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Global Energy Scenarios 2050 of the World Energy Council

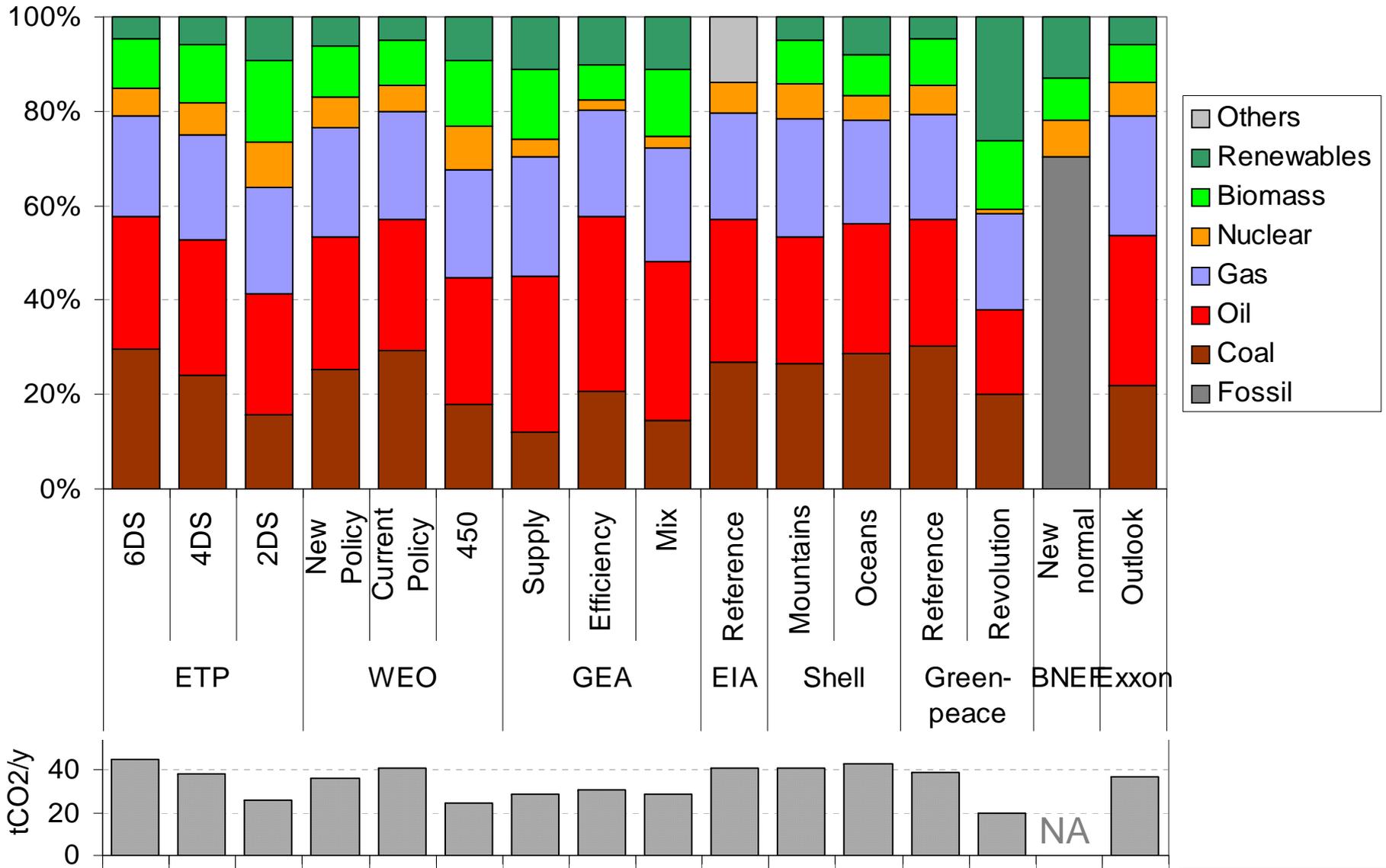
IEW 2013, Paris

- Why another global energy-system scenario-study?
- Regional disaggregation of the PSI/WEC model
- Model structure, scenario assumptions, and results focusing on **transport sector sub-model**

[PSI/WEC Global Mobility 2050]

→ Global results of **whole energy system** are launched at World Energy Congress in Daegu, South Korea, Oct. 2013

