Supplementary Materials: Can Australia Power the Energy Hungry Asia with Renewable Energy?

Ashish Gulagi, Dmitrii Bogdanov, Mahdi Fasihi and Christian Breyer

Table S1. Financial assumptions for energy system components [1–8].

Technology	Capex (€/kW)	Opex Fix (€/(kW·a))	Opex Var (€/kWh)	Lifetime (a)
PV optimally tilted	550	8	0	35
PV single-axis tracking	620	9	0	35
PV rooftop	813	12	0	35
Wind onshore	1000	20	0	25
CSP (solar field)	528	11	0	25
Hydro run-of-river	2560	115.2	0.005	60
Hydro dam	1650	66	0.003	60
Geothermal energy	4860	87	0	30
Water electrolysis	380	13	0.0012	30
Methanation	234	5	0.0015	30
CO_2 scrubbing	356	14	0.0013	30
CCGT	775	19.4	0.001	30
OCGT	475	14.25	0.001	30
Steam turbine	600	12	0	30
Hot heat burner	100	2	0	30
Heating rod	20	0.4	0.001	30
Biomass CHP	2500	175	0.001	30
Biogas CHP	370	14.8	0.001	30
Waste incinerator	5240	235.8	0.007	20
Biogas digester	680	27.2	0	20
Biogas upgrade	250	20	0	20
	Capex (€/kWh)	**Opex fix (€/(kWh·a))**	**Opex var (€/kWh)**	**Lifetime (a)**
Battery	150	10	0.0002	10/20
PHS	70	11	0.0002	50
A-CAES	31	0.4	0.0012	40
TES	24	2	0	20
Gas storage	0.05	0.001	0	50
	Capex (€/(kW$_{NTC}$·km))	**Opex fix (€/(kW$_{NTC}$·km·a))**	**Opex var (€/kWh$_{NTC}$)**	**Lifetime (a)**
HVDC line on ground	0.612	0.0075	0	50
HVDC line submarine	0.992	0.0010	0	50
	Capex (€/kW$_{NTC}$)	**Opex fix (€/(kW$_{NTC}$·a))**	**Opex var (€/kWh$_{NTC}$)**	**Lifetime (a)**
HVDC converter pair	180	1.8	0	50
	Capex (€/(m³·a))	**Opex fix (€/(m³·a))**	**Opex var (€/m³)**	**Lifetime (a)**
Water desalination	2.23	0.09	0	30
	Capex (€/(m³·h·km))	**Opex fix (€/(m³·h·km·a))**	**Opex var (€/m³·h·km)**	**Lifetime (a)**
Horizontal pumping and pipes	19.3	0.39	0	30
Vertical pumping and pipes	15.5	0.31	0	30

Table S2. Efficiencies and energy to power ratio of storage technologies [2].

Technology	Efficiency (%)	Energy/Power Ratio (h)	Self-Discharge (%/h)
Battery	90	6	0
PHS	85	8	0
A-CAES	70	100	0.001
TES	90	8	0.002
Gas storage	100	80 × 24	0

Table S3. Efficiency assumptions for energy system components for the 2030 reference year [1,2].

	η_{el} (%)	η_{th} (%)
CSP (solar field)		51
Steam turbine	42	
Hot heat burner		95
Heating rod		99
Water electrolysis		84
Methanation		77
CO_2 scrubbing		78
CCGT	58	
OCGT	43	
Geothermal	24	
Biomass CHP	40	45
Biogas CHP	42	43
Waste incinerator	34	
Biogas upgrade		98

Table S4. Efficiency assumptions for HVDC transmission according to Dii [9].

	Power Losses
HVDC line	1.6 %/1000 km
HVDC converter pair	1.4%

Table S5. Assumptions for RE-SNG value chain [10,11].

	Unit	2030
Liquefaction plant		
Capex	k€/mcm/a SNG	196
Opex	% of capex p.a.	3.5
Lifetime	years	25
Efficiency	%	92
LNG shipping		
Ship size	m^3 LNG	138,000
Capex	m€/ship	151
Opex	% of capex p.a.	3.5
Lifetime	years	25
Boil-off gas	%/day	0.1
Speed	knots	20
West Australia–Japan Sea distance	km	8334
West Australia–Korea Sea distance	km	8082
West Australia–East China Sea distance	km	7476
Regasification plant		
Capex	k€/mcm/a SNG	74
Opex	% of capex p.a.	3.5
Lifetime	years	30
Efficiency	%	98.5

Table S6. Regional biomass potentials [12].

Region	Biomass Potential (TWh_{th}/a)		
	Solid Waste	**Solid Biomass**	**Biogas Sources**
Total area	171.8	1337.0	140.8
New Zealand	2.3	15.1	9.6
East Australia	14.2	50.3	36.1
West Australia	2.2	17.7	5.6
Indonesia-Papua + Papua New Guinea	0.5	21.2	0.5
Sumatra	4.2	56.6	5.0
Java + Timor Leste	13.5	101.8	16.1
East Indonesia	2.7	51.5	3.2
Malaysia + Singapore + Brunei	2.5	25.3	2.6
Philippines	5.3	71.1	15.4
Vietnam + Laos + Cambodia	7.8	72.3	14.9
Myanmar + Thailand	11.2	49.1	31.7
South China	12.7	142.8	0.0
Central China	19.1	214.6	0.0
East China	13.0	146.1	0.0
Northwest China + Tibet + Uygur	5.1	57.6	0.0
North China	13.4	150.8	0.0
Northeast China	5.6	63.4	0.0
Mongolia	0.1	0.1	0.0
South Korea + North Korea	14.3	10.2	0.0
Japan	21.9	19.2	0.0

Table S7. Regional biomass costs.

