ME-409
2025/2026

Project

Arthur Chuat
EPFL-IPESE

IPESE
EPFL

8th of September 2025

Outline

1. Context & Goals
2. Energy System Modelling
3. Interface Guidelines & Demonstration
4. Organisation

Towards a culture of respect

@ EPFL

We are all concerned

We all have a role to play!

*EPFL wants to be an institution free from **harassment, violence, or discrimination.***

- Report a case :
  Respect Compliance Office (RCO)
  >> respect@epfl.ch
- Express yourself and seek support:
  Trust & Support Network (TSN)
  >> Trust Point application

At IPESE Lab, we have **zero tolerance** for discrimination.
If you face any issues, **feel free to speak up** by coming to us or any communication channels.
The sooner you come to us, the quicker we can find a solution !

Context & Goals

Project description

At the end of the **Course Compendium**

https://ipese-lectures.epfl.ch/energy-conversion-2019/project-description.html

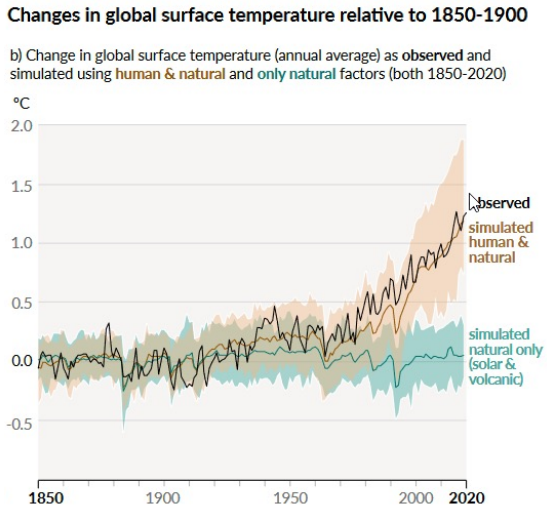
Project description

The *aim* of this project is to investigate the possible energy mixes of Switzerland under the horizon 2050. You are given a model that represents an energy system, which does *not* correspond to the current Swiss energy system. You can expand or restrict the model by progressively adding or removing energy conversion technologies. You may also vary the model parameters: resources costs, carbon content and availability, end-use energy demands, and technologies characteristics. You can then run an optimization to minimize the system costs (economical objective) or impacts (environmental objective), and analyze the results.

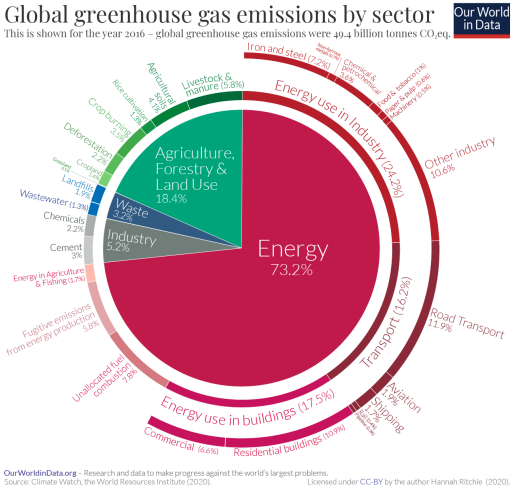
Goals

Write a scientific report to help **support decision-making in national energy policy** at the **2050 horizon** as a consultant of the Swiss government

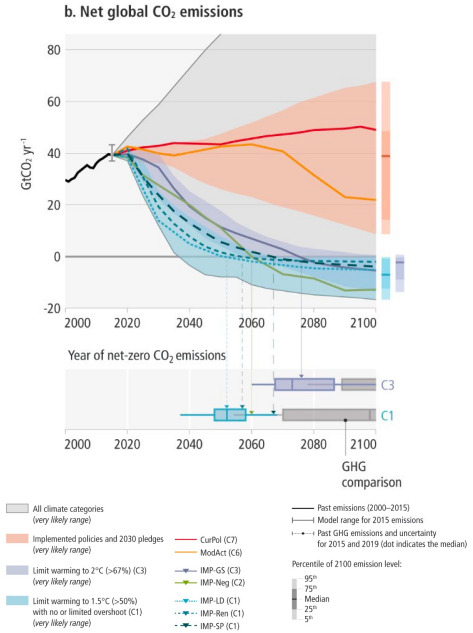
Why ?



