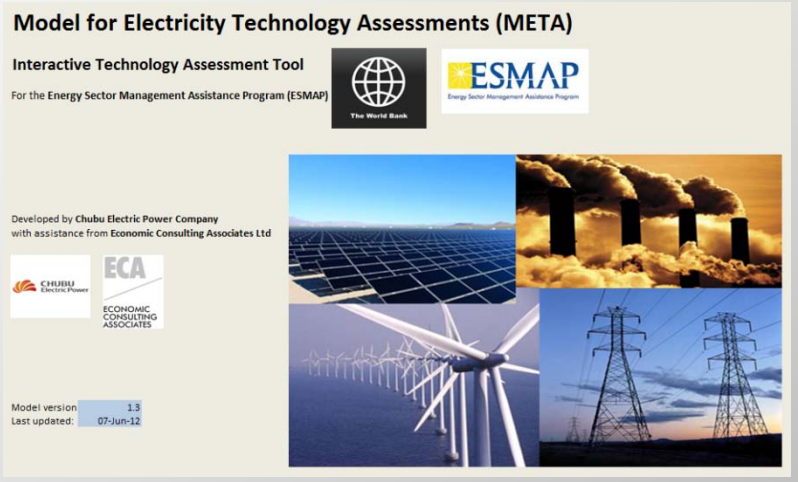
# Model for Electricity Technology Assessments (META)




## World Bank
## Washington D.C., June 2012

CHUBU ELECTRIC POWER

ECONOMIC CONSULTING ASSOCIATES LIMITED

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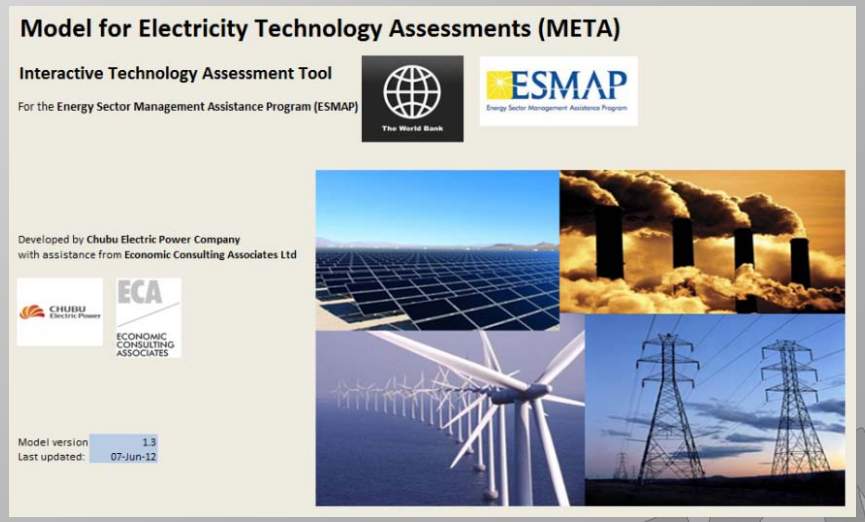
ECA

# Overview

- What is META?
- How is it structured?
- How do I use it?
- What are the other (advanced) details?







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# What is META?

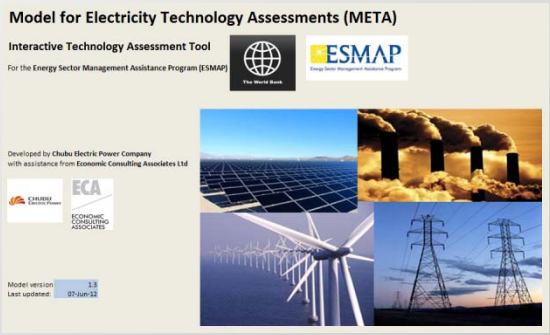
## How is it structured?

## How do I use it?

## What about the other details?

# Objectives of the META model

- Expand on and augment the ETOAG document
- Widely accessible
  - Downloadable from the internet
- A dynamic tool
- Interactive
- User-modifiable
- Data can be updated (e.g., annually)







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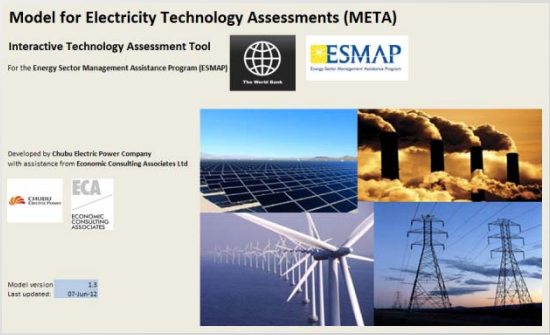
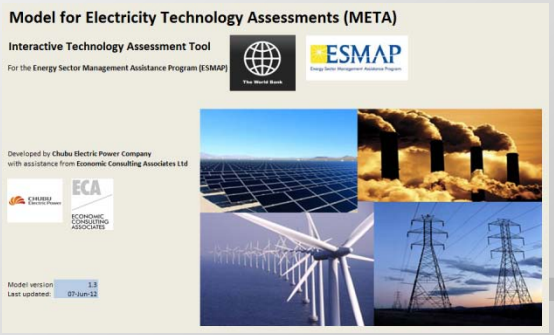
# Scope – time and place

- **Covers 3 country types:**
  - **Large Developed Country (proxied with USA data)**
  - **Middle Income Country (proxied with Romania data)**
  - **Developing Country (proxied with India data)**
- **Across 3 present and future years:**
  - **2010 base year**
  - **Projections for 2015 and 2020**



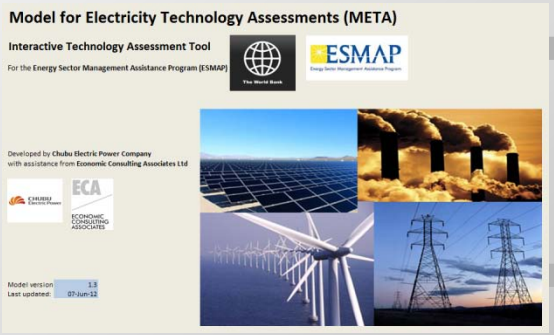
# Scope - technologies

- **Generation technologies (>50):**
  - **Conventional**
    - **Steam-fired, gas-fired, nuclear, etc**
    - **Advanced conventional technologies**
  - **Non-conventional**
    - **Renewable generation technologies**
    - **Energy storage technologies**
    - **Carbon Capture and Storage (CCS)**
- **Transmission technologies**
  - **Multiple voltage levels**
  - **Overhead, underground**
- **Distribution technology**



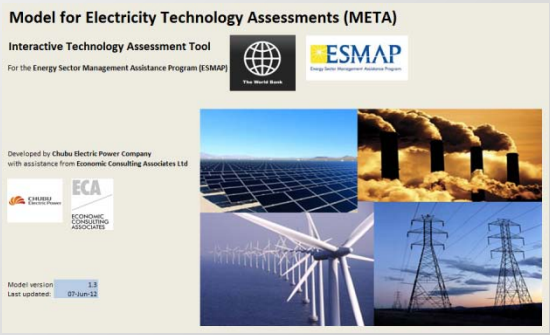
# Other features

- **Incorporates environmental costs**
  - **$CO_2$, NOx, $SO_2$, PM**
- **User can customise emissions control equipment**
  - **Equipment cost, abatement rates**
- **By-product net revenues**
- **Costs adjusted for seismic zones**
- **Can adjust for technology improvements over time**
- **Uncertainty Analysis Module**



