



26TH INPRO DIALOGUE FORUM · DEPLOYMENT OF NUCLEAR ENERGY SYSTEMS
FOR APPLICATIONS BEYOND ELECTRICITY



Deploying a Licensed SMR for Industrial Hydrogen:

Cost Conditions for SMART100 Pink Hydrogen in the Republic of Korea

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Outline of This Presentation



1. Context

Korea's clean hydrogen challenge and the three production pathways



2. SMART100

A licensed, construction-ready Korean SMR — the Standard Design Approval milestone



3. Methodology

Plant-gate LCOE–LCOH model with explicit steam-superheating treatment



4. Results

Deterministic competitiveness against blue and green hydrogen benchmarks



5. Implications

Cost levers, policy implications, and conclusions for Member States

Hydrogen Deployment Is Gated by Production Cost



Hard-to-abate demand

Hydrogen is a key vector for high-temperature industrial heat, selected transport, and dispatchable power — sectors that electrification alone cannot reach.



Cost sensitivity

Scale-up of hydrogen value chains is highly sensitive to production cost; national roadmaps assume steep LCOH reductions at low emissions intensity.



Beyond technology

Feasibility depends not only on electrolyzer readiness, but on financing conditions, infrastructure maturity, supply chains, and policy design.

THE KOREAN QUESTION

A widening gap between long-term hydrogen cost targets and near-term market conditions raises a strategic question:

Which clean production pathway can Korea actually scale — and at what cost?

Three Clean Hydrogen Pathways — Different Constraints

THIS STUDY

Blue Hydrogen

Natural gas reforming + CCS

- Cost-competitive under favorable gas price and CCS conditions
- Requires CO₂ transport, storage, permitting, and long-term liability frameworks
- Korea's CO₂ networks remain early-stage → cost advantage ≠ near-term deployability

Green Hydrogen

VRE-powered electrolysis

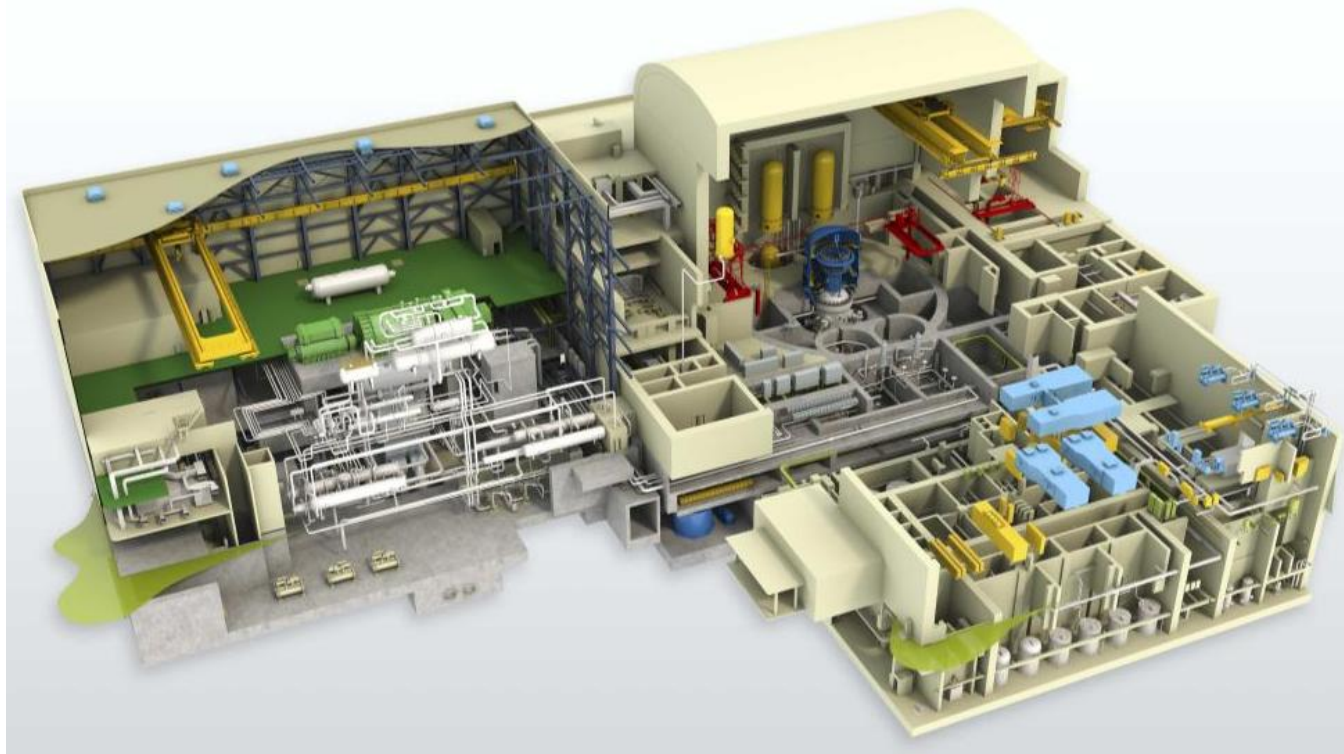
- Zero-carbon electricity input; strong policy support globally
- Economics driven by renewable capacity factor and electrolyzer utilization
- Benchmarks: dominant ≤ 4.33 , competitive ≤ 6.05 USD/kg-H₂