Total Primary Energy Supply, year 2030

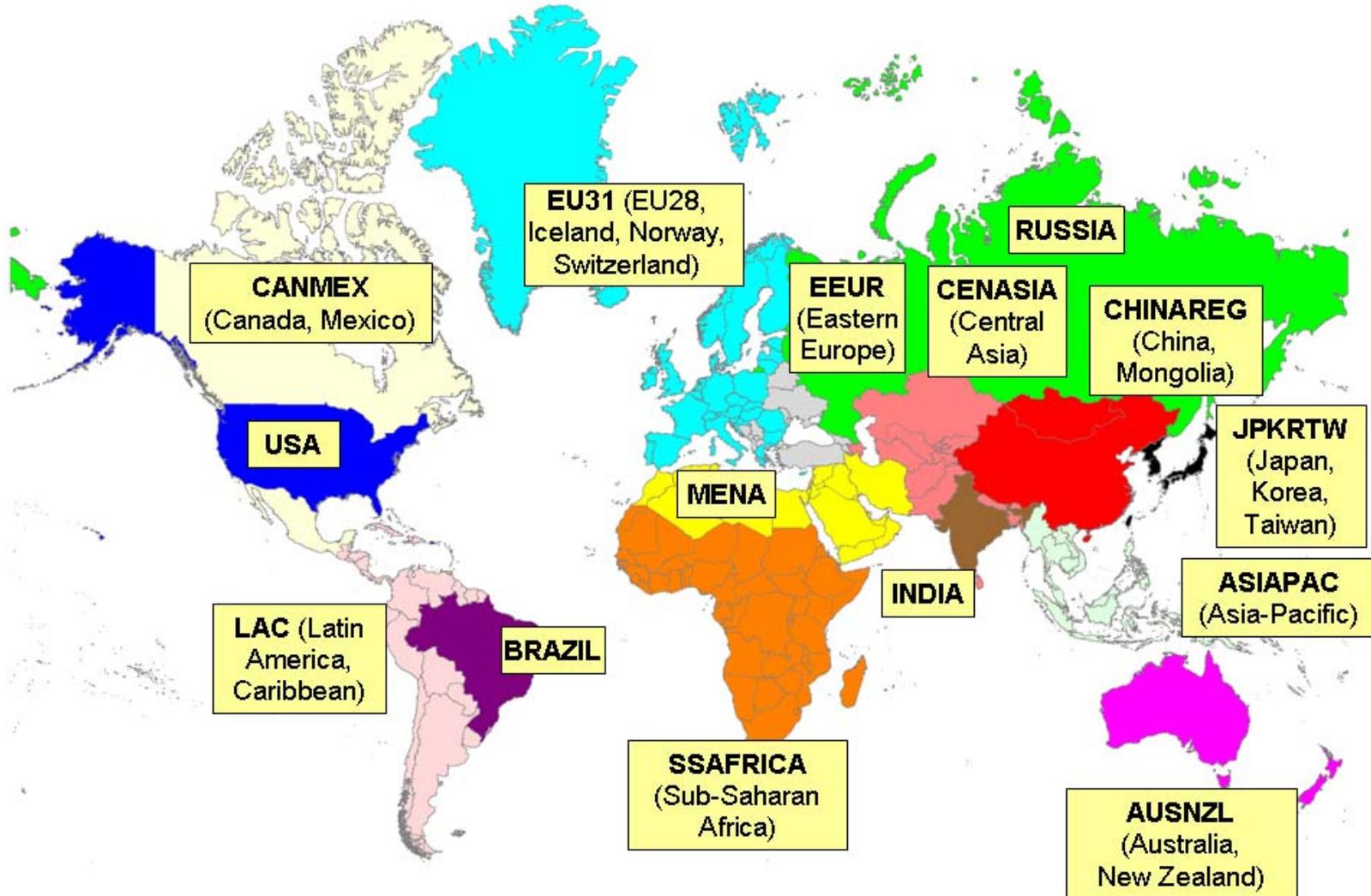


- Broad view of academics and of **practitioners**; hands-on experience by: **Siemens, Tokyo Gas, Eletrobras, Petrobras, EdF, GDF Suez, Saudi Aramco, RWE, Eskom** etc.
- **Coherent scenario storylines** of **social, political** and **economical** drivers (developed in regional workshops over the last 2 years) addressing emerging energy issues:
 - **Shale gas**: 32% of global gas resources [EIA 2013]
 - **PV uptake**: 2008 → 2010 → 2012: 15 → 38 → 97 GW [IEA, PVPS 2012]
 - **CCS vs. renewables**: CSS cost-effective at 50\$/tCO₂? [IEA; PSI]
 - **Nuclear (after Fukushima)**: capacity extension in USA, Europe, Japan ?
 - **Poverty, Access**: 20% of people have no electricity [WEO 2011]
 - **Efficiency**: in primary energy –or– conversion –or– consumption ?

Approach:

- **2 scenarios** (not a sensitivity analysis by varying a single parameter of the energy system)
- **Energy system model GMM (Global Multi-regional MARKAL)** [Gül 2007; Densing&Turton 2012]
 - **Cost-optimization** of the energy system; **bottom-up model** with a detailed representation of resources, technologies, energy flows, and technological change
 - **Non-cost** and behavioural assumptions are modelled with side-constraints
 - **Optional: Endogenous technology learning** [Barreto 2001]

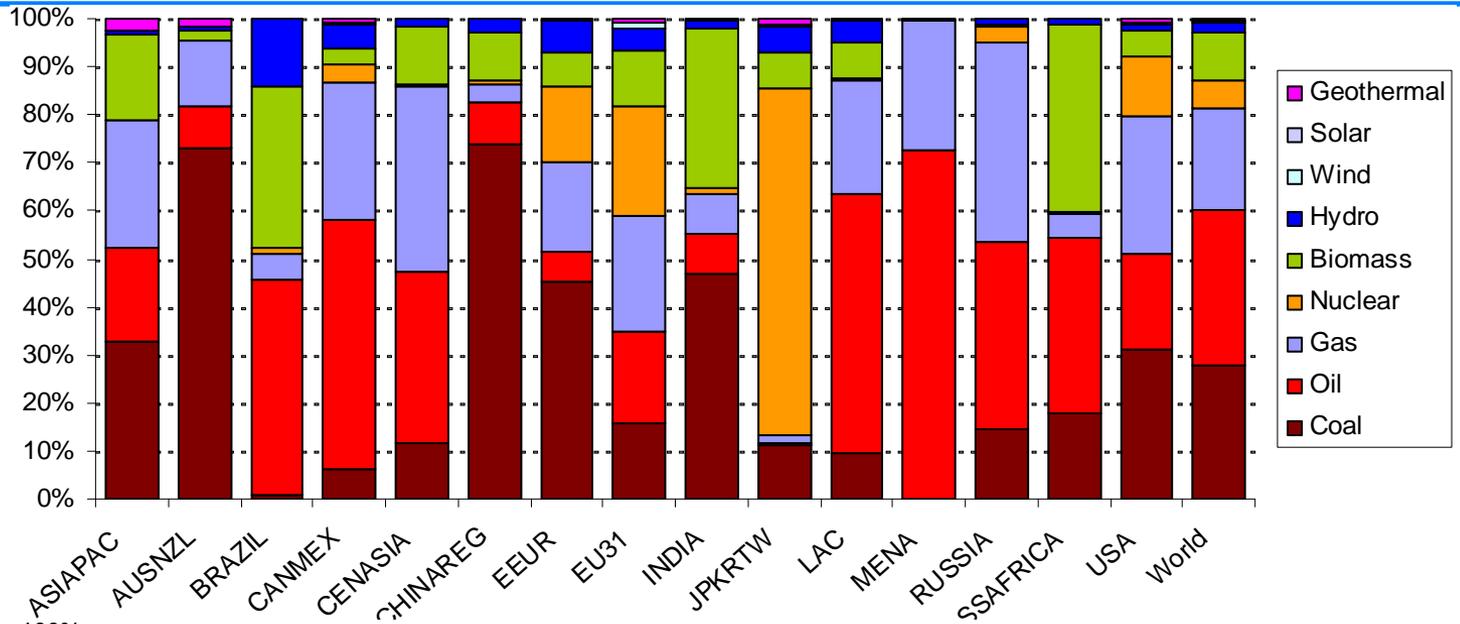
Regional partition: 15 Regions (final version)



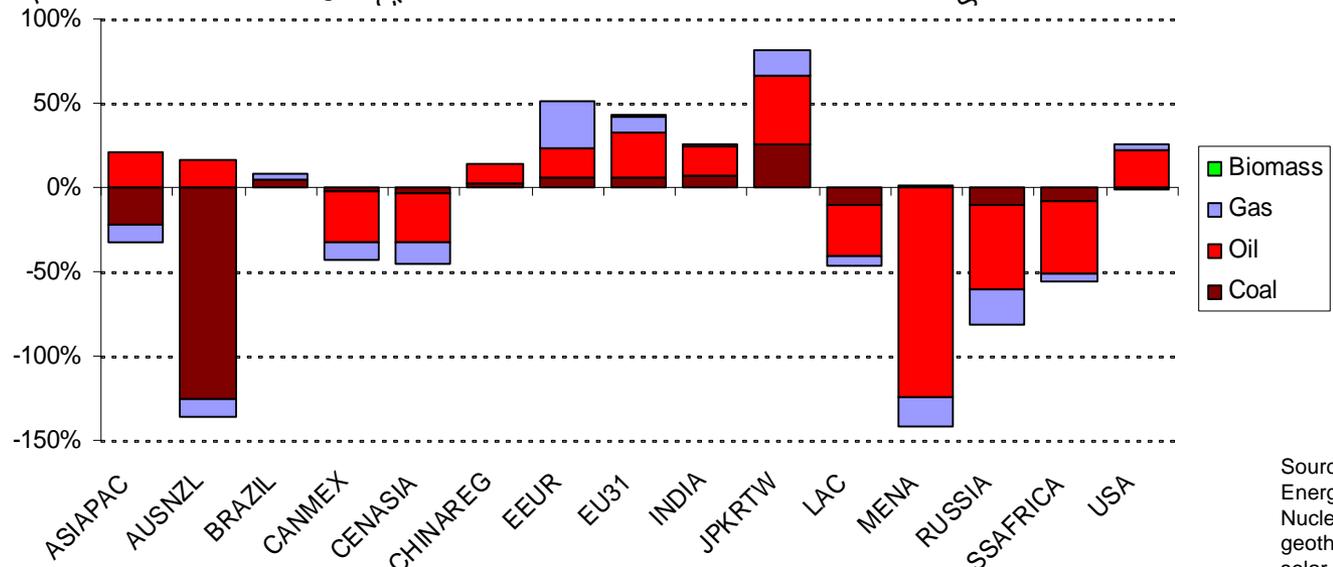
Why a regional model? →

Regional partition: Diversity of TPES and of trade

Domestic production of primary energy (year 2010)



