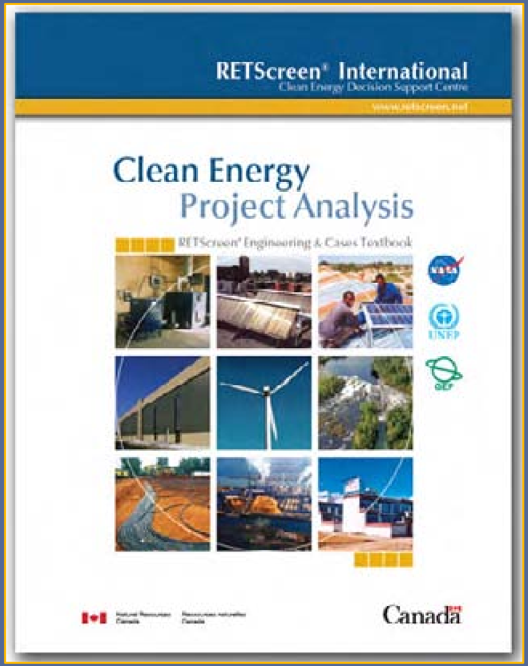
Introduction to Clean Energy Project Analysis

RETSCREEN® INTERNATIONAL www.retscreen.net

Clean Energy Project Analysis Course

"Clean Energy Project Analysis" is a case-study based course for professionals & university students who want to learn how to better analyse the technical & financial viability of possible clean energy projects



RETScreen® International
Clean Energy Decision Support Centre

- Develops enabling tools that make it easier for planners, decision-makers and industry to consider energy efficient and renewable energy technologies (RETs) at the critically important initial planning stage

- Enabling tools significantly reduce the cost of assessing possible projects

- Disseminates these tools free-of-charge to users around the world via the Internet & CD-ROM

- Training & technical support provided via an international network of RETScreen® Trainers

- Industry products & services accessible via an Internet Marketplace

Upon Completion of the Course

- You will be more aware of viable clean energy applications
- And you will be able to perform high-quality & low-cost preliminary feasibility studies using the RETScreen® Software

Solarwall - Apartment Building

Photo Credit: Enermodal

Teacher's Housing, Botswana

Photo Credit: Vadim Belotserkovsky

Course Outline

Introduction to Clean Energy Project Analysis

Wind Energy Project Analysis

Small Hydro Project Analysis

Photovoltaic Project Analysis

Combined Heat & Power Project Analysis

Biomass Heating Project Analysis

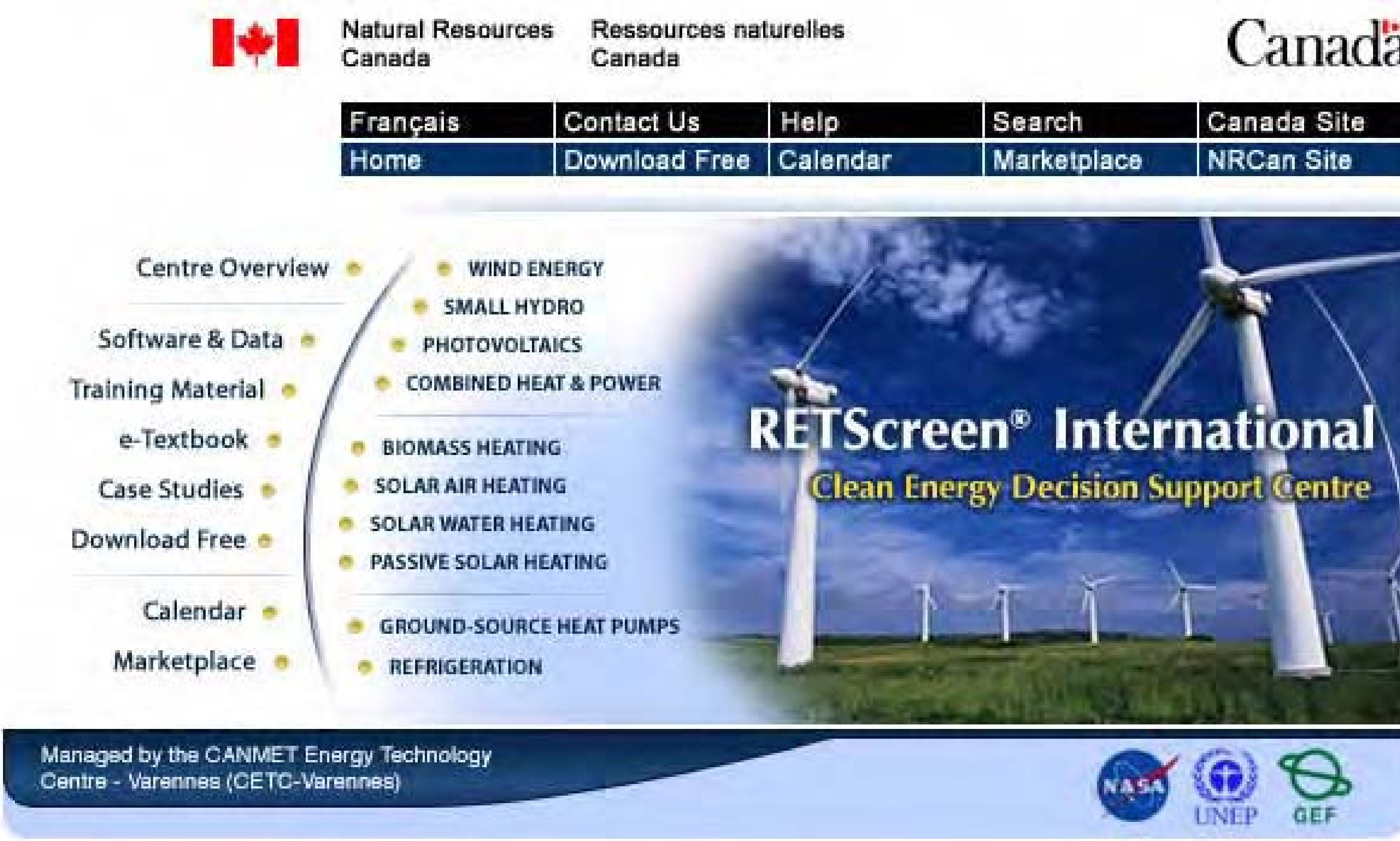
Solar Air Heating Project Analysis

Solar Water Heating Project Analysis

Passive Solar Heating Project Analysis

Ground-Source Heat Pump Project Analysis

Refrigeration Project Analysis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PHOTOVOLTAICS
COMBINED HEAT & POWER
BIOMASS HEATING
SOLAR AIR HEATING
SOLAR WATER HEATING
PASSIVE SOLAR HEATING
GROUND-SOURCE HEAT PUMPS
REFRIGERATION
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Clean Energy Decision Support Centre
Managed by the CANMET Energy Technology Centre - Varennes (CETC-Varennes)
NASA
UNEP
GEF

Course Materials

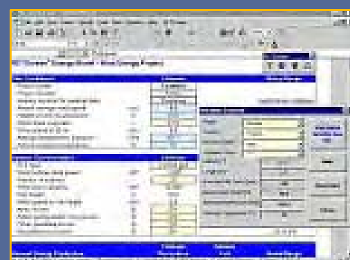
RETScreen® International Clean Energy Decision Support Centre	Project Analysis **Software** Model	Project Analysis **Training Course** Module	Engineering **e-Textbook** Chapter	Project **Case Studies** Collection
Introduction		☐	☐	
Wind Energy	☐	☐	☐	☐
Small Hydro	☐	☐	☐	☐
Photovoltaics	☐	☐	☐	☐
Combined Heat & Power	☐	☐	☐	☐
Biomass Heating	☐	☐	☐	☐
Solar Air Heating	☐	☐	☐	☐
Solar Water Heating	☐	☐	☐	☐
Passive Solar Heating	☐	☐	☐	☐
Ground-Source Heat Pumps	☐	☐	☐	☐
Refrigeration	☐	☐	☐	☐

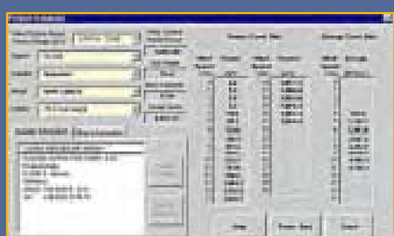
Managed by the CANMET Energy Technology Centre - Varennes (CETC-Varennes)

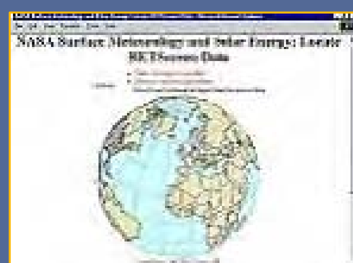
Download Free-of-Charge at: www.retscreen.net

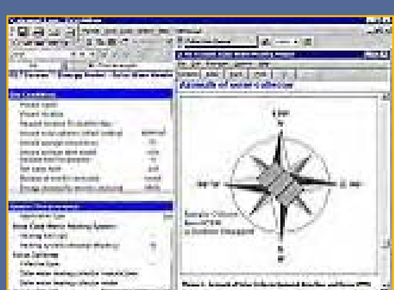
Software & Data

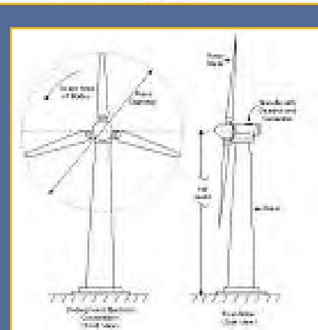
RETScreen® International Clean Energy Project Analysis Software











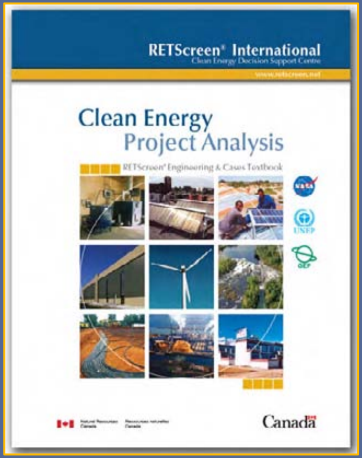
- Clean Energy Technology Models
- International Product Data
  1,000 Equipment Suppliers
- International Weather Data
  - 1,000 ground monitoring stations
  - Satellite-derived NASA Surface meteorology and Solar Energy Data Set
- Online User Manual
- Available free-of-charge
  in English & French

Training Material

- Clean Energy Project Analysis Course
    - Presentation slides
    - e-Learning tool
        - Voice
        - Speaker's notes
    - e-Textbook & Case Studies

e-Textbook & Case Studies

- Clean Energy Project Analysis: RETScreen® Engineering & Cases
  - Professional and University-level electronic textbook
  - Background of technologies
  - Detailed description of RETScreen® algorithms
  - 60+ international case studies of real projects
  - Available free-of-charge in English & French



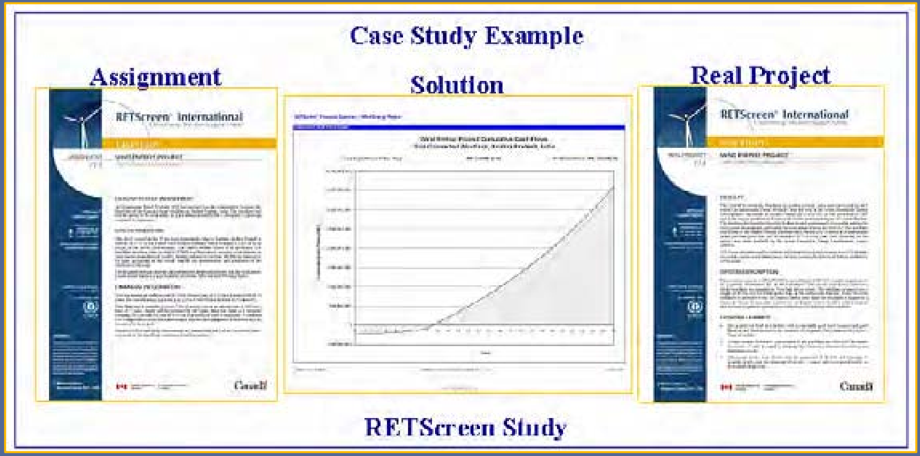

RETScreen® International: CLEAN ENERGY PROJECT CASE STUDIES

Wind Energy Project Case Studies:
These files are a collection of project case studies, including assignments, worked-out solutions (RETScreen Software Analysis) and information about how the projects fared in the real world.

Requirements: Adobe Acrobat Reader 4.0 or higher.

Click on the buttons below to open or download the PDF files (approx. 250 KB each)

File Name	Project Name	Location	Country	Assignment	Solution	Real Project
WIND01	Remote Community	Yukon Territory	Canada			
WIND02	Windfarm Repowering	Alberta	Canada			
WIND03	Green Power Production	Alberta	Canada			
WIND04	Grid-Connected Windfarm	Andhra Pradesh	India			
WIND05	Large Wind Turbines	Niedersachsen	Germany			
WIND06	Offshore Windfarm	Copenhagen	Denmark			



Marketplace & Calendar

- Internet-Based Marketplace
  - Linking industry and customers online
  - Search by subject, technology & region
  - Examples:
    - equipment suppliers, PV, North-America
    - service providers, wind energy, Europe

- Public & Private Internet Forums

- Online training calendar and registration

Introductory Module Outline

- Overview of Course (completed)
- Status of Clean Energy Technologies
- Clean Energy Project Analysis with RETScreen® Software
- Greenhouse Gas Emissions Analysis with RETScreen® Software
- Financial and Risk Analysis with RETScreen® Software
- Summary

CANMET Energy Technology Centre - Varennes

Status of Clean Energy Technologies

RETScreen® International www.retscreen.net

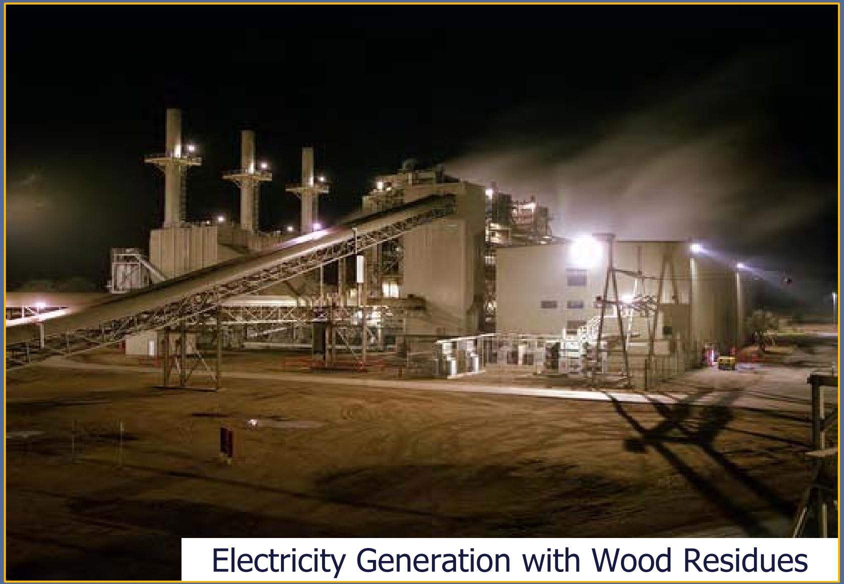
Clean Energy Project Analysis Course

Photo Credit: Nordex Gmbh

Photo Credit: McFadden, Pam DOE/NREL

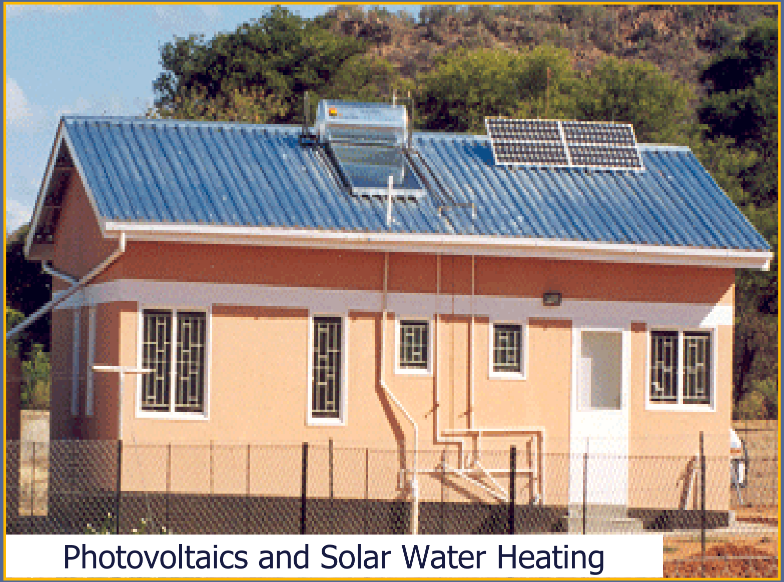
Objective

- Increase awareness about renewable energy technologies (RETs) and energy efficiency measures
  - Markets
  - Typical applications



Electricity Generation with Wood Residues

Photos Credit: Warren Gretz, NREL PIX



Photovoltaics and Solar Water Heating

Photo Credit: Vadim Belotserkovsky

Definitions

Clean Energy Technologies

Energy Efficiency

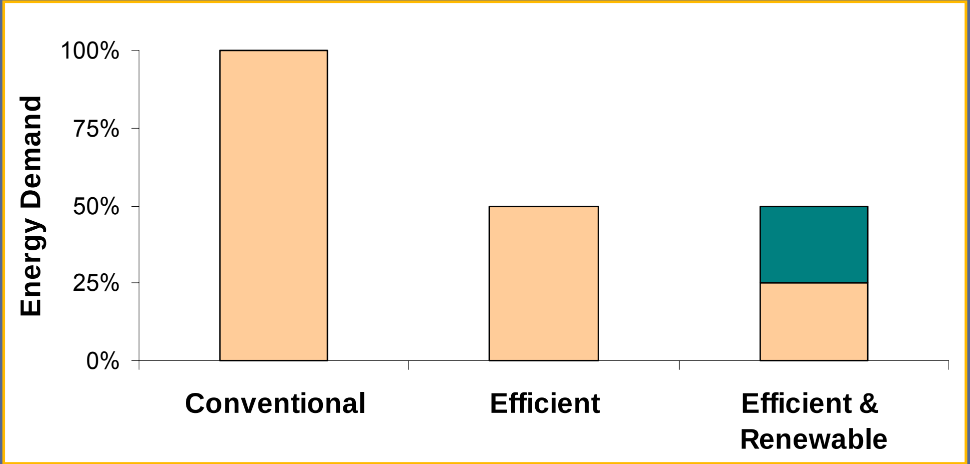
- Using less energy resources to meet the same energy needs

Renewable Energy

- Using non-depleting natural resources to meet energy needs

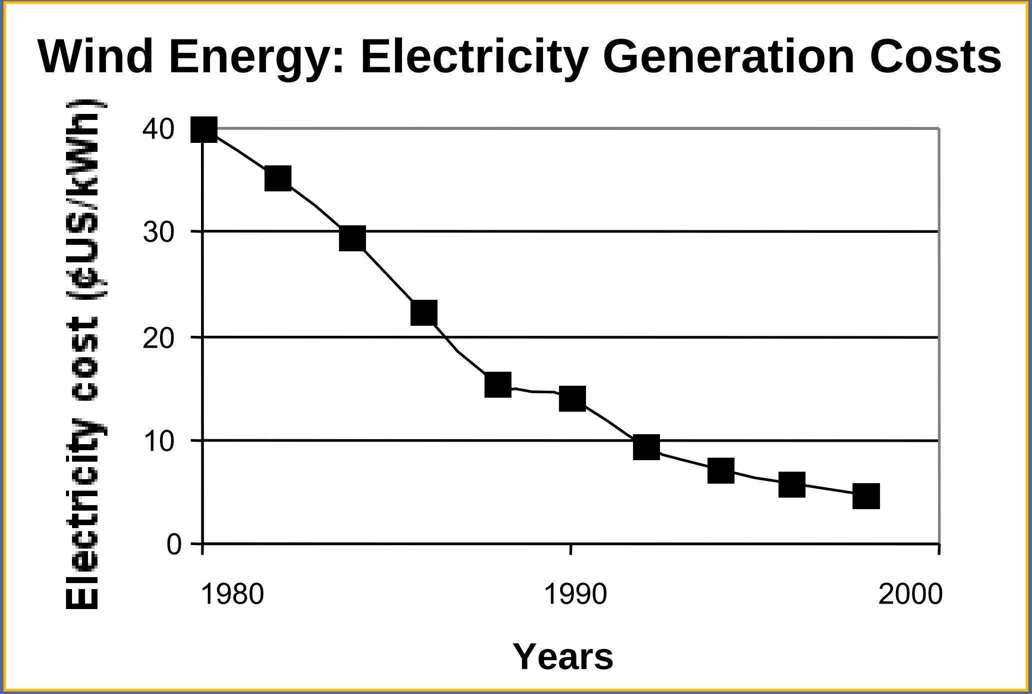

Super Insulated Passive Solar Home

Photo Credit: Jerry Shaw



Reasons for Clean Energy Technologies

- Environmental
  - Climate change
  - Local pollution
- Economic
  - Life-cycle costs
  - Fossil fuel depletion
- Social
  - Employment generation
  - Reduced drain of local $$$
  - Growth in energy demand (x3 by 2050)



Source: National Laboratory Directors for the U.S. Department of Energy (1997)

Common Characteristics of Clean Energy Technologies

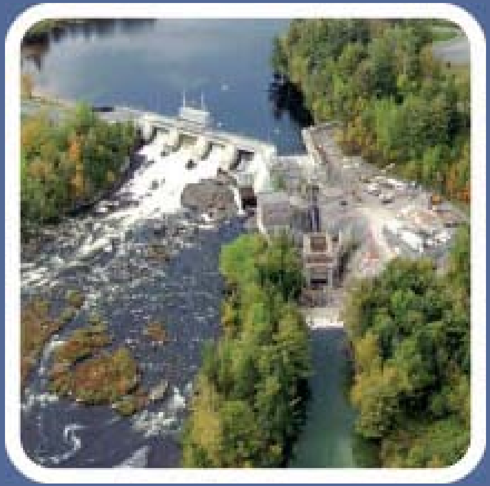
- Relative to conventional technologies:
  - Typically higher initial costs
  - Generally lower operating costs
  - Environmentally cleaner
  - Often cost effective on life-cycle cost basis

Total Cost of an Energy Generating or Consuming System

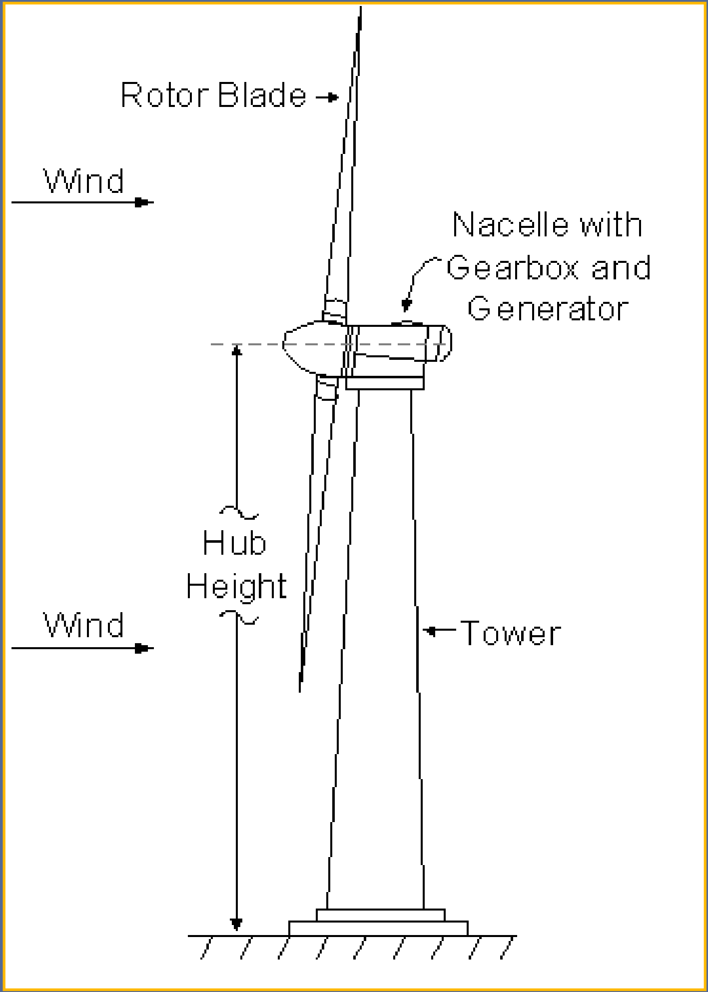
- Total cost ≠ purchase cost
- Total cost = purchase cost

+ *annual fuel and O&M costs*
+ *major overhaul costs*
+ *decommissioning costs*
+ *financing costs*
+ *etc.*

Renewable Energy Electricity Generating Technologies



Wind Energy Technology & Applications



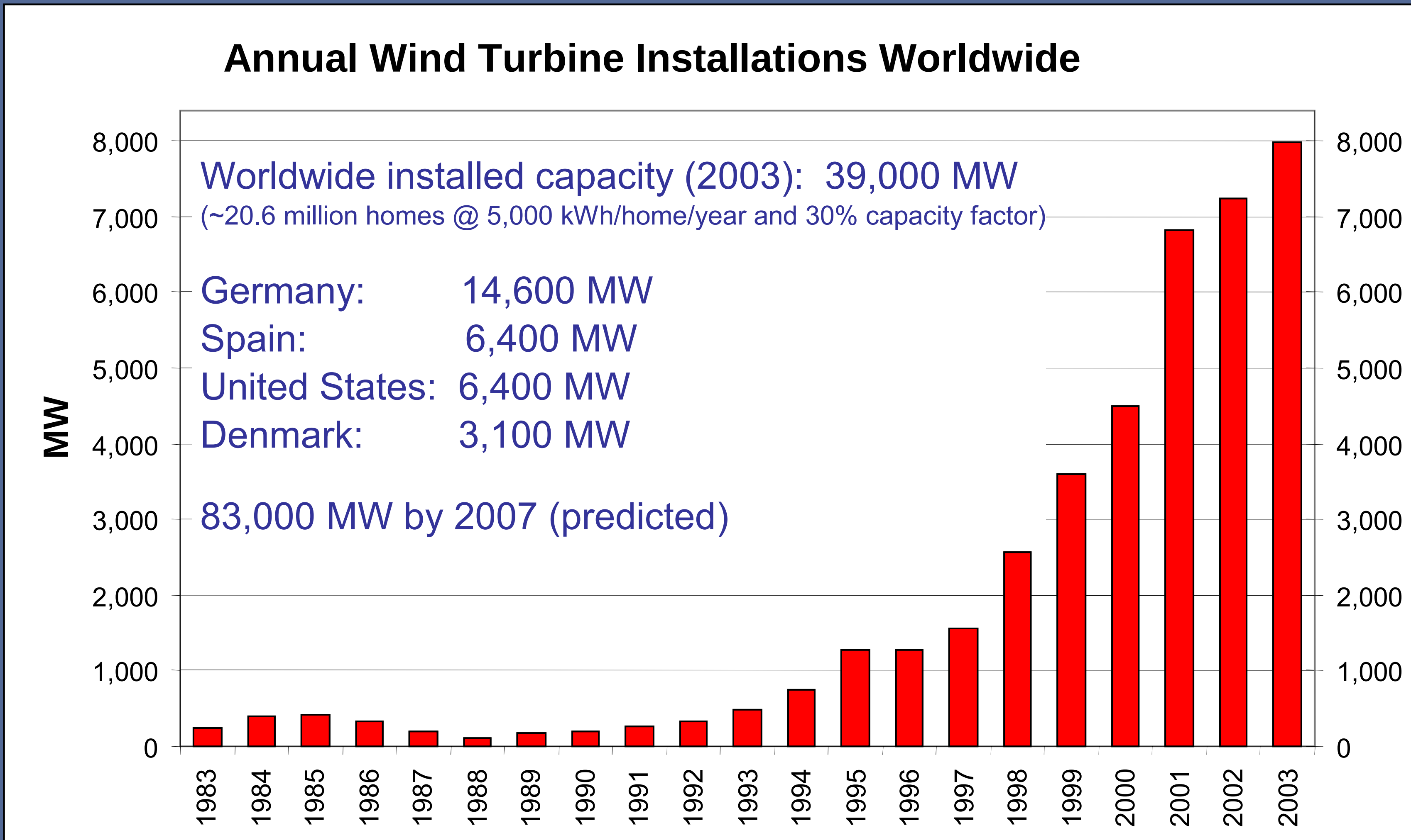
- Need good winds
  - (>4 m/s @ 10 m)
  - Coastal areas, rounded ridges, open plains
- Applications:


