Global Scenarios for the Century Ahead:

Searching for Sustainability

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Concern about the sustainability of nature and society is rising, and with good reason. Scientists report with ever-greater urgency the need for action to avoid severe risks of climate change and widespread destruction of the world's ecosystems [1,2]. Parallel efforts are needed to ease looming shortages of critical resources such as oil, water, and food. Meanwhile development specialists call for mitigating poverty and oppression, strengthening social justice, and enhancing human well-being. Many other observers emphasize the need for more effective transnational governance as the unregulated growth of globalizing capital, finance, production, and labor markets threaten the long-term stability and fairness of the world economy.

Addressing these critical concerns is central to the broad challenge of sustainable development, a commitment that the world took on nearly two decades ago at the 1992 Earth Summit in Rio de Janeiro. At the core of the concept of sustainable development lies the moral imperative to pass on an undiminished world to future generations. The call to reorient our current actions and choices to ensure the well-being of the unborn requires that we consider the consequences of today for the long-term tomorrow.

This report explores the challenge of sustainability by considering four contrasting global scenarios that might emerge from the turbulence and uncertainty of the present. Market Forces and Policy Reform are evolutionary scenarios that are assumed to evolve gradually, despite episodic setbacks, from the dominant forces governing world development today. The other two assume a basic restructuring of the global order: regression in Fortress World and positive transformation in Great Transition. Each scenario tells a different story of the twenty-first century with varying patterns of resource use, environmental impact, and social conditions.

It is important to note the distinction between scenarios and forecasts. The interactions among co-evolving human and environmental systems are highly complex and inherently uncertain rendering prediction impossible in any rigorous statistical sense [3,4]. The scenarios presented here represent not predictions but plausible possibilities designed to stimulate the imagination, warn of pitfalls ahead, and guide action today.

We have examined our four scenarios in great quantitative detail to the year 2100, drawing lessons for policy strategies, institutional change, and, ultimately, for human values and choices. Comparing the scenarios reveals the fundamental forces driving world development away from or toward sustainability. This report summarizes the results, painting broad-brush pictures of alternative futures and the insights they provide.

The scenarios are updates and enhancements of earlier analyses conducted by the Tellus Institute on behalf of the Global Scenario Group [5,6,7]. The base year has been advanced from 1995 to 2005, adding ten additional years to the massive database on which the simulations rest. That data feeds the PoleStar System, a computational framework originally designed in the early 1990s by the Tellus Institute and the Stockholm Environment Institute to explore long-range scenarios [8]. PoleStar unpacks global scenarios in great detail, analyzing major sectors and subsectors of the economy, key social variables, and numerous aspects of the environment and natural resources for eleven world regions. This summary report focuses on global results only [9].[1]

One overarching message is clear: we stand at a historical crossroads, heading into an uncertain and perilous future. Continuing to muddle forward in a business-as-usual mode would risk collapse of civilized norms and deterioration of the planet's life support ecosystems. In principle, we find that a long and tenacious process of adjustments in the form of new technologies and policies – as embodied in the Policy Reform scenario – could conceivably get us to a sustainable world. We shall see, however, that this

[1] Key issues simulated in PoleStar are summarized in the Appendix. Assumptions and computations are documented in [9]. PoleStar regional results are reported at the Tellus website: http://www.tellus.org/result_tables/results.cgi.

would be extremely difficult to achieve: marshalling the globally-coordinated, government-driven interventions needed, in the context of a growth-oriented development model, may be politically infeasible.

At the same time, the challenge of forging a sustainable and just form of planetary civilization in this century presents an opportunity for a transition to a new and vital phase of human history. An alternative approach, though requiring a basic shift in the development paradigm, holds promise: coupling enhanced technologies and policies to fundamental adjustments in dominant values and institutions. If humanity musters the will for such a Great Transition, a new and rich chapter of civilization built on greater equity, a high quality of life, and comprehensive ecosystem protection becomes possible.

THE SCENARIOS: AN OVERVIEW

Scenarios are often defined as plausible stories about the future. But deep uncertainties lurk on the path to the future: How will the climate system respond? What geo-political formations will emerge? How will human values adjust? The plausibility, and even the internal consistency, of different visions is itself uncertain. Indeed, the exploration of internal inconsistencies – the ways surprises and feedback might knock a scenario off course – is also revealing.

Our four scenarios are:

THE SCENARIOS
Conventional Worlds:
Market Forces (MF) *– Risks of Market-centered Development*
Policy Reform (PR) *– Redirecting Growth*
Alternative Visions:
Fortress World (FW) *– An Authoritarian Path*
Great Transition (GT) *– A Sustainable Civilization*

The two Conventional Worlds scenarios assume the persistence of many of the dominant forces driving development and globalization in recent decades. They envision worlds able to tolerate and recover from socio-ecological crises, and able to achieve high rates of global economic expansion, similar to that of the last several decades – where GDP growth remains the primary measure of successful development. Poor countries gradually converge toward the consumption and production patterns of rich nations as their incomes rise, and as cultural and social influences of globalization spread.

Market Forces: Market-centered Development

Market Forces is constructed as a future in which free market optimism proves well-founded: policy prioritizes economic growth, free trade, and competitive markets. Average global incomes grow at nearly two percent per year, even as the population expands by some 40 percent from 2005 to 2050 [10]. The global economy grows over three-fold by 2050 and over eightfold by 2100.[2]

Where would the raw materials, land, water, and energy resources come from to sustain such a huge economy? How would environmental resilience be maintained? These critical uncertainties call into question the viability of the Market Forces path. As we shall see, our analysis shows that such a course would have great difficulty remaining consistent with bio-physical sustainability constraints, and it will remain a world of profound inequalities between rich and poor countries, and within each country. Conflicts over scarce energy, water, and food resources, amplified by climate impacts, could lead to a descent toward a Fortress World future.

Policy Reform: Directing Growth

This government-driven scenario assumes a massive implementation of reform policies aimed at meeting sustainability objectives. As a Conventional Worlds scenario, Policy Reform assumes no major changes in the international order rooted in the nation-state, institutional structures, and the continuity of dominant consumerist cultural values. However, unlike Market Forces, governments intervene to redirect

[2] All economic figures are stated in purchasing power parity (PPP) dollars which takes account of national differences in the cost of living when converting to a common currency.

economic growth to achieve key internationally recognized goals for poverty reduction, climate change, ecosystem preservation, water supply adequacy, and pollution control. For example, the scenario meets tough stabilization targets for carbon dioxide and, in rough compatibility with the United Nations (U.N.) Millennium Development Goals, halves world hunger between 2005 and 2025 (then halves it again by 2050).

The poverty alleviation goals are achieved through targeted redistribution policies to raise incomes of the poorest regions and most impoverished people. This shift, in turn, allows poorer nations to accelerate sustainable energy and other environmental investments as they more rapidly convergence toward the living standards and technologies of richer countries. By 2050, the annual GDP in OECD regions is about 20 percent lower than in the Market Forces scenario (though still much higher than now) as a result of the higher levels of financial transfers to poor regions. Such transfers have been debated at climate negotiations, with little success to date. Yet the analysis indicates that a Policy Reform scenario designed to simultaneously achieve social and environmental sustainability outcomes will require a deep and widespread commitment to greater economic equity.

The Policy Reform scenario also includes aggressive goals for mitigating climate change. It allows for some growth in greenhouse gas emissions in developing countries with an aggregate declining trajectory that cuts world CO_2 emissions by 70 percent by 2050, and reaches zero emissions by 2070 to meet a climate protection goal of 350 parts per million (ppm) of atmospheric CO_2 by 2100.[3] In addition, the scenario meets other objectives such as moderating stress on freshwater supplies, and protecting natural habitats from land-use incursions. Implementing this grand policy program in the context of Conventional Worlds values and institutions would not be easy; indeed, sustained attempts over the past two decades within the U.N. frameworks to address climate change, biodiversity protection, poverty reduction and other sustainability challenges have not succeeded. Policy Reform would require an unprecedented mobilization of political will to make the regulatory, economic, social, technological, and legal decisions that would align development with sustainability goals. That political will is nowhere in sight, and remains the critical uncertainty in the plausibility of the reform strategy for sustainable development.

Fortress World: An Authoritarian Path

If market adaptations and policy reforms are unable to redirect development away from destabilization, the global trajectory could bend toward a pessimistic future. Fortress World explores the possibility that powerful world forces, faced with dire systemic crises, impose an authoritarian order in which elites retreat to protected enclaves leaving impoverished masses outside.[4] In the Fortress World, the trend seen in Market Forces of greater income inequality within and between regions becomes extreme, allowing only elites everywhere to reach a Western lifestyle. As economic progress stagnates or reverses, the standard of living for many people would be a modestly improved version of that typical in Africa today.

