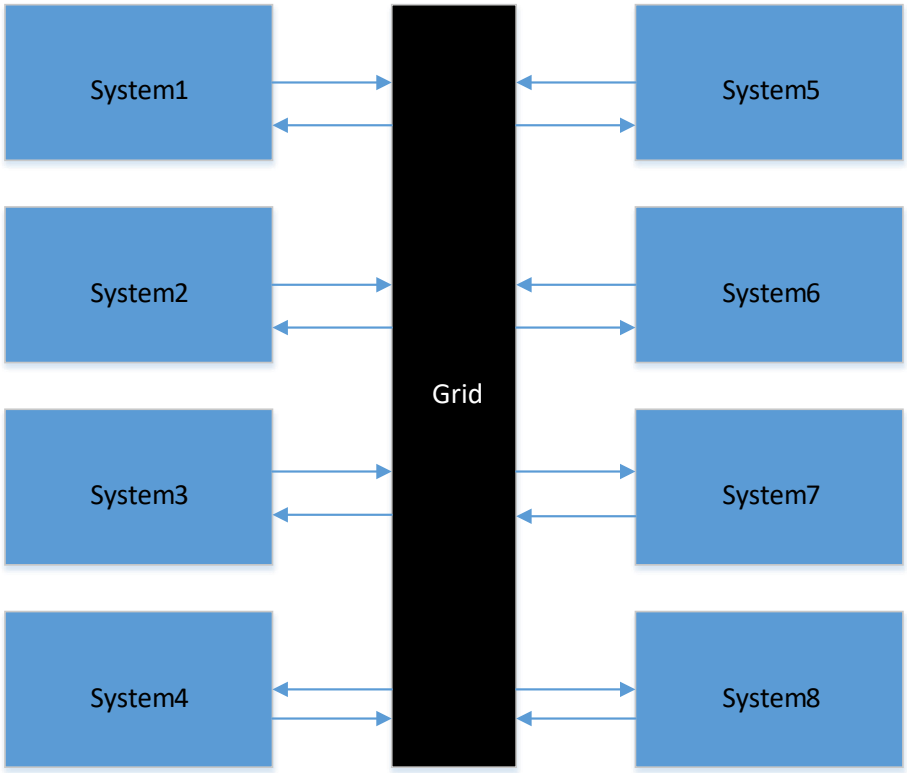
Energy PLAN

Advanced energy system analysis computer model

MultiNode v2 for EnergyPLAN Documentation



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Preface

The MultiNode add-on tool for EnergyPLAN was initially developed as a central part of the PhD project "Energy System Analysis of Multiple Systems". The PhD was part of the Centre for IT–Intelligent Energy System in Cities (CITIES) Research Project funded by Innovation Fund Denmark. The tools draw on research and development related to EnergyPLAN, the 4DH Research Center also funded by Innovation Fund Denmark, and the various Heat Roadmap Europe Studies.

Since the initial version of MultiNode, developed in 2016 for EnergyPLAN V12 and the current version 16.3 of EnergyPLAN, the structure of the files that describe EnergyPLAN system models has changed. Therefore, to use the original tool, it is necessary to use only part of the available options. The way to use the MultiNode original tool with the current version is described at the end of this document.

This manual describes the updates of MultiNode tool for the current version of EnergyPLAN, with a new graphical user interface and an update to the algorithm that defines the cross-border flows between the nodes. This tool was named MultiNode2.

Carlos Santos Silva, Prof. IST/U Lisboa has done the major development of MultiNode2, with the support and guidance of Henrik Lund, Prof. AAU and Jakob Zinck Thellufsen, Prof. AAU (who has done the main development of the tool with assistant and feedback from Henrik Lund, Prof. AAU, and Anders N. Andersen and Henning Mæng from EMD International).

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The MultiNode Concept in EnergyPLAN

The goal of the MultiNode Add-on Tool to EnergyPLAN is to be able to run and link several EnergyPLAN analyses. The concept currently only looks at the electricity sector and defines the link through the cross-border connection.

MultiNode has the possibility of linking between 2 or more systems. These energy systems can be of all kind of sizes, meaning it is suitable to run both on local connected systems like energy communities, regional or national analyses and even linking multiple national energy systems, e.g. the European Union.

MultiNode is an add-on tool that utilizes EnergyPLAN as a base framework. Therefore, MultiNode does not make changes to the way EnergyPLAN runs.

Figure 1 shows the overall concept of the MultiNode add on tool. The figure illustrates how the tool identifies exchange options.

