(A) Key parameters utilized in the studies:

TABLE S1
KEY ECONOMIC-TECHNICAL PARAMETERS OF OEIS AND THE CPHS

Parameter	Value	Parameter	Value
cc^{ELZ}	500 (10^4¥/MW)	cc^{DES}	50 (10^4¥/MW)
cc^{WT} (fixed-bottom)	900 (10^4¥/MW)	cc^{WT} (floating)	2500 (10^4¥/MW)
cc^{WE}	4500 (10^4¥/MW)	cc^{HS}	374.6 (10^4¥/ton)
$cc^{\mathrm{LN}}_{\mathrm{ons}}$	0.95 (10^4¥/MW/km)	$cc^{\mathrm{HP}}_{\mathrm{ons}}$	99.6 [10^4¥/(ton·h·km)]
$cc^{\mathrm{HP}}_{\mathrm{offs}}$	124.5 [10^4¥/(ton·h·km)]	cc^{TR}	15 (10^4¥/MW)
cc^{VSC}	120 (10^4¥/MW)	c^{ves}	0.49 (10^4¥/ton)
c^{gas}	(10^4¥/MW)	c^{input}	(10^4¥/MW)
P^{WTr}	10 MW	P^{WEr}	1 (MW)
$\bar{\Phi}^{\mathrm{HP}}$	0.5 (ton/h)	$\underline{\Phi}^{\mathrm{HP}}$	3 (ton/h)
γ^{AC}	0.05	γ^{DC}	0.025
R^{CU}	50 (MW)	η^{GU}	0.45
ν^{H2}	39.44 (MWh/ton)	ν^{gas}	14.58 (MWh/ton)
ρ^{gas}	2.75 (ton CO_2/ton H_2)	ρ^{CU}	0.85 (ton CO_2/MWh)
ρ^{input}	15 (ton CO_2/ton H_2)	ϑ^{emi}	20000 (10^4¥/ton)

TABLE S2
PARAMETERS OF CANDIDATE SUBMARINE CABLES

Index	Type	$n^{\mathrm{AC}}/n^{\mathrm{DC}}$	Cost (10^4¥/km)	Capacity (MW)
1	Three-core AC cable	1	880	356
2	Three-core AC cable	1	1063	449
3	Three-core AC cable	1	1188	514
4	Three-core AC cable	1	1396	618
5	Single-core AC cable	3	838	356
6	Single-core AC cable	3	1012	449
7	Single-core AC cable	3	1132	514
8	Single-core AC cable	3	1329	618
9	Two-core DC cable	1	552	478
10	Two-core DC cable	1	673	600
11	Two-core DC cable	1	811	737
12	Two-core DC cable	1	1011	937
13	Single-core DC cable	2	501	478
14	Single-core DC cable	2	612	600
15	Single-core DC cable	2	737	737
16	Single-core DC cable	2	919	937

TABLE S3
PARAMETERS OF POWER TRANSMISSION CORRIDORS

Index	From bus	To bus	Length (km)	S^{line} (MW)
1	1	2	30	120
2	1	4	35	100
3	2	3	52	100
4	2	9	33	250
5	3	4	50	160
6	4	5	31	200
7	5	6	40	300
8	5	9	57	150
9	5	10	53	100
10	6	7	56	200
11	7	8	56	100
12	8	11	53	100
13	8	14	63	100
14	9	12	73	300
15	10	13	41	100
16	11	13	82	100
17	11	14	77	100
18	12	15	63	250
19	13	16	79	100
20	13	17	43	100
21	14	16	47	100
22	14	17	40	100
23	15	16	57	100
24	15	22	52	100
25	16	19	54	70
26	16	21	46	100
27	17	18	38	120
28	17	20	36	60
29	17	21	30	120
30	18	23	43	100
31	19	23	38	100
32	20	22	27	100
33	21	24	45	120
34	22	23	47	100
35	OEI-1	OEI-2	56	--
36	OEI-1	OEI-3	79	--
37	OEI-1	OEI-4	119	--
38	OEI-2	OEI-3	69	--
39	OEI-2	OEI-5	147	--
40	OEI-3	OEI-4	77	--

41	OEI-3	OEI-5	94	--
42	OEI-4	OEI-5	200	--
43	OEI-1	22	21	--
44	OEI-2	23	38	--
45	OEI-2	24	44	--
46	OEI-5	24	500	--
47	OEI-6	OEI-1	189	--
48	OEI-6	OEI-2	182	--
49	OEI-6	OEI-3	116	--
50	OEI-6	OEI-4	176	--
51	OEI-6	OEI-5	80	--

