Conducting simple Emission Scenarios

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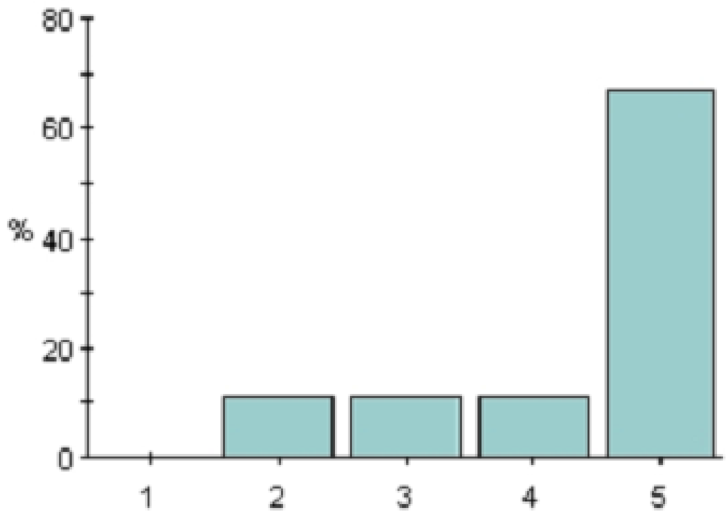
Outline

- Definitions
- Review of the bottom-up emission factor approach
  - Modeling future activity rates
  - Modeling future emission factors
  - Modeling technology penetration rates
- Models and tools for emission scenarios

Feedback obtained after the July 2006 workshop

- About which topics would you like to learn more to support your professional work?

How to conduct an Emission Scenario



	%	#
1	0%	0
2	11.1%	1
3	11.1%	1
4	11.1%	1
5	66.7%	6
Total	100%	9
Mean		4.3

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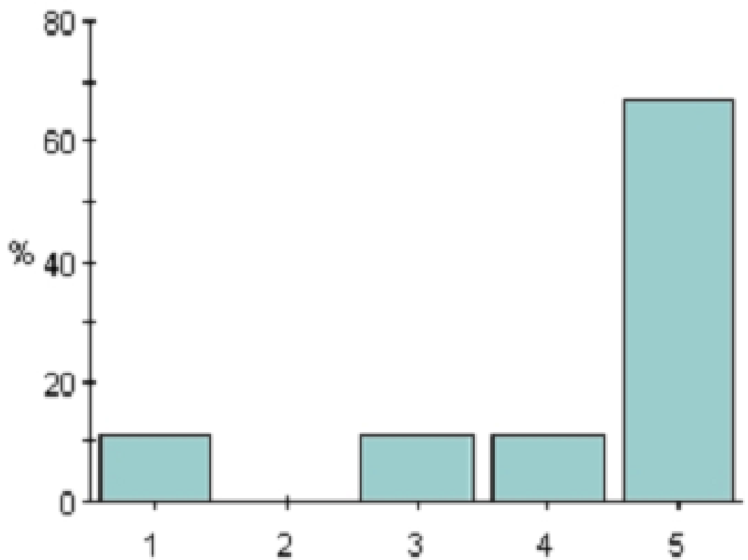
Tools and modeling approaches for emission scenarios



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What are emission scenarios?

- *A plausible quantitative description of how emissions in the future may develop, based on a coherent and internally consistent set of assumptions ("scenario logic") about key relationships and driving forces.*

(IPCC)

Models and tools

- Emission scenarios typically use quantitative models built from a number of mathematical equations.
- A model is a representation of a system. A good model behaves sufficiently like the real system that conclusions can be drawn from the model's behaviour to aid in making decisions about the real system.
- A tool is a PC software that computes the equations of the model.