Region	Biomass Costs (€/MWh)		
	Solid Waste	**Solid Biomass**	**Biogas Sources**
Total area	−10.1	9.5	3.0
New Zealand	−10.2	16.0	0.0
East Australia	−10.0	8.5	3.6
West Australia	−10.0	13.1	3.6
Indonesia-Papua + Papua New Guinea	−10.2	15.2	4.4
Sumatra	−10.2	11.6	4.4
Java + Timor Leste	−10.2	7.6	4.4
East Indonesia	−10.2	13.1	4.4
Malaysia + Singapore + Brunei	−10.2	14.9	1.5
Philippines	−10.2	7.7	7.9
Vietnam + Laos + Cambodia	−10.1	5.4	4.5
Myanmar + Thailand	−10.2	5.8	8.6
South China	−10.0	8.2	2.0
Central China	−10.0	8.2	2.0
East China	−10.0	8.2	2.0
Northwest China + Tibet + Uygur	−10.0	8.2	2.0
North China	−10.0	8.2	2.0
Northeast China	−10.0	8.2	2.0
Mongolia	−10.2	5.3	0.0
South Korea + North Korea	−9.8	5.3	0.0
Japan	−9.9	11.6	0.3

Table S8. Average full load hours and LCOE for PV single-axis tracking, PV optimally tilted, solar CSP and wind power plants in East Asian sub-regions.

Region	Pop. (mio. Pop)	Electr. Demand (TWh)	PV-Single-Axis FLH	PV Optimally Tilted FLH	CSP FLH	Wind FLH	PV Single-Axis LCOE (€/MWh)	PV Optimally Tilted LCOE (€/MWh)	CSP LCOE (€/MWh)	Wind LCOE (€/MWh)
Total area	2192	11,280	1527	1903	1605	2363	33	30	77	82
New Zealand	5	44	1430	1765	1541	4122	35	32	76	26
East Australia	21	194	1764	2397	2424	3782	29	24	48	28
West Australia	3	30	1733	2316	2261	3500	29	25	52	30
Indonesia-Papua + Papua New Guinea	5	12	1465	1816	1300	1182	34	31	90	90
Sumatra	50	89	1445	1746	1193	440	35	33	98	240
Java + Timor Leste	161	133	1683	2203	2008	1225	30	26	58	86
East Indonesia	32	28	1503	1869	1467	394	34	30	80	269
Malaysia + Singapore + Brunei	29	216	1488	1821	1347	327	34	31	87	324
Philippines	102	76	1503	1929	1585	1799	34	29	74	59
Vietnam + Laos + Cambodia	116	391	1482	1776	1309	1463	34	32	89	72
Myanmar + Thailand	122	189	1524	1823	1530	1228	33	31	77	86
South China	251	1523	1434	1676	1206	2313	35	34	97	46
Central China	376	2289	1472	1728	1286	2606	34	33	91	41
East China	242	1558	1340	1549	1229	2060	38	37	95	51
Northwest China + Tibet+Uygur	100	614	1840	2427	2134	4318	27	23	55	25
North China	251	1609	1593	2012	1846	3543	32	28	63	30
Northeast China	121	676	1457	1832	1706	3517	35	31	69	30
Mongolia	3	6	1572	2062	1975	3287	32	28	59	32
South Korea + North Korea	75	576	1467	1740	1491	2902	34	33	79	36
Japan	128	1026	1346	1574	1262	3258	37	36	93	32

Table S9. Lower limits of installed capacities in the East Asian sub-regions. Data taken from Farfan and Breyer [13].

Region	Installed Capacity (MW)			
	Solar PV	Wind	Hydro RoR and Dams	PHS
Total area	54,756.7	133,840.7	357,666.7	74,919.7
New Zealand	23.5	682.9	5442.1	0.0
East Australia	3233.5	3316.8	6720.6	2391.1
West Australia	12.2	489.6	198.0	0.0
Indonesia-Papua + Papua New Guinea	0.6	0.0	96.5	0.0
Sumatra	0.0	0.0	945.6	0.0
Java + Timor Leste	46.1	1.5	5375.0	0.0
East Indonesia	0.0	0.3	596.0	0.0
Malaysia + Singapore+Brunei	120.1	0.2	4543.2	0.0
Philippines	45.2	331.5	2875.3	684.6
Vietnam + Laos + Cambodia	22.5	137.2	20,417.9	0.0
Myanmar+Thailand	1195.0	282.6	6291.0	1243.8
South China	1045.9	3686.2	78,724.4	3394.8
Central China	742.1	1055.2	95,380.7	6991.1
East China	2210.6	3444.5	13,035.0	8666.6
Northwest China + Tibet + Uygur	2571.0	10,083.5	16,335.1	4884.1
North China	16,410.8	97,852.8	67,843.1	15,101.4
Northeast China	124.4	8628.0	8691.1	4708.9
Mongolia	4.5	49.6	36.0	0.0
South Korea + North Korea	2028.5	877.6	2375.3	572.3
Japan	24,920.1	2920.6	21,744.8	26,281.0

Table S10. Upper limits on installable capacities in the East Asian sub-regions in units of GW_{th} for CSP and GW_{el} for all other technologies.

Region	Area			Limits (GW)			
	(1000 km²)	Solar CSP	Solar PV	Wind	Hydro RoR	Hydro Dams	PHS
Total area	24,435	219,918	109,959	8210	125	411	150
New Zealand	268	2412	1206	90	4	4	0
East Australia	4193	37,733	18,867	1409	5	5	5
West Australia	3513	31,621	15,810	1181	0	0	0
Indonesia-Papua + Papua New Guinea	394	3542	1771	132	0	0	0
Sumatra	602	5417	2709	202	1	1	0
Java + Timor Leste	202	1815	908	68	4	4	0
East Indonesia	719	6469	3234	242	1	0	0
Malaysia + Singapore + Brunei	330	2969	1484	111	3	3	0
Philippines	300	2700	1350	101	3	1	1
Vietnam + Laos + Cambodia	928	8355	4177	312	14	17	0
Myanmar + Thailand	1192	10,725	5363	400	4	5	2
South China	1023	9209	4604	344	27	91	7
Central China	1297	11,675	5837	436	27	116	14
East China	472	4247	2123	159	4	15	17
Northwest China + Tibet + Uygur	4336	39,025	19,512	1457	5	19	10
North China	1240	11,156	5578	417	0	102	30
Northeast China	1267	11,402	5701	426	2	11	9
Mongolia	1566	14,094	7047	526	0	0	0
South Korea + North Korea	221	1987	993	74	0	4	1
Japan	374	3366	1683	126	20	13	53

Table S11. Annual industrial gas demand [14] and water demand Caldera et al. [3] for year 2030 in the East Asian sub-regions.