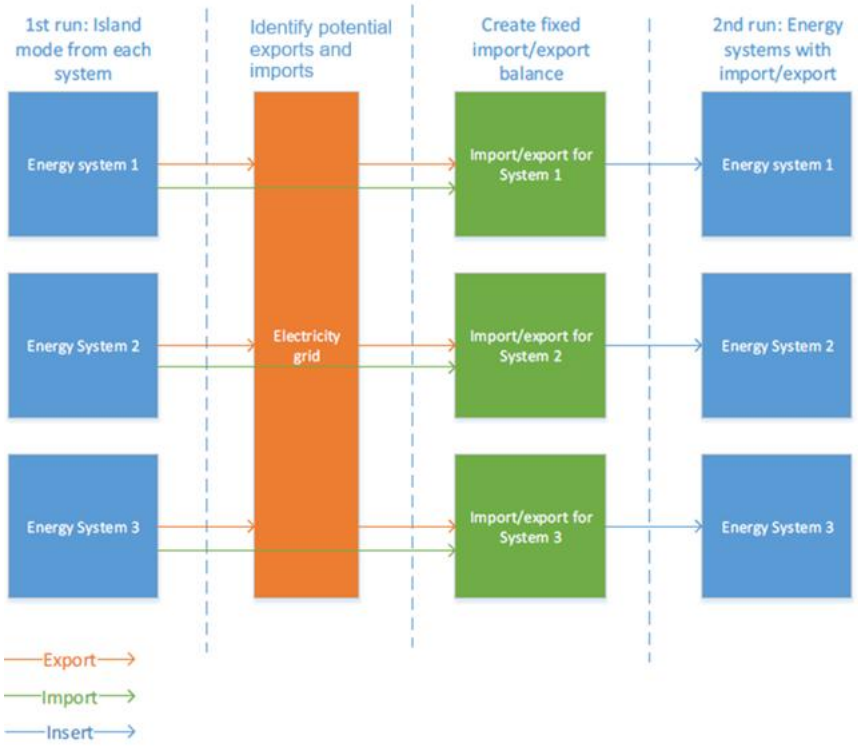


Figure 1 - MultiNode framework

First, MultiNode runs all selected energy systems. From this analysis, MultiNode identifies two sets of information for each system:

1) the hourly amount of exportable electricity and
2) the potential for electricity import every hour.

The potential import demand is computed as hours with:

- Lack of sufficient capacity
- Hours with fossil fuel power plant production

From the information regarding the hourly available exportable electricity and hourly potential for importing electricity, MultiNode then links the exportable electricity in some nodes with the demand for import in the other nodes.

Each individual energy system will get access to the electricity available for import and export based on a merit order, defined by the order in which the systems are defined (first system1, then system2, etc.)

After defining how much can be imported and exported in each of the energy systems, an import/export balance is created for each energy system.

Note that the tool uses a total grid capacity for transmission since it views the electricity grid as one unison between all systems that have a defined grid capacity over zero.

Finally, the MultiNode add-on tool runs each of the selected energy systems again now with the information regarding import and export, which is used as fixed imports/exports.

MultiNode2 algorithm

The algorithm of multimode is explained considering the generic example described in **Error! Reference source not found.**, with 8 isolated systems interconnected)

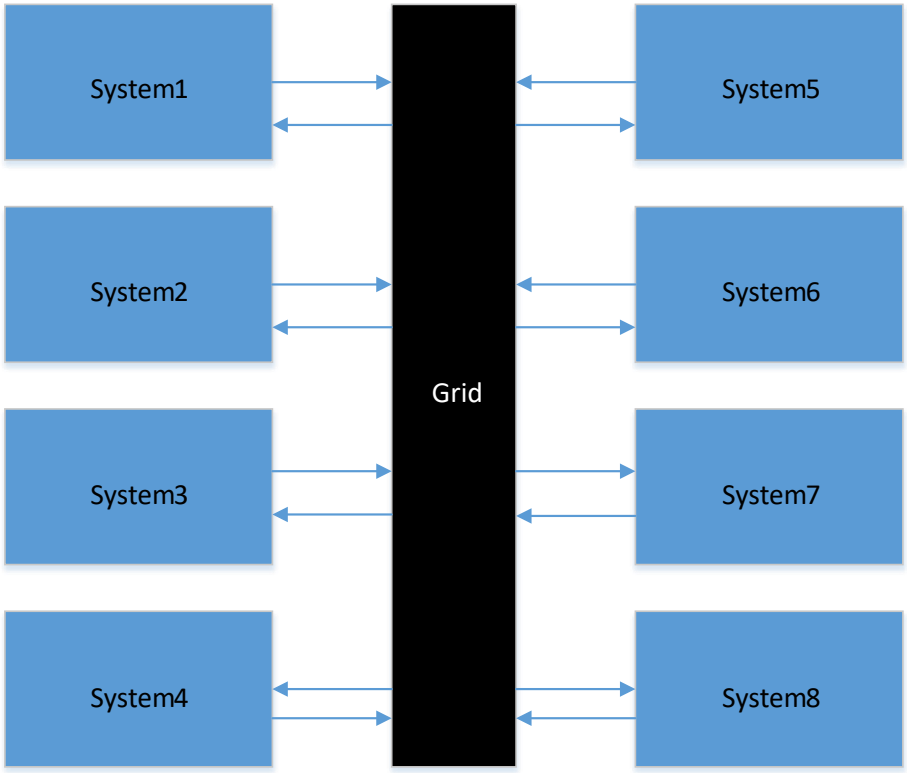


Figure 2 – Connection between 8 nodes

The first step consists in defining the system model for each node. These models should follow the rules:

- The models of the different nodes should be defined using the same capacity and energy units (check the Settings menu)
- The system should not consider the existence of a transmission capacity with other systems. In the tab "Supply->Central Power Production" consider a *Transmission line capacity* of 0

Then, multimode will run the model for each node and use the outputs of the model to implement the multimode algorithm.

