# Whither World Oil Demand:
## Emerging Market Growth and Alternatives to Oil

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Oil and the Macroeconomy in a Changing World
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9 June 2010

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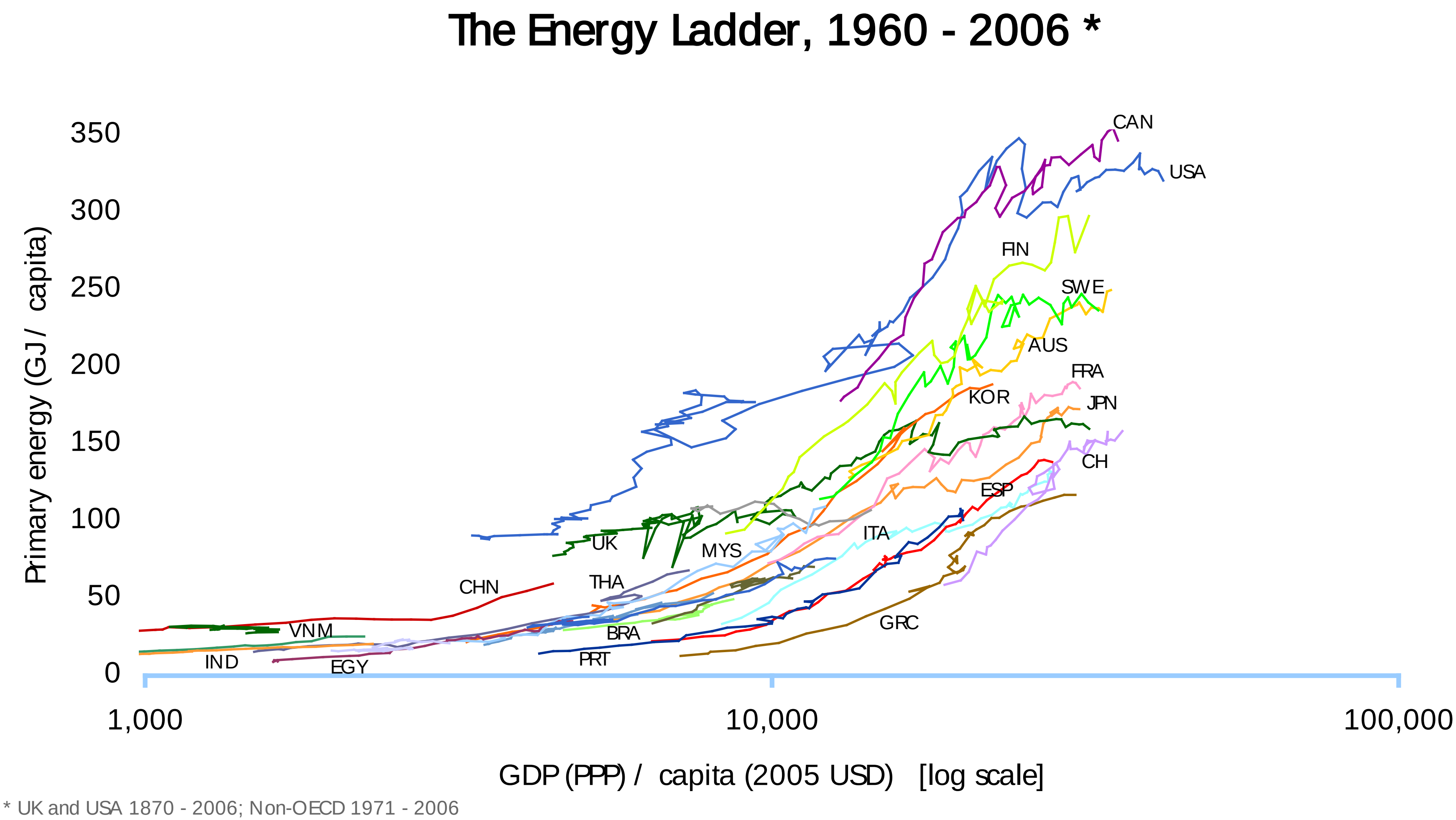
# Whither World Oil Demand

- Long-run energy challenges and scenarios
- Structure of world oil use (some basics)
- World energy end-use demand for transport
- Alternatives to oil in road transport
  - Vehicle efficiency
  - Biofuels
  - Vehicle electrification (plug-in hybrids and fuel cells)
- Other uses of oil and their alternatives

# Long-run energy challenges

- Surge in energy demand, mostly in emerging markets
  - By 2050, 50% rise in population from 6 to 9 billion
  - Increase in global GDP of more that 200%
  - Primary energy demand set to roughly double
- Energy supplies from all sources struggles to keep pace
  - Continued dependence on cleaner fossil fuels
  - Rapid growth in renewables and potentially nuclear
- Environmental stresses from energy are increasing
  - $CO_2$ emissions from energy set to double by 2050
  - Climate stablisation requires a halving of energy emissions

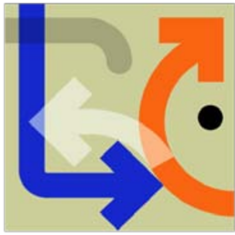
# Energy demand surge and the energy ladder




Source: Haigh （2008）

# Shell energy scenarios to 2050

- Scramble – energy security and reactive change to stresses
  - Focus on existing energy infrastructure
  - Sequential responses to three energy challenges
  - Flight to coal and then bio-fuel
  - Late focus on energy efficiency
  - Knee-jerk reactions to climate events and limited $CO_2$ pricing



- Blueprints – energy security and sustainability
  - Anticipation of energy and climate challenges
  - Critical mass of early responses to the three energy challenges
  - Early and effective $CO_2$ pricing and efficiency standards
  - Energy growth shifts to electrification and CCS emerges after 2020

# Structure of world oil use

# Transport and other uses of oil

- Oil accounts for about 95% of final energy use for transport
  - Biofuels account for about 1 – 2 % of transport fuels
  - Road transport accounts for about 75% of total transport energy use
- About 70% of world crude oil is refined into transport fuels
  - Gasoline (petrol), diesel, LPG, jet fuel and marine bunker
- About 15% goes into fuel oil for power generation and heating
  - Heating oil (diesel), residual fuel oil, and petroleum coke
- Crude oil also provides feedstock for petrochemicals
- Other uses of crude oil include lubricants, waxes and bitumen

# World energy end-use demand for transport

# Energy end-use demand for transport

- Energy end-use demand per capita is a function of
  - Real income/output per capita
  - End-use prices of energy
  - Technological change
  - Consumer preferences, behaviour and choices
- Non-linear, partial adjustment model of energy end-use demand for transport
  - Panel estimation across countries i and time t
  - $\mathit{ln}\ tfc_{i,t} = \alpha_0 + \alpha_1\ \mathit{ln}\ gdp_{i,t} + \alpha_2\ (\mathit{ln}\ gdp_{i,t})^2 + \alpha_3\ \mathit{ln}\ p_{i,t} + \gamma\ \ln tfc_{i,t-1}$ + fixed effects + $\varepsilon_{i,t}$
  - Long-run income elasticity: $e_{gdp} = [\alpha_1 + 2\alpha_2\ (\mathit{ln}\ gdp_{i,t})]/(1 - \gamma)$
  - Long-run price elasticity: $e_p = \alpha_3\ /(1 - \gamma)$
  - Income elasticity is a function of per capita income level

# Energy end-use demand for transport

- Model specification follows Medlock and Soligo (2001)
- Data for OECD countries from International Energy Agency and for non-OECD countries from Rice University and IEA
  - Non-OECD end-use prices are from Rice University
- Dataset partitioned between OECD and non-OECD because of differences in data
  - Combined passenger and freight transport for non-OECD
- Estimation results for panel of 24 non-OECD countries for 1978 – 2003 published in van Bentham and Romani (2009)
- Estimation results for a panel of 27 OECD countries for 1978 – 2003 are not published, but in line with existing literature

# Model estimates for transport energy demand

| | OECD – Passenger | OECD – Freight | Non-OECD |
|---|---|---|---|
| *ln* gpp | 2.3636*** | 2.1396*** | -3.0177* |
| (*ln* gdp)$^2$ | -0.1127*** | -0.0967*** | 0.2267** |
| *ln* p | -0.1239*** | -0.0573*** | -0.0185 |
| *ln* tfc | 0.7705*** | 0.7754*** | 0.8503*** |
| Fixed effects | Yes | Yes | Yes |
| R2 (within) | 0.9641 | 0.9520 | 0.9583 |
| Long run-coefficients | | | |
| *ln* gpp | 10.2989 | 9.5263 | -3.0177 |
| (*ln* gdp)$^2$ | -0.4911 | -0.4305 | 0.2267 |
| *ln* p | -0.5399 | -0.2551 | -0.1260 |

- Non-linear income effects significant for both samples
- $e_{gdp}$ increasing in the level of income for non-OECD
- $e_{gdp}$ decreasing in the level of income for OECD
- Significantly negative OECD price elasticity
- Insignificant non-OECD price elasticity but correctly signed
- See also Dargay and Gately (2010)

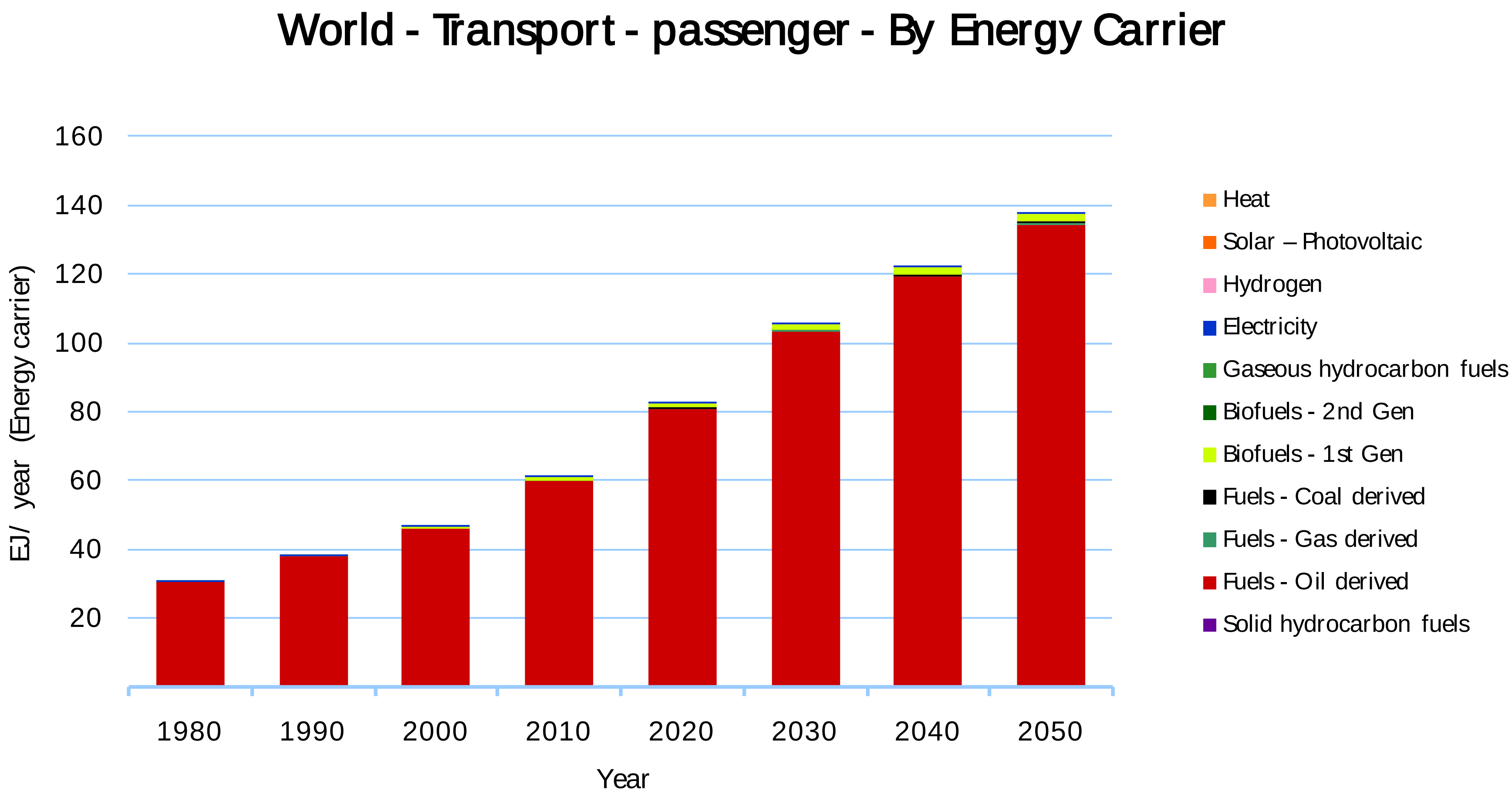
# Projected long-run energy demand for transport

