IEA OECD ETSAP

Using MARKAL as an Analytic Tool for Pollution Control and Energy Policy Options: The Shanghai and 3-Cities' Cases

ir. Koen Smekens

ECN Policy Studies

smekens@ecn.nl

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MARKAL

- **MARK**et **AL**location
- Long-term, Technology-based Bottom-up Optimisation Model
- Development started in early 1980's
- Is supported, developed and maintained in IEA's ETSAP : **E**nergy **T**echnology **S**ystem **A**nalysis **P**rogramme
- Evolved from energy sector to energy system coverage and beyond

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MARKAL & ETSAP

- World wide use: 15 active partner countries, almost 80 users in 38 countries
- ECN is Operating Agent for ETSAP and primary contact for MARKAL
- Own ETSAP website : http://www.ecn.nl/unit_bs/etsap/main.html
  - reports & information
  - activities
  - partners

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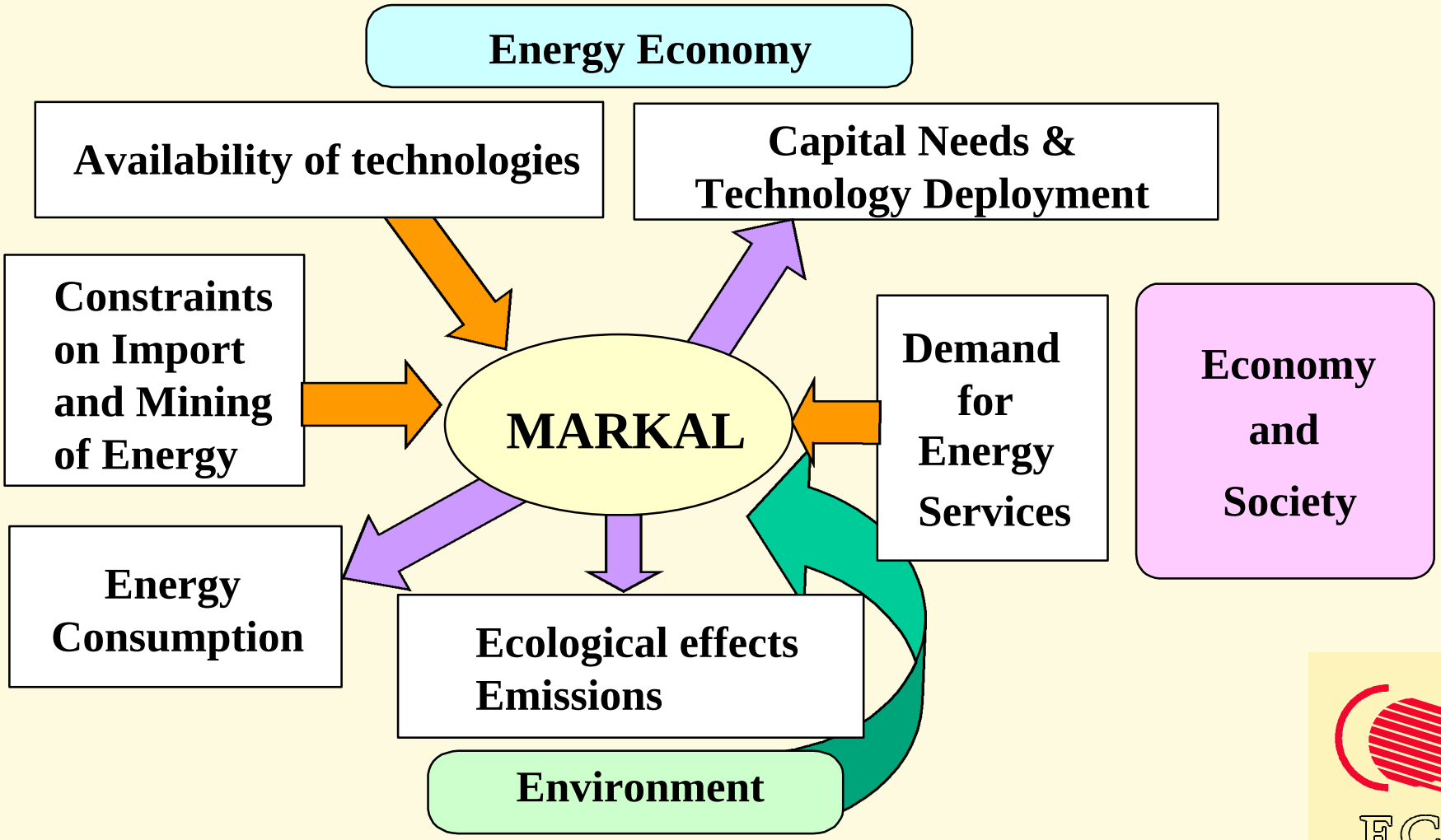
MARKAL Model Structure



