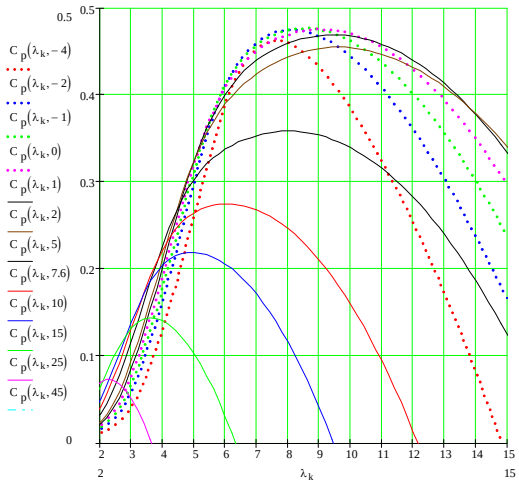
Economics of Distributed Renewable Projects

Wind Interconnection Workshop
Golden, CO
May 22, 2013

Tom McDermott, tom@meltran.com
MelTran, Inc.

UWIG Utility Wind Integration Group

Power ➔ Wind Speed Cubed



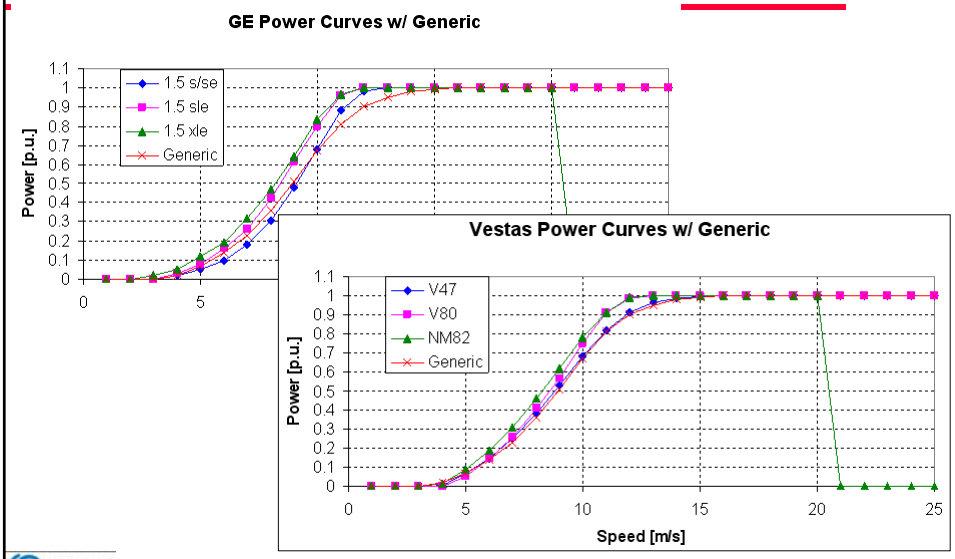
$$P = \frac{1}{2} \cdot \rho \cdot \pi \cdot R^2 \cdot \upsilon^3 \cdot C_p \cdot \eta_G \cdot \eta_B$$

ρ = relative air density
R = swept area radius
v = wind speed
C_p = coefficient of performance
η_G = generator eff.
η_B = bearings/gearbox eff.
λ_k = tip speed ratio

UWIG Utility Wind Integration Group

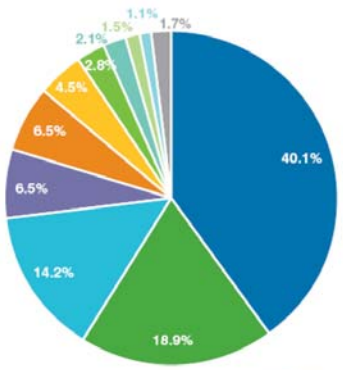
2

Sample WTG Power Curves



3

Top Turbine Suppliers



Ranking	Company	Capacity through 2012, MW
1	GE Energy, Enron, Zond, Tacke	24,085
2	Vestas, NEG Micon, Micon, Nordtank, NedWind, Wind World	11,363
3	Siemens, Bonus	8,506
4	Gamesa	3,923
5	Mitsubishi	3,899
6	Suzlon	2,685
7	Clipper	1,700
8	REpower	1,259
9	Acciona	908
10	Nordex	674
	Others	1,005

Others includes AAER, Alstom, CCWE, DeWind, Elecon, EWT, Fuhrlander, Goldwind, Guodian, Hyundai, HZ Windpower, Kenersys, Leitner-Poma, Nordic, Northern Power Systems, PowerWind, Samsung, Sany, Sinovel, Unison, VENSYS and more.

