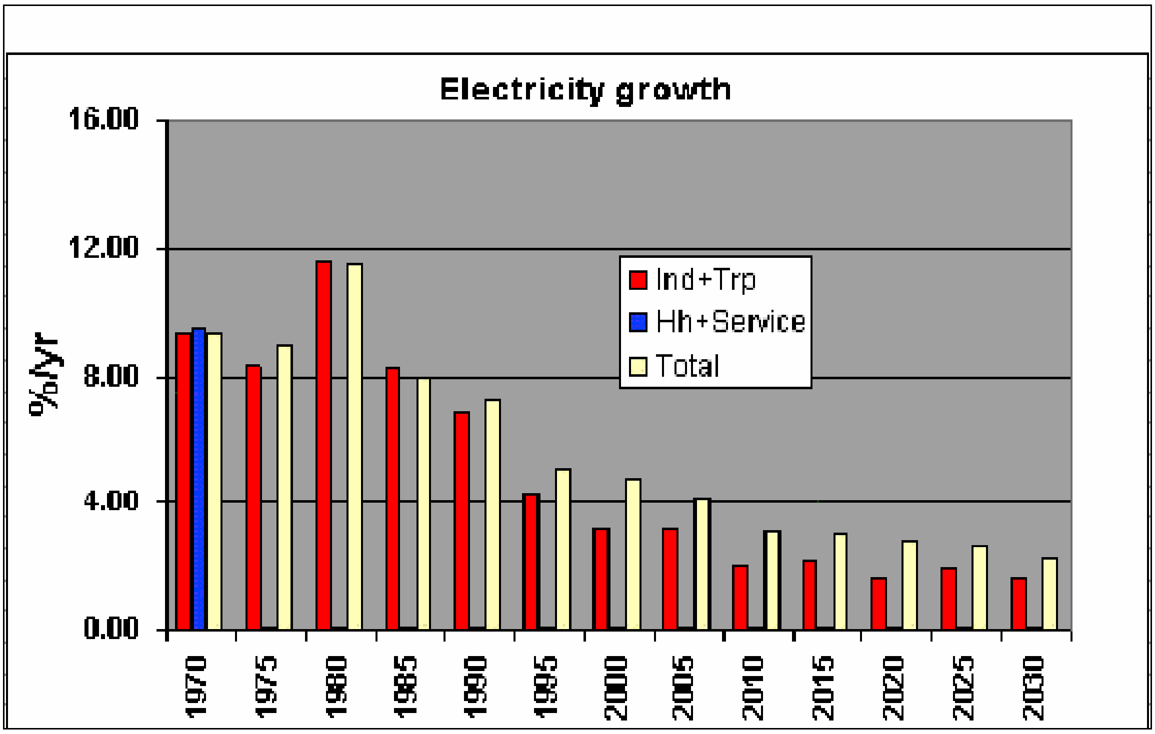


Figure 6.13. Graph of total and sectoral electricity growth rates in worksheet "FinEle".

Table 2: Electricity Demand during the Year (CASENB/low):

Table 2a:Transmission losses:

	unit	1970	1975	1980	1985	1990	1995	2000	2005
transmlosses	%	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

Table 2b1: Distribution losses:

	unit	1970	1975	1980	1985	1990	1995	2000	2005
Industry	%	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Transport	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Households	%	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Services	%	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00

Table 2b2: Highest peak:

	unit	1970	1975	1980	1985	1990	1995	2000	2005
multiplier	[%]	10.00	9.04	8.17	7.39	6.68	6.03	5.45	4.93
addition	[MW]	100.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00
duration	[h]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00

Figure 6.14. Transmission and distribution losses and information about the peak load in worksheet "SecEle".

(vii) Worksheet "SecEle"

This worksheet contains the input data about the total transmission losses at the system level and sectoral distribution losses on annual basis during the study period. The section of the worksheet including these data is shown in Figure 6.14. Some details of the peak loads are also present in this worksheet and is also shown in Figure 6.14. This information is used to adjust the peak load if it does not match with the actual values experienced in the country. At the end of the worksheet, the electricity requirements, including the transmission and distribution losses, are reported as the secondary electricity requirements as shown in Figure 6.15.

Table 1c1: Secondary Electricity requirements [GWa]:

	unit	1970	1975	1980	1985	1990	1995	2000	2005
Industry	GWa	0.61	0.90	1.54	2.29	3.18	3.90	4.51	5.26
Transport	GWa	0.00	0.00	0.03	0.05	0.08	0.12	0.18	0.24
Households	GWa	0.22	0.36	0.61	0.87	1.30	1.78	2.65	3.45
Services	GWa	0.14	0.22	0.38	0.54	0.78	1.06	1.38	1.76
Total	GWa	0.96	1.48	2.57	3.77	5.34	6.86	8.73	10.71
		FALSE							

Table 2c1: Secondary Electricity requirements [GWh]:

	unit	1970	1975	1980	1985	1990	1995	2000	2005
Industry	GWh	5311	7884	13557	20086	27837	34172	39654	46057
Transport	GWh	0	0	299	475	720	1035	1603	2129
Households	GWh	1891	3130	5352	7657	11399	15551	23276	30233
Services	GWh	1243	1937	3353	4766	6792	9294	12122	15425
Total	GWh	8444	12952	22561	32984	46747	60051	76655	93844

Figure 6.15. Electricity requirements including transmission & distribution losses in worksheet "SecEle".

(viii) Worksheet "LdFac(1)"

This worksheet contains the input data of seasonal, daily and hourly load modulation coefficients for the Industrial sector. The information can be provided for each (at maximum 6) client and for different reference years considered over the study period. These data are provided for the base year and can be modified for the future years of the study period if desired so by the user.

Figure 6.16 shows a part of the seasonal coefficients and daily ponderation coefficients and the control buttons provided to input these data. The cells of the worksheet having marked with borders are the daily coefficients of the first day of months as shown in this Figure by comment boxes. Various control buttons are present in this part of the worksheet to show these data in graphical form, to clear data and to normalize these data. A button "Check" is meant for validation of the input data. If the data for a certain year is not valid, the color of the cell showing the sum of the column or row is changed to "Red" indicating a warning message to the user.

01Feb 2030

Table 3: Load Coefficients for Industry (CASENB/low):

TOC

Check

Table 3a: Annual and weekly coefficients (see color codes at end of sheet)

Show Graphic
Close Graphic
Normalize values

2030															show/save data for selected year											
		Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh												
		Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl												
		N	N	N	N	N	N	N	N	N	N	N	N	N	2030	show	save									
week	season	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Total				
1	winter	1.01	1.60	1.02	1.50	1.02	1.50	1.02	1.02	1.02	1.02	1.02	1.02	1.02	0.98	0.99	1.01	1.02	1.01	1.02	0.98	7.00	Sh	Cl	N
2	winter	1.02	1.61	1.03	1.61	1.03	1.61	1.03	1.03	1.03	1.03	1.03	1.03	1.03	0.98	0.99	1.01	1.02	1.01	1.02	0.98	7.00	Sh	Cl	N
3	winter	1.03	1.60	0.98	1.60	1.05	1.60	1.05	1.05	1.05	0.95	1.05	1.05	1.05	0.99	1.00	0.99	1.00	1.00	1.02	0.99	7.00	Sh	Cl	N
4	winter	0.94	1.40	0.98	1.40	0.99	1.40	1.00	0.96	0.96	0.96	0.96	0.96	0.96	1.00	1.11	0.98	0.94	0.98	0.99	1.00	6.98	Sh	Cl	N
5	winter	1.00	1.66	1.02	1.86	1.02	1.66	1.02	1.02	1.02	1.02	1.02	1.02	1.02	0.96	0.99	1.00	1.00	1.04	1.04	0.96	7.00	Sh	Cl	N
6	winter	0.99	1.59	1.00	1.59	1.00	1.59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.01	0.99	1.00	1.00	1.01	0.99	7.00	Sh	Cl	N
7	winter	0.99	1.34	1.01	1.34	1.01	1.34	1.01	1.01	1.01	1.01	1.01	1.01	1.01	0.94	1.03	1.03	1.04	0.65	1.02	0.94	6.65	Sh	Cl	N
8	winter	0.95	1.20	0.97	1.20	0.97	1.20	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	1.02	1.02	1.02	1.05	0.95	0.97	7.00	Sh	Cl	N
9	winter	0.99	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	0.96	1.02	1.03	1.01	1.00	1.03	0.96	7.00	Sh	Cl	N
10	spring	1.00	0.72	1.02	0.72	1.02	0.72	1.02	1.02	1.02	1.02	1.02	1.02	1.02	0.95	1.01	1.01	1.02	1.04	1.02	0.95	7.00	Sh	Cl	N
11	spring	0.97	0.55	0.98	0.55	0.98	0.55	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.97	1.00	1.04	1.05	0.98	7.00	Sh	Cl	N
12	spring	1.01	0.38	1.03	0.38	1.03	0.38	1.03	1.03	1.03	1.03	1.03	1.03	1.03	0.98	0.99	0.97	1.00	1.04	1.05	0.98	7.00	Sh	Cl	N
13	spring	1.01	0.31	1.03	0.31	1.03	0.31	1.03	1.03	1.03	1.03	1.03	1.03	1.03	0.98	1.01	1.01	1.01	1.01	1.01	0.98	7.00	Sh	Cl	N
14	spring	0.86	0.34	0.87	0.34	0.87	0.34	0.87	0.87	0.87	0.87	0.87	0.87	0.87	1.01	0.98	0.97	0.98	1.00	1.05	1.01	7.00	Sh	Cl	N
15	spring	0.93	0.34	0.95	0.34	0.95	0.34	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.96	1.00	0.98	1.01	1.05	1.04	0.96	7.00	Sh	Cl	N
16	spring	0.91	0.47	0.92	0.47	0.92	0.47	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.95	0.97	1.00	1.04	1.04	1.04	0.95	7.00	Sh	Cl	N

