Interdisciplinary methods in Energy & Resources Modelling

Session 4C: Interdisciplinary modelling of the Whole Energy System

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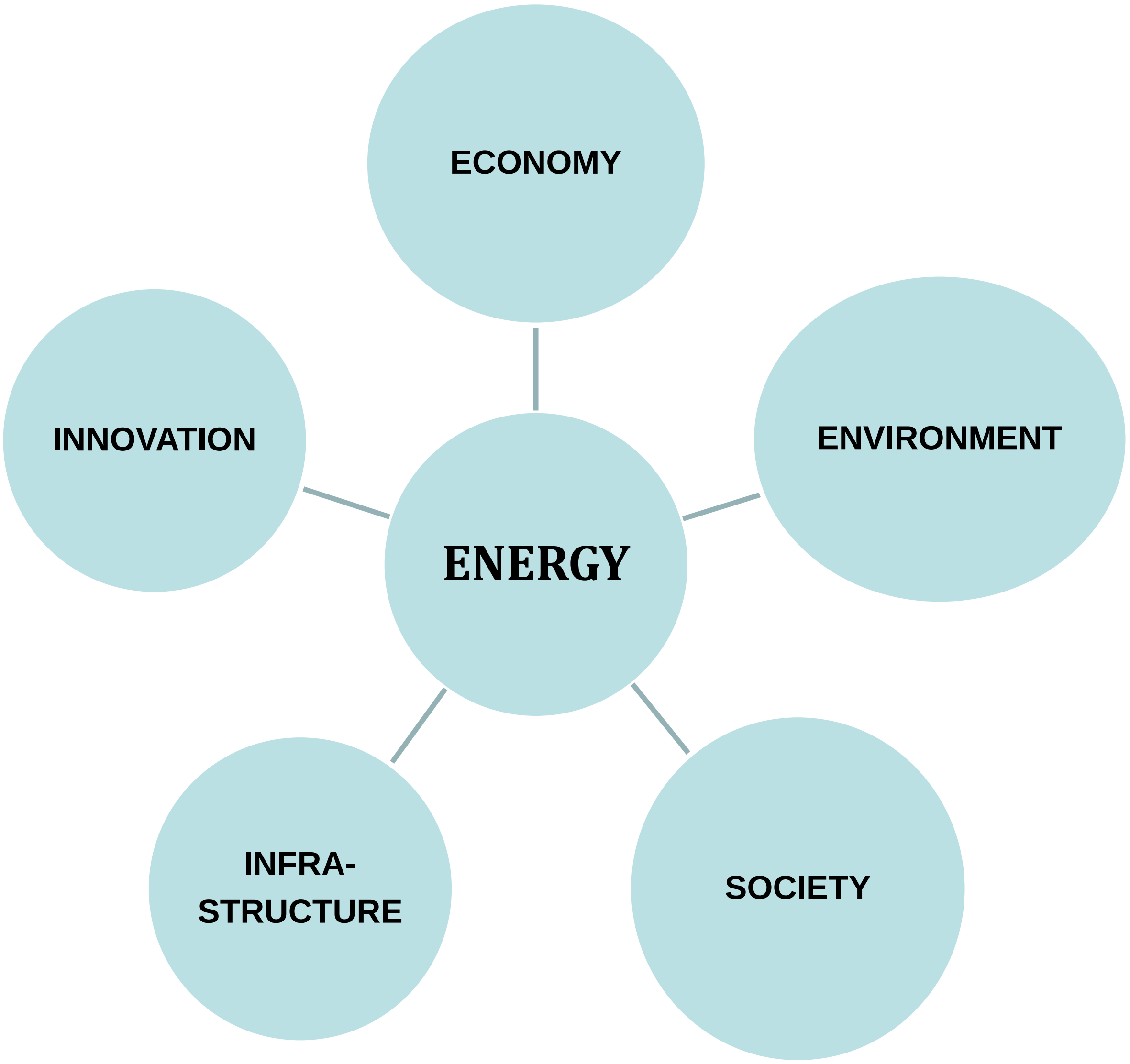
(Presented by Ms. Garima Vats)

Energy Systems Modelling



Social, Infrastructure and Innovation Aspects

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- Demands—Behaviour Change
- Handling structural shifts (price effects on demand)
- Development, modelling unmet demands, and rebound effects
- Impacts on Employment, Health
- Up-scaling unit level to urban centres (buildings)
- Impacts on demand due to technological shifts or innovation

TERI's MARKAL Modeling Framework

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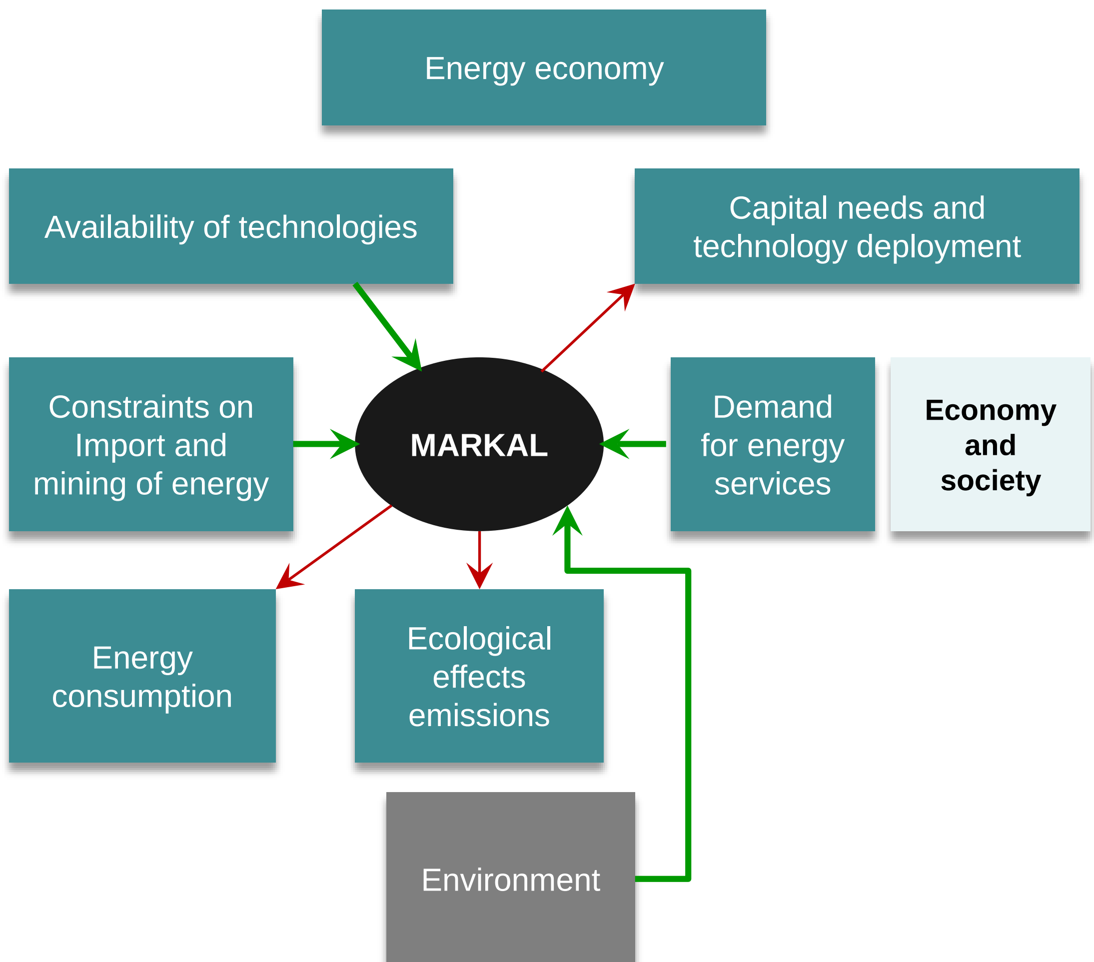
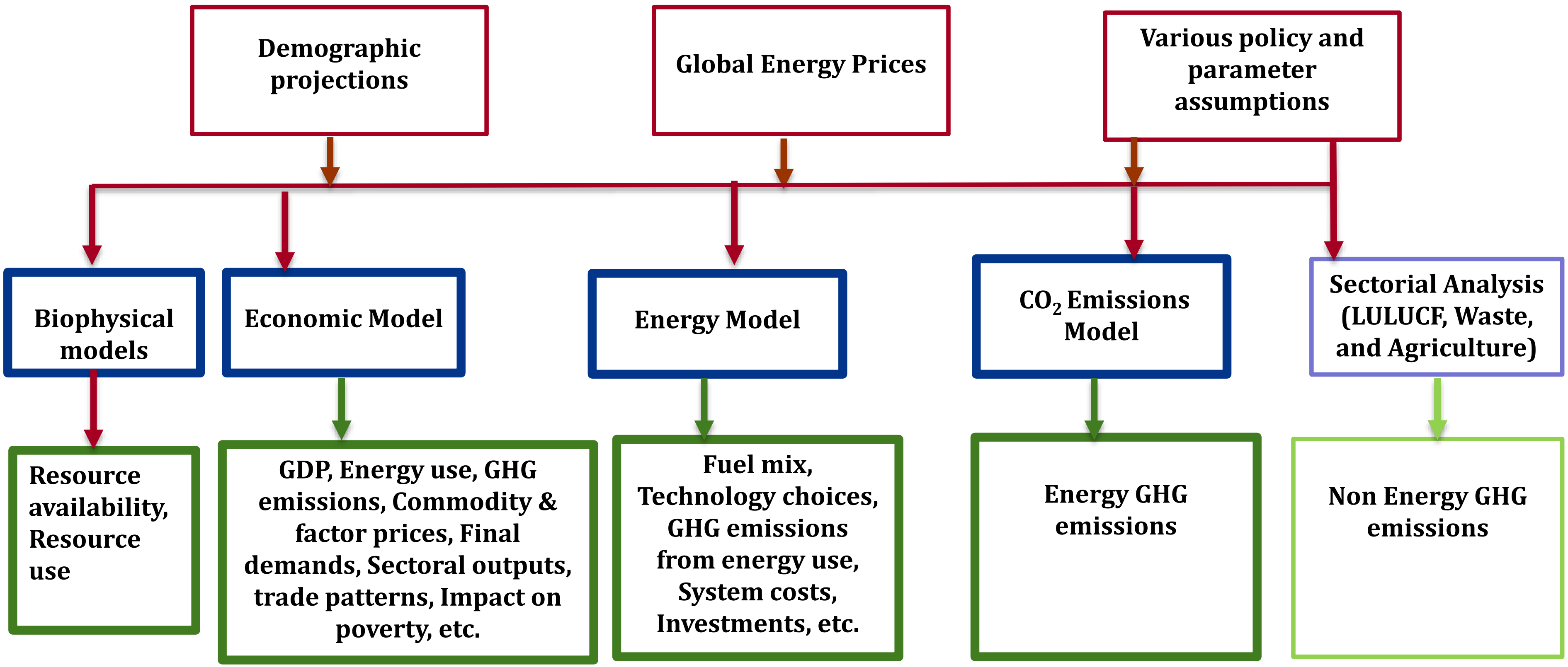
- Detailed bottom-up technological representation of the energy system: over 300 technologies & ~ 100,000 variables
- **Multi-time period, dynamic LP model extending from 2001-2051**
- Objective function minimizes total energy system costs while incorporating various elements of sustainable development, energy access, self sufficiency, emissions reduction

