world hydrogen latin america

Ammonia as Energy Vector: Challenges and Opportunities

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December, 12 , 2023 Santiago.Chile

MIGA
MILLENNIUM INSTITUTE ON GREEN AMMONIA

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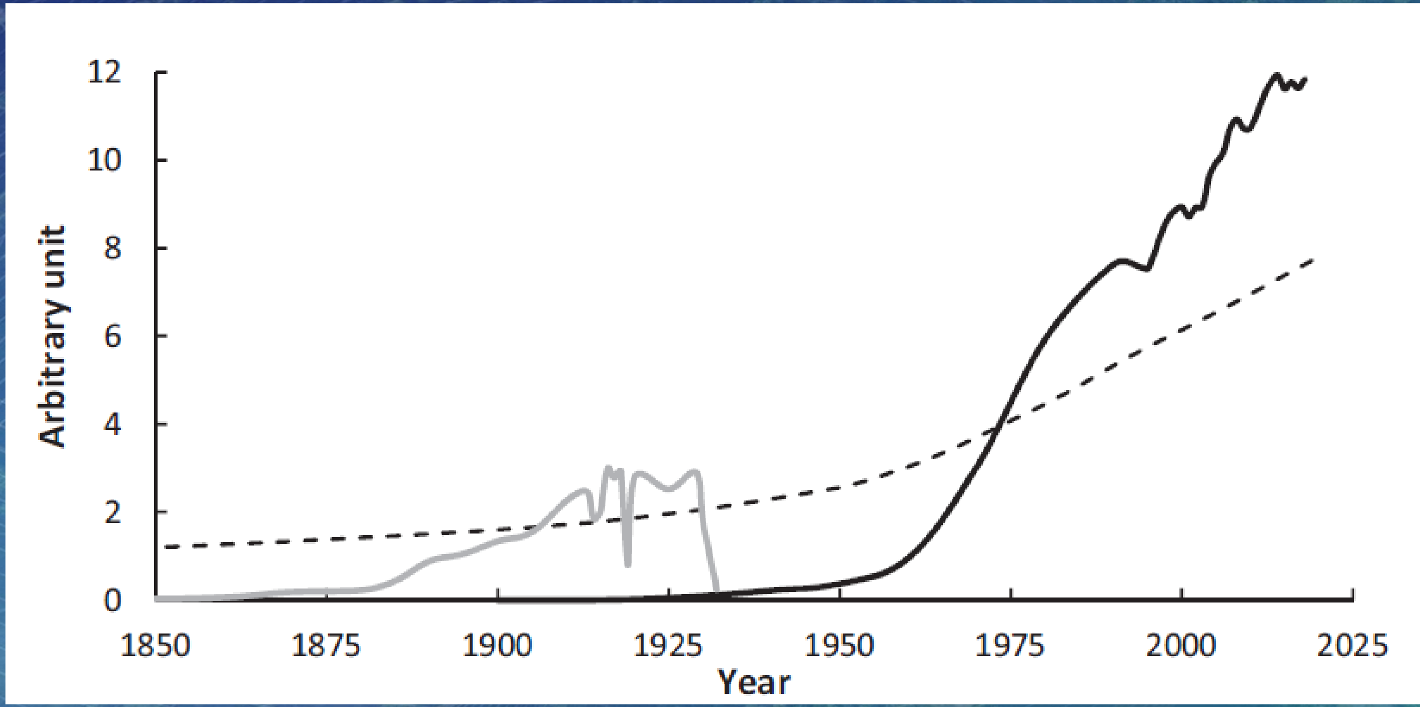
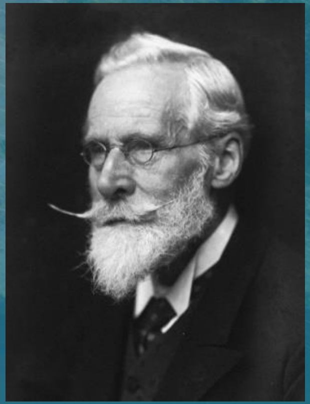
• Why green ammonia?



The dependence of the human population on the Haber-Bosch process. Dotted black line: World population (107). Gray line: Annual export of Chilean nitrate (103 kt/a). Black line: Ammonia Production by the HabereBosch process (107 t-N/a).

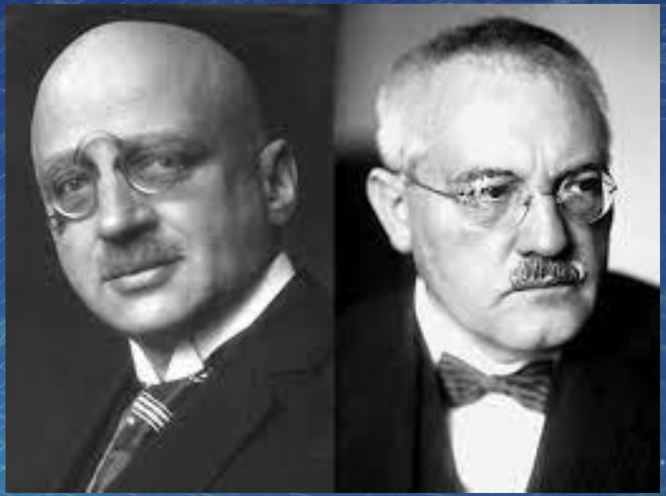
Thomas R. Malthus
1798
publishes essay on population increase and finite resources of the planet

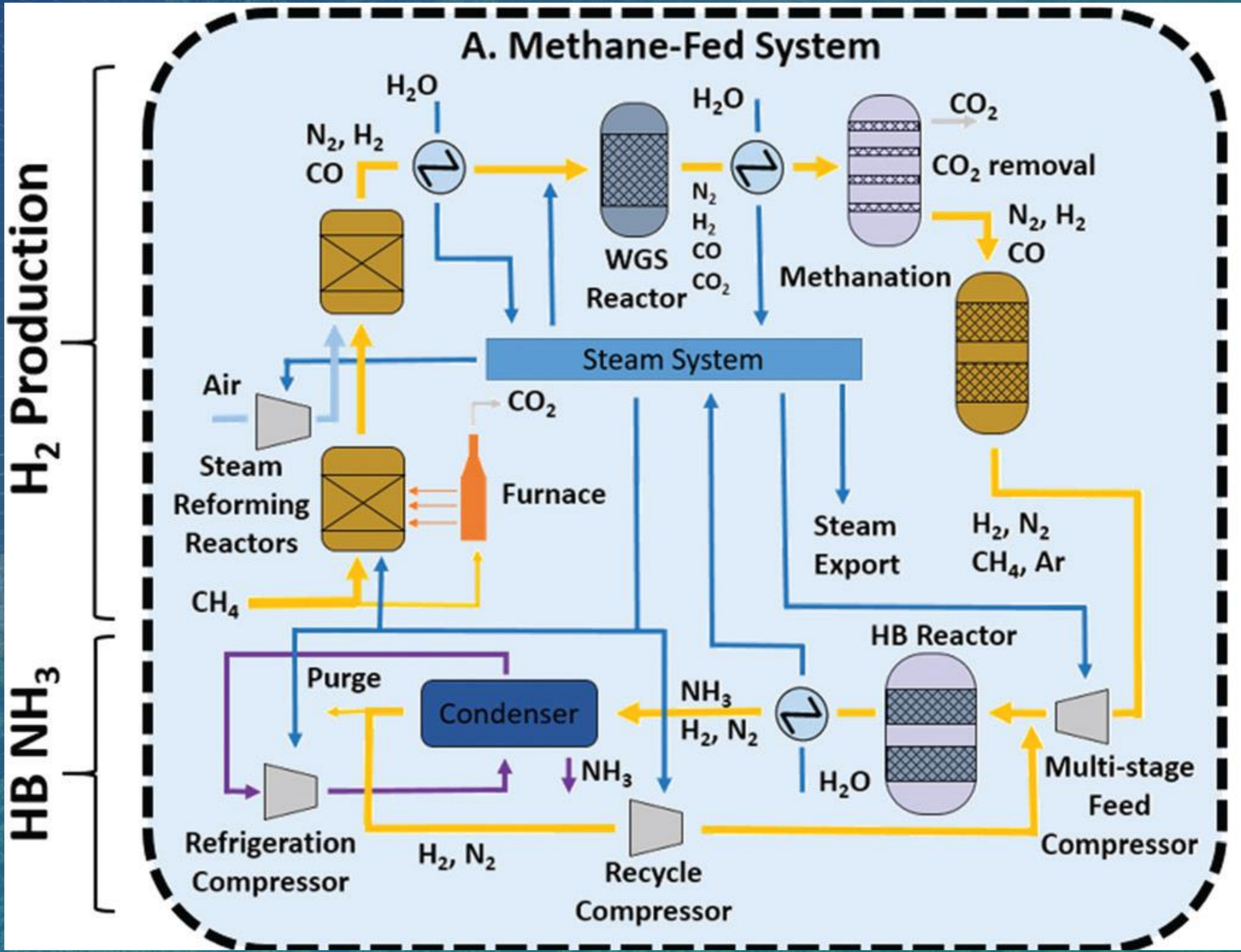


Sir William Crookes in 1898 gave a landmark speech at the British Association for the Advancement of Science in Bristol, in which he argued that the world's population would starve by 1921 due to the depletion of natural nitrate fertilizer located in deposits in Chile. Crookes called on scientists around the world to develop a synthetic process for nitrogen fixation and many heeded the call.

Techno-Economic Challenges of Green Ammonia as an Energy Vector. https://doi.org/10.1016/B978-0-12-820560-0.00004-7
2021

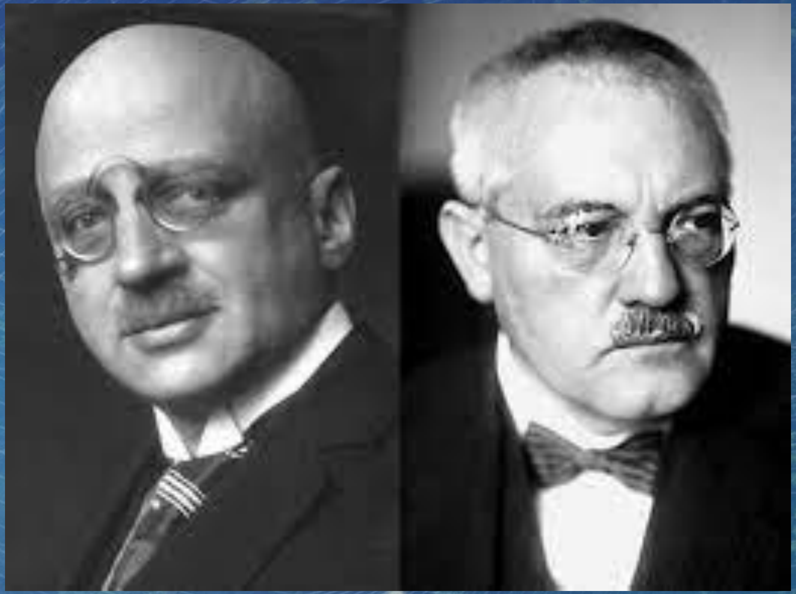
• Why green ammonia?





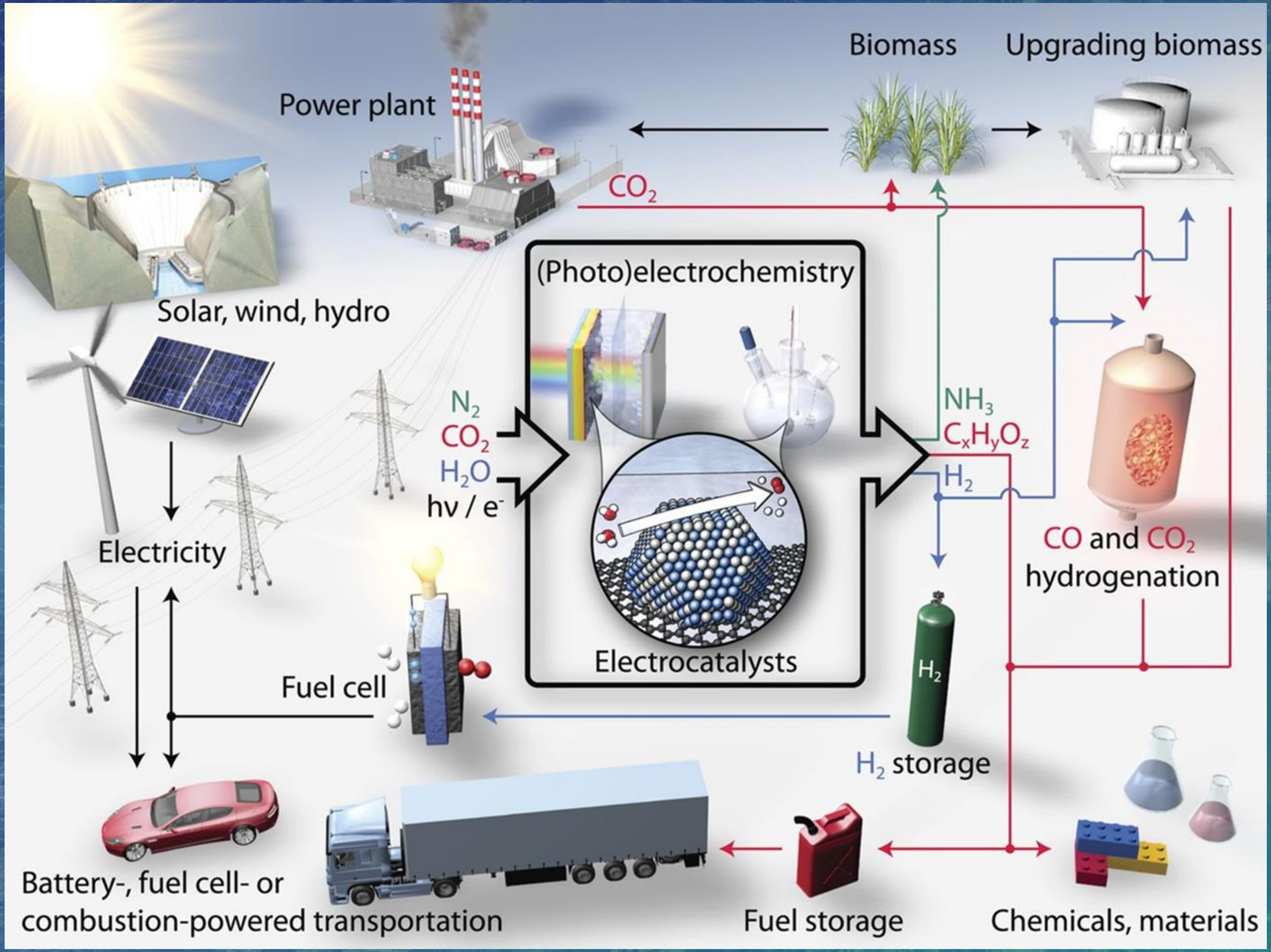
Energy Environ. Sci., 2020, 13, 331

- Why green ammonia?