Central-Grid
Warren Gretz, NREL PIX


Isolated-Grid
Phil Owens, Nunavut Power

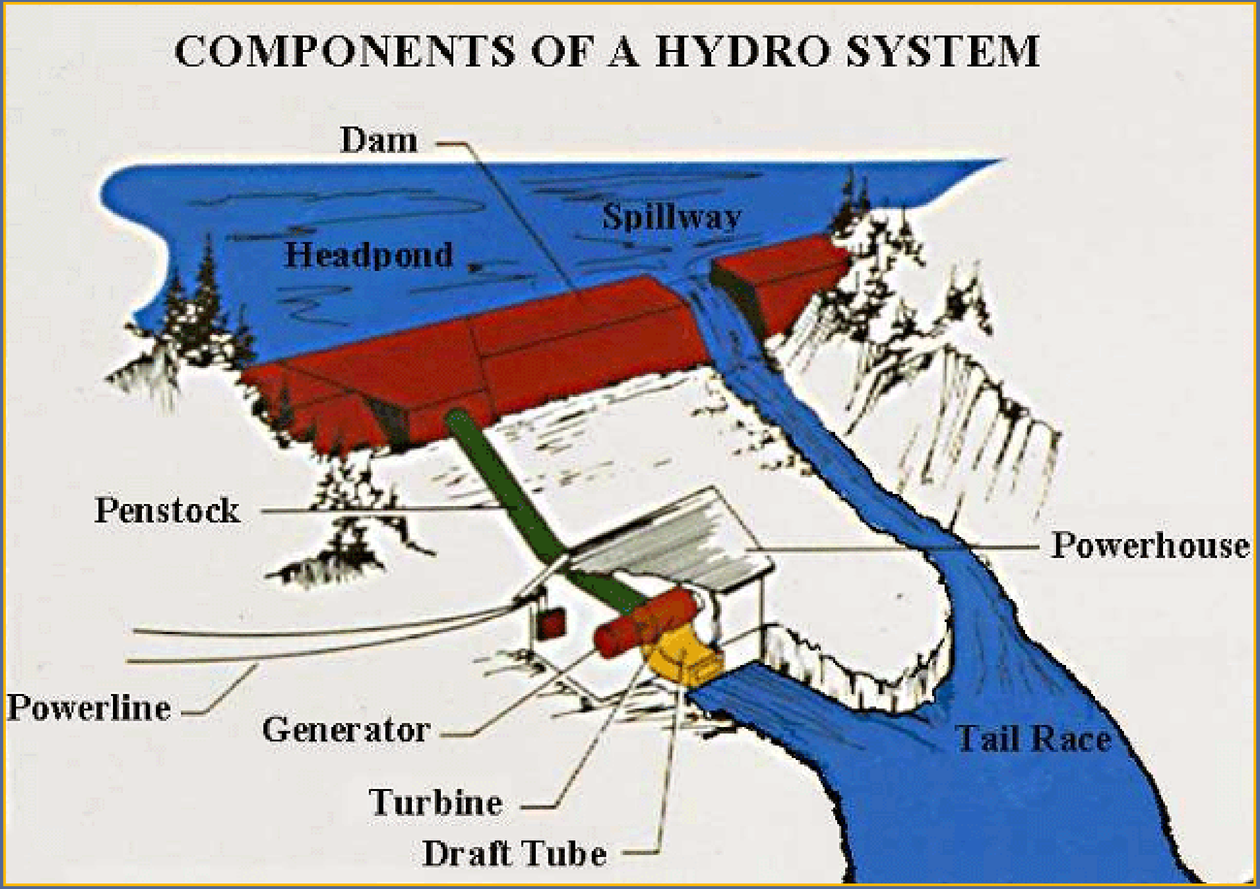

Off-Grid
Southwest Windpower, NREL PIX

Wind Energy Market



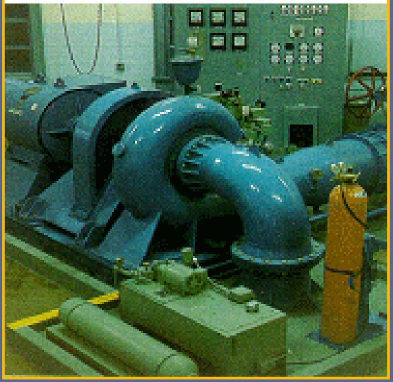
Source: Danish Wind Turbine Manufacturers Association, BTM Consult, World Wind Energy Association, Renewable Energy World

Small Hydro Technology & Applications



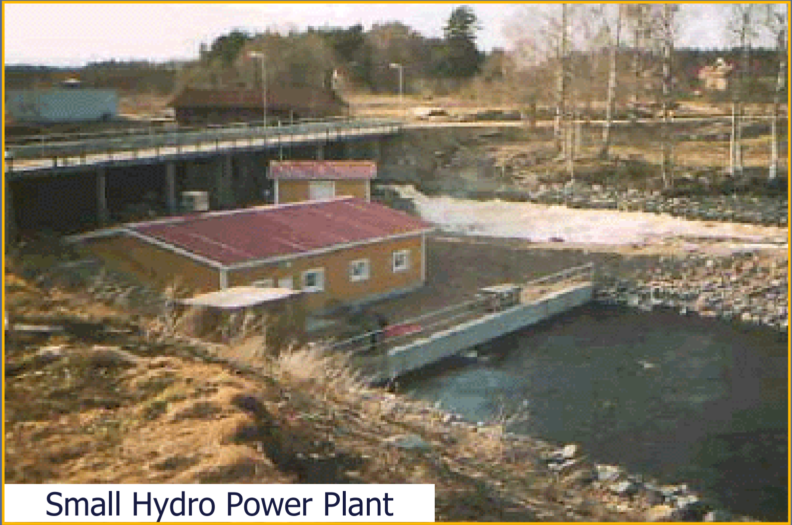
- Project types:
  - Reservoir
  - Run-of-river
- Applications:
  - Central-grid
  - Isolated-grid
  - Off-grid

Francis Turbine



Small Hydro Market

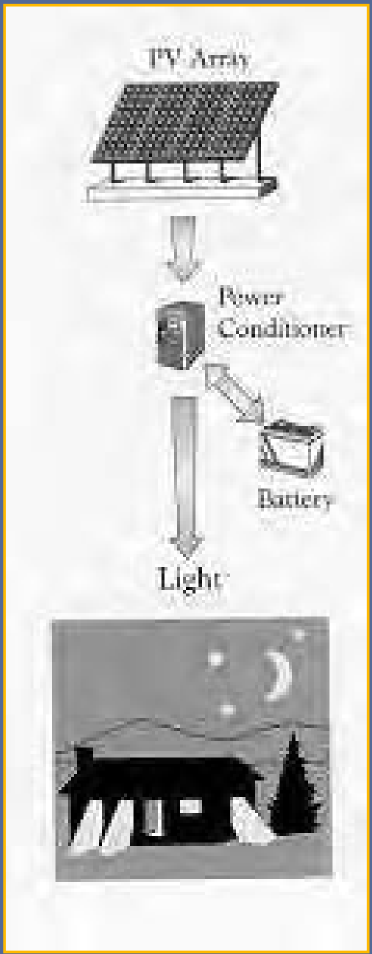
- 19% of world electricity produced by large & small hydro
- Worldwide:
  - 20,000 MW developed (plant size < 10 MW)
  - Forecast: 50,000 to 75,000 MW by 2020
- China:
  - 43,000 existing plants (plant size < 25 MW)
  - 19,000 MW developed
  - further 100,000 MW econ. feasible
- Europe:
  - 10,000 MW developed
  - further 4,500 MW econ. feasible
- Canada:
  - 2,000 MW developed
  - further 1,600 MW econ. feasible



Small Hydro Power Plant

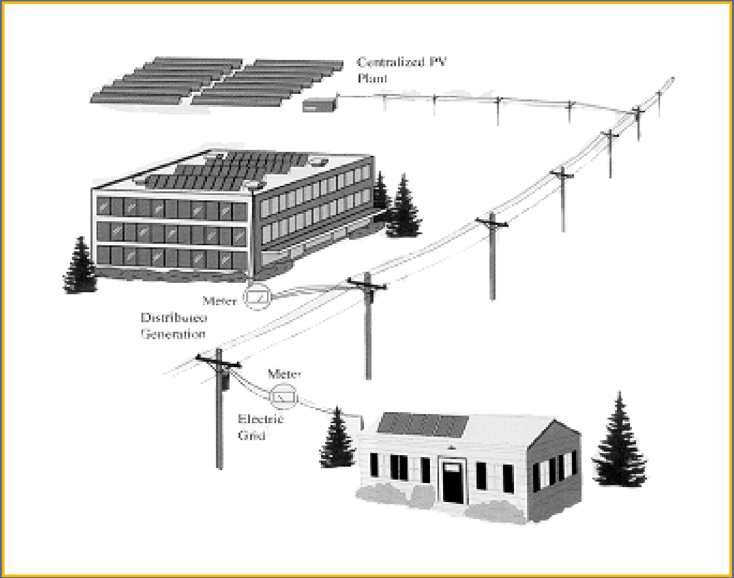
Data source: ABB, Renewable Energy World, and International Small Hydro Atlas

Photovoltaic (PV) Technology & Applications



Household PV System

Photo Credit: Tsuo, Simon DOE/NREL

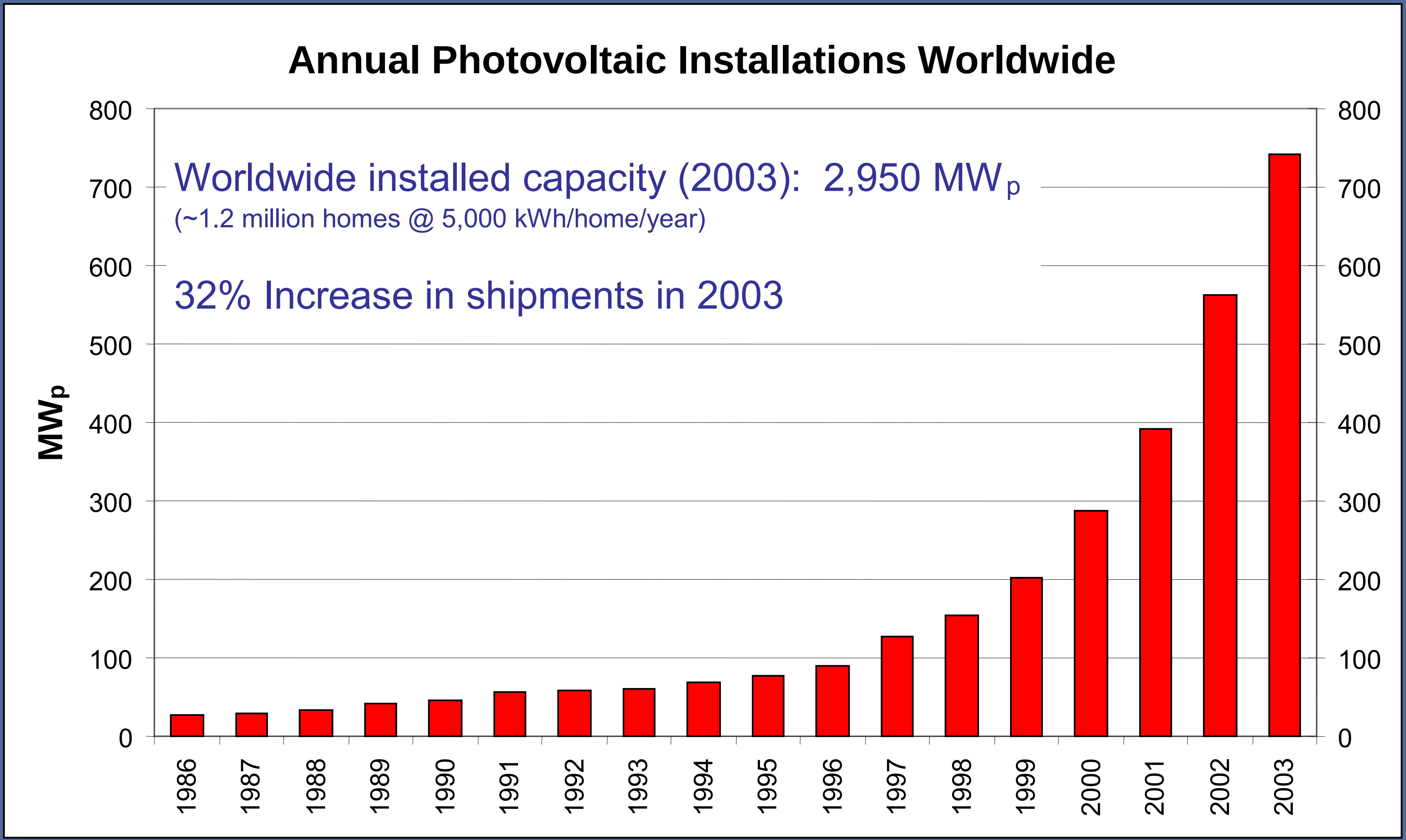


PV Water Pumping

Grid-tied Building Integrated PV

Photo Credit: Strong, Steven DOE/NREL

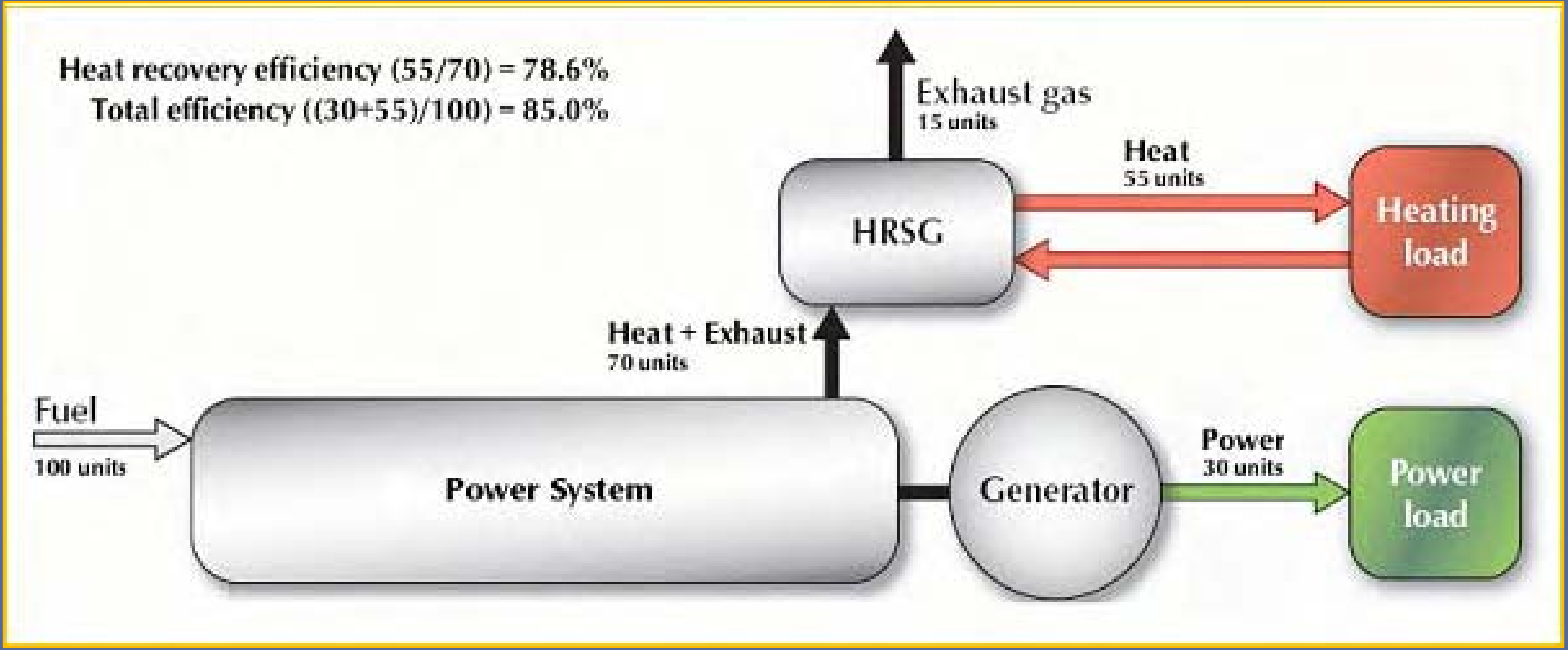
Photovoltaic Market



Source: PV News

Combined Heat and Power (CHP)

- Simultaneous production of two or more types of usable energy from a single energy source (also called "Cogeneration")



Combined Heat and Power Applications, Fuels and Equipment

Various Applications

Biomass for CHP

Photo Credit: Gretz, Warren DOE/NREL

Various Fuels

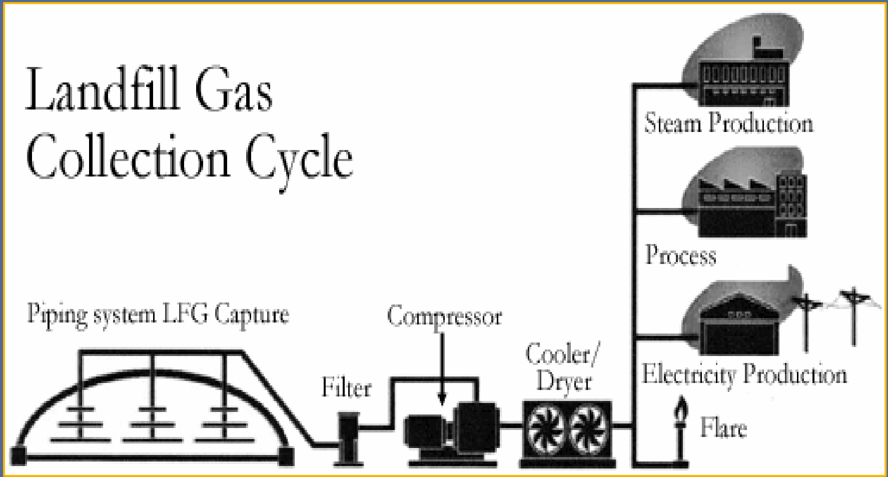


Photo Credit: Gaz Metropolitan

Various Equipment

Reciprocating Engine for Power Generation

Photo Credit: Rolls-Royce plc

Combined Heat and Power Applications

- Single buildings
- Commercial and industrial
- Multiple buildings
- District energy systems (e.g. communities)
- Industrial processes

CHP Kitchener City Hall

Photo Credit: Urban Ziegler, NRCan

LFG CHP for district heating system, Sweden

Photo Credit: Urban Ziegler, NRCan

Micro turbine at greenhouse

Photo Credit: Urban Ziegler, NRCan

Combined Heat and Power Fuel Types

- Renewable fuels
  - Wood residue
  - Landfill gas (LFG)
  - Biogas
  - Agricultural bi-products
  - Bagasse
  - Purpose-grown crops
  - Etc
- Fossil fuels
  - Natural gas
  - Diesel
  - Etc.
- Geothermal energy
- Hydrogen

Biomass for CHP

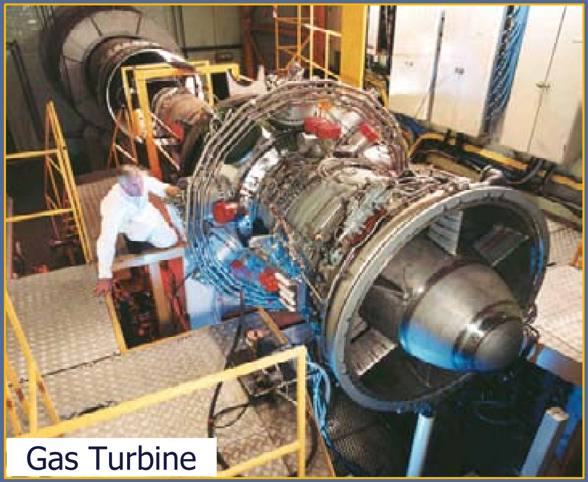
Photo Credit: Gretz, Warren DOE/NREL

Geothermal Geyser

Photo Credit: Joel Renner, DOE/ NREL PIX

Combined Heat and Power Equipment & Technologies

- Cooling equipment
  - Compressors
  - Absorption chillers
  - Free cooling
- Power generation
  - Gas turbine
  - Gas turbine combined cycle
  - Steam turbine
  - Reciprocating engine
  - Fuel cell
  - Etc.
- Heating equipment
  - Boilers
  - Waste heat recovery



Gas Turbine

Photo Credit: Rolls-Royce plc

Cooling Equipment

Photo Credit: Urban Ziegler, NRCan

Combined Heat and Power Market

Region	Capacity	Comments
Canada	12 GW	Mostly to pulp & paper and oil industry
USA	67 GW	Growing rapidly, policy support for CHP
China	32 GW	Predominantly coal fired CHP
Russia	65 GW	Around 30% of electricity from CHP
Germany	11 GW	Rising market for municipal CHP
UK	4.9 GW	Strong incentives for renewable energy
Brazil	2.8 GW	DE associated with off-grid installations
India	4.1 GW	Mostly bagasse based CHP for sugar mills
South Africa	0.5 GW	Replacing mainly coal fired electricity
World	**247 GW**	**Expected to grow by 10 GW per year**

Source: World Survey of Decentralized Energy 2004, WADE

Renewable Energy Heating & Cooling Technologies

RETScreen® International

www.retscreen.net

Biomass Heating Technology & Applications

- Controlled combustion of wood, agricultural residues, municipal waste, etc., to provide heat

Wood Chipping

Photo Credit: Wiseloger, Art DOE/NREL

Heating Plant

Single Buildings and/or District Heating

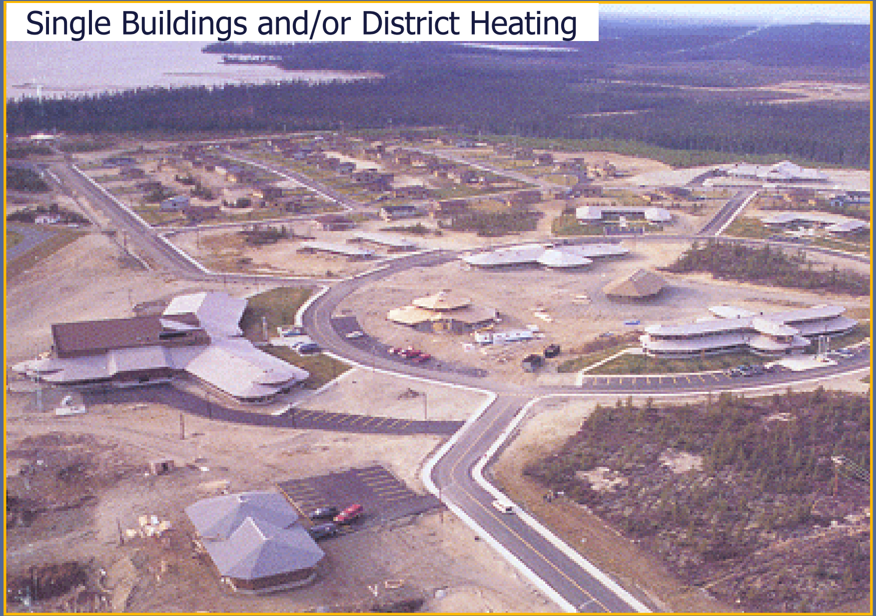


Photo Credit: Oujé-Bougoumou Cree Nation

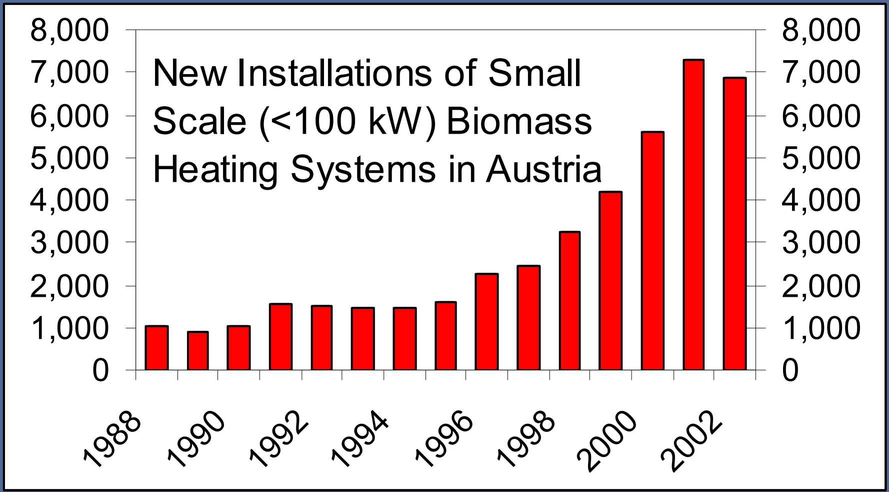
Biomass Heating Market

- Worldwide:
  - Biomass combustion provides 11% of world's Total Primary Energy Supply (TPES)
  - Over 20 GW_{th} of controlled combustion heating systems
- Developing countries:
  - Cooking, heating
  - Not always sustainable
  - Africa: 50% of TPES
  - India: 39% of TPES
  - China: 19% of TPES
- Industrialised countries:
  - Heat, power, wood stoves
  - Finland: 19% of TPES
  - Sweden: 16% of TPES
  - Austria: 9% of TPES
  - Denmark: 8% of TPES
  - Canada: 4% of TPES
  - USA: 68% of all renewables

Source: IEA Statistics– Renewables Information 2003, Renewable Energy World 02/2003

