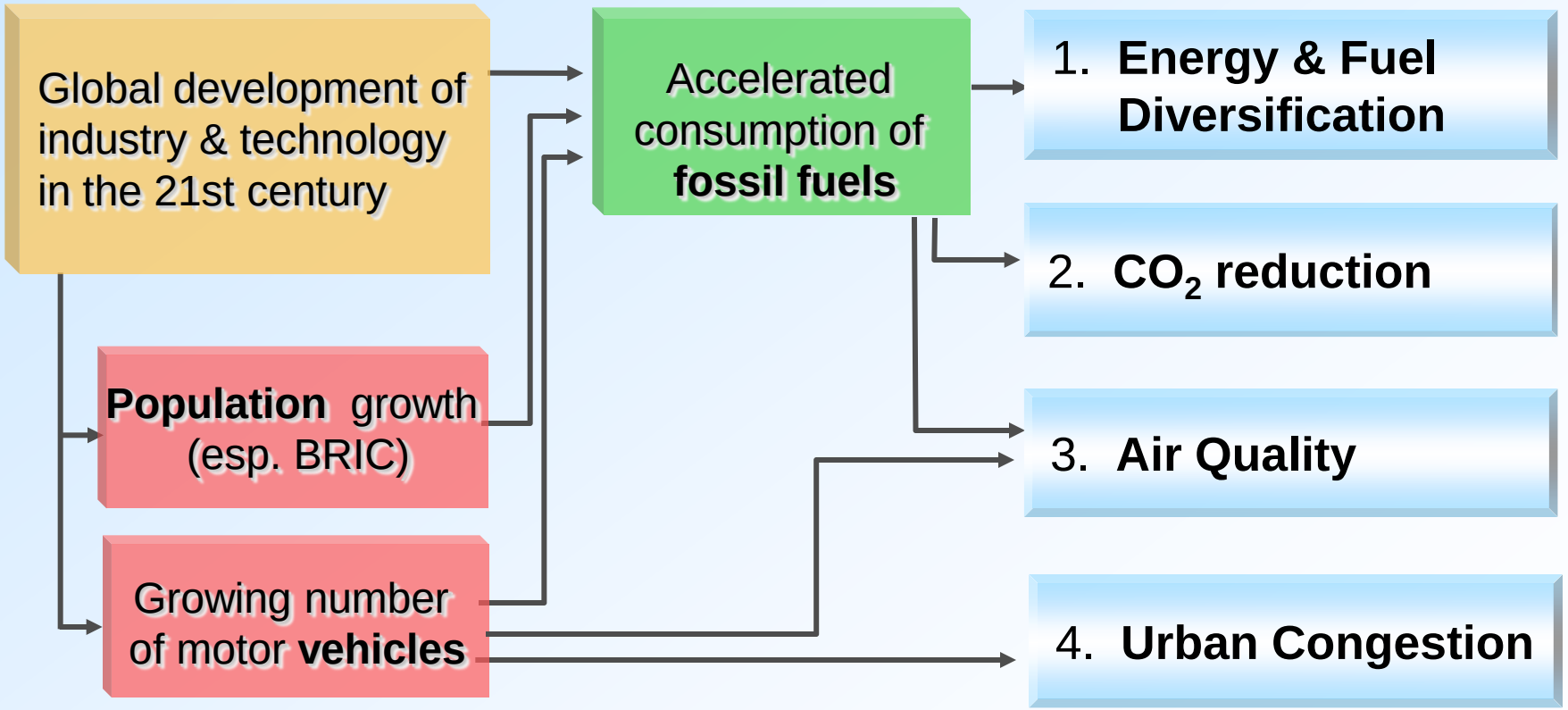
Steps Towards Sustainable Mobility

Bill Reinert
Toyota Motor Sales, U.S.A.
May 7, 2007




The “Big 4” –
Issues facing the auto industry



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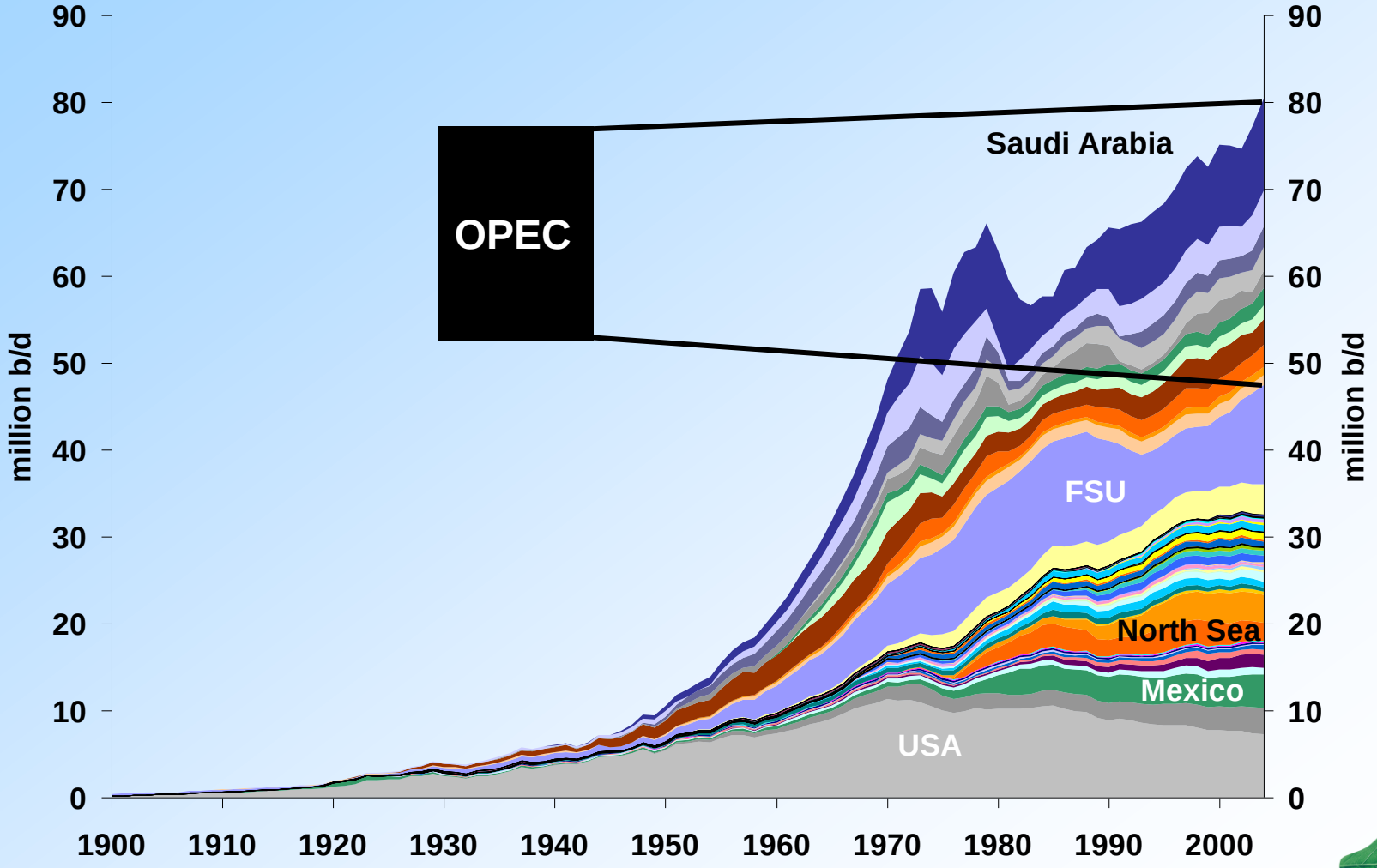
World oil production has risen eight fold in a generation



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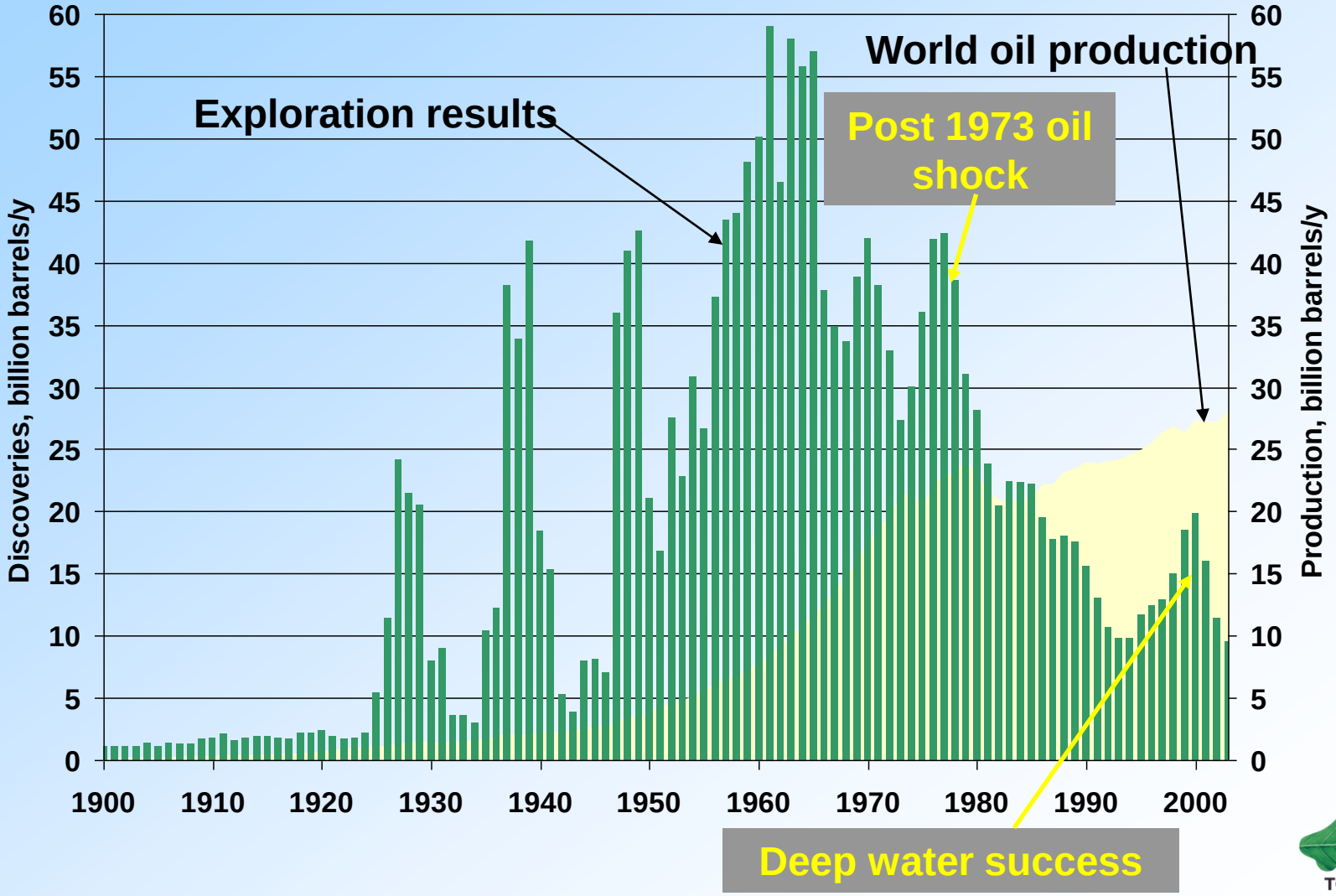
Exploration Success peaked in the 1960s…



