Optimization at Artelys

Florian Fontan

Artelys France

L'optimisation, au cœur des défis des sciences informatiques,
October 03, 2024

Table of contents

Artelys

- Artelys is an independent company, founded in 2000, specialized in decision engineering, modelling and optimization
- Offices in Paris, Lyon, Nantes, Brussels, Montréal, Madrid, Milan
- 15% of continuous annual growth
- 100+ experts (engineers, doctors)
- 25% to 35% of our activity in R&D

Artelys

Software services

- Customized software
- Off-the-shelf software
- Numerical solver

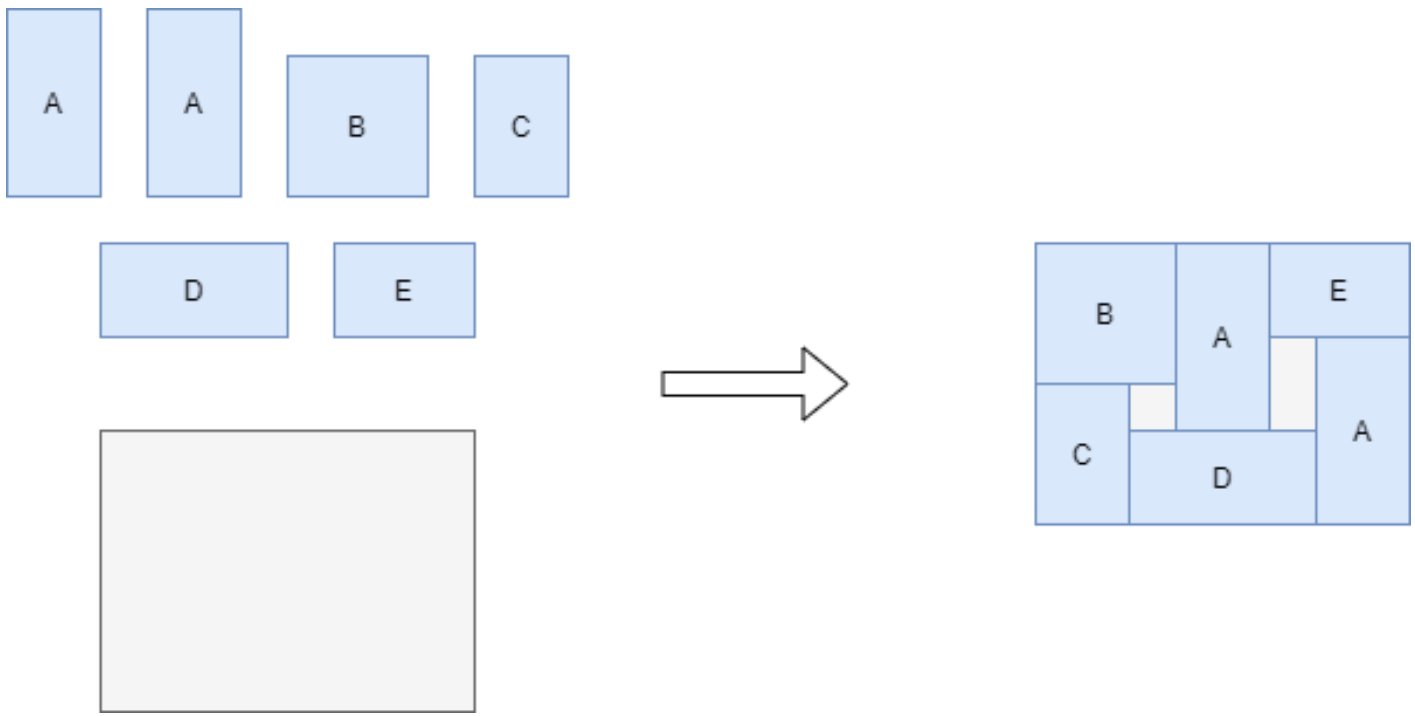
Consultancy services

- Optimization, DataScience and business expertise

Table of contents

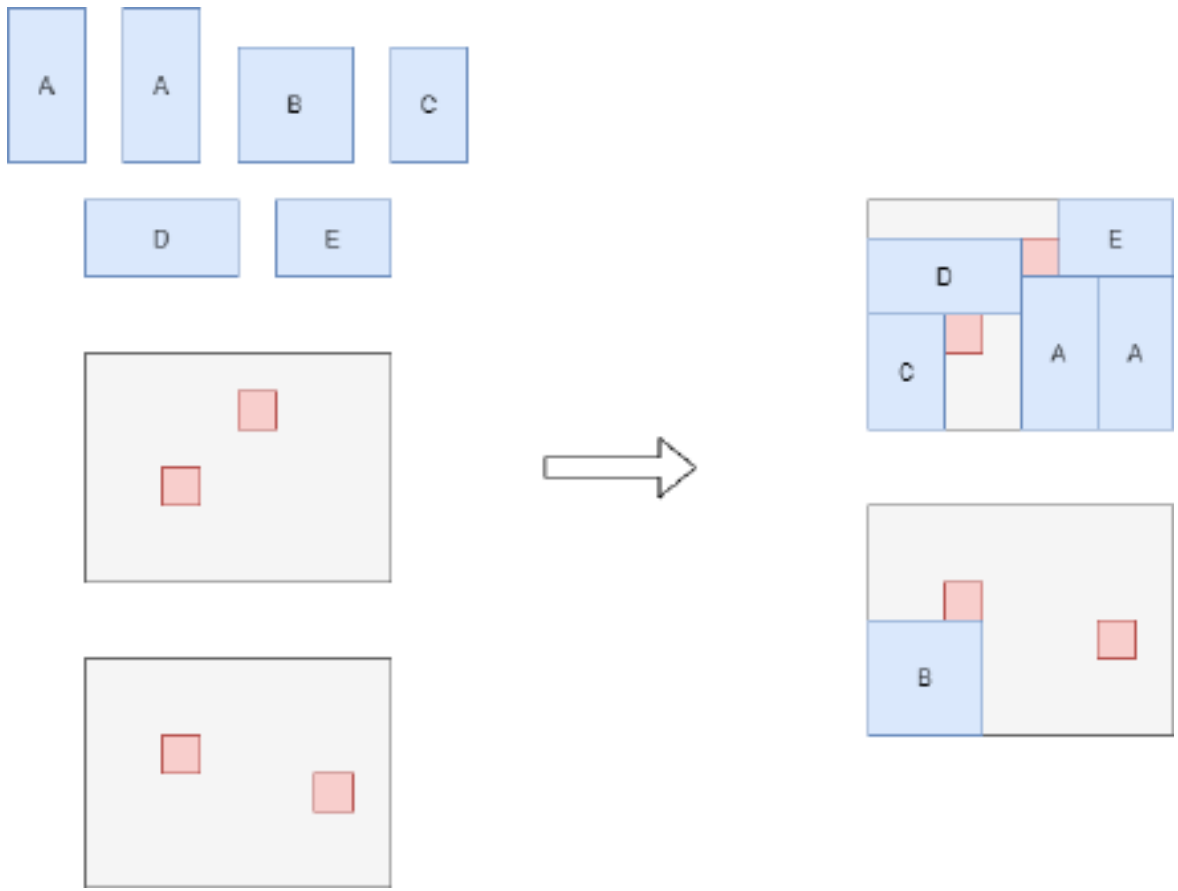
Problem definition

- Glass production
- Large glass sheets are produced and then need to be cut into customer demands
- The problem is to produce all customer demands with the least number of large glass sheets (minimize waste)



Additional constraints

- The real problems to solve include dozens of additional constraints
- For example, the large glass sheets may contain defective areas



