OIL & GAS

SMART DESIGN OF SMALL-SCALE LNG DISTRIBUTION VALUE CHAIN

TAKING ACCOUNT OF BOIL-OFF GAS AND LNG QUALITY ASPECTS

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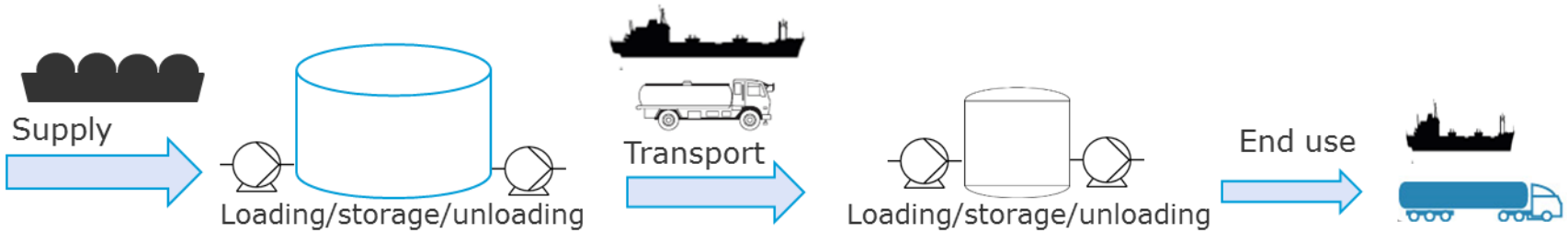
Developing small-scale LNG market needs well-established networks of transport, storage and supply facilities

- LNG is growing as transportation fuel: ships, trucks and off-road
- In this development there are logistical challenges to be overcome:
  - There are only a few bunker terminals (for short sea or inland shipping) and service stations (for road-freight transportation)
  - The LNG fuel quality provided to the end-user must match end-user requirements (e.g. engine specifications, voyage distance etc.)
  - Gas quality variation along the gas value chain
- Decision tools are needed to support infrastructural investment decisions (location, LNG tank types, procurement of LNG qualities etc.) in an economically attractive way, ultimately assuring end-users of a stable, 'fit-for-purpose' and commercially attractive LNG quality.



Why is LNG quality important?

- Worldwide supplies of LNG vary substantially depending on the geographical origin, e.g.

Origin	N_2, %	CH_4, %	C_2H_6, %	C_3H_8, %	C_4H_{10}, %
Australia – Darwin	0.1	87.64	9.97	1.96	0.33
Algeria – Skikda	0.63	91.4	7.35	0.57	0.05
Algeria – Arzew	0.71	88.93	8.42	1.59	0.37
Brunei	0.04	90.12	5.34	3.02	1.48
Egypt – Idku	0.02	95.31	3.58	0.74	0.34
Indonesia – Badak	0.01	90.14	5.46	2.98	1.40
Indonesia – Tangguh	0.13	96.91	2.37	0.44	0.15
Libya	0.59	82.57	12.62	3.56	0.65
Nigeria	0.03	91.7	5.52	2.17	0.58
USA - Alaska	0.17	99.71	0.09	0.03	0.01
Bio LNG		**~100**			

- Furthermore, change of composition in the value chain as a result of boil-off.

Gas composition variations, so what?

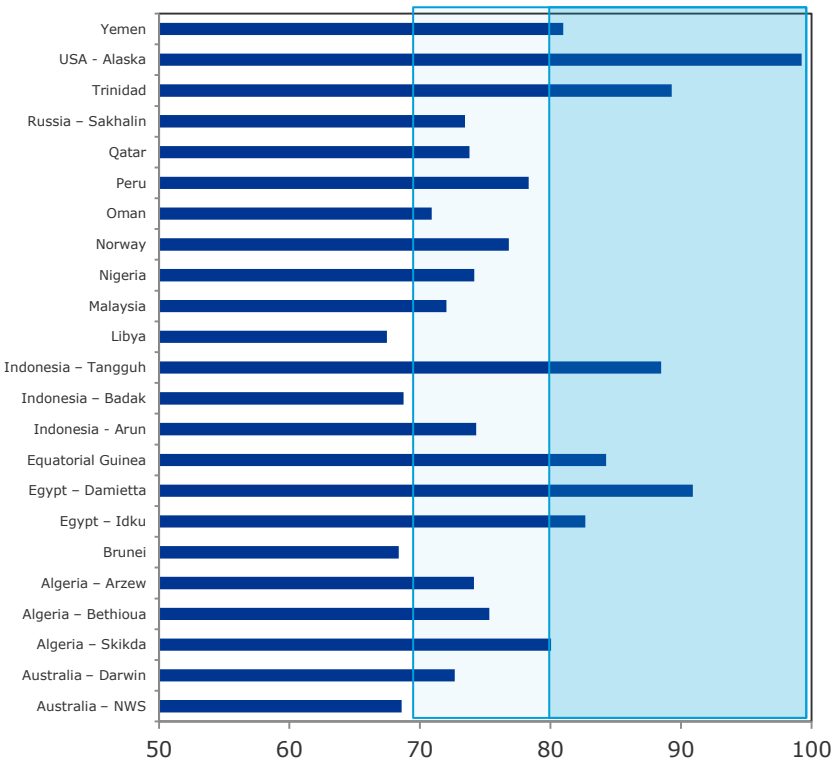
- Different LNG compositions have different **combustion properties**: most critical for engine performance is resistance to knock
- The occurrence of **engine knocking** leads to significant loss of performance (power reduction), potential engine shutdown and potentially extensive damage!
- Larger amount of higher hydrocarbons in the fuel (ethane, propane butane) increases the risk of the occurrence of engine knock

*Must **match fuel and engines** → octane number of gasoline and automotive engines → methane number of LNG gases and gas engines*

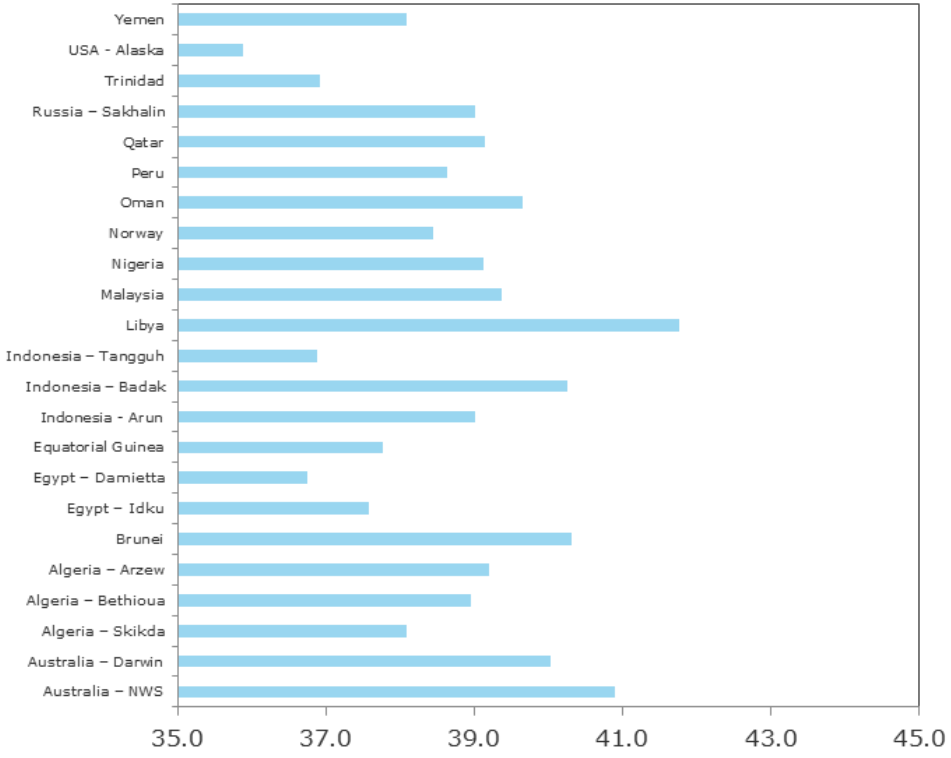
- DNV GL developed a new method to characterize LNG gases for their knock resistance (**PKI MN number**, recently published in the SAE journal)

