Bending the Curve: Toward Global Sustainability

Paul Raskin, Gilberto Gallopin, Pablo Gutman, Al Hammond and Rob Swart

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Stockholm Environment Institute
Lilla Nygatan 1, Box 2142
S-103 14 Stockholm
Sweden
Phone: +46 8 412 14 00
Fax: +46 8 723 0348
Email: postmaster@sei.se
Web: http://www.sei.se

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DEDICATION

As this document was going to print, we learned of the untimely passing of Katsuo Seiki. The world has lost a great champion for a just and liveable future, and we have lost a close colleague and friend. He will live on in the work of those he inspired.

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SUMMARY

Introduction

Over the last few centuries, a mere heartbeat of historic time, humanity has moved to the brink of a new evolutionary milestone — the planetary phase of civilization. The world economy is expanding and become more integrated, profoundly reshaping the cultural and political landscape everywhere. This expansion is taking its toll on the natural resources that support development. The human impact on the global environment has grown from diminutive to elephantine. And, despite great wealth in the world, there is still great poverty and suffering. As we drift along the arc of history, we see ahead of us the risk of both greater environmental peril and social friction. We also see the opportunity of a safer passage to a more just and sustainable global society.

Bending the Curve looks at what it would take to steer human development onto a more sustainable pathway during the 21st century. In its previous publication, *Branch Points: Global Scenarios and Human Choice*, the Global Scenario Group developed three classes of scenarios to show possible pathways for the future. *Conventional Worlds* scenarios assume we will continue on the current pathway of economic globalization, with evolutionary changes in institutions, and that developing regions of the world will move toward industrial country patterns and values. Another set of scenarios, called *Barbarization*, depicts a world in which deepening social and environmental tensions are not resolved, civilized norms erode, and great human misery ensues. The third type of scenario, *Great Transitions*, envisions fundamental social and institutional transformation toward more sustainable forms of economic and social development, bringing a new and arguably higher stage of human civilization.

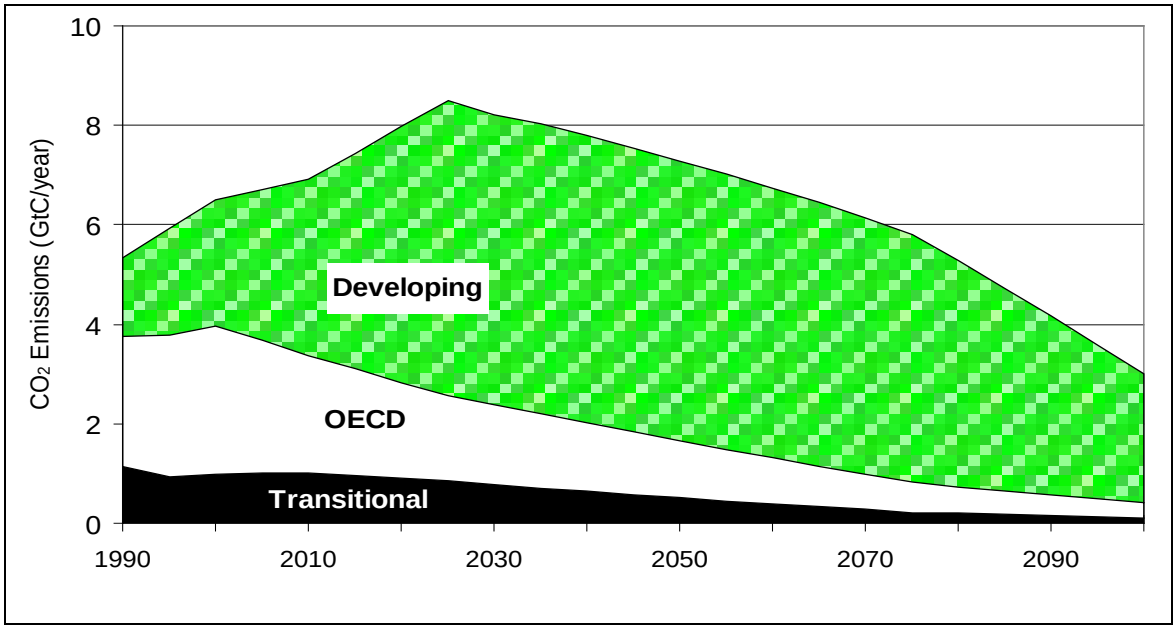
Bending the Curve examines the possibilities for sustainable development by pushing for important changes within an evolutionary *Conventional Worlds* context. The shift to more sustainable forms of development must at least begin at this level, although we will likely need more fundamental social changes to complete the transition to a sustainable global society. This study shows how a comprehensive set of policy reforms could bend the curve of development toward sustainability.

The Challenge of Sustainable Development

To assess the implications of current trends and to guide policies to change those trends, we introduce a set of explicit goals for long range sustainability. In developing sustainability goals, we include both the environmental and social dimensions of the sustainable development concept. Environmental sustainability means changing human activities so that they no longer threaten the natural resource base and ecological systems upon which economic development, human health, and social well-being depend. Social sustainability highlights the need to reduce absolute poverty and extreme inequality on both moral and practical grounds. Social sustainability is essential because poverty is both a cause and an effect of environmental degradation. Moreover, a society festering with social tension will not have the means or inclination to make the environment a priority.

There are no blueprints for a transition to sustainability, but there are policy reforms that could reduce environmental degradation, income disparity, and persistent poverty. Humanity's sustainability goals of today will need to be refined over time in light of new information and events in the spirit of "adaptive management." However, setting provisional targets for sustainability will allow us to start developing strategies to avoid critical risks and will keep options open for the future.

We suggest sustainability indicators and targets for five broad environmental challenges: stabilizing the climate within safe ecological limits, reducing the flow of materials through economies, decreasing toxic waste loads on the environment, easing the pressure on freshwater resources, and maintaining the integrity of ecosystems. The targets call for substantial decreases in environmental pressures from OECD economies. Developing and transitional regions of the world would increase some impacts, then gradually move toward OECD standards. The targets for carbon dioxide emissions, shown below, illustrate the pattern.



CO2 Emissions Targets

There can be no easy consensus on broad *social goals*, which will vary across worldviews and societies. We consider only a minimal set of objectives that have wide international consensus: the provision of basic human needs such as adequate food, clean drinking water, and access to health care and education. It is a sad legacy of our time that the extraordinary expansion of the aggregate global economy, which grew by a factor of five since 1950 alone, has not diminished the sum total of human misery. Some 1.3 billion people live in absolute poverty, with nearly 900 million undernourished. The following table underscores both the scale of destitution and the contrast between industrialized OECD countries and other regions.

Social Indicators in 1995

Macro-Region	Income ($/capita)	Population (millions)	Hunger (%)	Unsafe Water (%)	Illiteracy (%)
OECD	20,250	910	1	1	1
Non-OECD	3,130	4,830	18	28	29
World	5,880	5,740	16	23	24

Guided by the declarations of recent international conferences, we propose a set of challenging though attainable social goals. They are reducing the incidence of hunger, unsafe water, and illiteracy in half by 2025 and in half again by 2050, based on 1995 figures. The number of hungry, for example, would fall from 890 billion in 1995 to 445 billion by 2025, and 220 billion by 2050. As a fraction of projected world population, hunger would fall even faster, from 16% in 1995 to about 2% in 2050.

The Problem of Unsustainability

Are the sustainability goals compatible with conventional development premises? Drawing on the analyses and assumptions of many international organizations, we have painted a picture of global development under a business-as-usual approach. We call this the *Reference* scenario and use it to examine emerging problems. We use this baseline to assess the types of policy changes needed.

If current trends continue, we will have larger, older, and more urban populations. Economies will continue to grow rapidly everywhere, driven by expanding global trade, financial transactions, and capital flows. Advances in information technology and biotechnology, along with other innovations, will gradually change production and consumption patterns. Developing countries will emulate the industrial country development model, and there will be progressive homogenization of global culture around the values of materialism and individualism. Significant income disparity between rich and poor countries, and between the rich and poor within countries, will remain a tenacious and debilitating a social trend. Development will continue to run down the environmental base upon which it depends by using resources faster than nature can produce them and by releasing pollution faster than it can be safely assimilated.

Among the projections in the *Reference* scenario are the following:

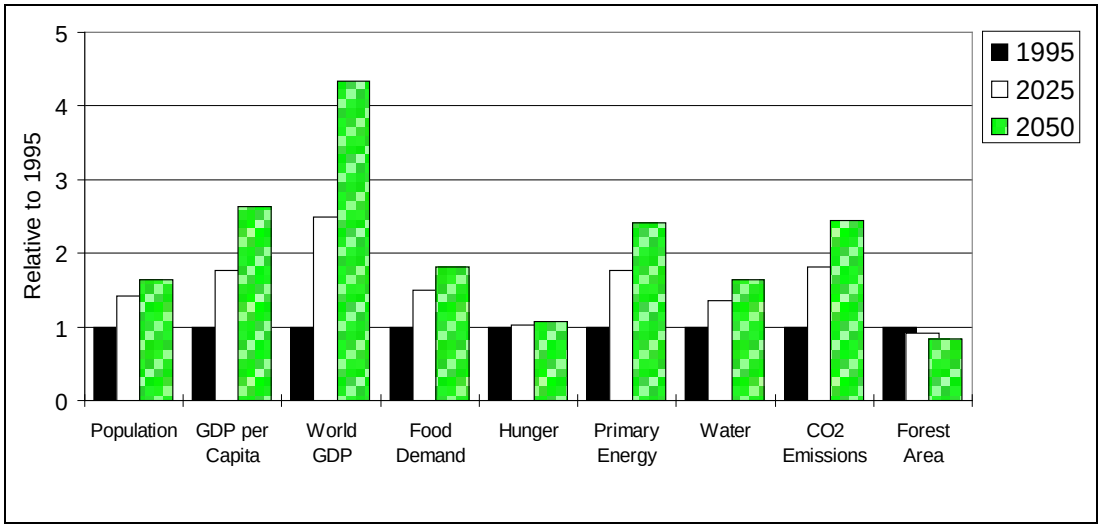
- Between 1995 and 2050, world population increases by more than 50 per cent, average income grows over 2.5 times, and economic output more than quadruples.
- Food requirements almost double, driven by growth in population and income.
- One billion remain hungry as growing populations and continuing inequity in the sharing of wealth counterbalance the poverty-reducing effects of general economic

growth.

- Requirements for energy and water increase substantially.

- Carbon dioxide emissions soar, threatening the global climate and risking serious ecological, economic, and human health impacts.

- Forests are lost to the expansion of agriculture and human settlement areas, as well as other land-use changes.



Overview of *Reference* Scenario

Measured against our sustainability criteria, the *Reference* scenario would be a risky bequest to our 21st century descendants. The increasing pressure on environmental systems — the combined effects of growth in the number of people, the scale of the economy, and the throughput of natural resources — is environmentally unsustainable. Environmental degradation could undermine a fundamental premise of the scenario: perpetual economic growth on a global scale. Conventional development patterns also fail to address the social goals for sustainability, as the level of absolute poverty and hunger persists into the middle of the next century.

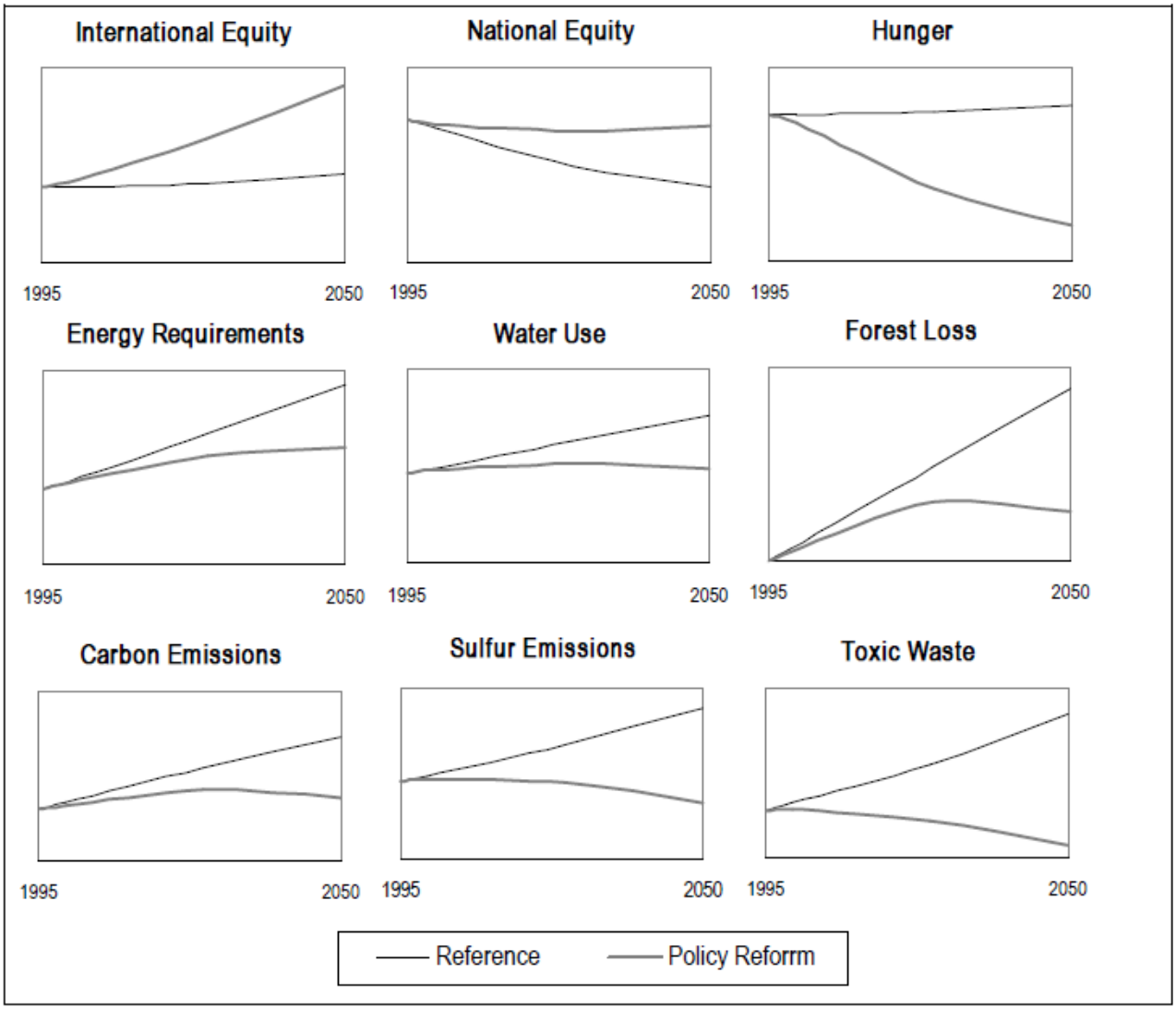
Strategies for a Transition

What strategies could bend the curve of development toward the sustainability goals? *Policy Reform* scenarios begin with visions of the future that satisfy the sustainability goals. Rather than a forecast, the scenario is constructed as a *backcast* from a desired future in 2050 and beyond. The aim is to identify plausible development pathways for getting there, including the choices and actions for shaping a sustainable future.

In the *Policy Reform* scenario, poverty reduction goals are realized through initiatives to increase the incomes of the poor. Two types of equity increases relative to current trends are critical to meeting these goals: greater international equity between rich and poor countries and greater national equity within countries. International equity

is aided by strategies that accelerate the convergence of developing and transitional regions toward OECD levels of development. National equity is improved through income distribution policies. Under the scenario, "growth with equity" becomes the prevailing philosophy in development strategies.

Meeting the environmental goals in the *Policy Reform* scenario requires dramatic adjustments in the use of resources, abatement of pollution, and protection of ecosystems. In the face of increasing populations and rapid economic growth, the simultaneous satisfaction of environmental and social targets presents an exceedingly daunting challenge. Energy, water, and resource use efficiency must increase substantially. Renewable energy, ecologically based agricultural practices, and integrated eco-efficient industrial systems must become the norm. To live within water and land constraints, a number of developing countries must rely more heavily on food imports, countering recent trends in industrialized regions of withdrawing lands from agricultural production. The scale of the required transition is illustrated by comparing *Reference* and *Policy Reform* scenarios across selected social and environmental dimensions, as shown in the figure below.



Global Patterns Compared

Conclusion

Environmental degradation is not a necessary outcome of development. It results from a set of historically contingent choices for technology, production processes, and consumption patterns. Similarly, poverty and extreme inequity are not inevitable, but are the outcome of a specific set of social policy choices. Reversing the negative trends and creating a transition to global sustainability will not be easy. It will require a widespread conviction that action is necessary and will depend on finding sufficient political will for such action. Then, the institutions, policies, and technologies for translating intentions into real-world solutions must be harnessed or forged. The primary agents for change are governments, businesses, and the new institutions of civil society, the proliferating collection of non-governmental organizations engaged in addressing the full range of environmental and social issues.

Science has a critical role in the sustainability transition. It must broaden its focus and develop a systems approach to understanding complex social and ecological processes and their interactions. The challenge is to develop a science of sustainability that maintains a commitment to rigor while recognizing the inherent uncertainty in complex systems, and the need for advice on how to make sustainable choices. Scenario analysis can play a linchpin role by synthesizing diverse findings from natural and social sciences and by linking science to the public and policy dialogues on the future.

The message of the *Reference* scenario is that emerging environmental and social stresses pose grave risks. Complacency is not a valid option for those who take the responsibility of passing on a secure future to our descendants as a moral imperative. The *Policy Reform* scenario shows that the cumulative effects of a comprehensive family of feasible incremental technological and policy adjustments can take us a long way down the sustainability path. Numerous policy levers could be used to induce environmentally sustainable practices and promote poverty alleviation. The appropriate package of instruments, including eco-taxes, market mechanisms, regulation, income transfers, human capital investment, technology transfer, economic stimulation, and information campaigns, will vary with the issue, level of governance, and local concerns.

The challenge ahead is to mobilize the political will needed to pick up the policy tools. Can the global movement for sustainability overcome the resistance of special interests, the myopia of narrow outlooks, and the inertia of complacency? Are fundamental changes required in values and lifestyles that transcend *Conventional Worlds* assumptions — a *Great Transition*? If this generation can begin to bend the curve of development toward sustainability, it will keep future options open, bestowing the gift of choice to posterity.

1. ISSUES AND CONCEPTS

Ours is an age of profound transformation and great uncertainty about the future. Over the last few centuries — a mere heartbeat of historic time — the human impact on the global environment has grown from diminutive to elephantine. Now the human enterprise is on the brink of a new evolutionary milestone — the planetary phase of civilization. This epochal transition poses weighty challenges for thought, policy, and action. To reflect on the human condition and destiny at the end of the 20th century is to enquire about the troubling perils ahead as we drift along the arc of history. But it is also to examine the possibility of a salutary passage to a more just and sustainable global society.

1.1 Triumphalism and Counterpoint

A striking feature of the current era is the astounding expansion of the world economic system, the culmination of forces launched several centuries ago with the emergence of European capitalism. By liberating nascent human potential for innovation and ingenuity, capacity for greed and acquisitiveness, and hunger for liberty and modernism, the new system set in motion a perpetual revolution in values, institutions, technology, and knowledge. This process was further accelerated by the industrial explosion, which continues in the form of the tumultuous technological changes of our time.

Looking ahead to the new century, conventional wisdom sees further massive change as these historic forces play out on a global field — populations may double, the world economy quadruple, and environmental pressures surge (IPCC, 1992b; Raskin et al., 1996). A common theme is that societies everywhere will gradually converge toward common institutional and cultural assumptions in the context of globalizing economies (OECD, 1997). War, social opposition, and stubborn traditionalism impeded the forward march of the ascendant market system in the past. But with the collapse of the socialist experiments in Russia and elsewhere, the expansion of global markets, and the heady advance of new technology, the millennial glee of cheerleaders for global capitalism, anticipating a cornucopia for all in the new century is, perhaps, understandable (Schwartz and Leyden, 1997).

But there are substantial challenges that must be overcome and fundamental questions addressed. How will a growing human enterprise, one that already is significantly perturbing natural planetary processes, be reconciled with environmental limits? How will the deep social fissures between the North and the South, the rich and the poor, parochialism and globalism, be ameliorated? And the question posed by Socrates long ago remains: How shall we live?

1.2 Dimensions of Sustainable Development

In rhetoric, if not yet in agenda and action, the nations of the world pronounced their commitment to *sustainable development* at the 1992 Earth Summit. In its classic formulation, sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

At the heart of the concept is the powerful ethical imperative that we strive to consume and produce in a manner that is tempered by concern for the well-being of our descendants. The new paradigm for development demands that we take a multi-generational view in seeking to harmonize socio-economic and environmental goals.

Broadly, what sustainable development seeks to sustain is the integrity of combined human and natural systems as they interact and condition one another over time. The sustainability of such *socio-ecological systems* is a dynamic process of development, not a static condition. A sustainable system is *resilient* to disturbance and *flexible* in adapting to changing circumstances (Raskin et al., 1996).

Not surprisingly, in the translation of the principle of sustainable development into specific targets and action, the philosophical consensus shatters into a cacophony of definitional debates, interpretations, and slogans. The concept is sufficiently rich and protean to refract the full diversity of human interests, values, and aspirations. Bankers, social critics, and environmentalists have all decanted old wine into this new bottle. Nevertheless, sustainability remains an irreducibly holistic concept that compels integration over perspectives, spatial scales, and time.

Sustainable development as a quality of coupled environmental and human systems has both biophysical and socio-economic dimensions. Biophysical sustainability seeks to maintain ecosystems, bio-geochemical cycles, and natural resources for perpetual human development. Beyond such anthropocentric requirements, for many, the preservation of the natural heritage and the survival of species are intrinsic values not requiring utilitarian justification. In any case, endless quantitative growth is an impossibility on a finite planet, though qualitative improvement in products, skills, and culture need never cease in an environmentally sustainable world (Daly, 1996). Biophysical sustainability draws attention to the scale of the economic system and the degree to which human activity transforms nature and threatens environmental systems. Biophysical goals can be made operational by setting criteria in terms of key environmental and resource indicators.

The second face of sustainability is socio-economic. For many who have joined the sustainability discussion, though certainly not all, achieving basic social goals — the "needs" of today and of future generations in the Brundtland formulation — is taken as a pre-analytic moral imperative. Eliminating hunger, providing access to education and health services, and diminishing inequality between and within regions are sufficient on ethical grounds alone, whether or not they are necessary antecedents to environmental sustainability. Indeed, there are plausible "solutions" to the problem of environmental sustainability that are politically and socially repressive (Gallopin et al., 1997).

However, beyond the moral imperative for reducing human deprivation, there are important objective links that couple social goals to environmental conditions. For example, poverty is both a cause and an effect of environmental degradation (World Bank, 1996). The desperately poor are likely to mine nature for immediate survival, not preserve it for a dubious future. Moreover, the social cohesion required for a comprehensive sustainability transition is undermined in a society where the needs of its citizens for material well-being and just treatment are not met. At the global level,

regional disparities foster migration pressure, environmentally unfriendly trade and development patterns, and difficulty negotiating international environmental agreements.

Thus, the socio-economic and environmental aspects of sustainability are highly interdependent. If a society permits excessive environmental deterioration, it risks undermining the economic welfare of its citizens, the legitimacy of its political systems, and the endurance of its institutions. If a society festers with social tension and instability, it is not likely to make the environment a priority, or enjoy the institutional capacity for implementing a sustainable form of development. We take as a fundamental principle, therefore, that the socio-economic and biophysical dimensions of the sustainability transition must be treated in a unified framework.

1.3 Scenarios of the Future

Scenario analysis offers structured accounts of possible long-range futures. The value of scenarios lies not in their capacity to predict the future, but in their ability to provide insight into the present. By helping to identify drivers of change, the implications of current trajectories and options for action, scenarios bring the future to bear in today's decisions. This is a critical contribution since the world is dominated by fragmented rationality — firms concerned with profit, decision-makers with short-term agendas, scientists with subspecialties, and households with material accumulation. The danger is that such local rationality taken in aggregate leads to global irrationality, to a pattern for the whole system that would have been chosen by no one.

Scenarios enlarge the canvass for reflection to include a holistic perspective over space, issues and time. They illuminate the ways in which the contradiction of unabated growth of human activity on a finite planet might be resolved. In conventional development paradigms, long-range global affluence and environmental preservation are assured, it is hoped, through market adaptations, perhaps with the prod of well-designed policies. But there are other ways in which the tension between economic growth and environmental limits might be reconciled. Some visions are bleak, including the possibility of catastrophic environmental and social collapse — or, perhaps to prevent such breakdown, the emergence of authoritarianism. Some are idealistic, picturing a root and branch transition where post-consumerist values and lifestyles form the basis for a more just, humane and ecological stage of civilization.

These three archetypal scenarios of the future — *Conventional Worlds*, *Barbarization*, and *Great Transitions* — are described in a previous publication (Gallopin et al., 1997). The *Conventional Worlds* class of scenarios assumes that current trends play out without major discontinuity and surprise in the evolution of institutions, environmental systems, and human values. In *Barbarization* scenarios, fundamental social change occurs, but is unwelcome, bringing great human misery and collapse of civilized norms. Finally, *Great Transitions* also represent fundamental social transformation, but a new and arguably higher stage of human civilization is posited.

This wide and contrasting scan of possible futures, all consistent with current conditions and trends, is necessary because the long-range future is not predictable. The global socio-ecological system is far too complex for that. Scientific understanding of

current conditions, forces of change, and systems dynamics is limited. But even with precise knowledge, uncertainty and surprise are inherent in complex systems.

Moreover, the future is subject to human choices that have not yet been made and actions that have not yet been taken. Indeed, the entire discussion of a transition to sustainable development is premised on the notion that humankind can, to a degree, influence its destiny. In this sense, scenarios can serve as self-fulfilling *attractors*, desirable visions of the future that help galvanize effective actions for their realization. The future beckons to the present through our capacity to envision goals and act to achieve them.

Scenarios can be elaborated in great narrative and quantitative detail with many variations possible within each of our major classes. Figure 1 shows two such variants for each of our three classes along with illustrative sketches of how key variables — population growth, economic scale, environmental quality, distributional equity, technological change, and social conflict — might change over time. In fact, the curves of change will vary depending on the worldview of the observer. For example, the curve suggesting increasing environmental deterioration under the market-driven *Conventional Worlds-Reference* scenario would be unacceptable if one believed that market responses (e.g., through changing prices) would induce the required behavioral changes and innovations for environmental protection.

The focus of this study is the *Conventional Worlds-Policy Reform* scenario. The *Policy Reform* scenario is distinguished from the business-as-usual *Reference* scenario by the assumption that comprehensive and coordinated government action is taken for sustainability. The scenario is used to explore the requirements for achieving sustainability and the challenges for policy within a *Conventional Worlds* framework. Of course, the emergence of the necessary political will for imposing sustainability constraints on a growth-driven global economy and consumerist culture — the essence of the *Policy Reform* scenario — is by no means assured. Nevertheless, policy reforms are the point of departure for a sustainability transition, even if, ultimately, one must imagine more basic changes in human institutions and values.

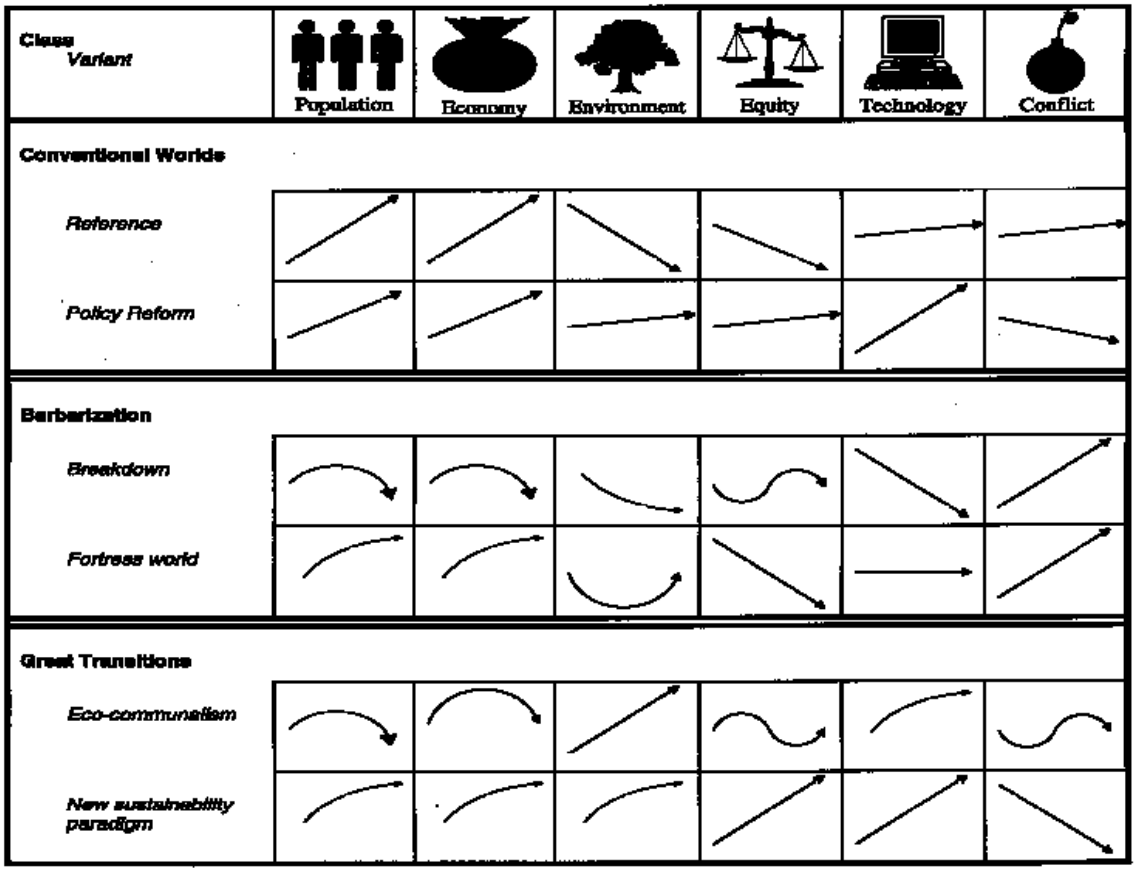


Figure 1. Scenarios Structure with Illustrative Patterns of Change

Source: Gallopin, et al. (1997)

Such changes might draw on elements of *Great Transitions* scenarios, which in their pure forms are visionary responses to the sustainability challenge that include a resurgence of quality values as a component of human welfare, high valorization of nature, equitable wealth distribution, and strong social solidarity. The *Eco-communalism* variant embraces the principles of strong decentralization, small-scale technology, and economic autarky. The *New Sustainability Paradigm* variant is a more cosmopolitan vision that would transcend and transform urban and industrial civilization, and maintain global linkages and solidarity, rather than retreat into localism.

But what if increasing environmental and social crises overwhelm market adaptations, and policy intervention and value change are insufficient? Then, the threat of a descent into *Barbarization* would loom. In an extreme variant, *Breakdown* scenarios envision cultural disintegration and economic collapse, a degeneration of civilization into a primitive world of all-against-all. The *Fortress World* variant features an authoritarian response to the threat of breakdown. Ensconced in protected enclaves, an elite safeguards its privilege by controlling an impoverished majority and managing critical natural resources. Outside the fortress there is repression, environmental destruction, and misery.

1.4 Aim and Structure of the Report

The taxonomy of scenarios offers a useful point of departure for understanding where the world system might be going — and where it would need to go to meet social and environmental goals. Though the framework is highly idealized, greater texture and richness can be introduced by allowing for variation across regions and providing concrete stories of how the scenario themes might play out. Also, a scenario may jump to a qualitatively different one at critical moments when unresolved socio-ecological tensions and contradictions lead to a branching of possibilities.

In this report, we reduce this complexity by narrowing our focus to the *Conventional Worlds* class of scenarios. It is true that the fundamental premises of these scenarios — evolutionary change in institutions, global convergence of economies, and continuity in values — are not inevitable. As we have argued, discontinuities lurk in the form of *Barbarization* nightmares and *Great Transitions* visions — or as surprises that we cannot anticipate. Complacency about deep threats to civilization would certainly be both imprudent and unethical. Moreover, the emergence of life-styles and values that transcend the conventional paradigm must be part of a sustainability transition.

Nevertheless, the center of the policy discussion today lives in the *Conventional Worlds* niche of the landscape of future visions. Political processes inherently tend to seek to resolve conflicting interests gradually. When it comes to sustainable development, the perception of conflict — between the environment and economic growth, between rich and poor, between the present and the future — is on a colossal scale. Despite some positive trends, the 1997 United Nations General Assembly review of progress in the five years since Rio found that critical problems were deepening (UNDPCSD, 1997). In the near term, a gradual tilt toward effective policies for sustainable development is the most that can be expected. Even this would constitute a critical historical shift toward sustainability.

In this spirit, we introduce a broad set of environmental and social criteria to serve as goals for long-term sustainability (Section 2). Then, to clarify the character and scale of the policy challenge, we examine how an illustrative business-as-usual *Conventional Development-Reference* scenario fares against these criteria (Section 3). Next, we develop a *Conventional Development-Policy Reform* scenario that includes an alternative set of socio-economic, environmental, and resource patterns, which seeks to meet the sustainability criteria (Section 4). Finally, we discuss the strategic implications — the kinds of policy steps needed to begin bending the curve of history toward a sustainable development path (Section 5).

2. GOALS

Sustainable development is about harmonizing human development with the environmental constraints of the planet. It is also about reconciling the needs of present generations with the needs of the future. In broad brush, a vision of sustainability for the next century might include the following aspirations:

- eradication of absolute poverty, malnutrition, and famine, combined with universal entitlement to basic social services such as health care and education;
- improving quality of life everywhere and expanding possibilities for fulfillment;
- declining economic and social disparities;
- increasing environmental quality, with critical biological resources recovering, pollution under control, and climate stability in sight;
- infrequent violence and armed conflict; and
- stable global population (Gallopin et al., 1997).

The challenge is to move the international commitment to sustainability from vision to action. To design and test appropriate policies, the broad goals must be expressed in terms of specific quantitative objectives. Recognizing that any set of criteria for a sustainable world must necessarily be tentative and partial, it is nonetheless useful to describe a preliminary set of minimum objectives — both social and environmental — and the indicators that might gauge progress toward them.

To establish quantitative objectives, three sets of choices must be made: first, which indicators are to be used to measure progress toward sustainability; second, which values of these indicators represent sustainable conditions and hence provide targets against which to measure progress; and third, how rapidly these targets are to be achieved. These choices are to some degree subjective by nature, dependent not only on the interpretation of uncertain scientific information, but also on the cultural preferences and interests of an individual, a community, or a country. This implies that different societies might choose different sustainability criteria.

For reasons of simplicity and comparability, a common set of core global indicators is used in this report. The indicators and targets set the constraints on *Policy Reform* scenarios. They provide provisional guidelines for the scope, scale, and timing of strategic actions required for a transition to sustainability. However, there are no blueprints — sustainability indicators and targets will need to be refined over time in light of new information, events and perspectives. Sound sustainable development practices will be an instance of "adaptive management." Today, we can only begin the long process of navigating a path across uncharted seas toward sustainability.

2.1 Social Objectives

Taken broadly, the notion of setting *social goals* could be construed to imply fundamental normative questions, such as visions of the good society of the future. There can be no easy consensus on these matters, since the range of perspectives will vary across the full

range of worldviews and political philosophies. The discussion here is more limited in scope, focusing on a narrower set of goals that have wide international consensus: the provision of basic human needs, such as adequate food, clean drinking water, and access to health care and education.[1]

At a minimum, this report argues, sustainability must mean achieving such social goals. However measured, the human condition today falls far short of this standard. It is a sad legacy of our time that the extraordinary expansion of the aggregate global economy — by a factor of five since 1950 alone — has not diminished the sum total of human misery. The percentage of people destitute may have declined, but the absolute number has not. Not only has absolute poverty coexisted with rapid economic growth, but it has also to a large degree been generated by the very systems that provide the engine of that growth (Gallopin, 1994).

The prevalence of poverty in the world today is an oft-told story that can only be summarized here (UNDP, 1997). We begin by considering the stunning contrast between highly developed countries (OECD) and others (Table 1).[2]

Table 1. Income, Population, and Poverty in 1995

Macro-Region	Income ($/capita)	Population (millions)	Absolute Poverty (millions)
OECD	20,250	910	12
Non-OECD	3,130	4,770	1,300
World	5,880	5,690	1,312

Sources: Income from CIA (1997); Population from UN (1997); Non-OECD poverty figures from UNDP (1997); OECD poverty figures equated with hunger estimates

Nearly 85% of world population resides in non-OECD countries, where 27% live in absolute poverty.[3] The 1.3 billion living in such dire poverty exceeds the entire population of the OECD countries. Using GDP per capita as a proxy for average income, we see from Table 1 that people in OECD countries are 6.5 times richer than in non-

[1] A broader perspective on alternative social visions will be the subject of a subsequent study of the *Global Scenario Group* that will take up *Great Transition* scenarios, which were referred to in Section 1 and elaborated in Gallopin et al. (1997).

[2] Throughout the report we summarize results for two macro-regions, a more developed region as represented by the member countries of the Organization for Economic Cooperation and Development (OECD), and the rest of the world (non-OECD). Mexico, the Czech Republic, Hungary, Poland, and Korea are not included in the OECD, although they are recent members.

[3] The absolute poverty level is defined by the World Bank (1990) as individual consumption expenditures less than $1/day or about $370/year in 1985 dollars, which is equivalent to about $525/year when inflated to 1995 dollars.

OECD countries.[4] Note that the 15% of world population that resides in the wealthier countries claims 55% of global income (the figure is 75% when GDP is expressed in MER rather than PPP terms). Moreover, the disparity between the world's rich and poor has been increasing. According to one estimate, the richest 20% were 30 times better off than the poorest 20% thirty years ago, and are now 61 times better off (UNDP, 1996).

There are many possible measures of the status of human development. We focus here on four indicators that serve to represent key categories of human well-being. These are chronic undernourishment (represented by *hunger* levels), availability of clean water (measured in terms of the *population with unsafe drinking water*), education (gauged by the level of *adult illiteracy*), and human health (a proxy is *life expectancy at birth*). The global situation for the four indicators is reported in Table 2. The indicators can be expanded and combined; for example, the Human Development Index (UNDP, 1997) combines average income per capita, literacy, and life span.

Table 2. Selected Social Indicators in 1995

Macro-Region	Hunger (%)	Unsafe Water (%)	Illiteracy (%)	Life Expectancy (years)
OECD	1	1	2	77
Non-OECD	19	28	29	64
World	16	24	24	66

Sources: See notes to Table 3

Not surprisingly, the disparities that were observed in the incidence of poverty between OECD and non-OECD regions are also reflected in these more tangible measures. In non-OECD regions, about 880 million people are undernourished today, 18% of the population in those regions. Moreover, 1.35 billion people, roughly 28% of the population, do not enjoy reliable and sanitary sources of drinking water. The cumulative effects of the lack of basic education are indicated by the 29% of the adult population that is illiterate. Finally, life expectancy at birth in non-OECD regions remains substantially below OECD averages, though there have been impressive increases in recent decades. Life expectancy in developing countries rose from 46 to 62 years between 1960 and 1994, as infant mortality declined from 149 to 39 per 1000 live births (UNDP, 1997) and death from infectious diseases declined (WHO, 1997c).

Values for the social indicators by region are presented in Table 3. The ten global

[4] Unless stated otherwise, national currencies in this report are expressed in common units adjusted for Purchasing Power Parity (PPP). National PPP-adjusted GDP per capita are taken from CIA (1997). The PPP approach, in which prices of a common "basket of goods" are compared across countries, gives a more realistic picture of relative incomes than the more commonly used Market Exchange Rates (MER) (WRI, 1996a). Use of PPP has the effect generally of raising the estimated incomes in developing countries relative to rich countries. In MER-converted terms, the ratio between OECD and non-OECD GDP per capita is about 19, considerably higher than the figure of 6.5 reported in the text.

regions used for the analysis throughout this report are shown in Figure 2. For context, also shown on Table 3 are GDP per capita and a measure of income inequality (the ratio of the income of the poorest 20% to that of the richest 20%).[5] Africa fares least well across all four indicators. More than one-third of the population is undernourished and nearly half are without safe drinking water. South and Southeast Asia and the Middle East also register high levels of deprivation, with China and Latin America not much better. The information on hunger and unsafe drinking water is presented graphically in Figure 3.

Table 3. Selected Indicators by Region in 1995

Region	Hunger (%)	Unsafe Water (%)	Illiteracy (%)	Life Expectancy (years)	GDP/Cap ($)	Poorest 20% divided by Richest 20%
Africa	34	49	45	55	1,620	0.13
China+	16	20	18	69	2,890	0.14
Latin America	14	17	14	69	6,000	0.07
Middle East	16	27	38	65	5,260	0.10
South & SE Asia	19	35	40	63	2,580	0.18
Eastern Europe	1	7	0	71	5,950	0.23
FSU	4	8	0	67	4,110	0.22
North America	2	0	0	77	26,950	0.11
Pacific OECD	1	0	0	79	21,100	0.16
Western Europe	1	1	4	76	15,730	0.19

Sources: Hunger (see notes to Sheet S-2); unsafe water = 100% - access to safe drinking water; access to safe drinking water for 1980-1995 (WHO, 1997b; World Bank, 1997), set to 100% for high-income OECD countries, value for Ukraine used for missing values in FSU; illiteracy = 100% - adult literacy; adult literacy for 1990-1995 (World Bank, 1997), set to 100% for countries in the OECD, Eastern Europe and FSU with no data; life expectancy at birth for 1990-1995 (World Bank, 1997); GDP per capita in PPP (CIA, 1997); income ratios (see notes to Sheet S-1).

[5] Regional income inequality is computed as the population-weighted average of country level data.

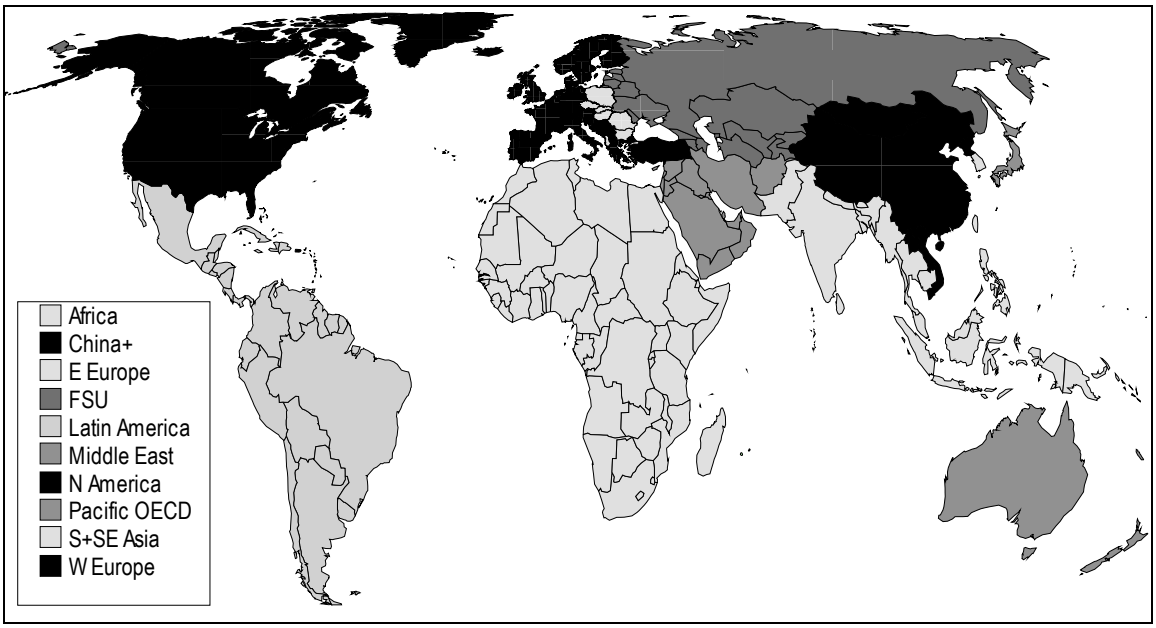


Figure 2. The Ten Regions

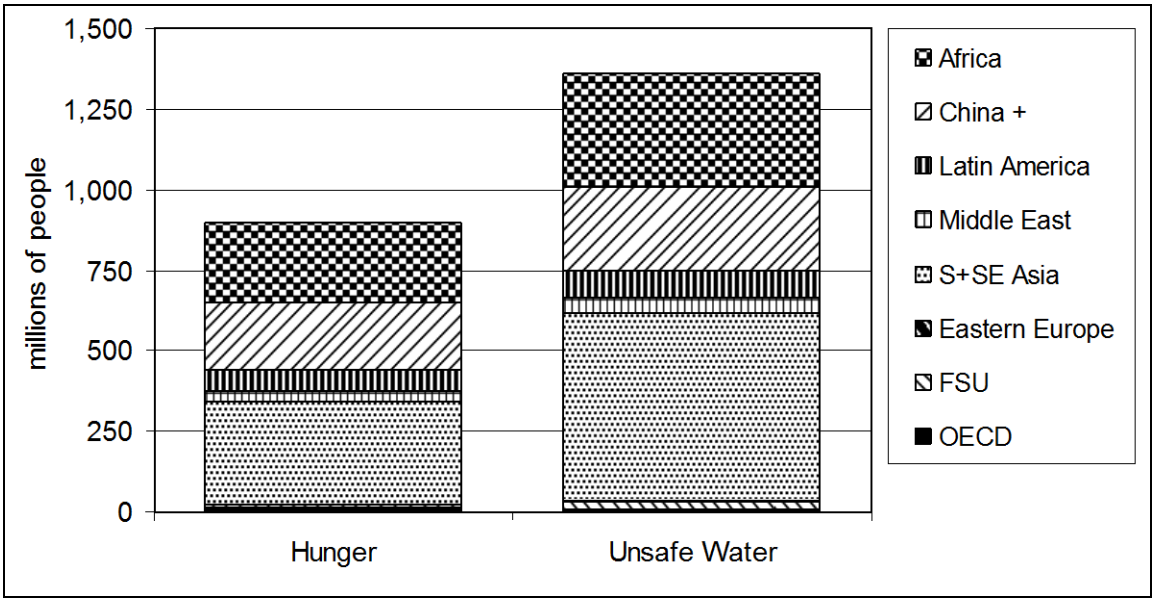


Figure 3. Population Suffering from Hunger and a Lack of Safe Drinking Water in 1995

Source: See Table 3

Poverty levels in a given country depend on both average income and distribution of income. As a general principle, for a given average level of income, the more skewed the distribution, the greater the fraction of the population in absolute poverty. This relationship can be gleaned from the data in Table 3. Eastern Europe and Latin America have similar average incomes, but income disparities are much greater in Latin America, as are levels of hunger. Income distributions are similar in China+ and Africa, but average incomes in Africa are much lower than in China+, with correspondingly higher

levels of absolute poverty. The compact income distributions for the Former Soviet Union and Eastern Europe — the ratios of the incomes of the poorest 20% to the richest 20% are greater than 0.2 — are consistent with the historic emphasis on meeting the basic needs of their citizens.

