

[www.modelisation-prospective.org](http://www.modelisation-prospective.org)

Chaire Modélisation prospective  
au service du développement durable

# Shift from Oil Fuelled Cars for a Sustainable Mobility in France

Edi Asoumou, Nadia Maïzi, Valérie Roy

Center for Applied Mathematics

Mines ParisTech

# Mobility Issues

Mobility is an essential element of modern societies

- *an important input to economic growth*
- *a core societal aspiration*
- *an enabler of well being or personal development*

Mobility is the key end-use sector for the battle against climate change :

- *“we won’t be able to satisfy growing demands for transportation services with current solutions without seriously harming the environment.”*

Transport became one of the main activities of human beings

# Externals Drivers of Mobility

Five main drivers develop outside the transport system and have a direct impact on it:

- *energy*
- *economy*
- *population*
- *technological change (diffusion of ICT technologies)*
- *social change*

# Social Change

the increased purchasing power (income growth)

le travail des femmes

les logements en peri-urbain

# *Internal Drivers of Mobility*

Drivers that develop within the transport sector itself and contribute to shape transport demand patterns:

- *the continuous development of new transport infrastructure*
- *vehicle and fuels technologies which make transport easier and faster*

Drivers where the transport system produces an impact on the environment and society contexts:

- *the contribution to climate change*
- *environment degradation*
- *safety concerns*

# *Policy Drivers of Mobility*

- Promouvoir ou dissuader – fiscalité
- Inciter – bonus/malus
- Imposer – réglementation

# Transport Evolution

The developments of transport networks were driven:

- *by the emergence of cheap and abundant fossil fuels*
- *By the development of high-quality distribution medium of fuels*

Travelling and transporting goods, has become faster, cheaper, more comfortable and reliable

This allowed for the impressive mobility growth we have experienced

The development of mobility was also for the take off of economic

# French Mobility

French mobility steadily increased

- *+ 40% from 1988 to 1998 for personal vehicles*
- *while travel time remains constant (1 hour per day)*
  - *and has not changed over the last 40 years*
- *increasing vehicle speed*
  - *Only 12% vehicle have a maximal speed less than 160km/h*



# The French GHG Emissions Specificity

The transport part in the French GHG total emissions is more important than in United States or all the European countries

However CO<sub>2</sub> emissions per capita for transport are the same 2,2 t

France is one of the industrial nations which emits least carbon dioxide per capita

- *French energy sector emits 58 MtCO<sub>2</sub>e against 345 for Germany or 178 for Poland*
- *France emits 386 MtCO<sub>2</sub>e a year against 846 in Germany or 307 in Poland*

# The French Energy Specificity

20% increase in overall primary energy consumption from 1990 to 2004 ... but the energy situation in France has improved

Thanks to

- *the rapid growth of nuclear power production (2<sup>nd</sup> WW rank)*
- *Importance of hydraulics in its energy balance*

However France is still very dependent on oil and gas, particularly for transport (98% dependency on oil)

# Focus on Road Transport Sector in France

Clearly a dominant sector with a consumption of 88% of the French domestic passengers transportation sector in 2005

- *It contributes for more than 18 % to the GHG Emissions*

Private cars account for 55.9 % of the total energy consumed in road transport in 2005 ... but this share was 60.6 % in 1990

between 1990 and 2005, road transport activity has improved

- *its energy efficiency increased by 20%*
- *its activity by 61%*
- *its energy consumption by 29%*
- *its related GHG emissions following a corresponding decreasing trend*

# The other Sectors have reduced or stabilized theirs emissions

## **Industry :**

- The '90s restructuring has driven a considerable reduction of energy intensity of industrial value added
- 2.74 % per year during 1990-2000 and 1.13 % after

## **Agriculture:**

- Energy intensity of has decreased substantially between 1990 and 2005 (1.5% per year)

## **Residential sector**

- Its consumption (26 % of total final energy consumption in 2005) is slightly up from 25 % in 1990

# Modeling the French Energy System

Because the answer is less straightforward, there is a need for scientific forecast based on modeling approach

- They are inadequate to predict exactly the long-range future
- But they are able to highlight
  - *links between issues*
  - *relationships between global and local activities*
  - *actions such as energy or mobility saving*
  - *policies such as taxes or emission constraints*

# Transport Sector Issues

The transport sector will have to

- *satisfy a greater demand for Mobility*
- *find solutions to address its negative externalities which affect*
  - the environment (pollution, CO<sub>2</sub> emissions, and noise)
  - the economy (congestion)
  - the society (health, safety and security).
- *Be the end-use sector for the battle against climate change*

# The French Markal/Times Reference Energy System

- *we define the contribution to mitigation from the transport sector*
- *which depends on efforts in others sectors*
- *“ we run different scenarios on the French Markal / TIMES Reference Energy System designed by **Edi Assoumou** ”*
- *Markal / TIMES is a bottom-up approach*
- *based on an explicit descriptions of the technologies used*
- *Where the input-output relationships is explicitly formulated for each technology*
- *investments levels, activities levels and total installed capacities are the main decision variables*

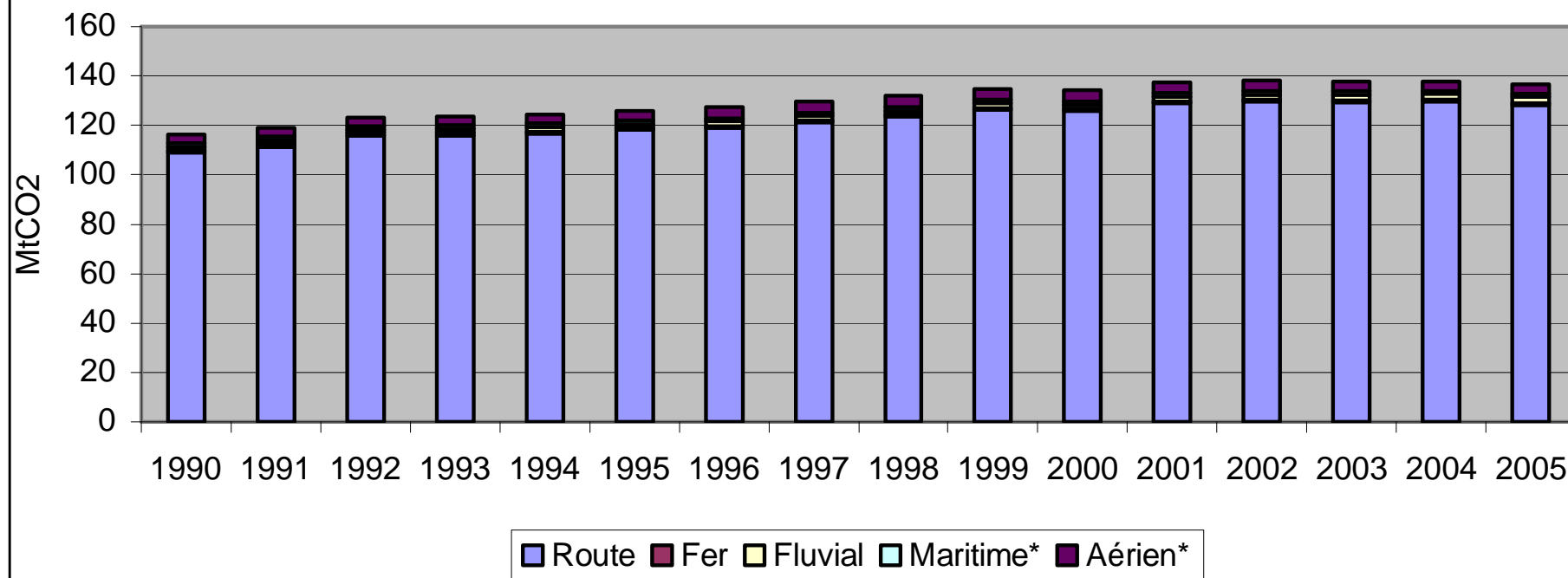
# The French Markal/Times RES

- *optimises energy systems in the long-term (2000-2050)*
- *minimises the total discounted cost*
  - *over the chosen time horizon and for given final services demands*
- *required demands for energy services*
- *Mobility demands*
  - *are differentiated in short and long distance travels*
  - *have to be satisfied with strong constraints on CO<sub>2</sub> emission levels*  
*(three scenarios will be studied)*
- *The systemic approach used ensures consistency of the results **across all end-use sectors***
- *This paper propose a focus on road sector more precisely on personal vehicles*



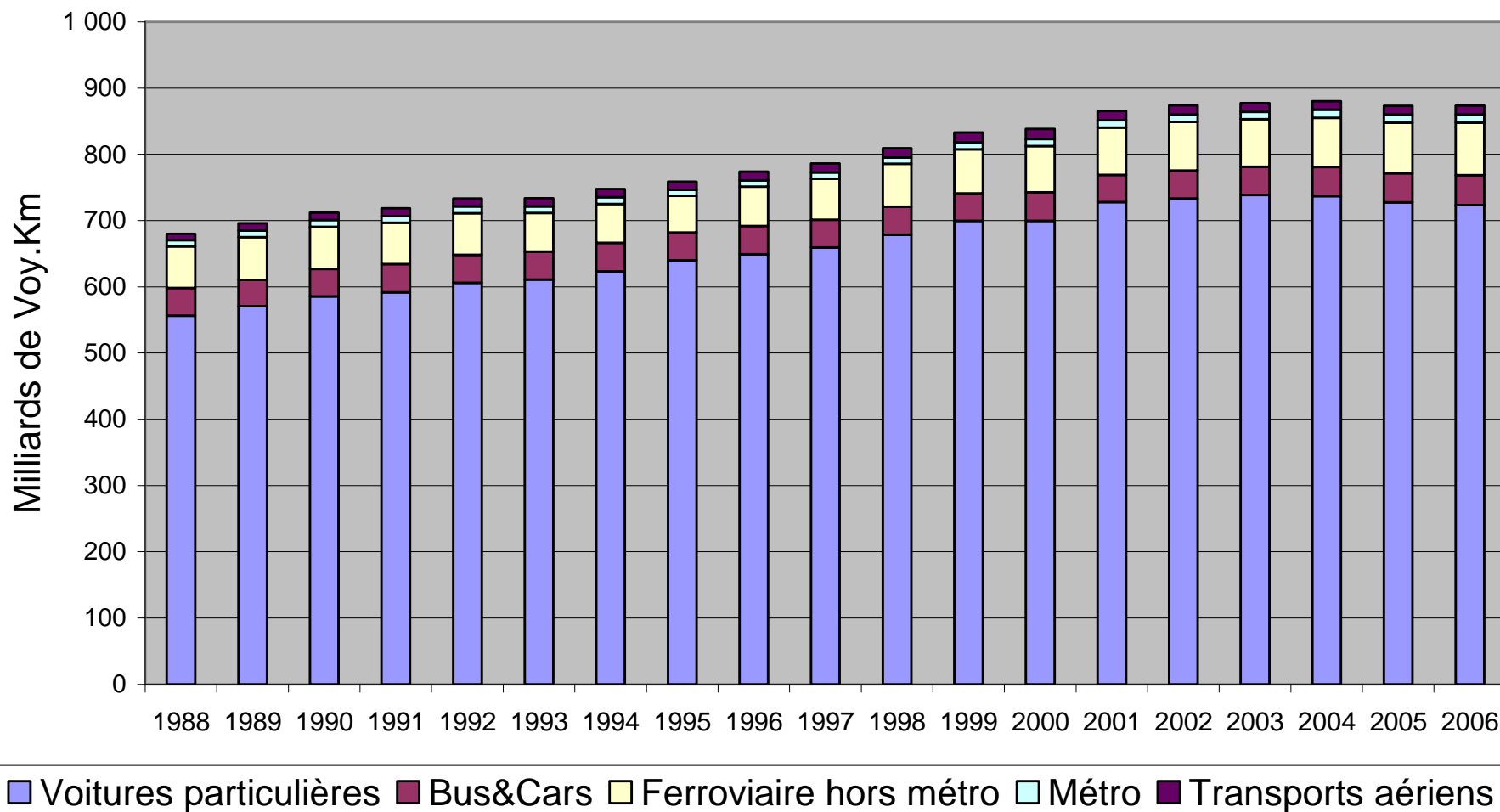
# CO2 emissions of the French Transport Sector

