Supplementary Information

Hydrogen economy driven by offshore wind in Regional Comprehensive Economic Partnership members

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Supplementary Text

Hydrogen demand prediction model.

In the hydrogen demand prediction, the substitution roles of hydrogen in power generation, heating, industry, and transportation are considered.

1) Hydrogen serves as a direct replacement for power generation. According to the assessment of Hydrogen Council,[1] about 10% of the electricity will be supplied by hydrogen in 2050.

2) The heating sector is further subdivided into building heating (low and medium grade) and industry heating (high grade), with hydrogen substitution ratios of 10% and 25%, respectively.[1]

3) The industry sector can be further subdivided into 7 sub-sectors, the substitution effects of which refer to Fig. S2.[2]

4) The corresponding substitution ratios in the transportation sector, which is further divided into 5 sub-sectors according to the type of transportation, are also different.[1]

The data on energy demand of various sectors are fetched from Asia Pacific Energy Research Centre (APERC).[3,4]

Based on the above basic data, the hydrogen demand in the various sectors can be calculated as follows:

1) Power generation

$$H_i^{\mathrm{POWER}} = \frac{1}{\eta^{\mathrm{POWER}}} \vartheta^{\mathrm{POWER}} \sum_{m \in \mathrm{M}_i} ED_{i,m} \tag{S1}$$

where $\vartheta^{\mathrm{POWER}}$ is the substitution ratio of hydrogen in power generation, η^{POWER} is the substitution efficiency of hydrogen in power generation, and $ED_{i,m}$ is the 2050 electricity load demand of the land area radiated by the *m*-th harbour of the *i*-th member.

2) Heating

$$H_i^{\mathrm{HEAT}} = \frac{1}{\eta^{\mathrm{LHD}}} \vartheta^{\mathrm{LHD}} LHD_i + \frac{1}{\eta^{\mathrm{HHD}}} \vartheta^{\mathrm{HHD}} HHD_i \tag{S2}$$

where ϑ^{LHD} and ϑ^{HHD} are the substitution ratios of hydrogen to the low-grade heating and high-grade heating, respectively, η^{LHD} and η^{HHD} are the substitution efficiencies of hydrogen to the low-grade heating and high-grade heating, respectively, LHD_i is the 2050 low-grade heating demand of the *i*-th member, and HHD_i is the 2050 high-grade heating demand of the *i*-th member.

3) Industry

$$H_{i,s,f}^{\mathrm{IND}} = \frac{1}{\eta_{s,f}^{\mathrm{IND}}} \vartheta_{s,f}^{\mathrm{IND}} FD_{i,s,f} \tag{S3}$$

where $\vartheta_{s,f}^{\mathrm{IND}}$ is the substitution ratio of hydrogen to the *f*-th fossil energy of the *s*-th sub-sector, $\eta_{s,f}^{\mathrm{IND}}$ is the substitution efficiency of hydrogen to the *f*-th fossil energy of the *s*-th sub-sector, $FD_{i,s,f}$ is the demand of the *f*-th fossil energy of the *s*-th sub-sector in the *i*-th member, and *f* refers to coal, oil, and gas.

4) Transportation

$$H_{i,p}^{\mathrm{TRAN}} = \frac{1}{\eta_p^{\mathrm{TRAN}}} \vartheta_p^{\mathrm{TRAN}} TD_{i,p} \tag{S4}$$

where $\vartheta_p^{\mathrm{TRAN}}$ is the substitution ratio of hydrogen to the *p*-th transport, η_p^{TRAN} is the substitution efficiency of hydrogen to the *p*-th transport, and $TD_{i,p}$ is the energy demand of the *p*-th transport in the *i*-th member.

The total hydrogen demand of the *i*-th member is:

$$H_i^d = H_i^{\mathrm{POWER}} + H_i^{\mathrm{HEAT}} + \sum_{s \in \Theta} \sum_{f \in \{coal, oil, gas\}} H_{i,s,f}^{\mathrm{IND}} + \sum_{n \in \Upsilon} H_{i,n}^{\mathrm{TRAN}} \tag{S5}$$

where Θ is the set of sub-sectors in the industry sector, and Υ is the set of transport in the transportation sector.

Model for transportation using methylcyclohexane (MCH) or ammonia.

The updated Eqs. (S6) to (S14) compared with Eqs. (1), (4), (5), (7), (8), (9), (10), (13), and (14), and one more Eq. (S15) for hydrogen conversion, are presented as follows:

1) Objective function

$$
\begin{aligned}
\min & \sum_{x\in\{\text{wt-grid},\text{wt-hydro},\text{elz-h},\text{elz-ma},\text{com},\text{ma-IM},\text{ma-EX},\text{sh},\text{cra}\}} \left(C_{\text{inv}}^{x}+C_{\text{om}}^{x}\right)+C^{\text{ope}}+C^{\text{loc}}-C^{\text{grid}} \\
&= \sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{k\in\Omega_{im}}\left[\kappa^{\text{wt}}c_{i,m,k}^{\text{wt}}\begin{pmatrix} I_{i,m,k}^{\text{wt-grid}}+ \\ I_{i,m,k}^{\text{wt-hydro}}\end{pmatrix}+\sigma_{\text{om}}^{\text{wt}}c_{i,m,k}^{\text{wt}}\begin{pmatrix} I_{i,m,k}^{\text{wt-grid}}+ \\ I_{i,m,k}^{\text{wt-hydro}}\end{pmatrix}\right]+ \\
&\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{y\in\{\text{elz-h},\text{elz-ma},\text{com},\text{ma-IM},\text{ma-EX},\text{cra}\}}\left(\kappa^{y}c_{i,m}^{y}I_{i,m}^{y}+\sigma_{\text{om}}^{y}c_{i,m}^{y}I_{i,m}^{y}\right)+ \\
&\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{j\in\Gamma_{im}}\sum_{n\in ¢_{imj}}\left(\kappa^{\text{sh}}N_{i,m,j,n}^{\text{sh}}c_{i,m}^{\text{sh}}+\sigma_{\text{om}}^{\text{sh}}N_{i,m,j,n}^{\text{sh}}c_{i,m}^{\text{sh}}\right)+ \\
&\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{t\in T}\left[c^{\text{we}}\delta^{\text{we}}\left(H_{i,m,t}^{\text{com}}+H_{i,m,t}^{\text{ma}}LHV_{\text{ma}}\big/LHV_{\text{H}_2}\right)\right]+ \\
&\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{j\in\Gamma_{im}}\sum_{n\in ¢_{imj}}\left(q^{\text{oil}}c^{\text{oil}}R_{i,m,j,n}F_{i,m,j,n}N_{i,m,j,n}^{\text{sh}}\right)+ \\
&\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\text{LCOH}_{i,m}^{\text{loc}}H_{i,m}^{\text{loc}}-\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{t\in T}\text{FIT}_{i,m}^{\text{grid}}E_{i,m,t}^{\text{grid}}
\end{aligned}
\tag{S6}
$$

where elz-ma denotes water electrolyser-MCH or ammonia, ma-IM denotes related storage equipment for MCH or ammonia in import terminals, ma-EX denotes related storage equipment for MCH or ammonia in export terminals, cra denotes the MCH or ammonia cracking equipment, $I_{i,m}^{\text{elz-ma}}$ denotes the capacity of water electrolyser-MCH or ammonia in the *m*-th harbour of the *i*-th member, $I_{i,m}^{\text{cra}}$ denotes the capacity of the MCH or ammonia cracking equipment in the *m*-th harbour of the *i*-th member, $H_{i,m,t}^{\text{ma}}$ denotes the output volume of the water electrolyser-MCH or ammonia at the *t*-th time in the *m*-th harbour of the *i*-th member, and LHV_{ma} denotes the lower heating value of MCH or ammonia.

2) Constraints

(1) Equipment operation constraint

a. Input power constraint of the water electrolyser-hydrogen, MCH, or ammonia

$$
\begin{cases} 0\le E_{i,m,t}^{\text{elz-h}}\le I_{i,m}^{\text{elz-h}} \\ 0\le E_{i,m,t}^{\text{elz-ma}}\le I_{i,m}^{\text{elz-ma}} \end{cases},\forall i\in\Xi, m\in \mathrm{M}_i, t\in T
\tag{S7}
$$

where $E_{i,m,t}^{\text{elz-ma}}$ denotes the input power of the water electrolyser-MCH or ammonia at the *t*-th time in the *m*-th harbour of the *i*-th member.

b. Hydrogen constraint of compression and cracking equipment

$$
\begin{cases} 0\le H_{i,m,t}^{\text{com}}\le I_{i,m}^{\text{com}} \\ 0\le H_{i,m,t}^{\text{cra}}\le I_{i,m}^{\text{cra}} \end{cases},\forall i\in\Xi, m\in \mathrm{M}_i, t\in T
\tag{S8}
$$

where $H_{i,m,t}^{\text{cra}}$ denotes the output volume of hydrogen of the cracking equipment at the *t*-th time in the *m*-th harbour of the *i*-th member.

(2) Hourly power balances

$$\begin{cases} E_{i,m,k,t}^{\text{use-grid}} + E_{i,m,k,t}^{\text{cur-grid}} = \rho_{i,m,k,t} I_{i,m,k}^{\text{wt-grid}}, 0 \le E_{i,m,k,t}^{\text{use-grid}}, 0 \le E_{i,m,k,t}^{\text{cur-grid}} \\ E_{i,m,t}^{\text{grid}} = \sum_{k \in \Omega_{im}} E_{i,m,k,t}^{\text{use-grid}} \\ E_{i,m,k,t}^{\text{use-hydro}} + E_{i,m,k,t}^{\text{cur-hydro}} = \rho_{i,m,k,t} I_{i,m,k}^{\text{wt-hydro}}, 0 \le E_{i,m,k,t}^{\text{use-hydro}}, 0 \le E_{i,m,k,t}^{\text{cur-hydro}} \\ E_{i,m,t}^{\text{elz-h}} + \lambda^{\text{com}} \eta^{\text{com}} H_{i,m,t}^{\text{com}} + E_{i,m,t}^{\text{elz-ma}} + \lambda^{\text{cra}} H_{i,m,t}^{\text{cra}} = \sum_{k \in \Omega_{im}} \left(E_{i,m,k,t}^{\text{use-hydro}} + E_{i,m,k,t}^{\text{cur-grid-hydro}} \right), \forall i \in \Xi, m \in \mathrm{M}_i, t \in T \\ 0 \le E_{i,m,k,t}^{\text{cur-grid-hydro}} \le E_{i,m,k,t}^{\text{cur-grid}} \\ SNSP = \dfrac{E_{i,m,t}^{\text{grid}}}{\beta_{i,m} E_{i,m,t}^{\text{elec}}} \\ 0 \le SNSP \le SNSP^{\max} \end{cases} \tag{S9}$$

where λ^{cra} denotes the electricity of the cracking equipment required to generate 1 kg hydrogen.

