ENGIE Impact

Internships

2023 – 2024

Internal | Restricted | Secret

What will you find?

Internship topics for 4 projects within the Advanced Analytics team:

- **SSo Tool**: long-term decarbonization planification software for big companies.
- **Prosumer**: generation expansion planning tool with decarbonization targets
- **NEMO**: web-based application for the optimization of district heating and cooling networks
- **Pegase**: short-term gas and power assets optimization tool.

How to apply?

- Send your CV and cover letter to internships-AA@engie.com and mention your preferred topic(s)
- **OR** directly apply on the Engie website using the links mentioned in the slides

Who are we?

Advanced Analytics:

We are 70 experts located in Belgium, France & Philippines

We optimize energy related decisions using advanced mathematical tools (Operation Research / Artificial Intelligence)

We are Solution Builders Experts

Advanced Analytics Delivers:

Advanced Mathematical Expertise

Digital Tools

Reporting, Descriptive, Forecasting & Optimization tools

Advanced Analytics 3 Pillars:

Understanding

Combination of Business Knowledge and Digital Technologies

Prototyping

Data Science and Operation Research

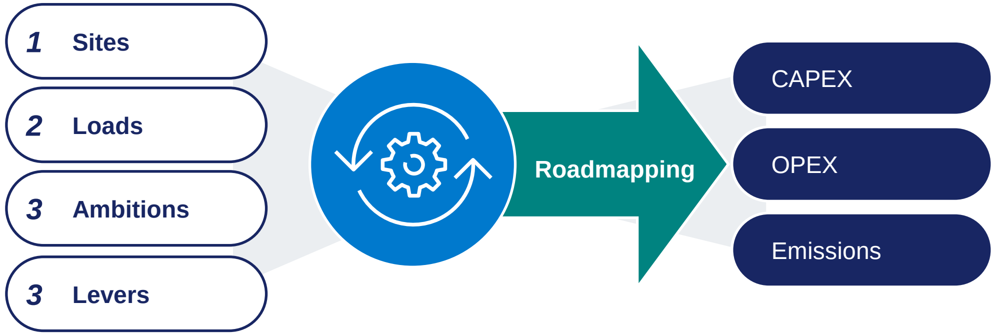
Industrializing

Development and Deployment of Solutions Maintenance and Operational Support

SSo Tool Topics

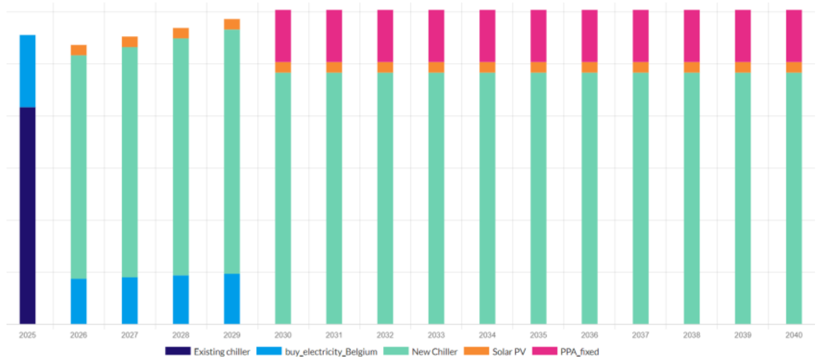
SSo Tool in a nutshell

SSo Tool helps clients with large portfolios transform their carbon reduction targets into actionable roadmaps.



