



Keynote Speech:

Clean Energy Technologies: How to assess their viability?

Luis R. Rojas-Solórzano, Ph.D.

Associate Professor, Dept. of Mechanical Engineering
School of Engineering

Nazarbayev University, Rep. of Kazakhstan



NAZARBAYEV
UNIVERSITY

OUTLINE

I. PART 1

Introduction to Nazarbayev University: Mission, Vision, Teaching and Research stats.

II. PART 2

Keynote lecture



Astana
March 2016

1. PART 1

Nazarbayev University: *Mission, Vision, Teaching and Research stats.*



- Founded by first President of the Republic of Kazakhstan Nursultan Nazarbayev in **June 2010**. Located in Astana, Kazakhstan.
- **Research university** aiming to develop as a renown international university combining **education, research and innovation**.
- **Vision:** to give **Kazakhstan** and the world the scientists, academics, managers and entrepreneurs they need to prosper and develop.
- **Mission:** To be a **model for higher education** reform and modern research in **Kazakhstan** and to contribute to the establishment of **Astana** as an international innovation and knowledge hub.

Academic Excellence

PARTNERSHIPS FOR EXCELLENCE

Cambridge University (UK), Colorado School of Mines (USA),
Duke University (USA), National University of Singapore (Singapore),
University College London (UK), University of Pennsylvania(USA),
University of Pittsburgh (USA), University of Warwick (UK),
University of Wisconsin-Madison (USA), Argonne National Laboratory (USA),
Lawrence Berkeley National Laboratory (USA),
University of Pittsburgh Medical Center (USA)



NU ACADEMIC PROGRAMS:

Foundation Program, 16 Undergraduate Programs, 18 Master Programs, 2 PhD Programs.

NU six strategic and technological research areas

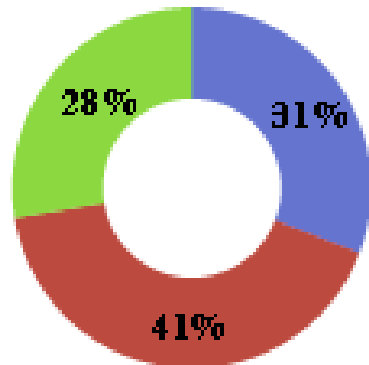
1. **Big Data:** ever more powerful computing, processing, and analyzing power of large data sets – the “digitization of the world”;
2. **Artificial Intelligence:** builds on the above but combines with behavioral sciences, neurosciences, neuromorphology;
3. **Biomedical, bioengineering and bioinformatics:** all data driven, that interact with both of the above and is transforming medical research, clinical services and medical education – based on a cross-disciplinary platform;
4. **Material sciences:** self-healing concrete, structures that revert back to the original shape when desired, new products such as graphene, new production methods such 3 and 4 D printing this advancement enabled the transformation of many major discoveries into innovative commercial products;
5. **Energy:** *interdisciplinary research in the fields using conventional types of energy production (coal, oil and gas), renewable source of energy and storage research (wind, water and solar energy, accumulator batteries and others) and high energy physics research, including but not limited to thermonuclear synthesis and atomic energy.*
6. **Socio-economic and political sciences:** including but limited research fields on business and finance, history and sociology, geography and anthropology and others.

NU Students

3268 STUDENTS AT NU

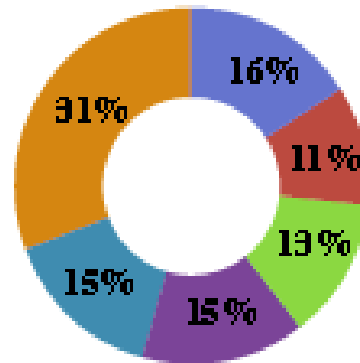
As of March 2016

UNDERGRADUATE STUDENTS
2104



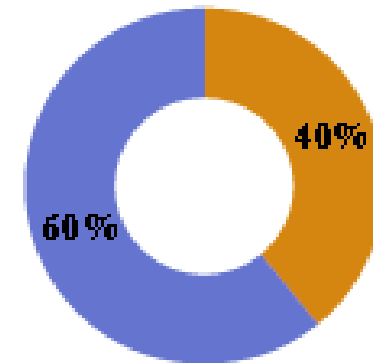
School of Engineering
School of Science and Technology

MASTER'S STUDENTS
392



School of Humanities and Social Sciences
Graduate School of Business

PHD STUDENTS
68



Graduate School of Public Policy
Graduate School of Education

DOCTOR OF MEDICINE STUDENTS – 20
FOUNDATION STUDENTS – 684

NU students by gender:

♂ **52%** ♀ **48%**

NU Graduates: Class of 2015

The first graduation class counted 522 students - 380 bachelors and 142 Master's students. The first Graduation Ceremony was held with participation of the President of RK N. Nazarbayev on June 15, 2015.

NU graduates	Graduate studies	Employed	Seeking employment and others	Career break
Bachelor's	190 (50%)	126 (33%)	54 (14%)	10 (3%)
Master's	9 (6%)	112 (79%)	15 (11%)	6 (4%)

BACHELORS WHO CONTINUED WITH GRADUATE STUDIES:

- 175 students to Master's degree program, 15 to PhD program
- 124 abroad, 63 at NU, 3 in other Kazakstani universities
- Examples of universities that accepted NU graduates: MIT, Stanford, University College London, Duke, Warwick, National University of Singapore, LSE, Columbia Imperial College London, Seoul National University and others;

FINANCING BY:





2nd. Part. OUTLINE

1. World Energy Demand and Challenges.
2. Clean Energy Technologies.
3. Introduction to RETScreen[®] software.
4. Wind Energy Project Analysis. Case Study: Wind Farm in Andhra Pradesh, India.
5. Risk and Sensitivity Analysis.
6. Q & A's.



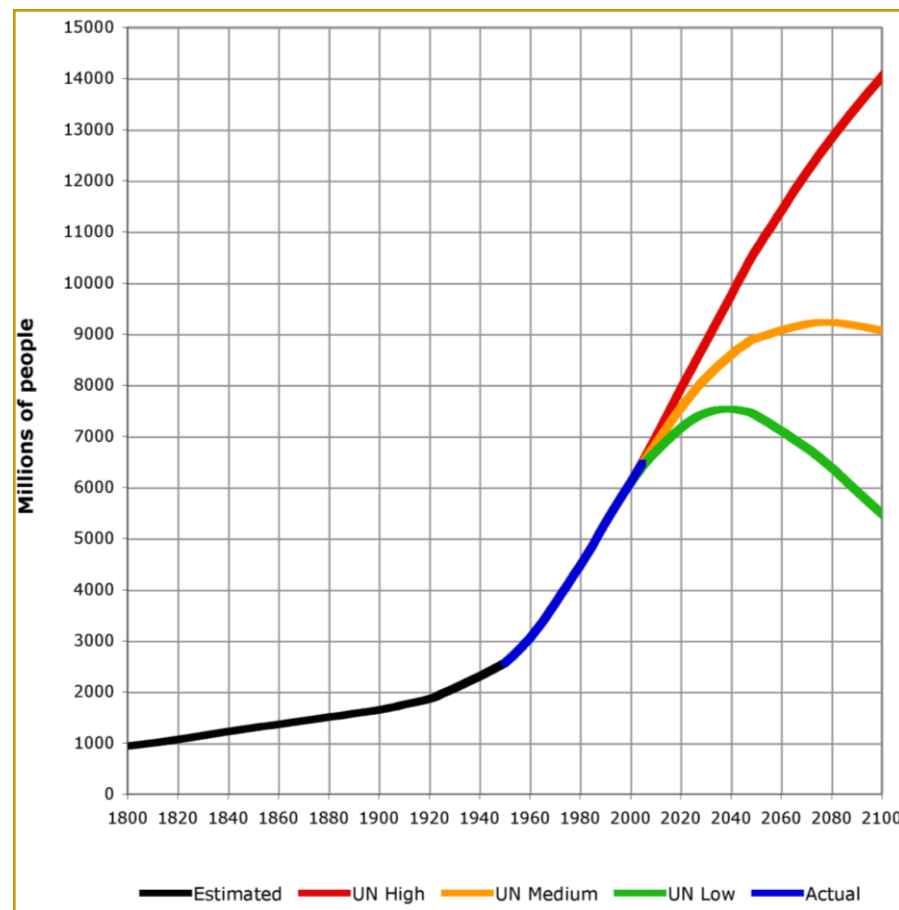
1. Introduction to World Energy Demand and Challenges

■ World population⁽¹⁾:

- 2500 Millions in 1950
- **6800 Millions in 2010**
- Projection: 8000/9000 Millions in 2025/2050

■ World population **growth rate** is decaying, but still positive and larger in less developed countries⁽¹⁾. Eg., by **2010**:

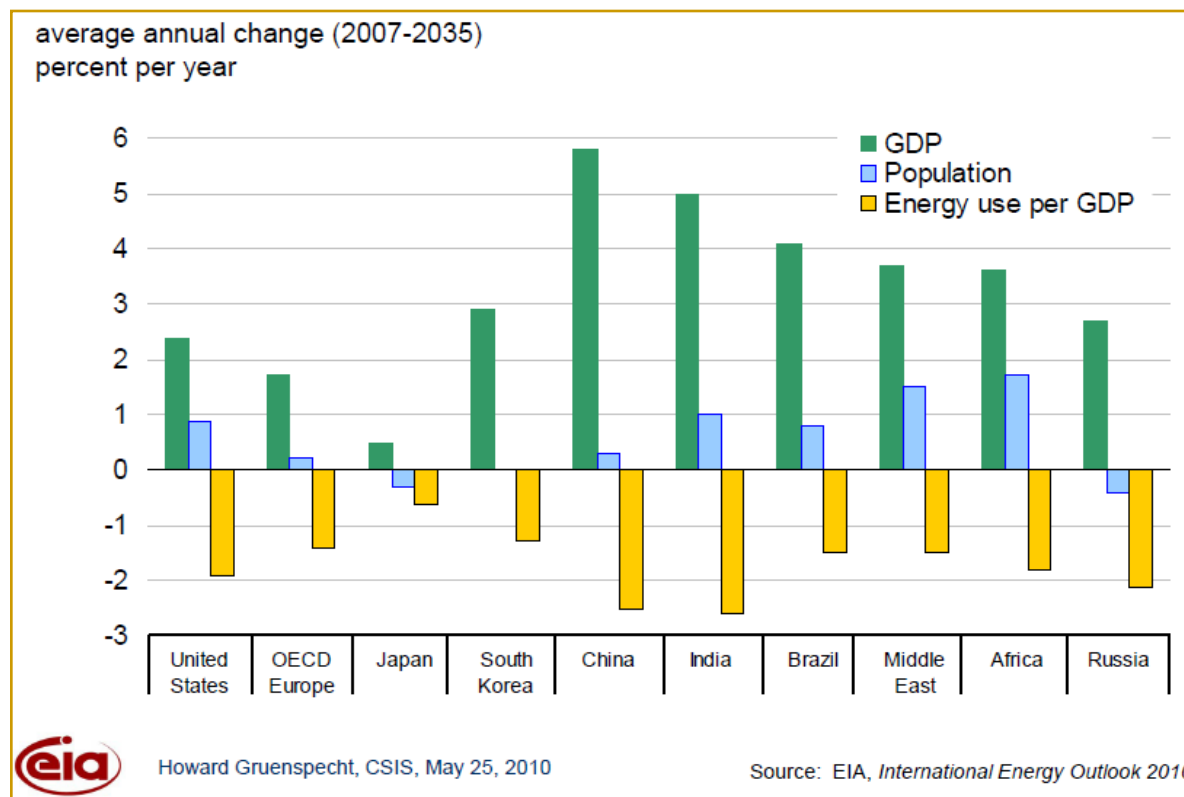
- **Africa (~2%)**
- **Lat. Am. and Caribbean (~1.2%)**
- **Asia (~1.1%)**
- Oceania (~1%)
- Northern America (~0.9%)
- Europe (~-0.15%).



