IEA-ETSAP Energy Technology Data Source (ETechDS)

Normalisation and Updating of Technical and Economic Data of Supply and End-Use Energy Technologies in the ETSAP Energy Technology Data Source

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1. Context, Objectives and Target Users

The aim of this work is to build methodology and a simple tool to update and homogenize (normalise) on a common basis the technical and economic data that characterise supply and end-use energy technologies[1] in the ETSAP Energy Technology Data Source (ETechDS).

The ETSAP ETechDS has been developed to provide energy analysts (e.g. users of the ETSAP-TIMES models), investors and policymakers with consistent data on all-sectors energy technologies.

ETechDS has been conceived as a series of Technology Briefs that provide basic information on process, status, performance, costs, market potential and projections for key energy technologies. Some 80 briefs on major demand/supply technology *clusters* have been prepared by selected authors from the IEA-ETSAP community, and posted on the ETSAP web (http://www.iea-etsap.org/Energy_Technologies/Energy_Technology.asp.)

Technical and economic data contained in the briefs have been derived from a number of different sources. They need periodic updates to track technology advances and market changes. They also need a sort of *homogenisation* process to ensure that figures on e.g. energy efficiency, capacity factor, investment and production costs are based on consistent assumptions.

The homogenisation process implies that technical and economic data are assessed using common methodology and framework, not actually the same figures. For example, when comparing electricity generation costs from different technology options we need to use similar assumptions for project financing, but we can use different interest rates on debt to reflect the investment risk associated with each technology.

Data normalisation, consistency and transparency are important requirements in energy scenarios and projections analysis using TIMES models where a huge number of data on energy technology performance and costs are needed to describe the energy system of a country or a region, and explore its evolution/optimisation over time. Normalisation and consistency are also key for

[1] i.e. technologies for energy production and conversion and end-use technologies for transportation and residential services, and industrial production

policymakers to compare investment in diverse energy sectors and plan energy policies, as well as for investors to plan their business strategies.

The normalisation exercise also aims to provide TIMES users with a simple tool to facilitate the input of the huge number of technology data they need in their energy system models.

The work has been planned in two phases: the first phase aims to establish and test the normalization method, with applications to a few energy technology clusters; in the second phase, the methodology is applied to all energy technology clusters and sectors. This report deals with the first phase.

2. The Basic Approach

The common feature of all supply and end-use energy technologies is that they use an energy input (primary energy sources, fossil fuels, electricity, heat) to produce the output, e.g. an energy carrier (electricity, fuels), a transportation service (km, p-km, t-km), a building service (heating, lighting, ...) or an industrial product (steel, cars, goods, ...). All energy technologies are therefore characterised by technical-economic performance such as energy efficiency and intensity, lifetime, capacity factor (or use factor), GHG emissions (if any), investment cost, O&M costs, energy input cost (if any), and the final product/service cost (e.g. \$/kWhe, \$/km, \$/kWht, \$/kg).

In this work, the well-known method to assess the electricity generation cost in the power sector (i.e. the *levelized electricity cost,* LEC) is used - with appropriate amendments - to assess the final production cost of all-sectors energy technologies. The key point is to make clear and transparent all technical-economic and financial data and assumptions that characterise the energy technologies and determine their performance and costs, and allow the users of the normalisation model to change all parameters, according to their own needs and market conditions.

The levelized electricity cost (LEC) method is widely used to assess and compare the electricity cost in power generation (1 to 6), but basic assumptions (e.g. project financing structure, debt to equity ratio, loan granting scheme, interest and discount rates, interest during construction, debt return time, etc.) are often unclear or differ significantly from real market conditions. For example, assuming the same interest rate on debt and the same discount rates for all technologies, or a debt return time equal to the technical lifetime may reflect incorrectly the market reality. Similarly, the lack of information on basic assumptions regarding the loan granting and spending curve and the interest during construction can make unclear or jeopardise the results of analysis and comparisons. For reliable, market-relevant assessments, transparency is also needed regarding the GHG emission costs in emission trading markets, policy incentives and subsidies, and selected criteria for final comparisons (e.g. busbar/factory production costs, un/taxed prices, profits, grid parity, distribution/delivery costs, etc.)

3. The Levelized Cost of Electricity

The busbar *levelized electricity cost* (LEC) is usually referred to as the ratio of total discounted[2] lifetime costs (**$\sum_i Ci$**) incurred by the investor to produce and supply electricity to the grid (busbar electricity) to the total amount of electricity generated by the power plant during its technical lifetime (**$\sum_i Ei$**).

$$\mathbf{LEC = \sum_i Ci / \sum_i Ei}$$

In other words, LEC is the minimum electricity price that compensates the investor for all discounted costs incurred for plant construction and operation over the entire plant lifecycle, with no added profit. Therefore, the LEC reflects only the cost of electricity production. It does not reflect electricity market (retail) prices, neither supply-demand dynamics nor investor's profit.

The costs incurred by the investor include:

- capital and for power plant construction;
- financial costs to fund the construction;
- plant operation and maintenance costs;
- fuel or energy costs, if any;
- waste management costs, if any;
- carbon and other GHG emissions-related costs, if any;
- end-of-life decommissioning cost;
- other accountable external costs, if any.

Capital Costs - Capital costs include *overnight construction costs* (with no financial cost), i.e. *direct construction costs* such as vendor prices for components and systems, costs for land and site preparations, assembly and construction infrastructure, and *indirect construction costs* such as design and engineering costs, insurance costs, etc.. Capital costs also include *pre-construction costs* such as authorization and licensing that may have a significant impact for large power plants and depend on complexity and duration of these processes (pre-construction costs may be reduced through standardisation of technical design and licensing procedures).

Financial Costs - Financial costs are the costs incurred to make available the capitals that are needed for construction. They depend on the project financing approach (share of debt, equity and bonds), the interest and discount rates, the debt-return time, the loan granting scheme, the investment risk associated to the proposed project, the construction time. For example, a loan granting scheme tailored on the spending curve during the construction phase can lead to a significant saving in terms of financial costs, as well as the interest during construction (IDC) determines a significant increase of capital and financial costs for capital-intensive technologies and for long or delayed construction time. The total capital and financial costs are often referred to as the **investment cost.**

[2] Discounted costs (expenses) are costs occurring at different points in time (**ti)** that are accounted for at a certain, reference time (**tr)** by multiplying their value by a discounting factor of $\mathbf{(1+dr)^{(tr-ti)}}$, where **dr** is the discount rate. If **tr** is the present time, then **past** costs/incomes (**ti<tr)** are valorised to the present economic value, while **future** costs/incomes (**ti>tr)** are discounted to the present value. The right numerical value to be assumed for the discount rate is often matter for discussion for financial analysts.

Operation and Maintenance Costs - O&M costs include labour costs, consumables and spares costs as well as inspection, safeguard, insurance and security costs incurred during plant operation. They are usually divided into variable O&M costs, which occur during plant operation (e.g. consumables, spare parts), and fixed O&M costs, which occur even if the power plant does not work (e.g. personnel cost). They often reflect local conditions (e.g. labour cost).

Fuel or Energy Input Costs - These costs apply to fossil fuels, nuclear- and biomass-based power plants. They include fuel and energy market prices including production (e.g. mining, extraction, transformation), as well as transportation and delivery to the power plant.

Waste Management Costs - Waste costs apply to power plants with significant production of waste (e.g. nuclear power) and - to a diverse extent - to coal and biomass power where waste is often considered as a low-value by-product.

Decommissioning Costs - These costs relate to the end-of-life decommissioning of the plant (particularly important for nuclear power). However, they usually occur decades after construction and if all costs are discounted (as usual) at the first year of operation then the impact of decommissioning costs is modest even for nuclear power. The appropriate approach to account for decommissioning costs is a matter for discussion.

Carbon and GHG Emissions Costs - Emissions costs apply basically to fossil fuel-fired power plants and account for costs associated with the GHG emissions if a carbon tax or an emission trading system is in place. For renewable power plants the emissions costs can be negative (emissions avoided) if a credit is granted for avoided GHG emissions.

Other External Costs - These costs include all accountable external costs that can be internalised and quantified based on a shared accounting method, (e.g. carbon emissions and carbon sequestration costs for fossil fuel-fired power, waste management costs for nuclear power, energy storage or back-up power cost for renewable power). In general, the LEC method apply to all power technologies and accounts for all accountable cost elements. It cannot account for cost items that are highly uncertain such as the costs associated to the social impact of a technology option, which quantification is still matter of discussion.

4. Applying the LEC Method to All-sectors Energy Technologies

To apply the LEC method to all-sectors energy technologies (either supply- and demand-side), the single energy technology is regarded (Figure 1) as a process/device where one or more energy inputs (renewable or nuclear energy, fossil fuels, electricity, heat) produce an output such as electricity, heat, fossil or renewable fuels, industrial goods, transport or residential (building) services, plus by-products, if any. The process and the associated device/plant are characterised by technical and economic parameters (e.g. energy efficiency, capacity factor, lifetime, emissions factor, size, costs). In addition, energy technologies may use key (special or strategic) materials, water and land, and produce GHG emissions, air pollutants, waste, etc. Obviously, the LEC is regarded here as the **levelized production cost (LPC)**.