TABLE S4
PARAMETERS OF HYDROGEN TRANSMISSION CORRIDORS

Index	From node	To node	Length (km)	Φ^{HP0} (ton/h)
1	1	2	30	0.26
2	2	3	53	0.6
3	3	5	56	0.8
4	4	5	37	1.3
5	4	8	49	1.2
6	5	6	43	2.26
7	6	9	35	1.2
8	6	12	56	0.51
9	7	9	38	2.5
10	8	11	77	0.77
11	9	10	46	1.1
12	9	13	58	0.26
13	9	19	61	0.26
14	10	16	39	0.76
15	11	14	42	0.52
16	12	15	55	0.26
17	14	18	42	0.26
18	16	17	47	0.52
19	17	20	33	0.31
20	OEI-1	OEI-2	56	--
21	OEI-1	OEI-3	79	--
22	OEI-1	OEI-4	119	--
23	OEI-2	OEI-3	69	--
24	OEI-2	OEI-5	147	--
25	OEI-3	OEI-4	77	--
26	OEI-3	OEI-5	94	--
27	OEI-4	OEI-5	200	--

28	OEI-1	18	21	--
29	OEI-2	19	38	--
30	OEI-2	20	44	--
31	OEI-5	20	500	--
32	OEI-6	OEI-1	189	--
33	OEI-6	OEI-2	182	--
34	OEI-6	OEI-3	116	--
35	OEI-6	OEI-4	176	--
36	OEI-6	OEI-5	80	--

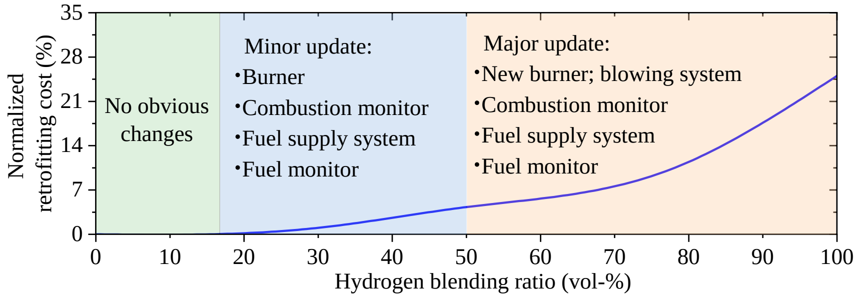

Fig. S1. Retrofitting cost of gas-fired units for high hydrogen blending ratio.

(B) Linearization method for nonlinear constraints:

(1) Nonlinear constraints of proton exchange membrane electrolyzer (PEME) are (21)-(23). The nonlinearity arises primarily from (22). Substituting (22) into (21) yields:

$$\begin{aligned} P_{id,t}^{\mathrm{ELZ}} &= z_{id}^{\mathrm{ELZ}} U_{id,t}^{\mathrm{ELZ}} I_{id,t}^{\mathrm{ELZ}} \\ &= z_{id}^{\mathrm{ELZ}} \times \left[U^{\mathrm{E}} + R^{\mathrm{C}} I_{id,t}^{\mathrm{ELZ}} + \alpha^{\mathrm{AN}} \operatorname{arsinh}(I_{id,t}^{\mathrm{ELZ}} / \theta^{\mathrm{AN}}) + \alpha^{\mathrm{CAT}} \operatorname{arsinh}(I_{id,t}^{\mathrm{ELZ}} / \theta^{\mathrm{CAT}})\right] I_{id,t}^{\mathrm{ELZ}} \\ &= z_{id}^{\mathrm{ELZ}} \times \left[U^{\mathrm{E}} I_{id,t}^{\mathrm{ELZ}} + R^{\mathrm{C}} \left(I_{id,t}^{\mathrm{ELZ}}\right)^2 + \alpha^{\mathrm{AN}} I_{id,t}^{\mathrm{ELZ}} \operatorname{arsinh}(I_{id,t}^{\mathrm{ELZ}} / \theta^{\mathrm{AN}}) + \alpha^{\mathrm{CAT}} I_{id,t}^{\mathrm{ELZ}} \operatorname{arsinh}(I_{id,t}^{\mathrm{ELZ}} / \theta^{\mathrm{CAT}})\right] \end{aligned} \tag{S1}$$

Denote function $f_{id,t}^{\mathrm{ELZ}}(I_{id,t}^{\mathrm{ELZ}})$ as:

$$f_{id,t}^{\mathrm{ELZ}}(I_{id,t}^{\mathrm{ELZ}}) = U^{\mathrm{E}} I_{id,t}^{\mathrm{ELZ}} + R^{\mathrm{C}} \left(I_{id,t}^{\mathrm{ELZ}}\right)^2 + \alpha^{\mathrm{AN}} I_{id,t}^{\mathrm{ELZ}} \operatorname{arsinh}(I_{id,t}^{\mathrm{ELZ}} / \theta^{\mathrm{AN}}) + \alpha^{\mathrm{CAT}} I_{id,t}^{\mathrm{ELZ}} \operatorname{arsinh}(I_{id,t}^{\mathrm{ELZ}} / \theta^{\mathrm{CAT}}) \tag{S2}$$

