Excitement in the Air: The Energy Revolution

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The Global Challenge

- We know that something is not working here
- The puzzle is striking: global warming is already affecting the lives of millions and will dramatically change the lives of virtually all of us within our life expectancy.
- Millions die every year as a result of fossil fuel related pollution
- Renewable energy is by now competitive, price wise, with most modes of fossil fuel generated energy.
- Renewable energy is not polluting and it is the only way to stop global warming. Energy Saving and Recycling are problematic policy solutions in more ways than one.
- Renewable energy technology is readily available
- And yet, the market is not investing more ... or, to be more accurate, it is not investing everything it’s got in renewable to get this whole issue done and over with.
- Hence a Global Challenge
Source: Global Carbon Project, 2013 data
Recycling is not a good policy solution: GHG
Emissions Of Virgin And Recycled Material
Production (Kg CO$_2$eq / kg)

<table>
<thead>
<tr>
<th>Material</th>
<th>Virgin</th>
<th>Recycled</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum cans</td>
<td>12.94</td>
<td>1.03</td>
<td>12.6</td>
</tr>
<tr>
<td>Steel cans</td>
<td>2.82</td>
<td>0.99</td>
<td>2.8</td>
</tr>
<tr>
<td>Copper wire</td>
<td>7.41</td>
<td>6.09</td>
<td>1.2</td>
</tr>
<tr>
<td>Glass</td>
<td>0.48</td>
<td>0.33</td>
<td>1.5</td>
</tr>
<tr>
<td>HDPE</td>
<td>1.76</td>
<td>0.18</td>
<td>9.8</td>
</tr>
<tr>
<td>LDPE</td>
<td>2.16</td>
<td>0.18</td>
<td>12.0</td>
</tr>
<tr>
<td>PET</td>
<td>2.05</td>
<td>0.18</td>
<td>11.4</td>
</tr>
<tr>
<td>Cardboard</td>
<td>0.84</td>
<td>0.92</td>
<td>0.9</td>
</tr>
<tr>
<td>Newspaper</td>
<td>2.13</td>
<td>1.27</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Examples: Energy Savings From Reuse and Recycling

<table>
<thead>
<tr>
<th>Material</th>
<th>Primary Production (cradle-to-gate in MJ/kg)*</th>
<th>Recycling (scrap-to-gate MJ/kg)</th>
<th>Savings Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>194.7</td>
<td>10.3</td>
<td>19</td>
</tr>
<tr>
<td>Copper</td>
<td>≈100</td>
<td>20 – 30</td>
<td>5 – 3.3</td>
</tr>
<tr>
<td>Steel</td>
<td>21.7</td>
<td>7.1</td>
<td>3</td>
</tr>
<tr>
<td>Steel section</td>
<td>33.3</td>
<td>16.0</td>
<td>2.1</td>
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<tr>
<td>PET</td>
<td>82.7</td>
<td>30.2</td>
<td>2.7</td>
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<tr>
<td>Paper</td>
<td>18</td>
<td>12</td>
<td>1.5</td>
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<tr>
<td>Glass</td>
<td>12</td>
<td>8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Slide by Roland Geyer, Santa Barbara UCSB

* 1 Kilowatt = 3.6 MJ
Energy Saving Is not an Effective Policy Solution due to the ever Growing Energy Needs
Nature’s Supply and Demand
The (non) Scarcity of Resources

- Solar: 23,000 TW
- Tidal: 0.3 TW
- Wave: 0.2–2 TW
- Geothermal: 0.3–2 TW
- Hydro: 3–4 TW
- Biomass: 2–6 TW
- Wind: 25–70 TW
- World Energy consumption (power demand of 16 TW)

Resources:
- Coal: 900 TW-yr
- Uranium: 90–300 TW-yr
- Oil: 240 TW-yr
- Natural gas: 215 TW-yr

Energy components annually vs. total reserves.
What do prices of Wind and Solar look like? Compared to Fossil Fuels

Hey, Guess what? Prices of wind and CSP Solar have just gotten Below coal and gas But no one bothered to tell us 😊

Should we start investing in solar and wind energy?