SSo Tool automatically selects and applies the appropriate **levers** to achieve the decarbonization targets at **portfolio level**…

allowing to estimate their total impact (CAPEX, OPEX, emissions) over the time horizon and the geographies using **simple models**



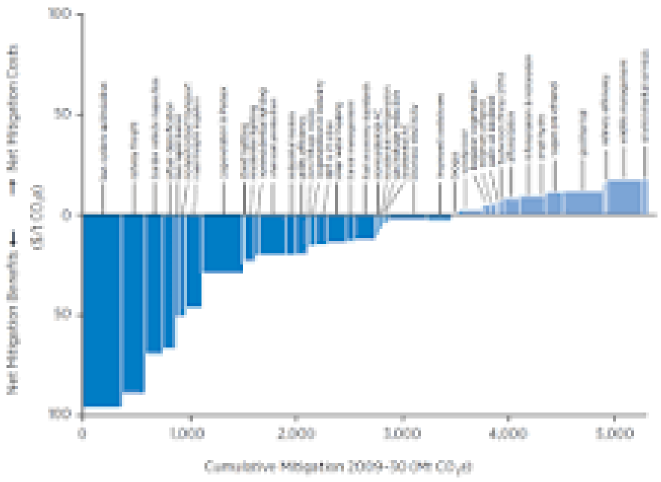
Incremental Abatement Cost Curve

Summary

Clients are usually interested in knowing how each individual lever is contributing to the decarbonization objective and the associated cost. One of the way to do so is to measure the cost impact (CAPEX+OPEX) and divide it by the emissions reduction to compute an *abatement cost*. Decarbonization levers are then ranked based on their abatement cost in a curve.
However, this representation poses some challenges, for instance taking into account synergies between technologies.

Goal

Supported by the SSo Tool team, the intern will have to develop a methodology to create meaningful abatement cost curves with a clear, useful interpretation for clients.



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Key information

IT | Maths

Coding | R&D

Proof of concept | Operational

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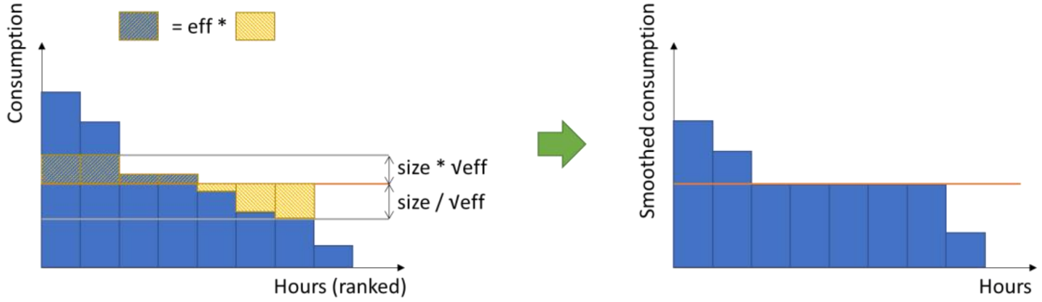
Storages & coupling constraints

Summary

Among the decarbonization levers, storages can help limiting the oversizing of renewable assets and favoring multifluid assets by synchronizing production and demand. Take-or-pay contracts with yearly volumes can also be concluded.
However, these assets introduce coupling constraints between the hours, which are currently not supported by the heuristic.

Goal

Supported by the SSo Tool team, the intern will have to develop a methodology to size and dispatch assets with coupling constraints, such as storages and take-or-pay contracts.



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Column generation for multi-site sizing

Summary

SSo Tool handles each site separately, but there are some coupling constraints, such as the total emissions limit, the usage of shared resources or the investment budget.
The current approach to enforce the emissions limit involves the use of an internal carbon price, but this line search doesn’t scale to multiple coupling constraints.
The idea is therefore to apply a column generation technique to write a master problem combining individual site-level solutions, potentially with some knapsack constraints.