It should be noted that the physical units of technical-economic parameters that are used to characterise the technology performance may differ from technology to technology and from sector to sector. The physical meaning of some technical parameters may also differ from sector to sector. For instance, while the capacity factor in the power sector is defined as the ratio of actual annual production to the nominal annual production assuming the plant to work for 8760 h/year at nominal capacity, in the transport sector the capacity factor may be simply defined as the number of km per year (mileage). An overview of meanings and units that have been used to define key technical-economic parameters and extend the LEC method to all-sector energy technologies is given in Table 1.

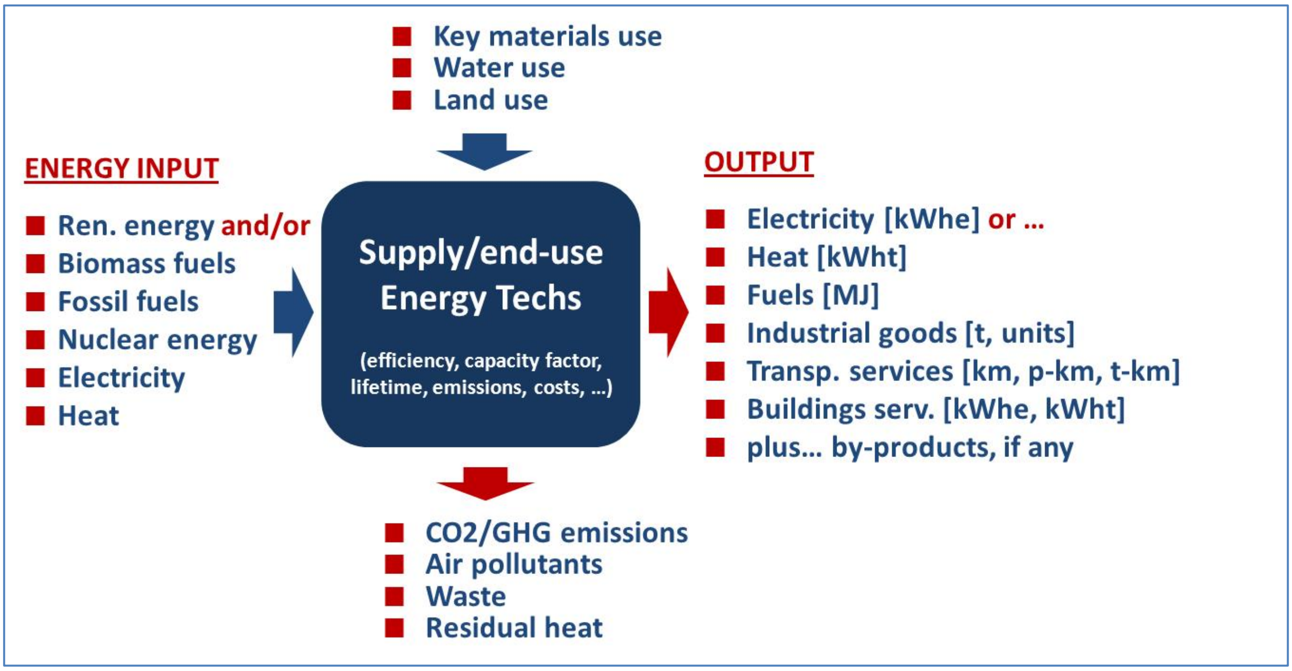

Figure 1 - Energy Technology Characterisation

Key Parameters	Energy Sectors			
	Energy Conv.	Transport	Industry	Residential
Net energy efficiency (output/unit of energy in)	kWh/MJ in, MJout /MJ in	km/MJ, p/t-km/MJ	t/MJ, unit/MJ, goods/MJ	kWhe/MJ, kWht/MJ
Gross energy intensity (energy in/unit of output)	1/energy efficiency			
Emission coeff. of energy input	gCO2/MJ in, if any			
Emission coeff. of tech process	gCO2/unit of output (kWh, km, t, units, ...), if any			
Plant/device size	kW, GJ/y	kW	t/y, unit/y, ...	kW, unit/y
Lifetime	years			
Capacity factor	hours/y	km/y	t/y, unit/y, ...	energy use/y
Annual production	kWh/y, GJ/y	km/y	t/y, unit/y, ...	energy use/y
Overnight capital cost	$/kW, $/GJ/y	$/kW	$/t/y, $/unit/y	$/unit
O&M cost	$/kWh, $/MJ	$/km	$/t, $/unit	$/unit of en. use
Fuel, emissions & other costs	$/kWh, $/MJ	$/km	$/t, $/unit	$/unit of en. use
Levelized production cost	$/kWh, $/MJ	$/km	$/t, $/unit	$/unit of en. use

Table 1 – Overview of key technical-economic parameters for all-sector energy technologies

From the economic and financial point of view, the lifecycle cash-flow that has been used to extend the LEC method to all-sectors energy technologies (devices/plants) is presented in Figure 2 where:

- **CT** = Construction time [y]
- **DRT** = Debt Return Time [y]
- **LT** = Technical lifetime or operation time [y]
- **DCT** = Decommissioning time [y]

Figure 2 summarises the following basic economic and financial assumptions that are used in the normalisation model and have a significant impact on the final production costs:

- The plant/device construction or purchasing is funded by a combination of equity and loans, with different remuneration and interest rates;
- In the case of a long construction time (CT > 1 year) and high capital costs, the loan is granted according to a linear spending curve over the construction time (this means the total loan is granted over CT years, assuming CT equal loans, one per each year of construction);
- Each loan includes the capitalisation of the interest during construction (IDC), assuming the investor has no financial capacity to refund capital and interest until the plant enters the production phase;
- The debt is refunded at a constant annual rates each one including varying capital and interest quotas;

- The debt return time DRT, as well as the interest rate on debt and the equity remuneration rate are variables which depend on market conditions and regulations;
- The equity remuneration rate is estimated at the beginning of the project. Equity remuneration starts at the 1st year of operation (CT+1) and lasts for LT years;
- Annual spending to refund debts and remunerate equity are discounted at the 1st year of operation (CT+1) using a discount rate equal to the interest rate and the remuneration rate, respectively;
- All other costs and incomes incurred during construction, operation and decommissioning are discounted at the 1st year of operation (CT+1) using the weighted average capital cost (WACC) which is calculated based on the interest rate and the equity remuneration rate.

In the normalisation model, all basic assumptions and variables can be changed by the users to reflect specific or local technical and market conditions. The model allows the user to consider a declining annual production over time to account for ageing (if applicable).

The need for considering a flexible structure of project financing (debt to equity ratio), the interest during construction and a linear granting of debt stems from the very significant impact that these items may have on the investment costs and the final production costs of capital-intensive technologies/devices with long or delayed construction time.

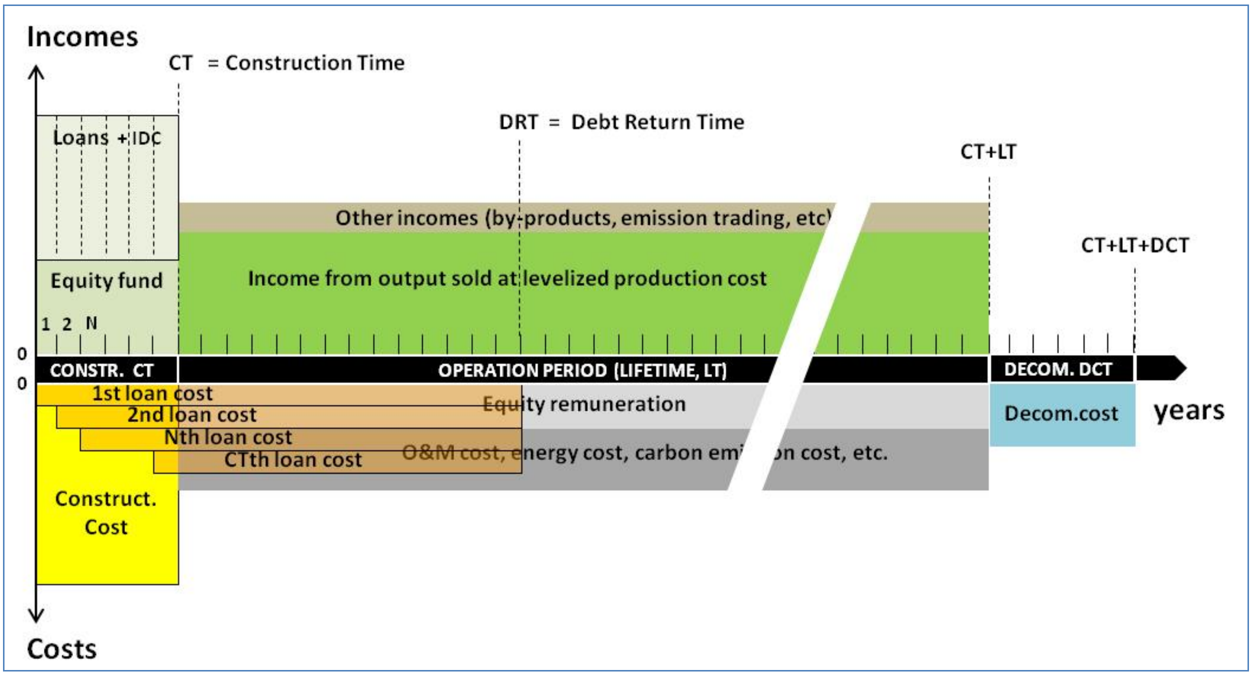

Figure 2 - General lifecycle cash-flow and balance of energy technologies

In Figure 2, the total lifecycle costs incurred by the investor during the technology lifecycle include discounted costs for: investment (capital plus financial cost); operation and maintenance; energy input; waste management; carbon emissions; production taxes, decommissioning costs, and other accountable costs, if any. The total lifecycle incomes include discounted revenues from: main output sold at the LPC; possible by-products; avoided carbon emissions (if any, and if an emission trading market is in place); policy incentives and subsidies, and other accountable incomes, if any.