(3) Related storage equipment constraints of import and export harbour, including storage constraint, charging and discharging balance constraint, and imported and exported MCH or ammonia balance. The specific charging and discharging mechanism is presented in Fig. S1b.

a. Related storage constraint of import and export harbour

$$\begin{cases} 0 \le S_{i,m,t}^{\text{ma-IM/EX}} \le I_{i,m}^{\text{ma-IM/EX}}, S_{i,m,0}^{\text{ma-IM/EX}} = S_{i,m,8760}^{\text{ma-IM/EX}} \\ S_{i,m,t+1}^{\text{ma-IM/EX}} = \left(1-\alpha^{\text{ma}}\right) S_{i,m,t}^{\text{ma-IM/EX}} + H_{i,m,t}^{\text{ma-IM/EX,cha}} - H_{i,m,t}^{\text{ma-IM/EX,dis}}, \forall i \in \Xi, m \in \mathrm{M}_i, t \in T \\ 0 \le H_{i,m,t}^{\text{ma-IM/EX,cha}} \le I_{i,m}^{\text{ma-IM/EX}}, 0 \le H_{i,m,t}^{\text{ma-IM/EX,dis}} \le I_{i,m}^{\text{ma-IM/EX}} \end{cases} \tag{S10}$$

b. Charging and discharging balance constraint

For imported storage:

$$H_{i,m,t}^{\text{ma-IM,cha}} = H_{i,m,t}^{\text{IM}}, H_{i,m,t}^{\text{ma-IM,dis}} = H_{i,m,t}^{\text{ma-loc,IM}}, \forall i \in \Xi, m \in \mathrm{M}_i, t \in T \tag{S11}$$

For exported storage:

$$\begin{cases} H_{i,m,t}^{\text{ma-EX,cha}} = H_{i,m,t}^{\text{ma}}, H_{i,m,t}^{\text{ma-EX,dis}} = H_{i,m,t}^{\text{ma-loc,EX}} + H_{i,m,t}^{\text{EX}} \\ 0 \le H_{i,m,t}^{\text{ma-loc,EX}}, 0 \le H_{i,m,t}^{\text{EX}} \end{cases}, \forall i \in \Xi, m \in \mathrm{M}_i, t \in T \tag{S12}$$

(4) Hydrogen balances of harbours

$$H_{i,m}^{\text{d}} = \eta^{\text{com}} \sum_{t \in T} H_{i,m,t}^{\text{com}} + \sum_{t \in T} H_{i,m,t}^{\text{cra}} + H_{i,m}^{\text{loc}}, \forall i \in \Xi, m \in \mathrm{M}_i \tag{S13}$$

(5) Energy balances of water electrolyser-hydrogen, MCH, or ammonia in harbours

$$\begin{cases} H_{i,m,t}^{\text{com}} = \dfrac{\eta^{\text{elz-h}} E_{i,m,t}^{\text{elz-h}}}{LHV_{\text{H}_2}} \\ H_{i,m,t}^{\text{ma}} = \dfrac{\eta^{\text{elz-ma}} E_{i,m,t}^{\text{elz-ma}}}{LHV_{\text{ma}}} \end{cases}, \forall i \in \Xi, m \in \mathrm{M}_i, t \in T \tag{S14}$$

where $\eta^{\text{elz-ma}}$ denotes the efficiency of water electrolyser-MCH or ammonia.

(6) Hydrogen conversion

$$H_{i,m,t}^{\text{cra}} LHV_{\text{H}_2} = \left(H_{i,m,t}^{\text{ma-loc,IM}} + H_{i,m,t}^{\text{ma-loc,EX}} \right) LHV_{\text{ma}} \eta^{\text{cra}}, \forall i \in \Xi, m \in \mathrm{M}_i, t \in T \tag{S15}$$

where η^{cra} denotes the efficiency of the cracking equipment.

<u>Cost calculation 1 for Sections 3.1 to 3.4.</u>

1) Levelized cost of hydrogen before optimisation (Sections 3.1 to 3.2)

The hydrogen production cost of each grid cell is affected by the offshore wind power generation cost, water electrolyser cost, and water charge. Taking an 8 MW wind turbine (MHI Vestas Offshore Wind's V164-8.0 MW turbine) as an example, all of the electricity produced is converted into hydrogen. The specific calculation of the levelized cost of hydrogen (LCOH) is as follows:

$$\text{LCOE}_{i,m,k} = \frac{\kappa^{\text{wt}} c_{i,m,k}^{\text{wt}} I_0^{\text{wt}} + \sigma_{\text{om}}^{\text{wt}} c_{i,m,k}^{\text{wt}} I_0^{\text{wt}}}{\sum_{t \in T} \rho_{i,m,k,t} I_0^{\text{wt}}} \tag{S16}$$

$$\mathrm{LCOH}_{i,m,k}=\frac{\kappa^{\text{elz-h}}c_{i,m}^{\text{elz-h}}I_0^{\text{elz-h}}+\sigma_{\text{om}}^{\text{elz-h}}c_{i,m}^{\text{elz-h}}I_0^{\text{elz-h}}+\mathrm{LCOE}_{i,m,k}E_{i,m,k}^{\text{elz-h}}+c^{\text{we}}\delta^{\text{we}}H_{i,m,k}^{\text{elz-h}}}{H_{i,m,k}^{\text{elz-h}}} \tag{S17}$$

where $\mathrm{LCOE}_{i,m,k}$ and $\mathrm{LCOH}_{i,m,k}$ are the levelized cost of electricity and hydrogen of the *k*-th grid cell of the *m*-th harbour in the *i*-th member, I_0^{wt} is the rated capacity of the offshore wind turbine with 8 MW, $I_0^{\text{elz-h}}$ is the rated capacity of the water electrolyser-hydrogen, set to 8 MW to ensure the 100% consumption of offshore wind power in any cell at any time, and $E_{i,m,k}^{\text{elz-h}}$ and $H_{i,m,k}^{\text{elz-h}}$ are the input electricity and output hydrogen of the water electrolyser-hydrogen of the *k*-th grid cell of the *m*-th harbour in the *i*-th member, which is calculated as follows:

$$H_{i,m,k}^{\text{elz-h}}=\frac{\eta^{\text{elz-h}}E_{i,m,k}^{\text{elz-h}}}{LHV_{\mathrm{H_2}}}=\frac{\eta^{\text{elz-h}}\sum_{t\in T}\rho_{i,m,k,t}I_0^{\text{wt}}}{LHV_{\mathrm{H_2}}} \tag{S18}$$

2) Levelized cost of landed hydrogen after optimisation (Sections 3.3 to 3.4)

The levelized cost of landed hydrogen (LCOH[L]) of the *n*-th harbour in the *j*-th member with hydrogen imported from the *m*-th harbour in the *i*-th member includes the shipping-loss considered levelized cost of hydrogen $\mathrm{LCOH}'_{i,m,j,n}$, liquefaction $\mathrm{LCOL}_{i,m,j,n}$, storage $\mathrm{LCOS}_{i,m,j,n}$, and shipping $\mathrm{LCOSH}_{i,m,j,n}$, namely:

$$\mathrm{LCOH}_{i,m,j,n}^{\mathrm{L}}=\mathrm{LCOH}'_{i,m,j,n}+\mathrm{LCOL}_{i,m,j,n}+\mathrm{LCOS}_{i,m,j,n}+\mathrm{LCOSH}_{i,m,j,n} \tag{S19}$$

$$\mathrm{LCOH}'_{i,m,j,n}=\frac{\mathrm{LCOH}_{i,m}^{*}}{\left(1-\alpha^{\text{sh}}\right)^{F_{i,m,j,n}}} \tag{S20}$$

$$\mathrm{LCOL}_{i,m,j,n}=\frac{\left(\kappa^{\text{liq}}c_{i,m}^{\text{liq}}I_{i,m}^{\text{liq}}+\sigma_{\text{om}}^{\text{liq}}c_{i,m}^{\text{liq}}I_{i,m}^{\text{liq}}\right)+\left[\mathrm{LCOE}_{i,m}^{\text{hydro},*}\mu_{i,m}+\mathrm{LCOE}_{i,m}^{\text{grid},*}\left(1-\mu_{i,m}\right)\right]\cdot\lambda^{\text{liq}}\eta^{\text{liq}}\sum_{t\in T}H_{i,m,t}^{\text{liq}}}{\left(1-\alpha^{\text{sh}}\right)^{F_{i,m,j,n}}\sum_{j\in\Gamma_{im}}\sum_{n\in ¢_{imj}}H_{i,m,j,n}^{\text{EX}}} \tag{S21}$$

$$\mathrm{LCOS}_{i,m,j,n}=\frac{\kappa^{\text{ls-EX}}c_{i,m}^{\text{ls-EX}}I_{i,m}^{\text{ls-EX}}+\sigma_{\text{om}}^{\text{ls-EX}}c_{i,m}^{\text{ls-EX}}I_{i,m}^{\text{ls-EX}}}{\left(1-\alpha^{\text{sh}}\right)^{F_{i,m,j,n}}\sum_{j\in\Gamma_{im}}\sum_{n\in ¢_{imj}}H_{i,m,j,n}^{\text{EX}}} \tag{S22}$$

$$\mathrm{LCOSH}_{i,m,j,n}=\frac{\left(\kappa^{\text{sh}}N_{i,m,j,n}^{\text{sh}}c_{i,m}^{\text{sh}}+\sigma_{\text{om}}^{\text{sh}}N_{i,m,j,n}^{\text{sh}}c_{i,m}^{\text{sh}}\right)+\left(q^{\text{oil}}c^{\text{oil}}R_{i,m,j,n}F_{i,m,j,n}N_{i,m,j,n}^{\text{sh}}\right)}{\left(1-\alpha^{\text{sh}}\right)^{F_{i,m,j,n}}H_{i,m,j,n}^{\text{EX}}} \tag{S23}$$

where $\mu_{i,m}$ denotes the ratio of used offshore wind power from turbines for hydrogen production to the total OWH-used offshore wind power in the developed sea area of the *m*-th harbour in the *i*-th member based on the optimisation results, and $\mathrm{LCOE}_{i,m}^{\text{hydro},*}$, $\mathrm{LCOE}_{i,m}^{\text{grid},*}$, and $\mathrm{LCOH}_{i,m}^{*}$ are the average levelized cost of electricity for hydrogen production, electricity for grid connection, and hydrogen in the developed sea area of the *m*-th harbour in the *i*-th member based on the optimisation results, which is:

$$\mu_{i,m}=\frac{\sum_{k\in\Omega_{im}}\sum_{t\in T}E_{i,m,k,t}^{\text{use-hydro}}}{\sum_{k\in\Omega_{im}}\sum_{t\in T}\left(E_{i,m,k,t}^{\text{use-hydro}}+E_{i,m,k,t}^{\text{cur-grid-hydro}}\right)} \tag{S24}$$

$$\mathrm{LCOE}_{i,m}^{\text{hydro},*}=\frac{\sum_{k\in\Omega_{im}}\left(\kappa^{\text{wt}}c_{i,m,k}^{\text{wt}}I_{i,m,k}^{\text{wt-hydro}}+\sigma_{om}^{\text{wt}}c_{i,m,k}^{\text{wt}}I_{i,m,k}^{\text{wt-hydro}}\right)}{\sum_{k\in\Omega_{im}}\sum_{t\in T}E_{i,m,k,t}^{\text{use-hydro}}} \tag{S25}$$

$$\mathrm{LCOE}_{i,m}^{\text{grid},*}=\frac{\sum_{k\in\Omega_{im}}\left(\kappa^{\text{wt}}c_{i,m,k}^{\text{wt}}I_{i,m,k}^{\text{wt-grid}}+\sigma_{\text{om}}^{\text{wt}}c_{i,m,k}^{\text{wt}}I_{i,m,k}^{\text{wt-grid}}\right)}{\sum_{k\in\Omega_{im}}\sum_{t\in T}\left(E_{i,m,k,t}^{\text{use-grid}}+E_{i,m,k,t}^{\text{cur-grid-hydro}}\right)} \tag{S26}$$

$$\mathrm{LCOH}_{i,m}^{*}=\frac{\kappa^{\rm elz\text{-}h}c_{i,m}^{\rm elz\text{-}h}I_{i,m}^{\rm elz\text{-}h}+\sigma_{om}^{\rm elz\text{-}h}c_{i,m}^{\rm elz\text{-}h}I_{i,m}^{\rm elz\text{-}h}+\left[\mathrm{LCOE}_{i,m}^{\rm hydro,*}\mu_{i,m}+\mathrm{LCOE}_{i,m}^{\rm grid,*}\left(1-\mu_{i,m}\right)\right]\sum_{t\in T}E_{i,m,t}^{\rm elz\text{-}h}}{H_{i,m,t}^{\rm com}+H_{i,m,t}^{\rm liq}}+c^{\rm we}\delta^{\rm we} \quad \text{(S27)}$$

The average $\mathrm{LCOH}^{\mathrm{L}}$ of the *n*-th harbour in the *j*-th member for importing hydrogen is computed as follows:

$$\mathrm{LCOH}_{j,n}^{\rm L}=\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\left(\frac{H_{j,n,i,m}^{\rm IM}}{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}H_{j,n,i,m}^{\rm IM}}\cdot \mathrm{LCOH}_{i,m,j,n}^{\rm L}\right) \quad \text{(S28)}$$

3) Levelized cost of compressed hydrogen after optimisation (Sections 3.3 to 3.4)

The average levelized cost of compressed hydrogen (LCOC) of the *n*-th harbour in the *j*-th member is calculated according to:

$$\mathrm{LCOC}_{j,n}=\mathrm{LCOH}_{j,n}^{*}+\frac{\left(\kappa^{\rm com}c_{j,n}^{\rm com}I_{j,n}^{\rm com}+\sigma_{om}^{\rm com}c_{j,n}^{\rm com}I_{j,n}^{\rm com}\right)+\left[\mathrm{LCOE}_{j,n}^{\rm hydro,*}\mu_{j,n}+\mathrm{LCOE}_{j,n}^{\rm grid,*}\left(1-\mu_{j,n}\right)\right]\cdot\lambda^{\rm com}\eta^{\rm com}\sum_{t\in T}H_{j,n,t}^{\rm com}}{\eta^{\rm com}\sum_{t\in T}H_{j,n,t}^{\rm com}} \quad \text{(S29)}$$

4) Levelized cost of used hydrogen after optimisation (Sections 3.3 to 3.4)

The average levelized cost of used hydrogen ($\mathrm{LCOH}^{\mathrm{U}}$) of the *n*-th harbour in the *j*-th member is calculated as follows:

$$\mathrm{LCOH}_{j,n}^{\rm U}=\frac{\mathrm{LCOH}_{j,n}^{\rm loc}\cdot H_{j,n}^{\rm loc}+\mathrm{LCOC}_{j,n}\cdot\sum_{t\in T}H_{j,n,t}^{\rm com}+\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\mathrm{LCOH}_{i,m,j,n}^{\rm L}\cdot H_{j,n,i,m}^{\rm IM}}{H_{j,n}^{\rm d}} \quad \text{(S30)}$$

<u>Cost calculation 2 for Sections 3.5.</u>

1) Average levelized cost of electricity and hydrogen after optimisation

Assume that:

$$\mu=\frac{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{k\in\Omega_{im}}\sum_{t\in T}E_{i,m,k,t}^{\rm use\text{-}hydro}}{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{k\in\Omega_{im}}\sum_{t\in T}\left(E_{i,m,k,t}^{\rm use\text{-}hydro}+E_{i,m,k,t}^{\rm cur\text{-}grid\text{-}hydro}\right)} \quad \text{(S31)}$$

Then:

$$\begin{cases}\overline{\mathrm{LCOE}}^{\rm hydro}=\dfrac{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{k\in\Omega_{im}}\left(\kappa^{\rm wt}c_{i,m,k}^{\rm wt}I_{i,m,k}^{\rm wt\text{-}hydro}+\sigma_{\rm om}^{\rm wt}c_{i,m,k}^{\rm wt}I_{i,m,k}^{\rm wt\text{-}hydro}\right)}{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{k\in\Omega_{im}}\sum_{t\in T}E_{i,m,k,t}^{\rm use\text{-}hydro}}\\ \overline{\mathrm{LCOE}}^{\rm grid}=\dfrac{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{k\in\Omega_{im}}\left(\kappa^{\rm wt}c_{i,m,k}^{\rm wt}I_{i,m,k}^{\rm wt\text{-}grid}+\sigma_{\rm om}^{\rm wt}c_{i,m,k}^{\rm wt}I_{i,m,k}^{\rm wt\text{-}grid}\right)}{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{k\in\Omega_{im}}\sum_{t\in T}\left(E_{i,m,k,t}^{\rm use\text{-}grid}+E_{i,m,k,t}^{\rm cur\text{-}grid\text{-}hydro}\right)}\end{cases} \quad \text{(S32)}$$

$$\overline{\mathrm{LCOH}}=\begin{bmatrix}\dfrac{\left(\overline{\mathrm{LCOE}}^{\rm hydro}\mu+\overline{\mathrm{LCOE}}^{\rm grid}(1-\mu)\right)\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{t\in T}E_{i,m,t}^{\rm elz\text{-}h/ma}+\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}c_{i,m}^{\rm elz\text{-}h/ma}\begin{pmatrix}\kappa^{\rm elz\text{-}h/ma}I_{i,m}^{\rm elz\text{-}h/ma}+\\ \sigma_{\rm om}^{\rm elz\text{-}h/ma}I_{i,m}^{\rm elz\text{-}h/ma}\end{pmatrix}}{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{t\in T}\left(\eta^{\rm elz\text{-}h/ma}E_{i,m,t}^{\rm elz\text{-}h/ma}/LHV_{\rm H_2}\right)}\\ c^{\rm we}\delta^{\rm we}\end{bmatrix}+\begin{bmatrix}\dfrac{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{t\in T}H_{i,m,t}^{\rm EX}}{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{t\in T}H_{i,m,t}^{\rm IM}}\end{bmatrix} \quad \text{(S33)}$$

2) Average levelized cost of liquefaction after optimisation

$$\overline{\mathrm{LCOL}}=\frac{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\left[\left(\kappa^{\rm liq}c_{i,m}^{\rm liq}I_{i,m}^{\rm liq}+\sigma_{\rm om}^{\rm liq}c_{i,m}^{\rm liq}I_{i,m}^{\rm liq}\right)+\left(\overline{\mathrm{LCOE}}^{\rm hydro}\mu+\overline{\mathrm{LCOE}}^{\rm grid}(1-\mu)\right)\lambda^{\rm liq}\eta^{\rm liq}\sum_{t\in T}H_{i,m,t}^{\rm liq}\right]}{\sum_{i\in\Xi}\sum_{m\in \mathrm{M}_i}\sum_{t\in T}H_{i,m,t}^{\rm IM}} \quad \text{(S34)}$$

3) Average levelized cost of storage after optimisation

$$\overline{\mathrm{LCOS}}=\frac{\sum_{i\in\Xi}\sum_{m\in\mathrm{M}_i}\left(\kappa^{\mathrm{ls/ma\text{-}EX}}c_{i,m}^{\mathrm{ls/ma\text{-}EX}}I_{i,m}^{\mathrm{ls/ma\text{-}EX}}+\sigma_{\mathrm{om}}^{\mathrm{ls/ma\text{-}EX}}c_{i,m}^{\mathrm{ls/ma\text{-}EX}}I_{i,m}^{\mathrm{ls/ma\text{-}EX}}\right)}{\sum_{i\in\Xi}\sum_{m\in\mathrm{M}_i}\sum_{t\in T}H_{i,m,t}^{\mathrm{IM}}} \tag{S35}$$

4) Average levelized cost of shipping after optimisation

$$\overline{\mathrm{LCOSH}}=\frac{\sum_{i\in\Xi}\sum_{m\in\mathrm{M}_i}\sum_{j\in\Gamma_{im}}\sum_{n\in ¢_{imj}}\left(\kappa^{\mathrm{sh}}N_{i,m,j,n}^{\mathrm{sh}}c_{i,m}^{\mathrm{sh}}+\sigma_{\mathrm{om}}^{\mathrm{sh}}N_{i,m,j,n}^{\mathrm{sh}}c_{i,m}^{\mathrm{sh}}\right)+\sum_{i\in\Xi}\sum_{m\in\mathrm{M}_i}\sum_{j\in\Gamma_{im}}\sum_{n\in ¢_{imj}}\left(q^{\mathrm{oil}}c^{\mathrm{oil}}R_{i,m,j,n}F_{i,m,j,n}N_{i,m,j,n}^{\mathrm{sh}}\right)}{\sum_{i\in\Xi}\sum_{m\in\mathrm{M}_i}\sum_{t\in T}H_{i,m,t}^{\mathrm{IM}}} \tag{S36}$$

5) Average levelized cost of cracking after optimisation

$$\overline{\mathrm{LCOCK}}=\frac{\sum_{i\in\Xi}\sum_{m\in\mathrm{M}_i}\left[\left(\kappa^{\mathrm{cra}}c_{i,m}^{\mathrm{cra}}I_{i,m}^{\mathrm{cra}}+\sigma_{\mathrm{om}}^{\mathrm{cra}}c_{i,m}^{\mathrm{cra}}I_{i,m}^{\mathrm{cra}}\right)+\left(\overline{\mathrm{LCOE}}^{\mathrm{hydro}}\mu+\overline{\mathrm{LCOE}}^{\mathrm{grid}}(1-\mu)\right)\lambda^{\mathrm{cra}}\sum_{t\in T}H_{i,m,t}^{\mathrm{cra}}\right]LHV_{\mathrm{H_2}}}{\sum_{i\in\Xi}\sum_{m\in\mathrm{M}_i}\sum_{t\in T}H_{i,m,t}^{\mathrm{IM}}LHV_{\mathrm{ma}}} \tag{S37}$$

6) Average levelized cost of landed hydrogen after optimisation

$$\overline{\mathrm{LCOH}^{\mathrm{L}}}=\begin{cases}\overline{\mathrm{LCOH}}+\overline{\mathrm{LCOL}}+\overline{\mathrm{LCOS}}+\overline{\mathrm{LCOSH}}\\ \overline{\mathrm{LCOH}}+\overline{\mathrm{LCOS}}+\overline{\mathrm{LCOSH}}+\overline{\mathrm{LCOCK}}\end{cases} \tag{S38}$$

Model simplification.