Source: AWEA 2012 Executive Summary Report

4

Turbine Power Curve Library

Model	kW	Model	kW	Model	kW
Acciona AW77 / 1500	1500	Gamesa G52-850	850	Northwind 100/19	100
AOC 15/50	65	Gamesa G80-2.0	2000	Northwind 100/20	100
Clipper C100 / 2500	2500	Gamesa G83-2.0	2000	NorthWind 100/21	100
Clipper C89 / 2500	2500	Gamesa G87-2.0	2000	RePower MD77 / 1500	1500
Clipper C93 / 2500	2500	GE 1.5 s/se	1500	RePower MM70 / 2000	2000
Clipper C96 / 2500	2500	GE 1.5 sle	1500	RePower MM82 / 2000	2000
Entegrity EW15 / 65	65	GE 1.5 xle	1500	RePower MM92 / 2000	2000
Fuhrlander 1500/70	1500	GE 2.5 xl	2500	Suzlon S64 / 1250	1250
Fuhrlander 1500/77	1500	MWT 92 / 2400	2400	Suzlon S64 / 950	950
Fuhrlander 2500/100	2500	MWT 95 / 2400	2400	Suzlon S66 / 1250	1250
Fuhrlander 2500/80	2500	NEG Micon 48 / 750	750	Suzlon S88 / 2100	2100
Fuhrlander 2500/90	2500	NEG Micon 52 / 900	900	SWT-1.3-62	1300
Fuhrlander FL100	100	NEG Micon 54 / 950	950	SWT-2.3-82	2300
Fuhrlander FL1250	1250	NEG Micon 72 / 1500	1500	Vestas NM82 / 1650	1650
Fuhrlander FL250	250	Nordex N100 / 2500	2500	Vestas V15 / 75	75
Fuhrlander FL30	30	Nordex N60 / 1300	1300	Vestas V27 / 225	225
Fuhrlander FL600	600	Nordex N80 / 2500	2500	Vestas V47 / 650	660
Fuhrlander MD 70 / 1500	1500	Nordex N90 / 2300	2300	Vestas V80 / 1800	1800
Fuhrlander MD 77 / 1500	1500	Nordex S70 / 1500	1500	Vestas V90-3.0 / 3000	3000
		Nordex S77 / 1500	1500		

UWIG Utility Wind Integration Group

5

Wind Production

UWIG Utility Wind Integration Group

Distributed Wind Economics

- Capacity Factor: Determines Energy Production
- Look at Wind as an Energy Source, not Capacity
- Tax Incentives: Enhance the cash flow
  - Production Tax Credit (PTC)
  - Clean Renewable Energy Bonds (CREB)
- Grants and other incentives may be available
- Plus the usual considerations
  - Debt and Equity financing
  - Insurance, O&M, tax requirements
  - Evaluate by net present value (NPV), internal rate of return (IRR), payback period, etc.

UWIG Utility Wind Integration Group

7

Economic Screening Applet

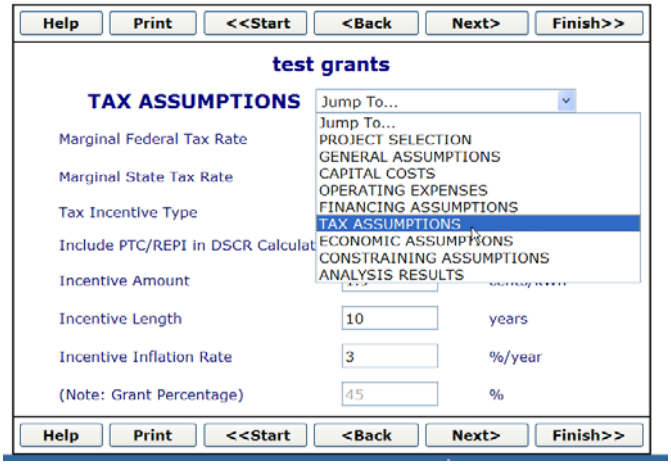
- Based on NREL's WindFinance
  - http://analysis.nrel.gov/windfinance/login.asp
- UWIG Added:
  - Power Curve download for the Feeder Simulator
  - Sensitivity Analysis: 1 output vs. 2 inputs
  - Almost 60 Power Curves
  - Temperature Effect on Air Density
  - Grant Effect on PTC and Depreciation

UWIG Utility Wind Integration Group

8

Economics: Base Case

- 7 Input Screens
- Saves Data on the Server
- Sample Files on the Server



9

Wind Cost Guidelines

- Capital: $2.2 (+/- 50%) million per MW capacity
- O&M: either $15-25/kW, or $0.005-0.01/kwhr
- Site Royalty: either $2.5-4.0 thousand per MW, or 3% of annual revenues
- Insurance: 0.25-1.0% of capital cost, annually
- Property Tax: check state and local laws
- Local Incentives: enter a Grant Percentage under “Financing Assumptions”

10

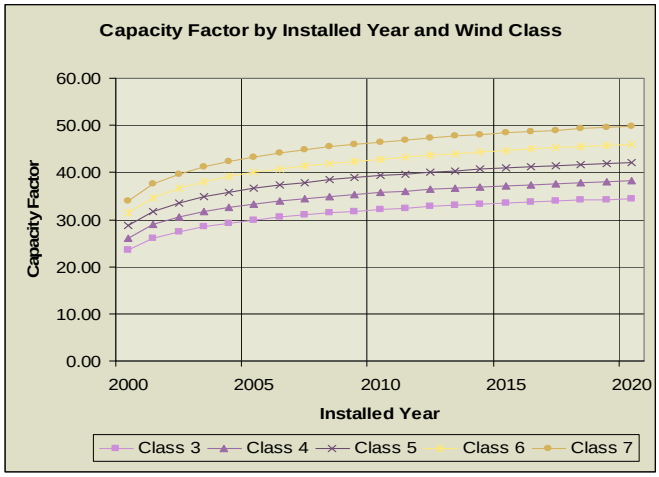
Wind Capacity Factor

- Energy = CF * (8760 hrs/yr) * (kW rating)
- Wind speeds are variable
  - Power depends on speed^3
  - Actual site measurements are best
- Electrical power output depends on the turbine and interface design
  - Complicated function of aerodynamics and controls
  - Controls are generally considered proprietary