As usual, fixed O&M costs - which depend on plant/device size and occur even if the plant/devices does not work and - are given as a percentage (%) of the overnight capital cost per year, while variable O&M costs - which depend on production - are given per unit of output.

The energy input cost is actually one of the most important variable O&M costs. However, it is accounted for separately from the O&M costs because of its importance in the energy analysis. In the normalisation model, the energy input costs (fossil fuels, electricity, heat and other energy inputs[3]) can be varied over time based on forecasting over the plant lifetime to reflect expected market fluctuations.

Other variable O&M costs such as waste management cost, carbon emissions cost in emission trading systems, production tax, carbon tax (if any), are also accounted for separately per unit of output. It should be noted that carbon emission costs are accounted for in the model regardless whether the emission permits are auctioned or allocated for free, and the total allowed emissions are exceeded or not. The specific cost of carbon emissions can also be varied over time according to carbon market fluctuations. The model accounts for carbon emissions from energy input (fossil fuels combustion) as well as for emissions from the production process, if any, and from plant/device construction.

Carbon capture systems (CCS) may be considered in the model an ancillary system of the basic plant/device, with impact on the overnight capital costs, energy efficiency and final CO2 emissions rates. If a CCS is installed, a credit is considered for *avoided* carbon emissions, which differ in general from the *captured* emissions because the energy efficiency of the device may decrease as a consequence of the CCS. The economic value of avoided carbon emissions can also be varied over time based on carbon market fluctuations.

The model can also consider energy storage systems in association with "basic" energy technologies (e.g. electrochemical accumulators with PV plants, water-based heat storage with building heating systems) taking into account their incremental capital and operation costs, impact on efficiency and associated benefits (increased capacity factor and production).

Decommissioning costs are taken into account per unit of capacity, as a percentage of the overnight capital costs. The decommissioning (the end-of-life dismounting and disposal/recycling of the plant/device) applies to all technologies, but it is particularly important for nuclear power plants.

Revenues from associated by-product production, avoided carbon emissions, and policy-based production incentives such as feed-in tariff are also accounted for in terms of income per unit of production. The by-product is defined as an additional product that comes out from the basic production process with no additional cost and energy input. Additional costs, energy input and emissions that may be needed to finalise the by-product are not accounted for.

[3] "Other energy input" is used in the normalization model to deal with technologies that have more than one fossil fuel input(e.g. industrial processes), and renewable technologies that have renewable energy inputs. This approach allows all-sectors technologies to be analyzed with the same model.

As mentioned in section 3, the *levelized production cost* (LPC) is the levelised, discounted economic value and selling price of the production that compensate the investor for all discounted costs incurred during the technology lifecycle. It is derived from the equation:

$$\mathbf{\sum_i Ci\ (1+dr)^{(tr-ti)} = \sum_i Pi\ {*}PCi\ {*}\ (1+dr)^{(tr-ti)}}$$

where

- Ci = costs incurred in the i^{th} year
- Pi = production in the i^{th} year
- Pi*PCi = incomes obtained in the i^{th} year from production Pi sold at the production cost PCi
- **$(1+dr)^{(tr-ti)}$** discounting factor.

The LPC is then given by the ratio:

$$\mathbf{LPC} = \mathbf{\sum_i Ci\ (1+dr)^{(tr-ti)}\ /\ \sum_i Pi\ {*}(1+dr)^{(tr-ti)}}$$

A discussion exists among experts (1) on whether discounting a physical quantity, i.e. the production **$\sum_i$Pi,** is correct or not. Actually, it seems that the discounted quantity is not a physical quantity i.e. the production Pi, but its economic value Pi*PCi. However, in the normalization model, the LPC is calculated under the three options:

- discounted costs and incomes (production);
- undiscounted costs and incomes (production); and
- discounted costs and undiscounted incomes (production).

Once the LPC is known, the model calculates the investment return time IRT based on LPC. In the IRT assessment, model users can also consider an expected “levelised” un/taxed market price of the production (including profit) instead of the LPC.

5. Structure of the Normalisation Model

The proposed structure[4] of the normalisation model reflects basically the categories of the ETechDS Briefs where supply and end-use energy technologies are divided into five sectors, i.e.

- Power and heat generation technologies,
- Energy conversion technologies,
- Transportation technologies,
- Industrial technologies and
- Buildings (residential/commercial) technologies.

Each sector includes a number of technology clusters. Each ETechDS Technology Brief characterises the technical and economic performance of a certain number of technology variants within the clusters.

[4] The proposed structure can be changed according to needs expressed by ETSAP members and TIMES analysts. The full functionality of the model with respect to a number of diverse technology clusters will be tested in the second phase of the project where the model will be applied to all technology clusters. Possible model changes may also be implemented in the second phase, based on comments received from users and users’ practice.

At the present stage of conception, the model consists of one .xls file for each sector. Each file is intended to include a number of spreadsheets, one for each technology cluster. For instance, the power generation file includes spreadsheets for natural gas-fired power, nuclear, CSP, PV, wind power, etc.. Each spreadsheet may include one or more key technology variants, e.g. the natural gas-fired power includes gas turbines (GT), combined cycle gas turbines (CCGT), and CCGT with carbon capture system (CCGT+CCS).

Actually, data for non-power, energy conversion technologies such as refineries, coal gasification, biofuels production, etc., can be characterised using the same model (apart from units) used for the power generation sector or for the industrial sector.

Therefore, at the present stage of development - and according to the objective of the first phase of the project - the model includes four .xls files for **power and heat generation**, **transport**, **industry** and **buildings**, with a few example clusters (spreadsheets) in each file, and a few technology variants for each cluster. Once the project is completed, each file is expected to include a number of spreadsheets, one for each technology cluster, each one including key technology variants.

In each spreadsheet, the first five columns include the normalisation model, with model cells and VBA macros in the 5^{th} column (column E). Apart from the units used for input and output data, which differ from cluster to cluster and from sector to sector, the same model is used in all spreadsheets. A very limited number of model variants is needed in some spreadsheets to take into account the peculiarities of some technology clusters. For instance, in the nuclear power technology the usage of nuclear fuel is usually expressed in terms of *nuclear burn-up* (MWd/t of fuel). The other columns in the spreadsheet provide a data repository (in/output data, performance and costs) regarding the technology variants (e.g. GT, CCGT, CCGT+CCS) that are calculated (normalised) using the model.

From each spreadsheet, TIMES-relevant data will be then collected and transferred to a *collector* spreadsheet, in a suitable form for TIMES input. The model is currently undergoing numerical validation and applications to different technology clusters and sectors.

6. Next Step

As planned at the beginning of the “normalisation project”, the next step includes using the model to populate the xls.files with the technology clusters (spreadsheets) and technology variants. A basic source of data for the 2^{nd} phase of the project is ETechDS. In this process, the data contained in the ETechDS Technology Briefs can be updated and normalised, and integrated with data from other authoritative, updated sources. This 2^{nd} phase is expected to be time-consuming, well beyond the initial estimate.

Major References

1. IEA-NEA - Projected Costs of Generating Electricity 2010 (next release 2015)
2. IRENA - Renewable Power Generation Costs 2012
3. IPCC - Ren. Energy Sources & Climate Change Mitigation - Special Report – 5th Assessment Report (AR5), WG III Climate Change 2014
4. US NREL & DOE - Levelized Cost of Energy Calculator (nrel.gov; en.openei.org)
5. US EIA - Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2014; Assessing the Economic Value of New Utility-Scale Gen. Projects
6. FRAUNHOFER (Institute for Solar Energy - Germany) - Levelized Cost of Electricity - Renewable Energy Technologies, 2013

Annex 1 - Essential *How-to-Use* of the : Normalisation Model

Introduction

According to the basic approach of the Normalisation project, in the Normalization model all supply and end-use energy technologies are regarded as processes (Figure A) in which an energy input (primary energy sources, fossil fuels, electricity, heat, etc.) produces an output, e.g. an energy carrier such as electricity and fuels, a transportation service (km, passenger-km, or t-km), a building service (heating, lighting, washing ...), or an industrial product (steel, cars, goods, etc. ...).

