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NATURALHY

“Preparing for the hydrogen economy by using the existing natural gas system as a catalyst”

Integrated Project

6.1.ii Call 1 Sustainable Energy Systems

Supplementary to Deliverable

Work Package No.1

Deliverable No D5

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"Guide to the Standard Results Spreadsheet"

Prepared by

University of Loughborough

1. INTRODUCTION

The main aim of Work Package 1 of the NATURALHY Project is the preparation and comparison of life cycle and socio-economic assessments of the energy and related technologies involved in the following Scenarios:

- the **Baseline Scenario** which reflects the current energy system of natural gas production, transmission, distribution and use, electricity generation, transmission and distribution, and oil production, processing, distribution and use in road vehicles,

- the **Intermediate Scenario** which, as a transition to the "full hydrogen economy", is based on the production, transmission, distribution and use of natural gas/hydrogen mixtures, and

- the **Final Scenario** which, as the basis of the "full hydrogen economy", represents the production, transmission, distribution and use of hydrogen.

These Scenarios are intended to be relevant to circumstances the **European Union** and, possibly, individual Member States, at the present time (Baseline Scenario = **2000**), during the transition to the "full hydrogen economy" (Intermediate Scenario = **2015**) and for the "full hydrogen economy" (Final Scenario = **2030**). The results covered by the life cycle and socio-economic assessments will consist of the following **natural resource inputs**, **environmental outputs**, **employment implications** and **economic costs**:

- primary energy inputs (consumption of depletable energy resources such as fossil and nuclear fuels),

- carbon dioxide (CO_2) emissions,

- methane (CH_4) emissions,

- nitrous oxide (N_2O) emissions,

- hydrogen (H_2) emissions,

- sulphur dioxide (SO_2) emissions,

- oxides of nitrogen (NO_x) emissions,

- particulate (PM10) emissions,

- ionising radiation (Curies) released into the environment,

- direct jobs (person-years),

- indirect jobs (person-years), and

- internal costs (Euros in 2000) excluding taxes, subsidies and other fiscal elements.

The standard results format for recording, calculating, presenting comparing the results of the life cycle and socio-economic assessment of relevant energy and

related technologies is an essential part of this work. The format is based on **EXCEL work books** because:

- it is a well-known, readily-accessible, convenient and relatively user-friendly software package,

- it provides a flexible and systematic means of producing results on a regular and repetitive basis,

- it offers a suitable means of representing each technology as a collection of separate process stages which can be copied and re-assembled to represent other related technologies, and

- it enables the necessary degree of transparency to be achieved to give users and their audiences confidence in the results.

In essence, it is intended that each technology addressed in NATURALHY Work Package 1 will be represented by a single **standard workbook** composed of a series of linked worksheets. The main features of these worksheets are described below. A fundamental aspect of each spreadsheet is that it will incorporate **key parameters** which have the strongest influence on the results derived for the relevant technology. By careful selection of these key parameters and preparation of appropriate relationships within the worksheets, it will be possible to produce results which represent expected circumstances in the Baseline, Intermediate and Final Scenarios.

The basic output of these workbooks are specific results, or **point values**, which reflect specific circumstances for each technology at a given point in time. However, ideally, it would be expected that the spreadsheets would be capable of deriving results which reflect possible important variations over time. Such variations arise due to two major considerations. First, natural resource inputs, environmental outputs and their impacts, as well as employment and costs arise at different periods of time. Second, actual or expected future resource conditions can have a significant effect on results which mean that energy technologies cannot be represented simply by point values. These considerations place important requirements on the structure of the standard spreadsheets. In particular, they must be capable of accommodating **time profiles** for natural resource inputs, environmental outputs, employment and costs at different periods of time for the energy technologies that they represent. Additionally, they must be able to produce **resource curves** which demonstrate how natural resource inputs, environmental outputs, employment implications and economic costs vary with assumed resource conditions. The incorporation of detailed time profiles could result in unnecessarily complicated worksheets. Consequently, simplifying assumptions need to be introduced to ensure that the worksheets are manageable. Less challenging requirements arise for producing the results needed to derive resource curves, provided that key parameters are properly selected and incorporated.

2. WORKBOOK STRUCTURE

The proposed structure of the standard workbook consists of the following major components:

- **flow chart worksheets** which present, in diagram form, the main process chain of the energy or related technology under consideration with the key parameters

for each stage in this process chain.

- **subsidiary data worksheets** which list other parameters that need to be specified for the energy or related technology under consideration,

- a **summary worksheet** which assembles, presents and illustrates all final results for the complete energy or related technology,

- a series of **process stage worksheets** which record basic data, notes, calculations and subsequent results for each individual stage in the process chain, and

- a **reference list** which provides details of all the sources that provide the data used in the previous worksheets.