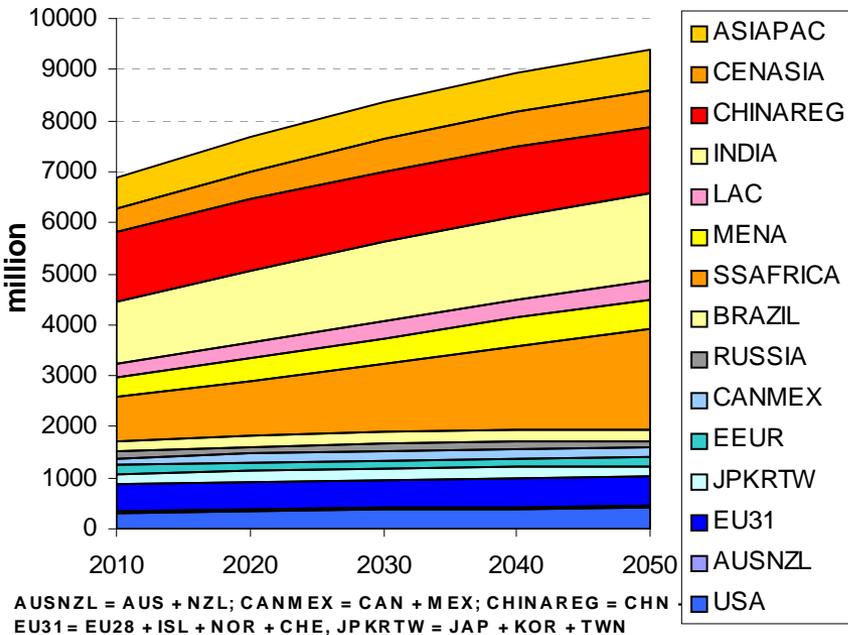
Net import (% of total primary energy supply)



BRAZIL: Bio -0.4%, Oil: 0.1%; CHINAREG: Gas 0.5%; INDIA: Gas 1.5%; LAC: Bio -0.4%; EU31: Bio: 0.3%

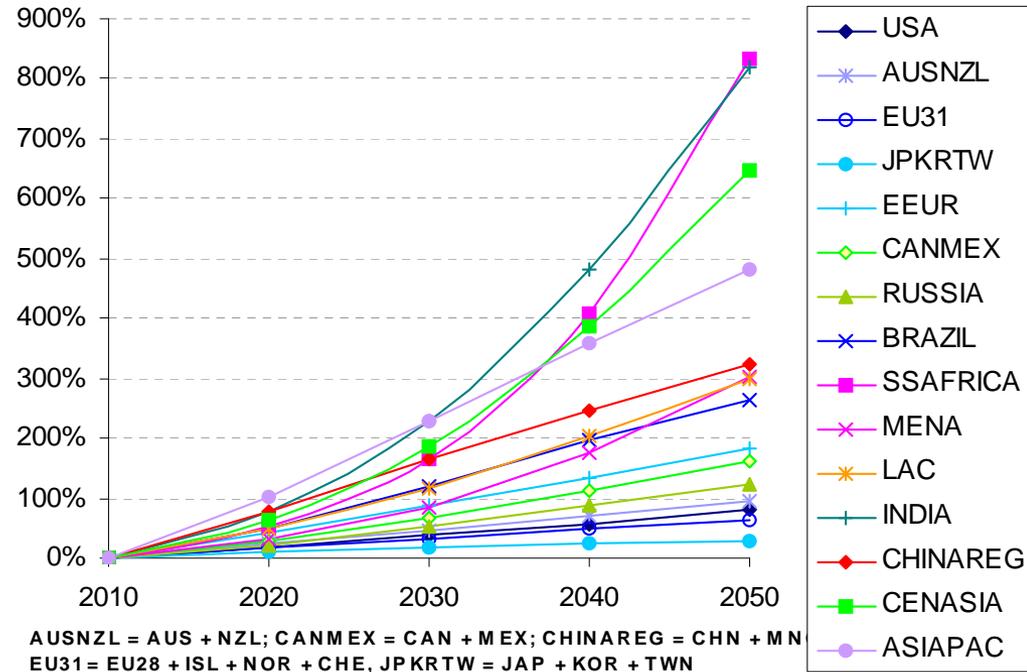
Source: IEA (2012), Energy Balances. Nuclear effi. 33%; geothermal effi. = 10%; solar, hydro and wind: actual production.

Population (Tollway Scenario)



AUSNZL = AUS + NZL; CANMEX = CAN + MEX; CHINAREG = CHN
EU31 = EU28 + ISL + NOR + CHE, JPKRTW = JAP + KOR + TWN

GDP growth rel. to year 2010 (Tollway Scenario)