Source: IPCC AR6, WG III



How ?

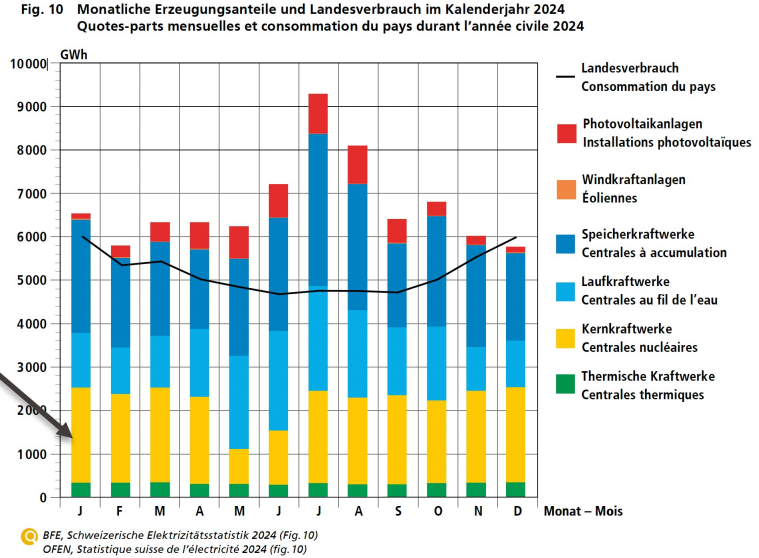


Context

The Swiss case: Nuclear Phase-out

March 11th, 2011
Fukushima nuclear disaster

How to fill this gap ?



2034 : Phase-out of nuclear power plants
(decided by Swiss citizens in 2017)

Sources:
- SFOE, Swiss electricity statistics 2011
- SFOE, Energy strategy 2050 explanatory document

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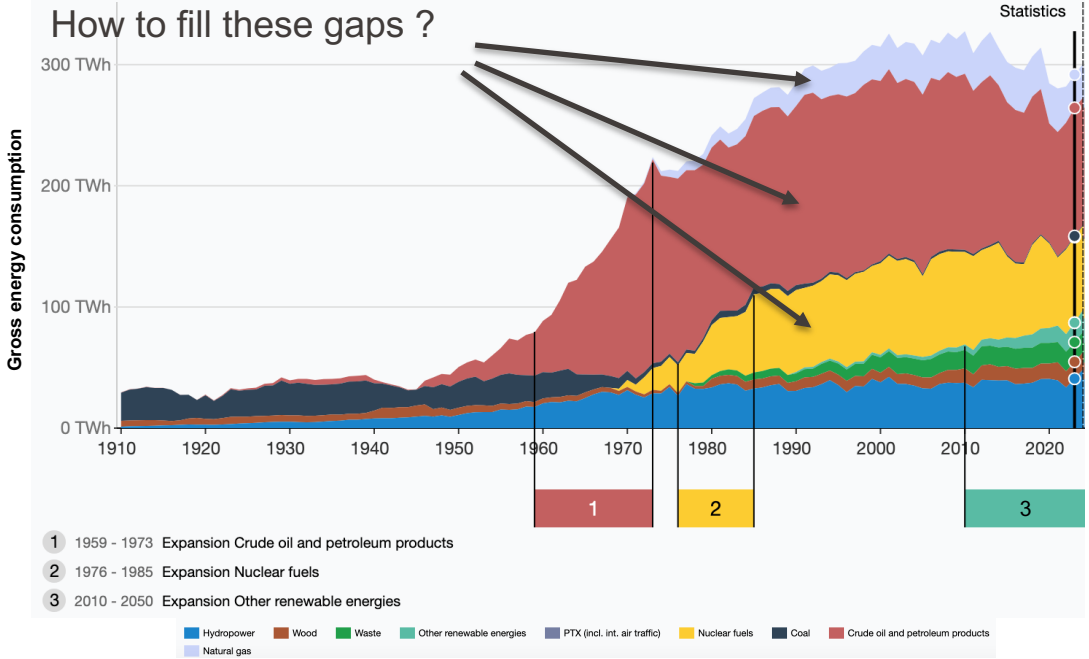
Context

The Swiss case: Nuclear Phase-out + Net-zero by 2050

October 2018
IPCC reports on impacts of warming above 1.5°C



Sources:
- IEA, Switzerland
- SFOE, What is the Energy Strategy 2050?

