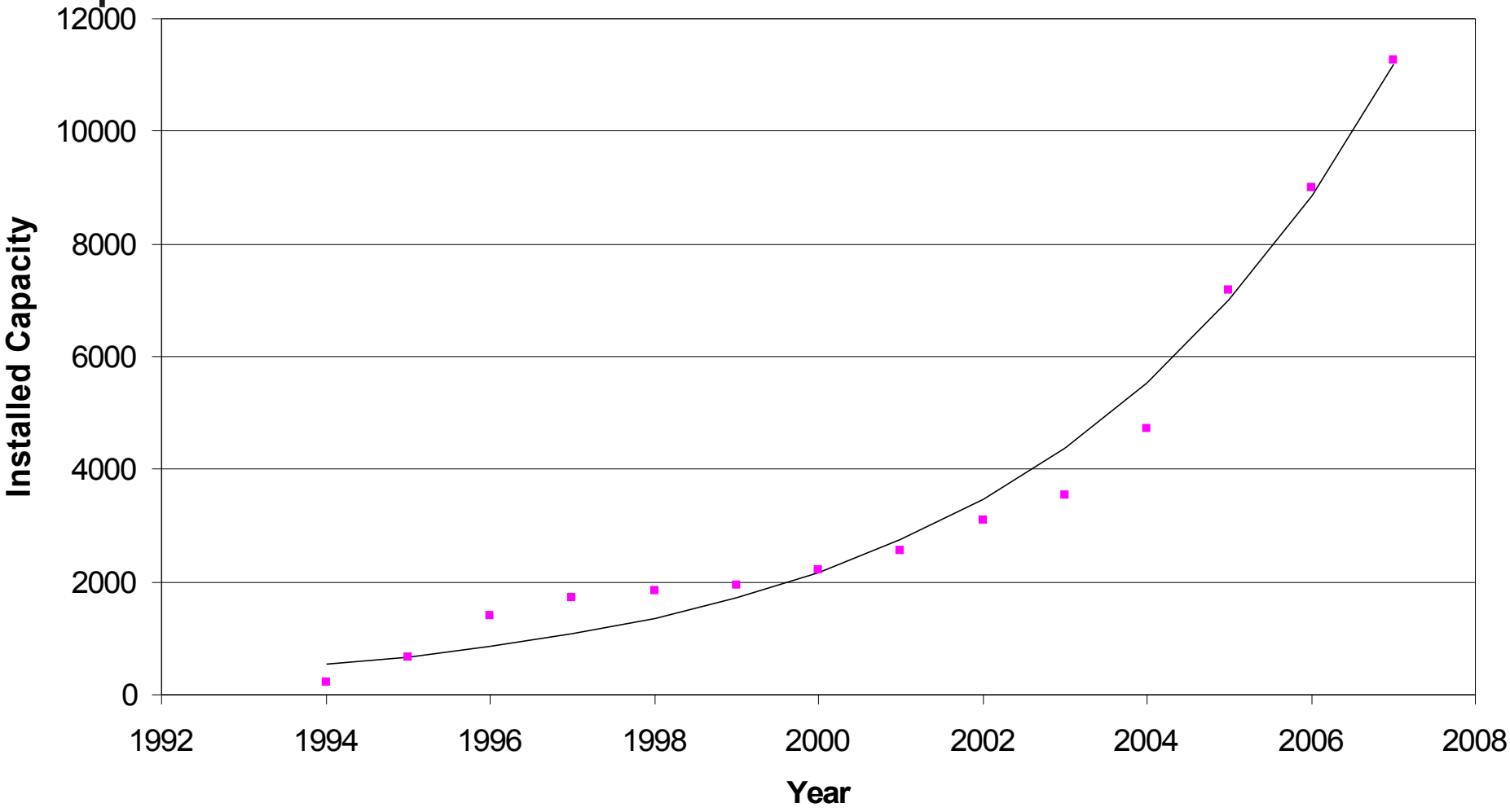
# Promoting Renewable Energy in Maharashtra

Department of Energy Science and Engineering

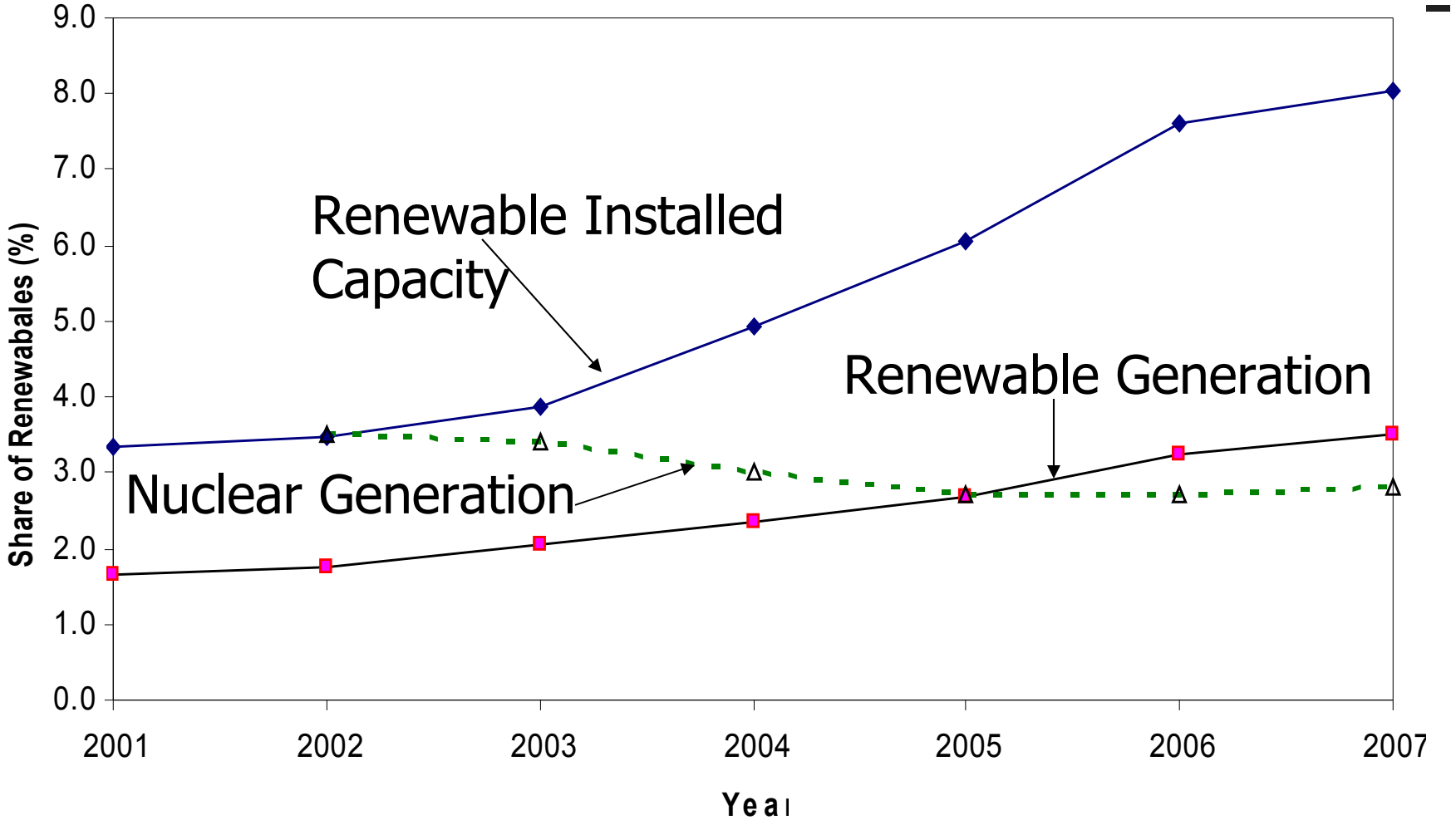
IIT Bombay

Presentation to Maharashtra Electricity Regulatory Commission, November 10, 2009

# India-Renewable Installed Capacity trend



# India-Renewable Share in Power



# Renewable Energy (2008) Installed Capacity

| | India | Maharashtra |
|---|---|---|
| Wind Power | 9.66 GW | 1.95 GW |
| Small Hydro | 2.0 GW | 0.2 GW |
| Biomass Power | 8.0 GW | 0.35 GW |
| Solar PV (grid) | 3 MW | 0 |
| Geothermal Power | 0 | 0 |
| Solar Thermal Power (CSP) | 0 | 0 |
| Total renewable power | 13 GW | 2.5 GW |
| Solar Water heater | 1.7 GW (th) (2.4 million $m^2$) | Not known |

