ความก้าวหน้าผลการศึกษามาตรฐาน และการรับรองด้านคาร์บอนของไฮโดรเจน เพื่อบริบทของประเทศไทยและสถานการณ์รอบโลก

งานวิจัยภายโครงการ: การศึกษามาตรฐานและการรับรองด้านคาร์บอนของไฮโดรเจนเพื่อบริบทของประเทศไทย
แหล่งทุนวิจัย: หน่วยบริหารและจัดการทุนด้านการเพิ่มความสามารถในการแข่งขันของประเทศ (บพข.) ปีงบประมาณ 2566

ดร.จิตติ มังคละศิริ
นักวิจัย/หัวหน้าโครงการ
สถาบันเทคโนโลยีและสารสนเทศเพื่อการพัฒนาที่ยั่งยืน (TIIS)
ศูนย์เทคโนโลยีโลหะและวัสดุแห่งชาติ (MTEC) สวทช.

วันศุกร์ที่ 29 มีนาคม 2567 เวลา 13:00 – 16:30 น.

ณ ห้องประชุมออดิทอเรียม CO-113 อาคารสำนักงานกลาง
อุทยานวิทยาศาสตร์ประเทศไทย จังหวัดปทุมธานี

บพข. หน่วยบริหารและจัดการทุนด้านการเพิ่มความสามารถในการแข่งขันของประเทศ
สวทช NSTDA
ENTEC a member of NSTDA
MTEC a member of NSTDA

NAC2024
19th NSTDA Annual Conference
การประชุมวิชาการประจำปี สวทช. ครั้งที่ ๑๙

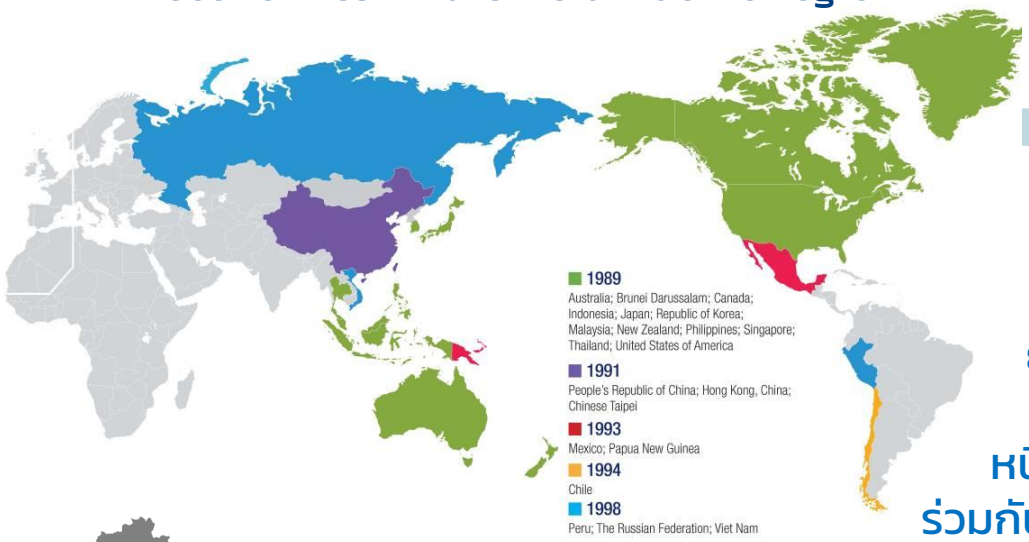
หัวข้อนำเสนอ

- ที่มาและความสำคัญของการศึกษามาตรฐานและการรับรองด้านคาร์บอนของไฮโดรเจน
- มาตรฐานด้านคาร์บอนของไฮโดรเจน/ไฮโดรเจนคาร์บอนต่ำรอบโลก
- ความก้าวหน้าของผลการศึกษามาตรฐานและการรับรองด้านคาร์บอนของไฮโดรเจนคาร์บอนต่ำเพื่อบริบทของประเทศไทย

Asia-Pacific Economic Cooperation (APEC) Meetings

Asia-Pacific Economic Cooperation

21 economies in the Asia-Pacific region



NEW ZEALAND APEC 2021

ส.ค. 2564 Low-Carbon Hydrogen International Standard ถูกหยิบยกมาพิจารณาในการประชุม

มี.ค. 2565 (2022) ยังไม่สามารถหาข้อสรุปร่วมกันถึงมาตรฐานฯ หนึ่งเดียว ที่ควรใช้อ้างอิงร่วมกันระหว่างทุกภาคีสมาชิก

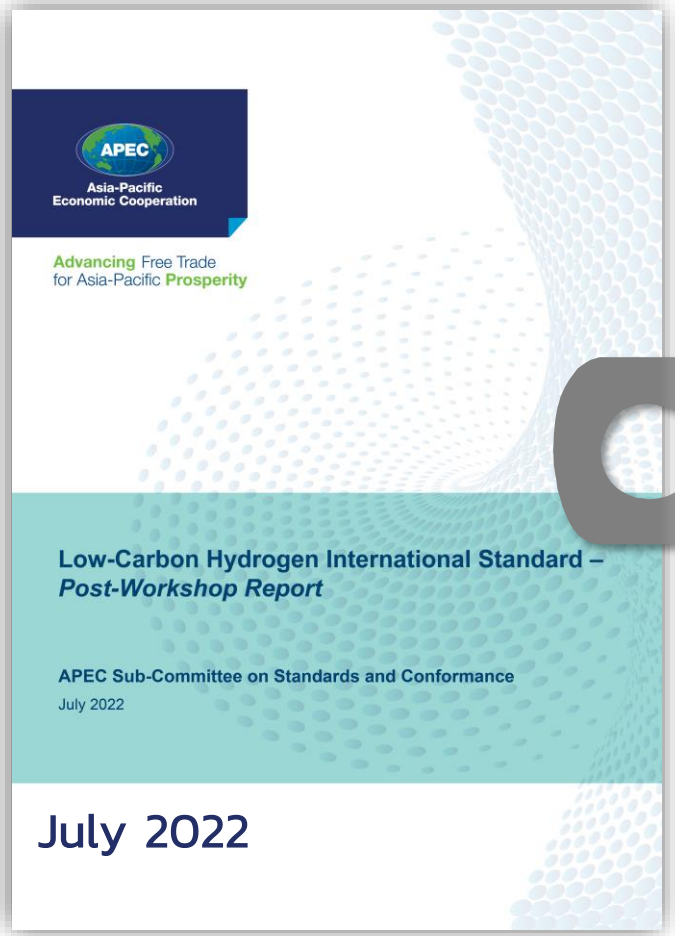
แต่ได้มีการวางแนวทางการพิจารณาไว้ **3 แนวทาง**

- <u>แนวทางที่ 1:</u> ภาคีสมาชิกแต่ละเขตเศรษฐกิจพัฒนามาตรฐานของตนเอง
- <u>แนวทางที่ 2:</u> ภาคีสมาชิก APEC ร่วมกันพัฒนา มาตรฐานใหม่ร่วมกัน
- <u>แนวทางที่ 3:</u> ภาคีสมาชิก ร่วมกันพิจารณาเลือกมาตรฐานฯ สากลร่วมกัน จากมาตรฐานฯ ของภาคีสมาชิก APEC ที่มีอยู่

40%

ประเทศไทย ยังไม่ได้กำหนดจุดยืนที่ชัดเจน ในการกำหนดเงื่อนไขหรือเลือกมาตรฐานฯ ใด และยังไม่ทราบว่ามาตรฐานฯ ใดที่เหมาะสมและเป็นประโยชน์สูงสุดสำหรับประเทศไทย

Low-Carbon Hydrogen International Standard – Post-Workshop Report



key message :

- Colours can fail to capture key information for the end user, such as the hydrogen's carbon intensity or the energy source.
- A low-carbon hydrogen standard for the APEC region should consider the criteria of existing standards and schemes.
- A low-carbon hydrogen standard could have multiple benefits beyond unifying definitions, such as economic and environmental benefits.
- A low-carbon hydrogen standard needs to be flexible and adaptable as the global hydrogen market continues to rapidly evolve

Low-carbon hydrogen standards are rapidly developing. A number of **certification schemes already exist** and have developed their own criteria, such as: **CertifHy (Europe), Green Gas Certification Scheme (UK), Standard and Assessment for Low-carbon Hydrogen, Clean Hydrogen and Renewable Hydrogen Energy (China), and The Climate Bonds Standard and International Renewable Energy Certificate Standards (international)**

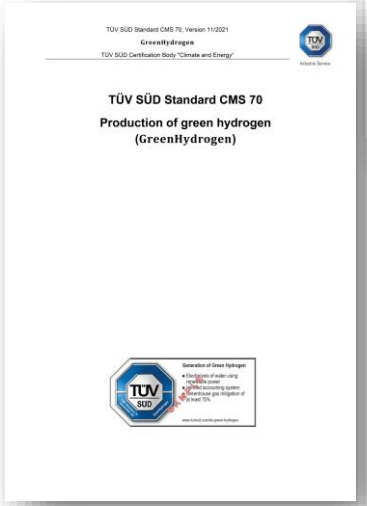
[URL: https://www.apec.org/publications/2022/07/low-carbon-hydrogen-international-standard-post-workshop-report]

