RETScreen® International

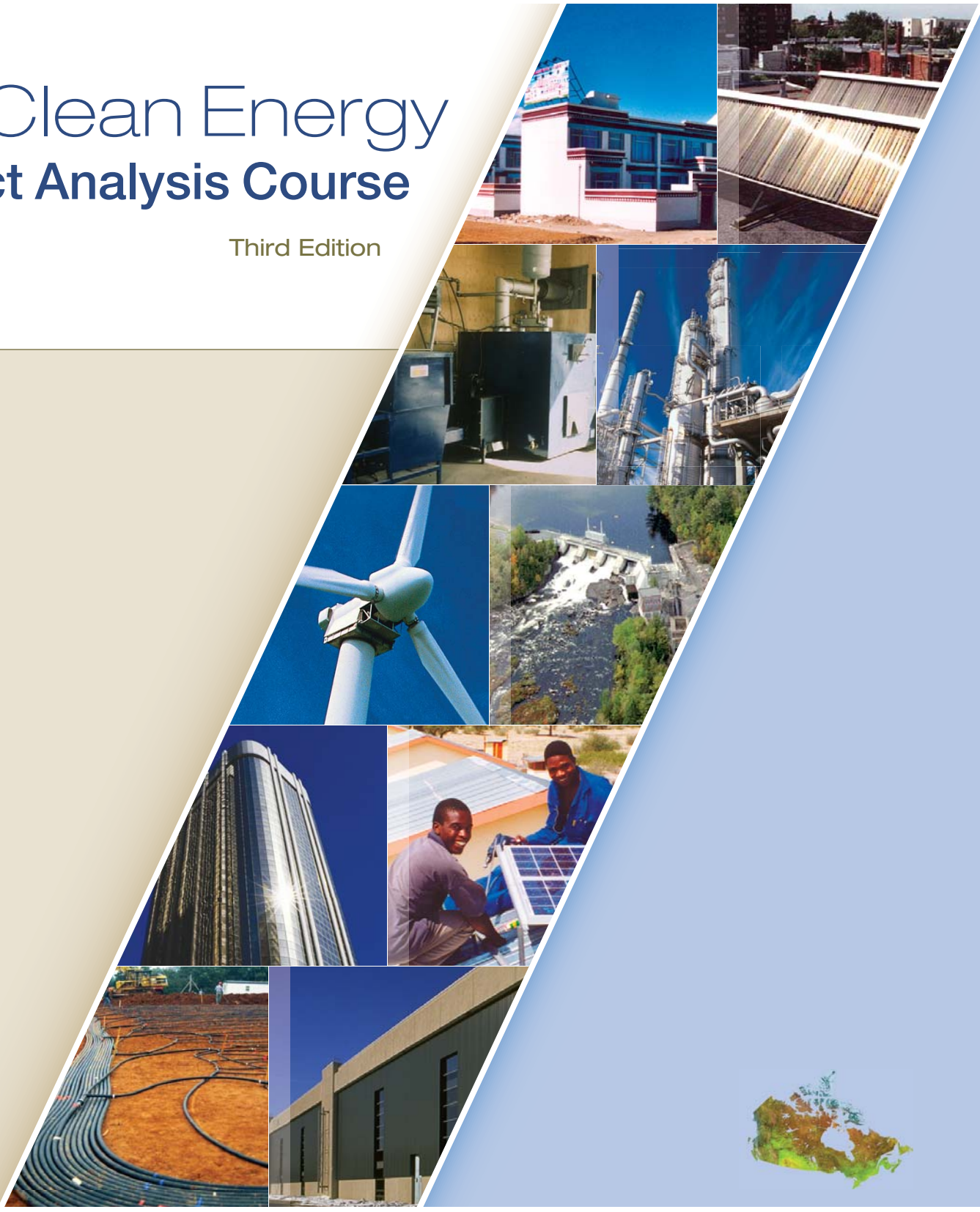
Clean Energy Decision Support Centre

www.retscreen.net

Clean Energy

Project Analysis Course

Third Edition



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This document allows for a printed version of the entire presentation slides of the *RETScreen® International Clean Energy Project Analysis Course*. This modular case study-based course has been created for use by recognised educational centres and training organisations around the globe, as well as for use by professionals and college/university students in a "self-study" distance learning format. Each module can be presented as a separate seminar or workshop for professionals, or as a section of a college/university course. All the modules combined can be presented either as a one- to two-week-long intensive course for professionals or as a one- to two-semester-long course for college/university students. The training course material (e.g. presentation slides, instructor's voice and notes, engineering e-textbook, project case studies, etc.) can be downloaded free-of-charge from the RETScreen Website: www.retscreen.net.

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- Financial and Risk Analysis with RETScreen® Software
- Summary of Introductory Module

WIND ENERGY PROJECT ANALYSIS MODULE

SMALL HYDRO PROJECT ANALYSIS MODULE

PHOTOVOLTAIC PROJECT ANALYSIS MODULE

COMBINED HEAT & POWER PROJECT ANALYSIS MODULE

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SOLAR AIR HEATING PROJECT ANALYSIS MODULE

SOLAR WATER HEATING PROJECT ANALYSIS MODULE

PASSIVE SOLAR HEATING PROJECT ANALYSIS MODULE

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Cette publication est disponible en français sous le titre «Cours d'analyse de projets d'énergies propres».

INTRODUCTION TO CLEAN ENERGY PROJECT ANALYSIS MODULE

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

Introduction to Clean Energy Project Analysis

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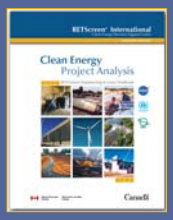
Clean Energy Project Analysis Course

"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



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RETScreen® International
Clean Energy Decision Support Centre

RETScreen® International — www.retscreen.net

- 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

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Upon Completion of the Course

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- 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

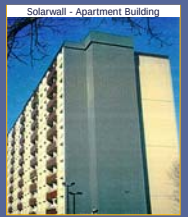

Photo Credit: Enermodal

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Course Outline

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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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Course Materials

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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)

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- Centre Overview
- Software & Data
- Training Material
- e-Textbook
- Case Studies
- Download Free
- Calendar
- Marketplace

- 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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NASA UNEP GEF

Software & Data

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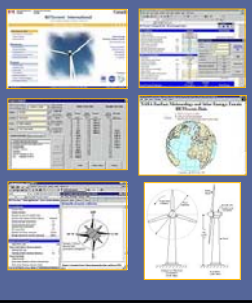
RETScreen® International Clean Energy Project Analysis Software



- 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

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Training Material

RETSCREEN® INTERNATIONAL www.retscreen.net

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

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e-Textbook & Case Studies

RETSCREEN® INTERNATIONAL www.retscreen.net

- 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

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Marketplace & Calendar

RETScreen® International www.retscreen.net

- 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

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Introductory Module Outline

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

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Status of Clean Energy Technologies

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Clean Energy Project Analysis Course

Windfarm

Photo Credit: Nordex Gmbh

Passive Solar Home

Photo Credit: McFadden, Pam DOE/NREL

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Objective

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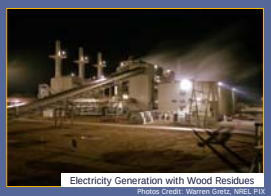
- Increase awareness about renewable energy technologies (RETs) and energy efficiency measures
  - Markets
  - Typical applications



Electricity Generation with Wood Residues

Photos Credit: Warren Gretz, NREL PIX

Photovoltaics and Solar Water Heating

Photo Credit: Vadim Belotserkovsky

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Definitions

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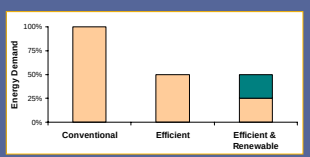
Clean Energy Technologies

- 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



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Reasons for Clean Energy Technologies

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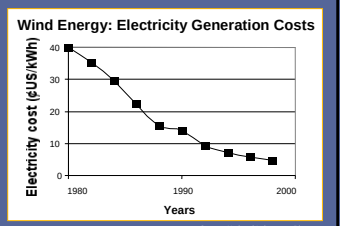
- Environmental
  - Climate change
  - Local pollution
- Economic
  - Life-cycle costs
  - Fossil fuel depletion
- Social
  - Employment generation
  - Reduced drain of local $$$
  - Growth in energy demand (x3 by 2050)



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

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Common Characteristics of Clean Energy Technologies

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

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Total Cost of an Energy Generating or Consuming System

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

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

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Renewable Energy Electricity Generating Technologies

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Wind Energy Technology & Applications

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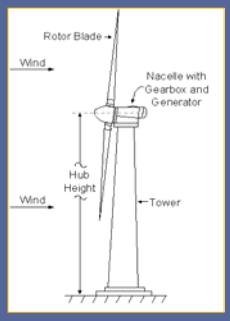

- Need good winds
  - (>4 m/s @ 10 m)
  - Coastal areas, rounded ridges, open plains
- Applications:

Central-Grid
Warren Gretz, NREL PIX

Isolated-Grid
Phil Owens, Nunavut Power

Off-Grid
Southwest Windpower, NREL PIX

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Wind Energy Market

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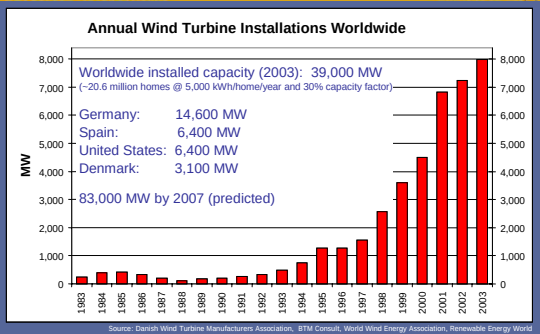

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Small Hydro Technology & Applications

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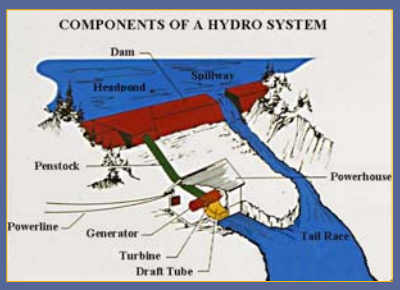

- Project types:
  - Reservoir
  - Run-of-river
- Applications:
  - Central-grid
  - Isolated-grid
  - Off-grid

Francis Turbine

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Small Hydro Market

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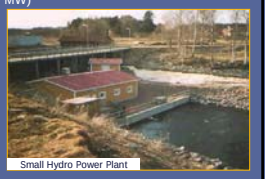
- 19% of world electricity produced by large & small hydro
- Worldwide:
  - 20,000 MW developed (plant size < 10 MW)
  - Forecast: 50,000 to 75,000 MW by 2020
- China:
  - 43,000 existing plants (plant size < 25 MW)
  - 19,000 MW developed
  - further 100,000 MW econ. feasible
- Europe:
  - 10,000 MW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



Small Hydro Power Plant

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Photovoltaic (PV) Technology & Applications

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Household PV System

Photo Credit: Tsuo, Simon DOE/NREL

PV Water Pumping

Grid-tied Building Integrated PV

Photo Credit: Strong, Steven DOE/NREL

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Photovoltaic Market

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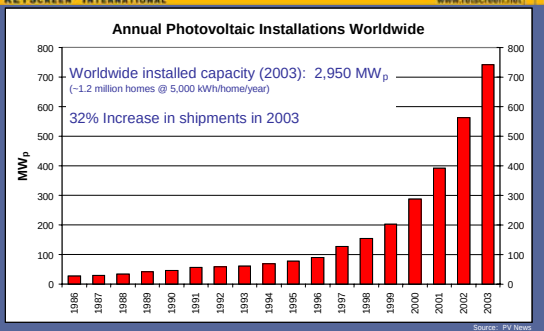

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Combined Heat and Power (CHP)

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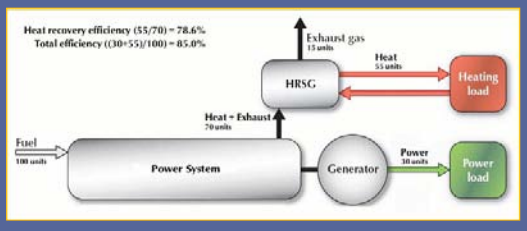
- Simultaneous production of two or more types of usable energy from a single energy source (also called "Cogeneration")



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Combined Heat and Power Applications, Fuels and Equipment

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Various Applications

Biomass for CHP

Photo Credit: Gretz, Warren DOE/NREL

Various Fuels

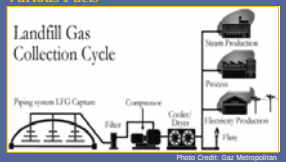

Photo Credit: Gaz Metropolitan

Various Equipment

Reciprocating Engine for Power Generation

Photo Credit: Rolls-Royce plc

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Combined Heat and Power Applications

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- 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

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Combined Heat and Power Fuel Types

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- 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

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Combined Heat and Power Equipment & Technologies

RETScreen® International www.retscreen.net

- 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

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Combined Heat and Power Market

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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

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Renewable Energy Heating & Cooling Technologies

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Biomass Heating Technology & Applications

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Wood Chipping

Photo Credit: Wiseloger, Art DOE/NREL

Heating Plant

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

Single Buildings and/or District Heating

Photo Credit: Oujé-Bougoumou Cree Nation

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Biomass Heating Market

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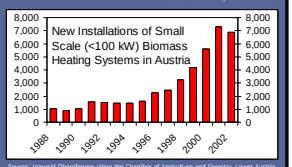
- Worldwide:
  - Biomass combustion provides 11% of world's Total Primary Energy Supply (TPES)
  - Over 20 GW_{th} of controlled combustion heating systems
- Developing countries:
  - Cooking, heating
  - Not always sustainable
  - Africa: 50% of TPES
  - India: 39% of TPES
  - China: 19% of TPES
- Industrialised 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

Combustion Chamber

Photo: Ken Sheinkopf/ Solstice CREST



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

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

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Solar Air Heating Technology & Applications

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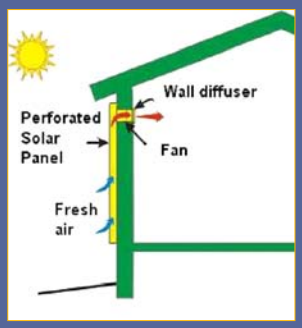
- Unglazed collector for air preheating
- Cold air is heated as it passes through small holes in the metal absorber plate (Solarwall™)
- A fan circulates this heated air through the building



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Solar Air Heating Market

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- 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

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Solar Water Heating Technology & Applications

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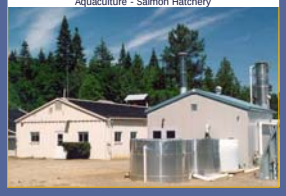
- Glazed and unglazed collectors
- Water storage (tank or pool)

Commercial/Institutional Buildings and Pools

Aquaculture - Salmon Hatchery



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Solar Water Heating Market

RETSCREEN® INTERNATIONAL www.retscreen.net

- 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

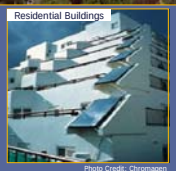

Photo Credit: Chromagen

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Passive Solar Heating Technology & Applications

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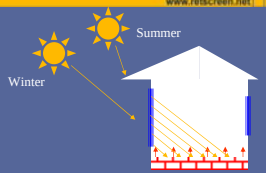
- Supply 20 to 50% of space heating required in the heating season
- Solar gains available through equator-facing high performance windows
- Store heat within building structure
- Use shading to reduce summer heat gains



Passive Solar Heating of Apartments

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

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Passive Solar Heating Market

RETScreen® International www.retscreen.net

- 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

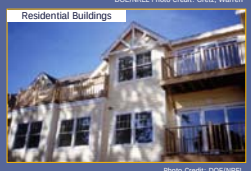

Photo Credit: DOE/NREL

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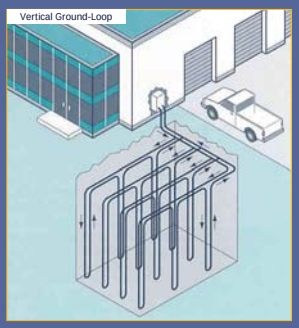
Ground-Source Heat Pump Technology & Applications

RETScreen® International www.retscreen.net

Vertical Ground-Loop



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

Horizontal Ground-Loop

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Ground-Source Heat Pump Market

RETScreen® International www.retscreen.net

Residential GSHP

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

- 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

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

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Other Commercial Clean Energy Technologies

RETScreen® International www.retscreen.net

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

Efficient Refrigeration at Ice Rink

Agriculture Waste Fuel Supply

Photo Credit: David and Associates DOE/NREL

Daylighting & Efficient Lighting

Photo Credit: Robb Williamson/ NREL Pix

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Emerging Clean Energy Technologies

RETScreen® International www.retscreen.net

- 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

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Conclusions

RETScreen® International www.retscreen.net

- 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

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Questions?

RETScreen® International www.retscreen.net

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

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Clean Energy Project Analysis with RETScreen® Software

RETScreen® International — www.retscreen.net

Clean Energy Project Analysis Course

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Natural Resources Canada / Ressources naturelles Canada — Canada

Objectives

RETScreen® International — www.retscreen.net

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

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Energy Project Implementation Process

RETScreen® International — www.retscreen.net

Pre-feasibility Analysis

Feasibility Analysis

Development & Engineering

Construction & Commissioning

Significant barrier

Clean Energy projects not being routinely considered up-front!

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Questions

RETScreen® International www.retscreen.net

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

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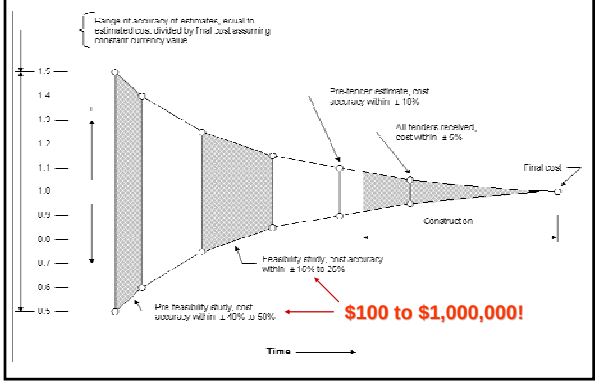
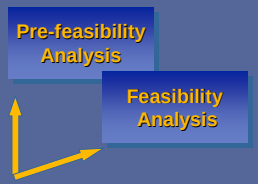
Accuracy vs. Investment Cost Dilemma



When should clean energy technologies be assessed?

RETScreen® International www.retscreen.net



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.

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Project Viability (Wind Example) Depends on Several Factors

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- **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

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

RETScreen® International www.retscreen.net

- **Avoided cost of energy**
  (e.g. wholesale electricity price)
- **Financing**
  (e.g. debt ratio & length, interest rate)

Wind Energy

Photo Credit: Middelgrunden Wind Turbine Co-operative

- **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)

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Why Use RETScreen®?

RETScreen® International www.retscreen.net

- 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

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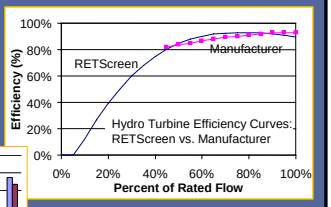
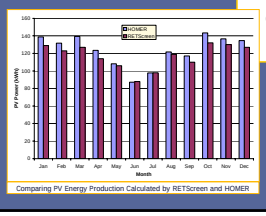
RETScreen® Validation- Examples

RETSCREEN® INTERNATIONAL www.retscreen.net

- 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.

