Maritime Decarbonization

Simulating the maritime industry's transition to net-zero emissions

Mathias Hintze & Frederik Lehn

GUROBI OPTIMIZATION

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping is a not-for-profit, independent research and development center looking to accelerate the transition towards a net-zero future for the maritime industry.

4/20/2023

Agenda

01 Introduction
02 How can shipping decarbonize?
03 NavigaTE – what is it?
04 Gurobi and why we use it?
05 How do we use NavigaTE to impact the transition to net-zero

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Who are we?

Mathias Hintze, Analyst

Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

- M.Sc. of Engineering in Mathematical Modelling and Optimization from Technical University of Denmark
- Worked in the Center for more than two years
- Previous experience from Boston Consulting Group and A. P. Møller Holding

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Frederik Lehn, Model developer

Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

- M.Sc. in Petroleum Engineering from Technical University of Denmark
- Worked in the Center for 1.5 years
- Previous experience from Maersk Oil and TotalEnergies

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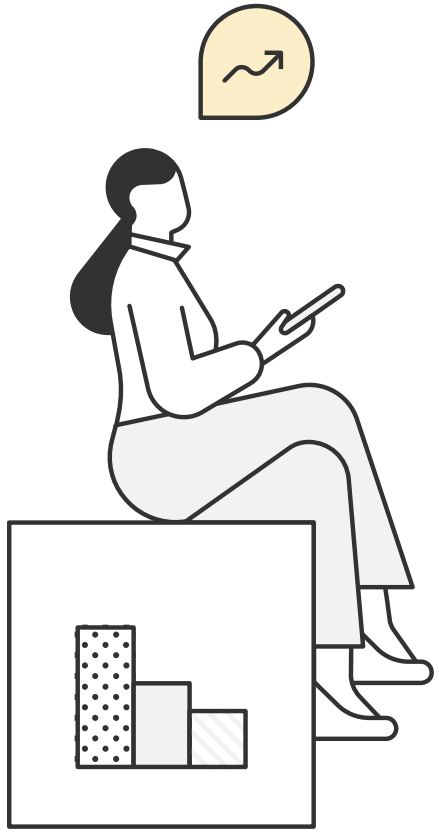
Who are we?

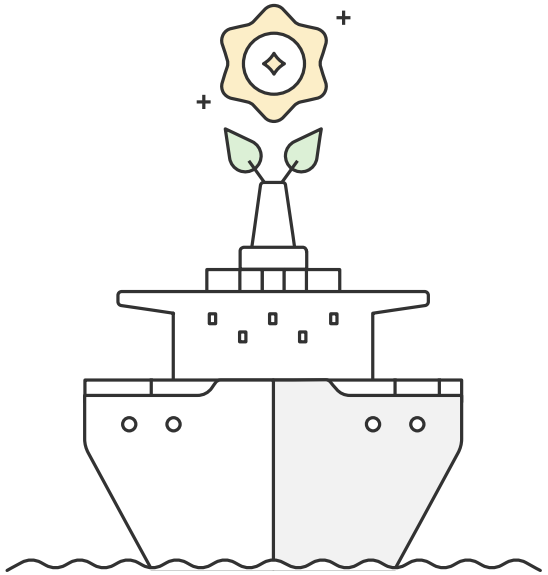
The ‘Center’ was founded in 2020 as an **independent research and development center** looking to accelerate the transition towards a net-zero future for the maritime industry

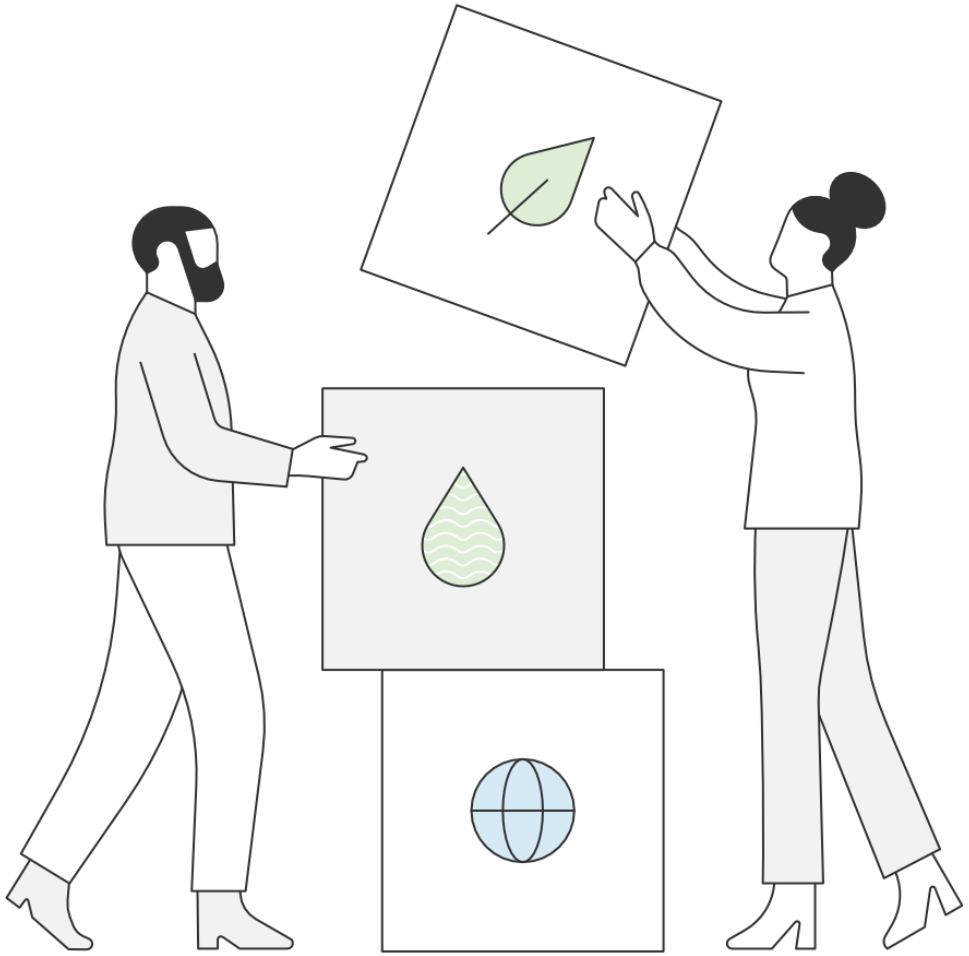


Who are we?

Our vision is to sustainably decarbonize the maritime industry by 2050

Our mission is to be an independent and significant driver of a sustainable maritime decarbonization





Our approach

Not-for-profit

Money earned by or donated to the Center is used in pursuing our mission.

Independent

We operate in a pre-competitive environment bringing together key players across the value chain.

Science-based

We explore viable decarbonization pathways by assessing available data and developing our own energy and technology solutions.

