Energy, Carbon, and Poverty

Is Compromise Possible

Scott W. Tinker
The Western Narrative

Renewables and batteries are “clean” and “good”...

Fossil energy and nuclear are “dirty” and “bad”...
The Dilemma

Most people do not know how electricity is made or where gasoline comes from.

But... they think they do!
Outline

- Energy
- Carbon
- Poverty
- Radical Middle
**Energy Security**

**Affordable**
- **Cost:** per unit of energy
- **Price Volatility:** stable or fluctuating
- **Infrastructure:** cost to build the plant

**Available**
- **Access:** substantial resources

**Reliable**
- **Intermittent:** source consistent or variable
- **Safe:** natural/human causes

**Sustainable**
- **Clean:** air and atmospheric emissions
- **Dense:** energy per area, weight and volume
- **Dry:** fresh water use/risk
The Global Energy Mix

Million Tonnes Oil Equivalent

Global Energy 2017

- Petroleum: 85%
- Nat Gas: 28%
- Coal: 23%
- Nuclear: 7%
- Hydro: 4%
- Renew: 1%

Global Population
Each color on the map represents ~ 1 billion people

The Global Energy Mix

Million Tonnes Oil Equivalent

Hydro
Renew
Nuclear
Coal
Nat Gas
Petroleum

Global Population
Each color on the map represents ~ 1 billion people

Data: BP Statistical View of World Energy (2016)
Global Energy Demand

Million Tonnes Oil Equivalent

Global Population
Each color on the map represents ~ 1 billion people

Data: BP Statistical View of World Energy (2016)
The Global Energy Mix

Change in energy demand, 2016-40 (Mtoe)
The world could be wind, water and solar in 50 years if just for political will…

Could the world could be wind, water and solar in 50 years, if just for political will…?

Electricity Generation By Region

World electricity generation\(^1\) from 1971 to 2015 by region (TWh)

- **Africa**
- **Non-OECD Americas**
- **Non-OECD Asia\(^2\)**
- **China**
- **Non-OECD Europe and Eurasia**
- **Middle East**
- **OECD**


1. Excludes electricity generation from pumped storage.
Electricity Generation by Source

World electricity generation\(^1\) from 1971 to 2015 by source (TWh)

1. Excludes electricity generation from pumped storage.
2. Includes geothermal, solar, wind, tide/wave/ocean, biofuels, waste, heat and other.

Electricity Generation by Source

World electricity generation\(^1\) from 1971 to 2015 by source (TWh)

- Non-hydro renewables and waste\(^2\)
- Hydro
- Nuclear
- Fossil thermal

1. Excludes electricity generation from pumped storage.
2. Includes geothermal, solar, wind, tide/wave/ocean, biofuels, waste, heat and other.

Global Coal Production

World coal\(^1\) production from 1971 to 2016 by region (Mt)

- Africa
- Non-OECD Americas
- Non-OECD Asia\(^2\)
- China
- Non-OECD Europe and Eurasia
- Middle East
- OECD

Source: *World Energy Outlook, 2017*, EIA

1. Includes steam coal, coking coal, lignite and recovered coal.
Total Primary Energy Supply (TPES) by Energy Source (Mtoe)

1. In this graph peat and oil shale are aggregated with coal.
2. Other includes nuclear, electricity trade, heat, non-renewable waste.

Electricity Generation by Source

World electricity generation from 1971 to 2015 by source (TWh)

- **Non-hydro renewables and waste**
- **Hydro**
- **Nuclear**
- **Fossil thermal**

1. Excludes electricity generation from pumped storage.
2. Includes geothermal, solar, wind, tide/wave/ocean, biofuels, waste, heat and other.

