SIXTH FRAMEWORK PROGRAMME

Project no: **502687**

NEEDS

New Energy Externalities Developments for Sustainability

INTEGRATED PROJECT

Priority 6.1: Sustainable Energy Systems and, more specifically,
Sub-priority 6.1.3.2.5: Socio-economic tools and concepts for energy strategy.

Technical Paper n° 8.1, 8.2 and 8.3 - RS 1b

"Specification of the interface between external cost computation and economy and energy modelling, inclusive the associated data"

and

"Model specification for the integration of external cost in economy and energy modelling and integration of the model specification into the energy system modelling framework (first part)"

and

"Specification of the interface between external cost and LCA"

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Specification of the interface for linking LCA data, external cost specification and TIMES modelling framework (Stream 1b WP 8.1, WP8.2 and WP8.3)

CES KULeuven

(2nd draft)

1 General Approach

The general framework for the integration of stream 1a, 1b and 2a has been described in the report from WP4 in the Integration stream. This report will, after a brief description of the general approach, concentrate on the precise interactions between the streams for a, as full as possible, integration of the results from the different streams and on their integration in the MARKAL/TIMES modelling framework.

Within this project, the external cost considered are those generated by the release of substances from the energy system. MARKAL/TIMES considered part of the substances emitted into the atmosphere, while Stream RS1b examines a broader set of external costs, including those generated by the release of substances into water, radioactive releases, land use, etc. and they will have a slightly different treatment for integration. For the emissions calculated in RS1a and RS2a, environmental and human health impacts and damage costs will be derived and provided by RS1b.

1.1 Approach for the substances explicitly modelled in TIMES

There are several complex intermediate steps between the emission of a pollutant and the damages caused by it. These steps are studied in much detail by stream RS1b and RS1c but are not explicitly modelled in TIMES. Instead, TIMES has a representation of the damage cost induced by one unit of each substance emitted in each country, in the form of a damage cost coefficient/function, for instance the damage cost due to one ton of SO2 emitted in France.

The damage factors or functions for the local and regional pollutants will be derived specifically by source sectors like residential/commercial, industry (where necessary subdivided into iron/steel production etc.), energy (power plants, refineries, gas distribution etc.) and transport (subdivided into urban/non-urban). This specification is needed in order to tackle the variation in the damage costs caused by different source characteristics. For MARKAL/TIMES the regional dimension is national, while for RS1a this dimension might be much more site specific and needs therefore other disaggregation.

1.2 Approach for the substances not explicitly modelled in TIMES

This approach covers two different types of substances, either substances not at all modelled in TIMES or substances modelled in TIMES but for which the step generating the substances is not modelled, e.g. the construction of technologies or the extraction/transport of fuels outside the EU27.

For external costs due to substances not explicitly modelled in TIMES and associated with specific technologies, a cost coefficient per unit of technology will be obtained by combining the LCA and external cost data into a cost coefficient which will then be attached to the relevant TIMES technology (e.g. per kWh, per vehicle-kilometer). For external costs occurring outside Europe (e.g. due to resource extraction) damage factors per activity/import will be provided by RS1b and RS1c.

This approach implicitly assumes that the cost is proportional to activity, a statement that may be inaccurate if the range of variation of emissions is very large. However, for reasonably narrow ranges of emissions, it is expected that the proportionality assumption will hold. The proportionality assumption may be revisited if it becomes evident that it is violated for some pollutants and/or countries. If such a case arises, an iteration of the entire integration process may be envisioned but has to be limited as much as possible.

1.3 List of the substances

The substances considered are:

- Those emitted to air and modelled explicitly in TIMES:

  NOX, SO2, NMVOC, particles (total particles, PM10 and PM2.5), greenhouse gasses (CO2, CH4, N2O, SF6, CxFy)

- Other substances not modelled explicitly in TIMES:

  CO, cadmium, lead, nickel, arsenic, mercury, chromium VI, PAH, benzene, BaP, PCDD/F, formaldehyde, radioactive substances.

Land use can also be taken into account.

2 MARKAL/TIMES and ExternAL Cost

The overall objective of the linkage between RS1b and RS2a is to be able to integrate the external cost in the evaluation of policy scenarios. It is not to compute the overall external cost of the energy system in one scenario. The different issues are discussed hereafter.

2.1 The modelling of external cost in MARKAL/TIMES

Two approaches are modelled:

1. the environmental damage are computed ex-post, without feedback into the optimisation process
2. the environmental damages are part of the objective function and therefore taken into account in the optimisation process.

