1 The Invert Simulation Tool

Michael Stadler, Lukas Kranzl, Claus Huber
Energy Economics Group, Vienna University of Technology
Gusshausstraße 25-29/373-2, 1040 Wien
Tel.: +43 1 58801/37361, Fax: +43 1 58801/37397
Email: stadler@eeg.tuwien.ac.at

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1.1 What is Invert?

Invert is a free available comprehensive dynamic bottom-up simulation tool[1] to evaluate the effects of different promotion schemes (investment subsidies, feed-in tariffs, tax exemptions, subsidy on fuel input, CO_2 taxes, soft loans, and additional aside premium) on the energy carrier mix, CO_2 reductions and costs for society due to promoting certain strategies. Furthermore, Invert allows in a very easy way to simulate different scenarios (price scenarios, insulation scenarios, different consumer behaviours, etc.) and the according impact on future trends of renewable as well as conventional energy sources.

Invert is applicable on the existing building stock (for heating, cooling, Domestic Hot Water Systems (DHW), solar thermal), Rational Use of Energy (RUE), as well as Renewable Energy Sources according electricity supply (RES-E) and heat production (RES-CHP) and for bio-fuel production on any region. Due to the flexible design Invert allows comparative and quantitative sensitivity analyses of the interactions between RUE, RES-E, RES-CHP, and Bio Fuels as well as Greenhouse Gas (GHG) -reduction for each selected region.

[1] Developed by the Energy Economics Group, Vienna (EEG) in the course of the project Invert.

1.2 First Steps

Before the tool is described in a more detailed manner a short description about the 'first steps' 'how to download and use the tool' is given in Figure 1.