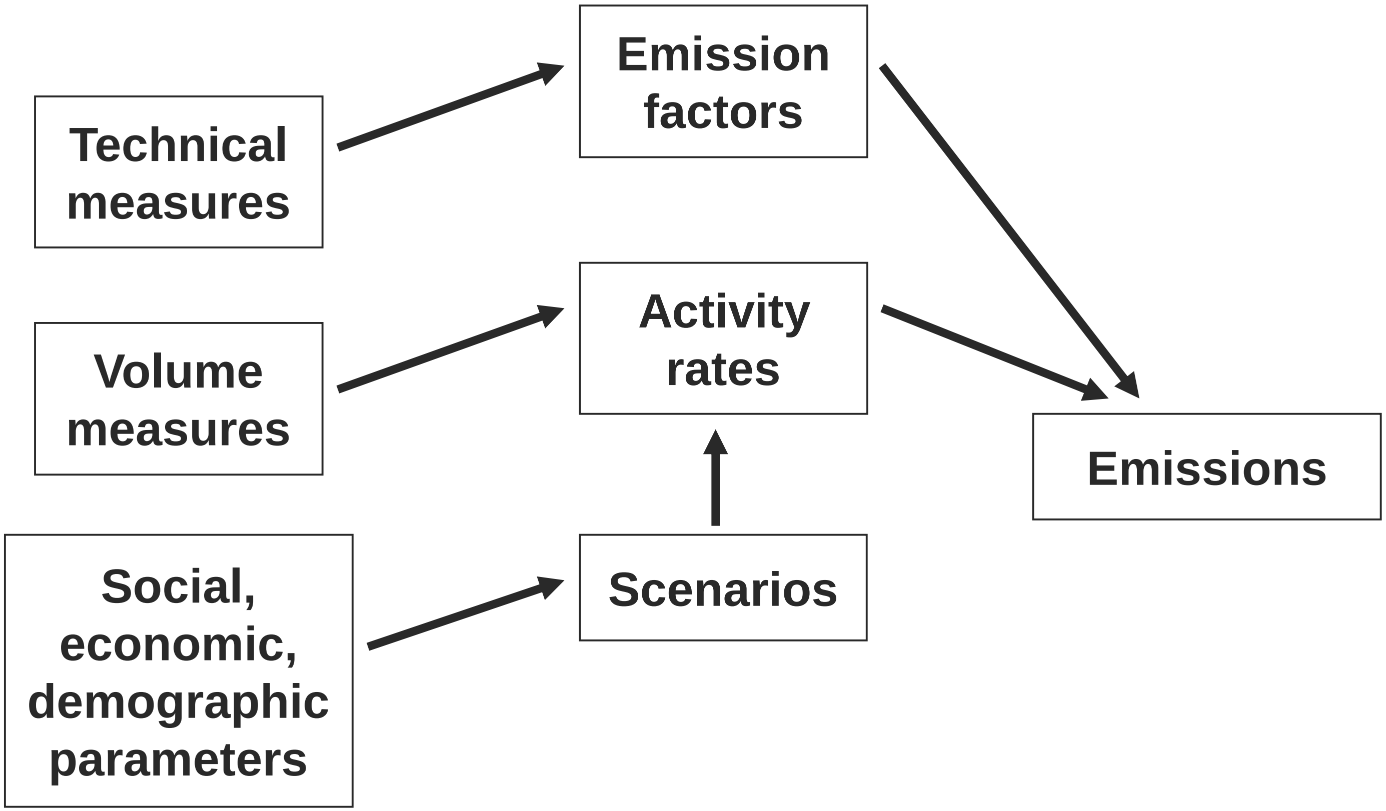
Integrated Assessment Modeling (IAM)

- "An interdisciplinary process of structuring knowledge elements from various scientific disciplines in such a manner that all relevant aspects of a complex societal problem are considered in their mutual coherence for the benefit of decision-making" (Rotmans, 1998).
- Emission scenarios are typically one component of Integrated Assessment Models for air quality management.