With poverty endemic, the demographic transition that comes with higher incomes is reversed in the poorest areas, and world population rises to 10 billion people by 2100, the highest of all scenarios. With investment in water infrastructure and land preservation curtailed, water scarcity soars despite lower demands from industry. Land degradation is exacerbated, biodiversity loss increases, and food is scarce. In contrast, military spending remains high, as the global archipelago of connected fortresses impose order on a discontent population. In this type of future, sustainable development is not in the cards, a half-remembered dream of a more hopeful time.

Great Transition: A Sustainable Civilization

In dramatic contrast, Great Transition envisions a values-led shift in which the citizens of the world drive fundamental change toward a just, sustainable,

[3] As discussed in Section IV, 350 ppm translates approximately into a two degree Celsius average global temperature increase, a goal endorsed by the Copenhagen Accord of 2009.

[4] In our troubled world, it is not surprising, perhaps, that many think Fortress World is the true "business-as-usual" scenario.

and livable future. The ascendant development paradigm is rooted in popular values stressing human solidarity, environmental stewardship, and quality of life. The emergence of far more equitable social arrangements and effectual institutions for global governance supports technological improvements and policy reforms, while more moderate lifestyles reduce the growth thrust of the Conventional Worlds scenarios.

The immense uncertainty of this scenario, of course, is whether the historical agents necessary for such grand political and cultural changes will appear. If they do, a sustainable future such as the Great Transition would become feasible and, for many people, a desirable legacy for future generations. The scenario assumptions lead to the eradication of poverty and hunger, reduction of material consumption and production, universal access to social services, reduced work weeks, diminished armed conflict, enhanced democracy, and a stabilized world population. World population stabilizes more rapidly than in other scenarios reaching only about 8 billion by 2050, then dropping about ten percent by 2100, as more equal gender roles and universal access to education and health care services lower birth rates. Diminished population pressure plays an important role in meeting environmental and social goals.

Lifestyles in the Great Transition are materially sufficient and culturally rich, with the notion of the "good life" shifting from an emphasis on possessions to qualitative dimensions of well-being: creativity, leisure, rewarding relationships, and community engagement. Average global income stabilizes after 2050, as the world approaches a steady-state economy, reaching about $30,000 per person by 2100. Although lower than the approximately $51,000 in Policy Reform, this is more than three times the 2005 global average, and, with a more egalitarian income distribution, most people are far better off. Indeed, "international equity" (the ratio of income in developing to developed regions) reaches 90 percent by 2100 – twice that of Policy Reform. At the same time, equity *within* each region rises with the ratio of the incomes of the richest to poorest 10 percent of the population no higher than 4 to 1 by 2100, more equitable than Sweden today. Greater social equity contributes to social cohesion and reduced conflict as the world confronts crises with enhanced resilience and cooperation. This kind of world, were it to come to pass, would be deeply sustainable.

GUIDELINES FOR SUSTAINABILITY

Though evocative, the concept of sustainability (or "sustainable development") is also vague. We operationalize the term here by introducing a set of trends for various indicators that, if realized, would foster a resilient, just, and desirable form of global development in the course of this century. These indicators serve as the lens through which we evaluate the compatibility of each scenario with sustainability broadly construed. The aim is to consider the *quality of development* – the degree of well-being in human lives, the strength of communities, and the resilience of the biosphere – rather than misleading conventional measures of "development," such as gross domestic product (GDP).

Socio-economic Dimensions

In a strict sense, the primary economic and social sustainability objectives are institutional stability and resilience. However, we take as desirable and necessary additional features of a stable society, including reduced social disparities, enhanced social cohesion, and poverty reduction. Important proximate goals contributing to these desiderata are universal access to clean water and adequate nutrition, stabilized world population, and improved quality of work and reduced work weeks. As we have seen, achieving these various objectives, in turn, correlates to better income distribution and a stronger ethic of cooperation. The primary socio-economic objectives are listed in Table 1.

TABLE 1: Economic & Social Dimensions
Social stability and resilience • *Enhance social cohesion* • *Democratize governance of key institutions* • *Strengthen cultural diversity*
Poverty and hunger reduction • *Decrease income and wealth disparities* • *Raise income to a sufficient level for all* • *Stabilize then reduce population* • *Improve access to adequate nutrition, sanitation, and freshwater*
De-materialize lifestyles • *Moderate materialistic values* • *Reduce formal work time* • *Promote quality of life activities*

Environmental and Resource Dimensions

Environmental sustainability objectives include controlling anthropogenic impacts on the global climate, reducing pollution, preserving natural resources and enhancing ecosystems and habitats. Key action dimensions contributing to these ends are summarized in Table 2. Reductions in economic growth can, presumably, help achieve these environmental objectives, if done correctly.

TABLE 2: Environmental & Resource Dimensions
Mitigate greenhouse gas emissions • *Reduce combustion of fossil-fuels and sequester CO_2 emissions* • *Minimize then reverse emissions from land-use changes* • *Reduce other greenhouse gas emissions*
Protect natural resources • *Reduce air and water pollution* • *Eliminate emissions of toxic chemicals* • *Reduce mineral flows through economy, and recycle intensively* • *Reduce water stress*
Preserve habitats • *Reduce urban sprawl* • *Protect forests and other ecosystems* • *Fish sustainably* • *Promote ecological agriculture*

Meeting Objectives

As we shall see, meeting all these objectives requires improvements in technology and significant changes in lifestyles, and ultimately, in core values. To radically reduce human impacts on the environment, a technology transformation is urgently needed in the ways we produce energy, grow food, construct buildings, provide for mobility, and fabricate products. However, technological progress, while necessary, will not be sufficient, if overwhelmed by the expansion of production and consumption brought about by increases in our numbers and wealth. If high-consumption lifestyles of the 'developed' countries remain the model for a world of nine or ten billion, the pace and scale of the required technological transformation would become daunting, thwarting sustainability. Rather, lifestyles need to evolve toward an emphasis on material sufficiency and richness of culture, relationships, and creativity. At a deeper level such behavioral changes imply a fundamental transformation in core values: from the dominant triad of consumerism, the domination of nature, and individualism, to an emphasis on quality of life, environmentalism, and human solidarity.

In summary, the Market Forces scenario relies on price-induced market adaptations and opportunities to address sustainability. Policy Reform focuses on governmental strategies to promote the diffusion of better technologies and mobilize international efforts to alleviate poverty. Great Transition envisions a shift to a development paradigm rooted in new set of core human values that entrains lifestyles, technology and policy to be compatible with broad sustainability objectives. Fortress World considers the dismal prospect of the collapse of civilized norms and degradation of the natural world.

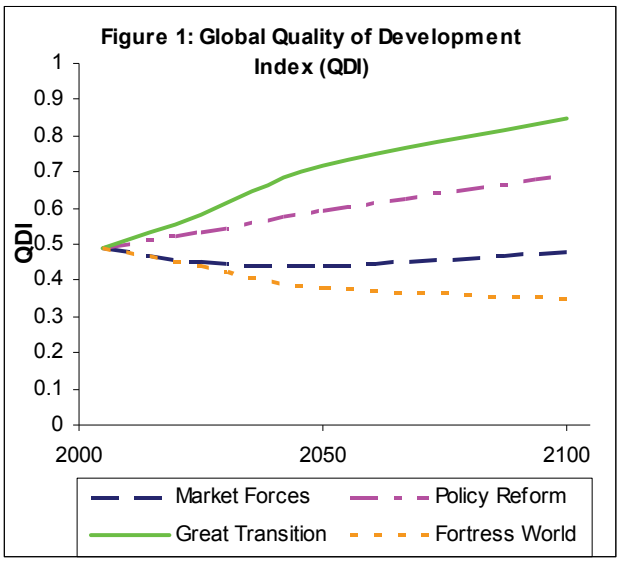
VIEWS OF THE FUTURE

We have simulated the four updated scenarios in great detail for eleven global regions (see the Appendix for a summary of key issues simulated) [9]. Policy Reform, Fortress World, and Great Transition are

constructed as "backcasts" that envision future states of the world, and then identify development pathways that could take us there. Again, Policy Reform focuses on meeting sustainability objectives within a Conventional World paradigm, while Great Transition and Fortress World consider fundamental structural shifts in institutions and culture. We summarize here the broad quantitative directions of change across these scenarios from 2005 to 2100.