2050: Reduce net greenhouse gas emissions to zero (net emissions target)

Goals

Write a scientific report to help **support decision-making in national energy policy** at the **2050 horizon** as a consultant of the Swiss government

- Suggested report structure is available in the project description
- You will have freedom!
  → Take (well-supported) decisions
- First follow the tasks, then you can go beyond

A suggestion of structure is given as follows - you may adapt it based on the results obtained in the various tasks.

- Introduction
  - Briefly introduce the aim of your report.
  - Give a short overview of the Swiss energy system in 2022.
- Methods
  - Which model was used ? What are the underlying hypotheses ? What are its limitations ?
  - How did you define your two scenarios ?
- Results
  - Present the two Pareto curves for each scenario.
  - Present the two energy system designs you recommend to the government, selection of one configuration on each Pareto curve.
  - Compare them to the baseline designs and the current energy system as of 2022, for example their pros and cons, their costs, impacts, etc.
- Discussion
  - Discuss these mathematically optimal solutions from different perspectives : are your designs realistic from a technical, social and geopolitical perspective?
  - These systems will not arise in a single year, there needs to be a whole transition leading to them. What kind of incentives could the government provide to end up with the recommended system in 2050 ?
  - Finally, highlight the limitations of the model and the main points of uncertainty.
- Conclusion
  - Recommendation for the Swiss energy system in 2050.

Tasks overview

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1

Status of the Swiss Energy System as of **2024**

- *Which resources and technologies are currently used?*

2

Swiss energy demands of **2050**

- *Considering economic development and population growth, how are our energy demands expected to change?*

3

Baseline scenarios for the future energy systems

- Which scenarios for the development of our energy system can be expected, at which costs and impacts?

The tasks are more detailed in the project description

Tasks overview

4

Trade-offs between economic costs and environmental impacts

- *How can we respect our 2050 targets at an acceptable cost?*

5

Impact of **energy sobriety and efficiency**

- *Which changes in our behaviours and technologies can help us reaching these targets?*

6

The future is **uncertain**

- Geopolitical changes impact prices and resource availabilities, are the proposed energy systems adequate?

The tasks are more detailed in the project description

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Energy System Modelling

Energy System Model (ESM)

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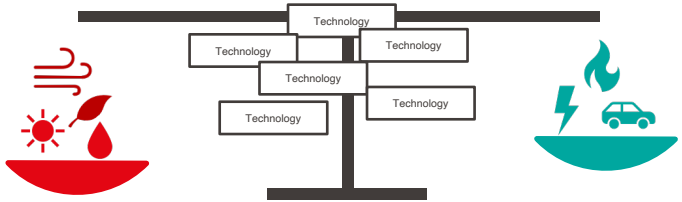
Technology

