Working Paper

A Comparison of Global and Regional Energy Emission Scenarios

Arnulf Grübler

WP-94-132
December 1994

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1. Introduction

Numerous scenarios of possible future developments of long-term energy consumption and supply and their environmental impacts have been developed. This is because scenarios reflect both an intrinsic interest to explore possible alternative futures, and are also an indispensable input for assessing long-term environmental impacts, e.g. of possible climate change. One of the most prominent and influential recent family of scenarios was developed within the framework of the IPCC, the Intergovernmental Panel on Climate Change (Houghton *et al.*, 1992, Leggett *et al.*, 1992, and Pepper *et al.*, 1992). These scenarios not only continue to be a central input for climate change and impact studies (in particular the central variant scenario IS92a), but also represent perhaps the most ambitious effort to explore a wide range of alternative development paths in the area of population growth, economic development, energy demand and resulting greenhouse gas (GHG) emissions.

1.1 Objectives and Scope of Paper

The objective of this paper is to review the 1992 IPCC energy and emission scenarios by way of comparison with other independently developed global and regional scenarios. As such, the comparison aims at identifying both possible areas of agreement ("central tendencies") among the scenarios published, as well as areas of differences and divergence (a measure of the inevitable degree of uncertainty, scenario projections far into the future entail). Particularly the regional scenario analysis performed here is in response to critique on the IPCC scenarios voiced from the perspective of the "South" (Parikh, 1992). The paper contributes to the evaluation of the 1992 IPCC scenarios to be published as part of the 1995 IPCC Second Assessment Report (Alcamo *et al.*, forthcoming).

The customary disclaimer particularly holds for this paper: views, conclusions and remaining errors are entirely the author's responsibility and should not be attributed to the other lead authors of the IPCC document.[1]

1.2 Data, Coverage, and Approach for Scenario Comparison

The following analysis focuses on energy related CO_2 emissions. This is because they represent the single most important category of GHG emissions and because a large number of published scenarios is available for comparison.[2] For reasons of comparability with the IPCC scenarios all emissions are reported in units of carbon weight (usually in Gigatons carbon).

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[1] Sincere thanks for their input and comments to this paper go to Joe Alcamo, Lex Bouwman, Jae Edmonds, Tsuneyuki Morita, and Aca Sugandhy.

[2] The number of published non-energy CO_2 emission scenarios is severely limited (cf. Alcamo *et al.*, forthcoming).

Emission scenarios and aggregate components of emission growth are compared for global totals, as well as for four selected regions,[3] including China and Centrally Planned Economies of Asia, Central and Eastern Europe and the former USSR, (Subsaharan) Africa, and the United States of America (USA). The choice of the latter two regions was either determined because of their importance with respect to projected demographic and economic development (and thus potential future GHG emissions) as in the case of Africa, or because they have been most intensively studied and therefore represent the largest "pool" of scenario studies that can be used in a comparative assessment.

Three time horizons are considered: up to 2020, 2050, and 2100. The number of available scenarios decreases significantly with further time horizons. The time horizon 2020 is of particular relevance due to the fact that:

1. It is the time horizon for which the largest number of scenarios can be included in the assessment.

2. Scenarios may be assessed in terms of their plausibility and are also to a certain extent falsifiable (i.e. can be compared to actual developments[4]) over a time horizon of the next 10-15 years. Such *ex post* analysis and evaluation of scenarios is, however, rare (a notable exception being Schrattenholzer, 1992).

Two types of literature sources have been used for the scenario assessment. First, published scenario results from a large variety of models and studies (cf. Appendix 3). For the purpose of this assessment only scenarios/studies which reported at least results for level of economic activity (or its growth), primary energy consumption and resulting emissions, were considered. Emphasis was given to recent scenarios (published after 1990) and to regionally disaggregated global energy/emission scenarios, because of their principal advantage of assuring model and scenario consistency (e.g. with respect to reference international energy prices, import possibilities, etc.). Such consistency is not necessarily assured by "adding up" (diverse) national/regional scenarios (as illustrated within the framework of the former Energy and Industry Subgroup 1990 scenario development, IPCC, 1991) or by developing only global scenarios without further corroboration by regional detail. As second data source, the results of model and scenario

[3] For the regional definition see Pepper *et al.*, 1992, and Leggett *et al.*, 1992. The original IPCC document contained results for four world regions, out of which only two (China and Centrally Planned Asia, and Central and Eastern Europe and the former USSR) are comparable directly to other scenario studies (and are thus discussed first in this assessment). Data for the IPCC scenarios for Africa and the USA were obtained directly in electronic form from the model outputs distributed by the IPCC WG I secretariat.

[4] As an example Schrattenholzer (1992) argues that the primary energy demand projected in Goldemberg *et al.*, 1988, for the year 2020 (7.3 Gtoe) was already surpassed by actual consumption in 1990 (8.3 Gtoe).

comparison projects[5] such as the International Energy Workshop (IEW) or the Energy Modeling Forum (EMF), as well as collaborative national/regional emission and policy studies, such as the CHALLENGE Project at IIASA and the GHG costing studies performed by UNEP, were included in the assessment. The size of the IEW lends itself as a basis of statistical analysis, reported as median values and 84 and 16 percentile ranges (median plus/minus one standard deviation, assuming the data are distributed log-normally).

Determined by the basic design of the 1992 IPCC scenarios as "no climate intervention policy" scenarios (i.e. none of the scenarios assumes any policy measures directly aimed at controlling climate change), two classes of scenarios are considered: reference ("business-as-usual" or "no-control") cases (including the IPCC scenarios), and policy ("mitigation") cases. Policy scenarios include a wide (combination) of possible policy measures to lower future GHG emission trajectories including energy conservation and efficiency improvements, fuel substitution and development of alternative and renewable energy sources, (macro-) economic policy instruments, among others. Comparison of this class of scenarios to reference cases is important for three reasons:

1. To identify the respective ranges in future emissions stemming from uncertainty in scenario driving forces proper and ranges stemming from impacts of policy intervention. These can be derived from the analysis of "controlled experiment" cases of reference scenarios with policy scenarios within the framework of consistent scenario and modeling exercises.

2. An analysis of overlapping ranges in emission projections between "reference" and "policy" scenarios can give possible insight into the scope of policy measures not aimed directly at reducing GHG emissions, but which may nevertheless have a significant impact on future emission levels (frequently referred to as "no-regrets" strategies).

3. Finally, controlled experiments can be additional plausibility and consistency checks for judging particular reference ("business-as-usual") scenarios.

Comparison of projected emission levels between scenarios is only the first step in scenario comparison. Only an analysis of the underlying driving force variables can shed light on internal consistency, plausibility, and comparability across scenarios. The underlying driving forces include, among others, demographic trends, economic development, level and efficiency of energy use, and structure of energy supply. These driving forces can in turn be represented by a number of aggregate variables including population, per capita level of economic activity, primary energy consumption per unit of economic activity (energy intensity, a proxy variable of energy efficiency) and emission

[5] On the IEW cf. Manne and Schrattenholzer, 1993, on CHALLENGE cf. Schrattenholzer, 1994. On EMF cf. Gaskins and Weyant, 1993, and Weyant, 1993. On the UNEP GHG abatement costing studies, cf. Christensen *et al.*, 1994.

intensity per unit of primary energy consumed (proxy for the energy supply structure and resulting CO_2 intensiveness of energy supply).

Emissions are broken down into the following components:

CO_2 Emissions = Population*(GDP/Population)*(Energy/GDP)*(CO_2/Energy)

Growth rates in emissions are therefore the sum of the growth rates of the components of population, per capita income (GDP/population) [or their aggregation into economic activity (GDP)], energy intensity (Energy/GDP), and carbon intensity (CO_2/Energy).[6] Such an approach for analyzing structural variables underlying future GHG emissions has been proposed by Kaya (1990) and applied by Ogawa (1991), Edmonds and Barns (1992), and Grübler *et al.*, (1993), among others.

The comparison of driving forces of energy related carbon emissions based on common measures is, however, difficult due to differences in statistical definitions and variables used in various scenario studies. For instance, the 1990 GNP/GDP data used in the scenario studies reviewed here vary from about 300 to some 3000 billion dollars for China and Centrally Planned Asia, and between 1400 to 3800 billion dollars for Central and Eastern Europe and the former USSR (ranges result from applying either market exchange rates or alternative exchange rates considering also purchasing power differences in national currency GNP/GDP estimates). Therefore, in the subsequent analysis the scenario comparison GDP variables are renormalized to a common 1990 base year index and the analysis focuses on growth rate (compounded average annual growth rates, AAGR) differences. A similar, though less significant uncertainty, also affects carbon intensities (carbon emissions per unit of primary energy consumed, expressed in kg C per GJ) derived from different scenario studies. Depending on whether traditional fuels, such as fuelwood and charcoal, are included in the energy consumption and emissions data, carbon intensities can vary, particularly for developing countries. These differences are visible in the base year differences of carbon intensities that retained the original data from the various scenario studies.

The decompositional analysis of four components of emission growth provides an indication of where to look for differences in scenario inputs (e.g. population growth) or modeling assumptions (e.g. resources availability, costs of alternative energy carriers and their influence on the evolution of the carbon intensity). However, the analysis does not provide an explanation of differences in data or modeling details between various scenarios. The decompositional analysis provides also policy relevant information as it coincides with four broad areas of policy concern that may influence emissions:

[6] Note that in the subsequent tables component growth rates may not add exactly to (sub)totals due to independent rounding errors. Note also that component growth rates do not add when calculated from the original frequency distributions of the IEW poll.

demographics, economic growth and development, energy conservation, and energy supply.

It should be noted that for the purpose of this scenario comparison the individual components of emission growth are considered as independent from each other. This assumption may not hold for scenarios/models that treat some components as interdependent (e.g. per capita income and energy intensity[7]). An additional word of caution is necessary. The influence of different components (in particular population growth) on emissions depends on the level of aggregation of the analysis (global versus regional, or national).[8] This is because population growth may occur in a different region where energy consumption (and emissions) grow. Hence, any analysis at the global level masks decisive differences between regions and should not be used to infer any simplifying relations particularly between demographics and emission growth.

1.3. Elements of Comparison

The following global and regional analysis will each be conducted in four steps:

1. Assessment of scenario base year (1990) emission data in comparison with the latest emission inventory based on UN energy statistics (Boden *et al.*, 1992 and Marland *et al.*, 1993 based on the methodology of Marland *et al.*, 1989).

2. Comparison of emission scenarios of energy-related carbon emissions shown in Figure 1 (global analysis) and Panel A (regional analysis). Ranges spanned by the IPCC scenarios in particular are compared with the range of all other scenarios reviewed and with the range spanned by the 84 and 16 percentile of the IEW poll. The full figures, allowing identification of individual scenarios are reproduced in Appendix 2.

3. Analysis of driving forces of emissions. Emission growth rates are decomposed into four driving force variables: demographic and economic development such as population growth and increases in per capita income, or their aggregation to total GNP or GDP growth; primary energy intensity per unit of GNP or GDP; and carbon intensity, i.e. CO_2 emissions per unit of primary energy consumption). Changes in these driving variables are represented by their respective average annual growth rates (AAGR) over the period 1990 to 2020 shown in Table 1 (global results) and Tables 2 to 5 (regional results). Their variation is analyzed statistically and compared for both reference and policy scenarios. More details, as well as similar results for the years 2050 and 2100, are given in Appendix 1.

[7] The rationale for such an assumption derives from considerations of technology availability and R&D, both important factors of improvements in energy intensity, and which are *ceteris paribus* higher with increasing per capita income. In addition, higher per capita GDP growth results in a faster rate of capital turnover and hence the possibly of higher energy intensity improvement rates.

[8] Cf. Lutz *et al.*, 1993, and Grübler, 1994, on this point.

4. Analysis of global (Figure 2) and regional (Panel B) energy intensity trends are reported renormalized to a common 1990 index, due to the incomparability of different 1990 GNP/GDP data considered in different studies. Global (Figure 3) and regional (Panel C) carbon intensity trends are reported as kg C per GJ and in original form, irrespective of whether they refer to "net" (i.e. only fossil fuel) or "gross" (including also biomass use) emissions. In both cases the 1992 IPCC scenarios are compared to the IEW range and the range spanned by all other scenarios. Full figures, allowing identification of individual scenarios are again reproduced in Appendix 2, which also contains graphics on total energy consumption globally and regionally for ease of comparison between scenarios.

5. A short interim summary concludes the discussion of each section on global and regional energy emission scenarios.

2. Review of Global Scenarios

Global energy and emissions scenarios are a widely covered field. Reviews of models and scenarios go back to the 1980s (Ausubel and Nordhaus, 1983; Nordhaus and Yohe, 1983; Keepin, 1986). In the comparison here, no attempt was made to review *all* global scenarios published in the reviewed or grey literature since these earlier surveys. Instead, emphasis was given to comparing the 1992 IPCC scenarios to scenarios published since

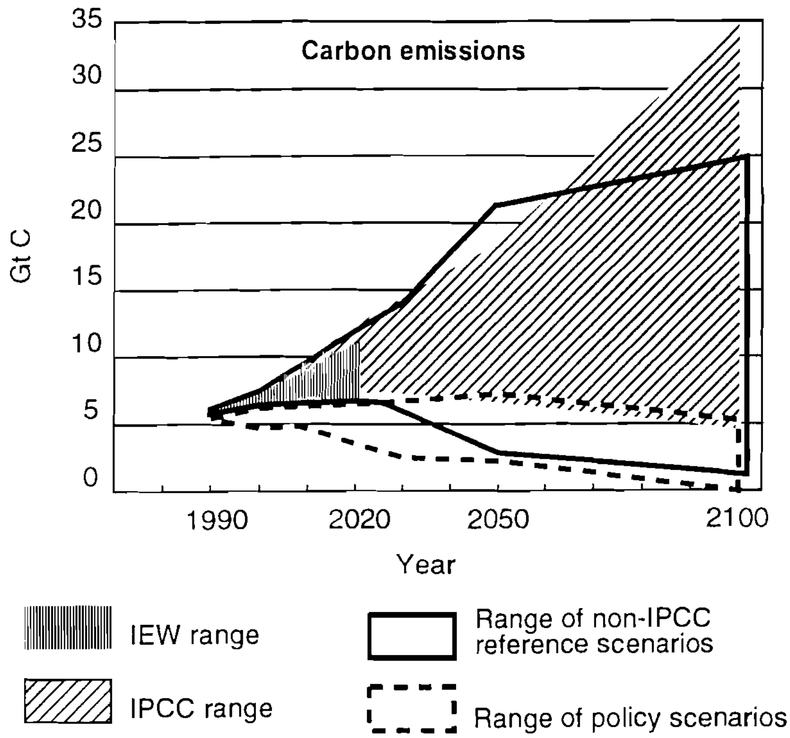


Figure 1. Scenarios of global energy related carbon emissions (in Gt C).

1990 (derived either directly from the original reports or as contained in the poll of scenarios of the International Energy Workshop, IEW), as well as to scenario studies containing both global and regional quantifications.

1. The 1990 base year emissions from energy production and use are estimated by Boden *et al.*, (1992) and Marland *et al.*, (1993) to amount to 5.94 Gt (gigatons) carbon (C), excluding the manufacture of cement. This is in good agreement with the 1990 base year value of 6 Gt adopted in the 1992 IPCC scenarios. The range of 1990 base year values in the other scenarios reviewed ranges from 5.4 to 6.2 Gt C. The lower range of these values comes from scenarios with earlier base year data than 1990 (i.e. 1990 values are already projected scenario values).

2. Carbon emissions (Figure 1) in almost all scenarios increase over time, as does the range spanned by the scenarios reviewed. By 2020, the emissions spanned by the 1992 IPCC scenarios range from 7.1 (IS92c) to 12.2 (IS92e) Gt C. The range spanned by the 16 and 84 percentiles of the IEW is somewhat lower (6.9 to 10.9 Gt C). The intermediate IPCC scenario IS92a is with some 9.9 Gt also higher than the median from all scenarios covered by the IEW (9.1 Gt by 2020). By 2050 emissions in the IPCC series span from 6.5 (IS92c) to 18.6 (IS92e) Gt, compared to a range between 2.8 to 21.6 Gt in the other reference scenarios reviewed. It is interesting to note that these values are significantly below the emissions range of the scenarios developed by some climate modelers (e.g. Jason, 1979, Bacastow and Keeling, 1981, and Siegenthaler and Oeschger, 1978) in the 1970s and early 1980s that reached up to 90 Gt C by 2050. The range spanned by the IPCC scenarios for 2100 (4.6 to 34.9 Gt C) is representative of other reference scenarios, a notable exception being the methane economy scenario (Ausubel *et al.*, 1988) with 1.2 Gt carbon emissions. Throughout the period analyzed no systematic agreement between the intermediate 1992 IPCC scenario IS92a and the median of all scenarios reviewed, could be identified.

3. Table 1 shows the components of growth in global emissions to 2020 (for comparable tables to 2050, and 2100 see Appendix 1). Individual reference scenarios and their range are compared with a range of policy scenarios (for individual policy scenarios see Appendix 1). Mean (and median) economic growth averages about 2.8 percent annually, about equally divided between population growth and growth in per capita income. The demographic assumptions of the 1992 IPCC scenarios significantly expand the range of other scenarios at both the high and low end.

Conversely the IPCC scenarios show a much smaller range in the derived variables of energy and carbon intensity. This indicates that the representativeness of the range of carbon emissions of the 1992 IPCC scenarios compared to the range available in the literature is, first of all, the results of the wide variation in demographic assumptions, whereas other salient scenario variables, in particular energy intensity improvements, show a comparatively small variation in the IS92 series (cf. also Appendix 1).

Table 1 - WORLD

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1]
FOR REFERENCE ("no-controls") SCENARIOS

REFERENCE SCENARIOS	POP	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	1.40	1.53	2.92	-0.97	-0.29	1.68
IS92b	1.40	1.53	2.92	-1.08	-0.26	1.54
IS92c	1.10	0.92	2.00	-0.86	-0.55	0.56
IS92d	1.10	1.75	2.83	-1.10	-0.68	1.00
IS92e	1.40	2.29	3.71	-1.16	-0.11	2.39
IS92f	1.75	1.36	3.10	-0.85	-0.03	2.19
IPCC-EIS	1.24	1.74	3.00	-0.80	+0.05	2.23
IEW-84%[2]			3.36	-0.75	+0.05	1.95
IEW-Median[2]			2.78	-1.16	-0.18	1.14
IEW-16%[2]			2.46	-1.71	-0.67	0.63
ECS '92	1.42	0.78	2.21	-0.75	-0.16	1.28
CH_4 - economy (eff.)	1.29	0.83	2.13	-0.78	-0.85	0.47
CHALLENGE			2.55	-0.94	-0.18	1.41
WEC A	1.43	2.36	3.82	-1.50	-0.01	2.25
WEC B	1.43	1.85	3.30	-1.84	-0.22	1.17
E&R B	1.13	1.68	2.83	-1.03	-0.23	1.54
EPA-SCW	1.43	0.35	1.79	-0.72	-0.07	0.98
EPA-RCW	1.29	1.35	2.65	-0.70	+0.04	1.98
green			2.71	-0.53	+0.14	2.31
12RT			2.50	-0.99	+0.00	1.49
IMAGE - CW	1.40	1.61	3.00	-0.56	-0.25	2.20
MINIMUM[2]	**1.10**	0.35	1.79	-0.53	-0.85	0.47
MEDIAN[2]	1.40	1.53	2.83	-0.94	-0.18	1.54
MEAN[2]	1.35	1.46	2.79	-0.99	-0.21	1.56
MAXIMUM[2]	**1.75**	2.36	3.82	-1.84	+0.14	**2.39**
POLICY SCENARIOS						
MINIMUM[2]	*1.17*	*0.35*	*1.79*	*-1.08*	*-0.52*	*-1.31*
MEDIAN[2]	*1.29*	*1.35*	*2.65*	*-1.78*	*-1.19*	*-0.32*
MEAN[2]	*1.32*	*1.37*	*2.66*	*-1.74*	*-1.16*	*-0.29*
MAXIMUM[2]	*1.43*	*2.19*	*3.50*	*-2.40*	*-1.94*	*+0.24*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

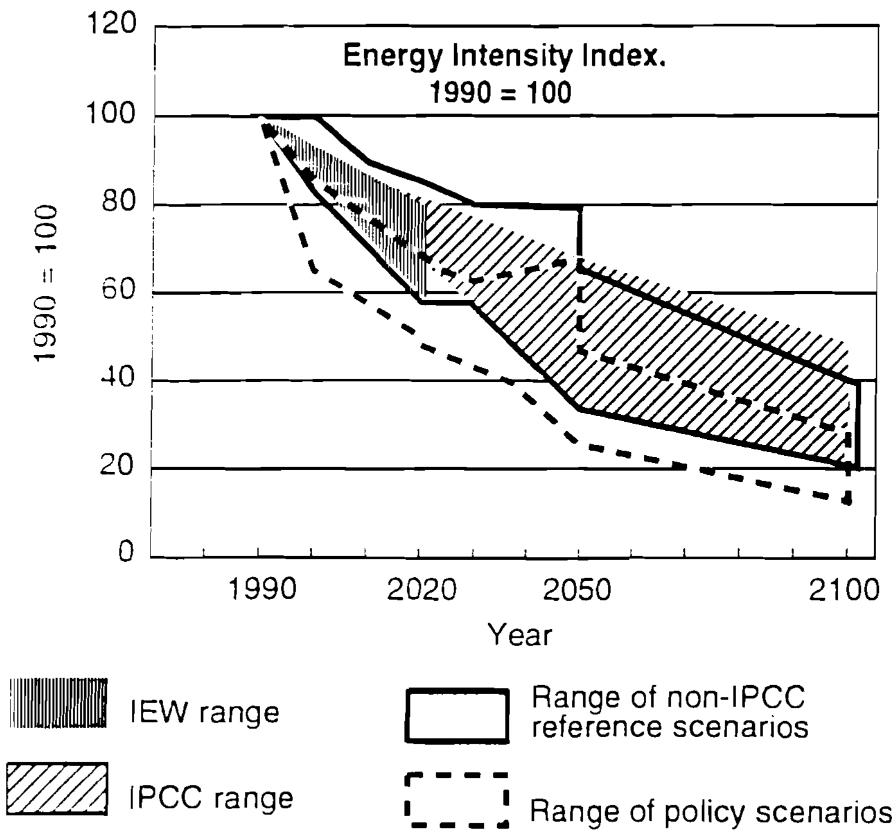


Figure 2. Energy intensity trends for global energy emission scenarios (index,1990=100).

4. Figures 2 and 3 show the evolution of energy and carbon intensity trends of the scenarios reviewed. It is worth noting that in all scenarios energy intensities decline, the mean value of energy efficiency improvement being 1 percent per year, in agreement with observed historical trends (cf. Nakićenović *et al.*, 1993). The trends with respect to carbon intensities are less dynamic. Mean decline rates are 0.2 percent per year up to 2020 and 0.3 to 0.5 over longer time horizons (cf. Appendix 1). This compares with the long-term historical average of 0.3 percent improvement rate since the middle of the 19th century (Nakićenović *et al.*, 1993). The 1992 IPCC scenarios display two distinguishing features: first, their range of energy efficiency improvement rates is significantly narrower than in other scenarios reviewed. This suggests that the scientific uncertainties of future energy efficiency gains are substantially larger than captured in the parametric variation within the 1992 IPCC scenarios. Secondly, the range of the carbon intensities of the 1992 IPCC scenarios is representative of other scenarios; however, none of the IPCC scenarios considers a case of increasing carbon intensity (shift to greater reliance on coal, including for synfuels production).

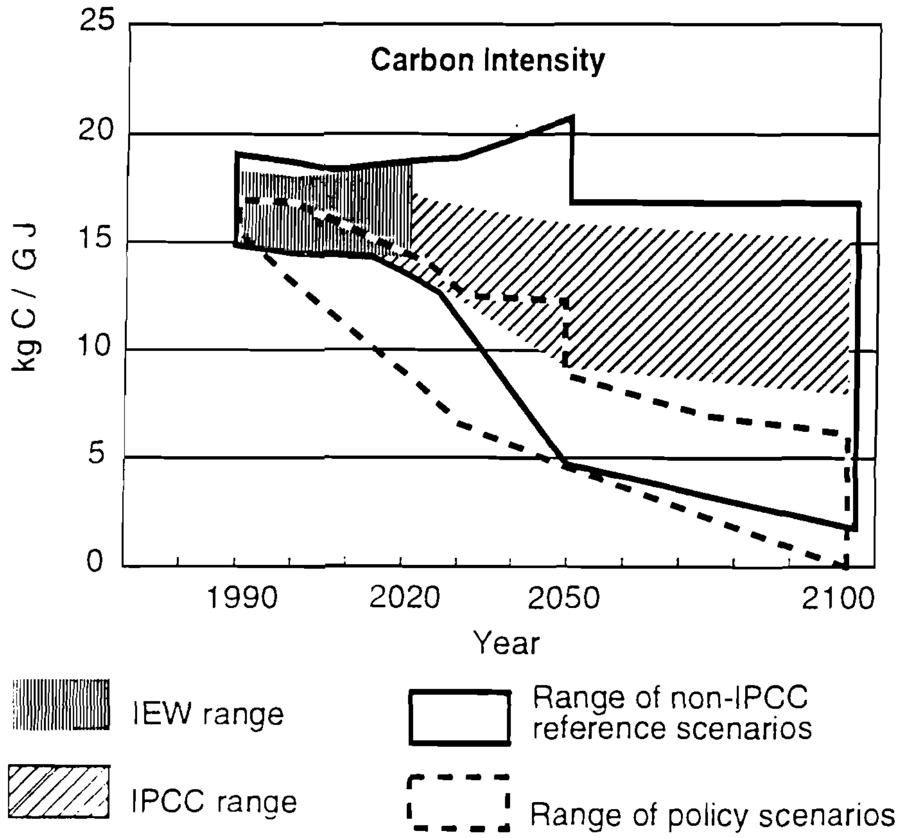


Figure 3. Carbon intensity trends for global energy emission scenarios (kg C per GJ primary energy).