UWIG Utility Wind Integration Group

11

Wind Capacity Factor Projections

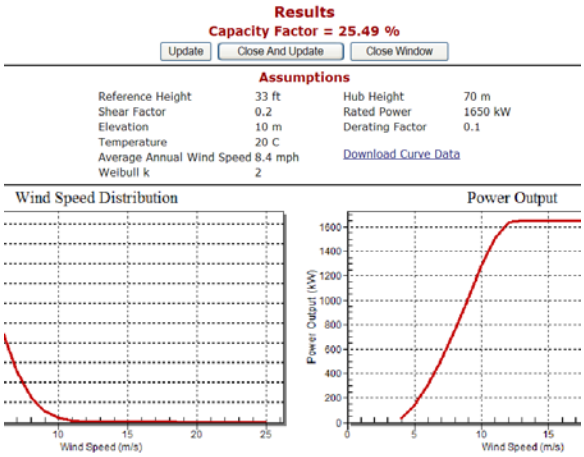


UWIG Utility Wind Integration Group

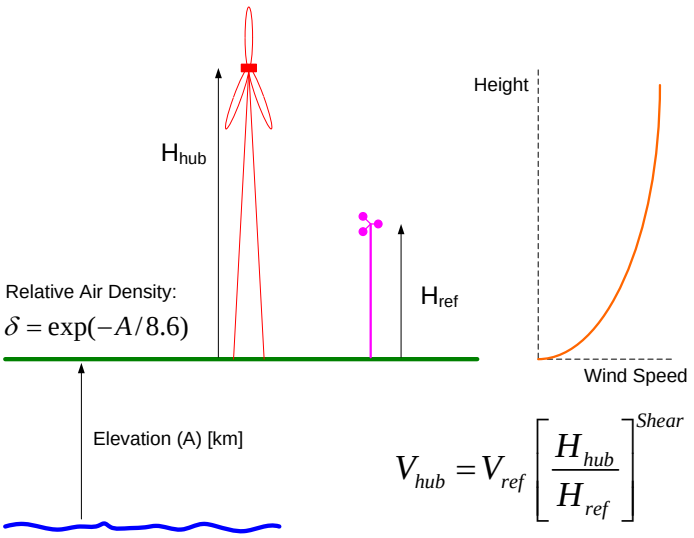
12

Wind Capacity Factor Module

- Wind Data:
  - Actual Measured Distribution
  - Measured Average Annual Speed
  - Average Annual Speed from a Map
- Power Curve:
  - Specific
    - » From Library
    - » Uploaded
  - Generic



Heights, Elevation, and Shear Factor



$$V_{hub} = V_{ref}\left[\frac{H_{hub}}{H_{ref}}\right]^{Shear}$$

Shear Factor Guidelines

- 0.10 Water
- 0.14 Low grass or steppe
- 0.20 Rural with obstacles
- 0.25 Suburbs and woodlands
- Measurements at 100 m reference height can look **much** better than at 50 m reference height

UWIG Utility Wind Integration Group

15

Relative Air Density

- Power Curves are for standard 1.225 kg/m^3
  - Elevation is 0 m, Temperature 15 °C or 288.15 °K
- Correction for Elevation only:

$$\delta = \frac{\rho}{1.225} = \left(\frac{288.15 - 0.0065h}{288.15} \right)^{5.2588}$$

- δ (0 m) = 1.000
- δ (1000 m) = 0.887
- "Lapse Temperature" at 1000 m is 281.65 °K
- Earlier version used 4.256 exponent
  - δ (1000 m) = 0.9074

UWIG Utility Wind Integration Group

16

Effect of Temperature w/ Elevation

- Correction for both Elevation and Temperature:

$$\delta = \frac{\rho}{1.225} = \frac{P_o}{RT}\exp\left(\frac{-gh}{RT}\right)$$

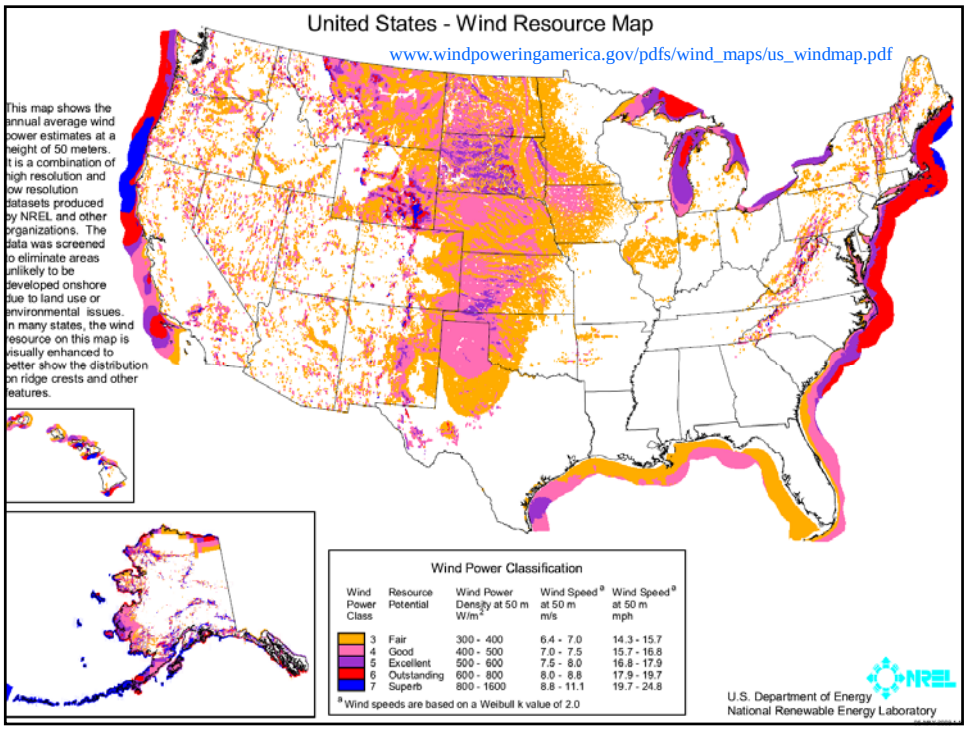
- P_0=101325, R=287.05, g=9.80665, T=273.15 + °C:

$$\delta = \frac{288.15}{T}\exp\left(\frac{-h}{29.271T}\right)$$

Example δ	T = 0 °C	T = 15 °C
h = 0 m	1.0549	1.0000
h = 1000 m	0.9309	0.8882

UWIG Utility Wind Integration Group

17



Wind Capacity Factor Data Sources

- Wind Speeds
  - www.nrel.gov/wind/resource_assessment.html
  - Links to state maps, or national map if no state map
- Elevation
  - earth.google.com (requires a download)
  - www.earthtools.org (no download)
- Temperature
  - www.weatherbase.com (by month)
- Turbine Power Curves
  - Google for the vendor's brochure
  - www.inl.gov/wind/software/ (Excel spreadsheets)

UWIG Utility Wind Integration Group

19

Solar Production

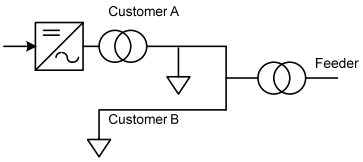
UWIG Utility Wind Integration Group

Photovoltaic Generation

Source: Charlie Williams, S&C

Inverter Based Interface

- Control Interactions?
- Cloudy Day Variability
- Limit Secondary Unbalance to 20% of Transformer Rating

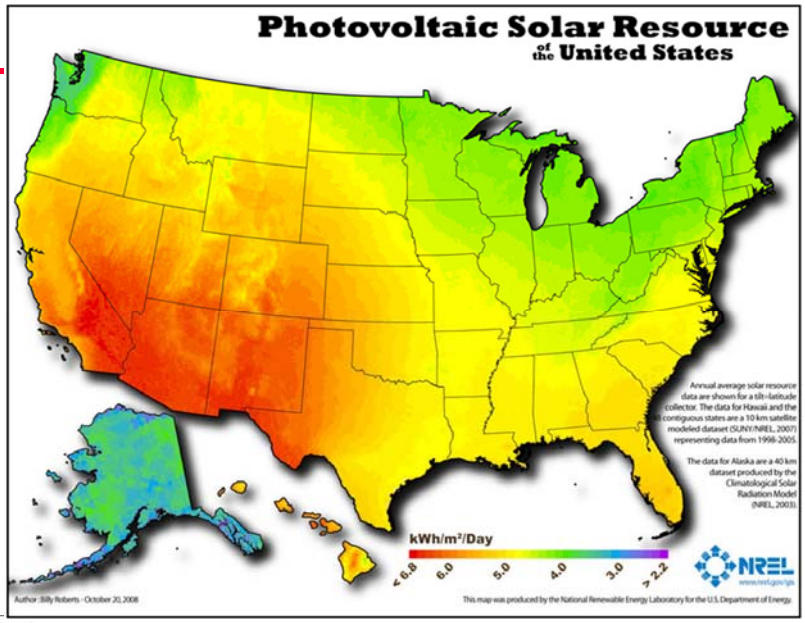


21

Distributed PV Economics

- "Capacity Factor" still crucial:
  - Technology and cell type
  - Latitude, azimuth, tracking systems
  - Temperature dependence
  - Summer peaking vs. typical winter peaking for wind
  - Daytime peaking vs. typical night peaking for wind
- No Production Tax Credit
- Other Tax Credits May Apply
- Financing and Cash Flow Considerations

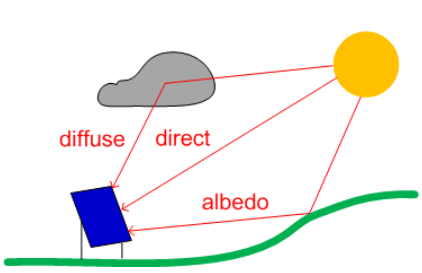
22

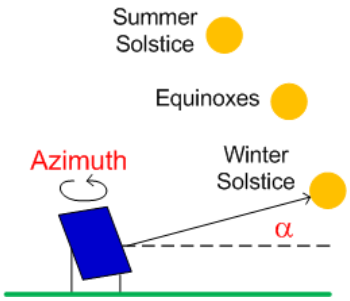


UWIG Utility Wind Integration Group

23

PV Angle Effects





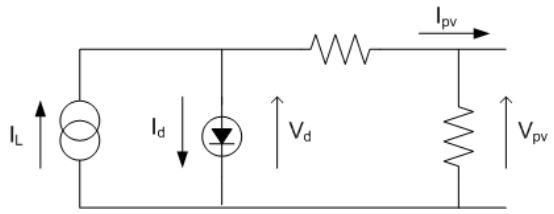
- Best elevation depends on latitude and season
- Best azimuth depends on time of day

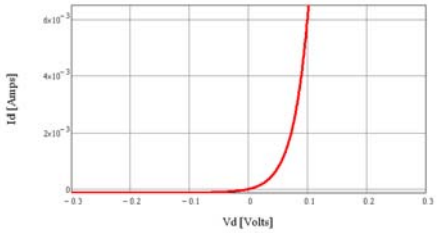
UWIG Utility Wind Integration Group

24

PV Cell

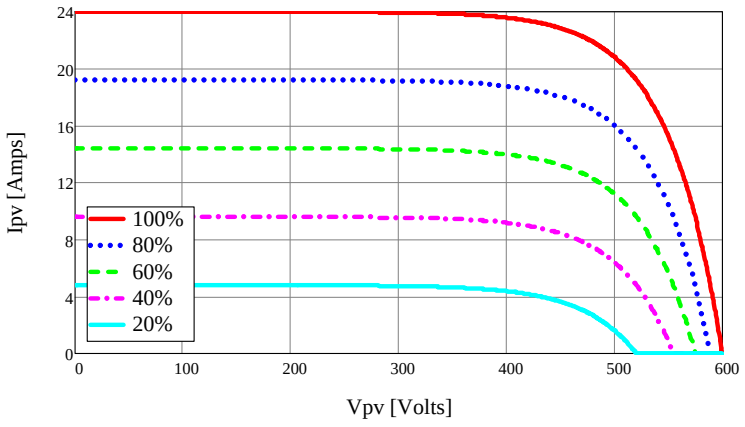
- p-n junction (diode)
- Trapped photons create electron/hole pairs and current



