

ANNEX: REGIONAL FACTSHEETS

ENERGY TRANSFORMATION

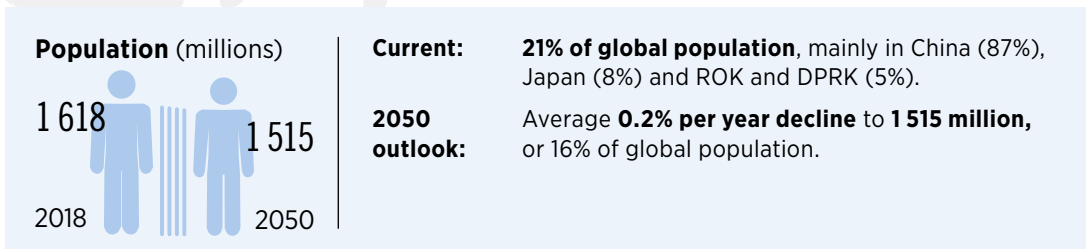
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ENERGY TRANSFORMATION EAST ASIA

Regional analysis covers five countries:

- China
- Democratic People's Republic of Korea (DPRK)
- Japan
- Mongolia
- Republic of Korea (ROK)

STATUS/CHARACTERISTICS AND NEEDS:

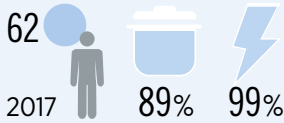


IRENA analysis based on E3ME.



IRENA analysis based on E3ME.



Energy consumption
(GJ/capita) and
energy access (%)**Energy consumption**
per capita:

Current: above global average (51 GJ/year).

2050 outlook:

▶ **PES:** Remains stable at 62 GJ/year.

Electricity
access:

Near-total in China, Japan and ROK; lower in Mongolia (>85%) and DPRK (44%).

Clean cooking
access:

Only 43% in Mongolia.

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

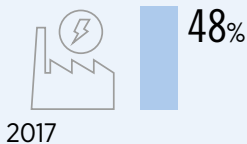
Fossil fuel net import**Current**
status:

Supply and demand roughly in balance; China is world's largest coal producer; ROK and Japan rely heavily on fossil-fuel imports.

2050
outlook:

Air pollution and resource challenges; vast untapped renewable energy potential.
▶ **PES:** The total generation (est. 15993 TWh) represents **36%** of overall renewable power potential.

Note: Current status, IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

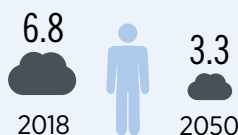
Energy-intensive
industries (%) in global
consumption)**Current**
status:

Over half of global **metal and minerals, chemicals, and iron and steel** energy demand is concentrated in the region.

2050
outlook:

Deploy a mix of **emerging clean technologies** and **carbon capture solutions**.

IRENA analysis based on 2017 values (IEA, 2019).

Energy-related CO₂
emissions per capita
(tCO₂/capita)**Recent:**

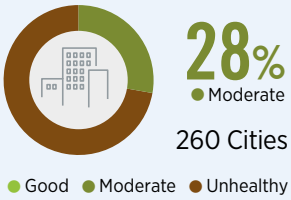
Region's annual emissions: 11.4 Gt (2018). 34% of global energy-related emissions.

2050
outlook:

- ▶ **PES: 53% reduction to 5.4 Gt** with enabling policies.
- Increased CO₂ emissions from transport.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



China: Rapid, mainly coal-fueled development accelerating since 2010, reducing poverty; death rate from air pollution now 2nd highest (after India's); new regulations cut air pollution by 20% in 2015-17.

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

Electricity prices and renewables costs

Electricity price:

Mid-range (for households and industries) compared to other regions.

Renewable power costs:

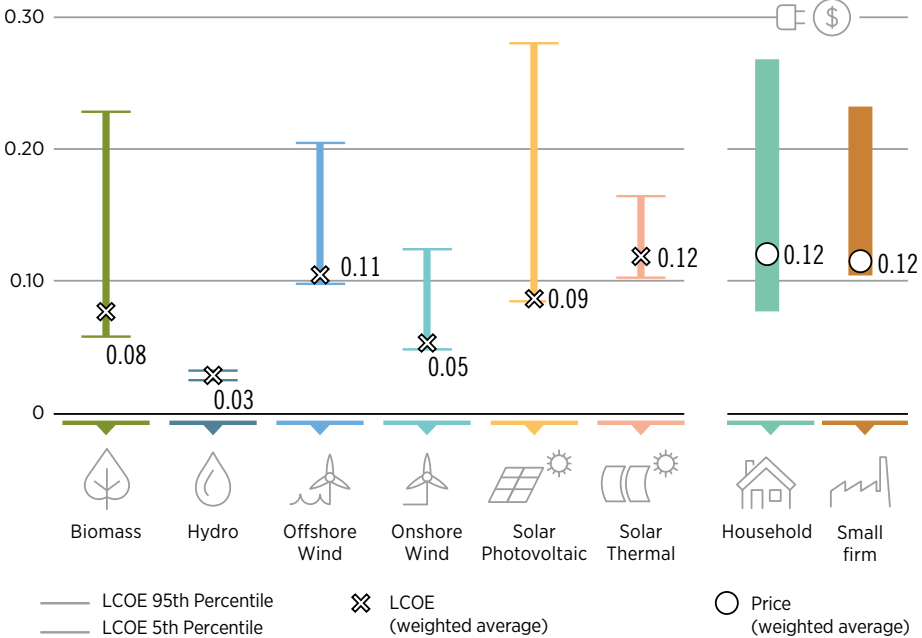
Onshore wind around G20 average (USD 0.05/kWh). Solar PV below G20 average (USD 0.096/kWh).

Auction prices:

Lower than other regions; China's largest solar auction (1 GW new capacity) achieved lowest price (USD 0.077/kWh) in 2017.

East Asia

LCOE 2018 (USD/kWh)



LCOE based on IRENA (2019a) and electricity prices based on Global Petrol Prices (2019). Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

ENERGY TRANSFORMATION: KEY BENEFITS

1

CLEAN ENERGY SUPPLY

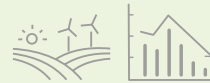
- ▶ Lower CO₂ emissions
- ▶ Better local air quality
- ▶ Leverage innovation (hydrogen, batteries, etc.)



2

ENERGY INDEPENDENCE

- ▶ Diversified energy supply
- ▶ Resilience to external shocks
- ▶ Lower investment risks



3

SUSTAINABLE DEVELOPMENT

- ▶ Added economic value
- ▶ Higher employment
- ▶ Empowered societies and improved awareness



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	159	185	172	159	160	138	115
Consumption (TFEC)	102	114	107	100	105	97	89

Renewables shares (modern)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	7%	17%	27%	39%	27%	44%	65%
Consumption (TFEC)	8%	20%	30%	43%	31%	49%	70%
Power generation	23%	42%	59%	73%	60%	77%	90%



Electricity share in final energy consumption

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
End-use consumption	25%	33%	40%	48%	37%	47%	58%
Industry	26%	39%	45%	53%	41%	51%	65%
Transport	3%	7%	20%	33%	14%	30%	46%
Buildings	32%	44%	48%	52%	45%	51%	57%

Renewable installed capacity (GW)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Bioenergy	14	74	74	74	82	84	87
Hydropower	349	484	533	582	490	539	588
Solar PV	186	1175	1734	2305	1644	2396	3118
Wind	169	706	1407	2106	1263	1990	2696



Biofuels

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Liquid biofuels (billions of litres per year)	5	31	32	33	36	36	37

Energy consumption per capita (GJ/capita)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Consumption (TFEC) per capita	62	67	64	62	62	58	55

CO₂ emissions (energy-related)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Annual level (Gt CO ₂ /yr)	11.2	10.3	7.8	5.4	8.4	5.3	2.2
Reduction vs. today	NA	-8%	-30%	-52%	-25%	-53%	-80%



● East Asia

Where we are heading
**Planned Energy
Scenario 2016 - 2050**
(PES)

Where we need to be
**Transforming Energy
Scenario 2016-2050**
(TES)

Energy system investments (average annual, 2016-50) USD billion/year

	Planned Energy Scenario 2016 - 2050 (PES)	Transforming Energy Scenario 2016-2050 (TES)
Power	314	386
– Renewable	172	246
– Non-renewable	63	35
– Power grids and system flexibility	80	105
Industry (RE + EE)	25	35
Transport (electrification + EE)	101	114
Buildings (RE + EE)	133	196
Biofuel supply	5.4	13.4
Renewable hydrogen – electrolyzers	2.2	5.9



Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019b; 2019c) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050

● East Asia

2019e 2030 2050

	2019e	2030	2050
Population (thousands) region-wide	1 621 179	1 627 194	1 514 571
GDP (USD 2015)			
GDP (million): PES	17 550 968	25 739 253	46 369 936
GDP (million): TES	18 075 537	26 577 659	47 521 377
GDP changes (million): TES vs. PES	524 569	838 406	1 151 441
GDP changes (%): TES vs. PES	3	3.3	2.5
Per capita GDP (thousand): PES	10.8	15.8	30.6
Per capita GDP (thousand): TES	11.1	16.3	31.4

**Employment**

Economy-wide employment (thousands)			
Employment: PES	997 554	979 427	839 204
Employment: TES	1 001 937	984 319	839 750
Employment changes: TES vs. PES	4 382	4 892	545
Employment changes (%): TES vs. PES	0.44%	0.50%	0.06%



● East Asia

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
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Energy sector jobs (thousands)

Nuclear power	139	222	254	215	185
Fossil fuels	9 952	10 170	7 765	8 765	4 800
Renewables	4 617	8 494	12 194	10 591	15 007
Energy efficiency	1 912	7 521	7 748	9 672	8 852
Power grids and energy flexibility	2 339	4 406	5 332	4 746	5 673
Total	18 959	30 813	33 293	33 989	34 517
Energy jobs in economy-wide employment (%)		3.1%	4.0%	3.5%	4.1%

Renewable energy jobs (thousands)

Bioenergy	414	1 069	801	1 185	1 005
Solar	3 211	5 571	7 630	6 725	9 404
Hydropower	469	621	716	604	688
Wind	519	1 225	2 999	2 061	3 844
Geothermal	4	7	46	12	50
Ocean	0	1	2	4	15
Total	4 617	8 494	12 194	10 591	15 007
Renewable energy jobs in energy-sector employment (%)		27.6%	36.6%	31.2%	43.5%


Job differential in 2050 (thousands) TES vs. PES

Economy-wide	545
Changes in conventional energy (A)	-3 034
Changes in transition related technologies (B)	4 257
Net energy sector jobs (A+B)	1 223

► Jobs in 2050: TES / ● East Asia

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	7 896	Construction & installation	5 894	Workers and technicians	9 972
Solar water heaters (SWH)	1 437	Manufacturing	4 236	Experts	1 475
Onshore wind	3 144	Operation and maintenance	3 098	Engineers and higher degrees	1 275
Offshore wind	699	Biofuel supply	-	Marketing and administrative	505
Geothermal	50				
Total	13 228		13 228		13 228

Welfare improvement (%):
TES vs. PES

Indicator	2030		2050	
	Value	Value	Value	Value
Economic	0.6		0.4	
Social	3.8		7.4	
Environmental	1.9		4	
Total	6.3		11.8	



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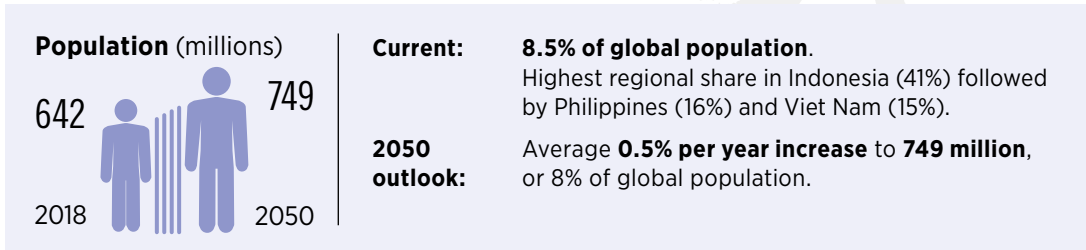
ENERGY TRANSFORMATION

SOUTHEAST ASIA

Regional analysis covers the 10 member states of the Association of Southeast Asian Nations:

- Brunei Darussalam
- Cambodia
- Indonesia
- Lao People's Democratic Republic
- Malaysia
- Myanmar
- Philippines
- Singapore
- Thailand
- Viet Nam

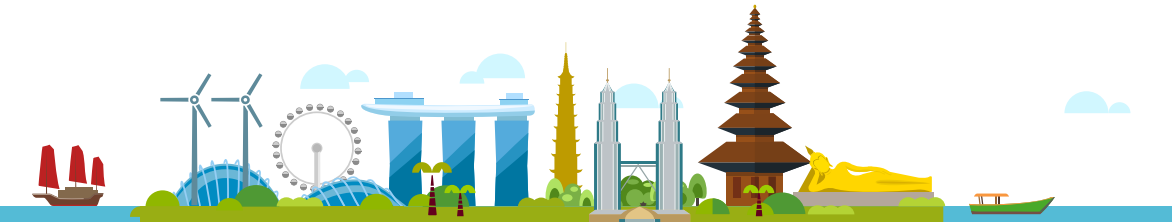
STATUS/CHARACTERISTICS AND NEEDS:

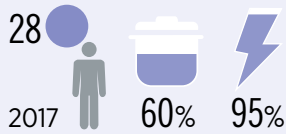


IRENA analysis based on E3ME.



IRENA analysis based on E3ME.



Energy consumption
(GJ/capita) and
energy access (%)**Energy consumption per capita:**

Current: well below the global average
(51 GJ/year).

2050 outlook:
▶ **PES:** high increase to 40 GJ/year.

Electricity access:

Some countries have not yet achieved full electrification. All governments plan for 100% electricity access before 2030.

Clean cooking access:

40% of the region's population lack access to modern fuels for cooking.

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

Fossil fuel net import

Current status: Indonesia: Large coal deposits; Malaysia: Moderate oil and gas reserves.

2050 outlook: Region shifting to net fossil-fuel imports; Vast untapped renewable energy potential.
▶ **PES:** The total generation (est. 3664 TWh) represents **25%** of overall renewable power potential.

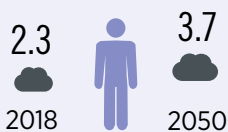
Note: Current status, IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

Energy-intensive industries (% in global consumption)

Current status: Regional energy use ranges from 1% of global levels in some industries up to **9%** (region's highest share) in **food and tobacco**.

2050 outlook: The region becoming more industrialised; Need for **emissions reductions** and specific solution to decarbonize in challenging sectors such as heavy industry.

IRENA analysis based on 2017 values (IEA, 2019).

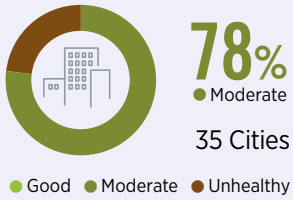
Energy-related CO₂ emissions per capita
(tCO₂/capita)

Recent: Region's annual emissions: 1.5 Gt (2018). 4% of global energy-related CO₂ emissions.

2050 outlook:
▶ **PES: Almost doubling to 2.9 Gt per year,** coal and natural-gas use drive increase, with more limited increase in oil demand.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



Unhealthy air pollution levels in 22% of region’s cities and moderately unhealthy levels in most of rest; Dataset (limited to 35 cities) points to poor and deteriorating urban air quality across region.