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RETScreen® Software Demonstration (Wind Energy Project Model Example)

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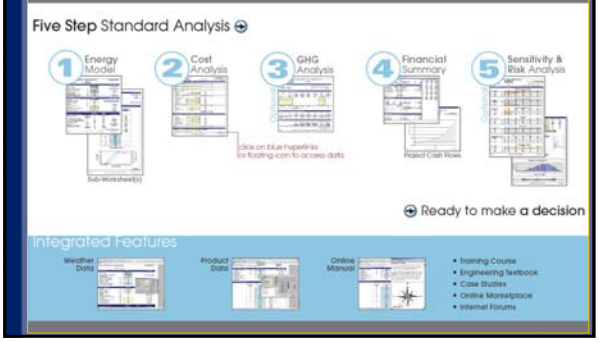

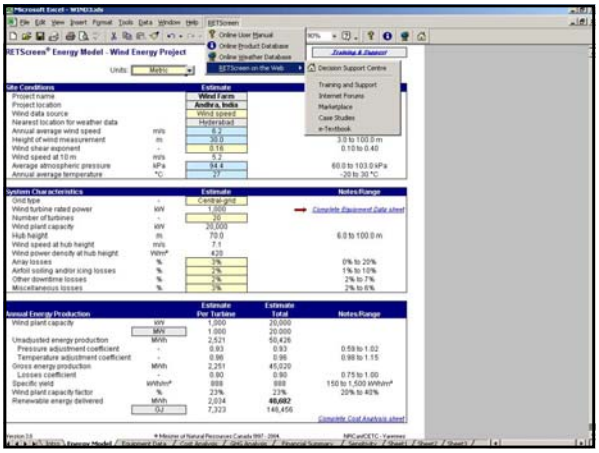

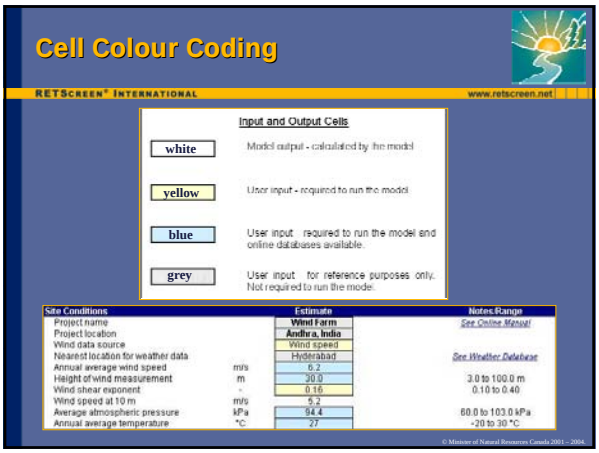
Cell Colour Coding
RETSCREEN® INTERNATIONAL
www.retscreen.net
Input and Output Cells
white
Model output - calculated by the model
yellow
User input - required to run the model
blue
User input - required to run the model and online databases available.
grey
User input - for reference purposes only. Not required to run the model.
Site Conditions
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
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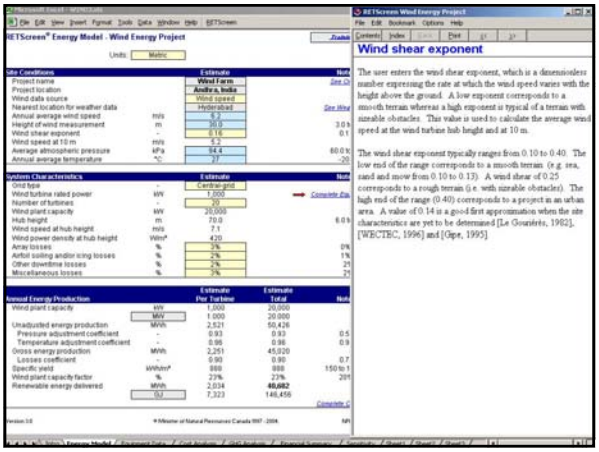
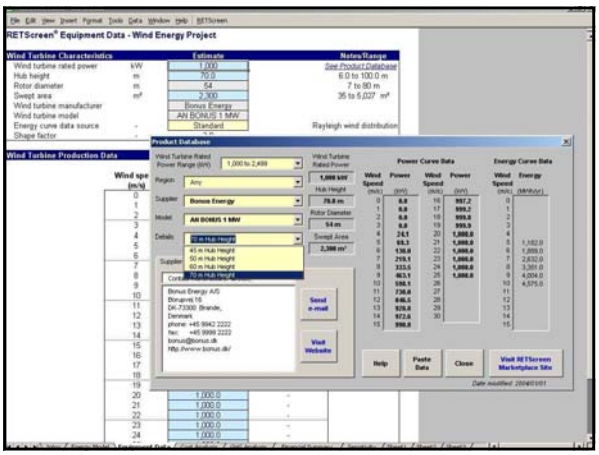
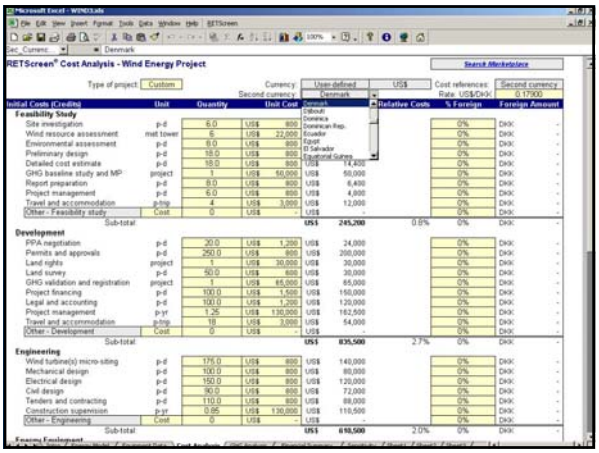
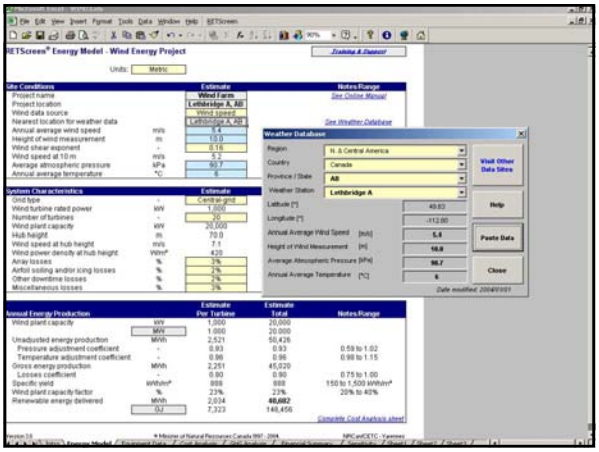
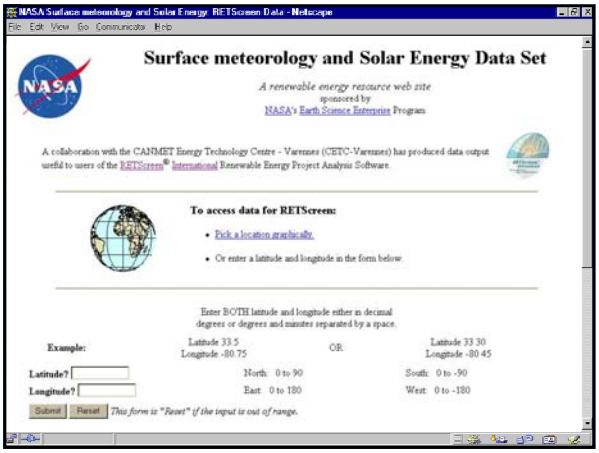
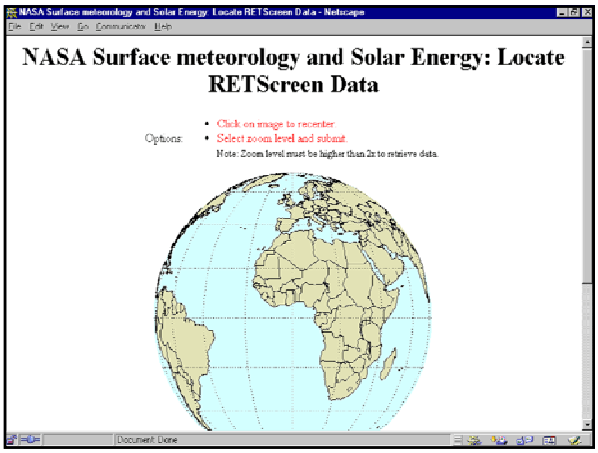

RETScreen® Energy Model - Wind Energy Project
Wind shear exponent
The user enters the wind shear exponent, which is a dimensionless number expressing the rate at which the wind speed varies with the height above the ground. A low exponent corresponds to a smooth terrain whereas a high exponent is typical 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].

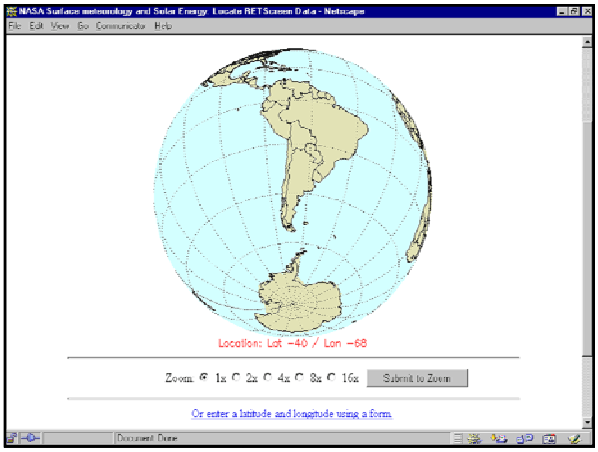

RETScreen® Equipment Data - Wind Energy Project
Wind Turbine Characteristics
Estimate
Notes/Range
Wind turbine rated power
kW
1,000
Hub height
m
70.0
6.0 to 100.0 m
Rotor diameter
m
54
7 to 80 m
Swept area
m²
2,300
35 to 5,027 m²
Wind turbine manufacturer
Bonus Energy
Wind turbine model
AN BONUS 1 MW
Energy curve data source
Standard
Shape factor
Rayleigh wind distribution
Wind Turbine Production Data
Product Database
Power Curve Data
Energy Curve Data
Bonus Energy A/S
Bonusvej 16
DK-7330 Brande,
Denmark
phone: +45 9942 2222
fax: +45 9999 2222
bonus@bonus.dk
http://www.bonus.dk/
Send e-mail
Visit Website
Help
Paste Data
Close
Visit RETScreen Marketplace Site

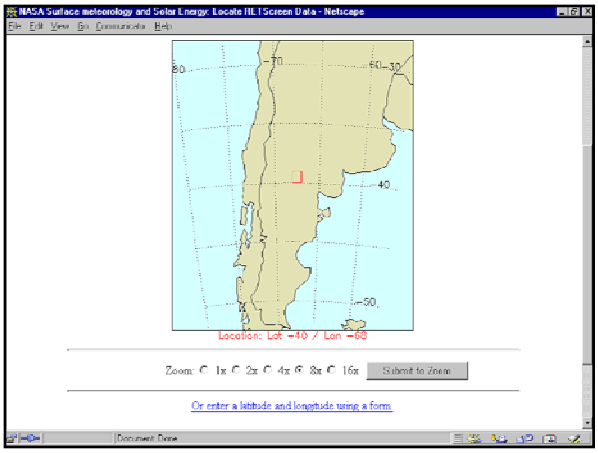

RETScreen® Cost Analysis - Wind Energy Project

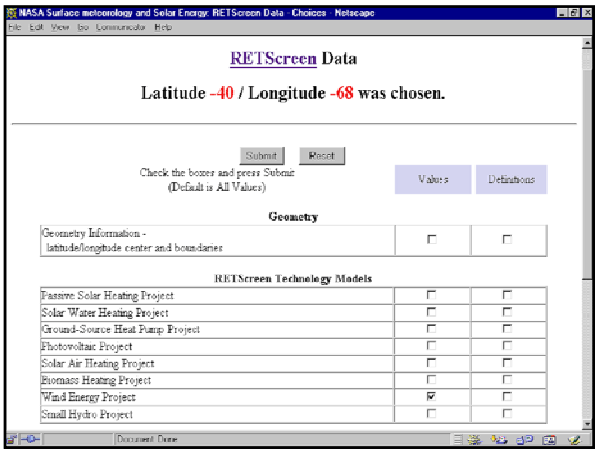

RETScreen® Energy Model - Wind Energy Project

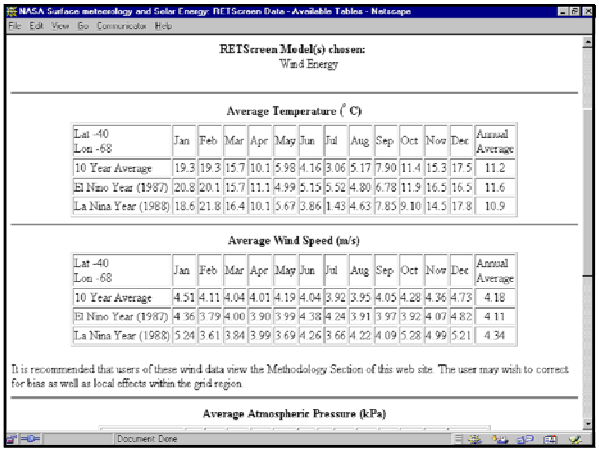

NASA Surface meteorology and Solar Energy: RETScreen Data - Netscape
Surface meteorology and Solar Energy Data Set
A renewable energy resource web site
sponsored by
NASA's Earth Science Enterprise Program
A collaboration with the CANMET Energy Technology Centre - Varennes (CETC-Varennes) has produced 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?
Longitude?
North: 0 to 90
South: 0 to -90
East: 0 to 180
West: 0 to -180
Submit
Reset
This form is "Reset" if the input is out of range.

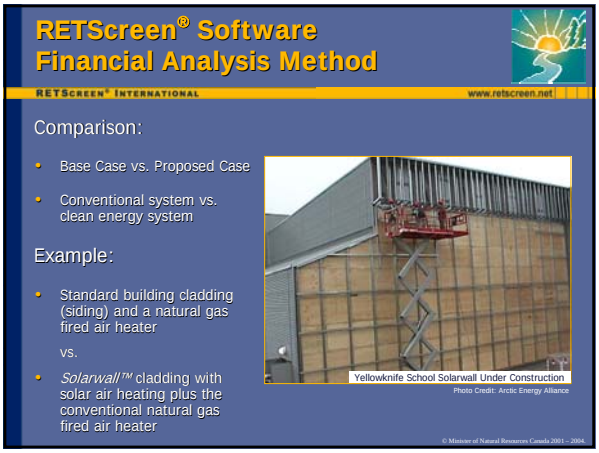

NASA Surface meteorology and Solar Energy: Locate RETScreen Data - Netscape
File Edit View Go Communicator Help
NASA Surface meteorology and Solar Energy: Locate RETScreen Data
Options:
Click on image to recenter
Select zoom level and submit.
Note: Zoom level must be higher than 2x to retrieve data.
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
80
70
60
30
40
50
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
RETScreen Data
Latitude -40 / Longitude -68 was chosen.
Submit
Reset
Check the boxes and press Submit
(Default is All Values)
Values
Definitions
Geometry
Geometry Information - latitude/longitude center and boundaries
RETScreen Technology Models
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


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


RETScreen® Software
Financial Analysis Method
RETScreen® International
www.retscreen.net
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
© Minister of Natural Resources Canada 2001 – 2004.

Software Demo
20 MW Wind Energy Project

RETScreen® International www.retscreen.net

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%**

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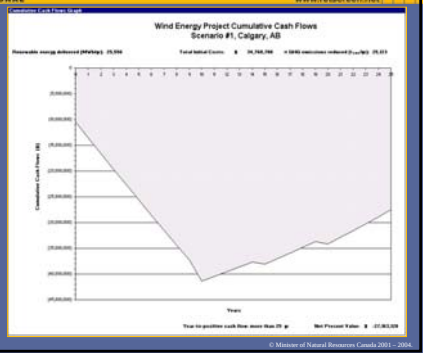
Software Demo
Scenario 1

RETScreen® International www.retscreen.net

Scenario #1
(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%



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Software Demo
Wind Speed & GHG Emission Reduction

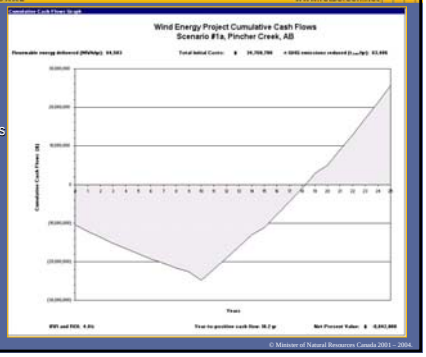
RETScreen® International www.retscreen.net

Scenario # 1a

(Green Power Plant)
Pincher Creek, AB
Lethbridge → 7.0 m/s

63,486 t_{CO_2}/yr

18.2 years
4.8%



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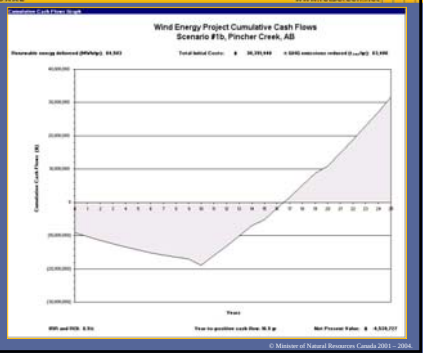
Software Demo
Wind Turbine Cost

RETSCREEN® INTERNATIONAL www.retscreen.net

Scenario # 1b

$1,000/kW

16.5 years
6.5 %



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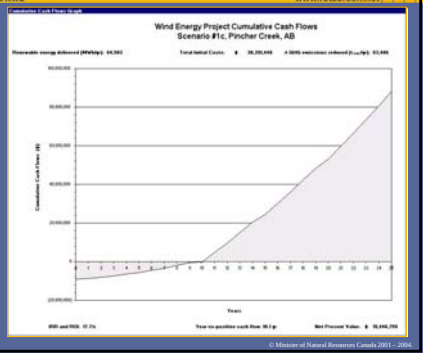
Software Demo
RE Production Credit

RETSCREEN® INTERNATIONAL www.retscreen.net

Scenario # 1c

$0.025/kWh

10.1 years
17.7 %



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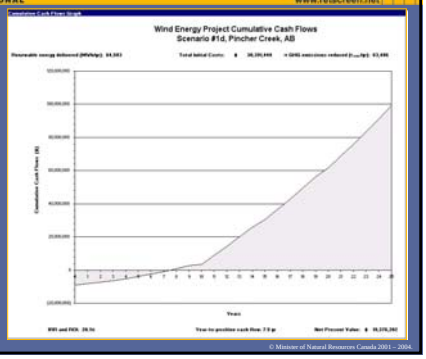
Software Demo
GHG Emissions Credit

RETSCREEN® INTERNATIONAL www.retscreen.net

Scenario # 1d

$5/ton

7.5 years
20.1 %



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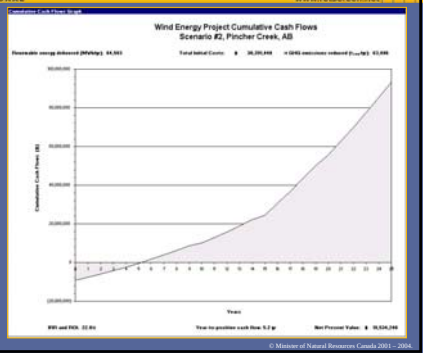
Software Demo
Debt Term

RETSCREEN® INTERNATIONAL www.retscreen.net

Scenario # 2

15 years

5.2 years
22.8 %



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Questions?

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Wind Energy Project Model

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- Colour Coding
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Worksheets

- Energy Model
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- Cost Analysis
- Greenhouse Gas Analysis
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Features

- Product Data
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- Unit Options
- Currency Options
- CDM / JI Project Analysis
- Sensitivity Analysis

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RETScreen® Energy Model - Wind Energy Project

Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Scenario #1	See Online Manual
Project location		Calgary, AB	
Wind data source		Wind speed	
Nearest location for weather data		Calgary Int'l. A, AB	See Weather Database
Annual average wind speed	m/s	4.4	
Height of wind measurement	m	10.0	3.0 to 100.0 m
Wind shear exponent	-	0.15	0.10 to 0.40
Wind speed at 10 m	m/s	4.4	
Average atmospheric pressure	kPa	88.9	60.0 to 103.0 kPa
Annual average temperature	°C	4	-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	45.0	6.0 to 100.0 m
Wind speed at hub height	m/s	5.5	
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	1,545	30,902	
Pressure adjustment coefficient	-	0.88	0.88	0.59 to 1.02
Temperature adjustment coefficient	-	1.04	1.04	0.98 to 1.15
Gross energy production	MWh	1,414	28,282	
Losses coefficient	-	0.90	0.90	0.75 to 1.00
Specific yield	kWh/m²	556	556	150 to 1,500 kWh/m²
Wind plant capacity factor	%	15%	15%	20% to 40%
Renewable energy delivered	MWh	1,278	**25,556**	
	GJ	4,600	92,003	

Complete Cost Analysis sheet

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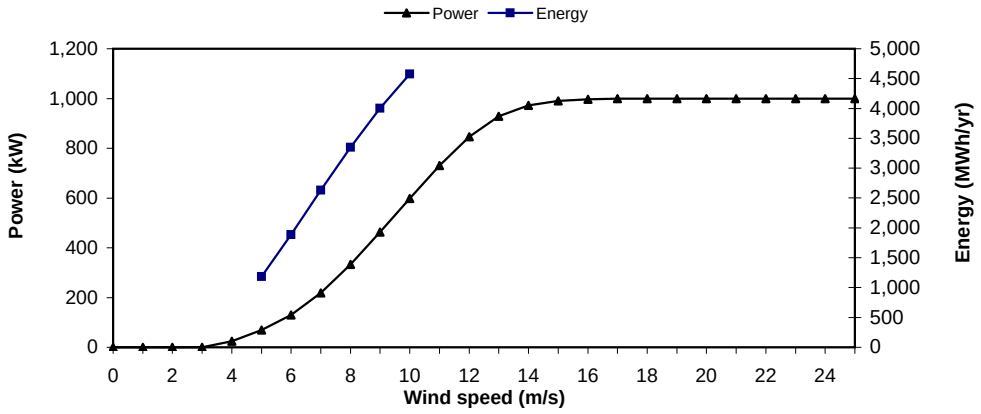
RETScreen® Equipment Data - Wind Energy Project

Wind Turbine Characteristics		Estimate	Notes/Range
Wind turbine rated power	kW	1,000	See Product Database
Hub height	m	45.0	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	-	User-defined	Site specific

Wind Turbine Production Data

Wind speed (m/s)	Power curve data (kW)	Energy curve data (MWh/yr)
0	0.0	-
1	0.0	-
2	0.0	-
3	0.0	-
4	24.1	-
5	69.3	1,182.0
6	130.0	1,889.0
7	219.1	2,632.0
8	333.5	3,351.0
9	463.1	4,004.0
10	598.1	4,575.0
11	730.0	-
12	846.5	-
13	928.8	-
14	972.6	-
15	990.8	-
16	997.2	-
17	999.2	-
18	999.8	-
19	999.9	-
20	1,000.0	-
21	1,000.0	-
22	1,000.0	-
23	1,000.0	-
24	1,000.0	-
25	1,000.0	-

Power and Energy Curves



Return to Energy Model sheet

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RETScreen® Cost Analysis - Wind Energy Project