Potential exports from each node

The excess electricity generation in each node is available to be exported within the limit of the transmission line capacity of that node.

$$Potential_{exports_i} = MIN(exports_i, Capacity_i)$$

Total available exports

The total exports describe the available electricity that is available at each hour in the interconnection between all nodes and that can be used by all systems.

$$exports_{total} = \sum_{i=1}^{n} Potential_{exports_i}$$

Potential imports

The potential imports describe the electricity that is required to supply the demand that cannot be provided by the existing power facilities (variable or dispatchable renewables, CHP, PP). However, if part of the demand is being supplied by fossil fuel power plants, the imports could be used to replace also the power plants generation except for the amount required to stabilize the grid and within the limits of the transmission line capacity. In this way, for each node, the potential imports at each hour can be defined as:

$$Potential_{imports_i} = MIN(imports_i + (PP_i - stabilization_i), Capacity_i)$$

Real imports for each node

The different nodes that are importing maybe competing for the total exports. Multinode assumes a merit order purely based on the order of the systems. In this way the total exports will assigned first supply the imports from node 1, then to node 2 all the way until node n. In this way we estimate the real imports for each node using the following formula

$$\boldsymbol{if}\ Potential_{exports_i} > 0, \boldsymbol{then}\ Real_{imports_i} = 0$$

$$\boldsymbol{else}\ Real_{imports_i} = \begin{cases} MIN\left(Potential_{imports_1},\ exports_{total}\right), for\ i = 1 \\ MIN\left(Potential_{imports_i},\ exports_{total} - \sum_{k=1}^{i-1} Real_{imports_k}\right), for\ i > 1 \end{cases}$$

In this formula we assume that if a node has exports, it will not import, even if the potential imports exist (it means that the fossil fuel power plants that generate potential imports are switched on to guarantee the system stability).

We are deducing from the total exports the imports that were made available to previous nodes. We also use the MIN operator to make sure that if a node has higher potential imports than what is available in total exports, then the available imports will be at the most what is remaining in the total exports.

Total Real imports

Eventually, not all available exports have been used, so we need to reduce the export level in the nodes. In this case we add all real imports in a total real imports, which will be the same as the total real exports.

$$Real_{imports_{total}} = \sum_{i=1}^{n} Real_{imports_i}$$

Real exports for each node

Then using the same merit order, we deduce the real imports from the potential exports to calculate the real exports, following the same merit order.

$$\boldsymbol{if}\ Real_{imports_i} > 0, \boldsymbol{then}\ Real_{exports_i} = 0$$

$$\boldsymbol{else}\ Real_{exports_i} = \begin{cases} MIN\left(Potential_{exports_1},\ Real_{imports_{total}}\right), for\ i = 1 \\ MIN\left(Potential_{exports_i},\ Real_{imports_{total}} - \sum_{k=1}^{i-1} Real_{exports_k}\right), for\ i > 1 \end{cases}$$

The balance for each node

After calculating what are the real imports and real exports, we can estimate the balance for each node, where the exports are assumed to be positive and the imports are assumed to be negative:

$$Balance_i = Real_{exports_i} - Real_{imports_i}$$

A distribution file $Dist_i.txt$ with the $Balance_i$ distribution is created for each node and this will be used as the fixed import/exports when the tool runs the system again.

Using the MultiNode2 tool

Installation

The executable file MULTINODE2.exe can be downloaded at the GitHub CarlosSantosSilvaTecnico/EnergyPLAN_tools repository and copied directly to the "energyPlan Tools" folder of energyPLAN (Figure 3).

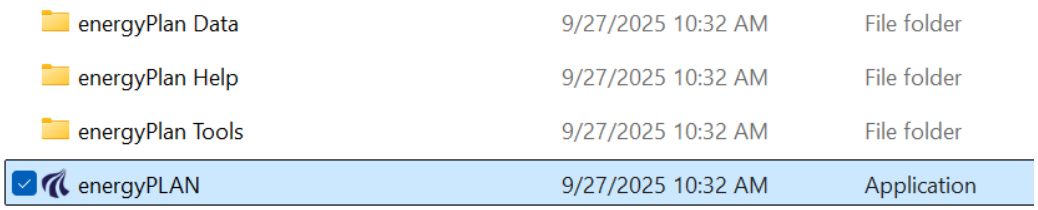


Figure 3 - EnergyPLAN folder structure

When the executable file is available in "energyPlan Tools" folder (see Figure 4), it will be visible in the Add-on Tools menu in EnergyPLAN (see Figure 5)

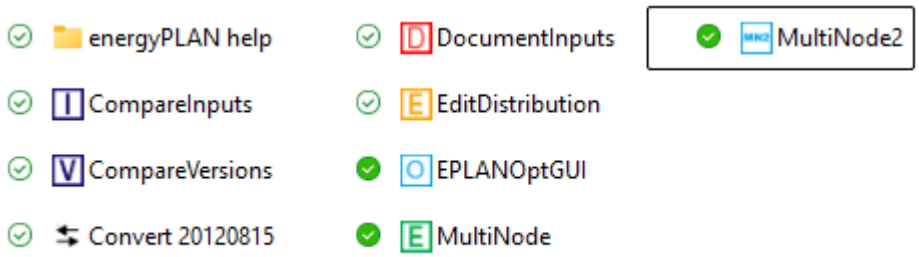


Figure 4 - EnergyPLAN tools folder contents

Using MultiNode2

In EnergyPLAN main window, go to the tab "Add-On Tools" and the tool will be available together with other add-ons.

