“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.
• 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

Teacher’s Housing, Botswana

Photo Credit: Vadim Belotserkovsky

Solarwall - Apartment Building

Photo Credit: Enermodal

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
Course Materials

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<tr>
<th>RETScreen® International</th>
<th>Project Analysis Software</th>
<th>Project Analysis Training Course</th>
<th>Engineering e-Textbook</th>
<th>Project Case Studies</th>
</tr>
</thead>
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<tr>
<td>Clean Energy Decision Support Centre</td>
<td>Model</td>
<td>Module</td>
<td>Chapter</td>
<td>Collection</td>
</tr>
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<tr>
<td>Wind Energy</td>
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<td>Small Hydro</td>
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<td>Photovoltaics</td>
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<td>Combined Heat &amp; Power</td>
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<td>Biomass Heating</td>
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</tr>
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<td>Refrigeration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
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
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

Windfarm

Passive Solar Home

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

Electrocity 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

<table>
<thead>
<tr>
<th>Energy Demand</th>
<th>Conventional</th>
<th>Efficient</th>
<th>Efficient &amp; Renewable</th>
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</thead>
<tbody>
<tr>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75%</td>
<td></td>
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<td></td>
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<tr>
<td>50%</td>
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<tr>
<td>25%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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)

---

**Wind Energy: Electricity Generation Costs**


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 \(\neq\) purchase cost
- Total cost \(=\) purchase cost

\[\text{Total cost} = \text{purchase cost} + \text{annual fuel and O&M costs} + \text{major overhaul costs} + \text{decommissioning costs} + \text{financing costs} + \text{etc.}\]
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
  - Isolated-Grid
  - Off-Grid

Wind Energy Market

Annual Wind Turbine Installations Worldwide

Worldwide installed capacity (2003): 39,000 MW
(~20.6 million homes @ 5,000 kWh/home/year and 30% capacity factor)

- Germany: 14,600 MW
- Spain: 6,400 MW
- United States: 6,400 MW
- Denmark: 3,100 MW

83,000 MW by 2007 (predicted)

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

**Components of a Hydro System**

- Dam
- Headpond
- Spillway
- Penstock
- Powerline
- Generator
- Turbine
- Draft Tube
- Powerhouse
- Tail Race
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

Data source: ABB, Renewable Energy World, and International Small Hydro Atlas
Photovoltaic (PV) Technology & Applications

Household PV System

PV Water Pumping

Grid-tied Building Integrated PV

Photo Credit: Tsuo, Simon DOE/NREL
Photo Credit: Strong, Steven DOE/NREL

Photovoltaic Market

Annual Photovoltaic Installations Worldwide

Worldwide installed capacity (2003): 2,950 MW_p
(~1.2 million homes @ 5,000 kWh/home/year)

32% Increase in shipments in 2003

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”)

Heat recovery efficiency \(\frac{55}{70} = 78.6\%\)
Total efficiency \(\frac{(30+55)}{100} = 85.0\%\)

Combined Heat and Power
Applications, Fuels and Equipment

Various Applications

- Biomass for CHP
  Photo Credit: Gretz, Warren DOE/NREL

Various Fuels

- Landfill Gas Collection Cycle

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

Photo Credit: Urban Ziegler, NRCan

CHP Kitchener City Hall

LFG CHP for district heating system, Sweden

Micro turbine at greenhouse

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**
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

Photo Credit: Rolls-Royce plc

## Combined Heat and Power Market

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

• Controlled combustion of wood, agricultural residues, municipal waste, etc., to provide heat
Biomass Heating Market

• Worldwide:
  - Biomass combustion provides 11% of world’s Total Primary Energy Supply (TPES)
  - Over 20 GWth 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: 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
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 m² of collectors worldwide

- Europe:
  - 10 million m² of collectors in operation
  - Annual growth rate of 12%
  - Germany, Greece, and Austria
  - Goal for 2010: 100 million m²

- Strong world market for solar swimming pool heaters

- Barbados has 35,000 systems

Source: Renewable Energy World, Oak Ridge National Laboratory
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

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
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

- **World:**
  - 800,000 units installed
  - Total capacity of $9,500 \text{ MW}_{\text{th}}$
  - Annual growth rate of 10%

- **USA:** 50,000 installations annually

- **Sweden, Germany, Switzerland**
  - Major European markets

- **Canada:**
  - 30,000+ residential units
  - 3,000+ industrial and commercial units
  - 435 MW$_{\text{th}}$ 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

Efficient Refrigeration at Ice Rink

Daylighting & Efficient Lighting

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.

Conclusions

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

Five Step Standard Analysis

1. Energy Model
2. Cost Analysis
3. GHG Analysis
4. Financial Summary
5. Sensitivity & Risk Analysis

Ready to make a decision
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

Range of accuracy of estimates, equal to estimated cost divided by final cost assuming constant currency value

Pre-tender estimate, cost accuracy within ±10%

All tenders received, cost within ±5%

Feasibility study, cost accuracy within ±15% to 25%

Pre-feasibility study, cost accuracy within ±40% to 50%

$100 to $1,000,000!
When should clean energy technologies be assessed?