Combustion Chamber

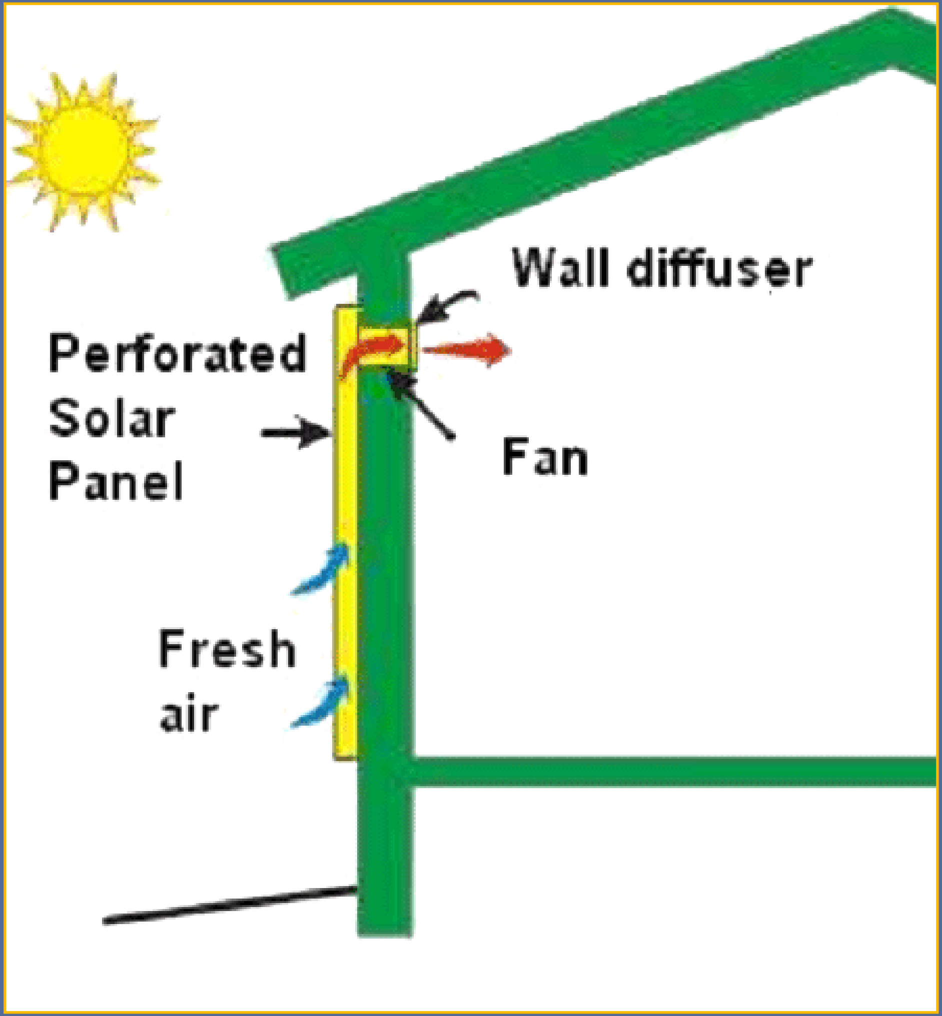
Photo: Ken Sheinkopf/ Solstice CREST



Source: Ingwald Obernberger citing the Chamber of Agriculture and Forestry, Lower Austria

Solar Air Heating Technology & Applications

- Unglazed collector for air preheating
- Cold air is heated as it passes through small holes in the metal absorber plate (Solarwall™)
- A fan circulates this heated air through the building



Solar Air Heating Market

- Preheating of ventilation air for buildings with large fresh air requirements
- Also for crop drying
- Cost competitive for new buildings or major renovations

Industrial Buildings

Photo Credit: Conserval Engineering

Solar Crop Drying

Photo Credit: Conserval Engineering

Solar Water Heating Technology & Applications

- Glazed and unglazed collectors
- Water storage (tank or pool)

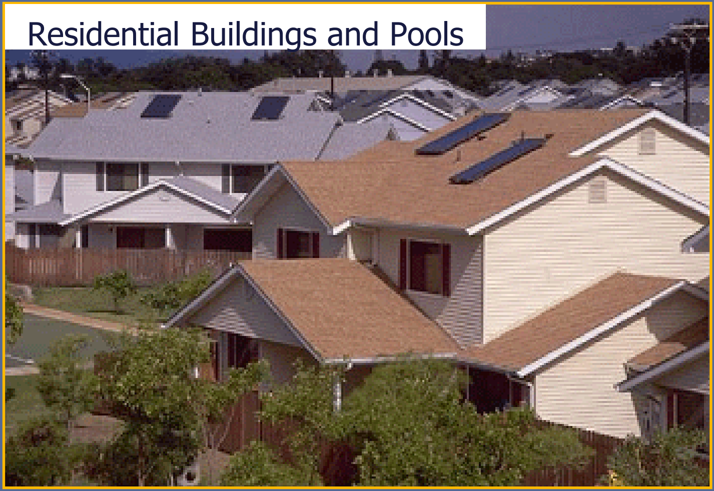
Commercial/Institutional Buildings and Pools

Aquaculture - Salmon Hatchery

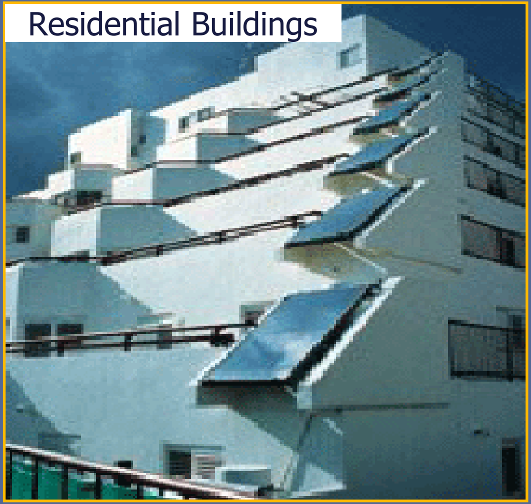
Solar Water Heating Market

- More than 30 million m^2 of collectors worldwide
- Europe:
  - 10 million m^2 of collectors in operation
  - Annual growth rate of 12%
  - Germany, Greece, and Austria
  - Goal for 2010: 100 million m^2
- Strong world market for solar swimming pool heaters
- Barbados has 35,000 systems

Source: Renewable Energy World, Oak Ridge National Laboratory



Residential Buildings and Pools

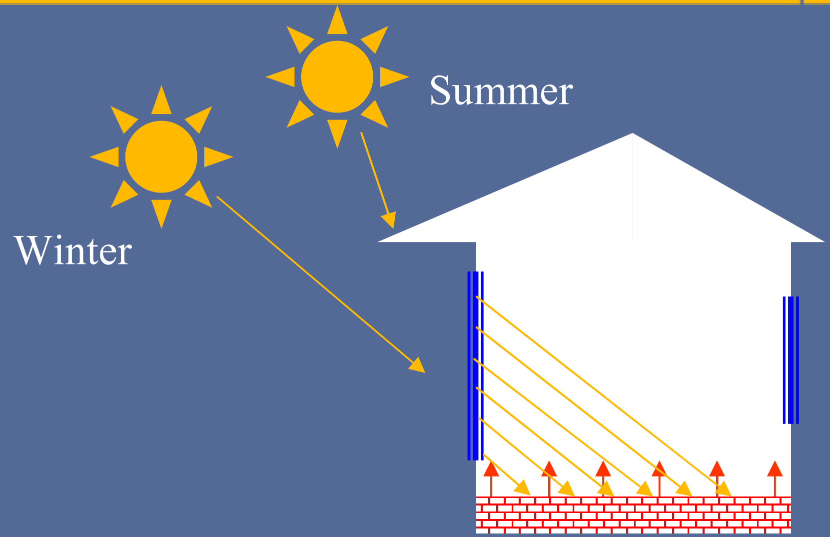


Residential Buildings

Photo Credit: Chromagen

Passive Solar Heating Technology & Applications

- Supply 20 to 50% of space heating required in the heating season
- Solar gains available through equator-facing high performance windows
- Store heat within building structure
- Use shading to reduce summer heat gains



Passive Solar Heating of Apartments

Photo: Fraunhofer ISE (from Siemens Research and Innovation Website)

Passive Solar Heating Market

- Use of efficient windows is actually passive solar - standard practice today
- For new construction - no to low cost increase
  - Higher efficiency windows
  - Building orientation
  - Proper shading
- Cost competitive for new buildings and retrofits


Commercial Buildings

DOE/NREL Photo Credit: Gretz, Warren

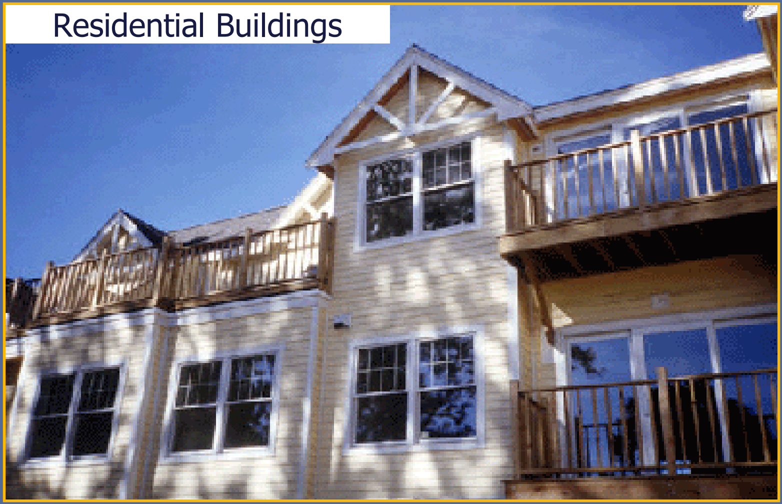
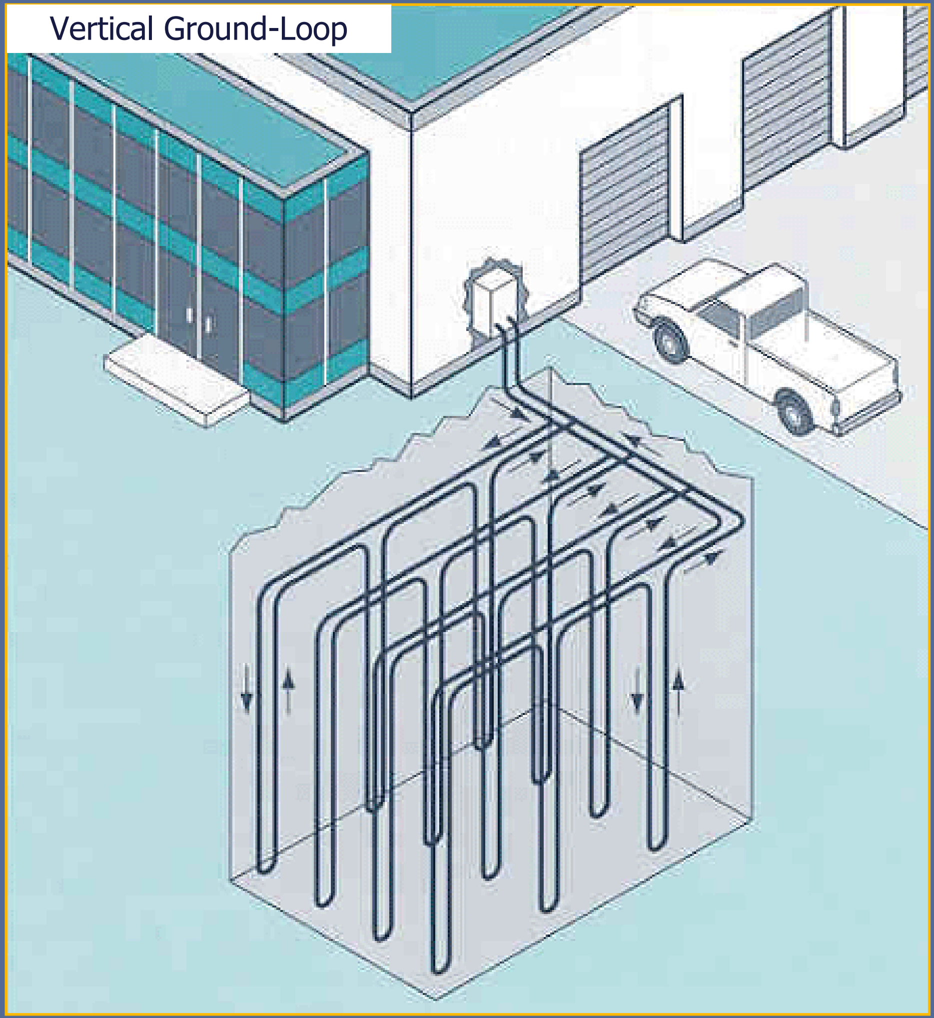

Residential Buildings

Photo Credit: DOE/NREL

Ground-Source Heat Pump Technology & Applications



- Space/water heating and cooling
- Electricity operates on vapor compression cycle
- Heat drawn from ground in winter and rejected to ground in summer

Ground-Source Heat Pump Market

Residential GSHP

- World:
  - 800,000 units installed
  - Total capacity of 9,500 MW_{th}
  - Annual growth rate of 10%
- USA: 50,000 installations annually
- Sweden, Germany, Switzerland major European markets

Commercial, Institutional & Industrial Buildings

- Canada:
  - 30,000+ residential units
  - 3,000+ industrial and commercial units
  - 435 MW_{th} installed

Photo Credit: Geothermal Heat Pump Consortium (GHPC) DOE/NREL

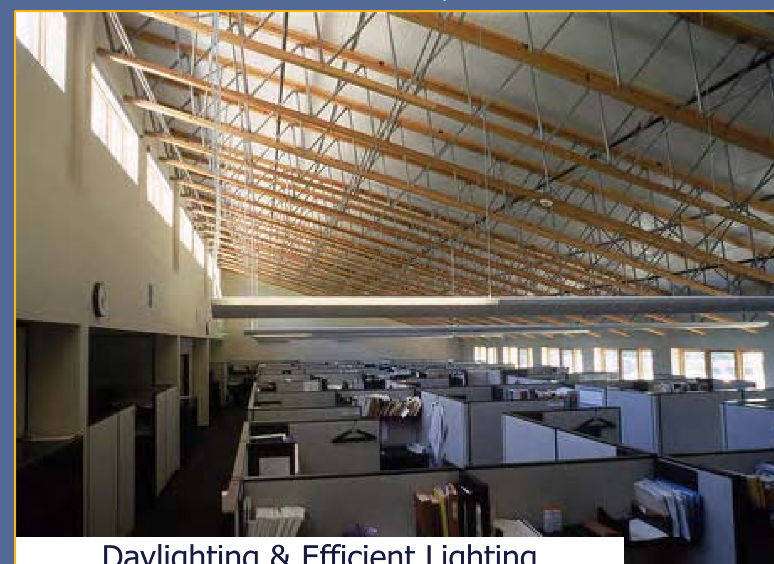
Other Commercial Clean Energy Technologies

- Fuels: ethanol and bio-diesel
- Efficient refrigeration systems
- Variable speed motors
- Daylighting & efficient lighting systems
- Ventilation heat recovery
- Others

Agriculture Waste Fuel Supply

Photo Credit: David and Associates DOE/NREL

Efficient Refrigeration at Ice Rink



Daylighting & Efficient Lighting

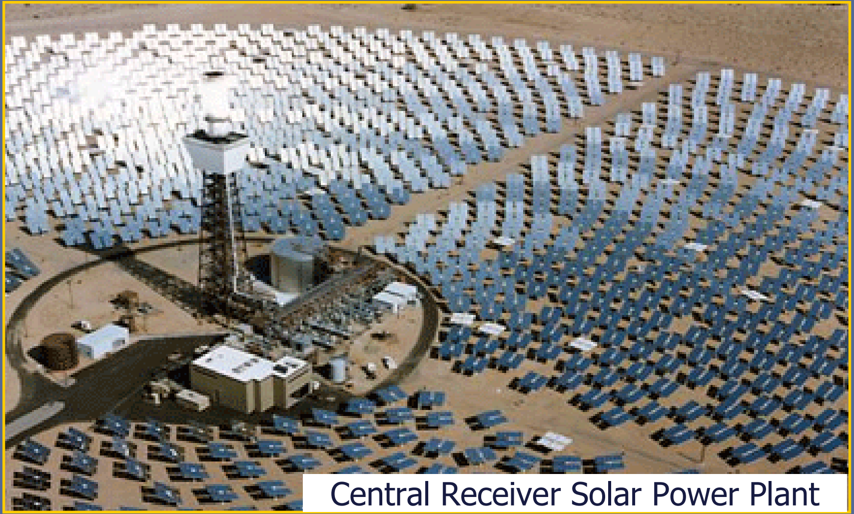
Photo Credit: Robb Williamson/ NREL Pix

Emerging
Clean Energy Technologies

- Solar-thermal power
- Ocean-thermal power
- Tidal power
- Ocean current power
- Wave power
- etc.

Parabolic-Trough Solar Power Plant

Photo Credit: Gretz, Warren DOE/NREL



Central Receiver Solar Power Plant

Photo Credit: Sandia National Laboratories DOE/NREL

Conclusions

- Cost-effective opportunities exist
- Many success stories
- Growing markets
- Renewable energy resources and energy efficiency opportunities are available

Parks Canada PV-Wind Hybrid System (Arctic at 81°N)

Photo Credit: Michael Ross Renewable Energy Research

600 kW Wind Turbine installation

Photo Credit: Nordex Gmbh

PV Phone

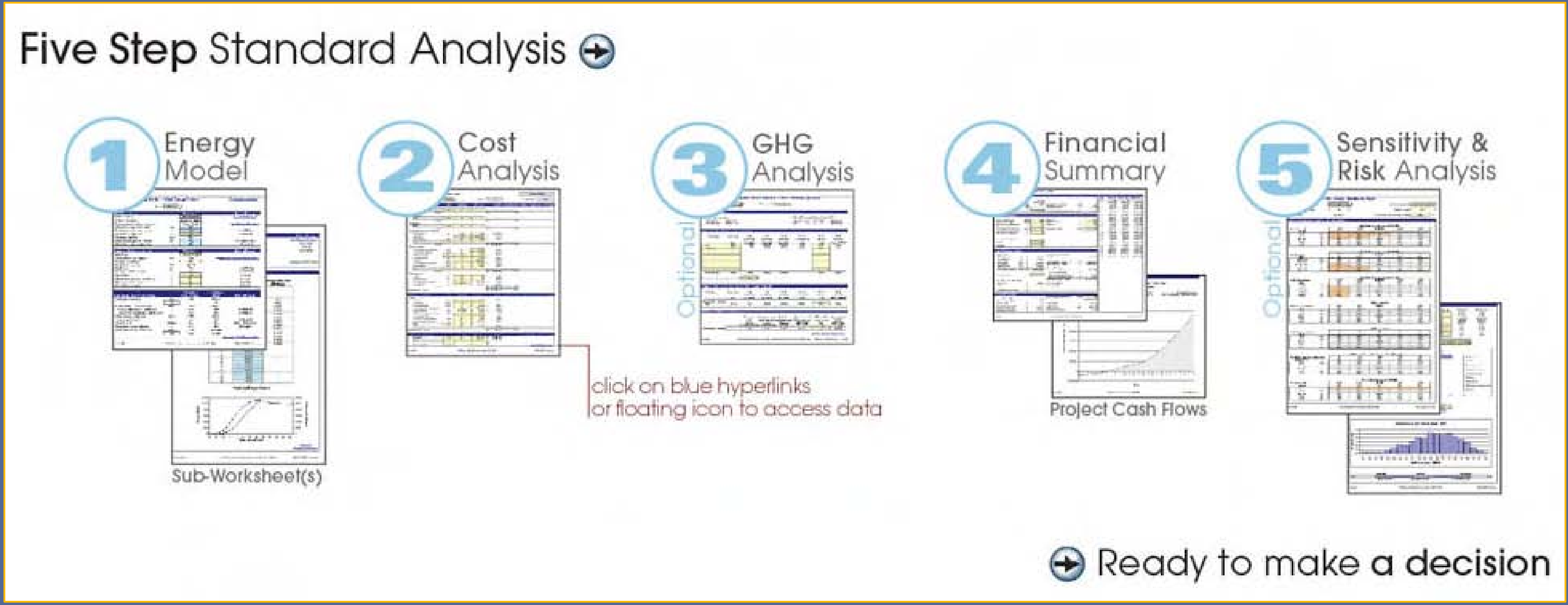
Photo Credit: Price, Chuck

Questions?

Introduction - Status of Clean Energy Technologies Module
RETScreen® International Clean Energy Project Analysis Course

For further information please visit the RETScreen Website at
www.retscreen.net

Clean Energy Project Analysis with RETScreen® Software



Objectives

- Illustrate role of preliminary feasibility studies
- Demonstrate how the RETScreen® Software works
- Show how RETScreen® makes it easier to help identify & assess potential projects

Energy Project Implementation Process

Pre-feasibility Analysis

Feasibility Analysis

Development & Engineering

Construction & Commissioning

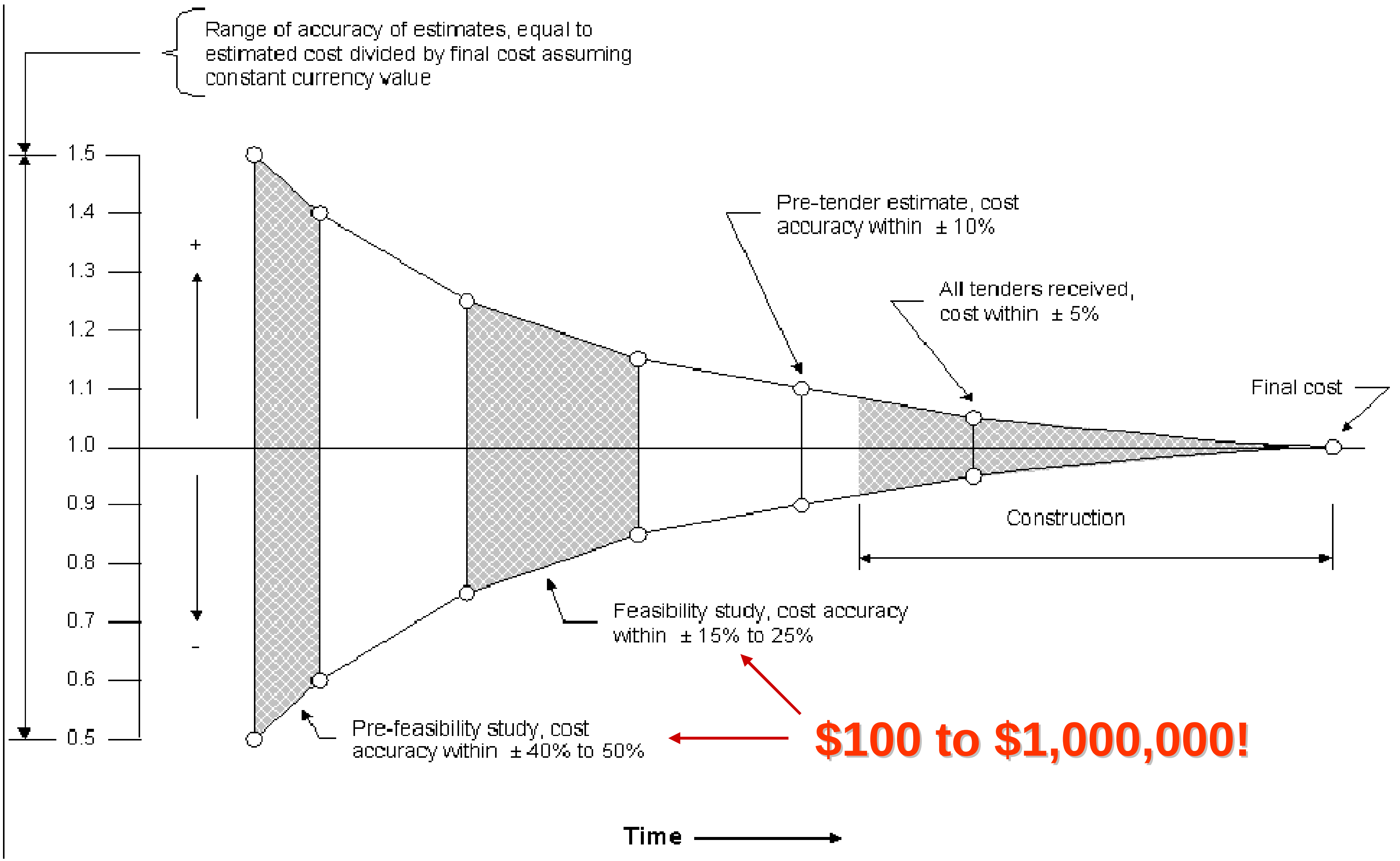
Significant barrier

Clean Energy projects not being routinely considered up-front!

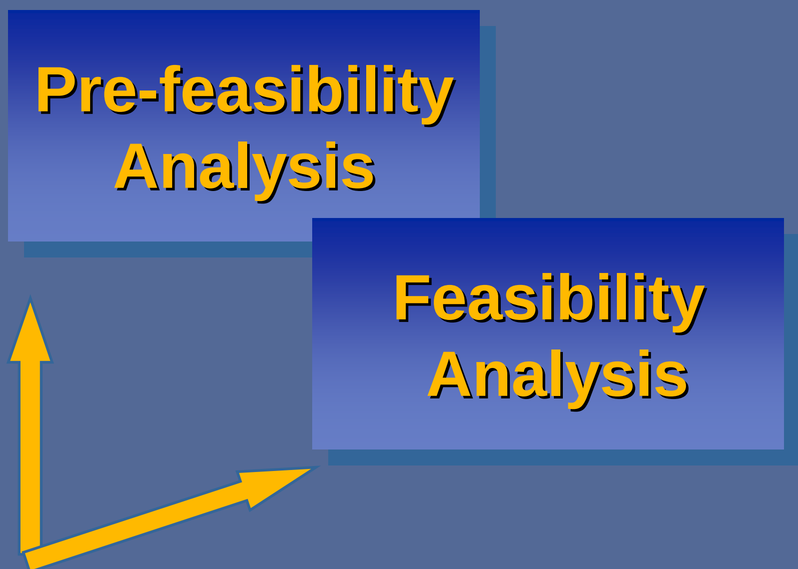
Questions

- What is an acceptable level of accuracy for project cost estimates?
- How much do these studies typically cost?

Accuracy vs. Investment Cost Dilemma



When should clean energy technologies be assessed?



Preliminary feasibility studies

- Need for energy system
- New construction or planned renovation
- High conventional energy costs
- Interest by key stakeholders
- Approvals possible
- Funding & financing accessible
- Good local clean energy resource, etc.

Project Viability (Wind Example) Depends on Several Factors

- **Energy resource available at project site**
  (e.g. wind speed)
- **Equipment performance**
  (e.g. wind turbine power curve)
- **Initial project costs**
  (e.g. wind turbines, towers, engineering)
- **"Base case" credits**
  (e.g. diesel generators for remote sites)
- **On-going and periodic project costs**
  (e.g. cleaning of wind turbine blades)


Wind Turbine & Tower

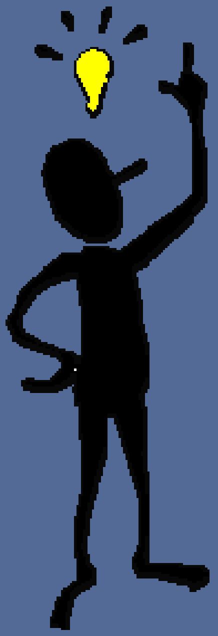
Project Viability (Wind Example) Depends on Several Factors - cont.