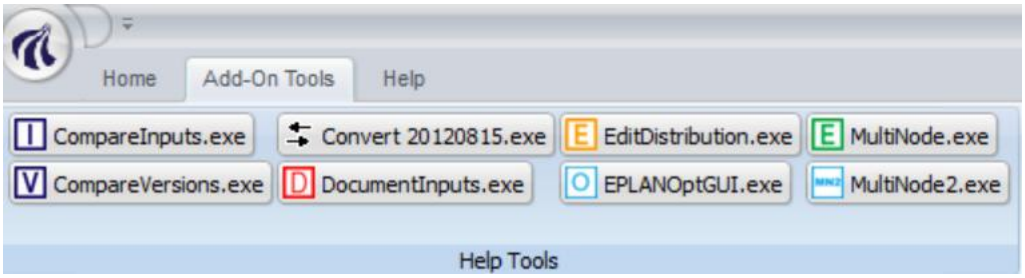


Figure 5 - Accessing EPLANoptGUI from the Add-on Tools menu in EnergyPLAN.

When clicking the MultiNode2.exe application (see Figure 5), the tool will open the following application window (see Figure 6).

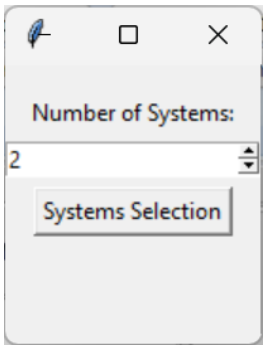


Figure 6 – MultiNode2 initial window.

In this window, you need to indicate how many systems/nodes will be connected to each other. In this version, there is no limit to the maximum number of nodes that you can connect to. After adding the number of nodes, please click "System Selection" and the main window will appear, as represented in Figure 7. Since the user chose 2 systems, only two lines will appear to define the system.

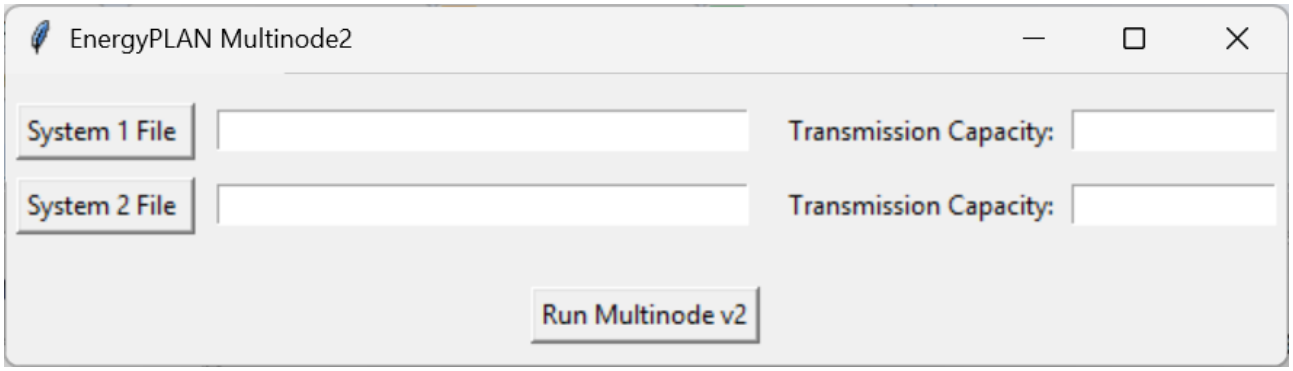


Figure 7 - MultiNode2 main window

In this tab:

- the users define the input files of the systems
- the users define the transmission capacity of each system
- the user runs the tool.

To choose the first system, please click the button "System File 1". He dialog window to choose files shown in Figure 8 will appear.

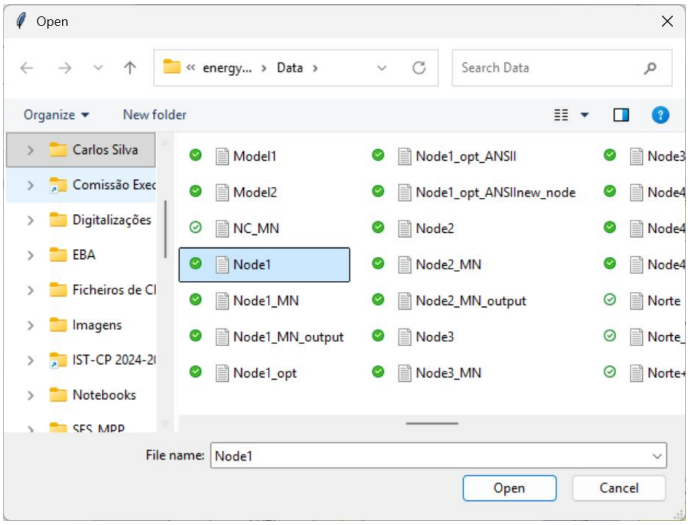


Figure 8 - Choose the system that is considered to be the first node.

The input file is identified in the text box next to the button "System File 1". Then please define the transmission capacity considered for the system by adding an integer (in the capacity units defined for system 1), as represented in Figure 9.