- **Pre-feasibility Analysis**
  - 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.

- **Feasibility Analysis**

- **Preliminary feasibility studies**
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)
Project Viability (Wind Example) Depends on Several Factors - cont.

- **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
• All models validated by comparison with monitored and manufacturer’s data...

• ... and/or by comparison with hourly simulation tools.

Comparing PV Energy Production Calculated by RETScreen and HOMER

RETScreen® Software Demonstration (Wind Energy Project Model Example)

Five Step Standard Analysis

1. Energy Model
2. Cost Analysis
3. GHG Analysis
4. Financial Summary
5. Sensitivity & Risk Analysis

Ready to make a decision

Integrated Features

- Weather Data
- Product Data
- Online Manual
- Training Course
- Engineering Textbook
- Case Studies
- Online Marketplace
- Internet Forums
# RETScreen® Energy Model - Wind Energy Project

## Site Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project name</strong></td>
<td>Wind Farm</td>
</tr>
<tr>
<td><strong>Project location</strong></td>
<td>Andhra, India</td>
</tr>
<tr>
<td><strong>Wind data source</strong></td>
<td>Wind speed</td>
</tr>
<tr>
<td><strong>Nearest location for weather data</strong></td>
<td>Hyderabad</td>
</tr>
<tr>
<td><strong>Annual average wind speed</strong></td>
<td>8.2 m/s</td>
</tr>
<tr>
<td><strong>Height of wind measurement</strong></td>
<td>30.0 m</td>
</tr>
<tr>
<td><strong>Wind speed at 10 m</strong></td>
<td>5.2 m/s</td>
</tr>
<tr>
<td><strong>Average atmospheric pressure</strong></td>
<td>94.4 kPa</td>
</tr>
<tr>
<td><strong>Annual average temperature</strong></td>
<td>27 °C</td>
</tr>
</tbody>
</table>

## System Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grid type</strong></td>
<td>Central-grid</td>
</tr>
<tr>
<td><strong>Wind turbine rated power</strong></td>
<td>1.000 kW</td>
</tr>
<tr>
<td><strong>Number of turbines</strong></td>
<td>26</td>
</tr>
<tr>
<td><strong>Wind plant capacity</strong></td>
<td>20,000 kW</td>
</tr>
<tr>
<td><strong>Hub height</strong></td>
<td>70.0 m</td>
</tr>
<tr>
<td><strong>Wind speed at hub height</strong></td>
<td>7.1 m/s</td>
</tr>
<tr>
<td><strong>Wind power density at hub height</strong></td>
<td>140 W/m²</td>
</tr>
<tr>
<td><strong>Array losses</strong></td>
<td>3%</td>
</tr>
<tr>
<td><strong>Airfoil sailing and/or icing losses</strong></td>
<td>2%</td>
</tr>
<tr>
<td><strong>Other downtime losses</strong></td>
<td>2%</td>
</tr>
<tr>
<td><strong>Miscellaneous losses</strong></td>
<td>3%</td>
</tr>
</tbody>
</table>

## Annual Energy Production

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate Per Turbine</th>
<th>Estimate Total</th>
<th>Notes/Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wind plant capacity</strong></td>
<td>1.000 kW</td>
<td>20,000</td>
<td></td>
</tr>
<tr>
<td><strong>Unadjusted energy production</strong></td>
<td>2.521 MWh</td>
<td>50,426</td>
<td>0.59 to 1.02</td>
</tr>
<tr>
<td><strong>Pressure adjustment coefficient</strong></td>
<td>0.93</td>
<td>0.93</td>
<td></td>
</tr>
<tr>
<td><strong>Temperature adjustment coefficient</strong></td>
<td>0.96</td>
<td>0.96</td>
<td>0.88 to 1.15</td>
</tr>
<tr>
<td><strong>Gross energy production</strong></td>
<td>2.251 MWh</td>
<td>45,020</td>
<td></td>
</tr>
<tr>
<td><strong>Losses coefficient</strong></td>
<td>0.90</td>
<td>0.90</td>
<td>0.75 to 1.00</td>
</tr>
<tr>
<td><strong>Specific yield</strong></td>
<td>888</td>
<td>888</td>
<td>150 to 1,500 kWh/m²</td>
</tr>
<tr>
<td><strong>Wind plant capacity factor</strong></td>
<td>23%</td>
<td>23%</td>
<td>20% to 40%</td>
</tr>
<tr>
<td><strong>Renewable energy delivered</strong></td>
<td>2,034 MWh</td>
<td>40,682</td>
<td></td>
</tr>
</tbody>
</table>