5. **Summary:** The range of future carbon emissions spanned by the 1992 IPCC scenarios is representative of the range of recent other scenarios available in the literature, without, however, covering the extremes. The emissions range covered by the IPCC scenarios can therefore be considered an adequate reflection of the uncertainties involved in projecting emissions up to 100 years into the future. This is, however, only in the aggregate of total carbon emissions. In their underlying structural input and/or modeling variables energy and carbon intensity, the IPCC scenarios reflect a much smaller range compared to other scenarios. This, together with the extreme scenarios available in the published literature that are not covered by the 1992 IPCC series, suggests that the related scientific uncertainties are substantially larger than covered in the IPCC scenarios. This does not reduce the value of the 1992 IPCC scenarios *per se,* but it reduces the usefulness of the scenarios as input to climate models and the policy debate for assessing extreme outcome scenarios (at both the high and low ends), whose probability of occurrence can, for the time being, not be established.

3. Review of Regional Scenarios

3.1 China and Centrally Planned Asia

1. Based on a UN energy statistics (Marland *et al.*, 1993) report energy related carbon emissions (excluding the manufacture of cement) of 0.705 Gt carbon for the year 1990. This compares with the base year value of 0.6 Gt for the IPCC scenarios (+15 percent). The World Energy Council (WEC) estimates 0.72 Gt for 1990, whereas all other scenarios/models reviewed assume lower base year emissions in the range of 0.6 yo 0.65 Gt. The resulting base year emission differences can (especially when compared to other regions) be considered small.

2. Panel A shows the range of carbon emission scenarios up to the year 2100. The IPCC scenarios IS92a (and its identical variant b), IS92d and IS92f are well within the uncertainty range of the IEW poll for 2020. IS92a is also consistent with the IEW poll median and consequently can be considered as a "consensus view" or "middle of the road" scenario. Conversely both IS92e and IS92c expand the range of all other long-term (2100) emission scenarios reviewed. IS92e being the highest, and IS92c the lowest of all reference scenarios analyzed with emissions ranging between 1 and 7.4 Gt by the year 2100. The range of policy scenarios is obviously lower, giving emissions between zero and 2 Gt by 2100 (cf. discussion below).

3. Analysis of the components in the growth of carbon emissions to 2020 (Table 2; for the years 2050 and 2100 cf. Appendix 1) indicates the predominance of the growth (particularly of per capita levels) of economic activity, followed by energy efficiency improvement rates. The IPCC scenarios expand the range of other long-term GDP scenarios available in the literature. By 2100, IS92e assumes the highest and IS92c the lowest GDP growth rates of all scenarios reviewed. Policy scenarios assume similar population and per capita GDP growth as reference scenarios and achieve emission reduction primarily via lower carbon and energy intensities.

4. In all scenarios the intensity of energy use decreases (Panel B), typically in the order of 1.5 percent per year in reference cases and well above 2 percent in policy cases. The resulting improvements in energy efficiency across all scenarios are impressive, but within the range of both historical experience and calculations of the theoretical minimum energy requirements derived from exergy analysis (cf. Nakićenović *et al.*, 1993). The range spanned by the IPCC scenarios is significantly narrower than in the scenarios analyzed here. Most scenarios also anticipate further decarbonization of the energy system, typically, a decrease in carbon intensity of 0.2 to 0.5 percent per year (Panel C). The IPCC range is lower than other reference scenarios (cf. the IEW poll). The low carbon intensities by 2050 and 2100 of IS92c, IS92d and IS92e are, instead, more characteristic of policy scenarios.

Table 2 - CHINA AND CENTRALLY PLANNED ASIA

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1]
FOR REFERENCE ("no-controls") SCENARIOS

REFERENCE SCENARIOS	POP	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	1.03	3.91	4.98	-1.73	-0.32	2.84
IS92b	1.03	3.91	4.98	-1.73	-0.32	2.84
IS92c	0.69	2.98	3.70	-1.61	-0.51	1.51
IS92d	0.69	4.09	4.81	-1.88	-0.57	2.25
IS92e	1.03	4.83	5.91	-2.00	-0.21	3.57
IS92f	1.31	3.75	5.12	-1.57	-0.22	3.24
IPCC-EIS	0.78	4.49	5.30	-2.44	+0.30	3.04
IEW-84%[2]			5.74	-0.96	-0.29	3.15
IEW-Median[2]			4.79	-1.61	-0.38	2.77
IEW-16%[2]			3.88	-2.49	-0.38	2.33
ECS '92	0.97	2.01	3.00	-1.02	-0.18	1.76
ESCAP S1			5.50	-1.42	-0.20	3.78
He *et al.* (c)	0.68	3.96	4.67	-1.60	-0.34	2.75
WEC A	0.94	5.07	6.06	-2.85	-0.24	2.79
WEC B	0.94	4.08	5.06	-2.40	-0.03	2.51
E&R B	0.91	2.34	3.28	-0.22	-0.52	2.52
EPA-SCW	0.90	2.25	3.17	-0.81	-0.58	1.74
EPA-RCW	1.02	4.11	5.17	-1.21	-0.47	3.41
green			4.40	-0.27	+0.25	4.38
12RT			4.03	-1.36	-0.38	2.22
IMAGE - CW	1.02	4.15	5.21	-0.82	-0.21	4.13
MINIMUM[2]	0.69	2.01	3.00	-0.22	-0.58	**1.51**
MEDIAN[2]	0.94	3.91	4.90	-1.59	-0.30	2.85
MEAN[2]	0.93	3.73	4.66	-1.52	-0.28	2.83
MAXIMUM[2]	**1.31**	5.07	6.06	-2.85	**+0.30**	4.38
POLICY SCENARIOS						
MINIMUM[2]	*0.81*	*2.25*	*2.34*	*-0.53*	*-0.52*	*-0.82*
MEDIAN[2]	*0.94*	*4.08*	*4.48*	*-1.89*	*-1.06*	*1.24*
MEAN[2]	*0.94*	*3.70*	*4.24*	*-2.24*	*-1.03*	*0.86*
MAXIMUM[2]	*1.02*	*4.11*	*5.17*	*-4.32*	*-1.72*	*2.29*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

5. **Summary:** The range spanned by the IPCC scenarios for the region's carbon emissions is within the range of other reference scenarios, i.e reflects current knowledge and modeling exercises. However, this is true only in the aggregate. The IPCC range of underlying driving forces of emissions is narrower (and lower) for both energy intensity and carbon intensity, but wider (and higher) with respect to economic growth rates assumed.

3.2 Central and Eastern Europe and former USSR (EEFSU)

1. Current estimates of 1990 carbon emissions in the regions amount to 1.304 Gt carbon (Marland *et al.,* 1993), congruent with the base year values adopted by the WEC and emerging as median from the energy scenarios analyzed within the IEW poll. Compared to this, the 1990 base year emissions of the 1992 IPCC scenarios (1.7 Gt) are 30 percent higher and the reason for such a big difference remains unresolved. This discrepancy in the base year data also explains why the IPCC emission scenarios are, up to 2020, systematically above the IEW median (which also applies to the lowest emission scenario [IS92c]).

2. The range of future energy-related carbon emissions, particularly up to 2020, is perhaps the widest of all regional emission scenarios (Panel A), reflecting the uncertainty about the pace and direction of economic restructuring and resulting carbon emissions in the region. Most long-term scenarios (including IPCC) represent more or less "business-as-usual" emission growth trajectories, indicating that the full extent of the economic crisis in EEFSU was not anticipated at the time these scenarios were constructed. The IPCC scenarios in 2025 span a range of 1.8 to 3.0 Gt, whereas the more representative and most recent IEW poll spans a lower range of 1 to 2.6 Gt by 2020. Particularly noteworthy is the existence of a number of recent scenarios (e.g. by the WEC) that project stable, even declining emissions up to 2020. The uncertainty of emissions over longer periods of time is larger still: by 2100 extending by over a factor 14. One reason for such a wide spread is that both IS92c and IS92d are beyond the emission range of alternative reference scenarios, and instead being more characteristic of policy scenarios.

3. The biggest uncertainty surrounding any particular emission driving variable (cf. Table 3 and Appendix 1) is the rate of (per capita) economic growth assumed. Recent scenarios (e.g. Bashmakov, 1993, and Sinyak *et al.*, 1992) assume much lower values (nearly a factor two) than scenarios developed before 1991. With a few exceptions there is consensus that energy and carbon intensities will decline until 2020 and also beyond. These, together with declining GDP growth rates, yield overall decreasing growth trends in emissions in the reference scenarios analyzed. In policy scenarios, emissions decline mostly through changes in the energy supply structure (falling carbon intensities), followed by energy efficiency improvements.

Table 3 - CENTRAL AND EASTERN EUROPE AND EX-USSR

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1]
FOR REFERENCE ("no-controls") SCENARIOS

REFERENCE SCENARIOS	POP	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	0.43	1.49	1.93	-0.66	-0.24	1.01
IS92b	0.43	1.49	1.93	-0.66	-0.24	1.01
IS92c	0.31	0.95	1.26	-0.69	-0.50	0.06
IS92d	0.31	1.88	2.21	-1.03	-0.67	0.48
IS92e	0.43	2.83	3.27	-1.37	-0.19	1.67
IS92f	0.67	1.73	2.31	-0.88	-0.13	1.28
IPCC-EIS	0.70	2.49	3.20*	-1.14	-0.17	1.84
IEW-84%[2]			2.98	-1.06	-0.34	0.46
IEW-Median[2]			2.16	-1.42	-0.36	0.07
IEW-16%[2]			1.51	-2.01	-0.41	-0.25
ECS '92	0.49	2.18	2.68	-1.52	-0.24	0.88
Bashmakov Base	0.58	0.77	1.36	-0.93	-0.05	0.37
Sinyak *et al.* BAU	0.56	1.44	2.00	-1.09	-0.41	0.49
WEC A	0.52	1.85	2.38	-1.81	-0.62	-0.10
WEC B	0.52	1.85	2.38	-2.13	-0.38	-0.18
E&R B	0.48	1.62	2.11	-1.07	-0.40	0.61
EPA-SCW	0.52	1.73	2.27	-1.29	-0.17	0.78
EPA-RCW	0.45	3.80	4.27	-2.97	-0.16	1.01
green			2.51	-0.63	+0.32	2.19
12RT			2.29	-2.00	-0.29	-0.05
IMAGE - CW	0.43	1.48	1.91	+0.72	-1.62	0.99
MINIMUM[2]	**0.31**	0.77	**1.26**	-2.97	-1.62	-0.25
MEDIAN[2]	0.48	1.73	2.29	-1.12	-0.23	0.61
MEAN[2]	0.49	1.85	2.63	-1.17	-0.29	0.76
MAXIMUM[2]	**0.70**	3.80	4.27	+0.72	+0.32	2.42
POLICY SCENARIOS						
MINIMUM[2]	*0.37*	*0.77*	*1.36*	*-1.45*	*-0.21*	*-0.25*
MEDIAN[2]	*0.52*	*1.85*	*2.38*	*-2.41*	*-1.24*	*-1.34*
MEAN[2]	*0.50*	*2.26*	*2.68*	*-2.59*	*-1.15*	*-1.13*
MAXIMUM[2]	*0.58*	*3.80*	*4.27*	*-4.01*	*-1.96*	*-1.79*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

4. The projected decline in energy intensity ranges between 1 to 2 percent per year (Panel B and Appendix 1). There are significant differences between short-term (up to 2000) and longer term (2020 and beyond) trends. As indicated by the 84 percentile band from the IEW poll, short-term energy intensities in the region could increase significantly. In fact, between 1990 and 1992 the energy intensity of the former USSR increased by 23 percent (ECE, 1993) as economic output fell faster than energy consumption. Over a longer term, significant improvements in energy intensities can be expected once the reforms initiated indeed lead to economic restructuring and a replacement of energy inefficient capital vintages. The extent and timing of these efficiency improvements is, however, at present uncertain and perhaps best reflected in the ranges emerging from the IEW poll. In any case both short-term and long-term energy intensity trends emerging from scenarios available cover a much wider domain than suggested by the IPCC scenarios. Most scenarios also project declining carbon intensities of around 0.3 percent per year (Panel C), although statistical data and base year calibration problems in some models/scenarios remain significant (illustrated by the wide range in 1990 carbon intensities). By 2020, the range spanned by the IPCC scenarios is narrow, but continues to be representative of "middle-of-the-road" scenarios available in the literature. Over the long-term (2100) the range of IPCC scenarios becomes much larger; on the low end, carbon intensities in reference scenarios could also be in the range up to now only characteristic for policy scenarios, as indeed is the case for IS92c and IS92d.

5. **Summary:** The IPCC scenarios do not appropriately reflect recent data and perceptions of the possible evolution of energy related emissions in EEFSU. First, the 1990 base year emission values (1.7 Gt) exceed by 30 percent the most recent estimates based on UN energy statistics of 1.304 Gt (Marland *et al.*, 1993). This discrepancy reduces the credibility of the IPCC scenarios especially in comparison with scenarios with more accurate base year energy consumption and emission data (e.g. WEC, 1993). Second, the medium-term (2020) high growth trends (particularly Table 3 for GDP) are challenged by the impacts of the current economic crisis. This is already reflected in some recent non-IPCC scenarios. As a result, uncertainty ranges in regional emissions are significantly larger (especially towards lower emissions) than suggested by the IPCC scenarios in terms of both absolute emissions, as well as in the underlying driving force variables (e.g. Bashmakov, 1993).

3.3 Africa

1. Estimates of 1990 regional emissions from energy consumption (Marland *et al.*, 1993) amount to 0.158 Gt C. This compares well with the 1990 IPCC scenario base year emissions of 0.18 and a range of base year emissions between 0.11 to 0.17 Gt of fossil energy emissions (and up to 0.244 for total energy emissions, including fuelwood use) in the scenarios reviewed.

2. The range of emissions scenarios for Africa is the among the widest, both in absolute and relative terms, of all regions covered in this review (Panel A). By 2020 regional

emissions range between 0.3 to 0.8 Gt, a range which increases to between 0.5 to 5.2 Gt (i.e. a factor of 10) by the year 2100 in comparable reference scenarios. However, even for the highest scenario, per capita carbon emissions by 2100 would still remain significantly below current OECD averages. Overall, the range of absolute emission projections spanned by the IPCC scenarios is in agreement with (the however limited number of) independent scenarios available from the literature.

3. Over the 2020 time horizon demographic growth rates dominate over per capita GDP growth (Table 4, and Appendix 1), however in the longer term (post 2050) the respective influence of demographic developments decreases compared to other driving forces. Up to 2020 per capita economic growth rates show a large uncertainty range (0 to 3 percent per year), with resulting GDP growth rates ranging from 2.6 to 6 percent annually. IS92c assumes the lowest GDP growth rate of all reference scenarios reviewed. It is also interesting to note that some policy scenarios for Africa suggest substantial emission reduction potentials, primarily via reduced carbon intensity (i.e. enhanced sustainable use of biomass and other renewables). However, the number of available non-IPCC scenarios beyond 2020 is severely limited, as are resulting conclusions from a scenario comparison.

4. An interesting bifurcation between scenarios, concerns the evolution of energy and carbon intensities up to 2020. Whereas the IPCC scenarios all assume increasing energy intensities (Panel B), all (but one) of the other scenarios project decreasing energy intensities. Conversely, the IPCC scenarios all project declining carbon intensities (Panel C), whereas all (but one) other scenarios anticipate increasing carbon intensities. Thus, large uncertainties do not only pertain to present data for Africa (cf. the range of 1990 carbon intensities in Panel C), but also to possible future trends in energy and carbon intensities. Compared to this, the parametric variation of intensity changes in the IPCC scenarios appears narrow. Another illustration of the uncertainty range is the overlap between reference and policy scenarios reviewed.

5. **Summary:** The IPCC scenarios account for half of all the scenarios available for analysis from the perspective of Africa. Their range in carbon emissions reflects current uncertainties and values emerging from alternative scenario exercises. Conversely, the IPCC scenarios reflect less the uncertainty ranges of driving forces of future emissions, in particular, energy and carbon intensities. Their parametric variation and the trends (to 2020) assumed in the IPCC scenarios diverge from other global and regional and national (e.g. UNEP) scenario studies indicating in particular, differences to the regional perspectives. The resulting scientific uncertainty is thus much larger than suggested by the IPCC scenarios.

Table 4 - AFRICA

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1]
FOR REFERENCE ("no-controls") SCENARIOS

REFERENCE SCENARIOS	POP	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	2.63	1.25	3.92	0.26	-0.21	3.98
IS92b	2.63	1.25	3.92	0.26	-0.21	3.98
IS92c	2.20	0.40	2.60	0.40	-0.39	2.61
IS92d	2.20	1.46	3.69	0.09	-0.44	3.32
IS92e	2.63	2.11	4.80	0.17	-0.19	4.78
IS92f	3.03	1.06	4.12	0.51	-0.12	4.53
IPCC-EIS	2.42	1.55	4.00	-0.48	0.46	3.99
IEW-84%[2]			3.82	-0.52	0.10	3.33
IEW-Median[2]			3.64	-0.28	-0.17	3.28
IEW-16%[2]			3.45	-0.63	-0.09	3.06
UNEP Baseline	1.86	2.53	4.44	-1.40	0.47	3.46
WEC A	2.94	2.98	6.00	-0.58	1.17	6.61
WEC B	2.94	2.00	5.00	-1.67	0.26	3.51
E&R B	1.56	2.29	3.89	-1.46	0.07	2.44
EPA-SCW	2.72	0.01	2.73	-0.17	0.86	3.45
EPA-RCW	2.42	1.71	4.17	-0.10	0.72	4.81
IMAGE - CW	2.63	1.25	3.92	0.53	-0.16	4.30
MINIMUM[3]	1.56	0.01	**2.60**	-1.67	**-0.44**	2.44
MEDIAN[3]	2.63	1.50	3.92	-0.17	-0.09	3.51
MEAN[3]	2.49	1.56	4.00	-0.30	0.13	3.85
MAXIMUM[3]	**3.03**	2.98	6.00	0.53	1.17	6.61
POLICY SCENARIOS						
MINIMUM[3]	*1.86*	*0.01*	*2.73*	*-0.30*	*-0.11*	*-0.31*
MEDIAN[3]	*2.57*	*1.71*	*4.15*	*-1.46*	*-1.13*	*1.25*
MEAN[3]	*2.51*	*1.53*	*4.08*	*-1.31*	*-1.47*	*1.21*
MAXIMUM[3]	*2.94*	*2.53*	*5.00*	*-2.19*	*-4.01*	*2.43*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2 Refers to non-OPEC developing countries. Component growth rates do not add as calculated from original frequency distributions.

3 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

3.4 USA

1. Based on UN energy statistics Marland *et al.*, (1993) estimate 1990 energy-related carbon emissions of 1.335 Gt C, practically identical to the 1.33 Gt adopted in the IPCC scenarios. The greenhouse gas emission inventory for the USA developed within the framework of the FCCC (EPA, 1994) indicates carbon emissions from fossil energy production and consumption of 1.367 Gt (and 1.57 Gt "gross" emissions, including fuelwood use).

2. The range spanned by scenarios of future US emissions is large (Panel A). This wide range emerges in the region for which the largest number of scenario studies is available (with over 50 covered in this review). For 2020 the range of reference scenarios spans between 1.2 (IS92c) to 2.2-2.3 Gt C (e.g. IPCC-EIS, or for the U.S. National Energy Strategy NES) and widens to a range of between 0.6 (IS92c) to 4.5 Gt (highest scenario from the EMF-12 model runs) by 2100. The wide range of potential future emission increases (up to 3.2 Gt additional emissions by 2100) has to be contrasted with projected emission increases in the regions discussed above, e.g. in the range of 2.3 to 3.6 additional Gt for Africa, and China and Centrally Planned Asia respectively in the IS92a scenario. The probability of actual realization of such extreme high emission growth in a mature, service oriented economy, as in the case of the USA, appears however, rather small as indicated by the frequency distribution of the reference scenarios reviewed here. In this sense, the IPCC scenarios cover the ground of "middle-of-the-road" reference scenarios well, but not their extremes on the high side.

The spread of emissions between the 1992 IPCC scenarios (0.8 Gt by 2020 and 2.2 Gt by 2100 between IS92c and IS92e) is representative of the spread between high and low scenarios emerging from the EMF-12 or the IEW poll by 2020. However, the range spanned by the IPCC scenarios is shifted towards lower emissions (and policy scenarios). The highest of the IPCC scenarios (IS92e and IS92f) is significantly below other high scenarios or the upper bound spanned by the EMF-12 modeling exercise. IS92c and IS92d are also the lowest of all reference scenarios reviewed. The uncertainty range between different reference scenarios is also as large as between comparable reference and policy scenarios. By 2020 the range between the lowest and highest reference scenario spans from 1.2 to 2.3 Gt (1.2 Gt difference) compared to an emission reduction of up to 1 Gt between comparable reference and policy scenarios. By 2050 the range of reference scenarios spans between 0.9 (IS92c) and 3.3 Gt (2.4 Gt difference) compared to a scope for emission reduction of up to 2 Gt in the scenarios reviewed.

3. Table 5 (and Appendix 1) shows that emission growth rates are dominated by growth in economic activity. IS92e and IS92f assume the highest GDP growth rates of all reference scenarios reviewed. All reference scenarios assume also improvements in energy intensity. The situation for changes in carbon intensity is more diverse including

Table 5 - U S A

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1]
FOR REFERENCE ("no-controls") SCENARIOS

REFERENCE SCENARIOS	POP	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	0.57	2.33	2.91	-1.81	-0.26	0.78
IS92b	0.57	2.33	2.91	-1.81	-0.26	0.78
IS92c	0.22	1.72	1.94	-1.59	-0.63	-0.31
IS92d	0.22	2.45	2.67	-1.94	-0.88	-0.21
IS92e	0.57	2.91	3.49	-1.98	-0.11	1.34
IS92f	0.90	2.09	3.00	-1.62	0.00	1.34
IPCC-EIS	0.56	0.90	1.46	-0.20	0.16	1.42
IEW-84% [2]			2.36	-0.88	0.29	1.37
IEW-Median [2]			2.20	-0.96	0.24	1.24
IEW-16% [2]			2.03	-1.18	-0.22	0.80
ECS '92	0.54	1.09	1.63	-1.21	-0.25	0.15
CHALLENGE			1.28	-0.66	0.03	0.80
EMF 12 (lowest)			2.20	-1.38	-0.24	0.49
EMF 12 (highest)			2.20	-1.04	0.13	1.24
WEC A	0.56	1.83	2.40	-1.94	-0.44	-0.02
WEC B	0.56	1.83	2.40	-2.08	-0.40	-0.13
E&R B	0.51	1.63	2.15	-1.09	0.22	1.26
EPA-SCW	0.53	1.13	1.67	-1.29	0.00	0.35
EPA-RCW	0.43	2.23	2.64	-1.83	0.02	0.81
NES			2.08	-0.32	-0.12	1.63
green			2.27	-0.97	-0.05	1.23
12RT			2.20	-1.06	0.16	1.28
IMAGE - CW	0.56	2.33	2.91	-2.17	-0.22	0.46
MINIMUM[2]	0.22	**0.90**	1.28	-2.17	**-0.88**	**-0.31**
MEDIAN[2]	0.56	1.96	2.20	-1.29	-0.11	0.80
MEAN[2]	0.52	1.91	2.31	-1.35	-0.12	0.79
MAXIMUM[2]	**0.90**	**2.91**	**3.49**	**-0.20**	0.29	1.63
POLICY SCENARIOS						
MINIMUM[2]	*0.43*	*1.04*	*1.19*	*-0.66*	*-0.53*	*-2.30*
MEDIAN[2]	*0.53*	*1.83*	*2.14*	*-1.91*	*-1.13*	*-0.97*
MEAN[2]	*0.51*	*1.69*	*2.08*	*-1.87*	*-1.18*	*-1.08*
MAXIMUM[2]	*0.56*	*2.23*	*2.67*	*-2.71*	*-2.98*	*+0.73*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

