The Evolution of Reefer Operations

MCI Reefer Conference 2025

STAR COOL

Sustainability Leaps in Reefer Operations

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Refrigerant Landscape

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Reefer OPEX
Impact of
alternative fuels

Legislations
Regulating
refrigerants

Refrigerant cost
Impact factors and
geopolitical evaluations

Outlook
Trends in automotive,
Quo vadis R134a/R1234yf?

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Typical considerations

Average power demand of an avg reefer (IMO default)

2.75 kW

×

Annual profile in operation

120 days x 24 hours

×

Average fuel consumption engine

240 g/kWh

×

Bunker fuel cost

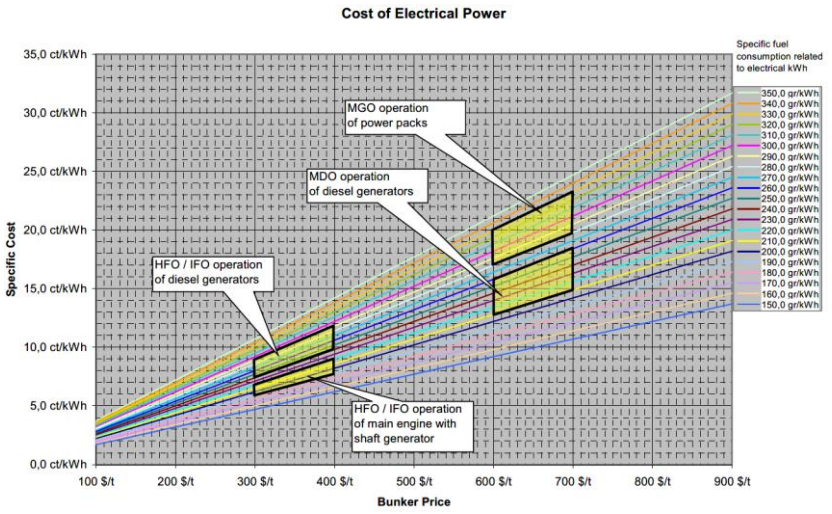
450 USD/t

=

Operational cost to power a reefer

855 USD

0.11 USD/kWh



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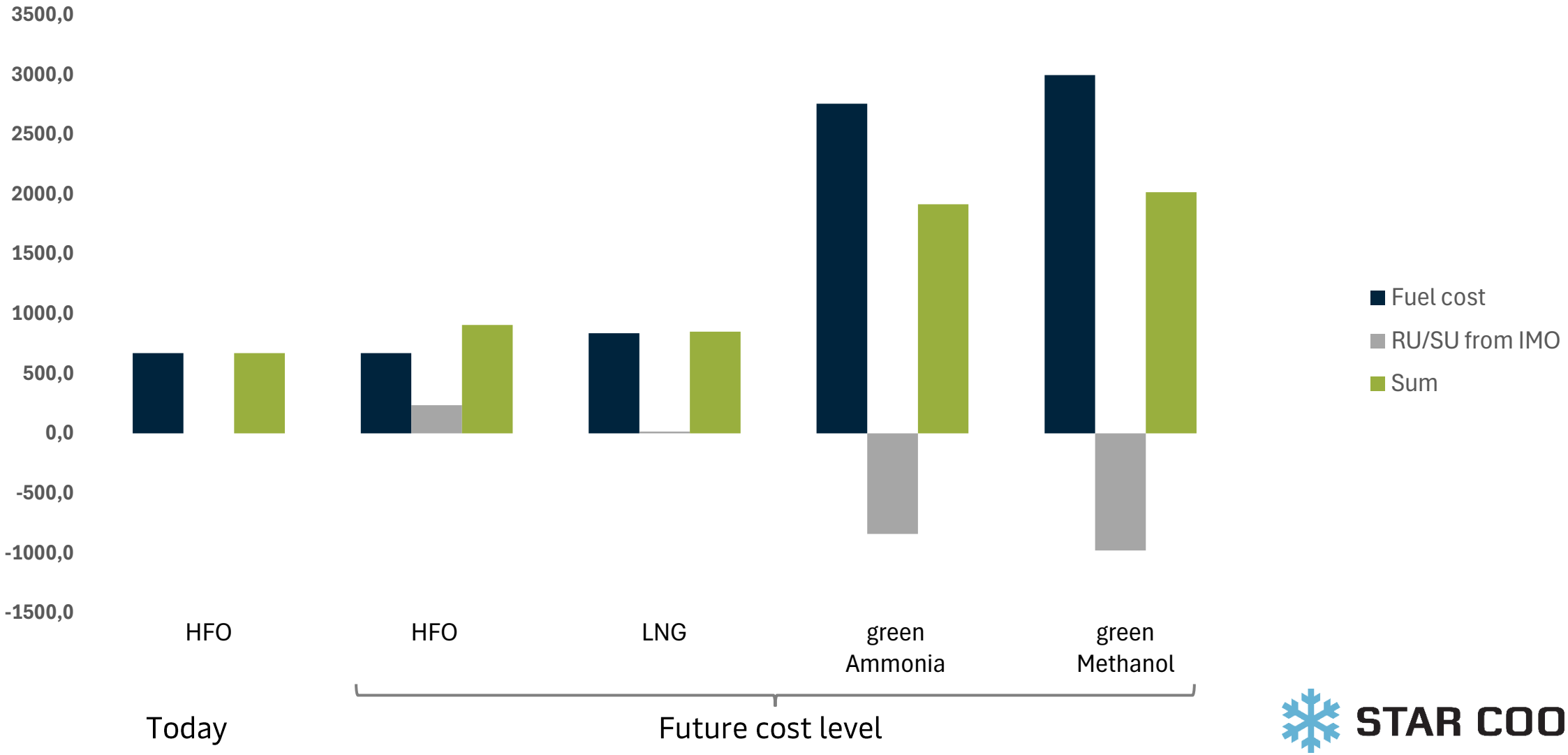
Operational cost per year and reefer (IMO avg at 2.75 kW per hour)



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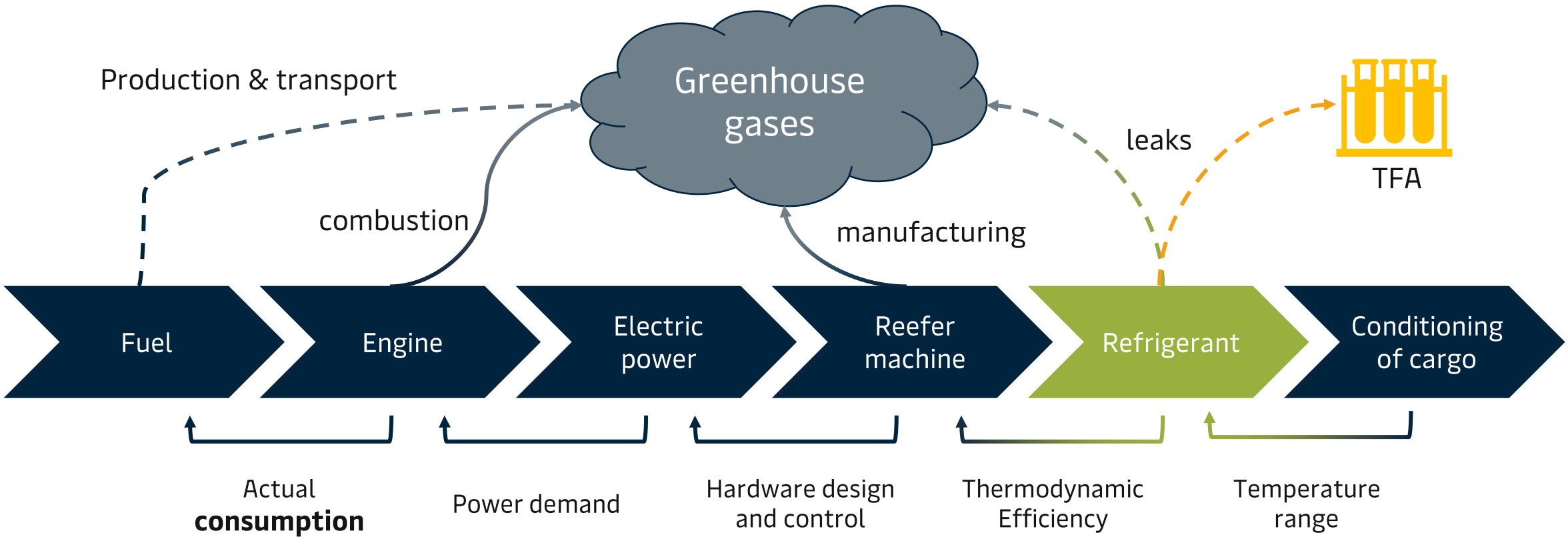
Refrigerant role in overall carbon emissions



