ECE 333 – GREEN ELECTRIC ENERGY

1. Introduction and Overview

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THE GLOBAL ENERGY DEMAND

- We view the electric energy within the global energy context.

- We discuss the two key aspects of demand:
  - population growth
  - future demand growth

- We examine the energy supply picture and the impacts on greenhouse gases.
WORLD POPULATION

1990: 5.3 billion
2020: 7.8 billion
2030: 8.6 billion
2050: 9.8 billion
2100: 11.2 billion

Source: United Nations Department of Economic and Social Affairs, Population Division, World Population Prospects: The 2017 Revision
Produced by: United Nations Department of Public Information
DEMOGRAPHIC TRANSFORMATIONS

2020 – 7.79 billion

- Asia: 59%
- Africa: 17%
- Latin America & Caribbean: 10%
- Europe: 8%
- N-America: 5%
- Oceania: 1%

Source: UN, Population Division; http://esa.un.org/unpd/wpp/Excel-Data/population.htm

2060 – 10.18 billion

- Asia: 52%
- Africa: 28%
- Latin America & Caribbean: 7%
- Europe: 4%
- N-America: 1%
- Oceania: 8%

Source: UN, Population Division; http://esa.un.org/unpd/wpp/Excel-Data/population.htm
1980 – 2011 ENERGY DEMAND TRENDS

Source: EIA, 2010; data exclude biomass
GLOBAL ENERGY CONSUMPTION MIX: 1995 – 2020

GLOBAL ENERGY DEMAND GROWTH FORECAST UP TO 2050

historical

forecast

petroleum and other liquids (includes biofuels)

renewables

natural gas

coal

nuclear

Source: US energy information administration, international energy outlook 2019
EIA GLOBAL ENERGY CONSUMPTION FORECAST

**Primary energy consumption**

- **All other uses**
- **Power generation**

**Primary energy sources for electricity generation**

- **Renewables**
- **Coal**
- **Natural gas**
- **Nuclear**
- **Liquids**

**Source:** U.S. Energy Information Administration, International Energy Outlook 2019
China and India are the largest projected electricity users.
## 2020 WORLD PRIMARY ENERGY CONSUMPTION

<table>
<thead>
<tr>
<th>source</th>
<th>consumption (exajoules)</th>
</tr>
</thead>
<tbody>
<tr>
<td>oil</td>
<td>173.73</td>
</tr>
<tr>
<td>coal</td>
<td>137.62</td>
</tr>
<tr>
<td>natural gas</td>
<td>151.42</td>
</tr>
<tr>
<td>hydroelectric power</td>
<td>23.98</td>
</tr>
<tr>
<td>nuclear power</td>
<td>38.16</td>
</tr>
<tr>
<td>renewables</td>
<td>31.71</td>
</tr>
<tr>
<td><strong>total consumption</strong></td>
<td><strong>556.63</strong></td>
</tr>
</tbody>
</table>

GLOBAL ENERGY CONSUMPTION:
1994 – 2020

2020 WORLD ENERGY CONSUMPTION BY REGION

[Bar chart showing the percentage of energy consumption by region for different fuel types: renewables, hydroelectricity, nuclear, coal, natural gas, and oil.]

GLOBAL OIL PRODUCTION AND CONSUMPTION BY REGION

GEOGRAPHIC MISALIGNMENT OF SUPPLY AND DEMAND

<table>
<thead>
<tr>
<th></th>
<th>N. America, Europe, Asia Pacific</th>
<th>rest of the world</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>oil</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>consumption</td>
<td>75.9</td>
<td>17.4</td>
</tr>
<tr>
<td>reserves</td>
<td>17.4</td>
<td>79.4</td>
</tr>
<tr>
<td><strong>gas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>consumption</td>
<td>63.7</td>
<td>36.3</td>
</tr>
<tr>
<td>reserves</td>
<td>36.3</td>
<td>63.7</td>
</tr>
<tr>
<td><strong>coal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>consumption</td>
<td>92.6</td>
<td>7.4</td>
</tr>
<tr>
<td>reserves</td>
<td>7.4</td>
<td>92.6</td>
</tr>
</tbody>
</table>