Search Marketplace

Type of project: Custom | Currency: $ | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Site investigation	p-d	6.0	$ 800	$ 4,800		-	-
Wind resource assessment	met tower	6	$ 22,000	$ 132,000		-	-
Environmental assessment	p-d	8.0	$ 800	$ 6,400		-	-
Preliminary design	p-d	18.0	$ 800	$ 14,400		-	-
Detailed cost estimate	p-d	18.0	$ 800	$ 14,400		-	-
GHG baseline study and MP	project			$ -		-	-
Report preparation	p-d	8.0	$ 800	$ 6,400		-	-
Project management	p-d	6.0	$ 800	$ 4,800		-	-
Travel and accommodation	p-trip	4	$ 3,000	$ 12,000		-	-
				$ -		-	-
Sub-total:				**$ 195,200**	0.6%		
Development							
PPA negotiation	p-d	20.0	$ 1,200	$ 24,000		-	-
Permits and approvals	p-d	250.0	$ 800	$ 200,000		-	-
Land rights	project	1	$ 30,000	$ 30,000		-	-
Land survey	p-d	50.0	$ 600	$ 30,000		-	-
GHG validation and registration	project			$ -		-	-
Project financing	p-d	100.0	$ 1,500	$ 150,000		-	-
Legal and accounting	p-d	100.0	$ 1,200	$ 120,000		-	-
Project management	p-yr	1.25	$ 130,000	$ 162,500		-	-
Travel and accommodation	p-trip	18	$ 3,000	$ 54,000		-	-
				$ -		-	-
Sub-total:				**$ 770,500**	2.2%		
Engineering							
Wind turbine(s) micro-siting	p-d	175.0	$ 800	$ 140,000		-	-
Mechanical design	p-d	100.0	$ 800	$ 80,000		-	-
Electrical design	p-d	150.0	$ 800	$ 120,000		-	-
Civil design	p-d	90.0	$ 800	$ 72,000		-	-
Tenders and contracting	p-d	110.0	$ 800	$ 88,000		-	-
Construction supervision	p-yr	0.85	$ 130,000	$ 110,500		-	-
				$ -		-	-
Sub-total:				**$ 610,500**	1.8%		
Energy Equipment							
Wind turbine(s)	kW	20,000	$ 1,200	$ 24,000,000		-	-
Spare parts	%	1.0%	$ 24,000,000	$ 240,000		-	-
Transportation	turbine	20	$ 33,000	$ 660,000		-	-
				$ -		-	-
Sub-total:				**$ 24,900,000**	71.6%		
Balance of Plant							
Wind turbine(s) foundation(s)	turbine	20	$ 78,000	$ 1,560,000		-	-
Wind turbine(s) erection	turbine	20	$ 52,000	$ 1,040,000		-	-
Road construction	km	3.00	$ 50,000	$ 150,000		-	-
Transmission line	km	8.50	$ 70,000	$ 595,000		-	-
Substation	project	1	$ 2,055,000	$ 2,055,000		-	-
Control and O&M building(s)	building	1	$ 125,000	$ 125,000		-	-
Transportation	project	1	$ 68,000	$ 68,000		-	-
				$ -		-	-
Sub-total:				**$ 5,593,000**	16.1%		
Miscellaneous							
Training	p-d	40.0	$ 800	$ 32,000		-	-
Commissioning	p-d	50.0	$ 800	$ 40,000		-	-
Contingencies	%	5%	$ 32,141,200	$ 1,607,060		-	-
Interest during construction	6.0%	12 month(s)	$ 33,748,260	$ 1,012,448		-	-
Sub-total:				**$ 2,691,508**	7.7%		
Initial Costs - Total				**$ 34,760,708**	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	$ 57,000	$ 57,000		-	-
Property taxes	project	1	$ 23,000	$ 23,000		-	-
Insurance premium	project	1	$ 46,000	$ 46,000		-	-
Transmission line maintenance	%	3.0%	$ 2,650,000	$ 79,500		-	-
Parts and labour	kWh	25,556,461	$ 0.008	$ 204,452		-	-
GHG monitoring and verification	project			$ -		-	-
Community benefits	-	1	$ 15,000	$ 15,000		-	-
Travel and accommodation	p-trip	12	$ 3,000	$ 36,000		-	-
General and administrative	%	6%	$ 460,952	$ 27,657		-	-
				$ -		-	-
Contingencies	%	10%	$ 488,609	$ 48,861		-	-
Annual Costs - Total				**$ 537,470**	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Drive train	Cost	10 yr	$ 1,000,000	**$ 1,000,000**	-	-
Blades	Cost	15 yr	$ 1,000,000	**$ 1,000,000**	-	-
				$ -	-	-
End of project life	Credit	-		**$ -**		Go to GHG Analysis sheet

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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

Project name	Scenario #1	Project capacity	20.0 MW	**Global Warming Potential of GHG**	
Project location	Calgary, AB	Grid type	Central-grid	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 factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Coal	100.0%	94.6	0.0020	0.0030	35.0%	8.0%	1.069
Electricity mix	100%	293.8	0.0062	0.0093		8.0%	1.069

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 factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Electricity system							
Wind	100.0%	0.0	0.0000	0.0000	100.0%	8.0%	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 emission reduction (t_{CO2})
Electricity system	1.069	0.000	23,512	25,123	0.0%	**25,123**

Complete Financial Summary sheet

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RETScreen® Financial Summary - Wind Energy Project

Annual Energy Balance

Project name		Scenario #1			
Project location		Calgary, AB			
Renewable energy delivered	MWh	25,556	Net GHG reduction	t_{CO2}/yr	25,123
Excess RE available	MWh	-			
Firm RE capacity	kW	-			
Grid type		Central-grid	Net GHG emission reduction - 25 yrs	t_{CO2}	628,067

Financial Parameters

Avoided cost of energy	$/kWh	0.0450	Debt ratio	%	70.0%
RE production credit	$/kWh	-	Debt interest rate	%	8.5%
			Debt term	yr	10
GHG emission reduction credit	$/$t_{CO2}$	-	Income tax analysis?	yes/no	No
Energy cost escalation rate	%	3.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	25			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.6%	$	195,200	O&M	$	537,470
Development	2.2%	$	770,500			
Engineering	1.8%	$	610,500	Debt payments - 10 yrs	$	3,708,460
Energy equipment	71.6%	$	24,900,000	**Annual Costs and Debt - Total**	**$**	**4,245,929**
Balance of plant	16.1%	$	5,593,000			
Miscellaneous	7.7%	$	2,691,508	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**34,760,708**	Energy savings/income	$	1,150,041
				Capacity savings/income	$	-
Incentives/Grants		$	-			
				Annual Savings - Total	**$**	**1,150,041**
Periodic Costs (Credits)						
Drive train		$	1,000,000	Schedule yr # 10,20		
Blades		$	1,000,000	Schedule yr # 15		
		$	-			
End of project life - Credit		$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	-7.1%			
After-tax IRR and ROI	%	-7.1%	Calculate GHG reduction cost?	yes/no	No
Simple Payback	yr	56.7			
Year-to-positive cash flow	yr	more than 25	Project equity	$	10,428,212
Net Present Value - NPV	$	(27,163,120)	Project debt	$	24,332,495
Annual Life Cycle Savings	$	(2,765,375)	Debt payments	$/yr	3,708,460
Benefit-Cost (B-C) ratio	-	(1.60)	Debt service coverage	-	(0.11)

Yearly Cash Flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	(10,428,212)	(10,428,212)	(10,428,212)
1	(3,074,824)	(3,074,824)	(13,503,037)
2	(3,053,061)	(3,053,061)	(16,556,097)
3	(3,030,575)	(3,030,575)	(19,586,672)
4	(3,007,345)	(3,007,345)	(22,594,017)
5	(2,983,345)	(2,983,345)	(25,577,362)
6	(2,958,551)	(2,958,551)	(28,535,913)
7	(2,932,937)	(2,932,937)	(31,468,850)
8	(2,906,477)	(2,906,477)	(34,375,328)
9	(2,879,143)	(2,879,143)	(37,254,471)
10	(4,130,992)	(4,130,992)	(41,385,463)
11	886,719	886,719	(40,498,745)
12	916,846	916,846	(39,581,899)
13	947,966	947,966	(38,633,933)
14	980,109	980,109	(37,653,824)
15	(434,988)	(434,988)	(38,088,812)
16	1,047,601	1,047,601	(37,041,211)
17	1,083,018	1,083,018	(35,958,192)
18	1,119,598	1,119,598	(34,838,594)
19	1,157,377	1,157,377	(33,681,217)
20	(442,222)	(442,222)	(34,123,438)
21	1,236,690	1,236,690	(32,886,748)
22	1,278,305	1,278,305	(31,608,443)
23	1,321,280	1,321,280	(30,287,163)
24	1,365,661	1,365,661	(28,921,503)
25	1,411,491	1,411,491	(27,510,011)

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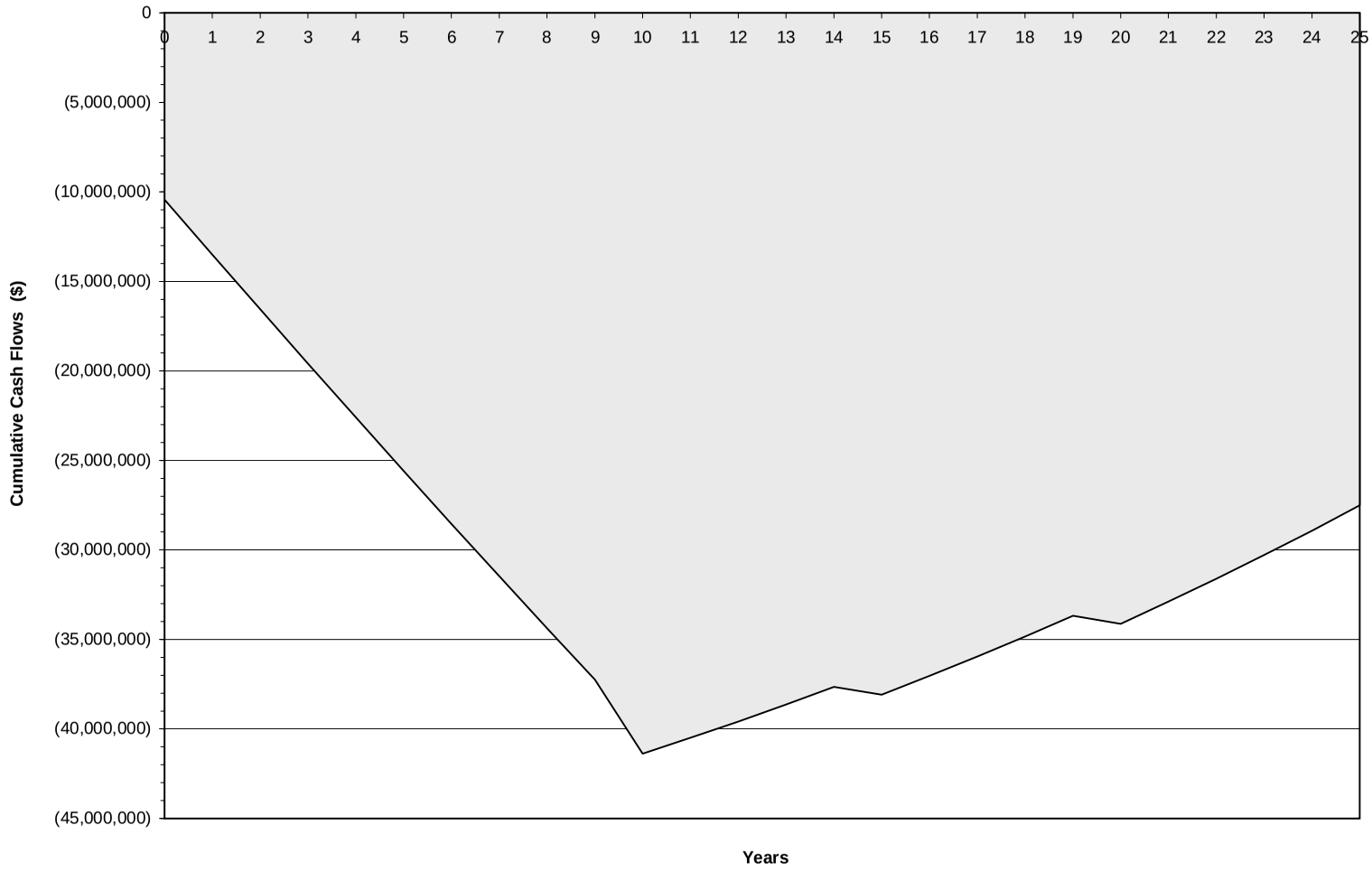
Cumulative Cash Flows Graph

Wind Energy Project Cumulative Cash Flows
Scenario #1, Calgary, AB

Renewable energy delivered (MWh/yr): 25,556 **Total Initial Costs: $ 34,760,708** **Net GHG emissions reduced (t_{CO2}/yr): 25,123**



Year-to-positive cash flow: more than 25 yr **Net Present Value: $ -27,163,120**

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Wind Energy Project Model

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RETScreen® Energy Model - Wind Energy Project

Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Scenario #2	See Online Manual
Project location		Pincher Creek, AB	
Wind data source		Wind speed	
Nearest location for weather data		Lethbridge A, AB	See Weather Database
Annual average wind speed	m/s	7.0	
Height of wind measurement	m	10.0	3.0 to 100.0 m
Wind shear exponent	-	0.15	0.10 to 0.40
Wind speed at 10 m	m/s	7.0	
Average atmospheric pressure	kPa	90.7	60.0 to 103.0 kPa
Annual average temperature	°C	6	-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	45.0	6.0 to 100.0 m
Wind speed at hub height	m/s	8.8	
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	3,855	77,097	
Pressure adjustment coefficient	-	0.90	0.90	0.59 to 1.02
Temperature adjustment coefficient	-	1.03	1.03	0.98 to 1.15
Gross energy production	MWh	3,573	71,469	
Losses coefficient	-	0.90	0.90	0.75 to 1.00
Specific yield	kWh/m²	1,404	1,404	150 to 1,500 kWh/m²
Wind plant capacity factor	%	37%	37%	20% to 40%
Renewable energy delivered	MWh	3,229	**64,583**	
	GJ	11,625	232,497	

Complete Cost Analysis sheet

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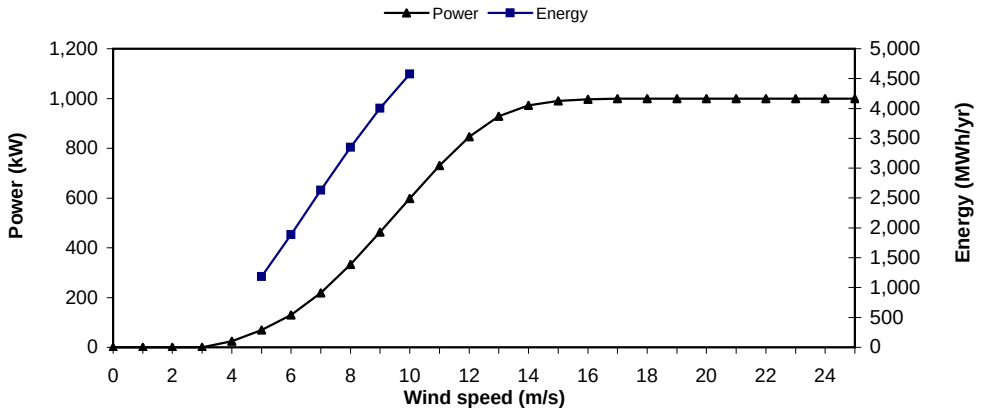
RETScreen® Equipment Data - Wind Energy Project

Wind Turbine Characteristics		Estimate	Notes/Range
Wind turbine rated power	kW	1,000	See Product Database
Hub height	m	45.0	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	-	User-defined	Site specific

Wind Turbine Production Data

Wind speed (m/s)	Power curve data (kW)	Energy curve data (MWh/yr)
0	0.0	-
1	0.0	-
2	0.0	-
3	0.0	-
4	24.1	-
5	69.3	1,182.0
6	130.0	1,889.0
7	219.1	2,632.0
8	333.5	3,351.0
9	463.1	4,004.0
10	598.1	4,575.0
11	730.0	-
12	846.5	-
13	928.8	-
14	972.6	-
15	990.8	-
16	997.2	-
17	999.2	-
18	999.8	-
19	999.9	-
20	1,000.0	-
21	1,000.0	-
22	1,000.0	-
23	1,000.0	-
24	1,000.0	-
25	1,000.0	-

Power and Energy Curves



Return to Energy Model sheet

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RETScreen® Cost Analysis - Wind Energy Project

Search Marketplace

Type of project: Custom | Currency: $ | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Site investigation	p-d	6.0	$ 800	$ 4,800		-	-
Wind resource assessment	met tower	6	$ 22,000	$ 132,000		-	-
Environmental assessment	p-d	8.0	$ 800	$ 6,400		-	-
Preliminary design	p-d	18.0	$ 800	$ 14,400		-	-
Detailed cost estimate	p-d	18.0	$ 800	$ 14,400		-	-
GHG baseline study and MP	project			$ -		-	-
Report preparation	p-d	8.0	$ 800	$ 6,400		-	-
Project management	p-d	6.0	$ 800	$ 4,800		-	-
Travel and accommodation	p-trip	4	$ 3,000	$ 12,000		-	-
				$ -		-	-
Sub-total:				**$ 195,200**	0.6%		
Development							
PPA negotiation	p-d	20.0	$ 1,200	$ 24,000		-	-
Permits and approvals	p-d	250.0	$ 800	$ 200,000		-	-
Land rights	project	1	$ 30,000	$ 30,000		-	-
Land survey	p-d	50.0	$ 600	$ 30,000		-	-
GHG validation and registration	project			$ -		-	-
Project financing	p-d	100.0	$ 1,500	$ 150,000		-	-
Legal and accounting	p-d	100.0	$ 1,200	$ 120,000		-	-
Project management	p-yr	1.25	$ 130,000	$ 162,500		-	-
Travel and accommodation	p-trip	18	$ 3,000	$ 54,000		-	-
				$ -		-	-
Sub-total:				**$ 770,500**	2.5%		
Engineering							
Wind turbine(s) micro-siting	p-d	175.0	$ 800	$ 140,000		-	-
Mechanical design	p-d	100.0	$ 800	$ 80,000		-	-
Electrical design	p-d	150.0	$ 800	$ 120,000		-	-
Civil design	p-d	90.0	$ 800	$ 72,000		-	-
Tenders and contracting	p-d	110.0	$ 800	$ 88,000		-	-
Construction supervision	p-yr	0.85	$ 130,000	$ 110,500		-	-
				$ -		-	-
Sub-total:				**$ 610,500**	2.0%		
Energy Equipment							
Wind turbine(s)	kW	20,000	$ 1,000	$ 20,000,000		-	-
Spare parts	%	1.0%	$ 20,000,000	$ 200,000		-	-
Transportation	turbine	20	$ 33,000	$ 660,000		-	-
				$ -		-	-
Sub-total:				**$ 20,860,000**	68.6%		
Balance of Plant							
Wind turbine(s) foundation(s)	turbine	20	$ 78,000	$ 1,560,000		-	-
Wind turbine(s) erection	turbine	20	$ 52,000	$ 1,040,000		-	-
Road construction	km	3.00	$ 50,000	$ 150,000		-	-
Transmission line	km	8.50	$ 70,000	$ 595,000		-	-
Substation	project	1	$ 2,055,000	$ 2,055,000		-	-
Control and O&M building(s)	building	1	$ 125,000	$ 125,000		-	-
Transportation	project	1	$ 68,000	$ 68,000		-	-
				$ -		-	-
Sub-total:				**$ 5,593,000**	18.4%		
Miscellaneous							
Training	p-d	40.0	$ 800	$ 32,000		-	-
Commissioning	p-d	50.0	$ 800	$ 40,000		-	-
Contingencies	%	5%	$ 28,101,200	$ 1,405,060		-	-
Interest during construction	6.0%	12 month(s)	$ 29,506,260	$ 885,188		-	-
Sub-total:				**$ 2,362,248**	7.8%		
Initial Costs - Total				**$ 30,391,448**	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	$ 57,000	$ 57,000		-	-
Property taxes	project	1	$ 23,000	$ 23,000		-	-
Insurance premium	project	1	$ 46,000	$ 46,000		-	-
Transmission line maintenance	%	3.0%	$ 2,650,000	$ 79,500		-	-
Parts and labour	kWh	64,582,523	$ 0.008	$ 516,660		-	-
GHG monitoring and verification	project			$ -		-	-
Community benefits	-	1	$ 15,000	$ 15,000		-	-
Travel and accommodation	p-trip	12	$ 3,000	$ 36,000		-	-
General and administrative	%	6%	$ 773,160	$ 46,390		-	-
				$ -		-	-
Contingencies	%	10%	$ 819,550	$ 81,955		-	-
Annual Costs - Total				**$ 901,505**	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Drive train	Cost	10 yr	$ 1,000,000	**$ 1,000,000**	-	-
Blades	Cost	15 yr	$ 1,000,000	**$ 1,000,000**	-	-
				$ -	-	-
End of project life	Credit	-		**$ -**		

Go to GHG Analysis sheet

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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

Project name	Scenario #2	Project capacity	20.0 MW	**Global Warming Potential of GHG**		
Project location	Pincher Creek, AB	Grid type	Central-grid	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 factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Coal	100.0%	94.6	0.0020	0.0030	35.0%	8.0%	1.069
Electricity mix	100%	293.8	0.0062	0.0093		8.0%	1.069

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 factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Electricity system							
Wind	100.0%	0.0	0.0000	0.0000	100.0%	8.0%	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 emission reduction (t_{CO2})
Electricity system	1.069	0.000	59,416	63,486	0.0%	**63,486**

Complete Financial Summary sheet

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RETScreen® Financial Summary - Wind Energy Project

