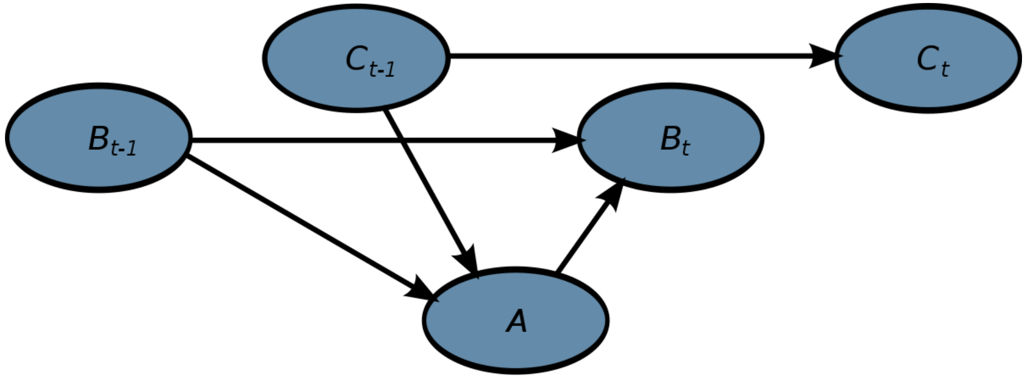
Demand Estimation for LNG Bunkering and Storage Services in Ports Using Bayesian Networks

Liquefied Natural Gas (LNG) in shipping and ports



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Agenda

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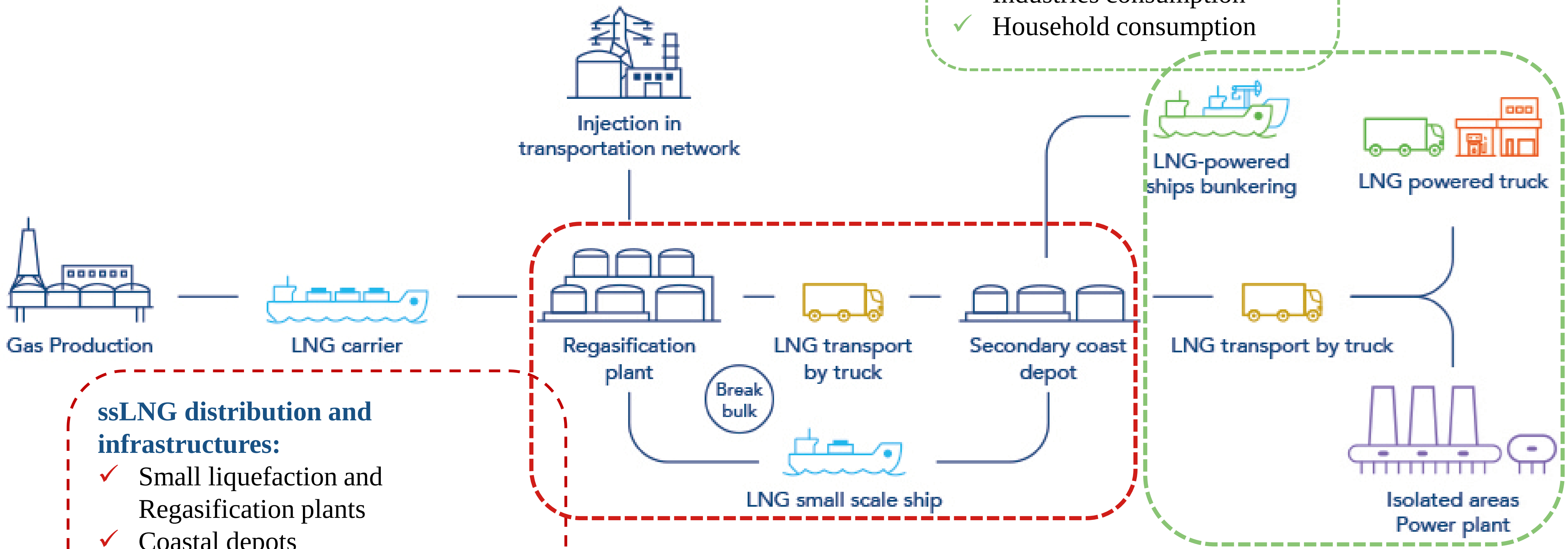
2. Objective
3. Data & method
4. Conclusion