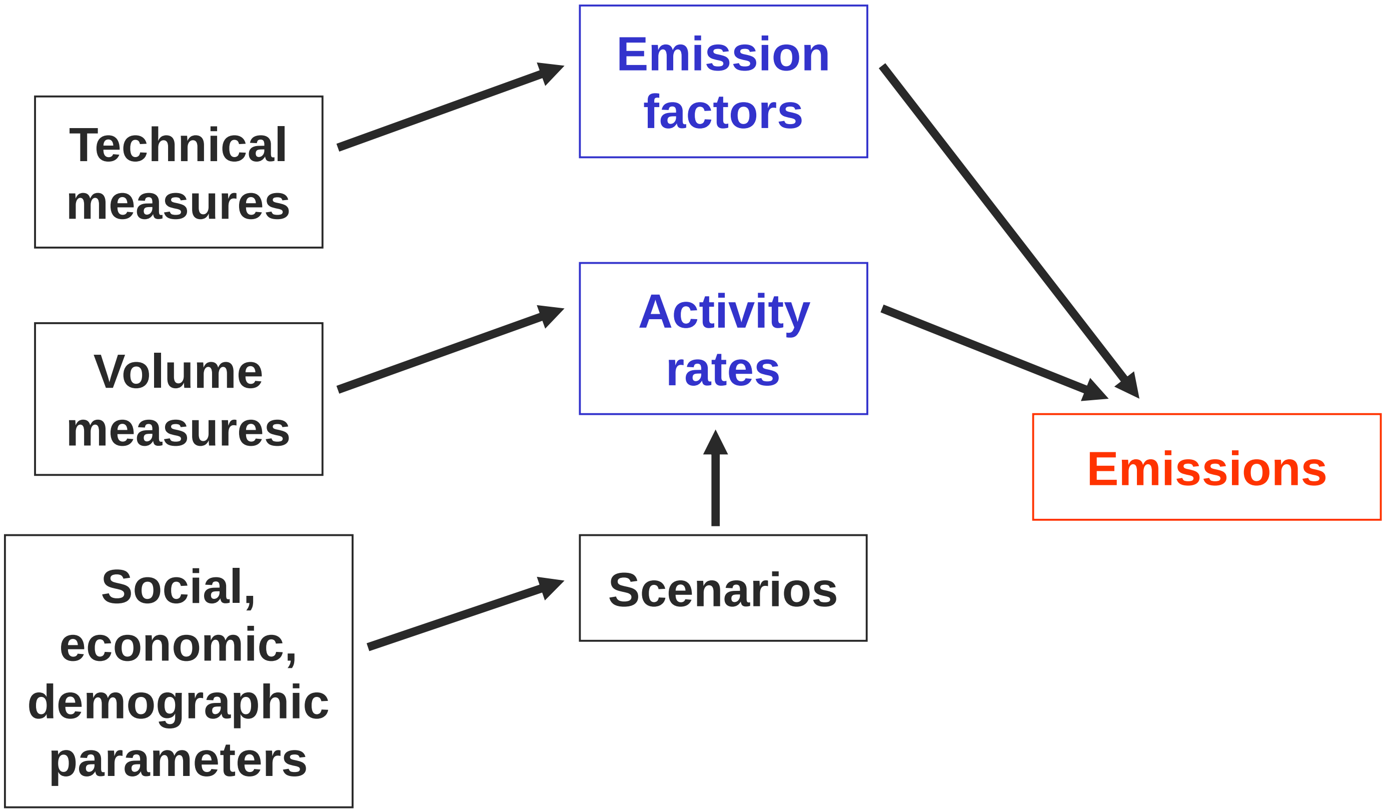
General approaches for emission scenarios

- **socio-economic**
  - correlate emissions with socio-economic time series, such as GDP development, without accounting in detail for technological change
  - top-down approach
- **technology based**
  - considers explicitly technological change
  - emission factor approach is widely used, mainly due to the fact that technological change became a prevailing parameter
  - bottom-up approach, can be rather detailed and resource-intensive

Technology-based, bottom-up approach



Technology-based, bottom-up approach



The fundamental formula

$$E = A \times \sum_{k=1}^{n} (F_k \times P_k)$$

E: emissions

A: activity rate

F: process level emission factors

P: activity share or penetration rate of a technology within a sector

k: technology type

Source: EEA

Activity rate, e.g.

- electricity consumption (kWh)
- transport volume (Pkm / tkm)
- steel production (tons)

Process level emission factor, e.g.

- g_{SO2} / kWh_{el}
- g_{NOx} / tkm
- g_{SO2} / ton_{steel}

Activity shares or **penetration rates** of a technology (k) within a sector

- eventually determined by the behaviour of people
- legislative requirements
- technology acceptance
- etc.

$$E = A \times \underbrace{\sum_{k=1}^{n} (F_k \times P_k)}$$

Sectoral emission factor

The fundamental formula

Data sources for emission inventories (PAST)

national statistics → A

measurements → F

- national statistics
- expert judgements

→ P

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The fundamental formula

Data sources for emission inventories (PAST)

