16 From *The Limits to Growth* to 2052

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Abstract

This chapter summarizes the content of and the debate around *The Limits to Growth* and its updates, from 1972 until 2012. It presents the background and political context to the original 1972 study, and follows the debate in and around the four books on whether a 'fair and free market' can provide sufficient benefits for us all. The methodology of systems dynamics is briefly introduced. The analyses are presented in some detail, as are the reactions from both academia and political and economic interests following the books' publication. The two main research questions are why the debate around *Limits to Growth* became so polarized, and what we have learned about the original scenarios over the last four decades. The chapter therefore includes a synthesis of research on how the original World3 Standard run has compared to subsequent reality. Randers' forecast for the next forty years constitutes the fitting end point for this analysis.

Keywords: Limits to Growth, economic growth, polarization, system dynamics, modelling.

16.1 Introduction[1]

In 1972 a small book appeared that was to have an impact far above what its modest size indicated. It presented a set of possible scenarios for the future. *The Limits to Growth* (hereafter: LTG) (Meadows/Meadows/Randers et al., 1972) kick-started a debate about the pros and cons of economic growth, and gave inspiration to the growing environmental movement in the industrialized world.

The hard and bitter debate that ensued is not yet concluded, but it has over the years changed in volume, intensity and character. If it is at all possible to identify one fundamental issue in a debate that has been going on for over four decades, it is first and foremost a question of whether our decision-making (mainly economic) models are capable of integrating sufficient information to ensure that the effect of human behaviour remains within the planet's carrying capacity—in other words, can we trust a free market to produce ultimate benefits for all?

Limits to Growth did not appear from nowhere. It followed an intellectual tradition that started at least a decade previously with Rachel Carson's (year) *Silent Spring*, which highlighted the dangers to our environment of using new technologies (in her case pesticides, in particular DDT) whose consequences are unknown. But it was not only the intellectual tradition of questioning human activity's impact on the environment that was followed from *Silent Spring*. As early as the 1960s powerful industrial interests had spent large sums of money on discrediting the kind of research in *Silent Spring*, and subsequently in LTG. The battlefronts of the conflict were therefore already set and hard before LTG was published, at least in the US, where the debate was the most polarized. Once the message had been sent that the authors were 'doomsayers', 'neo-Malthusians' and 'anti-growth', it proved almost impossible to alter the impression in the public mind.

Two questions are of particular interest in this context. Firstly, why did the debate raised by the *Limits to Growth* become so polarized? And secondly, what have we learned over the last four decades about the essential questions posed by the LTG team?

In order to answer these questions this chapter will synthesize the main message from the Limits to Growth study (hereafter the LTG) as well as the two updates: *Beyond the Limits* (BLT), from 1992, and *Limits to Growth—the 30-Year Update* from 2004.

1 I wish to thank Prof. Jørgen Randers for helpful information and moral support throughout the writing process. Any errors are mine alone.

H.G. Brauch et al. (eds.), *Handbook on Sustainability Transition and Sustainable Peace*,
Hexagon Series on Human and Environmental Security and Peace 10, DOI 10.1007/978-3-319-43884-9_16

Finally the main findings from 2052—*A Global Forecast for the Next 40 Years* will be presented. This book can in some ways be seen as a sequel to the others, but unlike the LTG series, '2052' is presented as a forecast, not as a collection of possible futures. It will therefore be possible to empirically validate (or not) its accuracy over the next forty years.

The chapter is organized in four main parts. Part one presents the Limits to Growth from 1972 (16.2), its methodological foundations, its context, and the immediate reactions. Part two reviews the two update studies from 1992 and 2004 (16.3). Part three looks at the message and conclusions from the book 2052*: the next 40 years* (16.4), while part four offers conclusions (16.5).

16.2 The Limits to Growth—A System Dynamic Analysis of Planet Earth (1972)

The LTG was written as a 'report for the Club of Rome's project on the predicament of mankind'. The Club of Rome[2] traces its origins back to a meeting in 1968 between thirty individuals who believed that 'the major problems facing mankind are of such complexity and are so interrelated that traditional institutions and policies are no longer able to cope with them, nor even to come to grips with their full content' (Meadows/Meadows/Randers et al. 1972: 9–10).

The Club of Rome commissioned a group of young researchers at MIT under the direction of Professor Dennis Meadows to carry out 'Phase One of the Project on the Predicament of Mankind'. The intellectual inspiration for their work came from Professor Jay Forrester, an engineer who had turned his attention to management systems and to using computers in the simulation of social systems (Forrester 1989). He is the founder of system dynamics.

16.2.1 Key Concepts and Methodology

Before summarizing the findings of the LTG, it is useful to give a brief presentation of the methodological foundations upon which the study was conducted. So much has been said and opined about the LTG results that it is worth clarifying the methodological ambitions from the outset.[3]

Models[4] are 'a formalization of our assumptions about a system' (Hall/Day 1977, cited in Bardi 2011: 16). We often refer to individuals having 'mental models'. Such mental models are a representation of the surrounding world, and are crucial to our ability to make sense of our observations. Scientific models, however, should start from clear, explicit assumptions, so that others can validate their appropriateness and usefulness in different contexts. Scientific models allow us to make explicit what we assume about a system, and when the models are quantitative (i.e. mathematically formulated expressions define how various system parameters are related), they allow us to calculate how the parameters—and hence the system—will vary with time.