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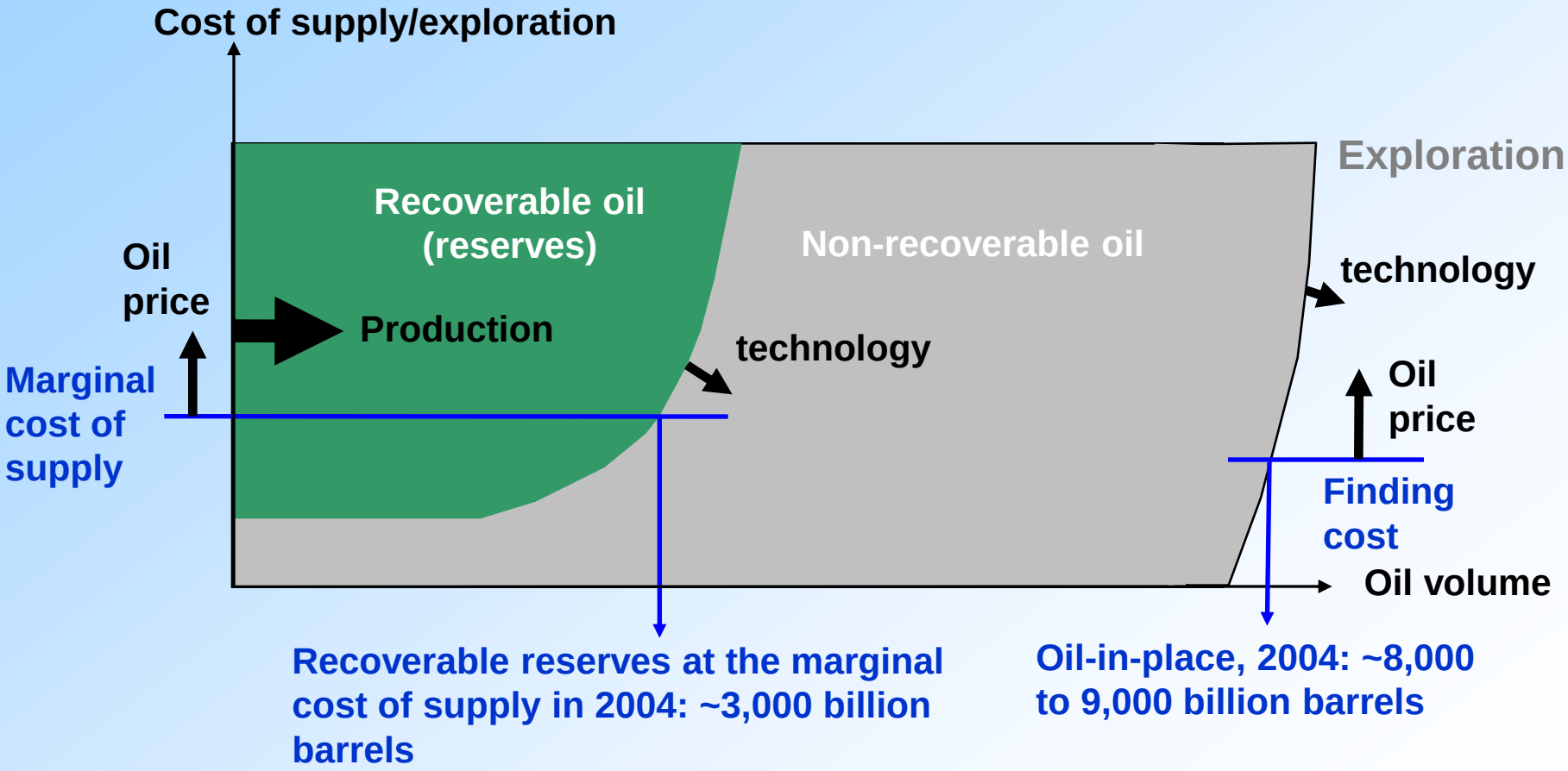
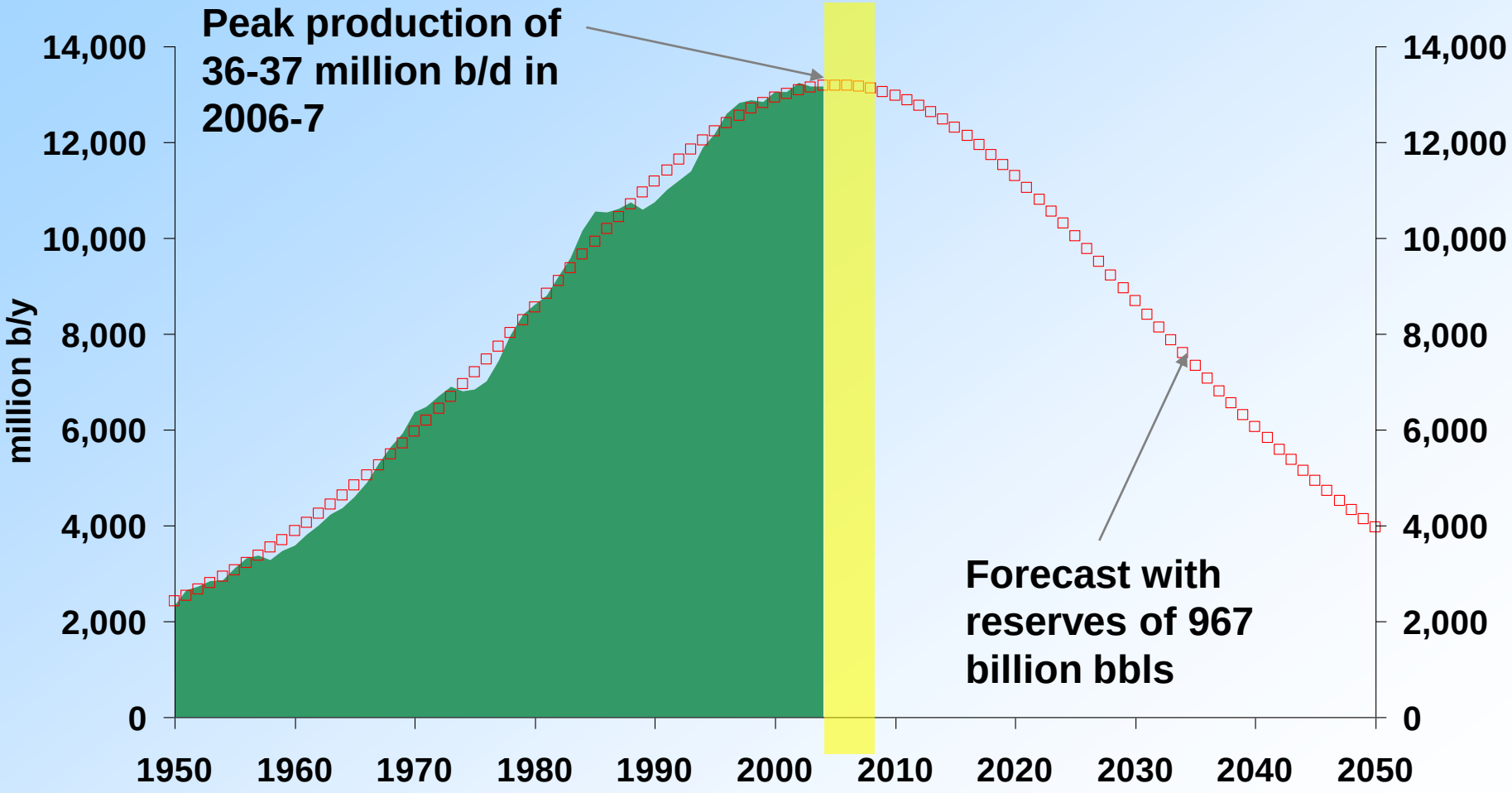
Oil reserves depend on geology…
but also on cost, technology and oil price