Source: BP Statistical Review of the World Energy 2021
CRUDE OIL PRICES: 1861-2020

the change over the period 1860-2000 is about 1 °C
KEELING CURVE

June 21, 2021
Carbon dioxide concentration at Mauna Loa Observatory

Full Record ending June 21, 2021

Charles D. Keeling
(1928 – 2005)
COMPELLING EVIDENCE

natural forcing only

natural (solar + volcanic) forcing alone does not account for warming in the past 50 years

anthropogenic forcing only

natural + anthropogenic forcing

adding human influences (greenhouse gases + sulfate aerosols) brings the models and observations into close agreement
$CO_2$ EMISSIONS: HISTORICAL AND FORECAST

COAL CAPACITY ANNUAL ADDITIONS AND RETIREMENTS

EMISSION HETEROGENEITIES

China

U.S.

billion tons of CO₂

year

‘90 ‘95 ‘00 ‘05 ‘10 ‘15 ‘20 ‘25 ‘30

0 2 4 6 8 10 12

Source: International Energy Agency
China consumed 50.7% of 2020 global coal production.

Sources: NYT article using China National Bureau of Statistics data; BP Statistical Review of World Energy 2021, p.50
GLOBAL $CO_2$ EMISSIONS FROM FOSSIL FUELS


Gt of $CO_2$

- **business as usual**
- **rapid**
- **net zero**
- **IPCC 2 °C median**
- **IPCC 1.5 °C median**
- **well below 2 °C**
- **1.5 °C**

Legend:

- Blue line: business as usual
- Green line: rapid
- Purple line: net zero
- Orange line: IPCC 2 °C median
- Blue dotted line: IPCC 1.5 °C median

Graph shows the emissions from 1980 to 2050 with different scenarios for reducing $CO_2$ emissions.
MAJOR CHALLENGES IN ENERGY

- **Energy security**: fuel supply resources for the future
- **Economic growth**: accommodation of the developing nations’ needs
- **Environmental effects**: global warming and emission control
- **Electricity system reliability**: assurance of the electric power infrastructure integrity/resilience
GLOBAL LACK OF ELECTRICITY ACCESS: SLOW PROGRESS

GLOBAL LACK OF CLEAN COOKING ACCESS: SLOWER PROGRESS

38% without access
62% with access

2% Others
28% Sub-Saharan Africa
70% Developing Asia

83% rural
17% urban

Source: REN 21
GLOBAL LACK OF ELECTRICITY AND CLEAN COOKING ACCESS

SUSTAINABILITY

- Sustainable development refers to living, production and consumption in a manner and at a level that meets the present needs without unduly impacting the ability to meet needs of future generations.

- The World Commission on Environment and Development set up by the UN issued a seminal report in 1987; the so-called Brundtland Report entitled Our Common Future established the concept and
definition of sustainable development:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

✧ the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and

✧ the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."
The major thrust of the report was to explicitly recognize that the scale and unevenness of economic development and population growth continue to place unprecedented pressures on the planet’s land, water and other natural resources and, in the absence of constraints, are sufficiently severe to wipe out regional populations and, over the longer term, to lead to global catastrophes.

Sustainability is a key guiding principle in policy formulation in many nations, states and localities.
UN’s SUSTAINABLE DEVELOPMENT GOALS

- In 2015, 193 countries gathered at the UN to adopt and commit to a comprehensive, long-term, strategy to tackle the world’s greatest challenges related to global sustainable development.