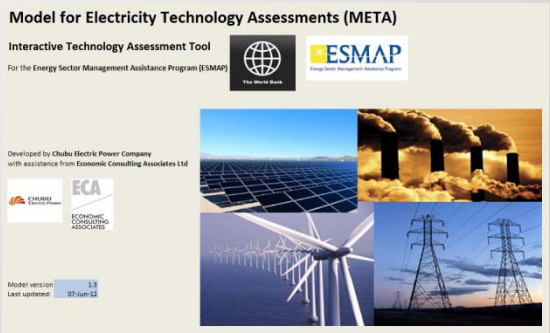
# Wide target user groups

- **Two types of users:**
- **1. General user**
  - **Interested in ‘the bottom line’**
  - **Happy to use the default inputs**
- **2. Advanced user**
  - **Very knowledgeable about electricity**
  - **Has good data of their own**
  - **Wants to look at the details**
  - **Might want to change the default inputs**



# Updating the model

- **Current inputs can be changed**
  - **Simply make changes in the input screens**
- **Over time the default inputs can be updated**
  - **Change data in DATABASE sheets**
- **All data are in <u>real</u> terms**
  - **(e.g., 2010 dollars)**



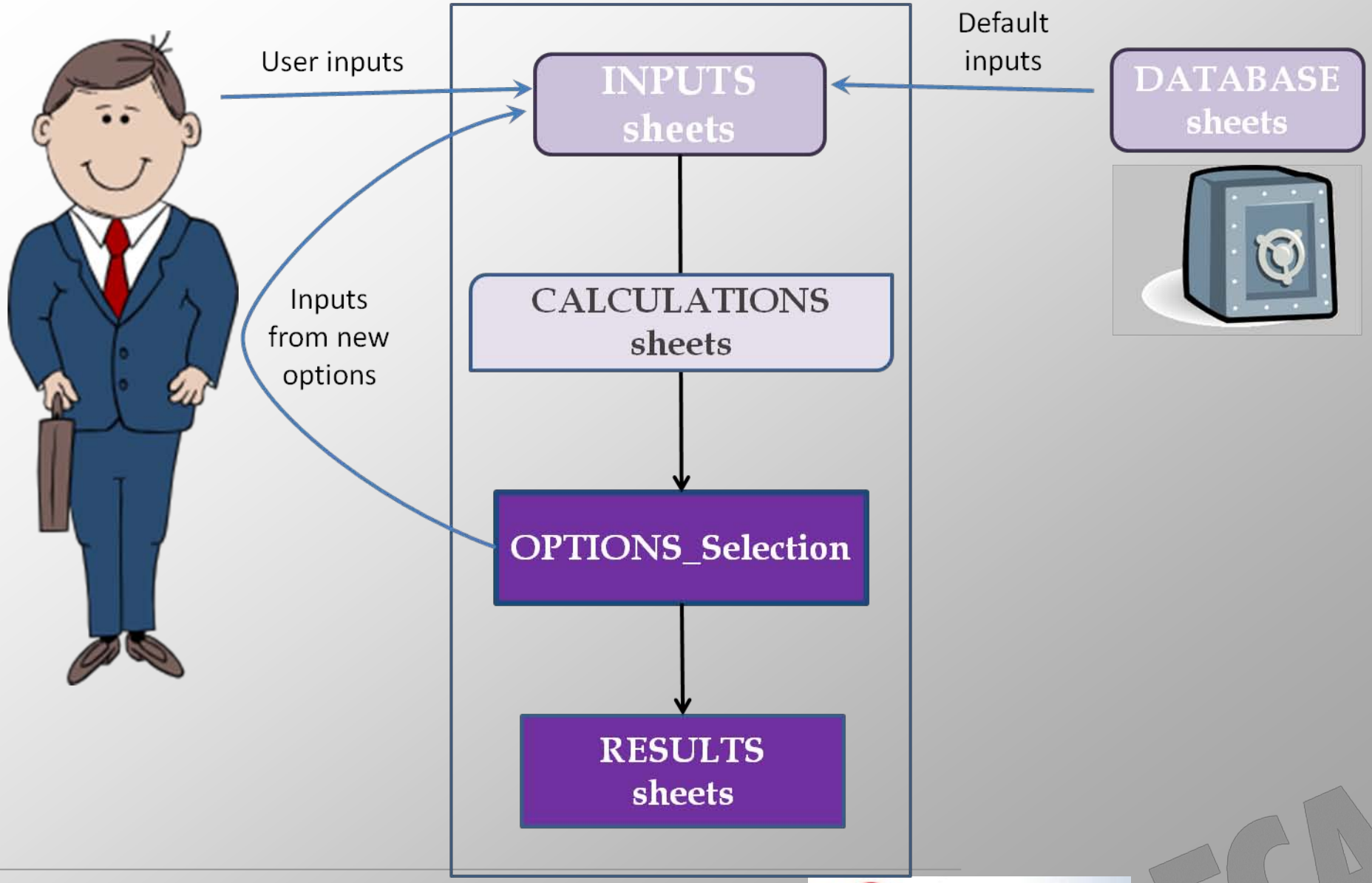
What is META?