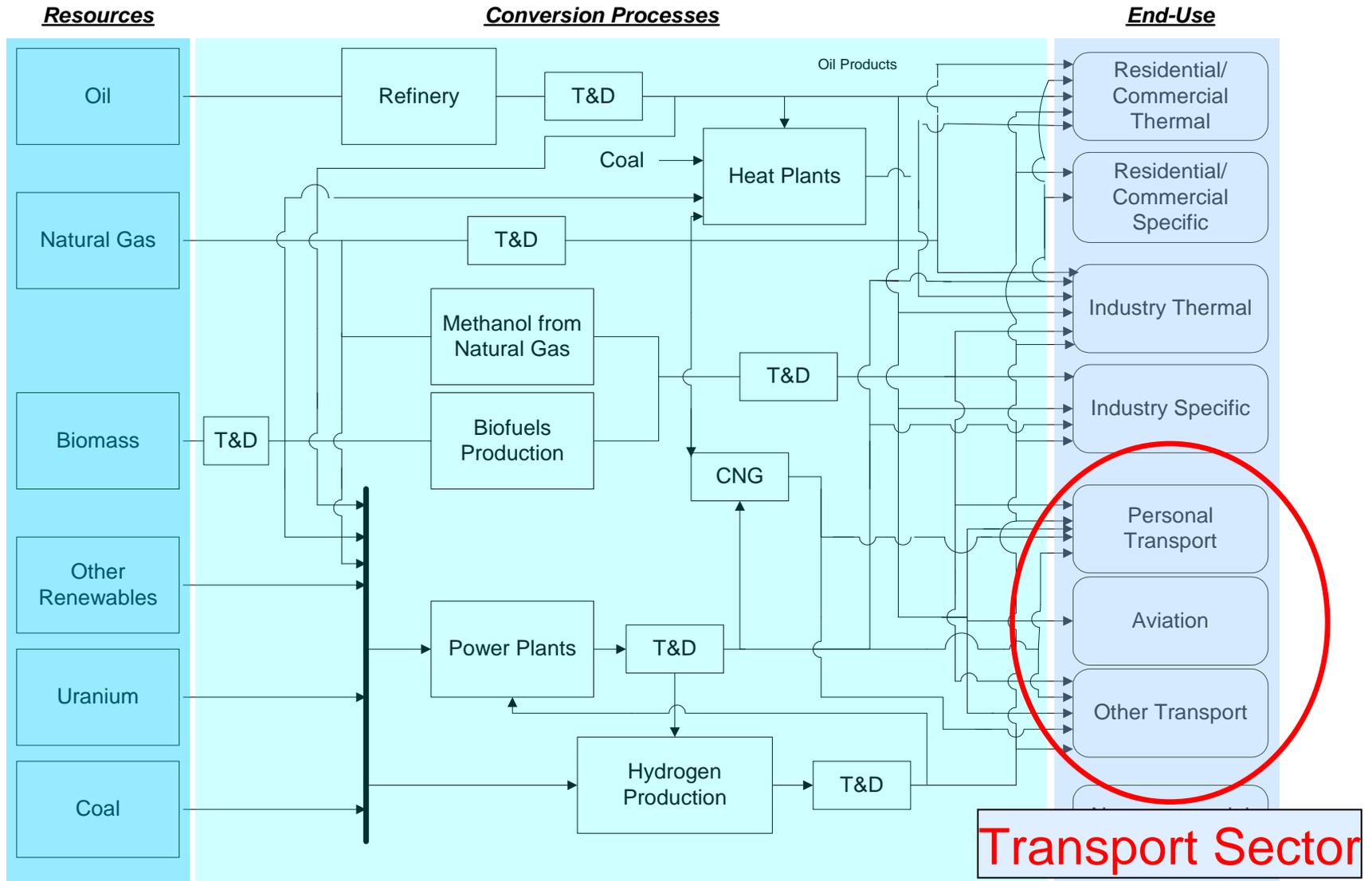


AUSNZL = AUS + NZL; CANMEX = CAN + MEX; CHINAREG = CHN + MN
EU31 = EU28 + ISL + NOR + CHE, JPKRTW = JAP + KOR + TWN

Source of year 2010: IMF 2012, UNDP

- Reference projections based on IPCC-SRES B2-scenario ("middle-of-the-road", "dynamics-as usual")
- 66% of world GDP (MER) in
 - year 2010: EU + USA + China + Japan,
 - year 2050 (reference): EU + USA + China + **India** + **Brazil** + Japan + **Indonesia**.
- traditional partitions by OECD and non-OECD countries no longer adequate, but difference in income between developed and some developing regions may persist

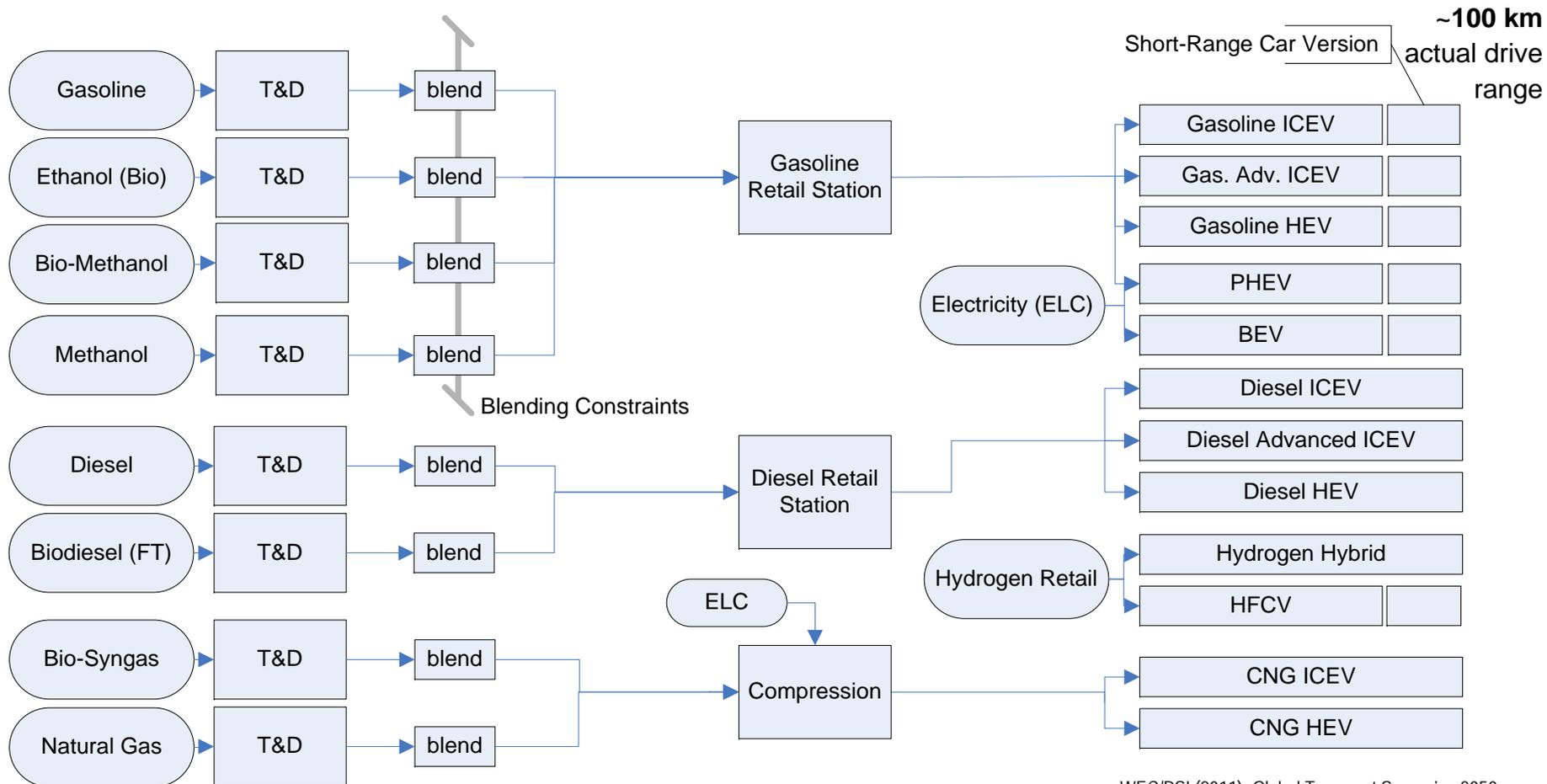
Reference Energy System (Flow of Energy Carriers)



GMM has approx. 400 technologies per region

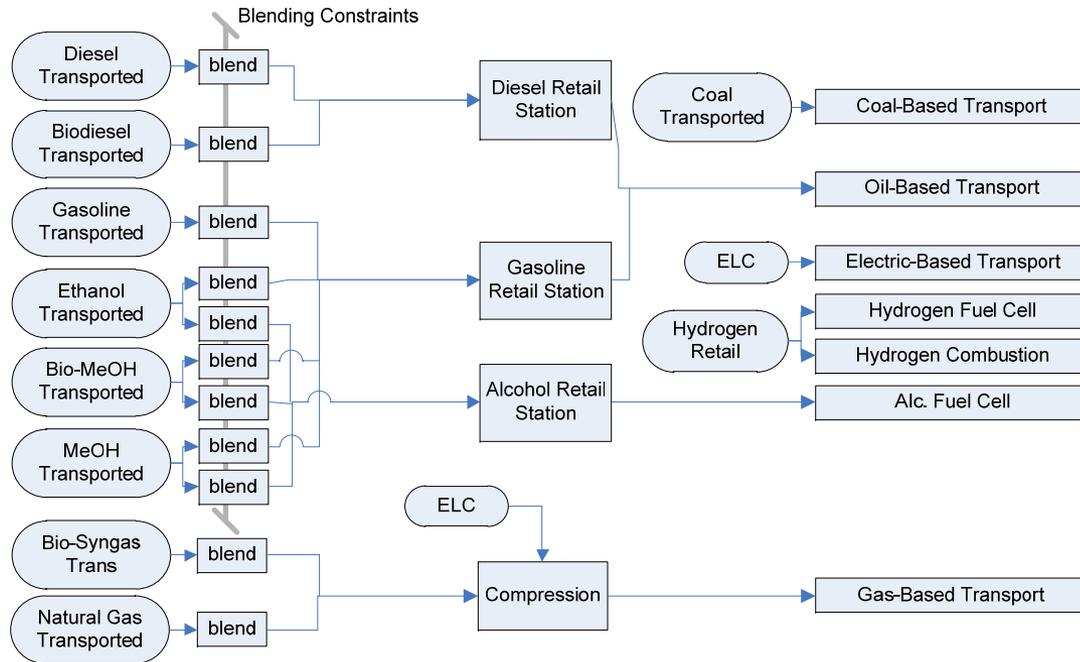
T&D: Transport and Distribution

- **Drivetrains:** Internal Combustion Engine Vehicle (ICEV), Advanced ICEV, Hybrid Electric (HEV), Plug-in (PHEV), Battery Electric (BEV), Hydrogen Fuel Cell with hybridisation (HFCV)
- **Fuels:** conventional liquid (gasoline, diesel); alternatives fuels: natural gas, electricity, hydrogen, different biofuels; fuel blending (e.g. maximal 10% (Bio-)Methanol into gasoline)