Figure 6.16. Annual and weekly coefficients in worksheet "LdFac(1)".

01 Jan 2030

Figure 6.17 shows the portion of the worksheet showing the information related to the date and time when the data for a particular year was saved last time. This information is very useful to keep record of the progress of data input if it is done in steps.

year	saved	last saved
1970	saved	2/20/02 16:19
1975	saved	1/28/02 19:26
1980	saved	1/28/02 19:26
1985	saved	1/28/02 19:26
1990	saved	1/28/02 19:27
1995	saved	1/28/02 19:27
2000	saved	1/28/02 19:27
2005	saved	2/20/02 16:19
2010	saved	2/20/02 16:19
2015	saved	2/20/02 16:19
2020	saved	2/20/02 16:19
2025	saved	2/20/02 16:18
2030	saved	2/20/02 16:19

Figure 6.17. Date and time of the saved data in worksheet "LdFac(1)".

Figure 6.18 shows a part of the input data for the hourly variation of load during each of the weekdays and for each of the four seasons. These data is provided for the base year and can be modified for the future years of the study period as desired.

Table 3b: Daily coefficients for Industry ,ind1																		
2030	winter							spring							summer		
hour	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon
00.00	0.93	1.01	1.01	1.09	0.93	1.01	1.01	0.93	1.01	1.01	1.09	0.93	1.01	1.01	0.93	1.01	1.01
01.00	0.89	0.96	0.96	1.06	0.89	0.96	0.96	0.89	0.96	0.96	1.06	0.89	0.96	0.96	0.89	0.96	0.96
02.00	0.86	0.92	0.92	1.02	0.86	0.92	0.92	0.86	0.92	0.92	1.02	0.86	0.92	0.92	0.86	0.92	0.92
03.00	0.85	0.93	0.91	1.00	0.85	0.93	0.91	0.85	0.93	0.91	1.00	0.85	0.93	0.91	0.85	0.93	0.91
04.00	0.86	0.96	0.94	1.01	0.86	0.96	0.94	0.86	0.96	0.94	1.01	0.86	0.96	0.94	0.86	0.96	0.94
05.00	0.90	0.96	0.96	1.02	0.90	0.96	0.96	0.90	0.96	0.96	1.02	0.90	0.96	0.96	0.90	0.96	0.96
06.00	0.97	0.98	0.97	1.00	0.97	0.98	0.97	0.97	0.98	0.97	1.00	0.97	0.98	0.97	0.97	0.98	0.97
07.00	1.03	1.02	0.99	0.97	1.03	1.02	0.99	1.03	1.02	0.99	0.97	1.03	1.02	0.99	1.03	1.02	0.99
08.00	1.05	0.99	0.99	1.00	1.05	0.99	0.99	1.05	0.99	0.99	1.00	1.05	0.99	0.99	1.05	0.99	0.99
09.00	1.02	1.00	0.96	1.03	1.02	1.00	0.96	1.02	1.00	0.96	1.03	1.02	1.00	0.96	1.02	1.00	0.96
10.00	1.02	0.99	0.95	1.02	1.02	0.99	0.95	1.02	0.99	0.95	1.02	1.02	0.99	0.95	1.02	0.99	0.95
11.00	1.01	0.98	0.97	0.98	1.01	0.98	0.97	1.01	0.98	0.97	0.98	1.01	0.98	0.97	1.01	0.98	0.97
12.00	1.03	0.99	0.98	0.98	1.03	0.99	0.98	1.03	0.99	0.98	0.98	1.03	0.99	0.98	1.03	0.99	0.98

Figure 6.18. Hourly coefficients for industrial sector in worksheet "LdFac(1)".

Finally, at the end of the worksheet, color codes used in the worksheet are given as shown.

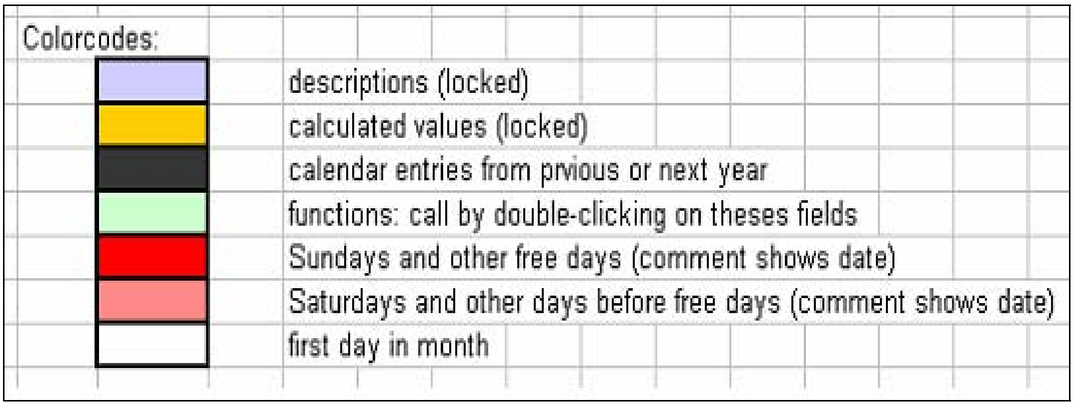


Figure 6.19. Color codes in worksheet "LdFac(1) ".

(ix) Worksheet "LdFac(2)"

This worksheet contains the same information as in the worksheet "LdFac(1)" but for the Transport sector.

(x) Worksheet "LdFac(3)"

This worksheet contains the same information as in the worksheet "LdFac(1)" but for the Household sector.

(xi) Worksheet "LdFac(4)"

This worksheet contains the same information as in the worksheet "LdFac(1)" but for the Service sector.

(xii) Worksheet "Check"

The information given in this worksheet is useful to locate the position of error in the load modulation coefficients if their sum is not correct. By looking at this worksheet, one can locate the errors if any in the input data for load coefficients. A part of this worksheet is shown in Figure 6.20.