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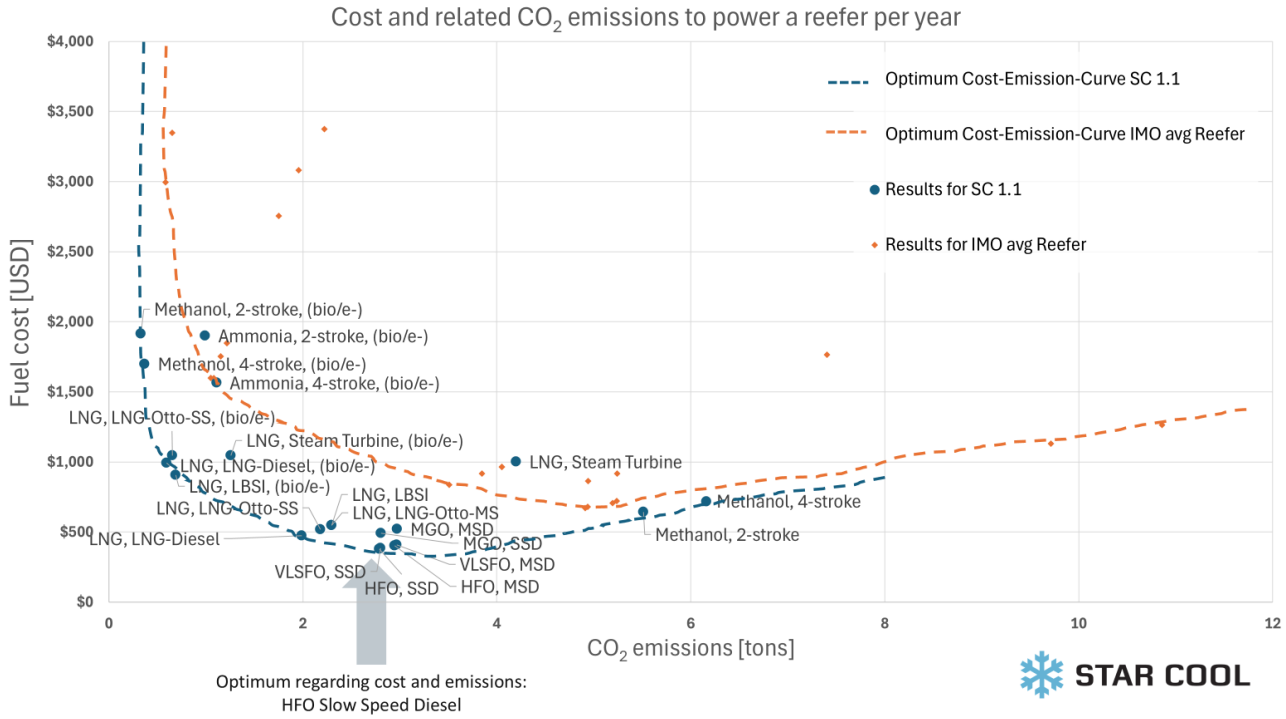
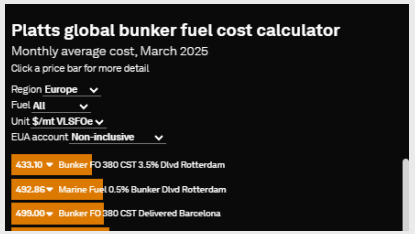
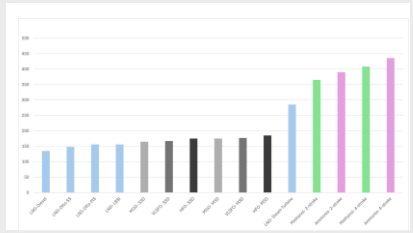
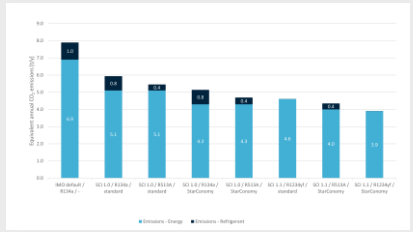




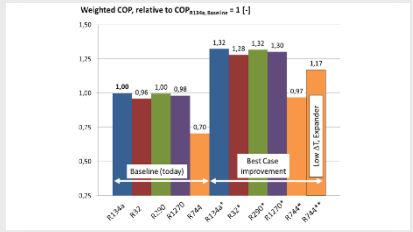
Current global **Fuel cost** information from Platts global bunker data



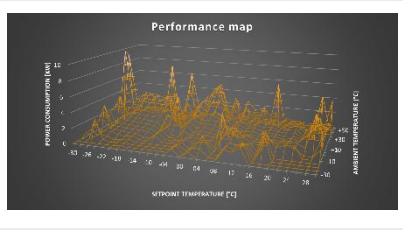
Fuel consumption data and **well-to-wake emissions** from DNV, ICCT, MAN and Danish Energy Agency



System performance benchmark tests done at MCI and third party



Refrigerant performance impact studied theoretically and experimentally



Operating conditions based on 570 Million hours of operation on 100,000 reefers by Sekstant™

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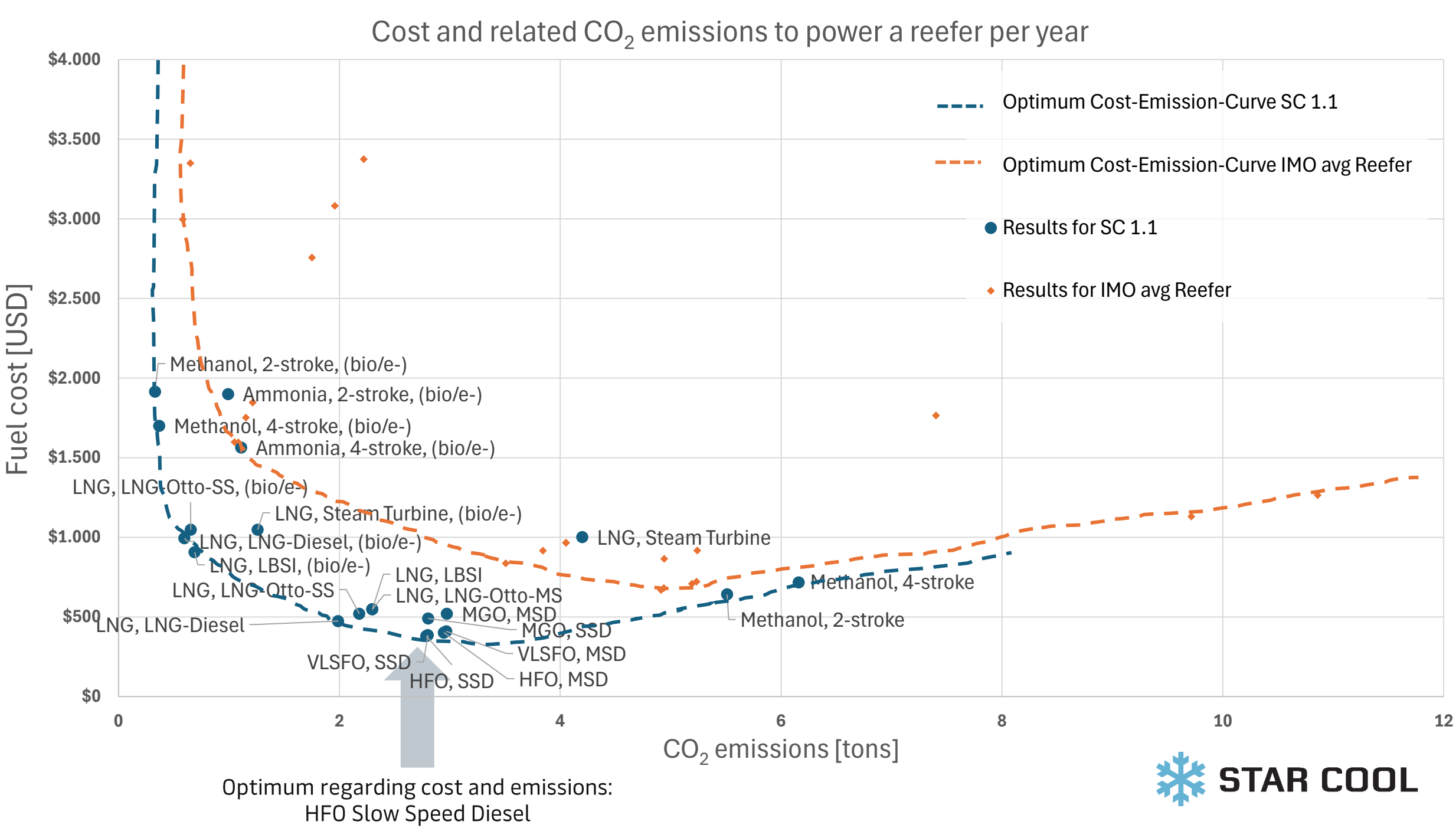
Cost and related CO_2 emissions to power a reefer per year
Fuel cost [USD]
$4.000
$3.500
$3.000
$2.500
$2.000
$1.500
$1.000
$500
$0
0
2
4
6
8
10
12
CO_2 emissions [tons]
Optimum Cost-Emission-Curve SC 1.1
Optimum Cost-Emission-Curve IMO avg Reefer
Results for SC 1.1
Results for IMO avg Reefer
Methanol, 2-stroke, (bio/e-)
Ammonia, 2-stroke, (bio/e-)
Methanol, 4-stroke, (bio/e-)
Ammonia, 4-stroke, (bio/e-)
LNG, LNG-Otto-SS, (bio/e-)
LNG, Steam Turbine, (bio/e-)
LNG, LNG-Diesel, (bio/e-)
LNG, LBSI, (bio/e-)
LNG, LNG-Otto-SS
LNG, LBSI
LNG, LNG-Otto-MS
LNG, LNG-Diesel
MGO, MSD
MGO, SSD
VLSFO, MSD
VLSFO, SSD
HFO, SSD
HFO, MSD
LNG, Steam Turbine
Methanol, 4-stroke
Methanol, 2-stroke
Optimum regarding cost and emissions:
HFO Slow Speed Diesel
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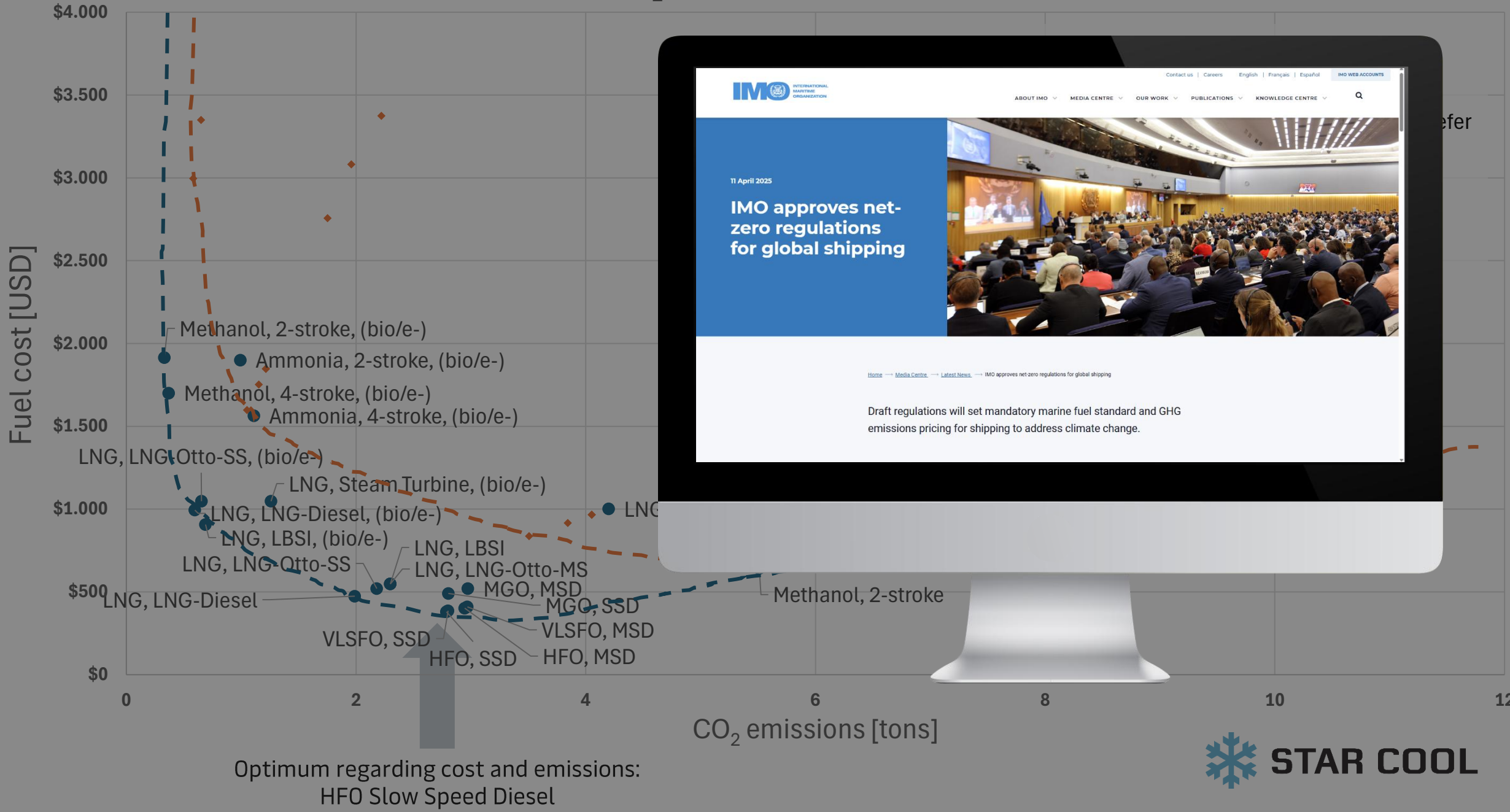
Cost and related CO_2 emissions to power a reefer per year