Social goals for sustainability may be expressed in the language of reduction targets for each measure of human deprivation. Here we rely on the work of a series of international conferences that over the past few years have attempted to define goals for the reduction of human deprivation and the provision of the opportunity for a dignified life for all.[6] Each of the indicators reflects a different dimension of poverty.

At the 1996 World Food Summit, it was resolved that undernutrition was to be halved by the year 2015 (FAO, 1996d). To achieve this goal, the number of undernourished people must decline from 900 million today to roughly 445 million over 20 years. Based on the historical record, this is a quite ambitious goal, because the number undernourished fell only about 70 million between 1970 and 1990 (FAO, 1996d).

In the spirit of the World Food Summit goal, but allowing for some slippage, this report proposes a minimum target for hunger reduction in *Policy Reform* scenarios of halving undernourishment by 2025 and halving it again by 2050. The targets are defined in terms of the absolute number of undernourished: by 2050, the number of undernourished people is targeted to fall to one-quarter of its 1995 value (Table 4). As a fraction of world population, hunger falls faster, from about 16% in 1995 to just over 2% in 2050, since population is assumed to grow from about 5.7 billion in 1995 to 9.4 billion over this period, assuming mid-range population projection levels (UN, 1997).

Table 4. Global Indicators and Targets

Indicator		1995	2025	2050
Hunger	millions of people	900	445	220
	% of 1995 value	-	50%	25%
	% of population	16%	6%	2%
Unsafe Water	millions of people	1,360	680	340
	% of 1995 value	-	50%	25%
	% of population	24%	9%	4%
Illiteracy	millions of people	1,380	690	345
	% of 1995 value	-	50%	25%
	% of population	24%	9%	4%
Life Expectancy	Years	66	> 70 in all countries	

[6] The approach follows BSD (1998).

Strong commitments to universal provision of safe drinking water have been a recurrent theme in human development conferences and in the policy goals of multi-national organizations (WHO, 1997a). Unfortunately, there is a history of bold pronouncements that go unmet, such as the Decade of Safe Drinking Water in the 1980s. As with hunger, we assume that the population without safe water is cut in half by 2025. This corresponds to a minimum level of safe water service of about 85% for rural and 95% for urban dwellers. The goal for 2025 may be compared to today figures of 50% and 75% safe water access in rural and urban areas, respectively, in many developing countries. The 2050 target assumes another halving, corresponding to over 95% access to safe water everywhere.

Similarly, the World Summit for Social Development (WSSD, 1995) and the Fifth International Conference on Adult Education (UNESCO, 1997) articulated extremely ambitious goals for the reduction of illiteracy, such as the elimination of female illiteracy by the year 2000. While these are no doubt unrealistic, meeting the goals of halving by 2025 and again by 2050, as shown in Table 4, is certainly a plausible minimal target in a world in which education for all is made a priority.

Finally, there is every reason to believe that aggressive policy actions in the health sector can continue. The goals expressed at such meetings as the World Summit for Social Development (WSSD, 1995) have been quite optimistic, though imprecise. A specific near-term goal is for life expectancy at birth to be greater than 60 years for every country of the world (WHO, 1997a). Ultimately, life expectancy in developing regions can be expected to approach that of the OECD regions. A reasonable intermediate goal is that average life expectancy in all countries exceeds 70 years by 2025.

The social goals for the sustainability transition that we have introduced here set a challenging agenda for development. Even as general economic growth tends to drive absolute poverty down, trends in population growth and increasing income disparity tend to drive it higher. Indeed, as will be seen in Section 3, the *Reference* scenario analysis shows that conventional development assumptions alone are not likely to lead to these reductions. Rather, the number of people in hunger, to take one example, would not diminish.

As expressions of different faces of poverty, the social needs represented by the various indicators have common roots. In assessing and constraining scenarios, we shall find it convenient to focus attention on a single indicator to highlight results and to bound the technical analysis. In particular, hunger-reduction targets will play a critical role in evaluating the sustainability of *Reference* scenarios and in defining targets for *Policy Reform* scenarios. A reduction in hunger is correlated with the alleviation of the entire nexus of unfulfilled basic needs associated with absolute poverty. The broad correlation between hunger levels and other aspects of poverty is apparent from the data in Table 3. In addition, there are virtuous circles coupling progress across a number of indicators; for example, reducing hunger also reduces vulnerability to disease and, in turn, improves access to livelihoods and food entitlements.

The reduction of absolute human deprivation as discussed here is a necessary condition for a humane transition to sustainability. However, it may not be sufficient. In particular, improved social equity within societies may be an important goal in its own

right, not merely as one mechanism for eradicating poverty. At issue is the possible link between social equity and social cohesion — between the perceived sense of fairness in the distribution of wealth and privilege in a society, on the one hand, and allegiance to prevailing social institutions, on the other. Inegalitarian societies are likely to be susceptible to relatively high rates of political violence and social instability (Gurr, 1968; Muller and Seligson, 1987; Muller, 1988), though the detailed empirical findings are debated (Wang, 1993). We must be satisfied here with simply noting the linkage between social sustainability and distributional equity and observing that strategies for alleviating poverty by moderating social inequality may also enhance social stability.

2.2 Environmental Objectives

In principle, changes to the Earth's environment that are irreversible on human time scales are not sustainable, since they diminish the opportunities for future generations. In practice, there is an inherent tension between such a strong formulation of the sustainability principle and more immediate goals, such as meeting current human needs and aspirations. Expanding food production may require clearing land for farming or withdrawing more water from streams for irrigation — putting additional pressure on natural ecosystems. Providing the jobs, products, and lifestyles of an industrialized, urban economy will require expanded use of energy — potentially increasing pollution.

The proper balance between the goals of sustainability in the long term and development in the near term is not easily resolved. The relative weight one puts on the rights of future generations and current generations has strong ethical and moral dimensions. Complicating the issue further is a lack of scientific certainty on many critical issues: How will the global climate change in response to rising greenhouse gas concentrations in the atmosphere? How much pressure from human activities can ecosystems withstand before collapsing?

The discussion here will focus on a limited set of environmental objectives. As with the social indicators, international conventions and agreements provide a starting point for selecting environmental criteria for sustainability. There is broad agreement, for example, that the stratospheric ozone layer and the global climate should be protected and that urban and industrial pollution—especially toxic pollution — should be curbed. There is agreement that various ecosystems should be preserved so that the services they provide can continue — from water purification to nutrient recycling to providing habitats for diverse species of plants and animals — and that future generations can enjoy the natural beauty and genetic wealth of forests, coral reefs, and the Earth's biological bounty. There is agreement that steps need to be taken to maintain the fertility of soils and prevent degradation or desertification.

Beyond such agreements, however, there is as yet no consensus on how to measure progress toward sustainability, although many different groups have proposed sets of indicators for this purpose (Munasinghe and Shearer, 1995; Moldan et. al, 1997). Moreover, lack of data is a serious barrier to making many proposed indicators operational. The indicators chosen for use in this report constitute a minimum but hardly sufficient set.

However measured, global environmental trends are not encouraging. Despite

improvements in reducing some local environmental pollution in OECD countries, pollution levels remain high and are rising rapidly in most developing regions. Pressures on the global commons — the atmosphere and the oceans — are steadily increasing (UNDPCSD, 1997). For example, most marine fisheries are now fished at or above sustainable levels (FAO, 1991; McGoodwin, 1990), and the incidence of toxic phytoplankton blooms in coastal waters is rising (WRI, 1994). Pressures on forests, coral reefs, and other vital ecosystems and on such renewable but finite resources as freshwater are also escalating (Bryant et al., 1997; Burke and Bryant, 1998).

A transition to sustainability will require reversing these trends. For the purpose of setting plausible targets for the *Policy Reform* scenario, this report adopts the point of view that such a transition should and could be completed in the second half of the 21st century. This will require abating or reversing, by 2025, the trend of rising pressures from human activity that drive environmental degradation and, by 2050, demonstrating observable improvements in environmental quality worldwide. These criteria applied to climate change, for example, would require that global emission of greenhouse gases peak no later than 2025 and that atmospheric concentrations begin to stabilize by 2050, with stabilization completed by 2100.

Indicators and targets are proposed for five environmental issues in Table 5 and discussed below. The indicators fall into two broad categories. Climate destabilization, eco-efficiency, and toxic wastes relate primarily to industrial activities and the demands of modern lifestyles. Deforestation, degradation of land, over-exploitation of fisheries, and potential scarcity of freshwater relate, in addition, to poverty and growing populations. The targets call for substantial decreases in the environmental pressures from OECD economies. At the same time, the targets for developing countries acknowledge that the process of development and industrialization must continue in these regions, and generally propose that developing regions converge gradually toward the decreasing OECD targets.

Table 5. Environmental Indicators and Targets

Region	Indicator	1995	2025	2050
Climate				
World	CO_2 concentration	360 ppmv	stabilize at < 450 ppmv by 2100	
	Warming rate		average 0.1°/decade, 1990-2100	
	CO_2 emissions		< 700 GtC cumulative, 1990-2100	
OECD	CO_2 emissions rate	various and rising	< 65% of 1990 (< 90% of 1990 by 2010)	<35% of 1990
non-OECD	CO_2 emissions rate	various and rising	increases slowing, energy efficiency rising	reach OECD per capita rates by 2075
Resource Use				
OECD	Eco-efficiency	$100 GDP/300 kg	4-fold increase ($100 GDP/75 kg)	10-fold increase ($100 GDP/30 kg)
	Materials use/capita	80 tonnes	< 60 tonnes	< 30 tonnes
non-OECD	Eco-efficiency	various but low	converge toward OECD practices	
	Materials use/capita	various but low	converge toward OECD per capita values	
Toxics				
OECD	Releases of persistent organic pollutants & heavy metals	various but high	< 50% of 1995	< 10% of 1995
non-OECD	Releases of persistent organic pollutants & heavy metals	various and rising	increases slowing	Converge to OECD per capita values
Freshwater				
World	Use-to-Resource ratio	various and rising	reaches peak values	0.2-0.4 maximum (in countries>.4 in 1995, less than 1995 values)
	Population in water stress	1.9 billion (34%)	less than 3 billion (<40%)	less than 3.5 billion, begins decreasing (<40%)
Ecosystem Pressure				
World	Deforestation	various but high	no further deforestation	net reforestation
	Land degradation	various but high	no further degradation	net restoration
	Marine over-fishing	fish stocks declining	over-fishing stopped	Healthy fish stocks

Climate

The long-term goal for climate, as formulated in the Framework Convention on Climate Change, is to stabilize concentrations of greenhouse gases in the atmosphere, although there is as yet no agreement on when and at what concentration levels stabilization should occur. The approach taken in this report is first to identify a goal for the protection of ecosystems and then, through a chain of arguments, to link the ecological goal to a restriction of carbon dioxide emissions. The criterion selected here is that warming should occur no faster than 0.1°C/decade on average between 1990 and 2100, a value that will allow many—but not all—ecosystems to adapt (Rijsberman and Swart, 1990; Hare, 1997).

As will be discussed in Section 3, this implies that the concentration of carbon dioxide in the atmosphere should stabilize at less than 450 parts per million by volume (ppmv) by 2100. This constraint, in turn, places limits on the cumulative carbon dioxide emissions from human activities of about 700 billion tonnes of carbon (GtC). The aggregate global emissions must be allocated to regions and countries. The targets introduced here take into account equity and burden-sharing considerations in the allocation of emission rights (see Section 4). Relative to 1990 levels, OECD regions are assumed to decrease emissions 10% by 2010 (more than the tentative targets of approximately 5% adopted in the Kyoto accords) and 35% by 2025. All regions approach a common emissions per capita target by 2075. Though ambitious, the targets are nonetheless required if climate stabilization at reasonably safe levels is to be achieved in the coming century.

Resource Use

Extracting, refining, manufacturing, transporting, and ultimately disposing of materials cause significant pollution and waste in industrial societies. These materials include the metals and plastics in automobiles; the chemicals that provide the basis for paints, pesticides, and thousands of other products; and the minerals, fibers, and other natural resources that comprise everything from clothes to computer chips. As global industrial activity expands several-fold over the next half century, pollution, waste, and the resulting environmental degradation may also expand, unless there is a transition to a cleaner and more efficient — or *eco-efficient* — industrial system.

To simultaneously increase economic output and reduce environmental stress requires profound changes in the technological infrastructure of modern societies. Historically, the throughput of materials into economies has risen with economic growth. In the sustainability transition, material use and economic scale must be delinked in a process sometimes referred to as *dematerialization* in order to moderate or reduce the pressure on resources and the environment. There are some signs of dematerialization processes now — the use of energy and various materials has grown less rapidly than GDP in many industrial countries in recent years. However, since the expansion of economic activity has tended to outpace the improvement in efficiency (e.g., the increase in demand for road transport has exceeded improvements in auto efficiency), aggregate use of materials and energy has continued to increase.

In order to stabilize environmental pressure as economies and populations grow, the flow of material into societies must be controlled through designing more durable products, reducing waste streams through reuse of materials, and developing cleaner production processes. Moreover, the mix of economic activity itself must shift (from resource-intensive to knowledge-intensive activities, for example), and ultimately consumer lifestyles may need to change, as well. One aggregate indicator of such a transformation is *eco-efficiency*, which is defined here as the ratio of economic outputs to natural resource inputs into an economy. Two useful indicators for resource use are the *eco-efficiency indicator*, defined here as the ratio of economic output divided by resources required, and *materials use per capita*.

Current values of the eco-efficiency ratio in the OECD regions are typically about

$100 GDP per 300 kilograms of materials (Adriaanse et al., 1997).[7] Material use per capita ranges between about 45 and 80 tons per person per year. The heterogeneous character of the material stream hampers the formulation of sustainability goals for material efficiency. In practice, the problem of reducing material intensities will need to be disaggregated into a number of component flows, indicators, and targets in national sustainability plans. Nevertheless, we introduce here provisional aggregate targets to suggest the direction and magnitude of improved eco-efficiency. The summary goal can be met by varying improvements across the various material components and sectors. A widely discussed goal is the reduction of resource intensities by a factor of ten (Factor 10 Club, 1995). With this level of improvement in the rich countries, it is possible to prevent global material requirements from increasing while allowing poor countries to approach an equitable claim on use (Carley and Spapens, 1998).

We take, as a sustainability target for OECD countries, a 10-fold increase in the eco-efficiency ratio by 2050. With this target, $100 of economic output requires only 30 kilograms of natural resources, as reported in Table 5. An ambitious but achievable interim goal is a 4-fold increase in the eco-efficiency ratio by 2025. Allowing for economic growth, these targets correspond roughly to a 25% reduction in materials use per capita by 2025 and an additional 50% decrease by 2050.

Developing economies have eco-efficiencies even lower than in OECD regions, but with generally much lower values of materials use per capita because the level of output per capita is much lower. In a scenario that assumes a transition to sustainable development, developing regions may be able to improve rapidly by adopting and adapting more efficient technologies and operating practices from developed countries or, in some instances, leapfrogging to advanced technologies. The sustainability target is that developing countries converge toward OECD practices in the course of economic growth.

Toxic Substances

Some forms of resource use have such pronounced environmental impacts that more specific objectives are needed. An important subset is the widespread industrial use and release of toxic substances — such as heavy metals and persistent organic pollutants — that can remain in the environment for long periods of time and accumulate to dangerous levels in soils and sediments, potentially entering the food chain. Long-lived toxic substances pose a growing threat of uncertain magnitude both to human health and to ecosystems. International efforts on persistent organic substances are focusing initially on limits to the production and use of twelve substances (aldrin, dieldrin, endrin, DDT, chlordane, heptachlor, hexachlorobenzene, mirex, toxaphene, PCBs, dioxins, and furans) but have not yet reached agreement on specific targets or timetables.

The target adopted here assumes an intermediate target of a 50% reduction, in OECD countries, of all emissions, discharges, and losses by 2025 and a 90% reduction by 2050 (allowing some unavoidable emissions related to high priority applications). For

[7] Included in the estimates of material requirements are direct inputs of minerals, metals, construction materials, and biomass from either domestic or foreign sources along with material that is moved or discarded in the process of extraction and processing.

heavy metals, which tend to accumulate in the soils and sediments, the proposed targets are the same as for persistent organic pollutants. Use and emissions of toxic substances in developing countries are far below OECD levels on a per capita basis but are rising rapidly and are likely to increase further as industrial activity intensifies. The target set here is that these increases begin to slow by 2025 and converge toward OECD per capita levels by 2050.

Freshwater

Freshwater is critical for meeting human needs, supporting economic activity, and preserving ecosystems. It is a finite and vulnerable resource that must be protected and allocated for these diverse needs. Sustainable development requires the provision of sufficient freshwater of good quality to growing economies, while protecting aquatic and marine ecosystems. Water sustainability presents one of the major challenges that human societies will face in the coming decades (UNDPCSD, 1997; UNEP, 1997; UN, 1997a).

The natural hydrological unit for water assessment is the river basin. Nevertheless, the global situation can be illuminated by introducing indicators of water stress at the national level, an exercise that was conducted for the recent Comprehensive Assessment of the Freshwater Resources of the World[8] (Raskin et al., 1997). The basic measure of water stress that will be used in this study is the *use-to-resource* ratio, defined as national annual withdrawals divided by annual renewable resources. There is no firm relationship between values of this measure and the degree of water stress. Countries differ in the amount of flow lost through floodwater runoff, in the accessibility of surface and groundwater resources to centers of demand, in down-river claims on water resources, and in the requirements for ecosystem preservation. Nevertheless, when values of the use-to-resource ratio exceed 0.4, a country is generally experiencing a high level of water stress. Indeed, signs of imminent competition between user groups, or between human and natural requirements, can begin when the ratio is as low as 0.1.

In principle, a valid sustainability goal would be that over the next decades, water pressure decreases in all areas where water scarcity threatens to impede development or degrade ecosystems. In practice, the momentum of growing water requirements is unstoppable. Water withdrawals have increased by nearly a factor of three since 1950 (Shiklomanov, 1997), and the continuing momentum of expanding populations, production, and food needs will imply continuing growth in water requirements (Section 3). Furthermore, if climate change significantly alters hydrological patterns, sustainable water strategies may be further complicated.

In light of these difficulties, a realistic sustainability goal is that, in river basins where freshwater has become or will become scarce, withdrawal requirements should peak by 2025. Specifically, in countries where there are indications of freshwater stress (use-to-resource ratios greater than 0.1), the target is for withdrawals to stop increasing by 2025. Since this goal allows for increasing use until 2025, water stress will increase.

[8] The Assessment was conducted in response to a 1994 call by the UN Commission for Sustainable Development by UN/DPCSD, FAO, UNEP, WMO, UNESCO, WHO, UNDP, UNIDO, the World Bank, and the Stockholm Environment Institute.

Indeed, assuming mid-range population growth, the target for 2025 implies that up to 3.0 billion people would be subject to water stress conditions. The goal for 2050 is that use-to-resource ratio values remain in the 0.2 to 0.4 range. An exception is the class of countries where the use-to-resource ratio is above the 0.4 level currently (there are some 17 countries in this category, primarily in the Middle East and North Africa). For these countries, the goal is simply that withdrawals in 2050 be less than withdrawals in 1995.

The freshwater targets are rather weak in reference to environmental sustainability criteria alone, since they recognize the inevitability of continuing water stress in many regions. As we shall see in Section 4, meeting even these targets is not easy under *Conventional Worlds* conditions. In any scenario for sustainability, freshwater sustainability requires a major policy focus aimed at increasing water-use efficiency, reducing losses, and enhancing dependable resources.

Ecosystem Pressure

Increasing demands for food, fiber, and timber are pressing against the limits of natural ecosystems. Expanding built environments to satisfy the housing, commercial, and transportation needs of expanding populations and economies compound the problem. To avoid serious damage, fragile ecosystems need to be protected, deforestation and destructive logging practices halted, arid lands carefully managed to avoid desertification, tilled lands managed to avoid erosion or other forms of degradation, and the expansion of built areas moderated.

Three indicators serve as imperfect proxies for these processes: the rate of deforestation, the rate of land degradation, and the extent of over-fishing in the major marine fisheries. Under the *Policy Reform* scenario, net loss of forested land should be much lower than historical rates (or those in the *Reference* scenario). The target is for deforestation rates (the net forests lost per year) to reach zero before 2025 in all regions. This implies the maintenance of critical levels of ecologically rich natural forests. A growing proportion of the world's expanding need for wood, paper, and other forest products should come from plantations or other sustainably managed forests. Both productive forests and plantations should increasingly be managed in order to enhance their ecological quality — their capacity to sustain biodiversity and deliver a range of ecosystem services.

Similarly, land degradation rates (e.g., the land lost to agriculture per year as a result of chemical or physical erosion) should also slow to zero by 2025. By 2050, forest cover (and quality) should be increasing, with most forest products coming from plantations or sustainably-managed forests, and reclamation efforts should be enlarging (and improving) the stock of arable land. Finally, over-fishing should be curtailed so that the world's fish stocks can rebuild themselves to healthy levels.

The environmental criteria for sustainability proposed here are ambitious and pose severe constraints on the *Policy Reform* scenario. But as with the social objectives considered above, they may not be sufficient, for they neglect many other important environmental issues. These include the destruction of coral reefs and other fragile habitats, more subtle pressures on ecosystems such as the growing introduction of invasive exotic species, and additional local water, air, and soil pollution concerns.

Moreover, scientific understanding of the Earth system is still fragmentary. It would be unwise to assume that additional, unexpected, and possibly urgent environmental concerns will not arise.

Future increases in economic activity will tend to aggravate environmental stress. Indeed, the *Reference* scenario analysis in Section 3 shows that under conventional development assumptions and weak environmental and social policies, the indicators of environmental sustainability are likely to drift further and further away from the sustainability targets. Nevertheless, economic development is not only probable, but also desirable if the social goals for sustainability described earlier are to be met. This defines the challenge for policy in the transition to a sustainable world.

3. THE PROBLEM OF UNSUSTAINABILITY

In the previous section, sustainable development goals were expressed in terms of specific targets for key social and environmental indicators. These provide an operational framework for defining the quantitative requirements for a sustainability transition and for devising strategies for inducing such a transition. Naturally, the set of indicators can be expanded and the targets refined. Moreover, the global perspective must be complemented with indicators and targets for guiding sustainable development at regional, national, and local levels.

In the spirit of *adaptive management*, sustainability criteria will need to be revised from time to time in response to new information and priorities. Nevertheless, our provisional suite of sustainability criteria offer reasonable initial directions for navigating toward sustainable development — and for weighing how far off course current trends may be taking us, the topic to which we now turn.

3.1 Reference Scenarios

The tension between the current patterns of world development and sustainability goals can be illustrated with *Conventional Worlds-Reference* scenarios. A *Reference* scenario is a story of a market-driven world in the 2lst Century in which current demographic, economic, environmental, and technological trends unfold without major surprise. Continuity, globalization, and convergence are key characteristics of world development — institutions gradually adjust without major ruptures, international economic integration proceeds apace, and the socio-economic patterns of poor regions converge slowly toward the model of the rich regions.

Reference scenarios are distinguished from *Conventional Worlds-Policy Reform* scenarios, the topic of the next section, by the absence of strong and coordinated action for achieving sustainability goals. Rather, policy focuses heavily on the removal of barriers to markets at national and international levels (OECD, 1997). In the international arena, an integrated world economy is promoted through liberalization of trade and finance. At the national level, the push is for thorough and rapid structural adjustment, deregulation, and privatization.

A number of trends and forces already in the pipeline drive *Reference* scenarios forward. The global population becomes larger, more urban, and older. Expanding global trade, financial transactions, and capital flows drive economic growth. The free cross-border flow of goods, services, and capital becomes a reality. Transnational corporations increasingly dominate economic activity and enjoy growing political influence. Spurred by modern media and information technology, people everywhere and especially the young are drawn to consumerism. Materialism and individualism spread as core human values.

Despite economic growth, extreme income disparity between rich and poor countries, and between the rich and poor within countries, remains a critical social trend. Environmental transformation and degradation are progressively more significant factors in global affairs. Technology is a continuing source of change through advances in

information technology, biotechnology, and myriad other fields that change the way we produce and consume. The trends are allowed to play out without major changes in policy.

3.2 An Illustration

Though many variations are possible, a specific quantitative example can shed light on the implications of *Reference* scenarios for sustainability in the next century. By incorporating conventional mid-range assumptions in our illustration, the main contours of a business-as-usual future are revealed. In that spirit, demographic, economic, and technology assumptions are drawn from international assessments wherever possible, e.g., United Nations projections and the scenarios of the Intergovernmental Panel on Climate Change (IPCC, 1990; 1992a).[9]

A global overview of the scenario is presented in Figure 4. Relative to 1995 values, world population increases by slightly more than 50% by 2050, income (expressed as GDP_{PPP} per capita[10]) grows to over 2.5 times the 1995 value, and economic output more than quadruples. Food requirements almost double, driven by growth in population and income. Despite higher incomes and greater agricultural output, world hunger remains almost constant, the result of population growth and unequal access to food. Requirements for energy and water increase by factors of 2.4 and 1.6, respectively. Resource requirements grow less rapidly than the economy as a whole in the scenario for two reasons: improving efficiency of use and a gradual shift toward less resource-intensive economic activities. Global carbon dioxide emissions from energy use, a major driver of global warming, increase by a factor of 2.4 over the scenario period. Increasing land requirements for agriculture and human settlements leads to a 17% drop in forest area.

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[9] Technical details on the scenario are presented in Heaps et al. (1998). The *Conventional Worlds-Reference* scenario is an update of the *Conventional Development* scenario *(CDS)* (Raskin et al., 1996). The *CDS* was elaborated in separate reports on energy (Raskin and Margolis, 1995), food and agriculture (Leach, 1995), water (Raskin et al., 1995, 1997), and toxic substances (Jackson and MacGillivray, 1995). RIVM/UNEP (1997) assessed the environmental implications of the *CDS*, while UNEP (1997) and DPCSD (1997) considered the scenario from a policy perspective. The base year in the *Conventional Worlds-Reference* is 1995 versus 1990 in the *CDS*, and considerable additional data and research are incorporated.

[10] GDP expressed using purchasing power parity is denoted by GDP_{PPP}, to distinguish it from GDP expressed at market exchange rates, GDP_{MER}.

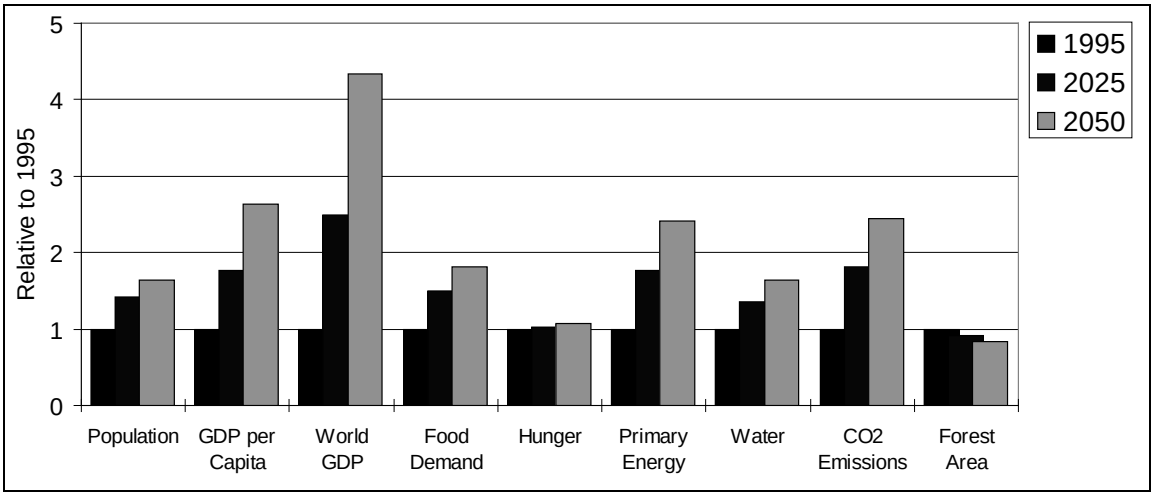

Figure 4. Global Overview of the *Reference* Scenario

The global results mask considerable regional variation in economic, social, and environmental patterns. The scenario analysis in this report is conducted for the ten major regions shown in Figure 2. Regional results are collected in the Annex as a series of tables and graphs. The population assumptions in the *Reference* scenario are summarized on Sheet D-1. In these mid-range projections, world population approaches 10 billion during the middle of the next century (UN, 1997) with nearly all the growth occurring in the developing regions. Of the net increase of 3.7 billion people by the year 2050, only 2% is in the OECD regions. The populations in Eastern Europe and the former Soviet Union actually decrease slightly in the scenario. The world continues to become more urban as the population in cities rises from 2.5 billion in 1995 to 6.7 billion in 2050, at which time 72% of the world population will live in cities (Sheet D-2).

Economic trends based on mid-range assumptions (IPCC, 1992a) are highlighted in Sheets E-1, E-2, and E-3. Global GDP_{PPP} increases from $33.4 trillion in 1995 to over $145 trillion in 2050, an average growth rate of 2.7% per year. The higher growth rate in developing region economies, about 3.4% per year, causes their share of world product to rise from about 40% to 60%. The immense scale of the economy implied by these assumptions is illustrated by the case of China+, where the GDP_{PPP} in 2050 is greater than the whole of the OECD today.

In all regions, GDP_{PPP} growth exceeds population growth, so GDP_{PPP} per capita (or "income") increases in every region (see Sheet E-3). The projections show a gradual convergence of the developing regions toward the industrialized ones in the sense that the ratio of average income of the OECD regions to that of the non-OECD decreases from 6.5 to 5.5. At the same time, the *absolute* difference between OECD and developing regions increases from about $17,000 per capita in 1995 to $47,000 per capita by 2050. In general, the scenario is one of wide prosperity by mid-century, in which developing regions approach standards of living enjoyed in Western Europe circa 1980 while OECD incomes soar, reaching $73,000 per capita in North America.

As the scale of economic output grows in the scenarios, the structure of economic activities changes. The share of GDP from agriculture continues to decline, a pattern long associated with the process of industrialization and development. Moreover, as consumption patterns shift toward greater emphasis on services and light manufacturing, the share of industry in economic output declines. These patterns are reflected in Sheet E-2. Finally, the composition of industrial production from heavy industry decreases in the scenario, reflecting de-materialization trends in advanced economies (Williams et al., 1987; Bernardini and Galli, 1993). Specifically, in OECD regions, output per capita of resource-intensive industries remains constant (non-ferrous metals, paper and pulp, and chemicals) or decreases by about 10% (iron and steel and non-metallic minerals). Non-OECD regions converge toward these patterns as GDP_{PPP} per capita increases.

The economic expansion assumed in the scenario drives energy demand higher (see Sheet En-3). The energy needs in developing regions grow by a factor of 3.7, reaching 60% of world demand by 2050 compared to 40% today. By the end of the scenario period, the energy requirements of China+ approach those of North America, while the energy requirements of South and South East Asia exceed them. While significant, energy growth is less than economic growth, a result of the changing composition of economic activity and the continued penetration of more energy-efficient devices and practices. Put another way, aggregate energy intensity (the ratio of energy requirements to GDP) decreases globally from 11.5 to 6.4 MJ/GDP_{PPP}$ between 1995 and 2050 (Sheet En-1).[11] While fossil fuels continue to dominate in energy production (see Sheet En-2), there is a notable absolute expansion in renewable and nuclear energy, by factors of 2.2 and 2.5, respectively.[12]

Population increases and diet changes drive the near doubling of world food requirements. The *Reference* scenario assumes continuity with past trends. Dietary patterns adjust with rising incomes, including greater food consumption in developing regions, with an increasing share of calories derived from animal products (Sheet F-1). The demand for fish and other seafood increases in the scenario from roughly 100 million tonnes per year currently to 170 million tonnes by 2050 (Sheet F-3). Assuming that marine resources, which are already overtaxed, remain steady at about 85 million tonnes, this requires substantial expansion of aquaculture (Sheet P-9), which adds to the agricultural requirements for feed.

On the production side, the scenario shows increased agricultural output in all regions. In the OECD regions as a whole, production of animal and crop products increases by almost 40% between 1995 and 2025 (Sheets F-2 and F-4, respectively). In Eastern Europe and the former Soviet Union, production rebounds from the collapse during the 1990s and then expands, as these regions become significant agricultural exporters. In Africa and the Middle East, populations nearly triple by 2050, and food

[11] Energy units are defined in the appendix.

[12] To convert renewable energy to primary energy equivalents, this study uses the International Energy Agency convention, which expresses hydropower and non-biomass renewables in their electrical energy equivalent (assuming 100% conversion efficiency). Since other studies (e.g., WEC/IIASA, 1995) express these as thermal energy equivalent values, which increases the reported values by about a factor of 3, care should be taken in comparing results.

requirements go up even faster because of increased caloric intake and more reliance on meat products. To meet the growing demands, agricultural production more than triples and imports rise — from about 37% of total requirements in 1995 to almost 44% by 2050 in the Middle East and from 12% to almost 15% in Africa. Both China+ and South and Southeast Asia maintain self-sufficiency in rice production, although rice declines as a fraction of the total diet in these regions in preference to other grains, meat, and higher-valued crops.

Underlying the increase in production in the scenario are assumptions on yield improvements and expansion of pastureland and cropland. The scenario is broadly compatible with the results of recent assessments of the prospects for world agriculture over the next two decades such as those of the Food and Agriculture Organization (Alexandratos, 1995), and the International Food Policy Research Institute (Rosegrant, et al., 1995). It shares their optimism of sustained improvement in agricultural performance. Yields gradually increase in all regions (Sheet F-5), the result of greater reliance on irrigated farming (Sheet F-7), and assumed improvements in plant varieties and farm practices. Global average cereal yields increase by about 1.3% per year between 1995 and 2025 and 0.8% per year between 1995 and 2050. While these increases are substantial, they are less than the 2.2% cereal yield improvement per year between 1961 and 1994, in part because of constraints on the expansion of irrigated farming (Leach, 1995). In addition to the intensive increases in yields, farmland expands extensively into forests and pasture lands (Sheets F-6 and P-6). The expansion is checked by the reduced availability of suitable land, constraints on irrigation expansion due to rising costs and limited freshwater resources, and competition for land use. Globally, farmland increases some 10%, mostly in Africa. Irrigated farm area increases slowly from 250 to 288 million hectares, remaining at around 18% of total farmland throughout the scenario (Sheet F-7). In addition, the numbers of harvests per year ("cropping intensities") gradually grow, further increasing farm output per area (Sheet F-5).

On the demand side, the requirements for food and other agricultural products rise with income. At the same time, higher-valued foods are slowly substituted for cereal staples as incomes rise. An exception is in North America, where health concerns continue to cause a gradual decline in reliance on animal products. In this picture, enough food can be produced to feed growing populations, a conclusion that is subject to important caveats: sufficient water must be available, serious land degradation and agrochemical pollution must be avoided, and trade flows from rich to poor regions must not face impediments. Finally, the problem of access to food among the very poor will remain and hunger will persist, as we discuss in Section 3.3.

The issue of water sufficiency and quality requires special attention. During the 1990s, awareness that water may be a limiting factor for development has grown, along with the recognition of water as a finite and fragile resource for ecosystem maintenance. The character of the looming water problem and strategies for the future were developed in a series of international meetings and studies including the Rio meeting (UNCED, 1992), the Comprehensive Assessment of the Freshwater Resources of the World (SEI, 1997), and the United Nations Commission on Sustainable Development (UNCSD, 1998).

Water use increased four-fold between 1940 and 1990, driven by irrigation expansion, population growth, and economic development (Shiklomanov, 1993). As water requirements rise, so does competition over the entitlement to finite water resources. The competition takes multiple forms depending on the conditions at the river basin level — between the farm and the city, between environmental and human use, and between upstream and downstream riverine countries.

In the *Reference* scenario, water requirements for development continue to increase because of growing populations, economies, and agricultural requirements. Global water requirements grow by a factor of 1.6 over the scenario period, and in developing regions by factors ranging from 1.7 in China+ to 2.2 in Africa (Sheet P-1). While substantial, the pace of water demand growth is much slower than was experienced over the past 50 years, an average growth rate of about 0.9% per year versus about 2.5% per year historically. There are three reasons for the moderation in growth rate: slower expansion of irrigated lands, shifts in the composition of economic activity toward less water intensive sectors, and greater efficiency in water use. The changing sectoral pattern of water use is summarized in Sheet P-2. Note that about 70% of current global freshwater withdrawals are for irrigation, decreasing to about 60% by 2050. Nevertheless, the absolute requirements for irrigation water increase by almost 50% as agricultural land under irrigation gradually expands (Sheet F-7), increasing by 15% by 2050, and more water is taken up by higher yielding plants (Raskin et al, 1997).

3.3 Environmental Risk

The *Reference* scenario presents a picture of increasing resource use and environmental pressure. By comparing these patterns to the sustainability goals introduced in Section 2, the scenario provides a benchmark for gauging — in the absence of major course changes in technology, demographics, and consumption patterns — the degree and character of environmental unsustainability.

3.3.1 Climate change

The proposed sustainability goal is to limit human-induced temperature change to no more than 0.1° per decade, or a cumulative change of about 1.1° between 1990 and 2100.[13] The rising temperatures are caused by increases in the atmospheric concentration of greenhouse gases, which trap some of the heat generated by sunlight falling on the earth's surface. As a consequence, eventual stabilization of average global temperature will require stable levels of greenhouse gases in the atmosphere. These concentrations, in turn, are determined by the rate at which the gases are emitted to and absorbed from the atmosphere as a result of both human activity and natural processes.

[13] Climate models relate changes in atmospheric concentrations of greenhouse gasses to estimates of changes in *equilibrium* temperature from pre-industrial levels. Because of inertia in the climate system, it may take several decades to reach such equilibrium. The target of *experienced* temperature changes of about 1.1° (all temperatures are reported for the Celsius scale) between 1990 and 2100 corresponds roughly to a committed change of about 1.5° over that period. Assuming greenhouse gas concentrations stabilize in 2100, and including the estimated 0.5° increase already experienced between pre-industrial times and 1990, the total change due to human activities under these conditions would be ultimately about 2°.

Are climate goals met in the scenario? The answer to this question requires several stages of analysis. First, the sustainability goal, expressed above in terms of temperature change, must be linked to a corresponding level of atmospheric concentrations of carbon dioxide and other greenhouse gasses. Second, the concentrations must be related to an allowable cumulative quantity of CO_2 emissions from human activity. Finally, this "carbon budget" for meeting the sustainability goal must be compared to the emissions computed for the scenario. In the *Policy Reform* scenario discussed in Section 4, the goal is imposed on the scenario, and the global carbon emission budget is allocated to regions (and ultimately countries) on the basis of economic, technological, and equity considerations, as well as political feasibility.

In order to link equilibrium CO_2 concentrations to temperature change, assumptions must be made about the contributions of greenhouse gasses other than CO_2. Also, the estimated temperature change depends upon the assumed value for the climate sensitivity parameter — the equilibrium temperature change associated with a doubling of CO_2 concentration. The climate sensitivity is estimated by the IPCC to lie within the range 1.5° to 4.5° (IPCC, 1996). Assuming a climate sensitive of 2.5°, global mean temperature is estimated to increase by about 1.0° between 1990 and 2100, assuming an equilibrium CO_2 concentration of 450 ppmv and a range of non-CO_2 gas emissions profiles (IPCC, 1997). This 1.0° change is close to the sustainability goal of 1.1° temperature change over the same period. This suggests an equilibrium concentration target of about 450 ppmv as a reasonable goal for policy.

The relationship between atmospheric CO_2 concentrations and cumulative emissions is summarized in Figure 5. Shown in the figure are long-term equilibrium concentrations for atmospheric carbon ranging from 350 parts per million by volume (ppmv) to 750 ppmv and the corresponding cumulative carbon emissions from human activity between 1990 and 2100 (IPCC, 1995). The carbon sources are primarily from energy combustion and net biomass loss through deforestation and land clearing. The uncertainty ranges reflect differences in the outputs of carbon cycle models, which simulate the interactions between atmospheric, oceanic, and terrestrial systems. The policy target of 450 ppmv corresponds to a cumulative carbon emissions allowance between 1990 and 2100 in the 640-800 GtC range.

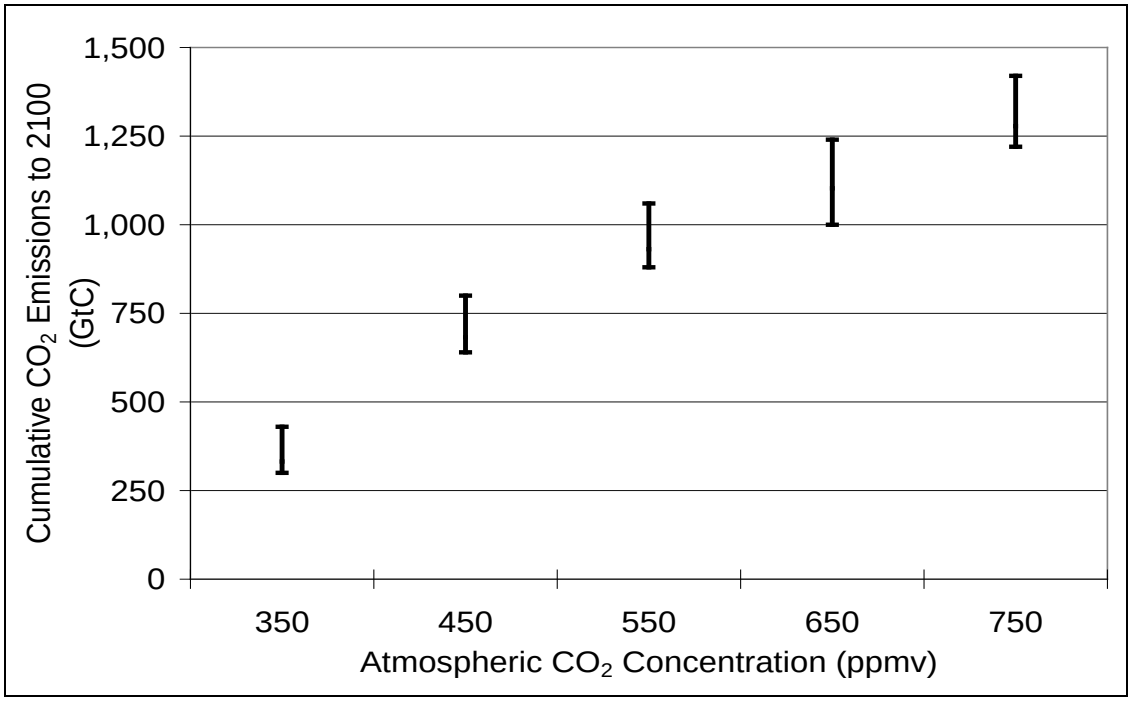

Figure 5. CO_2 Emissions to 2100 Corresponding to Different Stabilization Concentrations
Source: IPCC (1995)

We stress that the goal of 450 ppmv is conservative in that it accepts that considerable global change is inevitable. Also, if the higher values in the climate sensitivity range (that is, 4.5°) turn out to be more accurate, an additional 0.5° of climate change would occur, and the sustainability target would be exceeded. Stronger goals — stabilization at 350 ppmv or even a return to the pre-industrial level of 280 ppmv — are arguable from an environmental sustainability perspective.[14] But given the recalcitrance to date among key countries for adopting vigorous greenhouse gas abatement strategies, it appears that achieving such ecologically driven goals would indeed require a *Great Transition* (Section 1). Within the *Conventional Worlds* framework, the focus of the scenarios considered in this study, the 450 ppmv goal presents a strong but realizable challenge for policy.

The *Reference* scenario does not meet the target. Annual carbon emissions are plotted in Figure 6 along with emissions in the IPCC IS92 scenarios. The *Reference* emissions trajectory tracks closely the mid-range IS92a scenario. This correspondence is due to the underlying compatibility of demographic, economic, and technological

[14] Azar and Rodhe (1997) explain, "If the climate system is sensitive to CO_2 increases in the IPCC upper range, then a CO_2 concentration of only 550 ppmv will be sufficient to yield a change in average global temperature of a magnitude approaching that which occurs during a transition to an ice age; it appears that to keep the changes in global temperature within the range of natural fluctuations during the past millennium, the climate sensitivity has to be low and the atmospheric CO_2 concentration has to be stabilized at around 350 ppmv."

assumptions in the two scenarios. Assuming that the *Reference* scenario continues to follow the IS92a path after 2050, cumulative carbon emissions between 1990 and 2100 would be about 1500 GtC (which includes about 80 GtC from tropical deforestation). This is about double the 640-800 GtC cumulative emissions to 2100 required to stabilize concentrations compatible with the sustainability goals. The total temperature change between 1990 and 2100 ranges from 1.4° to 2.9°, depending on the value of the climate sensitivity parameter (IPCC, 1997), and thus exceeds the sustainability target of 1.1°.