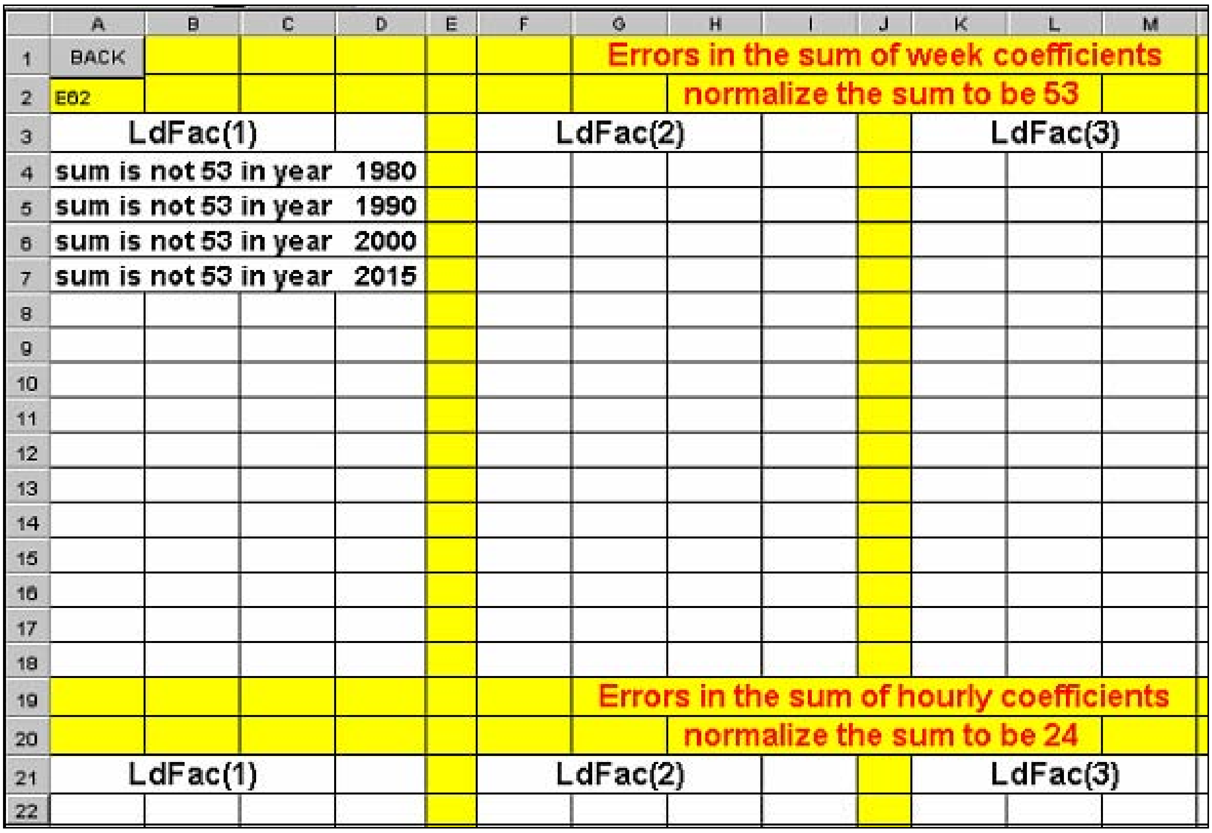


Figure 6.20. Errors in sums of the weekly, daily and hourly load coefficients in worksheet "Check".

(xiii) Worksheet "LDC"

The annual and seasonal peak loads (MW), electricity requirements (GWh), load factors (%) and number of hours as well as the numerical data for the four seasonal load duration curves are given in this worksheet. The portion of this worksheet showing the peak load and electricity requirements as calculated by the model are shown in Figure 6.21. Figure 6.22 shows the section of the worksheet giving the numerical data for the seasonal load duration curves.

Table 7: Ordered Load Duration Curves (Total) (CASENB/low):

Calculate | Print | Output | C:\tmp\loadwasp1.

Summary:
use growth: yes

1970	total	winter	spring	summer	autumn
Maximum load (MW):	2361.993	1939.466	1197.757	1342.227	2361.993
Rel. to ann. peak	1.000	0.821	0.507	0.568	1.000
Energy (GWh):	8446.911	2036.733	1993.513	2278.039	2138.626
Load factor (%):	40.82	49.16	75.38	75.23	41.92
Number of hours:	8760	2136	2208	2256	2160
Diff. to annual deman	2.593				
% Diff. to ann. deman	0.0				

1975	total	winter	spring	summer	autumn
Maximum load (MW):	2847.349	2847.349	1747.071	1828.343	1885.921
Rel. to ann. peak	1.000	1.000	0.614	0.642	0.662
Energy (GWh):	12938.962	3446.302	2611.616	3470.013	3411.032
Load factor (%):	51.87	56.66	67.70	84.13	83.74
Number of hours:	8760	2136	2208	2256	2160
Diff. to annual deman	-12.792				
% Diff. to ann. deman	-0.1				

Figure 6.21. Peak load, electricity requirements and load factor data in worksheet "LDC".

GRAPH | TOC | Clear temp data

Loadcurve:

season	item	data		
winter	length	0	0.00046816	0.00093633
	power	1	1	0.99239811
spring	length	0	0.00181159	0.00407609
	power	1	1	0.99056203
summer	length	0	0.00088652	0.00310284
	power	1	1	0.99378474
autumn	length	0	0.00046296	0.00092593
	power	1	1	0.90459574

Figure 6.22. Load and duration values for annual load duration curves in worksheet "LDC".

(xiv) Worksheet "LDC-G"

This worksheet shows the seasonal and annual load duration curves in graphical form for different years considered in the study. Figure 6.23 shows a part of this worksheet containing load duration curves for 1970 and 1975.

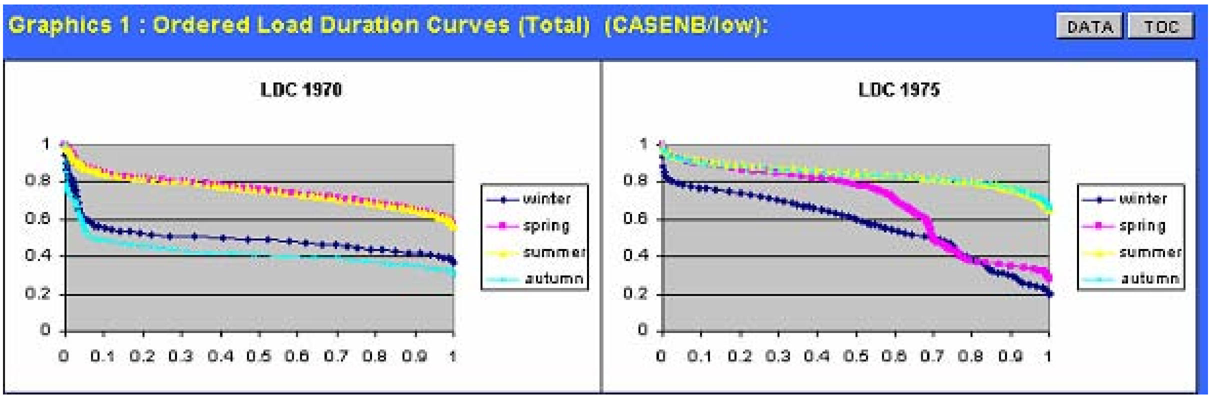


Figure 6.23. Graphical representation of annual load duration curves in worksheet "LDC-G".

(xv) Worksheet "ChrLdc"

This worksheet contains the chronological load data for each hour for all years considered in the study period. Figure 6.24 shows a section of this worksheet.

	A	B	C	D	E
1	1970	1975	1980	1985	1990
2	0.85106798	1.84911117	2.68809191	5.87579495	5.19515786
3	0.812643424	1.7656382	2.60190606	5.68738563	4.95964039
4	0.779829497	1.69435445	2.50927286	5.48488466	4.75251013
5	0.772089678	1.67754924	2.44979786	5.35486354	4.70601335
6	0.788654832	1.71355251	2.49140021	5.44578134	4.8630513
7	0.81732712	1.77586225	2.51139841	5.48947566	4.92599951
8	0.886730804	1.92667331	2.45292965	5.36165528	5.00210656
9	0.935309684	2.03223832	2.39005522	5.2242058	5.11818975
10	0.953425758	2.0716148	2.46925326	5.39729957	5.11293663
11	0.930887397	2.02265678	2.52392216	5.51677651	4.93143344
12	0.934710538	2.03097745	2.52097432	5.5103147	4.9143919
13	0.919901351	1.99881288	2.40224243	5.25077441	4.97169445
14	0.940781917	2.04419708	2.41804617	5.28530021	5.06018908
15	0.918686195	1.99619936	2.40118877	5.2484362	5.12852016

Figure 6.24. Chronological load data in worksheet "ChrLdc".

(xvi) Worksheet "SvFac(1)"

The data for seasonal, daily and hourly load coefficients for the Industrial sector is saved in this worksheet. The program reads data from this worksheet in order to display data for a specific year in the "**LdFac(1)**" worksheet as requested by the user. Figure 6.25 shows a section of this worksheet.

	A	B	C	D	E
1	1.00649924	0.97627389	0.9943227	1.00682981	1.01942877
2	1.01573379	0.97627389	0.9943227	1.00682981	1.01942877
3	1.03203728	0.99228999	0.99848426	0.99397797	1.00100116
4	0.94309134	0.9999857	1.10881871	1.00457394	0.93768576
5	0.9987058	0.96326209	0.99135904	0.9953109	1.00493484
6	0.98542771	0.99093155	1.00953344	0.99423366	0.9969697
7	0.98898188	0.94147867	1.03408624	1.02809268	1.03634766
8	0.95073397	0.97036573	1.01524181	1.01822269	1.01763629
9	0.98815694	0.95694241	1.02313988	1.025108	1.0085352
10	0.99776615	0.95111053	1.00695404	1.00734398	1.02253562
11	0.96671231	0.97860316	0.98951028	0.97158076	0.99903949
12	1.0120434	0.97860316	0.98951028	0.97158076	0.99903949
13	1.01187676	0.97534807	1.00582374	1.01244131	1.01294792
14	0.85954924	1.01269579	0.98453714	0.96546312	0.98003176
15	0.92886875	0.95669924	0.99930807	0.98262306	1.01008094

Figure 6.25. Data for saved coefficients in worksheet "SvFac(1)".

