COAL GASIFICATION AND COAL-TO-LIQUID CONVERSION

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INTERNATIONAL CENTRE FOR
SUSTAINABLE CARBON

PRESENTATION OUTLINE

- Who we are and what we do
- Coal to chemicals and fuels
- Coal conversion options
- Coal to non-energy products
- Strategic considerations

INTERNATIONAL CENTRE FOR
SUSTAINABLE CARBON

Technology Collaboration Programme
by iea

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General Manager

WHO WE ARE NOW AND WHAT WE DO

INTERNATIONAL CENTRE FOR
SUSTAINABLE CARBON

Technology Collaboration Programme
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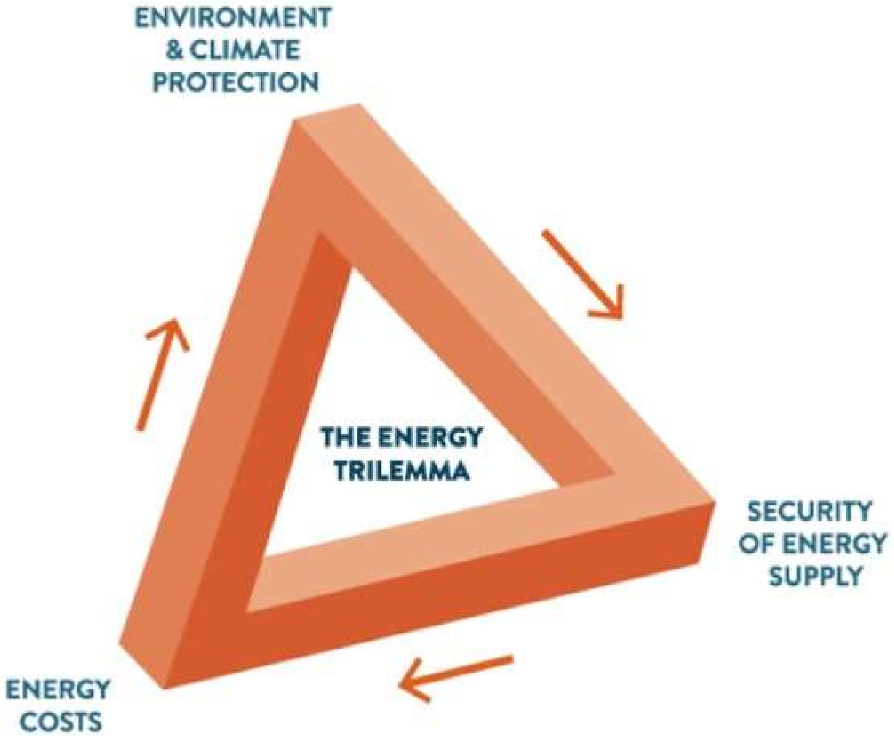
- **We are dedicated to providing independent information and analysis** on how biomass, coal and other carbon sources can become cleaner sources of energy, compatible with the UN Sustainable Development Goals

- **The International Centre for Sustainable Carbon (ICSC)** is part of a network of autonomous collaborative partnerships focused on a wide range of energy technologies known as Technology Collaboration Programmes (TCPs)

- The TCPs are organised under the auspices of the International Energy Agency (IEA), but are functionally and legally autonomous

- We are funded by national governments (contracting parties) and by corporate industrial organisations (sponsors)

SUSTAINABILITY AND ENERGY TRILEMMA CONSIDERATIONS



Drivers for coal remain, as a means to lift populations out of poverty and to ensure robust reliable energy sources, including chemicals/future fuels

- Coal has to be a part of the global energy mix, while best meeting the energy trilemma issues
- The aim should be to minimise the adverse emissions from coal, through the introduction of commercial scale environmental control systems, improvements in efficiency and the subsequent introduction of CCS

COAL TO CHEMICALS AND FUELS

- Conversion of coal to chemicals and fuels is undergoing a significant expansion with new plants under construction. The advantage of coal as a feedstock is its relatively low cost and abundance. The scale of the coal chemical industry will have a meaningful impact on global coal demand but faces commercial and environmental challenges
- China is the leading driver for a commercial based extensive coal to chemicals and fuels industry
- Starting to se other nations establish first steps in gasification based coal conversion options