Our work

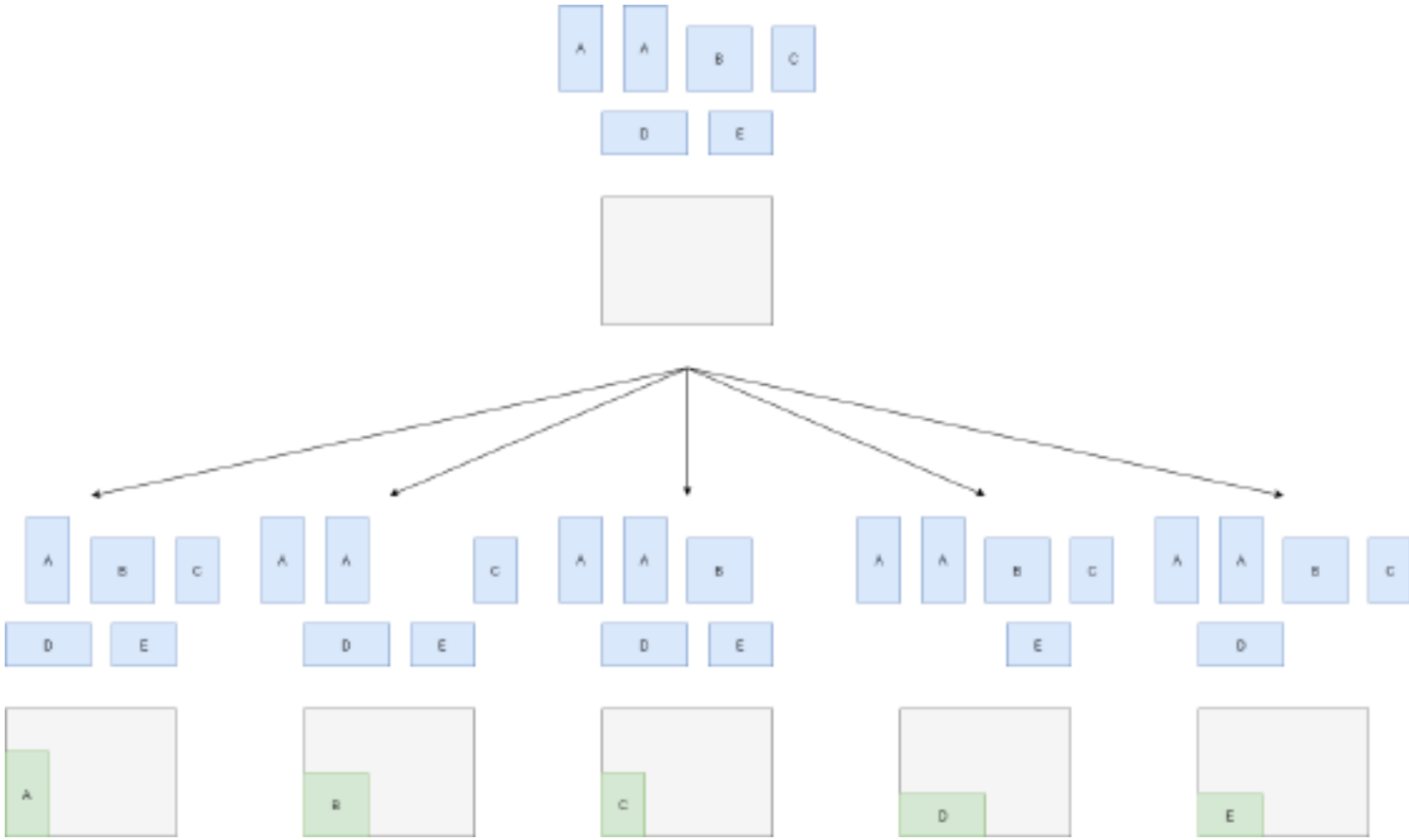
- For this project, we develop the optimization engine
- We design and implement the optimization algorithm
- The optimization engine is used in production

Resolution

- We solve the problem using an approach based on tree search
- The solution space is represented as an implicit search tree
  - Root node: empty solution (no glass piece packed)
  - Children of a node: generate a node for each remaining glass piece, for each relevant position