Fossils & Renewables
Investments & O&M
Efficiencies & Emissions
Storage

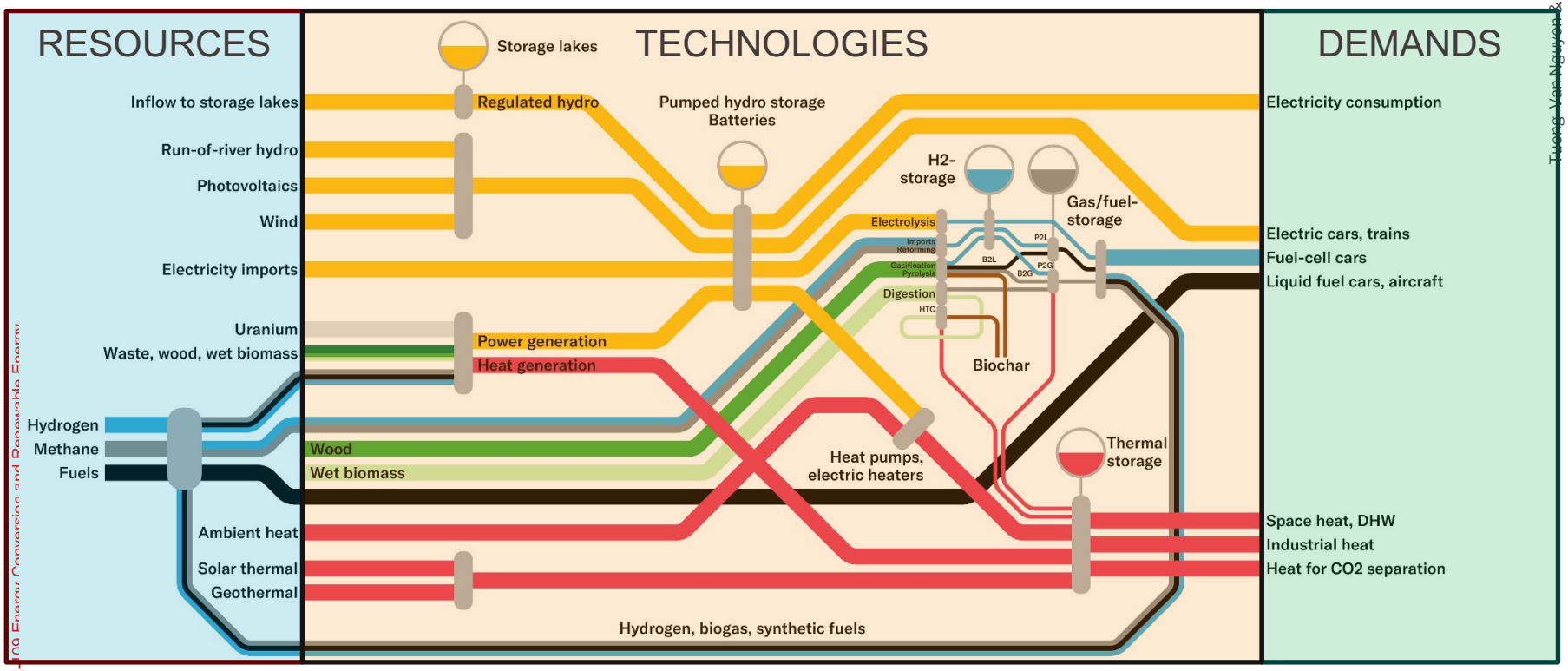


Resources

Costs & Emissions
Annual availability

Energy demands

Energy System Model (ESM)