- Growth in real per capita income and population by country
- Projections for population from United Nations and per capita income by country from Oxford Economics
  - Projections to 2020 based on “mainstream” econometrics-based macroeconomic model
  - Projections for 2020 - 2050 based on conditional convergence model of long-run growth
- Country income elasticities of demand depend on per capita income levels (smoothed across pre capita income bands)
- Assumptions for business-as-usual projections and two scenarios
  - Same growth in population and per capita incomes in BAU and scenarios
  - Constant real oil price in BAU (assumes perfectly elastic supply)
  - Real oil price consistent with demand structure and Shell projections for world crude oil production in two scenarios

# Projected long-run energy demand for transport

- Assumptions continued
  - Choices of vehicle technology and fuel mix for transport are modelled using a multinomial logit discrete choice model
    - Explanatory variables: energy service costs (price and any efficiency gains), unit capital costs associated with an energy type and a fuel convenience factor
  - Scenario based inputs
    - Vehicle costs and ICE (hybrid) efficiency gains and associated rebound effect
    - Cost and performance of biofuels (1G and 2G), plug-in hybrid electric vehicles and fuel cells (more detail later)
  - Average vehicle life of 15 – 20 years, implying a fleet turnover rate of 5 – 7% per annum
    - Governs the extent and timing of new technologies' affects on energy demand
    - Global vehicle fleet roughly doubles to 2 billion by 2030 (Dragay and Gately (2008))
  - Significant end-user subsidies for transport fuels in some countries maintained in BAU and Scramble scenario but phased out in Blueprints

# Business-as-usual energy demand

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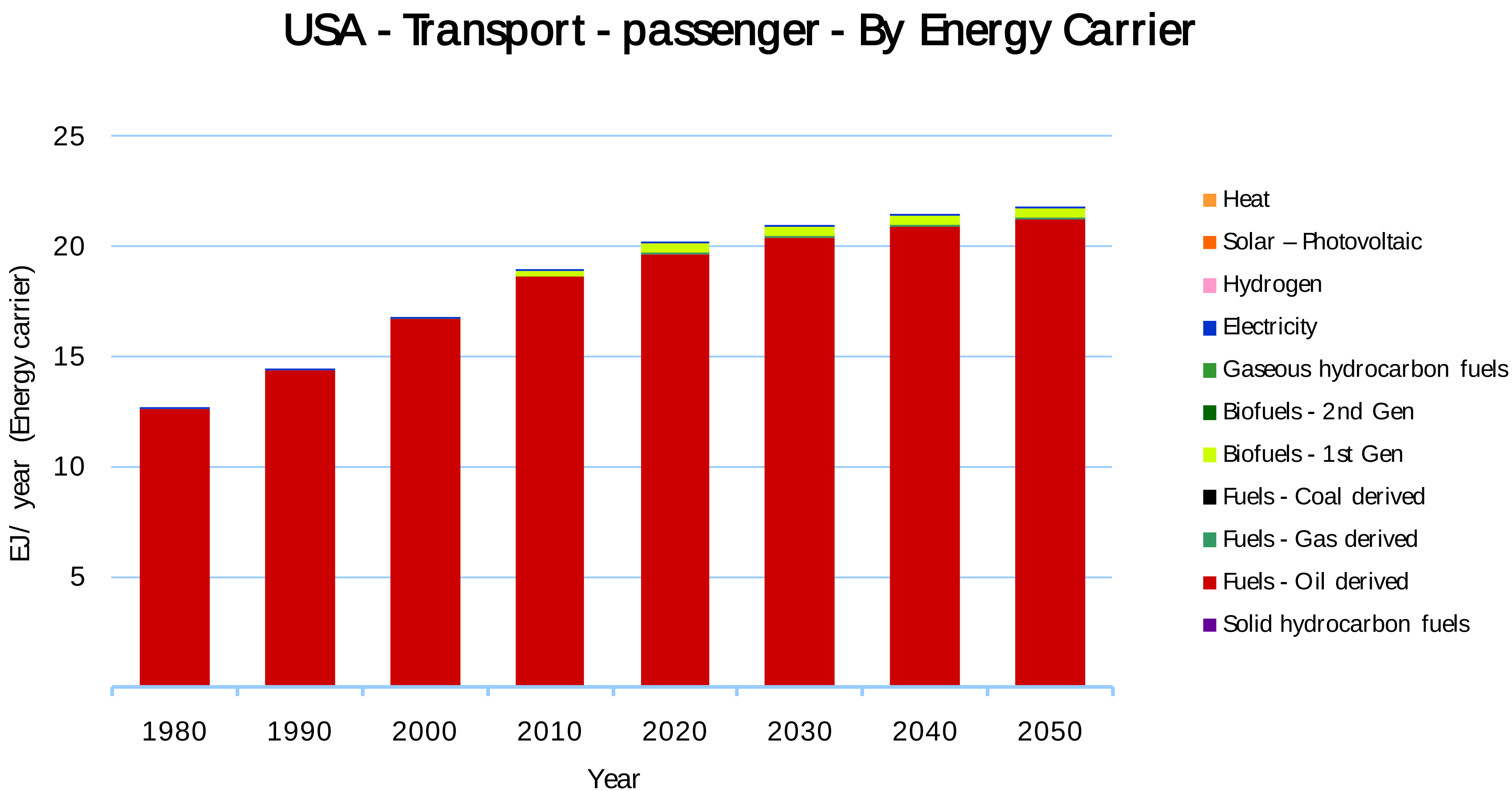
# Business-as-usual energy demand

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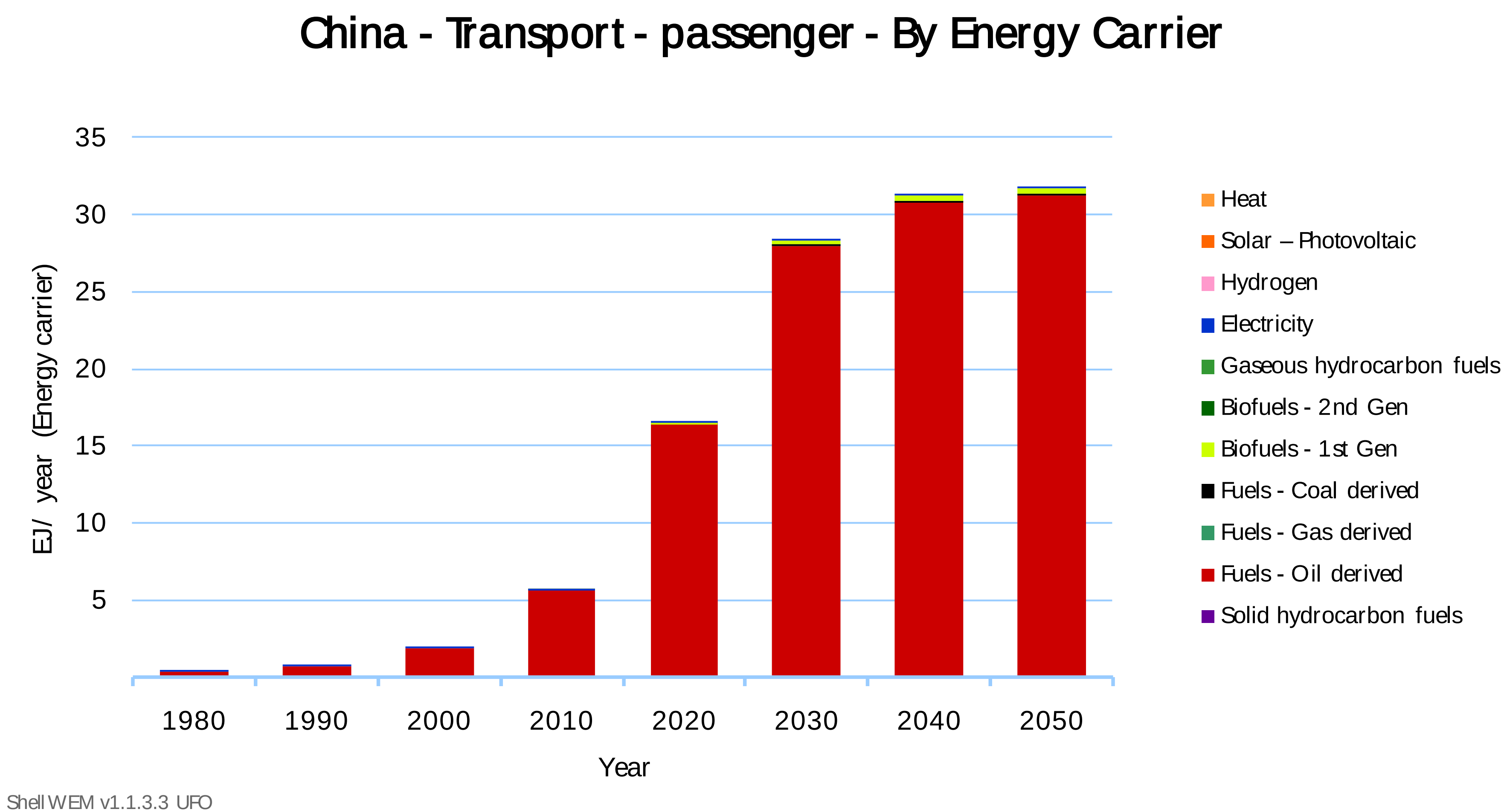
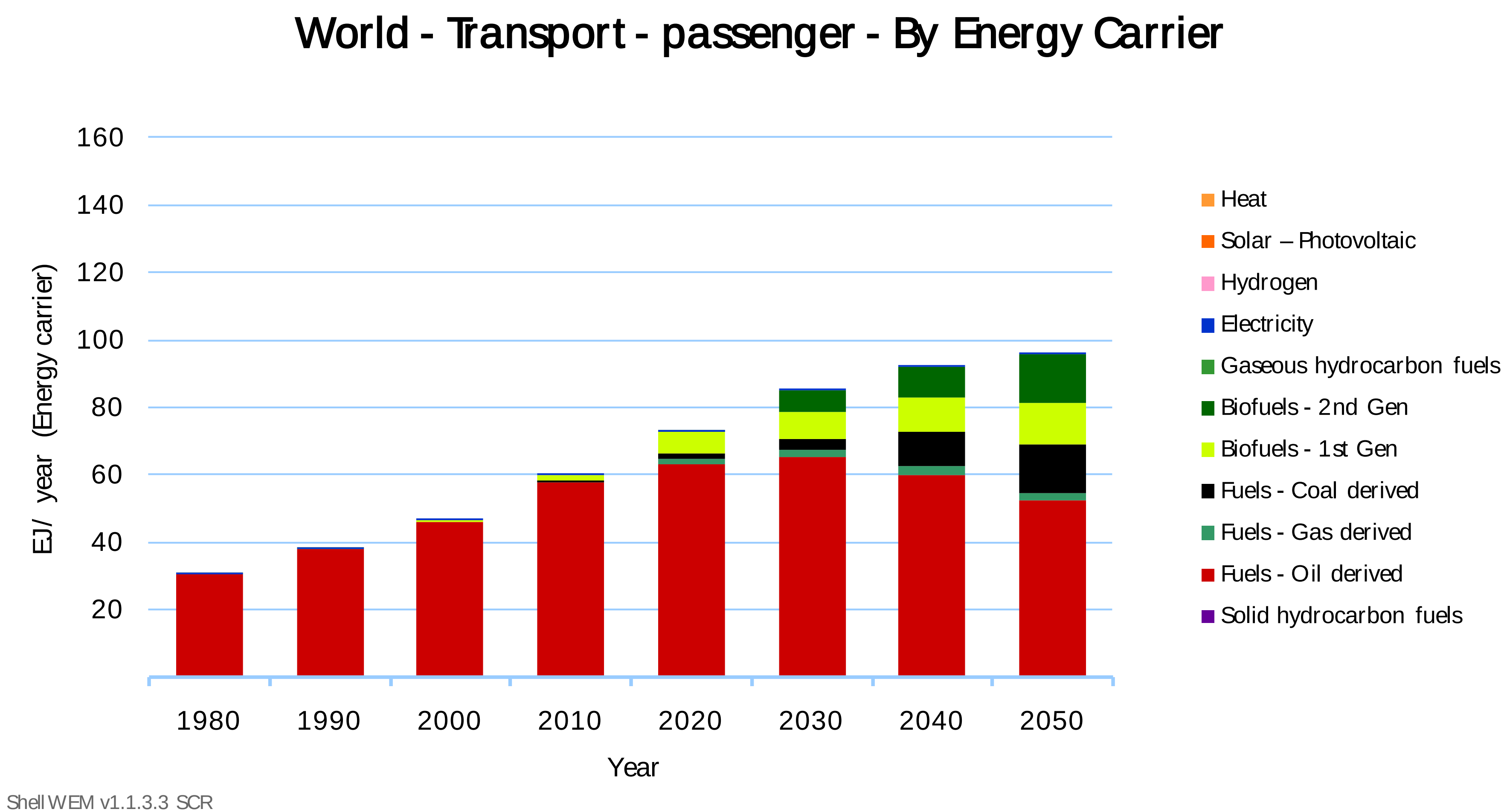
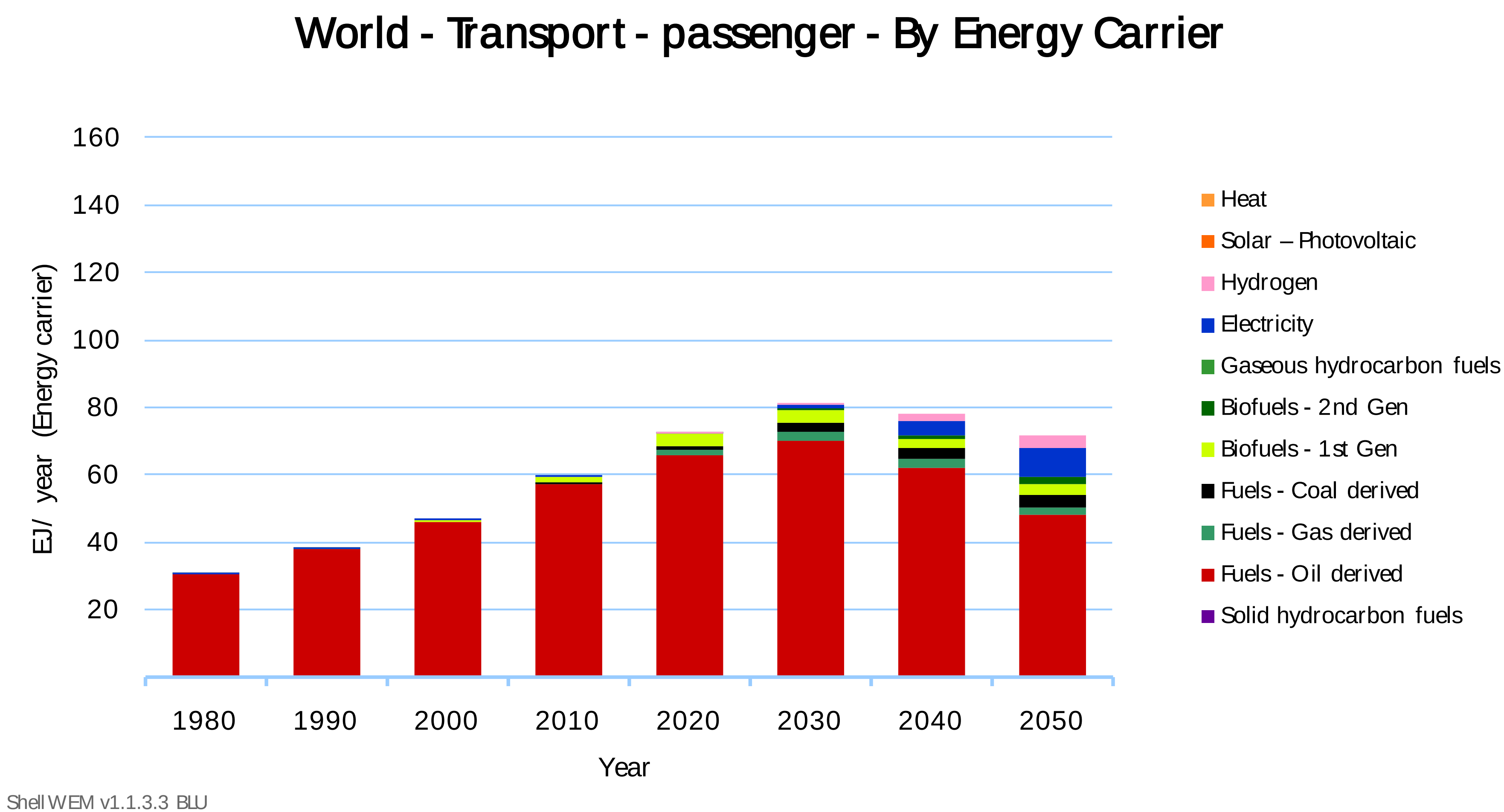
# Business-as-usual energy demand



