THE TRANSPORTATION SECTOR: GROWING DEMAND AND EMISSIONS

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ABSTRACT

The paper reviews current and historical energy demand for transportation at the global and world regional level and discusses its underlying structure and trends in goods and (long-distance and short-distance) passenger transport. Various scenarios for transportation energy demand over the next decades are reviewed and analyzed with respect to the relationship between population growth and transport energy demand. The paper concludes that the relationship is rather weak if analyzed at the appropriate level of disaggregation. The range of scenarios analyzed indicates flat, even negative growth of transport energy demand in the OECD countries and growth between a factor two to three in developing countries. With persistent urban/rural income inequalities most of this growth will occur in urban areas, compounding already existing problems of congestion and urban air quality. Consequently, the latter is seen as a more immediate resource constraint than availability of crude oil resources to accommodate possible demand growth for transportation in the median range of scenarios of 800 Mtoe over the next three decades.

INTRODUCTION

The purpose of this paper is to sketch out some historical developments in the transport sector and to discuss a number of scenarios of its future evolution with special emphasis on the role of population growth and its impacts on natural resources. The transport sector is of particular interest for two reasons: First, global transportation energy demand is the fastest growing end-use category,

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[1] Paper presented at the Seminar on Population and Natural Resources, TERI, New Delhi, September 30 & October 1, 1993.

and has proven quite inelastic in response to the energy price increases that prevailed in the 1970s and early 1980s. Secondly, it is the sector where the impact of population growth on natural resource consumption and resulting environmental pollution is perhaps the most indirect of all energy demand categories. Access to, and ways of utilization of transport modes and associated technologies instead are the key variables determining levels of resource consumption and environmental impacts.

Exhibit 1 summarizes 1990 (commercial) energy demand by sector and by broad geographical/socio-economic world region as well as some dynamics since 1971. Currently, transportation accounts for about one quarter of commercial energy consumption worldwide, and for some 43 percent of oil consumption. At face value this consumption, especially when compared to known reserves of crude oil or even to potential geological resources, does not suggest that Malthusian resource limits are likely to materialize well beyond the middle of the next century.

This situation might change however, should some projected scenarios materialize. For instance, the recent global energy scenario developed by Greenpeace (Lazarus et al., 1993) discusses also a baseline transportation scenario in which the current number of 700 million road vehicles (cars, motorcycles and trucks) would grow to some 5 billion[2] by the end of the 21st century. Even considering efficiency improvements this would translate into a demand growth of a factor 3 to 4. Transportation alone could require in such a scenario up to 50 percent more than the present total oil consumption worldwide.

TWO DECADES OF TRANSPORTATION ENERGY DEMAND

Perhaps the most notable dynamic trend emerging from Exhibit 1 is the dominance of transportation energy consumption increases in total demand growth in the OECD countries. Around two thirds of additional energy demand

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[2] One may note however, that the objective of this baseline scenario might exactly have been to highlight the undesirability of such a high scenario. Alternative approaches indicate that developing countries may not follow the same development path of growing individual mobility based on private cars, or at least not at a comparable intensity level. For such a "saturation" scenario see e.g. Grübler and Nakicenovic, 1991, and Grübler et al., 1992.

growth over the last twenty years derived from increases in mobility. Conversely, transportation demand growth while being significant in both absolute and percentage terms, accounted typically only for around 15% of additional energy demand in reforming and developing economies. Considering the differences in population growth this allows us to draw already a first conclusion: increases in per capita consumption levels were a more powerful influencing variable than population growth proper.

Based on the data presented in Exhibit 1, per capita energy consumption for mobility of goods and people varies from around 70 kgoe in developing countries to some 1900 kgoe in North America, i.e. nearly by a factor of 30. Looking across different income levels and individual lifestyles, these disparities are likely to be even higher. It has to be emphasized that such disparities not only exist between different countries but also **within** countries. Transportation energy demand differences between urban elites and subsistence level rural farmers in developing countries will be much larger than differences between income groups within their national capital or even between cities in different countries, as large as they are.

Thus, the situation with respect to transport energy demand and its resulting implications on resource consumption and the environment is quite heterogeneous. Significant disparities in levels of economic activity and its materials and transport intensiveness, access to motorized individual mobility, modal split choices, distances travelled and energy efficiency of transport technologies among other factors have to be considered. A further complication is the absence of reliable statistics linking transportation energy demand to transport activities. In fact energy statistics concentrate on a detailed account of products subject to market transactions and are usually "blind" to the different uses a product (such as a liter of diesel) can serve (in a passenger car, in a truck, etc.). Conversely, transportation statistics and mobility surveys focus on level and structure of transportation services (such as ton- or passenger-kilometers or number of trips) without collecting information how these actually translate into final energy demand. The missing elements include information on load factors (e.g. passengers per car) and the energy or fuel efficiency of the technological devices used to render a particular transportation service among others.

Goods Transportation

Based on estimates developed at IIASA (Nakićenović et al., 1993, Messner and Strubegger, 1991) global transportation energy consumption can be roughly subdivided into 60 percent for passenger travel, and 40 percent for movement of goods. In the materials and energy intensive economies of Central and Eastern Europe and the former USSR this ratio is inverse: 60 percent of transport energy serves for goods transport and only 40 percent for passenger mobility. Differences are the result of many factors: structure and level of economic activities, size of the country and the spatial division of production and consumption, international trade, etc., determine the amount of transportation services (ton-km) for an economy. Choice of different transport modes, their relative energy efficiency and capacity utilization in turn determine the amount of energy required to deliver the service demand.

Exhibit 2 shows estimates of total ton-km freight transported for a number of countries as a function of the size of the economy. Whereas the positive correlation comes at no surprise, it is nevertheless noteworthy to note persistent differences even between countries of similar size of economic activities and area (e.g. between India and China, or the USA in 1960 and the former USSR in 1980). Moreover, the correlation between economic activity and goods transport is not a one to one proportional one. With increasing degree of economic development, GNP growth requires fewer additional ton-km, due to changes in output mix and a shift towards more advanced, light-weight materials, i.e. **dematerialization.**

Counterbalancing effects for energy consumption come from changes in the goods transport modal split away from rail and inland navigation (low value, bulk commodities) to trucks, even aircraft. Schipper and Meyers (1992) have analyzed resulting changes in the goods transport energy intensity of a number of OECD countries concluding that with the exception of West Germany and the UK modal split changes (changes in structure) have outweighed declines in the transport intensity of OECD economies (Exhibit 3). As a result, goods transport energy demand in the eight OECD countries analyzed has grown by 41 percent over the 1973-1988 period, whereas ton-km have grown only by 31 percent.

