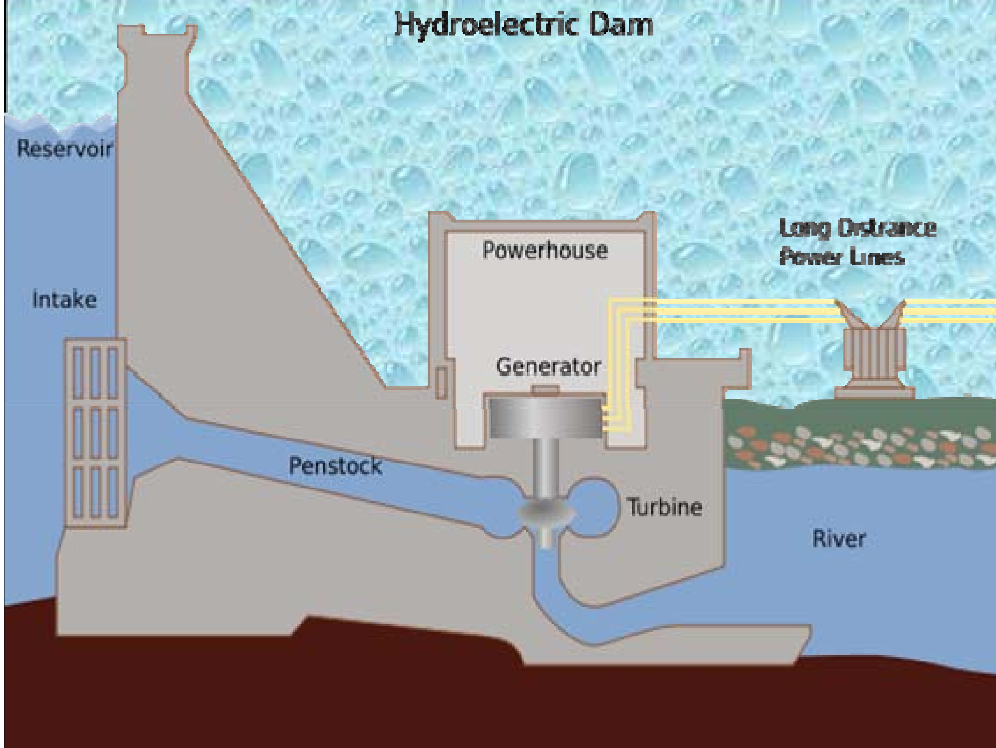

CLIMATE CHANGE AND HYDROPOWER GENERATION

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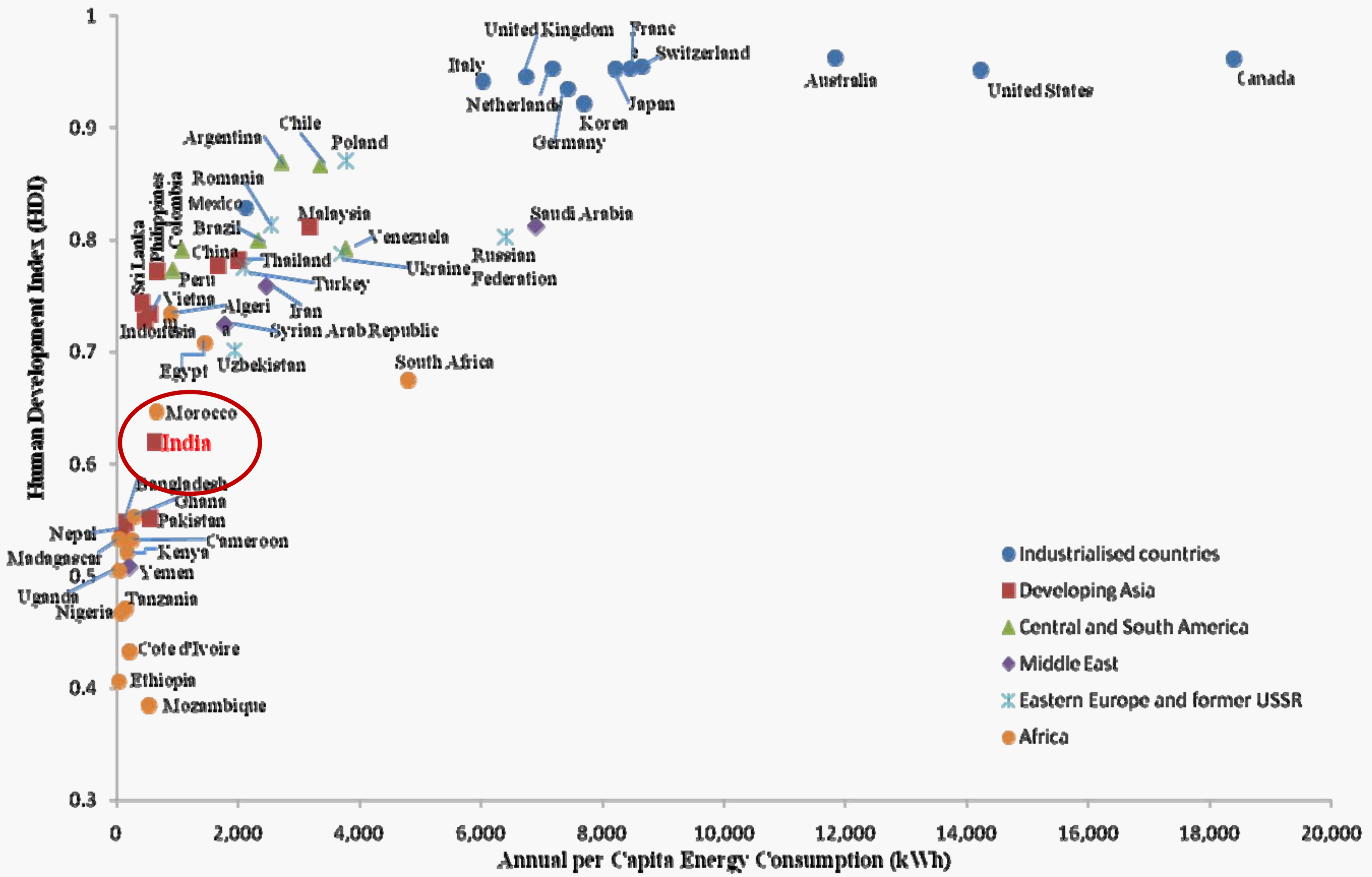


The United National HDI and Annual per capita energy consumption (kWh) for 60 most popular countries, Human Development report 2007-08

ENERGY CONSUMPTION

HYDROPOWER IN THE WORLD

- About 20% of all electricity in the world, is generated by hydropower.
- Canada is the largest producer of HP in the world. United States is the second.
- Norway produces more than 99% of its electricity by HP. New Zealand uses HP for 75% of its electricity.
- Highest per-capita demand for energy is from OECD economies, but the most rapid growth is in many developing countries.

Hydropower Generation

- Concept: water falling under gravity turns blades of a turbine, which rotates generator to generate energy.
- Basic elements of water power are river flow and hydraulic head.
- Two major types of HP Projects:
  – Run-of-river: use river flows, as it happens; vulnerable to CC
  – Storage based schemes: can overcome seasonality in river flows.

Hydropower Generation

- HP is a proven, mature, efficient and cost competitive renewable energy source.
- Requires relatively high initial investment but has low operation costs.
- HP plant can come "on line" quickly and respond to emergency energy needs.
- Offers a hedge against volatile energy prices.
- Multipurpose projects give additional benefits - manage flood and droughts.

FEATURES OF HYDROPOWER

- 1 GWh from HP corresponds to appr. 220 t oil
- 1 GWh from HP corresponds to appr. 330 t hard coal
- Ideal partner for other energy generation options

HP Generation and CC

CC may influence HP through Q and H:

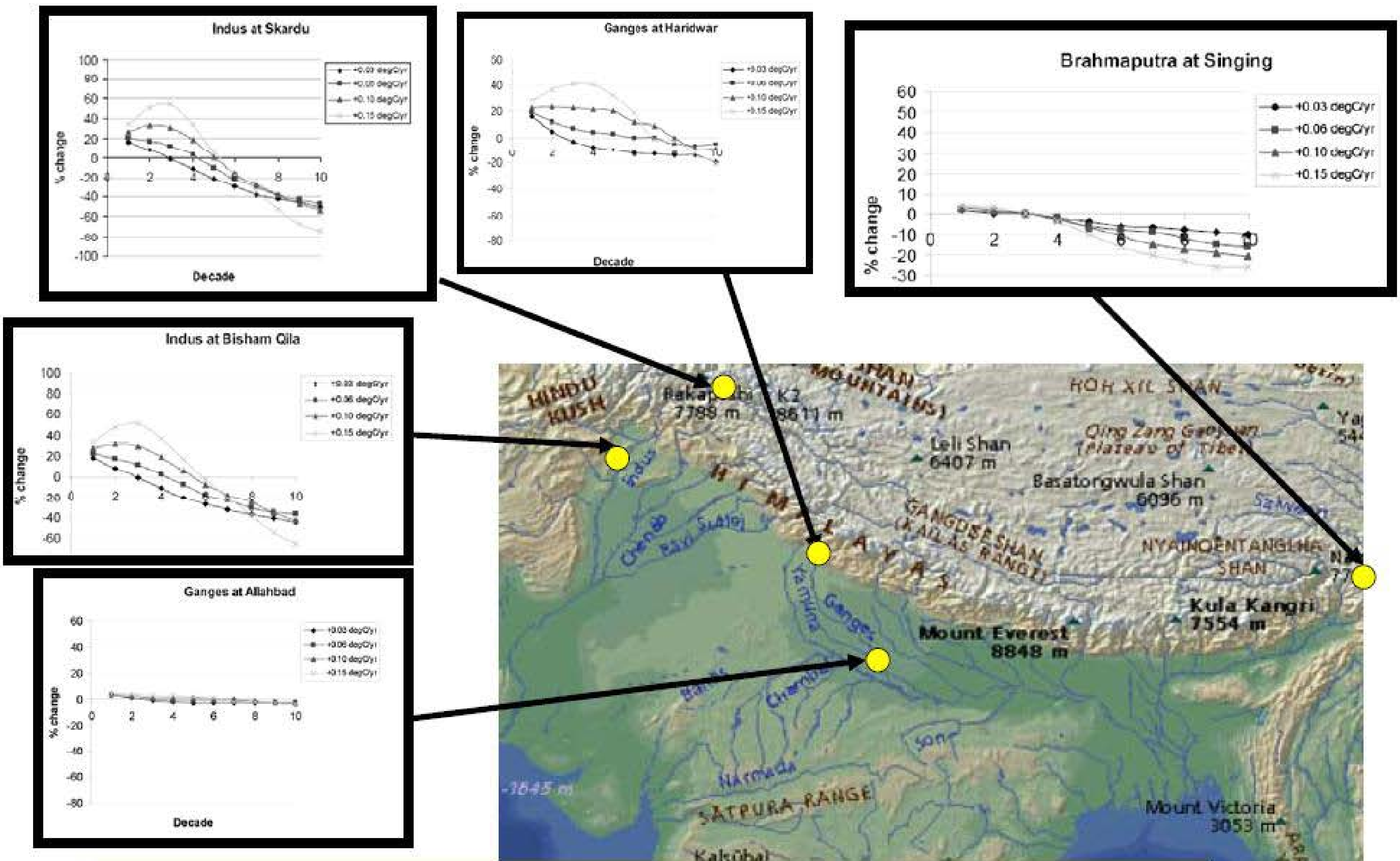
$$P = \gamma Q H$$

- **Q: Discharge**
  - **Water availability and distribution**
  - **Smaller quantity, less HP generation**
  - **If flows are concentrated in fewer months, more chances of spill, less HP**
- **H: Head**
  - **Less ppt in higher reaches, less HP.**
  - **Less inflow → lower water level → smaller generation.**

HP Generation and CC

- Due to impacts on Q & H, HP generation depends on climate and hydrology.
- CC could induce a timing mismatch between energy generation and demand.
- Additionally, higher inflows in wet season could lead to greater spillage and less overall energy generation.
- Impact of CC on HP generation can be studied using an optimization/simulation model of hydropower systems.

SIMULATED EFFECTS OF DEGLACIATION ON HIMALAYAN RIVER FLOWS



Source : Rees et al., 2005

Methodology to Study Impacts

To identify the potential initiatives that HP industry need to undertake, it is important to determine impacts of CC on hydrological variables.

Usually, the following steps are taken:

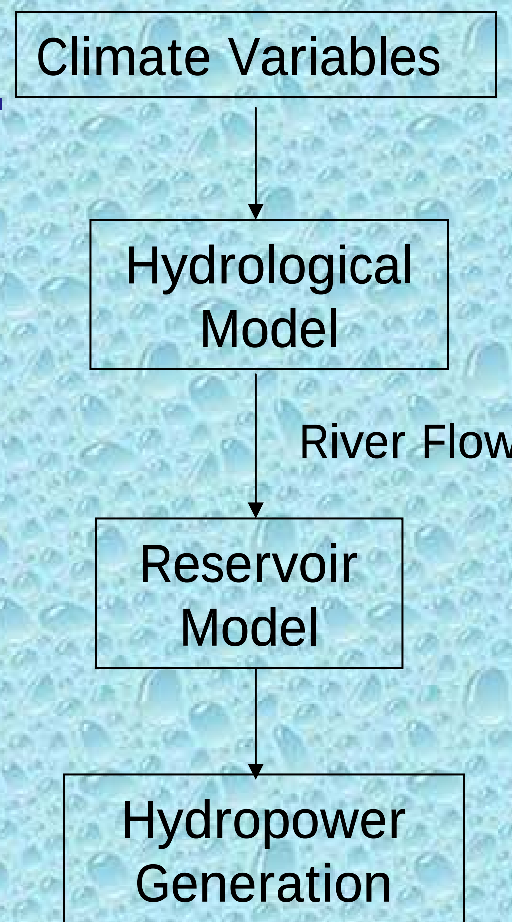
- General circulation models (GCMs) are used to simulate future climate under assumed climatic (including GHG emission) scenarios.

METHODOLOGY

- GCM outputs are downscaled to the appropriate scales of hydrological models by applying techniques such as statistical downscaling, RCM.
- Hydrologic models are employed to simulate effects of climate change at regional and local scales.
- Outputs from these models serve as inputs to reservoir simulation models that give details about hydropower production.

METHODOLOGY

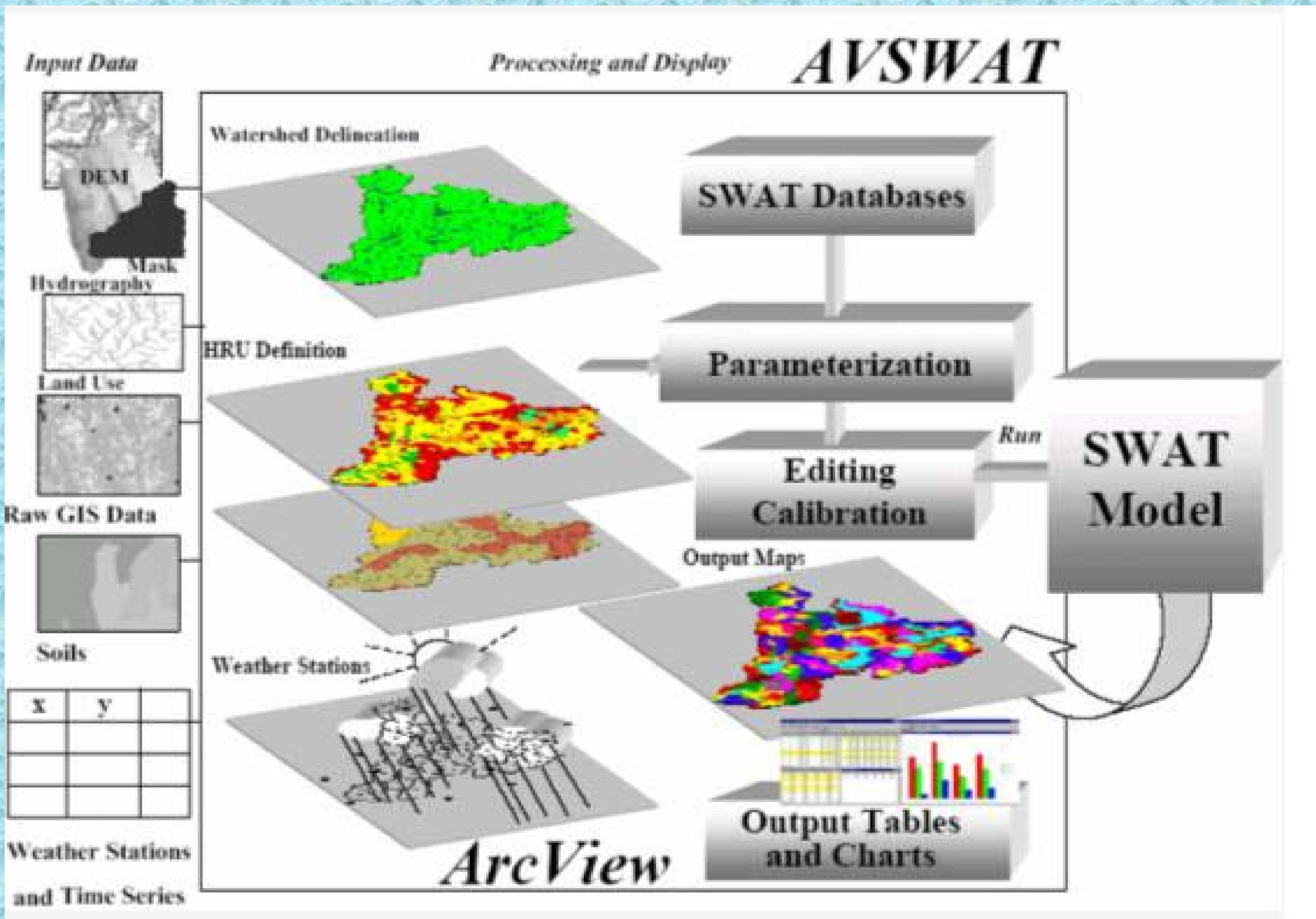
- **Climate variables can be estimated using GCM + scenarios.**
- **Using observed discharge and other data, operation of project is simulated to obtain baseline energy generation.**
- **Discharge of river under likely future climate can be computed by a hydrologic model.**
- **Hydropower generation can be computed using likely discharge series and compared with baseline scenario to infer change.**