First shock - Non-OPEC without the FSU



Published remaining reserves = 176 billion bbls

BP Statistical Review of World Energy, 2005

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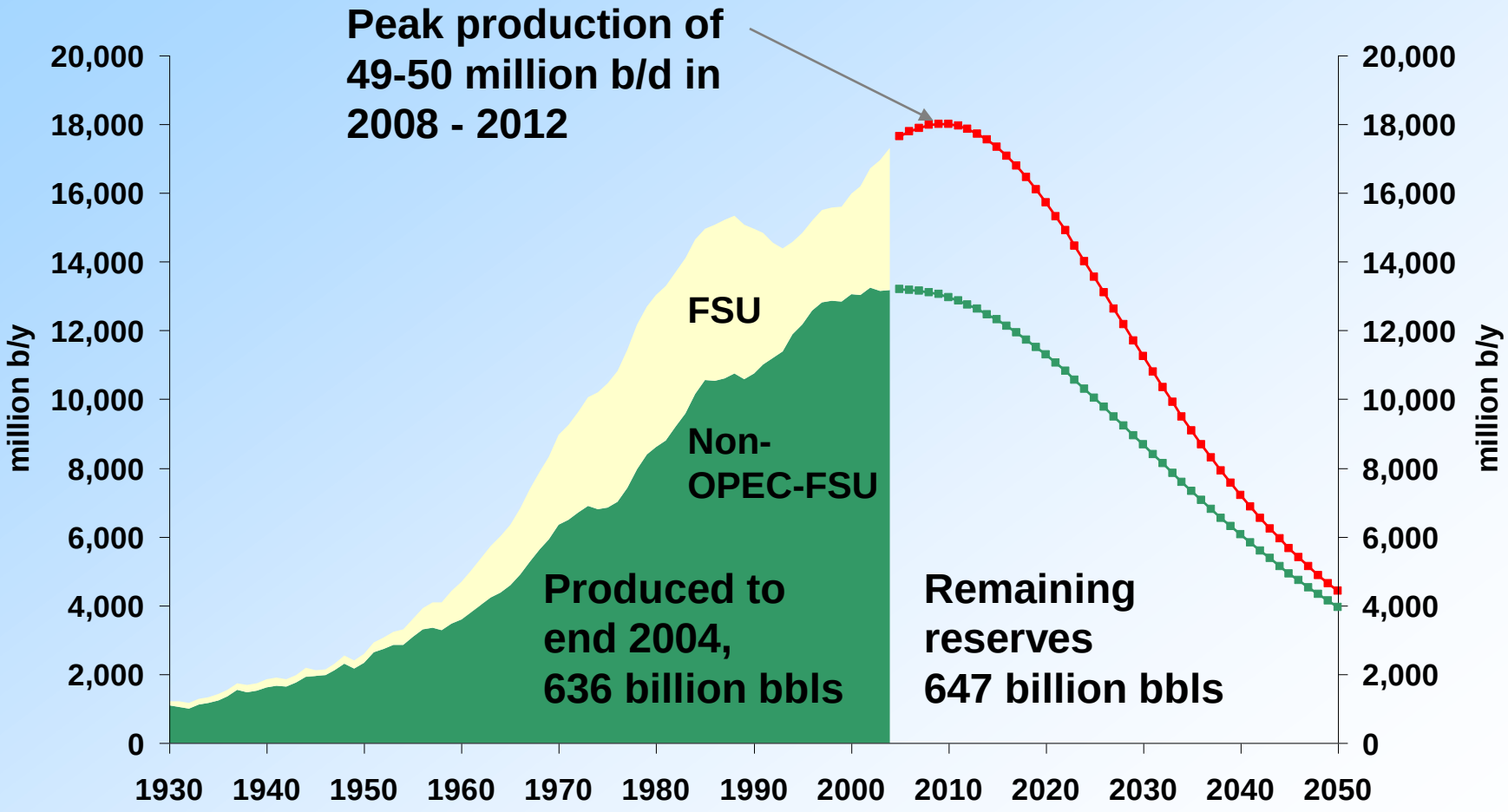
Second shock - Non-OPEC



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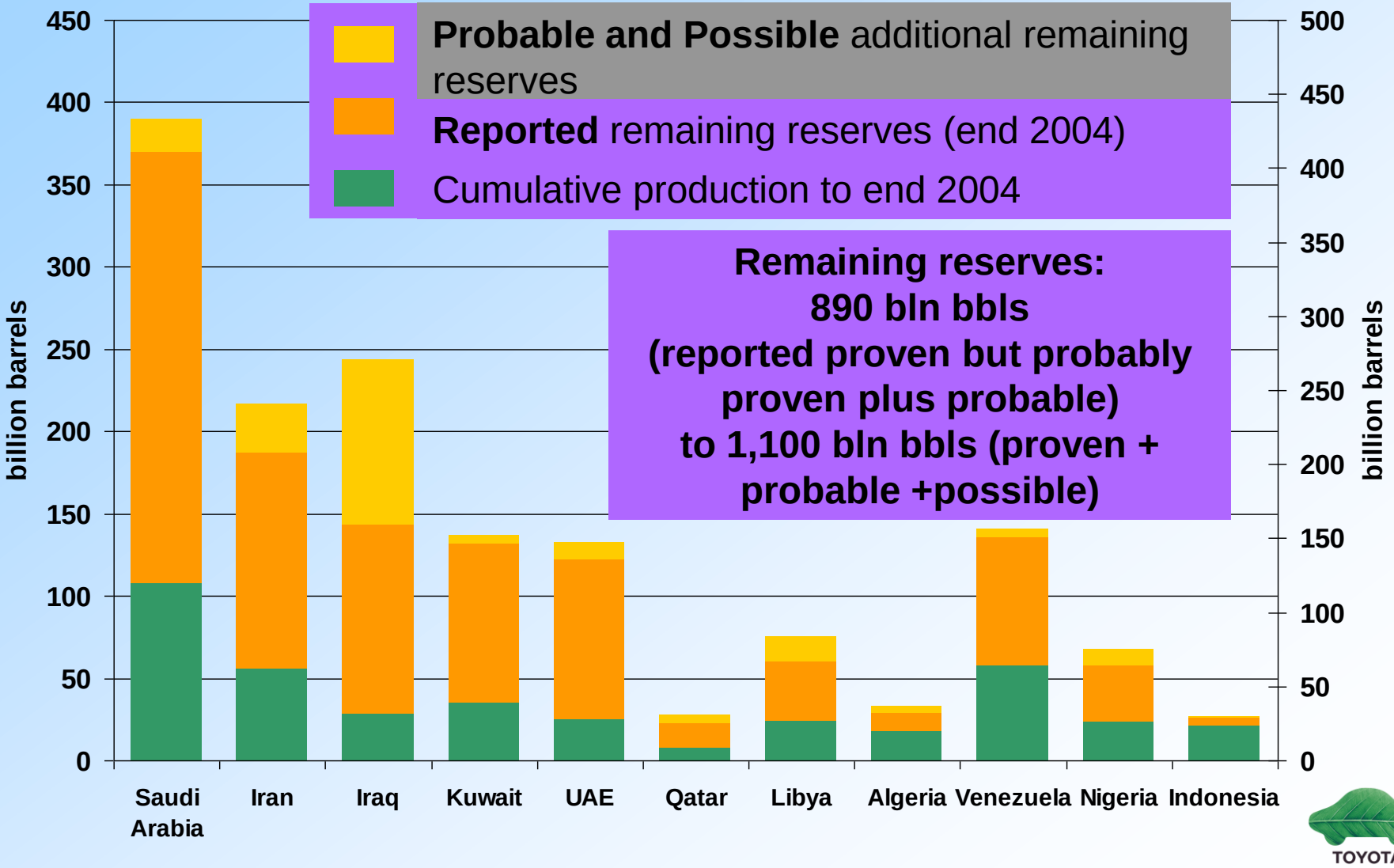
Can OPEC Deliver?



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Five Persian Gulf producers: Saudi Arabia, Iran, Iraq, Kuwait and the UAE

In 2004, Persian Gulf 5 supplied 25% of world oil production, ~20 million bbls

(current rate)	Long term (>10 years) sustainable rate million b/d	Maximum rate for a 5-10 year period (before 2020) million b/d
Saudi Arabia (10)	9 - 12	12 - 14
Iran (4)	4 - 5	6 - 8
Iraq (1.5)	**6 - 8**	**8 - 10**
Kuwait (2.1)	3 - 4	4 - 5
UAE (2.6)	3 - 4	4 - 5
TOTAL (20.2)	**25 - 33**	**34 - 42**

More than HALF the increase in production must come from Iraq

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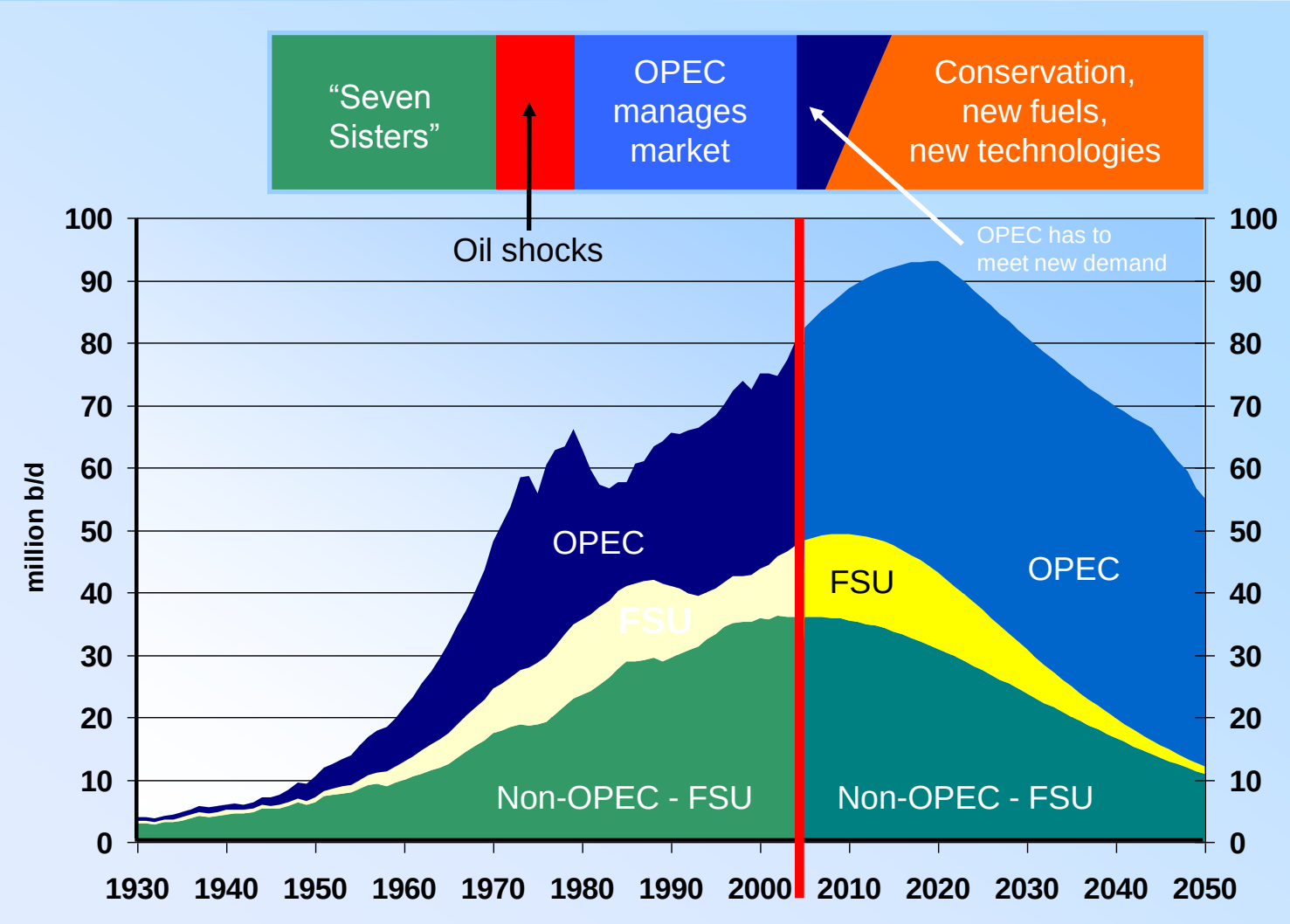
Total Oil Picture



