# DIGITAL SOLUTIONS FOR ENERGY EFFICIENCY AND DECARBONIZATION STRATEGIES

# *SOLUȚII DIGITALE PENTRU STRATEGII DE EFICIENȚĂ ENERGETICĂ ȘI DECARBONIZARE*

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***Abstract:*** *The paper presents two digital solutions developed by ENGIE Digital, ENGIE Impact and Tractebel Advisory & Advanced Analytics (T3A): Nemo – a tool to optimize the District Heating & Cooling (DHC) Networks and Prosumer – a tool to harmonize climate change imperatives with business profitability, by designing the investment strategy of zero-carbon journey.*

*These tools are used for and enriched by various studies supporting implementation of energy efficiency and decarbonization investments in relation with private and institutional clients.*

**Keywords**: energy efficiency, nemo, strategic planning, energy investments, decarbonization, prosumer

***Rezumat:*** *Lucrarea prezintă două soluții digitale dezvoltate de Engie Digital, Engie Impact și Tractebel Advisory & Adanced Analytics (T3A): Nemo – un instrument software dedicat optimizării rețelelor de încălzire și răcire centralizată (DHC) și Prosumer – un instrument software menit să armonizeze respectarea restricțiilor impuse de schimbările climatice cu profitabilitatea în operarea afacerilor prin asistență suport în definirea strategiilor de emisii zero de carbon. Aceste două instrumente software sunt utilizate și îmbunătățite în mod continuu prin intermediul*

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*diverselor studii realizate în vederea implementării investițiilor în eficiență energetică și decarbonizare pentru clienți privați și instituționali.*

**Cuvinte cheie:** eficiență energetică, nemo, planificare strategică, investiții energetice, decarbonizare, prosumer

## 1. Introduction

One of the most important topics, current one and for the years to come, is and will be to identify decarbonisation strategies for all energy sectors in order to act efficiently against the climate change problems we are already facing. Therefore, a lot of efforts are concentrated worldwide in putting in place dedicated digital tools with the main purpose of facilitating the identification of sustainable solutions for CO2 neutral environment addressing specific sectors like District Heating and Cooling (DHC) and/or electricity supply for local energy communities and industries. In line with all these efforts, present paper will highlight the benefits of two different digital tools: one dedicated to Optimized DHC networks (*NEMO*) and one dedicated to provide Decarbonization Roadmaps (*Prosumer*). These tools are the results of the research and development effort put in place internally at Engie Group level as continuous innovation process in order to address current energy markets needs.

*NEMO* is a digital solution able to optimize DHC industrial assets and meet operational constraints at a system level. Itis the most comprehensive data processing tool, enabling operators to improve their heating and cooling network's efficiency. With Nemo, the users can take advantage of every available data to optimize energy use and operate assets with the optimal economic & environmental settings. Nemo makes it possible to obtain the best energy efficiency possible, while controlling operating costs. This way, ENGIE DHC operators can commit to truly differentiating levels of performance compared to their competitors.

*Prosumer* is an advanced simulation and optimization tool developed by Tractebel Advisory & Advanced Analytics (T3A). The tool aims at defining a strategic planning for multifluid (i.e. heating, cooling, electricity, gas, mobility, water, waste, etc.) energy investments at territory level. It designs the optimal configuration minimizing the total cost of ownership (TCO) of the system. The focus of the tool is on strategic assessment of distributed energy projects (focus on pre-feasibility studies).

Even if main objectives of the two digital solutions are different, present paper is presenting both of theme as innovations addressing the current challenges of the energy markets of today.