To simplify the model, the clustering of 12 typical days (288 hours) in 12 months applying K-means in a year based on the average of 5 years (from 2016 to 2020) are selected as typical scenarios for optimisation calculation.

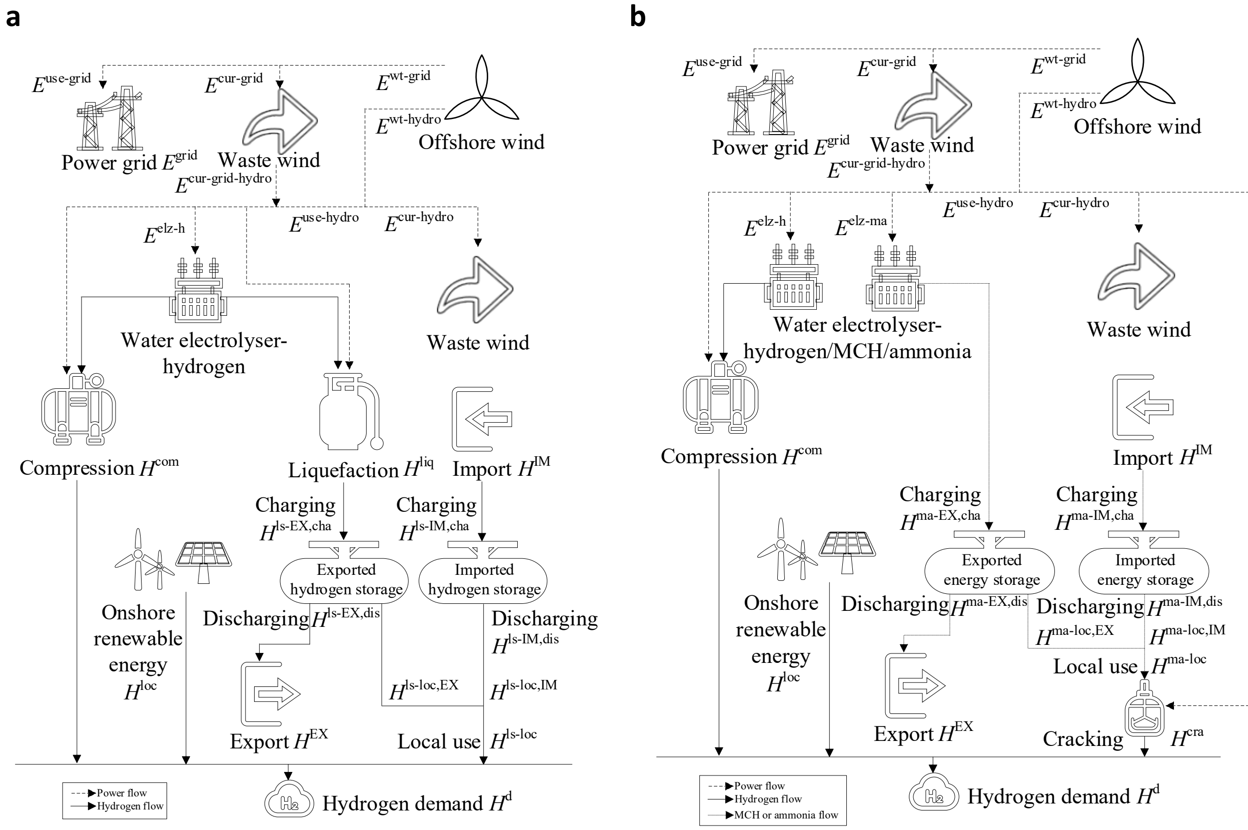

Fig. S1. Hydrogen-based trade chain model. (a) Transport by liquid hydrogen. (b) Transport by MCH or ammonia. The solid lines represent hydrogen flow, the dashed lines represent power flow, and the dotted lines represent MCH or ammonia flow. $E^{wt\text{-}grid}$ denotes the total offshore wind power for grid connection, equal to $\rho I^{wt\text{-}grid}$, ρ denotes the unit output of the offshore wind turbine, $I^{wt\text{-}grid}$ denotes the capacity of offshore wind turbine for grid connection, $E^{wt\text{-}hydro}$ denotes the total offshore wind power for hydrogen production, equal to $\rho I^{wt\text{-}hydro}$, $I^{wt\text{-}hydro}$ denotes the capacity of offshore wind turbine for hydrogen production, $E^{use\text{-}grid}$ denotes the used offshore wind power for grid connection, $E^{cur\text{-}grid}$ denotes the curtailed offshore wind power in grid connection, $E^{use\text{-}hydro}$ denotes the used offshore wind power for hydrogen production, $E^{cur\text{-}hydro}$ denotes the curtailed offshore wind power in hydrogen production, $E^{cur\text{-}grid\text{-}hydro}$ denotes the recycled offshore wind power for hydrogen production, which is curtailed in grid connection, E^{grid} denotes the electricity sold to the power grid , $E^{elz\text{-}h/ma}$ denotes the input power of the water electrolyser-hydrogen, MCH or ammonia, H^{liq} denotes the input volume of the liquefaction equipment, H^{com} denotes the input volume of the compression equipment, H^{loc} denotes the hydrogen production volume from onshore renewable energy, H^{IM} denotes the imported volume of hydrogen, MCH or ammonia, H^{EX} denotes the exported volume of hydrogen, MCH or ammonia, $H^{ls/ma\text{-}EX,cha}$ denotes the charging volume of exported storage, $H^{ls/ma\text{-}EX,dis}$ denotes the discharging volume of exported storage, $H^{ls/ma\text{-}loc,EX}$ denotes the discharging volume of hydrogen, MCH or ammonia for local demand in the exported storage, $H^{ls/ma\text{-}IM,cha}$ denotes the charging volume of imported storage, $H^{ls/ma\text{-}IM,dis}$ denotes the discharging volume of imported storage, $H^{ls/ma\text{-}loc,IM}$ denotes the discharging volume of hydrogen, MCH or ammonia for local demand in the imported storage, $H^{ls/ma\text{-}loc}$ denotes the total discharging volume of hydrogen, MCH or ammonia for local demand, H^{cra} denotes the output hydrogen of the cracking equipment, and H^{d} denotes the local hydrogen demand satisfied by renewables.

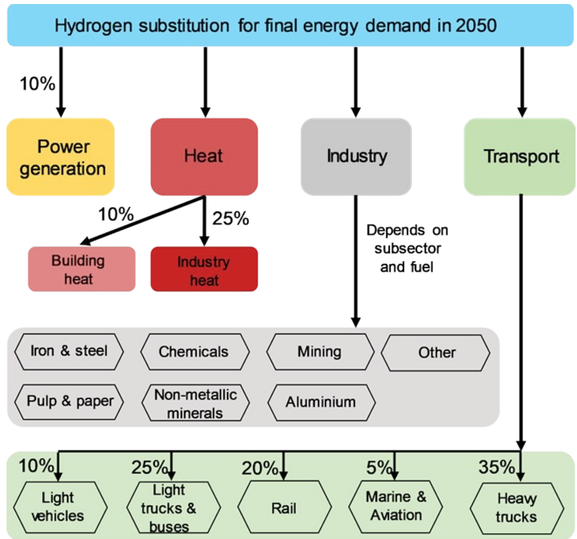

Fig. S2. Hydrogen demand prediction. Numbers on the side of the arrows indicate the substitution ratios of hydrogen in various sectors.

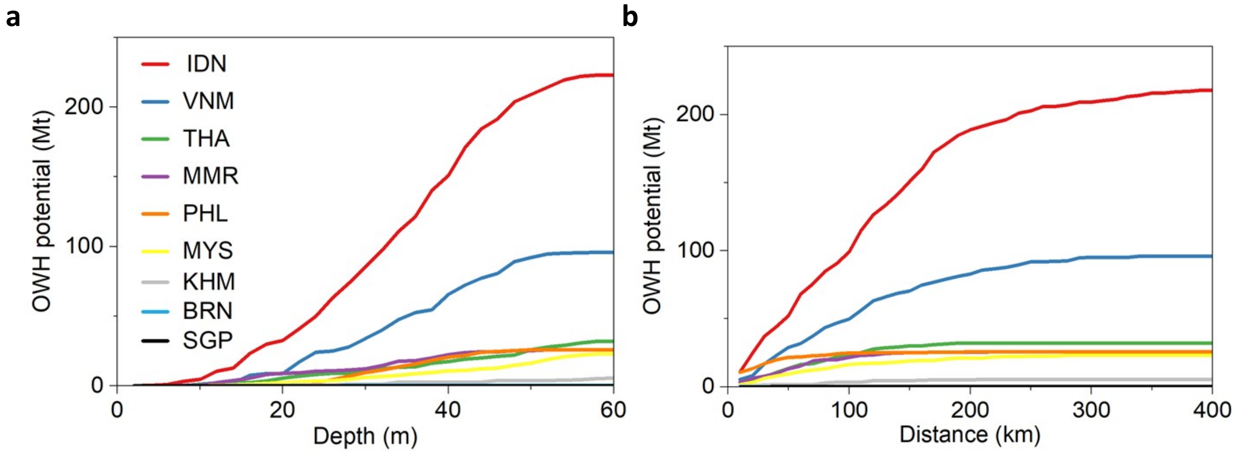

Fig. S3. Offshore wind-based hydrogen (OWH) production potentials at different depths and offshore distances in nine countries of the Association of Southeast Asian Nations (ASEAN) with sea areas. (a) OWH potential in nine countries of ASEAN at different depths. (b) OWH potential in nine countries of ASEAN at different distances.

