



Investment and Operational Optimization Model for Future Hydrogen Infrastructure *(Application and definition to Belgium)*

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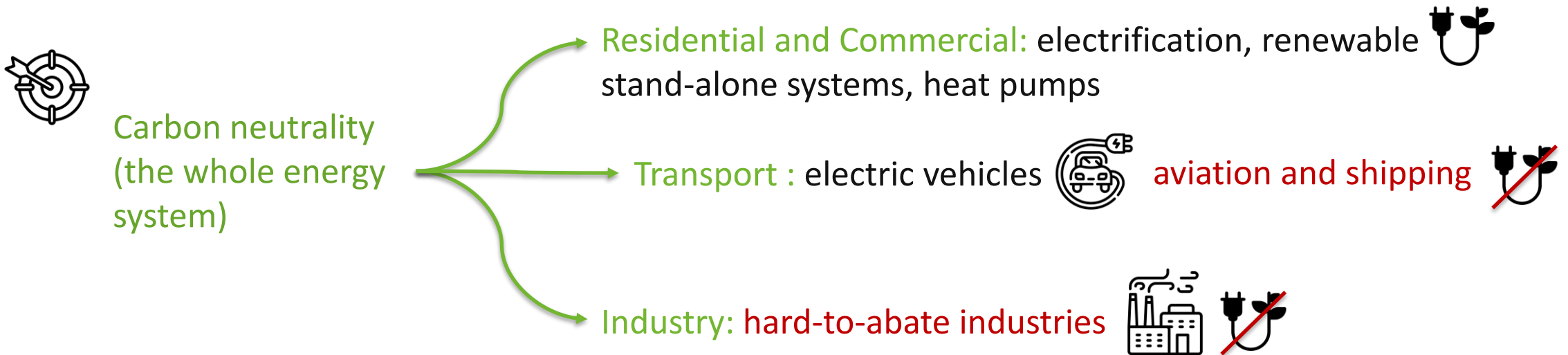
Agenda

-  Introduction
-  Research Gap
-  Methodology
-  Results
-  Conclusion

Introduction

European green deal and climate law

- The target of EU to become climate neutrality by 2050
- Energy security – highlighted after Russia's invasion of Ukraine