A Bird's-Eye Perspective

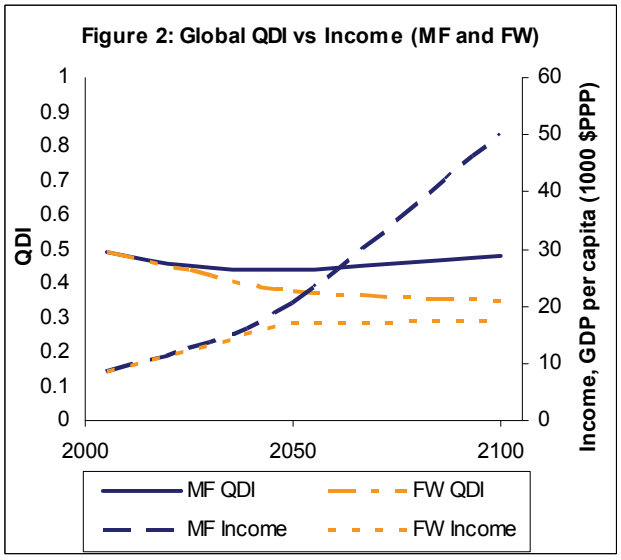
We begin with the Quality of Development Index (QDI), an overarching measure of the sustainability performance of each scenario when measured against our socio-economic and environmetal guidelines. The QDI combines three sub-indices of material, community, and environmental well-being.[5] As Figure 1 indicates, Market Forces does not improve the global QDI despite rapid and continuous economic growth. (A similar pattern is seen at the regional scale, e.g., the QDI falls in OECD regions and rises only modestly in non-OECD regions.) By contrast, we see that in Policy Reform, with its assumed commitments to meeting environmental and poverty alleviation objectives, the QDI improves with time.

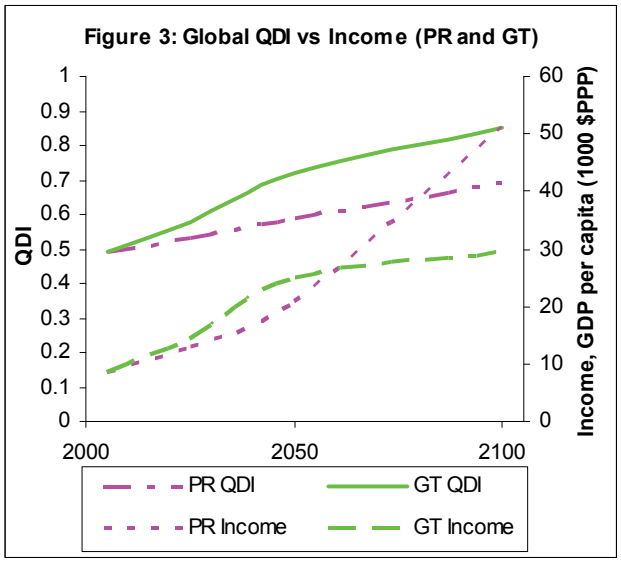


[5] The material Well-being Index includes Time Affluence (essentially leisure time) and Prosperity indicators; the Community Index includes Poverty Reduction and Social Cohesion (related to income disparity) indicators; the Environment Index includes Climate and Habitat indicators. For details, see pp. 321–329 of the technical documentation for these scenarios [9].

The QDI rises still higher in Great Transition, which features a strong emphasis on quality-of-life and an ethic of cooperation.

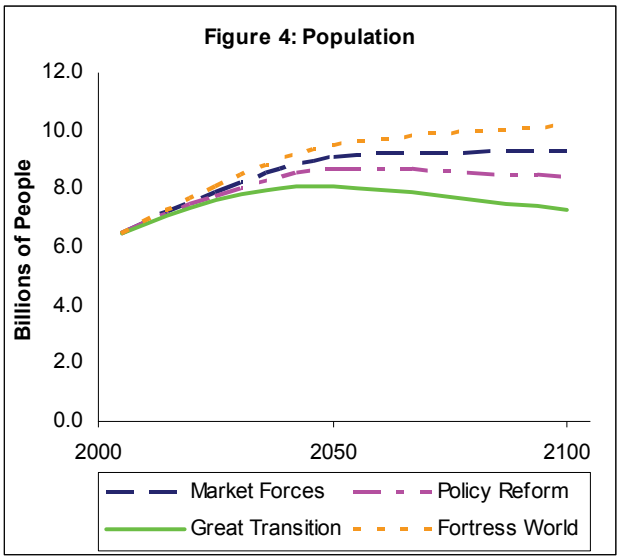
Figures 2 and 3 underscore the deviation of QDI, a broad measure of development, from income per capita, the conventional measure that equates development with economic growth. Again, income rapidly increases in Market Forces while QDI stagnates. By contrast, income growth is more modest in Great Transition, yet QDI increases rapidly. Not surprisingly, the Fortress World QDI falls continuously from 2005 to 2100, traceable to low incomes along with community and environmental degradation.





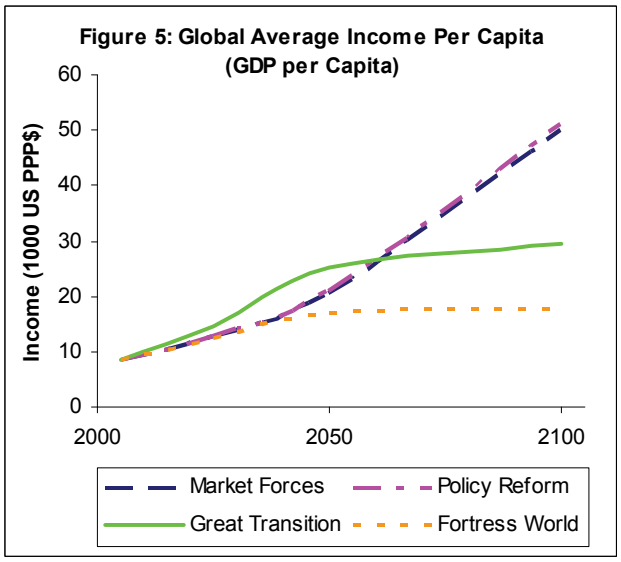
Economic and Social Patterns

Population. Across the four scenarios, world population grows to 7.2-10.2 billion people in 2100 from 6.5 billion in 2005 (Figure 4), with most of the increase in developing regions. The variation in population trends is due primarily to differences in fertility rates (children per woman), which correlates to access to education (especially for girls), occurs to family planning services, and poverty reduction. The demographic transition to lower birth rates is accelerated in the Policy Reform and, especially, in the Great Transition scenarios, and delayed in Fortress World, where the process of modern development is truncated.

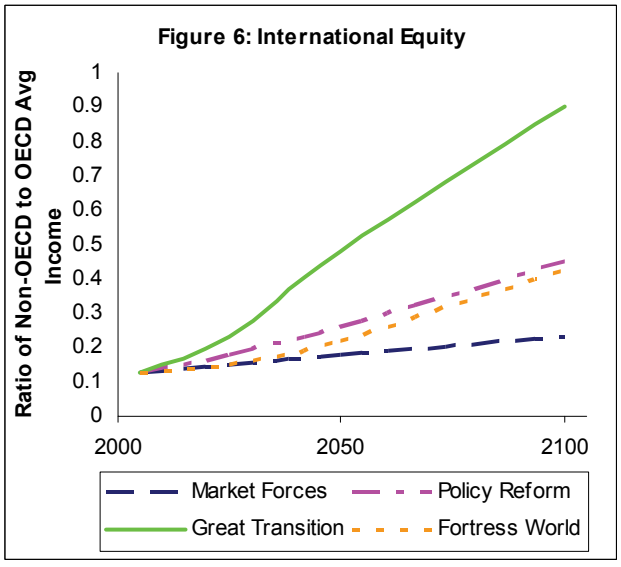


Income. Average income soars in both Policy Reform and Market Forces (Figure 5). Income growth stagnates in Fortress World as the majority of the world's population is mired in poverty. Global average income grows substantially in Great Transition before 2050, where it is assumed that strong commitments to development equity spur rapid economic development in the global South. Then, as greater equity is achieved, growth moderates as regional incomes converge and the world approaches a steady state economy of high equity and QDI [11,12].[6] Great Transition incomes average roughly $30,000 per person in 2100, about 75 percent of per capita income in North America in 2005, but are distributed far more equally.