The damage per pollutant (*env*), for the substances explicitly modelled in MARKAL/TIMES, is computed in a two step procedure:

Step1: from emission to air quality, i.e. the chemical transformation in the atmosphere. This step can be implemented through linear transformation functions based on EMEP data when the changes in emissions are not large compared to the reference. But as the relation between emission and air quality depends on the background emissions and thus on the scenario, the linearity assumption might be incorrect. RS1b is trying to represent the relation between emissions and air quality with a functional form to be implemented in MARKAL/TIMES which therefore have to be convex.

Step2: damage from a change in air quality computed with dose response functions and the monetisation of the damage. RS1b considers that the linearity assumption, i.e. the constancy of the marginal damage, can be adopted for this step. However it should be examined if this assumption can remain valid when reduction as high as 50% of SO2 reduction are imposed.

As the computation are based on dose response functions which give the incremental damage from air pollution, the results should also be interpreted in these terms, i.e. in terms of the change in total damage compared to a reference year (the base year).

The specification, as now set up in TIMES, is rather simple:

$$DAM(env) = EV_{coef}(env) * EM(env)^{EV\beta(env)}$$

where $EV\beta\,(env)$ reflects the relation between the air quality and the level of emissions and $EV_{coef}(env)$ is the marginal cost, as derived from the dose response functions. The non linearity between air quality and emissions is reflected in $EV\beta\,(env)$. This will be further examined when more data become available from the other WPs in RS1b as it seems that the linearity assumption ($EV\beta\,(env)=1$) is difficult to be maintained when there are large variations in the emissions compared to a reference scenario. The model code, as it is written, allows any convex functional form which is then linearised.

2.2 Damage categories in MARKAL/TIMES

The damages considered are principally those linked to air quality, acid deposition and climate change generated from the use of energy and linked to the emission modelled; other categories linked to the use of a fuel or a technology within the energy system can also be considered, e.g. damage linked to the nuclear technology, if RS1b produces such data.

The model can take explicitly into account the damage from the operation and from construction of technologies; i.e. the damages generated from an activity within the energy system (e.g., from the use of heat or electricity), and the damages induced by the construction or the dismantling of technologies as generated from the LCA data. The issue of avoiding double counting the damage is very important and this has already been amply discussed within RS2a and with RS1a. The section on the link with LCA will briefly cover this aspect which is more fully developed in the integration stream WP4.

Ideally, it should be possible to link the region causing the damage and the region suffering the damage through dispersion/transformation matrices, though this is only needed for the ex-post evaluation of the damage per country. Within the optimization, it is sufficient to associate a damage figure in monetary terms to the emissions or to the activity/technology in a country generating the damage (the damage considered can be national, within the EU and/or outside the EU).

The damage generated abroad because of the import of a fuel within the EU can also be taken into account through the association of a damage figure to the import category considered. This does not seem to be a specific problem, with the emissions generated by the imported fuels computed in the other streams.

3 MARKAL/TIMES and LCA

Within the NEEDS project, LCA will analyse a certain number of electricity generation technologies for the periods 2000/2025/2050. LCA data are basic inputs to the calculation of site specific marginal external costs of electricity generation with the models developed in RS1b. They are also important for the modelling in TIMES of the damage linked to the construction of a technology.

Though the quantification of external costs is site dependent, as the environmental damage from a unit emission to the environment depends on meteorological conditions, on the distribution of receptors (e.g. population) or on background concentration of pollutants it was agreed for practical reasons of data handling, in discussion with RS1b not to differentiate LCA data by location in the LCA database, but to provide additional information in the accompanying technology specific reports on where the main life cycle phases are located. The height of release (stack height) has influence on air dispersion and thus on the quantification of impacts. It was decided to allocate emission sources to the sector ‘industry’, ‘residential/commercial’, ‘transportation’, and ‘power generation’, so that average release heights for these sectors can be applied in the quantification of external costs.

The following table summarises the data from LCA to other streams which will be included in their database or technical reports. The report of the integration stream (WP4) covers more fully this issue.

Table 1: Information of LCA data for external cost computation in RS1b and RS2a

Source Characteristic in focus	**Classification by**	**Minimum information required**
Time of release	Life cycle phase	Four phases: power plant construction, fuel supply, operation, end-of-life

Location	Region	Inside Europe: maximum of 4 to 5 regions, Outside Europe: (sub-) continents
Release height over ground	Source type	Sectors ‘transportation’, ‘residential/commercial’, ‘industry’, and ‘power generation’
Number of receptors affected locally	Population density around source (has to be defined)	Urban, non-urban

Emission/energy/material use accounting in the energy system

The key problem in integrating LCA and energy modelling is to avoid double counting of energy and emissions and, if possible, to avoid iterations between the two streams (or reduce them to a minimum) when policies are simulated.

