Disclaimer: The views expressed are those of Paul Gipe and are not necessarily those of the sponsor.

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Paul Gipe, wind-works.org
Renewable Revolution: How Renewable Energy is Remaking Electricity Generation

Paul Gipe, wind-works.org

Wörstadt, Rheinland-Pfalz, Germany
Galicia, Spain

Paul Gipe, wind-works.org
Freiburg -- Germany’s Solar City
Themes

• World Status: Wind & Solar PV
• Why Wind
• Nomenclature & Applications
• Myths to Dispel
• Wind & Solar: Better Together
• Scale of the Problem or Potential Market
• Electricity Rebels

Paul Gipe, wind-works.org

Montfort, Wisconsin
Where Are We Now?

Whitelee, Glasgow, Scotland
Paul Gipe, wind-works.org
World Wind Generating Capacity

Year

Megawatts (Thousands)

Europe
North America
Asia

More than 1/2 From Feed-in Tariffs

Paul Gipe, wind-works.org
World Wind Capacity 2011
~230,000 MW

North America 22%
Africa 0%
Asia 36%
Europe 41%
South America 1%
2011 World Major Wind Markets

Thousands MW

- China
- USA
- Germany
- Spain
- India

Paul Gipe, wind-works.org
2011 North American Wind Capacity

Paul Gipe, wind-works.org
2011 Asian Wind Capacity

Paul Gipe, wind-works.org
European Wind Capacity 2011

Paul Gipe, wind-works.org
Worldwide Wind Energy
US$100+ Billion in 2011

Project Development 54%
Electricity Sales 42%
O&M 4%
Solar PV Growing Rapidly

- 2011: 65,000 MW Worldwide
- 20,000+ MW/yr
- Major Markets
  - Germany—7,400+ MW/yr
  - Italy—9,000 MW/yr
  - China—3,000 MW/yr
  - USA—2,000 MW/yr
  - Japan—2,000 MW/yr

Paul Gipe, wind-works.org
Rancho Seco, California
Paul Gipe, wind-works.org

World Solar PV Capacity 2011
~65,000 MW

2/3 in Europe
3/4 from Feed-in Tariffs

Paul Gipe, wind-works.org
Leading World Solar PV Markets
Total Installed 2011

- Germany: 24.0
- Italy: 12.5
- Spain: 4.8
- Japan: 4.7
- USA: 4.2
- China: 2.3
- France: 2.2
- Czech Republic: 1.9
- California: 1.5
- New Jersey: 0.6
- Ontario: 0.5

Paul Gipe, wind-works.org
Worldwide Solar PV Market
US$100+ Billion in 2011

Paul Gipe, wind-works.org
Why Wind?

- Reduces Use of Fossil & Nuclear Fuels
- Most Cost-Effective of New Renewables
- Relatively Benign

Paul Gipe, wind-works.org
Why Now?

- **Wind Works**
  - Greater Reliability
- **Productivity Improved**
  - More Efficient
  - Taller Towers
- **Costs Declined**
  - Economies-of-Scale

Paul Gipe, wind-works.org
Kincardine, Ontario

40 m, 500 kW

80 m, 1.8 MW

Northern Ireland

Paul Gipe, wind-works.org

Kincardine, Ontario
We Know What Works
...and What Doesn’t

© Vortec

Paul Gipe, wind-works.org
Wind is Modular

• Quickly Installed
• When Needed
• As Needed
• Where Needed
• By Anyone

Paul Gipe, wind-works.org

Tehachapi, California
Wind is Flexible

- **Scale**
  Large or Small Projects

- **Location**
  Near or Far

- **Time**
  Short Lead Times

- **Ownership**
  Local or Absentee

Paul Gipe, wind-works.org
Wind Energy’s Benefits

• Clean & Green (Mostly)
  No SOx, NOx, or CO2
• Renewable
  Net Positive Energy Balance (4-6 months)
• Domestic: Not Subject to Embargo
• Does Not Consume Water
• Modular = Flexible
• ... and Can Be Removed

