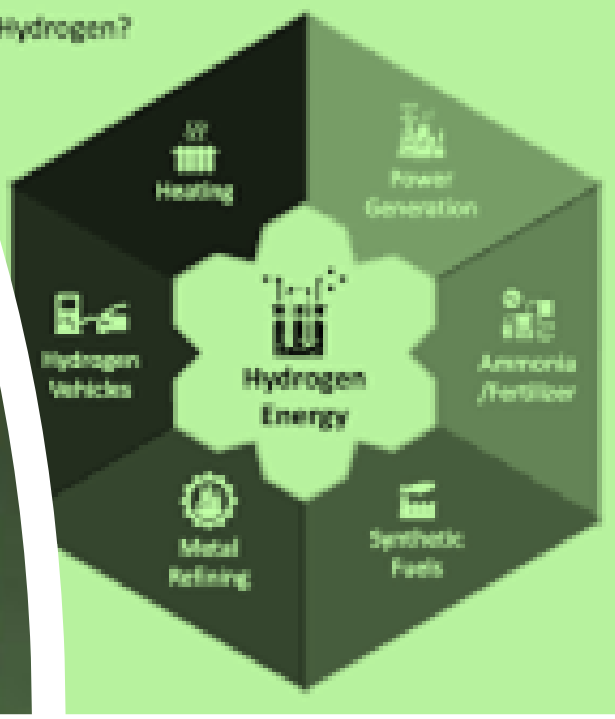
5th World Future Fuel Summit 2023

Biofuels: A Sunshine Opportunity for the Green Growth (Biodiesel, Biomethane, BioLPG, Synthetic Fuels Towards Carbon Neutral Path)



Views are personal

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Indicators of hydrogen's momentum

NH_3 – GH_2

Global problems need global solutions

Renewed interest in hydrogen

Stronger push to limit carbon emissions

8 Years remaining in the global carbon budget to achieve the 1.5°C goal

137 Countries - announced net-zero emissions as a target by 2050+ (80% Global GHGs)

Falling costs of renewables and hydrogen technologies

80% Decrease in global average renewable energy prices since 2010

55x Growth in electrolysis capacity by 2025 vs. 2015

Hydrogen's growing momentum

Strategic push in national roadmaps

70% Share of global GDP linked to hydrogen country roadmaps to date

"10-10-10" H2 Energy Ministerial, Japan & 10 MMT Europe & IRA (Carbon Credits - $ 50 B)

10 million fuel cell systems1 , 10,000 hydrogen refueling station, in 10 years

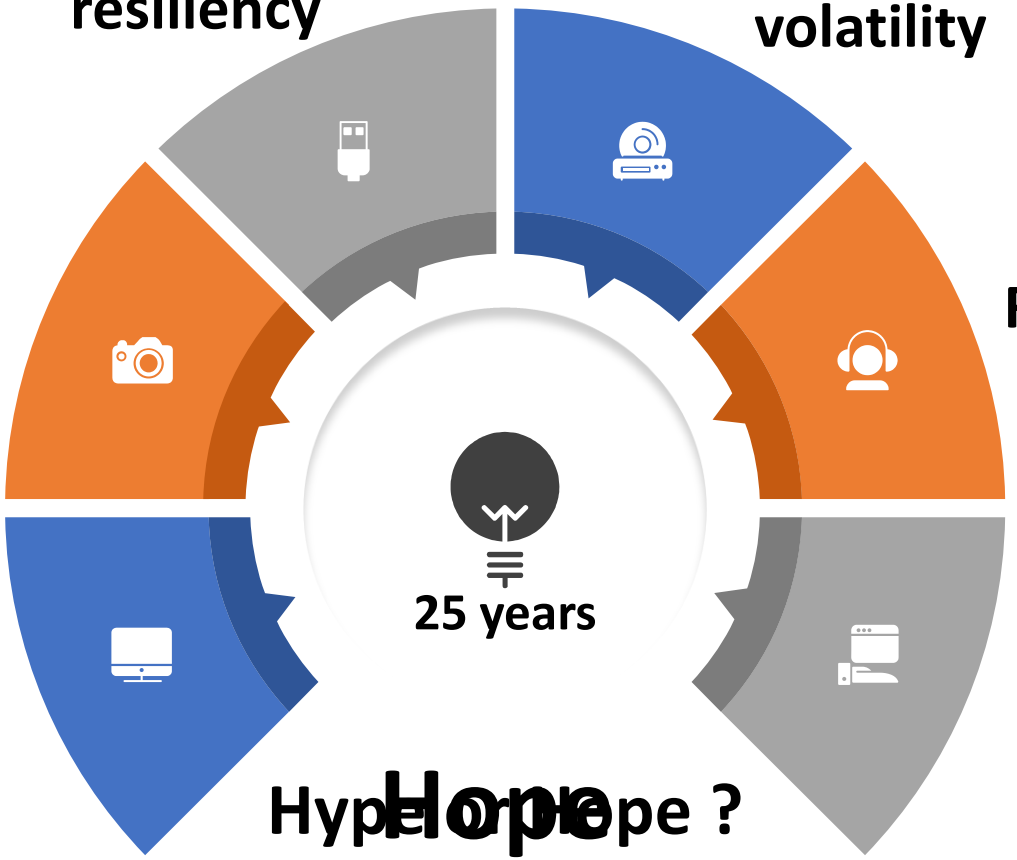
Industry alliances and momentum growing

60 Members of the Hydrogen Council today, up from 13 members in 2017

30+ Major investments announced globally since 2017, in new segments, e.g. heavy duty and rail

