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

Disclosure: Paul Gipe has worked with Aerovironment, ANZSES, An Environmental Trust, APROMA, ASES, AusWEA, AWEA, David Blittersdorf, Jan & David Blittersdorf Foundation, BWEA, BWE, CanWEA, Canadian Co-operative Assoc., CAW, CEERT, Deutsche Bank, DGW, DSF, EECA, ES&T, GEO, GPI Atlantic, IREQ, KWEA, MADE, Microsoft, ManSEA, MSU, NRCan, NRG Systems, NASA, NREL, NZWEA, ORWWG, OSEA, Pembina, PG&E, SeaWest, SEI, TREC, USDOE, WAWWG, WE Energies, the Folkecenter, the Izaak Walton League, the Minnesota Project, the Sierra Club, World Future Council, and Zond Systems, and written for magazines in the USA, Canada, France, Denmark, and Germany.
Wind Energy 101

By Paul Gipe
Why Now?

• Wind Works
  Greater Reliability

• Productivity Improved
  More Efficient
  Taller Towers

• Costs Declined
  Economies-of-Scale

Paul Gipe, wind-works.org
We Know What Works 
...and What Doesn’t

Eole, Cap Chat

© Vortec

Paul Gipe, wind-works.org
40 m, 500 kW
Northern Ireland

80 m, 1.8 MW
Kincardine, Ontario

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
Wind is Modular

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

Paul Gipe, wind-works.org

Tehachapi, California
Wind is Flexible

• Scale
  Big 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
Birds & Bats

- Before & After Studies of Big Projects
- Studies Necessary for Small Projects?
Mortality Rate

• 45 Deaths in 36 years
• Most in Construction
• Highest Mortality Rate
  CAD, GB, NL
• 4 with Small Turbines
• 2 Members of the Public
  German Parachutist,
  American Pilot

Paul Gipe, wind-works.org
Public Safety

- No Passerby Killed or Injured
- Ice Throw
  Max. 100 m
  1.5 X Height
  Post Warnings
- Blade Throw
- Suicides
  Attractive Nuisance

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

Paul Gipe & Assoc.
Applications--Farms

Paul Gipe & Assoc.
Wind Plant Arrays Clusters

Paul Gipe & Assoc.
Cluster
Applications--Wind Power Plants
Typical California Spacing

3 RD

6 RD

Paul Gipe & Assoc.
Wind Plant Arrays--Rectilinear

160-250 kW: Mojave, California

Paul Gipe, wind-works.org
Lessons
From 30+ Years of Experience

• No Panaceas
• No Cheap Solutions
• No Breakthroughs--No Miracles
• Numbers Matter
• Experience Matters
• Size Matters

Paul Gipe, wind-works.org
Lessons

• Always Check the Numbers
  Vortec: The Numbers Didn’t Add Up

• Always Check the References
  Vortec: References Discredited in the USA

• Always Google
  Vortec: Ducted Turbine Critics on the Web

• Always Go to the Library
  . . . Or to Your Neighborhood Bookstore!
  Lots of Wind Books Now Available

Paul Gipe, wind-works.org
Lessons

• Always Be Wary of “New” Designs

Paul Gipe, wind-works.org

© Vortec
Scams, Frauds, & Flakes
Tell-Tale Signs

• Hype High--Experience Low
• New Design-- “Not Like Those Others”
• “New” Patents
• “Works @ 2 m/s!
• Drag Devices (Squirrels in a Cage)
• Ducted Turbines!
• Pyramid Schemes
  “Get in on the Ground Floor Now”
• Fancy Web Sites
  Cheaper than Hardware

Paul Gipe, wind-works.org
Measures of Productivity

- **Capacity (Plant) Factor**
  - Misleading Indicator
  - Used for Fossil-Fired Plants
  - Not Suited for Wind Energy Use

- **kWh/kW/yr (for Planning Purposes)**
  - When Sufficient Data is Unavailable

- **Annual Specific Yield (kWh/m²/yr)**
  - The Only Measure Specific to Wind Energy
Measures of Cost

- $/kW of Installed Capacity
  Often a Misleading Indicator

- $/m^2 of Installed Swept Area
  Most Useful When Resource is Unknown

- $/kWh/yr of Annual Generation
  Most Important Criteria in the End

Paul Gipe, wind-works.org
Power in the Wind

\[ P = \frac{1}{2} \rho A V^3 \]

Where \( \rho \) is air density (kg/m\(^3\)),
\( A \) is area (m\(^2\)), and
\( V \) is velocity (m/s).