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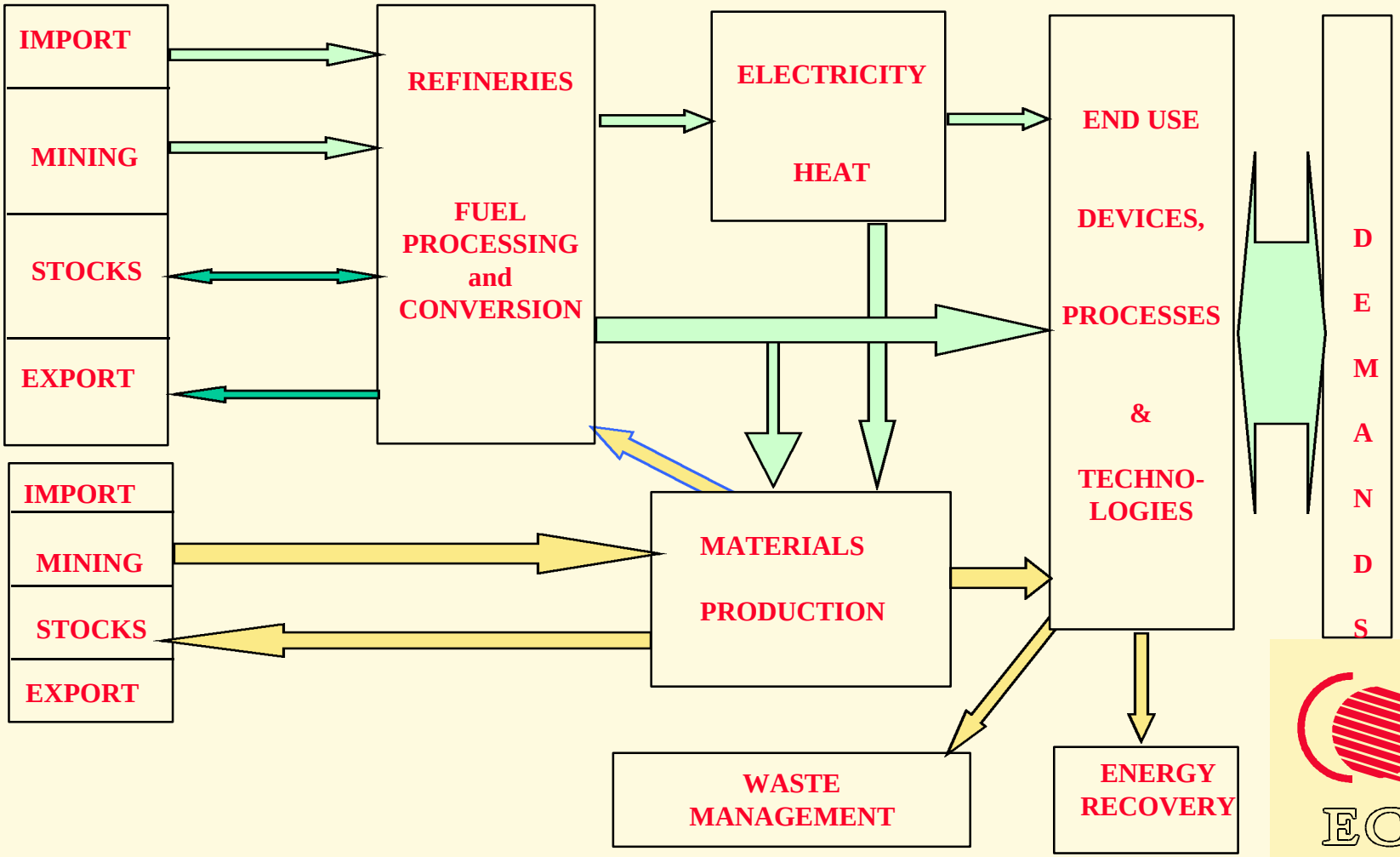
Reference Energy and Material system in MARKAL



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MARKAL Characteristics

- DYNAMIC : multiple periods simultaneous
- INTEGRATED :
  - vertically : extraction -> transformation -> distribution -> end use consumption of each energy form
  - horizontally : in diverse sectors of the economy (industry, residential, commercial and service sector, transport,…)
- DETAILED : user controlled, typical hundreds of existing & new technologies, investment, operating costs, emissions, market instruments
- EQUILIBRIUM : competitive partial equilibrium between supply and demand based on marginal cost pricing and in an ideal market

What MARKAL does

- Identifies mix of energy technologies (production, conversion & transformation, consumption) and resources:
  - that balance the energy budget and that satisfies the demands for energy services over a long time period
  - that meet (multiple) environmental or other constraints simultaneously
  - at the lowest cost for the energy system

Weaknesses

- Perfect foresight
- Ideal market
- Cost based decisions
- Lack of behavioural effects or lifestyle options
- No forecasting, optimisation model
- Demand is exogenuous

MARKAL developments

- **Economic Interactions**:
  - MARKAL-MACRO: Hard link with (simple) economic neoclassical growth model
  - MARKAL-MICRO/MARKAL-ED: Own price (and cross-price) elasticities for demands
- **Materials**
- **Myopic, non clairvoyant**
- **Multi-region**
- **Stochastic, hedging strategies**
- **Monte Carlo Analysis**
- **Endogenous Technology Learning ETL**

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MARKAL database

- Global economic parameters (discount rates, monetary units,…)
- End Use Demands (exogenous)
- Technology data : technical (efficiency, fuels, lifetime ,…) and economic (investment costs, operating costs,…)
- Fuel data : availability, cost, ...
- Emission factors : fuel related like CO_2 and SO_2 or technology related like NO_x and PM
- User defined constraints

MARKAL Options for Incorporation of Environmental issues

- Technology/Fuel Standards
- End of Pipe and Integrated Emission Reduction Options
- Annual Emission Limits
- Cumulative Emission Limits
- Emission Fees/Taxes (External Costs)
- Combinations of instruments - Simultaneous Multiple Effects
- Multiple Gas Baskets (e.g. GHGs)

Application for the Shanghai Municipality

- Collaboration between SAES (dr. Chen Changhong) and ECN in a subproject of a larger Dutch government financed project on options for CO_2 reduction
- Emphasis on a sustainable energy future for Shanghai:
  local economic development at high growth rate and the impact on energy supply and consumption and the effect on the local environment
- Integration of policy options in a MARKAL model