**How is it structured?**

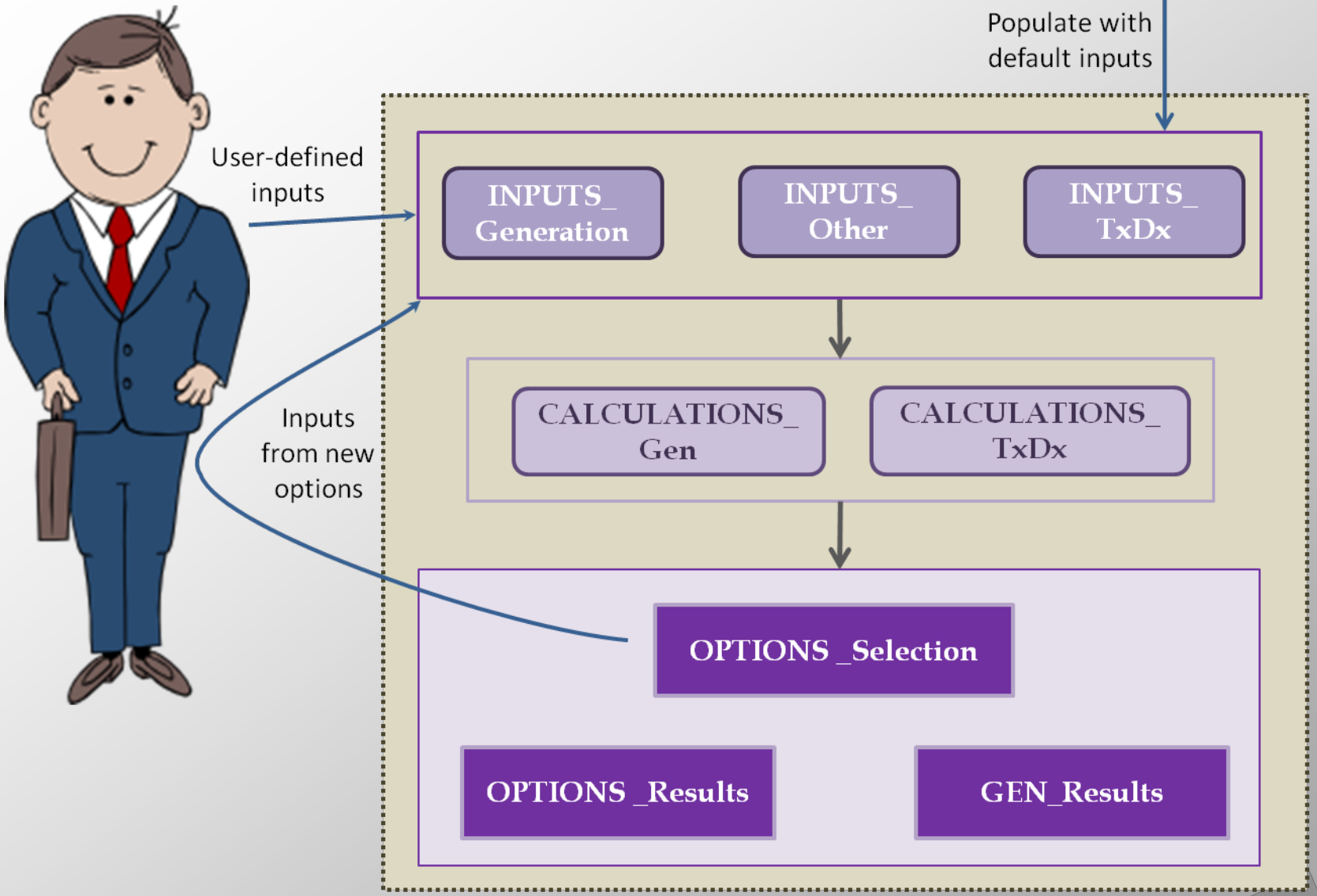
How do I use it?

What about the other details?

# Basic model structure



# Detailed model structure

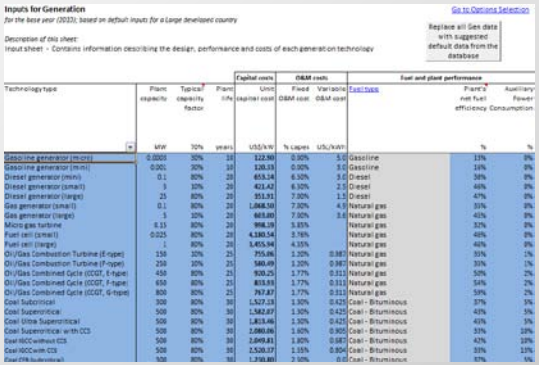


# Key Inputs

- **Generation technologies**
  - **Conventional**
  - **Non-conventional**

  } **54 technologies**

- **Delivery technologies**
  - **Transmission**
    - **Overhead, underground, substations**
  - **Distribution network**



Inputs for Generation

*for the base year (2013); based on default inputs for a Large developed country*

Go to Options Selection

Replace all Gen data with suggested default data from the database

*Description of this sheet:*
Input sheet - Contains information describing the design, performance and costs of each generation technology

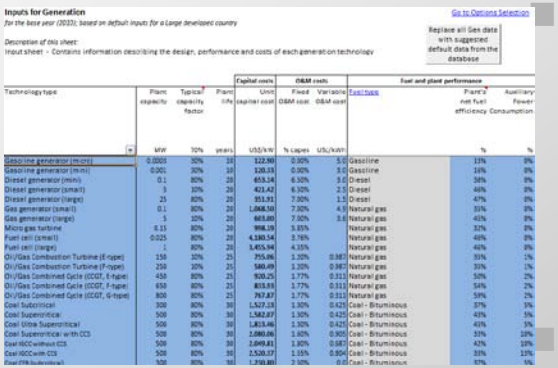
| Technology type | Plant capacity | Typical capacity factor | Plant life | Capital costs: Unit capital cost | O&M costs: Fixed O&M cost | O&M costs: Variable O&M cost | Fuel and plant performance: Fuel type | Fuel and plant performance: Plant net fuel efficiency | Fuel and plant performance: Auxiliary Power Consumption |
|---|---|---|---|---|---|---|---|---|---|
| | MW | 70% | years | USD/kW | % capex | USc/kWh | | % | % |
| Gasoline generator (micro) | 0.0001 | 30% | 10 | 122.90 | 0.90% | 5.0 | Gasoline | 15% | 9% |
| Gasoline generator (mini) | 0.001 | 30% | 10 | 120.15 | 0.90% | 5.0 | Gasoline | 16% | 9% |
| Diesel generator (mini) | 0.1 | 80% | 20 | 653.24 | 6.30% | 5.0 | Diesel | 38% | 9% |
| Diesel generator (small) | 3 | 10% | 20 | 421.42 | 6.30% | 2.5 | Diesel | 46% | 9% |
| Diesel generator (large) | 25 | 80% | 20 | 351.91 | 7.90% | 1.5 | Diesel | 47% | 9% |
| Gas generator (small) | 0.1 | 80% | 20 | 1,868.50 | 7.90% | 4.6 | Natural gas | 35% | 9% |
| Gas generator (large) | 5 | 10% | 20 | 663.89 | 7.90% | 3.6 | Natural gas | 41% | 9% |
| Micro gas turbine | 0.15 | 80% | 20 | 998.19 | 3.35% | | Natural gas | 32% | 9% |
| Fuel cell (small) | 0.025 | 80% | 20 | 4,180.54 | 3.76% | | Natural gas | 46% | 9% |
| Fuel cell (large) | 1 | 80% | 20 | 3,455.94 | 4.35% | | Natural gas | 46% | 9% |
| Oil/Gas Combustion Turbine (E-type) | 150 | 10% | 25 | 755.06 | 1.30% | 0.867 | Natural gas | 35% | 1% |
| Oil/Gas Combustion Turbine (F-type) | 250 | 10% | 25 | 580.09 | 1.30% | 0.867 | Natural gas | 35% | 1% |
| Oil/Gas Combined Cycle (CCGT, E-type) | 450 | 80% | 25 | 930.25 | 1.77% | 0.313 | Natural gas | 50% | 2% |
| Oil/Gas Combined Cycle (CCGT, F-type) | 650 | 80% | 25 | 833.93 | 1.77% | 0.313 | Natural gas | 54% | 2% |
| Oil/Gas Combined Cycle (CCGT, G-type) | 800 | 80% | 25 | 767.87 | 1.77% | 0.313 | Natural gas | 59% | 2% |
| Coal Subcritical | 300 | 80% | 30 | 1,527.13 | 1.30% | 0.425 | Coal - Bituminous | 37% | 5% |
| Coal Supercritical | 500 | 80% | 30 | 1,582.07 | 1.30% | 0.425 | Coal - Bituminous | 43% | 5% |
| Coal Ultra Supercritical | 500 | 80% | 30 | 1,813.46 | 1.30% | 0.425 | Coal - Bituminous | 45% | 5% |
| Coal Supercritical with CCS | 500 | 80% | 30 | 2,080.06 | 1.30% | 0.905 | Coal - Bituminous | 33% | 10% |
| Coal IGCC without CCS | 500 | 80% | 30 | 2,049.81 | 1.30% | 0.587 | Coal - Bituminous | 42% | 10% |
| Coal IGCC with CCS | 500 | 80% | 30 | 2,520.17 | 1.15% | 0.804 | Coal - Bituminous | 35% | 10% |
| Coal CFB (subcritical) | 500 | 80% | 30 | 1,710.88 | 2.10% | 0.0 | Coal - Bituminous | 37% | 5% |