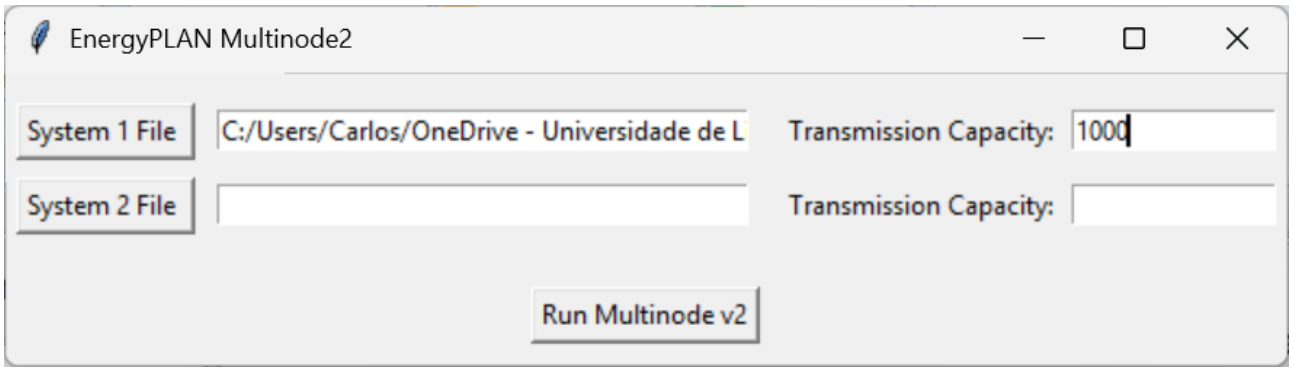


Figure 9 - Defining the transmission capacity of a system.

Then, repeat the process for all the remaining systems. Please notice that the energy units definition of all systems must be alike (this is not verified by the current version). In this case, since there are only two systems, it is necessary to define a second System File 2 and its transmission capacity (in this case is considered to be the same). Then click the "Run Multinode V2" button, as shown in Figure 10.

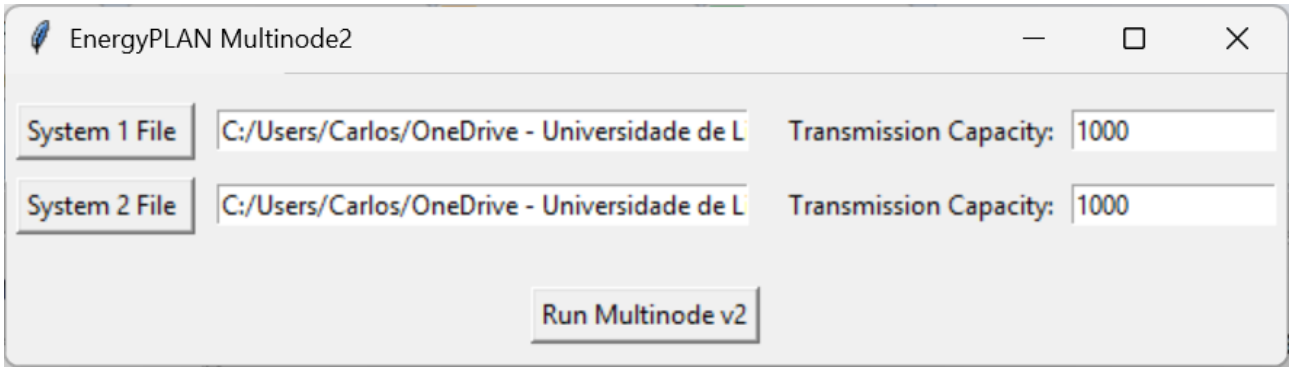


Figure 10 - All systems defined

The MultiNode algorithm s divided into 3 steps:

1) first it runs each node model as is;

2) then it creates the Dist1.txt, Dist2.txt, DistN.txt files in the Distributions folder. These are the files of the distribution of imports and exports calculated by MultiNode, as represented in Figure 11.

Figure 11 - Dist1.txt and Dist2.txt files created for the current example.

3) Finally, the tool runs each node model with fixed-import-export using Dist1, Dist2, DistN files. These updated system models are named SystemName1_MN.txt, SystemName2_MN.txt, SystemNameN_MN.txt, as represented in

Figure 12 - Node1_MN.txt and Node2_MN.txt files created by MultiNode

In this file, as shown in Figure 13, the MultiNode2 tool has added the Dist1.txt file and the fixed import/export distribution and has added the energy balance from that distribution.