(xvii) Worksheet "SvFac(2)"

This worksheet contains the same information as in the "**SvFac(1)**" worksheet but for the Transport sector.

(xviii) Worksheet "SvFac(3)"

This worksheet contains the same information as in the "**SvFac(1)**" worksheet but for the Household sector.

(xix) Worksheet "SvFac(4)"

This worksheet contains the same information as in the "**SvFac(1)**" worksheet but for the Service sector.

(xx) Worksheet "temp"

This worksheet is used by the program to store some data temporarily during the execution of the program. The information contained in this worksheet can be deleted to decrease the size of the workbook file "**MAED_El.xls**".

7 EXECUTION OF MAED MODULE 2

7.1 Introduction

Before starting the execution of MAED Module 2, it is necessary to appropriately set the computer by:

- changing the date format as explained in Figure 7.1;
- set the security level of Excel program to medium (Tools/Macro/Security/Medium).

With this security level setting, when the user opens the Microsoft Excel workbook file <**MAED_El.xls**>, a **Dialogue Box** appears on the computer screen inquiring the user whether to enable Macros in the workbook or not (see Figure 7.2). The user must click **Enable Macros** button in order to use the **Macros** available in the workbook. This is necessary to allow the use of various Microsoft Visual Basic subroutines present in the workbook, which activate various buttons to perform various functions e.g. to move control from one worksheet to another, to calculate the load duration curves and to check the validity of input data etc.

Before starting to use MAED , it is necessary to change the date format used by Microsoft Windows programs as described below.

For Microsoft Windows 95 & 98
1.Open the **Regional Settings Properties** dialog box by clicking **Start** button, pointing to **Settings**, clicking **Control Panel**, and then clicking Control Panel, and then clicking **Regional Settings**.
2.On the **Date** tab,select "**yyyy-MM-dd**" from the **Short date style** Listbox.
3.Press **OK** button to close the **Regional Settings Properties** Dialogue box.
For Microsoft Windows 2000 & Windows XP
1. Open the Regional and Language Options in Control Panel.
2. On the **Regional Options tab**, under **Standards** and **formats**, click **Customize**.
3. On the **Date** tab, select "**yyyy-MM-dd**" from the **Short date style** Listbox.
4. Press **OK** button to close the **Customize regional Options** Dialogue box.
5. Press **OK** button to close the **Regional and Language Options** Dialogue box.

Figure 7.1. Change Date Format before using MAED.

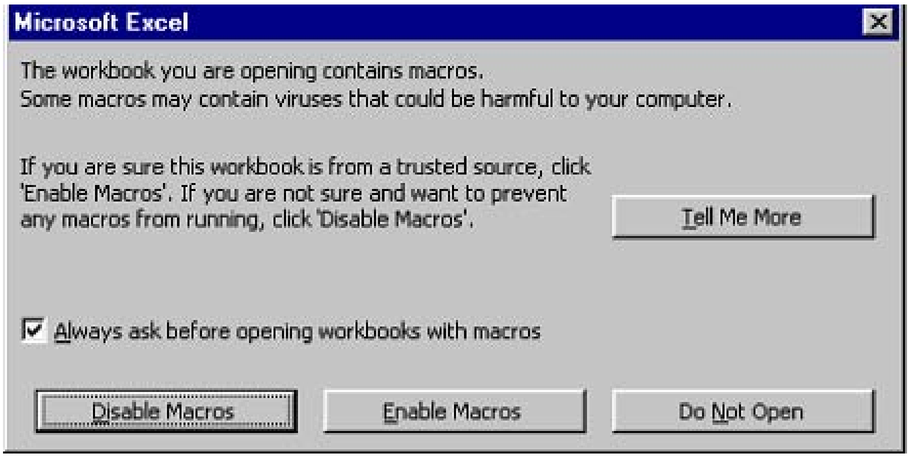


Figure 7.2. Microsoft Excel dialogue box asking to Enable Macros.

Another Dialogue Box may also appear during opening the <MAES_El.xls> Excel file asking the user whether to update the automatic links of this workbook file to other workbook files (See Figure 7.3). The answer for this question depends on what version of the MAED_D program is used for energy demand analysis. If the energy demands by sectors used in MAED_El program were estimated with the version I of MAED_D program, distributed before December 2004 and which is automatically linked to MAED_El program, the first time a user opens the <MAED_El.xls> file, it is necessary to click the Yes button in order to import the necessary data from Module 1 of MAED contained in the <MAED_D.xls> workbook file. However, once data is imported from this file, it is not necessary to click the Yes button unless the user has made some changes to the <MAED_D.xls> workbook file. If the MAED_E program is used in conjunction with the version II of MAED_D program, distributed after January 2005 and which is not yet automatically linked to MAED_El program, it is necessary to click the No button and to enter the respective energy demands directly in Table 1 of worksheet "FinEle" of <MAED_El.xls> workbook file.

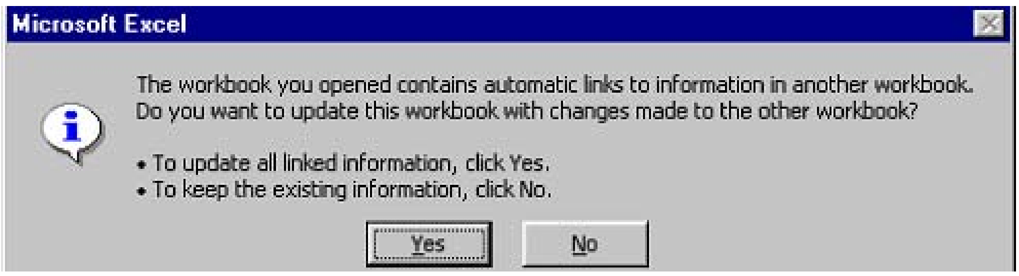


Figure 7.3. Microsoft Excel Dialogue Box asking to update the automatic linked information from other workbooks.

7.2 Execution of MAED_El Program

As described in Chapter 6, MAED Module 2 is designed to generate the hourly load demand for an electric system based on:

(i) the annual electricity demand calculated either using Module 1 of MAED or using any other methodology;

(ii) load growth over the year due to increased electricity demand;

(iii) seasonal load variation coefficients;

(iv) daily load variation by day type, and

(v) hourly load variation during day for all day types.

Therefore, all these five categories of input data are required for execution of Module 2.

The major steps involved in the execution of this Module are:

(i) Preparation of necessary input data;

(ii) Input and validate the required data in various worksheets described in previous section;

(iii) Execute the Module 2 program; and

(iv) Check the model results.

The user may need to repeat the step (ii) to (iv) if he is not satisfied with the model results. We shall describe these steps in more detail in the following paragraphs.

Step-I: Preparation of Necessary Input Data

The first step is to gather the information required for execution of the model. Some of which may be based on the Module 1 or otherwise, while the information related to seasonal (weekly), daily (by day type) and hourly variation of electricity load in various economic sectors and sub-sectors (clients) is based on historical data. The details for preparation of these parameters based on historical statistics are given in Appendix C of Reference 12.

If Module 1 of MAED is used for electricity demand projections, then sector wise annual electricity demand (GWh) and annual growth rates will be available from Module 1 and user is not required to input this information, otherwise these information is required to be collected from some other similar study. Shares of different clients within each sector are also needed for the base year as well as for the future years considered in the study.

Step-II: Data Entry in the Worksheets

The data required for Module 2 is divided into various worksheets as described in previous section of the User's Manual. As a general rule, user needs to input data in the cells with white background. All the input parameters required in different worksheets are described below.

I. Worksheet "Descr"

The first worksheet in which some user input is required is the "Descr" worksheet. In this worksheet, the user provides some general information related to the electricity demand scenario e.g. Country/region name, Scenario name and number, Author's name and Date etc.