Annual Energy Balance

Project name		Scenario #2			
Project location		Pincher Creek, AB			
Renewable energy delivered	MWh	64,583	Net GHG reduction	t_{CO2}/yr	63,486
Excess RE available	MWh	-			
Firm RE capacity	kW	-			
Grid type		Central-grid	Net GHG emission reduction - 25 yrs	t_{CO2}	1,587,158

Financial Parameters

Avoided cost of energy	$/kWh	0.0450	Debt ratio	%	70.0%
RE production credit	$/kWh	0.025	Debt interest rate	%	8.5%
RE production credit duration	yr	25	Debt term	yr	15
RE credit escalation rate	%	2.5%			
GHG emission reduction credit	$/$t_{CO2}$	5.0	Income tax analysis?	yes/no	No
GHG reduction credit duration	yr	25			
GHG credit escalation rate	%	2.5%			
Energy cost escalation rate	%	3.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	25			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.6%	$	195,200	O&M	$	901,505
Development	2.5%	$	770,500			
Engineering	2.0%	$	610,500	Debt payments - 15 yrs	$	2,561,827
Energy equipment	68.6%	$	20,860,000	**Annual Costs and Debt - Total**	**$**	**3,463,331**
Balance of plant	18.4%	$	5,593,000			
Miscellaneous	7.8%	$	2,362,248	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**30,391,448**	Energy savings/income	$	2,906,214
				Capacity savings/income	$	-
Incentives/Grants		$	-	RE production credit income - 25 yrs	$	1,614,563
				GHG reduction income - 25 yrs	$	317,432
				Annual Savings - Total	**$**	**4,838,208**
Periodic Costs (Credits)						
Drive train		$	1,000,000	Schedule yr # 10,20		
Blades		$	1,000,000	Schedule yr # 15		
		$	-			
End of project life - Credit		$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	22.8%			
After-tax IRR and ROI	%	22.8%	Calculate GHG reduction cost?	yes/no	No
Simple Payback	yr	7.7			
Year-to-positive cash flow	yr	5.2	Project equity	$	9,117,434
Net Present Value - NPV	$	19,534,240	Project debt	$	21,274,013
Annual Life Cycle Savings	$	1,988,708	Debt payments	$/yr	2,561,827
Benefit-Cost (B-C) ratio	-	3.14	Debt service coverage	-	1.58

Yearly Cash Flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	(9,117,434)	(9,117,434)	(9,117,434)
1	1,487,826	1,487,826	(7,629,609)
2	1,604,034	1,604,034	(6,025,575)
3	1,723,596	1,723,596	(4,301,979)
4	1,846,610	1,846,610	(2,455,368)
5	1,973,176	1,973,176	(482,192)
6	2,103,397	2,103,397	1,621,205
7	2,237,378	2,237,378	3,858,583
8	2,375,230	2,375,230	6,233,813
9	2,517,064	2,517,064	8,750,876
10	1,382,911	1,382,911	10,133,787
11	2,813,145	2,813,145	12,946,932
12	2,967,633	2,967,633	15,914,565
13	3,126,588	3,126,588	19,041,153
14	3,290,137	3,290,137	22,331,291
15	2,010,118	2,010,118	24,341,408
16	6,193,388	6,193,388	30,534,796
17	6,371,540	6,371,540	36,906,336
18	6,554,847	6,554,847	43,461,183
19	6,743,456	6,743,456	50,204,639
20	5,298,906	5,298,906	55,503,545
21	7,137,205	7,137,205	62,640,750
22	7,342,668	7,342,668	69,983,418
23	7,554,077	7,554,077	77,537,495
24	7,771,608	7,771,608	85,309,103
25	7,995,436	7,995,436	93,304,539

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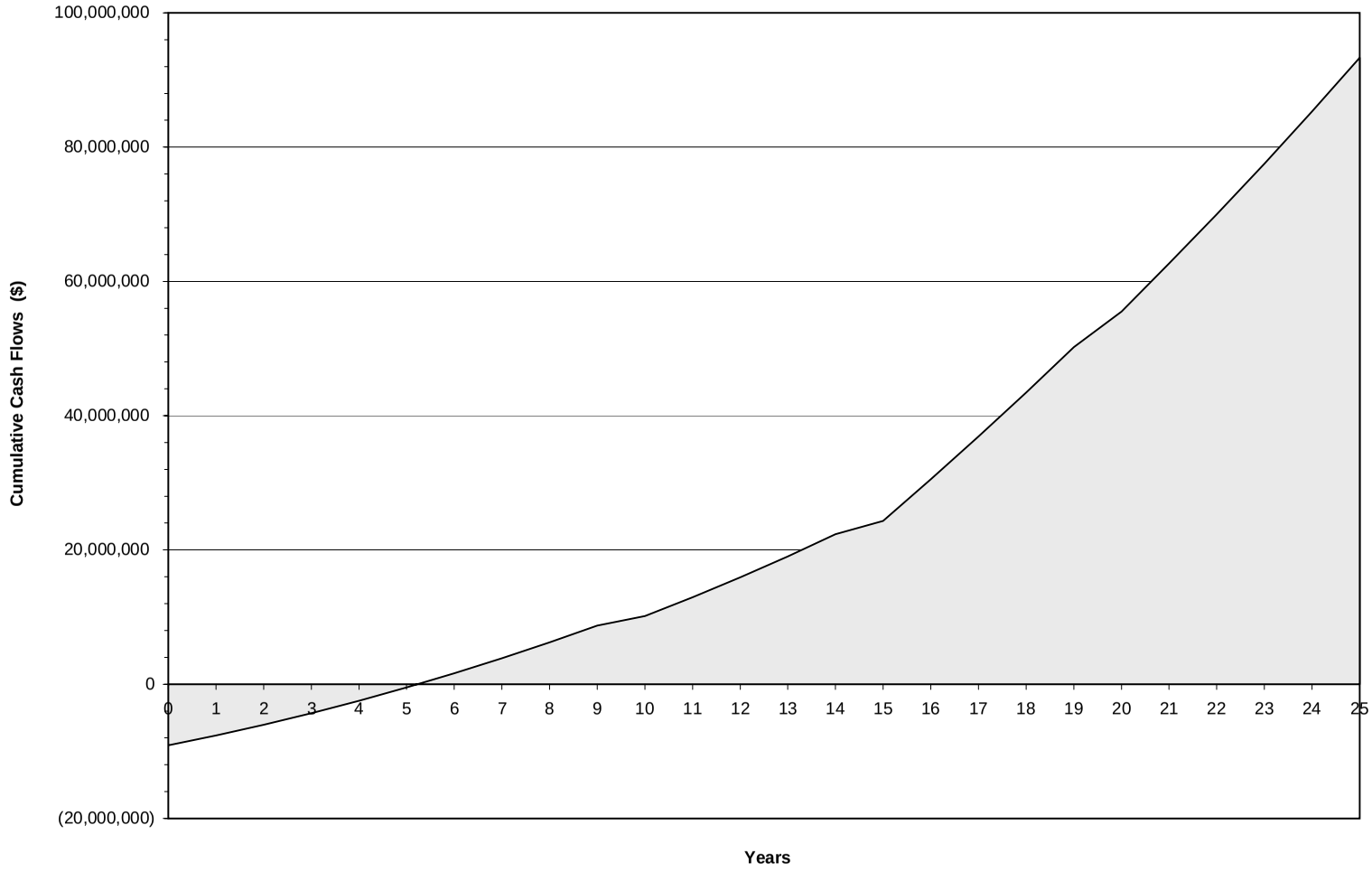
Cumulative Cash Flows Graph

Wind Energy Project Cumulative Cash Flows
Scenario #2, Pincher Creek, AB

Renewable energy delivered (MWh/yr): 64,583 **Total Initial Costs: $ 30,391,448** **Net GHG emissions reduced (t_{CO2}/yr): 63,486**



IRR and ROI: 22.8% **Year-to-positive cash flow: 5.2 yr** **Net Present Value: $ 19,534,240**

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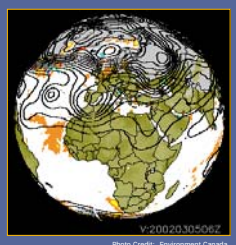
Greenhouse Gas Emission Analysis with RETScreen® Software

RETScreen® International — www.retscreen.net

Clean Energy Project Analysis Course



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Natural Resources Canada — Ressources naturelles Canada

Canada

Objectives

RETScreen® International — www.retscreen.net

- Introduce a methodology for calculating reductions in greenhouse gas (GHG) emissions
- Demonstrate the RETScreen® GHG Emission Reduction Analysis Model

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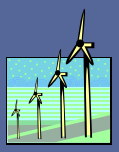
What needs to be calculated?

RETScreen® International — www.retscreen.net

- 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



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How is this calculated?

RETScreen® International www.retscreen.net

Annual GHG emission reduction (t_{CO_2}) =

(Base case GHG emission factor (t_{CO_2}/MWh) - Proposed case GHG emission factor (t_{CO_2}/MWh)) x End-use annual energy delivered (MWh)

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

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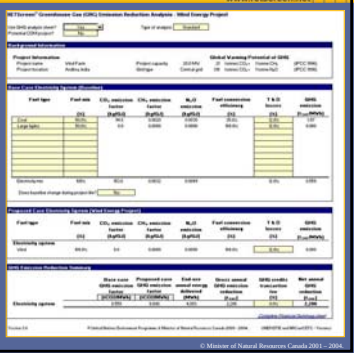
RETScreen® GHG Emission Reduction Analysis Model

RETScreen® International www.retscreen.net

- 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



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Type of Analysis

RETScreen® International www.retscreen.net

- 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

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Defining Baseline

RETScreen® International www.retscreen.net

- 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

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RETScreen® Facilitates Kyoto Protocol CDM and JI Projects

RETScreen® International www.retscreen.net

- 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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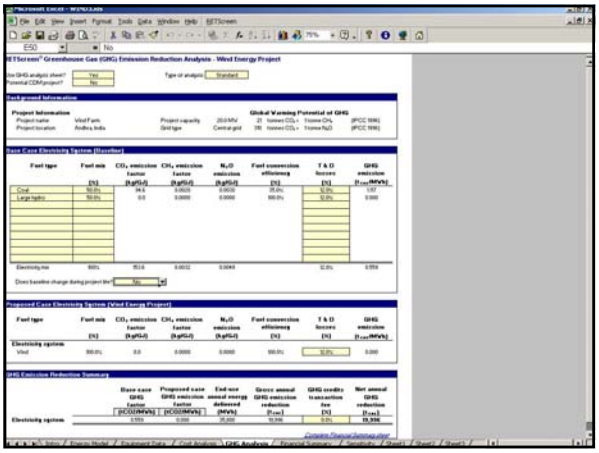

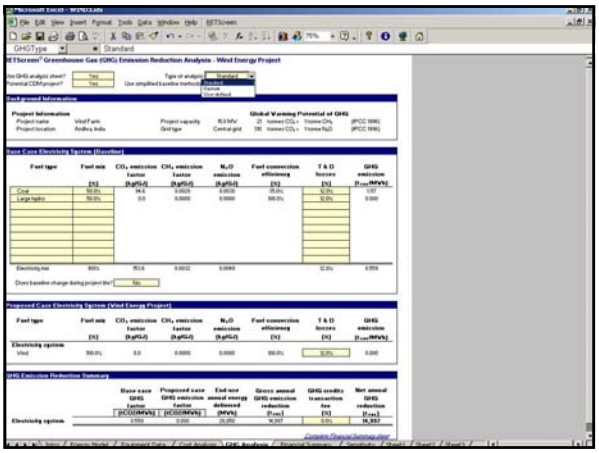

Conclusions

RETSCREEN® INTERNATIONAL www.retscreen.net

- 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

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Questions?

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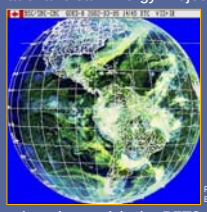
Greenhouse Gas Emission Analysis with RETScreen® Software Module
RETScreen® International Clean Energy Project Analysis Course



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

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Financial and Risk Analysis with RETScreen® Software

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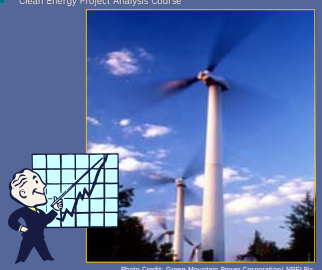
Clean Energy Project Analysis Course



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Natural Resources Canada / Ressources naturelles Canada — Canada

Objectives

RETScreen® International — www.retscreen.net

- 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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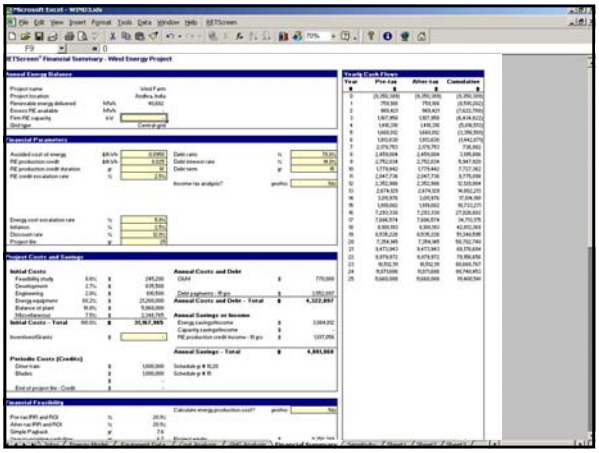
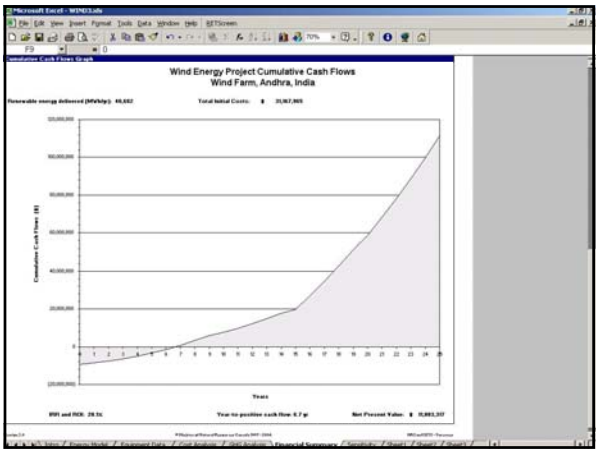
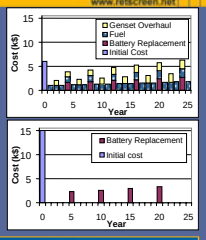




Initial Cost versus Ongoing Costs:
Remote Telecommunications Example

RETScreen® International www.retscreen.net

- 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%

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Determining Financial Viability:
Remote Telecommunications Example

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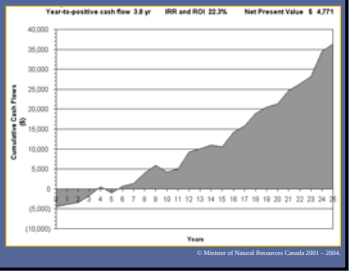
- How can we compare the genset & the PV system?
  - Genset: lower initial costs
  - Photovoltaics: lower annual and periodic costs
- RETScreen® calculates indicators that look at revenues and expenses over the life of the project!



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Cashflow Calculations: What does RETScreen® do?

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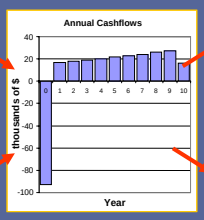
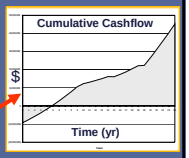
Cash Inflows
Fuel Savings
O&M Savings
Periodic Savings
Incentives
Production Credits
GHG Credits

Cash Outflows
Equity Investment
Annual Debt Payments
O&M Payments
Periodic Costs





Indicators
Net Present Value
Simple Payback
IRR
Debt Service Coverage
Etc.

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Financial (Input) Parameters Used by RETScreen®

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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)

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Key (Output) Indicators of Financial Viability

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	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

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Comparison of Indicators:
Remote Telecommunications Example

RETSCREEN® INTERNATIONAL www.retscreen.net

	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

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Indicators of Financial Viability:
Remote Telecommunications Example

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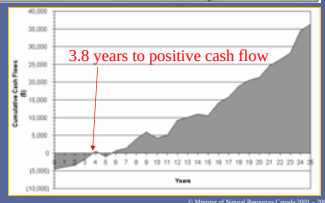
Financial Feasibility

			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	-	2.09

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



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Dealing with Uncertainty:
Sensitivity and Risk Analysis

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- 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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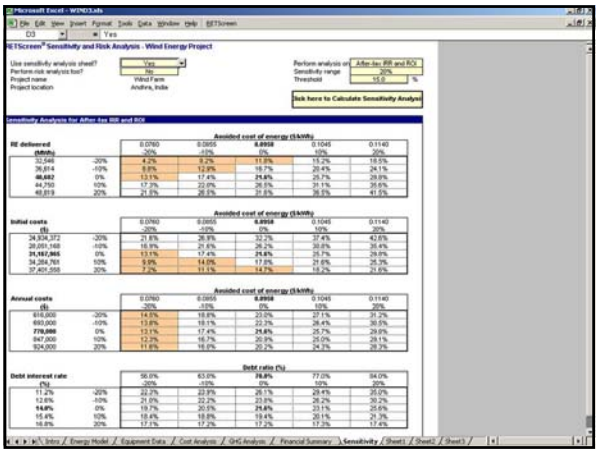

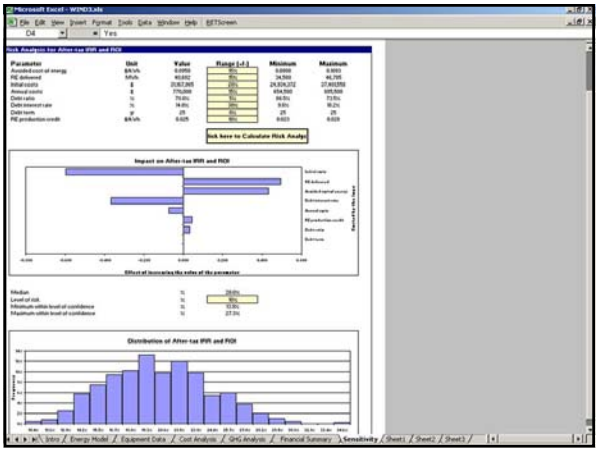

Sensitivity Analysis

RETSCREEN® INTERNATIONAL www.retscreen.net

- 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%	11.6%	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

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Sensitivity Analysis: Parameters

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- RETScreen® calculates sensitivity of...
  - Internal rate of return (IRR/ROI)
  - Year-to-positive cash flow
  - Net Present Value (NPV)

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

Click here to Calculate Sensitivity Analysis

- ...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

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Risk Analysis

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- User is uncertain of many parameters:

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Avoided cost of energy	$/kWh	0.0960	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?

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Risk Analysis: Monte Carlo Simulation

RETSCREEN® INTERNATIONAL www.retscreen.net

- 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%

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Risk Analysis: Level of Risk

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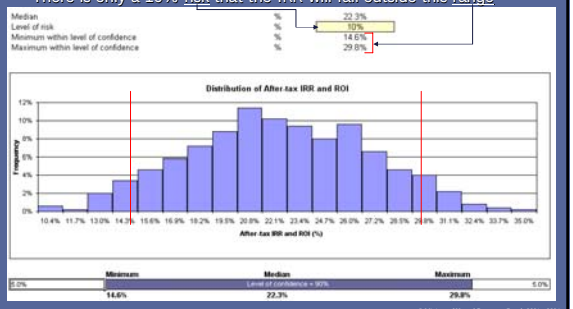
- There is only a 10% risk that the IRR will fall outside this range



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Risk Analysis: Influence of Parameters

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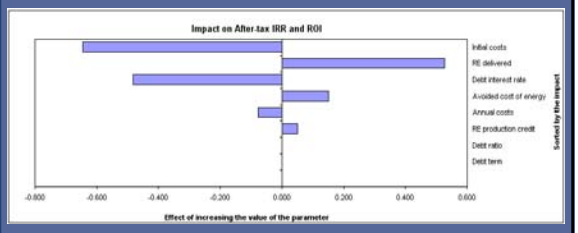
- "Tornado chart" reveals:
  - Which parameters have the most influence
  - How changes in parameters affect after-tax IRR, NPV, or year-to-positive cash flow



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Conclusions

RETSCREEN® INTERNATIONAL www.retscreen.net

- 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

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Questions?

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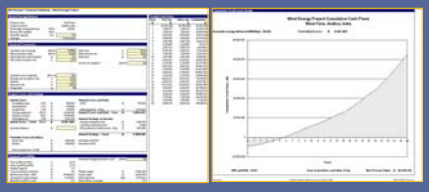
Financial and Risk Analysis with RETScreen® Software Module
RETScreen® International Clean Energy Project Analysis Course



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Summary of Introductory Module

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Photo : Nordex Gmbh

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Conclusions

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- 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

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Growth of RETScreen Software User Base

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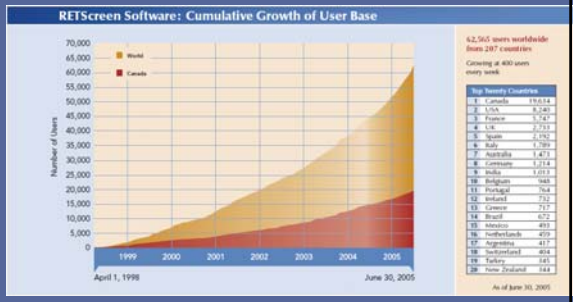

A Decision Support & Capacity Building Tool

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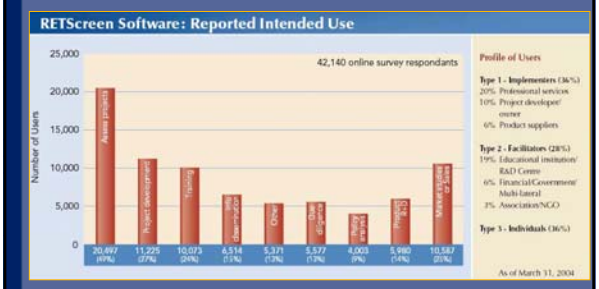

Common Platform for Project Evaluation & Development

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Questions?