Ungraded

Engine knock (*methane number*) & Energy content (*calorific value*)



Methane Number, PKI method



lower calorific value, MJ/m³(n)

***Engine performance**: The variation in methane number is more than 32 points*

***Energy content**: The variation in calorific value is up to 17% which substantially effects the driving/voyage distance*

Ungraded

Weathering of LNG due to boil-off

- A key issue in LNG transportation is the generation of Boil-Off Gas (BOG).

- The "boil-off" of the volatile components in the LNG stored leads to a change in composition of LNG

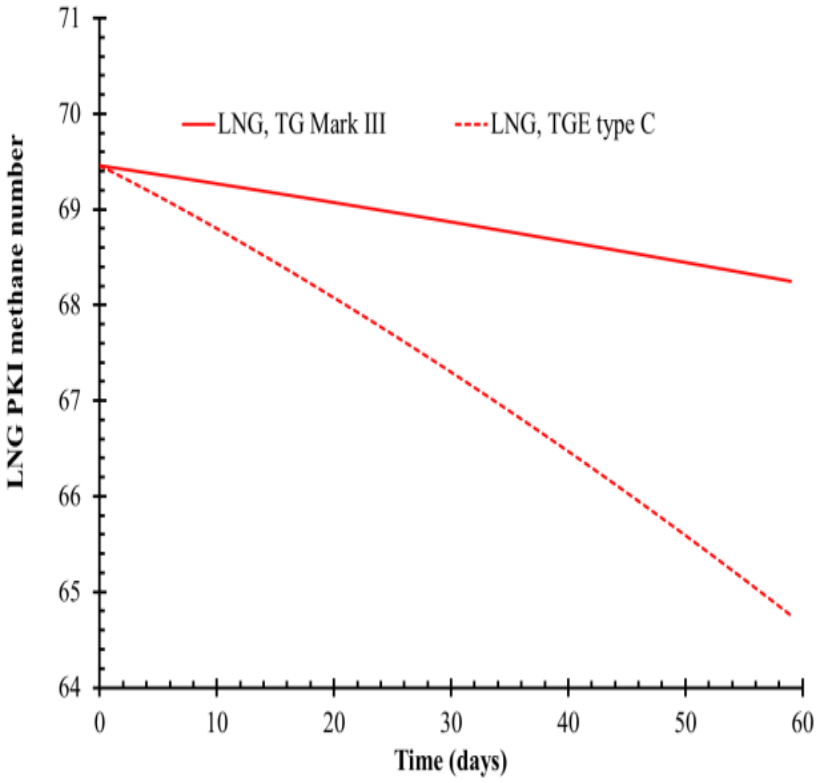
- Boil-off rate depends on:
  1. Original composition of the LNG
  2. Temperature of the LNG
  3. Heat transfer rate to the LNG through the tank
  4. Residence time of LNG in the chain
  5. Operating pressure
  6. "Motion"

Component	Boiling point [° C]
Nitrogen	-196
Methane	-162
Ethane	-88.5
Propane	-42
Butane	-0.5

Effect of boil-off on knock resistance LNG (methane number)

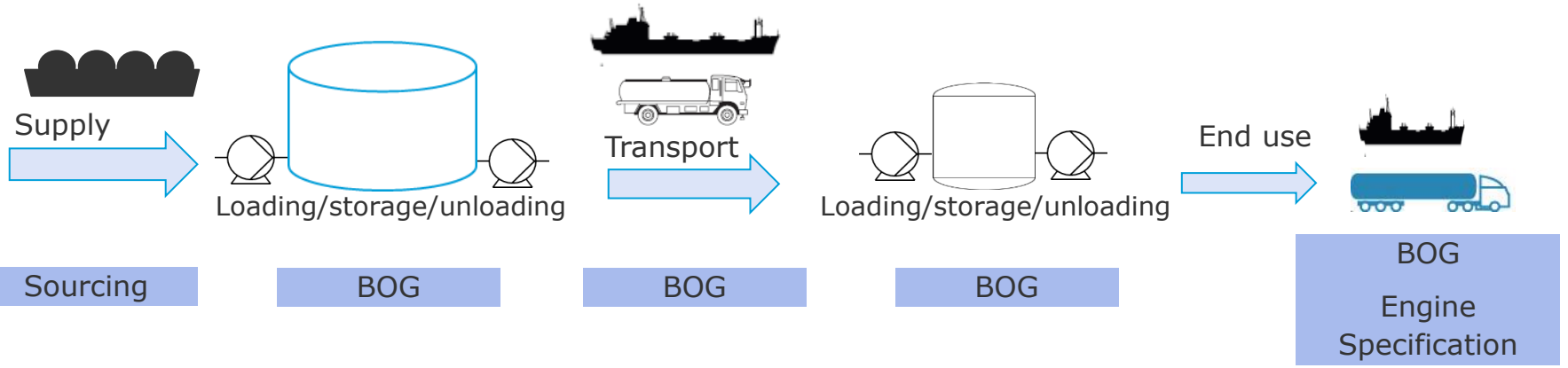
- A model was developed by DNV GL that calculates the natural boil-off rate and the changes in the knock resistance (methane number) of the LNG as function of time.

- After 40 days the methane number dropped with 0.8 points (for TG Mark III tanks) or 3 points (for TGE type C container)