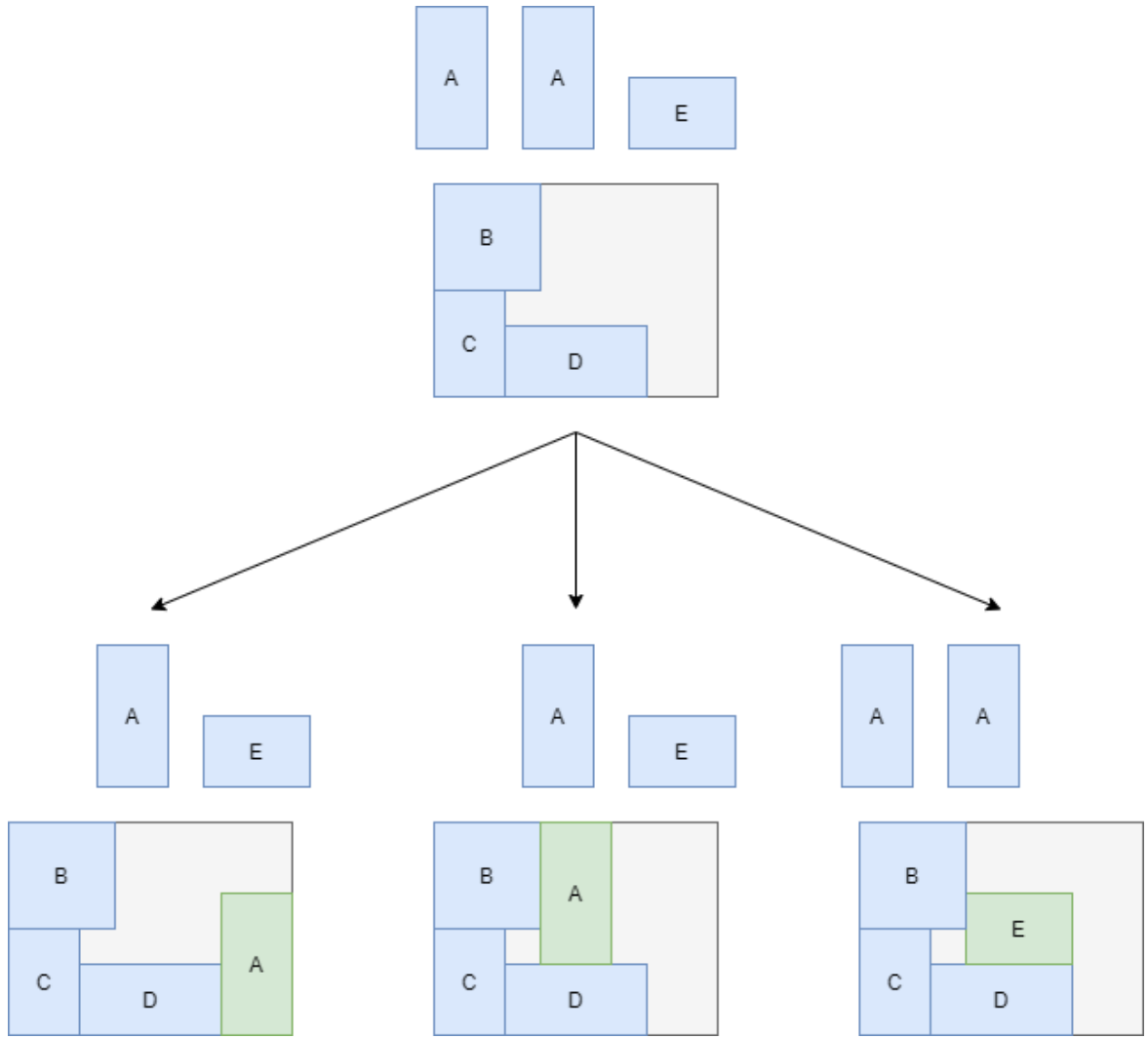
Resolution

At the root node:



Resolution

At an internal node:



Resolution

- The search tree is huge
  - Each node may have hundreds of child nodes
  - That's way too large to be explored exhaustively for practical cases
- We use algorithms that search in this tree in a smart way to quickly find the good solutions

Table of contents

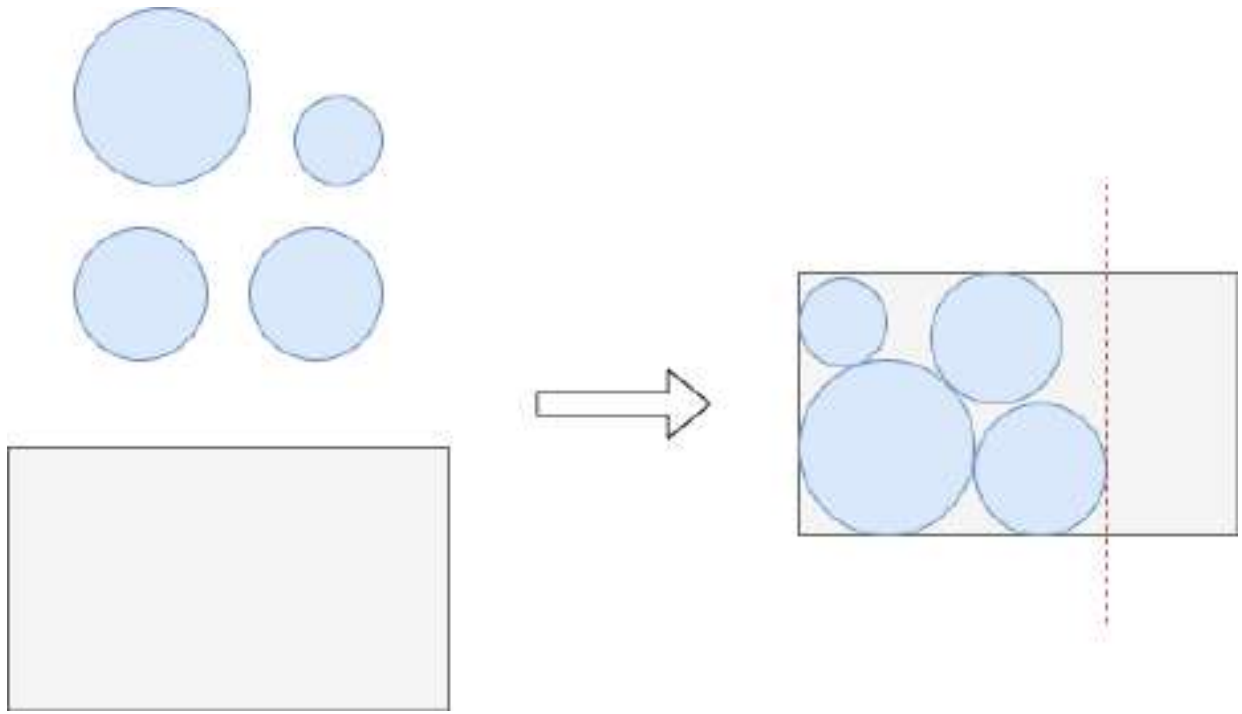
Mathematical programming

- The tree search method mentionned above requires programming
- Some optimization methods may work on a general mathematical formalism
- There are libraries, called optimization solvers, that implement such methods
- It is then possible to solve an optimization problem by writing it as equations in a given mathematical formalism and solve it with such a library

Example: circle packing

To illustrate how a problem can be written as equations, let's consider another variant of a packing problem

- The pieces to pack are n cirlces with radius r_j, $j = 1, \ldots, n$
- The objective is to minimize the width used on the large sheet



Example: circle packing, mathematical model

Variables:

- $x_j \in \mathbb{R}$, $j = 1, \ldots;$ n: x-coordinate of the center circle j
- $y_j \in \mathbb{R}$, $j = 1, \ldots, n$: y-coordinate of the center circle j
- $w \in \mathbb{R}^+$: width of the container

Objective:

- Minimize the width of the container

$$\min w$$

Example: circle packing, mathematical model

Constraints:

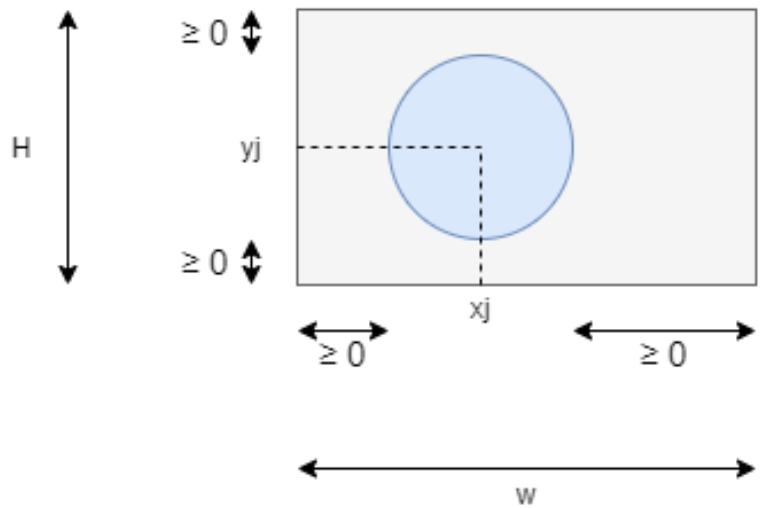
- Each circle must be packed inside the container:

$$\forall j = 1, \ldots, n, \qquad x_j + R_j \leq w$$

$$\forall j = 1, \ldots, n, \qquad y_j + R_j \leq H$$

$$\forall j = 1, \ldots, n, \qquad x_j - R_j \geq 0$$

$$\forall j = 1, \ldots, n, \qquad y_j - R_j \geq 0$$



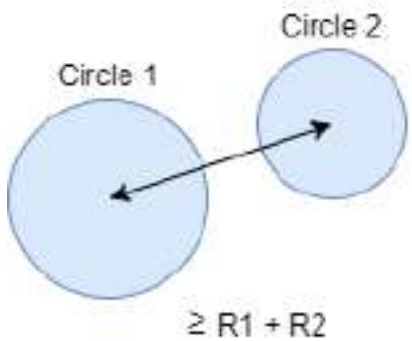
Example: circle packing, mathematical model

Constraints:

- Each pair of circles must not intersect:

$$\forall j_1, j_2 = 1, \ldots, n, j_1 < j_2,$$

$$\sqrt{(x_{j_2} - x_{j_1})^2 + (y_{j_2} - y_{j_1})^2} \geq R_1 + R_2$$



Artelys Knitro

- At Artelys, we develop Artelys Knitro
- Artelys Knitro is a solver which can solve this kind of problems
- Widely used in academia...
  - US Top Universities: Berkeley, Columbia, Harvard, MIT, Stanford...
  - Worldwide Top Universities: ETH Zürich, EPFL, LSE, NUS (Singapore), Melbourne...
- ...and industry
  - Economic consulting firms
  - Financial institutions
  - Mechanical engineering companies
  - Oil & Gas companies
  - Regulator & Policy maker
  - Software developers
    - Used as a third-party optimization engine

Resolution illustration

Table of contents

METIS

- Project led by Artelys on behalf of the European Commission
- Provide the European Commission with enhanced energy modelling capabilities in order to support their evidence-based policy making processes
- Conduct a series of studies building on the developed models, on topics such as the design of electricity markets, the role of gas and electricity infrastructure, the future of district heating, the impacts of power-to-X technologies, etc

METIS

Recent study

- When and what production assets to install to meet targetted emission level in 2050 at a minimum cost?