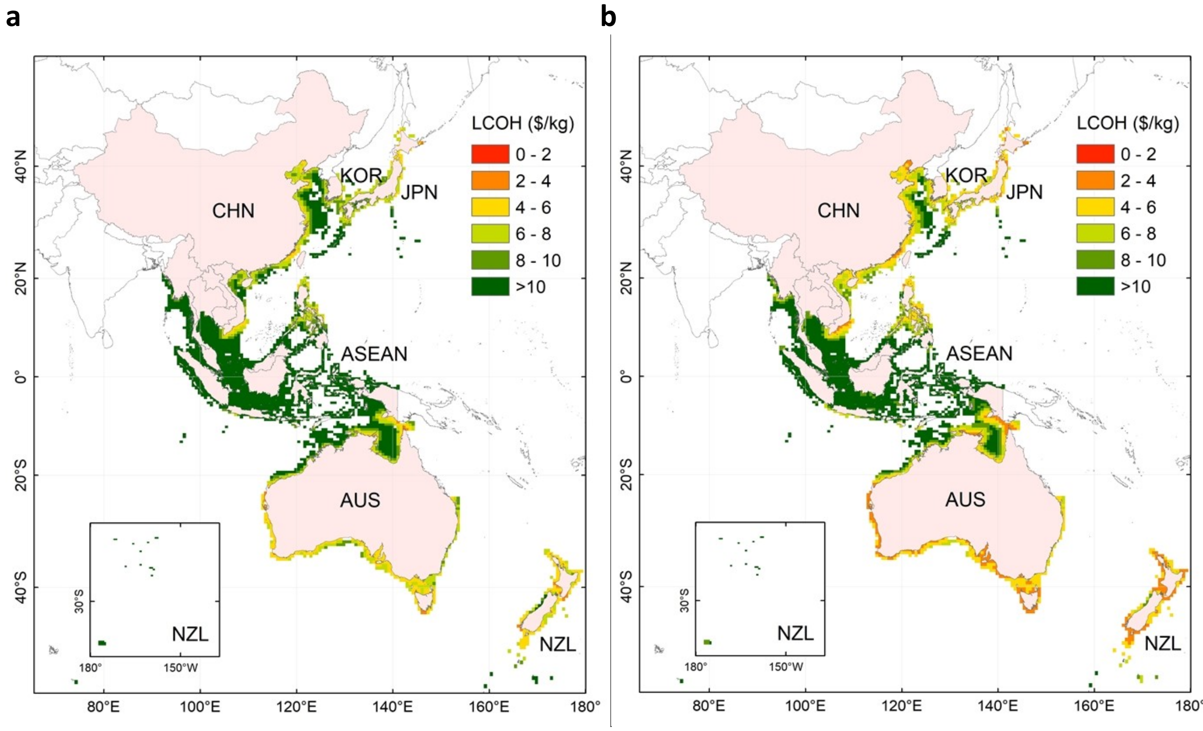

Fig. S4. Geographical distribution of the levelized cost of hydrogen (LCOH). (a) LCOH in 2030. (b) LCOH in 2040.

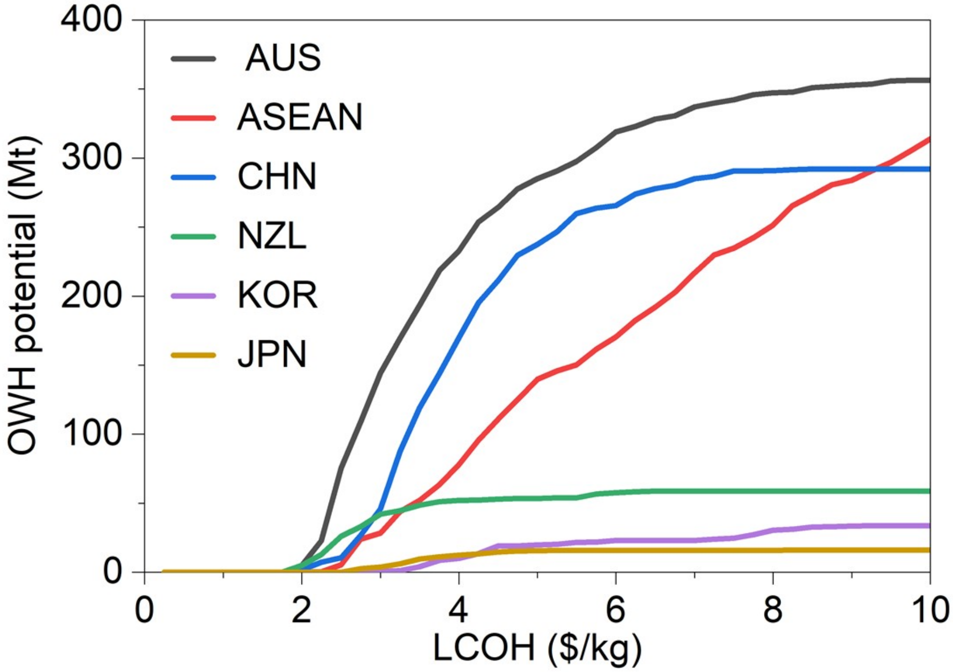

Fig. S5. Offshore wind-based hydrogen (OWH) potential among RCEP members that can offer a price range of 0-10 $/kg.

Table S1. Location, hydrogen demand, and LCOH from onshore renewables in RCEP from 2030 to 2050.

Country	Harbour name	Longitude	Latitude	Hydrogen demand (Mt)			LCOH from onshore renewables ($/kg)		
				2030	2040	2050	2030	2040	2050
AUS	Gladstone	151.2	-23.8	0.27	0.74	1.26	3	2.5	2
AUS	Darwin	130.8	-12.5	0.02	0.05	0.09	3	2.5	2
AUS	Onslow	115.1	-21.7	0.22	0.59	1.02	3	2.5	2
AUS	Kembla	150.9	-34.5	0.85	2.35	4.02	3	2.5	2
AUS	Adelaide	138.6	-34.9	0.08	0.22	0.38	3	2.5	2
NZL	Auckland	174.5	-36.5	0.19	0.51	0.88	4	3.5	3
NZL	Bluff	168.22	-46.34	0.05	0.15	0.25	4	3.5	3
CHN	Haikou	110	20	0.14	0.39	0.67	3.5	3	2.5
CHN	Beihai	109.4	21.4	0.57	1.56	2.67	3.5	3	2.5
CHN	Shenzhen	114.5	22.6	2.83	7.79	13.35	3.5	3	2.5
CHN	Xiamen	118.1	24.5	1.12	3.09	5.29	3.5	3	2.5
CHN	Wenzhou	120.7	28	1.65	4.54	7.79	3.5	3	2.5
CHN	Shanghai	122.1	30.6	0.99	2.72	4.66	3.5	3	2.5
CHN	Yancheng	120.5	33.7	2.63	7.22	12.38	3.5	3	2.5
CHN	Qingdao	120.4	36.1	1.87	5.14	8.81	3.5	3	2.5
CHN	Tianjin	117.7	39	0.36	0.99	1.70	3.5	3	2.5
CHN	Qinhuangdao	118.8	39.1	0.93	2.55	4.36	3.5	3	2.5
CHN	Dalian	121.9	39	0.64	1.77	3.03	3.5	3	2.5
KOR	Gunsan	126.7	35.9	1.24	3.42	5.86	4	3.5	3
KOR	Donghae	129.1	37.5	0.92	2.53	4.33	4	3.5	3
JPN	Otaru	141	43.2	0.05	0.14	0.24	5	4.5	4
JPN	Kushiro	144.4	42.97	0.05	0.14	0.24	5	4.5	4
JPN	Kanazawa	136.6	36.55	0.91	2.49	4.28	5	4.5	4
JPN	Hitachi	140.7	36.6	0.91	2.49	4.28	5	4.5	4
JPN	Tobata	133.7	34.5	0.64	1.75	3.00	5	4.5	4
JPN	Kagoshima	130.6	31.6	0.24	0.65	1.12	5	4.5	4
IDN	Tangguh	133.1	-2.4	0.09	0.24	0.41	4.5	4	3.5
IDN	Makassar	119.4	-5.16	0.25	0.68	1.17	4.5	4	3.5
IDN	Bontang	117.5	0.1	0.32	0.87	1.49	4.5	4	3.5
IDN	Jakarta	107	-6.1	3.27	9.00	15.43	4.5	4	3.5
MYS	Sungai Udang	102.36	2.14	1.05	2.89	4.95	4.5	4	3.5
MYS	Johor	103.8	1.5	0.39	1.09	1.86	4.5	4	3.5
PHL	Batangas	120.6	13.8	0.41	1.13	1.94	4.5	4	3.5
PHL	Cebu	123.56	10.23	0.25	0.70	1.20	4.5	4	3.5
PHL	Davao	125.32	7.4	0.16	0.45	0.76	4.5	4	3.5
THA	Map Ta Phut	101.2	12.7	1.66	4.57	7.83	4.5	4	3.5
SGP	Singapore	103.7	1.3	0.13	0.37	0.63	4.5	4	3.5
BRN	Muara	115	5	0.02	0.06	0.10	4.5	4	3.5
KHM	Phnom-Penh	104.8	11.5	0.16	0.43	0.74	4.5	4	3.5
MMR	Yangon	96.2	16.8	0.25	0.69	1.19	4.5	4	3.5
VNM	Nha Trang	109.15	12.2	1.80	4.94	8.46	4.5	4	3.5

Note: Demand for 2030 and 2040 and LCOH from onshore renewables are obtained from Hydrogen Council[5] and IEA[6,7]. The supply ratios by renewables are set to be 20%, 50%, and 80% in 2030, 2040, and 2050, respectively.[5] The hydrogen demand of LAO is merged into that of VNM since that LAO, as a landlocked country, has no offshore wind power resources, but can also satisfy the hydrogen demand using vehicles from the harbour.

Table S2. Feed-in tariff, electricity demand satisfied by offshore wind plants, and conversion ratio for electricity load used to consume offshore wind power in RCEP from 2030 to 2050.