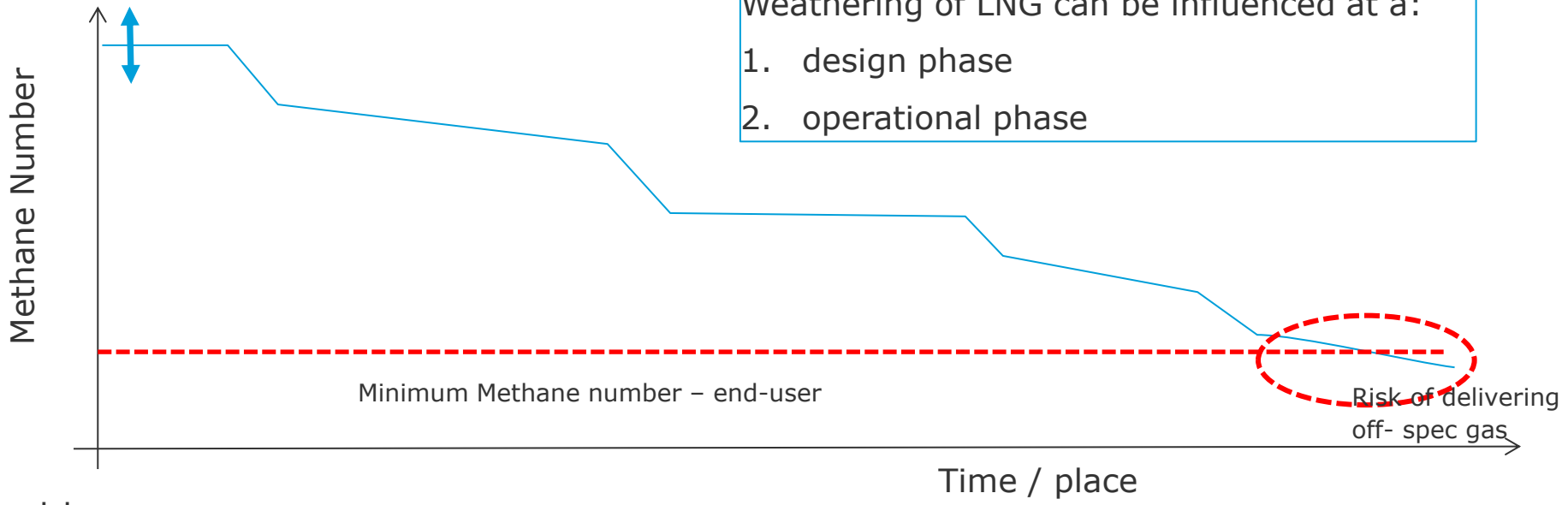
1 – 5 MN points/60 days variation

Risk of delivering "off spec" LNG in ssLNG value chain



Weathering of LNG can be influenced at a:

1. design phase
2. operational phase

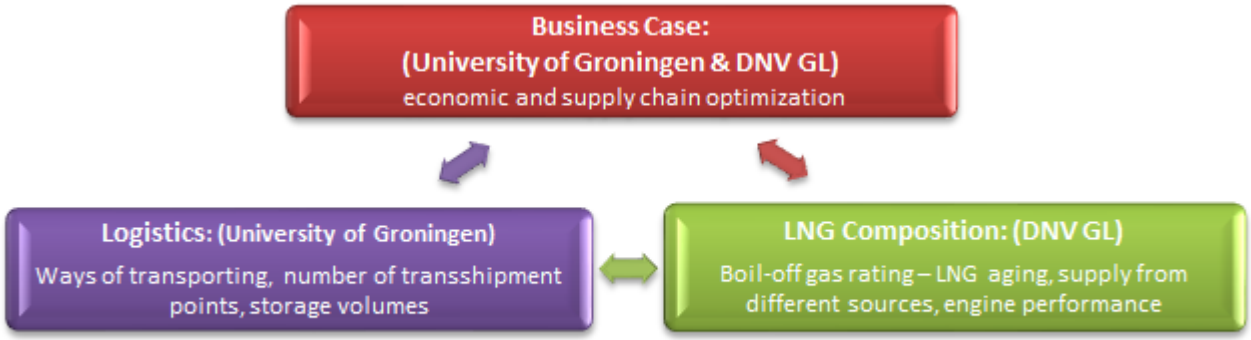


Ungraded

DNV GL & RuG join forces:
Smart Design of the small-scale LNG Distribution Value Chain.

The main research question:

- how do changes in LNG composition along the value chain affects logistic decisions and the design parameters of the ssLNG value chain, ultimately changing the business case?



Main building blocks of project

Questions that arise in design and operational phase:

- What is the impact of changing LNG quality in the value chain?
- What is the optimum number of transshipment points and storage volumes?
- What are the opportunities for supplying LNG from different sources, or for blending LNG, for manipulating/maintaining LNG quality?
- Are there options for different ways of transporting LNG or the ability to use other tank types to maintain LNG quality?

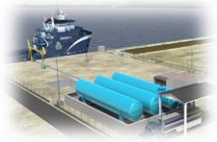
Designing an efficient distribution network