Emissions de CO2 du secteur des transports



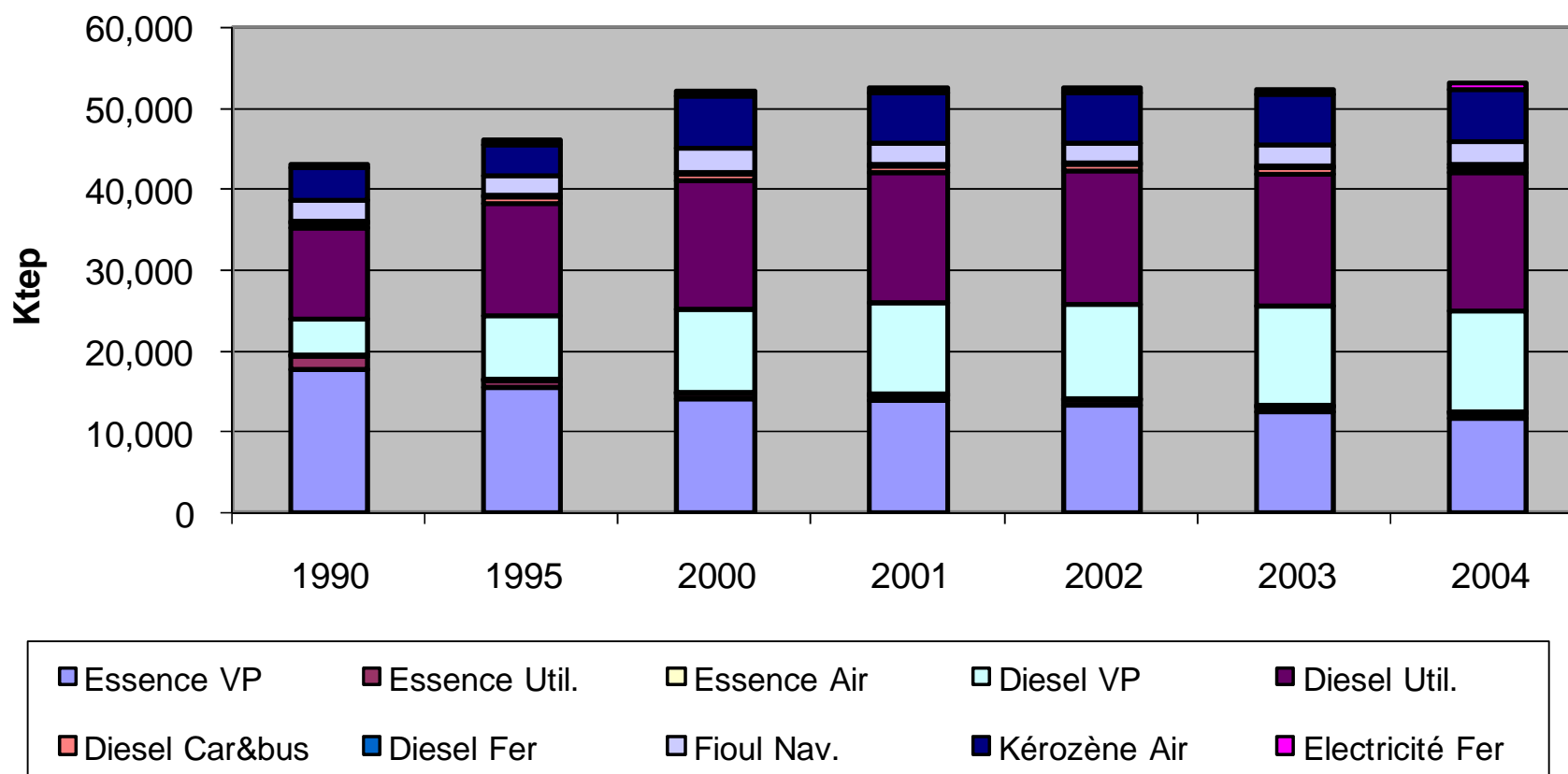
# Passengers Transport by Mode:

## A Major Contribution of Personal Vehicles

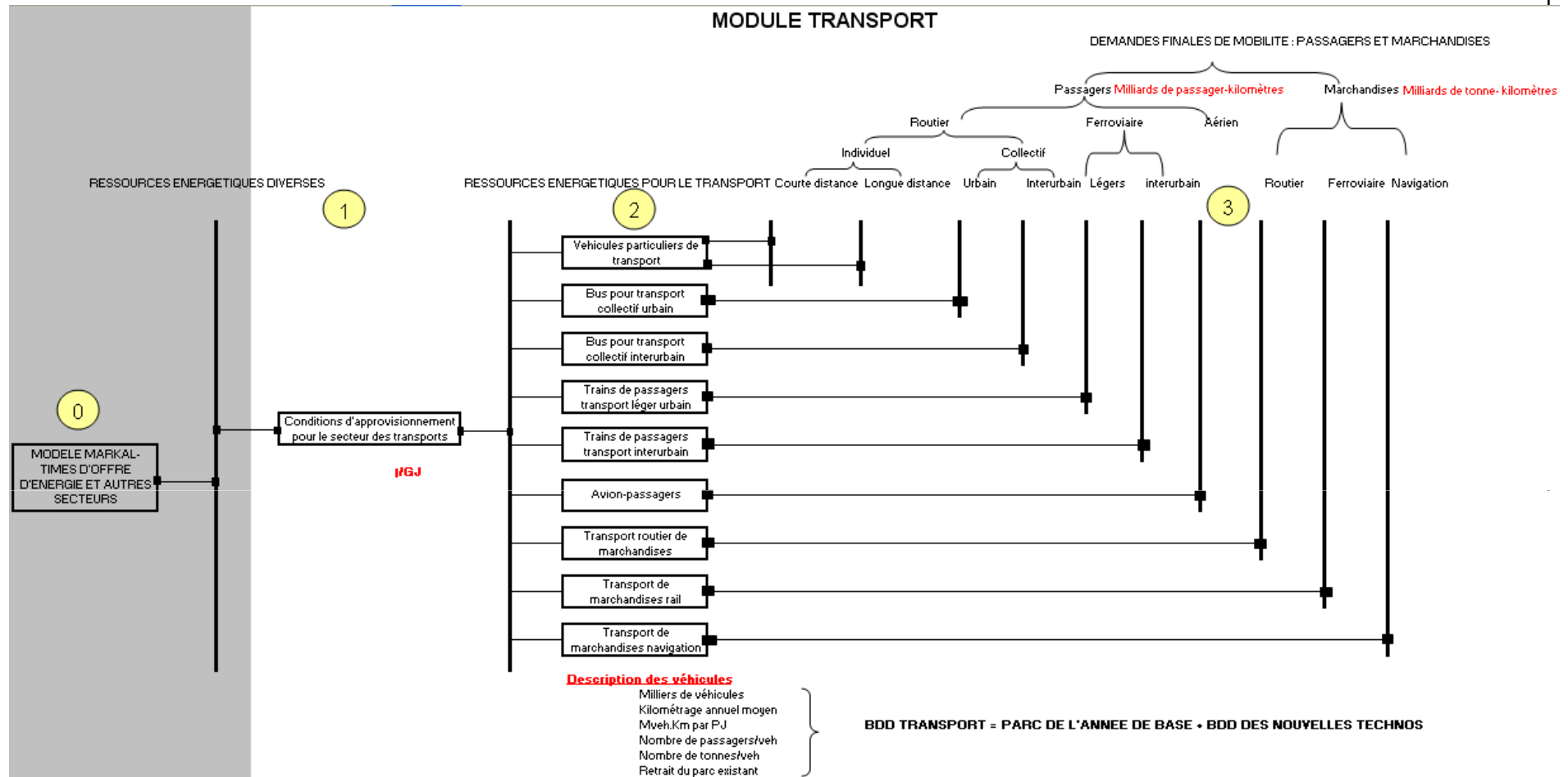


# Energy Consumption for the transport sector from 1990 to 2004 [DGEMP] in ktoe

## Modes and Resources



# Focus on French Transport Sector



Passengers Mobility in giga of passengers kilometres (Gvoy.km)

Goods Mobility in giga of metric tons kilometres (Gt.km)

CO2 emissions from energy consumption in kilo metric tons (Kt)