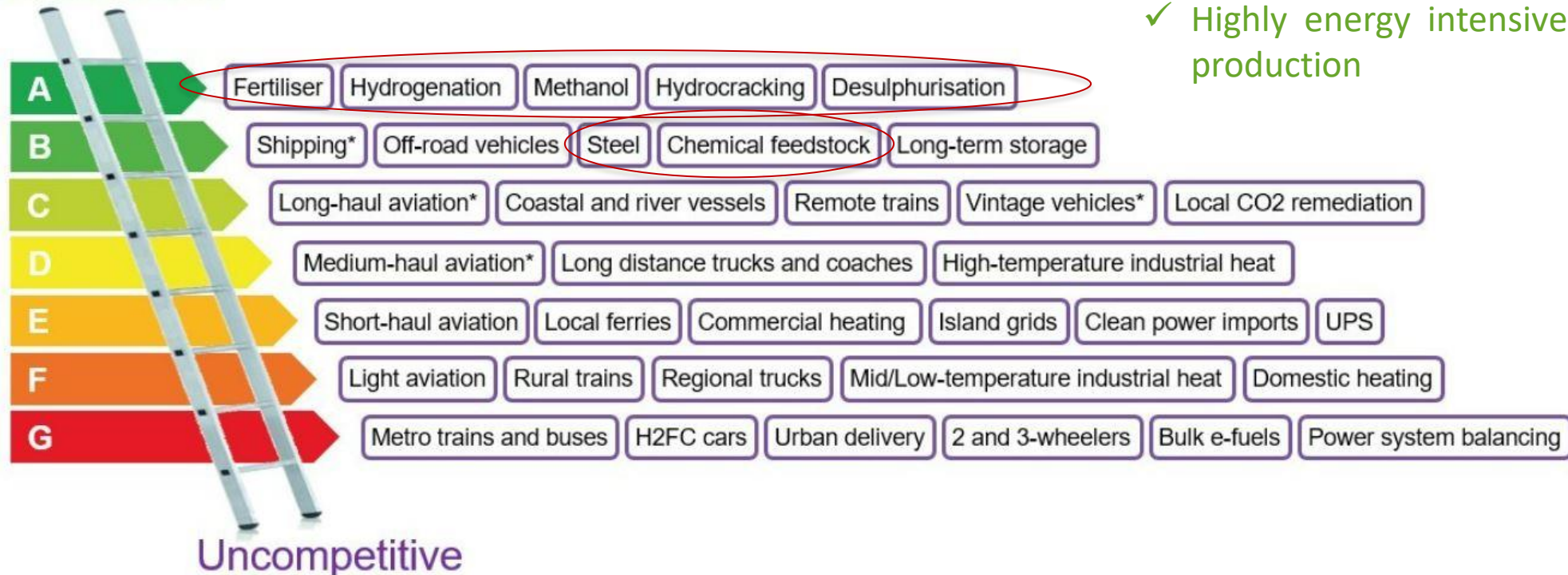


Introduction

Heavy (hard to abate) industries

Hydrogen is a crucial candidate to decarbonize the heavy industries

Unavoidable

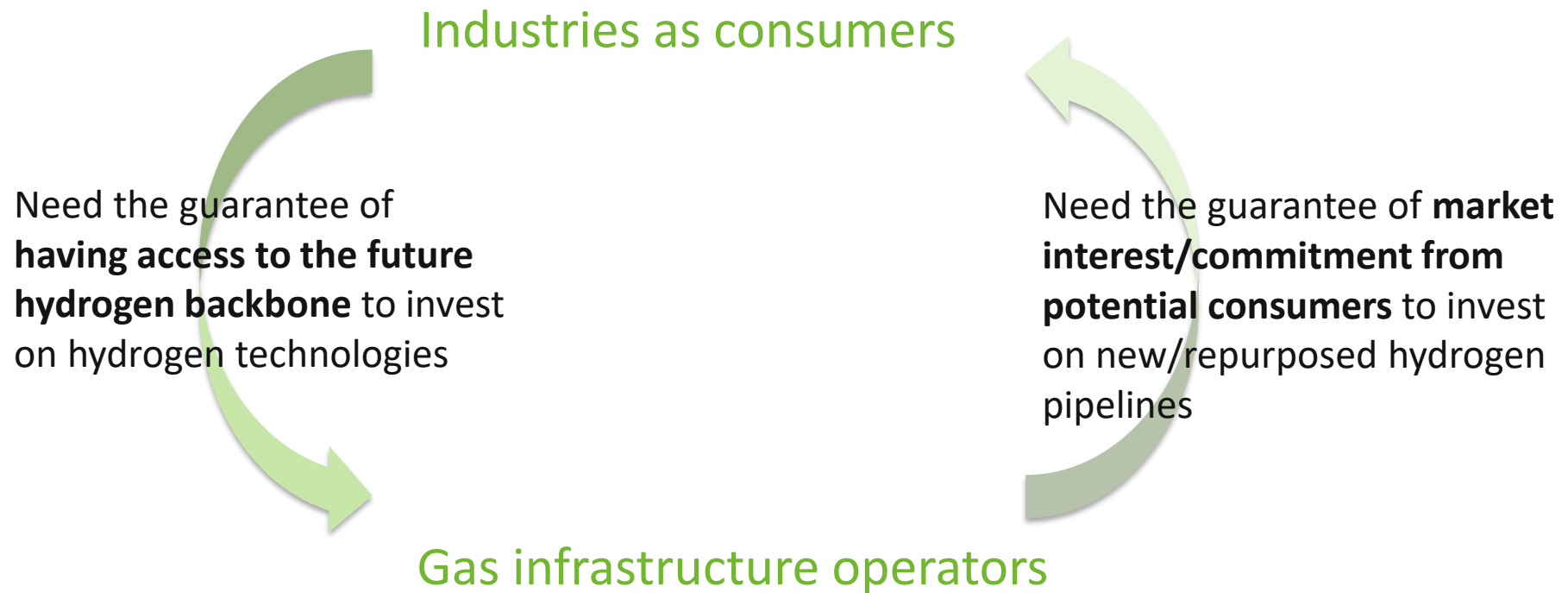


- ✓ Consume fossil fuels (NG) both as energy carrier and feedstocks
- ✓ Highly energy intensive per unit of production