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

Electricity prices and renewables costs

Electricity price:

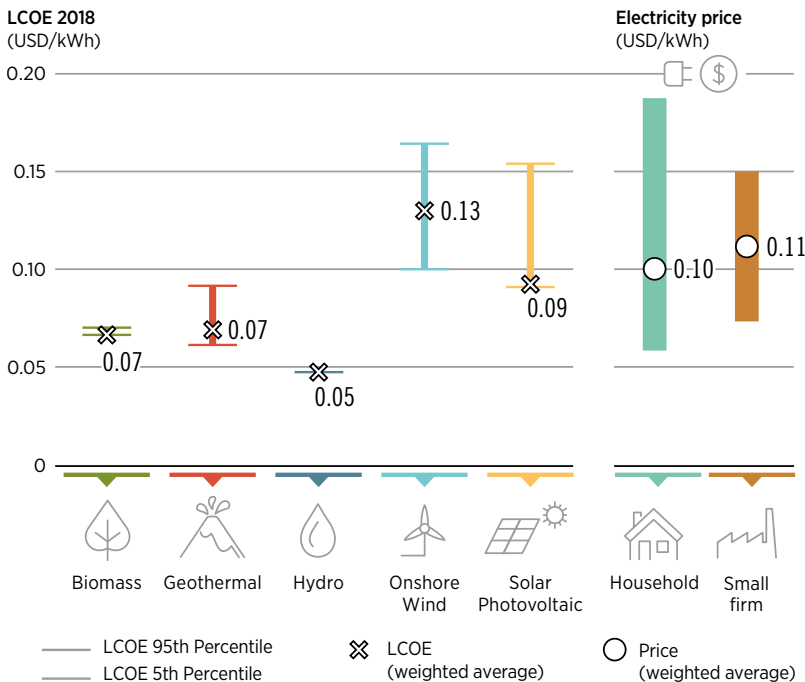
USD 0.10–0.11/kWh
average across region (lower compared to other regions).

Renewables cost and auctions:

Cost-competitiveness of renewables increasingly reflected in region;

Viet Nam has auctioned 5.5 GW (2019), region’s largest installed solar PV capacity.

Southeast Asia



LCOE based on IRENA (2019a) and electricity prices based on Global Petrol Prices (2019).

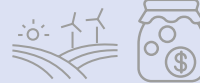
Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

ENERGY TRANSFORMATION: KEY BENEFITS

1

**ENERGY
ACCESS AND
INFRASTRUCTURE**

- ▶ Diversified energy supply
- ▶ Lower system costs
- ▶ Green industrial revolution



2

**ENERGY
SECURITY**

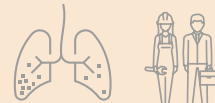
- ▶ Greater energy self-sufficiency
- ▶ Low-cost renewable energy use
- ▶ Increased regional interconnections
- ▶ Increasingly electrified transport



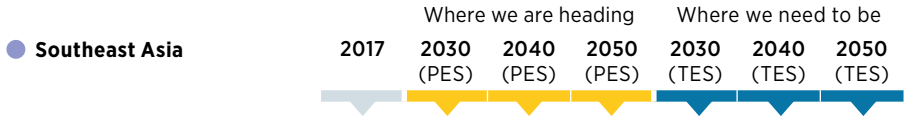
3

**SUSTAINABLE
DEVELOPMENT**

- ▶ Economic growth driven by trade gains
- ▶ High growth in renewable energy jobs
- ▶ Better air quality and improved health
- ▶ Improved education and empowered citizens



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	28	40	50	60	35	42	46
Consumption (TFEC)	18	21	27	31	21	25	28

Renewables shares (modern)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	13%	28%	29%	31%	41%	59%	75%
Consumption (TFEC)	12%	16%	19%	22%	27%	48%	68%
Power generation	20%	31%	34%	37%	53%	73%	85%



Electricity share in final energy consumption	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
End-use consumption	18%	22%	26%	31%	20%	32%	42%
Industry	22%	16%	19%	23%	16%	22%	27%
Transport	0.2%	1%	2%	3%	3%	12%	23%
Buildings	30%	68%	77%	83%	63%	82%	91%

Renewable installed capacity (GW)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Bioenergy	7	26	32	37	66	111	176
Hydropower	39	41	51	70	71	81	100
Solar PV	4	54	109	198	106	399	647
Wind	1	5	8	11	13	22	32



Biofuels	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Liquid biofuels (billions of litres per year)	7	34	39	62	47	57	93

Energy consumption per capita (GJ/capita)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Consumption (TFEC) per capita	28	29	35	40	29	33	35



CO ₂ emissions (energy-related)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Annual level (Gt CO ₂ /yr)	1.4	2	2.6	2.9	1.6	1.3	0.8
Reduction vs. today	NA	45%	81%	106%	15%	-10%	-46%

● Southeast Asia

Where we are heading
**Planned Energy
Scenario 2016 - 2050**
(PES)

Where we need to be
**Transforming Energy
Scenario 2016-2050**
(TES)

Energy system investments (average annual, 2016-50) USD billion/year

	Where we are heading Planned Energy Scenario 2016 - 2050 (PES)	Where we need to be Transforming Energy Scenario 2016-2050 (TES)
Power	39	66
- Renewable	12	39
- Non-renewable	13	5
- Power grids and system flexibility	15	22
Industry (RE + EE)	7	13
Transport (electrification + EE)	10	20
Buildings (RE + EE)	27	40
Biofuel supply	3.2	6.9
Renewable hydrogen – electrolyzers	0	0

Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019b; 2019c) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050

● Southeast Asia

2019e 2030 2050

	2019e	2030	2050
Population (thousands) region-wide	647 605	700 587	749 019

GDP (USD 2015)

GDP (million): PES	2 465 787	3 981 401	10 065 561
GDP (million): TES	2 495 821	4 155 442	10 360 523
GDP changes (million): TES vs. PES	30 034	174 041	294 962
GDP changes (%): TES vs. PES	1.2	4.4	2.9
Per capita GDP (thousand): PES	3.8	5.7	13.4
Per capita GDP (thousand): TES	3.9	5.9	13.8

Employment**Economy-wide employment (thousands)**

Employment: PES	319 692	354 865	369 980
Employment: TES	319 792	354 512	369 664
Employment changes: TES vs. PES	101	-353	-316
Employment changes (%): TES vs. PES	0.03%	-0.10%	-0.09%



● Southeast Asia

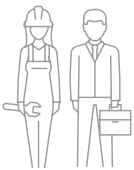


Energy sector jobs (thousands)

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Nuclear power	1	5	10	10	20
Fossil fuels	2 000	2 682	2 764	2 647	2 429
Renewables	779	1 681	2 028	3 780	6 720
Energy efficiency	1 005	645	564	978	703
Power grids and energy flexibility	308	474	451	501	638
Total	4 092.7	5 487.5	5 817.2	7 915.2	10 509.4
Energy jobs in economy-wide employment (%)		1.5%	1.6%	2.2%	2.8%

Renewable energy jobs (thousands)

Bioenergy	502	1 302	1 457	2 752	4 412
Solar	91	186	372	628	1 882
Hydropower	155	139	154	285	283
Wind	15	18	19	40	45
Geothermal	15	35	27	56	63
Ocean	0	0	0	18	34
Total	779	1 681	2 028	3 780	6 720
Renewable energy jobs in energy-sector employment (%)		30.6%	34.9%	47.8%	63.9%



Job differential in 2050 (thousands) TES vs. PES

Economy-wide	-316
Changes in conventional energy (A)	-325
Changes in transition related technologies (B)	5 018
Net jobs (A+B)	4 692

► Jobs in 2050: TES / ● Southeast Asia

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	1560	Construction & installation	805	Workers and technicians	1515
Solar water heaters (SWH)	322	Manufacturing	988	Experts	206
Onshore wind	45	Operation and maintenance	198	Engineers and higher degrees	176
Offshore wind	-	Biofuel supply	-	Marketing and administrative	94
Geothermal	63				
Total	1991		1991		1991

Welfare improvement (%):
TES vs. PES

Indicator	2030		2050	
Economic		0.1		0.0
Social		1.5		7.7
Environmental		1.6		3.5
Total		3.2		11.2



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- World Bank Group (2019b), *Access to clean fuels and technologies for cooking (% of population)*, World Bank Group.

ENERGY TRANSFORMATION

REST OF ASIA

Regional analysis covers 16 countries:

West Asia:

- Armenia
- Azerbaijan
- Turkey

Central Asia:

- Kazakhstan
- Kyrgyz Republic
- Tajikistan
- Turkmenistan
- Uzbekistan

South Asia:

- Afghanistan
- Bangladesh
- Bhutan
- India
- Maldives
- Nepal
- Pakistan
- Sri Lanka

STATUS/CHARACTERISTICS AND NEEDS:

Population (millions)



Current: **27% of global population**, mainly in India (68%) followed by Pakistan (11%), Bangladesh (8%) and Turkey (4%).

2050 outlook: Average **0.7% per year increase to 2 602 million**, or 28% of global population.

IRENA analysis based on E3ME.

GDP per capita (thousand USD 2015)

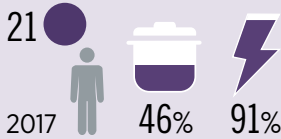


Current: **Well below the global average (10.9).**

2050 outlook: **Rapid development;** ► **PES: CAGR = 4.9%**

IRENA analysis based on E3ME.

Energy consumption (GJ/capita) and energy access (%)



Energy consumption per capita:

Current: well below the global average (51 GJ/year).

2050 outlook:
▶ **PES** rapid increase to 35 GJ/year.

Electricity access:

Over 91% (2017) up from 75% (2010). Still, 178 million people in the region lack electricity access (IEA, IRENA, UNSD, WB, WHO, 2019).

Clean cooking access:

Available to less than 50% of region's population (2017), with especially large access deficit in India (IEA, IRENA, UNSD, WB, WHO, 2019).

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

Fossil fuel net import



Current status:

West and South Asian countries are net importers, while Central Asian countries are net exporters (mainly oil and gas).

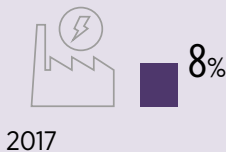
2050 outlook:

Rising air pollution and resource challenges; Large untapped renewable energy potential.

▶ **PES:** The total generation (est. 7514 TWh) represents **23%** of overall renewable power potential.

Note: Current status, IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

Energy-intensive industries (% in global consumption)



Current status:

Accounts for **14% of global energy demand for iron and steel** and around **9% for non-ferrous metals and non-metallic minerals** industries.

2050 outlook:

Increasing output of iron and steel, metals, chemicals and petrochemicals; **India and Pakistan require concentrated effort and specific decarbonisation solutions.**

Source: IRENA analysis based on 2017 values (IEA, 2019).

Energy-related CO₂ emissions per capita (tCO₂/capita)



Recent:

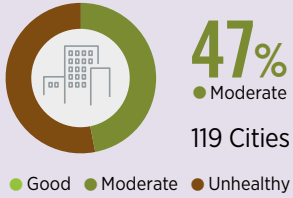
Region's annual emissions: 3.8 Gt (2018). 11% of global energy-related CO₂ emissions.

2050 outlook:

▶ **PES: Almost doubling to 7.2 Gt** with enabling policies. CO₂ emissions from transport are poised to triple to 1.4 Gt propelled by population growth and urbanization.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



South Asia currently has the world's most toxic air, with 18 of the planet's 20 most-polluted cities found in India (15), Pakistan (2) and Bangladesh (1).

Record-high air pollution has periodically shut down regular activities and caused serious health issues in Delhi, India.

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

Electricity prices and renewables costs

Electricity price:

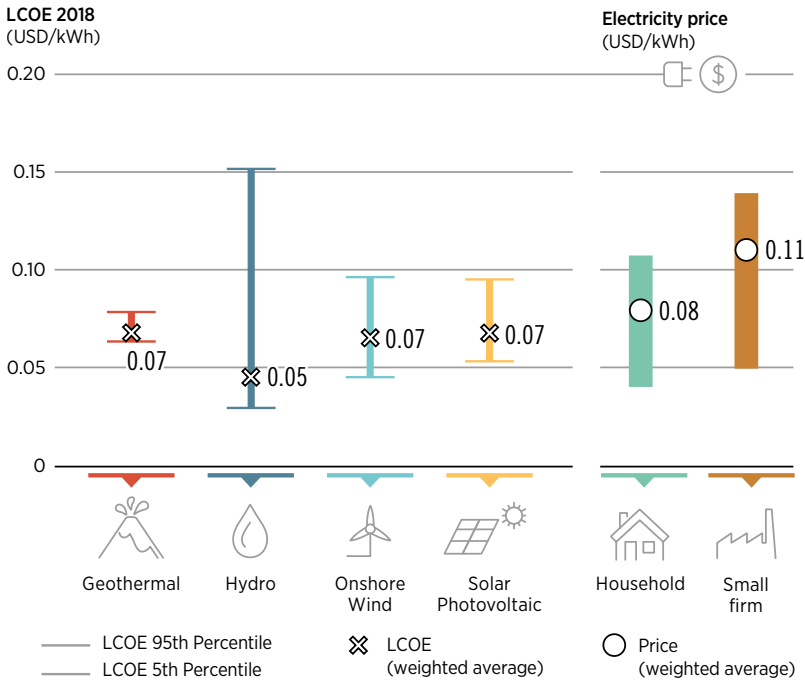
Among the lowest in the world, only in MENA is lower. Similar to Rest of Europe.

Renewables cost and auctions:

Onshore wind: Similar to G20 average levels of USD 0.05/kWh (weighted average LCOE);
Solar PV: Below G20 average (USD 0.096/kWh);

India: Solar PV cost-competitive compared to thermal power generation (USD 0.068/kWh for coal and USD 0.093/kWh for combined-cycle gas).

Rest of Asia



LCOE based on IRENA (2019a) and electricity prices based on Global Petrol Prices (2019).

Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

ENERGY TRANSFORMATION: KEY BENEFITS

1

REDUCED EMISSIONS

- ▶ Clean local air
- ▶ Lower CO₂ output
- ▶ Improved health and well-being



2

ENERGY INDEPENDENCE AND ACCESS

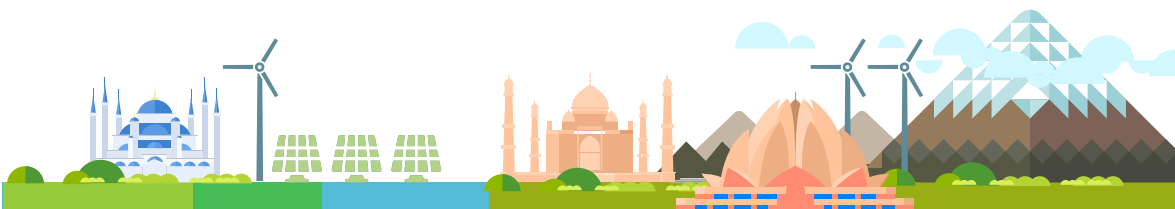
- ▶ Distributed renewable power to isolated communities
- ▶ Diversified energy supply
- ▶ Improved clean cooking access



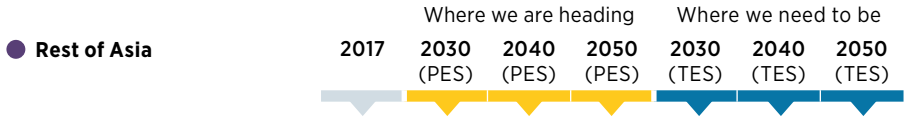
3

ECONOMIC AND SUSTAINABLE DEVELOPMENT

- ▶ Economic growth and poverty alleviation
- ▶ Modern energy job creation and skills development
- ▶ Transformative health impacts
- ▶ Active role for communities



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	64	89	107	124	75	80	82
Consumption (TFEC)	42	61	75	87	51	54	55

Renewables shares (modern)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	8%	17%	19%	22%	27%	41%	58%
Consumption (TFEC)	8%	14%	17%	21%	24%	40%	59%
Power generation	18%	37%	44%	51%	52%	68%	81%

Electricity share in final energy consumption

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
End-use consumption	18%	21%	24%	26%	26%	37%	47%
Industry	21%	15%	15%	15%	19%	25%	32%
Transport	1%	6%	7%	9%	18%	37%	52%
Buildings	20%	45%	57%	66%	51%	63%	75%

Renewable installed capacity (GW)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Bioenergy	12	30	32	35	39	45	55
Hydropower	110	149	175	185	154	202	240
Solar PV	24	216	430	733	314	706	1072
Wind	41	162	254	404	223	374	541

Biofuels

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Liquid biofuels (billions of litres per year)	1	11	29	38	14	53	81

Energy consumption per capita (GJ/capita)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Consumption (TFEC) per capita	21	27	31	35	23	23	22

CO₂ emissions (energy-related)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Annual level (Gt CO ₂ /yr)	3.5	5.4	6.4	7.2	3.8	3.1	2
Reduction vs. today	NA	53%	81%	105%	8%	-11%	-43%

● Rest of Asia

Where we are heading
**Planned Energy
Scenario 2016 - 2050**
(PES)

Where we need to be
**Transforming Energy
Scenario 2016-2050**
(TES)

Energy system investments (average annual, 2016-50) USD billion/year

	Planned Energy Scenario 2016 - 2050 (PES)	Transforming Energy Scenario 2016-2050 (TES)
Power	122	151
- Renewable	46	84
- Non-renewable	30	16
- Power grids and system flexibility	45	52
Industry (RE + EE)	22	33
Transport (electrification + EE)	37	70
Buildings (RE + EE)	78	114
Biofuel supply	2	12
Renewable hydrogen – electrolyzers	0.2	3

Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019b; 2019c) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050

● Rest of Asia

	2019e	2030	2050
Population (thousands) region-wide	2 088 441	2 326 499	2 601 942
GDP (USD 2015)			
GDP (million): PES	5 699 443	11 092 911	31 609 299
GDP (million): TES	5 892 431	11 194 938	31 994 075
GDP changes (million): TES vs. PES	192 988	102 027	384 776
GDP changes (%): TES vs. PES	3.4	0.9	1.2
Per capita GDP (thousand): PES	2.7	4.8	12.1
Per capita GDP (thousand): TES	2.8	4.8	12.3
Employment			
Economy-wide employment (thousands)			
Employment: PES	1 020 945	1 251 416	1 562 473
Employment: TES	1 021 164	1 250 735	1 561 263
Employment changes: TES vs. PES	219	(681)	(1 210)
Employment changes (%): TES vs. PES	0.02%	-0.05%	-0.08%



● Rest of Asia

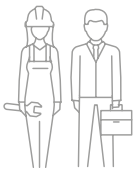


Energy sector jobs (thousands)

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Nuclear power	60	103	86	91	65
Fossil fuels	3 424	6 170	6 621	5 163	4 495
Renewables	1 422	2 846	3 577	3 795	5 164
Energy efficiency	2 615	2 596	1 034	3 925	1 815
Power grids and energy flexibility	1 654	2 483	3 009	2 551	3 220
Total	9 175	14 198	14 326	15 523	14 759
Energy jobs in economy-wide employment (%)		1.1%	0.9%	1.2%	0.9%

Renewable energy jobs (thousands)

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Bioenergy	238	860	756	1 243	1 491
Solar	340	941	1 687	1 422	2 504
Hydropower	760	821	798	821	774
Wind	80	220	333	305	386
Geothermal	4	4	4	5	9
Ocean	0	0	0	0	0
Total	1 422	2 846	3 577	3 795	5 164
Renewable energy jobs in energy-sector employment (%)		20.0%	25.0%	24.4%	35.0%



Job differential in 2050 (thousands) TES vs. PES

Economy-wide	-1210
Changes in conventional energy (A)	-2147
Changes in transition related technologies (B)	2579
Net jobs (A+B)	432

► Jobs in 2050: TES / ● Rest of Asia

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	1819	Construction & installation	1580	Workers and technicians	2191
Solar water heaters (SWH)	519	Manufacturing	195	Experts	250
Onshore wind	295	Operation and maintenance	958	Engineers and higher degrees	253
Offshore wind	91	Biofuel supply	-	Marketing and administrative	39
Geothermal	9				
Total	2733		2733		2733

Welfare improvement (%):
TES vs. PES

Indicator	2030		2050	
Economic		0.1		0.2
Social		7.7		11.3
Environmental		2.0		4.2
Total		9.8		15.7



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- Deng, Y., Haigh, M., Pouwels, W., Ramaekers, L., Brandsma, R., Schimschar, S., Grözinger, J. & de Jager, D. (2015), *Quantifying a realistic, worldwide wind and solar electricity supply*, Global Environmental Change 31, 239-52, <https://doi.org/10.1016/j.gloenvcha.2015.01.005>.
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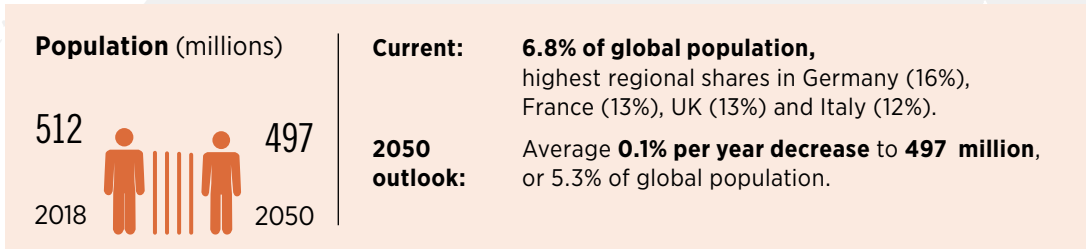
ENERGY TRANSFORMATION

EUROPEAN UNION

Regional analysis covers 28 member countries*:

- Austria
- Belgium
- Bulgaria
- Croatia
- Cyprus
- Czech Republic
- Denmark
- Estonia
- Finland
- France
- Hungary
- Germany
- Greece
- Ireland
- Italy
- Latvia
- Lithuania
- Luxembourg
- Malta
- Poland
- Portugal
- Romania
- Slovakia
- Slovenia
- Spain
- Sweden
- Netherlands
- United Kingdom (UK)*

STATUS/CHARACTERISTICS AND NEEDS:



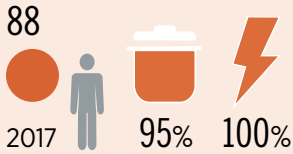
IRENA analysis based on E3ME.



IRENA analysis based on E3ME.

* The UK officially exited the European Union (EU) in January 2020. Since the analysis was based on developments until April 2019, this report considers the UK as part of the EU.

Energy consumption (GJ/capita) and energy access (%)



Energy consumption per capita:

Current: well above the global average (51 GJ/year).

2050 outlook:

▶ **PES:** slight decrease to 85 GJ/year.

Electricity access:

The region has long achieved full electrification and access to electricity.

Clean cooking access:

There remains some marginal use of inefficient biomass cookstoves, particularly in rural areas.

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

Fossil fuel net import



Current status:

Very limited domestic fossil fuel resources

compared to primary energy consumption; heavy dependence on imported oil (93% of oil supply) and gas (79% of gas supply).

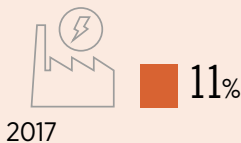
2050 outlook:

Improved regional energy security; the region has planned to be **climate-neutral** by 2050.

▶ **PES:** The total generation (est. 3796 TWh) represents **15%** of overall renewable power potential.

Note: IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

Energy-intensive industries (% in global consumption)



Current status:

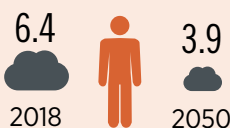
Accounts for about **20% of global energy demand for pulp and paper, 17% for food and tobacco, about 11% for chemical and petrochemical industry** and the share in the **metals and minerals industry** accounts to roughly **9%**.

2050 outlook:

Need for urgent **emissions reduction** in heavy industries.

Note: Current status, IRENA analysis based on 2017 values (IEA, 2019).

Energy-related CO₂ emissions per capita (tCO₂/capita)



Recent:

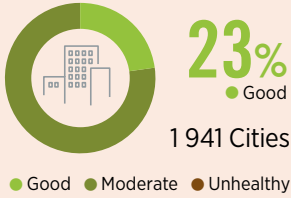
Region's annual emissions: 3.3 Gt (2018). 10% of global energy-related emissions.

2050 outlook:

▶ **PES: Drop by 41% to 1.9 Gt** with enabling policies; Reductions driven by improvements in energy intensity and the adoption of renewable energy.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



Air pollution moderate to unhealthy in about 75% of the EU cities, mainly from transport (passenger cars, trucks).

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

Electricity prices and renewables costs

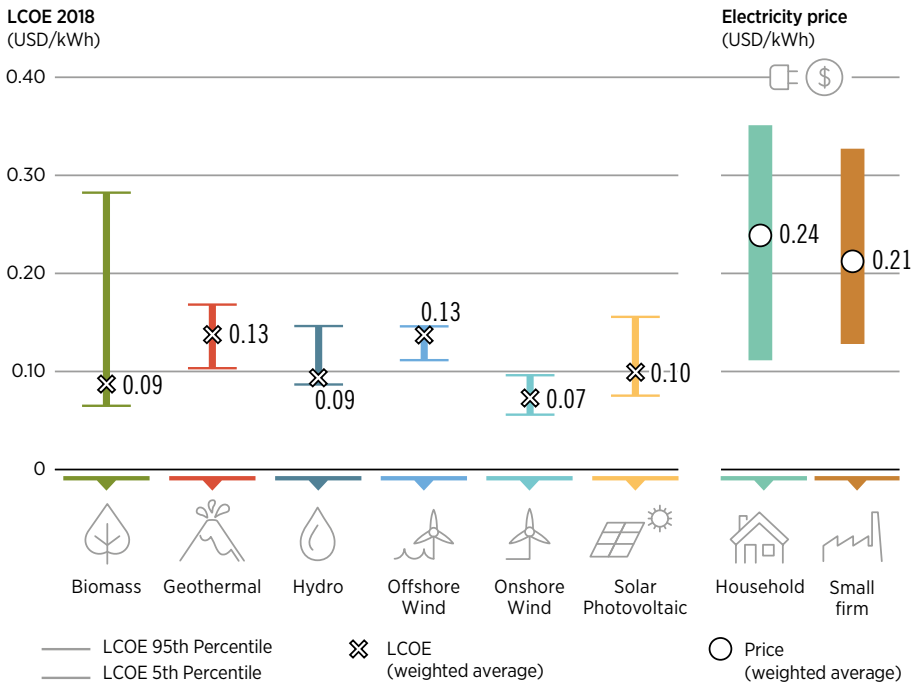
Electricity price:

The highest values for households and the second-highest for industries compared to the other regions

Renewables cost and auctions:

Cost-competitive, or even least cost, when compared to coal or natural gas. Average prices for historical projects are around USD 0.08/kWh for solar and USD 0.05/kWh for wind. Lower than other regions; new solar projects showing costs of around USD 0.02-0.03/kWh, and wind projects at around USD 0.03-0.04/kWh.

European Union



Note: LCOE based on IRENA (2019a) and electricity prices based on Global Petrol Prices (2019).
 Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

ENERGY TRANSFORMATION: KEY BENEFITS

1

**CLEAN
TECHNOLOGY
HUB**

- ▶ Global leadership on energy transition
- ▶ Carbon neutrality by 2050 (EU target)
- ▶ High-efficiency levels
- ▶ Affordable energy supply



2

**ENERGY
SECURITY**

- ▶ Increased energy self-sufficiency
- ▶ Reduced oil and gas dependence
- ▶ Transformative shift to efficiency and renewables



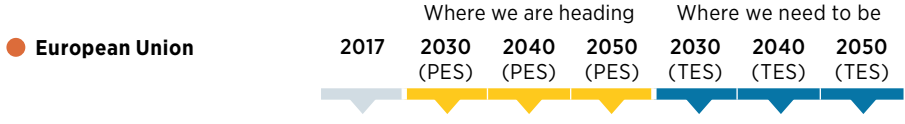
3

**ECONOMIC
AND SOCIAL
DEVELOPMENT**

- ▶ Economic growth driven by investment and supportive policies
- ▶ Job creation and skills development
- ▶ Pollution reduction, improved health and well-being



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	68	62	57	55	54	47	42
Consumption (TFEC)	45	43	42	42	38	34	29

Renewables shares (modern)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	15%	23%	28%	33%	39%	50%	71%
Consumption (TFEC)	17%	24%	30%	34%	36%	48%	70%
Power generation	31%	44%	50%	58%	55%	73%	86%



Electricity share in final energy consumption	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
End-use consumption	22%	25%	27%	29%	30%	38%	49%
Industry	31%	31%	37%	38%	40%	47%	54%
Transport	2%	4%	6%	8%	7%	14%	32%
Buildings	33%	35%	37%	39%	42%	48%	55%

Renewable installed capacity (GW)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Bioenergy	34	45	44	47	55	82	107
Hydropower	130	136	137	140	140	141	143
Solar PV	107	204	243	281	284	512	784
Wind	169	235	288	360	319	469	621



Biofuels	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Liquid biofuels (billions of litres per year)	25	42	46	52	72	86	97

Energy consumption per capita (GJ/capita)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Consumption (TFEC) per capita	88	84	83	85	74	66	59



CO ₂ emissions (energy-related)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Annual level (Gt CO ₂ /yr)	3.4	2.6	2.2	1.9	1.9	1.2	0.6
Reduction vs. today	NA	-22%	-35%	-42%	-43%	-64%	-82%



● **European Union**

Where we are heading
**Planned Energy
Scenario 2016 - 2050**
(PES)

Where we need to be
**Transforming Energy
Scenario 2016-2050**
(TES)

Energy system investments (average annual, 2016-50) USD billion/year

	Where we are heading Planned Energy Scenario 2016 - 2050 (PES)	Where we need to be Transforming Energy Scenario 2016-2050 (TES)
Power	98	145
- Renewable	38	78
- Non-renewable	22	12
- Power grids and system flexibility	38	56
Industry (RE + EE)	6	8
Transport (electrification + EE)	18	32
Buildings (RE + EE)	89	130
Biofuel supply	2	5
Renewable hydrogen – electrolyzers	0	0.7

Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019b; 2019c) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050

● **European Union**

2019e

2030

2050

	2019e	2030	2050
Population (thousands) region-wide	511 528	506 687	496 892

GDP (USD 2015)

GDP (million): PES	20 903 940	26 987 610	34 800 915
GDP (million): TES	21 279 174	27 940 359	37 372 375
GDP changes (million): TES vs. PES	375 234	952 749	2 571 460
GDP changes (%): TES vs. PES	1.8	3.5	7.4
Per capita GDP (thousand): PES	40.9	53.3	70.0
Per capita GDP (thousand): TES	41.6	55.1	75.2

Employment

Economy-wide employment (thousands)

Employment: PES	237 331	241 626	228 604
Employment: TES	238 323	244 026	234 073
Employment changes: TES vs. PES	992	2 400	5 469
Employment changes (%): TES vs. PES	0.42%	0.99%	2.39%

● European Union

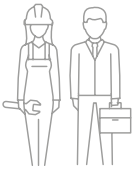


Energy sector jobs (thousands)

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Nuclear power	104	118	73	96	27
Fossil fuels	1113	1645	1135	1346	726
Renewables	1290	1730	1636	2502	2701
Energy efficiency	312	1715	1496	2723	1717
Power grids and energy flexibility	483	694	574	757	821
Total	3 303	5 901	4 914	7 424	5 993
Energy jobs in economy-wide employment (%)		2.4%	2.1%	3.0%	2.6%

Renewable energy jobs (thousands)

Bioenergy	661	736	709	968	1065
Solar	139	282	311	646	866
Hydropower	136	245	151	280	144
Wind	344	456	454	592	608
Geothermal	9	10	9	13	15
Ocean	1	1	2	2	4
Total	1 290	1 730	1 636	2 502	2 701
Renewable energy jobs in energy-sector employment (%)		29.3%	33.3%	33.7%	45.1%



Job differential in 2050 (thousands) TES vs. PES

Economy-wide	5 469
Changes in conventional energy (A)	-454
Changes in transition related technologies (B)	1533
Net jobs (A+B)	1079

► Jobs in 2050: TES / ● European Union

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	629	Construction & installation	600	Workers and technicians	1101
Solar water heaters (SWH)	221	Manufacturing	549	Experts	164
Onshore wind	443	Operation and maintenance	324	Engineers and higher degrees	139
Offshore wind	165	Biofuel supply	-	Marketing and administrative	69
Geothermal	15				
Total	1473		1473		1473

Welfare improvement (%):
TES vs. PES

Indicator	2030		2050	
Economic		0.9		2.0
Social		3.1		5.1
Environmental		1.7		3.5
Total		5.7		10.6



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Deng, Y., Haigh, M., Pouwels, W., Ramaekers, L., Brandsma, R., Schimschar, S., Grözinger, J. & de Jager, D. (2015), *Quantifying a realistic, worldwide wind and solar electricity supply*, *Global Environmental Change* 31, 239-52, <https://doi.org/10.1016/j.gloenvcha.2015.01.005>.