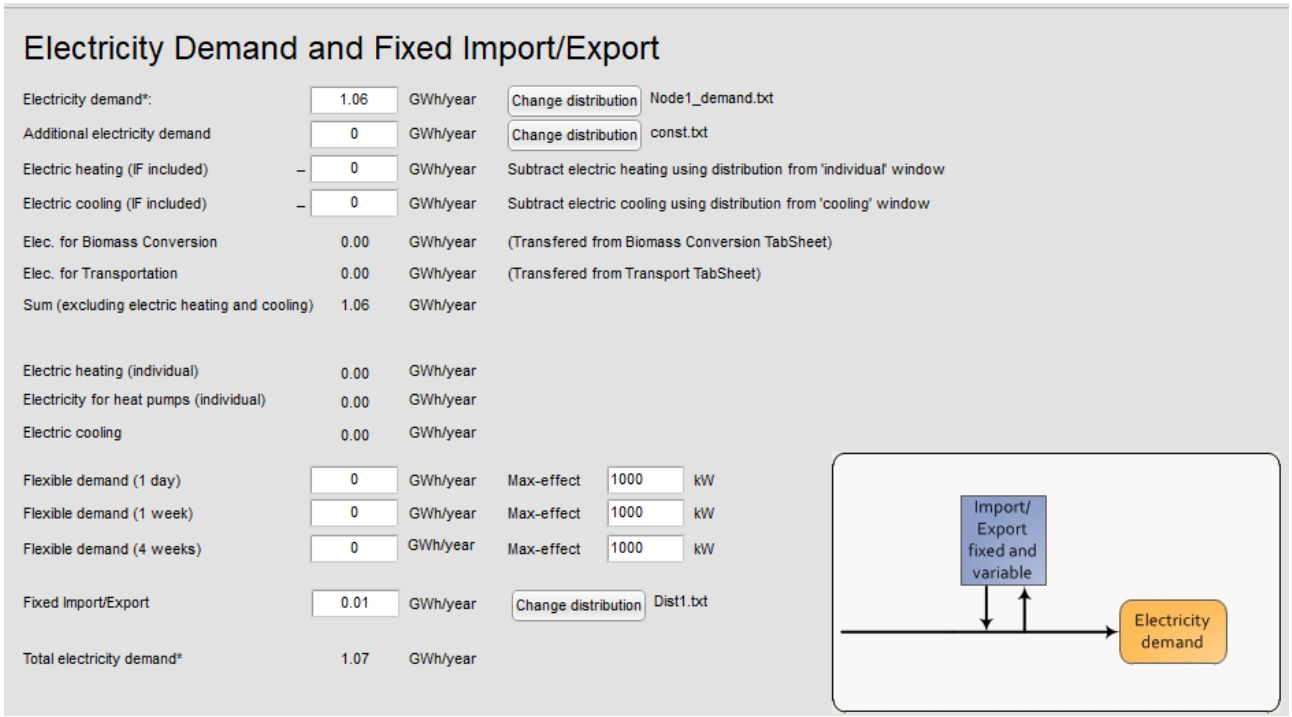


Figure 13 - Electricity Demand and Fixed Import/Export window of Node1_MN.txt file

Using the Original MultiNode add-on with current versions of EnergyPLAN

The original MultiNode graphical user interface is structured in four tabs:

- The “Front page” where the user defines the model and runs the different parts;
- The “Input files” where the user defines the different energy plan systems and the transmission capacities;
- The “Settings” where the user defines energy units and RES sources.

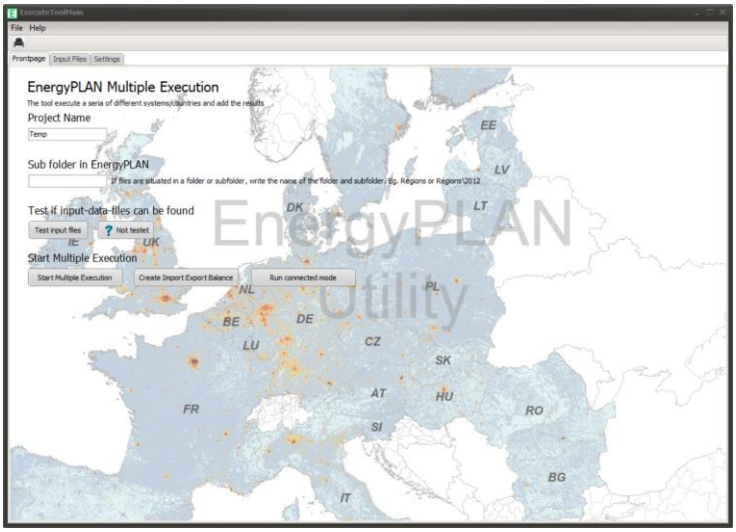


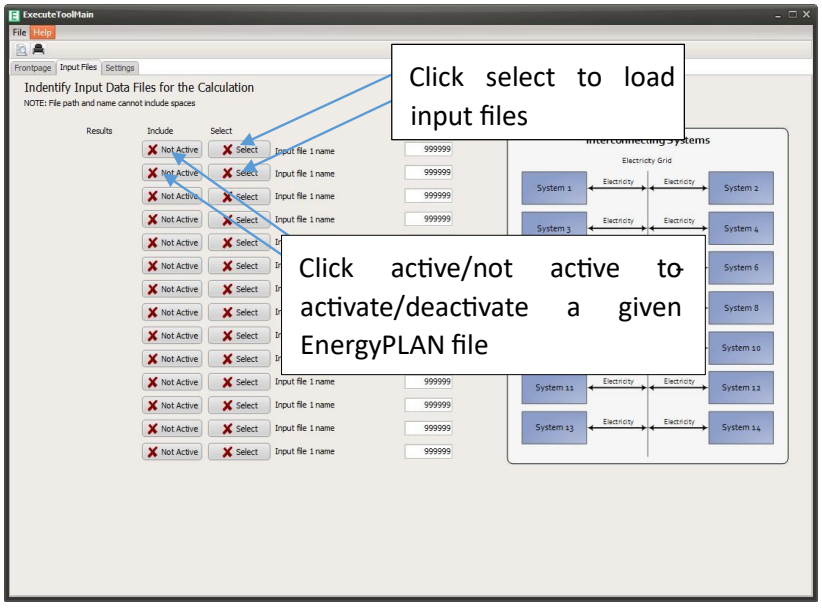
Figure 14 - Frontpage of the original MultiNode tool

The following takes you through the tabs, to run your model successfully.