Photo Credit: Middelgrunden Wind Turbine Co-operative

- **Avoided cost of energy**
  (e.g. wholesale electricity price)
- **Financing**
  (e.g. debt ratio & length, interest rate)
- **Taxes on equipment & income (or savings)**
- **Environmental characteristics of energy displaced**
  (e.g. coal, natural gas, oil, large hydro, nuclear)
- **Environmental credits and/or subsidies**
  (e.g. greenpower rates, GHG credits, grants)
- **Decision-maker's definition of cost-effective**
  (e.g. payback period, IRR, NPV, Energy production costs)

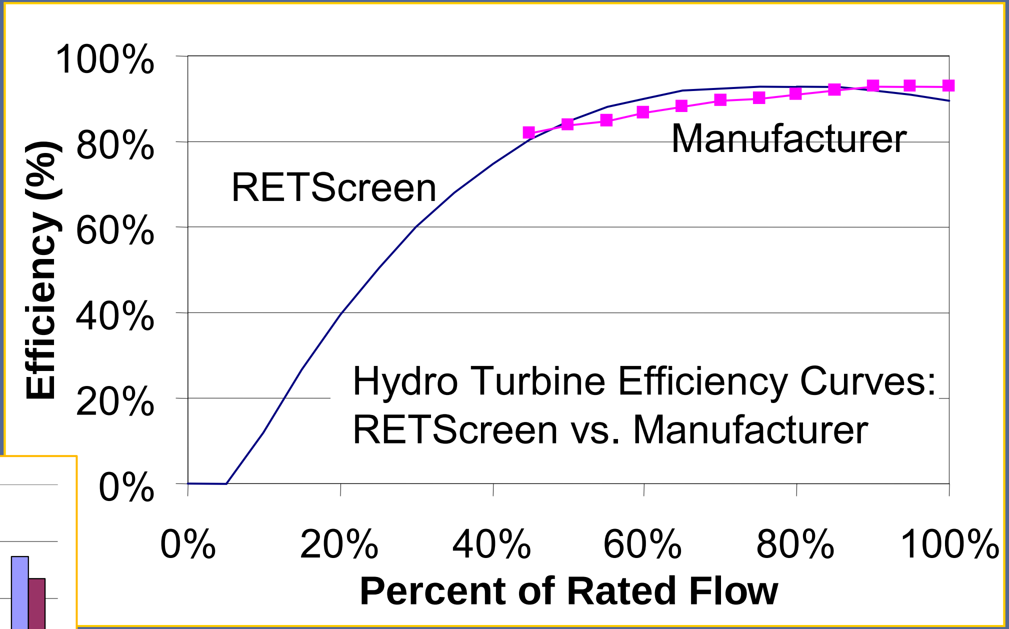
Why Use RETScreen®?

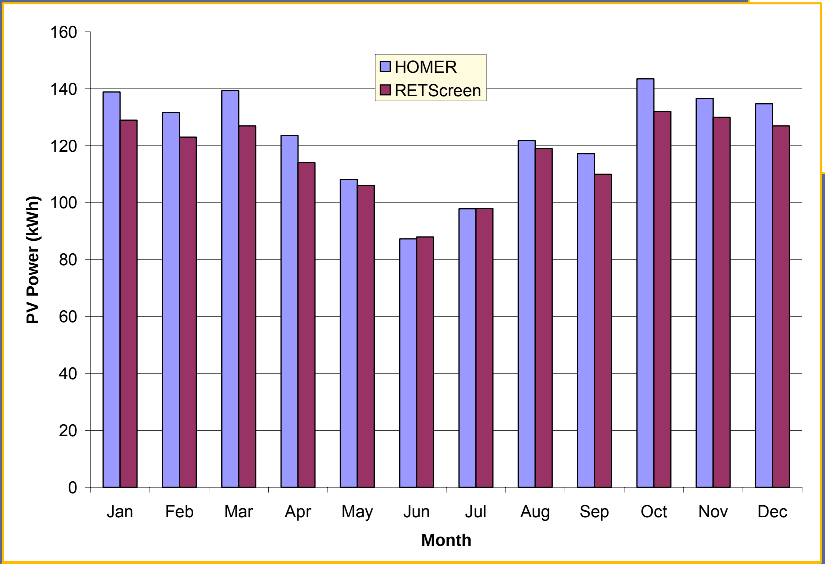
- Simplifies preliminary evaluations
  - Requires relatively little user input
  - Calculates key technical and financial viability indicators automatically
- Costs 1/10th the amount of other assessment methods
- Standardized procedures allow objective comparisons
- Increases potential for successful clean energy project implementation



RETScreen® Validation- Examples

- All models validated by comparison with monitored and manufacturer's data…

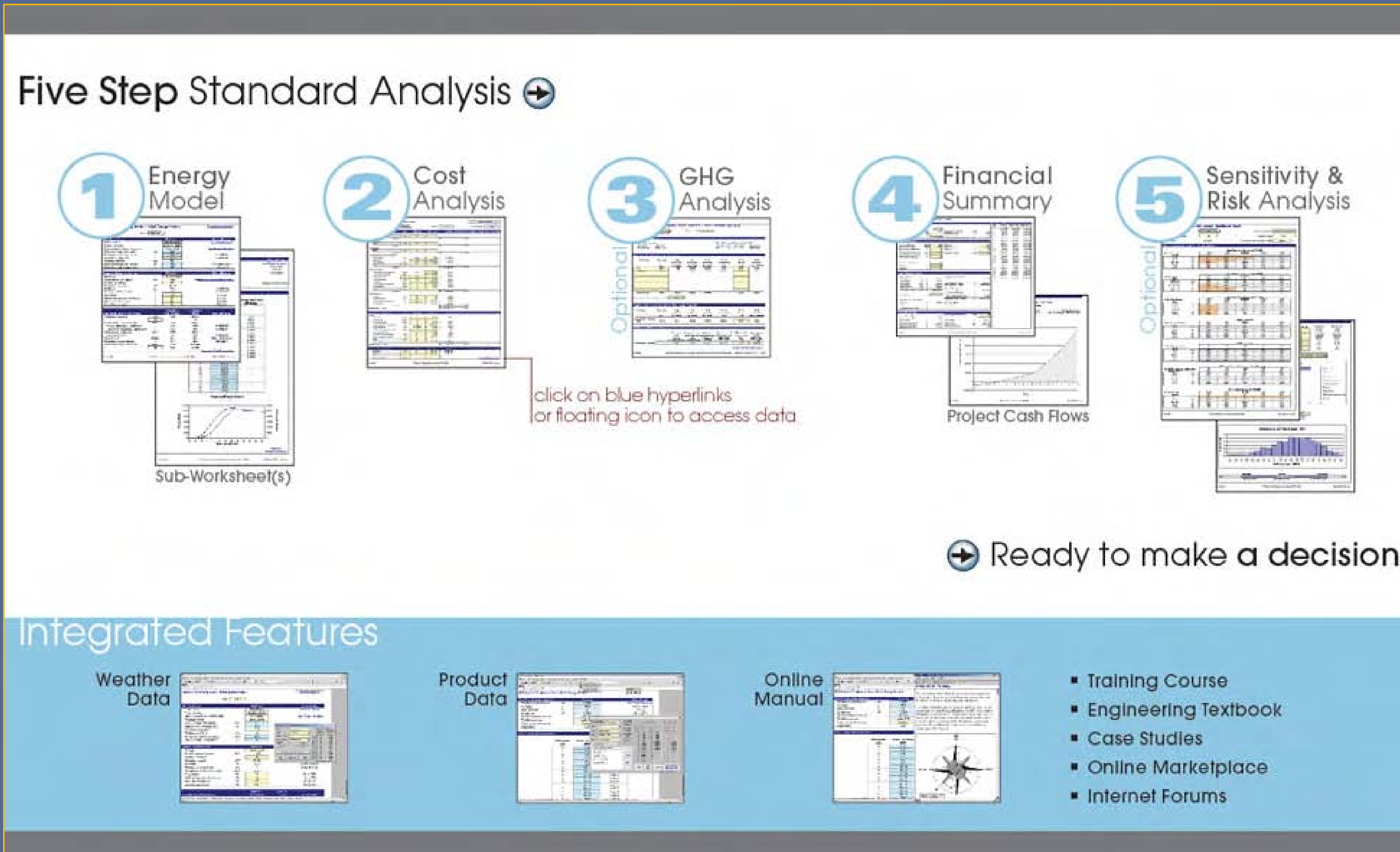


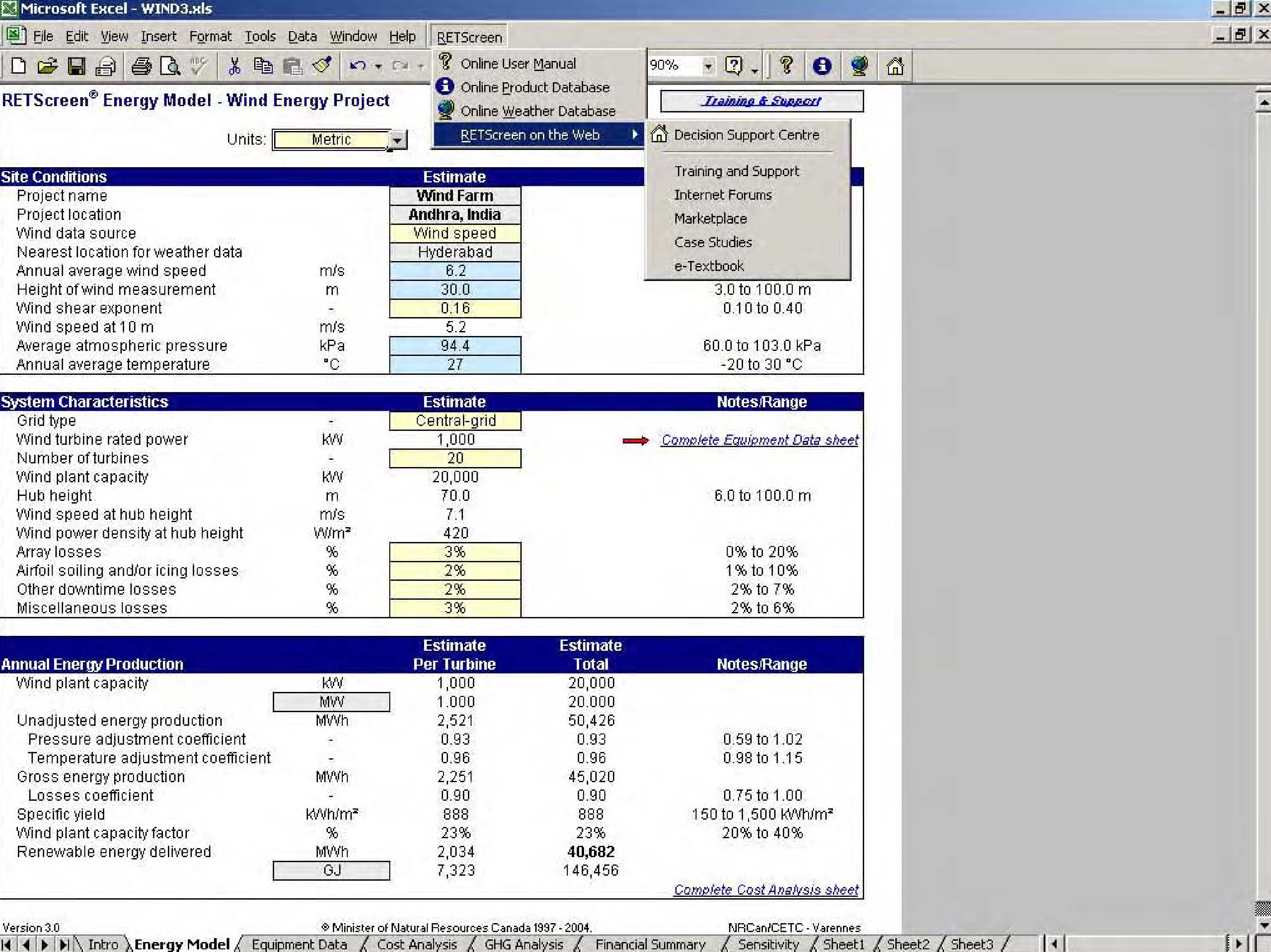


Comparing PV Energy Production Calculated by RETScreen and HOMER

- … and/or by comparison with hourly simulation tools.

RETScreen® Software Demonstration (Wind Energy Project Model Example)





RETScreen® Energy Model - Wind Energy Project

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Wind Farm	
Project location		Andhra, India	
Wind data source		Wind speed	
Nearest location for weather data		Hyderabad	
Annual average wind speed	m/s	6.2	
Height of wind measurement	m	30.0	3.0 to 100.0 m
Wind shear exponent	-	0.16	0.10 to 0.40
Wind speed at 10 m	m/s	5.2	
Average atmospheric pressure	kPa	94.4	60.0 to 103.0 kPa
Annual average temperature	°C	27	-20 to 30 °C

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Wind turbine rated power	kW	1,000	Complete Equipment Data sheet
Number of turbines	-	20	
Wind plant capacity	kW	20,000	
Hub height	m	70.0	6.0 to 100.0 m
Wind speed at hub height	m/s	7.1	
Wind power density at hub height	W/m²	420	
Array losses	%	3%	0% to 20%
Airfoil soiling and/or icing losses	%	2%	1% to 10%
Other downtime losses	%	2%	2% to 7%
Miscellaneous losses	%	3%	2% to 6%

Annual Energy Production		Estimate Per Turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	1,000	20,000	
	MW	1.000	20.000	
Unadjusted energy production	MWh	2,521	50,426	
Pressure adjustment coefficient	-	0.93	0.93	0.59 to 1.02
Temperature adjustment coefficient	-	0.96	0.96	0.98 to 1.15
Gross energy production	MWh	2,251	45,020	
Losses coefficient	-	0.90	0.90	0.75 to 1.00
Specific yield	kWh/m²	888	888	150 to 1,500 kWh/m²
Wind plant capacity factor	%	23%	23%	20% to 40%
Renewable energy delivered	MWh	2,034	**40,682**	
	GJ	7,323	146,456	

Complete Cost Analysis sheet

Version 3.0 | | NRCan/CETC - Varennes

Intro | Energy Model | Equipment Data | Cost Analysis | GHG Analysis | Financial Summary | Sensitivity | Sheet1 | Sheet2 | Sheet3

Cell Colour Coding

Input and Output Cells

Colour	Meaning
white	Model output - calculated by the model.
yellow	User input - required to run the model.
blue	User input - required to run the model and online databases available.
grey	User input - for reference purposes only. Not required to run the model.

Site Conditions		Estimate	Notes/Range
Project name		Wind Farm	See Online Manual
Project location		Andhra, India	
Wind data source		Wind speed	
Nearest location for weather data		Hyderabad	See Weather Database
Annual average wind speed	m/s	6.2	
Height of wind measurement	m	30.0	3.0 to 100.0 m
Wind shear exponent	-	0.16	0.10 to 0.40
Wind speed at 10 m	m/s	5.2	
Average atmospheric pressure	kPa	94.4	60.0 to 103.0 kPa
Annual average temperature	°C	27	-20 to 30 °C

Microsoft Excel - WIND3.xls

File Edit View Insert Format Tools Data Window Help RETScreen

RETScreen® Energy Model - Wind Energy Project

Units: Metric

Site Conditions		Estimate	Note
Project name		Wind Farm	See O
Project location		Andhra, India	
Wind data source		Wind speed	
Nearest location for weather data		Hyderabad	See Wea
Annual average wind speed	m/s	6.2	
Height of wind measurement	m	30.0	3.0 t
Wind shear exponent	-	0.16	0.1
Wind speed at 10 m	m/s	5.2	
Average atmospheric pressure	kPa	94.4	60.0 to
Annual average temperature	°C	27	-20

System Characteristics		Estimate	Note
Grid type	-	Central-grid	
Wind turbine rated power	kW	1,000	Complete Equ
Number of turbines	-	20	
Wind plant capacity	kW	20,000	
Hub height	m	70.0	6.0 t
Wind speed at hub height	m/s	7.1	
Wind power density at hub height	W/m²	420	
Array losses	%	3%	0%
Airfoil soiling and/or icing losses	%	2%	1%
Other downtime losses	%	2%	2%
Miscellaneous losses	%	3%	2%

Annual Energy Production		Estimate Per Turbine	Estimate Total	Note
Wind plant capacity	kW	1,000	20,000	
	MW	1.000	20.000	
Unadjusted energy production	MWh	2,521	50,426	
Pressure adjustment coefficient	-	0.93	0.93	0.5
Temperature adjustment coefficient	-	0.96	0.96	0.9
Gross energy production	MWh	2,251	45,020	
Losses coefficient	-	0.90	0.90	0.7
Specific yield	kWh/m²	888	888	150 to 1
Wind plant capacity factor	%	23%	23%	20%
Renewable energy delivered	MWh	2,034	**40,682**	
	GJ	7,323	146,456	

Complete C

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Intro | Energy Model | Equipment Data | Cost Analysis | GHG Analysis | Financial Summary | Sensitivity | Sheet1 | Sheet2 | Sheet3

RETScreen Wind Energy Project

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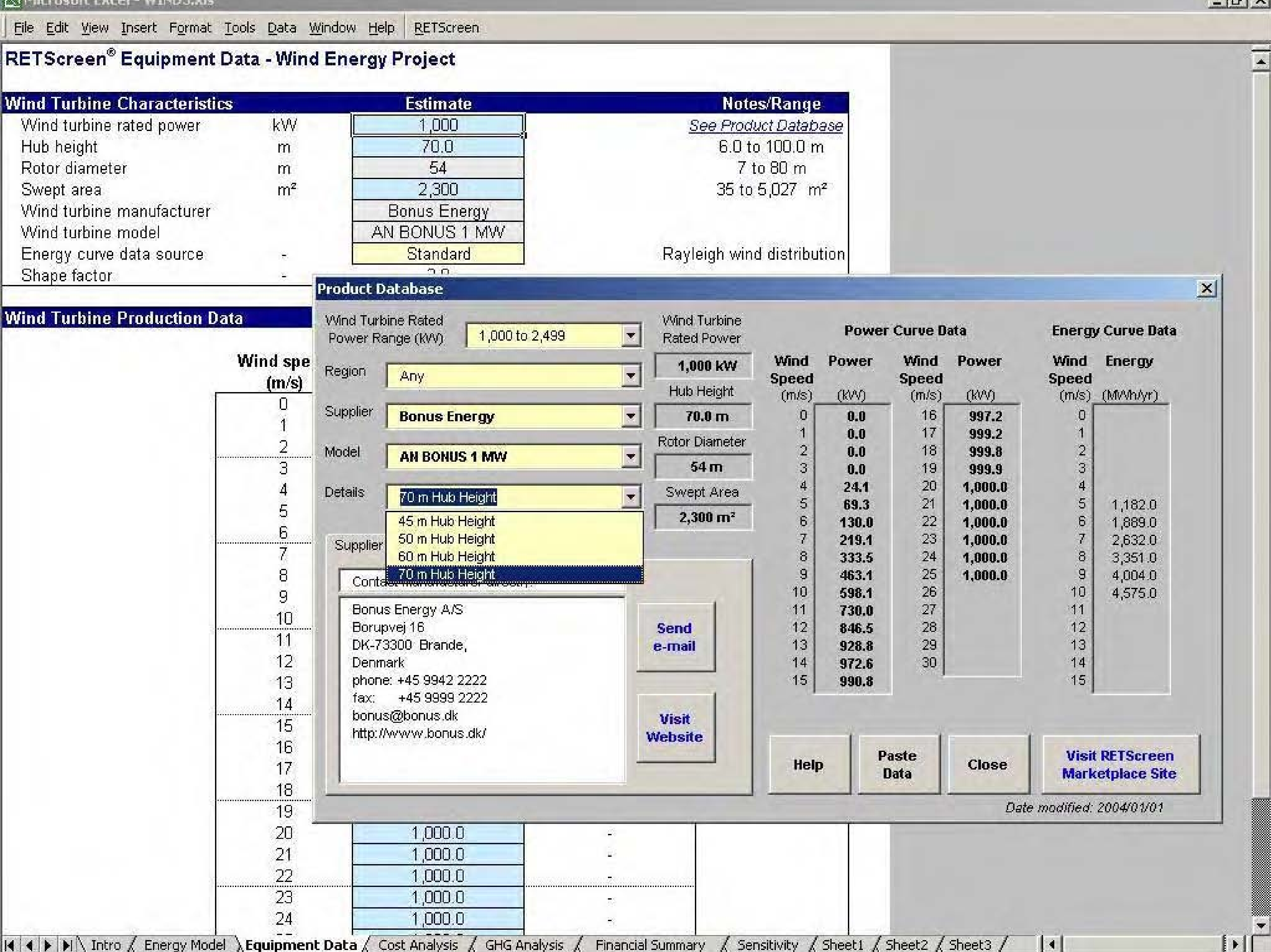
Contents Index Back Print << >>

Wind shear exponent

The user enters the wind shear exponent, which is a dimensionless number expressing the rate at which the wind speed varies with the height above the ground. A low exponent corresponds to a smooth terrain whereas a high exponent is typical of a terrain with sizeable obstacles. This value is used to calculate the average wind speed at the wind turbine hub height and at 10 m.

The wind shear exponent typically ranges from 0.10 to 0.40. The low end of the range corresponds to a smooth terrain (e.g. sea, sand and snow from 0.10 to 0.13). A wind shear of 0.25 corresponds to a rough terrain (i.e. with sizeable obstacles). The high end of the range (0.40) corresponds to a project in an urban area. A value of 0.14 is a good first approximation when the site characteristics are yet to be determined [Le Gouriérès, 1982], [WECTEC, 1996] and [Gipe, 1995].


Microsoft Excel - WIND3.xls
File Edit View Insert Format Tools Data Window Help RETScreen
RETScreen® Equipment Data - Wind Energy Project
Wind Turbine Characteristics
Estimate
Notes/Range
Wind turbine rated power kW 1,000 See Product Database
Hub height m 70.0 6.0 to 100.0 m
Rotor diameter m 54 7 to 80 m
Swept area m² 2,300 35 to 5,027 m²
Wind turbine manufacturer Bonus Energy
Wind turbine model AN BONUS 1 MW
Energy curve data source - Standard Rayleigh wind distribution
Shape factor -
Wind Turbine Production Data
Wind spe
(m/s)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20 1,000.0 -
21 1,000.0 -
22 1,000.0 -
23 1,000.0 -
24 1,000.0 -
Product Database
Wind Turbine Rated Power Range (kW) 1,000 to 2,499
Region Any
Supplier Bonus Energy
Model AN BONUS 1 MW
Details 70 m Hub Height
45 m Hub Height
50 m Hub Height
60 m Hub Height
70 m Hub Height
Supplier
Bonus Energy A/S
Borupvej 16
DK-73300 Brande,
Denmark
phone: +45 9942 2222
fax: +45 9999 2222
bonus@bonus.dk
http://www.bonus.dk/
Send e-mail
Visit Website
Wind Turbine Rated Power
1,000 kW
Hub Height
70.0 m
Rotor Diameter
54 m
Swept Area
2,300 m²
Power Curve Data
Wind Speed (m/s) Power (kW) Wind Speed (m/s) Power (kW)
0 0.0 16 997.2
1 0.0 17 999.2
2 0.0 18 999.8
3 0.0 19 999.9
4 24.1 20 1,000.0
5 69.3 21 1,000.0
6 130.0 22 1,000.0
7 219.1 23 1,000.0
8 333.5 24 1,000.0
9 463.1 25 1,000.0
10 598.1 26
11 730.0 27
12 846.5 28
13 928.8 29
14 972.6 30
15 990.8
Energy Curve Data
Wind Speed (m/s) Energy (MWh/yr)
0
1
2
3
4
5 1,182.0
6 1,889.0
7 2,632.0
8 3,351.0
9 4,004.0
10 4,575.0
11
12
13
14
15
Help
Paste Data
Close
Visit RETScreen Marketplace Site
Date modified: 2004/01/01
Intro Energy Model Equipment Data Cost Analysis GHG Analysis Financial Summary Sensitivity Sheet1 Sheet2 Sheet3

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Sec_Currenc... = Denmark

RETScreen® Cost Analysis - Wind Energy Project

Search Marketplace

Type of project: Custom | Currency: User-defined US$ | Cost references: Second currency

Second currency: Denmark | Rate: US$/DKK 0.17900

Initial Costs (Credits)	Unit	Quantity	Unit Cost		Amount		Relative Costs	% Foreign	Foreign Amount	
Feasibility Study										
Site investigation	p-d	6.0	US$	800				0%	DKK	-
Wind resource assessment	met tower	6	US$	22,000				0%	DKK	-
Environmental assessment	p-d	8.0	US$	800				0%	DKK	-
Preliminary design	p-d	18.0	US$	800				0%	DKK	-
Detailed cost estimate	p-d	18.0	US$	800	US$	14,400		0%	DKK	-
GHG baseline study and MP	project	1	US$	50,000	US$	50,000		0%	DKK	-
Report preparation	p-d	8.0	US$	800	US$	6,400		0%	DKK	-
Project management	p-d	6.0	US$	800	US$	4,800		0%	DKK	-
Travel and accommodation	p-trip	4	US$	3,000	US$	12,000		0%	DKK	-
Other - Feasibility study	Cost	0	US$	-	US$	-		0%	DKK	-
Sub-total:					**US$**	**245,200**	0.8%	0%	DKK	-
Development										
PPA negotiation	p-d	20.0	US$	1,200	US$	24,000		0%	DKK	-
Permits and approvals	p-d	250.0	US$	800	US$	200,000		0%	DKK	-
Land rights	project	1	US$	30,000	US$	30,000		0%	DKK	-
Land survey	p-d	50.0	US$	600	US$	30,000		0%	DKK	-
GHG validation and registration	project	1	US$	65,000	US$	65,000		0%	DKK	-
Project financing	p-d	100.0	US$	1,500	US$	150,000		0%	DKK	-
Legal and accounting	p-d	100.0	US$	1,200	US$	120,000		0%	DKK	-
Project management	p-yr	1.25	US$	130,000	US$	162,500		0%	DKK	-
Travel and accommodation	p-trip	18	US$	3,000	US$	54,000		0%	DKK	-
Other - Development	Cost	0	US$	-	US$	-		0%	DKK	-
Sub-total:					**US$**	**835,500**	2.7%	0%	DKK	-
Engineering										
Wind turbine(s) micro-siting	p-d	175.0	US$	800	US$	140,000		0%	DKK	-
Mechanical design	p-d	100.0	US$	800	US$	80,000		0%	DKK	-
Electrical design	p-d	150.0	US$	800	US$	120,000		0%	DKK	-
Civil design	p-d	90.0	US$	800	US$	72,000		0%	DKK	-
Tenders and contracting	p-d	110.0	US$	800	US$	88,000		0%	DKK	-
Construction supervision	p-yr	0.85	US$	130,000	US$	110,500		0%	DKK	-
Other - Engineering	Cost	0	US$	-	US$	-		0%	DKK	-
Sub-total:					**US$**	**610,500**	2.0%	0%	DKK	-

Denmark
Djibouti
Dominica
Dominican Rep.
Ecuador
Egypt
El Salvador
Equatorial Guinea

Intro / Energy Model / Equipment Data / Cost Analysis / GHG Analysis / Financial Summary / Sensitivity / Sheet1 / Sheet2 / Sheet3

Microsoft Excel - WIND3.xls

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RETScreen® Energy Model - Wind Energy Project

Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Wind Farm	See Online Manual
Project location		Lethbridge A, AB	
Wind data source		Wind speed	
Nearest location for weather data		Lethbridge A, AB	See Weather Database
Annual average wind speed	m/s	5.4	
Height of wind measurement	m	10.0	
Wind shear exponent	-	0.16	
Wind speed at 10 m	m/s	5.2	
Average atmospheric pressure	kPa	90.7	
Annual average temperature	°C	6	

System Characteristics		Estimate
Grid type	-	Central-grid
Wind turbine rated power	kW	1,000
Number of turbines	-	20
Wind plant capacity	kW	20,000
Hub height	m	70.0
Wind speed at hub height	m/s	7.1
Wind power density at hub height	W/m²	420
Array losses	%	3%
Airfoil soiling and/or icing losses	%	2%
Other downtime losses	%	2%
Miscellaneous losses	%	3%

Weather Database

Region		N. & Central America
Country		Canada
Province / State		AB
Weather Station		Lethbridge A
Latitude [°]		49.63
Longitude [°]		-112.80
Annual Average Wind Speed	[m/s]	5.4
Height of Wind Measurement	[m]	10.0
Average Atmospheric Pressure	[kPa]	90.7
Annual Average Temperature	[°C]	6

Visit Other Data Sites | Help | Paste Data | Close

Date modified: 2004/01/01

Annual Energy Production		Estimate Per Turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	1,000	20,000	
	MW	1.000	20.000	
Unadjusted energy production	MWh	2,521	50,426	
Pressure adjustment coefficient	-	0.93	0.93	0.59 to 1.02
Temperature adjustment coefficient	-	0.96	0.96	0.98 to 1.15
Gross energy production	MWh	2,251	45,020	
Losses coefficient	-	0.90	0.90	0.75 to 1.00
Specific yield	kWh/m²	888	888	150 to 1,500 kWh/m²
Wind plant capacity factor	%	23%	23%	20% to 40%
Renewable energy delivered	MWh	2,034	**40,682**	
	GJ	7,323	146,456	

Complete Cost Analysis sheet

Version 3.0

NRCan/CETC - Varennes

Intro | Energy Model | Equipment Data | Cost Analysis | GHG Analysis | Financial Summary | Sensitivity | Sheet1 | Sheet2 | Sheet3

NASA Surface meteorology and Solar Energy: RETScreen Data - Netscape

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Surface meteorology and Solar Energy Data Set

A renewable energy resource web site
sponsored by
NASA's Earth Science Enterprise Program

A collaboration with the CANMET Energy Technology Centre - Varennes (CETC-Varennes) has produced data output useful to users of the RETScreen® International Renewable Energy Project Analysis Software.