All energy technologies are therefore characterised by technical-economic performance such as energy efficiency and intensity, lifetime, capacity factor (or use factor), GHG emissions (if any), investment cost, O&M costs, energy input cost (if any), and the final product/service cost (e.g. $/kWhe, $/km, $/kWht, $/kg).

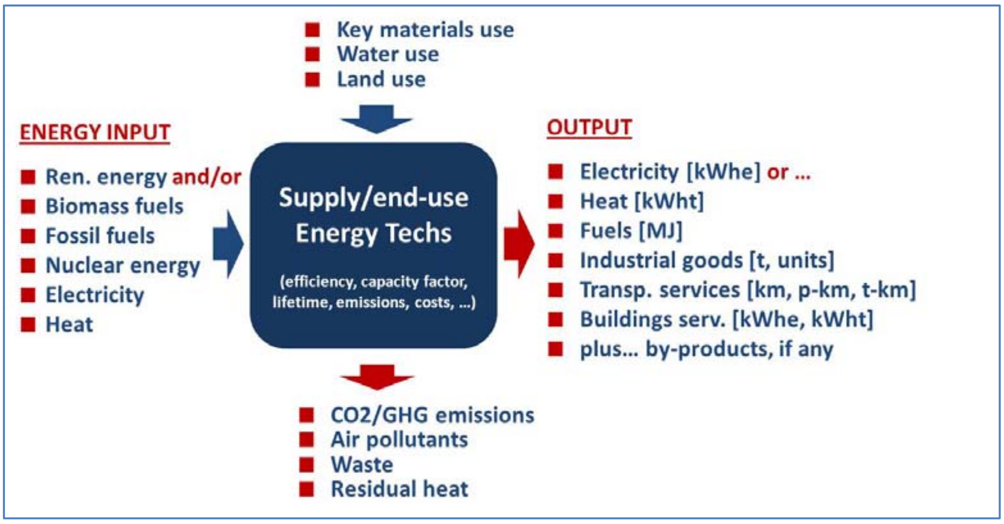

Figure A - Energy Technology Characterisation

As mentioned in Section 5 of this report, at the present state of development, the model consists basically of **four** files.xls:

- POWER.xls for *power and heat generation technologies*
- TRANSPORT.xls for *transportation technologies*
- INDUSTRY.xls for *industrial technologies*
- BUILDINGS.xls for *residential/commercial technologies*.

According to Figure A, the four files include basically the same normalization model apart from the units that are used for input and output data, and minor changes to account for peculiarities of some technologies. For instance, in nuclear power technology the nuclear fuel is characterised in terms of *nuclear burn-up* (MWd/t of fuel) while in technologies using fossil fuels the fuel is characterised by the low/high heating value (L/HHV).

Processes and technologies for energy transformation other than heat and power generation, e.g. primary energy production (coal mining), transformation and conversion (oil refinery, coal gasification, biofuels production, etc.), can be considered as industrial processes with energy as the input and output. Therefore, can be analysed using either the model available in POWER.xls or the model in INDUSTRY.xls.

Each file is intended to include a number of spreadsheets, one for each technology cluster. For instance, the POWER.xls file includes spreadsheets for gas-fired power technology (Gas Power), nuclear power (Nuc Power), photovoltaic power (PV Power), etc.

In each spreadsheet the same model (with proper units) is available to analyse all key technology variants in the cluster, for example, the natural gas-fired power technology includes open-cycle gas turbines (GT), combined cycle gas turbines (CCGT), and CCGT with carbon capture system (CCGT+CCS).

In each spreadsheet (Figure 1), the first five columns include the model area: columns A to D (1 to 4) include input/output variables names, co-relations and units, while the 5th column (column E, yellow) includes the cells with co-relations and cells with VBA macros. Brown cells contain VBA macros. The other columns in the spreadsheet provide a data repository (in/output data) for the technology variants (e.g. GT, CCGT, CCGT+CCS) that have been analysed and normalised using the model.

An auxiliary Excel-VBA programme explores the data repository and select/collect the data that are needed to prepare the technology input for TIMES Models

In each file, a spreadsheet (Annual Tables) provides year-by-year results (performance and costs) for the technology under investigation, over its entire lifecycle including construction time CT, operation time LT, and decommissioning time DCT.

The Normalisation model includes three kinds of data

- Key input data (red colour) are necessary to run the model. If they are not available or their value is inconsistent with the technology the model does not run or provides incorrect results.
- Optional input data (blue colour) are not necessary to run the model. They provide additional information, but the model run even if these data are not available.
- Calculated data (black colour) are output data that are calculated by the model based on co-relations or VBA macros

Users can basically access and changes only red and blue data (cells) while black data (cells) and macro are not accessible to avoid involuntary changes in the model.

The range of some basic input variables may be limited:
- The lifetime (LT) of a technology spans from 0 to 60 years, integer multiples of 5 (LT_{max}=60 y);
- The construction time (CT) and decommissioning time (DCT) of a plant/device spans from 0 to 10 y (integer values), with CT_{max} = DCT_{max} = 10 y;

1st Model Section: Input/Output and Energy Input Breakdown (Figure 1)

In the 1st section of the model (Figure1), the user can provide the (energy) input and the output of the process, and the breakdown of the energy input, with relevant data. The energy input of the process may include: fossil fuels, electricity, heat and *other energy input.* The *other energy input* includes other fossil fuels, a nuclear fuel, or a primary renewable energy input such as solar energy, wind energy, hydro energy, etc. For each specific energy input, key data are the energy intensity of the process (input energy for unit of output), the energy content of the energy source (e.g. LHV for fossil fuels), and the energy-related carbon emissions (from combustion).

In the case of electricity and heat input, the model offers the opportunity to account for energy and carbon emissions that are associated with the production of used electricity and heat, based on world (or national) average values of generation efficiency and carbon emission coefficient.

For renewable power technologies, this approach allows the user to give as an input the primary energy intensity of the process. The amount of primary renewable energy that is needed to produce the output can be calculated depending on the specific kind of renewable technology under investigation.

1	1	2	3	4	5
2	ETSAP ETechDS NORMALIZATION MODEL - JAN 31,2015 - NUMERICAL CHECK OK				MODEL COLUMN WITH MACROS
3	POWER SECTOR - GAS FIRED POWER				
4					
5	PLEASE NOTE: MODEL WITH VB MACROS, DO NOT INSERT/DELETE ROWS/COLUMNS				
6	KEY INPUT DATA in RED; OPTIONAL INPUT DATA in BLUE; CALCULATED DATA in BLACK;				
7	LT=5,10,15,20 .... Y; LTmax=60Y; CT=0,1,2,3 ... Y; CTmax=10Y; DCT=0,1,2,...; DCTmax=10 Y 1kWh = 3.6 MJ				VBA CELLS
8					0.00
9		VARIABLES	CO-RELATIONS	UNITS	
10	INPUT/OUTPUT				
11	Main Energy Input			GJ	nat gas
12	Main Output			MWhe	electricity
13	By-Product			MWht	NO
14	ENERGY INPUT BREAKDOWN				
15	Fossil Fuel (input) Intensity - please specify: NAT. GAS	FFI		GJ/MWhe	9.23
16	Fossil Fuel LHV	FFLHV		MJ/kg	47.00
17	Fossil Fuel Density	FFD		kg/m3	0.77
18	Fossil Fuel Use	FFU	FFI*1000/(FFLHV*FFD)	m3/MWhe	255.04
19	Fossil Fuel Carbon Emission Factor (combustion)	FFCEF		kgCO2/GJ	55.00
20	Fossil Fuel Carbon Emissions	FFCE	FFI*FFCEF	kgCO2/MWhe	507.65
21	ELectricity (input) Intensity	ELI		MWhe/MWhe	0.00
22	ELectricity input in GJ	ELI(J)	ELI*3.6	GJ/MWhe	0.00
23	Electricity Generation Effic. (world average WEO 2013)	ELGE(%)	CONSTANT		0.40
24	intentionally left blank				
25	(Primary) Energy Use as Electricity	EUEL	ELI(J)/ELGE(%)	GJ/MWhe	0.00
26	Electricity Carbon Emission Factor (world average WEO2013)	ELCEF	CONSTANT	kgCO2/MWhe	585.80
27	Electricity Carbon Emissions	ELCE	ELI*ELCEF	kgCO2/MWhe	0.00
28	HEat (input) Intensity	HEI		MWht/MWhe	0.00
29	HEat input in GJ	HEI(J)	HEI*3.6	GJ/MWhe	0.00
30	Heat Generation Effic. (world average WEO2013)	HEGE(%)	CONSTANT		0.90
31	(Primary) Energy Use as Heat	EUHE	HEI(J)/HEGE(%)	GJ/MWhe	0.00
32	Heat Carbon Emission Factor - (world average WEO2013)	HECEF	CONSTANT	kgCO2/MWht	237.00
33	Heat Carbon Emissions	HECE	HEI*HECEF	kgCO2/MWhe	0.00
34	Other Energy (input) Intensity - please specify	OEI		GJ/MWhe	0.00
35	Other Energy input LHV	OELHV		MJ/kg	0.00
36	Other Energy Density	OED		kg/m3	0.00
37	Other Energy Use	OEU	OEI*1000/(OELHV*OED)	m3/MWhe	NA
38	Other Energy Carbon Emission Factor (combustion)	OECEF		kgCO2/GJ	0.00
39	Other Energy Carbon Emissions	OECE	OEI*OECEF	kgCO2/MWhe	0.00

Figure 1 – Normalization Model – 1st Section: Input/Output and Energy Input Breakdown

2nd Model Section: Process Performance (Figure 2)

This section (Figure 2) provides the technical performance of the process (overall gross energy intensity and efficiency, carbon and GHG emissions, non-GHG pollutants) including the "ultimate" energy intensity and emissions that account for the energy and emissions associated to the electricity and heat used in the process, if any. Apart from the ultimate carbon emissions, the model accounts for carbon emissions due to fossil fuel combustion, carbon emission due to the plant/device constriction, and carbon emissions emerging from the process under investigation (e.g. cement production technologies and chemicals production processes can produce GHG emissions other than those associated to the energy use.