Picture by Loren Cobb. <http://creativecommons.org/licenses/by-sa/3.0/deed.en>

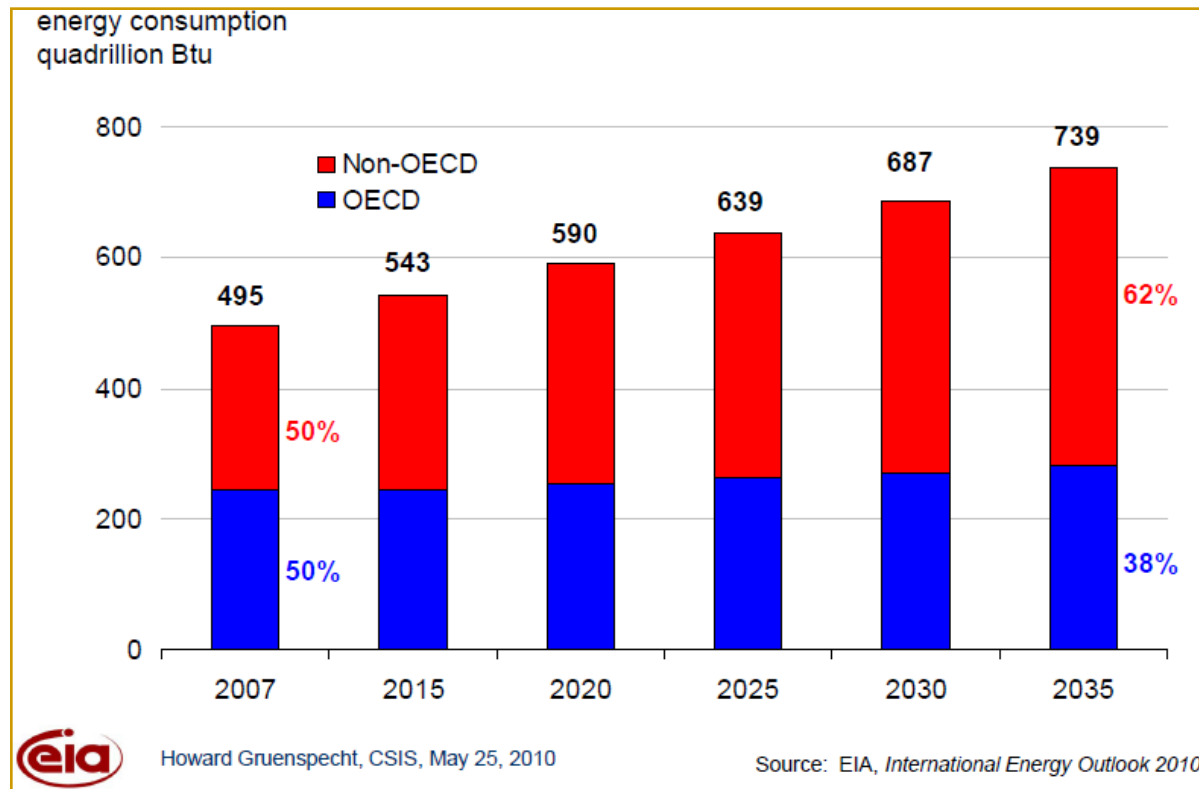


- **Economy and population drive increase in energy demand. *China and India* with largest projected average annual growth (>5%) 2007/2035⁽¹⁾.**



Source: (1) International Energy Outlook 2010, with Projections to 2035 by Howard Gruenspecht, Deputy Administrator of US-EIA. csis.org/files/attachments/100525_HGruenspecht_IEO2010.pdf

- **Energy consumption** is projected to growth from 495 to 739 quadrillions BTU (2007-2035). **86% increase from non-OECD countries**⁽¹⁾.



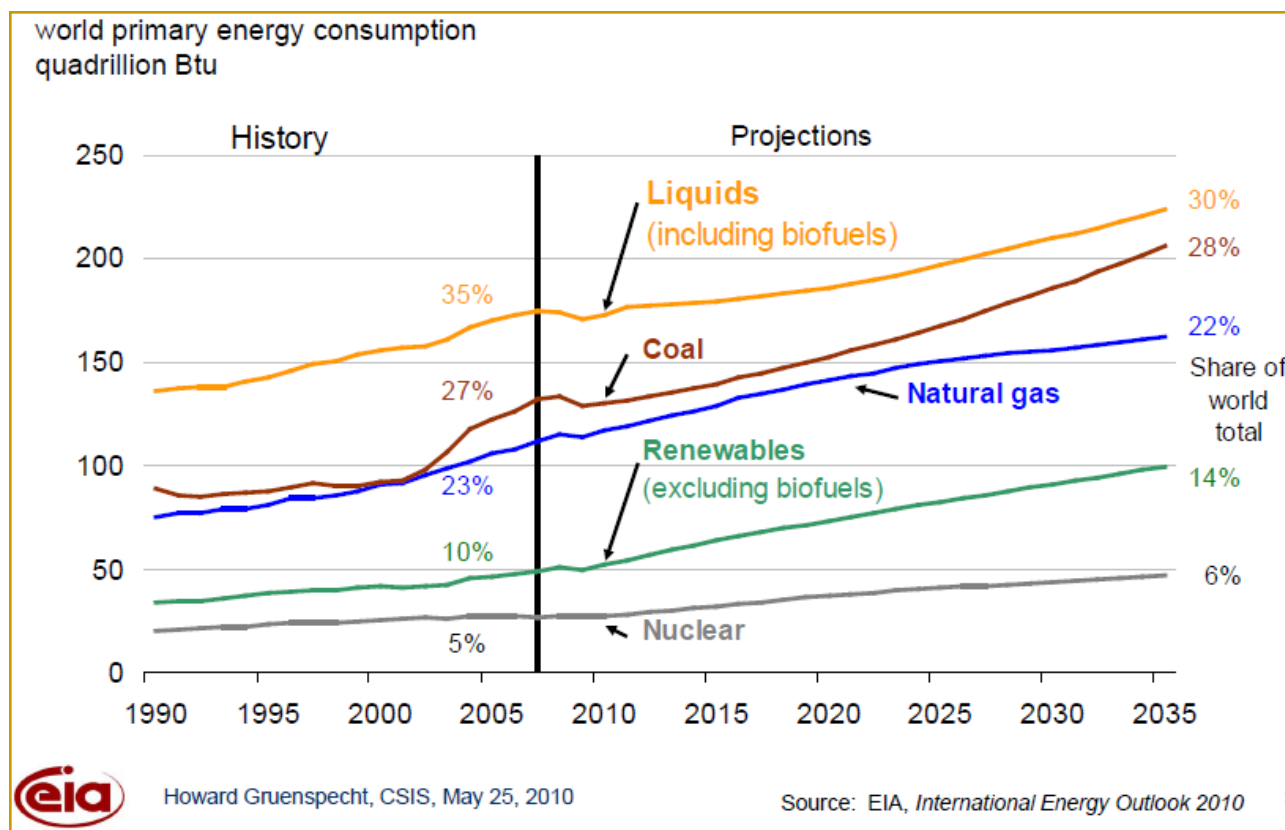
OECD Countries (2010):

Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK and USA.

- 59% World GDP
- ¾ world trade
- 95% world official assist.
- 50% energy consumption
- 18% world population



- **Renewable energy (exc. biofuels) is the fastest growing source w/shares 10% to 14% (2007-2035)⁽¹⁾.**



Source: (1) International Energy Outlook 2010, with Projections to 2035 by Howard Gruenspecht, Deputy Administrator of US-EIA.

www.csis.org/files/attachments/100525_HGruenspecht_IEO2010.pdf ; EIA: US Energy Information and Administration (not to confuse with European-located IEA)

... however, today:

- 1300 millions (20%) lack of electricity**
- 2700 millions (40%) rely on biomass for cooking**
- Global GHG emissions keep growing and we live irreversible climate changes.



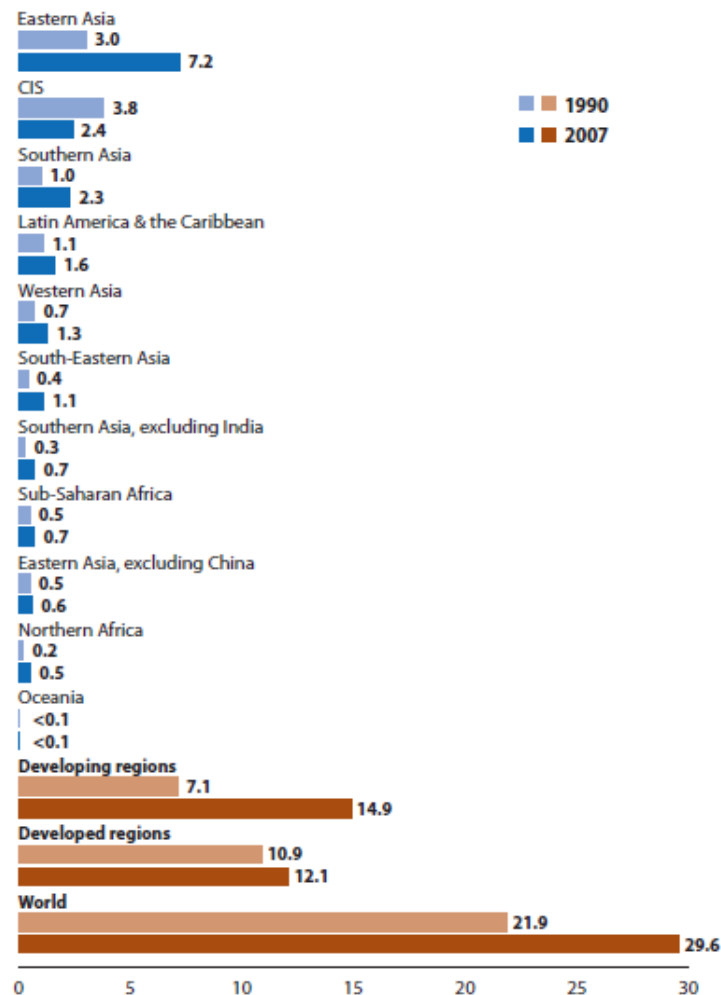
Picture: <http://www.antemedius.com/content/climate-change-effects-hugely-unequal-globally>



Picture: http://www.aboutmyplanet.com/files/2009/03/climate-change_1.jpg

→ We need to increase the rate of implementation of Clean Energy Technologies

Emissions of carbon dioxide (CO₂), 1990 and 2007
 (Billions of metric tons)



CIS: Commonwealth of Independent Countries (Former Soviet Union countries)

Source: The Millennium Development Goals Report, UN, 2010

2. Clean Energy Technologies

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Clean Energy Technologies

Pursue the reduction of ecological footprint & pollution vs. conventional technologies

Energy Efficiency

- ▶ Using less energy resources to meet the same energy needs

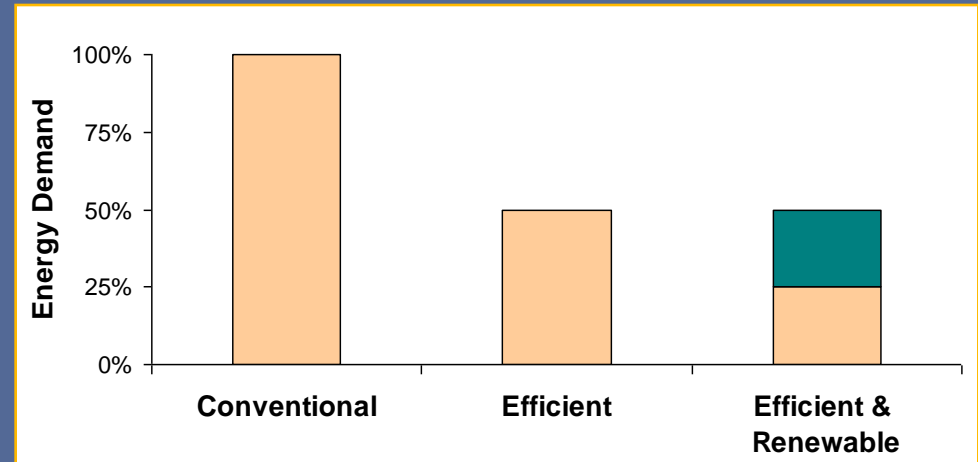
Renewable Energy

- ▶ Using non-depleting natural resources to meet energy needs



Super Insulated Passive Solar Home

Photo Credit: Jerry Shaw





India: Energy Efficiency (EE) Executive Summary

- India's **EE is the fifth lowest** in the world, but there is the potential for substantial energy savings.
- **Industrial** sector consumes **~30% of total** commercial energy available in India, **70% of which** is in energy-intensive sectors, for example **fertilisers, aluminium, textiles, cement, iron and steel, and paper**. **15-25%** of this consumption is **avoidable**.
- **5-10% energy saving possible** by better “housekeeping” measures.
- Another **10-15% saving** is possible with small investments, such as **low cost retrofits**, the use of energy efficient devices and controls etc.
- Space for improvements: @2009, Final energy consumption: **37.5% Residential**, 11.4% Transport, 3.9% Agriculture, **3.3% commercial**, etc.



Common Features of Clean Energy Technologies

LR

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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
 - ▶ Favor generation of local jobs
- Most common clean energy technologies: wind, hydro, pv, swh, chp, etc.

