Markal-Times assessment of long term CO_2 emissions targets for France

Nadia Maïzi, Edi Assoumou, Marc Bordier, Gilles Guerassimoff

Centre for Applied Mathematics
Mines Paris - ParisTech

July 9, 2007
22nd European Conference on Operational Research

MINES PARIS ParisTech

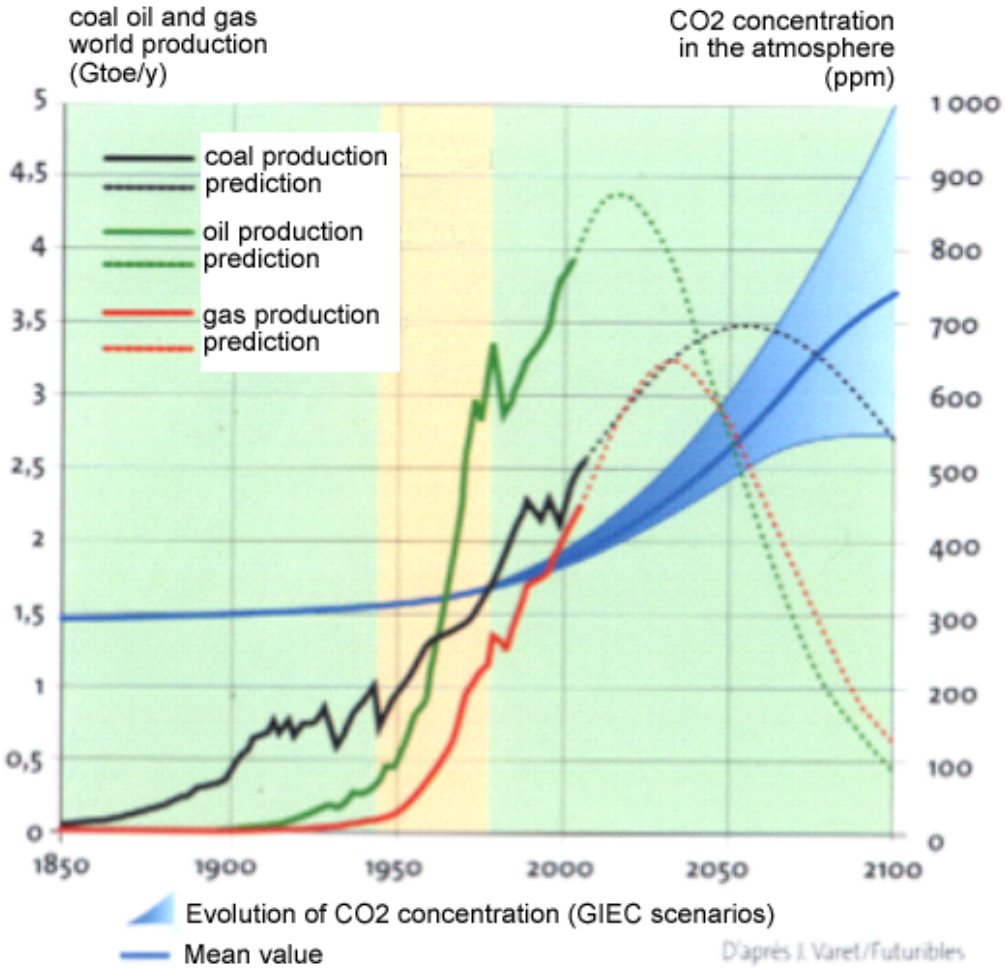
Agenda

1. Motivations
   - International Environmental Commitments
   - Prospective exercises
2. Energy planning models: MARKAL/Times
3. The French paradigm
   - Mitigation targets : methodology
   - Low Carbon Scenarios
4. Prospective sensitivity analysis
   - Alternative nuclear future
5. Conclusion

MINES PARIS ParisTech

Environmental impacts

In order to cope with environmental impacts



Environmental impacts

In order to cope with environmental impacts most countries are engaged in international agreements

- Kyoto protocol for 2012 horizon :
  - stabilize GHG emissions at 1990's level
  - France currently satisfies Kyoto targets
- Dividing by a factor 2 GHG worlwide by 2050 horizon induces
  - Factor 4 for France, Norway
  - Mitigation of 60% for UK
  - Mitigation of 80% for Germany

MINES PARIS ParisTech

Prospective exercises

Whilst Prediction **imposes** the future

Prospective approaches give a tool for reflexion, debate, in order to evaluate decisions and measures

Prospective exercises

- **envision** all the possible futures
- in order to **lighten** tomorrow's consequences of today's choices and decisions

In other words Prospective exercises enable to :

- **be prepared** to unexpected trends or events thanks to the assessment of a **diversity of imagined futures**

MINES PARIS ParisTech

Energy planning models: MARKAL/Times

Necessity to assess stakes for decision and policy makers in the energy field

Energy planning models answer a variety of questions raised for energy issues:

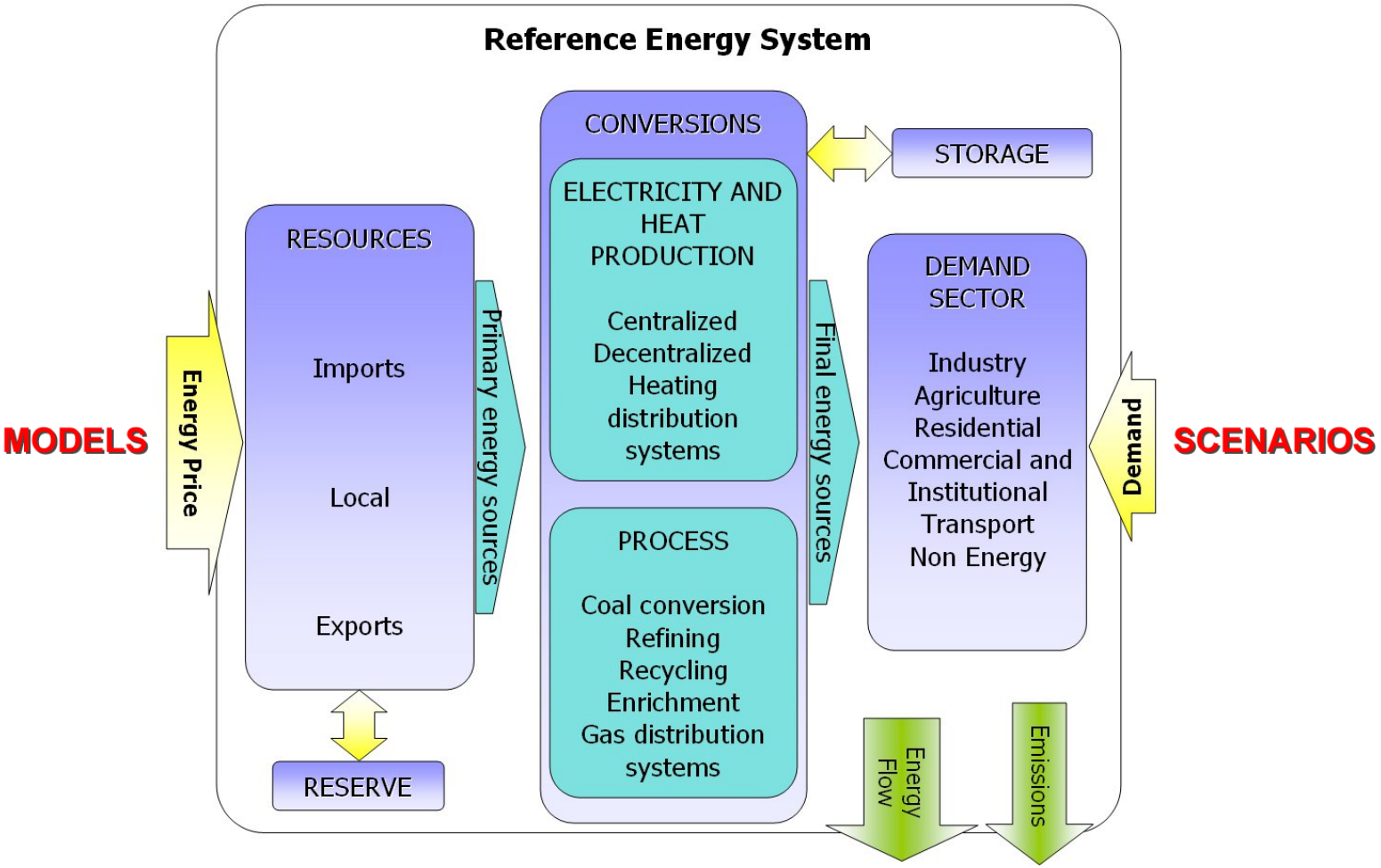
- **future investments** for the mix?
- **measures** for the environmental impact?
- what **susbtitution** between energies?
- how to handle the **huge losses**?