II. Worksheet "Calendar"

In this worksheet, information related to the calendar days is provided. The user lists the normal and special holidays during each of the year considered under the study period. This information is provided for the weekly holidays as well as those holidays occurring at special occasions. In the next section of the worksheet, the starting dates of different seasons for each year are provided. Four typical seasons are considered by the model, i.e. winter, spring, summer and autumn. A season that starts at the end of a year and continue at the beginning of the next year can have two starting dates for a model reference year, once on 1st of January and second at the beginning of the season at the end of the year. Therefore, the user has to define the start dates for 5 seasons. At the end of this Table, the last date of the year i.e., 31 December is also provided. In the next section of the worksheet, the starting and ending dates of a special season are defined for each reference year in the study period. A special season could be "Ramadan" in Muslim countries, Christmas in some other countries or any other special period of year having different pattern of electricity consumption during this period. At the end of the worksheet, the user has to provide the sequence of names of weekdays in a typical week (for example, from Monday to Sunday in Europe and from Saturday to Friday for Islamic countries) and the typical days for hourly load variation (for example, Wednesday, as a typical working day, Saturday and Sunday in Europe).

III. Worksheet "FinEle"

The user input in this worksheet is the share of different clients in different sectors of economy. At maximum, six clients can be defined for each sector and the sum of shares of all clients in each sector must be equal to 100% in all sectors. In the sample case, four sectors of economy (Industry, Transport, Household and Service) and one client for each sector are considered. However, user can change the names of these sectors as well as the names and number of clients to be considered in each sector.

Definition of Clients

It may be noted that the number of clients defined in the worksheet "**FinEle**" is very important and the input data required and calculations made by the model are dependent upon this information. The number of non-empty names of clients in a particular sector determines the number of clients present in that sector and all the future calculations will be made for only these clients. A second important point to be considered regarding the clients data is that all the clients in a sector should be defined in consecutive rows starting from the first row below the years row of that sector. For example, if 3 clients are defined as shown in Figure 7.4, the model will consider only the 2 clients defined in the first two rows and will ignore the third client "**ind3**" for its further calculations.

Table 1a1a: Share of industrial clients:

	unit	1970	1975	1980	1985
ind1	%	50.00	50.00	50.00	50.00
ind2	%	20.00	20.00	20.00	20.00
	%	0.00	0.00	0.00	0.00
ind3	%	30.00	30.00	30.00	30.00
	%	0.00	0.00	0.00	0.00
	%	0.00	0.00	0.00	0.00
Total	%	100.00	100.00	100.00	100.00

Figure 7.4. Definition of Clients in worksheet "FinEle".

IV. Worksheet "SecEle"

This worksheet requires information of Transmission losses of the overall power system and distribution losses for each sector considered in the study. All of these data are required for each reference year considered in the study period. In addition to that, some information related to adjustment of peak demand can also be provided in this worksheet if the peak demand calculated by the model does not match with the actually experienced value by the power system. The user may use the "**multiplier**" or "**addition**" and "**duration**" values to adjust the peak demand.

V. Worksheet "LdFac(1)"

This worksheet requires extensive input data for seasonal (weekly), daily and hourly load variation coefficients. Information to be provided by the user is subdivided into a number of Tables (3a through 3g) in this worksheet.

Table 3a requires information of seasonal (weekly) and daily (day type) load coefficients for various reference years in the study period. The first few columns contain weekly load variation coefficients for each year considered in the study. In total, there are 53 coefficients required for each year. The first and the last week may have less than 7 days due to different day of week on the 1st of January. Thus the sum of all coefficients must be equal to 53.

In the section of Table 3a towards the right side, the user has to provide the load variation coefficients by day type during a week. These coefficients are required for the all seven days of week and for each week in a year (53 weeks, due to the reason described earlier). The names of weekdays are shown in the first row. The sum of the coefficients for each week, given in the last column, must be equal to 7.

Table 3b contains the information of hourly load variation coefficients for the client-1 in the Industrial sector. These coefficients are defined for 24 hours for each weekday (7 in total) and for each season (for all of the four seasons and for the special season). The sum of hourly coefficients in each day must be equal to 24. Tables 3c to 3g contain the similar information for the rest of 5 clients in the Industrial sector respectively. The user has to supply these data for as many clients as defined in the worksheet "**FinEle**" in Table 1a1a.

Description of various buttons and the areas that could be double-clicked in worksheet "**LdFac(1)**" are shown in Figures 7.5, 7.6 and 7.7.

Note: Before using the buttons 'N', 'Cl' and 'Sh' the respective "**LdFac(?)**" worksheet must be unprotected using the standard Excel procedure (Tools/Protection/Unprotect Sheet). No password is required.

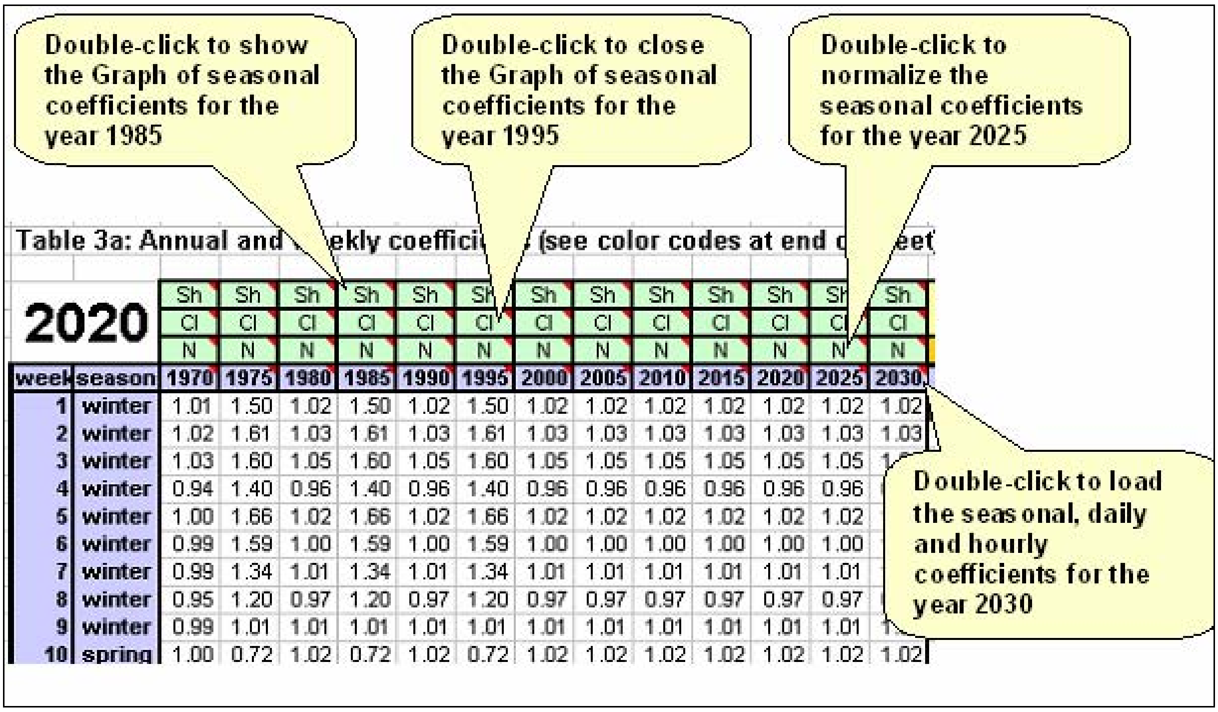


Figure 7.5. Illustration of various double-click options in the seasonal coefficients section of Table 3a in worksheet "LdFac(1)".