Benefits of Standards and Certifications to Different Hydrogen Users

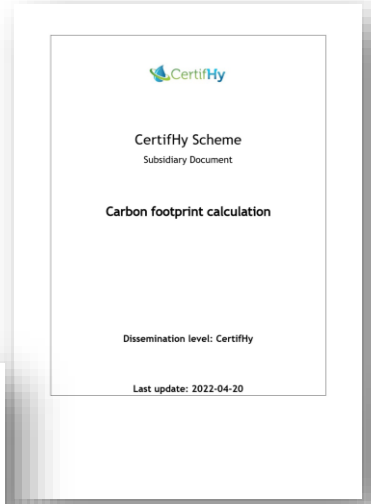
	Standard	Certification
Producer	• Provides clear guidelines on how to produce low-carbon hydrogen that can be trusted by an end user • Alignment to production standard may increase product interchangeably allowing for importation/exportation of hydrogen production equipment across economies	• Enable access to a low-carbon hydrogen market • May justify a premium price for the hydrogen due to its low-carbon nature • Allows for greater confidence that product meets performance standard
Transporter	• Provides guidelines on how to transport low-carbon hydrogen to ensure safety • May provide guidance on low-carbon transport methods	• Guarantees that the hydrogen transported is low-carbon, regardless of the mode of transport (e.g., as liquid hydrogen or ammonia) • Provides assurance to off-takers that the product is low-carbon • Certification of transport emissions may enable compliance with the EU's RED II and grant access to EU low-carbon fuels market
User	• Gives assurance that the hydrogen is low-carbon	• Allows users to report on reductions in carbon emissions

[URL: https://www.apec.org/publications/2022/07/low-carbon-hydrogen-international-standard-post-workshop-report]

Hydrogen Standard & Certification (example)

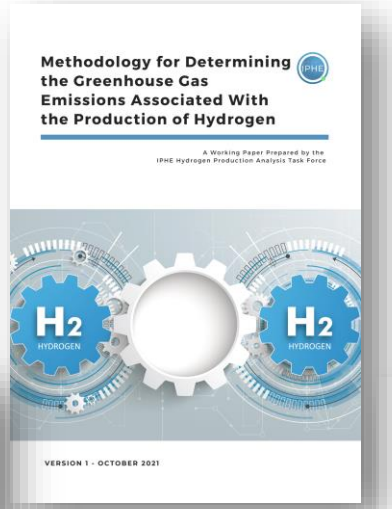


Last updated:
November 2021



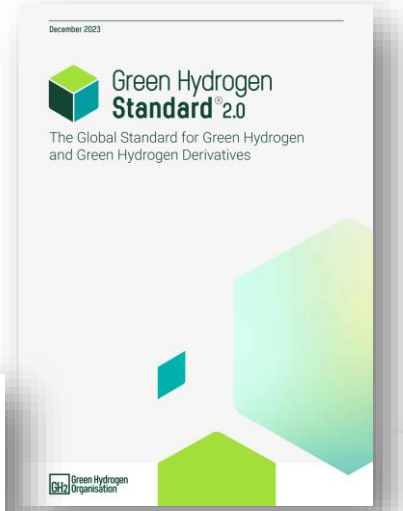
Last updated:
April 2022

Last updated:
April 2023

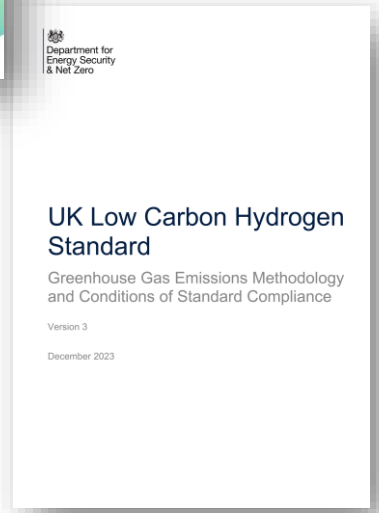


Published:
November 2023

Published:
November 2023



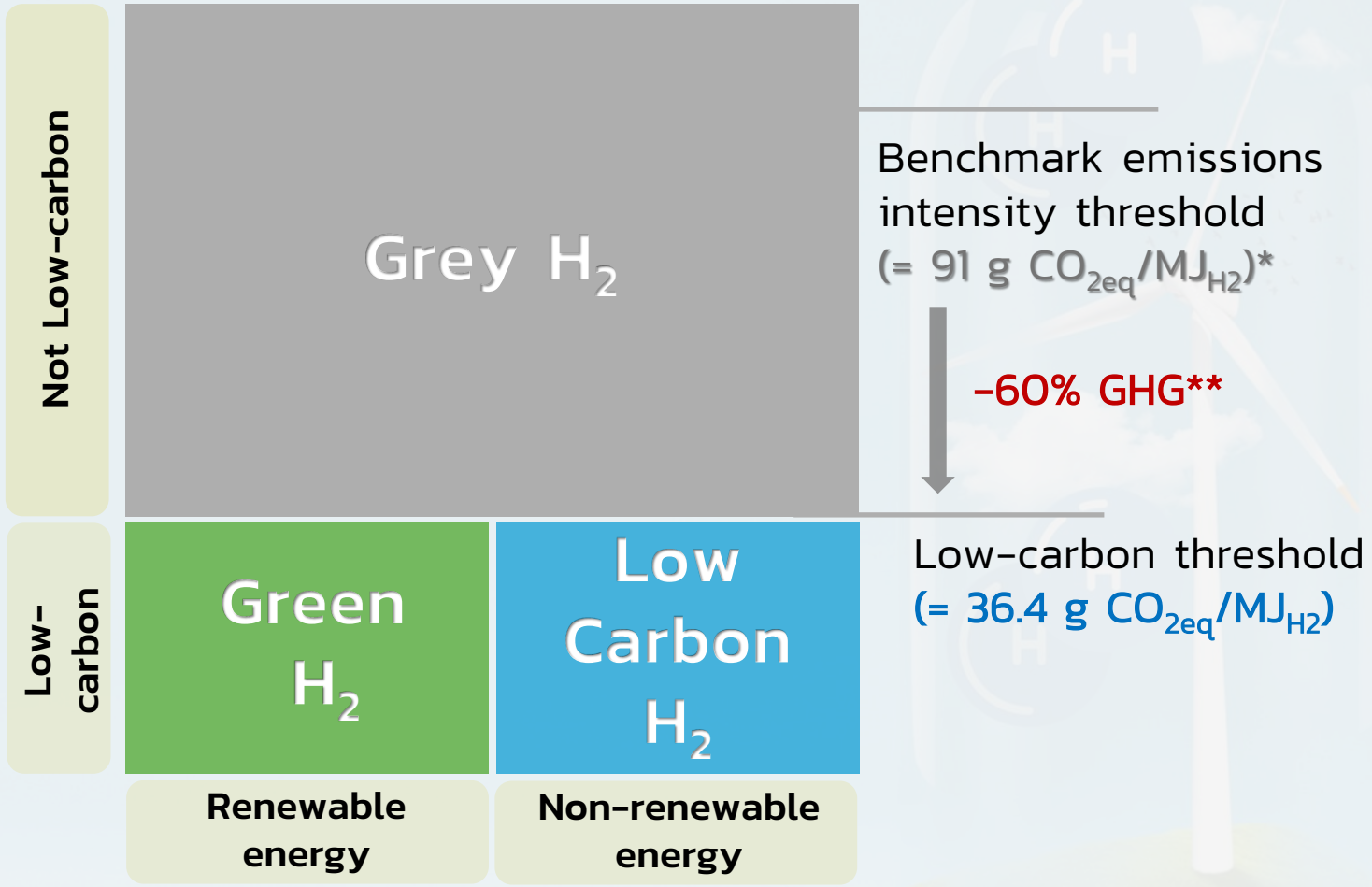
Last updated:
December 2023
(v.2)



Last updated:
March 2024

Low-Carbon Hydrogen Definition

"Low carbon" defined as a 60% reduction compared to a BAT emission benchmark



* Best Available Technology
  = Natural gas steam methane reforming,
  = >95% of the provided merchant hydrogen market