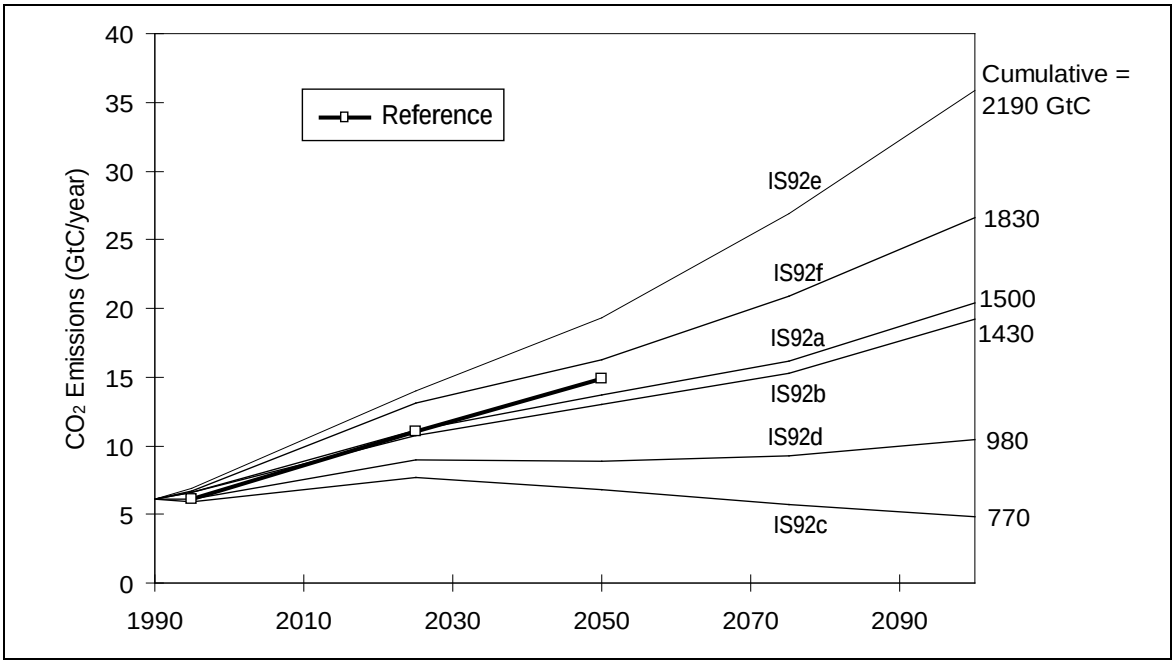

Figure 6. Industrial CO_2 Emissions in *Reference* and IPCC Scenarios

Source: CSIRO, 1994; IPCC, 1996
Note: Emissions from land clearing included in IPCC scenarios (about 80 GtC in IS92a)

Global patterns of carbon emissions in the *Reference* scenario are reported by region on Sheet P-4. Annual emissions more than double over the 1995-2050 period. The share of emissions from OECD regions drops from about 50% to 30% over this time frame as developing region emissions soar, driven by population growth and the long-range economic and technological convergence assumptions in the scenario. The changing regional composition of emissions is striking. In 1995, North America is responsible for 1.5 GtC emissions, accounting for 25% of the global total. During the first decades of the next century, two developing regions — China+ and South and Southeast Asia — surpass North America in total emissions. Emissions in Africa increase by over a factor of eight in the scenario.

Despite the rapid rise in developing country emissions in the *Reference* scenario, substantial inequities remain. Emissions per capita grow much faster in developing regions, so there is some convergence — the ratio of the value in North America to that in Africa is 22 in 1995 but falls to 9 by 2050 (Sheet P-4). Nevertheless, large absolute differences in emission loads persist throughout the scenario period, another expression

of the slow process toward the amelioration of current disparities in economic development the *Reference* scenario. Reduction in regional differences in emission rates is an element of the normative goals defining the *Policy Reform* (Section 4).

3.3.2 Fossil Fuel Reserves

The question of the adequacy of fossil fuel resources over the long term is closely related to the issues of climate change and sustainable energy. Since the oil crises of the 1970s, concern over petroleum reserve limits has vanished from the newspapers and dropped off the policy agenda. Prices have dropped, new oil fields have been brought into production, and advanced techniques have increased the recovery rates at existing fields. At existing rates of extraction, proven reserves are adequate for 40-50 years. Despite the comforting oil scene today, from the long-term perspective of the *Reference* scenario, with rapid growth in global demands, the oil problem is likely to re-emerge. Estimates of ultimately recoverable reserves — the total of previously extracted, proved, and undiscovered reserves recoverable — have not increased greatly since the 1960s (Masters et al., 1990). Rather, estimated additional reserves have been gradually reclassified as *proved* reserves.

Remaining proved *and* estimated undiscovered oil reserves are approximately 1600 billion barrels (WEC, 1995; Masters et al., 1994), of which 1000 billion barrels is proved.[15] As the demand for oil grows in the scenario, these reserves would be depleted around 2035 (see Sheet En-5). However, according to standard theories of oil exploitation, production decreases may occur much sooner, perhaps as early as 2010, when half of the global resource will have been extracted (Hubbert, 1956; Mackenzie, 1996). The geopolitics of oil becomes a resurgent theme in the scenario as industrialized regions increasingly depend on imports from the Middle East and Latin America (Swart, 1996).

Of course, the gap between oil supply and demand will be closed in practice. Supply might be increased by vast new discoveries of conventional sources, though this is not likely, or by unconventional options such as tar sands and oil shale. However, exploitation of unconventional resources is likely to pose severe environmental problems and to be much more costly than conventional crude.[16] On the demand side, the pressure on oil resources could be curtailed through massive fuel switching and efficiency improvements, options taken up in the *Policy Reform* scenario (Section 4). In the *Reference* scenario, the heightened risk of economic vulnerability and international conflict challenges the continuity and growth assumptions of the scenario.

Global proved and undiscovered natural gas reserves are estimated at about 10-15 EJ (WEC, 1995; Masters et al. 1994), roughly 300-400 trillion cubic meters. In the

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[15] A recent critique of industry figures suggests that remaining reserves may only be about 1000 billion barrels (Campbell and Laherre, 1998), far less than the 1600 billion barrels assumed here. On the other hand, another recent study (WEC/IIASA, 1995) assumes nearly 2100 billion barrels, but these are based on "P05% estimates", i.e., reserves that are only 5% likely to be met or exceeded.

[16] Natural gas hydrates (icy substances composed of methane and water) are a potentially enormous source of fossil energy, perhaps more than 8500 billion barrels of oil equivalent (WEC/IIASA, 1995), but would also be economically and environmentally costly.

Reference scenario, cumulative requirements for natural gas between 1995 and 2050 are about 200 trillion cubic meters, implying growing stress on reserves, though not as severe as petroleum (Sheet En-5).[17] Coal reserves remain abundant despite the increasing demands in the scenario; environmental concerns are the limiting factor on coal use.

3.3.3 Nuclear energy

The long-term role of nuclear power in addressing the climate problem and a transition to sustainable energy use is a key uncertainty for the future. The nuclear power industry enjoyed an astonishing boom from its inception in the mid-1950s to the late 1980s. In 1995, nuclear reactors accounted for 17% of world electricity production. But in recent years, the industry stagnated, with new construction starts barely keeping pace with plant retirements. Both the rising costs of nuclear energy and public concerns about nuclear safety have plagued the industry and brought it to a standstill.

Nevertheless, as world electricity demand grows, there will be great pressure to turn to the nuclear option, a relatively abundant and virtually CO_2-free resource (OECD, 1997). In the *Reference* scenario, global electricity demand grows by a factor of four between 1995 and 2050, and more than a factor of ten in developing regions. In this context, nuclear installed generating capacity more than doubles by 2050. All of the growth is in non-OECD countries, where nuclear energy expands by a factor of 3.5. The scenario assumes that nuclear cost and safety concerns are mitigated, perhaps through a new generation of modular units with advanced designs. The environmental and resource problems associated with growing demands for fossil fuels help to revive the nuclear alternative.

However, serious challenges to the sustainability of nuclear energy will persist. First, another Chernobyl-like accident could trigger renewed public outcry for nuclear moratoria. Second, the need to contain highly toxic radioactive waste for tens of thousands of years is an imposition on future generations that does not square easily with the basic sustainability notion of increasing, not limiting, future options.

Finally, the most vexing problem for nuclear energy may be the link between civilian commercial power generation to issues of peace and security. Civilian nuclear programs have fostered nuclear weapons development in a number of countries. Moreover, an expansion of the global commerce in reactor-grade fuel and plutonium, as envisioned in the scenario, would increase the danger of the diversion of these materials to nuclear weapons fabrication and to nuclear proliferation. These problems could intensify as the once-through nuclear technology that dominates today gradually gives way to a closed-cycle process, in which plutonium is recovered from spent fuel in reprocessing facilities and resold on global markets. With the growth of nuclear energy comes the rising risk that extremist social movements and rogue states gain nuclear weapons capability. The increased threats to domestic and international security, and the danger of regional conflicts spiraling out of control, could compromise the institutional stability of the scenario.

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[17] Rogner (1996) suggests that an additional 820,000 EJ unconventional resources (mainly in the form of clathrates) can be made at least partly available.

3.3.4 Toxic Waste

The material and chemical flows underlying a modern industrial economy are immensely complex and are neither well-tracked nor well-understood. Nearly 100,000 synthetic industrial chemicals contribute to the toxic and hazardous loads on the environment. The pathways into the environment of hazardous chemicals and heavy metals are from mineral extraction and refinement processes, emissions at industrial production facilities, and dissipative losses from materials embodied in products. While some of the substances may not pose environmental or toxicological threats, there is insufficient scientific information for assessing about 90% of them (NAS, 1984).

Estimates of current and future values under *Reference* scenario conditions are collected in Sheet P-10 (Heaps et al., 1998). Assuming that current practices and levels of regulatory control persist in developed regions and that developing regions gradually converge toward these practices, toxic emissions by 2050 are about three times higher than current levels. There is a roughly five-fold increase in the developing regions as a whole and an almost two-fold increase in the OECD regions. These increases are somewhat less than the growth in the global economy, because of structural shifts in outputs and the playing out of current policies.

International efforts to limit waste production remain at current levels in the *Reference* scenario and are unable to initiate the "clean production" revolution required to counteract the growth in the scale of production and consumption. By contrast, our sustainability goals for persistent organic pollutants (POPs), heavy metals, and radio-active wastes are reductions of 50% in 2025 and 90% in 2050 in OECD regions, with convergence toward the implied emission intensities in developing regions.

3.3.5 Water resources

In the *Reference* scenario, the pressure on freshwater resources grows more severe in all regions. The situation in Middle East countries, which is already grave, deteriorates, while problems deepen in Eastern Europe, China, Africa, and various river basins elsewhere. Despite the much greater water-use efficiencies assumed in the scenario, population and economic growth drive up overall requirements. Of course, regional analysis is far too aggregate for water assessment and can mask problems at the basin level. Therefore, the evaluation of water sustainability for the scenario has been conducted on a national basis (Raskin, et. al., 1997).

In 1995, some 1.9 billion people lived in countries experiencing some water stress (use-to-resource ratio greater than 0.1) and of these nearly one half billion were in high stress areas (ratio greater than 0.4).[18] An additional 1.6 billion people had sufficient water on average, but the supply was unreliable because of variations in precipitation, dependence on import flows from external sources, or inadequate infrastructure such as storage capacity. In the scenario, the population experiencing some water stress rises to about 4 billion by the year 2025, with 2.3 billion under high stress. In 2050, nearly 5

[18] For each country, the population in water stress is assumed to rise from zero to 100 percent as the use-to-resource ratio increases from 0.1 to 0.4, with high stress defined as a use-to-resource ratio greater than 0.4 (Raskin et al., 1997).

billion people contend with water stress, with 3 billion of them, over half of the total, in areas of high stress (Figure 7). Regional water stress indicators are summarized on Sheet P-3, while regional and sectoral breakdowns of water withdrawals are summarized on Sheets P-1 and P-2 respectively. The Middle East, already short of water today, faces a deepening water crisis, while huge populations in the Asian regions move toward high water stress levels. Africa is another region with increasingly intense water "hot spots."

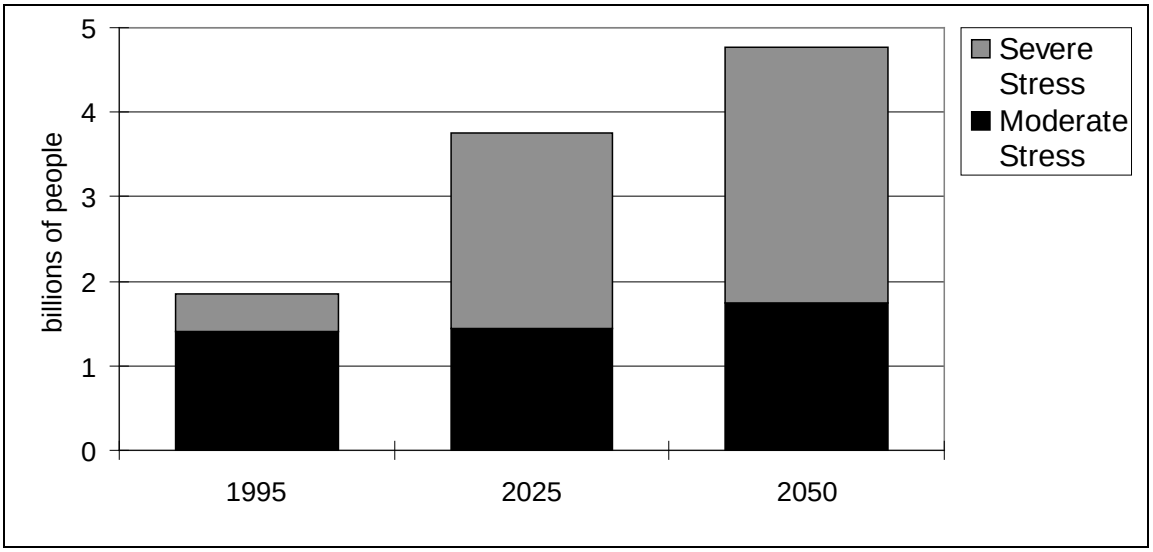

Figure 7. Population in Water Stress

Finally, the climate change impacts of the scenario may exacerbate the water situation in vulnerable areas (Alcamo et al., 1997; Morita et al., 1995). Water scarcity would also pose increasing security risks in shared water basins, such as in the Middle East (Wallensteen and Swain, 1997). Finally, competition for scarce freshwater resources would hamper attempts to increase access to safe drinking water and sanitation. Far from meeting our sustainability criteria, water scarcity may be a limiting factor on the robust population and income growth of the *Reference* scenario.

3.3.6 Land Resources and Biodiversity

In the course of development, human activity alters the landscape. The dynamics of land change are complex, depending on settlement patterns, agricultural practices, economic growth and natural resource industries. Several key factors drive land change in the *Reference* scenario:

- **Settlement area.** The so-called "built environment" expands onto agricultural, forestal, pastoral, and other land types as populations grow (Sheet D-1) and economies modernize. The settled area per person has been increasing historically and currently is estimated at 0.13 hectares per capita in North America and 0.06 hectares per capita in Western Europe and Pacific OECD (Heaps et al., 1998). In the scenario, the growth is assumed to abate as area per person gradually approaches 0.15 and 0.07 hectares in North America and the other OECD regions, respectively. Africa

and Latin America, where population densities are relatively low, converge gradually toward average OECD values, while other developing regions are assumed to converge toward the more compact Western European standards (Sheet P-7). With a global increase of some 345 million hectares (Sheet P-6), the expansion of settled areas places significant pressure on agricultural lands and valued ecosystems. Settled areas expand into agriculture, forest, rangeland or other land types with the shares varying from region to region (Heaps et al., 1998).

- **Pasture and Rangeland.** The utilization of land for grazing livestock changes in the scenario for several reasons. First, total output of meat products grows, primarily in response to population growth and diet changes, and to a lesser extent because of trade adjustments in these products. Second, the share of livestock in feedlots continues the historic pattern of increasing with economic growth, thereby moderating the increased pressure on grazing lands. These patterns are reflected in the figures reported on Sheet F-2. Finally, in developing regions the intensity of livestock production (output per hectare) increases in the scenario on the assumption that changing pasturing practices and improved livestock characteristics accompany economic development and scientific advances (e.g., related to biotechnology). Despite the increased intensity of use, grazing areas increase in all developing regions (Sheet P-7). The increase is at the expense of cropland, forest, and marginal land. Considering the substantial uncertainty in current data on all these factors, changing pastureland requirements in the scenario can only be considered indicative of trends.
- **Crop land.** New farmland comes from potentially cultivable land under forest, pasture, and rangeland (Sheet F-8), with the shares varying by regions (Heaps, et al, 1998). In addition, in some regions agriculture expands onto marginal land, which will require considerable inputs and careful management.
- **Land degradation.** Unsustainable land-use practices can lead to various forms of land degradation, including wind and soil erosion, soil compaction, waterlogging, salinization, and nutrient depletion. Global land degradation of various degrees of severity has been estimated at 2 billion hectares in the last fifty years, or nearly a quarter of agricultural land, forest, woodland, and pastureland (Oldeman et al., 1991). Much of the effect of the degradation is reflected in diminished yields and deforestation assumptions. The quantity of land so severely degraded that it is removed from agriculture production has been reported at from 5-10 million hectares per year (Kendall and Pimentel, 1994) though the basis for these estimates is weak and they may be high (Alexandratos, 1995). In the *Reference* scenario it is assumed that about 3 million hectares per year are withdrawn from agricultural production globally because of severe land degradation.

The combined effect of these various factors is to alter regional land cover. In particular, the area under forest decreases by nearly 700 million hectares during the 1995 to 2050 period, a loss of about 17% of existing forest stands. Deforestation by region is reported in Figure 8. The *Reference* scenario forest loss rate is compatible with recent trends in which over 200 million hectares were lost between 1980 and 1995 (FAO, 1997b). The scenario is consistent with other "business-as-usual" scenarios, which

generally suggest that deforestation persists during the first decades of the next century (Alcamo et al., 1995).

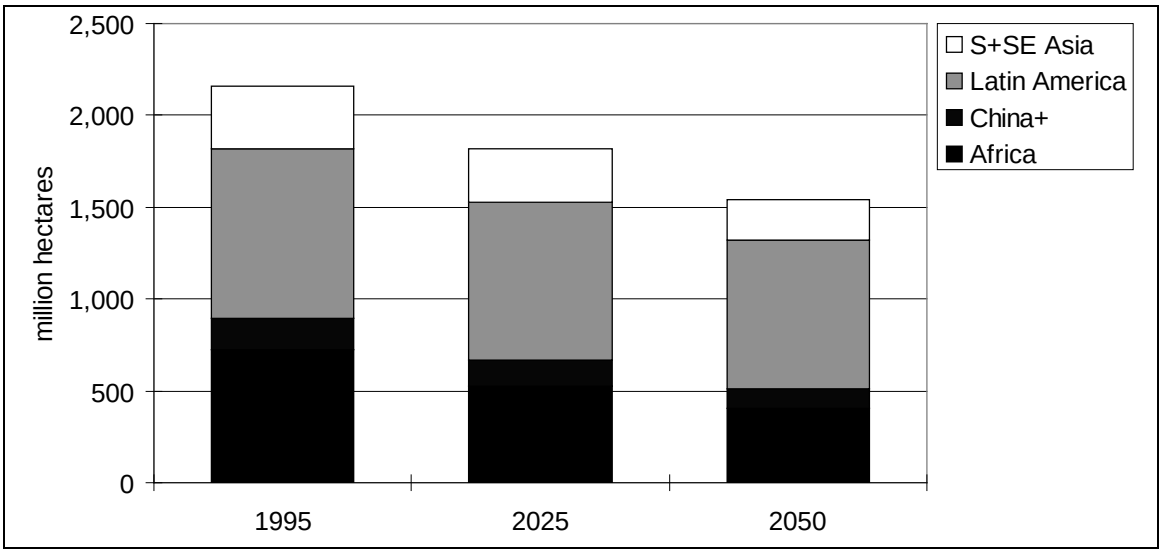

Figure 8. Forest Areas in Developing Regions in the *Reference* Scenario

As a result of the competing pressures, land change in general, as well as deforestation in particular, is substantial under *Reference* scenario conditions. For example, the target for environmental sustainability (Section 2) of decreasing annual rates of deforestation toward zero by 2025 and reforestation after that point are severely violated. Instead, deforestation rates are about 12 million hectares per year throughout the 1995-2025 period and, rather than reversing, continue after that period at about the same rate. Moreover, the maintenance of protected forest areas, let alone their expansion, would not be easy in the scenario with its free market emphasis and avoidance of government intervention. With respect to sustainable use of land resources — and biodiversity preservation that is closely correlated with the maintenance of ecosystem integrity — the *Reference* scenario fares poorly.

3.4 Persistent Poverty

The *Reference* scenario presents a picture of increased pressure on resources and the environment. If the environmental criteria for sustainability are to be met, policies will be needed to induce alternative patterns of resource use and to stimulate the development and deployment of better technologies. The kinds of adjustments necessary to meet environmental goals will be taken up in the *Policy Reform* discussion (Section 4).

The *Reference* scenario also is problematic with respect to the social goals introduced in Section 2. We focus on the changing levels of poverty in the scenario and the manifestation of poverty in the form of chronic hunger, lack of clean water, and other shortfalls in the provision of basic needs. The number of people in poverty in any country will depend on several factors. On the one hand, all else equal, population growth in the scenario (Sheet D-1) will increase the absolute numbers of impoverished people. On the

other hand, the rapid growth assumed for average income will tend to reduce poverty (Sheet E-3). The third key factor is the manner in which income is distributed over the population. If the trend in income distribution is toward more egalitarian distributions, the effect will be to reduce poverty. Increasing inequality will exacerbate poverty levels.

To proceed, we must further examine income distribution patterns. National income distributions are typically skewed, with most of the population concentrated at lower incomes. A useful measure of the degree of inequality in a given society is the *Gini coefficient*. The Gini coefficient is defined with reference to the Lorenz curve, a plot of the fraction of total income held by a given fraction of the population, beginning with the lowest-income populations (see Figure 9). In a society where everyone has the same income, the Lorenz curve would be a straight line, while in actuality the curves take the concave form as illustrated in the figure. The Gini coefficient, a measure of the deviation of an actual income distribution from a condition of perfect equality, equals the ratio of the areas A/(A+B). The coefficient ranges from values of zero (complete equality) to one (extreme inequality).

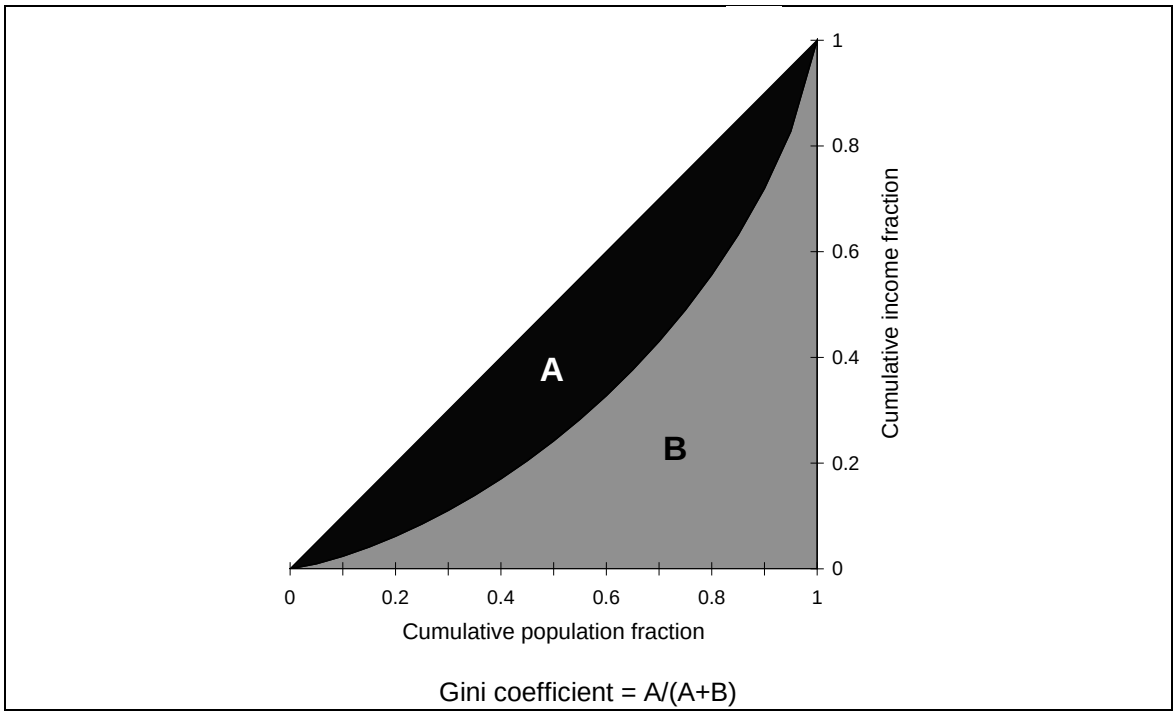

Figure 9. The Lorenz Curve and Gini Coefficient

The degree of income inequality found in the world today varies widely from country to country. Gini coefficients by region are presented in Sheet S-1, computed by averaging country level coefficients weighted by population (Heaps et al., 1998). Note that the values of the Gini coefficient range from around 0.30 to over 0.50.

The trends in the income distribution in the *Reference* scenario are based on the assumption of a general pattern of regional convergence toward industrial country

standards, in a context of economic globalization and weak social policies to address poverty and inequality. For thirty years, inequality has been increasing in the United States as redistributive social policies have eroded (Figure 10). In the scenario, income inequality continues to increase in the United States, but at half the historic rate as policy shifts play out. The Gini coefficient reaches 0.50 in 2050, with other countries gradually converging toward this pattern (Sheet S-1). The general trend is one of increasing Gini coefficients, with the largest increases occurring in the "transitional" regions of Eastern Europe and the former Soviet Union.

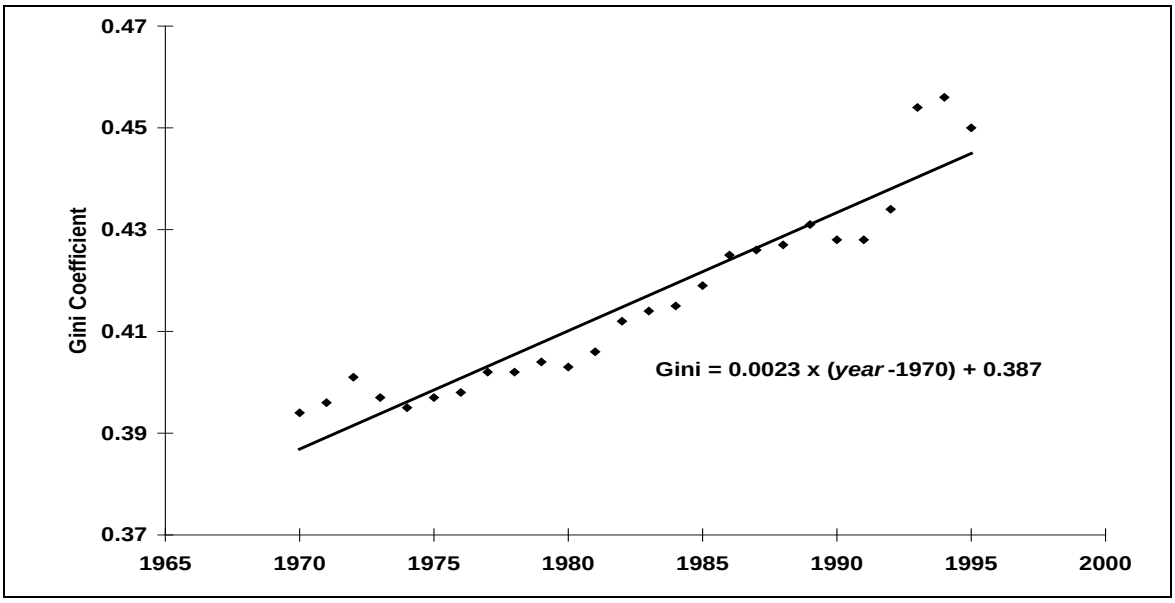

Figure 10. Historical U.S. Gini Coefficients

Source: U.S. Census (1997)

The assumptions on regional population, economic growth and distribution provide a picture of changing income distributions in the course of time. This is illustrated for the United States and China in Figure 11.[19]

[19] Income distributions are approximated throughout this study by a lognormal curve:

$$p(i) = \frac{P}{\sqrt{2\pi}\sigma i} \exp\left[-\frac{1}{2\sigma^2}\left(\ln(i / i_{ave}) + \sigma^2/2\right)^2\right]$$

where $p(i) \cdot \Delta i$ is the number of people with incomes between i and $i + \Delta i$, P is total population, i_{ave} is the mean income and σ characterizes the degree of income inequality. The Gini coefficient is an increasing function of σ (Heaps, et al., 1998).

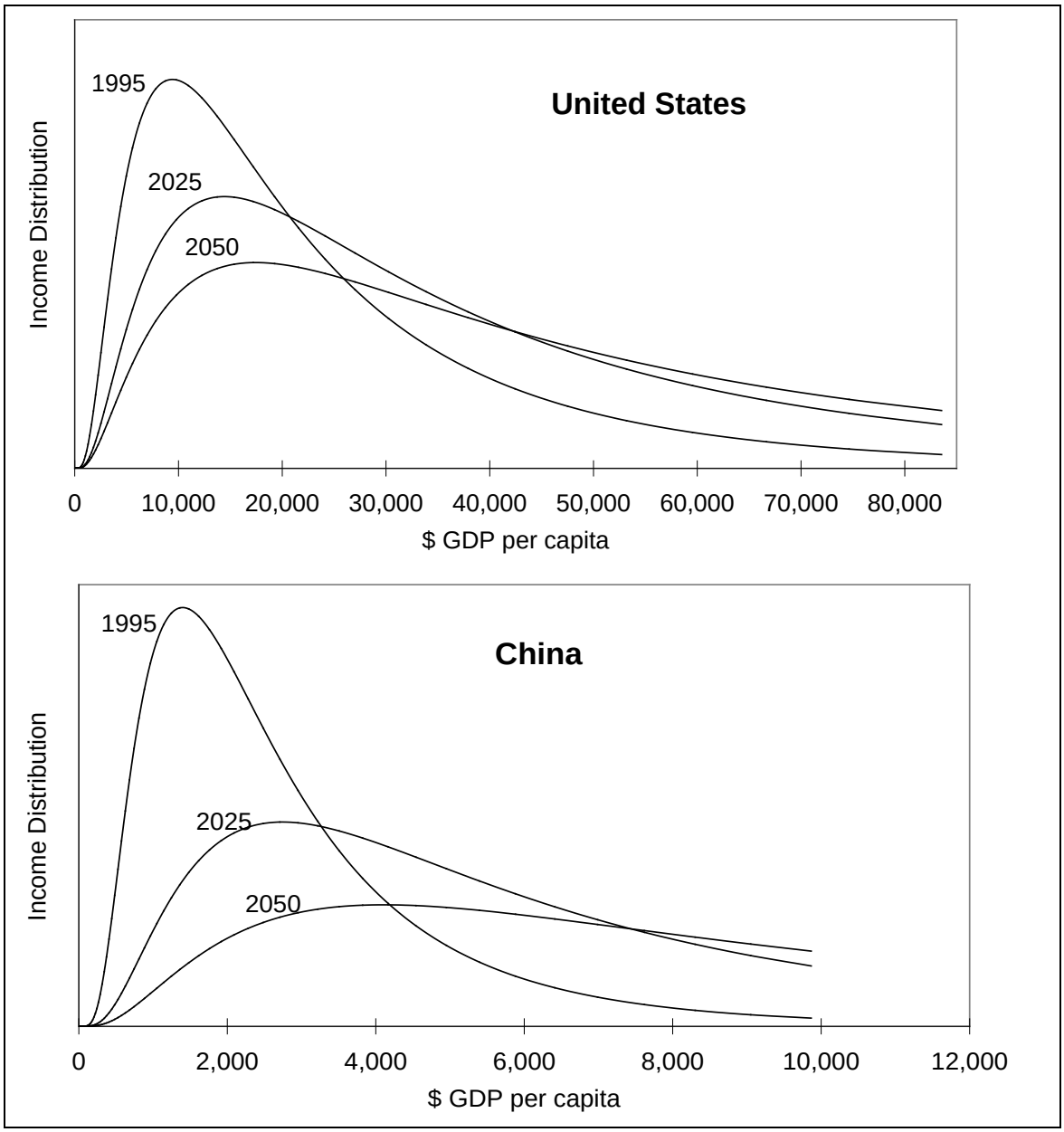

Figure 11. Changing Income Distributions

We turn our focus now to hunger levels in the scenario — the changing pattern of chronic undernourishment. In this study, hunger serves as a proxy indicator for poverty (see Section 2). The approach is to define a "hunger line," the income at which a family or individual is just barely able to meet the minimum dietary requirement for a normally active life (Heaps et al., 1998). This is analogous to the "poverty line," a minimum income or expenditure level below which a person or household is barely able to satisfy basic needs requirements. For the poorest countries, the poverty line used by the World Bank is about $525 per person annually in today's dollars (PPP). The relationship

between the number of hungry people in a region and the hunger line is shown in Figure 12.

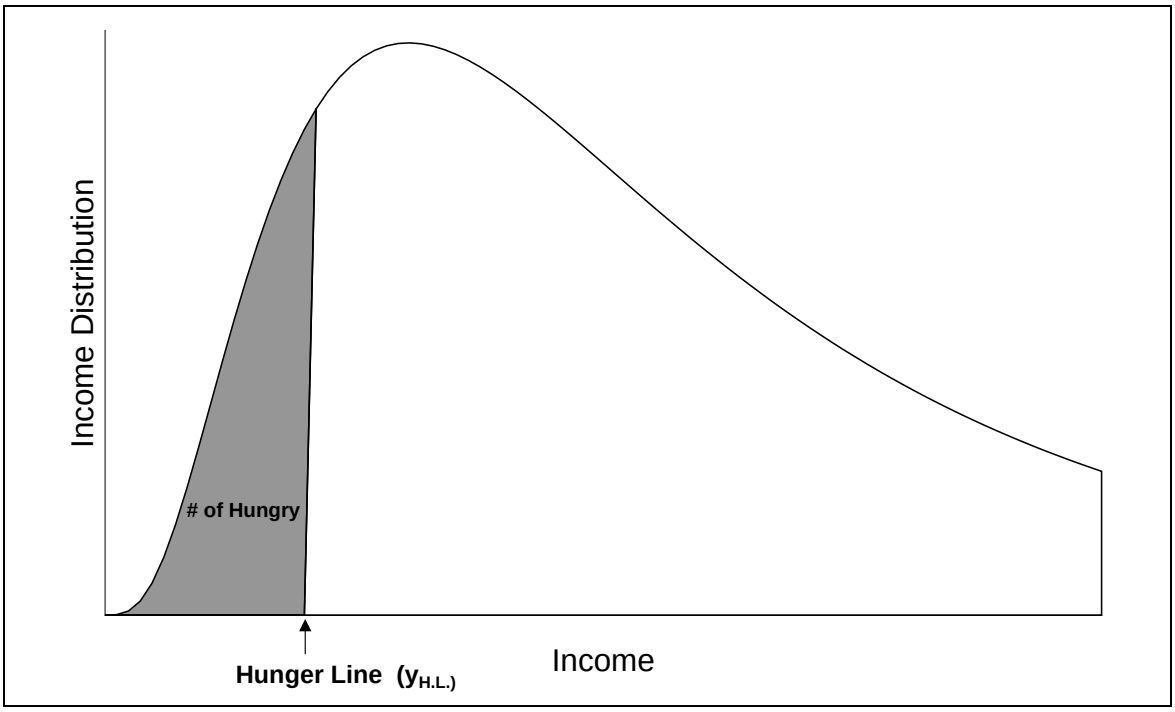

Figure 12. Relationship Between Number of Hungry and the Hunger Line

Survey data on hunger and income distribution are used to compute the current values of the hunger line (Heaps, et al., 1998). The hunger line cut-off tends to increase as countries develop (Figure 13).[20] This may be due to decreased access to informal sources of food — informal food gathering is a form of income that is not well-captured in household surveys. Furthermore, as countries grow wealthier, more must be spent on non-food items even by those just able to acquire the nutrients they need for a normally active life. The increase in hunger lines is analogous to the well-known observation that poverty lines tend to rise as average incomes do (Ravallion et al., 1991; World Bank, 1990). It takes a larger income to barely survive as traditional sources of material support are eroded in the process of modernization.

[20] In the scenarios, hunger lines increase toward $3,670, the current inferred value for the United States, as mean income approaches $21,880 (based on a linear fit to the data in Figure 13), and remain constant thereafter. Since we do not have evidence that hunger lines stop increasing, this may be a conservative assumption.

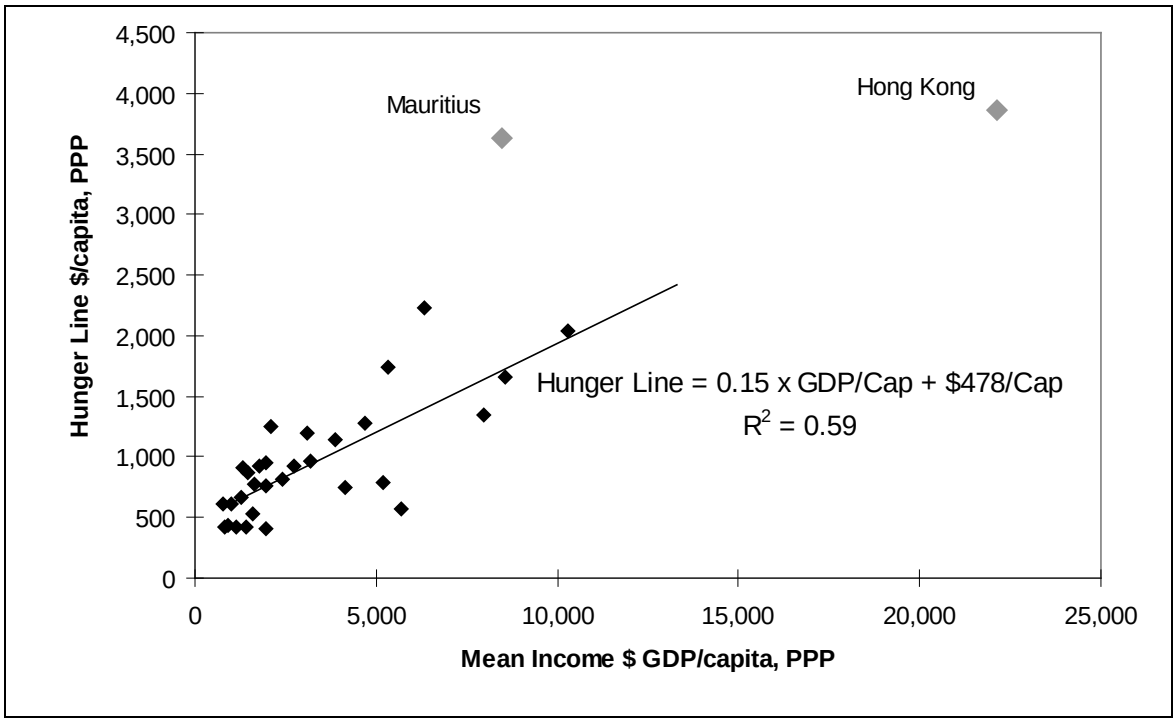

Figure 13. Hunger Lines vs. Mean Income

Sources: Current hunger levels from FAO (1997a); Incomes from WRI (1996b). Hong Kong and Mauritius excluded from regression. See Heaps, et al. (1998) for details.

Hunger in the scenario is computed as a function of population, income distribution, and the hunger line value in each region. The results are reported in Sheet S-2. There is some increase in the number of undernourished people over the course of the scenario, from 900 million currently, to 920 million in 2025, and 950 million in 2050.[21] The result suggests that a significant decrease in hunger, as called for by the sustainability targets, cannot be expected if current patterns of growth and distribution persist into the future.

Regional variation of the incidence of hunger in the scenario is significant (Sheet S-2). Africa shows the sharpest decrease in the percent hungry from about one-third in 1995 to one-fifth in 2050, but by far the largest increase in absolute numbers. In China+ and South and Southeast Asia, hunger decreases, while in other developing regions there is some increase. In the transitional regions of the Former Soviet Union and Eastern Europe, the figures gradually creep higher as relatively equal income distributions tend toward industrial country patterns.

While the quantitative analysis has focused on hunger, similar factors govern the other social indicators in *Conventional Worlds-Reference* scenarios — unsafe water, illiteracy, and life expectancy. Economic growth will tend to improve the conditions of the poor, while growing populations and greater inequity are counteracting effects. In

[21] By comparison, hunger declines between 1989 and 2010 in a recent scenario (Alexandratos, 1995), apparently based on income growth and a more egalitarian distribution of food, such as in the *Policy Reform* scenario (Sec. 4).

general, the patterns for these indicators will be similar to those for nutrition. For example, the percentage of those who are illiterate or lack safe water will decline, but the sustainability goals of significant reductions in absolute number will not be achieved.

3.5 Conclusions

Measured against our sustainability criteria, the *Conventional Worlds-Reference* scenario would be a risky bequest to our 21st century descendants. The increasing pressure on environmental systems — the combined effects of growth in the number of people, the scale of the economy, and the throughput of natural resources — is environmentally unsustainable. While there is great scientific uncertainty on how ecological systems would respond to such increasing pressure and where thresholds of sudden change might lie, it does seem clear that the scenario would flirt with major ecosystem state changes and unwelcome surprises. Environmental feedbacks and impacts on human systems could undermine a fundamental premise of the scenario: perpetual economic growth on a global scale.

The scenario also fails to address the social goals for sustainability. Absolute poverty persists, as nearly one billion people remain hungry in the middle of the next century. The rapid average income growth assumed for all regions, which tends to reduce poverty, is negated by population expansion and the continued, even deepening, pattern of large income disparities. This contradicts the sustainability goal of substantial poverty reduction. Beyond failing the ethical imperative of sharply reducing human deprivation, social conditions would be maintained that link human desperation and environmental stress.

The persistence of economic polarization could compromise social cohesion and make the spread of liberal democratic institutions more difficult and their maintenance more fragile. Domestic and international tensions would be magnified by the resource and environmental pressures: conflict over water, regional concentration of petroleum supplies, scarcity of land, climate change impacts on land and water resources, and biodiversity loss.

In addition to greater disparities within many countries and regions, the absolute disparity between rich and poor countries increases, though income grows fastest in poorer regions. The desire to migrate to rich areas would grow stronger as would the resistance to such migration. Interregional inequity also could aggravate geopolitical tensions. The fundamentalist backlash to the process of global cultural homogenization, spurred in the scenario by advancing markets and the information revolution, would be reinforced.

These social frictions, in the context of progressive environmental degradation, could abrogate the business-as-usual continuity assumptions of the scenario. If allowed to fester, a xenophobic and isolationist *Fortress World* mentality could flourish in privileged areas — and the United Nations may have a weakened capacity to mediate such tensions in the market-driven world of the scenario. The danger would grow that the path of history would branch toward some form of *Barbarization* scenario.

These risks are not inevitable. The tensions inherent in a *Reference* scenario can be relaxed if development becomes more sustainable. While a *Great Transition* in social arrangements and values may ultimately emerge, the transition to sustainability can be substantially advanced within a *Conventional Worlds* paradigm. We turn now to a consideration of the scope for such *Policy Reform* scenarios.

4. STRATEGIES FOR A TRANSITION

Can a successful transition to sustainability be achieved within the confines of *Conventional Worlds* development assumptions? The policy-complacent *Reference* scenario presents a picture of widening international prosperity in the next century. But it is also a picture with disquieting elements — increasing environmental risk, resource scarcity, tenacious poverty, and social stress. These threats could well negate the continuity assumption that underlies *Conventional Worlds* futures — steady economic growth, gradual globalization, and cultural convergence. In other words, *Reference*-like scenarios may be both unsustainable and unrealistic. We ask next what types of strategies could bend the curve of future development toward sustainability goals.

4.1 Policy Reform Scenarios

Policy Reform scenarios maintain the essential assumptions of the *Conventional World* paradigm. The elements are by now familiar — the steady march of economic globalization, the gradual convergence of all regions toward the evolving model of development in industrial regions, and progressive homogenization of global culture around the values of materialism and individualism. But there is a critical difference between the scenarios. In contrast to the *Reference* scenario, *Policy Reform* scenarios assume the emergence of a popular consensus and strong political will for taking action to ensure a successful transition to a sustainable future. In this context, an integrated set of initiatives are crafted and implemented including economic reform, regulatory instruments, social programs, and technology development.

In constructing the *Reference* scenario, we began with existing global conditions and drivers of change. We then examined how the future might unfold over time. A different method is required for formulating *Policy Reform* scenarios. Rather than a forecast into the future, a normative scenario like the *Policy Reform* scenario is constructed as a backcast *from* the future (Robinson, 1990). We begin with a vision of a desired future state, defined by the sustainability goals, and seek to identify plausible development pathways for getting there. Whereas business-as-usual scenarios pose the question of the forecaster — "where are we going?" — normative scenarios add the questions of the traveler — "where do we want to go?" and "how do we get there?"

Policy Reform scenarios elucidate the requirements for simultaneously achieving social and environmental goals of sustainability. The illustrative scenarios developed in this study are based on the provisional sustainability goals described in Section 2. In some ways these two sets of objectives are at cross-purposes — the economic growth required for poverty reduction and greater equity tends to increase environmental pressure. In other ways they are compatible, since more countries would have the economic wherewithal for greater attention to long-range resource and environmental preservation.

We begin with the conditions for meeting the social goals, specifically the targets for the reduction of human deprivation. The demographic, social equity, and economic development assumptions for meeting the social goals in *Policy Reform* scenarios become the drivers of resource use and environmental impact in the scenario. Environmental

sustainability goals are addressed in the scenarios through strategies at the sectoral level — energy, food, land, water, waste. These are discussed in subsequent subsections.

4.2 Meeting the Social Goals

The absolute number of those in deprivation in the various regions of the world will be determined by population levels and the entitlement of the poor to the means to obtain food and other basic services (Sen, 1981). In *Policy Reform* scenarios, poverty reduction and social goals are achieved through increasing the incomes of the poor. In principle, this could be achieved both through structural changes that provide greater access to income-generating activities and through welfare transfers, such as direct food aid. Targeted assistance programs for meeting basic needs must have high priority, as they address urgent and immediate needs, and can contribute to a self-sustaining process of raising the incomes of the poor (UNDP, 1997). However, a sustainable and resilient response to the challenge of poverty reduction must ultimately be reflected structurally in access to decent and secure livelihoods.

Population growth is assumed to be lower in *Policy Reform* scenarios than in the *Reference* scenario for two reasons. First, the improved condition of the lives of the very poor are assumed to be associated with declines in fertility rates as the cycle of poverty is broken, access to education increases, and women become more empowered. Second, more active family planning efforts in the policy scenario are assumed to reduce the number of unwanted pregnancies.

The critical elements in achieving the poverty reduction targets in the *Policy Reform* scenarios are two types of equity increases. First, greater equity is assumed *between* regions, aided by strategies that lead to more rapid economic growth in developing and transitional regions, as well as faster convergence toward OECD levels of development. Second, greater equity *within* regions and countries is incorporated, as "growth with equity" becomes the prevailing philosophy in national development strategies. Human development indicators become as important as the aggregate growth in gauging national economic performance (UNDP, 1996).

These considerations inform the quantitative assumptions of the illustrative *Policy Reform* scenario. Non-OECD population in 2025 is taken to be 98% of the UN mid-range projection, and in 2050 to be 95% of the UN value (see Sheet D-1). This is a conservative but reasonable assumption given the great uncertainty on the drivers of population growth (Bongaarts, 1997). The lower population levels help modestly in meeting the scenario goals of reducing poverty and environmental stress. In all regions, the tendency toward increasing urbanization persists, as shown in Sheet D-2.

The economic and equity assumptions of the scenario are governed by three key variables: *world economy*, *international equity*, and *national equity*. The world economy, expressed in terms of global GDP, is a measure of aggregate output, while the international equity variable characterizes the level of interregional equity, the manner in which the world economic pie is apportioned between poor and rich nations. The measure of international equity is the ratio of average income per capita in non-OECD regions to OECD regions. The current value of this ratio is about 0.15, while perfect interregional equity corresponds to a value of 1.0.