Source: REN21 Renewables Global Status Report-2009 Update

# India Renewable installed capacity and generation

| | Installed Capacity* (MW) | Estimated Capacity factor | Estimated Generation (GWh) |
|---|---|---|---|
| Wind | 7845 | 14% | 9621 |
| Biomass Power | 606 | 70% | 3185 |
| Biomass Gasifier | 86 | 60% | 527 |
| Bagasse Cogeneration | 720 | 60% | 3784 |
| Small Hydro | 2046 | 40% | 7169 |
| Waste to Energy | 55 | 50% | 241 |
| Solar PV | 2.74 | 20% | 5 |
| Total | 11360 | 25% | 24380 |

*as on Jan 1, 2008

# Maharashtra Renewable installed capacity and generation

| | Installed Capacity (MW) | Estimated Capacity factor | Estimated Generation (GWh) |
|---|---|---|---|
| Wind | 1948 | 14% | 2389 |
| Biomass Power | 95 | 70% | 582 |
| Bagasse Cogeneration | 262 | 60% | 1377 |
| Small Hydro | 211 | 40% | 924 |
| Waste to Energy | 6.1 | 50% | 37.4 |
| Solar PV | - | 20% | - |
| Total | 2522 | 25% | 5310 |

*in 2009

# Solar resource


- Area 26.8 km x 26.8 km Nagpur district
- Solar insolation 1800 kWh/m$^2$/year
- 20% capacity factor, plant efficiency 20%
- 150000 MU annual generation

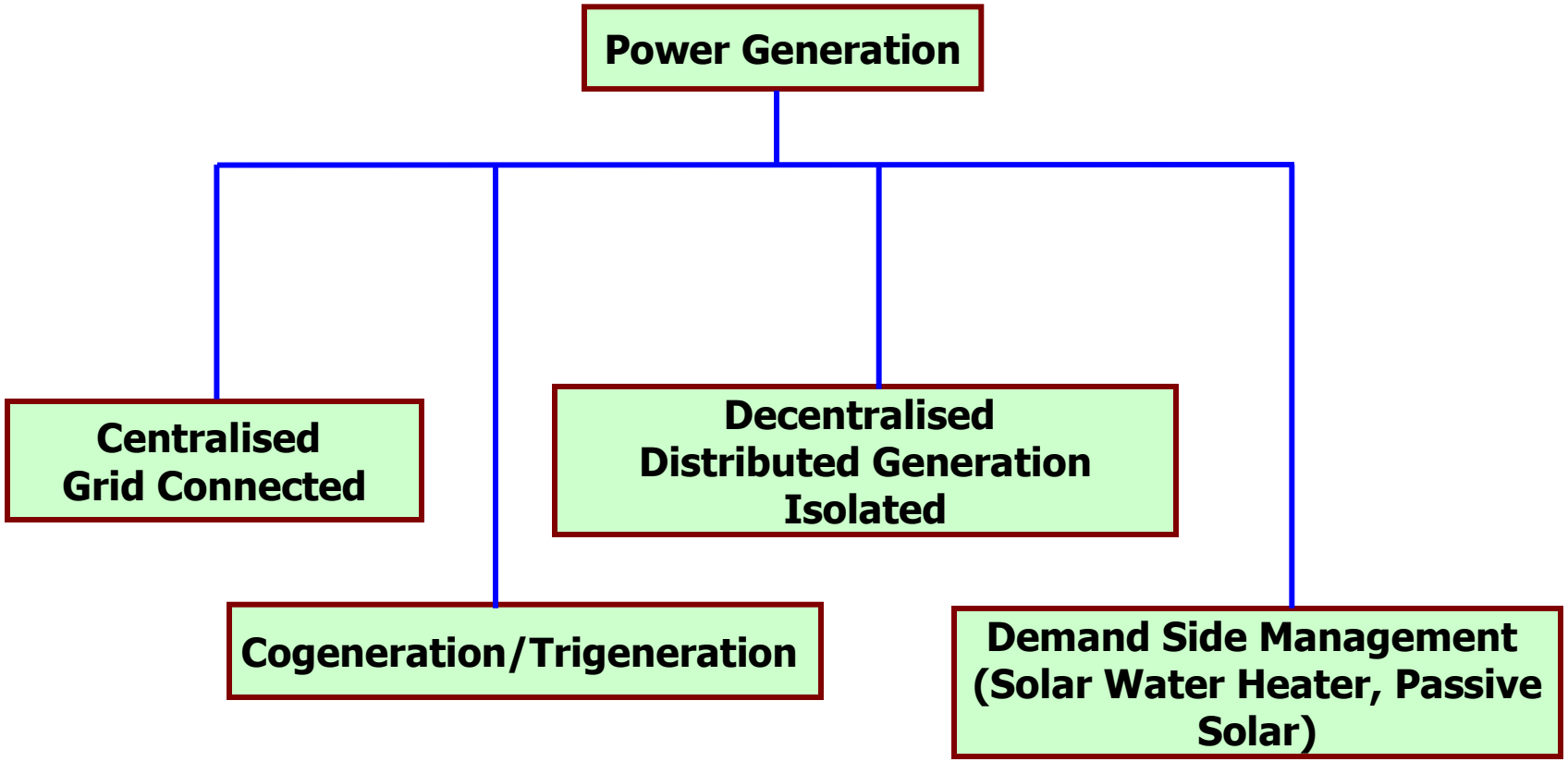
# Renewable Energy Issues

- Energy Security
- Energy Access
- Local and Global Emissions
- Marginal to Mainstream
- Incentives for Investors/ Technology Developers
- Impact on cost of supply to consumers
- Long term – capability development
- Employment potential
- Level playing field between technologies

# Renewable Energy Policies

- Capital Subsidy
- Tax Benefits (accelerated depreciation)
- Preferential Tariffs (feed-in) – technology differentiated, performance based incentives
- Renewable Portfolio Standards
- Renewable Energy Certificates

# Power Generation Options



# Renewable Energy Certificates

#1 Does it provide "stable" signals to investors?

#2 Does it promote renewable energy in the state?

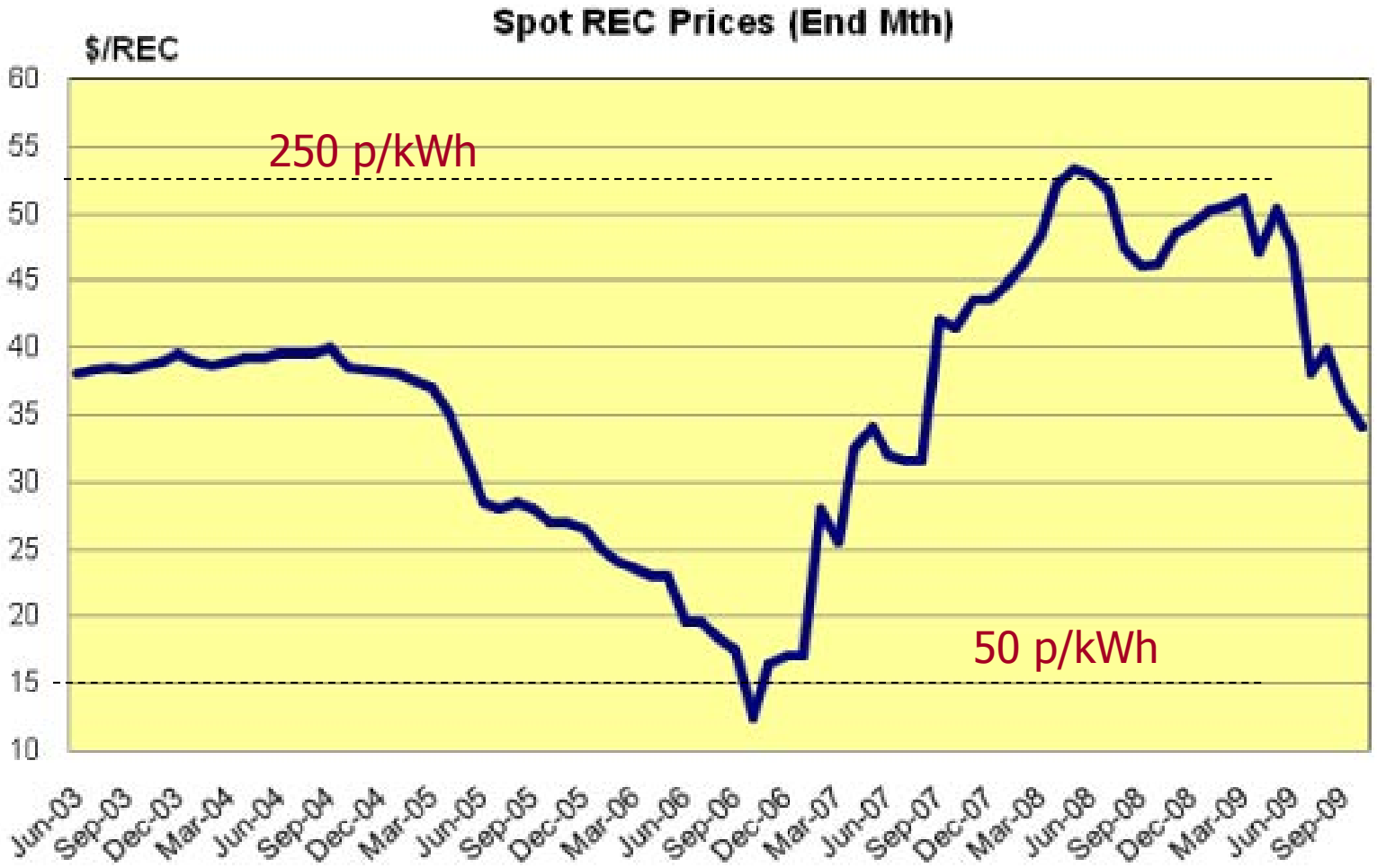
#3 How do we differentiate between different technologies ? Do we have multiplication factors based on technology type/ status?