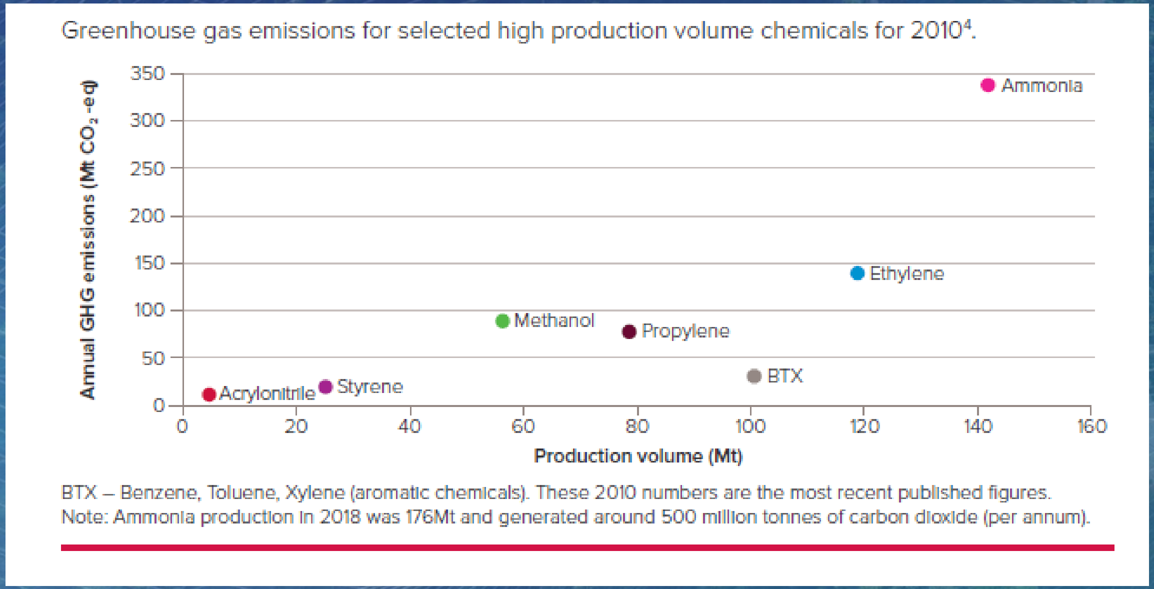


Based on the Haber-Bosch process, generates twice as much CO_2 due to the impacts of NH3
~ 2% energy consumption

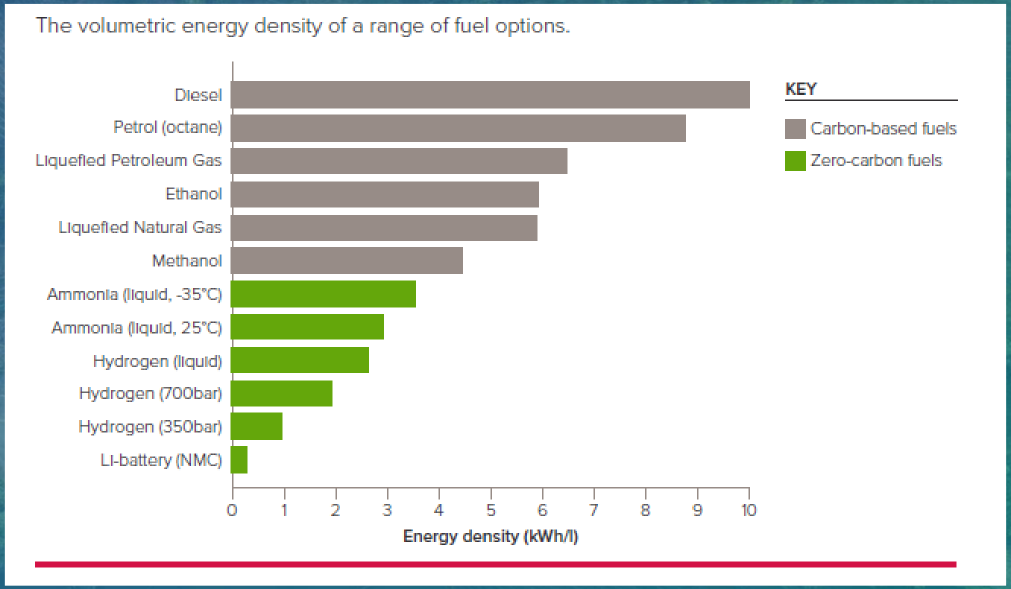
• Why green ammonia?



Ammonia as fuel



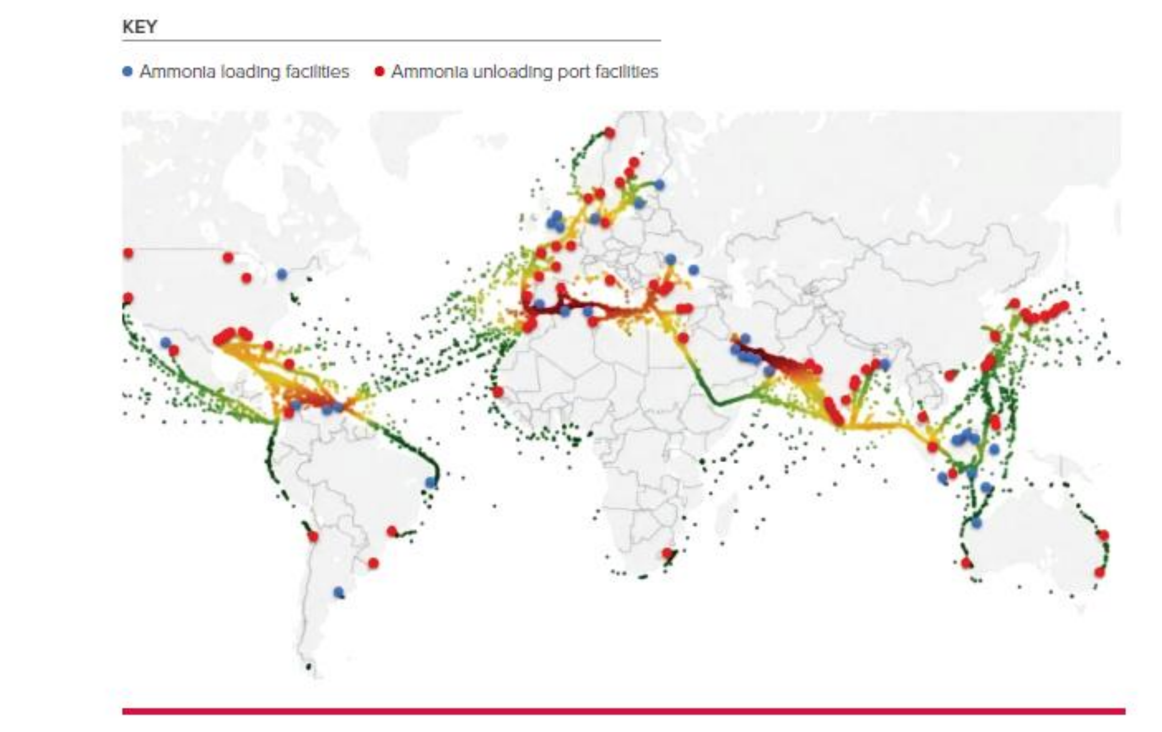
Greenhouse gas emissions for chemicals



Volumetric energy density of a range of fuel options

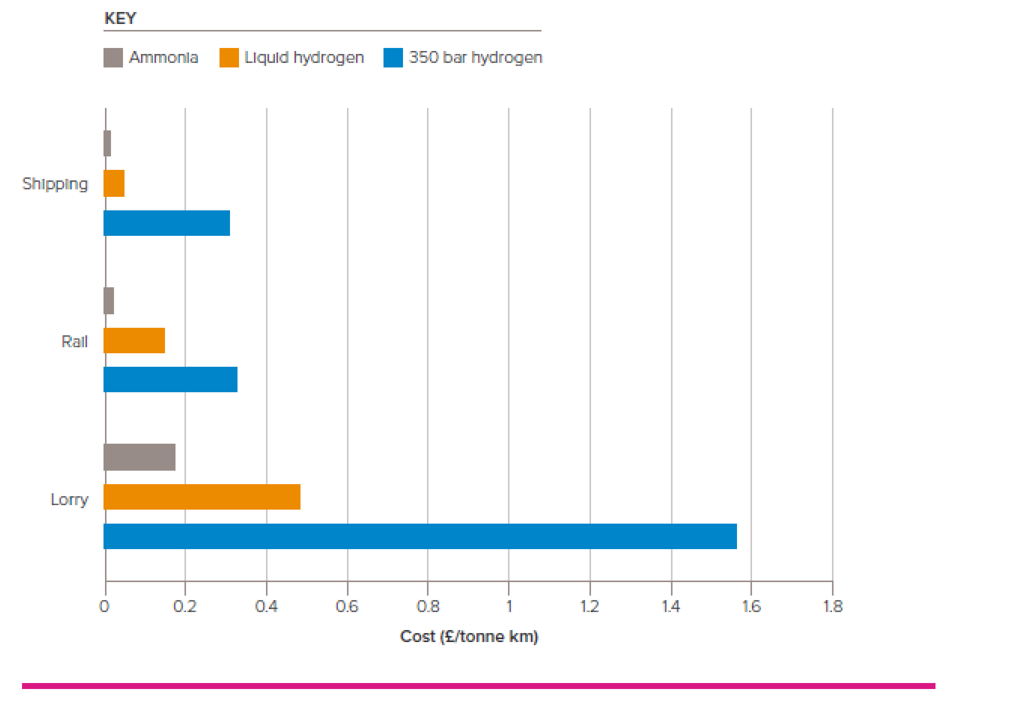
*Ammonia: zero-carbon fertiliser, fuel and energy store*Issued: February 2020 DES5711
ISBN: 978-1-78252-448-9

Ammonia as fuel



Ammonia transport networks around the world

Estimated costs for transport of hydrogen and ammonia by lorry, rail and ship[34].



Estimated costs of transporting energy vectors

*Ammonia: zero-carbon fertiliser, fuel and energy store*Issued: February 2020 DES5711
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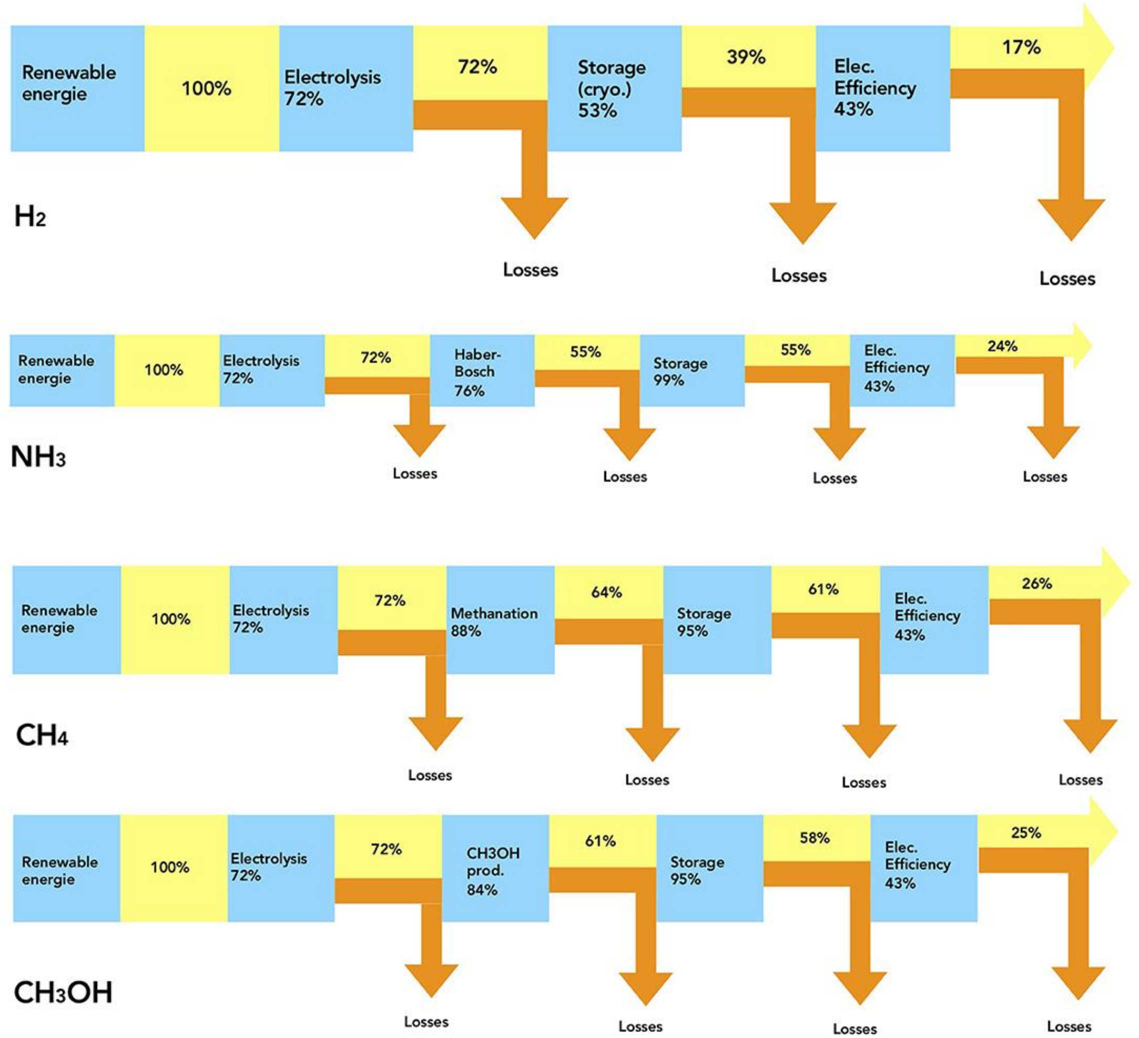
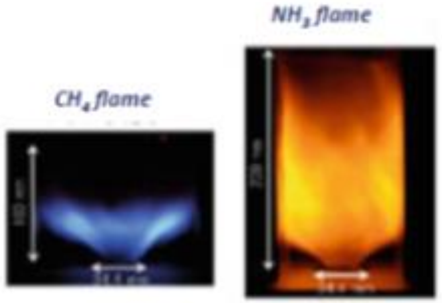
Ammonia as fuel



	Alkaline	PEM	SOEC
Electrolyte	Electrolyte potassium hydroxide (KOH) of typically 25–35% w/w[a]	Thin (0.2 mm) polymer, such as perfluorosulfonic acid (PFSA) polymers[a]	ZrO2 doped with 8 mol% of Y2O3 (YSZ)[a]
Maturity	Mature[b]	Early phase of commercialization[b]	Development[b]
Operation parameters			
Cell temperature (°C)	80–140[a]	20–80[a]	650–1,000[a]
	40–90[b]	20–100[b]	600–1,000[b]
	60–90[c]	50–80[c]	700–900[c]
Pressure (bar)	35[a]	10–30[a]	10[a]
	<30[b]	<100[b]	–
	10–30[c]	20–50[c]	1–15[c]
Current density (A/cm^2)	0.2–0.4[b]	1–2[b]	–
	0.25–0.45[c]	1–2[c]	0.3–1[c]
Flexibility			
Load Flexibility (% of nominal load)	20–100[c]	0–100[c]	–100/+100[c]
Cold start-up time	20 min[b]	5 min[b]	–
	1–2 h[c]	5–10 min[c]	Hours[c]
Warm start-up time	1–5 min[c]	<10 s[c]	15 min[c]
Efficiency			
Nominal sta ck efficiency (LHV) %	63–71[c]	60–68[c]	100[c]
Nominal system efficiency (LHV) %	62–82[b]	67–82[b]	–
	51–60[c]	46–60[c]	76–81[c]
	67–70[d]	67–74[d]	–
Electricity-to-hydrogen efficiency (%)	65–74[e]	62–79[e]	77–81[e]
Available capacity			
Max. nominal power per stack (MW)	6[c]	2[c]	<0.01[c]
H2 production per stack (NM^3/h)	1,400[c]	400[c]	<10[c]
Cell area (m^3)	<3.6[c]	<0.13[c]	<0.06[c]
Durability			
Life time (kh)	55–120[c]	60–100[c]	(8–20)[c]
Efficiency degradation (%/y)	0.25–1.5[c]	0.5–2.5[c]	3–50[c]
Economic Parameter			
Investment costs (€/kW)	800–1,500[c]	1,400–2,100[c]	(>2,000)[c]
	1,000[d]	2,000[d]	–
	600–2,600[e]	1,900–3,700[e]	–
Maintenance costs (% of inve stment costs per year)	2–3[c]	3–5[c]	n.a.[c]
	2–5[e]	2–5[e]	2–3[e]

Ammonia as fuel



■ Elucidation of NH_3 combustion mechanism

By the scientific research on NH_3 combustion mechanism, it was confirmed that:

- stable combustion of NH_3 is possible;
- formation of NO_X can be controlled and emission of other air pollutants, such as N_2O and NH_3 can be contained by adjusting combustion conditions.

■ Development of 100% NH_3 or Coal-NH_3, CH_4-NH_3 mixed combustion equipment

(Gas turbine)		
- Micro (50-300kW) gas turbine	(NH_3 100% fuel) :	Developed and in a commercialization stage
- MW class gas turbine	(20% NH_3 mixed combustion):	Developed and in a commercialization stage
	(~70% NH_3 mixed combustion):	Under development
- 500-600 MW class gas turbine	(NH_3 used as H_2 carrier):	Under development
(Coal fired boiler)		
- 10 MW pulverized coal fired boiler	(20% NH_3 mixed combustion):	Developed and in a commercialization stage
	(~60% NH_3 mixed combustion):	Under development
- 1 GW pulverized coal fired boiler	(20% NH_3 mixed combustion):	Plan to implement in 2025-26
(Industrial furnace)		
- 100 kW furnace:	(20% NH_3 - Coal mixed combustion):	Demonstrated.
- Degreasing furnace:	(30% NH_3- CH_4 mixed combustion):	Verified applicability of the mixed combustion.