Paul Gipe, wind-works.org
AEO Estimating Methods

• Back-of-the-Envelope (Swept Area)
  Simple Approximation

• Power Curve & Speed Distribution
  Method Used by the Pros
  Accuracy Dependent Upon Data

• Manufacturers’ Tables
  Dependent Upon Honesty of Manufacturer

• Software
  Must Know Assumptions Used (RETScreen)
Energy in the Wind

Annual Energy Output (AEO)
Annual Energy Production (AEP)

\[ \text{AEO} = \frac{1}{2} \rho \ A \ V^3 \ \eta \ (8,760 \ \text{hrs/year}) \]

Paul Gipe, wind-works.org
Rotor Dimensions

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

Rotor Diameter (m)

Swept Area (m²)

Paul Gipe, wind-works.org
## Typical Size in Swept Area

<table>
<thead>
<tr>
<th>Rotor Diameter (m)</th>
<th>Swept Area (m²)</th>
<th>Rating (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>80</td>
<td>25</td>
</tr>
<tr>
<td>25</td>
<td>500</td>
<td>250</td>
</tr>
<tr>
<td>36</td>
<td>1,000</td>
<td>500</td>
</tr>
<tr>
<td>50</td>
<td>2,000</td>
<td>750</td>
</tr>
<tr>
<td>62</td>
<td>3,000</td>
<td>1,000</td>
</tr>
<tr>
<td>71</td>
<td>4,000</td>
<td>1,500</td>
</tr>
<tr>
<td>80</td>
<td>5,000</td>
<td>2,000</td>
</tr>
</tbody>
</table>

Paul Gipe, wind-works.org
### Tararua Wind Plant New Zealand Specific Yields

<table>
<thead>
<tr>
<th>Diameter m</th>
<th>Swept Area m²</th>
<th>Specific Yield kWh/m²/yr</th>
<th>Approximate kWh/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>1,735</td>
<td>840</td>
<td>1,457,901</td>
</tr>
<tr>
<td>47</td>
<td>1,735</td>
<td>1,440</td>
<td>2,500,000</td>
</tr>
<tr>
<td>47</td>
<td>1,735</td>
<td>1,760</td>
<td>3,050,622</td>
</tr>
</tbody>
</table>

AEO Medium & Large Turbines

AEO for Large Wind Turbines
Per Square Meter of Swept Area

Average Annual Wind Speed (m/s)

AEO Annual Wind Speed (mph)

Average Annual Wind Speed (m/s)

Average Annual Wind Speed (mph)

Paul Gipe, wind-works.org
Configuration: Axis of Rotation

HAWT

VAWT

Paul Gipe & Assoc.
VAWT Configurations

“H”  DELTA  DIAMOND  “Y”  PHI

Paul Gipe, wind-works.org
VAWTs
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
Towers & Tower Safety
Towers-Tubular Medium & Large Wind Turbines

Paul Gipe, wind-works.org
Aerial Lifts

Paul Gipe, wind-works.org
Ladders

Paul Gipe, wind-works.org
Ladder Fall Protection

fall protection device
climbing cable
lock
hook

© Lagerwey

Paul Gipe, wind-works.org
Safety

- Helmet
- Gloves
- Harness
- Radio

Paul Gipe, wind-works.org
Small Wind--A Checkered Past

• Poor Performance
• Poor Reliability
• Costly
• Noisy
• Magnet for Hustlers & Charlatans
• Unsafe