Country	Harbour name	Feed-in tariff ($/kWh)			Electricity demand satisfied by offshore wind plants (TWh)			Conversion ratio for electricity load used to consume offshore wind power		
		2030	2040	2050	2030	2040	2050	2030	2040	2050
AUS	Gladstone	0.090	0.099	0.107	1.60	4.61	12.41	0.024	0.054	0.122
AUS	Darwin	0.090	0.099	0.107	0.11	0.33	0.89	0.024	0.054	0.122
AUS	Onslow	0.090	0.099	0.107	1.28	3.71	9.98	0.024	0.054	0.122
AUS	Kembla	0.090	0.099	0.107	5.08	14.68	39.49	0.024	0.054	0.122
AUS	Adelaide	0.090	0.099	0.107	0.48	1.37	3.70	0.024	0.054	0.122
NZL	Auckland	0.080	0.088	0.096	0.71	2.13	6.10	0.024	0.054	0.122
NZL	Bluff	0.080	0.088	0.096	0.20	0.62	1.76	0.024	0.054	0.122
CHN	Haikou	0.044	0.048	0.053	2.05	7.29	22.74	0.019	0.05	0.132
CHN	Beihai	0.044	0.048	0.053	8.21	29.21	91.06	0.019	0.05	0.132
CHN	Shenzhen	0.044	0.048	0.053	41.03	146.01	455.19	0.019	0.05	0.132
CHN	Xiamen	0.044	0.048	0.053	16.27	57.88	180.43	0.019	0.05	0.132
CHN	Wenzhou	0.044	0.048	0.053	23.94	85.18	265.54	0.019	0.05	0.132
CHN	Shanghai	0.044	0.048	0.053	14.34	51.02	159.05	0.019	0.05	0.132
CHN	Yancheng	0.044	0.048	0.053	38.06	135.41	422.14	0.019	0.05	0.132
CHN	Qingdao	0.044	0.048	0.053	27.09	96.40	300.53	0.019	0.05	0.132
CHN	Tianjin	0.044	0.048	0.053	5.22	18.57	57.88	0.019	0.05	0.132
CHN	Qinhuangdao	0.044	0.048	0.053	13.41	47.73	148.80	0.019	0.05	0.132
CHN	Dalian	0.044	0.048	0.053	9.30	33.11	103.21	0.019	0.05	0.132
KOR	Gunsan	0.070	0.077	0.083	22.18	47.09	95.92	0.066	0.13	0.256
KOR	Donghae	0.070	0.077	0.083	16.40	34.82	70.93	0.066	0.13	0.256
JPN	Otaru	0.111	0.121	0.132	0.36	1.16	3.85	0.021	0.067	0.214
JPN	Kushiro	0.111	0.121	0.132	0.36	1.16	3.85	0.021	0.067	0.214
JPN	Kanazawa	0.111	0.121	0.132	6.57	20.93	69.73	0.021	0.067	0.214
JPN	Hitachi	0.111	0.121	0.132	6.57	20.93	69.73	0.021	0.067	0.214
JPN	Tobata	0.111	0.121	0.132	4.61	14.67	48.88	0.021	0.067	0.214
JPN	Kagoshima	0.111	0.121	0.132	1.72	5.49	18.29	0.021	0.067	0.214
IDN	Tangguh	0.053	0.058	0.063	0.60	2.46	8.43	0.024	0.054	0.122
IDN	Makassar	0.053	0.058	0.063	1.69	6.95	23.83	0.024	0.054	0.122
IDN	Bontang	0.053	0.058	0.063	2.14	8.84	30.30	0.024	0.054	0.122
IDN	Jakarta	0.053	0.058	0.063	22.22	91.57	313.86	0.024	0.054	0.122
MYS	Sungai Udang	0.037	0.040	0.044	4.78	15.79	45.97	0.024	0.054	0.122
MYS	Johor	0.037	0.040	0.044	1.79	5.92	17.25	0.024	0.054	0.122
PHL	Batangas	0.087	0.095	0.103	4.17	20.47	81.26	0.024	0.054	0.122
PHL	Cebu	0.087	0.095	0.103	2.58	12.64	50.19	0.024	0.054	0.122
PHL	Davao	0.087	0.095	0.103	1.64	8.05	31.95	0.024	0.054	0.122
THA	Map Ta Phut	0.056	0.062	0.067	11.24	37.84	101.7	0.024	0.054	0.122
SGP	Singapore	0.103	0.112	0.122	2.06	5.45	13.48	0.024	0.054	0.122
BRN	Muara	0.031	0.034	0.037	0.14	0.38	1.00	0.024	0.054	0.122
KHM	Phnom-Penh	0.070	0.077	0.084	0.55	2.92	13.87	0.024	0.054	0.122
MMR	Yangon	0.026	0.029	0.031	3.58	19.66	76.14	0.024	0.054	0.122
VNM	Nha Trang	0.043	0.047	0.051	10.83	46.12	153.82	0.024	0.054	0.122

Note: Hourly demand is obtained from Toktarova *et al.*,[8] where the electricity demand of LAO is neglected since that LAO, as a landlocked country, has no offshore wind power resources available for grid connection. $SNSP^{max}$ is set as 0.75.[9,10] Conversion ratios for electricity load used to consume offshore wind power are fetched from ratios of predicted offshore wind power to the total power generation based on International Energy Agency (IEA)[11] to calculate the electricity demand satisfied by offshore wind plants. The feed-in tariff is calculated as half of the grid electricity cost.[12] The grid electricity price is set to be increased by 5%, 15%, and 25% in 2030, 2040, and 2050,[13] respectively, compared with the current tariff, which is obtained from www.cable.co.uk.[14]

Table S3. Distance among harbours.