# Key Inputs

- **Design basis**
- **Capital costs**
- **O&M costs**

**For Generation, Transmission & Distribution**

- **Fuel characteristics and costs**
- **Externality costs**
  - **$CO_2$, NOx, $SO_2$, PM**
- **Commodity costs and forecasts**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*for the base year (2013); based on default inputs for a Large developed country*

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|---|---|---|---|---|---|---|---|---|---|
| | MW | 70% | years | US$/kW | % capex | US$/kWh | | % | % |
| Gasoline generator (micro) | 0.0001 | 30% | 10 | 122.90 | 0.90% | 5.0 | Gasoline | 15% | 9% |
| Gasoline generator (mini) | 0.001 | 30% | 10 | 120.15 | 0.90% | 5.0 | Gasoline | 16% | 9% |
| Diesel generator (mini) | 0.1 | 80% | 20 | 653.16 | 6.30% | 5.0 | Diesel | 58% | 9% |
| Diesel generator (small) | 3 | 10% | 20 | 421.42 | 6.30% | 2.5 | Diesel | 46% | 9% |
| Diesel generator (large) | 25 | 80% | 20 | 351.91 | 7.90% | 1.5 | Diesel | 47% | 9% |
| Gas generator (small) | 0.1 | 80% | 20 | 1,868.50 | 7.90% | 4.6 | Natural gas | 35% | 9% |
| Gas generator (large) | 5 | 10% | 20 | 663.89 | 7.90% | 3.6 | Natural gas | 41% | 9% |
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| Oil/Gas Combustion Turbine (F-type) | 250 | 10% | 25 | 580.09 | 1.30% | 0.867 | Natural gas | 35% | 1% |
| Oil/Gas Combined Cycle (CCGT, E-type) | 450 | 80% | 25 | 930.25 | 1.77% | 0.313 | Natural gas | 50% | 2% |
| Oil/Gas Combined Cycle (CCGT, F-type) | 650 | 80% | 25 | 813.93 | 1.77% | 0.313 | Natural gas | 54% | 2% |
| Oil/Gas Combined Cycle (CCGT, G-type) | 800 | 80% | 25 | 767.87 | 1.77% | 0.313 | Natural gas | 59% | 2% |
| Coal Subcritical | 300 | 80% | 30 | 1,527.13 | 1.30% | 0.425 | Coal - Bituminous | 37% | 5% |
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| Coal Ultra Supercritical | 500 | 80% | 30 | 1,813.46 | 1.30% | 0.425 | Coal - Bituminous | 45% | 5% |
| Coal Supercritical with CCS | 500 | 80% | 30 | 2,980.06 | 1.80% | 0.900 | Coal - Bituminous | 33% | 10% |
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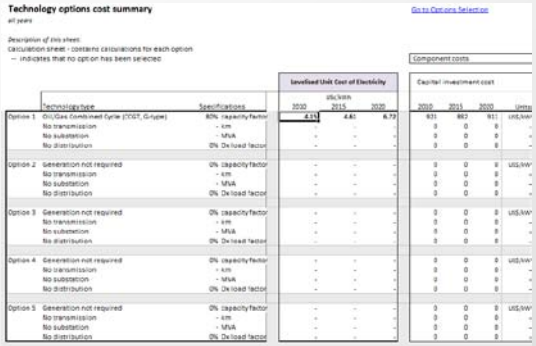
| Coal NGCC with CCS | 500 | 80% | 30 | 2,520.17 | 1.15% | 0.804 | Coal - Bituminous | 35% | 10% |
| Coal IGB (subcritical) | 500 | 80% | 30 | 1,710.80 | 2.10% | 0.0 | Coal - Bituminous | 37% | 5% |

# Key Results

- Levelized capital costs
- Energy costs
- Delivery costs
- Externality costs
- Delivered energy costs
- COMPARISONS among technologies



Technology options cost summary

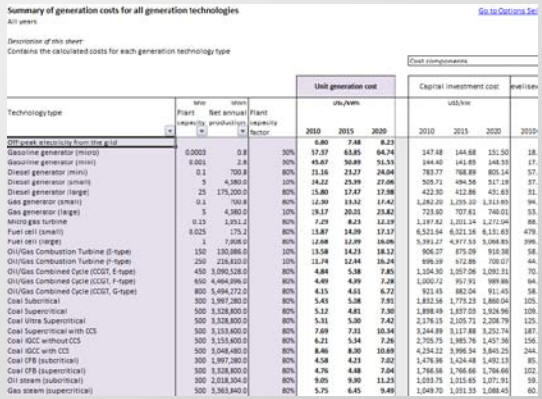
all years

Description of this sheet:
Calculation sheet - contains calculations for each option
-- indicates that no option has been selected

Go to Options Selection

Component costs

| Technology type | Specifications | Levelised Unit Cost of Electricity US$/kWh 2010 | 2015 | 2020 | Capital investment cost 2010 | 2015 | 2020 | Units |
|---|---|---|---|---|---|---|---|---|
| Option 1 Oil/Gas Combined Cycle (CCGT, G-type) | 80% capacity factor | 4.11 | 4.81 | 6.72 | 931 | 882 | 911 | US$/kW |
| | No transmission | | | | 0 | 0 | 0 | |
| | - km | | | | 0 | 0 | 0 | |
| | No substation | | | | 0 | 0 | 0 | |
| | - MVA | | | | 0 | 0 | 0 | |
| | No distribution | | | | 0 | 0 | 0 | |
| | 0% Dx load factor | | | | | | | |
| Option 2 Generation not required | 0% capacity factor | | | | 0 | 0 | 0 | US$/kW |
| | No transmission | | | | 0 | 0 | 0 | |
| | - km | | | | 0 | 0 | 0 | |
| | No substation | | | | 0 | 0 | 0 | |
| | - MVA | | | | 0 | 0 | 0 | |
| | No distribution | | | | 0 | 0 | 0 | |
| | 0% Dx load factor | | | | | | | |
| Option 3 Generation not required | 0% capacity factor | | | | 0 | 0 | 0 | US$/kW |
| | No transmission | | | | 0 | 0 | 0 | |
| | - km | | | | 0 | 0 | 0 | |
| | No substation | | | | 0 | 0 | 0 | |
| | - MVA | | | | 0 | 0 | 0 | |
| | No distribution | | | | 0 | 0 | 0 | |
| | 0% Dx load factor | | | | | | | |
| Option 4 Generation not required | 0% capacity factor | | | | 0 | 0 | 0 | US$/kW |
| | No transmission | | | | 0 | 0 | 0 | |
| | - km | | | | 0 | 0 | 0 | |
| | No substation | | | | 0 | 0 | 0 | |
| | - MVA | | | | 0 | 0 | 0 | |
| | No distribution | | | | 0 | 0 | 0 | |
| | 0% Dx load factor | | | | | | | |
| Option 5 Generation not required | 0% capacity factor | | | | 0 | 0 | 0 | US$/kW |
| | No transmission | | | | 0 | 0 | 0 | |
| | - km | | | | 0 | 0 | 0 | |
| | No substation | | | | 0 | 0 | 0 | |
| | - MVA | | | | 0 | 0 | 0 | |
| | No distribution | | | | 0 | 0 | 0 | |
| | 0% Dx load factor | | | | | | | |