** cfr RED reduction requirement for biofuels in 2018

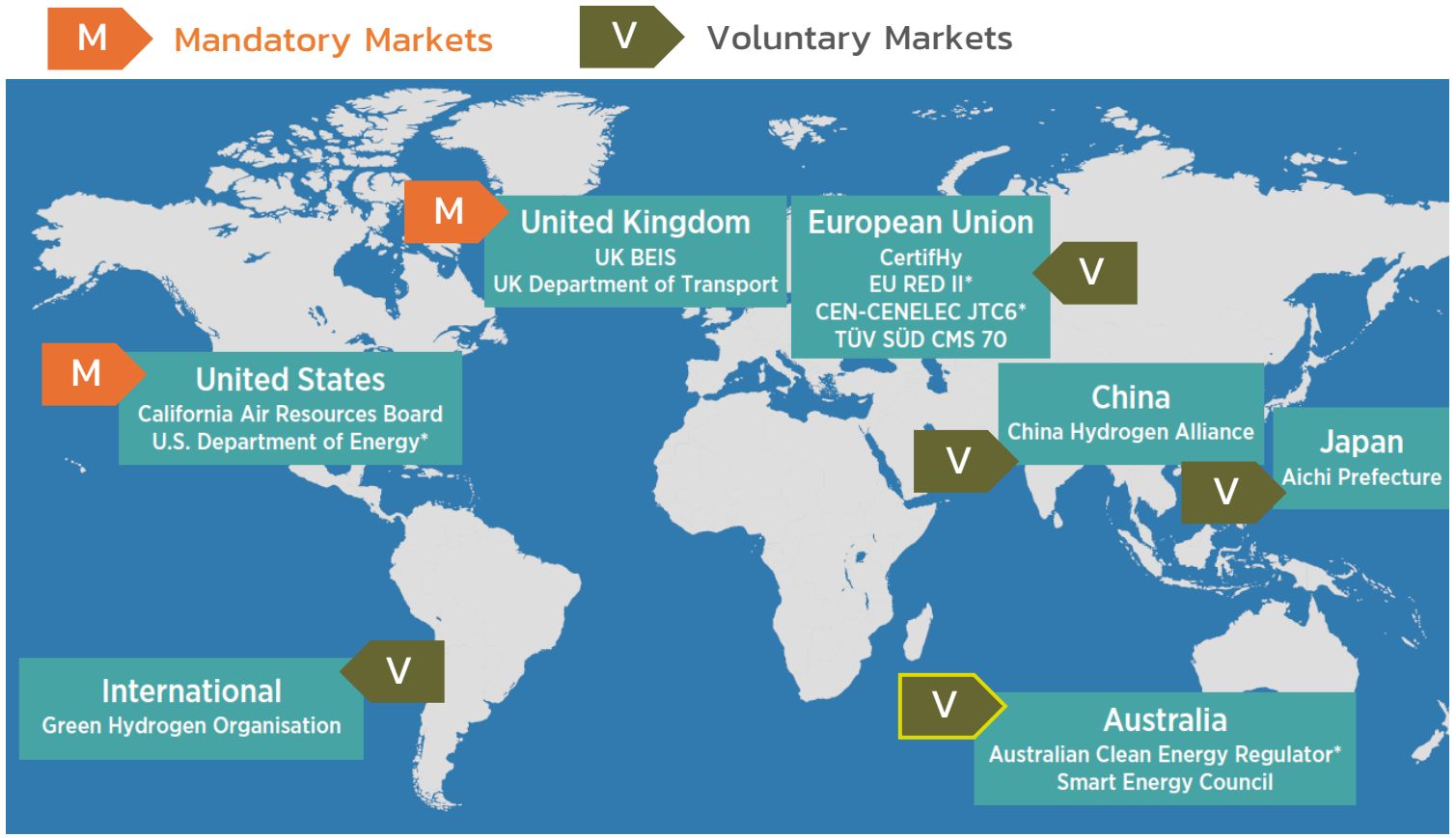
[source: CertifHy: – Developing a European Framework for the generation of guarantees of origin for green hydrogen]

Standard/Certification Scheme: Study in this Project

	CertifHy	The US Standard	Green Hydrogen Standard	EU Taxonomy	UK Low Carbon Standard	TUV SUD CMS70	Climate Bonds
Description	Guarantee of origin scheme	National standard	Global standard	Classification system	National standard	Industry standard	Sustainable finance standard
Geographic level	EU level	US National level	Global	EU level	UK National level	EU	Global
Criteria Approach	Green hydrogen criteria Low carbon criteria Same GHG threshold	Clean hydrogen criteria GHG threshold regardless of the technology	Green hydrogen criteria Other renewable non-fossil sources on a case-by-case basis	Low carbon criteria GHG threshold regardless of the technology	Low carbon criteria GHG threshold regardless of the technology	Green hydrogen criteria GHG threshold regardless of the technology	Low-carbon criteria GHG thresholds regardless of the technology
System Boundary	Cradle-to-gate	Cradle-to-gate	Cradle-to-gate	Life cycle emissions	Cradle-to-gate	Cradle to site (Cradle to gate plus transportation emissions)	
GHG Emissions Criteria	< 4,3 kg CO_2eq/kgH2	4 kg CO_2eq/kgH_2	1 kg CO_2eq/kgH_2	< 3 kg CO_2eq/kgH_2	2,4 kg CO_2eq/kgH_2 (20 gCO_2/MJLHV)	3,5 kg CO_2eq/kgH_2 (from the REDII in the EU)	3,0 kg CO_2eq/kgH_2 (Sliding scale target)
GHG Calculation Methodology	ISO 140444 and 14067	ISO 140444 and aligned with the IPHE methodology	IPHE methodology with some modifications	EU Directive or ISO 14067:2018 or ISO 14064-1:2018	ISO 14040 ISO 14044 ISO 14067-2 GHG Protocal	EU Directive ISO 14040 ISO 14044 ISO 14067-2	EU Directive ISO 14040 ISO 14044 ISO 14067-2

[source: 4 Criteria Overview. 4.2.2.1 Carbon intensity benchmark.]

Map of Organisations Working on Hydrogen Certification

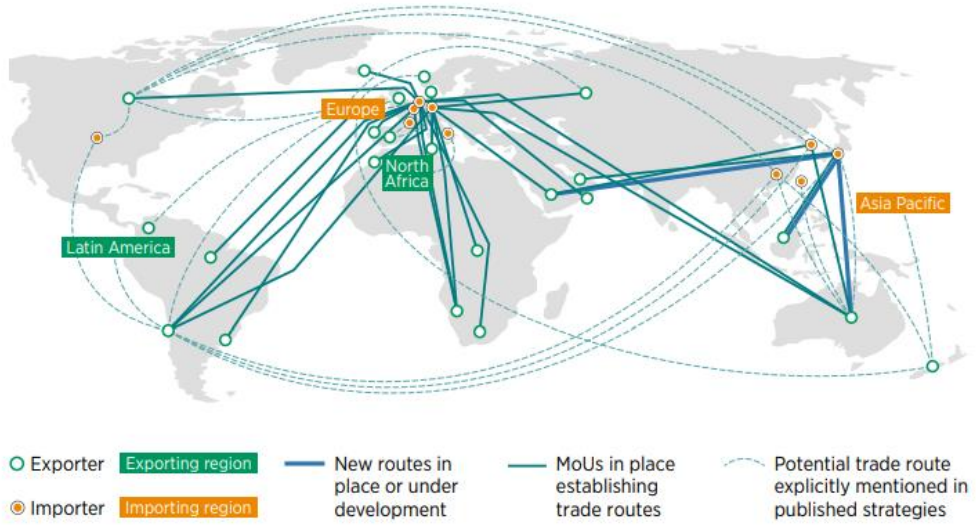


Notes: * in development. BEIS = Department for Business, Energy and Industrial Strategy; CEN = European Committee for Standardization; CENELEC = European Committee for Electrotechnical Standardization; JTC = Joint Technical Committee; RED II = Renewable Energy Directive II.

VOLUNTARY MARKET		MANDATORY MARKET
Aichi Prefecture Low Carbon Hydrogen Certification	**China Hydrogen Alliance** Standard and Assessment for Low Carbon Hydrogen, Clean Hydrogen, and Renewable Hydrogen Energy	**California Air Resources Board** Low Carbon Fuel Standard
Australian Clean Energy Regulator* Hydrogen Guarantee of Origin	**Green Hydrogen Organisation** Green Hydrogen Standard	**European Commission*** Renewable Energy Directive (RED II)
CertifHy Green and Low-Carbon Hydrogen Certification	**Smart Energy Council** Zero Carbon Certification Scheme	**UK Department for Business, Energy & Industrial Strategy** Low Carbon Hydrogen Standard
CEN-CENELEC* Joint Technical Committee 6	**TÜV SÜD** CMS 70	**UK Department for Transport** Renewable Transport Fuel Obligation
		US Department of Energy** Clean Hydrogen Production Standard

*in development.
**in development for specific program eligibility.

Notes: CEN = European Committee for Standardization; CENELEC = European Committee for Electrotechnical Standardization.



[source: IRENA 2023. CREATING A GLOBAL HYDROGEN MARKET. CERTIFICATION TO ENABLE TRADE.]