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

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WIND ENERGY PROJECT ANALYSIS MODULE

Wind Energy Project Analysis

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Clean Energy Project Analysis Course

Utility-Scale Turbine

Photo Credit: Nordex AG

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Objectives

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- Review basics of Wind Energy systems
- Illustrate key considerations for Wind Energy project analysis
- Introduce RETScreen© Wind Energy Project Model

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What do wind energy systems provide?

RETScreen® International www.retscreen.net

- Electricity for
  - Central-grids
  - Isolated-grids
  - Remote power supplies
  - Water pumping

...but also...

  - Support for weak grids
  - Reduced exposure to energy price volatility
  - Reduced transmission and distribution losses

San Gorgino Windfarm, Palm Springs, California, USA

Photo Credit: Warren Gretz/ NREL Pix

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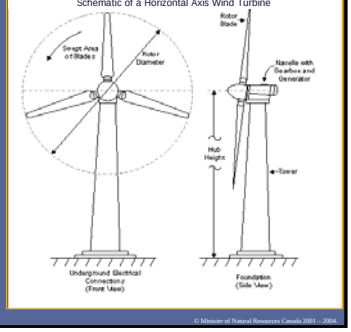
Wind Turbine Description

RETScreen® International www.retscreen.net

- Components
  - Rotor
  - Gearbox
  - Tower
  - Foundation
  - Controls
  - Generator
- Types
  - Horizontal axis
    - Most common
    - Controls or design turn rotor into wind
  - Vertical axis
    - Less common

Schematic of a Horizontal Axis Wind Turbine



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Utilisation of Wind Energy

RETScreen® International www.retscreen.net

- Off-Grid
  - Small turbines (50 W to 10 kW)
  - Battery charging
  - Water pumping
- Isolated-Grid
  - Turbines typically 10 to 200 kW
  - Reduce generation costs in remote areas: wind-diesel hybrid system
  - High or low penetration
- Central-Grid
  - Turbines typically 200 kW to 2 MW
  - Windfarms of multiple turbines

Off-Grid, 10-kW Turbine, Mexico

Photo Credit: Charles Newcomber/ NREL Pix

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Elements of Wind Energy Projects

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- Wind resource assessment
- Environmental assessment
- Regulatory approval
- Design
- Construction
  - Roads
  - Transmission line
  - Substations

Installing a 40-m Meteorological Mast, Quebec, Canada

Photo Credit: GPCo Inc.

Substation, California, USA

Photo Credit: Warren Gretz/NREL Pix

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Wind Resource

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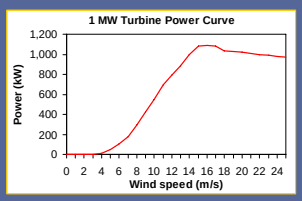
- High average wind speeds are essential
  - 4 m/s annual average is minimum
  - People tend to overestimate the wind
  - Wind speed tends to increase with height
- Good resource
  - Coastal areas
  - Crests of long slopes
  - Passes
  - Open terrain
  - Valleys that channel winds
- Typically windier in
  - Winter than summer
  - Day than night



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Wind Energy System Costs

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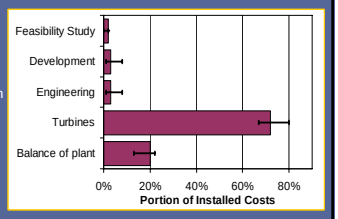
- Windfarms
  - $1,500/kW installed
  - O&M: $0.01/kWh
  - Selling price: $0.04-$0.10/kWh
- Single turbines & isolated-grid
  - Higher costs (more project specific)
  - Feasibility study, development & engineering represent a higher portion of costs
- Expect one major component replacement of 20 to 25% of initial costs
  - Rotor blades or gearbox



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Wind Energy Project Considerations

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- Good wind resource dramatically reduces cost of production
  - Good resource assessment is a worthwhile investment
- Additional sources of revenue
  - Government/utility production credits or Greenpower rates
  - Sales of emissions reduction credits (ERC's)
- Constraints and criteria
  - Environmental acceptability
  - Acceptance of local population
  - Grid interconnection and transmission capacity
- Financing, interest rates, currency exchange rates

Turbine of the Le Nordais Windfarm, Quebec, Canada

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Examples: Europe and USA

Central-Grid Wind Energy Systems

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- Intermittent generation not a problem: 17% of Denmark's electricity is from wind with no additional reserve generation
- Quick projects (2 to 4 years) that can grow to meet demand

Coastal Windfarm, Denmark

Photo Credit: Danmarks Tekniske Universitet

Windfarm in Palm Springs, California, USA

Photo Credit: Warren Gretz/ NREL Pix

- Land can be used for other purposes, such as agriculture
- Individuals, businesses, and co-operatives sometimes own and operate single turbines

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Examples: India and Canada

Isolated-Grid Wind Energy Systems

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- Electricity generation expensive due to cost of transporting diesel fuel to remote areas
  - Wind turbines reduce consumption of diesel fuel
- Reliability & maintenance are important

Installation of a 50-kW Turbine, West Bengal, India

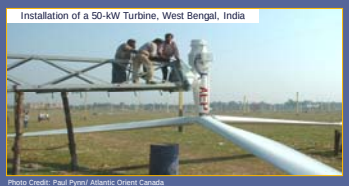

Photo Credit: Paul Pynn/ Atlantic Orient Canada

50-kW Turbine, Nunavut, Canada

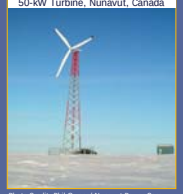

Photo Credit: Phil Owens/ Nunavut Power Corp.

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Examples: USA, Brazil and Chile

Off-Grid Wind Energy Systems

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- Electricity for small loads in windy off-grid areas
- Batteries in stand-alone systems provide electricity during calm periods
- Water pumping: water reservoir is storage
- Can be used in combination with fossil fuel gensets and/or photovoltaic arrays in a "hybrid" system

Power for a Telecommunications Tower, Arizona, USA

Photo Credit: Southwest Windpower/ NREL Pix

Power for a Remote Village, Brazil

Photo Credit: Roger Taylor/ NREL Pix

Hybrid Wind Energy System, Chile

Photo Credit: Arturo Kunstmann/ NREL Pix

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RETScreen® Wind Energy Project Model

RETSCREEN® INTERNATIONAL www.retscreen.net

- World-wide analysis of energy production, life-cycle costs and greenhouse gas emissions reductions
  - Central-grid, isolated-grid and off-grid
  - Single turbines or windfarms
  - Rayleigh, Weibull, or user-defined wind distributions
- Only 1 point of data for RETScreen® vs. 8,760 for hourly simulation models
- Currently not covered:
  - Stand-alone systems requiring storage

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RETScreen® Wind Energy Calculation

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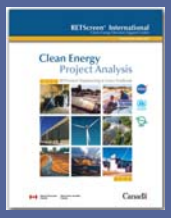
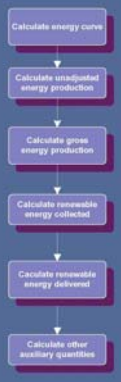


See e-Textbook

Clean Energy Project Analysis: RETScreen® Engineering and Cases

Wind Energy Project Analysis Chapter



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Example Validation of the RETScreen® Wind Energy Project Model

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- RETScreen® compared to HOMER hourly simulation
  - 10 turbines of 50 kW each installed in Kotzebue, Alaska
  - RETScreen's estimate of annual energy production is within **1.1%** of HOMER
- RETScreen® compared to monitored data from same system:

Period	RETScreen Energy (MWh)	Monitored Energy (MWh)	Difference
1998 (3 turbines)	250	271	-8%
1999-2000	1,057	1,170	-10%

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Conclusions

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- Wind turbines provide electricity on and off grid world-wide
- A good wind resource is an important factor for successful projects
- Availability of production credits or Greenpower rates are important for on-grid projects
- RETScreen® calculates energy production using annual data with an accuracy comparable to hourly simulations
- RETScreen® can provide significant preliminary feasibility study cost savings

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Questions?

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Wind Energy Project Analysis Module
RETScreen® International Clean Energy Project Analysis Course

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SMALL HYDRO PROJECT ANALYSIS MODULE

Small Hydro Project Analysis

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Run-of-River Small Hydro Project, Canada

Photo Credit: SNC-Lavalin

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Objectives

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- Review basics of Small Hydro systems
- Illustrate key considerations for Small Hydro project analysis
- Introduce RETScreen® Small Hydro Project Model

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What do small hydro systems provide?

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- Electricity for
  - Central-grids
  - Isolated-grids
  - Remote power supplies

...but also...

- Reliability
- Very low operating costs
- Reduced exposure to energy price volatility

Photo Credit: Robin Hughes/ PNS

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Small Hydro System Description

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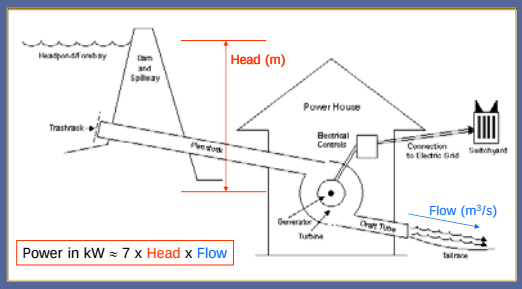

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"Small" Hydro Projects

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- "Small" is not universally defined
  - Size of project related not just to electrical capacity but also to whether low or high head

	Typical Power	RETScreen® Flow	RETScreen® Runner Diameter
Micro	< 100 kW	< 0.4 m^3/s	< 0.3 m
Mini	100 to 1,000 kW	0.4 to 12.8 m^3/s	0.3 to 0.8 m
Small	1 to 50 MW	> 12.8 m^3/s	> 0.8 m

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Types of Small Hydro Projects

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- Type of grid
  - Central-grid
  - Isolated-grid or off-grid
- Type of civil works
  - Run-of-river
    - No water storage
    - Power varies with flow available from river: lower firm capacity
  - Reservoir
    - Higher firm capacity year-round
    - Significant damming usually required

17.6-MW Run-of-River Hydro Project, Massachusetts, USA

Photo Credit: PG&E National Energy Group/ Low Impact Hydropower Institute

4.3-MW Run-of-River Hydro Project, Oregon, USA

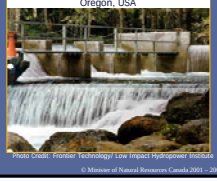

Photo Credit: Frontier Technology/ Low Impact Hydropower Institute

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Components: Civil Works

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- Typically account for 60% of plant initial costs
- Diversion dam or weir
  - Low dam of simple construction for run-of-river
  - Concrete, wood, masonry
  - Cost of dam alone can render project unviable
- Water passage
  - Intake with trashrack and gate; tailrace at exit
  - Excavated canal, underground tunnel and/or penstock
  - Valves/gates at turbine entrance/exit, for maintenance
- Power house
  - Houses turbine, mechanical, and electrical equipment

Photo Credit: Ottawa Engineering

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Components: Turbine

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- Scaled-down versions of large-hydro turbines
- Efficiency of 90% possible
- In run-of-river, flow rate is quite variable
  - Turbine should function well over a range of flow rates or multiple turbines should be used
- Reaction: Francis, fixed pitch propeller, Kaplan
  - For low to medium head applications
  - Submerged turbine uses water pressure and kinetic energy
- Impulse: Pelton, Turgo, crossflow
  - For high head applications
  - Uses kinetic energy of a high speed jet of water

Pelton Turbine

Photo Credit: PO Sjöman Hydrotech Consulting

Francis Turbine

Photo Credit: PO Sjöman Hydrotech Consulting

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Components: Electrical and Other Equipment

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- Generator
  - Induction
    - Must be tied to other generators
    - Use to feed electricity onto large grid
  - Synchronous
    - Can function in isolation from other generators
    - For stand-alone and isolated-grid applications
- Other equipment
  - Speed increaser to match turbine to generator
  - Valves, electronic controls, protection devices
  - Transformer

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World Hydro Resource

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- More rain falls on continents than evaporates from them
- For equilibrium, rain must flow to the oceans in rivers

	Technical Potential (TWh/year)	% Developed
Africa	1,150	3
South Asia and Middle East	2,280	8
China	1,920	6
Former Soviet Union	3,830	6
North America	970	55
South America	3,190	11
Central America	350	9
Europe	1,070	45
Australasia	200	19

Source: *Renewable Energy: Sources for Fuels and Electricity*, 1993, Island Press.

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Site Hydro Resource

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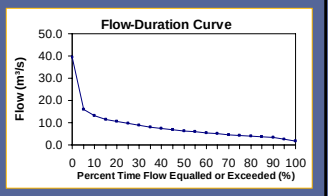
- Very site specific: an exploitable river is needed!
  - Change in elevation over a relatively short distance (head)
  - Acceptable variation in flow rate over time: flow duration curve
    - Residual flow reduces flow available for power
- Estimate flow duration curve based on
  - Measurements of flow over time
  - Size of drainage above site, specific run-off, and shape of flow duration curve



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Small Hydro System Costs

RETScreen® International www.retscreen.net

- 75% of costs are site specific
- High initial costs
  - But civil works and equipment can last >50 years

Photo Credit: Ottawa Engineering

- Very low operating and maintenance costs
  - One part-time operator is usually sufficient
  - Periodic maintenance of major equipment requires outside contractor
- High head developments tend to be less costly
- Typical range: $1,200 to $6,000 per installed kW

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Small Hydro Project Considerations

RETScreen® International www.retscreen.net

- Keep costs down with simple design and practical, easily-constructed civil structures
- Existing dams and civil structures can be used
- Development time of 2 to 5 years
  - Resource and environmental studies: approvals
- Four phases for engineering work:
  - Reconnaissance surveys/hydraulic studies
  - Pre-feasibility study
  - Feasibility study
  - System planning and project engineering

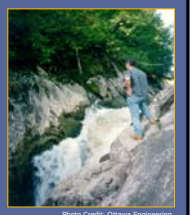

Photo Credit: Ottawa Engineering

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Small Hydro Environmental Considerations

RETScreen® International www.retscreen.net

- Small hydro development can change
  - Fish habitat
  - Site aesthetics
  - Recreational/navigational uses
- Impacts and environmental assessment requirements depend on site & type of project:
  - Run-of-river at existing dam: relatively minor
  - Run-of-river at undeveloped site: dam/weir/diversion construction
  - Water storage developments: larger impacts that increase with scale of project

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Examples: Slovakia, Canada and USA

Central-Grid Small Hydro Systems

RETScreen® International www.retscreen.net

- Run-of-river projects will feed grid when flow available
- Utility-owned or independent power producer with long-term PPA

Small Hydro Development, Southeastern, USA

Photo Credit: CHI Energy

2.3-MW, 2 Turbine, Jasenie, Slovakia

Photo Credit: Emil Bedi (Foundation for Alternative Energy)/ Inforse

Small Hydro Development, Newfoundland, Canada

Photo Credit: CHI Energy

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Examples: USA and China

Isolated-Grid Small Hydro Systems

RETScreen® International www.retscreen.net

- Remote communities
- Remote residences & industry

Small Hydro Generators, China

Photo Credit: International Network on Small Hydro Power

King Cove 800 kW Small Hydro System, Town of 700 People

Photo Credit: Duane Hippe/ NREL Pix

- Higher price paid for electricity
- Run-of-river projects typically need supplemental capacity and may have flow in excess of demand

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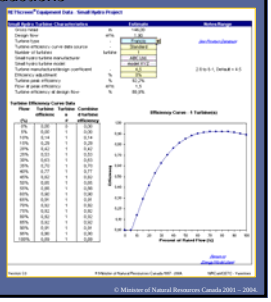
RETScreen® Small Hydro Project Model

RETScreen® International www.retscreen.net

- World-wide analysis of energy production, life-cycle costs and greenhouse gas emissions reductions
  - Central-grid, isolated-grid and off-grid
  - Single turbine micro hydro to multi-turbine small hydro
  - "Formula" costing method
- Currently not covered:
  - Seasonal variations in isolated-grid load
  - Variations in head in storage projects (user must supply average value)



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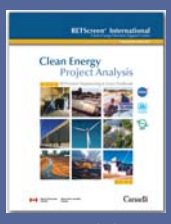
RETScreen® Small Hydro Energy Calculation

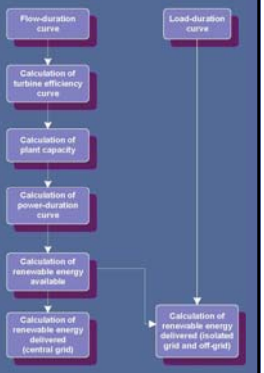
RETScreen® International



See e-Textbook

Clean Energy Project Analysis: RETScreen® Engineering and Cases

Small Hydro Project Analysis Chapter



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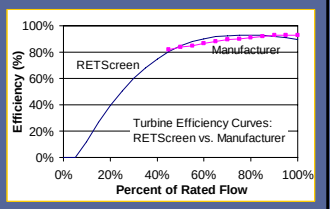
Example Validation of the RETScreen® Small Hydro Project Model

RETScreen® International www.retscreen.net

- Turbine efficiency
  - Compared with manufacturer's data for an installed 7 MW GEC Alsthom Francis turbine
- Plant capacity & output
  - Compared with HydrA for a Scottish site
  - All results within 6.5%
- Formula costing method
  - Compared with RETScreen®, within 11% of a detailed cost estimate for a 6 MW project in Newfoundland



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Conclusions

RETScreen® International www.retscreen.net

- Small hydro projects (up to 50 MW) can provide electricity for central or isolated-grids and for remote power supplies
- Run-of-river projects:
  - Lower cost & lower environmental impacts
  - But need back-up power on isolated grid
- Initial costs high and 75% site specific
- RETScreen® estimates capacity, firm capacity, output and costs based on site characteristics such as flow-duration curve and head
- RETScreen® can provide significant preliminary feasibility study cost savings

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Questions?

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Small Hydro Project Analysis Module
RETScreen® International Clean Energy Project Analysis Course

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PHOTOVOLTAIC PROJECT ANALYSIS MODULE

Photovoltaic Project Analysis

RETScreen® International www.retscreen.net

Clean Energy Project Analysis Course

Photovoltaics on National Research Laboratory, Quebec, Canada

Photo Credit: CANMET Energy Technology Centre -Varennes

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Canada

Objectives

RETScreen® International www.retscreen.net

- Review basics of Photovoltaic (PV) systems
- Illustrate key considerations for PV project analysis
- Introduce RETScreen® PV Project Model

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What do PV systems provide?

RETScreen® International www.retscreen.net

- Electricity (AC/DC)
- Pumped Water

...but also...

- Reliability
- Simplicity
- Modularity
- Image
- Silence

Solar Home Lighting System, West Bengal, India

Photos Credit: Harin Ullal (NREL PIX)

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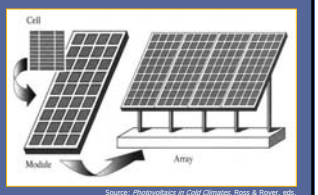
Components of PV Systems

RETScreen® International www.retscreen.net

- Modules
- Storage: batteries, tank
- Power conditioner
  - Inverter
  - Charge controller
  - Rectifier
  - DC-DC converter
- Other generators: diesel/gasoline, wind turbine
- Pump



Source: *Photovoltaics in Cold Climates*, Ross & Royer, eds.

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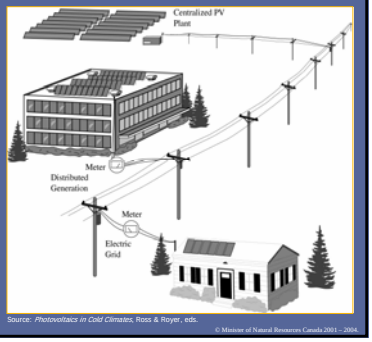
On-Grid Systems

RETScreen® International www.retscreen.net

- PV Integration
  - Distributed
  - Centralised
- Grid-Type
  - Central
  - Isolated
- Not usually cost-effective without subsidies



Source: *Photovoltaics in Cold Climates*, Ross & Royer, eds.

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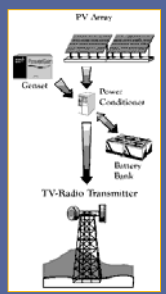
Off-Grid Systems

RETScreen® International www.retscreen.net

- Configuration
  - Stand-alone
  - Hybrid
- Often very cost-effective
  - Small loads best (< 10 kW_p)
  - Lower capital costs than grid extension
  - Lower O&M costs than gensets and primary batteries



Source: *Photovoltaics in Cold Climates*, Ross & Royer, eds.

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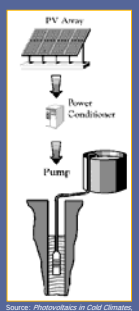
Water Pumping Systems

RETScreen® International www.retscreen.net

- Special class of off-grid system
- Often cost-effective
  - Livestock watering
  - Village water supply
  - Domestic water supply



Source: *Photovoltaics in Cold Climates*, Ross & Royer, eds.