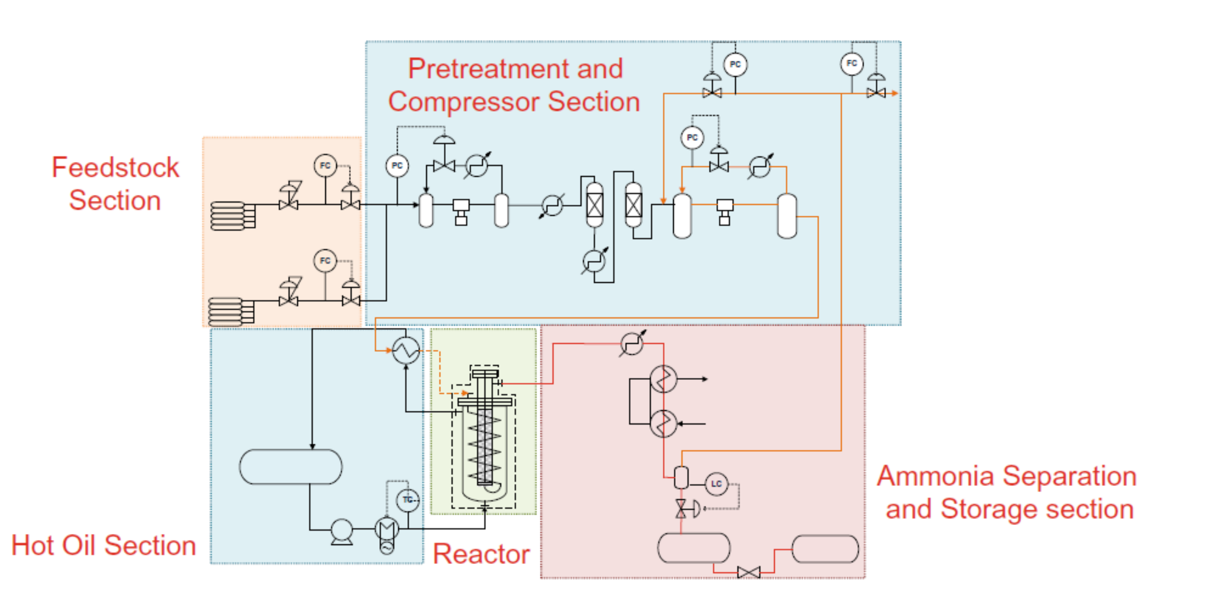
■ NH_3 fueled SOFC (Solid oxide fuel cell)

- 1 kW NH_3 fueled solid oxide fuel cell system:	Developed.
- 300 kW NH_3 fueled solid oxide fuel cell system:	Under development

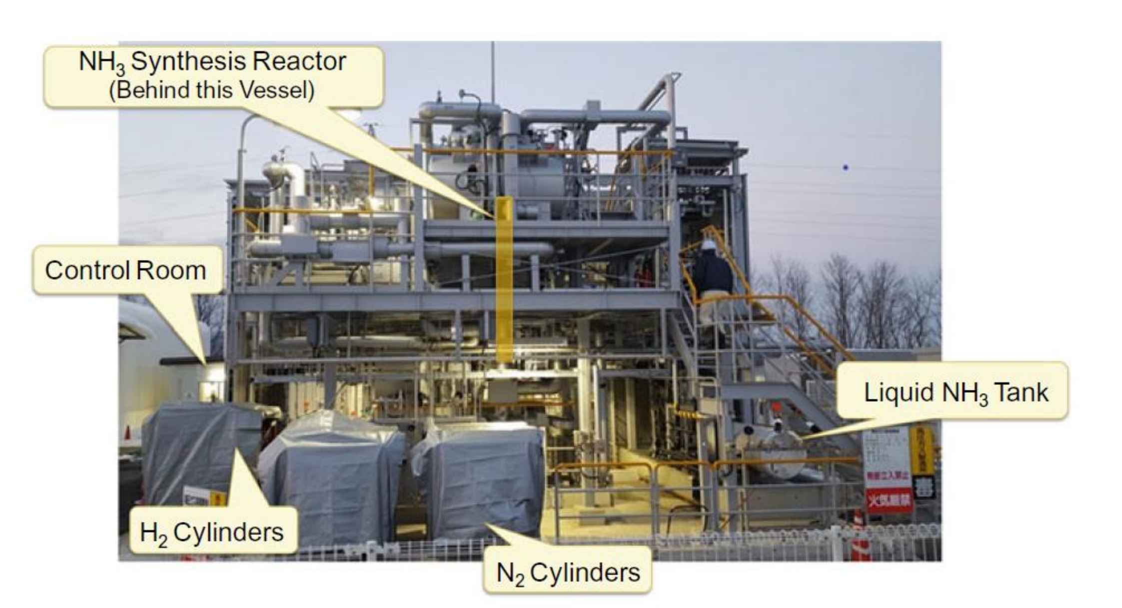
Combustion projects developed in Japan

ISBN 978-981-19-4766-7
ISBN 978-981-19-4767-4 (eBook) https://doi.org/10.1007/978-981-19-4767-4

• New trends in ammonia production



Schematic process flow diagram of the demonstration plant in AIST FREA



Photograph of the demonstration plant in AIST FREA (courtesy of AIST)

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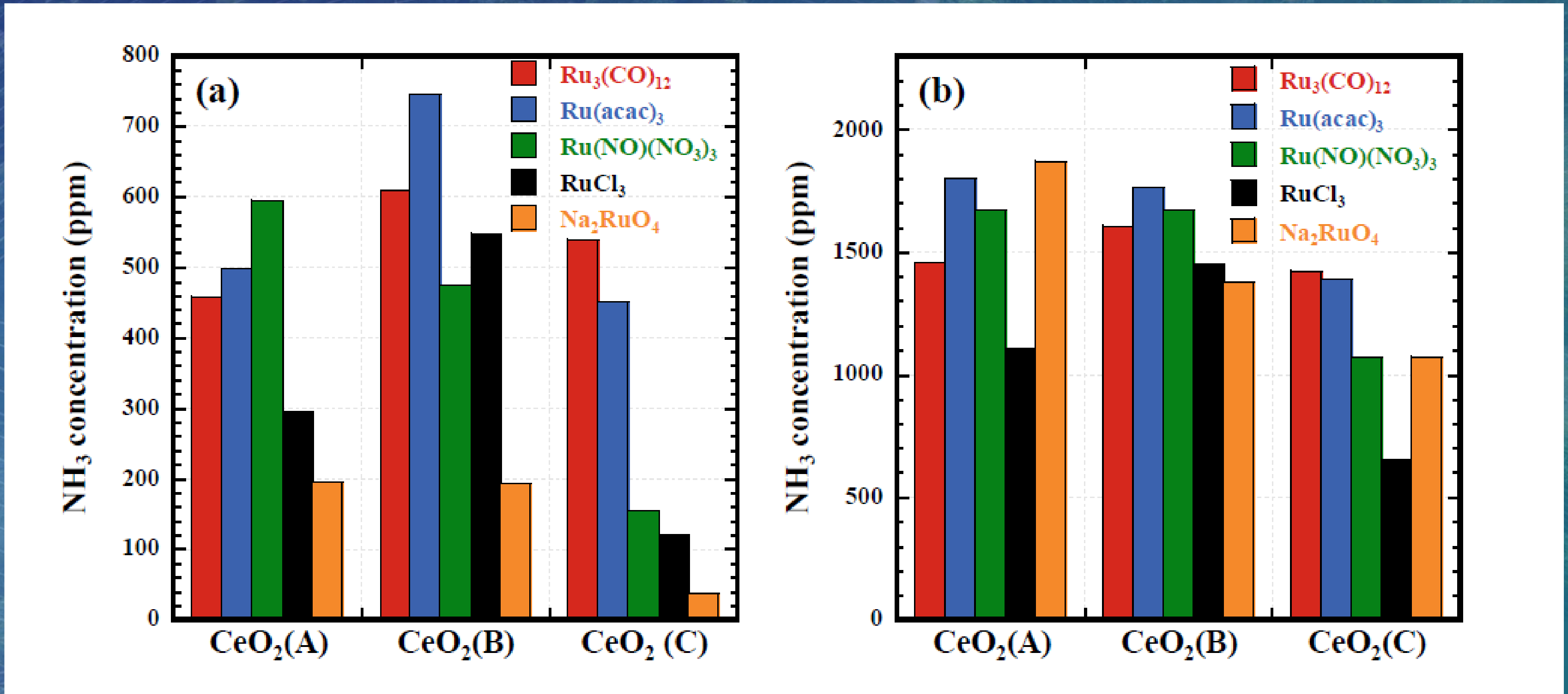
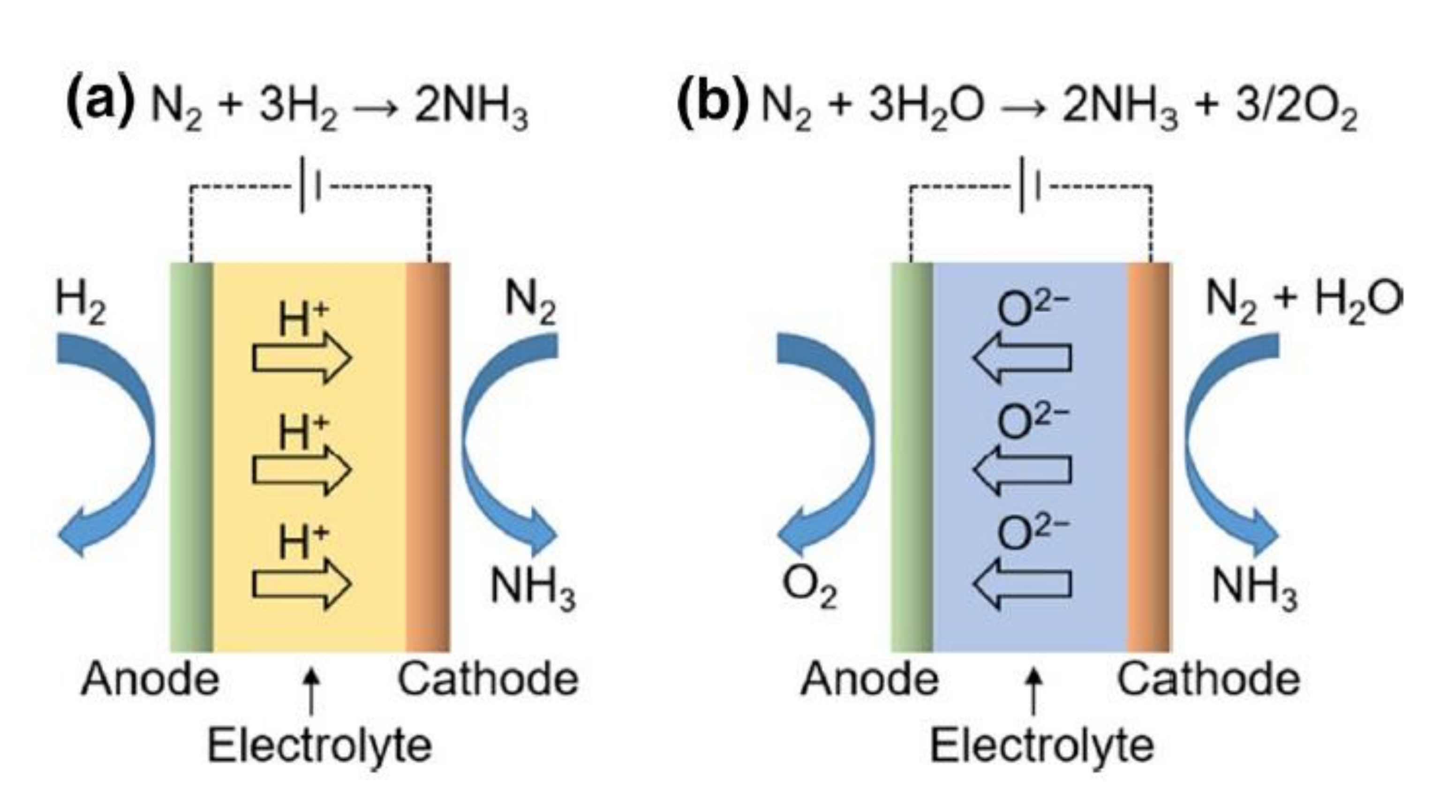
Ammonia as fuel



NH_3 synthesis activity of various 1 wt% Ru/CeO_2 catalysts prepared using the indi-cated catalyst and support precursors. a NH3 concentration in the effluent gas. b Maximum NH3 concentration. Catalyst weight: 0.2 g, flow rate: 80 mL/min (H2/N2 = 3), ambient pressure, 325 °C

• New trends in ammonia production

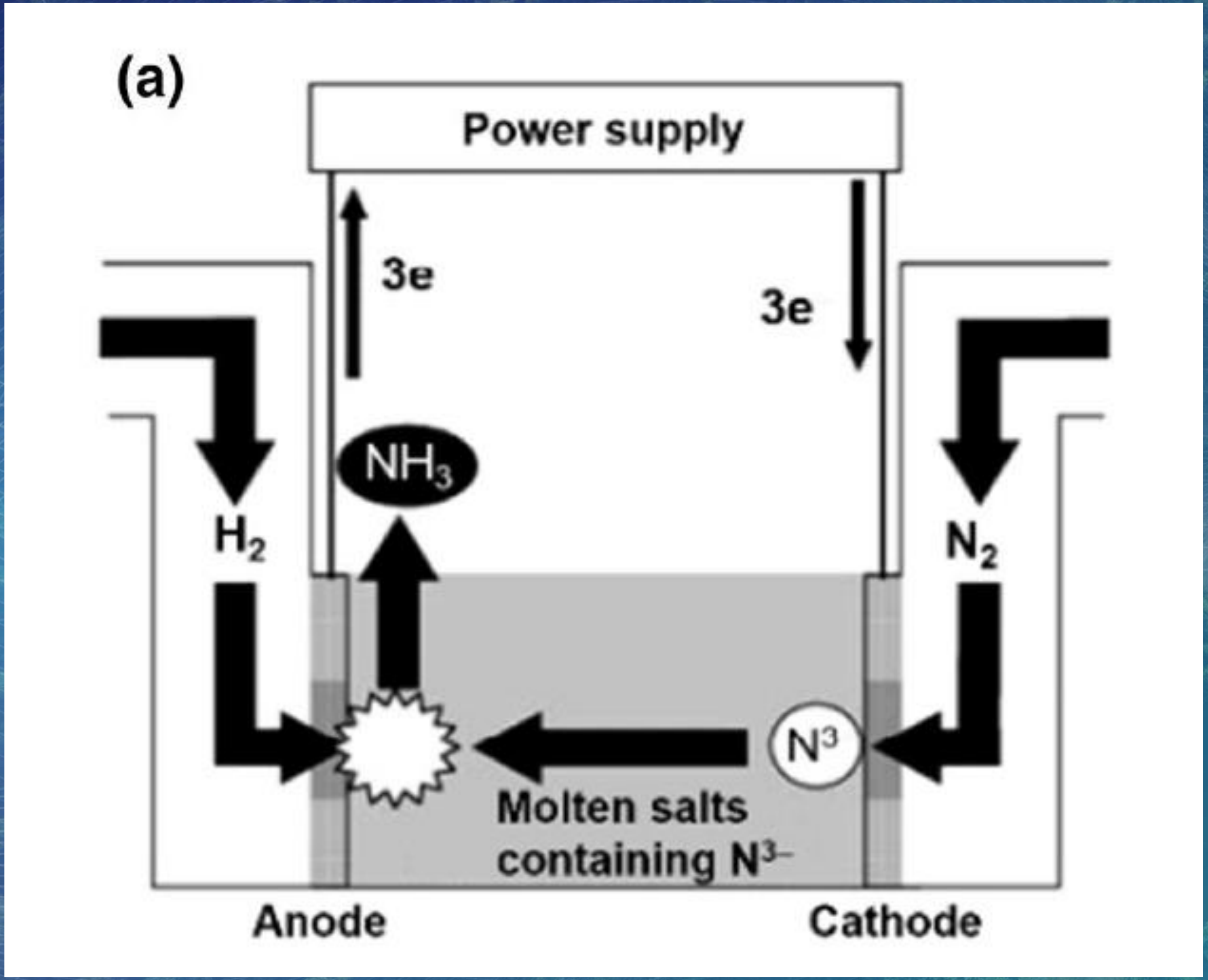


Solid state processes

Schematic of SSAS systems using A) solid-state proton-conducting electrolyte and B) solid-state oxygen anion-conducting electrolyte. The inert carrier gas is omitted.