Voluntary Market Mechanisms with Published Technical Criteria

TITLE	LABEL	EMISSIONS THRESHOLD ($kgCO_2eq/kgH_2$)	BOUNDARY	POWER SUPPLY REQUIREMENT FOR ELECTROLYSIS	HYDROGEN PRODUCTION PATHWAY	CHAIN OF CUSTODY MODEL
Australia **Smart Energy Council** Zero Carbon Certification Scheme	Renewable H_2	No threshold				Unclear
China **China Hydrogen Alliance** Standard and Assessment for Low-carbon Hydrogen, Clean Hydrogen, and Renewable Hydrogen Energy	Renewable H_2	4.9				Not specified
	Clean H_2	4.9				Not specified
	Low-carbon H_2	14.5		n/a		Not specified
European Union **CertifHy** Green and Low-Carbon Hydrogen Certification	Green H_2	4.4				B&C
	Low-carbon H_2	4.4				B&C
Germany **TÜV SÜD** CMS 70	Green H_2 (non-transport)	2.7				B&C
	Green H_2 (transport)	2.8				Mass
Japan **Aichi Prefecture** Low-Carbon Hydrogen Certification	Low-carbon H_2	No threshold				B&C
International **Green Hydrogen Organisation** Green Hydrogen Standard	Green H_2	1.0				Not specified

*Aligned with REDII methodology and may be updated once EU delegated act is finalised.

Indicates threshold value

Includes upstream methane
To point of production
To point of use

Power supply requirements
- GO + additionality
- GO required
- No GO/additionality specified
- Solar, wind or hydro
- Nuclear
- Grid (or unspecified)

Hydrogen production pathway specified
- Electrolysis
- Fossil SMR/ATR with carbon capture
- Biogas SMR

Notes: ATR = autothermal reforming; B&C = book and claim; GO = guarantee of origin; SMR = steam methane reforming.

[source: IRENA 2023. CREATING A GLOBAL HYDROGEN MARKET. CERTIFICATION TO ENABLE TRADE.]

Mandatory Markets with Published Technical Criteria

COUNTRY/ REGION	NATIONAL HYDROGEN STRATEGY	BOUNDARY AND SCOPE (SECTORS)	EMISSIONS THRESHOLD ($kgCO_2eq/kgH_2$)	POWER SUPPLY REQUIREMENT FOR ELECTROLYSIS	HYDROGEN PRODUCTION PATHWAY	REGULATORY MECHANISM	STATUS OF REGULATORY MECHANISM
United Kingdom	**Government of the United Kingdom** UK Hydrogen Strategy	(Energy)	2.4	◑ ● ● ●	Electrolysis, Fossil SMR/ATR with carbon capture, Biogas SMR	**BEIS** Low Carbon Hydrogen Standard	To be implemented in 2022 Certification scheme **to be developed by 2025**
		(Transport)	3.9	● ○ ○ ●	Fossil SMR/ATR with carbon capture	**UK Dept. for Transport** Renewable Transport Fuel Obligation	**Active**
European Union (Proposed)	**European Commission** A hydrogen strategy for a climate-neutral Europe	(Transport, energy)	3.4	●* ○ ○ ●	Fossil SMR/ATR with carbon capture	**European Commission** RED II	**Active** New Delegated Act of RED II **proposed in May 2022**
		Boundary not specified	3.0	◑ ● ● ●	Electrolysis, Fossil SMR/ATR with carbon capture, Biogas SMR	**European Commission** EU Taxonomy	**Active**
United States (Proposed)	**US Department of Energy** National Clean Hydrogen Strategy and Roadmap	(Transport, energy)	4.0	○** ● ● ●	Electrolysis, Fossil SMR/ATR with carbon capture, Biogas SMR	**US Department of Energy** H2Hubs draft *(may be adopted by standard for clean H_2 production)*	CHPS not yet finalised H2Hubs criteria requires 2 $kgCO_2/kgH_2$ at point of production to qualify
		(Transport)	No threshold (Certificate issued based on reduction from annual target)	◑ ● ○ ●	Electrolysis, Fossil SMR/ATR with carbon capture, Biogas SMR	**California Air Resources Board** Low Carbon Fuel Standard - California only	**Active**

*refers to delegated act criteria, grid connected conditions in delegated act undergoing revision and are subject to change.
**denotes no detail of additionality in draft, but is yet to be finalized.

Indicates threshold value

Includes upstream methane
To point of production
To point of use

Power supply requirements
- GO + additionality
- GO required
- No GO/additionality specified
- Solar, wind or hydro
- Nuclear
- Grid (or unspecified)

Hydrogen production pathway specified
- Electrolysis
- Fossil SMR/ATR with carbon capture
- Biogas SMR

Notes: ATR = autothermal reforming; B&C = book and claim; GO = guarantee of origin; SMR = steam methane reforming.

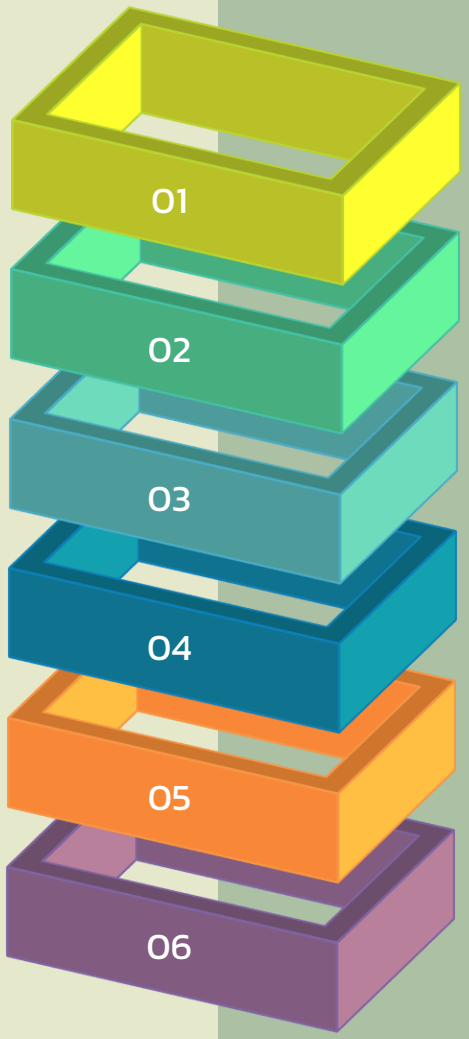
[source: IRENA 2023. CREATING A GLOBAL HYDROGEN MARKET. CERTIFICATION TO ENABLE TRADE.]

Key Characteristics of Mandatory and Voluntary Standards

Mandatory Standard

- Compulsory, government-regulated schemes.
- Legislation would also dictate a verification framework, audit, and compliance.
- May be established through regulation to:
  - o Mandate a registration and reporting framework
  - o Oversee certificate creation, issuance, transfer, and cancellation.
- Financial incentives are provided through trading or through a subsidy scheme, referred to as "compliance" markets.
- Legislation could build on existing gas or renewables legislation which could be adapted to include low-carbon hydrogen, or alternatively new legislation could be established.
- more difficult to implement a mandatory standard for low-carbon hydrogen internationally, as consensus is needed across multiple economies.

Key Characteristics

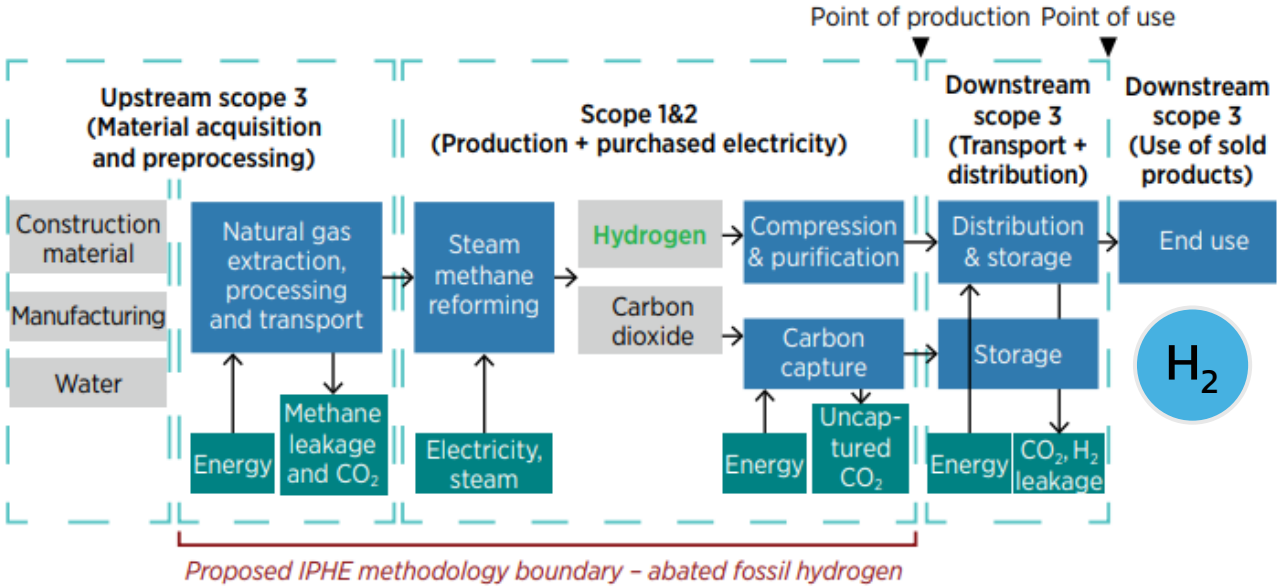


Voluntary Standard

- It is generally easier to implement a voluntary standard on an international scale.
- No penalties for producers who chose not to participate in the standard, instead relying on self-regulation of the low-carbon hydrogen market.
- No legislation is necessary, instead certification will be guided by a framework and adherence to this will be overseen by a scheme administrator, which is usually a not-for-profit entity.
- Provide a framework that acts in a way that adds value by providing trust for consumers.
- The customer trust, additional demand and price differentials provided by the standard drives participation.