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World Bank Group (2019b), *Access to clean fuels and technologies for cooking (% of population)*, World Bank Group.

ENERGY TRANSFORMATION

REST OF EUROPE

Regional analysis covers:

- Albania
- Andorra
- Belarus
- Bosnia and Herzegovina
- Iceland
- Liechtenstein
- Monaco
- Montenegro
- Norway
- Republic of Moldova
- Russian Federation
- Serbia
- Switzerland
- North Macedonia
- Ukraine

STATUS/CHARACTERISTICS AND NEEDS:

Population (millions)



Current: 3% of global population, mainly in the Russian Federation (61%) and Ukraine (19%).

2050 outlook: Average 0.3% per year decrease to 208 million, or 2.2% of global population.

IRENA analysis based on E3ME.

GDP per capita (thousand USD 2015)



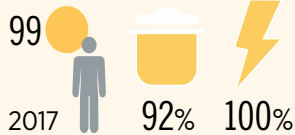
Current: Above the global average (10.9).

2050 outlook: Slight development; **PES: CAGR = 1.5%**

IRENA analysis based on E3ME.



Energy consumption (GJ/capita) and energy access (%)



Energy consumption per capita:

Current: well above the global average (51 GJ/year).

2050 outlook:

► **PES:** high increase to 138 GJ/year.

Electricity access:

The region has **long achieved full electrification.**

Clean cooking access:

8% lacks; marginal use of inefficient biomass stoves for cooking and home heating continues, mainly in rural areas.

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

Fossil fuel net import



Current status:

Net fossil-fuel exporter, mainly due to the Russian Federation, the world's largest oil and gas exporter, covering almost 6% of energy consumption in the rest of the world (2018).

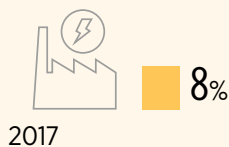
2050 outlook:

Vast untapped renewable potential.

► **PES:** The total generation (est. 1997 TWh) represents 7% of overall renewable power potential.

Source: IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

Energy-intensive industries (% in global consumption)



Current status:

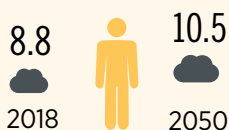
Accounts for over **11% of global energy demand for iron and steel**, around **8% for chemical and petrochemical industries** and **7% for food and tobacco.**

2050 outlook:

Need for alternative emission-free technological solutions.

Note: Current status, IRENA analysis based on 2017 values (IEA, 2019).

Energy-related CO₂ emissions per capita (tCO₂/capita)



Recent:

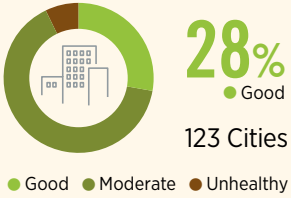
Region's annual emissions: 2.1 Gt (2018). 6% of global energy-related emissions.

2050 outlook:

► **PES: 7% increase to 2.3 Gt** based on current policies.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



Air pollution is problematic for some countries, such as in Southeast Europe, which have high levels of PM 2.5 compared to Norway and Switzerland that have better air quality.

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

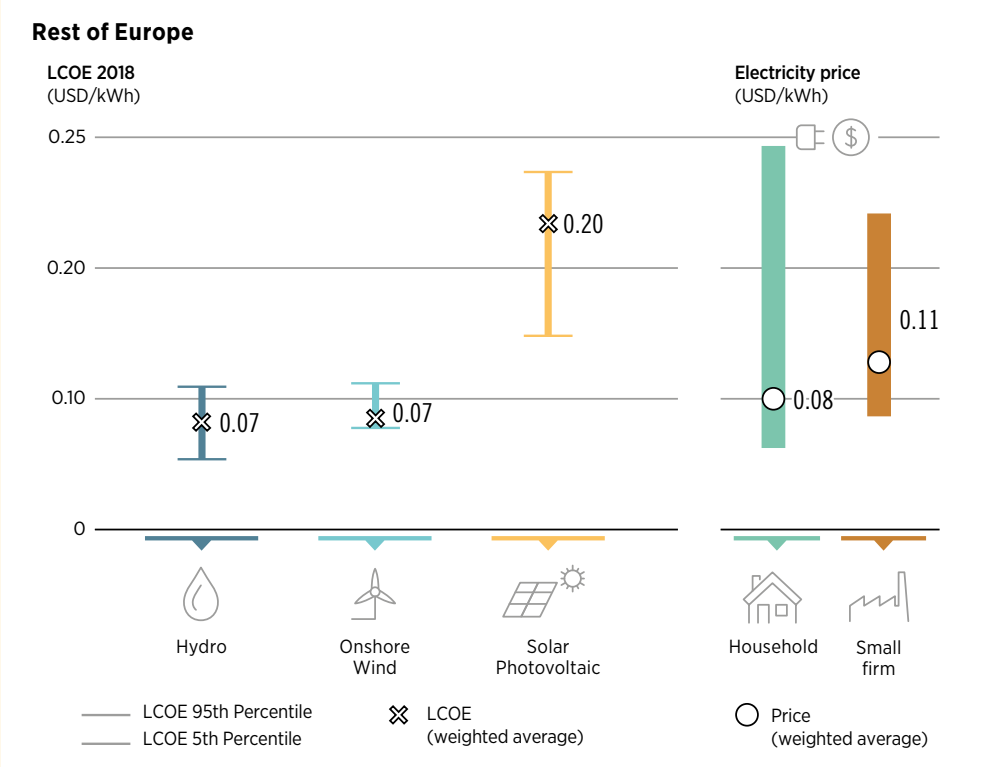
Electricity prices and renewables costs

Electricity price:

Among the lowest in the world, only in MENA is lower. Similar to Rest of Asia.

Renewables cost and auctions:

Average prices for historical projects are around USD 0.08/kWh and USD 0.05/kWh for solar and wind, respectively.



LCOE based on IRENA (2019a) and electricity prices based on Global Petrol Prices (2019). Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

ENERGY TRANSFORMATION: KEY BENEFITS

1

SUSTAINABLE DEVELOPMENT

- ▶ Affordable energy for citizens
- ▶ Economic growth and competitiveness
- ▶ Increase in energy sector jobs
- ▶ Improved welfare



2

ENERGY SECURITY

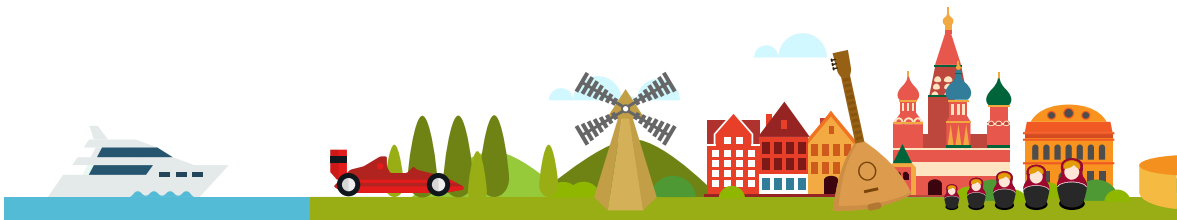
- ▶ Reduce oil and gas dependence (net importers)
- ▶ Diversified economy and energy supply (net exporters, e.g. Russian Federation)



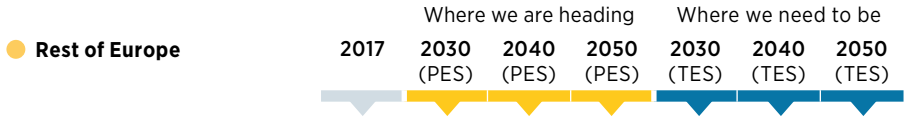
3

CLIMATE SUSTAINABILITY

- ▶ Better air quality
- ▶ Increased use of renewables
- ▶ Cost-effective path to achieve climate goals



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	39	46	46	47	38	33	29
Consumption (TFEC)	24	29	30	30	23	21	18

Renewables shares (modern)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	6%	10%	10%	12%	19%	34%	54%
Consumption (TFEC)	7%	9%	11%	12%	20%	37%	61%
Power generation	27%	28%	28%	31%	42%	63%	82%

Electricity share in final energy consumption

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
End-use consumption	18%	18%	20%	22%	23%	28%	38%
Industry	20%	22%	24%	25%	27%	30%	35%
Transport	6%	6%	8%	12%	12%	21%	37%
Buildings	21%	24%	26%	28%	28%	33%	42%

Renewable installed capacity (GW)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Bioenergy	2	3	6	17	27	56	83
Hydropower	111	105	95	94	127	140	157
Solar PV	3	25	25	38	39	58	107
Wind	2	16	31	45	33	57	79

Biofuels

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Liquid biofuels (billions of litres per year)	1	12	18	23	22	34	47

Energy consumption per capita (GJ/capita)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Consumption (TFEC) per capita	99	124	131	138	98	94	82

CO₂ emissions (energy-related)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Annual level (Gt CO ₂ /yr)	2	2.4	2.3	2.3	1.6	1.2	0.7
Reduction vs. today	NA	17%	15%	12%	-19%	-42%	-68%



● **Rest of Europe**

Where we are heading
Planned Energy Scenario 2016 - 2050
(PES)

Where we need to be
Transforming Energy Scenario 2016-2050
(TES)

Energy system investments (average annual, 2016-50) USD billion/year

	Planned Energy Scenario 2016 - 2050 (PES)	Transforming Energy Scenario 2016-2050 (TES)
Power	25	33
- Renewable	4	21
- Non-renewable	16	5
- Power grids and system flexibility	5	6
Industry (RE + EE)	5	7
Transport (electrification + EE)	12	20
Buildings (RE + EE)	57	83
Biofuel supply	2	8
Renewable hydrogen – electrolyzers	0.1	1



Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019b; 2019c) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050

● **Rest of Europe**

2019e 2030 2050

	2019e	2030	2050
Population (thousands) region-wide	230 174	223 224	208 212
GDP (USD 2015)			
GDP (million): PES	2 991 058	3 242 176	4 289 467
GDP (million): TES	3 150 705	3 181 845	4 356 940
GDP changes (million): TES vs. PES	159 647	-60 332	67 473
GDP changes (%): TES vs. PES	5.3	-1.9	1.6
Per capita GDP (thousand): PES	13.0	14.5	20.6
Per capita GDP (thousand): TES	13.7	14.3	20.9
Employment			
Economy-wide employment (thousands)			
Employment: PES	144 339	148 766	154 839
Employment: TES	144 472	148 635	154 527
Employment changes: TES vs. PES	133	-131	-313
Employment changes (%): TES vs. PES	0.09%	-0.09%	-0.20%

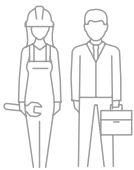


● Rest of Europe



	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Energy sector jobs (thousands)					
Nuclear power	167	181	184	148	65
Fossil fuels	3 139	3 085	2 962	2 771	2 407
Renewables	275	500	716	1 044	1 730
Energy efficiency	420	373	435	577	940
Power grids and energy flexibility	927	964	1 001	978	1 063
Total	4 928	5 103	5 298	5 518	6 205
Energy jobs in economy-wide employment (%)		3.4%	3.4%	3.7%	4.0%

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Renewable energy jobs (thousands)					
Bioenergy	97	228	395	579	1 049
Solar	31	82	169	193	450
Hydropower	143	128	50	171	86
Wind	4	61	97	95	122
Geothermal	1	1	5	5	23
Ocean	0	0	0	0	0
Total	275	500	716	1 044	1 730
Renewable energy jobs in energy-sector employment (%)		9.8%	13.5%	18.9%	27.9%



Job differential in 2050 (thousands) TES vs. PES	
Economy-wide	-313
Changes in conventional energy (A)	-674
Changes in transition related technologies (B)	1581
Net jobs (A+B)	908

► Jobs in 2050: TES / ● Rest of Europe

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	311	Construction & installation	400	Workers and technicians	485
Solar water heaters (SWH)	138	Manufacturing	34	Experts	49
Onshore wind	122	Operation and maintenance	160	Engineers and higher degrees	53
Offshore wind	-	Biofuel supply	-	Marketing and administrative	8
Geothermal	23				
Total	594		594		594

Welfare improvement (%):
TES vs. PES

Indicator	2030		2050	
Economic		(0.3)		0.2
Social		4.2		7.8
Environmental		2.1		4.5
Total		6.0		12.4



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Deng, Y., Haigh, M., Pouwels, W., Ramaekers, L., Brandsma, R., Schimschar, S., Grözinger, J. & de Jager, D. (2015), *Quantifying a realistic, worldwide wind and solar electricity supply*, *Global Environmental Change* 31, 239–52, <https://doi.org/10.1016/j.gloenvcha.2015.01.005>.

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ENERGY TRANSFORMATION

LATIN AMERICA AND THE CARIBBEAN

Regional analysis extends from the Caribbean Islands and Central America to the southernmost tip of South America.

STATUS/CHARACTERISTICS AND NEEDS:

Population (millions)



Current: **6.1% of global population.**
Highest regional share in Brazil (40%) followed by Colombia (10%) and Argentina (9%).

2050 outlook: Average **0.4% per year increase** to **536 million**, or 5.7% of global population.

IRENA analysis based on E3ME.

GDP per capita (thousand USD 2015)

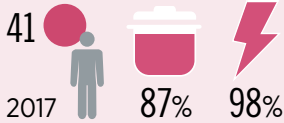


Current: **Below the global average (10.9).**

2050 outlook: **Swift development;**
▶ **PES: CAGR = 3.8%**

IRENA analysis based on E3ME.



Energy consumption (GJ/capita) and energy access (%)**Energy consumption per capita:**

Current: below global average (51 GJ/year).

2050 outlook:

► **PES:** high increase to 56 GJ/year.

Electricity access:

Almost complete except for few countries such as Honduras and Haiti.