Our +35 partners share the zero-carbon vision and are committed to collaborative climate action

Agenda

01 Introduction

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04 Gurobi and why we use it?

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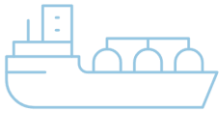
The scale of the shipping industry and its fossil fuel consumption is significant, but it is possible to reduce emission!

What is the scale of shipping in a cross-industry context?



~100,000 ships in operation globally

~300 million tonnes of fuel oil consumed every year

3% of global greenhouse gas emissions

... and how can shipping decarbonize?

Reduce emissions per energy consumed (new fuels)

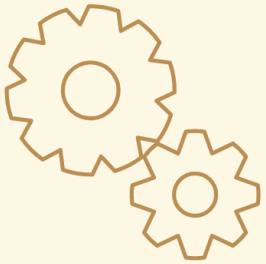
Reduce total energy demand (energy efficiency technology, speed reduction, etc.)

To reduce emissions, four key areas must be addressed

Promoting abatement action via regulation and policy

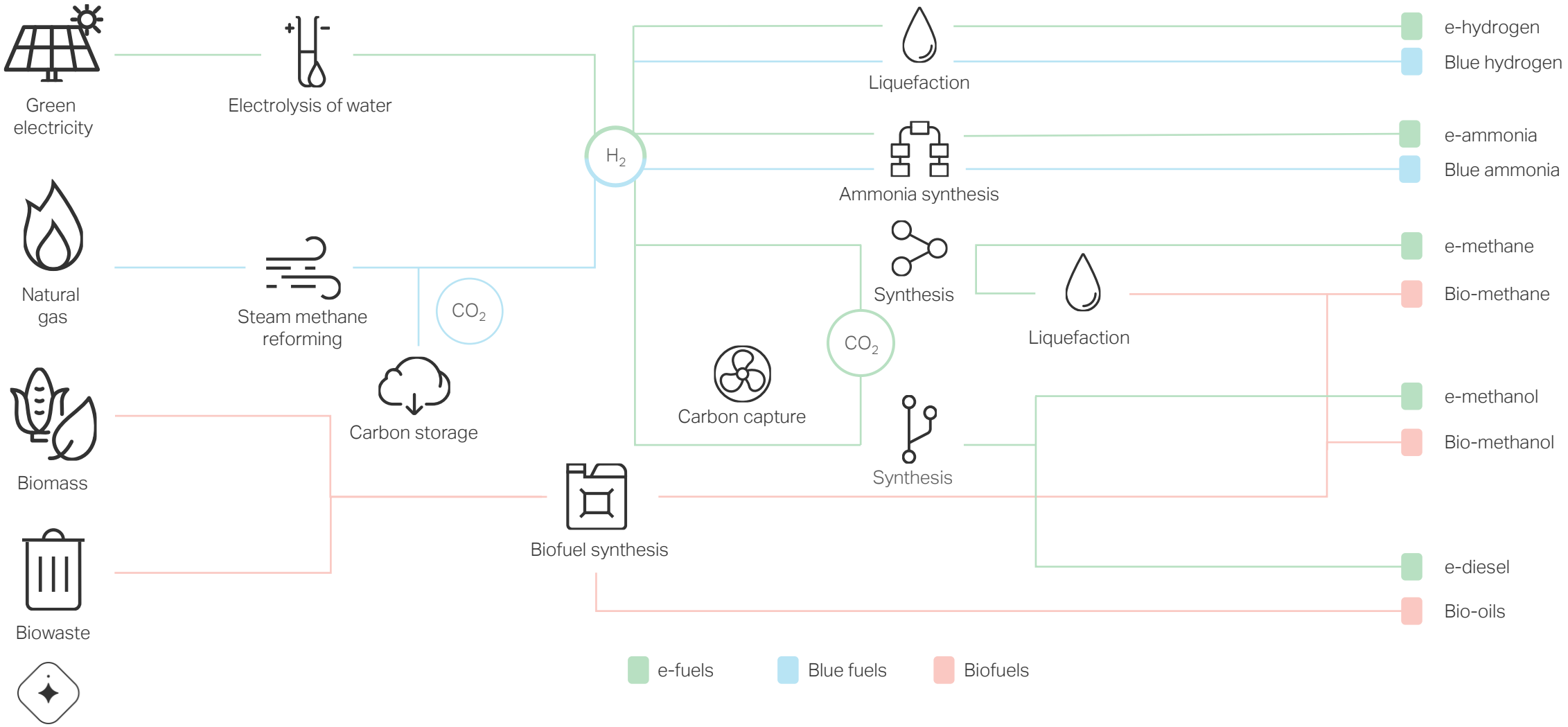
Scale alternative fuel supply

Reduce energy demand onboard



Supporting first movers and fast followers

The diversity of alternative fuel options makes it difficult to agree on a common pathway




NavigaTE

Agenda

01 Introduction
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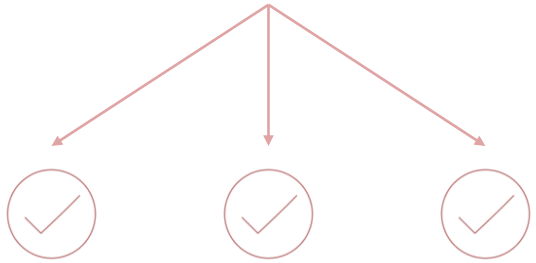
NavigaTE models expected decisions by a broad group of actors, not optimal decisions

NavigaTE

Decision process modeling

Group of decision makers

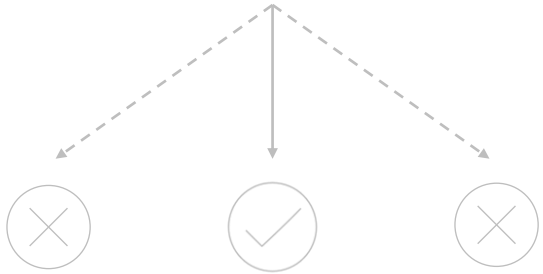


Multiple options are selected with different shares

Other models

Cost-optimization modeling

Individual decision maker



The cheapest option is selected

- Simulates the shipping industry transition
- Models 'what-if' scenarios
- Differs from optimization models
- Simulating expected decisions is ideal for this use-case

NavigaTE models the shipping value chain from feedstock in fuels to use in an engine