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Solar Resource

RETScreen® International www.retscreen.net

- 1 W_p of PV= 800 to 2,000 Wh per year
  - Latitude
  - Cloudiness
- Winter solar resource critical for off-grid systems
  - Higher tilt angles (latitude +15°)
  - Hybrid systems
- Annual solar resource critical for on-grid systems
  - Trackers when high proportion of beam radiation

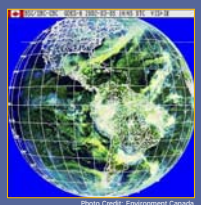

Photo Credit: Environment Canada

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Solar-Load Correlation

RETScreen® International www.retscreen.net

- Seasonal correlation
  - Irrigation
  - Cottage systems
- Diurnal correlation
  - Positive, zero & negative

Photo Credit: Sandia Nat. Lab. (NREL PIX)

Source: *Photovoltaics in Cold Climates*, Ross & Royer, eds.

Photo Credit: BP Solarex (NREL PIX)

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Examples of PV System Costs

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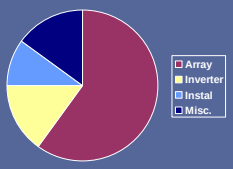
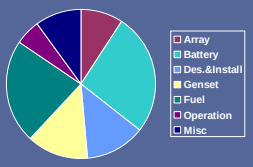
- On-grid house, 1 kW (38°N, California)
- Off-grid telecom hybrid, 2.5 kW (50°S, Argentina)





- Energy = 1.6 MWh/year
- Cost = $0.35/kWh
- Grid Cost = $0.08/kWh

- Energy = 5MWh/year, (PV=50%)
- Cost = $2.70/kWh
- Genset/Battery Cost = $4.00/kWh

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Photovoltaic Project Considerations

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- Distance to grid
- Cost of site visits
- O&M costs
- Reliability vs. cost
- Managing expectations
- Social aspects
- Value of intangibles
  - Image
  - Environmental benefits
  - Reduced noise and visual pollution
  - Modularity & simplicity

NorthwesTel Mountaintop Repeater Station, Northern British Columbia, Canada

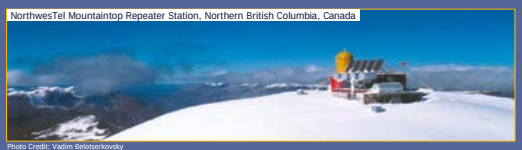

Photo Credit: Vadim Belotserkovsky

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Examples: Tibet, Botswana, Swaziland and Kenya

Solar Light and Home PV Systems

RETScreen® International www.retscreen.net

- Cost of grid extension prohibitive
- Small loads
- Maintained locally
- Simple
- Reliable

Photo Credit: Energy Research Center of the Netherlands

Batik for Educational Purposes

Photo Credit: Frank Van Der Vleuten (Renewable Energy World)

Solar Home System

Photo Credit: Simon Tsuo (NREL PIX)

Medical Clinic Staff Housing

Photo Credit: Vadim Belotserkovsky

Solar Home System

Photo Credit: Energy Research Center of the Netherlands

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Examples: Finland and Canada

Remote Cottages and Homes

RETScreen® International www.retscreen.net

- Modular
- Simple
- Reduced noise
- No power lines
- Cottage: seasonal load correlation
- Year-round: hybrid systems

Cottage

Photo Credit: Fortum NAPS (*Photovoltaics in Cold Climates*)

Home

Photo Credit: Vadim Belotserkovsky

Hybrid System

Photo Credit: Vadim Belotserkovsky

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Examples: Morocco and Brazil

Hybrid Village Power Systems

RETScreen® International www.retscreen.net

- Cost of grid extension prohibitive
- Cost of diesel fuel and genset maintenance high
- Human Aspects
  - Expectations
  - Managing demand
  - Social impacts

Village

Photo Credit: Roger Taylor (NREL PIX)

Rural College

Photo Credit: BP Solarex (NREL PIX)

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Examples: Antarctica and Canada

Industrial System: Telecom & Monitoring

RETScreen® International www.retscreen.net

- Very remote sites...
  - Cost of O&M
  - Genset and PV complementary
- ...and even sites near grid...
  - Transformer cost
  - Can be relocated
  - More reliable than grid

Seismic Monitoring System

Photo Credit: Northern Power Systems (NREL PIX)

Gas Well-head Monitoring System

Photo Credit: Soltek Solar Energy

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Examples: Switzerland and Japan

On-Grid Buildings with PV

RETScreen® International www.retscreen.net

- Not usually cost-effective without subsidies
- Justified by:
  - Image
  - Environmental benefits
  - Market stimulus
- Long-term commitments by manufacturers, governments and utilities have reduced costs

Solar Roofing System
Photo Credit: Atlantis Solar Systeme AG

PV Integrated in Office Glazing
Photo Credit : Solar Design Associates (IEA PVPS)

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Examples: India and USA

Water Pumping PV Systems

RETScreen® International www.retscreen.net

- Cost-effective when off-grid
- Load correlation
  - Storage in water tank
  - Seasonal load correlation
- Improved water quality
- Convenient
- Reliable
- Simple

Cattle Watering System
Photo Credit: Jerry Anderson, Northwest Rural Public Power District (NREL PIX)

Domestic Water
Photo Credit: Harin Ullal, Central Electronics Ltd. (NREL PIX)

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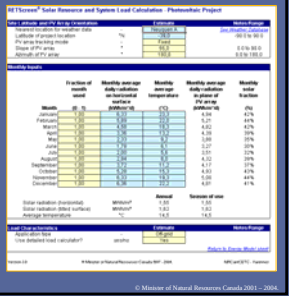
RETScreen® Photovoltaic Project Model

RETScreen® International www.retscreen.net

- World-wide analysis of energy production, life-cycle costs and greenhouse gas emissions reductions
  - On-grid (central or isolated grids)
  - Off-grid (PV-battery or PV-genset-battery)
  - Water pumping
- Only 12 points of data for RETScreen® vs. 8,760 for hourly simulation models
- Currently not covered:
  - Concentrator systems
  - Loss-of-load probability calculations



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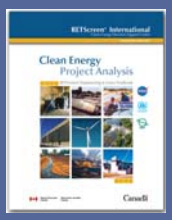
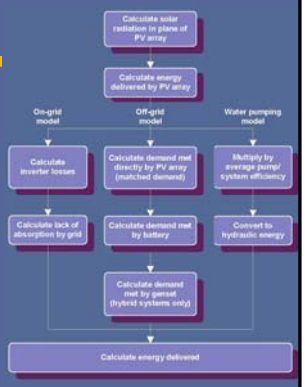
RETScreen®
PV Energy Calculation

RETSCREEN® INTERNATIONAL



Clean Energy Project Analysis: RETScreen® Engineering and Cases

Photovoltaic Project Analysis Chapter



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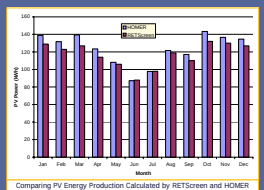
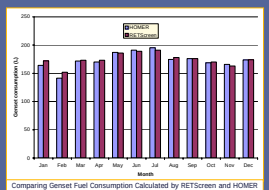
Example Validation of the RETScreen® PV Project Model

RETSCREEN® INTERNATIONAL www.retscreen.net

- PV/genset/battery hybrid system in Argentina compared to HOMER hourly simulation
  - 500 W_{AC} load
  - 1 kW_p array, 60 kWh battery, 7.5 kW genset, 1kW inverter



Comparing PV Energy Production Calculated by RETScreen and HOMER



Comparing Genset Fuel Consumption Calculated by RETScreen and HOMER

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Conclusions

RETSCREEN® INTERNATIONAL www.retscreen.net

- PV for on-grid & off-grid electricity, water pumping
- The solar resource is good around the world
  - PV systems installed in all climates
- Capital costs high
  - Cost-effective off-grid
  - Subsidies required for on-grid
- RETScreen® is an annual analysis with monthly resource calculation that can achieve accuracy comparable to hourly simulation models
- RETScreen® can provide significant preliminary feasibility study cost savings

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Questions?

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Photovoltaic Project Analysis Module
RETScreen® International Clean Energy Project Analysis Course

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COMBINED HEAT & POWER PROJECT ANALYSIS MODULE

Combined Heat and Power Project Analysis

RETScreen® International

www.retscreen.net

Clean Energy Project Analysis Course

Power Plant

Photo Credit: Warren Gretz, DOE/NREL PIX

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Canada

Objectives

RETScreen® International

www.retscreen.net

- Review basics of Combined Heat and Power (CHP) Systems
- Illustrate key considerations for CHP project analysis
- Introduce RETScreen® CHP Project Model

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What do Combined Heat and Power (CHP) systems provide?

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www.retscreen.net

- Electricity
- Heat
  - Buildings
  - Communities
  - Industrial processes

...but also...

- Increased energy efficiency
- Reduced waste & emissions
- Reduced T&D losses
- An opportunity to use district energy system
- Cooling

Biomass Fired Power Plant, USA

Photo Credit: Andrew Carlin, Tracy Operators/NREL PIX

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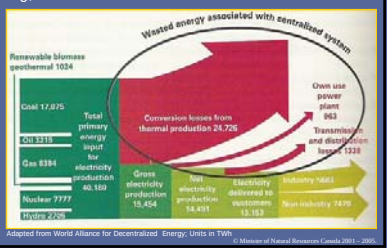
CHP System Motivation

RETScreen® International www.retscreen.net

- Traditional central power system is inefficient
  - One-half to two-thirds of energy is wasted as heat
  - This heat, otherwise lost, can be used for industrial processes, space and water heating, cooling, etc.
- Electricity is typically more valuable than heat



Adapted from World Alliance for Decentralized Energy; Units in TWh

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The CHP Concept

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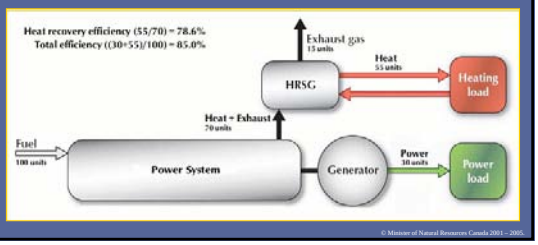
- Simultaneous production of two or more types of usable energy from a single energy source (also called "Cogeneration")
- Use of waste heat from power generation equipment



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CHP Description
Equipment & Technologies

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- Power equipment
  - Gas turbine
  - Steam turbine
  - Gas turbine-combined cycle
  - Reciprocating engine
  - Fuel cell, etc.
- Heating equipment
  - Waste heat recovery
  - Boiler / Furnace / Heater
  - Heat pump, etc.
- Cooling equipment
  - Compressor
  - Absorption chiller
  - Heat pump, etc.

Gas Turbine

Photo Credit: Rolls-Royce plc

Cooling Equipment

Photo Credit: Urban Ziegler, NRCan

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CHP Description (cont.)
Fuel Types

RETScreen® International www.retscreen.net

- Fossil fuels
  - Natural gas
  - Diesel (#2 oil)
  - Coal, etc.
- Renewable fuels
  - Wood residue
  - Biogas
  - Agricultural byproducts
  - Purpose-grown crops, etc.
  - Bagasse
  - Landfill gas (LFG)
- Geothermal energy
- Hydrogen, etc.

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

Geothermal Geyser
Photo Credit: Joel Renner, DOE/ NREL PIX

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CHP Description (cont.)
Applications

RETScreen® International www.retscreen.net

- 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

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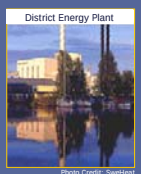
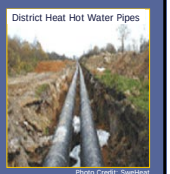
District Energy Systems

RETScreen® International www.retscreen.net

- Heat from a CHP plant can be distributed to multiple nearby buildings for heating and cooling
  - Insulated steel pipes are buried 0.6 to 0.8 m underground
- Advantages compared to each building having own plant:
  - Higher efficiency
  - Emissions controls on single plant
  - Safety
  - Comfort
  - Operating convenience
- Initial costs typically higher


District Energy Plant
Photo Credit: SweHeat


District Heat Hot Water Pipes
Photo Credit: SweHeat

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CHP System Costs

RETScreen® International www.retscreen.net

- Costs highly variable
- Initial costs
  - Power generation equipment
  - Heating equipment
  - Cooling equipment
  - Electrical interconnection
  - Access roads
  - District energy piping
- Recurring costs
  - Fuel
  - Operation & maintenance
  - Equipment replacement & repair

RETScreen power equipment type	Typical installed cost ($/kW)
Reciprocating engine	700 to 2,000
Gas turbine	550 to 2,500
Gas turbine - combined cycle	700 to 1,500
Steam turbine	500 to 1,500
Geothermal system	1,800 to 2,100
Fuel cell	4,000 to 7,700
Wind turbine	1,000 to 3,000
Hydro turbine	550 to 4,500
Photovoltaic module	8,000 to 12,000

Note: Typical installed cost values in Canadian $ as of January 1, 2005. Approximate exchange rate at time was 1 CAD = 0.81 USD and 1 CAD = 0.62 EUR

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CHP Project Considerations

RETScreen® International www.retscreen.net

- Reliable, long-term supply of fuel
- Capital costs must be kept under control
- Need "customer" for both heat and power
  - Must negotiate sale of electricity onto grid if not all consumed on-site
- Typically plant is sized for heating base load (i.e. minimum heating load under normal operating conditions)
  - Heat output typically equal to 100% to 200% of the electricity output
  - Heat can be used for cooling through absorption chillers
- Risk associated with uncertainty of future electricity / natural gas ("spark") price spread

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Example: Canada

Single Buildings

RETScreen® International www.retscreen.net

- Buildings requiring heating, cooling, and a reliable power supply
  - Hospitals, schools, commercial buildings, agricultural buildings, etc.

Hospital, Ontario, Canada

Photo Credit: GE Jenbacher

Reciprocating Engine

Photo Credit: GE Jenbacher

Exhaust Heat Recovery Steam Boiler

Photo Credit: GE Jenbacher

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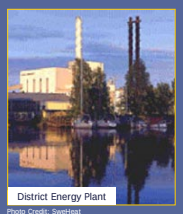
Examples: Sweden and USA

Multiple Buildings

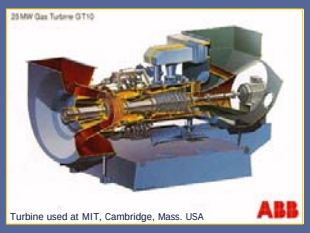
RETScreen® International www.retscreen.net

- Groups of buildings served by a central heating/cooling power plant
  - Universities, commercial complexes, communities, hospitals, industrial complexes, etc.
  - District energy system



District Energy Plant

Photo Credit: SweHeat



Turbine used at MIT, Cambridge, Mass. USA

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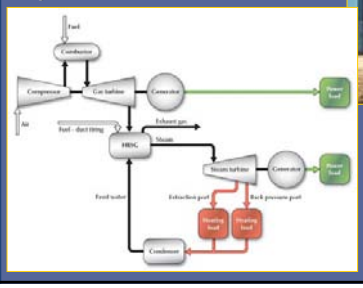
Example: Brazil

Industrial Processes

RETScreen® International www.retscreen.net

- Industries with a high, constant heating or cooling demand are good candidates for CHP



Bagasse for Process Heat at a Mill, Brazil

Photo Credit: Ralph Overend/ NREL Pix

- Also applicable to industries that produce waste material which can then be used to generate heat and power

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Examples: Canada and Sweden

Landfill Gas

RETScreen® International www.retscreen.net

- Landfills produce methane as waste decomposes
- This can be used as the fuel for cooling, heating or power projects

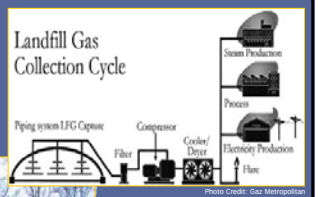

Photo Credit: Gaz Metropolitan

LFG CHP for district heating system, Sweden

Photo Credit: Urban Ziegler, NRCan

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RETScreen® CHP Project Model

RETSCREEN® INTERNATIONAL www.retscreen.net

- World-wide analysis of energy production, life-cycle costs and greenhouse gas emissions reductions
  - Cooling, heating, power, and all combinations thereof
  - Gas or steam turbines, reciprocating engines, fuel cells, boilers, compressors, etc.
  - Vast range of fuels, ranging from fossil fuels to biomass & geothermal
  - Variety of operating strategies
  - Landfill gas tool
  - District energy systems
- Also includes:
  - Multiple languages and currencies, unit switch, and user tools

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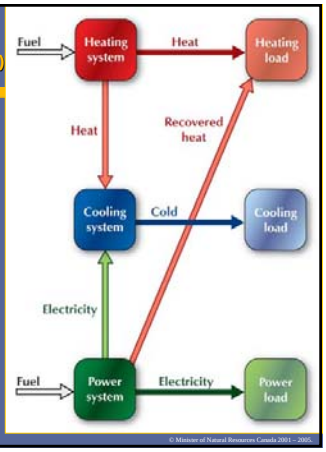
RETScreen® CHP Project Model (cont.)

RETSCREEN® INTERNATIONAL

- Capabilities for various type of projects
  - Heating only
  - Power only
  - Cooling only
  - Combined heating & power
  - Combined cooling & power
  - Combined heating & cooling
  - Combined cooling, heating & power



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RETScreen® CHP Project Model Heating Systems

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RETScreen® CHP Project Model Cooling Systems

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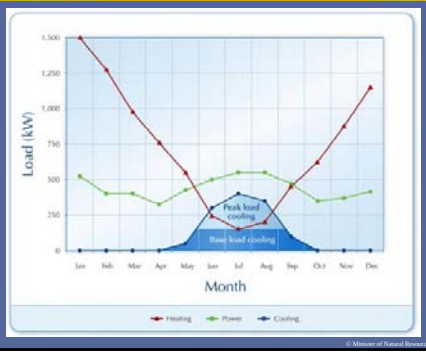

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RETScreen® CHP Project Model Power Systems

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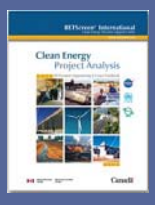
RETScreen® CHP Energy Calculation

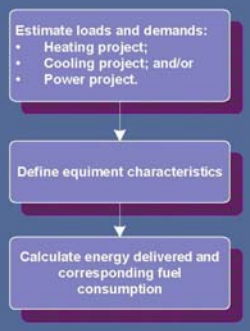
RETSCREEN® INTERNATIONAL



See e-Textbook

Clean Energy Project Analysis: RETScreen® Engineering and Cases

Combined Heat and Power Project Analysis Chapter



Simplified CHP Energy Model Flowchart

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Example Validation of the RETScreen® CHP Project Model

- Overall validation by independent consultant (FVB Energy Inc.) and by numerous beta testers from industry, utilities, government and academia
- Compared with several other models and/or measured data, with excellent results (e.g. steam turbine performance calculations compared with GE Energy process simulation software called GateCycle)

Steam Turbine Performance Calculation Comparison

Run	Inlet Flow, P, T Kpph/psia/F	Outlet Flow P, T Kpph/psia/F	Extract Flow, P, T Kpph/psia/F	Efficiency	GateCycle Power Output MW	RETScreen CHP Power Output MW
1	50/1000/750	40/14/210	10/60/293	80%	3,896	3,883
2	50/1000/545	50/60/293	0	80%	2,396	2,404
3	50/450/457	50/60/293	0	80%	1,805	1,827
4	50/450/457	50/14.7/212	0	81%	2,913	2,915

Kpph = 1000 lbs/hr

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Conclusions

- Combined Heat and Power (CHP) systems make efficient use of heat that would otherwise be wasted
- RETScreen calculates demand and load duration curves, energy delivered, and fuel consumption for various combinations of heating, cooling and/or power systems using minimal input data
- RETScreen provides significant preliminary feasibility study cost savings

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Questions?

Combined Heat and Power Project Analysis Module
RETScreen® International Clean Energy Project Analysis Course

For further information please visit the RETScreen Website at
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BIOMASS HEATING PROJECT ANALYSIS MODULE

Biomass Heating Project Analysis

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Clean Energy Project Analysis Course

Biomass District Heating Plant, Sweden

Photo Credit: Bioenerginovator

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Natural Resources Canada — Ressources naturelles Canada — Canada

Objectives

RETScreen® International — www.retscreen.net

- Review basics of Biomass Heating Systems
- Illustrate key considerations for Biomass Heating project analysis
- Introduce RETScreen® Biomass Heating Project Model

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What do biomass heating systems provide?

RETScreen® International — www.retscreen.net

- Heat for
  - Buildings
  - Communities
  - Industrial processes

...but also...

- Job creation
- A use for waste materials
- An opportunity to use district heating and waste heat recovery

District Heating Plant, Heat Provided from Rapeseed, Germany

Photo Credit: Centrales Agrar-Rohstoff-Marketing- und Entwicklungs-Netzwork

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Biomass Heating System Description

RETSCREEN® INTERNATIONAL www.retscreen.net

- Heating Plant
  - Waste heat recovery system
  - Biomass combustion system for base load
  - Peak load heating system
  - Optional backup system
- Heat Distribution System
  - Hot water supply, cold water return
  - For single building or district heating system
- Fuel Supply Operation
  - Fuel receiving, storage, and transport facilities
  - Typically automated fuel transfer from day bin to combustion

Small Diameter Wood Waste Packaged in Bales, Finland

Photo Credit: Bioenergia Suomessa

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Biomass Heating System Description (Cont.)