Clean cooking access:

13% of region's population lack access; major concern in some countries.

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

Fossil fuel net import**Current status:**

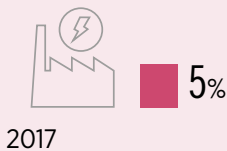
Comparatively energy self-sufficiency region-wide; Central America imports fossil fuels, while Andean and Southern Cone sub-regions are net exporters.

2050 outlook:

Resource diversification; enormous untapped potential.

► **PES:** The total generation (est. 3138 TWh) just represents **6%** of overall renewable power potential.

Note: Current status, IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

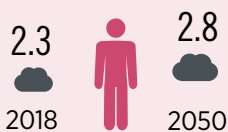
Energy-intensive industries (% in global consumption)**Current status:**

Accounts for **17%** of the world's energy demand for **food and tobacco** and **over 10%** of global energy consumption in the **paper industry**.

2050 outlook:

Require significant **efforts and specific solutions to decarbonise** energy-intensive industries.

Note: Current status, IRENA analysis based on 2017 values (IEA, 2019).

Energy-related CO₂ emissions per capita (tCO₂/capita)**Recent:**

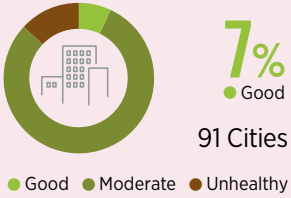
Region's annual emissions: 1.2 Gt (2018). 4% of global energy-related CO₂ emissions.

2050 outlook:

► **PES:** **39% increase to 1.7 Gt** with enabling policies.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



Rising transport emissions with continued population growth and urbanisation.

Current plans would boost light-vehicle sales, but also intensify traffic jams and local pollution.

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

Electricity prices and renewables costs

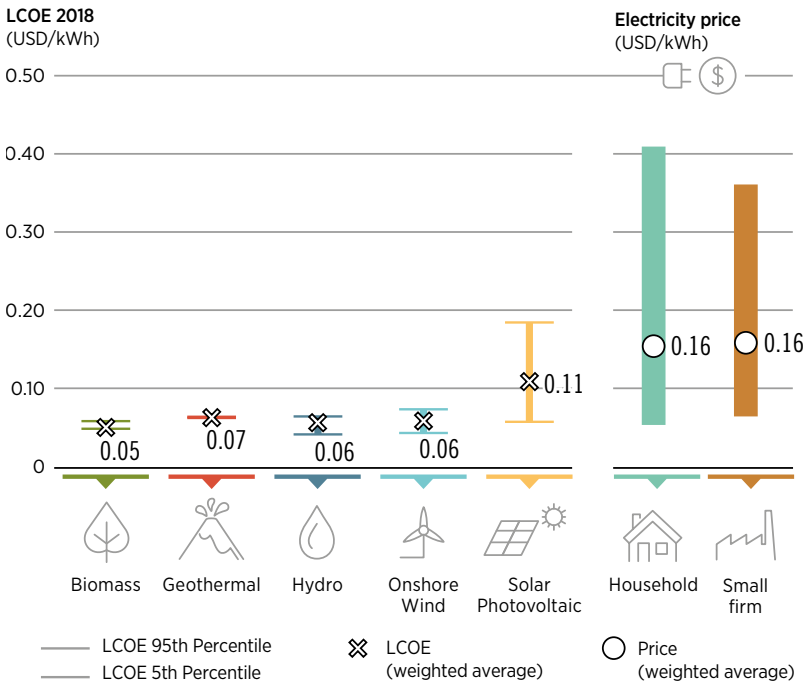
Electricity price:

Mid-range (for households and industries) compared to other regions.

Renewables cost and auctions:

Cost-competitive; Argentina attained wind price at an average of USD 0.041/kWh in 2017; Brazil attained solar price at an average of USD 0.021/kWh in 2019 (IRENA, 2019a). Hydropower projects remain highly competitive.

Latin America and the Caribbean



Source: LCOE based on IRENA (2019b) and electricity prices based on Global Petrol Prices (2019). Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

ENERGY TRANSFORMATION: KEY BENEFITS

1

AFFORDABLE, ACCESSIBLE ENERGY

- ▶ Lower system costs
- ▶ Distributed power for isolated communities
- ▶ Clean cooking



2

ENERGY SECURITY, CLIMATE-RESILIENCE

- ▶ Resilience to climate, other risks
- ▶ Diversified energy supply
- ▶ Reduced energy demand with improved efficiency measures
- ▶ Improved infrastructure



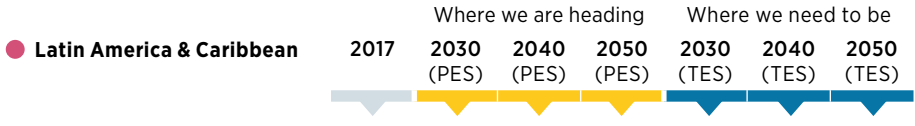
3

CLEAN, CLIMATE-SAFE ECONOMIES

- ▶ Economic development
- ▶ Trade gains by moving away from fossil fuels
- ▶ Better air quality and reduced local pollution
- ▶ Improved education and empowered citizens



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)	2017	Where we are heading			Where we need to be		
		2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	27	35	42	46	29	31	31
Consumption (TFEC)	21	27	31	34	22	22	21

Renewables shares (modern)							
	2017	2030	2040	2050	2030	2040	2050
Supply (TPES)	30%	40%	42%	46%	53%	63%	73%
Consumption (TFEC)	30%	36%	37%	40%	47%	57%	67%
Power generation	65%	73%	75%	79%	85%	90%	93%



Electricity share in final energy consumption							
	2017	2030	2040	2050	2030	2040	2050
End-use consumption	18%	22%	24%	26%	26%	31%	39%
Industry	21%	24%	24%	25%	27%	29%	33%
Transport	0.2%	1%	1%	2%	9%	14%	24%
Buildings	45%	58%	63%	67%	61%	70%	78%

Renewable installed capacity (GW)							
	2017	2030	2040	2050	2030	2040	2050
Bioenergy	19	45	61	79	50	72	94
Hydropower	173	181	201	226	186	211	240
Solar PV	5	76	128	177	108	196	281
Wind	17	74	111	148	93	141	188



Biofuels							
	2017	2030	2040	2050	2030	2040	2050
Liquid biofuels (billions of litres per year)	31	61	74	79	61	75	73

Energy consumption per capita (GJ/capita)							
	2017	2030	2040	2050	2030	2040	2050
Consumption (TFEC) per capita	41	47	53	56	38	38	35



CO ₂ emissions (energy-related)							
	2017	2030	2040	2050	2030	2040	2050
Annual level (Gt CO ₂ /yr)	1.2	1.4	1.6	1.7	1	0.8	0.6
Reduction vs. today	NA	19%	35%	38%	-21%	-35%	-54%

● Latin America & Caribbean

Where we are heading
**Planned Energy
Scenario 2016 - 2050**
(PES)

Where we need to be
**Transforming Energy
Scenario 2016-2050**
(TES)

Energy system investments (average annual, 2016-50) USD billion/year

	Where we are heading Planned Energy Scenario 2016 - 2050 (PES)	Where we need to be Transforming Energy Scenario 2016-2050 (TES)
Power	39	45
– Renewable	21	28
– Non-renewable	5	3
– Power grids and system flexibility	13	15
Industry (RE + EE)	7	11
Transport (electrification + EE)	10	19
Buildings (RE + EE)	29	42
Biofuel supply	2.4	2.5
Renewable hydrogen – electrolyzers	0.03	0.5



Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019c; 2019d) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050

● Latin America & Caribbean

2019e 2030 2050

	2019e	2030	2050
Population (thousands) region-wide	474 076	505 546	535 802

**GDP (USD 2015)**

	2019e	2030	2050
GDP (million): PES	3 679 104	5 158 950	13 240 587
GDP (million): TES	3 700 954	5 194 779	13 563 681
GDP changes (million): TES vs. PES	21 850	35 828	323 093
GDP changes (%): TES vs. PES	0.6	0.7	2.4
Per capita GDP (thousand): PES	7.8	10.2	24.7
Per capita GDP (thousand): TES	7.8	10.3	25.3

Employment**Economy-wide employment (thousands)**

	2019e	2030	2050
Employment: PES	272 097	282 324	251 102
Employment: TES	272 239	281 399	250 700
Employment changes: TES vs. PES	143	-925	-402
Employment changes (%): TES vs. PES	0.05	-0.33	-0.16



● Latin America & Caribbean

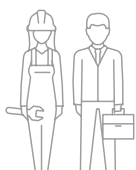


Energy sector jobs (thousands)

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Nuclear power	8	12	8	10	6
Fossil fuels	1180	1104	953	962	700
Renewables	2 027	2 575	2 585	3 295	3 212
Energy efficiency	887	870	735	1211	818
Power grids and energy flexibility	364	466	403	463	455
Total	4 467	5 026	4 685	5 941	5 190
Energy jobs in economy-wide employment (%)		1.80%	1.90%	2.10%	2.10%

Renewable energy jobs (thousands)

Bioenergy	1 620	1 971	1 875	2 331	2 133
Solar	64	173	301	474	570
Hydropower	300	320	264	351	306
Wind	42	109	143	136	199
Geothermal	1	2	2	2	4
Ocean	0	0	0	0	0
Total	2 027	2 575	2 585	3 295	3 212
Renewable energy jobs in energy-sector employment (%)		51.2%	55.2%	55.5%	61.9%



Job differential in 2050 (thousands) TES vs. PES

Economy-wide	-402
Changes in conventional energy (A)	-255
Changes in transition related technologies (B)	761
Net jobs (A+B)	506


Jobs in 2050: TES / ● Latin America & Caribbean

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	276	Construction & installation	372	Workers and technicians	631
Solar water heaters (SWH)	293	Manufacturing	225	Experts	64
Onshore wind	195	Operation and maintenance	174	Engineers and higher degrees	52
Offshore wind	5	Biofuel supply	-	Marketing and administrative	25
Geothermal	4				
Total	771		771		771

**Welfare improvement (%):
TES vs. PES**

Indicator	2030		2050	
Economic		-0.1		0.2
Social		2.8		10.0
Environmental		2.2		4.6
Total		5.0		14.8


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- World Bank Group (2019b), *Access to clean fuels and technologies for cooking (% of population)*, World Bank Group.

ENERGY TRANSFORMATION

MIDDLE EAST AND NORTH AFRICA

STATUS/CHARACTERISTICS AND NEEDS:

Regional analysis covers major oil and gas exporters as well as net importers, spanning the Gulf States, other parts of the Middle East, and North Africa.

Middle East:

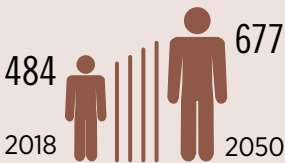
- Bahrain
- Iran (Islamic Republic of)
- Iraq
- Israel
- Jordan
- Kuwait
- Lebanon

- Oman
- Qatar
- Saudi Arabia
- State of Palestine
- Syrian Arab Republic
- United Arab Emirates
- Yemen

North Africa:

- Algeria
- Egypt
- Libya
- Morocco
- Tunisia
- Western Sahara
- Djibouti

Population (millions)



Current:

6% of global population, highest regional share in Egypt (22%), Iran (18%) and Algeria (9.4%).

2050 outlook:

Average **1.1% per year increase** to **677 million**, or 7% of global population.

IRENA analysis based on E3ME.

GDP per capita (thousand USD 2015)



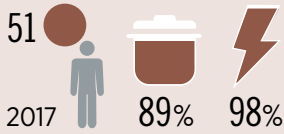
Current:

Below the global average (10.9).

2050 outlook:

Adequate development;
 ▶ **PES: CAGR = 3%**

IRENA analysis based on E3ME.

Energy consumption
(GJ/capita) and
energy access (%)**Energy consumption**
per capita:

Current: in line with global average
(51 GJ/year).

2050 outlook:
▶ **PES:** Slight increase to 62 GJ/year.

Electricity access:

Countries reached high electrification (close to 100%).

Clean cooking access:

Rural areas depend on traditional energy sources or diesel generators.

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

Fossil fuel net import**Current status:**

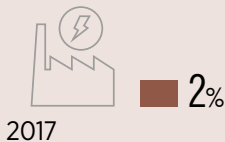
Region contributes to **37% of global oil production and 35% of global natural gas production**; with oil production dominated by Saudi Arabia (35%), Iran (14%) and Iraq (13%) and gas production dominated by Iran (28%), Qatar (22%) and Saudi Arabia (14%) (Tagliapietra, 2019).

2050 outlook:

Vast untapped renewable energy potential.

▶ **PES:** The total generation (est. 3477 TWh) just represents **5%** of overall renewable power potential.

Note: Current status, IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

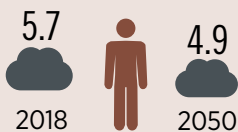
Energy-intensive industries (% in global consumption)**Current status:**

Only a tiny share (2%) comes from energy intensive industries of the region (mainly from the **chemical and petrochemical** sector).

2050 outlook:

Need for **alternative clean energy technological solutions and emission-capture measures.**

IRENA analysis based on 2017 values (IEA, 2019).

Energy-related CO₂ emissions per capita
(tCO₂/capita)**Recent:**

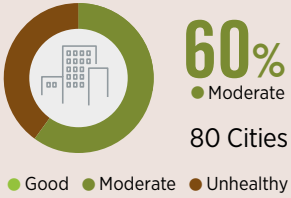
Region's annual emissions: 2.6 Gt (2018). 8% of global energy-related emissions.

2050 outlook:

▶ **PES: 27% increase to 3.2 Gt** with enabling policies.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



Air quality has **deteriorated dramatically** in recent decades. Few cities (3%) with more than 100 000 inhabitants in low- and middle-income MENA countries meet **WHO air quality guidelines** (2018).

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

Electricity prices and renewables costs

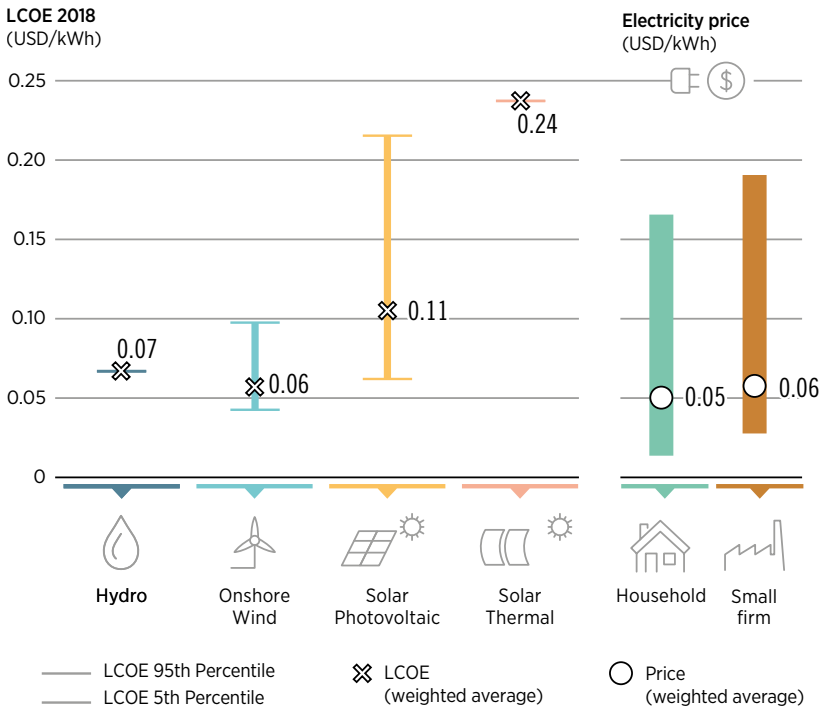
Electricity price:

The lowest compared to the other regions due to fossil-fuel subsidies.