Paul Gipe, wind-works.org
Wind Energy’s Impacts

- Aesthetics or Intrusiveness
- Erosion & Scarring from Roads
  - Length, Width, Number and Slope
- Shadow Flicker & Disco Effect
- Climate?
- Noise--They are Audible
- Wildlife
  - Habitat Disruption
  - Bird & Bat Kills: Collisions, Electrocutions

Paul Gipe, wind-works.org
Nomenclature
What is a Wind Turbine

• Turbine: Rotor
  Assemblage of Blades

• Generator
  Nacelle

• Tower
  Guyed, Freestanding

• Foundation

Paul Gipe, wind-works.org
Nomenclature

- Mid-80s HAWT
- Internal Ladder
- w/ Fall Restraint
- Work Platform
- Tip Brakes
- “Rocket” Tower
VAWT Configurations

“H”

DELTA

DIAMOND

“Y”

PHI

Paul Gipe, wind-works.org
VAWTs

φ Darrieus

2 Blades

DAF-Indal
Atlantic Wind Test Site, PEI

Paul Gipe, wind-works.org
Giromill

Articulating Straight Blade VAWT

Paul Gipe, wind-works.org
HAWT Configurations

Paul Gipe, wind-works.org
Medium-Size & Large Wind Turbines

Rotor Diameter (m)

- 3000
- 2000
- 1000
- 500
- 250
- 50

Swept Area (m²)

- 10,000
- 8,000
- 6,000
- 4,000
- 2,000
- 0

Diameter (meters)

- 15
- 25
- 40
- 60
- 80
- 110

Paul Gipe, wind-works.org
Size Today

- 3 MW
- 10,000 m²
- 10,000,000 kWh/yr
- 250 t

Hvide Sande, Denmark

Paul Gipe, wind-works.org
Applications—Off-the-Grid

Paul Gipe, wind-works.org
Applications--Homes
Applications--Farms

Paul Gipe, wind-works.org
Single Turbine Interconnection
Cluster

Paul Gipe, wind-works.org
Wind Plant Arrays Clusters

Paul Gipe, wind-works.org
Wind Plant Arrays
Rectilinear

Paul Gipe, wind-works.org
Myths to Dispel

• Renewables Are Free or Cheap
  But They Are Affordable & They Are Worth It
• Renewables Can’t Be Added Quickly
  or Can’t Make a Difference
• Feed-in Tariffs Are Costly
Note:
500 kWh/m²/yr ~ 5 m/s
1400 kWh/m²/yr ~ 8 m/s
Renewables Can Scale Quickly

Paul Gipe, wind-works.org

Whitelee, Glasgow, Scotland
Wind Generation Growth in Selected Markets

Population in Millions


Year

0 2 4 6 8 10 12 14

TWh/year

California (40)
Ontario (13)
Portugal (10)
France (60)
GB (60)

Note that France started later than Great Britain but is now comparable.
German and Spanish Wind & Solar Generation

Germany 2012: ~50 TWh Wind; ~25 TWh Solar

Paul Gipe, wind-works.org
2011: ~50% of Total Renewables in Large Hydro. Hydro is highly variable, year to year.

Paul Gipe, wind-works.org
High Penetration Quickly is Possible

<table>
<thead>
<tr>
<th></th>
<th>Percent Wind</th>
<th>TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>2.5%</td>
<td>11.9</td>
</tr>
<tr>
<td>California</td>
<td>1.5-2.3</td>
<td>6.0</td>
</tr>
<tr>
<td>Germany</td>
<td>7.7%</td>
<td>47.0</td>
</tr>
<tr>
<td>Spain</td>
<td>16%</td>
<td>41.0</td>
</tr>
<tr>
<td>Portugal</td>
<td>18%</td>
<td>9.2</td>
</tr>
<tr>
<td>Denmark</td>
<td>28%</td>
<td>9.8</td>
</tr>
</tbody>
</table>