## 2. General description

*NEMO* tool can handle all type of fluids: steam, hot water and cold water retrieved in DHC systems. The main objectives and technical improvements of the platform are listed below:

- Forecast demand based on prediction models, fitted to each client, and continuously fed by weather forecast;
- Provide a decision support tool for the dispatching teams, handling simultaneously:
    - Mid and long-term planning: fuel supply nominations and long-term energy targets, such as yearly renewables constraint;
    - Short term plants commitments for next hours and days;
    - Real time management to take into account weather forecast errors or technical faults;
- Provide to studies teams an optimisation tool able to calculate economic savings for different scenarios of equipment investments (piping, regulation devices, production means), or new configurations of network (new ETS connections, new extensions);
- Provide a way to assess new network acquisition opportunities or contract renewal opportunities.

The proposed solution is able to run optimisations on large networks within reasonable time. However, the given problem is known to be really hard to solve. It is a Mixed Integer Non-Linear Problem (MINLP) [1], [2], [3], [4], [5], [6], due to:

- A great number of binary variables to model production means (technical minimum powers, start-up costs, minimum uptimes and downtimes…) and regulation devices (valves, pumps, upstream and downstream pressure regulators…);
- A great number of nonlinear equations to model pressure drop along each pipe, to model power equivalent to a product of a variable mass flow and a variable difference of temperature, as well as to model several production means (non-constant efficiencies, pumps cascade and hysteresis cycles).

*Prosumer* tool determines the optimal size of the different assets in order to fill the different energy needs [7]. One of the strengths of *Prosumer* is that the tool may consider any kind of input energy fluids for **genericity**: common energy fluids (Hydrogen, electricity, heat, gas) but also more specific ones (chemicals, Ammonia, Oxygen, water, …) or very specific elements like mobility. This genericity makes the tool **very flexible** and it may therefore be adapted to multiple applications for B2B (industries, mines, airports, utilities, etc.) and B2T (Campus, villages, eco-districts, islands, etc.), as shown by Figure 1 below.

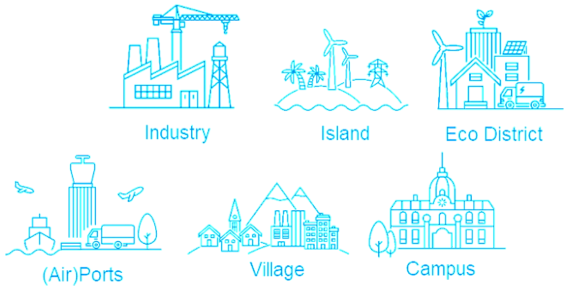


**Figure 1.** Types of applications with *Prosumer*

## 3. Optimized DHC networks with *NEMO*

### *3.1. Input data requirements*

*NEMO* allows dispatching teams to forecast the consumption of the clients, to economically optimize the use of plants and fuels, in order to answer demand while respecting many constraints, being operational or physical. Figure 2 below describes the tool structure: input can be fixed parameters (blue), real time data updated on an hourly or weekly basis (grey), or manually updated constraints such as availability constraints (turquoise). The workflow on the right split the user daily workflow into 3 steps: the demand forecast, the optimisation step and the visualization step.

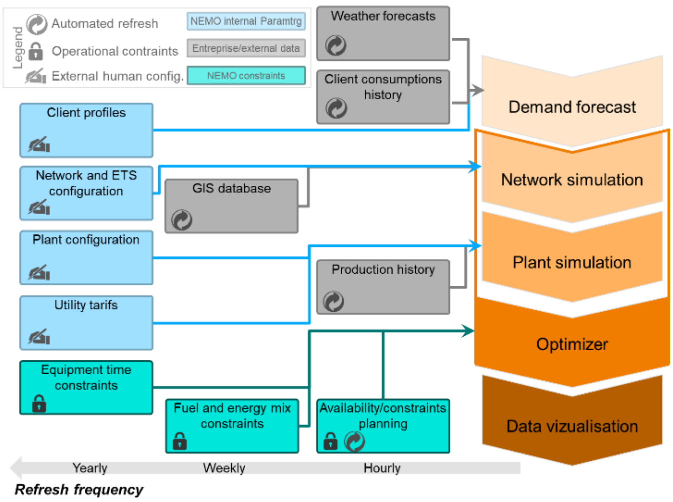


**Figure 2.** *NEMO* structure

The demand forecast step is crucial for the whole process: if the forecasted demand does not match the real demand, the results of following steps will not be relevant. Considerable time has been spent by mathematics experts to find the best machine learning models to forecast clients demand.