COAL GASIFICATION TO CHEMICALS

- Chemicals production accounts for 1.1 $GtCO_2/y$
- Over 30% of these CO_2 emissions are process related
- China is the leading global producer of ammonia with 36% of the global 181 Mt/y market and an important producer of ethylene and methanol
- Coal is the primary feedstock in China using gasification related technology
- Portfolio approach for emissions control will be necessary including CCUS

CHINA COAL CHEMICAL AND FUEL PLANTS

(Asiachem, 2019; Aizhu, 2020)

Product	2019-21 Under construction or commissioning, Mt/y	2020-24 Planned and under development, Mt/y
Methanol	19.2	32.2
Mono ethylene glycol, MEG	8.3	17.3
Polyester		9
Methanol/coal to olefins MTO/CTO	7.7	13
Polyethylene, PE	1.8	2
Polypropylene, PP	2.9	2.5
Ethanol	0.5	2.1
Formaldehyde	0.4	
Dimethyl ether, DME	0.9	
Methanol to gasoline, MTG	0.9	4.8
Acetic acid	1.6	1.2
Coal to liquids, CTL or gasification by Fischer Tropsch (FT)	1.2	33
Tar deep processing, coal tar hydrogenation and lignite upgrading	15.8	86.8
Synthetic natural gas, SNG	6.5	95.2
Ammonia	10.2	6.9
Urea	11.7	7.4

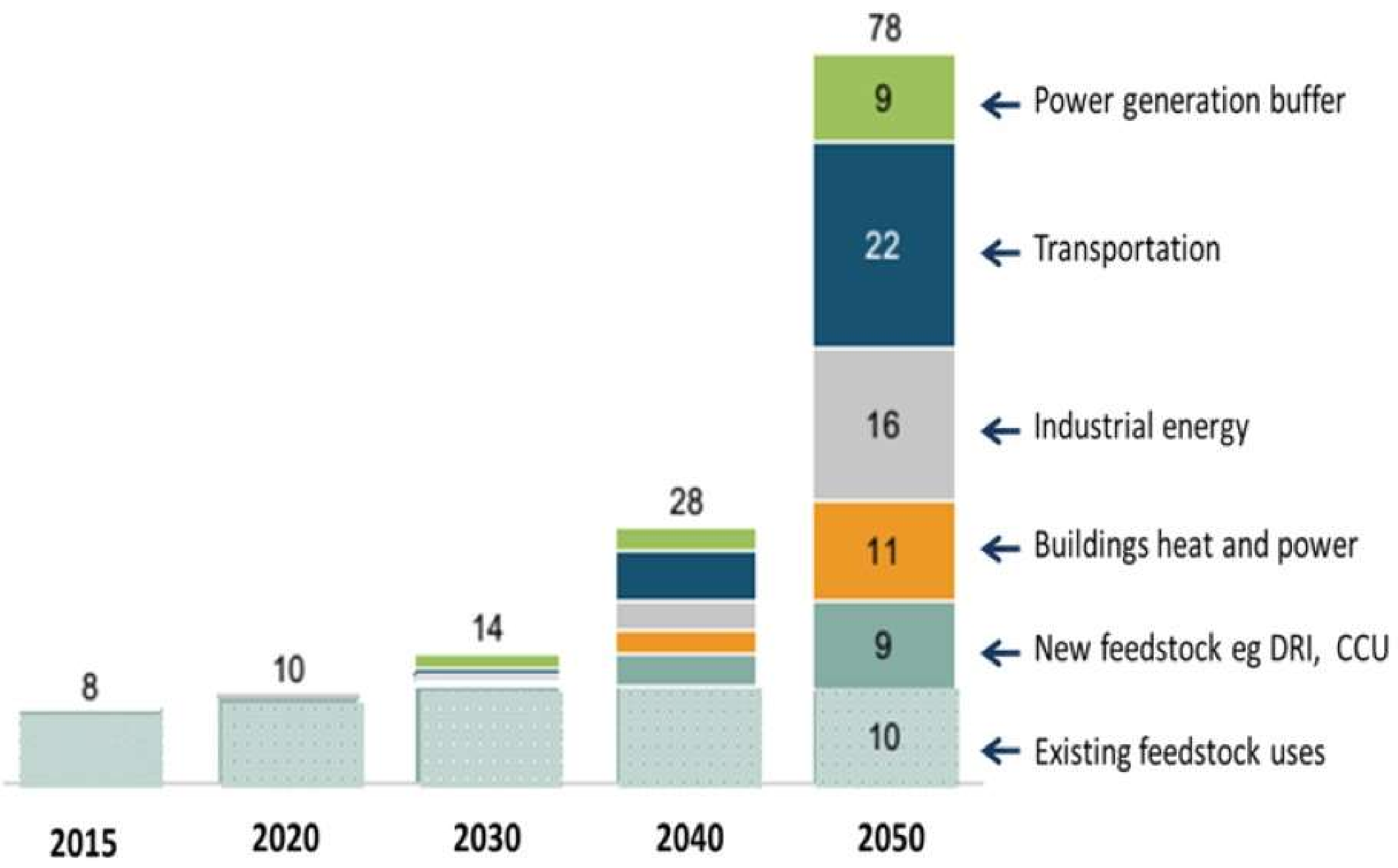
CHINA ENERGY MAJOR COAL TO LIQUIDS PROJECTS (WORLD CTX, 2017)