Feedstock

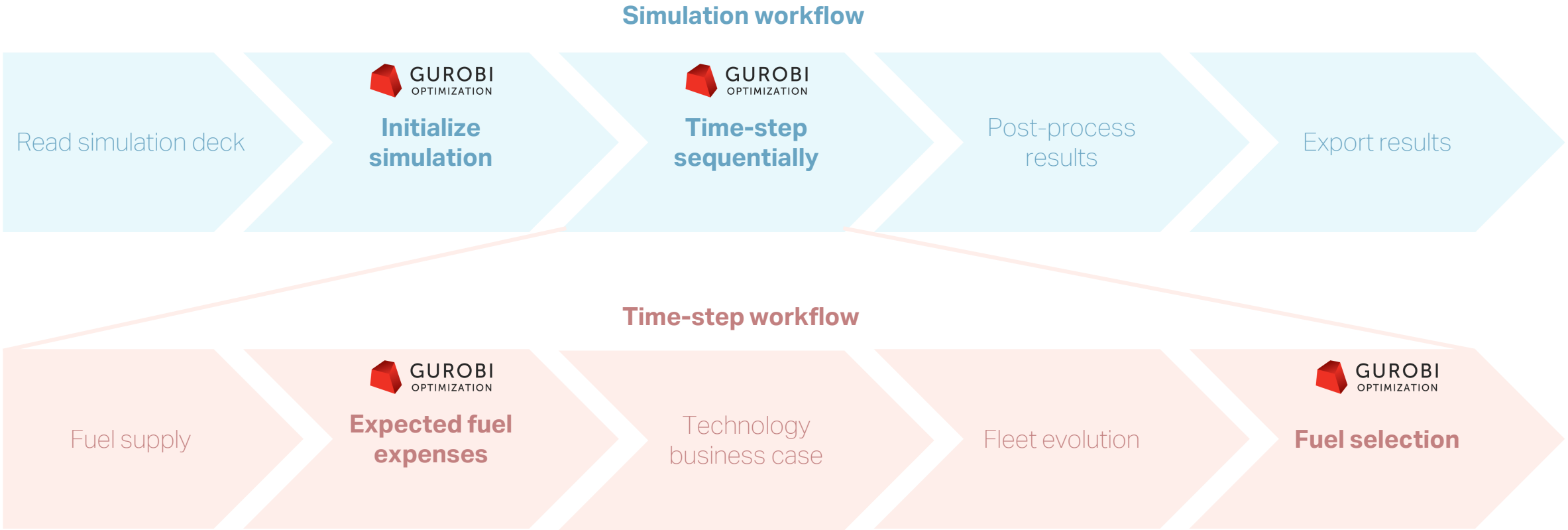
Fuel production

Bunkering & logistics

Onboard vessel

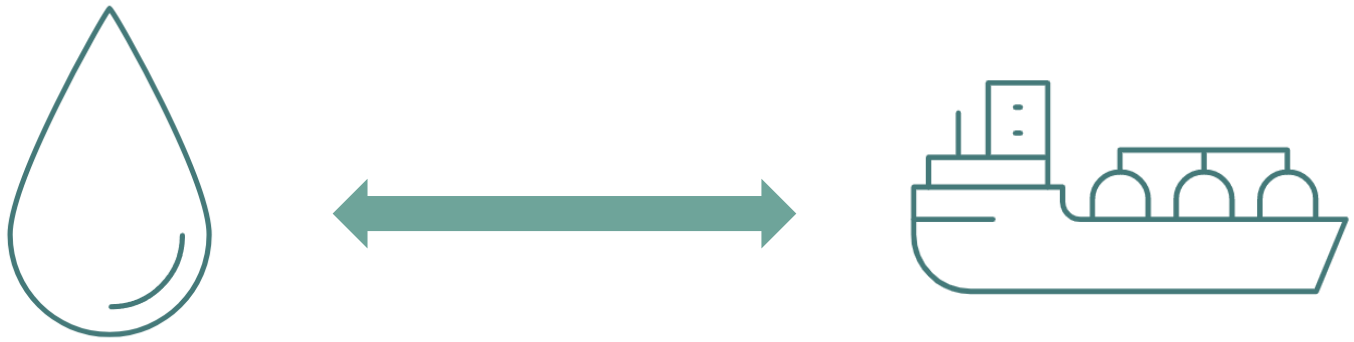
- Integrates entire shipping value chain
- Focus on global fleet transition
- Model predictions carry uncertainty
- Interpretation is key

NavigaTE is a dynamic model which time-steps forward in time predicting decisions based on past decisions and future expectations



The investment horizon of the decision determines the mathematical approach

Illustration of mathematical approach based on investment horizon



Short time horizon
Cost-optimal

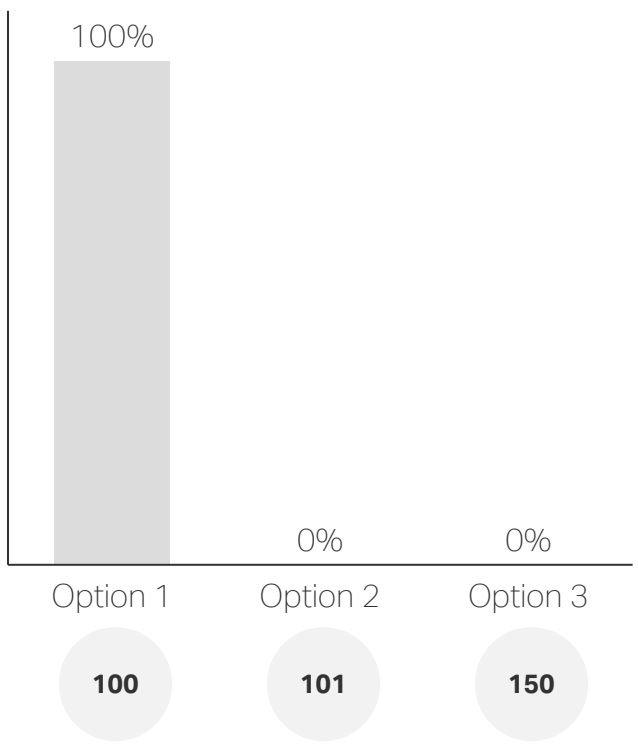
Long time horizon
Probabilistic

- Different investment decisions
- Investment horizon influences approach
- Long vs. short investment horizon
- Probabilistic vs. cost-optimal
- Buying a car vs filling up the tank

The market-share using either an optimal or probabilistic approach can differ significantly