Pink Hydrogen

Nuclear-powered electrolysis

- High capacity factor and stable output → high electrolyzer utilization
- Evaluated on a new-build SMR basis — not marginal-cost existing nuclear
- SMART100: a licensed, near-term deployable heat and power source

SMART100 — Korea's Integral Light-Water SMR



SMART100 power plant layout (KAERI)



110 MWe / 365 MWth

60-year design life, 90% capacity factor



Integral PWR architecture

Steam generators and coolant pumps inside the reactor vessel — large-break LOCA piping eliminated by design



Fully passive safety

Cooling by gravity and natural circulation; no AC power or operator action required in accidents



Built for cogeneration

Electricity, seawater desalination, district heating, and industrial process heat/steam

Licensed Today — Ready for Construction Now



2012

Original SMART becomes the world's first SMR to receive Standard Design Approval



26 Sept 2024

SMART100 receives SDA from Korea's Nuclear Safety and Security Commission (NSSC)



Today

Standard design review complete — projects can proceed directly to site-specific construction licensing

With SDA secured, SMART100 is a **regulator-approved standard design** — first-of-a-kind licensing risk is minimized, and construction planning can begin immediately on a standardized design basis.

Jointly developed by **KAERI · KHNP · K.A.CARE (Saudi Arabia)** — an export-ready design open to partnership with IAEA Member States

Research Question and Approach



Under what conditions can SMART100 pink hydrogen be cost-competitive against blue and green hydrogen — and which variables most effectively expand its competitive region?



Plant-gate LCOE–LCOH model

Transparent linkage from SMR electricity cost to hydrogen cost; transport, distribution, and retail excluded



Deterministic scenario screening

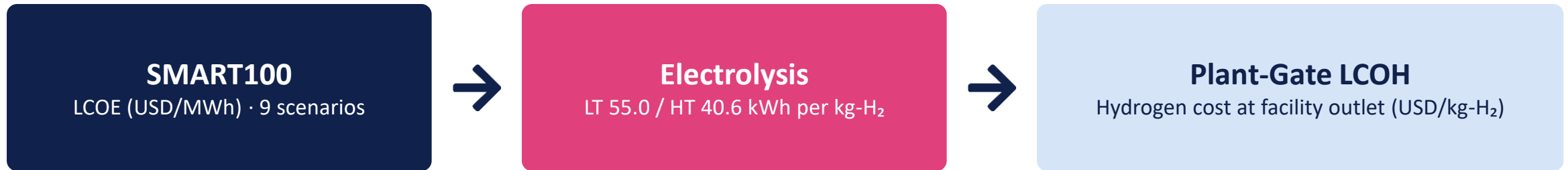
3 cost cases × 3 WACC levels × 3 non-electricity cost levels, against blue and green benchmarks



Explicit superheating penalty

PWR steam at ~300°C must be raised to 750°C for high-temperature electrolysis — modeled, not ignored

Plant-Gate System Boundary and Cost Model



$$\text{LCOH}_{\text{pink}} = \text{LCOE}_{\text{SMR}} \times (P_{\text{elec}} / 1000) + C_{\text{non-elec}} - C_{\text{credit}} \quad (\text{base case: } C_{\text{credit}} = 0)$$

INCLUDED WITHIN BOUNDARY

- SMR electricity input cost
- Annualized electrolyzer CAPEX incl. BOP and stack replacement
- Fixed / variable O&M, water treatment, in-plant processing

EXCLUDED (PLANT-GATE COMPARISON)

- Long-distance transport and retail distribution
- Refueling-station capital and operating costs
- Retail margins — delivered prices used for context only

Coupling a PWR to High-Temperature Electrolysis



The 80% steam utilization represents a high-performance case; lower values are a target of future sensitivity analysis.