Economy-Energy-Environment linkages



Modeling Framework



Link of Energy Sector Model & CGE Structure and Process

SAM Constructed

Emerges from – commodity*commodity IO table (Matrix 6)

Nesting done, demand and supply side equation written, closure rules defined

Base run and simulations done with the closure rules

SAM with all sectors, subsectors, are incorporated through the call file

- SAM has all sectors, subsectors, intermediate input numbers
- The SAM file has all sectoral flows

Sectoral demand and supply side equations and functional specifications are written

- All parameters are called from outside through call files
- They are integrated to the equation

Results

- Savings and Investment Closure is followed to simulate
- Alternate scenarios are made through changing the call file numbers in spread sheet

Intermediate input flow

CGE-MARKAL Integration: Supply side

GDP of the economy for various green growth and development interventions

CGE simulations

CGE Outputs

set of demand for goods and services, change in relative prices

CGE Outputs going as an input to the MARKAL

Change in the GDP and demand for goods and services are incorporated into the MARKAL model leading to a change in sectoral energy demand.

The increase in the energy demand within the MARKAL model is then matched by an increase in the energy supply over time across scenarios through a cost optimization exercise

Policy insights

Impact of energy supply, conservation, energy efficiency related policy measures initiated by BEE on future sectoral energy demand

Impact on future sectoral and overall economic outputs owing to energy efficiency and conservation policies

CGE-MARKAL Integration: Demand Side

CGE Outputs:

GDP

Sectoral outputs

Relative prices

As an input to the MARKAL

MARKAL Outputs:

Sectoral energy demands

Sectoral GHG Emissions

Incremental investments in the energy sector

Optimal set of energy technologies

Policy Insights

- Change in relative prices of goods and services of the economy owing to renewable energy promotion, natural resource management, energy conservation policies

Policy Insights

- Future impact of policies on promotion of energy efficient technologies on sectoral energy demands, GHG emissions and incremental investments

MARKAL - CGE Integration: An example from Transport Sector

	Reference Scenario	Alternative Scenario
Passenger Transport Demand	31,392 BPKM by 2046–47	Reduced by 18% of the Reference levels of 2046–47
Modal Shares of total passenger traffic	till 2051	till 2051
	Rail: 12%	Rail : 19%
Share of total road based transport	Public: 46%,Private: 54%	Share of road based public transport as a per cent of total road passenger transport increases to 66% by 2046–47
Electric Vehicles	2Ws - 9% in 2046 - 47	2W - 10% in 2046 - 47
Freight Transport Demand	14,843 BTKM by 2046–47 till 2051	Reduced by 13% of the Reference levels of 2046–47
Modal Share of total freight traffic		Rail: 45% by 2046–47 till 2051

Sectorial Linkages

- Example: Transport mode/infrastructure decisions are taken at state/city levels – need to model/estimate the impact of varying transport infrastructure at these scales

- Develop state/city level transport demand and related energy use and emissions model

Energy System Models

- Link with environment
- Low carbon and other pollutants
- Health implications

Developing Multi-pollutant Emission Inventories

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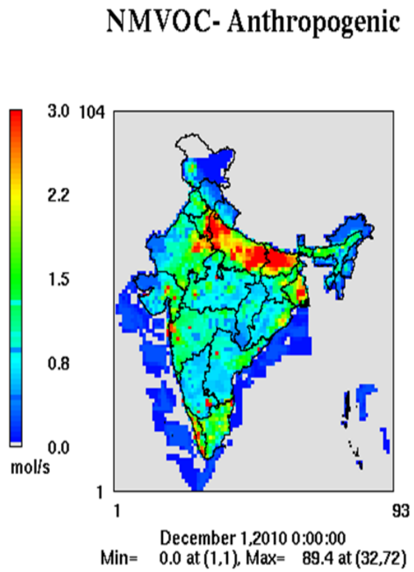
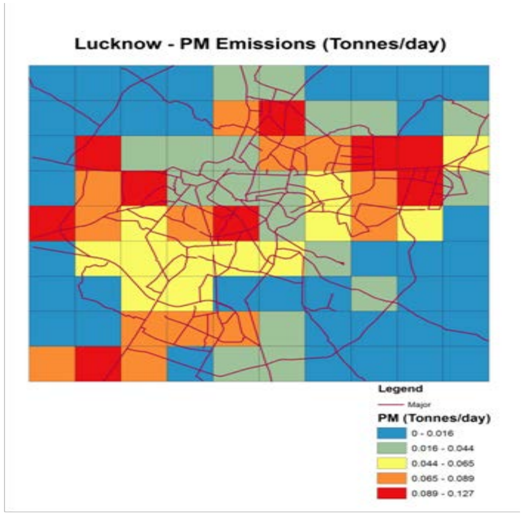
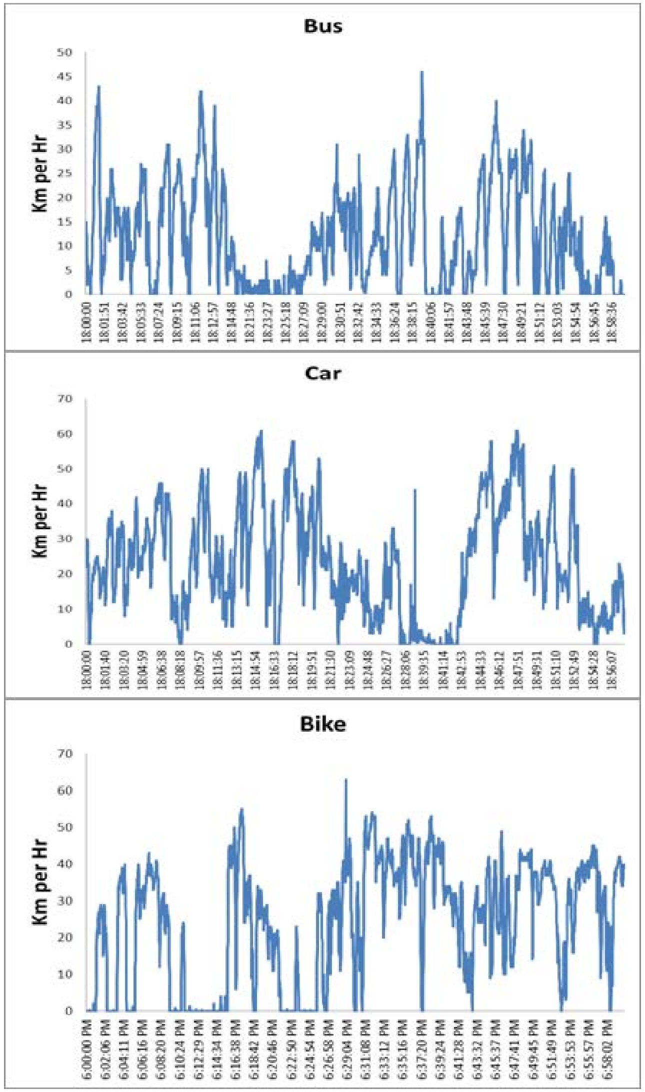
- National level inventories
- City inventories