Multiple Sources
Paul Gipe, wind-works.org
Cowley Ridge, Alberta
High Penetration Quickly is Possible

<table>
<thead>
<tr>
<th></th>
<th>Percent Solar</th>
<th>2011 TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>3.7%</td>
<td>9.4</td>
</tr>
<tr>
<td>Germany</td>
<td>3.2%</td>
<td>19.3</td>
</tr>
<tr>
<td>Italy</td>
<td>3.1%</td>
<td>10.7</td>
</tr>
</tbody>
</table>
## World Biomass Penetration

<table>
<thead>
<tr>
<th></th>
<th>% Consumption</th>
<th>TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>8.6%</td>
<td>12.6</td>
</tr>
<tr>
<td>Germany</td>
<td>6.1%</td>
<td>37.0</td>
</tr>
<tr>
<td>Italy</td>
<td>3.3%</td>
<td>11.3</td>
</tr>
<tr>
<td>California</td>
<td>2.0%</td>
<td>5.7</td>
</tr>
</tbody>
</table>
## Geothermal Penetration Worldwide

<table>
<thead>
<tr>
<th>Country</th>
<th>% Consumption</th>
<th>TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iceland</td>
<td>30.0%</td>
<td>4.6</td>
</tr>
<tr>
<td>Philippines</td>
<td>27.0%</td>
<td>10.3</td>
</tr>
<tr>
<td>El Salvador</td>
<td>14.0%</td>
<td>1.4</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>13.1%</td>
<td>1.3</td>
</tr>
<tr>
<td>New Zealand</td>
<td>10.0%</td>
<td>4.1</td>
</tr>
<tr>
<td>California</td>
<td>4.4%</td>
<td>12.7</td>
</tr>
<tr>
<td>Indonesia</td>
<td>3.7%</td>
<td>9.6</td>
</tr>
<tr>
<td>Mexico</td>
<td>3.0%</td>
<td>7.0</td>
</tr>
<tr>
<td>Italy</td>
<td>1.6%</td>
<td>5.7</td>
</tr>
<tr>
<td>USA</td>
<td>0.3%</td>
<td>14.4</td>
</tr>
<tr>
<td>Japan</td>
<td>0.1%</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Reykjanesvirkjum, Iceland

Paul Gipe, wind-works.org
Overcost of French Renewable Tariffs

Source: www.cre.fr
Paul Gipe, wind-works.org

Year

Million Euros

Wind
Small Hydro
Other
Waste

TWh

0 5 10 15 20
0 50 100 150 200 250 300 350

2003 2004 2005 2006 2007 2008 2009

Source: www.cre.fr
Paul Gipe, wind-works.org
Cost of German EEG (2010) ~$110/yr/household

BMU: EEG Surcharge €0.023/kWh, 2010.

Paul Gipe, wind-works.org
Renewables: Making a Difference Today

Paul Gipe, wind-works.org

Dardesheim, Germany
## French Peak Electricity Consumption and the Great Freeze

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>MW</th>
<th>%</th>
<th>Installed MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear*</td>
<td>58,816</td>
<td>58.8%</td>
<td>63,100</td>
</tr>
<tr>
<td>Hydro</td>
<td>11,620</td>
<td>11.6%</td>
<td>25,200</td>
</tr>
<tr>
<td>Imports</td>
<td>7,350</td>
<td>7.4%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>5,680</td>
<td>5.7%</td>
<td></td>
</tr>
<tr>
<td>Oil</td>
<td>5,001</td>
<td>5.0%</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>4,722</td>
<td>4.7%</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>3,631</td>
<td>3.6%</td>
<td>6,640</td>
</tr>
<tr>
<td>Gas</td>
<td>3,177</td>
<td>3.2%</td>
<td></td>
</tr>
<tr>
<td><strong>Peak Demand</strong></td>
<td><strong>99,997</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Three reactors were off line.