Regions	Annual Gas Demand	Annual Electricity Demand for Gas Synthesis	Annual Water Desalination Demand	Annual Electricity Demand for Water Desalination
	(TWh$_{el}$)	(TWh$_{el}$)	(mil. m^3)	(TWh$_{el}$)
Total	2080.0	3735.6	145,307	688.3
New Zealand	9.3	5.3	0	0.0
East Australia	204.9	344.5	10	0.0
West Australia	124.1	230.0	2219	8.5
Indonesia-Papua + Papua New Guinea	0.0	0.0	0	0.0
Sumatra	39.8	71.0	153	0.5
Java + Timor Leste	69.9	117.7	98	0.4
East Indonesia	27.4	49.2	0	0.0
Malaysia + Singapore + Brunei	0.0	0.0	0	0.0
Philippines	0.8	0.0	431	1.3
Vietnam + Laos + Cambodia	0.0	0.0	5	0.0
Myanmar + Thailand	0.0	0.0	0	0.0
South China	218.4	390.3	12	0.1
Central China	328.1	586.6	25,471	102.9
East China	223.5	399.1	13,232	43.4
Northwest China + Tibet + Uygur	0.0	0.0	16,866	158.9
North China	230.6	414.6	77,638	336.4
Northeast China	0.0	0.0	9139	35.7
Mongolia	0.0	0.0	28	0.3
South Korea + North Korea	164.1	307.3	0	0.0
Japan	439.1	819.9	4	0.0

Table S12. Total LCOE components in all sub-regions of East Asian region.

Region-Wide	LCOE Primary	LCOC	LCOS	LCOT	LCOE Total	Export (–)/Import (+)
	(€/MWh)	(€/MWh)	(€/MWh)	(€/MWh)	(€/MWh)	(%)
Area average	41.9	2.6	21.8	0.0	66.3	0.0
New Zealand	37.4	0.3	7.5	0.0	45.2	0.0
East Australia	34.9	2.9	11.9	0.0	49.7	0.0
West Australia	33.5	3.2	11.2	0.0	47.9	0.0
Indonesia-Papua + Papua New Guinea	47.1	1.5	20.0	0.0	68.6	0.0
Sumatra	50.2	0.3	7.6	0.0	58.1	0.0
Java + Timor Leste	50.4	0.0	12.6	0.0	63.0	0.0
East Indonesia	43.5	0.0	13.2	0.0	56.7	0.0
Malaysia + Singapore + Brunei	41.2	3.0	27.7	0.0	71.9	0.0
Philippines	47.5	1.0	16.0	0.0	64.5	0.0
Vietnam + Laos + Cambodia	44.9	0.7	20.2	0.0	65.8	0.0
Myanmar + Thailand	45.5	1.0	15.9	0.0	62.4	0.0
South China	47.2	2.3	14.6	0.0	64.1	0.0
Central China	45.0	2.0	14.4	0.0	61.4	0.0
East China	44.0	3.7	43.4	0.0	91.1	0.0
Northwest China + Tibet + Uygur	33.6	2.3	12.2	0.0	48.1	0.0
North China	37.9	3.4	18.7	0.0	60.0	0.0
Northeast China	37.0	3.1	24.3	0.0	64.4	0.0
Mongolia	46.6	0.2	19.5	0.0	66.3	0.0
South Korea + North Korea	35.7	3.4	34.2	0.0	73.3	0.0
Japan	39.4	2.7	25.1	0.0	67.2	0.0