MARKAL/Times (MARKet ALlocation) a technological energy-sector model

MINES PARIS ParisTech

The MARKAL/Times model

A technical linear optimization model driven by demand



Solutions given by MARKAL/Times

MARKAL/Times solves a linear programming problem:

minimizes the RES actualized global cost
over a certain model horizon
while respecting all constraints (technical and/or environmental)

assessing the energy mix to satisfy the demand over time

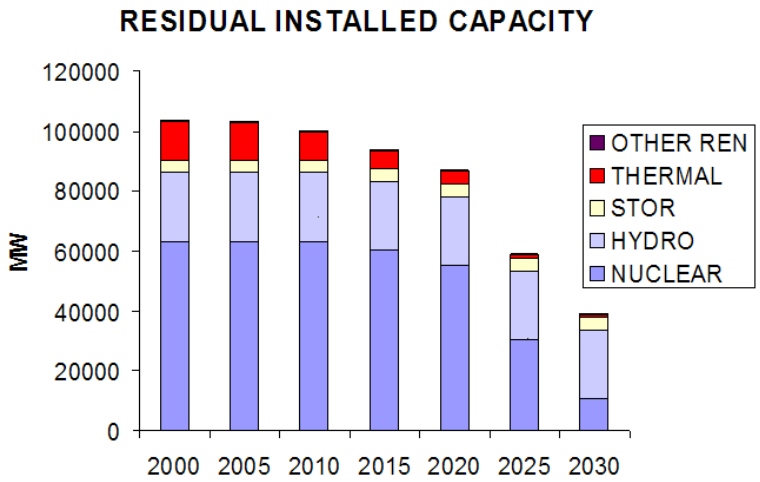
for each technology, for each period

1. levels of activity (energy)
2. levels of investment (power)
3. associated costs (reduced and marginal costs)
4. if available : level of emissions, level of taxes, etc.

MINES PARIS ParisTech

The specifities of the French electricity sector

1. Nuclear power replacement is the main driver for the future
2. French electricity production is dominated by nuclear power (79%)



- Replacement of existing capacities
- Future mix: Nuclear + Hydro + Fossil + Wind ?

MINES PARIS ParisTech

Mitigation targets : methodology

- Assessment of feasible mitigation targets for France (French energy commission)
- Through various prospective exercices

2 types of scenarios have been assessed :

1. Baseline or **business as usual** scenarios : based on the *trends*
2. Volontary based or **low carbon society** scenarios : based on hypotheses on *demand side management* and *energy efficiency*

$\Rightarrow$ All scenarios rely on **common hypotheses**

MINES PARIS ParisTech

Common Economical hypotheses

- **Time horizon**: 2000-2050 (perfect foresight)
- **Discount rate**: 5%
- **Fuel costs**:

	2005	2030	2050
oil $/bbl	54	150	100
gas $/Mbtu	8	11	15
coal $/T	60	100	120

- **Transmission and Distribution Losses**: 7%
- **Trade**: Fixed 252 PJ (70 TWh) electricity exports then variable
- French energy Law commitment 13/07/2005
- **Renewable**: 21% of domestic demand in 2010
- **Restricted technologies options**: No CCS, No H_2, No geothermal (HDR)

MINES PARIS ParisTech

Low Carbon Scenarios

In order to assess the feasible level of mitigation for CO_2 emissions by 2050, alternative low carbon scenarios are assessed.

Low Carbon Scenarios include specific hypotheses on *Demand Side Management* and *Energy efficiency*

Residential sector:

- insulation (100% to 75% of 190 TWh)
- heat-pump dissemination

Transportation sector:

- improvement of engine efficiency
- mitigation of mobility

MINES PARIS ParisTech

Alternative low carbon scenarios

The sensitivity analysis evaluates

1. Alternative nuclear future
2. Alternative transportation technology options

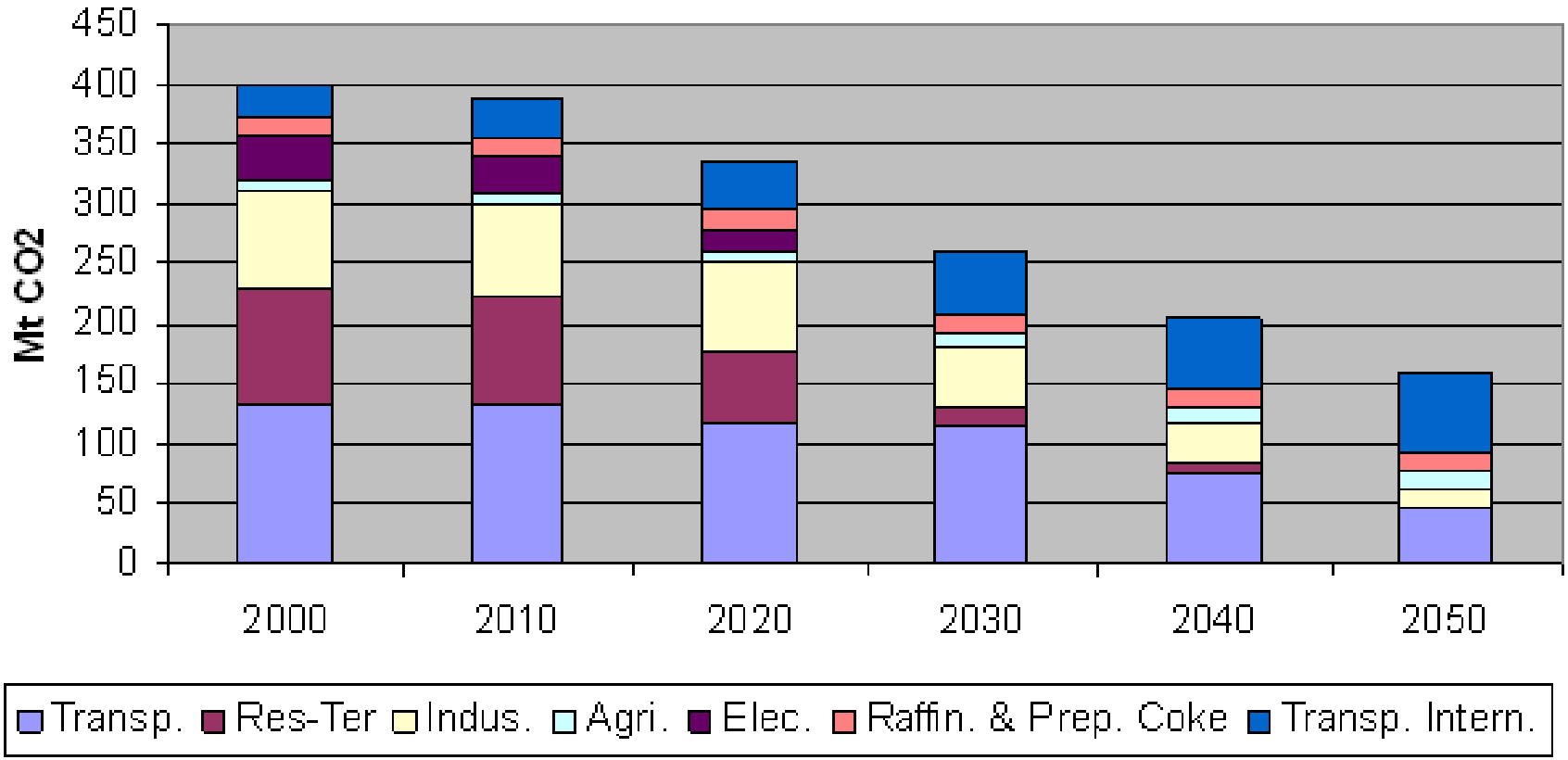
associated with either

- **constraints** on the CO_2 emission level :
  To avoid adjustments in the last periods alone, an emission path is specified.
- **taxes** on CO_2 emitted : euro/tCO_2

MINES PARIS ParisTech

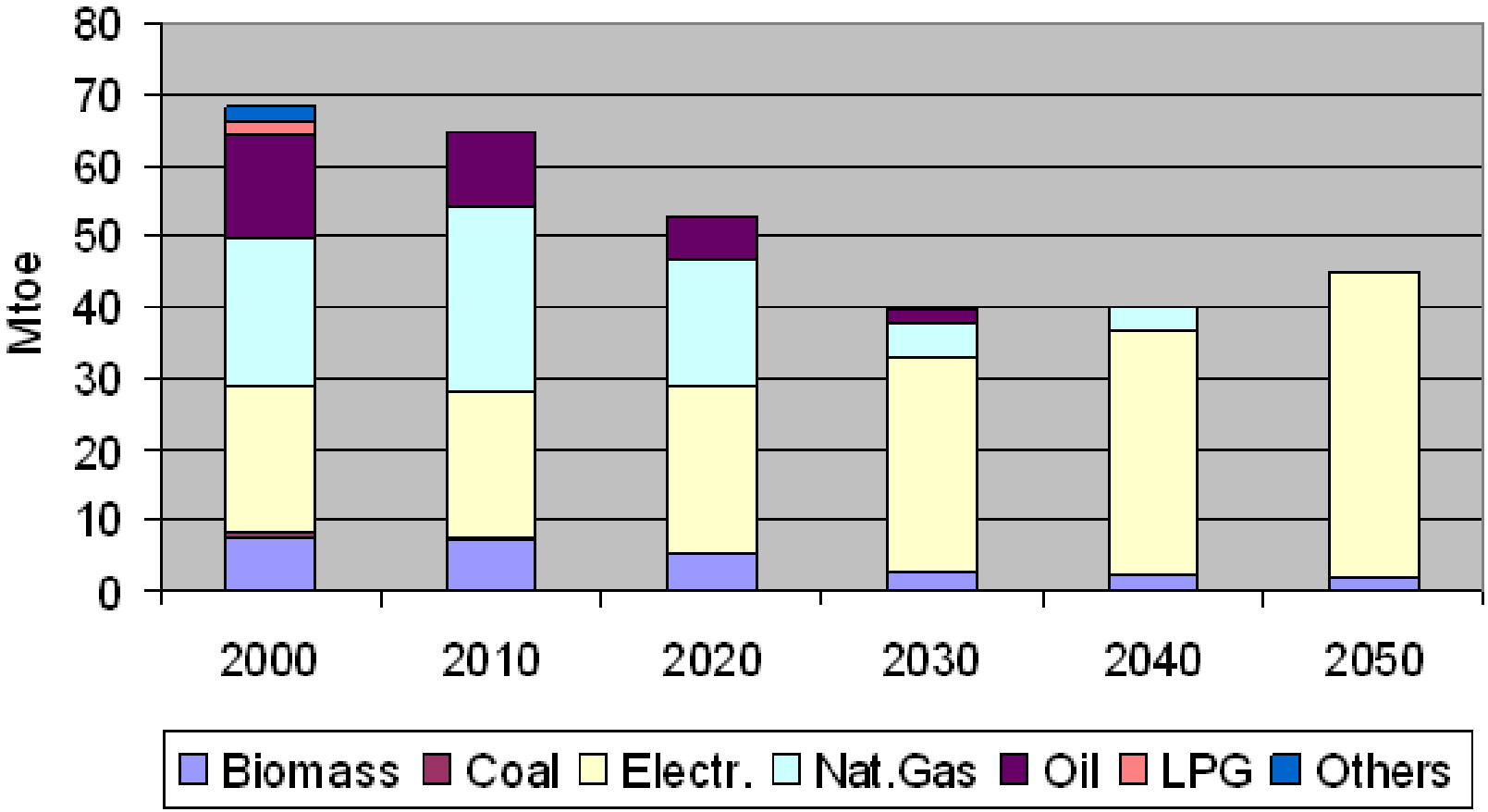
Low Carbon Scenarios : Mitigation by a factor 4