Renewables cost and auctions:

In 2019, Morocco auctioned an advanced hybrid (CSP/PV) plant for a record-low peak-hour tariff of USD 0.071/kWh (IRENA, 2019a). United Arab Emirates contracted solar power at USD 0.299/kWh (IRENA, 2017).

Middle East and North Africa



LCOE based on IRENA (2019b) and electricity prices based on Global Petrol Prices (2019). Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

ENERGY TRANSFORMATION: KEY BENEFITS

1

REDUCED EMISSIONS AND LOCAL AIR POLLUTION

- ▶ Lower CO₂ emissions
- ▶ Better local air quality
- ▶ Efficient energy services extended to rural areas



2

ENERGY SECURITY AND ECONOMIC SELF-RELIANCE

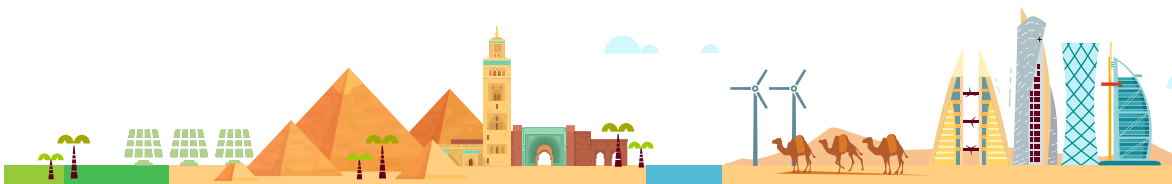
- ▶ Diversified energy supply
- ▶ Reduced import dependence (oil importers)
- ▶ Focus on high-value exports (oil exporters)
- ▶ Cross-border electricity trade



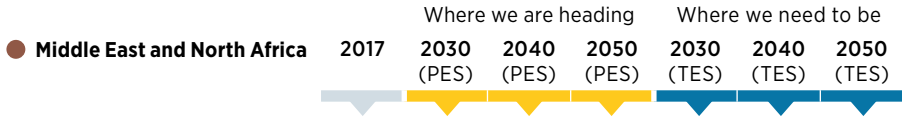
3

SUSTAINABLE DEVELOPMENT

- ▶ Diversified economy and sustainable economic activities
- ▶ Local job creation
- ▶ Improved welfare



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	40	52	60	62	40	35	29
Consumption (TFEC)	23	33	39	41	25	24	20

Renewables shares (modern)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	1%	4%	6%	7%	9%	16%	26%
Consumption (TFEC)	1%	4%	4%	5%	8%	15%	26%
Power generation	3%	14%	17%	20%	27%	39%	53%



Electricity share in final energy consumption	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
End-use consumption	19%	16%	18%	20%	20%	27%	38%
Industry	12%	8%	8%	9%	12%	15%	20%
Transport	0.1%	0.3%	1%	2%	2%	7%	16%
Buildings	43%	44%	46%	50%	48%	59%	77%

Renewable installed capacity (GW)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Bioenergy	0	2	2	3	2	3	3
Hydropower	20	18	21	23	20	23	26
Solar PV	2	53	71	85	66	108	147
Wind	2	51	100	138	76	158	212



Biofuels	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Liquid biofuels (billions of litres per year)	NA	3	3	4	4	5	6

Energy consumption per capita (GJ/capita)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Consumption (TFEC) per capita	51	62	65	62	47	40	30



CO ₂ emissions (energy-related)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Annual level (Gt CO ₂ /yr)	2.5	2.9	3.2	3.2	2	1.6	1.1
Reduction vs. today	NA	16%	29%	30%	-20%	-34%	-56%



● Middle East and North Africa

Where we are heading
**Planned Energy
Scenario 2016 - 2050**
(PES)

Where we need to be
**Transforming Energy
Scenario 2016-2050**
(TES)

Energy system investments (average annual, 2016-50) USD billion/year		
Power	55	53
– Renewable	9	16
– Non-renewable	22	14
– Power grids and system flexibility	24	23
Industry (RE + EE)	8	11
Transport (electrification + EE)	11	15
Buildings (RE + EE)	52	76
Biofuel supply	1.1	3
Renewable hydrogen – electrolyzers	0.3	2.8

Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019c; 2019d) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050

● Middle East and North Africa

	2019e	2030	2050
Population (thousands) region-wide	491 460	567 708	677 439
GDP (USD 2015)			
GDP (million): PES	4 516 464	7 372 988	15 494 435
GDP (million): TES	4 580 811	7 358 619	15 112 505
GDP changes (million): TES vs. PES	64 347	-14 368	-381 930
GDP changes (%): TES vs. PES	1.4	-0.2	-2.5
Per capita GDP (thousand): PES	9.2	13.0	22.9
Per capita GDP (thousand): TES	9.3	13.0	22.3
Employment			
Economy-wide employment (thousands)			
Employment: PES	175 696	187 016	186 184
Employment: TES	175 742	186 825	185 801
Employment changes: TES vs. PES	46	-191	-382
Employment changes (%): TES vs. PES	0.03%	-0.10%	-0.21%

● Middle East and North Africa



	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Energy sector jobs (thousands)					
Nuclear power	15	56	70	55	42
Fossil fuels	2 815	3 693	3 379	3 257	2 625
Renewables	542	789	895	1 226	2 064
Energy efficiency	1 113	1 809	1 328	2 731	1 537
Power grids and energy flexibility	622	927	885	900	1 014
Total	5 108	7 274	6 557	8 168	7 283
Energy jobs in economy-wide employment (%)		3.9%	3.5%	4.4%	3.9%

Renewable energy jobs (thousands)					
Bioenergy	196	290	282	584	846
Solar	88	180	265	283	703
Hydropower	250	262	250	266	239
Wind	7	55	93	90	273
Geothermal	1	2	4	3	4
Ocean	0	0	0	0	0
Total	542	789	895	1 226	2 064
Renewable energy jobs in energy-sector employment (%)		10.8%	13.6%	15.0%	28.3%

Job differential in 2050 (thousands) TES vs. PES	
Economy-wide	-382
Changes in conventional energy (A)	-782
Changes in transition related technologies (B)	1 507
Net jobs (A+B)	726

► Jobs in 2050: TES / ● Middle East and North Africa

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	343	Construction & installation	559	Workers and technicians	774
Solar water heaters (SWH)	332	Manufacturing	153	Experts	80
Onshore wind	273	Operation and maintenance	240	Engineers and higher degrees	76
Offshore wind	0	Biofuel supply	-	Marketing and administrative	22
Geothermal	4				
Total	952		952		952

Welfare improvement (%):
TES vs. PES

Indicator	2030		2050	
Economic	0.0		0.0	
Social	4.3		7.7	
Environmental	1.9		4.6	
Total	6.2		12.3	



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- Deng, Y., Haigh, M., Pouwels, W., Ramaekers, L., Brandsma, R., Schimschar, S., Grözinger, J. & de Jager, D. (2015), *Quantifying a realistic, worldwide wind and solar electricity supply*, Global Environmental Change 31, 239-52, <https://doi.org/10.1016/j.gloenvcha.2015.01.005>.
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ENERGY TRANSFORMATION

NORTH AMERICA

Regional analysis covers three countries:

- Canada
- Mexico
- United States

STATUS/CHARACTERISTICS AND NEEDS:

Population (millions)



Current: **6.5% of global population**, mainly in the United States (67%), Mexico (26%) and Canada (7%).

2050 outlook: Average **0.6% per year increase** to **591 million**, or 6.3% of global population.

IRENA analysis based on E3ME.

GDP per capita (thousand USD 2015)



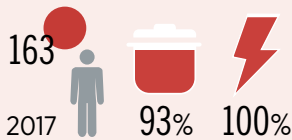
Current: **Well above the global average** (10.9).

2050 outlook: **Slight development;** **▶ PES: CAGR = 1.6%**

IRENA analysis based on E3ME.



Energy consumption (GJ/capita) and energy access (%)



Energy consumption per capita:

Current: well above the global average (51 GJ/year).

2050 outlook:
▶ **PES** slight decrease to 161 GJ/year.

Electricity access:

Achieved in all the countries.

Clean cooking access:

Near 100% except in Mexico (93%).

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

Fossil fuel net import



Current status:

Largely self-sufficient; US, while still a net importer of crude oil, exports refined oil products and natural gas; Canada and Mexico have significant oil and gas reserves.

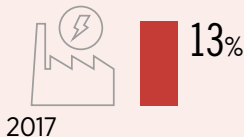
2050 outlook:

Continued negative health effects due to rising fossil fuel use; considerable untapped renewable potential.

▶ **PES:** The total generation (est. 7071 TWh) represents **13%** of overall renewable power potential.

Note: Current status, IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

Energy-intensive industries (% in global consumption)



Current status:

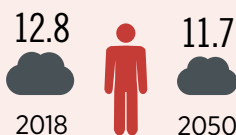
Over one-third of global **paper** energy demand is found in the region, as well as **around one-fifth** of global **chemical and petrochemical** and **food and tobacco** energy consumption.

2050 outlook:

Urgent need for emissions reduction in heavy industries.

IRENA analysis based on 2017 values (IEA, 2019).

Energy-related CO₂ emissions per capita (tCO₂/capita)



Recent:

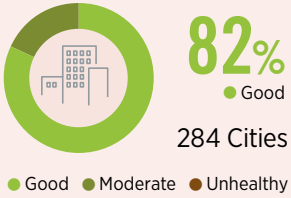
Region's annual emissions: 6.3 Gt (2018). 19% of global energy-related CO₂ emissions.

2050 outlook:

- ▶ **PES: 8% increase to 6.8 Gt** based on current policies.
- More renewables and continuing switch from coal to natural gas mitigate increase.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



- **80% urban population**, often concentrated in large cities.
- Air pollution **at moderate to unhealthy** levels in **18% of cities** mainly due to transport sector emissions.

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

Electricity prices and renewables costs

Electricity price:

Above the global average for both households and industries.

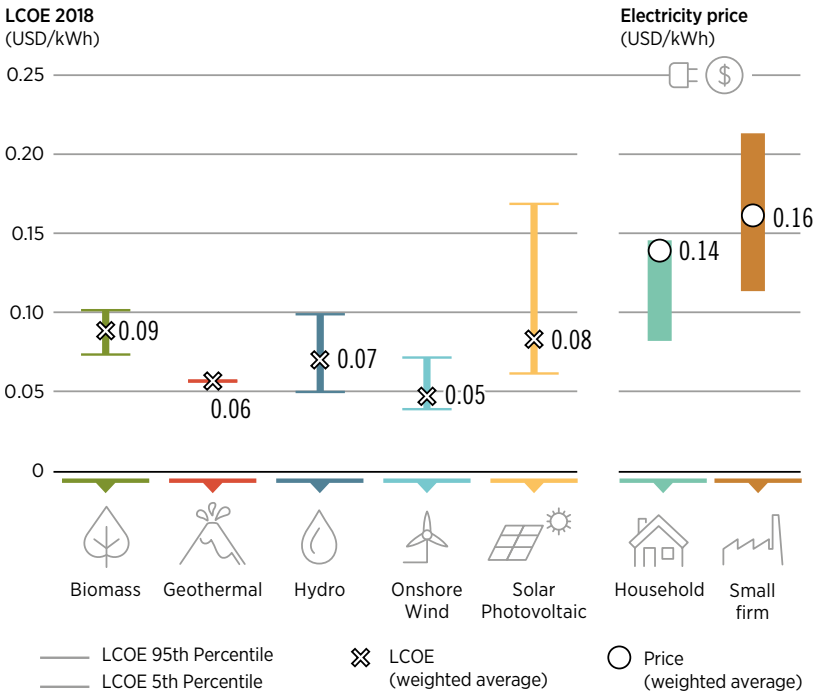
Renewable power costs:

Competitive or least-cost compared to coal or natural gas, with solar PV averaging USD 0.08 cents/kWh and wind USD 0.05/kWh (2018).

Auction prices:

Lower than other regions; new solar projects achieve around USD 0.02-0.03/kWh, and new wind projects around USD 0.03-0.04/kWh.

North America



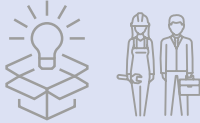
LCOE based on IRENA (2019a) and electricity prices based on Global Petrol Prices (2019).
 Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

ENERGY TRANSFORMATION: KEY BENEFITS

1

CUTTING-EDGE INNOVATION

- ▶ Advanced manufacturing and services
- ▶ Reduced energy system costs
- ▶ High-value job creation



2

ENERGY SECURITY

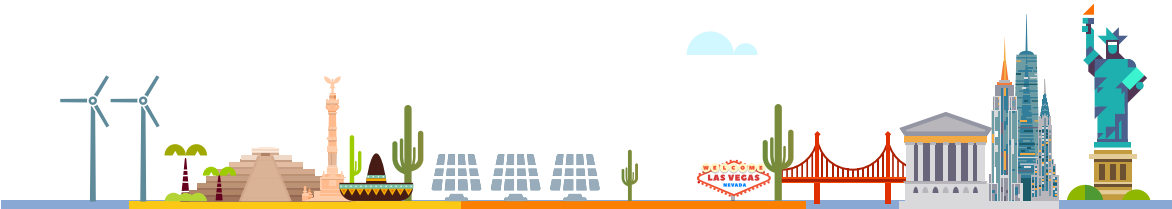
- ▶ Regional energy self-sufficiency
- ▶ High energy efficiency
- ▶ Renewable power and end-use applications
- ▶ Improved interconnections



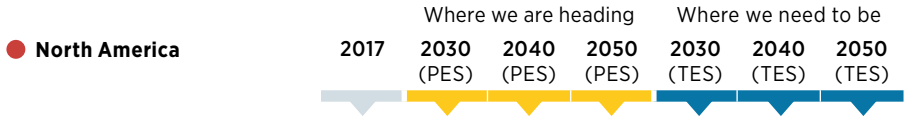
3

SOCIO-ECONOMIC DEVELOPMENT

- ▶ Economic growth
- ▶ Higher economy-wide and energy sector jobs
- ▶ Improved environment and well-being



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	112	116	120	127	87	82	77
Consumption (TFEC)	79	86	89	93	69	64	58

Renewables shares (modern)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	10%	13%	14%	17%	30%	50%	67%
Consumption (TFEC)	10%	12%	13%	15%	29%	48%	68%
Power generation	23%	30%	33%	38%	60%	79%	85%



Electricity share in final energy consumption	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
End-use consumption	20%	21%	21%	22%	28%	40%	52%
Industry	20%	19%	19%	19%	20%	25%	28%
Transport	0.2%	1%	2%	2%	13%	35%	57%
Buildings	48%	48%	49%	50%	54%	63%	78%

Renewable installed capacity (GW)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Bioenergy	16	19	18	30	22	26	25
Hydropower	177	182	198	238	180	192	204
Solar PV	45	153	296	512	485	1054	1728
Wind	104	174	189	191	448	946	1314



Biofuels	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Liquid biofuels (billions of litres per year)	64	63	62	70	96	144	183

Energy consumption per capita (GJ/capita)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Consumption (TFEC) per capita	163	163	159	161	130	114	101



CO ₂ emissions (energy-related)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Annual level (Gt CO ₂ /yr)	6.2	6.6	6.7	6.8	3.7	2.5	1.4
Reduction vs. today	NA	7%	8%	10%	-41%	-59%	-77%