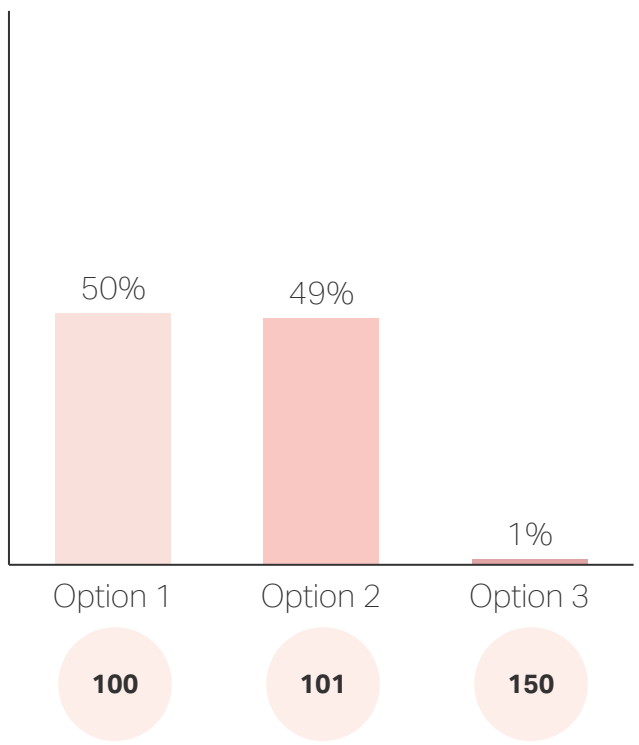
Short-term

Cost-optimal approach



Long-term

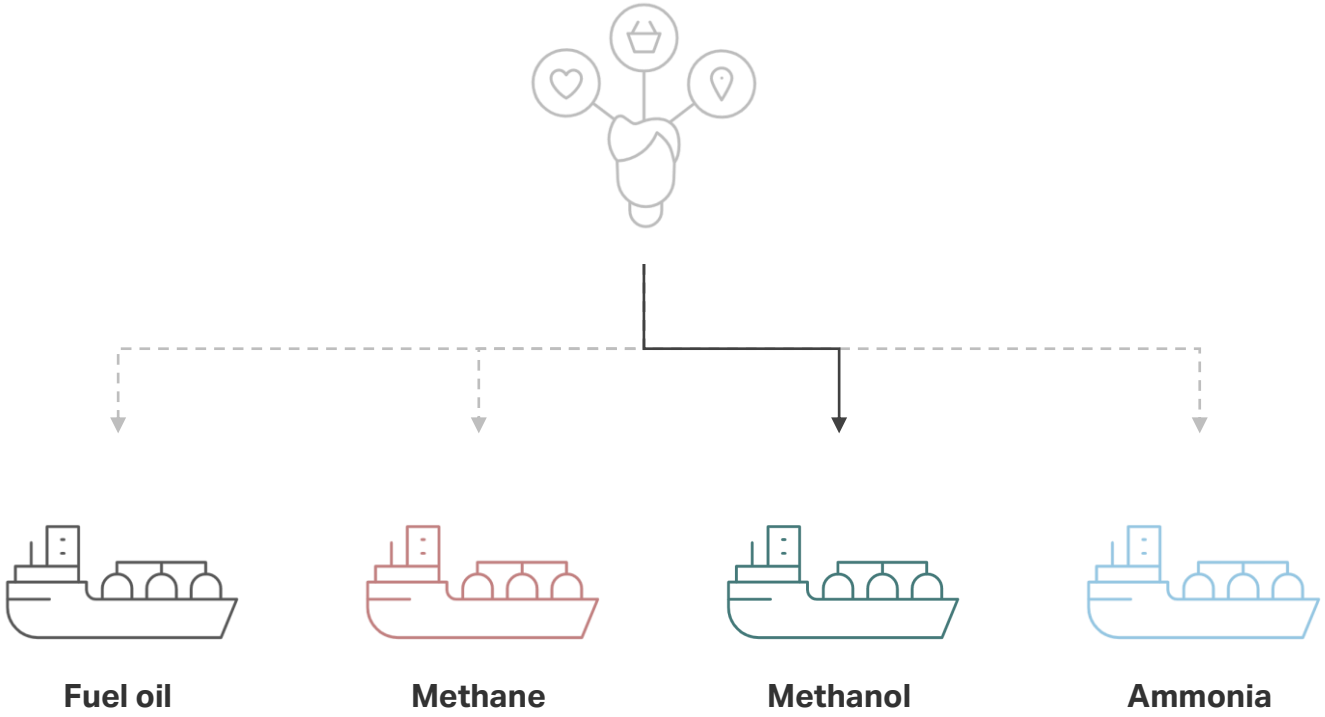
Probabilistic approach



- Cost-optimal vs. probabilistic models yield different results
- Cost-optimal methods can provide unstable simulations
- Probabilistic method provides robust simulations

An example of a long horizon investment in the model is when investing in a new ship

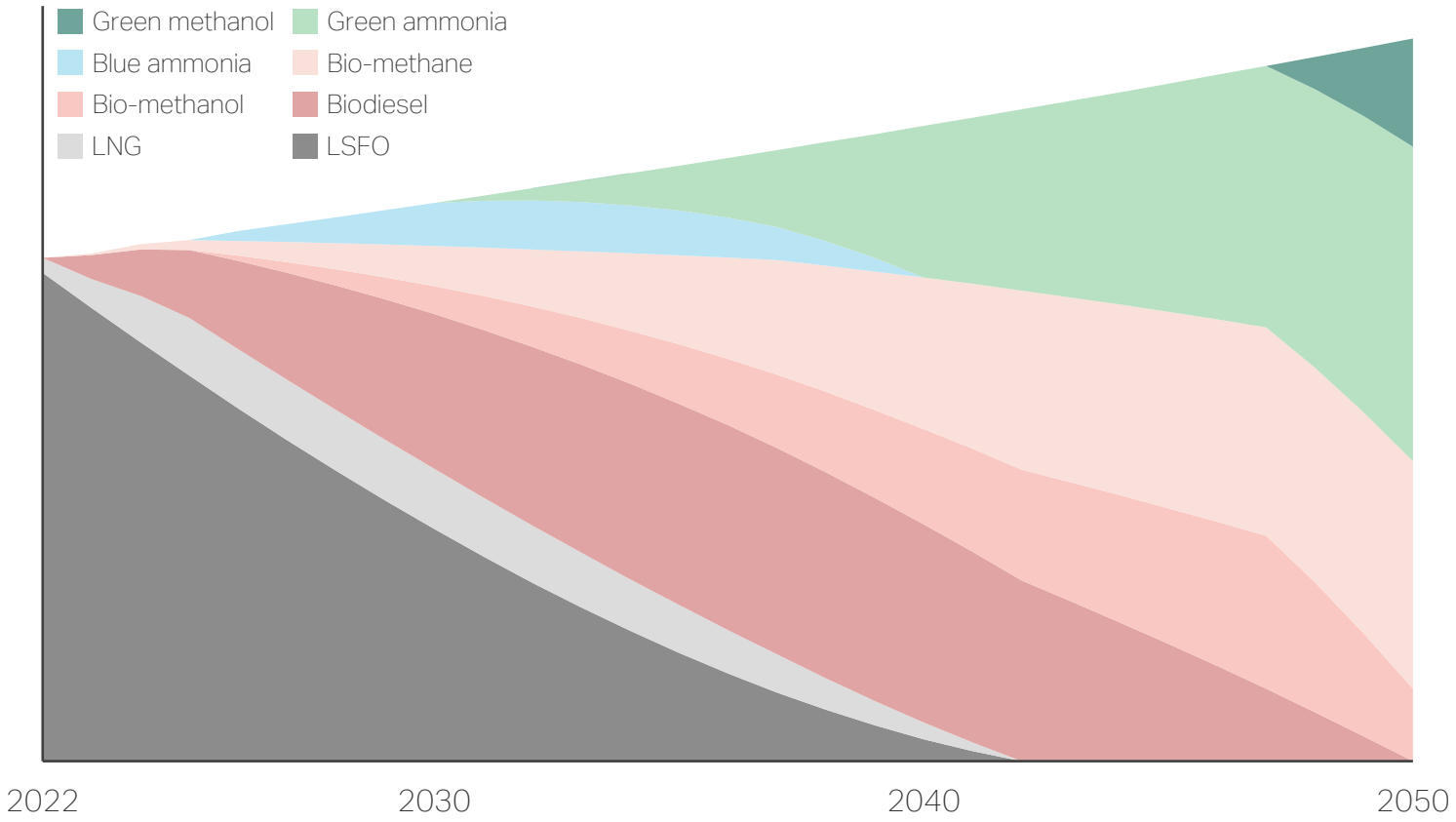
Decision regarding fuel technology on new ships