Summary of generation costs for all generation technologies

All years

Go to Options Sel

Description of this sheet:
Contains the calculated costs for each generation technology type

Cost components

| Technology type | Min Plant capacity | Max Net annual production | Plant capacity factor | Unit generation cost US$/kWh 2010 | 2015 | 2020 | Capital investment cost US$/kW 2010 | 2015 | 2020 | Levelised |
|---|---|---|---|---|---|---|---|---|---|---|
| Off-peak electricity from the grid | | | | 6.00 | 7.48 | 8.23 | | | | |
| Gasoline generator (micro) | 0.0003 | 0.8 | 30% | 57.37 | 63.85 | 64.74 | 147.48 | 144.68 | 151.50 | 18. |
| Gasoline generator (mini) | 0.001 | 2.8 | 30% | 45.67 | 50.89 | 51.53 | 144.40 | 141.65 | 148.33 | 17. |
| Diesel generator (mini) | 0.1 | 700.8 | 80% | 21.16 | 23.27 | 24.04 | 783.77 | 768.89 | 805.14 | 97. |
| Diesel generator (small) | 5 | 4,380.0 | 10% | 24.22 | 25.99 | 27.06 | 505.71 | 494.56 | 517.19 | 57. |
| Diesel generator (large) | 25 | 175,200.0 | 80% | 15.80 | 17.47 | 17.98 | 422.30 | 412.86 | 431.63 | 31. |
| Gas generator (small) | 0.1 | 700.8 | 80% | 12.30 | 13.52 | 17.42 | 1,282.20 | 1,255.10 | 1,311.85 | 94. |
| Gas generator (large) | 5 | 4,380.0 | 10% | 19.17 | 20.21 | 23.82 | 723.60 | 707.61 | 740.01 | 53. |
| Micro gas turbine | 0.15 | 1,351.2 | 80% | 7.29 | 8.23 | 12.19 | 1,197.82 | 1,201.14 | 1,271.04 | 88. |
| Fuel cell (small) | 0.025 | 175.2 | 80% | 13.87 | 14.39 | 17.17 | 6,521.64 | 6,321.16 | 6,131.63 | 479. |
| Fuel cell (large) | 1 | 7,008.0 | 80% | 12.68 | 12.99 | 16.06 | 5,391.27 | 4,977.53 | 5,068.85 | 396. |
| Oil/Gas Combustion Turbine (E-type) | 150 | 130,886.0 | 10% | 13.58 | 14.23 | 18.12 | 906.27 | 875.09 | 910.38 | 58. |
| Oil/Gas Combustion Turbine (F-type) | 250 | 216,810.0 | 10% | 11.74 | 12.44 | 16.24 | 996.39 | 972.86 | 700.07 | 44. |
| Oil/Gas Combined Cycle (CCGT, E-type) | 450 | 3,090,528.0 | 80% | 4.84 | 5.38 | 7.85 | 1,104.30 | 1,057.06 | 1,091.31 | 70. |
| Oil/Gas Combined Cycle (CCGT, F-type) | 650 | 4,464,096.0 | 80% | 4.49 | 4.99 | 7.28 | 1,000.72 | 957.91 | 989.86 | 64. |
| Oil/Gas Combined Cycle (CCGT, G-type) | 800 | 5,494,272.0 | 80% | 4.15 | 4.61 | 6.72 | 921.45 | 882.04 | 911.45 | 58. |
| Coal Subcritical | 300 | 1,997,280.0 | 80% | 5.43 | 5.38 | 7.91 | 1,852.56 | 1,773.23 | 1,866.04 | 105. |
| Coal Supercritical | 500 | 3,328,800.0 | 80% | 5.12 | 4.81 | 7.30 | 1,898.49 | 1,837.03 | 1,924.96 | 109. |
| Coal Ultra Supercritical | 500 | 3,328,800.0 | 80% | 5.31 | 5.30 | 7.42 | 2,176.35 | 2,105.71 | 2,208.79 | 125. |
| Coal Supercritical with CCS | 500 | 3,153,600.0 | 80% | 7.69 | 7.31 | 10.34 | 3,244.89 | 3,117.88 | 3,252.74 | 187. |
| Coal IGCC without CCS | 500 | 3,153,600.0 | 80% | 6.21 | 5.34 | 7.26 | 2,705.75 | 1,985.76 | 1,457.36 | 156. |
| Coal IGCC with CCS | 500 | 3,048,480.0 | 80% | 8.46 | 8.30 | 10.69 | 4,234.12 | 3,996.34 | 3,843.25 | 244. |
| Coal CFB (subcritical) | 300 | 1,997,280.0 | 80% | 4.58 | 4.23 | 7.02 | 1,476.96 | 1,424.48 | 1,492.13 | 85. |
| Coal CFB (supercritical) | 500 | 3,328,800.0 | 80% | 4.76 | 4.48 | 7.04 | 1,766.98 | 1,766.66 | 1,784.66 | 102. |
| Oil steam (subcritical) | 500 | 2,018,304.0 | 80% | 9.05 | 9.80 | 11.23 | 1,033.75 | 1,015.65 | 1,071.91 | 59. |
| Gas steam (supercritical) | 500 | 3,363,840.0 | 80% | 5.75 | 6.45 | 9.49 | 1,049.70 | 1,031.33 | 1,088.45 | 60. |

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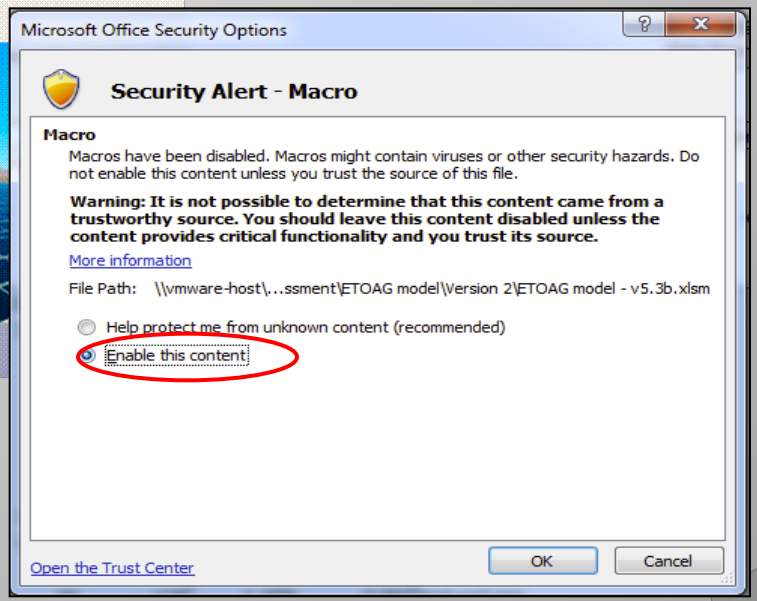
What is META?

