

## Novel Energy Saving Technologies Evaluation Tool

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### Abstract

The lead-time for development of a new energy technology, from first idea to commercial application can take many years. The main objective of EMINENT2 project (Early Market Introduction of New Energy Technologies) is to identify and accelerate introduction and implementation of leading edge European technology into the market place. A software tool and an integrated database on new technologies and sectoral energy supplies and demands were implemented. The tool is capable to analyse the potential impact of new, yet underdeveloped energy technologies in different sectors over different countries. Case studies have been analysed using the developed software tool.

### Keywords

Emerging energy technologies, energy supply chains, decision-evaluation tool

### 1. Introduction

Many novel energy-related concepts are formulated and developed in leading research centres and laboratories throughout the industrial world. If and when implemented, they could lead to significant economic and social benefits. The problem is in identifying them, evaluating their practicality and speeding up the time of getting them into the market e. The lead-time for development of an

early stage energy technology (EST), from first idea to commercial application can take many years. During the previous project launched by EC DG TREN an expert network for systematic evaluation and rapid dissemination of ESTs was established [1]. A tool was developed enabling evaluation of ESTs within different national and economic contexts [2]. No similar tool has been reported. It provides a rapid appraisal of the geographic potential and a reduction in market lead-time of the promising ESTs.

## 2. Problem statement, background

The aim of EMINENT tool is to evaluate the market potential of energy-related ESTs in various energy supply chains and their performance in terms of: (i) CO<sub>2</sub> emissions, (ii) costs of energy supply, (iii) use of primary fossil energy, (iv) in different subsectors of society. Technology developers and financial supporters are often not aware of the application potential and the market attractiveness across countries and society sectors. The EMINENT provides insight into the future market attractiveness and can accelerate the development as research and development efforts could be targeted more effectively.

## 3. Paper approach

The EMINENT tool evaluates given ESTs uses two databases:

- A database of national energy infrastructures, contains information of the number of consumers per sector, type of demand, typical quality of the energy required and the consumption and installed capacity per end-user;
- A database of ESTs and other already commercial technologies. It contains key information on new energy technologies currently under development. Proven energy technologies available and in use are also included.

### 3.1. Methodology – the description of the algorithm

As the availability and price of primary energy resources and the geographical conditions, demand and price differs significantly worldwide, it is needed to evaluate the impact of ESTs within a national energy supply system.

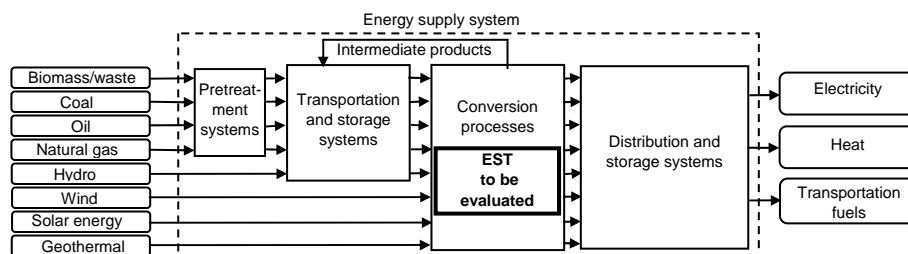


Figure 1. Methodology used in EMINENT tool

The algorithm for designing and evaluating energy supply chains consist of:

**Step 1. Composing energy supply chains.** For each energy demand combinations of energy technologies (ET) are proposed to form various supply chains that could supply the requested specific demand. Linkages are on the basis of energy type. For each individual chain Steps 2-6 are done.

**Step 2. Dimensioning of final ET (including EST) and validating ET links.** Starting from the final energy demand, characteristics of the previous ET validate the supply energy. This validation contains checks on:

**(i) Characteristics of the energy demand**, e.g. temperature and pressure levels of heating or cooling. If the check fails, the energy supply chain is not feasible.

**(ii) Requested energy supply capacity.** It is evaluated if multiple units of the ET can exactly deliver the requested energy. The proposed number of units  $n_p$  to be operated in parallel is calculated as the ratio of requested capacity  $P_{dem}$  and maximum unit size in which the ET is available  $P_{out,max}$  and rounded to the above integer:  $n_p = P_{dem} / P_{out,max} + 1$ .