**Inputs:** Users can choose any exogenous parameters, such as atmosphere temperature, irradiance or wind to explain the demand. Note that a demand forecast will always be based on forecasted exogenous parameters. For example, if one uses irradiance to predict demand, one will always have to get an irradiance prediction before being able to predict demand. Therefore, one has to be careful when selecting these input parameters: past values are always available, future values are rarely predictable with a small uncertainty. As a result, if an exogenous parameter explains 99% of the demand, and if this parameter is predicted with a 30% error, it will automatically lead to a 30% error on the predicted demand.

**Models:** The tool enables users to select one or several models within a list of classic models. Experience has shown that Random Forest regressions are generally performing better than simpler models. They can detect threshold effects and non-linearities. However, they tend to be bad extrapolators, emphasizing the need of even more historical data.

**Outputs:** During the forecasting step, the demand can either be a heating or cooling total power production for the whole network, or one individual forecast for each client. For both cases, a significant amount of historical data must be provided, in order to get a model as flexible as possible with regards to external conditions. This is even more important as climate conditions have been deviating notably these last years. As a consequence, if a model has not trained on a hot February month, it will not be efficient when predicting February 2020 heating demand in Paris, as temperatures have been 3.6°C above average.

**Connectors:** It is also possible to connect your own data sources to the tool, in order to bypass this step.

### *3.2. Methodology*

Once the data shown on Figure 2 has been provided, the objective is to get the best dispatch between the plants to answer the forecasted demand, for the next hours or days.

In France, one of the fuel constraints imposes a 50% share of renewable energy consumption within the yearly energy mix. In addition, gas supply monthly maximum and minimum quantities must usually be respected. These two constraints must be considered for each daily commitment. However, if one thinks of optimizing the power dispatch for the next days, one cannot add directly these long-term constraints into the problem without increasing significantly the timeframe of the problem and its size, making it most of time unsolvable.

To bypass this dimension issue, a first long term problem is solved without taking the network into account (reducing drastically the problem), in order to draw a target for each long-term constraint. This long-term optimisation is based on a long term forecasted demand, taking into account a mix of short-term weather predictions and long-term estimations stemming from historical averages. For example, Figure 3 shows in green dashes the optimal targeted renewable rate resulting from a long-term optimisation.

Then only, short term optimisations are run on the next hours or days, considering the previous computed targets as new constraints. The same long term forecasted demand is considered to simplify the process. The resulting renewable rate in grey on the Figure 3 below must follow as much as possible the green dashes. One long term optimisation can of course be used by several short-term optimisations.

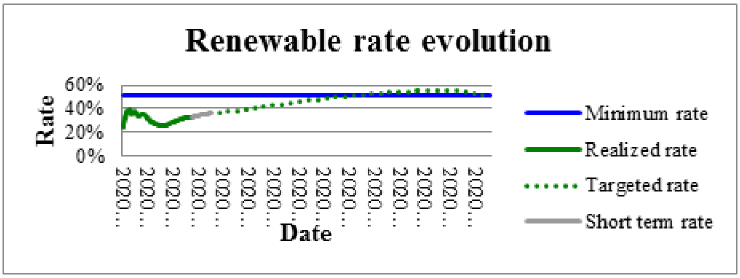


**Figure 3.** *NEMO* renewable rate evolution

### *3.3. Results*

The current *NEMO* tool cuts the daily primary energy consumption of heating and cooling networks by 3 to 12% in France and internationally. A typical user journey begins with the demand forecast, which is done automatically following a rule that the user chose. An example is shown on Figure 4 for March 10$^{th}$, 2020:

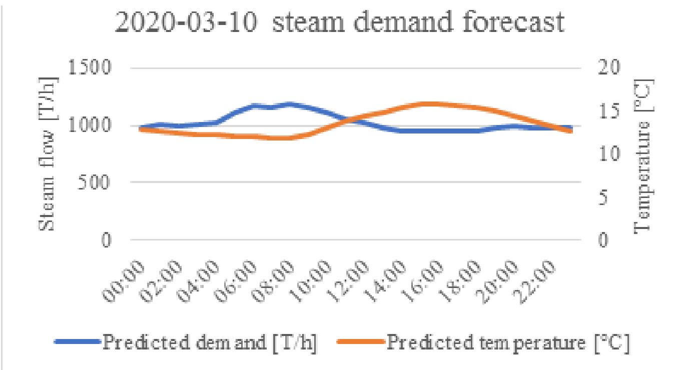


**Figure 4.** *NEMO* steam demand forecast

This forecasted demand is given as an input of an optimisation. Once the mathematical model has done the job, a report is made on the optimal dispatch from the production point of view, shown on Figure 5. For each chosen time step, a production flow is proposed for each production site. This commitment is of course respecting every technical unavailability, maximum and minimal powers, ramp-up, ramp-down, uptimes and downtimes. 24-hour optimisations terminate within less than 10 minutes for all the networks that have been used so far.

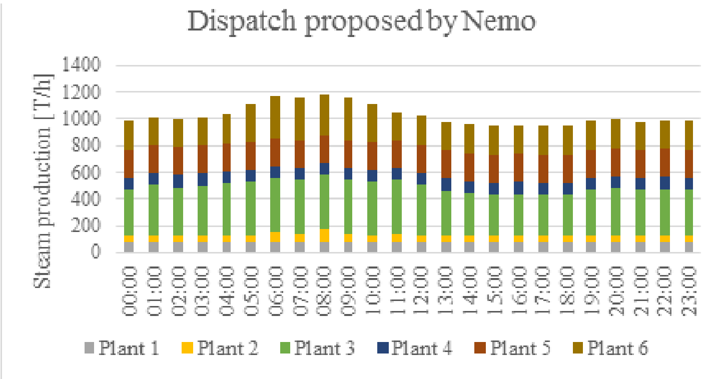


**Figure 5.** Dispatch proposed by *NEMO*

In addition, a full report on thermodynamics variables is available on a 3-dimensional map, enabling to visualize easily pressures, temperatures, flow speeds, thermal losses, and many other quantities deduced from the first ones. Figure 6 shows a sample of the results obtained with *NEMO* for the optimisation of a network in Aosta (Italy). This visualization is a great tool to understand more deeply the behaviour of networks.

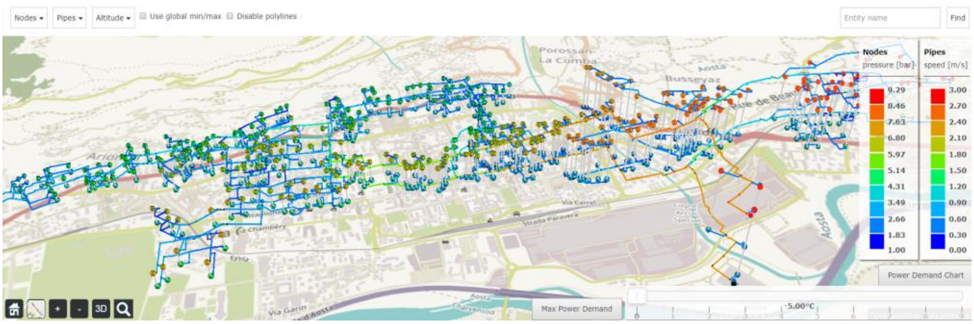


**Figure 6.** *NEMO* optimisation results

Every outputs of optimisation are of course available as raw csv files to enable user to connect their own software layer on top of the tool.