# Scramble scenario energy demand

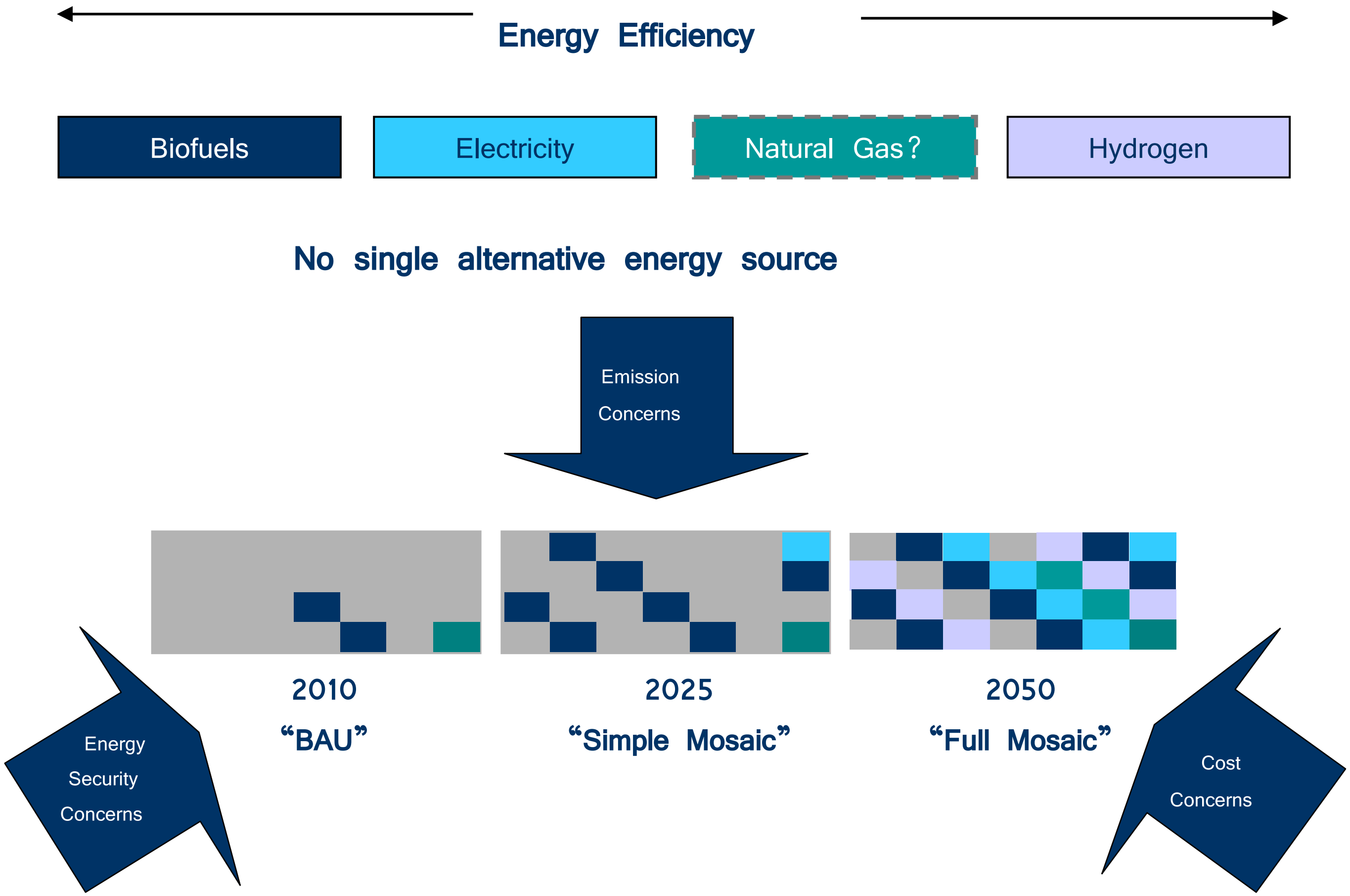


# Blueprints scenario energy demand



# Alternatives to Oil in Road Transport – Blueprints Scenario

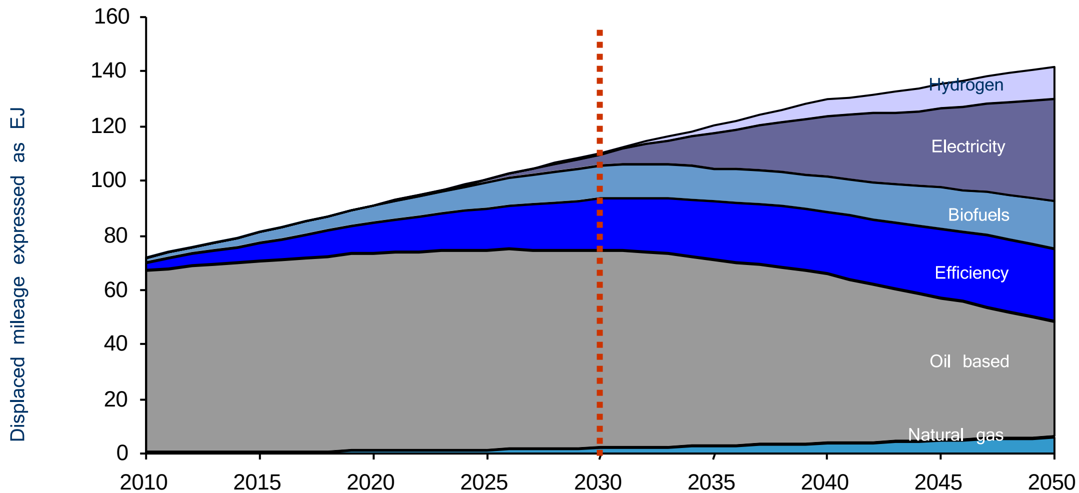
# Alternatives to oil in road transport



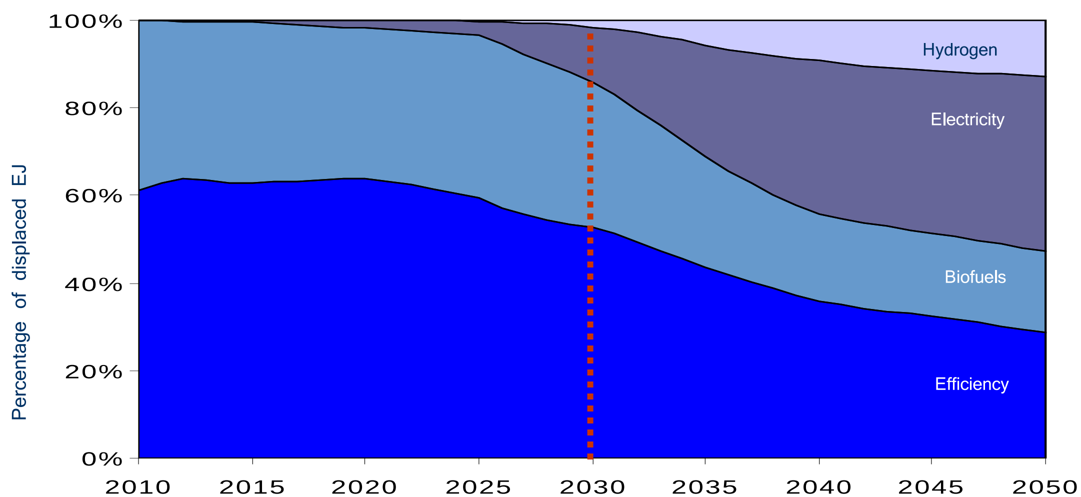

Mandates and standards set to be the main policy drivers in the transport sector （Morrow et al. （2010））