How is it structured?

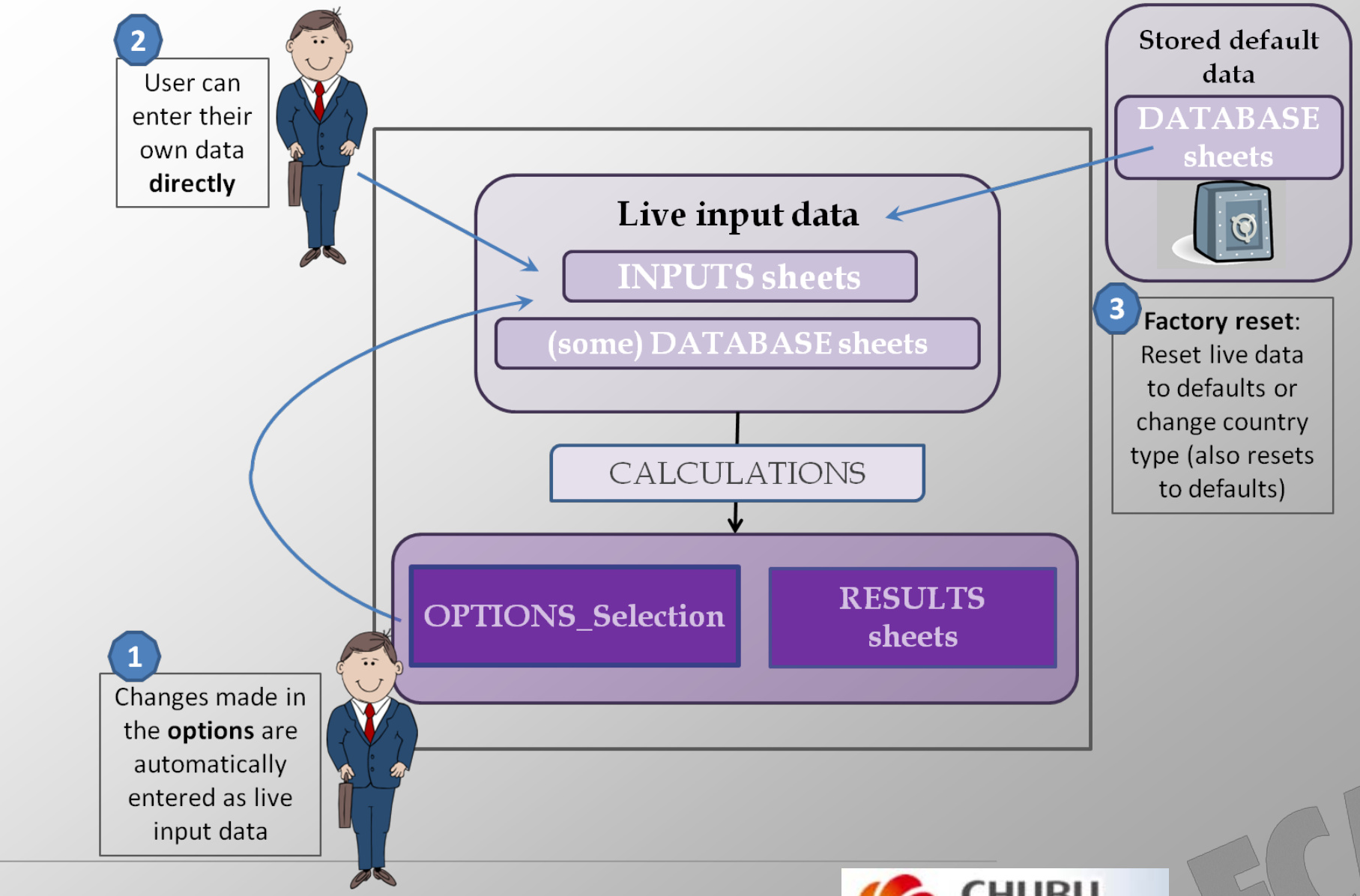
**How do I use it?**

What about the other details?

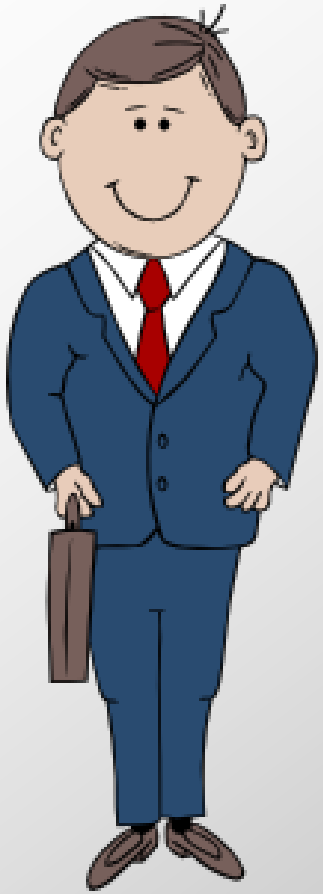
# Start: MUST Enable Macros

# 3 ways to change the live inputs



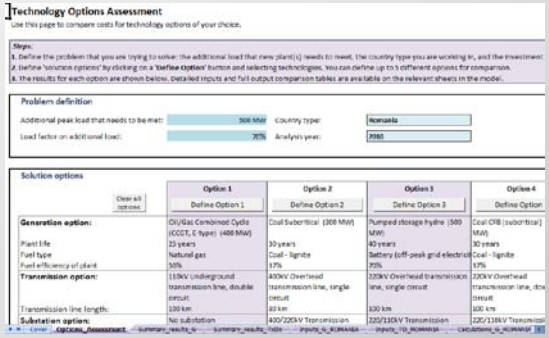
# General users



- First stop: OPTIONS_Selection 1
- Would focus on 2 screens:
  - OPTIONS_Selection
  - OPTIONS_Results
- User can:
  - Select options
  - Compare results
  - Change options
  - Compare again

# OPTIONS_ Selection screen

- Mission Control
- A one-stop shop
- Allows the user to define different technology options:
  - Select a generation technology
  - Specify delivery technologies
    - Grid, mini-grid, off-grid
  - Define key variables
- User can define up to 5 options
- Model then gives comparison of results for all 5


Technology Options Assessment

Use this page to compare costs for technology options of your choice.

Steps:

1. Define the problem that you are trying to solve: the additional load that new plant(s) needs to meet, the country type you are working in, and the investment
2. Define 'solution options' by clicking on a 'Define Option' button and selecting technologies. You can define up to 5 different options for comparison.
3. The results for each option are shown below. Detailed inputs and full output comparison tables are available on the relevant sheets in the model.