Nuclear Electricity Production

World nuclear electricity production from 1971 to 2015 by region (TWh)


1. Non-OECD Asia excludes China.  2. Other includes Africa, Non-OECD Americas and the Middle East.
Electricity Generation by Source

World electricity generation\(^1\) from 1971 to 2015 by source (TWh)

- **Non-hydro renewables and waste\(^2\)**
- **Hydro**
- **Nuclear**
- **Fossil thermal**

1. Excludes electricity generation from pumped storage.
2. Includes geothermal, solar, wind, tide/wave/ocean, biofuels, waste, heat and other.

Hydro Electricity Production

World hydro electricity production\(^1\) from 1971 to 2015 by region (TWh)


1. Includes electricity production from pumped storage. 2. Non-OECD Asia excludes China.
Electricity Generation by Source

World electricity generation\(^1\) from 1971 to 2015 by source (TWh)

- Non-hydro renewables and waste\(^2\)
- Hydro
- Nuclear
- Fossil thermal

1. Excludes electricity generation from pumped storage.
2. Includes geothermal, solar, wind, tide/wave/ocean, biofuels, waste, heat and other.

World wind electricity production from 2005 to 2015 by region (TWh)


1. Non-OECD Asia excludes China.
Electricity Generation by Source

World electricity generation by fuel (TWh)

- Non-hydro renewables and waste
- Hydro
- Nuclear
- Fossil thermal

1. Excludes electricity generation from pumped storage.
2. Includes geothermal, solar, wind, tide/wave/ocean, biofuels, waste, heat and other.

Wind Electricity

Growth in U.S. Wind Generation
2000–2014

Million Kwh

1. Non-OECD Asia excludes China.
Solar Photovoltaic Electricity Production

World solar PV electricity production from 2005 to 2015 by region (TWh)

- Africa
- Non-OECD Americas
- Non-OECD Asia
- China
- Non-OECD Europe and Eurasia
- Middle East
- OECD

1. Non-OECD Asia excludes China.
Solar Photovoltaic Electricity

United States
Solar photovoltaics

Source: Economist, Solar Energy Industries Association

Average Module Price $ / watt

1. Non-OECD Asia excludes China.
Electricity Generation by Source


1. Excludes electricity generation from pumped storage.
2. Includes geothermal, solar, wind, tide/wave/ocean, biofuels, waste, heat and other.
Could the world could be wind, water and solar in 50 years if just for political will...?
Population and Energy

Data: BP Statistical View of World Energy (2016)
Source: From the UN, as appeared in *The Economist*, August 23, 2014

98% Renewable
Highly unlikely, and not really desirable
Population and Energy

Data: BP Statistical View of World Energy (2016)

Source: From the UN, as appeared in The Economist, August 23, 2014
Population and Energy

Data: BP Statistical View of World Energy (2016)
Source: From the UN, as appeared in The Economist, August 23, 2014
Population and Energy

Data: BP Statistical View of World Energy (2016)

Source: From the UN, as appeared in The Economist, August 23, 2014
Global Primary Energy

- Natural Gas, Nuclear, Coal, Oil, Biomass
- Wind, Solar, Hydro

2015
- 12% Renewable
- 37% Coal
- 38% Natural Gas
- 25% Oil
- 75% Biomass

2065
- 20% Renewable
- 60% Coal
- 30% Natural Gas
- 10% Oil
- 80% Biomass
Global Energy 2065

Global Energy Consumption (MTOE)

By 2065
~7200 Tcf
~1500 Bbo

Oil Cost of Supply

Resources and Cost

Natural Gas Cost of Supply

Resources v. Cost

Production cost (2008 $/Mbtu)

- **Tight**
- **Shale**
- **Coal Bed Methane**
- **Sour**
- **Arctic**
- **Deep Water**
- **Hydrates**

Natural Gas Cost of Supply

Resources v. Cost

Global Consumption
115 Tcfy

~ 300 year total resource

Natural Gas Cost of Supply

Resources v. Cost

Global Consumption
115 Tcfy

Production Cost (2008 $/Mmbtu)

Resources (Tcf)

Natural Gas Cost of Supply

Resources v. Cost

Global Consumption
115 Tcfy

Production cost (2008 $/Mmbtu)