2.1 BASIC SPECIFICATION

To assist understanding of information presented in any given workbook and to avoid subsequent confusion, each worksheet includes the basic specification of the energy or related technology in the top left hand corner. This specification consists of the following information:

- the **description of the functional unit** which is the principal output(s) of the energy or related technology under consideration,

- the **final unit of measurement** in which the principal output(s) is(are) expressed,

- the **relevant location** where the principal output(s) is(are) provided, and

- the **relevant period** when the principal output(s) is (are) provided.

2.2 FLOW CHART WORKSHEETS

The flow chart illustrates, by means of a suitable diagram in the worksheet, the main process stages of the energy or related technology under consideration. Process stages are linked together to form the main process chain that begins with the main natural resource used by the process and ends, ultimately, with the functional unit (energy or related product) provided by the technology in question. Any by-products and waste products generated by the energy or related technology are also shown in the flow chart at the relevant points where they occur. Each process stage in the flow chart is specified by means of a suitable simple name and relates to a subsequent process stage worksheet (see below). Additionally, each process stage includes **input/output data** which establishes the amounts of main process product exchanged between the previous and subsequent process stages. Furthermore, relevant **key parameters**, which are associated with the assumed activities within a process stage, are recorded and facilities for changing their default values are provided. Selected values for key parameters are used in calculating subsequent results; in particular, the input/output data for each process stage and, amounts of by-products and waste products illustrated in the flow chart and the results derived in the process stage worksheets.

The standard spreadsheet contains two versions of the flow chart worksheet:

- the **unit flow chart worksheet** provides a version of the flow chart which is normalised in terms of a single unit of principal output(s) from the energy or related technology under consideration, and

- the **life flow chart worksheet** provides a version of the flow chart which reflects the whole life cycle of the complete energy or related technology under consideration.

The unit flow chart worksheet is the main part of the spreadsheet of specifying the values of the key parameters. Once these have been established, these parameters and subsequent input/output data are translated into whole life cycle values which are recorded in the life flow chart worksheet where additional parameters may be specified.

2.2.1 Subsidiary Data Worksheets

The subsidiary data worksheets provide facilities for entering values of data for the energy or related technology which were not directly relevant to the flow chart worksheets and, hence, could not be specified there. There are three major types of subsidiary data:

- the **allocation data** which are used to partition natural resource inputs, environmental outputs, employment implications and economic costs between the main product and any co- or by-products produced by the energy or related technology,

- the **global warming potentials** which are used to convert greenhouse gas emissions into equivalent units of carbon dioxide emissions, and

- the **time profile** which summarises the start and end years of the main phases in the life cycle of the energy or related technology.

2.2.2 Summary Worksheet

The detailed results summary worksheet brings together all the results derived in the individual process stage worksheets and converts them into two main forms of final results:

- **per unit output results** which indicate the natural resource inputs, environmental outputs, employment implications and economic costs per unit of the principal product(s) of the entire process chain, and

- **time profile results** which illustrate the annual natural resource inputs, environmental outputs, employment implications and economic costs over the complete life cycle of the energy or related technology.

These per unit output results are obtained by combining the **level 3 results** (highest level of detail) of the process stage worksheets (see below) with the appropriate information contained in the unit flow chart worksheet. Results are organised in terms of successive process stages. Since the full details of calculations are not presented in the detailed results summary worksheet, the values of natural resource inputs, environmental outputs, employment implications and economic costs shown

are referred to as **level 2 results** (intermediate level of detail). Total average values and ranges of natural resource inputs, environmental outputs, employment implications and economic costs are provided by summation and the "propagation of errors" routine, respectively.

Part of the summary worksheet contains the most aggregated form of results, referred to as **level 1 results** (lowest level of detail). Average values and ranges for natural resource inputs, environmental outputs, employment implications and economic costs are normalised in terms a single unit of the principal product(s) of the energy or related technology under consideration.

The time profile summary shows the variation of results over the whole life cycle of the energy or related technology under consideration. For simplicity, it is necessary to assume that natural resource inputs, environmental outputs, employment implications and economic costs for each phase of the life cycle are evenly spread over that particular phase. Although it is recognised that variations can occur within phases, such detailed simulation introduces unnecessary complications and implies a degree of sophistication which is not needed in the standard spreadsheet workbooks. The variation of total values of results are recorded both in numbers as well as charts.

Specification of the phase data assists the production of time profile results. This is important because both the timing as well as the magnitude of these considerations must be simulated to determine their consequences properly. For simplicity, the following four distinct phases in the whole life cycle of an energy or related technology are accommodated:

- the **preparation phase** during which the main facilities for the provision of the principal product(s) of the energy or related technology under consideration are established,

- the **operation phase** during which all activities involved directly in the provision of the principal product(s) of the energy or related technology under consideration take place,

- the **decommissioning phase** during which the main facilities and processes required for the provision of the principal product(s) of the energy or related technology under consideration are dismantled, and

- the **aftermath phase** during which activities associated with the treatment of significant long-term wastes from the energy or related technology under consideration are undertaken.