Carbon capture/sequestration (CCS) processes may also be accounted for by means their emission abatement factors. The avoided carbon emissions are calculated taking into account the energy efficiency (line 62, Energy intensity increasing factor for CCS) of the same process without CCS systems. Further basic information on the process may be added, if available, at the end of the section, but they are not indispensable to run the model.

40	PROCESS PERFORMANCE				
41	Gross Energy Intensity	GEI	FFI+ELI(MJ)+HEI(MJ)+OEI	GJ/MWhe	9.23
42	Net Energy Efficiency	NEE	1/GEI	MWhe/GJ	0.11
43	Net Energy Efficiency (1=100%)	NEE%	3.6*NEE		0.39
44	Ultimate Energy Intens. (incl. en. used for electricty/heat)	UEI	FFI+EUEL+EUHE+OEI	GJ/MWhe	9.23
45	Ultimate Energy Effic. (incl. en. used for electricty/heat)	UEE	1/UEI	MWhe/GJ	0.11
46	By-Product Production	BPP		MWht/MWhe	0.00
47	Energy (fuel) Carbon Emissions	ECE	FFCE+OECE	kCO2/MWhe	507.65
48	Process-based Carbon Emissions	PCE		kgCO2/MWhe	0.00
49	Construction Carbon Emissions	CCE		kgCO2/MWhe	0.00
50	Total Carbon Emission	TCE	ECE+PCE+CCE+OGHGE	kgCO2/MWhe	507.65
51	Ultimate Energy Carbon Emissions (incl. electricity/heat)	UECE	FFCE+ELCE+HECE+OECE+OGHGE+PCE+CCE	kgCO2/MWhe	507.65
52	Other GHG Emissions (CH4, N2O)	OGHGE		kgCO2e/MWhe	0.00
53	NOx EMission	NOXE		g/MWhe	na
54	VOC EMission	VOCE		g/MWhe	na
55	PM EMission	PME		g/MWhe	na
56	SO2 EMission	SO2E		g/MWhe	na
57	CCS system (specify, if any)				no
58	Energy Carbon emission Abatement factor	ECA			0.00
59	Process Carbon emission Abatement factor	PCA			0.00
60	Net Carbon Emission	NCE	ECE*(1-ECA)+PCE*(1-PCA)+CCE + OGHGE	kgCO2e/MWhe	507.65
61	Captured Carbon Emission	CCE	ECE*ECA+PCE*PCA	kgCO2e/MWhe	0.00
62	Energy Intensity Increasing Factor for CCS	EIIF			1.00
63	Carbon Emission with NO CCS	CENOCCS	ECE/EIIF+PCE+CCE+OGHGE	kgCO2e/MWhe	507.65
64	Avoided Carbon Emission	ACE	CENOCCS-NCE	kgCO2e/MWhe	0.00
65	Main Process Fluid 1 (specify) per unit of capacity	MPF1C		kg/MW	na
66	Main Process Fluid 1 (specify) per unit of production	MPF1P		kg/MWhe	na
67	Main Process Material 1 (specify)	MPM1		kg/MWhe	na
68	Main Process Waste 1 (specify)	MPW1		kg/MWhe	na
69	Max Process Temperature	MPT		°C	na
70	Max Process Pressure	MPP		bar	na
71	Water Use per unit of Capacity	WUC		kg/MW	na
72	Water Use per unit of Production	WUP		kg/MWhe	na
73	Land Use per unit of Capacity	LUC		m2/MW	na

Figure 2 – 2nd Section: Process Performance

3rd Model Section: Plant/Device Performance (Figure 3)

Based on key input data such as the typical plant/device size or capacity, the capacity or use factor (CF), the technical lifetime (LT), this section provides annual and lifetime production of the plant (main product and by-product, if any), and carbon emissions. The model allows the user to consider a declining annual production over time to account for ageing (if applicable).

Data on energy storage devices, if any, can be given as input, although they are not indispensable to run the model. The technical and the economic impacts of energy storage and CCS systems – if any – are in fact accounted for in the model in terms of overall energy intensity of the process, capacity factor of the plant, capital, investment and production costs. The information on the specific performance of the energy storage system is important for the user, but it is not essential for the model to run.

74	**PLANT/DEVICE PERFORMANCE**				
75	Typical Net Capacity	TNC		MWe	150.00
76	Typical Gross to Net Capacity ratio	TGNCR			1.05
77	Typical Gross Capacity	TGC	TNC*TGNCR	MWe	157.50
78	Service	SER			baseload
79	Capacity Factor	CF			0.40
80	Availability Factor	AF			0.92
81	technical LifeTime (LT max = 60 years)	LT		y	30.00
82	Energy PayBack Time	EPBT		y	na
83	Nominal Annual Production	NAP	TNC*CF*8760	MWhe/y	525,600.00
84	Annual Production Reduction (0.2%, if any)	APR			0.0000
85	Annual Net Production (year jth)	ANP(j)	NAP*(1-APR)^(j-(CT+1))	MWhe/y	see annual tables
86	LifeTime Production	LTP	Σj ANP(j)	MWhe	15,768,000.00
87	Average Annual Production	AAP	LTP/LT	MWhe/y	525,600.00
88	Nominal Annual BP Production	NABPP	BPP*NAP	MWht/y	0.00
89	LifeTime BP Production	LTBPP	BPP*LTP	MWht	0.00
90	Nominal Annual Carbon Emission	NACE	NCE*NAP/1000	tCO2/y	266,820.84
91	LifeTime Carbon Emission	LTCE	NCE*LTP/1000	tCO2	8,004,625.20
92	Nominal Annual Avoided Carbon Emissions	NAACE	ACE*NAP/1000	tCO2/y	0.00
93	LifeTime Avoided Carbon Emissions	LTACE	ACE*LTP/1000	tCO2	0.00
94	Energy Storage (specify, if any)	ES			none
95	Energy Storage Medium System (specify, if any)	ESM		t	NA
96	Energy Storage Capacity	ESCAP		GWh	NA
97	Energy Storage Efficiency	ESEFF			NA

Figure 3 – 3rd Section: Plant/Device Performance

4th Model Section: Capital and Investment Costs (Figure 4)

This section provides capital and investment costs are calculated taking into account:

- The structure of project financing (i.e. debt and equity quotas as well as their relevant interest and remuneration rate, respectively);
- A linear granting scheme of the loan, which reflects a linear spending curve during the construction time (if the total capital financed by debt is D, and the construction time is CT, the basic assumption is that the debt is granted at a rate of D/CT per year)
- The interest during construction IDC. The IDC are assumed to be capitalized. Each single annual debt D/CT includes its capitalized IDC)
- Al capital and financing costs related to debt and equity over the plant lifetime are discounted using as the discount rate their respective interest and remuneration rates.
- All other costs and incomes incurred during the plant lifecycle are discounted using as a discount rate a weighted average capital cost (WACC) based on the interest and the remuneration rates

All these calculations are carried out based on macros in the associated VBA cells.

The basic cash-flow assumed in the model for capital and investment costs, operation and maintenance, energy and other costs, and incomes during the lifecycle is given in Figure B

5th Model Section: Operation and Maintenance Costs (Figure 5)

Fixed and variable operation and maintenance costs (FOMC and VOMC) are accounted for in section 5.

FOMC are given as a percentage of the overnight capital cost per year per unit of capacity ($/kW per year).

VOMC are given per unit of production ($/kWh, $/t, $/km, etc.) and do not account for energy costs.