Multi-Pollutant Emission Inventories

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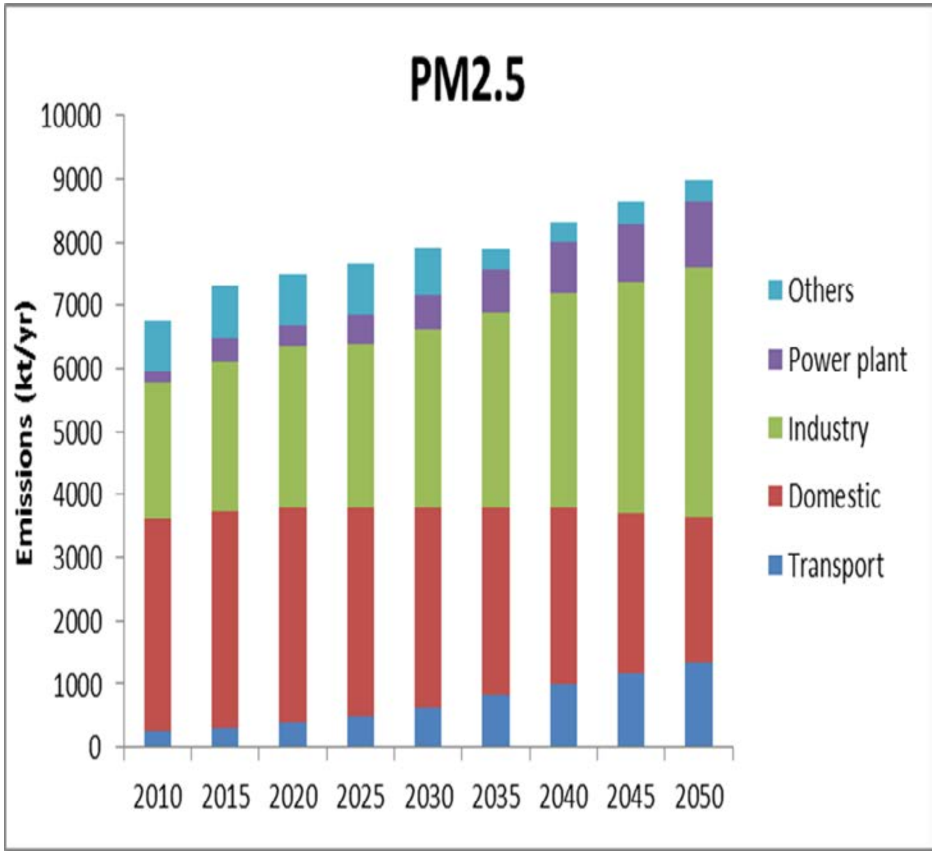

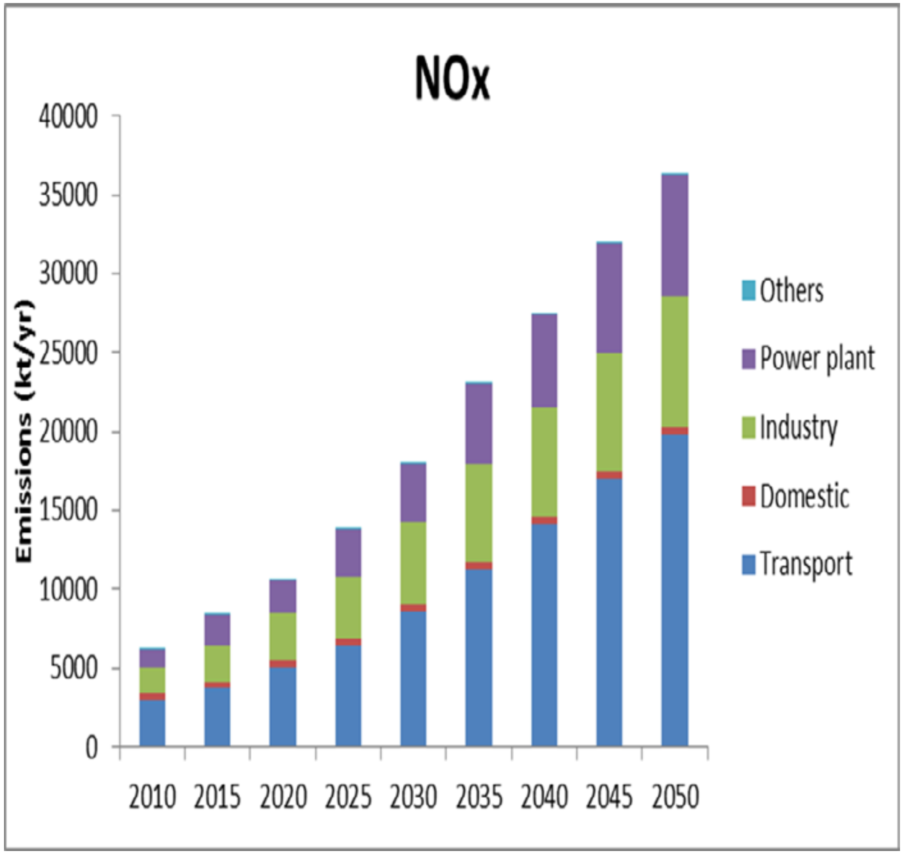

Air Pollution Modelling using different approaches – Source Apportionment

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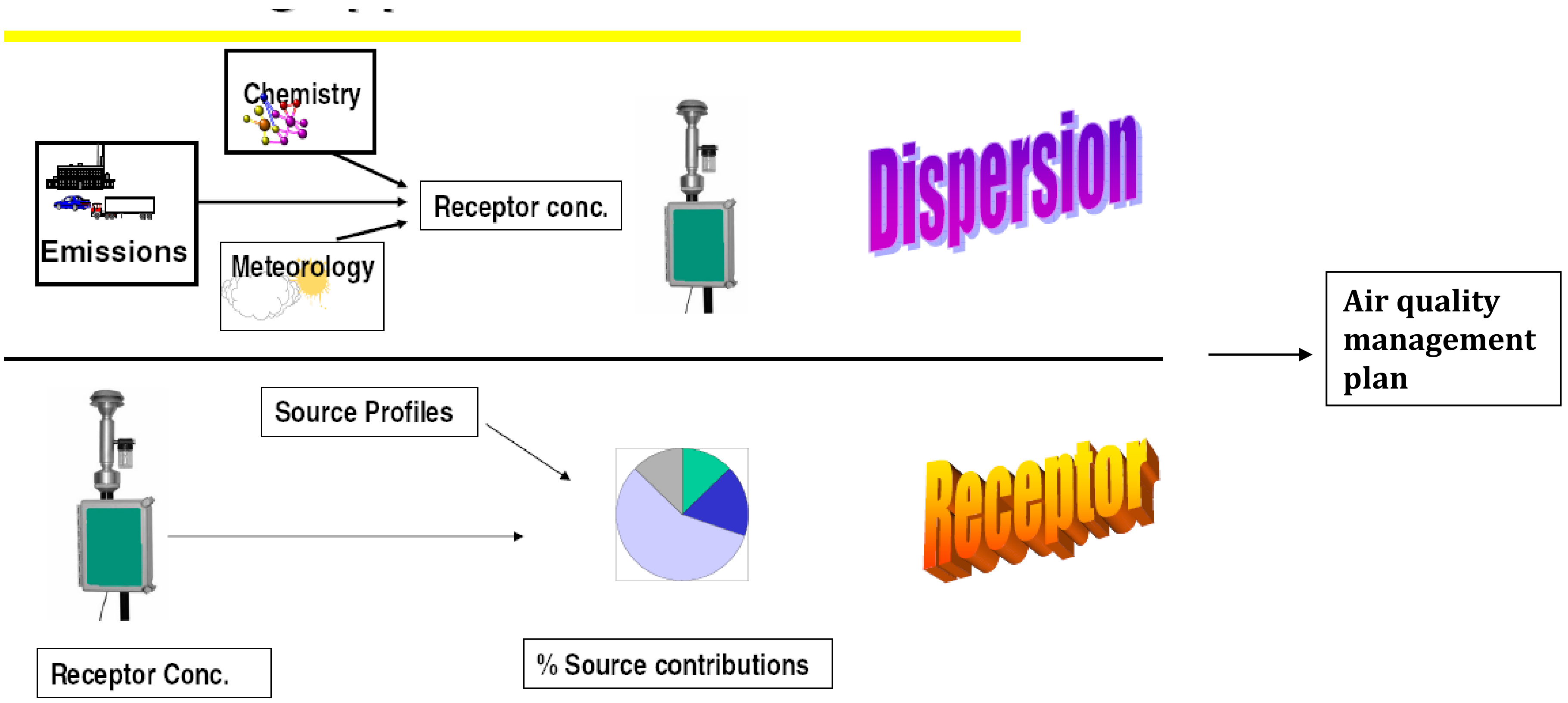
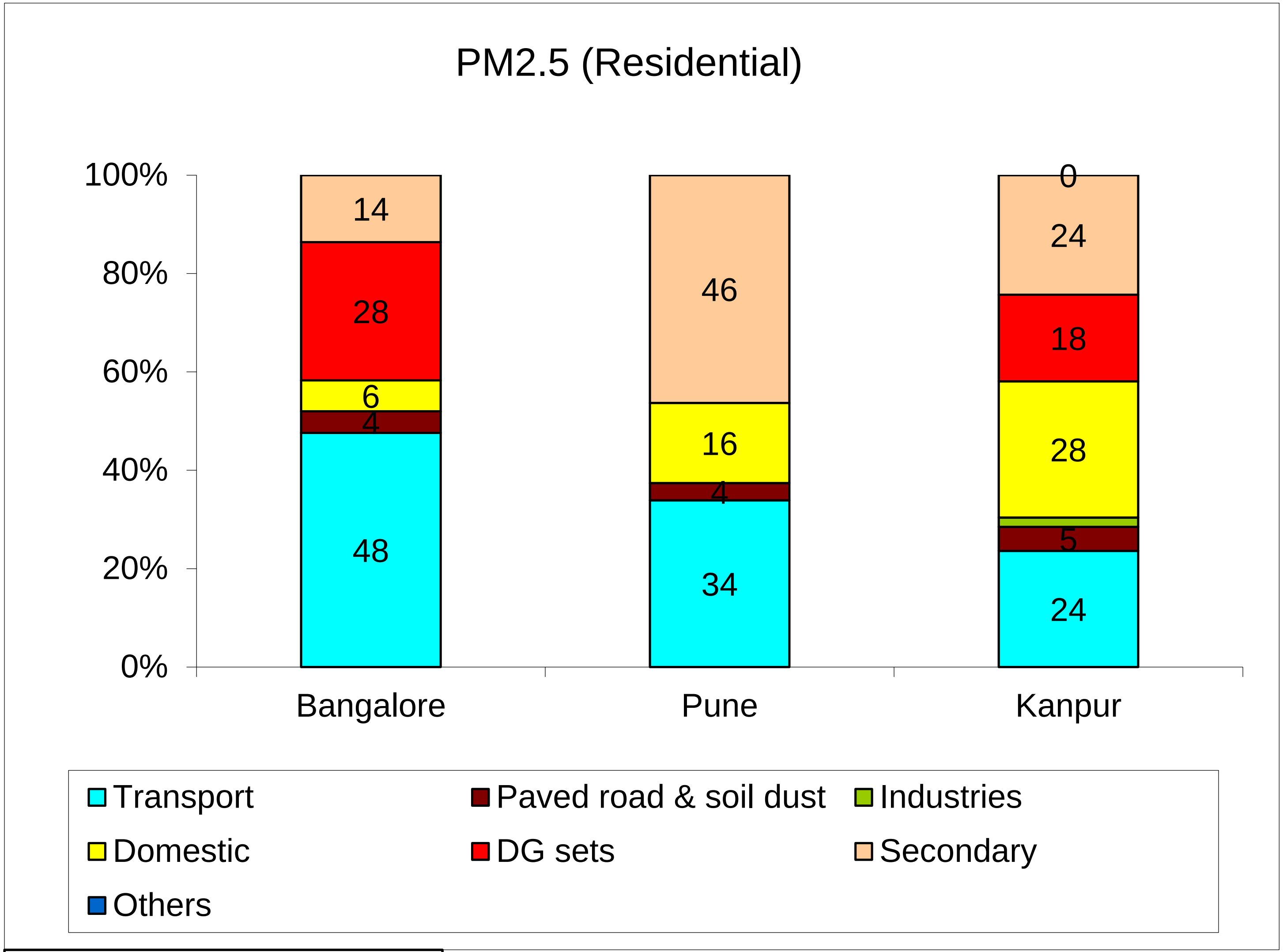