Passenger Transportation

The relationship between energy demand and passenger transport service requirements is even more intricate than for goods transport. The main reason is the diversity of human activities resulting in mobility and the complex nexus of values, preferences and resulting lifestyle variables influencing mobility levels, and in particular which transport modes are chosen and how they are used. This can perhaps be best illustrated by analyzing the different reasons for individual mobility as done in Exhibit 4 for the US, one of the countries with the highest mobility[3] levels. Based on the detailed Nation-wide Personal Transportation Survey the US population travelled some 6.7 trillion passenger-km in 1990, or some 26,900 km per capita and year. It is perhaps surprising to note that less than 18 percent of all passenger-km are associated with commuting to and from the workplace, whereas some 44 percent are associated with household and childcare business. In 1990 nearly 2.5 trillion passenger-km were travelled in the US for leisure purposes including vacations, seeing friends, and other social and recreational activities. This exceeds for example the total mobility level of the former USSR, a country with comparable geographical and population size. Parenthetically, we may note also that the trips for which respondents to the survey could not give any other reason than "to go for a ride" resulted in some 55 billion passenger-km, exceeding the total mobility of the Norwegian population.

About half of the passenger-km travelled in the US are over short and medium distances, the other half long-distance. The situation in other OECD countries is similar (Grübler, 1990). For the OECD countries the bulk of long-distance passenger transport is covered by automobiles and aircraft, with bus

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[3] Walking and bicycling are excluded as no data are available. In addition, in terms of passenger-km (not in terms of number of trips) their contribution will be quite small (less than 5 percent of motorized mobility).

and rail accounting for the remainder. Over time, public transport like railways or buses have lost out to cars and air travel (Exhibit 5), implying that modal split changes have favored faster more energy intensive transport modes. It is interesting to note that similar tendencies can also be observed for reforming and developing economies as shown in Exhibit 6 for the former USSR and China (with some lagged developments). The main difference to the OECD countries --apart from lower levels of per capita long-distance mobility-- is that instead of the dominant role of the private automobile, collective road transport (buses) account increasingly for the bulk of long-distance mobility.

This dichotomy in modal split choices is mirrored also in the ways individual mobility is satisfied over shorter distances, primarily in urban areas (Exhibit 7). On one extreme, more than 4 Million cars were registered in the city of Los Angeles in the mid-1980s (over 1.6 cars per inhabitant), with car densities in Dallas being of similar magnitude. In such "automobile cities", the market niche for public transportation is obviously rather small. Conversely, low car densities such as in Beijing or Hongkong do not imply necessarily lower levels of mobility, but rather that public transport modes (metros, trams, buses, and rapid rail systems) are used instead. Such differences are not the result of differences in income alone. Surveys of car ownership rates of households as a function of income indicate decisive differences between cities (Exhibit 8). Hence, transport policies, infrastructure availability, and urban form make a large difference in urban modal split choices.

Mobility in urban areas is of particular interest, because cities tend to focus both the functional and environmental problems inherent to transportation. Limits of space and high densities of land-intensive individual transport modes (cars) result in congestion: a breakdown of the functional capabilities of transport systems to fulfill their very role: moving people.

Because of high population density and resulting concentration of trips yet another constraint becomes most visible in cities: the limited capacity of the environment to assimilate emissions. Even cities where most cars are already equipped with catalytic converters (like Los Angeles) are notoriously plagued by smog. Cities of developing countries share the problems of traffic congested cities in the OECD countries, and have additional problems of their own (Exhibit 9). Some environmental problems which were tackled already successfully in many OECD countries such as lead poisoning persist, specific emissions per vehicle are larger due to absence of control technologies, greater age of vehicles, and poor maintenance. Finally, and perhaps most important of all, capital shortages constrain heavily the investment intensive upgrading of infrastructures and the construction of efficient mass transit systems.

Thus, the overall conclusion of our discussion of current patterns of transport energy demand and their recent evolution indicates that limits of functionality and environment may have been reached already in many large cities. Additional demand growth due to the joint effects of population growth and rising incomes will therefore face constraints of available space, congestion, and local environmental quality much earlier than any physical "running out" of crude oil reserves and resources.

FUTURE TRANSPORT ENERGY DEMAND SCENARIOS

What is the current perception about possible future evolution of transportation energy demand and resulting environmental impacts? Comparisons are to some degree difficult as only few scenarios are sufficiently disaggregated to allow a more detailed analysis, especially at the world regional level. Among the scenarios discussed here are: EPA's (1990) RCW (Rapidly Changing World) and SCW (Slowly Changing World) scenarios, Greenpeace's Fossil Free Energy System (FFES) scenario (Lazarus et al., 1993), two variants (A and B) of SHELL's 1989 scenarios (Holmes, 1991, and SHELL, 1990), and the ECS'92 scenario developed at IIASA (Nakićenović et al., 1993). For comparison, the global transport scenario of the IPCC-EIS (Energy and Industry Subgroup of IPCC, EIS, 1990) is also discussed. It is important to recall here that scenarios are not projections of what **will** happen in future, but rather what **could** (or is likely to) happen, given a set of circumstances, policies and absence of potential surprises. Scenarios may also entail normative elements (describing more desirable futures)[4], illustrating the effects of policy changes and variations in other salient input assumption of the scenario building exercise, without necessarily implying that these changes actually indeed will happen with a high probability.

At the global level transportation energy demand scenarios (Exhibit 10) can be regrouped into three categories: "middle of the road", high, and low. Common to them all (with the exception of the Greenpeace scenario) is the perception that observed trends in increases in mobility, modal split changes, and evolution of fuel efficiency of transport vehicles will continue in absence of radical changes in trends of socio-economic development and transportation policies. Such assumptions imply growth of global transportation energy demand at more or less similar (linear) rates as in the past two decades. However regional development patterns and resulting evolution of transportation energy demand will be quite different. Medium scenarios (e.g. the ECS'92 or EPA's SCW scenario) indicate possible growth of global transportation energy demand to some two billion toe (Btoe) by the year 2020. EPA's RCW scenario lies some 500 Mtoe higher. The IPCC Energy and Industry Subgroup (EIS) scenario is beyond even the range spanned by the RCW scenario, reaching some 3.5 Gtoe by 2025, apart from having apparent calibration problems for the base year data. On the other end of the spectrum are the lower variant of SHELL's 1989 scenario (B) and the Fossil Free Energy System (FFES) scenario of Greenpeace, leading to a saturation of 2030 transport energy demand at 1990 levels.