Ref: Liebreich Associates

Introduction

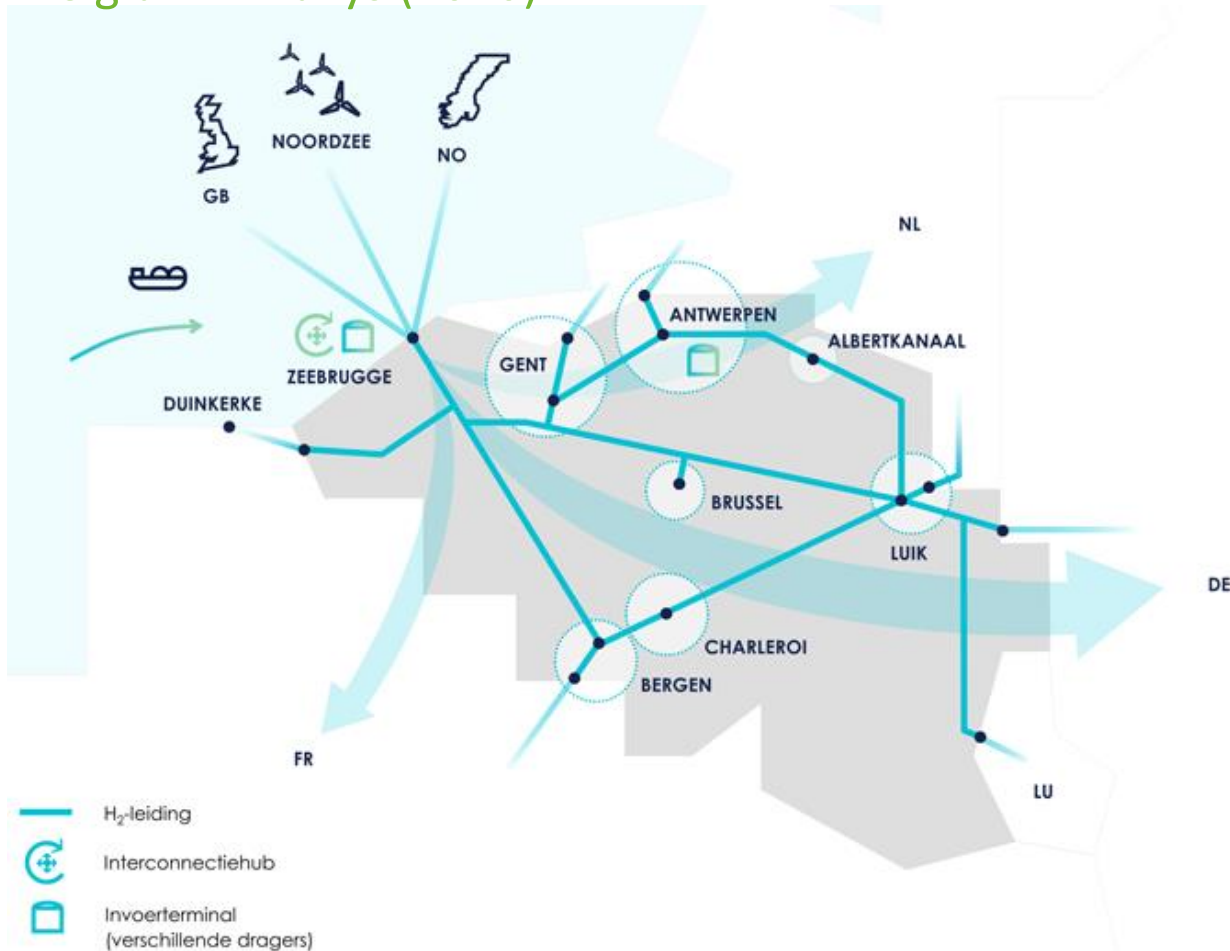
Transition: adopting hydrogen technologies



Introduction

Roadmaps on the future hydrogen backbone

Belgium – Fluxys (2040)



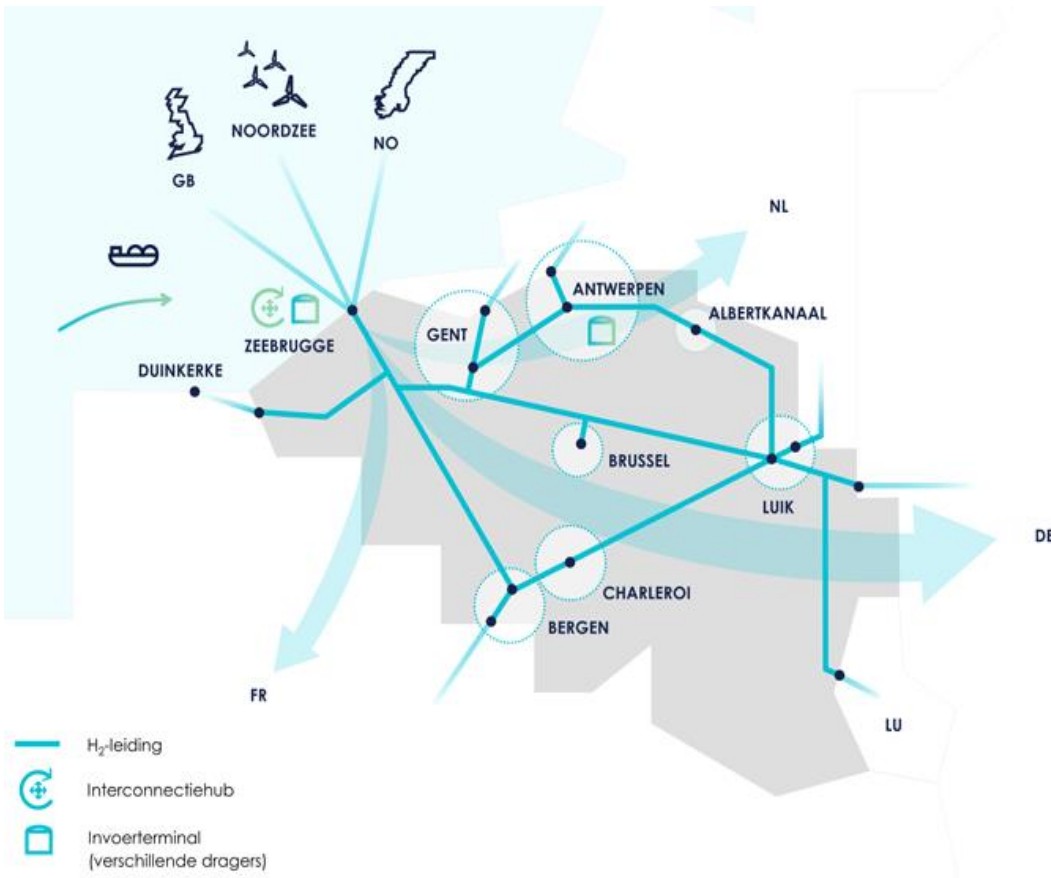
Netherlands – Gasunie (2030)