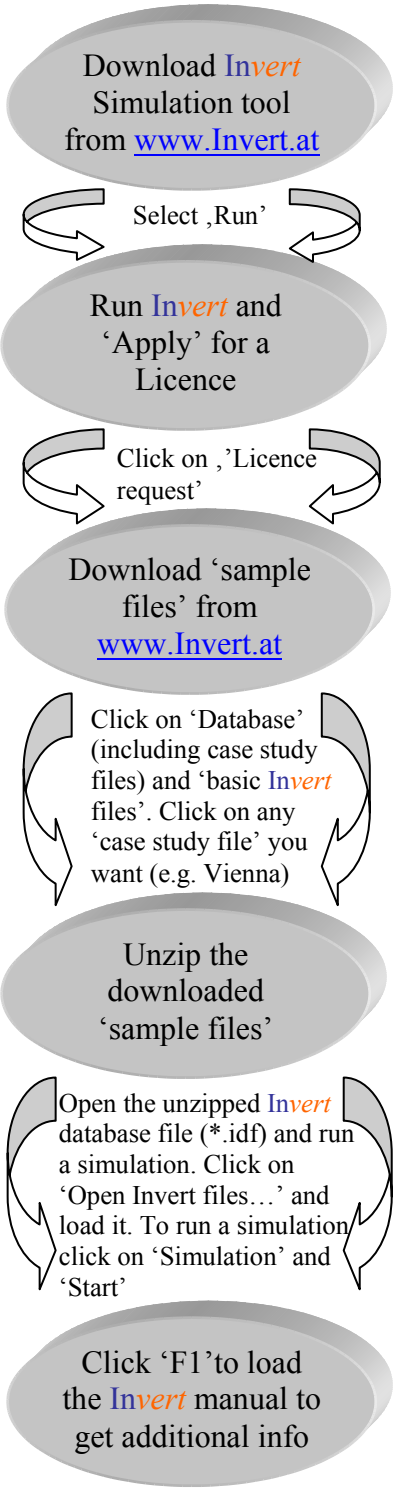

Figure 1: First Steps to run Invert

1.3 Short Description of the Model

1.3.1 Consumers' point of view[2]

The most important background you have to understand is the difference between 'Payback Time' and 'Lifetime' within the model Invert. The simulation tool considers all costs and benefits (e.g. due to solar thermal systems and 'Insulation' as well as 'Windows') for the individual 'Payback Time'. The program neglects all benefits after the 'Payback Time'. With this approach Invert is able to calculate the maximum yearly costs seen by the consumer. Exactly these costs are the important decision making parameters. This approach corresponds with a risk evaluation of the future. This means the consumers can not or do not want to estimate longer periods. Which energy price will be relevant? Which heating system will be the best in the future? This means, if a consumer decides to invest in a new insulation with a lifetime of 30 years it is difficult for her/him to estimate this long period. Therefore, the consumer wants to repay the loan earlier, let's say in 10 years. Therefore, the relevant time for the decision is 10 years. It is difficult to say which heating system will be attractive in 10 years. Maybe, with a new technology coming up in 10 years he/she would have saved money with this technology instead of the new insulation.

[2] This approach is especially true for the simulation of the building sector (DSM, Heating, Cooling, DHW, Solar Thermal). In the electricity and bio-fuel part of the model a slightly different approach is used. For more details please take a look to the Manual of Invert available on www.Invert.at

1.3.2 Decision making process in Invert

Invert models the decisions making process of the stakeholders taking into account market restrictions (e.g. RES-E market barriers, learning curves, consumer behaviour). However, basically two different approaches - depending on the sector - are used in Invert.

For the building sector (including DSM, heating, cooling, DHW, solar thermal) an option approach based on a replacement rate (~1/lifetime) is used. In contrast to the option approach in the RES-E, RES-CHP and bio-fuel sector a dynamic cost curve approach is used. These two different approaches are roughly described in Figure 2 and Figure 3.

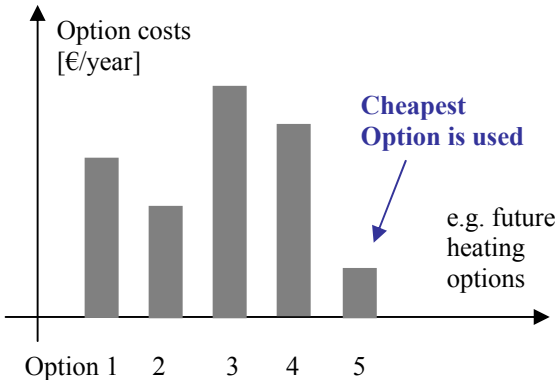

Figure 2: Option based approach in the building sector

Very important for this option approach is the fact that Invert allows modelling the cheapest option seen by the stakeholder via so called Soft Barriers. The decision making process of the consumer is influenced by a variety of different technical and non technical aspects (e.g. comfort, social barriers, education). All these aspects together are modelled with a soft barrier depending on the used technology and consumer behaviour.

These soft barriers allow to increase or decrease the monetary costs of a technology (on basis of the lifetime/individual payback time) depending on the estimated consumers preferences and behaviour (=soft barrier factor). This results in the fact that Invert enables the combination of rational monetary decisions and consumers' behaviour in a unique way.

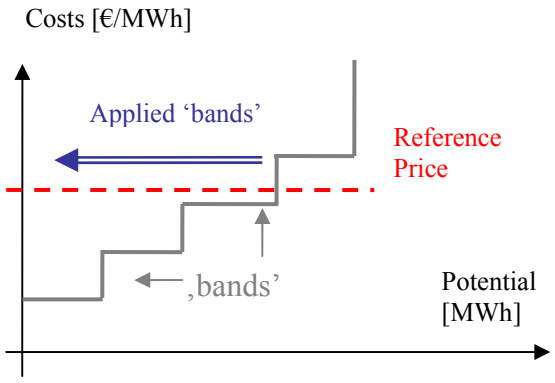

Figure 3: Cost curve approach used in the RES-E, RES-CHP and bio-fuel part of Invert

In the RES-E, RES-CHP and bio-fuel part of Invert for each 'band' the potentials and costs (short term/long term marginal costs) for the electricity/heat as well as bio-fuel production are gathered and sorted in a least cost order. Each 'band' is described by a certain set of parameters. For example wind: All wind farms/plants with the same full loud hour can be gathered and treaded as one unique 'band'. Of course, there are different costs for each plant in a 'band'. In other words, in the real we would obtain a continuous cost curve. However, for the modelling in Invert we use stepped discrete functions as an approximation.