- 1Mty direct coal to liquids (2009-)

- 2Mty indirect coal to liquids (2017-)

LOW EMISSIONS PRODUCTION OF HYDROGEN AND OTHER CHEMICALS

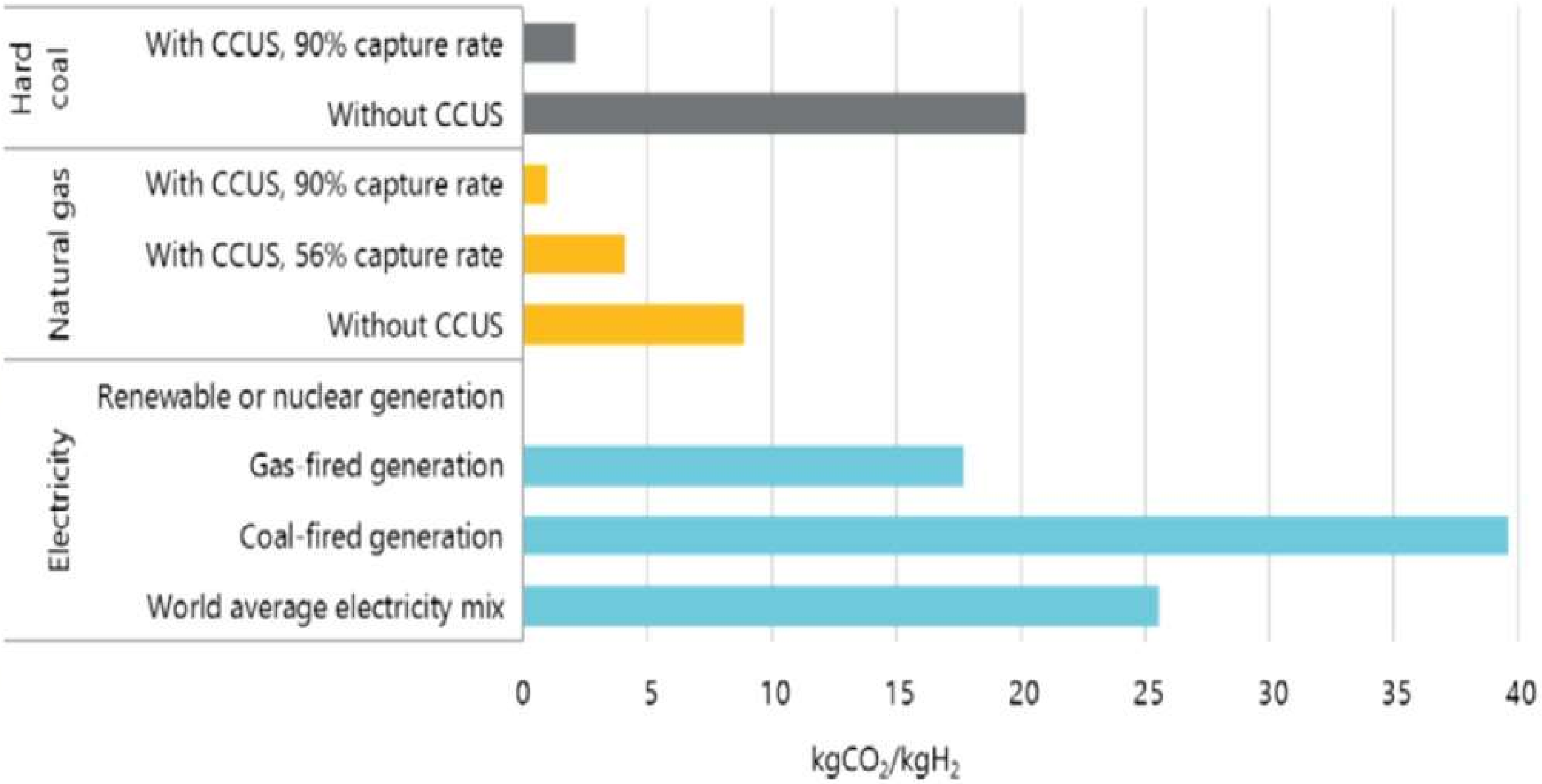
- Hydrogen global demand could increase to 78 EJ, or 650 MtH_2/y, representing around 14% of the expected world total energy demand in 2050
- There will be regional variations depending on local factors
- Low carbon H_2 from coal gasification with CCUS is lower cost than water electrolysis, typically by a factor of approaching 3