Goal

Supported by the SSo Tool team, the intern will have to develop a column generation methodology to size and dispatch assets with coupling constraints across sites, such as target emissions, power purchase agreements and investment budget.

$$\min_{\lambda_{ij}} \sum_{ij} z_{ij}\lambda_{ij}$$

$$st.\begin{cases} \sum_{j} \lambda_{ij} = 1 \quad \forall i \\ \sum_{ij} c_{ijk}\lambda_{ij} \leq \hat{c}_k \quad \forall k \end{cases}$$

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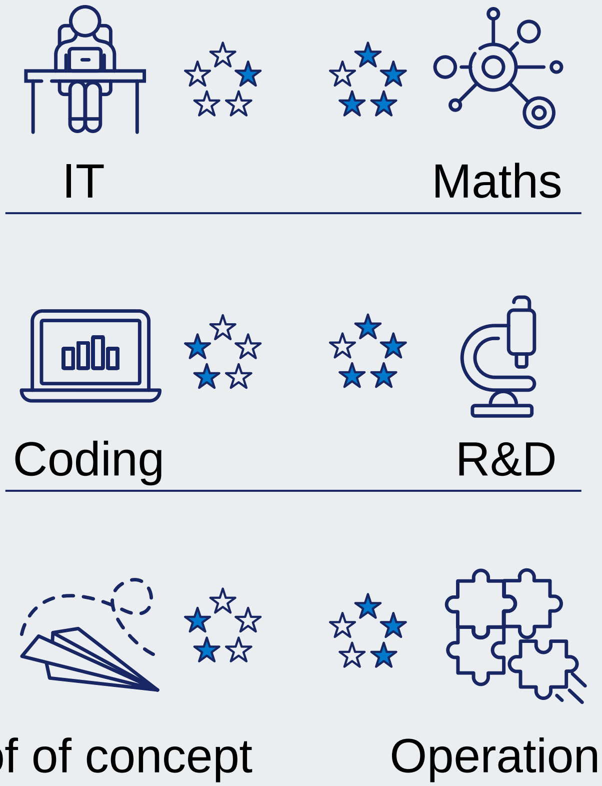

Industrial load profiling

Summary

In order to size and optimize decentralized assets (batteries, multi-fluid converters…) for industrial clients, we need to have their hourly consumption profiles. However, such profiles are sometimes difficult to get from the client, at least in the beginning of the project.

Goal

Supported by the SSo Tool team, the intern will have to develop a simple methodology to generate timeseries disaggregating yearly consumption profiles into hourly profiles based on (e.g.)

- Monthly industrial production
- Production shift schedule
- Seasonality
- External temperature

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Rewrite the SSo Tool core in Julia

Summary

The existing core of SSo Tool is written in Python, which has several limitations:

Performance on computationally intense tasks is not ideal (can be improved, but needs much scaffolding)

Code is not very functional / mathematical

Julia is an emerging scientific language getting a lot of traction in the academic and opensource worlds

Goal

Supported by the SSo Tool team, the intern will have to show whether Julia can contribute to:

- Increase the performance
- Facilitate the experimentation of new algorithmic approaches

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Data oracles

Summary

Clients for SSo Tool have typically very few data

We need therefore to do a lot of guesswork to fill in the gaps (e.g. using default values from more coarse-grained sources)

This applies to many properties (commodity prices, investment and maintenance costs, remaining lifetime of existing equipments etc.)

Goal

Supported by the SSo Tool team, the intern will have to develop a flexible and generic data structure able to:

- Manage information at various granularities using hierarchies (e.g. world/country/city…)
- Interpolate/extrapolate the data on demand for each request