- Trucks, buses, other commercial road vehicles, 2-wheel, rail, ships: aggregated by fuel option
- Aviation: current + future technology

Other Surface Transport Sector



technologies categorized by

- fuelling option, and
- engine type

Aviation Sector



Freeway:

- More market driven
- Large demand growth in all transport sectors
- CO₂ markets establish slowly
- Alternative fuels, technologies, and infrastructure are promoted only if cost-effective (in short term)
- Cost-effective efficiency measures
- Developing world is tending to developed world

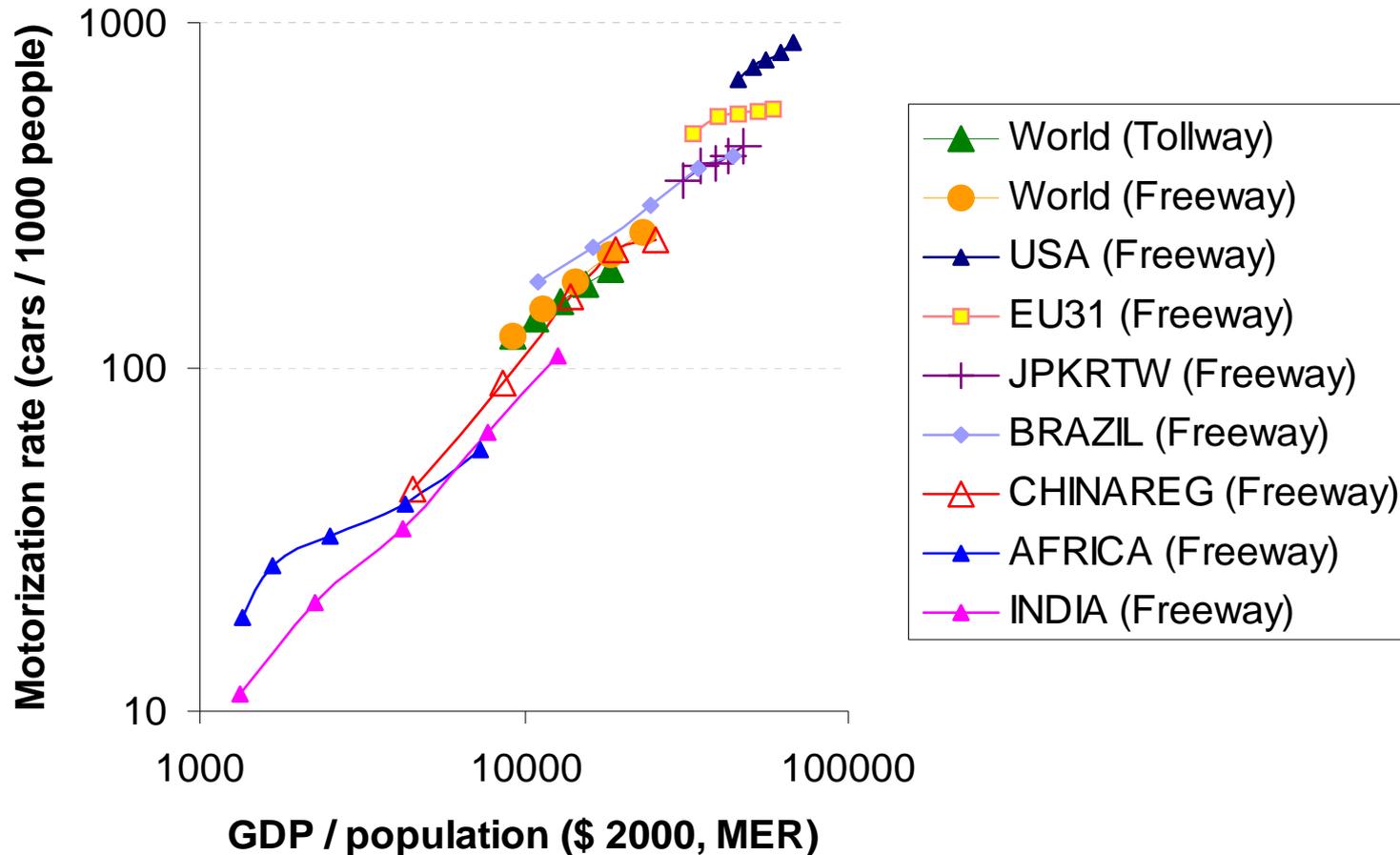
Tollway:

- More policy driven (e.g. by energy security)
- Moderate demand growth in car transport; other sectors with considerable growth (depends on regions)
- CO₂ tax increases (lagging in developing regions); promotion of renewables
- Alternative fuels are promoted (2nd gen biofuels)
- Promotion of BEV & HFCV in EU, Japan, USA
- Mandated efficiency measures
- Developed world is tending to developing world

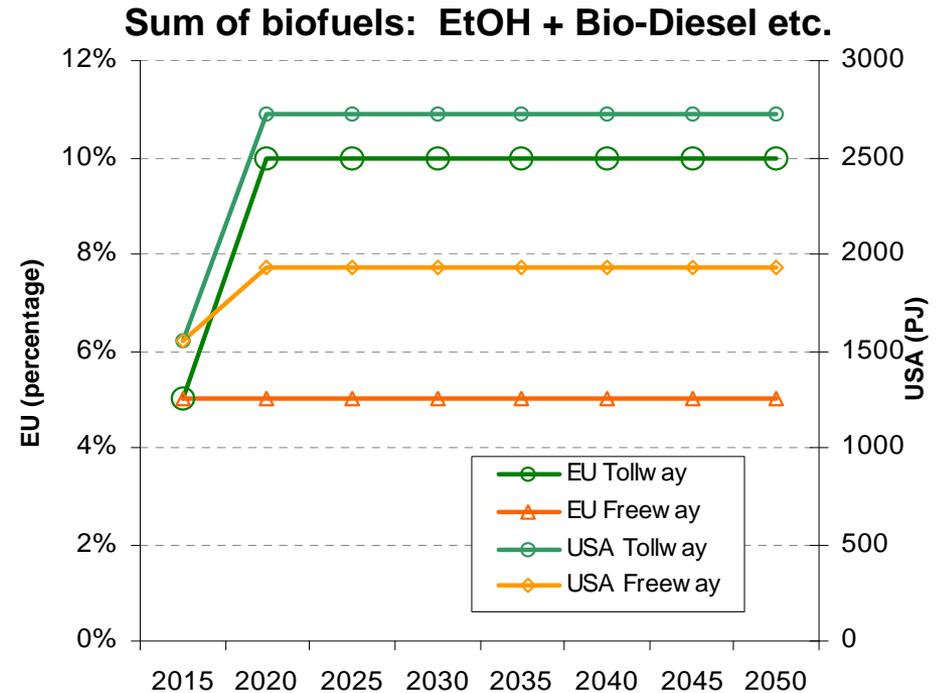
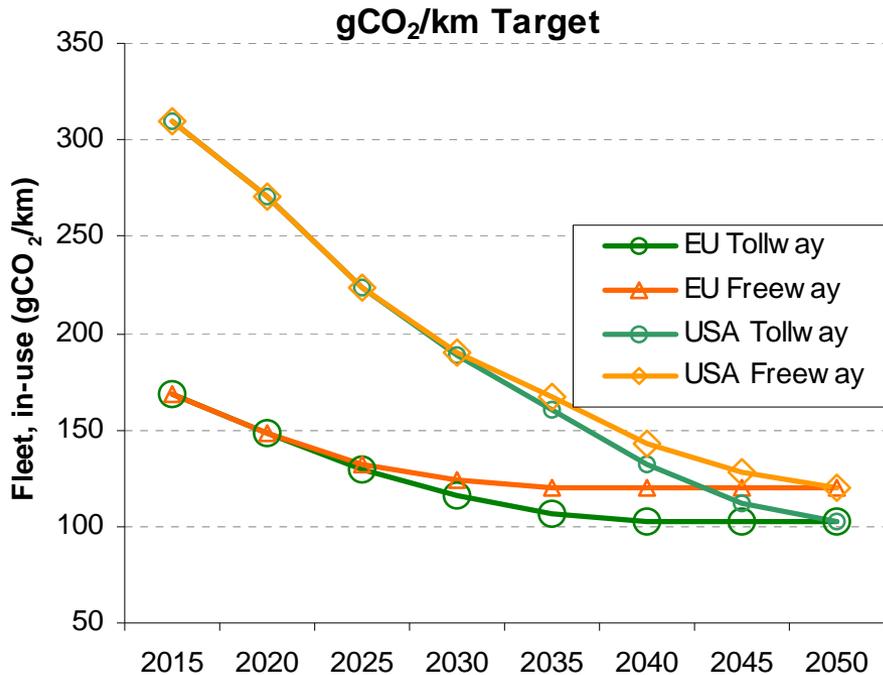
Country	Income growth	Population growth
Africa, Asia, Brazil, China, India, LAM, MENA, Mexico	Freeway > B2, IMF, WB Tollway ≈ B2, IMF, WB	Freeway < UNDP Tollway ≈ UNDP
Canada, Europe, FSU, OECD Pacific, Russia, USA	Freeway ≈ B2, IMF, WB Tollway < B2, IMF, WB	Freeway ≈ UNDP Tollway > UNDP