Plant Parameters and LCOE Scenarios

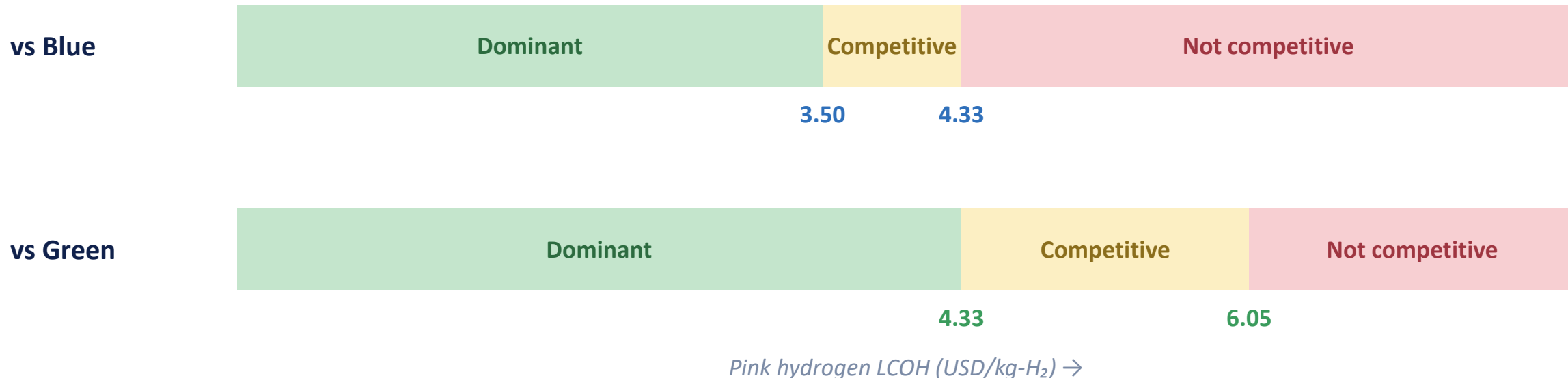
Parameter	Value
Net electric output	110 MWe
Thermal output	365 MWth
Plant lifetime	60 years
Capacity factor	90%
Annual generation	867,240 MWh/yr
Electrolysis pathways	LT 55.0 / HT 40.6 kWh/kg
Non-electricity cost	1.0 / 1.5 / 2.0 USD/kg-H ₂

SMART100 LCOE scenarios (USD/MWh)

Cost case	WACC 5%	WACC 7%	WACC 9%
Optimistic	67.5	83.3	101.0
Base	90.7	115.2	142.7
Conservative	119.5	152.5	190.2

Derived from published SMR cost parameterizations (overnight cost, O&M, construction duration, financing, lifetime) — INL Net Zero World 2024 update. **Financing alone moves LCOE by roughly 50–60% across the WACC range.**

Competitiveness Benchmarks and Classification



Interpretation note. The blue thresholds (3.50 dominant / 4.33 competitive USD/kg) are production-cost benchmarks under favorable gas and CCS assumptions — a cost yardstick, **not a Korea deployment-feasibility assessment**. Green thresholds (4.33 / 6.05 USD/kg) reflect representative green hydrogen cost ranges.

Plant-Gate LCOH vs Blue Hydrogen Benchmarks

Scenario	WACC	Low-Temperature Electrolysis (55.0 kWh/kg)			High-Temperature Electrolysis (40.6 kWh/kg)		
		C _{ne} 1.0	C _{ne} 1.5	C _{ne} 2.0	C _{ne} 1.0	C _{ne} 1.5	C _{ne} 2.0
Optimistic	5%	4.71	5.21	5.71	3.74	4.24	4.74
	7%	5.58	6.08	6.58	4.38	4.88	5.38
	9%	6.55	7.05	7.55	5.09	5.59	6.10
Base	5%	5.99	6.49	6.99	4.68	5.18	5.68
	7%	7.33	7.83	8.33	5.68	6.18	6.68
	9%	8.85	9.35	9.85	6.79	7.29	7.79
Conservative	5%	7.58	8.08	8.58	5.85	6.35	6.85
	7%	9.39	9.89	10.39	7.19	7.69	8.19
	9%	11.47	11.97	12.47	8.73	9.23	9.73

D — dominant (≤ 3.50)
 C — competitive (≤ 4.33)
 N — disadvantaged (> 4.33)
 C_{ne} = non-electricity cost (USD/kg-H₂)

On plant-gate cost alone, pink hydrogen rarely beats blue: only the most favorable optimistic HT cases reach the blue-competitive range. Blue must therefore be judged jointly with Korea's CCS transport and storage feasibility.