- Ship lifetime in model: 25 years
- Combines three modeling techniques
- Actual data for next 3-4 years
- Past decisions influence present ones
- Market shares based on cost

An example of a short investment horizon is the fuel used to operate the ship

Annual fuel consumption in energy/year



- Ships refuel multiple times a year
- LP used for cost-optimal decisions
- Various types of constraints
- ‘Assignment problem’
- LP calculated per time-step, not for entire simulation
- Goal is to mimic decisions

Agenda

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Linear Programming is used extensively in every time-step of the simulation

Linear Programming statistics for a single NavigaTE simulation

Future expenses

Number of LPs solved
~30.000

Number of variables per LP
~300

Number of constraints per LP
~80

Fraction of simulation time
~1/2

Fuel selection

Number of LPs solved
~30

Number of variables per LP
~25.000

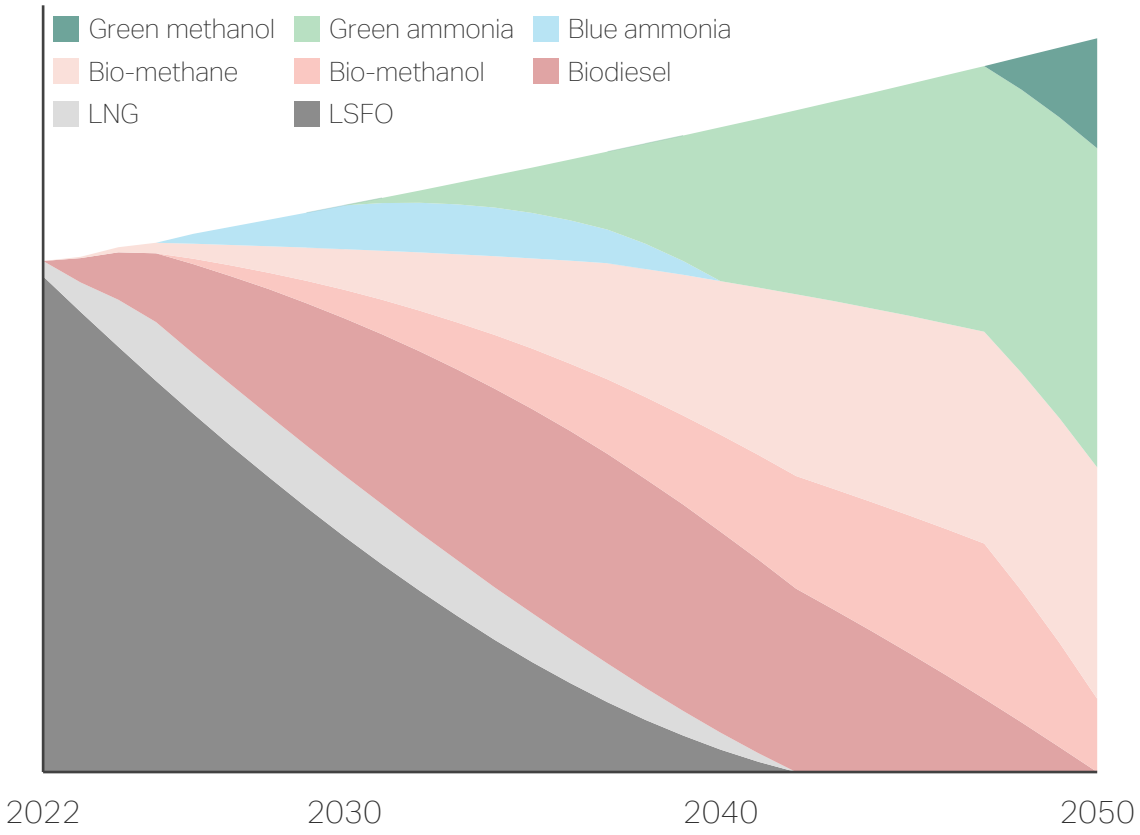
Number of constraints per LP
~7.000

Fraction of simulation time
~1/10

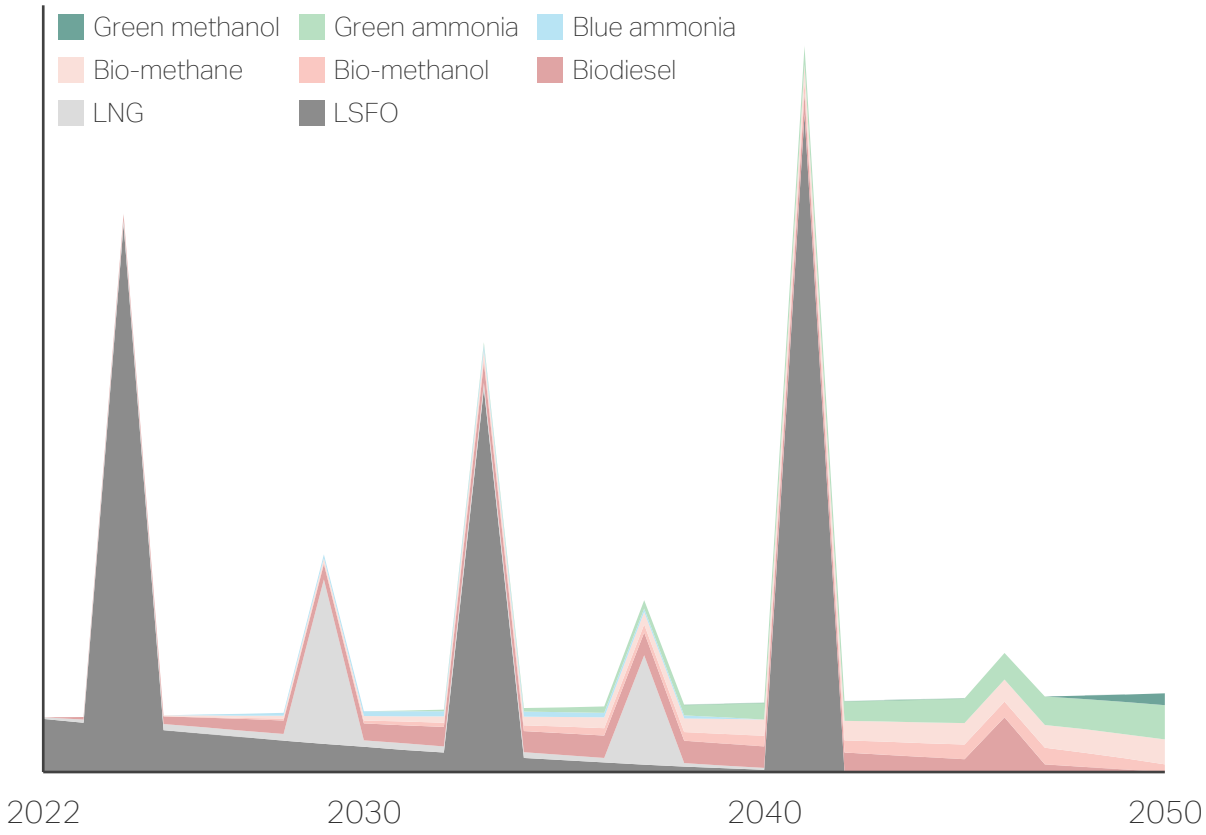
- Linear Programming is used for two purposes
- Many small problems and a few moderate problems
- Around half of the simulation time
- Majority of time spent building the model