Future values of these two factors — the scale of the world economy and the relative incomes between rich and poor countries — determine the *average* incomes in each country over time. To go beyond average income in order to describe the level of poverty in a scenario, we must also specify the income distribution *within* a given society. The national equity variable is defined here as the ratio of the incomes of the lowest-earning 20% of a population to the highest-earning 20% (alternative ways of representing income distributions were discussed in Section 3.3). Perfect equity within a given society would correspond to a value of 1.0. Actual values range widely across countries, e.g., 0.14 in Denmark, 0.08 in the United States, and 0.04 in Brazil. Current average regional values are reported in Sheet S-1 along with values for the illustrative scenarios. It is also convenient to introduce a single global variable describing the average pattern of national equity in a given scenario (see Sheet S-1).[22]

These variables — world economy, international equity, and national equity — define a three-dimensional space (Figure 14). For a given year, a scenario appears as a point in the space. Scenarios move through the space as the values of the variables change over time. All trajectories depart from a common point, given by current values of the world economy, international equity, and national equity (1995 is the base year in this study). In the course of time, each scenario defines a trajectory.

Reference scenario trajectories are shown in the figure as a family of scenarios consistent with the underlying narrative and reflecting an uncertainty range across the variables. The spheres suggest ranges of uncertainty in the variables. The central *Reference* scenario described in Section 3 traces a path in which the world economy quadruples by 2050, international equity improves gradually, and national equity decreases.

Policy Reform scenarios also define a family of trajectories in the economic space of Figure 14, all of which must satisfy the sustainability goals. A specific goal is the requirement that the number of people who remain hungry in 2025 is one half and in 2050 is one-fourth current levels. In principle, there are multiple possibilities for lifting the incomes of sufficient numbers of the very poor above the "hunger line."[23] At one extreme, if national equity continues to decrease, extraordinarily high global economic growth is required. At the other extreme, if the world economy grows at the same general levels as in the *Reference* scenario, then a much more equitable world would be necessary in order to meet the social goals.

[22] The global average value of national equity (X) is computed as the population-weighted average of the national equity in each country (X_c). Thus, $X_t = \sum_c \left(P_{c,t} \cdot X_{c,t} \right) \Big/ P_t$,where P_t is global population and the indices c and t signify country and year, respectively.

[23] The hunger line and the approach for linking incomes to estimates of hunger are discussed in Section 3.3.

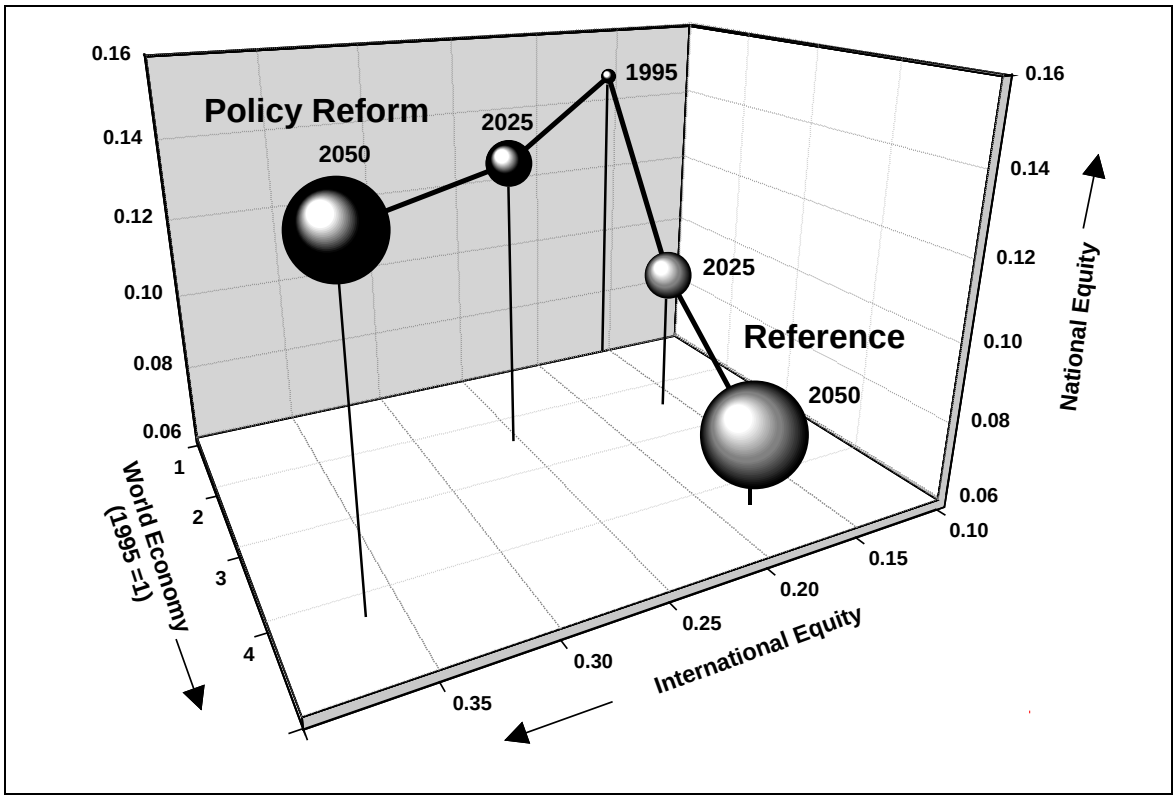

Figure 14. Scenario Trajectories

Note: International Equity = average income in non-OECD/OECD
National Equity = income of poorest 20%/richest 20%

The sphere of uncertainty for the *Policy Reform* scenario in Figure 14 suggests ranges of economic scale and distribution variables that satisfy the social targets. In practice, the set of scenarios of interest is limited to values of the economic growth and equity levels that are both compatible with the scenario narrative and lie within plausible ranges. For example, since economic growth and global convergence are fundamental premises of the *Policy Reform* story, the world economy and international equity variables must increase substantially. National equity would also be expected to increase in a scenario where poverty eradication became a policy priority.

At the same time, reasonable upper limits on GDP growth rates over the half-century time horizon of the scenario can be gleaned from an examination of historical data. For example, the growth of the United States economy was around 3% annually over the last 30 years. Some of the "Asian tiger" economies grew much faster over the same period, by as much as 9% annually in some cases, but that era seems to be drawing to a close in light of recent economic downturns and instability. Taking a longer perspective, Thurow (1996) claims that "…over the past century, no country's economic growth rate has averaged better than 3.6 percent per year."

The illustrative *Policy Reform* scenario assumes high but plausible economic growth in light of the robust global economy that is a key premise of the scenario. The average annual GDP growth rate to 2050 is 2.7% for the world and 3.8% for developing

regions (Sheet E-1). To meet the hunger targets under these conditions, national equity needs to improve. This would be the case even if one were to posit very high average economic growth to 2050. With the levels of inequality assumed in the *Reference* scenario, GDP_{PPP} in developing regions would have to increase at 6.5% per year to meet the sustainability target. Such high growth is implausible and implies an immense expansion in the scale of the world economy — by a factor of 15 — with correspondingly greater strains on environmental systems.

In the illustrative *Policy Reform* scenario, the social targets are met through a balanced combination of effects — relatively strong regional economic growth, significant but gradual motion toward international equity, and the maintenance of national equity at close to current levels. The scenario satisfies the hunger reduction target of 50% percent by 2025 and an additional 50% by 2050 (see Sheet S-2). As a result of differential income growth (Sheet E-3), international equity — the ratio of non-OECD to OECD incomes — increases from 0.15 in 1995 to 0.36 in 2050. Though the gap between rich and poor nations is far from closed, the level of international equity is twice that of the *Reference* scenario.

National equity in the *Policy Reform* scenario stays roughly constant at about 0.14 (Sheet S-2). While this is nearly twice the *Reference* scenario value in the year 2050, it is well within the bounds of recent historical experience. For example, the United States had comparable levels of national equity as recently as 1970 (Figure 10), while Europe is higher today. The scenario calls for negating the trends toward high inequity, through reforms in the policies governing distributional systems — policy reform, not extreme egalitarianism.

The challenges are to simultaneously foster world economic growth, development convergence and greater national equity while remaining within environmental sustainability goals. With the *Policy Reform* economic development assumptions set to meet the social targets, we turn to the environmental aspects of the sustainability transition.

4.3 Climate

In a *Policy Reform* scenario, strategies for the energy sector are strongly influenced by climate change goals. The sustainability target for climate change is set as an upper limit on global temperature change of 0.1° per decade (Section 2). To achieve this, atmospheric concentrations of carbon dioxide should stabilize at no more than 450 ppmv by the year 2100, implying a cumulative carbon dioxide emission allowance of the order of 700 GtC between 1990 and 2100 (Section 3).

The issue of setting goals for carbon emissions has been the subject of considerable international negotiation and contention. In these early years of the United Nations Framework Conventions on Climate Change, the focus is on near-term targets for carbon reductions for the so-called Annex I countries.[24] These more industrialized countries, which have accounted for the bulk of carbon emissions historically, are

[24] The Annex I parties to the FCCC correspond roughly to our three OECD regions and the two transitional regions of Eastern Europe and FSU.

committed to taking positive initiatives to reducing carbon emissions as an initial phase towards a comprehensive agreement. To attain climate stabilization, eventually all countries will need to adopt greenhouse gas emission constraints. How should the burdens be shared? What levels of allowable emissions are reasonable for each region and country?

An acceptable global agreement must include realistic reduction goals for the industrialized countries while allowing some emission increases in developing countries as economies converge in the course of the 21st century. Some form of equitable emission rights must ultimately guide long-term policy. These principles are reflected in the *Policy Reform* scenario. Several conditions determine regional emissions. First, abatement targets are set for OECD and transitional regions through the year 2025. Second, all regions approach a common per capita emission allowance in the long term. Third, developing region emissions are restricted so that the cumulative global emissions from all regions to the year 2100 are about 700 Gt.

Relative to 1990 levels, OECD regions are assumed to reduce annual emissions by 10% in 2010 and by 35% in 2025. The 2010 reduction target is somewhat greater than agreed at the Kyoto climate meetings (UNFCCC, 1997). The goal for 2025, as we shall discuss below, is achievable through policies to promote additional energy efficiency, renewable energy use, and forest protection. The transitional regions, where emissions dropped precipitously between 1990 and 1995 as their economies shrank, increase emissions per capita between 1995 and 2010 as their economies recover, and then reduce emissions from 2010 onwards.

The assumption of eventual convergence of all countries toward common per capita emissions (or “emission rights” in a tradable permit approach) addresses equity concerns. The immense disparities in per capita emissions today (Sheet P-4) are the result of many decades of divergent economic growth between rich and poor countries. They cannot be eliminated rapidly without politically unacceptable disruption. However, the goal of eventual equality is compatible with the assumptions in the *Policy Reform* world of eventual equity and convergence across regions. In the scenario, it is assumed that annual emissions converge to a common rate of 0.6 tC per capita in 2075, with equal per capita emissions thereafter. This constrains emissions to about 3 GtC per year by 2100 – given the mid-range population projections in the scenario – which is required by the climate stabilization goal. Finally, developing country emissions increase substantially over the next decades, constrained by the global cap on cumulative emissions of 700 GtC and the convergence target. The emission pattern for each of the three macro-regions, expressed as emissions per capita, is shown in Figure 15.

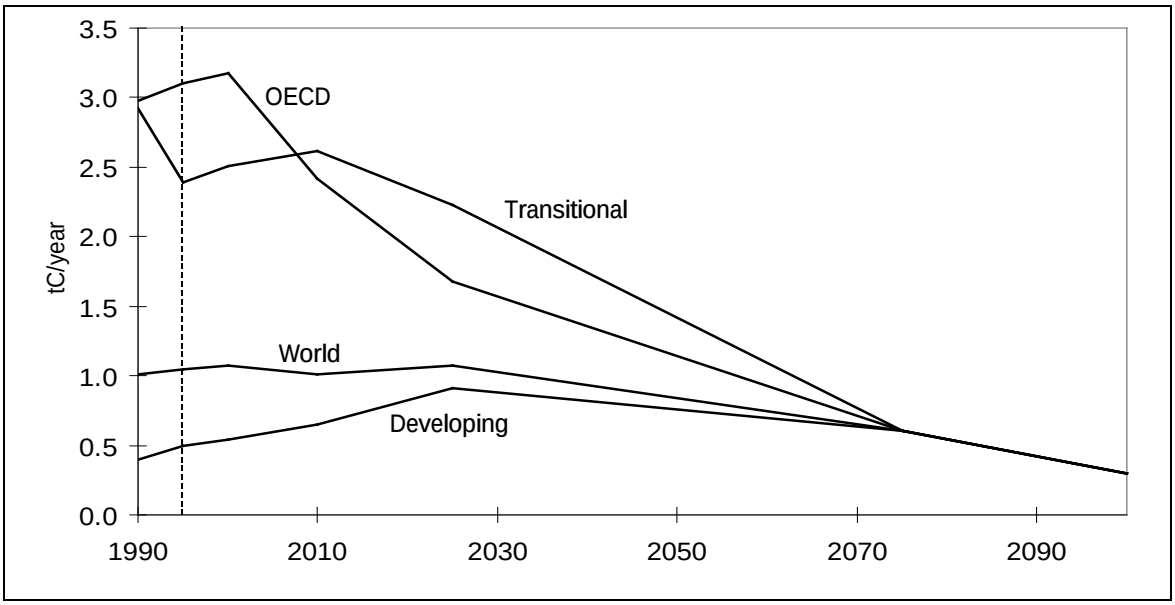

Figure 15. Energy-Related CO_2 Emissions per Capita

In the developing regions, per capita emissions start from a much lower level than in the OECD or transitional ones. They grow steadily until 2025, without ever exceeding the industrial or transitional rates, then drop gradually to reach the 2075 convergence target. On a global basis, emissions per capita remain almost constant between 1990 and 2025 and decrease from 2025 to 2100. Combining emissions per capita with the population projections, we obtain total annual emissions in each macro-region, which are plotted in Figure 16. The total integrated emissions from fossil fuel combustion of about 700 GtC — the area under the curve in the figure — achieve the sustainability target.

Applying the same approach, emission goals can be assigned at the regional and country level (Sheet P-4). The OECD and transitional regions follow the general patterns outlined above, while emissions in the developing regions follow various paths, depending on their base year levels and their differing rates of economic growth. Achieving these carbon emission constraints requires a significant improvement in the way energy is used and produced, a topic to which we now turn.

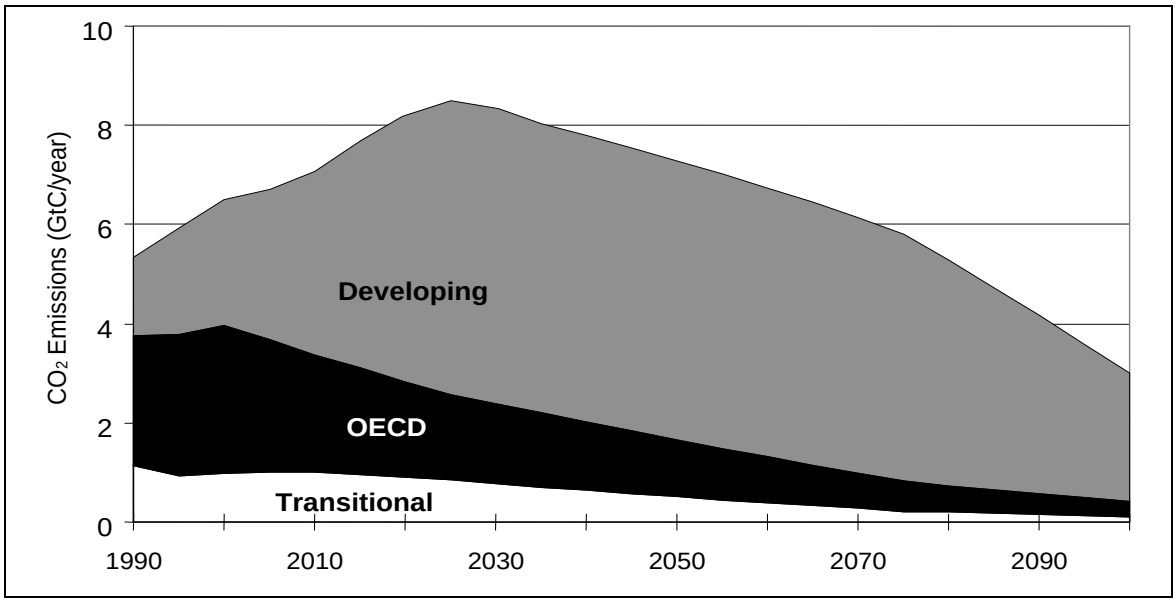

Figure 16. Annual CO_2 Emissions

4.4 Energy

If there is to be a passage to an environmentally sustainable world over the next fifty years, an energy transition will be at its foundation. The era of industrial development was based on the emergence of modern forms of energy — coal, oil, natural gas, and electricity — that were abundant, inexpensive and increasingly flexible. But energy has been a scourge as well as an engine for industrial society, implicated deeply in many of its environmental depredations — air and water pollution, acid rain, climate change, oil spills, toxic emissions, and many others.

The lesson of the *Reference* scenario is that gradual energy efficiency improvement and modest renewable energy growth are insufficient to meet sustainability goals (Section 3). Aggressive action will be needed on both the demand and supply sides of the energy equation. First, the intensity of energy use (energy requirements per unit of activity) will need to be significantly moderated through the adoption of highly efficient energy use practices. Second, energy supplies must come increasingly from natural gas, as a transition fuel, and ultimately from solar, wind, biofuel, and other renewables sources. Assuming appropriate levels of regulation, research, and economic incentives, technologically and economically feasible pathways are available for each region that meet the stringent constraints imposed by climate stabilization and other environmental goals.

Energy Intensity

The *Policy Reform* scenario illustrates how a sustainable energy transition might be realized (Figure 17). Global energy requirements increase from 384 EJ in 1995 to 599 EJ in 2050, a 56% increase from present consumption, but 35% lower than the 929 EJ in 2050 in the *Reference* scenario (Sheet En-1). Energy use declines in the OECD by about 40% in 2050 relative to 1995 levels, compared to an increase of about 46% in the *Reference* scenario. In the transitional regions, energy requirements remain stable to

2025 because improvements in energy efficiency are negated by a strong economic recovery. Developing region energy requirements increase by a factor of 3.1 between 1995 and 2050, less than in the *Reference* scenario, despite more rapid economic growth (Sheet E-1).

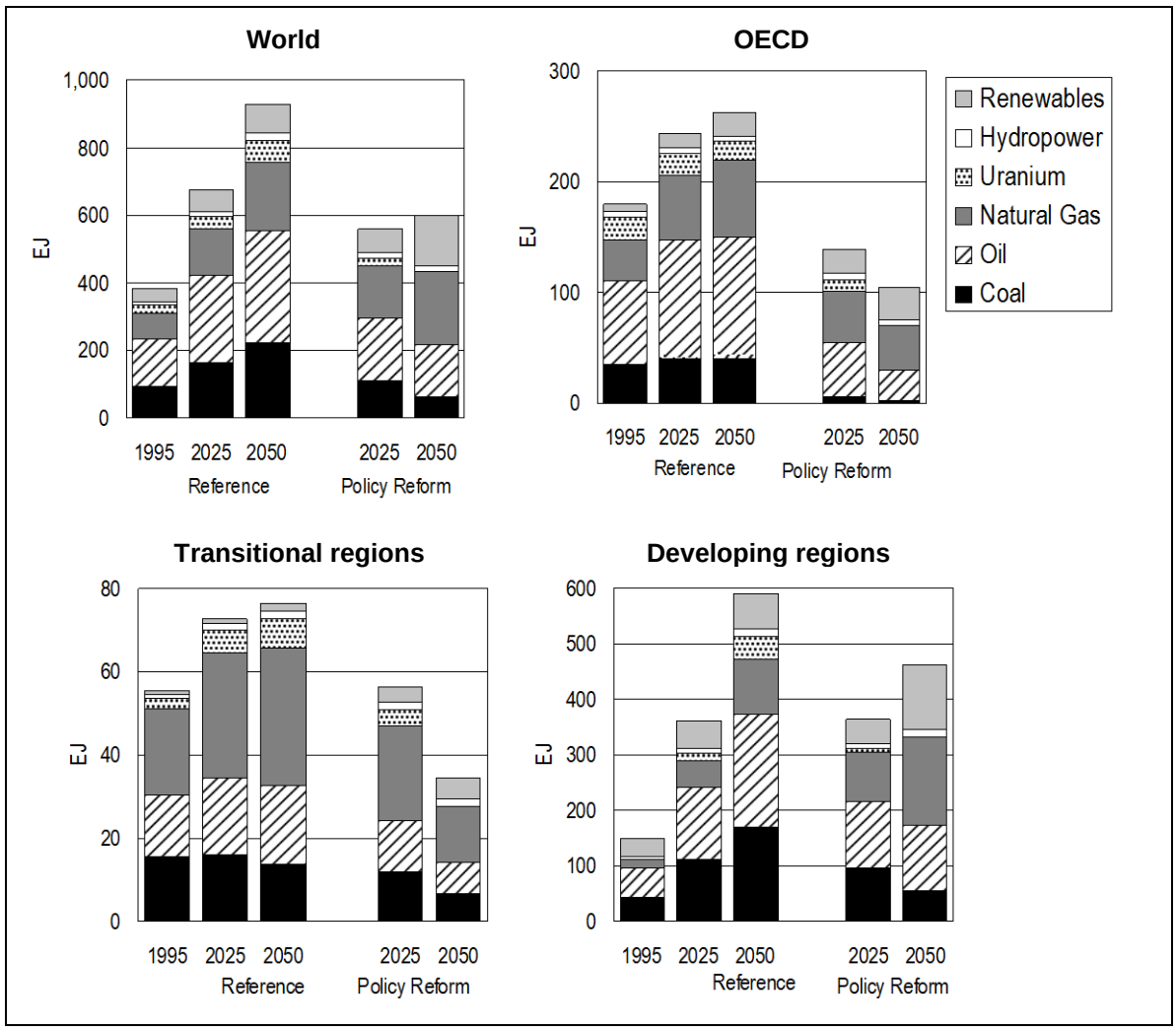

Figure 17. Primary Energy Requirements

Renewables include traditional and modern biofuels, as well as other renewable energy forms such as solar, wind, and geothermal energy.

Energy intensity changes for the *Policy Reform* and *Reference* scenarios are shown in Figure 18. In the *Policy Reform* scenario, the energy required per unit of economic activity decreases in OECD regions by 70% between 1995 and 2050. In developing regions, the decrease is 60%. In transitional regions, where energy use is currently very inefficient, energy intensities decrease by 78% between 1995 and 2050. The patterns in the scenario are developed by first setting goals for OECD regions, based on technological and economic feasibility, and allowing gradual convergence toward these standards in other regions as income increases. In the scenario, some degree of

technological "leapfrogging" is assumed as developing regions approach best future practices for energy utilization. The trends in energy intensity for OECD regions are shown at the sectoral level in Figure 19 (Heaps et al., 1998).

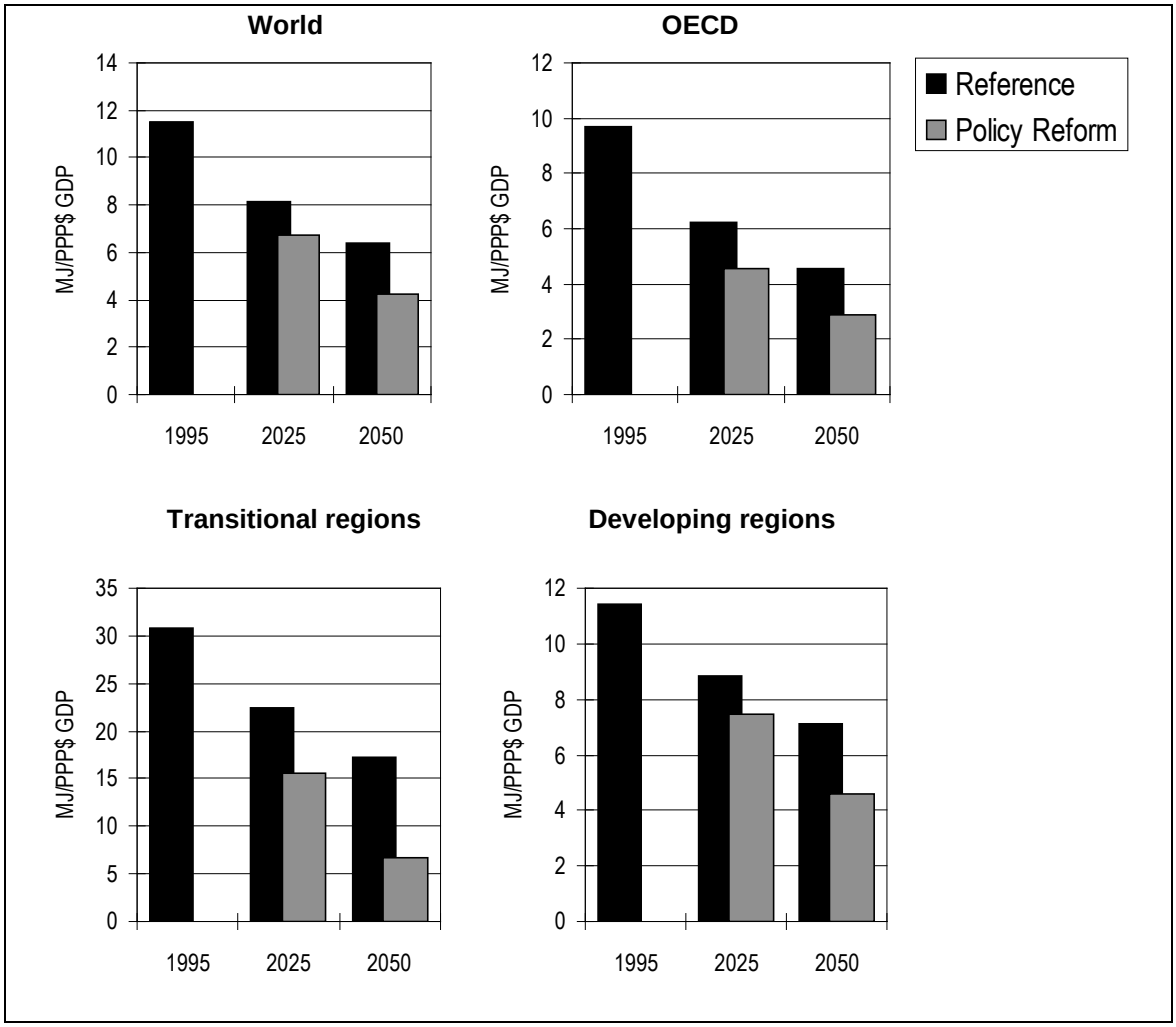

Figure 18. Energy Intensities in the Scenarios

The *Policy Reform* scenario incorporates a wide variety of measures for achieving energy intensity improvements. In the residential and service sectors, these include improved space heating and cooling systems, more efficient appliances and lighting, better glazing and building insulation, and greater use of heat pumps and passive solar heating and cooling. In the industrial sector, there is greater use of recycled material feedstocks, efficient motors, and combined heat and power technologies. In the transport sector, vehicle efficiency improves sharply, e.g., in North America the current average mileage for automobiles of 19 miles per gallon (mpg) reaches 32 mpg in 2025 and 51 mpg by 2050. These improvements are well within the bounds of what is considered to be technically and economically feasible over the period to 2025. For example, efficiencies in new automobiles could reach 75 mpg by that time (Energy Innovations,

1997). In the electric power sector, a new generation of technologies, such as combined cycle thermal plants and integrated coal and biomass gasification, provides substantial efficiency increases in the medium term. In the longer term, fuel cell-based technologies and greater use of combined heat and power will be required to meet the sector efficiency goals of the scenario.

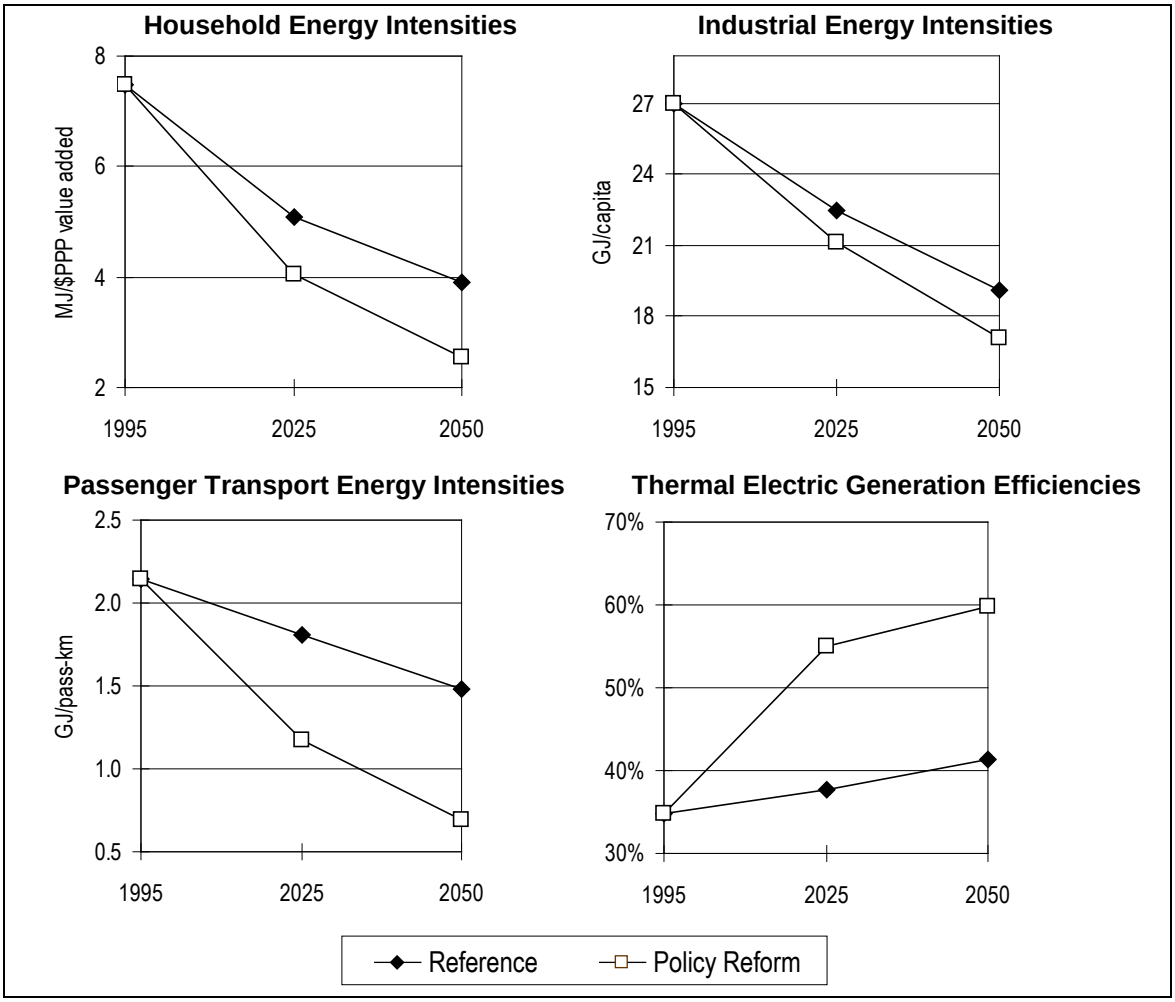

Figure 19. OECD Energy Intensity Improvements by Sector in the Scenarios

Fuel Switching

The second prong of a sustainable energy strategy is fuel switching to a greater reliance on renewable energy sources, with natural gas as a near-term bridge fuel. The composition of energy supplies shifts fundamentally in the *Policy Reform* scenario, driven by carbon emission targets (Figure 17). Similar patterns apply at the regional level (Sheet En-2).

The combined share of the most carbon-intensive fuels, coal and oil, decreases from 62% in 1995 to 37% in 2050, while the share of natural gas increases from 19% in 1995 to 36% in 2050. This can be compared to the *Reference* scenario, in which the

share of coal and oil remains almost constant (60% in 2050). Severe pressure on fossil fuel resource availability (Section 3.3.2) is postponed but not entirely alleviated (Sheet En-5). In addition, the scenario assumes the phase-out of nuclear generation for reasons noted in Section 3.2. If the nuclear option were included, carbon emission and other environmental targets could be met with corresponding decreases in the requirements for renewables and efficiency improvement.

The mix of renewable energy forms varies from region to region according to natural resource endowments — hydro potential, insolation, availability of land, and the presence of suitable water and soil conditions for modern biomass plantations. Renewable options include biofuels as a feedstock for the industrial, transport, and electricity generation sectors; solar energy for electric generation and for direct applications in households and industries; and wind and geothermal energy for electric power generation. Hydropower development is limited to the same levels foreseen in the *Reference* scenario because of the need to avoid the environmental impacts often associated with many large hydro schemes. Solar and wind development for electricity generation is limited by their intermittent nature.

Levers of Change

The efficiency and fuel-switching initiatives in the scenario require neither heroic technological assumptions nor economic disruption. Indeed, not only is the promotion of energy efficiency and renewables compatible with economic development and job stimulation, but it may also, in fact, further these goals (Energy Innovations, 1997). The primary constraints to achieving the energy goals are institutional and political.

Numerous policy options are available. Fiscal mechanisms can be used to internalize environmental costs into energy prices, e.g., through the use of carbon taxes or carbon-trading systems. Carbon taxes can be coupled to reductions in other taxes as in tax shift policies already adopted in some European countries. Fossil fuel subsidies can be eliminated. Progressively more stringent energy efficiency standards can be set. New financing initiatives and economic incentives can help spur investment in energy-efficient and renewable technologies. Increased research, development, and demonstration efforts can offer new technological opportunities. Market barriers to efficiency and renewables investment can be overcome through better information, capacity building, and institutional frameworks. Globally, initiatives to transfer technology and know-how can help make energy efficiency and renewables a foundation for the growing infrastructure of developing economies.

4.5 Food and Land

The *Reference* scenario offers a mixed picture for food and agriculture. On the one hand, production keeps pace with steadily increasing requirements for food and other agricultural commodities. On the other hand, the doubling of agricultural output by 2050 contributes to substantially increased pressures on land and water resources. Also, increased chemical inputs to farming systems add to terrestrial and water pollution. The need for new agricultural land is amplified by the continuing degradation of existing cropland. Along with expanding settlement areas, this leads to the loss of forest areas and other ecosystems, at rates comparable to those in the recent past.

The difficulties of meeting global food requirements in environmentally sustainable ways are even greater in *Policy Reform* scenarios. Meeting the *social* goals of the scenarios implies rapid economic development, more equitable income distributions, and greater food demands. While dietary patterns remain invariant in rich countries, diets improve and animal products grow as a share of dietary intake elsewhere (Sheet F-1). Global food requirements for cereals increase 60%, from 990 million tonnes to 1,560 million tonnes over the scenario, while the demand for meat rises almost 2.5 times, from 260 million tonnes to 630 million tonnes.

The challenge of simultaneously meeting all the sustainability criteria introduced in Section 2 is formidable. Increased agricultural requirements must be met under multiple constraints: forest and habitat protection reduces the scope for the expansion of agricultural land, decreasing the level of stress on water resources in water scarce areas limits the use of irrigated water, and reducing land degradation and chemical inputs to agriculture requires more sustainable farming practices, while maintaining yield increases.

In the *Policy Reform* scenario, the often conflicting goals of providing space for human settlements, protecting ecosystems, and feeding human populations can be reconciled only through a combination of measures:

- **Sustainable farming practices.** A transition to agricultural sustainability will require a "doubly green" revolution, in which agricultural productivity continues to improve but with practices that preserve the environmental foundation for the long term (Conway, 1997). The focus shifts from the genetic manipulation of crops to increase yields toward enhancing the productivity of complex farming systems (Swaminathan, 1997). In the scenario, a campaign for sustainable agriculture is launched, resulting in a gradual shift toward ecologically sound practices, rather than the replication of high-input farming. The challenge is to maintain yield improvements at something like *Reference* scenario levels. As part of the pollution-reduction goals of the *Policy Reform* scenario, fertilizer and pesticide use per hectare declines. To maintain yields, the nutrient requirements of plants must be met, and pests kept in check, in other ways (Conway, 1997). Nutrient recycling partly substitutes for fertilizer, for example, by using livestock manure in combined crop-livestock systems and through large-scale composting. Nitrogen requirements are met in part through the use of nitrogen-fixing plants that can be grown in rotation with or in combination with other crops. Pesticide requirements are reduced through the development of pest-resistant strains of plants and the widespread use of integrated pest management. The poverty alleviation goals of the scenario support these trends, as increasing income allows farmers to diversify their production (Scherr and Yadav, 1996). Additional actions needed include the development and application of biotechnology and other research (e.g., disease resistant varieties), education and training of farmers, land reform, infrastructure development, and reform of economic policies. Programs for sustainable agriculture must be carried out in cooperation with farmers and targeted to local needs (Leach, 1995).
- **Fisheries and Aquaculture.** In the *Policy Reform* scenario, fish consumption increases, from about 100 million tonnes in 1995 to about 160 million tonnes in 2050,

only slightly less than the 170 million tonnes required in the *Reference* scenario (Sheet F-3). Better management of capture fisheries extends the current production of around 85 million tonnes per year to a sustained annual production of 100 million tonnes (FAO, 1997c). About 10 million tonnes of the total increase comes from replenished stocks, as access to overexploited fisheries is restricted through the creation of limited fishing rights and other initiatives. A further 5 million tonnes is gained through a reduction of losses and discarded by-catch. These changes are brought about by better technology, legal limits on discards, and the expansion of markets for the products of by-catch. About 60 million tonnes of global requirements cannot be met on a sustained basis from capture fisheries. Aquaculture expands to meet this additional demand, with production roughly tripling from the 20 million tonnes from this source in the base year (FAO, 1997c). In the past, aquaculture has led to pollution and pressures on freshwater resources (Brown, et al, 1998). These are reduced in the scenario by the introduction of water-conserving technologies, encouraged by water-conservation and pollution-prevention policies.

- **Pasture and rangeland.** Changes in grazing land for livestock production are subject to competing effects. On the one hand, the robust *Policy Reform* economic growth assumptions drive the demand for meat products higher. On the other hand, the scenario assumes a greater reliance on feedlots in livestock production (Sheet F-2). Greater reliance on feedlot production is both a consequence of rapid economic growth and a matter of policy. While agriculture production must expand to meet increased livestock feed demand, reducing the requirements for grazing land has the net effect of reducing pressure on forests and other ecosystems. In addition, some improvement in grazing land productivity can also be expected because of the adoption of modern practices and improvements in herd quality. At the same time, both grazing and feedlot production practices must become more sustainable in order to reduce environmental pollution. For example, large feedlot facilities produce vast quantities of concentrated manure, contributing to nitrate pollution of ground water and ammonia emissions, a precursor of acid rain. Part of the answer is more integrated crop-livestock systems in which manure is recycled to crops as fertilizer (Durning and Brough, 1991; Bender, 1994). The transition to sustainable livestock practices can be reinforced by providing information through extension services and by enforcing anti-pollution laws. In arid lands, where the availability of forage can vary greatly from year to year because of climate fluctuations, policies to provide timely access to markets and land can allow pastoralists to cope without overtaxing biomass resources (Conway, 1997).
- **Cropland.** Driven by the combination of food and feed requirements, global cropland area expands by about 20% between 1995 and 2050, a larger increase than the 11% of the *Reference* scenario. However, because of land and water constraints in many regions, the largest increases occur in regions with the least land and water constraints (Sheet F-6). This implies more extensive trade in food commodities, as discussed below. In North America, where cropland grows by over 40%, some of the increase is met by returning to production land held in the U.S. Conservation Reserve Program. Globally, a greater share of the cropland is on rainfed land than in the *Reference* scenario. Expansion of irrigated land is discouraged by increases in water

prices, as countries try to limit the incidence of water stress, the topic of the next section.

- **Land degradation.** Consistent with the sustainability goals (Section 2), the rate of land degradation slows between 1995 and 2025, and then reverses between 2025 and 2050. Loss of cropland due to severe degradation drops to 1.5 million hectares per year over the first half of the scenario, half the rate assumed in the *Reference* scenario. From 2025 to 2050, cropland is restored, leading to the return of degraded land to cropland, forests, and other land types. Depending on the nature of the land and its use, degradation is reduced through different means. Improving drainage and delivery systems for irrigation water can restore irrigated land subject to waterlogging and salinization and simultaneously conserve water resources. Nutrient loss from shifting cultivation can be reduced by lengthening fallow periods. Loss of land through water erosion can be reduced by building terraces and through conservation tillage. When the terraces are reinforced by planting nitrogen-fixing trees, they can add to the fertility of the soil, as well as retaining water and reducing erosion (Conway, 1997).
- **Built environment.** Under business-as-usual conditions, the expansion of settlement areas is likely to claim a significant amount of arable land, forest area, and drylands, as illustrated in the *Reference* scenario (Sheet P-6). The expansion of the built environment is curtailed in the *Policy Reform* scenario, as concerns for protecting productive cropland, forests, and other ecosystems lead to urban planning policies that favor more compact settlement patterns. This would be supported by a higher valorization of arable lands, driven by increasing domestic demands and, in some regions, profitable opportunities for increased trade. All regions gradually move toward Western European patterns (Sheet P-7).
- **Forest land.** The preservation of forests and other valued habitats and ecosystems is a key sustainability goal. Specifically, the rate of forest loss gradually decreases to zero in the scenario by 2025, and forest areas increase thereafter. These goals contrast with both historic and *Reference* scenario patterns in which deforestation proceeds at about 10 to 15 million hectares per year. These trends are reversed by forest protection policies and land-use strategies that support more compact settlements, the contraction of grazing lands, and land restoration. In the scenario, the amount of forest land set aside as protected areas increases. Also, opportunities are developed for encouraging the sustainable use of forest products among the poor, e.g., by granting secure land rights (Scherr and Yadav, 1996). Finally, the sustainable management of forests by the timber trades, including the preservation of critical levels of old forests and other ecosystems for the support of biodiversity, becomes a priority everywhere,. As a result, loss of forest is reduced from 700 million hectares in the *Reference* scenario to below 250 million hectares between 1995 and 2025. Between 2025 and 2050, there is net reforestation.
- **Agricultural Trade.** Many countries and regions butt against the limits of their resource constraints in the *Policy Reform* scenario. Indeed, we find that meeting expanding food requirements while staying within environmental constraints will require greater reliance on imports in a number of countries (e.g., those in Africa and the Middle East). Increased reliance on imports is made possible by the rapid

economic development assumed in the *Policy Reform* scenario, which supports enhanced participation of developing regions in international commerce (Sheet F-4). This requires considerable expansion of production from exporting regions, such as North America, Western Europe, and Latin America, and from the transitional regions of the former Soviet Union and Eastern Europe (RIVM/UNEP, 1997). While this would counter trends over the last twenty years of withdrawing lands from production in industrialized regions, the scenario assumes heightened concern in the OECD regions for maintaining forests and other ecosystems in developing regions. Furthermore, growing demand for agricultural commodities from increasingly wealthy developing regions makes expanded production more profitable. However, to maintain production so that the food requirements of developing regions are met while preserving ecosystems worldwide will likely require far-sighted policy measures that do not rely on markets alone (Leach, 1995).

Land-use patterns in the *Policy Reform* scenario that result from these considerations are reported in Sheets P-6 and P-7 and summarized in Figure 20. The rapid expansion of the built environment and grazing land areas in developing regions that occurs in the *Reference* scenario is slowed or reversed. In OECD and transitional regions, the slowly changing land-use distributions of the *Reference* scenario are replaced by a more dynamic picture, as cropland area grows to supply the increasing import needs of countries facing land and water constraints.

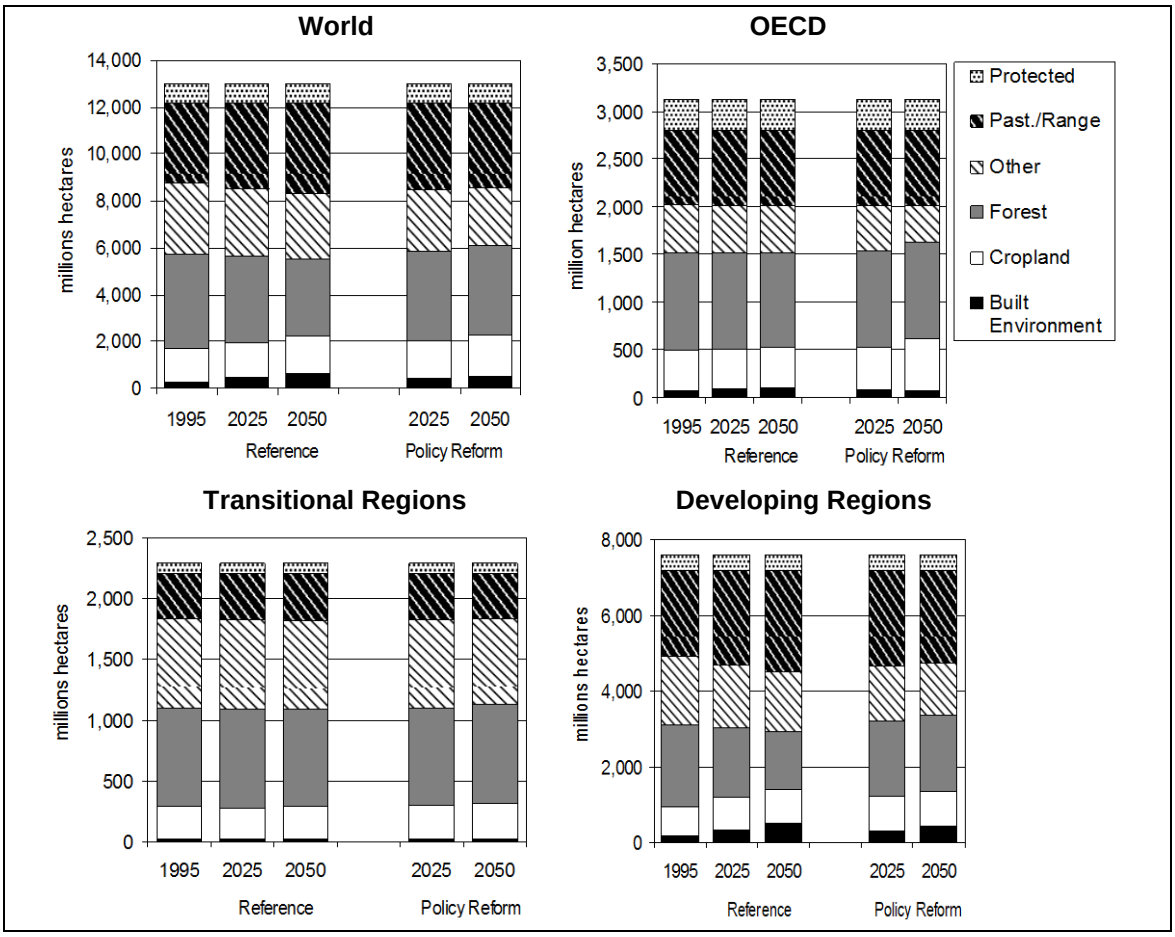

Figure 20. Land-use in the Scenarios

The task of feeding a world with almost twice as many people as today, while maintaining the productivity of cropland and forests, and avoiding unmanageable pollution, presents numerous challenges. There is no simple recipe for achieving sustainability in land-use and agricultural production. The scenario presents a picture of how this might be accomplished. It also underscores the multidimensional character of the problem, the variety of the types of initiatives needed, and the immense policy challenge. Concerted government action will be needed to build the required capacity for research and extension services, provide well-functioning markets and adequate infrastructure, correct perverse subsidies, and implement incentives for a shift toward more ecological agriculture, forestry, and land-use practices. The adequacy of water resources will play a critical role in achieving these goals.