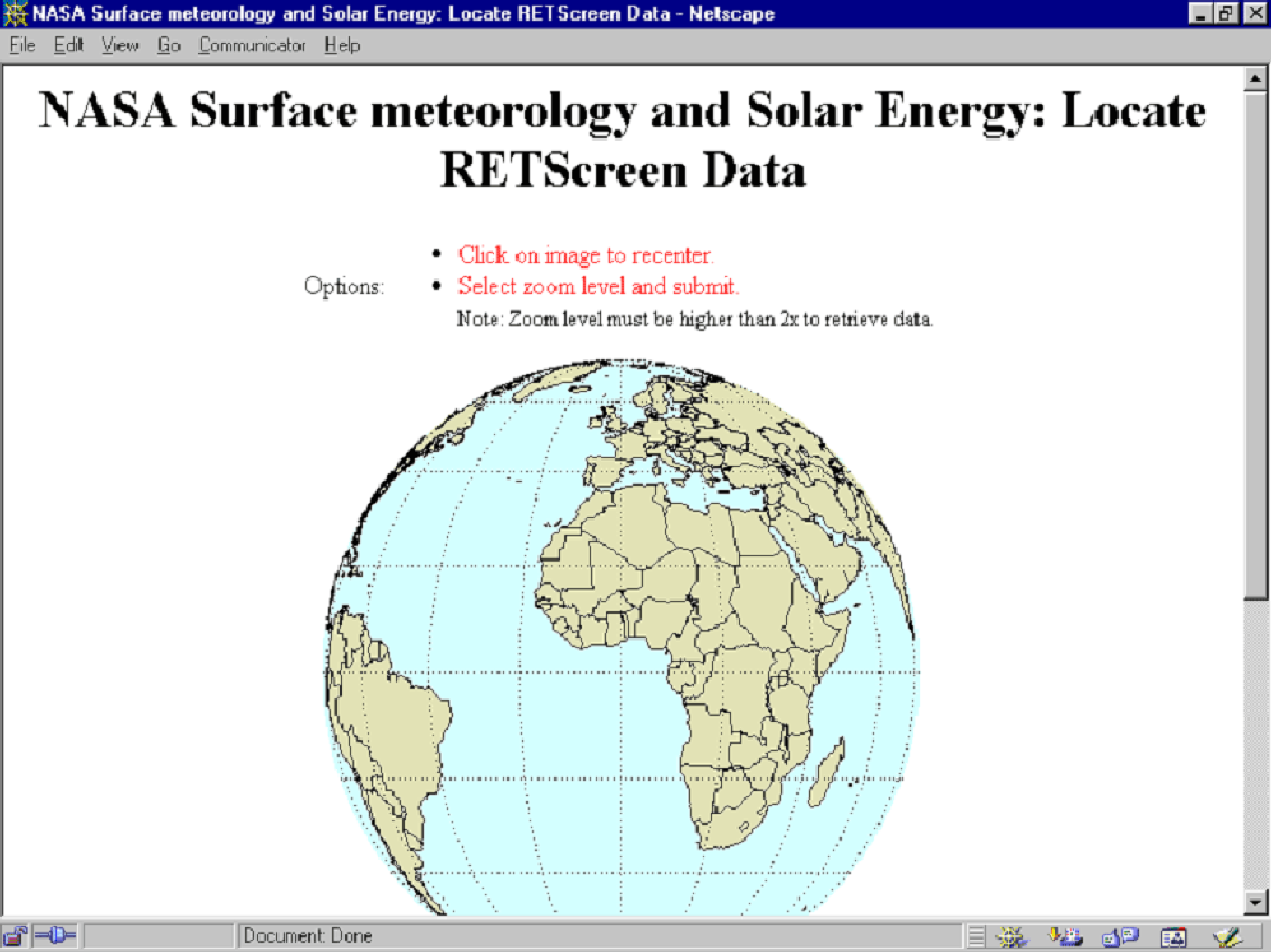
To access data for RETScreen:

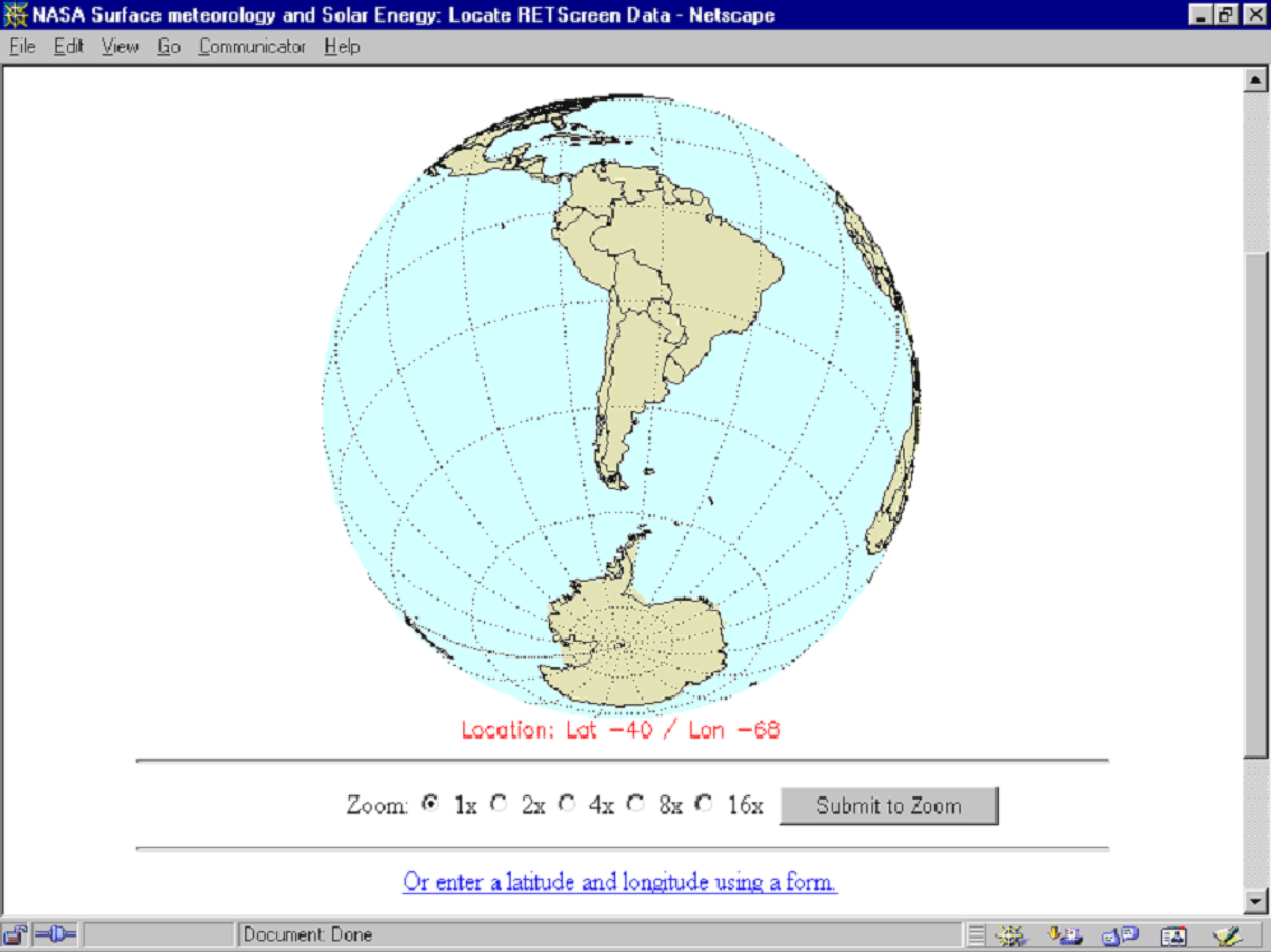
- Pick a location graphically.
- Or enter a latitude and longitude in the form below.

Enter BOTH latitude and longitude either in decimal degrees or degrees and minutes separated by a space.

Example:	Latitude 33.5 Longitude -80.75	OR	Latitude 33 30 Longitude -80 45
Latitude?	North: 0 to 90		South: 0 to -90
Longitude?	East: 0 to 180		West: 0 to -180

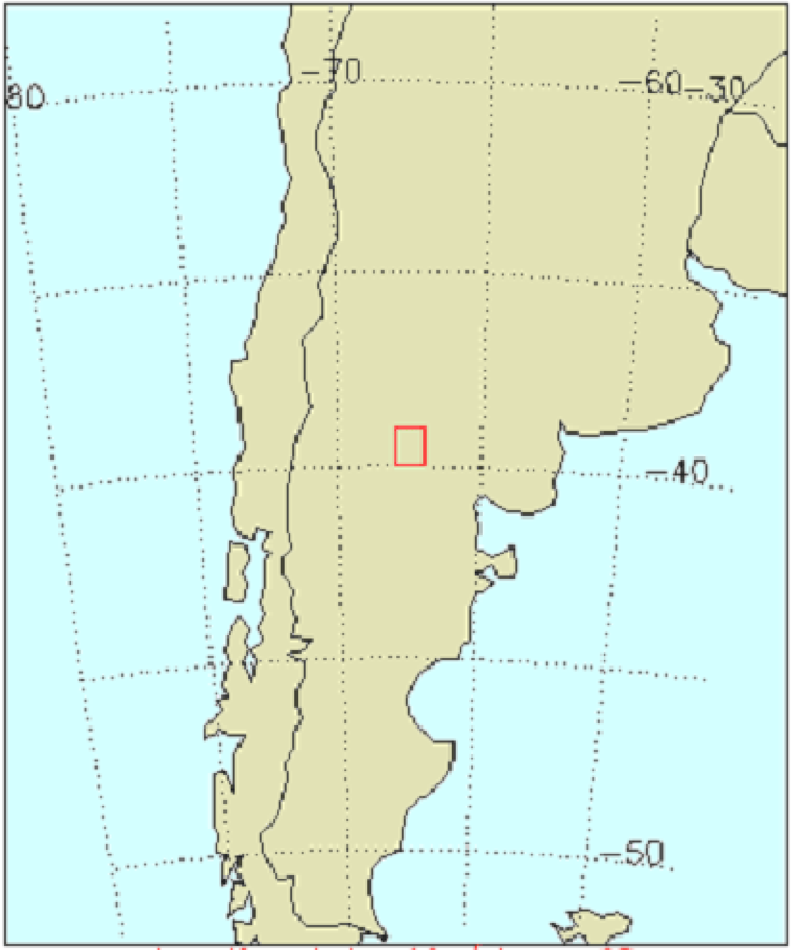
Submit Reset *This form is "Reset" if the input is out of range.*


NASA Surface meteorology and Solar Energy: Locate RETScreen Data - Netscape
File Edit View Go Communicator Help
NASA Surface meteorology and Solar Energy: Locate RETScreen Data
Options:
Click on image to recenter.
Select zoom level and submit.
Note: Zoom level must be higher than 2x to retrieve data.
Document: Done


NASA Surface meteorology and Solar Energy: Locate RETScreen Data - Netscape
File Edit View Go Communicator Help
Location: Lat -40 / Lon -68
Zoom: 1x 2x 4x 8x 16x
Submit to Zoom
Or enter a latitude and longitude using a form.
Document: Done

NASA Surface meteorology and Solar Energy: Locate RETScreen Data - Netscape

File Edit View Go Communicator Help



Location: Lat -40 / Lon -68

Zoom: ○ 1x ○ 2x ○ 4x ● 8x ○ 16x [Submit to Zoom]

Or enter a latitude and longitude using a form.

Document: Done

NASA Surface meteorology and Solar Energy: RETScreen Data - Choices - Netscape

File Edit View Go Communicator Help

RETScreen Data

Latitude -40 / Longitude -68 was chosen.

Submit Reset

Check the boxes and press Submit
(Default is All Values)

Geometry

	Values	Definitions
Geometry Information - latitude/longitude center and boundaries	☐	☐

RETScreen Technology Models

	Values	Definitions
Passive Solar Heating Project	☐	☐
Solar Water Heating Project	☐	☐
Ground-Source Heat Pump Project	☐	☐
Photovoltaic Project	☐	☐
Solar Air Heating Project	☐	☐
Biomass Heating Project	☐	☐
Wind Energy Project	☑	☐
Small Hydro Project	☐	☐

Document: Done

NASA Surface meteorology and Solar Energy: RETScreen Data - Available Tables - Netscape

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RETScreen Model(s) chosen:

Wind Energy

Average Temperature (° C)

Lat -40 Lon -68	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10 Year Average	19.3	19.3	15.7	10.1	5.98	4.16	3.06	5.17	7.90	11.4	15.3	17.5	11.2
El Nino Year (1987)	20.8	20.1	15.7	11.1	4.99	5.15	5.52	4.80	6.78	11.9	16.5	16.5	11.6
La Nina Year (1988)	18.6	21.8	16.4	10.1	5.67	3.86	1.43	4.63	7.85	9.10	14.5	17.8	10.9

Average Wind Speed (m/s)

Lat -40 Lon -68	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10 Year Average	4.51	4.11	4.04	4.01	4.19	4.04	3.92	3.95	4.05	4.28	4.36	4.73	4.18
El Nino Year (1987)	4.36	3.79	4.00	3.90	3.99	4.38	4.24	3.91	3.97	3.92	4.07	4.82	4.11
La Nina Year (1988)	5.24	3.61	3.84	3.99	3.69	4.26	3.66	4.22	4.09	5.28	4.99	5.21	4.34

It is recommended that users of these wind data view the Methodology Section of this web site. The user may wish to correct for bias as well as local effects within the grid region.

Average Atmospheric Pressure (kPa)

Document: Done

RETScreen® Software Financial Analysis Method

Comparison:

- Base Case vs. Proposed Case
- Conventional system vs. clean energy system

Example:

- Standard building cladding (siding) and a natural gas fired air heater

  vs.

- *Solarwall™* cladding with solar air heating plus the conventional natural gas fired air heater

Yellowknife School Solarwall Under Construction

Photo Credit: Arctic Energy Alliance

Software Demo
20 MW Wind Energy Project

Input/Output (RETScreen®)	Scenario #1 (Merchant Plant)	Scenario # 2 (Green Power Plant)
Project location:	Calgary, AB	Pincher Creek, AB
Wind speed:	4.4 m/s	Lethbridge → 7.0 m/s
GHG emissions reduction:	25,123 tCO_2/yr	→ 63,486 tCO_2/yr
Wind turbine cost:	$1,200/kW	→ $1,000/kW
RE production credit:	$0/kWh	→ $0.025/kWh
GHG credit (coal plant):	$0/ton	→ $5/ton
Debt term:	10 years	→ 15 years
Positive cash flow:	**42.7 years**	**5.2 years**
Return on investment:	**- 7.1%**	**22.8%**

Software Demo
Scenario 1

RETSCREEN® INTERNATIONAL www.retscreen.net

<u>Scenario #1</u>

(Merchant Plant)

Calgary, AB

4.4 m/s

$1,200/kW

25,123 t_{CO_2}/yr

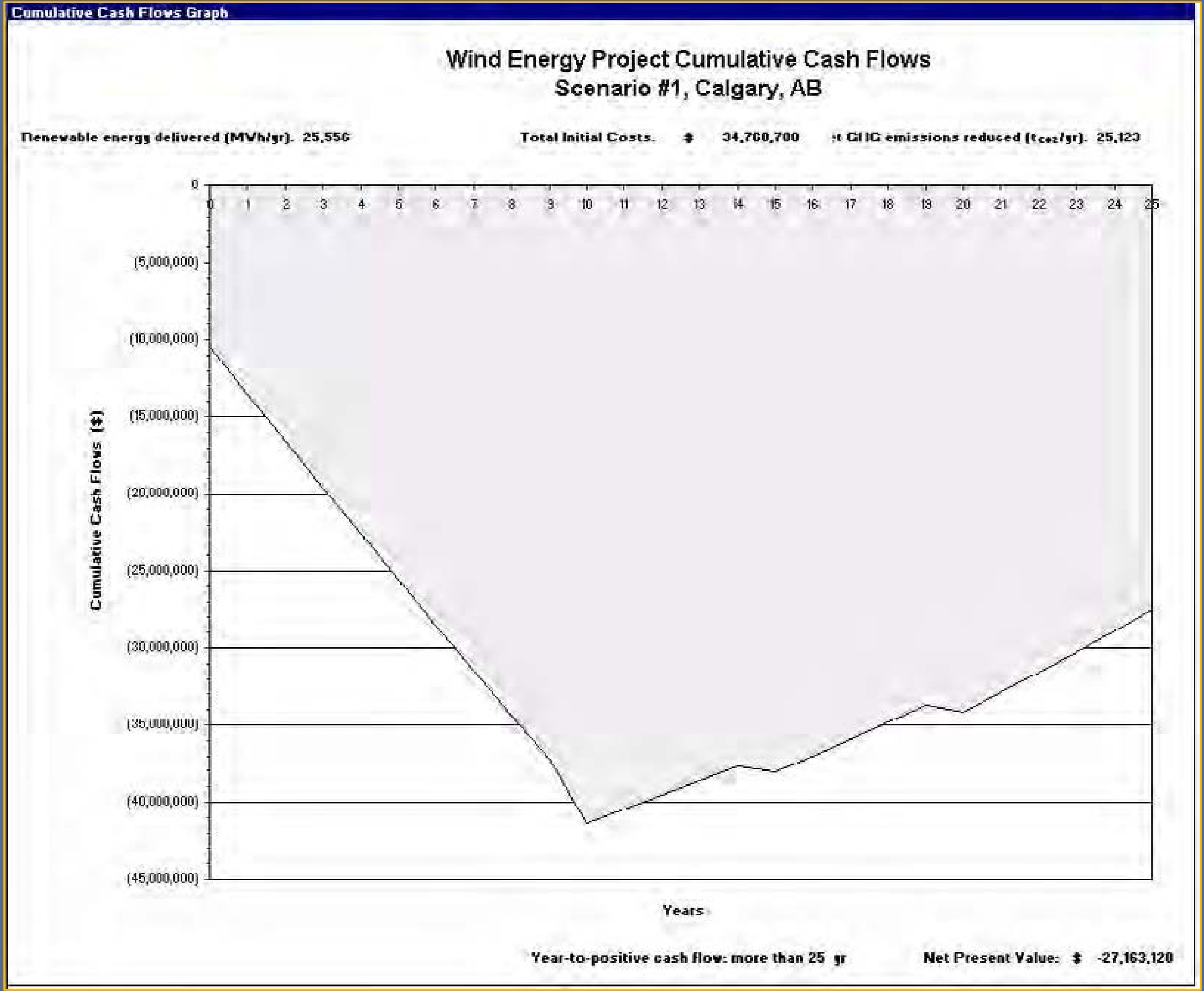
$0/kWh

$0/ton

10 years

42.7 years

- 7.1%



Software Demo
Wind Speed & GHG Emission Reduction

RETSCREEN® INTERNATIONAL www.retscreen.net

Scenario # 1a

(Green Power Plant)