[More information](http://sciences.blogs.liberation.fr/home/2012/02/le-grand-froid-met-le-syst%C3%A8me-%C3%A9lectrique-en-haute-tension.html)

Paul Gipe, wind-works.org
Renewables & the Great Freeze
German Solar & Wind Penetration February 7, 2012

Paul Gipe, wind-works.org
Germany’s Renewable Mix

- **Wind & Solar Mid-2012**
  - Wind: ≈30,000 MW
  - Solar: ≈30,000 MW

- **Yields ≈2X Higher with Wind**
  - Wind: ≈1,800 kWh/kW/yr
  - Solar: ≈900 kWh/kW/yr

Paul Gipe, wind-works.org
Daily “Smoothing” Wind & Solar

Average Daily Productivity Ratios in 2012
Wh/W.day (hour/day at rated power). Source of data: EEX

Bernard Chabot, www.renewablesinternational.net, 10 August 2012
Paul Gipe, wind-works.org
Wind or Solar? Mix is Best

• Intuitive: Wind & Solar Together Better than Each Alone
• Now We Have the Data Due to Germany
• Very Strong Daily “Smoothing”
• Extremely Strong Monthly “Smoothing”

Or, the Variability of Wind & Solar is Less Than the Variability of Wind & Solar Alone

Paul Gipe, wind-works.org
What is Optimum Mix?

• We Don’t Know
  Varies with Nation and Load Profile

• Winter Peaking Systems
  More Wind Than Solar
  Wind Peaks in Winter

Paul Gipe, wind-works.org
Schauinsland, Germany
What Does This Mean?

- Not Less Solar
- But More Wind
- Especially More Wind on Land

Landau, Rheinland-Pfalz, Germany
Offshore Wind

• Important?
  Yes--But No Panacea

• Essential?
  No

• High Risk, High Cost
  Germany: 1.7X Onshore Tariff

• Long Lead Times

Image: Google Earth
Paul Gipe, wind-works.org
Middelgrunden, Denmark
Titanium & Renewables?

- Wind Industry?
  Select Components
- Geothermal Industry?
  Highly Corrosive Environment
- Biogas?
  Highly Corrosive Environment
World Wind Industry

- Growth Rate: 20%-30%/yr
- Metal Mass
  - Tower: 200 t
  - Nacelle: 100 t

Paul Gipe, wind-works.org
Hvide Sande, Denmark
# Wind Industry Demand for Metal

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass/2 MW Turbine</td>
<td>300</td>
<td>t</td>
</tr>
<tr>
<td>Market</td>
<td>40,000</td>
<td>MW/yr</td>
</tr>
<tr>
<td>Turbines/yr</td>
<td>20,000</td>
<td></td>
</tr>
<tr>
<td>Steel Consumption</td>
<td>6,000,000</td>
<td>t/yr</td>
</tr>
<tr>
<td>% of World</td>
<td>0.5%</td>
<td></td>
</tr>
</tbody>
</table>

Paul Gipe, wind-works.org

Løgstør, Denmark
Scale of the Problem

. . . Or Size of the Market

North American Example
US Electricity Generation
~4,000 TWh/yr

- Nuclear: 801 TWh/yr
- Hydro: 289 TWh/yr
- Other: 81 TWh/yr
- Fossil-Fired: 2850 TWh/yr
Canadian Electricity Generation
~530 TWh/yr

- Hydro: 325 TWh/yr
- Nuclear: 75 TWh/yr
- New RE: 10 TWh/yr
- Fossil-Fired: 155 TWh/yr

Paul Gipe, wind-works.org
# Scale Needed: North America

<table>
<thead>
<tr>
<th>Thermal Generation</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>75,000</td>
</tr>
<tr>
<td>USA</td>
<td>1,500,000</td>
</tr>
<tr>
<td>Total</td>
<td>1,600,000</td>
</tr>
</tbody>
</table>