4.6 Freshwater

Approximately one-third of the world's population lives in areas experiencing some form of water stress. In the *Reference* scenario, the figure rises to over 50% in 2050, or close to 5 billion people. The heightened competition for water increasingly threatens valuable ecosystems and habitats that depend on an adequate supply of clean water, and causes

tension between users sharing common water resources. These trends violate sustainability criteria.

Abating freshwater degradation and scarcity is an exceedingly daunting task. The practical difficulty is reflected already in the sustainability goals articulated in Section 2. They accept that increased water stress is unavoidable, though they do target levels well below those in the *Reference* scenario. In the *Policy Reform* scenario, the transition to the environmentally sustainable use of water resources is in some ways at cross purposes with efforts to meet the social goals. The requirements for water services increase as a result of efforts to deliver household water services to the poor and by the rapid expansion of developing country economies.

In the context of rising end-use requirements, freshwater withdrawal is moderated in the scenario through several types of measures: efficiency improvement, resource enhancement, and agricultural trade increase. The scenario analysis is conducted at the national level in order to more accurately match water demands and resources. Measures are introduced in each country for satisfying the freshwater sustainability goals of Table 5. Aggregate global water requirements in the *Policy Reform* scenario increase 10% between 1995 and 2025, and then decrease by less than 5% from 2025 to 2050. Regional patterns are shown in Sheet P-1 and are compared to the *Reference* scenario. In the developing regions as a whole, requirements change little between 2025 and 2050, after a 25% increase between 1995 and 2025. In the water-stressed Middle East, water withdrawals increase by about 15% from 1995 to 2025, substantially less than the 50% increase in the *Reference* scenario, and between 2025 and 2050 withdrawals decline, to reach levels slightly above those in the base year. Industrial intensity improvements in the former Soviet Union, where current values are relatively high, lead to lower total requirements in 2050 than in 1995. In the OECD as a whole, withdrawals decrease throughout the scenario, dropping by over 30% between 1995 and 2050.

The major features underlying these results include the following:

- **Increasing drivers of water use.** All else equal, growing economies, particularly in developing regions under *Policy Reform* assumptions, drive water demands beyond environmentally sustainable limits in many countries and river basins. As discussed below, end-use water requirements would have to be met far more efficiently and, to some extent, with non-conventional water sources. Additionally, in some cases water demands can only be kept within sustainability goals by reducing requirements, e.g., land under irrigation. In the Middle East, where water scarcity is particularly acute today, irrigated land areas decrease in the scenario, by about 10% relative to 1995 levels. The reduced agricultural production is made up through trade; in effect, countries in this region import the water embodied in agricultural products.
- **Efficiency improvement.** Overall improvements in aggregate water intensity (use per unit GDP) are summarized in Figure 21 for the macro-regions. Two factors contribute to the decrease in aggregate intensity. First, the composition of economies changes in the scenario so that the water-intensive agriculture sector contributes a diminishing share. This alone lowers water intensities in the scenarios. Second, water is used more efficiently as illustrated by the sectoral water intensity trends illustrated in Figure 22 for the OECD region. We begin with irrigation intensities.

Recall that water requirements increase to meet the water requirements of higher-yielding crops as reflected in the increasing *Reference* scenario intensities in Figure 22. The lower intensities in the *Policy Reform* scenario are due to the implementation of a variety of methods to increase the efficiency of irrigation over conventional practices (Postel, 1992; Seckler, et al., 1998). For example, spray irrigation systems can be replaced by trickle and drip irrigation systems, open canals can be covered, and subirrigation, in which groundwater is raised to the level of roots, can be introduced in some areas. Numerous opportunities are available in the domestic sector, as well, through higher market penetration of water-efficient appliances and tighter plumbing codes. In many developing regions, domestic water intensities increase as incomes rise, but do so more slowly than in the *Reference* scenario. Industrial water intensities also decrease towards best practice levels today, such as those in Israel, where aggressive water-pricing schedules and standards for water-conserving technologies have led to highly efficient water use by industry (Lonergan and Brooks, 1994). Measures to achieve these targets include water recycling, using saline or brackish water for cooling, and changing to less water-intensive industrial processes. Aggregate intensities also change in response to changing industrial mix, toward less water intensive subsectors.

- **Resource expansion.** The scenario assumes greater investment in desalinization facilities, particularly in coastal water-scarce areas, and increased capture of treated wastewater for reuse in selected applications. Currently, in the Middle East and North Africa, some countries meet a substantial amount of their domestic and industrial water requirements through desalinization and wastewater treatment (FAO, 1996a). For example, in Kuwait over half of water withdrawals are met with these non-conventional sources. For the region as a whole, desalinization and wastewater recapture is not cost-effective for most countries, constituting less than 1% of total supplies. In the scenario, water shortages stimulate increased investment in these sources, and by 2050 the Middle East meets about 6% of its water requirements from desalinization and wastewater treatment. Individual countries satisfy between 10% and over 50% of their requirements this way. In North Africa, countries that currently supply some of their water requirements through water treatment plants expand their capacity so that by 2050, 10% of their water withdrawals are supplied by desalinated or treated wastewater.

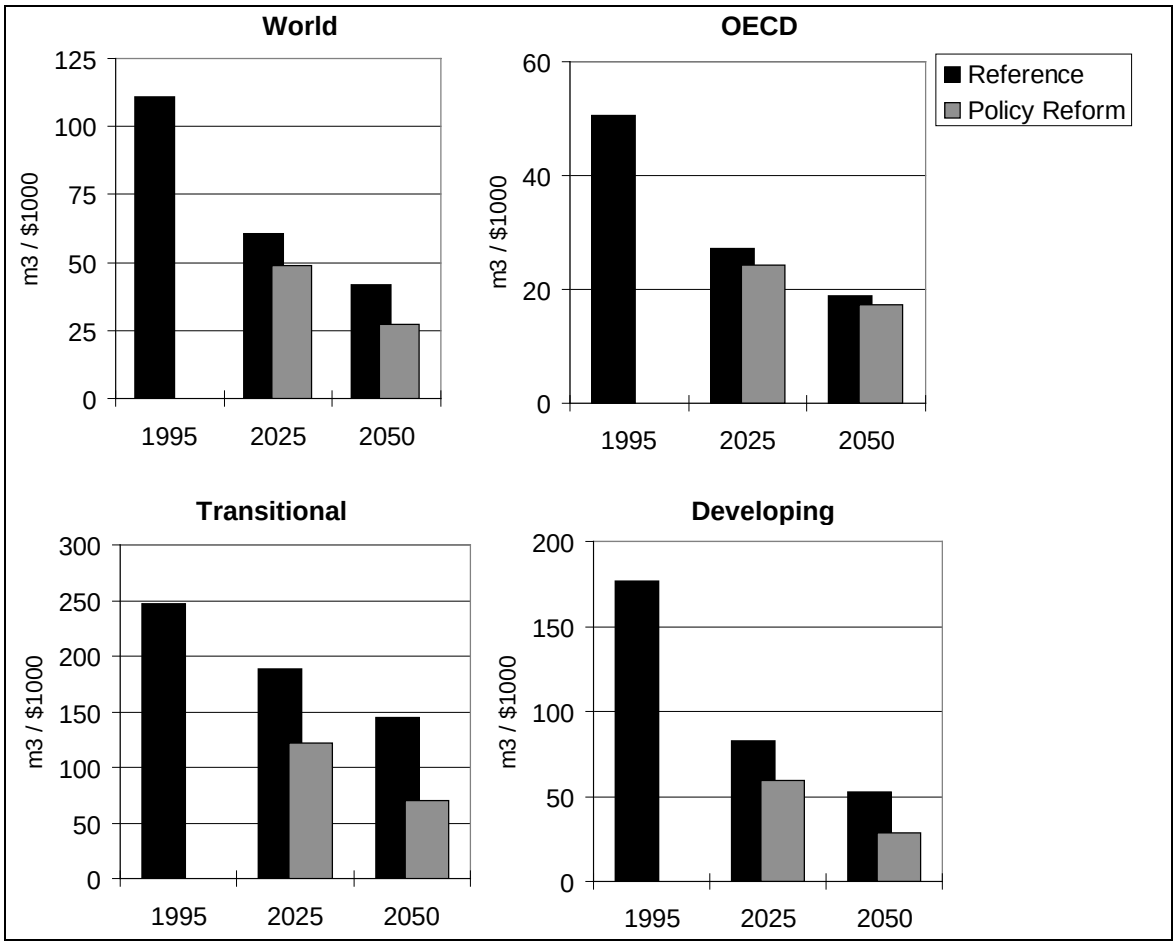

Figure 21. Water Intensities in the Scenarios

Cubic meters per $1000 of GDP_{PPP}

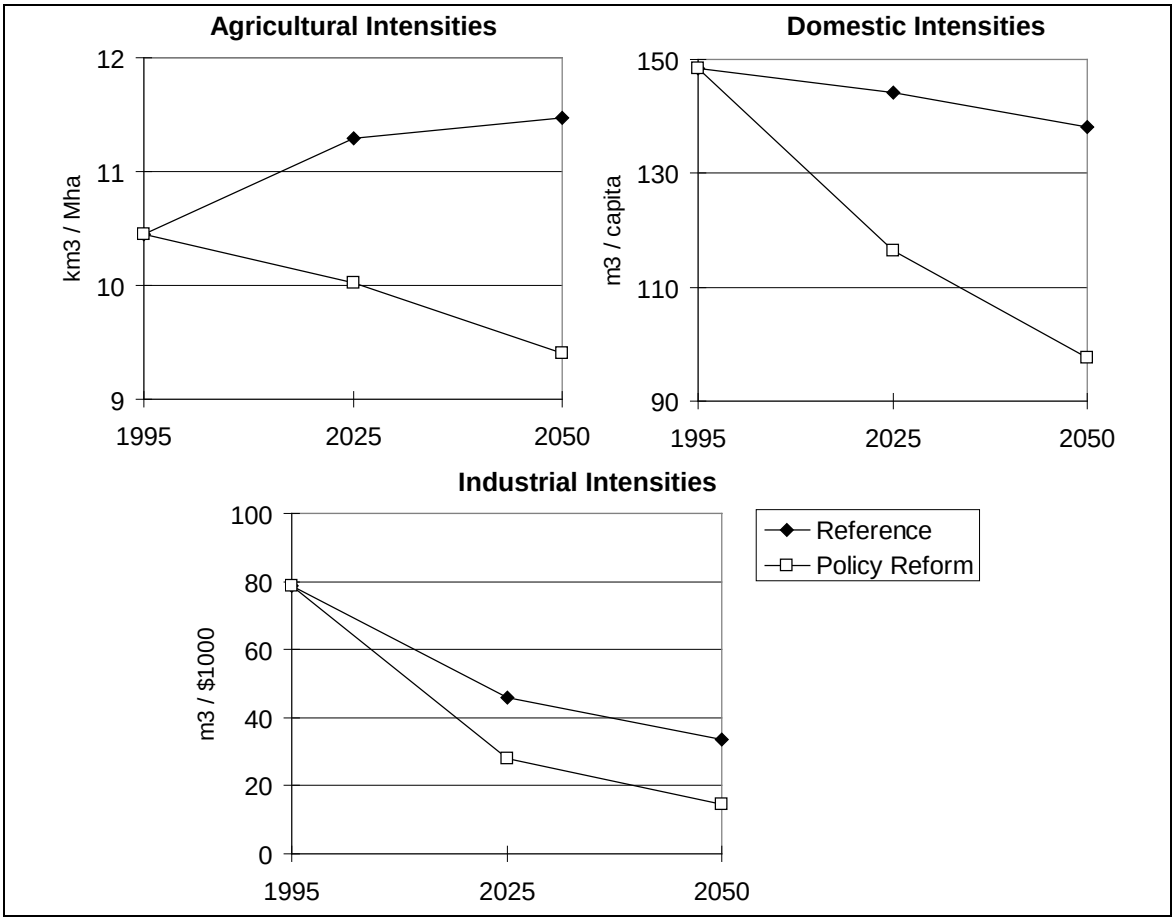

Figure 22. OECD Water Intensity Improvements by Sector in the Scenarios

These factors combine to keep national freshwater withdrawal requirements within the sustainability targets (Table 5). Aggregating to the regional level, trends in the use-to-resource ratio in the scenario are reported in Sheet P-3. Globally, the population in water stress rises to nearly 40% in 2025 and stays at that level from 2025 to 2050.[25] Global totals for the number of people in water stress in the *Reference* and *Policy Reform* scenarios are shown in Figure 23. In the *Policy Reform* scenario, the incidence of severe stress (national use-to-resource ratios greater than 0.4) remains almost constant between 2025 and 2050, in contrast to the *Reference* scenario, where it increases by about 30% over the same period. The population in moderate stress is greater in the *Policy Reform* scenario than in the *Reference* scenario, but this increase is from countries that are severely stressed in the *Reference* scenario.

[25] As with the *Reference* scenario, the fraction of national populations in water stress is assumed to rise from zero to 100% as the use-to-resource ratio rises from 0.1 to 0.4.

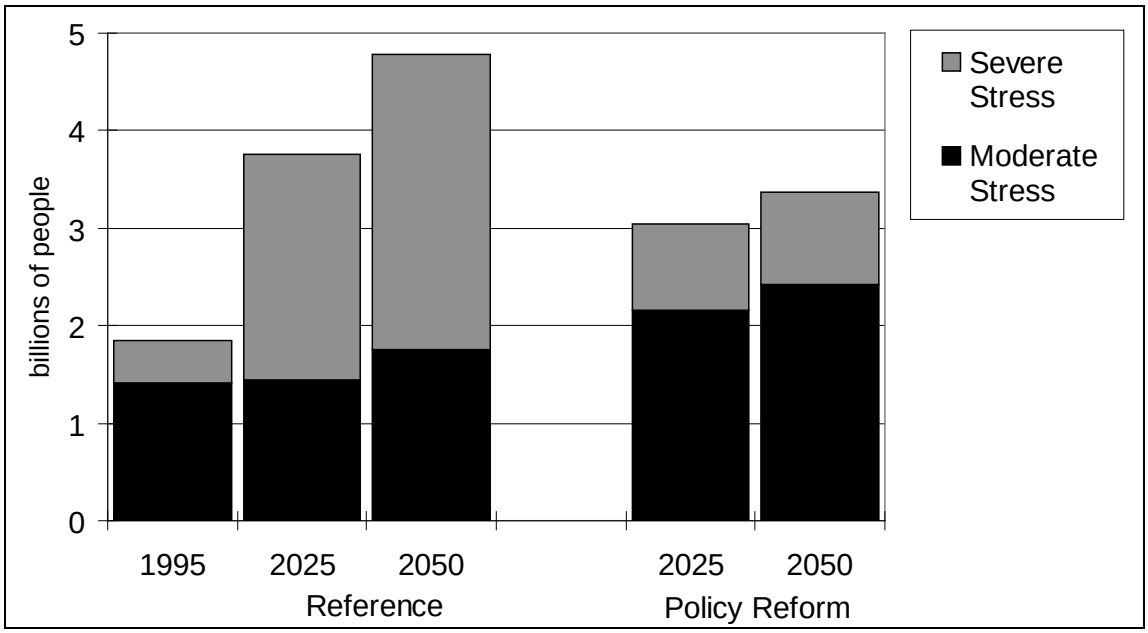

Figure 23. Population in Water Stress in the Scenarios

The *Policy Reform* scenario suggests that pressures on freshwater resources can be substantially reduced. The sustainability goals, though rather weak, can be met in principle but would require vigorous policy initiatives. The most efficient new irrigation technologies are expensive, as are desalinization plants, and their introduction will need to be encouraged by water-pricing policies and efficiency standards. In many places today, water use is subsidized, perversely favoring inefficient use (Postel, 1992). To reach the sustainability goals, these subsidies must be removed or reduced, and water priced to reflect its full economic and environmental value. Policies directed at other sustainability goals will also be useful; for example, water pollution abatement can induce benefits such as increased water-use efficiency.

In the past, freshwater development was largely about water systems engineering, infrastructure development, and flood control. Water sustainability will require an expanded perspective that considers the multi-faceted role that water plays in servicing human and ecological systems. If water development remains fragmented and wasteful, the prospects for sustaining the environment diminish and the possibilities for conflict rise as economies grow. But if an integrated river basin planning framework takes hold, one that can involve stakeholders in a process of collaboration in order to balance the many claims on freshwater, then the water sustainability era can begin. The goals of developing a new paradigm for sustainable water use and building the capacity for its implementation command policy attention.

4.7 Materials and Waste

The resource use sustainability targets (Section 2.2) are partially addressed through strategies already discussed to reduce the intensity of fossil fuel extraction, to control soil erosion, and so on. But much more would be required to manage the level of material

inputs to industrial economies and the environmental impacts of waste loads. Dematerialization at the required level requires efforts across several dimensions (Jackson, 1993).

At the facility level, processes can become cleaner and far more efficient in their use of natural resources. At the commodity level, product lifetimes can be lengthened, thereby reducing the discard rate and need for virgin materials. At the system level, "waste" streams can be reconceptualized as resource streams through the reuse of products, remanufacturing of components, and recycling of materials. Ultimately, detailed consideration must be given to the system impacts of alternative processes and materials through life-cycle analyses that considers both the direct and indirect impacts of alternatives.

In addition, aggregate reduction in the intensity of resource use will be aided by shifts in the composition of the economy from resource-intensive to knowledge-intensive sectors. In the end, reducing the throughput of materials to lie within tolerable sustainability boundaries may require a moderation in consumerist lifestyles. However, this would carry us beyond the premises of *Policy Reform* scenarios.

Scanning across the various elements that comprise the *Policy Reform* scenario, the complex and multi-dimensional character of a policy-driven sustainability transition becomes apparent. The discussion of the food-water-land nexus of issues illustrates the many obstacles that will be faced in servicing growing economies, meeting human needs, and passing on a healthy environment. Moreover, the tension between two assumptions in the scenario will not be easily reconciled — the continuity of dominant values and institutions, on the one hand, and the greater equity for addressing poverty reduction, climate protection, and other goals, on the other hand. At the very least, a comprehensive action agenda will be needed to begin to bend the curve of development toward sustainability.

5. IMPLICATIONS FOR ACTION

The *Conventional Worlds-Reference* scenario allows us to gauge the risk of inaction. The scenario fails to meet fundamental sustainability goals across a number of dimensions — basic human welfare, international equity, environmental quality, and resource preservation. The case is compelling for immediate and strong initiatives to change course. But history teaches that a need for action, in principle, does not mean that appropriate action will be taken, in practice.

The *Conventional Worlds-Policy Reform* scenario gives a concrete illustration of how a redirection towards sustainability could come to pass. It shows that simultaneously meeting social, environmental, and resource goals requires overcoming a daunting and interacting set of constraints. Nevertheless, gradual changes in social, technological, and resource-use patterns become cumulatively significant over the coming decades. The curve of global development bends toward a more equitable and environmentally healthy future. What then are the challenges to a transition to a *Policy Reform* scenario? What policies are needed? Is policy reform enough?

5.1 Challenges

The quest for a sustainability transition within the *Policy Reform* framework poses challenges that should not be underestimated. Recall that this scenario assumes essential continuity with current institutions and trends. The values, lifestyles, governance systems, and economic structures of *Conventional Worlds* may evolve slowly, but their fundamental character endures. Change comes as a set of corrections and adjustments to market-driven development, rather than as a passage to a new mode of civilization, as envisioned in *Great Transition* scenarios.

In the *Policy Reform* context, an effective campaign for a sustainability transition will require the fulfillment of several conditions:

- widespread awareness of the issues and the conviction that action is necessary;
- adequate institutions, policies, and technologies; and
- sufficient political will to accept the costs of carrying out the required actions.

Growing scientific understanding of the risks of unsustainable development is a necessary ingredient. But science alone is insufficient to galvanize timely and appropriate action: witness the many climate change skeptics despite the high level of international scientific consensus on the threat of global warming. In the social realm, resistance to strong measures to reduce inequity and eliminate poverty persists. Even among the international financial institutions charged with poverty alleviation, such as the World Bank, there is continued reliance on “trickle down” economics. In developing countries, the structural adjustment programs of the last decade, while correcting macroeconomic failures, have not adequately addressed increasing income disparities.

Ultimately, the greatest challenge is the third item identified above: the willingness to implement and accept the costs of necessary changes. Many stakeholders — governments, businesses, political parties, and other social groups — remain reluctant to make sustainability a real priority for action. In the absence of that resolve, pressures

that reinforce unsustainable patterns prevail: economic subsidies often foster environmental disruption, emphasis on short-term economic benefits discounts the future, policies weaken support for the poor out of concern for global economic competitiveness, business practices pollute and deplete resources, and consumerism remains the dominant lifestyle.

The sustainability transition calls for placing higher values on interests that heretofore have been neglected: the plight of the poor, the rights of future generations, and the integrity of ecological systems. As with any call for a major reordering of social priorities, the transition to sustainability can expect resistance. Proposals for the empowerment of disenfranchised people, for more moderate per capita material consumption of affluent groups, and for increased international commitments for sustainable development will be contested, particularly by those who benefit most from the current state of affairs. The dialectic of political change — public pressure from below and leadership from above — will need to overcome such resistance by building a new vision and consensus for a politics of sustainability.

5.2 Agents of Change

Within a *Conventional Worlds* framework, the transition to sustainability entails both the deployment of environmentally friendly technologies and the reform of institutions. The *Policy Reform* scenario, summarized in Section 4, confirms that much of the technology and practices necessary for a transition to sustainability are at hand. A vast repertoire of technical means is available for sustainable food production, cleaner energy, materials recycling, efficient water use, and pollution prevention. While continuing research and development will further enrich the technological possibilities, the immediate challenge is the redirection of institutional forces.

Environmental degradation is not an inherent fact of our time. It results from a set of historically contingent choices for technology, production processes, and consumption patterns. Similarly, poverty and extreme inequity are not inevitable, but rather are the outcome of a specific period of world history. These distributional patterns are embedded in a set of institutional mechanisms that are stubborn, but not immutable. For millennia, human societies produced little surplus and functioned near the edge of survival. With limited social wealth, economic redistribution could not eradicate the poverty of the many. The surge in productivity since the industrial revolution has changed the problem of poverty eradication from a technological to an institutional issue. The challenge is not so much to increase output as it is to fairly distribute resources, know-how, and entitlements.

The precondition for sustainability is forging the political and social will for change. That resolve will need to then find expression through reshaping traditional institutions and harnessing the potential of emerging ones. The former refers to the formal processes of economies and governance, and the latter to the full gamut of social arrangements that offer opportunity for discussion and action concerning social goals and means.

Regarding economic institutions, some advocates of laissez-faire see modern market economies as something akin to natural phenomena. Yet economies are human

arrangements, which are not above society, but are part of it. Economic institutions have undergone enormous changes through history, including the abolition of slavery, the rise of the welfare state, the transformation of financial sectors, and globalization. In the discussion of strategies for sustainability, economic institutions need to be understood, not as a given, but as part of both the problem and the solution. Eventually, changes in social values and technology could lead to fundamental economic transformation. But even in a *Policy Reform* world, a wide array of economic instruments is readily available to motivate environmental sustainability in the market place, as we shall review in the following section.

Large corporations are increasingly powerful agents of change as the global sweep of their influence advances. On the one hand, they have the capacity to accelerate the transition to sustainability. On the other hand, they are accountable ultimately to their shareholders, not to an electorate, since the primary objective of business is profit, not social welfare. Nevertheless, there are preliminary signals that the private sector may be changing in response to the challenges of sustainability and environmental responsibility, as some of its leaders articulate a genuine concern for the state of the future.

It is naïve to blame government and international agencies for all of society's flaws — or look to them as the panacea for the transition to sustainability. Enlightened initiatives by governments and agencies, spurred by politically engaged constituencies, will be necessary ingredients of major change. Governments remain the locus of public policy and the primary bodies concerned with public welfare. Yet nation-states are in some ways too big for the small problems and too small for the big ones. The power of nation-states has been diminishing as globalization makes national borders more porous. Moreover, governmental bodies are constrained by inertia, the lobbying pressure of powerful stakeholders, and a short-term interpretation of voters' aspirations — a natural consequence of electoral cycles that last just a few years. The momentum for overcoming these constraints will need to come from outside, rising among the countless new associations taking shape today.

Myriad new institutional actors have entered the stage in recent years. A chorus of new social actors is appearing: grassroots movements, non-governmental organizations (NGOs), interest groups, and emerging forms of social organization such as virtual networks. The agendas are as diverse as the players. Some address broad themes such as gender, the environment, and the rights of indigenous peoples. Specific local matters motivate many others. The capacity of these groups to educate, articulate demands, and foster change is growing. As never before, transnational businesses, international agencies, and governments must acknowledge and answer the challenge of these new institutions. Meanwhile, traditional organizations, such as religious groups and charities, are changing their roles, and networks of scientists, citizens, artists, special interest groups, and many others proliferate.

As with any major technological breakthrough, the communications revolution offers contrasting possibilities for society as a whole. It provides the means to communicate at a scale and speed that is unprecedented. The communication revolution can serve to foster social mobilization for a more sustainable and just world. But it can

also lead to a media-dependent citizenry that overreacts to contradictory messages, marketing slogans, and media-manipulated fears.

The primary agents for a *Policy Reform* scenario are likely to be governments, businesses, and NGOs. The new institutions of civil society have a critical role to play in championing such a change of direction. Furthermore, for the fundamental value transformations envisioned in *Great Transition* scenarios to emerge, these groups will play the critical role.

5.3 Science for Sustainability

Science has much to contribute to the sustainability transition, supporting discussion and action with analysis, information, and solutions. The last twenty years have witnessed an accelerating translation of environmental concerns into scientific research programs. Stratospheric ozone depletion, global warming, biodiversity loss, and ocean pollution are only a few of the issues that have received focused research attention. We can be hopeful that others will follow.

As society turns increasingly to science for answers to environmental dilemmas, the scientific professions progressively have come to see environmental studies as legitimate areas of research. Conventional disciplinary boundaries have been transcended as the needs are acknowledged for interdisciplinary approaches and for scientific participation in the discussion of social choices. Indeed, we hope this study will be seen as part of the initiative to build bridges between scientific discourse, social values, and the policy agenda.

The challenge is considerable: to understand the dynamics and possibilities of whole socio-ecological systems with approaches that are scientifically rigorous yet sensitive to the inherent uncertainty and the normative character of the problem. There is growing recognition of the need for such a new scientific paradigm. The discussion of scientific research priorities for a sustainability transition is continuing within the scientific community (BSD, 1998) and need not be elaborated here.

What is worth stressing is that scenario analysis can play a key integrative role in coupling science to the public dialogue on the future. Scenarios provide a framework for synthesizing diverse findings from natural and social sciences. Moreover, scenario analysis guides research by identifying missing information and key areas of uncertainty. Scenarios for the sustainability transition must be both comprehensive and integrated, and they are needed at various spatial levels in order to "see" issues that only come into focus in the zoom from the global, to the regional, to the local.

This implies practical action. One of the most urgent knowledge-needs is for integration across policies, instruments, sectors, and issues. The need for a systemic approach was explicitly recognized in Agenda 21, but there has been little progress since. Integrated sustainability studies should be conducted at all levels. They should be comprehensive, participatory, and adaptive. Useful science for the transition must stress integration, recognize uncertainty, appreciate irreducible normative aspects, and engage the public in discourse on sustainable development. Action is needed to develop

appropriate methodologies, train a new cadre of sustainability professionals, and build institutional capacity. The task is no less than forging a new science of sustainability.

5.4 Symptoms and Causes: A Framework for Guiding Policy

We have associated the unsustainability of the current global trajectory with three major trends:

- environmental degradation and resource depletion,
- increasing income disparity, and
- poverty and marginalization.

Each defines a major area for policy attention. A set of *proximate* drivers is immediately responsible for propelling and regenerating these trends. *Ultimate* drivers condition the proximate drivers. For example, water pollution from factories depends directly on the process technology in use, the volume and pattern of industrial activity, and prevailing regulation and economic incentives. Ultimately, these depend on the value society puts on environmental quality, the lobbying power of interested parties, consumption patterns setting the demand for the industry's products, and the scientific understanding of the causes, impacts, and dynamics of water pollution.

A structure for critical trends and their drivers is introduced in Figure 24. The "critical trends" are associated with the *Reference* scenario. The "proximate drivers" draw attention to the direct levers of change that define *Policy Reform* variations. The "ultimate drivers" refer to the shape of the fundamental structure of values, knowledge, and empowerment that, if suitably altered, could initiate a *Great Transition* scenario. Though the distinction is not always sharp, the grouping of drivers into proximate and ultimate categories is useful for discussing policies and priorities. Proximate drivers include those factors that have a direct influence on trends and are subject to short-term policy intervention. Ultimate drivers are more stable and are a subject for the long-term policy-making agenda: they tend to influence trends indirectly by acting upon proximate drivers.

Instances of ultimate drivers, proximate drivers, and critical trends can be seen at different spatial levels from the local to the global. At each level, the analysis of critical trends and drivers will provide the framework for developing effective policy strategies. Each level requires its own analysis, and each will require disaggregation of the broad categories mentioned below in order to gain sufficient precision.

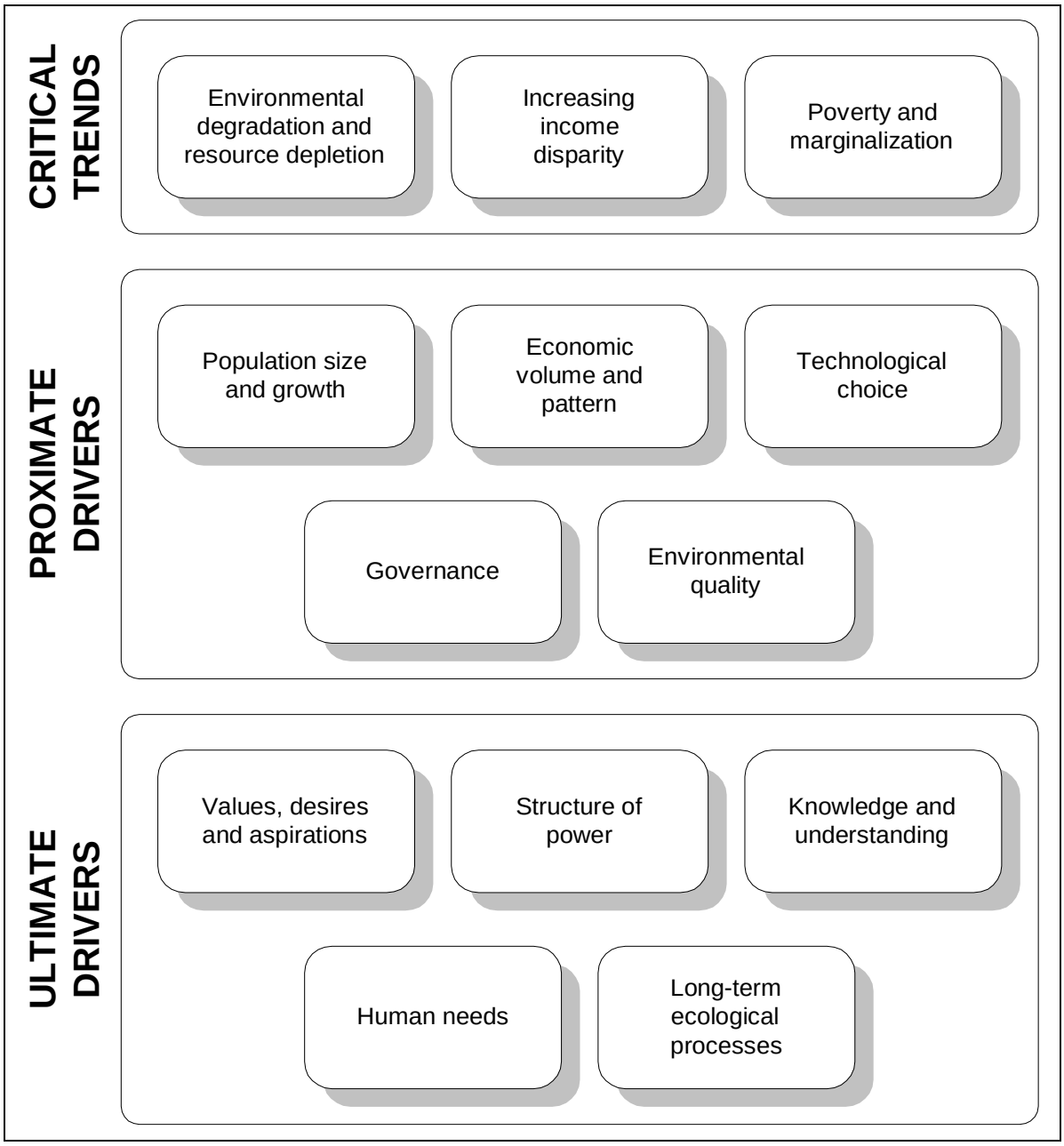

Figure 24. Unsustainability Trends and Drivers

With reference to Figure 24, the major proximate drivers requiring policy attention include the following:

- **Population size and growth.** Population size is a major determinant of total pressure on the environment and resources. Population density often correlates to local environmental pressure. Rapid rates of population growth tax the capacity of governments to provide adequate infrastructure and services. The stresses are manifest in developing regions in both burgeoning urban centers and zones of rural poverty.

- **Economic volume and pattern.** All else equal, the bigger the economy, the larger the throughput of material resources and energy. Levels of natural resource consumption and waste production tend to correlate with the level of economic output. The detailed relationship is closely linked to the pattern of consumption, lifestyles, income distribution, and poverty.
- **Technological choice.** The choice of technology — the means by which societies, organizations and individuals accomplish tasks — influences the environmental and social impact per unit of production or consumption. Eco-efficient production technologies play a major role in formulating *Policy Reform* scenarios, as do the choice of consumption technologies, e.g., use of recycled and resource-efficient products. The choice of technology depends on engineering criteria, cost, and cultural preference.
- **Governance.** Construed broadly, governance includes the aggregate of processes, systems, relationships, and arrangements by which human communities interact, both through governments and non-governmental mechanisms. Current governance structures are a serious obstacle to sustainable development in many countries. At national and regional levels, institutional and legal fragmentation undermines the development of the integrated policy responses required for a transition to a *Policy Reform* scenario. Inappropriate allocation mechanisms contribute both to environmental degradation and to poverty (e.g., land tenure systems in some parts of the world foster deforestation and impoverishment). Meanwhile, global systems of governance are struggling to cope with the immense challenges of economic globalization and transnational environmental threats.
- **Environmental quality.** Poor soils, extreme climate, or fragile ecosystems characterize some areas of the world. These conditions may either be natural or human-induced. Many of the rural poor live in resource-poor and fragile lands, while often the urban poor are confined to the most polluted areas. Impoverishment and low environmental quality can combine in a downward spiraling process. Human action can address certain aspects of environmental quality through environmental restoration efforts and the reduction of pressure on environmental systems.

The categories of ultimate drivers introduced in Figure 24 are the following:

- **Values, desires and aspirations.** The prevailing values in a society set the criteria for individual ambition, ethics, and aesthetic sensibility. Values are culturally conditioned, defining the social consensus on what is considered normal or desirable. Depending on the underlying values, a society will be characterized somewhere along a spectrum between a sense of common purpose and antagonism, between social solidarity and individualism, between materialism and a concern for deeper meaning. Consumerism is a significant value in shaping current trends and driving human desires and aspirations in directions that appear to be unsustainable. A sense of solidarity with both current and future generations, were it to become a defining global value, would form the motivational basis for a transition to sustainable development.
- **Human needs.** Here, we include material needs, such as for food and shelter, as well as non-material needs, such as for love and meaning. Fundamental human needs —

the generic human requirements for health — are invariable and universal. But the specific elements to satisfy them are to a high degree culturally determined. Policies cannot modify underlying human needs, but they can affect the choice of specific "satisfiers." Furthermore, advertising and the media can influence the creation of wants and their conversion into felt needs.

- **Knowledge and understanding.** The scientific enterprise — the formal organization of knowledge into theory and observation — shapes both the world view of modern societies and the capacity to manipulate natural and social systems. The evolution of science to reflect the complexity, holism, and normative character of the sustainability problem could be both a harbinger and a driver of change. In addition, informal knowledge — the manner in which people perceive and make sense of their conditions as individuals and participants in society — is critical in influencing behavior and responses to changing circumstances. Culture, education, and the media are important in shaping understanding.
- **Structure of power.** The control of resources, influence, and decision-making authority defines the power structure. The structure circumscribes the limits of the possible, particularly for the non-powerful, and sets priorities for society. It influences allocation and redistribution processes and, through the media, even shapes human values, preferences, and consumption patterns. A notable property of the current global power structure is its pronounced international asymmetry.
- **Long-term ecological processes.** Ecological processes mold the physical background against which human trends and scenarios play out. These include long-term evolutionary processes, short-term natural changes and disturbances such as hurricanes and volcanic eruptions, and natural cycles such as seasonal variations or El Niño events. At this stage of history, the human footprint on the environment has grown to a point where global ecology is significantly disturbed. Notable are the severe impacts on biodiversity loss and the perilous modification of the global climate system due to greenhouse gas emissions.

Policy Reform scenarios examine the instrumental changes that are needed without altering fundamental values and institutions. The focus is on redirecting the proximate drivers through economic reform, regulation, redistribution, and technological initiative. Whether this would suffice is an open question. The ultimate drivers concern the basic character of human motivation and social structure. The greater challenge of addressing ultimate drivers is left for *Great Transition* scenarios.

5.5 Policy Directions

As its name implies, the *Policy Reform* scenario has numerous implications for policy making. Targets for poverty alleviation, international economic convergence, social equity, and the environment set specific goals for the sustainability transition. Social goals are represented, for example, by a call to reduce the hungry population to one quarter of current figures by the middle of the 21st century and by patterns of convergent development both between and within economic regions. Environmental goals are expressed in terms of regional targets, such as carbon emission levels with convergence

toward equal per capita emissions. The *Policy Reform* scenario defines directions for change: the issue now becomes choosing the set of policy instruments that can help steer development in the same direction.

Innumerable policy proposals for sustainable development have been put forward. The array of options for attaining social objectives is summarized in Table 6 and for environmental objectives in Table 7. Within each of these aggregate policy categories, there is an enormous variety of specific alternatives and variations. Specific sectoral initiatives are suggested in Section 4. It is encouraging that many of the instruments are currently being employed at local, national, or international levels. Yet, policy packages do not have the necessary breadth and depth required for a transition to sustainable development. While success stories exist — the international ban on ozone-depleting substances, the worldwide reduction in lead use, the significant increase in life expectancy among developing countries' populations — much more is needed for global changes on the scale of a *Policy Reform* scenario.

Table 6. Policy Instruments to Attain the Proposed Social Objectives

- **International income transfers** through multilateral or bilateral official development assistance, special international funds, and voluntary donations mobilized by UN agencies, charities, NGOs, and others.
- **International agreements to safeguard the rights of the poor** from, e.g., child exploitation and trade, labor and migration discrimination.
- **National income transfers** through public taxes and subsidies, as well as voluntary donations mobilized by charities, NGOs, and others.
- **Economic growth stimulation** in less developed countries through international assistance programs, trade arrangements, capacity building, and a variety of national structural adjustment efforts (note that social objectives are addressed only to the extent that increased income inequality does not negate the benefits of overall growth accruing to the poor).
- **Social empowerment measures** to recognize the rights of women, minorities, and children.
- **Investment in people** ("human capital") through education, health care, and training.
- **Participation by new social actors** through encouragement of communities, grass roots organizations and NGO initiatives, and provision of mechanisms for taking part in decision-making.
- **Access of the poor to productive assets and income generating opportunities** through a variety of steps including land and natural resources tenure, technology transfer, infrastructure investment (such as transport and storage facilities), and credit and marketing services targeted for poor producers.
- **Solidarity policies** ("safety nets") for disadvantaged groups such as destitute households, poor children, the sick, the handicapped and the elderly.
- **Persuasion efforts** to promote solidarity values conducted by governments, religious groups, NGOs, advocacy organizations, and others through formal and informal education, information provision, public debate, media programming, etc.

Table 7. Policy Instruments to Attain the Proposed Environmental Objectives

- **International agreements** on treatment of global commons, biodiversity, and resource and technology transfers.
- **Environmental codes of conduct** associated with international commerce, investment, tourism, transport, migration, biodiversity uses, etc.
- **Reactive regulations, laws, and rules** that discourage known environmental disruption (e.g., regulation to control pollution and natural resource depletion).
- **Proactive regulations, laws, and rules** that encourage the introduction of sustainable practices (e.g., measures that foster energy efficiency, recycling and clean technologies, biodiversity and natural resource conservation).
- **Scientific and technological development** for a) pollution prevention, b) clean production and consumption technologies, c) sustainable use of natural environments and resources, d) deepening the understanding of environment and society interactions, and e) enhancing decision making tools (e.g., green accounting, long range assessment, EIA).
- **Green budgets** which use fiscal measures as a lever to promote environmental goals, including a) directing public expenditure to ecologically-friendly products (e.g., efficient technologies, recycled products), b) using pollution and natural resource depletion taxes ("eco-taxes") as a primary source of public revenue, and c) moving subsidies from activities that foster resource inefficiency and environmental degradation to those that promote sustainability.
- **Social empowerment policies** that acknowledge and support traditional property rights of local and indigenous communities and traditional sustainable uses of biodiversity.
- **Persuasion efforts** to promote environmental sustainability values conducted by governments, religious groups, NGOs, advocacy organizations, and others through formal and informal education, information provision, public debate, media programming, etc.
- **Economic policies** to motivate sustainable behavior based on individual and corporate economic self-interest and to use market allocation mechanisms to attain environmental goals in an economically efficient manner, including:
  - **full pricing of environmental goods and services** ("internalization of externalities") through a) charges or royalty fees on pollution, production, resource extraction, or resource development, b) ecological taxes, c) deposit-refund systems, bond and deposit systems, and d) import tariffs and export taxes.
  - **stimulation of environmental markets** through a) tradable permits for pollution and resource use, b) assigning property rights to own, use, or develop resources, and c) liability and insurance markets.
  - **distribution of subsidies** through a) tax breaks, b) tax differentials, c) exemptions from charges, d) grants, e) soft loans, f) accelerated depreciation allowances, etc.

There is no single best package of options. Rather, diverse approaches will be needed that are appropriate to the issue, level of governance and local concerns. A number of considerations come into play: social and political acceptability, economic efficiency, implementation and enforcement hurdles, equity impacts and the local environmental features. Many of these concerns are specific to national and local

contexts, and cannot be properly addressed from the global perspective assumed here. Nevertheless, the global scenario approach can offer the following important guidelines for formulating policies for the transition:

- **Seek consistency across sectors.** A complex and interacting set of processes that span environmental, economic, technological, social, cultural, and political dimensions drive the global system. Policies aimed at one aspect, such as poverty alleviation, may exacerbate other problems, such as environmental degradation. Contradictory sectoral policies can negate one another or backfire. Scenario analysis helps identify opportunities for mutual reinforcement between sectoral policies. For example, the *Policy Reform* scenario provides a guide for avoiding measures for environmentally sustainable goals that are at the expense of the poor or that promote social goals in an environmentally unsustainable way. Similarly, the need for compatibility and synergy between initiatives in agriculture, water, and energy sectors is underscored in the integrated scenario analysis.
- **Aim for spatial integration while recognizing local diversity.** Policies need to be consistent across scales, as well as across sectors. For instance, national policies should neither inhibit local initiatives nor undermine global policies. Moreover, since each human community and ecosystem is unique, policies should allow for and encourage adaptations to the local context and conditions. Again, the integrated scenario approach can illuminate the requirements for a multilevel policy framework.
- **Harmonize short-term and long-term outlooks.** A long time horizon is an obvious requirement for policies that aim to affect development over many decades. But long-term policy is often, by default, the cumulative result of a series of policies with a shorter-term outlook. Therefore, short-term policies should be designed and assessed for their long-range impacts. Alternative policies may achieve similar short-term goals but have very different long-term impacts. Ideally, policies should create a platform for the next round of new and more advanced policies. The scenario approach is particularly appropriate for incorporating long-term considerations into today's policy discussions.
- **Preserve flexibility and future options.** Because of the many uncertainties inherent in the unfolding future, flexibility and adaptability to change is critical for the design of resilient policies. Wherever possible, major policy proposals should be assessed in this regard, and scenario techniques can help in doing so.
- **Promote pluralism.** As we have noted, new social actors are becoming increasingly important, complementing traditional modes of decision-making and action. In particular, NGOs encompass a dizzying variety of interests including educational organizations, trade unions, religious organizations, charities, and media. While governments must shoulder their responsibility for confronting the challenge of the sustainability transition, the policy process should involve and mobilize all relevant institutions, tapping into their diverse capacity and potential for interaction, synergy, and complementarity. This means that participation, negotiation, and the articulation of multiple goals should substitute for antagonism and exclusion. Again, a scenario-building process that can cultivate contrasting visions and perspectives is a critical technique for fostering pluralistic dialogue.

The *Policy Reform* scenario focuses on policies for adjusting the current trends, not on a fundamental alteration in institutions and values. Nevertheless, sustainability policy must be open to opportunities for addressing the evolution of what we have called ultimate drivers, as well. An appreciation of the interplay between immediate and ultimate causes is important to the design of the appropriate policy instruments, since environmental problems can have similar symptoms but different causes. For instance, very different policy instruments are necessary when land erosion is driven by the commercial search for short-term profits, instead of by the survival needs of the poor. Regulations or economic incentives can discourage environmentally disruptive practices, while education for new social values can change behaviors.