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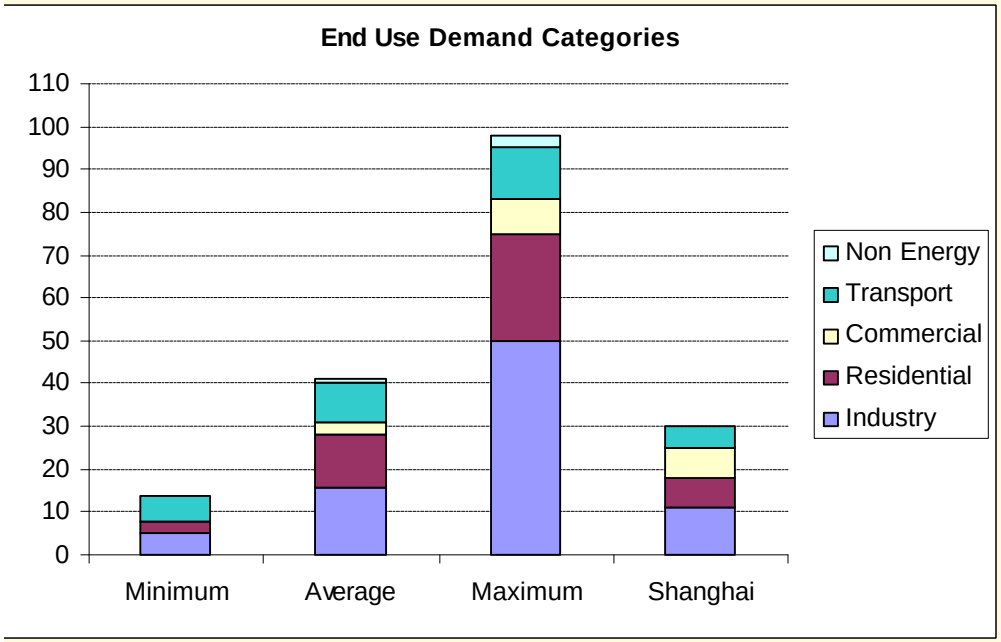
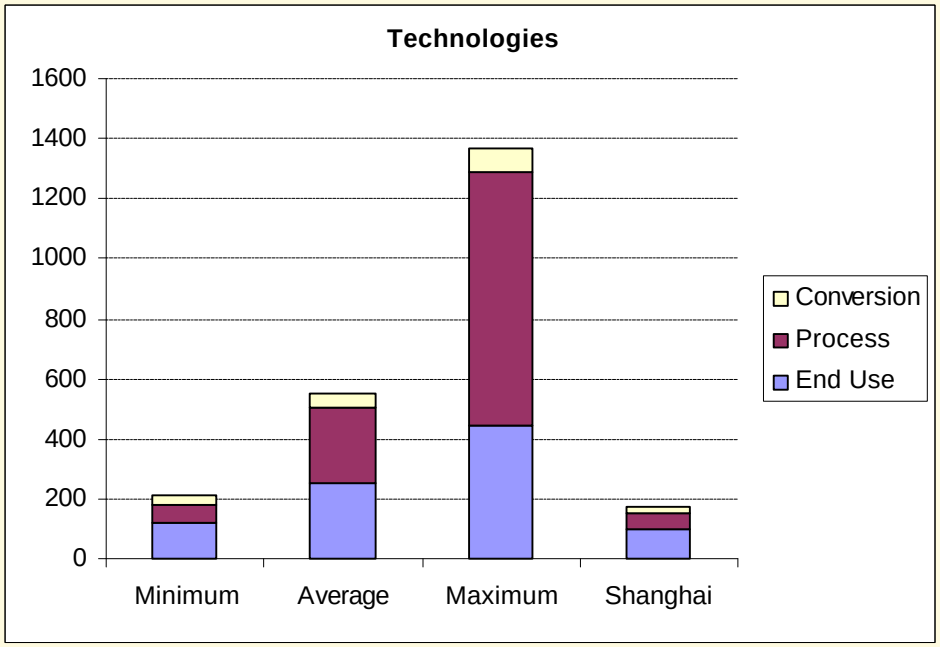
Shanghai model statistics

- Covers 1995-2035 period
- 173 technologies of which 21 conversion technologies
- 61 flow variables of which 30 materials
- 30 end use demand categories
- 7 environmental variables (emissions)

The Shanghai model in perspective





Policy options considered for the Shanghai Municipality

- Low, medium and high economic growth
- Increased use of natural gas through:
  - Construction of LNG terminal
  - Import from West China
  - Import from Siberia
  - Planned capacity for gas combined cycle power generation
  - Fuel switch in industrial boilers
  - Fuel switch in commercial and residential sectors
- Energy efficiency improvement through:
  - Autonomous technology improvement towards advanced technologies based on cost effectiveness (internal to the model)
  - Thermal efficiency improvements for industrial boilers

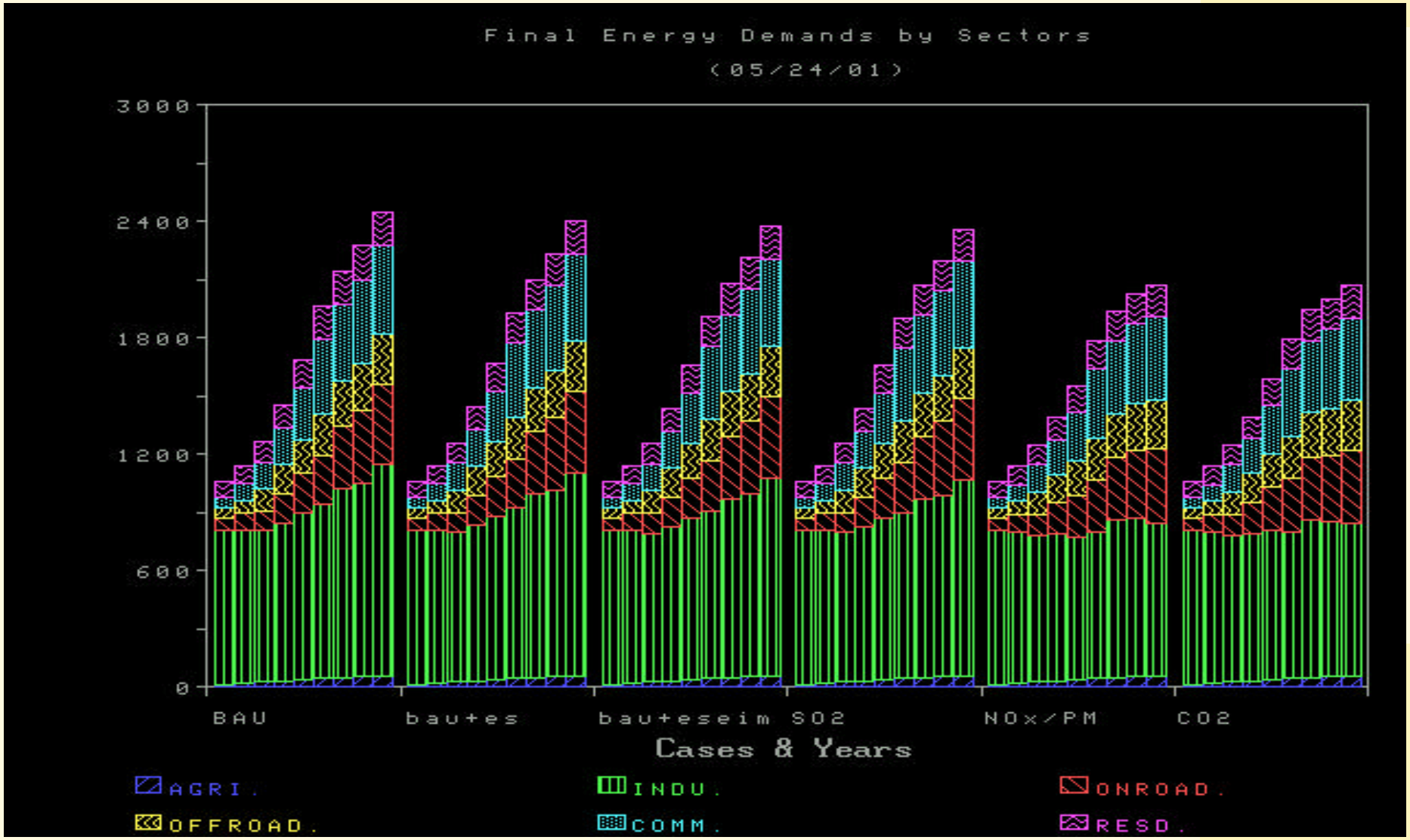
Policy options considered for the Shanghai Municipality (2)