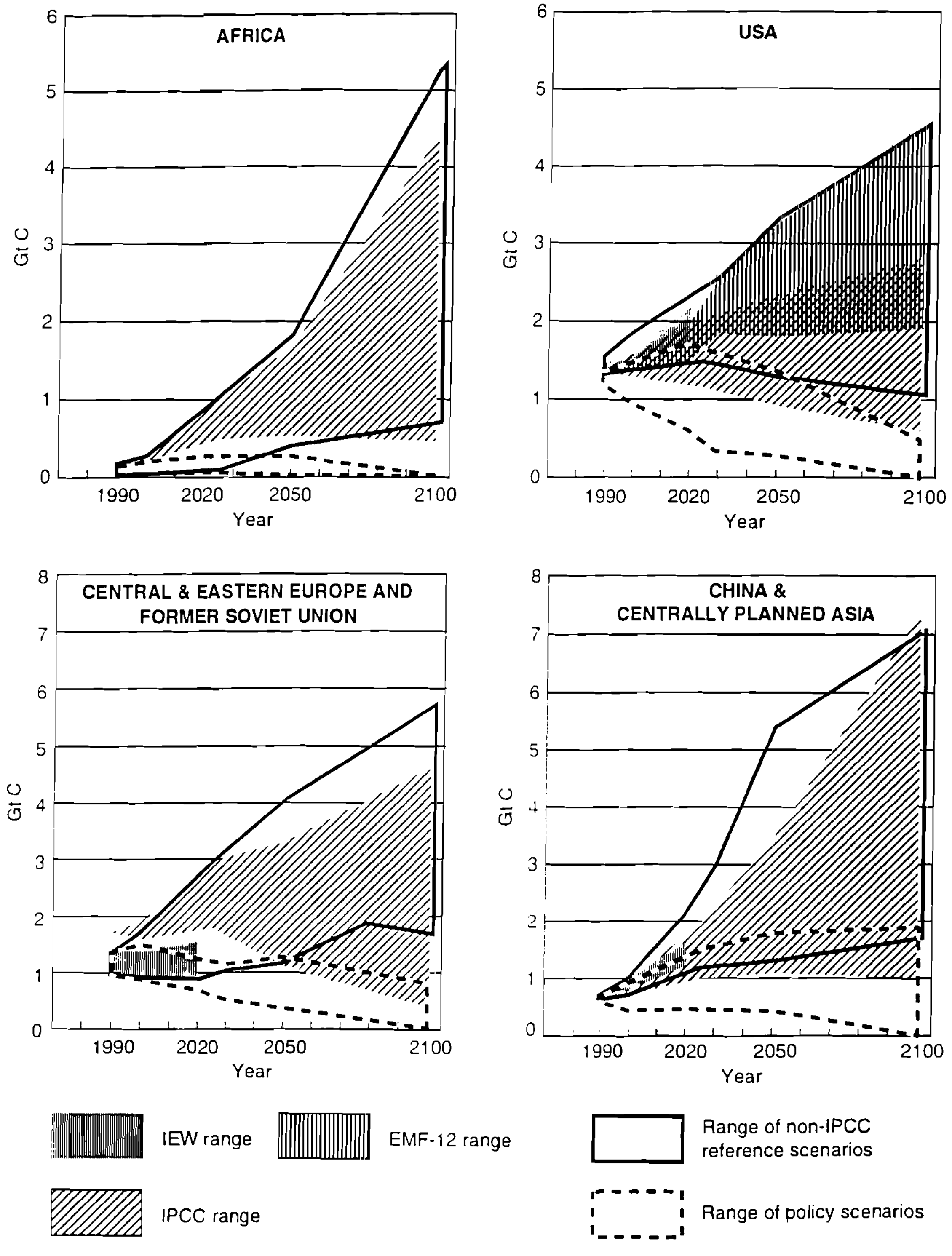
2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

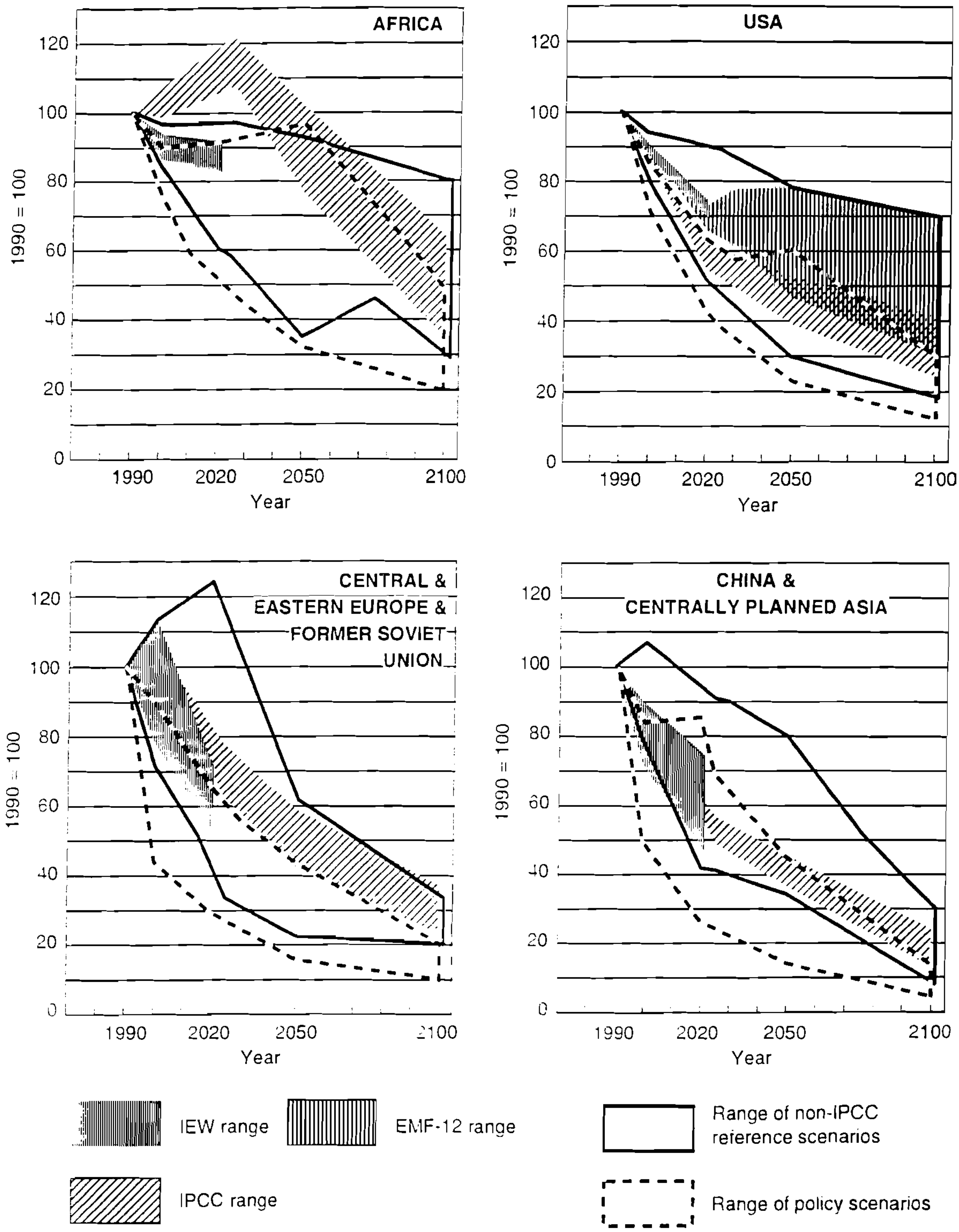
both improvements (IS92d being the most extreme of all scenarios reviewed) and deteriorating carbon intensity of the energy system. Over longer periods of time, the importance of changes in energy intensity and carbon intensity increases compared to economic growth rates (cf. Appendix 1). This implies that uncertainties stemming from differences in models and scenario assumptions may become more important than uncertainties from future levels of economic activity, a conclusion also confirmed by the EMF-12 modeling round (Gaskins and Weyant, 1993, and Weyant 1993). This suggests that scenario uncertainty ranges are perhaps more appropriately explored by a decentralized approach involving a diversity of models and viewpoints on structural changes in the economy and its supporting energy system, rather than by the use of a single model with parametric variations of the most important scenario input variables.

4. Energy intensity trends indicate a broad range of possible futures (Panel B). There is agreement on the direction of change, but disagreement on rate and ultimate improvement potential. The range spanned by the IPCC scenarios (and for that matter also by the IEW poll) appears narrow, especially up to 2020. Over the long-term (2050 and beyond), there is also a significant overlap between reference and policy scenarios, indicating that the distinction between policy action geared towards emission reduction and overall productivity increases in the economy (incl. energy efficiency) becomes progressively blurred. The range spanned by different scenarios for changes in the carbon intensity of energy supply is particularly large (Panel C). Reference scenarios span from slight improvements to a deterioration in the carbon intensity (e.g. in case of enhanced reliance on coal, incl. synfuel production). Both IS92c and IS92d are outside the range spanned by alternative reference scenarios. In this instance, the IPCC scenario exercise has therefore contributed towards developing alternative and independent views, rather than just mirroring the range of scenarios available in the literature.

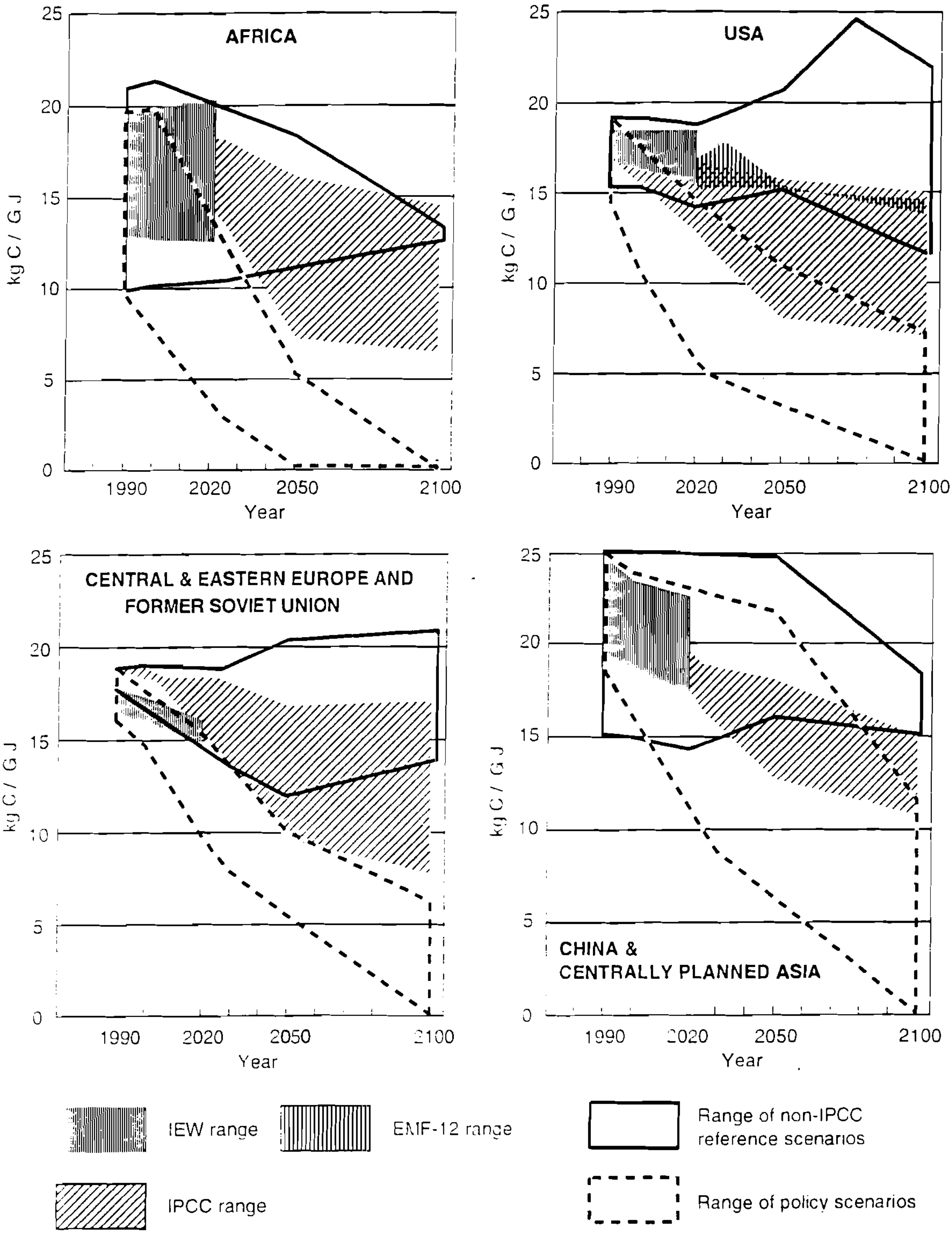
5. **Summary:** The IPCC scenarios reflect only to a certain degree, the wide range emerging from scenarios of future energy and carbon emissions of the USA. The IPCC scenarios are representative of the spread between low and high emission scenarios. They are, however, not fully representative of the absolute range of future emissions, particularly on the high emission side. Conversely IS92c and IS92d are in the emission range of policy scenarios. In terms of driving forces of future emission growth, the IPCC scenarios partly reflect the range of other reference scenarios, and partly expand that range. For instance, the GDP growth by 2020 of IS92e is the highest, and the carbon intensity of IS92c and IS92d is the lowest of all reference scenarios reviewed.



Panel A. Regional carbon emission scenarios (in Gt C).



Panel B. Regional energy intensity scenarios (index, 1990 = 100).



Panel C. Regional carbon intensity scenarios (in kg C per GJ).

4. Scenario Sensitivity

The sensitivity of future energy related CO_2 emissions to variations in critical input assumptions is analyzed in Figure 4 (cf. also the tables given in Appendix 1). Extremes of the range of driving force variables of reference and policy scenarios respectively over three time horizons (2020, 2050, and 2100) are contrasted with the IPCC IS92a scenario as a proxy of the underlying uncertainties. The sensitivity expressed in Gt C is the difference between the IS92a energy-related CO_2 emissions and the emissions resulting from changing a particular variable to its minimum/maximum value of the range of all scenarios, whilst holding all other variables at IS92a values.[9]

The results confirm the preponderance in uncertainties on future levels of economic activity, followed by energy intensity improvements over the medium-term horizon (to 2020), whereas changes in carbon intensity become particularly important in policy scenarios. Over the longer term (2050 and 2100) however, changes in carbon intensities assume a progressively larger role both on the negative side (in scenarios increasingly relying on dirty fossil fuels, including synfuels from coal) and on the positive side (in scenarios assuming further decarbonization of global and regional energy systems).

By 2100 uncertainties in future levels of economic activity maintain their leading role explaining emission differences across scenarios only in cases of (yet) higher GNP growth rates assumed than in IS92a. In cases of lower GNP growth, energy and carbon intensity contribute a similar order of magnitude of uncertainty than GNP growth across all regional scenarios analyzed. Comparison of reference and policy scenarios suggests that uncertainties in driving forces of emissions within reference cases is at least as large as the uncertainties between reference and policy cases. This illustrates the difficulty over long periods of time to clearly discern the impact of climate directed policy actions from the uncertainties of future driving forces of emissions.

5. Discussion and Conclusion

The stated purpose of the IPCC scenario exercise was to derive a range of future GHG emissions scenarios as input to climate models. The scenarios fulfill these objectives as they are both comprehensive (i.e. cover emissions of all climate relevant trace gases) and cover a comparatively wide range. This however, is a (perhaps too narrow) technical definition. Of policy relevance are rather questions like: do the scenarios reflect the current state of knowledge, or rather of uncertainty, and do the results represent possible (and to degree plausible) futures? These two issues are important to lend the derived

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[9] E.g. the emission impact of a difference in energy intensity between IS92a and the min/max values of all scenarios taken together is:

$$C_{IS92a} - (GNP_{IS92a} \times (PE/GNP)_{min/max} \times (C/PE)_{IS92a}).$$

For reasons of data consistency, min/max values are calculated using IS92a 1990 base year values and applying respective min/max growth rates from the total scenario sample to them.

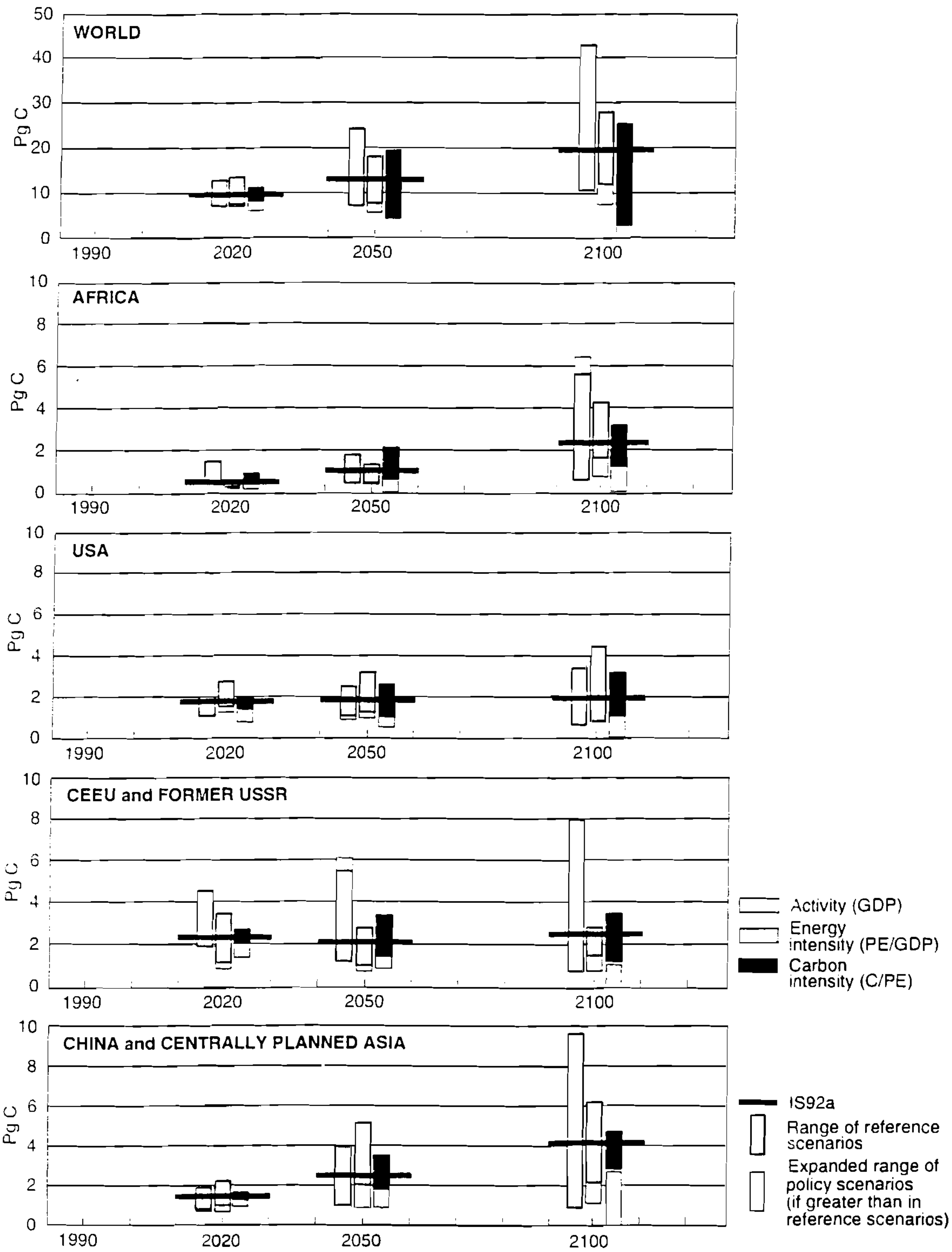

Figure 4. Sensitivity of energy-related carbon emissions to variations in levels of economic activity, energy intensity, and carbon intensity. Difference in emissions (in Gt C) between IS92a and min/max values of all other reference and policy scenarios analyzed.

climate change and impact scenarios sufficient weight to be considered in a policy context. The answer to the first question (reflection of scientific uncertainty) can, to a certain degree, be answered by comparison with other published scenarios. The second question of scenario possibility and plausibility is a judgmental issue rather than a scientific one. The regional analysis reported here aims to provide further background information on the global scenarios, in particular, to elucidate if the range of emissions spanned by the global scenarios reflects the diversity of initial conditions and possible future development paths in North and South, East and West.

The principal conclusion from the assessment of the 1992 IPCC global energy-related carbon emissions scenarios is that the scenarios are representative of the range of other recent scenarios available in the literature, without, however, covering the extremes. The emissions range covered by the IPCC scenarios reflects the uncertainties involved in projecting emissions up to 100 years into the future. This is, however, only in the aggregate of total carbon emissions. In their underlying structural input and/or modeling variables energy and carbon intensity the IPCC scenarios reflect a much smaller range compared to other scenarios. This, together with the extreme scenarios available in the published literature that are not covered by the 1992 IPCC series, suggests that the related scientific uncertainties are much larger than covered in the IPCC scenarios. This does not reduce the value of the 1992 IPCC scenarios *per se,* however it does reduce the usefulness of the scenarios as input to climate models and the policy debate for assessing extreme outcome scenarios (at both the high and low ends), whose probability of occurrence can at present, not be established.

The main conclusion from the assessment of regional scenarios is that the range between high and low emissions spanned by the global scenarios is supported from a regional perspective. However, this is the result of compensating effects (of regional under- and overestimation) and sometimes also due to counterbalancing errors. As such, the regional perspective gives more insight on the plausibility of the global scenarios than a simple analysis of main input and output variables at the global level.

In interpreting the global totals of the IPCC scenarios, one has to keep in mind that at the regional level there are a number of instances in which the IPCC scenarios do not fully reflect the uncertainty range emerging from other scenario studies. For instance, future emission levels in Central and Eastern Europe and the Former USSR (EEFSU) are higher than in more recent scenario studies taking the effects of economic crisis into account, whereas the IPCC range for the USA spans a lower range than the full spectrum of scenarios available in the literature. The 1990 base year emission data for EEFSU in the IPCC scenarios are also 30 percent higher than most recent regional emission inventories (Marland *et al.*, 1993) suggest. This implies that the global total of 6 Gt energy related carbon emissions for 1990 which agrees with the available estimates of emissions has to be contrasted with counterbalancing errors of regional base year emission data used as a starting point for the IPCC scenarios.

Even if the IPCC scenarios can be considered representative of the range of future emission trajectories spanned in the available literature, they are not necessarily representative of the uncertainty ranges of the underlying structural variables of future emission levels: including demographic and economic development, energy intensity (efficiency) and carbon intensity (structure of energy supply). In a number of instances, the IPCC scenarios cover a much smaller range than emerging from other scenarios, whereas in other cases the IPCC scenarios define the uncertainty range rather than reflect the range from other scenario studies. Examples for the former include, for instance, the much smaller range of future energy intensity improvement rates in the IPCC scenarios for China and Centrally Planned Asia as well as the USA compared to other scenario studies. Examples of the latter include the long-term economic growth rate assumed in IS92e which is the highest found in all scenarios reviewed for both China and Centrally Planned Asia, as well as the USA. There are also examples of differences in trend and not only of parametric variation. For instance, up to 2020 the IPCC scenarios for Africa assume increasing energy intensities (energy efficiency deterioration) along with decreasing carbon intensities (shift to cleaner energy supply structures), whereas all (except for one, that was, in fact, developed to follow IS92a closely) of the scenarios reviewed, assume exactly opposing trends for these two structural variables.

Thus, the 1992 IPCC scenarios not necessarily reflect the full range of regional perspectives that would be a prerequisite for considering the scenarios as a reference baseline for assessing policy options or even as input to a possible negotiation process. These perspectives, in turn, cannot be developed in a centralized approach but rely on inputs of the scientific and policy community familiar with the diversity of local, national and regional circumstances (cf. the approach of regional fora used by the World Energy Council [WEC] in its scenario development process).

Throughout all of the regions discussed here, a certain ambiguity in the basic design of the low emission scenarios (particularly IS92c) emerged as it fell systematically into an emission range considered by other studies only in deliberate (climate oriented) policy intervention (not the least due to the low assumptions with respect to demographic and economic growth). Perhaps other scenario developers have failed to explore more fully the uncertainty ranges of future low emission paths even in the absence of climate policies. However, in terms of reception of the IPCC scenarios, the development of reference low emission scenarios without considering policy scenarios has given rise to possible misinterpretation of these scenarios.

Overall, the IPCC scenarios can be considered to be indicative of the uncertainty spread in future energy related carbon emission and (to a lesser degree) of the underlying driving variables at the regional (and in their aggregate also at the global) level, without, however, being always representative of the absolute uncertainty ranges given in the available literature.

This is not so much a drawback of the family of IPCC scenarios *per se* (which in any case spans a much wider domain than previously performed global scenario exercises), but rather relates to certain limits of the approach adopted (parametric variation within one model). The regional scenarios discussed here (particularly for the USA) clearly indicate that a fuller appreciation of the inherent and substantial uncertainties of very long-term perspectives is more appropriately reflected in a decentralized approach. By involving different models and modeling groups and their resulting diversity of viewpoints of possible future developments a wider domain of possible futures can be explored. Successful examples like the Energy Modeling Forum (EMF), the International Energy Workshop (IEW), or the GHG scenario costing studies projects CHALLENGE (IIASA) and the one carried out by UNEP, illustrate the potential benefits from such a decentralized scenario approach.

Such a "free speech of models" however has to go hand-in-hand with a range of harmonized input assumptions and standardized reporting formats to ensure model and scenario comparability. If all modeling groups would, in fact, have followed the positive example statuted by the IPCC scenario developers in terms of input and output data documentation (or e.g. in using a standardized reporting form for scenario comparison as done, for instance, in the IEW poll), the task of scenario comparison would have been not only easier but also more instructive. In the end this may well be the most important contribution from the 1992 IPCC scenario exercise: enabling an informed (and quantifyable) debate about possible futures. Scenarios will never be able to resolve the inherent uncertainties the future may hold, but scenarios are an indispensable tool to educate both the scientific and policy community about them.

Acknowledgements

The contributions of Leo Schrattenholzer (IIASA), Igor Bashmakov (Moscow Center for Energy Efficiency), James Edmonds (Battelle, Washington D.C.), Sujata Gupta (TATA Energy Research Institute, New Delhi) and Zhihong Wei (Tsinghua University, Beijing) to the regional scenario assessment, and the assistance of Andrei Gritsevskii and Nadezhda Makarova in the data analysis, are gratefully acknowledged.

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7. Appendices[10]

Appendix 1: Tables (30 pages)

Appendix 2: Figures (20 pages)

Appendix 3: List of Scenarios Reviewed (1 page)

[10] The original data derived from published scenario studies underlying the tables and figures, can be obtained upon request from the author (Arnulf Grübler at IIASA, 2361 Laxenburg, Austria - telephone: #43-2236-807-470 or email: gruebler@iiasa.ac.at).