Area-Wide	**LCOE Primary**	**LCOC**	**LCOS**	**LCOT**	**LCOE Total**	**Export (−)/Import (+)**
	(€/MWh)	**(€/MWh)**	**(€/MWh)**	**(€/MWh)**	**(€/MWh)**	**(%)**
Area average	41.8	2.4	14.7	2.3	61.2	11.2
New Zealand	37.4	0.3	7.5	0.0	45.2	0.0
East Australia	34.9	2.8	11.8	0.0	49.5	−0.2
West Australia	33.5	3.2	11.2	0.0	47.9	0.0
Indonesia-Papua + Papua New Guinea	44.8	1.4	20.6	0.7	67.5	3.4
Sumatra	56.8	0.0	5.8	3.3	65.9	−16.3
Java + Timor Leste	49.6	0.0	12.4	0.3	62.3	−0.4
East Indonesia	43.7	0.0	13.3	0.6	57.6	−0.5
Malaysia + Singapore + Brunei	41.9	1.0	21.0	1.8	65.7	7.3
Philippines	47.2	1.2	14.9	1.6	64.9	−0.3
Vietnam + Laos + Cambodia	44.0	0.8	13.4	2.0	60.2	2.3
Myanmar+Thailand	45.2	0.9	13.7	1.1	60.9	2.9
South China	47.8	2.1	9.7	1.3	60.9	−4.2
Central China	45.4	1.8	11.3	1.0	59.5	1.1
East China	50.5	1.7	20.3	8.3	80.8	39.3
Northwest China + Tibet + Uygur	30.9	2.5	11.6	1.0	46.0	−3.2
North China	36.3	3.5	14.7	3.2	57.7	−23.0
Northeast China	35.2	3.6	22.1	2.0	62.9	−8.6
Mongolia	35.0	3.7	17.2	3.4	59.3	8.2
South Korea + North Korea	36.4	2.8	20.4	3.0	62.6	7.0
Japan	39.6	2.5	20.1	1.4	63.6	3.1
Integrated Scenario	**LCOE Primary**	**LCOC**	**LCOS**	**LCOT**	**LCOE Total**	**Export (−)/Import (+)**
	(€/MWh)	**(€/MWh)**	**(€/MWh)**	**(€/MWh)**	**(€/MWh)**	**(%)**
Area average	39.1	1.7	10.2	2.0	53.0	8.9
New Zealand	37.7	0.6	4.5	0.0	42.8	0.0
East Australia	30.7	1.6	3.2	0.1	35.6	−0.3
West Australia	29.9	1.7	0.9	0.0	32.5	0.0
Indonesia-Papua + Papua New Guinea	36.5	1.3	23.7	2.6	64.1	13.1
Sumatra	49.2	0.0	3.3	2.5	55.0	−8.5
Java + Timor Leste	37.9	0.5	7.1	0.2	45.7	−0.3
East Indonesia	35.3	0.9	4.8	0.2	41.2	0.0
Malaysia + Singapore + Brunei	40.9	1.1	18.9	2.4	63.3	6.9
Philippines	46.3	1.4	15.3	1.7	64.7	3.5
Vietnam + Laos + Cambodia	43.5	1.2	13.2	1.8	59.7	0.6
Myanmar + Thailand	45.0	1.0	14.1	0.8	60.9	1.3
South China	45.1	1.7	7.7	1.2	55.7	−5.9
Central China	42.1	1.2	10.8	0.8	54.9	1.2
East China	44.1	1.1	19.0	5.5	69.7	29.0
Northwest China + Tibet + Uygur	29.7	3.6	6.6	1.5	41.4	−5.2
North China	35.8	1.8	8.6	2.1	48.3	−14.5
Northeast China	34.7	3.7	15.1	4.2	57.7	−24.0
Mongolia	37.4	3.5	14.6	3.0	58.5	2.0
South Korea + North Korea	35.0	1.3	9.8	3.2	49.3	10.2
Japan	38.1	1.7	9.3	1.4	50.5	6.5
Integrated RE-SNG Scenario	**LCOE Primary**	**LCOC**	**LCOS**	**LCOT**	**LCOE Total**	**Export (−)/Import (+)**
	(€/MWh)	**(€/MWh)**	**(€/MWh)**	**(€/MWh)**	**(€/MWh)**	**(%)**
Area average	38.7	1.7	10.3	1.9	52.6	8.3
New Zealand	37.5	0.6	4.5	0.0	42.6	0.0
East Australia	30.6	1.6	3.1	0.0	35.3	−0.3
West Australia	29.7	1.7	0.2	0.0	31.6	0.0

Indonesia-Papua+Papua New Guinea	36.4	1.3	24.2	2.5	64.4	11.7
Sumatra	49.2	0.0	3.2	2.6	55.0	−8.3
Java + Timor Leste	38.0	0.5	7.1	0.2	45.8	−0.3
East Indonesia	35.3	0.9	4.7	0.2	41.1	0.0
Malaysia + Singapore + Brunei	40.9	1.1	18.9	2.4	63.3	6.8
Philippines	46.6	1.4	14.9	1.8	64.7	3.5
Vietnam + Laos + Cambodia	43.8	1.1	13.0	2.0	59.9	0.1
Myanmar + Thailand	45.0	1.0	14.1	0.9	61.0	1.5
South China	45.3	1.7	7.8	1.2	56.0	−4.6
Central China	42.2	1.2	10.9	0.8	55.1	2.2
East China	45.4	1.3	21.5	5.7	73.9	28.5
Northwest China + Tibet + Uygur	29.6	2.8	6.5	1.8	40.7	−7.1
North China	35.8	2.0	8.8	2.1	48.7	−14.1
Northeast China	34.6	3.5	16.1	4.1	58.3	−23.1
Mongolia	39.1	3.8	8.3	3.0	54.2	−0.5
South Korea + North Korea	35.3	1.3	12.2	4.4	53.2	21.0
Japan	39.0	1.6	14.2	1.4	56.2	4.4

Table S13. Overview on storage capacities, throughput, and full cycles per year for the four scenarios.

			Region-Wide	**Area-Wide**	**Integrated**	**Integrated RE-SNG**
Storage capacities	Battery SC	(TWh_{el})	2.1	2.1	2.1	2.1
	Battery system	(TWh_{el})	3.1	1.6	2.7	2.7
	PHS	(TWh_{el})	1.2	1.2	1.2	1.2
	A-CAES	(TWh_{el})	3.3	0.0	0.0	0.0
	Gas	(TWh_{th})	426.1	292.1	349.4	316.5
Throughput of storage technologies	Battery SC	(TWh_{el})	631.9	631.9	631.9	631.9
	Battery system	(TWh_{el})	906.7	515.5	823.9	826.7
	PHS	(TWh_{el})	270.5	290.1	271.1	285.8
	A-CAES	(TWh_{el})	72.5	0.0	0.0	0.4
	Gas	(TWh_{th})	737.0	521.2	134.0	155.2
Full cycles per year	Battery SC	[-]	306.0	306.0	306.0	306.0
	Battery system	[-]	297.0	322.7	302.0	304.0
	PHS	[-]	227.2	248.6	229.8	242.3
	A-CAES	[-]	22.3	28.7	0.0	21.5
	Gas	[-]	1.7	1.8	0.4	0.5