- Increased use of low and zero-emission power generation technologies (LEPP and ZEPP) through:
  - Limitation on classic coal power plants
  - Limitation on coal use
  - Import from 3 Gorges dam
  - Import from nuclear power site
  - Construction of wind turbine power site
- Local air pollution abatement through:
  - Emission reduction objectives for SO_2, NO_x (overall and from transport) and PM10

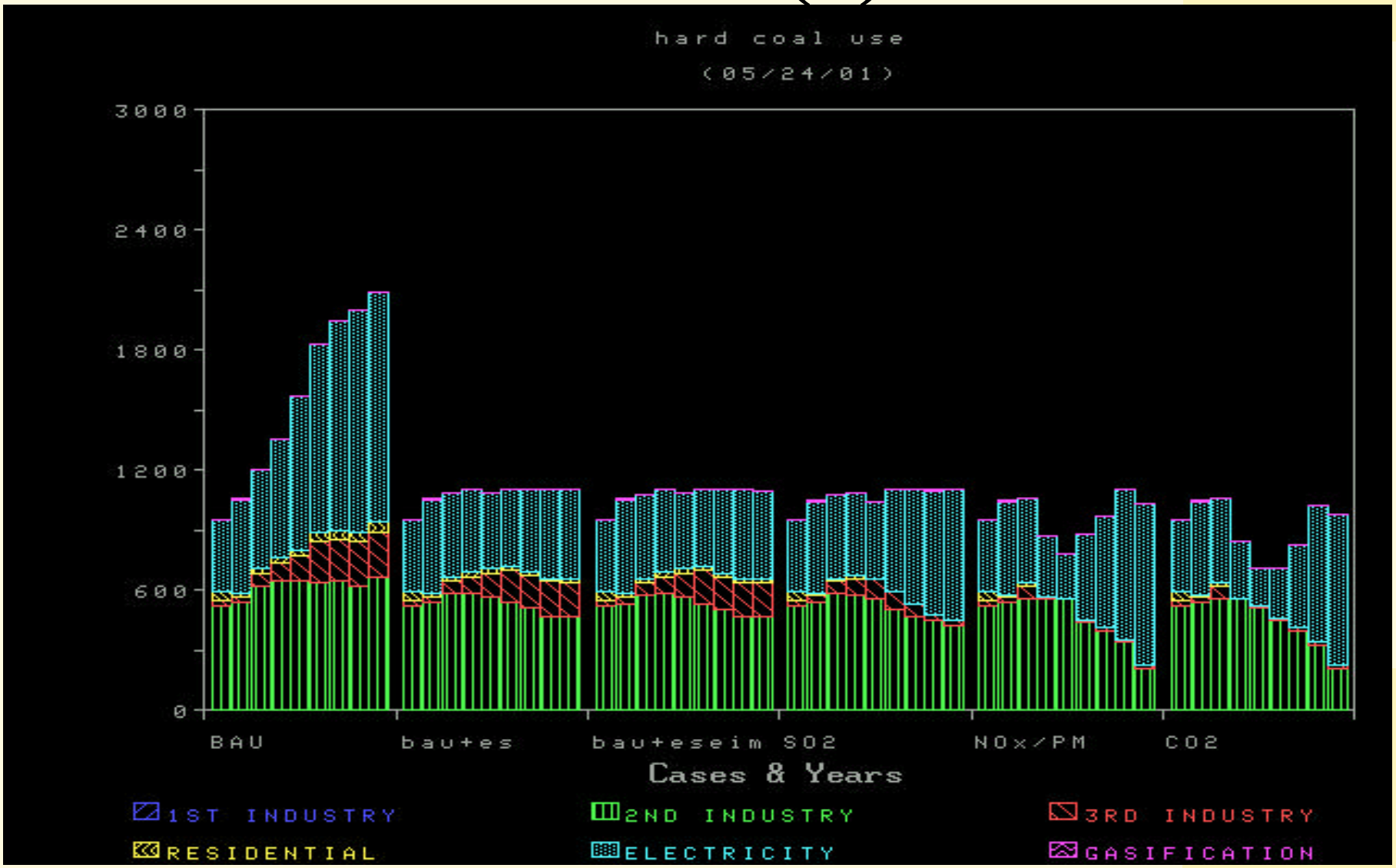
Results

- Examples of result parameters:
  - Final energy Demand
  - Hard Coal use
  - Total NO_x emissions
  - Installed capacity power plants
  - Specific emissions for electricity
  - Marginal costs for commodities, emission intensities
- In addition, on each of the desired parameters, user defined constraints or objectives can be applied