- A: national statistics
- F_k: measurements
- P_k:
  - national statistics
  - expert judgements

$$E = A \times \sum_{k=1}^{n} (F_k \times P_k)$$

- A: economic scenarios
- F_k: technological investigation
- P_k:
  - technological investigation
  - financial economic basic assumptions
  - behaviour projections

Data sources for emission projections / scenarios (FUTURE)

E: emissions

A: activity rate

F: process level emission factors

P: activity share or penetration rate of a technology within a sector

k: technology type

Key assumptions & data quality

- Some aspects of the future are relatively easy to predict
  - e.g. a 20 year old consumer of 2025 is already born
  - economic growth can be derived from the experience of other comparable economies in the past
  - long planning and investment horizons in the energy sector make this sector transform at slow rates
- In other fields, uncertainty is much higher
  - political stability and overall policy directions
  - energy and world oil prices
  - technological innovation

The link between inventories and projections / scenarios

- Each emission projection must be based on an existing emission inventory as a starting point.

Data sources for emission inventories (PAST)

national statistics

measurements

- national statistics
- expert judgements

$$E = A \times \sum_{k=1}^{n} (F_k \times P_k)$$

economic scenarios

technological investigation

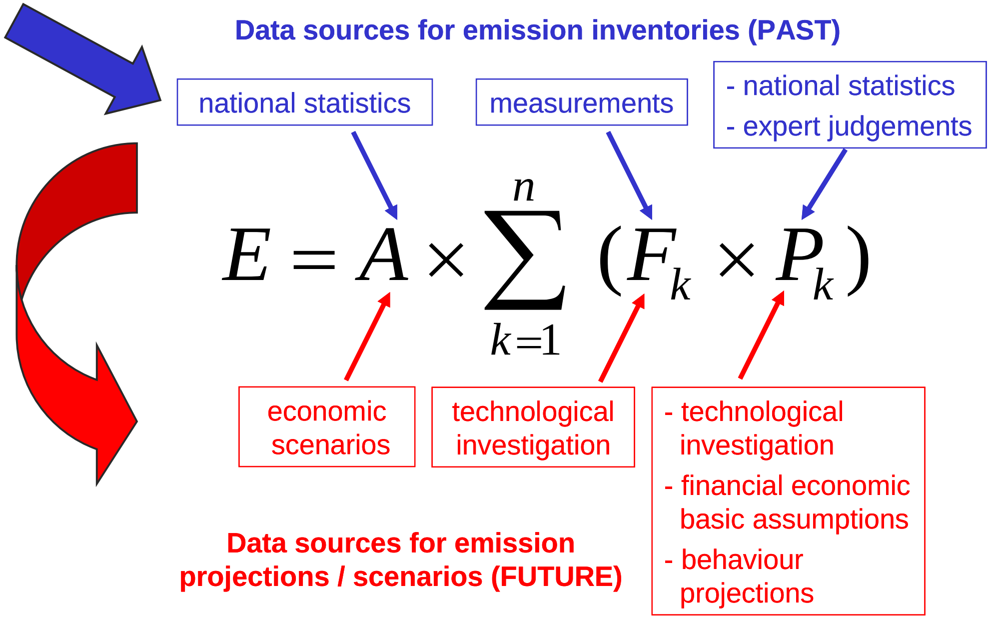
- technological investigation
- financial economic basic assumptions
- behaviour projections

Data sources for emission projections / scenarios (FUTURE)

The link between inventories and projections / scenarios

- Each emission projection must be based on an existing emission inventory as a starting point.

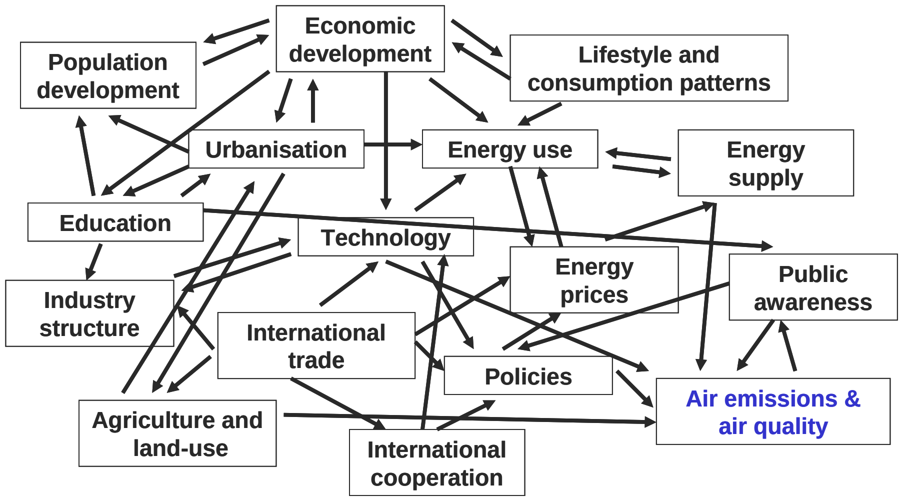
- The main difference between an emission inventory and an emission projection / scenario is the time reference.