B2: IPCC-SPRES B2,
WB: World Bank;
UNDP: median

- Passenger car demand = motorization rate \times population \times km-driven/car/y



- Other surface demand: 45% (50%) of GDP growth rate
- Aviation demand: 85% (100%) of GDP growth rate



- **EU:** Directive 443/2009, European standard for new passenger cars (130g/km in 2015+, 120g/km with other contribution)
- **USA:** Energy Independence and Security Act 2007 (e.g., 35mpg in 2020+)
- **In-use emissions** = + 17% of full target (based on car sample average) → fleet-average

- **EU:** Directive 2009/28/EC
- **USA:** Energy Independence and Security Act (EISA): Renewable Fuels Standard (RFS)
- etc.

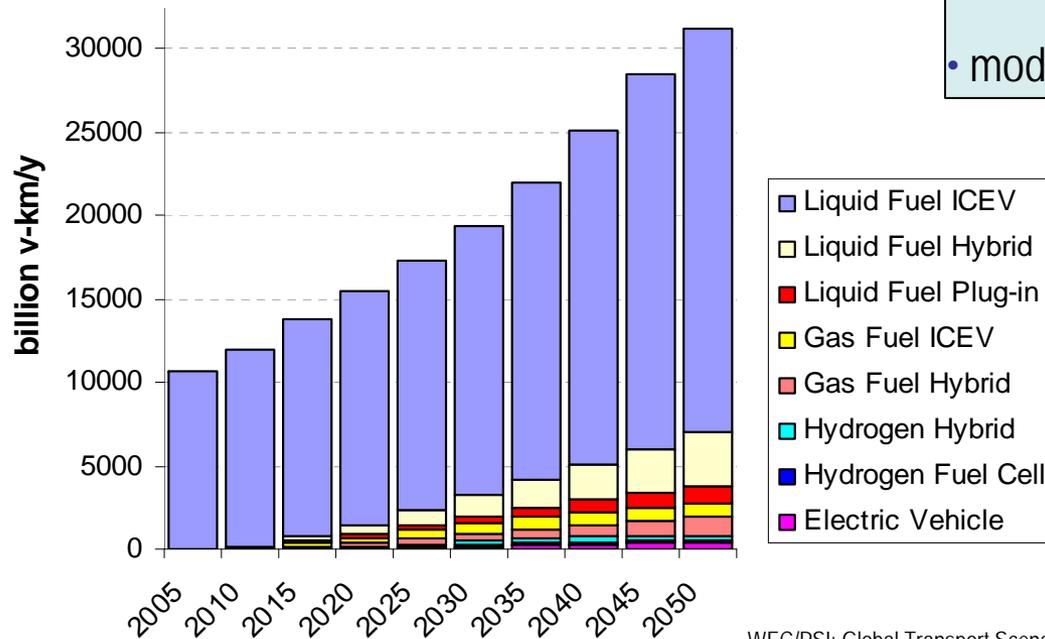
Fuel	Reference	Tollway assumptions	Freeway assumptions	regional adjustments
Biofuels (Bio-Diesel, EtOH, MeOH, Syngas)	EIA	↓ ↓ ↓ (short / mid / long-term)	↓ - ..	↓ AFRICA, BRAZIL, LAM, ASIA
Diesel	EIA	↑ - ↓	↓ ↑ ↑	↓ MENA
Gasoline	EIA			↓ MENA
MeOH	IEA			↓ CHINA
H ₂	DoE	- ↓ ↓	↓ - -	
Coal	EIA	- - -	- - -	↓ CHINA, RUSSIA, FSU, USA, INDIA, ASIA, AFRICA
CNG	EIA	↑ ↑ -	- ↑ ↑	↓ MENA, RUSSIA, FSU
Electricity	EIA	↑ ↓ -	↓ - ↑	

Sources: Annual Energy Outlook (EIA, 2011); Clean Cities - Alternative Fuel Price Report (US DoE, 2011); IEA, Automotive Fuels for the Future (1999)

Freeway:

- Market driven (market power)
- Large demand growth in all transport sectors
- CO₂ price is very slowly developing
- Alternative fuels, technologies, and infrastructure are promoted only if they are short-term cost-effective

Freeway Personal Cars:

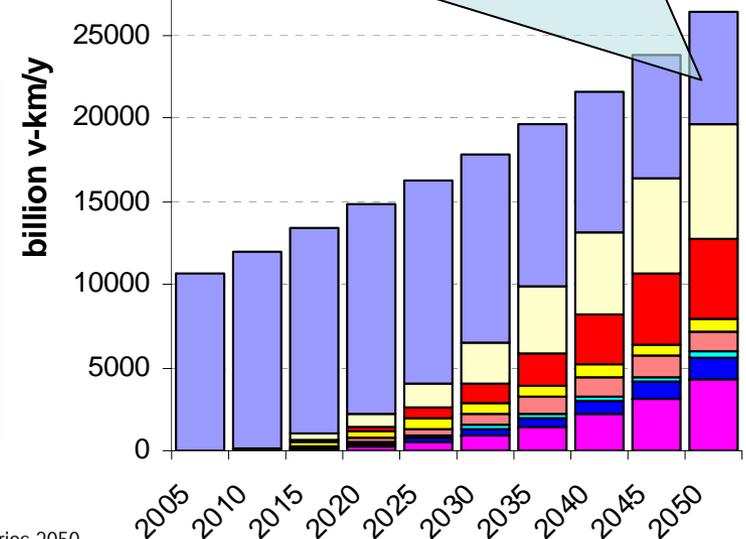


Tollway:

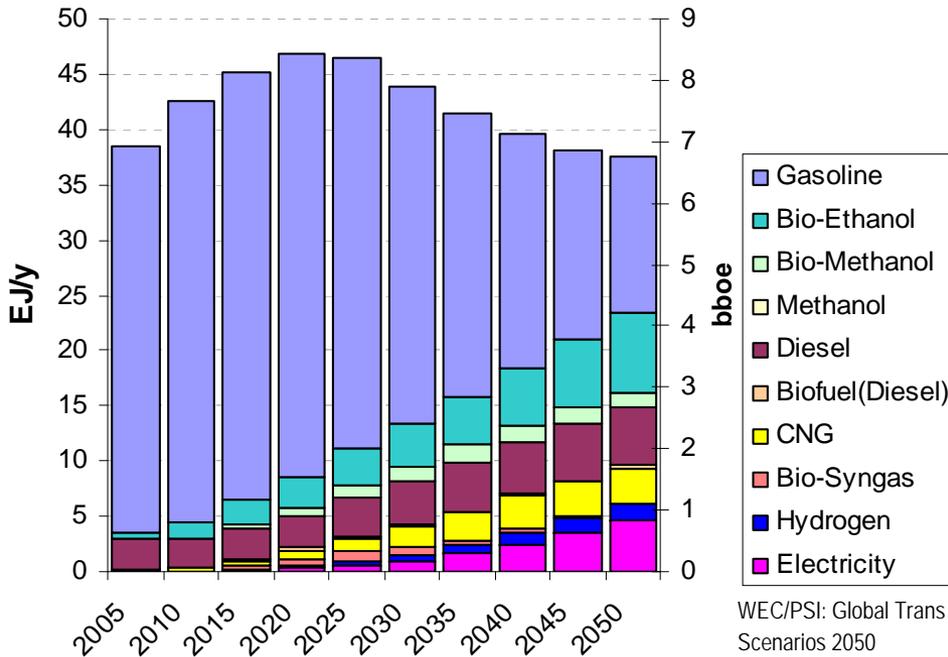
- More regulative power of citizen/voter
- Moderate demand growth in car transport; other sectors with considerable growth (depends on regions)
- CO₂ price increases (lagging in developing regions)
- Alternative fuels are promoted: 2nd generation biofuels (larger targets), lower-carbon electricity
- Promotion of BEV and HFCV in EU, Japan, and USA

Tollway Personal Cars:

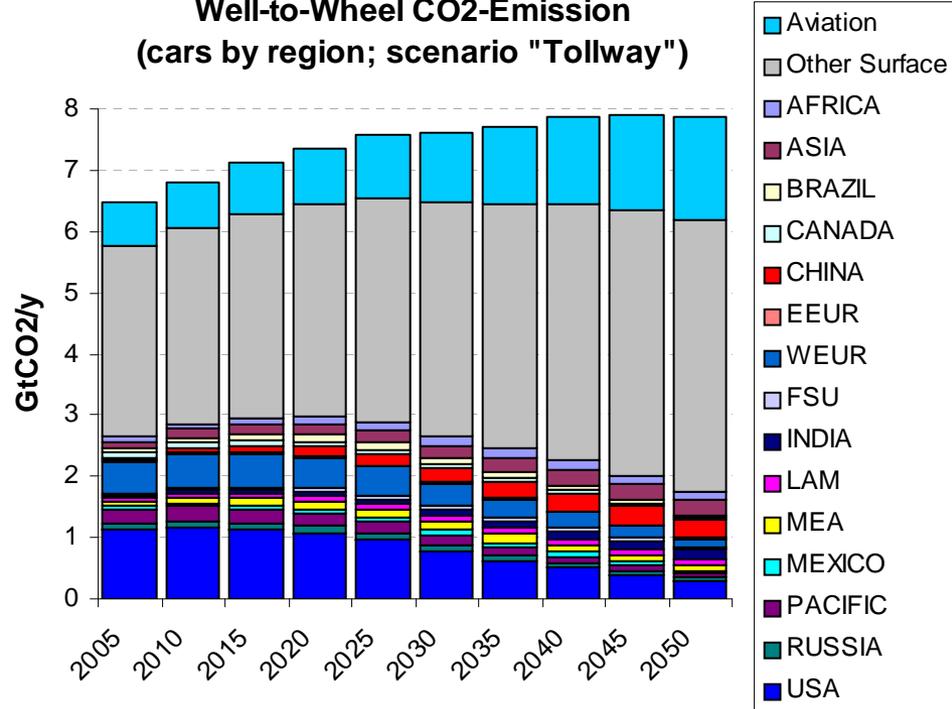
• large increase in hybridisation (electric motor) in different degrees: HEV → PHEV → BEV
 • moderate share of CNG and hydrogen FC vehicles



Fuels for Cars ("Tollway" Scenario)

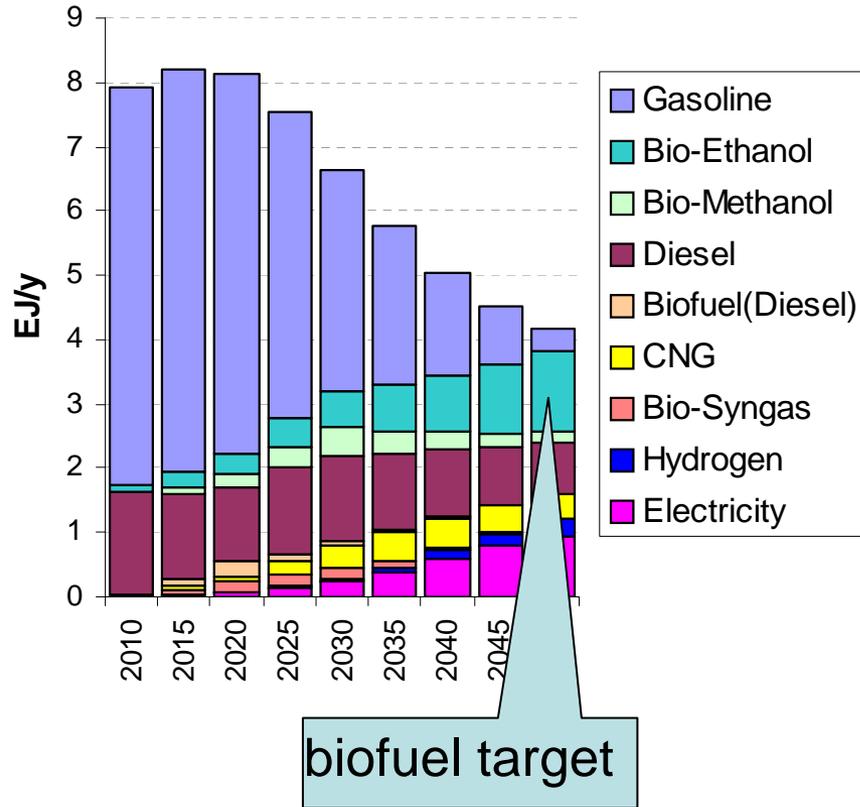


Well-to-Wheel CO₂-Emission
(cars by region; scenario "Tollway")