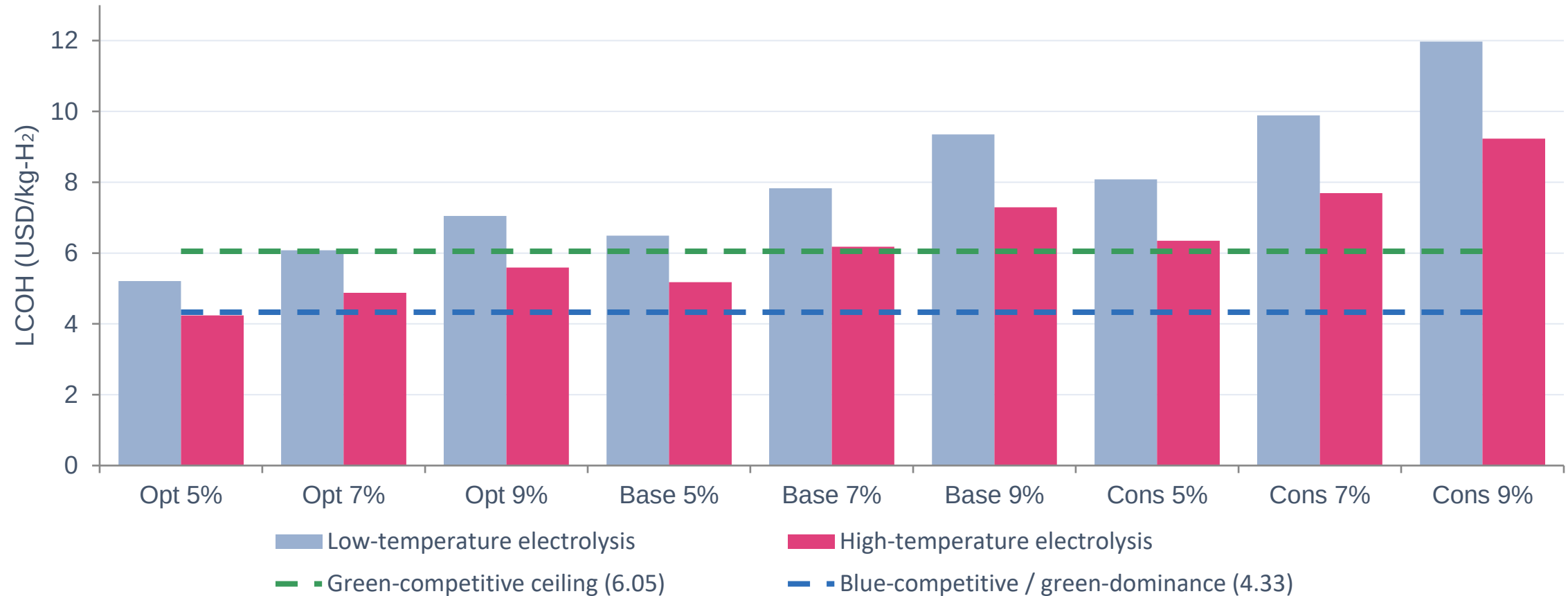
Plant-Gate LCOH vs Green Hydrogen Benchmarks

Scenario	WACC	Low-Temperature Electrolysis (55.0 kWh/kg)			High-Temperature Electrolysis (40.6 kWh/kg)		
		C _{ne} 1.0	C _{ne} 1.5	C _{ne} 2.0	C _{ne} 1.0	C _{ne} 1.5	C _{ne} 2.0
Optimistic	5%	4.71	5.21	5.71	3.74	4.24	4.74
	7%	5.58	6.08	6.58	4.38	4.88	5.38
	9%	6.55	7.05	7.55	5.09	5.59	6.10
Base	5%	5.99	6.49	6.99	4.68	5.18	5.68
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Conservative	5%	7.58	8.08	8.58	5.85	6.35	6.85
	7%	9.39	9.89	10.39	7.19	7.69	8.19
	9%	11.47	11.97	12.47	8.73	9.23	9.73

■ D — dominant (≤ 4.33)
 ■ C — competitive (≤ 6.05)
 ■ N — not competitive (> 6.05)
 C_{ne} = non-electricity cost (USD/kg-H₂)