ME-100 Energy Conversion and Renewable Energy
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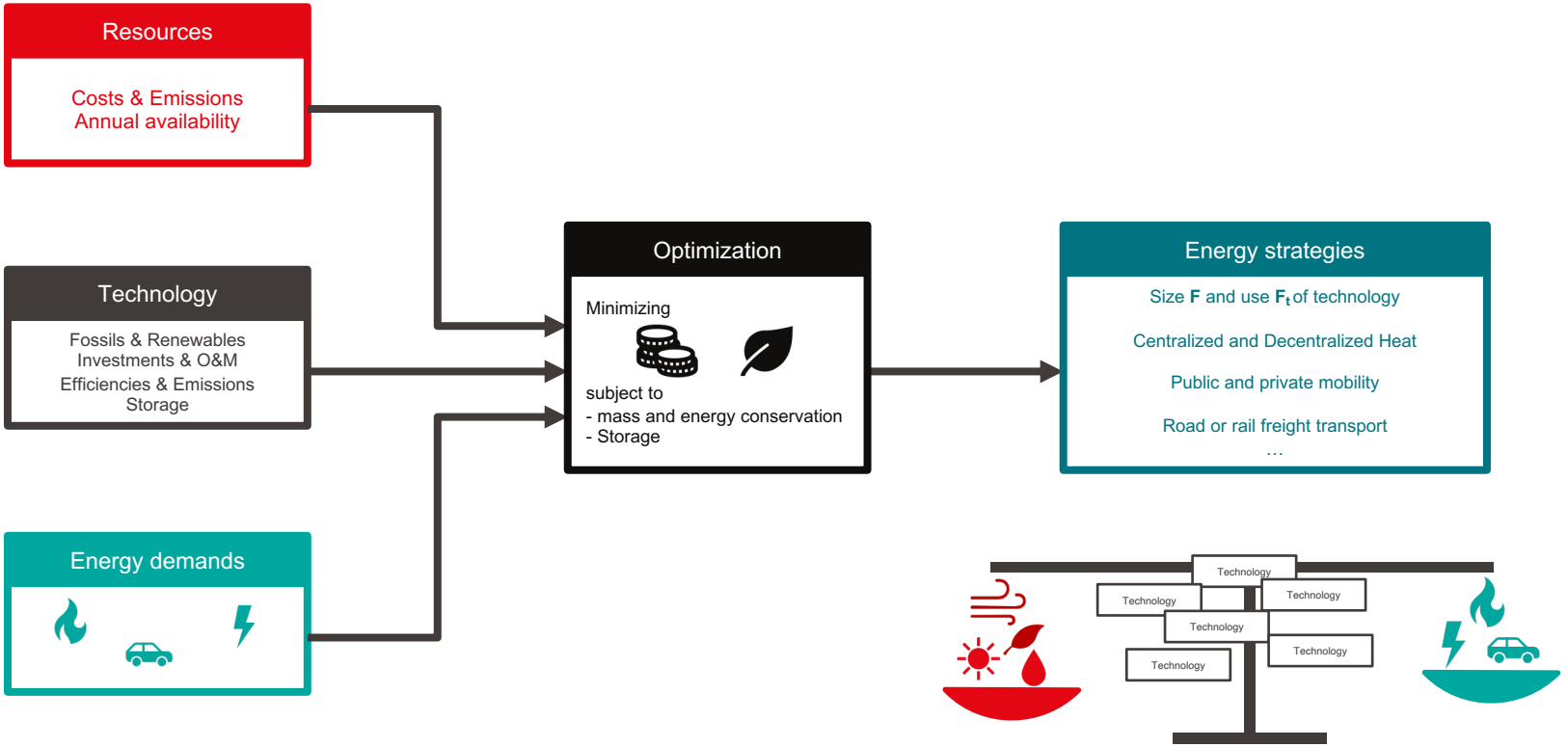
Credits to G. Guidati (Energy Science Center)

Energy System Model (ESM)



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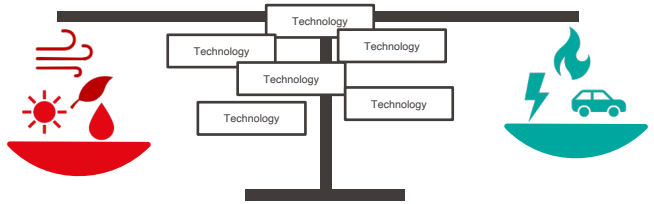
Energy System Model (ESM)



Resources

Costs & Emissions
Annual availability

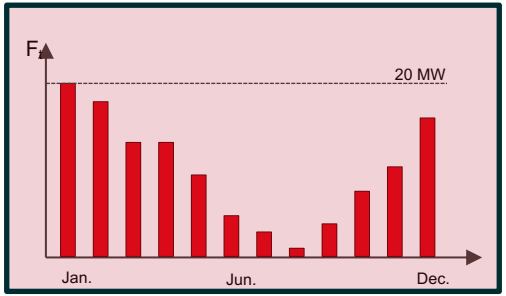
Technology

Fossils & Renewables
Investments & O&M
Efficiencies & Emissions
Storage

Energy demands

Technology Example: *Combined Cycle Gas Turbine (CCGT)*

Investment costs:	1334 [k$/MW]
Maintenance costs:	40 [k$/MW]
Construction emissions:	491 [t CO_2/MW]
Lifetime:	24 [y]
Annual availability factor:	85 [%]