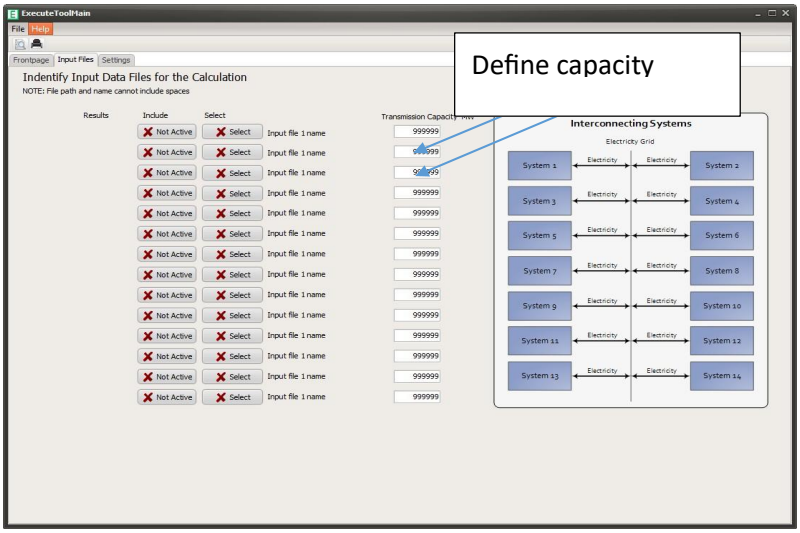
Go to input files and select the number of EnergyPLAN systems you want to connect. Click select to load the files.

Click the “active” button to deactivate a file if you do not want to include it in a given analysis.

Make sure the systems were defined with Transmission line capacity=0 in the **Supply->Central Power Production** tab

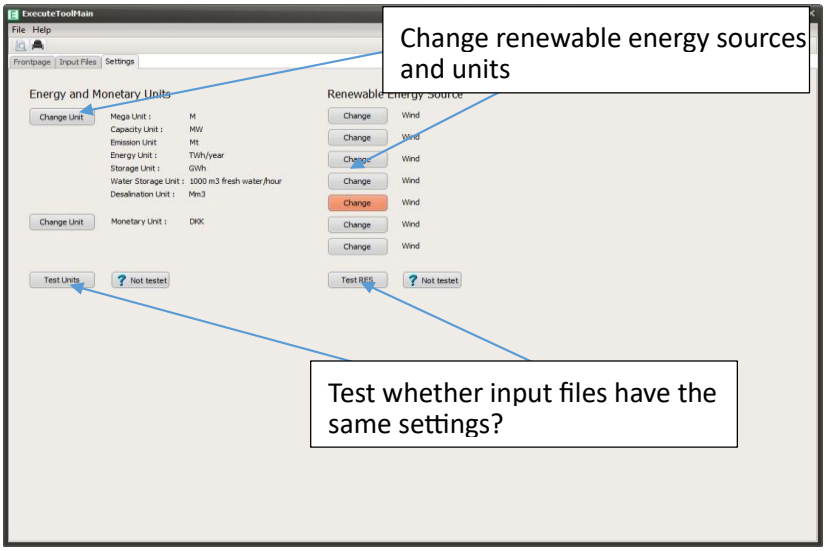


Define transmission capacity from each system going into the grid.

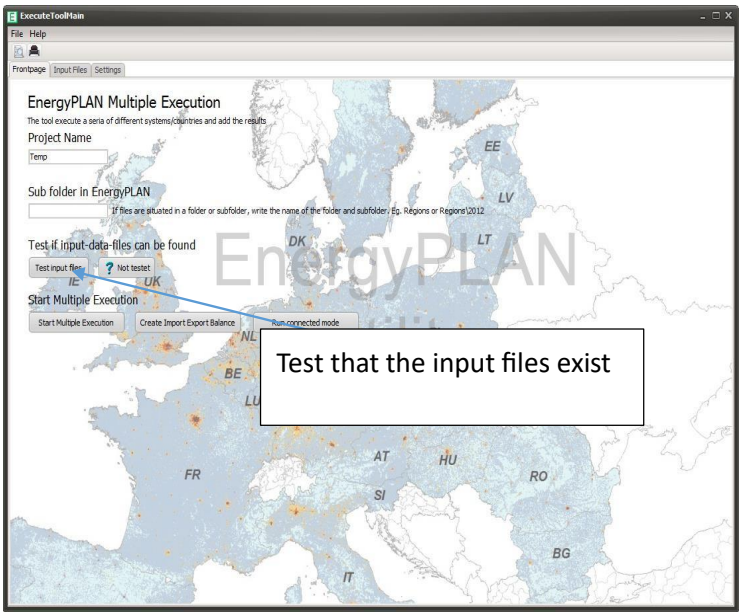


Go to settings to define the size of the system, the currency, and renewable energy technologies. For each setting there is a button that confirms whether the input files are set correct.