Import terminal

LBG production

Distribution network

End users

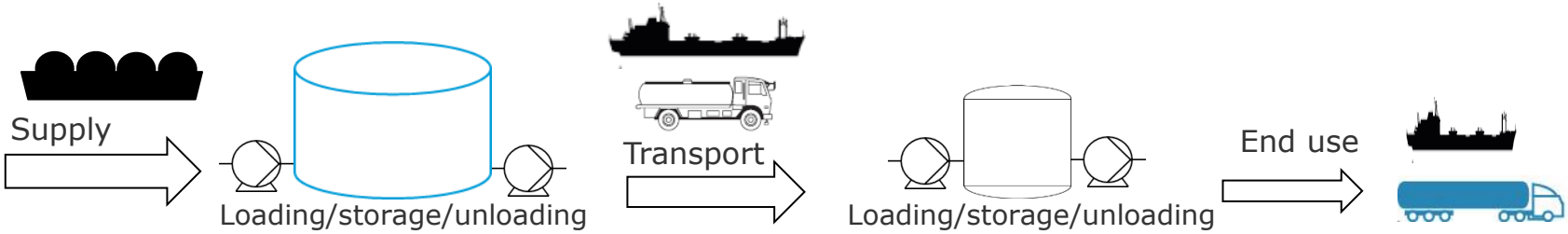


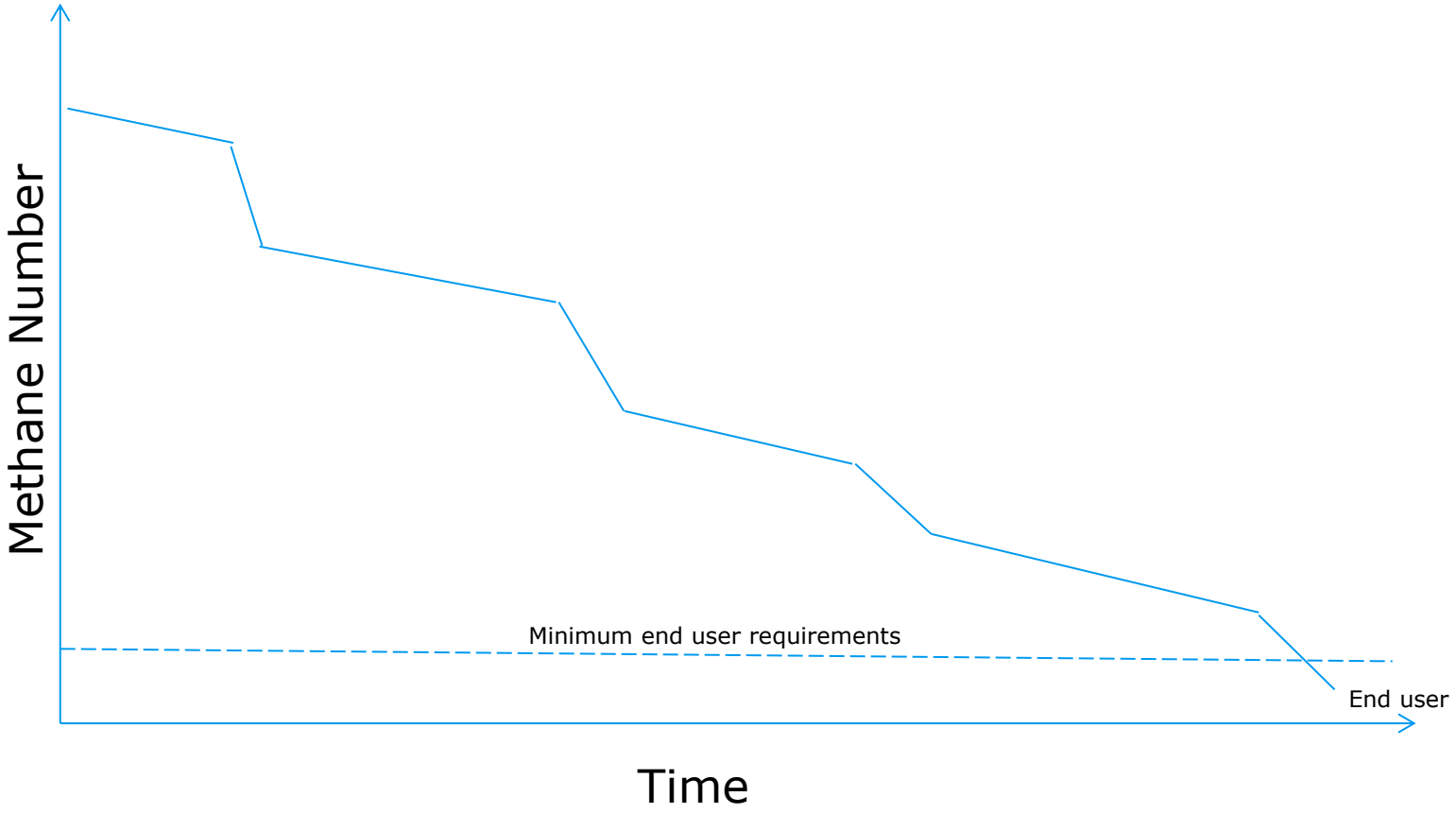
Cost?
Service levels?
Emissions?
MN?

Basic cases

- Reduce/Limit number of transfers
- Flow planning / Replenishment decisions