Appendix 1: Tables

WORLD

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	*GDP / Capita*	*GDP*	*Energy / GDP*	*Carbon / Energy*	*Carbon Emissions*
WEC C	*1.43*	*1.85*	*3.30*	*-2.40*	*-0.58*	*0.24*
EPA-SCW-P	*1.43*	*0.35*	*1.79*	*-1.08*	*-0.52*	*0.16*
EPA-RCW-P	*1.29*	*1.35*	*2.65*	*-1.19*	*-1.19*	*0.23*
green (200$/tc)			*2.66*	*-2.25*	*-0.92*	*-0.58*
12RT (200$/tc)			*2.44*	*-1.43*	*-1.40*	*-0.44*
RIGES	*1.29*	*2.19*	*3.50*	*-1.78*	*-1.94*	*-0.32*
FFES	*1.17*	*1.12*	*2.30*	*-2.02*	*-1.55*	*-1.31*
MINIMUM[2]	*1.17*	*0.35*	*1.79*	*-1.08*	*-0.52*	*-1.31*
MEDIAN[2]	*1.29*	*1.35*	*2.65*	*-1.78*	*-1.19*	*-0.32*
MEAN[2]	*1.32*	*1.37*	*2.66*	*-1.74*	*-1.16*	*-0.29*
MAXIMUM[2]	*1.43*	*2.19*	*3.50*	*-2.40*	*-1.94*	*+0.24*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wp_kwor20a

WORLD

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	1.08	1.48	2.57	-0.87	-0.35	1.32
IS92b	1.08	1.48	2.57	-0.92	-0.39	1.23
IS92c	0.67	0.85	1.49	-0.63	-0.71	0.13
IS92d	0.67	1.71	2.37	-0.70	-1.07	0.56
IS92e	1.08	2.17	3.27	-1.07	-0.25	1.90
IS92f	1.46	1.27	2.74	-0.93	-0.16	1.63
IPCC-EIS						
IEW-84% [2]						
IEW-Median [2]						
IEW-16% [2]						
ECS '92						
CH_4 - economy (eff.)	0.99	1.00	2.00	-1.00	-2.20	-1.23
CHALLENGE						
WEC A					-0.39	1.49
WEC B					-0.42	1.19
E&R B	0.82	1.68	2.51	-0.97	-0.05	1.46
EPA-SCW	1.20	0.79	1.99	-1.21	-0.14	0.62
EPA-RCW	0.99	2.58	3.60	-1.81	-0.02	1.70
green			2.43	-0.51	+0.27	2.18
12RT			2.21	-0.39	-0.25	1.57
IMAGE - CW	1.08	1.59	2.70	-0.87	-0.32	1.48
MINIMUM [2]	**0.67**	0.79	**1.49**	-0.39	-2.20	-1.23
MEDIAN [2]	1.08	1.48	2.51	-0.92	-0.32	+1.46
MEAN [2]	1.01	1.51	2.50	-0.91	-0.43	+1.15
MAXIMUM [2]	**1.46**	2.58	3.60	-1.81	+0.27	+2.18

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

wp-kwor.50

WORLD

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	*GDP / Capita*	*GDP*	*Energy / GDP*	*Carbon / Energy*	*Carbon Emissions*
WEC C					*-0.55*	*0.33*
EPA-SCW-P	*1.20*	*0.79*	*1.99*	*-1.25*	*-1.09*	*-0.37*
EPA-RCW-P	*0.99*	*2.58*	*3.60*	*-2.24*	*-1.28*	*-0.02*
green (200$/tc)			*2.40*	*-1.62*	*-0.60*	*0.14*
12RT (200$/tc)			*2.19*	*-0.65*	*-1.12*	*0.38*
RIGES	*0.99*	*2.25*	*3.26*	*-1.89*	*-1.75*	*-0.47*
FFES	*0.90*	*1.41*	*2.32*	*-1.73*	*-1.94*	*-1.40*
MINIMUM[2]	*0.90*	*0.79*	*1.99*	*-0.65*	*-0.55*	*-1.40*
MEDIAN[2]	*0.99*	*1.83*	*2.36*	*-1.67*	*-1.12*	*-0.02*
MEAN[2]	*1.02*	*1.76*	*2.63*	*-1.56*	*-1.19*	*-0.20*
MAXIMUM[2]	*1.20*	*2.58*	*3.60*	*-2.24*	*-1.94*	*+0.38*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wp_kwor50a

WORLD

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	0.70	1.59	2.29	-0.95	-0.22	1.09
IS92b	0.70	1.59	2.29	-0.98	-0.25	1.03
IS92c	0.18	0.89	1.07	-0.66	-0.64	-0.24
IS92d	0.18	1.84	2.02	-0.82	-0.71	0.46
IS92e	0.70	2.29	3.00	-1.15	-0.20	1.61
IS92f	1.11	1.36	2.48	-0.99	-0.12	1.34
IPCC-EIS						
IEW-84% [2]						
IEW-Median [2]						
IEW-16% [2]						
ECS '92						
CH_4 - economy (eff.)	0.62	1.38	2.00	-1.35	-2.05	-1.44
CHALLENGE						
WEC A					-0.52	0.91
WEC B					-0.60	0.60
E&R B	0.61	1.68	2.30	-0.89	-0.05	1.34
EPA-SCW	0.85	0.76	1.62	-0.96	-0.05	0.59
EPA-RCW	0.62	2.19	2.82	-1.41	-0.01	1.36
green						
12RT						
IMAGE - CW	0.70	1.70	2.42	-0.83	-0.33	1.23
MINIMUM [2]	**0.18**	0.76	**1.07**	**-0.66**	-0.01	-1.44
MEDIAN [2]	0.70	1.59	2.29	-0.97	-0.29	+0.97
MEAN [2]	0.64	1.56	2.20	-1.01	-0.48	+0.71
MAXIMUM [2]	**1.11**	**2.29**	**3.00**	-1.41	-2.05	**+1.61**

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

wp_kwor100

WORLD

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
WEC C					*-1.41*	*-0.68*
EPA-SCW-P	*0.85*	*0.76*	*1.62*	*-1.15*	*-1.09*	*-0.64*
EPA-RCW-P	*0.62*	*2.19*	*2.82*	*-1.87*	*-0.92*	*-0.03*
green (200$/tc)						
12RT (200$/tc)						
RIGES						
FFES	*0.65*	*1.67*	*2.33*	*-1.39*	*-6.43*	*-5.57*
MINIMUM[2]	*0.62*	*0.76*	*1.62*	*-1.15*	*-0.92*	*-0.03*
MEDIAN[2]	*0.66*	*1.67*	*2.34*	*-1.39*	*-1.25*	*-0.66*
MEAN[2]	*0.71*	*1.54*	*2.26*	*-1.47*	*-2.46*	*-1.73*
MAXIMUM[2]	*0.85*	*2.19*	*2.82*	*-1.87*	*-6.43*	*-5.57*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wp_kwor100a

CHINA AND CENTRALLY PLANNED ASIA

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
ESCAP S3			*5.50*	*-2.34*	*-0.60*	*2.41*
WEC C	*0.94*	*4.08*	*5.02*	*-2.82*	*-0.52*	*1.56*
EPA-SCW-P	*0.90*	*2.25*	*3.15*	*-1.07*	*-0.80*	*1.24*
EPA-RCW-P	*1.02*	*4.11*	*5.13*	*-1.69*	*-1.06*	*2.29*
green (200$/tc)			*4.34*	*-4.32*	*-0.65*	*-0.82*
12RT (200$/tc)			*2.34*	*-0.53*	*-1.72*	*0.04*
RIGES	*1.02*	*4.10*	*5.12*	*-1.89*	*-1.09*	*2.05*
FFES	*0.81*	*3.97*	*4.78*	*-3.33*	*-1.35*	*-0.37*
MINIMUM[2]	*0.81*	*2.25*	*2.34*	*-0.53*	*-0.52*	*-0.82*
MEDIAN[2]	*0.94*	*4.08*	*4.48*	*-1.89*	*-1.06*	*1.24*
MEAN[2]	*0.94*	*3.70*	*4.42*	*-2.24*	*-1.03*	*0.86*
MAXIMUM[2]	*1.02*	*4.11*	*5.17*	*-4.32*	*-1.72*	*2.29*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wpcpa20a

CHINA AND CENTRALLY PLANNED ASIA

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	0.71	3.69	4.42	-1.57	-0.36	2.41
IS92b	0.71	3.69	4.42	-1.57	-0.36	2.41
IS92c	0.19	2.85	3.05	-1.33	-0.65	1.02
IS92d	0.19	3.95	4.15	-1.46	-0.86	1.75
IS92e	0.71	4.50	5.23	-1.86	-0.29	2.98
IS92f	0.91	3.57	4.51	-1.62	-0.40	2.41
IPCC-EIS						
IEW-84% [2]						
IEW-Median [2]						
IEW-16% [2]						
ECS '92						
ESCAP S1						
He *et al.* (c)						
WEC A						
WEC B						
E&R B	0.64	2.30	2.96	-0.69	-0.21	2.03
EPA-SCW	0.63	2.23	2.87	-1.23	-0.46	1.14
EPA-RCW	0.71	4.14	4.87	-1.74	-0.30	2.74
green			3.90	-0.36	0.22	3.75
12RT			3.64	-0.60	-0.54	2.46
IMAGE - CW	0.71	3.78	4.51	-1.07	-0.24	3.13
MINIMUM[2]	**0.19**	2.23	2.87	-0.36	**-0.86**	1.02
MEDIAN[2]	0.70	3.69	4.29	-1.39	-0.36	2.41
MEAN[2]	0.61	3.47	4.04	-1.26	-0.37	2.35
MAXIMUM[2]	**0.91**	**4.50**	**5.23**	**-1.86**	0.22	3.75

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

wpcpa50

CHINA AND CENTRALLY PLANNED ASIA

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
ESCAP S3						
WEC C						
EPA-SCW-P	*0.63*	*2.23*	*2.87*	*-1.34*	*-0.96*	*0.52*
EPA-RCW-P	*0.71*	*4.14*	*4.87*	*-2.22*	*-0.90*	*1.62*
green (200$/tc)			*3.85*	*-3.25*	*-0.00*	*0.47*
12RT (200$/tc)			*3.49*	*-1.06*	*-1.46*	*0.90*
RIGES	*0.71*	*4.14*	*4.87*	*-2.64*	*-1.49*	*0.59*
FFES	*0.57*	*4.02*	*4.29*	*-3.12*	*-1.99*	*-0.97*
MINIMUM[2]	*0.57*	*2.23*	*2.87*	*-1.06*	*-0.00*	*-0.97*
MEDIAN[2]	*0.67*	*4.08*	*4.07*	*-2.43*	*-1.21*	*+0.55*
MEAN[2]	*0.65*	*3.52*	*4.04*	*-2.27*	*-1.13*	*+0.52*
MAXIMUM[2]	*0.71*	*4.14*	*4.87*	*-3.25*	*-1.99*	*+1.62*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wpcpa50a

CHINA AND CENTRALLY PLANNED ASIA

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	0.42	3.37	3.79	-1.65	-0.30	1.78
IS92b	0.42	3.37	3.79	-1.65	-0.30	1.78
IS92c	-0.24	2.59	2.34	-1.29	-0.55	0.47
IS92d	-0.24	3.71	3.47	-1.50	-0.62	1.27
IS92e	0.42	4.17	4.60	-1.88	-0.32	2.31
IS92f	0.78	3.26	4.04	-1.84	-0.36	1.78
IPCC-EIS						
IEW-84% [2]						
IEW-Median [2]						
IEW-16% [2]						
ECS '92						
ESCAP S1						
He *et al.* (c)						
WEC A						
WEC B						
E&R B						
EPA-SCW	0.43	2.26	2.69	-1.55	-0.25	0.86
EPA-RCW	0.42	3.93	4.35	-2.21	-0.28	1.77
green						
12RT						
IMAGE - CW	0.41	3.44	3.85	-1.38	-0.18	2.25
MINIMUM[2]	**-0.24**	2.26	**2.34**	**-1.29**	-0.18	**0.47**
MEDIAN[2]	0.42	3.37	3.80	-1.64	-0.30	1.78
MEAN[2]	0.31	3.34	3.67	-1.66	-0.35	1.59
MAXIMUM[2]	**0.78**	**4.17**	**4.60**	-2.21	**-0.62**	**2.31**

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

wpcpa100

CHINA AND CENTRALLY PLANNED ASIA

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
ESCAP S3						
WEC C						
EPA-SCW-P	*0.43*	*2.26*	*2.70*	*-1.82*	*-0.78*	*+0.05*
EPA-RCW-P	*0.42*	*3.96*	*4.36*	*-2.63*	*-0.67*	*+0.93*
green (200$/tc)						
12RT (200$/tc)						
RIGES						
FFES	*0.37*	*3.76*	*4.13*	*-2.71*	*-5.11*	*-3.87*
MINIMUM[2]	*0.37*	*2.26*	*2.70*	*-1.82*	*-0.67*	*-3.87*
MEDIAN[2]	*0.42*	*3.93*	*4.13*	*-2.63*	*-0.78*	*+0.05*
MEAN[2]	*0.41*	*3.38*	*3.73*	*-2.39*	*-2.19*	*-0.96*
MAXIMUM[2]	*0.43*	*3.96*	*4.36*	*-2.71*	*-5.11*	*+0.93*

1) Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2) Component growth rates do not add as calculated from original frequency distributions.

wpcpa10a

CENTRAL AND EASTERN EUROPE AND EX-USSR

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
Bashmakov Efficiency	*0.58*	*0.77*	*1.36*	*-2.05*	*-0.21*	*-0.92*
Sinyak et al. Efficiency	*0.56*	*1.44*	*2.00*	*-1.45*	*-1.96*	*-1.44*
WEC C	*0.52*	*1.85*	*2.37*	*-1.78*	*-1.90*	*-1.34*
EPA-SCW-P	*0.52*	*1.73*	*2.25*	*-1.85*	*-0.62*	*-0.25*
EPA-RCW-P	*0.45*	*3.80*	*4.25*	*-3.49*	*-1.12*	*-0.51*
green (200$/tc)			*2.91*	*-4.01*	*-0.22*	*-1.44*
12RT (200$/tc)			*2.19*	*-2.41*	*-1.24*	*-1.51*
RIGES	*0.45*	*3.80*	*4.25*	*-3.70*	*-1.39*	*-0.98*
FFES	*0.37*	*2.14*	*2.51*	*-2.56*	*-1.68*	*-1.79*
MINIMUM[2]	*0.37*	*0.77*	*1.36*	*-1.45*	*-0.21*	*-0.25*
MEDIAN[2]	*0.52*	*1.85*	*2.38*	*-2.41*	*-1.24*	*-1.34*
MEAN[2]	*0.50*	*2.26*	*2.68*	*-2.59*	*-1.15*	*-1.13*
MAXIMUM[2]	*0.58*	*3.80*	*4.27*	*-4.01*	*-1.96*	*-1.79*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wpcee20a

CENTRAL AND EASTERN EUROPE AND EX-USSR

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	0.32	1.63	1.95	-1.14	-0.43	0.35
IS92b	0.32	1.63	1.95	-1.14	-0.43	0.35
IS92c	0.07	0.85	0.92	-0.88	-0.76	-0.72
IS92d	0.07	1.79	1.86	-1.02	-1.13	-0.32
IS92e	0.32	2.50	2.82	-1.45	-0.23	1.11
IS92f	0.65	1.50	2.15	-1.22	-0.20	0.71
IPCC-EIS						
IEW-84% [2]						
IEW-Median [2]						
IEW-16% [2]						
ECS '92						
Bashmakov Base						
Sinyak *et al.* BAU	0.46	1.70	2.16	-1.29	-0.33	0.51
WEC A						
WEC B						
E&R B	0.32	1.58	1.90	-1.09	-0.09	0.70
EPA-SCW	0.36	1.61	1.97	-1.44	-0.17	0.33
EPA-RCW	0.32	3.43	3.76	-2.46	-0.05	1.16
green			2.16	-0.71	+0.34	1.78
12RT			1.95	-1.37	-0.50	0.05
IMAGE - CW	0.32	1.34	1.66	-0.50	-0.67	0.47
MINIMUM [2]	**0.07**	**0.85**	**0.92**	-0.71	**-1.13**	**-0.72**
MEDIAN [2]	0.32	1.63	1.95	-1.14	-0.33	0.47
MEAN [2]	0.32	1.80	2.11	-1.23	-0.36	0.50
MAXIMUM [2]	**0.65**	3.43	3.76	-2.46	+0.34	1.78

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distribtions.

BOLD denotes IPCC scenarios

wpcee50

CENTRAL AND EASTERN EUROPE AND EX-USSR

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
Bashmakov Efficiency						
Sinyak et al. Efficiency	*0.46*	*1.70*	*2.16*	*-1.63*	*-2.03*	*-1.53*
WEC C						
EPA-SCW-P	*0.36*	*1.61*	*1.97*	*-1.60*	*-0.99*	*-0.65*
EPA-RCW-P	*0.33*	*3.43*	*3.76*	*-3.00*	*-1.33*	*-0.69*
green (200$/tc)			*2.38*	*-2.31*	*-0.18*	*-0.16*
12RT (200$/tc)			*1.92*	*-1.34*	*-1.34*	*-0.80*
RIGES	*0.33*	*3.43*	*3.76*	*-3.07*	*-1.63*	*-1.06*
FFES	*0.31*	*1.63*	*1.94*	*-2.05*	*-1.79*	*-1.90*
MINIMUM[2]	*0.31*	*1.61*	*1.92*	*-1.34*	*-0.18*	*-0.16*
MEDIAN[2]	*0.33*	*1.93*	*2.17*	*-2.05*	*-1.34*	*-0.80*
MEAN[2]	*0.36*	*2.42*	*2.56*	*-2.14*	*-1.33*	*-0.97*
MAXIMUM[2]	*0.46*	*3.43*	*3.76*	*-3.07*	*-2.03*	*-1.90*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wpcee50a

CENTRAL AND EASTERN EUROPE AND EX-USSR

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	0.16	1.40	1.56	-1.01	-0.19	0.35
IS92b	0.16	1.40	1.56	-1.01	-0.19	0.35
IS92c	-0.22	0.63	0.41	-0.89	-0.83	-1.31
IS92d	-0.22	1.62	1.40	-1.05	-0.81	-0.48
IS92e	0.16	2.20	2.36	-1.31	-0.12	0.91
IS92f	0.63	1.16	1.79	-1.06	-0.09	0.63
IPCC-EIS						
IEW-84% [2]						
IEW-Median [2]						
IEW-16% [2]						
ECS '92						
Bashmakov Base						
Sinyak *et al.* BAU						
WEC **A**						
WEC **B**						
E&R **B**						
EPA-SCW	0.24	1.56	1.80	-1.41	0.01	0.37
EPA-RCW	0.22	2.41	2.63	-1.46	0.12	1.25
green						
12RT						
IMAGE - CW	0.16	1.40	1.56	-0.97	-0.42	0.16
MINIMUM[2]	**-0.22**	**0.63**	**0.41**	**-0.89**	**-0.83**	**-1.31**
MEDIAN[2]	0.16	1.40	1.57	-1.05	-0.19	0.35
MEAN[2]	0.15	1.53	1.68	-1.13	-0.28	0.25
MAXIMUM[2]	**0.63**	2.41	2.63	-1.46	+0.12	1.25

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

wpcee100

CENTRAL AND EASTERN EUROPE AND EX-USSR

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
Bashmakov Efficiency						
Sinyak et al. Efficiency						
WEC C						
EPA-SCW-P	0.24	1.56	1.80	-1.69	-0.97	-0.89
EPA-RCW-P	0.22	2.41	2.63	-2.07	-0.99	-0.48
green (200$/tc)						
12RT (200$/tc)						
RIGES						
FFES	0.16	1.38	1.43	-1.43	-4.22	-4.24
MINIMUM[2]	0.16	1.27	1.43	-1.43	-0.97	-0.48
MEDIAN[2]	0.22	1.56	1.80	-1.69	-0.99	-0.89
MEAN[2]	0.20	1.79	1.96	-1.73	-2.06	-1.87
MAXIMUM[2]	0.24	2.41	2.63	-2.07	-4.22	-4.24

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distribtions.

wpcee10a

AFRICA

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
UNEP Abatement	*1.86*	*2.53*	*4.39*	*-2.19*	*-0.11*	*2.04*
WEC C	*2.94*	*2.00*	*4.94*	*-2.08*	*-0.37*	*2.43*
EPA-SCW-P	*2.72*	*0.01*	*2.73*	*-0.35*	*-0.80*	*1.55*
EPA-RCW-P	*2.42*	*1.71*	*4.13*	*-0.30*	*-4.01*	*-0.31*
RIGES	*2.38*	*1.71*	*4.09*	*-1.03*	*-2.04*	*0.95*
FFES	*2.74*	*1.28*	*4.02*	*-1.89*	*-1.45*	*0.57*
MINIMUM[2]	*1.86*	*0.01*	*2.73*	*-0.30*	*-0.11*	*-0.31*
MEDIAN[2]	*2.57*	*1.71*	*4.15*	*-1.46*	*-1.13*	*1.25*
MEAN[2]	*2.51*	*1.53*	*4.08*	*-1.31*	*-1.47*	*1.21*
MAXIMUM[2]	*2.94*	*2.53*	*5.00*	*-2.19*	*-4.01*	*2.43*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wpafr20a

AFRICA

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	2.08	1.86	3.94	-0.23	-0.59	3.12
IS92b	2.08	1.86	3.94	-0.23	-0.59	3.12
IS92c	1.56	1.04	2.60	+0.04	-0.85	1.78
IS92d	1.56	2.10	3.66	-0.00	-1.58	2.06
IS92e	2.08	2.64	4.78	-0.45	-0.50	3.78
IS92f	2.49	1.65	4.14	-0.31	-0.25	3.60
IPCC-EIS						
IEW-84% [2]						
IEW-Median [2]						
IEW-16% [2]						
UNEP Baseline						
WEC A						
WEC B						
E&R B	1.14	2.14	3.28	-1.71	+0.45	2.00
EPA-SCW	2.35	0.11	2.46	-0.31	-0.19	1.94
EPA-RCW	1.90	1.94	3.84	-0.60	-0.15	3.10
IMAGE - CW	2.08	1.86	3.94	-0.12	-0.76	3.07
MINIMUM[2]	1.14	0.11	2.46	-1.71	**-1.58**	**1.78**
MEDIAN[2]	2.08	1.86	3.93	-0.27	-0.48	3.11
MEAN[2]	1.93	1.72	3.69	-0.39	-0.47	2.79
MAXIMUM[2]	**2.49**	**2.64**	**4.78**	**+0.04**	+0.45	**3.78**

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

wpafr50

AFRICA

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
UNEP Abatement						
WEC C						
EPA-SCW-P	*2.35*	*0.11*	*2.46*	*-0.05*	*-6.39*	*-4.13*
EPA-RCW-P	*1.90*	*1.94*	*3.84*	*-0.89*	*-6.88*	*-4.13*
RIGES	*1.88*	*1.94*	*3.82*	*-1.43*	*-1.89*	*0.43*
FFES	*2.08*	*2.15*	*4.23*	*-1.90*	*-1.41*	*0.81*
MINIMUM[2]	*1.88*	*0.11*	*2.46*	*-0.05*	*-1.41*	*-4.13*
MEDIAN[2]	*1.99*	*1.94*	*3.86*	*-1.15*	*-4.14*	*-1.85*
MEAN[2]	*2.05*	*1.53*	*3.61*	*-1.06*	*-4.15*	*-1.76*
MAXIMUM[2]	*2.35*	*2.12*	*4.23*	*-1.90*	*-6.88*	*0.81*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wpafr50a

AFRICA

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	1.37	2.13	3.50	-0.74	-0.35	2.41
IS92b	1.37	2.13	3.50	-0.74	-0.35	2.41
IS92c	0.84	1.34	2.20	-0.41	-0.91	0.86
IS92d	0.84	2.39	3.23	-0.61	-0.96	1.65
IS92e	1.37	2.89	4.30	-0.96	-0.34	2.96
IS92f	1.79	1.91	3.70	-0.79	-0.23	2.68
IPCC-EIS						
IEW-84% [2]						
IEW-Median [2]						
IEW-16% [2]						
UNEP Baseline						
WEC A						
WEC B						
E&R B						
EPA-SCW	1.64	0.64	2.28	-0.59	-0.12	1.57
EPA-RCW	1.20	2.14	3.34	-1.11	-0.13	2.09
IMAGE - CW	1.37	2.13	3.50	-0.21	-0.80	2.49
MINIMUM[2]	**0.84**	0.64	**2.20**	-0.21	-0.12	**0.86**
MEDIAN[2]	1.37	2.13	3.53	-0.74	-0.35	2.41
MEAN[2]	1.31	1.97	3.30	-0.68	-0.43	2.16
MAXIMUM[2]	**1.79**	**2.89**	**4.30**	-1.11	**-0.96**	**2.96**

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

wpafr100

AFRICA

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
UNEP Abatement						
WEC C						
EPA-SCW-P	*1.64*	*0.64*	*2.30*	*-0.64*	*-3.85*	*-2.28*
EPA-RCW-P	*1.20*	*2.14*	*3.34*	*-1.45*	*-4.07*	*-2.28*
RIGES						
FFES	*1.48*	*2.91*	*4.43*	*-1.80*	*-4.91*	*-2.49*
MINIMUM[2]	*1.20*	*0.64*	*2.30*	*-0.64*	*-3.85*	*-2.28*
MEDIAN[2]	*1.48*	*2.14*	*3.36*	*-1.45*	*-4.07*	*-2.28*
MEAN[2]	*1.44*	*1.90*	*3.36*	*-1.30*	*-4.28*	*-2.35*
MAXIMUM[2]	*1.64*	*2.91*	*4.43*	*-1.80*	*-4.91*	*-2.49*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wpafr10a