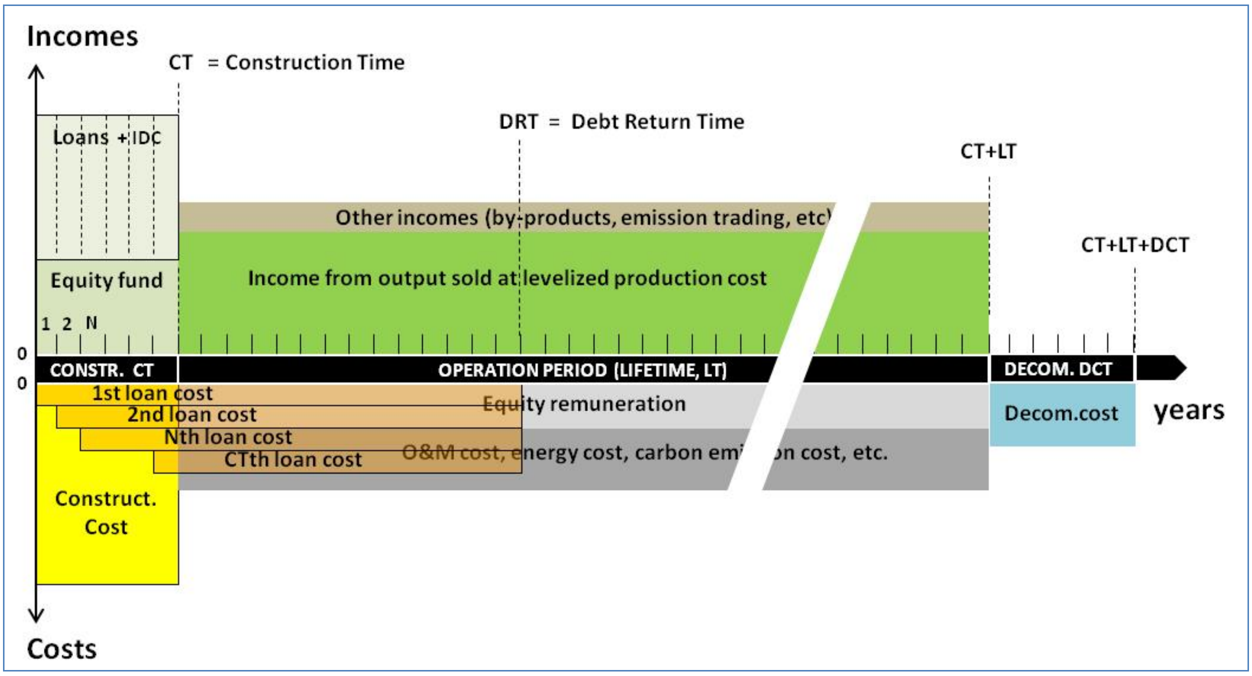

Figure B - General lifecycle cash-flow and balance of energy technologies

98	CAPITAL AND INVESTMENT COSTS				
99	Specific Overnight Capital Cost	SOCC		$/MWe	650,000.00
100	Total Overnight Capital Cost	TOCC	SOCC*TGC	$	102,375,000.00
101	Construction Time (CTmax = 10 years)	CT		y	2.00
102	DePretiation Time	DPT		y	9.00
103	Debt Capital Quota	DCQ			0.50
104	Debt-Funded Capital	DFC	TOCC*DCQ	$	51,187,500.00
105	Debt Interest Rate	DIR			0.07
106	Debt Return Time	DRT	CT+DPT	y	11.00
107	Annual Loan (assuming CT equal loans over CT years)	ALO	DFC/CT		25,593,750.00
108	Total Debt (total loan incl Interest During Construction, IDC)	TDEBT	Σj DEBT(j)	$	64,745,487.57
109	Total Interest During Construction	TIDC	Σj IDC(j)	$	13,557,987.57
110	Total Investment Cost of Debt	TICD	Σj CAICD(j)	$	93,689,096.99
111	Equity Capital Quota	ECQ			0.50
112	Equity Funded Capital	EFC	TOCC*ECQ	$	51,187,500.00
113	Equity Remuneration Rate	ERR			0.09
114	Annual Investment Cost Equity (over LT yrs)	AICE	EFC*ERR	$/y	4,606,875.00
115	Weighted Average Capital Cost (no IDC)	WACC	(DFC*DIR+EFC*ERR)/(DFC+EFC)		0.08
116	Total Investment Cost Equity	TICE	AICE*LT	$	138,206,250.00
117	Discount Rate	DR	WACC		0.080
118	Discounting Time (CT+1) = 1st year of operation	DT	CT+1	y	3.00
119	Total Discounted Investment Cost - Debt	TDICD	AICD*Σj(1+DIR)^(DT-j)	$	76,924,324.78
120	Total Discounted Investment Cost - Equity	TDICE	AICE*Σj(1+ERR)^(DT-j)	$	51,589,089.57
121	Total Discounted Investment Cost	TDIC	TDICD+TDICE	$	128,513,414.35

Figure 4 – 4th Section: Capital and Investment Costs

122	**FIXED O&M COSTS (FOMC)**				
123	FOMC given as a SOCC's quota per year	%FOMC			0.030
124	Annual FOMC	AFOMC	%FOMC*TOCC	$/y	3,071,250.00
125	Nominal Specific FOMC	NSFOMC	AFOMC/NAP	$/MWhe	5.84
126	LifeTime FOMC	LTFOMC	AFOMC*LT	$	92,137,500.00
127	Average specific FOMC	ASFOMC	LTFOMC/LTP	$/MWhe	5.84
128	LifeTime Discounted FOMC	LTDFOMC	AFOMC*Σj(1+WACC)^(DT-j)	$	37,341,504.46
129	**VARIABLE O&M COSTS (VOMC)**				
130	Specific VOMC	SVOMC		$/MWhe	0.00
131	Nominal Annual VOM Cost	NAVOMC	SVOMC*NAP	$/y	0.00
132	LifeTime VOMC	LTVOMC	SVOMC*ΣjANP(j)	$	0.00
133	LifeTime Discounted VOMC	LTDVOMC	SVOMC*Σj ANP(j)*(1+WACC)^(DT-j)	$	0.00
134	**(TOTAL) O&M COST (OMC)**				
135	Nominal Annual OMC	NAOMC	AFOMC+NAVOMC	$/y	3,071,250.00
136	Nominal Specific OMC	NSOMC	NSFOMC+SVOMC	$/MWhe	5.84
137	LifeTime OMC	LTOMC	LTFOMC+LTVOMC	$	92,137,500.00
138	LifeTime Discounted OMC	LTDOMC	LTDFOMC+LTDVOMC	$	37,341,504.46

Figure 5 – 5th Section: Operation and Maintenance Costs

6th Model Section: Energy/Fuel Input Costs (Figure 6)

According to the energy input breakdown (Section 1), energy input prices are given for each single energy input (fossil fuels, electricity, heat, other energy input). Prices ca be given as a function of time, varying every 5th year, over the plant/device lifetime to reflect expected market trends. Nominal specific costs refer to the nominal production in the first year of operation. The nominal production can decline over time if an annual production reduction rate is accounted for in Section 3 (line 84).