Problem definition

Additional peak load that needs to be met: 300 MW  Country type: Romania

Load factor on additional load: 70%  Analysis year: 2030

Solution options

Clear all options

| | Option 1 | Option 2 | Option 3 | Option 4 |
|---|---|---|---|---|
| | Define Option 1 | Define Option 2 | Define Option 3 | Define Option |
| **Generation option:** | Oil/Gas Combined Cycle (CCGT, E-type) (400 MW) | Coal Subcritical (300 MW) | Pumped storage hydro (500 MW) | Coal CFB (subcritical) (300 MW) |
| Plant life | 25 years | 30 years | 40 years | 30 years |
| Fuel type | Natural gas | Coal - lignite | Battery (off-peak grid electricity) | Coal - lignite |
| Fuel efficiency of plant | 56% | 37% | 75% | 37% |
| **Transmission option:** | 110kV Underground transmission line, double circuit | 400kV Overhead transmission line, single circuit | 220kV Overhead transmission line, single circuit | 220kV Overhead transmission line, double circuit |
| Transmission line length: | 100 km | 80 km | 100 km | 100 km |
| **Substation option:** | No substation | 400/220kV Transmission | 220/110kV Transmission | 220/110kV Transmission |

Options_Assessment | Summary_results_G | Summary_results_HDH | Inputs_G_ROMANIA | Inputs_TD_ROMANIA | Calculations_G_ROMANIA

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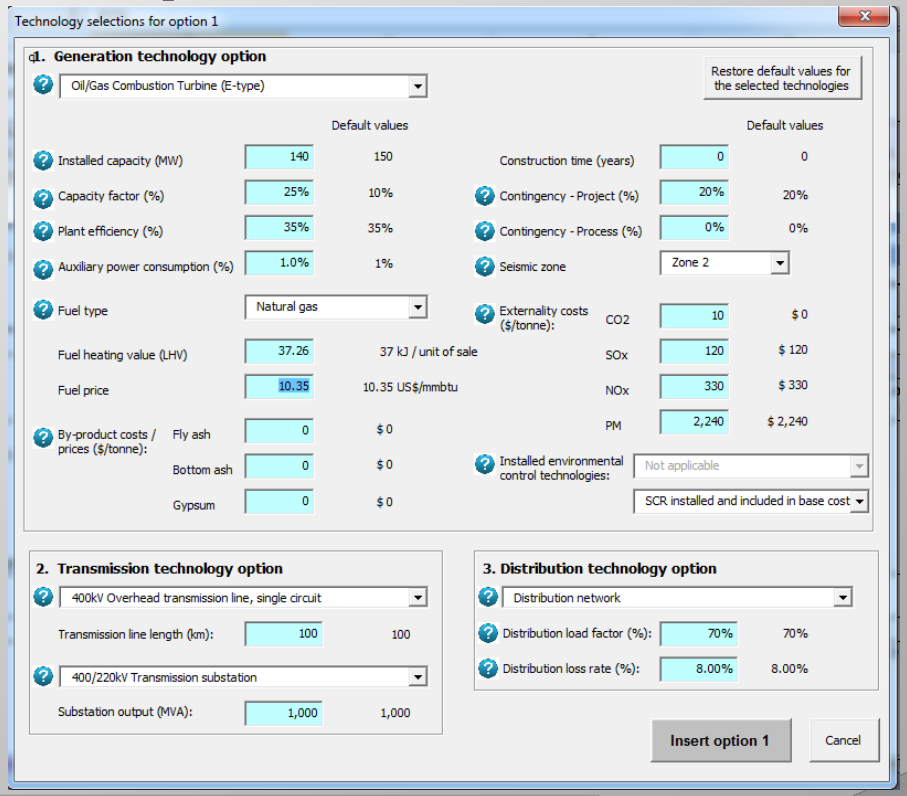
# OPTIONS_ Selection screen

- Designed to be user-friendly:
- Pop-up boxes
- Drop-down menus
- User-inputs



# OPTIONS_ Selection screen

- **Allows easy comparison of technologies**
- **Shows results for user's options side-by-side**
- **Allows easy comparison of costs**

Define Option 1 | Define Option 2 | Define Option 3

| Cost comparison | Option 1<br>Oil/Gas Combustion Turbine (E-type), operating at 25% CF | Option 2<br>Coal Supercritical with CCS, operating at 80% CF | Option 3<br>PWR (VVER), operating at 85% CF |
|---|---|---|---|
| Energy cost | 14.62 USc/kWh | 6.49 USc/kWh | 3.82 USc/kWh |
| *including environmental costs of:* | 0.57 USc/kWh | 0.96 USc/kWh | - |
| Transmission cost | 0.69 USc/kWh | 0.06 USc/kWh | no transmission |
| Substation cost | 0.82 USc/kWh | 0.07 USc/kWh | no substn. |
| Distribution cost | 3.18 USc/kWh | 3.18 USc/kWh | no distn. |
| **Total delivered energy cost (USc/kWh)** | **19.31 USc/kWh** | **9.80 USc/kWh** | **3.82 USc/kWh** |

| Summary of key inputs | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Generation technology | Oil/Gas Combustion Turbine (E-type) | Coal Supercritical with CCS | PWR (VVER) |
| Plant capacity | 140.0 MW | 500.0 MW | 1,200.0 MW |
| Capacity factor (%) | 25% | 80% | 85% |
| Plant efficiency (%) | 35% | 33% | 33% |
| Auxiliary power consumption (%) | 1% | 13% | 4% |
| Fuel type | Natural gas | Coal - Bituminous | Uranium (enriched) |
| Fuel heating value: | 37.26 MJ/m3 | 15,816 MJ/T | 3,900 GJ/kg |

# Quick glossary

## Sheet name conventions:

| Sheet identifiers | Example |
|---|---|
| INPUTS_ | INPUTS_Gen |
| CALCULATIONS_ | CALCULATIONS_TxDx |
| _Results | GEN_Results |
| DATABASE_ | DATABASE_Environmental |
| OPTIONS_ | OPTIONS_Selection |

- ***Gen* is Generation**
- ***TxDx* is Transmission and Distribution**

What is META?

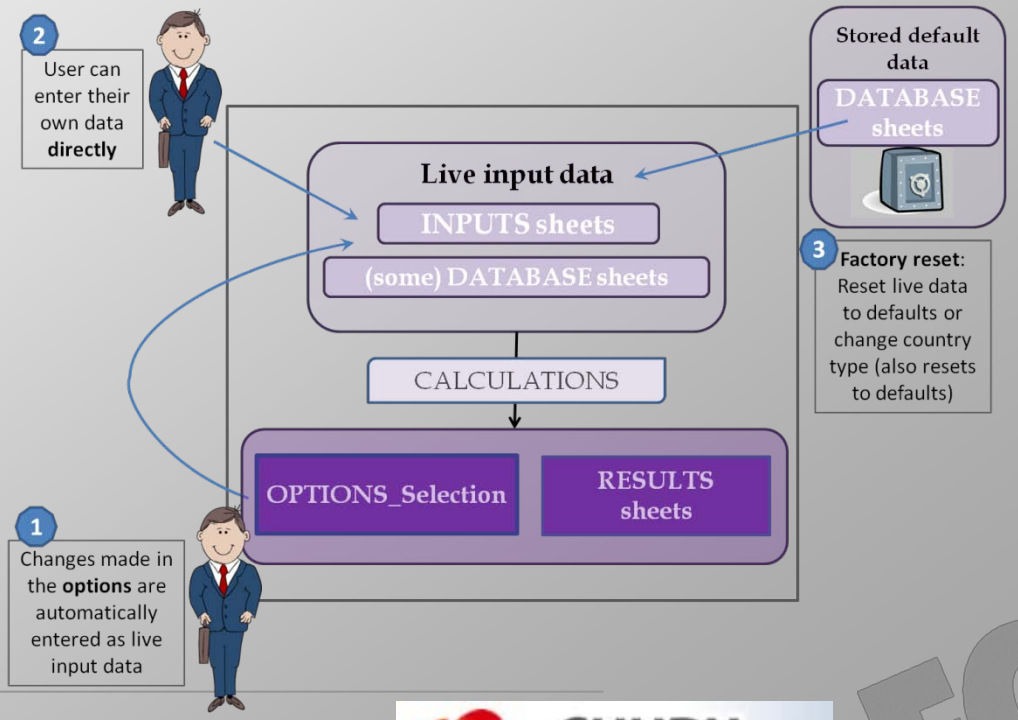
How is it structured?

