Merit Mapping of Alternative Maritime Fuels

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1 Background, objectives and scope

Background

Maritime shipping is essential for global trade and faces growing pressure to reduce greenhouse gas emissions in line with climate objectives. While many lower-carbon fuel options are being developed, information across pathways remains fragmented, making comparison and strategic decision-making difficult. A common, transparent framework is therefore needed to support informed discussion and alignment.

Objectives

- The Shipfuels Matrix, commissioned by Concawe and international partners in the fuels and maritime industry, provides a structured, data-driven tool to compare alternative maritime fuel pathways on a consistent well-to-wake basis.
- It enables users to explore fuels, feedstocks, conversion routes and applications across key performance indicators, supporting the development of maritime decarbonisation strategies.
- It is intended to help stakeholders navigate the complexity of maritime decarbonisation using a transparent, consistent and shared evidence base.

Scope and interpretation

- Designed to support comparison and exploration, recognising that multiple alternative fuels will be required and that detailed techno-economic analysis is needed for specific deployment decisions.
- Not intended to rank fuels, as fuel choice is influenced by factors such as operational requirements, technology maturity, infrastructure availability, regional context and policy or regulatory environment.

2 Methodology

Methodology - Development of the Shipfuels Matrix

Technical development of the Shipfuels Matrix was carried out by Ludwig-Bölkow-Systemtechnik GmbH (LBST) on behalf of the project partners.

Structured pathway construction

- All possible maritime fuel pathways are systematically constructed by combining feedstocks, conversion processes, final fuels, transport assumptions and propulsion systems on a well-to-wake basis
- Each pathway is uniquely defined and traceable across the full value chain

Comprehensive database development

- A modular database is built covering feedstocks, conversions, final fuels and applications
- Data are compiled from literature, existing studies and expert assessment, using consistent assumptions and boundaries

Merit mapping across key dimensions

- Each pathway is characterised using a common set of environmental, technical and operational indicators, including GHG emissions, energy efficiency, technology maturity, fuel properties and application suitability
- This enables transparent, like-for-like comparison across a large number of pathways

Interactive analysis and visualisation

- The database is implemented in a Power BI platform, allowing users to filter, explore and compare pathways across multiple KPIs and perspectives

Pathways Overview

46 feedstocks, 33 processes, 17 final fuels and 8 propulsion systems currently covering around 260+ pathways

Feedstocks	Count	Conversion processes	Count	Final fuel/ electricity	Count	Propulsion systems	Count
Vegetable oil from oil crops	4	Transesterification, Hydrotreating	2	Ammonia	1	Slow speed Diesel ICE	1
Waste oils	5	Raw Glycerol conversion	2	Electricity	1	2-stroke Diesel cycle dual fuel ICE	1
Sugar & starch crops	4	Fermentation 1st gen	1	Ethanol	1	Fuel cell (PEMFC)	1
Agricultural residues	3	Methanol synthesis	1	FAME	1	Otto dual fuel, medium speed	1
Residues for anaerobic digestion	4	Methanol-to-Diesel (MTD)	1	FAEE	1	Otto dual fuel, slow speed	1
Algae for anaerobic digestion	1	Fischer-Tropsch synthesis	1	HTL-based diesel	1	Lean-burn spark ignited (LBSI)	1
Woody biomass incl. SRF	6	Haber-Bosch synthesis	1	LH2	1	Catalytic NH3 electrolysis + Fuel cell + electric motor	1
Other residues	5	Pyrolysis & upgrading	1	Liquefied methane	1	Battery electric propulsion	1
Non-bio-waste	2	HTL & upgrading	1	Methanol	1		
Sewage sludge	1	Anaerobic digestion	1	Paraffinic diesel (e.g. HVO)	1		
Miscanthus	1	Gasification, Pyro-gasification, hydrothermal gasification	3	Pyrolysis-based diesel	1		
PV electricity	1	Water electrolysis	1	Straight vegetable oil	1		
Wind electricity (onshore)	1	Co electrolysis of water and CO2	1	FAME residues	1		
Wind electricity (offshore)	1	H2 & CH4 liquefaction	2	CNSL	1		
CSP electricity	1	Methanation	1				
Hydro electricity	1	SMR w CCS, ATR w CCS	2				
Nuclear fuel	1	CO2 capture technologies	3				
Coal	1	Biomass power stations	4				
Natural gas	1	Fossil power stations	4				
HFO and diesel for electricity	2						
Number of feedstocks	**46**	**Number of conversion processes**	**33**	**Number of final fuels/electricity**	**14 (+ 3 fossil)**	**Number of propulsion systems**	**8**