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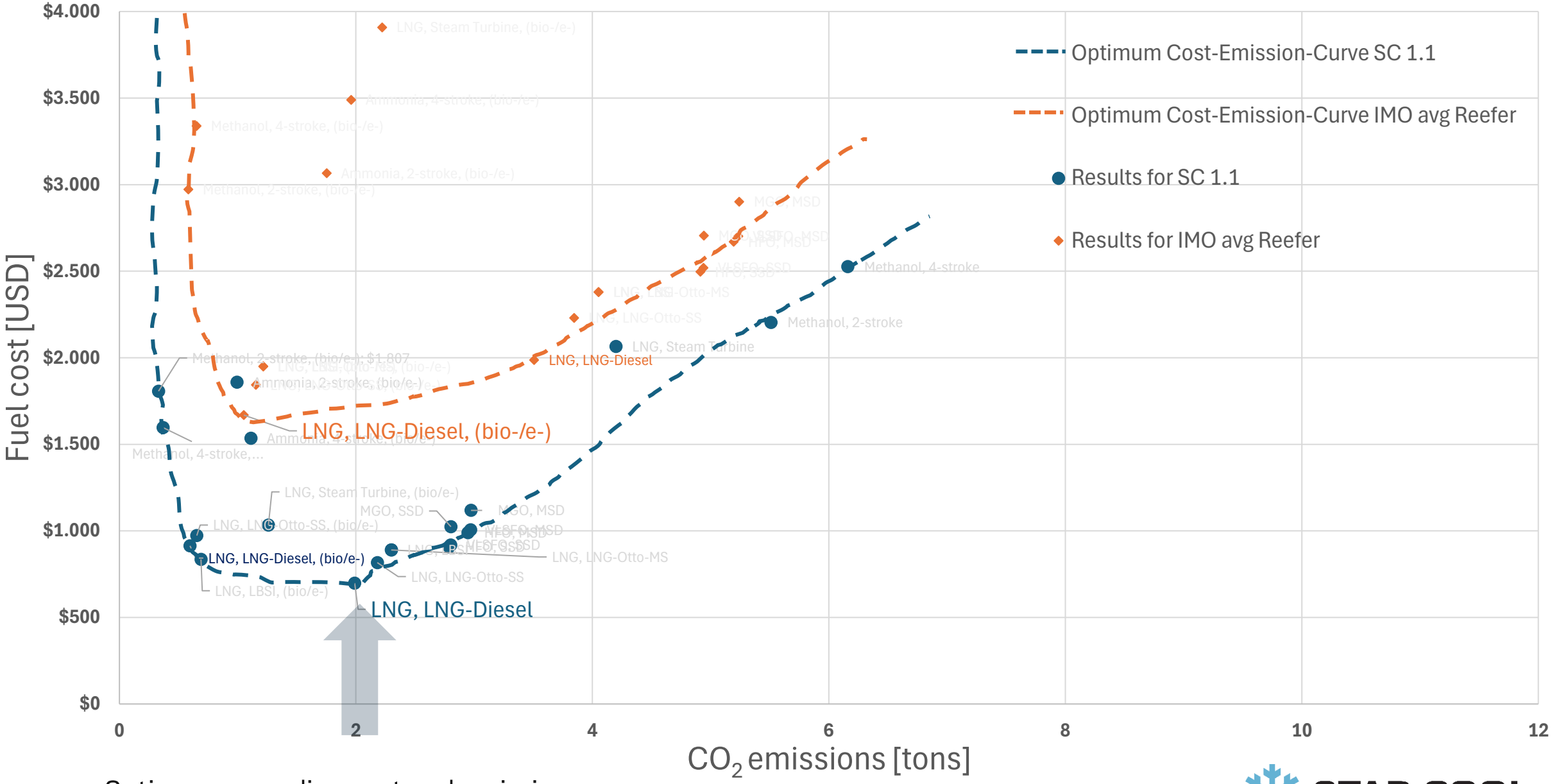
Cost and related CO_2 emissions to power a reefer per year, incl. IMO scheme



Optimum regarding cost and emissions:
LNG with Diesel Engine

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Conclusion reefer OPEX:

To be in control of operational cost, today and in future, all factors contributing to power demand need to be evaluated meticulously, ensuring no stone is left unturned.