Case study: Climate Change Projection

Scenario	Year	Seasons	Trend analysis		IPCC 2007	
			Precipitation (%)	Temperature (ºC)	Precipitation (%)	Temperature (ºC)
Observed	1984 – 2003	DJF	Observed	Observed	Observed	Observed
		MAM	Observed	Observed	Observed	Observed
		JJA	Observed	Observed	Observed	Observed
		SON	Observed	Observed	Observed	Observed
Medium term	2024 - 2043	DJF	(-3)	(-0.1)	(-1) - (+2)	(+0.86) - (+2.25)
		MAM	(+3)	(+0.4)	0 - (+3)	(+0.92) - (+2.32)
		JJA	(+1)	(-0.5)	(-1) - 0	(+0.83) - (+2.13)
		SON	(-3)	(+0.7)	(-2) - (-1)	(+0.85) - (+1.32)
Long term	2074 - 2093	DJF	(-12)	NO DATA	(+6)	(+3.92)
		MAM	(-1)	NO DATA	(+12)	(+3.83)
		JJA	(-3)	NO DATA	(+7)	(+3.61)
		SON	(-9)	NO DATA	(+7)	(+3.72)

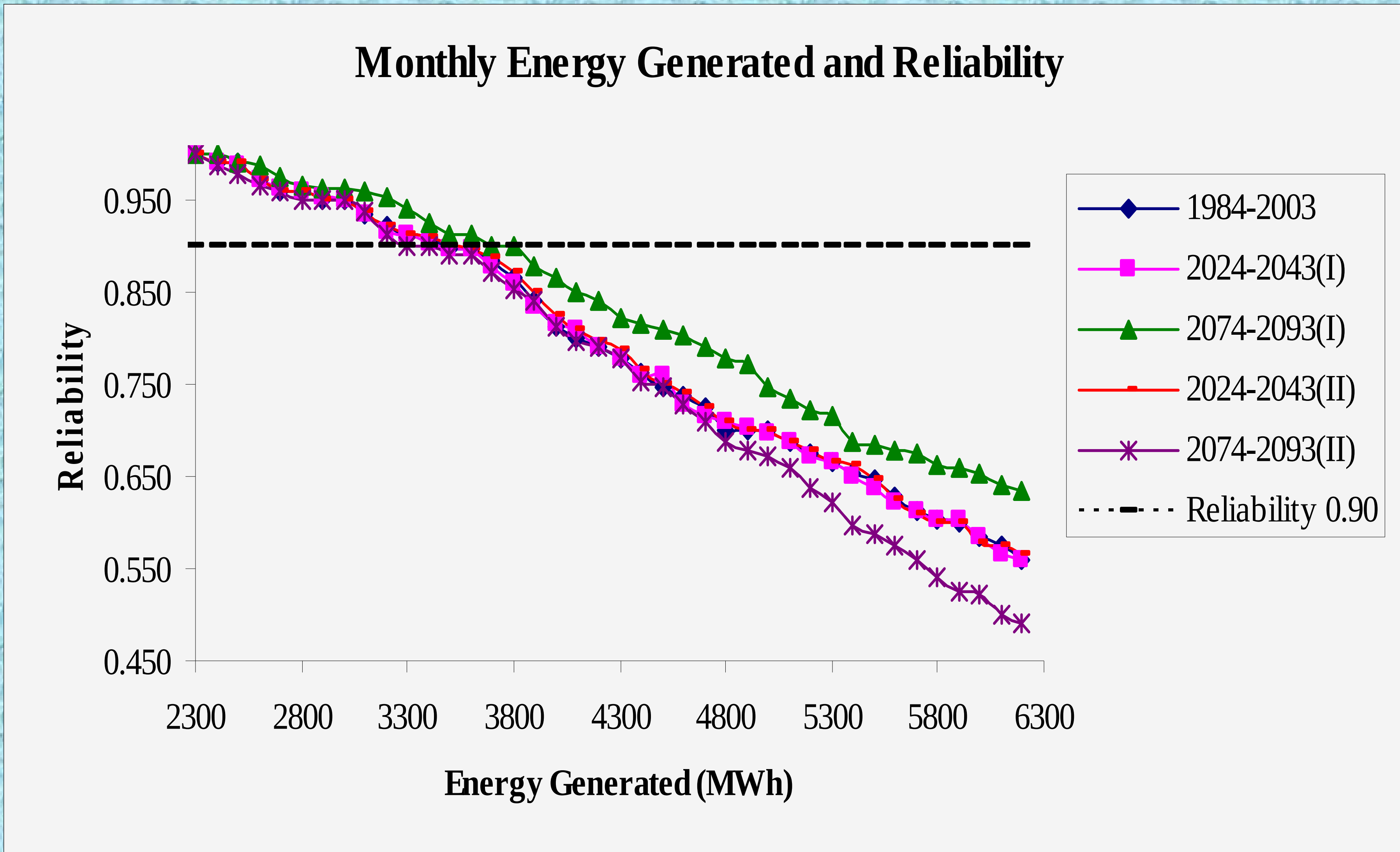
Catchment Modelling with SWAT



Assessment of HP Generation

- Assessment of firm power
- Assessment of energy generated
- Data required:
  - Reservoir features
  - Hydropower plant features
  - Inflows under different climate scenarios
- Inter-comparison will bring out climate change impact

SIMULATION RESULTS



Case study: Summary

- Change in precipitation in study area ranges between ±3% in medium-term (up to 40 years ahead) and ±12% in long-term (up to 90 years ahead).
- Likely temp. change range between -5 ˚C to +2.32 ˚C and +3.61 ˚C to +3.92 ˚C for medium and long term scenario.
- In medium-term, inflow is not likely to change much.
- Generation with reliability > 0.90 is likely same in almost all scenarios.
- Deviation increase when energy > 4800 MWh or when reliability < 0.688.

Current Energy Scene

- Shortages in electricity supply are about 10%.
- Shortage in peak capacity amount to > 15 GW.
- High T&D losses, about 32% of total electricity generation, sometimes 50%.
- Inadequate transmission capacity.