CO_2 mitigation level



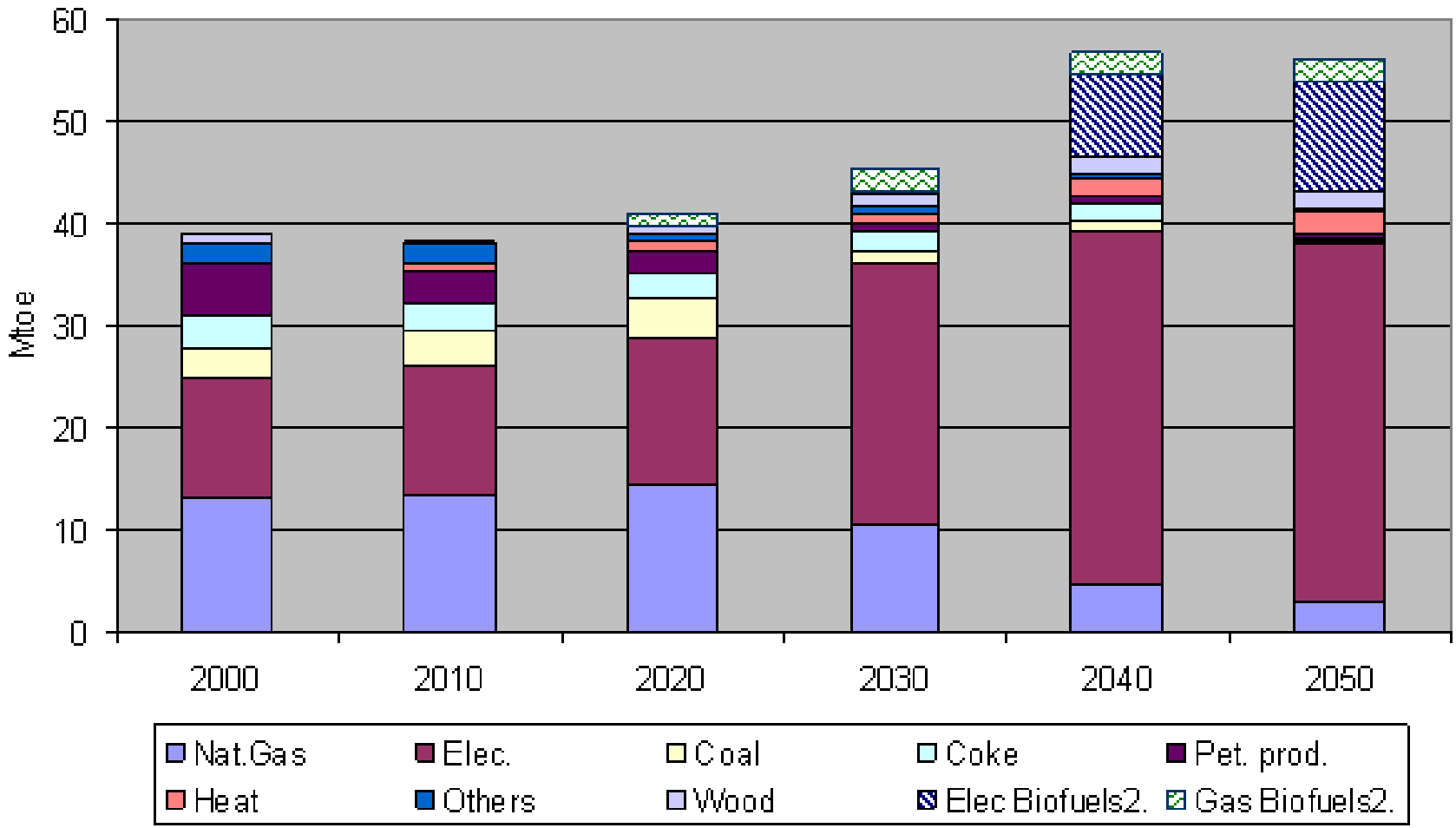
Low Carbon Scenarios : Mitigation by a factor 4

Final energy consumption for residential/tertiary sector



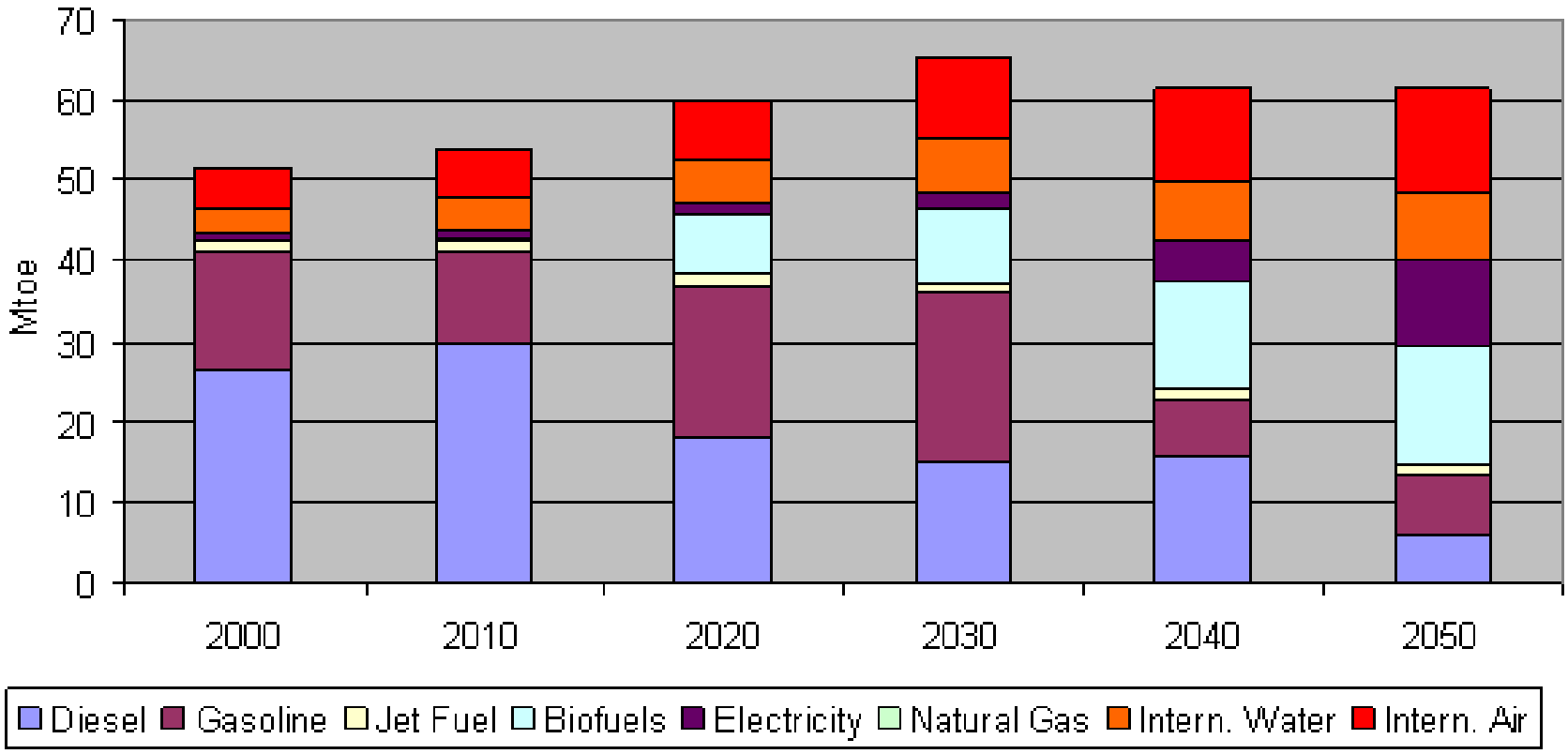
Low Carbon Scenarios : Mitigation by a factor 4