U S A

1990 - 2020 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
CHALLENGE (200$/tc)			*1.19*	*-0.66*	*-0.84*	*-1.05*
EMF-12 -20% (highest)			*2.08*	*-1.69*	*-0.63*	*-0.75*
EMF-12 -20% (lowest)			*2.16*	*-2.09*	*-1.43*	*-0.97*
EPA-SCW-P	*0.53*	*1.13*	*1.67*	*-1.76*	*-0.53*	*-0.66*
EPA-RCW-P	*0.43*	*2.23*	*2.67*	*-2.71*	*-1.14*	*-1.25*
NES - Action			*2.08*	*-0.75*	*-0.58*	*+0.73*
green (200$/tc)			*2.23*	*-1.98*	*-1.12*	*-0.92*
12RT (200$/tc)			*2.14*	*-1.62*	*-1.43*	*-0.94*
RIGES	*0.46*	*2.20*	*2.67*	*-1.91*	*-2.98*	*-2.30*
FFES	*0.56*	*1.04*	*1.60*	*-2.49*	*-1.15*	*-2.06*
MINIMUM[2]	*0.43*	*1.04*	*1.19*	*-0.66*	*-0.53*	*-2.30*
MEDIAN[2]	*0.53*	*1.83*	*2.14*	*-1.91*	*-1.13*	*-0.97*
MEAN[2]	*0.51*	*1.69*	*2.08*	*-1.87*	*-1.18*	*-1.08*
MAXIMUM[2]	*0.56*	*2.23*	*2.67*	*-2.71*	*-2.98*	*+0.73*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wp_usa20a

U S A

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	0.29	1.85	2.15	-1.33	-0.27	0.51
IS92b	0.29	1.85	2.15	-1.33	-0.27	0.51
IS92c	-0.10	1.33	1.22	-1.05	-0.77	-0.61
IS92d	-0.10	2.05	1.94	-1.19	-1.19	-0.47
IS92e	0.29	2.38	2.68	-1.57	-0.11	0.96
IS92f	0.68	1.64	2.33	-1.38	-0.10	0.82
IPCC-EIS						
IEW-84%						
IEW-Median						
IEW-16%						
ECS '92						
CHALLENGE						
EMF 12 (lowest)			2.20	-1.25	-0.12	0.49
EMF 12 (highest)			2.20	-0.41	-0.08	1.49
WEC A						
WEC B						
E&R B	0.32	1.58	1.91	-0.99	0.34	1.24
EPA-SCW	0.31	1.06	1.37	-1.21	0.06	0.08
EPA-RCW	0.21	2.16	2.37	-1.73	0.03	0.64
NES						
green			1.95	-0.91	0.13	1.16
12RT			1.89	-0.40	0.06	1.43
IMAGE - CW	0.29	1.85	2.15	-1.98	-0.32	-0.20
MINIMUM[2]	**-0.10**	1.06	**1.22**	-0.40	**-1.19**	**-0.61**
MEDIAN[2]	0.29	1.85	2.05	-1.26	-0.11	+0.51
MEAN[2]	0.25	1.77	2.03	-1.20	-0.20	+0.58
MAXIMUM[2]	**0.68**	**2.38**	**2.68**	-1.98	+0.34	1.49

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

wp_usa50

U S A

1990 - 2050 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
CHALLENGE (200$/tc)						
EMF-12 -20% (highest)						
EMF-12 -20% (lowest)						
EPA-SCW-P	*0.31*	*1.06*	*1.37*	*-1.38*	*-0.74*	*-0.76*
EPA-RCW-P	*0.21*	*2.16*	*2.37*	*-2.43*	*-1.13*	*1.24*
NES - Action						
green (200$/tc)			*1.93*	*-1.50*	*-1.05*	*-0.66*
12RT (200$/tc)			*1.86*	*-0.85*	*-1.05*	*-0.07*
RIGES	*0.23*	*2.14*	*2.37*	*-2.00*	*-2.38*	*-2.06*
FFES	*0.33*	*0.83*	*1.16*	*-1.82*	*-1.75*	*-2.42*
MINIMUM [2]	0.21	0.83	1.16	-0.85	-0.74	-0.07
MEDIAN [2]	0.27	1.60	1.90	-1.66	-1.09	-1.00
MEAN [2]	0.27	1.54	1.85	-1.66	-1.35	-1.21
MAXIMUM [2]	0.33	2.16	2.37	-2.43	-2.38	-2.42

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wp_usa50a

U S A

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR REFERENCE ("no-controls") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
IS92a	0.15	1.51	1.67	-1.09	-0.23	0.32
IS92b	0.15	1.51	1.67	-1.09	-0.23	0.32
IS92c	-0.37	1.02	0.64	-0.79	-0.57	-0.72
IS92d	-0.37	1.77	1.39	-1.00	-0.78	-0.41
IS92e	0.15	2.03	2.18	-1.29	-0.18	0.69
IS92f	0.56	1.31	1.88	-1.12	-0.10	0.64
IPCC-EIS						
IEW-84%						
IEW-Median						
IEW-16%						
ECS '92						
CHALLENGE						
EMF 12 (lowest)			2.20	-1.09	-0.15	0.32
EMF 12 (highest)			2.20	-0.32	-0.09	1.11
WEC A						
WEC B						
E&R B						
EPA-SCW	0.16	1.04	1.20	-1.03	0.01	0.17
EPA-RCW	0.11	1.75	1.86	-1.20	0.22	0.86
NES						
green						
12RT						
IMAGE - CW	0.15	1.51	1.67	-1.51	-0.42	-0.29
MINIMUM[2]	**-0.37**	1.04	**0.64**	-0.32	**-0.78**	**-0.72**
MEDIAN[2]	0.15	1.51	1.67	-1.09	-0.17	+0.32
MEAN[2]	0.08	1.49	1.69	-1.05	-0.23	+0.27
MAXIMUM[2]	**0.56**	**2.03**	2.20	-1.51	+0.22	+1.11

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2 Component growth rates do not add as calculated from original frequency distributions.

BOLD denotes IPCC scenarios

wp_usa100

U S A

1990 - 2100 AVERAGE ANNUAL GROWTH RATES[1] FOR POLICY ("control") SCENARIOS

	Population	GDP / Capita	GDP	Energy / GDP	Carbon / Energy	Carbon Emissions
CHALLENGE (200$/tc)						
EMF-12 -20% (highest)						
EMF-12 -20% (lowest)						
EPA-SCW-P	*0.16*	*1.04*	*1.20*	*-1.27*	*-0.76*	*-0.84*
EPA-RCW-P	*0.11*	*1.75*	*1.86*	*-1.89*	*-0.98*	*-1.04*
NES - Action						
green (200$/tc)						
12RT (200$/tc)						
RIGES						
FFES	*0.16*	*0.59*	*0.76*	*-1.11*	*-3.92*	*-4.27*
MINIMUM[2]	*0.11*	*0.59*	*0.76*	*-1.11*	*-0.76*	*-0.84*
MEDIAN[2]	*0.16*	*1.04*	*1.20*	*-1.27*	*-0.98*	*-1.04*
MEAN[2]	*0.14*	*1.13*	*1.27*	*-1.42*	*-1.89*	*-2.05*
MAXIMUM[2]	*0.16*	*1.75*	*1.86*	*-1.89*	*-3.92*	*-4.27*

1 Component growth rates do not add exactly to (sub)totals due to independent rounding errors.
2 Component growth rates do not add as calculated from original frequency distributions.

wp_usa100a

Appendix 1 (cont'd): Sensitivity Analysis Tables

WORLD

Comparison of impact of range of driving forces on energy-related CO_2 emissions.
Difference (in Gt C) to IPCC IS92a scenario.[1]

	Δ activity (GDP) (a)	Δ efficiency (PE/GDP) (b)	Δ carbon intensity (C/PE) (c)	Δ emissions (IS92a)
2020 Reference Cases				(9.9)
Minimum[2]	-2.8	-2.3	-1.7	-3.0
Maximum[2]	+2.9	+1.4	+1.2	+2.3
2020 Policy Cases				
Minimum[2]	-2.8	-3.5	-4.0	-5.9
Maximum[2]	+1.8	-0.3	-0.8	-3.5
2050 Reference Cases				(13.2)
Minimum[2]	-6.2	-5.7	-8.9	-10.4
Maximum[2]	+10.8	+4.4	+6.0	+8.7
2050 Policy Cases				
Minimum[2]	-3.8	-7.8	-8.2	-10.6
Maximum[2]	+10.8	+1.9	-1.5	-5.7
2100 Reference Cases				(19.8)
Minimum[2]	-9.4	-7.9	-17.2	-18.6
Maximum[2]	+22.6	+7.7	+5.2	+15.1
2100 Policy Cases				
Minimum[2]	-10.2	-12.7	-19.8	-19.8
Maximum[2]	+15.2	-3.9	-12.7	-14.0

[1] Assuming alternative variable (ranges) whilst keeping all others at IS92a values.

[2] All scenarios.

regwor

CHINA AND CENTRALLY PLANNED ASIA

Comparison of impact of range of driving forces on energy-related CO_2 emissions.
Difference (in Gt C) to IPCC IS92a scenario.[1]

	Δ activity (GDP) (a)	Δ efficiency (PE/GDP) (b)	Δ carbon intensity (C/PE) (c)	Δ emissions (IS92a)
2020 Reference Cases				(1.39)
Minimum[2]	-0.60	-0.40	-0.11	-0.45
Maximum[2]	+0.50	+0.81	+0.28	+0.78
2020 Policy Cases				
Minimum[2]	-0.74	-0.77	-0.48	-0.92
Maximum[2]	+0.08	+0.61	-0.08	-0.21
2050 Reference Cases				(2.50)
Minimum[2]	-1.48	-0.40	-0.65	-1.40
Maximum[2]	+1.48	+2.70	+1.05	+3.00
2050 Policy Cases				
Minimum[2]	-1.48	-1.61	-1.57	-2.17
Maximum[2]	+0.74	+0.92	+0.61	-0.93
2100 Reference Cases				(4.20)
Minimum[2]	-3.22	-1.95	-1.26	-3.20
Maximum[2]	+5.54	+2.10	+0.60	+3.20
2100 Policy Cases				
Minimum[2]	-2.90	-2.93	-4.20	-4.20
Maximum[2]	+3.38	-0.73	-1.42	-2.54

[1] Assuming alternative variable (ranges) whilst keeping all others at IS92a values.

[2] All scenarios.

regcpa

CENTRAL AND EASTERN EUROPE AND FORMER USSR

Comparison of impact of range of driving forces on energy-related CO_2 emissions.
Difference (in Gt C) to IPCC IS92a scenario.[1]

	Δ activity (GDP) (a)	Δ efficiency (PE/GDP) (b)	Δ carbon intensity (C/PE) (c)	Δ emissions (IS92a)
2020 Reference Cases				(2.30)
Minimum[2]	-0.41	-1.16	-0.28	-1.33
Maximum[2]	+2.24	+1.18	+0.42	+0.49
2020 Policy Cases				
Minimum[2]	-0.36	-1.48	-0 93	-1.62
Maximum[2]	+2.24	-0.49	+0.02	-1.06
2050 Reference Cases				(2.10)
Minimum[2]	-0.96	-1.16	-0.73	-1.00
Maximum[2]	+3.34	+0.62	+1.24	+2.00
2050 Policy Cases				
Minimum[2]	-0.04	-1.45	-1.30	-1.73
Maximum[2]	+3.94	-0.24	+0.34	-0.81
2100 Reference Cases				(2.50)
Minimum[2]	-1.79	-1.00	-1.27	-2.10
Maximum[2]	+5.39	+0.35	+1.00	+3.20
2100 Policy Cases				
Minimum[2]	-0.34	-1.74	-2.50	-2.50
Maximum[2]	+5.39	-0.94	-1.45	-1.70

[1] Assuming alternative variable (ranges) whilst keeping all others at IS92a values.

[2] All scenarios.

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AFRICA

Comparison of impact of range of driving forces on energy-related CO_2 emissions.
Difference (in Gt C) to IPCC IS92a scenario.[1]

	Δ activity (GDP) (a)	Δ efficiency (PE/GDP) (b)	Δ carbon intensity (C/PE) (c)	Δ emissions (IS92a)
2020 Reference Cases				(0.58)
Minimum[2]	-0.18	-0.26	-0.02	-0.21
Maximum[2]	+0.47	+0.04	+0.32	+0.65
2020 Policy Cases				
Minimum[2]	-0.17	-0.30	-0.39	-0.42
Maximum[2]	+0.21	-0.09	+0.03	-0.21
2050 Reference Cases				(1.14)
Minimum[2]	-0.67	-0.67	-0.51	-0.62
Maximum[2]	+0.66	+0.20	+0.99	+0.53
2050 Policy Cases				
Minimum[2]	-0.67	-0.72	-1.12	-1.14
Maximum[2]	+0.18	+0.14	-0.45	-0.85
2100 Reference Cases				(2.47)
Minimum[2]	-1.88	-0.83	-1.22	-2.01
Maximum[2]	+3.12	+1.78	+0.69	+1.98
2100 Policy Cases				
Minimum[2]	-1.81	-1.71	-2.46	-2.47
Maximum[2]	+3.93	+0.28	-2.40	-2.46

[1] Assuming alternative variable (ranges) whilst keeping all others at IS92a values.

[2] All scenarios.

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U S A

Comparison of impact of range of driving forces on energy-related CO_2 emissions.
Difference (in Gt C) to IPCC IS92a scenario.[1]

	Δ activity (GDP) (a)	Δ efficiency (PE/GDP) (b)	Δ carbon intensity (C/PE) (c)	Δ emissions (IS92a)
2020 Reference Cases				(1.68)
Minimum[2]	-0.64	-0.17	-0.29	-0.47
Maximum[2]	+0.31	+1.06	+0.30	+0.54
2020 Policy Cases				
Minimum[2]	-0.44	-0.47	-0.95	-1.08
Maximum[2]	-0.11	+0.70	-0.13	+0.02
2050 Reference Cases				(1.81)
Minimum[2]	-0.76	-0.59	-0.78	-0.89
Maximum[2]	+0.67	+1.38	+0.80	+1.51
2050 Policy Cases				
Minimum[2]	-0.96	-0.88	-1.31	-1.53
Maximum[2]	+0.26	+0.61	-0.45	-0.45
2100 Reference Cases				(1.90)
Minimum[2]	-1.28	-1.12	-0.86	-1.30
Maximum[2]	+1.47	+2.54	+1.27	+2.60
2100 Policy Cases				
Minimum[2]	-1.19	-1.12	-1.90	-1.90
Maximum[2]	+0.44	-0.05	-0.84	-1.40

[1] Assuming alternative variable (ranges) whilst keeping all others at IS92a values.

[2] All scenarios.

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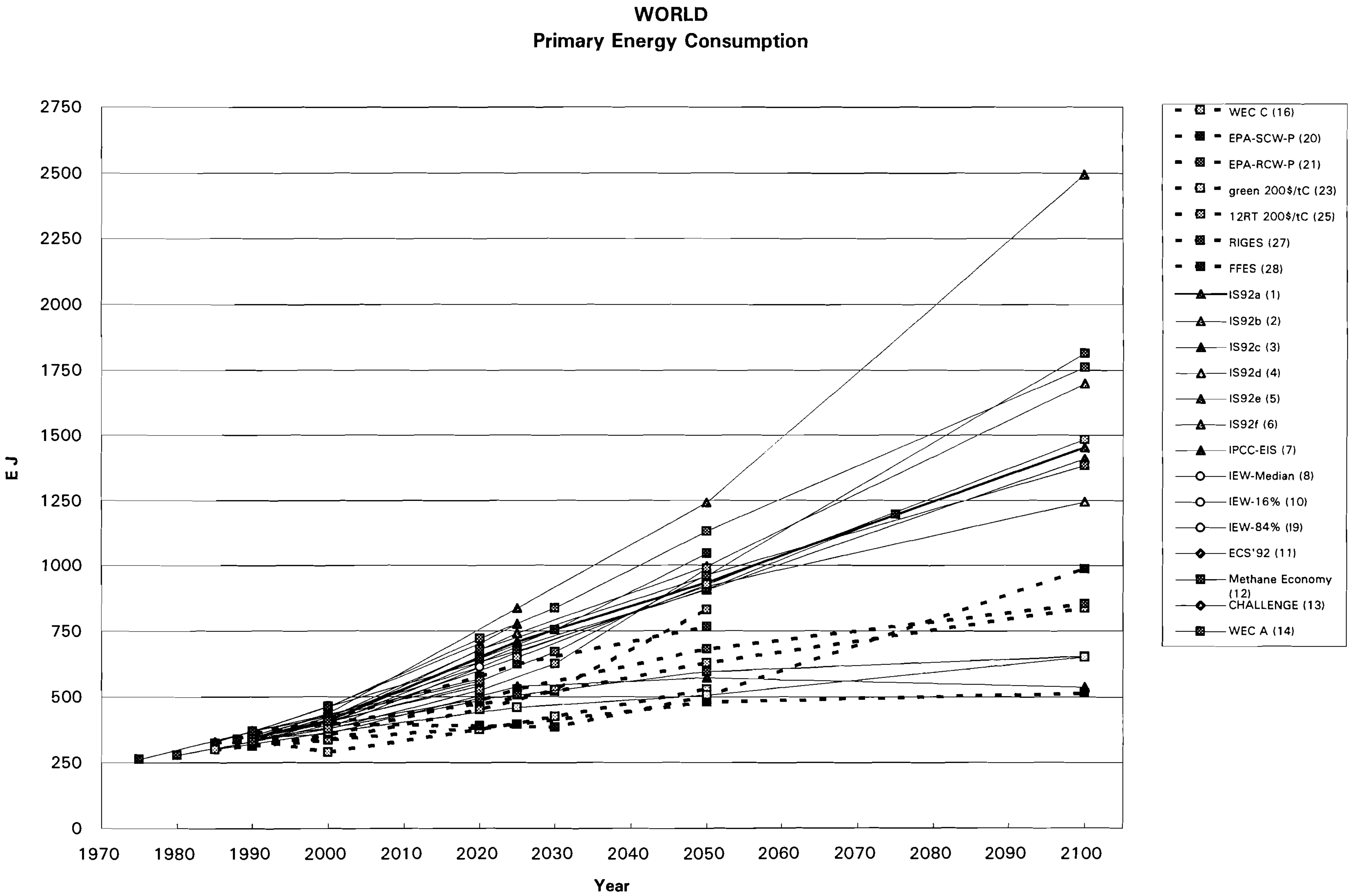
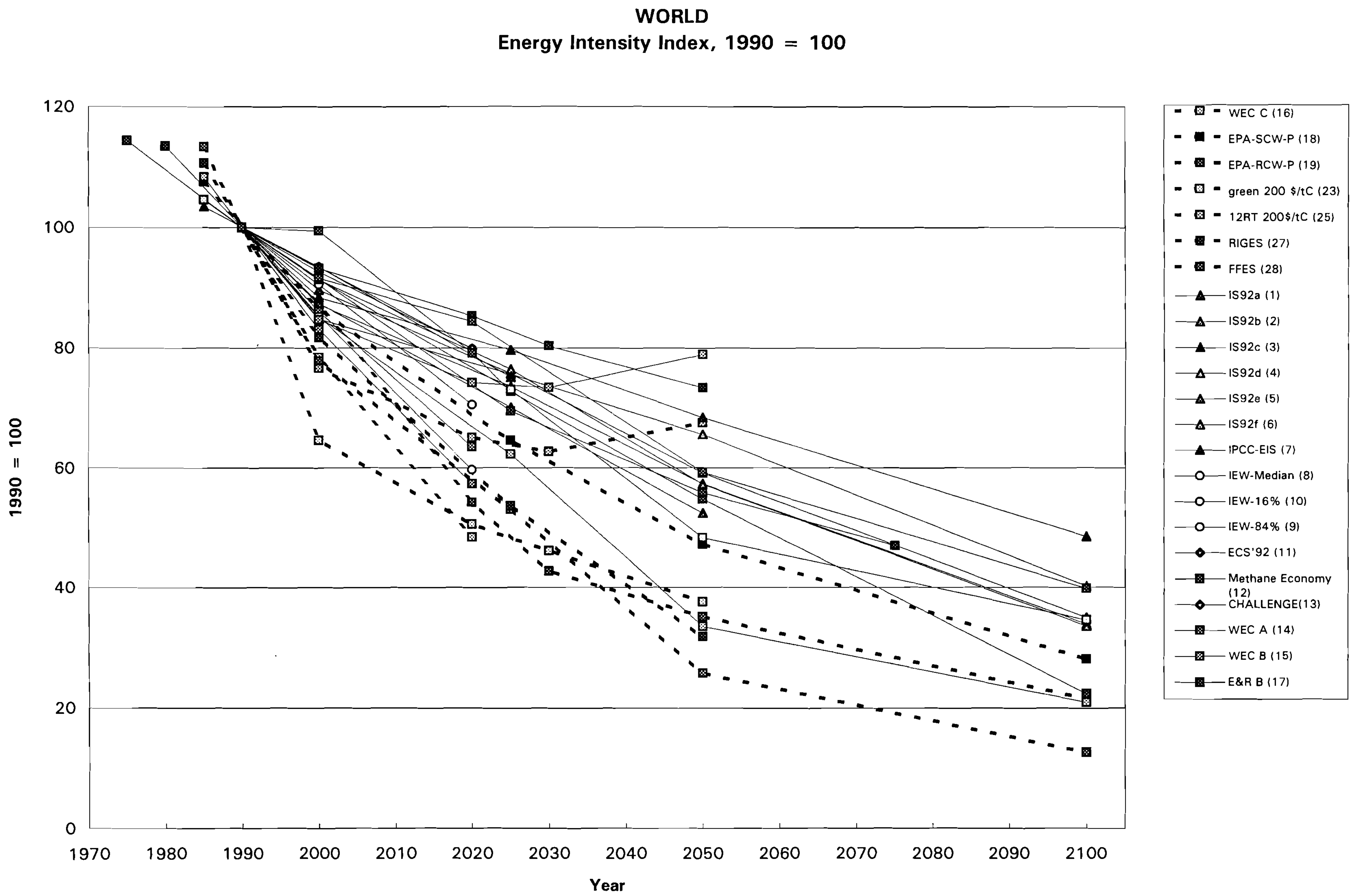
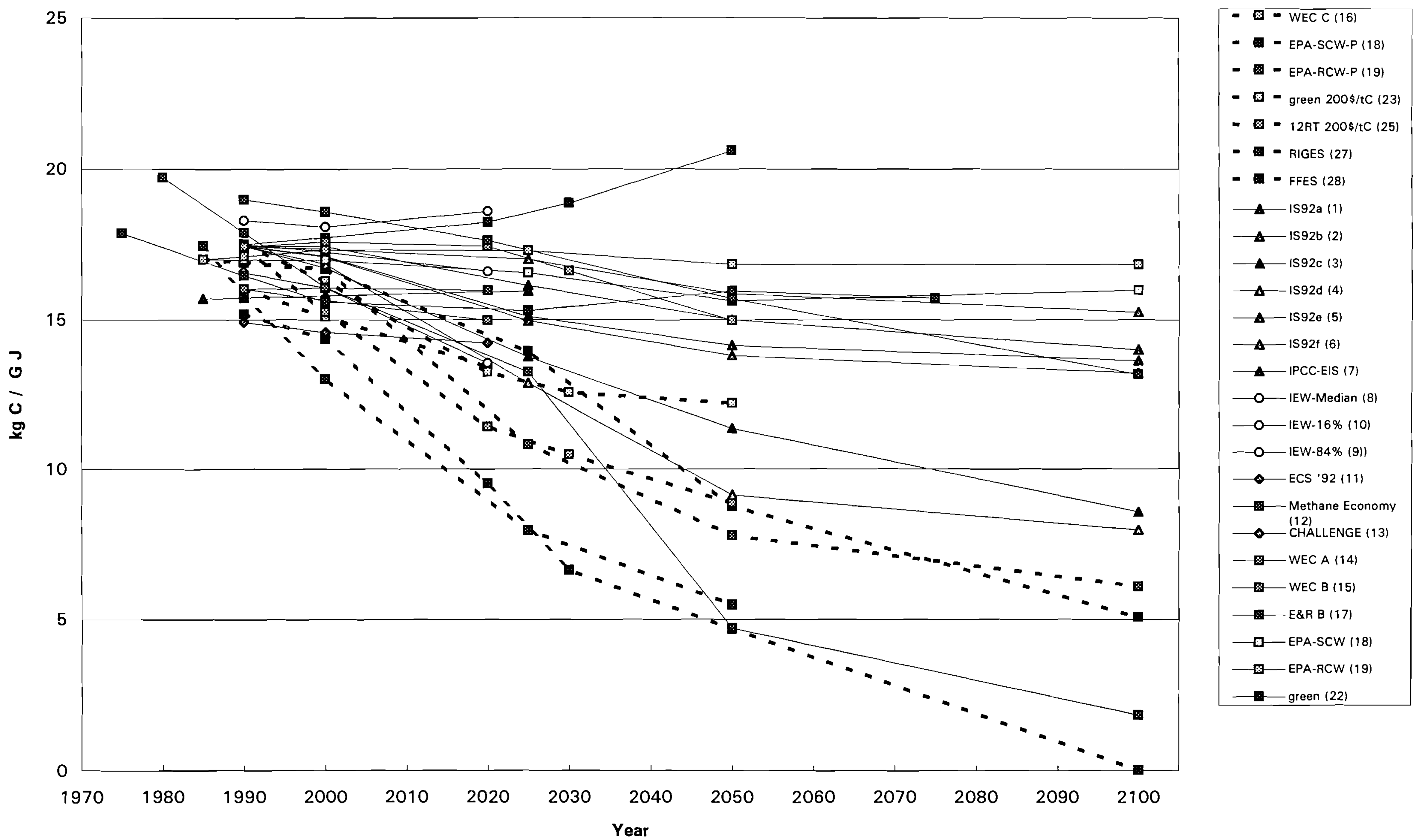
Appendix 2: Figures