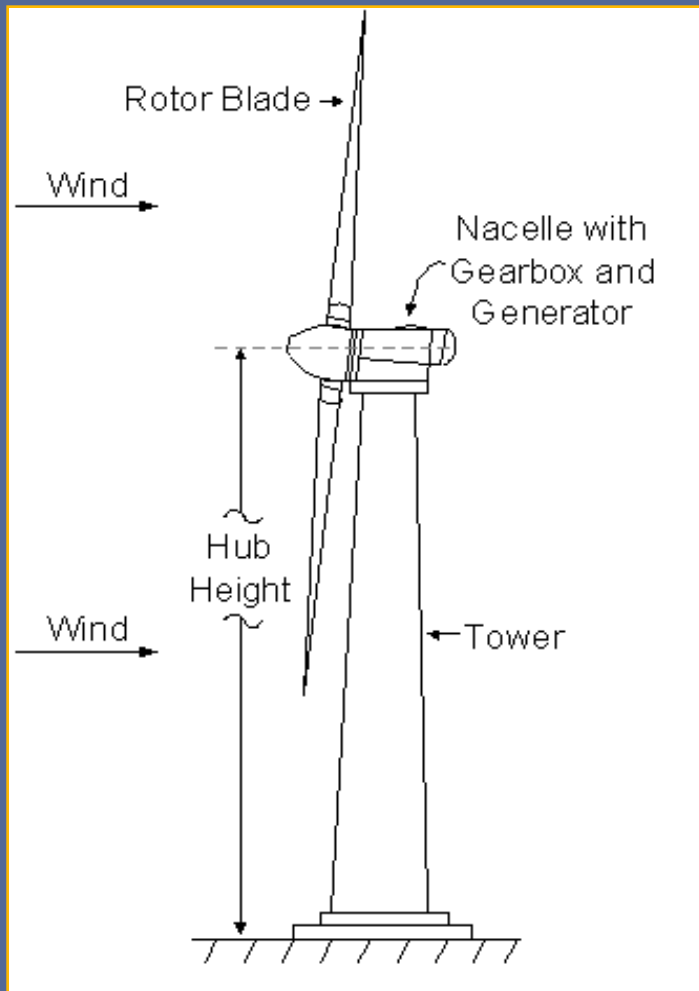




Wind Energy: Technology & Applications

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

1MW-5MW



Central-Grid

Warren Gretz, NREL PIX

10kW-200kW



Isolated-Grid

Phil Owens, Nunavut Power

50W-10kW LR



Off-Grid

Southwest Windpower, NREL PIX



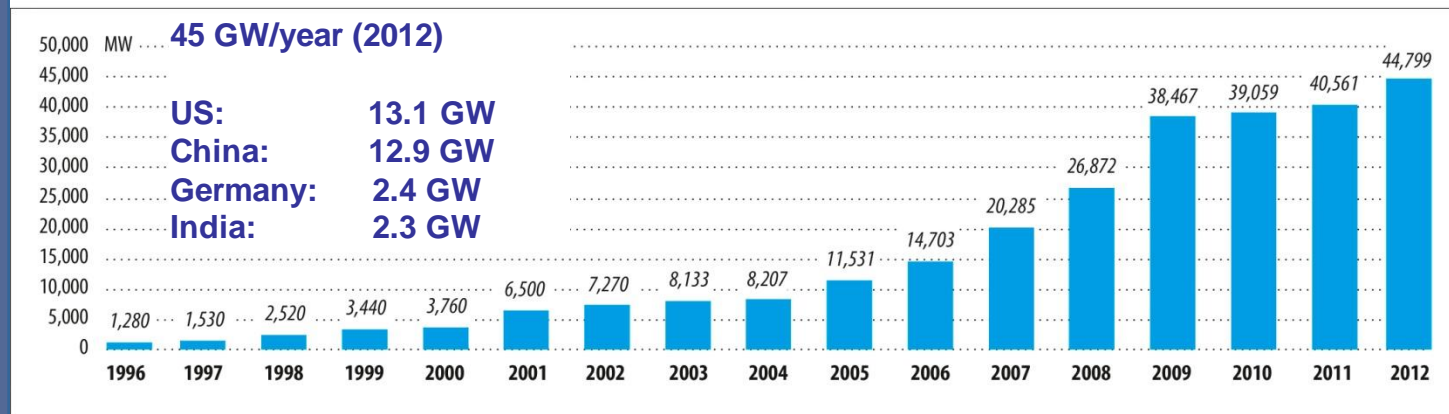
Wind Energy Market

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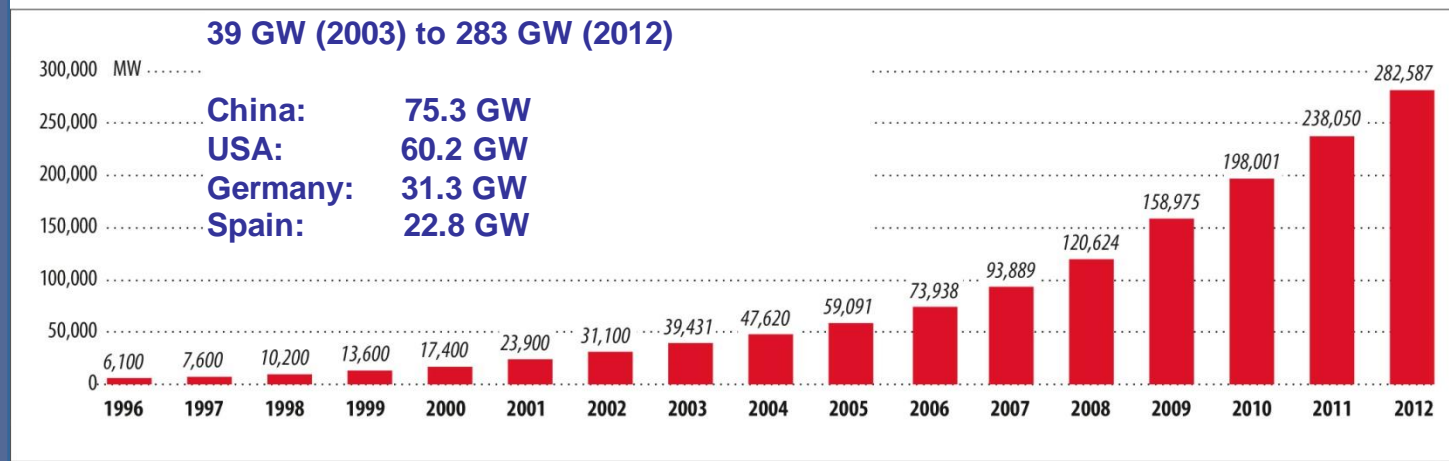
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Cumulative and Annual Wind Turbine Installations Worldwide by 2012

Global Annual Installed Wind Capacity 1996-2012



Global Cumulative Installed Wind Capacity 1996-2012



Source: GWEC

Source: BTM Consult, World Wind Energy Association, Renewable Energy World & Global Wind Energy Council (www.gwec.net)

(*) Since 1990, wind energy technology emerged as the fastest electricity generation tech in the world. LR



India Renewable Energy: Wind Executive Summary

- Most of India's windy territory is category Class 2 (200-300 W/m² or 5.6-6.4 m/s* at 50 MAGL or 4.4-5.1 m/s* at 10 MAGL).

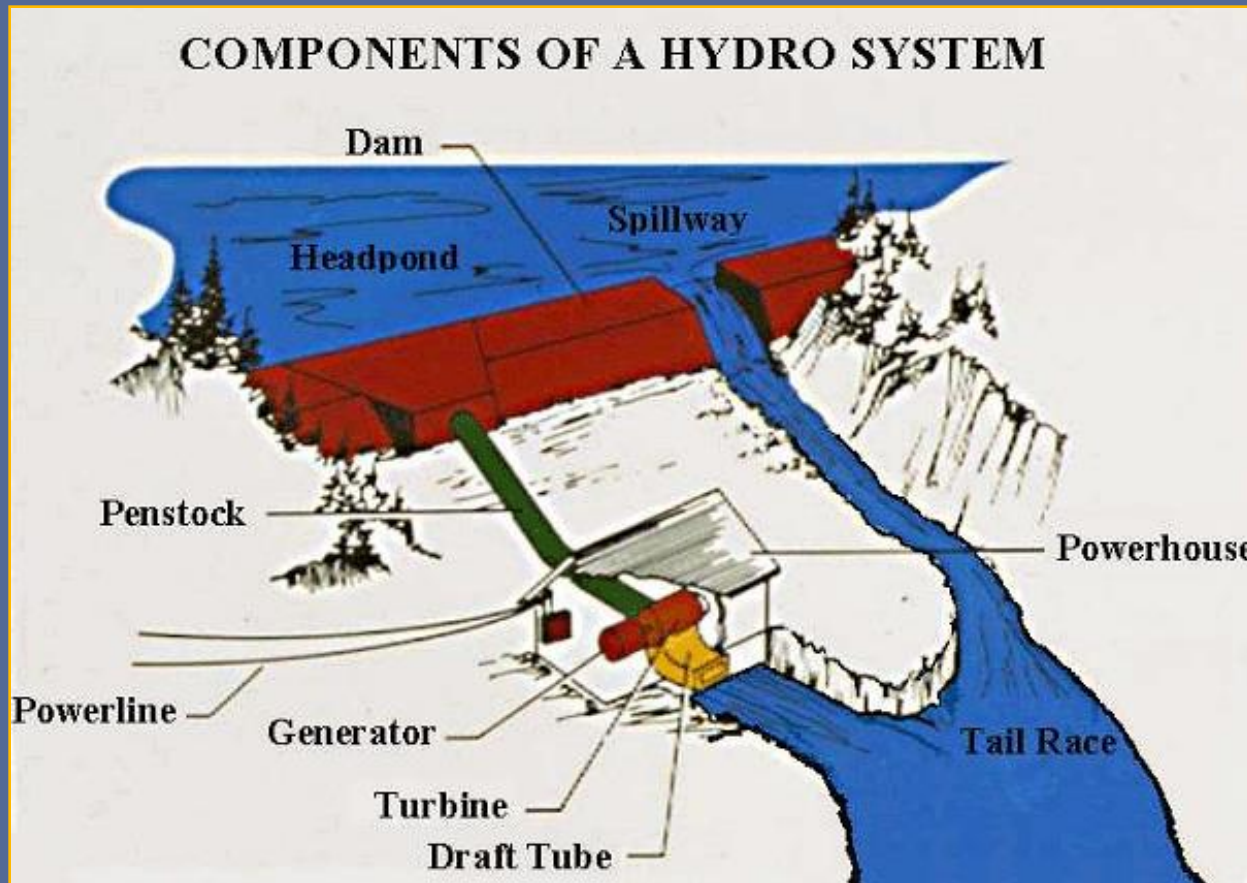
(*) <http://rredc.nrel.gov/wind/pubs/atlas/tables/1-1T.html>

- Regions with good wind resources are located in: Tamil Nadu, Karnataka, Kerala, Gujarat, Andhra Pradesh, Maharashtra, Rajasthan and Madhya.
- @2011, installed capacity of 14.9 GW (71% of total renewable energy capacity) led by Tamil Nadu (6.3 GW), Maharashtra (2.4 GW), Gujarat (2.3 GW), Karnataka (1.8 GW), Rajasthan (1.7 GW), Madhya Pradesh (0.3 GW), Andhra Pradesh (0.2 GW), Kerala (0.04 GW) and West Bengal (0.001 GW).

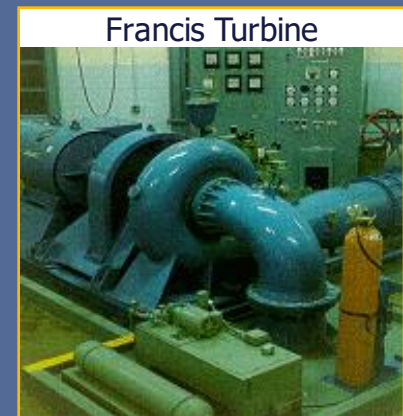
Small Hydro: Technology & Applications

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

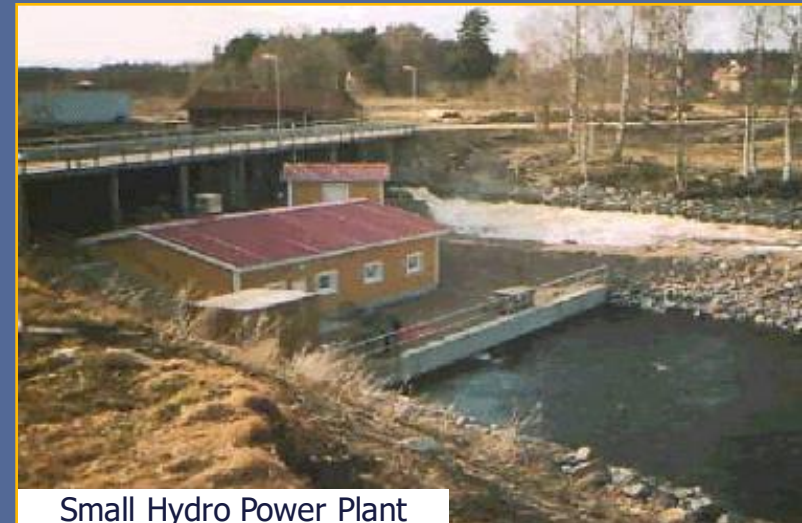


Small Hydro Market

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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



Small Hydro Power Plant

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



India Renewable Energy: Hydro Executive Summary

- Hydropower installed capacity of **37.4 GW** @ 31-March, 2011 (represents **18.6% of total installed capacity** of power generation).
- Small-Hydro **potential of 15 GW**. 16% of this has been already developed.
- **5415 places** have been identified for Small-Hydros (**14.3 GW**) by Ministry of New and Renewable Energy.
 - Largest number of sites in **Arunachal Pradesh** (total of 1.3 GW).
 - Largest potential in **Himachal Pradesh** with 547 sites (total of **2.3 GW**).