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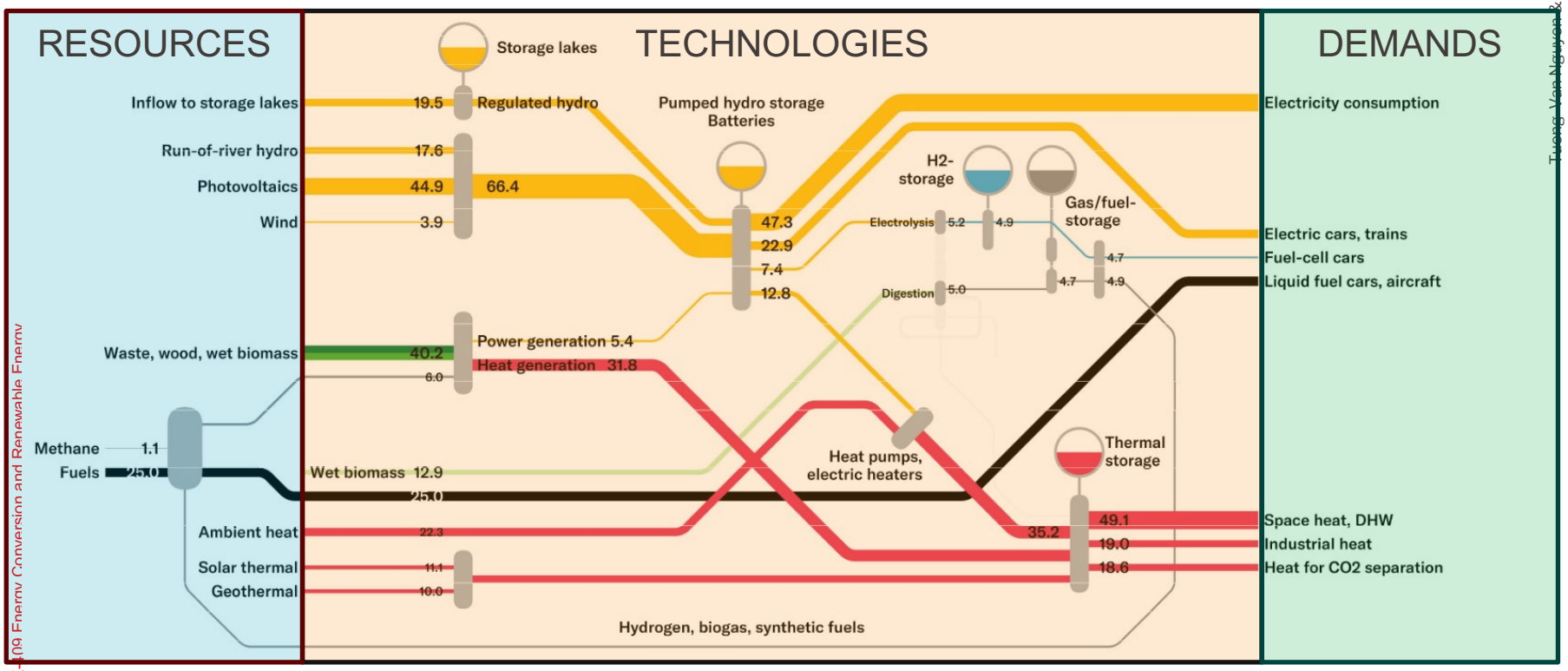
Energy System Model (ESM)



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Model structure

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The model is defined as a linear optimization problem, which matches the energy demand with the available resources, while minimizing a specified objective function.