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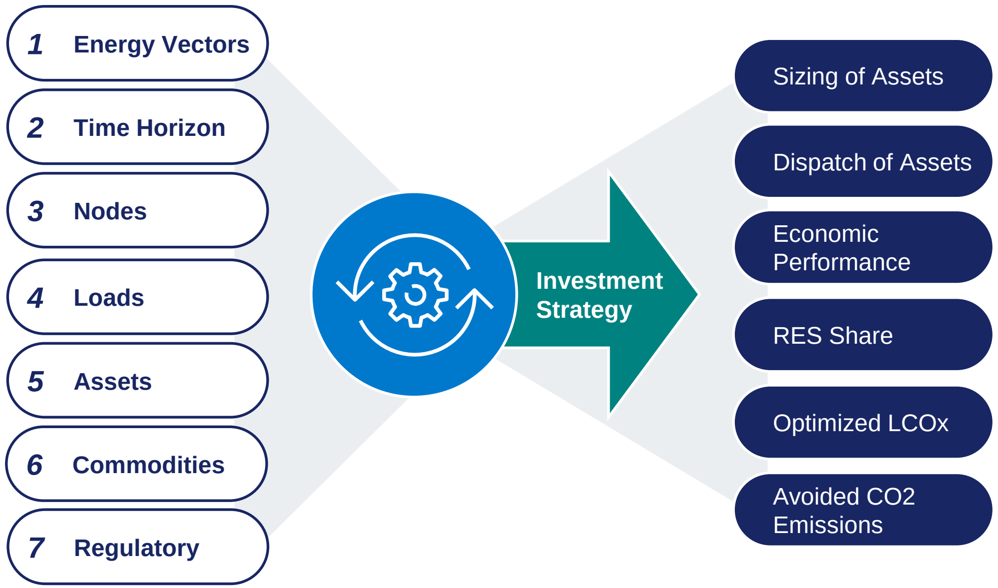
Prosumer Topics

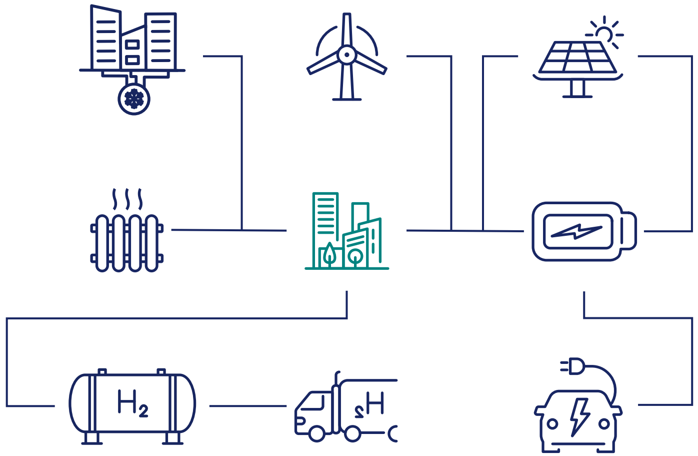
Prosumer in a nutshell

Prosumer allows to co-construct with clients their investment strategy. It's a fully flexible simulation tool that can be adapted to a wide range of complex decarbonization cases considering the multi-fluid synergies.



Prosumer designs the **optimal configuration** of a system minimizing its **Total Cost of Ownership and/or CO2 emissions** …

… allowing to assess the **sensitivity** of the business case to key parameters by running **multiple scenarios**



Maintenance Periods

Summary

To improve the realism of the model, the objective of this end-of-year study/internship is to include a description of the maintenance periods of the production assets in the core algorithm. Adding such constraints will refine the solution, and potentially lead to new investments. However, for this implementation, technical difficulties related to variables that should be included (binary or linear), which can highly impact computational time, have to be overcome.

Goal

Supported by the Prosumer team, the intern will have to:

- Understand existing models in literature;
- Implement the solution in the core, in Python and GAMS using Engie Impact's libraries;
- Test and analyze the outputs on business cases;
- Iterate with users to fine-tune the model;
- Present the results to the whole team and write technical documentation to illustrate the main takeaway of the internship.

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Use GamsTransfer for transformers

Summary

To improve the performance of the model, the objective of this end-of-year study/internship is to migrate the transformers phase in the core algorithm. The instantiation of the model, is done by reading, validating, **transforming** and storing the inputs. The pre-processing phase can take a significant part of the total process, mainly due to the transformation phase. Coupling Pandas library and GamsTransfer would decrease the complexity of the code and reduce the time spent in such preliminary phase.

Goal

Supported by the Prosumer team, the intern will have to:

- Understand current design and GamsTransfer functionalities;
- Implement the solution in the core, in Python and GAMS using Engie Impact’s libraries;
- Test and analyze the outputs on business cases;
- Present the results to the whole team and write technical documentation to illustrate the main takeaway of the internship.