- The UN issued the Sustainable Development Goals (SDGs), and known as the Global Goals, to serve as a universal call to action to end poverty, protect the planet and ensure that by 2030 all people enjoy peace and prosperity.
UN’s SUSTAINABLE DEVELOPMENT GOALS

- The 17 SDGs are designed to end poverty, AIDS, hunger and discrimination against women/girls
- The implementation of the SDGs must carefully balance social, economic and environmental sustainability
- The creativity, knowhow, technology and financial resources from all of society is necessary to achieve the SDGs in every context
- All countries have committed to prioritize progress for those who are furthest behind
<table>
<thead>
<tr>
<th>no.</th>
<th>name</th>
<th>goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no poverty</td>
<td>eradicate poverty in all its forms everywhere</td>
</tr>
<tr>
<td>2</td>
<td>zero hunger</td>
<td>end hunger, achieve food security and improved nutrition and promote sustainable agriculture</td>
</tr>
<tr>
<td>3</td>
<td>good health and well-being</td>
<td>ensure healthy lives and promote well-being for all at all ages</td>
</tr>
<tr>
<td>4</td>
<td>quality education</td>
<td>ensure inclusive and equitable quality education and promote lifelong learning opportunities for all</td>
</tr>
<tr>
<td>5</td>
<td>gender equality</td>
<td>achieve gender equality and empower all women and girls</td>
</tr>
<tr>
<td>6</td>
<td>clean water and sanitation</td>
<td>ensure availability and sustainable management of water and sanitation for all</td>
</tr>
<tr>
<td>7</td>
<td>affordable and clean energy</td>
<td>ensure access to affordable, reliable, sustainable and modern energy for all</td>
</tr>
</tbody>
</table>
## THE 17 SDGs

<table>
<thead>
<tr>
<th>no.</th>
<th>name</th>
<th>goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>decent work and economic growth</td>
<td>promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all</td>
</tr>
<tr>
<td>9</td>
<td>industry, innovation and infrastructure</td>
<td>build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation</td>
</tr>
<tr>
<td>10</td>
<td>reduced inequality</td>
<td>reduce inequality within and among countries</td>
</tr>
<tr>
<td>11</td>
<td>sustainable cities and communities</td>
<td>make cities and human settlements inclusive, safe, resilient and sustainable</td>
</tr>
<tr>
<td>12</td>
<td>responsible consumption and production</td>
<td>ensure sustainable consumption and production patterns</td>
</tr>
<tr>
<td>13</td>
<td>climate action</td>
<td>take urgent action to combat climate change and its impacts</td>
</tr>
</tbody>
</table>
## THE 17 SDGs

<table>
<thead>
<tr>
<th>no.</th>
<th>name</th>
<th>goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>life below water</td>
<td>conserve and sustainably use the oceans, seas and marine resources for sustainable development</td>
</tr>
<tr>
<td>15</td>
<td>life on land</td>
<td>protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss</td>
</tr>
<tr>
<td>16</td>
<td>peace and justice strong institutions</td>
<td>promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels</td>
</tr>
<tr>
<td>17</td>
<td>partnerships to achieve the goal</td>
<td>strengthen the means of implementation and revitalize the global partnership for sustainable development</td>
</tr>
</tbody>
</table>
ROLE OF RENEWABLES IS OF GROWING IMPORTANCE
2020 US GENERATION BY SOURCE


4.009 trillion kWh

- **coal** 19.3%
- **natural gas** 40.3%
- **nuclear** 19.7%
- **hydro** 7.3%
- **petroleum/other gases** 0.4%
- **other renewable sources** 12.5%
2020 NET GENERATION OF RENEWABLE ENERGY SOURCES


- wind 44.0%
- hydroelectric 37.6%
- solar 11.8%
- geothermal 2.2%
- wood and biomass 4.8%