Yet more interesting than these global aggregates is to zoom down into the regional scenarios of transportation energy demand (Exhibit 11). Perhaps the two most interesting regions are North America and "developing countries" (i.e. non-OECD and countries outside the reforming economies of Central and Eastern Europe and the former USSR) as they portray two entirely different dynamic futures of transportation energy demand.

For North America in fact no scenario anticipates noticeable growth in transportation energy demand. Approaching saturation of car ownership rates

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[4] The FFES of Greenpeace in our interpretation is an example of such a normative type of scenario.

and continuation of historical improvements in car fuel efficiencies are the main rationale underlying such scenarios. The situation in other OECD countries is somehow similar: very flat demand growth (with exception of EPA-RCW) and even a possible decline in transportation energy demand. The apparent discrepancies between the scenario base year values is due to variations in the regional definitions for the OECD region outside US/North America between the scenarios.

The range of scenarios spanned for the OECD region as a whole indicates certainly a change in perception: despite vigorous demand growth in the past, historical trends are no longer extended further out into the future. In addition, differences in per capita transportation energy demand between OECD countries continue to persist in all scenarios, indicating a departure from the frequently assumed hypothesis of a homogenization of transportation patterns. This does of course not mean that surprises (at both the higher and lower end) may not materialize, but rather it indicates an increasing consensus that current patterns of mobility and resulting energy demand cannot continue to grow indefinitively. New technologies and new organizational forms for providing mobility of people and goods will be necessary in the long run to overcome the functional and environmental limits of present transport systems in the OECD countries.

For the transitional economies of Eastern Europe and the former USSR - despite the large uncertainties involved in their transition- there appears to be some agreement between different scenarios indicating demand growth to some 300 Mtoe by 2020. On the low end, the FFES scenario assumes stabilization at about current levels. On the high end, EPA-RCW implies demand growth in the region reaching close to 500 Mtoe by 2025.

Whereas the emerging scenario consensus for the OECD indicates forthcoming saturation of demand, there is also consensus that transportation energy demand in developing countries will increase substantially. It is interesting to note, that FFES, being for the industrialized countries systematically the lowest of the scenarios analyzed, is higher than both the EPA-SCW and the two SHELL cases. Both EPA-RCW and ECS'92 are the most optimistic with respect to future growth of mobility (or rather: with respect to economic development and resulting mobility increases) in the developing world. In view of current urbanization trends and concentration of incomes in urban agglomerations most of this increase in mobility will take place in cities. The perspective of a doubling of current (mostly urban) motorized mobility as in the Greenpeace scenario, or even a tripling as in the case of the EPA-RCW and ECS'92 scenarios certainly represents a huge challenge for urban transport and environmental policy in developing countries.[5]

Impact of Population Growth

Let us conclude this discussion of future transport scenarios with an analysis of their implications for the theme of this conference: population growth and resource use. To this end, we perform a simple decompositional analysis of the factors contributing to transport energy demand growth in terms of changes in levels of population and of changes in per capita consumption. Exhibit 12 presents an analysis of past trends per world region and for the world as a whole.

It is important to emphasize that the impact of population growth on resource consumption is primarily a function of the level of aggregation (cf. Lutz et al., 1993, for a more detailed discussion and examples). The higher the aggregation level, the higher the (hypothetical) impact of population growth. This because such an aggregation does not differentiate where children are born as opposed to where (per capita) energy demand growth occurs. In a nutshell, aggregates mask disparities: it is the poor that have more children and it is the poor that have low energy consumption. Equating thus more children from the poor with rising consumption of the rich can only lead to erroneous conclusions on the impact of population growth on resource use. This aggregation problem not only refers to comparisons between world regions, or between different countries but also between different social strata **within** countries. Thus, there is no relation between the population growth of the rural poor and the growth in energy consumption and motorized mobility of the urban elites in developing

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[5] For a comprehensive overview of transportation and other urban policy issues in large cities of the developing world cf. the reports of the UN megacities project (UN, 1986 to 1991). For a discussion of urban transport policy issues in Asia see AEI, 1993.

countries either, when discussing the nexus of population growth and the environment.[6]

Exhibit 12 provides a simple illustration of this aggregation problem. In looking at the world total, population growth between 1971 and 1990 would be equated to a transport energy demand increase of 350 Mtoe. Taking a disaggregated look at the four world regions, the impact of population growth adds up to some 188 Mtoe, or only 54 percent of the (inappropriate) global calculation. A further disaggregation would still further reduce the impact of population growth proper on transport energy requirements.

With these precautions in mind, let us conclude on the impact of population growth on transport energy use over the last two decades. Population growth mattered, ironically more in the "North" than in the "South". Holding 1971 per capita consumption constant, population growth (additional 50 million people) in North America resulted in some additional 87 Mtoe transportation energy demand, which is larger than the 60 Mtoe additional energy demand for some 1436 million additional people in all the developing countries taken together. Even more important however, is the fact that with exception of North America *per capita mobility increases mattered more than population growth in all regions* in the period considered.

This indicates that much of the discussion on the impact of population growth on resources is misleading. What matters more than sheer numbers are the economic and social conditions people live in and are born into. Levels of economic development, incomes, access to transport modes and lifestyles have much a larger impact on transport energy demand than population growth proper. A child born into a poor rural family is unlikely to consume a lot of oil for its individual mobility. Instead, its spatial activity range is likely to remain at the village level, where mobility is assured by the oldest of known transport technologies: walking on foot. Conversely, a child born into an affluent middle-class family (in Vienna and New Dehli alike) will enjoy an extended spatial activity range: in going by bus to a school chosen on preference rather than

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[6] Of course there are also environmental problems directly linked with population growth of the poor like overgrazing or deforestation.

neighborhood, going to vacations on the countryside or even abroad by car, or by air. Later on, it may enjoy even higher levels of individual mobility at work and at play through access to, or ownership of a scooter, or a private car.

Perceptions and anticipation of changes in the economic and social conditions people will live in influence future mobility and energy demand scenarios more than any projection of population growth. This can clearly be discerned by analyzing again via decompositional analysis scenarios of future transport energy demand (Exhibit 13).[7] The potential impact of population growth in the "North" remains considerable. However, due to the anticipated demand saturation and eventual decline, changes in per capita demand constitute the paramount influencing variable in the equation of the OECD. Compared to the historical experience (Exhibit 12 above) this indeed represents a major discontinuity. For developing countries the situation is almost paradoxical: the more pessimistic the scenario with respect to development and resulting increases in mobility, the higher the impact of population growth. But, as discussed above this result derives largely from the high level of aggregation of our analysis. If there is no or little development, the growing number of the poor are unlikely to be major contributors to the (comparatively low) transportation demand growth in developing countries. Only in a scenario of high demand growth there is a higher probability that motorized transportation becomes affordable to a wider social strata. In such a scenario however, the decompositional impact of population growth would be no more than one third compared to the influence of per capita demand growth (cf. the ECS '92 scenario in Exhibit 13).