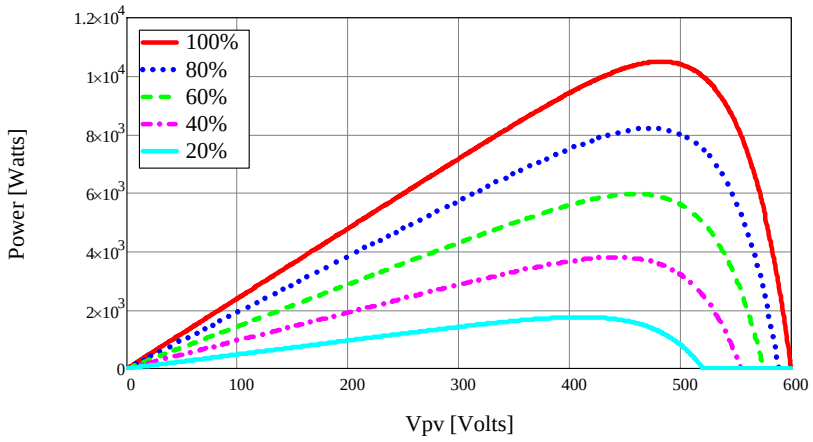


$$I_{pv} = I_L - I_0\left[\exp\left(\frac{qV}{kT}\right) - 1\right]$$

Maximum Power Point Tracking

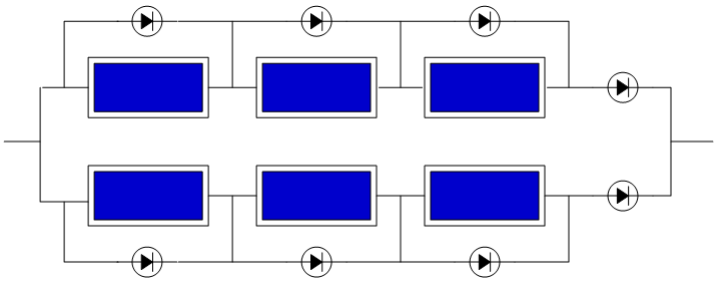


MPPT In Steady State



27

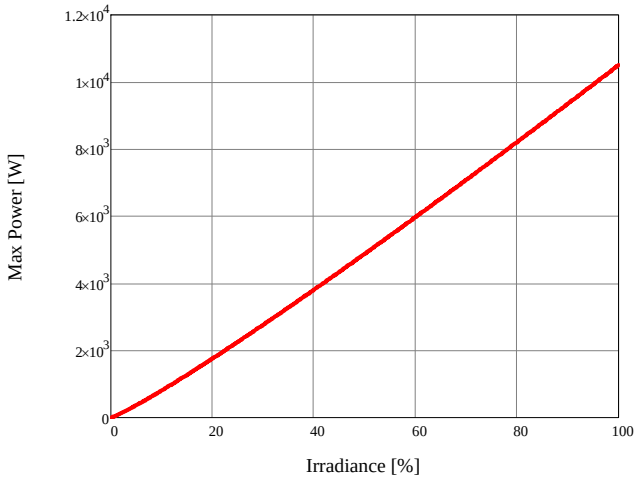
PV System



- Bypass failed modules and strings
- Performance degraded by temperature, shading, dirt

28

MPPT Almost Linear Output



29

PV Capacity Factor Data Sources

- HOMER, www.homerenergy.com
- NREL In My Back Yard (IMBY) www.nrel.gov/eis/imby/
- SEPA Solar Tools at www.solarelectricpower.org

30

Incentives

Types of Incentives

- Fixed Quantity
  - United Kingdom, Australia, Italy, Netherlands
  - State Renewable Portfolio Standards (RPS) would fall into this category
- Fixed Price
  - European "Feed-In" laws, guaranteed % of retail price
- Production Tax Credit
  - United States at the Federal level
- Clean Renewable Energy Bond (CREB)
  - For non-taxable entities, a zero-interest loan
- Grants – USDA and others
- Check state & local tax incentives

32

Production Tax Credit (PTC)

- Energy Policy Act of 1992 – 1.5 ¢/kWhr
- Has been extended eight times
- Adjusted for inflation – currently 2.3 ¢/kWhr for Wind
- Lasts for 10 years
- Must pay federal income taxes in order to use the PTC
  - Equivalent REPI for non-taxable entity, under-funded at about $5M annually
- Currently expires on December 31, 2013
  - **Project must have started construction by that date**

UWIG Utility Wind Integration Group

33

Renewable Energy Production Incentive (REPI)

- Direct payment for public utilities that don't pay taxes, and would not benefit from PTC
- "Equivalent" to PTC, currently 2.1 ¢/kWhr
- Congress must appropriate REPI funds annually:
  - Competes with other funding priorities
  - May not be able to obtain the full REPI payments
  - Tier 1 (Wind & Solar) 33% paid in 2009
  - Tier 1 last paid 100% in 2003
- Varied from $3.7M to $5M from FY2000 through FY2009