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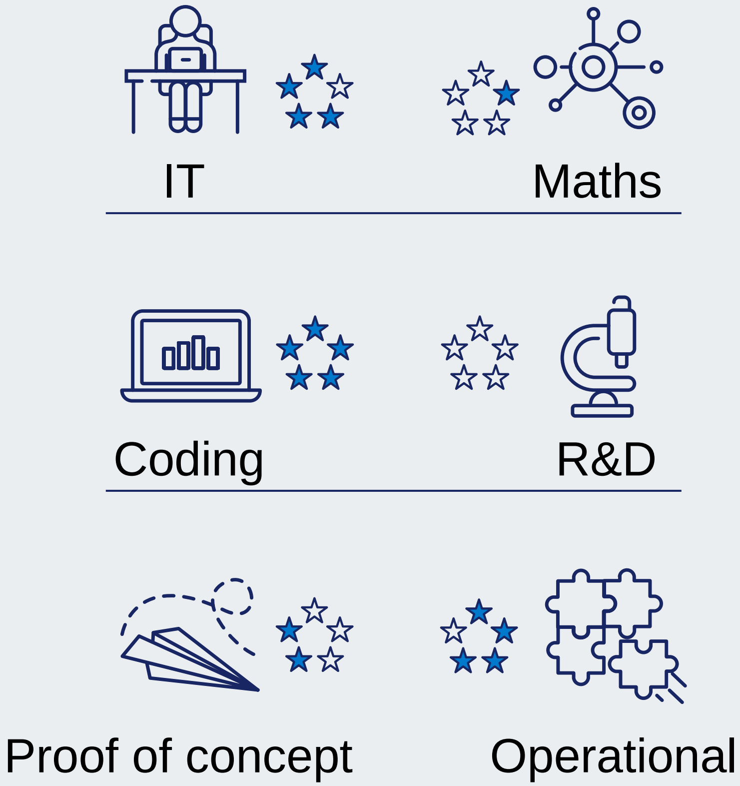

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Scenario-based optimization

Summary

To anticipate growing uncertainty, to aim is to extend the prosumer optimization framework with the tools needed to allow robust decision-making. First, a robust, scenario-based optimization model shall be formulated and implemented. For that, a pilot implementation exists that can be used as a starting point. Secondly, this implementation shall be tested on a real-world case, which could be done in cooperation with our consultants.

Goal

Supported by the Prosumer team, the intern will have to:

- Understand existing models in literature;
- Implement the solution in the core, in Python and GAMS using Engie Impact's libraries;
- Implement and align data input/output of the model;
- Test and analyze the outputs on business cases;
- Present the results to the whole team and write technical documentation to illustrate the main takeaway of the internship.

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NEMO Topics

NEMO in a nutshell

NEMO is a web-based optimization software which models district heating and cooling networks. Engie Impact develops the mathematical core of the tool which helps dispatchers in the day-to-day operations of their networks.

Objective

Ensure the supply of heat and/or cooling power to customers **while minimizing the cost** of primary energy and water/water treatment

Levers

- **Production planning** of production assets (boilers, chillers…) and their production level
- **Flow rates and pressure differentials** of pumps within the plant (condenser, evaporator, distribution ...) or on the network
- **Injection temperatures** at each departure on the network
- **Storage strategy**

Constraints

Power balance constraints

Network constraints
- Pressure drops
- Heat losses
- Valve and regulator configurations
- Condensation (steam)

Environmental constraints
- Annual renewable energy ratio
- Amount of CO2 emitted

Fuel/Power contracts
- Gas contracts
- Monthly, quarterly minimum, …

Clients' constraints
- Min or max supply temperature
- Minimum inlet pressure

Technical and operational constraints
- Power ramp-up and down
- Maintenance planning…

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Changing the order of time-step resolution

- The NEMO model is too large to be tackled in one piece. It is then divided in time-steps that are solved sequentially.