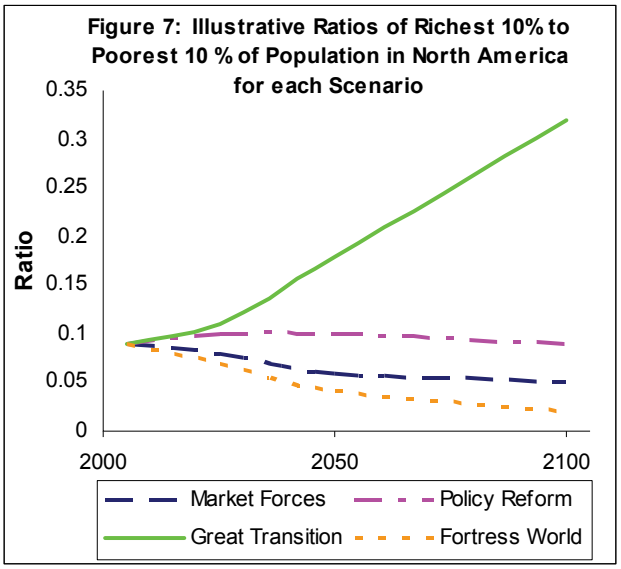
[6] Though incomes converge, social and cultural diversity remains across and within each region in the pluralistic Great Transition scenario.

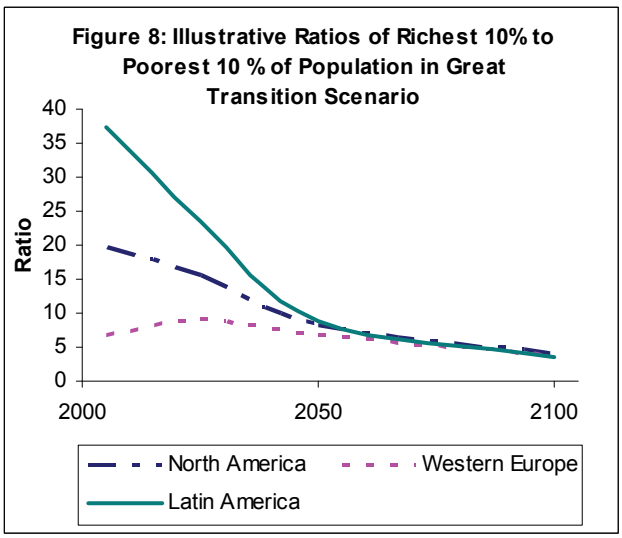


Inter-regional equity. In 2005, the ratio of average income in OECD to non-OECD nations was 0.13. The scenarios contrast markedly in the degree they address that inequity in the future (Figure 6). In Market Forces, international equity remains low, rising to just 0.23 in 2100. Ironically, it improves more in Fortress World, but only because regions become more equally poor. Policy Reform, in pursuing its poverty reduction goals, sees international equity improve to 0.45 as a result of financial transfers from OECD to non-OECD regions. Rooted in the core values of justice and solidarity, Great Transition envisions a far more equitable world by 2100, reaching a value of 0.90.

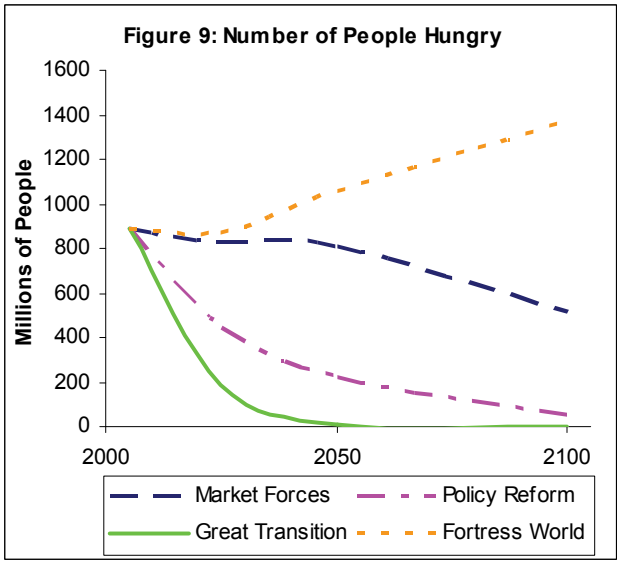


Intra-regional equity. The distribution of income *within* regions also varies across scenarios. With the ratio of income of the richest 10 percent to the poorest 10 percent in a given region as a measure of inequality, Figure 7 displays the range of variation for North America across scenarios. The patterns for three different regions in the highly equitable Great Transition are shown in Figure 8, where a ratio of about 4 to 1, somewhat lower than Western Europe today, is taken as a reasonable long-run goal.





Poverty and hunger. The incidence of chronic hunger serves as our primary indicator of poverty. The sustainability target for the Policy Reform scenario is to halve world hunger by 2025, and halve it again by 2050, in the spirit of the U.N. Millennium Development Goals which call for a first halving by 2015. The number of chronically undernourished people in a region depends on four key parameters: population, average income in a region, income distribution, and the "hunger line," the income below which most people today are hungry.[7] Since these evolve differently across the scenarios, hunger trends differ, as well (Figure 9). Strikingly, the Great Transition scenario reduces hunger far more rapidly than the Policy Reform scenario as incomes converge more quickly both between and within regions. In Market Forces, despite growing average income in non-OECD regions, current levels of hunger persist through 2050 due to skewed income distributions and rising hunger lines. In the polarized Fortress World, hunger rises indefinitely over the long run.

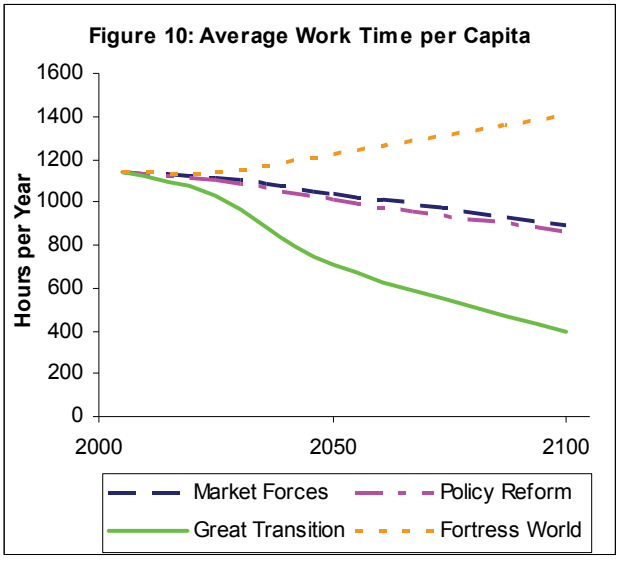


Work and leisure time. A key factor in human well-being is the time people have available for discretionary activities. Market Forces and Policy Reform assume the maintenance of current work weeks in developed countries, and gradual convergence to those levels in developing countries (leading to the decreases in global averages as shown in Figure 10).[8] Work time trends higher in Fortress World as the

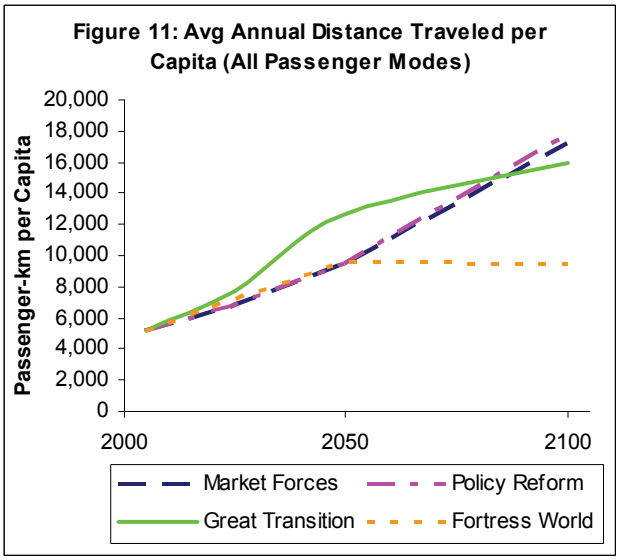
[7] The hunger line increases as countries get richer. For details on the hunger calculations, see [9], p. 26.

[8] Work time is defined here as the average number of hours worked per person across a whole population, including children, unemployed, and the elderly. Declining work time may be due to individuals working fewer hours and/or fewer people in the labor force, for example, due to the elimination of child labor or earlier retirements. Work time is related to two other variables: GDP per capita and productivity (GDP per hour), since income equals productivity times work time.

poor, with high work loads, increase as a percentage of the population. In contrast, work time falls substantially in Great Transition as the emphasis shifts from production and consumption to quality of life. In this scenario, the United States in 2100 would see 3-day work weeks at 7 hours per day, with vacations at current relatively high Western European levels.