Total: 792 TWh
2019 RENEWABLE ENERGY SHARE OF GLOBAL ELECTRICITY GENERATION


- **Non-renewable electricity**: 72.7%
- **Renewable electricity**: 27.3%
  - **Hydropower**: 15.9%
  - **Wind power**: 5.9%
  - **Solar PV**: 2.8%
  - **Bio-power**: 2.2%
  - **Geothermal, CSP and ocean power**: 0.4%
US POPULATION DENSITY AND RENEWABLE RESOURCE LOCATIONS

Source: http://www.census.gov/popest/data/maps/2009/PopDensity_09.jpg
RENEWABLE PORTFOLIO STANDARDS

ANNUAL ADDITION OF RENEWABLE POWER CAPACITY: 2014 – 2020


Over 291 GW added in 2020
GLOBAL GENERATION CAPACITY INSTALLED IN 2020

Solar 138 GW; 39%
Other RE: 18 GW; 5%
Hydro: 21 GW; 6%
Gas: 59 GW; 17%
Wind: 114 GW; 33%

total capacity added = 350 GW

GLOBAL NET ELECTRICITY GENERATION SOURCES


2019 snapshot: 27.3% of world electricity produced by renewables

2050 forecast: over 50% of world electricity produced by renewables

All other fuels
SHARE OF GLOBAL RENEWABLE CAPACITY AND GENERATION: 2008 – 2019

Source: IRENA (2019)

- Share of renewable resource capacity of the added capacity
- Share of renewable power capacity of the cumulative global capacity
- Renewable energy share of global electricity
- Solar energy share of global electricity

Yearly Data:
- Share of renewable resource capacity of the added capacity:
  - 2008: 39%
  - 2009: 39%
  - 2010: 38%
  - 2011: 44%
  - 2012: 53%
  - 2013: 54%
  - 2014: 49%
  - 2015: 60%
  - 2016: 57%
  - 2017: 62%
  - 2018: 63%
  - 2019: 80.48%

- Share of renewable power capacity of the cumulative global capacity:
  - 2008: 23%
  - 2009: 24%
  - 2010: 24%
  - 2011: 25%
  - 2012: 26%
  - 2013: 27%
  - 2014: 28%
  - 2015: 30%
  - 2016: 31%
  - 2017: 32%
  - 2018: 33%
  - 2019: 33.3%

- Renewable energy share of global electricity:
  - 2008: 0.1%
  - 2009: 0.1%
  - 2010: 0.2%
  - 2011: 0.3%
  - 2012: 0.4%
  - 2013: 0.8%
  - 2014: 0.8%
  - 2015: 1.0%
  - 2016: 1.3%
  - 2017: 1.8%
  - 2018: 2.2%
  - 2019: 2.6%
LEVELIZED COSTS OF NEWLY–BUILT WIND AND SOLAR RESOURCES

$ / MWh

$ / MWh


CCGT 59 40 37
wind

50
100
150
200
250
300

solar

nuclear 163

cost

112

40

37

ELECTRICITY COSTS TRENDS: LCOE

- Solar PV–Rooftop Residential: $227
- Solar PV–Rooftop C&I: $179
- Solar PV–Community: $94
- Solar PV–Crystalline Utility Scale: $42
- Solar PV–Thin Film Utility Scale: $38
- Solar Thermal Tower with Storage: $156
- Geothermal: $101
- Wind: $86
- Gas Peaking: $198
- Nuclear: $198
- Coal: $159
- Gas Combined Cycle: $127

Source: Lazard (2021); all prices in 2020 USD; https://www.lazard.com/media/451419/lazard-levelized-cost-of-energy-version-140.pdf, p. 4

$/MWh
LEVELIZED COSTS OF NEWLY–BUILT WIND AND SOLAR RESOURCES

Source: Lazard (2021); all prices in 2020 USD; https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf; p. 8

levelized cost of new-build wind and solar

marginal cost of selected existing conventional generation

unsubsidized solar PV

unsubsidized wind

subsidized solar PV

subsidized wind

Coal

Nuclear

Gas-combined cycle

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UNSUBSIDIZED RENEWABLE LCOEs

unsubsidized wind LCOE

Wind 2009 – 2020 Percentage Decrease: (71%)