The assumptions may be more or less right or wrong. Large discrepancies between predictions and observations can lead us to conclude that the model is wrong, but the opposite is not true. A model is not necessarily right even if it predicts what we go on to observe. However, the more empirical data that agree with simulated results, the more we tend to 'trust' the model—we have a higher degree of confidence that it will be useful for predicting the future behaviour of the system.

System dynamics[5] emerged as a discipline in the 1950s. Initially it was used for industrial purposes, but from the 1960s it was used to model social and eco-

2 The Club of Rome is a "global network of independent and renowned thinkers [...that...] analyses today's challenges facing the world, their root causes and the possible futures, in a systematic and holistic manner. The Club of Rome encourages global debate in order to set in motion actions that by the middle of the century will ensure a more secure, equitable, and prosperous world." See at: <http://www.clubofrome.org/> and <http://www.clubofrome.org/?p=324>

3 This is not meant as an exhaustive introduction to system dynamics. For those interested, see for example Ford 2009, <http://www.public.asu.edu/~kirkwood/sysdyn/SDIntro/SDIntro.htm> or <http://www.systemdynamics.org/what-is-s/>.

4 For an excellent overview of the debate surrounding *Limits to Growth* see Ugo Bardi (2011), *Limits to Growth Revisited*. Ugo Bardi's blog can be found at: <www.cassandralegacy.blogspot.com>.

5 One typically distinguishes between linear and non-linear systems. In linear systems there are well-defined and well-known causal relationships, whereas non-linear systems involve parameters that interact, and they are often very difficult to predict over longer time spans. Cause and effect are often not well understood in non-linear systems. They are central to the group of systems called 'complex', i.e. systems that involve feedback relations.

nomic systems. System dynamics looks at several fundamental elements in a system: stocks, flows and feedback.[6] These elements vary over time and are interdependent. The stock is something's actual amount (e.g. the number of individuals in a population), whereas the flow is the variation over time of the stock (e.g. births and deaths). Feedback occurs when the intensity of a flow into a stock depends on the size of the stock. The feedback can be positive (for example, a larger population increases the number of births, if the birth rate is constant) or negative (a larger population increases the number of deaths, if the death rate is constant). However, "the fact that a system is dominated by feedback effects (...) does not imply that it is completely random. On the contrary, these systems often follow well-defined patterns" (Bardi 2011: 8), and this allows us to build models that help us analyse possible trajectories of the system's behaviour.

16.2.2 Key Scientific Approach and Messages of *The Limits to Growth* Study

LTG was a study of the Earth system using system dynamics. The research group identified what they saw as the five most central system parameters, and built a quantitative model expressing the relationship between these parameters (and some others) using mathematical expressions.

The ambition of the LTG research group was to study the interrelatedness of five basic factors that determine growth in population and ecological footprint on Earth. The question they asked was simple: how do changes in one of these factors impact on the other factors?

The five factors were:

- population
- agricultural production
- natural resources
- industrial production
- pollution.

Defining and explaining the nature of the growth of the system was a central part of the LTG study. The book goes to some length to explain the characteristics of 'exponential growth', and to emphasize how exponential growth differs from linear growth. It explains the concepts of 'doubling time' and 'positive feedback loops'. It is hard to overestimate how difficult the human mind finds it to think about exponential growth, particularly in relation to processes that take a long time. The classic illustration used in the book is the old French riddle that visualizes the suddenness with which the 'end' is approaching:

> Suppose you own a pond on which a water lily is growing. The lily plant doubles in size each day. If the lily were allowed to grow unchecked, it would completely cover the pond in 30 days, choking off the other forms of life in the water. For a long time the lily plant seems small, and so you decide not to worry about cutting it back until it covers half the pond. On what day will that be? On the twenty-ninth day, of course. You have one day to save your pond (Meadows/Meadows/ Randers et al. 1972: page).

The LTG research group built a system dynamic model of the world, and called it World3. Like all models, it was a simplified representation of the *real* world system—this is one of the purposes of modelling—and in this case many constraints were obvious: there was insufficient knowledge about the physical processes specifying the relationships between the parameters, and it was (and is) difficult to quantify the effects of socio-psychological factors (for example, of the population's potential value change on the consumption of both industrial goods and services). The authors grouped these sources of uncertainties into three categories:

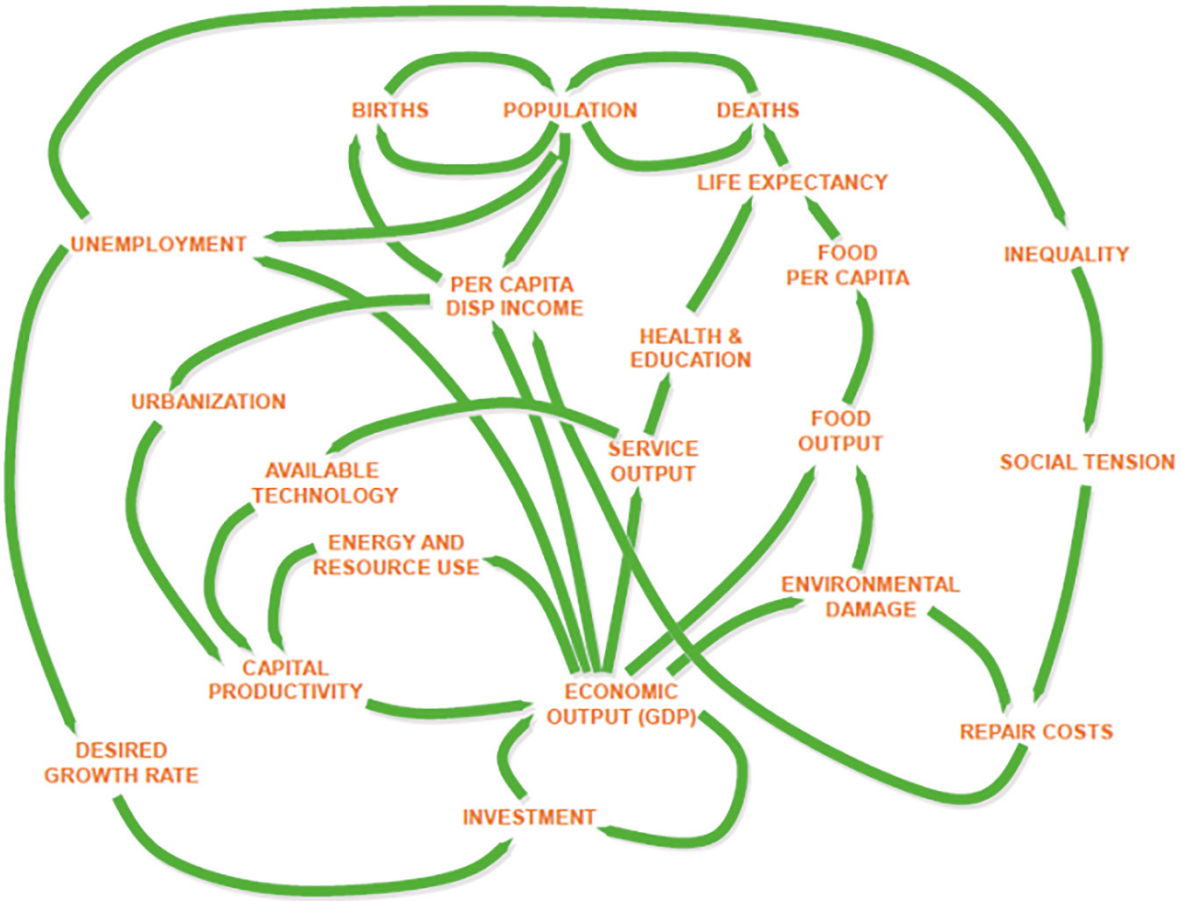
1. the relationship between economic variables that are relatively well understood,
2. the effect of socio-psychological factors that are difficult to quantify, and
3. the biological variables which are largely unknown (Meadows/Meadows/Randers et al. 1972: 103–104).

The authors were therefore aware of the shortcomings in knowledge about the system they wanted to simulate. However, rather than waiting for more research about the exact effects of socio-psychological factors or biological variables, which would take a long time in coming, they proceeded to develop the World Model, representing the world system to the best of their ability. A visual presentation of the causal links in the World Model is given in figure 16.1.

In 1972, the recent development of sufficiently sophisticated computer technology had profoundly changed our ability to handle large amounts of data simultaneously. We have become nonchalant when it comes to computing capacity, but in 1972 this was still in its infancy, and while the World Model used in the

6 For a highly readable introduction to the basics of system dynamics as used in the LTG study, see Bardi (2011), chapters 3 and 4.

Figure 16.1: Causal diagram of the World3 model. **Source**: Jørgen Randers presentation material; he also granted permission to use this figure.



Limits to Growth is simple from our current perspective, it was the most sophisticated in its time.

The discussion in the LTG study started from a 'standard run' of World3, where one assumed 'no significant change'[7] in the physical, economic or social relationships that were seen to govern the world system. The standard run was concurrent with historical data for the period 1900–1970. This is not surprising; the parameters of the model were chosen to ensure such a match, so the match is in itself not a sign of the correctness of the model. The model was built empirically, in some cases using historical relationships between the five basic factors to specify the equations used in the model. The standard run showed that if continued unchanged, the exponential growth in population, food and industrial output would result in a rapidly diminishing resource base that again would lead to a slowdown in industrial growth, and subsequently (because of delays in the system) to a rapid decline in food production and population.

To investigate the effect of various policies in World3, the researchers used the 'standard run' as a baseline and simulated policy implementation by changing one or more of the input parameters. 'Policies' should here be understood as behavioural changes at the system level, rather than as a political process or pronounced ambitions (for example about recycling rates or reduction of ozone-depleting gases). The policy changes included unlimited access to nuclear energy (enabling extensive recycling and resource substitution), and controls on population and pollution. The overwhelming majority of scenarios produced futures with overshoot and collapse.

Having observed collapse, i.e. a sudden and dramatic decline in population or production, the

7 This important fact is often overlooked. The model was built so that it concurred with observed data in the period 1900–1970, and the standard run therefore assumed that the interdependent processes simply would continue as they had done for the previous seven decades.

researchers set themselves the task of identifying policies that would stabilize the system so that uncontrollable collapses would be avoided, and that at the same time would be capable of satisfying the basic material requirements of all people.