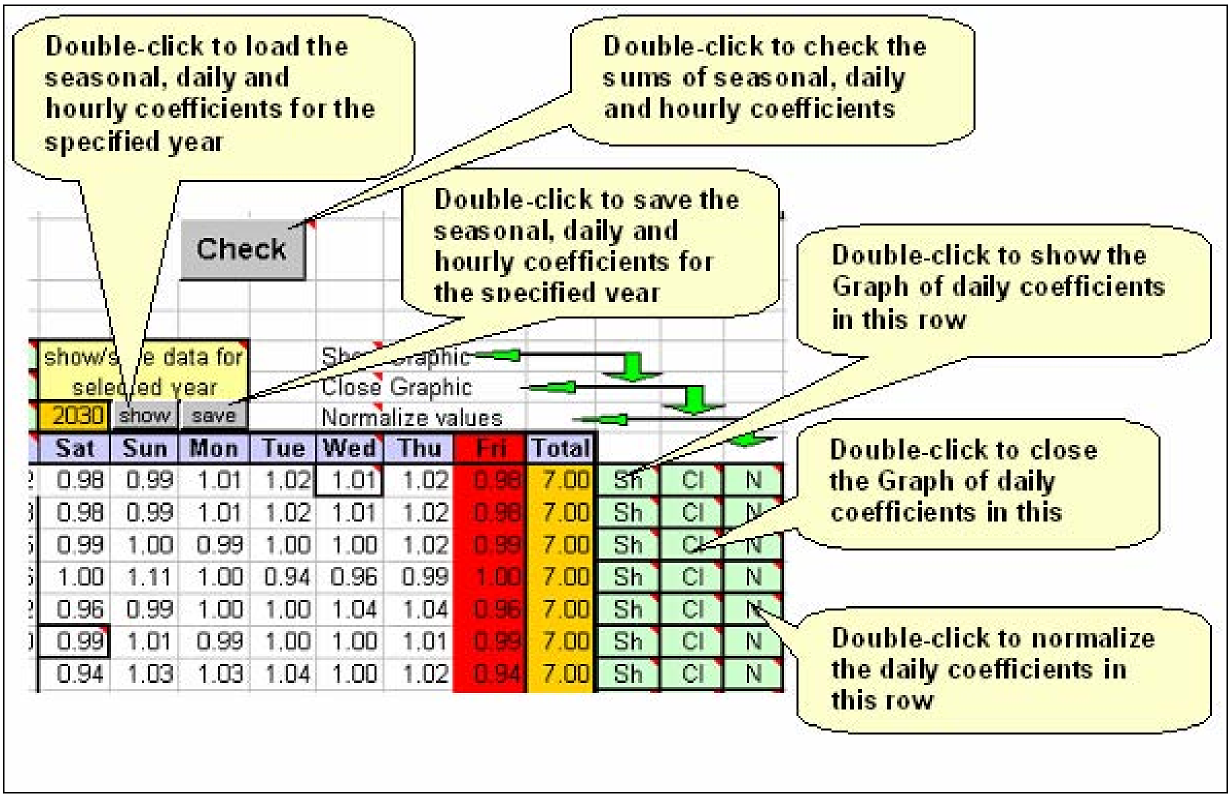


Figure 7.6. Illustration of various buttons and double-click options available in the daily coefficient section of Table 3a in worksheet "LdFac(1)".

Display/Edit Data for a Particular Year

User can retrieve the seasonal, daily and hourly coefficients for a particular year from the respective **SavFac(?)** worksheet by either pressing the "**Show**" button (and selecting the year in the drop down list) as shown in Figure 7.6 or by double-clicking the respective year in seasonal variation coefficients title row as illustrated in Figure 7.5.

Save Data for a Particular Year

Data for the current year can be saved to the respective "**SavFac(?)"** worksheet by pressing the "**Save**" button as illustrated in Figure 7.6. A small Table towards right of the Table 3a shows the date and time of the data saved for each reference year in the study period as shown in Figure 6.17 in previous section of the User's Manual.

Display Data in Graphical Form

The user can show the seasonal, daily and hourly coefficients in graphical form by double-clicking the "**Sh**" cell in the respective row or column as illustrated in Figures 7.5, 7.6 and 7.7. Once graph for weekly, daily or hourly coefficients is displayed, the color of the respective "**Cl**" cell is changed to red. It means that the displayed graph window can be closed by double-clicking this red color "**Cl**" cell.

Close the Graph Window

The graph window can be closed by double-clicking the "**Cl**" cell as illustrated in Figures 7.5, 7.6 and 7.7.

Check Validity of Coefficients Data

Press the "**Check**" button to check the sum of the seasonal, daily or hourly coefficients equal to 53 in the case of seasonal coefficients, 7 in the case of daily coefficients and 24 in the case of hourly coefficients. The resulting **Error Messages** are stored in the "**Check**" worksheet.

Normalize the Coefficients

Any set of weekly, daily or hourly load coefficients can be normalized by double-clicking the respective "**N**" cell located in the respective column or row. Normalization of coefficients means to adjust the values of the coefficients in order to make their sum equal to 53 in the case of seasonal coefficients, 7 in the case of daily coefficients and 24 in the case of hourly coefficients.

Note: The "**Sh**", "Cl" and "**N**" buttons for the **seasonal** coefficients are in the top rows of the Table 3a, the **daily** variation coefficients are located towards the right of the Table 3a and **hourly** coefficients are in the bottom rows of the Table 3b. The color codes used in this worksheet are given at the bottom of the worksheet.

VI. Worksheet "LdFac(2)"

This worksheet contains the same information as given in worksheet "**LdFac(1)**" but for the **Transport** sector.