Travel. Travel, an energy intensive activity, can be a positive or negative feature of life, a source of pleasure and cosmopolitanism, on the one hand, or of the drudgery of commuting or business travel, on the other. In the Market Forces and Policy Reform scenarios, trends toward more travel continue into the future, driven by rising incomes and the modernization of economies (Figure 11).



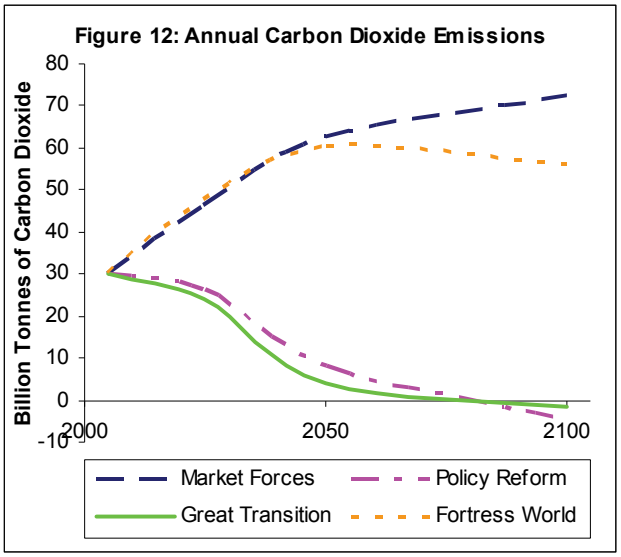
In Fortress World, increases in travel are limited to the wealthy, and average travel declines after 2050 as a larger fraction of the population becomes impoverished. Global travel per capita increases rapidly in Great Transition due to rapid development in poor regions, then slows in the approach to equitable, steady-state economies. Due to the greater use of public transportation, bicycles, and other low-energy-intensive modes, the energy required per kilometer traveled becomes far lower in a Great Transition world, with 26 percent of passenger travel being via public transportation in 2100 versus only 7 percent in Market Forces.

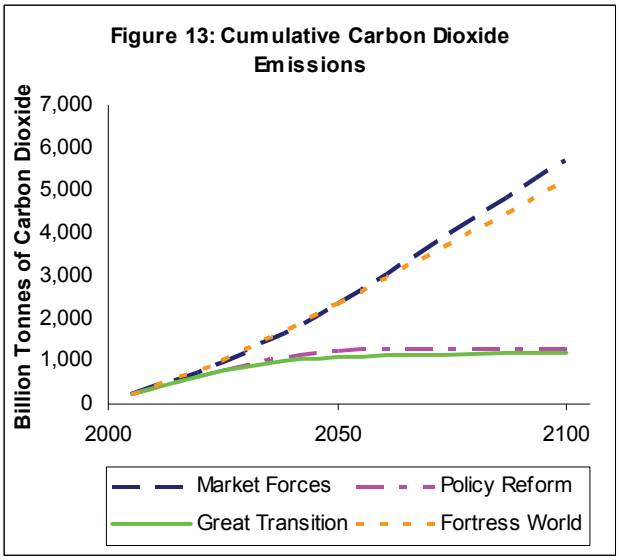
Environment and Natural Resources

Climate change. Carbon dioxide, the most significant greenhouse gas, is emitted from the combustion of fossil fuels, industrial processes, and land-use changes. With measures to improve efficiency and promote renewable energy weak in Market Forces, CO_2 emissions increase from 30 billion metric tonnes in 2005 to 73 billion in 2100. This occurs despite a 1.3 percent annual *decrease* in the economy's carbon intensity (CO_2 emissions per dollar of GDP) — a slightly more rapid decline than in recent decades. In contrast, the Policy Reform and Great Transition scenarios are designed to maintain cumulative global warming to at most 2° C above pre-industrial levels. To achieve this, annual CO_2 emissions fall in 2025 to 26 and 24 billion tonnes in the Policy Reform and Great Transition scenarios, respectively, and emissions fall more rapidly thereafter. The negative annual emissions after 2075 shown in Figure 12, needed to meet the climate stabilization goals, imply removal of carbon from the atmosphere through improved land-use and forestry practices, and by sequestering emissions from power plants that burn biomass.[9] Due to the long atmospheric residence time of CO_2, controlling *cumulative* emissions is the key to mitigating climate change. The 2°C target corresponds to an atmospheric CO_2 concentration of

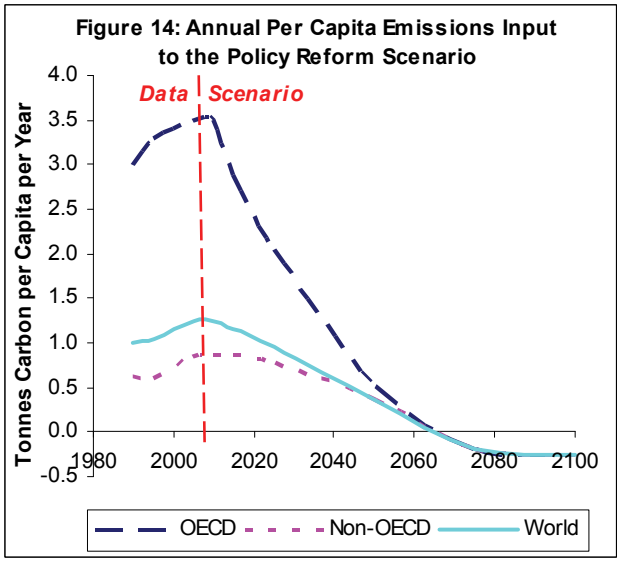
[9] When biomass harvest is balanced by regeneration, burning biomass for electricity is carbon neutral. If, in addition, post-combustion CO_2 is captured and stored underground (say, in abandoned mines), the net effect is to remove that quantity of CO_2 from the atmosphere.

roughly 350 parts per million (ppm) in 2100 [13,14,15].[10] Cumulative CO_2 emissions from 2005 to 2050 compatible with that level are about 1,250 billion tonnes CO_2, the values reached in Policy Reform and Great Transition (Figure 13) [16].

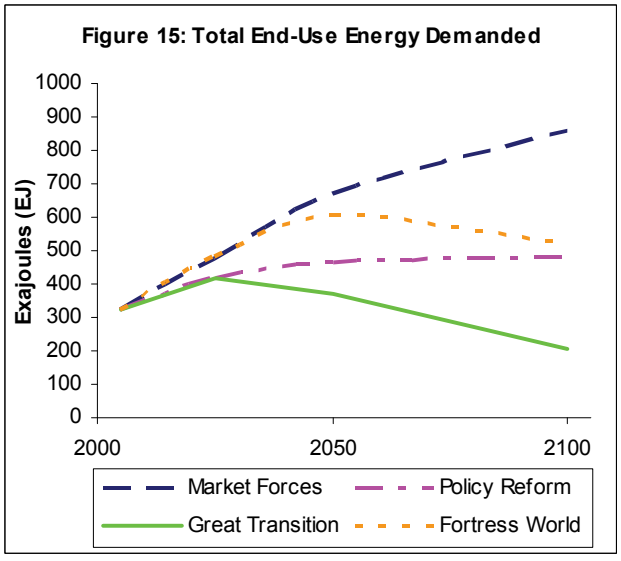




Global emissions are allocated to countries based on equity criteria that allow increases in poorer countries, approaching convergence to close to equal per capita emissions by 2050 (Figure 14). Note that based on this allocation, per capita CO_2 emissions from OECD countries must fall about 85 percent from 2010 to 2050.



Energy demand. Achieving climate goals requires both moderating energy demand, and switching to renewable forms of energy production. Great Transition and Policy Reform meet the emission reduction goals in different ways. End-use demand of the former scenario becomes about one-half the latter, which, in turn, is far below Market Forces (Figure 15).[11]



Along with improved technologies, Great Transition achieves this reduction through dematerialized lifestyles due to the moderated consumption of goods

[10] This result is based on the 450 ppm CO_2-equivalent stabilization scenario in [13] and in the International Panel on Climate Change SRES B1- 480 ppm CO_2-equivalent scenario. The 350 ppm CO_2 concentration target is approximately equivalent to a 450 ppm CO_2-equivalent concentration by 2100 when other greenhouse gases are included. Whether this would actually cap global warming at 2°C is the subject of much debate. See [14].

[11] One exajoule is equal to 10^{18} Joules.

and services, more compact settlement patterns, and less meat-intensive diets. With its lower energy demands, Great Transition much more easily meets its supply requirements, and somewhat reduces the dependence Policy Reform has on carbon sequestration to achieve climate stabilization goals. Fortress World energy demand decreases eventually, but for unwelcome reasons: increasing underdevelopment.