The input parameters were thus changed with the explicit goal of identifying a stable solution for world population with an adequate food supply and industrial output. Of course, several input combinations would be able to produce a stable system, and one set was presented in the LTG study. It consisted of:

- Stabilizing the population at 1975 levels (by setting the birth rate equal to the death rate)
- Stabilizing industrial capital at 1990 levels (by setting the investment rate equal to the depreciation rate)
- Setting resource consumption per unit of industrial output to one-fourth of its 1970 value (introduced in 1975)
- Shifting society's consumption preferences more towards services and less towards manufactured goods (starting in 1975)
- Setting pollution generation per unit of industrial and agricultural output to one-fourth of its 1970s value (introduced in 1975)
- Diverting some capital from industrial to agricultural production even if it was 'uneconomic' (to ensure proper nourishment for all)
- Maintaining soil quality through altered use of agricultural capital
- Increasing average lifetime for industrial capital.

These policies were, according to LTG, one (of several) possible sets that it was physically possible to maintain on Earth. Resource depletion would still occur, but at a rate sufficiently slow to allow for technology to adjust to changes in resource availability.

To reach this sustainable model, however, one would have to implement the above assumptions, which were highly unlikely. Simulations with less unrealistic assumptions[8] avoided collapse in the period up to 2100, whereas a simulation where policy implementation was delayed until 2000 showed collapse before 2100.

Thus, of the twelve model runs that were presented in the book, only two represented a system that would not overshoot and collapse before 2100. Two conclusions stand out. Firstly, a free-market-oriented, liberal, individualistic world will not deliver the set of measures needed for the system to stabilize. Secondly, the later growth-reducing policies are implemented, the smaller the chances of avoiding overshoot and collapse.

The basic message from LTG can be summarized thus:

a.) The planet we live on is finite, and as the population and its ecological footprint increase in size, the relative size of the Earth system on which we depend becomes smaller.
b.) If developments in population, economic activity and use of nature's resources continue unchanged, overshoot of global carrying capacity is likely within the twenty-first century.
c.) Once in overshoot, physical contraction is inevitable. This may happen as a sudden contraction and collapse, or as a 'managed decline'.

16.2.3 Immediate Reactions—Academic and Political Debate During the 1970s

When looking at the debate that followed the publication of LTG, one should be excused for believing that the book had prophesied apocalypse and the end of humankind as we know it. However, as is often the case with highly polarized debates, the basic text seems to have been little read and even less understood. Far from being apocalyptic in its approach, the LTG study was presented as a warning signal and an invitation to think about the possible futures if the growth model we live by are to continue unchanged.

The title of the book, *Limits to Growth*, was provocative in an age where economic growth was hailed as the panacea for the world's ills. Economists, therefore, would be expected to take issue with the LTG conclusions, and they did. This academic debate was, at least initially, relatively civil in form. The LTG conclusions were out of sync with the consensual wisdom among mainstream economists and public policymakers in the 1970s, which led to questioning both of model and methodology.

One of many criticisms of the LTG came from a research team in Sussex University's *Science Policy Research Unit* (SPRU), who in 1973 published their own run of World3. Their results differed significantly from those of the LTG team. The Sussex team abolished the basic assumption of absolute resource limits, and replaced them with 'ongoing exponential increases in available resources' (Ekins 1993: 270). Thus, they

8 The less unrealistic assumptions were 'perfect birth control', meaning that only wanted children would be born; an average family size of two children; and industrial output stabilized at the level of average per capital output in 1975.

effectively embraced the idea that human ingenuity would develop good substitutes for non-renewable resources, and that we would learn to use existing resources much more effectively. "To postpone collapse indefinitely these rates of improvement must obviously be competitive with growth rates of population and consumption so that even if the overall growth is rapid, it is also balanced" (Cole/Freeman/Jahoda et al. 1973).

How could different scientists reach such widely different conclusions when they used the same model? Lecomber identified three points of contention that could explain the modellers' differences: their optimism regarding the rate of technical progress, how they saw future changes in the composition of output, and the possibilities of substitution. He took care, however, to emphasize that "this establishes the *logical* conceivability, not the certainty, probability or even the possibility in practice, of growth continuing indefinitely" (Lecomber, cited in Cole 1999: 89).

The economist William Nordhaus has been a vociferous participant in the debate about limits to growth since the early 1970s. In a 1973 article he criticized the World3 model, mainly on the grounds that it in his view was built on (mostly) plausible hypotheses about relationships between parameters, but that none of these relationships were empirically tested. His criticism was strongly worded:

> the dynamic theory put forward in the work represents no advance over earlier work. [...T]he economic theory put forth in *World Dynamics* is a major retrogression from current research in economic growth theory. [...W]ithout the scantest reference to economic theory or empirical data, Forrester predicts that the world's material standard of living will peak in 1990 and then decline. *Sic transit gloria* (Nordhaus 1973: 1182–1183).

Nordhaus gave voice to a widely held view among economists, namely that the researchers working with the World3 model had neglected economic research, and that they did so at their own peril. Apart from the factual error that the World3 did not *predict* the future (it merely simulated and produced scenarios based on a simplified model of the world system),[9] Nordhaus can be excused for wanting to defend economists' intellectual territory. With hindsight we may regret this lack of curiosity and mutual understanding between system dynamics and conventional economics—and conventional economists.