Key Drivers of hydrogen's momentum

NH_3 – GH_2



We cannot solve our problems with the same thinking we used when we created them - Albert

Questions and discussions

NH_3 – GH_2

»India and/or Global (Target geographies)

»Single or multiple technology

»East coast or west cost (exports to be competitive)

»Ammonia, CH2OH or LOHC as derivatives

»Whole value chain or specific portfolio

»Location of solar or wind (integrated)

»Battery storage or molecule storage or others

»Demonstration/pilot vs viable projects

»Lower size or bigger size plants (Decentralized or Centralized)

»Own investment or shared risk distribution

»Government policy vs tenders

»Green certification or carbon credits or mixed

»Single partner or multiple partners

»Capturing off-takers or calculated risk for pilots

»Consortiums (Participation) and/or global engagements

»Priorities vs Aspirations
»Diversified assessments & resources vs own assessment
»Rapid developments vs continuity vs evolution

Living strategy

Green Hydrogen Demand – Global/India

NH_3 – GH_2

- RMI Analysis, 2022
- IEA's outlook, 2022
- Bloomberg NEF, 2022

Sector wise green H2 - a challenges

Key sectors in MMT	2025	2030	2035	2040	2045	2050
Refinery	0.1	4.9	7.9	18.8	23.9	27.5
Fertilizers	0.1	2.9	7.2	18.3	25.9	33.7
Steel	1.2	1.6	8.1	28.7	56.3	86.7
Road	0.1	0.3	2.0	5.4	10.0	14.6
Shipping	0.0	0.1	1.2	5.6	14.5	31.3
Captive + IPP Power	0.2	1.6	12.6	27.3	47.4	73.0
Synfuels	1.1	5.8	10.1	21.7	36.5	63.1
CNG Blending	0.1	0.8	9.9	16.2	22.5	27.0
Other Industry	0.0	1.3	6.0	12.6	20.7	32.0
Total	**3**	**19**	**65**	**154**	**258**	**389**

10%, 8%, 6% 5% and 4% - 2030, 2035, 2040, 2045 and 2050

Key sectors in MMT	2025	2030	2035	2040	2045	2050
Refinery	0.1	0.7	2.2	4.1	4.8	5.1
Fertilizers	0.0	0.4	1.8	3.4	4.9	5.5
Steel	0.0	0.1	0.4	2.1	4.7	5.8
Road	0.0	0.0	0.2	1.0	2.3	3.1
Shipping	0.00	0.03	0.1	0.2	0.7	1.2
Captive + IPP Power	0.0	0.0	0.2	0.9	2.7	4.0
Synfuels	0.0	0.0	0.1	0.3	0.8	1.4
CNG Blending	0.0	0.4	0.6	1.0	1.4	2.5
Export	0.1	1.9	5.2	9.3	12.9	13.6
Total	**0.2**	**3.5**	**10.7**	**22.2**	**35.2**	**42.2**

- Hydrogen Markets in India (ICF-FIPI report) - April'23
- Green hydrogen potential by RMI – Niti Aayog – Jun'22
- USAID Report – May 2023
- Deloitte's 2023 global green hydrogen outlook – May'23
- **Industry interactions and assessment**

Japan, Korea and Europe likely importers of low-carbon H2

NH_3 – GH_2

Region	Market conditions to supply	Key import market?
North America	Favorable PV and wind, cheap gas, CCUS potential	Likely exporter
South America	Favorable PV and wind	Likely exporter
Africa	Favorable PV and wind	Likely self-sufficient
Middle East	Favorable PV and wind, cheap gas, CCUS potential	Likely exporter
Oceania	Favorable PV and wind, CCUS potential	Likely exporter
India	Favorable renewables potential	POTENTIAL WORLD LEADER IN EXPORT
China	Favorable renewables potential, large investments	Uncertain
Japan	Limited natural resources and renewables potential	Likely major importer
South Korea	Limited natural resources and renewables potential	Likely major importer
Rest of Asia	Fragmented smaller markets, favorable RE potential	Likely self-sufficient
Western Europe	Limited RE and CCUS potential particularly DE and NL	Likely major importer
Rest of Europe	More favorable renewables potential	Likely importer

Source: BCG Global H2 Demand Model; BCG Supply Model; BCG analysis. CCU = Carbon capture utilization and storage