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Reefer OPEX
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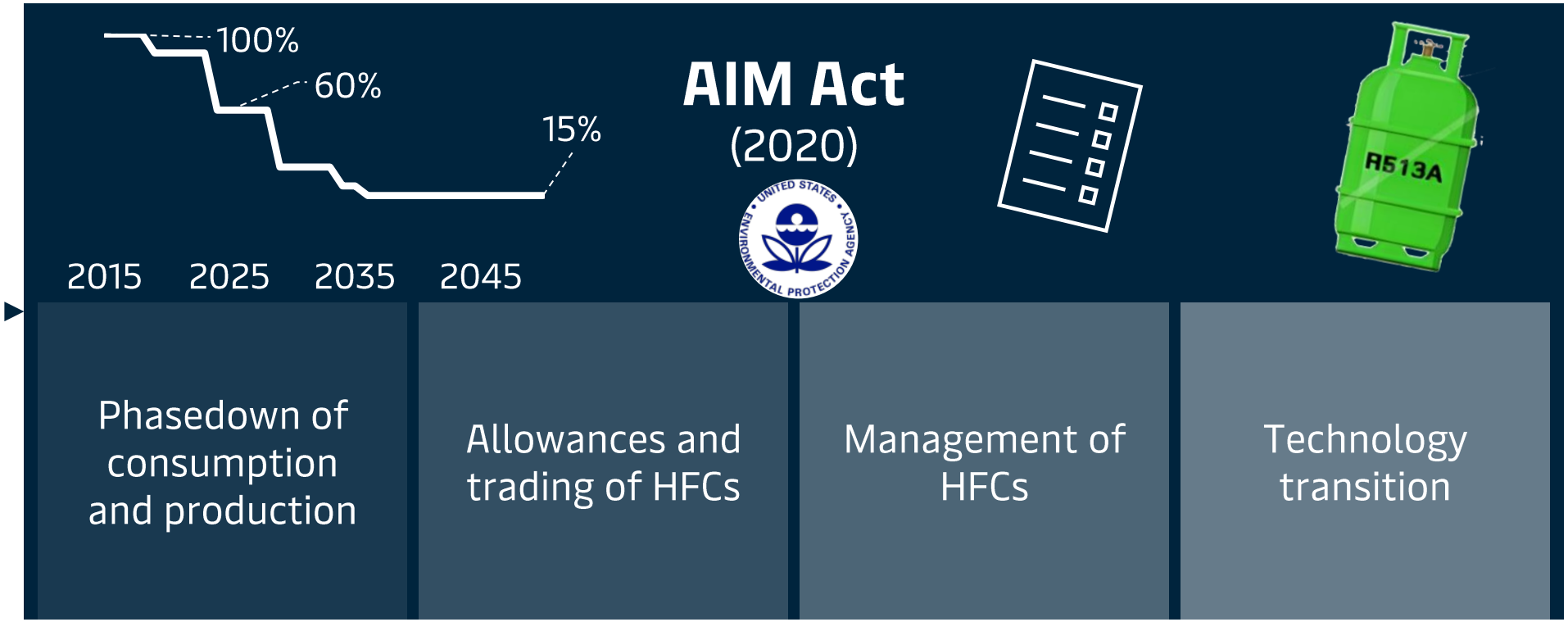
United States of America – Federal level

Kigali Amendment (2016)

Ratified (69-27) 2022



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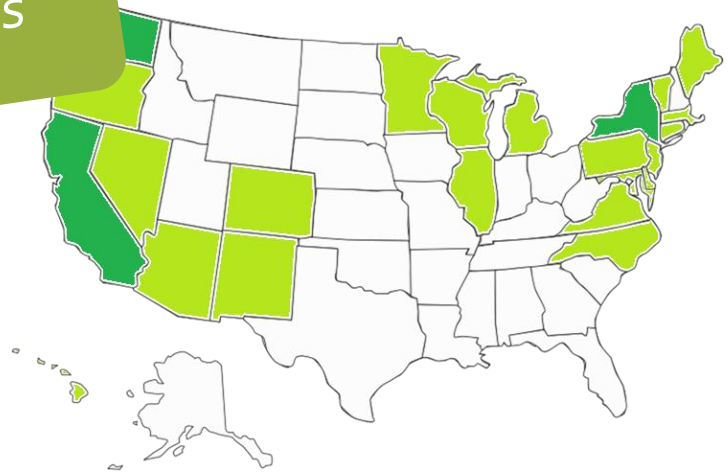
United States of America
State level environmental policies

CA, NY

AHRI & HARDI
Trump executive order

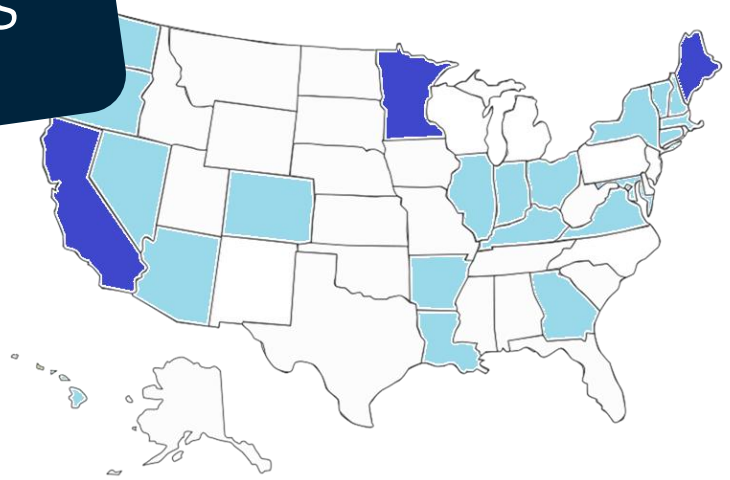
State level climate and clean energy regulations

F-gas



- “progressive states”, e.g. ratification of SNAP
- States with legislation exceeding AIM Act

PFAS



- States following PFAS definition of OECD, like EU
- States looking into TFA, the decomposition product of fluorinated refrigerants

Source: HFC Policy Tracker - North American Sustainable Refrigeration Council

European Union

Regulations pushing for ultra-low GWP refrigerants

F-gas regulation 2024/573

- In effect since March 2024
- Phase out of HFCs by 2050
- Increased policing
- Review in 2030

PFAS restriction proposal

- Potentially ban fluorinated refrigerants like R134a, R513A and R1234yf that break down to TFA
- Only applicable to products that are manufactured, (permanently) imported or used in EU territory
- Review ongoing, earliest expected entry into force 2028
- Current derogation period until 2035
- COA advocated for derogation until 2048

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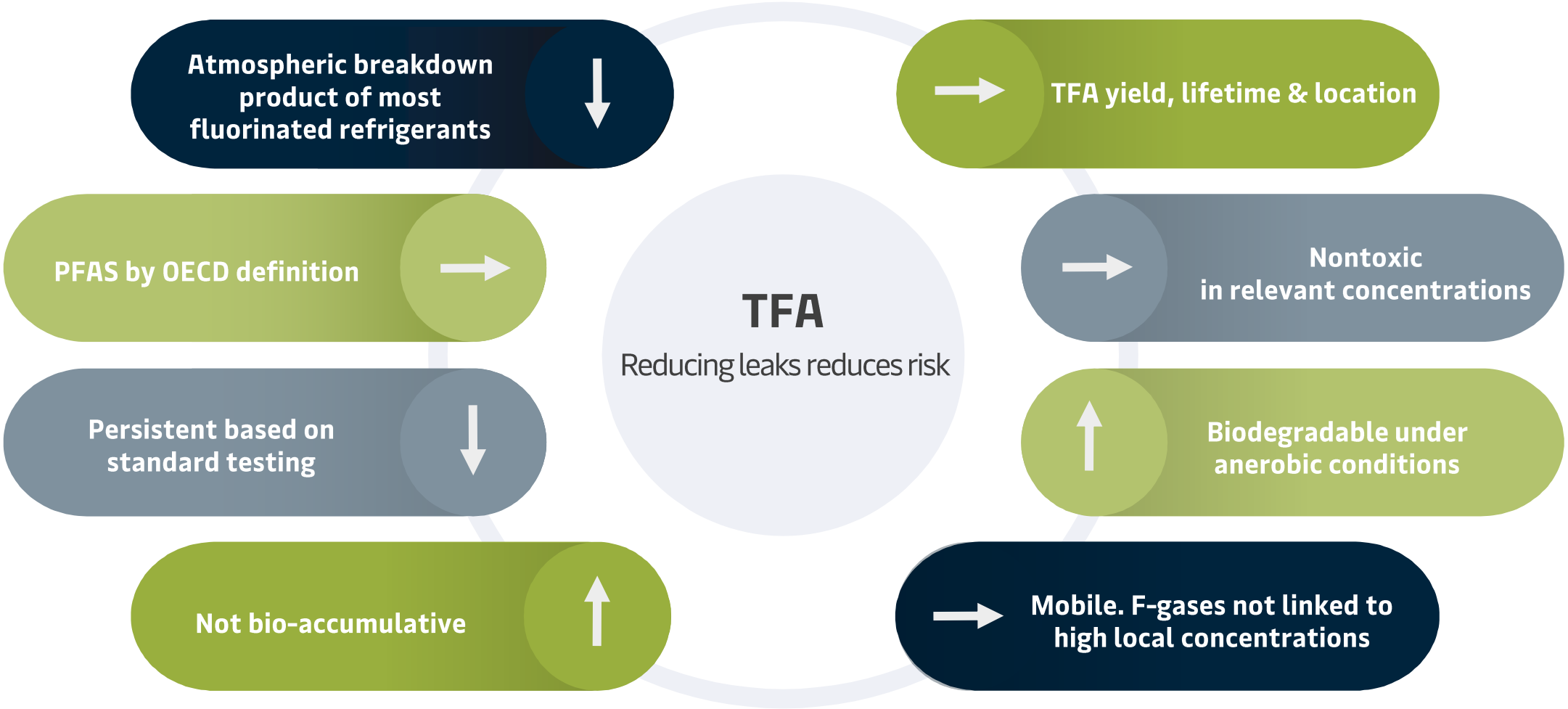
TFA – Need to know