Paul Gipe, wind-works.org
Poor Performance

- 1/2 That of Large Turbines At Best
- Seldom Meet Projections
- Short Towers = Big Problem

Holzhausen, Germany
Paul Gipe, wind-works.org
Typical Yields
Large & Small Turbines

Paul Gipe, wind-works.org
Wulf Field Tehachapi, California
Turbines Tested

Paul Gipe, wind-works.org
Incredible Shrinking Wind Turbine

- Air 403: 400 W
- AirX: 300 W
- Air Breeze: 200 W
- Air Breeze: 150 W
- Measured: 125 W
Too Short a Tower
Worst Turbine Install?

• Helix VAWT
• Seattle, WA
• If You Don’t Know What’s Wrong with This Picture, You Are in the Wrong Business!

Paul Gipe, wind-works.org

Photo by Mike Nelson, WSU
Too Short a Tower
Worst Turbine Install?

• Mariah VAWT
• Indianapolis, IN
• Kinetic Sculpture--Not a Wind Turbine

Photo by Laura Arnold, INREA

Paul Gipe, wind-works.org
Poor Reliability

- Cheap = Short Life
- Seldom Last Long Enough
- Many Remain Derelict For Years

Paul Gipe, wind-works.org
H40 Wulf Test Field
H40 4-Year Life

- Blade Failure
- Yaw Failure
- Insulation Failure
## Small Wind Too Costly
### 3X Large Wind

<table>
<thead>
<tr>
<th>Size</th>
<th>Low ($/m²)</th>
<th>High ($/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro</td>
<td>1,500</td>
<td>2,500</td>
</tr>
<tr>
<td>Mini</td>
<td>1,250</td>
<td>2,500</td>
</tr>
<tr>
<td>Household</td>
<td>1,250</td>
<td>2,250</td>
</tr>
<tr>
<td>Small Commercial</td>
<td>800</td>
<td>1,250</td>
</tr>
<tr>
<td>Large</td>
<td>700</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Adapted from Wind Energy Basics: A Guide to Home- and Community-Scale wind Energy Systems

Paul Gipe, wind-works.org
Small Wind Turbines Too Noisy

Noise Emissions: Source Sound Power Level at 8 m/s
Paul Gipe, wind-works.org
Magnet for Hustlers & Charlatans

- Ease of Entry
- Preying on Ignorance
- Pyramid Schemes
- Drag & Ducted Devices
- Fantasy Wind
- Roof Top Wind

Magwind, Whitby Ontario

Paul Gipe, wind-works.org
Roof Top Mounting?

- Turbulence
- Poor Performance
  ~0 Net Energy!
- Noise & Vibration
- Safety
- Simply a Bad Idea

Possibly Dublin, circa 1990s

Paul Gipe, wind-works.org
Roof Top Mounting?

• No, Don’t Do This!
Roof Top Mounting?

• Tied Off

Paul Gipe, wind-works.org
Small Wind Turbine Tower Safety

- No Fall-Arrest System
- No Work Platform
- No Anchors
- No Training

Paul Gipe, wind-works.org
Canyon, Texas, 1979
Small Wind Turbine Tower Safety

• Tilt-up Towers for Micros & Minis Always Preferable

Paul Gipe, wind-works.org
Small Wind Turbine Tower Safety

- Person Lifts
- Fall Arrest Systems
- Work Platforms
- Anchors
- Rotor Locking Pins
- Tower Training

Paul Gipe, wind-works.org
Small Wind Turbine Fall Safety

- Work Platform
- Anchors
- Full Harness
- Lanyard
Small Wind Programs Overview

• The “Best” On-Grid Programs in USA by Mick Sagrillo & Mike Bergey

• The Results
  Units, MW, Performance

• Time for Change
  Long Overdue

• Proposed Feed-in Tariffs

Paul Gipe, wind-works.org
Small Wind Programs in USA

- Wisconsin: Failed
- California: Failed
- Oregon: Failed
- Washington State: Failed
- USA: Failed
Small Wind Programs Worldwide Summary