Source Apportionment Study (PM)



Source: CPCB, 2010

- Share of transport sector increases if we move from PM10 to PM2.5 (finer fractions)
- In non-industrial cities, it is the largest source

3-D Air Quality Modelling (WRF-CMAQ)

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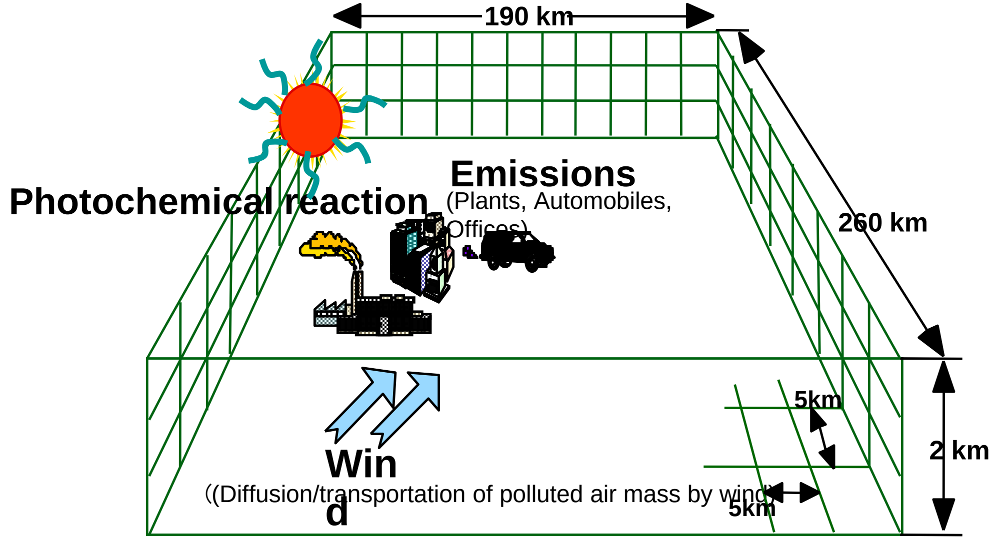
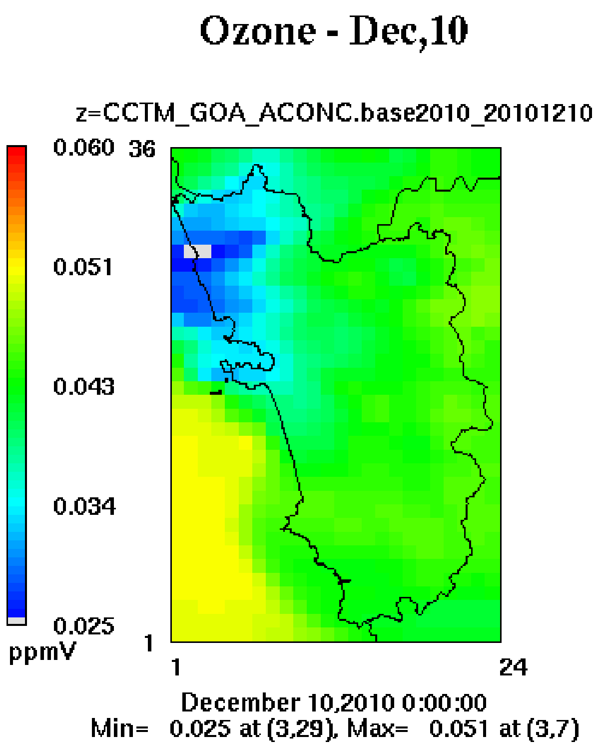
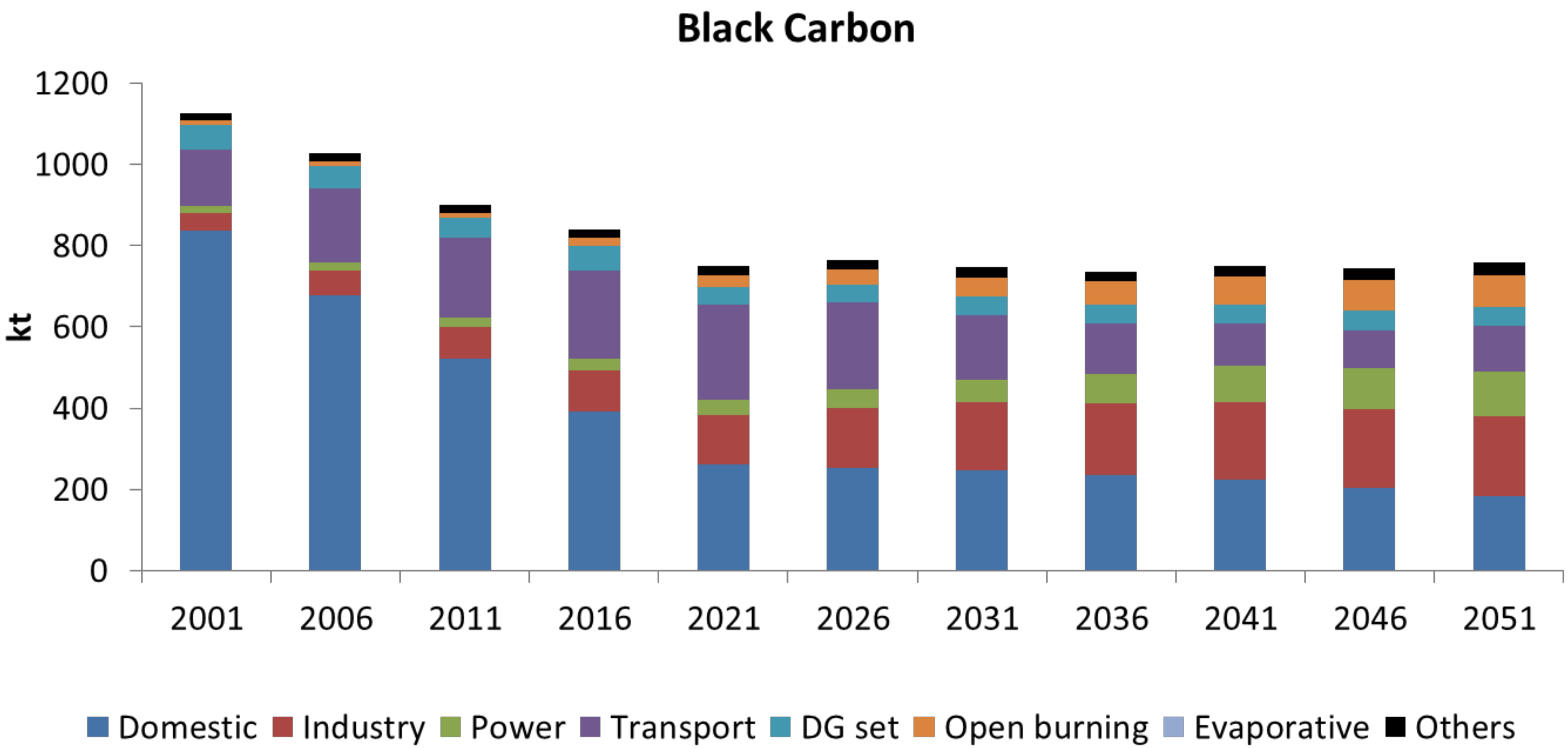