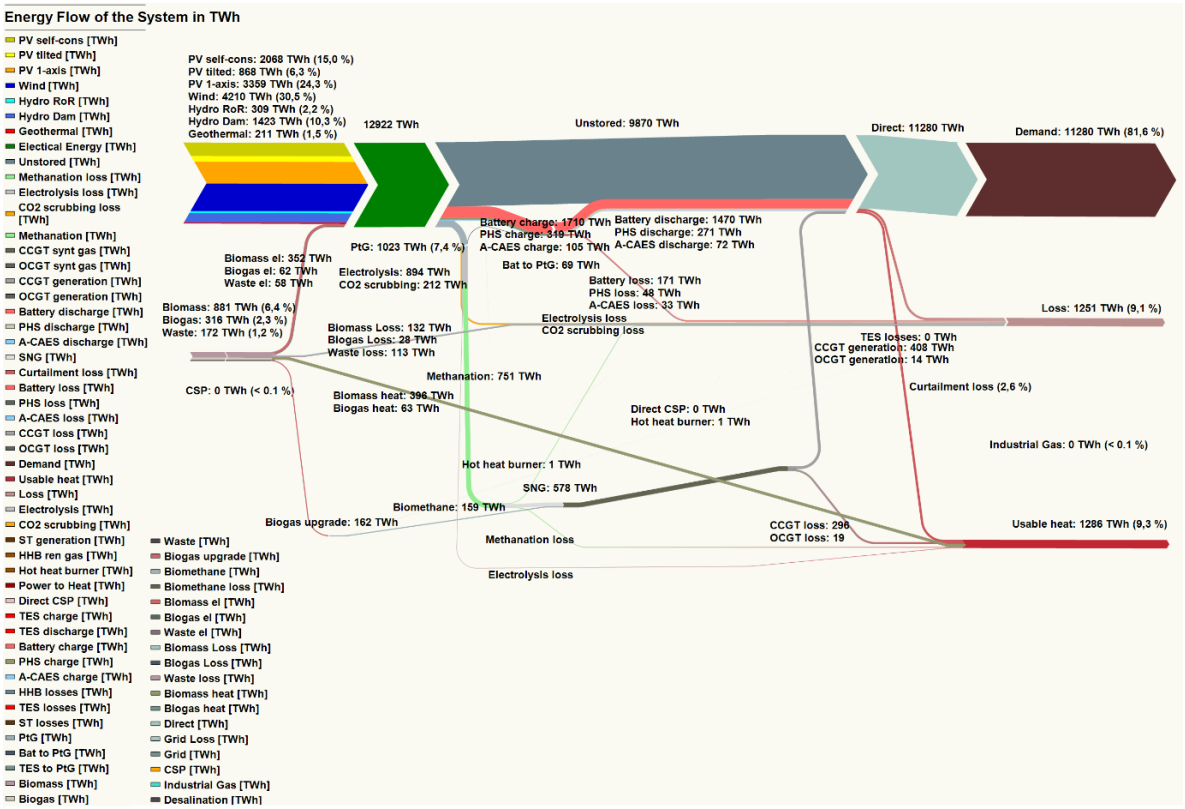

Figure S1. Energy flow of the system in the region-wide scenario.

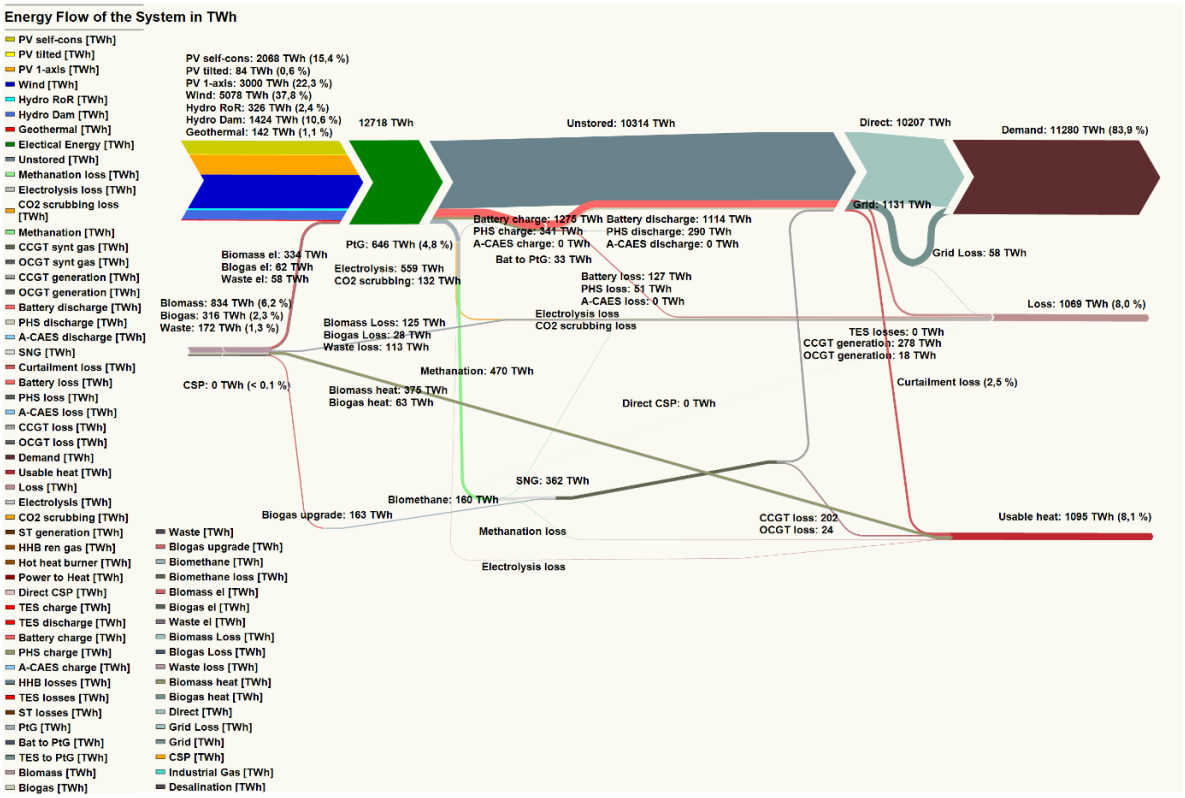

Figure S2. Energy flow of the system in the area-wide scenario.