Forecast increase in global H_2 demand (EJ) to 2050 (Hydrogen Council, 2017)

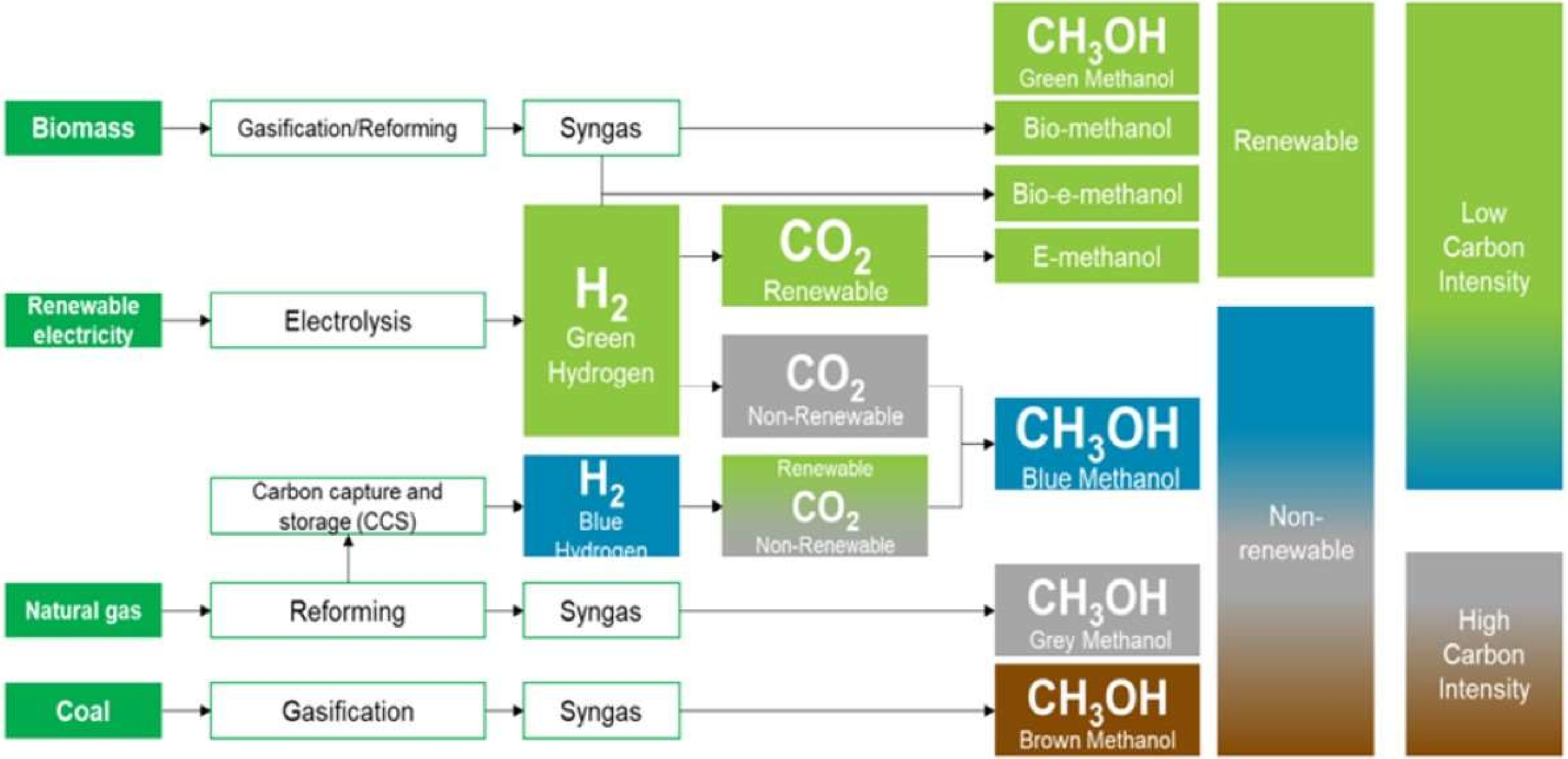
HYDROGEN EMISSIONS COMPARISON

- Carbon intensity of Grey-H_2 from coal is 19 $kgCO_2/kgH_2$
- Adding CCUS (90% capture) can reduce this to 3 $kgCO_2/kgH_2$
- Higher capture rate of cofiring with biomass/waste can reduce further
- Water electrolysis can be detrimental to net zero targets unless low capacity factor to use mainly RE, or significant increase in RE on the grid



CO_2 intensity of H_2 production (IEA, 2019)

METHANOL - PRODUCTION



Source: IRENA

While there is not a standard color code for the different types of methanol production processes. This illustration of various types of methanol is meant to be a basis for further discussion within the industry.

- Methanol can be made from various feedstocks
- Currently about 65% made from natural gas, the rest mainly coal

CHINA - LEADER IN METHANOL TRANSPORTATION

- China is the second-largest economy in the world
- the greatest producer, consumer and importer of methanol
- Most of methanol (70%) comes from coal
- Leader in methanol transportation with various projects, policies and incentives
- Building up infrastructure which can be then used for green methanol once it is available at competitive cost