Euro actualisation rate is 5% for all sectors

# Personal Vehicle Technology Description

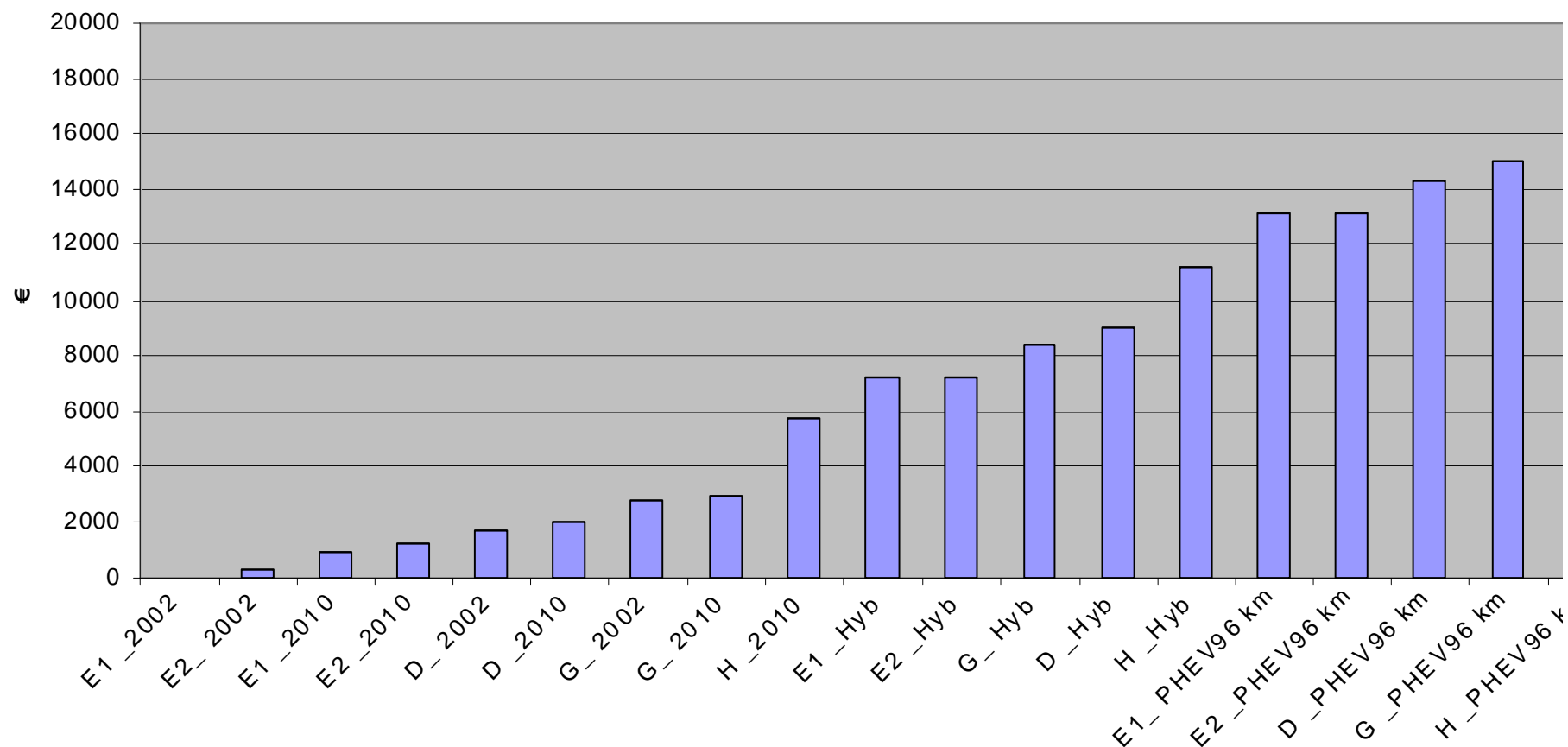
Characteristics of the Personal Vehicle	
Global Description	Performances, class, ...
Average number of kilometres travelled per year	
Average rate of occupancy	
Energy source (commodity on)	
Energy efficiency per mobility type	Short distance mobility
	Long distance mobility
Minimal part of each mobility type (%)	Short distance mobility
	Long distance mobility
costs	investissement
	Opération et maintenance
Actualisation rate	

# Personal Vehicle Technologies (Heat Engine)

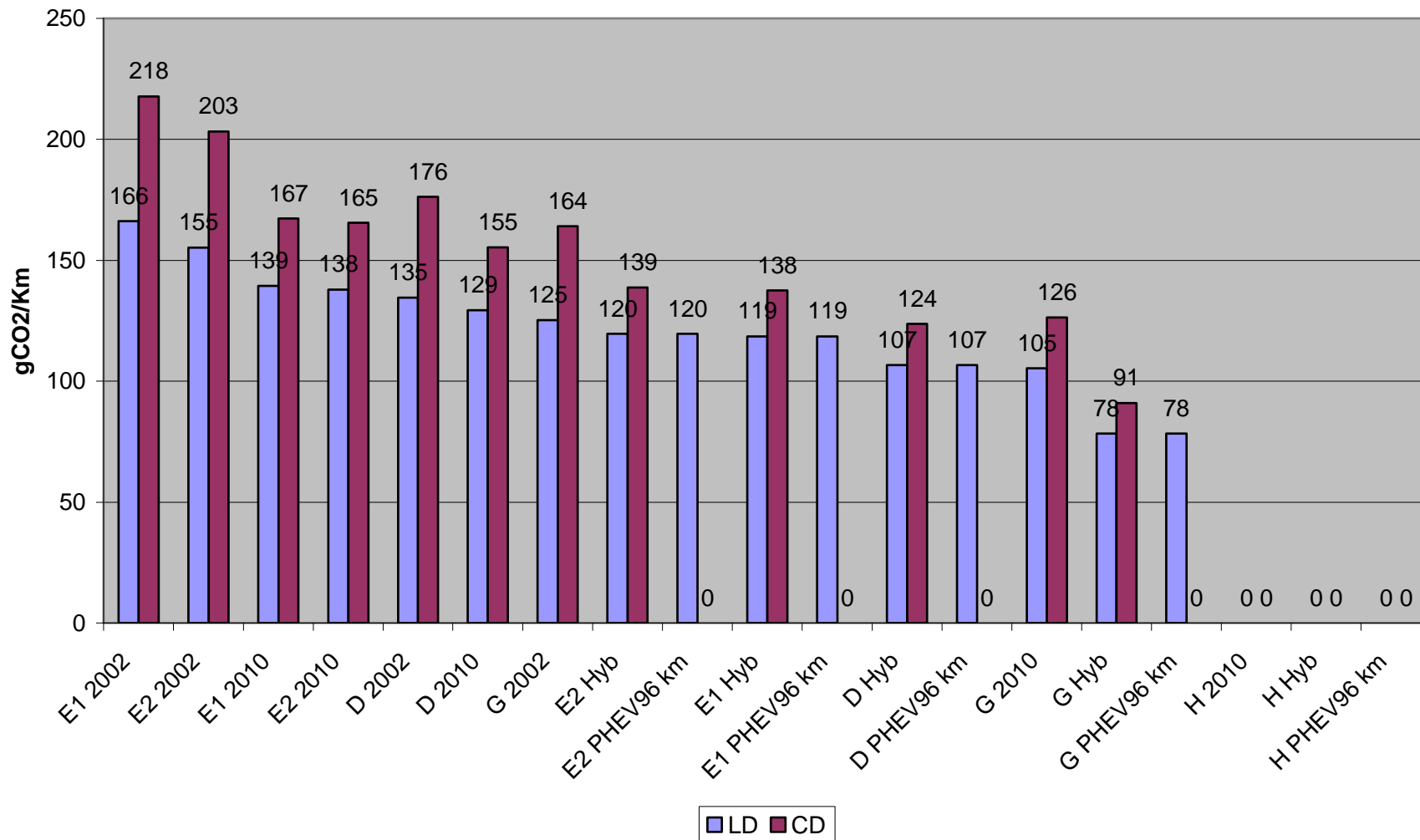
CODE	DESCRIPTION					
E1_2002	Gasole	Indirecte injection	Ignition spark			2002+
E2_2002	Gasole	Directe injection	Ignition spark			2002+
E1_2010	Gasole	Indirecte injection	Ignition spark			2010+
E2_2010	Gasole	Directe injection	Ignition spark			2010+
D_2002	Diesel	Directe injection	Ignition by compression			2002+
D_2010	Diesel	Directe injection	Ignition by compression			2010+
G_2002	Gas naturel	Indirecte injection	Ignition spark			2002+
G_2010	Gas naturel	Indirecte injection	Ignition spark			2010+
H_2010	Hydrogen	Indirecte injection	Ignition spark			2010+
E1_Hyb	Gasole	Indirecte injection	Ignition spark	Hybrid		2010+
E2_Hyb	Gasole	Directe injection	Ignition spark	Hybrid		2010+
D_Hyb	Diesel	Directe injection	Ignition by compression	Hybrid		2010+
G_Hyb	Diesel	Indirecte injection	Ignition spark	Hybrid		2010+
H_Hyb	Hydrogen	Indirecte injection	Ignition spark	Hybrid		<b>2010+</b>
E1_PHEV96 km	Gasole	Indirecte injection	Ignition spark	Hybrid	Rec.60 miles - 96Km	<b>2020+</b>
E2_PHEV96 km	Gasole	Directe injection	Ignition spark	Hybrid	Rec.60 miles	<b>2020+</b>
D_PHEV96 km	Diesel	Directe injection	Ignition by compression	Hybrid	Rec.60 miles	<b>2020+</b>
G_PHEV96 km	Gas naturel	Indirecte injection	Ignition spark	Hybrid	Rec.60 miles	2020+
		Indirecte			Rec.60 miles	