A general approach could be to consider explicitly the emissions and possibly the energy use for the construction of a technology. We can ignore the build-up of infra-structures because it would lead us too far. To account for these energy consumption/emissions MARKAL/TIMES needs the data relating energy consumption and emissions[1] with the construction of a technology per unit of capacity. Injecting this data in MARKAL/TIMES will then induce the correct energy consumption and emissions in the model when there is an investment in a technology. The energy/emissions from investment will be taken into account in the balance equations and thus the energy/emissions from construction and demolition of technologies can be explicitly taken into consideration in the optimization. This approach endogenises the externalities, and makes iterations unnecessary. This can also be done for the materials explicitly modelled in MARKAL/TIMES.

There are however some problems related to this general approach:

1. The energy/material consumption linked to the construction of technologies are already accounted for in the energy consumption of the sectors producing the material and/or constructing the technologies in the reference scenario; this can be partly[2] corrected by taking only the difference in investment compared to the reference,
2. The investment cost of the technologies must be adjusted (energy and material cost are included in the private cost of a technology).
3. In the policy scenarios, the impact on the energy consumption and emissions from construction might also already partly be included through the price elasticity
4. The country investing is not always the country producing the technology (except for the site specific portion of the investment), therefore even knowing the energy/material consumption associated with the production of technology it is

[1] The emissions not directly linked to energy consumption or the total emissions linked to construction but then the energy consumption should not be included.

[2] partly, because the correction does not take into account that the country producing the technology is not the country investing (cf. next remark).

difficult to associate energy/material consumption correctly; moreover it is not foreseen to have trade in materials in MARKAL/TIMES.

Implementing the described approach fully might therefore induce double counting and /or be very time consuming.

The ‘middle way’ approach chosen is to include only the emissions from the construction of new technologies above the average level for existing technologies, and then only if the difference between technologies is significant. The data for these additional parameters will be based on data from RS1a.

The data in the LCA database are far too detailed for their direct use in MARKAL/TIMES but it was agreed with RS1a that they would deliver for each technology considered, the cumulated emissions from the construction of the technology. This includes all the emissions coming from the energy consumed for construction of the technology, the production of the material included in the technology and the transportation of what is needed. The emissions per unit of investment in a technology can then be directly implemented in MARKAL/TIMES. One crucial point is to examine how significant the differences between technologies[3] are when the first results from RS1a are available. A distinction between imported or indigenous investment can be envisaged, though taking into account the overall damage is quite defendable.

One other difficulty is that RS1a covers only electricity producing technologies and it remains to be seen how to treat the other technologies. Introducing it only for part of the technologies penalised these technologies compared to the others.

4 Conclusion

The data exchange between streams will be done through excel sheets. The data will be integrated in the model database. The model software is ready for the integration of the damage when the data become available in the next year. It will be tested with two scenarios, one with the single country model and one with the multi region model.

[3] Only the differences between technologies matter for the improvement of MARKAL/TIMES.

5 Annex: The MARKAL/TIMES modelling framework

MARKAL/TIMES is a generic model tailored by input data to represent the evolution over a period of usually 20 to 50 years of a specific energy-environment system at the world, national, regional, state or province, or community level. As depicted in Figure 1, technology characterizations (e.g., efficiency, availability, emission rates, costs), resource availability (e.g., amount available at a certain price), and environmental constraints (e.g., CAA requirements) are provided as inputs to the model, along with demands for energy services (e.g. commercial lighting, residential air conditioning, and many others). The model then determines the optimal mix of technologies and fuels at each period, the associated emissions, trading activity, and the equilibrium level of demands.