These settings are not needed to run the model.

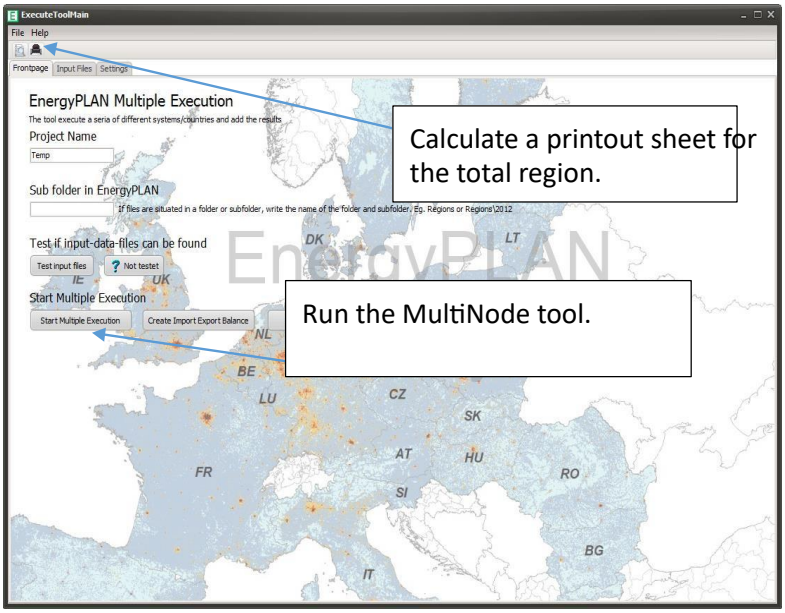


To run the tool the first step is to test that all the input files exist on the front page.

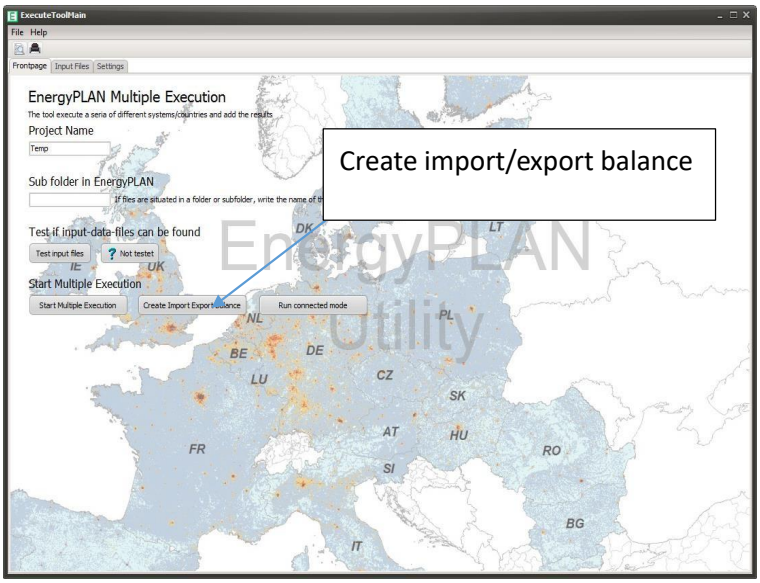


The next step is to press the start Multiple Execution. This will run each EnergyPLAN model as an island mode, and store the results.

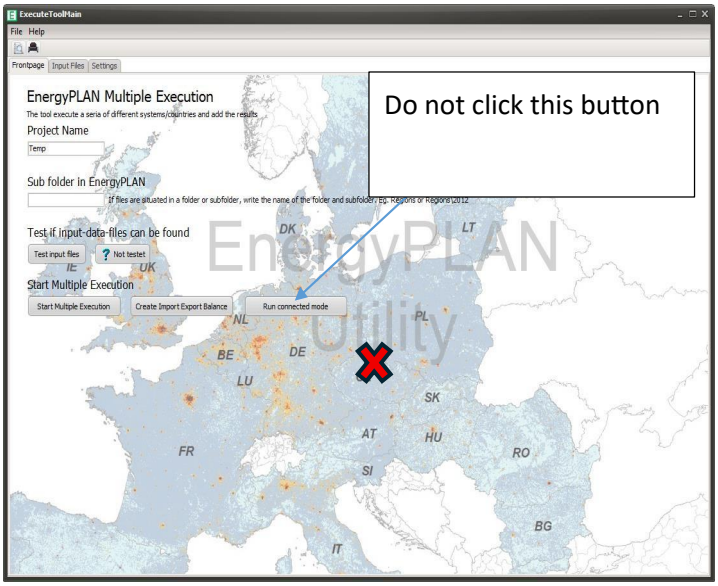
Hereafter, you can create a printout to see how the system operates without interconnection between them.



After that, pressing the create import/export balance will analyze each system, and define how much should be imported and exported to each system. New files called Dist1.txt, Dist2.txt, etc. are created in the Distributions folder.



Do not run the connected mode using this button. See explanation below



Load the model files relative to each system

(system1.txt, system2. txt, etc.) and in the **Demand->Electricity** tab add the Dist1.txt into the Fixed Import-Export and the sum of its values (positive or negative) in the textbox related to the total energy amount.

Finally run the model again.