#4 How do we prevent gaming? Can we ensure validation? Monitoring and verification?

#5 Can we extend to smaller grid connected systems? (e.g BIPV)

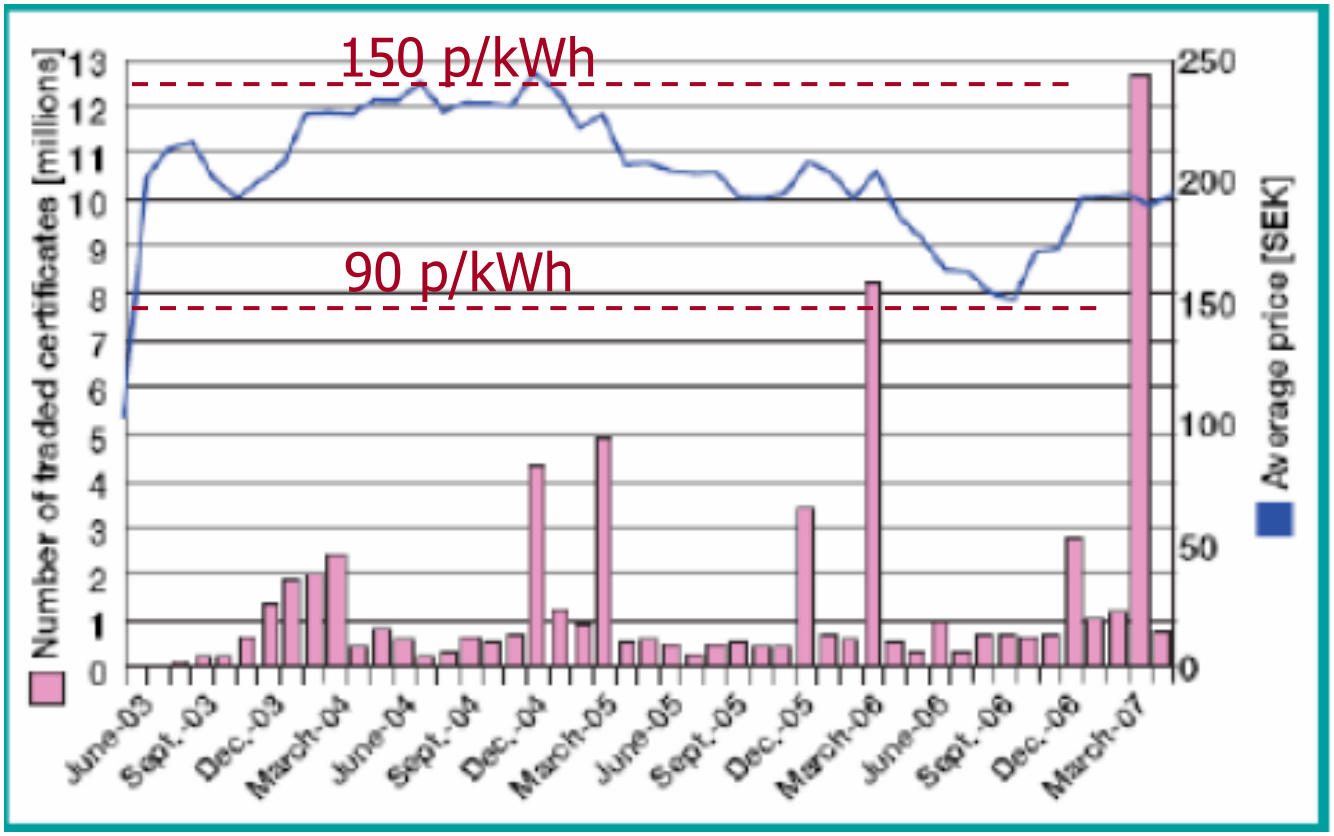
#6 Solar Water Heaters as "Deemed Generation"?