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Consequences? – Oil Price…

We are NOT running out of oil but the tank is nearly half empty

IF demand moderates and OPEC expands capacity (Iraq is the key unknown) :-

- the oil price may decline between now and 2010 (when non-OPEC peaks), but will rise thereafter to new highs
- non-conventional oil, alternative fuels and conservation have time to develop

IF demand does not moderate OR OPEC fails to expand capacity fast enough (failure in Iraq):

- rising and volatile prices are likely to be accompanied by global economic and political instability
- time will be short to develop alternatives and foster conservation

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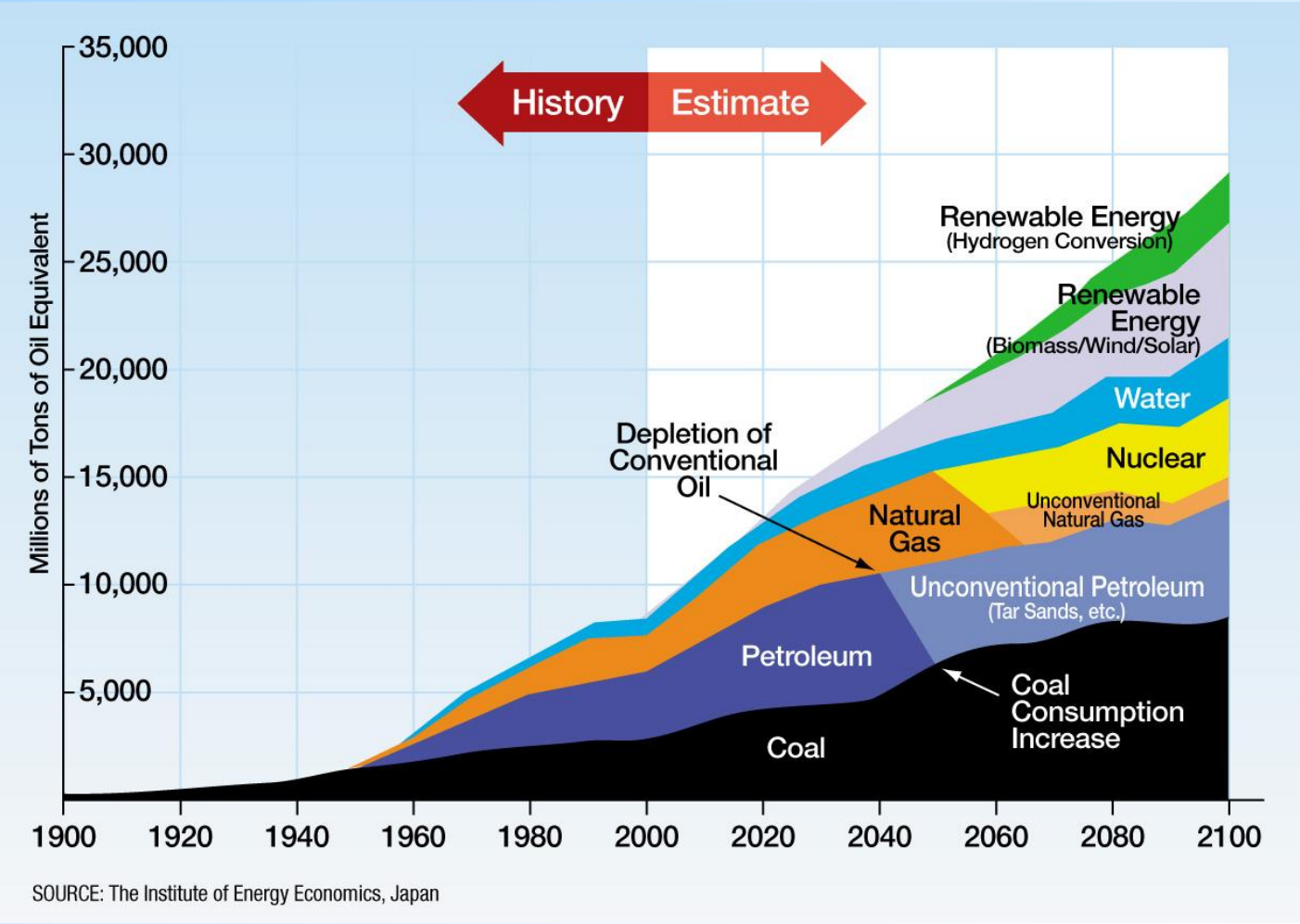
Energy Diversification



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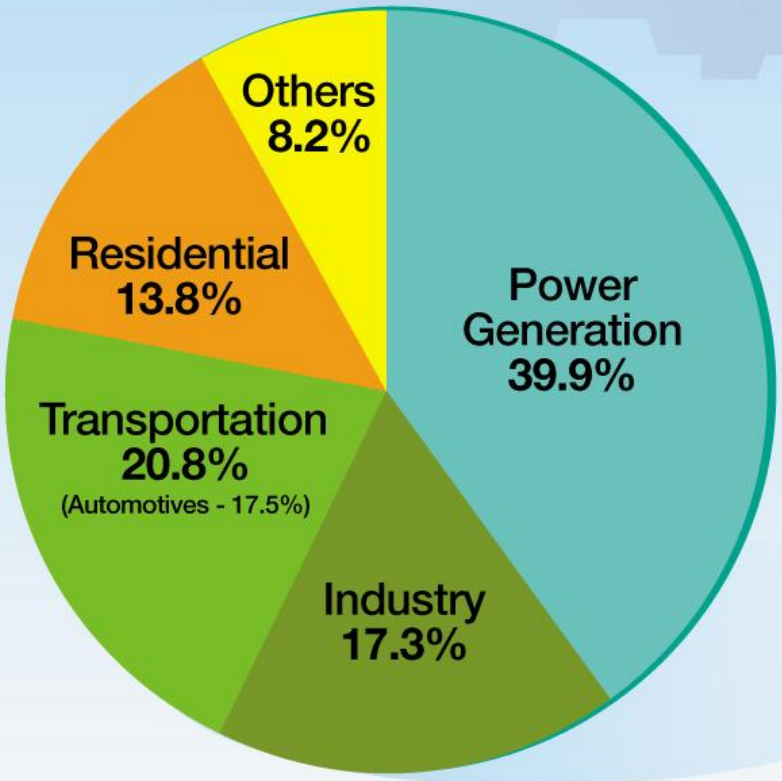
Breakdown of CO_2 Emissions



World CO_2 emissions arising from fuel combustion by sector

Total CO_2 Emissions:
23.6 billion tons

SOURCE: "IEA CO_2 Emissions From Fuel Combustion" (2004 Edition)

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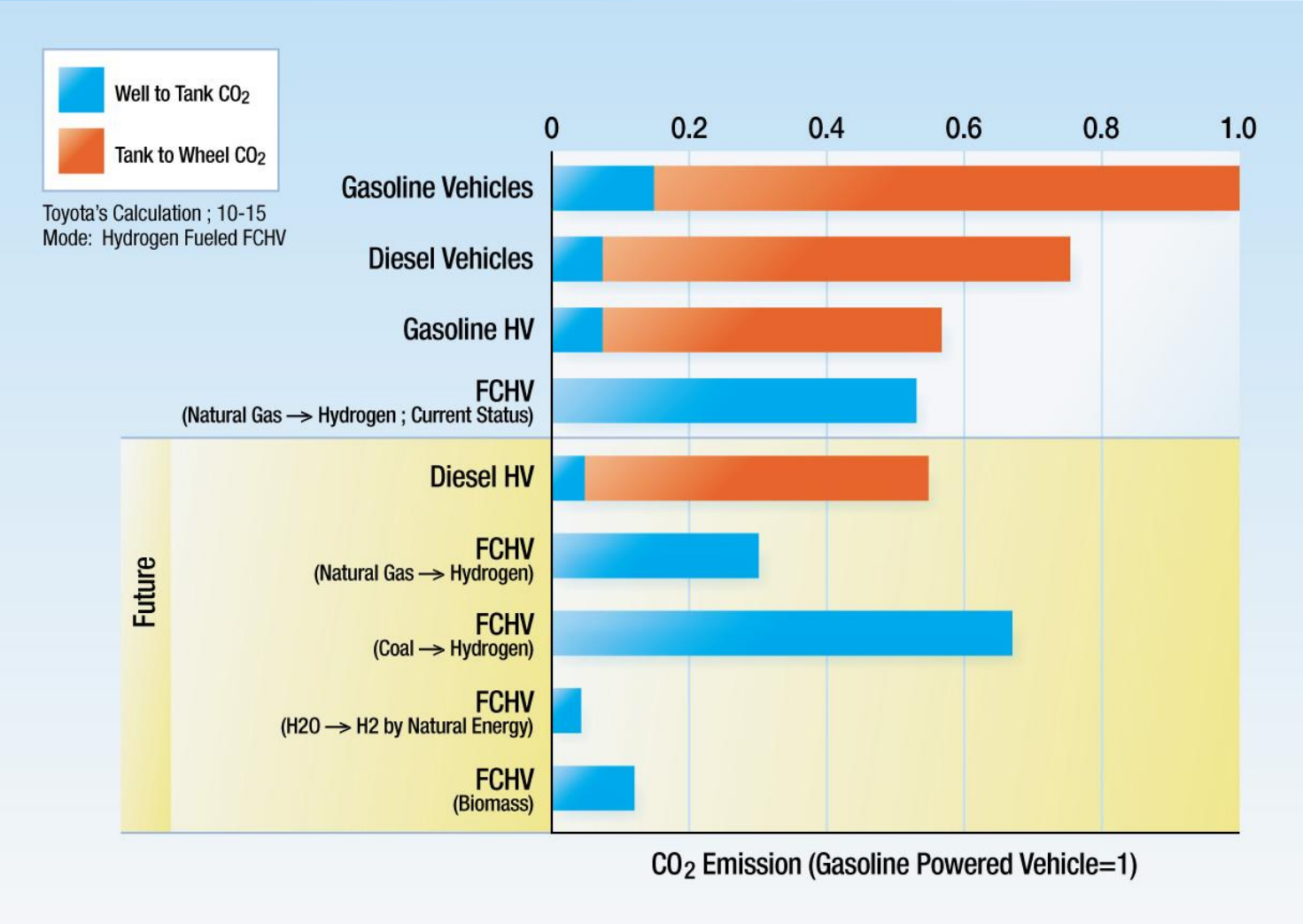
Well-to-Wheel CO_2 Emissions