UWIG Utility Wind Integration Group

34

Clean Renewable Energy Bonds

- A "tax credit bond" for municipals, cooperatives, tribal governments, others who can't use PTC
- Issuer pays no interest; instead the bondholder receives a Federal tax credit
- Energy Tax Incentives Act of 2005 authorized $800M for CREBs issued in 2006 and 2007
  - Up to $500M for government organizations
  - 786 Applications Filed by April 26, 2006
  - 610 Approved; 112 for Wind and 434 for Solar
- Tax Relief and Health Care Act of 2006
  - Extended CREB another $400M (Total $1.2B)
  - Up to $750M for government organizations
  - Extended CREB to December 31, 2008
  - Applications Were Due at IRS by July 13, 2007
  - Fully Allocated by the end of 2007

UWIG Utility Wind Integration Group

35

"New" CREBs

- Two 2008 Acts, plus 2009 Recovery Act
  - $800M each for government, cooperatives, public power
  - Reduced the payments; may need to offer at discount
- Applications due August 4, 2009; awards made:
  - Government: $800M in 739 projects (smallest-to-largest allocated from $3068M in 997 applications)
  - Cooperatives: $609M in 31 projects (may have a followup)
  - Public Power: $800M in 35 projects (pro rated from $1446M in 38 applications)
  - So, about $191M was left over **(now gone)**

UWIG Utility Wind Integration Group

36

New CREB Credit Rate Schedules

https://www.treasurydirect.gov/GA-SL/SLGS/selectCREBDate.htm

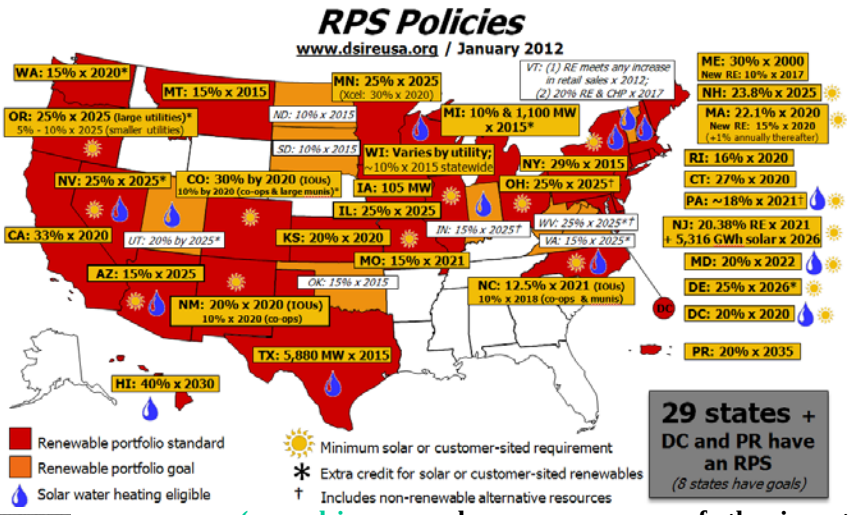
CREB Table of Rates for Issuance on December 1, 2009

Term to Maturity	Credit Rate
1 year	1.84%
2 years	2.29%
3 years	3.04%
4 years	3.70%
5 years	3.94%
6 years	4.32%
7 years	4.59%
8 years	4.72%
9 years	4.94%
10 years	5.18%
11 years	5.27%
12 years	5.38%
13 years	5.47%
14 years	5.53%
15 years	5.58%
16 years	5.68%

UWIG Utility Wind Integration Group

37

Renewable Portfolio Standards (RPS)

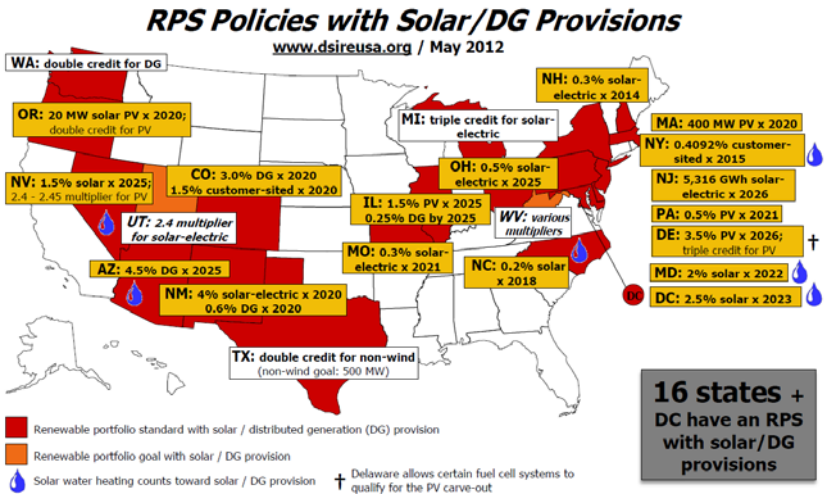


(www.dsireusa.org has summary maps of other incentives)