[URL: https://www.apec.org/publications/2022/07/low-carbon-hydrogen-international-standard-post-workshop-report]

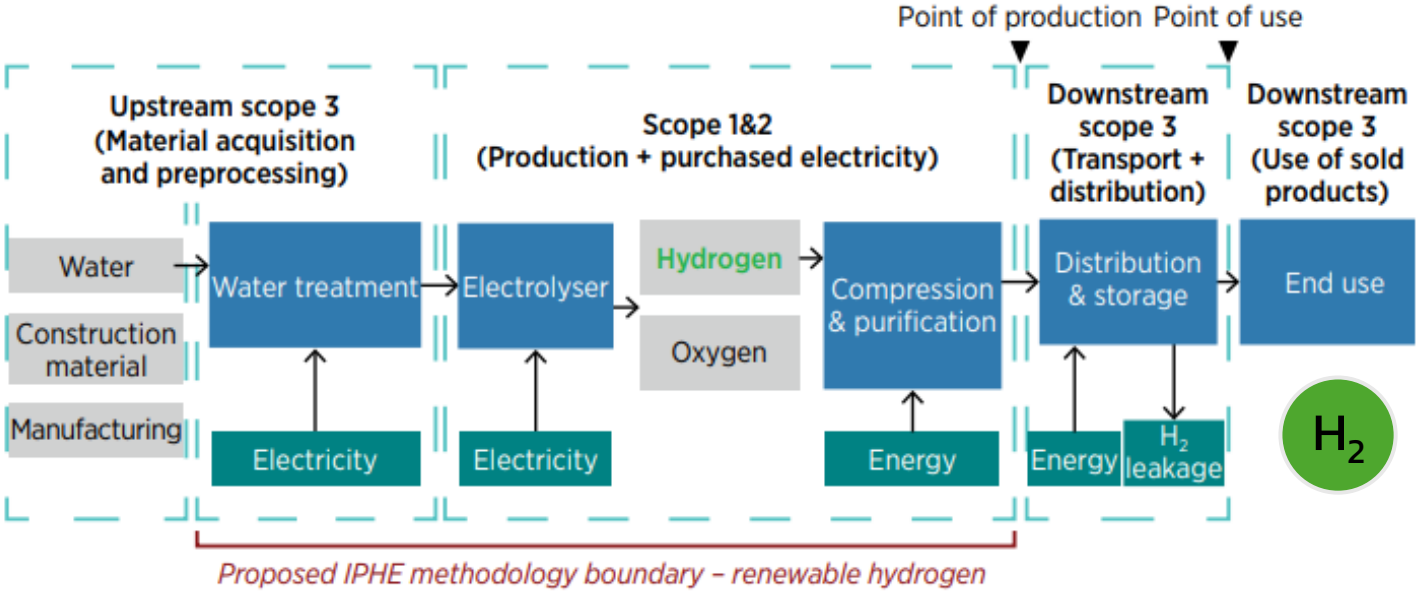
IPHE Methodology



Supply chain and system boundary for blue (top) and green (bottom) hydrogen

based on the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) methodology (IPHE, 2021), which is in the process of being established as an International Organization for Standardization (ISO) standard.

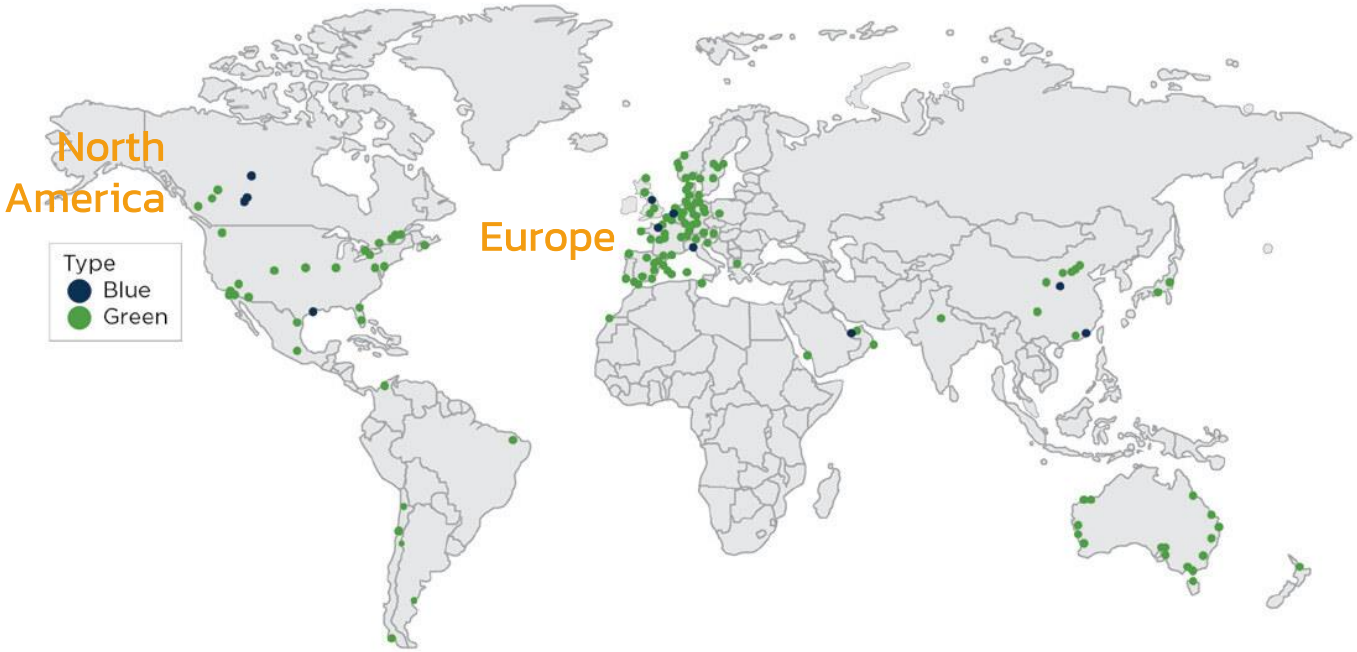
- System boundaries are typically defined to capture either well-to-gate (up to point of production) or well-to-wheel (up to point of use) pathways.
- These boundaries serve as the basis for differentiating hydrogen production pathways.

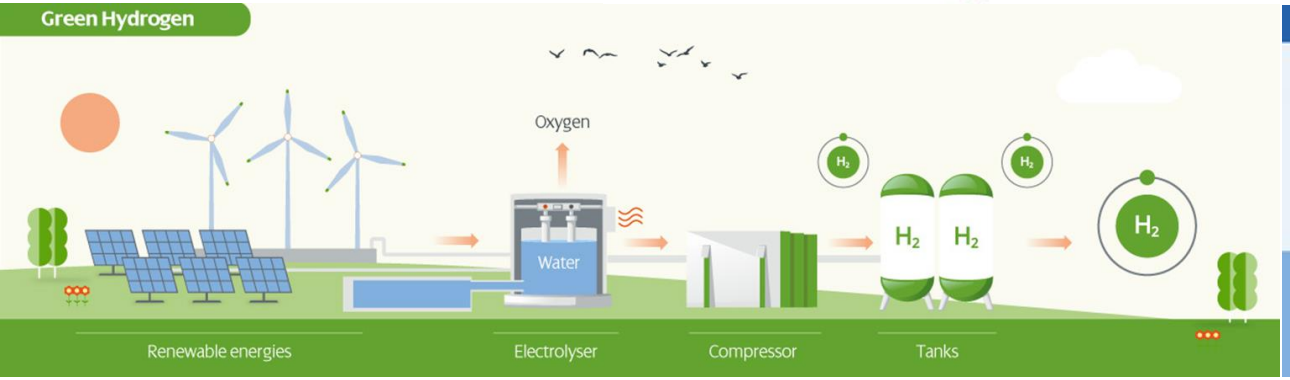


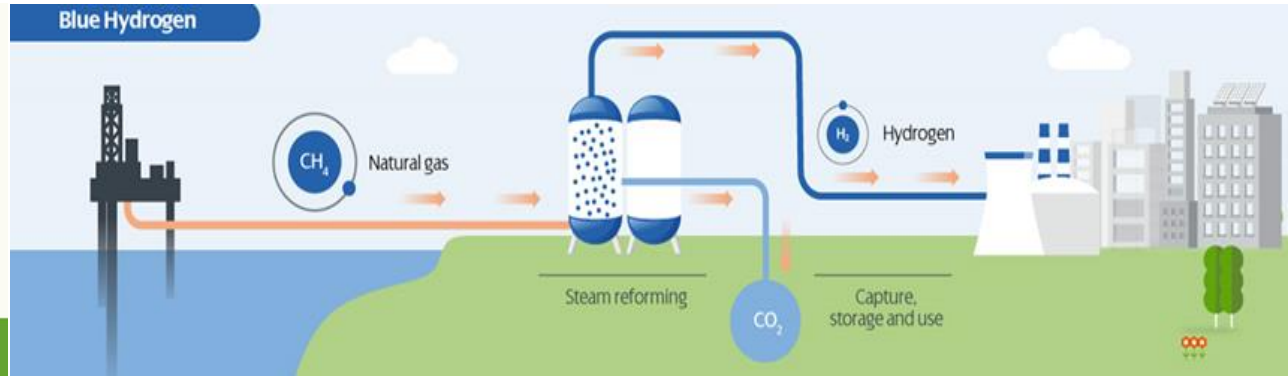
[source: IRENA 2023. CREATING A GLOBAL HYDROGEN MARKET.]