5.6 Conventional Worlds and Beyond

The lesson of the *Conventional Worlds-Reference* scenario is not that the world will inevitably follow an unsatisfactory development path in the absence of proactive policy interventions. Even without action, it is possible that unforeseen surprises, feedbacks, and adaptations could mitigate the social and environmental pressures of the *Reference* world — or exacerbate them. The message is, rather, that there are deepening risks and uncertainties and that complacency is not a valid option for those who believe that passing on a more secure future is a moral imperative.

The discussion of *Conventional Worlds-Policy Reform* scenarios brought both good news and bad news. The good news is that making great strides toward the sustainability transition does not require that we posit either a social revolution or the *deus ex machina* of a technological miracle. Though there are numerous constraints and challenges, the cumulative effects of a comprehensive family of feasible incremental adjustments can make a substantial difference. An evolutionary process that promotes appropriate technology, improved environmental management, and greater international and social equity would take us a long way. The bad news is that *Policy Reform* scenarios do require a strong postulate — the *hypothesis of sufficient political will*. They assume that an unprecedented commitment arises for achieving sustainability goals and that effective economic, social, and institutional reforms are introduced for achieving them. The hypothesis poses critical questions for the *Policy Reform* route to the sustainability transition. Can today's nascent political formations acting on behalf of sustainability overcome the resistance of special interests, the myopia of narrow outlooks, and the inertia of complacency? Or are fundamental changes required in values and lifestyles that transcend *Conventional Worlds* assumptions — a *Great Transition*?

These basic questions will be addressed in the struggle over the design and implementation of specific actions. The scenario approach reminds us that there is more than one route to sustainability and that a successful transition does not depend on a world-wide endorsement of any blueprint. We see before us a process of social discussion, of forging alliances to foster the implementation of short and medium term agendas, and of the ascendancy of new values in the long run. Progress will probably not be linear — social and environmental surprises are likely to jolt the world system and reorient public awareness. Slowly a consensus can be built for an agenda to avoid major

social and environmental disruptions. This generation will bestow the gift of choice to posterity if it can begin to bend the curve of development toward sustainability.

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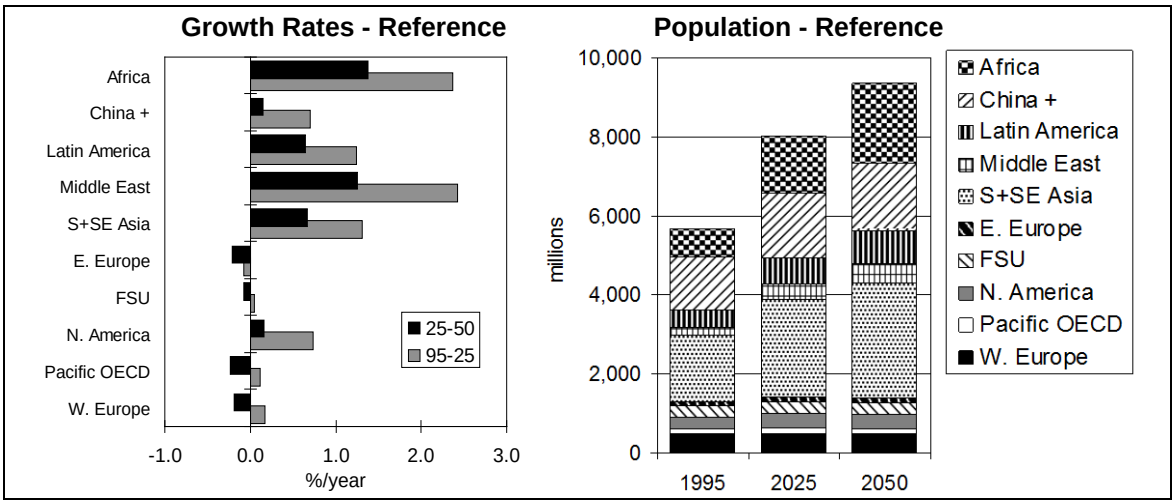


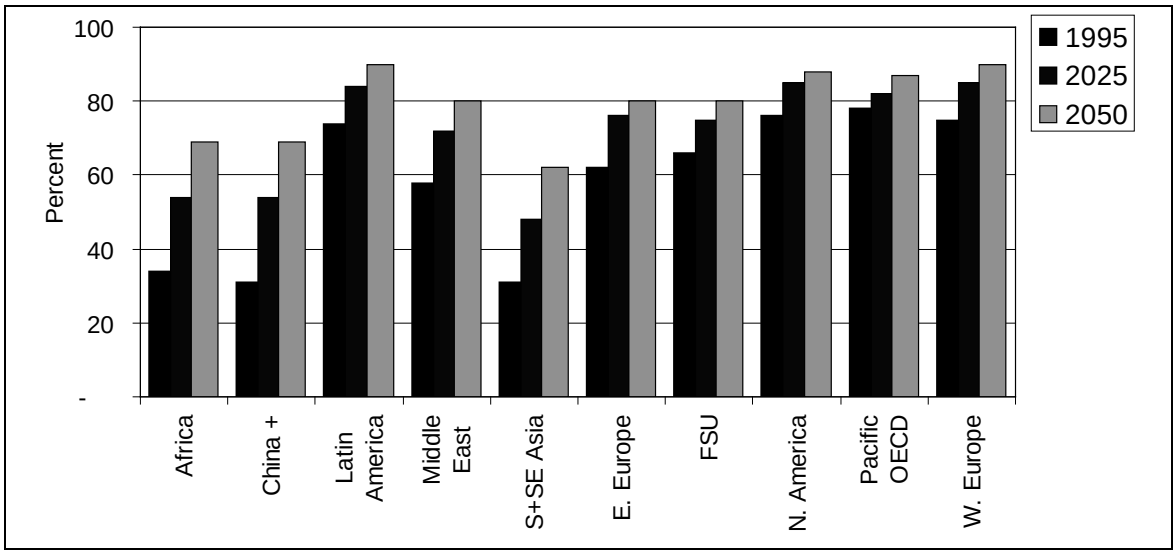
Reference

	Population (millions)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	719	1,454	2,046	2.4	1.4	1.9	2.0	2.8
China +	1,330	1,642	1,704	0.7	0.1	0.5	1.2	1.3
Latin America	477	689	810	1.2	0.6	1.0	1.4	1.7
Middle East	178	365	499	2.4	1.3	1.9	2.1	2.8
S+SE Asia	1,677	2,479	2,925	1.3	0.7	1.0	1.5	1.7
E. Europe	99	97	92	-0.1	-0.2	-0.1	1.0	0.9
FSU	293	297	291	0.0	-0.1	0.0	1.0	1.0
N. America	297	369	384	0.7	0.2	0.5	1.2	1.3
Pacific OECD	149	154	146	0.1	-0.2	0.0	1.0	1.0
W. Europe	467	492	469	0.2	-0.2	0.0	1.1	1.0
Developing	4,382	6,630	7,985	1.4	0.7	1.1	1.5	1.8
Transitional	392	394	383	0.0	-0.1	0.0	1.0	1.0
OECD	913	1,015	998	0.4	-0.1	0.2	1.1	1.1
World	5,687	8,039	9,367	1.2	0.6	0.9	1.4	1.6

Policy Reform

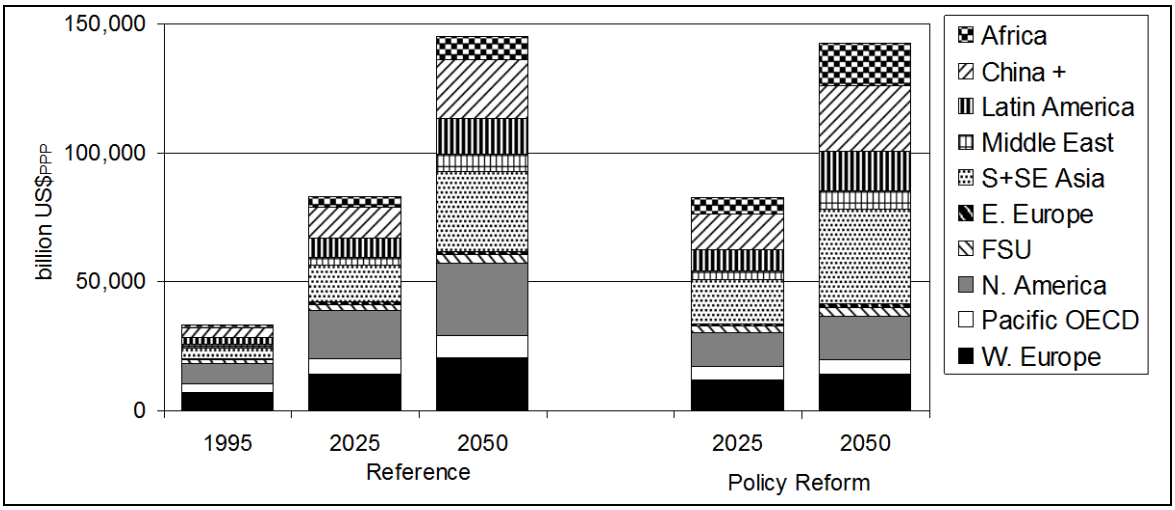
	Population (millions)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	719	1,425	1,944	2.3	1.3	1.8	2.0	2.7
China +	1,330	1,609	1,619	0.6	0.0	0.4	1.2	1.2
Latin America	477	676	770	1.2	0.5	0.9	1.4	1.6
Middle East	178	358	474	2.4	1.1	1.8	2.0	2.7
S+SE Asia	1,677	2,430	2,779	1.2	0.5	0.9	1.4	1.7
E. Europe	99	95	87	-0.1	-0.3	-0.2	1.0	0.9
FSU	293	291	277	0.0	-0.2	-0.1	1.0	0.9
N. America	297	369	384	0.7	0.2	0.5	1.2	1.3
Pacific OECD	149	154	146	0.1	-0.2	0.0	1.0	1.0
W. Europe	467	492	469	0.2	-0.2	0.0	1.1	1.0
Developing	4,382	6,498	7,586	1.3	0.6	1.0	1.5	1.7
Transitional	392	386	364	-0.1	-0.2	-0.1	1.0	0.9
OECD	913	1,015	998	0.4	-0.1	0.2	1.1	1.1
World	5,687	7,899	8,948	1.1	0.5	0.8	1.4	1.6

Sheet D-2. Urbanization



	Urbanization (%)		
Region	1995	2025	2050
Africa	34	54	69
China +	31	54	69
Latin America	74	84	90
Middle East	58	72	80
S+SE Asia	31	48	62
E. Europe	62	76	80
FSU	66	75	80
N. America	76	85	88
Pacific OECD	78	82	87
W. Europe	75	85	90
Developing	37	56	70
Transitional	65	75	80
OECD	76	84	89
World	45	61	72

Sheet E-1. GDP



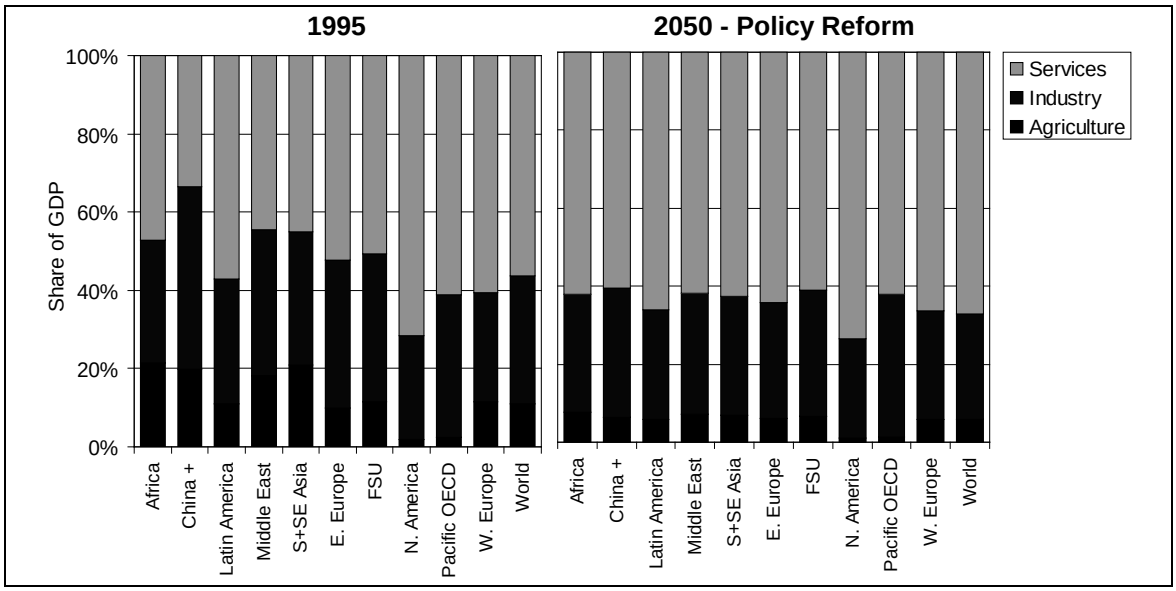
Reference

GDP (billion US$)	MER	PPP			Growth Rate (%/year)			Index (95=1)	
Region	1995	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	475	1,165	3,958	9,279	4.2	3.5	3.8	3.4	8.0
China +	893	3,839	12,099	22,555	3.9	2.5	3.3	3.2	5.9
Latin America	1,651	2,858	7,449	14,071	3.2	2.6	2.9	2.6	4.9
Middle East	522	938	3,159	6,554	4.1	3.0	3.6	3.4	7.0
S+SE Asia	1,769	4,329	14,160	30,745	4.0	3.1	3.6	3.3	7.1
E. Europe	274	588	1,039	1,396	1.9	1.2	1.6	1.8	2.4
FSU	528	1,206	2,197	3,032	2.0	1.3	1.7	1.8	2.5
N. America	7,464	7,995	18,552	28,016	2.8	1.7	2.3	2.3	3.5
Pacific OECD	5,544	3,146	6,082	8,524	2.2	1.4	1.8	1.9	2.7
W. Europe	9,085	7,352	14,422	20,953	2.3	1.5	1.9	2.0	2.8
Developing	5,310	13,129	40,825	83,204	3.9	2.9	3.4	3.1	6.3
Transitional	802	1,794	3,236	4,427	2.0	1.3	1.7	1.8	2.5
OECD	22,094	18,493	39,056	57,492	2.5	1.6	2.1	2.1	3.1
World	28,205	33,416	83,117	145,124	3.1	2.3	2.7	2.5	4.3

Policy Reform

GDP (billion US$)	MER	PPP			Growth Rate (%/year)			Index (95=1)	
Region	1995	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	475	1,165	6,381	16,427	5.8	3.9	4.9	5.5	14.1
China +	893	3,839	13,762	25,368	4.3	2.5	3.5	3.6	6.6
Latin America	1,651	2,858	8,026	15,177	3.5	2.6	3.1	2.8	5.3
Middle East	522	938	3,501	7,383	4.5	3.0	3.8	3.7	7.9
S+SE Asia	1,769	4,329	17,013	36,417	4.7	3.1	3.9	3.9	8.4
E. Europe	274	588	1,120	1,533	2.2	1.3	1.8	1.9	2.6
FSU	528	1,206	2,501	3,610	2.5	1.5	2.0	2.1	3.0
N. America	7,464	7,995	13,341	16,494	1.7	0.9	1.3	1.7	2.1
Pacific OECD	5,544	3,146	4,742	5,451	1.4	0.6	1.0	1.5	1.7
W. Europe	9,085	7,352	12,202	14,524	1.7	0.7	1.2	1.7	2.0
Developing	5,310	13,129	48,683	100,772	4.5	3.0	3.8	3.7	7.7
Transitional	802	1,794	3,622	5,143	2.4	1.4	1.9	2.0	2.9
OECD	22,094	18,493	30,285	36,468	1.7	0.7	1.2	1.6	2.0
World	28,205	33,416	82,590	142,383	3.1	2.2	2.7	2.5	4.3

Sheet E-2. Structure of GDP



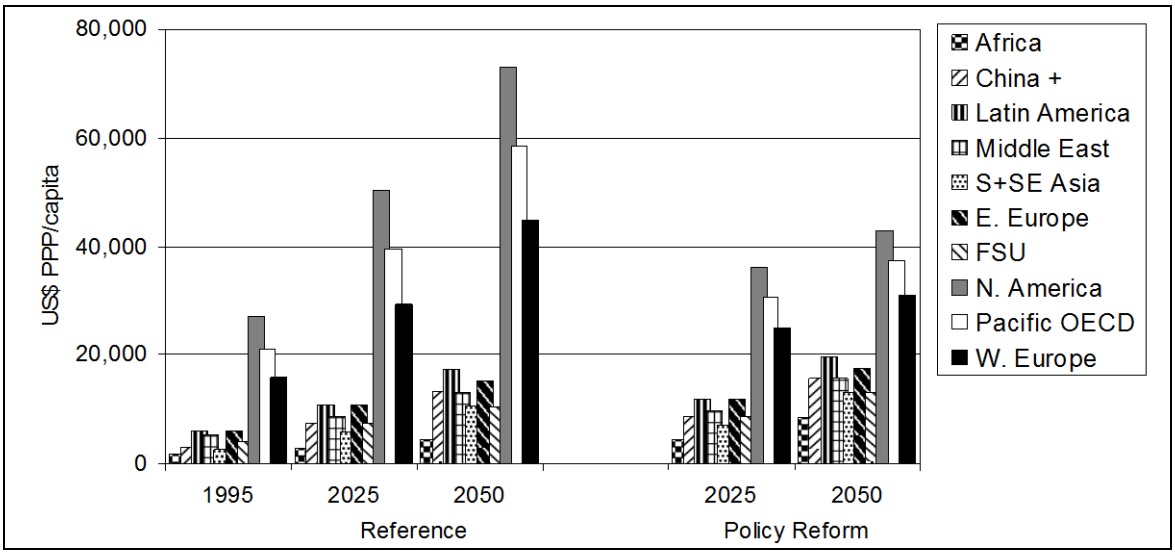
Reference

Share of GDP (%)		1995			2025			2050	
Region	Agriculture	Industry	Services	Agriculture	Industry	Services	Agriculture	Industry	Services
Africa	21	31	47	15	31	54	11	31	59
China +	20	47	34	10	42	48	7	36	58
Latin America	11	32	57	8	31	62	6	29	65
Middle East	18	37	44	12	35	53	8	33	59
S+SE Asia	21	34	45	11	33	56	8	31	61
E. Europe	10	38	52	7	35	58	6	32	62
FSU	12	38	51	8	36	56	7	34	59
N. America	2	27	72	1	26	73	1	25	74
Pacific OECD	2	37	61	1	37	62	1	37	63
W. Europe	11	28	61	6	28	66	4	28	68
Developing	18	37	44	11	35	55	8	30	62
Transitional	11	38	51	8	35	57	7	31	62
OECD	6	29	65	3	26	71	2	24	74
World	11	33	56	7	31	63	5	28	67

Policy Reform

Share of GDP (%)		1995			2025			2050	
Region	Agriculture	Industry	Services	Agriculture	Industry	Services	Agriculture	Industry	Services
Africa	21	31	47	11	31	59	8	30	62
China +	20	47	34	9	41	51	6	33	61
Latin America	11	32	57	7	31	62	6	28	66
Middle East	18	37	44	10	35	55	7	31	62
S+SE Asia	21	34	45	10	33	57	7	31	63
E. Europe	10	38	52	7	34	59	6	30	64
FSU	12	38	51	8	35	57	7	32	61
N. America	2	27	72	1	26	73	1	25	74
Pacific OECD	2	37	61	2	37	62	1	37	62
W. Europe	11	28	61	7	28	65	6	28	66
Developing	18	37	44	9	34	57	7	28	65
Transitional	11	38	51	7	34	59	6	29	64
OECD	6	29	65	4	26	70	3	24	73
World	11	33	56	7	31	62	6	27	67

Sheet E-3. Income



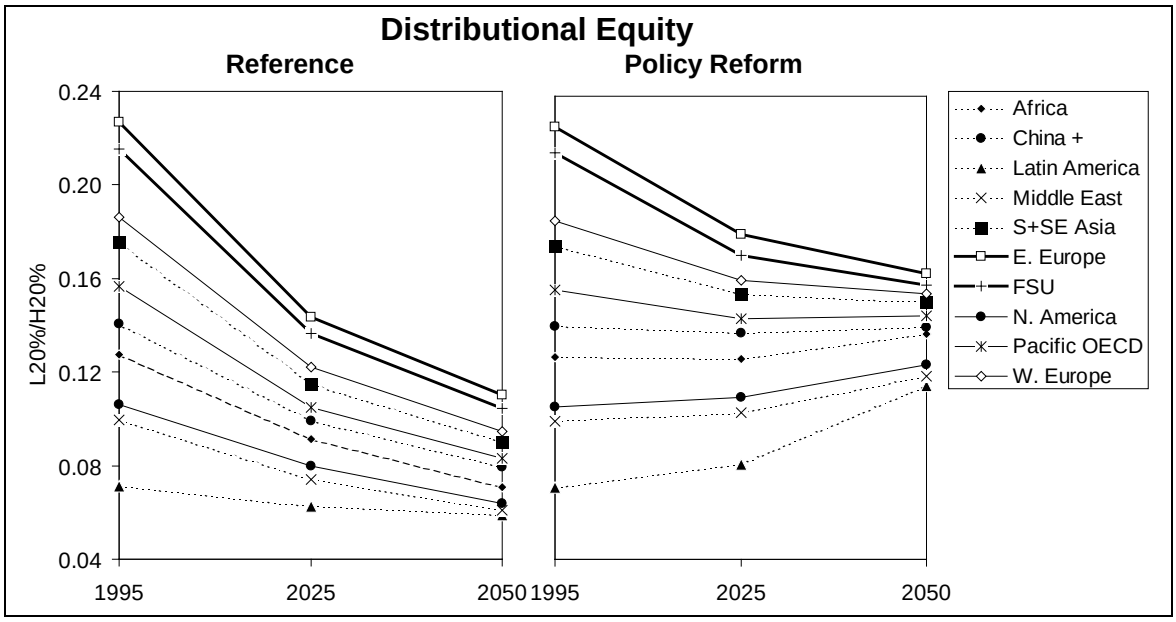
Reference

	GDP per capita (1995 US$ PPP)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	1,619	2,722	4,534	1.7	2.1	1.9	1.7	2.8
China +	2,887	7,369	13,234	3.2	2.4	2.8	2.6	4.6
Latin America	5,999	10,804	17,366	2.0	1.9	2.0	1.8	2.9
Middle East	5,261	8,643	13,123	1.7	1.7	1.7	1.6	2.5
S+SE Asia	2,581	5,711	10,512	2.7	2.5	2.6	2.2	4.1
E. Europe	5,946	10,760	15,220	2.0	1.4	1.7	1.8	2.6
FSU	4,111	7,394	10,405	2.0	1.4	1.7	1.8	2.5
N. America	26,946	50,265	72,932	2.1	1.5	1.8	1.9	2.7
Pacific OECD	21,104	39,368	58,544	2.1	1.6	1.9	1.9	2.8
W. Europe	15,727	29,337	44,714	2.1	1.7	1.9	1.9	2.8
Developing	2,996	6,157	10,420	2.4	2.1	2.3	2.1	3.5
Transitional	4,574	8,220	11,558	2.0	1.4	1.7	1.8	2.5
OECD	20,249	38,472	57,589	2.2	1.6	1.9	1.9	2.8
World	5,876	10,339	15,494	1.9	1.6	1.8	1.8	2.6

Policy Reform

	GDP per capita (1995 US$ PPP)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	1,619	4,479	8,450	3.5	2.6	3.1	2.8	5.2
China +	2,887	8,553	15,668	3.7	2.5	3.1	3.0	5.4
Latin America	5,999	11,879	19,717	2.3	2.0	2.2	2.0	3.3
Middle East	5,261	9,774	15,561	2.1	1.9	2.0	1.9	3.0
S+SE Asia	2,581	7,001	13,106	3.4	2.5	3.0	2.7	5.1
E. Europe	5,946	11,835	17,596	2.3	1.6	2.0	2.0	3.0
FSU	4,111	8,590	13,041	2.5	1.7	2.1	2.1	3.2
N. America	26,946	36,147	42,937	1.0	0.7	0.9	1.3	1.6
Pacific OECD	21,104	30,696	37,437	1.3	0.8	1.0	1.5	1.8
W. Europe	15,727	24,821	30,995	1.5	0.9	1.2	1.6	2.0
Developing	2,996	7,492	13,284	3.1	2.3	2.7	2.5	4.4
Transitional	4,574	9,386	14,131	2.4	1.7	2.1	2.1	3.1
OECD	20,249	29,833	36,530	1.3	0.8	1.1	1.5	1.8
World	5,876	10,456	15,912	1.9	1.7	1.8	1.8	2.7

Sheet S-1. Income Distribution



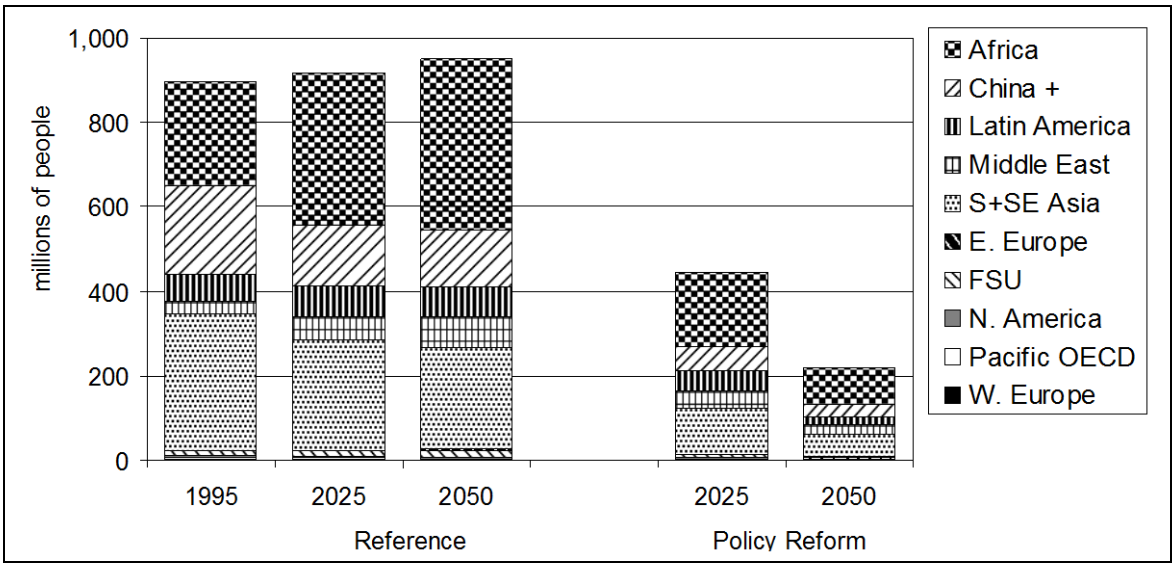
Reference

	Distributional Equity (L20%/H20%)			Gini Coefficient		
Region	1995	2025	2050	1995	2025	2050
Africa	0.13	0.09	0.07	0.42	0.46	0.50
China +	0.14	0.10	0.08	0.38	0.44	0.47
Latin America	0.07	0.06	0.06	0.50	0.51	0.52
Middle East	0.10	0.07	0.06	0.45	0.49	0.51
S+SE Asia	0.18	0.11	0.09	0.34	0.41	0.45
E. Europe	0.23	0.14	0.11	0.29	0.37	0.42
FSU	0.22	0.14	0.10	0.30	0.38	0.43
N. America	0.11	0.08	0.06	0.43	0.47	0.51
Pacific OECD	0.16	0.11	0.08	0.36	0.43	0.47
W. Europe	0.19	0.12	0.09	0.33	0.41	0.45
World (pop. weighted)	0.15	0.10	0.08			

Policy Reform

	Distributional Equity (L20%/H20%)			Gini Coefficient		
Region	1995	2025	2050	1995	2025	2050
Africa	0.13	0.13	0.14	0.42	0.42	0.39
China +	0.14	0.14	0.14	0.38	0.38	0.38
Latin America	0.07	0.08	0.12	0.50	0.47	0.41
Middle East	0.10	0.10	0.12	0.45	0.44	0.41
S+SE Asia	0.18	0.15	0.15	0.34	0.36	0.37
E. Europe	0.23	0.18	0.16	0.29	0.33	0.35
FSU	0.22	0.17	0.16	0.30	0.34	0.36
N. America	0.11	0.11	0.12	0.43	0.43	0.40
Pacific OECD	0.16	0.14	0.15	0.36	0.37	0.37
W. Europe	0.19	0.16	0.15	0.33	0.36	0.36
World (pop. weighted)	0.15	0.14	0.14			

Sheet S-2. Hunger



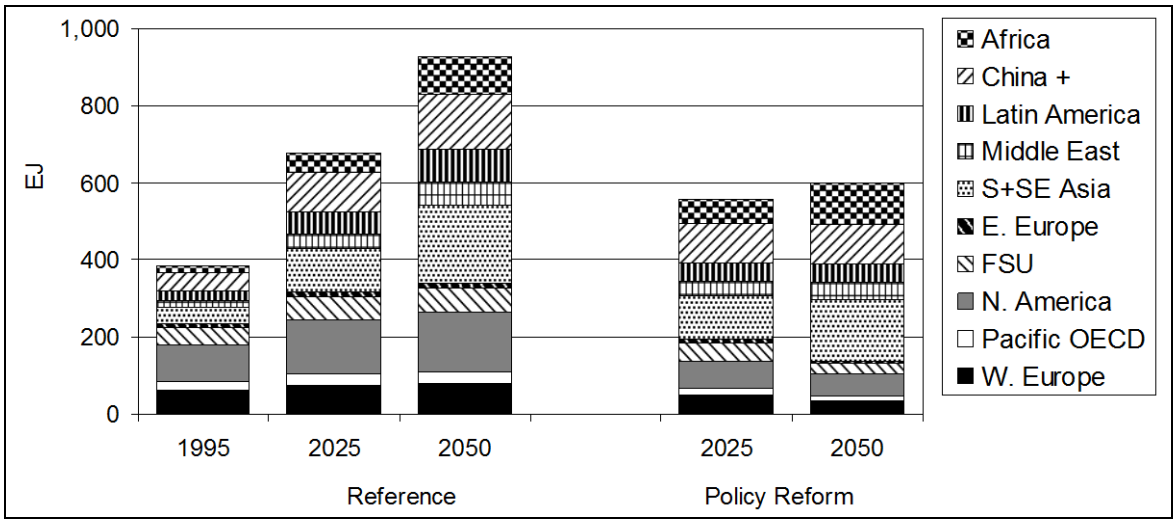
Reference

	Incidence (% of population)			Incidence (millions)			Index (95=1)	
Region	1995	2025	2050	1995	2025	2050	2025	2050
Africa	34	25	20	247	361	404	1.46	1.63
China +	16	9	8	211	142	136	0.67	0.64
Latin America	14	11	9	65	73	72	1.13	1.11
Middle East	16	16	14	29	57	72	1.95	2.45
S+SE Asia	19	10	8	320	259	240	0.81	0.75
E. Europe	1	2	3	1	2	3	2.72	4.24
FSU	4	5	6	11	14	18	1.24	1.55
N. America	2	1	1	7	3	2	0.45	0.34
Pacific OECD	1	1	0	1	1	0	0.53	0.32
W. Europe	1	1	1	4	4	4	1.06	0.94
Developing	20	13	12	873	893	924	1.02	1.06
Transitional	3	4	5	12	16	21	1.33	1.71
OECD	1	1	1	12	8	6	0.64	0.52
World	16	11	10	898	917	951	1.02	1.06

Policy Reform

	Incidence (% of population)			Incidence (millions)			Index (95=1)	
Region	1995	2025	2050	1995	2025	2050	2025	2050
Africa	34	12	5	247	174	87	0.70	0.35
China +	16	4	2	211	59	29	0.28	0.14
Latin America	14	7	2	65	49	18	0.75	0.28
Middle East	16	11	5	29	40	24	1.39	0.81
S+SE Asia	19	4	2	320	109	54	0.34	0.17
E. Europe	1	1	1	1	1	1	1.01	0.94
FSU	4	2	2	11	7	5	0.57	0.40
N. America	2	1	0	7	4	1	0.50	0.12
Pacific OECD	1	0	0	1	1	0	0.35	0.11
W. Europe	1	1	0	4	3	1	0.69	0.37
Developing	20	7	3	873	431	212	0.49	0.24
Transitional	3	2	1	12	7	5	0.60	0.43
OECD	1	1	0	12	7	2	0.54	0.19
World	16	6	2	898	445	220	0.50	0.25

Sheet En-1. Primary Energy Requirements by Region



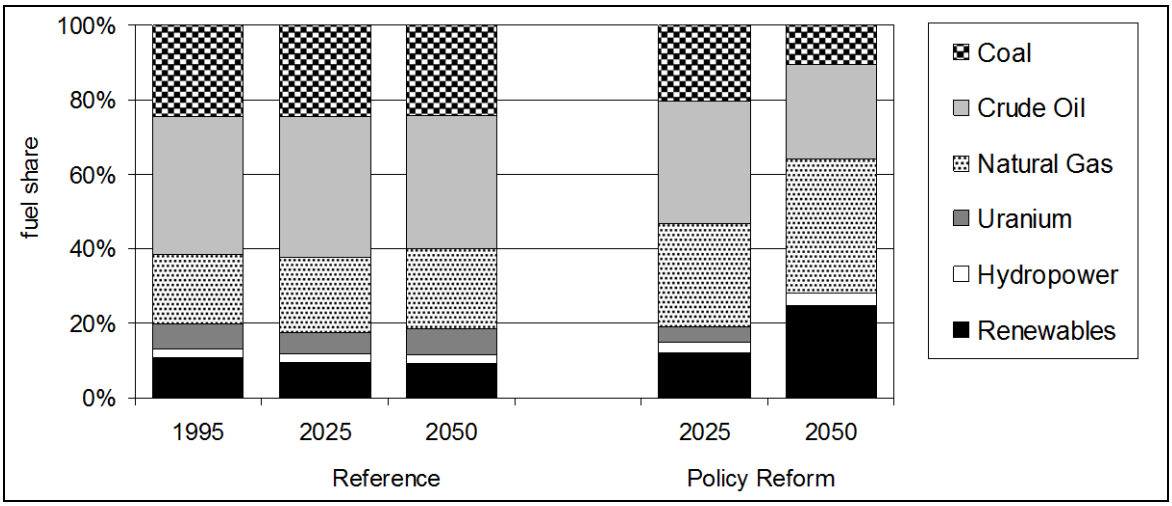
Reference

	Primary Energy (EJ)			Growth Rate (%/year)			Index (95=1)		Intensity (MJ/$ PPP)		
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050	1995	2025	2050
Africa	17	50	98	3.6	2.7	3.2	2.9	5.7	15	13	11
China +	48	105	144	2.7	1.3	2.0	2.2	3.0	12	9	6
Latin America	24	55	84	2.7	1.8	2.3	2.3	3.5	8	7	6
Middle East	18	38	60	2.5	1.9	2.2	2.1	3.3	19	12	9
S+SE Asia	43	114	205	3.3	2.4	2.9	2.7	4.8	10	8	7
E. Europe	10	13	12	0.8	-0.2	0.4	1.3	1.2	17	12	9
FSU	45	60	64	0.9	0.3	0.6	1.3	1.4	38	27	21
N. America	94	138	152	1.3	0.4	0.9	1.5	1.6	12	7	5
Pacific OECD	23	29	31	0.8	0.2	0.5	1.3	1.3	7	5	4
W. Europe	63	76	79	0.6	0.2	0.4	1.2	1.3	9	5	4
Developing	150	361	591	3.0	2.0	2.5	2.4	3.9	11	9	7
Transitional	55	73	76	0.9	0.2	0.6	1.3	1.4	31	22	17
OECD	179	243	262	1.0	0.3	0.7	1.4	1.5	10	6	5
World	384	677	929	1.9	1.3	1.6	1.8	2.4	12	8	6

Policy Reform

	Primary Energy (EJ)			Growth Rate (%/year)			Index (95=1)		Intensity (MJ/$ PPP)		
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050	1995	2025	2050
Africa	17	63	107	4.4	2.1	3.4	3.7	6.2	15	10	6
China +	48	104	105	2.6	0.0	1.4	2.2	2.2	12	8	4
Latin America	24	45	48	2.1	0.2	1.2	1.9	2.0	8	6	3
Middle East	18	37	41	2.4	0.4	1.5	2.1	2.3	19	11	6
S+SE Asia	43	114	160	3.3	1.4	2.4	2.7	3.8	10	7	4
E. Europe	10	9	6	-0.3	-1.4	-0.8	0.9	0.7	17	8	4
FSU	45	47	28	0.1	-2.0	-0.9	1.0	0.6	38	19	8
N. America	94	73	57	-0.8	-1.0	-0.9	0.8	0.6	12	5	3
Pacific OECD	23	17	12	-1.0	-1.3	-1.2	0.7	0.5	7	4	2
W. Europe	63	49	36	-0.8	-1.3	-1.0	0.8	0.6	9	4	2
Developing	150	363	460	3.0	0.9	2.1	2.4	3.1	11	7	5
Transitional	55	56	35	0.1	-1.9	-0.9	1.0	0.6	31	16	7
OECD	179	138	105	-0.9	-1.1	-1.0	0.8	0.6	10	5	3
World	384	558	599	1.2	0.3	0.8	1.5	1.6	12	7	4

Sheet En-2. Primary Energy Requirements by Source



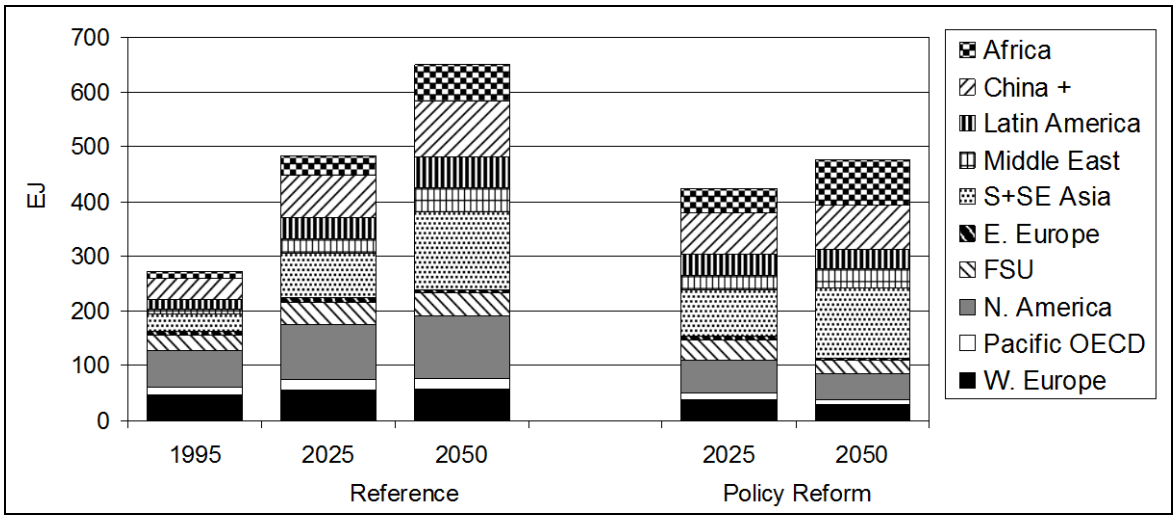
Reference

	Primary Energy (EJ)			Share of Total (%)			Growth Rate (%/year)			Index (95=1)	
Fuel	1995	2025	2050	1995	2025	2050	95-25	25-50	95-50	2025	2050
Coal	95	166	224	25	25	24	1.9	1.2	1.6	1.8	2.4
Crude Oil	141	256	332	37	38	36	2.0	1.0	1.6	1.8	2.3
Natural Gas	73	136	203	19	20	22	2.1	1.6	1.9	1.9	2.8
Uranium	25	39	64	7	6	7	1.5	2.0	1.7	1.5	2.5
Hydropower	9	16	20	2	2	2	1.9	0.9	1.4	1.7	2.2
Renewables	41	64	87	11	9	9	1.5	1.3	1.4	1.6	2.1
Total	384	677	929	100	100	100	1.9	1.3	1.6	1.8	2.4

Policy Reform

	Primary Energy (EJ)			Share of Total (%)			Growth Rate (%/year)			Index (95=1)	
Fuel	1995	2025	2050	1995	2025	2050	95-25	25-50	95-50	2025	2050
Coal	95	113	63	25	20	11	0.6	-2.3	-0.7	1.2	0.7
Crude Oil	141	183	153	37	33	26	0.9	-0.7	0.1	1.3	1.1
Natural Gas	73	156	215	19	28	36	2.6	1.3	2.0	2.1	2.9
Uranium	25	22	-	7	4	-	-0.4	-	-	0.9	0.0
Hydropower	9	16	20	2	3	3	1.9	0.9	1.4	1.7	2.2
Renewables	41	68	148	11	12	25	1.7	3.2	2.4	1.7	3.6
Total	384	558	599	100	100	100	1.2	0.3	0.8	1.5	1.6

Sheet En-3. Final Fuel Demand by Region



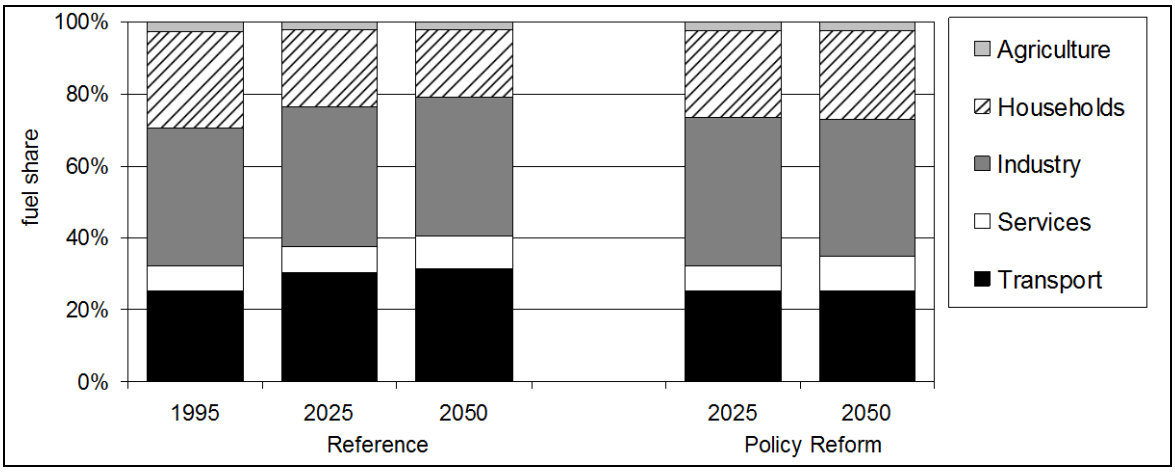
Reference

	Final Energy Demand (EJ)			Growth Rate (%/year)			Index (95=1)		Intensity (MJ/$ PPP)		
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050	1995	2025	2050
Africa	13	35	66	3.3	2.6	3.0	2.7	5.1	11	9	7
China +	37	77	103	2.5	1.1	1.9	2.1	2.8	10	6	5
Latin America	18	39	56	2.7	1.4	2.1	2.2	3.2	6	5	4
Middle East	9	26	42	3.7	2.0	2.9	2.9	4.8	9	8	6
S+SE Asia	33	82	143	3.1	2.2	2.7	2.5	4.3	8	6	5
E. Europe	6	8	8	0.8	-0.1	0.4	1.3	1.2	11	8	6
FSU	29	40	42	1.0	0.2	0.7	1.4	1.4	24	18	14
N. America	64	101	112	1.5	0.4	1.0	1.6	1.7	8	5	4
Pacific OECD	17	19	20	0.5	0.1	0.3	1.2	1.2	5	3	2
W. Europe	46	55	58	0.6	0.2	0.4	1.2	1.3	6	4	3
Developing	109	260	409	2.9	1.8	2.4	2.4	3.7	8	6	5
Transitional	36	48	50	1.0	0.2	0.6	1.3	1.4	20	15	11
OECD	126	176	190	1.1	0.3	0.7	1.4	1.5	7	4	3
World	272	483	649	1.9	1.2	1.6	1.8	2.4	8	6	4

Policy Reform

	Final Energy Demand (EJ)			Growth Rate (%/year)			Index (95=1)		Intensity (MJ/$ PPP)		
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050	1995	2025	2050
Africa	13	46	84	4.3	2.4	3.4	3.5	6.4	11	7	5
China +	37	76	80	2.5	0.2	1.4	2.1	2.2	10	6	3
Latin America	18	37	37	2.5	0.0	1.4	2.1	2.1	6	5	2
Middle East	9	26	33	3.7	1.0	2.5	2.9	3.8	9	7	5
S+SE Asia	33	88	129	3.3	1.5	2.5	2.6	3.9	8	5	4
E. Europe	6	6	5	0.1	-1.0	-0.4	1.0	0.8	11	6	3
FSU	29	37	24	0.7	-1.7	-0.4	1.2	0.8	24	15	7
N. America	64	59	47	-0.3	-0.9	-0.6	0.9	0.7	8	4	3
Pacific OECD	17	13	9	-0.9	-1.2	-1.0	0.8	0.6	5	3	2
W. Europe	46	38	29	-0.6	-1.1	-0.8	0.8	0.6	6	3	2
Developing	109	272	363	3.1	1.2	2.2	2.5	3.3	8	6	4
Transitional	36	43	29	0.6	-1.6	-0.4	1.2	0.8	20	12	6
OECD	126	109	85	-0.5	-1.0	-0.7	0.9	0.7	7	4	2
World	272	425	476	1.5	0.5	1.0	1.6	1.8	8	5	3