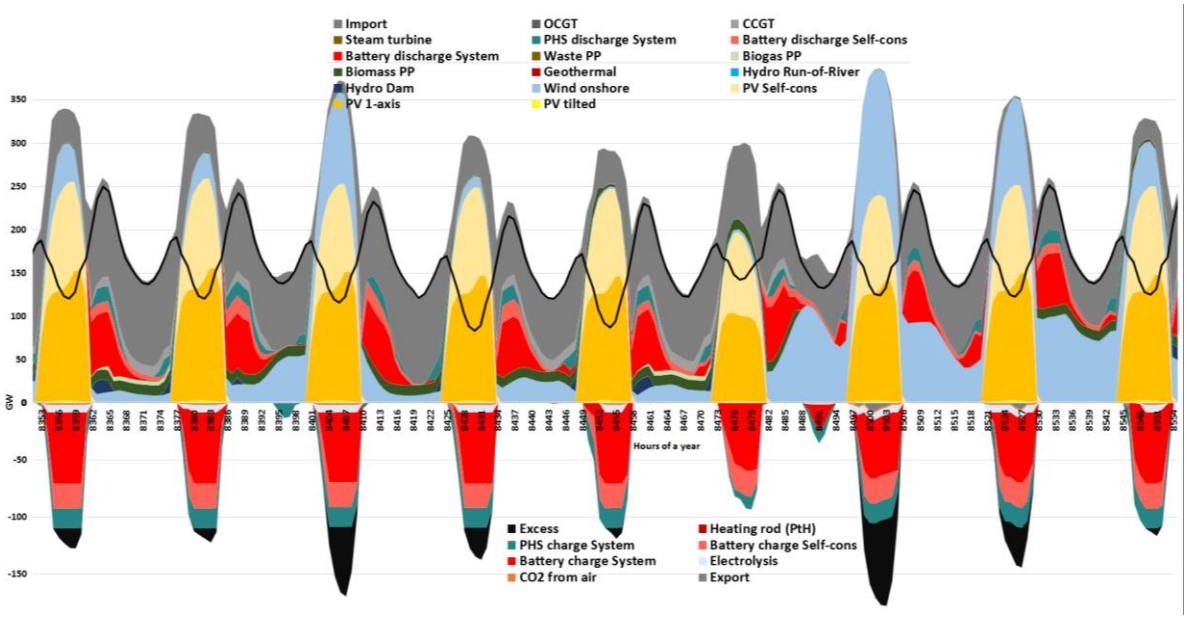

Figure S3. Hourly generation profile for net importer region, East China in a winter week.

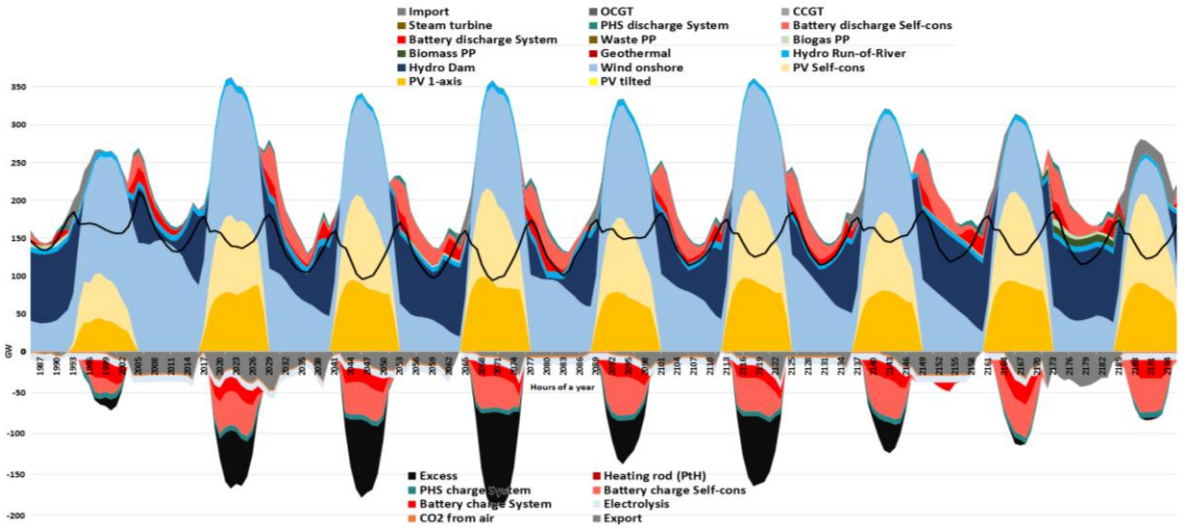

Figure S4. Hourly generation profile for a region with high wind generation and exporter region, South China.

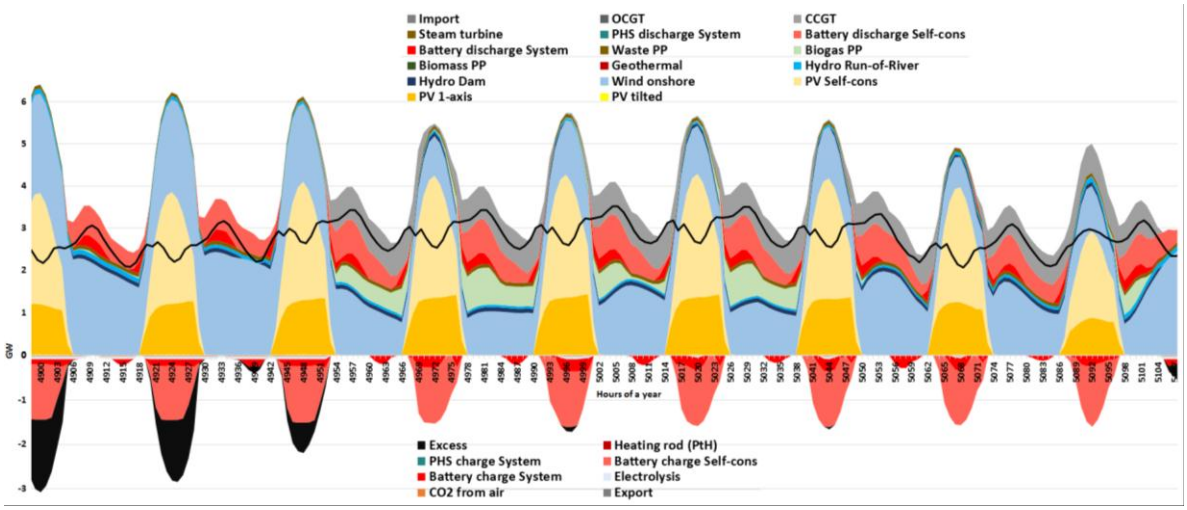

Figure S5. Hourly generation profile for Western Australia.in a winter week.