CONCLUSION: Energy versus Environmental Resource Scarcity

Our discussion of human mobility aimed at providing an overall framework against which to assess possible scenarios of future transportation energy demand. The scenarios analyzed agree to a large extent that future demand growth in OECD countries could be rather flat, even negative. Forthcoming

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[7] The three scenarios were chosen on basis of their trends in transport energy demand growth in developing countries: high (ECS'92), medium (FFES), and low (EPA-SCW).

saturation of ownership rates and continued improvernents in fuel efficiency are the principal reasons for such anticipated developments.

Scenarios for developing countries indicate possible growth of transportation energy demand of a factor two to three over the next three decades. Existing disparities in rural/urban incomes are likely to persist over the time period spanned by the scenarios. This implies that the bulk of mobility increases will occur in urban areas, already plagued today by congestion and air pollution. This clearly illustrates the challenge ahead for transportation and environmental policies in metropolitan areas of the developing world. At the same time these developments also indicate clearly that in the decades to come resource constraints will be noticed much sooner with respect to (urban) environmental quality than with the availability of crude oil resources for transportation purposes.

As regards transportation energy demand, a historical analysis concludes that population growth matters in the "North" rather than in the "South". This simply because of the persistent large disparities in per capita consumption levels. Motorized mobility and resulting energy demand is a privilege of the affluent, which tend to have few children. Conversely, mobility of the poor, who have many children, is largely confined to non-motorized transport modes which do not consume fossil fuels. As regards the future, scenarios indicate that declines in per capita transport energy consumption are likely to dominate the demand picture in the OECD countries. Scenarios differ in their evaluation of per capita demand growth in developing countries. But as argued above, only when there will be genuine development, the impact of population growth on transport energy demand will move from a statistical artefact to a reality. With no or slow development, demand will be confined to an (slowly) urban elite, whose demand growth cannot be equated with the rapidly rising number of children of the poor.

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1971	Industry	Transport	Residential & Commercial	Total	Transport or % of Total
OECD-North America	499	392	456	1347	29%
OECD-Europe & Pacific	518	199	336	1053	19%
Eastern Europe & ex-USSR	430	112	243	785	14%
Developing countries	145	110	312[2]	567[2]	19%
World	1592	813	1347[2]	3752[2]	22%
1990					
OECD-North America	542	526	461	1529	34%
OECD-Europe & Pacific	527	372	443	1342	28%
Eastern Europe & ex- USSR	577	167	420	1164	14%
Developing countries	681	287	702[2]	1670[2]	17%
World	2327	1351	2027[2]	5705[2]	24%
AAGR (% /yr)					
OECD-North America	.44	1.56	.06	.67	74%
OECD-Europe & Pacific	.09	3.35	1.47	1.28	60%
Eastern Europe & ex-USSR	1.56	2.12	2.92	2.09	15%
Developing countries	8.48	5.18	4.36[2]	5.85[2]	16%
World	2.02	2.71	2.17[2]	2.23[2]	28%

Exhibit 1. Final (commercial) energy demand by sector and world region, 1971 and 1990, in million tons oil equivalent (Mtoe) and average annual growth rates (percent/year). Source: IEA, 1993.

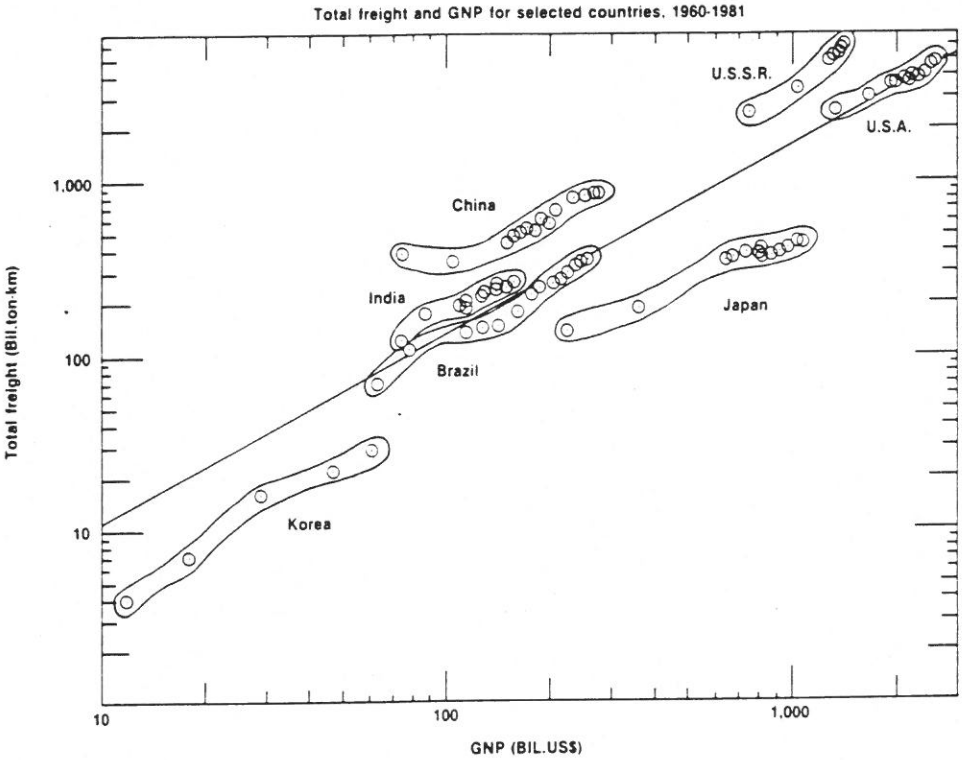

Exhibit 2. Total goods transport volume (Billion ton-km) versus size of different economies (Billion US $) 1960-1981. Source: OTA, 1992, based on Venny and Uy, 1985.