Distance among harbours (km)		AUS	AUS	AUS	AUS	AUS	NZL	NZL	CHN	CHN	CHN	CHN	CHN	CHN	CHN	CHN	CHN	CHN	CHN	KOR	KOR	JPN	JPN	JPN	JPN	JPN	JPN	IDN	IDN	IDN	IDN	MYS	MYS	PHL	PHL	PHL	THA	SGP	BRN	KHM	MMR	VNM
		Gladstone	Darwin	Onslow	Kembla	Adelaide	Auckland	Bluff	Haikou	Beihai	Shenzhen	Xiamen	Wenzhou	Shanghai	Yancheng	Qingdao	Tianjin	Qinhuangdao	Dalian	Gunsan	Donghae	Otaru	Kushiro	Kanazawa	Hitachi	Tobata	Kagoshima	Tangguh	Makassar	Bontang	Jakarta	Sungai Udang	Johor	Batangas	Cebu	Davao	Map Ta Phut	Singapore	Muara	Phnom-Penh	Yangon	Nha Trang
AUS	Gladstone	0.00	3409.72	5556.00	1441.78	3704.00	2841.15	3093.40	7963.60	8547.91	7603.94	7277.99	7263.17	7326.14	7408.00	7924.71	8409.75	8224.18	8499.38	8251.03	7734.32	8334.00	7900.63	8148.80	8101.20	7526.53	6111.60	6111.60	5556.00	6142.16	6852.40	7620.98	7592.83	6802.95	5411.54	5288.02	8611.80	7235.02	7963.60	8148.80	9074.80	8334.00
AUS	Darwin	3409.72	0.00	2222.40	4630.00	6482.00	6310.50	6049.37	5185.60	5571.56	5209.49	5278.20	5370.80	5418.77	5741.20	6111.60	6318.65	6296.80	6420.70	6723.32	5556.00	7408.00	7037.60	6482.00	6137.53	5562.48	5419.32	1423.08	1983.68	2567.24	2592.80	3889.20	3564.17	3704.00	3391.57	2963.20	4772.05	3627.88	4074.40	4630.00	5370.80	4444.80
AUS	Onslow	5556.00	2222.40	0.00	7408.00	3889.01	7455.23	6667.20	5444.69	6129.93	5389.51	5460.62	5823.43	6269.58	6608.49	6829.44	7348.18	7251.14	7049.64	6781.47	7045.75	8119.17	8061.02	7667.28	7298.55	6773.13	6465.52	3396.94	2037.20	2588.36	2407.60	320.95	370.40	4180.89	3909.76	3691.41	4630.00	3374.90	4074.40	4259.60	5071.33	4630.00
AUS	Kembla	1441.78	4630.00	7408.00	0.00	1852.00	2422.05	2049.42	8778.48	8900.53	8408.45	8330.85	8458.27	8668.47	8889.60	9019.05	9528.73	9499.28	9182.22	8871.45	8871.45	10186.00	8889.60	9501.13	8220.10	8290.48	8146.95	7222.80	6667.20	7253.36	7963.60	8732.18	8704.03	7586.35	4300.34	4176.26	9179.25	8236.21	6852.40	7037.60	9905.05	7222.80
AUS	Adelaide	3704.00	6482.00	3889.01	1852.00	0.00	3813.27	3092.28	9143.51	9445.20	8889.60	9149.81	9514.65	10144.89	10278.60	10808.83	10964.03	11043.85	10999.58	10472.32	10736.97	11259.60	10880.69	11297.20	10268.41	10436.58	9979.13	7131.68	5721.38	6279.58	5556.00	7222.80	6936.67	7868.04	7600.61	7382.44	8148.80	6849.25	7778.40	7963.60	8441.23	8334.00
NZL	Auckland	2841.15	6310.50	7455.23	2422.05	3813.27	0.00	1789.59	9850.42	11205.16	9710.96	9315.37	9389.08	9553.73	9630.40	10047.47	10485.65	10331.38	10136.18	9915.42	9644.85	9863.75	9609.84	10000.80	9047.76	9074.80	8704.40	7380.22	7593.20	8193.80	8889.60	8982.20	8926.64	8639.77	8053.05	7447.08	10680.48	9384.82	10000.80	10371.20	11575.56	10556.40
NZL	Bluff	3093.40	6049.37	6667.20	2049.42	3092.28	1789.59	0.00	10741.60	12038.00	9710.96	9315.37	9389.08	10596.77	10556.40	10973.47	11411.65	11257.38	11062.18	10841.42	10570.85	10789.75	10535.84	10926.80	9973.76	10000.80	9689.48	8306.22	8519.20	9119.80	9815.60	9908.20	9852.64	9565.77	8979.05	8373.08	11606.48	10078.77	10926.80	11297.20	12501.56	11482.40
CHN	Haikou	7963.60	5185.60	5444.69	8778.48	9143.51	9850.42	10741.60	0.00	220.20	505.78	994.34	1522.71	1991.27	2037.20	2520.57	3081.17	2963.20	2843.38	2598.54	2937.27	4028.10	4220.34	3518.80	3653.81	2682.07	2503.90	4082.18	3751.23	3078.21	3296.56	2771.89	3092.84	1440.12	2173.32	2854.12	2407.60	2518.53	2222.40	1814.96	4570.92	1074.16
CHN	Beihai	8547.91	5571.56	6129.93	8900.53	9445.20	11205.16	12038.00	220.20	0.00	735.98	1255.47	1743.29	2244.62	2705.03	2790.41	3134.14	2999.87	3208.40	2818.93	3157.66	4748.71	4578.14	3909.76	4189.04	2935.23	2779.67	5156.89	3877.16	3204.15	3333.60	2816.52	3137.47	1554.94	2407.41	2968.94	1551.42	2552.06	2160.73	1852.00	5299.68	1111.20
CHN	Shenzhen	7603.94	5209.49	5389.51	8408.45	8889.60	9710.96	9710.96	505.78	735.98	0.00	500.60	1041.19	1507.53	1872.00	2057.94	2660.95	2590.02	2386.86	2304.44	2733.74	3850.86	4076.44	3083.21	3676.03	2504.46	2451.12	4018.10	3710.48	3037.47	3159.14	2945.98	3153.77	1314.92	2167.40	2728.92	2685.40	2734.29	2291.85	2037.20	5315.98	1296.40
CHN	Xiamen	7277.99	5278.20	5460.62	8330.85	9149.81	9315.37	9315.37	994.34	1255.47	500.60	0.00	615.05	1074.35	1449.56	1639.02	2187.95	2089.98	1892.00	1691.25	2023.68	3102.10	3363.42	2458.34	2714.48	1766.44	1536.23	3963.28	3632.33	2959.31	3984.95	3342.49	3047.84	1387.52	2185.73	2453.34	3190.81	3106.36	2300.37	2503.35	5129.30	1762.55
CHN	Wenzhou	7263.17	5370.80	5823.43	8458.27	9514.65	9389.08	9389.08	1522.71	1743.29	1041.19	615.05	0.00	602.64	872.85	1071.57	1648.28	1558.83	1399.19	1399.56	1321.22	2645.95	2806.34	2178.32	2275.74	1270.66	1088.61	4206.82	3980.13	3307.12	4588.89	3881.61	3732.71	1792.00	2548.17	2730.59	3704.00	3658.81	2778.00	3107.29	5719.16	2366.49
CHN	Shanghai	7326.14	5418.77	6269.58	8668.47	10144.89	9553.73	10596.77	1991.27	2244.62	1507.53	1074.35	602.64	0.00	294.28	731.91	1303.62	1228.99	1024.71	796.92	1250.47	2343.34	2568.91	1575.68	2168.51	996.93	943.59	4482.21	4581.85	3837.16	4645.37	4416.28	4279.60	2257.03	2822.82	3132.84	4253.86	4129.77	3218.96	3474.17	6119.93	2733.37
CHN	Yancheng	7408.00	5741.20	6608.49	8889.60	10278.60	9630.40	10556.40	2037.20	2705.03	1872.00	1449.56	872.85	294.28	0.00	225.39	923.96	853.59	741.73	648.20	1273.25	2592.80	2778.00	1666.80	2407.60	1111.20	1111.20	4808.72	4908.36	4163.67	4971.88	4742.79	4606.11	2583.54	3310.26	3437.50	4580.37	4456.28	3545.47	3800.67	6446.44	3059.87
CHN	Qingdao	7924.71	6111.60	6829.44	9019.05	10808.83	10047.47	10973.47	2520.57	2790.41	2057.94	1639.02	1071.57	731.91	225.39	0.00	632.46	528.56	507.63	584.12	1178.80	2437.97	2575.39	1610.87	2371.12	1116.20	1185.65	5000.40	4815.20	4364.79	5278.20	5497.29	4825.39	2903.01	3379.16	4038.84	4815.20	4620.18	3965.32	4074.40	6667.20	3333.60
CHN	Tianjin	8409.75	6318.65	7348.18	9528.73	10964.03	10485.65	11411.65	3081.17	3134.14	2660.95	2187.95	1648.28	1303.62	923.96	632.46	0.00	147.42	404.85	876.37	1667.17	2808.74	3024.50	2102.76	2724.66	1469.38	1622.54	5686.94	5463.40	5027.62	5926.40	5448.77	5326.54	3329.71	3714.37	4192.19	5370.80	5240.05	4348.68	4630.00	7271.51	3796.60
CHN	Qinhuangdao	8224.18	6296.80	7251.14	9499.28	11043.85	10331.38	11257.38	2963.20	2999.87	2590.02	2089.98	1558.83	1228.99	853.59	528.56	147.42	0.00	303.91	784.32	1559.57	2710.96	2898.01	1944.60	2587.80	1358.44	1533.83	5498.96	5278.20	4853.54	5741.20	5355.61	5065.78	3238.78	3750.49	4046.62	5278.20	5128.93	4167.56	4537.40	7176.31	3704.00
CHN	Dalian	8499.38	6420.70	7049.64	9182.22	10999.58	10136.18	11062.18	2843.38	3208.40	2386.86	1892.00	1399.19	1024.71	741.73	507.63	404.85	303.91	0.00	561.71	1374.74	2541.13	2713.74	1827.00	2437.05	1136.02	1319.36	5351.17	5093.00	4710.56	5648.60	5215.60	5424.32	3078.39	3520.47	3899.94	5197.64	4989.66	3999.39	4352.20	6934.44	3518.80
KOR	Gunsan	8251.03	6723.32	6781.47	8871.45	10472.32	9915.42	10841.42	2598.54	2818.93	2304.44	1691.25	1399.56	796.92	648.20	584.12	876.37	784.32	561.71	0.00	894.70	2121.28	2291.66	1389.00	1997.94	758.58	940.26	4949.28	4815.20	4414.80	5370.80	4883.72	4832.24	2773.18	3353.05	3543.62	4907.80	4632.96	3796.60	4167.00	6704.43	3426.20
KOR	Donghae	7734.32	5556.00	7045.75	8871.45	10736.97	9644.85	10570.85	2937.27	3157.66	2733.74	2023.68	1321.22	1250.47	1273.25	1178.80	1667.17	1559.57	1374.74	894.70	0.00	1242.32	1476.97	710.24	1696.43	451.70	955.82	5072.44	5185.60	4678.71	5741.20	5210.97	4926.51	3014.50	3351.56	3710.48	5278.20	4970.03	4167.00	4630.00	7031.49	3796.60
JPN	Otaru	8334.00	7408.00	8119.17	10186.00	11259.60	9863.75	10789.75	4028.10	4748.71	3850.86	3102.10	2645.95	2343.34	2592.80	2437.97	2808.74	2710.96	2541.13	2121.28	1242.32	0.00	770.06	1071.94	1056.57	1452.52	2010.72	6057.15	6296.80	5752.50	6759.80	6298.28	6111.60	4087.73	4600.37	4778.90	6389.40	6068.08	5098.74	5648.60	8118.98	4691.67
JPN	Kushiro	7900.63	7037.60	8061.02	8889.60	10880.69	9609.84	10535.84	4220.34	4578.14	4076.44	3363.42	2806.34	2568.91	2778.00	2575.39	3024.50	2898.01	2713.74	2291.66	1476.97	770.06	0.00	1121.57	802.66	1636.98	2083.31	5765.09	6389.40	5694.53	7408.00	6490.89	6948.70	4279.97	4500.55	4612.22	6574.60	6249.94	5291.16	5741.20	8311.41	5000.40
JPN	Kanazawa	8148.80	6482.00	7667.28	9501.13	11297.20	10000.80	10926.80	3518.80	3909.76	3083.21	2458.34	2178.32	1575.68	1666.80	1610.87	2102.76	1944.60	1827.00	1389.00	710.24	1071.94	1121.57	0.00	1481.60	674.31	1183.61	5741.20	5556.00	5000.40	6111.60	5648.60	5370.80	3518.80	3611.40	4074.40	5556.00	5298.76	4444.80	5000.40	7408.00	4167.00
JPN	Hitachi	8101.20	6137.53	7298.55	8220.10	10268.41	9047.76	9973.76	3653.81	4189.04	3676.03	2714.48	2275.74	2168.51	2407.60	2371.12	2724.66	2587.80	2437.05	1997.94	1696.43	1056.57	802.66	1481.60	0.00	1216.21	1308.44	5002.81	5556.00	4932.06	6574.60	5808.43	5648.60	3571.77	3738.08	3849.94	5833.80	5607.49	4722.60	5093.00	7615.05	4352.20
JPN	Tobata	7526.53	5562.48	6773.13	8290.48	10436.58	9074.80	10000.80	2682.07	2935.23	2504.46	1766.44	1270.66	996.93	1111.20	1116.20	1469.38	1358.44	1136.02	758.58	451.70	1452.52	1636.98	674.31	1216.21	0.00	529.30	4675.37	4907.80	4498.88	5278.20	4952.43	4784.83	2741.70	3206.74	3368.42	5000.40	4741.49	3752.15	4259.60	6773.13	3426.20
JPN	Kagoshima	6111.60	5419.32	6465.52	8146.95	9979.13	8704.40	9689.48	2503.90	2779.67	2451.12	1536.23	1088.61	943.59	1111.20	1185.65	1622.54	1533.83	1319.36	940.26	955.82	2010.72	2083.31	1183.61	1308.44	529.30	0.00	4343.87	4630.00	4142.00	5093.00	4705.38	4475.17	2500.94	2852.27	3016.72	4689.63	4465.73	3504.72	3889.20	6517.19	3140.07
IDN	Tangguh	6111.60	1423.08	3396.94	7222.80	7131.68	7380.22	8306.22	4082.18	5156.89	4018.10	3963.28	4206.82	4482.21	4808.72	5000.40	5686.94	5498.96	5351.17	4949.28	5072.44	6057.15	5765.09	5741.20	5002.81	4675.37	4343.87	0.00	1760.51	2479.64	2479.64	4120.33	3796.60	2665.21	2463.72	1691.25	4901.50	3880.50	3007.46	4074.40	5931.40	3611.40
IDN	Makassar	5556.00	1983.68	2037.20	6667.20	5721.38	7593.20	8519.20	3751.23	3877.16	3710.48	3632.33	3980.13	4581.85	4908.36	4815.20	5463.40	5278.20	5093.00	4815.20	5185.60	6296.80	6389.40	5556.00	5556.00	4907.80	4630.00	1760.51	0.00	670.79	1481.60	2244.07	1981.27	2243.51	2024.05	1762.55	3493.98	2078.68	2315.00	3055.80	4299.42	2778.00
IDN	Bontang	6142.16	2567.24	2588.36	7253.36	6279.58	8193.80	9119.80	3078.21	3204.15	3037.47	2959.31	3307.12	3837.16	4163.67	4364.79	5027.62	4853.54	4710.56	4414.80	4678.71	5752.50	5694.53	5000.40	4932.06	4498.88	4142.00	2479.64	670.79	0.00	1759.40	2881.90	2240.92	1810.52	1543.09	1274.55	3368.79	2470.94	1759.40	2963.20	4371.46	2315.00
IDN	Jakarta	6852.40	2592.80	2407.60	7963.60	5556.00	8889.60	9815.60	3296.56	3333.60	3159.14	3984.95	4588.89	4645.37	4971.88	5278.20	5926.40	5741.20	5648.60	5370.80	5741.20	6759.80	7408.00	6111.60	6574.60	5278.20	5093.00	2479.64	1481.60	1759.40	0.00	1296.40	1111.20	2963.20	3148.40	2963.20	2222.40	1296.40	1852.00	2222.40	3148.40	2222.40
MYS	Sungai Udang	7620.98	3889.20	320.95	8732.18	7222.80	8982.20	9908.20	2771.89	2816.52	2945.98	3342.49	3881.61	4416.28	4742.79	5497.29	5448.77	5355.61	5215.60	4883.72	5210.97	6298.28	6490.89	5648.60	5808.43	4952.43	4705.38	4120.33	2244.07	2881.90	1296.40	0.00	320.95	2749.66	2836.15	3213.03	1668.84	320.40	1697.73	1666.80	1837.37	1705.32