Sheet En-4. Final Fuel Demand by Sector



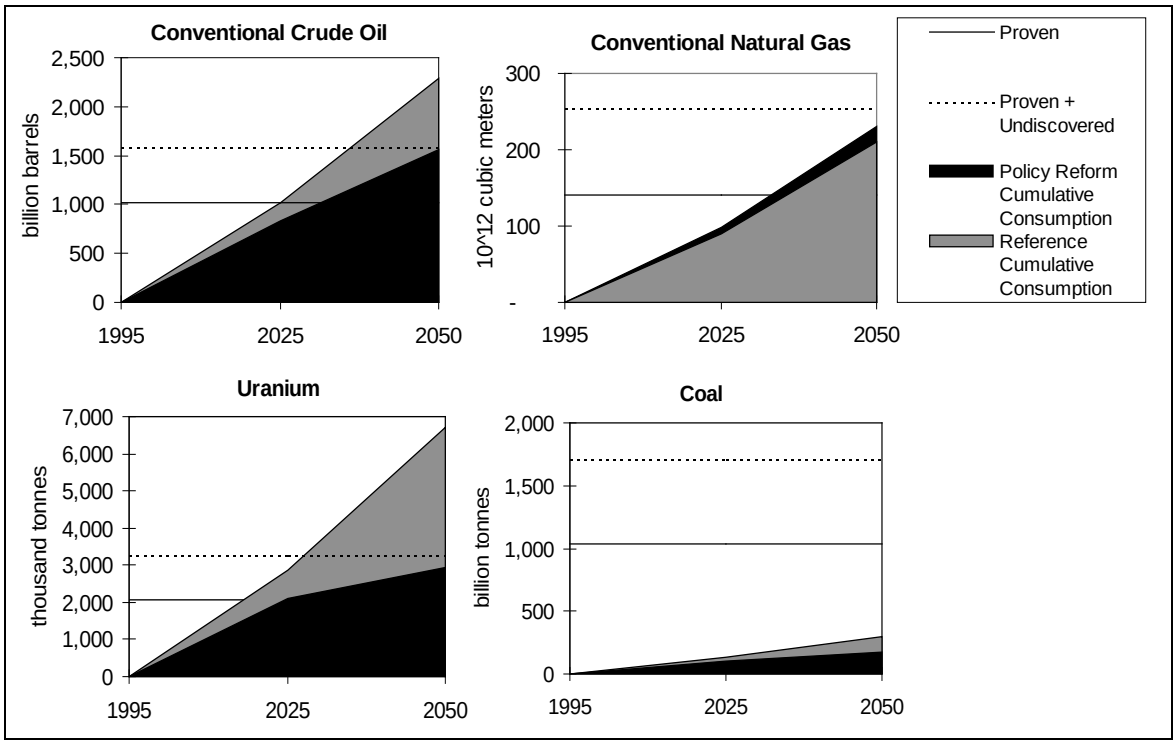
Reference

	Final Energy Demand (EJ)			Share of Total (%)			Growth Rate (%/year)			Index (95=1)	
Sector	1995	2025	2050	1995	2025	2050	95-25	25-50	95-50	2025	2050
Agriculture	8	11	14	3	2	2	1.1	1.0	1.0	1.4	1.8
Households	72	102	123	27	21	19	1.2	0.7	1.0	1.4	1.7
Industry	104	188	250	38	39	39	2.0	1.1	1.6	1.8	2.4
Services	19	34	58	7	7	9	2.1	2.1	2.1	1.9	3.1
Transport	69	147	204	25	30	31	2.6	1.3	2.0	2.1	3.0
Total	272	483	649	100	100	100	1.9	1.2	1.6	1.8	2.4

Policy Reform

	Final Energy Demand (EJ)			Share of Total (%)			Growth Rate (%/year)			Index (95=1)	
Sector	1995	2025	2050	1995	2025	2050	95-25	25-50	95-50	2025	2050
Agriculture	8	10	12	3	2	3	0.9	0.6	0.8	1.3	1.5
Households	72	102	116	27	24	24	1.2	0.5	0.9	1.4	1.6
Industry	104	175	184	38	41	39	1.7	0.2	1.0	1.7	1.8
Services	19	29	44	7	7	9	1.5	1.7	1.6	1.6	2.4
Transport	69	108	121	25	26	25	1.5	0.4	1.0	1.6	1.8
Total	272	425	476	100	100	100	1.5	0.5	1.0	1.6	1.8

Sheet En-5. Fossil Fuel Reserves

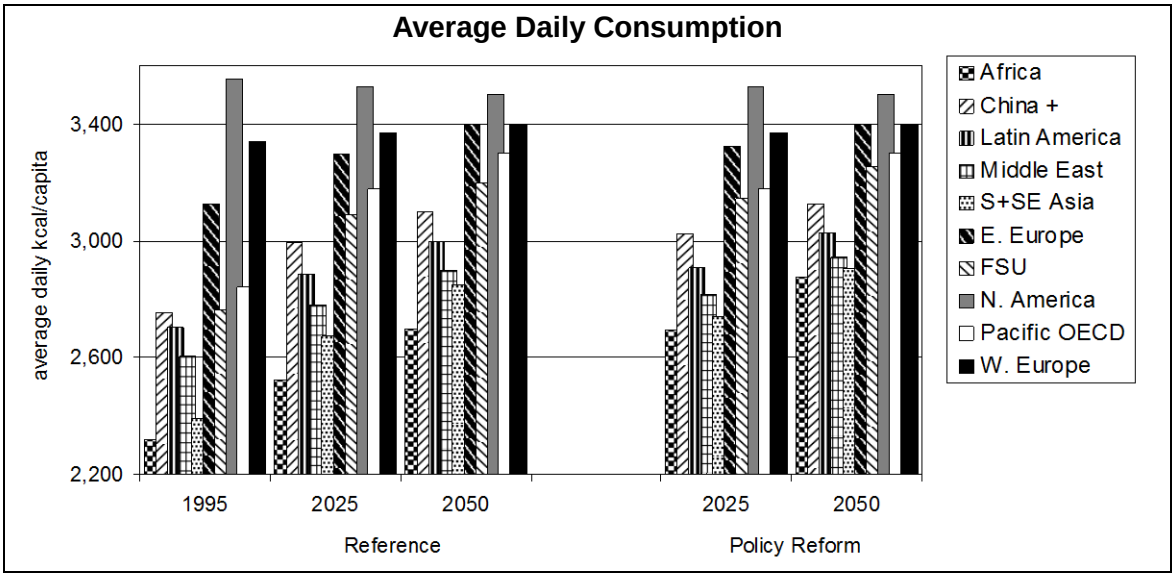


Total Remaining Reserves

Proven + Undiscovered, 1995

Region	Coal (10^9 t)	Crude Oil (10^9 barrels)	Natural Gas (10^{12} m^3)	Uranium (10^3 t)	Share of Reserves (%) Coal	Crude Oil	Natural Gas	Uranium
Africa	62	84	15	1,142	4	5	6	35
China+	265	276	4	5	16	17	2	0
Latin America	20	407	20	174	1	26	8	5
Middle East	0	670	80	-	0	42	31	-
S+SE Asia	151	24	13	57	9	2	5	2
E Europe	92	2	2	21	5	0	1	1
FSU	241	58	91	-	14	4	36	-
N America	249	45	21	799	15	3	8	24
Pacific OECD	525	3	2	926	31	0	1	28
W Europe	105	25	8	157	6	2	3	5
Developing	499	1,461	131	1,378	29	92	52	42
Transitional	333	60	92	21	19	4	36	1
OECD	879	73	31	1,881	51	5	12	57
World	1,711	1,594	254	3,281	100	100	100	100
World (EJ)	51,336	9,279	8,900	1,102				

Sheet F-1. Diets



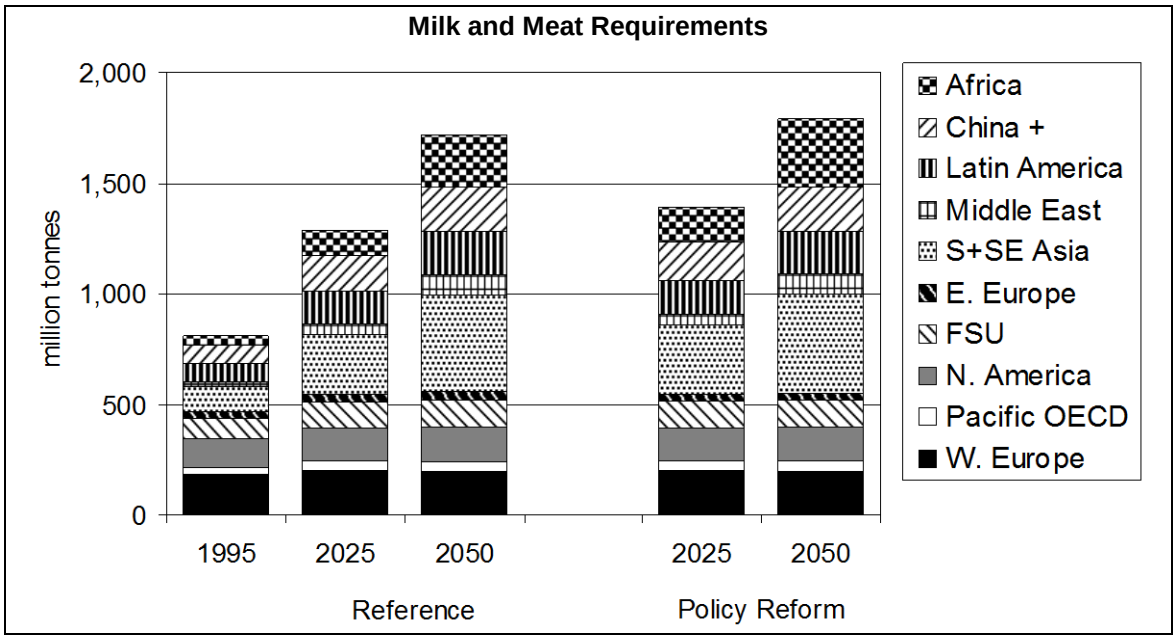
Reference

	Avg. Daily Consumption (kcal/capita)			Share from Animal Products (% cal)		
Region	1995	2025	2050	1995	2025	2050
Africa	2,322	2,526	2,700	7	10	13
China +	2,755	2,993	3,100	16	19	21
Latin America	2,704	2,884	3,000	18	20	22
Middle East	2,604	2,778	2,900	10	14	18
S+SE Asia	2,393	2,675	2,850	8	12	16
E. Europe	3,125	3,296	3,400	27	29	30
FSU	2,764	3,088	3,200	25	28	30
N. America	3,552	3,526	3,500	31	30	30
Pacific OECD	2,840	3,177	3,300	24	26	28
W. Europe	3,339	3,370	3,400	30	30	30
Developing	2,534	2,748	2,883	12	14	17
Transitional	2,855	3,139	3,248	25	28	30
OECD	3,327	3,397	3,424	29	29	30
World	2,683	2,850	2,956	16	17	19

Policy Reform

	Avg. Daily Consumption (kcal/capita)			Share from Animal Products (% cal)		
Region	1995	2025	2050	1995	2025	2050
Africa	2,322	2,696	2,876	7	13	17
China +	2,755	3,023	3,126	16	20	22
Latin America	2,704	2,909	3,027	18	21	22
Middle East	2,604	2,816	2,944	10	15	19
S+SE Asia	2,393	2,738	2,904	8	14	17
E. Europe	3,125	3,324	3,400	27	29	30
FSU	2,764	3,143	3,252	25	29	30
N. America	3,552	3,526	3,500	31	30	30
Pacific OECD	2,840	3,177	3,300	24	26	28
W. Europe	3,339	3,370	3,400	30	30	30
Developing	2,534	2,821	2,959	12	16	19
Transitional	2,855	3,187	3,287	25	29	30
OECD	3,327	3,397	3,424	29	29	30
World	2,683	2,913	3,024	16	19	21

Sheet F-2. Meat and Milk Requirements and Production



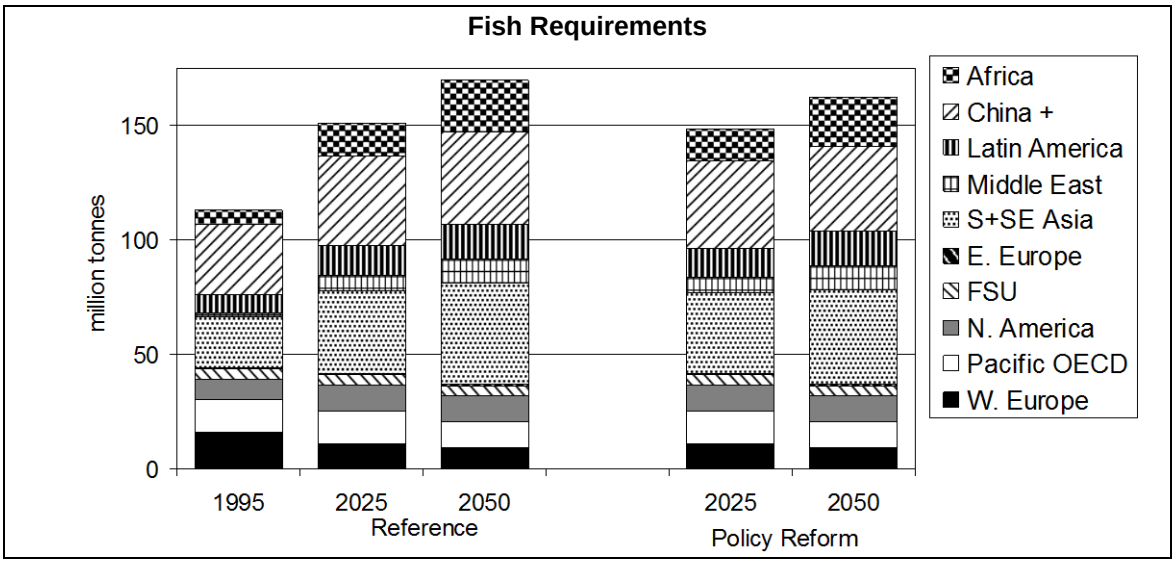
Reference

	Requirements (million tonnes)			Production (million tonnes)			Self-Sufficiency Ratio			Fraction of Meat from Feedlots (%)		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	41	120	232	36	101	197	0.9	0.8	0.9	28%	32%	33%
China +	80	159	203	79	160	205	1.0	1.0	1.0	18%	19%	20%
Latin America	86	146	196	79	143	194	0.9	1.0	1.0	40%	41%	40%
Middle East	18	50	90	14	34	60	0.8	0.7	0.7	75%	85%	89%
S+SE Asia	117	269	435	110	254	419	0.9	0.9	1.0	18%	21%	23%
E. Europe	32	35	35	34	38	39	1.1	1.1	1.1	71%	75%	76%
FSU	95	115	125	102	126	142	1.1	1.1	1.1	73%	79%	81%
N. America	126	152	157	127	166	179	1.0	1.1	1.1	70%	76%	79%
Pacific OECD	30	42	47	40	50	59	1.3	1.2	1.3	30%	45%	52%
W. Europe	185	201	195	196	217	221	1.1	1.1	1.1	35%	42%	46%
Developing	343	744	1,156	317	691	1,075	0.9	0.9	0.9	24%	27%	29%
Transitional	127	150	160	135	163	181	1.1	1.1	1.1	72%	78%	80%
OECD	341	394	399	363	434	459	1.1	1.1	1.2	49%	56%	61%
World	811	1,288	1,715	816	1,288	1,715	1.0	1.0	1.0	37%	39%	39%

Policy Reform

	Requirements (million tonnes)			Production (million tonnes)			Self-Sufficiency Ratio			Fraction of Meat from Feedlots (%)		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	41	162	306	36	136	261	0.9	0.8	0.9	28%	45%	58%
China +	80	171	208	79	172	210	1.0	1.0	1.0	18%	19%	24%
Latin America	86	152	188	79	150	187	0.9	1.0	1.0	40%	42%	50%
Middle East	18	53	92	14	36	61	0.8	0.7	0.7	75%	87%	92%
S+SE Asia	117	309	445	110	291	429	0.9	0.9	1.0	18%	30%	35%
E. Europe	32	34	33	34	38	38	1.1	1.1	1.1	71%	75%	78%
FSU	95	118	121	102	131	140	1.1	1.1	1.2	73%	80%	81%
N. America	126	152	157	127	168	182	1.0	1.1	1.2	70%	78%	82%
Pacific OECD	30	42	47	40	52	60	1.3	1.2	1.3	30%	50%	55%
W. Europe	185	201	196	196	220	224	1.1	1.1	1.1	35%	43%	47%
Developing	343	846	1,239	317	786	1,148	0.9	0.9	0.9	24%	31%	41%
Transitional	127	153	155	135	169	178	1.1	1.1	1.2	72%	79%	80%
OECD	341	395	400	363	440	467	1.1	1.1	1.2	49%	58%	63%
World	811	1,394	1,793	816	1,394	1,793	1.0	1.0	1.0	37%	41%	47%

Sheet F-3. Fish Requirements and Production



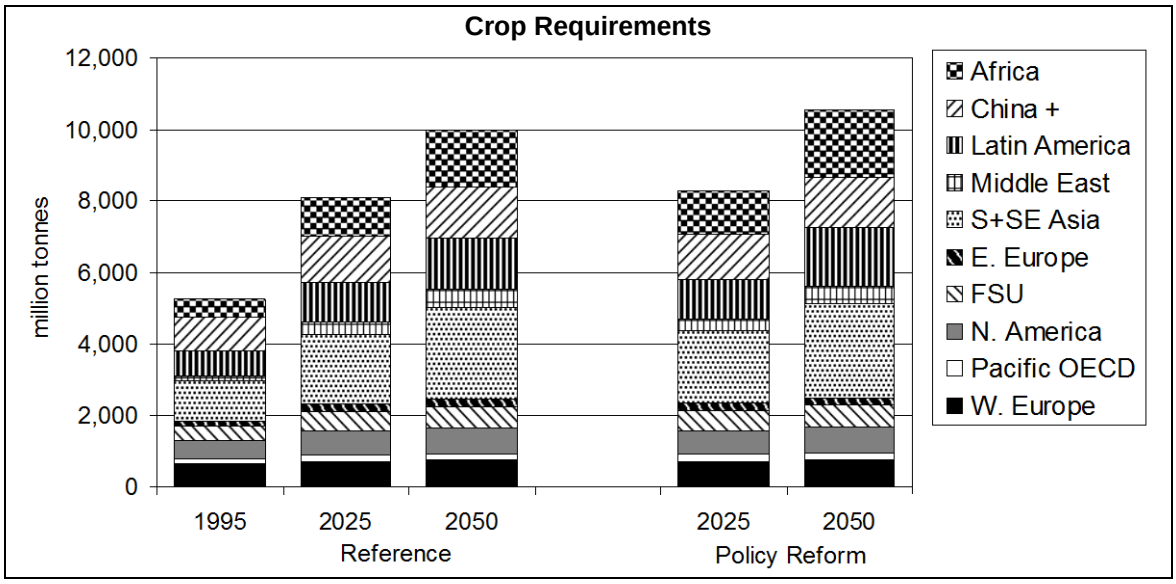
Reference

	Requirements (million tonnes)			Production (million tonnes)			Self-Sufficiency Ratio		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	6	15	23	5	11	17	0.8	0.8	0.8
China +	31	39	40	27	35	38	0.9	0.9	0.9
Latin America	8	13	15	20	31	35	2.4	2.3	2.3
Middle East	2	7	11	1	3	5	0.4	0.5	0.5
S+SE Asia	22	36	44	21	35	42	1.0	1.0	1.0
E. Europe	1	1	1	1	0	0	0.6	0.4	0.5
FSU	4	5	4	4	4	4	1.0	1.0	1.0
N. America	9	11	11	7	11	11	0.8	1.0	1.0
Pacific OECD	14	14	11	10	12	10	0.7	0.9	0.9
W. Europe	16	11	9	13	8	7	0.8	0.7	0.8
Developing	68	109	132	73	115	137	1.1	1.1	1.0
Transitional	5	5	5	5	5	5	0.9	0.9	0.9
OECD	39	37	32	30	32	28	0.8	0.9	0.9
World	113	151	170	108	151	170	1.0	1.0	1.0

Policy Reform

	Requirements (million tonnes)			Production (million tonnes)			Self-Sufficiency Ratio		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	6	14	22	5	11	17	0.8	0.8	0.8
China +	31	38	37	27	34	35	0.9	0.9	0.9
Latin America	8	13	15	20	30	33	2.4	2.4	2.3
Middle East	2	7	11	1	3	5	0.4	0.5	0.5
S+SE Asia	22	35	41	21	34	40	1.0	1.0	1.0
E. Europe	1	1	1	1	0	0	0.6	0.4	0.5
FSU	4	5	4	4	5	4	1.0	1.0	1.0
N. America	9	11	11	7	11	11	0.8	1.0	1.0
Pacific OECD	14	14	11	10	12	10	0.7	0.9	0.9
W. Europe	16	11	9	13	8	7	0.8	0.7	0.8
Developing	68	107	126	73	113	130	1.1	1.1	1.0
Transitional	5	5	5	5	5	5	0.9	0.9	0.9
OECD	39	37	32	30	32	28	0.8	0.9	0.9
World	113	149	163	108	149	163	1.0	1.0	1.0

Sheet F-4. Crop Requirements and Production



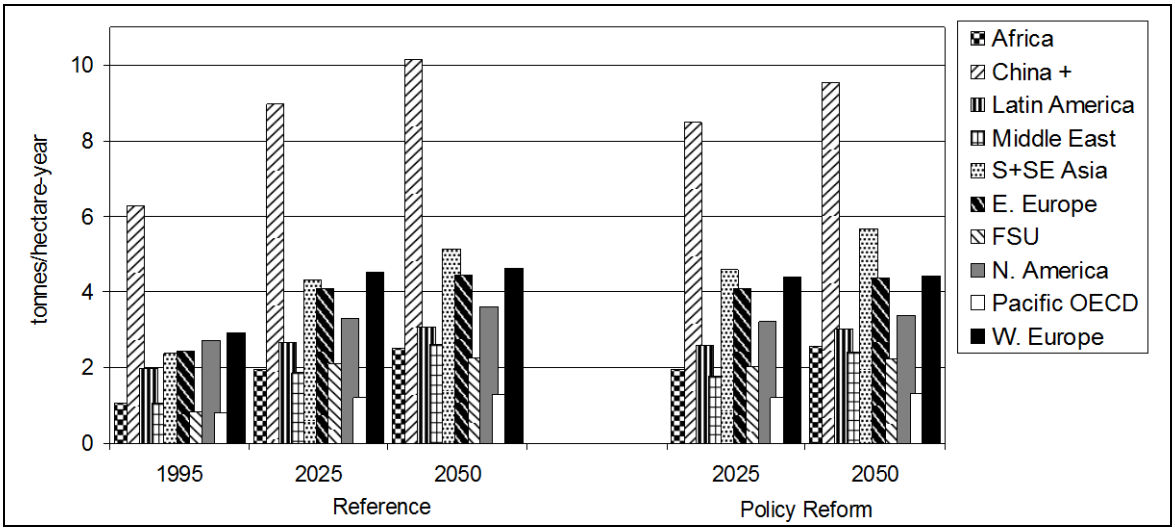
Reference

	Requirements (million tonnes)			Production (million tonnes)			Net Exports (million tonnes)			Self-Sufficiency Ratio		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	500	1,080	1,610	438	887	1,369	-61	-193	-241	0.9	0.8	0.9
China +	908	1,283	1,424	864	1,228	1,412	-44	-55	-12	1.0	1.0	1.0
Latin America	729	1,131	1,438	836	1,268	1,534	106	137	96	1.1	1.1	1.1
Middle East	153	347	503	95	201	273	-58	-146	-231	0.6	0.6	0.5
S+SE Asia	1,101	1,941	2,578	1,094	1,917	2,562	-7	-24	-16	1.0	1.0	1.0
E. Europe	163	183	191	156	211	238	-7	28	47	1.0	1.2	1.2
FSU	405	563	614	310	612	691	-95	48	77	0.8	1.1	1.1
N. America	515	659	708	659	821	928	144	161	219	1.3	1.2	1.3
Pacific OECD	130	177	194	101	146	157	-29	-31	-37	0.8	0.8	0.8
W. Europe	638	724	738	610	798	836	-29	74	97	1.0	1.1	1.1
Developing	3,390	5,782	7,553	3,327	5,501	7,150	-64	-281	-403	1.0	1.0	0.9
Transitional	569	747	805	466	823	929	-103	76	124	0.8	1.1	1.2
OECD	1,284	1,560	1,641	1,369	1,765	1,920	86	204	279	1.1	1.1	1.2
World	5,243	8,089	9,999	5,162	8,089	9,999	-81	0	0	1.0	1.0	1.0

Policy Reform

	Requirements (million tonnes)			Production (million tonnes)			Net Exports (million tonnes)			Self-Sufficiency Ratio		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	500	1,211	1,865	438	956	1,412	-61	-255	-453	0.9	0.8	0.8
China +	908	1,272	1,425	864	1,236	1,466	-44	-36	40	1.0	1.0	1.0
Latin America	729	1,104	1,635	836	1,259	1,758	106	155	124	1.1	1.1	1.1
Middle East	153	349	494	95	192	252	-58	-157	-242	0.6	0.5	0.5
S+SE Asia	1,101	2,001	2,642	1,094	1,899	2,279	-7	-102	-363	1.0	0.9	0.9
E. Europe	163	186	188	156	228	264	-7	42	76	1.0	1.2	1.4
FSU	405	575	615	310	640	807	-95	65	192	0.8	1.1	1.3
N. America	515	668	732	659	892	1,201	144	224	469	1.3	1.3	1.6
Pacific OECD	130	184	199	101	146	154	-29	-39	-45	0.8	0.8	0.8
W. Europe	638	733	744	610	835	946	-29	103	202	1.0	1.1	1.3
Developing	3,390	5,937	8,060	3,327	5,542	7,167	-64	-395	-893	1.0	0.9	0.9
Transitional	569	761	803	466	869	1,071	-103	107	268	0.8	1.1	1.3
OECD	1,284	1,585	1,676	1,369	1,873	2,301	86	288	626	1.1	1.2	1.4
World	5,243	8,284	10,539	5,162	8,284	10,539	-81	0	0	1.0	1.0	1.0

Sheet F-5. Cereal Yields



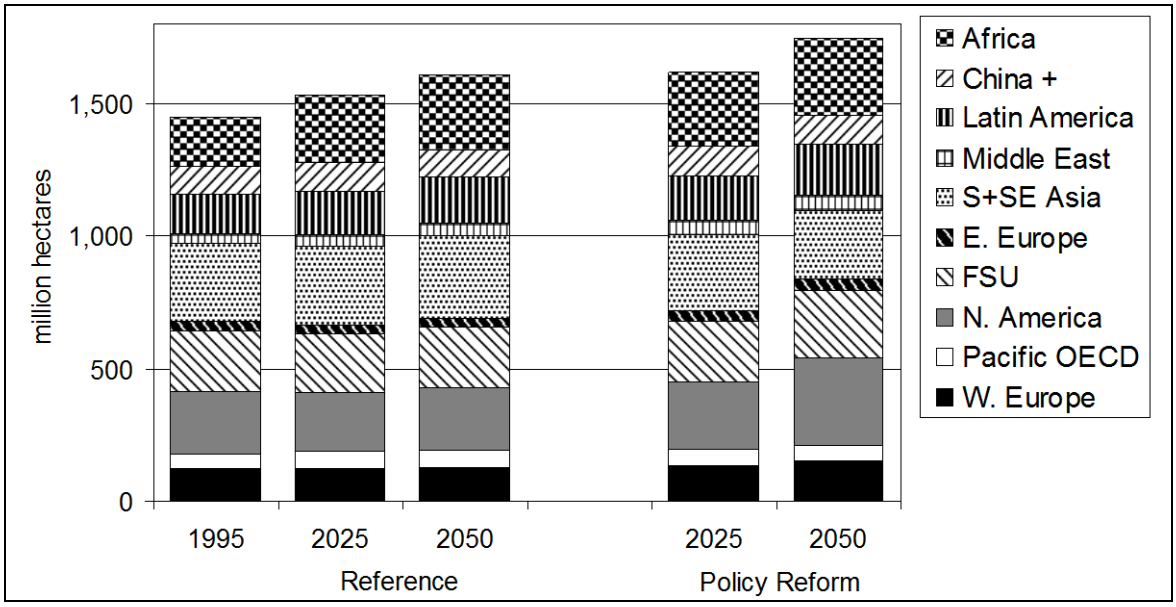
Reference

	Harvest yield (tonnes/hectare)			Cropping Intensity (harvests/yr)			Annual yield (tonnes/hectare-yr)			Index (95=1)	
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050	2025	2050
Africa	1.2	2.3	2.8	0.85	0.85	0.89	1.0	1.9	2.5	1.9	2.4
China +	4.4	5.8	6.2	1.44	1.53	1.62	6.3	9.0	10.1	1.4	1.6
Latin America	2.4	3.2	3.5	0.81	0.84	0.87	2.0	2.7	3.1	1.3	1.5
Middle East	1.6	2.6	3.1	0.64	0.71	0.85	1.0	1.9	2.6	1.8	2.5
S+SE Asia	2.4	3.9	4.3	1.01	1.10	1.18	2.4	4.3	5.1	1.8	2.1
E. Europe	3.0	5.2	5.7	0.80	0.79	0.79	2.4	4.1	4.4	1.7	1.8
FSU	1.5	3.3	3.5	0.55	0.63	0.65	0.8	2.1	2.3	2.5	2.7
N. America	4.9	6.0	6.2	0.56	0.55	0.58	2.7	3.3	3.6	1.2	1.3
Pacific OECD	2.1	3.0	3.1	0.38	0.40	0.42	0.8	1.2	1.3	1.5	1.6
W. Europe	4.1	6.0	6.2	0.72	0.75	0.74	2.9	4.5	4.6	1.5	1.6
Developing	2.5	3.7	4.1	0.98	1.01	1.06	2.5	3.7	4.3	1.5	1.7
Transitional	1.8	3.6	3.8	0.59	0.65	0.67	1.1	2.4	2.6	2.2	2.4
OECD	4.3	5.7	5.9	0.58	0.58	0.60	2.5	3.3	3.5	1.3	1.4
World	2.8	4.1	4.4	0.77	0.81	0.84	2.2	3.3	3.7	1.5	1.7

Policy Reform

	Harvest yield (tonnes/hectare)			Cropping Intensity (harvests/yr)			Annual yield (tonnes/hectare-yr)			Index (95=1)	
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050	2025	2050
Africa	1.2	2.3	2.8	0.85	0.85	0.89	1.0	1.9	2.5	1.9	2.4
China +	4.4	5.6	6.0	1.44	1.51	1.59	6.3	8.5	9.5	1.4	1.5
Latin America	2.4	3.1	3.5	0.81	0.83	0.87	2.0	2.6	3.0	1.3	1.5
Middle East	1.6	2.6	2.9	0.64	0.69	0.82	1.0	1.8	2.4	1.7	2.3
S+SE Asia	2.4	4.1	4.7	1.01	1.11	1.20	2.4	4.6	5.7	1.9	2.4
E. Europe	3.0	5.2	5.6	0.80	0.79	0.78	2.4	4.1	4.4	1.7	1.8
FSU	1.5	3.3	3.5	0.55	0.63	0.65	0.8	2.0	2.2	2.4	2.7
N. America	4.9	5.9	5.9	0.56	0.54	0.57	2.7	3.2	3.4	1.2	1.2
Pacific OECD	2.1	3.0	3.1	0.38	0.40	0.42	0.8	1.2	1.3	1.5	1.6
W. Europe	4.1	5.9	6.0	0.72	0.75	0.73	2.9	4.4	4.4	1.5	1.5
Developing	2.5	3.7	4.2	0.98	1.01	1.06	2.5	3.7	4.4	1.5	1.8
Transitional	1.8	3.6	3.8	0.59	0.65	0.67	1.1	2.3	2.5	2.2	2.4
OECD	4.3	5.6	5.7	0.58	0.58	0.60	2.5	3.3	3.4	1.3	1.4
World	2.8	4.1	4.5	0.77	0.80	0.81	2.2	3.3	3.7	1.5	1.7

Sheet F-6. Cropland



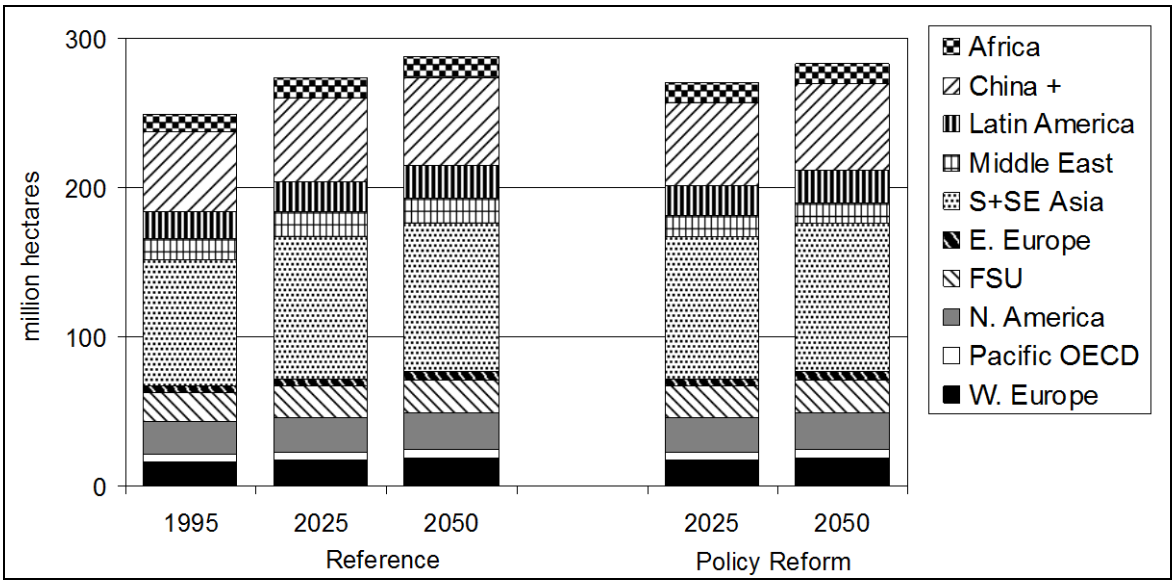
Reference

	Total Cropland (million ha)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	186	255	277	1.1	0.3	0.7	1.4	1.5
China +	107	110	105	0.1	-0.2	0.0	1.0	1.0
Latin America	144	162	176	0.4	0.3	0.4	1.1	1.2
Middle East	44	46	46	0.1	0.1	0.1	1.0	1.1
S+SE Asia	289	294	309	0.1	0.2	0.1	1.0	1.1
E. Europe	39	38	38	-0.2	0.0	-0.1	1.0	1.0
FSU	228	219	226	-0.1	0.1	0.0	1.0	1.0
N. America	233	225	237	-0.1	0.2	0.0	1.0	1.0
Pacific OECD	55	63	65	0.4	0.1	0.3	1.1	1.2
W. Europe	124	122	127	0.0	0.2	0.0	1.0	1.0
Developing	770	867	913	0.4	0.2	0.3	1.1	1.2
Transitional	268	256	264	-0.1	0.1	0.0	1.0	1.0
OECD	412	410	429	0.0	0.2	0.1	1.0	1.0
World	1,450	1,534	1,606	0.2	0.2	0.2	1.1	1.1

Policy Reform

	Total Cropland (million ha)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	186	275	287	1.3	0.2	0.8	1.5	1.5
China +	107	114	109	0.2	-0.2	0.0	1.1	1.0
Latin America	144	171	196	0.6	0.5	0.6	1.2	1.4
Middle East	44	53	57	0.6	0.3	0.5	1.2	1.3
S+SE Asia	289	283	258	-0.1	-0.4	-0.2	1.0	0.9
E. Europe	39	40	41	0.0	0.1	0.1	1.0	1.0
FSU	228	235	251	0.1	0.3	0.2	1.0	1.1
N. America	233	252	331	0.3	1.1	0.6	1.1	1.4
Pacific OECD	55	63	60	0.4	-0.1	0.2	1.1	1.1
W. Europe	124	133	153	0.2	0.6	0.4	1.1	1.2
Developing	770	896	907	0.5	0.1	0.3	1.2	1.2
Transitional	268	275	293	0.1	0.2	0.2	1.0	1.1
OECD	412	447	545	0.3	0.8	0.5	1.1	1.3
World	1,450	1,618	1,744	0.4	0.3	0.3	1.1	1.2

Sheet F-7. Irrigation



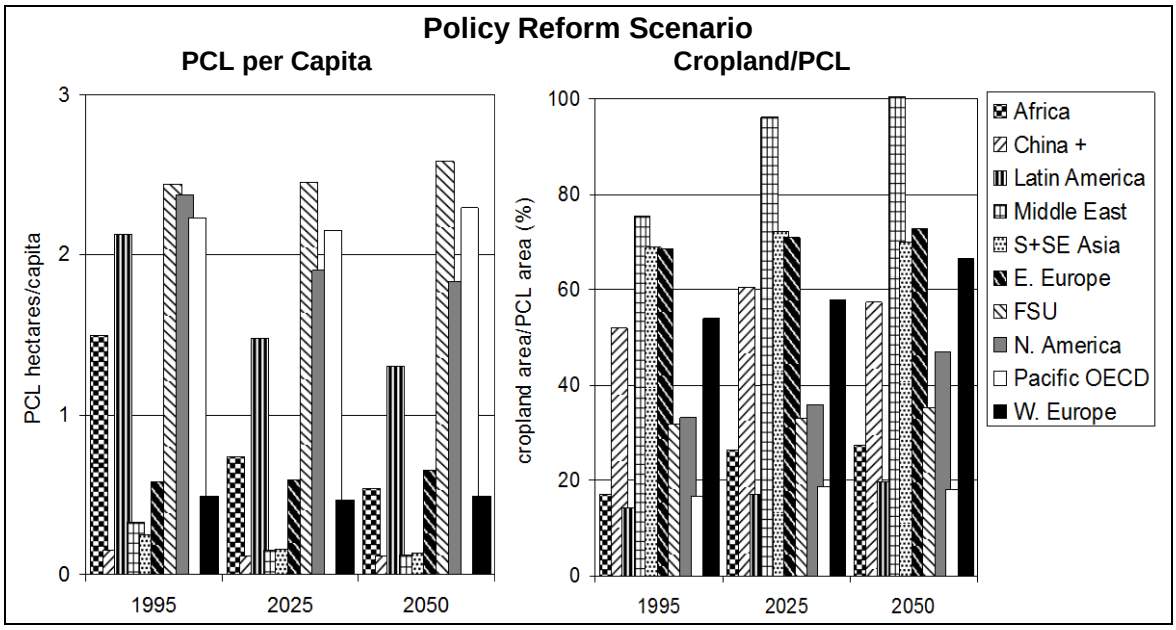
Reference

	Irrigated Cropland (million ha)			Index (95=1)		Fraction of Cropland Irrigated (%)		
Region	1995	2025	2050	2025	2050	1995	2025	2050
Africa	12	14	14	1.1	1.1	7	5	5
China +	53	56	58	1.1	1.1	49	51	56
Latin America	18	20	22	1.1	1.3	12	12	13
Middle East	15	17	17	1.1	1.1	34	37	37
S+SE Asia	84	95	99	1.1	1.2	29	32	32
E. Europe	5	5	5	1.1	1.2	12	14	14
FSU	19	21	23	1.1	1.2	8	10	10
N. America	22	23	24	1.0	1.1	9	10	10
Pacific OECD	5	6	6	1.1	1.1	9	9	9
W. Europe	16	17	19	1.1	1.2	13	14	15
Developing	182	201	211	1.1	1.2	24	23	23
Transitional	24	26	28	1.1	1.2	9	10	11
OECD	43	46	49	1.1	1.1	11	11	11
World	250	274	288	1.1	1.2	17	18	18

Policy Reform

	Irrigated Cropland (million ha)			Index (95=1)		Fraction of Cropland Irrigated (%)		
Region	1995	2025	2050	2025	2050	1995	2025	2050
Africa	12	14	14	1.1	1.1	7	5	5
China +	53	56	58	1.0	1.1	49	49	53
Latin America	18	20	22	1.1	1.3	12	12	11
Middle East	15	14	13	0.9	0.9	34	27	24
S+SE Asia	84	95	99	1.1	1.2	29	34	38
E. Europe	5	5	5	1.1	1.1	12	13	13
FSU	19	21	23	1.1	1.2	8	9	9
N. America	22	23	24	1.0	1.1	9	9	7
Pacific OECD	5	6	6	1.1	1.1	9	9	10
W. Europe	16	17	19	1.1	1.2	13	13	12
Developing	182	198	206	1.1	1.1	24	22	23
Transitional	24	26	28	1.1	1.2	9	9	10
OECD	43	46	49	1.1	1.1	11	10	9
World	250	271	283	1.1	1.1	17	17	16

Sheet F-8. Potential Cultivable Land



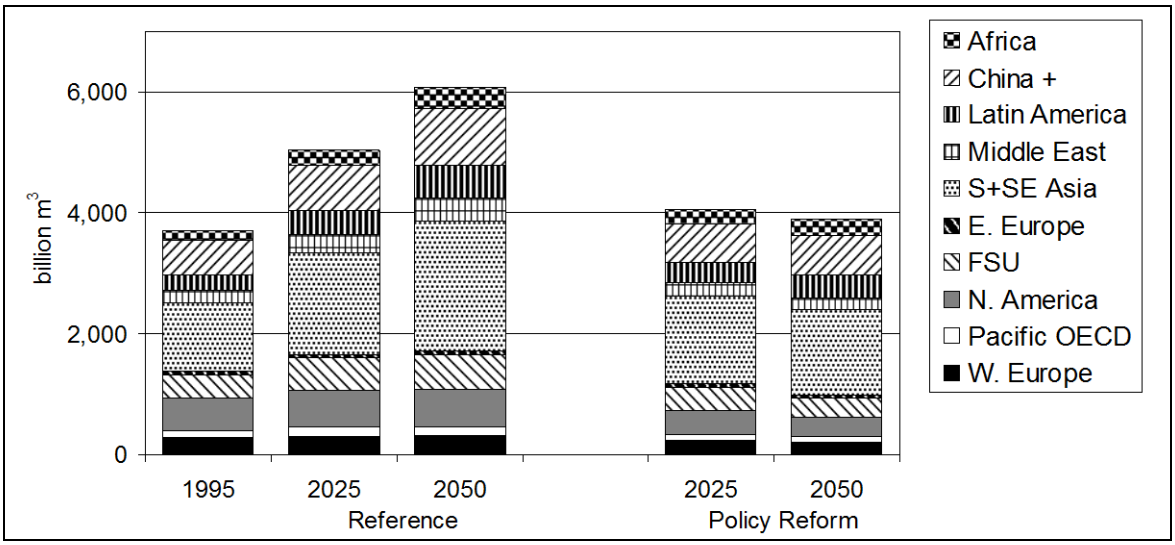
Reference

	PCL (million ha)			PCL per capita (ha/capita)			Cropland/PCL (%)		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	1,077	1,024	978	1.5	0.7	0.5	17	25	28
China +	206	178	153	0.2	0.1	0.1	52	62	68
Latin America	1,010	981	953	2.1	1.4	1.2	14	16	18
Middle East	59	52	47	0.3	0.1	0.1	75	87	99
S+SE Asia	420	391	356	0.3	0.2	0.1	69	75	87
E. Europe	57	56	54	0.6	0.6	0.6	69	68	70
FSU	716	713	710	2.4	2.4	2.4	32	31	32
N. America	705	697	693	2.4	1.9	1.8	33	32	34
Pacific OECD	333	331	330	2.2	2.1	2.3	17	19	20
W. Europe	229	227	226	0.5	0.5	0.5	54	54	56
Developing	2,772	2,626	2,487	0.6	0.4	0.3	28	33	37
Transitional	773	768	764	2.0	2.0	2.0	35	33	35
OECD	1,267	1,254	1,249	1.4	1.2	1.3	33	33	34
World	4,812	4,649	4,500	0.8	0.6	0.5	30	33	36

Policy Reform

	PCL (million ha)			PCL per capita (ha/capita)			Cropland/PCL (%)		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	1,077	1,043	1,048	1.5	0.7	0.5	17	26	27
China +	206	188	189	0.2	0.1	0.1	52	61	57
Latin America	1,010	996	1,003	2.1	1.5	1.3	14	17	20
Middle East	59	55	57	0.3	0.2	0.1	75	96	100
S+SE Asia	420	392	369	0.3	0.2	0.1	69	72	70
E. Europe	57	56	57	0.6	0.6	0.7	69	71	73
FSU	716	714	714	2.4	2.5	2.6	32	33	35
N. America	705	702	704	2.4	1.9	1.8	33	36	47
Pacific OECD	333	333	333	2.2	2.2	2.3	17	19	18
W. Europe	229	229	230	0.5	0.5	0.5	54	58	67
Developing	2,772	2,674	2,667	0.6	0.4	0.4	28	34	34
Transitional	773	770	771	2.0	2.0	2.1	35	36	38
OECD	1,267	1,264	1,267	1.4	1.2	1.3	33	35	43
World	4,812	4,708	4,705	0.8	0.6	0.5	30	34	37

Sheet P-1. Water Withdrawals by Region



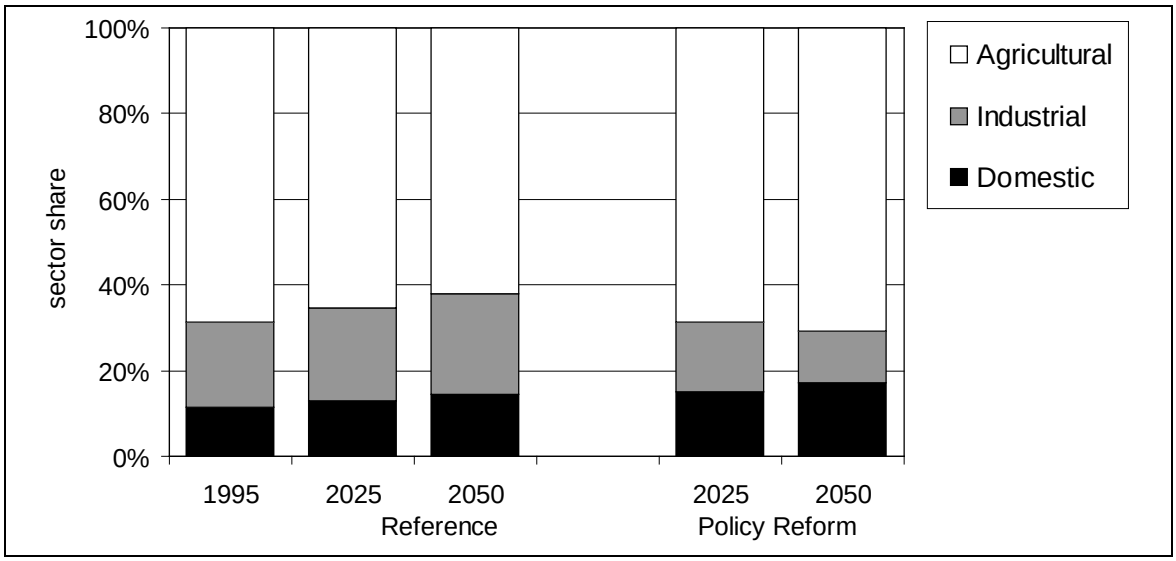
Reference

	Withdrawals (billion m^3)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	167	255	371	1.4	1.5	1.5	1.5	2.2
China +	553	755	933	1.0	0.8	1.0	1.4	1.7
Latin America	257	389	543	1.4	1.3	1.4	1.5	2.1
Middle East	200	302	377	1.4	0.9	1.2	1.5	1.9
S+SE Asia	1,142	1,674	2,128	1.3	1.0	1.1	1.5	1.9
E. Europe	63	75	73	0.6	-0.1	0.3	1.2	1.2
FSU	381	535	568	1.1	0.2	0.7	1.4	1.5
N. America	540	607	626	0.4	0.1	0.3	1.1	1.2
Pacific OECD	121	144	150	0.6	0.2	0.4	1.2	1.2
W. Europe	275	308	311	0.4	0.0	0.2	1.1	1.1
Developing	2,319	3,375	4,352	1.3	1.0	1.2	1.5	1.9
Transitional	444	610	641	1.1	0.2	0.7	1.4	1.4
OECD	936	1,059	1,088	0.4	0.1	0.3	1.1	1.2
World	3,699	5,044	6,081	1.0	0.8	0.9	1.4	1.6