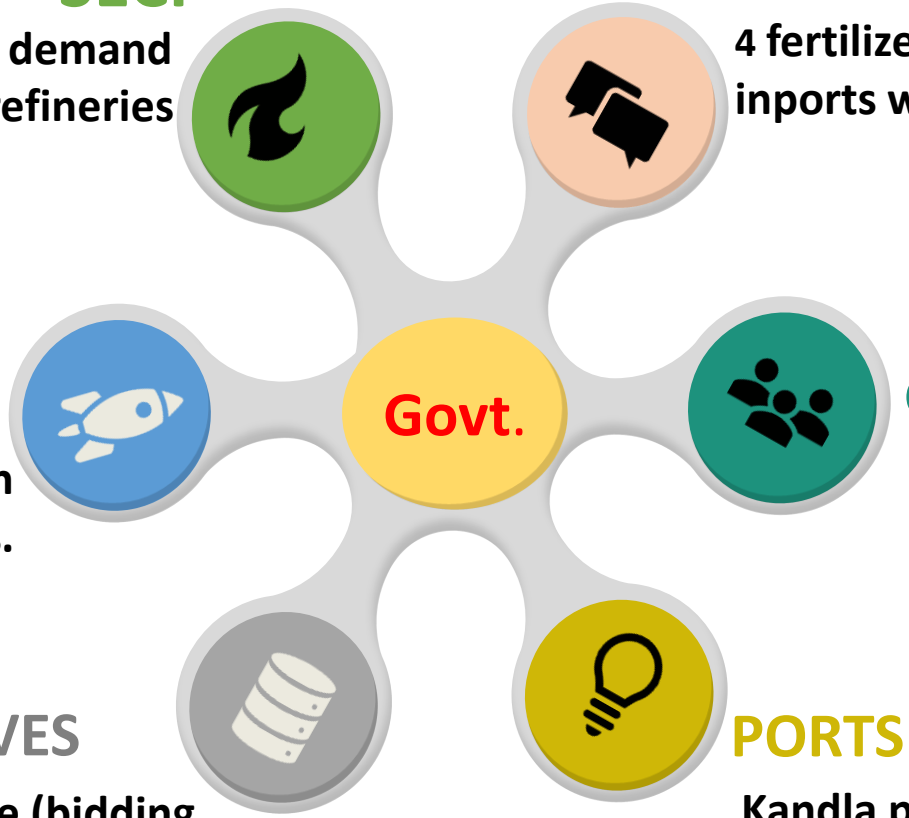
US Dept of Energy (DoE) released National Clean Hydrogen Strategy & Roadmap:

- 10-20-50 Mn Tn of Clean H_2 by 2030-40-50
- $ 1/kg by 2031
- 4+ regional clean H_2 hubs with $8 Bn fund
- Infra & investment act
- Incentivize high-impact usage of H_2

GH_2 / GNH_3 Potential – Government push

NH_3 – GH_2

Green Hydrogen Consumption Obligations (GHCO) – Fertilizers and Refining (100% by FY 2035)



SECI

Mega tender to aggregate demand for fertiliser plants & refineries

GREEN AMMONIA

4 fertilizer plants (replace all fertilizer inports with geren by 2035)

RAILWAYS

FCTs to power 8 trains on narrow-gauge heritage routes.

GH2 MANUFACTURING

3.6 MMT over the next three years, 5 MMTPA (115 GW RE + 50 BL DM) (7:3)

10 Potential States- Zones or clusters (4 States GH2 Policies)

INCENTIVES

SIGHT programme- Rs >17.5K crore (bidding process), Carbon credits (JCM Article 6- Japan, EU, Singapore)

PORTS

Kandla port and Tuticorin port – India's First GH2 & GNH3 refueling hubs

ISTS waiver + Round-The-Clock (RTC) RE – 25 Years (<31st Dec

JCM –Joint crediting mechanism

SIGHT - Strategic Interventions for Green Hydrogen

India's competitiveness on price will depend on incentives; however, scale advantage to benefit India

$NH_3 - GH_2$

2023 prices

	India	Australia	Oman & Saudi Arabia	USA
RE addition in last year (GW)	15.75 ↑	2.75	<1	~71 ↑
Total Renewable energy capacity (GW)	105	37	<2	~296

- India and USA well positioned in renewable energy adding capacities at a faster pace
- Other regions / countries like Australia, Oman and Saudi Arabia have announced large projects:
  - To match this, their capabilities to build evacuation infrastructure at GW level, availability of labour, environmental clearances and EPC skills sets needs to come at a faster pace