**Complete Cost Analysis sheet**
## Cell Colour Coding

### Input and Output Cells

- **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

<table>
<thead>
<tr>
<th>Site Conditions</th>
<th>Estimate</th>
<th>Notes/Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project name</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind data source</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearest location for weather data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual average wind speed</td>
<td>m/s</td>
<td>6.2</td>
</tr>
<tr>
<td>Height of wind measurement</td>
<td>m</td>
<td>30.0</td>
</tr>
<tr>
<td>Wind shear exponent</td>
<td></td>
<td>-0.16</td>
</tr>
<tr>
<td>Wind speed at 10 m</td>
<td>m/s</td>
<td>5.2</td>
</tr>
<tr>
<td>Average atmospheric pressure</td>
<td>kPa</td>
<td>94.4</td>
</tr>
<tr>
<td>Annual average temperature</td>
<td>°C</td>
<td>27</td>
</tr>
</tbody>
</table>

**Andhra, India**

**Hyderabad**

**See Online Manual**

**See Weather Database**

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 Gournèrs, 1982], [WECTEC, 1996] and [Gipe, 1995].
### RETScreen® Equipment Data - Wind Energy Project

#### Wind Turbine Characteristics
<table>
<thead>
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<th>Characteristic</th>
<th>Estimate</th>
<th>Notes/Range</th>
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<tr>
<td>Wind turbine rated power</td>
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<tr>
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<tr>
<td>Rotor diameter</td>
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<td>Swept area</td>
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#### Wind Turbine Production Data

**Product Database**

<table>
<thead>
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<th>Supplier</th>
<th>Model</th>
<th>Details</th>
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<td></td>
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**Contact Information**
- Bonus Energy A/S
- Boruvaj 16
- DK-73300, Brondby
- Denmark
- phone: +45 3942 2222
- fax: +45 9999 2222
- bonus@bonus.dk
- http://www.bonus.dk/
# RETScreen® Cost Analysis - Wind Energy Project

**Type of project**: Custom  
**Currency**: User-defined  
**Second currency**: Denmark  
**Cost references**: US$/DKK  
**Rate**: US$/DKK 0.17900

### Feasibility Study

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<th>Foreign Amount</th>
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**Sub-total**: 
- **Cost**: US$ 245,200  
- **Relative Costs**: 0.8%  
- **% Foreign**: 0%  
- **Foreign Amount**: DKK

### Development

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<th>Unit Cost</th>
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<th>% Foreign</th>
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**Sub-total**: 
- **Cost**: US$ 835,500  
- **Relative Costs**: 2.7%  
- **% Foreign**: 0%  
- **Foreign Amount**: DKK

### Engineering

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<td>US$ -</td>
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**Sub-total**: 
- **Cost**: US$ 610,500  
- **Relative Costs**: 2.0%  
- **% Foreign**: 0%  
- **Foreign Amount**: DKK

---

**Energy Equipment**
# RETScreen® Energy Model - Wind Energy Project

## Site Conditions

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### Estimate

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<table>
<thead>
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<td>Wind data source</td>
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<td>Nearest location for weather data</td>
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<thead>
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<th>m/s</th>
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<td>Annual average wind speed</td>
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<td>Height of wind measurement</td>
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<tr>
<td>Wind speed at 10 m</td>
<td>m/s</td>
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<tr>
<td>Average atmospheric pressure</td>
<td>kPa</td>
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<tr>
<td>Annual average temperature</td>
<td>°C</td>
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### System Characteristics

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<th>Grid type</th>
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<tr>
<td>Wind turbine rated power</td>
<td>kW</td>
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<tr>
<td>Number of turbines</td>
<td>20</td>
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<table>
<thead>
<tr>
<th>Wind Plant Capacity</th>
<th>kW</th>
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<tbody>
<tr>
<td>Hub height</td>
<td>m</td>
</tr>
<tr>
<td>Wind speed at hub height</td>
<td>m/s</td>
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<tr>
<td>Wind power density at hub height</td>
<td>kW/m²</td>
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<table>
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<th>Array losses</th>
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<tr>
<td>Airfoil soiling and/or icing losses</td>
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<tr>
<td>Other downtime losses</td>
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<tr>
<td>Miscellaneous losses</td>
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### Annual Energy Production

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<th>kW</th>
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<thead>
<tr>
<th>Unadjusted energy production</th>
<th>MMWh</th>
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<tr>
<td>Pressure adjustment coefficient</td>
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<tr>
<td>Temperature adjustment coefficient</td>
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<td>Gross energy production</td>
<td>MMWh</td>
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<table>
<thead>
<tr>
<th>Specific yield</th>
<th>kW/m²</th>
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<td>Wind plant capacity factor</td>
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<tr>
<td>Renewable energy delivered</td>
<td>MMWh</td>
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**Notes/Range**: See Online Manual

**Weather Database**

- **Region**: N. & Central America
- **Country**: Canada
- **Province/State**: AB
- **Weather Station**: Lethbridge A
- **Latitude**: 49.00
- **Longitude**: -112.60
- **Annual Average Wind Speed**: [m/s]
- **Height of Wind Measurement**: [m]
- **Average Atmospheric Pressure**: [kPa]
- **Annual Average Temperature**: [°C]

**Date modified**: 2004/01/01

**Complete Cost Analysis sheet**
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

North: 0 to 90
East: 0 to 180

South: 0 to -90
West: 0 to -180

This form is "reset" if the input is out of range.
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.
Location: Lat -40 / Lon -68

Zoom: 1x 2x 4x 8x 16x  Submit to Zoom

Or enter a latitude and longitude using a form.
**RETScreen Data**

Latitude -40 / Longitude -68 was chosen.