Source: US National Renewable Energy Lab (NREL)
'Source: Photon Consulting
Most Current Price Estimates

Levelized Cost of Electricity in € per kWh

Source: Fraunhofer ISE, Germany November 2013

- PV small
- PV utility
- Wind onshore
- Wind offshore
- Biogas
- Coal lignite
- Coal hard
- CCGT natural gas
Another Estimate

Components of levelized cost of energy

<table>
<thead>
<tr>
<th>Type</th>
<th>Technology</th>
<th>Capital Cost Average</th>
<th>Fixed O&amp;M Average</th>
<th>Variable O&amp;M Average</th>
<th>Fuel Cost Average</th>
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</thead>
<tbody>
<tr>
<td>Alternative</td>
<td>Onshore Wind</td>
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<td></td>
<td>Solar PV Utility</td>
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<td>Biomass Direct</td>
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<td></td>
<td>Geothermal</td>
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<td>Microturbine</td>
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<td>Solar Thermal</td>
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<td>Fuel Cell</td>
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<td>Solar PV Rooftop C&amp;I</td>
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<td></td>
<td>Solar PV Rooftop Residential</td>
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<td></td>
<td>Battery Storage</td>
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<td>Conventional</td>
<td>Gas Combined Cycle</td>
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<td></td>
<td>Coal</td>
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<td>Nuclear</td>
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<td>IGCC</td>
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<td>Gas Peaking</td>
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<td>Diesel Generator</td>
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Source: Lazard's Levelized Cost of Energy Analysis--Version 8.0, September 2014
LOWER PRICES DRIVE DRAMATIC GROWTH IN SOLAR

- 80% decline in cost since 2008
- 600% increase in MW installed in the last 3 years
More Current Data on Actual Capacity Installations
The Virtuous Cycle

Tom Randall of the Bloomberg Report October 5 2015
Bloomberg and MacKensie Conclusion

• Tom Randall of Bloomberg, October 2015: Solar and Wind has just past another (no return) turning point: It never made less sense to build fossil fuel power plants

• Wood MacKensie Februar 2015: Just as shale extraction reconfigured oil and gas, no other technology is closer to transforming power markets than distributed and utility scale solar.
The Theoretical Question: Why then do we not see more of it yet?

- The study of misconceptions
- Concentrated versus diffused interests
- The Tipping Point Theory
- Social Movements or lack thereof...
- Market Failures
  - Information
  - Externalities
- The Institutional Approach
  - Path Dependence
  - The Lack in Market Structures
  - The structure of the existing market
  - Economies and diseconomies of scale
Economies and Diseconomies of Scale

- Scientific Observation:
  - There are no Economies of Scale in the production of renewable energy
  - There are huge economies of scale in the production of energy off fossil fuels
Why?

• Transaction costs
• Technicalities
• Technological barriers
  – Cannot transport
  – Cannot store
  – Cannot really trade globally
    • The failure of CO2 global markets
    • ARCH COAL collapses; Barrel of Oil at $ 30
    • And yet – Renewable Energy is doing just fine
    • Market Failure or Market Resilience?
    • Whatever the case may be, it explains the remarkable attractiveness of investing in renewable energy
  • Warning: I am not an investment consultant
Requirements for Success

Remains a Problem

No longer a problem

Not Really a Problem
German energy transition is a democratic movement

Ownership of renewables in 2012

Source: AEE, www.unendlich-viel-energie.de

Energy suppliers

12%

Institutional and strategic investors

41%

Total installed capacity 2012

73 GW

Citizens and coops

47%

“The Energiewende”
Off Grid Prosumerism is probably the best option for Renewable Energy

It is Efficient

It Does not require of us to worry about System and grid effects

It allows us to bypass the storage problem

In most developing economies it provides more energy than they are used to get

It would and does work in many developed countries as well
What do we need to worry about: An Ongoing Research Project

Secure property rights

Enabling regulations

Leave the prosumer alone attitude

Most Importantly: Educating a new Generation of Professionals to know how to Install, maintain and Secure these Systems, technically legally and Financially

But in Order to teach and train, we need to figure it all first, hence the urgent need for applied research
How do we cover and what Roof Tops?

<table>
<thead>
<tr>
<th>Building</th>
<th>PV/Grid</th>
<th>Grid</th>
</tr>
</thead>
<tbody>
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Thank you,

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