Merit mapping of each pathway

Besides GHG emissions and energy, merit mapping spans environmental, technical and operational dimensions

	Feedstock	Process (conversion)	Final Fuel Transport & handling	Application (use in assets)
Energy efficiency and process maturity	• Bioenergy potential • Seasonality of availability • Production limited by industry	• Process technical maturity (TRL)	• Energy efficiency	• Propulsion efficiencies (max.) • Onboard carbon capture
Operability (at industrial scale)		• Opportunities of scaling-up the units	• Energy density • Storage conditions • Regulatory readiness • Max. blending ratios	• Refuelling duration • Co-activity during refuelling • Suitability for operations • Fuel consumption of different ship types
Potential impact on the environment (qualitative risk assessment)	• Water consumption • Biodiversity		• Safety risks (explosion, fire, etc.) • toxicity risks (danger to the environment and to human health in case of spillage) • Pollutants / emissions	• Pollutant emission limits • Well-to-Wake GHG emissions

3 Shipfuels Matrix Dashboard overview

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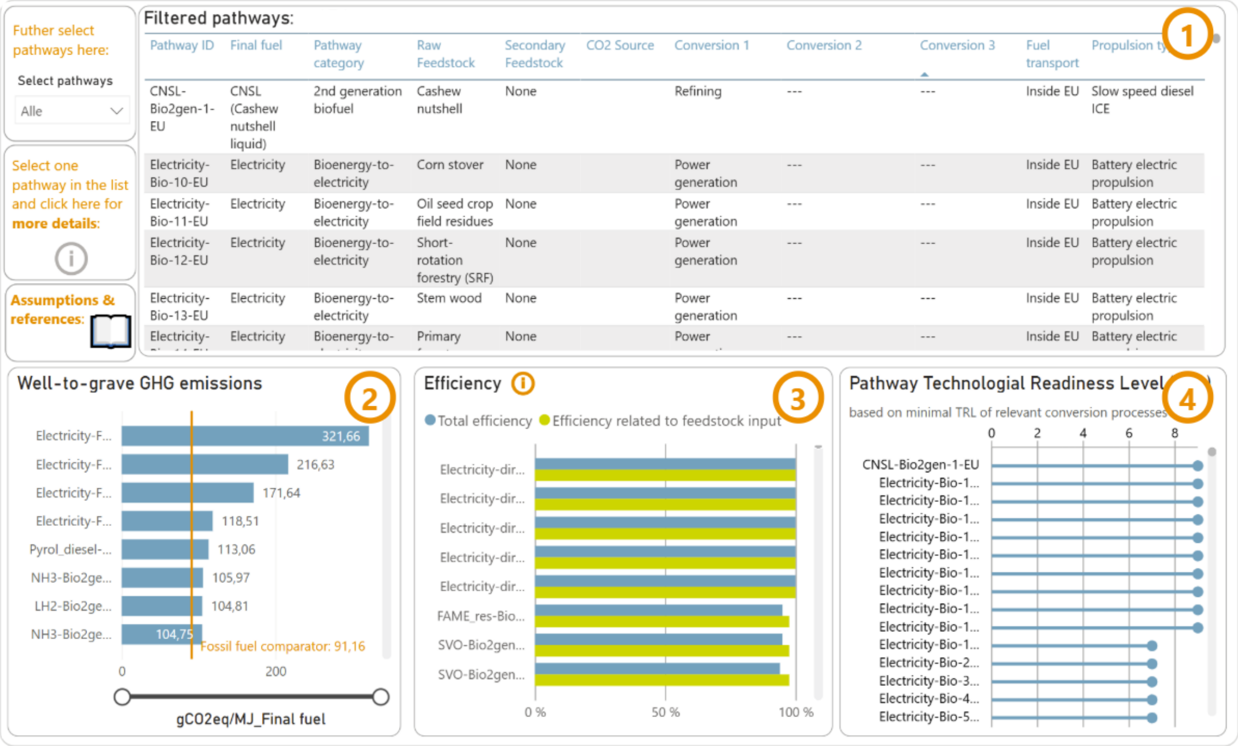
Pathways page overview