Photovoltaic (PV): Technology & Applications

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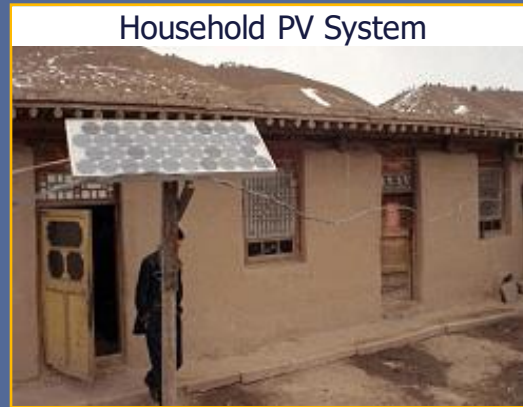
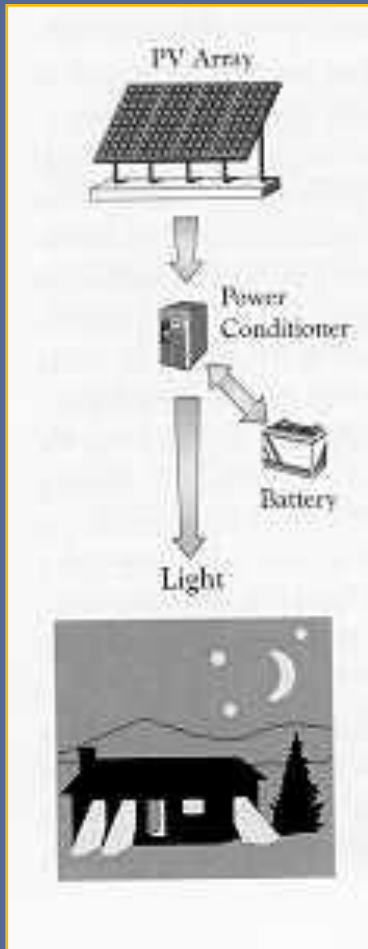


Photo Credit: Tsuo, Simon DOE/NREL

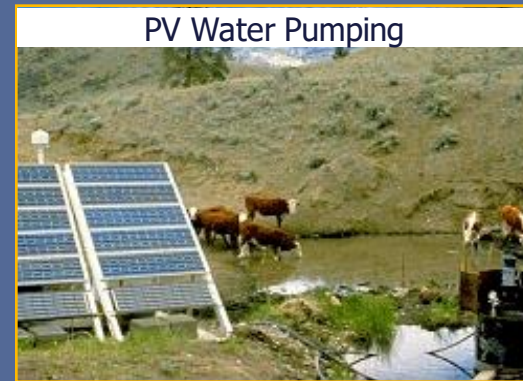
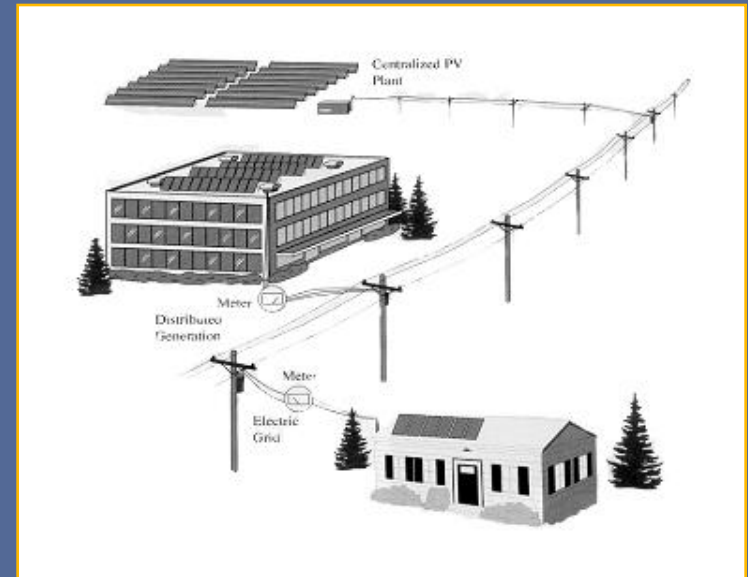


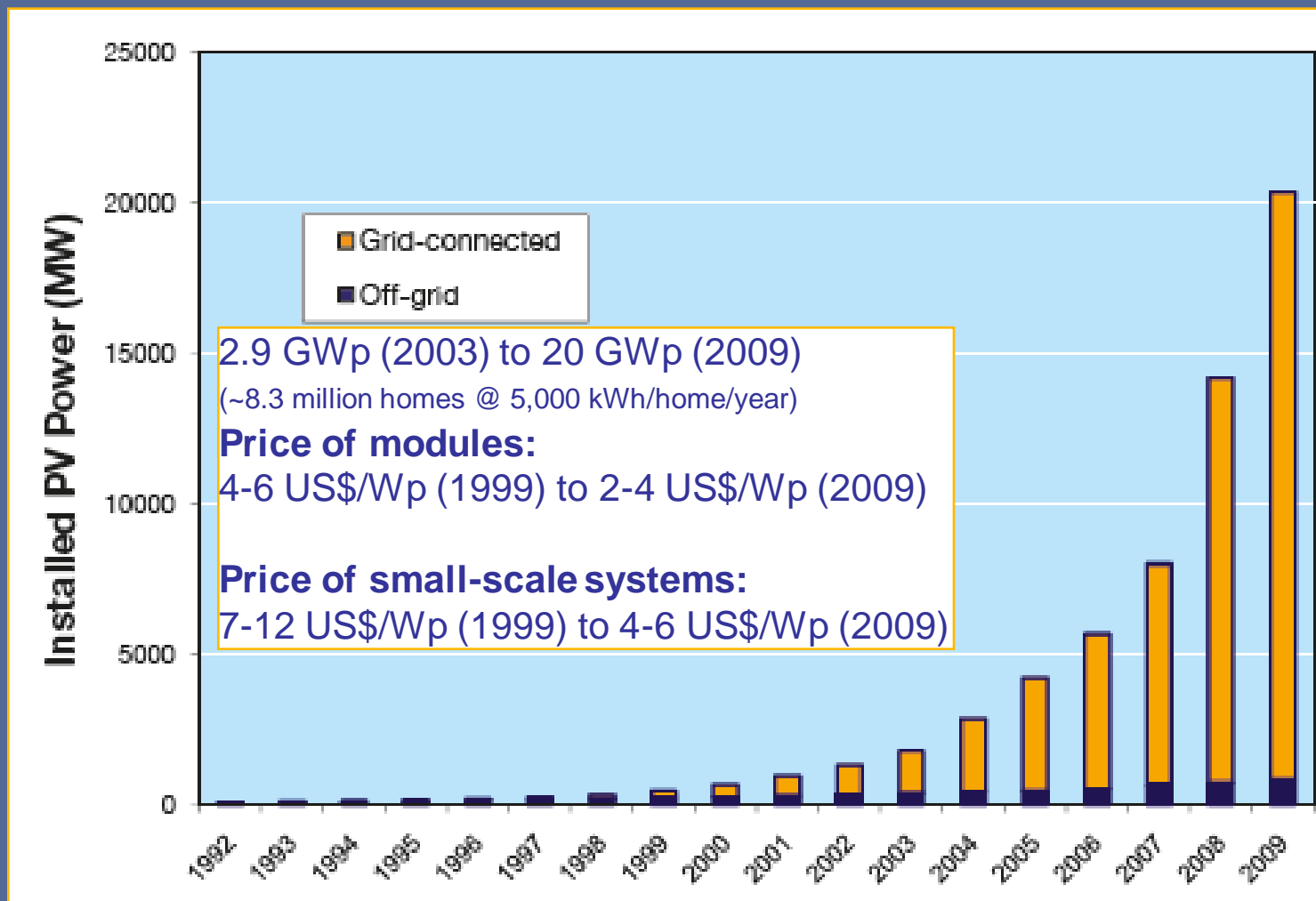
Photo Credit: Strong, Steven DOE/NREL



Photovoltaic Market

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Source: <http://www.iea-pvps.org/> Trends in PV, IEA Report 2010



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





India Renewable Energy: Solar Executive Summary

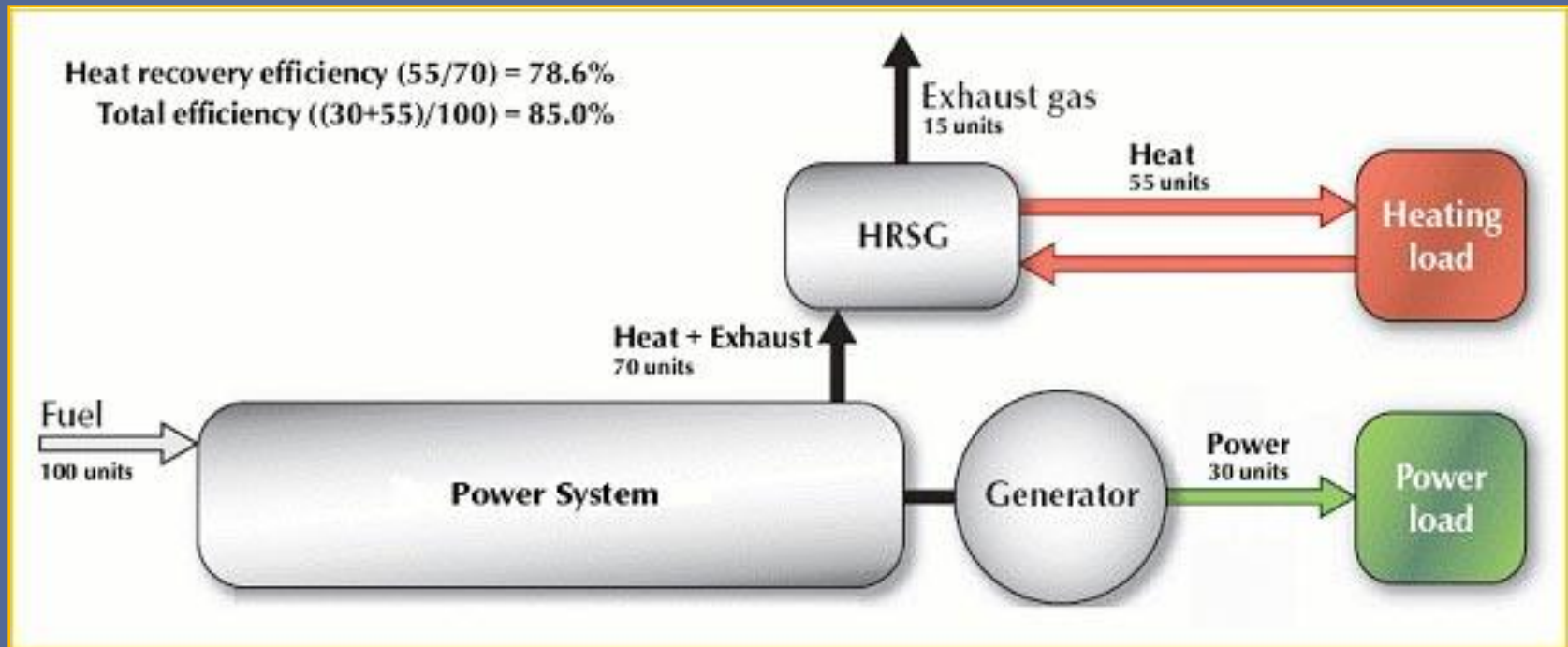
- Annual solar radiation ranges from **1.2 to 2.3 MWh/m²**, but most of the country has above 1.9 MWh/m²/year (**~300 clear sunny days**). (For example, Germany ranges from 0.8 MWh/m² to 1.2 MWh/m².)
- India might be fully supplied with PV (10% of efficiency) by covering only **0.1% of its land area**.
- India produces **less than 1%** of its total energy demand by solar energy. Active **On-grid** was just **10 MW** @Dec-2010. Jawaharlal Nehru National Solar Mission (JNNSM) (2009) plans to enable deployment of **20 GW of solar power by 2022**.
- **Cochin International Airport** will become the first airport in the country to run its utility grid on solar PV.
- **Kerala airport** has **100kWp** PV capacity and produces around 148MWh/year, primarily for air conditioning. The project is favored by 30% subsidy under the JNNSM.

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”)



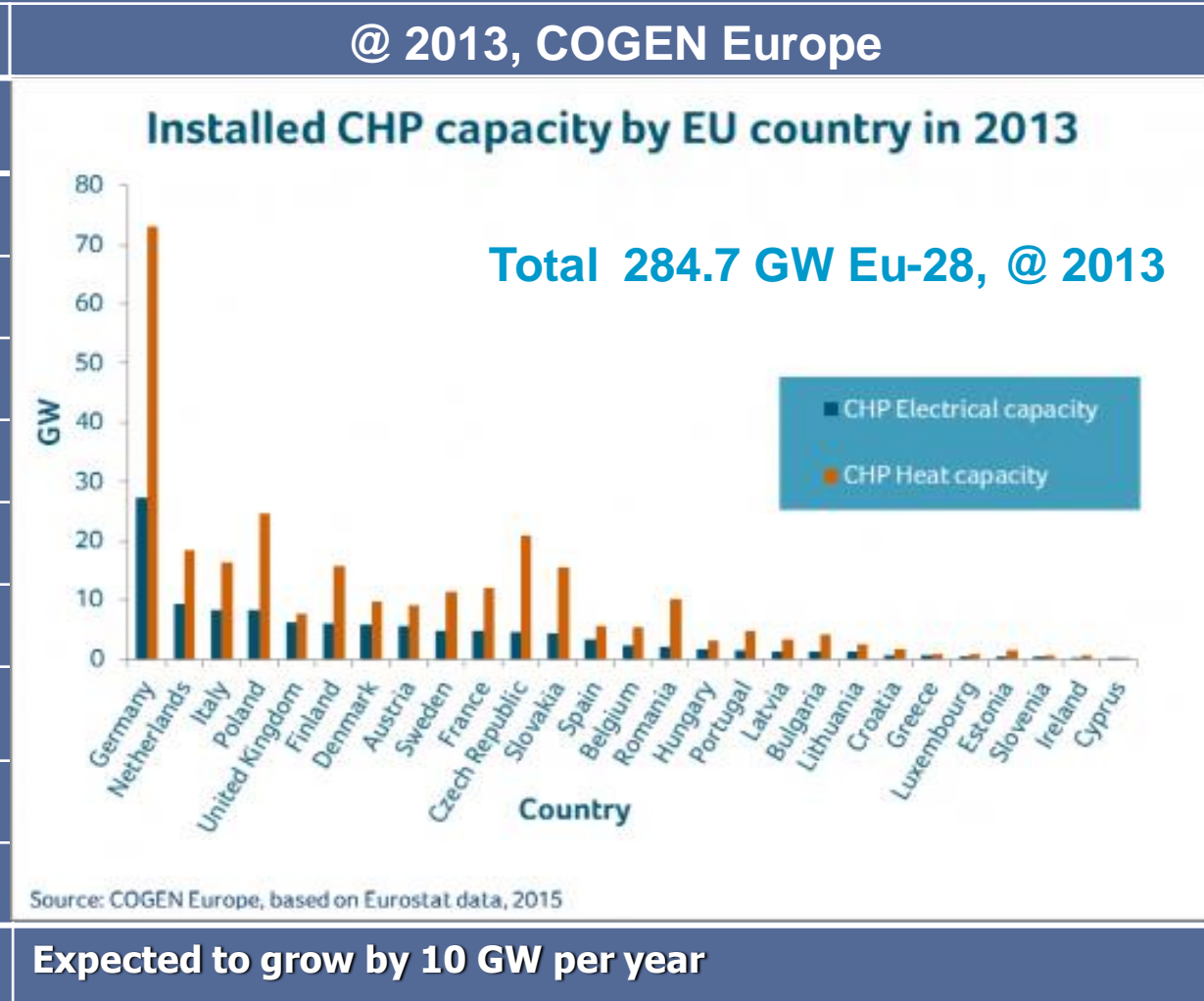


Combined Heat and Power Market

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@ 2004, WADE	
Region	Capacity
Canada	12 GW
USA	67 GW
China	32 GW
Russia	65 GW
Germany	11 GW
UK	4.9 GW
Brazil	2.8 GW
India	4.1 GW
South Africa	0.5 GW
World	247 GW