# Vehicle Additional Cost/ MCI Essence 2002

Surcoûts véhicules MCI divers vs MCI Essence 2002

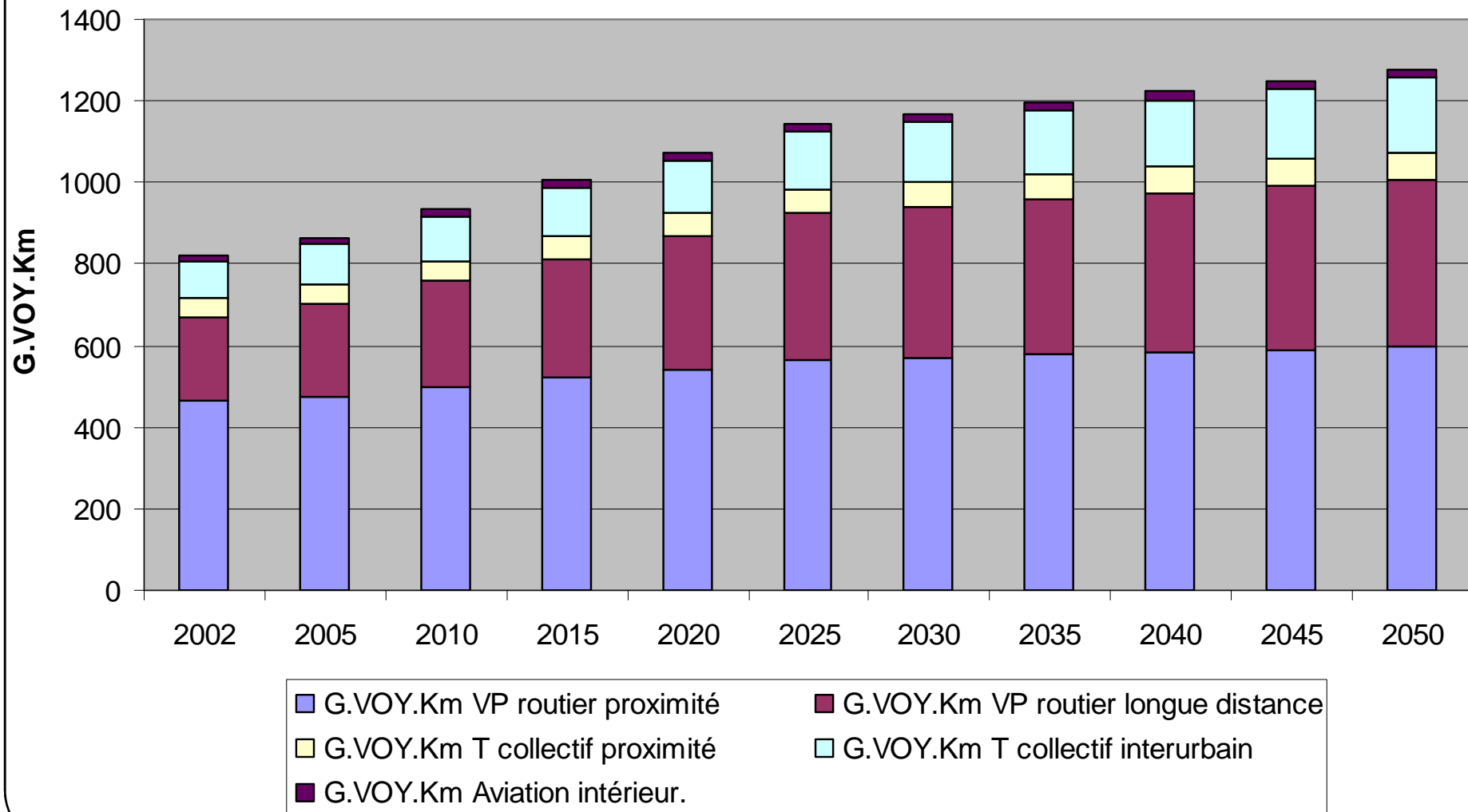


# Influence of Short/Long Distances (freeway/city) on Personal Vehicles CO2 Emissions

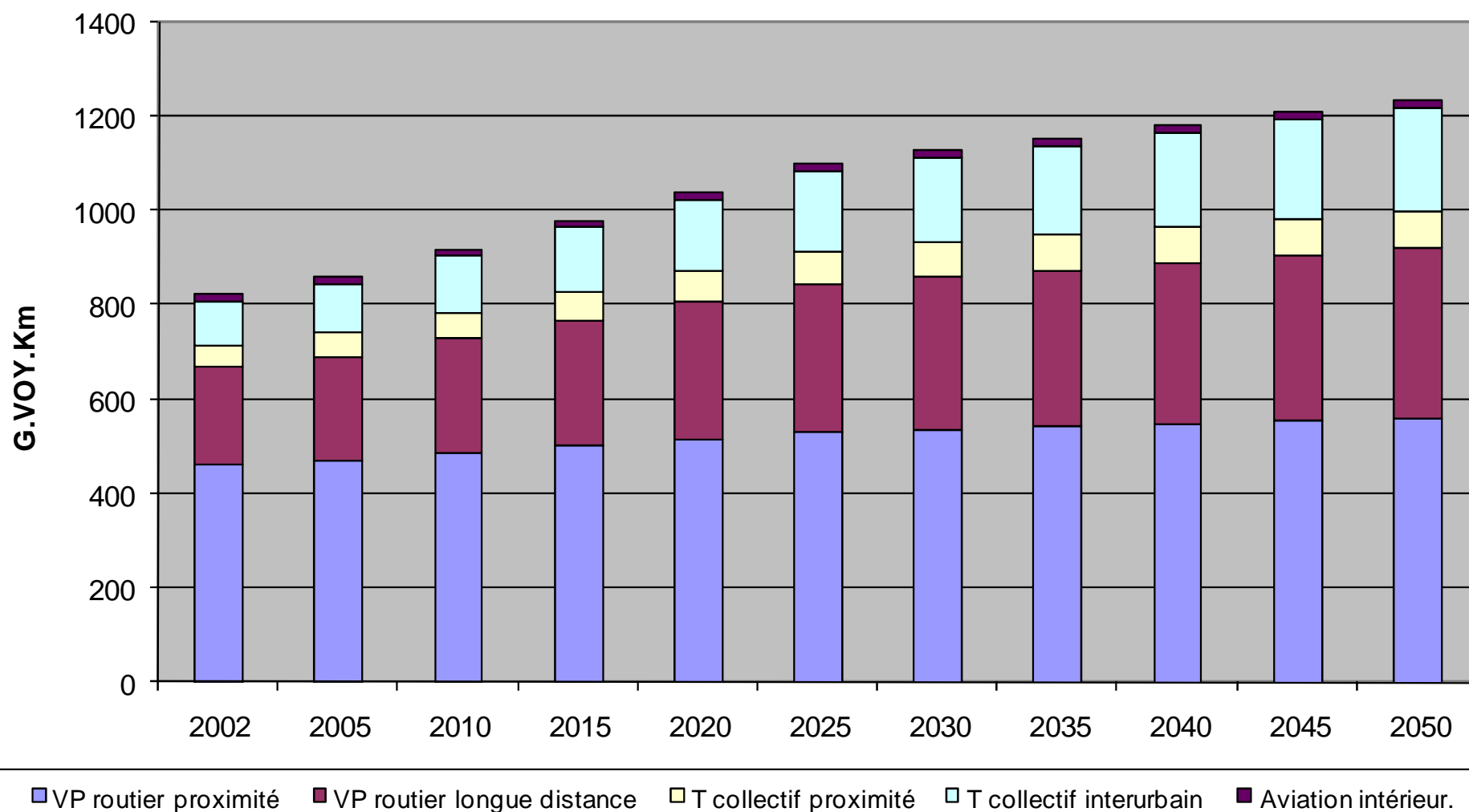




# Demand Projection for Domestic Passengers Transportation



# Hypothesis for Demands Projection For Domestic Passengers-Mobility Voluntarist Scenario



# Hypothesis

## Economic growth

Croissance annuelle moyenne (monde)	➤ 3% par an
Croissance annuelle moyenne (France)	➤ 2,5% par an jusqu'en 2015 1,8% au-delà

## Demography growth

INSEE scénario central	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Population en milliers	58 796	60 702	62 302	63 728	64984	66 123	67 204	68 214	69 019	69 563	69 961

# Hypothesis of Energy Price

		2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
gazole	(\$/baril)	<b>54</b>	67	<b>80</b>	103	126	<b>150</b>	137,5	125	112,5	<b>100,0</b>
gas	(\$/MBT U)	6,4	7,7	9	11,3	13, 7	16	15,75	15,5	15,25	<b>15,0</b>
coal	(\$/tonne )	<b>60,0</b>	68,0	76,0	84,0	92,0	<b>100,0</b>	105,0	110,0	115,0	<b>120,0</b>

# Hypothesis of Mobility

		Base	Volontariste	
		2002		
		2004	2025	2050
G.VOY.Km Millions de passagers	VP routier proximité	<b>463</b>	<b>530</b>	<b>560</b>
	VP routier longue distance	<b>205</b>	<b>315</b>	<b>360</b>
	T collectif proximité	<b>48</b>	<b>70</b>	<b>80</b>
	T collectif longue distance	<b>93</b>	<b>170</b>	<b>220</b>
	Aviation : intérieur.	<b>14</b>	<b>16</b>	<b>16</b>
	Aviation : international	<b>76</b>	<b>132</b>	<b>213</b>

# Scenarios with Environmental Constraints

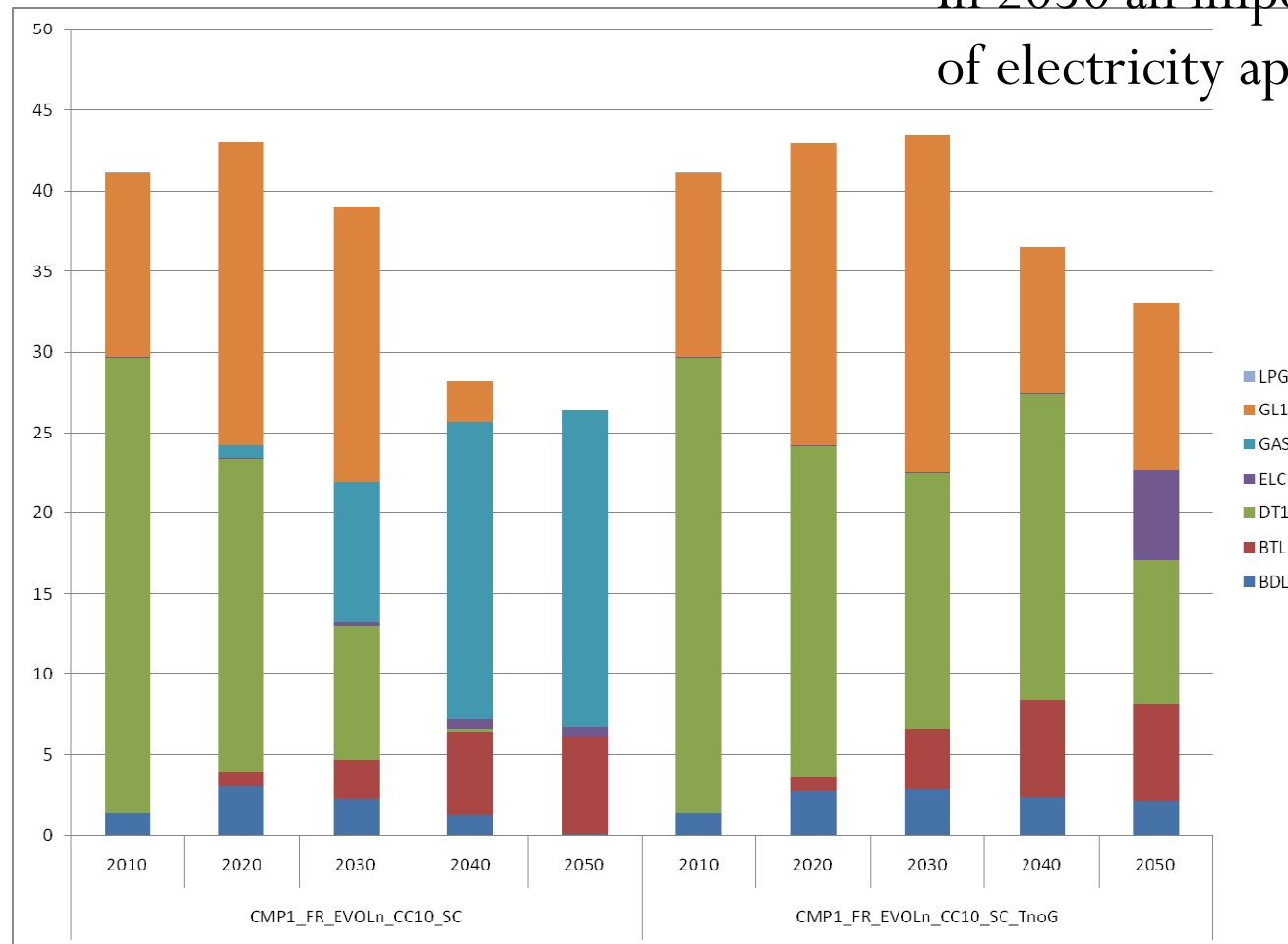
CMP1\_FR\_EVOLn\_CC<sub>x</sub>\_SC

CMP1\_FR\_EVOLn\_CC<sub>x</sub>\_SC\_TnoG

- CMP = Chaire de Modélisation Prospective
- FR = France
- EVOLn = Demandes VOLontaristes
- SC = scenarios Sans Crise (without crisis)
- TnoG = No gas for transport
- CC<sub>x</sub> = Contrainte carbone de *x* (*x from 0 to 50*)
  - from 2010 to 2020, the CO<sub>2</sub> emissions must decrease by *x*% / 1990
  - After they'll decrease by 47 %