LNG value chain

Small scale LNG (ssLNG) and related demand

Users:

- ✓ Heavy Duty Truck and trains
- ✓ LNG-powered ships
- ✓ Off-grid plants and depots
- ✓ Industries consumption
- ✓ Household consumption



ssLNG distribution and infrastructures:

- ✓ Small liquefaction and Regasification plants
- ✓ Coastal depots
- ✓ Bunkering stations
- ✓ LNG small scale ships/shuttle ships
- ✓ Trucks
- ✓ ISO-containers

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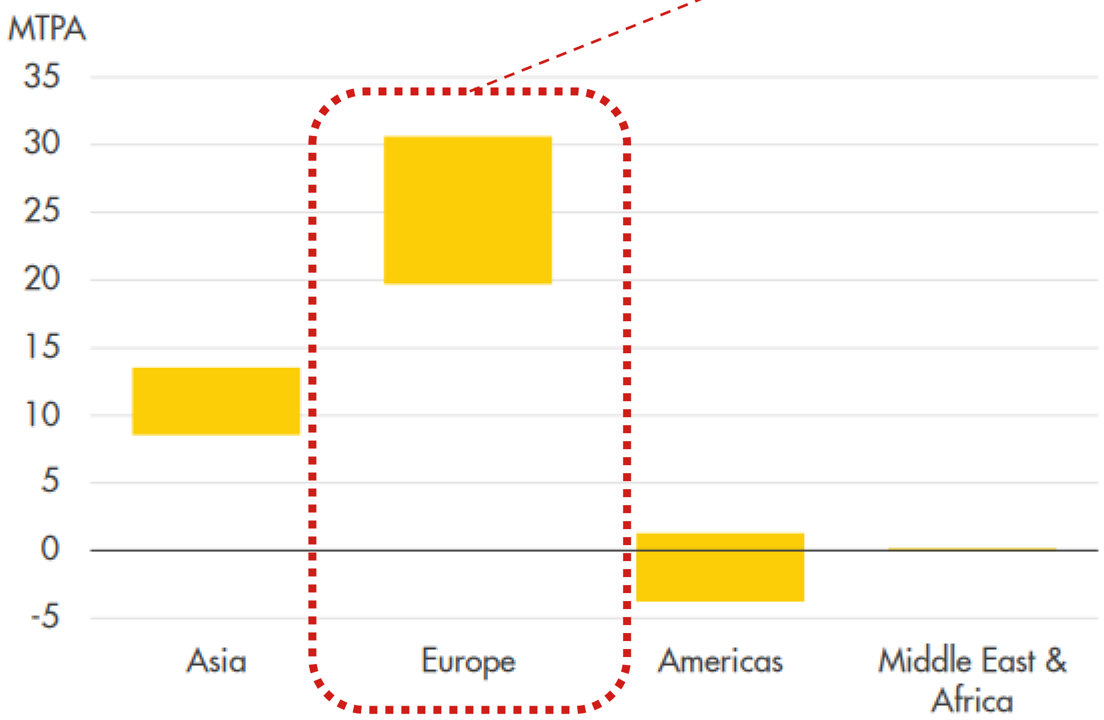
LNG demand

Demand trends

- ✓ Increasingly stringent environmental regulation
- ✓ New investment in LNG-propelled ships