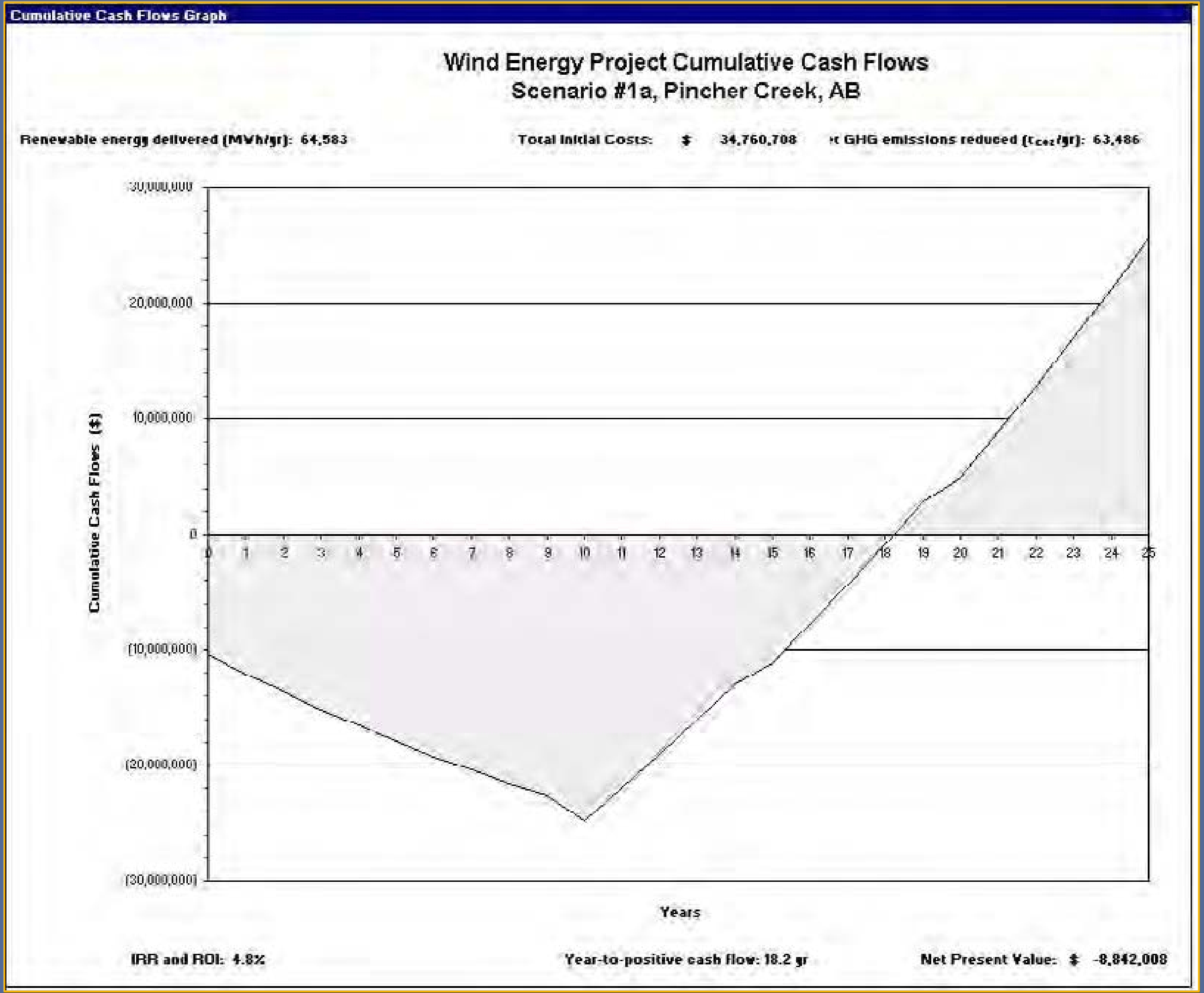
Pincher Creek, AB

Lethbridge → 7.0 m/s

63,486 t_{CO_2}/yr

18.2 years

4.8%



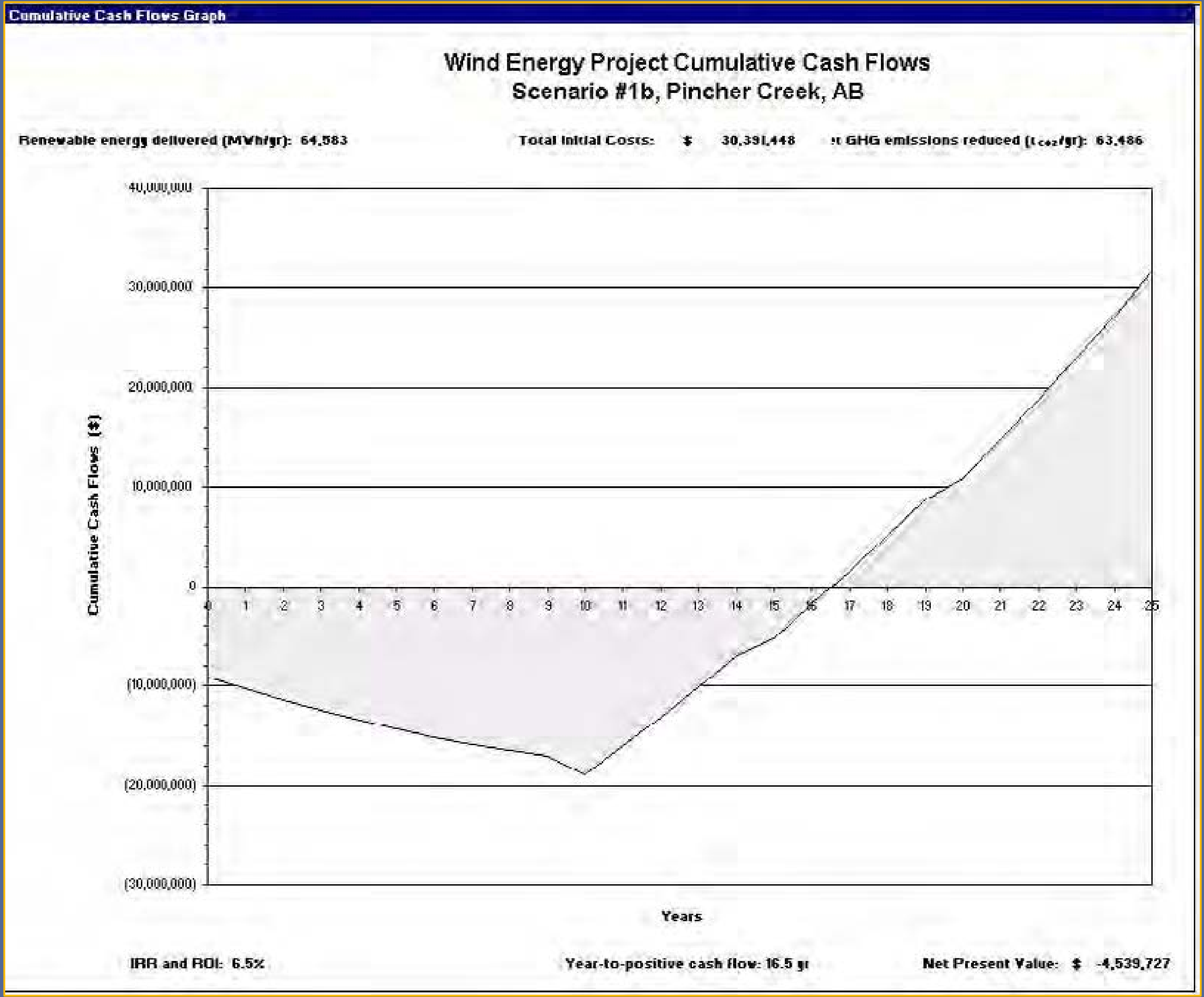
Software Demo
Wind Turbine Cost

Scenario # 1b

$1,000/kW

16.5 years

6.5%



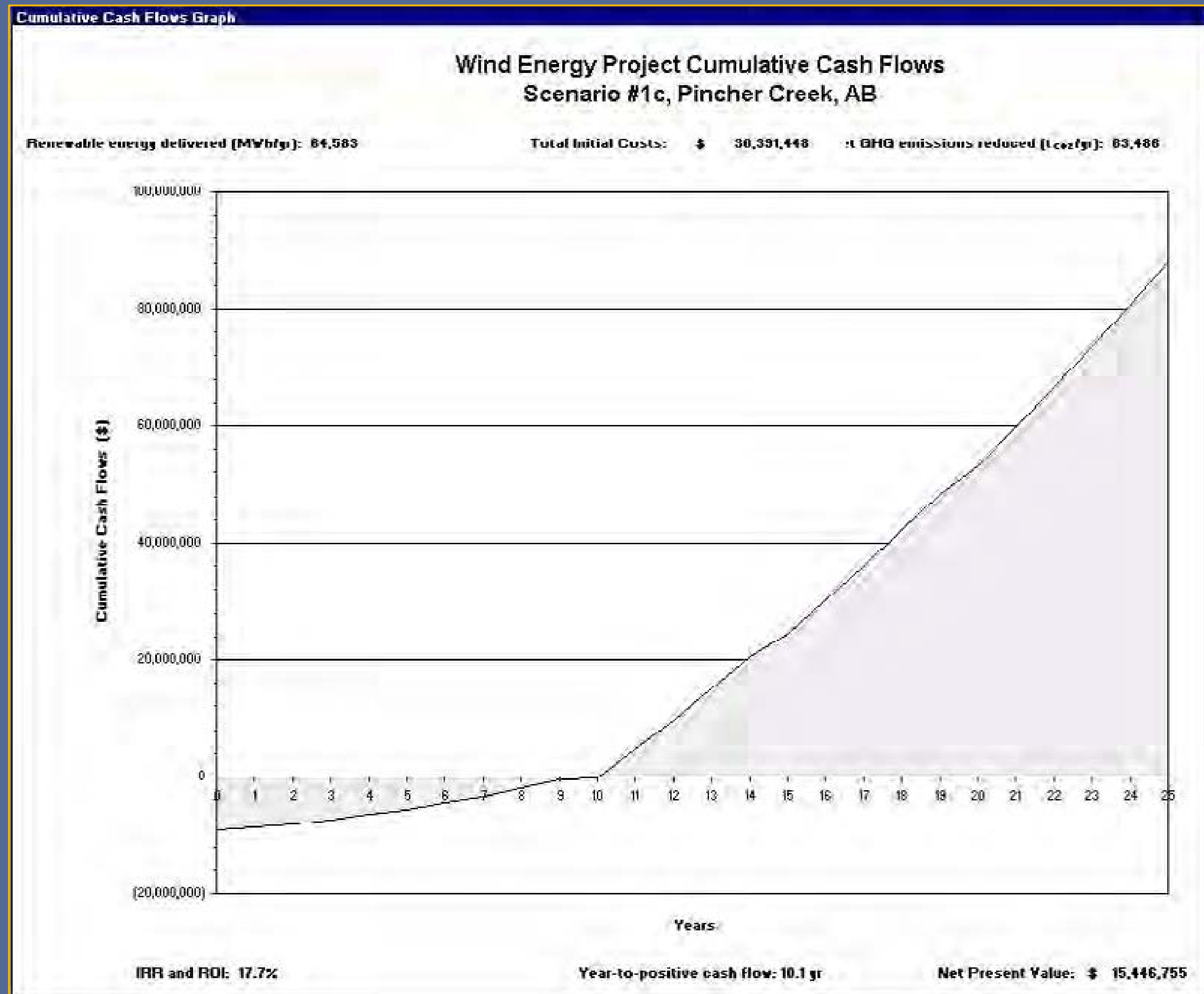
Software Demo
RE Production Credit

Scenario # 1c

$0.025/kWh

10.1 years

17.7%



Software Demo
GHG Emissions Credit

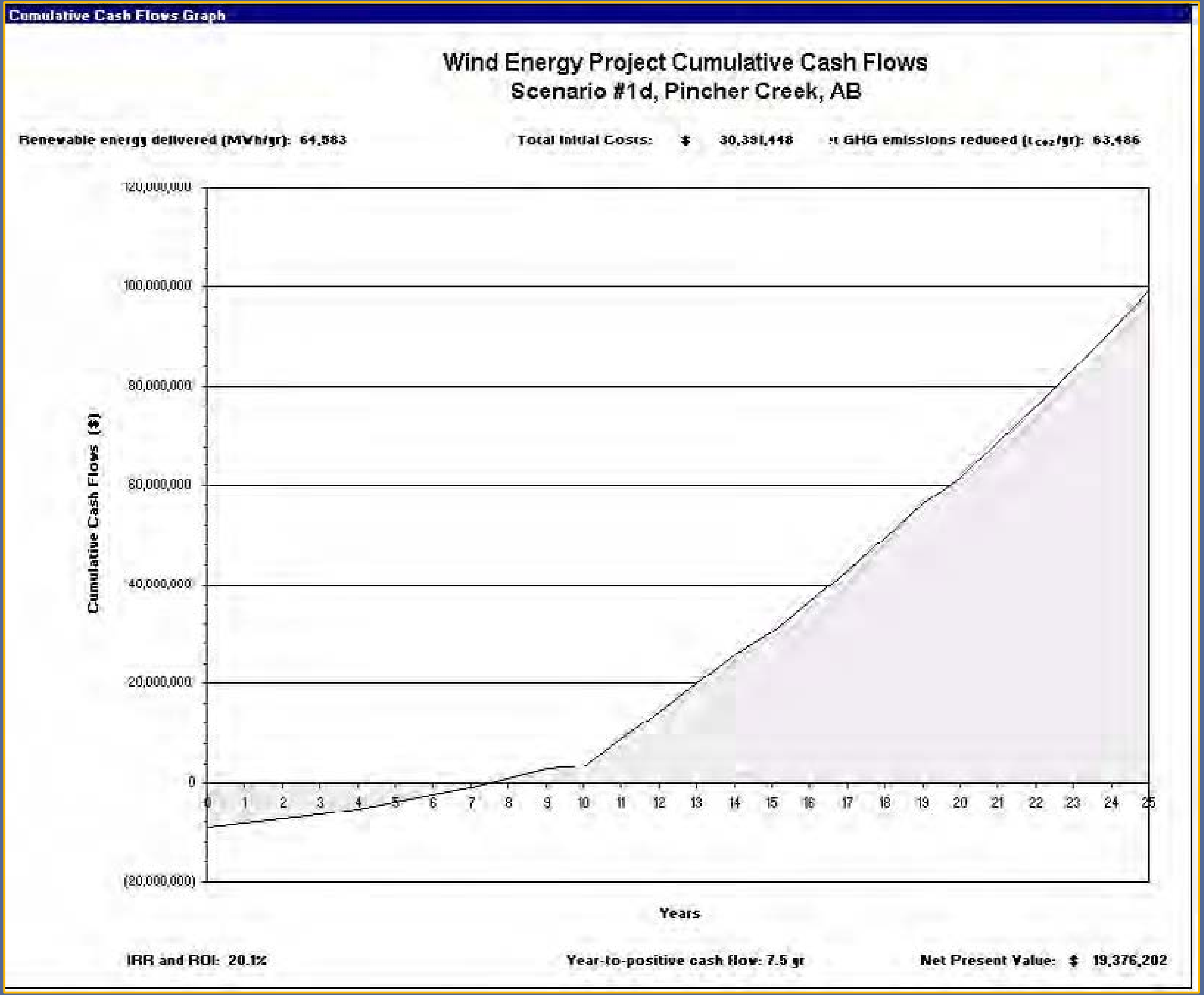
RETSCREEN® INTERNATIONAL www.retscreen.net

Scenario # 1d

$5/ton

7.5 years

20.1%



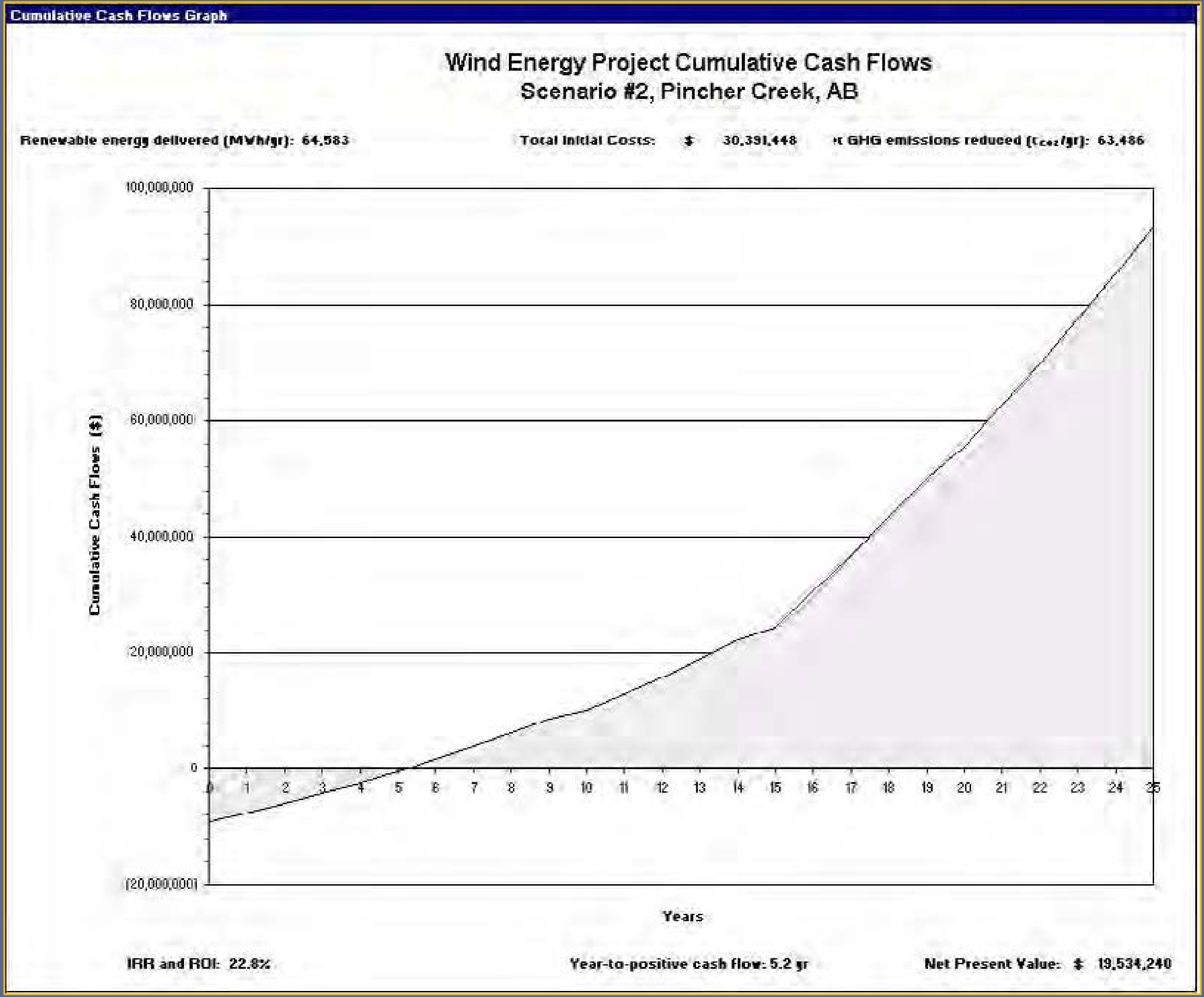
Software Demo
Debt Term

Scenario # 2

15 years

5.2 years

22.8%



Questions?

Clean Energy Project Analysis with RETScreen® Software Module
RETScreen® International Clean Energy Project Analysis Course

For further information please visit the RETScreen Website at
www.retscreen.net

Greenhouse Gas Emission Analysis with RETScreen® Software

RETScreen® International www.retscreen.net

Clean Energy Project Analysis Course

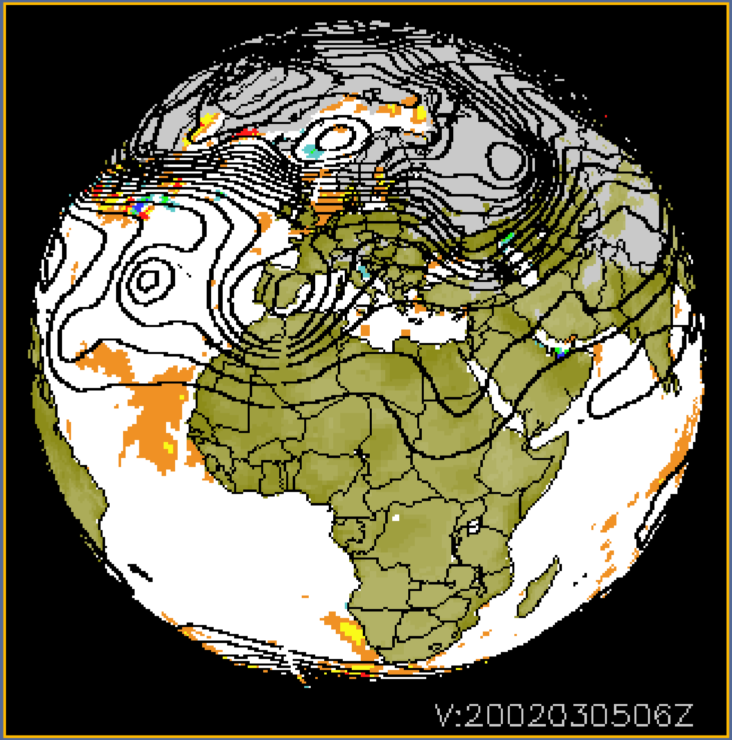


Photo Credit: Environment Canada

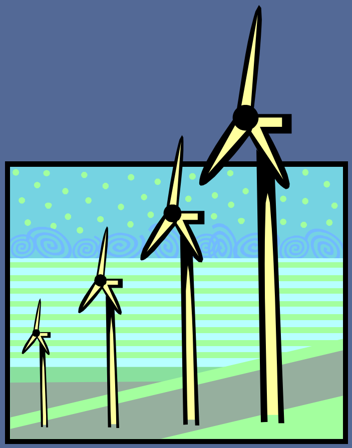
Objectives

- Introduce a methodology for calculating reductions in greenhouse gas (GHG) emissions

- Demonstrate the RETScreen® GHG Emission Reduction Analysis Model

What needs to be calculated?

- Annual greenhouse gas emission reduction
  - Base case (typically conventional technology) vs. Proposed case (clean energy technology)
  - Units: tonnes of CO_2 per year
  - CH_4 and N_2O emissions converted to equivalent CO_2 emissions in terms of their global warming potential



How is this calculated?

$$\text{Annual GHG emission reduction } (t_{CO_2}) = \left(\begin{array}{c} \text{Base case} \\ \text{GHG emission} \\ \text{factor} \\ (t_{CO_2}/\text{MWh}) \end{array} - \begin{array}{c} \text{Proposed case} \\ \text{GHG emission} \\ \text{factor} \\ (t_{CO_2}/\text{MWh}) \end{array} \right) \times \begin{array}{c} \text{End-use} \\ \text{annual energy} \\ \text{delivered} \\ (\text{MWh}) \end{array}$$

- RETScreen® adjusts the annual reduction to account for transmission & distribution losses and GHG credits transaction fees (Version 3.0 or higher)

RETScreen® GHG Emission Reduction Analysis Model

- Standardised methodology developed by NRCan with the United Nations Environment Programme (UNEP), the UNEP RISØ Centre on Energy, Climate and Sustainable Development (URC), and the World Bank's Prototype Carbon Fund (PCF)

- Validated by a team of experts from Government and Industry

RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Wind Energy Project

Use GHG analysis sheet? Yes
Potential CDM project? No
Type of analysis: Standard

Background Information

Project Information

Project name	Wind Farm	Project capacity	20.0 MW
Project location	Andhra, India	Grid type	Central-grid

Global Warming Potential of GHG

21	tonnes CO_2 =	1 tonne CH_4	(IPCC 1996)
310	tonnes CO_2 =	1 tonne N_2O	(IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission (t_{CO2}/MWh)
Coal	50.0%	94.6	0.0020	0.0030	35.0%	12.0%	1.117
Large hydro	50.0%	0.0	0.0000	0.0000	100.0%	12.0%	0.000
Electricity mix	100%	150.6	0.0032	0.0048		12.0%	0.559

Does baseline change during project life? No

Proposed Case Electricity System (Wind Energy Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission (t_{CO2}/MWh)
Electricity system							
Wind	100.0%	0.0	0.0000	0.0000	100.0%	12.0%	0.000

GHG Emission Reduction Summary

	Base case GHG emission factor (tCO2/MWh)	Proposed case GHG emission factor (tCO2/MWh)	End-use annual energy delivered (MWh)	Gross annual GHG emission reduction (t_{CO2})	GHG credits transaction fee (%)	Net annual GHG reduction (t_{CO2})
Electricity system	0.559	0.000	4,093	2,286	0.0%	**2,286**

Complete Financial Summary sheet

Version 3.0 UNEP/DTIE and NRCan/CETC - Varennes

Type of Analysis

- Standard analysis: RETScreen® automatically uses IPCC and industry standard values for:
  - CO_2 equivalence factors for CH_4 and N_2O
  - CO_2, CH_4, and N_2O emissions for common fuels
  - Efficiency for conversion of fuel to heat or electricity

- Custom analysis: the user specifies these values
- User-defined analysis: user enters GHG emission factors directly (Version 3.0 or higher)
  - Does not specify fuels and conversion efficiencies

Defining Baseline

- Different baselines for GHG emission calculations:
  - Historic static baseline (all existing generating capacity)
  - Historic static baseline based on recent trends
  - Future static baseline based on expansion plans
  - Future marginal dynamic baseline
  - Others

- RETScreen® permits one baseline change during course of project (Version 3.0 or higher)
- Can be based on international, national, or sub-national areas
- Still under negotiation via the Kyoto Protocol
- User must be able to defend choice of baseline and should not overestimate emission reductions

RETScreen® Facilitates Kyoto Protocol CDM and JI Projects

- Clean Development Mechanism (CDM) Projects:
  - Industrialised countries or companies that invest in GHG emission reduction projects in developing countries gain credits from these projects
- Small-scale CDM projects can use simplified baseline methods
  - Electricity projects ≤ 15 MW
  - Energy efficiency projects saving ≤ 15 GWh per year
- Joint Implementation (JI) Projects:
  - Industrialised countries or companies gain GHG emission reduction credits by investing in a project in another country that has emission reduction targets under the Kyoto Protocol (i.e. Annex I countries)
  - Project typically in an economy-in-transition country
- CDM and JI projects need to demonstrate "additionality" – emission reductions beyond those achieved in baseline scenario

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E50 = No

RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Wind Energy Project

Use GHG analysis sheet?	Yes	Type of analysis:	Standard
Potential CDM project?	No		

Background Information

Project Information

				Global Warming Potential of GHG			
Project name	Wind Farm	Project capacity	20.0 MW	21	tonnes CO_2 =	1 tonne CH_4	(IPCC 1996)
Project location	Andhra, India	Grid type	Central-grid	310	tonnes CO_2 =	1 tonne N_2O	(IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission (t_{CO2}/MWh)
Coal	50.0%	94.6	0.0020	0.0030	35.0%	12.0%	1.117
Large hydro	50.0%	0.0	0.0000	0.0000	100.0%	12.0%	0.000
Electricity mix	100%	153.6	0.0032	0.0049		12.0%	0.559

Does baseline change during project life? No

Proposed Case Electricity System (Wind Energy Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission (t_{CO2}/MWh)
Electricity system							
Wind	100.0%	0.0	0.0000	0.0000	100.0%	12.0%	0.000

GHG Emission Reduction Summary

	Base case GHG factor (tCO2/MWh)	Proposed case GHG emission factor (tCO2/MWh)	End-use annual energy delivered (MWh)	Gross annual GHG emission reduction (t_{CO2})	GHG credits transaction fee (%)	Net annual GHG reduction (t_{CO2})
Electricity system	0.559	0.000	35,800	19,996	0.0%	**19,996**

Complete Financial Summary sheet

Intro / Energy Model / Equipment Data / Cost Analysis / GHG Analysis / Financial Summary / Sensitivity / Sheet1 / Sheet2 / Sheet3

Microsoft Excel - WIND3.xls

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GHGType = Standard

RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Wind Energy Project

Use GHG analysis sheet? Yes
Potential CDM project? Yes
Type of analysis: Standard
Use simplified baseline methods
Standard
Custom
User-defined

Background Information

Project Information

Project name	Wind Farm	Project capacity	15.0 MW	21	tonnes CO_2 =	1 tonne CH_4	(IPCC 1996)
Project location	Andhra, India	Grid type	Central-grid	310	tonnes CO_2 =	1 tonne N_2O	(IPCC 1996)

Global Warming Potential of GHG

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission (t_{CO2}/MWh)
Coal	50.0%	94.6	0.0020	0.0030	35.0%	12.0%	1.117
Large hydro	50.0%	0.0	0.0000	0.0000	100.0%	12.0%	0.000
Electricity mix	100%	153.6	0.0032	0.0049		12.0%	0.559

Does baseline change during project life? No

Proposed Case Electricity System (Wind Energy Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission (t_{CO2}/MWh)
Electricity system							
Wind	100.0%	0.0	0.0000	0.0000	100.0%	12.0%	0.000

GHG Emission Reduction Summary

	Base case GHG factor (tCO2/MWh)	Proposed case GHG emission factor (tCO2/MWh)	End-use annual energy delivered (MWh)	Gross annual GHG emission reduction (t_{CO2})	GHG credits transaction fee (%)	Net annual GHG reduction (t_{CO2})
Electricity system	0.559	0.000	26,850	14,997	0.0%	**14,997**

Complete Financial Summary sheet

Intro / Energy Model / Equipment Data / Cost Analysis / GHG Analysis / Financial Summary / Sensitivity / Sheet1 / Sheet2 / Sheet3

Conclusions

- RETScreen® calculates the annual GHG emission reduction for a clean energy project compared to a base case system

- Easy to use, but does require the user to define the base case scenario carefully for larger projects

- Model takes into account emerging rules under the Kyoto Protocol at the pre-feasibility study level

- To maintain credibility, user should not overestimate GHG emission reductions of the proposed project

Questions?