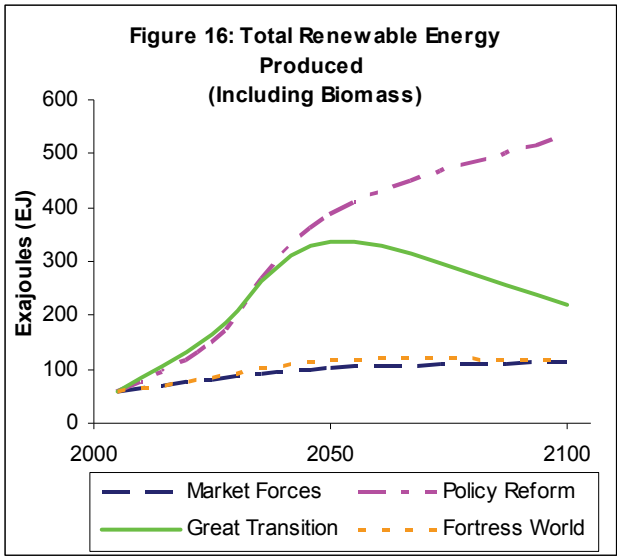
Energy Supply. The gap between growing fossil fuel demand and limited conventional fuel resources must be filled by unconventional sources: shale oil, tar sands, biomass-based oils, and oil from coal (Table 3). Market Forces assumes that a "peak oil" economic crisis can be avoided by bringing some combination of these unconventional alternatives to market in the next couple of decades in vast quantities and at modest costs. Even if this comes to pass, these unconventional substitutes typically carry heavier environmental impacts than conventional sources, requiring higher energy inputs in extraction and reformation stages.

TABLE 3: Year Conventional Fossil Fuels Exhausted

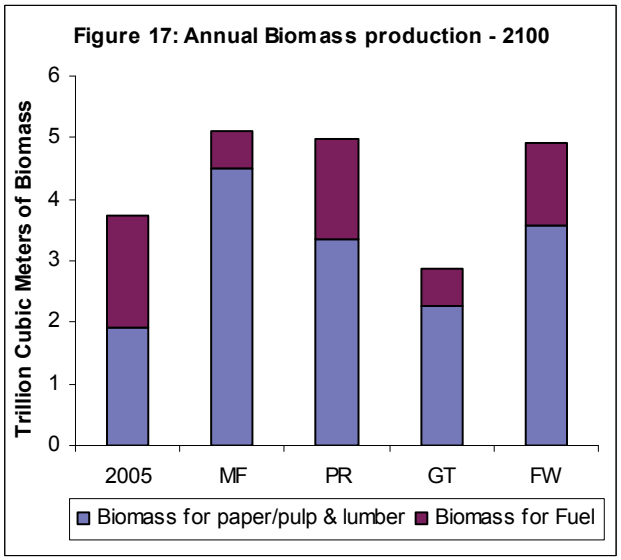
	Market Forces	*Policy Reform*	*Fortress World*	*Great Transition*
Crude Oil	2034	2071*	2034	>2105
Natural Gas	2047	2088*	2049	>2123

Note: Estimates of resources from industry sources [17,18].
*Some fossil fuels are used as feedstock in non-carbon-emitting processes after 2050, but not for heat, electricity, or transport.

At the same time, nuclear-generated electricity will remain a problematic alternative due to risks of contributing to nuclear arms proliferation, the absence of a long-term solution for storage of highly radioactive waste, safety concerns, and high costs. Policy Reform would postpone the exhaustion of conventional oil and gas for several decades. Figure 16 shows trends in the deployment of renewable energy in the scenarios: a gradual increase in Market Forces and Fortress World, and a rapid increase in Policy Reform. Renewable energy rapidly increases in Great Transition, as well, then moderates, requiring only half the amount by 2100 as Policy Reform with its higher total energy demand.



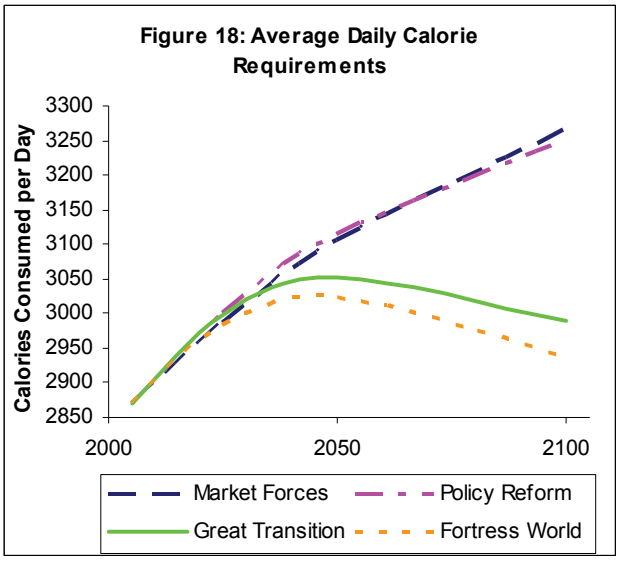
Biomass. Biomass is used as both a fuel (firewood, biodiesel, bio-kerosene, and ethanol) and as a raw material for the paper and pulp, lumber, furniture, and construction industries. High economic growth in Market Forces and Policy Reform drive biomass demand higher, except for firewood (Figure 17).



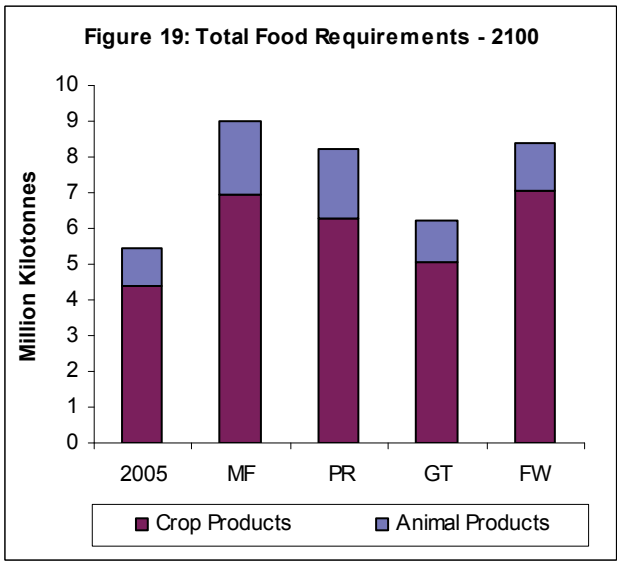
Despite heavy recycling of waste and strong energy efficiency, biomass production rises in Policy Reform due to soaring industrial and energy demands. Yet, biomass is not a panacea for replacing dwindling conventional oil and natural gas supplies, for it competes with food production and drives food staple prices higher. Only in Great Transition, with its moderated consumption and travel, does biomass demand eventually decline from current levels, sparing land for nature.

Food and Agriculture. Adequate nutrition and sound agriculture practices are central to human and environmental well-being. However, the conversion of land to crops and pastures has had a major impact on natural forests and other important ecosystems. The great achievement of the Green Revolution of the past half century has been to rapidly increase yields that avoided then looming food shortages. But modern farming practices require high inputs of chemicals and irrigation water that pollute, cause water stress, and degrade soil. A more sustainable development pathway would include both shifting away from crop-intensive high meat diets, and adopting ecological farming practices.

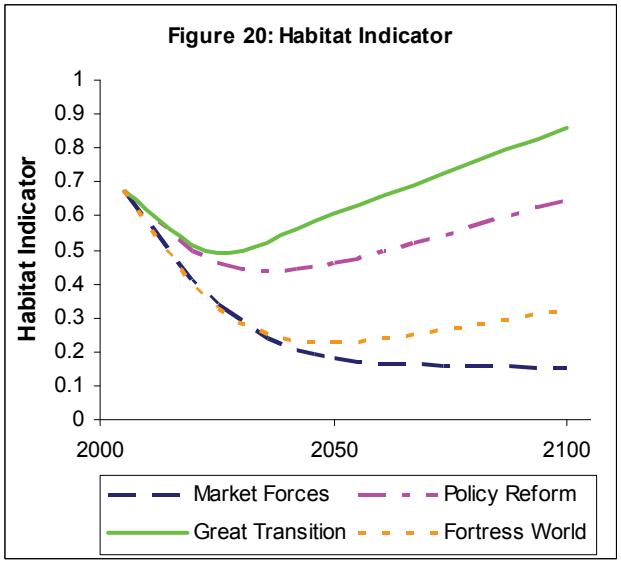
Global food consumption averages about 2,870 Calories per person per day, ranging from 2,400 to 3,600 Calories across regions, depending on income. (Figure 18.) The average demand for food grows to around 3,260 Calories per person in Market Forces and Policy Reform by 2100, a result of economic growth and meat-intensive diets. In Great Transition, per capita food consumption peaks by 2050 as developing regions converge toward richer region consumption patterns, then decrease as health and environmental motives foster diets high in nutrition and moderate in meat intake.