---

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

**Geometry**

Geometry Information -
latitude/longitude center and boundaries

---

**RETScreen Technology Models**

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<th>Values</th>
<th>Definitions</th>
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<td>Solar Water Heating Project</td>
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<td>Ground-Source Heat Pump Project</td>
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<tr>
<td>Photovoltaic Project</td>
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<td>Solar Air Heating Project</td>
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**RETScreen Model(s) chosen:**

Wind Energy

### Average Temperature (°C)

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<th>Mar</th>
<th>Apr</th>
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<th>Jul</th>
<th>Aug</th>
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<td>10.1</td>
<td>5.98</td>
<td>4.16</td>
<td>3.06</td>
<td>5.17</td>
<td>7.90</td>
<td>11.4</td>
<td>15.3</td>
<td>17.5</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>El Nino Year (1987)</td>
<td>20.8</td>
<td>20.1</td>
<td>15.7</td>
<td>11.1</td>
<td>4.99</td>
<td>5.15</td>
<td>5.52</td>
<td>4.80</td>
<td>6.78</td>
<td>11.9</td>
<td>16.5</td>
<td>16.5</td>
<td>11.6</td>
<td></td>
</tr>
<tr>
<td>La Nina Year (1988)</td>
<td>18.6</td>
<td>21.8</td>
<td>16.4</td>
<td>10.1</td>
<td>5.67</td>
<td>3.86</td>
<td>1.43</td>
<td>4.63</td>
<td>7.85</td>
<td>9.10</td>
<td>14.5</td>
<td>17.8</td>
<td>10.9</td>
<td></td>
</tr>
</tbody>
</table>

### Average Wind Speed (m/s)

<table>
<thead>
<tr>
<th>Lat -40</th>
<th>Lon -68</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Year Average</td>
<td>4.51</td>
<td>4.11</td>
<td>4.04</td>
<td>4.01</td>
<td>4.19</td>
<td>4.04</td>
<td>3.92</td>
<td>3.95</td>
<td>4.05</td>
<td>4.28</td>
<td>4.36</td>
<td>4.73</td>
<td>4.18</td>
<td></td>
</tr>
</tbody>
</table>

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)
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
## Software Demo
### 20 MW Wind Energy Project

#### Input/Output

(RETScreen®)

- **Project location:**
- **Wind speed:**
- **GHG emissions reduction:**
- **Wind turbine cost:**
- **RE production credit:**
- **GHG credit (coal plant):**
- **Debt term:**
- **Positive cash flow:**
- **Return on investment:**

#### Scenario #1

( Merchant Plant)

- Calgary, AB
- 4.4 m/s
- 25,123 tCO₂/yr
- $1,200/kW
- $0/kWh
- $0/ton
- 10 years
- **42.7 years**
- **- 7.1%**

#### Scenario #2

( Green Power Plant)

- Pincher Creek, AB
- Lethbridge → 7.0 m/s
- → 63,486 tCO₂/yr
- → $1,000/kW
- → $0.025/kWh
- → $5/ton
- → 15 years
- **5.2 years**
- **22.8%**

Software Demo
Scenario 1

Scenario #1 (Merchant Plant) Calgary, AB
4.4 m/s
$1,200/kW
25,123 t\text{CO}_2/yr
$0/kWh
$0/ton
10 years

42.7 years
- 7.1%
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

**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
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 CO₂ per year
  - CH₄ and N₂O emissions converted to equivalent CO₂ emissions in terms of their global warming potential
How is this calculated?

Annual GHG emission reduction
\( (t_{CO_2}) \)

\[
\begin{align*}
\text{Base case} & \quad \text{Proposed case} \\
\text{GHG emission factor} & \quad \text{GHG emission factor} \\
(t_{CO_2}/\text{MWh}) & \quad (t_{CO_2}/\text{MWh}) \\
\end{align*}
\]

\[ \times \]

End-use annual energy delivered (MWh)

RETScreen \(^\circledR\) adjusts the annual reduction to account for transmission & distribution losses and GHG credits transaction fees (Version 3.0 or higher)
• 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
Type of Analysis

- **Standard** analysis: RETScreen® automatically uses IPCC and industry standard values for:
  - CO$_2$ equivalence factors for CH$_4$ and N$_2$O
  - CO$_2$, CH$_4$, and N$_2$O 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
• 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
## RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Wind Energy Project

### Background Information

#### Project Information
- **Project name**: WindFarm
- **Project location**: Andhra India
- **Project capacity**: 26.0 MW
- **Habitat**: Central-grid