Objective function : CAPEX, OPEX, TOTEX, GWP_op, GWP

Constraints :

- Mass balance, energy balance, cyclic conditions (storage)
- Technologies limitations (deployment potential, capacity factor)
- Additional constraints on the defined key performance indicators (KPIs)

Decision variables :

- Installed capacity for each technology
- Operation of each technology (on a monthly basis)
- Shares of : centralized heating (DHN) / public vs private mobility / rail vs road freight

Model structure

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Energy-based model, with a “snapshot” modeling approach : optimization of the system in a target year

Simplified yet complete energy system : electricity, heat and mobility demand

Multi-periods formulation : seasonality of demand and energy storage

Based on the input data and objective function, the optimizer selects the optimal :

- Generation capacity of each technology (wind, solar, nuclear, etc.)
- Storage capacities required
- Operation of each power plant at a time t
- Imports of resources

→ Complete Energy Strategy for 2050

Interface guidelines

+ live demo

Interface
Excel sheet

4 tabs defining the input data for the model

- Control: Specify your objective function, constraints
- Resources: Availability, cost, carbon content
- Demand: Electricity, heat and mobility
- Technologies: +50 characterized energy technologies

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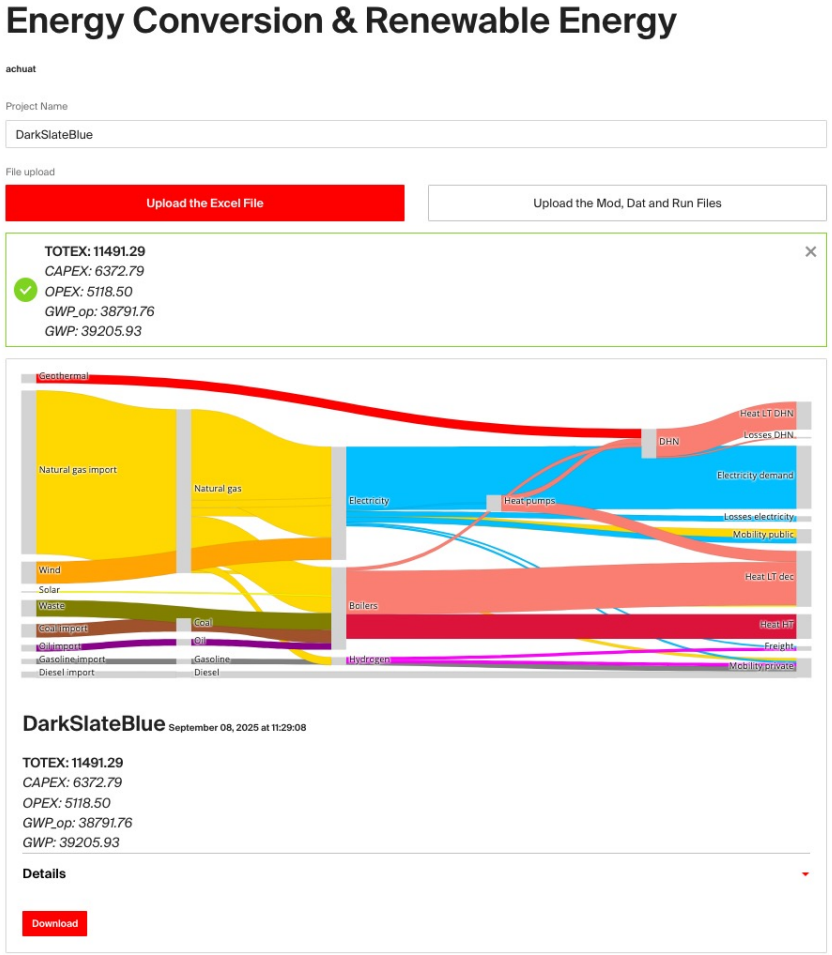
Interface
Platform