MYS	Johor	7592.83	3564.17	370.40	8704.03	6936.67	8926.64	9852.64	3092.84	3137.47	3153.77	3047.84	3732.71	4279.60	4606.11	4825.39	5326.54	5065.78	5424.32	4832.24	4926.51	6111.60	6948.70	5370.80	5648.60	4784.83	4475.17	3796.60	1981.27	2240.92	1111.20	320.95	0.00	2422.23	3119.69	3169.14	1441.41	42.41	1419.37	1444.56	2162.21	1481.60
PHL	Batangas	6802.95	3704.00	4180.89	7586.35	7868.04	8639.77	9565.77	1440.12	1554.94	1314.92	1387.52	1792.00	2257.03	2583.54	2903.01	3329.71	3238.78	3078.39	2773.18	3014.50	4087.73	4279.97	3518.80	3571.77	2741.70	2500.94	2665.21	2243.51	1810.52	2963.20	2749.66	2422.23	0.00	852.48	1414.00	2603.54	2470.01	1256.40	2037.20	4571.66	1296.40
PHL	Cebu	5411.54	3391.57	3909.76	4300.34	7600.61	8053.05	8979.05	2173.32	2407.41	2167.40	2185.73	2548.17	2822.82	3310.26	3379.16	3714.37	3750.49	3520.47	3353.05	3351.56	4600.37	4500.55	3611.40	3738.08	3206.74	2852.27	2463.72	2024.05	1543.09	3148.40	2836.15	3119.69	852.48	0.00	1048.23	3278.04	2532.98	1298.99	2407.60	4650.00	1944.60
PHL	Davao	5288.02	2963.20	3691.41	4176.26	7382.44	7447.08	8373.08	2854.12	2968.94	2728.92	2453.34	2730.59	3132.84	3437.50	4038.84	4192.19	4046.62	3899.94	3543.62	3710.48	4778.90	4612.22	4074.40	3849.94	3368.42	3016.72	1691.25	1762.55	1274.55	2963.20	3213.03	3169.14	1414.00	1048.23	0.00	3253.22	2864.12	1635.13	2778.00	5033.55	2315.00
THA	Map Ta Phut	8611.80	4772.05	4630.00	9179.25	8148.80	10680.48	11606.48	2407.60	1551.42	2685.40	3190.81	3704.00	4253.86	4580.37	4815.20	5370.80	5278.20	5197.64	4907.80	5278.20	6389.40	6574.60	5556.00	5833.80	5000.40	4689.63	4901.50	3493.98	3368.79	2222.40	1668.84	1441.41	2603.54	3278.04	3253.22	0.00	1429.00	2040.35	1296.40	3611.40	1481.60
SGP	Singapore	7235.02	3627.88	3374.90	8236.21	6849.25	9384.82	10078.77	2518.53	2552.06	2734.29	3106.36	3658.81	4129.77	4456.28	4620.18	5240.05	5128.93	4989.66	4632.96	4970.03	6068.08	6249.94	5298.76	5607.49	4741.49	4465.73	3880.50	2078.68	2470.94	1296.40	320.40	42.41	2470.01	2532.98	2864.12	1429.00	0.00	1386.78	1481.60	2054.05	1456.60
BRN	Muara	7963.60	4074.40	4074.40	6852.40	7778.40	10000.80	10926.80	2222.40	2160.73	2291.85	2300.37	2778.00	3218.96	3545.47	3965.32	4348.68	4167.56	3999.39	3796.60	4167.00	5098.74	5291.16	4444.80	4722.60	3752.15	3504.72	3007.46	2315.00	1759.40	1852.00	1697.73	1419.37	1256.40	1298.99	1635.13	2040.35	1386.78	0.00	1481.60	3518.80	1111.20
KHM	Phnom-Penh	8148.80	4630.00	4259.60	7037.60	7963.60	10371.20	11297.20	1814.96	1852.00	2037.20	2503.35	3107.29	3474.17	3800.67	4074.40	4630.00	4537.40	4352.20	4167.00	4630.00	5648.60	5741.20	5000.40	5093.00	4259.60	3889.20	4074.40	3055.80	2963.20	2222.40	1666.80	1444.56	2037.20	2407.60	2778.00	1296.40	1481.60	1481.60	0.00	3518.80	740.80
MMR	Yangon	9074.80	5370.80	5071.33	9905.05	8441.23	11575.56	12501.56	4570.92	5299.68	5315.98	5129.30	5719.16	6119.93	6446.44	6667.20	7271.51	7176.31	6934.44	6704.43	7031.49	8118.98	8311.41	7408.00	7615.05	6773.13	6517.19	5931.40	4299.42	4371.46	3148.40	1837.37	2162.21	4571.66	4650.00	5033.55	3611.40	2054.05	3518.80	3518.80	0.00	3518.80
VNM	Nha Trang	8334.00	4444.80	4630.00	7222.80	8334.00	10556.40	11482.40	1074.16	1111.20	1296.40	1762.55	2366.49	2733.37	3059.87	3333.60	3796.60	3704.00	3518.80	3426.20	3796.60	4691.67	5000.40	4167.00	4352.20	3426.20	3140.07	3611.40	2778.00	2315.00	2222.40	1705.32	1481.60	1296.40	1944.60	2315.00	1481.60	1456.60	1111.20	740.80	3518.80	0.00

Table S4. Hydrogen demand prediction in RCEP in 2050.

	Power generation (Mt)	Building heat (Mt)	Industry heat (Mt)	Transportation (Mt)	Industry (Mt)	Total demand (Mt)
CHN	41.92	2.45	6.78	57.54	13.30	122.00
JPN	4.38	0.02	0.00	7.41	1.33	13.15
KOR	3.19	0.09	0.42	5.93	0.57	10.19
AUS	1.47	0.00	0.00	4.69	0.61	6.77
NZL	0.26	0.00	0.00	0.80	0.08	1.13
IDN	4.62	0.00	0.00	10.70	3.18	18.51
MYS	1.20	0.00	0.00	5.27	0.33	6.80
PHL	1.17	0.00	0.00	2.58	0.16	3.91
SGP	0.30	0.00	0.00	0.24	0.09	0.63
THA	2.19	0.00	0.00	5.04	0.60	7.83
VNM	1.77	0.00	0.00	5.58	0.55	7.90
BRN	0.02	0.00	0.00	0.07	0.00	0.10
KHM	0.17	0.00	0.00	0.52	0.05	0.74
LAO	0.13	0.00	0.00	0.39	0.04	0.56
MMR	0.33	0.00	0.00	0.77	0.09	1.19

Table S5. Techno-economic data for offshore wind turbine and water electrolyser.

	Offshore wind turbine			Water electrolyser-hydrogen (PEMEC[c])			Water electrolyser -MCH	Water electrolyser-ammonia
	2030	2040	2050	2030	2040	2050	2050	2050
Investment cost (\$/kW)	2500	1900	1300	700	575	450	1100	750
Electrical efficiency (%, LHV[a])	—	—	—	69	71.5	74	63	64
Annual O&M[b] cost (% of investment cost)	2	2	2	1.5	1.5	1.5	1.5	1.5
Water demand (m^3/kgH_2)	—	—	—	0.015	0.015	0.015	0.015	0.015
Water tariff (\$/m^3)	—	—	—	4.8	4.8	4.8	4.8	4.8
System lifetime (year)	20	20	20	20	20	20	20	20
Reference	11, 15-17			2,7,17,18			17,19,20	17,20,21

[a] LHV = lower heating value, 33.3 kWh/kg for hydrogen, 12.1 kWh/kg for MCH, 5.2 kWh/kg for ammonia.
[b] O&M = operation and maintenance.
[c] PEMEC = proton exchange membrane electrolyser cell.

Table S6. Techno-economic data for hydrogen conversion.

	Compression			Liquefaction			MCH cracking	Ammonia cracking
	2030	2040	2050	2030	2040	2050	2050	2050
Investment cost (k$/kg$H_2$)	0.41	0.385	0.36	25	21.5	18	0.7	0.9
Loss (%)	0.5	0.5	0.5	1.65	1.65	1.65	2	2
Annual O&M[a] cost (% of investment cost)	2	2	2	4	4	4	4	4
Electricity demand (kWh/kgH_2)	0.84	0.84	0.84	6.76	6.38	6	1.52	1.51
System lifetime (year)	15	15	15	20	20	20	20	20
Reference	[17,18]			[17,18,20]			[17]	[17]

[a] O&M = operation and maintenance.

Table S7. Techno-economic data for storage and transportation.

	Liquid H_2 storage (IM[b]/EX[c])			MCH storage (IM/EX)	Ammonia storage (IM/EX)	Liquid H_2 ship			MCH ship	Ammonia ship
	2030	2040	2050	2050	2050	2030	2040	2050	2050	2050
Investment cost ($/kg$H_2$ $/kg$CH_4$ $/kg$NH_3$)	26	22	18	0.81	2.0	—	—	—	—	—
Investment cost (M$/ship)	—	—	—	—	—	398	305.5	213	76	85
Unit capacity (ktH_2 ktCH_4 ktNH_3)	—	—	—	—	—	11	11	11	110	53
Loss (%)	0.1 day^{-1}	0.1 day^{-1}	0.1 day^{-1}	0	0	0.2 day^{-1}	0.2 day^{-1}	0.2 day^{-1}	0	0
Annual O&M[a] cost (% of investment cost)	2	2	2	2	4	4	4	4	4	4
Fuel consumption (ton/day)	—	—	—	—	—	45	45	45	80	50
Fuel tariff ($/ton)	—	—	—	—	—	480	480	480	480	480
System lifetime (year)	20	20	20	20	20	25	25	25	25	25
Average speed (km/h)	—	—	—	—	—	30	30	30	30	30
Load/unload time (hour)	—	—	—	—	—	48	48	48	48	48
Reference	[17,20]			[17,20]	[17,20]	[17,18,20]			[17,20]	[17,20]

[a] O&M = operation and maintenance.

[b] IM = import.

[c] EX = export.

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