Global Green and Blue Hydrogen Projects

Overview of Operational, Under-construction and Pending FID blue and green hydrogen projects worldwide* © IEA



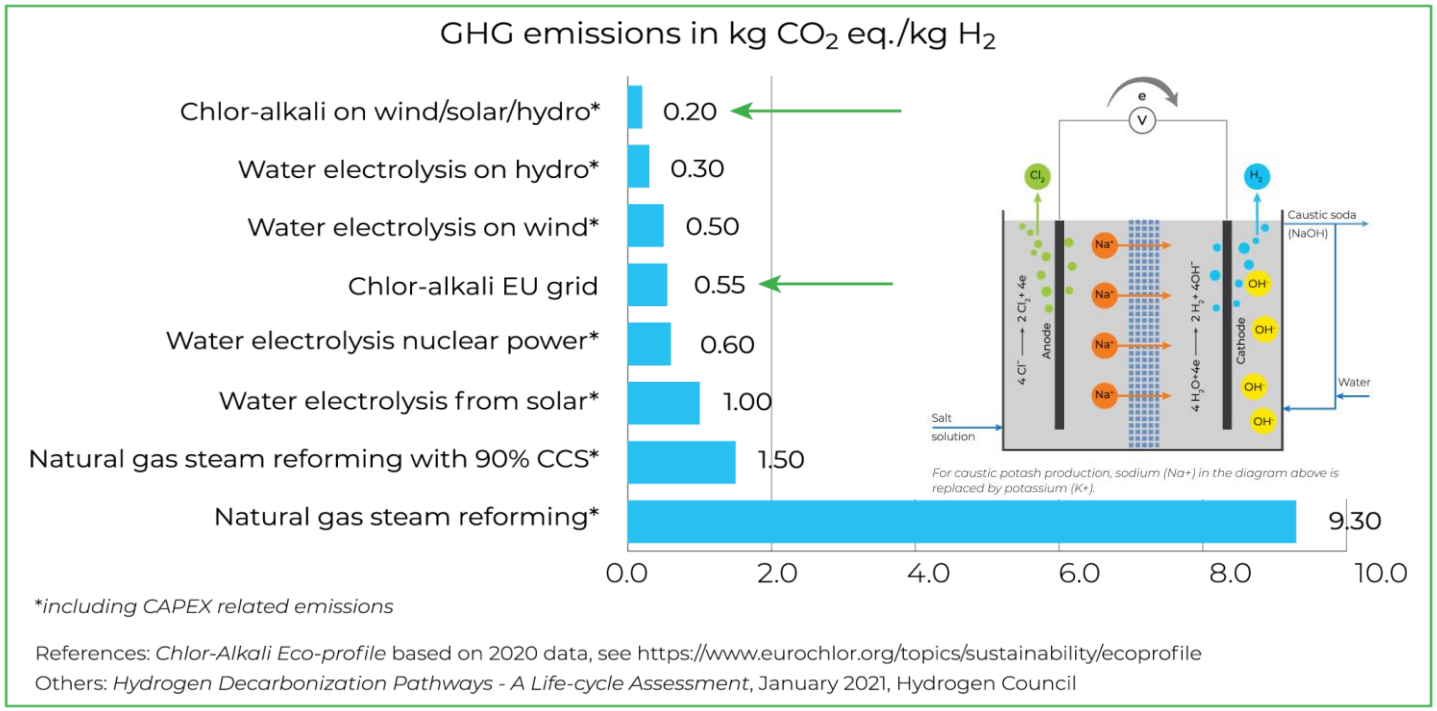




[*source: American Bureau of Shipping (ABS). Setting the Course to Low Carbon Shipping: Zero Carbon Outlook. June 2022.]

[source: https://www.iberdrola.com/sustainability/green-hydrogen/green-hydrogens-promise-carbon-free-future]

European Chlor-Alkali Industry



References: *Chlor-Alkali Eco-profile* based on 2020 data, see https://www.eurochlor.org/topics/sustainability/ecoprofile
Others: *Hydrogen Decarbonization Pathways - A Life-cycle Assessment*, January 2021, Hydrogen Council

Note: environmental performance data representative of the average European production of chlorine by chlor-alkali electrolysis from cradle to gate (from production of salt/brine to liquid chlorine, sodium hydroxide, hydrogen and hypochlorite at plant).

Impact Factor	Allocation Method	Chlorine	Sodium Hydroxide	Hydrogen	Sodium Hypochlorite
Global Warming Potential (GWP) in kg CO_2 eq. per kg product	Base case	0.71	0.66	0.55	0.64
	Pure mass allocation	0.68	0.68	0.55	0.67
	Economic allocation	0.53	0.73	4.24	0.84

$$2\ NaCl + 2\ H_2O \rightarrow Cl_2 + H_2 + 2\ NaOH$$

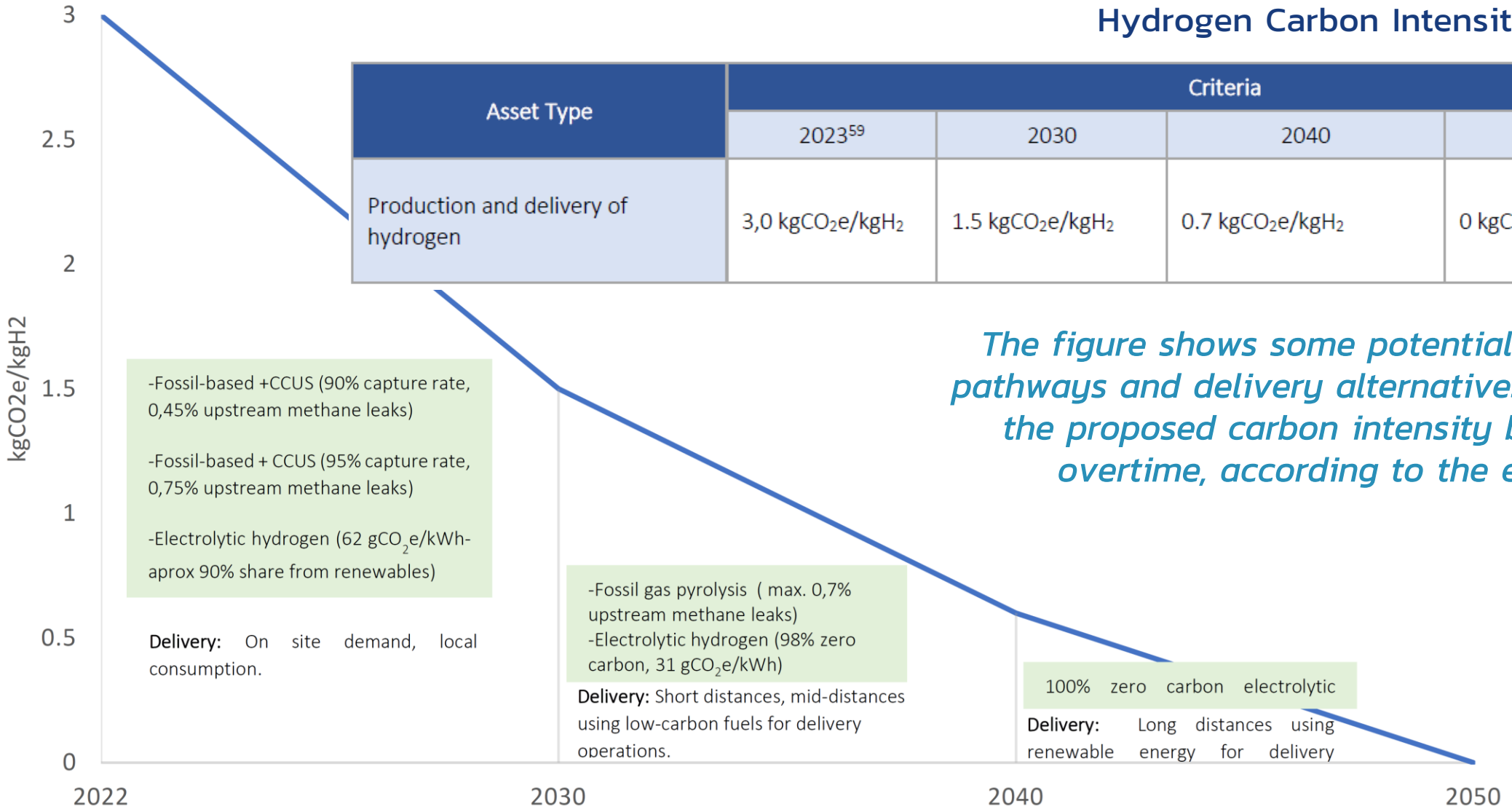
- Environmental Product Declaration (EPD): 35 Euro Chlor-member companies
- Representativeness: covering 75% of European (EU + GB, NO, CH) chlorine production capacity
- Electrolysis techniques: Diaphragm and membrane cell technology (monopolar, mono/bipolar, bipolar, oxygen depolarised cathodes)
- Allocation method: Stoichiometric allocation for salt, mass allocation for all other input and emissions > influence of the allocation method on Global Warming Potential (GWP)
- Fixed stochiometric ratio of 1.1 kg sodium hydroxide and 0.03 kg hydrogen per kg of chlorine

[source: Chlorine (The Chlor-Alkali Process) Euro Chlor September 2022. Final report – updated.]