Methanol Fueled Vehicles in China (by Sept, 2021)

Province	City	Vehicle Type	Vehicle No.
Shanxi	Jinzhong	Taxi	260
	Tai Yuan	Passenger car	3
	Xin Zhou	Passenger car	12
	Yun Cheng	Taxi	14
Shannxi	**Xi'An**	**Taxi**	**8,124**
	Baoji	Taxi	585
		Mini MPV	15
	Yulin	Self-Dumping Truck	5
	Hanzhong	Taxi	20
Guizhou	**Guiyang**	**Taxi**	**16407**
	Tongren	Taxi	239
	Bijie	Taxi	100
Gansu	Pingliang	Taxi	150
Xin Jiang		HD Truck	200
		Total	26134

Table and images source: Methanol Institute, 2021

METHANOL PRODUCTION COST

- Production cost vary significantly depending on the feedstock and region
- Price of green methanol often unclear as projects are small and bespoke
- Some green projects, such as the one in Rotterdam, Netherlands and Tarragona in Spain, which will use municipal waste as feedstock, may effectively have negative costs, with companies paid by local councils to take it and convert it into valuable products including methanol.
- According to IRENA, green methanol will achieve cost parity with fossil fuel based methanol by 2050

METHANOL COSTS FROM DIFFERENT FEEDSTOCK (ADOPTED FROM HIS MARKIT, 2021)				
	Fossil fuels	**Bio-methanol**	**e-methanol (CO2 from BECCS)**	**e-methanol (CO2 from DAC)**
Cost of methanol ($/t)	100-500	320-770	800-1600	1200-2400