	Change in aggregate intensity	Decomposition		
		Structure	Intensity	Interaction
United States	4	3	1	0
Japan	12	30	−13	−5
Europe-6	12	13	−2	1
West Germany	−6	15	−20	−1
Sweden	31	4	27	0
Norway	7	15	−5	−3
France	46	22	18	6
United Kingdom	−14	1	−12	−3
Italy	32	15	14	3
OECD-8	6	8	−2	0

Exhibit 3. Decomposition of change of aggregate freight transport energy intensity 1973-1988 (total % change over period), changes in aggregate intensity, and decomposition into structure (changes in modal split), and energy intensity proper (proxy for fuel efficiency). Source: Schipper and Meyers, 1992.

	10^9 pass-km	%
Work	1190	17.7
Household and family	2981	44.4
Leisure[b]	2484	37.0
"Go for a ride"	55	0.8
Total	6710	100.0
For comparison, total mobility in:		
China	607	
Ex-USSR	1770	
France	704	
Norway	47	

[a] Excluding walking and cycling.
[b] Vacation, seeing friends, other social and recreational activities.

Exhibit 4. Individual mobility by trip purpose in the US and comparison to total mobility in selected countries, in billion passenger-km and percent. Data sources: NPTS, 1992; SSB PRC, 1991; IMF, 1990 to 1993; Grübler, 1990.

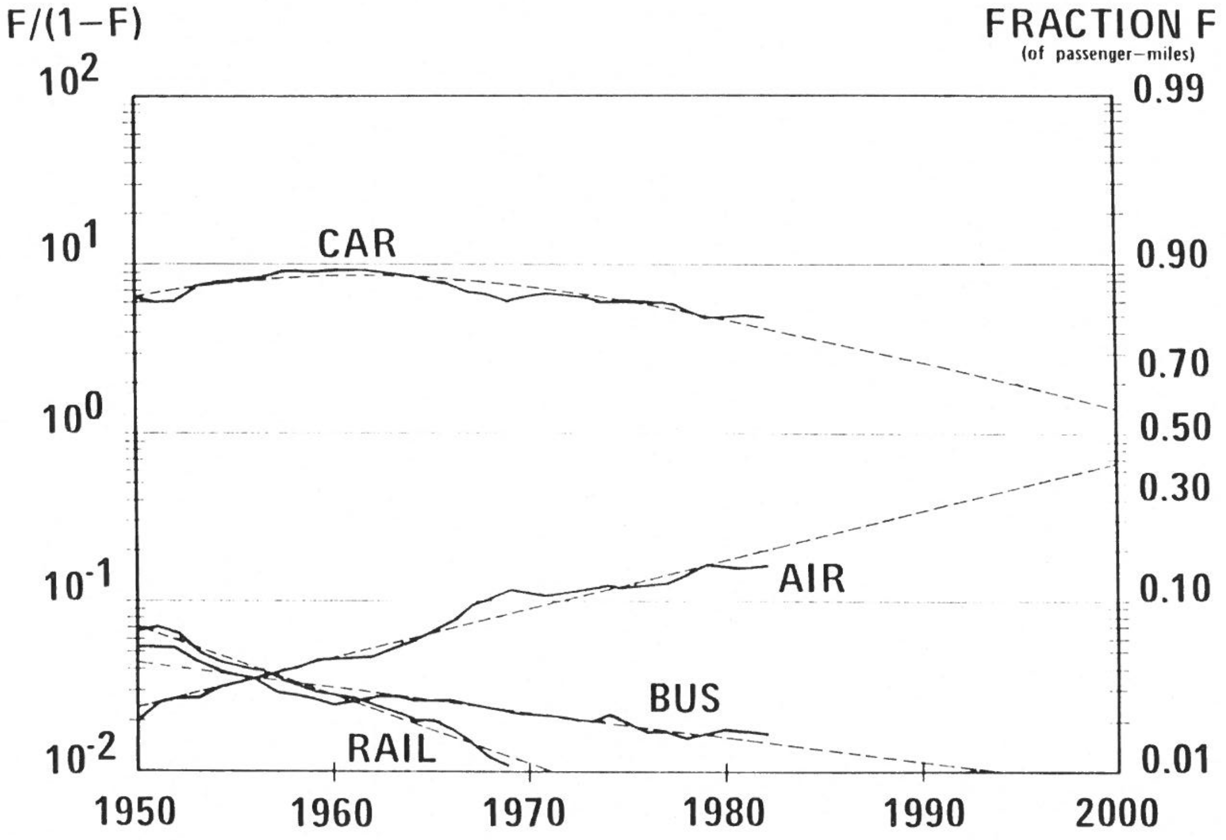

Exhibit 5. Changes in long-distance passenger transport modal split in the US, in fractional shares (F) of intercity passenger-miles, logit transformation log(F/1-F). Source: Grübler, 1990, based on Nakićenović, 1986.