Source: IEA, IRENA & BCG Analysis

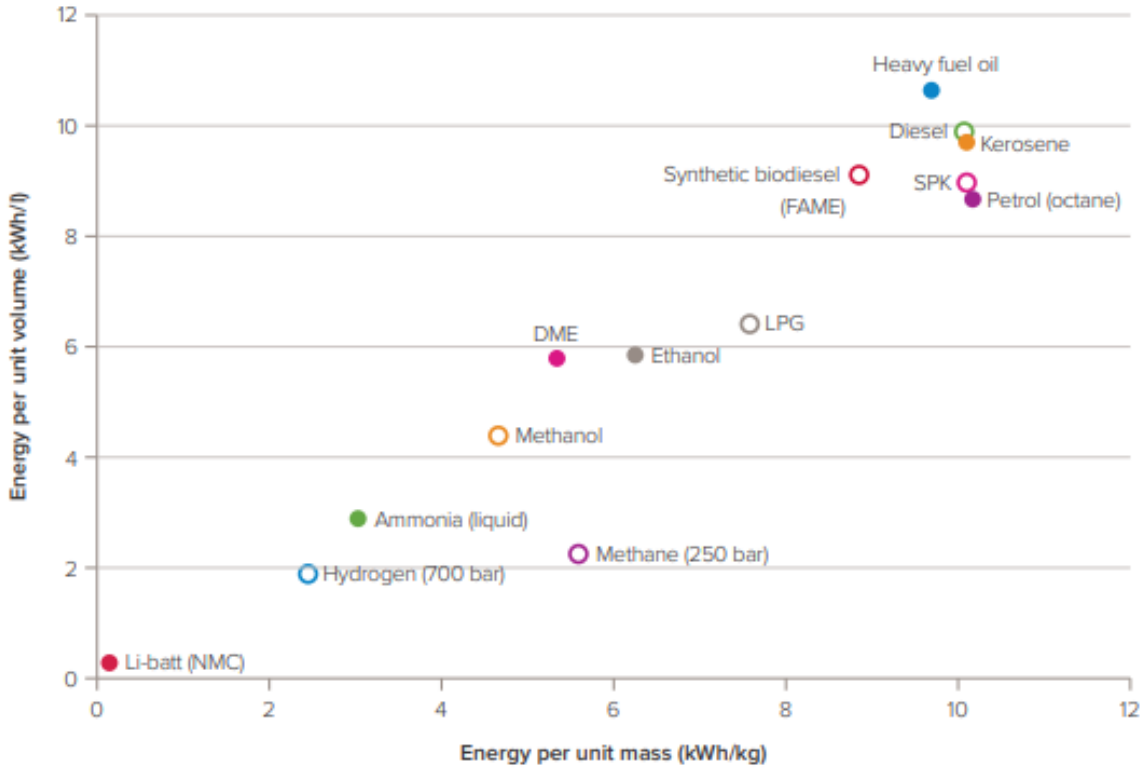
Suitability of different energy sources and vehicle types based on energy density infrastructure requirements.

NH_3 – GH_2

Fully compatible | Minor restrictions | Major restrictions | Severe restrictions

Refuelling infrastructure challenge | Distribution infrastructure challenge

Vehicle and duty cycle compatibility		Synthetic efuels	Biomethane	Hydrogen	Electricity	% Contribution total CO_2[5]
City car			CNG			7
Long distance car			CNG			10
Urban van			CNG			2
Heavy-duty truck			LNG			5
Aviation	Short haul					9
	Long haul					
Marine	Short journey		LNG			4
	Long journey		LNG			
Distribution and refuelling challenge						