If reactions from the academic community were strong, they remained civil compared to some of the reactions in the public political debate. The LTG's conclusions were in many ways stark and depressing, despite the non-alarmist language used in the book. However, it is reported that none of the researchers involved in the study envisaged the uproar their publication would cause. The book's American publishers, Potomac Associates, "were arranging to present a copy of the book to every senator, representative, governor and UN ambassador" (AtKisson 2011: 10), in addition to organizing an event at the Smithsonian institute. The publication thereby received high-level political attention, reported in the American press with headlines such as "Mankind warned to curb growth or face catastrophe" (Chicago Sun Times), "Scientists warn of global catastrophe", and "Panel on growth strives to stave off world ruin" (AtKisson 2011). The subsequent debate was often hostile, polarized, and increasingly dominated by 'public legends', perceived as facts, but without root in the LTG study.

The most important of these legends is that the LTG study predicted a crisis. Far from predicting anything at all, the LTG presented twelve different scenarios based on the World3 model. The fact that an overwhelming majority of the scenarios they produced led to overshoot and collapse some time during the twenty-first century was clearly threatening to all those with a stake in the existing system. Moreover, the 'Cassandra effect', that we are reluctant to listen to bringers of bad news, may explain why many dug in to their trenches rather than participating in constructive debate about how to preserve the benefits of the existing model while attempting to change it to avoid its negative effects.

The authors of LTG were unprepared for the massive reaction the publication would create, and for the polarization that followed. If they had known the stir they would cause, maybe they would have taken greater care to emphasize that their scenarios were not predictions, but an invitation to start a debate about

9 The difference between a prediction and a scenario is not always obvious, and the two terms are often used interchangeably in daily speech. However, they differ both in intent and in level of precision. Whereas a 'prediction' is a statement about something that will happen in the future, and is therefore empirically testable, a scenario is one (of several possible) internally consistent stories about the future. Therefore, whilst a prediction can be said to be right or wrong once the future that was predicted has arrived, a scenario can be neither right nor wrong. Rather, the scenario is produced to inform and encourage thinking and debate about the choices we face. See also <http://www.ipcc-data.org/guidelines/pages/definitions.html>.

the paradigm within which we live our lives. This, at least, seems to be one lesson they have learned in the updated versions of the World3 simulations, which appeared in 1992 and 2004, and to which we now turn our attention.

16.2.4 Legacy: Long-Term Impact of *The Limits to Growth Study*

The LTG study was hotly debated in the 1970s, but attention receded throughout the 1980s. The general mood lifted after a decade of economic difficulties (remember the world oil crisis in 1973), and '[i]f the 1973 oil crisis had looked to many as the crisis predicted by the LTG, the end of the crisis, in the mid 1980s, seemed to be the refutation of the same predictions' (Bardi 2011: 87).

16.3 The Updates

Despite being in the business of mapping possible futures, none of the authors of the LTG had anticipated the ferocity and acerbity of the debate that followed its publication. They were scientists, not politicians or demagogues, and had not prepared for a public exchange of words on the scale of what actually happened. Two updates were published twenty and thirty years after the LTG study respectively. This part of the chapter will take a closer look at the results from these updates, and inscribe them in the political context they appeared in.

16.3.1 *Beyond the Limits*

Three of the authors of the LTG decided to publish an updated version of the World3 simulations with new numbers twenty years after the original publication. They called the new book *Beyond the Limits* (hereafter: BTL) (Meadows/Meadows/Randers 1992). In the preface they wrote:

> Much has happened in twenty years to bring about technologies, concepts, and institutions that can create a sustainable future. (...) When we began working on the present book, we simply intended to document those countervailing trends in order to update The Limits to Growth for its reissue on its twentieth anniversary. We soon discovered that we had to do more than that. As we compiled the numbers, reran the computer model, and reflected on what we had learned over two decades, we realized that the passage of time and the continuation of many growth trends had brought the human society to a new position relative to its limits (Meadows/Meadows/Randers 1992: page).

The rerun of the World3 model with updated numbers led the authors to conclude that we had already passed the point of sustainable use of many resources and generation of many pollutants, that is, we were in 'overshoot'. Having learned from the debate following the LTG publication, they took great care to spell out that theirs was a message of hope and opportunity to do something that would improve the possibilities for choice in the future, although the latter was relatively rapidly vanishing.

The structure of BTL is very similar to the structure of the LTG. It starts with an explanation of the phenomenon of exponential growth, followed by a presentation of the limits to growth in the form of sources (renewable and non-renewable) and sinks (nature's capacity to absorb the wastes of human activity, in particular the atmosphere's reaction to greenhouse gases and some other air pollutants). The book subsequently explains the drivers of growth in the world system, including feedback loops, and finally presents a discussion of technological possibilities for solving the problems identified.

This logic underlines one important fact about their basic message, namely that the economy is a subsystem of the physical world, and therefore constrained by it. This might seem uncontroversial today, but it still proved a hard sell to many economists. The idea has been further developed by many within the field of ecological economics.[10]

Beyond the Limits was published in the year of the United Nations Conference on Environment and Development, better known as the Rio Earth Summit. This conference resulted in Agenda 21, which brought the 'sustainable development' concept on to the global political agenda.[11] Many environmentalists at the time were optimistic that world society finally would rise to the task and bring about sustainable living. But at the same time the awareness grew that the tools we had for managing these challenges were inad-

10 See Constanza and Daly (1987). For further information about ecological economics, see the website of the International Society of Ecological Economics: <http://www.isecoeco.org/>.