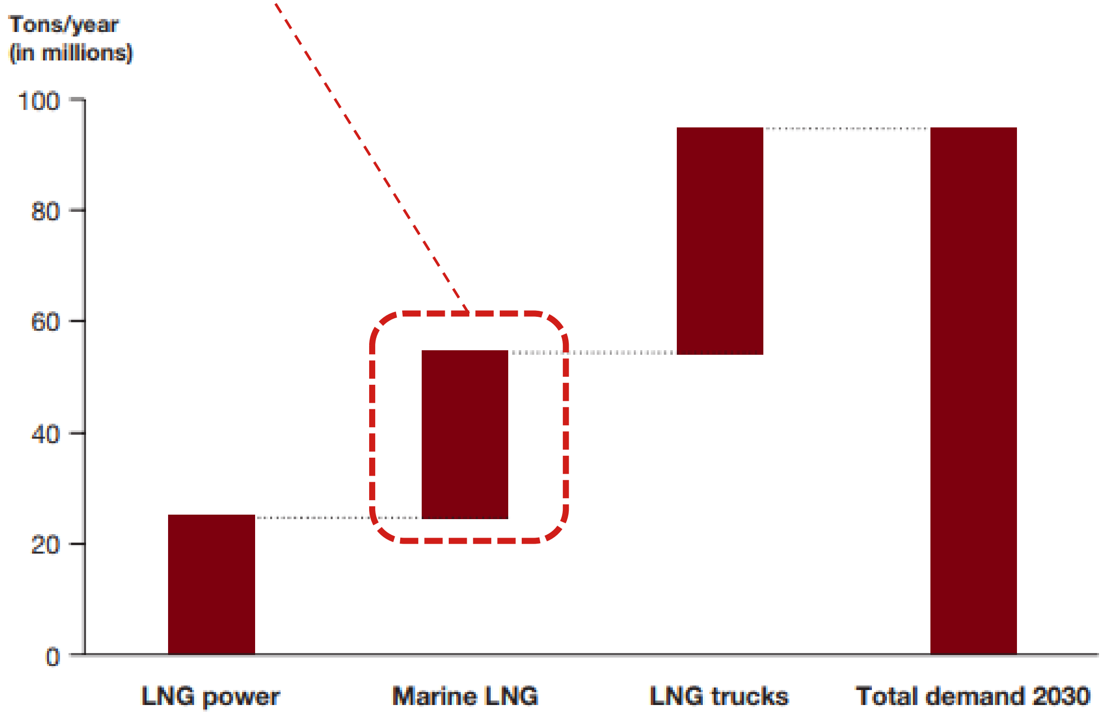
ssLNG is currently a small market...but demand is likely to grow rapidly

LNG demand growth range by region (2018)



Source: Shell interpretation of S&P Global Platts data and IHS Markit, 2018

ssLNG demand in 2030



Source: PwC, 2017

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Rationale of the study

Complexity of LNG demand estimation

- ✓ **High number of drivers** are shaping (future) ssLNG markets:
  - Regulatory drivers
  - Environmental drivers
  - Economics and managerial drivers
- ✓ **Novelty of LNG** as alternative greener fuel for shipping and inland transport
- ✓ Increasing **interest of geographic regions** for LNG (the most are at early stage)
- ✓ **LNG infrastructure is still at the planning stage** and viable bunkering and storage solutions are still subjected to rapid technological updates.

- ➢ **Significant level of uncertainty** affects public and private investment decisions in the business
- ➢ **Traditional forecasting techniques** used to predict future fuel consumption trends in ports are inadequate with regard to rising LNG geographical markets

Two Research objectives

Original conceptual framework for determining LNG demand in ports

1. Design of an **original conceptual map** to scrutinise the main endogenous and exogenous variables affecting LNG bunkering and storage demand in ports. It shows the expected interactions between variables and facilitates the analysis of interdependences and causal relationships. It is articulated in 3 analytical segments:
   - ✓ *maritime demand*
   - ✓ *port demand*
   - ✓ *hinterland demand*

__BN__ represents an __innovative method__ to estimate mid-term and long-term LNG demand

2. Modelling **LNG demand** through **Bayesian Network (BN)**, focusing on LNG maritime demand originating from LNG-propelled fleet and operating/planned LNG bunkering/storage facilities (2 time-frame periods: 2025 and 2030).