Since a calorie of meat requires many calories of vegetation for animal feed, this switch, along with lower population, reduces aggregate requirements after 2050 (Figure 19). Market Forces and Fortress World rely on the heavy use of chemicals for farming, while Policy Reform and Great Transition shift toward organic and ecologically sustainable agricultural methods.

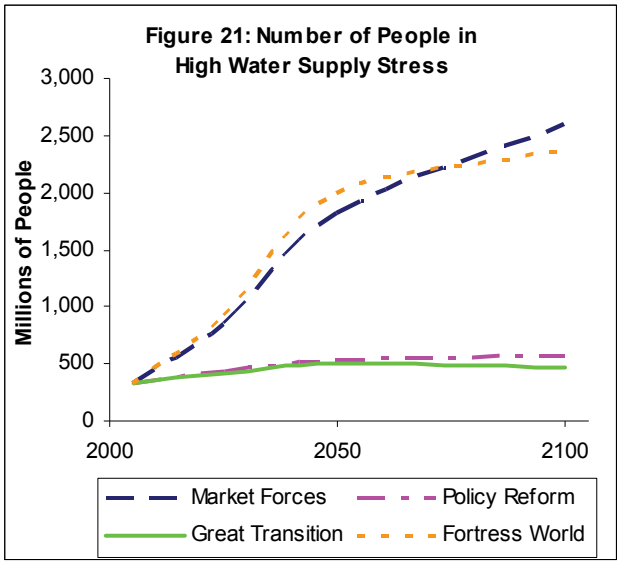


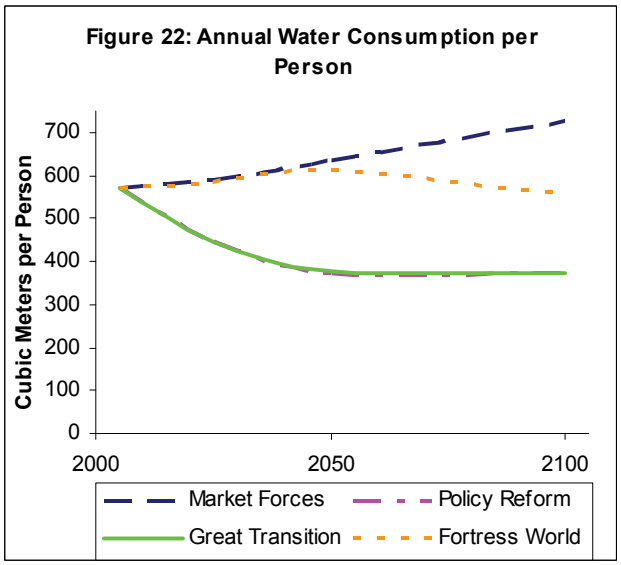
Land. As growing populations and economies further press on scarce land resources, sound land-use practices become ever more important for sustainable development. Agriculture, grazing, human settlements, forest products, and biofuels all require land, while the need to preserve forestland and ecosystems constrains options. Figure 20 indicates the habitat preservation trends for the scenarios. As Market Forces fails to align economic pressures with environmental objectives, ecosystems suffer further loss and degradation.



The growing masses of land-hungry poor in Fortress World, combined with technological stagnation, drives land degradation in that scenario, though the impact from the affluence of Market Forces is still greater. The Policy Reform scenario, which includes concentrated governmental efforts to protect and restore ecosystems, sees a slowing and, then, modest reversal of habitat degradation during the next few decades. Yet, with its Conventional World premises of high economic and substantial population growth, Policy Reform takes until 2100 for corrective policies to restore ecosystems to their current compromised condition. By contrast, Great Transition, with lower population and economic growth, compact settlements, less land-intensive diets, and much lower use of biomass, is able to enhance ecosystems, though doing so is still a long-term struggle.

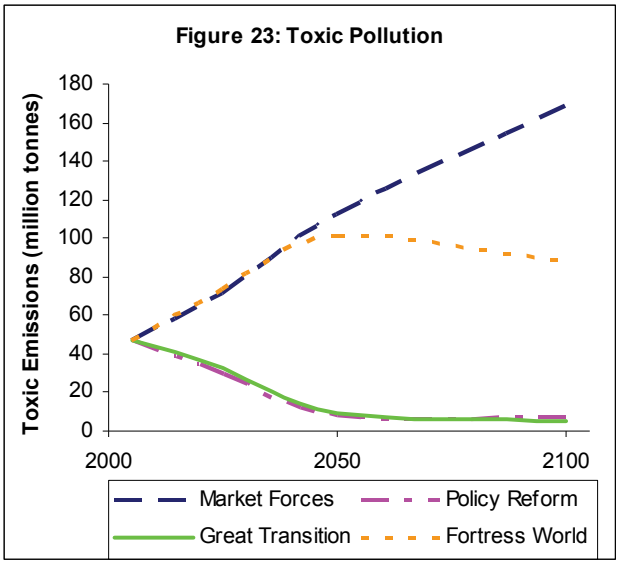
Water. Today, some 1.7 billion people are in "water stress," residing in areas of competition over the allocation of scarce water among agricultural, industrial, public, and environmental claims. Furthermore, several hundred million people endure "high water stress," areas suffering from absolute shortages of freshwater resources.[12] Figure 21 shows that water stress will be an enduring feature of the twenty-first century landscape, increasing considerably absent vigorous efforts to improve the efficiency of water use, harvest more water sustainably, and control demand. The numbers in high water stress increase nearly seven-fold in Market Forces and Fortress World, and climate change could exacerbate this problem further by altering hydrologic patterns. In contrast, the aggressive action in Policy Reform and Great Transition to improve the efficiency of water use (Figure 22) prevents rises in water stress and mitigates the wild-card of negative climate change impacts. Yet, even in spite of these actions, water stress remains at current levels as population grows, and limits are reached on improvements in irrigation efficiency. Today agriculture (irrigation) accounts for 70 percent of withdrawals.





Local Pollution. Our simulations track changes in representative air pollutants (e.g., sulfur oxides), water contaminants (nitrogen and biochemical oxygen demand), industrial toxics, and municipal solid waste. The results shown in Figure 23 for toxic pollution from industrial processes illustrate the broad patterns. Rapid economic growth combined with weak emissions control technology in Market Forces lead to extreme contamination, while the deployment of clean technology, recycling, and less toxic inputs (source reduction) substantially address the problem in Policy Reform or the Great Transition.

[12] We deem a population in 'water stress' when water demand divided by renewable water resources (use-to-resource ratio) exceeds critical values, and 'high' stress at more stringent values.



CONCLUSION

We have sketched four very different worlds that could emerge from the forces currently driving the global system forward as the world confronts critical environmental and social uncertainties.[13] We face a multifaceted and interacting set of dire problems: climate change, water availability, food sufficiency, biodiversity and ecosystem preservation, energy sufficiency, persistent poverty, social tension, financial crises, and geo-political conflicts. This troubling state of affairs is the inauspicious point of departure for all scenarios.

The overarching insight of this scenario exercise is that multiple and strongly contrasting possibilities exist for the twenty-first century. The future could branch in fundamentally different directions depending on how critical bio-physical and cultural uncertainties manifest themselves, and how society responds. With a nascent global system in formation, the destiny of people and planet rest with human choice: the ways we respond to the challenges of unsustainability and act to shape a sustainable planetary civilization. If complacency prevails, world prospects are dubious. If our collective response to the great challenge of turning toward a sustainable form of global development proves tardy and tepid, the risk looms of an historic descent of civilization: perhaps an authoritarian Fortress World, or even a substantial collapse of society and organized institutions.

By contrast, our Policy Reform scenario shows that if governments find the will and ways to mount a proactive, aggressive, and globally-coordinated action program, many sustainability goals could be reached: climate stabilization, ecosystem preservation, poverty reduction, and greater equity within and between regions. Yet, within a conventional economic development paradigm, implementing remedial technologies and policies at the required pace and magnitude would be daunting, indeed, like trying to go up a down escalator. A twenty-first century world of rising population, consumerism, and universal convergence toward affluent lifestyles would create incessant pressure for ever more energy and materials, land and food. We have seen, for example, that the Policy Reform energy demand in 2100 would be twice that in a Great Transition, an alternative vision where value changes underpin lifestyles of greatly reduced material and energy requirements, with similar changes for agriculture and other resource requirements.