Greenhouse Gas Emission Analysis with RETScreen® Software Module
RETScreen® International Clean Energy Project Analysis Course

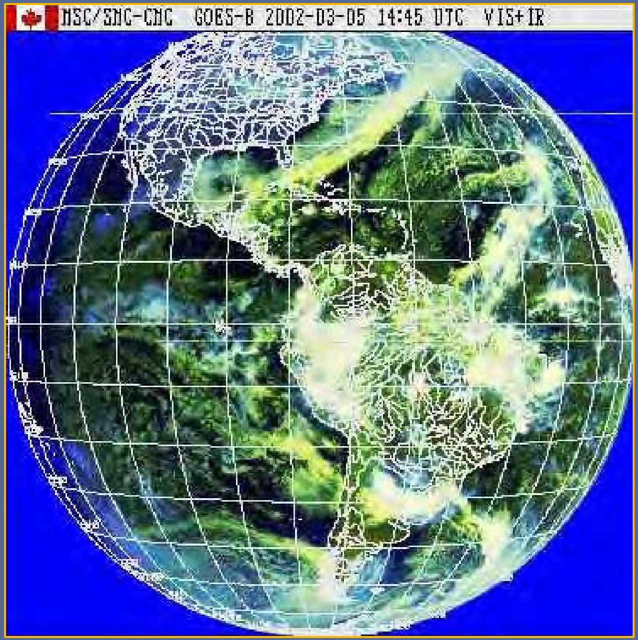

Photo Credit:
Environment Canada

For further information please visit the RETScreen Website at
www.retscreen.net

Financial and Risk Analysis with RETScreen® Software

RETScreen® International www.retscreen.net

Clean Energy Project Analysis Course

Photo Credit: Green Mountain Power Corporation/ NRELPix

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Canada

Objectives

- Introduce the RETScreen® methodology for assessing the financial viability of a potential clean energy project
  - Overview important financial (input) parameters
  - Review key indicators of financial viability
  - Examine assumptions for cashflow calculations
  - Highlight differences between initial costs, simple payback and key financial indicators

- Demonstrate the RETScreen® Financial Summary Worksheet
- Show how incentives, production credits, GHG credits and taxes can be included in the financial analysis
- Introduce sensitivity analysis and risk analysis with RETScreen®
- Demonstrate the RETScreen® Sensitivity and Risk Analysis Worksheet (Version 3.0 or higher)

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RETScreen® Financial Summary - Wind Energy Project

Annual Energy Balance

Project name		Wind Farm
Project location		Andhra, India
Renewable energy delivered	MWh	40,682
Excess RE available	MWh	-
Firm RE capacity	kW	-
Grid type		Central-grid

Financial Parameters

Avoided cost of energy	$/kWh	0.0950	Debt ratio	%	70.0%
RE production credit	$/kWh	0.025	Debt interest rate	%	14.0%
RE production credit duration	yr	10	Debt term	yr	15
RE credit escalation rate	%	2.5%			
			Income tax analysis?	yes/no	No
Energy cost escalation rate	%	5.0%			
Inflation	%	2.5%			
Discount rate	%	12.0%			
Project life	yr	25			

Project Costs and Savings

Initial Costs

Feasibility study	0.8%	$	245,200
Development	2.7%	$	835,500
Engineering	2.0%	$	610,500
Energy equipment	68.2%	$	21,260,000
Balance of plant	18.8%	$	5,868,000
Miscellaneous	7.5%	$	2,348,765
Initial Costs - Total	100.0%	**$**	**31,167,965**
Incentives/Grants		$	-

Periodic Costs (Credits)

Drive train	$	1,000,000	Schedule yr # 10,20
Blades	$	1,000,000	Schedule yr # 15
	$	-	
End of project life - Credit	$	-	

Annual Costs and Debt

O&M	$	770,000
Debt payments - 15 yrs	$	3,552,097
Annual Costs and Debt - Total	**$**	**4,322,097**

Annual Savings or Income

Energy savings/income	$	3,864,812
Capacity savings/income	$	-
RE production credit income - 10 yrs	$	1,017,056
Annual Savings - Total	**$**	**4,881,868**

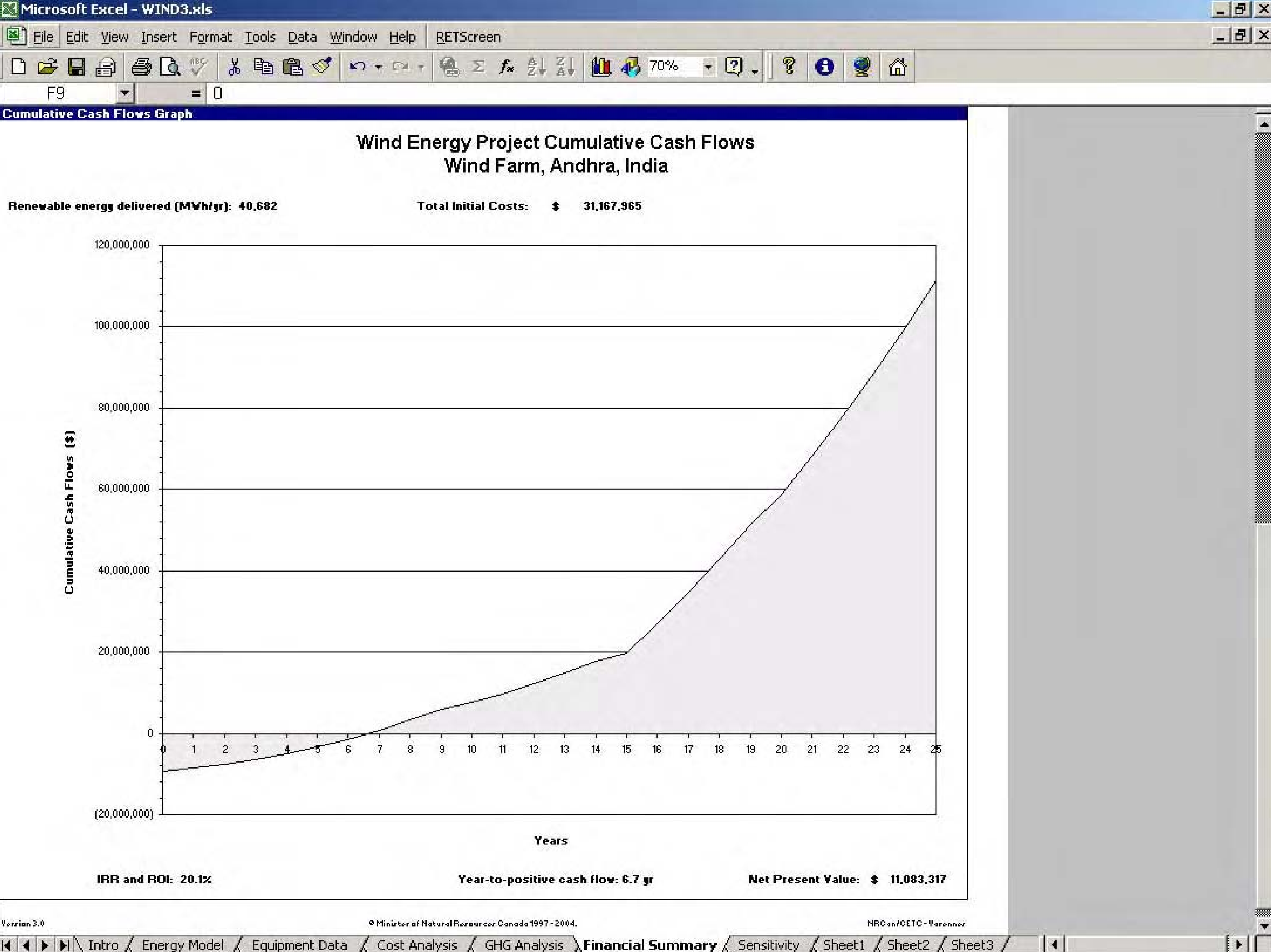
Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	20.1%			
After-tax IRR and ROI	%	20.1%			
Simple Payback	yr	7.6			
Year-to-positive cash flow	yr	6.7	Project equity	$	9,350,389

Yearly Cash Flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	(9,350,389)	(9,350,389)	(9,350,389)
1	759,188	759,188	(8,591,202)
2	968,421	968,421	(7,622,780)
3	1,187,958	1,187,958	(6,434,822)
4	1,418,310	1,418,310	(5,016,513)
5	1,660,012	1,660,012	(3,356,501)
6	1,913,630	1,913,630	(1,442,871)
7	2,179,753	2,179,753	736,882
8	2,459,004	2,459,004	3,195,886
9	2,752,034	2,752,034	5,947,920
10	1,779,442	1,779,442	7,727,362
11	2,047,736	2,047,736	9,775,098
12	2,352,986	2,352,986	12,128,084
13	2,674,129	2,674,129	14,802,213
14	3,011,976	3,011,976	17,814,190
15	1,919,082	1,919,082	19,733,271
16	7,293,330	7,293,330	27,026,602
17	7,686,574	7,686,574	34,713,175
18	8,100,193	8,100,193	42,813,368
19	8,535,226	8,535,226	51,348,595
20	7,354,145	7,354,145	58,702,740
21	9,473,943	9,473,943	68,176,684
22	9,979,972	9,979,972	78,156,656
23	10,512,111	10,512,111	88,668,767
24	11,071,686	11,071,686	99,740,453
25	11,660,088	11,660,088	111,400,541

Intro / Energy Model / Equipment Data / Cost Analysis / GHG Analysis / Financial Summary / Sensitivity / Sheet1 / Sheet2 / Sheet3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Cumulative Cash Flows Graph
Wind Energy Project Cumulative Cash Flows
Wind Farm, Andhra, India
Renewable energy delivered (MWh/yr): 40,682
Total Initial Costs: $ 31,167,965
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
0
(20,000,000)
Cumulative Cash Flows ($)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Years
IRR and ROI: 20.1%
Year-to-positive cash flow: 6.7 yr
Net Present Value: $ 11,083,317
Version 3.0
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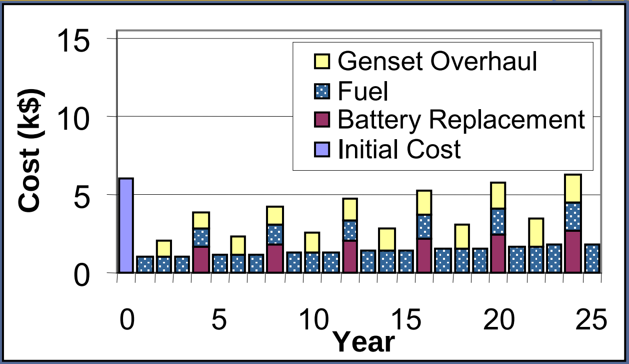
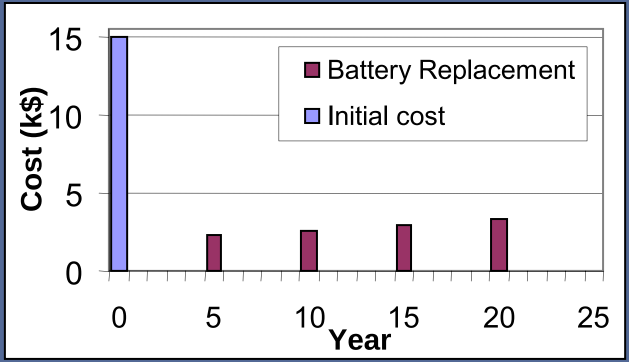
NRCan/CETC - Varennes
Intro Energy Model Equipment Data Cost Analysis GHG Analysis Financial Summary Sensitivity Sheet1 Sheet2 Sheet3

Initial Cost versus Ongoing Costs:
Remote Telecommunications Example

- Genset+battery (base case):
  - Initial cost: $6,000
  - Annual cost: $1,000 for fuel*
  - Battery replacement every 4 years ($1,500)*
  - Genset overhaul every 2 years ($1,000)*
- Photovoltaics+battery (proposed case):
  - Initial cost: $15,000
  - Battery replacement every 5 years ($2,000)*



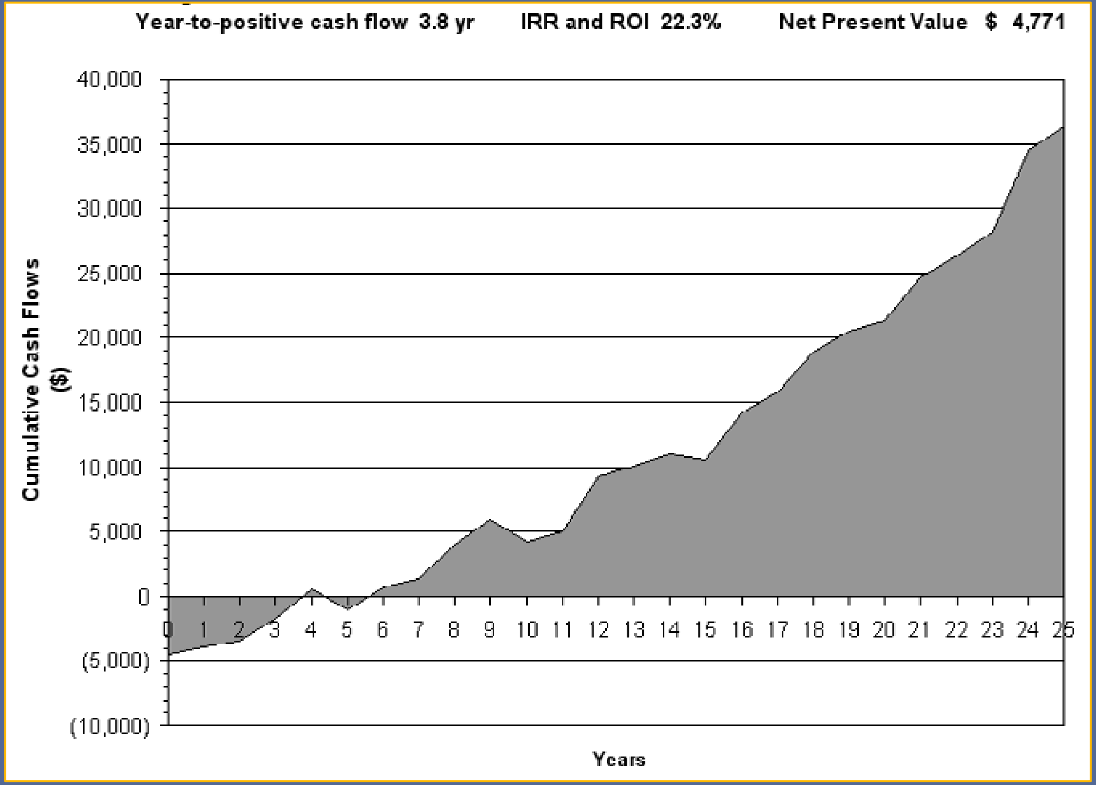


*Inflation rate and energy escalation rate of 2.5%

Determining Financial Viability:
Remote Telecommunications Example

- How can we compare the genset & the PV system?
  - Genset: lower initial costs
  - Photovoltaics: lower annual and periodic costs

- RETScreen® calculates indicators that look at revenues and expenses over the life of the project!



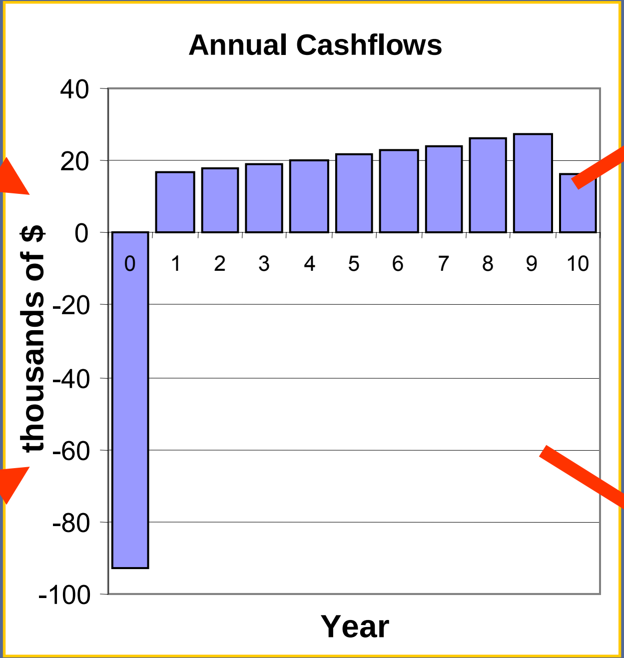
Cashflow Calculations: What does RETScreen® do?

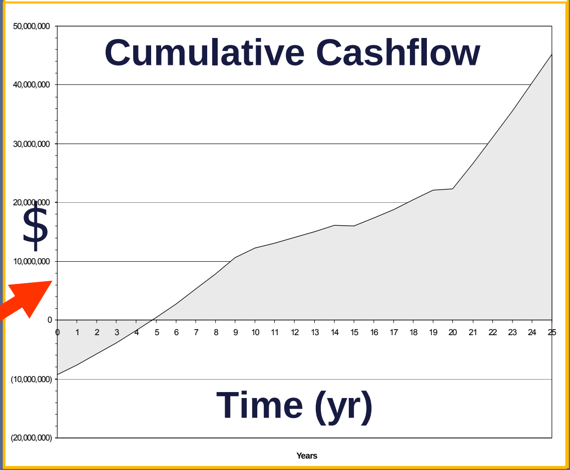
Cash Inflows

Fuel Savings
O&M Savings
Periodic Savings
Incentives
Production Credits
GHG Credits

Cash Outflows

Equity Investment
Annual Debt Payments
O&M Payments
Periodic Costs





Indicators

Net Present Value
Simple Payback
IRR
Debt Service Coverage
Etc.

Financial (Input) Parameters Used by RETScreen®

Financial Parameters

Avoided cost of energy	\$/kWh	0.0950	Debt ratio	%	70.0%
RE production credit	\$/kWh	0.025	Debt interest rate	%	14.0%
RE production credit duration	yr	10	Debt term	yr	25
RE credit escalation rate	%	2.5%			
GHG emission reduction credit	\$/t_{CO2}	5.0	Income tax analysis?	yes/no	Yes
GHG reduction credit duration	yr	21	Effective income tax rate	%	35.0%
GHG credit escalation rate	%	0.0%	Loss carryforward?	yes/no	Yes
			Depreciation method	-	Declining balance
			Depreciation tax basis	%	95.0%
Energy cost escalation rate	%	5.0%	Depreciation rate	%	30.0%
Inflation	%	2.5%			
Discount rate	%	12.0%	Tax holiday available?	yes/no	Yes
Project life	yr	25	Tax holiday duration	yr	5

- Discount rate: rate used to convert future cash flows to the present
- Avoided cost of energy:
  - For heating and cooling projects: the price of fuel in the base-case scenario
  - For electricity projects selling to the grid: the price paid for a unit of clean electricity sold (for developers) or marginal costs (for utilities)

Key (Output) Indicators of Financial Viability

	Simple Payback	Net Present Value (NPV)	Internal Rate of Return (IRR & ROI)
Meaning	# of years to recoup additional costs from annual savings	Total value of project in today's dollars	Interest yield of project during its lifetime
Example	3 year simple payback	$1.5 million NPV	17 % IRR
Criteria	Payback < n years	Positive indicates profitable project	IRR > hurdle rate
Comment	• Misleading • Ignores financing & long-term cashflows • Use when cashflow is tight	• Good measure • User must specify discount rate	• Can be fooled when cashflow goes positive-negative-positive

Comparison of Indicators:
Remote Telecommunications Example

	Simple Payback	Net Present Value (NPV)	Internal Rate of Return (IRR & ROI)
PV vs genset*	9 years	$4,800	22%
Decision	Genset	PV	PV

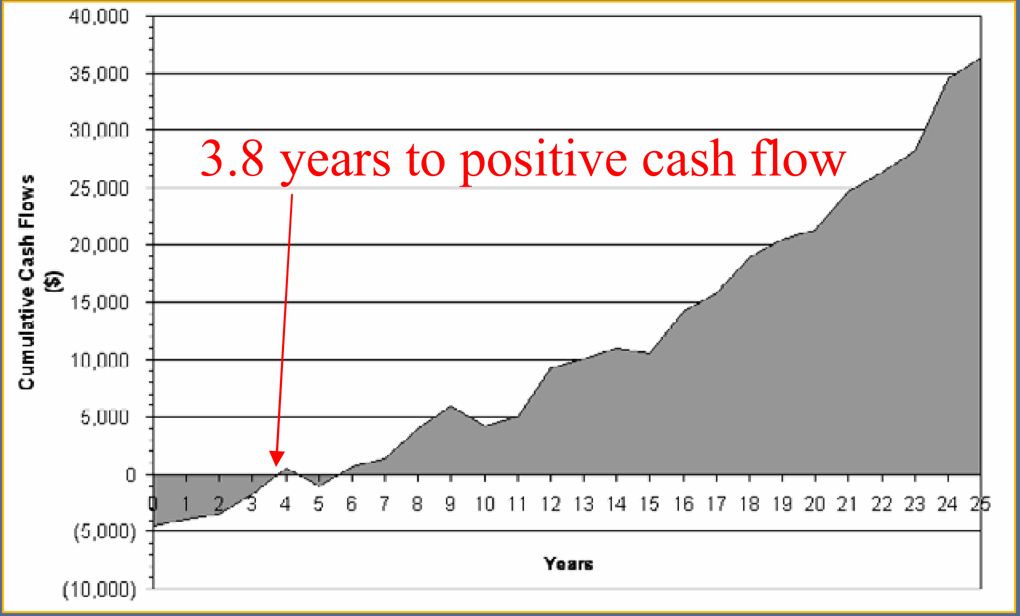
* Discount rate of 12%; 50% debt financed over 15 years at 7% interest rate

Indicators of Financial Viability: Remote Telecommunications Example

Financial Feasibility

			Calculate energy prod	yes/no	No
Pre-tax IRR and ROI	%	22.3%			
After-tax IRR and ROI	%	22.3%	Calculate GHG reduct	yes/no	No
Simple Payback	yr	9.0			
Year-to-positive cash flow	yr	3.8	Project equity	$	4,500
Net Present Value - NPV	$	4,771	Project debt	$	4,500
Annual Life Cycle Savings	$	608	Debt payments	$/yr	494
Benefit-Cost (B-C) ratio	-	1.98	Debt service coverage	-	2.08

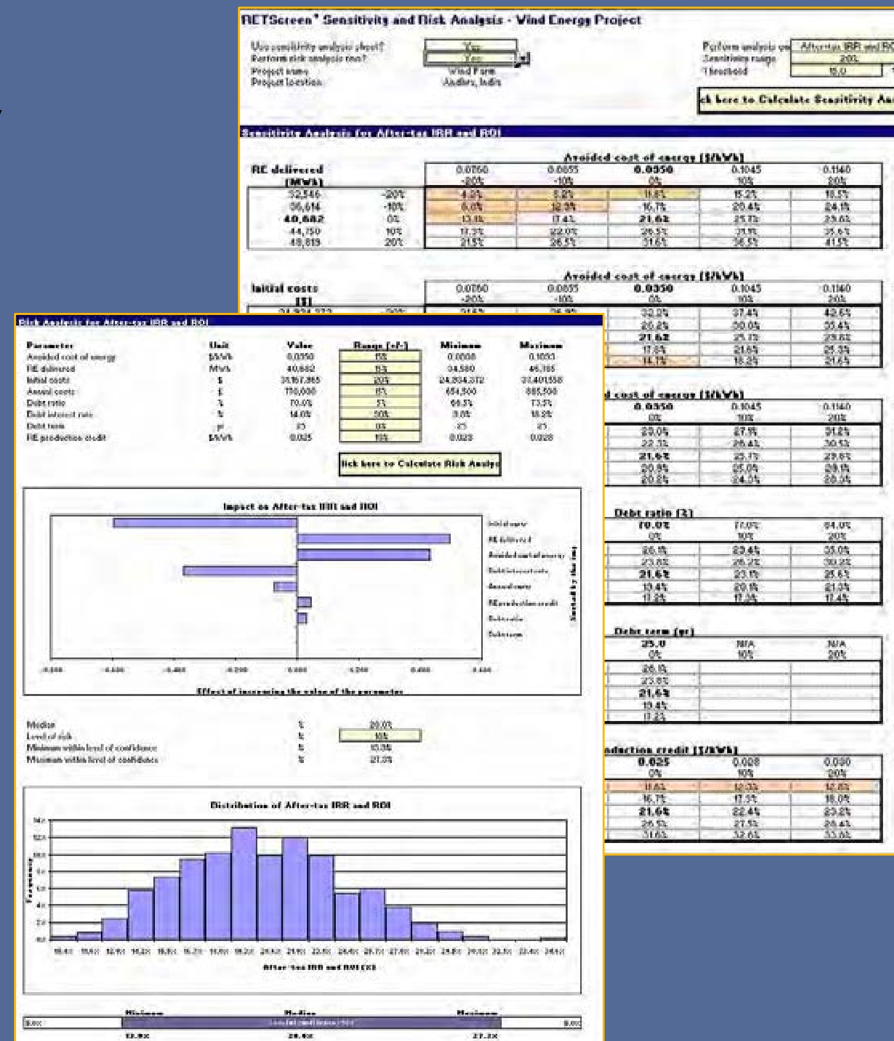
- RETScreen® provides a range of indicators and a cumulative cash flow graph for the project



Dealing with Uncertainty: Sensitivity and Risk Analysis

- At the preliminary feasibility stage, there is much uncertainty about many input parameters

- How is the profitability of the project affected by errors in the values provided by the user?