UWIG Utility Wind Integration Group

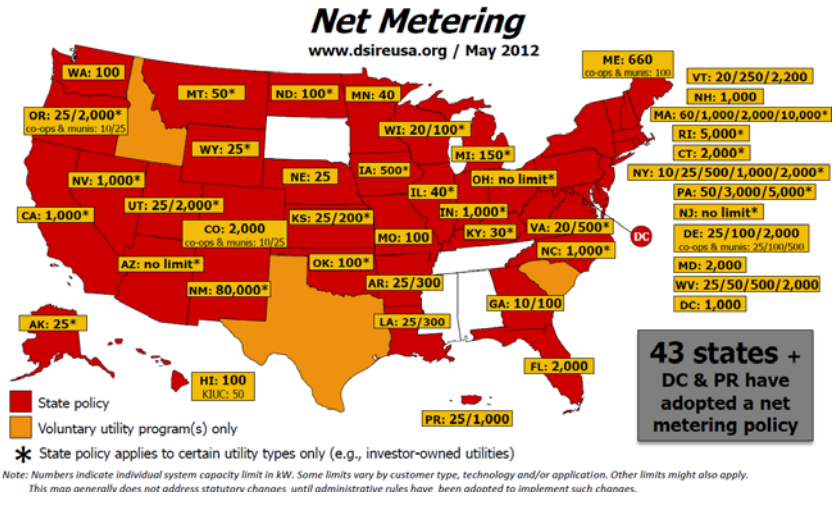
38

RPS with Solar/DG Provisions



39

State Net Metering Policies



40

3 MW ➔ 3 * 1 MW for Net Metering

Source: Neil LaBrake, Jr., National Grid

41

Performance Based Incentives

- MA – 400 MW Solar Carve Out
  - Qualifying facilities sell Solar Renewable Energy Certificates (SREC) with 30.0¢/kwhr floor price
  - Solar Alternative Compliance Payment (SACP) for the state RPS; 55.0¢ ➔ 36.5¢/kwhr over 10 years
- NY – Solar/Biogas Near NYC; Apply for up to 50% installed costs, up to $3M per applicant
- NJ – has an SREC and SACP program for PV
  - 10 – 20% up-front grant for wind, biogas, LFG
- CA – feed-in tariff for PV, around 1.4x CC gas

42

Some Other MA Incentives

- Commonwealth Solar II Rebates: 40 – 85¢/W for 1 kW – 15 kW Residential/Commercial PV
- Personal Tax Credit: up to $1K for PV & Wind
- Property Tax Exemption: 20 years for PV, Wind and Hydro
- Community Wind Grants: $30k for 2 MW, at least 3 turbines
- Sales Tax Exemption: Renewable Energy Equip.

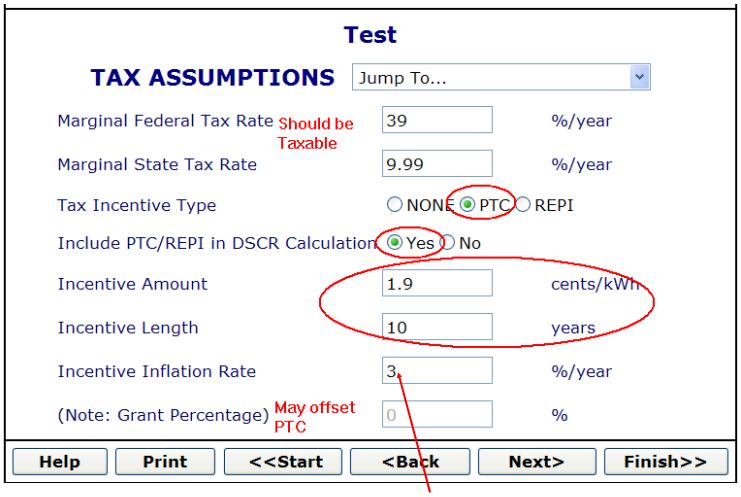
UWIG Utility Wind Integration Group

43

Screening

UWIG Utility Wind Integration Group

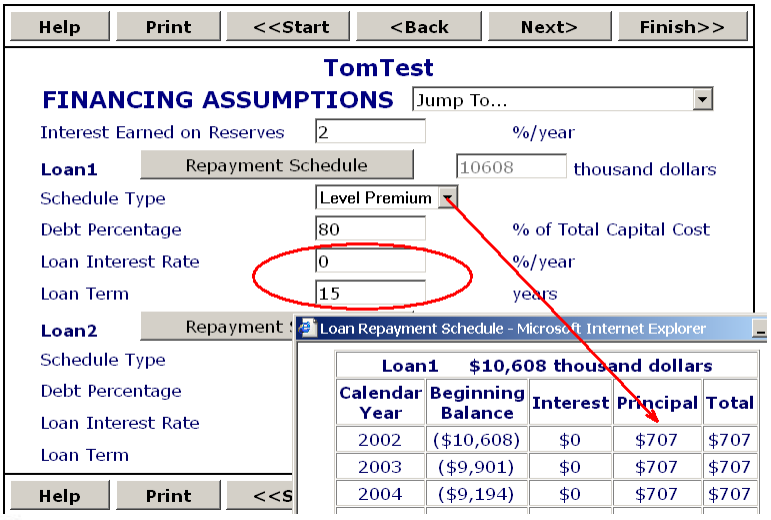
PTC In WindFinance



PTC used to be 1.9 cents, is now actually 2.3 cents / kWh
"Incentive Inflation Rate" approximates this growth