Wind 2009 – 2020 CAGR: (11%)

Wind 2015 – 2020 CAGR: (5%)

unsubsidized solar PV LCOE

Utility-Scale Solar 2009 – 2020 Percentage Decrease: (90%)

Utility-Scale Solar 2009 – 2020 CAGR: (19%)

Utility-Scale Solar 2015 – 2020 CAGR: (11%)

Source: Lazard (2021); all prices in 2020 USD; https://www.lazard.com/media/45141/lazards-levelized-cost-of-energy-version-140.pdf, p. 10

$ / MWh

$169 $148 $101 $92 $95 $95 $81 $62 $60 $56 $54 $54

$166 $149 $148 $104 $86 $70 $61 $53 $46 $44 $42

$394 $323 $270 $226 $166 $149 $104 $86 $70 $53 $46 $44 $42

wind average LCOE

average crystalline utility-scale solar LCOE

$ / MWh
LCOE COMPARISON: 2020

SOME LOW SOLAR PRICES IN THE 2020 AUCTIONS

OECD COUNTRIES’ ANNUAL SOLAR GENERATION/GROWTH RATE: 2010 – 2020

GLOBAL NET SOLAR GENERATION

US: MORE THAN 2,500 UTILITY - SCALE PV SYSTEMS

Source: EIA, Preliminary Monthly Electric Generator Inventory, November 2018, available online at https://www.eia.gov/todayinenergy/detail.php?id=38272
Source: EIA, Solar Explained, March 2021, available online at https://www.eia.gov/energyexplained/solar/where-solar-is-found.php
WIND FARMS
2005 – 2020 GLOBAL WIND CAPACITY

GW


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GLOBAL WIND CAPACITY ADDITIONS IN 2020


86.9 GW

USA 19 %
PR China 56 %
rest of world 11 %

rest of world 1 %
Belgium 12 %
Netherlands 25 %
Germany 4 %

United Kingdom 8 %
China 50 %

on shore

off – shore

Indonesia 4 %
Australia 2 %
Argentina 2 %
Germany 2 %
Mexico 2 %
France 2 %
Sweden 3 %

86.9 GW

6.1 GW
TOTAL GLOBAL WIND INSTALLED CAPACITY: 2020

2020 TOP 10 COUNTRIES IN TOTAL INSTALLED WIND CAPACITY

- China: 288,320 MW
- US: 122,317 MW
- Germany: 62,850 MW
- India: 38,625 MW
- Brazil: 17,750 MW
- France: 17,946 MW
- UK: 23,937 MW
- Canada: 13,577 MW
- Turkey: 9,280 MW
- Sweden: 9,811 MW

World total: 742,689 MW

2020 INSTALLED WIND CAPACITY BY REGION

Africa & Middle East 1.0 %

Americas 22.8 %

Europe 29.5 %

Pacific Asia 46.7 %

Total installed capacity: 742,689 MW

## 2020 INSTALLED WIND CAPACITY

<table>
<thead>
<tr>
<th>region</th>
<th>installed capacity in MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa &amp; Middle East</td>
<td>7,427</td>
</tr>
<tr>
<td>Americas</td>
<td>169,333</td>
</tr>
<tr>
<td>Asia Pacific</td>
<td>346,836</td>
</tr>
<tr>
<td>Europe</td>
<td>219,093</td>
</tr>
<tr>
<td><strong>global installed capacity</strong></td>
<td><strong>742,689</strong></td>
</tr>
</tbody>
</table>
US ANNUAL AND CUMULATIVE WIND INSTALLED CAPACITY: 2000 - 2020

Source: American clean power 2021, q1; available at https://cleanpower.org/wp-content/uploads/2021/05/CPQ-2021Q1_public.pdf; p. 14
US WIND DEVELOPMENTS IN 2020