**(iii) The corresponding output capacity is established** by the ratio capacity as requested by the demand:  $P_{out} = P_{dem} / n_p$

**(iv) Capacity matching.** For electricity a mismatch in demand and supply can be always balanced by a grid. For other energy forms, the suggested capacity should be within the available capacity range  $P_{out,min} < P_{out} < P_{out,max}$ . Then it is possible and the number of units and output capacity are known. If the suggested output capacity is smaller than the minimum capacity available  $P_{out} < P_{out,min}$  but by using multiple units in parallel ( $n_p > 1$ ), then the output capacity could be suitable if one unit less is applied: *IF  $n_p > 1$  THEN  $n_p = n_p - 1$* , repeat the procedure (iii). If  $n_p$  is already equal to 1, too much energy is generated, even with the smallest ET and the whole chain is infeasible. After the checks of ET to deliver demand, the energy inputs and outputs of the final ET are dimensioned by the energy conversion matrix.

**Step 3. Dimensioning of other energy technologies (including EST) and validating technology linkages.** If the proposed energy chain has multiple ETs, Step 2 is repeated for all other previous ones, using the demand of until all ETs are dimensioned. If ready, go to Step 4.

**Step 4. Availability check of energy resources.** After dimensioning the first ET in a supply chain under Step 3, the availability of energy is checked. If resource is sufficient, the design of the energy chain is finalised. Continue to Step 7. If availability is insufficient, dimensioning of the energy chain should be done starting with a limited resource. This is done under Step 5.

**Step 5. Re-dimensioning of first ET (including EST) and validating technology links.** Starting from the energy resource availability, the input of the first ET is dimensioned. A validation checks on temperature levels etc have already been carried, this only checks dimensioning of equipment. It is evaluated if the ET can consume the available energy:

**(i)** The ideal number of units to be operated in parallel is evaluated by evaluating the ratio of available resource and maximum supply capacity.

(ii) The proposed number of units  $n_p$  to be operated in parallel is calculated as the ratio of requested capacity  $P_{res}$  and maximum unit size of the supplying technology in which the ET is available  $P_{in,max}$  and rounded to the above integer:  $n_p = P_{res} / P_{in,max} + 1$ .

(iii) The corresponding output capacity is established by the ratio capacity as requested by the demand:  $P_{in} = P_{res} / n_p$

(iv) If the suggested capacity is within the available capacity range  $P_{in,min} < P_{in} < P_{in,max}$ , then the option is possible and the number of units and input capacity is known. The dimensioning is then ready.

(v) If the suggested input capacity  $P_{in}$  is smaller than the minimum capacity available ( $P_{in} < P_{in,min}$ ) but by using multiple units in parallel ( $n_p > 1$ ), then it could be considered if the output capacity could be suitable if one unit less is applied: if  $n_p > 1$  THEN  $n_p = n_p - 1$ , repeat the Step 3. If  $n_p$  is already equal to 1, there is always insufficient energy available at the resource, even with the smallest ET and the whole chain can therefore be considered as impossible. After the checks on the suitability of the first et to consume whatever limited resource is available to deliver, the energy inputs and outputs are dimensioned based on the given energy conversion matrix.

**Step 6. Dimensioning other energy technologies (incl. EST) and validating technology links.** If the proposed energy chain comprises multiple individual energy technologies, Step 5 is repeated for the technologies, using the energy output of previous technologies, until all technologies in the chain are dimensioned.

**Step 7. Feeding side inputs and using side outputs.** After validating the energy supply chain with Steps 1-6, the other inputs are considered using outputs of the same or other technologies in the chain. If not, energy needs to be purchased from other sources. It is examined if energy outputs can cover other demands in the same sector, or energy inputs in the same energy supply chain.

**Step 8. Evaluating energy chains.**

After dimensioning energy supply chains, all energy flows are known and the total chain efficiency, CO<sub>2</sub> emission and use of renewable energy are assessed.

### 3.2. EMINENT tool description

EMINENT software tool consists of integrated resource manager, demand manager, EST manager, databases on resources, demand and the analysis tool:

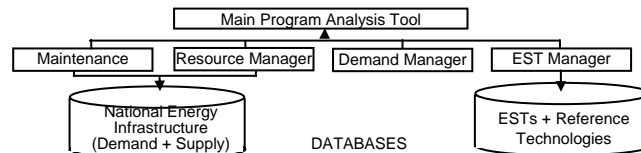


Figure 2. The EMINENT software tool

The Fig 3 shows main components of EMINENT and their interface.

**Resource manager** modifies, enters and selects data on resources in a country (electricity, fuels, geothermal, hydro, ocean tidal, wave and wind energy)  
**Demand manager** describes energy demands per subsector in a country, modifies and enters new data, selects data for the technology assessment.