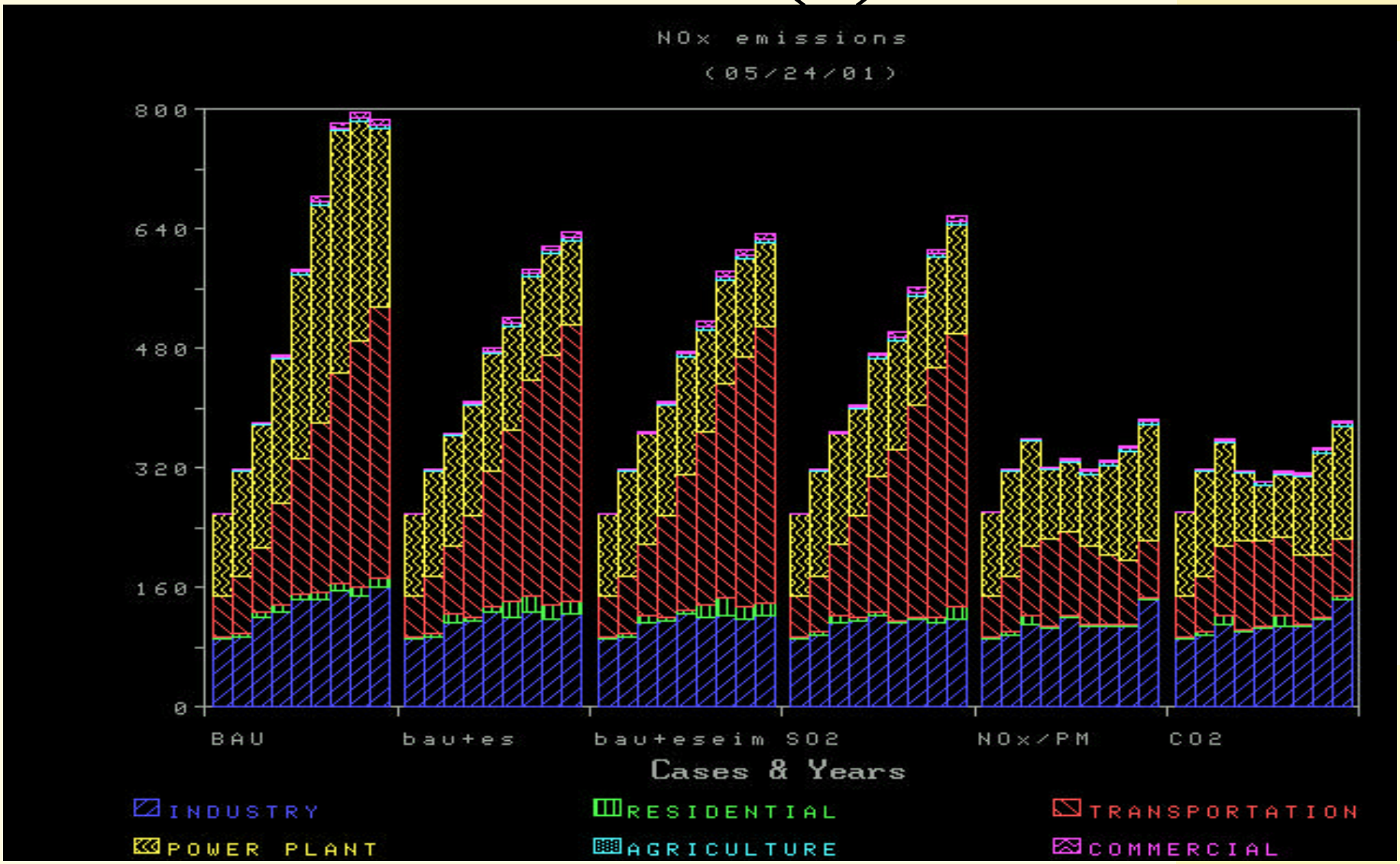
Results


Final Energy Demands by Sectors
(05/24/01)
3000
2400
1800
1200
600
0
BAU
bau+es
bau+eseim
SO2
NOx/PM
CO2
Cases & Years
AGRI.
INDU.
ONROAD.
OFFROAD.
COMM.
RESD.

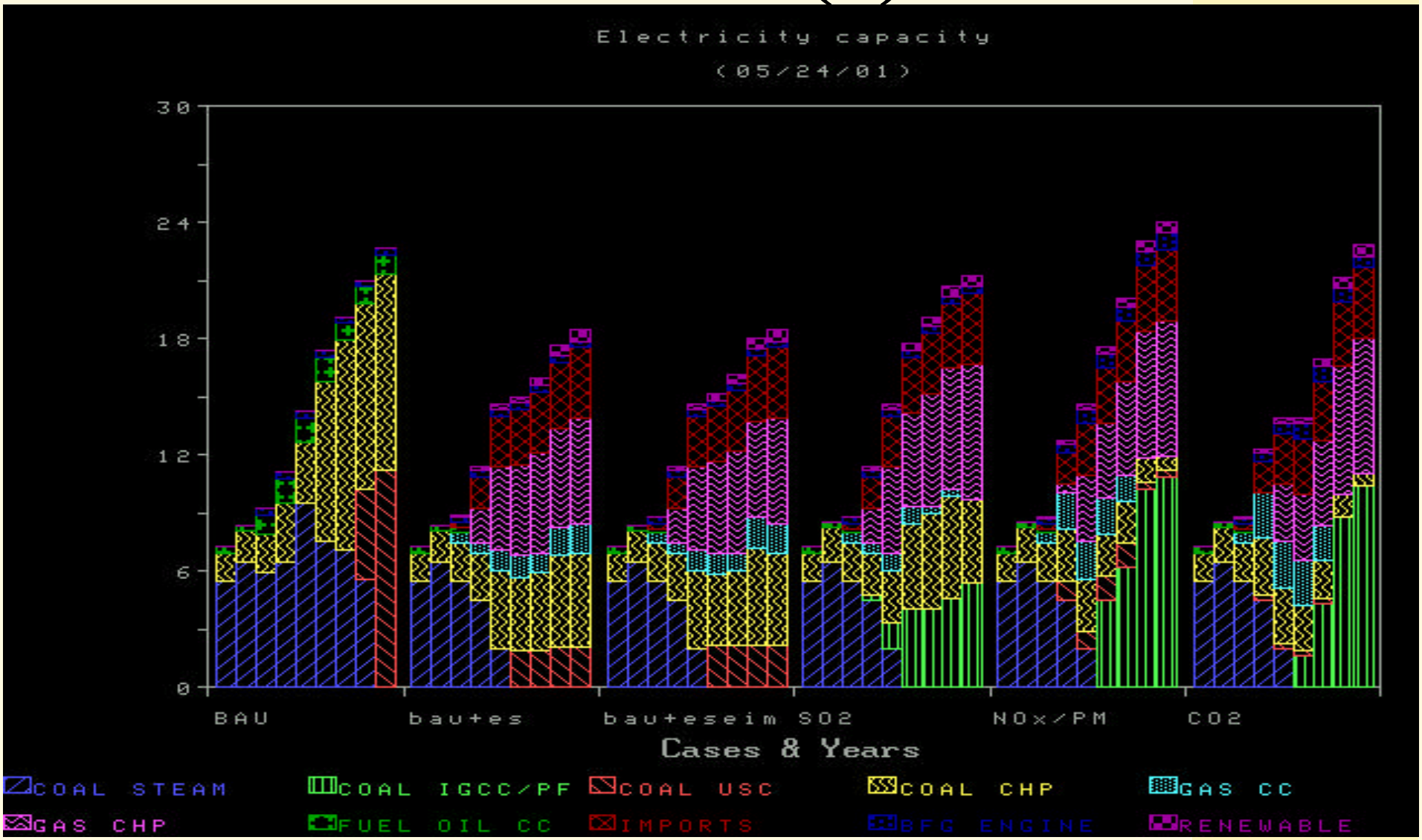
Results (2)


hard coal use
(05/24/01)
3000
2400
1800
1200
600
0
BAU
bautes
bauteseim SO2
NOx/PM
CO2
Cases & Years
1ST INDUSTRY
2ND INDUSTRY
3RD INDUSTRY
RESIDENTIAL
ELECTRICITY
GASIFICATION