## 4. Decarbonization roadmaps with *Prosumer*

### *4.1. Input data requirements*

A wide range of heterogenous input data is necessary to fuel the model – general information such as the time horizon of the analysis, specific information related to each site/area where the project is going to be developed, fluid network topology, but also technical data associated to each piece of equipment. Figure 7 shows on the left the inputs needed by the tool.

### *4.2. Methodology*

*Prosumer* incorporates a mathematical model (forming a mixed integer linear optimization program) that is solved using state of the art commercial solver. As any other optimization tool, *Prosumer* is structured with objective function, multiple system variables and a restriction system. By default, the objective function is the Total Cost of Ownership (TCO).

The program minimizes the TCO (including all investment and operation costs) of the system, while setting the optimal values of the variables and complying with all technical constraints of the assets. System variables are technical and refer to the loads of the different fluids, such as fluids consumption profiles or fluid flows. Restrictions mainly address capacity limitations of fluid generation sources and fluid networks. A synthetic representation of informational flows is presented below.

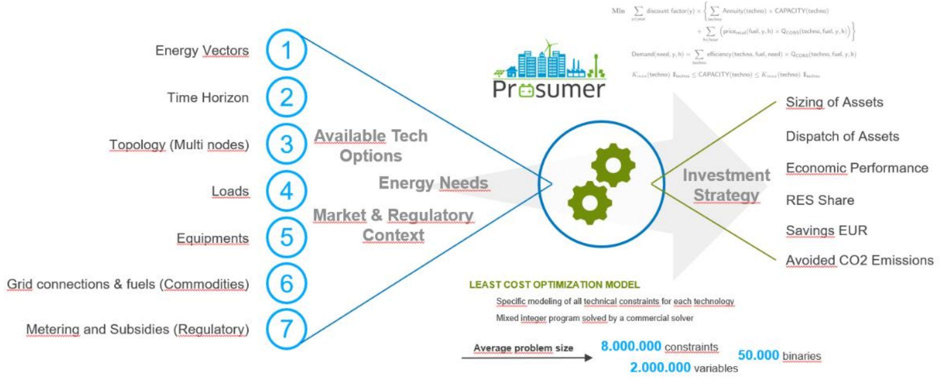


**Figure 7.** *Prosumer* informational flows

*Prosumer* has a three-layer structure: **project/case/scenario**, allowing the user to develop multiple sensitivity analyses on various technical solutions, finally arriving to the optimal scenario which equates with the best investment decision.

- **Projects:** the projects correspond for example to the different final clients for which the user is performing simulations;

- **Cases:** the cases are an intermediate level inside the projects, corresponding to the different sites of a client;
- **Scenarios:** the scenarios are the real simulation level of *Prosumer*. They address a specific input / output data set and contain a specific configuration launched for a site of a client.

### *4.3. Results as per case study implementation*

The tool provides different indicators to assess the optimal solution including information as the size of each equipment and how they should be operated to minimize the operation cost, but also other indicators like the production RES share or the avoided $CO_2$ emissions. The model outputs shown on the right of Figure 7 are described below:

- Sizing of the assets – provides the optimal dimension of the assets necessary to be installed;
- Dispatch of the assets – exhibits the flow distribution of all fluids present at site/area level;
- Economic performance – economic indicators specific to pre-feasibility analyses are provided, such as Return on Investment (ROI), Net Present Value (NPV), Levelized Cost of Energy (LCOE);
- RES share in the total energy consumption at site/area level;
- Savings brought after project implementation, as compared to the baseline – monetary savings (EUR)
- Avoided $CO_2$ emissions

With the scope of exhibiting the large variety of *Prosumer* application areas, a number of 3 case studies are presented hereunder.