$$E = A \times \sum_{k=1}^{n} (F_k \times P_k)$$

There are many driving forces behind future emissions…

- Population
- Economic and social development
- Energy
- Technology
- Agriculture and land-use
- Policies



Data collection and modeling of causal interrelations is a big task!

Modeling future activity rates

- Future activity rates are determined by numerous socioeconomic factors, e.g.
  - Population
  - land use
  - GDP overall or industry volume
  - number of households and vehicles

Examples of economic factors that determine future activity rates

- The world oil price influences the fuel consumption behaviour of industry as well as of private consumers and the competitiveness of alternative fuels
- The electricity price in a country influences consumption and the competitiveness of electricity towards other fuels in the end-use stage.
- The dynamic structure of the power generating sector determines future activity rates and fuel consumption. The development depends on e.g.:
  - availability of domestic energy carriers
  - the legislative framework of the power sector (state-controlled vs. deregulated)
  - trade connections and national energy policies with regard to security of supply
  - political and public attitude towards nuclear power
  - national environmental policies and international agreements

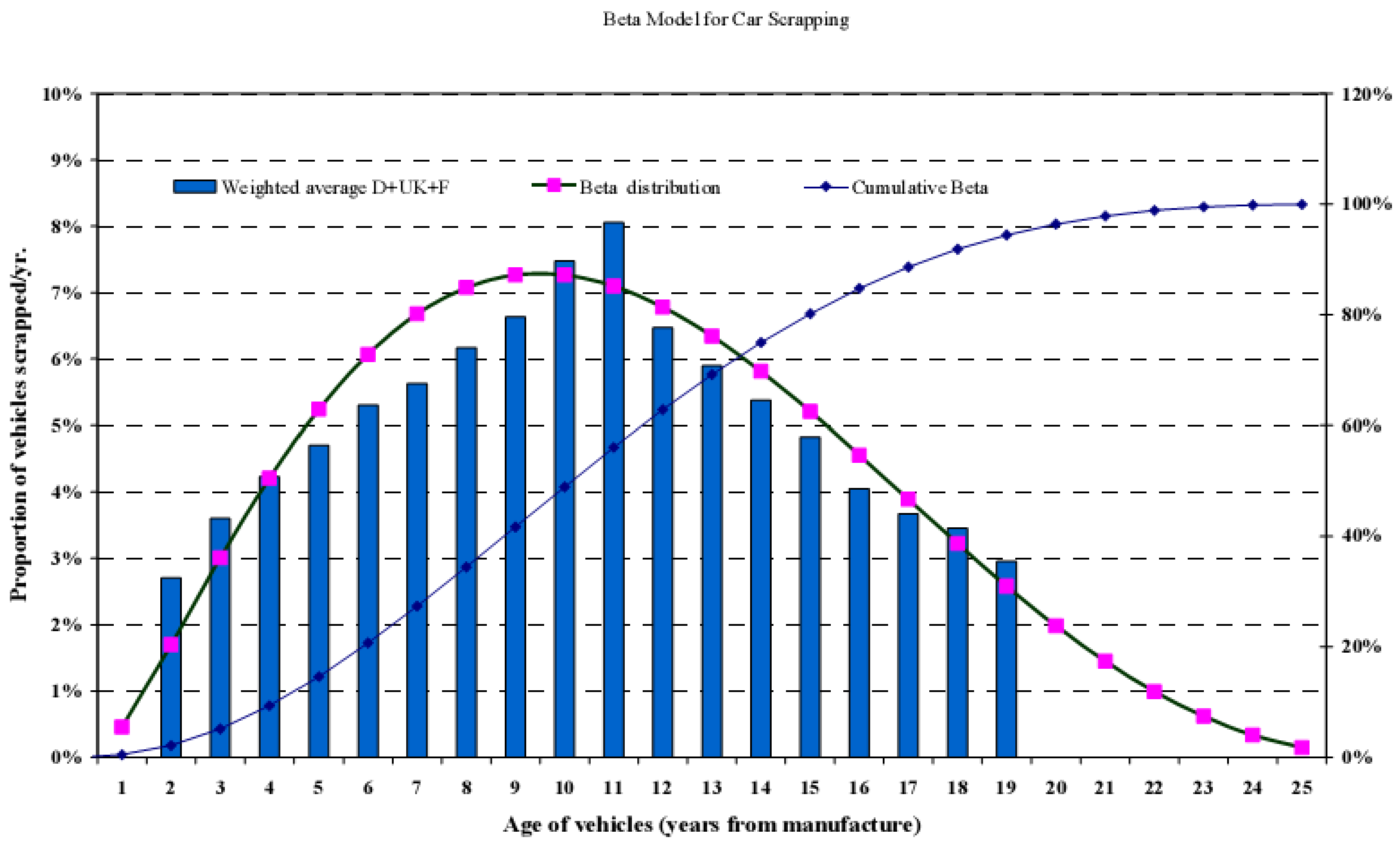
Examples of economic factors that determine future activity rates