Transactions of Tianjin University (2020) 26:67–91
https://doi.org/10.1007/s12209-020-00243-x

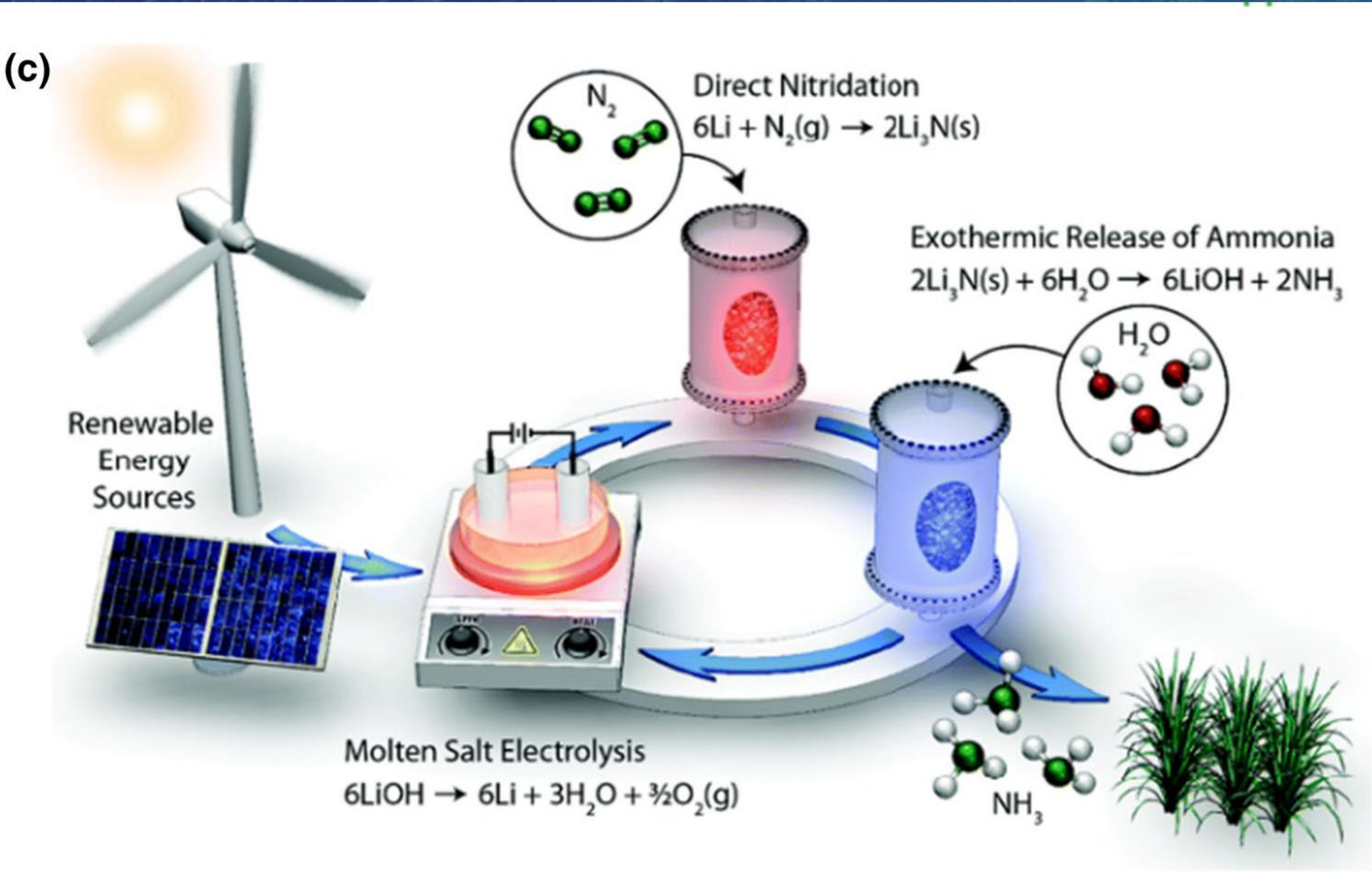
• New trends in ammonia production



Electrochemical synthesis of NH3 in molten electrolytes.
Scheme of the principle of electrolytic synthesis of NH_3 from N_2 and H_2 in molten salts of LiCl–KCl–CsCl containing
N_3–.

Transactions of Tianjin University (2020) 26:67–91
https://doi.org/10.1007/s12209-020-00243-x

• New trends in ammonia production



C) Scheme of a lithium-mediated step-by-step cycle process for sustainable production of NH3 from N2 and H2O driven by renewable energy sources

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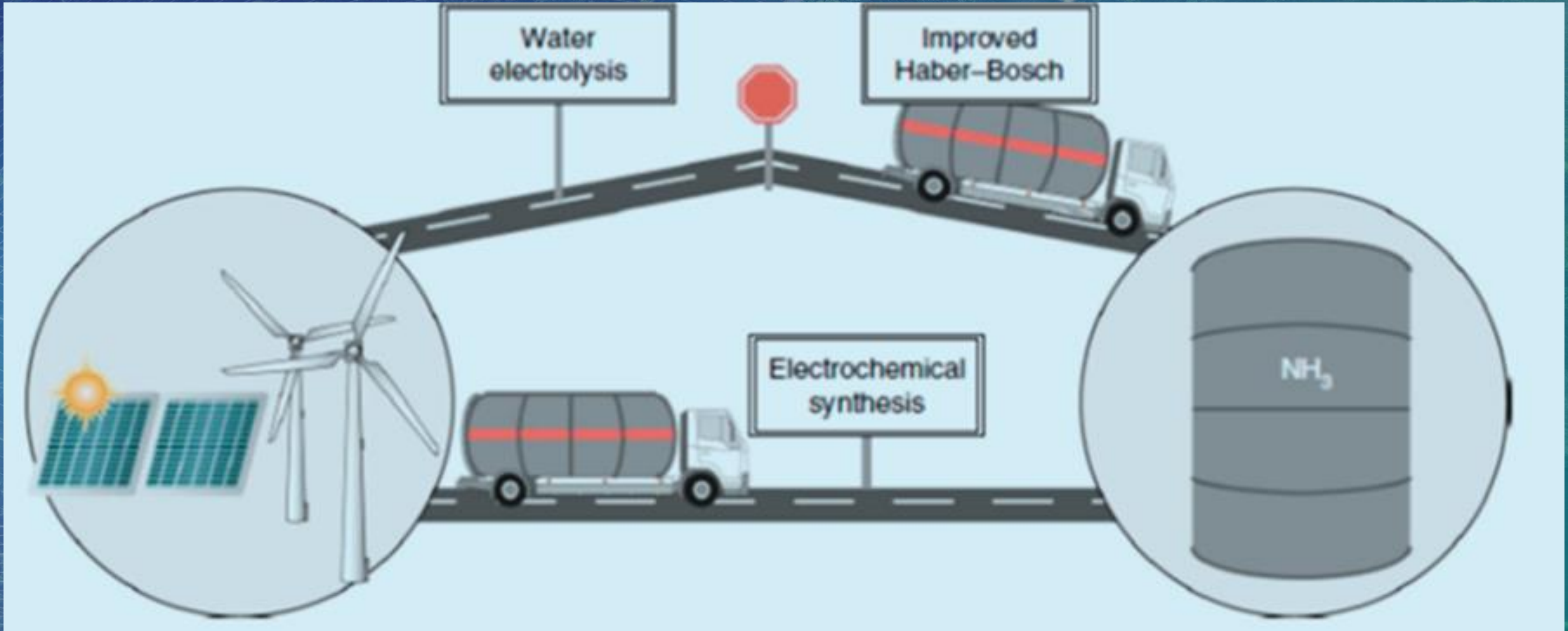
- New trends in ammonia production



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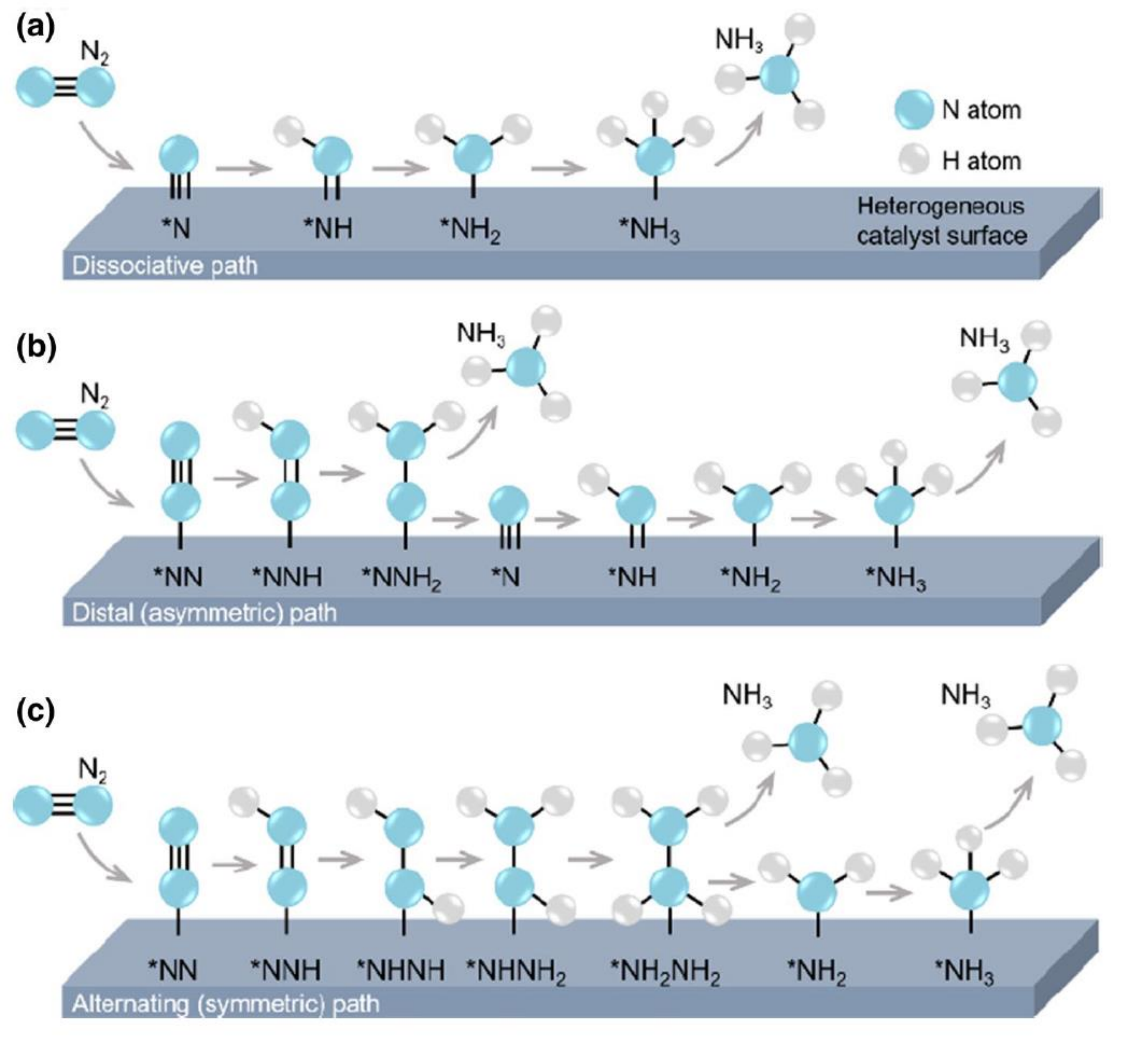

Nitrogen reduction pathways in heterogeneous CAT dissociative pathway where the N≡N bond is broken before hydrogenation. Association pathways that include B) distal or asymmetric hydrogenation and C) alternating or symmetrical hydrogenation.

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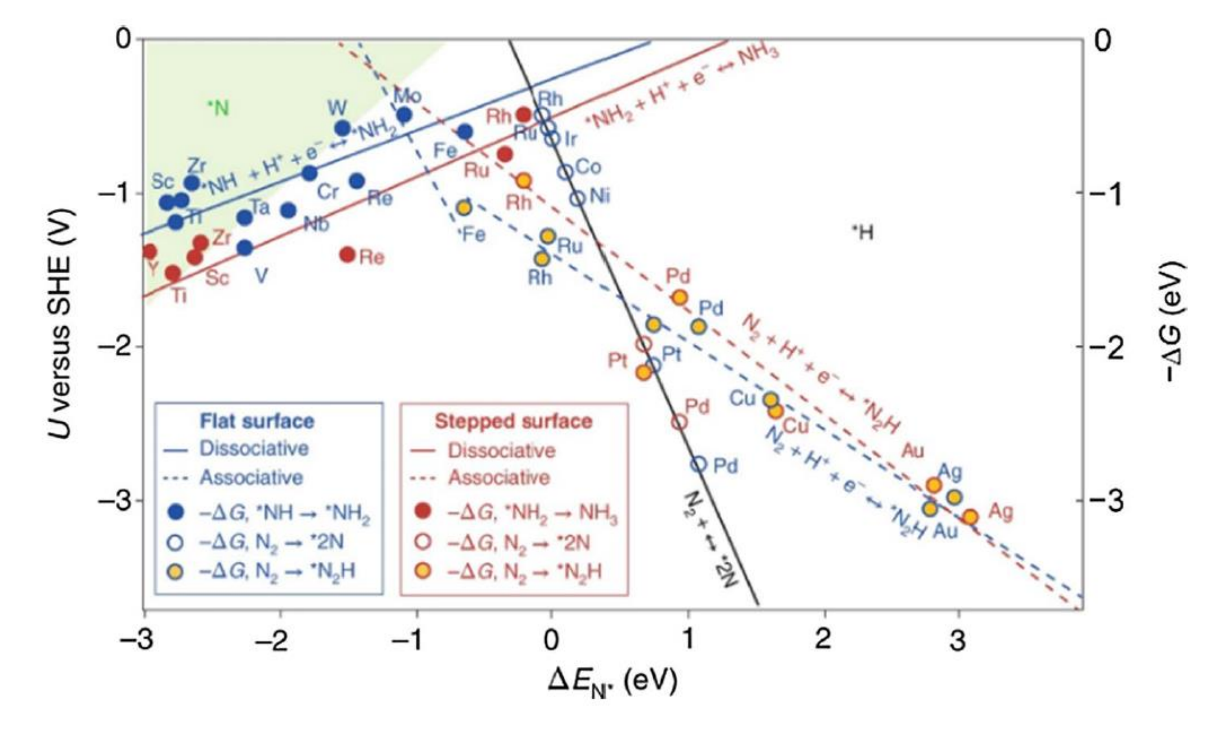

Combined volcano diagrams evaluating the onset potential (U) on different transition metals. Solid lines represent dissociative mechanisms and dashed lines represent associative mechanisms.

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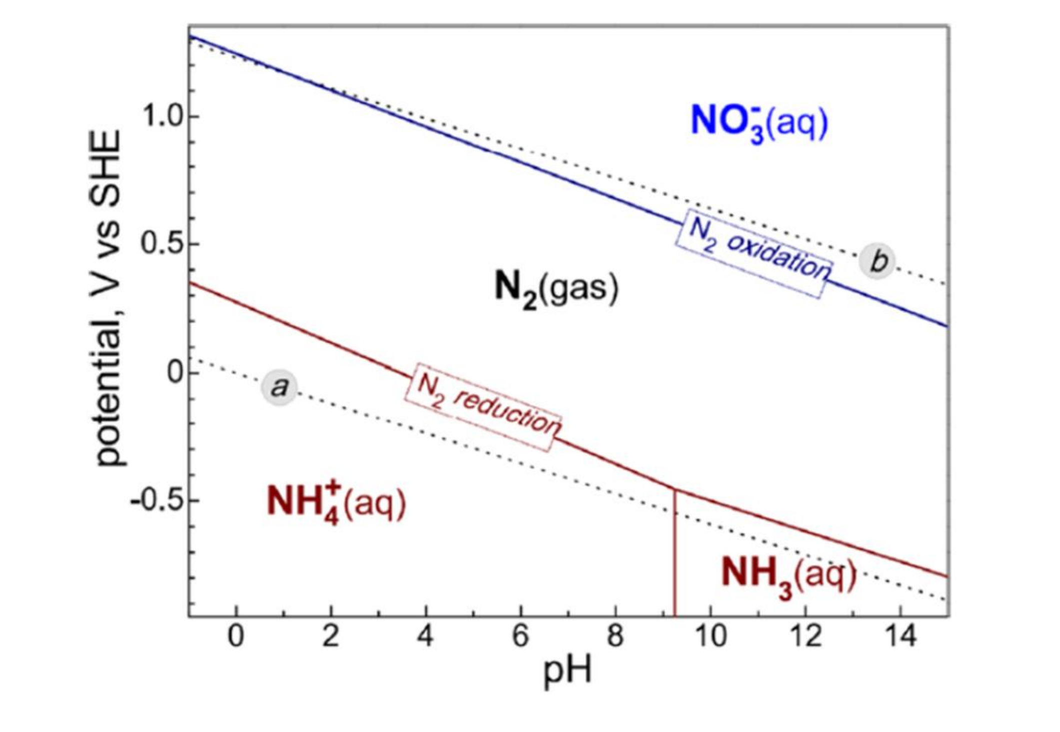
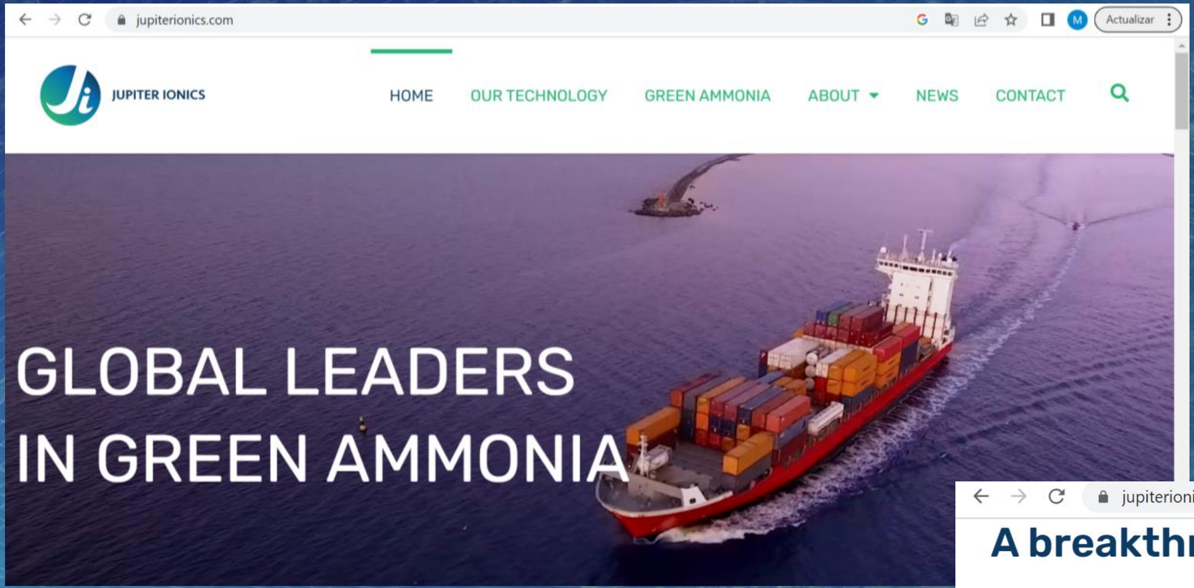


Partial Pourbaix diagram for the N2–H2O system. The red line represents the reduction of N2 to NH4 + or NH3, while the blue line denotes oxidation of N2 oxidation to NO3 −. Dashed lines a and b represent reduction of H2O to H2 and oxidation to O2, respectively.