- To assess regional scale pollution (of PM and Ozone) and formulate long term policy measures at National, regional and urban scales
- To assess secondary pollutant formulations in a one atmosphere-multi-pollutant approach

Emission Inventories (National)



Emission Inventories (National)

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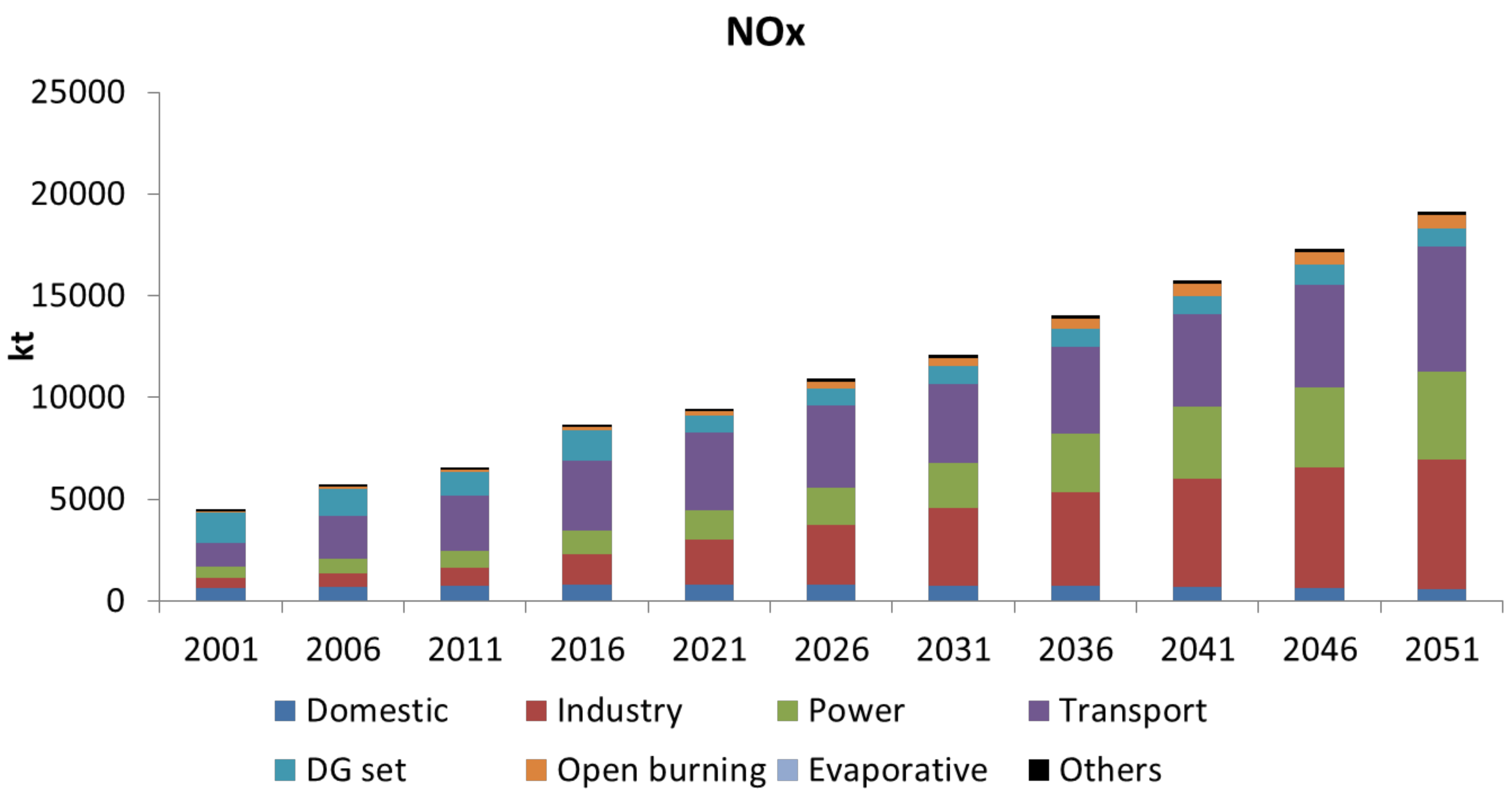

Simulations : PM2.5 concentrations and health impacts

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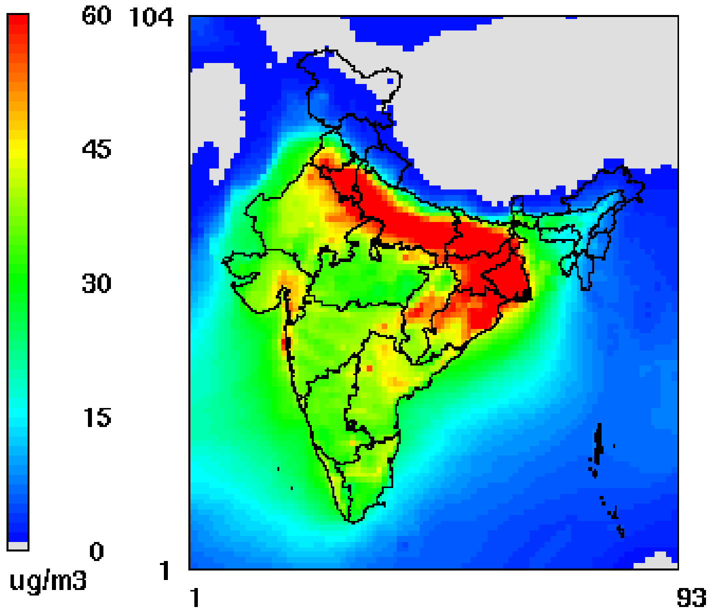
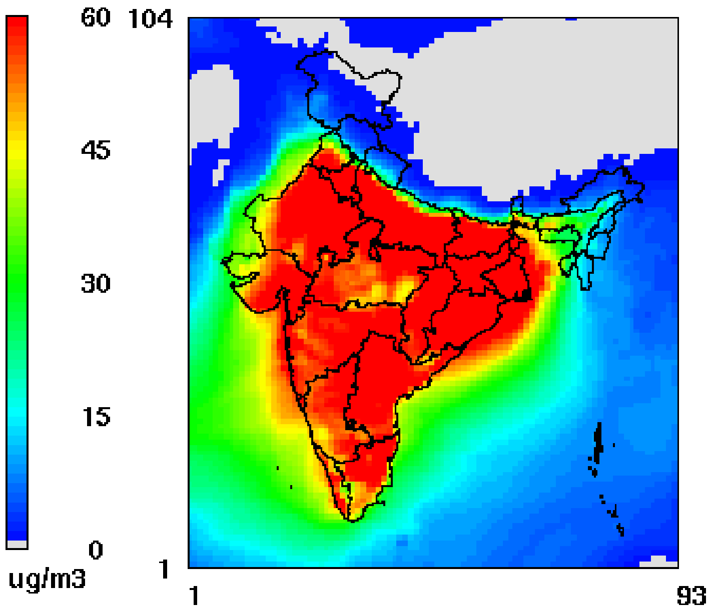
PM2.5 (2011: Winter)



PM2.5 (2031: Winter)



- **By 2011/12, most cities in the country had already exceeded the ambient air quality standard**
  - **Mortality from PM 2.5 estimated at 5.73 lakhs in 2011/12**
  - **Air quality could worsen increasing mortality to 11 lakhs by 2031/32**

Source: TERI's Integrated MARKAL, WRF, CMAQ Models Results

Growing Motor Vehicles !
Can we reduce emissions ?