# Efficiency and biofuels would likely be the main alternatives to oil for next 20 years

Road Transport Fuels（2010 to 2050）

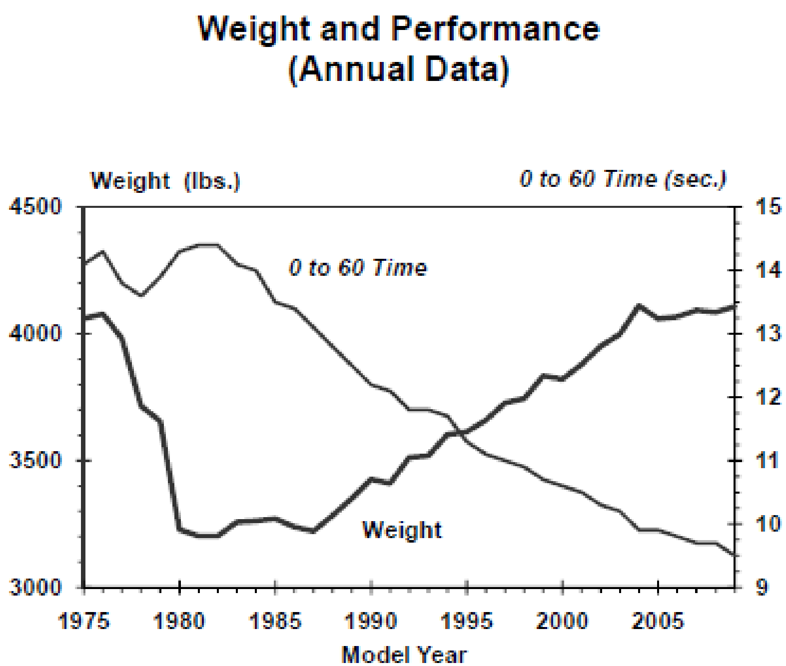



Displacement of Oil（2010 to 2050）



# Vehicle technology gains have tended to go into better performance and features

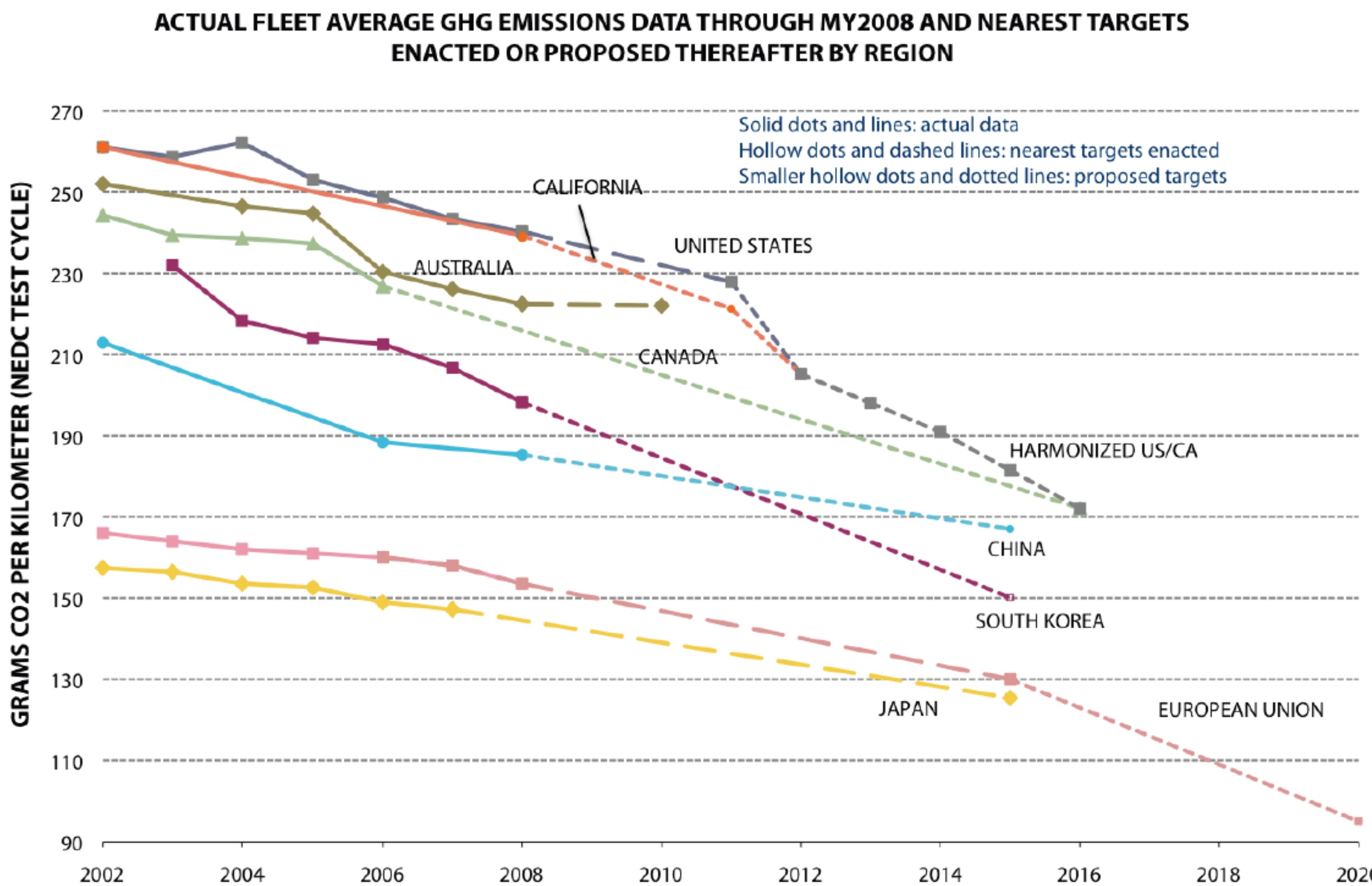
US light duty vehicles




Source: EPA

- Technology improvements have tended to go into better performance and weight (more features and options)
- Also reflects composition of sales between cars and light trucks/SUVs
- Higher weight and faster performance tend to lower fuel efficiency and raises $CO_2$ emissions
- Significant potential efficiency gains from reducing vehicle weight and improving engine efficiency

# Vehicle standards set to drive significant efficiency gains

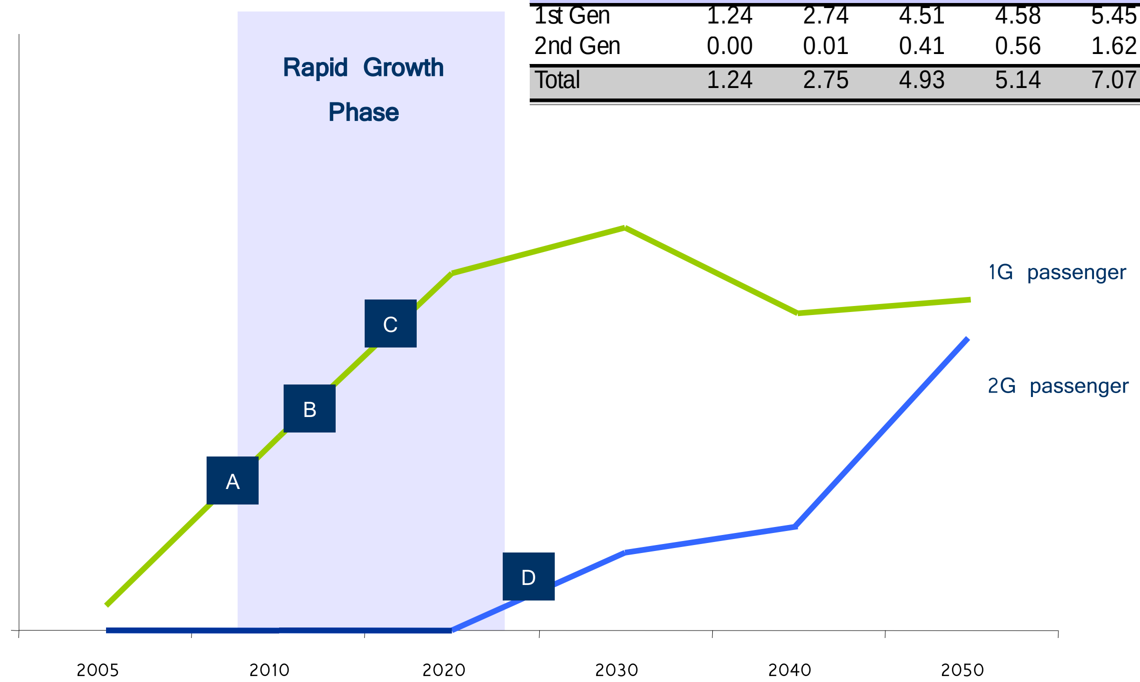



Source: ICCT

# Two key growth drivers for biofuels will be regulation and advanced technology

**Global penetration of biofuels volumes**

| Total biofuels volumes - million barrels per day | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| 1st Gen | 1.24 | 2.74 | 4.51 | 4.58 | 5.45 |
| 2nd Gen | 0.00 | 0.01 | 0.41 | 0.56 | 1.62 |
| Total | 1.24 | 2.75 | 4.93 | 5.14 | 7.07 |




A — Adoption of biofuel mandates

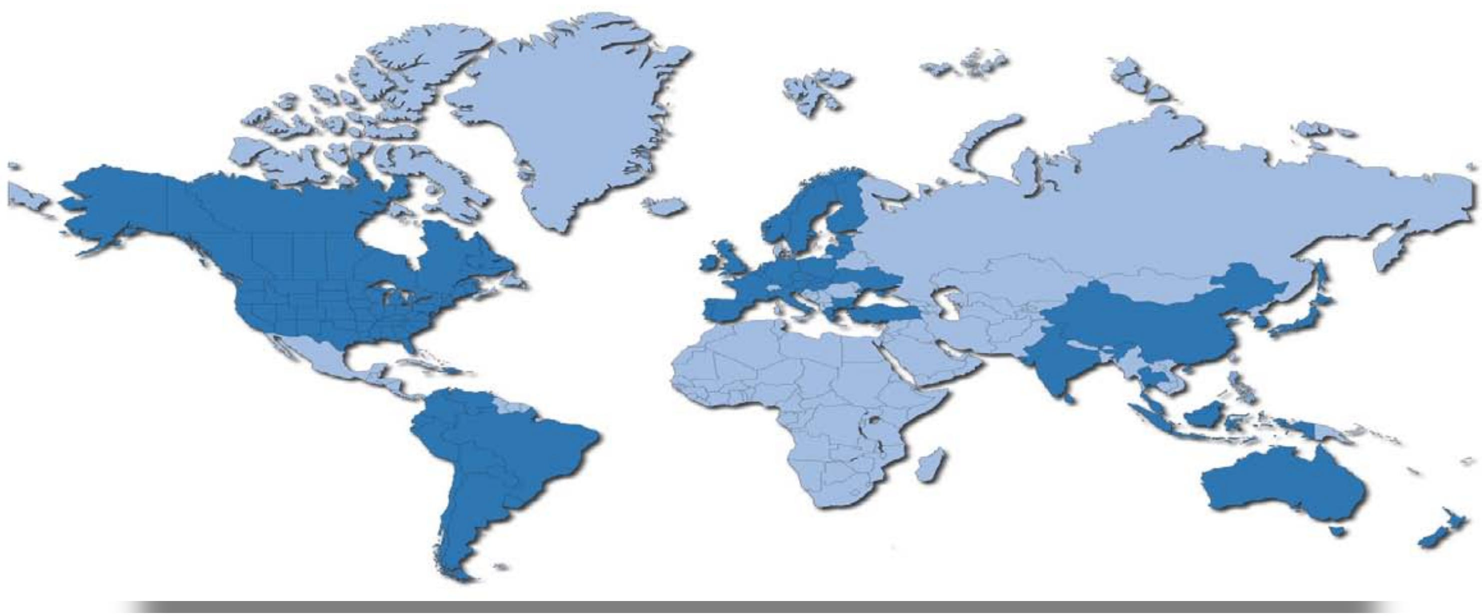
B — Fuel specifications raised in EU to E10 and B7

C — Development of GHG based legislation, including indirect land use change.

D — Development of 2G feedstock production and conversion process technologies

# Government biofuels policy

- Increasing demand for non-oil liquid fuels for transport and more than 50 countries are developing renewable fuels mandates
  - The European Union Renewable Energy Directive proposes 10% (energy basis) of road vehicle fuel should come from renewable sources by 2020
  - The USA Energy Independence and Security Act 2007 requires 36 billion gallons of renewable road transport fuels by 2022
- Biofuels could grow from just 1% of the world's transport fuel mix today to as much as 7–10% over the next few decades

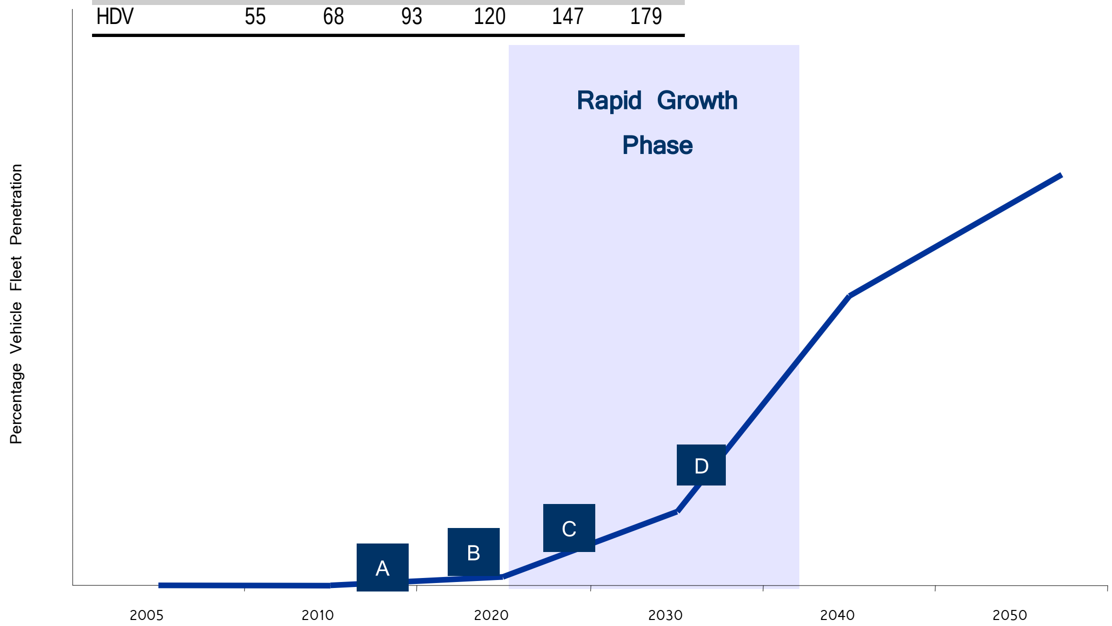


# Plug-in hybrid electric vehicles will require better batteries and new infrastructure

## Global Plug-in Hybrid Electric Vehicles % of total vehicle fleet

**(50:50 gasoline electricity average)**

| Total Vehicle Fleet Size (Million) | 2005 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| LDV | 900 | 1001 | 1138 | 1301 | 1517 | 1624 |
| 2/3 Wheeler | 314 | 400 | 709 | 1185 | 1680 | 2110 |
| HDV | 55 | 68 | 93 | 120 | 147 | 179 |




A — Economic incentives offered to early adopters (not in all markets).