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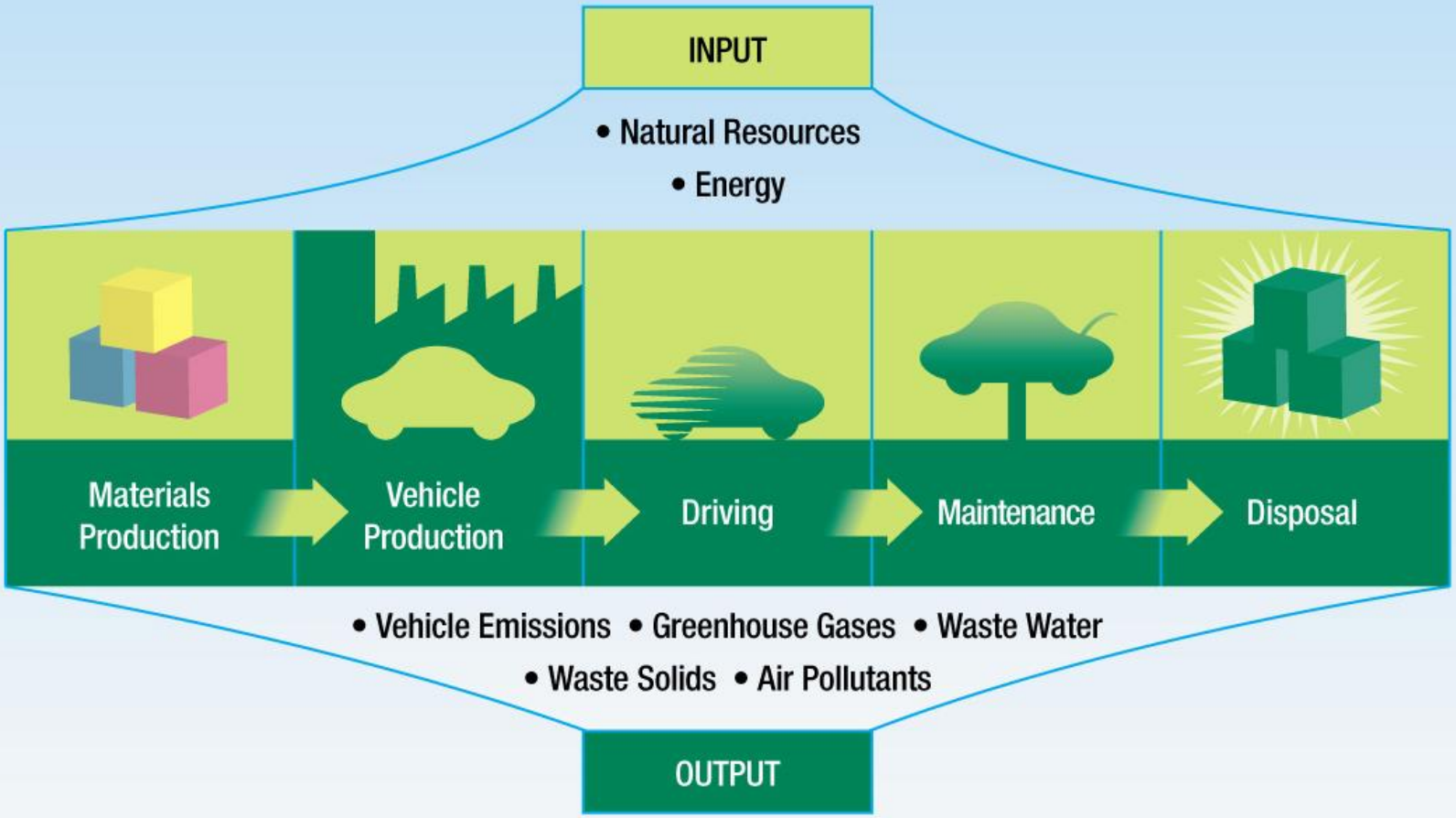
Life Cycle Assessment and Air Quality



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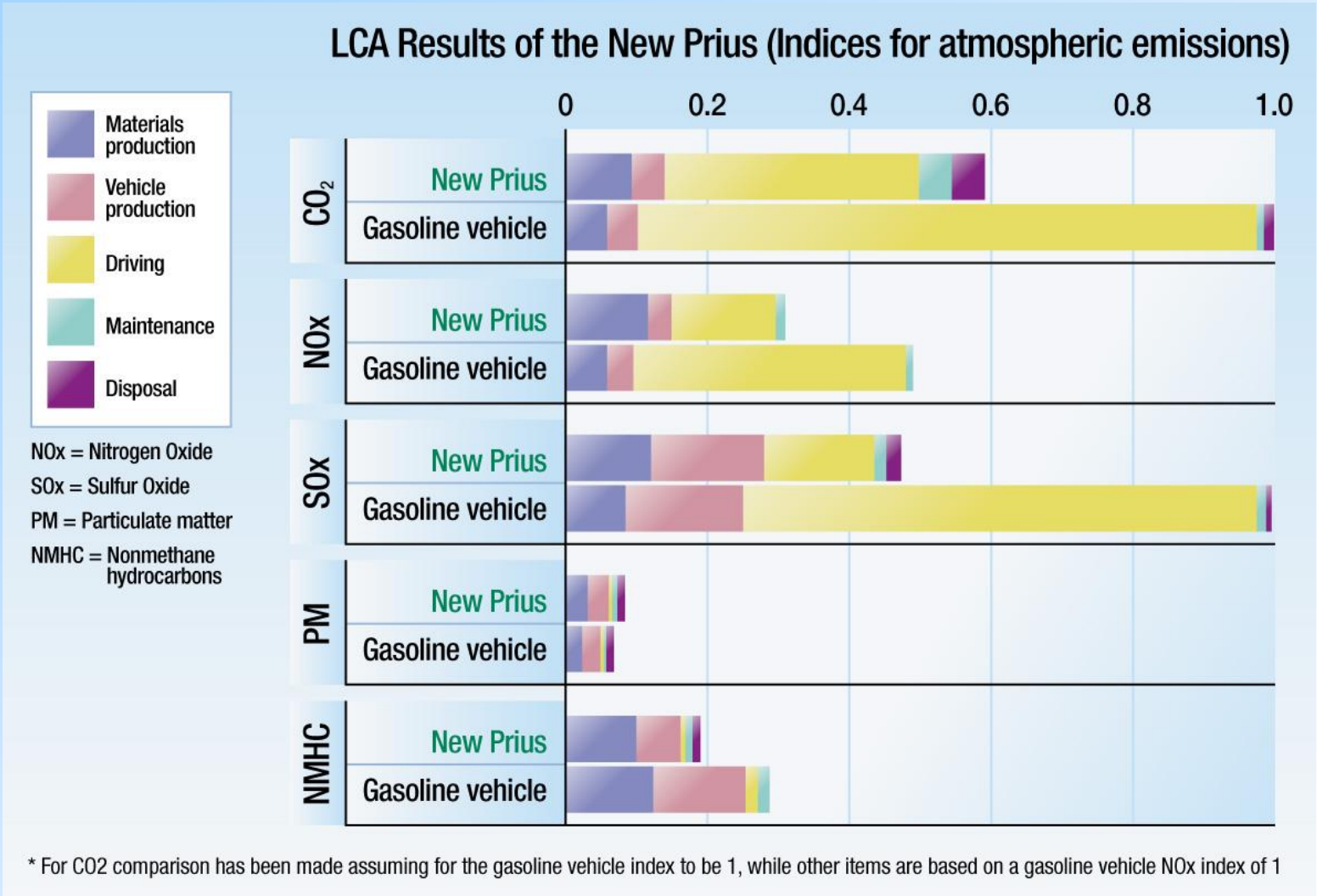
Prius LCA and Air Quality



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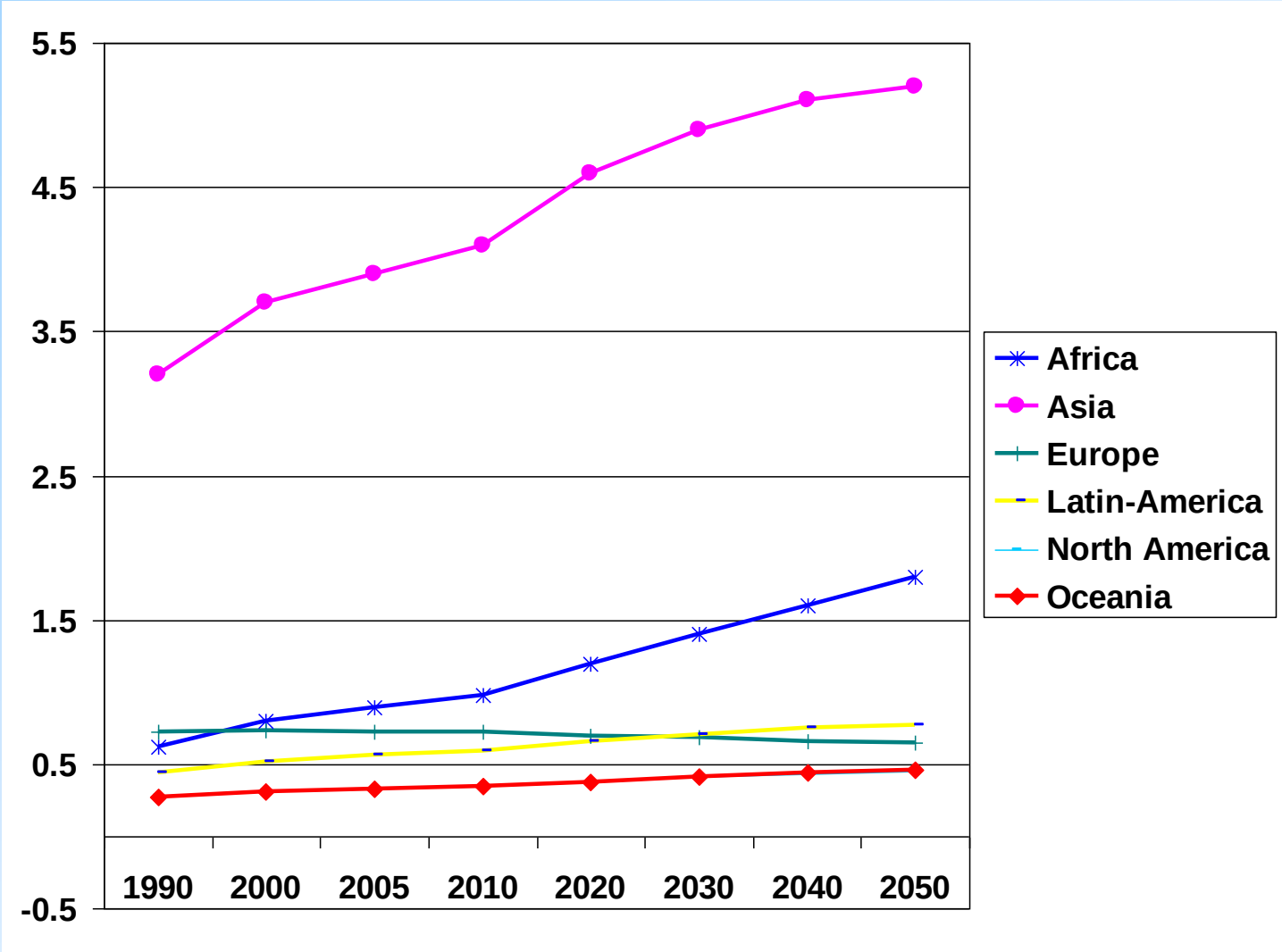
World Population Growth and Urban Congestion