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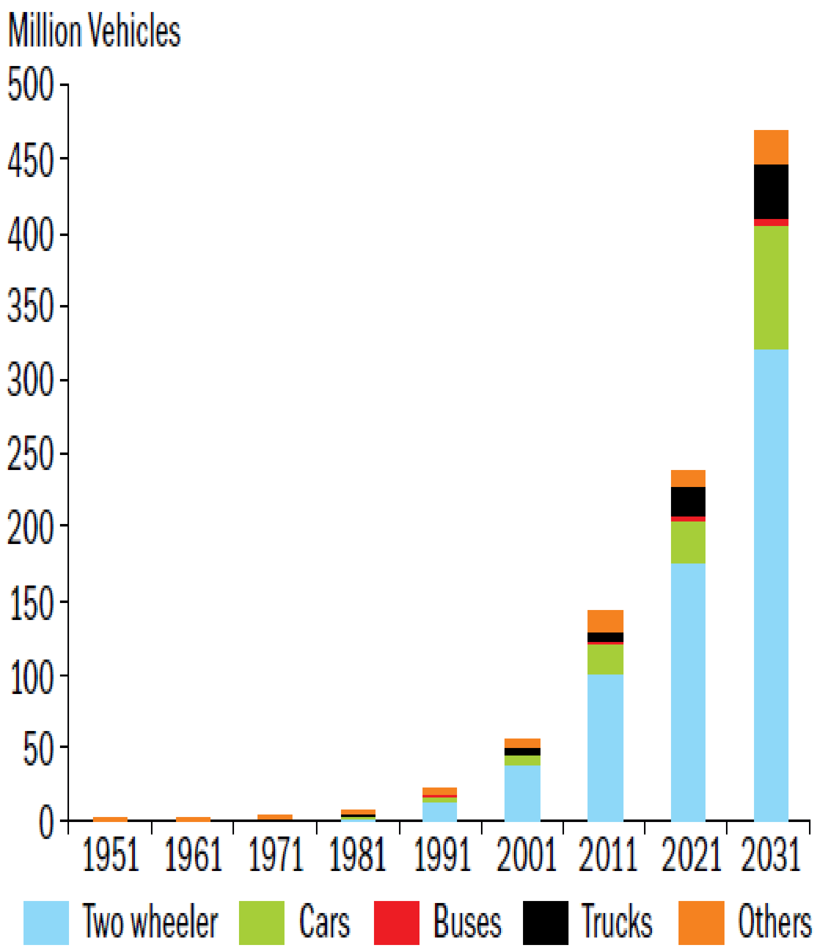

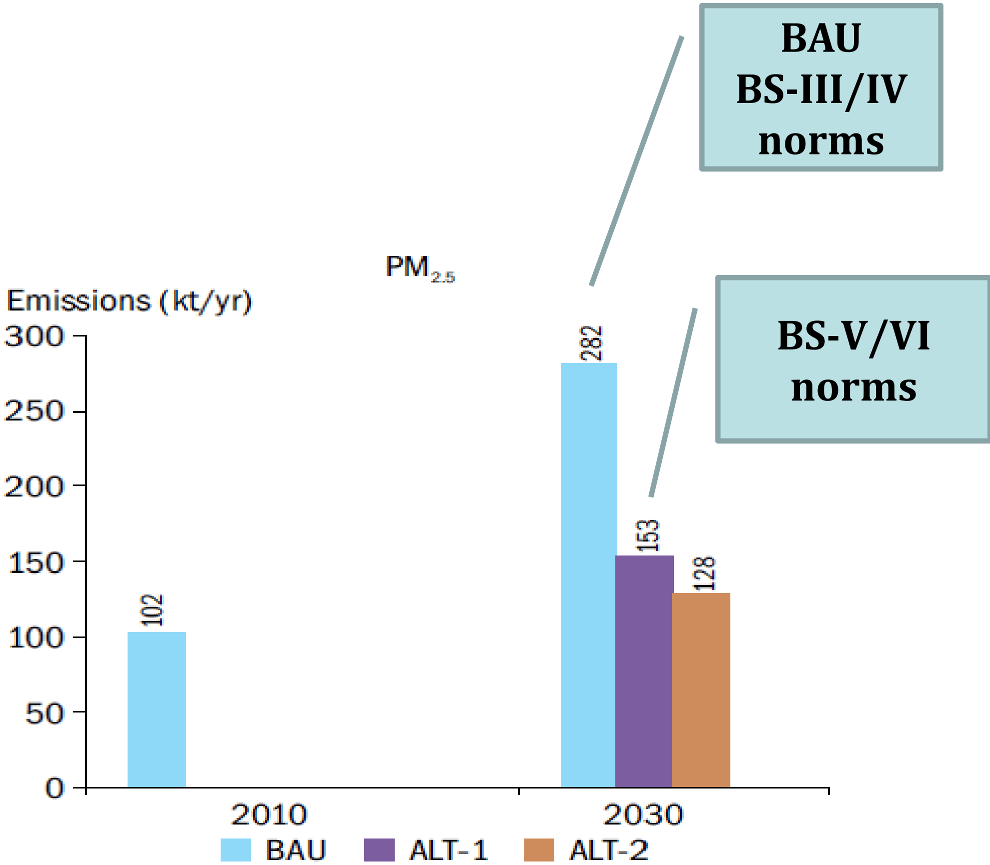

MoRTH, ROAD TRANSPORT YEAR BOOK (2009-10 & 2010-11), http://morth.nic.in/writereaddata/mainlinkFile/File838.pdf

Components of Transport Modeling within TERI

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Transport Demand Assessment

- **Use of activity based models to assess demand**
  - National, State, City level
  - Assisted by household, traffic, etc. surveys
- **Specific types of models**
  - TERI-TDM, TRANUS

Creating Transport Energy and Emissions inventories

- **Energy estimation from**
  - Bottom-up activity based models
  - Top-down energy use metrics
- **Emissions estimation at various scales**
  - GAINS, IVE, Excel based models, evaporative emission models, etc.

Simulation and impact assessment

- **Energy impact studies**
  - Demand, mode share, technology, efficiency related
- **Transport related air quality impact assessment**
  - Local air quality (dispersion modeling studies)
  - Health and economic impact

Linkages with Water, Land, Climate etc.

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Simulation modeling:

ArcSWAT for SWAT 2012

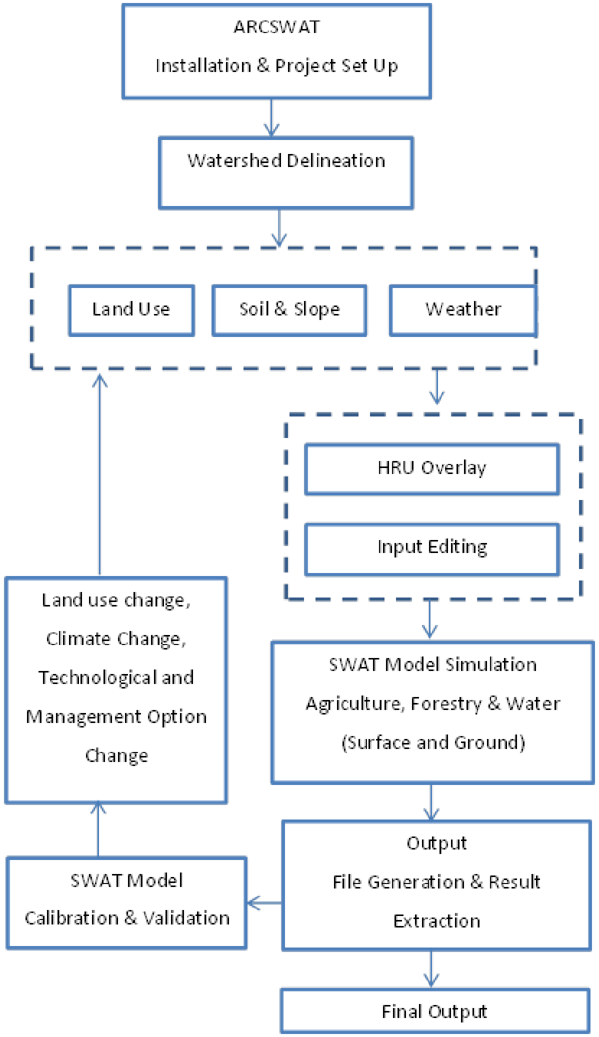
SWAT: river basin scale, physical model

- **Use of** specific information on **weather, soil properties, topography, vegetation and land management practices** to directly model physical process associated with **water movement, sediment movement, crop growth etc.**
- **Modeling of both surface and ground water.**

Modelling Unit:

River Basin (Watershed) – Sub-basin – HRU (Hydrologic Response Unit) – Administrative Boundary