Project description

Course material

Moodle

https://ipese-lectures.epfl.ch/energy-conversion/project/



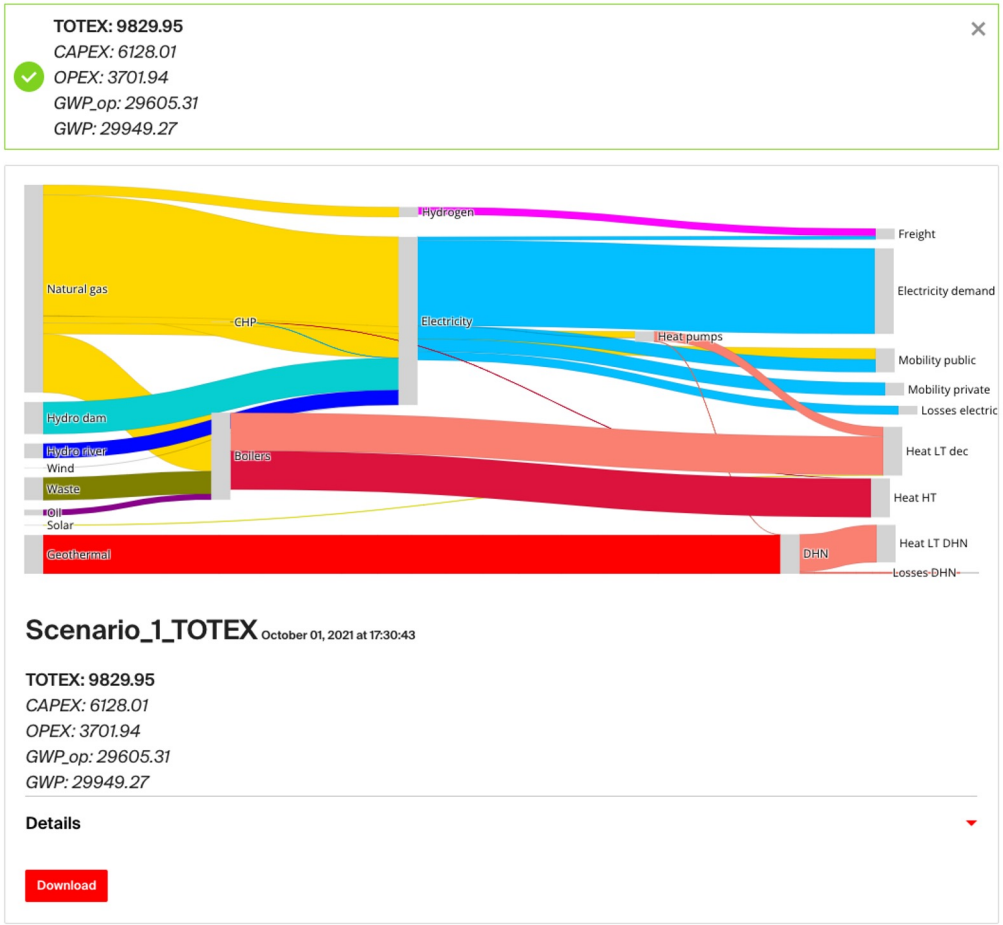
Interface
Platform

Performance indicators

Sankey diagram

Run name and date

Output data
(10 .csv files)



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Demonstration

As any live demonstration, this will obviously not work properly as

Organization

Organization
General

Groups of 5 students → Please register for the group before the 15.09

Monday 10-11h – Exercise session
- On campus (CO 3)

Monday 11-13h – Lecture
- On campus (CO 3)

Monday 13-14h – Project session
- **On campus (AAC 2 31)**

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Organization
Material

Course website **[VPN needed / access from EPFL]**

- Contains *Project description*

Online platform **[VPN needed / access from EPFL]**

- To run your optimizations

ed : Forum for project related questions

Moodle

- Excel file (*EC_interface.xlsx*)
- Group formation
- Final report submissions (+ Declaration of authorship)

Organization
Deliverables

Group formation → Next Monday 15/09/2024

Final report → Final report 19/12/2024

- Graded, 100% of pr
- Maximum limit of 10

This doesn't mean, you don't have to work for the final exam !!

Last year 26% of student with project grade > 4.5 failed the course, 14% with > 5 and 3% with > 5.5

Project accounts for 40% of course final grade

40% Project | 60% Written exam

Project related questions

Questions & communication

Use first and foremost the weekly project session

Use the ed forum

- The answer to your question there will benefit everyone
- You can ask questions anonymously

Avoid as much as possible to send emails to the assistants

And finally, get to work ahead of time. You are +130 students, it will be impossible for us to help you if the 30 groups bombard us at the same time with questions the day before a milestone ! 🤯