Production

Resources (Tcf)

Conventional

Tight

Shale

Coal Bed Methane

Sour

Arctic

Deep Water

Hydrates

The Global Resource is Vast

Reserves and production are a function of Price, Cost, Technology, Policy and Demand

Tinker, 2015

Gas

<table>
<thead>
<tr>
<th>Resource-in-Place</th>
<th>Original In</th>
<th>Tech. Recoverable</th>
<th>Production to date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3100</td>
<td>700</td>
<td>70</td>
</tr>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizontal wells to date</th>
<th>Future wells (base case)</th>
</tr>
</thead>
<tbody>
<tr>
<td>~</td>
<td>~500,000</td>
</tr>
</tbody>
</table>

For presentation or publication, reference:
Bureau of Economic Geology
Shale Resource and Production Project
http://www.beg.utexas.edu/research/programs/shale

Fayetteville
~6,500
~13,000

Eagle Ford
~16,500
~90,000

Bakken/Three Forks
~18,000
~100,000

Haynesville
~6,000
~35,000

Marcellus
~10,500
~200,000

Barnett
~16,500
~63,000

Permian Basin
in progress

Marcellus
Fayetteville
Haynesville
Barnett
Eagle Ford
Bakken/Three Forks
Permian Basin
Tinker, 2015 & Tinker, 2016

<table>
<thead>
<tr>
<th>Gas</th>
<th>Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tcf</td>
<td>Bbbl</td>
</tr>
<tr>
<td>Original In-Place</td>
<td>3100</td>
</tr>
<tr>
<td>Tech. Recoverable</td>
<td>700</td>
</tr>
<tr>
<td>Production to date</td>
<td>70</td>
</tr>
</tbody>
</table>

Horizontal wells to date: ~75,000
Future wells (base case): ~500,000

For presentation or publication, reference:
Bureau of Economic Geology Shale Resource and Production Project
http://www.beg.utexas.edu/research/programs/shale
<table>
<thead>
<tr>
<th></th>
<th>Gas</th>
<th>Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tcf</td>
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<td>450</td>
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<tr>
<td>Bbbl</td>
<td>700</td>
<td>27</td>
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<tr>
<td>Production to date</td>
<td>70</td>
<td>5</td>
</tr>
<tr>
<td>Horizontal wells to date</td>
<td>~75,000</td>
<td>~500,000</td>
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<tr>
<td>Future wells (base case)</td>
<td>~500,000</td>
<td></td>
</tr>
</tbody>
</table>

**Recovery to Date**

- **Gas**
  - Resource-in-Place
  - TRR
  - Produced to-date

- **Oil**
  - Original In-Place
  - Tech. Recoverable
  - Production to date

For presentation or publication, reference: Bureau of Economic Geology Shale Resource and Production Project [http://www.beg.utexas.edu/research/programs/shale](http://www.beg.utexas.edu/research/programs/shale)
U.S. Crude Oil Production

- Rest of U.S.
- Federal Gulf of Mexico
- Permian Region
- Eagle Ford Region
- Bakken Region


~ 70% of U.S. Oil Production from Shale

10.7 Mbo/d
Data: BP Statistical View of World Energy (2016)  
Source: From the UN, as appeared in *The Economist*, August 23, 2014
Population and Energy

Forecast

Asia
Rest of World
Africa 2X

Global Population (B)

Data: BP Statistical View of World Energy (2016)
Source: From the UN, as appeared in The Economist, August 23, 2014
Global Energy 2065

Global Energy Mix

Global Energy Mix

Environmental Impact
Coal, Oil, Natural Gas

- Mining and Manufacturing: *Land, Water, Emissions*
- Drilling and Completion: *Land, Water*
- Transportation: *Pipelines, Trucks, Ships, Rail*
- Refining and Petrochemicals: *Emissions*
- Combustion: *Vehicle and Power Plant Emissions*
Is this a Shale Basin?
No, it’s New York!
Environmental Impact
Renewables and Batteries