Modelling Framework



Integrated Systems Modelling Framework

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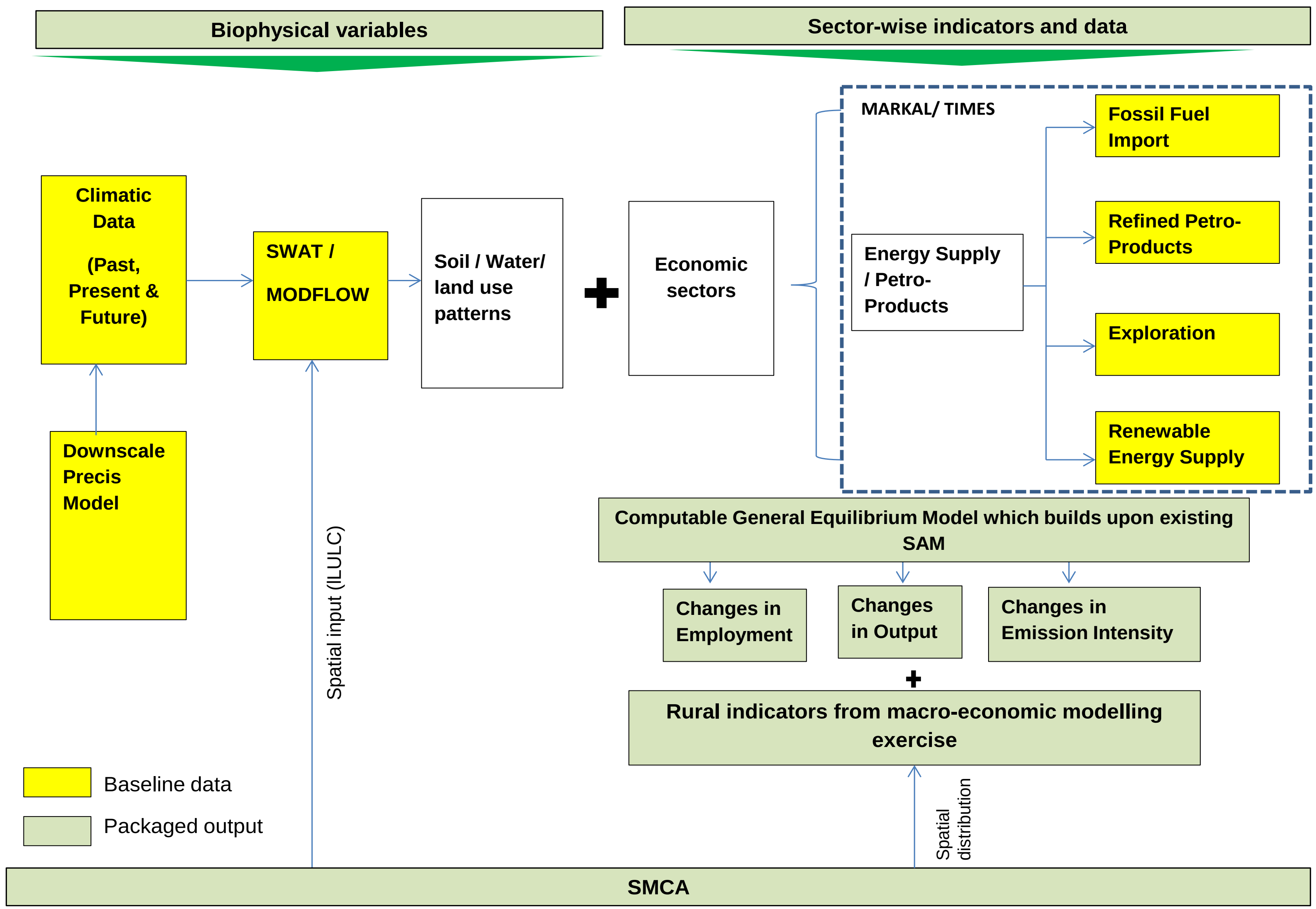

Use of Spatial Analysis for modelling in Indus Basin (India)

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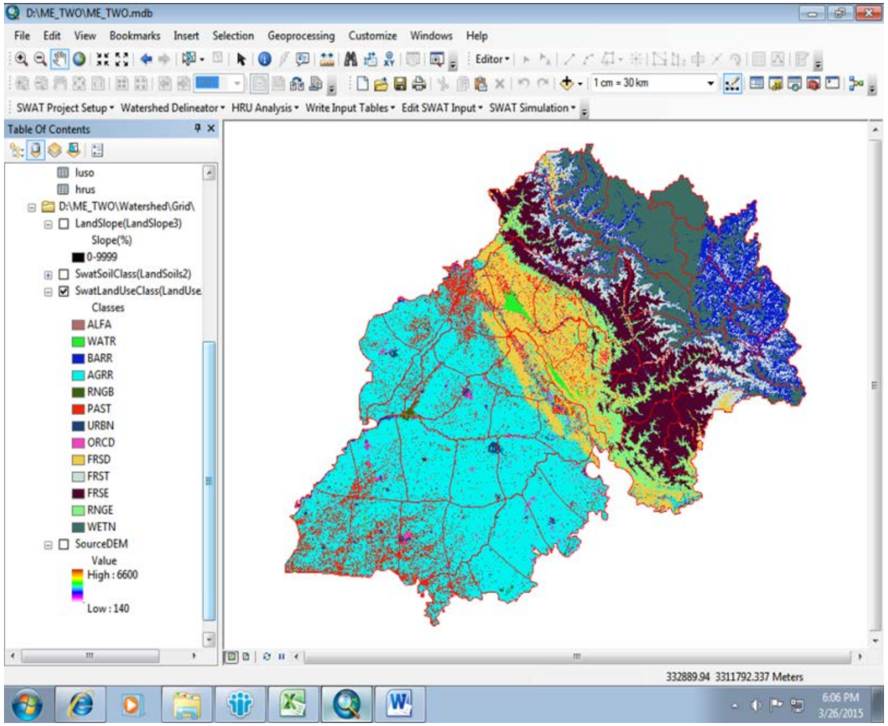
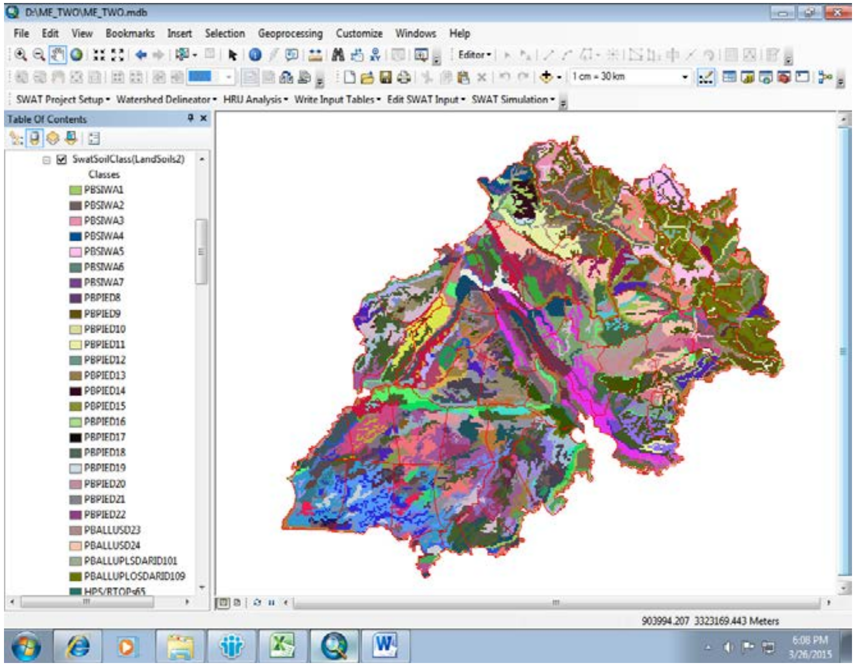
Remote Sensing Images

Platform: LANDSAT

Land Use Analysis for 1998

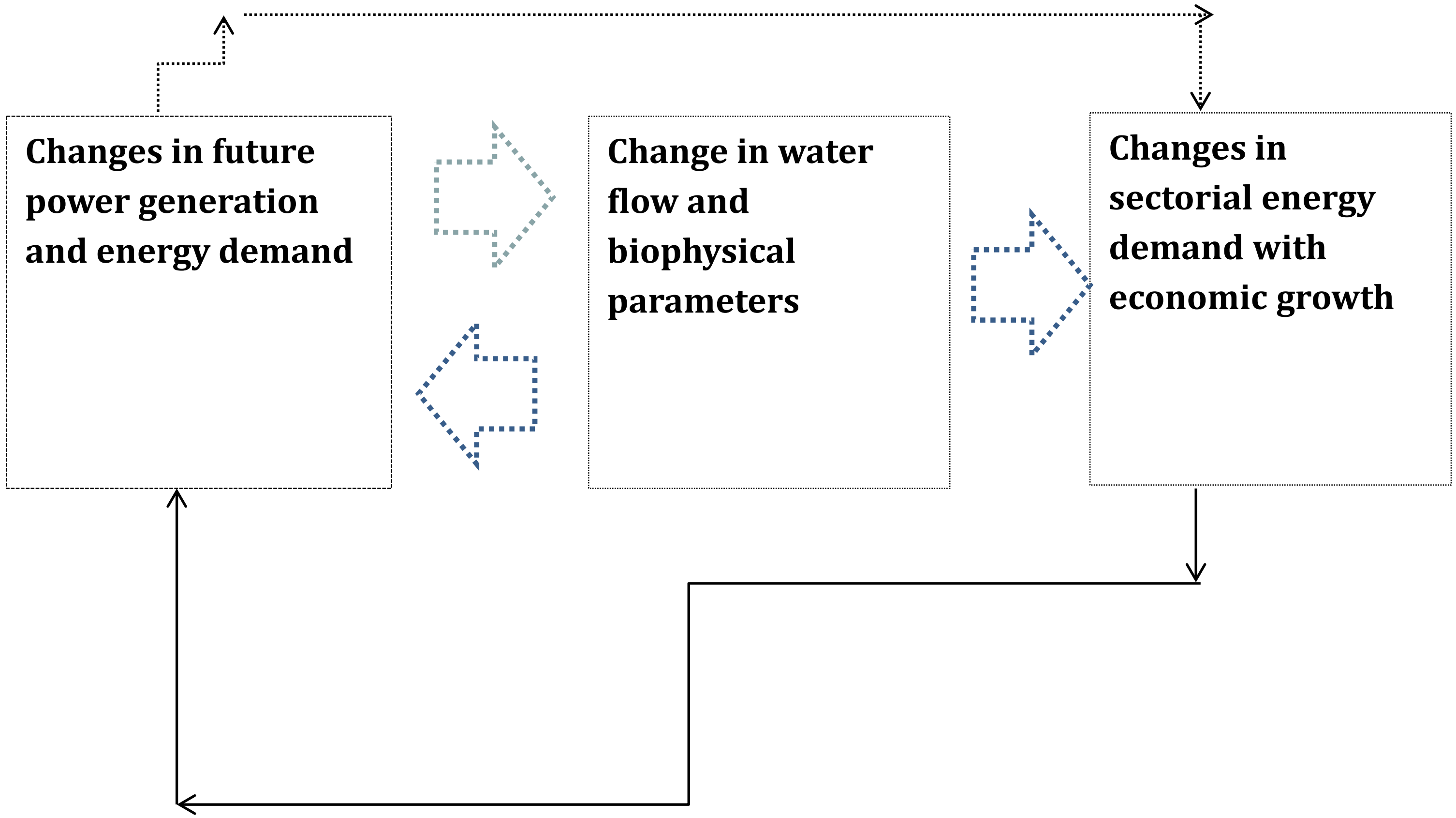




Spatial Soil Properties

Database

Interlinkages between Energy, Economy and Biophysical parameters



Some findings – State level

- River flow affecting power generation and therefore having implications on energy and economy