Using Gurobi allows us to solve the model faster but the most important element is stability in the solution

Solution with Gurobi



Solution with Scipy



Agenda

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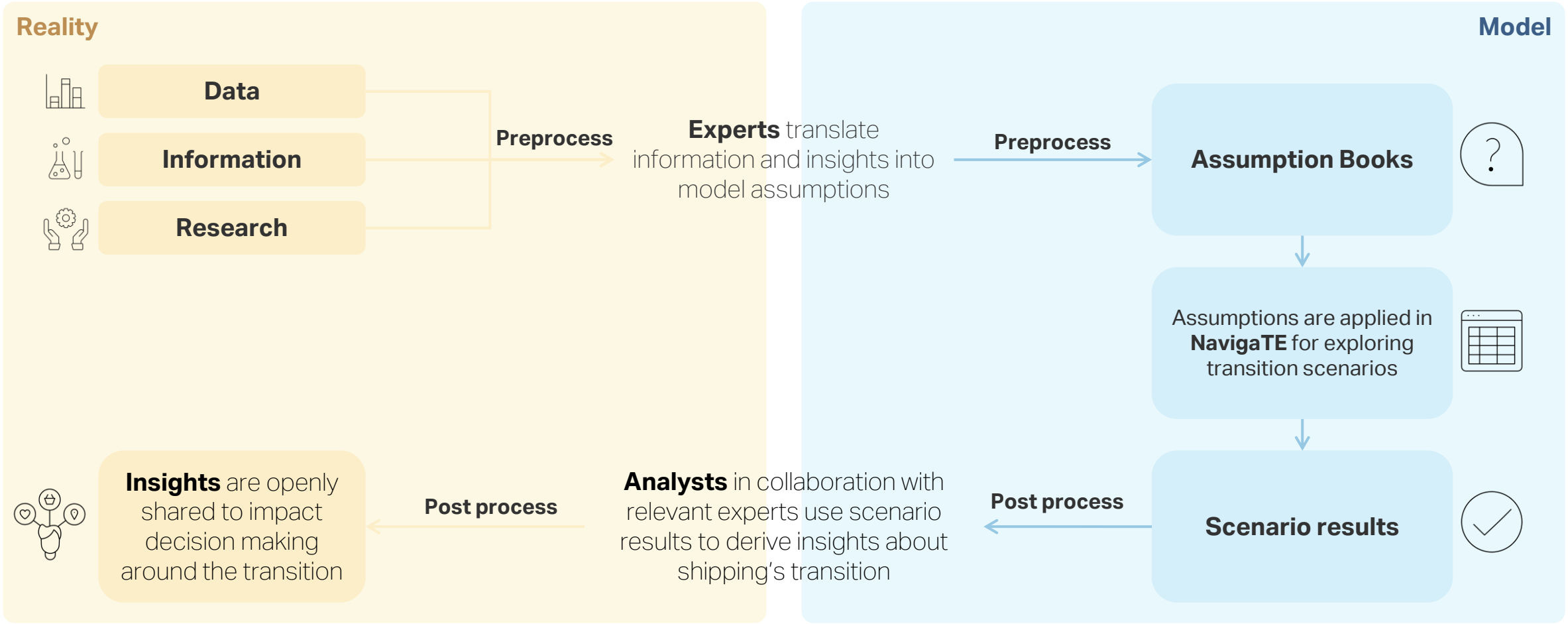
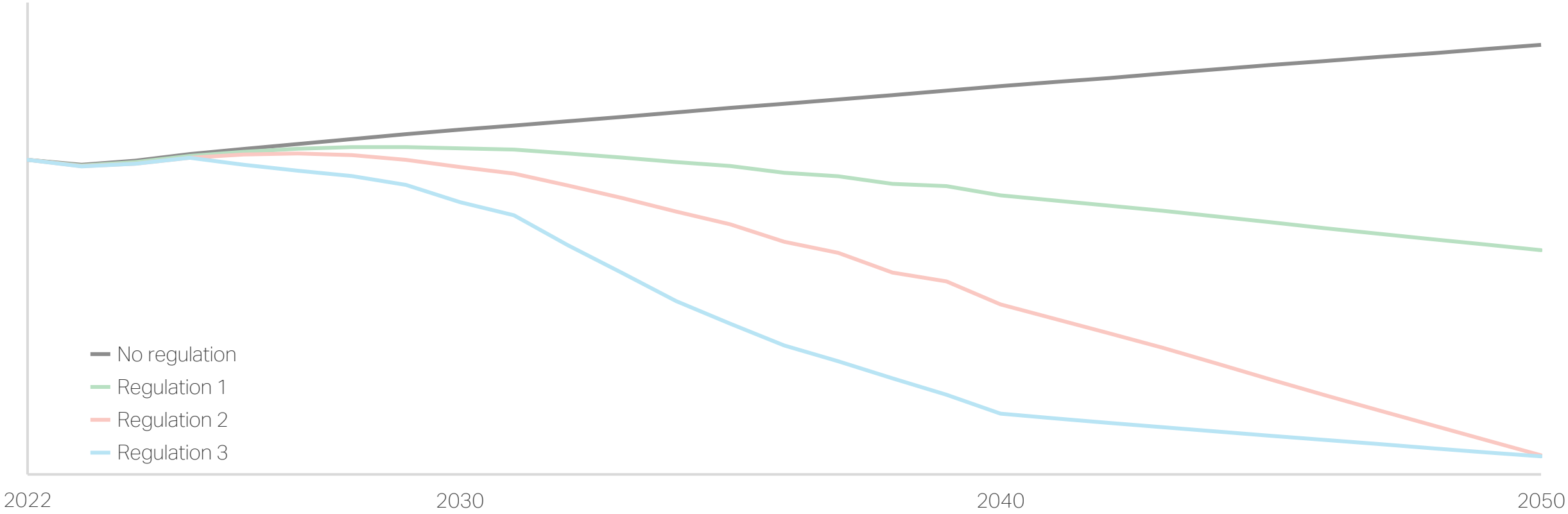
The overall transition analytics process is needed for converting information and data into transition insights via the use of NavigaTE