11 The concept's most common definition, 'sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs', first appeared in the report of the World Commission on Environment and Development, also known as the Brundtland Commission.

equate. To the extent that agreement was achieved on UN documents and policies, these remained vague and non-binding on the member states. This reflected the underlying old conflict about which role the state should have in the economy: on the one hand, states who were positive to global, binding regulations, and on the other, states who advocated as little state intervention as possible, in the interest of individual freedom of choice and free, unregulated markets.

BTL, like its predecessor, presented scenarios resulting from the World3 model. The 1991 run was for technical reasons carried out in a different computer language from the 1972 run, but the model itself remained unchanged. Some of the parameters were slightly altered to take into account historical data from 1972 to 1990. For example, World3 had underestimated both the (negative) impact of erosion on arable land and the (positive) effect of technological development in agriculture, and World3/91 was changed to make a better fit with observed data (Meadows/Meadows/Randers 1992: 245).[12]

However, *Beyond the Limits* is not only a product of a new run of an existing system dynamic model with adjusted numbers. It is also in many ways a communications exercise, inasmuch as it is an attempt to explain more clearly what had been misunderstood in the debate after the *Limits to Growth*. The authors emphasize that they are aware of the shortcomings of their model, and that they do not want to make predictions, but to present a set of possible futures. In the spirit of providing not only hope, but also guidance on preferred action (to answer the question 'but what can we *do*?'), they provide an 'action plan' for transition to a sustainable system. This plan consists of six elements that will improve our chances of building a sustainable society: improving the signals; speeding up response times; minimizing use of non-renewable resources; preventing erosion of renewable resources; using all resources with maximum efficiency; and slowing and eventually stopping exponential growth in population and physical capital.

William Nordhaus, one of the loudest academic critics of the 1972 book, was not convinced of the model's appropriateness despite the result from the new data. Rather, in his 1992 paper "Lethal Model 2: The Limits to Growth Revisited", he clearly ridicules what he terms the 'anti-growth movement'[13] on the grounds that the 'predicted' resource shortages never materialized (despite this being clearly a wrong interpretation of the 1972 study). He is, however, open to the possibility that there might be physical limits to human activity. Having presented his own model for studying the future of economic growth, he concedes that "our ignorance is vast [...but...] I will hazard the guess that resource constraints are likely to be a small but noticeable impediment to economic growth over the next few decades in advanced industrial countries—although an obstacle that will continue to be surmounted by technological advance" (Nordhaus 1992: 39).

During the 1990s, not long after the publication of BTL, Mathias Wackernagel and William Rees developed a metric for measuring the ecological impact of human consumption, the now well-known 'ecological footprint'.[14] The concept of ecological footprint was clearly useful in the debate about limits to growth, as it provided a clear link between the physical environment on our planet and human consumption. It has since become a household staple in almost all debates about environmental policy in its broadest interpretation, and is incorporated in subsequent LTG studies.

16.3.2 The 30-Year Update

Limits to Growth: The 30-Year Update (Meadows/Meadows/Randers 2004) was 'the third edition in a series'. The World3 model was updated slightly. The most important changes were (1) that the cost of technology was estimated to decline more rapidly than in previous analyses, and (2) that the desired family size was set to respond more strongly to growth in industrial output, i.e. that as material welfare grew, women would choose to have fewer children, and this process was also assumed to be speedier than in previous analyses.

The preceding thirty years had seen many important developments in the public debate about sustainability and the difficulties with unlimited growth. The Brundtland Commission had brought the concept of sustainable development to the fore, and inspired much academic research around questions of nature's

12 Other similar changes were made. For a complete overview, see BTL appendix: Research and Teaching with World3.

13 The authors of LTG, as ecological economists, had never purported to be 'anti-growth'. They did, however, try to distinguish between material throughput and societal welfare.

14 The ecological footprint is a measure of how much land and water area is required for human activity. It is estimated that we currently (2015) use 1.5 Earths. For more information and updates, see at: <http://www.footprintnetwork.org/en/index.php/GFN/>.

constraints on human activity. This was obviously important in and of itself, but in our context it provided the authors with new concepts in their communication. In particular, the 'ecological footprint', both concept and measurements, was incorporated in their text. It also proved an invaluable tool in visualizing the meaning of 'overshoot', so central to their findings. Their new Human Welfare Index proved an effective tool for visualizing whether the future would be better or worse for those living there.

The 30-year update therefore included the variables 'human welfare' and 'ecological footprint'. The Human Welfare Index in World3 was inspired by the UN Human Development Index, and was calculated using *gross domestic product* (GDP), life expectancy and education. The Ecological Footprint Indicator in World3 was inspired by Wackernagel's 'ecological footprint' and was built using arable land used for crop production in agriculture, urban land used for urban-industrial-transportation infrastructure, and the amount of absorption land required to neutralize the emission of pollutants (Meadows/Meadows/Randers 2004: appendix 2).