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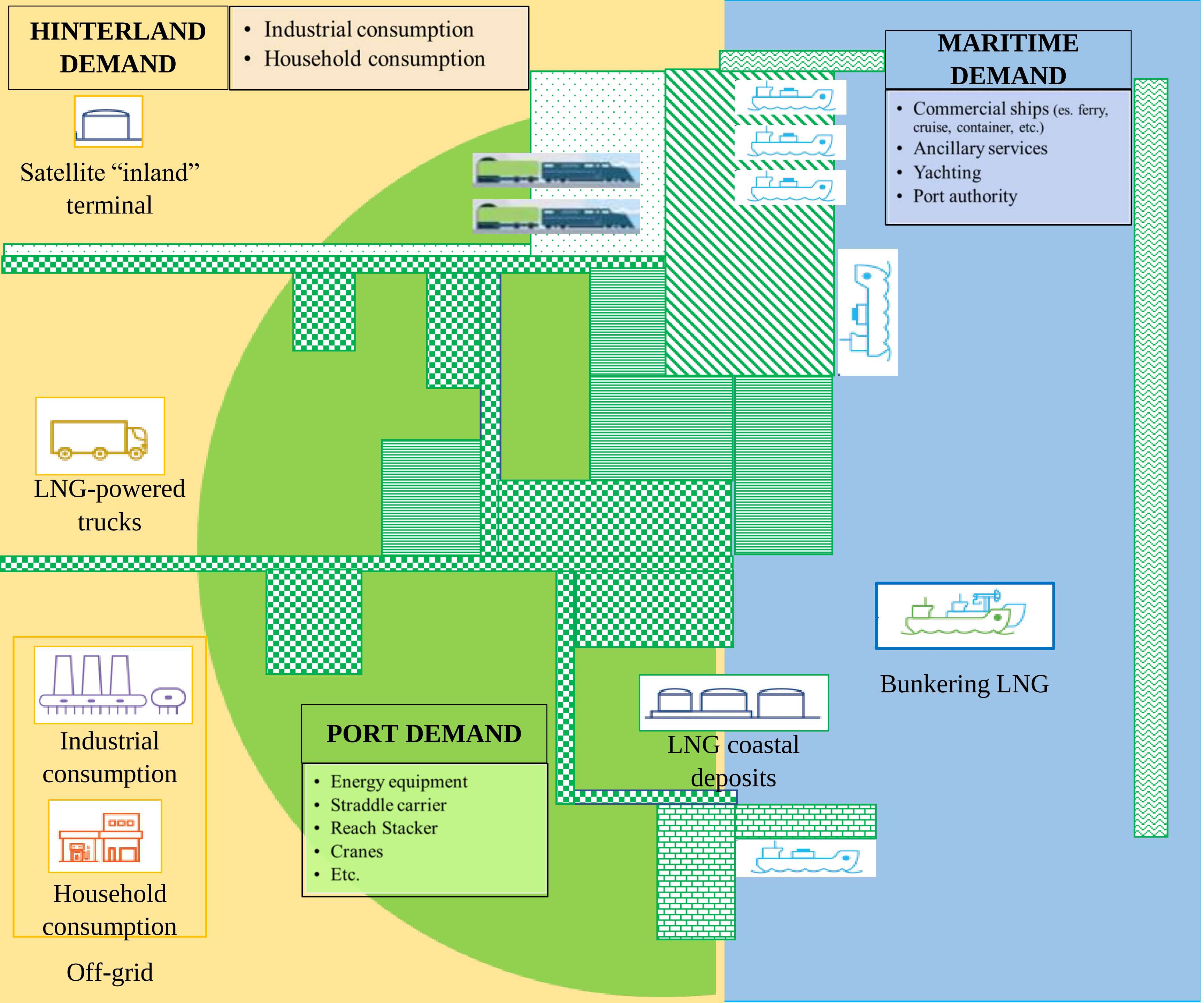
Method

LNG maritime demand in the target area of TDI RETE-GNL project

- The proposed method grounds on the **approach employed for TDI RETE-GNL project** (EU interregional project ITA-FRA 1420)
- Definition of:
  1. **Target geographic area and time-frame**: specific Italian (Liguria, Tuscany and Sardinia) and French regions (Corsica and PACA) – 2025 and 2030
  2. **Variables**: endogenous and exogenous
  3. **Unit of measurements & intensity** for each variable