139	**ENERGY/FUEL INPUT COSTS - variable over time**				
140	Fossil Fuel Cost 1st 5-year period	FFC1		$/GJ	10.00
141	Fossil Fuel Cost 2nd 5-year period	FFC2		$/GJ	10.00
142	Fossil Fuel Cost 3rd 5-year period	FFC3		$/GJ	10.00
143	Fossil Fuel Cost 4th 5-year period	FFC4		$/GJ	10.00
144	Fossil Fuel Cost 5th 5-year period	FFC5		$/GJ	10.00
145	Fossil Fuel Cost 6th 5-year period	FFC6		$/GJ	10.00
146	Fossil Fuel Cost 7th 5-year period	FFC7		$/GJ	10.00
147	Fossil Fuel Cost 8th 5-year period	FFC8		$/GJ	10.00
148	Fossil Fuel Cost 9th 5-year period	FFC9		$/GJ	10.00
149	Fossil Fuel Cost 10th 5-year period	FFC10		$/GJ	10.00
150	Fossil Fuel Cost 11th 5-year period	FFC11		$/GJ	10.00
151	Fossil Fuel Cost 12th 5-year period	FFC12		$/GJ	10.00
152	Nominal Specific FFC	NSFFC	FFC1*FFI	$/MWhe	92.30
153	Nominal Annual Fossil Fuel Cost	NAFFC	NSFFC*NAP	$/y	48,512,880.00
154	LifeTime Fossil Fuel Cost	LTFFC	ΣjFFC(j)*FFI*ANP(j)	$	1,455,386,400.00
155	LifeTime Discounted Fossil Fuel Cost	LTDFFC	ΣjFFC(j)*FFI*ANP(j)*(1+WACC)^(DT-j)	$	589,839,291.78
156	Average Annual Fossil Fuel Cost	AAFFC	LTFFC/LT	$/y	48,512,880.00
157	Electricity Cost 1st 5-year period	ELC1		$/MWhe	0.00
158	Electricity Cost 2nd 5-year	ELC2		$/MWhe	0.00
159	Electricity Cost 3rd 5-year	ELC3		$/MWhe	0.00
160	Electricity Cost 4th 5-year	ELC4		$/MWhe	0.00
161	Electricity Cost 5th 5-year	ELC5		$/MWhe	0.00
162	Electricity Cost 6th 5-year	ELC6		$/MWhe	0.00
163	Electricity Cost 7th 5-year	ELC7		$/MWhe	0.00
164	Electricity Cost 8th 5-year	ELC8		$/MWhe	0.00
165	Electricity Cost 9th 5-year	ELC9		$/MWhe	0.00
166	Electricity Cost 10th 5-year	ELC10		$/MWhe	0.00
167	Electricity Cost 11th 5-year	ELC11		$/MWhe	0.00
168	Electricity Cost 12th 5-year	ELC12		$/MWhe	0.00
169	Nominal Specific ELC	NSELC	ELC1*ELI	$/MWhe	0.00
170	Nominal Annual Electricty Cost	NAELC	NSELC*NAP	$/y	0.00
171	LifeTime Electricity Cost	LTELC	ΣjELC(j)*ELI*ANP(j)	$	0.00
172	LifeTime Discounted Electricty Cost	LTDELC	ΣjELC(j)*ELI*ANP(j)*(1+WACC)^(DT-j)	$	0.00
173	Average Annual Electricity Cost	AAELC	LTELC/LT	$/y	0.00
174	Heat Cost 1st 5-year period	HEC1		$/MWht	0.00
175	Heat Cost 2nd 5 year	HEC2		$/MWht	0.00
176	Heat Cost 3rd 5 years	HEC3		$/MWht	0.00
177	Heat Cost 4th 5-year	HEC4		$/MWht	0.00
178	Heat Cost 5th 5-year	HEC5		$/MWht	0.00
179	Heat Cost 6th 5-year	HEC6		$/MWht	0.00
180	Heat Cost 7th 5-year	HEC7		$/MWht	0.00
181	Heat Cost 8th 5-year	HEC8		$/MWht	0.00
182	Heat Cost 9th 5-year	HEC9		$/MWht	0.00
183	Heat Cost 10th 5-year	HEC10		$/MWht	0.00
184	Heat Cost 11th 5-year	HEC11		$/MWht	0.00
185	Heat Cost 12th 5-year	HEC12		$/MWht	0.00
186	Nominal Specific HEC	NSHEC	HEC1*HEI	$/MWhe	0.00
187	Nominal Annual Heat Cost	NAHEC	NSHEC*NAP	$/y	0.00
188	LifeTime Heat Cost	LTHEC	ΣjHEC(j)*HEI*ANP(j)	$	0.00
189	LifeTime Discounted Heat Cost	LTDHEC	ΣjHEC(j)*HEI*ANP(j)*(1+WACC)^(DT-j)	$	0.00
190	Average Annual Heat Cost	AAHEC	LTHEC/LT	$/y	0.00
191	Other Energy Cost 1st 5-year period	OEC1		$/GJ	0.00
192	OE Cost 2nd 5 year	OEC2		$/GJ	0.00
193	OE Cost 3rd 5 year	OEC3		$/GJ	0.00
194	OE Cost 4th 5-year	OEC4		$/GJ	0.00
195	OE Cost 5th 5-year	OEC5		$/GJ	0.00
196	OE Cost 6th 5-year	OEC6		$/GJ	0.00
197	OE Cost 7th 5-year	OEC7		$/GJ	0.00
198	OE Cost 8th 5-year	OEC8		$/GJ	0.00
199	OE Cost 9th 5-year	OEC9		$/GJ	0.00
200	OE Cost 10th 5-year	OEC10		$/GJ	0.00
201	OE Cost 11th 5-year	OEC11		$/GJ	0.00
202	OE Cost 12th 5-year	OEC12		$/GJ	0.00
203	Nominal Specific OEC	NSOEC	OEC1*OEI	$/MWhe	0.00
204	Nominal Annual OE Cost	NAOEC	NSOEC*NAP	$/y	0.00
205	LifeTime OE Cost	LTOEC	ΣjOEC(j)*OEI*ANP(j)	$	0.00
206	LifeTime Discounted OE Cost	LTDOEC	ΣjOEC(j)*OEI*ANP(j)*(1+WACC)^(DT-j)	$	0.00
207	Average Annual OE Cost	AAOEC	LTOEC/LT	$/y	0.00
208	**TOTAL LIFETIME ENERGY COST**				
209	Total Nominal Specific Energy Cost	TNSEC	NSFFC+NSELC+NSHEC+NSOEC	$/MWhe	92.30
210	Total Nominal Annual Energy Cost	TNAEC	NAFFC+NAELC+NAHEC+NAOEC	$/y	48,512,880.00
211	Total LifeTime Energy Cost	TLTEC	LTFFC+LTELC+LTHEC+LTOEC	$	1,455,386,400.00
212	Total LifeTime Discounted Energy Cost	TLTDEC	LTDFFC+LTDELC+LTDHEC+LTDOEC	$	589,839,291.78
213	Total Average Annual Energy Cost	TAAEC	AAFFC+AAELC+AAHEC+AAOEC	$/y	48,512,880.00

Figure 6 – 6th Section: Energy/Fuel Input Costs

7th Model Section: Other Costs (Figure 7)

This section deals with other costs incurred during plant/device lifecycle, in particular:

- CO2 emission costs incurred if an emission trading market is in place (e.g. European Union);
- Waste management costs, which are particular important for some power (nuclear and coal power) and industrial technologies;
- Production taxes costs, if any;
- Decommissioning costs incurred at the end of the plant/device life.

Input carbon emission prices can be varied over time, every 5th year, same as the energy and fuel prices. Decommissioning costs are given as a percentage of the overnight capital cost per unit of capacity.

214	**CO2 EMISSION COST CEC - variable over time**				
215	CEC 1st 5-year period	CEC1		$/tCO2	10.00
216	CEC 2nd 5-year	CEC2		$/tCO2	10.00
217	CEC 3rd 5 year	CEC3		$/tCO3	10.00
218	CEC 4th 5-year	CEC4		$/tCO4	10.00
219	CEC 5th 5-year	CEC5		$/tCO5	10.00
220	CEC 6th 5-year	CEC6		$/tCO6	10.00
221	CEC 7th 5-year	CEC7		$/tCO7	10.00
222	CEC 8th 5-year	CEC8		$/tCO8	10.00
223	CEC 9th 5-year	CEC9		$/tCO9	10.00
224	CEC 10th 5-year	CEC10		$/tCO10	10.00
225	CEC 11th 5-year	CEC11		$/tCO11	10.00
226	CEC 12th 5-year	CEC12		$/tCO12	10.00
227	Nominal Specific CEC	NSCEC	CEC1/1000*NCE	$/MWhe	5.08
228	Nominal Annual CEC	NACEC	NSCEC*NAP	$/y	2,668,208.40
229	LifeTime CEC	LTCEC	ΣjCEC(j)*NCE/1000*ANP(j)	$	80,046,252.00
230	LifeTime Discounted CEC	LTDCEC	ΣjCEC(j)*NCE/1000*ANP(j)*(1+WACC)^(DT-j)	$	32,441,161.05
231	Average Annual CEC	AACEC	LTCEC/LT	$/y	2,668,208.40
232	**WASTE MANAGEMENT COST (WMC)**				
233	Specific WMC	SWMC		$/MWhe	0.00
234	Nominal Annual WMC	NAWMC	SWMC*NAP	$/y	0.00
235	LifeTime WMC	LTWMC	SWMC*ΣjANP(j)	$	0.00
236	LifeTime Discounted WMC	LTDWMC	SWMC*ΣjANP(j)*(1+WACC)^(DT-j)	$	0.00
237	Average Annual WMC	AAWMC	LTWMC/LT	$/y	0.00
238	**PRODUCTION TAXES COST (PTC)**				
239	Specific PTC	SPTC		$/MWhe	0.00
240	Nominal Annual PTC	NAPTC	SPTC*NAP	$/y	0.00
241	LIfeTime PTC	LTPTC	SPTC*ΣjANP(j)	$	0.00
242	Lifetime discounted PTC	LTDPTC	SPTC*ΣjANP(j)*(1+WACC)^(DT-j)	$	0.00
243	Average Annual WMC	AAPTC	LTPTC/LT	$/y	0.00
244	**DECOMMISSIONING COST (DC)**				
245	DC given as SOOC's quota	%DC			0.05
246	Specific DC	SDC	%DC*SOCC	$/MWe	32,500.00
247	Total DC	TDC	SDC*TGC	$	5,118,750.00
248	Decommissioning Time (DCT max = 10 years)	DCT		y	2.00
249	Annual DC	ADC	TDC/DCT	$/y	2,559,375.00
250	Total Discounted DC	TDDC	ADC*Σj(1+WACC)^(DT-j)	$	489,847.44

Figure 7 – 7th Section: Other Costs

8th Model Section: Incomes during operation (Figure 8)

During its lifetime, a supply or end-use energy technology can provide incomes other than those obtained from its main output. These incomes can be obtained for instance from:

- avoided carbon emissions (if an emission trading system is in place) by processes using renewable energy in comparison with similar processes using fossil fuels;
- production of by-products (by-products are defined as products that are made available by the process in addition to the main output, with no additional energy input or costs);
- policy incentives associated to the production of the main output such as feed-in tariff.

These incomes are accounted for in the section 8 of the model. The expected price of the avoided carbon emissions can be varied over time same as the energy prices, and depend on market as well as the price of the by-products. The level of policy incentives depend on policy measures and regulations.