INDIA AND ITS METHANOL ECONOMY

- Growing energy demand
- Currently production capacity of 2 Mt/y
- Potential to produce 20 Mt/y by 2025 from domestic coal, stranded gas, biomass and waste
- A number of project underway with a recent opening of BHEL's coal to methanol pilot plant in Hyderabad (0.25 t/d)
- Interest in various applications, including maritime and road fuel as well as replacement of LPG in cooking stoves
- Methanol seen as a complementary product to hydrogen

Methanol economy program by NITI Aayong, aims to decrease dependence form oil imports and improve air quality while creating jobs, improving energy security and reducing energy bill by about 30% by 2030

Image: NITI Aayong https://www.niti.gov.in/

METHANOL IN INDONESIA

- Indonesia has abundant coal reserves and looks into new ways of monetising it s resources as well as lowering its oil import
- New projects are emerging
- One of the primary markets for biodiesel and has significant production potential in this area

Air Products to build $2bn coal-to-methanol production facility in Indonesia

WCN EDITORIAL TEAM 15 MAY 2020 ASIA ENERGY & UTILITIES

Image: https://www.worldconstructionnetwork.com/news/air-products-to-build-2bn-coal-to-methanol-production-facility-in-indonesia

JAPAN - METHANOL PROSPECTS

Basic substances

Technologies to produce methanol etc

Thermal chemistry (catalysts, etc)

CO_2 → methanol

Technological challenges

- Reaction at low temperature (improvement in conversion rate/selectivity)
- Separation/removal of the water arising from the reaction
- Direct utilisation of low quality exhaust gas (at research stage)
  Measures against deterioration/improvements of durability of catalysts

Other challenges

- Examination and comparison with current practical process (reaction through syngas)
- Utilisation of CO_2 in existing methanol production equipment

Syngas → methanol (or DME)

Technological challenges

- Improvement of yields in methanol production
- Methanol and DME production control technology

Photochemistry (photocatalysts, etc.)

Electrochemistry (electrochemical reduction, etc)

Synthesis utilising organisms (such as microorganisms)

Implement various types of R&D

Technological challenges

- Direct synthesis of formic acid/methanol (by utilising the protons in water)
- Improvement in reaction rate and efficiency

Other challenges

- Securing massive, stable, CO_2-free electricity supply at reasonable prices (in the case of utilising electricity)

Specific practical example

- Demonstration of integrated bioethanol production from syngas (derived from waste incineration facilities) using microorganisms (the technology to be established by 2023: goal 500 ~ 1000 kL/y scale demonstration to be implemented)

Target for 2030

Common challenges

- Reduction in process cost

Others

- Development of renewable energy combined systems
- Development of hybrid systems (photo + electricity etc.)
- Considering large-scale methanol supply chain
- Apply the technology to existing production systems/ secure affinity

Challenges to be taken up when methanol is utilised as a raw material

- Demonstrate the technology for methanol to be used in an actual environment
- Expand mixed utilisation of existing fuels and methanol as well as the mixed ratio

Technological goal

- Establish a reaction control technology for large-scale processes
- Develop production technologies responding to CO_2 and H_2 supply and demand fluctuations