B — Smart metering and tariff structuring implemented to balance generation load.

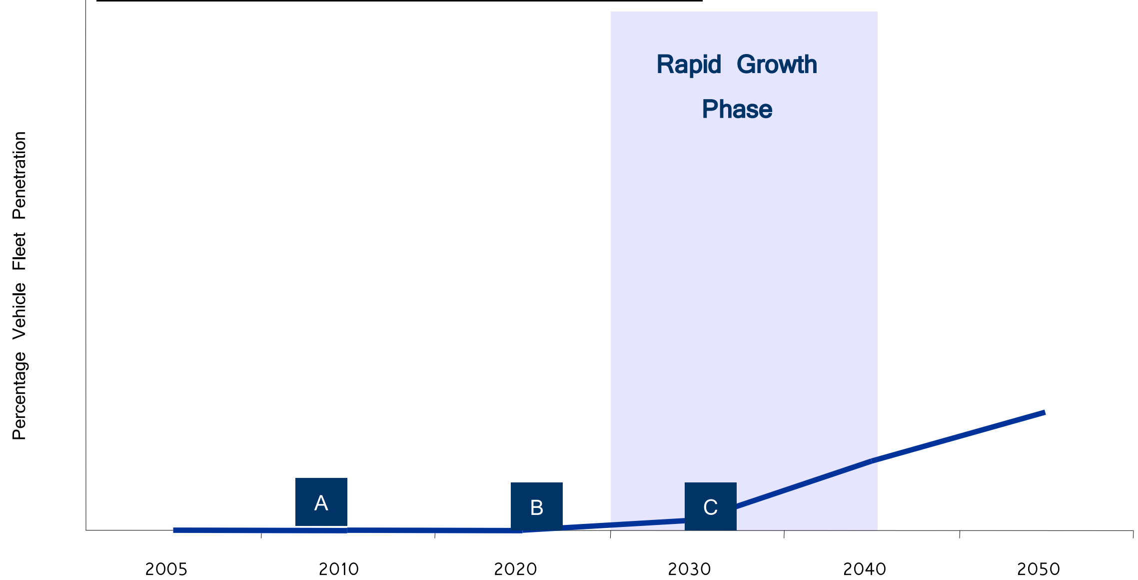
C — Additional electricity capacity (network and generation stock) investment ~ 2025 once transport needs ~5% of additional electricity

D — Limited supply of lithium in geo-politically uncertain regions overcome

# Fuel cell vehicles expected only once OEMs and fuel suppliers build customer acceptance

## Global FCV % of total vehicle fleet

| | Total Vehicle Fleet Size (Million) | | | | | |
|---|---|---|---|---|---|---|
| | 2005 | 2010 | 2020 | 2030 | 2040 | 2050 |
| LDV | 900 | 1001 | 1138 | 1301 | 1517 | 1624 |
| 2/3 Wheeler | 314 | 400 | 709 | 1185 | 1680 | 2110 |
| HDV | 55 | 68 | 93 | 120 | 147 | 179 |




**A** Public Private Partnerships “Lighthouse” projects and market preparation

**B** Start of commercialisation: Series production of FCV starts.

**C** Expansion of hydrogen supply infrastructure; transition phase to reach material market share.

# Other uses of oil and the alternatives

# Fuel oil, feedstock and their alternatives

- Fuel oil, petrochemical feedstock, lubricants, bitumen and other uses account for about 30% of total oil demand
  - Almost no use of fuel oil in OECD power generation after oil price shocks
  - Still used for power particularly in Middle East and Asia – Pacific region
- Main alternatives are natural gas and coal
- Supply outlook for natural gas in North America has shifted fundamentally with the recent ramp-up of shale gas production
  - Potential unconventional supplies also in China, Australia and Europe
  - IEA estimates 250 years of natural gas supply at current production rates
- Even more abundant potential supplies of coal, but $CO_2$ may constrain their use

# Fuel oil, feedstock and their alternatives

- Long-run income elasticities of demand for fuel oil and feedstock higher in most non-OECD countries than in OECD countries
- Significant evidence of past asymmetric responses of fuel oil and feedstock demand to oil price shocks
  - Fuel switching induced by price shocks not reversed when price falls
  - OECD and non-OECD fuel oil demand and OECD other demand
  - See Dargay and Gately (2010) for estimated demand parameters
- Current, historically wide oil-natural gas price differential in the United States due in part to ramp-up of unconventional gas
- Potential for supply tightness to gradually re-emerge in oil but not necessarily in natural gas, but regional variation possible

# Conclusion

# Conclusions

- Emerging market growth is main long-run driver of oil demand
  - Consistent with their recent macroeconomic performance
- At the same time, alternatives to oil in road transport can be expected in the coming decades
  - Vehicle efficiency improvements set to drive oil demand declines in OCED
  - Biofuels have significant potential to reduce road transport $CO_2$ emissions and displace oil demand over the next two decades
  - Plug-in hybrids and hydrogen fuel cells could be important later, but there are technical barriers and costs still to overcome
- Renewable fuel and vehicle efficiency standards, rather than carbon pricing, are likely to be the main policy drivers

# Conclusions

- BAU energy demand for transport grows by 75 EJ by 2030
- In Blueprints, energy demand for transport grows by 40 EJ
  - In road transport, energy services demand grows by 30 EJ
  - Of this, vehicle efficient accounts for about 15 EJ, biofuels (primarily 1G) 10 EJ and electrification 5 EJ
- Other uses of oil are primarily as fuel for power generation and heating and feedstock for petrochemicals
- Potential for substitution of natural gas for oil in these end uses, but depends on outlook for natural gas supplies and distribution
  - A rise in the relative price of oil versus natural gas could drive substitution

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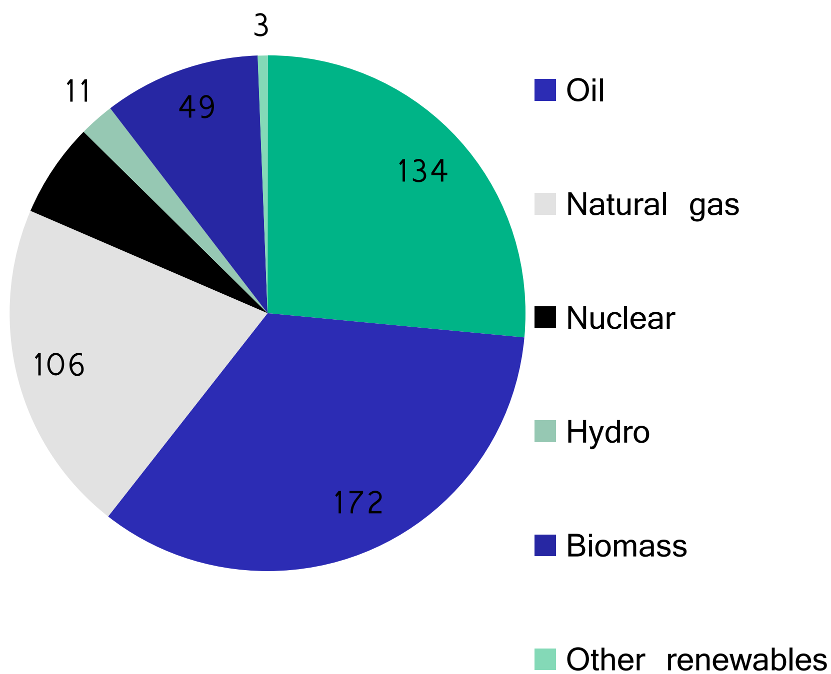
van Bentham, A. and M. Romani (2009), “Fuelling growth: What drives energy demand in developing countries”, *The Energy Journal* 30(3): 147 – 170

# World energy and oil use (2007): some basics

**Total primary energy (in EJ)**

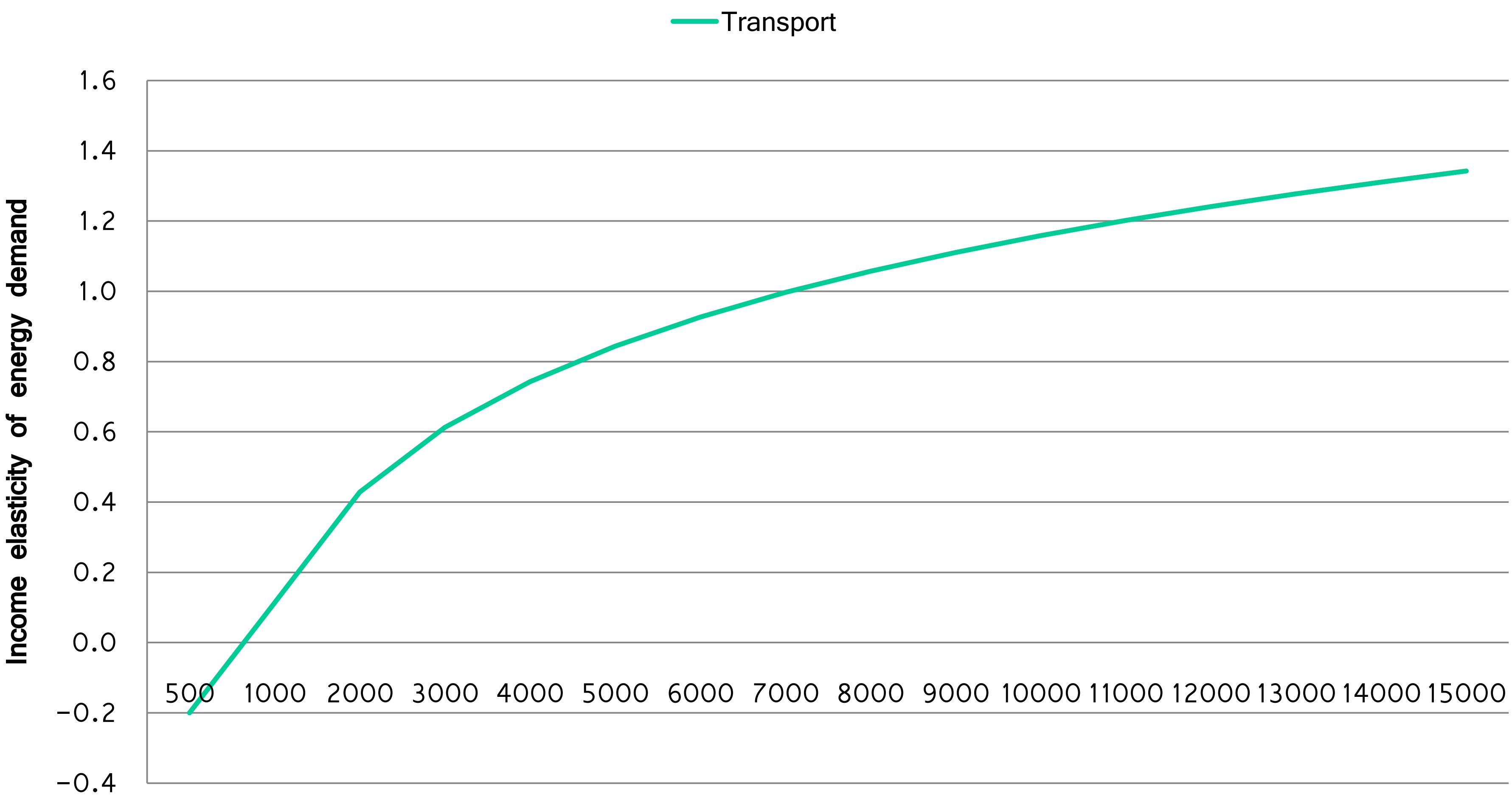



- Total primary energy use = 505 EJ (240 MBOE/D)
- Total final energy use = 346EJ (165 MBOE/D)
- 30% conversion loss, such as waste heat from power generation
- Oil accounts for 34% of primary energy and 42% of final energy use