• All Have Failed To Date
  In Volume
  In Capacity
  In Generation
  In Reliability

Paul Gipe, wind-works.org
Paying for Performance Leads to Maturity

• After 30 Years
  Time for Small Turbine Industry to Grow Up

Paul Gipe, wind-works.org
Skystream
Cost of Energy Estimates

Skystream, Alexandria, Indiana

Paul Gipe, wind-works.org
Skystream Tariff Needed

Assumptions

• $13,500 Installed
• Yield from SWP Estimates*
• Annual Reoccurring Expenses: 4%
• 6 m/s

* Not Independently Verified.
Paul Gipe, wind-works.org
## Skystream Tariff Needed
### Chabot Profitability Index Method

<table>
<thead>
<tr>
<th>Average Weighted Cost of Capital Before Tax</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity</td>
<td>20%</td>
</tr>
<tr>
<td>Return on Equity</td>
<td>13.0%</td>
</tr>
<tr>
<td>ROE</td>
<td></td>
</tr>
<tr>
<td>Debt</td>
<td>80%</td>
</tr>
<tr>
<td>Interest on Debt</td>
<td>6.94%</td>
</tr>
<tr>
<td>Nominal AWCC</td>
<td>0.0815</td>
</tr>
<tr>
<td>Inflation</td>
<td>3.0%</td>
</tr>
<tr>
<td>AWCC real</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td>5.0%</td>
</tr>
</tbody>
</table>

Paul Gipe, wind-works.org
### Skystream Tariff Needed

#### Chabot Profitability Index Method

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor Diameter</td>
<td>3.7 m2</td>
</tr>
<tr>
<td>Installed Cost</td>
<td>$13,500</td>
</tr>
<tr>
<td>Specific Installed Cost</td>
<td>$1,256</td>
</tr>
<tr>
<td>Annual Expenses</td>
<td>4.0%</td>
</tr>
<tr>
<td>Term</td>
<td>20 years</td>
</tr>
<tr>
<td>Discount Rate (AWCC)</td>
<td>5.0%</td>
</tr>
<tr>
<td>Specific Yield</td>
<td>446 kWh/m2/y</td>
</tr>
<tr>
<td>Capital Recovery Factor (n,t)</td>
<td>0.0802</td>
</tr>
<tr>
<td>Profitability Index Target</td>
<td>0.3 NPV/I</td>
</tr>
<tr>
<td>Cost of Energy</td>
<td>$0.406</td>
</tr>
<tr>
<td>Simple Payback</td>
<td>9.6 years</td>
</tr>
</tbody>
</table>

Paul Gipe, wind-works.org
Skystream Tariff Needed
$0.30-$0.38/kWh at 6 m/s

Paul Gipe, wind-works.org
## Canadian Proposed Small Wind Tariff

<table>
<thead>
<tr>
<th>Tier</th>
<th>Coverage Area</th>
<th>CAD/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1:</td>
<td>&lt;50 m²</td>
<td>0.30-0.40</td>
</tr>
<tr>
<td>Tier 2:</td>
<td>&gt;50 m² &lt;500 m²</td>
<td>0.20-0.25</td>
</tr>
</tbody>
</table>

Proposed by Paul Gipe  
Paul Gipe, wind-works.org  
Iles de la Madeleine, Quebec
## Small Wind Tariff Summary

<table>
<thead>
<tr>
<th>Country</th>
<th>CAD/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>0.50</td>
</tr>
<tr>
<td>Israel</td>
<td>0.40-0.50</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.21</td>
</tr>
<tr>
<td>Vermont</td>
<td>0.20</td>
</tr>
<tr>
<td>Britain</td>
<td>0.30-0.40</td>
</tr>
<tr>
<td>Nova Scotia</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Paul Gipe, wind-works.org
Small Wind--What’s Needed

• Compulsory Standards
  For Products & Installers

• Testing
  with Published Results!