- However, there are coupling constraints between successive time-steps (ramps of production units, storage constraints, …) and so the decision taken at one time-step limits the possible decisions for the next ones.

- It has been observed that solving the time-steps in the chronological order might not be the best solution because some constraints are not well anticipated.

- The goal of this internship is to investigate the idea of changing the order of resolution of the time-steps. For example, a possible solution is to solve the time-steps in order of decreasing demand. It would include the following tasks:
    - **Implementation** of the adaptation to the model and algorithm to modify the order of resolution
    - **Assessment** of the solution on pre-defined test cases
    - Management of (un)foreseen **challenges** (respect of planning constraints, smoothing of the dispatch, …)

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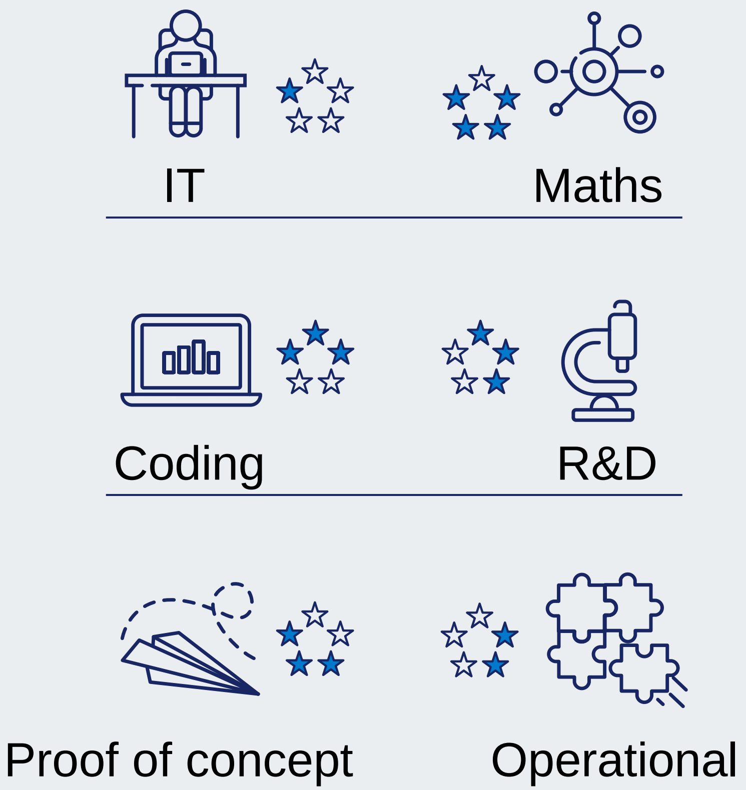

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Benders decomposition for steam network approximations

- **Benders decomposition** is a well-known optimization algorithm. It divides the model into efficiently-solved subproblems and solves them iteratively.

- The existing NEMO model optimizing steam networks is currently solved with a standard Branch-and-Cut algorithm of a commercial solver. However, it can be straightforwardly split into 2 :
  - The unit commitment that optimizes the dispatch of the production units
  - The network model that propagates the optimized steam productions to the clients through pipes.

- The goal of the internship would be to apply the Benders decomposition to the NEMO model. It would include the following tasks:
  - **Implementation** of the decomposition and algorithm
  - **Assessment** of its performances on defined test cases
  - Study of possible **improvements**, including parallelization.

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Optimization of cooling power production using Cython

- Optimizing cooling power production plants requires optimizing the simultaneous operation of dozens of chillers. To select the most efficient combination of chillers, an algorithm has been developed in C language to run through numerous combinations and select those that consume the least electricity for the desired cooling output.

- This algorithm is starting to age, and for reasons of readability, ease of access to the code and debugging, we are willing to convert this algorithm to Python, while using the Cython library to maintain the same level of performance in terms of computation time.