Policy Reform

	Withdrawals (billion m^3)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	167	227	276	1.0	0.8	0.9	1.4	1.7
China +	553	647	650	0.5	0.0	0.3	1.2	1.2
Latin America	257	331	364	0.8	0.4	0.6	1.3	1.4
Middle East	200	228	206	0.5	-0.4	0.1	1.1	1.0
S+SE Asia	1,142	1,442	1,414	0.8	-0.1	0.4	1.3	1.2
E. Europe	63	56	47	-0.4	-0.8	-0.5	0.9	0.7
FSU	381	386	315	0.0	-0.8	-0.3	1.0	0.8
N. America	540	391	335	-1.1	-0.6	-0.9	0.7	0.6
Pacific OECD	121	110	95	-0.3	-0.6	-0.4	0.9	0.8
W. Europe	275	235	199	-0.5	-0.7	-0.6	0.9	0.7
Developing	2,319	2,876	2,909	0.7	0.0	0.4	1.2	1.3
Transitional	444	442	361	0.0	-0.8	-0.4	1.0	0.8
OECD	936	736	628	-0.8	-0.6	-0.7	0.8	0.7
World	3,699	4,054	3,899	0.3	-0.2	0.1	1.1	1.1

Sheet P-2. Water Withdrawals by Sector



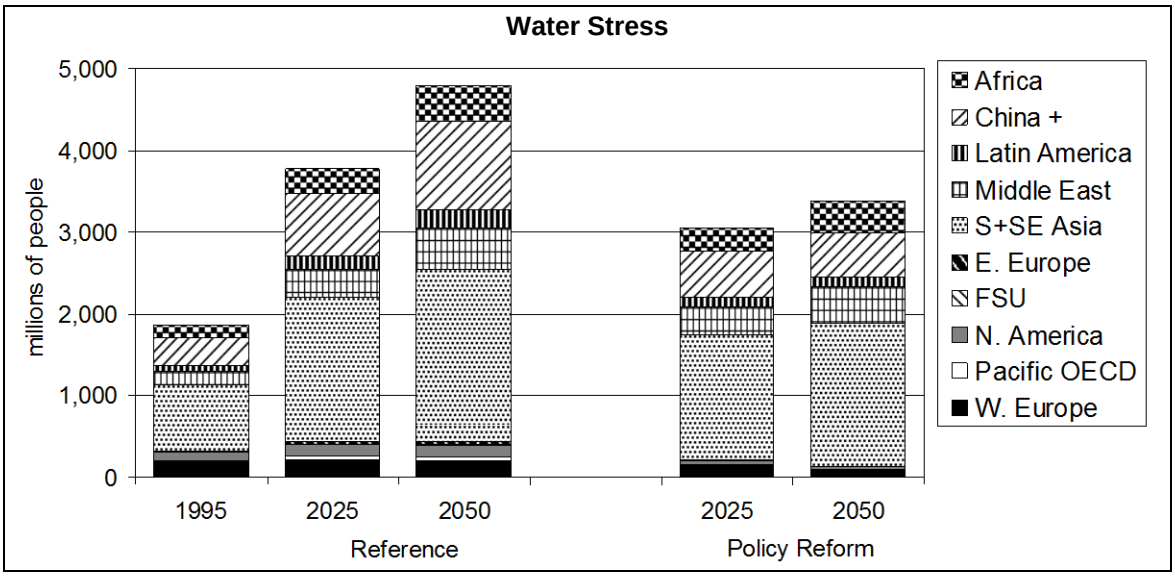
Reference

	Withdrawals (billion m^3)			Growth Rate (%/year)			Sectoral Share (%)		
Sector	1995	2025	2050	95-25	25-50	95-50	1995	2025	2050
Agricultural	2,538	3,301	3,782	0.9	0.5	0.7	69	65	62
Industrial	738	1,090	1,417	1.3	1.1	1.2	20	22	23
Domestic	423	653	882	1.5	1.2	1.3	11	13	15
Total	3,699	5,044	6,081	1.0	0.8	0.9	100	100	100

Policy Reform

	Withdrawals (billion m^3)			Growth Rate (%/year)			Sectoral Share (%)		
Sector	1995	2025	2050	95-25	25-50	95-50	1995	2025	2050
Agricultural	2,538	2,788	2,756	0.3	0.0	0.1	69	69	71
Industrial	738	659	475	-0.4	-1.3	-0.8	20	16	12
Domestic	423	607	667	1.2	0.4	0.8	11	15	17
Total	3,699	4,054	3,899	0.3	-0.2	0.1	100	100	100

Sheet P-3: Water Stress



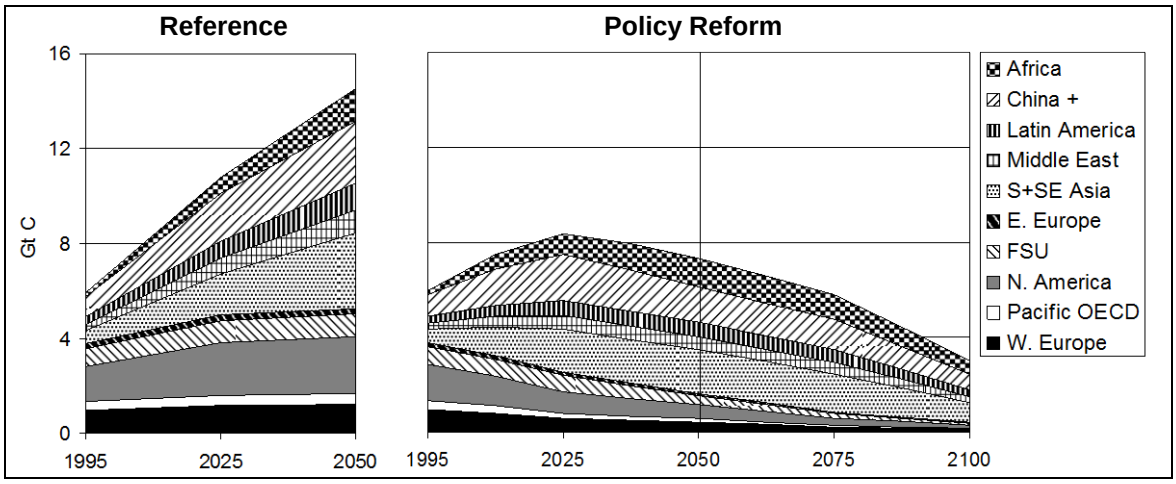
Reference

	Use/Resource Ratio			Water Stress (millions of people)			Water Stress (% of population)		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	0.03	0.05	0.07	155	309	442	22	21	22
China +	0.16	0.21	0.26	338	751	1,083	25	46	64
Latin America	0.02	0.03	0.04	74	167	223	16	24	28
Middle East	0.56	0.84	1.05	164	353	496	92	97	99
S+SE Asia	0.10	0.15	0.19	816	1,764	2,119	49	71	72
E. Europe	0.09	0.11	0.10	17	25	23	17	26	25
FSU	0.08	0.11	0.12	-	9	15	-	3	5
N. America	0.10	0.11	0.12	88	137	151	30	37	39
Pacific OECD	0.10	0.12	0.12	29	41	41	19	27	28
W. Europe	0.12	0.13	0.13	182	223	207	39	45	44
Developing	0.07	0.10	0.13	1,549	3,346	4,366	35	50	55
Transitional	0.08	0.11	0.11	17	34	38	4	9	10
OECD	0.10	0.12	0.12	298	400	399	33	39	40
World	0.08	0.10	0.13	1,863	3,780	4,803	33	47	51

Policy Reform

	Use/Resource Ratio			Water Stress (millions of people)			Water Stress (% of population)		
Region	1995	2025	2050	1995	2025	2050	1995	2025	2050
Africa	0.03	0.04	0.05	155	285	393	22	20	20
China +	0.16	0.18	0.18	338	562	545	25	35	34
Latin America	0.02	0.02	0.03	74	122	116	16	18	15
Middle East	0.56	0.64	0.57	164	336	450	92	94	95
S+SE Asia	0.10	0.13	0.13	816	1,526	1,750	49	63	63
E. Europe	0.09	0.08	0.07	17	11	6	17	12	7
FSU	0.08	0.08	0.06	-	-	-	-	-	-
N. America	0.10	0.07	0.06	88	50	28	30	14	7
Pacific OECD	0.10	0.09	0.08	29	21	11	19	14	8
W. Europe	0.12	0.10	0.08	182	139	88	39	28	19
Developing	0.07	0.08	0.09	1,549	2,833	3,256	35	44	43
Transitional	0.08	0.08	0.06	17	11	6	4	3	2
OECD	0.10	0.08	0.07	298	210	127	33	21	13
World	0.08	0.08	0.08	1,863	3,055	3,391	33	39	38

Sheet P-4. Carbon Emissions



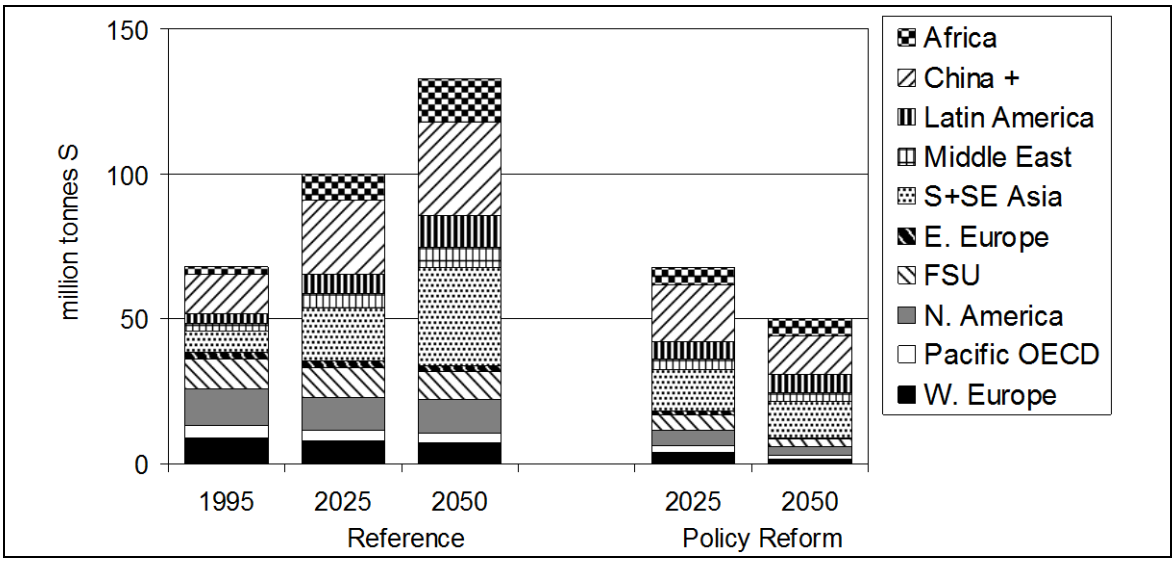
Reference

	Total Annual Emissions (Gt C)			Index (95=1)		Annual Per Capita (t C)			Annual Per Dollar GDP_{PPP} (kg C)		
Region	1995	2025	2050	2025	2050	1995	2025	2050	1995	2025	2050
Africa	0.17	0.65	1.39	3.9	8.3	0.2	0.4	0.7	0.14	0.16	0.15
China +	0.87	2.00	2.60	2.3	3.0	0.7	1.2	1.5	0.23	0.17	0.12
Latin America	0.30	0.75	1.15	2.5	3.8	0.6	1.1	1.4	0.10	0.10	0.08
Middle East	0.25	0.64	0.93	2.5	3.7	1.4	1.8	1.9	0.27	0.20	0.14
S+SE Asia	0.57	1.75	3.22	3.1	5.6	0.3	0.7	1.1	0.13	0.12	0.10
E. Europe	0.19	0.23	0.20	1.2	1.1	1.9	2.3	2.2	0.32	0.22	0.15
FSU	0.75	0.94	0.96	1.3	1.3	2.6	3.2	3.3	0.62	0.43	0.32
N. America	1.49	2.22	2.40	1.5	1.6	5.0	6.0	6.2	0.19	0.12	0.09
Pacific OECD	0.39	0.44	0.44	1.1	1.1	2.6	2.8	3.0	0.12	0.07	0.05
W. Europe	0.95	1.16	1.24	1.2	1.3	2.0	2.4	2.6	0.13	0.08	0.06
Developing	2.16	5.79	9.29	2.7	4.3	0.5	0.9	1.2	0.16	0.14	0.11
Transitional	0.94	1.17	1.16	1.2	1.2	2.4	3.0	3.0	0.52	0.36	0.26
OECD	2.83	3.82	4.08	1.3	1.4	3.1	3.8	4.1	0.15	0.10	0.07
World	5.94	10.78	14.53	1.8	2.4	1.0	1.3	1.6	0.18	0.13	0.10

Policy Reform

	Total Annual Emissions (Gt C)			Index (95=1)		Annual Per Capita (t C)			Annual Per Dollar GDP_{PPP} (kg C)		
Region	1995	2025	2050	2025	2050	1995	2025	2050	1995	2025	2050
Africa	0.17	0.89	1.19	5.3	7.2	0.2	0.6	0.6	0.14	0.14	0.07
China +	0.87	1.95	1.47	2.2	1.7	0.7	1.2	0.9	0.23	0.14	0.06
Latin America	0.30	0.61	0.61	2.0	2.0	0.6	0.9	0.8	0.10	0.08	0.04
Middle East	0.25	0.61	0.54	2.4	2.2	1.4	1.7	1.1	0.27	0.17	0.07
S+SE Asia	0.57	1.78	1.86	3.1	3.2	0.3	0.7	0.7	0.13	0.10	0.05
E. Europe	0.19	0.15	0.10	0.8	0.5	1.9	1.6	1.1	0.32	0.14	0.06
FSU	0.75	0.68	0.38	0.9	0.5	2.6	2.3	1.4	0.62	0.27	0.11
N. America	1.49	0.90	0.59	0.6	0.4	5.0	2.4	1.5	0.19	0.07	0.04
Pacific OECD	0.39	0.21	0.14	0.6	0.4	2.6	1.4	1.0	0.12	0.05	0.03
W. Europe	0.95	0.59	0.41	0.6	0.4	2.0	1.2	0.9	0.13	0.05	0.03
Developing	2.16	5.83	5.67	2.7	2.6	0.5	0.9	0.7	0.16	0.12	0.06
Transitional	0.94	0.83	0.48	0.9	0.5	2.4	2.2	1.3	0.52	0.23	0.09
OECD	2.83	1.70	1.15	0.6	0.4	3.1	1.7	1.1	0.15	0.06	0.03
World	5.94	8.37	7.30	1.4	1.2	1.0	1.1	0.8	0.18	0.10	0.05

Sheet P-5. Sulfur Emissions



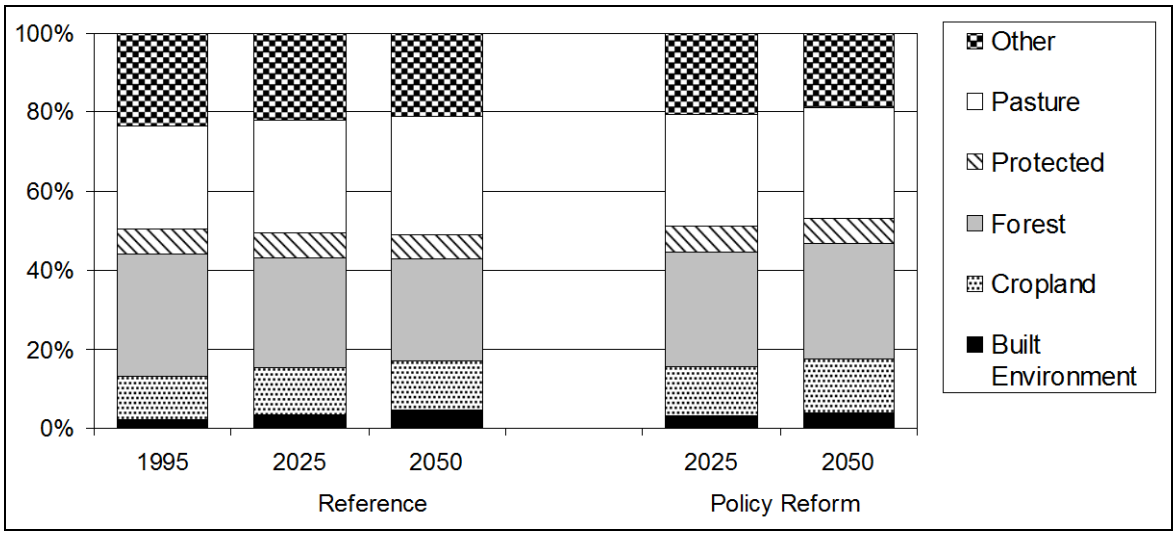
Reference

	Emissions (million tonnes S)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	3	9	15	3.9	2.2	3.1	3.1	5.4
China +	13	25	32	2.1	0.9	1.6	1.9	2.4
Latin America	3	7	11	2.3	1.9	2.1	2.0	3.2
Middle East	2	5	7	2.6	1.3	2.0	2.1	2.9
S+SE Asia	7	18	34	3.1	2.5	2.8	2.5	4.6
E. Europe	2	2	2	0.2	0.0	0.1	1.1	1.0
FSU	10	10	9	-0.1	-0.4	-0.2	1.0	0.9
N. America	12	11	12	-0.3	0.2	-0.1	0.9	1.0
Pacific OECD	5	4	4	-0.9	-0.3	-0.6	0.8	0.7
W. Europe	9	8	7	-0.3	-0.4	-0.3	0.9	0.8
Developing	29	65	99	2.7	1.7	2.2	2.2	3.4
Transitional	13	12	11	-0.1	-0.3	-0.2	1.0	0.9
OECD	26	23	23	-0.4	-0.1	-0.3	0.9	0.9
World	68	100	133	1.3	1.1	1.2	1.5	2.0

Policy Reform

	Emissions (million tonnes S)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	3	6	6	2.5	-0.1	1.3	2.1	2.0
China +	13	19	14	1.2	-1.4	0.0	1.4	1.0
Latin America	3	6	6	1.9	0.0	1.1	1.8	1.8
Middle East	2	3	3	1.0	-0.2	0.5	1.4	1.3
S+SE Asia	7	15	13	2.4	-0.6	1.0	2.0	1.7
E. Europe	2	1	1	-2.3	-2.1	-2.2	0.5	0.3
FSU	10	5	2	-2.3	-3.0	-2.6	0.5	0.2
N. America	12	6	3	-2.5	-2.7	-2.6	0.5	0.2
Pacific OECD	5	2	1	-2.7	-2.8	-2.7	0.4	0.2
W. Europe	9	4	2	-2.7	-2.7	-2.7	0.4	0.2
Developing	29	49	41	1.7	-0.7	0.6	1.7	1.4
Transitional	13	6	3	-2.3	-2.8	-2.5	0.5	0.2
OECD	26	12	6	-2.6	-2.7	-2.6	0.5	0.2
World	68	67	50	0.0	-1.2	-0.6	1.0	0.7

Sheet P-6. Land-Use by Land-Type



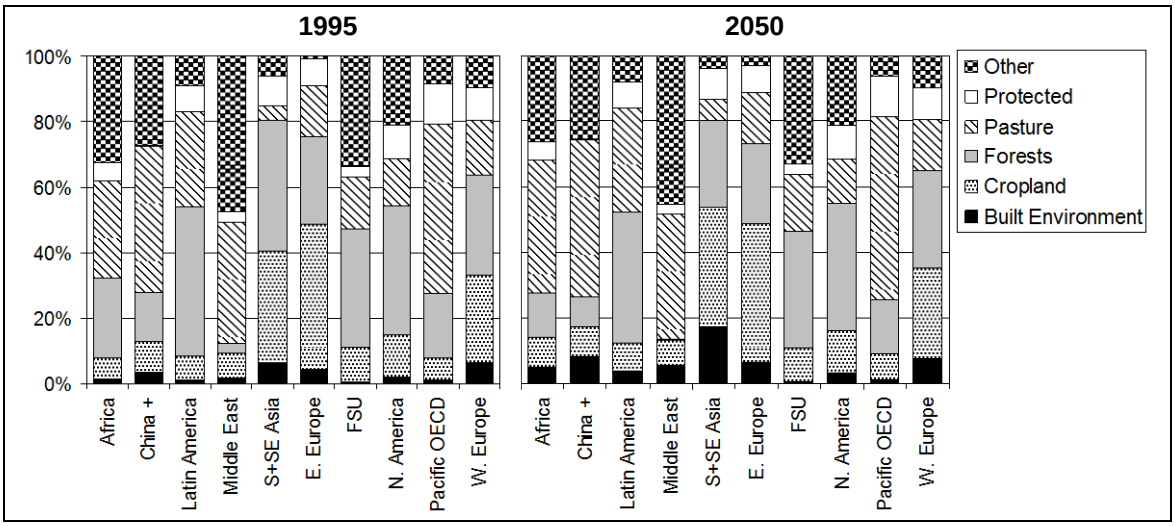
Reference

	Land area (million ha)			Growth Rate (%/year)			Index (95=1)	
Land Type	1995	2025	2050	95-25	25-50	95-50	2025	2050
Built Environment	268	440	613	1.7	1.3	1.5	1.6	2.3
Cropland	1,450	1,534	1,606	0.2	0.2	0.2	1.1	1.1
Forest	4,022	3,650	3,334	-0.3	-0.4	-0.3	0.9	0.8
Pasture	3,395	3,674	3,862	0.3	0.2	0.2	1.1	1.1
Protected	825	825	825	0.0	0.0	0.0	1.0	1.0
Other	3,042	2,880	2,762	-0.2	-0.2	-0.2	0.9	0.9
Total	13,002	13,002	13,002	-	-	-	1.0	1.0

Policy Reform

	Land area (million ha)			Growth Rate (%/year)			Index (95=1)	
Land Type	1995	2025	2050	95-25	25-50	95-50	2025	2050
Built Environment	268	404	505	1.38	0.89	1.16	1.5	1.9
Cropland	1,450	1,618	1,744	0.37	0.30	0.34	1.1	1.2
Forest	4,022	3,803	3,845	-0.19	0.04	-0.08	0.9	1.0
Pasture	3,395	3,691	3,605	0.28	-0.09	0.11	1.1	1.1
Protected	825	821	821	-0.02	0.00	-0.01	1.0	1.0
Other	3,042	2,666	2,483	-0.44	-0.28	-0.37	0.9	0.8
Total	13,002	13,002	13,002	-	-	-	1.0	1.0

Sheet P-7. Land-Use by Region
Reference Scenario



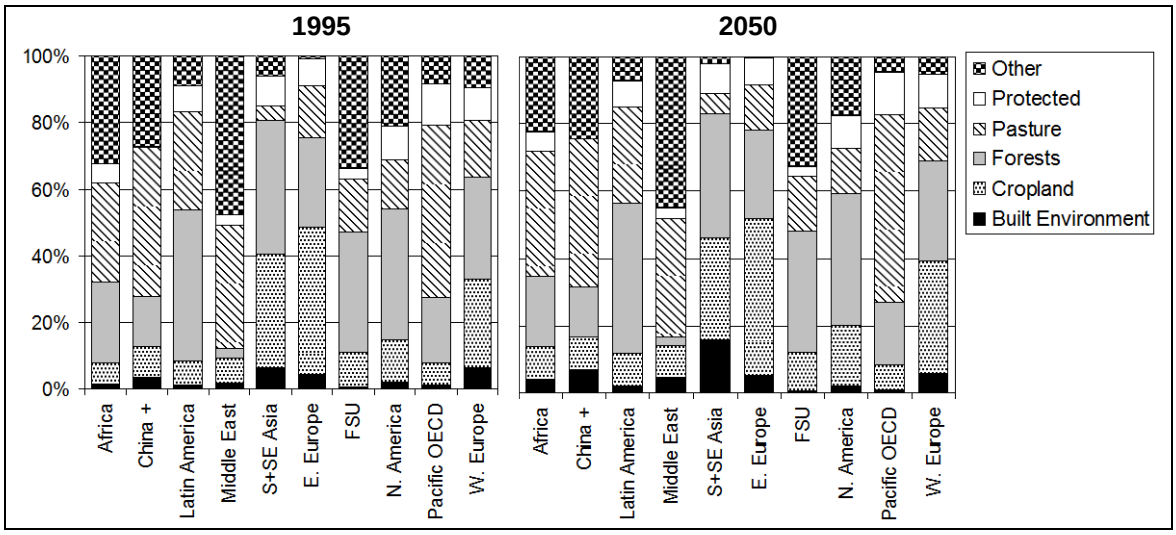
1995

Region	Land area (%) Built	Cropland	Forests	Pasture	Protected	Other	Total Area (million ha)
Africa	2	6	24	30	5	33	2,964
China +	3	9	15	45	0	27	1,158
Latin America	1	7	46	29	8	9	2,018
Middle East	2	7	3	37	3	47	604
S+SE Asia	6	34	40	4	9	6	848
E. Europe	4	44	27	16	8	1	89
FSU	1	10	36	16	3	34	2,195
N. America	2	13	39	15	10	21	1,838
Pacific OECD	1	7	20	52	12	9	829
W. Europe	6	27	31	17	10	10	461
Developing	2	10	29	30	5	24	7,591
Transitional	1	12	36	16	3	32	2,284
OECD	2	13	33	25	11	16	3,127
World	2	11	31	26	6	23	13,002

2050

Region	Land area (%) Built	Cropland	Forests	Pasture	Protected	Other
Africa	5	9	14	41	5	26
China +	8	9	9	48	0	26
Latin America	4	9	40	32	8	8
Middle East	6	8	0	38	3	45
S+SE Asia	17	36	26	7	9	4
E. Europe	6	42	25	16	8	3
FSU	1	10	35	17	3	33
N. America	3	13	39	14	10	21
Pacific OECD	1	8	16	56	12	6
W. Europe	7	28	30	16	10	10
Developing	6	12	20	35	5	20
Transitional	1	12	35	17	3	32
OECD	3	14	32	25	11	16
World	5	12	26	30	6	21

Sheet P-7. Land-Use by Region (continued)
Policy Reform Scenario



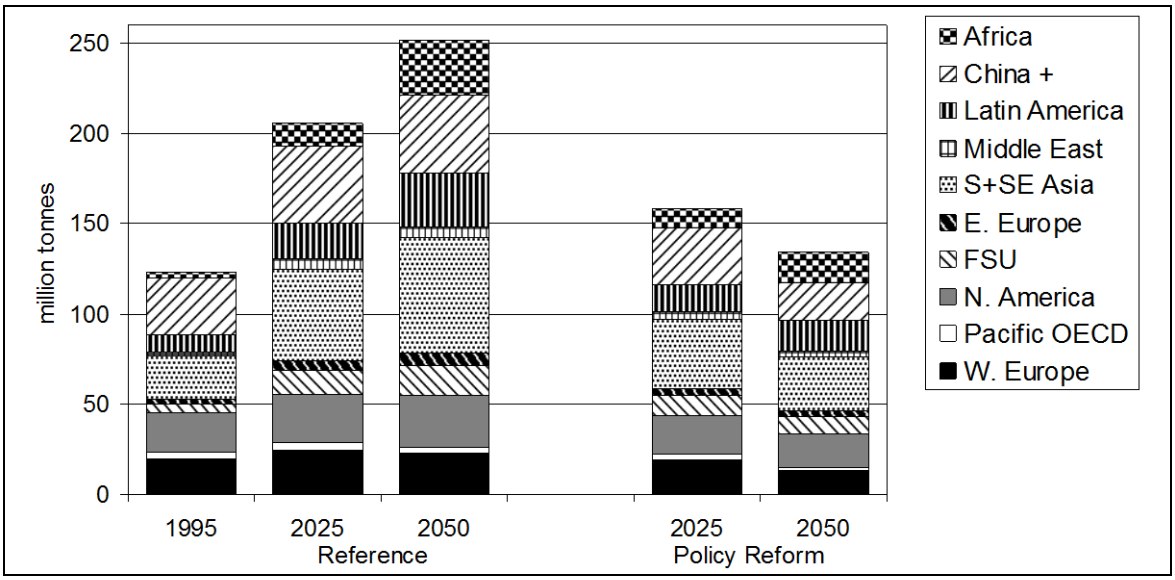
1995

Region	Land area (%) Built	Cropland	Forests	Pasture	Protected	Other	Total Area (million ha)
Africa	2	6	24	30	5	33	2,964
China +	3	9	15	45	0	27	1,158
Latin America	1	7	46	29	8	9	2,018
Middle East	2	7	3	37	3	47	604
S+SE Asia	6	34	40	4	9	6	848
E. Europe	4	44	27	16	8	1	89
FSU	1	10	36	16	3	34	2,195
N. America	2	13	39	15	10	21	1,838
Pacific OECD	1	7	20	52	12	9	829
W. Europe	6	27	31	17	10	10	461
Developing	2	10	29	30	5	24	7,591
Transitional	1	12	36	16	3	32	2,284
OECD	2	13	33	25	11	16	3,127
World	2	11	31	26	6	23	13,002

2050

Region	Land area (%) Built	Cropland	Forests	Pasture	Protected	Other
Africa	4	10	21	37	5	23
China +	7	9	15	44	0	24
Latin America	2	10	45	29	8	7
Middle East	5	9	3	35	3	45
S+SE Asia	16	30	37	6	9	2
E. Europe	5	46	26	14	8	0
FSU	1	11	36	16	3	33
N. America	2	18	39	14	10	17
Pacific OECD	1	7	19	56	12	5
W. Europe	6	33	30	16	10	5
Developing	5	12	27	32	5	18
Transitional	1	13	35	16	3	31
OECD	2	17	32	25	11	12
World	4	13	30	28	6	19

Sheet P-8. Fertilizer Consumption



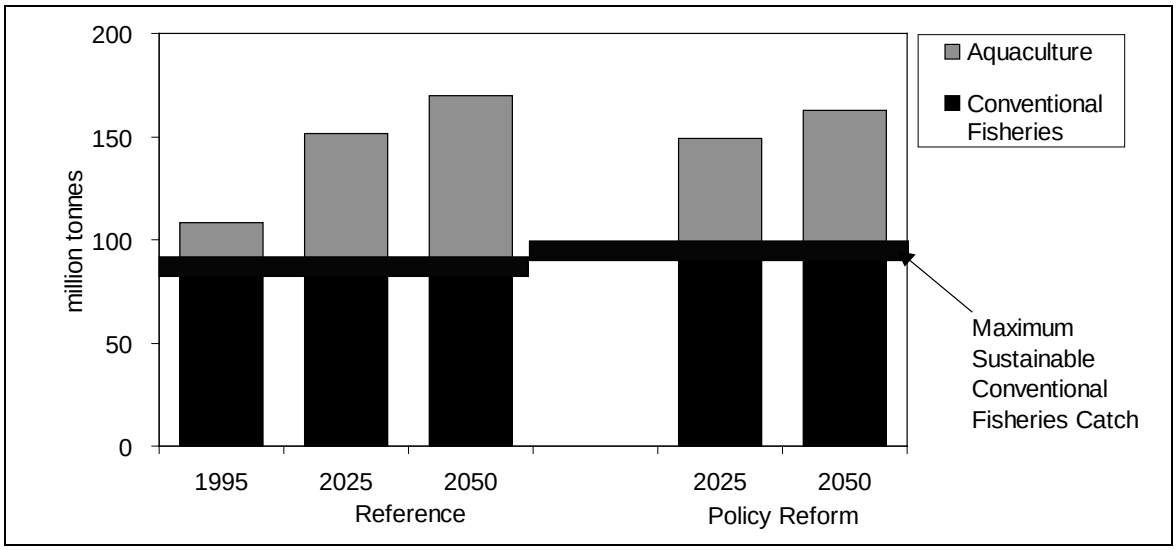
Reference

	Consumption (million tonnes)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	4	13	30	4.4	3.5	4.0	3.7	8.6
China +	32	42	43	1.0	0.1	0.6	1.3	1.4
Latin America	9	20	30	2.6	1.6	2.1	2.1	3.2
Middle East	2	6	6	2.9	0.4	1.8	2.4	2.6
S+SE Asia	24	51	64	2.6	0.9	1.8	2.1	2.7
E. Europe	3	5	6	2.2	0.7	1.5	1.9	2.3
FSU	5	13	17	3.7	0.9	2.4	3.0	3.7
N. America	22	26	28	0.7	0.3	0.5	1.2	1.3
Pacific OECD	4	4	3	0.3	-1.1	-0.3	1.1	0.8
W. Europe	20	24	23	0.7	-0.3	0.3	1.2	1.2
Developing	71	132	174	2.1	1.1	1.6	1.9	2.5
Transitional	7	19	23	3.2	0.9	2.1	2.6	3.2
OECD	45	55	55	0.7	0.0	0.3	1.2	1.2
World	123	205	251	1.7	0.8	1.3	1.7	2.0

Policy Reform

	Consumption (million tonnes)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	4	11	17	3.8	1.7	2.9	3.1	4.7
China +	32	31	21	0.0	-1.5	-0.7	1.0	0.7
Latin America	9	15	17	1.6	0.5	1.1	1.6	1.8
Middle East	2	4	3	1.9	-1.2	0.5	1.7	1.3
S+SE Asia	24	38	30	1.6	-1.0	0.4	1.6	1.2
E. Europe	3	4	3	1.5	-0.9	0.4	1.6	1.3
FSU	5	10	10	2.8	-0.3	1.4	2.3	2.1
N. America	22	21	19	0.0	-0.6	-0.3	1.0	0.9
Pacific OECD	4	3	2	-0.6	-2.8	-1.6	0.8	0.4
W. Europe	20	19	13	-0.1	-1.5	-0.7	1.0	0.7
Developing	71	100	88	1.1	-0.5	0.4	1.4	1.2
Transitional	7	15	13	2.4	-0.5	1.1	2.0	1.8
OECD	45	44	34	-0.1	-1.1	-0.5	1.0	0.7
World	123	158	134	0.8	-0.7	0.2	1.3	1.1

Sheet P-9. Fisheries



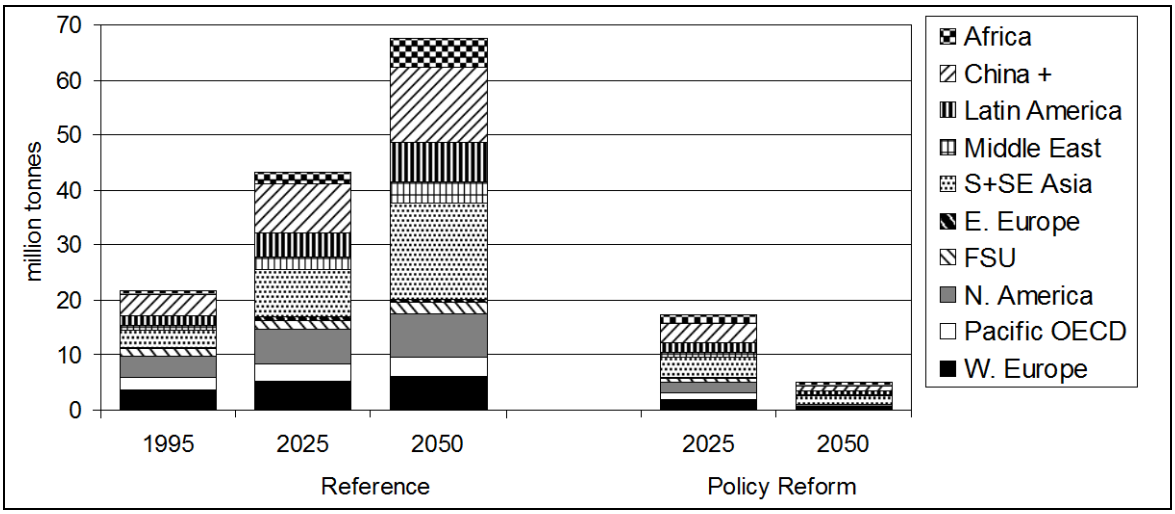
Reference

	Production (million tonnes)			Growth Rate (%/year)			Index (95=1)	
Type	1995	2025	2050	95-25	25-50	95-50	2025	2050
Conventional Fisheries	88	88	88	0.0	0.0	0.0	1.0	1.0
Aquaculture	20	63	82	3.9	1.0	2.6	3.2	4.1
Total	108	151	170	1.1	0.5	0.8	1.4	1.6

Policy Reform

	Production (million tonnes)			Growth Rate (%/year)			Index (95=1)	
Type	1995	2025	2050	95-25	25-50	95-50	2025	2050
Conventional Fisheries	88	93	93	0.2	0.0	0.1	1.1	1.1
Aquaculture	20	56	70	3.5	0.9	2.3	2.8	3.5
Total	108	149	163	1.1	0.4	0.7	1.4	1.5

Sheet P-10. Toxic Waste



Reference

	Toxic Waste (million tonnes)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	0.7	2.3	5.3	4.0	3.3	3.7	3.2	7.3
China +	3.8	8.8	13.6	2.9	1.7	2.4	2.3	3.6
Latin America	1.9	4.4	7.3	2.7	2.1	2.4	2.3	3.8
Middle East	0.8	2.2	3.9	3.5	2.3	2.9	2.8	4.9
S+SE Asia	3.0	8.6	17.2	3.6	2.8	3.3	2.9	5.8
E. Europe	0.4	0.6	0.8	1.6	0.8	1.2	1.6	2.0
FSU	1.2	1.7	2.0	1.1	0.7	0.9	1.4	1.7
N. America	3.9	6.4	7.9	1.6	0.9	1.3	1.6	2.0
Pacific OECD	2.2	3.0	3.4	1.0	0.6	0.8	1.4	1.6
W. Europe	3.8	5.3	6.1	1.1	0.6	0.9	1.4	1.6
Developing	10	26	47	3.2	2.4	2.8	2.6	4.6
Transitional	2	2	3	1.2	0.8	1.0	1.4	1.7
OECD	10	15	17	1.3	0.7	1.0	1.5	1.8
World	22	43	68	2.3	1.8	2.1	2.0	3.1

Policy Reform

	Toxic Waste (million tonnes)			Growth Rate (%/year)			Index (95=1)	
Region	1995	2025	2050	95-25	25-50	95-50	2025	2050
Africa	0.7	1.4	0.6	2.1	-3.0	-0.2	1.9	0.9
China +	3.8	3.6	1.0	-0.2	-4.9	-2.4	0.9	0.3
Latin America	1.9	1.8	0.5	-0.4	-4.6	-2.3	0.9	0.3
Middle East	0.8	0.9	0.3	0.3	-4.3	-1.8	1.1	0.4
S+SE Asia	3.0	3.8	1.4	0.8	-3.9	-1.4	1.3	0.5
E. Europe	0.4	0.2	0.1	-1.5	-5.7	-3.4	0.6	0.1
FSU	1.2	0.7	0.2	-1.9	-5.7	-3.6	0.6	0.1
N. America	3.9	2.0	0.4	-2.3	-6.2	-4.1	0.5	0.1
Pacific OECD	2.2	1.1	0.2	-2.3	-6.2	-4.1	0.5	0.1
W. Europe	3.8	1.9	0.4	-2.3	-6.2	-4.1	0.5	0.1
Developing	10	11	4	0.4	-4.2	-1.7	1.1	0.4
Transitional	2	1	0	-1.8	-5.7	-3.6	0.6	0.1
OECD	10	5	1	-2.3	-6.2	-4.1	0.5	0.1
World	22	17	5	-0.8	-4.8	-2.6	0.8	0.2

Abbreviations

GDP	gross domestic product
MER	market exchange rate
PPP	purchasing power parity
GDP_{PPP}	GDP in international dollars adjusted for PPP
GDP_{MER}	GDP in US dollars at MER
OECD	Organization for Economic Cooperation and Development
PCL	potential cultivable land
^{o}	degree centigrade
cal	calories
g	gram
ha	hectare
m	meter
mpg	miles per gallon
t	tonne
tC	tonne of carbon
J	Joules
E	Exa, 10^{18}
P	Peta, 10^{15}
T	Tera, 10^{12}
G	Giga, 10^{9}
M	Mega, 10^{6}
k	kilo, 10^{3}

Selected Conversion Factors

Energy							
1 GJ	=	0.172 BOE	=	0.0239 TOE	=	0.0341 TCE	
Volume							
1 km^3	=	$264.2 \cdot 10^9$ US gallons	=	$810.7 \cdot 10^3$ acre·foot			
Mass							
1 tonne	=	1000 kg	=	1.10 short ton	=	$2.20 \cdot 10^3$ pounds	
Area							
1 ha	=	2.47 acre	=	0.0100 km^2			
Fuel Efficiency							
1 mpg (US)	=	0.425 km/liter					

Data Notes

All Sheets: Scenario assumptions are summarized in text and described in detail in Heaps, et al. (1998).

Sheet D-1: Base year and *Reference* population from mid-range UN (1997). For *Policy Reform* population, see Section 4.2.

Sheet D-2: Values for 1995 and 2025 computed using data from WRI (1994; 1996). Changes from 2025 to 2050 assume a slowing urbanization trend relative to 1995-2025.

Sheet E-1: GDP_{PPP} and GDP_{MER} computed using GDP_{PPP} per capita from CIA (1997), GDP_{MER} per capita from World Bank (1997) and populations from mid-range UN (1997).

Sheet E-2: Value added by sector from World Bank (1997). Estimates based on market exchange rates, using the most recent available data from 1992-1995. Percentages based on countries where data available.

Sheet E-3: Regional values are population-weighted averages of country GDP_{PPP} per capita from CIA (1997). Scenario growth rates based on GDP_{MER} growth rates (IPCC, 1992a), adapted for the regions in this study and converted to PPP growth rates (Heaps, et al., 1998).

Sheet S-1: All values weighted by national populations. Based on Gini coefficients from Deininger and Squire (1996), U.S. Census (1997), Tabatabai (1996) and World Bank (1998), with additional estimates (Heaps, et al., 1998). Distributional equity is the ratio of the average income of the lowest earning 20% to the highest earning 20% of the population, estimated assuming lognormal national income distributions.

Sheet S-2: For most developing countries, data are based on FAO estimates of the incidence of chronic undernutrition (FAO, 1997a); for the US, the incidence of food insecurity was used (Rose et al., 1995); for all other countries estimates are based on income distribution (Heaps, et al., 1998).

Sheets En-1…4: Data from IEA energy statistics (IEA, 1997a,b). In sheets En-3 and En-4, final energy demand is defined as consumption of electricity and fuels by end-users. In sheets En-1 and En-2, primary energy in each region is the sum of final energy demand in the region, energy lost through the transformation of primary to secondary fuel forms, and net energy lost or used during transmission and distribution. Care should be taken in interpreting primary energy supply figures since different statistical sources use different conventions for reporting the primary energy content of nuclear and renewable sources of energy. The conventions for efficiency adopted in this study are: uranium at 33%, geothermal at 10%, and hydro, wind, solar and other renewables at 100%. Other sources may express hydro resources in terms of an equivalent fossil fuel feedstock requirement.

Sheet En-5: Data from WEC Survey of Energy Resources (WEC, 1995)**.** See definition of proven and undiscovered reserves in Section 3.3.2. Uranium estimates assume conventional fission reactors. Estimates do not include non-conventional oil and natural gas resources.

Sheet F-1: Base year values from FAO (1996b). Daily consumption is the amount available for consumption.

Sheets F-2…4: Base year values from FAO (1996b). Self-sufficiency ratio calculated as production/requirements. Net exports in the base year include net additions to stocks. Meat includes eggs; milk includes all products derived from milk. Fraction from feedlots is the fraction of total production in caloric terms. Fish includes all seafood.

Sheet F-5: Base year values from FAO (1996b). Annual yield defined as total annual production per unit area of cropland. Harvest yield is production per unit area per harvest. Cropping intensity is a measure of multiple cropping, given by:

$$\text{cropping intensity} = \text{annual yield} \big/ \text{harvest yield} .$$

The index shown is for Annual yield.

Sheets F-6, 7: Base year values from FAO (1996b). Cropland includes land for growing sugarcane for energy and food.

Sheets F-8: Existing cropland from FAO (1996b). Potential cropland for developing regions based on data from Fischer (1993). For OECD and transitional regions, see Heaps, et al. (1998). Potential cultivable

land includes active farmland and other land-types potentially suitable for farming. It is lost through land degradation and conversion to other land uses.

Sheets P-1, 2: Data are for total freshwater withdrawals from Najlis (1996) and Shiklomanov (1997), supplemented by Raskin et al. (1995).

Sheet P-3: Use/Resource ratio is total freshwater requirements divided by renewable freshwater resources, including river flows from adjacent countries. Base year data from Najlis (1996) and Shiklomanov (1997), supplemented by Raskin et al. (1995). Water stress is discussed in Sections 2.2, 3.3 and 4.6.

Sheet P-4: Emissions are estimated from energy consumption data and emissions factors based on IPCC (1995b). 1 GtC = 1 billion tonnes carbon. Emissions are from combustion of fossil fuel only; they exclude net emissions from land-use changes and from non-energy industrial processes, which contributed an additional 1.5 GtC in 1995 (IPCC, 1996).

Sheet P-5: Data based on Posch et al. (1996) and Kuylenstierna (1998) with additional assumptions. Includes energy sector SO_x emissions and industrial process SO_x emissions.

Sheets P-6, 7: Areas currently under cropland, forest and pasture from FAO (1996b); areas under built environment for developing regions from Fischer (1993); other regions estimated from various sources (see Heaps, et al., 1998); protected areas Fischer (1993) and WCMC (1998a,b); area of "Other Land" computed as balance using total land area from FAO (1996b).

Sheet P-8: Consumption of manufactured fertilizer (FAO, 1996b).

Sheet P-9: Total production from FAO (1996b); aquaculture production and maximum sustainable fisheries catch from FAO (1997). Maximum sustainable catch is higher in the *Policy Reform* scenario. Better management of capture fisheries is assumed to extend the current production of around 85 million tonnes per year to a sustained annual production of 100 million tonnes (FAO, 1997c).

Sheet P-10: Data based on World Bank Industrial Pollution Projection System (Hettige et al., 1994).