The message from the third book in the series does not make cheerful reading. The language is still both clear and accessible, but the message is stark. The authors also concede that this third book is not so much about making new contributions to the debate as about providing the old debate with new numbers. Their review of the initial World3 scenarios shows that the actual development of the central parameters follow closely the standard run in World3 from 1972. The previous decade had shown that the lofty ambitions of the Earth Summit in 1992 were not being implemented.[15] Therefore, the 'action plan' from BTL was substituted by a list of 'the tools we don't yet know how to use'. These tools were: visioning; networking; truth-telling; learning; and loving.

16.3.3 Reactions to the Updates

Debate about the human condition within the physical boundaries of planet Earth had also taken on new forms since the 1970s. The strands had multiplied, and it is almost impossible to map them all. But two issues stand out: the question of limits to economic growth, and the debate about climate change.

The old question of whether there are limits to economic growth, so much ridiculed by both academics and politicians after the publication of LTG, saw a sea-change with the publication of an article by economist Matthew R. Simmons in 2000 entitled "Revisiting the Limits to Growth—could the Club of Rome have been right, after all?"[16] He compared some of the LTG scenarios within the energy sector with what had happened in the succeeding quarter of a century, and concluded that a shortage of non-renewable energy sources was a real worry. He then says: "Is there time to begin the thoughtful work which the Club of Rome hoped would take place post 1972? I would hope so. But, another 10 years of neglect to these profound issues will probably leave any satisfying solutions too late to make a difference. In hindsight, The Club of Rome turned out to be right. We simply wasted 30 important years by ignoring this work."

Graham Turner compared the last thirty years of historical developments with the LTG scenarios in 2008 (Turner 2008), and found that the LTG scenario with the closest match to historical data was the standard run of World3. His paper was another example of a re-appreciation of the LTG study in the twenty-first century, also exemplified by Hall and Day (2009) who note that "[i]f we are to resolve these issues, including the important one of climate change, in any meaningful way, we need to make them again central to education at all levels of our universities, and to debate and even stand up to those who negate their importance" (Hall/Day 2009: 237). The lower intensity of the debate in the 1980s and 1990s had allowed the hard fronts to soften, and a new generation of researchers appeared, with little or no stake in the debate from the 1970s.

This softening of the fronts in the conflict seem also to have spilt over on the mainstream macroeconomists, who are increasingly participating in the debate about environmental policy and the place of economic policy instruments in it. Moreover, social scientists of different hues have recently turned their attention to environmental problems, in particular climate change. The new voices in the debate contribute to broadening the discussions wider than simply for or against economic growth.

Since the turn of the century, and particularly after 2007, the climate policy debate has become more institutionalized and better anchored in the political

15 This is of course in itself a complex story, and it can be argued that some important developments took place in the global arena in the 1990s, particularly with the signing of the Kyoto Protocol in 1997.

16 See at: <http://www.resilience.org/stories/2000-09-30/revisiting-limits-growth-could-club-rome-have-been-correct-after-all-part-one>.

process both nationally and globally, and scientific knowledge about nature's processes is significantly greater than in 1972. Extreme weather events are increasingly seen as evidence of a changing climate, and the loss of biodiversity, pollution problems, and rising energy prices have all contributed to a general acceptance (among many if not all mainstream economists) that there are physical limits to what nature can sustain. This might seem rather a small achievement, but the hope is that the seed contained in this fundamental truth can flourish into a real change in how we use economic modelling, and subsequently in how modern societies arrive at decisions for collective action.

It may, of course, be a case of too little too late. As was argued both in BTL and in the 30-year update, time is running out. Humankind is already in overshoot and unless large structural changes take place, collapse seems the likely scenario. This was the background against which the book 2052—*A Global Forecast for the Next Forty Years* appeared.

16.4 2052—A Global Forecast for the Next Forty Years

There are two important differences between 2052—*A Global Forecast for the Next Forty Years* (Randers 2012) and the three other books that were discussed above. Firstly, it has only one author. Secondly, '2052' is not a scenario study, but a *forecast* of what Randers believes will actually happen by 2052. This means that the author himself has identified one scenario among several possible ones that fulfil three criteria:

- the described future must be internally consistent, i.e. the development in different variables must not cause them to contradict one another;
- the trend lines are developed based on existing data, which means that the basic assumption is *no major change* in any of the large global trends;
- the described future is what the author finds the most likely when the two first conditions are met.

The central global trends that form the basis of the forecast are GDP (based on population growth and productivity), investment, consumption, energy use, climate impacts, food production, and land use. The story is based on the same 'fairly simple' set of cause-and-effect relationships as in the World3 models, with the following important amendments:

- Urbanization leads to smaller families. This will not be because of lack of food or ill health, but because more people will wish to have fewer children, and can better control the number of offspring because of access to education, health services and contraception.
- Labour productivity will continue to grow, but ever more slowly, because of resource depletion, pollution, climate change, and rising inequity.
- CO2 emissions will at first increase with energy use (although at a slower rate than in many other forecasts, because of increased energy efficiency), but then gradually disconnect as the share of renewable energy accelerates. The emissions will lead to higher concentrations of greenhouse gases in the atmosphere, higher temperatures, and more climate damage to planet Earth (Randers 2012: 55ff).