Technologies to Reduce Emissions from Hydrogen Production

Hydrogen Carbon Intensity Thresholds

Asset Type	Criteria			
	2023[59]	2030	2040	2050
Production and delivery of hydrogen	3,0 $kgCO_2e/kgH_2$	1.5 $kgCO_2e/kgH_2$	0.7 $kgCO_2e/kgH_2$	0 $kgCO_2e/kgH_2$



The figure shows some potential production pathways and delivery alternatives that meet the proposed carbon intensity benchmarks overtime, according to the explanation.

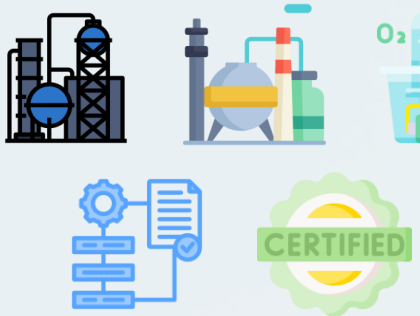
[4 Criteria Overview. 4.2.2.1 Carbon intensity benchmark. https://www.climatebonds.net/files/files/background-paper-hydrogen-production-and-delivery-draft-for-public-consultation-100823.pdf]

กรอบแนวคิดโครงการวิจัย

ศึกษามาตรฐานการให้การรับรอง ไฮโดรเจนคาร์บอนต่ำในระดับนานาชาติ

- ศึกษาขอบเขตของระบบการผลิต H_2 คาร์บอนต่ำ
- เกณฑ์และระดับรับรอง

Low-Carbon H_2 STD



ศึกษาสถานภาพการผลิต ไฮโดรเจนในไทย

TH H_2 Production

- โครงสร้างการผลิต H_2 และขีดความสามารถในการผลิต H_2 ในอุตสาหกรรมไทย
- ประเภทของวัตถุดิบที่ใช้ในการผลิต

ประเมินและเปรียบเทียบปริมาณการปล่อย GHG จากการผลิต H_2 ที่แตกต่างกันในประเทศไทย **ด้วยวิธี LCA**
เปรียบเทียบมาตรฐานการให้การรับรอง H_2 คาร์บอนต่ำของนานาประเทศ

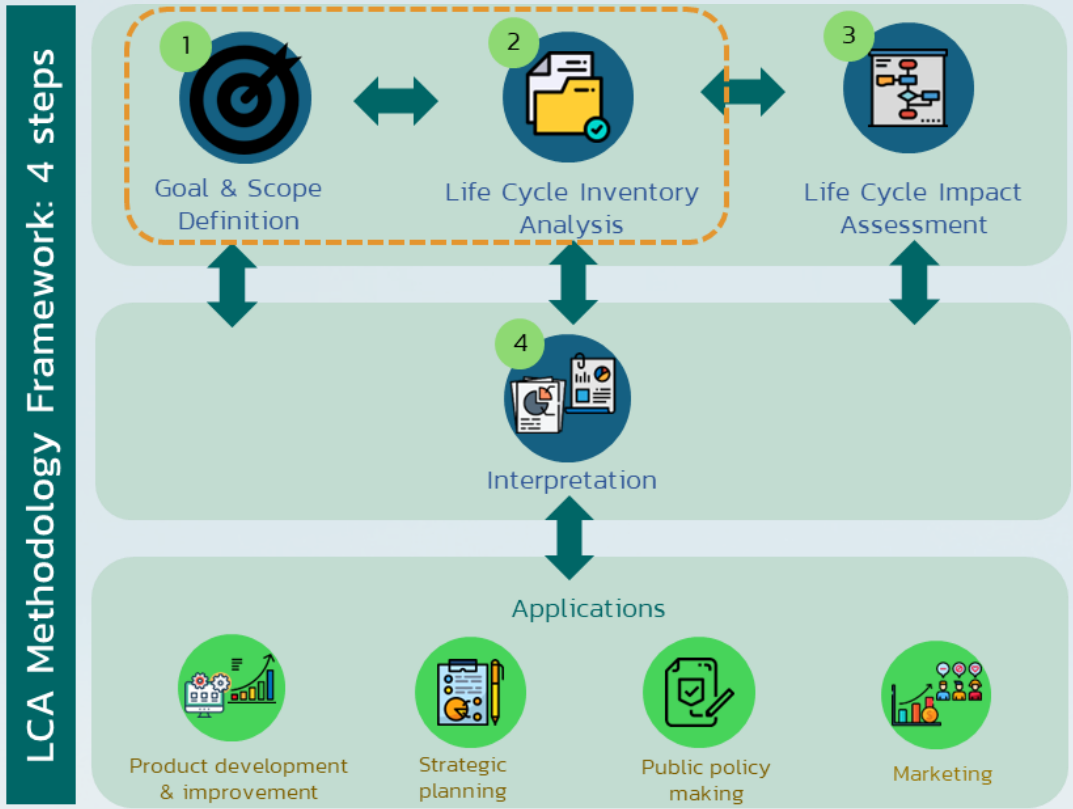
ประเมินและเปรียบเทียบความได้เปรียบ/เสียเปรียบ ในการประยุกต์ใช้มาตรฐานการรับรอง H_2 คาร์บอนต่ำของนานาประเทศกับกรณีของไทย

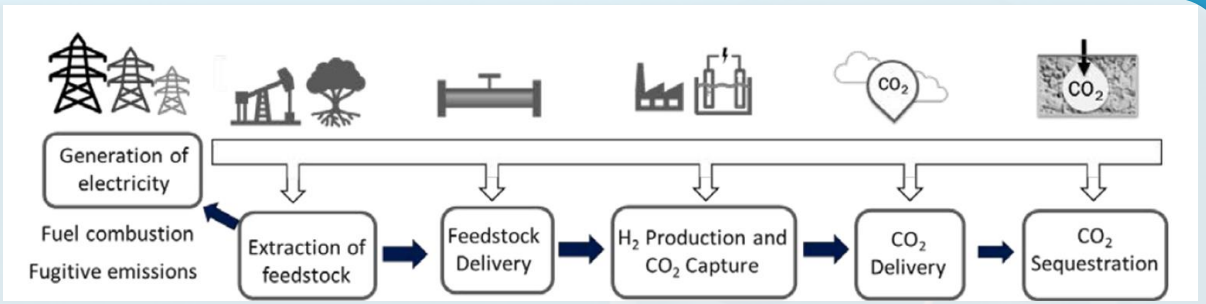
****นำเสนอทางเลือกที่เหมาะสมสำหรับไทยในเวทีระหว่างประเทศ****

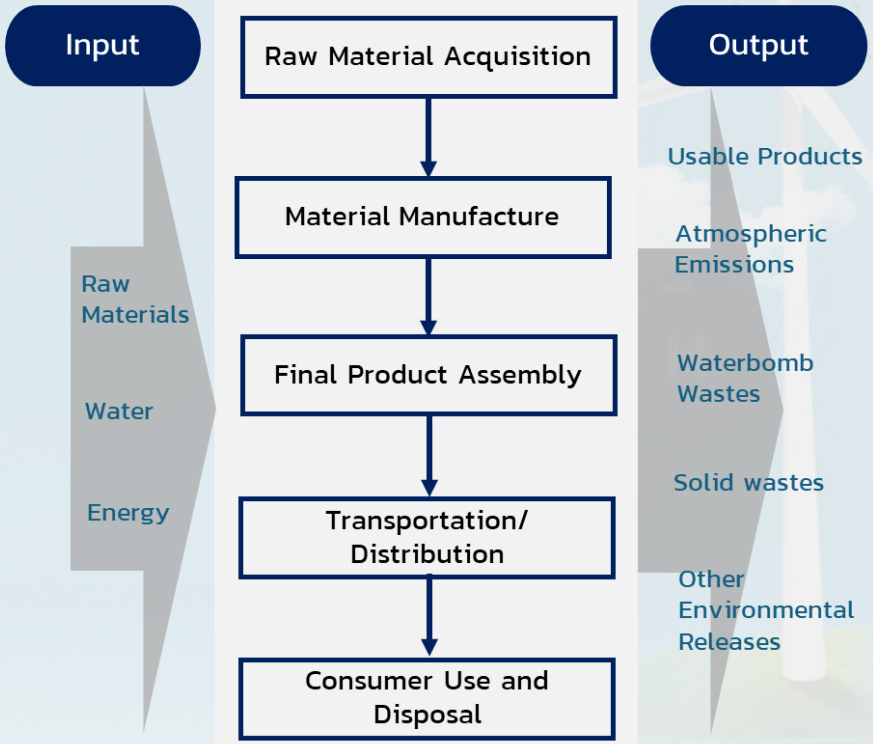
กรอบแนวคิดโครงการวิจัย: แนวทางการประเมิน LCA