Fortunately, $f_{id,t}^{\mathrm{ELZ}}(I_{id,t}^{\mathrm{ELZ}})$ is a univariate function of $I_{id,t}^{\mathrm{ELZ}}$, and its derivative increases with $I_{id,t}^{\mathrm{ELZ}}$. This implies that it can be piecewise linearly without introducing binary variables. The domain of $I_{id,t}^{\mathrm{ELZ}} \in [\underline{I}^{\mathrm{ELZ}}, \overline{I}^{\mathrm{ELZ}}]$ can be partitioned into N equal segments using the following N+1 points: $[I_{id,t}^{\mathrm{ELZ}(0)}, f_{id,t}^{\mathrm{ELZ}}(I_{id,t}^{\mathrm{ELZ}(0)})], [I_{id,t}^{\mathrm{ELZ}(1)}, f_{id,t}^{\mathrm{ELZ}}(I_{id,t}^{\mathrm{ELZ}(1)})], \ldots, [I_{id,t}^{\mathrm{ELZ}(n)}, f_{id,t}^{\mathrm{ELZ}}(I_{id,t}^{\mathrm{ELZ}(n)})], \ldots, [I_{id,t}^{\mathrm{ELZ}(N)}, f_{id,t}^{\mathrm{ELZ}}(I_{id,t}^{\mathrm{ELZ}(N)})]$.

By introducing auxiliary variables $\Delta I_{id,t}^{\mathrm{ELZ}(n)}$ and $\Delta f_{id,t}^{\mathrm{ELZ}(n)}$, (S2) can be linearized into the following linear constraints:

$$0 \le \Delta I_{id,t}^{\mathrm{ELZ}(n)} \le (\overline{I}^{\mathrm{ELZ}} - \underline{I}^{\mathrm{ELZ}}) / N, \forall n = 1, 2, \cdots\cdots, N \tag{S3}$$

$$0 \le \Delta I_{id,t}^{\mathrm{ELZ}(n)} \le (\overline{I}^{\mathrm{ELZ}} - \underline{I}^{\mathrm{ELZ}}) / N, \forall n = 1, 2, \cdots\cdots, N \tag{S4}$$

$$\Delta I_{id,t}^{\mathrm{ELZ}(n)} \le \Delta I_{id,t}^{\mathrm{ELZ}(n+1)}, \forall n = 1, 2, \cdots\cdots, N-1 \tag{S5}$$

$$\Delta f_{id,t}^{\mathrm{ELZ}(n)} = \frac{f_{id,t}^{\mathrm{ELZ}}(I_{id,t}^{\mathrm{ELZ}(n)}) - f_{id,t}^{\mathrm{ELZ}}(I_{id,t}^{\mathrm{ELZ}(n\text{-}1)})}{(\overline{I}^{\mathrm{ELZ}} - \underline{I}^{\mathrm{ELZ}}) / N} \times \Delta I_{id,t}^{\mathrm{ELZ}(n)}, \forall n = 1, 2, \cdots\cdots, N \tag{S6}$$

$$I_{id,t}^{\mathrm{ELZ}} = \sum_{n=1}^{N} \Delta I_{id,t}^{\mathrm{ELZ}(n)} \tag{S7}$$

$$f_{id,t}^{\mathrm{ELZ}} = \sum_{n=1}^{N} \Delta f_{id,t}^{\mathrm{ELZ}(n)} \tag{S8}$$

The cost function of hydrogen-ready retrofit $\hbar(\varphi_u^{\mathrm{H_2}})$ in Fig. S1 can also be linearized using the same method.

(2) Nonlinear constraints from the product of an integer variable and a continuous variable, e.g., (20)-(21). We use binary expansion method to cope with this type of nonlinearity. Assume that z is an integer variable and u is a continuous variable. We can replace the product $z \times u$ with a continuous auxiliary variable y and K auxiliary binary variables $x^{(k)}$ ($1 \leqslant k \leqslant K$) that satisfy the following linear constraints:

$$z = \sum_{k=1}^{K} 2^{k-1} x^{(k)} \tag{S9}$$

$$y = zu = \sum_{k=1}^{K} 2^{k-1} x^{(k)} u \tag{S10}$$

For the product of $x^{(k)} \times u$, we can further replace it with an auxiliary variable w that satisfies the following linear constraints:

$$w \le u - \underline{u} \times [1 - x^{(k)}] \tag{S11}$$

$$w \ge u - \overline{u} \times [1 - x^{(k)}] \tag{S12}$$

$$\underline{u} x^{(k)} \le w \le \overline{u} x^{(k)} \tag{S13}$$

where $\underline{u}$ and $\overline{u}$ are minimum and maximum value of u.

(3) Nonlinear constraints with absolute value terms, e.g., Eqs. (28)-(29) and (50). We can replace the absolute value term $|x|$ with w by introducing continuous auxiliary variables x^+, x^- that satisfy the following linear constraints:

$$x = x^+ - x^- \tag{S14}$$

$$w = x^+ + x^- \tag{S15}$$

$$w \ge x \tag{S16}$$

$$w \ge -x \tag{S17}$$