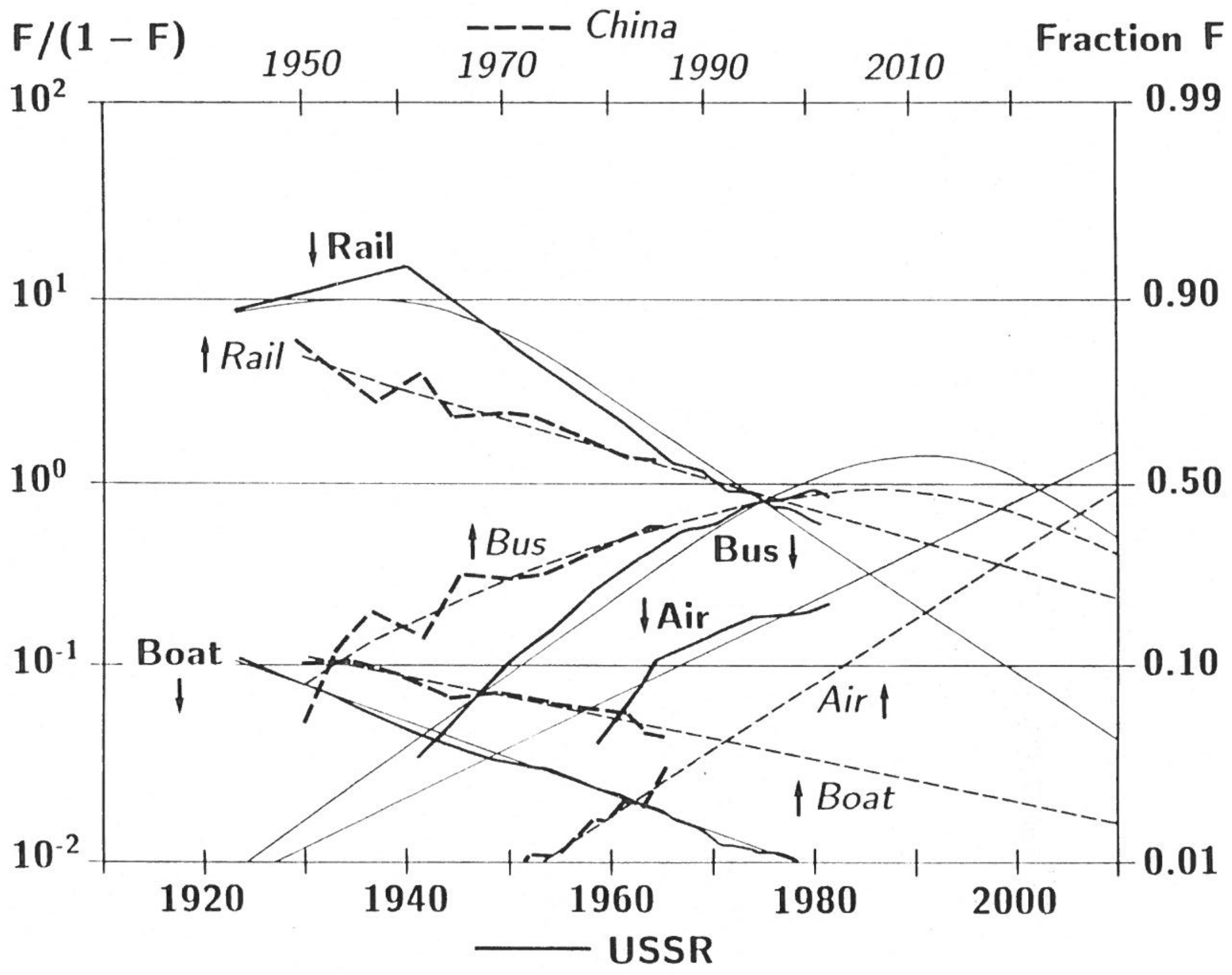

Exhibit 6. Changes in long-distance passenger modal split in the former USSR and China (with shifted time axis), in fractional shares (F) of intercity passenger-km, logit transformation log(F/1-F). Source: Grübler et al., 1992.

	Passenger cars registered		Public transport[a]
	10^6	per 1000 inh.	trips/day per 1000 inh.
Beijing	0.06	2	1641
Dallas	1.53	1624	160
Hongkong	0.16	29	1274
Los Angeles (MA)[b]	4.18	1409	402
Mexico City (MA)	1.85	96	1570
Paris	1.00	460	1779
São Paulo	2.29	619	1878
Tokyo (MA)[b]	2.15	182	2139
Warsaw	0.32	193	2609

[a] Bus, taxi, metro and railways.

[b] 1980 data

Exhibit 7. Transport in selected cities or metropolitan areas (MA) in 1985, passenger cars registered (million), cars per 1000 inhabitants, and public transport trip rate, in trips per day per 1000 inhabitants. The two measures become comparable assuming on average each car is used for a trip per day (in fact, every second car for two trips a day as traffic surveys in European cities suggest). Data source: IEM, 1988.

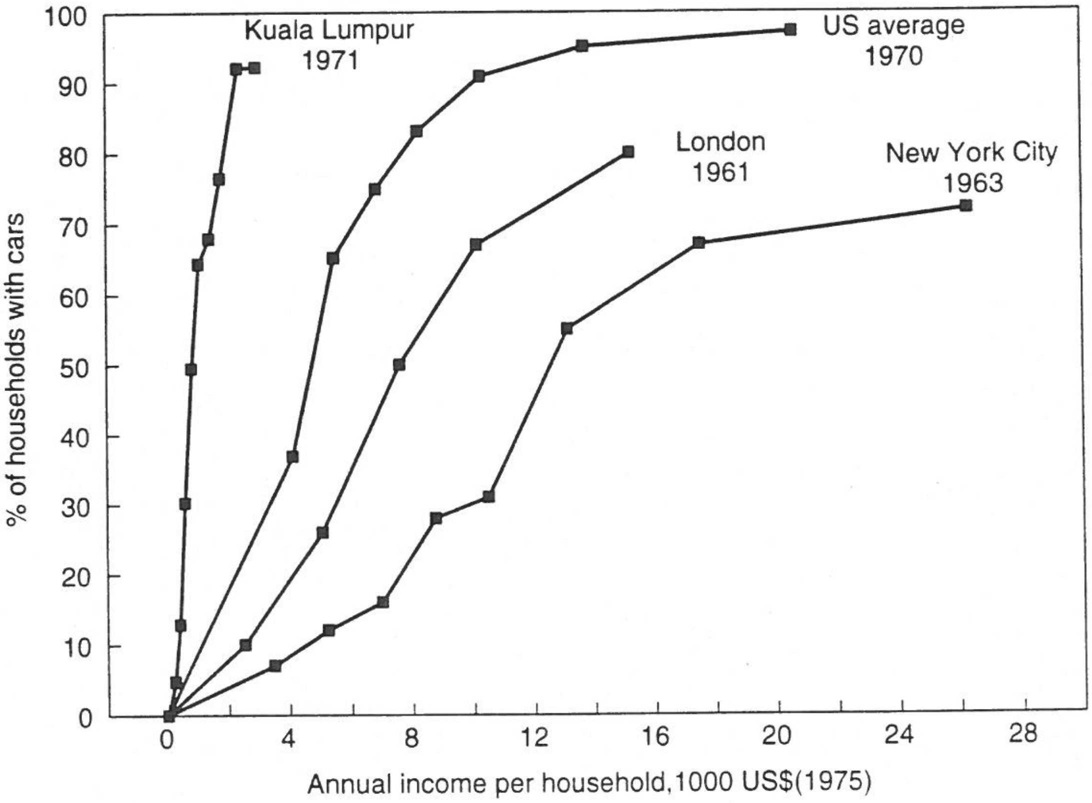

Exhibit 8. Diversity in car ownership rates versus family income for selected cities and US average, in percent of households owning a car versus annual family income (constant 1000 US $ 1975). Note in particular the much lower elasticity of car ownership rates versus income in New York, and the high elasticity in Kuala Lumpur. The latter would remain significantly higher even if income would be corrected for purchasing power differences. Data source: Zahavi, 1976.