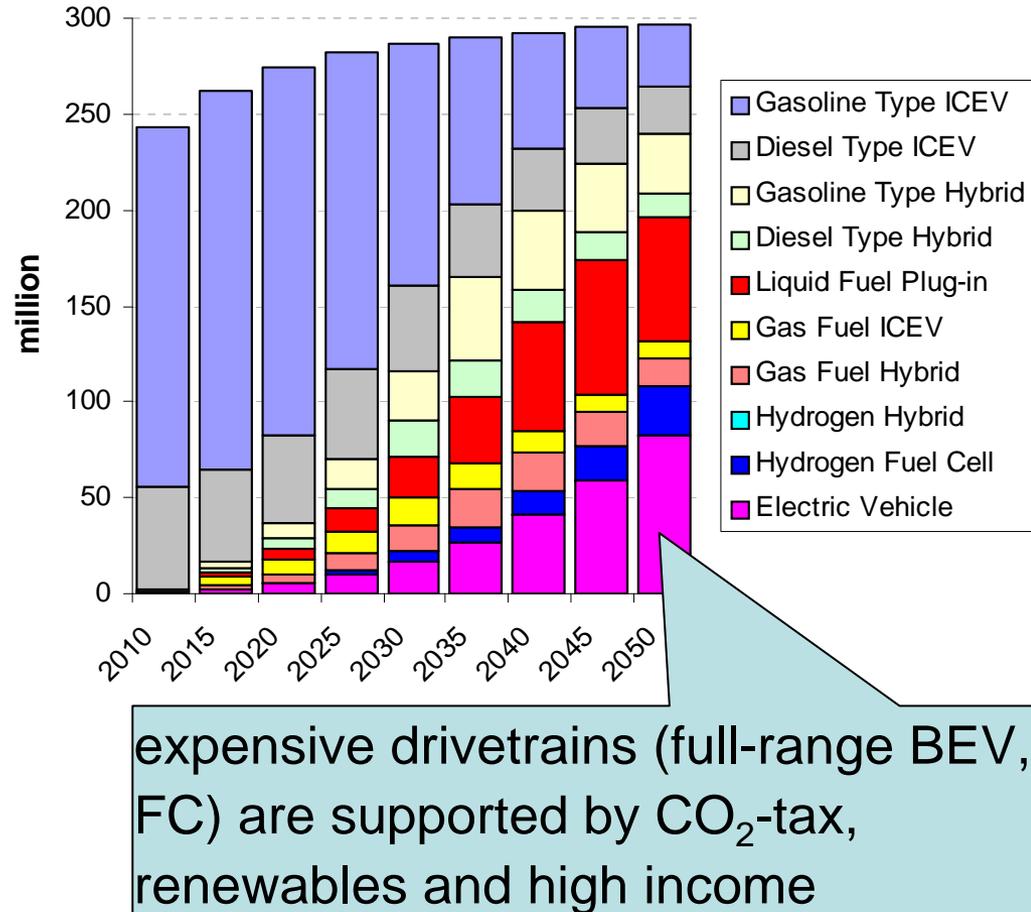


- Efficiency increase is cost-effective (hybridisation, electric motor, learning) → fuel demand decreases
- CNG is attractive (fossil gas is more abundant / less emissions than fossil oil)
- Biofuels (1st & 2nd generation) promoted by targets and by increasing fossil fuel costs
- Other surface & aviation: biofuels are not cost-effective, efficiency improvements limited → emissions increase
- Developing world: increase in car-emissions (due to large increase in demand) is partially offset by mid- and long-term efficiency improvements

Fuels for Cars, Region Western Europe

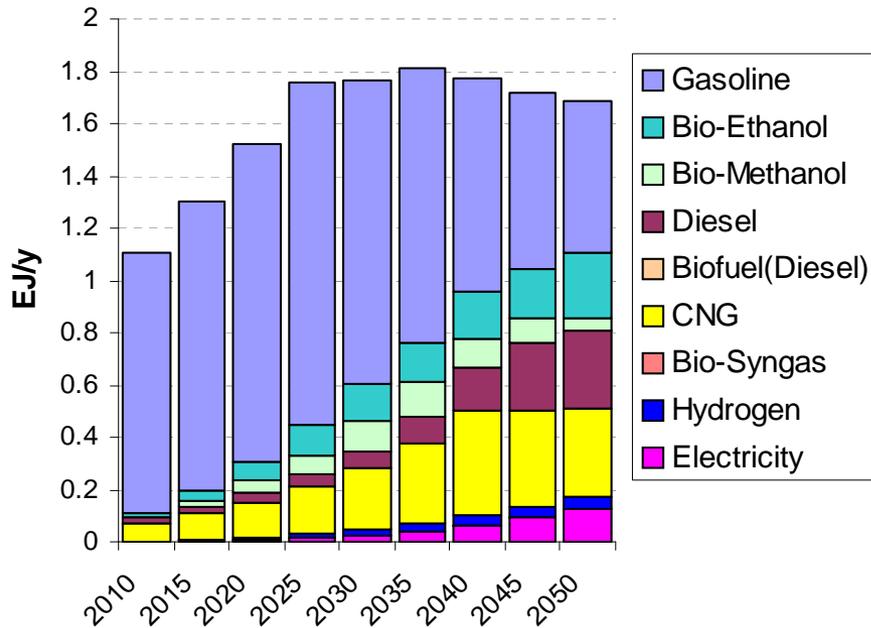


Technology Mix for Cars, Western Europe

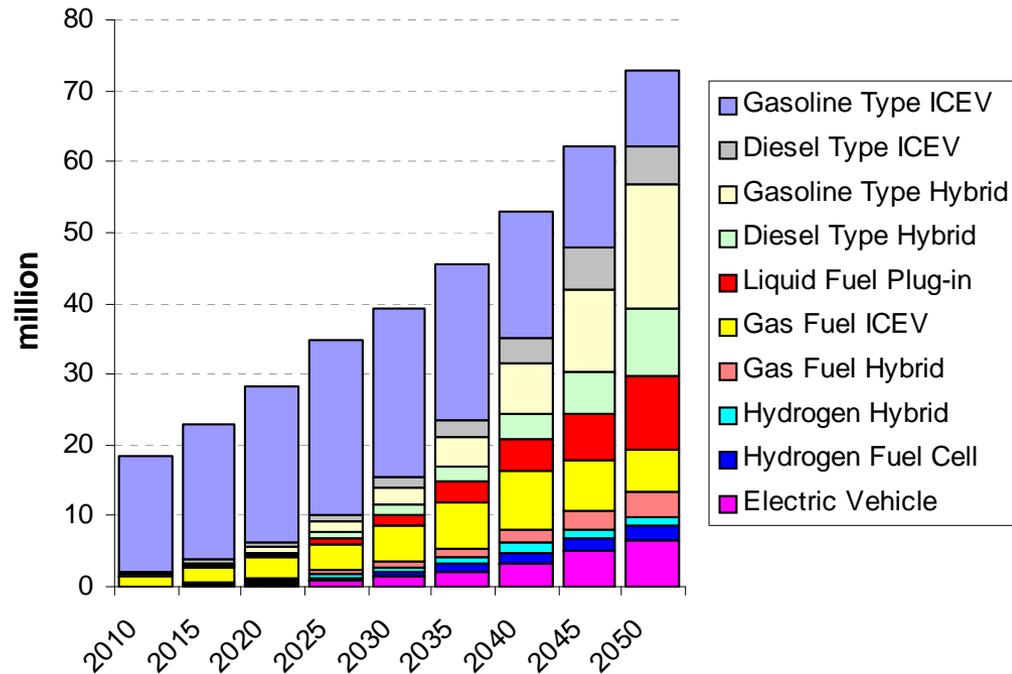


- Efficiency: 2.8 litre/100 km in year 2050 (gasoline equivalent, fleet, in-use)

Fuels for Cars, Region LAM



Technology Mix for Cars, Region LAM



- Energy Security → Gas

- Efficiency: 3.6 litre/100 km in year 2050 (gasoline equivalent, fleet, in-use)

- Demand growth especially in **aviation** and **personal cars in developing regions**
- **Gas in transport** is a cost-effective option: low CO₂-emissions, gas resources are still abundant
- Alternative drivetrains enter gradually: HEV → PHEV → BEV
- Commercial surface transport:
 - Existing engines are relatively efficient (e.g. only few start-stop cycles disfavour electric motors)
- Aviation: Biofuels, Synfuels?

Outlook:

- Launch of study for full energy system in Oct. 2013 in Daegu
- Model Extensions: LCA integration,...