In contrast to the option based approach of the building sector in the RES-E/CHP and bio-fuel part no replacement rate is used. It is assumed that all RES-E/CHP or bio-fuel bands get installed or used when the costs for the electricity/heat or bio-fuel production is lower than the electricity or bio-fuel reference price.

1.3.3 Brief description of the implemented promotion schemes

All currently[3] in Invert implemented promotion schemes are shown in Table 1 and Table 2.

Table 1: Currently in Invert implemented Promotion Schemes, part one

Sector	Sub sector	CO_2 tax	Invest-ment subsidy	Soft Loan	Feed in tariff
Building	Heating	√	√	√	x
	DHW (including solar thermal)	√	√	√	x
	Cooling	√	√	√	x
	DSM	x	√	√	x
	District heating	√	√	√	x
Electricity	RES-E[4]	√	√	x	√
	RES-CHP[5]	√	√	x	√
	District heating	√	√	x	√
Bio-fuel	Bio-fuels	√	x	x	x

Table 2: Currently in Invert implemented Promotion Schemes, part two

Sector	Sub sector	Tax exemption	Subsidy on fuel input	Additional aside premium
Electricity	RES-E	√	√	x
	RES-CHP	√	√	x
	District Heating	√	√	x
Bio-fuel	Bio-fuel	√	x	√

At the electricity part the promotion schemes are separated to RES-E and RES-CHP. Invert considers in this part only promotion schemes for renewables. In principle, promotion schemes for conventional energy carriers can be

[3] April 2005.
[4] Renewable Energy Source - Electricity
[5] Renewable Energy Source - Combined Heat and Power

considered only in the building part (heating, cooling, DHW).

The two major promotion schemes in the building sector (Investment Subsidy and Soft Loans) can be applied on each defined (by the user) building category (e.g. single family households, multifamily households) and defined technology for heating, cooling, DHW, solar thermal systems. Furthermore, it is possible to assign a certain Demand-Side (DS) strategy for each defined building category and building part (walls, ceiling, floor, and windows).

1.3.4 Reference Scenario Tool

Originally, the basic idea for designing Invert was to estimate the efficiency of different promotion schemes and strategies to reduce CO_2 emissions in the different sectors as building, electricity and transport.

In this context a 'Cumulated Promotion Scheme Efficiency' (CPSE) was defined to investigate the described issue.

$$CPSE = \frac{\sum_{i=1}^{n} \Delta CO_2 Emissions_i}{\sum_{i=1}^{n} \Delta TransferCosts_i}$$

The CPSE estimates the efficiency of a certain strategy compared to a Business As Usual (BAU) scenario by comparing the CO_2 emissions and transfer costs (≈society costs for promoting a certain technology) of the BAU (= reference) scenario with the CO_2 emissions and transfer costs of the sensitivity scenario.

The most efficient promotion schemes are indicated by high decreases in CO_2 emissions and low increases of transfer costs compared to the BAU scenario.

The flexible design of Invert allows to run such investigations very easily and fully automatically.

1.3.5 Brief description of the results achievable with Invert

The results achievable with Invert can be displayed on an aggregated as well as disaggregated level. All outputs according technologies, energy carriers, RES-E/CHP as well as bio-fuel technologies are on an disaggregated level displayable.

All outputs necessary for the estimation of the promotion scheme efficiency in the different (sub)-sectors (building, electricity, bio-fuel, heating, cooling, etc.) are on an aggregated level displayable (CO_2 emissions and transfer costs).

General Outputs (for Heating, Cooling, DHW, DSM, RES-E/CHP, Bio Fuel):

- Public transfer costs for promoting RES & RUE technologies (Mio Euro/year)
- CO_2-emissions (total and reductions due to promotion schemes) (kt/year))

Heating, Cooling and DHW:

- Energy demand reductions due to insulation and window replacement (DSM) for various building types (GWh/year)
- Mix of energy carriers for heating, domestic hot water and cooling systems (numbers of systems (1); numbers of buildings (1);
- final energy demand (GWh/year);...)