251	**AVOIDED CARBON (EMISSION) INCOME (ACI)**				
252	ACI 1st 5-year period	ACI1		$/tCO2	0.00
253	ACI 2nd 5-year	ACI2		$/tCO2	0.00
254	ACI 3rd 5 year	ACI3		$/tCO2	0.00
255	ACI 4th 5-year	ACI4		$/tCO2	0.00
256	ACI 5th 5-year	ACI5		$/tCO2	0.00
257	ACI 6th 5-year	ACI6		$/tCO2	0.00
258	ACI 7th 5-year	ACI7		$/tCO2	0.00
259	ACI 8th 5-year	ACI8		$/tCO2	0.00
260	ACI 9th 5-year	ACI9		$/tCO2	0.00
261	ACI 10th 5-year	ACI10		$/tCO2	0.00
262	ACI 11th 5-year	ACI11		$/tCO2	0.00
263	ACI 12th 5-year	ACI12		$/tCO2	0.00
264	Nominal Specific ACI	NSACI	ACI1/1000*ACE	$/MWhe	0.00
265	Nominal Annual ACI	NAACI	NSACI*NAP	$/y	0.00
266	LifeTime ACI	LTACI	ΣjACI(j)*ACE/1000*ANP(j)	$	0.00
267	LifeTime Discounted ACI	LTDACI	ΣjACI(j)*ACE/1000*ANP(j)*(1+WACC)^(DT-j)	$	0.00
268	Average Annual ACI	AAACI	LTACI/LT	$/y	0.00
269	**BY-PRODUCT INCOME (BPI)**				
270	Specific BP Price	SBPP		$/MWht	0.00
271	Nominal Annual BPI	NABPI	SBPP*BPP*NAP	$/y	0.00
272	LifeTime BPI	LTBPI	SBPP*BPP*ΣjANP(j)	$	0.00
273	LifeTime Discounted BPI	LTDBPI	SBPP*BPP*ΣjANP(j)*(1+WACC)^(DT-j)	$	0.00
274	Average Annual BPI	AABPI	LTBPI/LT	$/y	0.00
275	**POLICY INCENTIVES INCOME (PII)**				
276	Specific Policy Incentive Value	SPIV		$/MWhe	0.00
277	Nominal Annual PII	NAPII	SPIV*NAP	$/y	0.00
278	LifeTime PII	LTPII	SPIV*ΣjANP(j)	$	0.00
279	LifeTime Discounted PII	LTDPII	SPIV*ΣjANP(j)*(1+WACC)^(DT-j)	$	0.00
280	Average Annual PII	AAPII	LTPII/LT	$/y	0.00

Figure 8 – 8th Section: Incomes

9th Model Section: Levelised Production Costs and investment return times (Figure 9)

This section provides the final result of the model including the Levelised Production Costs (LPC) and the investment return times (IRT). The model provides the levelised production costs under the following three basic options:

- (discounted costs – discounted incomes)/ discounted production;
- (undiscounted costs –undiscounted incomes)/ undiscounted production; and
- (discounted costs - discounted incomes)/undiscounted production.

The model also provides a breakdown of the discounted cost components.

Once the LPC is known, the model calculates the investment return time IRT based on LPC. Instead of the LPC, in the IRT assessment model users can also consider an expected “levelised” un/taxed market price of the production (including profit).

281	**LEVELISED PRODUCTION COST (LPC)**				
282	Plant/Device End-of-Life Residual Value	RV	TOCC*(1-2.3/LT)^(LT-1)	$	**10,129,565.82**
283	Gross Total Production Cost	GTPC	TICD+TICE+LTOMC+TLTEC+LTCEC+LTWMC+LTPTC+TDC	$	**1,864,584,248.99**
284	Total Production Income	TPI	LTACI+LTBPI+LTPII	$	**0.00**
285	Net Total Production Cost	NTPC	GTPC-TPI-RV	$	**1,854,454,683.17**
286	LifeTime Discounted Production	LTDP	ΣjANP(j)*(1+WACC)^(DT-j)	MWhe	**6,390,458.20**
287	Gross Total Discounted Production Cost	GTDPC	TDIC+LTDOMC+TLTDEC+LTDCEC+LTDWMC+LTDPTC+TDDC	$	**788,625,219.07**
288	Total Discounted Production Income	TDPI	LTDACI+LTDBPI+LTDPII	$	**0.00**
289	Discounted Residual Value	DRV	RV*(1+WACC)^(DT-(CT+LT))	$	**1,087,181.17**
290	Net Total Discounted Production Cost	NTDPC	GTDPC-TDPI-DRV	$	**787,538,037.90**
291	Levelised Production Cost (undisc. costs & production)	LPC (UCUP)	NTPC/LTP	$/MWhe	**117.61**
292	**Levelised Production Cost LPC (disc. costs & production)**	**LPC (DCDP)**	**NTDPC/LTDP**	**$/MWhe**	**123.24**
293	Levelised Production Cost (disc. costs, undisc. production)	LPC(DCUP)	NTDPC/LTP	$/MWhe	**49.95**
294	**PRODUCTION COST BREAKDOWN (based on discounted costs)**				
295	Investment Cost	%IC	TDIC/GTDPC*100	%	**16.30**
296	O&M Cost	%OMC	LTDOMC/GTDPC*100	%	**4.74**
297	Energy Cost	%EC	TLTDEC/GTDPC*100	%	**74.79**
298	Emission Cost	%EMC	LTDCEC/GTDPC*100	%	**4.11**
299	Waste Management Cost	%WMC	LTDWMC/GTDPC*100	%	**0.00**
300	Production Tax Cost	%PTC	LTDPTC/GTDPC*100	%	**0.00**
301	Decommisisoning Cost	%DC	TDDC/GTDPC*100	%	**0.06**
302	Total Cost %	%TCOST	%(IC+OMC+EC+EMC+WMC+PTC+DC)	%	**100.00**
303	Avoided Emission Income	%AGHGI	LTDACI/TDPI*100	%	**na**
304	ByProduct Iincome	%BPI	LTDBPI/TDPI*100	%	**na**
305	Policy Incentive Income	%PII	LTDPII/TDPI*100	%	**na**
306	Total Income %	%TINCOME	%(ACI+BPI+PII)	%	**na**
307	**INVESTMENT RETURN TIME**				
308	Levelized Untaxed (discounted) Market Price	LUMP		$/MWhe	**123.24**
309	Levelized Taxed (discounted) Market Price	LTMP		$/MWhe	**NA**
310	Levelized Untaxed Profit	LUP	LUMP-LPC(DCDP)	$/MWhe	**0.00**
311	Nominal Annual Untaxed Income	NAUI	NAP*LUMP	$/y	**64,773,132.04**
312	Nominal Annual Untaxed Profit	NAUP	NAP*LUP	$/y	**0.00**
313	Average Annual Untaxed Income	AAUI	AAP*LUMP	$/y	**64,773,132.04**
314	Average Annual Untaxed Profit	AAUP	AAP*LUP	$/y	**0.00**
315	Annual Untaxed Income	AUI	ANP(j)*LUMP	$/y	**see annual tables**
316	Annual Discounted Untaxed Income	ADUI	ANP(j)*LUMP*(1+WACC)^(DT-j)	$/y	**see annual tables**
317	Annual Untaxed Profit	AUP	ANP(j)*LUP	$/y	**see annual tables**
318	Annual Discounted Untaxed Profit	ADUP	ANP(j)*LUP*(1+WACC)^(DT-j)	$/y	**see annual tables**
319	LifeTime Untaxed Income	LTUI	ΣjANP(j)*LUMP	$	**1,943,193,961.16**
320	LifeTime Discounted Untaxed Income	LTDUI	ΣjANP(j)*LUMP*(1+WACC)^(DT-j)	$	**787,538,037.90**
321	LifeTime Untaxed Profit	LTUP	ΣjANP(j)*LUP	$	**0.00**
322	LifeTime Discounted Untaxed Profit	LTDUP	ΣjANP(j)*LUP*(1+WACC)^(DT-j)	$	**0.00**
323	Average Annual Discounted Untaxed Income	AADUI	LTDUI/LT	$/y	**26,251,267.93**
324	Investment Return Time (Undiscounted)	IRT (U)	(TICD+TICE)/AAUI		**3.58**
325	Investment Return Time (Discounted)	IRT (D)	TDIC/AADUI	y	**4.90**

Figure 9 – 9th Section: Levelised Production Costs and investment Return Time

10th Model Section: Market information (Figure 10)

This section collects additional market information for the technology under investigation. Though of interest, this information has no impact on the model analysis.

326	**MARKET**				
327	Total (installed) Capacity	TC		MW	
328	Total number of Units	TU			
329	Average Unit Capacity	AUC	TC/TU	MW	**na**
330	Annual installed Capacity	AC		MW	
331	Capacity Under Construction	CC		MW	
332	Planned Capacity (filed)	PC		MW	
333	Time Span of filed Planned Capacity	TSPC		y	
334	Market Share (current)	MS		%	

Figure 10 – 10th Section: Market information

Running the model

Once the input is completed (input data in red), the user can run the model by clicking the whitw button (CALCULATE) on top of the yellow model column. Results obtained for each technology option and variant can be copied and pasted in the data repository available in each spreadsheet, where key input data for Times models can be collected and transferred to TIMES for energy scenario analyses and projections.

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