Final energy consumption for industrial sector



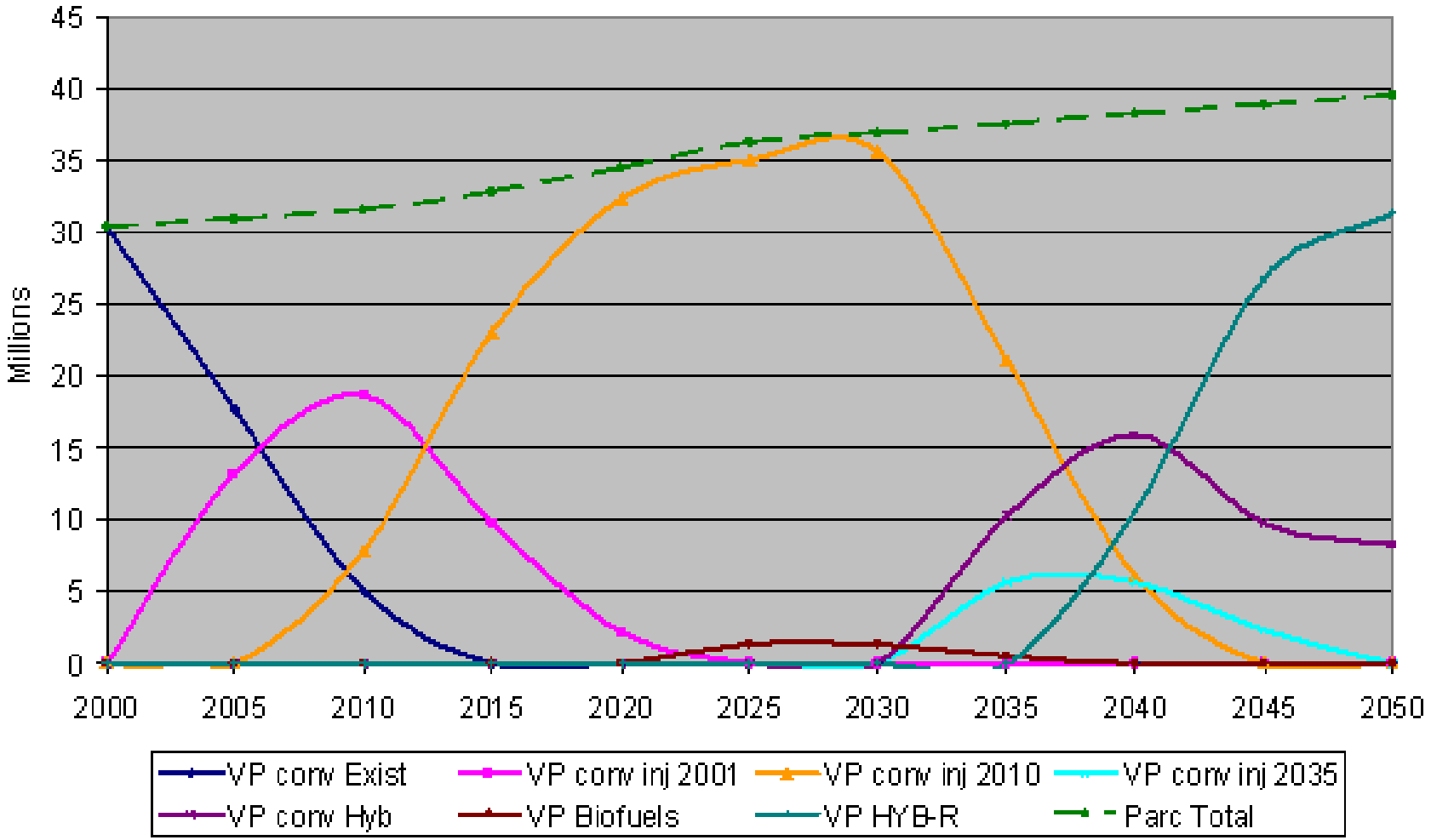
Low Carbon Scenarios : Mitigation by a factor 4

Final energy consumption for transportation sector



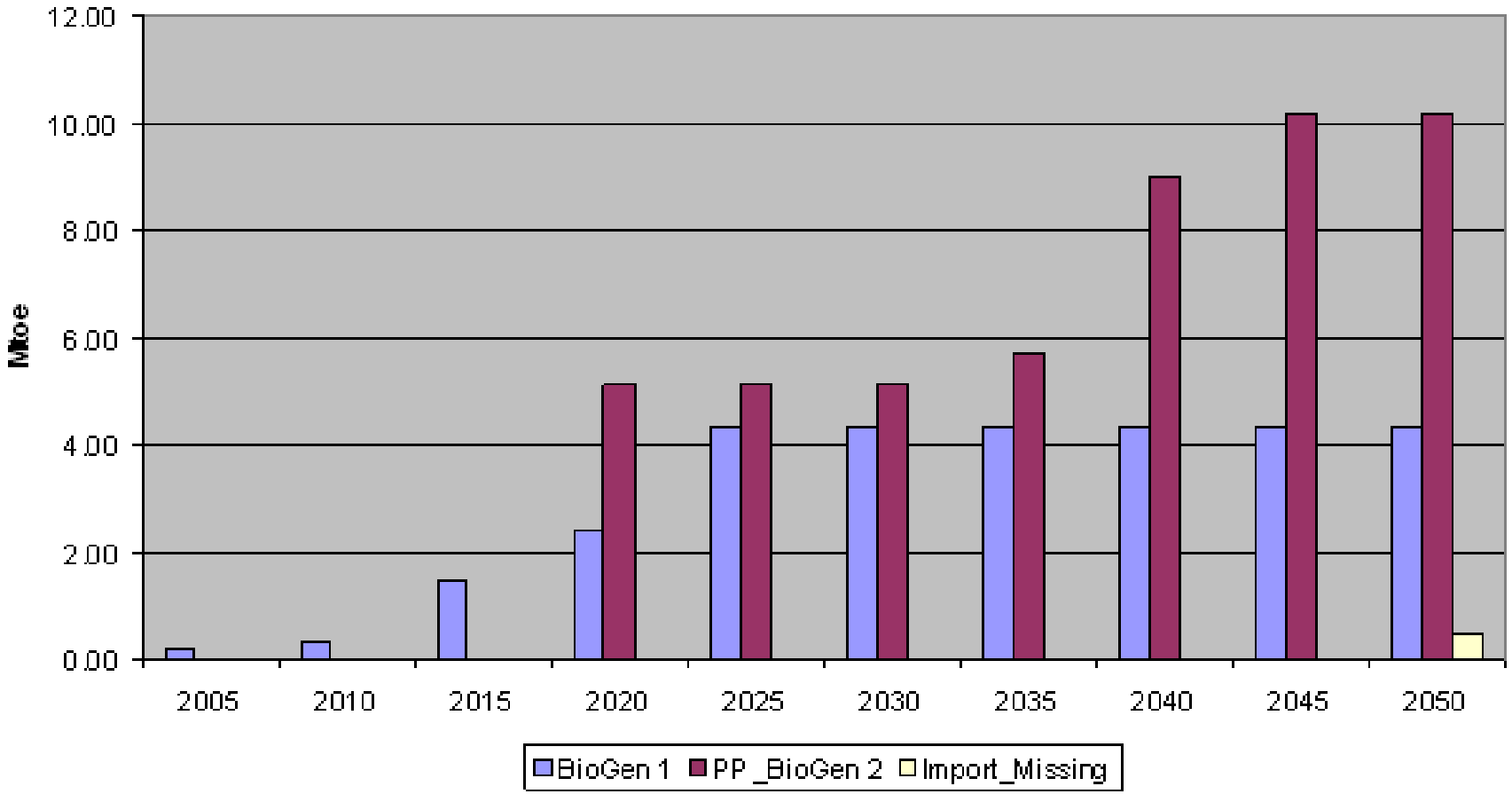
Low Carbon Scenarios : Mitigation by a factor 4