Research Gap

Long-term analysis of the future required network capacity

Belgium – Fluxys (2040)



- ✓ Potential **industrial demand clusters** are known based on the **surveys** on future hydrogen **market interest**
- ✓ **Commitments** from **some** of the interested potential users
- ✗ **Scenarios on the future required volumes of hydrogen in each cluster?** (High uncertainty in the future demand)
- ✗ **Scenarios on the required capacities of the hydrogen pipe segments?** (how many parallel pipe segment are required among each pair of clusters?)
- ✗ **Scenarios on the required installed capacity of hydrogen-related supply/production technologies in each cluster of the network**

Methodology

Future demand scenarios

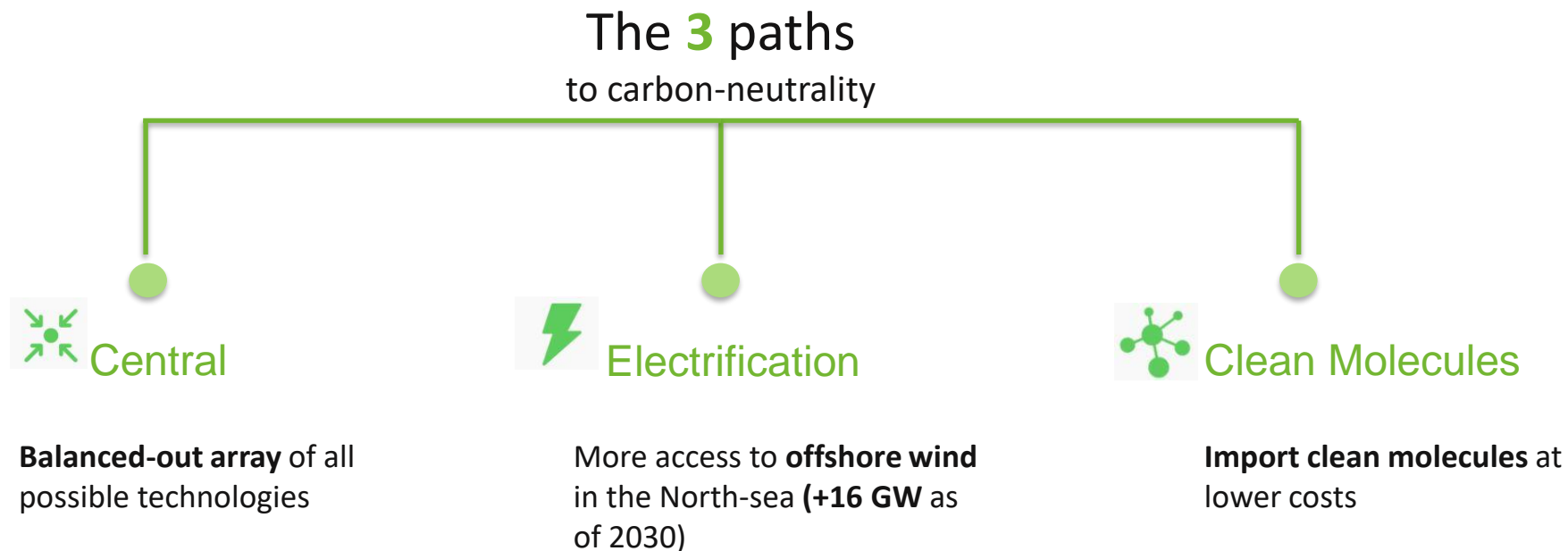
- **Market commitment data** of all industrial clusters for the future years
- Decarbonizing the potential industries **defining different consumption routes** (electrification vs hydrogen consumption)
- Considering **whole energy system net zero scenario** until 2050 with **long-term planning cost optimization models** and obtain the **optimal required hydrogen consumption for the industrial sector**

Methodology

Future demand scenarios – Belgium perspective 2050

Long-term planning optimization (2020-2050), Minimizing the total system cost, Belgium as one single region

[Ref: PATHS2050 | Energy outlook \(energyville.be\)](#)



Methodology

Future demand scenarios – regionalization

Belgium outlook model

- High sectoral resolution
- High technological resolution
- Long-term planning
- Representative days

Overall industrial
hydrogen consumption



Regionalization of
demand for each:
cluster
industry
Sector
Based on **production
capacities**