LNG demand segmentation

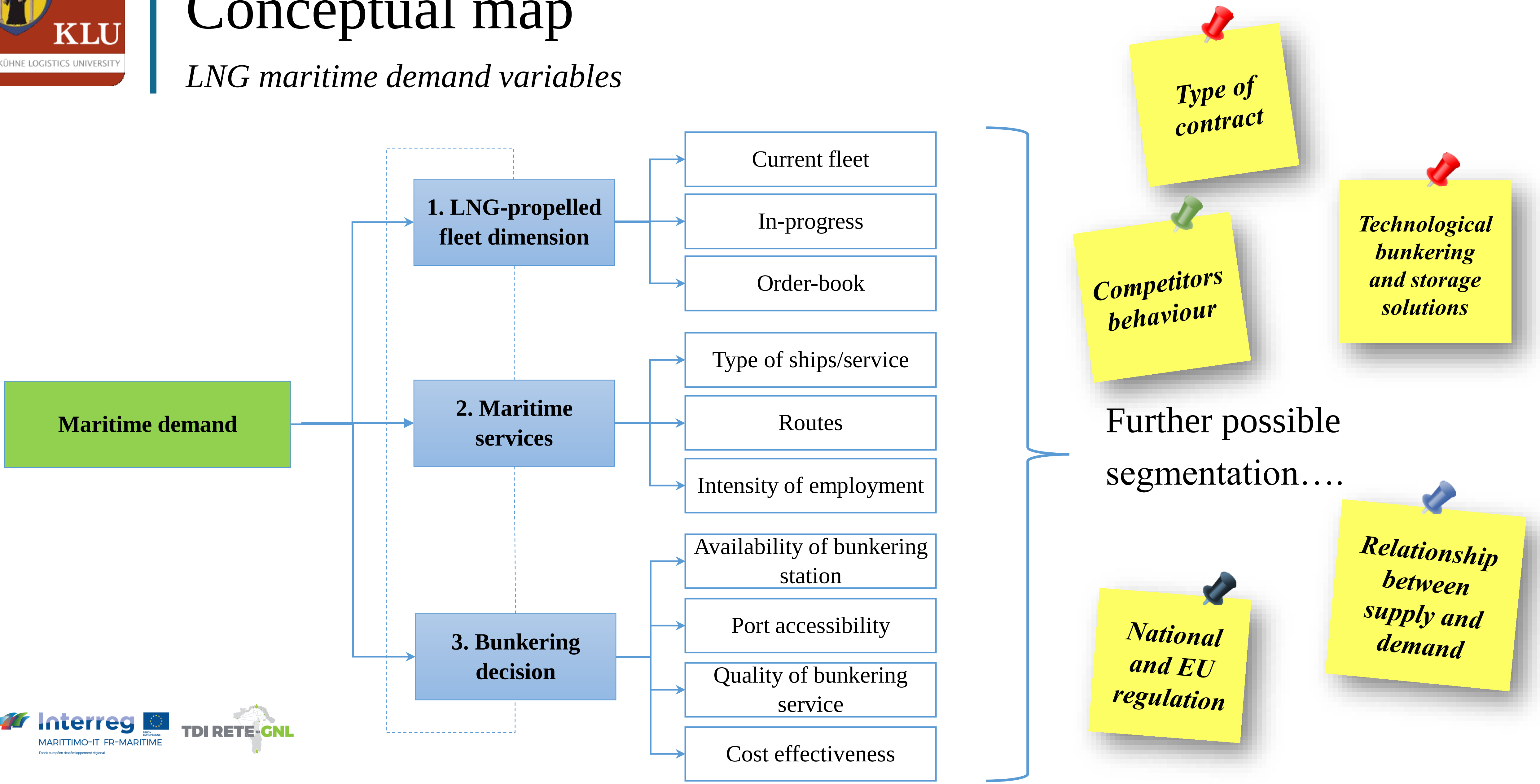


Legend

- Maritime infrastructure
- Commercial terminal
- Common area
- Shipyard and industrial area
- Marshalling yard
- Touristic and cruise activities

Conceptual map

LNG maritime demand variables



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Data gathering

(1) LNG-propelled fleet dimension and (2)Maritime services

LNG-propelled fleet	*Components of analysis*	*Time horizon*	*Uncertainty of estimation*
Current fleet	A. Current LNG-propelled fleet on the market	2019	Increasing level of uncertainty
In-progress	B. Fleet in refitting to LNG	2020	
	C. Fleet on order-book	2021/2022	
Order-book	D. Future orders	2025 e 2030	
	E. Future refitting and conversions	2025 e 2030	

Data gathered from **IHS Seamarket** (Seaweb database):

- ✓ **457** LNG-propelled ships current on the market worldwide **(A)**
- ✓ **201** LNG-propelled ships on order-book worldwide **(C)**

Which proportion of worldwide fleet operates in the target area?