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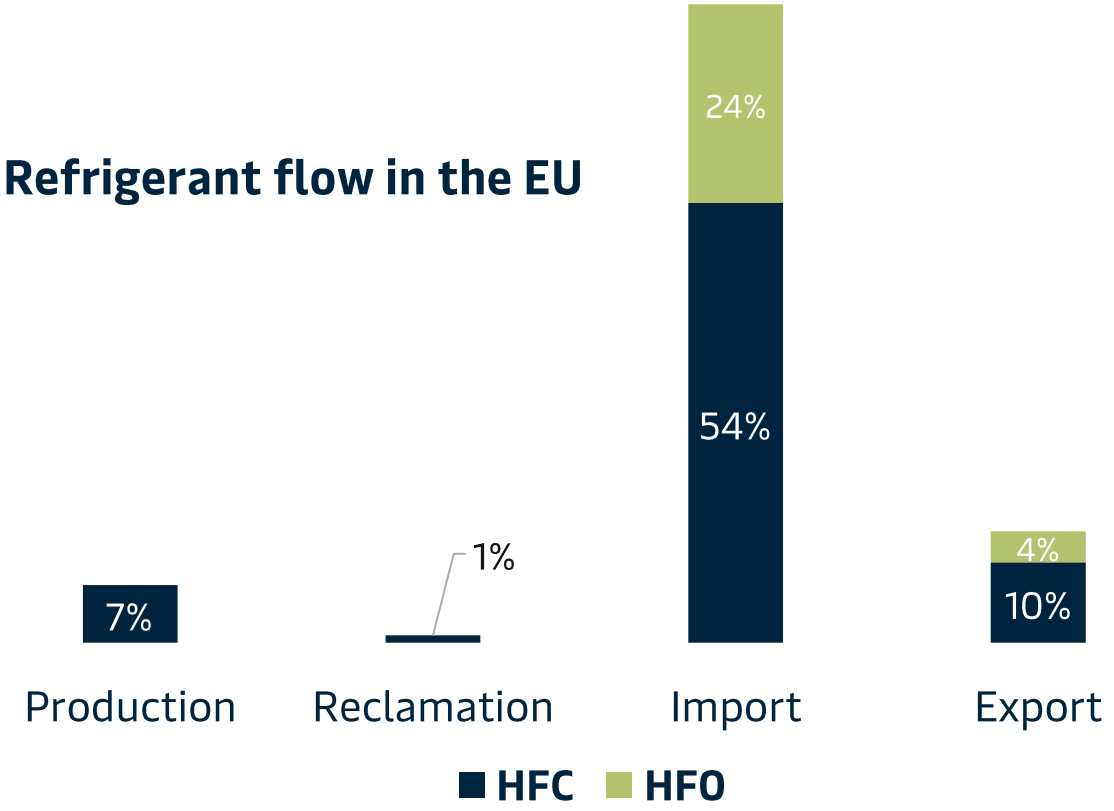
Refrigerants

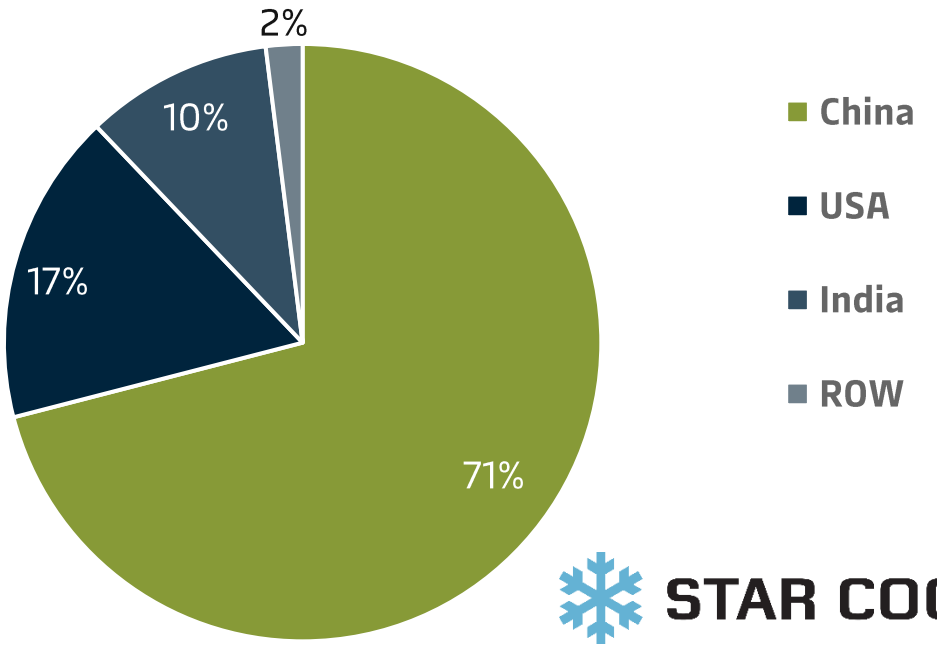
Where are they produced?

Refrigerant flow in the EU



R1234yf

R134a



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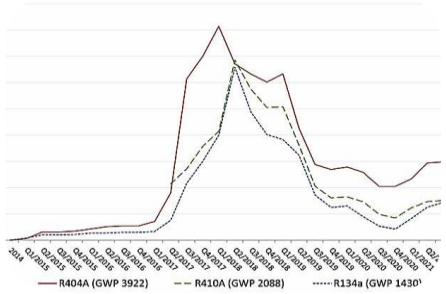
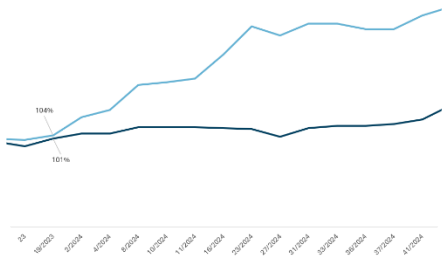
Refrigerant cost and drivers



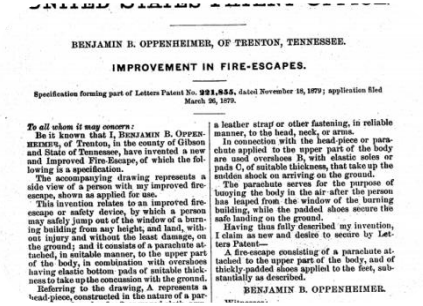
Quota



Production cap

Raw materials

Tariffs



Patent

R513A

R1234yf

R1234yf

R134a

R513A

R134a

R513A

R134a

R513A

R1234yf

R134a

R513A

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Current refrigerant prices
Global snapshot

Production cost est.

R134a: 4 $/kg
R513A: 10-25 $/kg
R1234yf: 13-39 $/kg

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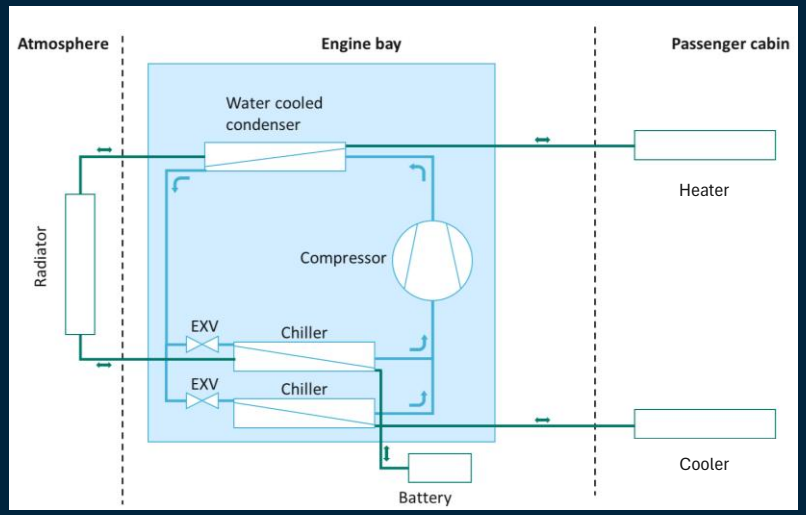
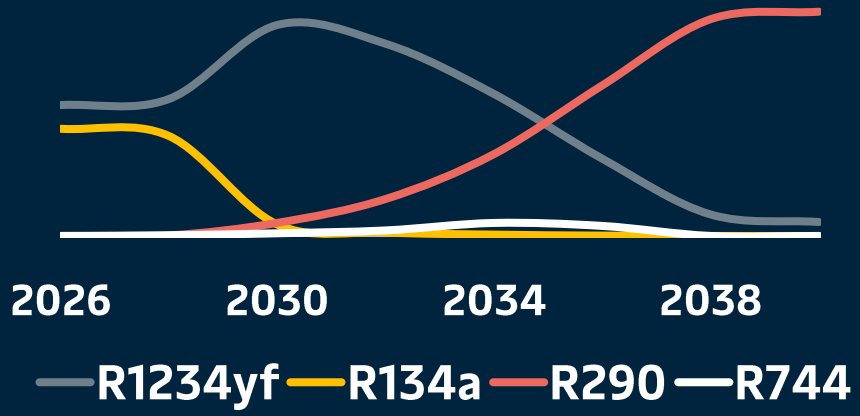
Trends in automotive
Guidance for reefers again?