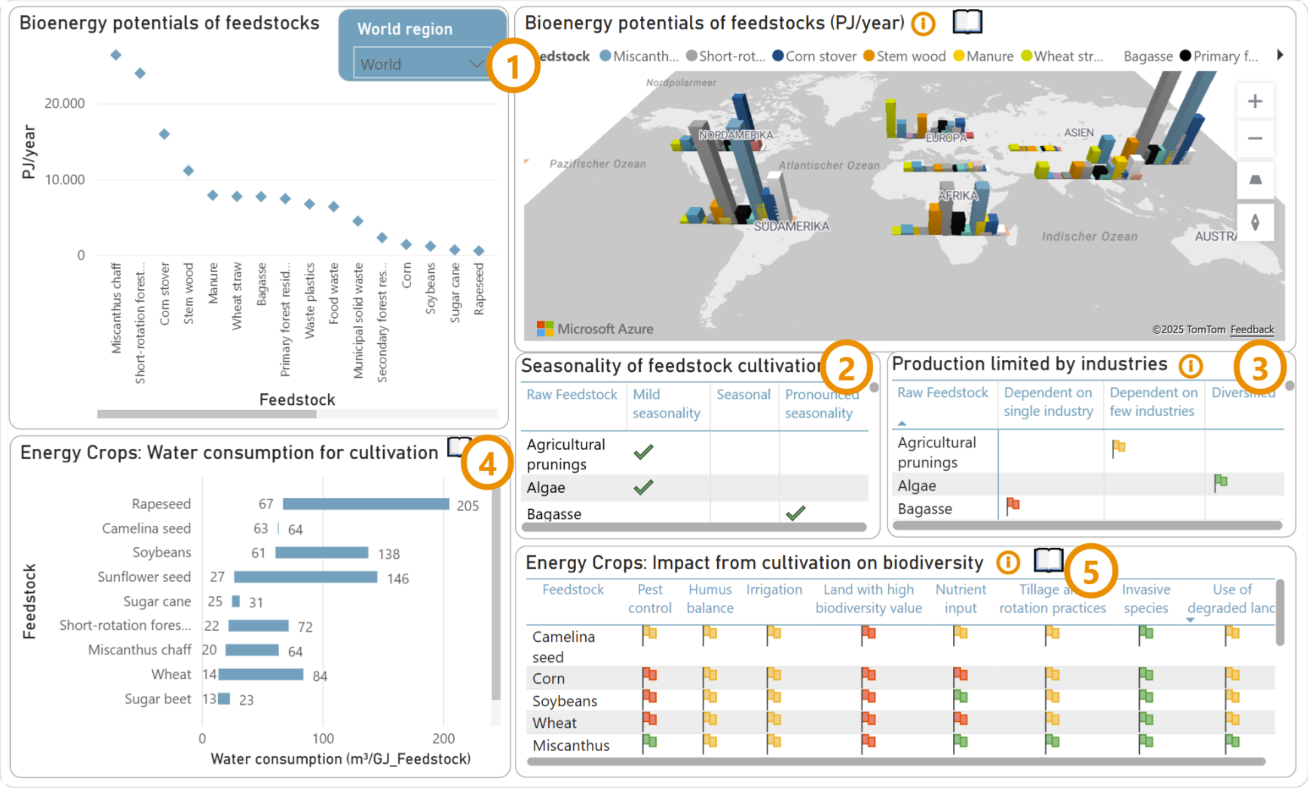


1. **Filtering** of pathways by final fuel, feedstock, conversion technology, pathway technological readiness level (TRL), propulsion type and location