Hydrogen infrastructure model

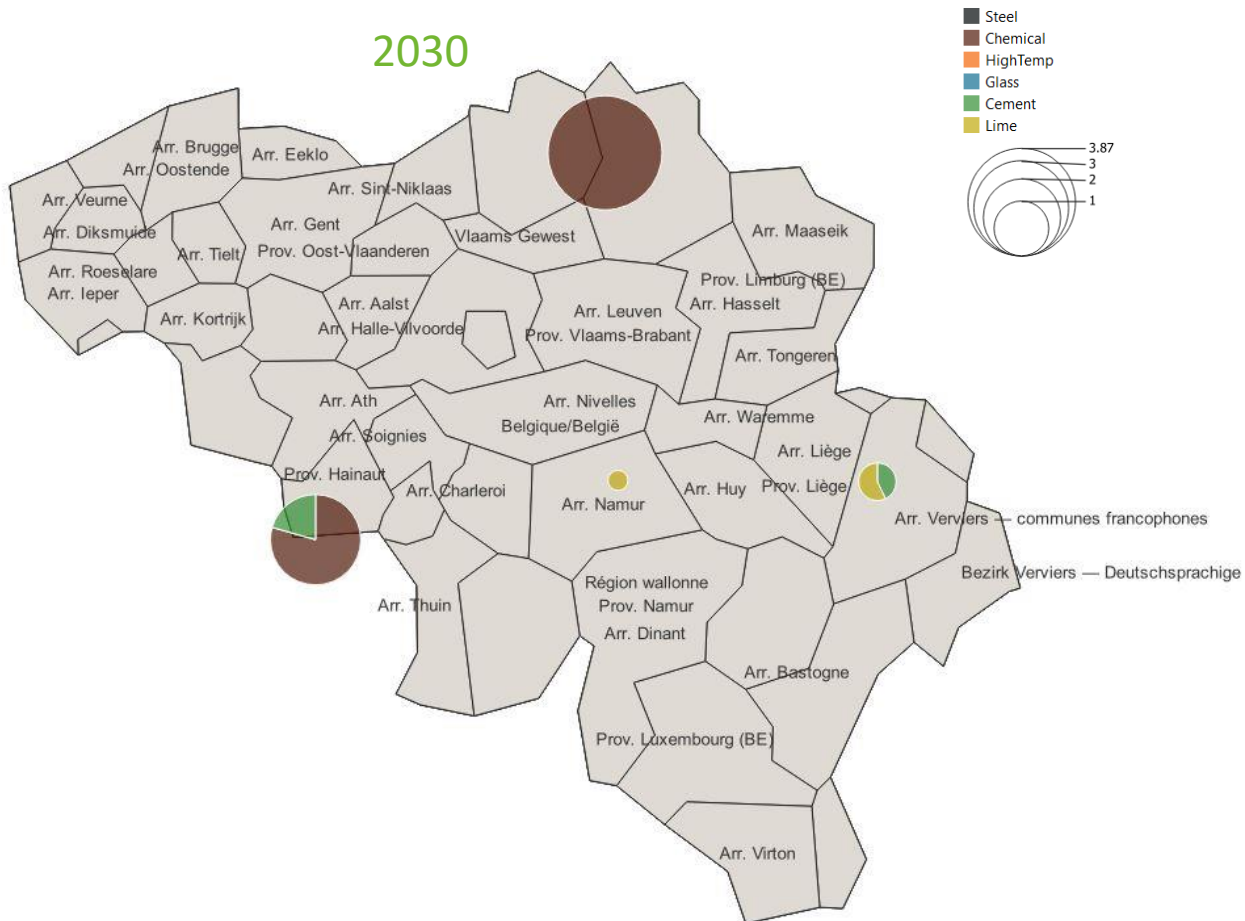
- Low sectoral resolution
(heavy industries)
- Low technological resolution
(renewables and hydrogen
technologies)
- High spatial resolution
(detailed cluster-level)
- Full hourly resolution