Paul Gipe, wind-works.org

Buffalo Ridge, Minnesota
Electric Vehicle Charging
### Scale Needed: North America

<table>
<thead>
<tr>
<th>Passenger Vehicle Miles</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>50,000</td>
</tr>
<tr>
<td>USA</td>
<td>750,000</td>
</tr>
<tr>
<td>Total</td>
<td>800,000</td>
</tr>
</tbody>
</table>
Scale Needed: North America

- ~2,500,000 MW Wind
- ~50x Today!
Can It Be Done Here?

- 300,000 Heavy Trucks/yr
- ~1/2 MW/Truck
- ~150,000 MW/yr Equivalent

Paul Gipe, wind-works.org

Buffalo Ridge, MN
Can It Be Done in North America?

- 2,500,000 MW / 200,000 MW/yr
- ~12.5 yrs
- <20 years Heavy Truck Production
  - Thermal Generation
  - Passenger Vehicle Miles
- Yes, It Can Be Done
- But Not At Current Pace

Paul Gipe, wind-works.org
North America is Capable of Huge National Undertakings

• TVA, BPA, WPA
• Ontario Hydro, Hydro Quebec
• Universal Health Care (Canada)
• Civil Rights, Anti-Smoking

Paul Gipe, wind-works.org
Aggressive Targets Require Aggressive Measures

### German Renewable Energy Targets

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>12.5%</td>
<td>39%</td>
<td>50%</td>
<td>80%</td>
</tr>
</tbody>
</table>
Elements of Success in Germany

- Right of Interconnection
- Right to Sell Electricity
- Right Price for Fixed Period

Paul Gipe, wind-works.org

Renewable Tariffs Launched

Advanced Renewable Tariffs (FITs) Launched
Germany’s 2020 Targets

- **52,000 MW Solar?**
  World Leading—Can Easily Be Met

- **46,000 MW Wind?**
  Insufficient Relative to Solar

- **36,000 MW Wind On Land?**
  More Wind on Land Needed
  Growth Must Quicken
  Need Public’s Support

Paul Gipe, wind-works.org
Increasing Acceptance: Rule #1

Your Own Pigs . . . Don’t Stink

Paul Gipe, wind-works.org

Biogas, Malstedt, Niedersacshsen, Germany
German Homeowners . . .

. . . New Revenue

• Anyone with a Roof Can Do Solar in Germany
• And Make Money Doing It!

Paul Gipe, wind-works.org
German Farmers . . .

. . . New Cash Crops

- Wind
- Solar PV
- Biogas

Friedrich-Wilhelm-Lübke-Koog, Germany
German Ownership of Renewables in 2010: 53,000 MW

- Individuals: 40%
- Farmers: 11%
- Developers: 14%
- Utilities: 13%
- Investment Funds: 11%
- Industrial: 9%
- Others: 1%

www.unendlich-viel-energie.de
Paul Gipe, wind-works.org
German Ownership of Biogas in 2010: 2,300 MW

- Farmers: 72%
- Developers: 13%
- Utilities: 6%
- Investment Funds: 3%
- Industrial: 5%
- Others: 0%
- Individuals: 0%

1,600 MW ~$10 Billion

USA Biogas: 50 MW!

Paul Gipe, wind-works.org
German Ownership of Solar PV in 2010: 17,000 MW

- Individuals: 39%
- Industrial: 19%
- Others: 1%
- Investment Funds: 8%
- Utilities: 8%
- Developers: 3%
- Farmers: 21%

10,000 MW ~$60 Billion!