Easily **compare** pathways by **Key Performance Indicators (KPI):**

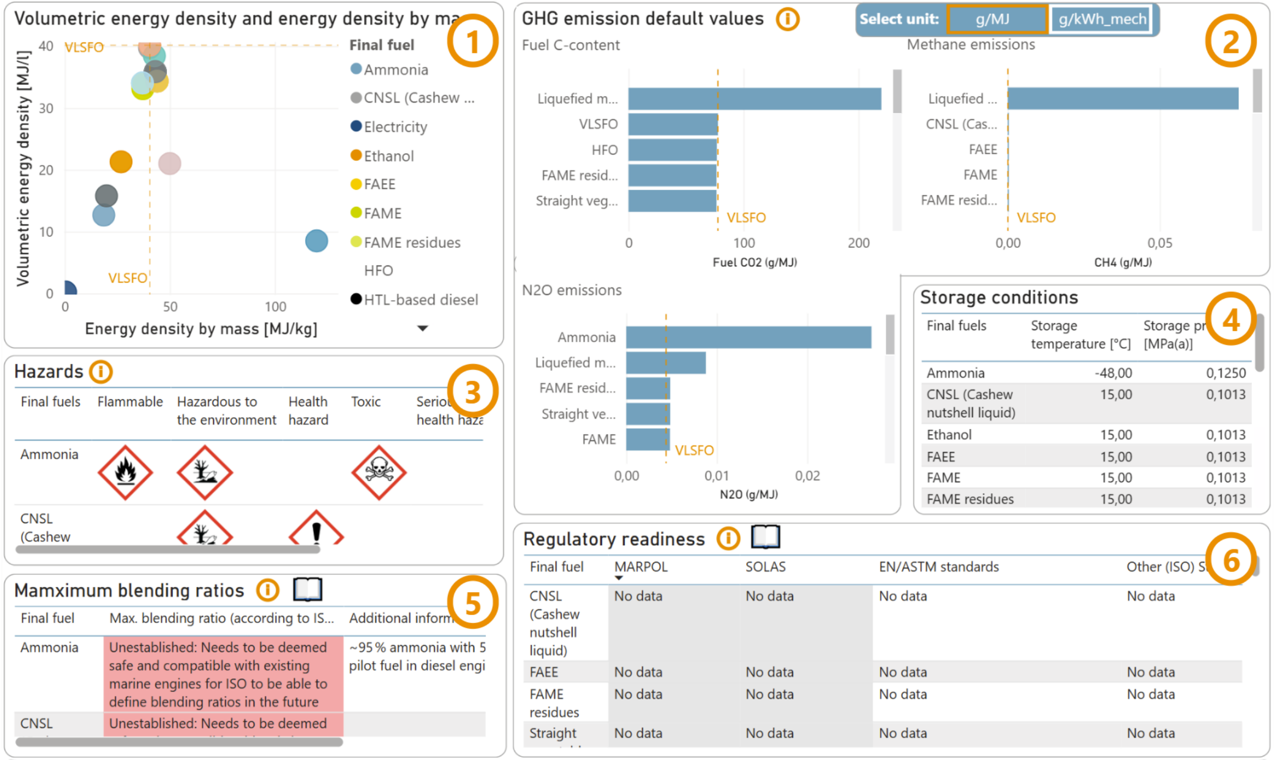
2. Well to wake GHG emissions (gCO2eq/MJ)
3. Efficiency:
   - *Overall Efficiency (based on overall energy input and outputs)*
   - *Feedstock efficiency*
4. Pathway TRL

Feedstock assessment page overview



1. Global Bioenergy Potentials
2. Seasonality of Feedstock
3. Production limited by industries
4. Water consumption for energy crop cultivation
5. Impact on biodiversity from energy crop cultivation

Final fuels page overview

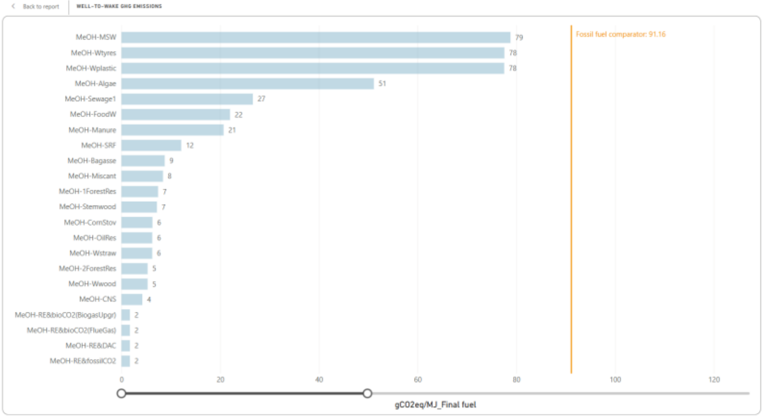


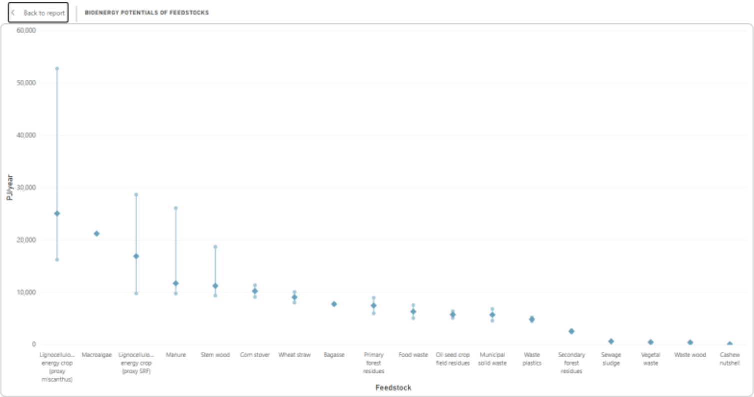
1. Energy density
2. Pollutant emission limits
3. Hazards
4. Storage conditions
5. Maximum blending ratio
6. Regulatory readiness

4 Case study

Case study: Comparing pathways to produce methanol

How do different methanol production pathways compare across emissions performance, technology maturity and feedstock availability?