- Intensity of boil off
- Mixing/Blanding LNG

Number of transfers:





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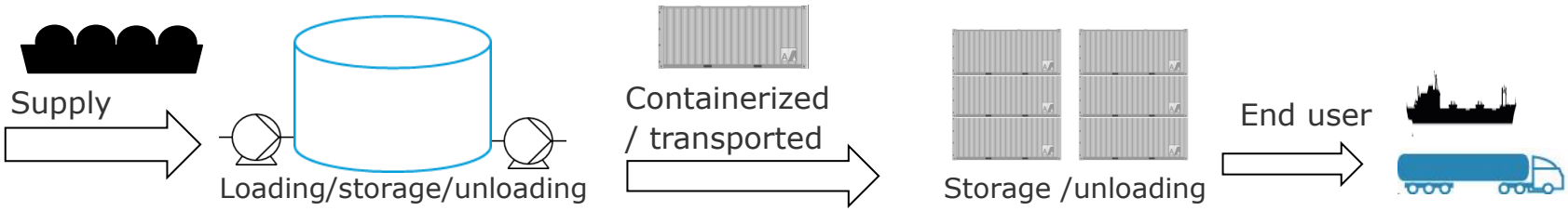
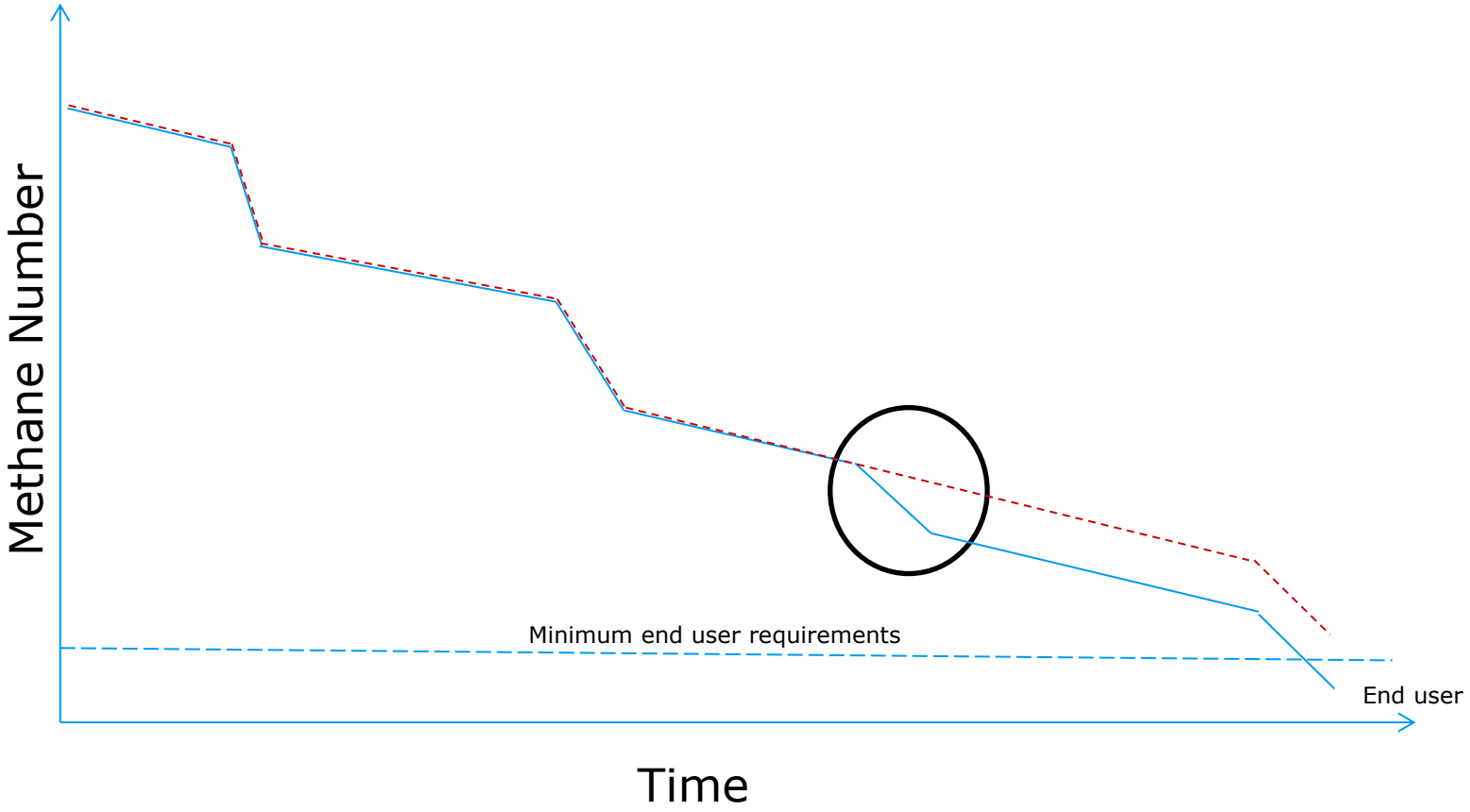
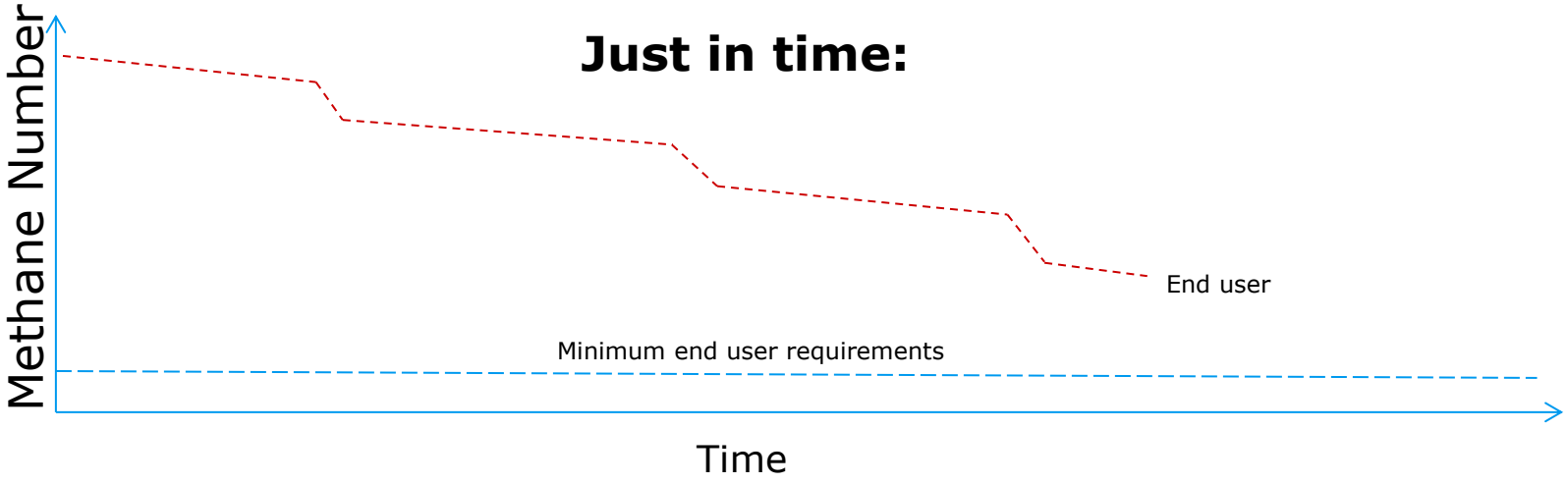
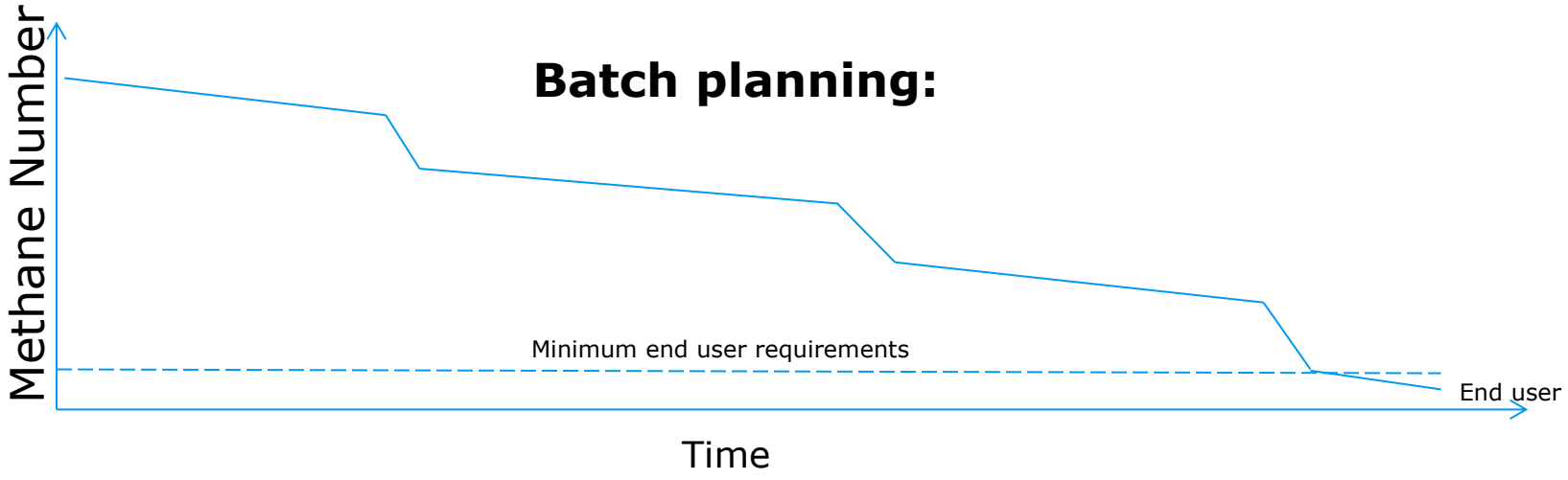