#### Global Warming Potential of GHGs
- **Global Warming Potential**
  - $1$ tonne $\text{CO}_2$: $21$ tonnes $\text{CO}_2$ = $1$ tonne $\text{CH}_4$  
  - $1$ tonne $\text{N}_2\text{O}$: $310$ tonnes $\text{CO}_2$ = $1$ tonne $\text{N}_2\text{O}$

### Base Case Electricity System (Baseline)

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Fuel mix [%]</th>
<th>$\text{CO}_2$ emission factor [kg/GJ]</th>
<th>$\text{CH}_4$ emission factor [kg/GJ]</th>
<th>$\text{N}_2\text{O}$ emission factor [kg/GJ]</th>
<th>Fuel conversion efficiency [%]</th>
<th>T &amp; D losses [%]</th>
<th>GHG emission [t CO₂/MWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>100.0%</td>
<td>94.6</td>
<td>0.0806</td>
<td>0.0030</td>
<td>35.0%</td>
<td>12.0%</td>
<td>1.117</td>
</tr>
<tr>
<td>Large hydro</td>
<td>100.0%</td>
<td>0.0</td>
<td>0.0000</td>
<td>0.0000</td>
<td>100.0%</td>
<td>12.0%</td>
<td>0.308</td>
</tr>
</tbody>
</table>

### Proposed Case Electricity System (Wind Energy Project)

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Fuel mix [%]</th>
<th>$\text{CO}_2$ emission factor [kg/GJ]</th>
<th>$\text{CH}_4$ emission factor [kg/GJ]</th>
<th>$\text{N}_2\text{O}$ emission factor [kg/GJ]</th>
<th>Fuel conversion efficiency [%]</th>
<th>T &amp; D losses [%]</th>
<th>GHG emission [t CO₂/MWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity mix</td>
<td>100.0%</td>
<td>153.0</td>
<td>0.0806</td>
<td>0.0030</td>
<td>103.0%</td>
<td>12.0%</td>
<td>0.308</td>
</tr>
</tbody>
</table>

Does baseline change during project life? **No**

### GHG Emission Reduction Summary

<table>
<thead>
<tr>
<th>Electricity system</th>
<th>Base case</th>
<th>Proposed case</th>
<th>End-use annual energy delivered [MWh]</th>
<th>Gross annual GHG emission reduction [t CO₂]</th>
<th>GHG credits transaction fee [%]</th>
<th>Net annual GHG reduction [t CO₂]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>(t CO₂/MWh)</td>
<td>(t CO₂/MWh)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.559</td>
<td>0.000</td>
<td>35.600</td>
<td>19.936</td>
<td>0.0%</td>
<td>19.936</td>
</tr>
</tbody>
</table>
## RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Wind Energy Project

### Background Information

<table>
<thead>
<tr>
<th>Project Information</th>
<th>Global Warming Potential of GHG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project name</td>
<td>WindFarm</td>
</tr>
<tr>
<td>Project capacity</td>
<td>15.0 MW</td>
</tr>
<tr>
<td>Location</td>
<td>Andhra, India</td>
</tr>
<tr>
<td>Genclass</td>
<td>Central-grid</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Base Case Electricity System (Baseline)

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Fuel mix (%)</th>
<th>( \text{CO}_2 ) emission factor (kg/GJ)</th>
<th>( \text{CH}_4 ) emission factor (kg/GJ)</th>
<th>( \text{N}_2\text{O} ) emission factor (kg/GJ)</th>
<th>Fuel conversion efficiency (%)</th>
<th>T &amp; D losses (%)</th>
<th>( \text{GHG} ) emission (t(\text{CO}_2)/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>100.0%</td>
<td>94.6</td>
<td>0.0042</td>
<td>0.0030</td>
<td>35.0%</td>
<td>12.0%</td>
<td>0.353</td>
</tr>
<tr>
<td>Large hydro</td>
<td>100.0%</td>
<td>0.0</td>
<td>0.0000</td>
<td>0.0000</td>
<td>100.0%</td>
<td>12.0%</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Does baseline change during project life? No

### Proposed Case Electricity System (Wind Energy Project)

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Fuel mix (%)</th>
<th>( \text{CO}_2 ) emission factor (kg/GJ)</th>
<th>( \text{CH}_4 ) emission factor (kg/GJ)</th>
<th>( \text{N}_2\text{O} ) emission factor (kg/GJ)</th>
<th>Fuel conversion efficiency (%)</th>
<th>T &amp; D losses (%)</th>
<th>( \text{GHG} ) emission (t(\text{CO}_2)/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind system</td>
<td>100.0%</td>
<td>0.0</td>
<td>0.0000</td>
<td>0.0000</td>
<td>103.0%</td>
<td>12.0%</td>
<td>0.308</td>
</tr>
</tbody>
</table>