• New trends in ammonia production



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A breakthrough cell

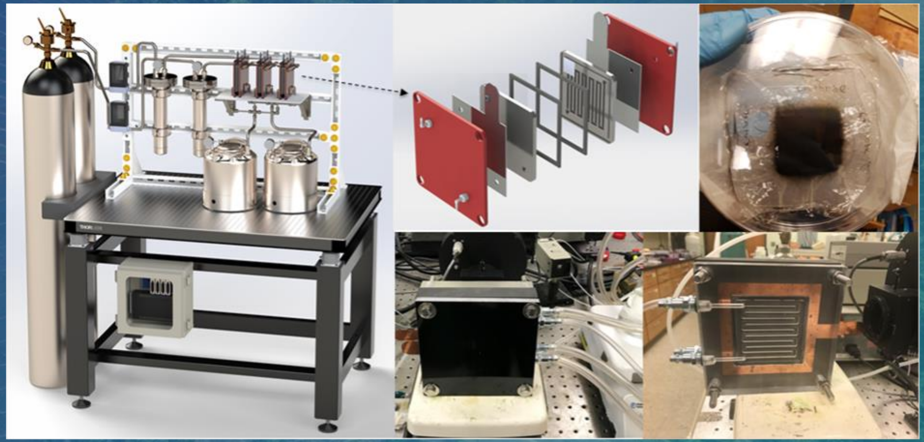
Developed by world-leading researchers at Monash University, Jupiter Ionics' breakthrough electrolytic cell* uses a unique, high-performance design that optimises efficiency, durability and ammonia production. Our team of talented scientists and engineers continues to push the boundaries of technology in search of ever greater performance.

The **MacFarlane Simonov Ammonia Cell** is the first of its kind to demonstrate ammonia generation with 100% selectivity, and has shown good stability in lab tests.

The MacFarlane Simonov Ammonia Cell

**A cell comprises two separated electrodes in a conductive liquid or gel electrolyte. Battery cells use chemical reactions to generate electrical energy. Conversely, electrolytic cells like ours use electrical energy to drive chemical reactions.*

- New trends in ammonia production



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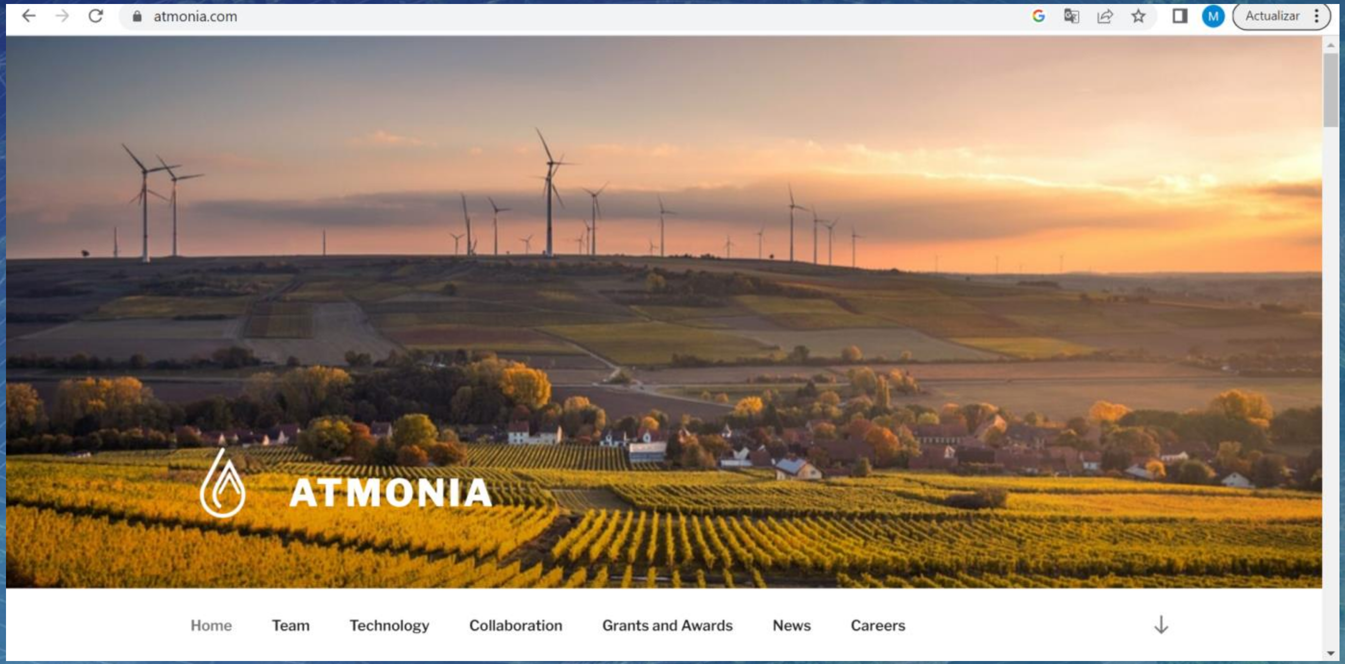

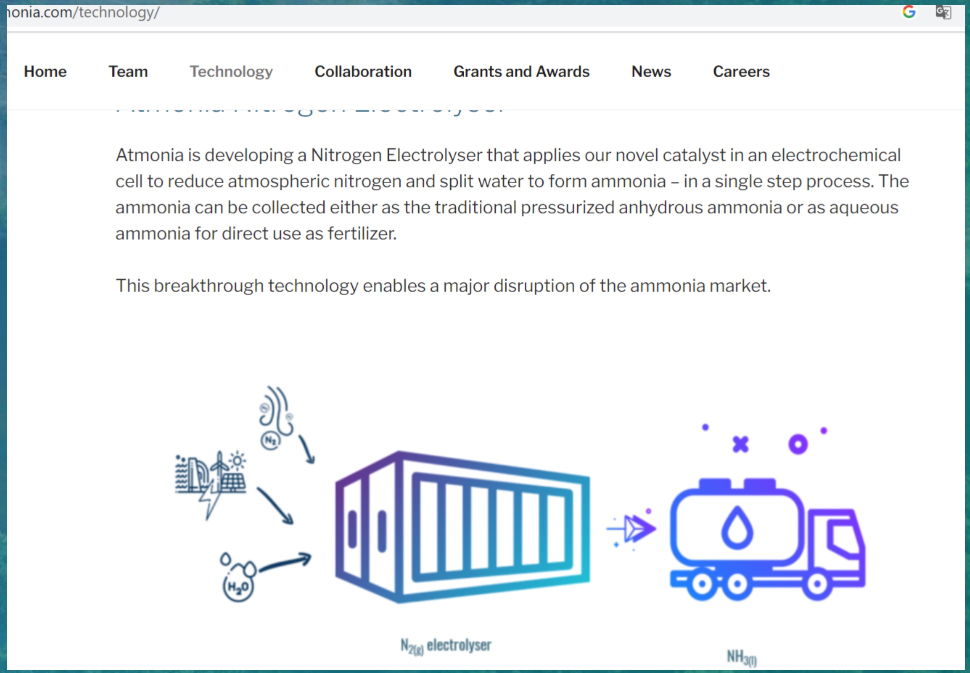

• New trends in ammonia production

Table 1 Summary of representative developments in electrochemical NH_3 synthesis

Electrolyte type	Reactants	Electrode/catalyst	Conditions[a]	NH_3 yield [mol/(cm^2 s)][b]	Current efficiency (%)	Applied potential[c]	References
Solid	N_2/H_2	Porous Pd	$SrCe_{0.95}Yb_{0.05}O_3$, 570 °C	4.5×10^{-9}	78.00	N.A.[d]	[37]
	N_2/H_2	Ag–Pd	$BaCe_{0.80}Gd_{0.10}Sm_{0.10}O_{3-\delta}$, 620 °C	5.82×10^{-9}	N.A.	0.6 V	[44]
	N_2/H_2	Ag–Pd	$Ce_{0.8}Sm_{0.2}O_{2-\delta}$, 650 °C	8.2×10^{-9}	N.A.	0.6 V	[47]
	N_2/H_2	$SmFe_{0.7}Cu_{0.3-x}Ni_xO_3$	Nafion, 80 °C	1.13×10^{-8}	90.40	2 V	[48]
Molten	N_2/H_2	Porous Ni	Molten LiCl–KCl–CsCl with 0.5 mol% Li_3N, 400 °C	3.33×10^{-8}	72.00	0.7 V versus Li^+/Li	[60]
	N_2/H_2O	Ni electrode, nano-Fe_2O_3 catalyst	Molten NaOH/KOH, 200 °C	1.0×10^{-8}	35.00	1.2 V	[36]
Aqueous	N_2/H_2O	Au film	0.1 mol/L KOH	3.84×10^{-12}	0.12	−0.5 V versus RHE	[81]
	N_2/H_2O	Au nanoclusters	0.1 mol/L HCl	1.12×10^{-10}	8.11	−0.2 V versus RHE	[84]
	N_2/H_2O	Pd NP	0.1 mol/L PBS	1.7×10^{-11}	8.20	0.1 V versus RHE	[86]
	N_2/H_2O	Bi nanocrystals	0.5 mol/L K_2SO_4, pH 3.5	1.44×10^{-8}	66.00	−0.6 V versus RHE	[87]
	N_2/H_2O	$Bi_4V_2O_{11}/CeO_2$	0.1 mol/L HCl	7.6×10^{-10}	10.16	−0.2 V versus RHE	[93]
	N_2/H_2O	Ru/MoS_2	0.01 mol/L HCl, 50 °C	1.14×10^{-10}	17.60	−0.15 V versus RHE	[97]
	N_2/H_2O	VN NP	0.05 mol/L H_2SO_4	3.3×10^{-10}	6.00	−0.1 V versus RHE	[104]
Nonaqueous liquid	N_2/H_2O	Nanostructured Fe	$[P_{6,6,6,14}]$[eFAP]	2.1×10^{-11}	60.00	−0.8 V versus RHE	[117]
	N_2/H_2O	Ag–Au@ZIF	$LiCF_3SO_3$ (0.2 mol/L) in THF/ethanol (99:1 *V/V*)	9.5×10^{-12}	18.00	2.9 V	[119]

[a]Conditions indicate electrolyte, temperature, and pressure. Unless otherwise specified, the experiments were conducted under RT and ambient pressure

[b]From given or calculated data based on reference data in the literature. Normalized based on the geometric areas of the electrodes

[c]The potentials without a reference refer to the cell potentials

[d]N.A. stands for not applicable

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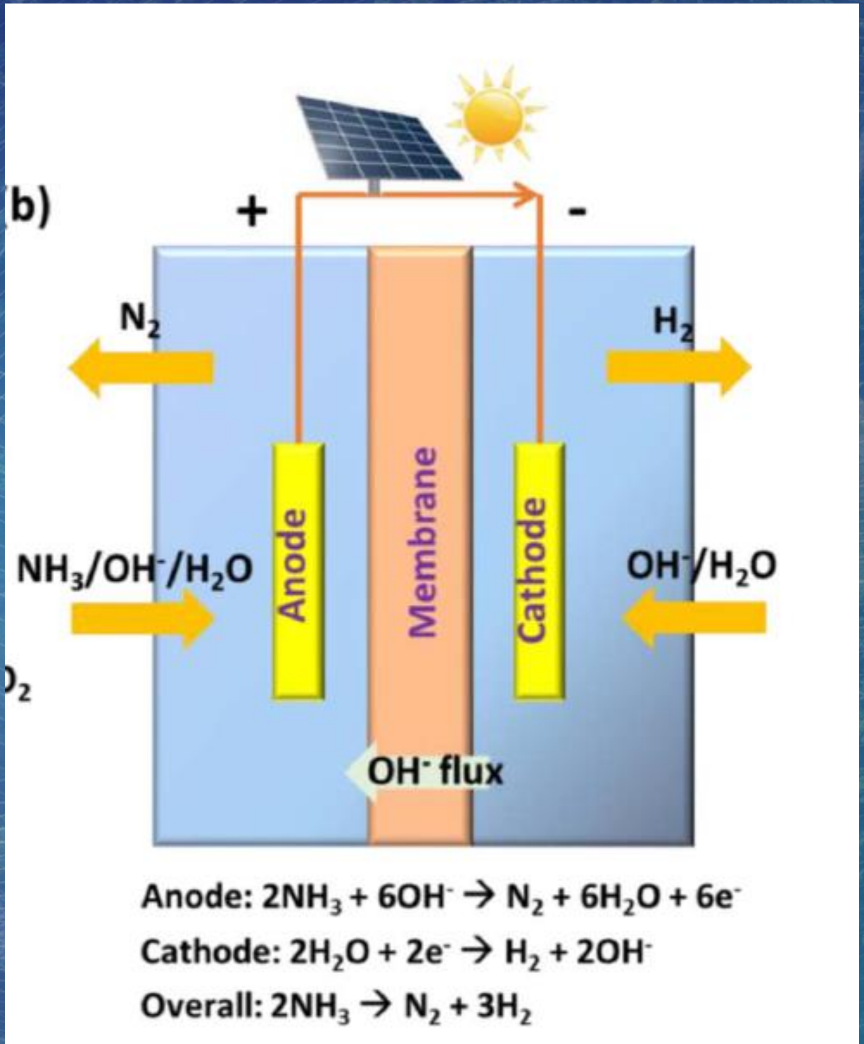
Ammonia Electrolysis (Hydrogen production)

The ammonia electro-oxidation reaction (AOR) is discussed as a means for energy application either by electrochemical decomposition for in situ hydrogen generation or by direct employment of ammonia as fuel in a direct ammonia fuel cell. . The development of a robust and stable AOR catalyst is critical for both applications, along with the development of high-performance HER and ORR catalysts.

Ammonia Electrolysis (Hydrogen production)



$$\textbf{Anode:}\quad 2\,NH_3 + 6\,OH^- \rightarrow N_2 + 6\,H_2O + 6\,e^- \qquad E^\circ = -0.77\ V\ vs.\ SHE \qquad [4a]$$

$$\textbf{Cathode:}\ 6\,H_2O + 6\,e^- \rightarrow 3\,H_2 + 6\,OH^- \quad E^\circ = -0.83\ V\ vs.\ SHE \qquad [4b]$$

$$\textbf{Overall:}\quad 2\,NH_3 \rightarrow N_2 + 3\,H_2 \quad E_{cell} = 0.06V \qquad [4c]$$

- Ammonia fuel cells

Ammonia fuel cells can be divided into external decomposition and direct utilization according to the working gas.