The preparation phase includes activities such as the construction of plants, the installation of transmission and distribution networks, the establishment of long-term energy crops, and the manufacture of machinery, equipment, road vehicles, etc. The operation phase incorporates maintenance and repair activities as well as those directly associated with operation. The decommissioning phase covers on major "end-of-life" period when initial removal activities occur, such as the demolition of plants, the dismantling of transmission and distribution networks, and the scraping of machinery, equipment, road vehicles, etc. The aftermath phase relates specifically to any major activities associated with the long-term waste disposal, such as nuclear waste management.

2.2.3 Process Stage Worksheets

The calculation of the basic results, in the form of natural resource inputs, environmental outputs, employment implications and economic costs for an energy or related technology, are performed in the process stage worksheets. There is a separate worksheet for each process stage in the flow chart (see above). The process stage worksheets contain the most detailed information used in the standard spreadsheet workbook. Hence, the values of natural resource inputs, environmental outputs, employment implications and economic costs (level 3 results; see above) recorded in these worksheets are also the most detailed in the standard spreadsheet workbook. The information used and the calculations performed in the process stage worksheets are organised systematically in a standard layout which consists of the following main features:

- each **contribution** to a given process stage, such as consumption of fuel, electricity, materials, chemicals, etc., use of machinery, equipment, etc., working time of personnel, etc., is specified by a short name,

- the **unit** used for recording each contribution to the process stage is specified,

- the **average value** and **range (+/-)** of each contribution to the principal product(s) of the process stage is recorded,

- the **multiplier** for each contribution, in appropriate **units** and specified in terms of its **average value** and **range (+/-)**, is recorded, separately, for natural resource inputs (primary energy), environmental outputs (CO_2, CH_4, N_2O, H_2, SO_2, NO_x, PM10 and ionising radiation), employment implications (direct and indirect jobs) and economic costs (internal costs),

- appropriate **notes** are included to summarise the main assumptions and references (see below) used in providing the average values and ranges of contributions and multipliers, and

- separate specific **results** which are subsequently calculated for each contribution to the principal product(s) of the process stage presented, in appropriate **units** and specified in terms of its **average value** and **range (+/-)**, for natural resource inputs (primary energy), environmental outputs (CO_2, CH_4, N_2O, H_2, SO_2, NO_x, PM10 and ionising radiation), employment implications (direct and indirect jobs) and economic costs (internal costs).

Total results for the natural resource inputs (primary energy), environmental outputs (CO_2, CH_4, N_2O, H_2, SO_2, NO_x, PM10 and ionising radiation), employment implications (direct and indirect jobs) and economic costs (internal costs) are derived for all contributions to the complete process stage. Average values are simply summed whilst ranges are determined using a simple "propagation of errors" routine which is based on the assumption that all frequency distributions for the data are symmetrical. This implies that the quotes ranges are, in fact, standard deviations.

2.2.4 References Worksheet

This worksheet simply records the original **references** quoted in the notes provided in previous worksheets. The references are listed by means of number followed by the title, author(s), publication details (report code, if any, and source, journal details, conference details, etc.), location and year. References obtained via the internet

should include the full website address and the date of access. Information obtained by "private communication" should record the name and affiliation of the original source as well as the date of the communication.

3. DATA ENTRY

To assist the preparation and subsequent use of standard spreadsheet workbooks, certain features have been incorporated into individual worksheets. In particular, colour coding has been added to certain cells to guide data entry. Data can be entered into cells with a green background provided that values are in the units specified by the adjacent cells and are of a realistic magnitude for the process stage and functional unit under consideration. Cells with a red background contain formulae and report values derived from parameters specified elsewhere. It is recommended that these cells are not overwritten with the user's own values since subsequent results may not be realistic or consistent with such pre-specified parameters. Overwriting should only be contemplated with extreme caution and the validity of subsequent results is entirely the responsibility of the user. Some of the cells have an orange background which indicates data that have been transferred from other worksheets. Such colour coding can be found in any of the worksheets apart from the summary worksheet, where extensive data occurs. It is designed to reduce problems in copying worksheets for the formulation of new spreadsheet workbooks (see below).

4. COPYING WORKBOOKS

Wherever possible, the transfer of data from other worksheets to the process stage worksheets has been avoided. This has been undertaken to enhance the modular nature of such worksheets and to prevent any unintentional linking of formulae in cells when workbooks are copied to form new workbooks. Where the use of transferred data cannot be avoided in process stage worksheets, such data are collected together in one group of cells, near the top left hand corner of a worksheet, and given an orange background. This indicates that the user engaged in copying and preparing a new workbook will have to remove the links and replace entries with appropriately transferred data. It should be noted that the summary worksheet and, to a lesser extent, the life flow chart worksheet, contain transferred data in cells which are not marked accordingly. In the case of the summary worksheet, in particular, this approach is adopted because of the considerable amount of transferred data which must be used in the preparation of final results. Extreme case must be taken in copying and modifying the summary worksheet, especially as the formulae in many cells may have to be changed substantially to reflect the particular energy or related technology which is being represented. However, it is important to replicate the layout and presentation of the summary worksheet since this provides the standard format for the final results.