# Variability in REC price (Australia)



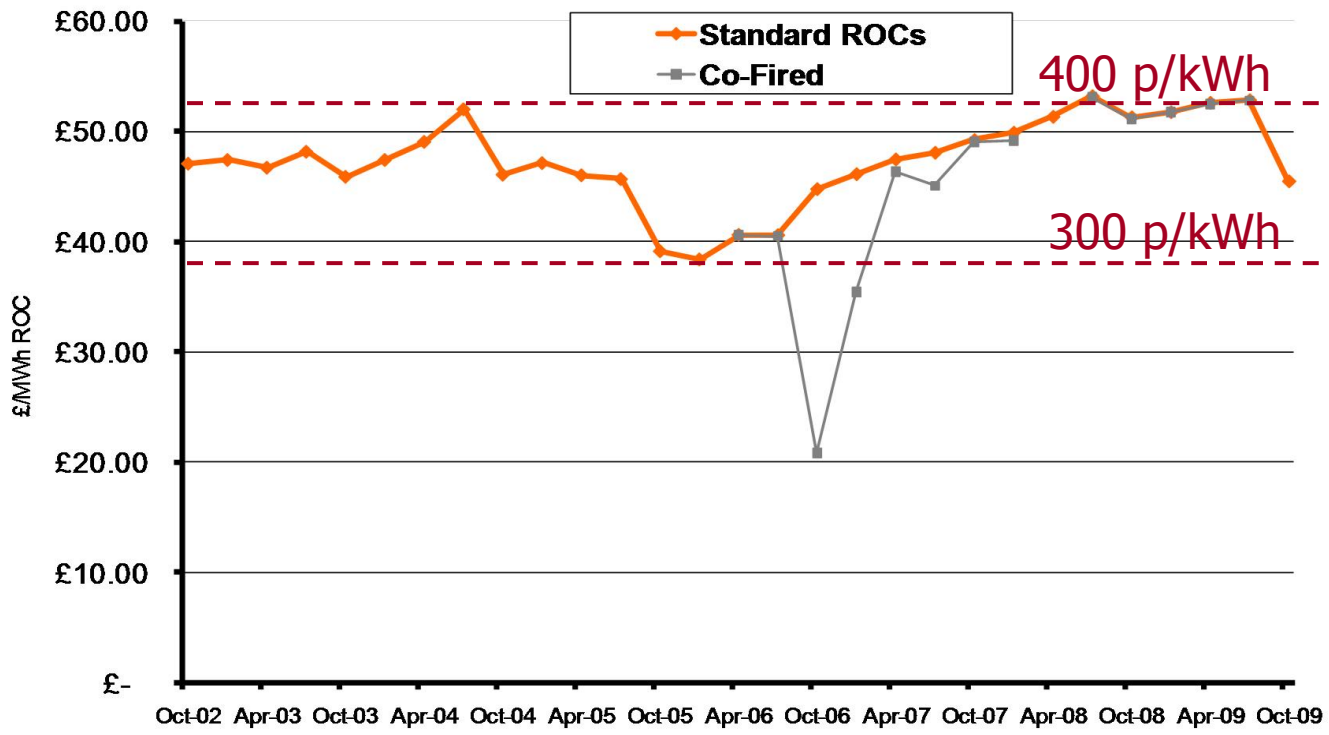

Source: http://www.greenenergytrading.com.au/how-are-recs-priced.html

# Variability in REC price (Sweden)




Source:InfralineEnergy Report on REC - October 2009

# Variability of ROCs in UK




Source: http://www.e-roc.co.uk/trackrecord.htm

# Sample REC rates

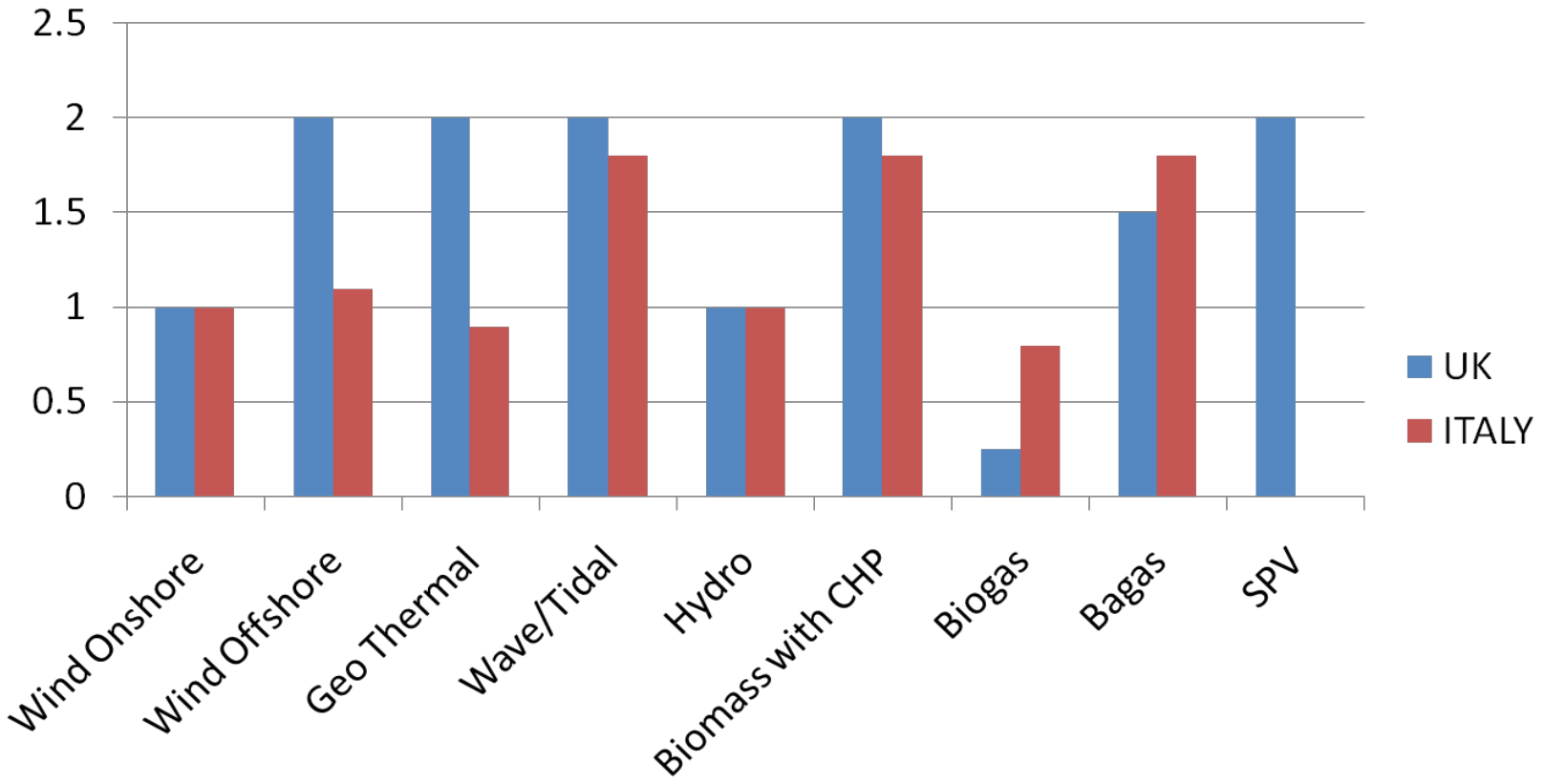
| | UK | AUSTRALIA | SWEDEN | ITALY |
|---|---|---|---|---|
| Price Range of REC ($/MWh) Rs/kWh | 63-86 2.9 – 4.0 | 11 – 49 0.5 – 2.3 | 14.6 – 36.4 0.7 – 1.7 | 123 – 195 5.7 – 9.0 |
| Multiplication Factor Based on Technology | YES | YES | NA | YES |
| Starting year | 2002 | 2001 | 2003 | 2001 |
| Penalty/Buyout $/MWh | 65 | 27 | - | - |

+Instantaneous values

Source: http://www.e-roc.co.uk/trackrecord.htm
InfralineEnergy Report on REC - October 2009
http://www.greenenergytrading.com.au/how-are-recs-priced.html
Renewable Energy Country Profiles, Report – February 2008.

#3

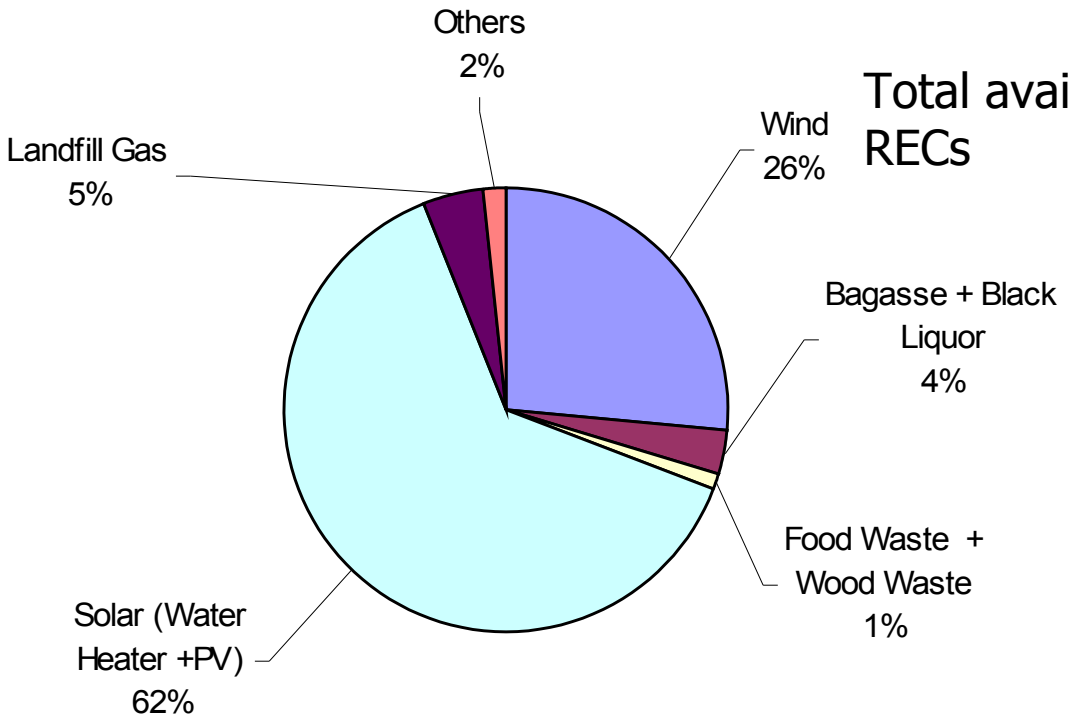
# Multiplication Factor




Source: Renewable Energy Country Profiles, Report – February 2008.
The UK Renewable Energy Strategy July 2009

#5,6

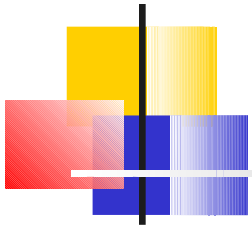
# Available REC's in Australia in 2009 for Trade