Each scenario raises critical questions of feasibility. The laissez-faire optimism of Market Forces would invite a host of environmental and social crises that could feedback and amplify, undercutting its rosy assumptions about perpetual economic growth. Policy Reform envisions a tremendous shift toward intergovernmental cooperation and effectiveness capable of aligning economic globalization with environmental goals, while muting the social disparities that perpetuate poverty. Fortress World-type scenarios would arise in the vacuum left by a failure of markets and policies to avert crises, and would require a high degree of organized cooperation by the global elite facing resistance from the excluded masses just for the world to remain stable, though underdeveloped.

The Great Transition stands, then, as a desirable vision of progressive adaptations of civilization to the fundamental material and social challenges of this century: living within the bio-physical boundaries of

[13] Although the focus of this summary report is on global patterns, zooming down to regional scales reveals local stories that are variations on global themes. Regional results are displayed at http://www.tellus.org/result_tables/results.cgi.

the planet, and living together harmoniously in a much more equitable and globalized world. Dematerialized lifestyles that emphasize the quality of development and individual fulfillment would reinforce technological and policy changes in favor of sustainability. Beyond the pragmatic benefits of such a scenario, a Great Transition would offer an attractive image of a much more livable world. If we can begin the journey, getting to sustainability down this path would become far more feasible than via alternative routes.

But such a deep shift in values and institutions can only emerge as a collective project of global citizens for a Great Transition, a development that is far from guaranteed. It will require a change of development direction on a par with earlier great transitions of civilization to settled agriculture and industrial society. Perhaps the findings presented here, in suggesting the desirability – even necessity – of a Great Transition, will help spur action to achieve it.

REFERENCES

[1] K. Richardson, et al., "Synthesis Report, Climate Change: Global Risks, Challenges & Decisions." Climate Change Congress Proceedings, University of Copenhagen, March 10 – 12, 2009. http://climatecongress.ku.dk/

[2] Millennium Ecosystem Assessment, "Ecosystems and Human Well-Being: Current State and Trends." Island Press, Series Vol. 1, December 2005. http://www.millenniumassessment.org/en/index.aspx

[3] P. Raskin,"World lines: A framework for exploring global pathways." Ecological Economics, 2008, 65:461-470.

[4] R. Swart, P. Raskin, and J. Robinson, "The problem of the future: sustainability science and scenario analysis." Global Environmental Change, 2004, 14:137–146.

[5] G. Gallopin and P. Raskin, *Global Sustainability: Bending the Curve*. Routeledge, 2002.

[6] P. Raskin, et al., "Great Transition: The Promise and lure of the Times Ahead," Tellus Institute, 2002. http://gtinitiative.org/resources/gtessay.html

[7] Global Scenario Group website: www.gsg.org.

[8] The PoleStar System website: www.polestarproject.org.

[9] C. Electris, et al., "The Century Ahead: Four Global Scenarios, Technical Documentation." Tellus Institute, 2009. http://www.tellus.org/publications/files/TheCentury Ahead_TechDoc.pdf

[10] United Nations, "Population, Resources, Environment and Development: The 2005 Revision." New York: United Nations, 2006. http://www.un.org/esa/population/un pop.htm

[11] P. Raskin, "The Great Transition Today: A Report from the Future." Tellus Institute, 2006. www.gtinitiative.org/resources/paperseries.html

[12] R. Rosen and D. Schweichart, "Visions of Regional Economies in a Great Transition World." Tellus Institute, 2006. www.gtinitiative.org/resources/paperseries.html

[13] N. Nakicenovic, "World Energy Outlook 2007: CO_2 Emissions Pathways Compared to Long-Term CO_2 Stabilization Scenarios in the Literature and IPCC AR4." http://www.iea.org/weo/docs/weo2007/CO2_Scenarios.pdf

[14] IIASA, Greenhouse Gas Initiative Scenario Database. http://www.iiasa.ac.at/Research/GGI/DB/

[15] J. Hansen, et al., "Target atmospheric CO_2: Where should humanity aim?" Open Atmos. Sci. J., 2008:217-231. http://pubs.giss.nasa.gov/abstracts/2008/Hansen_etal.html

[16] M. Meinshausen, et. al, "Greenhouse gas emission targets for limiting global warming to 2 °C." Nature, Vol 458, 30 April 2009, p. 1158 – 1162.

[17] BP, "BP Statistical Review of World Energy." June 2007.

[18] World Energy Council, "Survey of Energy Resources 2007." 2007. http://www.worldenergy.org/publications/survey_of_energy_resources_2007/default.asp

APPENDIX: Key Issues Simulated in PoleStar

Social
- Population
- Gross Domestic Product (GDP) and value-added by sector
- Income (GDP per capita)
- Income distribution within and between regions
- Poverty
- Hunger line (income for adequate diet)
- Employment (productivity and length of work week)

Household
- Energy use by fuel
- Water use
- Air pollution
- Water pollution

Service
- Energy use by fuel
- Water use
- Air pollution
- Water pollution

Transportation
- Passenger by mode: public road (buses, etc.), private road, rail, air
- Freight transportation in following modes: road, rail, water, air
- Energy use by mode and fuel
- Air pollution

Agriculture
- Diet by crop and animal product categories
- Livestock: animal type, seafood (wild, farmed), other products (milk, etc)
- Crops: coarse grains, rice, other (fruits, vegetables, etc.), sugarcane, biofuels
- Energy use by fuel
- Irrigation
- Fertilizer use
- Air pollution
- Water pollution

Industry
- Energy use by fuel and subsector: iron and steel, non-ferrous metals, stone, glass, and clay, paper and pulp, chemical, other
- Energy feedstock by subsector.
- Water use by subsector
- Air pollution from both fuel combustion and process
- Water and toxic pollution

Forestry
- Primary wood requirements
- Secondary wood for final demand, and input to paper and pulp, lumber, biofuel

Land-Use
- Conversions between built environment, cropland, pasture, forest types (unexploitable, exploitable, plantation, and protected), other protected (marshes, bays, etc.), other
- Each category broken down by arable and non-arable areas
- Cropland disaggregated by crop type, and irrigated/non-irrigated

Energy Conversion
- Conversion from primary to secondary fuels (i.e., electricity production and oil refining)
- Requirements for coal, biomass, natural gas, renewable (wind, solar, geothermal, etc), crude oil, nuclear, hydropower
- Air pollution

Water
- Freshwater resources
- Desalinization and waste-water recycling for water resources
- Use-to-resource ratios
- Water stress

Solid Waste
- Generation from household and service sectors
- Landfill, incineration, recycling and other disposal technologies
- Energy generation from incineration

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Executive Vice-President and a founder of Tellus Institute, Dr. Rosen has thirty years of experience in energy sector resource planning and environmental compliance, including the economics and feasibility of restructuring the electric utility industry. He has presented analyses of alternative supply options, renewable resources, environmental impacts, conservation, and integrated power plans in scores of regulatory and public policy settings. His current research focuses on economic visions and models for the global economy, including new approaches to capital markets, regulation, and design of the production unit. He has been a leader on the project to update the PoleStar model scenarios, and is active on these issues through the Great Transition Initiative and Corporation 2020 networks convened by the Tellus Institute. Dr. Rosen received a Ph.D. in Physics from Columbia University in 1974.

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Christi Electris was appointed an Associate at Tellus Institute in 2007 with a primary focus on updating the PoleStar model simulations and its application to the work of the Great Transition Initiative. She has developed an updated data set and helped enhance and extend the original work of the Global Scenarios Group, and also conducted research in energy, climate, well-being, and corporate redesign. Ms. Electris holds both a Masters of Science in Technology and Policy at Massachusetts Institute of Technology and a Masters of Arts in Law and Diplomacy at The Fletcher School, Tufts University. She received her Bachelors of Science and Engineering in Computer Science from the University of Pennsylvania in 2002.

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Paul Raskin is the founding President of the Tellus Institute, and founder of the Global Scenario Group and Great Transition Initiative. The overarching theme of his work has been developing visions, strategies, policies and values for a transition to a sustainable and just future. Toward this larger aim, his work has ranged across themes (energy, water, climate change, ecosystems, development) and spatial scales (regional, national, river basin, global). He has conducted hundreds of research projects and published widely on these themes. He has been a lead author for the National Academy of Science's Board on Sustainability, the International Panel on Climate Change, the Millennium Ecosystem Assessment, the Earth Charter, UNEP's Global Environment Outlook, and numerous other international efforts. Dr. Raskin received a Ph.D. in Theoretical Physics from Columbia University in 1970.

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