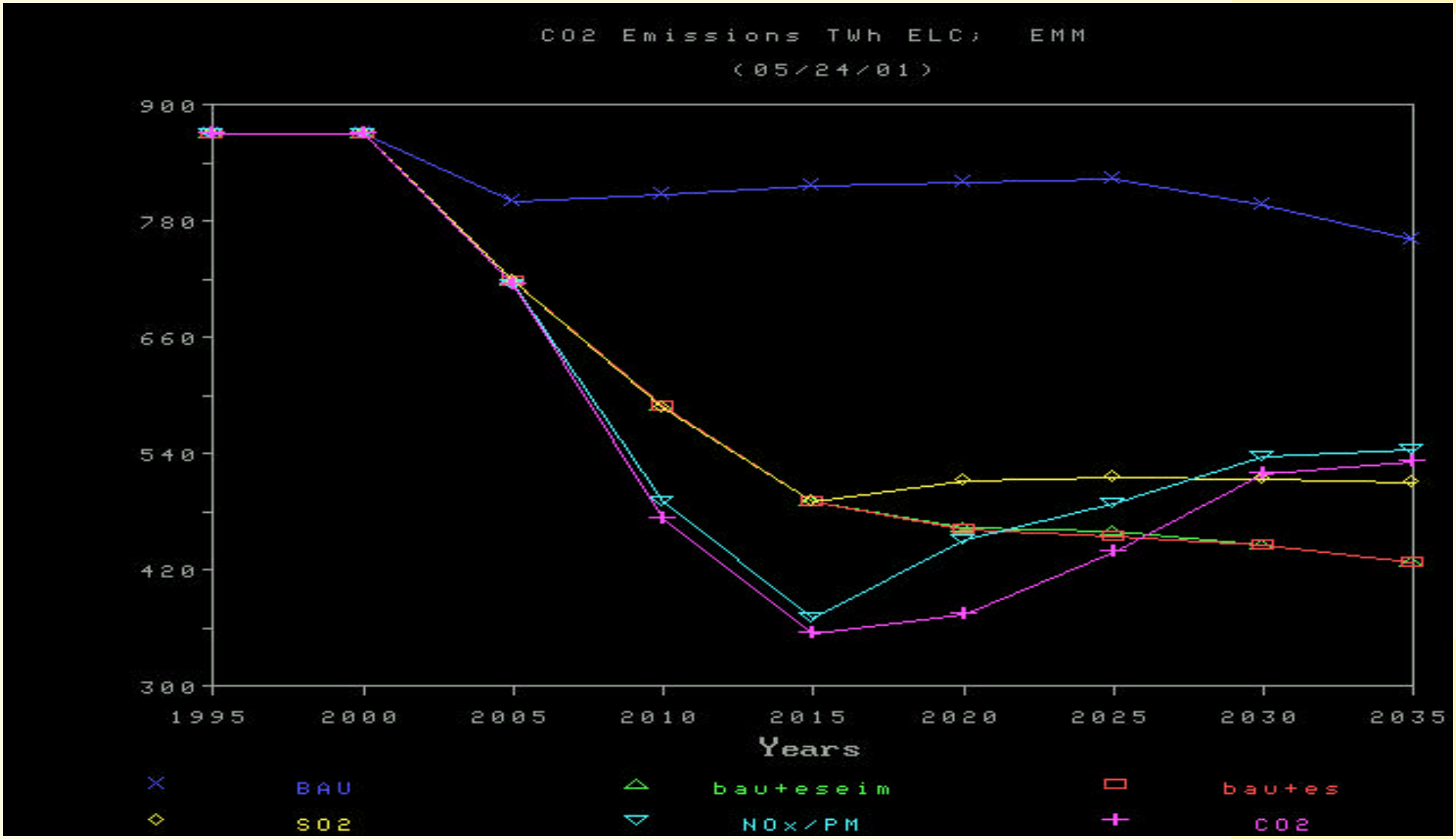
Results (3)


NOx emissions
(05/24/01)
800
640
480
320
160
0
BAU
bautes
bauteseim SO2
NOx/PM
CO2
Cases & Years
INDUSTRY
RESIDENTIAL
TRANSPORTATION
POWER PLANT
AGRICULTURE
COMMERCIAL