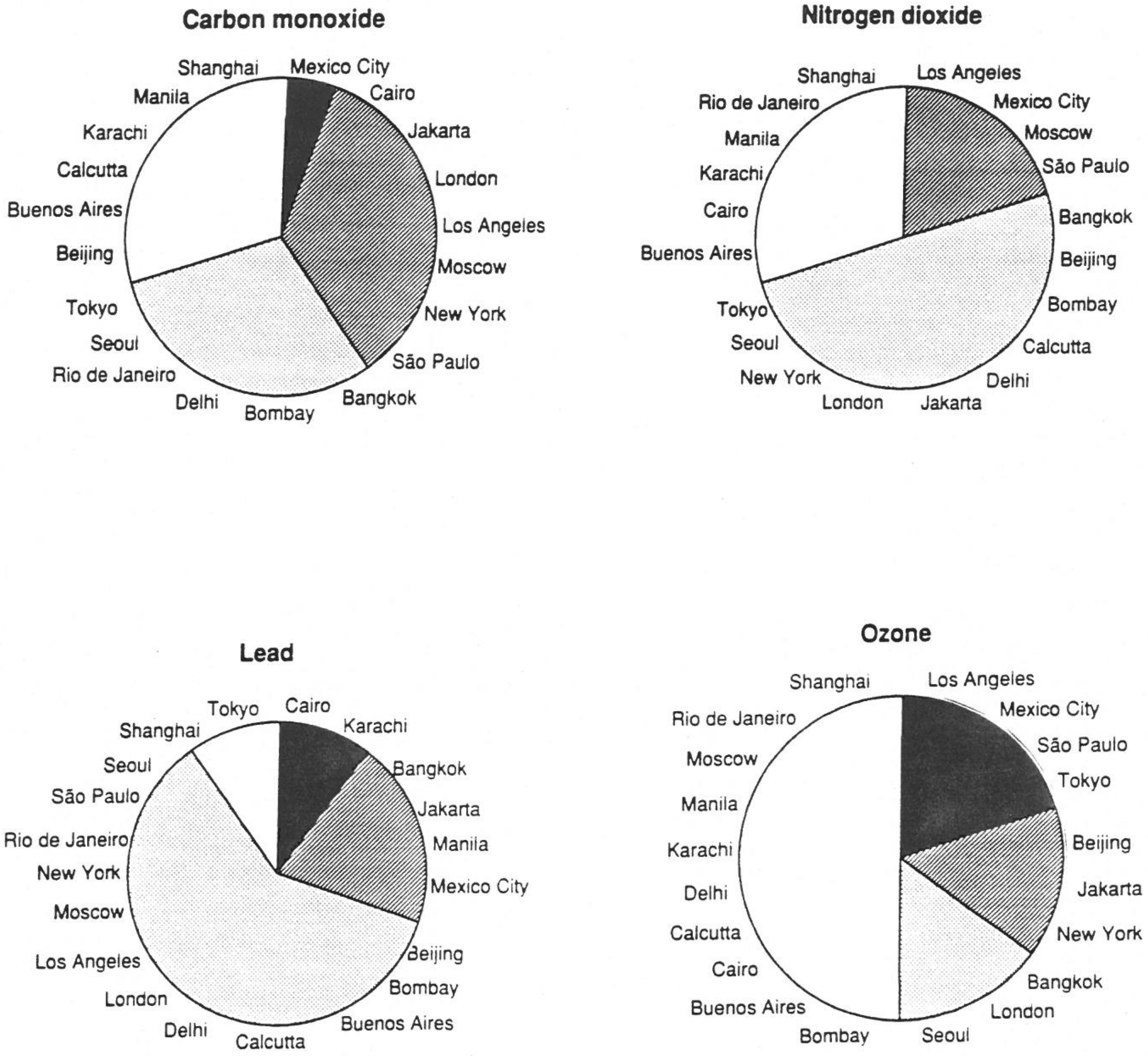

Exhibit 9. Overview of air quality in 20 megacities for lead, carbon monoxide, nitrogen oxide, and ozone. Color coding: Black denotes a serious problem (concentration at least two times above WHO guidelines), Hatched area denotes moderate to heavy pollution (concentration exceeds WHO guidelines up to a factor of two), Grey indicates low pollution (WHO guidelines met), White refers to no data available. Source: UNEP and WHO, 1992.

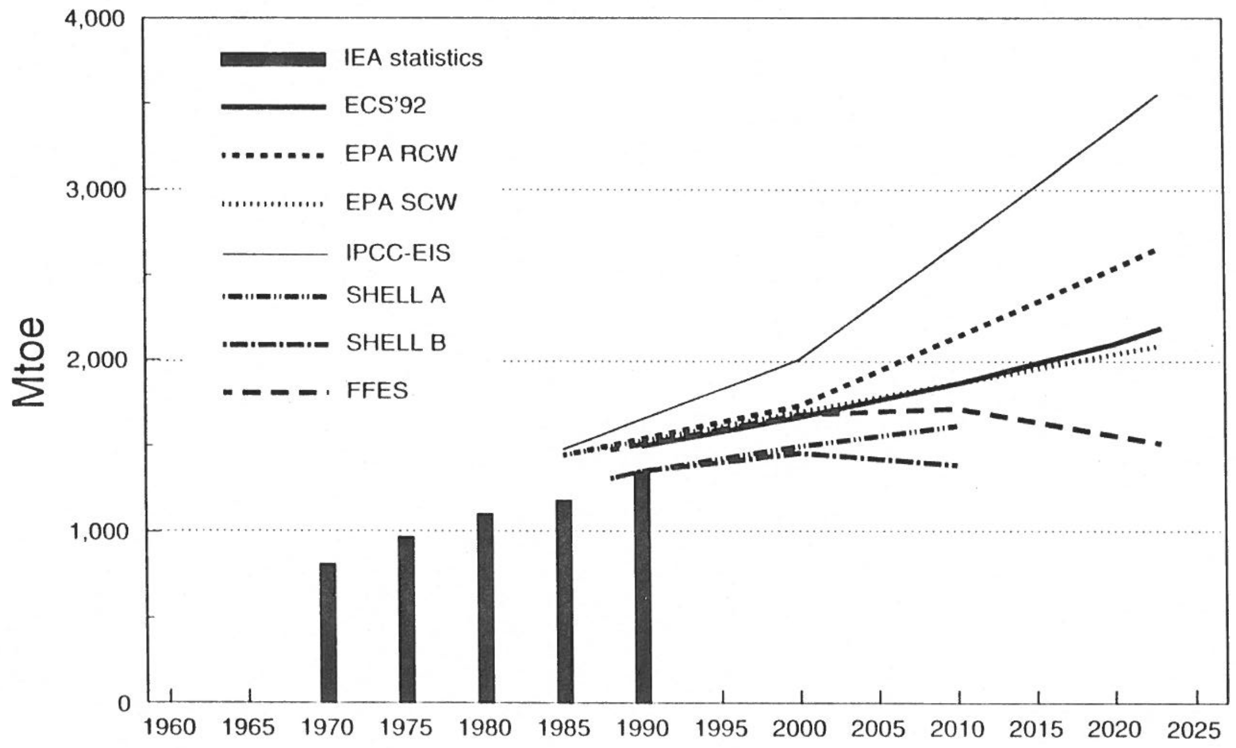

Exhibit 10. Global transport energy demand scenarios, in Mtoe. Data source: see text.