- Mining and Processing: Land, Water, Emissions
- Manufacturing: Turbines, Panels, Batteries
- Production: Land for “Farms”
- Transmission: Electricity
- Disposal: Landfill
Energy
Key Points

• Fossil energy demand remains strong, and resources are vast

• Wind and solar are a small component of the mix, but growing quickly in some regions

• No form of energy, at scale, is without environmental impact
Outline

❖ Energy
❖ Carbon
❖ Poverty
❖ Radical Middle
CO₂ Emissions

CO₂ Emissions (Million Tonnes)

- Total Europe
- Total North America

CO₂ Emissions

Don’t blame Asia! They make products for the world.

Data: BP Statistical View of World Energy (2016)
Source: Emerging Trends in Electricity Consumption for Consumer ICT, Peter Corcoran and Andres Andrae (2013) and CIA World Factbook. China/Russia/Canada figures are from 2014.
The Future Electricity Mix

Electricity Generation by Fuel

North America

Europe

Asia Pacific

U.S. Electric Generation Shares (2005-15)

Source: EIA
US Energy Mix

Total Energy Consumed

Imports
Nuclear
Oil
Natural Gas
Coal
Wind & Solar
Biofuels
Hydro

Quadrillion Btu

US Energy Mix

Growth 0.55% less than GDP
80 Quads
“Efficiency”

Total Energy Consumed

Fracking

Wind & Solar
Biofuels
Hydro

Oil
Nuclear
Imports
Natural Gas
Coal

Quadrillion Btu

The Future Electricity Mix

Electricity Generation by Fuel

North America

- Oil
- Coal
- Gas
- Renewables
- Nuclear

Europe

- Oil
- Coal
- Gas
- Renewables
- Nuclear

Asia Pacific

- Oil
- Coal
- Gas
- Renewables
- Nuclear

European Coal Generation

Power generation (TWh)


Germany: 819 841 892 960 798 788 694
Poland: 177 173 164 157 136 132 120
Czech: 109 143 131 101 76
Italy: 25 24 25 29 40
Spain: 40 47 44 42 43
Netherlands: 23 24 25 29 40
UK: 40 47 44 42
Other: 263 262 277 283 274 272 260

*preliminary
European Natural Gas Power Generation

Power generation (TWh)

Coal

UK | Italy | Germany | Spain | Netherlands | Other

2010: 176, 95, 153, 176, 147, 129, 101, 119
2012: 586, 73, 79, 586, 56, 56, 101, 119
2013: 511, 55, 70, 511, 123, 109, 97, 119
2014: 461, 57, 64, 461, 103, 94, 102, 119
2015: 497, 52, 64, 497, 124, 109, 101, 119
2016*: 598, 53, 81, 598, 147, 119, 146, 119

*preliminary
The Future Electricity Mix

Electricity Generation by Fuel

North America

Quadrillion BTUs
Europe

Asia Pacific

Actual Cost of Electricity

Average national electricity prices (in 2011 US cents/kWh)

Data: average prices from 2011 converted at mean exchange rate for that year

Affordable
Available
Reliable

Sources: IEA, EIA, national electricity boards, OANDA, shrinkthatfootprint.com
Actual Cost of Electricity

2017 U.S. Average Electricity Retail Prices (cents per kilowatt hour)

- 7.00 to 9.00
- 9.01 to 10.00
- 10.01 to 12.00
- 12.01 to 15.00
- 15.01 and Higher

National Average = 10.54
Auto Sales Developing Nations
Rolling 12-month (million)

Source: National car data, Macquarie Research, January 2017
Global Annual Sales
Light-Duty Plug-In Electric Vehicles (2011 – 2016)

Annual sales (light plug-in electric vehicles)

- Canada
- Japan
- China
- Western Europe
- United States

Source: Argonne National Laboratory, United States Department of Energy
Cumulative Electric-Vehicle Forecasts