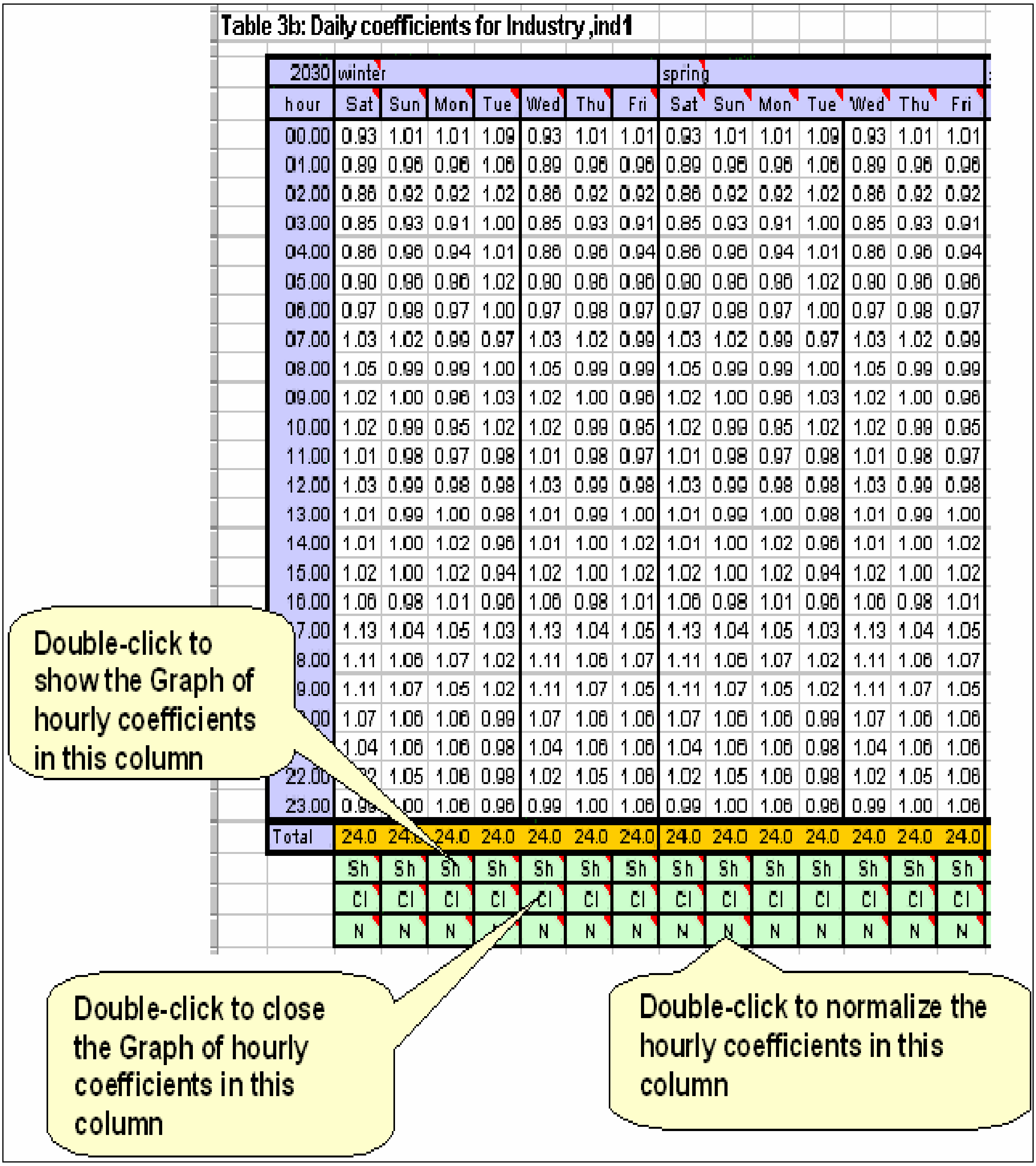


Table 3b: Daily coefficients for Industry ,ind1

2030	winter							spring						
hour	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri
00.00	0.93	1.01	1.01	1.09	0.93	1.01	1.01	0.93	1.01	1.01	1.09	0.93	1.01	1.01
01.00	0.89	0.96	0.96	1.06	0.89	0.96	0.96	0.89	0.96	0.96	1.06	0.89	0.96	0.96
02.00	0.86	0.92	0.92	1.02	0.86	0.92	0.92	0.86	0.92	0.92	1.02	0.86	0.92	0.92
03.00	0.85	0.93	0.91	1.00	0.85	0.93	0.91	0.85	0.93	0.91	1.00	0.85	0.93	0.91
04.00	0.86	0.96	0.94	1.01	0.86	0.96	0.94	0.86	0.96	0.94	1.01	0.86	0.96	0.94
05.00	0.90	0.96	0.96	1.02	0.90	0.96	0.96	0.90	0.96	0.96	1.02	0.90	0.96	0.96
06.00	0.97	0.98	0.97	1.00	0.97	0.98	0.97	0.97	0.98	0.97	1.00	0.97	0.98	0.97
07.00	1.03	1.02	0.99	0.97	1.03	1.02	0.99	1.03	1.02	0.99	0.97	1.03	1.02	0.99
08.00	1.05	0.99	0.99	1.00	1.05	0.99	0.99	1.05	0.99	0.99	1.00	1.05	0.99	0.99
09.00	1.02	1.00	0.96	1.03	1.02	1.00	0.96	1.02	1.00	0.96	1.03	1.02	1.00	0.96
10.00	1.02	0.99	0.95	1.02	1.02	0.99	0.95	1.02	0.99	0.95	1.02	1.02	0.99	0.95
11.00	1.01	0.98	0.97	0.98	1.01	0.98	0.97	1.01	0.98	0.97	0.98	1.01	0.98	0.97
12.00	1.03	0.99	0.98	0.98	1.03	0.99	0.98	1.03	0.99	0.98	0.98	1.03	0.99	0.98
13.00	1.01	0.99	1.00	0.98	1.01	0.99	1.00	1.01	0.99	1.00	0.98	1.01	0.99	1.00
14.00	1.01	1.00	1.02	0.96	1.01	1.00	1.02	1.01	1.00	1.02	0.96	1.01	1.00	1.02
15.00	1.02	1.00	1.02	0.94	1.02	1.00	1.02	1.02	1.00	1.02	0.94	1.02	1.00	1.02
16.00	1.06	0.98	1.01	0.96	1.06	0.98	1.01	1.06	0.98	1.01	0.96	1.06	0.98	1.01
[illegible]	1.13	1.04	1.05	1.03	1.13	1.04	1.05	1.13	1.04	1.05	1.03	1.13	1.04	1.05
[illegible]	1.11	1.06	1.07	1.02	1.11	1.06	1.07	1.11	1.06	1.07	1.02	1.11	1.06	1.07
[illegible]	1.11	1.07	1.05	1.02	1.11	1.07	1.05	1.11	1.07	1.05	1.02	1.11	1.07	1.05
[illegible]	1.07	1.06	1.06	0.99	1.07	1.06	1.06	1.07	1.06	1.06	0.99	1.07	1.06	1.06
[illegible]	1.04	1.06	1.06	0.98	1.04	1.06	1.06	1.04	1.06	1.06	0.98	1.04	1.06	1.06
22.00	[illegible]	1.05	1.06	0.98	1.02	1.05	1.06	1.02	1.05	1.06	0.98	1.02	1.05	1.06
23.00	[illegible]	[illegible]	1.06	0.96	0.99	1.00	1.06	0.99	1.00	1.06	0.96	0.99	1.00	1.06
Total	24.0	[illegible]	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh
	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl
	N	N	N	[illegible]	N	N	N	N	N	N	N	N	N	N

Figure 7.7. Illustration of various double-click options available in the hourly coefficients of Table 3b in worksheet "LdFac(1)".

VII. Worksheet "LdFac(3)"

This worksheet contains the same information as given in worksheet "**LdFac(1)**" but for the **Household** sector.

VIII. Worksheet "LdFac(4)"

This worksheet contains the same information as given in worksheet "**LdFac(1)**" but for the **Service** sector.

After completing the input data for the seasonal, daily and hourly coefficients for all the sectors, user may press the "**Check"** button in each of these worksheets and then check for any error messages displayed in the "**Check**" worksheet. In case, any error messages are there, the user can modify the respective set of coefficients in the corresponding "**LdFac(?)**" worksheets as indicated by the error messages.

Step-III: Execution of Module 2

Once the coefficient data are correct to the full satisfaction, the user can move to the "**LDC**" worksheet. By pressing the "**Calculate**" button, the user can start the process of calculating the resultant hourly loads in the system for each year considered in the study. The results of these calculations are saved/updated in the "**LDC**", "**ChrLDC**" and "**temp**" worksheets. This step takes relatively longer time, as it requires extensive calculations done in the background. However, some messages are displayed during the execution of the model, about the status of the program execution at a particular time under the "**Calculate**" button.

The list and brief description of buttons available in various worksheets of the MAED Module 2 file <**MAED-el.xls**> is given in Table 7.1.

Step-IV: Check the Model Results

After completion of the execution of the MAED Module 2 program, the results of the model are presented in worksheets "**LDC**", "**LDC-G**" and "**ChrLDC**". Description of these worksheets has already been given in previous sections of the User's Manual. The load characteristics for each season as well as those for the overall system are displayed in the same worksheet ("**LDC**") for each year considered in the study. The respective load duration curves data are also displayed for all the four seasons considered for each year. These data are required by the LOADSY module of WASP (Wien Automatic System Planning Package) model developed by the IAEA for power system expansion planning. However, these data may not be useful, if the user decides to use the number of periods in a year other than four periods in WASP. In that case, the user will need to use the chronological load data stored by the model in the worksheet "**ChrLDC**" and generate the LOADSY data by him. The annual and seasonal load duration curves in graphical form are stored in the worksheet "**LDC-G**". The chronological load values as well as the load duration curves generated by the model can be compared with the actual data for the base year and the user should try to explain any discrepancies, if found between the two values. If the results are not in line with the expectations of the user, he should check again the input data entries and may need to repeat steps II to IV again.

Table 7.1: Description of buttons available in various worksheets of the **MAED Module 2 file <MAED-el.xls>**

Button	**Worksheet/(s)**	**Description**
TOC	All worksheets except MAED_EL, check, ChrLDC, SvFac(1), SvFac(2), SvFac(3), SvFac(4), and temp	To move to the worksheet "TOC".
Notes	TOC	To move to the worksheet "**Notes".**
Descr	TOC	To move to the worksheet "**Descr".**
FinEle	TOC	To move to the worksheet "**FinEle**".
SecEle	TOC	To move to the worksheet "**SecEle".**
LdFac(1)	TOC	To move to the worksheet "**LdFac(1)".**
LdFac(2)	TOC	To move to the worksheet "**LdFac(2)".**
LdFac(3)	TOC	To move to the worksheet "**LdFac(3)".**
LdFac(4)	TOC	To move to the worksheet "**LdFac(4)".**
LDC	TOC	To move to the worksheet "**LDC".**
LDC-G	TOC	To move to the worksheet "**LDC-G**" containing the graphs for the load duration curves.
LDC(2)	TOC	To move to the worksheet "**temp".**
Check	LdFac(1), LdFac(2), LdFac(3), LdFac(4)	To check the sum of the seasonal, daily or hourly coefficients. The results are displayed in worksheet "**check**".
show	LdFac(1), LdFac(2), LdFac(3), LdFac(4)	To retrieve the seasonal, daily and hourly coefficients for a particular year from the respective "**SvFac(?)"** worksheet.
save	LdFac(1), LdFac(2), LdFac(3), LdFac(4)	To save the seasonal, daily and hourly coefficients for a particular year from the respective "**SvFac(?)"** worksheet.
Calculate	LDC	To start the process of calculating the resultant hourly loads in the system for each year considered in the study. The results of these calculations are saved/updated in "LDC", "**ChrLDC**" and "temp" worksheets.
Print	LDC	To export the annual peak load, period peak load ratios an load duration curves data for the four seasons considered l **MAED** to an input data file specified by the user using th Output file button. The format of this file is in line with th required by the **LOADSY** module of the **IAEA**'s power system expansion planning model **WASP.**
Output file:	LDC	**To specify/select the output file to be used to export the MAED results as described in the description of the Print button..**
GRAPH	LDC	**To move to the worksheet "LDC-G" containing the graphs for the load duration curves.**
Clear temp data	LDC	**To delete the information contained in the worksheet "temp" in order to decrease the size of the workbook "MAED_El.xls" file.**
DATA	LDC-G	To move to the worksheet "LDC" containing the numerical data of the load duration curves.