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D3 = Yes

RETScreen® Sensitivity and Risk Analysis - Wind Energy Project

Use sensitivity analysis sheet?	Yes		Perform analysis on	After-tax IRR and ROI
Perform risk analysis too?	No		Sensitivity range	20%
Project name	Wind Farm		Threshold	15.0 %
Project location	Andhra, India			

Click here to Calculate Sensitivity Analysis

Sensitivity Analysis for After-tax IRR and ROI

RE delivered (MWh)		Avoided cost of energy ($/kWh) 0.0760 -20%	0.0855 -10%	**0.0950** 0%	0.1045 10%	0.1140 20%
32,546	-20%	4.2%	8.2%	11.8%	15.2%	18.5%
36,614	-10%	8.8%	12.9%	16.7%	20.4%	24.1%
40,682	0%	13.1%	17.4%	**21.6%**	25.7%	29.8%
44,750	10%	17.3%	22.0%	26.5%	31.1%	35.6%
48,819	20%	21.5%	26.5%	31.6%	36.5%	41.5%

Initial costs ($)		Avoided cost of energy ($/kWh) 0.0760 -20%	0.0855 -10%	**0.0950** 0%	0.1045 10%	0.1140 20%
24,934,372	-20%	21.6%	26.9%	32.2%	37.4%	42.6%
28,051,168	-10%	16.9%	21.6%	26.2%	30.8%	35.4%
31,167,965	0%	13.1%	17.4%	**21.6%**	25.7%	29.8%
34,284,761	10%	9.9%	14.0%	17.8%	21.6%	25.3%
37,401,558	20%	7.2%	11.1%	14.7%	18.2%	21.6%

Annual costs ($)		Avoided cost of energy ($/kWh) 0.0760 -20%	0.0855 -10%	**0.0950** 0%	0.1045 10%	0.1140 20%
616,000	-20%	14.5%	18.8%	23.0%	27.1%	31.2%
693,000	-10%	13.8%	18.1%	22.3%	26.4%	30.5%
770,000	0%	13.1%	17.4%	**21.6%**	25.7%	29.8%
847,000	10%	12.3%	16.7%	20.9%	25.0%	29.1%
924,000	20%	11.6%	16.0%	20.2%	24.3%	28.3%

Debt interest rate (%)		Debt ratio (%) 56.0% -20%	63.0% -10%	**70.0%** 0%	77.0% 10%	84.0% 20%
11.2%	-20%	22.3%	23.9%	26.1%	29.4%	35.0%
12.6%	-10%	21.0%	22.2%	23.8%	26.2%	30.2%
14.0%	0%	19.7%	20.5%	**21.6%**	23.1%	25.6%
15.4%	10%	18.4%	18.8%	19.4%	20.1%	21.3%
16.8%	20%	17.1%	17.2%	17.2%	17.3%	17.4%

Intro / Energy Model / Equipment Data / Cost Analysis / GHG Analysis / Financial Summary / **Sensitivity** / Sheet1 / Sheet2 / Sheet3

Microsoft Excel - WIND3.xls

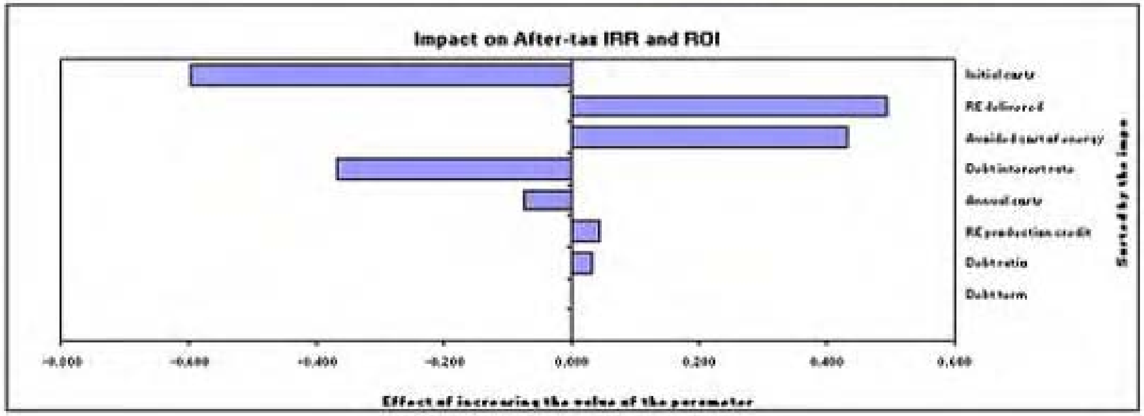
File Edit View Insert Format Tools Data Window Help RETScreen

D4 = Yes

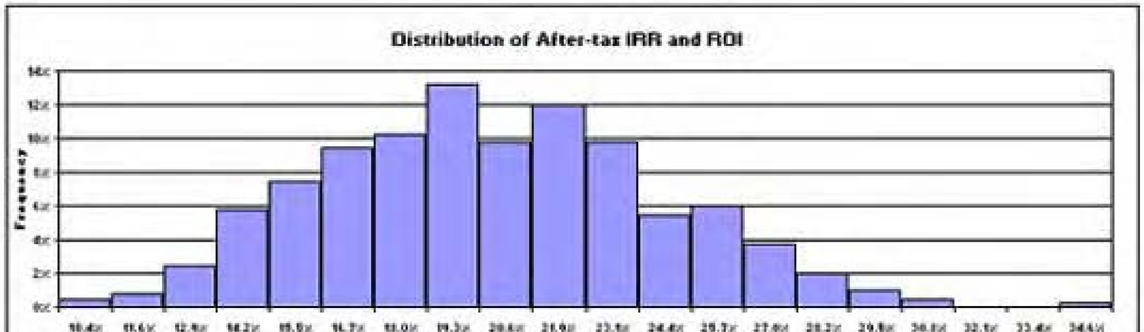
Risk Analysis for After-tax IRR and ROI

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Avoided cost of energy	$/kWh	0.0950	15%	0.0808	0.1093
RE delivered	MWh	40,682	15%	34,580	46,785
Initial costs	$	31,167,965	20%	24,934,372	37,401,558
Annual costs	$	770,000	15%	654,500	885,500
Debt ratio	%	70.0%	5%	66.5%	73.5%
Debt interest rate	%	14.0%	30%	9.8%	18.2%
Debt term	yr	25	0%	25	25
RE production credit	$/kWh	0.025	10%	0.023	0.028

lick here to Calculate Risk Analys



Median	%	20.0%
Level of risk	%	10%
Minimum within level of confidence	%	13.9%
Maximum within level of confidence	%	27.3%



Intro / Energy Model / Equipment Data / Cost Analysis / GHG Analysis / Financial Summary / **Sensitivity** / Sheet1 / Sheet2 / Sheet3

Sensitivity Analysis

- Shows how the profitability of project changes when two key input parameters vary simultaneously
- For example:
  - Initial costs 10% higher than estimated
  - Avoided cost of energy 20% higher than estimated
  - Does the IRR exceed the 15% IRR threshold desired by the user?

Initial costs ($)		Avoided cost of energy ($/kWh) 0.0760 -20%	0.0855 -10%	**0.0950** 0%	0.1045 10%	0.1140 20%
24,934,372	-20%	11.5%	16.1%	20.4%	24.5%	28.6%
28,051,168	-10%	7.5%	11.8%	15.7%	19.4%	23.1%
31,167,965	0%	4.1%	8.3%	**12.0%**	15.4%	18.7%
34,284,761	10%	1.0%	5.3%	8.9%	12.2%	15.2%
37,401,558	20%	-1.9%	2.6%	6.2%	9.4%	12.3%

- Yes, it is 15.2%
  - Combinations of initial costs and avoided cost of energy below threshold are shaded

Sensitivity Analysis: Parameters

Perform analysis on	After-tax IRR and ROI	
Sensitivity range	20%	
Threshold	15.0	%

Click here to Calculate Sensitivity Analysis

- RETScreen® calculates sensitivity of…
  - Internal rate of return (IRR/ROI)
  - Year-to-positive cash flow
  - Net Present Value (NPV)
- …to simultaneous changes in (for example)…
  - RE delivered & avoided cost of energy
  - Initial costs & avoided cost of energy
  - Debt interest rate & debt term
  - Net GHG emission reduction & GHG emission reduction credit
  - RE delivered & RE production credit
- …with changes of $\pm x$, $\pm\frac{1}{2}x$, and 0, where x is sensitivity range specified by user

Risk Analysis

- User is uncertain of many parameters:

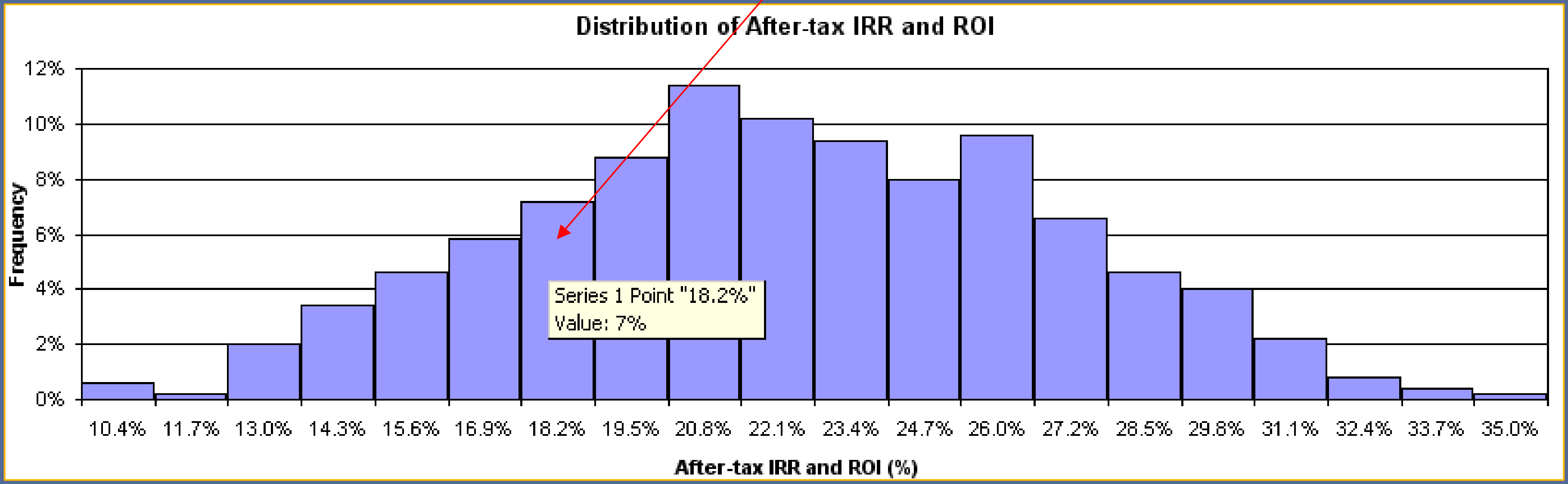
Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Avoided cost of energy	$/kWh	0.0950	5%	0.0903	0.0998
RE delivered	MWh	40,682	15%	34,580	46,785
Initial costs	$	31,167,965	20%	24,934,372	37,401,558
Annual costs	$	770,000	15%	654,500	885,500
Debt ratio	%	70.0%	0%	70.0%	70.0%
Debt interest rate	%	14.0%	30%	9.8%	18.2%
Debt term	yr	15	0%	15	15
RE production credit	$/kWh	0.025	10%	0.023	0.028

  - User specifies range of uncertainty for each parameter (e.g., ±5%)
  - All parameters simultaneously and independently deviate from estimate
- How does this affect the financial indicators?

Risk Analysis: Monte Carlo Simulation

- RETScreen® calculates the frequency distribution of the financial indicators (IRR, NPV, and year-to-positive cash flow) by calculating the values for 500 combinations of parameters
  - Parameters vary randomly according to uncertainty specified by user

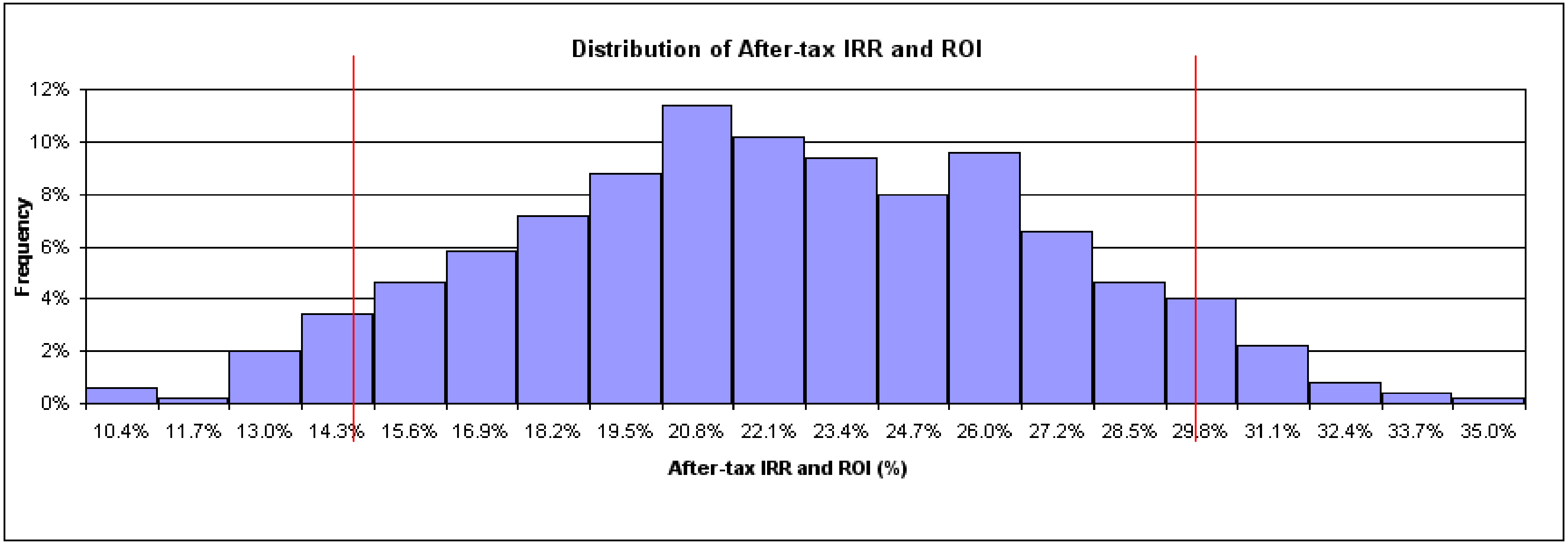
7% of the time IRR is 18.2±0.7%



Risk Analysis: Level of Risk

- There is only a 10% risk that the IRR will fall outside this range

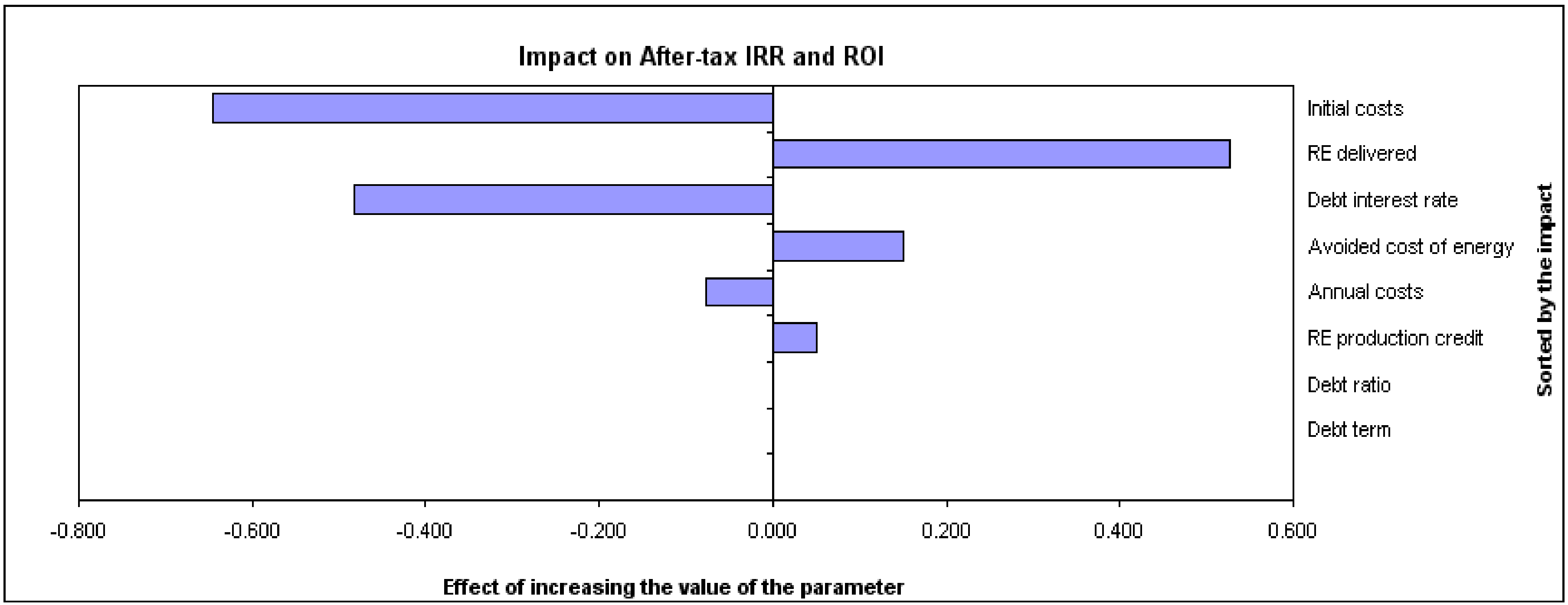
Median	%	22.3%
Level of risk	%	10%
Minimum within level of confidence	%	14.6%
Maximum within level of confidence	%	29.8%



Minimum	Median	Maximum	
5.0%	Level of confidence = 90%		5.0%
14.6%	22.3%	29.8%	

Risk Analysis: Influence of Parameters

- "Tornado chart" reveals:
  - Which parameters have the most influence
  - How changes in parameters affect after-tax IRR, NPV, or year-to-positive cash flow



Conclusions

- RETScreen® accounts for cashflows due to initial costs, energy savings, O&M, fuel costs, taxation, GHG and RE production credits

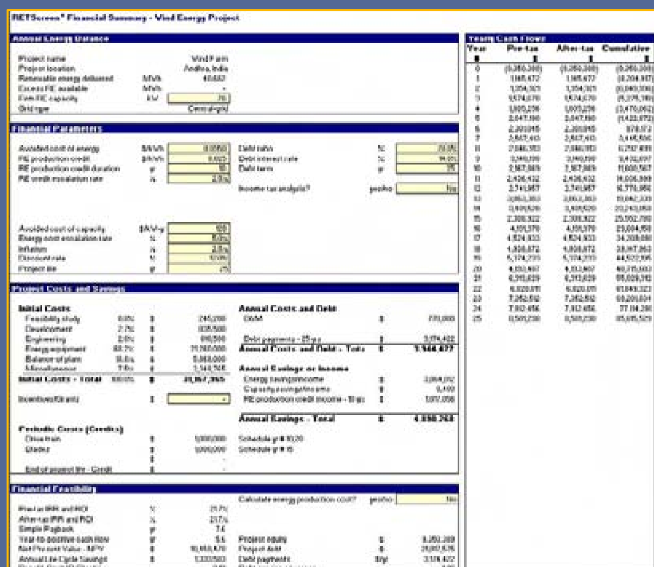
- RETScreen® automatically calculates important indicators of financial viability

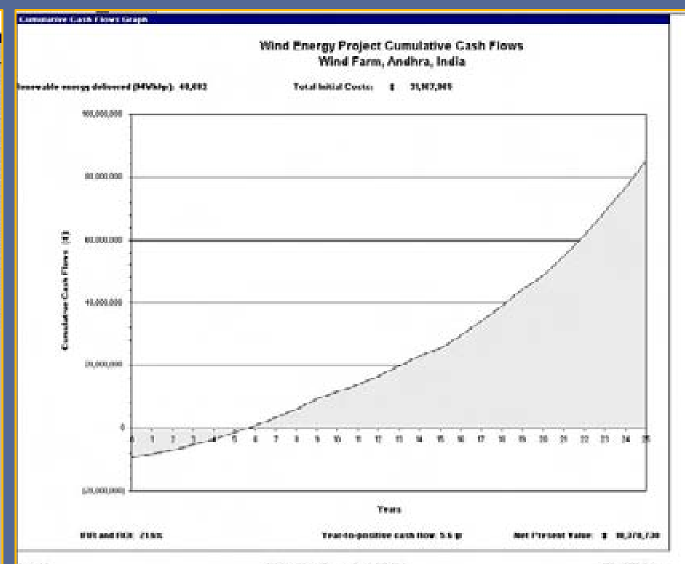
- The sensitivity of the key financial indicators to changes in the inputs can be investigated with RETScreen®

- Indicators that consider profitability over the life of the project, such as the IRR and NPV, are preferable to the simple payback method

Questions?

Financial and Risk Analysis with RETScreen® Software Module
RETScreen® International Clean Energy Project Analysis Course





For further information please visit the RETScreen Website at
www.retscreen.net

Summary of Introductory Module

RETScreen® International www.retscreen.net

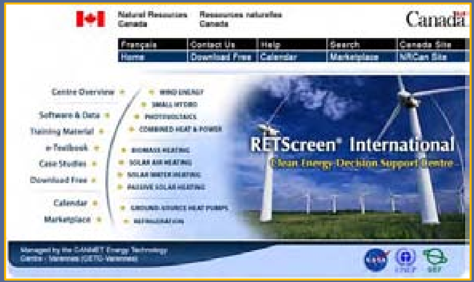
Clean Energy Project Analysis Course

Photo : Nordex Gmbh

Conclusions

RETSCREEN® INTERNATIONAL www.retscreen.net

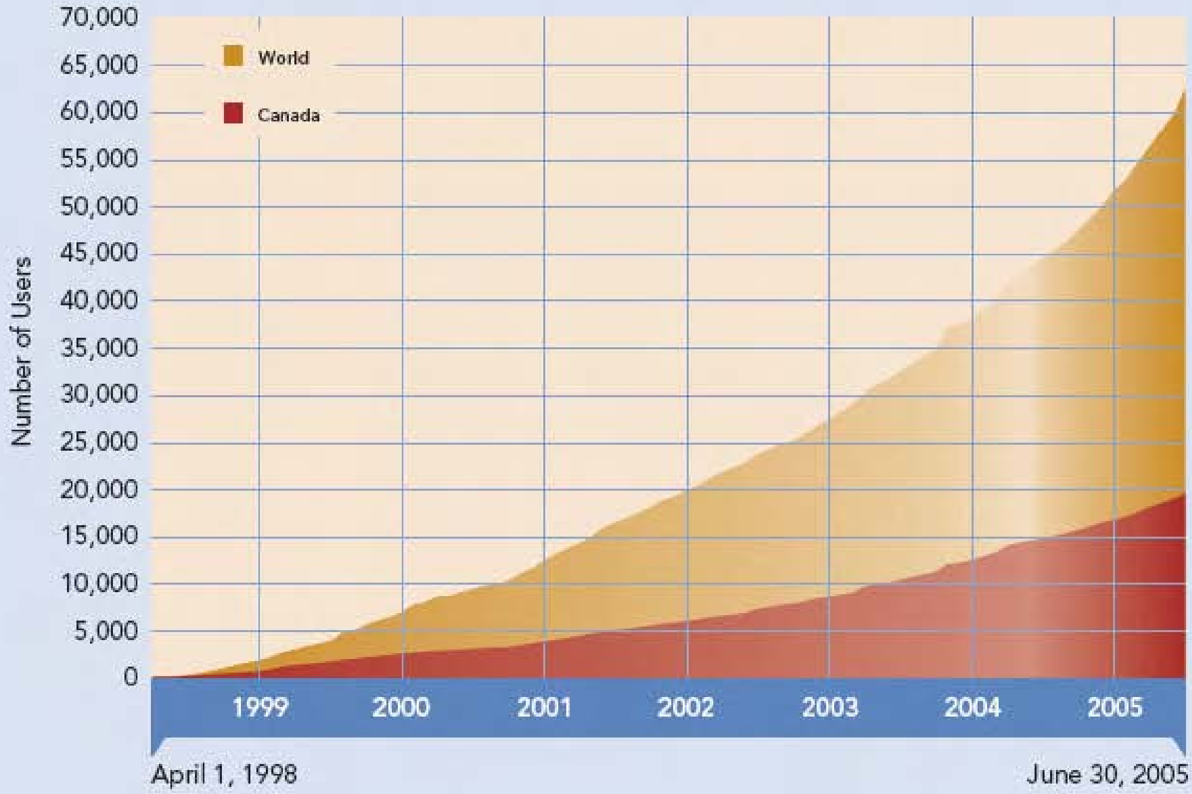
- Clean energy technologies have matured, many cost-effective applications exist and markets are growing rapidly
- Initial planning stage is where clean energy technologies must be properly considered by planners, decision-makers and industry



- RETScreen® simplifies preliminary evaluations
  - Requires relatively small amounts of input data
  - Calculates key technical & financial viability indicators automatically
  - Costs 1/10th the amount of other assessment methods
  - Standardized procedures allow objective comparisons
  - Increases potential for successful clean energy project implementation

Growth of RETScreen Software User Base

RETScreen Software: Cumulative Growth of User Base



62,565 users worldwide from 207 countries

Growing at 400 users every week

Top Twenty Countries		
1	Canada	19,634
2	USA	8,240
3	France	5,747
4	UK	2,733
5	Spain	2,192
6	Italy	1,789
7	Australia	1,473
8	Germany	1,214
9	India	1,013
10	Belgium	948
11	Portugal	764
12	Ireland	732
13	Greece	717
14	Brazil	672
15	Mexico	493
16	Netherlands	459
17	Argentina	417
18	Switzerland	404
19	Turkey	345
20	New Zealand	344

As of June 30, 2005

A Decision Support & Capacity Building Tool

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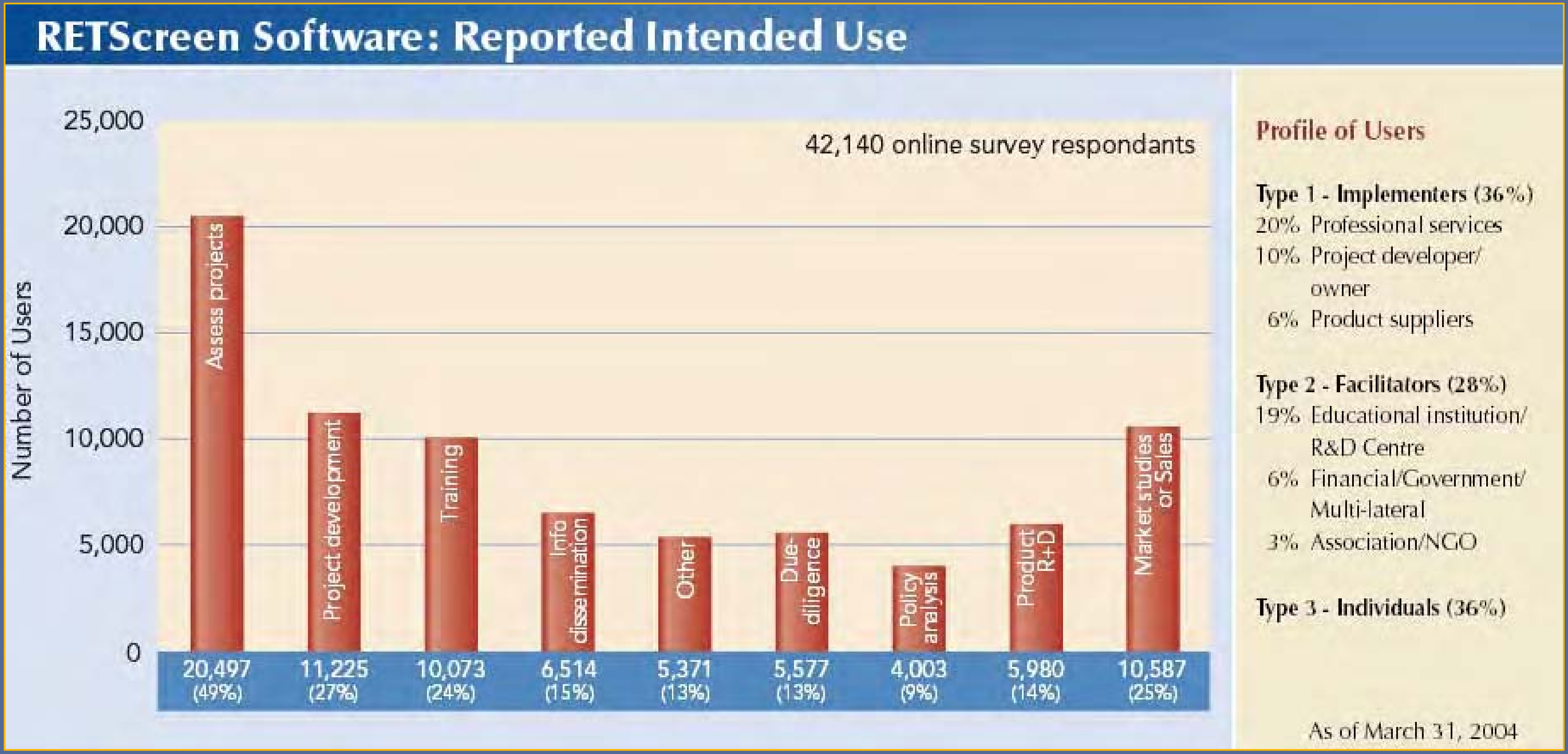

Common Platform for Project Evaluation & Development

Questions?

RETSCREEN® INTERNATIONAL www.retscreen.net

Summary of Introductory Module
RETScreen® International Clean Energy Project Analysis Course

RETScreen® International Clean Energy Decision Support Centre	Project Analysis Software Model	Project Analysis Training Course Module	Engineering e-Textbook Chapter	Project Case Studies Collection
Introduction		☐	☐	
Wind Energy	☐	☐	☐	☐
Small Hydro	☐	☐	☐	☐
Photovoltaics	☐	☐	☐	☐
Combined Heat & Power	☐	☐	☐	☐
Biomass Heating	☐	☐	☐	☐
Solar Air Heating	☐	☐	☐	☐
Solar Water Heating	☐	☐	☐	☐
Passive Solar Heating	☐	☐	☐	☐
Ground-Source Heat Pumps	☐	☐	☐	☐
Refrigeration	☐	☐	☐	☐

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