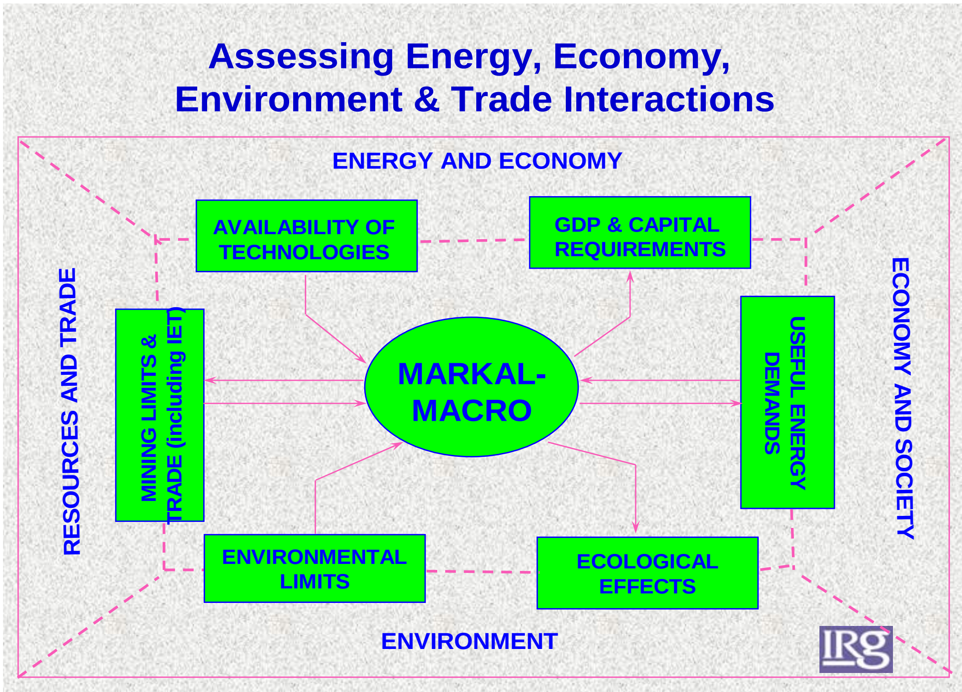

Figure 1: Integrated Model Overview

MARKAL/TIMES supports a partial equilibrium formulation which maximizes the producer and consumer surplus. The *total surplus* of an economy is the sum of the suppliers' and the consumers' surpluses. The term *supplier* designates any economic agent that produces (and sells) one or more commodities (i.e., energy forms, emission permits, and/or energy services). A *consumer* is a buyer of one or more commodities. The RES defines the suppliers and consumers for each commodity. By maximizing surpluses the model is free to adjust the demand levels in response to price, while the total cost of the energy system is minimized. The system is at equilibrium when the amount supplied at a given price matches the willingness to pay for said commodity, as shown in figure 2.

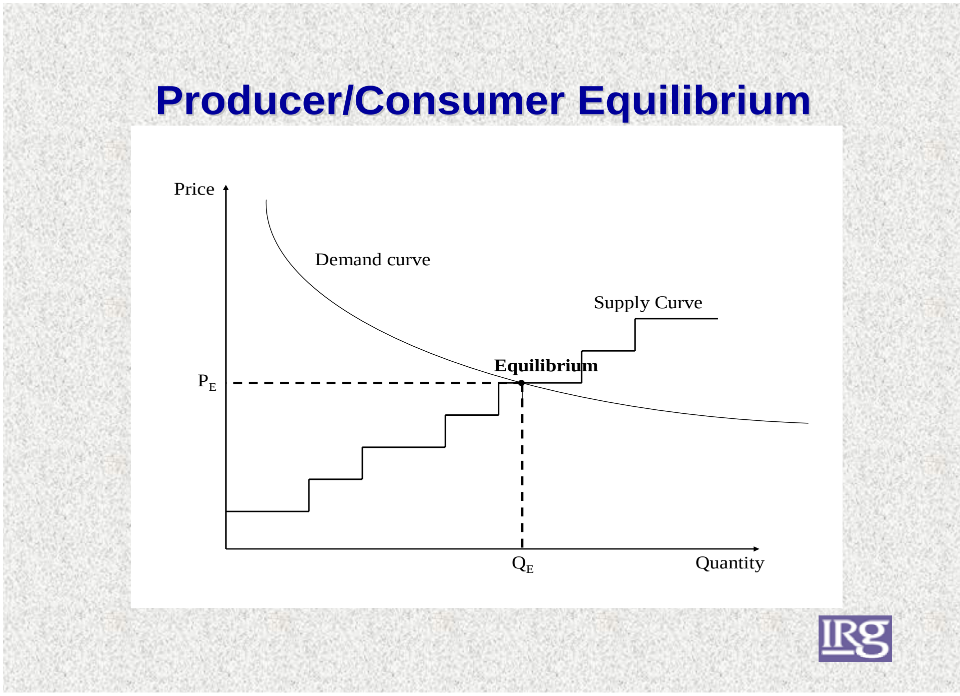

Figure 2: Basic Producer/Consumer Equilibrium

The energy (and materials) system is represented as a network, depicting all possible flows of energy from resource extraction, through energy transformation and end-use devices, to demand for useful energy services.