• Facing Reality
  Small Wind’s Limits
  What Small Wind Can &
  Cannot Do

Paul Gipe, wind-works.org

Chateau Lastours, France
Small Wind--Facing Reality

• Many SWT Not Ready for Prime Time
• Much Must be Done
• Performance Will Lag Large Turbines
• Micros & Minis for Battery Charging

Paul Gipe, wind-works.org

Chateau Lastours, France
The Small Wind Industry Needs Advanced Renewable Tariffs or it Will Remain Insignificant

Paul Gipe, wind-works.org
What is Community Wind?

- Local
  Rooted in and Responsible to the Community
- Locally Owned
  Cooperative, First Nation, Farmer-Owned
- Commercial-Scale Generation
- Small Projects Making a Big Difference

Paul Gipe, wind-works.org
Why Community Wind?

- Participation = Greater Acceptance
- Distributed = Greater Resiliency
- Clean & Green (Mostly)
- Human Scale
- Enables Local Ownership
- New Cash Crop For Farmers

Paul Gipe, wind-works.org

Schleswig-Holstein, Germany
Community Wind--The Third Way

Is North America Being Left Behind?

• No
  Time to Get It Right
• It’s Not Easy Here
  Frustrating? Yes!
• Only the Beginning
  Minnesota
  Ontario

Paul Gipe, wind-works.org
Chateau de Lastours, France
Wieringemeer
Noord Holland

- 5 x 600 kW
- Co-owned
  1/2 by Two Farmers
  1/4 by NEG-Micon
  1/4 by Utility
Lynetten Co-op København

- 7 x 600 kW
- 4 Owned by Co-op
- 3 Owned by Municipal Utility

Paul Gipe, wind-works.org
Middelgrunden Co-op København

- 20 x 2 MW Off-shore
- 1/2 Owned by Co-op
- 1/2 Owned by Utility
- 8,500 Investors
- €570 per Share
- Visible from Christiansborg Palace

Paul Gipe, wind-works.org
German Co-ops (*Bürgerbeteiligung*)

- +200,000 Own Shares
- 80% Schleswig-Holstein
- 90% Nordfriesland Amt

Schauinsland, Germany

Paul Gipe, wind-works.org
## Co-Op & Farmer-Owned Wind

<table>
<thead>
<tr>
<th>Country</th>
<th>Farmer</th>
<th>Co-op</th>
<th>Corporate</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Netherlands</td>
<td>60%</td>
<td>5%</td>
<td>35%</td>
</tr>
<tr>
<td>Germany</td>
<td>10%</td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>Denmark</td>
<td>64%</td>
<td>24%</td>
<td>12%</td>
</tr>
<tr>
<td>Great Britain</td>
<td>1%</td>
<td>1%</td>
<td>98%</td>
</tr>
<tr>
<td>Spain</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: Dave Toke, University of Birmingham, 2005, 2008

Paul Gipe, wind-works.org
# Community Wind Economic Impact

From Operations

<table>
<thead>
<tr>
<th></th>
<th>Community Wind (5%)</th>
<th>Community Wind (8%)</th>
<th>Corporate Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value Added</td>
<td>$1,300,000</td>
<td>$640,000</td>
<td>$250,000</td>
</tr>
<tr>
<td>Jobs</td>
<td>14.5</td>
<td>8.2</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Arne Kildegaard  
University of Minnesota, Morris

Paul Gipe, wind-works.org
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
Heinrich Bartelt, Dardesheim

- 62 MW Wind
- 380 kW Solar PV
- 5% Royalties
  - 1% for Nearby Villages
  - 2% for Landowners with Turbines
  - 2% for Landowners without Turbines

Paul Gipe, wind-works.org
François Pélissier, Erélia

- Le Haut des Ailes, Lorraine
- 32 MW
- Objectives
  - New Jobs Locally
  - New Opportunity Locally

Paul Gipe, wind-works.org
Wind Works!