Total available 10 million RECs

Source: https://www.rec-registry.gov.au/getSearchPublicRecHoldings.shtml

# #6 Framework for Potential Estimation of Solar Water Heating Systems in a Country



**Country details**
(Area, Average Weather Data)

Locations where weather data available

Locations where weather data unavailable

Weather data

Identification of sectors and classification within each sector

End use details for each sub-class

Selection of base city

**Methodology for potential estimation for a target area**

Potential of SWHS in base city

Weather data

End use details

**Identification of variables for a different location**

Potential of SWHS in different location

**Spatial Interpolation**

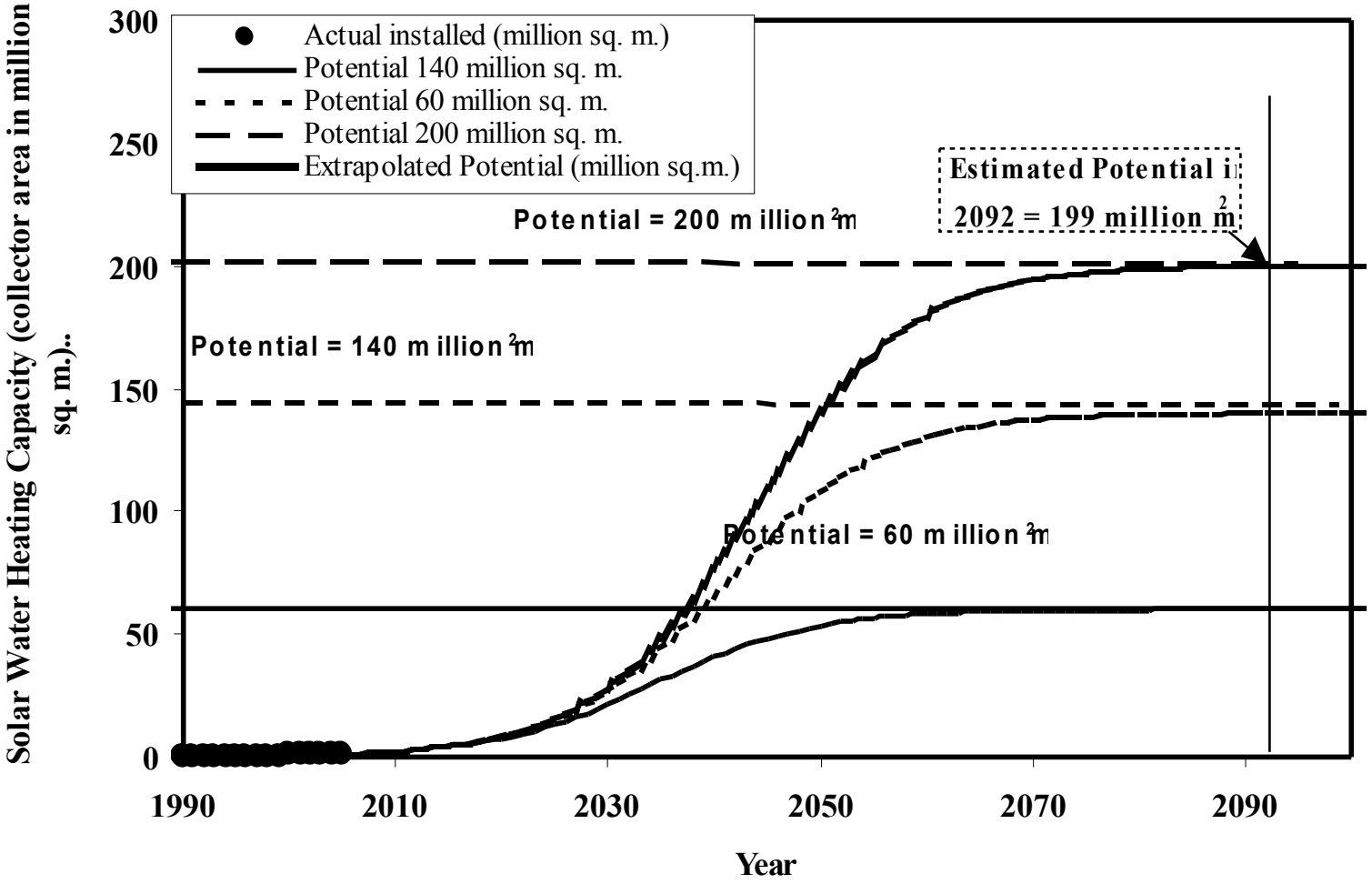
Potential of SWHS in nearby area where weather data is not available location

**Aggregation for all the locations**

**Potential of SWHS in the country**

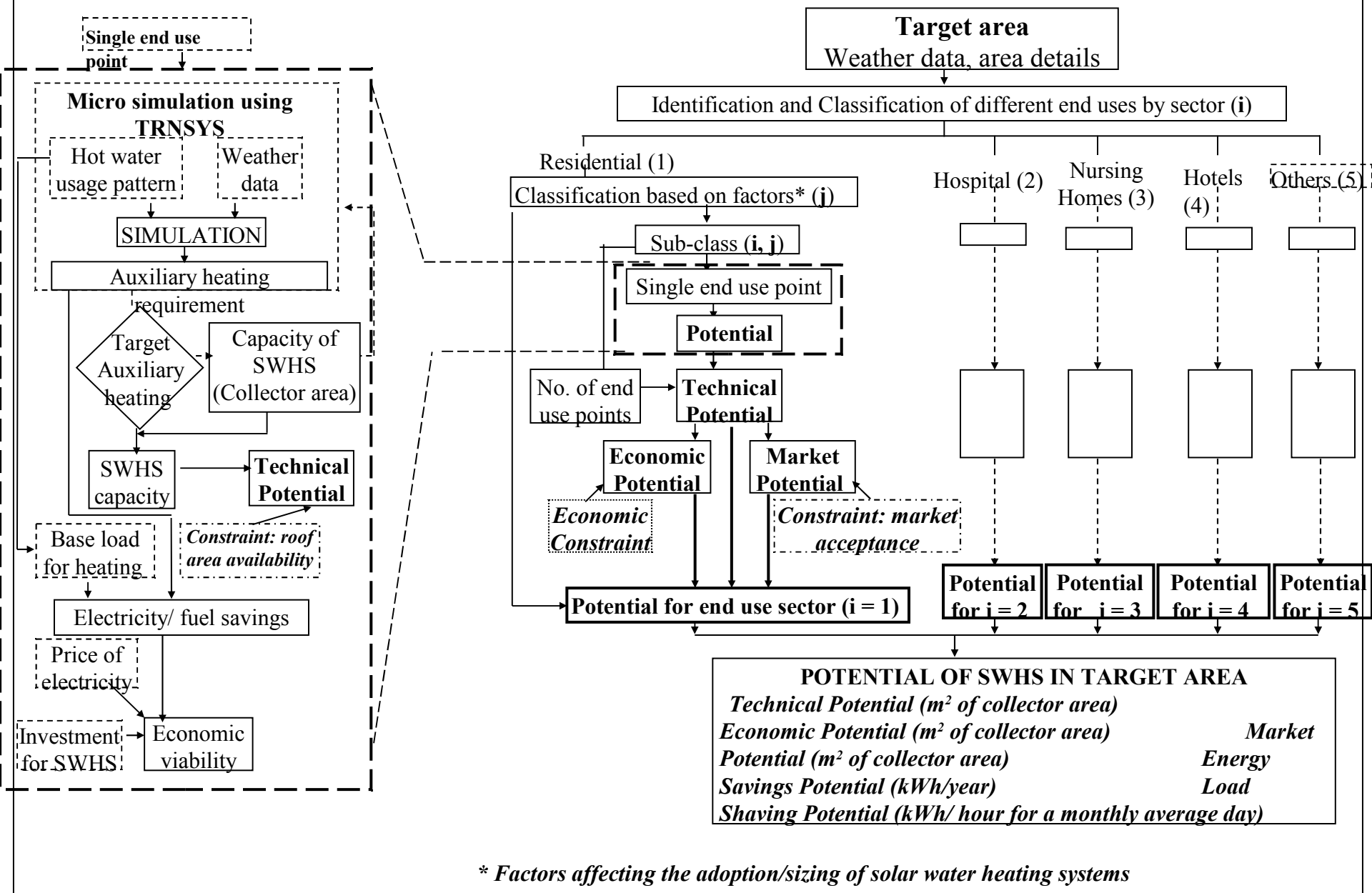
- **Technical potential**
- **Electricity savings**