- The dynamic structure of the transport sector is driven by economic growth and rising incomes. Peoples' income is the most decisive factor that influences private car ownership.
  - Typically vehicle ownership grows relatively slowly at the lowest levels of per-capita income, then about twice as fast as income at middle-income levels (from $3,000 to $10,000 per capita), and reaches saturation at the highest levels of income.
  - Projecting these trends into the future would, for instance, mean that in India with a projected increase of per-capita GDP by 3.5 % annually in the 2002-2030 period, vehicle ownership would increase by 7 % annually until 2030 (Dargay, Gately, & Sommer, 2006).
- Similarly, economic growth and national and international trade are key factors that influence the activity rate in the freight sector.
- Urbanization and the growth of cities entails increasing needs for commuter transport service.

Modeling future emission factors

- Emission factors on technology level undergo external influences e.g. by environmental legislation requiring compliance with certain emission limit values.
- Consequences are retrofitting of existing technologies and improved performance of new technologies and phasing out of old technologies
- Modeling (average sectoral) future emission factors requires information about
  1. Phase-in of new technologies (e.g. vehicles with state-of-the-art flue gas cleaning)
  2. Phase-out of old polluting technologies (e.g. old vehicles without any flue gas cleaning)

Modeling the phase-out of "old" vehicles



Source: Peck (2003)

Environmental polices and technology penetration

- Technology penetration is influenced, amongst others by
  - availability and costs of new technologies
  - investment programs
  - energy prices
  - environmental legislation.

- The enforced penetration of technologies by environmental legislation may even cause the disappearance of certain technologies even in a short time perspective.
  - Example: mandated conversion of all public transport buses, taxis, and three-wheelers to compressed natural gas in Delhi, India in 2000–2002.

Emission scenario variants

- Simple baseline growth scenario
  - Considers only changes in the activity rate, emission factors in future years remain constant to the base year.
- Baseline scenario
  - Considers future activity rates and future emission factors taking into account the impacts of the presently decided legislation on emission controls.
- Alternative policy scenario
  - Considers future activity rates and future emission factors taking into account the impacts additional policies

Models and tools that may support emission scenarios

- the RAINS integrated assessment model for air pollution and greenhouse gases
- the TREMOVE transport model
- the TIMER energy demand and supply and emission model
- the Long-range Energy Alternatives Planning tool (LEAP)
- the MARKAL energy-economic-environmental model
- GAINS - a model about Greenhouse Gas and Air Pollution Interactions and Synergies
- and many more….
- see RAPIDC scenario handbook for an overview

Scenario and IAM exercise

- More in the Scenario and Integrated Assessment Modeling exercise later
- For the exercise we will use the SIM-AIR tool to…
  - project future activity rates,
  - built some simple alternative policy scenarios,
  - find a cost-effective combination of prevention and control measures to attain emission reduction targets.