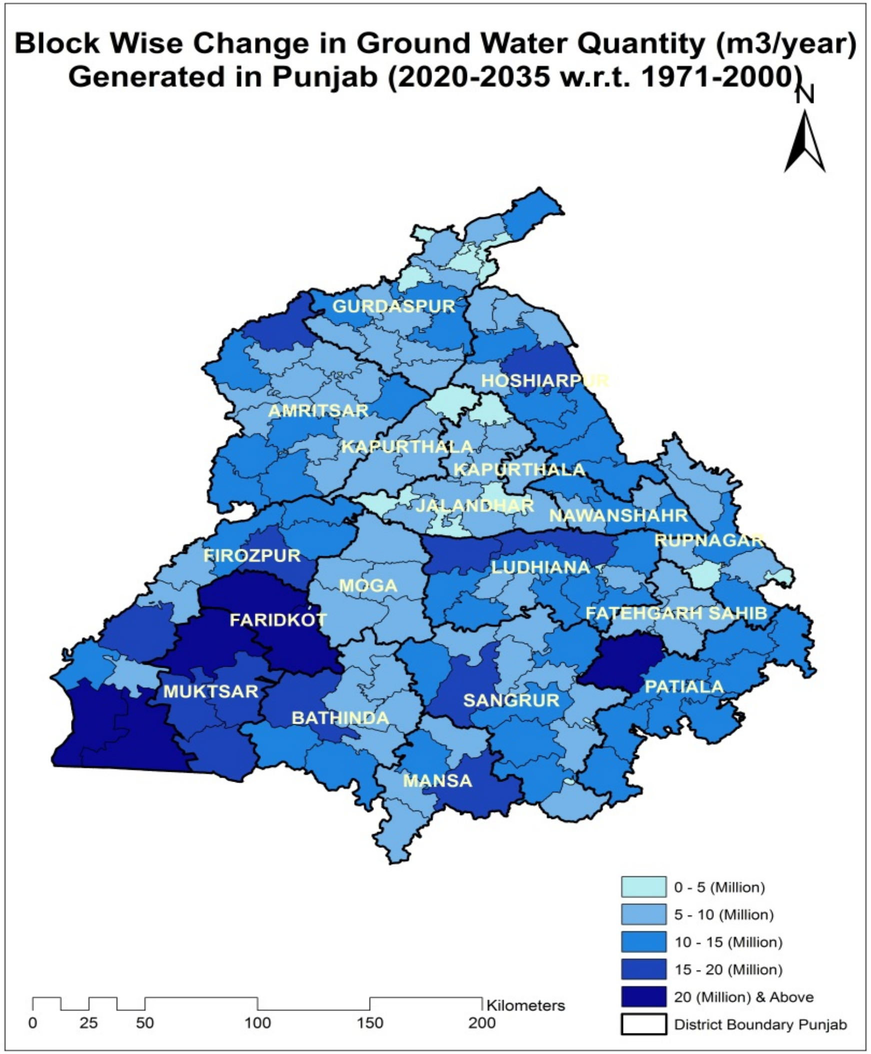
  Average flow (m^3/sec) pattern of rivers in Himachal Pradesh

	1970-2000	2020-40	2020-50
Avg.	2.98	3.06	3.00
Max	5.29	6.13	5.51
Min	1.37	1.42	1.39
Range	3.92	4.71	4.12

  - Average flow (m^3/sec)in the rivers is increasing in future
  - Range (maximum – minimum) of flow is increasing
  - Average & range is more for 2020-40 period than 2020-50 period

- Another example—Closure of Parli power plant due to increase in other activities in the area

Block-wise Change in the Ground Water Quantity (m^3/year) Generated in the Punjab (2020-2035 compared to 1970 -2000)



Academic Engagements

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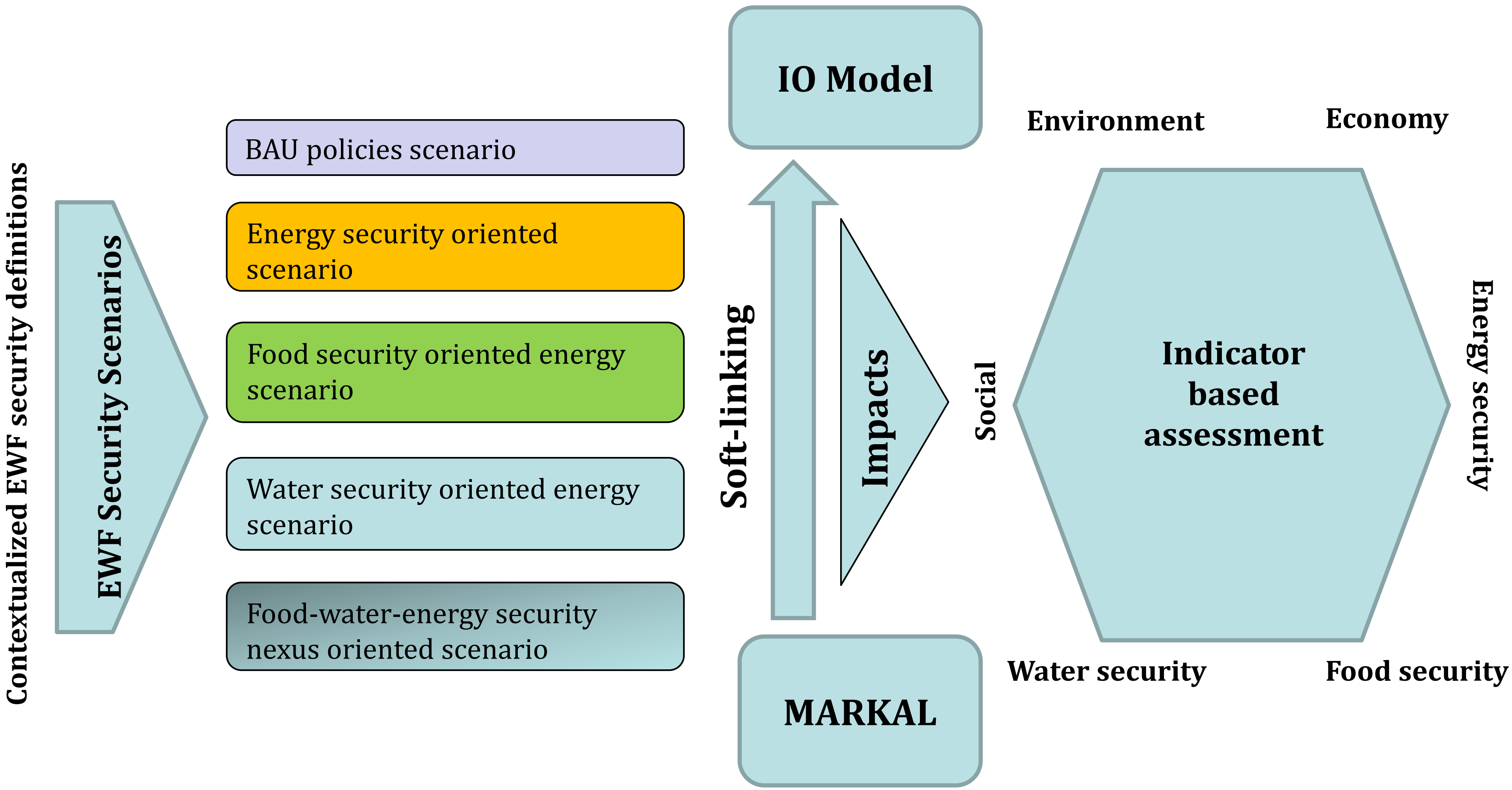
- A fresh water withdrawal assessment for India using an Environmentally Extended Input Output (EEIO) Model: measuring the vulnerability of economic sectors to disruptions in the water cycle
- Water-Food-Energy security nexus for India
  - Soft linking bottom up MARKAL model with top down IO model to assess social, environmental, and economic impacts of food, water, and energy security policies informed by nexus and non nexus considerations


Contextualized EWF security definitions
EWF Security Scenarios
BAU policies scenario
Energy security oriented scenario
Food security oriented energy scenario
Water security oriented energy scenario
Food-water-energy security nexus oriented scenario
IO Model
Soft-linking
Impacts
MARKAL
Environment
Economy
Social
Indicator based assessment
Energy security
Water security
Food security

Thank you !

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