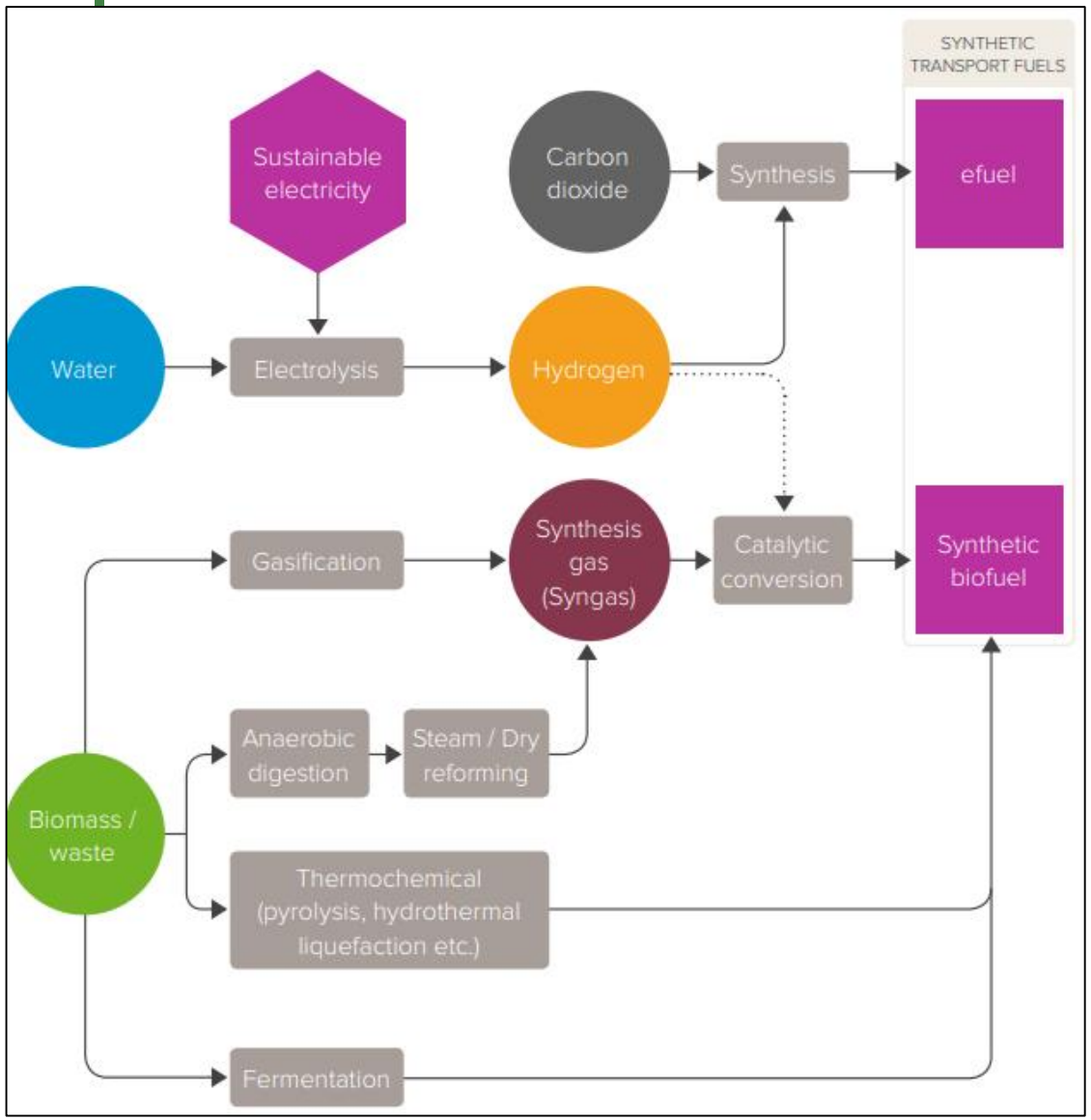


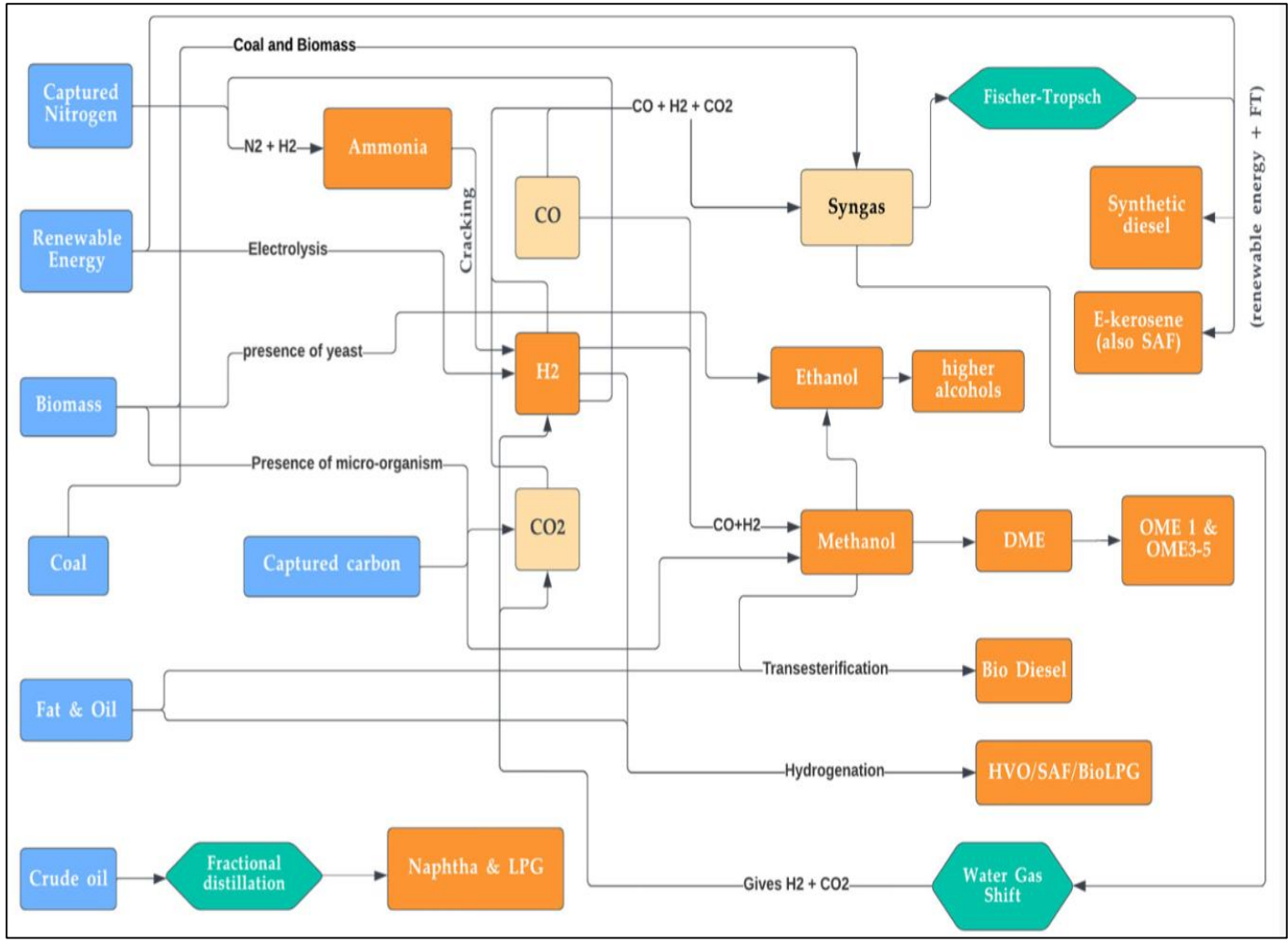
Sustainable synthetic fuels

i. electro fuels (efuels) made using captured carbon dioxide in a reaction with hydrogen, generated by the electrolysis of water, and
ii. synthetic biofuels made through the chemical or thermal treatment of biomass or biofuels.

Routes to carbon based sustainable liquid synthetic fuels

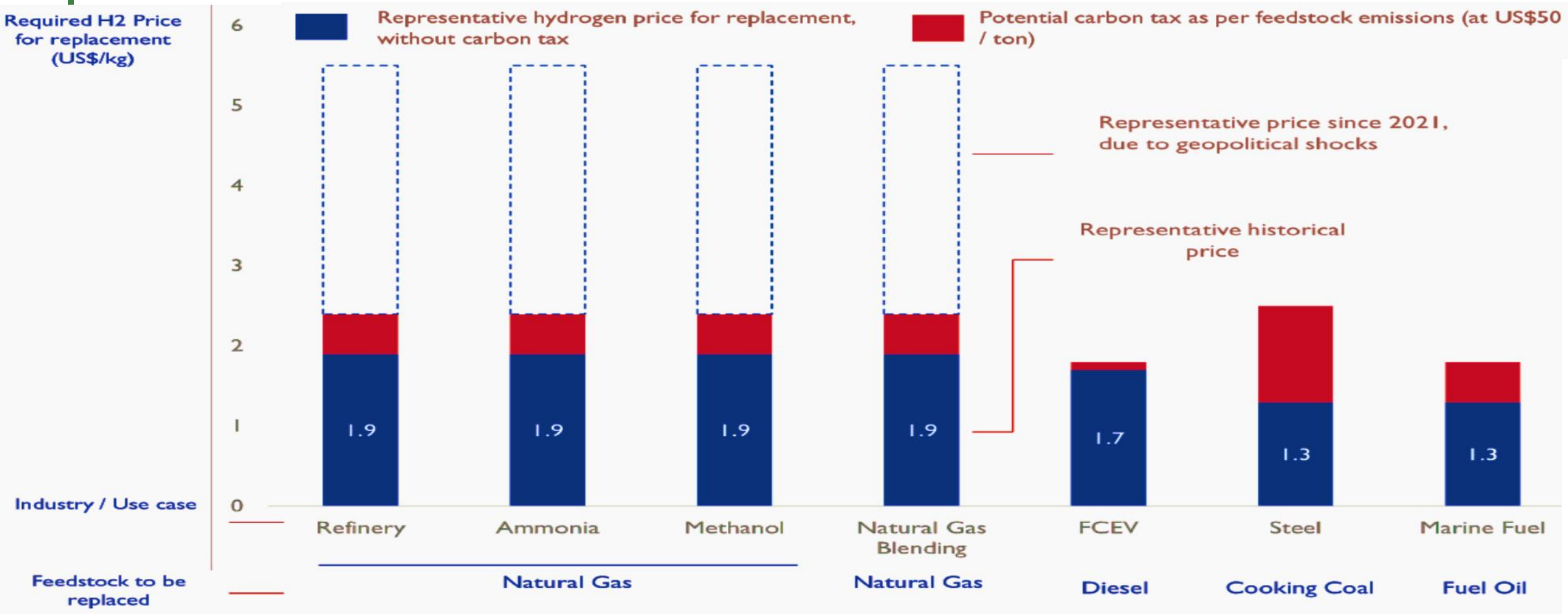
NH_3 – GH_2





Cost competitiveness – unfavorable

NH_3 – GH_2



- $ 0.6 per KG incentive Production + $ 0.04 per KG electrolyzer incentives
- $0.15 per KG due to carbon credits (may rise)
- Possibly $1.5-$2.0 per KG through scaling up & design of the plant size

- $ 0.79 – 2.79 per KG

Current demonstration efuel plant facilities

NH_3 – GH_2

Facility/Operator name	Country	CO_2 feedstock	Efuel output	Output quantity
Carbon Recycling International (Vulcanol)[111]	Iceland	Geothermal plant flue gas	Methanol	4000 tonnes/year
FReSME project (2020)[112]	Sweden	Blast furnace gas	Methanol	50 kg/hr
MefCO_2[113] (final phase construction)	Germany	Power plant flue gas	Methanol	1 tonne/day (planned)
Soletair[114]	Finland	Direct Air Capture	Petrol, Kerosene and Diesel	100 kg/hr
Sunfire[115]	Germany	Direct Air Capture	E-Crude (E-diesel)	Demonstration: 3 tonnes in 1500 hrs
Sunfire (2022)[116]	Norway	Direct Air Capture	E-Crude (E-diesel)	8000 tonnes/year (planned 1st stage)