# Diffusion of SWH



# Model for Potential Estimation of Target Area

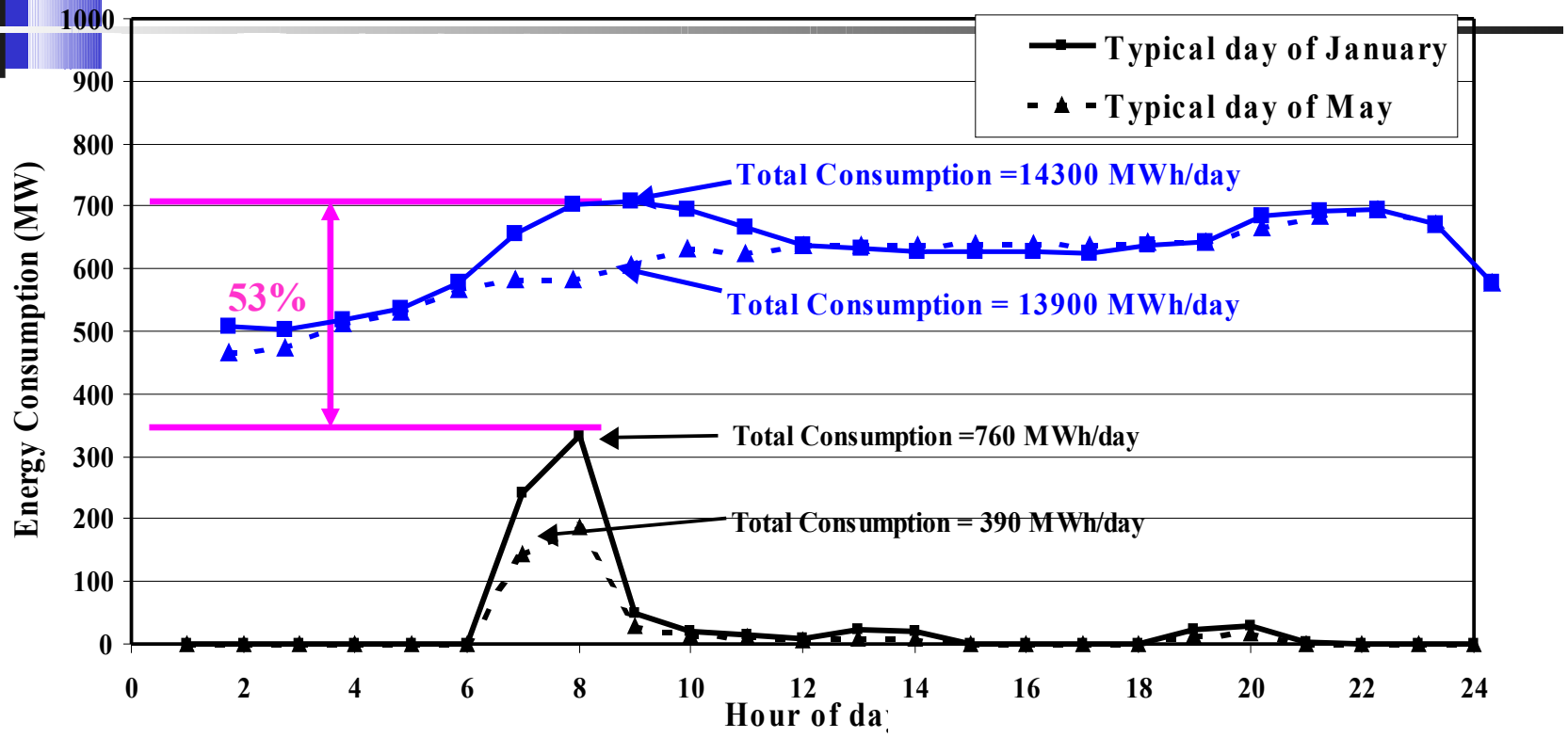





** Factors affecting the adoption/sizing of solar water heating systems*

# Load Curve Representing Energy Requirement for Water Heating

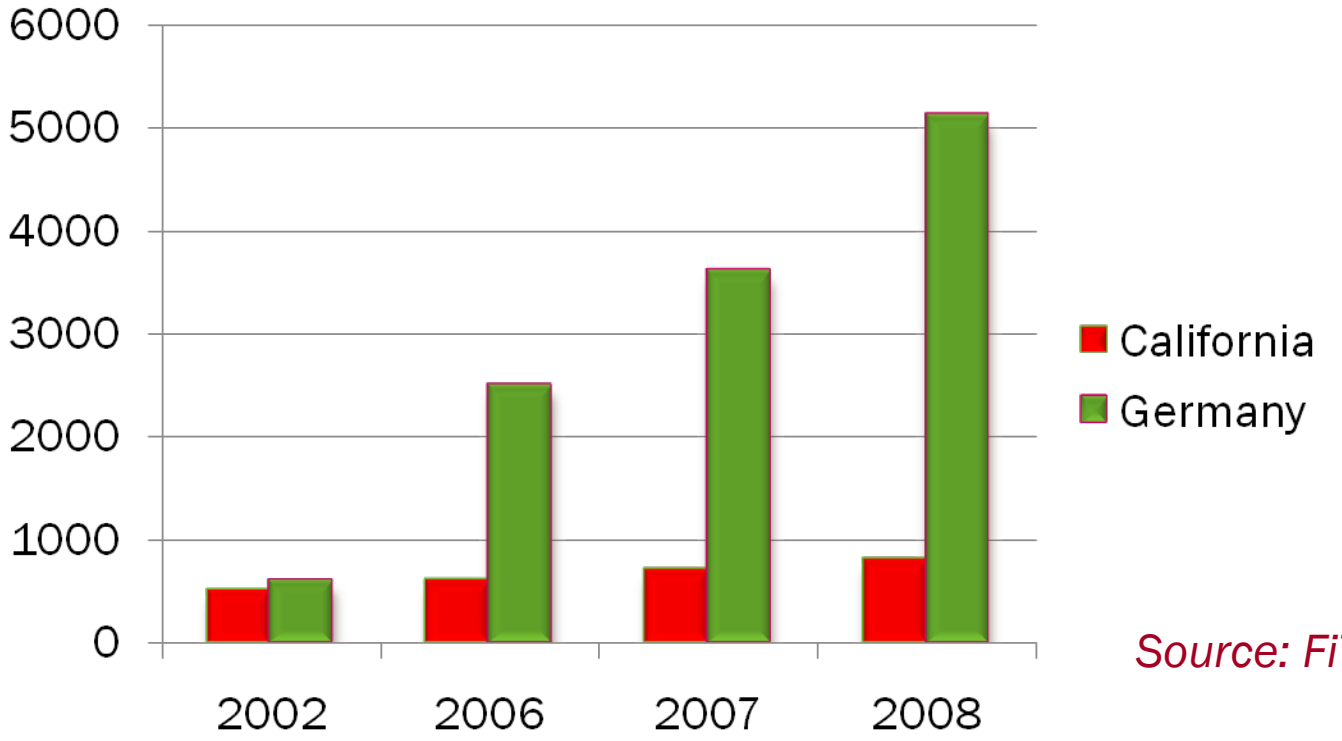





- *Total Electricity Consumption of Pune*
- *Electricity Consumption for water heating of Pune*

# RECs (California) Vs FiT (Germany) Comparison

- California enjoys 50% more sunshine
- But Germany installed 10 time solar than California




*Source: FiT for America*

# Feed in tariffs Vs REC's

| | Price Variability | Incentive to Investor | Market Driven | Trade across states | Comments |
|---|---|---|---|---|---|
| Feed in Tariff | Low | High | No | Exchange Possible | Within State development Differentiation between technologies |
| Renewable Energy Certificate | High | Medium (Uncertain) | High | High | Gamingposible |

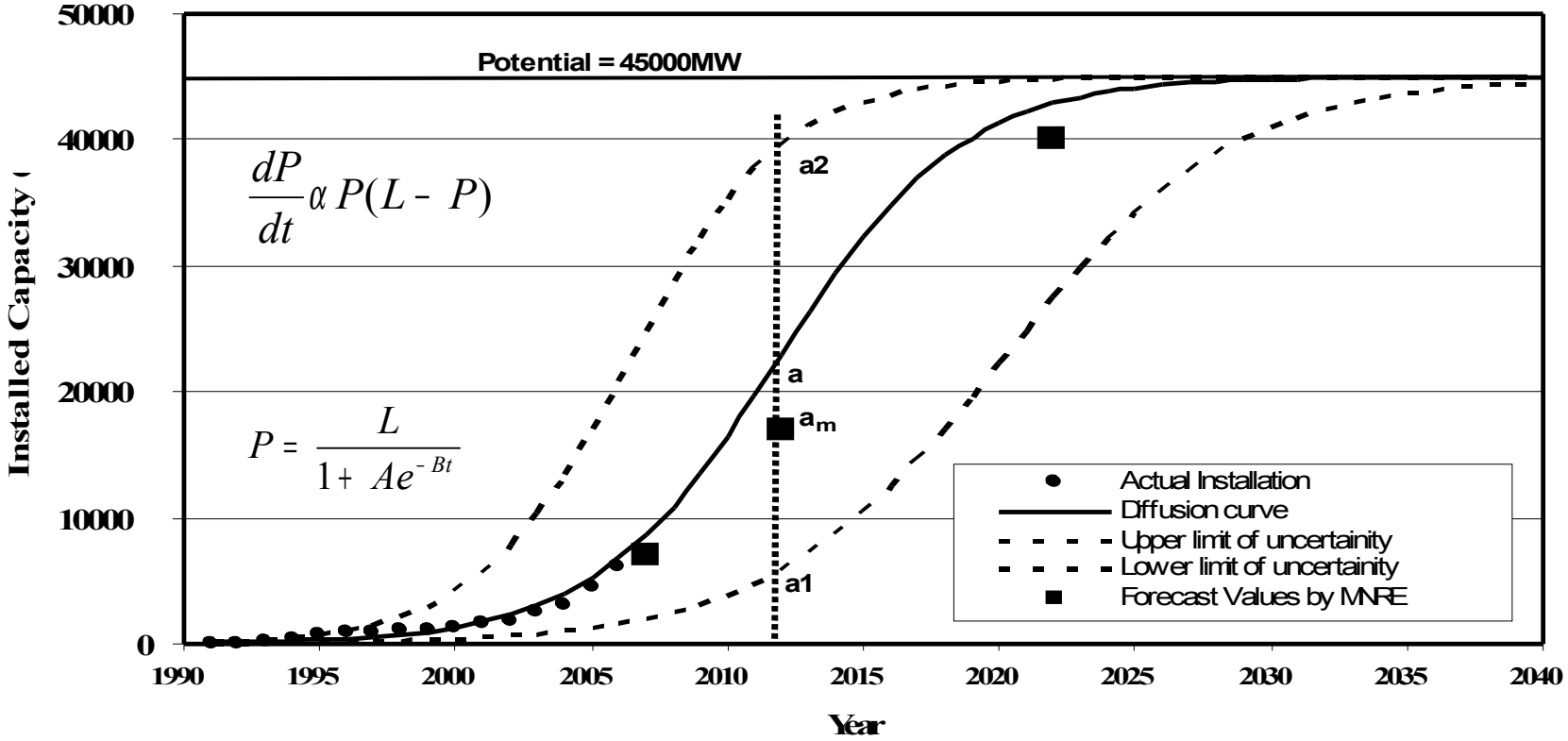
# Mainstreaming of renewables

#1 Technology Development and Research challenge -Cost Reduction challenge

#2 System Integration/ System Planning challenge – Need for better methods for potential estimation, Impact on rest of grid