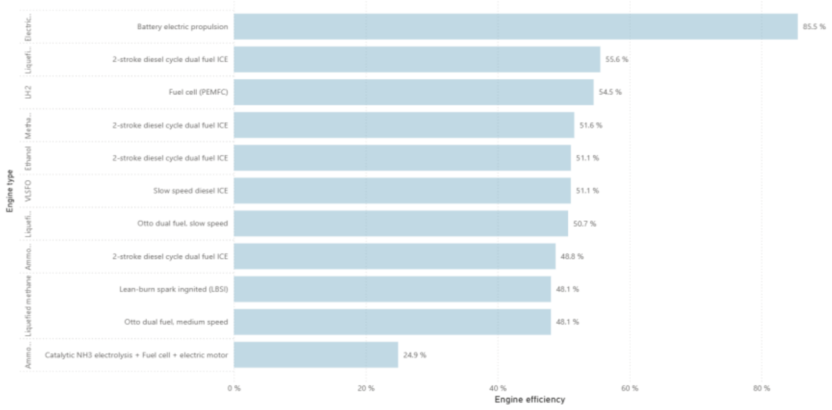


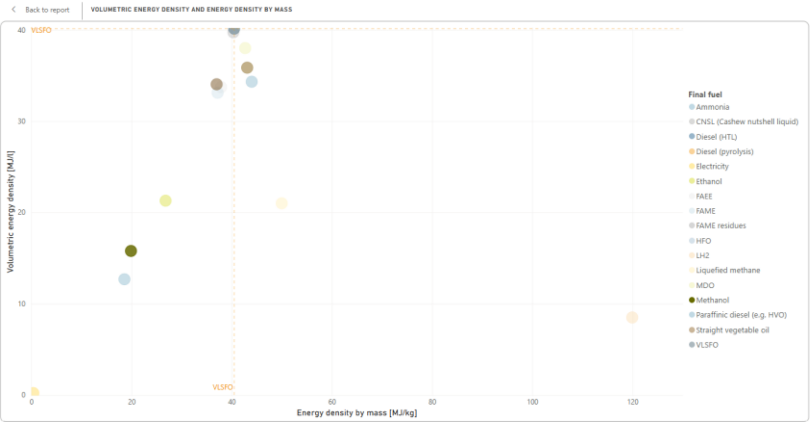


- Illustrates how methanol pathways differ in GHG performance, efficiency and technology maturity
- Highlights the role of feedstock type and availability as a key factor
- Supports identification of promising pathway families for further, use-case-specific analysis

Case study: Comparing methanol to other maritime fuels

How does methanol compare with other maritime fuels across key operational and safety-related characteristics?





- This comparison places methanol in context with other fuel options, highlighting differences in operational characteristics rather than identifying a preferred fuel.
- Different fuels show distinct trade-offs across efficiency, safety and energy density.
- Fuel suitability depends on ship type, operational profile and deployment context

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Conclusions

Conclusions

Value of the tool

- Supports consistent comparison across fuels, feedstocks, conversion routes and applications using harmonised performance indicators
- Improves understanding of pathway characteristics and constraints, supporting informed, evidence-based discussion
- Acts as a common reference framework to support alignment, dialogue and collaboration across maritime stakeholders

How stakeholders can use the Shipfuels Matrix

- Policy makers & regulators: explore the breadth of potential decarbonisation options and understand implications across feedstocks, fuels, conversion technologies and applications
- Industry & fuel suppliers: assess pathway feasibility, maturity and operational characteristics to inform technology development and investment priorities
- Shipping companies & other stakeholders: compare fuel options for different ship types, operational needs and long-term decarbonisation strategies

Looking ahead

- The Shipfuels Matrix is expected to be launched later this year via the Concawe website, with access available on request.
- Designed as a living framework, the Shipfuels Matrix can be updated over time to reflect new data, technologies and fuel pathways as they emerge.

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Thank you for your attention

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