- District heating related outputs

Electricity/District Heating:

- Output from RES-E plants (GWh)
- Installed capacity of RES-E plants (MWel)
- Heat output from RES-CHP plants (GWh)
- Installed capacity of RES-CHP plants (MWel)
- Heat output from conventional Heat/CHP plants (GWh)

Bio fuels:

- Total production of various types of bio-fuels (l)
- Entire agricultural surface needed for the bio-fuel production (hectare)

1.3.6 Program features

The design of Invert aims to users who are slightly trained in energy economics and modelling with the need of support and user friendly handling. It is not necessary to be an export in energy modelling. Invert has been designed in a way to be very flexible and self explaining. A lot of hints are incorporated in the model. At crucial steps you always get additional information at the bottom of the program. Furthermore, a comprehensive help file exists with explanations of the used formulas and algorithm. The model is still under enhancement and therefore a 'Live Update Tool' exists to update Invert automatically via the Internet. Furthermore, the program allows to import outdated Invert database files automatically in the new required format.

Following section shows briefly the main features of Invert:

- Dynamic Bottom-Up modeling tool
- Reference Scenario Tool to evaluate different scenarios compared to a basic scenario (e.g. CO2 Emissions, see also chapter 1.3.4)
- Database Management System to avoid predefined data sets ('Definition area and linked data sets')
- File Management System to work with database, simulation and portfolio (result) files
- Data Import Tool (automatic and semi automatic import functions)
- Support of the major Microsoft standards (eg. copy paste from Excel and copy paste to Excel)
- Validation tool to check input data
- Direct data manipulation in Invert (Calculator functions: Multiplication, Division…)
- Interactive simulation modus vs. fully automatic simulation modus
- 'Multiple Simulation Runs' to simulate up to 20 data files fully automatically
- Simulation Error Information System
- Graph Wizard (Diagram Wizard)
- Comprehensive help file with search function
- Live Update Tool

1.3.7 Screenshots of Invert

In this section some screenshots of Invert are provided to give you an impression how the simulation tool is designed.