- Wind installed power capacity exceeds the US hydro capacity since 2016; as such, wind became the largest capacity RER today in the US.
- New wind capacity added in 2020 exceeded 16 GW.
- Total installed wind capacity was above 120 GW.
- The US wind industry employed 116,801 persons in 2020, according to the ACPA.
- Wind turbine technician is among the fastest growing jobs in the US.
WIND ENERGY REDUCES US GHG EMISSIONS


189 million metric tons of CO₂

201 (198) million metric tons of CO₂ avoided in 2018 (2019), equivalent to the emissions of 43 (42) million cars
US WIND ENERGY IMPACTS: WATER CONSUMPTION SAVINGS


95 (103) billion gallons of water avoided in 2018 (2019), equivalent to 308 (312) gallons per person in US

95 billion gallons
2009 – 2020 \textit{US} WIND ENERGY PRODUCTION

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{us_wind_energy_production_bar_chart.png}
\caption{US Wind Energy Production, 2009–2020.}
\end{figure}

Source: https://www.eia.gov/electricity/data/browser/
GLOBAL NET WIND GENERATION


Japan
Canada
OECD
Europe
India
China
r. o. t. w.

history

forecast

billion MWh

1990
2010
2020
2030
2050

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EAST COAST OFFSHORE WIND PROJECTS AND LEASE AREAS

Source: AWEA WPA Executive Summary p. 4; available at https://www.awea.org/resources/publications-and-reports

- Revolution Wind (704 MW)
- South Fork Wind Farm (130 MW)
- Sunrise Wind (880 MW)
- Park City Wind (804 MW)
- Bay State Wind
- Vineyard Wind 1 (800 MW)
- Vineyard Wind
- Equinor
- Mayflower Wind (804 MW)
- Atlantic Shores Offshore Wind
- Ocean Wind (1,100 MW)
- Ørsted, PSEG
- Skipjack Wind Farm (120 MW)
- MarWin (269 MW)
- Unnamed Dominion Energy Project (2,640 MW)
- Coastal Virginia Offshore Wind (12 MW)
- Avangrid Renewables

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OFFSHORE WIND STATE TARGETS

Source: AWEA WPA Executive Summary p. 4; available at https://www.awea.org/resources/publications-and-reports
SOLAR ENERGY

Images From: http://www.scientificamerican.com/article.cfm?id=how-to-use-solar-energy-at-night
GLOBAL ANNUAL CUMULATIVE PV CAPACITY: 2010 – 2020

GLOBAL ANNUAL PV CAPACITY ADDITIONS BY REGION: 2000 – 2020

ANNUAL US SOLAR CAPACITY ADDITIONS: 2010 – 2020

Source: Wood Mackenzie and SEIA; available online at https://www.seia.org/solar-industry-research-data

installed capacity in MW dc

blended average PV system price ($/W)


0.00 1.00 2.00 3.00 4.00 5.00 6.00

0 2,000 4,000 6,000 8,000 10,000 12,000 14,000 16,000 18,000 20,000
ANNUAL US SOLAR CAPACITY ADDITIONS: 2010 - 2019

Source: Wood Mackenzie and SEIA; available online at https://www.seia.org/solar-industry-research-data

<table>
<thead>
<tr>
<th>Year</th>
<th>Residential</th>
<th>Non-Residential</th>
<th>Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1,000</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>2011</td>
<td>2,000</td>
<td>1,000</td>
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<td>2012</td>
<td>3,000</td>
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<tr>
<td>2019</td>
<td>10,000</td>
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</tr>
</tbody>
</table>
ANNUAL NON–RESIDENTIAL SOLAR PV INSTALLATIONS: 2010 - 2019