India: Biofuel Research and Development Classification

NH_3 – GH_2

Fuel	Substitute	Technologies Deployed
Diesel	*Biodiesel, **HDRD (Green Diesel), Bio-based oxygenates, (alcohols and ethers)	Esterification, Hydro-Processing, Fermentation, Syngas Conversion
Aviation Turbine Fuel (ATF)	**Sustainable Aviation Fuel (or, Bio-ATF)	Hydro-Processing, Sugar Conversion, Alcohol-to-Jet, Fischer–Tropsch Process
Gasoline (Petrol/Motor Spirit)	*Ethanol (1G), **Ethanol, (2G), **Methanol, Green (drop-in) gasoline	Fischer–Tropsch Process, Gas Fermentation, Alcohol-to-Gasoline, Hydro-Processing, Pyrolysis/Catalytic Cracking
Compressed natural gas (CNG)/piped natural (PNG)	*Bio-CNG/Bio-PNG, HCNG, **Bio-H2	Waste Fermentation
Marine Fuel/Industrial/Fuel Oil	**Green heavy distillate, biomass-derived oils	Hydro-Processing, Pyrolysis/Fluid Catalytic Cracking, Hydrothermal Liquefaction, MSW-thermochemical processing

(*) Indicates technologies are available.

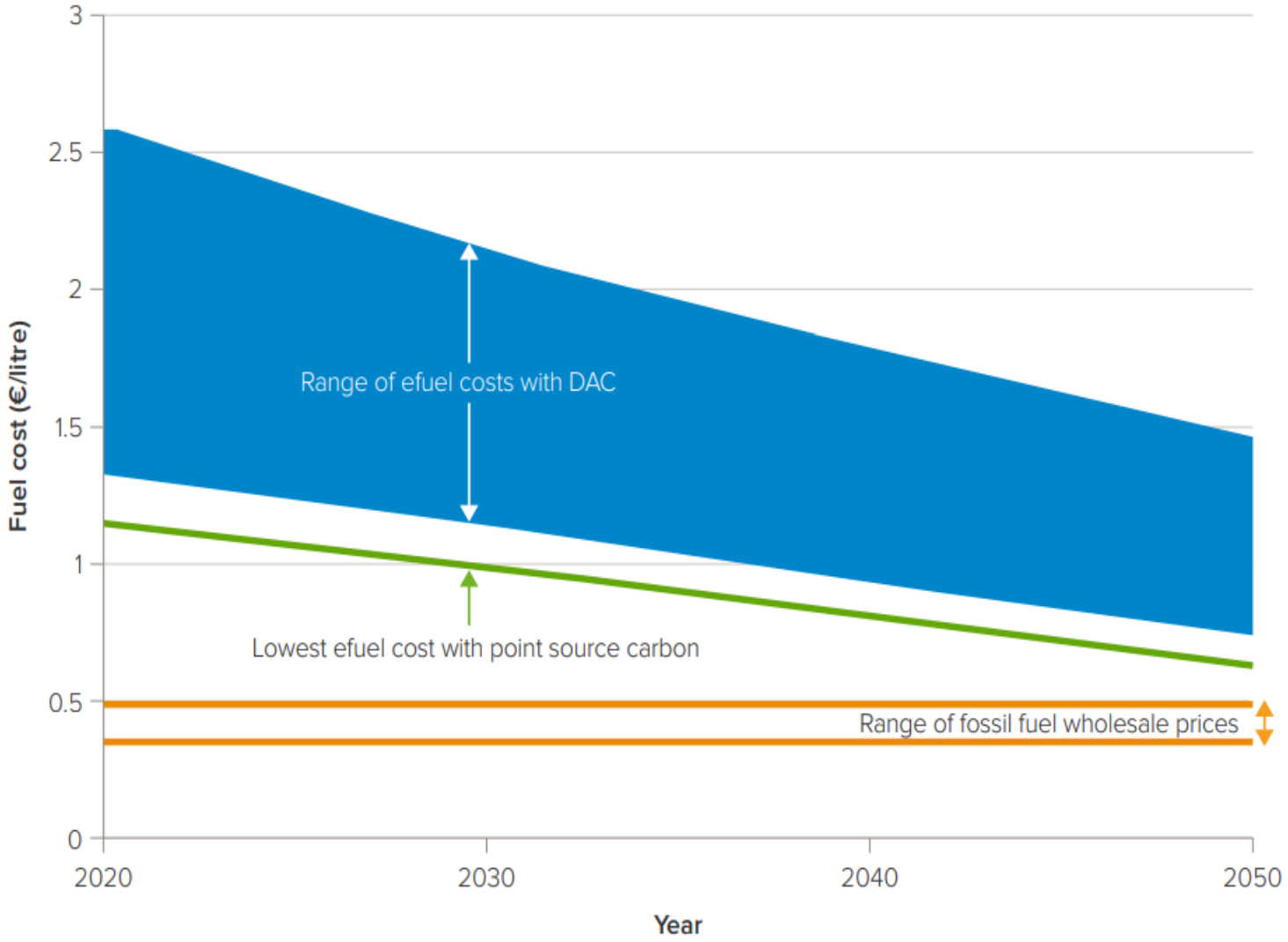
(Indicates emerging technologies (in development). (Hydrogenation-Derived Renewable Diesel)

Source: DBT, Ministry of Science and Technology.