● North America	Where we are heading	Where we need to be
	Planned Energy Scenario 2016 - 2050 (PES)	Transforming Energy Scenario 2016-2050 (TES)
Energy system investments (average annual, 2016-50) USD billion/year		
Power	117	195
- Renewable	31	108
- Non-renewable	45	22
- Power grids and system flexibility	41	65
Industry (RE + EE)	18	27
Transport (electrification + EE)	29	97
Buildings (RE + EE)	118	177
Biofuel supply	0.5	5.9
Renewable hydrogen – electrolyzers	0.05	2.1

Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019b; 2019c) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050

● North America	2019e	2030	2050
Population (thousands) region-wide	496 175	536 927	590 667
GDP (USD 2015)			
GDP (million): PES	21 913 288	27 877 680	42 199 950
GDP (million): TES	22 188 303	28 117 917	42 814 939
GDP changes (million): TES vs. PES	275 016	240 237	614 990
GDP changes (%): TES vs. PES	1.3	0.9	1.5
Per capita GDP (thousand): PES	44.2	51.9	71.4
Per capita GDP (thousand): TES	44.7	52.4	72.5
Employment			
Economy-wide employment (thousands)			
Employment: PES	250 014	279 310	288 609
Employment: TES	251 639	281 435	291 621
Employment changes: TES vs. PES	1 625	2 125	3 012
Employment changes (%): TES vs. PES	0.05	-0.33	-0.16



● North America



	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Energy sector jobs (thousands)					
Nuclear power	60	69	53	71	18
Fossil fuels	1126	1380	1318	1053	816
Renewables	992	1197	1367	2335	2987
Energy efficiency	733	3945	3363	6058	3805
Power grids and energy flexibility	375	572	510	656	837
Total	3 285	7 163	6 610	10 174	8 463
Energy jobs in economy-wide employment (%)		2.56%	2.29%	3.61%	2.90%

Renewable energy jobs (thousands)					
Bioenergy	449	431	422	625	764
Solar	269	390	601	1137	1520
Hydropower	97	127	121	135	125
Wind	134	202	174	386	512
Geothermal	43	47	49	52	61
Ocean	-	-	-	0	5
Total	992	1197	1367	2335	2987
Renewable energy jobs in energy-sector employment (%)		16.7%	20.7%	23.0%	35.3%

Job differential in 2050 (thousands) TES vs. PES	
Economy-wide	3 012
Changes in conventional energy (A)	-537
Changes in transition related technologies (B)	2 390
Net jobs (A+B)	1853

▶ Jobs in 2050: TES / ● North America

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	991	Construction & installation	915	Workers and technicians	1639
Solar water heaters (SWH)	516	Manufacturing	561	Experts	199
Onshore wind	462	Operation and maintenance	604	Engineers and higher degrees	174
Offshore wind	49	Biofuel supply	-	Marketing and administrative	67
Geothermal	61				
Total	2 079		2 079		2 079

Welfare improvement (%):
TES vs. PES

Indicator	2030		2050	
	Value	Value	Value	Value
Economic	0.3		0.6	
Social	4.0		8.4	
Environmental	3.3		6.5	
Total	7.7		15.5	



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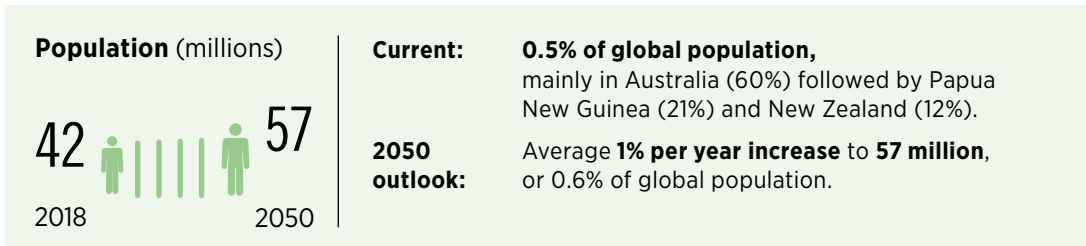
World Bank Group (2019b), *Access to clean fuels and technologies for cooking (% of population)*, World Bank Group.

ENERGY TRANSFORMATION OCEANIA

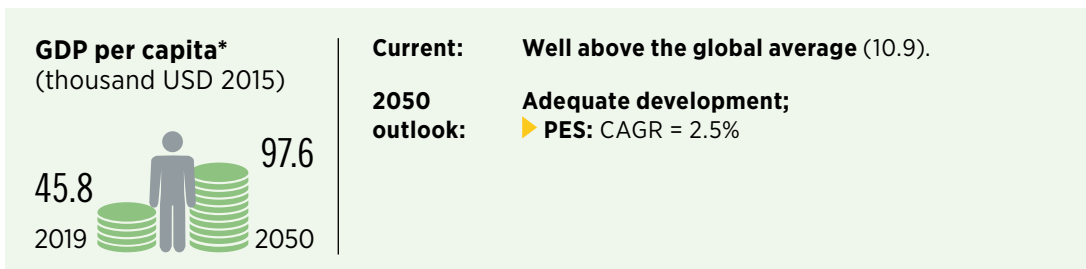
Regional analysis covers countries and territories between the Indian, Pacific and Southern Oceans.:

- Australia
- Christmas Island
- Cocos (Keeling) Islands
- Fiji
- Heard Island and McDonald Islands
- The Federated States of Micronesia
- New Caledonia
- New Zealand
- Norfolk Island
- Papua New Guinea
- French Polynesia
- Solomon Islands
- Vanuatu

STATUS/CHARACTERISTICS AND NEEDS:

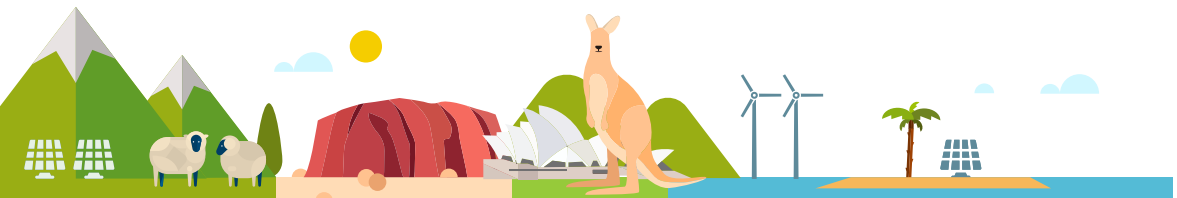


Source: UNSD (2019).

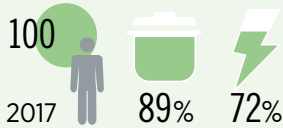


IRENA analysis based on E3ME.

*Due to data gaps, the economic analysis only includes Australia and New Zealand.



Energy consumption (GJ/capita) and energy access (%)



Energy consumption per capita:

Current: well above global average (51 GJ/year).

2050 outlook:

► **PES:** high increase to 134 GJ/year.

Electricity access:

Only 54.4% in Papua New Guinea.

Clean cooking access:

Less than 13% in Kiribati.

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

Fossil fuel net import



Current status:

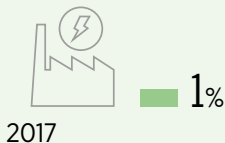
Region produces 3.6% of global fossil fuels, with Australia as leading coal and Liquefied Natural Gas (LNG) exporter; New Zealand's coal mines are closing; small island states import diesel for power generation.

2050 outlook:

Enormous untapped renewable energy potential.
► **PES:** The total generation (est. 477 TWh) just represents **1%** of overall renewable power potential.

Note: Current status, IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

Energy-intensive industries (% in global consumption)



Current status:

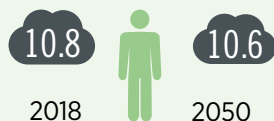
Concentrated mainly in Australia and New Zealand. At regional level, highest demand for **non-ferrous metal** and **food and tobacco industries**.

2050 outlook:

Need for **alternative emission-free technological solutions**.

IRENA analysis based on 2017 values (IEA, 2019).

Energy-related CO₂ emissions per capita (tCO₂/capita)



Recent:

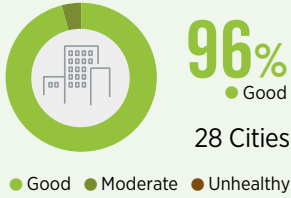
Region's annual emissions: 0.45 Gt (2018). 1% of global energy-related emissions.

2050 outlook:

► **PES: 36% increase to 0.61 Gt** with enabling policies.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



Mainly due to **city transport**; Light-vehicle sales set to grow with population; Ambitious plans promise to ramp up use of **electric vehicles** in New Zealand (IEA, 2017).

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

Electricity prices and renewables costs

Electricity price:

The highest values for industries and the second-highest for households compared to the other regions.

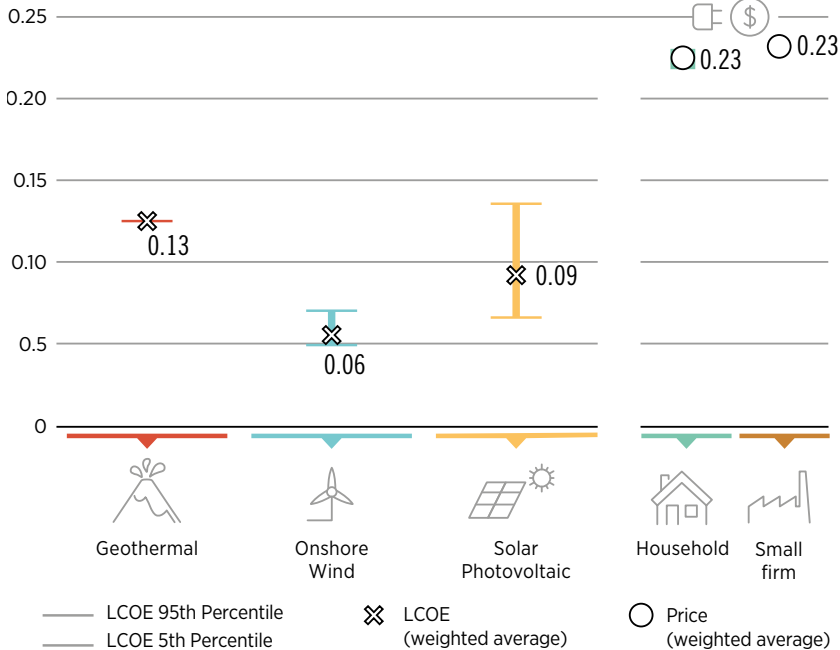
Renewables cost and auctions:

In 2017, an auction for concentrated solar power (CSP) was held in the state of South Australia and 150 MW was awarded at a price of USD 0.061/kWh (IRENA, 2019a).

Oceania

LCOE 2018 (USD/kWh)

Electricity price (USD/kWh)



Source: LCOE based on IRENA (2019b) and electricity prices based on Global Petrol Prices (2019).
 Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world. Small firm electricity price analysis is based only on Australia values.

ENERGY TRANSFORMATION: KEY BENEFITS

AFFORDABILITY AND SUSTAINABILITY

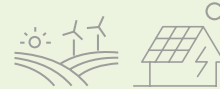
- ▶ Diversified clean energy mix
- ▶ Lower CO₂ emissions
- ▶ Lower prices
- ▶ Greater competition



2

ENERGY INDEPENDENCE AND ACCESS

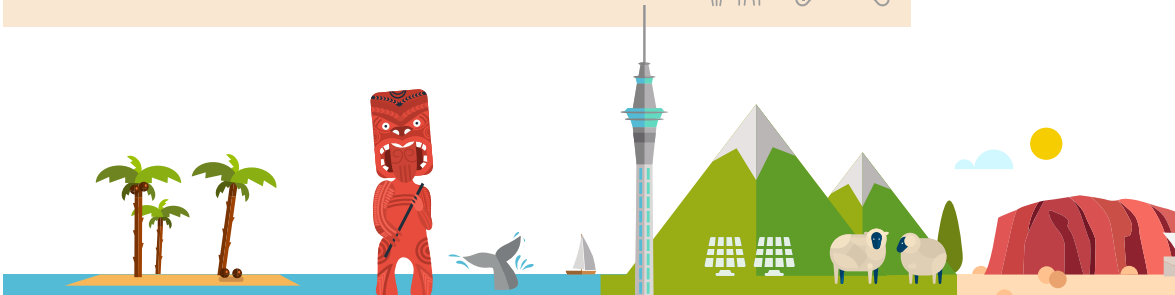
- ▶ Increased renewable energy use
- ▶ Effective power generation
- ▶ Improved energy security
- ▶ Sustainable power to rural/remote areas



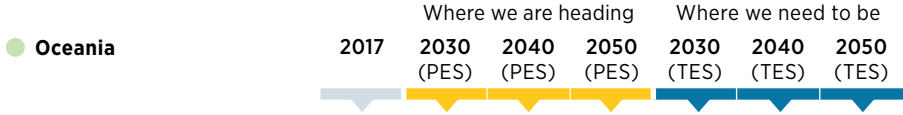
3

SOCIO-ECONOMIC DEVELOPMENT

- ▶ Job creation
- ▶ Improved education and skills development
- ▶ Reduced respiratory disease and improved health



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)

	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	7	10	11	12	10	6	10
Consumption (TFEC)	4	6	7	8	6	6	5

Renewables shares (modern)

Supply (TPES)	10%	22%	27%	34%	39%	71%	85%
Consumption (TFEC)	11%	14%	15%	18%	26%	58%	75%
Power generation	25%	45%	51%	61%	66%	92%	93%



Electricity share in final energy consumption

End-use consumption	23%	20%	19%	20%	22%	32%	45%
Industry	27%	19%	18%	18%	20%	48%	67%
Transport	1%	1%	1%	1%	6%	13%	31%
Buildings	57%	60%	60%	61%	64%	36%	34%

Renewable installed capacity (GW)

Bioenergy	1	1	1	2	3	2	3
Hydropower	13	17	14	14	21	20	22
Solar PV	6	11	17	27	27	84	109
Wind	6	11	18	26	25	46	65



Biofuels

Liquid biofuels (billions of litres per year)	0.2	0.5	1	1	3	3	3
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Energy consumption per capita (GJ/capita)

Consumption (TFEC) per capita	100	133	135	134	117	104	91
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CO₂ emissions (energy-related)

Annual level (Gt CO ₂ /yr)	0.4	0.6	0.6	0.6	0.4	0.2	0.1
Reduction vs. today	NA	32%	38%	37%	-8%	-54%	-73%



● Oceania

Where we are heading
**Planned Energy
Scenario 2016 - 2050**
(PES)

Where we need to be
**Transforming Energy
Scenario 2016-2050**
(TES)

**Energy system investments (average annual, 2016-50) USD billion/year**

	Planned Energy Scenario 2016 - 2050 (PES)	Transforming Energy Scenario 2016-2050 (TES)
Power	7	16
– Renewable	3	10
– Non-renewable	1	1
– Power grids and system flexibility	2	4
Industry (RE + EE)	2	3
Transport (electrification + EE)	2	5
Buildings (RE + EE)	6	11
Biofuel supply	0.1	0.3
Renewable hydrogen – electrolyzers	0	1.1

Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019c; 2019d) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050*

● Oceania

2019e 2030 2050

	2019e	2030	2050
Population (thousands) region-wide	29 739	32 982	37 063
GDP (USD 2015)			
GDP (million): PES	1 361 509	1 935 173	3 618 538
GDP (million): TES	1 311 801	1 936 844	3 595 574
GDP changes (million): TES vs. PES	-49 708	1 671	-22 964
GDP changes (%): TES vs. PES	-3.7	0.1	-0.6
Per capita GDP (thousand): PES	45.8	58.7	97.6
Per capita GDP (thousand): TES	44.1	58.7	97.0

**Employment****Economy-wide employment (thousands)**

	2019e	2030	2050
Employment: PES	16 479	18 955	19 816
Employment: TES	16 471	19 020	19 923
Employment changes: TES vs. PES	-8	65	107
Employment changes (%): TES vs. PES	-0.05%	0.34%	0.54%



* Due to data gaps, only Australia and New Zealand are considered for the socio-economic analysis.