We also use NavigaTE to evaluate the impact from different types of regulation including carbon prices, emissions caps, and energy efficiency requirements

Annual emissions in CO_2/year



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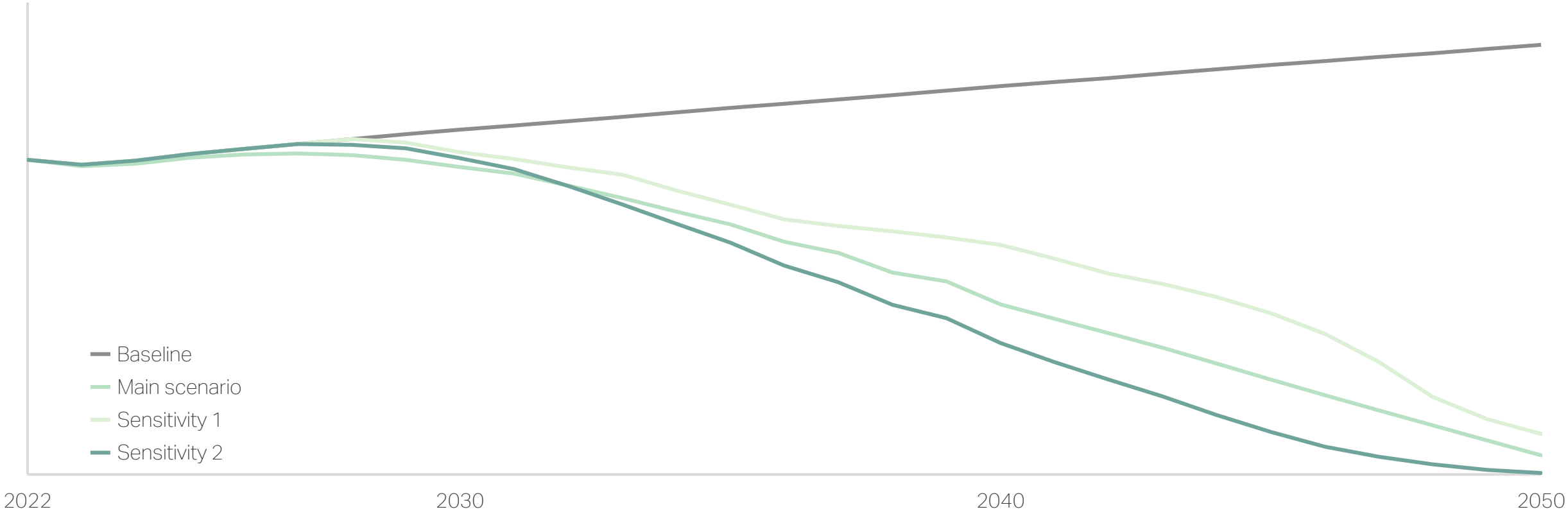
Example output

But we can also test other sensitivities such as fuel availability and cost, technology readiness, business model impact, and more

Annual emissions in CO_2/year



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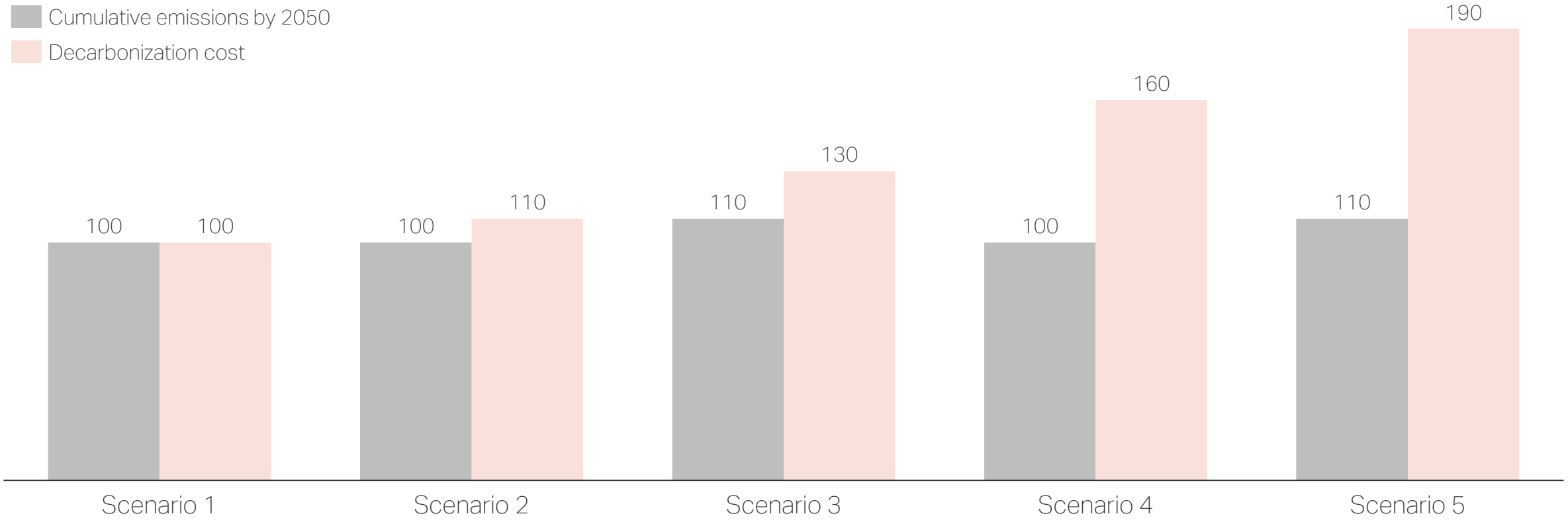
We evaluate on multiple indicators apart from the emissions impact including the transition cost for the industry

Cumulative emissions by 2050 and decarbonization cost increase (indexed)