Administering *ad hoc* questionnaires to shipowners that operate vessels into the target area for:

- ✓ identifying the **current and future fleet** (type of ships)
- ✓ outlining the **routes and ports of call** (services and intensity of employment)

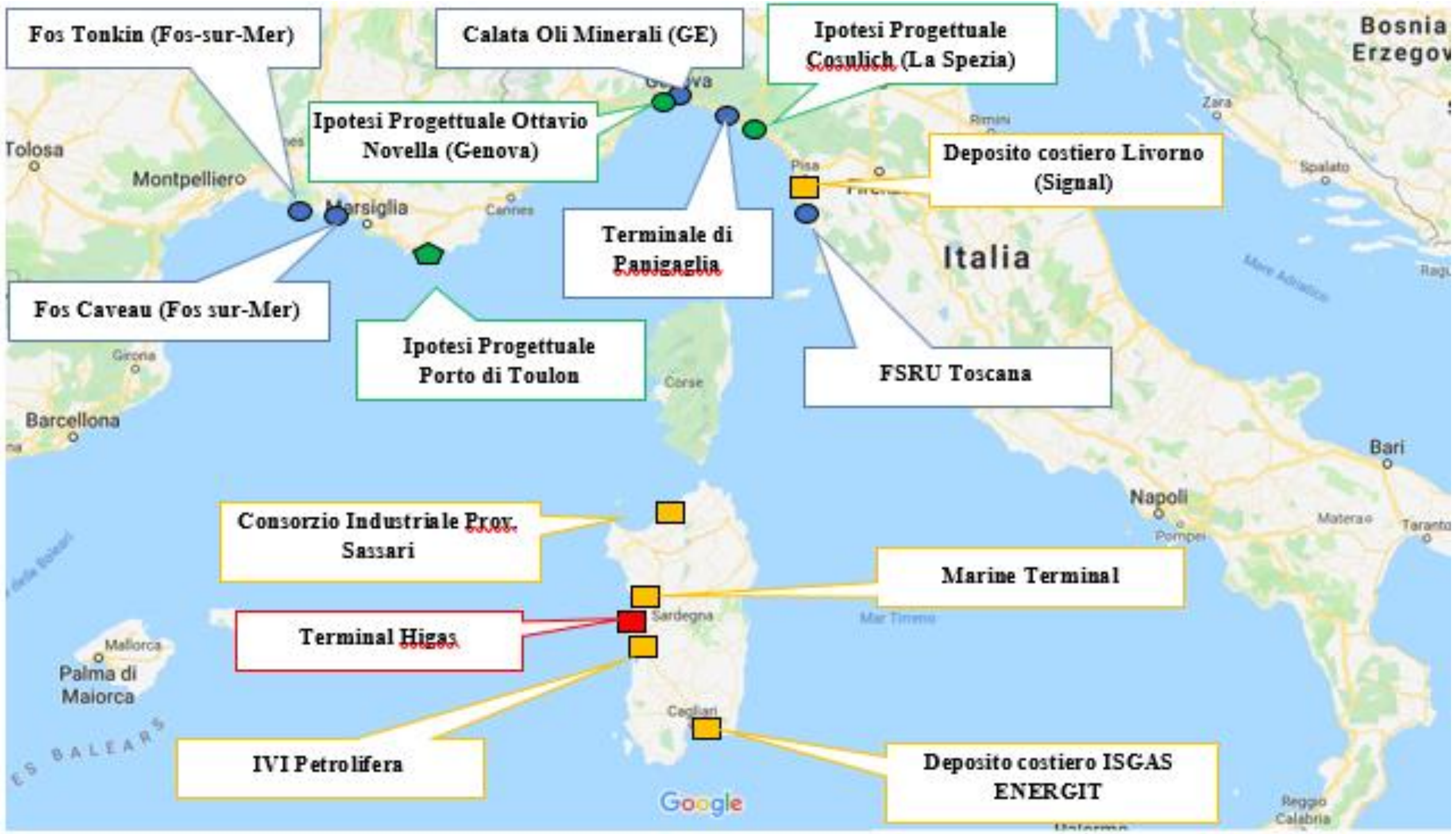
Source: TDI RETE-GNL, Interreg Project

Data gathering

(3) Bunkering decision

- ✓ Bunkering decision of shipowners is strictly related to the **supply of LNG bunkering and storage services in ports**
- ✓ We have mapped the **current and future LNG infrastructure** for the target area as well as the different technological bunkering solutions adopted