- The aim of the internship is to:
  1. **Analyze and understand** the existing dynamic programming algorithm in C to become familiar with it,
  2. **Rewrite a new algorithm in Python** that can take the same input data to calculate the right outputs, respecting coding standards, Cython standards and trying to refactorize the code as much as possible.

- The intern will be part of the team in charge of developing the computing cores of the NEMO platform.

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Initialization of runs

- The NEMO model is solved with an iterative algorithm. It is then dependent on the initialization for the speed of convergence and the optimality of the solution. Choosing a good starting point is not an easy task and is still an open question in NEMO. Since the different time steps are solved sequentially, one can benefit from the previous time-step to initialize the next one, but this is not possible for the first-solved time-step.

- Moreover, a first run is done in some cases to optimize targets of storages (for which we need to have a long-term vision). In this run, a simplified model is optimized to be computationally tractable. Therefore, some variables must be fixed to an initial value that must be defined as well.

- The goal of this internship is to investigate solutions to better define the initialization of the runs. Different options are possible such as:
  - Use a previous run to initialize the current one
  - Solve a first model to extract relevant information for the initialization

It would then include the following tasks:

- **Design** of innovative solutions
- **Assessment** of the solutions on pre-defined test cases
- **Implementation** of the most promising solutions

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Improvement of the pump model

Pumps electrical consumption is not linear:

1. The hydraulic power delivered by a pump is the product between its flow (m3/s) which is a variable of the model, and its pressure differential (Pa), which is also a variable of the model.

$$P_{hydraulics} = flow \ * (pressure_{out} - pressure_{in})$$

2. The electrical power consumed by a pump is its hydraulic power divided by its efficiency. This efficiency depends on its flow and its pressure differential.

$$P_{elec} = \frac{P_{hydraulics}}{efficiency(flow, \ pressure_{out} - pressure_{in})}$$

3. First investigations were carried to model linearly this power consumption without success. Other solutions were proposed, and the aim of the internship would be to test them, to compare them, and to propose new solutions to model pumps.

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Convexification of the pumping electricity consumption

- Minimizing the pumping electricity consumption can be approximated by minimizing the hydraulic power delivered by these pumps.
  The total hydraulic power delivered by pumps must compensate all friction losses within the network:

$$network\_hydraulic\_power = \sum_{pump} hydraulic\_power_{pump} = \sum_{pipe} friction\_power\_loss_{pipe}$$

$$network\_hydraulic\_power = \sum_{pump} flow_{pump} * delta\_P_{pump} = \sum_{pipe} flow_{pipe} * delta\_P_{pipe}$$

$$\forall\, pipe, \qquad delta\_P_{pipe} \propto flow_{pipe} * |flow_{pipe}|$$

$$network\_hydraulic\_power \propto \sum_{pipe} |flow_{pipe}|^3$$

As the total network hydraulic power to be minimized is proportional to the sum of cube signed flows, which are convex functions, it is also a convex function.

- From an operational point of view, the pumping cost to be minimized (that is not linear at first sight, see internship subject “Improvement of the pump model”) is thus equivalent to the minimization of a convex function.

- As minimizing a convex function is easier and faster than our non-linear, non-convex current model of pumping power consumption, **the aim of the internship would be to test an approximated pumping power consumption**:

$$\sum_{pump} electricity\_consumption_{pump} \cong \frac{\sum_{pump} hydraulic\_power_{pump}}{average\_effiency} \propto \frac{\sum_{pipe} |flow_{pipe}|^3}{average\_effiency}$$

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Key information

IT ★★☆☆☆ — Maths ★★★★☆

Coding ★★★☆☆ — R&D ★★★★☆

Proof of concept ★★★★☆ — Operational ★★★★☆

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Pegase Topics

Pegase in a nutshell

Pegase is an optimization tool used to solve two main problems. The first model searches the optimal gas storage management over a mid-term horizon. The second model is a power unit commitment problem over a short-term horizon.