2034 production

Dominant refrigerant in combustion engines

60% R1234yf

Dominant refrigerant battery electric vehicles

34% Propane

Initial technology in battery electric vehicles

5% Carbon Dioxide

Still dominating the existing fleet

1% R134a

Ford/ Denso:

"R1234yf is still the best option ICE/ Hybrid/ Plug-in"

Bosch:

"Propane offers a more favorable efficiency and cost level"

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Summary

- Efficient reefer machines are key to keep the cost under control
- Refrigerant choice has a significant impact
- R134a is being phased out in the global automotive industry within this decade
- Use of R1234yf is growing in the next years, in both reefer and automotive
- Automotive is transitioning to a thermal management system – a simple “copy” and ”paste” in reefer would offset energy efficiency and drive operational costs upwards

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Break

Practical Experience with R1234yf Operation

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Star Cool 1.1
Feedback

The Evolution of Reefer Operations
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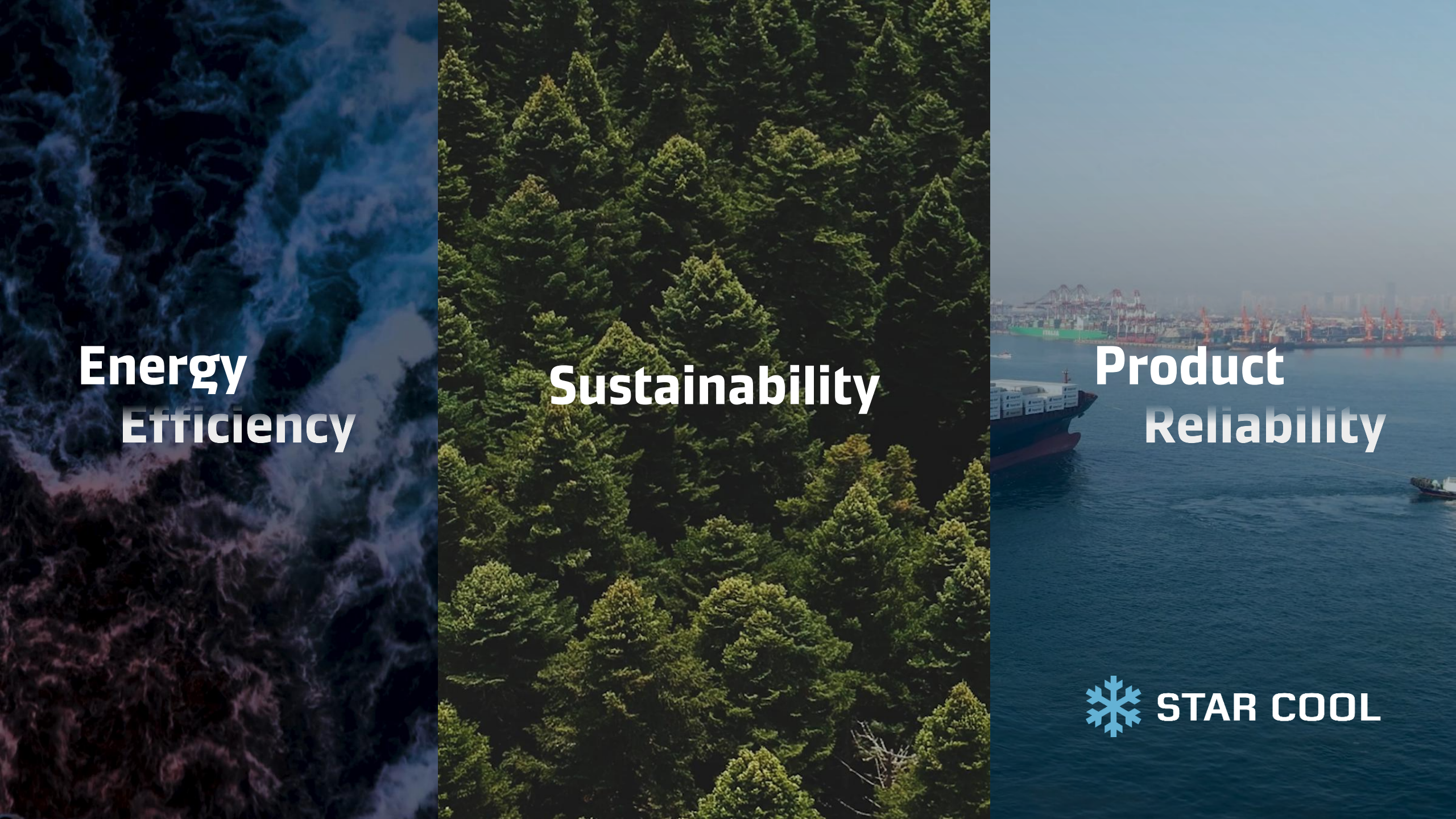
Energy
Efficiency
Sustainability
Product
Reliability
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Sustainability

TR - TRIPLE REFRIGERANT

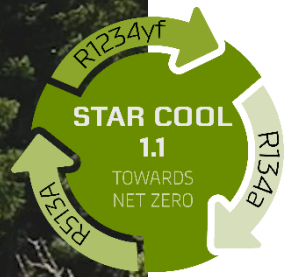
Factory charge options

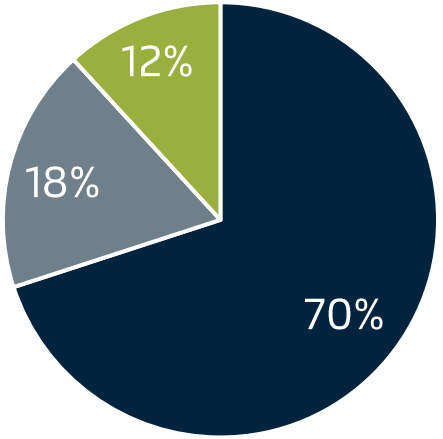
- R134a
- R513A
- R1234yf

TRR - TRIPLE REFRIGERANT READY

Factory charge options

- R134a
- R513A





Split in over **25,000** produced SC 1.1

■ TRR ■ TR ■ TR (1234yf charged)

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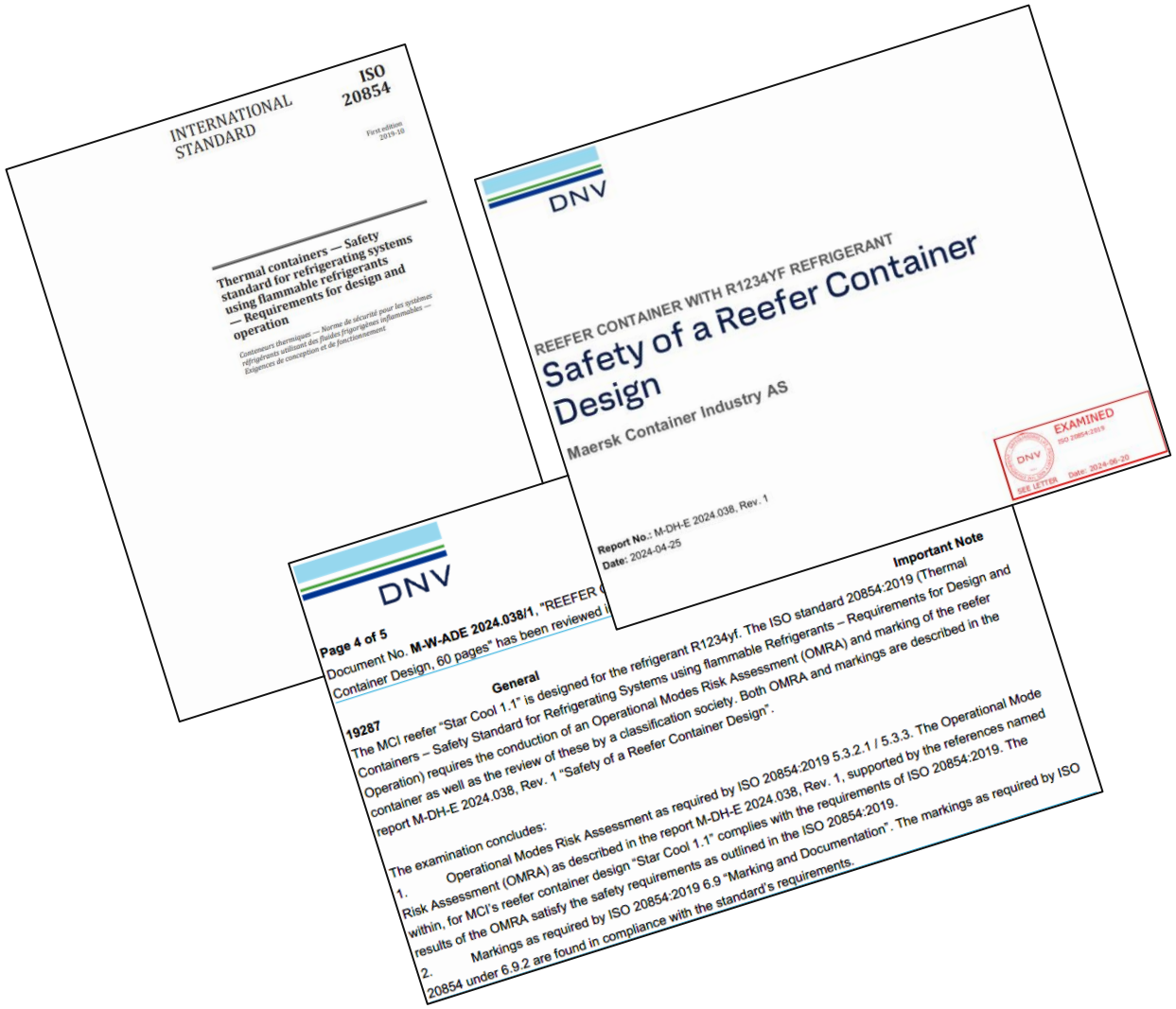
R1234yf charged reefers