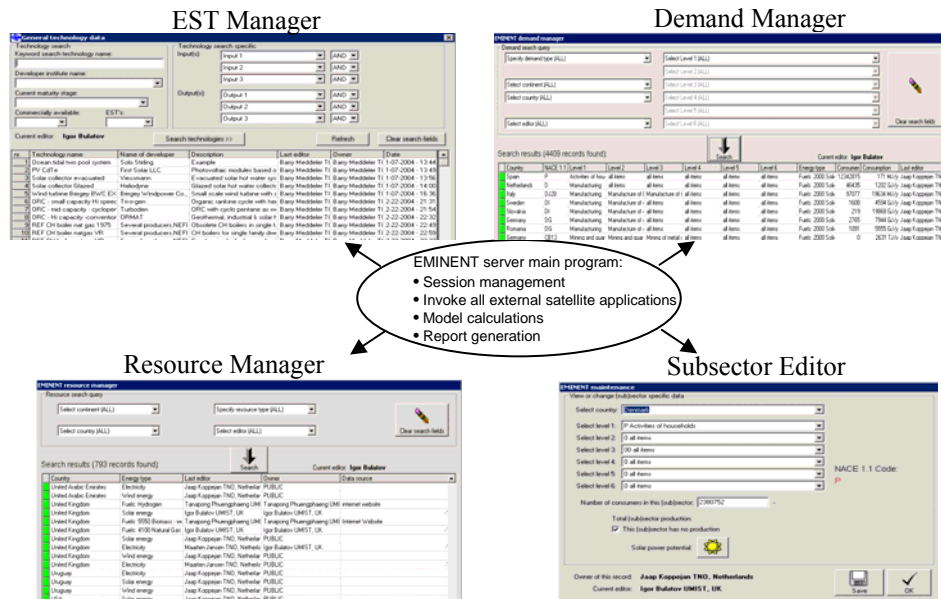


Figure 3. EMINENT software components

**Technology manager** contains key data for existing technologies and ESTs.  
**User input:** (i) The sectoral energy demands to which EST applied is to be evaluated, (ii) Other peripheral technologies to establish full energy supply chains, (iii) Resources that may feed the full energy supply chains with the EST.  
**Output:** (i) Aggregate numbers, (ii) Application potential of ESTs per (sub)sector, (iii) Annual costs of energy delivery per consumer and per (sub)sector, (iv) Annual CO<sub>2</sub> emission. **Performance indicators:** (i) Chain efficiency, (ii) Primary fossil energy usage, (iii) CO<sub>2</sub> emission per MWh, (iv) Costs of delivered energy (€/MWh)

### 3.3. Case studies

Several case studies have been analysed using EMINENT tool (Table 2)

### 3.4. Results and discussions

Most of ESTs analysed still have to improve to achieve the cost levels of the existing technologies. Some of the ESTs (e.g. ZENG, MCFC) could become competitive with relatively small additional efforts aimed at reduction of costs.

Table 2. ESTs analysed using EMINENT tool

Name of EST	Brief description	Maturity
Power cycle with fuel cells (FC)	The power production 58.29 \$/MWh - market price 55.00 \$/MWh. Competitive only if fuel prices rise or/and MCFC waste heat is used. Process integration [3] suggests a FCCC cycle [4]	Lab.
Biomass reactor	Fluidised bed reactor for biomass and/or waste gasification [4]	Lab.
Autothermal reforming (ATR) with membrane reactors	Still less cost effective than the reference technology: Energy supply costs per unite delivered energy are 52.5 €/y vs 29.3 €/y of the reference technology. ATR concept is not so far commercially viable. The gap between capture cost and EUA price level to be closed. [5]	Pilot
Zero Emission Norwegian Gas (ZENG)	A closed cycle, the products water and 100% captured CO <sub>2</sub> . Still less cost effective than the reference technology: Energy costs 42.2 €/y vs 29.3 €/y. The gap between capture cost and EUA price level to be closed eg by technology improvements. R&D action and incentives are required, new market opportunities for CO <sub>2</sub> , carbon storage under the Kyoto treaty [5]	Dem.
Electricity Transport by Ship	Electricity transport by ship from Iceland to the Netherlands based on Redox concept. Different capacity ships and a reference technology, cable to Iceland. The crucial factor being energy density. R&D is required on Redox flow systems and high energy density electrolytes [5]	Pap. idea

#### 4. Conclusions and future work

EMINENT tool has been developed and tested on case studies. It consists of energy resource and energy demand databases with their managers, EST database and analysis module. The results show the emerging technologies potential and scope for improvements. The tool is still being developed, new features are being added.

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