8 THEORETICAL BACKGROUND OF MAED MODULE 2

As stated earlier, the main objective of MAED Module 2 is to convert the total annual demand for electricity of each of the four economic sectors considered in the model (Industry, Transport, Household, and Service sectors) into the electric power demand of these sectors on an hour-by-hour basis. A generalized methodological approach used in MAED Module 2 is given in this section of the User's Manual. The annual electricity demand of a consumer sector is converted into the electric power requested by the same sector at a given hour of a certain day and week of the corresponding year by taking into account the following factors:

(i) The trend of the average growth rate of the demand over the year;

(ii) The variation of electricity consumption due to the seasonal impact (which could be expressed in terms of semesters, quarters, months, weeks);

(iii) The impact of the type of day considered in the electricity consumption (whether a working day, a weekend day etc.);

(iv) The variation of energy consumption due to the period of the day considered (whether in the morning, lunchtime, evening etc.).

Each of these factors is represented by a certain coefficient that in a sense "modulates" the electric power requested by the sector (thus, they are called load-modulating coefficients). Each coefficient can be seen as the variation of electricity consumption of the sector with respect to the "standard" consumption of the sector. The latter is represented by the consumption in an equivalent working day.

The general purpose of the methodology consists of calculating the electric power requested by a consumer sector from the grid at hour h in a day j of a week number i, from the power requested by the same sector in the same hour of an average equivalent working day. Following methodology is used for these calculations:

Identification of calendar

In MAED model, the year is divided into four seasons and a special holiday period, which may have different electricity consumption pattern from these four seasons. The user defines the date of the first day of each season, for each reference year considered in the study period, in order to identify different seasons during the year. Similarly, the starting and the ending dates of the special holiday period are also defined. The user also specifies the sequence of the weekdays (for example, from Monday to Sunday in Europe and from Saturday to Friday for Islamic countries) and the typical days for hourly load variation (for example, working day, Saturday and Sunday in Europe).

Consideration of electricity demand growth rate during the year: Coefficient T(i)

In order to come to a standard day, the first correction to be made corresponds to the general trend of the growth of electricity consumption during the year. This is represented by a "deflator" which is calculated on a weekly basis (with a total of 52 values in the year), so that the deflator of the gross electricity consumption (i.e. the growth trend coefficient) for week " i" is :

$$T(i) = \left[1 + \frac{GROWTH}{100}\right]^{\left(\frac{i-26}{52}\right)}$$

where GROWTH is the average annual growth rate of electricity demand of the current sector between the previous last and the current year which is either specified by the user (for the first year) or calculated by the program from the information read in from the MAED Module 1 Microsoft Excel workbook file <**MAED_D.xls**>(for the subsequent years).

Seasonal coefficients: K(i)

In order to take into account the seasonal impact on electricity consumption of a sector, the "seasonal deflator" is used. For the time period "i" (either a semester, a quarter, a month, a week etc.), K(i) represents the average weight of this period in the total electricity consumption for the year.

Consequently, the sum of the K(i) values over the year should be equal to the total number of periods into which the year is subdivided. (Note: The subdivision of the year into seasons for the purposes of preparing the input data for a given case study will depend on data availability for the country being studied. Also, the K(i) coefficients should reflect changes in demand due only to seasonal effects, i.e. in calculating the K(i) values the growth trend effect should be removed first. Section C.4 of Reference 12 describes how the modulation coefficients can be calculated from the knowledge of the chronological electric load curve of a given sector).

In the MAED Module 2, the week has been selected as the elementary time unit for representing these seasonal variations and, therefore, 53 K(i) coefficients must be given as input data for each reference year of study period, keeping in mind that at least one of the first and last week will be not an entire week. If the user does not want to change these coefficients for a future year, he may repeat the same coefficients as for the previous year. Therefore, the only calculation performed by the program for these coefficients is a check:

$$\sum_{i=1}^{53} K(i) = 53$$

If the SUM is not equal to 53, the color of the cell showing the sum of coefficients is turned to red showing a warning message to the user.

Daily ponderation coefficients: P(i, id)

This type of coefficient reflects fluctuations of electricity consumption due to the type of day being considered, i.e. a working day, Saturday, Sunday, etc. Since the general goal of the exercise is to compare the electricity consumption of every time unit to the consumption in the equivalent working day, the relative weight of a working day is chosen to be equal to 1, and the other types of day are weighted in comparison to their relative consumption relative to that of the working day, e.g. a Saturday could be assumed at 0.8 of a working day, a Sunday at 0.7, etc.

In general, these coefficients fluctuate over the year according to the time period considered (in MAED, the week, as stated in the preceding subsection) so that they are more properly represented as P(i, id), I = 1, 53 and id = 1, 7. Again, these coefficients must be given as input data for each reference year of the study period. If the user does not want to change these coefficients for a future year, he may repeat the same coefficients as for the previous year.

Hourly coefficients: LCS(h, id)

The objective of the hourly coefficient is to weigh the energy consumption over the 24 hours of the day. Each hour "h" of a day will be given a coefficient according to the level of consumption in the hour, such as that the sum of the coefficients over the day is equal to 24.

In general, these coefficients are dependent on the time period of the year and the typical days for hourly load variation being considered. The typical days for hourly load variation have been already defined at the beginning of this section. They may be some particular days of the week (for example, Wednesday, as a typical working day, Saturday and Sunday). Concerning the variation according to the time period of the year, a differentiation can be made in the program between the consumption in each of the four seasons as well as for the special holidays period. Several types of clients or consumers with varying daily load characteristics can also be distinguished for the sector being considered.

Each client type -ic- (in MAED, the user can define up to 6 clients for each sector) has a weight in each day type -id- (in this case -id- may be less than 7, depending upon how many typical days are considered to reflect the load hourly variation) and for each season -is- (four seasons and the special holidays period considered in MAED) equal to -$LCONT_{is}$- as well as hourly variation of electricity demand -LCOEF(h,ic,id)- which are given as input. Consequently, from these data the program calculates the aggregated hourly coefficients LCS_{is} of the sector for each season –is- from:

$$LCS_{is}(h,id) = \sum_{ic=1}^{6} LCONT_{is}(ic,id) * LCOEF_{is}(h,ic,id)$$

Before carrying out the above calculations, the program performs the following checks for all seasons -is-:

and

$$\sum_{ic=1}^{6} LCONT_{is}(ic,id) = 100 \qquad \sum_{h=1}^{24} LCOEF_{is}(h,ic,id) = 24$$

and if they are not fulfilled, a warning message, in the form of changed color to red of the cell showing the sum of the coefficients for a particular day type, is displayed in the respective worksheet.

The LCONT and LCOEF values must be given as input data for each reference year of study period. If the user does not want to change these coefficients for a future year, he may repeat the same coefficients as for the previous year.

Number of equivalent working days in a year

Having identified all above-mentioned coefficients, the total number of equivalent working days for current year and sector is:

$$N = \sum_{m=1}^{NODAYT} P(i,id) * K(i) * T(i)$$

where NODAYT is the total number of days in the year, -id- stands for day type and -i- for the week number of calendar day m.

Thus, the energy consumption of the sector in the equivalent average working day:

$$EWDS = ENERGY / N$$

where **ENERGY** is the annual electricity consumption of the current sector in the current model year estimated with MAED Module 1.

Determination of the average hourly power demand of the sector

The total electricity consumption of the current sector for the calendar day -m- of current year is given by:

$$E(m) = EWDS * K(i) * T(i) * P(i,id) \qquad \text{where -id- is the day type.}$$

The electric power demand of the sector -it- in hour -h- of the day -m- is calculated as:

$$PV_{is}(it, h, m) = E(m) * LCS_{is}(h,id) / 24$$

Finally, the total annual electricity demand of the sector is:

$$ESUM(it) = \sum_{m=1}^{NODAYT} E(m)$$

Determination of the average hourly power demand (or electric load) imposed on the power generating system of the country

The methodology described above is applied to each of the four sectors considered in the program, i.e. Industry, Transportation, Household and Service sectors. Once all sectoral total annual demand and hourly loads have been determined, the program calculates the total annual demand of the power generating system (ET) and the growth rate (GROWAV) of this demand for the current year as following:

$$ET = \sum_{it=1}^{4} ESUM(it)$$

$$GROWAV = \sum_{it=1}^{4} ESUM(it) * GROWTH(it) / ET$$

The total electric load imposed to the generating system in hour -h- is simply obtained by adding the load of each sector for the same hour, i.e.:

$$PT_{is}(h,m) = \sum_{it=1}^{4} PV_{is}(it, ih, m)$$

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