Expected to grow by 10 GW per year



India Renewable Energy: CHP and Biomass, Executive Summary

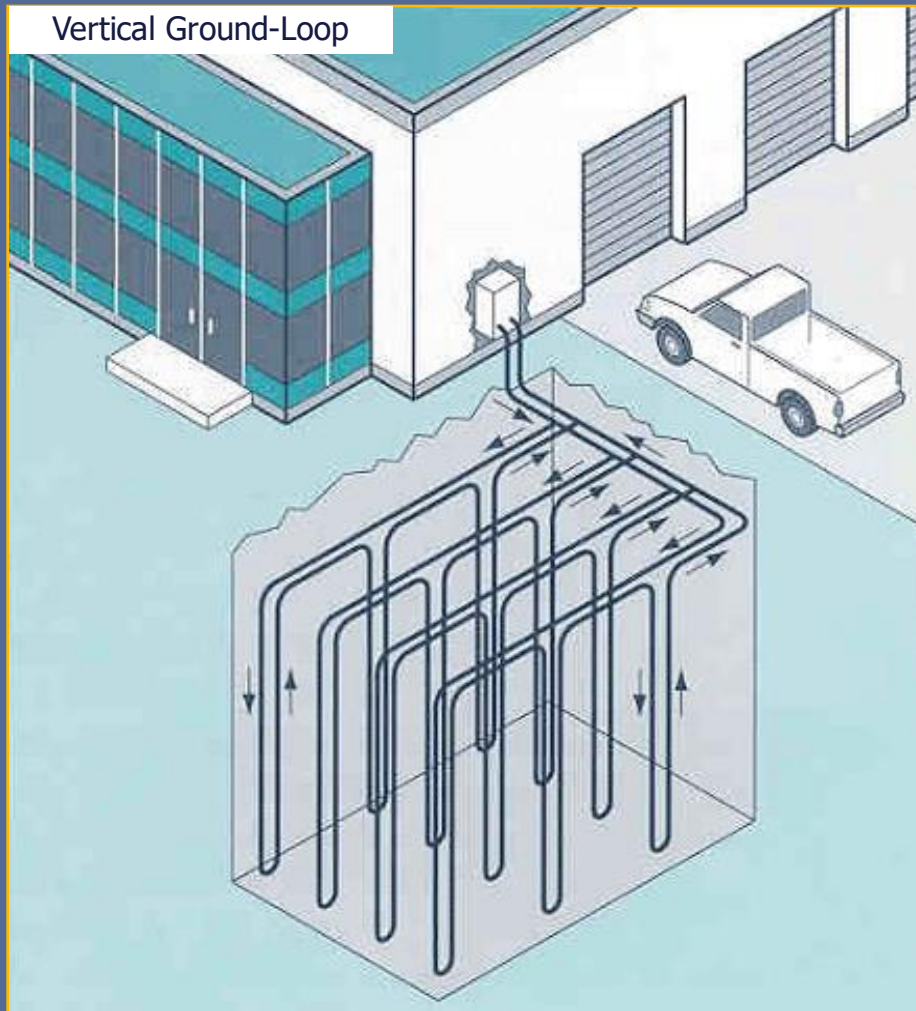
- The Ministry of New and Renewable Energy has implemented biomass power/co-generation programme **since mid-90's**.
- Approximately **500 biomass** power and cogeneration projects (@2016) with **4760 MW capacity** have been installed in the country for feeding power to the grid. In addition, around **30 more ongoing** biomass power projects for **350 MW**.
- Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Uttar Pradesh are leading regions in implementation of **bagasse cogeneration** projects.
- Andhra Pradesh, Chattisgarh, Maharashtra, Madhya Pradesh, Gujarat and Tamil Nadu are leading in biomass power projects.
- Biomass projects are benefited from **fiscal incentives**, concessional import duty, **tax holiday for 10 years**, bank loans, among others.



Ground-Source Heat Pump Technology & Applications

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





Ground-Source Heat Pump Market

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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



India Renewable Energy: Geothermal, Executive Summary

- **Little commercial use** of geothermal resources in India for heat or power generation.
- Geothermal resources, however, have been mapped, and the Geological Survey of India estimates the **power generation potential** to be in the order of **10 GW**.
- Geothermal energy is **currently used mostly** for direct use; i.e., **bathing and swimming**.
- It is estimated an **installed capacity of 0.2 GW (thermal)**, with energy use of 1607 TJ/year and capacity factor of 25%.



... However,

When is it technically and economically viable to implement Clean Energy Technologies?

→ We need to perform Life Cycle Cost Analysis (LCCA)

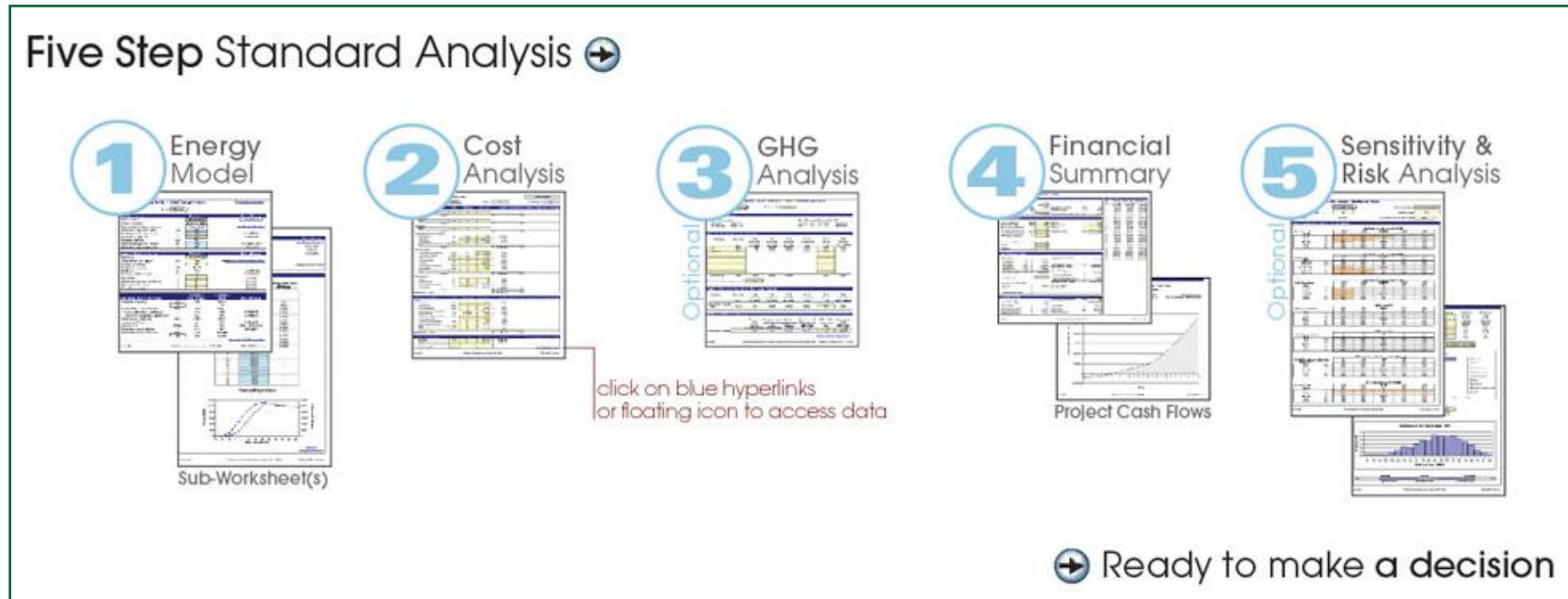
How to perform LCCA? with tools like RETScreen (What is it?)



3. Introduction to RETScreen® Software

Lecturer:

Luis R. Rojas-Solórzano, Ph.D.
 Associate Professor, Dept. of Mechanical Engineering
 School of Engineering
 Nazarbayev University, Rep. of Kazakhstan





What is RETScreen® Approach?

LR

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- Comparison between a **“base case”** —typically the conventional technology or measure—and a **“proposed case”**—the clean energy technology.
- Cost analysis based on **incremental values**.
- **Energy benefits** are the **same** for base and proposed case. Thus, X units of energy produced by proposed technology are compared to X units of energy from base case.
- **End goal** is to determine whether or not the **balance of costs** of the proposed technology is attractive along the **life-cycle** of the project.





Cashflow Calculations: What does RETScreen® do?

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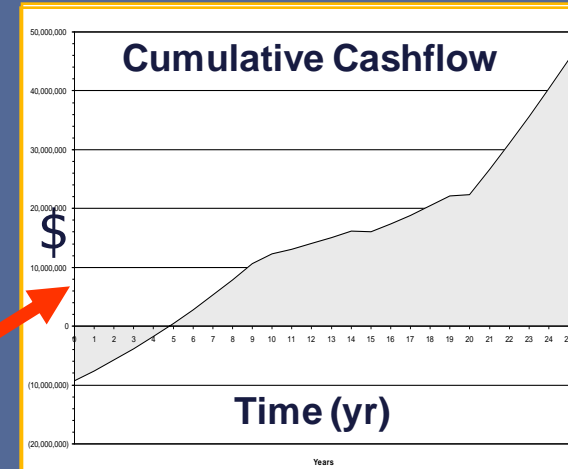
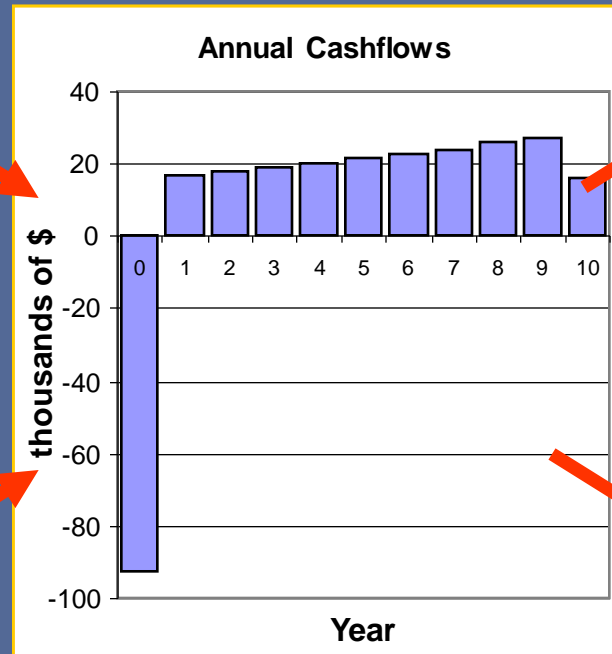
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Cash Inflows

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.