How do I use it?

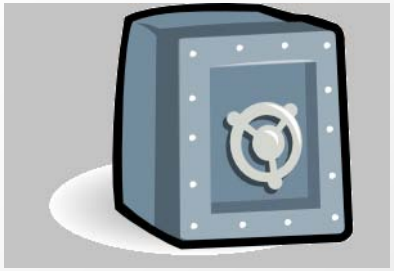
**What about the other details?**

# Advanced users

- Would want to look at the details
- Might want to enter data directly into the input sheets 2
- Might want to change the default inputs in the database sheets 3



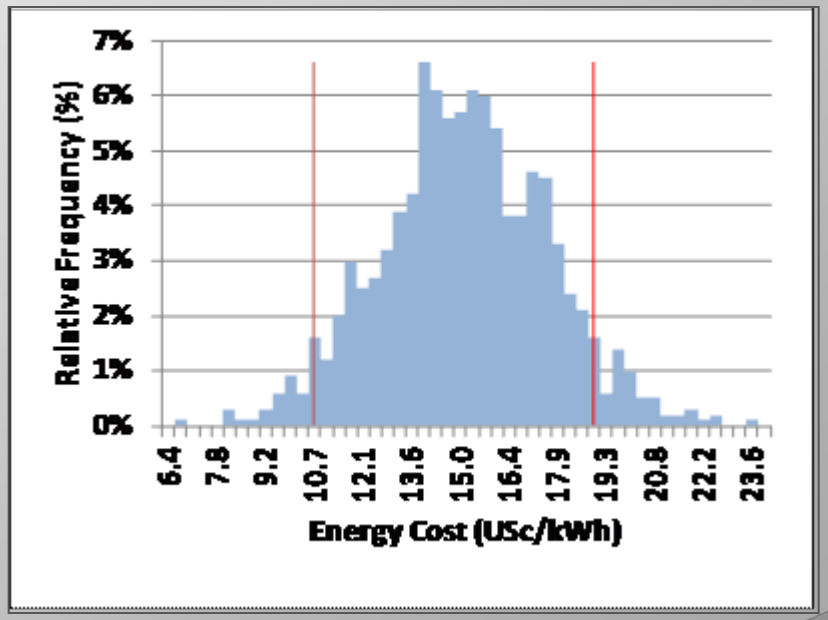
# DATABASE sheets



- Store the default data for each base country:
  - Generation technologies
  - Transmission and distribution technologies
  - Commodity and fuel prices
  - Other input data

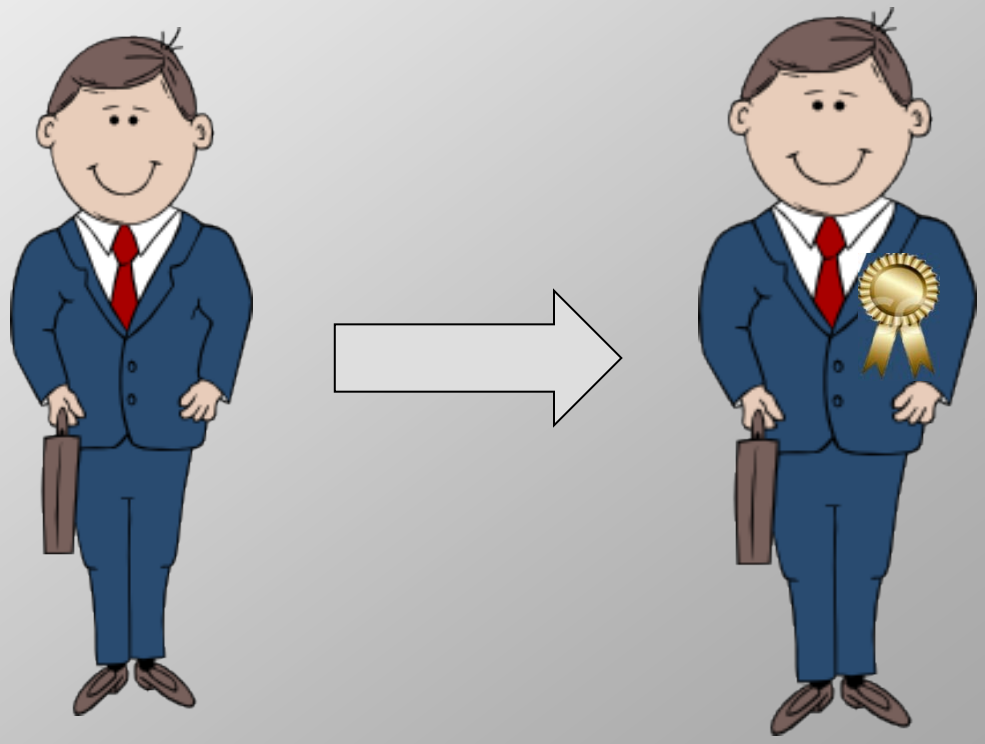
# Uncertainty analysis module

- Monte Carlo simulation tool
- Uses an Excel add-in called @risk
- User must buy a separate licence for @risk

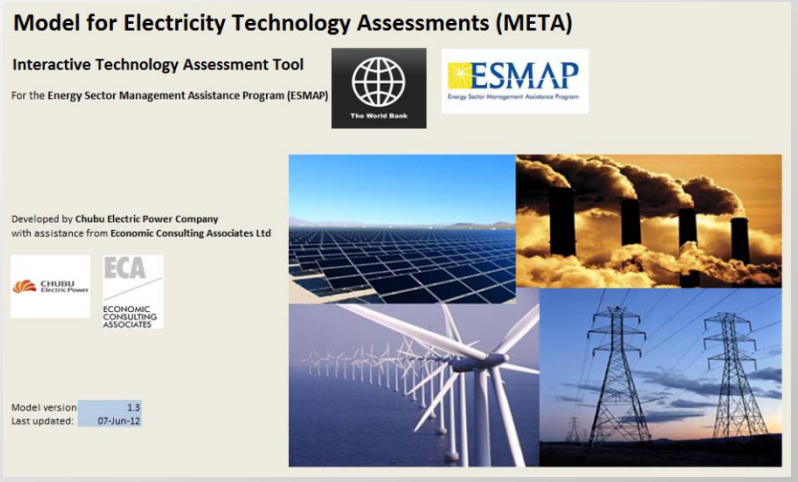


# Hands-on training

- **Afternoon session:**
- **hands-on training in detailed use of the model**



# Model for Electricity Technology Assessments (META)

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## Washington D.C., June 2012

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