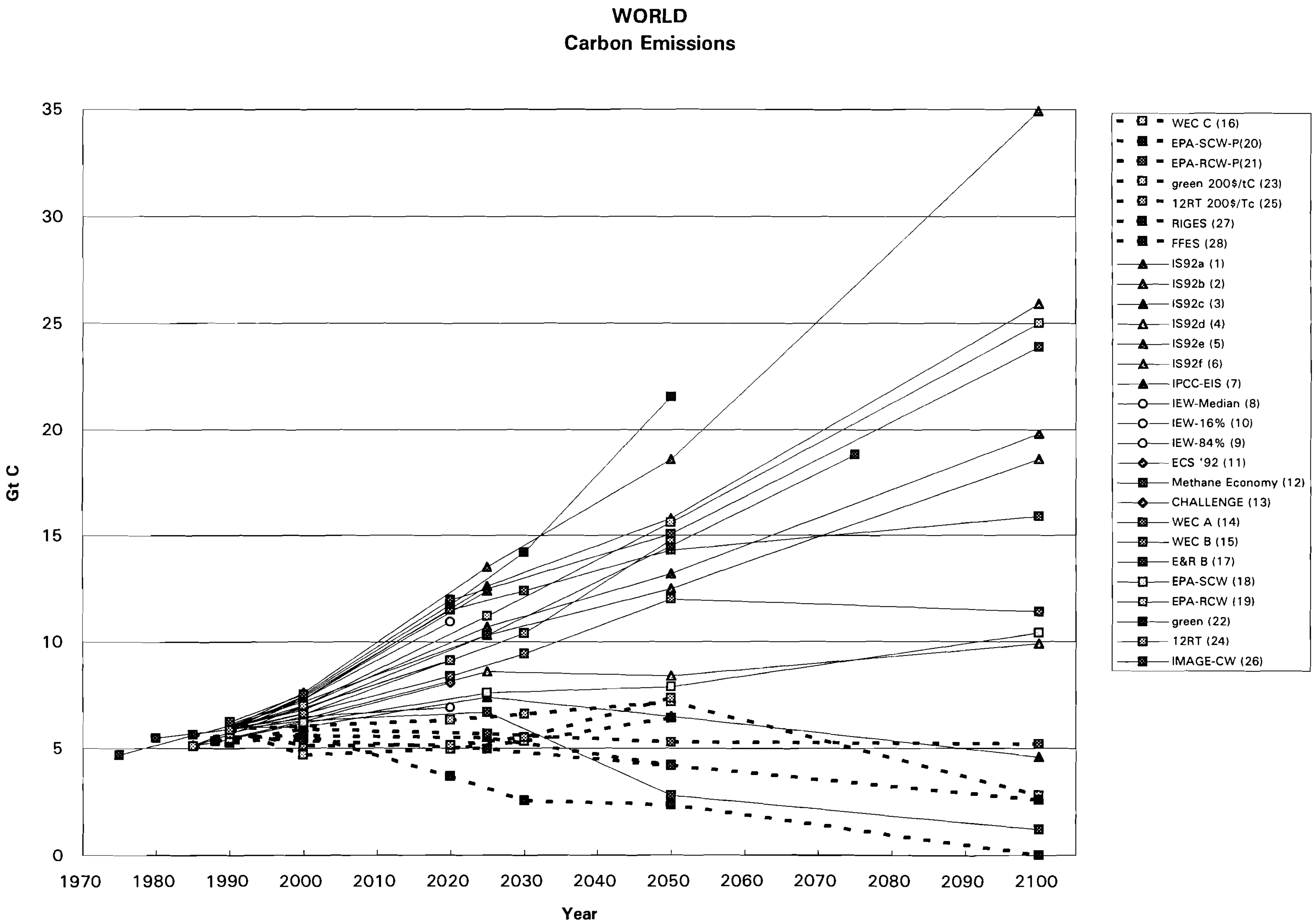

WORLD
Primary Energy Consumption
EJ
Year
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
WEC C (16)
EPA-SCW-P (20)
EPA-RCW-P (21)
green 200$/tC (23)
12RT 200$/tC (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW-Median (8)
IEW-16% (10)
IEW-84% (19)
ECS'92 (11)
Methane Economy (12)
CHALLENGE (13)
WEC A (14)



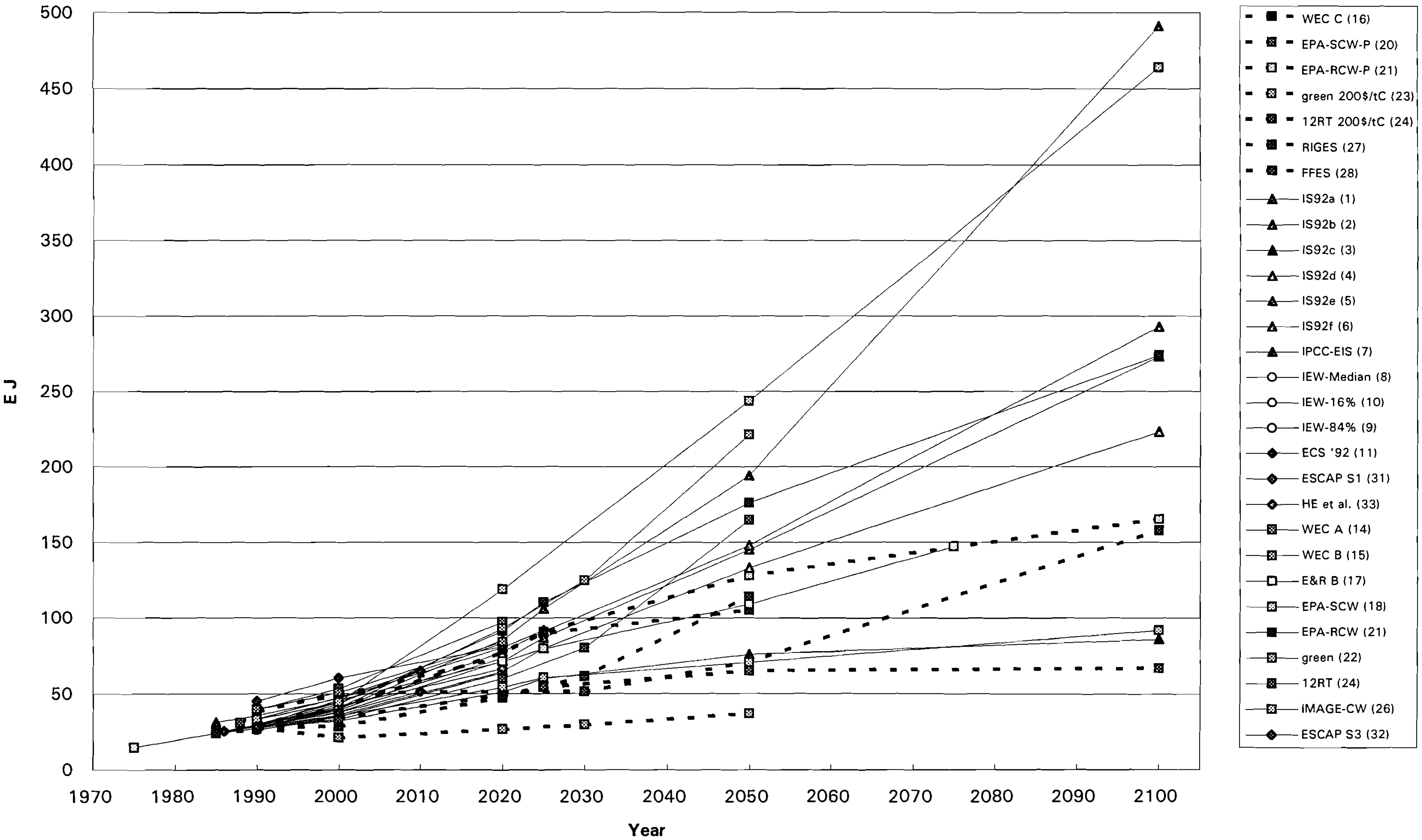
WORLD
Energy Intensity Index, 1990 = 100
120
100
80
60
40
20
0
1990 = 100
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
WEC C (16)
EPA-SCW-P (18)
EPA-RCW-P (19)
green 200 $/tC (23)
12RT 200$/tC (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW-Median (8)
IEW-16% (10)
IEW-84% (9)
ECS'92 (11)
Methane Economy (12)
CHALLENGE(13)
WEC A (14)
WEC B (15)
E&R B (17)

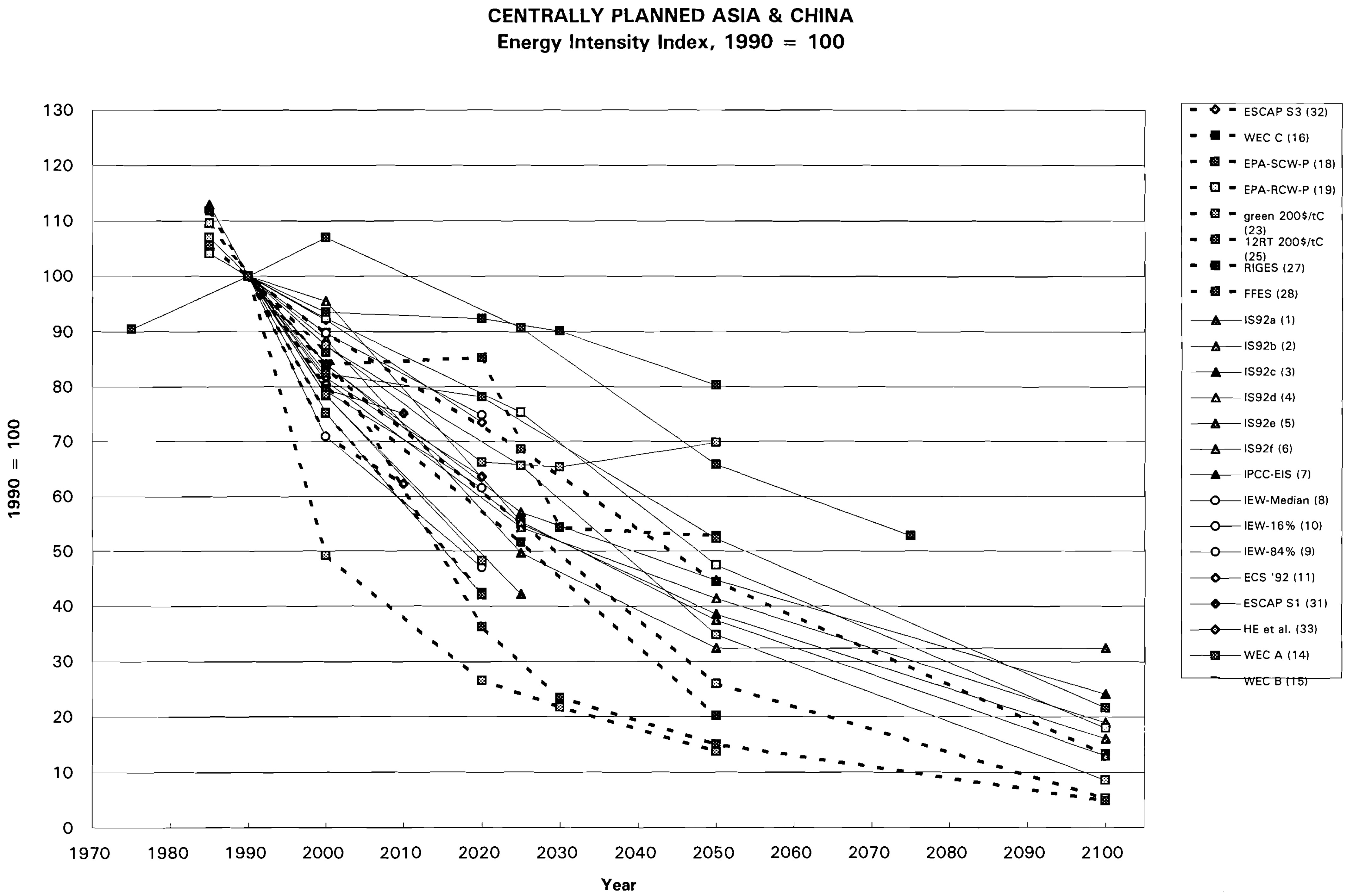
WORLD
Carbon Intensity



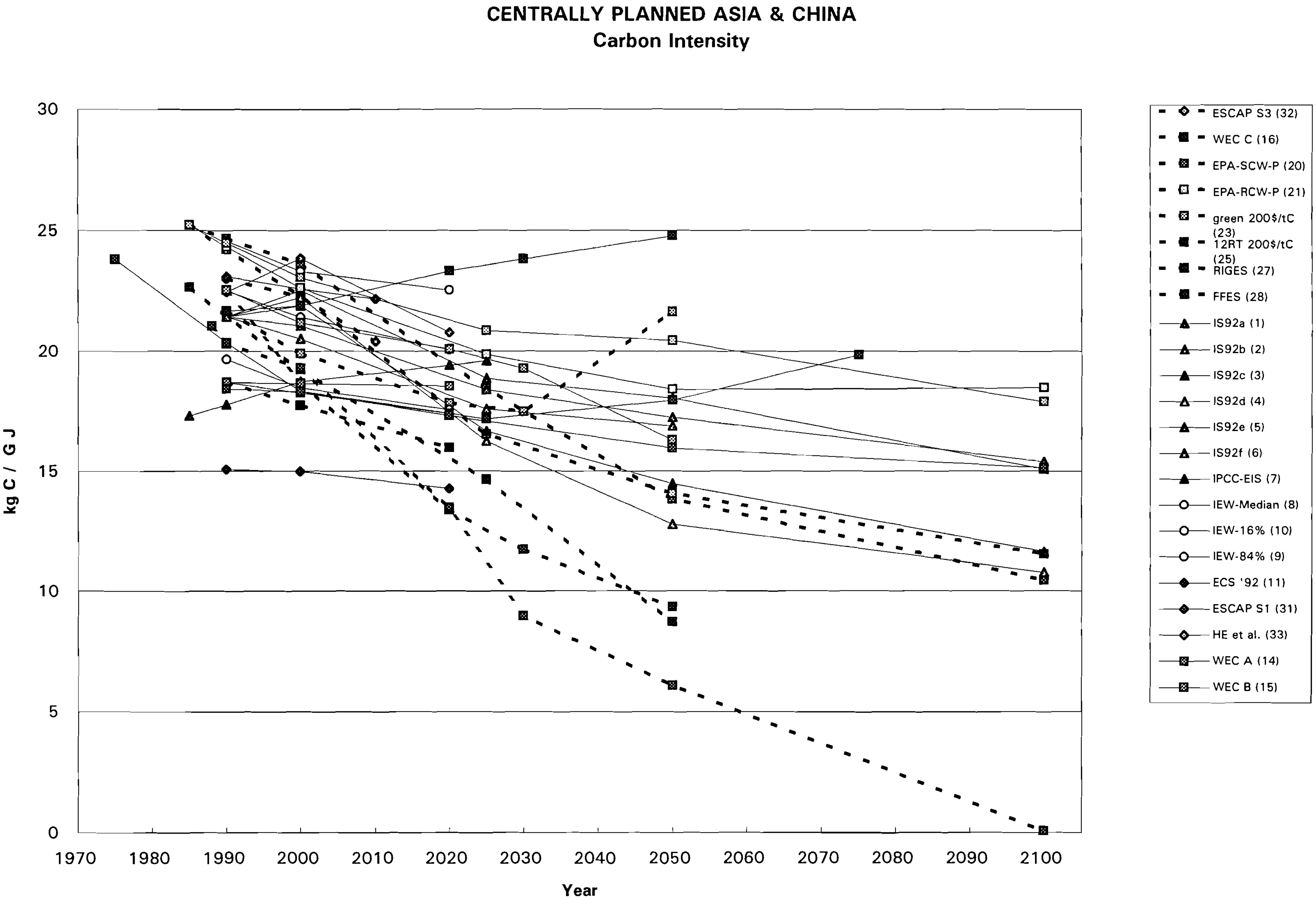

WORLD
Carbon Emissions
Gt C
Year
WEC C (16)
EPA-SCW-P(20)
EPA-RCW-P(21)
green 200$/tC (23)
12RT 200$/Tc (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW-Median (8)
IEW-16% (10)
IEW-84% (9)
ECS '92 (11)
Methane Economy (12)
CHALLENGE (13)
WEC A (14)
WEC B (15)
E&R B (17)
EPA-SCW (18)
EPA-RCW (19)
green (22)
12RT (24)
IMAGE-CW (26)

CENTRALLY PLANNED ASIA & CHINA
Primary Energy Consumption



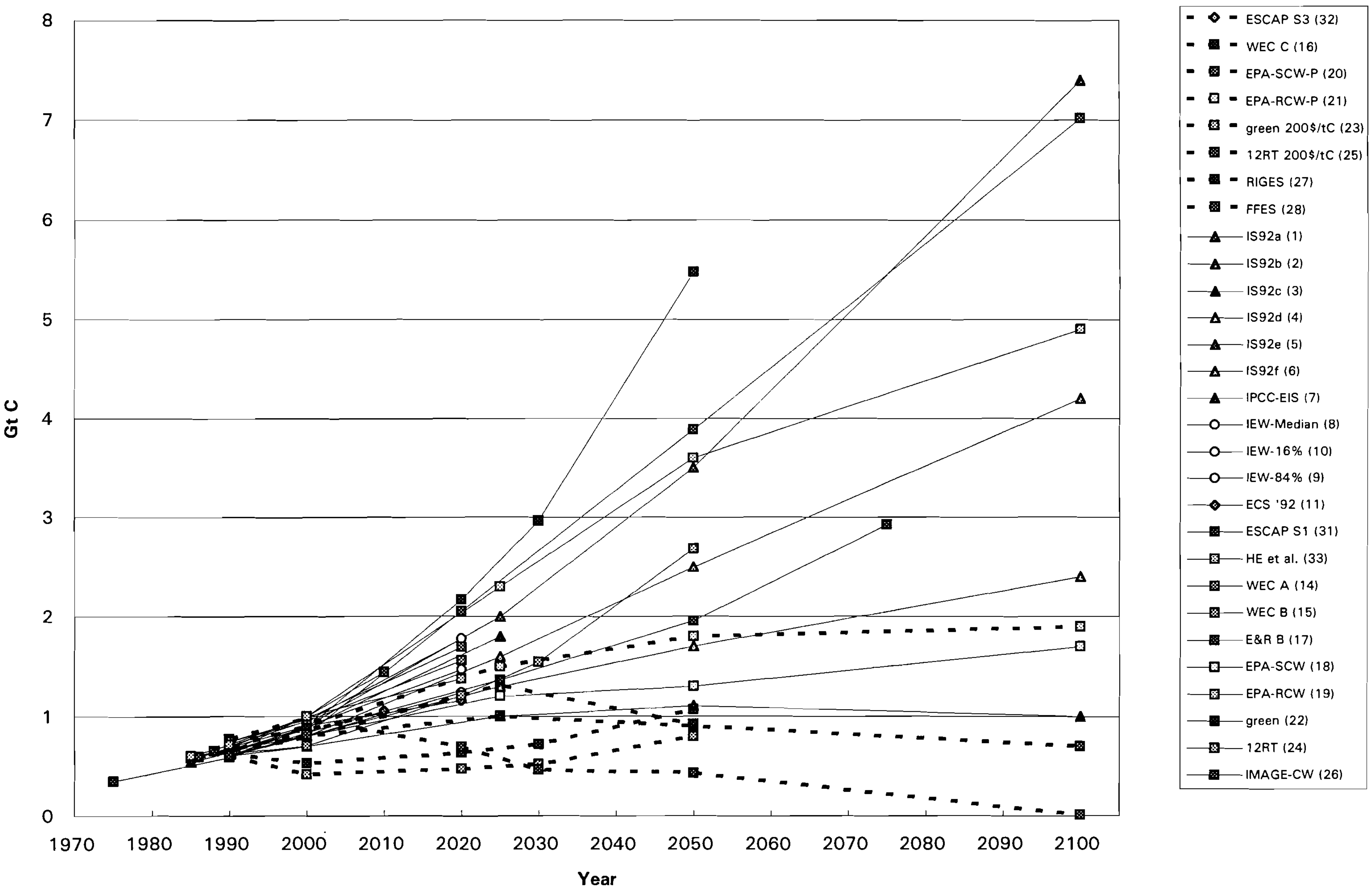


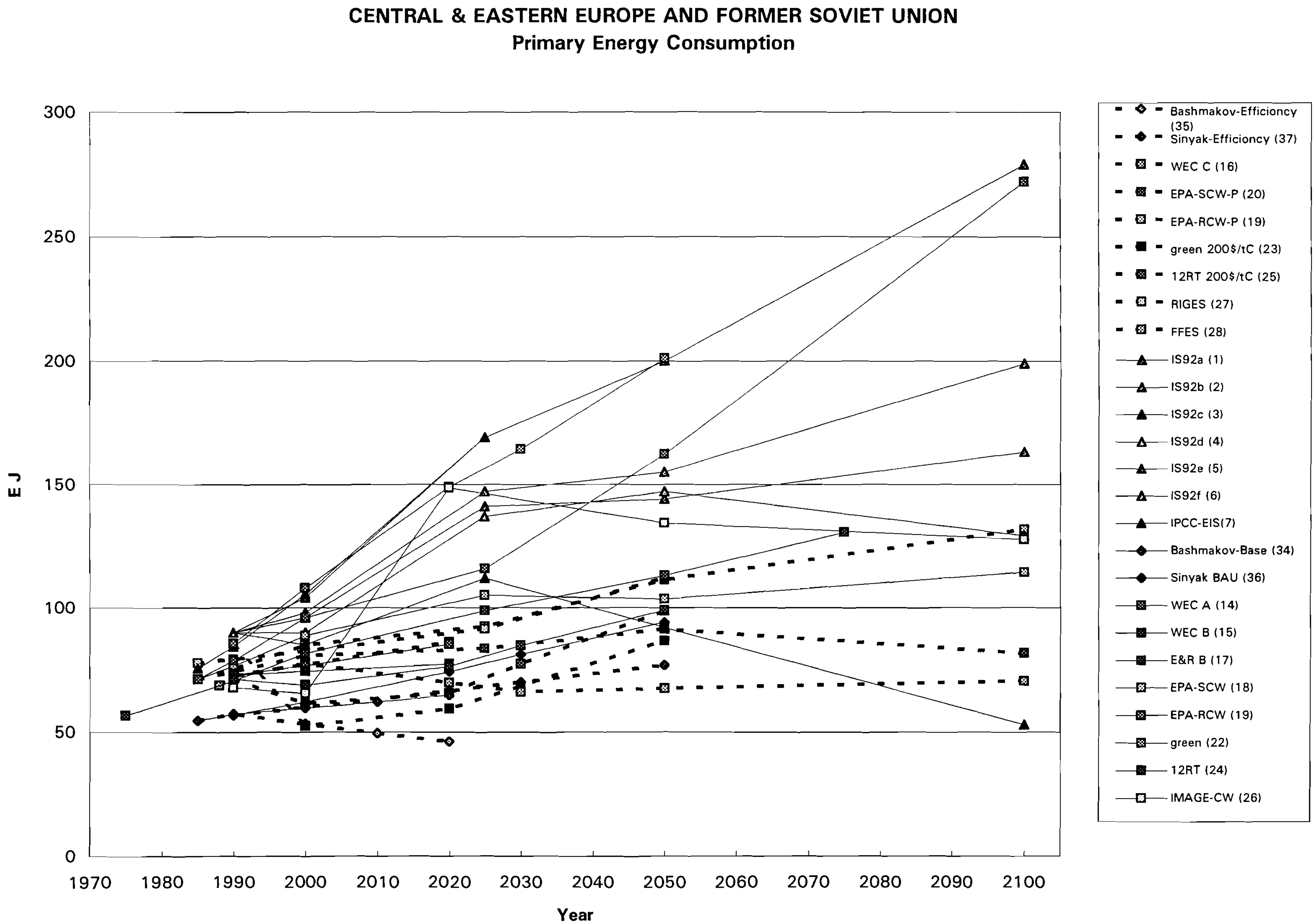
CENTRALLY PLANNED ASIA & CHINA
Energy Intensity Index, 1990 = 100
1990 = 100
Year
ESCAP S3 (32)
WEC C (16)
EPA-SCW-P (18)
EPA-RCW-P (19)
green 200$/tC (23)
12RT 200$/tC (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW-Median (8)
IEW-16% (10)
IEW-84% (9)
ECS '92 (11)
ESCAP S1 (31)
HE et al. (33)
WEC A (14)
WEC B (15)