Target from 2040 onwards

Common challenges

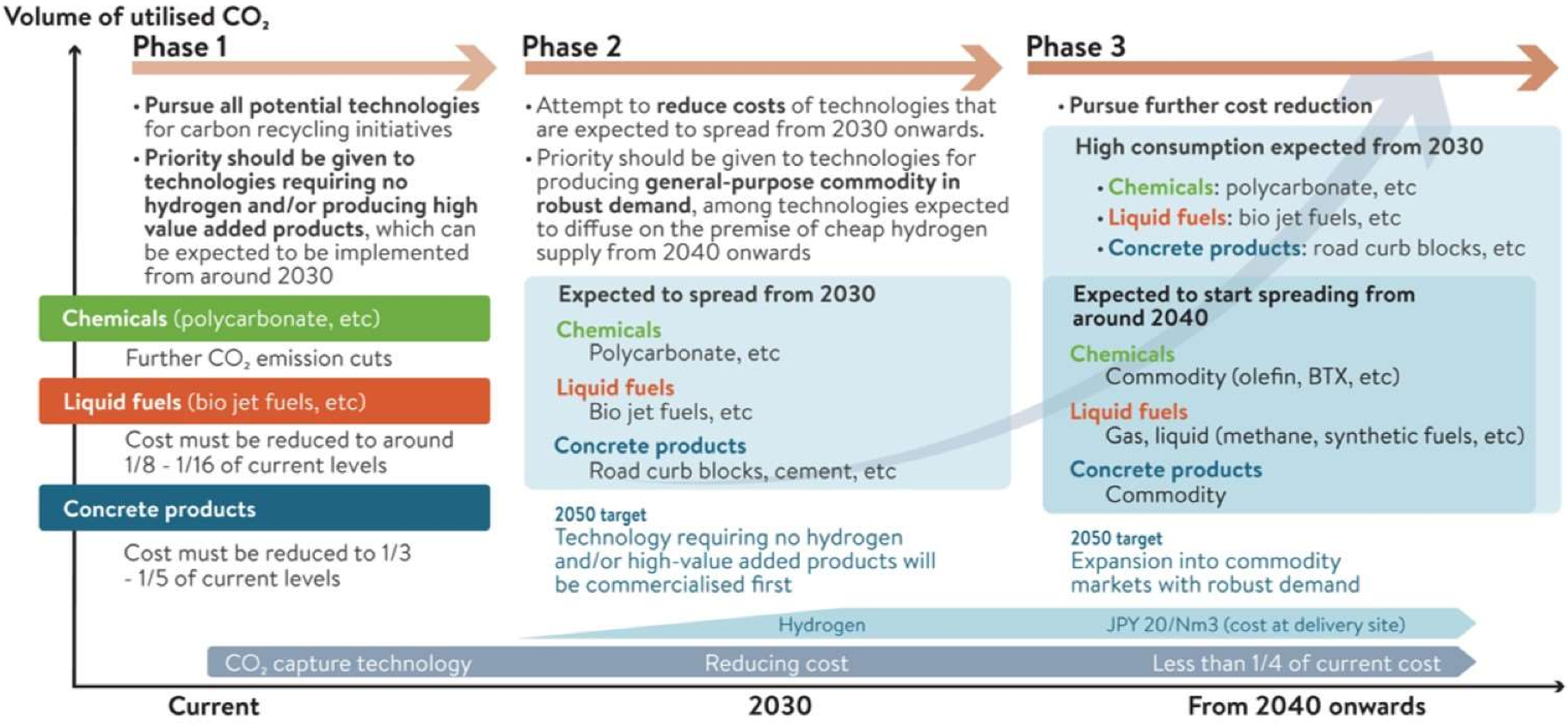
- Further reduction in process cost

Expected cost

- The expected costs are roughly equal to those incurred for the product synthesised from natural gas-derived methanol

Source: METI, 2021

JAPAN'S CARBON RECYCLING AMBITION



Source: METI, 2021

NON-ENERGY PRODUCTS FROM COAL

OPPORTUNITIES FOR COAL PRODUCTS

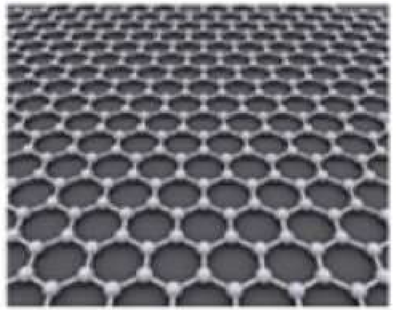
- REE
- Electrodes
- High strength lightweight materials
- Nanomaterials
- Purification
- Fertiliser
- Chemicals and fuels