External decomposition breaks ammonia into nitrogen and hydrogen using additional apparatus, adding complexity and cost to the system. In contrast, the direct ammonia fuel cell does not require external gas reforming, leading to a simplified system and better cost effectiveness. Direct ammonia fuel cells are divided into two main types, namely, alkaline electrolyte types (alkaline solution, molten hydroxide, alkaline membrane) and solid electrolyte types.

are summarized in the following Table

Direct ammonia SOFC-H

Anode: $2\,NH_3 \rightarrow 3\,H_2 + N_2$

$H_2 \rightarrow 2\,H^+ + 2\,e^-$

Cathode: $\frac{1}{2}\,O_2 + 2\,H^+ + 2\,e^- \rightarrow H_2O$

Direct ammonia SOFC-O

Anode: $2\,NH_3 \rightarrow 3H_2 + N_2$

$H_2 + O^{2-} \rightarrow H_2O + 2\,e^-$

Cathode: $\frac{1}{2}\,O_2 + 2\,e^- \rightarrow O^{2-}$

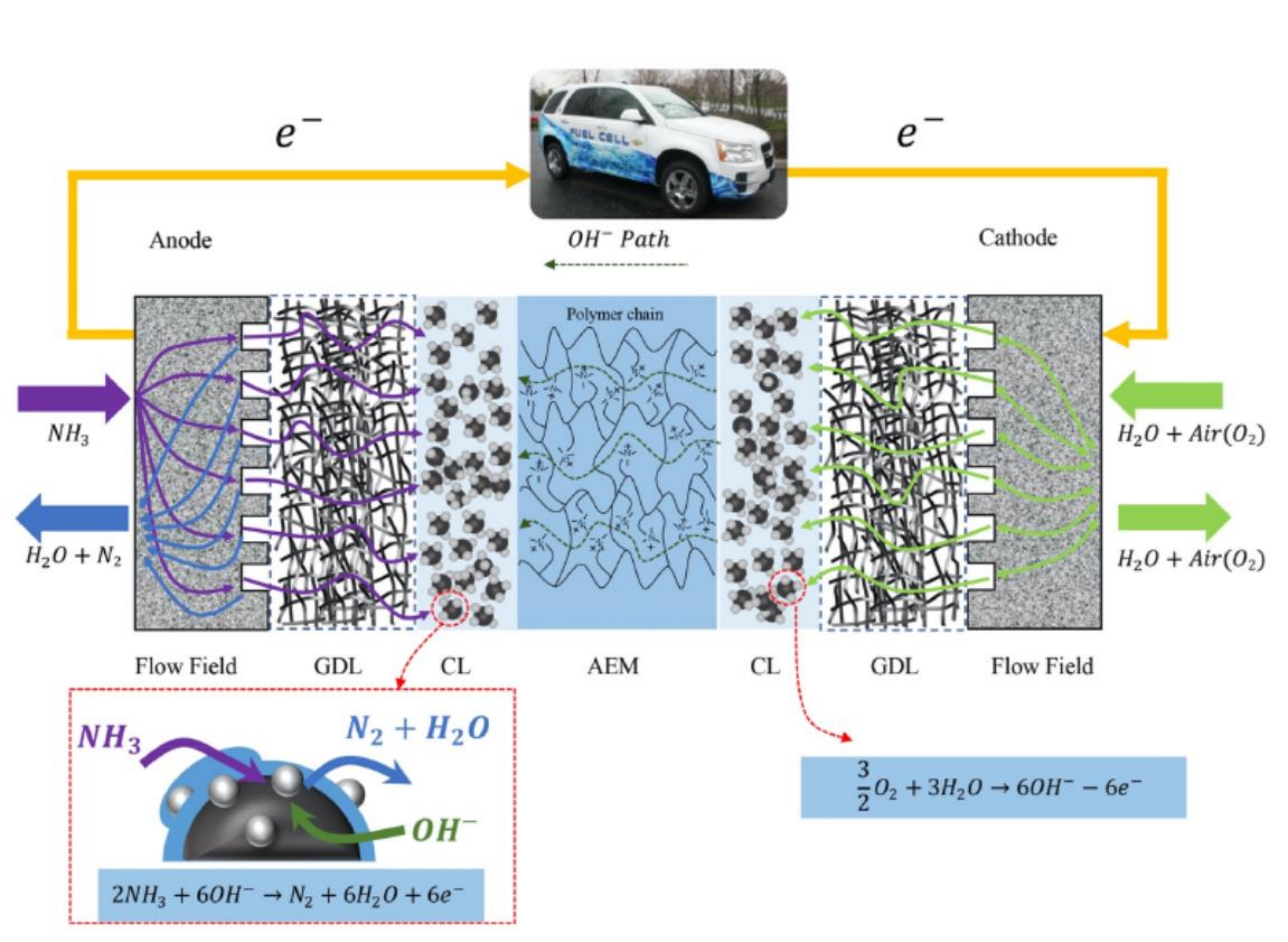
• Ammonia fuel cells

Table 5

Comparison of different direct ammonia fuel cells [7].

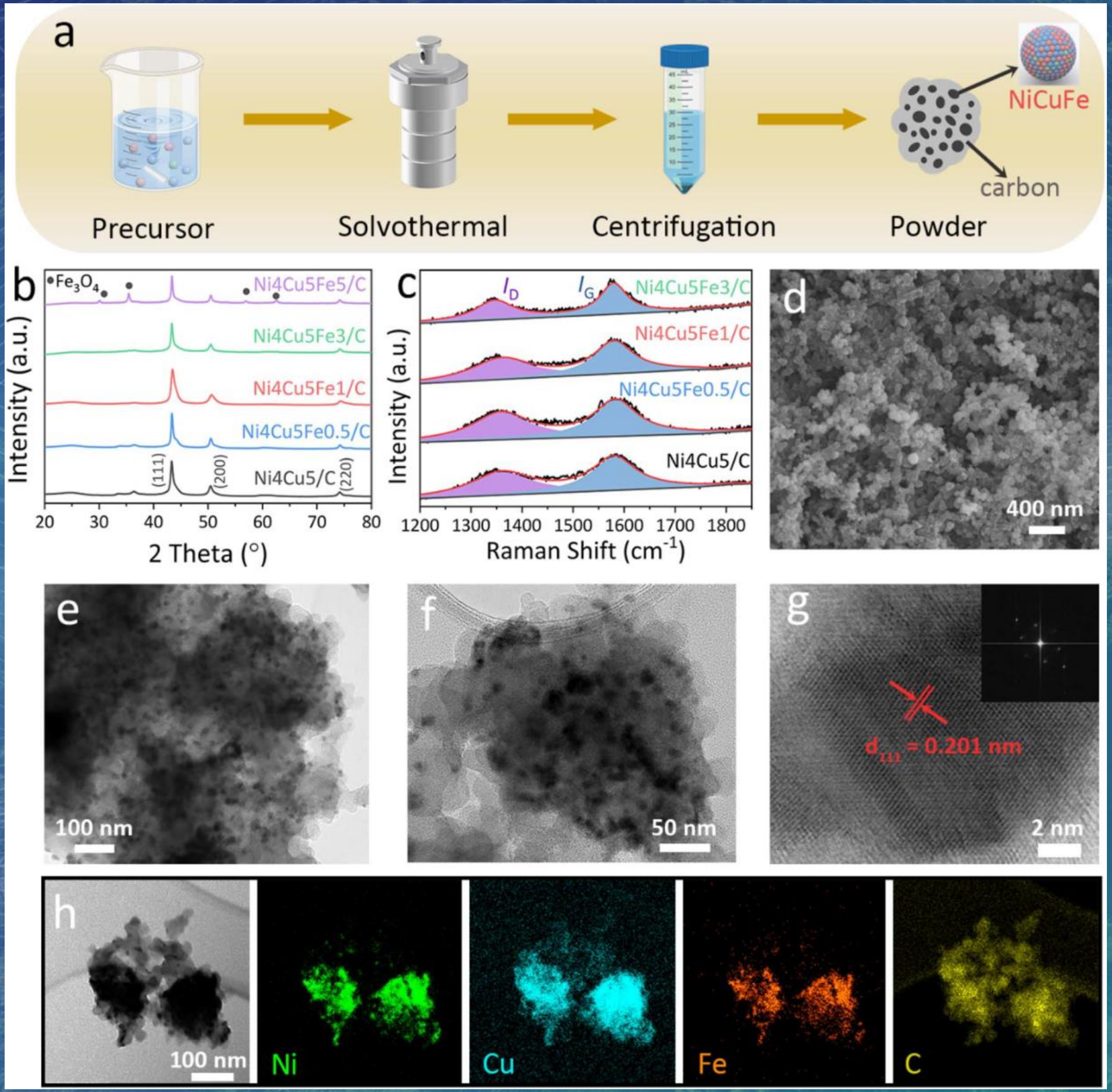
Electrolyte types	Temperature (°C)	Electrolyte transported ions	Advantages	Disadvantages
Alkaline electrolyte	25–100	OH^-	• Low operating temperature. • No ammonia decomposition process; low cost.	• Slow oxidation at low temperatures; low power density. • Degradation of membrane electrolytes. • Ammonia crossover.
Solid electrolyte	500–1000	O^{2-}/H^+	• High power density.	• Incomplete decomposition of ammonia at low temperature. • Catalyst deactivation and long-term stability.

• Ammonia fuel cells



Journal of Power Sources 476 (2020) 228454

• Ammonia fuel cells



Synthesis and characterization. (a) Schematic illustration of the preparation process of ternary NiCuFe alloy by solvothermal synthesis. (b) XRD patterns of Ni4Cu5/C, Ni4Cu5Fe0.5/C, Ni4Cu5Fe1/C, Ni4Cu5Fe3/C and Ni4Cu5Fe5/C. (c) Raman spectra of Ni4Cu5/C, Ni4Cu5Fe0.5/C, Ni4Cu5Fe1/C and Ni4Cu5Fe3/C. (d) SEM image, (e and f) TEM images and (g) HRTEM image (inset: FFT pattern of the corresponding nanoparticle) of Ni4Cu5Fe1/C sample. (h) HAAD-STEM image and corresponding EDS elemental mappings of Ni, Cu, Fe and C.

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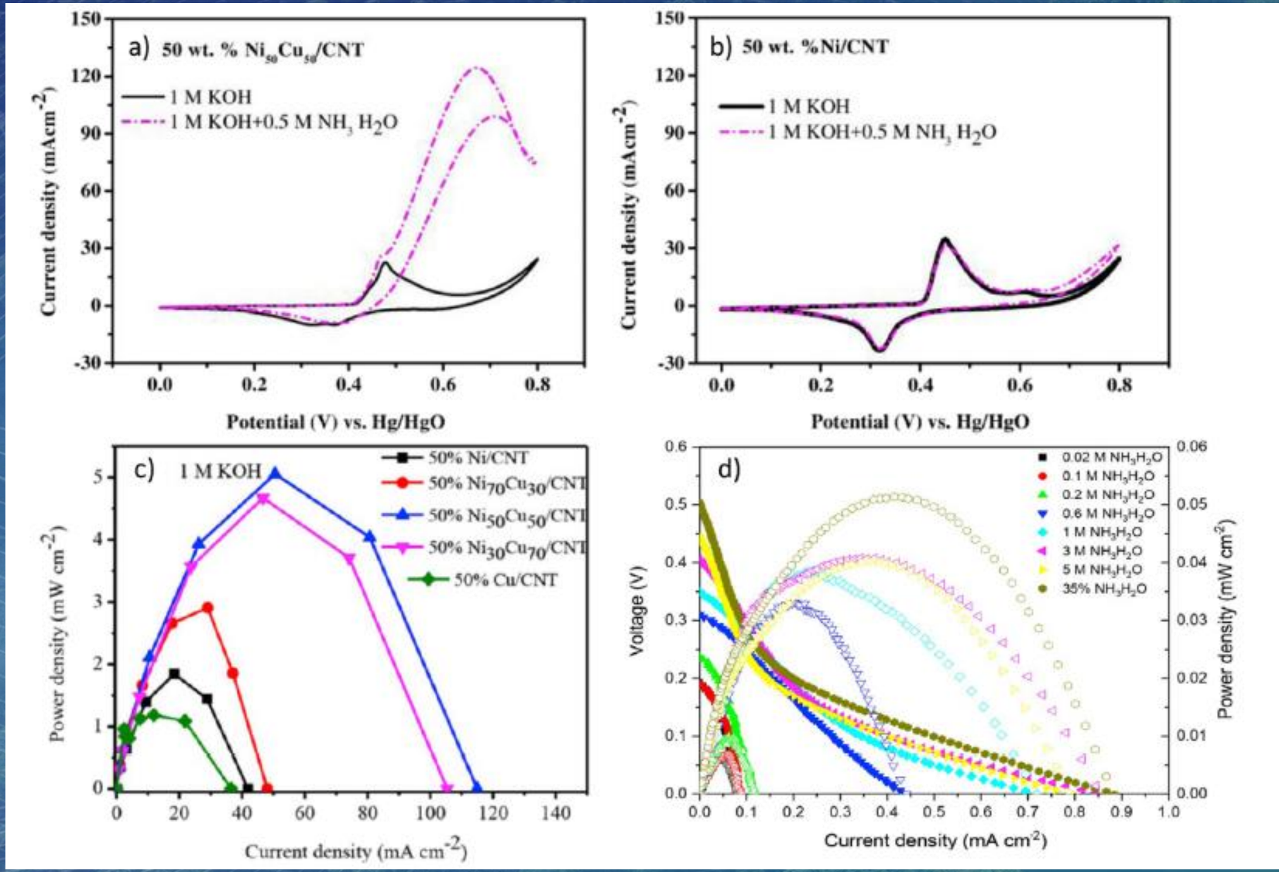
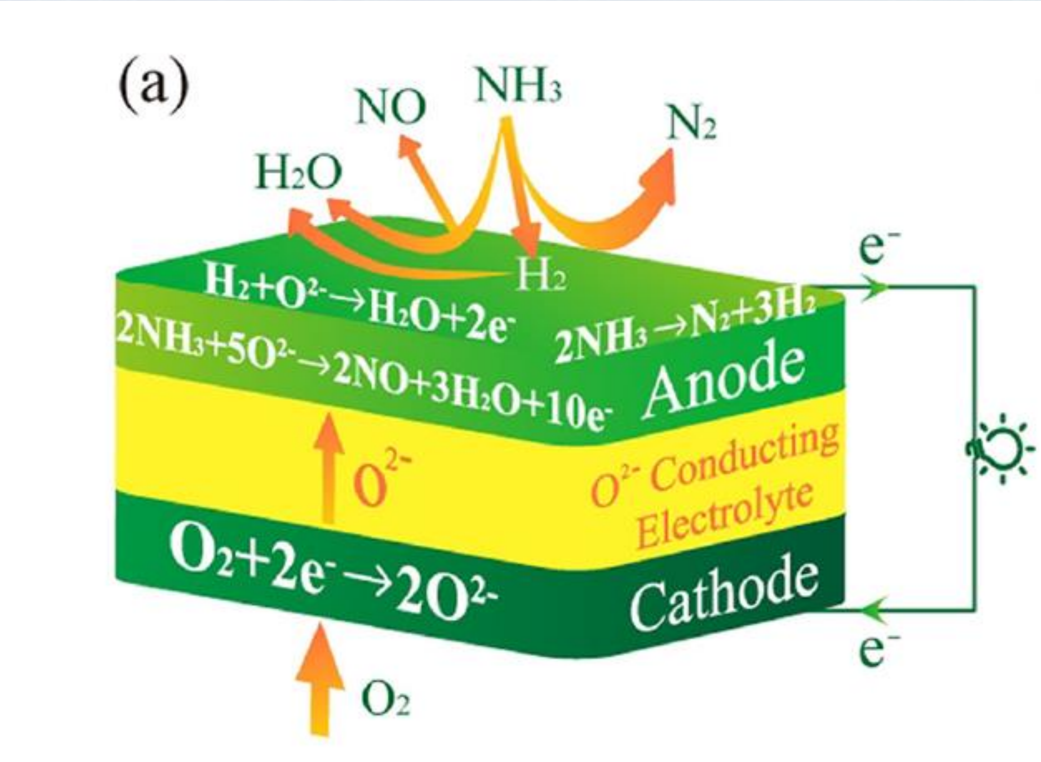
• Ammonia fuel cells

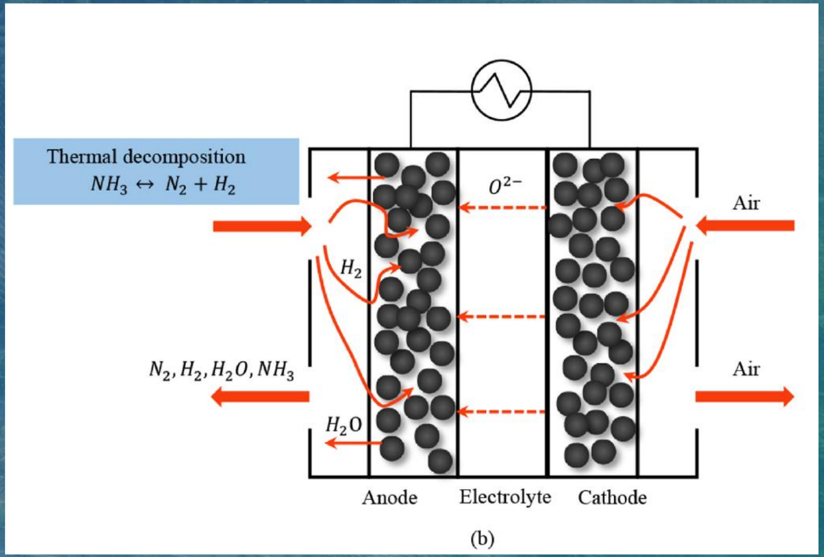


(a) The current density of 50 wt% Ni50Cu50/CNT; (b) The current density of 50 wt% Ni/CNT; (c) Comparison of power density between various catalysts for AOR; (d) The maximum power density for the ammonia fuel cell made with NiCu/C and single-phase perovskite oxide