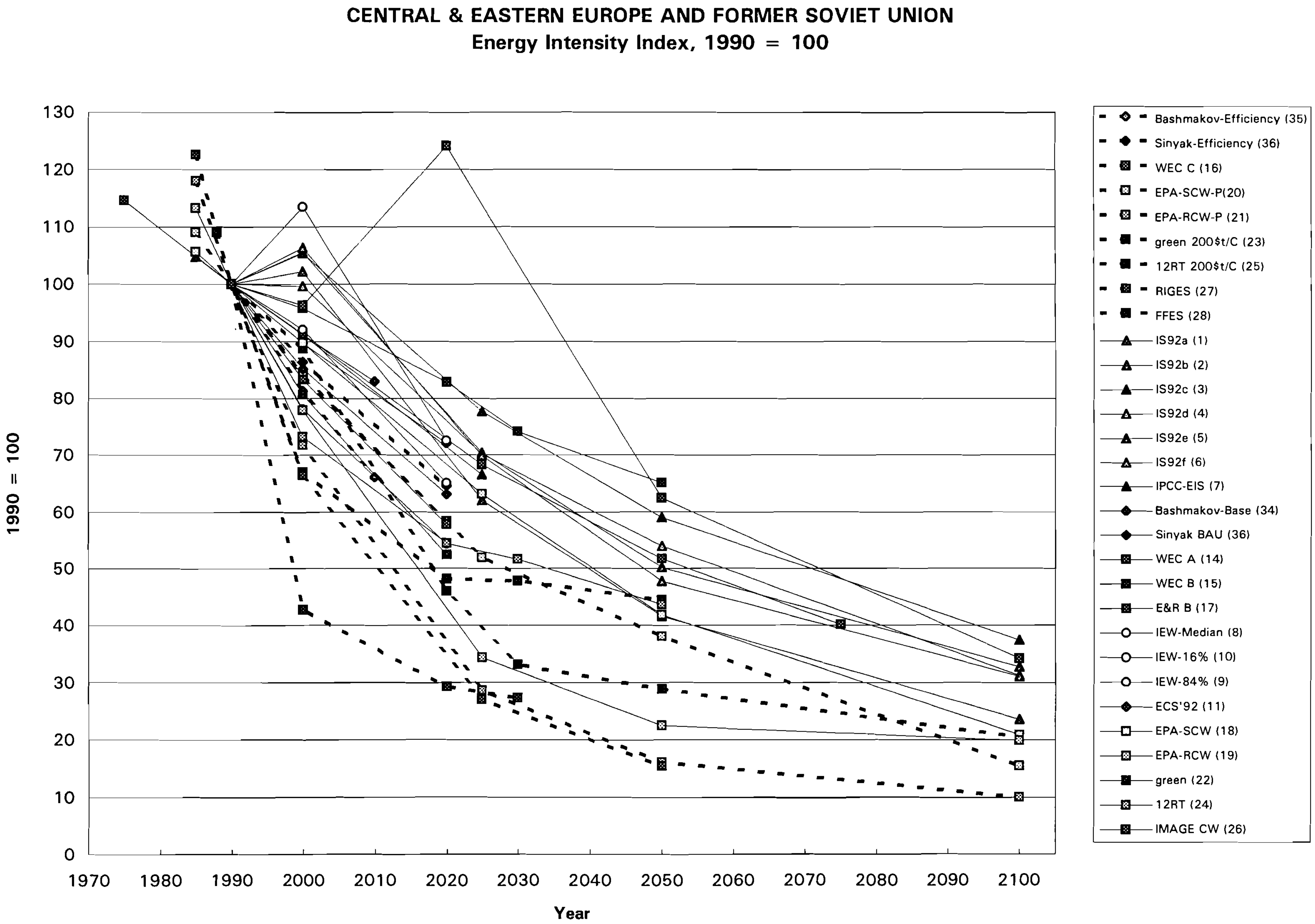


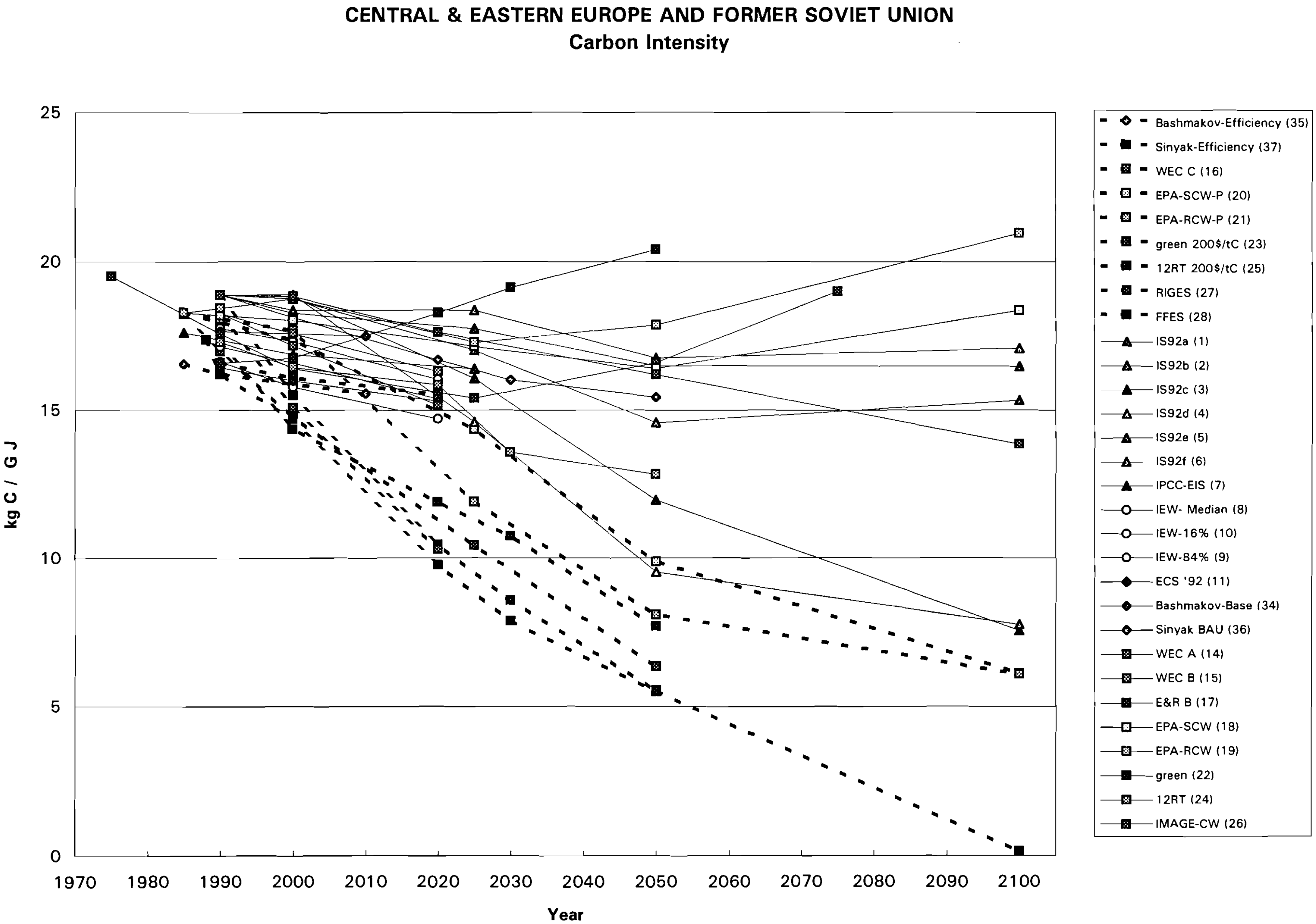
CENTRALLY PLANNED ASIA & CHINA
Carbon Intensity
kg C / G J
Year
0
5
10
15
20
25
30
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
ESCAP S3 (32)
WEC C (16)
EPA-SCW-P (20)
EPA-RCW-P (21)
green 200$/tC (23)
12RT 200$/tC (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW-Median (8)
IEW-16% (10)
IEW-84% (9)
ECS '92 (11)
ESCAP S1 (31)
HE et al. (33)
WEC A (14)
WEC B (15)

CENTRALLY PLANNED ASIA & CHINA
Carbon Emissions

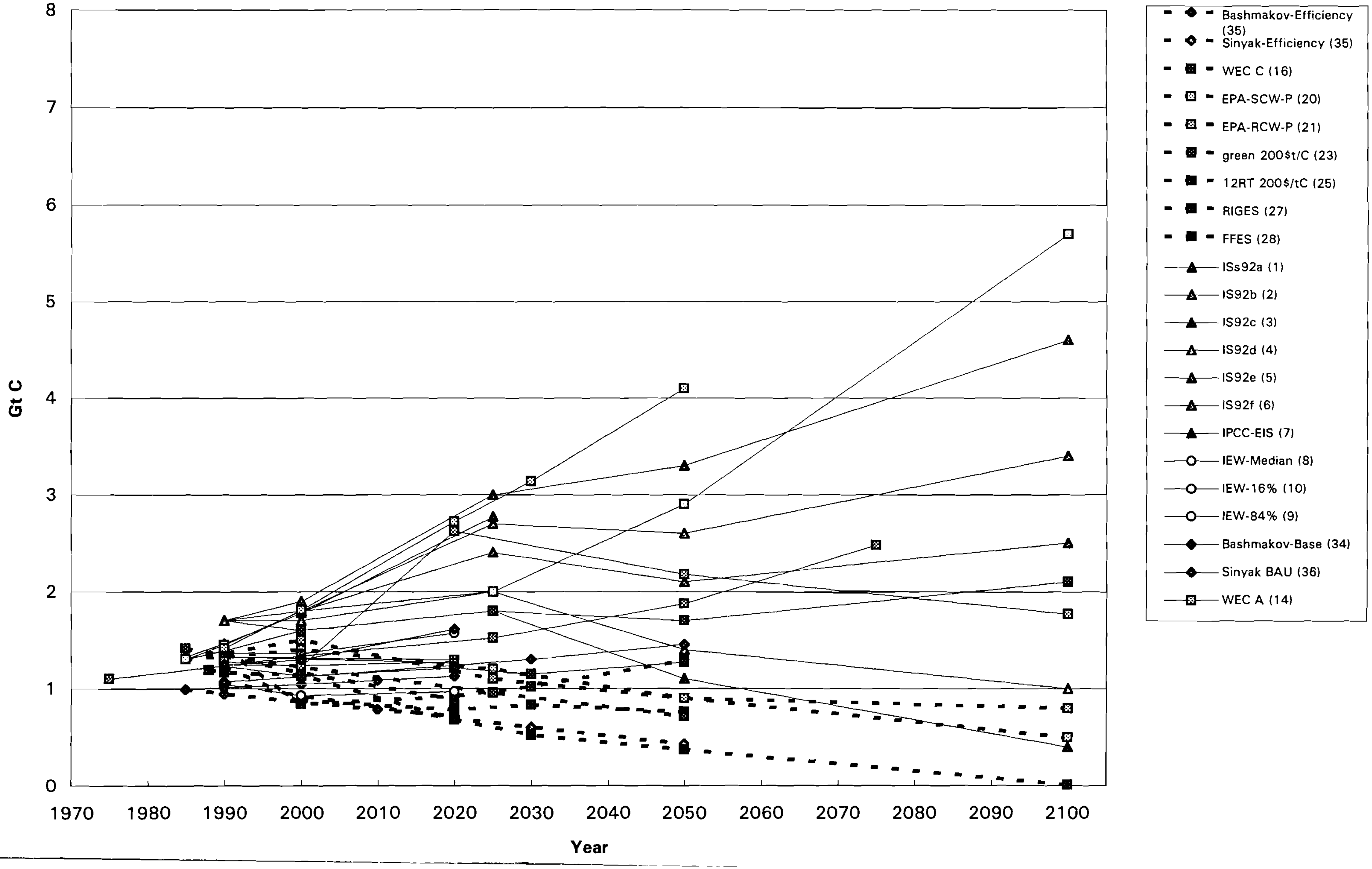



CENTRAL & EASTERN EUROPE AND FORMER SOVIET UNION
Primary Energy Consumption
E J
Year
0
50
100
150
200
250
300
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Bashmakov-Efficiency (35)
Sinyak-Efficiency (37)
WEC C (16)
EPA-SCW-P (20)
EPA-RCW-P (19)
green 200$/tC (23)
12RT 200$/tC (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS(7)
Bashmakov-Base (34)
Sinyak BAU (36)
WEC A (14)
WEC B (15)
E&R B (17)
EPA-SCW (18)
EPA-RCW (19)
green (22)
12RT (24)
IMAGE-CW (26)

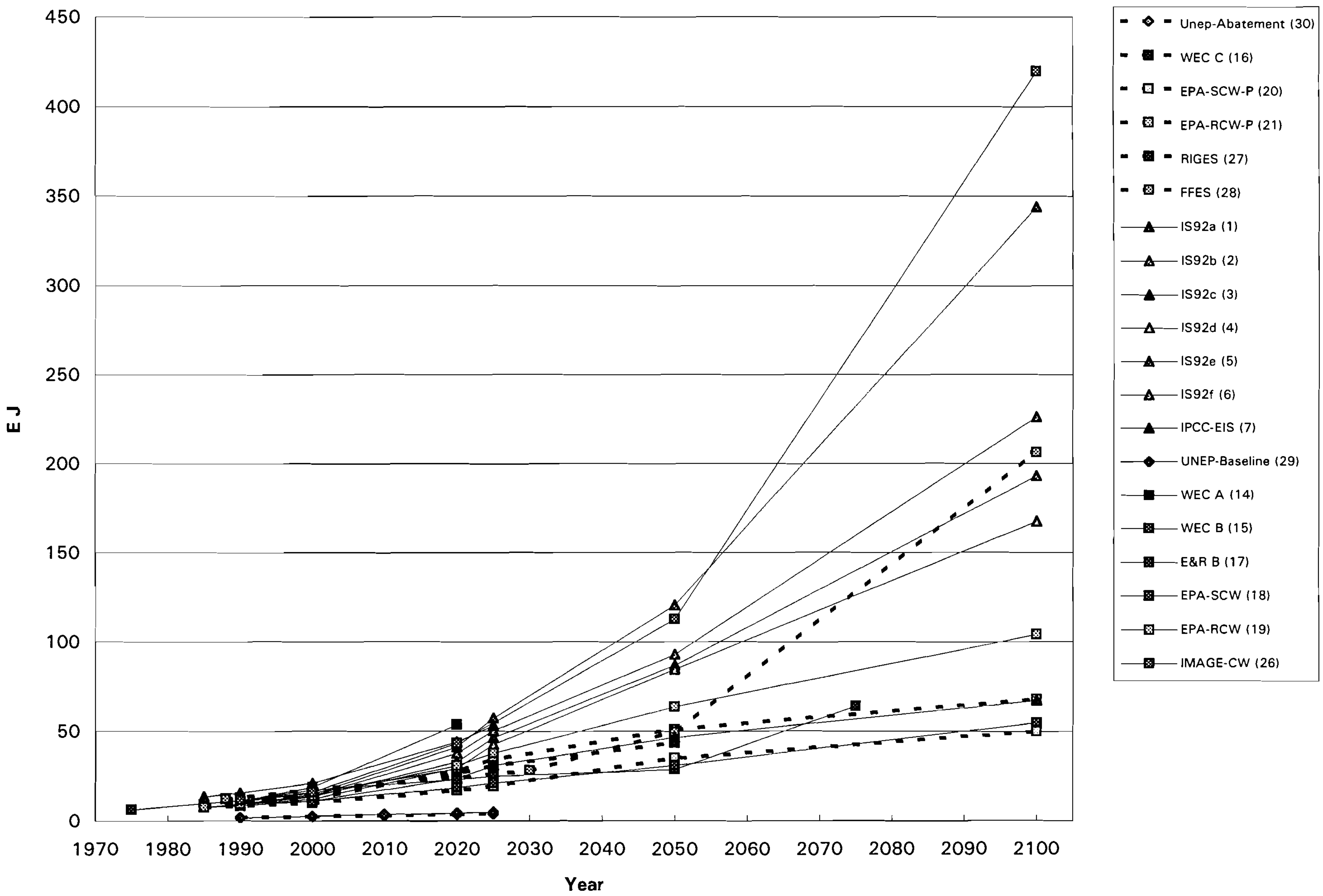

CENTRAL & EASTERN EUROPE AND FORMER SOVIET UNION
Energy Intensity Index, 1990 = 100
1990 = 100
Year
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Bashmakov-Efficiency (35)
Sinyak-Efficiency (36)
WEC C (16)
EPA-SCW-P(20)
EPA-RCW-P (21)
green 200$t/C (23)
12RT 200$t/C (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
Bashmakov-Base (34)
Sinyak BAU (36)
WEC A (14)
WEC B (15)
E&R B (17)
IEW-Median (8)
IEW-16% (10)
IEW-84% (9)
ECS'92 (11)
EPA-SCW (18)
EPA-RCW (19)
green (22)
12RT (24)
IMAGE CW (26)

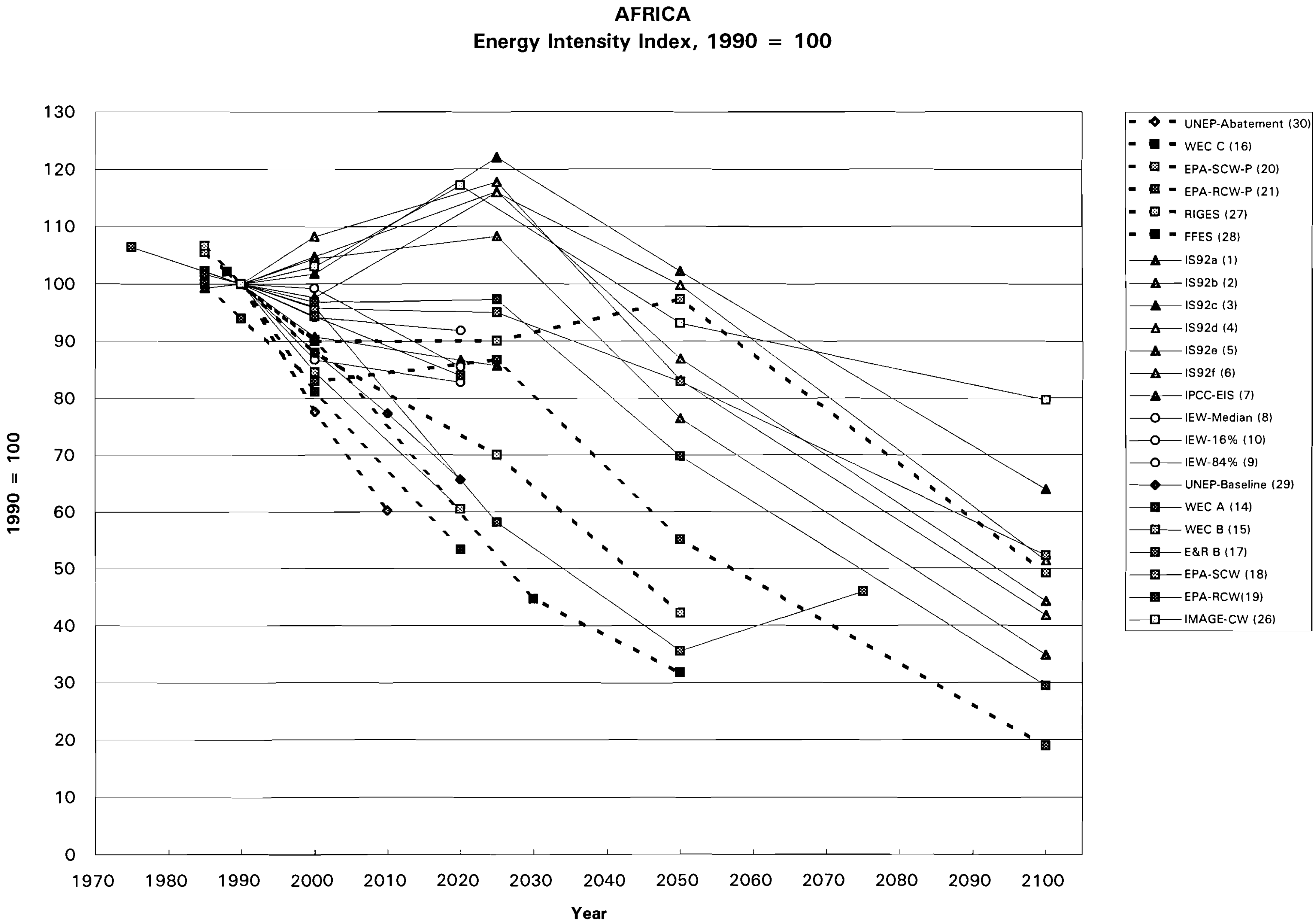

CENTRAL & EASTERN EUROPE AND FORMER SOVIET UNION
Carbon Intensity
kg C / G J
Year
0
5
10
15
20
25
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Bashmakov-Efficiency (35)
Sinyak-Efficiency (37)
WEC C (16)
EPA-SCW-P (20)
EPA-RCW-P (21)
green 200$/tC (23)
12RT 200$/tC (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW- Median (8)
IEW-16% (10)
IEW-84% (9)
ECS '92 (11)
Bashmakov-Base (34)
Sinyak BAU (36)
WEC A (14)
WEC B (15)
E&R B (17)
EPA-SCW (18)
EPA-RCW (19)
green (22)
12RT (24)
IMAGE-CW (26)