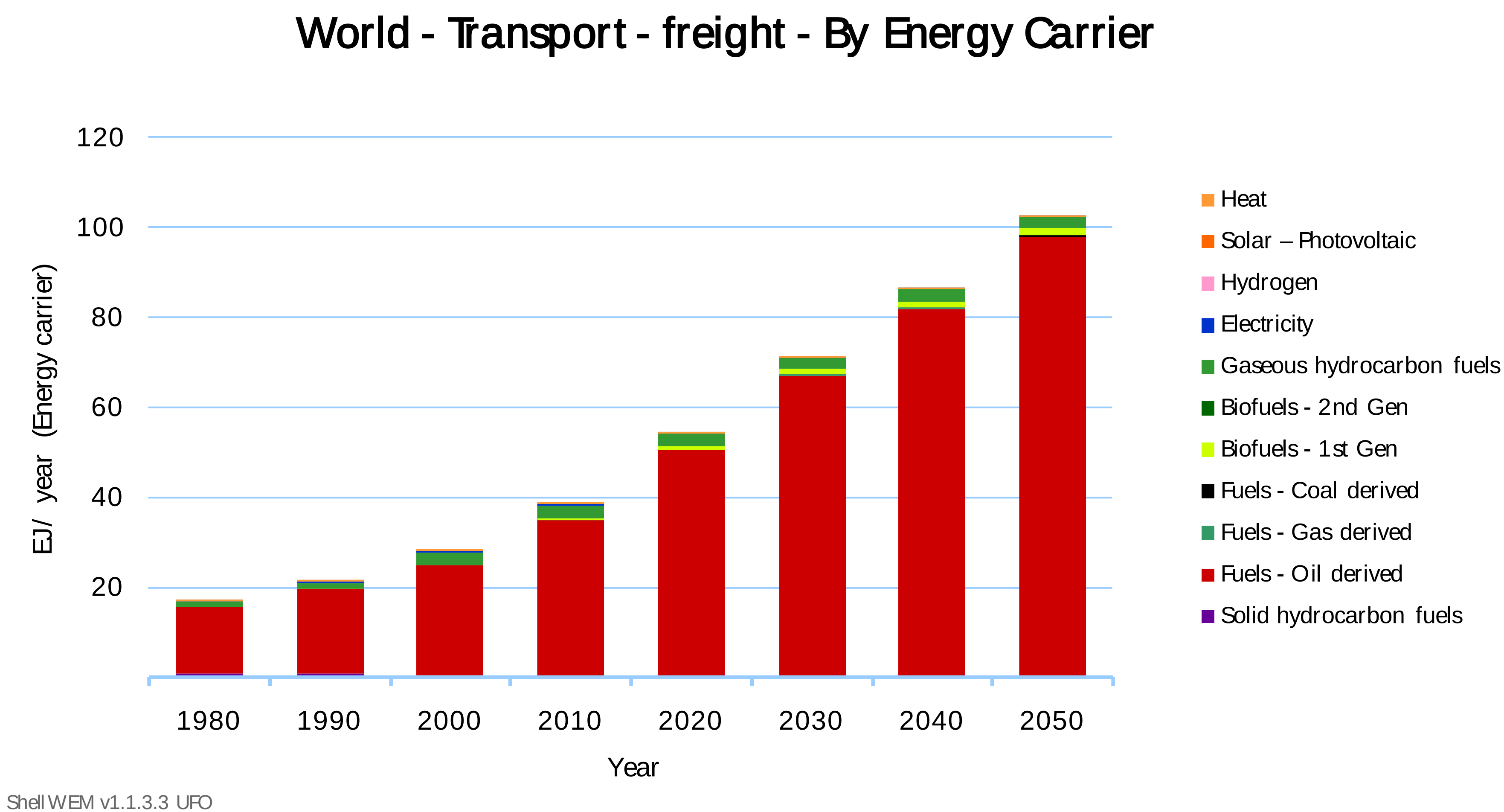
Source: International Energy Agency (2009)

# OECD income elasticity of energy demand

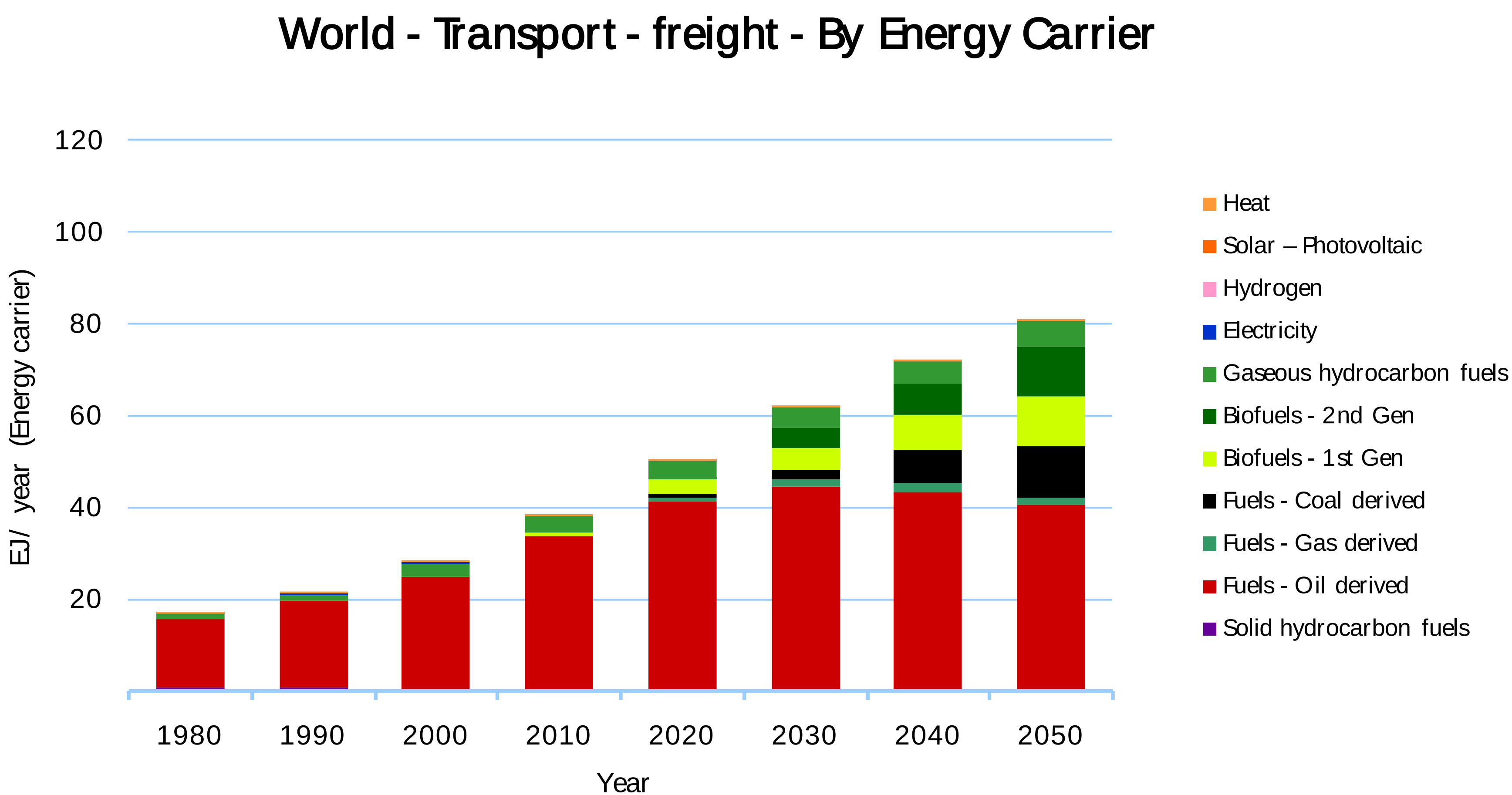
# Non-OECD income elasticity of energy demand



# Business-as-usual energy demand



# Scramble scenario energy demand

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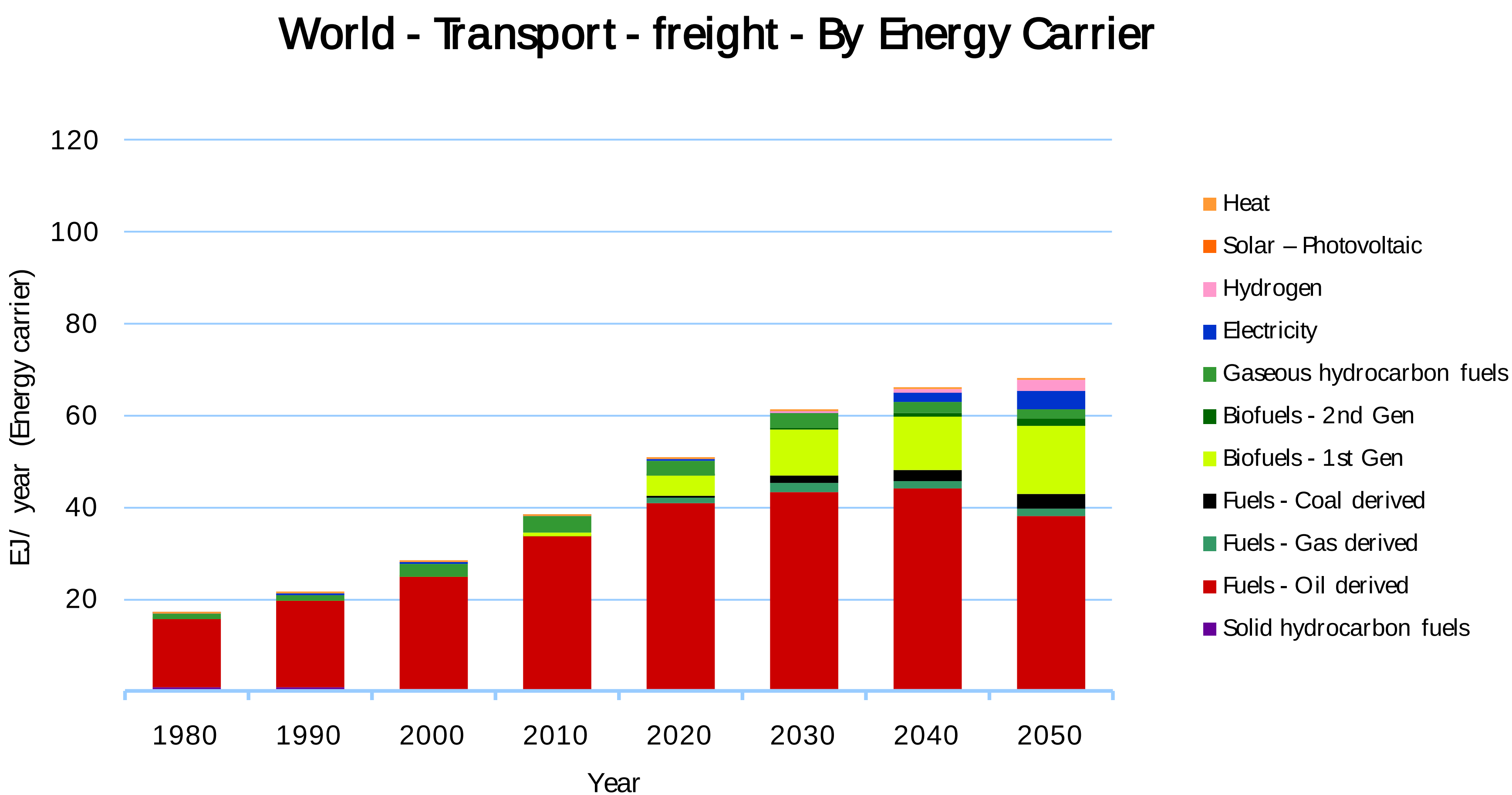
# Blueprints scenario energy demand