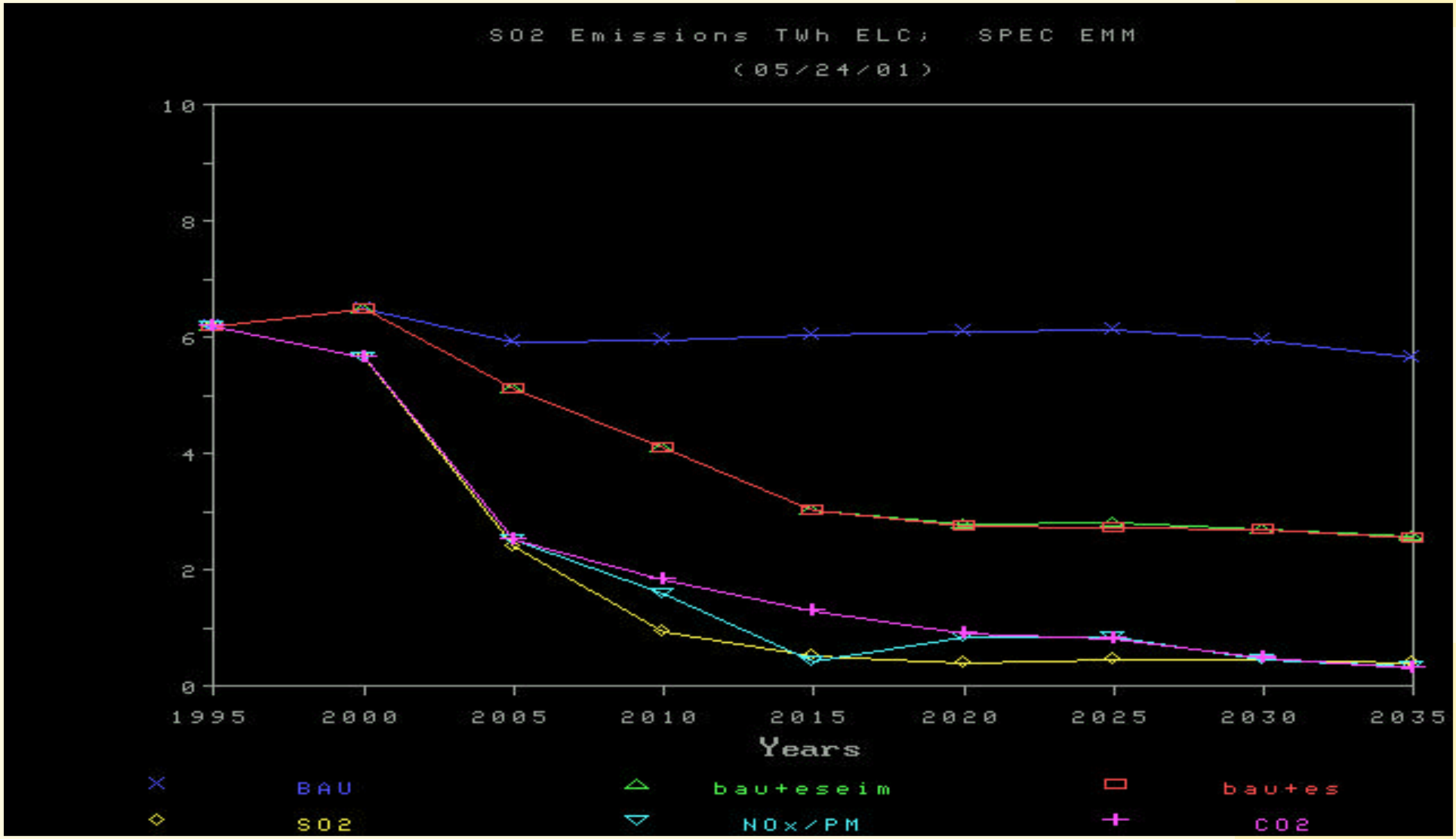
Results (4)


Electricity capacity
(05/24/01)
30
24
18
12
6
0
BAU
bau+es
bau+eseim
SO2
NOx/PM
CO2
Cases & Years
COAL STEAM
COAL IGCC/PF
COAL USC
COAL CHP
GAS CC
GAS CHP
FUEL OIL CC
IMPORTS
BFG ENGINE
RENEWABLE

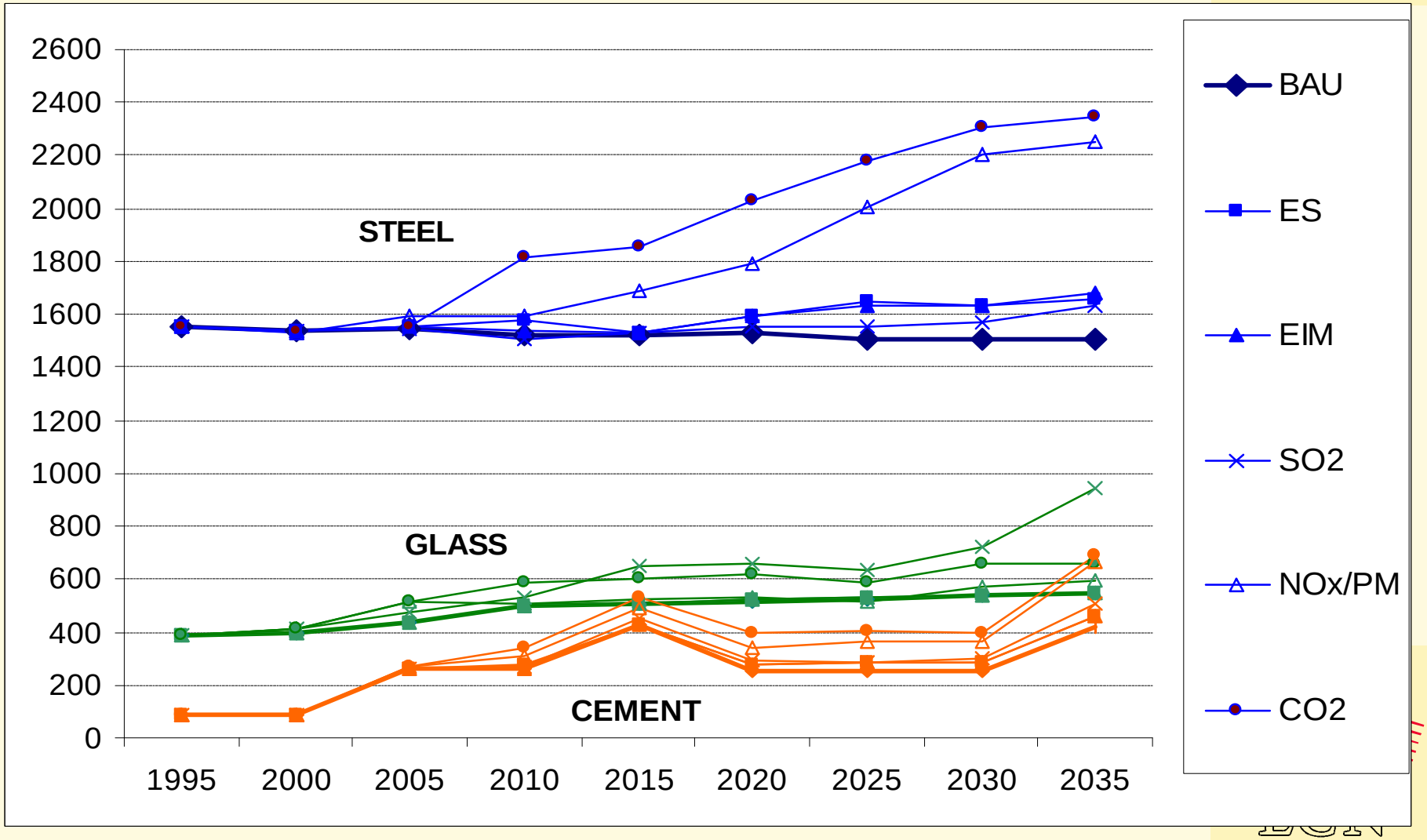
Results (5)