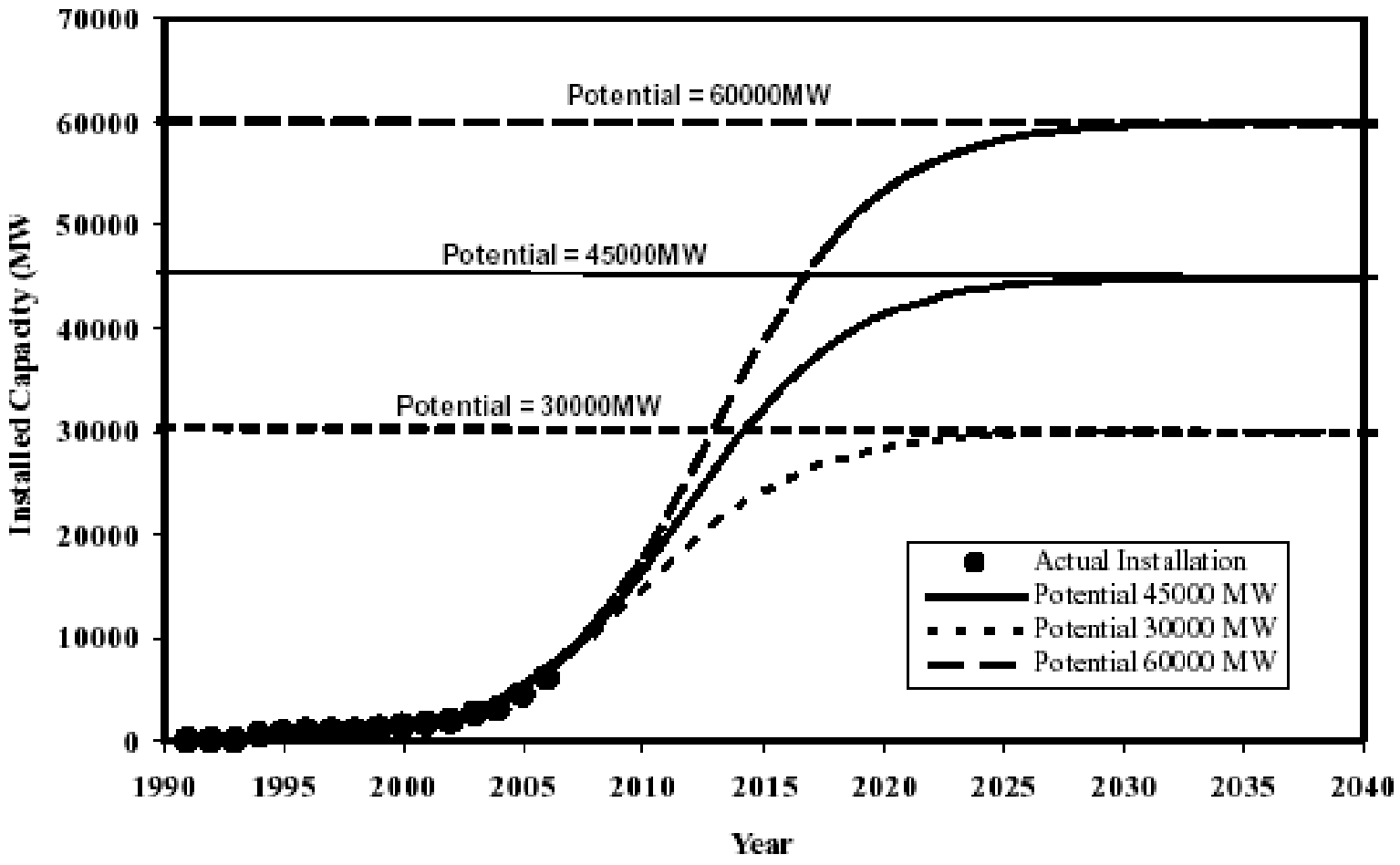
#3 Sustainability- Land, Water, Materials, Emissions

# Diffusion Curves for wind energy #2




| Year | Projection by MNRE | Projection by diffusion curve | Values in the uncertainty limit of 5% | |
|---|---|---|---|---|
| | | | Lower limit | Higher limit |
| 2007 | 7000 | 8700 | 2000 | 24800 |
| 2012 | 17500 | 23000 | 5800 | 39600 |
| 2022 | 40000 | 42900 | 27400 | 44800 |