	Gas	Power
Objective	Maximizing **profit and losses** of **portfolio** of assets	
Levers	• **Storage strategy** (injection and withdrawal) • **Contract delivery** • **Market decisions** (forward and spot markets)	• **Unit commitment** (Start, stop and production) • **Market decisions** (forward and spot markets)
Constraints	• **Technical constraints** (storage, network,…) • **Contract** and **market** bounds • **Demand**	• **Technical constraints** (min uptime, min downtime, startup curves,...) • **Demand**
Horizon	• **Daily** and **monthly** time steps • ~4 years	• **15min** and **hourly** time steps • ~2 days
Problem type	• **MILP**	• **MILP**

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Improve performance of small granularity runs

Among all possible usage of **Pegase**, the **power day-ahead bidding** process is one of the most critical one in term of **time sensitivity**.

- **Problem and challenges**
  - Finding **optimal dispatch** of portfolio of power plants based on market prices or determined demand
  - Portfolio includes **gas and hydro** power plants
  - Horizon of two 48 hours in **15min granularity**
  - **Time limit of 10min**
- **Tasks**
  - Understanding **clients' business and needs**
  - Design and **introduce heuristics** and **improve optimization model** to meet the time limit, **tune solver options**
- **Main languages:** Python, GAMS, possibly Cython

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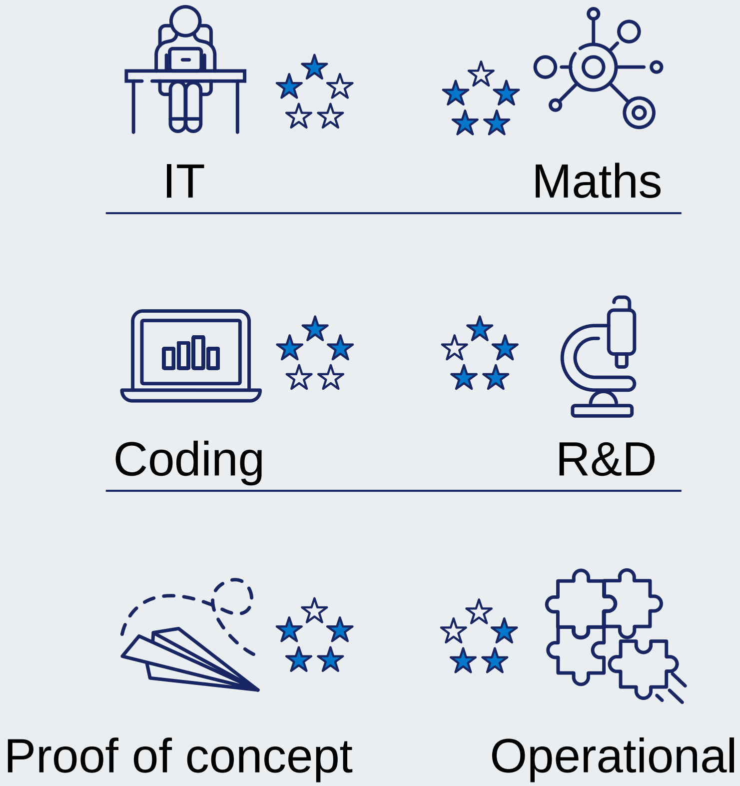

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Refactoring of reporting

At the end of the **Powered Pegase Process**, comes a reporting phase to output the solution in a readable way for our users. The current code for **reporting** has a lot of **drawbacks**:

1. Not build with the **standard** used in the department to **manipulate data.**
2. **Unclear structure.**
3. Very complex to dive into it, **source of bugs** and tough-explained behaviors.
4. **Time consuming** because could be simplified a lot to reproduce the same outputs.

- **Tasks**
    - Understanding **clients' business and needs.**
    - Understanding **optimization model.**
    - **Refactoring** of reporting **structure and code.**
- **Main languages:** ***Python, Cython***

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Key information

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