Solve the production-demand problem

- European scale
- Multi-energy: model with detailed representation of sector coupling
- Horizon 2030-2050: pathway optimization over multiple decades
- Hourly time resolution, that is well adapted to capturing flexibility needs

METIS, interface

- Web-based interface including customised KPI views and interactive maps

METIS, interface

- Web-based interface including customised KPI views and interactive maps

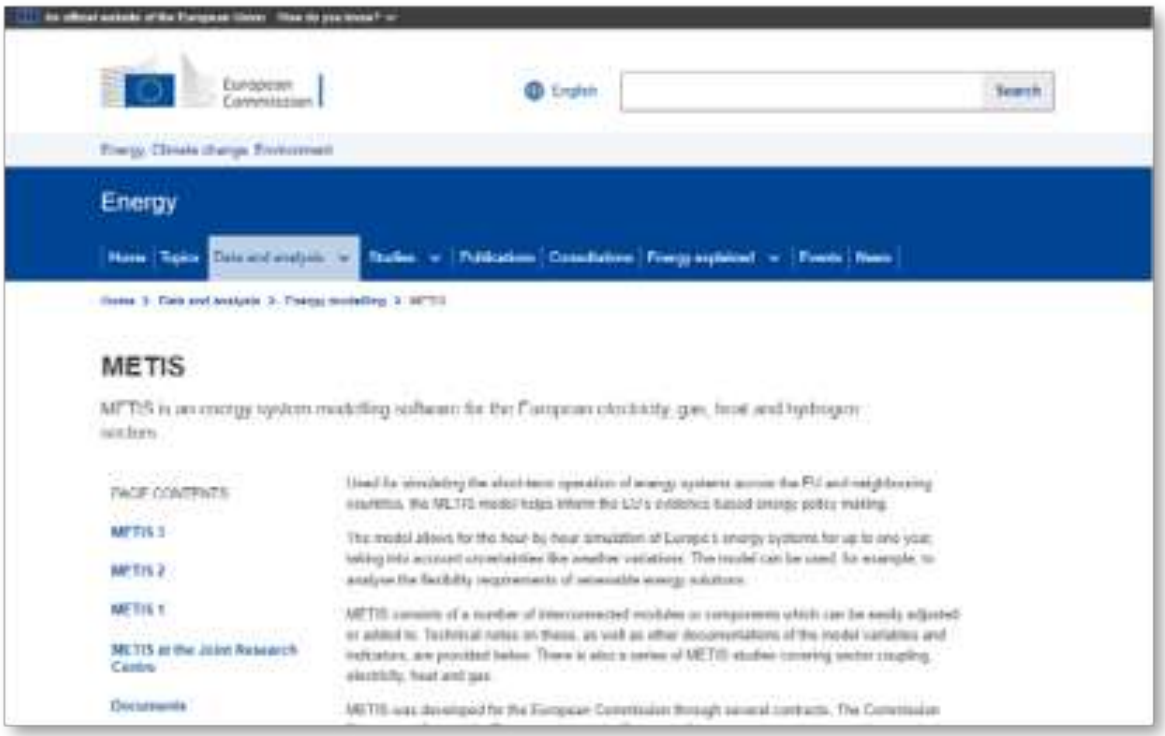
METIS

METIS has become a key asset to inform EU policymaking, combining strong analytical capabilities with a high level of transparency.

- 10+ studies using METIS published by the JRC to date
- 40+ studies conducted by Artelys for DG ENER and DG CLIMA over the years, including around thirty METIS 1-2-3 studies and a dozen additional studies.
- Supporting the impact assessment of key policy packages: Clean Energy Package, Hydrogen and Decarbonised Gas Package, 2040 GHG target.
- Extensive datasets and documentation available on the European Commission website.

METIS, interface

- METIS page on the European Commission website



Optimization at Artelys

Florian Fontan

Artelys France

L'optimisation, au cœur des défis des sciences informatiques,
October 03, 2024