CO2 Emissions TWh ELC; EMM
(05/24/01)
900
780
660
540
420
300
1995
2000
2005
2010
2015
2020
2025
2030
2035
Years
BAU
bauteseim
bautes
SO2
NOx/PM
CO2

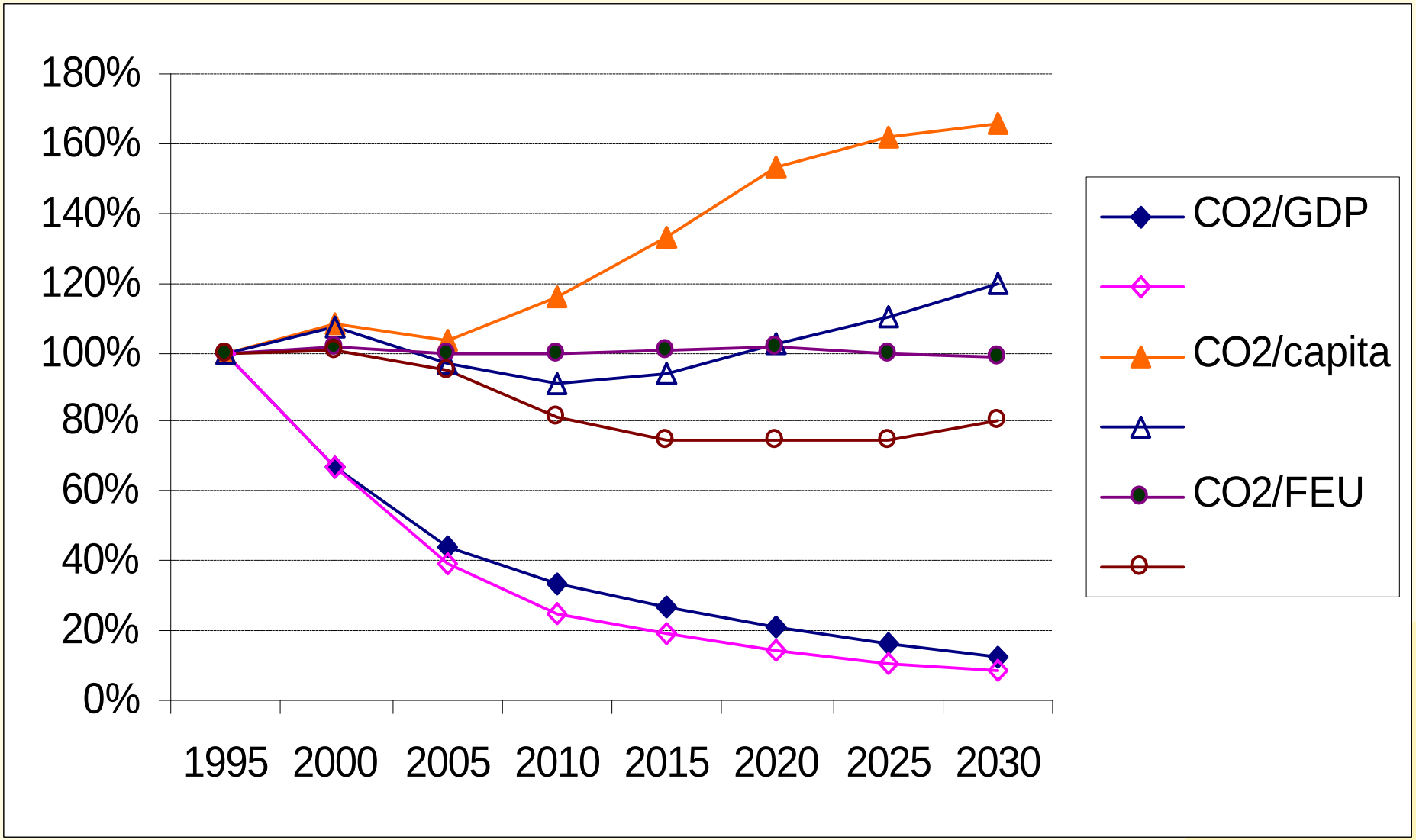
Results (6)


SO2 Emissions TWh ELC; SPEC EMM
(05/24/01)
10
8
6
4
2
0
1995
2000
2005
2010
2015
2020
2025
2030
2035
Years
BAU
bauteseim
bautes
SO2
NOx/PM
CO2

Results (7)


2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1995
2000
2005
2010
2015
2020
2025
2030
2035
STEEL
GLASS
CEMENT
BAU
ES
EIM
SO2
NOx/PM
CO2

Results (8)


180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
1995
2000
2005
2010
2015
2020
2025
2030
CO2/GDP
CO2/capita
CO2/FEU

The 3 Cities

- EU funded project for urban energy development strategies and energy efficiency
- Cities involved: Shanghai, Tianjin and Chongqing
- Co-ordinator in China is Tsinghua University (prof Liu Deshun)
- Objective: analyse current situation and set up separate model for each of the cities and perform scenario runs to make projections for the future development

The 3 Cities (2)

- Current status:
  - interim report ready with analysis of the historical evolution and present situation
  - databases in stadium of finalisation and ready for scenario runs
- Scenarios:
  - economic growth : medium, low and high
  - technological progress
  - local air pollutants control scenarios (SO_2, NO_x)

MARKAL Uses

- Analytical tool to study (the changes in) the energy system over time considering all (user defined) assumptions and constraints
- To compare different scenarios :
  - evaluate policy options,
  - perform sensitivity analysis,
  - emissions and emission reductions,
  - changes in technology deployment

Implications for Analysis/1

- LT perspective essential
- Structural and technological dynamics
- Dealing with uncertainty (e.g. *'hedging'*)
- Sensitivity analysis
- Multi-regional modelling (consistency & comparability)
- Measures of (cost-)effectiveness and equity

Implications for Analysis/2

- Comprehensive coverage :

  multi-sector, multi-gas, multiple environmental issues, shared resources (land)
  - Sectors : energy, industry, agriculture, waste and land-use-change (limited)
  - Comprehensive multi-gas basket (GHGs, acidification)
  - Local Air Quality & Climate Change topics: emission targets; Kyoto mechanisms