Structure of vehicules through the horizon



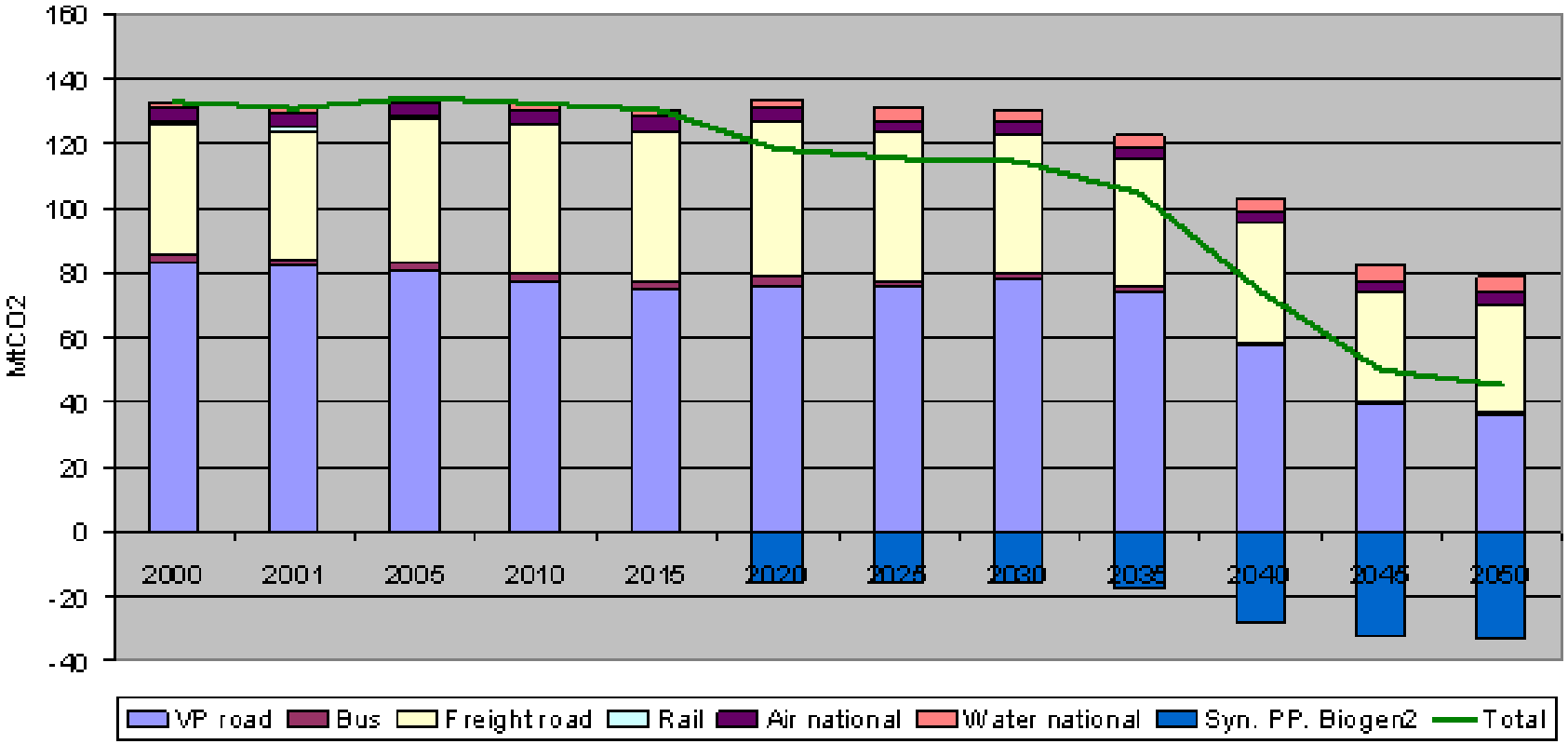
Low Carbon Scenarios : Mitigation by a factor 4

Focusing on biofuels consumption



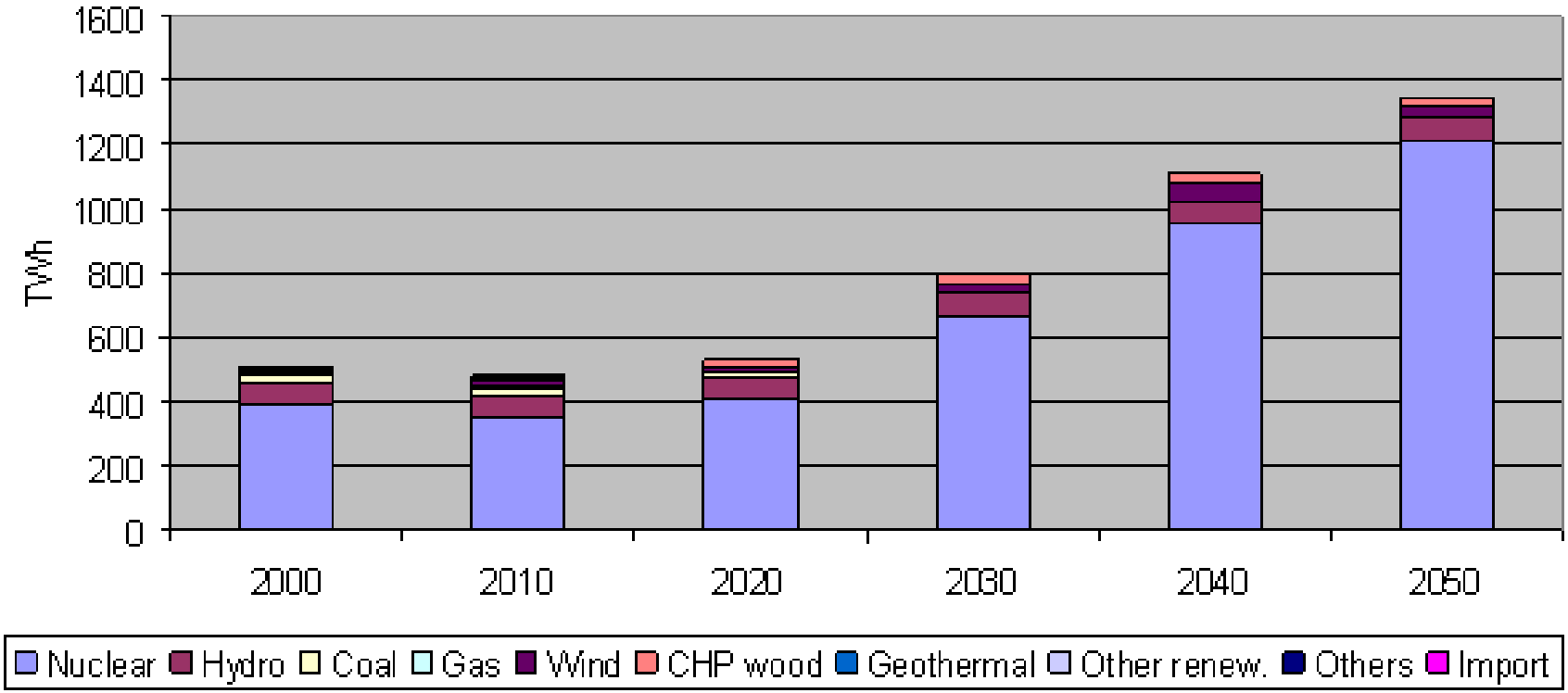
Low Carbon Scenarios : Mitigation by a factor 4