Source: Wood Mackenzie and SEIA; available online at https://www.seia.org/solar-industry-research-data

installed capacity in MW dc

C&I, Non-Profit, Government
Community Solar

ANNUAL RESIDENTIAL SOLAR PV INSTALLATIONS: 2010 - 2020


capacity in MW dc

California  Next 9 States  Other

ANNUAL RESIDENTIAL SOLAR PV SYSTEM COSTS: 2014 - 2021

Source: Wood Mackenzie and SEIA; available online at https://www.seia.org/solar-industry-research-data

residential solar PV system price ($/Watt)

软成本占总体系统成本的百分比

ANNUAL COMMERCIAL SOLAR PV CAPACITY AND PENETRATION: 2010 - 2020

Source: SEIA/wood mackenzie power & renewables US solar market insight 2020 q2, available online at https://www.seia.org/solar-industry-research-data

Annual commercial solar installations

Estimated share of total commercial electricity sales

Installed annual capacity in MWdc

Share of total commercial electricity sales in %

THE TOP 10 US STATES WITH THE LARGEST 2020 PV CAPACITY

Source: https://www.seia.org/research-resources/top-10-solar-states-0
CUMULATIVE US COMMUNITY SOLAR INSTALLATIONS

Source: SEIA/wood mackenzie power & renewables US solar market insight 2020 q2, available online at https://www.seia.org/solar-industry-research-data

installed capacity in MW<sub>dc</sub>

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US CUMULATIVE SOLAR CAPACITY
2010 – 2020

Source: https://www.eia.gov/outlooks/aeo/electricity/sub-topic-02.php
US NET SOLAR GENERATION 2010 – 2020


- total annual distributed
- total annual utility-scale
US ANNUAL SOLAR WORKERS BY JOB CATEGORY: 2010 - 2020

Source: national solar jobs census 2020, available online at https://www.seia.org/solar-industry-research-data

Installation & Developers • Manufacturing • Sales & Distribution • Operations & Maintenance • Other

280,000
240,000
200,000
160,000
120,000
80,000
40,000
0

Global corporate renewable energy deals continued at record pace in the first 7 months of 2020, according to a BloombergNEF report issued August 11, 2020.

In 2020, Latin America, Europe and Asia-Pacific have picked up the slack as US purchases slowed.
GLOBAL PURCHASES OF RENEWABLE ENERGY: JULY 31, 2020, STATUS

- US corporations, primarily in the technology sector signed on for approximately 4,300 MW of renewable energy through July 31, 2020

- More than 240 companies worldwide have committed to cover 100% of their electricity use with renewables with a combined annual electricity demand of 247 TWh
10 LARGEST CORPORATE PURCHASERS OF WIND ENERGY IN 2019

Source: AWEA Wind Powers American Business, p. 3; available at https://www.awea.org/resources/publications-and-reports

The contracted wind power capacity (MW) for the top corporate purchasers is as follows:

- Google: 2,397 MW
- Facebook: 1,459 MW
- Walmart: 1,333 MW
- AT&T: 1,000 MW
- Microsoft: 750 MW
- Amazon Web Services: 750 MW
- Kimberly-Clark: 750 MW
- General Motors: 750 MW
- Dow: 750 MW
- T-Mobile: 750 MW

Total 10 top corporate purchasers = 9,400 MW
CORPORATE WIND PURCHASERS SERVED BY 198 WIND PROJECTS IN 29 STATES

+23.7 GW\textsubscript{dc} increase in 2020
10 LARGEST CORPORATIONS IN SOLAR CAPACITY INSTALLATIONS

Source: Wood Mackenzie and SEIA; available online at https://www.seia.org/solar-industry-research-data
MAJOR ENVIRONMENTAL BENEFITS

- Wind capacity tied to corporate buyers avoids 20 million metric tons of $CO_2$ annually, equivalent to the emissions from 4.2 million cars.

- Annually, these wind projects avoid 24,000 metric tons of $SO_2$ and 16,000 metric tons of $NO_x$ – important environmental improvements.