World's first from MCI



INTERNATIONAL STANDARD

ISO 20854

First edition 2019-10

Thermal containers — Safety standard for refrigerating systems using flammable refrigerants — Requirements for design and operation

Conteneurs thermiques — Norme de sécurité pour les systèmes frigorifiques utilisant des fluides frigorigènes inflammables — Exigences de conception et de fonctionnement

DNV

REEFER CONTAINER WITH R1234YF REFRIGERANT

Safety of a Reefer Container Design

Maersk Container Industry AS

EXAMINED ISO 20854:2019 DNV SEE LETTER Date: 2024-06-20

Report No.: M-DH-E 2024.038, Rev. 1

Date: 2024-04-25

DNV

Page 4 of 5

Document No. **M-W-ADE 2024.038/1**, "REEFER C

Container Design, 60 pages" has been reviewed i

General

19287

The MCI reefer "Star Cool 1.1" is designed for the refrigerant R1234yf. The ISO standard 20854:2019 (Thermal Containers – Safety Standard for Refrigerating Systems using flammable Refrigerants – Requirements for Design and Operation) requires the conduction of an Operational Modes Risk Assessment (OMRA) and marking of the reefer container as well as the review of these by a classification society. Both OMRA and markings are described in the report M-DH-E 2024.038, Rev. 1 "Safety of a Reefer Container Design".

Important Note

The examination concludes:

1. Operational Modes Risk Assessment as required by ISO 20854:2019 5.3.2.1 / 5.3.3. The Operational Mode Risk Assessment (OMRA) as described in the report M-DH-E 2024.038, Rev. 1, supported by the references named within, for MCI's reefer container design "Star Cool 1.1" complies with the requirements of ISO 20854:2019. The results of the OMRA satisfy the safety requirements as outlined in the ISO 20854:2019.
2. Markings as required by ISO 20854:2019 6.9 "Marking and Documentation". The markings as required by ISO 20854 under 6.9.2 are found in compliance with the standard's requirements.

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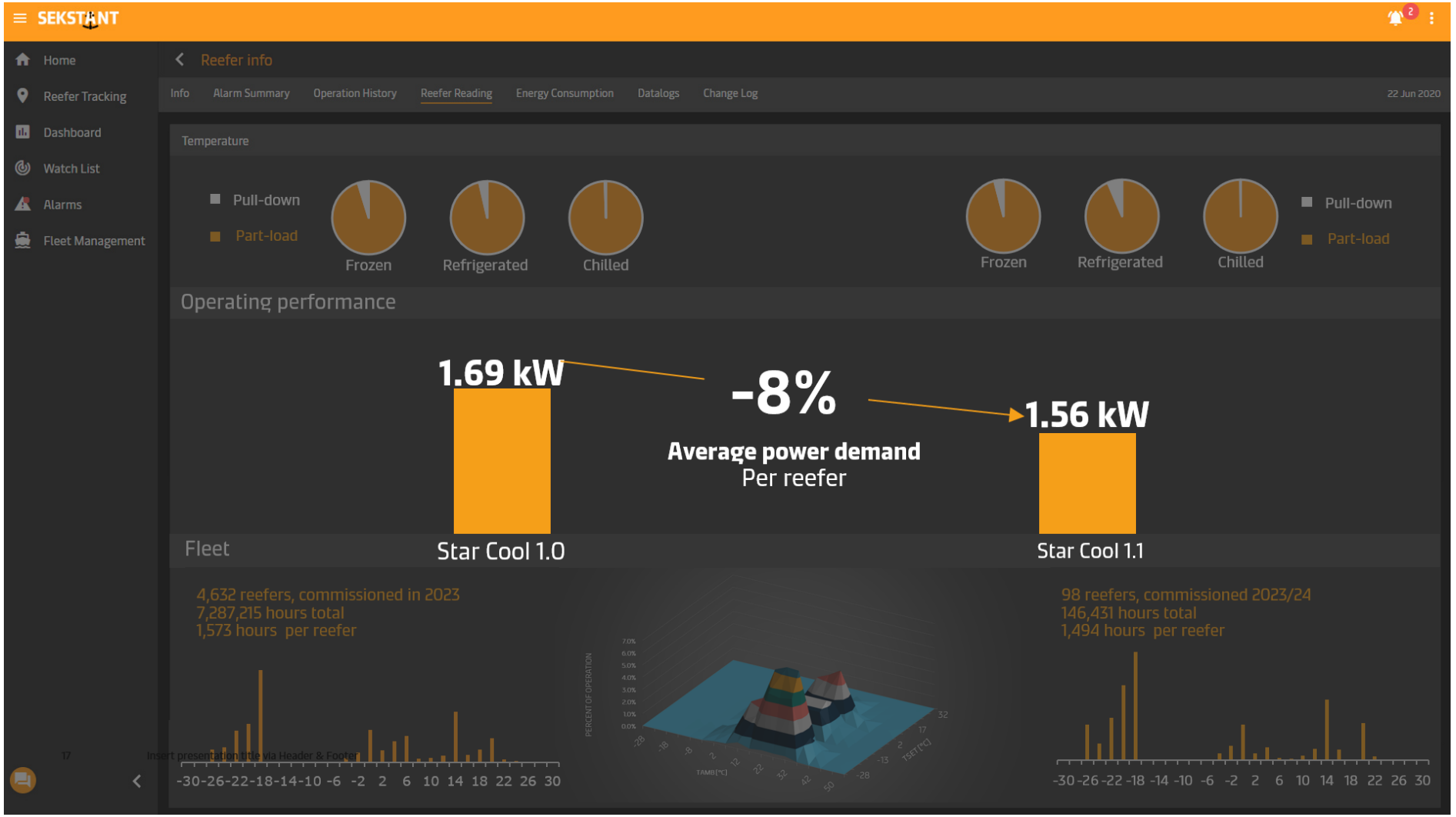
Sekstant data demonstrating 8% improvement over SC 1.0