Methodology

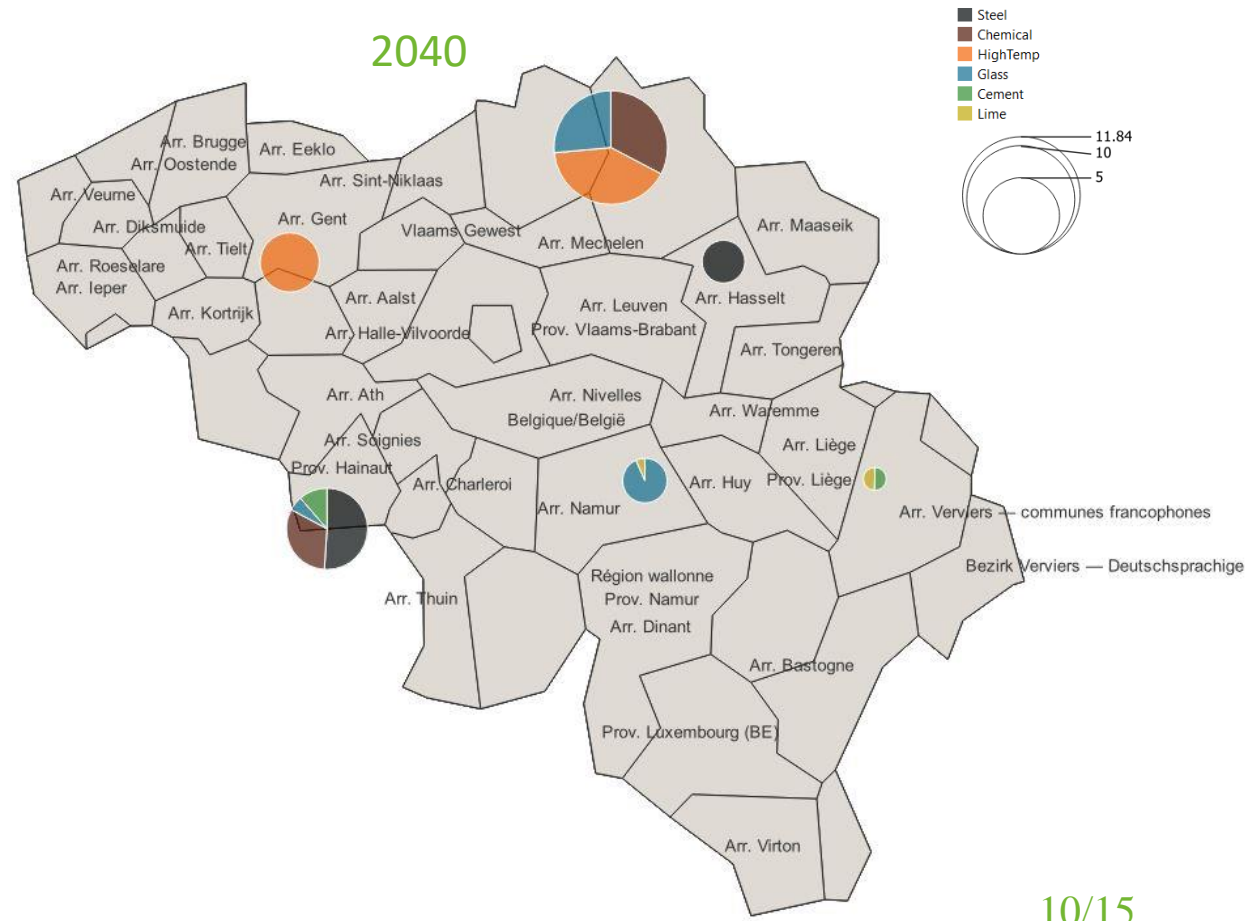
Future demand scenarios – regionalization

Clean molecules scenario:

2030

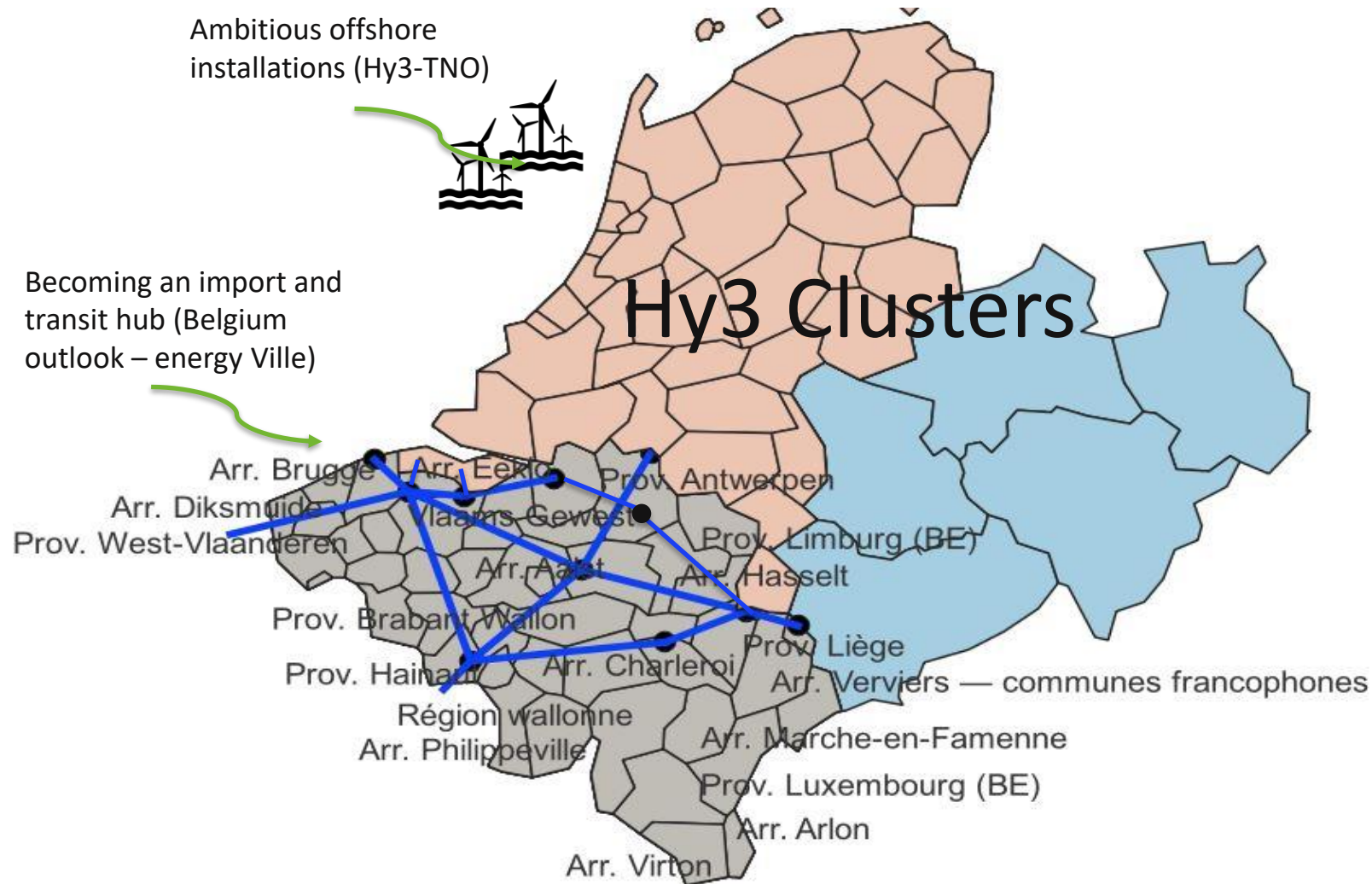


2040



Model Structure and Methodology

Spatial resolution and supply side scenarios



- **Green Hydrogen production:**
 - Onsite renewable technologies + onsite electrolyzers
 - Central renewable + central electrolyzers
 - Offshore wind turbines + off/onshore electrolyzers
- **Low carbon Hydrogen production (3-ton CO2 per ton H2)**
 - Onsite grid connected electrolyzers
- **Blue Hydrogen production**
 - Steam methane reforming + carbon capture and storage
- **Molecule import**

Methodology

Techno-economic linear investment and operational optimization problem

- The final objective is to minimize **the total discounted system cost over the whole-time horizon:**
 - All **actualized regional costs** of supply technologies
 - All **actualized inter-cluster pipeline costs** (depending on both the **km and capacity** required of each pipe segment)

- Decision variables:
 - Local **electrolysis/SMR+CCS hourly production** curves in each region
 - **Import and export curves** with neighboring countries
 - **Pipeline required capacities** and investments

- Constraints on :
 - Capacity and flow rate of the hydrogen pipe network (**network- typology**)
 - **Overall installed capacities** of renewable and hydrogen supply technologies (TIMES-BE and Hy3-NL)
 - **Resource availability and max technical potential** in cluster-level resolution

Methodology

Techno-economic linear investment and operational optimization problem: Hypatia framework

[GitHub - Hypatia-Energy-Modelling-Framework/Hypatia: An Operation and Planning Energy System Modelling Framework](#)



main 6 branches 1 tag

Go to file Code

File	Commit Message	Time
Negnamazi Update README.rst		5721a68 on Jul 14 131 commits
doc	Update installation.rst	7 months ago
examples	doc modification	9 months ago
hypatia	Merge pull request #12 from AAmedeo/create_technology_columns	7 months ago
.gitignore	Storage charge and discharge efficiency	9 months ago
.readthedocs.yaml	Update .readthedocs.yaml	10 months ago
.zenodo.json	docs	8 months ago
CHANGELOG.rst	Complete changelog v0.1.1	8 months ago
LICENSE	Update LICENSE	11 months ago
MANIFEST.in	adding manifest.in	10 months ago
Pipfile	init in parameter files of the example gallery	10 months ago
Pipfile.lock	init in parameter files of the example gallery	10 months ago
README.rst	Update README.rst	3 months ago
requirements_docs.yml	doc api	10 months ago
setup.py	update version	9 months ago

About

An Operation and Planning Energy System Modelling Framework

- Readme
- Apache-2.0 license
- 2 stars
- 0 watching
- 5 forks

Releases 1

Release v0.1.1 **Latest**
on Feb 13

Packages

No packages published

Contributors 3

- Negnamazi
- mohammadamint Mohammad Amin Ta...