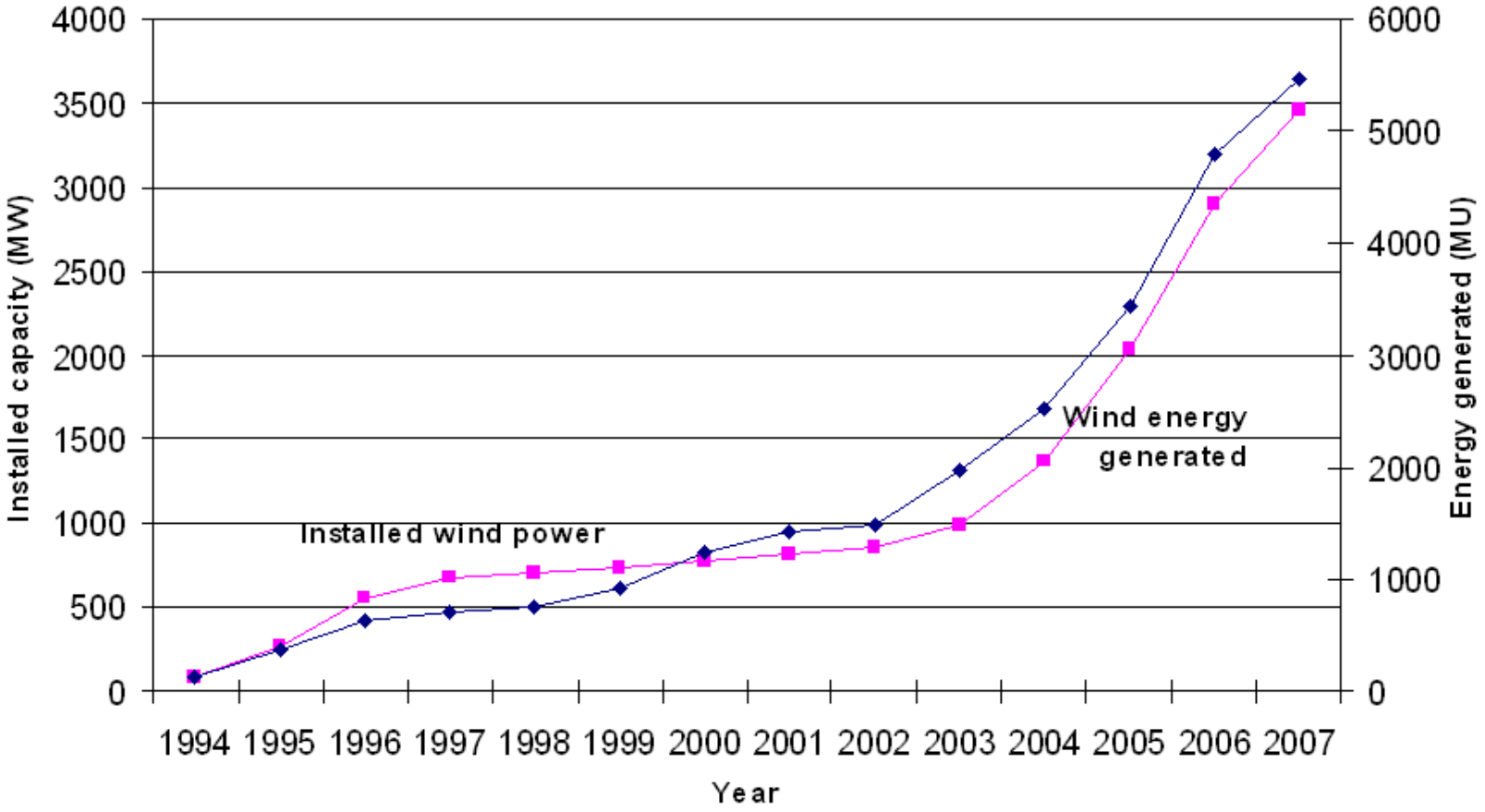
# Wind Diffusion #2



# Tamil Nadu – Grid Details

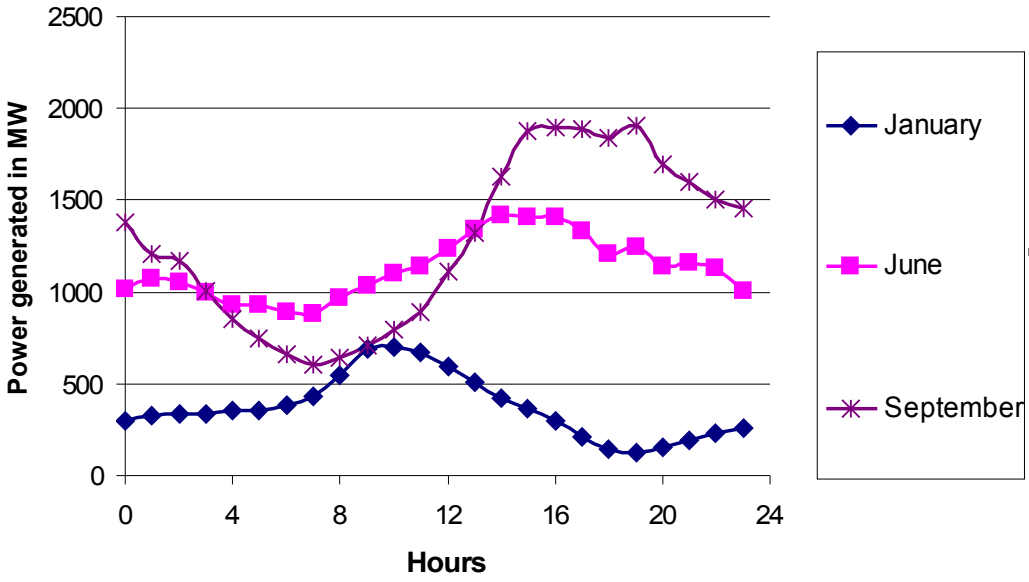
| Source | Installed capacity (MW) | Annual Energy generated (MU) | Annual average capacity factor (%) |
|---|---|---|---|
| Coal | 2970 | 21230 | 81.6 |
| Gas | 424 | 1945 | 52.4 |
| Hydro | 2187 | 6290 | 32.8 |
| Firm central share# | 2825 | 17785 | 71.9 |
| Wind (state + private) | 3856 | 5270 | 18.6 |
| Other renewables (solar PV, biomass and Bagasse based cogeneration) | 556 | 1220 | 25.1 |
| Independent power projects (coal, lignite, diesel or gas based) | 1180 | 6360 | 61.5 |
| Assistance from other regional grids | 519 | 2280 | 50.1 |
| **Total** | **14517** | **63370** | **49.8** |

# #2 TN – Installed wind power and wind energy generated

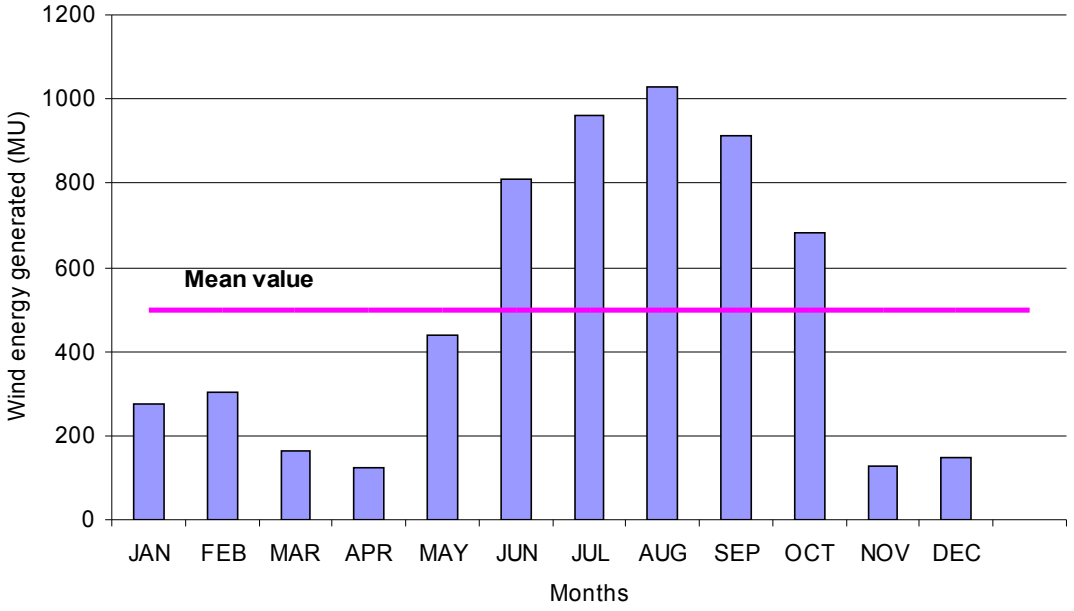


# Hourly variation of wind power

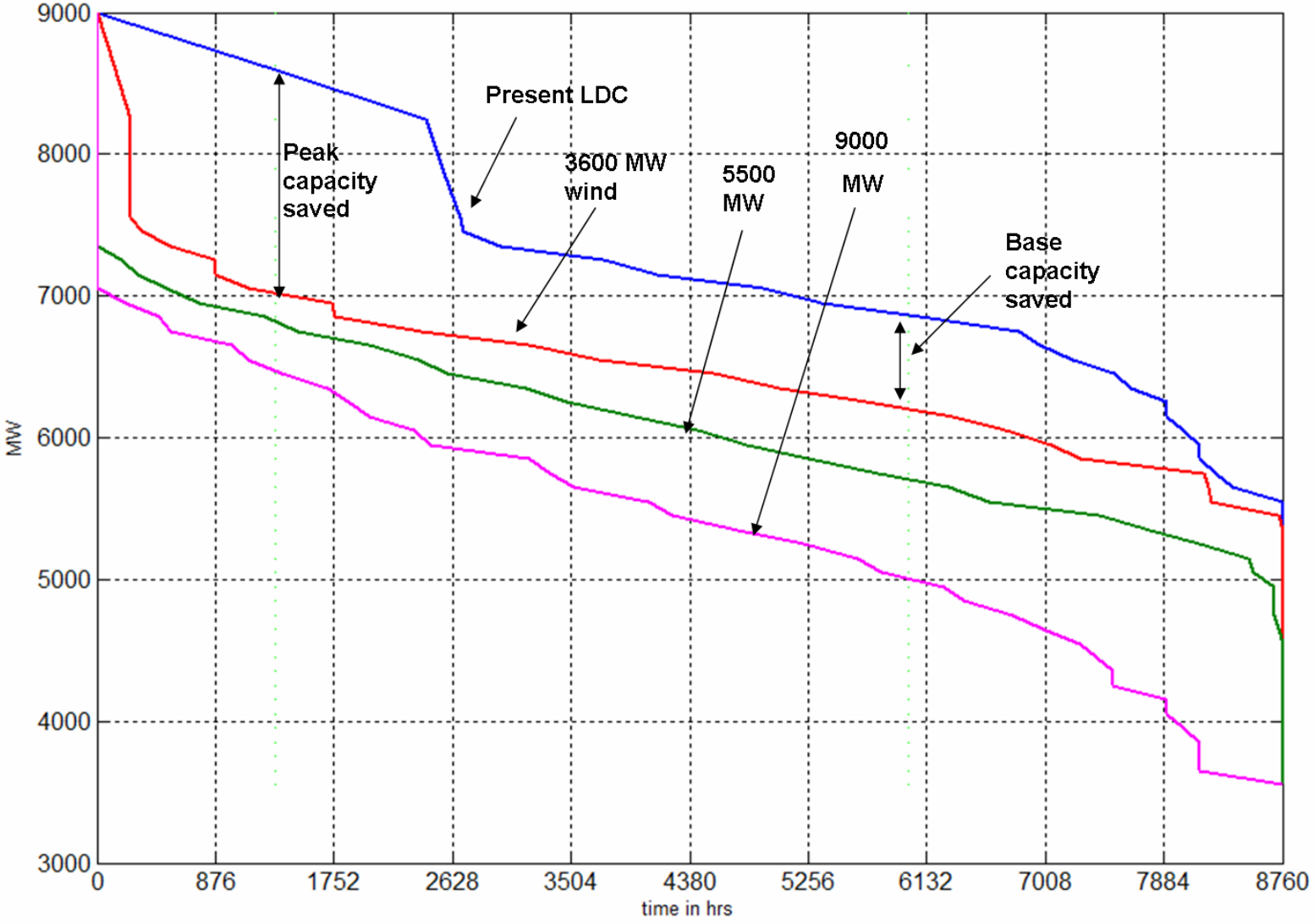
#2




# Monthly variation of wind energy generated

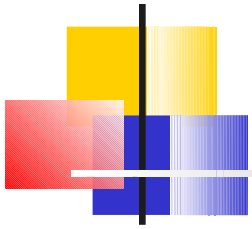


# Impacts on LDC #2



# Summing up

- Long term – capability development, employment potential for Maharashtra
- Level playing field between technologies – New technologies, cofiring, hybrids, technologies at different stages of development
- Local and Global Emissions
- Sustainability – Area, materials, water
- Marginal to Mainstream – System integration and planning issues, need for new methodologies
- Policies to foster cost effective renewable for future

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# Thank you

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