CENTRAL & EASTERN EUROPE AND FORMER SOVIET UNION
Carbon Emissions



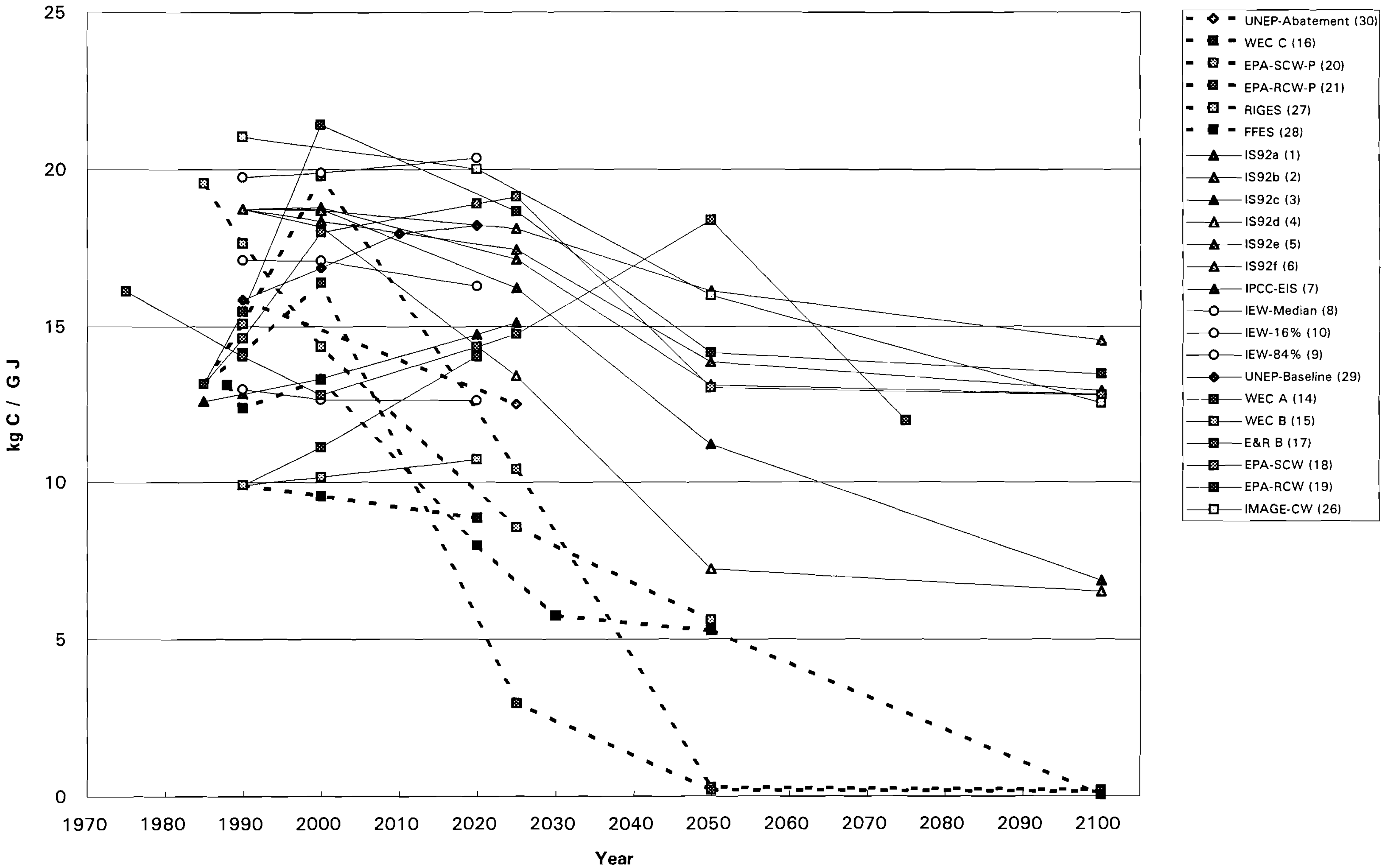
AFRICA
Primary Energy Consumption

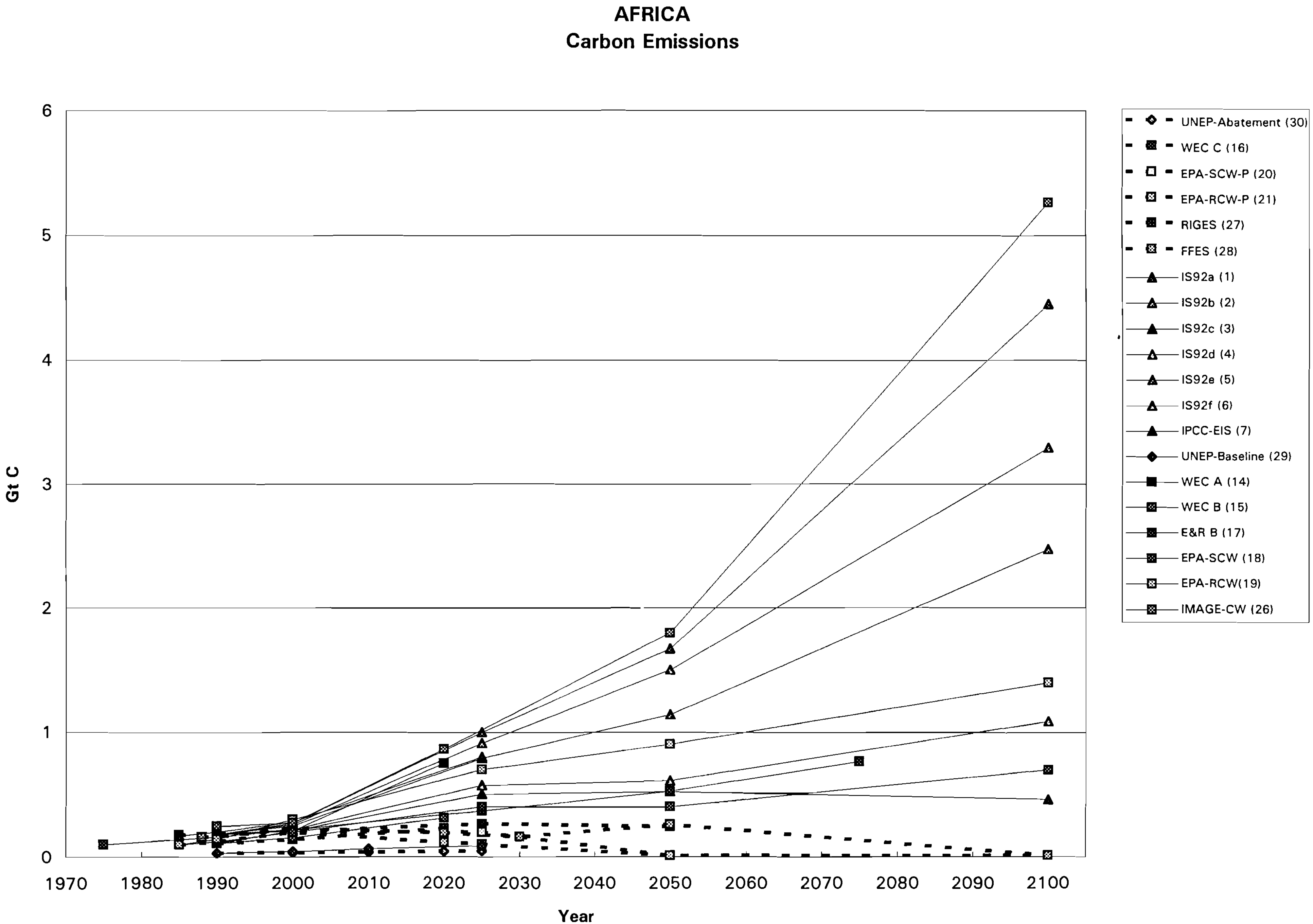




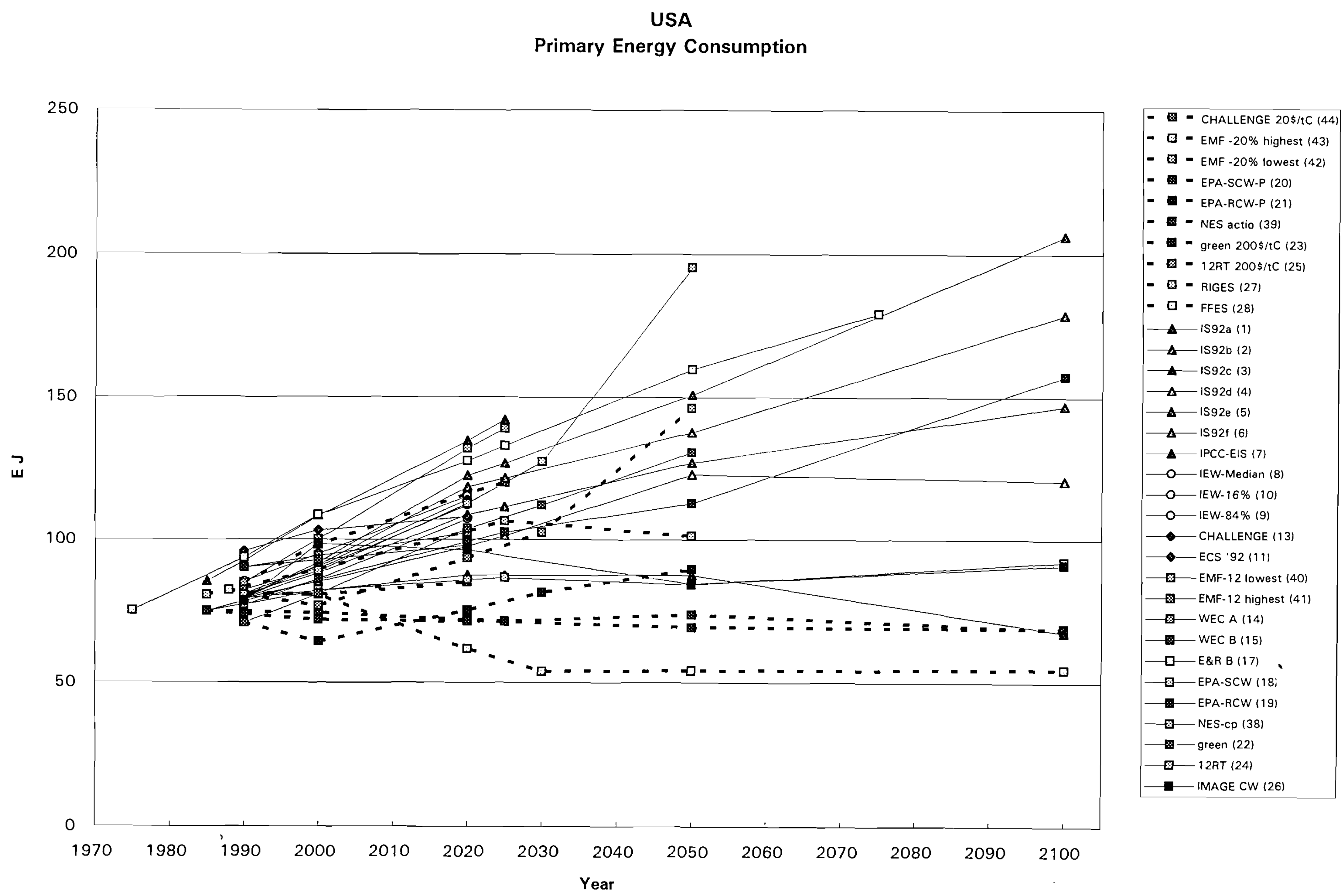
AFRICA
Energy Intensity Index, 1990 = 100
1990 = 100
Year
0
10
20
30
40
50
60
70
80
90
100
110
120
130
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
UNEP-Abatement (30)
WEC C (16)
EPA-SCW-P (20)
EPA-RCW-P (21)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW-Median (8)
IEW-16% (10)
IEW-84% (9)
UNEP-Baseline (29)
WEC A (14)
WEC B (15)
E&R B (17)
EPA-SCW (18)
EPA-RCW(19)
IMAGE-CW (26)

AFRICA
Carbon Intensity



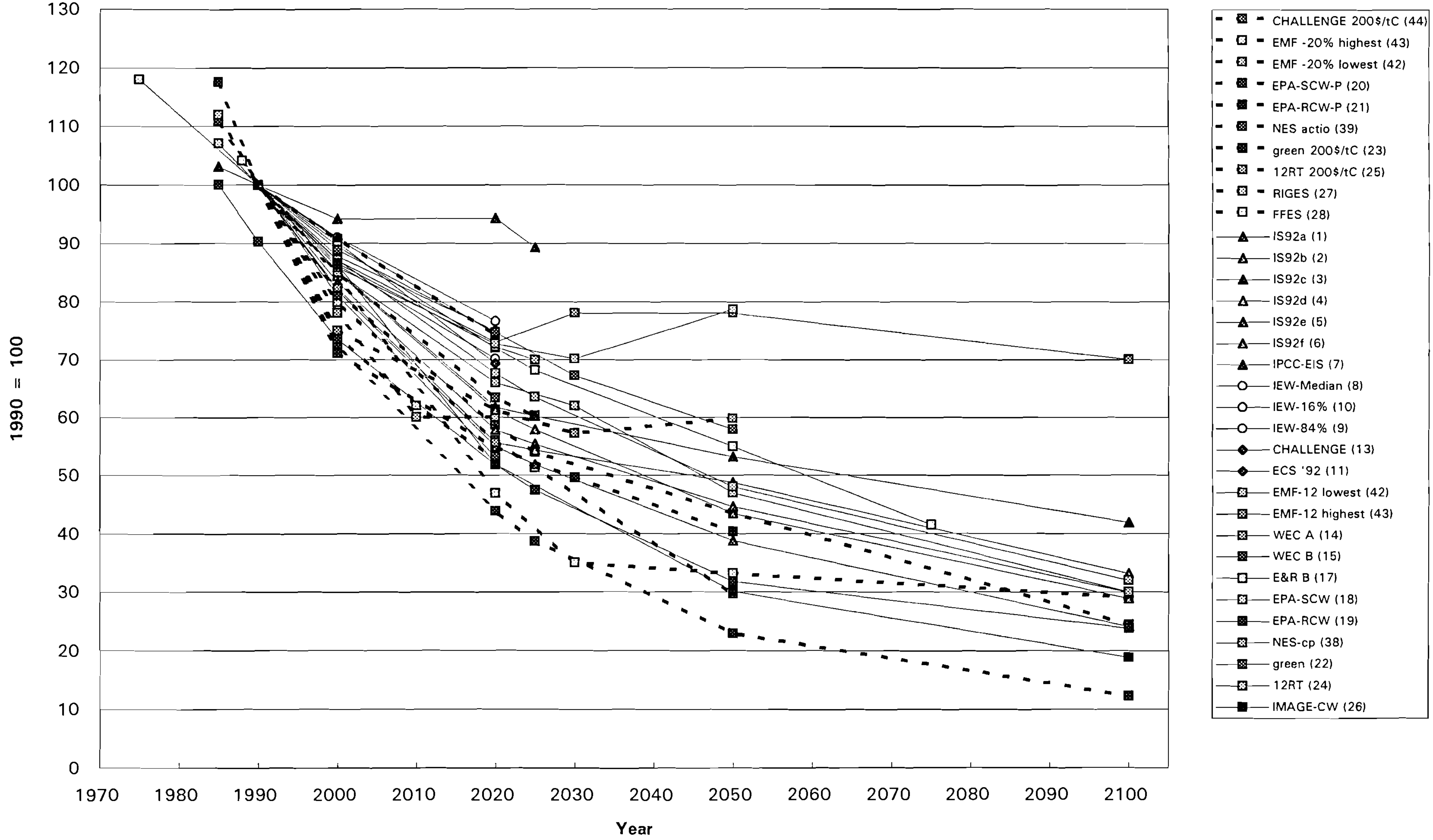


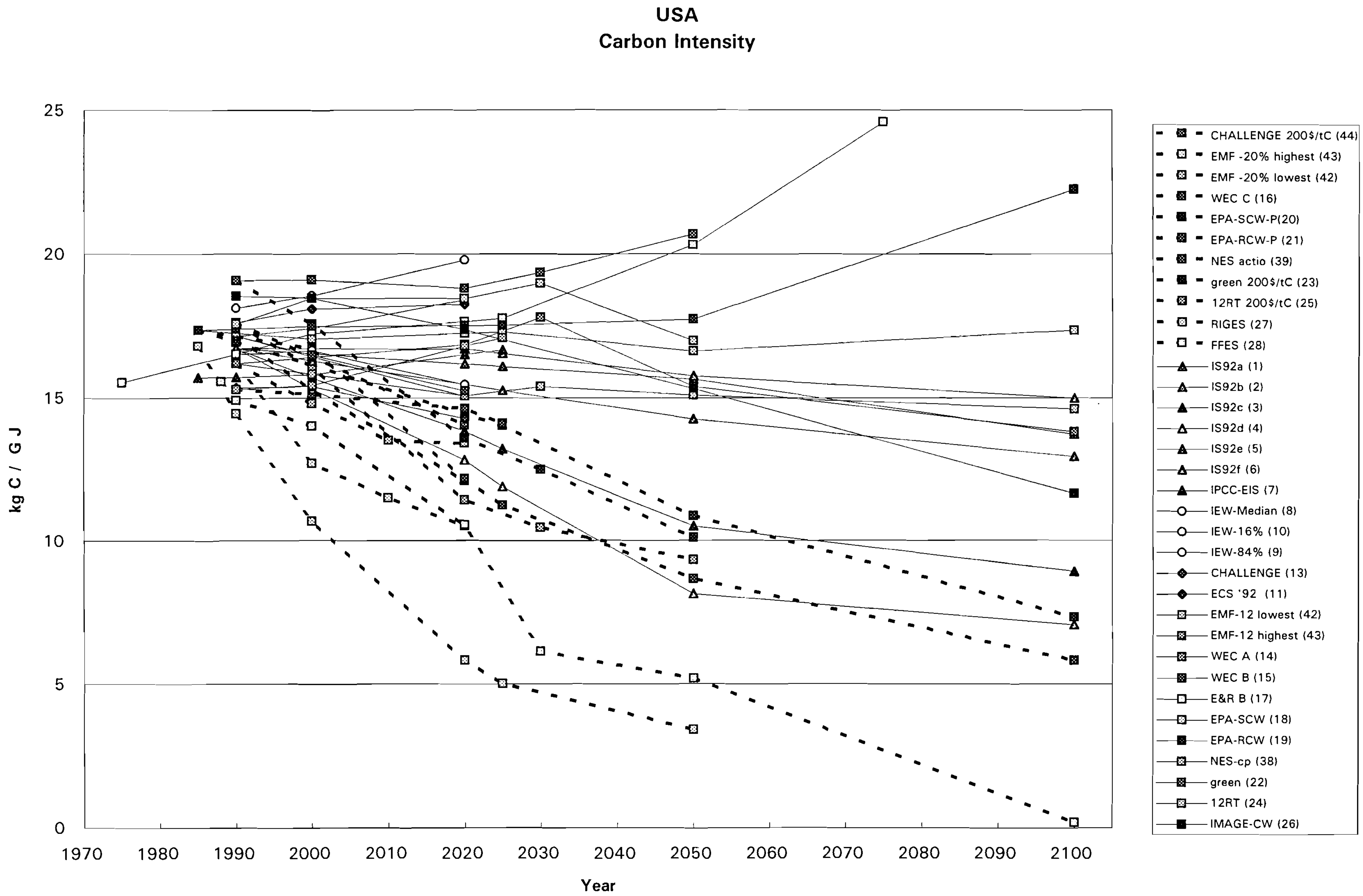
AFRICA
Carbon Emissions
Gt C
6
5
4
3
2
1
0
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
UNEP-Abatement (30)
WEC C (16)
EPA-SCW-P (20)
EPA-RCW-P (21)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
UNEP-Baseline (29)
WEC A (14)
WEC B (15)
E&R B (17)
EPA-SCW (18)
EPA-RCW(19)
IMAGE-CW (26)

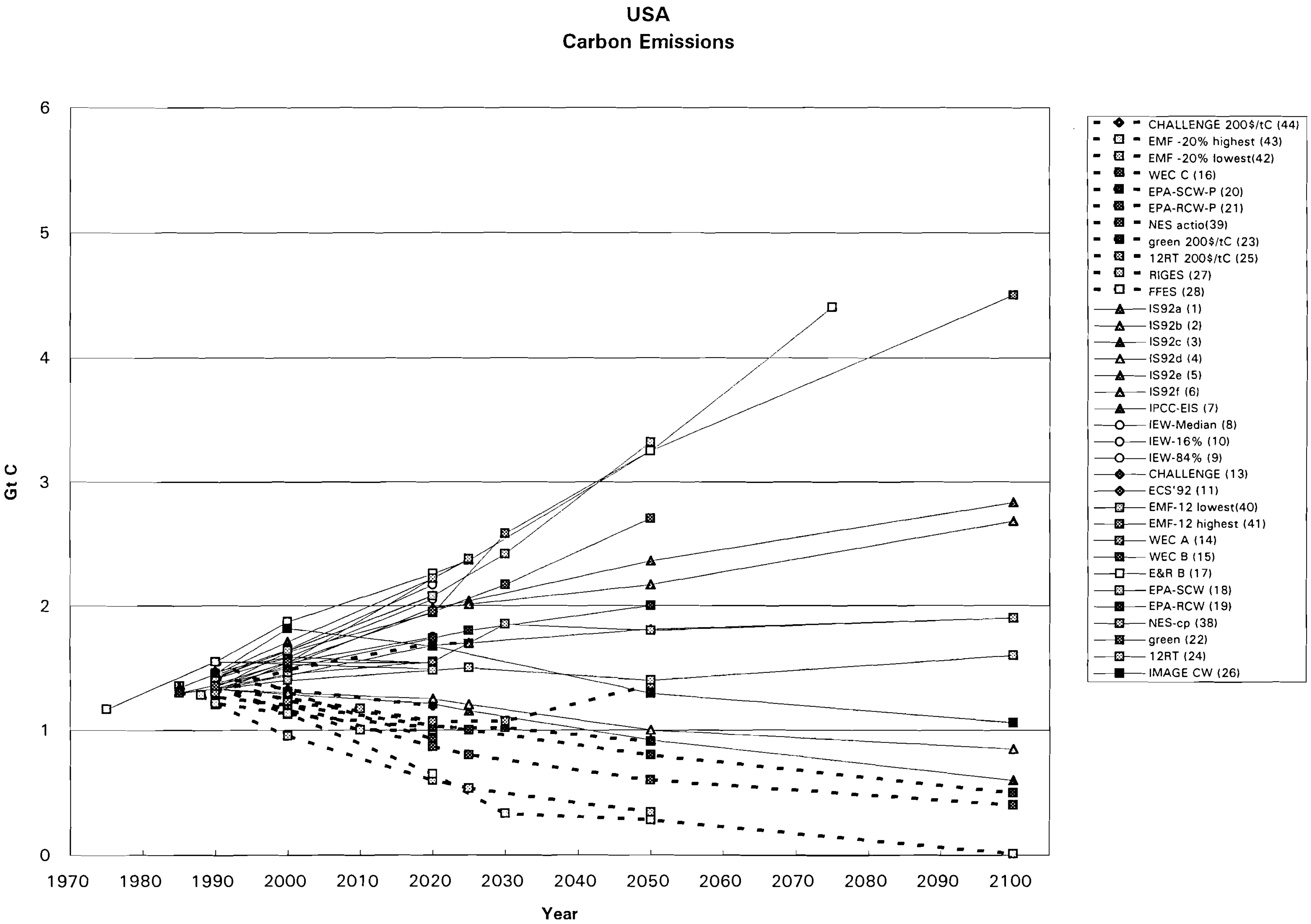


USA
Primary Energy Consumption
EJ
Year
250
200
150
100
50
0
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
CHALLENGE 20$/tC (44)
EMF -20% highest (43)
EMF -20% lowest (42)
EPA-SCW-P (20)
EPA-RCW-P (21)
NES actio (39)
green 200$/tC (23)
12RT 200$/tC (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW-Median (8)
IEW-16% (10)
IEW-84% (9)
CHALLENGE (13)
ECS '92 (11)
EMF-12 lowest (40)
EMF-12 highest (41)
WEC A (14)
WEC B (15)
E&R B (17)
EPA-SCW (18)
EPA-RCW (19)
NES-cp (38)
green (22)
12RT (24)
IMAGE CW (26)

USA
Energy Intensity Index, 1990 = 100




USA
Carbon Intensity
kg C / G J
Year
0
5
10
15
20
25
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
CHALLENGE 200$/tC (44)
EMF -20% highest (43)
EMF -20% lowest (42)
WEC C (16)
EPA-SCW-P(20)
EPA-RCW-P (21)
NES actio (39)
green 200$/tC (23)
12RT 200$/tC (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW-Median (8)
IEW-16% (10)
IEW-84% (9)
CHALLENGE (13)
ECS '92 (11)
EMF-12 lowest (42)
EMF-12 highest (43)
WEC A (14)
WEC B (15)
E&R B (17)
EPA-SCW (18)
EPA-RCW (19)
NES-cp (38)
green (22)
12RT (24)
IMAGE-CW (26)



USA
Carbon Emissions
Gt C
Year
0
1
2
3
4
5
6
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
CHALLENGE 200$/tC (44)
EMF -20% highest (43)
EMF -20% lowest(42)
WEC C (16)
EPA-SCW-P (20)
EPA-RCW-P (21)
NES actio(39)
green 200$/tC (23)
12RT 200$/tC (25)
RIGES (27)
FFES (28)
IS92a (1)
IS92b (2)
IS92c (3)
IS92d (4)
IS92e (5)
IS92f (6)
IPCC-EIS (7)
IEW-Median (8)
IEW-16% (10)
IEW-84% (9)
CHALLENGE (13)
ECS'92 (11)
EMF-12 lowest(40)
EMF-12 highest (41)
WEC A (14)
WEC B (15)
E&R B (17)
EPA-SCW (18)
EPA-RCW (19)
NES-cp (38)
green (22)
12RT (24)
IMAGE CW (26)

Appendix 3: List of Scenarios Reviewed

NO.	CODE	SCENARIO NAME	SCEN. TYPE[1]	REGIONAL COVERAGE[2]	REFERENCE
1	IS92a	1992 IPCC A	R	G + R	Pepper *et al.*(1992)
2	IS92b	1922 IPCC B	R	G + R	Pepper *et al.*(1992)
3	IS92c	1992 IPCC C	R	G + R	Pepper *et al.*(1992)
4	IS92d	1992 IPCC D	R	G + R	Pepper *et al.*(1992)
5	IS92e	1992 IPCC E	R	G + R	Pepper *et al.*(1992)
6	IS92f	1992 IPCC F	R	G + R	Pepper *et al.*(1992)
7	IPCC-EIS	1990 IPCC EIS reference	R	G + R	IPCC EIS, 1990
8	IEW-Median	IEW poll Median	Poll of		Manne & Schrattenholzer
9	IEW-84%	IEW poll 84 percentile	Scenarios	G + R	(1991, 1993, 1994)
10	IEW-16%	IEW poll 16 percentile	R		
11	ECS '92	IIASA ECS 'dynamics as usual'	R	G + R	Nakicenovic *et al.* (1993) Messner & Strubegger (1991)
12	Methane Economy	Methane Economy (efficiency)	R	G	Ausubel *et al.* (1988)
13	CHALLENGE	CHALLENGE reference	R	G + R	Schrattenholzer (1994)
14	WEC A	WEC High Growth	R	G + R	WEC (1993)
15	WEC B	WEC Reference	R	G + R	WEC (1993)
16	*WEC C*	*WEC Ecologically Driven*	*P*	*G + R*	*WEC (1993)*
17	E&R B	Edmonds & Reilly Case B	R	G + R	Edmonds *et al.* (1986)
18	EPA-SCW	EPA Slowly Changing World	R	G + R	Lashof & Tirpak (1990)
19	EPA-RCW	EPA Rapidly Changing World	R	G + R	Lashof (1991)
20	*EPA-SCW-P*	*EPA-SCW with Stablization Policies*	*P*	*G + R*	*Lashof & Tirpak (1990)*
21	*EPA-RCW-P*	*EPA-RCW with Stablization Policies*	*P*	*G + R*	Lashof (1991)
22	green	OECD GREEN model reference	R	G + R	Burineaux *et al.* (1992)
23	*green 200$/tC*	*200$/tC carbon tax*	*P*	*G + R*	*Martins (1993)*
24	12RT	12RT Reference	R	G + R	Manne (1993)
25	*12RT 200$/tC*	*12RT 200$/tC carbon tax*	*P*	*G + R*	*Manne (1993)*
26	IMAGE-CW	IMAGE Conventional Wisdom	R	G + R	Alcamo *et al.* (1994)
27	*RIGES*	*Renewables Intensive Global Energy System*	*P*	*G + R*	*Johansson et al. (1993)*
28	*FFES*	*Fossil Free Energy System*	*P*	*G + R*	*Lazarus et al. (1993)*
29	UNEP-Baseline	UNEP GHG abatement costing studies, baseline scenario	R	R	Christensen *et al.* (1994)
30	*UNEP-abatement*	*UNEP Abatement scenario*	*P*	*R*	*Christensen et al.* (1994)
31	ESCAP S1	S1 business as usual	R	R	ESCAP (1991)
32	*ESCAP S3*	*S3 emission control*	*P*	*R*	*ESCAP (1991)*
33	He *et al.* C	Gradual change scenario C	R	R	He *et al.* (1993)
34	Bashmakov-Base	Base case (Russia)	R	R	Bashmakov (1993)
35	*Bashmakov-Efficiency*	*Efficiency scenario*	*P*	*R*	*Bashmakov (1993)*
36	Sinyak BAU	Business as usual (ex-USSR)	R	R	Sinyak & Nagano (1992)
37	*Sinyak-Efficiency*	*Efficiency scenario*	*P*	*R*	*Sinyak & Nagåno (1992)*
38	NES-cp	National Energy Strategy (USA) current policies	R	R	NES, (1991)
39	*NES-action*	*NES "Action"*	*P*	*R*	*NES, (1991)*
40	EMF-12 lowest	Energy Modeling Forum 12	R	R	Gaskins & Weyant (1993)
41	EMF-12 highest	lowest/highest reference scenarios	R	R	Weyant (1993)
42	*EMF-12 -20% lowest*	*EMF-12 20% emission reduction*	*P*	*R*	*Gaskins & Weyant (1993)*
43	*EMF-12 -20% highest*	*lowest/highest scenarios*	*P*	*R*	*Weyant (1993)*
44	*CHALLENGE 200$/tC*	*200$/tC carbon tax*	*P*	*R*	*Schrattenholzer (1994)*

1) R = Reference Scenario. P = Policy Scenario.
2) G = Global R = Regional (National)

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