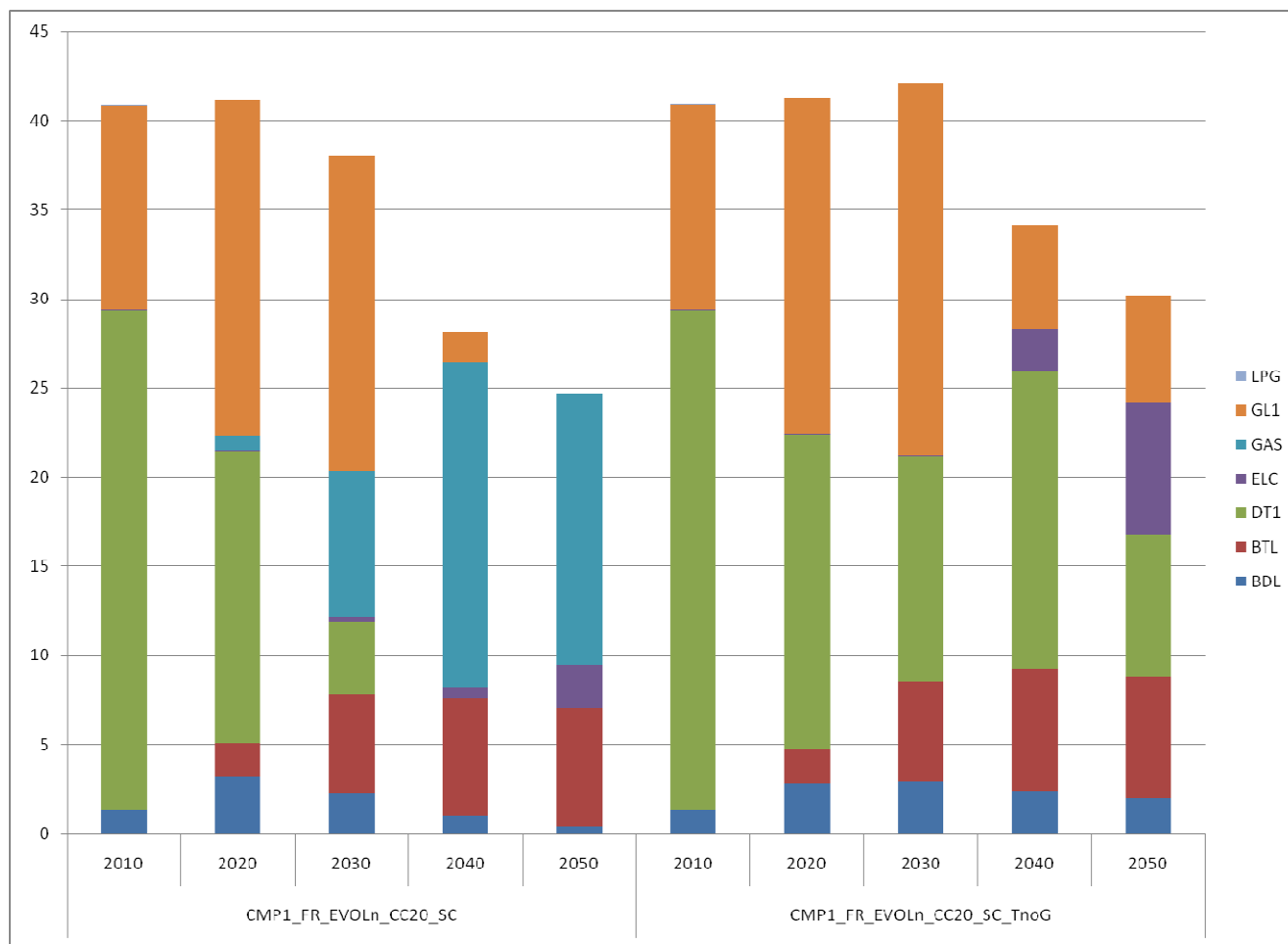
# Comparison of CMP1\_FR\_EVOLn\_CC10\_SC and CMP1\_FR\_EVOLn\_CC10\_SC\_TnoG

In 2050 an important level of electricity appeared

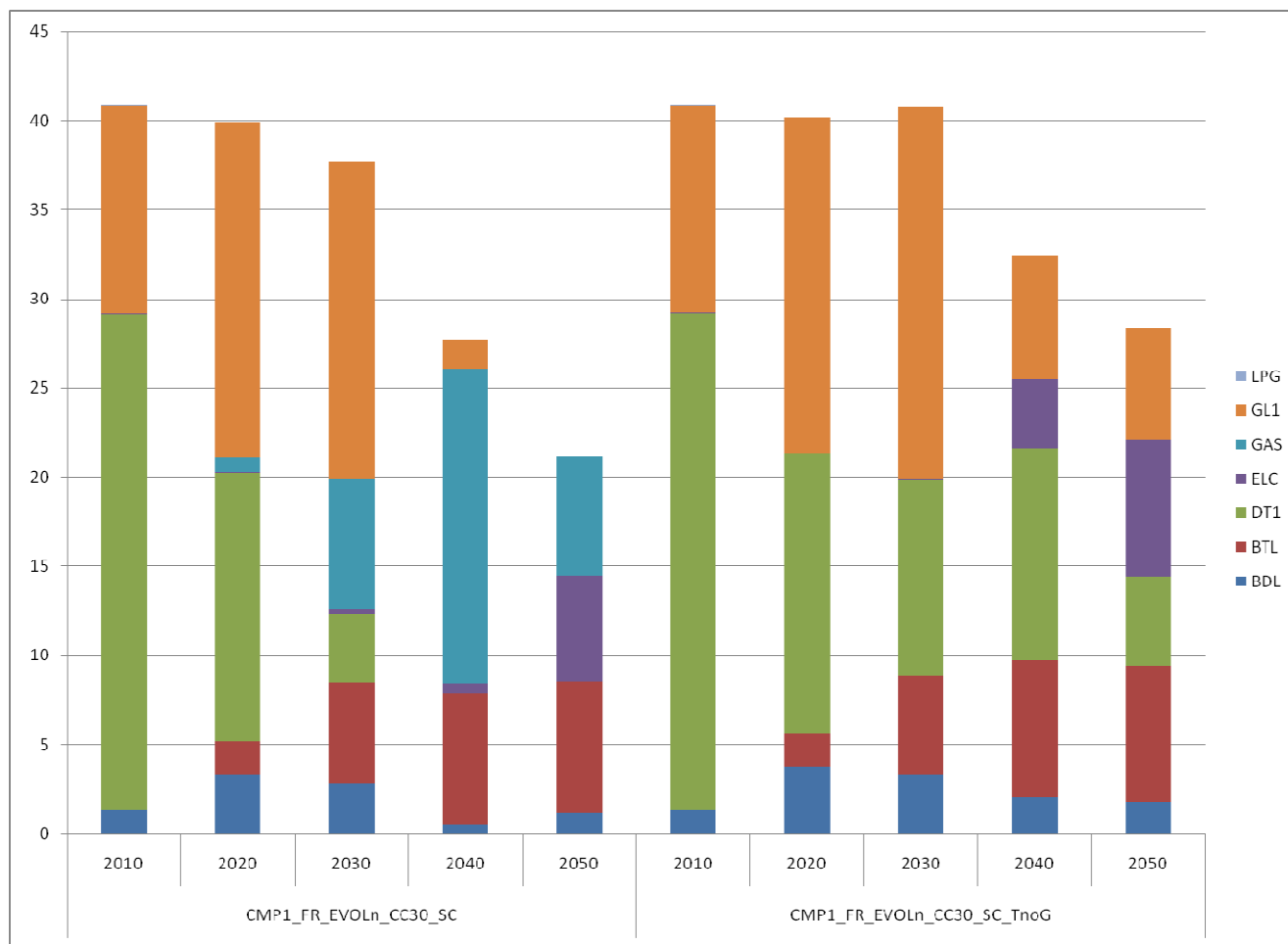


2040 gas becomes predominant

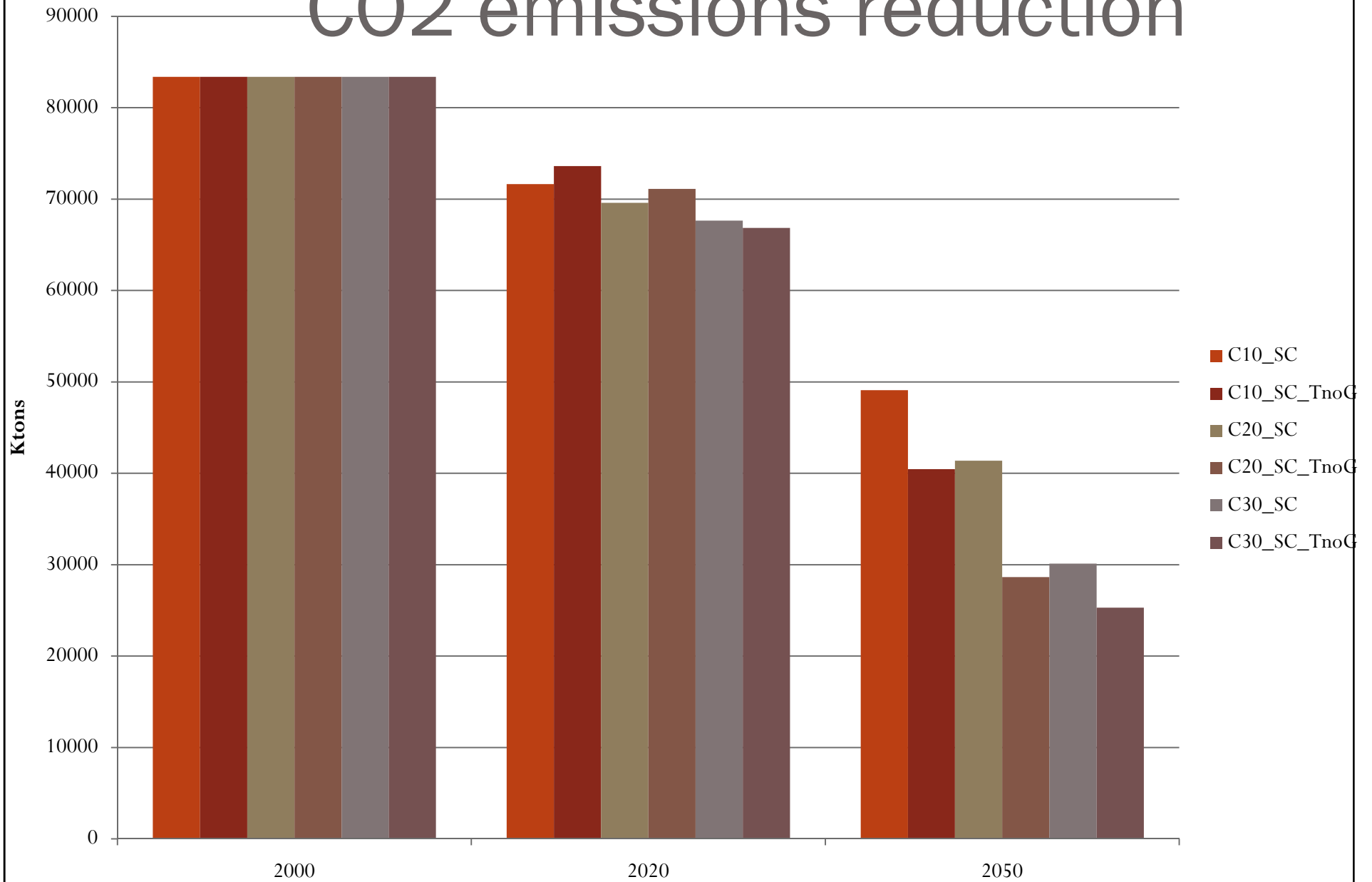
2050 gas is replaced by electricity, diesel and gasoline