● Oceania



Energy sector jobs (thousands)

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Nuclear power	-	-	-	-	-
Fossil fuels	215	266	227	240	193
Renewables	37	54	61	116	293
Energy efficiency	3	52	56	97	62
Power grids and energy flexibility	53	60	54	66	78
Total	307	432	398	519	626
Energy jobs in economy-wide employment (%)		2.3%	2.0%	2.7%	3.1%

Renewable energy jobs (thousands)

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Bioenergy	19	24	22	42	56
Solar	8	14	30	54	216
Hydropower	8	9	2	9	3
Wind	1	4	5	9	12
Geothermal	1	3	1	3	5
Ocean	-	-	-	0	1
Total	37	54	61	116	293
Renewable energy jobs in energy-sector employment (%)		12.5%	15.3%	22.4%	46.8%

Job differential in 2050 (thousands) TES vs. PES

Economy-wide	107
Changes in conventional energy (A)	-34
Changes in transition related technologies (B)	262
Net energy sector jobs (A+B)	228

► Jobs in 2050: TES / ● Oceania

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	52	Construction & installation	134	Workers and technicians	203
Solar water heaters (SWH)	159	Manufacturing	27	Experts	11
Onshore wind	11	Operation and maintenance	67	Engineers and higher degrees	9
Offshore wind	0	Biofuel supply	-	Marketing and administrative	4
Geothermal	5				
Total	227		227		227

Welfare improvement (%):
TES vs. PES

Indicator	2030		2050	
	Value	Value	Value	Value
Economic	0.0	0.0	0.0	0.0
Social	5.0	5.0	12.3	12.3
Environmental	2.2	2.2	5.0	5.0
Total	7.2	7.2	17.3	17.3



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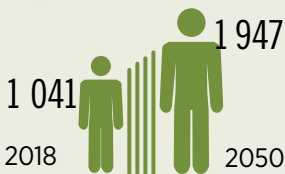
ENERGY TRANSFORMATION

SUB-SAHARAN AFRICA

Regional analysis extends from the Sahel region to the continent's southernmost tip, in addition to associated island countries.

STATUS/CHARACTERISTICS AND NEEDS:

Population (millions)



Current: 14% of global population (end-2018), Highest regional shares in Nigeria (18%) and Ethiopia (10%).

2050 outlook: Average 2% per year increase to 1 947 million, or 21% of global population.

IRENA analysis based on E3ME.

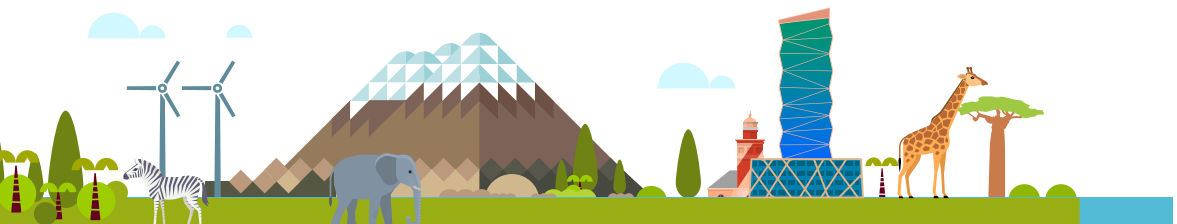
GDP per capita (thousand USD 2015)



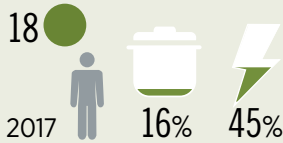
Current: Well below the global average (10.9).

2050 outlook: Swift development; **PES:** CAGR = 3.2%

IRENA analysis based on E3ME.



Energy consumption (GJ/capita) and energy access (%)



Energy consumption per capita:

Current: well below global average (51 GJ/year).

2050 outlook:

▶ **PES:** high decrease to 6 GJ/year.

Electricity access:

Lowest in the world, with two-thirds of region's population lacking access.

Expansion doubling annually since 2000, with about 18 million people now gaining access each year.

Clean cooking access:

Growing numbers of people without access, resulting in substantial degradation of forests and indoor air pollution.

Source: Access to electricity, 2017 values (World Bank Group, 2019a), access to clean cooking, 2016 values (World Bank Group, 2019b), TFEC, 2017 values (IEA, 2019).

Fossil fuel net import



Current status:

Holds over half the oil and gas reserves of the African continent. Bioenergy dominates the primary energy mix, accounting for 60% of primary energy demand but the share of energy supply from modern renewables is only about 10%.

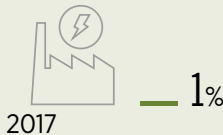
2050 outlook:

Rising air pollution and resource challenges; Vast untapped renewable energy potential.

▶ **PES:** The total generation (est. 975 TWh) just represents **1%** of overall renewable power potential.

Note: Current status, IRENA analysis based on proportion of net imports of fossil fuels in TPES, 2017 values (IEA, 2019). 2050 outlook, IRENA analysis and potential based on Deng *et al.* (2015).

Energy-intensive industries (% in global consumption)



Current status:

Only a tiny share (1%) of global consumption comes from the region's energy intensive industries.

2050 outlook:

With accelerated demand growth, low carbon technologies will play a key role.

IRENA analysis based on 2017 values (IEA, 2019).

Energy-related CO₂ emissions per capita (tCO₂/capita)



Recent:

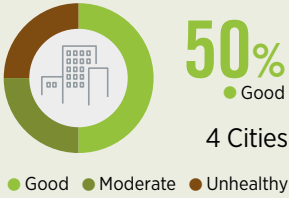
Region's annual emissions: 0.8 Gt (2018). 2% of global energy-related CO₂ emissions.

2050 outlook:

▶ **PES: 23% increase to 0.97 Gt** based on current policies.

Note: 2050 values based on IRENA analysis and historical data based on Global Carbon Atlas (2019).

Urban air quality (%)



Deteriorating urban air quality, with some cities having fine particle pollution (PM 2.5) among highest in world (dataset limited to 4 cities). **Indoor biomass combustion causes thousands of premature deaths each year.**

IRENA analysis based on PM 2.5 concentration, 2016 and 2017 values (WHO, 2019).

Electricity prices and renewables costs

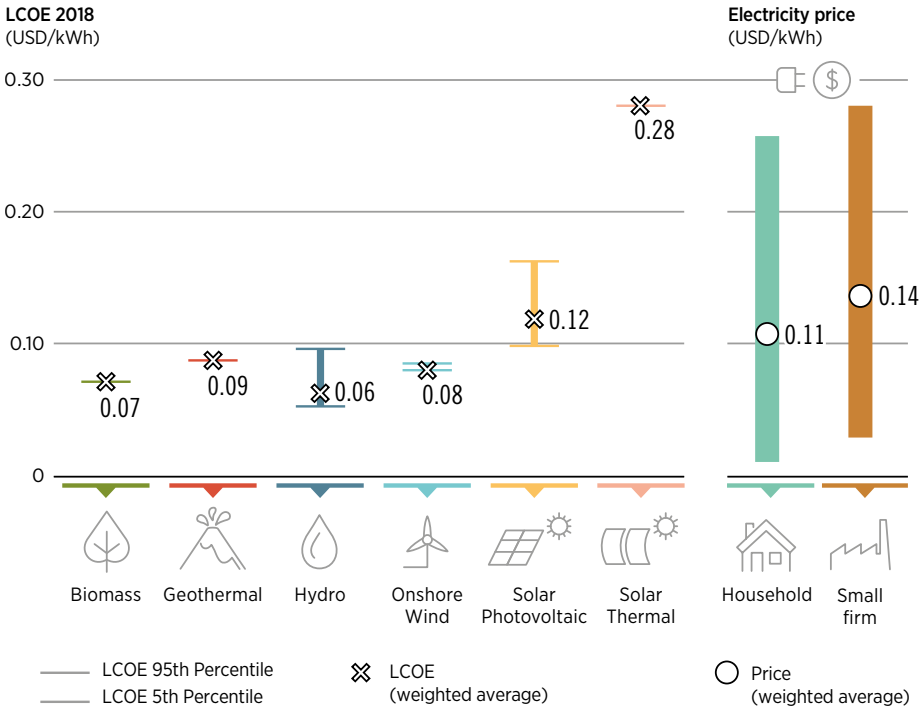
Electricity price:

Lower range for households and **mid-range** for industries (compared to other regions). The prices are very high compared to the average income.

Renewable cost and auctions:

Decentralised mini-grid systems attractive to reach rural/remote populations.

Sub-Saharan Africa



LCOE based on IRENA (2019a) and electricity prices based on Global Petrol Prices (2019). Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

ENERGY TRANSFORMATION: KEY BENEFITS

1

SOCIAL AND ECONOMIC PROGRESS

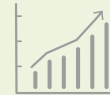
- ▶ Economic growth leading to poverty alleviation
- ▶ Distributed power for isolated communities and local job creation
- ▶ Transformative health and education impacts



2

INVESTMENTS TO BOOST ENERGY SECURITY

- ▶ Reduced network losses, improved financial performance
- ▶ Long-term finance for capital-intensive projects
- ▶ Robust regulatory frameworks



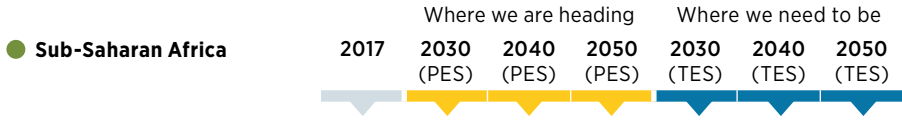
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CLEAN AIR, LOWER EMISSIONS

- ▶ Minimised reliance on traditional fuelwood
- ▶ Use of modern energy for productive uses
- ▶ Clean cooking and electricity access



ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	25	17	19	20	15	22	31
Consumption (TFEC)	18	12	13	13	9	17	26

Renewables shares (modern)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	7%	24%	29%	34%	43%	75%	89%
Consumption (TFEC)	8%	22%	26%	29%	42%	72%	86%
Power generation	26%	48%	53%	51%	67%	88%	95%



Electricity share in final energy consumption	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
End-use consumption	7%	16%	20%	23%	23%	33%	48%
Industry	26%	27%	28%	29%	31%	23%	29%
Transport	1%	1%	1%	1%	2%	23%	54%
Buildings	4%	26%	43%	58%	57%	78%	89%

Renewable installed capacity (GW)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Bioenergy	1	7	10	12	11	27	56
Hydropower	27	44	72	54	55	95	108
Solar PV	3	49	69	85	79	255	548
Wind	3	20	28	35	33	131	314



Biofuels	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Liquid biofuels (billions of litres per year)	0.04	8	10	12	13	17	21

Energy consumption per capita (GJ/capita)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Consumption (TFEC) per capita	18	8	7	6	6	9	12



CO ₂ emissions (energy-related)	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Annual level (Gt CO ₂ /yr)	0.8	0.8	1.0	1.0	0.6	0.5	0.3
Reduction vs. today	NA	6%	24%	26%	-24%	-35%	-60%

Note: The findings presented in the table are based on IRENA's REmap (Renewable Energy Roadmap) approach which is consistent with the Paris climate targets. In addition, IRENA has also been conducting in-depth power sector analysis and long-term planning on the African continent, using a capacity expansion modelling tool that IRENA developed for 47 African countries - the SPLAT model. For more details, please visit <https://irena.org/energytransition/Energy-Planning-Support/System-Planning-Test-Model>

● Sub-Saharan Africa

Where we are heading
**Planned Energy
Scenario 2016 - 2050**
(PES)

Where we need to be
**Transforming Energy
Scenario 2016-2050**
(TES)

Energy system investments (average annual, 2016-50) USD billion/year

	Planned Energy Scenario 2016 - 2050 (PES)	Transforming Energy Scenario 2016-2050 (TES)
Power	17	56
- Renewable	7	34
- Non-renewable	4	4
- Power grids and system flexibility	6	18
Industry (RE + EE)	2	10
Transport (electrification + EE)	3	20
Buildings (RE + EE)	13	19
Biofuel supply	1	3
Renewable hydrogen – electrolyzers	0.02	0.2



Note: RE = renewable energy; EE = energy efficiency

The findings in this report consider targets and developments as of April 2019. The wind and solar PV capacities in the Transforming Energy Scenario in 2030 in this report are slightly higher than the estimates presented in IRENA's reports (IRENA, 2019b; 2019c) which consider developments as of the third quarter of 2019.

SOCIO-ECONOMIC OUTLOOK TO 2050

● Sub-Saharan Africa

2019e 2030 2050

	2019e	2030	2050
Population (thousands) region-wide	1 065 761	1 352 421	1 947 326
GDP (USD 2015)			
GDP (million): PES	2 562 424	4 330 057	12 582 520
GDP (million): TES	2 572 269	4 354 122	12 673 559
GDP changes (million): TES vs. PES	9 846	24 065	91 039
GDP changes (%): TES vs. PES	0.4	0.6	0.7
Per capita GDP (thousand): PES	2.4	3.2	6.5
Per capita GDP (thousand): TES	2.4	3.2	6.5

**Employment****Economy-wide employment (thousands)**

	2019e	2030	2050
Employment: PES	280 021	307 757	337 215
Employment: TES	279 997	307 688	337 240
Employment changes: TES vs. PES	-23	-69	25
Employment changes (%): TES vs. PES	-0.01%	-0.02%	0.01%



● Sub-Saharan Africa

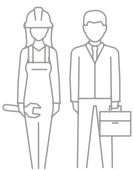


Energy sector jobs (thousands)

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Nuclear power	6	3	3	1	2
Fossil fuels	3 122	3 060	2 753	2 929	2 489
Renewables	306	442	519	859	2 023
Energy efficiency	506	758	801	1 217	1 016
Power grids and energy flexibility	313	462	502	462	694
Total	4 253	4 725	4 577	5 468	6 224
Energy jobs in economy-wide employment (%)		1.5%	1.4%	1.8%	1.8%

Renewable energy jobs (thousands)

	2017	2030 (PES)	2050 (PES)	2030 (TES)	2050 (TES)
Bioenergy	176	243	279	581	1 270
Solar	44	97	135	154	583
Hydropower	71	76	64	91	111
Wind	14	25	37	30	57
Geothermal	1	2	3	3	3
Ocean	0	0	0	0	0
Total	306	442	519	859	2 023
Renewable energy jobs in energy-sector employment (%)		9.4%	11.3%	15.7%	32.5%



Job differential in 2050 (thousands) TES vs. PES

Economy-wide	25
Changes in conventional energy (A)	-265
Changes in transition related technologies (B)	191
Net jobs (A+B)	1647



Jobs in 2050: TES / ● Sub-Saharan Africa

Technology jobs (thousands)		Segment value chain (thousands)		Occupational requirements (thousands)	
Solar PV	257	Construction & installation	380	Workers and technicians	532
Solar water heaters (SWH)	311	Manufacturing	95	Experts	44
Onshore wind	57	Operation and maintenance	153	Engineers and higher degrees	39
Offshore wind	0	Biofuel supply	-	Marketing and administrative	13
Geothermal	3				
Total	628		628		628

Welfare improvement (%): TES vs. PES

Indicator	2030		2050	
Economic		0.0		0.1
Social		4.2		9.2
Environmental		1.9		4.2
Total		6.2		13.5

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