- Bloomberg
- OPEC
- ExxonMobil
- EIA

**Batteries in 12 yrs avg 10,000,000/yr.**

- ~10% of Global Vehicle Fleet

Source: Bloomberg New Energy Finance, Economist.com; EIA, WEO, 2017
Cumulative Electric-Vehicle Forecasts

- **Bloomberg**
- **OPEC**
- **ExxonMobil**
- **EIA**

**Source:** Bloomberg New Energy Finance, Economist.com; EIA, WEO, 2017

- **20,000,000 Batteries in 24 yrs**
- **avg 5,000,000/yr.**

**~10% of Global Vehicle Fleet**
Total Final Consumption by Sector

Electricity

<table>
<thead>
<tr>
<th>Year</th>
<th>Electricity TFC by sector (Mtoe)</th>
<th>Other¹</th>
<th>Transport</th>
<th>Commercial and public services</th>
<th>Residential</th>
<th>Industry</th>
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<td>1971</td>
<td>200</td>
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<td>1975</td>
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<td>2010</td>
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<td>2015</td>
<td>1100</td>
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</tbody>
</table>

1. Includes agriculture, fishing and non-specified other.

CO$_2$ Reduction Strategies

- Efficiency
- Fuel Substitution
  - Nuclear, Nat Gas, Renewables
- Carbon Capture and Sequestration
Carbon

Key Points

• Renewables will grow, but not soon enough or large enough to reduce CO₂ emissions at scale

• Natural gas and nuclear can reduce CO₂ emissions at scale and in needed time frames
  ✓ Reduce methane emissions!

• Electric Vehicle growth will not mitigate the demand for liquid petroleum fuels
Outline

❖ Energy
❖ Carbon
❖ Poverty
❖ Radical Middle
People Without Access to Electricity and Clean Cooking Facilities

Limited Access to Electricity Restricts Standard of Living

- United States
- Australia
- Japan
- Germany
- South Korea
- Russia
- Saudi Arabia
- Malaysia
- Brazil
- Mexico
- China
- Ecuador
- Haiti
- Ghana
- Niger
- India
- India

**Developed**

**U.S. GDP > 2X**

**Developing**

**Emerging**

**Undeveloped**

**ELECTRIC POWER CONSUMPTION, KWH/CAP**

**GDP/CAPITA, PPP CURRENT INTERNATIONAL $**

Source: World Bank Databank
Limited Access to Electricity Restricts Standard of Living

2.5 billion people

Source: World Bank Databank
Limited Access to Electricity Propagates Inequality

Source: World Bank Databank
Limited Access to Electricity Propagates Inequality

Switch On
2.5 billion

Source: World Bank Databank
Limited Access to Electricity Propagates Inequality

Switch On
2.5 billion

Source: World Bank Databank
It’s Time to Educate & Power the People
Limited Access to Electricity Propagates Inequality

It's Time to Educate & Power the People
Limited Access to Electricity Propagates Inequality

It's Time to Educate & Power the People
Energy does not end poverty.

Poverty cannot be ended without energy.
Poverty
Key Points

• Energy underpins modern economies and helps lift the world from poverty

• Energy resources vary by region and nations will use the energy resources that they have to reduce energy poverty
Outline

- Energy
- Carbon
- Poverty
- Radical Middle
Poverty is the major issue of our time, and fossil fuels are the solution.

Climate Change is the major issue of our time, and fossil fuels are the problem.

Interactive Systems
Poverty
Carbon
Energy
Political
Social
Legal
Politics, economics, and passion run deep on all sides of the climate change and poverty debate.
Is civil energy discourse possible?

can we find compromise and move forward?
Towards Compromise

• Recognize that no form of energy is good or bad
• Assess the environmental impact of *all* energy
• Focus energy policy on energy security
• Make energy efficiency and energy storage tactical
• Recognize energy poverty as a critical challenge

Engage in Energy Education!
...keep it in the Ground.
Keep *them* in Poverty.
Lift them from Poverty!
SwitchOn.org

Inspire an Energy Educated Future