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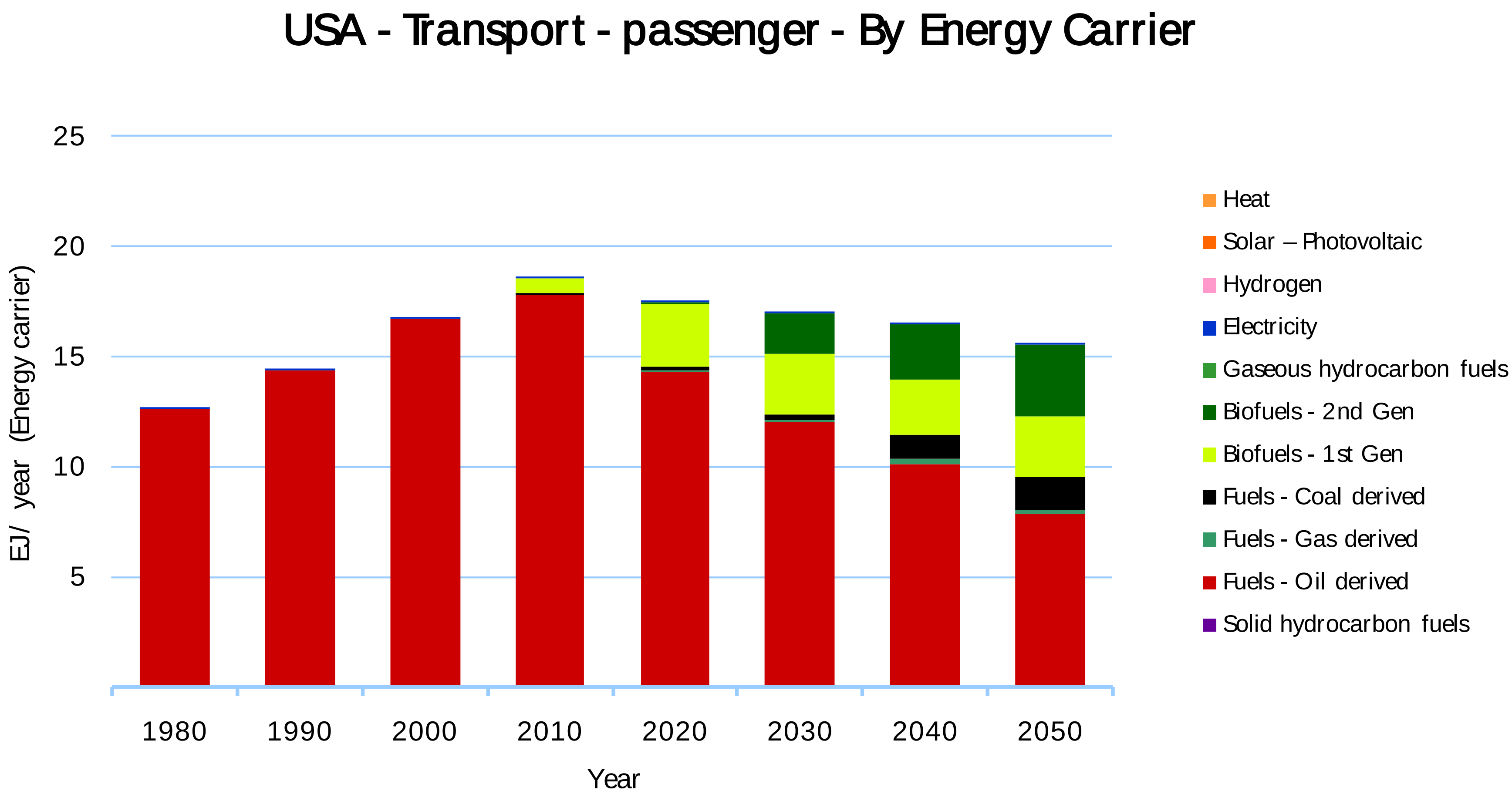
# Scramble scenario energy demand

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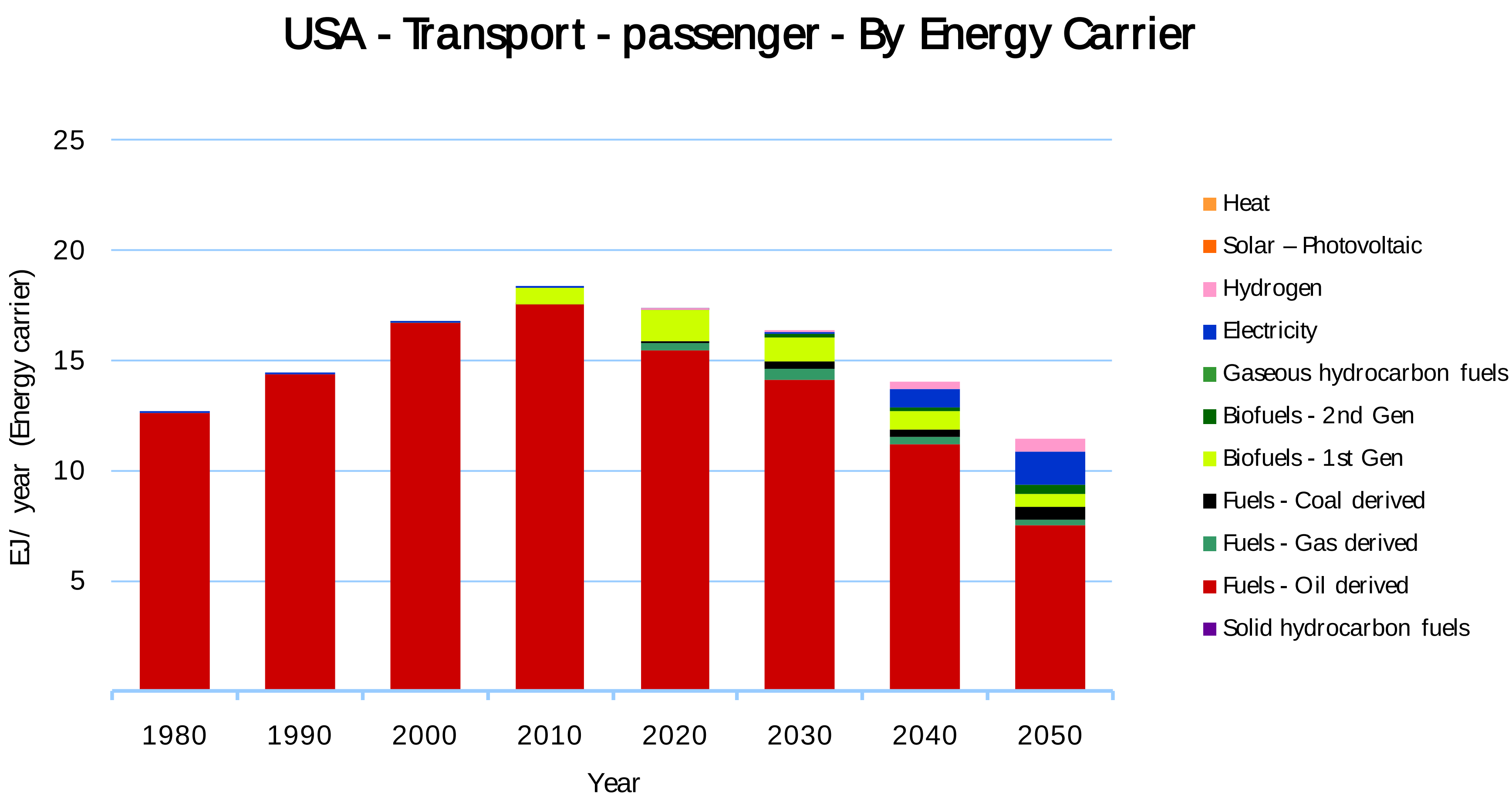
# Blueprints scenario energy demand

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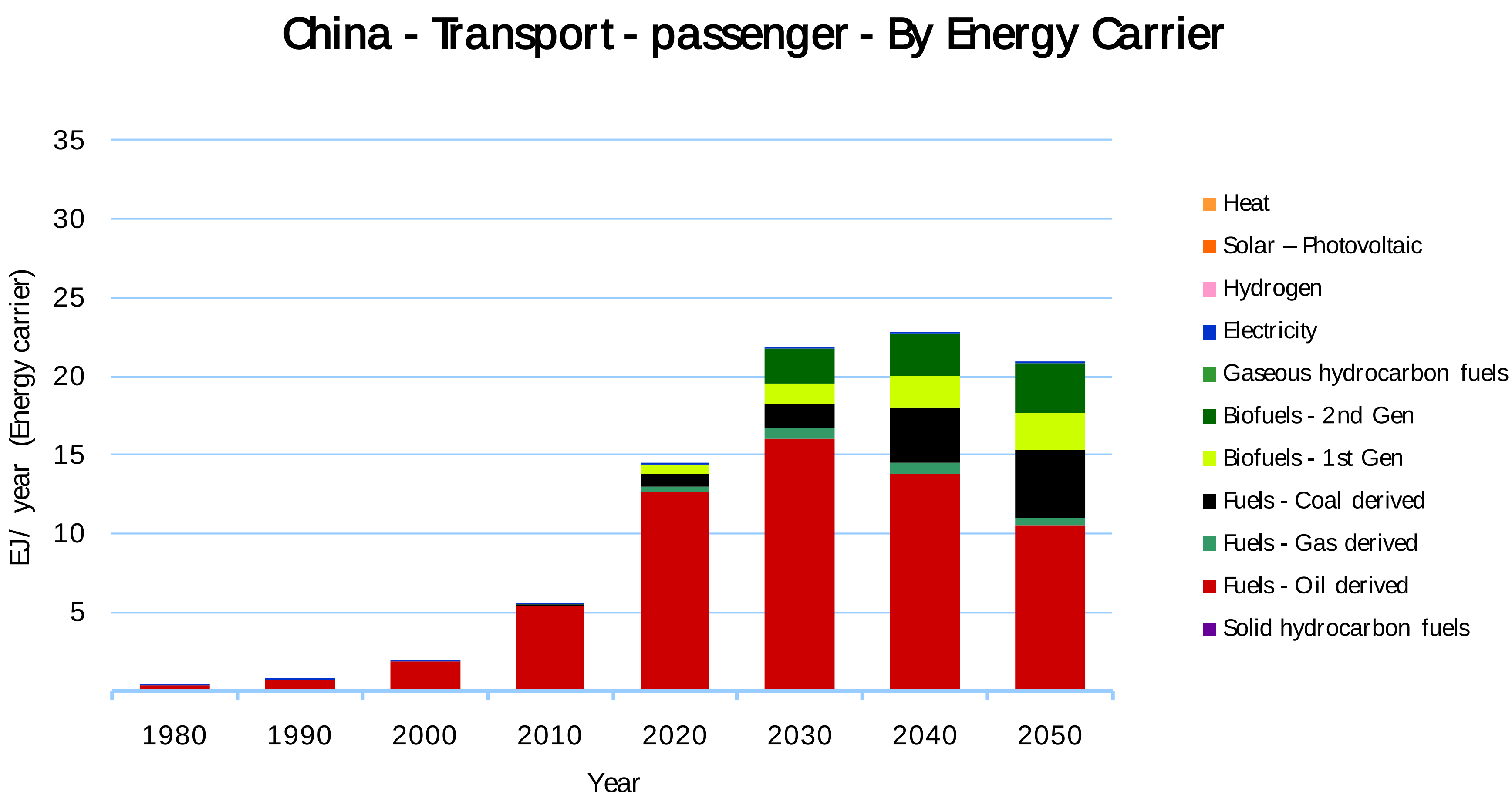
# Scramble scenario energy demand