Transportation by mode and emissions



Low Carbon Scenarios : Mitigation by a factor 4

French electricity generation 2000-2050



Low Carbon Scenarios : Mitigation by a factor 4

Is the EPR growth feasible? : installed capacity for factor 4

capacity (GW)	2000	2010	2020	2030	2040	2050
total	113	116	116	140	174	195
nuclear	63	64	69	88	122	155

100 EPR nuclear reactors in 30 years

Marginal cost of abatement per ton of CO_2 avoided for factor 4

2010	2015	2020	2025	2030	2035	2040	2045	2050
10	36	46	75	94	176	192	303	29214

MINES PARIS ParisTech

Alternative nuclear future

The alternative scenarios rely on common specific nuclear hypotheses:

- **Lifespan** for existing nuclear power plants : 40 years
- **Lifespan** for new REP nuclear power plants: 60 years (1 REP in 2012)
- **Nuclear specific costs**: nuclear-waste treatment costs (fuel price) and decommisioning costs (plant operation costs)

Three **Volontary based alternative scenarios** are assessed :

Nuclear no limit scenario : No limit on future nuclear development

Feasable scenario :

- insulation potential from 100% to 75%
- 90 GW (58 EPR) on the horizon by 2050

MINES PARIS ParisTech

Sensitivity to the level of mitigation

Marginal cost (euro/tCO_2) of abatement evolution per ton of CO_2 avoided

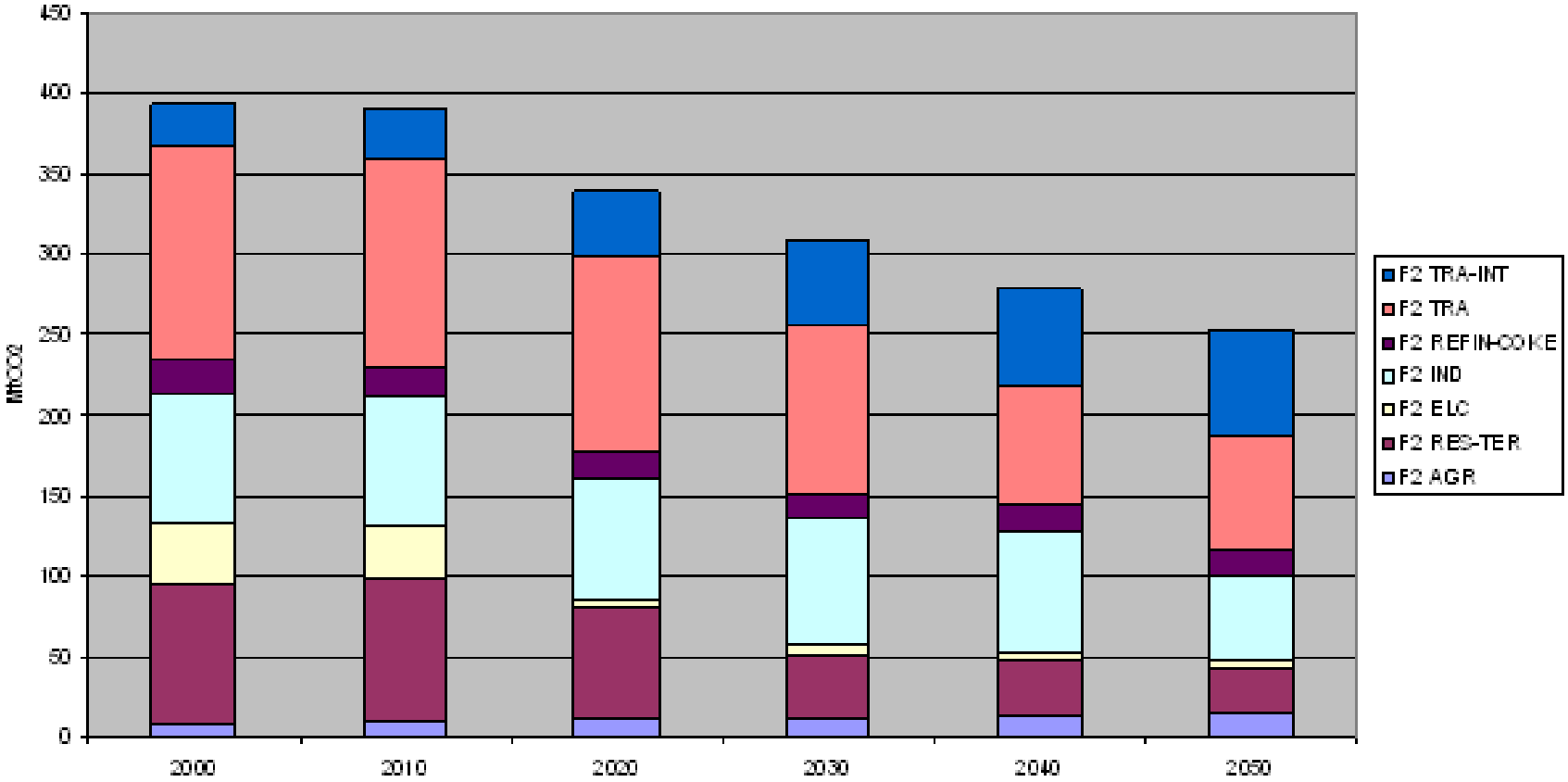
	2015	2020	2025	2030
F4	43,6	82,4	489,8	1317,6
F3	45,0	110,2	455,7	505,3
F2	41,4	103,5	254,9	257,2