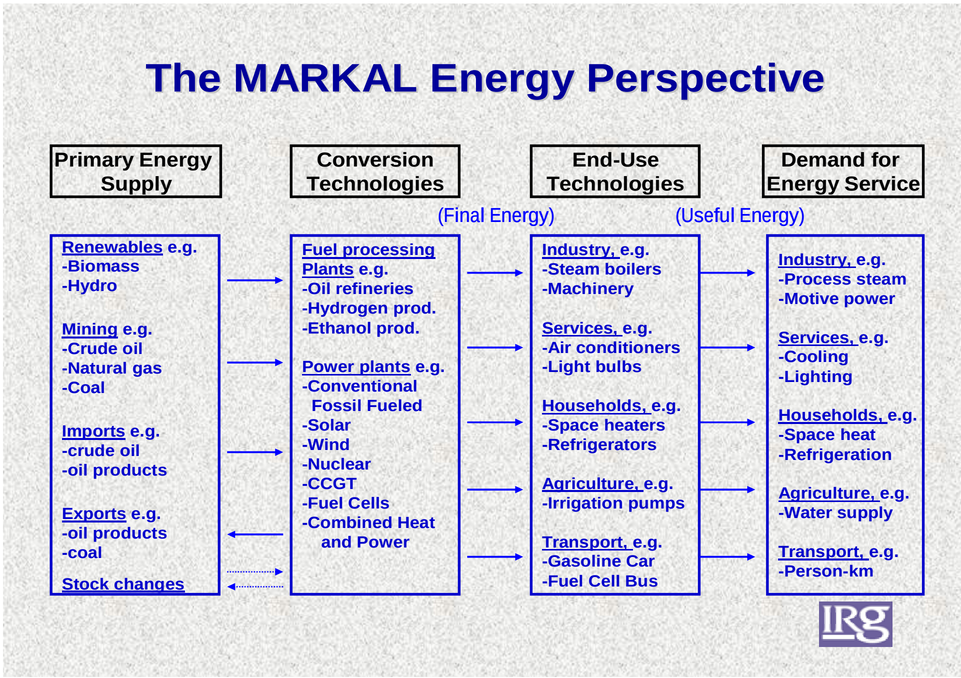

Figure 3: Basic Organization of MARKAL/TIMES Energy/Material Components

Each element in the network is characterized by a set of technologies described by means of technical coefficients (e.g., capacity, efficiency), environmental emission coefficients (e.g., CO_2, SOx, NOx), and economic coefficients (e.g., capital costs, date of commercialization). Many such energy networks or Reference Energy Systems (RES) are feasible for each time period. MARKAL/TIMES finds the “best” RES for each time period by selecting the set of technologies and fuels that minimizes total system cost over the entire planning horizon.

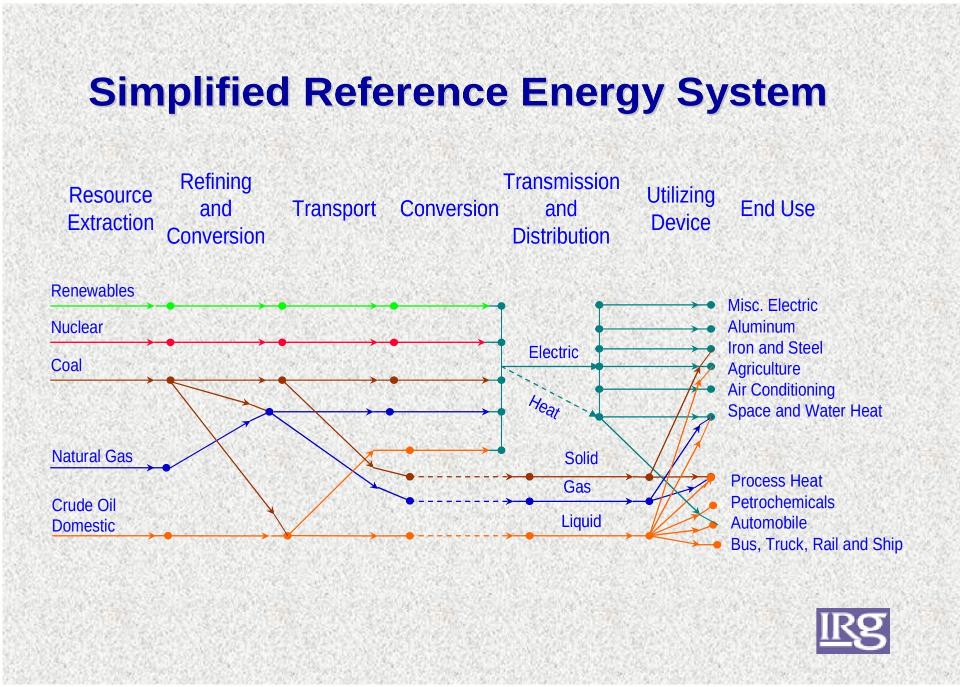

Figure 4: Reference Energy System Diagram