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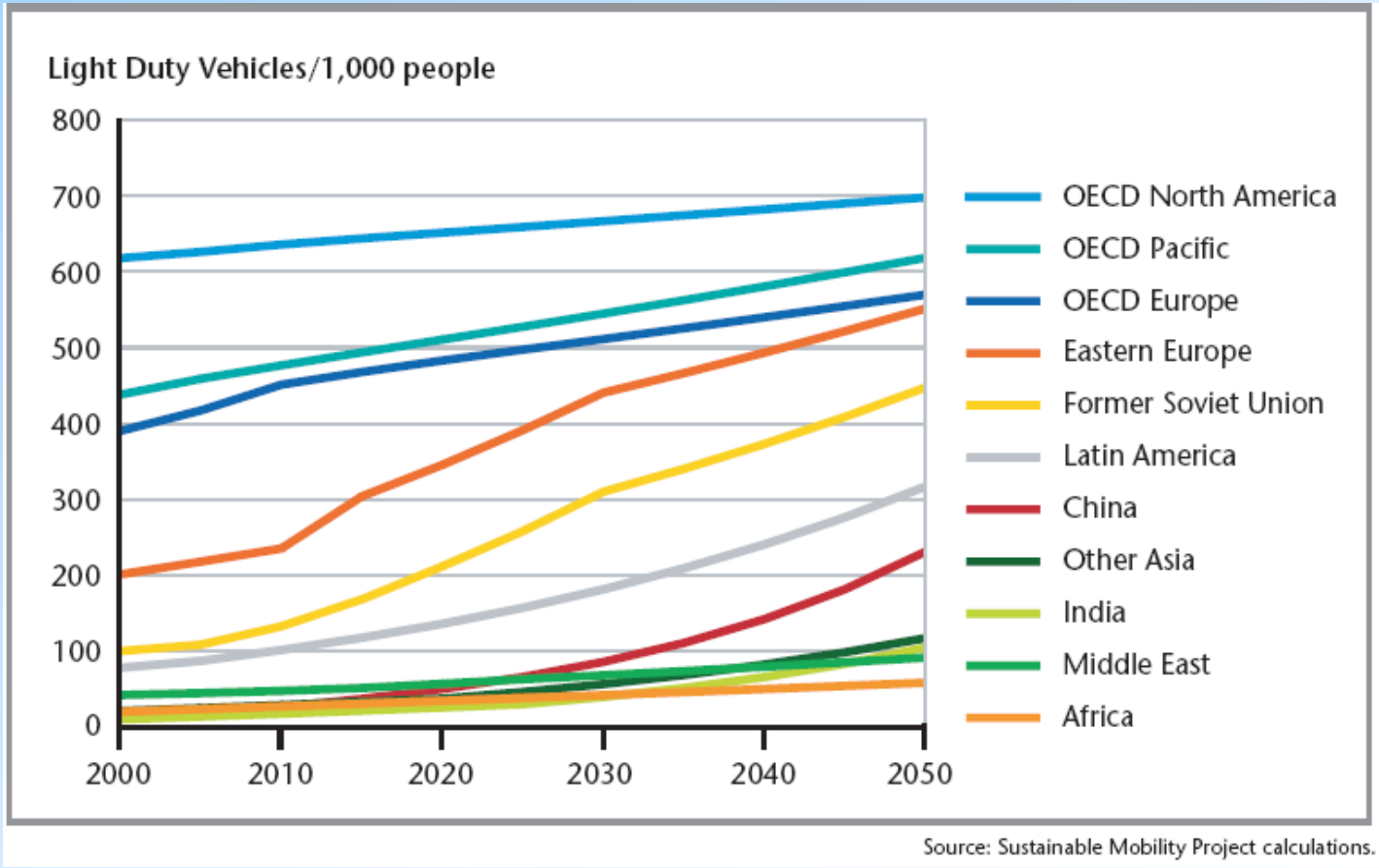
Growth in Vehicle Ownership and Urban Congestion



Source: Sustainable Mobility Project calculations.

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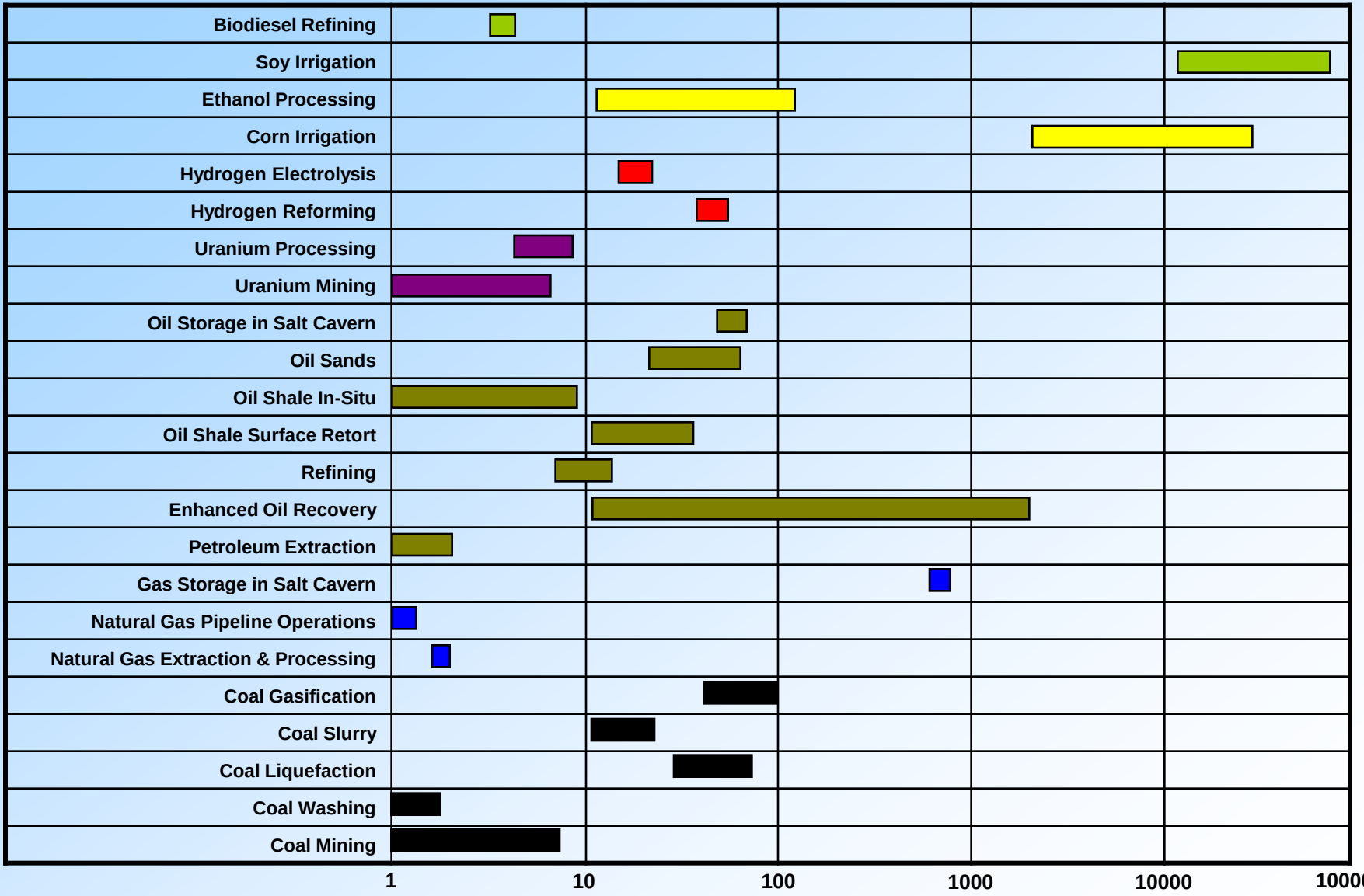
Energy Use and Water Requirements



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Toyota's Basic Philosophy

Do what we can
"today for tomorrow."

Develop innovative technologies
for the future

while continuously improving the
mainstream technologies of today.