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?
- Need to perform: Sensitivity and Risk Analyses (see example)

RETScreen® Sensitivity and Risk Analysis - Wind Energy Project

Use sensitivity analysis sheet? Yes
 Perform risk analysis too? Yes
 Project name: Wind Farm
 Project location: Andhra, India

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

[Click here to Calculate Sensitivity Analysis](#)

Sensitivity Analysis for After-tax IRR and ROI

RE delivered (MWh)	Avoided cost of energy (\$/kWh)				
	0.0760 -20%	0.0855 -10%	0.0950 0%	0.1045 10%	0.1140 20%
32,545	4.2%	8.2%	11.8%	15.2%	18.5%
36,614	8.2%	12.3%	16.7%	20.4%	24.1%
40,682	13.1%	17.4%	21.6%	25.7%	29.8%
44,750	17.3%	22.0%	26.5%	31.1%	35.6%
48,818	21.5%	26.5%	31.6%	36.5%	41.5%

Initial costs (\$)	Avoided cost of energy (\$/kWh)				
	0.0760 -20%	0.0855 -10%	0.0950 0%	0.1045 10%	0.1140 20%
24,524,023	32.2%	31.4%	31.4%	31.4%	32.5%
24,524,023	26.2%	26.2%	26.2%	26.2%	26.4%
24,524,023	21.6%	21.6%	21.6%	21.6%	21.6%
24,524,023	17.2%	17.2%	17.2%	17.2%	17.2%
24,524,023	14.7%	14.7%	14.7%	14.7%	14.7%

Risk Analysis for After-tax IRR and ROI

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Avoided cost of energy	\$/kWh	0.0950	15%	0.0808	0.1093
RE delivered	MWh	40,682	15%	34,580	46,785
Initial costs	\$	31,161,365	20%	24,934,312	37,401,558
Annual costs	\$	770,000	15%	654,500	885,500
Debt ratio	%	10.0%	5%	66.5%	73.5%
Debt interest rate	%	14.0%	30%	3.8%	18.2%
Debt term	yr	25	0%	25	25
RE production credit	\$/MWh	0.025	30%	0.003	0.068

[Click here to Calculate Risk Analysis](#)

Impact on After-tax IRR and ROI

Parameter	Value	Level of risk
Median	20.0%	20.0%
Level of risk	10%	10%
Minimum within level of confidence	13.3%	13.3%
Maximum within level of confidence	27.3%	27.3%

Distribution of After-tax IRR and ROI

Debt ratio (%)	0%	10%	20%
70.0%	77.0%	84.0%	84.0%
26.1%	23.4%	25.0%	25.0%
26.2%	26.2%	26.2%	26.2%
21.6%	23.1%	25.6%	25.6%
19.4%	20.1%	21.3%	21.3%
17.2%	17.2%	17.2%	17.2%

Debt term (yr)	0%	10%	20%
25.0	N/A	N/A	N/A
25.1%			
23.4%			
21.6%			
20.1%			
19.4%			
17.2%			

Production credit (\$/kWh)	0%	0.028	0.030
11.8%	12.3%	12.8%	12.8%
16.7%	17.3%	18.0%	18.0%
21.6%	22.4%	23.2%	23.2%
26.2%	21.5%	24.4%	24.4%
31.6%	32.6%	32.8%	32.8%



4. Wind Energy Project Analysis



Utility-Scale Turbine



Photo Credit: Nordex AG



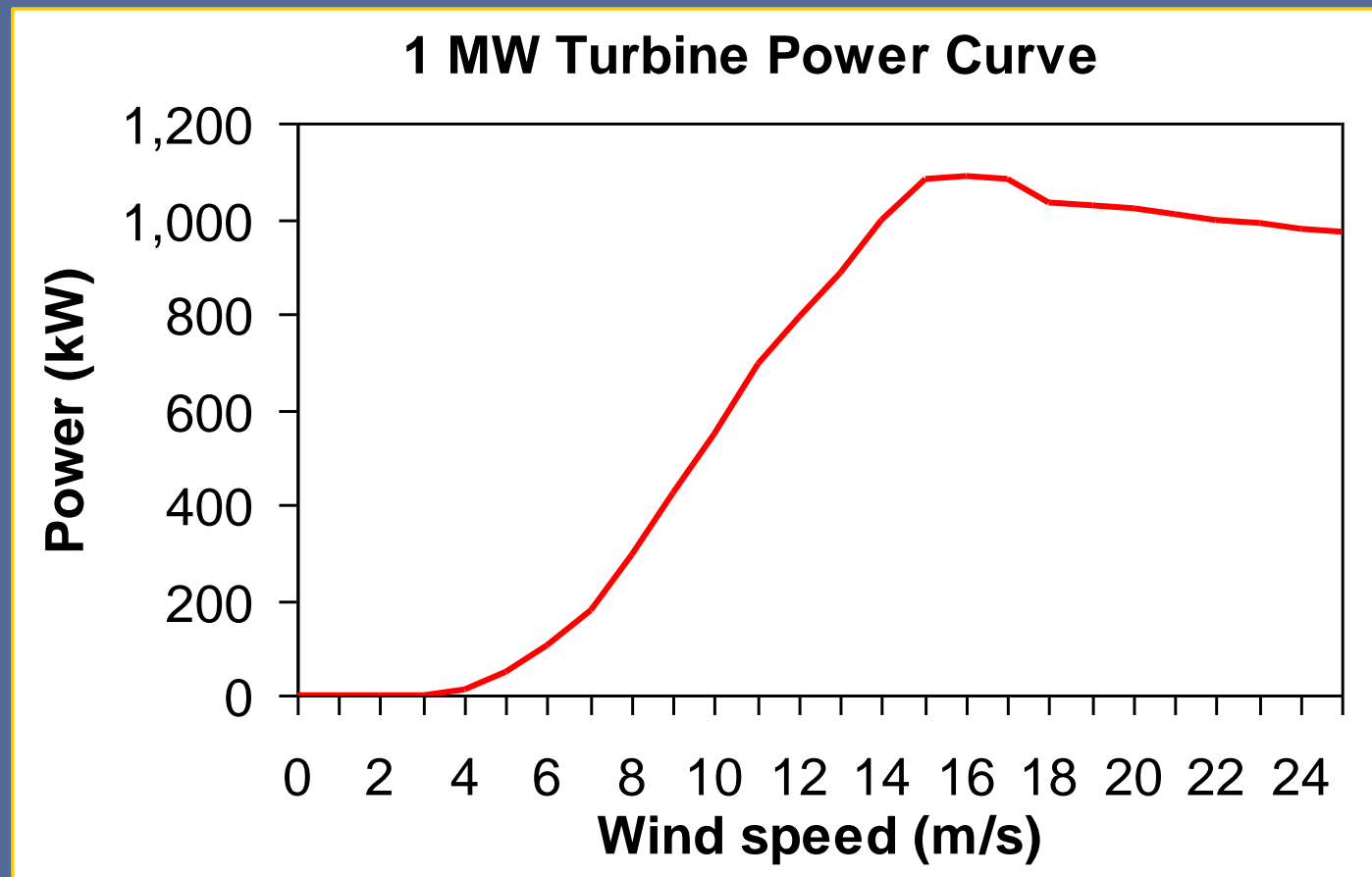


Wind Turbine Description

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www.retscreen.net

- Typical Wind Turbine Power Curve





Elements of Wind Energy Projects

RETScreen® INTERNATIONAL

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- Wind resource assessment (1-2 years)
- 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

Elements of Wind Energy Projects

RETScreen® INTERNATIONAL

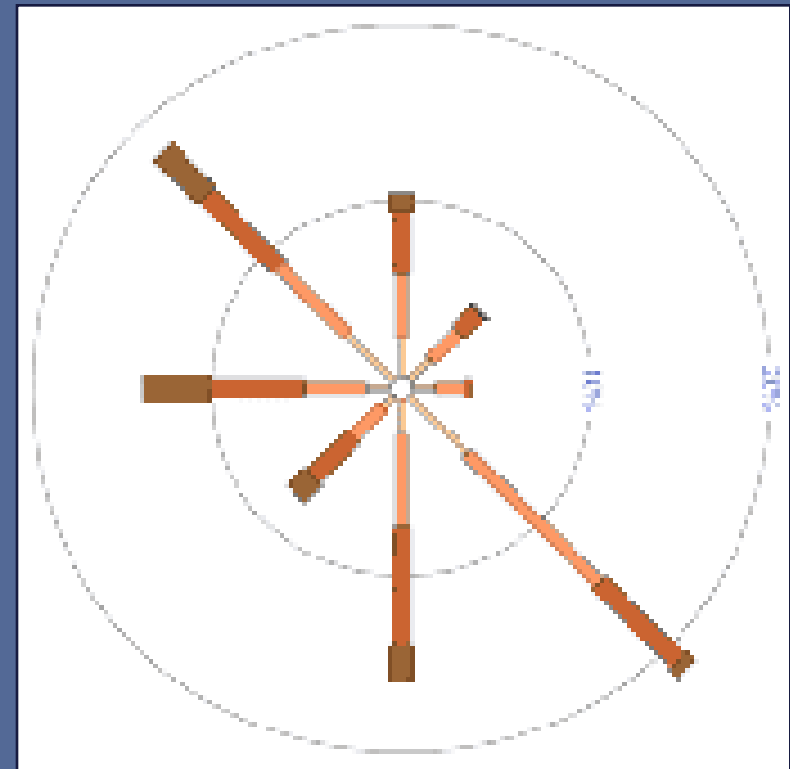
www.retscreen.net

● Wind resource assessment

▶ Wind Rose

- **wind frequency-amplitude-direction** diagram, very important for tower placement
- **8min-32max directions** (N,S,W,E,..) from which wind blows; every color represents a 10 km/h velocity range; length means frequency
- when unavailable, for small projects it might be taken from previous years and/or neighbor areas forecasts

Note: 10 km/h = 2.8 m/s



Wind Resource

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- Effects of the Ground on Wind Speed
 - Roughness of Surface

$$\frac{v_h}{v_{ref}} = \left(\frac{h}{h_{ref}} \right)^n$$

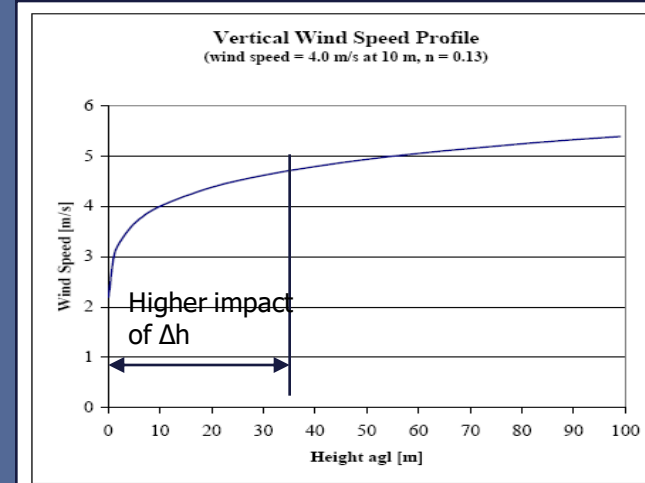
Where:

- n : wind shear index (see table)
- v_h : wind speed at height "h"
- v_{ref} : wind speed at reference height "h_{ref}"

Source:
<http://rlsenergy.com/products/wind-power/wind-speed-data/>

Surface type	Wind shear exponent, n
<i>Smooth</i>	
Ice	0.08
Mud/snow	0.11
Sea	0.12
<i>Moderately rough</i>	
Short grass	0.13
Crops	0.14
<i>Rough</i>	
Rural	0.20
Woods	0.23
<i>Very rough</i>	
Suburban	0.25-0.4

Surface roughness and estimated wind shear exponent





Wind Resource

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• Wind Speed Distribution

- **Weibull Probabilistic Function: $p(x)$**
- **Rayleigh PF (Weibull with shape factor = 2)**
- Allows to predict speed distribution along the year starting from averaged monthly data
- Conforms well to long-term distribution of wind speed for several sites

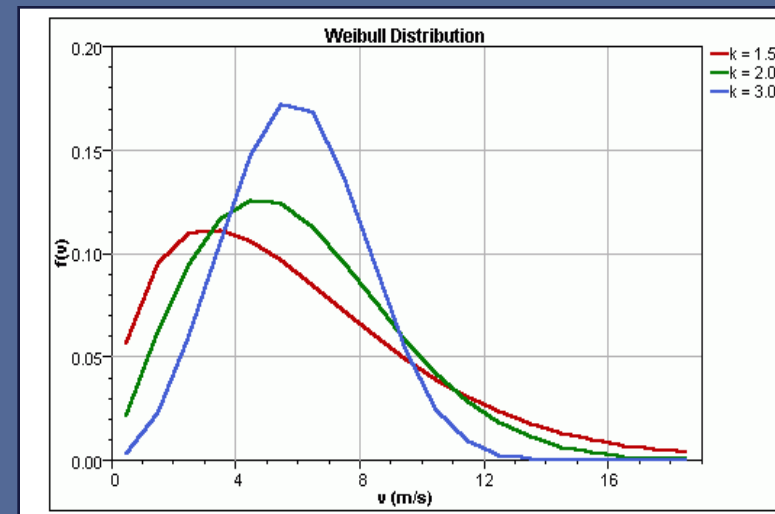
$$p(x) = \left(\frac{k}{C}\right) \left(\frac{x}{C}\right)^{k-1} \exp\left[-\left(\frac{x}{C}\right)^k\right]$$

Where:

- $p(x)$: probability "p" of having a wind speed "x" during the year
- $x \geq 0$
- k, typically between 1 and 3(shape factor)

- $C > 0$

$$C = \frac{\bar{x}}{\Gamma\left(1 + \frac{1}{k}\right)}$$





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

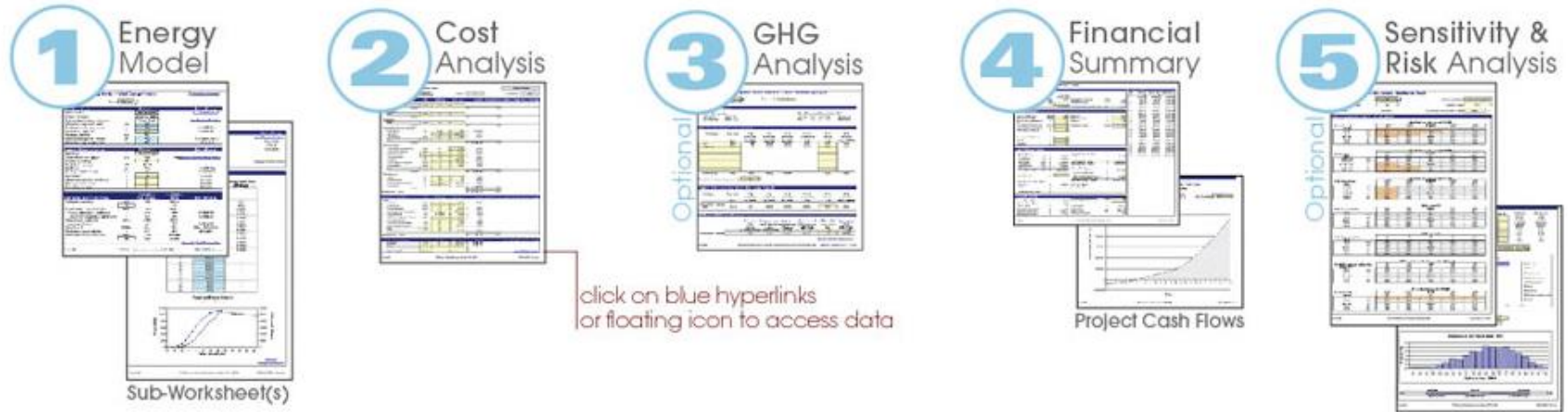


RETScreen® Demo: Wind Farm in Andhra Pradesh, India

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Five Step Standard Analysis ➔