- Environmental concerns: GHG emission, fly ash disposal.

HP and Energy Security for India

Technology	Installed capacity 2011 (TW)	Future projections 2050 (TW)
Fossil Fuel (coal-100, Gas-18, others)	119 (65%)	485 (76%)
Nuclear	5 (3%)	35 (5%)
Hydropower	39 (21%)	70 (11%)
Renewable	20 (11%)	50 (8%)
Total	183	640

Source: CEA and others

Energy Security for India

Coal:

- Recoverable resource for India = 59 bt
- Will require 1740 mt of coal pa to generate energy
- High ash content in Indian coal.
- Limited capacity of railway network.
- About 10% of generation capacity is lost due to inadequate coal supply.
- Environmental problems: emission of GHGs, fly ash.
- Foreign exchange is needed to import coal, infrastructure – ports, inland transport.

Energy Security for India

Gas:

- **Will require about 350 MMSCMD of gas pa to generate energy**
- **Limited domestic production unless new and significant discoveries.**
- **Limited capacity of pipeline network.**
- **Global warming issues.**
- **Large foreign exchange will be needed to import gas, infrastructure – sea terminals, pipelines for inland transport.**

Energy Security for India

Nuclear:

- India has limited Uranium reserves.
- India has large Thorium reserves but technology is difficult.
- Safety concerns, particularly due to recent events.
- Recent global trends do not project optimal picture.

Energy Security for India

Hydropower

- Hydropower has many advantages compared to other sources.
- Life cycle analysis shows HP as cleanest electricity technology with low carbon footprint.
- Reservoir based projects will be needed to overcome seasonality of flows.
- Out of estimated investment needs of $2700 billion, large foreign exchange will be needed. HP can help.
- HP will also help in “Green energy” generation.

THANK YOU