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Solutions—Toyota's Approach

1. Balance reduction of environmental impact with meeting Consumer Wants

2. Mass market appeal

3. Life Cycle Assessment

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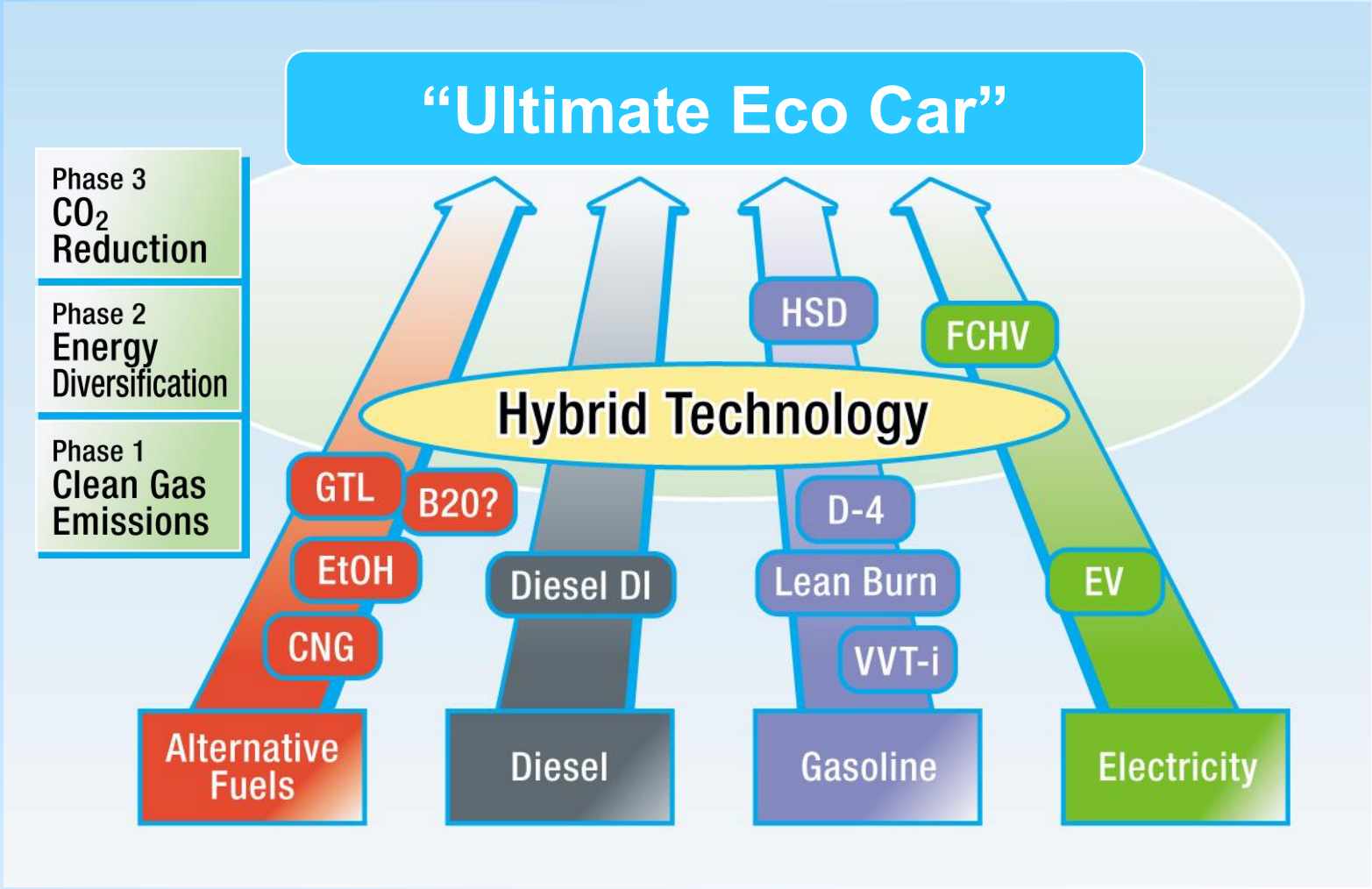
Toyota's Approach



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Prius Development

	1998-2000*	2001-2003	2004-
City Label Fuel Economy	43	52	60
Highway Label Fuel Economy	41	45	51
Combined Label Fuel Economy	42	48	55
0 - 60 Acceleration	14.5	12.5	10.5
Emissions	LEV	SULEV	AT-PZEV
Size Class	Sub-Compact	Compact	Mid-Size

*Japan only

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Challenges for New Technologies

Most customers are unwilling to accept compromises for the sake of new technology

New automotive technologies must be

- Transparent to the user
- Reliable and durable as present vehicles
- Offer consistent performance
- Offer benefits to most users
- Detriments to few

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Plug-ins Defined

A Plug-in Hybrid Electric Vehicle (PHEV) is a hybrid gasoline-electric vehicle

with greater battery capacity (than a “regular” gas-electric hybrid),

in which the battery can be directly charged from an external power source

- “Plugged in,” vs. passive charging from the engine
- May have the capability of driving in electric-only mode.
- Also called “Grid-connected hybrid”
  - often refers to the vehicle providing power back to the grid

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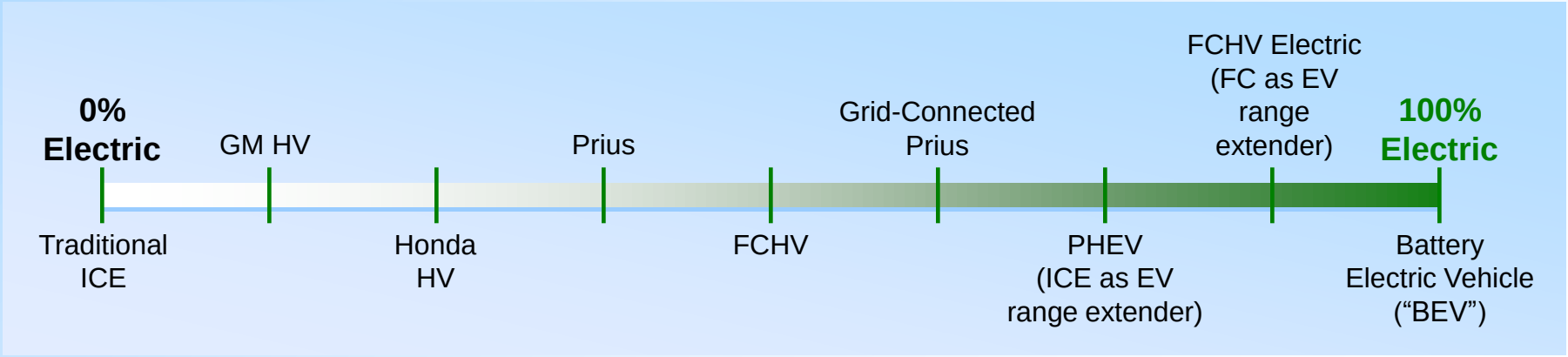
Types of Plug-ins

There are many variations on the PHEV idea

- Different battery sizes
- Degree of ICE involvement
- All Electric Range (AER) vs. Blended Strategy



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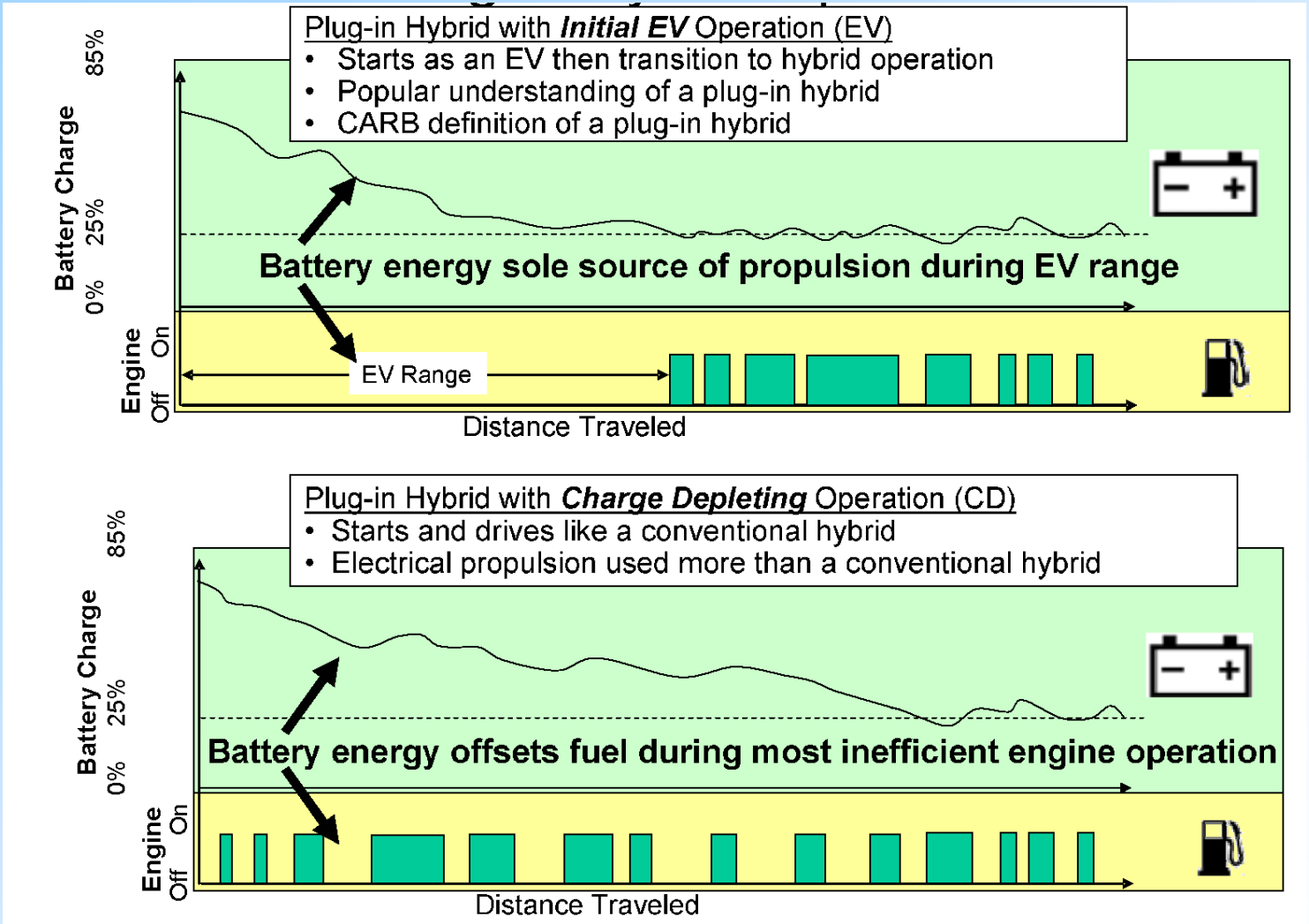
PHEV Types



AER

- Volt
- Hy-Series
- Prius Conversions

Blended

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Powertrain Comparison

PHEV

		Gasoline	Diesel	HV	EV	FC
Primary Issues	Energy Diversity	△	△	○	◎	◎
	CO2	×～△	△～○	○	◎	◎
	Emissions	○	×→△	○	◎	◎
others	Single Fill Range	○	○	◎	×	○
	Infrastructure	○	○	○	×	××
	Fuel cost	△	△	○	◎	?