➔ Ready to make a decision

Integrated Features

Weather Data



Product Data



Online Manual



- Training Course
- Engineering Textbook
- Case Studies
- Online Marketplace
- Internet Forums



Case Study: Wind Farm in Andhra Pradesh, India

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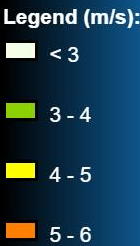
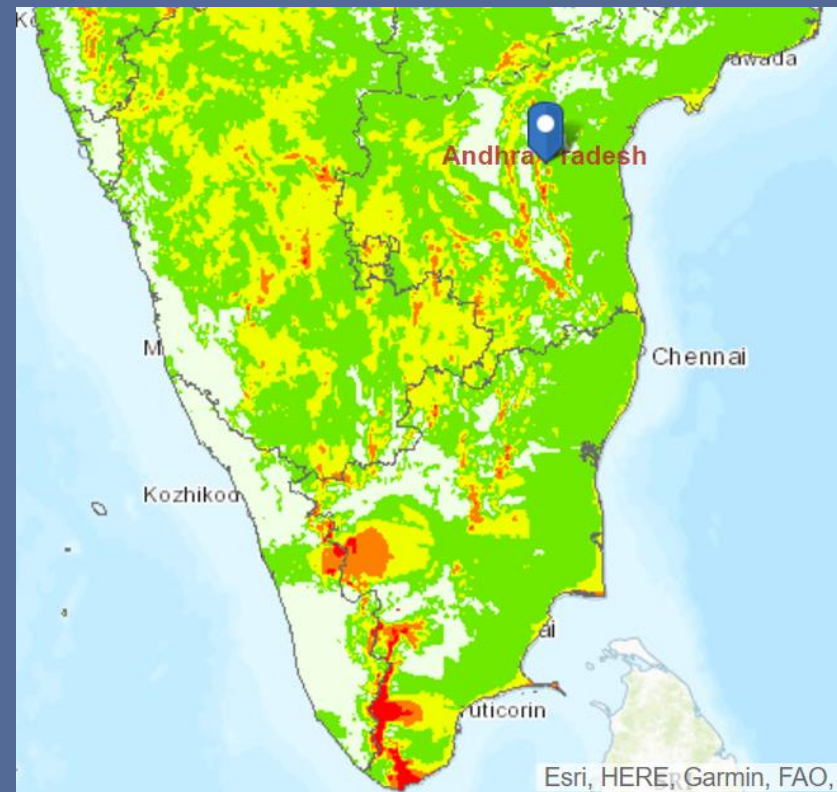


<http://14.139.172.6:8899/WindResource/>



20m Wind Speed Map

National Institute of Wind Energy
 (Ministry of New and Renewable Energy)



<http://www.mapsofopen.com/images/andhra-pradesh-location-map.gif>

Is it feasible to install a 20 MW Wind Farm in Kadavakallu ridge, using Lagerwey 250 kW turbines?

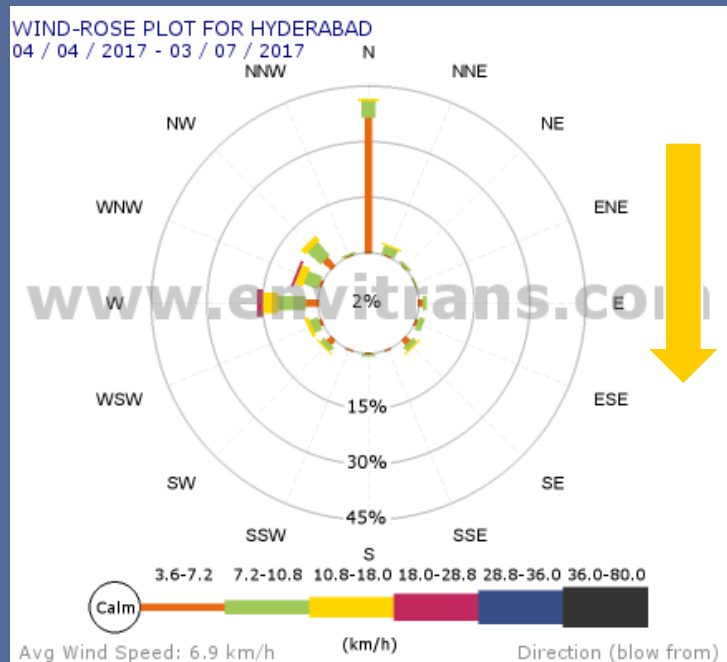
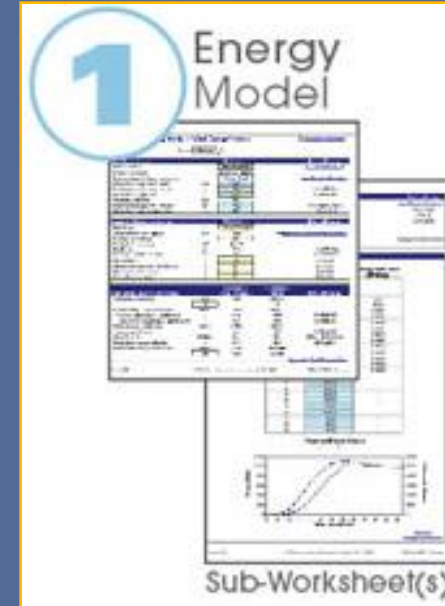


RETScreen[®] Software / Energy Model:

RETSCREEN[®] INTERNATIONAL

www.retscreen.net

- Constructor: RCI Power (Independent Producer)
- Plan for 80 LW30/250 kW (Manufactured by Lagerwey, Netherlands)
- Site: 20-km Kadavakallu ridge, North-South



Wind Rose at nearby Hyderabad
 (3-month example)

Ave. Speed: 6.2 m/s @ 30m agl
 (on-site measurements)

<https://www.envitrans.com/windrose.php>

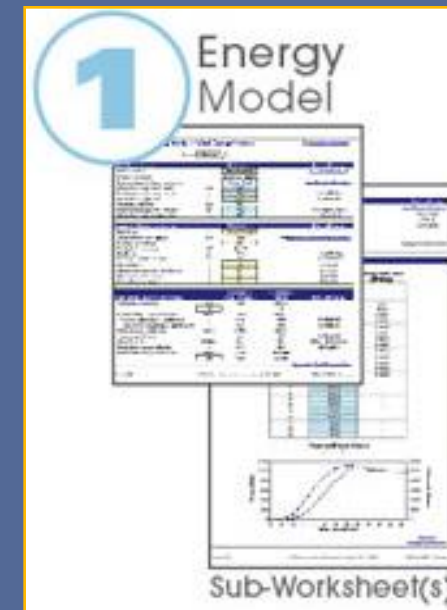
RETScreen[®] Software / Energy Model:

RETSCREEN[®] INTERNATIONAL

www.retscreen.net

Technical Assessment Data:

- Plan for 80 LW30/250 kW (Manufactured by Lagerwey, Netherlands) @ 36 m AGL
- Terrain data ⇒ **Wind Shear Exp. ≈ 0.15**
([http://www.ijirae.com/volumes/vol1/issue8/SPCE10082\(26\).pdf](http://www.ijirae.com/volumes/vol1/issue8/SPCE10082(26).pdf))
- **Airfoil losses (sand) : 1%**
- **Miscellaneous losses (on-site electrical and degradation) : 2%**
- **Availability : 94%**
- **FIT : 4.160 INR/kWh**



RETScreen[®] Software / Cost Analysis:

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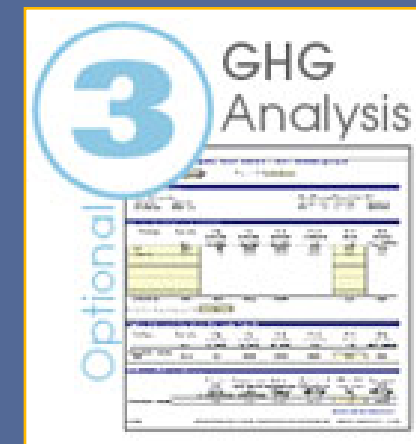
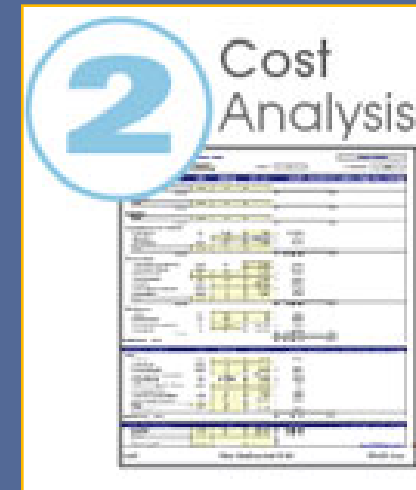
www.retscreen.net

Cost Assessment Data:

- **Capital cost: 30 800 INR/kW turbine** (does not include study, engineering, development, transportation and spare parts).
- **O&M: 13 340 000 INR/year**

GHG Emission Reduction Analysis Data:

- **Baseline: Grid power from India (50% coal, 50% hydro)**
- **Transmission & Distribution Losses: 12%**



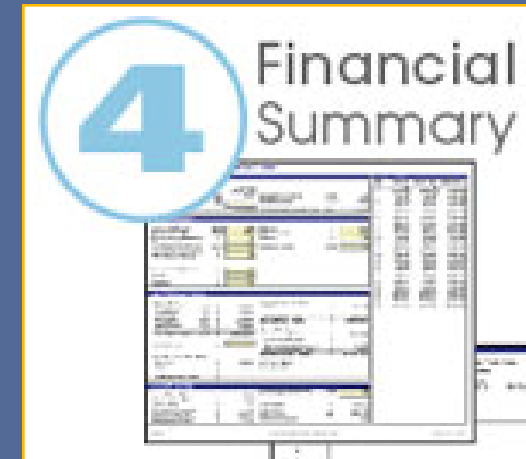
RETScreen[®] Software / Financial Summary:

RETScreen[®] INTERNATIONAL

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Financial Input Data:

- Lifetime of project: **25 years**
- Inflation rate: **2.5 %**
- Discount rate: **12 %**
- Debt ratio: **75%**
- Debt interest rate: **14 %**
- Debt term: **7 years**
- Income taxes: **35 %**
- FIT escalation rate: **5 %**
- Accelerated **100%** depreciation on electromechanical equip.





RETScreen® Software / Financial Summary:

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Financial Output:

Project costs and savings/income summary

Initial costs			
Feasibility study	0.3%	INR	2,190,000
Development	0.8%	INR	6,125,000
Engineering	0.6%	INR	5,200,000
Power system	75.9%	INR	616,000,000
<hr/>			
Balance of system & misc.	22.4%	INR	181,901,283
Total initial costs	100.0%	INR	811,416,283

Annual costs and debt payments

O&M	INR	14,773,000
Fuel cost - proposed case	INR	0
Debt payments - 7 yrs	INR	141,912,069
Total annual costs	INR	156,685,069

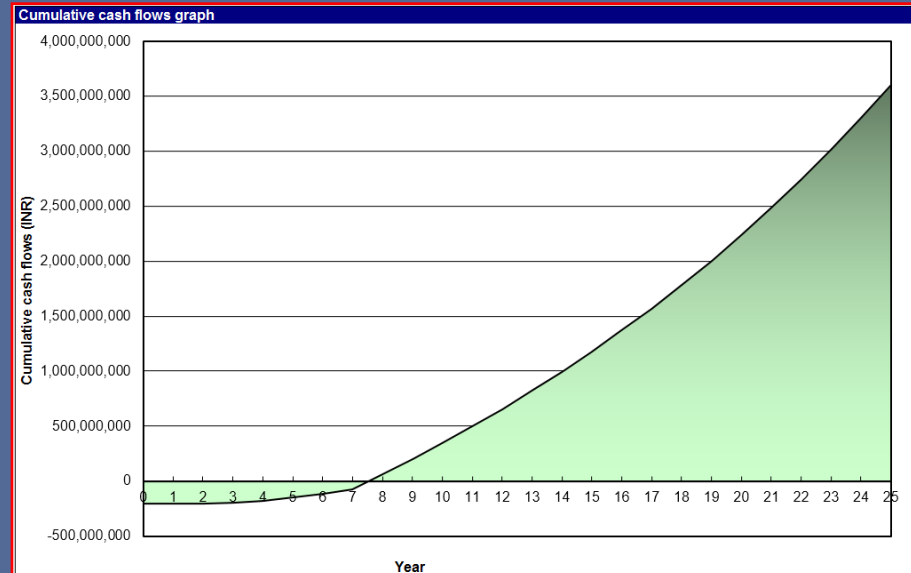
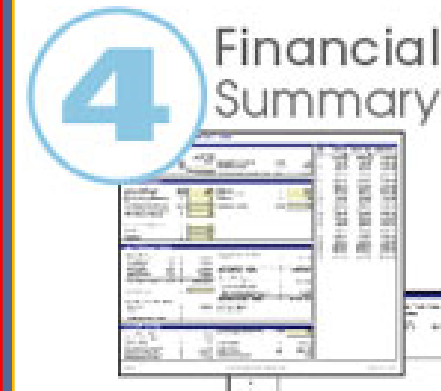
Periodic costs (credits)