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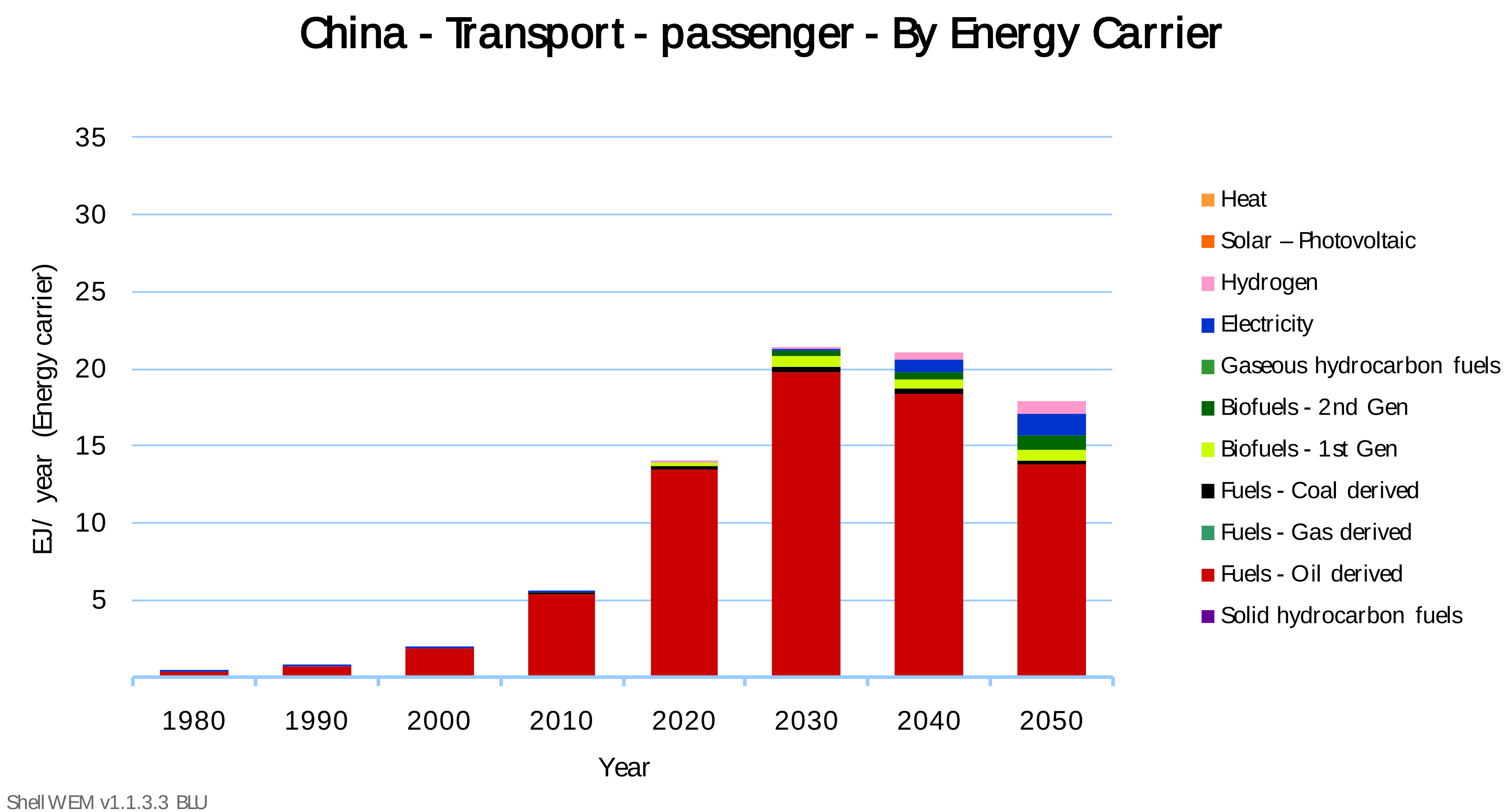
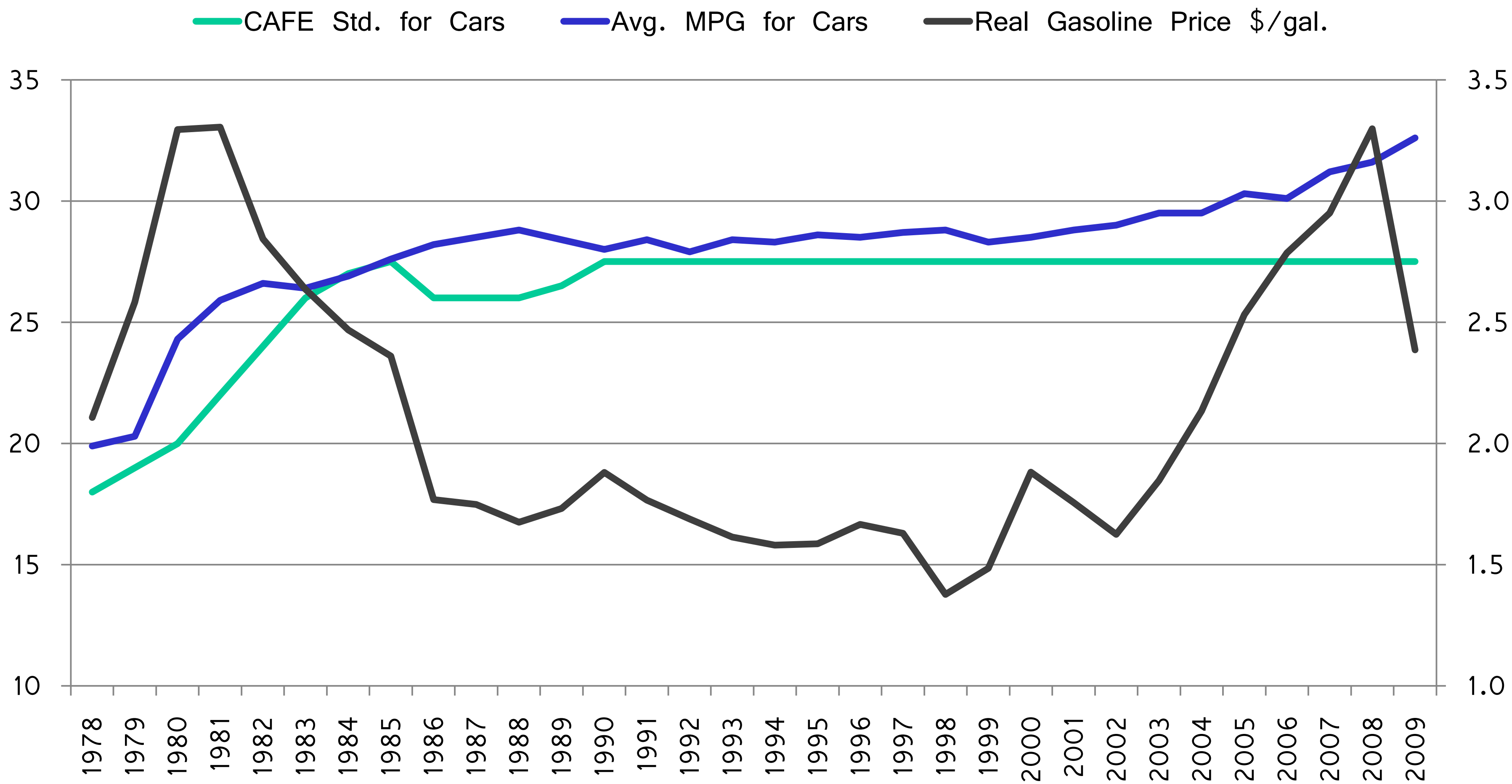
# Blueprints scenario energy demand



# US vehicle efficiency standard and performance




Source: US NHTSA, US EIA

# Production of advanced biofuels (2G)

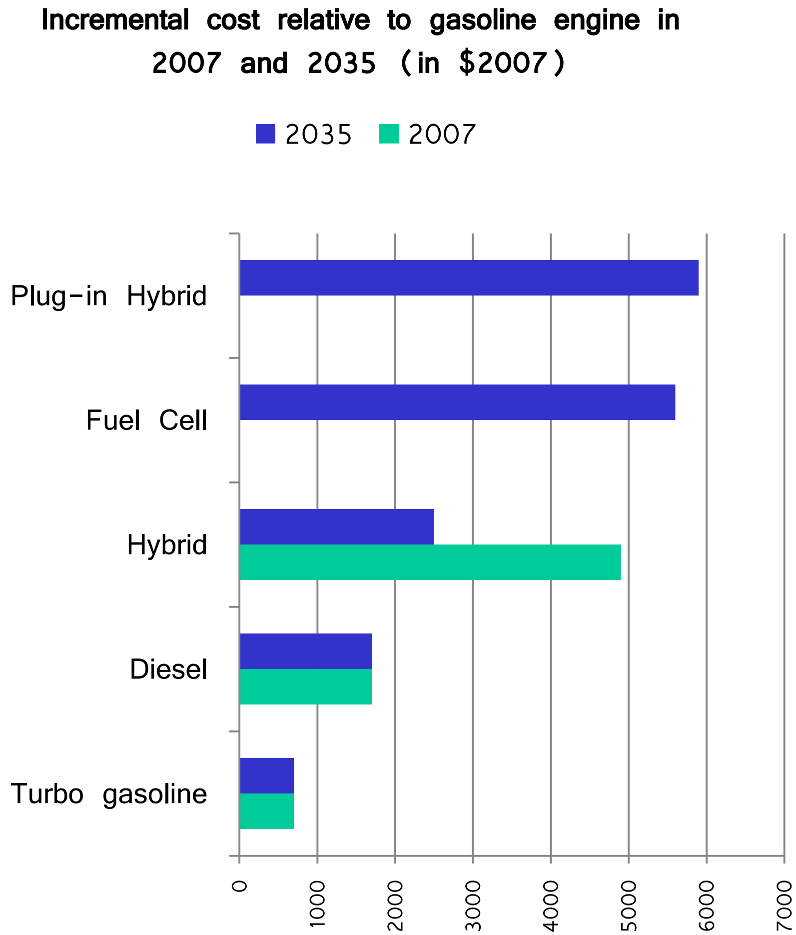
**Alternative raw materials:**

- Lignocellulose (tough molecules that make up cell walls):
  - Prairie grasses, fast-growing trees
  - Food crop residues
  - Leftover from timber
  - Post consumer waste
- Lipids (oil droplets in organisms):
  - Algae
  - Jatropha

**Alternative processes:**

- Breaking down and converting new raw materials is far more complex than for current biofuels
- Processing at scale is challenging
- Processes include
  - Biological catalysts (enzymes)
  - Gasification and Fischer-Tropsch
  - Hydro-treating over catalysts
  - Thermo-chemical routes

# Electric mobility will require better battery/ fuel cell technologies and new infrastructure




- Baseline price of gasoline powered car in 2035 is $21,600 ($2007)
- Turbo gasoline engines have 4 year payback at $2.50/gal
- Diesels remain relatively expensive to gasoline engines
- Hybrids pay off at $2.50/gal over 15 years in 2035
- Fuel cells and plug-in hybrids do not break even until $3.75/gal
- Based on MIT projections of vehicle technology development to 2035

Source: Bandivadekar et al. (2008)

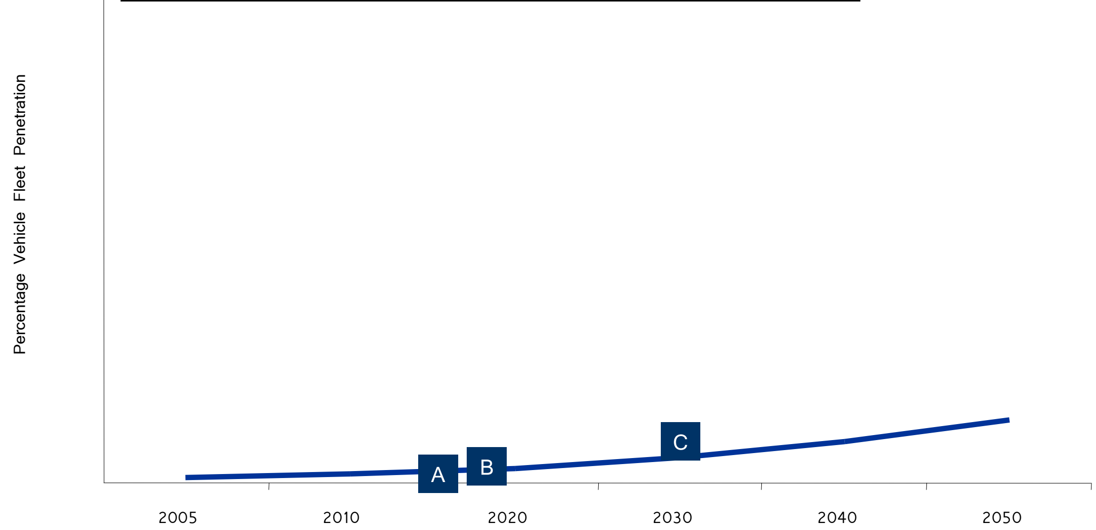
# Current constraints on electrification can – and likely will – be addressed in the longer term

| Short term *(until 2020?)* | | Long term *(2020 to 2050)* |
|---|---|---|
| **Issue** | **Impact** | **Resolution** |
| Avoidance of daytime charging. | Peaks in daily load profile with increased costs and emissions. | Smart-metering and/or differentiated tariff structures. |
| Avoidance of fast-charging on low-voltage network. | Network integrity and performance of transformers. | Authorised, fast-charging points on high-voltage network. |
| Concerns on overall network integrity. | Higher load creates extra strain on transformers, cables, etc.. | Investment in electricity networks, needing regulatory approval. |
| Resources constraints (lithium and lanthanides) | Key commodities for battery production. | Overcome by new sources or substitution. |
| Existing cost and range of batteries. | Limits customer appeal and affects growth rates. | Progress until reach competitiveness against ICEs. |
| Maintenance of relative cost advantage. | Investment needs and transport tax erodes lower cost advantage. | Correct charging and avoidance of "displaced fuels taxation". |

# CNG expected to remain focused but will grow and could offer significant, valuable niches

## Global penetration of CNG vehicles

| Total Vehicle Fleet Size (Million) | 2005 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| LDV | 900 | 1001 | 1138 | 1301 | 1517 | 1624 |
| 2/ 3 Wheeler | 314 | 400 | 709 | 1185 | 1680 | 2110 |
| HDV | 55 | 68 | 93 | 120 | 147 | 179 |




A — Fuel tax incentives in CNG for early adopters

B — OEM collaboration enabling lower conversion cost

C — Additional penetration of CNG achieved as home base refuelling introduced