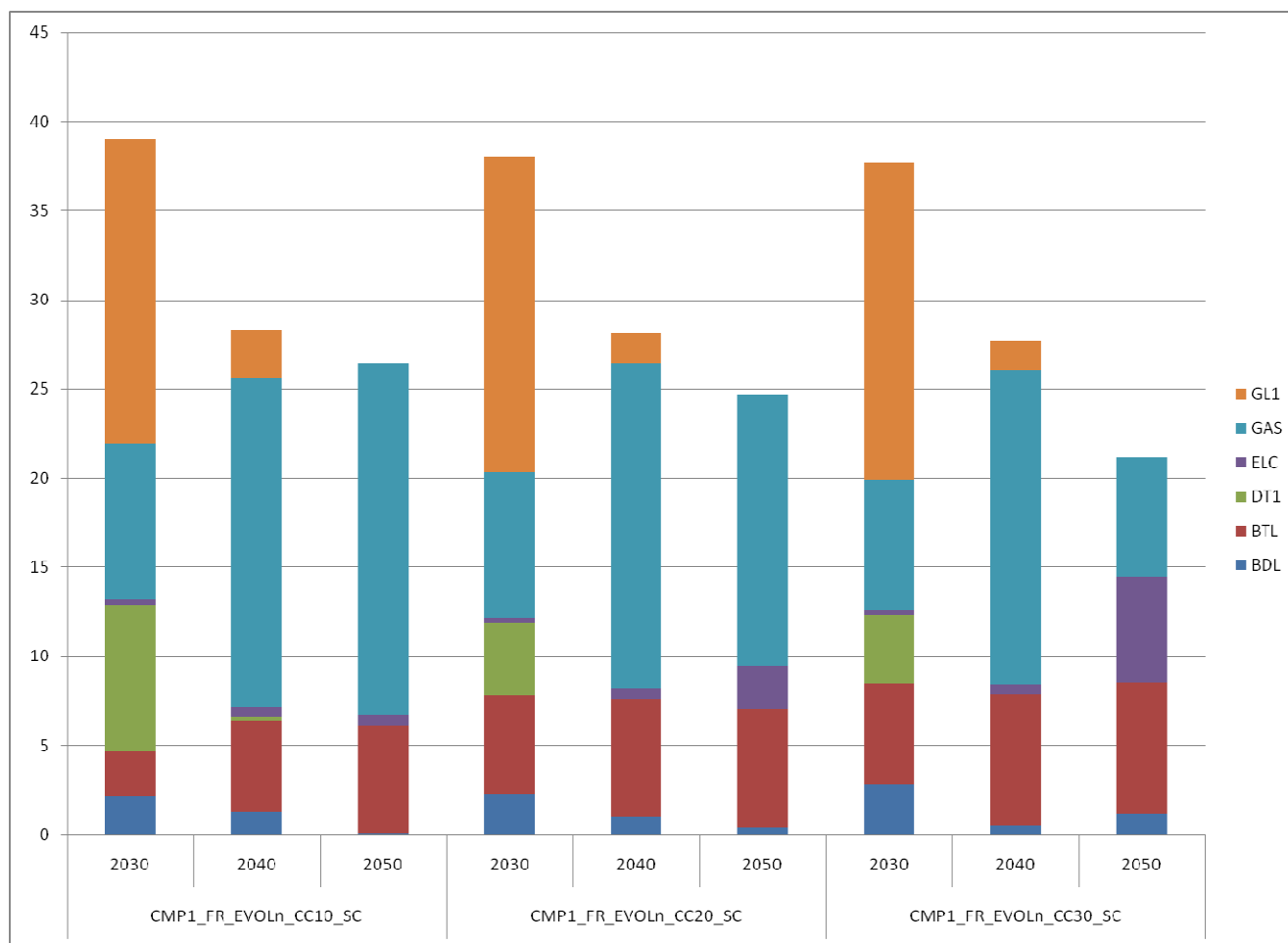


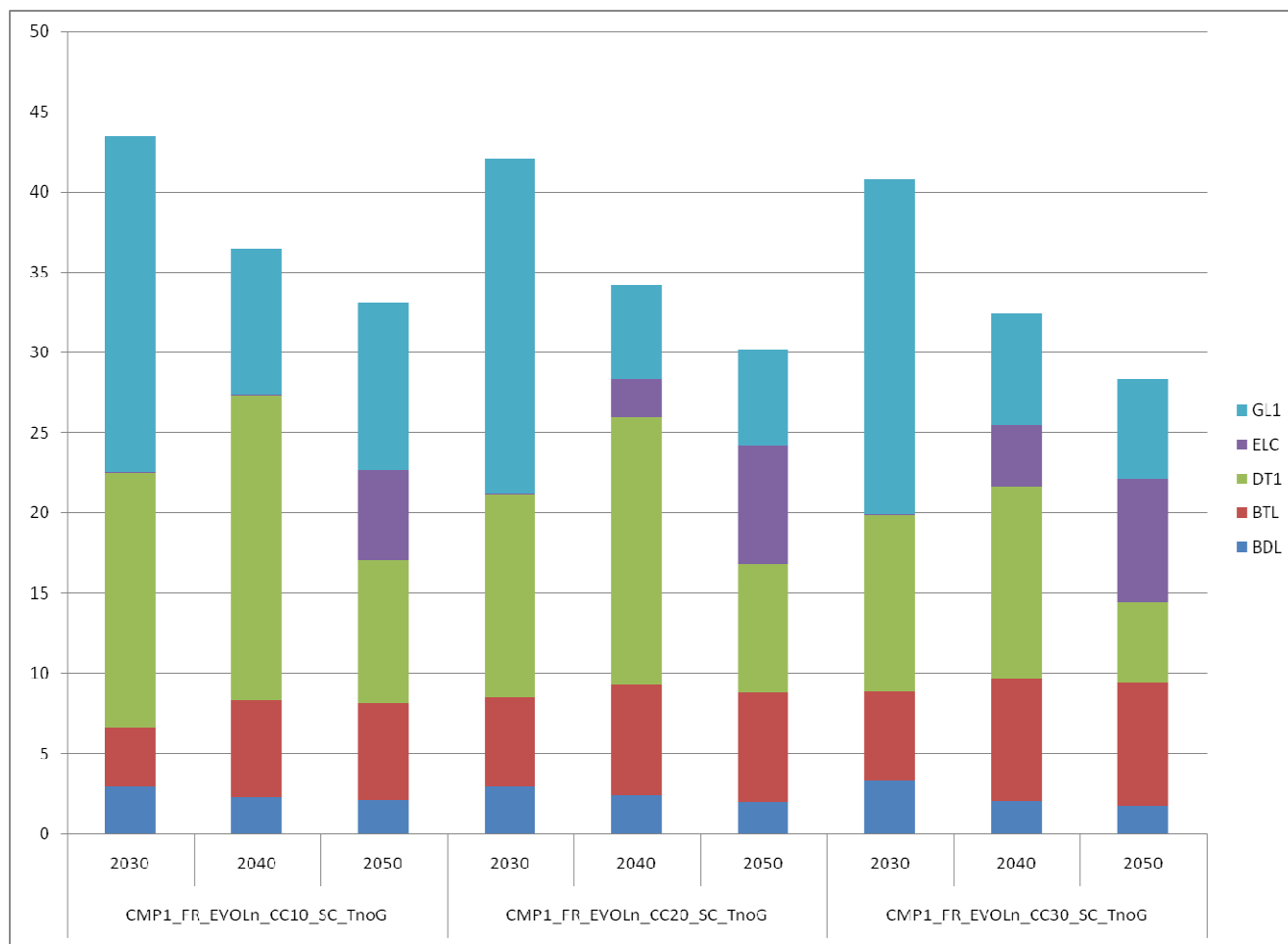


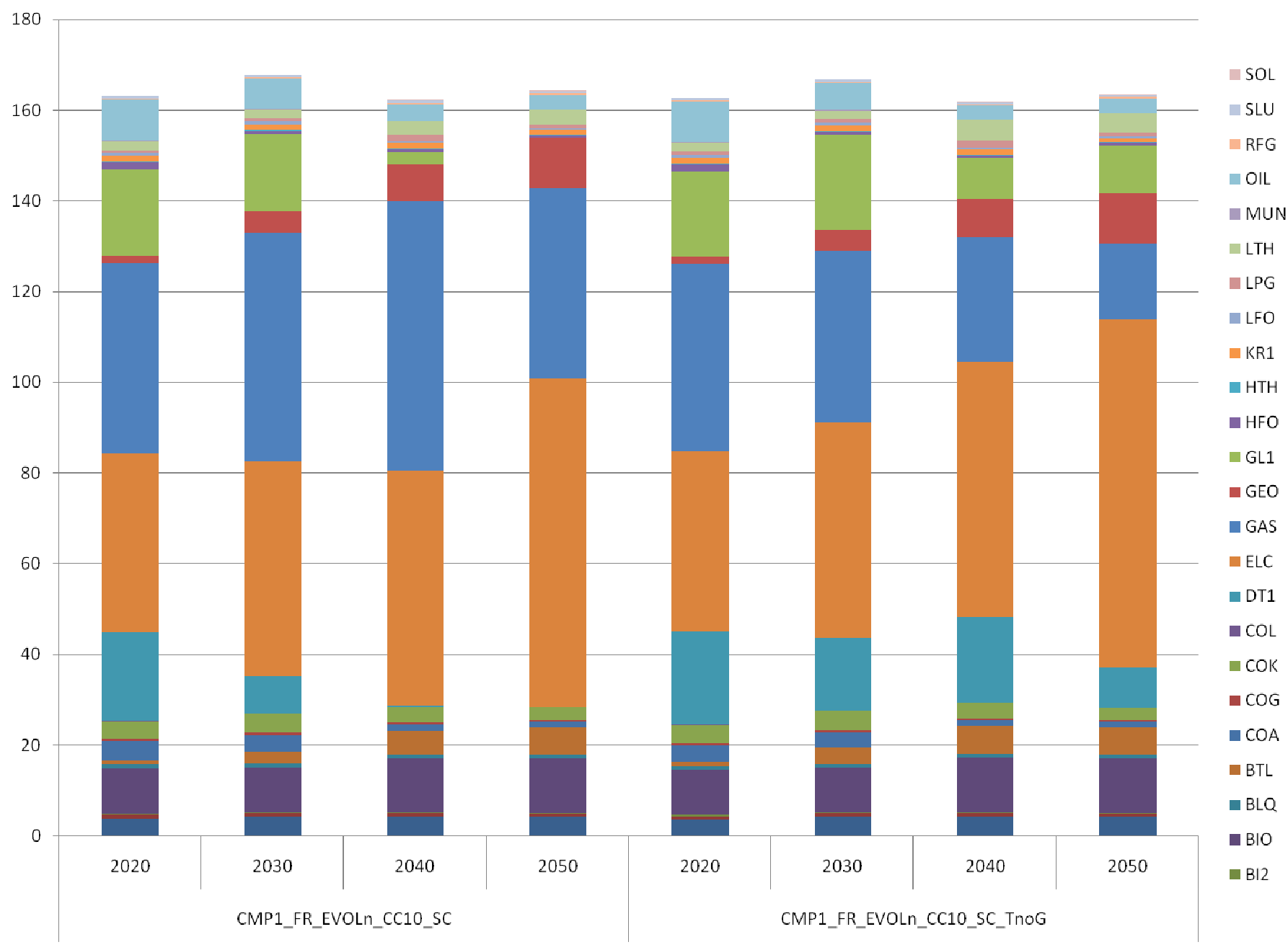


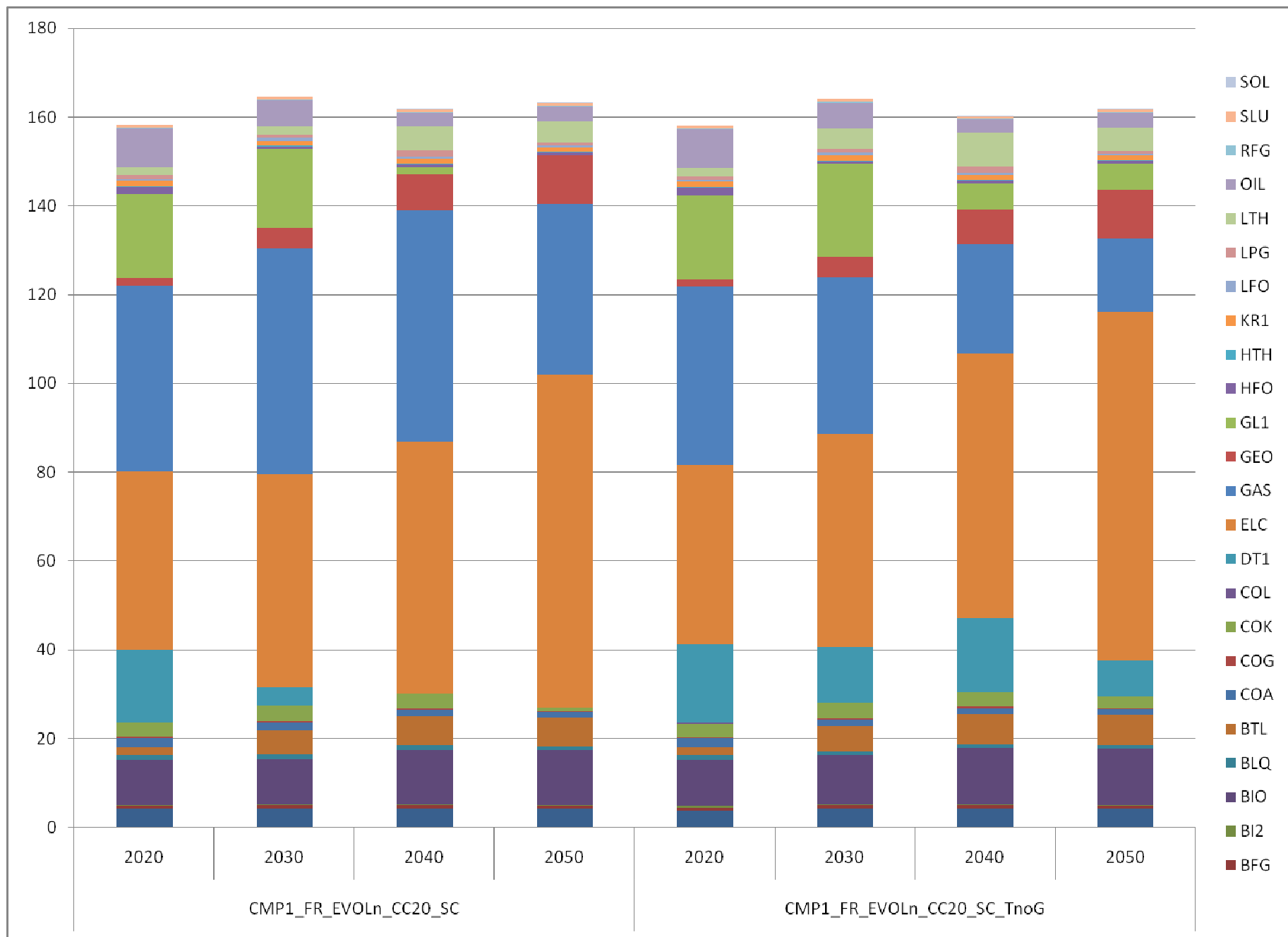
# CO2 emissions reduction

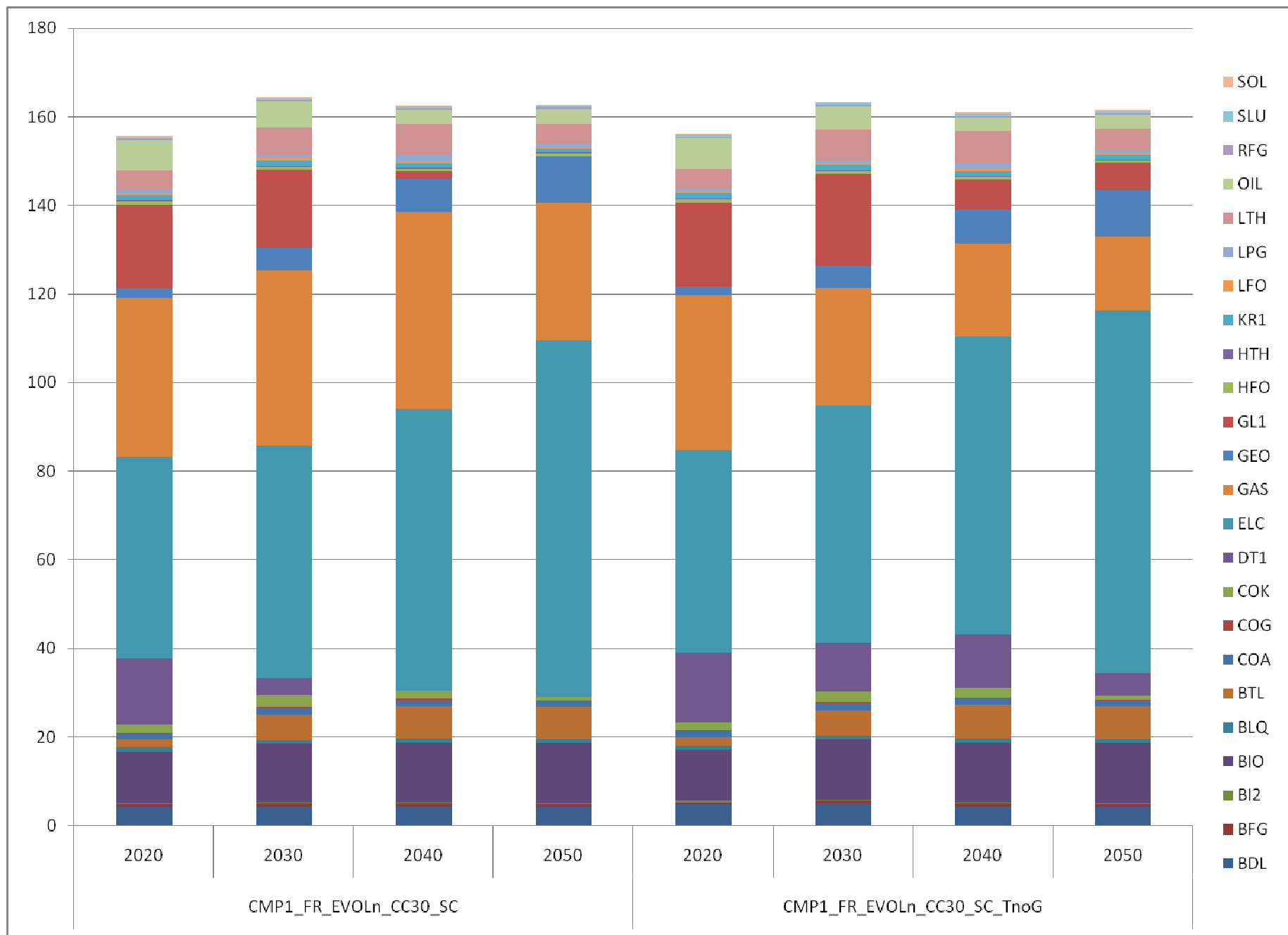


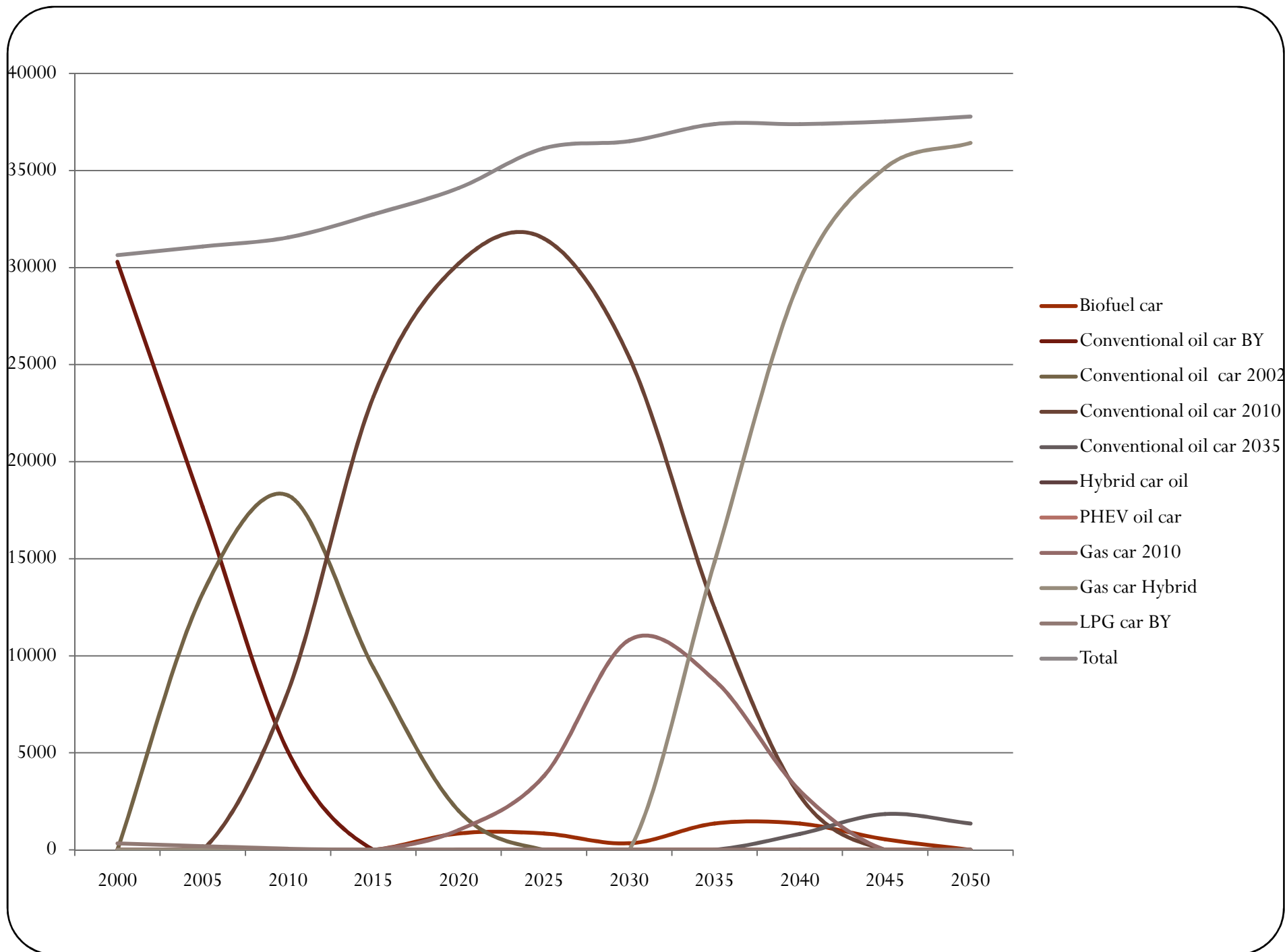




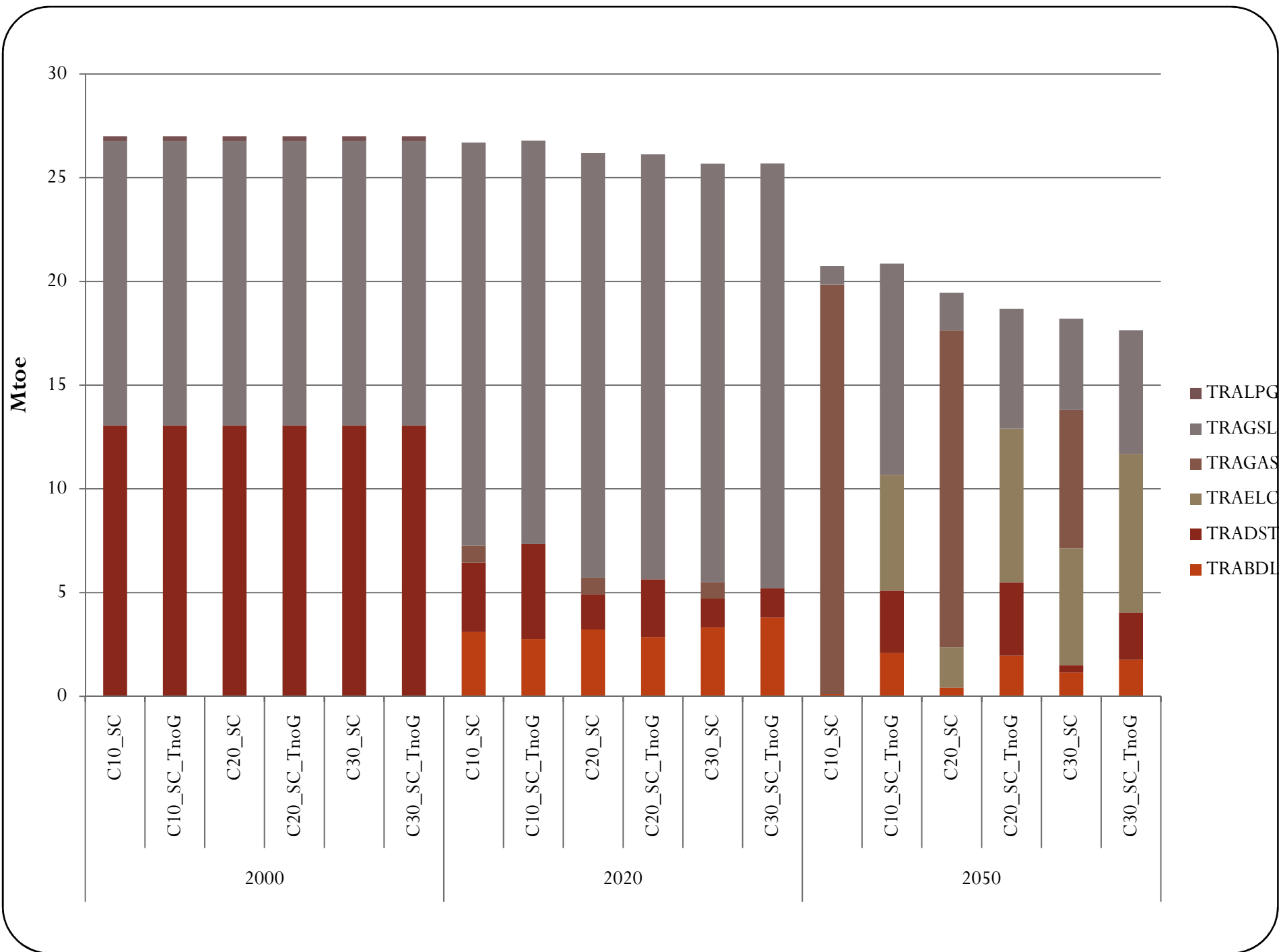




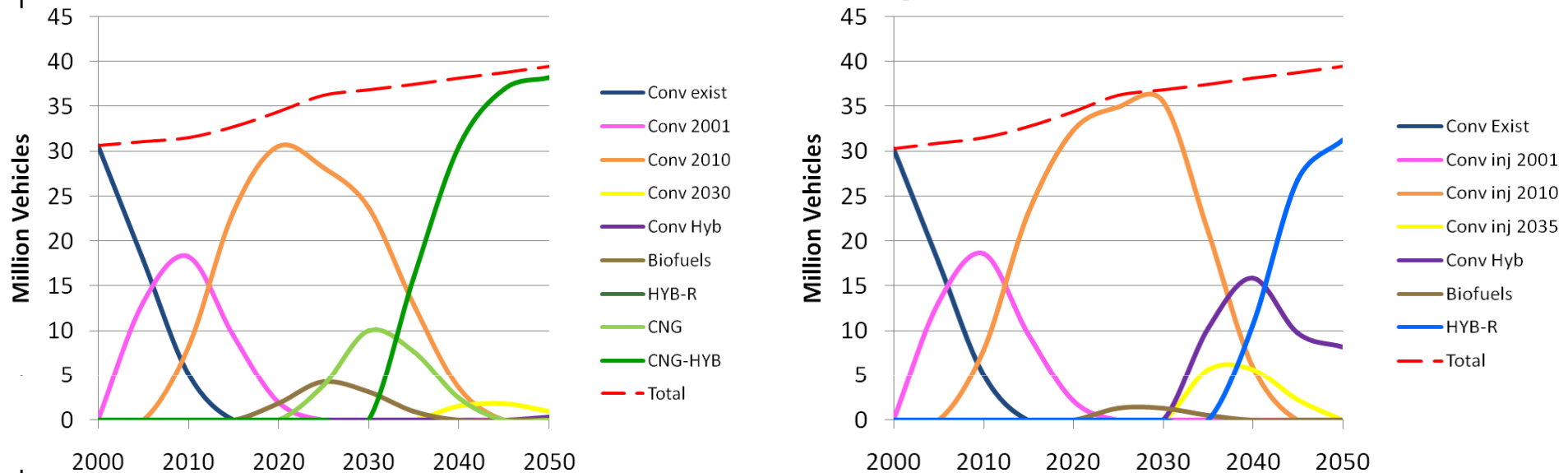








## Evolution of Private Vehicles fleet with/without gas propulsion over the modeling horizon



until 2020, conventional injection motorisation technologies are the preferred technologies;  
between 2020 and 2030 the tighter carbon constraints induces a shift to gas powered vehicles  
to conventional hybrid;

from 2030 on, the trend confirms previous technological choices;  
from gas to hybrid gas, and from hybrids to plug-in hybrids;

pure biofuel vehicles remain marginal (they appear and disappear over a vehicle life time);  
without support, pure electric vehicles are not selected.

# conclusion

in order to achieve sustainable mobility, our quantitative results highlighted:

- appropriate substitutions between energy sources (and sectors)
- the quick apparition of pure Biofuel (or non hybrid natural gas vehicle) only used as a transition in the French market, may reflect either a world-wide diffusion of the technologies with regard to local conditions, or the high pressure of the environmental constraint and the lack of mature alternative carbon-free technologies at that period. Selected road-maps through enforced R&D and investments could also enable a direct shift from conventional vehicles towards the more promising ones.

The history of innovations of course reminds us that good strategies, diffusion channels and distribution infrastructures are equally important for a commercial success. Yet technical-economic assessments as proposed here provide a valuable first step in order to validate technological landscapes in a prospective vision.