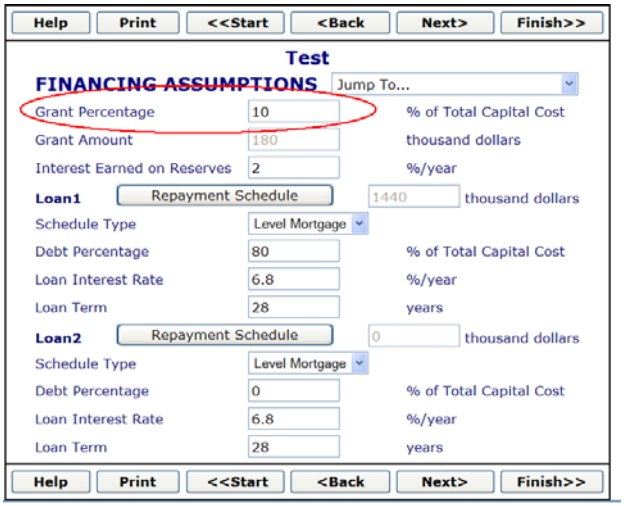
45

CREB In WindFinance



46

Grants in WindFinance



47

Effect of Grants on PTC

- USDA and other Federal grants offset the PTC
  - The PTC offset is capped at 50%
- Example: project cost of $1.8M with $500K Grant

$$PTC = 2.1\left(\frac{1800-500}{1800}\right) = 1.52$$

- Most state grants don't offset the PTC, so you have to make this adjustment manually depending on the type of grant
- All grants reduce the depreciable basis for MACRS

48

Discounted Cash Flow Analysis

- Future Dollars Worth Less than Present Dollars
  - You Could Have Earned Interest on Present Dollars

$$PV = \frac{FV}{(1+rate)^n}$$

- Net Present Value (NPV) is the sum of all future cash flows back to the starting year
- Internal Rate of Return (IRR) is the interest rate that makes NPV Zero
- Payback is the time period for zero NPV

UWIG Utility Wind Integration Group

49

Present Value Example

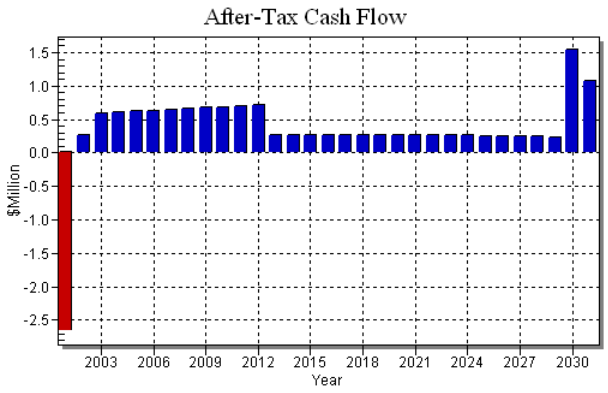
- 10 years, 5% interest rate
- $(1.05)^{10} = 1.6289$
- FV – multiply by 1.6289
  - $1000 today grows to $1628.90 in 10 years
- PV – divide by 1.6289
  - $1000 in 10 years has a present value of $613.91 today
- IRR – if you invest $1000 today and then have $1628.90 in 10 years, your internal rate of return was 5%

UWIG Utility Wind Integration Group

50

NPV, IRR, and Payback Example

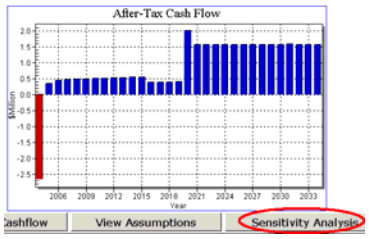
- NPV
  - $3,696K
  - @ 15.22%
- Payback
  - 5 years
  - @ 15.22%
- IRR
  - 19.46%

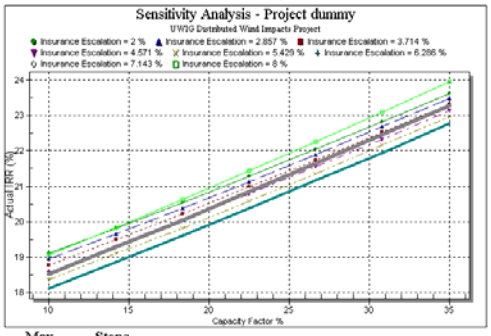


UWIG Utility Wind Integration Group

51

Economics: Sensitivity Analysis





Input quantities:	Min	Max	Steps
Capacity Factor (%)	10	35	6
Insurance Escalation (%)	2	8	7

Output quantity: Actual IRR (%)

UWIG Utility Wind Integration Group

52

HOMER Modeling

- Started at NREL
- Spun off to www.homerenergy.com
- Free download version 2.68
- Capabilities:
  - 8760-hour energy balance simulation of loads and sources
  - Optimization and sensitivity analysis of costs
  - Models of PV output, wind output, batteries, and diesel generator dispatching
  - No electrical simulation, CREB or PTC analysis

UWIG Utility Wind Integration Group

53

When to Use WindFinance or Homer?

- WindFinance
  - More detailed effects on Wind Capacity Factor
  - Effects of PTC, CREB, Grants, Taxes, Loans, etc.
  - Larger single projects
  - More Turbines in the library
- HOMER
  - 8760 Energy simulations with Load and Pricing
  - How many wind turbines, PV arrays, batteries, etc.?
  - PV Capacity Factor estimates
  - Hydro, Biomass, and Fuel Cells

UWIG Utility Wind Integration Group

54

NREL In My Back Yard (IMBY)

- http://www.nrel.gov/eis/imby/ and then click
- "Use IMBY Now"
  - Find your home address, choose Solar energy
  - Draw a PV panel on your rooftop, Run the simulation
  - After the initial results appear, choose a nearby sample load profile and Run the load profile
  - Switch to Wind energy, place a Generic 3-kW wind turbine nearby, and Run. The capacity factor is your annual production, divided by (3*8760).

55

Workshop Links for Exercises

- http://www.uwig.org/distwind/Default.htm
- Your login credentials are based on the two-digit computer number, on the "ETRAIN" label
  - User Name = goldnguest**??**
  - Password = guest**??**#
  - Where **??** is the computer number, with a leading zero if necessary (e.g. goldnguest02 and guest02#)
- For the new toolbox developmental version
  - http://www.meltran.com/uwig/DGToolBox.html

56