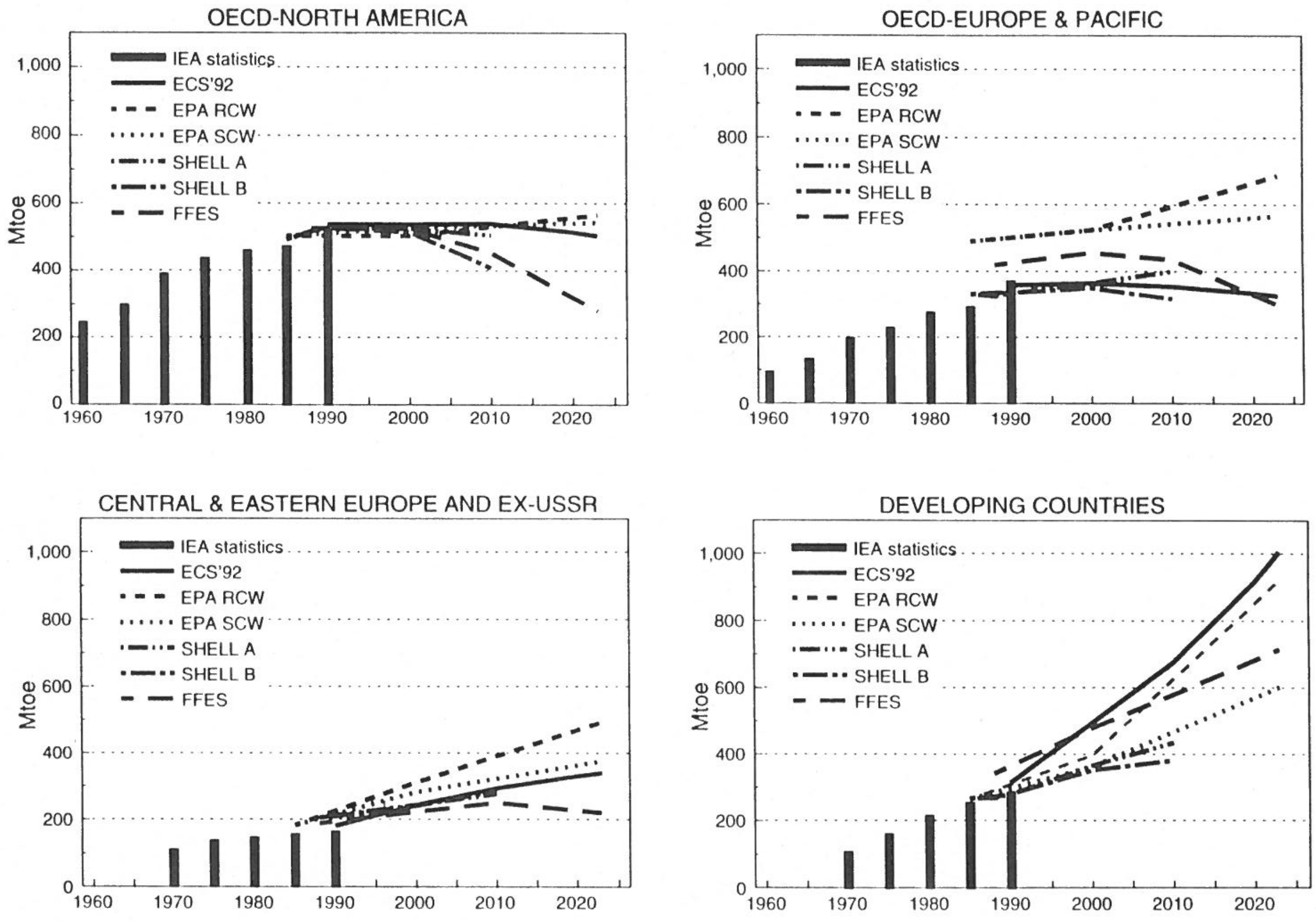

Exhibit 11. Transport energy demand scenarios for four world regions, in Mtoe. Data source: see text.

1971 - 1990 Actual	Δ population	Δ toe due to Δ pop 1)	Δ toe due to Δ per capita toe 2)	interaction 3)	Δ toe
OECD-North America	50.3	86.9	38.5	8.0	133.4
OECD-Other	55.9	22.4	135.2	15.3	172.9
C&EEU and ex-USSR	56.1	19.6	29.0	6.0	54.6
Developing Countries	1436.1	59.6	76.3	41.2	177.1
World4)	1598.3	351.6 4)	147.9 4)	38.5 4)	538.0

1) constant 1970 per capita toe x Δpopulation
2) constant 1970 population x Δper capita consumption
3) interaction term, growth of per capita consumption of growth in population
4) impact depends on level of aggregation. Regional and global values are therefore not commeasurable non-additive

Exhibit 12. Decompositional analysis of factors contributing to transport energy demand growth for four world regions and world total, in contribution to absolute demand growth 1971-1990 in Mtoe. Note that impact of population growth is first of all function of the level of aggregation. Data source: IEA, 1993 (energy balances), and World Tables, 1993 (population).

	Δ toe due to Δ pop	Δ toe due to Δ per capita	interaction	Δ toe
ECS'92 (1990-2025)				
OECD	127	-167	-24	-69
REFS	37	101	-21	159
DCS	221	264	195	680
FFES (1988-2030)				
OECD	159	-531	-69	-441
REFS	45	-19	-3	23
DCS	322	59	44	425
EPA-SCW (1985-2025)				
OECD	177	-51	-9	117
REFS	44	120	27	191
DCS	237	74	26	337

Exhibit 13. Decompositional analysis of factors contributing to transport energy demand growth: comparison of three scenarios until 2025/2030 for three world regions, in contribution to absolute demand growth in Mtoe. Data source: population projection: UN, 1992 (medium variant), transport energy demand scenarios: see text.