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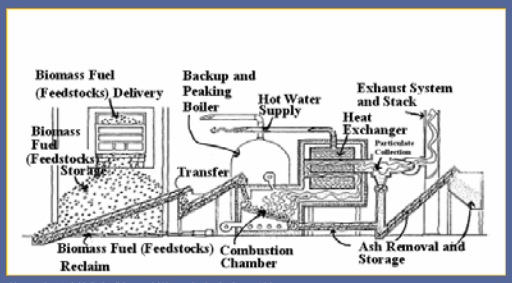

Diagram: *Buyer's Guide To Small Commercial Biomass Combustion Systems* NRCan

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Peak vs. Base Load Systems

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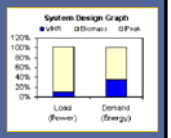
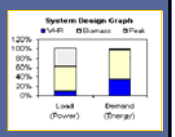
The biomass system can be sized for:

- Peak load
  - Biofuel use maximized and fossil fuel use minimized
  - Larger, more expensive system
  - Part load operation lowers efficiency if load variable



- Base load
  - Operates near design capacity, so efficiency high
  - Capital costs much lower
  - Conventional system required for peak load



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District Heating Systems

RETScreen® International www.retscreen.net

- Heat from a central plant can be distributed to multiple nearby buildings for heating and service hot water
  - Insulated steel pipes are buried 0.6 to 0.8 m underground
- Advantages compared to each building having own plant:
  - Higher efficiency
  - Lower emissions
  - Safety
  - Comfort
  - Operating convenience
- Initial costs high
- Needs more attention than fossil fuel systems

District Heating Plant

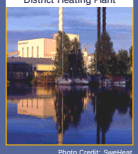

Photo Credit: SweHeat

District Heat Hot Water Pipes

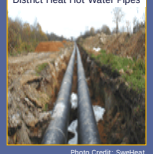

Photo Credit: SweHeat

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Biomass Fuels

RETScreen® International www.retscreen.net

- Biomass fuels (feedstocks) include
  - Wood & wood residues (chunks, sawdust, pellets, chips)
  - Agricultural residues (straw, chaff, husks, animal litter and manure)
  - Energy crops (hybrid poplars, switchgrass, willows)
  - Municipal Solid Waste (MSW)
- Important feedstock considerations
  - Heating value and moisture content
  - Reliability, security, and price stability of supply
  - Transportation and storage facilities

Wood for Biomass Combustion

Photo Credit: ECOMatters Inc

Walnut Shells for Biomass Combustion

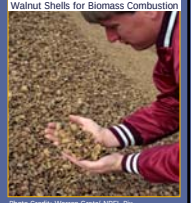

Photo Credit: Warren Gretz/ NREL Pix

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Environmental Attributes of Biomass Fuels

RETScreen® International www.retscreen.net

- If harvested in sustainable manner:
  - Zero net production of greenhouse gases
- Low sulphur content reduces acid rain
- Emissions of local air pollutants
  - Particulates (soot)
  - Gaseous pollutants
  - Trace carcinogens
  - May be subject to regulation

Wood chips

Photo Credit: Bioenerginovator

Bagasse

Photo credit: Warren Gretz/NREL Pix

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Examples of Biomass Heating System Costs

RETScreen® International www.retscreen.net

- For a 150 kW system to heat a 800 m² building:

	Oil	Wood chips
Initial Costs	$21,000	$80,000
Annual O&M	$1,000	$8,000
Annual fuel	$18,000	$1,700

- High initial costs, potentially low fuel costs:

	Price	Cost of heat ($/GJ)
Electricity	$0.08/kWh	22.50
Propane	$0.40/L	15.60
Fuel Oil	$0.30/L	8.50
Gas	$0.20/m³	5.80
Mill residue	$10/tonne	1.70
Tree chips	$40/tonne	6.70

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Biomass Heating Project Considerations

RETScreen® International www.retscreen.net

- Availability, quality and price of biomass feedstock versus fossil fuels
  - Future non-energy uses of biomass (e.g., pulp)
  - Long term contracts
- Space available for fuel delivery, storage, and large boiler
- Dedicated and reliable operators necessary
  - Fuel procurement and handling ash removal
- Environmental regulations on air quality and ash disposal
- Insurance and safety issues

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Examples: Austria, Germany and Slovenia

Community Energy Systems

RETScreen® International www.retscreen.net

- Groups of buildings including schools, hospitals, and clusters of residences

DH Converted from Fossil Fuel to Biomass, Slovenia

Wood-Fired Boiler

Photo Credit: Centrales Agrar-Rohstoff-Marketing-und Entwicklungs-Netzwerk

Automatic Feedstock Handler

Photo Credit: Ken Sheinkopf/ Solstice CREST

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Example: Canada

Institutional and Commercial Buildings

RETScreen® International www.retscreen.net

- Individual buildings can provide their own heat from biomass
  - Institutional: schools, hospitals, municipal buildings
  - Commercial: stores, garages, etc.

Photo Credit: ECOMatters Inc.

Small Commercial Biomass Heating System, Canada

Photo Credit: Grove Wood Heat

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Examples: Brazil and USA

Process Heat

RETScreen® International www.retscreen.net

- Often used where biomass is produced and process heat required
  - Saw mills, sugar and alcohol factories, furniture manufacturing sites, and drying sites for agricultural processes.

Sugar Cane for Process Heat, Hawaii

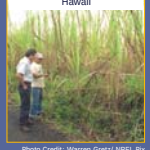

Photo Credit: Warren Gretz/ NREL Pix

Bagasse for Process Heat in Mill, Brazil

Photo Credit: Ralph Overend/ NREL Pix

Interior of a Combustion Chamber

Photo Credit: Ken Sheinkopf/ Solstice CREST

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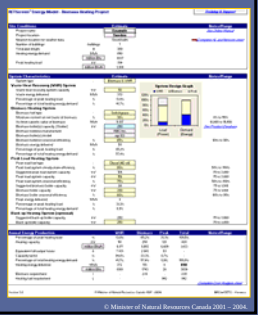
RETScreen® Biomass Heating Project Model

RETScreen® International www.retscreen.net

- World-wide analysis of energy production, life-cycle costs and greenhouse gas emissions
  - Individual buildings to large clusters with district heat
  - Biomass, peak, backup and waste-heat recovery
  - Sizing and costing of district heat piping network
- Currently not covered:
  - Large-scale district heating (>2.5 MW)
    - Use CHP Model instead



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RETScreen® Biomass Heating Energy Calculation

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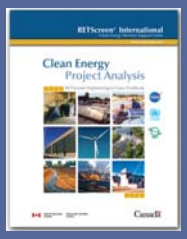

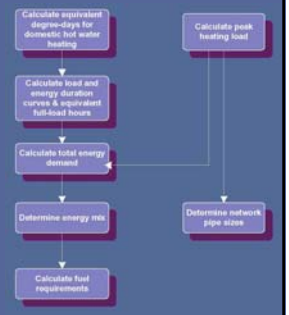

See e-Textbook

Clean Energy Project Analysis: RETScreen® Engineering and Cases

Biomass Heating Project Analysis Chapter

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Example Validation of the RETScreen® Biomass Heating Project Model

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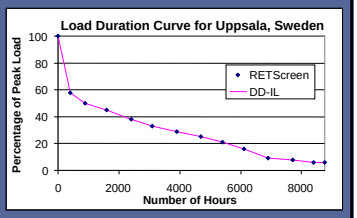
- Calculation of load duration curve
  - Compared with Swedish DD-IL model for 4 cities in Europe and North America
- District heating network pipe sizing
  - Compared with ABB R22 program – good results
- Heating value of wood
  - Compared with 87 samples of tree bark from Eastern Canada
  - RETScreen® estimate for wood waste within 5% of sample data



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Conclusions

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- Biomass heating energy costs can be much lower than conventional heating costs, even when considering higher initial capital costs of biomass systems
- RETScreen® calculates load duration curves, required biomass and peak plant capacity, and district heating network pipe sizes using minimal input data
- RETScreen® provides significant preliminary feasibility study cost savings

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Questions?

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Biomass Heating Project Analysis Module
RETScreen® International Clean Energy Project Analysis Course

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SOLAR AIR HEATING PROJECT ANALYSIS MODULE

Solar Air Heating Project Analysis

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Clean Energy Project Analysis Course

Industrial Solar Air Heating System, Quebec, Canada

Photo Credit: Conserval Engineering

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Natural Resources Canada Ressources naturelles Canada

Canada

Objectives

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- Review basics of Solar Air Heating (SAH) systems
- Illustrate key considerations for SAH project analysis
- Introduce RETScreen® SAH Project Model

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What do SAH systems provide?

RETScreen® International www.retscreen.net

- Warm ventilation air
- Warm process air

...but also...

- Weather cladding
- Reduced heat loss through wall
- Reduced stratification
- Better air quality
- Reduced negative pressure problems

School, Yellowknife, Canada

Photo Credit: Arctic Energy Alliance

Solar Collector

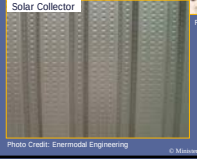

Photo Credit: Enermodal Engineering

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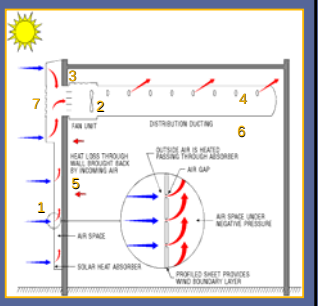
SAH System Operation

RETScreen® International www.retscreen.net

1. Dark perforated absorber captures solar energy
2. Fan draws air through collector & canopy
3. Controls regulate temperature
   - Dampers
   - Auxiliary heating
4. Air is distributed through building
5. Wall heat loss recovered
6. Destratification
7. Summer bypass damper



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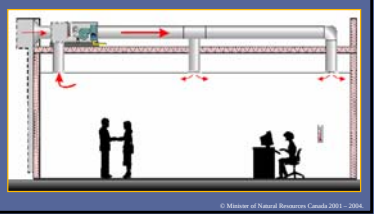
Commercial/Residential SAH Systems

RETScreen® International www.retscreen.net

- Two types of systems
  - Dedicated ventilation (apartments & schools)
  - Heating, cooling & ventilation with 10-20% fresh air
- SAH collector connects to conventional fans and ductwork
- Conventional heat added as required
- No destratification
- Economiser cycle permits using more fresh air



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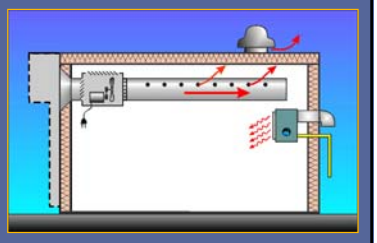
Industrial SAH Systems

RETScreen® International www.retscreen.net

- For ventilation air in factories, warehouses, etc.
- Perforated fabric ducting distributes air at ceiling level
- Temperature control: mix fresh and recirculated air, add heat if necessary
- Destratification: cool air mixes with ceiling air and descends



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SAH System for Process Heat

RETScreen® International www.retscreen.net

- Collector mounted on any convenient surface
- Output of collector ducted to process
- Temperature can be regulated by
  - Conventional heater
  - Bypass damper
- Crop drying
  - Requires low temperatures to avoid crop damage
- Preheat air for industrial processes

Photo Credit: Conserval Engineering

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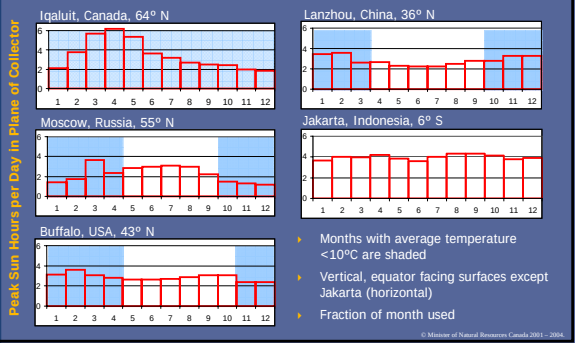
Solar Resource vs. Demand for Ventilation Heat

RETScreen® International www.retscreen.net



- Months with average temperature <10°C are shaded
- Vertical, equator facing surfaces except Jakarta (horizontal)
- Fraction of month used

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SAH System Costs and Savings

RETScreen® International www.retscreen.net

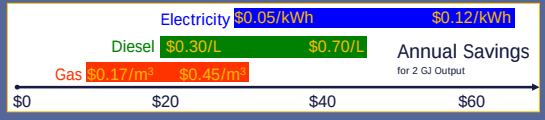
Energy Collected:

- 1 to 3 GJ/year

Installed costs:

- Collector: $100 to $250/m²
- Ventilation system: $0 to $100/m²
- Total: $100 to $350/m²

minus cost of conventional cladding



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Solar Air Heating Project Considerations

RETScreen® International www.retscreen.net

- Most cost-effective in new construction and renovation
  - Cladding credit
  - Ensure that existing ventilation system accommodates SAH easily
- Most dark colors have absorptivity of 0.80-0.95
  - Architectural concerns can be very important
- Higher occupancy more cost-effective
- Can be fitted around windows and doors
- Existing fans & ducting can be used
- Low or no added maintenance costs

Photo Credit: NRCan

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Examples: Canada and USA

Ventilation Air Heating Systems

RETScreen® International www.retscreen.net

- Improved air quality at low cost
- Size ranges from a few m^2 to 10,000 m^2
- Ducts should be located near south wall
- Paybacks of 2 to 5 years typical
- Industrial systems often have quickest payback

Apartment Building, Ontario, Canada

Brown Collector on Industrial Building, Connecticut, USA

Portable Classroom, Ontario, Canada

Photo Credit: Conserval Engineering

Photo Credit: Conserval Engineering

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Example: Indonesia

Process Heat Systems

RETScreen® International www.retscreen.net

- Normally constant flow rate systems with very simple controls
- Used for drying crops that are harvested throughout the year
- Best if sunny season coincides with harvest

Tea Drying Shelter, West Java, Indonesia

Photo Credit: Conserval Engineering

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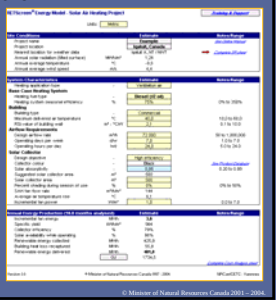
RETScreen® Solar Air Heating Project Model

RETSCREEN® INTERNATIONAL www.retscreen.net

- World-wide analysis of energy production, life-cycle costs and greenhouse gas emissions reductions
  - Ventilation air
  - Process heat
  - Heat recovery
  - Destratification
- Only 12 points of data for RETScreen® vs. 8,760 for hourly simulation models
- Currently not covered:
  - Advanced HRV systems
  - Non Solarwall® technology
  - Unbalanced ventilation systems



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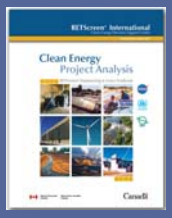
RETScreen®
SAH Energy Calculation

RETSCREEN® INTERNATIONAL



See e-Textbook

Clean Energy Project Analysis: RETScreen® Engineering and Cases

Solar Air Heating Project Analysis Chapter

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Example Validation of the RETScreen® SAH Project Model

RETSCREEN® INTERNATIONAL www.retscreen.net

Comparison with SWift™	RETScreen	SWift	Difference
	[kWh/m²/d]	[kWh/m²/d]	
Toronto, Ontario, Canada			
Industrial (High Temp Rise)	1.23	1.21	2%
Industrial (High Eff.)	1.64	1.79	-8%
Commercial (High Eff.)	1.39	1.28	9%
Winnipeg, Manitoba, Canada			
Industrial (High Temp Rise)	1.40	1.64	-15%
Industrial (High Eff.)	2.00	2.20	-9%
Commercial (High Eff.)	2.03	1.93	5%

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Conclusions

RETScreen® International www.retscreen.net

- SAH provides ventilation and process air heating
- Locations throughout world have solar energy available when ventilation air heating is required
- SAH serves as weather cladding and feeds into conventional ventilation systems
- For SAH systems, RETScreen® calculates
  - Energy collected, efficiency, and temperature rise
  - Wall heat loss recovery
  - Reduced heat loss due to destratification
- RETScreen® is an annual analysis with monthly resource calculation that can achieve accuracy comparable to hourly simulation models
- RETScreen® can provide significant preliminary feasibility study cost savings

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Questions?

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Solar Air Heating Project Analysis Module
RETScreen® International Clean Energy Project Analysis Course

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SOLAR WATER HEATING PROJECT ANALYSIS MODULE

Solar Water Heating Project Analysis

RETScreen® International — www.retscreen.net

Clean Energy Project Analysis Course

Glazed Flat Plate Collectors, Ontario, Canada

Photo Credit: NRCan

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Natural Resources Canada — Ressources naturelles Canada — Canada

Objectives

RETScreen® International — www.retscreen.net

- Review basics of Solar Water Heating (SWH) systems
- Illustrate key considerations for SWH project analysis
- Introduce RETScreen® SWH Project Model

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What do SWH systems provide?

RETScreen® International — www.retscreen.net

- Domestic Hot Water
- Process Heat
- Swimming Pool Heating

...but also...

- Increased hot water storage
- Extended swimming season (pool heating)

Conference Centre, Bethel, Lesotho

Photo Credit: Vadim Belotserkovsky

Housing Development, Kungsbacka, Sweden

Photo Credit: Alpo Winberg/ Solar Energy Association of Sweden

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Components of SWH Systems

RETScreen® International www.retscreen.net

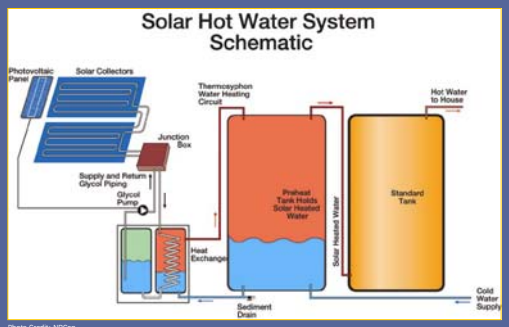

Photo Credit: NRCan

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Unglazed Solar Collectors

RETScreen® International www.retscreen.net

- Low cost
- Low temperature
- Rugged
- Lightweight
- Seasonal pool heating
- Low pressure
- Poor performance in cold or windy weather

Photo Credit: NRCan

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Glazed Flat Plate Solar Collectors

RETScreen® International www.retscreen.net

- Moderate cost
- Higher temperature operation
- Can operate at mains water pressure
- Heavier and more fragile

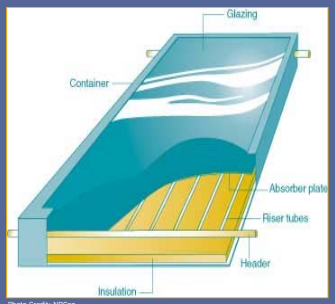

Photo Credit: NRCan

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Evacuated Tube Collectors

RETScreen® International www.retscreen.net

- Higher cost
- No convection losses
- High temperature
- Cold climates
- Fragile
- Installation can be more complicated
- Snow is less of a problem

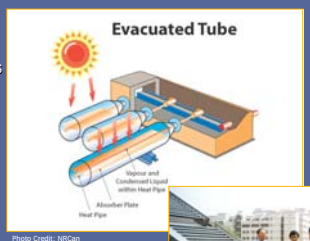

Photo Credit: NRCan

Tube Developed and Manufactured in China

Photo Credit: Nautilus

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Solar Water Heating in Various Climates

RETScreen® International www.retscreen.net

- For a domestic solar water heating system with 6 m^2 of glazed collector, a demand of 300 L/day of hot water at 60°C and 300 L of storage, the solar fraction is:

21% in Tromsø, Norway (70°N)	81% in Matam, Senegal (16°N)
40% in Yellowknife, Canada (62°N)	59% in Puerto Limón, Costa Rica (10°N)
32% in Warsaw, Poland (52°N)	59% in Jakarta, Indonesia (6°S)
51% in Harbin, China (46°N)	86% in Huancayo, Peru (12°S)
67% in Sacramento, USA (39°N)	69% in Harare, Zimbabwe (18°S)
39% in Tokyo, Japan (36°N)	65% in Sydney, Australia (34°S)
78% in Marrakech, Morocco (32°N)	39% in Punta Arenas, Chile (53°S)
75% in Be'er-Sheva, Israel (31°N)	

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Examples of SWH System Costs and Benefits

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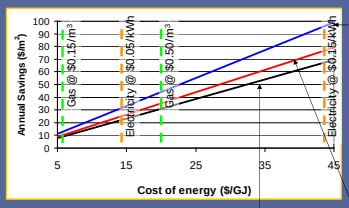

Glazed year-round system (w/storage)

La Paz, Bolivia
2.2 GJ/m^2
$400/$m^2$

Evacuated tube year-round system (w/storage)

Copenhagen, Denmark
1.8 GJ/m^2
$1,000/$m^2$

Unglazed summer-only swimming pool

Montreal, Canada
1.5 GJ/m^2
$150/$m^2$

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Solar Water Heating Project Considerations

RETScreen® International www.retscreen.net

- Factors for successful projects:
  - Large demand for hot water to reduce importance of fixed costs
  - High energy costs (e.g. natural gas not available)
  - No reliable conventional energy supply
  - Strong environmental interest by building owner/operator

- Daytime hot water loads require less storage
- Lower cost, seasonal systems can be financially preferable to higher-cost year-round systems
- Maintenance similar to any plumbing system, but operator must be committed to timely maintenance and repairs

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Examples: Australia, Botswana and Sweden

Domestic Hot Water Systems

RETScreen® International www.retscreen.net

- On-grid, need a committed homeowner
  - Can have long payback when energy prices are low
  - Systems provide 20 to 80% of hot water
- Off-grid or where the energy supply is unreliable

Thermosiphon System, Australia

Photo Credit: The Australian Greenhouse Office

Homes, Malmö, Sweden

Photo Credit: Marie Andrén, Solar Energy Association of Sweden

House for Medical Staff in Rural Area, Botswana

Photo Credit: Vadim Belotserkovsky

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Examples: USA and Canada

Swimming Pool Systems

RETScreen® International www.retscreen.net

- Low-cost unglazed collectors
  - Summer pools in cold climates
  - Extend the season in warm climates
  - For summer use on a year-round pool in cold climates
  - Can have 1 to 5-year paybacks
- Glazed collectors for heat year-round
- Filtration system serves as pump