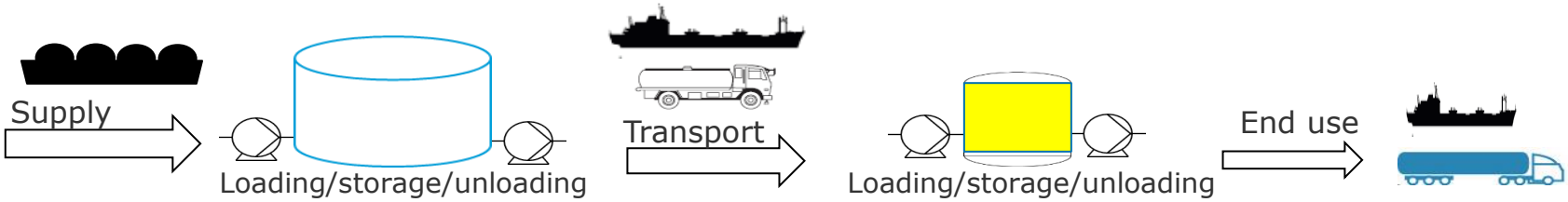


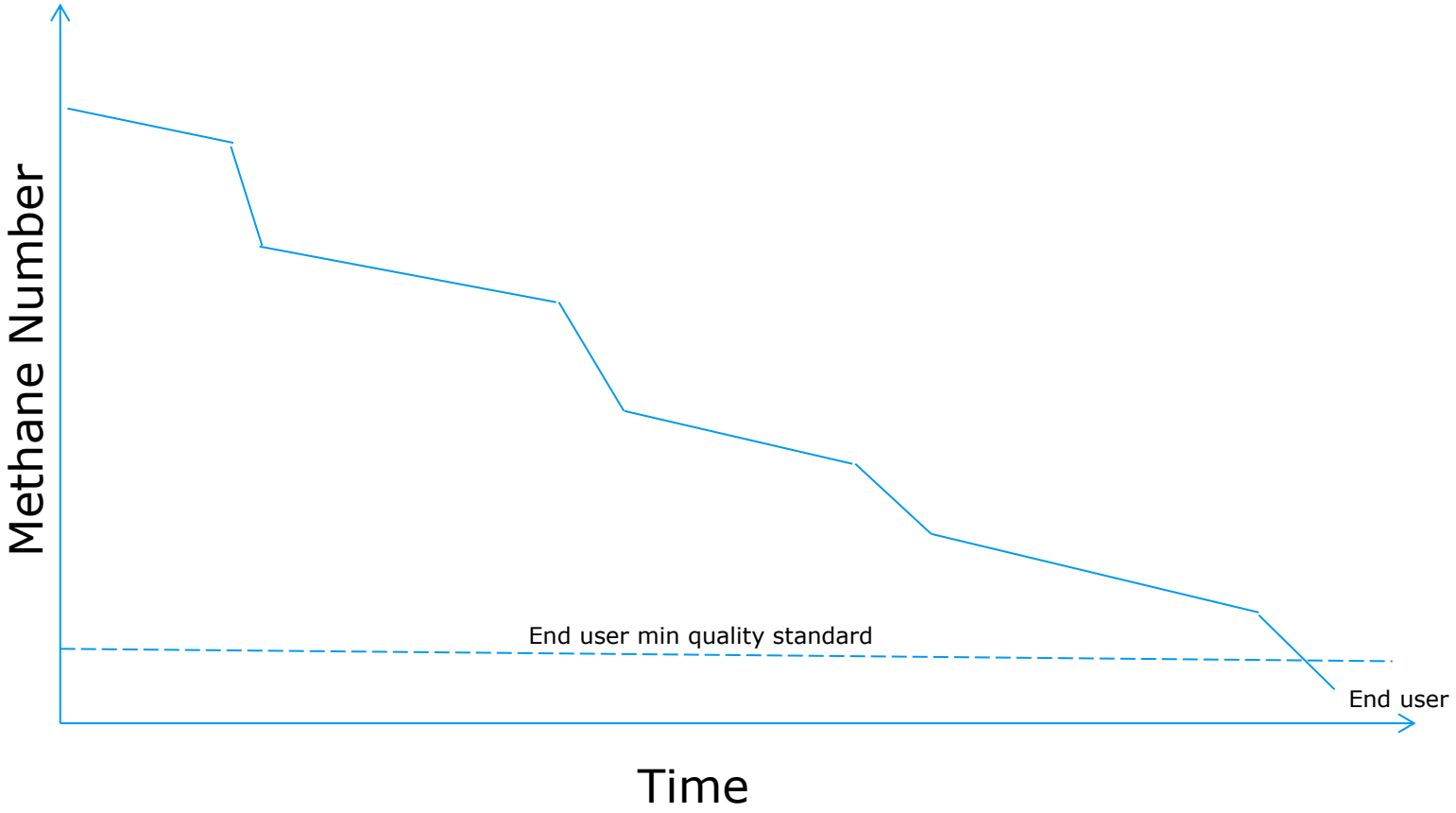
Flow planning:





Reduction of boil off:





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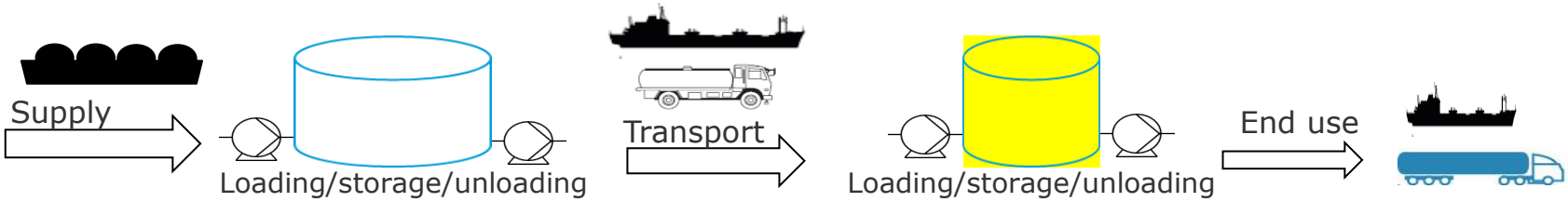
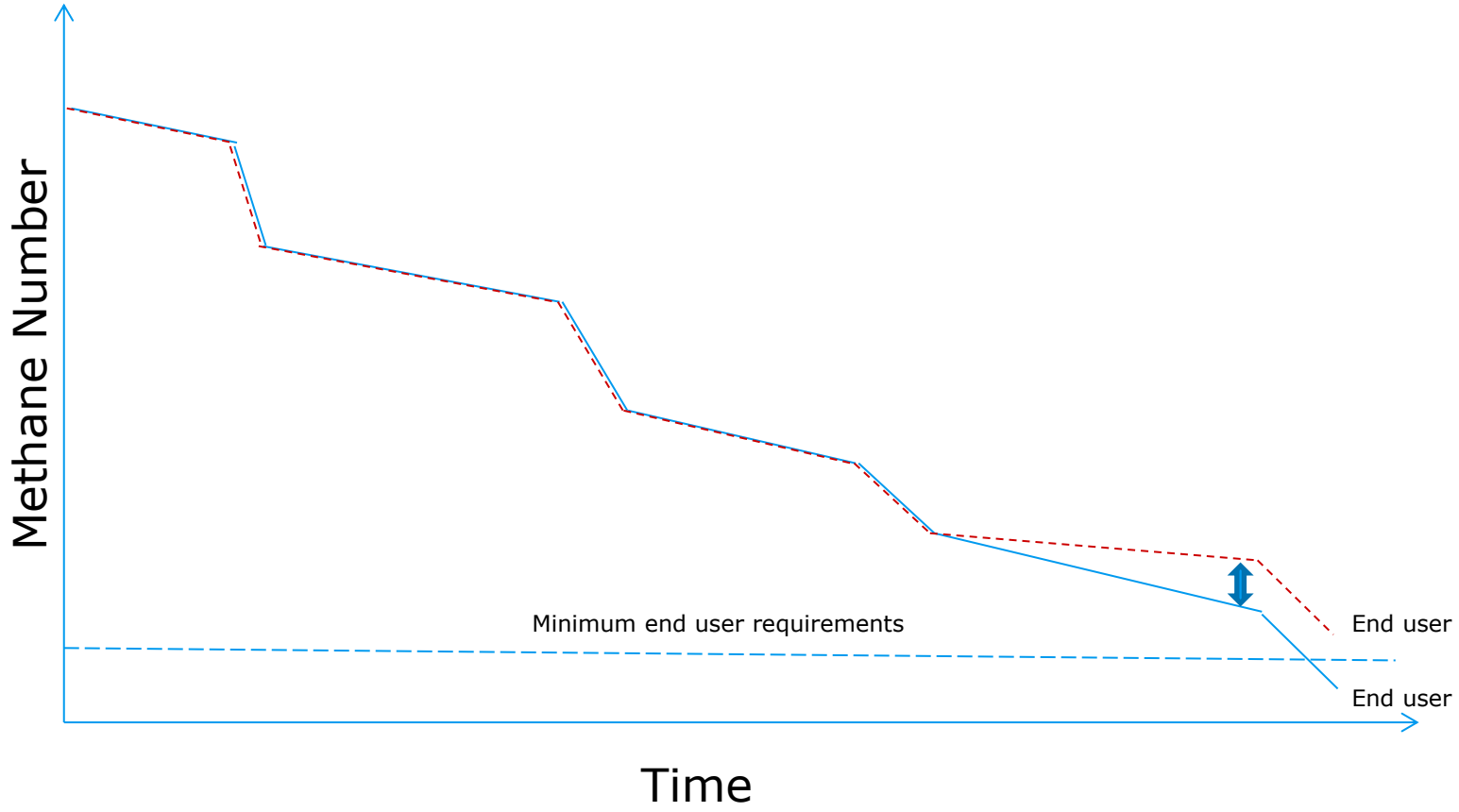
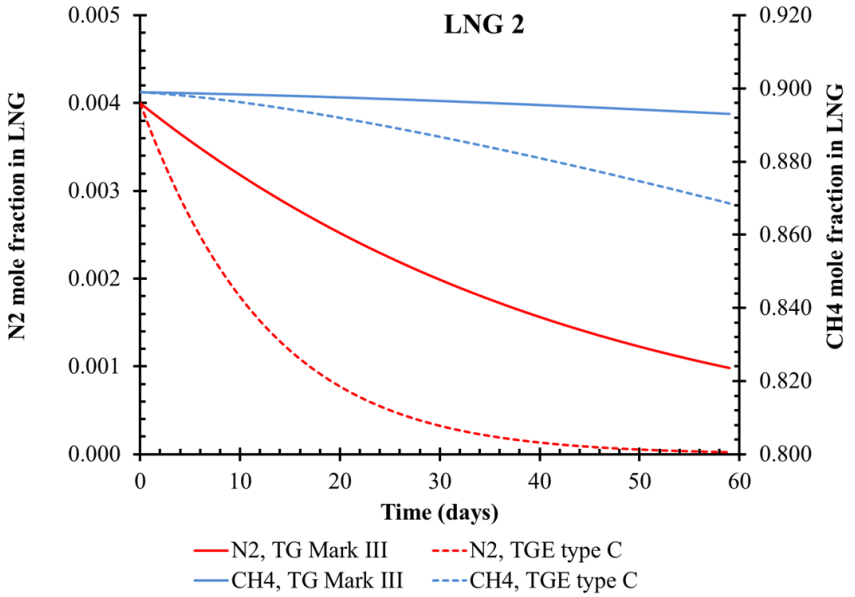