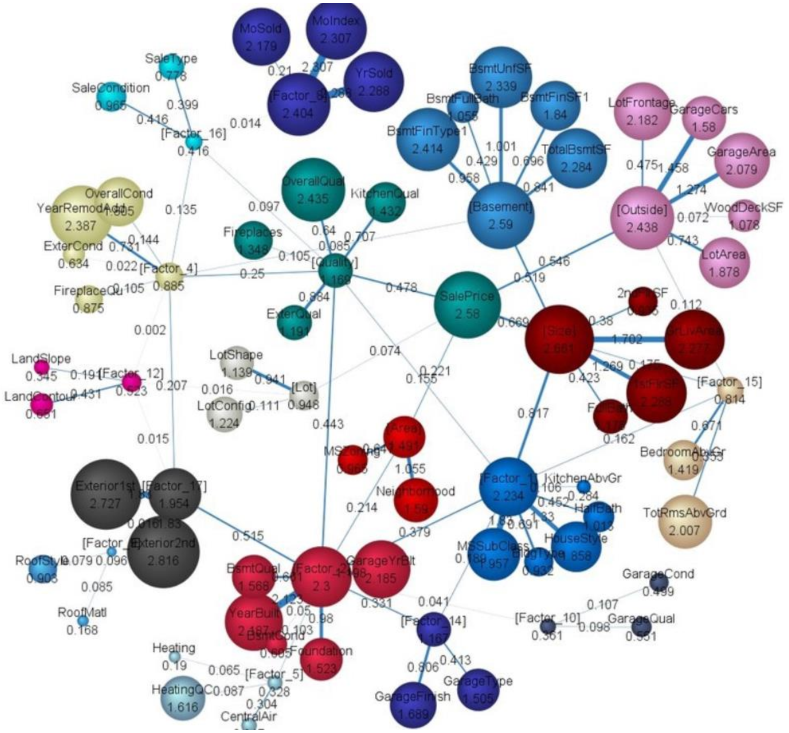
Four technological solutions which determine positive/negative effects on the bunkering decision



Bayesian Networks

Definition

Bayesian Network (BN): *Directed Acyclic Graph (DAG) with nodes representing random variables and arcs expressing the probabilistic dependencies between variables.*



Source:https://medium.com/@amit02093/

Elements of a BN are:

- ✓ **the graph structure** G = (V, E), where V = $\{v_1, v_2, \ldots, v_n\}$ is the set of vertexes, and E is the set of directed edges;
- ✓ **a finite probability space** (W,A,P), where W is the probability space, A is a *s*–algebra on W, and P a measure on W, such that: P(W) = 1; P(∅) = 0, and P(*A*) ≤ P(*B*), if *A* ⊆ *B*;
- ✓ **a set of random variables** defined on (W,A,P), one for each node of the graph whose conditional probability distributions express the strengths of dependency relations between the random variable and its parent connection on the graph:

$$p(v_1, v_2, \ldots, v_n) = \prod_{k=1}^{n} p(v_k | \mathcal{G}(v_k)).$$

Definition of **Conditional Probability Tables (CPT)** representing the mutual relationships between nodes and parent nodes.

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Conclusions

Upcoming data & results

Outcomes very soon… work in progress

- ✓ We are going to **test the BN model** on data from TDI RETE-GNL Project:
  - Conclusion of data gathering (ad hoc questionnaires to shipowners) *July 2019*
  - Data elaboration and analysis *August 2019* (in line with Project deadlines)
- ✓ Giving the upcoming environmental EU regulation, **LNG** represents a **valuable alternative greener fuel** and **potential energy source for Mediterranean ports**.
- ✓ **The estimation of LNG demand in ports is a hard task**: a complex scenario due to the high number of drivers and uncertainty.
- ✓ **Bayesian Network model represents an innovative approach** for estimating the LNG demand in ports.

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Conclusions

Future studies

- ✓ **Extensive future studies** are required **to assess the investments** for bunkering facilities and coastal storage deposits (i.e. design of ports' LNG supply)
- ✓ The **original conceptual framework and BN** would lay the **groundwork for further academic researches** aimed at determining more specifically the dimension of current and future LNG demand in ports, considering the three proposed segments (i.e. port, hinterland and maritime demand).
- ✓ The paper would provide **valuable insights for private stakeholders** involved in ssLNG supply chain.
- ✓ The present study may contribute to **disseminate the opportunities related to LNG in port domain**, considering the pivotal role of policymakers and public entities as promoters of LNG facilities.

Thank for your attention

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