การประเมินวัฏจักรชีวิต
(Life Cycle Assessment: LCA)

"กระบวนการวิเคราะห์และประเมินค่าผลกระทบต่อสิ่งแวดล้อมของผลิตภัณฑ์หรือบริการ โดยพิจารณาตลอดวัฏจักรชีวิตของผลิตภัณฑ์หรือบริการนั้น ๆ ตั้งแต่การได้มาซึ่งวัตถุดิบ กระบวนการผลิต การขนส่ง การใช้งาน จนกระทั่งการจัดการของเสียหลังจากการใช้งาน โดยมีการระบุค่าในเชิงปริมาณของพลังงานและวัตถุดิบที่ใช้ รวมถึงปริมาณของเสียที่ปล่อยออกสู่สิ่งแวดล้อม"







Standard/Certification Scheme: Study in this Project

No	Standard/ Certification scheme	Coverage	Unit	System Boundary	H2 Pathway	Benchmark	Threshold
1	CertifHy	European Union (included Switzerland)	gCO_2eq/MJ_{H2}	- Point of H_2 production (Well-to-Gate) - GO Scheme	- Green Hydrogen (Renewable Energy) - Low-carbon Hydrogen (Non-Renewable Energy) (Guarantee of Origin (GO))	Hydrogen produced via SMR of Natural gas (emitted 91.0 gCO_2eq/MJ_{H2}; a RED II reference value)	36.4 gCO_{2eq}/MJ_{H2} (or 4.37 $kgCO_{2eq}/kg_{H2}$) (60% reduction from Benchmark)
2	UK Low Carbon Hydrogen Standard	UK National Level	gCO_2e/MJ_{LHV}	- Point of H_2 production - Well-to-Gate	- Electrolysis - SMR with CCUS - Biomass/Waste with or without CCUS	n/a	≤ 20 gCO_2e/MJ_{LHV}
3	Clean Hydrogen Production Standard (CHPS)	United States	$kgCO_{2e}q/kgH_2$	- Well-to-Gate	n/a	n/a	≤ 4.0 $kgCO_{2e}/kgH_2$
4	Standard and Assessment for Low-carbon Hydrogen, Clean Hydrogen and Renewable Hydrogen Energy	The People's Republic of China	$kgCO_{2eq}/kg\ H_2$	- Well-to-Gate	- Green carbon hydrogen (Renewable Energy) - Clean carbon hydrogen (Non-Renewable Energy) - Low carbon hydrogen (Coal Gasification with CCUS)	Hydrogen produced via Coal Gasification (emitted 20.02 kg gCO_2eq/kg_{H2})	- Green and Clean Hydrogen < 4.91 $kgCO_{2eq}/kg_{H2}$ (65% reduction from Benchmark) - Low Carbon Hydrogen < 14.51 $kgCO_{2eq}/kg_{H2}$ (60% reduction from Benchmark)
5	Australian National Hydrogen Certification Scheme (implementation will be started in 2024)	Australia	n/a	- Preferred Well-to-Gate - GO Scheme	- Electrolysis - Coal gasification with car bon capture and storage (CCS)) - Steam Methane Reforming with CCS	n/a	n/a

[source: https://www.certifhy.eu/go-definition/]

Hydrogen Production: Study in this Project

Company A | Company B | Company C | Company D | Company E

Feedstocks

Energy

Input Inventory

Output Inventory

Carbon Intensity

- H_2 BAU — High Carbon Hydrogen
- H_2 BAU — Low Carbon Hydrogen
- H_2 BAU — Low Carbon Hydrogen
- H_2 EST — Clean Hydrogen

System boundary: Cradle-to-gate

EST: Project Estimate

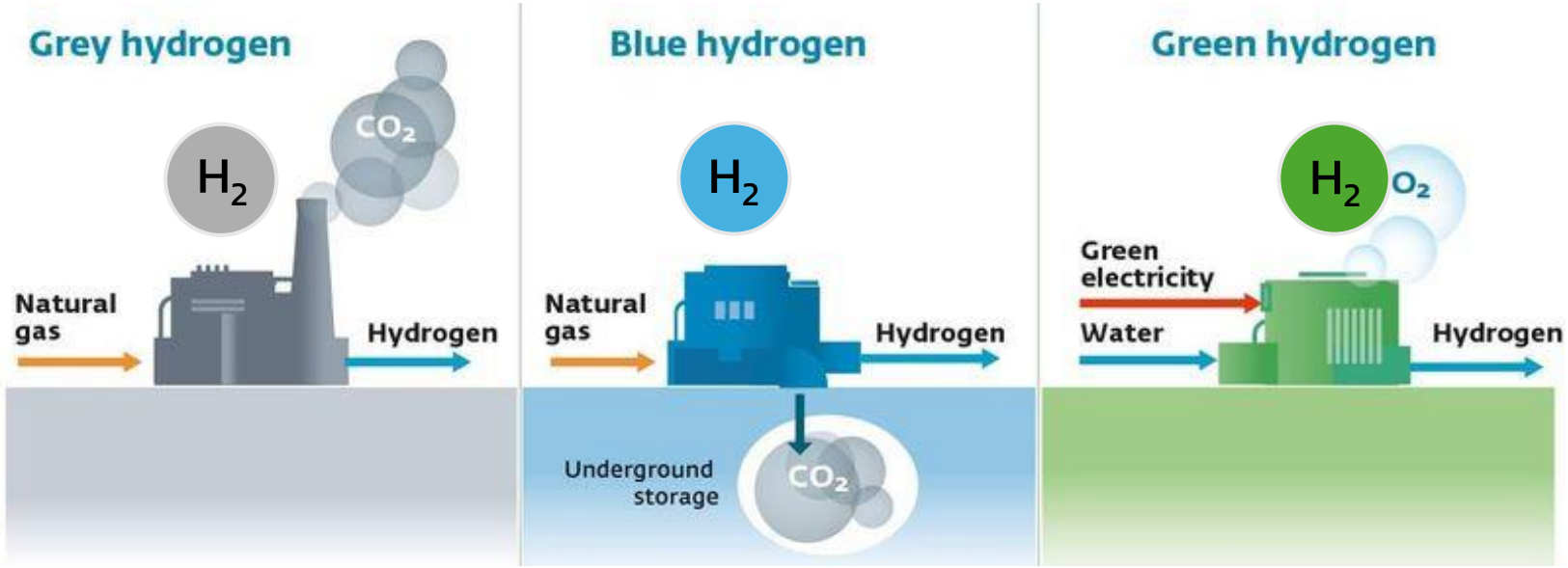
BAU: Business as Usual

THANK YOU

NAC2024
19th NSTDA Annual Conference
การประชุมวิชาการประจำปี สวทช. ครั้งที่ ๑๙

ติดต่อ:
สถาบันเทคโนโลยีและสารสนเทศเพื่อการพัฒนาที่ยั่งยืน (TIIS)
ศูนย์เทคโนโลยีโลหะและวัสดุแห่งชาติ (MTEC)
สำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ (สวทช.)
โทร. 0 2564 6500 ต่อ 4063
อีเมล์: jittim@mtec.or.th

Types of Hydrogen Fuel



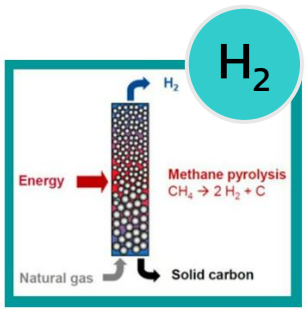
Bituminous coal is used to make black hydrogen[6]

Brown coal (lignite) is used to make brown hydrogen.[7]

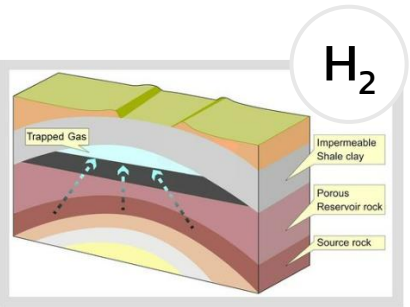
Biomass is used to make red hydrogen[8]

Nuclear power is used to make pink hydrogen.[9]

Solar power or a mix of energy sources from the electrical grid are used to make yellow hydrogen.[10]



Methane pyrolysis is used to make turquoise hydrogen.[11]



Naturally occurring geological hydrogen is called white hydrogen.[12]

[source: https://energyeducation.ca/encyclopedia/Types_of_hydrogen_fuel#cite_note-2]