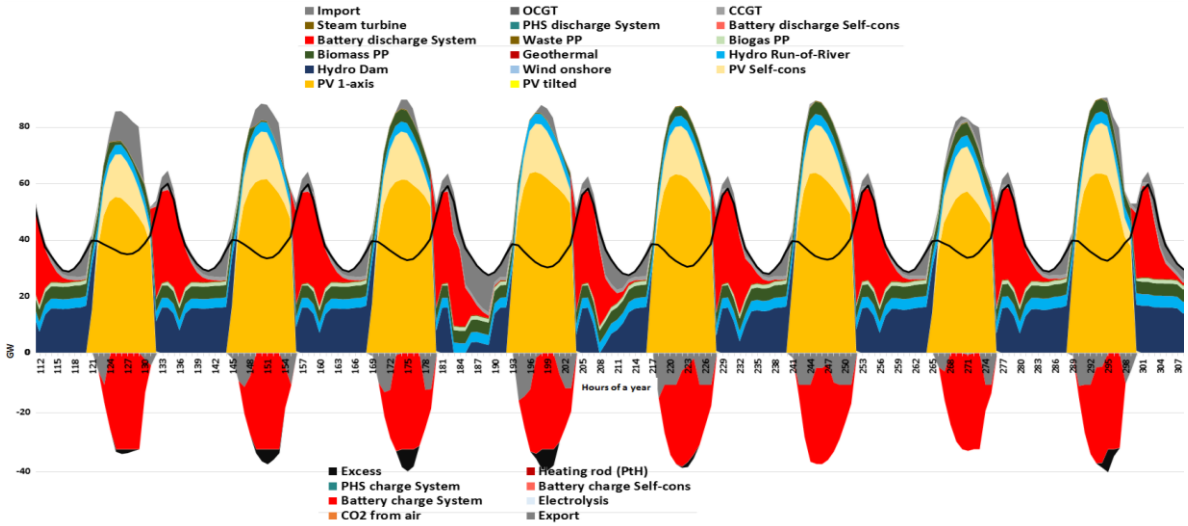

Figure S6. Hourly generation profile for the region of Vietnam, Cambodia and Laos, which profits from interconnection to Northeast Asia.

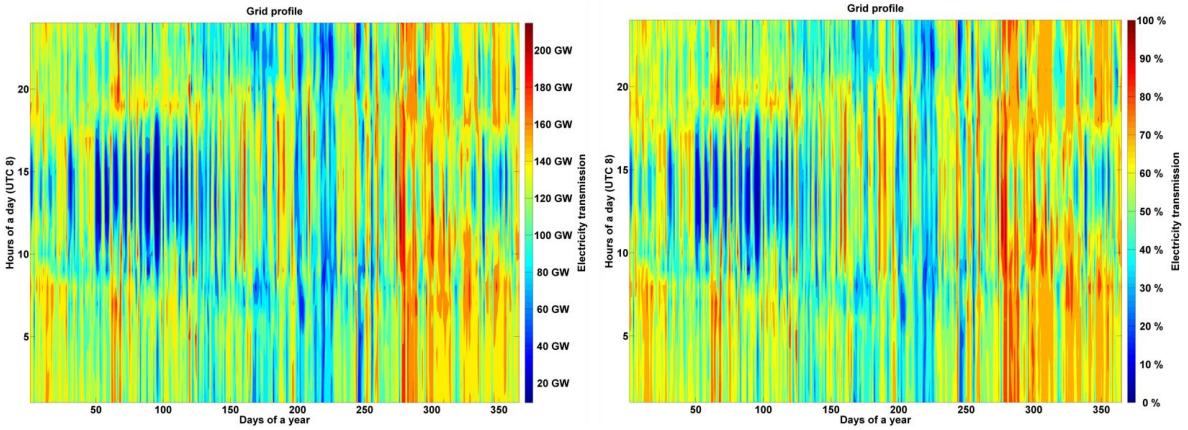

Figure S7. Interregional electricity trade between the East Asian regions in an area-wide scenario in absolute (**left**) and relative (**right**) terms.