#### *4.3.1. Defining the zero-carbon strategy for a new urban eco-district*

The context of this application was to optimize the zero-carbon investment strategy for a new eco-district in Europe (Figure 8).

This district is composed of 5 different zones and includes needs for electricity, heat and cold. There were possibilities for grid connection for electricity and gas with typical supply contracts.

*Prosumer* application was used in this context to determine the size of the different equipment that were needed locally. The obtained solution was completely **avoiding $CO_2$ emissions** and the **NPV of the system could be reduced by 20%**.


**Figure 8.** *Prosumer* application for zero-carbon urban eco-district definition

### *4.3.2. Optimal sizing of decentralized equipment for a new smart village*

The context of this application was the techno economic analysis of the best energy solution for meeting electricity and heat demand for a village in Europe in visualizing the benefits of implementing the smart village concept (Figure 9).

The initial configuration was to consider only grid connections and geothermal pumps. *Prosumer* has been used and proposed an alternative solution where more local equipment was installed (thermal storage, heat pumps, CHP).

This solution (with an 80% RES share) implied a **reduction of 10.000 tons of $CO_2$ emissions** a year and the **NPV of the system was reduced by 32%**.


**Figure 9.** *Prosumer* application for smart village concept definition

### *4.3.3. Investment plan of an industry to be fully green by 2040*

This application concerned two industrial sites in Europe that intend to be fully green by 2040. The application consisted in the optimization of electricity, steam and cold production and industry processes (Figure 10).


**Figure 10.** *Prosumer* application for fully green industrial sites definition

The solution provided by *Prosumer* included different kind of equipment to reach the **100% RES share**. The **NPV of the system was increased by 37%**. Power Purchase Agreement and on-site biogas were used to secure the long-term needs.

## 5. Conclusions

In order to be able to cope with the ambitious targets for reduction of the CO2 emissions world-wide with essential background motivation in securing life continuity on our Planet for the future generation key domains are analysed these days from the perspective of efficient action strategies to be effectively implemented with high priority, such as:

- Power, Heat and Cooling generation;
- Energy-intensive sectors including oil refineries, steel works and production of iron, aluminium, metals, cement, glass, ceramics, paper.

Addressing these needs, specialized digital tools are needed in order to identify best energy efficiency solutions and strategic energy investments planning towards a zero CO2 emissions environment. The benefits of such tools are highlighted in present paper focusing on two digital solutions developed by ENGIE Digital, ENGIE Impact and Tractebel Advisory & Advanced Analytics (T3A):

- *NEMO* - a tool to optimize the District Heating & Cooling (DHC) Networks operation and
- *Prosumer* – a tool to harmonize climate change imperatives with business profitability, by designing the investment strategy of zero-carbon journey.

*NEMO* is a technical and economic optimization tool to simulate the best unit commitment at a system level. It accounts for main operational constraints at different time level (Long Term and Short Term).

*NEMO* is a state-of-the-art study and operation platform for heating and cooling networks that provides:

- Consumption forecasting
- Physical flow modelling
- Production and dispatch optimization
- Losses minimization
- What-if analysis

*NEMO's major benefits to design and operate DHC systems are:*

- OPEX reduction
- Project comparisons
- Unique reference

*Prosumer* deals with complex multifluid energy systems and it is adapted to multiple applications for Business-to-Business (industries, mines, airports, utilities, etc.) and Business-to-Tertiary (eco-districts, villages, campus, islands, etc.)

*Prosumer* designs the optimal configuration of a system minimizing its total cost of ownership. The focus of the tool is on strategic assessment of distributed energy projects (focus on pre-feasibility studies). This digital solution optimizes the costs and revenues of an energy production and/or storage investment over its lifetime. The model provides both optimal size and dispatch of the production and storage unit(s).

All pilot case studies performed using the two digital solutions highlighted positive results. Thus, presented tools may successfully be used to address the current needs of energy markets in facilitating the implementation of energy efficiency and decarbonization strategies.

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