### GHG Emission Reduction Summary

<table>
<thead>
<tr>
<th>Electricity system</th>
<th>Base case GHG emission reduction (t(\text{CO}_2)/MWh)</th>
<th>Proposed case GHG emission reduction (t(\text{CO}_2)/MWh)</th>
<th>Annual energy delivered (MWh)</th>
<th>Gross annual GHG emission reduction (t(\text{CO}_2))</th>
<th>GHG credits transaction fee (%)</th>
<th>Net annual GHG reduction (t(\text{CO}_2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>0.000</td>
<td>0.000</td>
<td>26,850</td>
<td>14,957</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>
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

For further information please visit the RETScreen Website at
www.retscreen.net
Financial and Risk Analysis with RETScreen® Software

Clean Energy Project Analysis Course

Photo Credit: Green Mountain Power Corporation/ NRELPix

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)
Wind Energy Project Cumulative Cash Flows
Wind Farm, Andhra, India

Renewable energy delivered (MWhyrs): 40,682
Total Initial Costs: $ 31,867,965

Cumulative Cash Flow ($)

| Years | 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 |
|-------|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|       |   |   |   |   |   |   |   |   |   |   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

Year to positive cash flow: 6.7 yr
Net Present Value: $ 11,863,217

IRR and ROE: 20.1%
## Initial Cost versus Ongoing Costs: Remote Telecommunications Example

<table>
<thead>
<tr>
<th>Case</th>
<th>Initial Cost</th>
<th>Annual Cost</th>
<th>Replacement Frequency</th>
<th>Overhaul Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Genset+battery (base case)</strong>:</td>
<td>$6,000</td>
<td>$1,000</td>
<td>every 4 years ($1,500)*</td>
<td>every 2 years ($1,000)*</td>
</tr>
<tr>
<td><strong>Photovoltaics+battery (proposed case)</strong>:</td>
<td>$15,000</td>
<td></td>
<td>every 5 years ($2,000)*</td>
<td></td>
</tr>
</tbody>
</table>

*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®*

<table>
<thead>
<tr>
<th>Financial Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoided cost of energy</td>
<td>$0.0950/kWh</td>
</tr>
<tr>
<td>RE production credit</td>
<td>$0.025/kWh</td>
</tr>
<tr>
<td>RE production credit duration</td>
<td>10 yr</td>
</tr>
<tr>
<td>RE credit escalation rate</td>
<td>2.5%</td>
</tr>
<tr>
<td>GHG emission reduction credit</td>
<td>$5.0/t CO₂</td>
</tr>
<tr>
<td>GHG reduction credit duration</td>
<td>21 yr</td>
</tr>
<tr>
<td>GHG credit escalation rate</td>
<td>0.0%</td>
</tr>
<tr>
<td>Energy cost escalation rate</td>
<td>5.0%</td>
</tr>
<tr>
<td>Inflation</td>
<td>2.5%</td>
</tr>
<tr>
<td>Discount rate</td>
<td>12.0%</td>
</tr>
<tr>
<td>Project life</td>
<td>25 yr</td>
</tr>
<tr>
<td>Debt ratio</td>
<td>70.0%</td>
</tr>
<tr>
<td>Debt interest rate</td>
<td>14.0%</td>
</tr>
<tr>
<td>Debt term</td>
<td>25 yr</td>
</tr>
<tr>
<td>Income tax analysis?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Effective income tax rate</td>
<td>35.0%</td>
</tr>
<tr>
<td>Loss carryforward?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Depreciation method</td>
<td>Declining balance</td>
</tr>
<tr>
<td>Depreciation tax basis</td>
<td>95.0%</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>30.0%</td>
</tr>
<tr>
<td>Tax holiday available?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Tax holiday duration</td>
<td>5 yr</td>
</tr>
</tbody>
</table>

- **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

<table>
<thead>
<tr>
<th></th>
<th>Simple Payback</th>
<th>Net Present Value (NPV)</th>
<th>Internal Rate of Return (IRR &amp; ROI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Meaning</strong></td>
<td># of years to recoup additional costs from annual savings</td>
<td>Total value of project in today’s dollars</td>
<td>Interest yield of project during its lifetime</td>
</tr>
<tr>
<td><strong>Example</strong></td>
<td>3 year simple payback</td>
<td>$1.5 million NPV</td>
<td>17 % IRR</td>
</tr>
<tr>
<td><strong>Criteria</strong></td>
<td>Payback &lt; n years</td>
<td>Positive indicates profitable project</td>
<td>IRR &gt; hurdle rate</td>
</tr>
<tr>
<td><strong>Comment</strong></td>
<td>• Misleading</td>
<td>• Good measure</td>
<td>• Can be fooled when cashflow goes positive-negative-positive</td>
</tr>
<tr>
<td></td>
<td>• Ignores financing &amp; long-term cashflows</td>
<td>• User must specify discount rate</td>
<td></td>
</tr>
</tbody>
</table>
## Comparison of Indicators: Remote Telecommunications Example