Fuels	H2 Content (by weight %)
H2O2	5.88%
NH3	17.65%
Methanol	12,5% (99 grams/litre)
Ethanol	13.13%
Natural Gas	25.13%
Gasoline/Gasoil	~14%

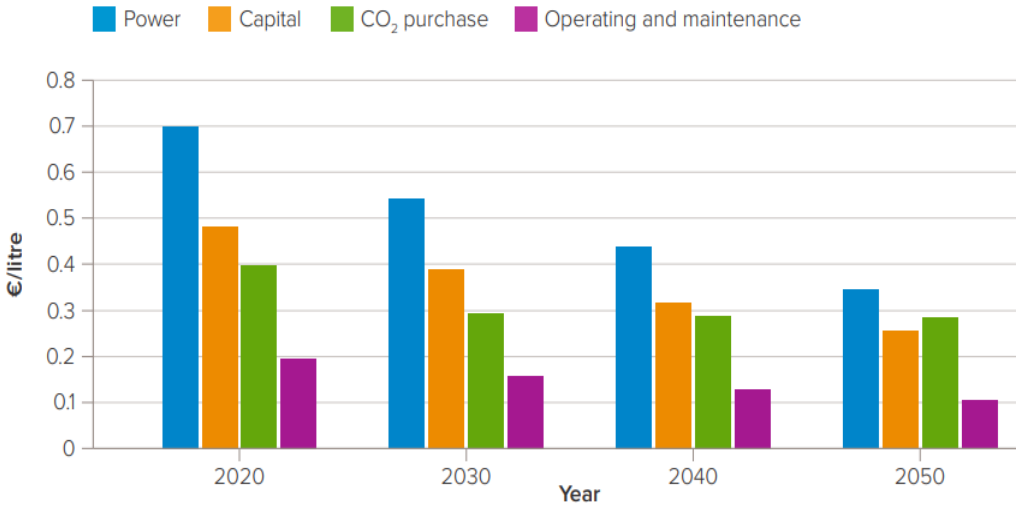
Efuel cost forecasts

NH_3 – GH_2



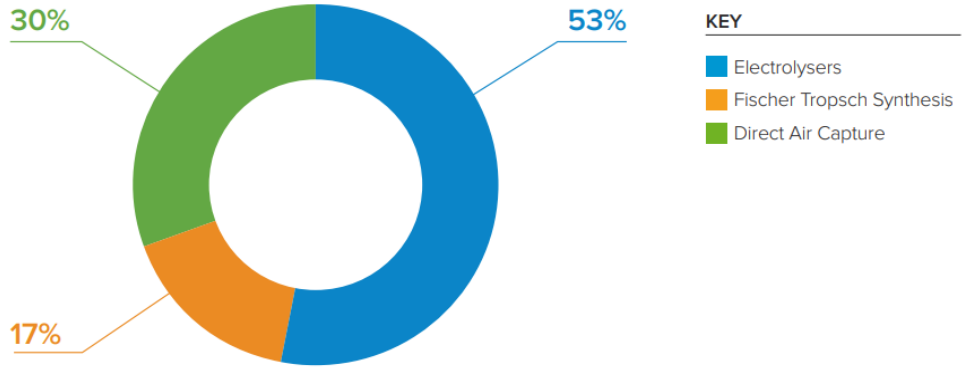
Note: Based on technology options for diesel using Direct Air Capture, 6% interest rate, 25 years' project lifetime, using solar (2344 hours/year) and wind power (3942 hours/year).

Contributions to the total efuel cost



Note: Based on 6% interest rate, 25 years' project lifetime, replacement of stacks after 15 years, using solar power (2344 hours full load hours/year).

Distribution of capital cost of efuels



Note: Based on 6% interest rate, 25 years' project lifetime, Direct Air Capture from Temperature Swing Absorption (TSA), using solar power (capacity factor not included in electrolyser capital estimate).

Way forward – (Cost competitiveness – unfavorable)

NH_3 – GH_2

- Promote sustainable development of hydrogen markets, beginning with local or regional networks close to renewable electricity supplies, hydrogen production plants and hydrogen consumption centres.

- Exploring options for the production of sustainable biomass feedstocks including **reliable** feedstock supply-chain

- Introduction of Renewable Transport Fuel Obligation (RTFO)

- Establish Fair carbon pricing mechanism (incl. Taxation), overall life-cycle costs per unit of
- greenhouse gas emission reduction

- Removal of GST anomalies

- Partnerships and collaborations

THANK YOU

A company's long-term success depends on how it progresses through the stages of industry consolidation. Speed is everything.