J. Mater. Chem. A, 2022, 10, 18701

- Ammonia fuel cells





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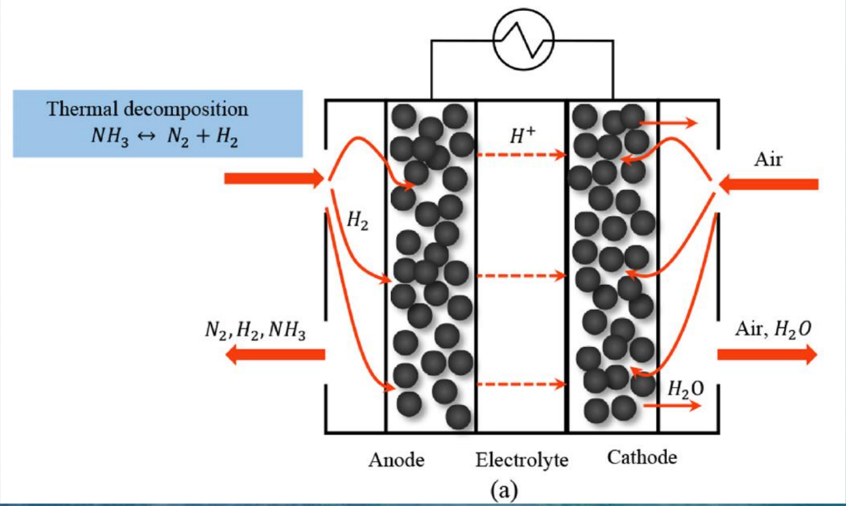
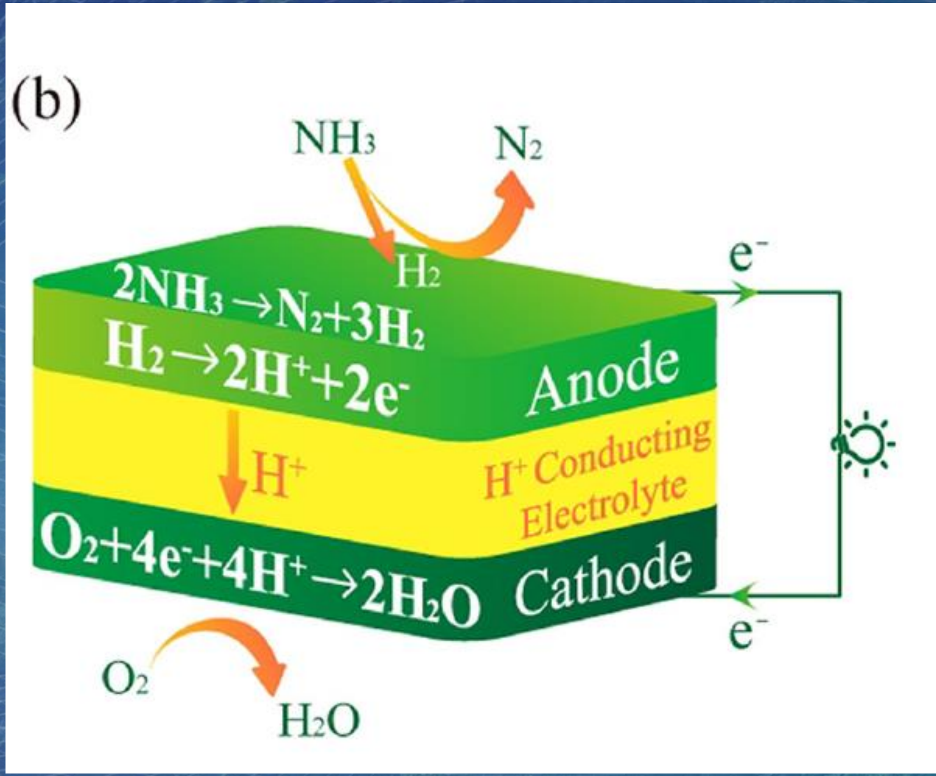
• Ammonia fuel cells





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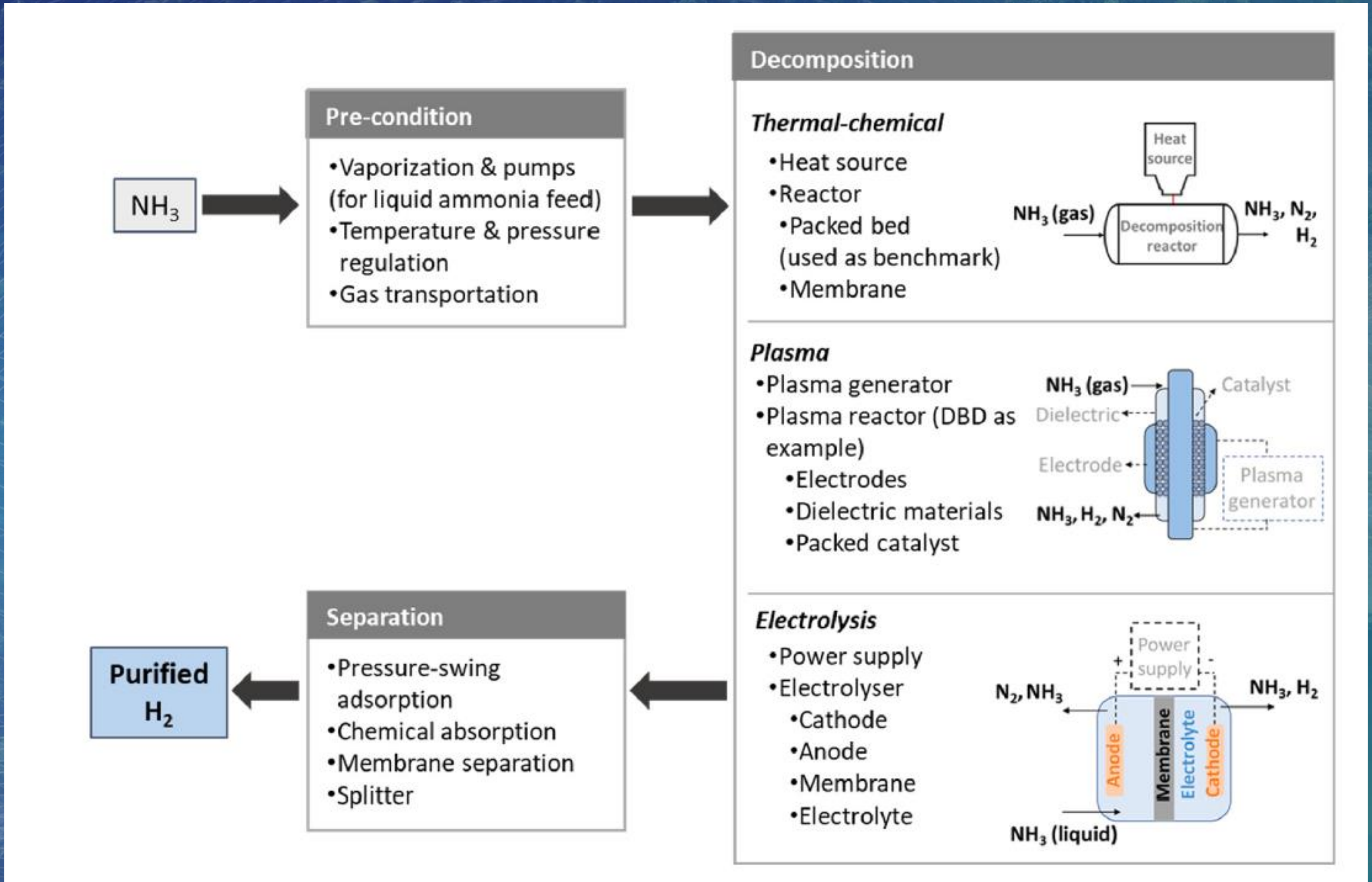

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Representative schemes and components of ammonia decomposition technologies

- Ammonia fuel cells

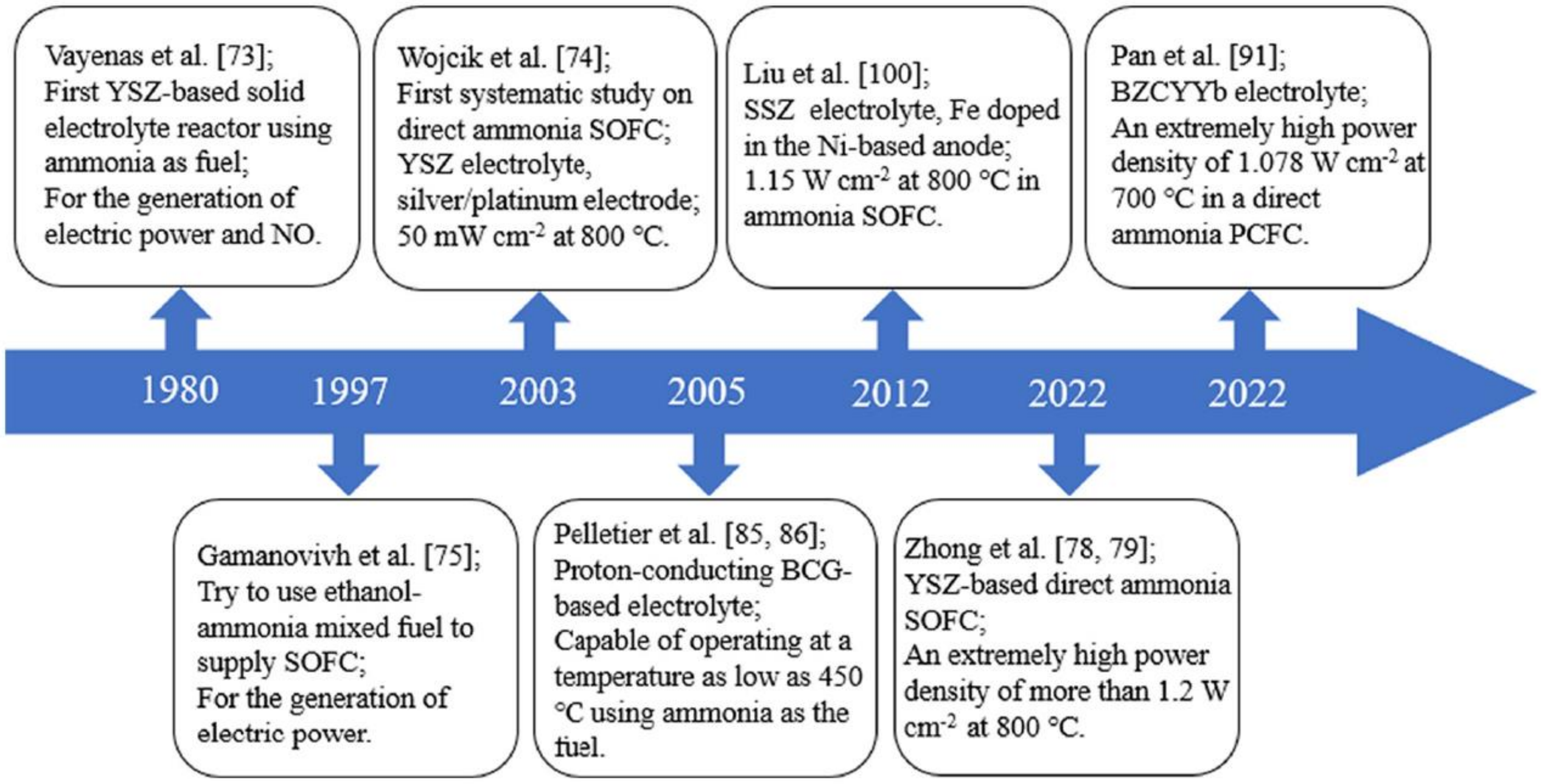

Fig. 7. Development History of Direct Ammonia SOFC/PCFC [73–75,78,79,85,86,91,100].

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• Ammonia fuel cells

Table 6
Summary of direct ammonia SOFC/PCFC.

Type	Electrolyte	Electrode (anode//cathode)	Temperature (°C)	Peak power density (mW/cm^2)	Ref.
SOFC/Anode support	YSZ	Ni-YSZ//SYO (0.1)-60YSZ	600	240	[79]-2022
			800	1210	
SOFC/Anode support	YSZ	NiO-YSZ//PZO	800	1220	[78]-2022
SOFC/Anode support	YSZ	Ni-YSZ//	800 (1 atm)	1078	[80]-2018
		LSC-GDC	850 (1 atm)	1174	
			800 (3 atm)	1148	
			850 (3 atm)	1202	
SOFC/Anode support	YSZ	Ni-YSZ//GDC-LSCF	700	325	[77]-2015
SOFC/Anode support	YSZ	Ni-YSZ//LSM-YSZ	900	88	[96]-2009
SOFC/Anode support	YSZ	NiO-YSZ//LSM-YSZ	850	526	[76]-2007
SOFC/Anode support	YSZ	Ni-YSZ//LSM-YSZ	800	200	[97]-2007
SOFC/Anode support	SDC/NCAL	Ni-NCAL//Ni-NCAL	550	755	[84]-2022
SOFC/Electrolyte support	SDC	LSTNC-SDC//BSCF	800	361	[83]-2020
		LSTN-SDC//BSCF	800	161	
		LSTC-SDC//BSCF	800	98	
		Ni-SDC//BSCF	800	314	
SOFC/Anode support	SDC	Ni-SDC//BSCF	650	1190	[82]-2007
SOFC/Anode support	SDC	Ni-SDC//SSC-SDC	700	253	[81]-2006
SOFC/Electrolyte support	LSGM	Ni (97.5) Mo (2.5)-SDC//SSC	900	416	[98]-2015
		Ni (97) Ta (3)-SDC//SSC	900	322	
		Ni (97) W (3)-SDC//SSC	900	313	
SOFC/Electrolyte support	LSGM	Ni-SDC//Pt	900	120	[99]-2014
		Fe-SDC//Pt	900	242	
		Co-SDC//Pt	900	85	
		Ni (40) Fe (60)-SDC//SSC	900	360	
		Ni-SDC//SSC	900	253	
SOFC/Anode support	SSZ	Ni-YSZ/Ni-SSZ//LSM-SSZ	800	1028	[100]-2012
		Ni (97.5) Fe (2.5)-YSZ/Ni-SSZ//LSM-SSZ	800	1150	
PCFC/Anode support	BCY10	Ni-BCY25//SSC	650	216	[101]-2015
PCFC/Anode support	BZCY	Pd//LSCF	600	580	[90]-2017
PCFC/Anode support	BZCY	NiO-BZCY//BSCF	750	390	[89]-2010
PCFC/Anode support	BCGP[1]	NiO-BCE//Pt	600	28	[85]-2008
PCFC/Electrolyte support	BCG	Pt//Pt	700	25	[86]-2005
	BCGP[2]	Pt//Pt	700	35	
PCFC/Anode support	BCGO	Ni-CGO//BSCFO-CGO	600	147	[87]-2008
PCFC/Anode support	BCGO	Ni-BCGO//LSCO-BCGO	700	355	[88]-2006
PCFC/Anode support	BCNO	NiO-BCNO//LSCO	700	315	[102]-2007
PCFC/Anode support	BZCYYb	Ni-BZCYYb//BCCY	650	383	[93]-2022
	BZCYYbN	Ni-BZCYYbN//BCCY	650	523	
PCFC/Anode support	BZCYYb	Ni-BZCYYb//PBSCF	700	1078	[91]-2022
PCFC/Anode support	BZCYYb	Ni-BZCYYb//BCFZY	650	450	[92]-2021
		Ni-BZCYYbPd//BCFZY	650	600	
	BZCYYbPd	Ni-BZCYYbPd//BCFZY	650	724	

Note: YSZ: Yttria Stabilized Zirconia; SYO (0.1): $Sr_{1+x}Y_{2-x}O_{4+\delta}$ ($x = 0.10$); PZO: $Pr_2Zr_2O_7$; LSC: $La_{0.6}Sr_{0.4}CoO_3$; GDC: Gd-doped Ceria; LSCF: $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$; LSM: $La_{1-x}Sr_xMnO_3$; SDC: Sm-Doped Ceria; NCAL: $LiNi_{0.815}Co_{0.15}Al_{0.35}O_2$; LSTNC: $L_{a0.52}Sr_{0.28}Ti_{0.94}Ni_{0.03}Co_{0.03}O_{3-\delta}$; LSTN: $La_{0.52}Sr_{0.28}Ti_{0.94}Ni_{0.06}O_{3-\delta}$; LSTC: $La_{0.52}Sr_{0.28}Ti_{0.94}Ni_{0.06}O_{3-\delta}$; BSCF: $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$; SSC: $Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$; LSGM: $La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_{2.85}$; SSZ: $Sc_{0.1}Zr_{0.9}O_{1.95}$; LSM: $La_{1-x}Sr_xMnO_3$; BCY10: $BaCe_{0.90}Y_{0.10}O_{3-\delta}$; BCY25: $BaCe_{0.75}Y_{0.25}O_{3-\delta}$; BZCY: $BaZr_{0.1}Ce_{0.7}Y_{0.2}O_{3-\delta}$; BCGP[1]: $BaCe_{0.8}Gd_{0.15}Pr_{0.05}O_{3-\delta}$; BCE: $BaCe_{0.85}Eu_{0.15}O_3$; BCG: $BaCe_{0.8}Gd_{0.2}O_{3-\delta}$; BCGP[2]: $BaCe_{0.8}Gd_{0.19}Pr_{0.01}O_{3-\delta}$; BCGO: $BaCe_{0.8}Gd_{0.2}O_{3-\delta}$; CGO: $Ce_{0.8}Gd_{0.2}O_{1.9}$; BSCFO: $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$; LSCO: $La_{0.5}Sr_{0.5}CoO_{3-\delta}$; BCNO: $BaCe_{0.9}Nd_{0.1}O_{3-\delta}$; BZCYYb: $BaZr_{0.1}Ce_{0.7}Y_{0.1}Yb_{0.1}$; BCCY: $BaCo_{0.7}Ce_{0.24}Y_{0.06}O_{3-\delta}$; BZCYYbN: $Ba(Zr_{0.1}Ce_{0.7}Y_{0.1}Yb_{0.1})_{0.95}Ni_{0.05}O_{3-\delta}$; PBSCF: $PrBa_{0.5}Sr_{0.5}Co_{1.5}Fe_{0.5}O_{5+\delta}$; BZCYYbPd: $Ba(Zr_{0.1}Ce_{0.7}Y_{0.1}Yb_{0.1})_{0.95}Pd_{0.05}O_{3-\delta}$; BCFZY: $BaCo_{0.4}Fe_{0.4}Zr_{0.1}Y_{0.1}O_{3-\delta}$.