Activated carbon

Li-ion battery

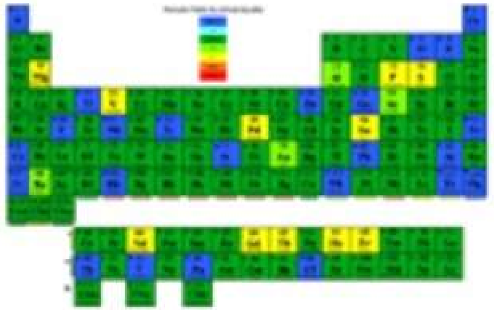
Carbon fibre

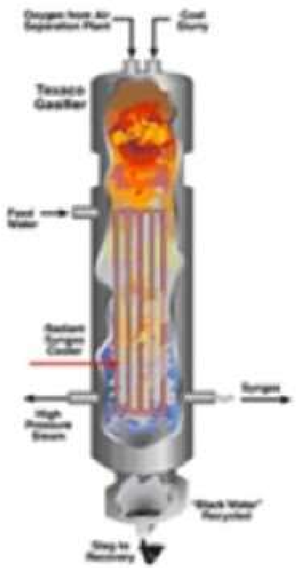
Synthetic graphite



graphene

Rare earths and others





Gasification and tar chemicals

Images: Wikipedia and Wikimedia Commons

GRAPHENE

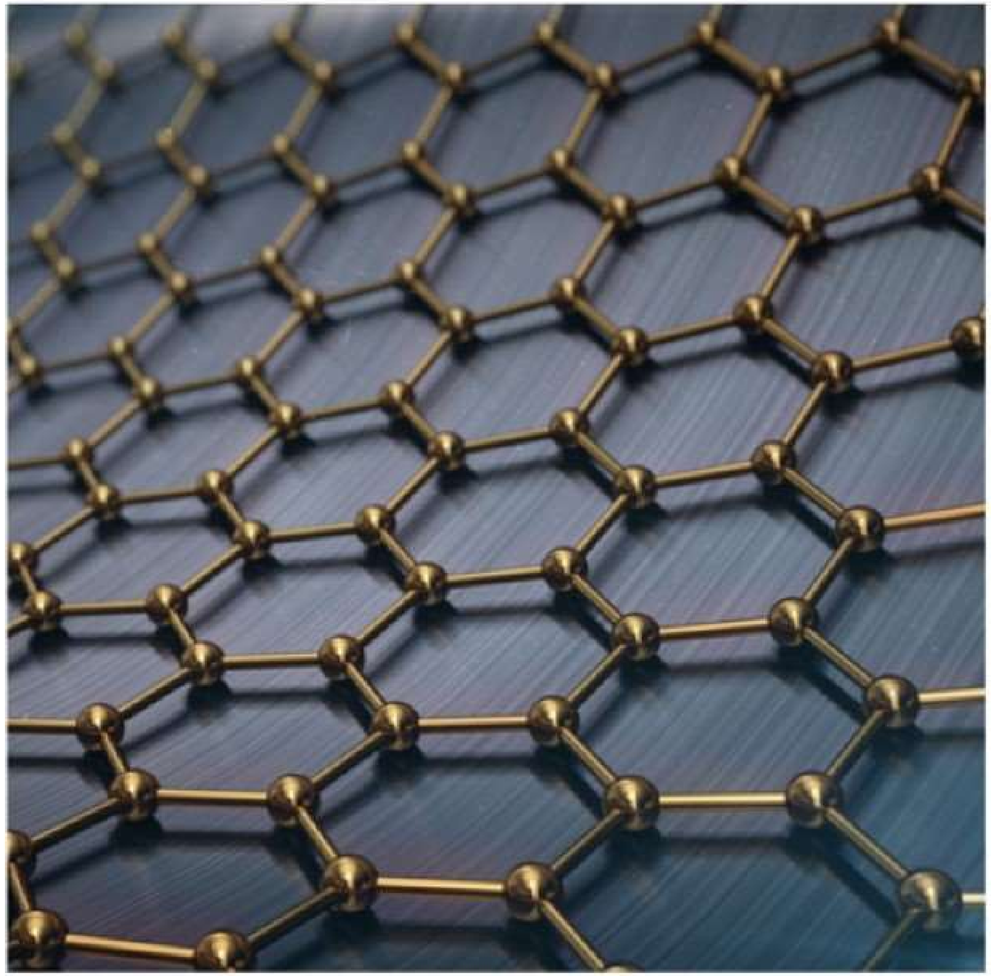


Image: Bigstock

Half of all graphene is used in Li-ion batteries but now over 50 commercial applications across industry

The key question for the coal industry though is can it be made economically from coal?

There are now 4 routes to graphene from coal

Chemical and electrochemical methods appeared a few years ago

Two new methods, one using molten salt and the other flash joule heating can make graphene from coal

Is the quality good enough?

a new computer memory device has been made using coal graphene QDs, a memristor, the latest advance in computer technology

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THANK YOU FOR PARTICIPATING

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