Reduction of boil off:

. TYPE

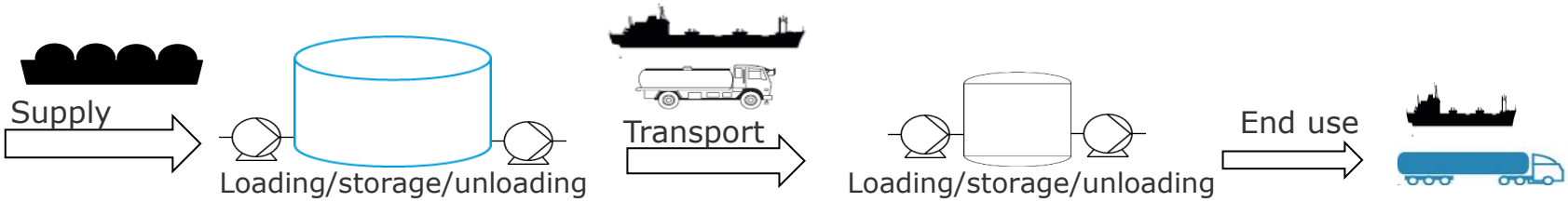
	TG Mark III	TGE type C
Application	Typical tank for LNG carrier	Small LNG (bunker) vessel
Boil-off rate [%/day]	0.135	0.35
Introduction year	>1993	2004
Material	Stainless steel AISI 304L	9% Ni steel of stainless steel AISI 304L

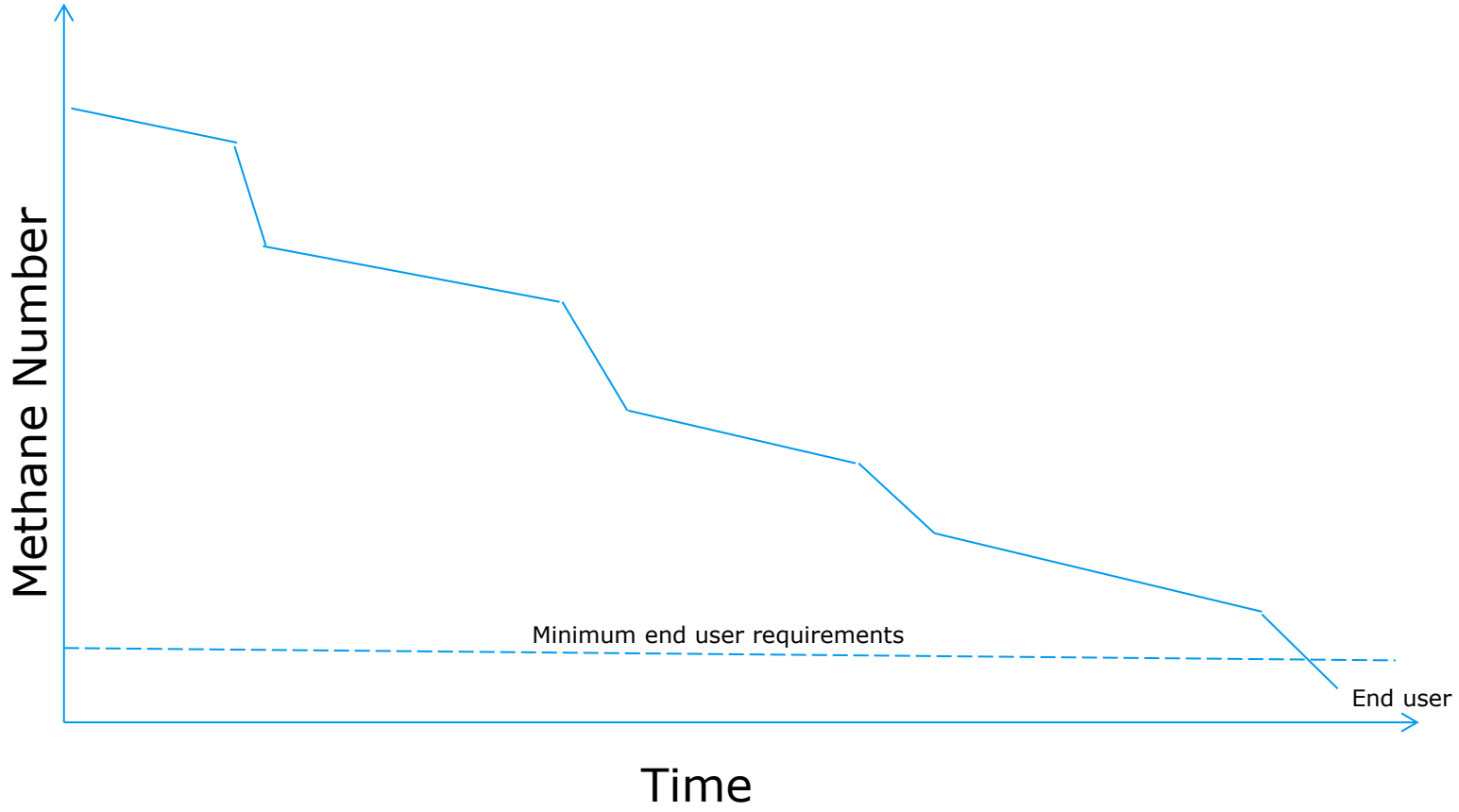


› Isolation propert transport modes.