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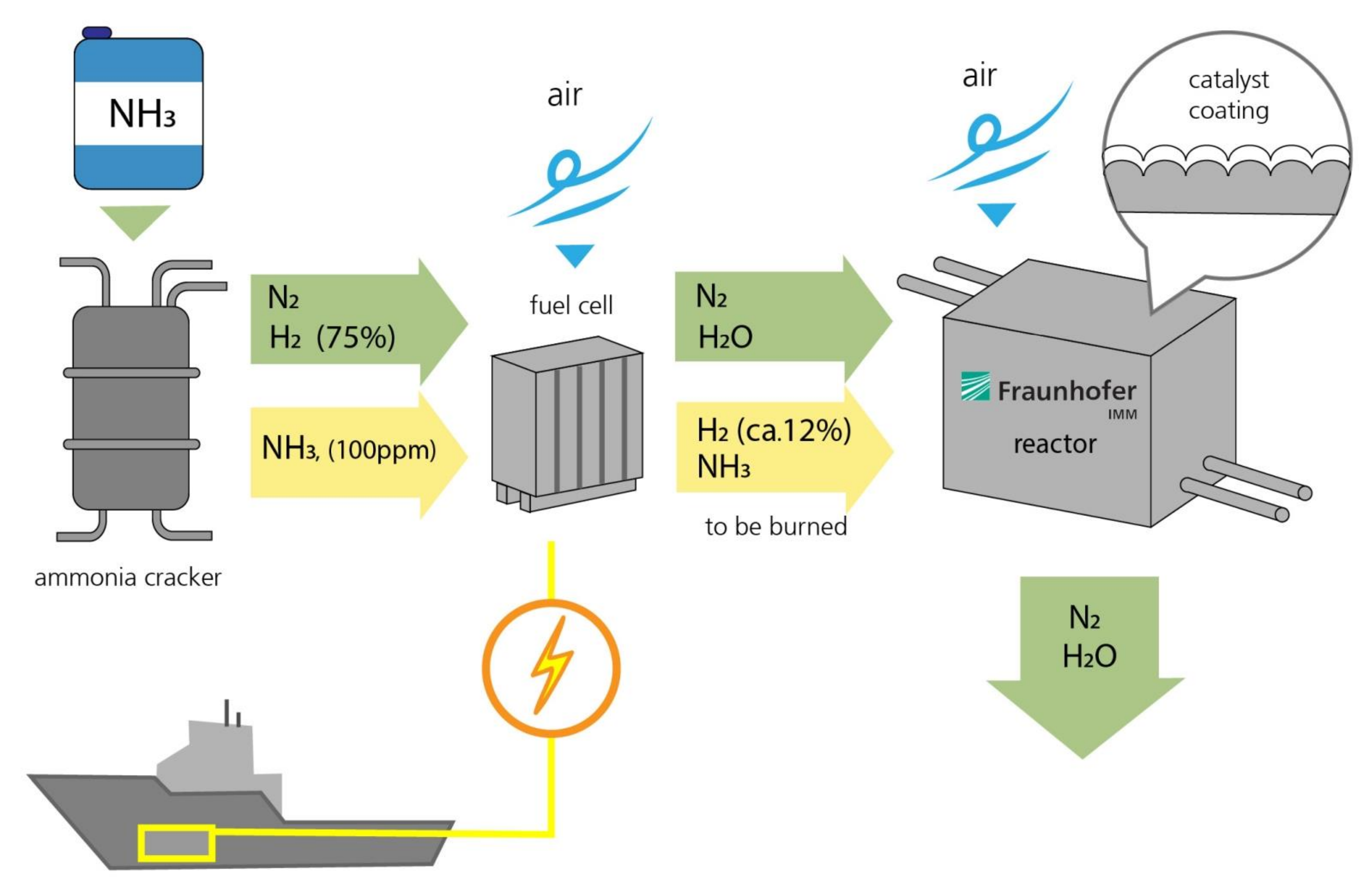
- Ammonia fuel cells



• Ammonia fuel cells

Hydrogen Energy Systems

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Ammonia Fuel Cells Project

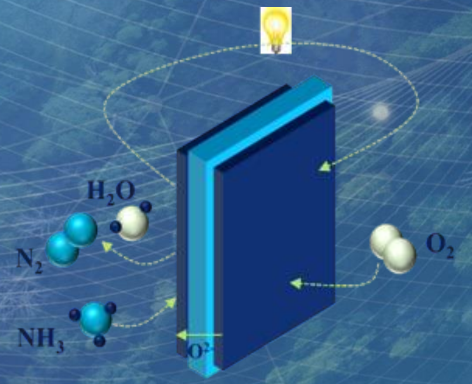
Why we are doing this?

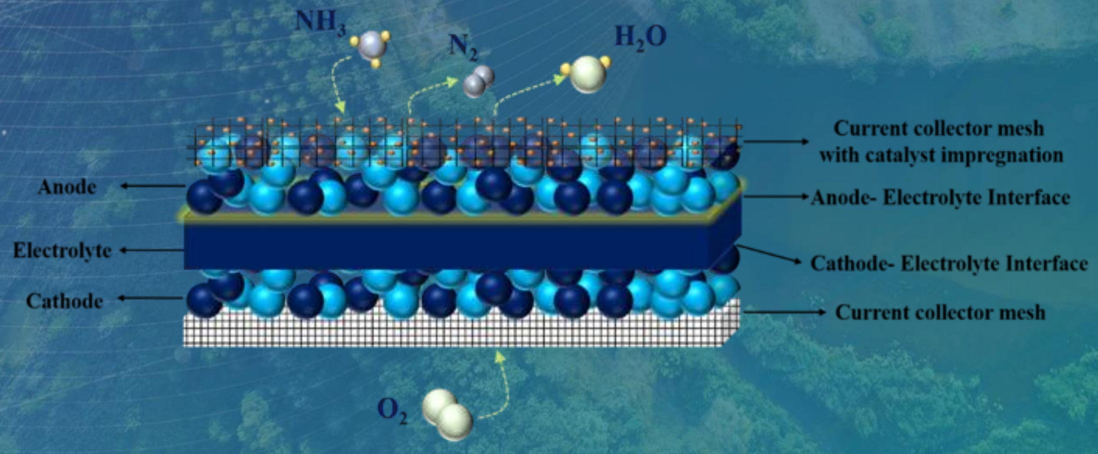
The storage and transport of Renewable Energy (RE) is by far the biggest hurdle preventing deeper penetration of RE technologies into the energy market. Ammonia has emerged as a potential candidate as technologies and standards for ammonia storage, handling and transportation are already available. There are commercial initiatives in this space, one of notables is Asian Renewable Energy Hub (AREH) in Western Australia, which is a 26 GW wind-solar power generation plant facilitating export of RE in form of green ammonia.

The project proposes use of ammonia-fed low to intermediate temperature solid-oxide fuel cells (SOFCs) to convert ammonia into electricity in a single step without a need for external ammonia cracking. The technology offers the highest round-trip electric and thermal efficiency (> 50%) amongst all known technologies for ammonia utilisation. Despite efficiency advantages, low to intermediate temperature

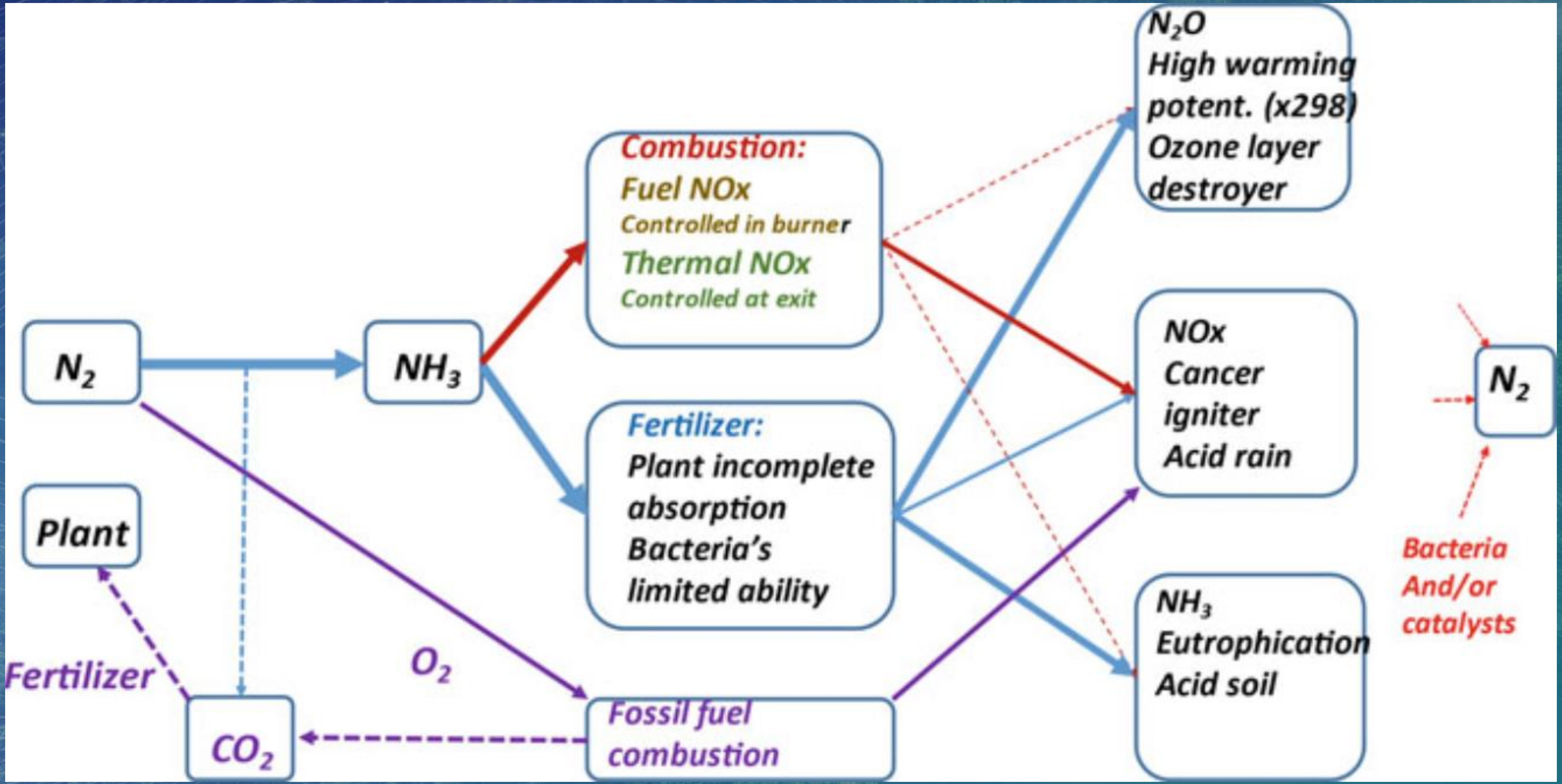
Projects

- Hydrogen and NH3 from organics
- Impact of Hydrogen on underground reservoir properties: Laboratory characterisation @ reservoir conditions
- Metal hybrides composites
- Ammonia Cracking using Catalytic Static Mixers (CSM)
- Ammonia Fuel Cells Project
- CO2 to Methanol Project
- Direct ammonia synthesis by alkaline





• Environmental Impact



Formation and transformation of reactive nitrogen and impact on the environment: effect of ammonia fuel on ammonia fertilizer

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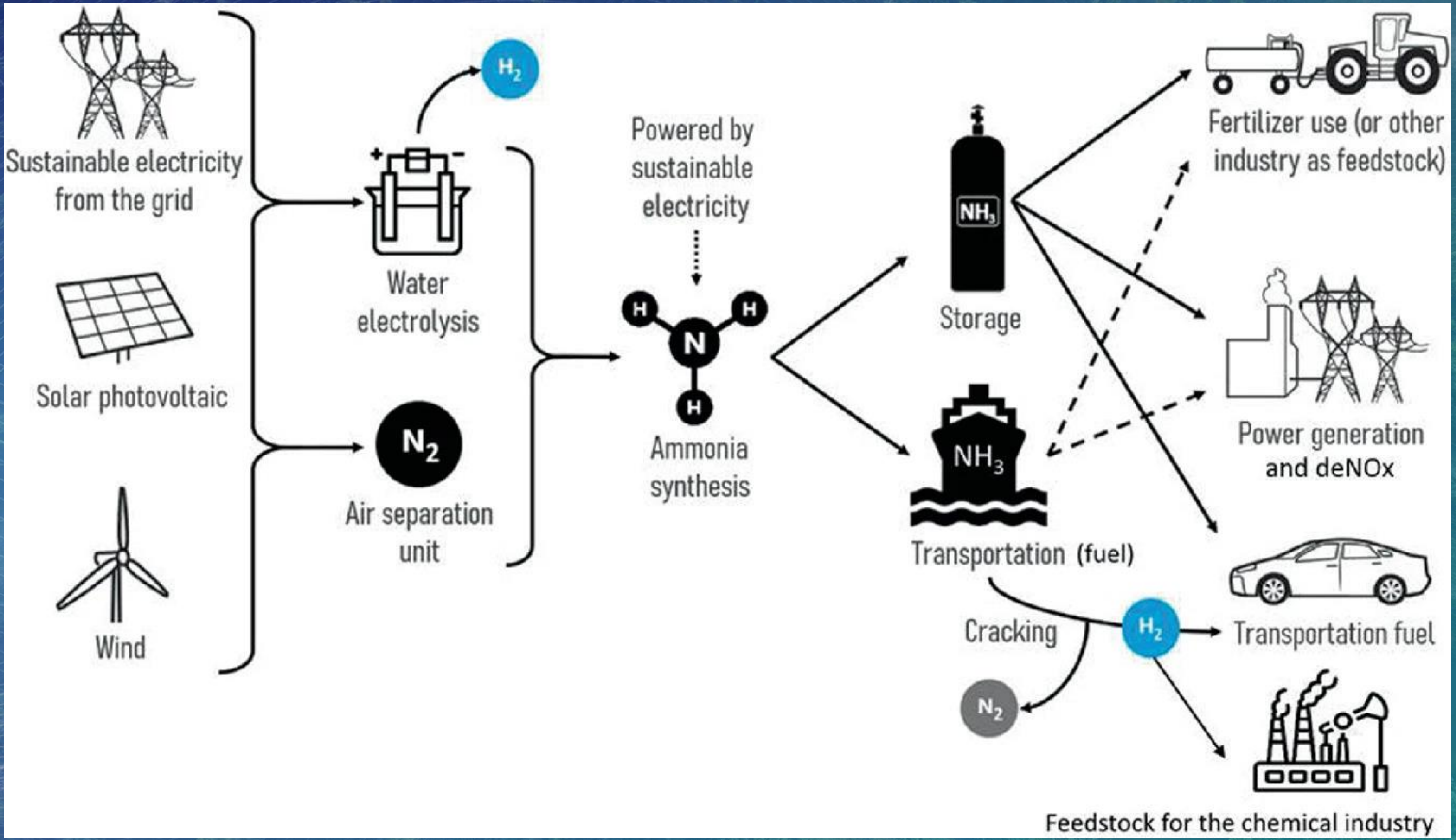
- Techno-economic aspects



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- Health, safety, and security

Ammonia gas cloud in Seward, Illinois. Cause: ruptured hose

explosions and cylinder damage, respectively.

Techno-Economic Challenges of Green Ammonia as an Energy Vector. https://doi.org/10.1016/B978-0-12-820560-0.00004-7
2021

Millennium Institute on Green Ammonia as an Energy Vector - MIGA

MIGA's goal is to provide the framework to produce green ammonia using a less energy-intensive process than Haber-Bosch (H-B) for Power-to-X applications.

This challenge is addressed with an interdisciplinary approach, which narrows the current technological gaps, to advance in knowledge and technology, generating interdisciplinary training in the area for new generations of researchers for Chile and the international community.

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