<table>
<thead>
<tr>
<th></th>
<th>Simple Payback</th>
<th>Net Present Value (NPV)</th>
<th>Internal Rate of Return (IRR &amp; ROI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV vs genset*</td>
<td>9 years</td>
<td>$4,800</td>
<td>22%</td>
</tr>
<tr>
<td>Decision</td>
<td>Genset</td>
<td>PV</td>
<td>PV</td>
</tr>
</tbody>
</table>

* Discount rate of 12%; 50% debt financed over 15 years at 7% interest rate
## Indicators of Financial Viability:
### Remote Telecommunications Example

<table>
<thead>
<tr>
<th>Financial Feasibility</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-tax IRR and ROI</td>
<td>22.3%</td>
</tr>
<tr>
<td>After-tax IRR and ROI</td>
<td>22.3%</td>
</tr>
<tr>
<td>Simple Payback</td>
<td>9.0 yr</td>
</tr>
<tr>
<td>Year-to-positive cash flow</td>
<td>3.8 yr</td>
</tr>
<tr>
<td>Net Present Value - NPV</td>
<td>$4,771</td>
</tr>
<tr>
<td>Annual Life Cycle Savings</td>
<td>$608</td>
</tr>
<tr>
<td>Benefit-Cost (B-C) ratio</td>
<td>1.98</td>
</tr>
</tbody>
</table>

- **Calculate energy prod** yes/no: No
- **Calculate GHG reduct** yes/no: No

| Project equity                              | $4,500      |
| Project debt                                | $4,500      |
| Debt payments                               | $494/yr     |
| Debt service coverage                       | 2.08        |

- **3.8 years to positive cash flow**

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?
## RETScreen® Sensitivity and Risk Analysis - Wind Energy Project

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

### Sensitivity Analysis for After-tax IRR and ROI

<table>
<thead>
<tr>
<th>RE delivered (MWh)</th>
<th>Avoided cost of energy ($/kWh)</th>
<th>-20%</th>
<th>-10%</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>32,546</td>
<td>0.0760</td>
<td>4.2%</td>
<td>8.2%</td>
<td>11.8%</td>
<td>15.2%</td>
<td>18.5%</td>
</tr>
<tr>
<td></td>
<td>0.0855</td>
<td>8.6%</td>
<td>12.9%</td>
<td>16.7%</td>
<td>20.4%</td>
<td>24.1%</td>
</tr>
<tr>
<td></td>
<td>0.0958</td>
<td>13.1%</td>
<td>17.4%</td>
<td>21.6%</td>
<td>25.7%</td>
<td>29.8%</td>
</tr>
<tr>
<td></td>
<td>0.1045</td>
<td>21.5%</td>
<td>26.5%</td>
<td>31.6%</td>
<td>36.5%</td>
<td>41.5%</td>
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<tr>
<td></td>
<td>0.1140</td>
<td>21.5%</td>
<td>26.5%</td>
<td>31.6%</td>
<td>36.5%</td>
<td>41.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Initial costs ($)</th>
<th>Avoided cost of energy ($/kWh)</th>
<th>-20%</th>
<th>-10%</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>24,393,372</td>
<td>0.0760</td>
<td>21.6%</td>
<td>26.9%</td>
<td>32.2%</td>
<td>37.4%</td>
<td>42.6%</td>
</tr>
<tr>
<td></td>
<td>0.0855</td>
<td>16.9%</td>
<td>21.6%</td>
<td>26.2%</td>
<td>30.8%</td>
<td>35.4%</td>
</tr>
<tr>
<td></td>
<td>0.0958</td>
<td>13.1%</td>
<td>17.4%</td>
<td>21.6%</td>
<td>25.7%</td>
<td>29.8%</td>
</tr>
<tr>
<td></td>
<td>0.1045</td>
<td>9.5%</td>
<td>14.0%</td>
<td>17.6%</td>
<td>21.8%</td>
<td>25.3%</td>
</tr>
<tr>
<td></td>
<td>0.1140</td>
<td>7.2%</td>
<td>11.1%</td>
<td>14.7%</td>
<td>18.2%</td>
<td>21.6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual costs ($)</th>
<th>Avoided cost of energy ($/kWh)</th>
<th>-20%</th>
<th>-10%</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>616,000</td>
<td>0.0760</td>
<td>14.5%</td>
<td>18.8%</td>
<td>23.0%</td>
<td>27.1%</td>
<td>31.2%</td>
</tr>
<tr>
<td></td>
<td>0.0855</td>
<td>13.8%</td>
<td>18.1%</td>
<td>22.3%</td>
<td>26.4%</td>
<td>30.5%</td>
</tr>
<tr>
<td></td>
<td>0.0958</td>
<td>13.1%</td>
<td>17.4%</td>
<td>21.6%</td>
<td>25.7%</td>
<td>29.8%</td>
</tr>
<tr>
<td></td>
<td>0.1045</td>
<td>12.3%</td>
<td>16.7%</td>
<td>20.9%</td>
<td>25.0%</td>
<td>29.1%</td>
</tr>
<tr>
<td></td>
<td>0.1140</td>
<td>11.6%</td>
<td>16.0%</td>
<td>20.2%</td>
<td>24.3%</td>
<td>28.3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Debt interest rate (%)</th>
<th>Debt ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.2%</td>
<td>56.0%</td>
</tr>
<tr>
<td>12.6%</td>
<td>63.0%</td>
</tr>
<tr>
<td>14.8%</td>
<td>70.0%</td>
</tr>
<tr>
<td>15.4%</td>
<td>77.0%</td>
</tr>
<tr>
<td>16.8%</td>
<td>84.0%</td>
</tr>
</tbody>
</table>
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?