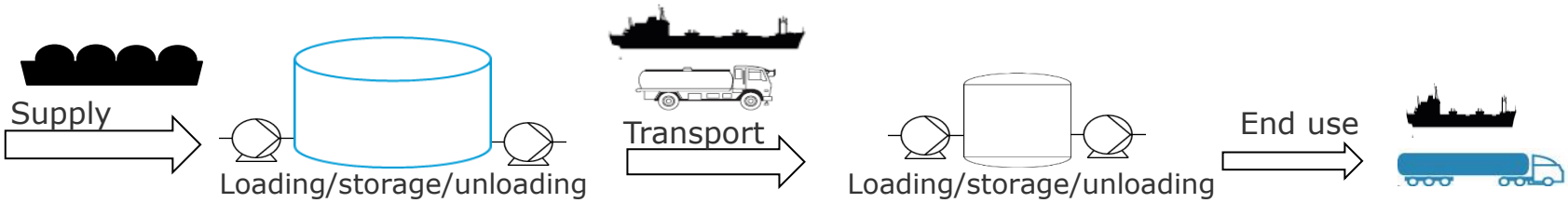
› Re-liquidification technology

Mixing LNG:


Supply
Loading/storage/unloading
Transport
Loading/storage/unloading
End use


Methane Number
Minimum end user requirements
End user
Time

Mixing LNG: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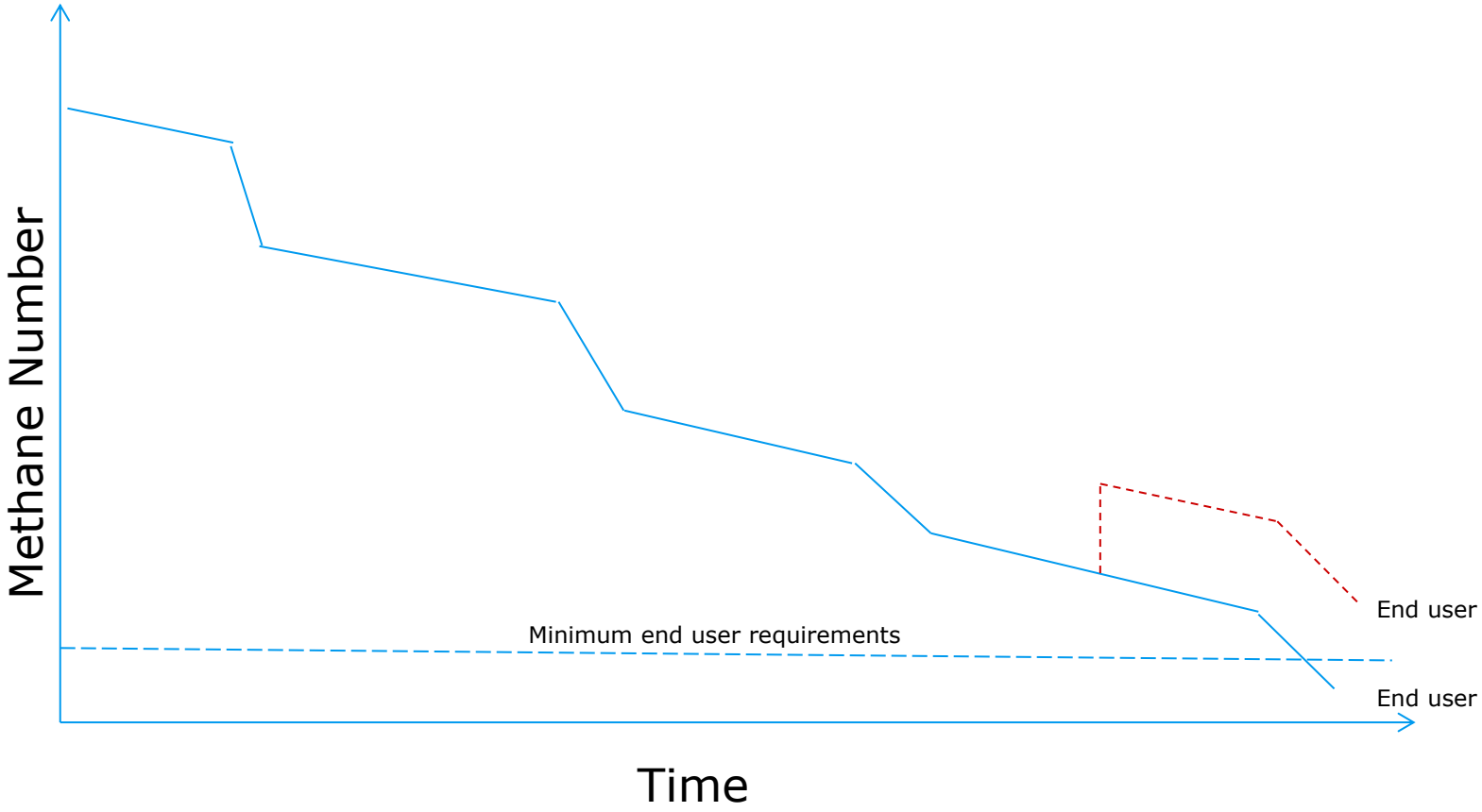
Methane Number
Minimum end user requirements
End user
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Possible effects of considering LNG quality

- At a facility design level
  - Reduce the number of transfers in the supply chain
  - Invest in larger/better insulated tanks
  - Invest in technology to manage the boil-off gas
  - Favour containerized-LNG over fixed tanks

- At an operational planning level
  - Frequent replenishment with low quantities of LNG
    - Replenishment by tanker trucks

    Or
  - Transport and store LNG in large quantities
    - Replenishment by large replenishment mode

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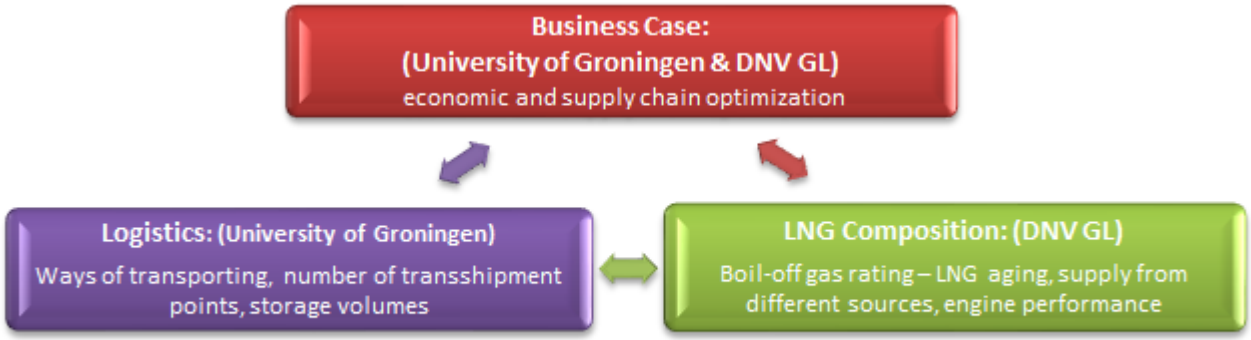

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Thanks for your attention

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SAFER, SMARTER, GREENER

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