

# ENERGY TRANSFORMATION

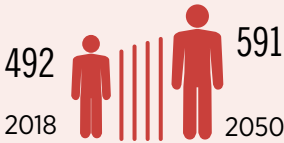
# NORTH AMERICA

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)



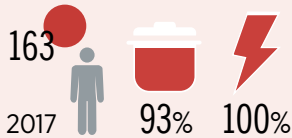
**Current:** **Well above the global average** (10.9).

**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).

### 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.

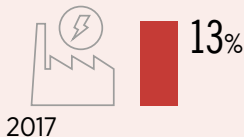
### 2050 outlook:

**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:

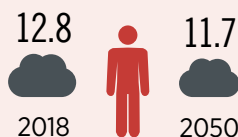
**Over one-third** of global **paper** energy demand is found in the region, as well as **around one-fifth** of global **chemical and petrochemical** and **food and tobacco** energy consumption.

### 2050 outlook:

**Urgent need for emissions reduction** in heavy industries.

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

### Energy-related CO<sub>2</sub> emissions per capita (tCO<sub>2</sub>/capita)



### Recent:

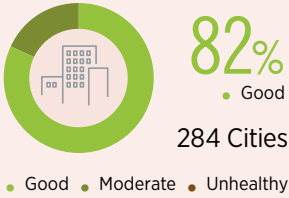
**Region's annual emissions: 6.3 Gt** (2018). 19% of global energy-related CO<sub>2</sub> emissions.

### 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.**

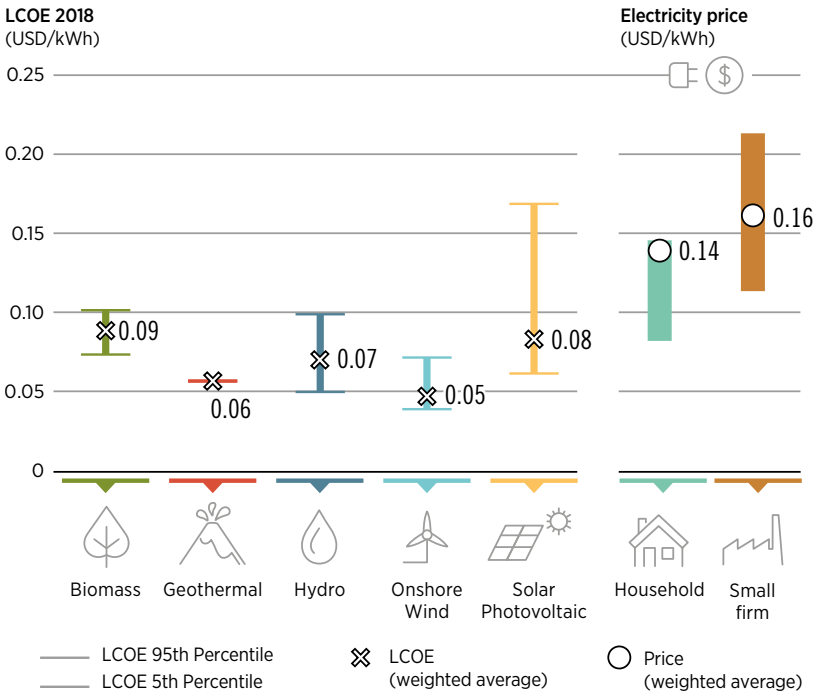
**Renewable power costs:**

**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**



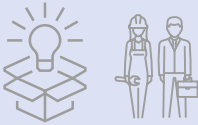
LCOE based on IRENA (2019a) and electricity prices based on Global Petrol Prices (2019). Note: The LCOE data is for projects commissioned in 2018. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world.

# ENERGY TRANSFORMATION: KEY BENEFITS

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## CUTTING-EDGE INNOVATION

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



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## ENERGY SECURITY

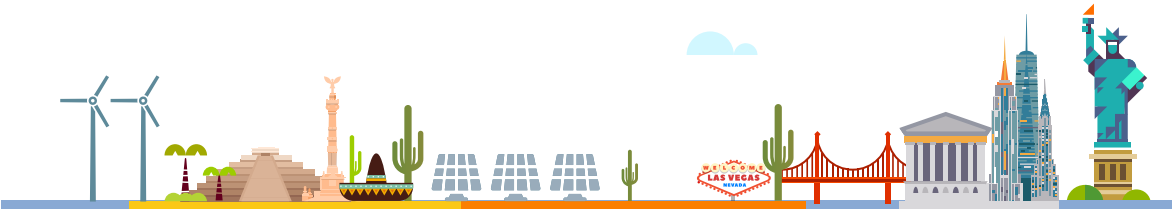
- ▶ Regional energy self-sufficiency
- ▶ High energy efficiency
- ▶ Renewable power and end-use applications
- ▶ Improved interconnections



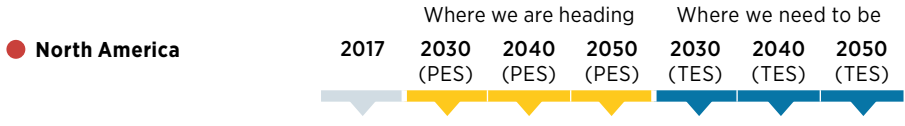
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## SOCIO-ECONOMIC DEVELOPMENT

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



## ENERGY TRANSFORMATION ROADMAP TO 2050



Energy (EJ)	2017	Where we are heading			Where we need to be		
		2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Supply (TPES)	112	116	120	127	90	86	82
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



CO <sub>2</sub> emissions (energy-related)							
	2017	2030 (PES)	2040 (PES)	2050 (PES)	2030 (TES)	2040 (TES)	2050 (TES)
Annual level (Gt CO <sub>2</sub> /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)
<b>Energy system investments (average annual, 2016-50) USD billion/year</b>		
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
<b>GDP (USD 2015)</b>			
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
<b>Employment</b>			
<b>Economy-wide employment (thousands)</b>			
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)
<b>Energy sector jobs (thousands)</b>					
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
<b>Total</b>	<b>3 285</b>	<b>7 163</b>	<b>6 610</b>	<b>10 174</b>	<b>8 463</b>
Energy jobs in economy-wide employment (%)		2.56%	2.29%	3.61%	2.90%

<b>Renewable energy jobs (thousands)</b>					
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
<b>Total</b>	<b>992</b>	<b>1197</b>	<b>1367</b>	<b>2335</b>	<b>2987</b>
Renewable energy jobs in energy-sector employment (%)		16.7%	20.7%	23.0%	35.3%

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

## ▶ 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				
<b>Total</b>	<b>2 079</b>		<b>2 079</b>		<b>2 079</b>

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	
<b>Total</b>	<b>7.7</b>		<b>15.5</b>	



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