Zero-Carbon Ammonia technology pathway analysis by IPAC-technology model in China

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INTRODUCTION:

- China is dominated by the coal-to-ammonia route, and the CO_2 generation per unit of NH_3 is much higher than that of natural gas-to-ammonia route used in Europe and the United States.
- Ammonia could be used as zero-carbon energy in maritime.
- This research analyzes the cost feasibility of a zero-carbon transition for the ammonia industry in China, presents detailed timelines, and indicates the impact of different renewable electricity costs on the key time points and leading technologies for a zero-carbon transition.

METHODS:

Table 1 Classification of ammonia production technology and proportions in 2020 and 2025.

Class	Raw material	Technology	Acronym of technology	CO_2 emission (t/tNH_3)	By-product CO_2 (t/tNH_3)	technology proportion	
						2020	2025(max)
Conventional technology	Coal	Circulating Fluidized-bed Gasification	CFG	0.76	3.07	0.32%	1.34%
		Coal Water Slurry Gasification	CWSG	0.89	2.26	24.15%	41.93%
		Fixed-bed Intermittent Gasification	FIG	1.58	2.71	22.39%	0%
		Fixed-bed Pure Oxygen Gasification	FOG	0.68	2.07	6.31%	-
		Pulverized Coal Gasification	PCG	0.79	2.32	26.67%	41.58%
	Natural gas	Steam Methane Reforming	SMR	2.05	-	12.99%	7.34%
	Coke oven gas	Coke Oven Gas Reforming	COGR	1.14	0.41	6.78%	9.99%
Electrolysis	Alkaline Electrolysis		E_AE	-	-	0%	-
	Proton Exchange Membrane Electrolysis		E_PEM	-	-	0%	-
	Solid Oxide Electrolysis		E_SOE	-	-	0%	-
Nuclear	High Temperature Gas Cooled Reactor		HTGC	-	-	0%	-

Table 2 Scenarios key assumptions.

Scenario	Classification	Acronym	Detail
Technology Development Scenario	Low LCOE of solar electricity	TDS_L	a. FIG would withdraw capacity completely by 2025 at the latest; b. FOG would withdraw capacity completely by 2030 at the latest; c. SMR and COGR would decline year by year; d. Energy demand for NH_3 is supplied by zero-carbon technology.
	Medium LCOE of solar electricity	TDS_M	
	High LCOE of solar electricity	TDS_H	

Table 3 LCOE assumptions.

Year	2020	2025	2030	2040	2050
Low LCOE (yuan/kWh)	0.3	0.24	0.19	0.13	0.10
Medium LCOE (yuan/kWh)	0.32	0.27	0.22	0.17	0.14
High LCOE (yuan/kWh)	0.38	0.32	0.26	0.19	0.16

RESULTS:

The development of the ammonia industry from 2020 to 2050 could be divided into four periods: slow transition period (SLTP), departure period (DP), sharp transition period (SHTP) and zero carbon period (ZCP).

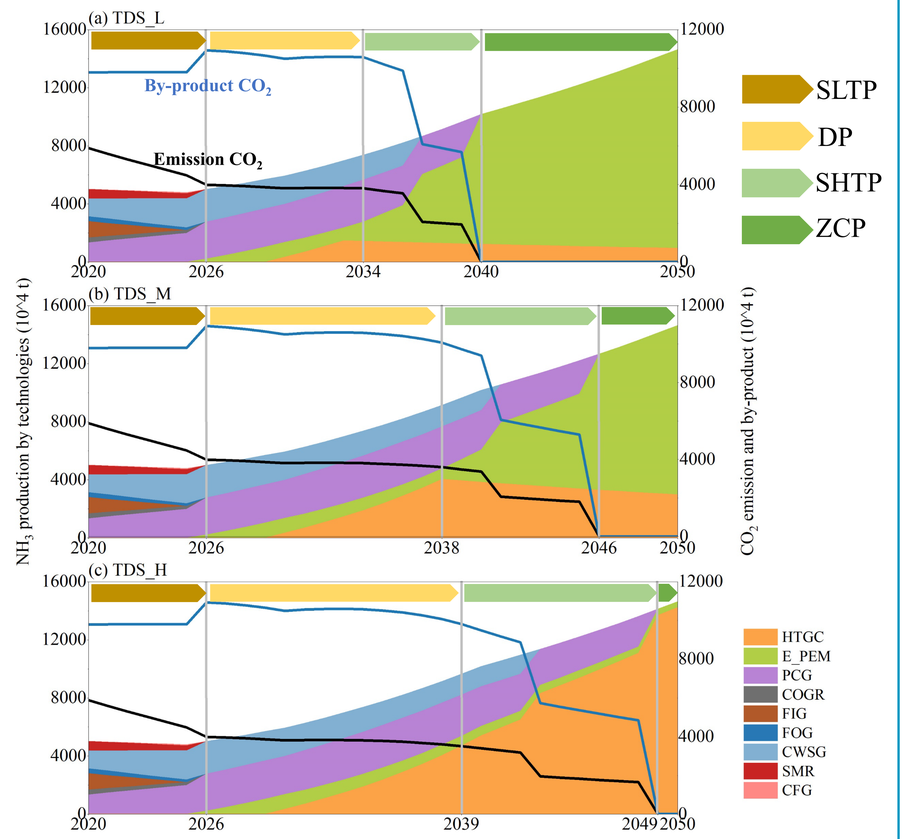

Fig.1 The ammonia industry zero carbon pathways, CO_2 emissions and by-product CO_2 generation under different scenarios.

Slow transition period: according to existing policies and projects-in-pipeline, this stage would be from 2020 to 2026.

Departure period: all of the conventional ammonia demand are supplied by PCG and CWSG.

Sharp transition period: Zero-carbon technologies replace CWSG first and then PCG.

Zero carbon period: all ammonia supplied by E-PEM and HTGC.