Pool system, USA

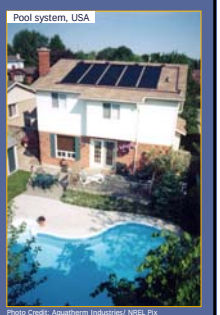

Photo Credit: Aquatherm Industries/ NREL Pix

Community Pool System, Ontario, Canada

Photo Credit: NRCan

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Examples: Greece and Canada
Commercial / Industrial Hot Water Systems

RETScreen® International www.retscreen.net

- Hotels/motels, apartments and office buildings
- Health centres & hospitals
- Car washes, laundromats, restaurants
- Sport facilities, schools, shower facilities
- Aquaculture, other small industry

Hotel, Agio Nikolaos, Crete

Photo Credit: Regional Energy Agency of Crete/ISES

Aquaculture Operation, British Columbia, Canada

Photo Credit: NRCan

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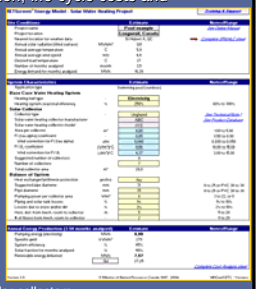
RETScreen® Solar Water Heating Project Model

RETScreen® International www.retscreen.net

- World-wide analysis of energy production, life-cycle costs and greenhouse gas emissions reductions
  - Glazed, unglazed, and evacuated tube
  - Indoor and outdoor swimming pools (w/ or w/o cover)
  - Service hot water systems (w/ and w/o storage)
- Only 12 points of data for RETScreen® vs. 8,760 for hourly simulation models
- Currently not covered:
  - Changes in service hot water daily loads
  - Stand-alone service hot water
  - Systems w/o storage having high solar fractions
  - Sun tracking, concentrator & integrated solar collectors



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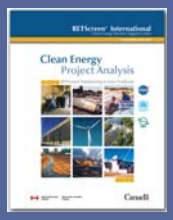
RETScreen®
SWH Energy Calculation

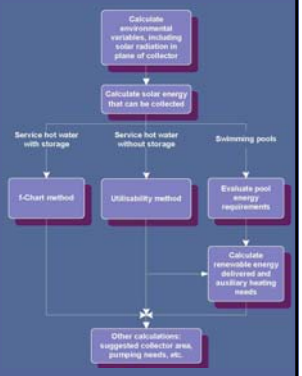
RETScreen® International



See e-Textbook

Clean Energy Project Analysis: RETScreen® Engineering and Cases

Solar Water Heating Project Analysis Chapter



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Example Validation of the RETScreen® SWH Project Model

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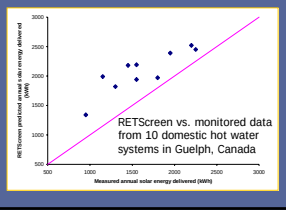
RETScreen® compared to:

- WATSUN for domestic hot water system in Toronto, Canada:

	RETScreen	WATSUN	Diff.
Incident radiation (GJ)	24.34	24.79	-1.8%
Load (GJ)	19.64	19.73	-0.5%
Energy delivered (GJ)	8.02	8.01	0.1%
Pump run time (h)	1,874	1,800	4.1%



RETScreen vs. monitored data from 10 domestic hot water systems in Guelph, Canada

- ENERPOOL for 48-m² summer pool in Montreal, Canada
  - Energy required to within 2%
- Monitored data from a 1,200 m² summer pool in Möhringen, Germany
  - Energy required to within 3% and solar energy production to within 14%

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Conclusions

RETSCREEN® INTERNATIONAL www.retscreen.net

- Unglazed, glazed and evacuated tube collectors provide hot water for many uses in any climate
- Significant hot water demand, high energy costs, and strong commitment on part of owner/operator are important factors in success
- RETScreen® calculates:
  - Service hot water load and swimming pool load
  - Performance of solar swimming pool and service hot water systems with or without storage
- RETScreen® is an annual analysis with monthly resource calculation that can achieve accuracy comparable to hourly simulation models
- RETScreen® can provide significant preliminary feasibility study cost savings

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Questions?

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Solar Water Heating Project Analysis Module
RETScreen® International Clean Energy Project Analysis Course

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www.retscreen.net

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PASSIVE SOLAR HEATING PROJECT ANALYSIS MODULE

Passive Solar Heating Project Analysis

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Clean Energy Project Analysis Course

Passive Solar Heating on Residence, France

Photo Credit: Pamm McFadden (NREL Pix)

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Natural Resources Canada Ressources naturelles Canada

Canada

Objectives

RETScreen® International www.retscreen.net

- Review basics of Passive Solar Heating (PSH) systems
- Illustrate key considerations for PSH project analysis
- Introduce RETScreen® PSH Project Model

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What does PSH provide?

RETScreen® International www.retscreen.net

- 20 to 50% of space heating requirements

...but also...

- Improved comfort
- Better daylight
- Can reduce cooling costs
- Reduced window condensation
- Can permit smaller heating/cooling plant

Passive Solar Heating Designed on Residential Building, Germany

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

The NREL Building in Golden, Colorado

Photo Credit: Warren Gretz (NREL Pix)

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Principles of Operation of PSH

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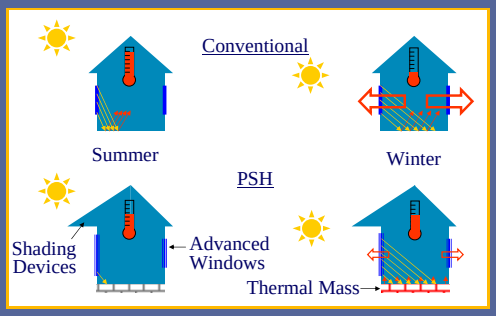

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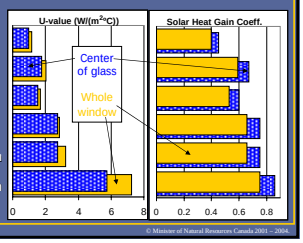
Advanced Window Technologies

RETScreen® International www.retscreen.net

- Double and triple glazed
- Low emissivity
- Inert gas fill
- Insulative spacers
- Insulated frames, thermal break

Panes	e	Fill	Spacer	Frame
3	0.1	Inert	Insul.	Wood
3	0.8	Air	Alumin.	Wood
2	0.1	Inert	Insul.	Wood
2	0.8	Air	Alumin.	Wood
2	0.8	Air	Alumin.	Aluminum
1	0.8	-	-	Aluminum



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Shading and Thermal Mass

RETScreen® International www.retscreen.net

- Shading prevents overheating in summer
  - Overhangs on equator-facing exposure for when sun is high
  - Deciduous trees, nearby buildings and structures
  - Screens, shutters, awnings, recessed windows, blinds, etc.
- Thermal mass stores heat, minimizing temperature swings
  - If equator-facing window area exceeds 8 to 10% of heated floor area, traditional light-weight construction house will overheat
  - Use double gyproc walls, ceilings, ceramic floors, brick fireplace, etc.
- Active systems can be used to distribute heat through building

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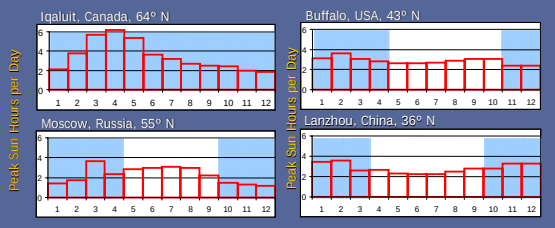
Solar Resource vs. Requirement for Space Heating

RETScreen® International www.retscreen.net



- Months with average temperature less than or equal to 10ºC are shaded

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Example of PSH Costs & Savings

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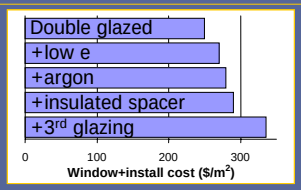
Canadian Single Family Dwelling



- Additional window costs
  - 5 to 35%
  - $400 to $2,000 per house

- Savings of 20 to 50% of space heating costs

Gas	$0.25/m³	$150 to $380 per year
Oil	$0.35/l	$210 to $520 per year
Electricity	$0.06/kWh	$270 to $680 per year

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Passive Solar Heating Project Considerations

RETScreen® International www.retscreen.net

- New construction most cost-effective
  - Freedom to orient windows to face equator and avoid west
  - Heating system size and perimeter heating can be reduced

- Retrofit cost-effective if windows being replaced anyways
- Most cost-effective where heating load high compared to cooling load
  - Low rise residential in moderate to cold climates are best
  - Commercial and industrial buildings have high internal gains
- Consider windows in conjunction with rest of envelope

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Examples: Canada and USA

Low Energy Buildings

RETScreen® International www.retscreen.net

- Passive solar techniques incorporated into conventional-looking buildings
- Financial considerations not always paramount: comfort, sound abatement, appreciation of quality, and environment

Good Shading and Advanced Windows, USA

Photo Credit: Hickory Corporation (NREL Pix)

Waterloo Green Home, Ontario, Canada

Photo Credit: Waterloo Green Home

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Examples: Germany and Lesotho

Self-sufficient Solar Houses

RETScreen® International www.retscreen.net

- More glazing, more thermal mass, and control of air distribution
- All space heating needs can be met by solar energy
- Advanced window technologies permit more flexible window placement, heat gains from diffuse radiation

Solar Rondavel, Thaba-Tseka, Lesotho

Photo Credit: Vadim Belotserkovsky

Freiburg, Solar Home

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

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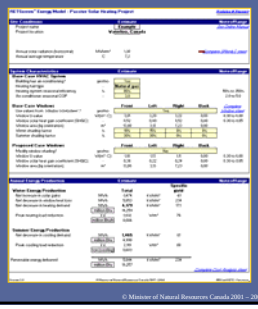
RETScreen® Passive Solar Heating Project Model

RETScreen® International www.retscreen.net

- World-wide analysis of energy production (or savings), life-cycle costs and greenhouse gas emissions reductions
  - Low-rise residential and small commercial buildings
  - In a heating dominated climate
  - Window gains and losses
  - Average effects of shading
- Only 12 points of data for RETScreen® vs. 8,760 for hourly simulation models
- Currently not covered:
  - Non-vertical windows
  - Instantaneous effects of shading
  - User-specified building thermal mass



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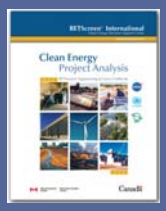
RETScreen®
PSH Energy Calculation

RETSCREEN® INTERNATIONAL



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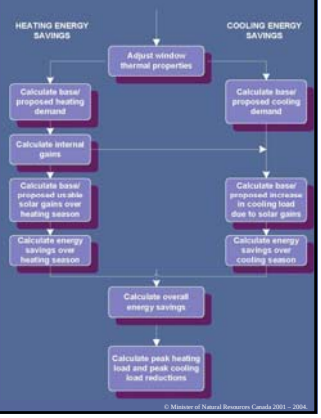
Clean Energy Project Analysis:
RETScreen® Engineering and Cases

Passive Solar Heating Project Analysis Chapter



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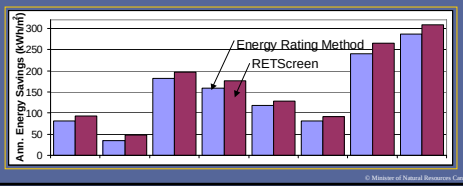
Example Validation of the RETScreen® PSH Project Model

RETSCREEN® INTERNATIONAL www.retscreen.net

- RETScreen® compared with HOT2-XP for a 200 m² typical wood frame home
  - Double glazed windows upgraded to double glazed low-e with argon
  - RETScreen® to within 18% of HOT2-XP
- RETScreen also compared to Energy Rating Method
  - Annual energy savings for 8 higher performance windows compared to base case double glazed windows



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Conclusions

RETSCREEN® INTERNATIONAL www.retscreen.net

- PSH involves building orientation, energy efficient windows, shading, and thermal mass to reduce space heating costs
- Minimal additional investment in windows can greatly improve performance of building envelope with long term financial benefits
- RETScreen® calculates:
  - Effect of window orientation, size, and technology on solar gains
  - Effect of window technology on heat losses
  - Effect of shading on cooling load
- RETScreen® is an annual analysis with monthly resource calculation that can achieve accuracy comparable to hourly simulation models
- RETScreen® can provide significant preliminary feasibility study cost savings

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Questions?

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GROUND-SOURCE HEAT PUMP PROJECT ANALYSIS MODULE

Ground-Source Heat Pump Project Analysis

RETScreen® International www.retscreen.net

Clean Energy Project Analysis Course

Philadelphia Enterprise Centre, USA – 28 GSHPs for Heating and Cooling

Photo Credit: Geothermal Heat Pump Consortium (NREL PIX)

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Objectives

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- Review basics of Ground-Source Heat Pump (GSHP) systems
- Illustrate key considerations for GSHP project analysis
- Introduce RETScreen© GSHP Project Model

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What do GSHP systems provide?

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- Heating
- Cooling
- Hot water
- Sound permafrost foundations

Impact 2000 Home, Massachusetts, USA

Photo Credit: Solar Design Associates (NREL PIX)

Residential Heat Pump

...but also...

- Efficiency
- Decreased maintenance
- Decreased space needs
- Low operating costs
- Stable capacity
- Comfort & air quality
- Reduced peak electrical loads for air conditioning

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Components of GSHP Systems

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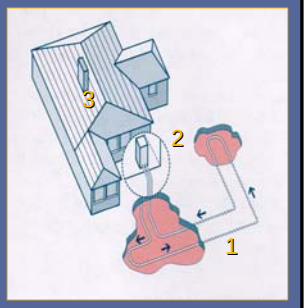
1. Earth connection
   - Ground-coupled
   - Groundwater
   - Surface water
2. Liquid-source heat pump
3. Interior heating/ cooling distribution subsystem
   - Conventional ductwork



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Liquid-Source Heat Pump

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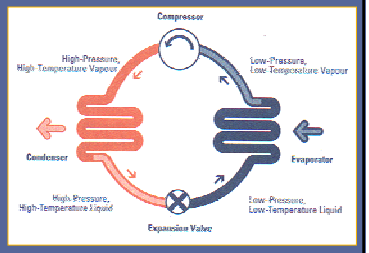
- Water-to-air heat pump
- Reverses direction
- 3.5 to 35 kW of cooling per unit
- Multiple units for big buildings



- Excess heat following compression provides hot water via desuperheater

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Types of Earth Connection

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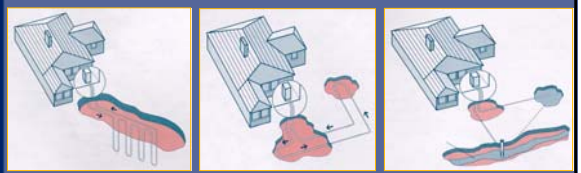
Vertical (GCHP)	Horizontal (GCHP)	Groundwater (GWHP)
Rocky ground	Most land used	Aquifer+Injection
More expensive	Less expensive	Least expensive
Little land used	Small buildings	Regulations
High efficiency	Temp. varies	Fouling



- Also surface water and standing column heat exchangers

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GSHP Resource: Ground Temperatures

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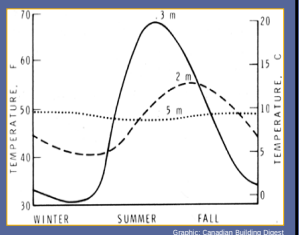
- Ground absorbs about half of sun's incident energy
- Ground dampens temperature variation
  - GSHP more efficient
- Temperature variation decreases with depth
  - Negligible below 15 m



Graphic: Canadian Building Digest

- Local ground temperatures depend on climate, ground & snow cover, slope, soil properties, etc.

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Examples of GSHP System Costs

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Photo Credit: Suomen Lämpöpumpputeknikka Oy

Finland, 150 m² House	Initial Costs	Annual Heating	Annual Energy
Electric	$8,000	$800	20 MWh
GSHP	$13,000	$350	6.5 MWh

- Rising energy costs
- Environmental concerns
- Air conditioning is bonus

Photo Credit: GeoExchange Consortium

Connecticut, USA, 275 m² House	Initial Costs	Annual Heating	Annual Cooling	Annual Total	Annual Energy
Oil/AC	$16,000	$600	$900	$1,500	27 MWh
GSHP	$20,500	$450	$600	$1,050	11 MWh

- Utility subsidy to lower peak air conditioning loads

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Ground-Source Heat Pump Project Considerations

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- Most cost-effective when:
  - Heating and cooling required
  - Large seasonal variations in temperature
  - New construction or HVAC replacement
  - For heating: low electricity costs and high gas & oil costs
  - For cooling: high electricity costs and peak load charges
- Availability of trenching and drilling equipment
- Uncertainty about cost of exchanger installation
- Customer's criteria for cost-effective

Heat Exchanger Layout, Commercial Building

GSHP Installation

Photo Credit: Craig Miller Productions and DOE (NREL PIX)

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Examples: Australia, Germany and Switzerland

Residential Building Systems

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- High-end homes
  - Higher capital costs
  - Longer term view of cost-effective
  - Environmental or comfort benefits
- Utility incentive can be a significant factor

20 kW Groundwater Heat Pump, Germany

Photo Credit: Bundesverband WärmePumpe (BWP) e.V.

320 Apartments, South Australia

Photo Credit: GeoExchange Consortium

Drilling Rig for Vertical Boreholes, Swiss Residence

Photo Credit: Eberhard & Partner AG

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Examples: UK and USA

Commercial Building Systems

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- Short payback periods often required (< 5 yrs)
- Land availability may pose problems
- Less internal space used
- Simple, distributed controls
- Reduced vandalism risk
- Reduced peak load charges
- Auxiliary heating not needed

Commercial Building, Croydon, UK

Photo Credit: Groenholland B.V.

Building Cluster, Kentucky, USA

Photo Credit: Marion Pinckley (NREL PIX)

Filling Station, Kansas, USA

Photo Credit: International Ground Source Heat Pump Association

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Examples: Canada and USA

Institutional Building Systems

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- Longer paybacks accepted
- More open to innovative systems
- Simultaneous heating and cooling loads

Trenching for Horizontal Exchanger

Photo Credit: Robert R. Jones/Oklahoma State University (NREL PIX)

School, Quebec, Canada

Photo Credit: Natural Resources Canada

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RETScreen® Ground-Source Heat Pump Project Model

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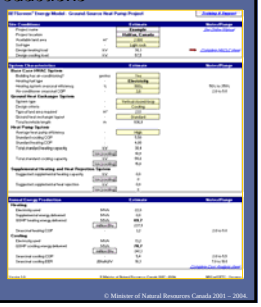
- World-wide analysis of energy production, life-cycle costs and greenhouse gas emissions reductions
  - Horizontal & vertical closed-loop
  - Groundwater open-loop
  - Residential, commercial, institutional & industrial
- Currently not covered:
  - Surface water GSHPs
  - Long-term thermal imbalances in the ground
  - Simultaneous heating & cooling (block loads only)
  - Water heating



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GSHP Energy Calculation

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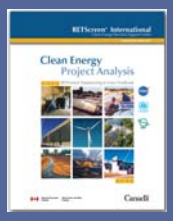
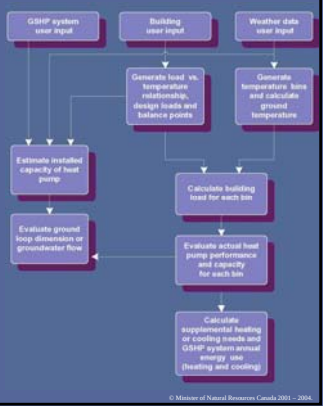


See e-Textbook

Clean Energy Project Analysis: RETScreen® Engineering and Cases

Ground Source Heat Pump Project Analysis Chapter



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Example Validation of the RETScreen® GSHP Project Model

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- Energy use compared for synthesized bins versus monitored data
- GHX length compared to 6 sizing programs and detailed simulation program

		Heating Energy use kWh	Difference %
Toronto	RETScreen	37,202	1.4
	Monitored	36,686	
Montreal	RETScreen	36,138	1.8
	Monitored	35,490	
Charlottetown	RETScreen	37,158	0.6
	Monitored	36,922	
Winnipeg	RETScreen	33,243	1.0
	Monitored	32,926	
Vancouver	RETScreen	37,888	-3.0
	Monitored	39,016	

Program	1 Year Design						10 Year Design*					
	Residence 1 Louisiana		Residence 2 Wisconsin		Commercial Nebraska		Residence 1 Louisiana		Residence 2 Wisconsin		Commercial Nebraska	
Average for other software	266		124		141		293		129		148	
vs. RETScreen Descriptive	257	-4%	135	9%	121	-14%	257	-12%	135	5%	121	-18%
vs. RETScreen Energy Use	236	-11%	127	2%	132	-6%	236	-19%	127	-2%	132	-12%
vs. Actual	344	29%	160	29%	141	0%	344	17%	160	24%	141	-5%

* 1 Year Design values used for RETScreen comparison

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Conclusions

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- GSHPs provide heating, cooling & hot water
- Ground dampens temp. variations & leads to high GSHP efficiencies
- GSHP initial costs are higher, but O&M costs are lower
  - Climates requiring heating and cooling are most promising
- RETScreen® estimates:
  - Frequency distribution of outside temperature
  - Building loads as a function of outside temperature
  - Annual space heating and cooling energy benefits
- RETScreen® is an annual analysis calculation that can achieve accuracy comparable to hourly simulation models
- RETScreen® can provide significant preliminary feasibility study cost savings

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Questions?

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For further information please visit the RETScreen Website at
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