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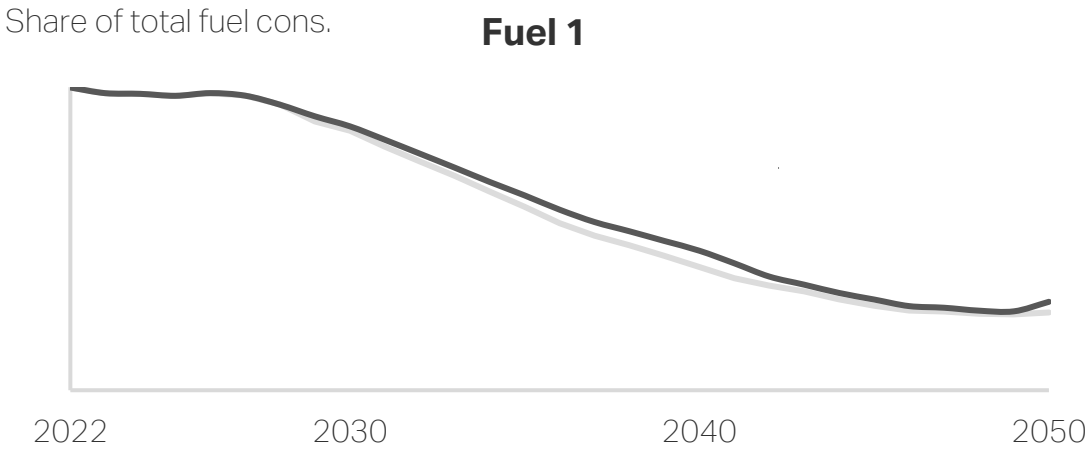
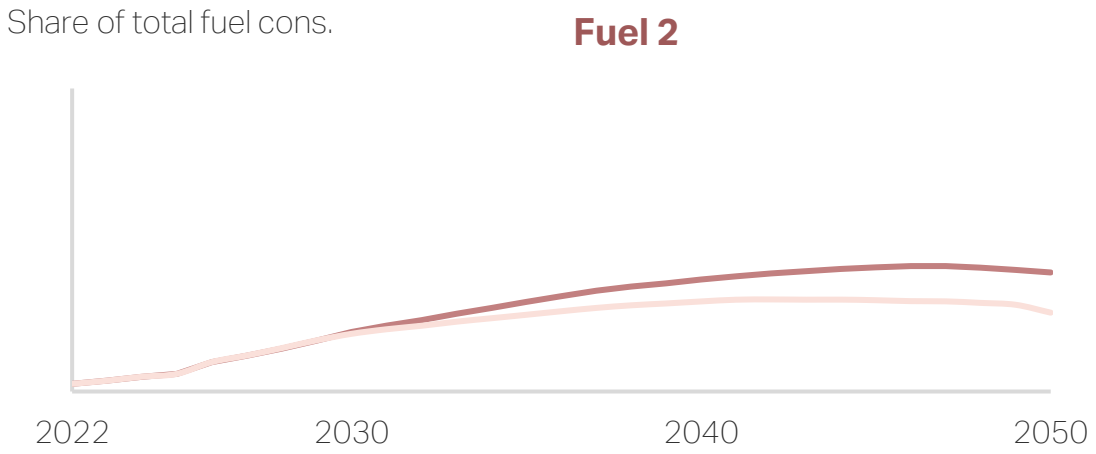
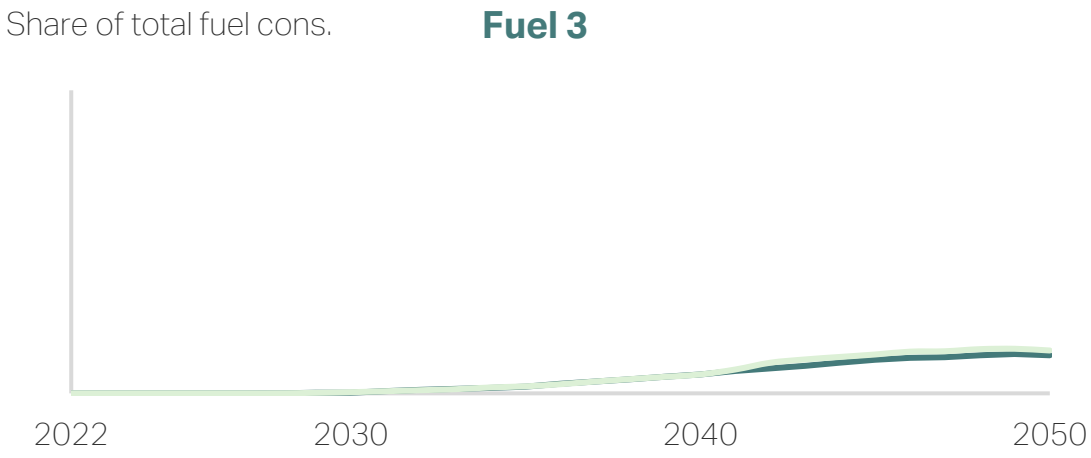
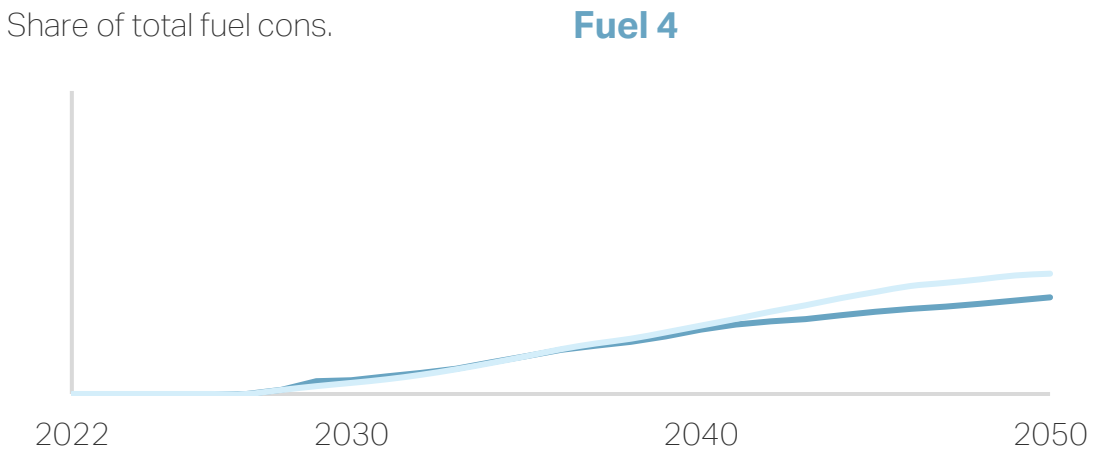
The fuel distribution is also a key parameter to consider for analyzing the different scenarios









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And we share our results with the public as part of our open-sharing principle exemplified through publications, tools, and more

NavigaTE Explainer

Launched before summer!

Maritime Decarbonization Strategy 2022

Available on our website:

https://www.zerocarbonshipping.com/publications/maritime-decarbonization-strategy/

FuelEU and EU ETS

Available on our website:

https://www.zerocarbonshipping.com/publications/fueleu-ets-analysis-what-can-the-industry-learn-and-adopt-from-regional-regulations/

More publications are available on zerocarbonshipping.com.


Thank you! Time
for questions