	2035	2040	2045	2050
F4	5094,3	9916,2	19699,9	29626,7
F3	1578,1	2442,9	5123,6	9926,9
F2	228,3	176,4	228,5	448,9

MINES PARIS ParisTech

Low Carbon feasible Scenario : Mitigation by a factor 2

CO_2 mitigation level



Low Carbon feasible scenario : CO_2 penalties

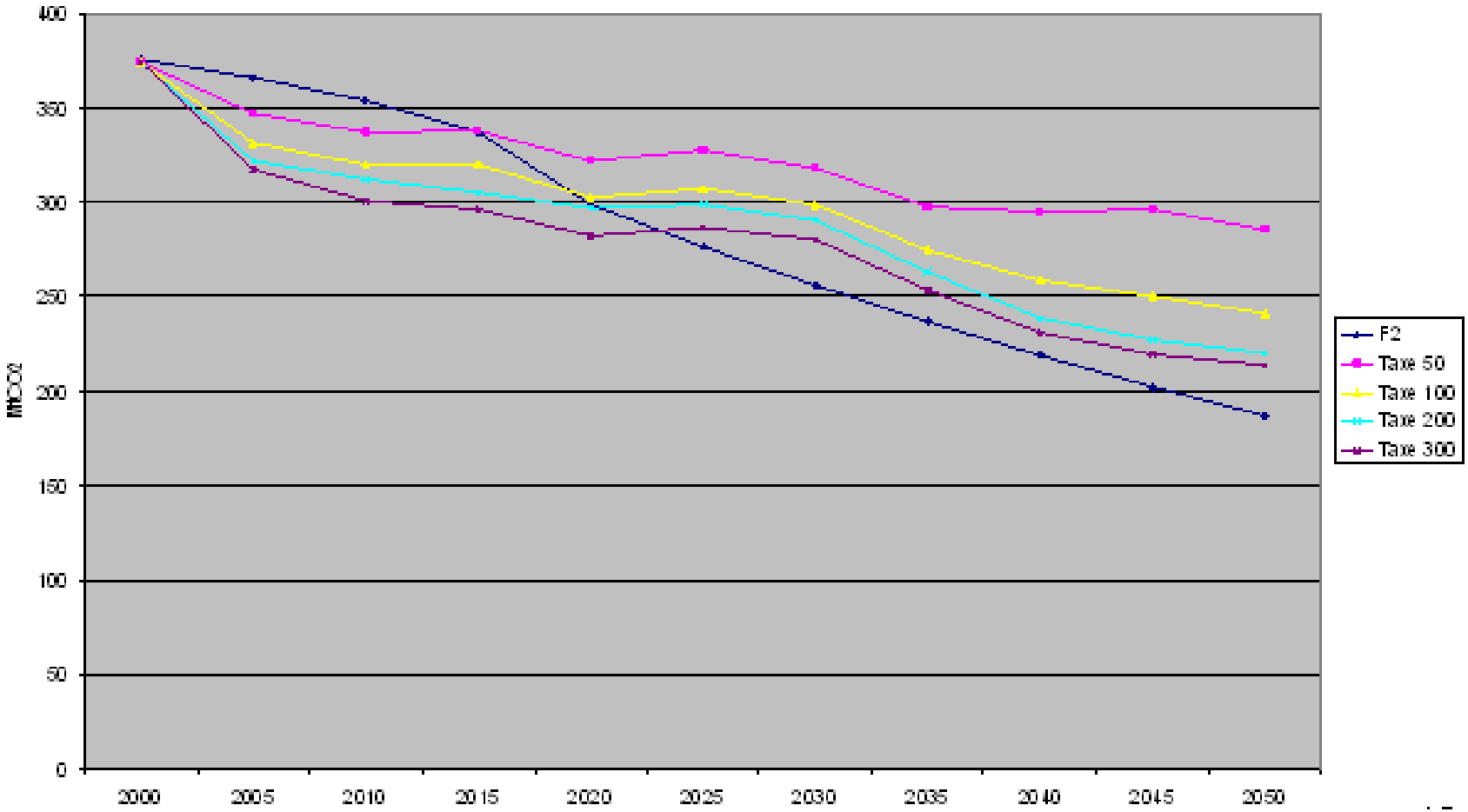
CO_2 emissions (Mt CO_2) with respect to CO_2 penalty levels (euro/tCO_2)

	2000	2010	2020	2030	2040	2050
0 (F2)	368,4	351	299,2	255,81	218,72	187
50	368,4	337,7	325,5	321,3	300,9	291
100	368,4	320,45	303	304	265,8	252,9
200	368,4	312,01	293,0	296,5	244,9	229,3
300	368,4	301,08	278,6	285,57	237,84	224,2

MINES PARIS ParisTech

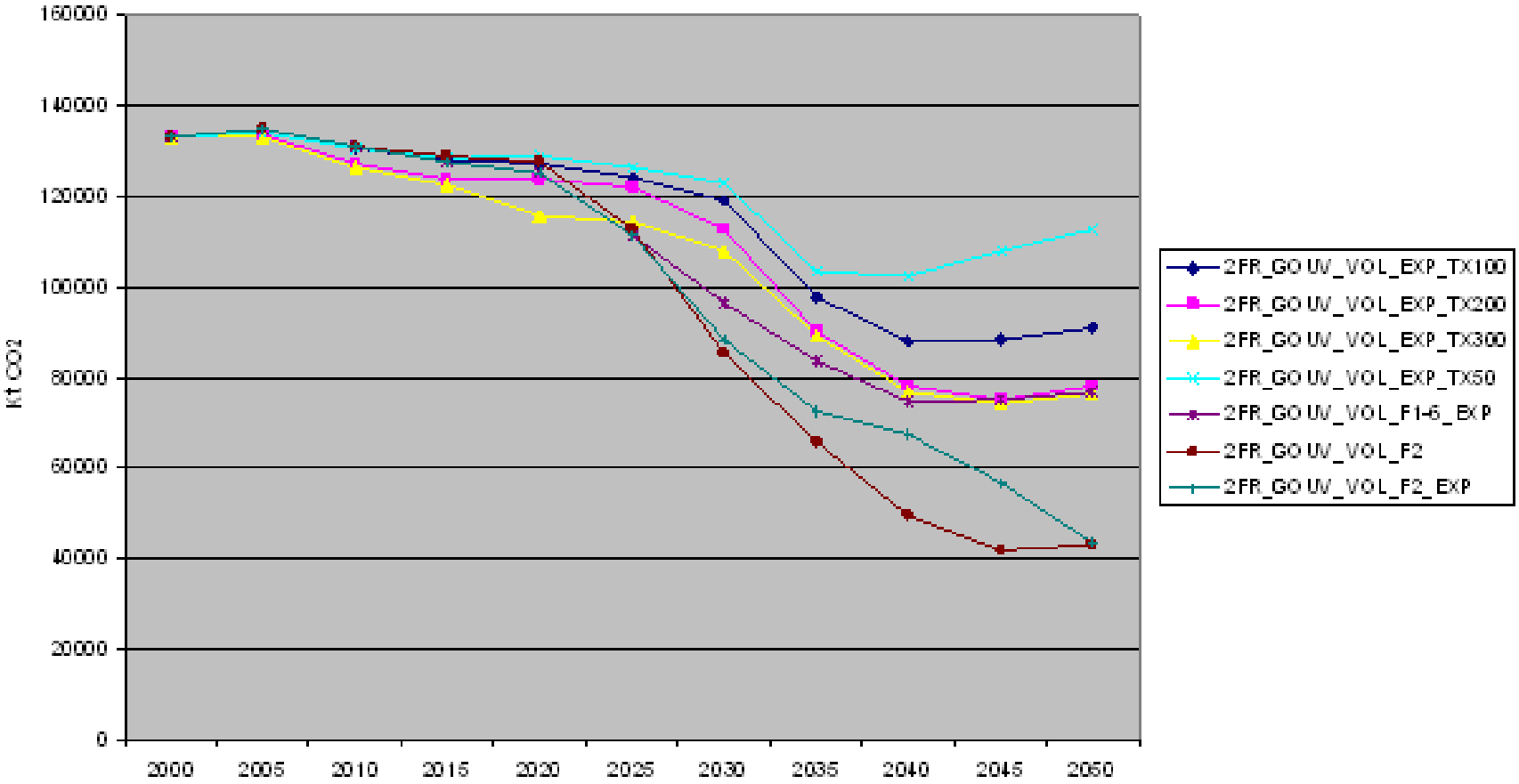
Low Carbon feasible scenario : CO_2 penalties

CO_2 emissions with respect to CO_2 penalty levels



Low Carbon feasible scenario : CO_2 penalties

Focus on transportation sector : CO_2 emissions with respect to CO_2 penalty levels



Summary

- Prospective tools relying on techno-economic optimization models are useful to assess impacts of future investments, measures and decisions in the energy field
- Applied to France, the results bear out a possible division by 2 of the CO_2 emission by the horizon 2050 if
  - some volontary assumptions in the residential and transportation sector are made
  - with “reasonable” technological options

MINES PARIS ParisTech

Alternative transportation options

The alternative scenarios rely on common technologies options:
The vehicule mix is limited to

- conventional
- biofuel
- hybrid
- plug-in hybrid

Two Volontary based alternative scenarios are assessed :

Only Liquid scenario : No gas

Reasonable scenario : gas + limited choice

MINES PARIS ParisTech