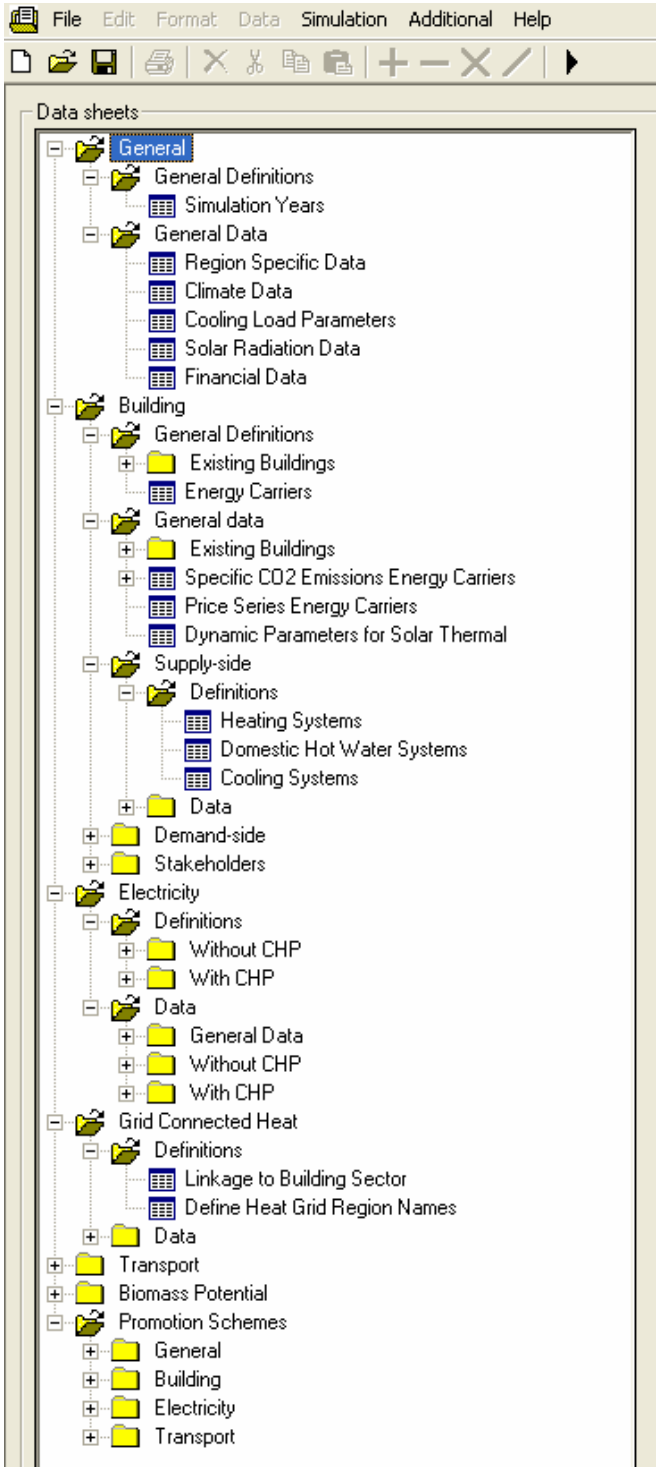

Figure 4: Tree view of an Invert database

Figure 4 shows the database tree view of Invert. As already mentioned in the introduction the program is very flexible and allows each user to define his/her own datasets. In the 'definition' section of each data block (General, Building, Electricity, etc.) the according datasets can be defined. E.g. in 'General Definitions' and 'Simulation Years' all needed simulation years (e.g. 2003 to 2020) can be defined. In the according 'data' section the according data can be entered.

Figure 5 shows exemplary the implementation of the promotion schemes in Invert for the building part. Each defined (by the user) building category (e.g. single family dwelling old) can be combined with a defined heating, cooling, DHW technology and linked with a certain promotion scheme (e.g. investment subsidy in the building sector).

Invert is designed in a way to simulate a region interactively. This means, after the successful simulation of a year Invert stops the simulation and gives you the possibility to change the promotion scheme strategy (you can switch to the promotion scheme window and change the parameters).

In principle, before you are able simulate a database file you have to specify the simulation parameters (see also Figure 6).