Paul Gipe, wind-works.org

www.unendlich-viel-energie.de
German Ownership of Wind in 2010: 27,000 MW

- Individuals: 52%
- Farmers: 21%
- Developers: 16%
- Utilities: 7%
- Investment Funds: 2%
- Industrial: 2%

14,500 MW ~$30 Billion!

www.unendlich-viel-energie.de
Paul Gipe, wind-works.org
Germany’s Jeffersonian Rebels
Powering an Energy Revolution

• The Power of Community Ownership
Local, Distributed, Democratic

Nico Petersen, Solar Park Rodenäs
Paul Gipe, wind-works.org
Rebel Agenda

• We Want Renewable Energy
• We Can Do It Ourselves
• We Bring Our Own Risk Capital and Invest in Our Own Region
• We Accept the Change in the Landscape that Results

Hans-Detlef Feddersen on the Bürgerwind Movement.

Paul Gipe, wind-works.org
Friedrich-Wilhelm-Lübke-Koog, Germany
Electricity Rebellion--the Rallying Cry

Renewable Energy “is a local resource. It is our resource. And we want to make money from it.”--Wolfgang Paulsen (Stromrebelle)
Anton Bro
Thyborøn-Harboøre Vindmøllelaug

- Near Offshore
- Share Cooperative
- 4 x 2 MW
- 35 Million kWh/yr
- All Information Public on the Web

Paul Gipe, wind-works.org
Josef Pesch, Fesa

- 45 MW
- 60 million kWh/yr
- Just One of Many

Paul Gipe, wind-works.org
Ursula Sladek, EWS
(Elektritzitätswerke Schönau)

- 31,000 Customers
- Hydro, Solar, & Wind
Meet the Rebel Mayor of Dardesheim
Bürgermeister Rolf-Dieter Künne

• Proud of Männerchor
• Proud of Brass Band
• Proud of Wind & Solar
  100% Renewable Energy

Paul Gipe, wind-works.org
Local People Helping Local People
Hans-Heinrich Andresen

- Manages 16 Wind Farms
- in 16 Villages
- All Locally Owned
  - 15 Owners in Smallest
  - 400 Owners in Largest
- Now Planning Their Own Transmission Line

Paul Gipe, wind-works.org
Revolutionary: 100% Renewable

- Dardesheim Today—Electricity
- Schleswig-Holstein 2020—Electricity
- Rheinland-Pfalz 2030—Electricity
- Scotland 2020—Electricity
- Denmark 2035—Electricity & Heat

50% Wind by 2020

Paul Gipe, wind-works.org

Druiberg, Sachsen-Anhalt, Germany
What Has Made the Revolution Possible? What Has Empowered the Rebels?

• Grid Access
• Priority to Renewables
• Advanced Renewable Tariffs
• Desire to Make it Work!

Paul Gipe, wind-works.org  Jutland, Denmark
Renewable Policy--Best Practice

• **Bold Targets**
  That Can Excite the Imagination

• **Advanced Renewable Tariffs**
  . . . A System of Feed-in Tariffs

Landau, Rheinland-Pfalz, Germany
Feed-in Tariff Best Practice

- Policies Must be Comprehensive and Inclusive . . . Open to All for All
Comprehensive & Inclusive

• Wind & Solar
• Biomass & Geothermal
• Renewable Heat
“Nothing is as powerful as an idea whose time has come.”
-- Victor Hugo*

*"Il n'est rien au monde d'aussi puissant qu'une idée dont l'heure est venue." Victor Hugo*
A Challenge Worthy of Great Nations

Paul Gipe, wind-works.org

Vestas V110, Denmark
Time to Take the Road to the Future

Freiburg, Germany

Paul Gipe, wind-works.org
We Need A Lot More Wind . . .

Paul Gipe, wind-works.org

Matane, Quebec
A Lot More Geothermal
A Lot More Renewable Energy Technology for Life*

*from N.F.S. Grundtvig, Danish Theologian
Paul Gipe, wind-works.org
Renewable Energy

The Revolution Has Begun!

Manawatu Gorge, New Zealand

www.wind-works.org