Must understand how PHEVs fit in

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Plug-ins change the source of the emissions

Unless the electricity used to charge the battery comes from a renewable source (e.g. wind, solar),

plug-ins trade off tailpipe emissions for emissions at the power plant.

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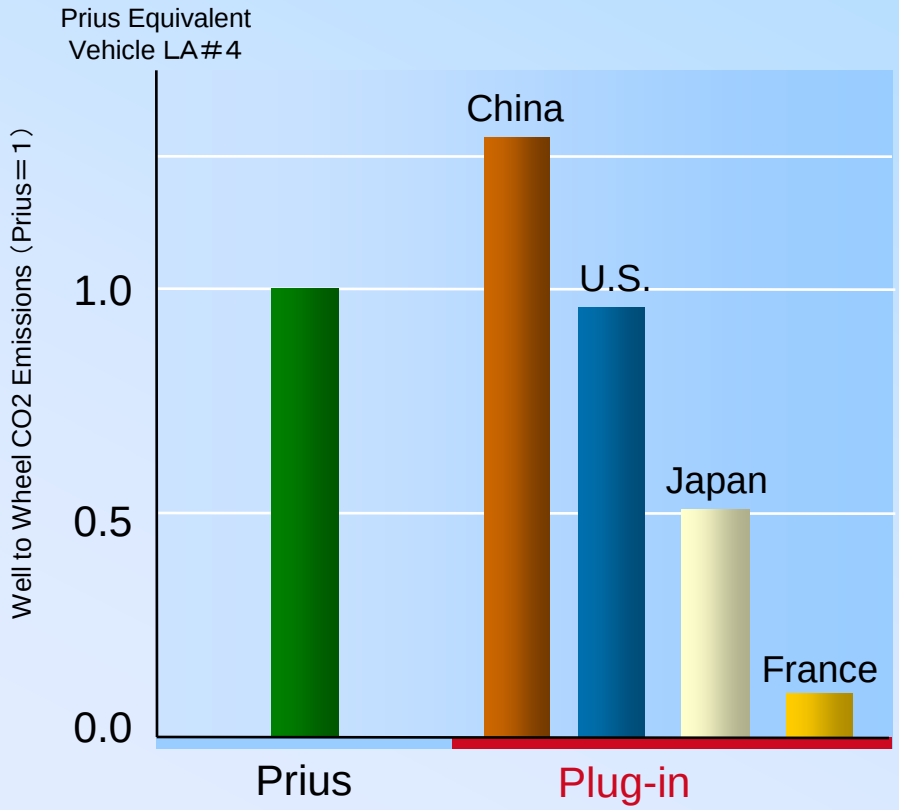
CO_2 Reduction

When electricity is generated from low-carbon sources, the CO_2 emissions of a PHV are lower than an HV



The advantage is big in France where nuclear power generation is common. There is no advantage in China, which mainly uses coal-fired power plants.

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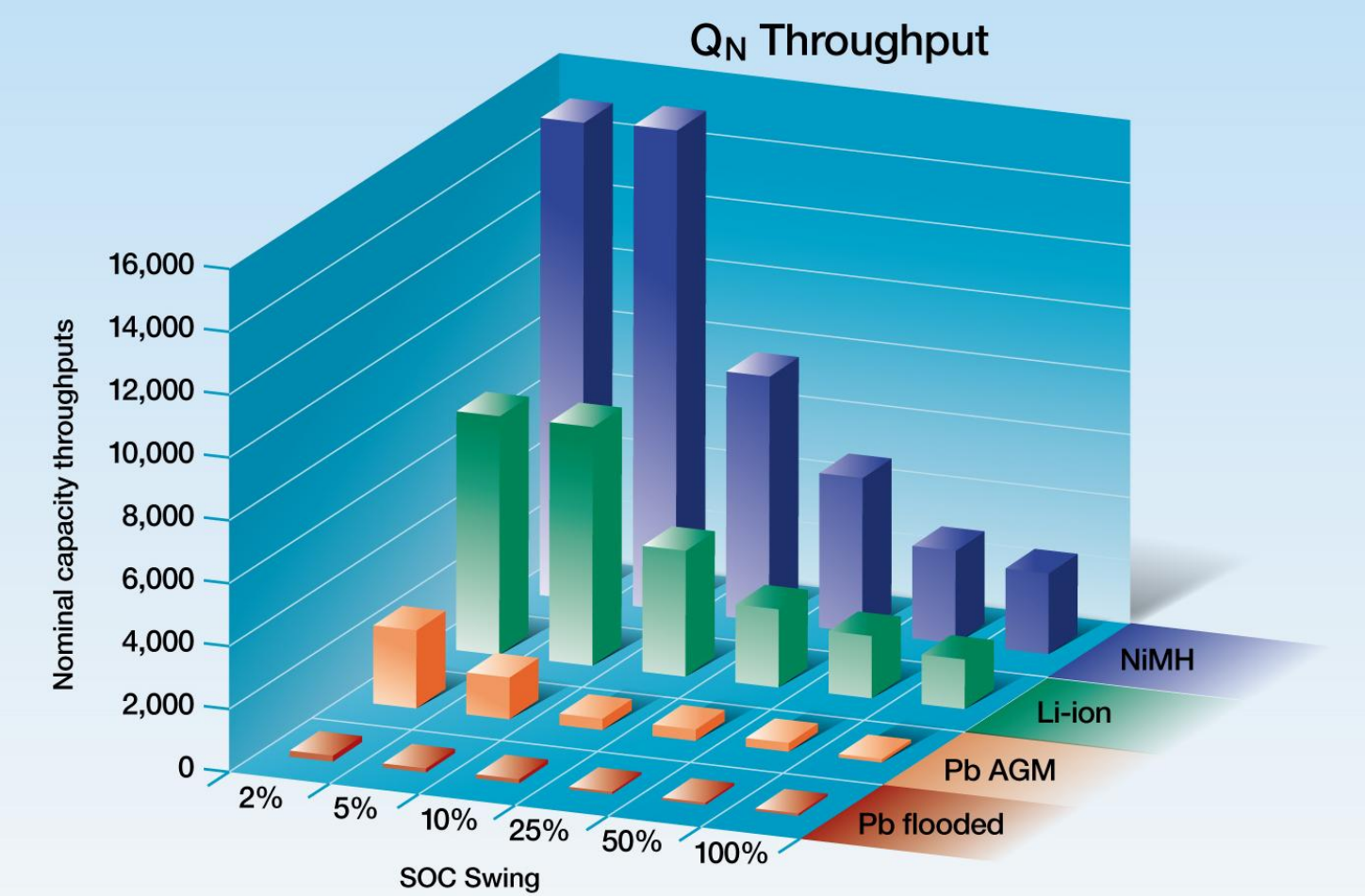
Battery Life vs. Charge Cycle



SOURCE: Christian Rosenkranz (VARTA) "Plug-in Hybrid Batteries" EPRI Workshop at EVS20

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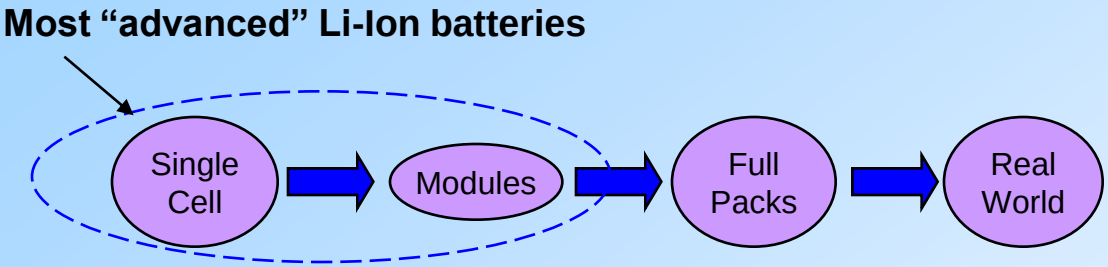
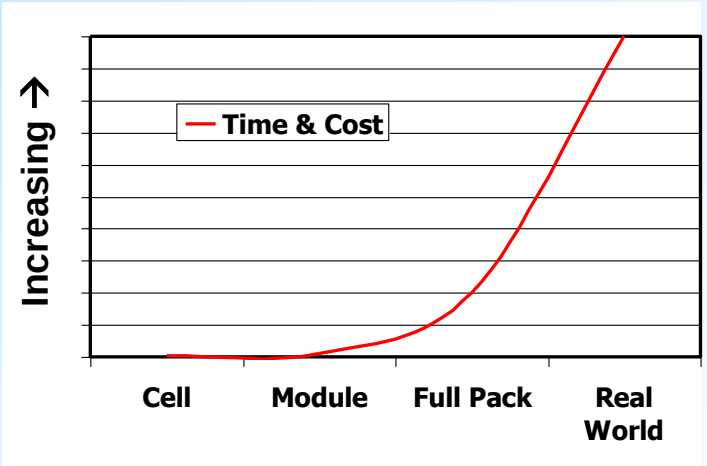
Li Ion Battery Technology – Development and Testing





- Limited “real world” knowledge in vehicle application
  - Toyota has experience with mild hybrid Vitz
  - Limited number of conversions and specialty vehicles
- Must gain experience with Li-Ion technology in HEV before PHEV
- Key issues to be resolved
  - Safety
  - Durability (Life of vehicle) & reliability (≥NiMH)
  - Cost
  - End of life recycling

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State of Battery Technology

Dr. Anderman's Senate Testimony – 01/26/07

President of Advanced Automotive Batteries

"It is our opinion that wide–spread commercialization of plug-in hybrids with the range of 20 miles or more is only possible if there is notable improvement in battery performance, proven battery longevity and reliability in well-designed lab and field tests … along with a significant reduction in battery cost."

It is also our opinion that as far as electric drive … technology is concerned, conventional HEV technology is the only one mature enough for its market growth to have an impact on the nation's energy usage in the next 10 years."

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For Commercialization, PHEVs need . . .

- Significant battery development
- An official test cycle
  - Industry Govt. and regulatory consensus
- Standardized infrastructure
- Govt. and industry support

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Conclusions

- Geopolitics surrounding remaining oil supplies will increase focus on energy security
- Climate change solutions will fight for “shelf space” with energy security and land use issues
- Decreased water supplies due to prolonged drought and contamination are a more near term threat than impacts from climate change
- Focus should be on most profound issues first
- Societal preparation for greatly increased energy costs is key for carbon reduction plans

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