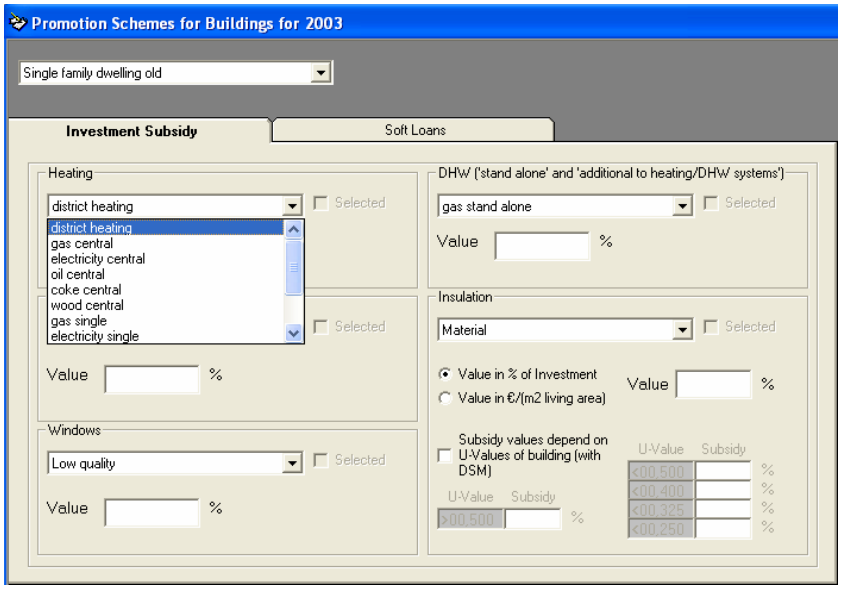

Figure 5: Promotion scheme window for buildings

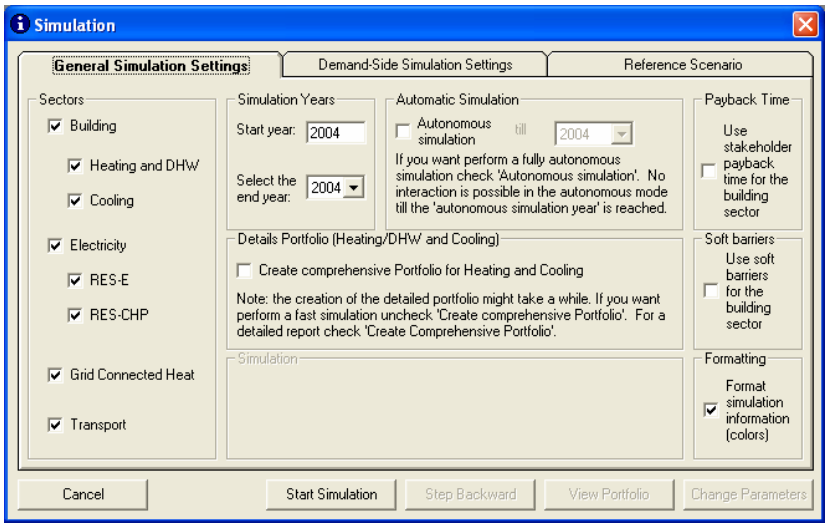

Figure 6: General simulation parameters in *Invert*

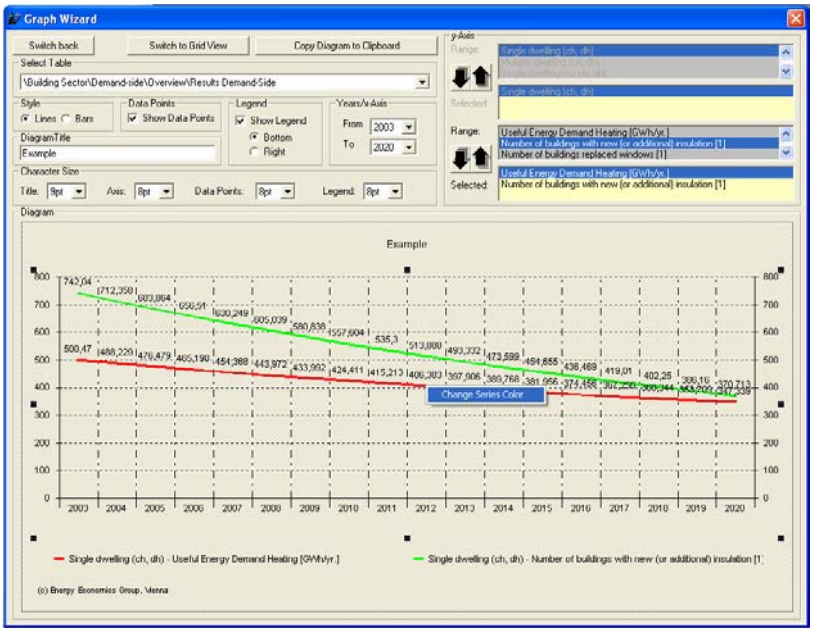

Figure 7: Generation of graphs in *Invert*

It is possible to simulate only parts of the entire file. E.g. only the 'Transport' sector by checking the according box.

At this 'Simulation' window all parameters according DSM simulation, reference scenario simulation (BAU scenario, see also chapter 1.3.4), as well as 'soft barriers' can be set.

After a successful finished simulation *Invert* switches to the Portfolio window automatically which represents all disaggregated and aggregated results in Excel sheet format. All results can be copied to Excel and further analyzed.

A very important feature in *Invert* is the 'Graph Wizard' which allows directly in *Invert* to prepare all needed graphs (see also Figure 7). All in the Portfolio file represented tables can be shown and prepared for graphical documentation and copied to Microsoft Word or an other application.

1.4 References

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