SEKSTANT

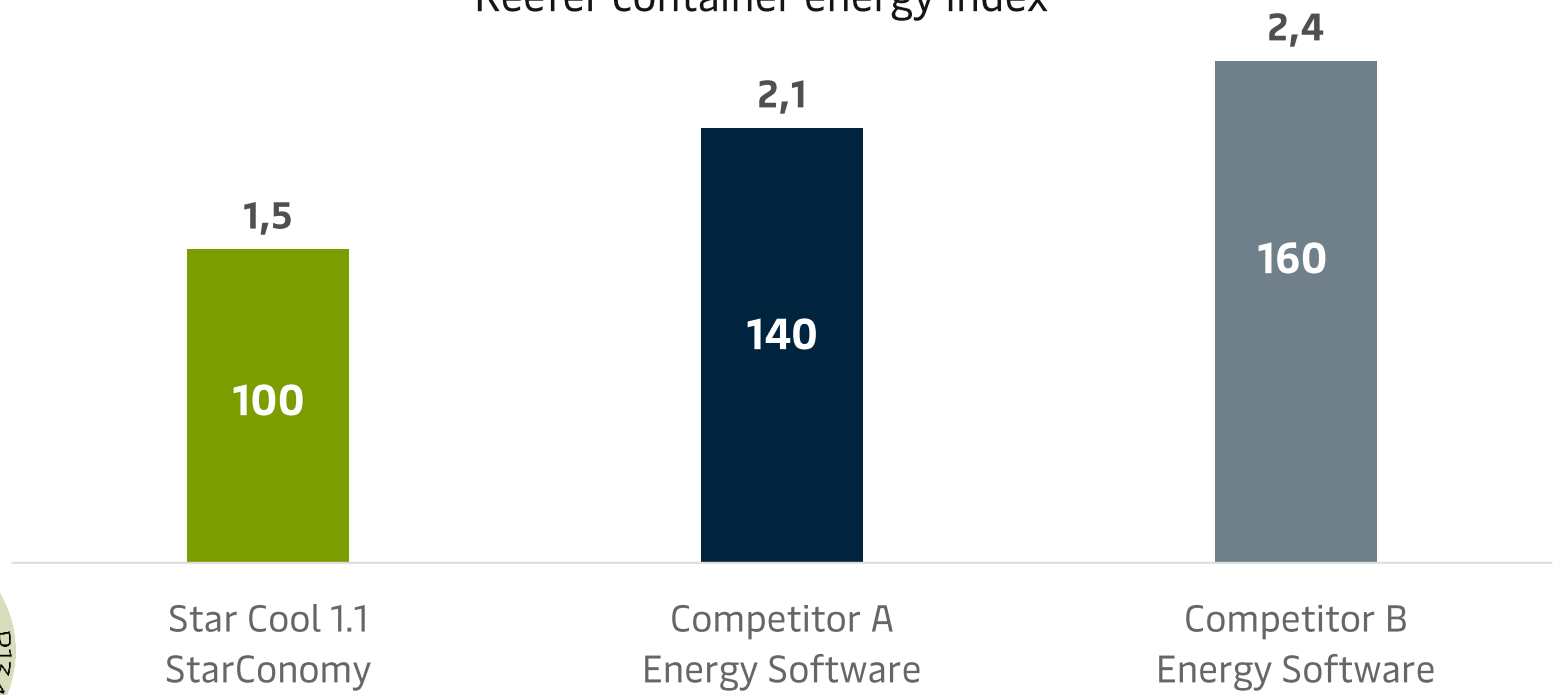
Energy Efficiency

Independent benchmark test

Substantial advantage over competition

Average power consumption of one reefer (kW)

Reefer container energy index



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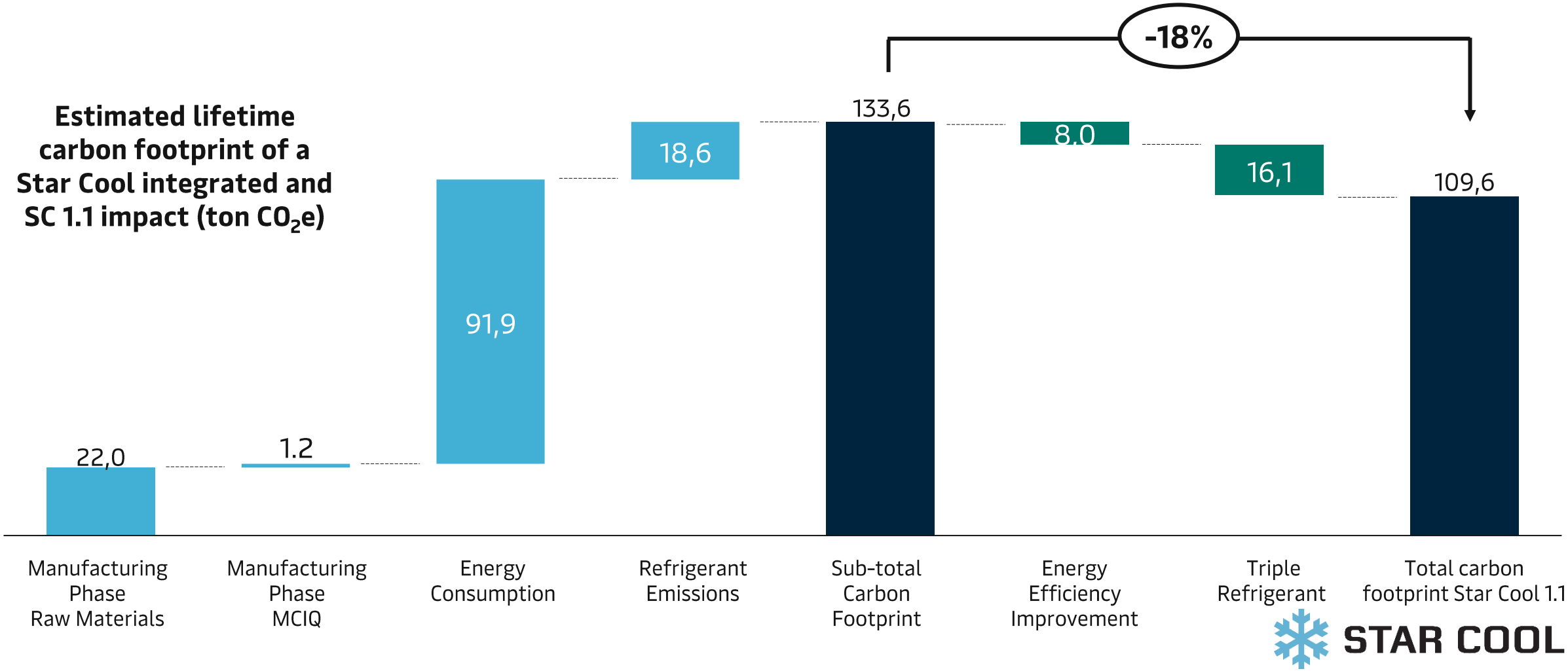
Carbon footprint reduction

Total impact of refrigerant and energy efficiency



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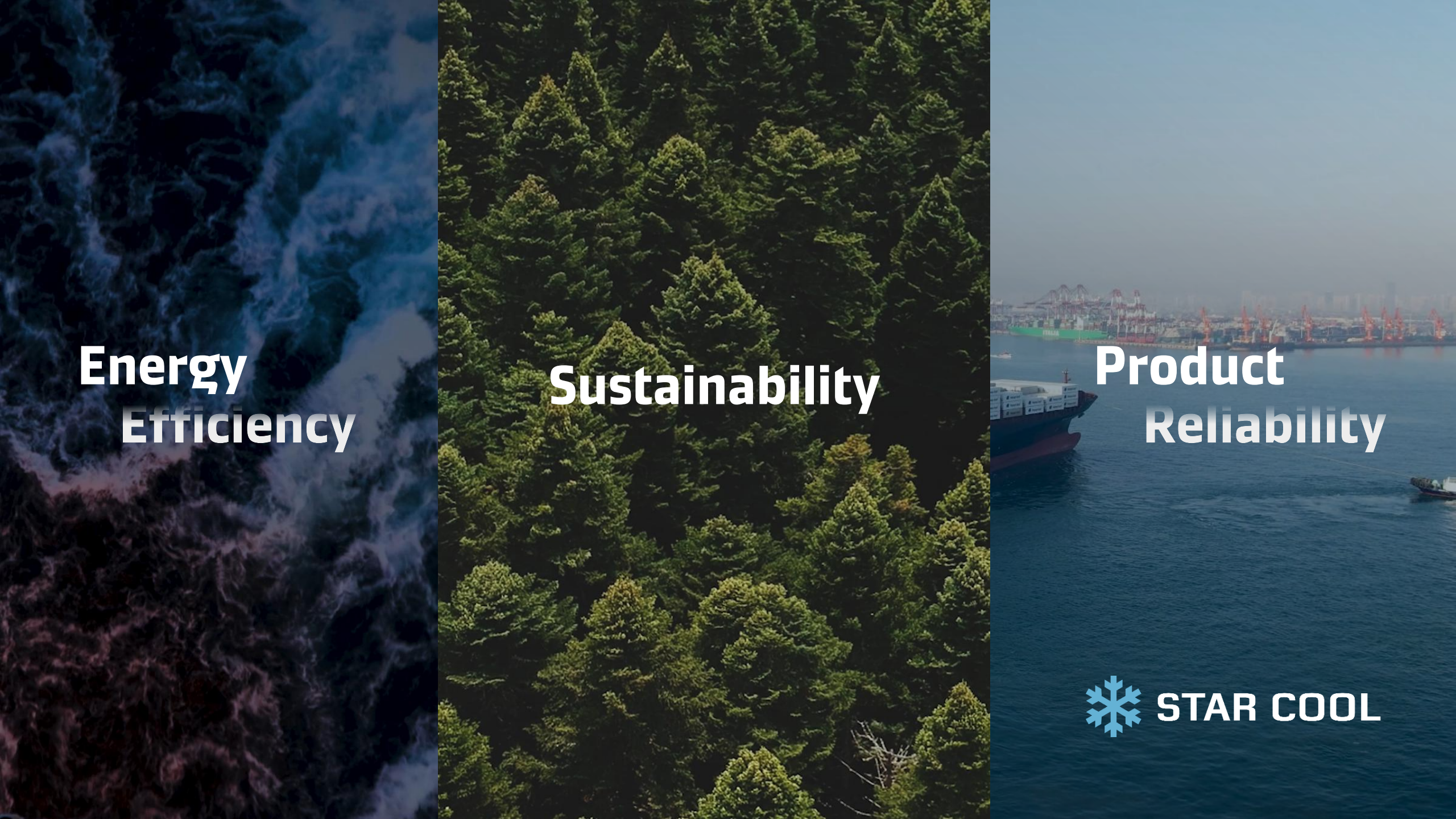
Product Reliability

Improving reliability

and closely following early indicators in data

SEKSTANT


Energy
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Energy Efficiency

Lowest Energy Consumption in the market documented, setting a new standards for operational efficiency.

Sustainability

Unparalleled Adaptability to evolving global refrigerant regulations and environmental standards, prepared for the uncertainties of the future.

Product Reliability

Product Reliability as a Key Priority, ensuring operational efficiency and safeguarding the highest level of protection and quality for temperature-sensitive goods.

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Thank you