hypatia latest

Search docs

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Introduction Edit on GitHub

Introduction

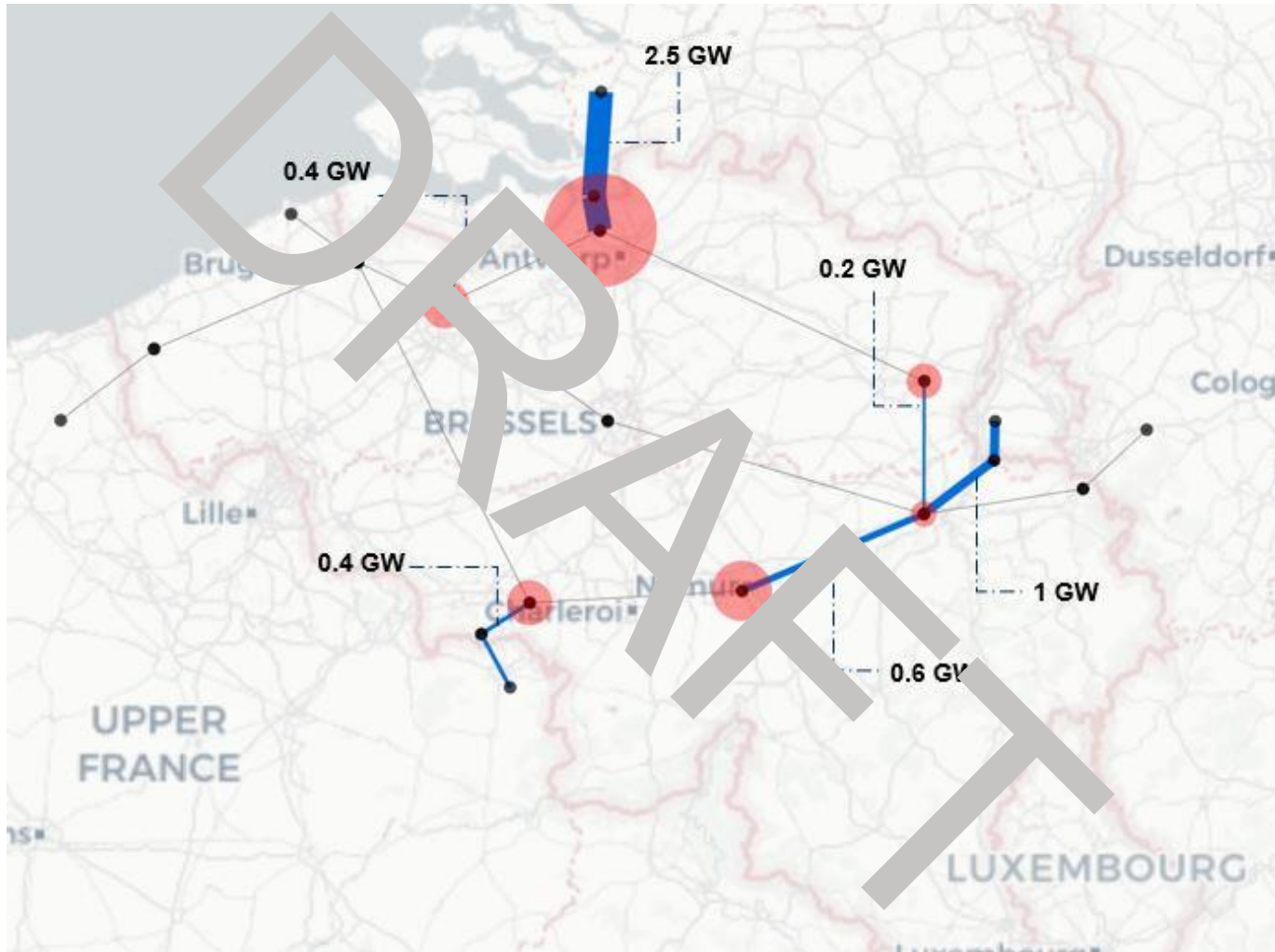
What is Hypatia

Hypatia is an energy system modelling framework written in the Objective Oriented Python programming language. Contrary to most of the Python-based open-source energy and power system modelling frameworks that are using `Pyomo` for solving the convex optimization problem, Hypatia is based on `CVXPY` domain-specific language developed by [Diamond2016]. Hypatia can optimize both the hourly dispatch and the annual capacity deployments of the energy system. Its final objective is to minimize the total discounted cost of the system by considering all the required cost components in each of its optimization modes. In summary, Hypatia is designed with the following main goals:

- Allow easy interaction with the model code by using excel-based input data
- Formulated to cover both operation and dynamic investment decisions
- Provide the possibility to consider the investment annuities in its planning mode based on the given economic lifetime and interest rate of each technology
- Allow to model various categories of technologies such as supply, conversion, transmission and storage.
- Able to consider the synergies among different sectors of the energy system including power, heat, transport, clean fuel (Hydrogen) and the others.
- Designed to follow both the single-node and multi-node approach at will by the user. Each node in Hypatia can be representative of a broad spectrum of spatial resolutions starting from small-scale applications to the national and continental applications.
- Allow to model the bilateral trade among any pairs of nodes through modelling the cross border transmission links for all the represented energy carriers within the Reference Energy System
- Able to adopt arbitrary resolutions in time for each modelling year, allowing to consider the full hourly variability of both demand and supply sides.
- Computationally affordable in running large model applications due to its element-wise matrix-based mathematical formulation
- Have a fully transparent and open-source code, flexible to any possible future modification and

Results

Required supply and backbone capacities - 2040



Assumptions:

- Clean molecules scenario of Belgium outlook
- Belgium: 15 nodes + offshore region+ Netherland and NRW as one single region
- Time horizon: 2020-2040 (snapshot of 20 years)
- Full hourly resolution

Conclusion

- There are **several market interest** announced from industrial sector to gas operators but no **estimation on future required hydrogen on the cluster and sector level**
- **High uncertainty** in the future demand **sets the necessity of various scenario analysis**
- **Peak industrial demand** and **trade** with the neighboring countries sets the **required pipe segment capacities**
- There is a **computational trade off** between **sectoral and spatial resolution** in techno-economic analysis
- Different **country-level supply assumptions and scenarios** might lead to unrealistic results (Biased results in the process of soft-linking two optimization model)



Thank you!