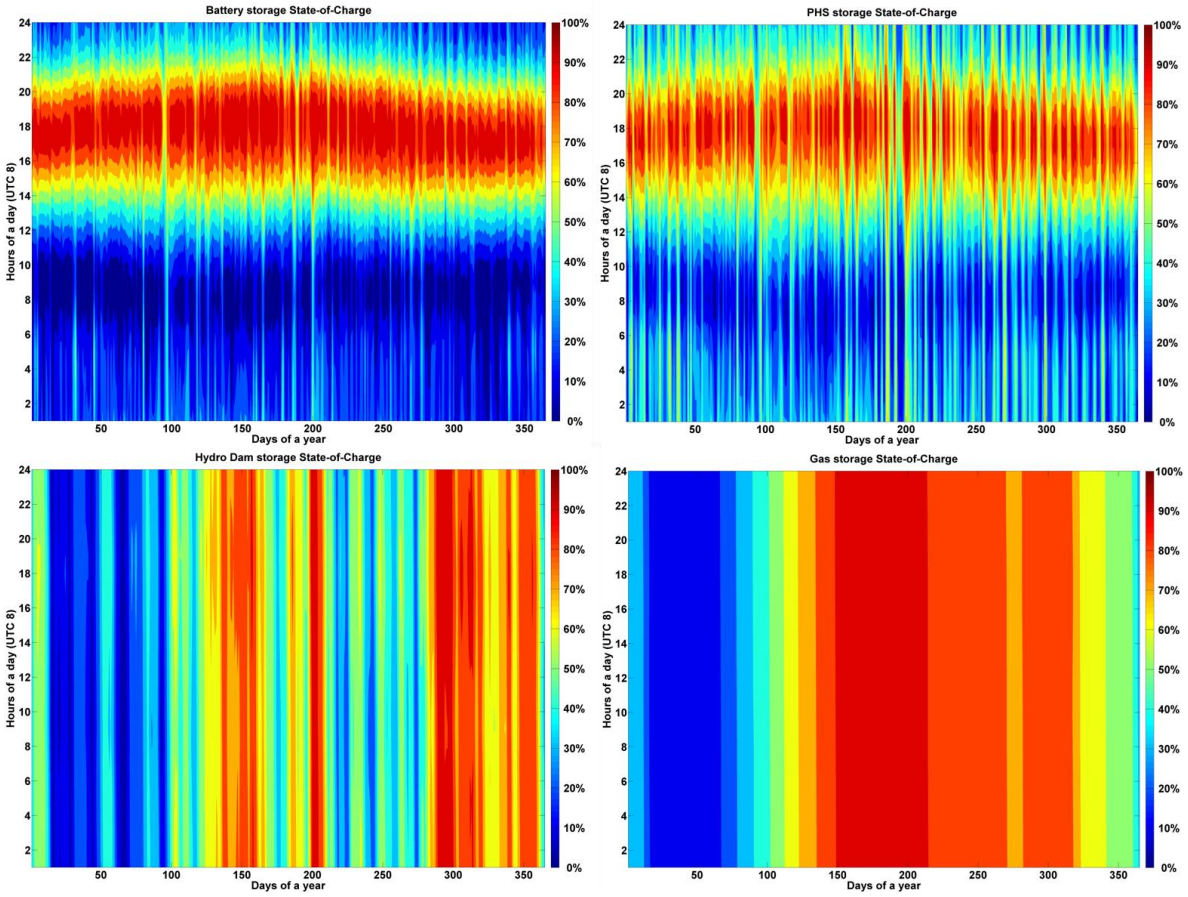

Figure S8. Aggregated yearly state-of-charge for storage technologies, battery (**top left**), PHS (**top right**), Hydro dam (**bottom left**), gas storage (**bottom right**).

References

1. Hoffmann, W. The Economic Competitiveness of Renewable Energy: Pathways to 100% Global Coverage; John Wiley & Sons: San Francisco, CA, USA, 2014.
2. Pleßmann, G.; Erdmann, M.; Hlusiak, M.; Breyer, C. Global energy storage demand for a 100% renewable electricity supply. *Energy Procedia* **2014**, *46*, 22–31.
3. Caldera, U.; Bogdanov, D.; Breyer, C. Local cost of seawater RO desalination based on solar PV and wind energy: A global estimate. *Desalination* **2016**, *385*, 207–216.
4. Komoto, K.; Ito, M.; Van der Vleuten, P.; Faiman, D.; Kurokawa, K. (Eds.) *Energy from the Desert—Very Large Scale Photovoltaic Systems: Socio-Economic, Financial, Technical and Environmental Aspects*; Earthscan: London, UK, 2009.
5. Agora Energiewende. Current and Future Cost of Photovoltaics—Long-Term Scenarios for Market Development System Prices and LCOE of Utility-Scale PV Systems. Report by Fraunhofer Institute for Solar Energy Systems on Behalf of Agora Energiewende, Berlin, Germany, 2015. Available online: www.fvee.de/fileadmin/publikationen/weitere_publikationen/15_AgoraEnergiewende-ISE_Current_and_Future_Cost_of_PV.pdf (accessed on 1 February 2017).
6. Urban, W.; Lohmann, H.; Girod, K. *Abschlussbericht für das BMBF-Verbundprojekt Biogaseinspeisung*; Fraunhofer UMSICHT: Liepzig, Germany, 2009. (In German)
7. European Commission. ETRI 2014—Energy Technology Reference Indicator Projections for 2010–2050. EC Joint Research Centre Institute for Energy and Transport: Petten, The Netherlands, 2014.
8. Vartiainen, E.; Masson, G.; Breyer, C. PV LCOE in Europe 2015–2050. In Proceedings of the 31th EU PVSEC, Hamburg, Germany, 14–18 September 2015.
9. Dii 2050, Desert Power—Perspectives on a Sustainable Power System for EUMENA. Munich. 2012. Available online: http://desertenergy.org/wp-content/uploads/2015/09/dp2050_study_web.pdf (accessed on 1 February 2017).

10. Fasihi, M.; Bogdanov, D.; Breyer, C. Economics of Global LNG Trading Based on Hybrid PV-Wind Power Plants. In Proceedings of the 31st European Photovoltaic Solar Energy Conference, Hamburg, Germany, 14–18 September 2015.
11. Fasihi, M.; Bogdanov, D.; Breyer, C. Long-Term Hydrocarbon Trade Options for the Maghreb Region and Europe—Renewable Energy Based Synthetic Fuels for a Net Zero Emissions World. In the Proceedings of the SGEM Vienna Green 2016 Sessions, Vienna, Austria, 2–5 November 2016.
12. DBFZ. *Regionale und Globale Räumliche Verteilung von Biomassepotenzialen*; German Biomass Research Centre: Leipzig, Germany, 2009. (In German)
13. Farfan, J.; Breyer, C. Structural changes of global power generation capacity towards sustainability and the risk of stranded investments supported by a sustainability indicator. *J. Clean. Prod.* **2017**, *141*, 370–384.
14. [IEA]—International Energy Agency. *Energy Balances of OECD and Non-OECD Countries*; IEA: Paris, France, 2013.