<table>
<thead>
<tr>
<th>Initial costs ($)</th>
<th>Avoided cost of energy ($/kWh)</th>
<th>0.0760</th>
<th>0.0865</th>
<th>0.0950</th>
<th>0.1045</th>
<th>0.1140</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-20%</td>
<td>11.5%</td>
<td>16.1%</td>
<td>20.4%</td>
<td>24.5%</td>
<td>28.6%</td>
</tr>
<tr>
<td>24,934,372</td>
<td>-10%</td>
<td>7.5%</td>
<td>11.8%</td>
<td>15.7%</td>
<td>19.4%</td>
<td>23.1%</td>
</tr>
<tr>
<td>26,051,168</td>
<td>0%</td>
<td>4.1%</td>
<td>8.3%</td>
<td>12.0%</td>
<td>15.4%</td>
<td>18.7%</td>
</tr>
<tr>
<td>31,167,965</td>
<td>10%</td>
<td>1.0%</td>
<td>5.3%</td>
<td>8.9%</td>
<td>12.2%</td>
<td>15.2%</td>
</tr>
<tr>
<td>34,284,761</td>
<td>20%</td>
<td>-1.9%</td>
<td>2.6%</td>
<td>6.2%</td>
<td>9.4%</td>
<td>12.3%</td>
</tr>
</tbody>
</table>
Sensitivity Analysis: Parameters

• 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

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

Click here to Calculate Sensitivity Analysis
• User is uncertain of many parameters:

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

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

Photo: Nordex GmbH
Conclusions

• 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

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Canada</td>
<td>19,634</td>
</tr>
<tr>
<td>2</td>
<td>USA</td>
<td>8,240</td>
</tr>
<tr>
<td>3</td>
<td>France</td>
<td>5,747</td>
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<tr>
<td>4</td>
<td>UK</td>
<td>2,733</td>
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<td>5</td>
<td>Spain</td>
<td>2,192</td>
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<td>6</td>
<td>Italy</td>
<td>1,789</td>
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<tr>
<td>7</td>
<td>Australia</td>
<td>1,473</td>
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<tr>
<td>8</td>
<td>Germany</td>
<td>1,214</td>
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<td>9</td>
<td>India</td>
<td>1,013</td>
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<td>Belgium</td>
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<td>11</td>
<td>Portugal</td>
<td>764</td>
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<tr>
<td>12</td>
<td>Ireland</td>
<td>732</td>
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<tr>
<td>13</td>
<td>Greece</td>
<td>717</td>
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<td>14</td>
<td>Brazil</td>
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<td>15</td>
<td>Mexico</td>
<td>493</td>
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<td>16</td>
<td>Netherlands</td>
<td>459</td>
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<td>17</td>
<td>Argentina</td>
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<td>18</td>
<td>Switzerland</td>
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<tr>
<td>20</td>
<td>New Zealand</td>
<td>344</td>
</tr>
</tbody>
</table>

As of June 30, 2005
A Decision Support & Capacity Building Tool

**RETScreen Software: Reported Intended Use**

<table>
<thead>
<tr>
<th>Number of Users</th>
<th>Assess projects</th>
<th>Project development</th>
<th>Training</th>
<th>Info dissemination</th>
<th>Other</th>
<th>Due-diligence</th>
<th>Policy analysis</th>
<th>Product R+D</th>
<th>Market Studies or Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20,497 (49%)</td>
<td>11,225 (27%)</td>
<td>10,073 (24%)</td>
<td>6,514 (15%)</td>
<td>5,371 (13%)</td>
<td>5,577 (13%)</td>
<td>4,003 (9%)</td>
<td>5,980 (14%)</td>
<td>10,587 (25%)</td>
</tr>
</tbody>
</table>

42,140 online survey respondents

**Profile of Users**

- **Type 1 - Implementers (36%)**
  - 20% Professional services
  - 10% Project developer/owner
  - 6% Product suppliers

- **Type 2 - Facilitators (28%)**
  - 19% Educational institution/R&D Centre
  - 6% Financial/Government/Multi-lateral
  - 3% Association/NGO

- **Type 3 - Individuals (36%)**

As of March 31, 2004
Common Platform for Project Evaluation & Development

RETScreen® International

[Diagram showing a central RETScreen Software surrounded by sectors labeled Funders & Lenders, Planners, Developers & Owners, Consultants & Product Suppliers, and Regulators & Policy Makers.]
Questions?

Summary of Introductory Module

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