Annual savings and income

Fuel cost - base case	INR	0
Electricity export income	INR	144,779,698
Total annual savings and income	INR	144,779,698

Financial viability

Pre-tax IRR - equity	%	26.6%
Pre-tax IRR - assets	%	13.3%
<hr/>		
After-tax IRR - equity	%	22.9%
After-tax IRR - assets	%	10.2%
<hr/>		
Simple payback	yr	6.2
Equity payback	yr	7.5
<hr/>		
Net Present Value (NPV)	INR	446,326,723
Annual life cycle savings	INR/yr	56,906,644
<hr/>		
Benefit-Cost (B-C) ratio		3.20
Debt service coverage		0.96
Energy production cost	INR/MWh	2,684.84
GHG reduction cost	INR/CO ₂	(3,386)





RETScreen® Software / Sensitivity and Risk Analysis:

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Sensitivity analysis

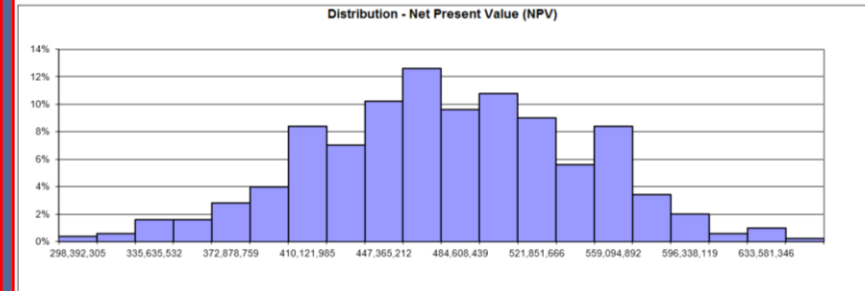
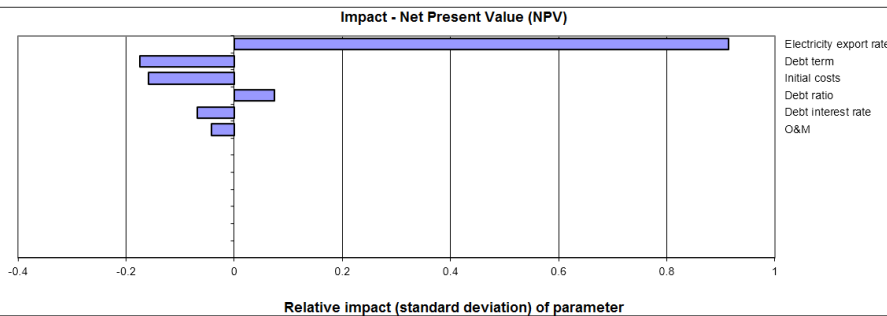
Perform analysis on		Net Present Value (NPV)				
Sensitivity range		20%				
Threshold		200000000				
		INR				
		Initial costs			INR	
Electricity export rate		649,133,027	730,274,655	811,416,283	892,557,911	973,699,540
INR/MWh		-20%	-10%	0%	10%	20%
3,328.00	-20%	336,676,286	268,305,304	198,223,860	126,976,209	54,777,177
3,744.00	-10%	458,135,508	391,503,556	323,156,465	253,515,380	182,965,225
4,160.00	0%	577,733,985	512,768,503	446,326,723	377,983,735	308,806,900
4,576.00	10%	695,849,277	632,443,861	567,401,499	500,959,719	432,811,005
4,992.00	20%	812,844,762	750,893,350	687,153,738	622,034,495	555,592,715



Risk analysis

Perform analysis on		Net Present Value (NPV)				
Parameter	Unit	Value	Range (+/-)	Minimum	Maximum	
Initial costs	INR	811,416,283	5%	770,845,469	851,987,097	
O&M	INR	14,773,000	10%	13,295,700	16,250,300	
Electricity export rate	INR/MWh	4,160.00	15%	3,536.00	4,784.00	
Debt ratio	%	75%	10%	68%	83%	
Debt interest rate	%	14.00%	5%	13.30%	14.70%	
Debt term	yr	7	10%	6.3	7.7	

Median	INR	477,931,963
Level of risk	%	10.0%
Minimum within level of confidence	INR	369,963,458
Maximum within level of confidence	INR	583,381,373





Wind Farm in Andhra Pradesh, India / Lessons Learned

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- Project developed at a location with **good wind** resource.
- **Good financial** and fiscal incentives favored viability of the project.
- Large number of turbines in one site favors **economies of scale** (single study, construction and O&M costs).
- Project **breaks even** just after repayment of debt.
- Project demonstrates **feasibility** of windfarms in India.
- **Favorable policies** of Ministry of Non-Conventional Energy Sources (MNES).
- Indian Renewable Energy Development Agency (IREDA) **key financing** role.

REFERENCES

Mohan, Ram, "Personal communication," NEDCAP, Wind Energy Division-Ananthapur, India, 2002.
Parthan, Binu K., "Personal communication," IT Power India, 2002.





Financial and Risk Analysis w/RETScreen®

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APPENDIX



Financial and Risk Analysis w/RETScreen®: Assumptions

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- Initial investment year is year "0"
- Costs and credits are given in year 0 terms, thus the inflation rate (or the escalation rate) is applied from year 1 onwards
- Timing of cash flows occurs at the end of the year



Debt Payments

LR

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$$D = C f_d \frac{i_d}{1 - \frac{1}{(1 + i_d)^{N'}}$$

- D: yearly constant debt payment during debt term
- C: total initial cost of the project
- f_d : debt ratio (initial loan/total initial cost)
- i_d : effective annual interest debt rate
- N' : debt term in years



Cash Outflows (pre-tax)

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$$C_{out,0} = C(1 - f_d)$$

Year 0

$$C_{out,n} = C_{O\&M} (1 + r_i)^n + C_{fuel} (1 + r_e)^n + D + C_{per} (1 + r_i)^n$$

Subsequent years

- $C_{out,0}$: project equity (portion of total investment funded by owner)
- C : total initial cost of the project
- f_d : debt ratio (initial loan/total initial cost)
- n : year
- $C_{O\&M}$: yearly operation and maintenance costs by proposed project
- r_i : inflation rate
- C_{fuel} : annual cost of fuel or electricity
- r_e : energy cost escalation rate
- C_{per} : periodic costs or credits incurred by the system



Cash Inflows (pre-tax)

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$$C_{in,0} = IG$$

Year 0

$$C_{in,n} = C_{ener} (1+r_e)^n + C_{capa} (1+r_i)^n + C_{RE} (1+r_{RE})^n + C_{GHG} (1+r_{GHG})^n$$

Subsequent years

- $C_{in,0}$: incentives and grants
- n: year
- C_{ene} : annual energy savings or income
- C_{capa} : annual capacity savings or income
- r_i : inflation rate
- C_{RE} : annual renewable energy (RE) production credit
- r_{RE} : RE credit escalation rate
- C_{GHG} : GHG reduction income
- r_{GHG} : GHG credit escalation rate
- For the last year, the project end-of-life credit escalated by inflation is added on RHS



Net Cash flows (pre-tax)

LR

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$$C_n = C_{in,n} - C_{out,n}$$

C_n : pre-tax cash flow for year n is simply the difference between inflow and outflow



Yearly Asset Depreciation

LR

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- Choices:
 - ▶ None
 - ▶ Declining balance: depreciates asset more rapidly in early years of the project
 - ▶ Straight line: assets are depreciated with a constant rate
- Used in calculation of income taxes and after-tax financial indicators
- At the “end of project life” (EPL), difference between EPL assets value and its undepreciated capital costs is treated as income if positive and as a loss if negative



Income Tax

LR

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$$T_n = t I_n$$

$$I_n = C_n + D_{p,n} - CCA_n$$

$$I_0 = IG - CCA_0$$

- t : Rate at which net income of the project is taxed every year (assumed as a constant rate)
- T_n : Amount of tax for year n
- I_n : Year n net income
- C_n : Pre-tax annual cash flow
- $D_{p,n}$: Payment on Debt-principal on year n
- CCA_n : Asset depreciation on year n
- IG : Incentives and grants



After-tax Cash Flow

LR

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$$\tilde{C}_n = C_n - T_n$$

- Considers:
 - ▶ pre-tax cash flow
 - ▶ asset depreciation
 - ▶ income tax
 - ▶ loss carry forward



Financial Feasibility Indicators

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$$0 = \sum_{n=0}^N \frac{C_n}{(1 + IRR)^n}$$

- Internal Rate of Return (IRR):
 - ▶ Discount rate that causes NPV of the project to be 0
 - ▶ N is project life years
 - ▶ C_n is cash flow for year n. C_0 is equity minus incentives and grants



Financial Feasibility Indicators

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$$SP = \frac{C - IG}{(C_{ener} + C_{capa} + C_{RE} + C_{GHG}) - (C_{O\&M} + C_{fuel})}$$

- Simple Payback:
 - ▶ Number of years it takes for the cash flow (excluding debt payments) to equal total investment (debt + equity)



Financial Feasibility Indicators

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$$0 = \sum_{n=0}^{N_{PCF}} \tilde{C}_n$$

- Year-to-positive cashflow (or Equity payback):
 - ▶ First year that the cumulative cash flows for the project are positive



Financial Feasibility Indicators

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$$NPV = \sum_{n=0}^N \frac{\tilde{C}_n}{(1+r)^n}$$

- Net Present Value (NPV):
 - ▶ Value of all future cash flows, discounted at the discount rate "r", in today's currency
 - ▶ Discount rate "r": interest rate used in discounting future cash flows; also called capitalization rate and is country-dependent



Financial Feasibility Indicators

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$$B - C = \frac{NPV + (1 - f_d) C}{(1 - f_d) C}$$

- Benefit-Cost (B-C) Ratio :
 - ▶ Relative profitability of the project, calculated as a ratio of present value of annual revenues (income and/or savings) less annual costs of project equity



Key (Output) Indicators of Financial Viability

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	Simple Payback	Net Present Value (NPV)	Internal Rate of Return (IRR)
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	<ul style="list-style-type: none"> • Misleading • Ignores financing & long-term cashflows • Use when cashflow is tight 	<ul style="list-style-type: none"> • Good measure • User must specify discount rate 	<ul style="list-style-type: none"> • Can be fooled when cashflow goes positive-negative-positive



Financial and Risk Analysis w/RETScreen®: Assumptions

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- Initial investment year is year "0"
- Costs and credits are given in year 0 terms, thus the inflation rate (or the escalation rate) is applied from year 1 onwards
- Timing of cash flows occurs at the end of the year



Debt Payments

LR

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Cash Outflows (pre-tax)

LR

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Year 0

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Subsequent years

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- r_i : inflation rate
- C_{fuel} : annual cost of fuel or electricity
- r_e : energy cost escalation rate
- C_{per} : periodic costs or credits incurred by the system



Cash Inflows (pre-tax)

LR

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$$C_{in,0} = IG$$

Year 0

$$C_{in,n} = C_{ener} (1+r_e)^n + C_{capa} (1+r_i)^n + C_{RE} (1+r_{RE})^n + C_{GHG} (1+r_{GHG})^n$$

Subsequent years

- $C_{in,0}$: incentives and grants
- n: year
- C_{ene} : annual energy savings or income
- C_{capa} : annual capacity savings or income
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Net Cash flows (pre-tax)

LR

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LR

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LR

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$$I_n = C_n + D_{p,n} - CCA_n$$

$$I_0 = IG - CCA_0$$

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- T_n : Amount of tax for year n
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- C_n : Pre-tax annual cash flow
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- CCA_n : Asset depreciation on year n
- IG : Incentives and grants



After-tax Cash Flow

LR

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$$\tilde{C}_n = C_n - T_n$$

- Considers:
 - ▶ pre-tax cash flow
 - ▶ asset depreciation
 - ▶ income tax
 - ▶ loss carry forward



Financial Feasibility Indicators

LR

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$$0 = \sum_{n=0}^N \frac{C_n}{(1 + IRR)^n}$$

- Internal Rate of Return (IRR):
 - ▶ Discount rate that causes NPV of the project to be 0
 - ▶ N is project life years
 - ▶ C_n is cash flow for year n. C_0 is equity minus incentives and grants



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$$SP = \frac{C - IG}{(C_{ener} + C_{capa} + C_{RE} + C_{GHG}) - (C_{O\&M} + C_{fuel})}$$

- Simple Payback:
 - ▶ Number of years it takes for the cash flow (excluding debt payments) to equal total investment (debt + equity)



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$$0 = \sum_{n=0}^{N_{PCF}} \tilde{C}_n$$

- Year-to-positive cashflow (or Equity payback):
 - ▶ First year that the cumulative cash flows for the project are positive



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$$NPV = \sum_{n=0}^N \frac{\tilde{C}_n}{(1+r)^n}$$

- Net Present Value (NPV):
 - ▶ Value of all future cash flows, discounted at the discount rate "r", in today's currency
 - ▶ Discount rate "r": interest rate used in discounting future cash flows; also called capitalization rate and is country-dependent



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$$B - C = \frac{NPV + (1 - f_d) C}{(1 - f_d) C}$$

- Benefit-Cost (B-C) Ratio :
 - ▶ Relative profitability of the project, calculated as a ratio of present value of annual revenues (income and/or savings) less annual costs of project equity



Key (Output) Indicators of Financial Viability

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	Simple Payback	Net Present Value (NPV)	Internal Rate of Return (IRR)
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	<ul style="list-style-type: none"> • Misleading • Ignores financing & long-term cashflows • Use when cashflow is tight 	<ul style="list-style-type: none"> • Good measure • User must specify discount rate 	<ul style="list-style-type: none"> • Can be fooled when cashflow goes positive-negative-positive