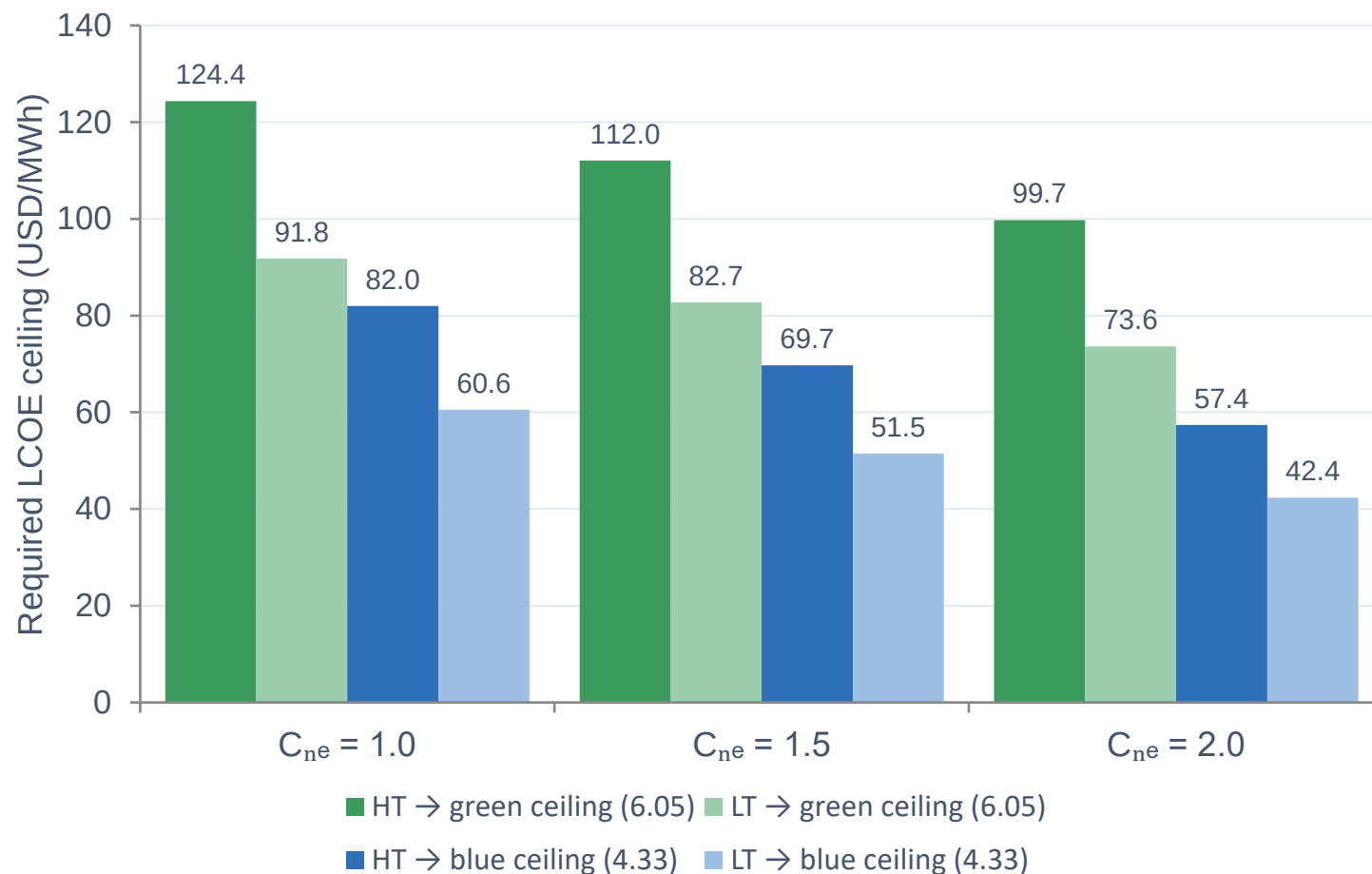
High-temperature electrolysis materially expands the green-competitive region: HT stays competitive across a broad set of optimistic and base cases, while LT qualifies only under the most favorable assumptions.

LCOH Across Scenarios — HT vs LT ($C_{ne} = 1.5$ USD/kg)



Across all nine scenarios the HT pathway lies 0.97–2.74 USD/kg below LT. At $C_{ne} = 1.5$ it stays under the green-competitive ceiling in every optimistic case and in the base case at 5% WACC.

Break-Even Ceilings — How Cheap Must Power Be?



READING THE CHART

- HT always grants more LCOE headroom than LT — about 26–33 USD/MWh against the green ceiling, but a smaller 15–21 USD/MWh against the blue ceiling
- To match green's upper range, HT needs $LCOE \leq 99.7\text{--}124.4$ USD/MWh — met by the optimistic cases (bar the 9% WACC / $C_{ne} = 2.0$ margin) and by base at 5% WACC
- To match blue on cost, LCOE must fall to 42.4–82.0 USD/MWh — why blue is hard to beat for new-build SMRs

Three Findings from the Deterministic Screening

1



HT electrolysis is the preferred pathway

Even after an honest 3.1 kWh/kg superheating penalty, effective consumption of 40.6 kWh/kg beats LT's 55.0 — expanding the green-competitive region.

2



Blue is a cost benchmark, not a verdict

New-build SMR pink hydrogen rarely undercuts blue at the plant gate — but blue's scalability in Korea hinges on CO₂ transport and storage infrastructure.

3



Marginal cases are strikingly close

In the optimistic / 9% WACC / $C_{ne} = 2.0$ case, LCOH is 6.101 vs the 6.05 ceiling — a 0.051 USD/kg gap. Competitiveness is a matter of increments.

Dominant Cost Levers — Closing a 0.051 USD/kg Gap



WACC (financing)

Enters LCOE multiplicatively; long-term offtake, guarantees, and regulated revenue mechanisms lower it



Overnight capital cost

Standardization and serial deployment of an approved design drive OCC down the learning curve



Non-electricity cost

Enters LCOH one-to-one; electrolyzer manufacturing scale-up and stack lifetime are the levers

THE MARGINAL CASE

6.101 vs **6.050**

Optimistic / WACC 9% / $C_{ne} = 2.0$ (USD/kg- H_2)

Any one of these closes the gap:

- LCOE: 101.0 → 99.7 USD/MWh (−1.3%)
- P_e : 40.6 → 40.1 kWh/kg (−1.2%)
- C_{ne} : 2.00 → 1.95 USD/kg (−2.5%)

No disruptive breakthrough required — targeted, incremental improvements suffice

Implications for Korea — and for Member States



De-risk financing

Long-term offtake contracts, guarantees, and regulated revenue mechanisms to compress WACC — the strongest lever on LCOH



Standardize and serialize

Deploy the SDA-approved SMART100 design in series to move overnight capital cost down the learning curve



Scale the electrolyzer chain

Manufacturing scale-up and longer stack lifetimes to cut non-electricity costs, which pass one-to-one into LCOH



Invest in thermal integration

R&D on SMR–SOEC coupling and alternative topping heat to shrink or eliminate the superheating penalty

Portfolio message: national clean hydrogen strategies should not rest on a single pathway — SMR-based pink hydrogen diversifies supply where CCS feasibility or renewable resources are constrained.

Limitations and Future Work



What this study is not (yet)

- Preliminary assessment on simplified plant-gate boundaries and publicly available cost ranges
- No detailed thermal-hydraulic design of SMART100–SOEC integration; heat-vs-electricity use not optimized
- Superheating uses a simplified heat-capacity approximation and assumes 95% electric heater efficiency
- 80% steam utilization is a high-performance assumption pending sensitivity analysis



Where the work goes next

- Refine SMART100–SOEC thermal integration and evaluate alternative topping heat sources
- Incorporate Korea-specific financing terms and electrolyzer cost data
- Quantify stack lifetime, dynamic operation, and clean-hydrogen certification impacts
- Extend to emissions intensity and delivered (not just plant-gate) hydrogen costs

What We Conclude — and What It Means

1

Pathway. High-temperature electrolysis, even with an explicit 3.1 kWh/kg superheating penalty, outperforms low-temperature electrolysis (40.6 vs 55.0 kWh/kg-H₂) and expands the green-competitive region.

2

Benchmarks. Blue hydrogen remains difficult to beat on plant-gate cost alone — but its Korean scalability depends on CCS infrastructure still at an early stage; cost and feasibility must be judged together.

3

Levers. Financing (WACC), overnight capital cost, and non-electricity costs are decisive; marginal cases sit within ~1–3% of competitiveness thresholds, so incremental improvements suffice.

4

Readiness. With Standard Design Approval in hand, SMART100 offers Member States a licensed, construction-ready platform for pink hydrogen and broader non-electric applications.



Thank You

감사합니다 · ขอบขอบคุณ

SMART100 — licensed, construction-ready, and open to international partnership



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