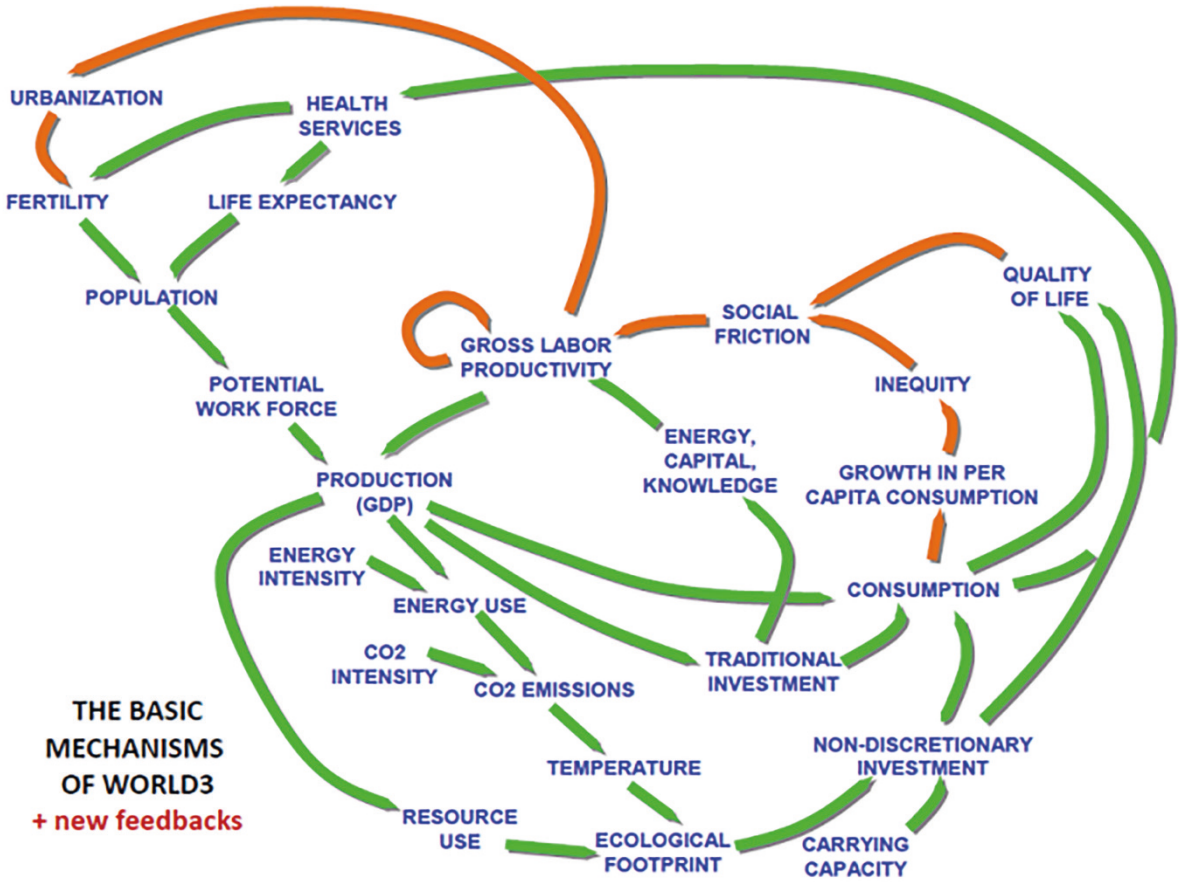
A visual representation of the causal mechanisms are given in figure 16.2, where the changes from the World model are marked in red.

After defining the fundamental causal relationships, detailed forecasts are presented about both physical and non-physical variables. The first of the physical variables is population growth, which, according to Randers' forecast, will peak in 2040, at just above eight billion. This is lower than most official UN estimates,[17] and the most important driver in Randers' forecast is that women will choose to have fewer children as urbanization increases. GDP will continue to grow, but not as rapidly as hitherto, and with a significantly different distribution from what we have seen to date. The big, emerging economies will continue to grow much faster (particularly China), and the US and Europe will remain relatively stable at around 2010 levels. The rest of the world "will stay unpleasantly near their current GDP per person" (Randers 2012: 77).

When it comes to energy use, Randers forecasts that use of fossil energy sources will peak around 2030, and that renewable energy use will increase throughout the period. This will lead among other things to lower climate intensity, a process that will increase in pace after 2030 because of the higher visibility of climate change impacts on the economy. Because of the peak in fossil use, emissions from energy will also peak around 2030. This, however, is not enough to meet the two-degree target. According

17 But there are other institutions that forecast along the same lines, see e.g. <http://www.businessinsider.com/deutsche-population-will-peak-in-2055-2013-9>.

Figure 16.2: Causal diagram for the 2052 study-changes from the World Model marked in red. **Source**: Jørgen Randers presentation material; he also granted permission to use this figure.



to this forecast, global warming will exceed two degrees compared to pre-industrial times around the middle of the twenty-first century.

Food production will increase and peak around 2040. Food per person will follow a similar curve, but the decline in population will mean that the 'food per person' curve will decrease slower than the 'food production' curve. "Grossly simplified, my forecast to 2052 says that there will be enough energy, grain, and chicken, plus some fish—with some exception for the poor" (Randers 2012: 143).

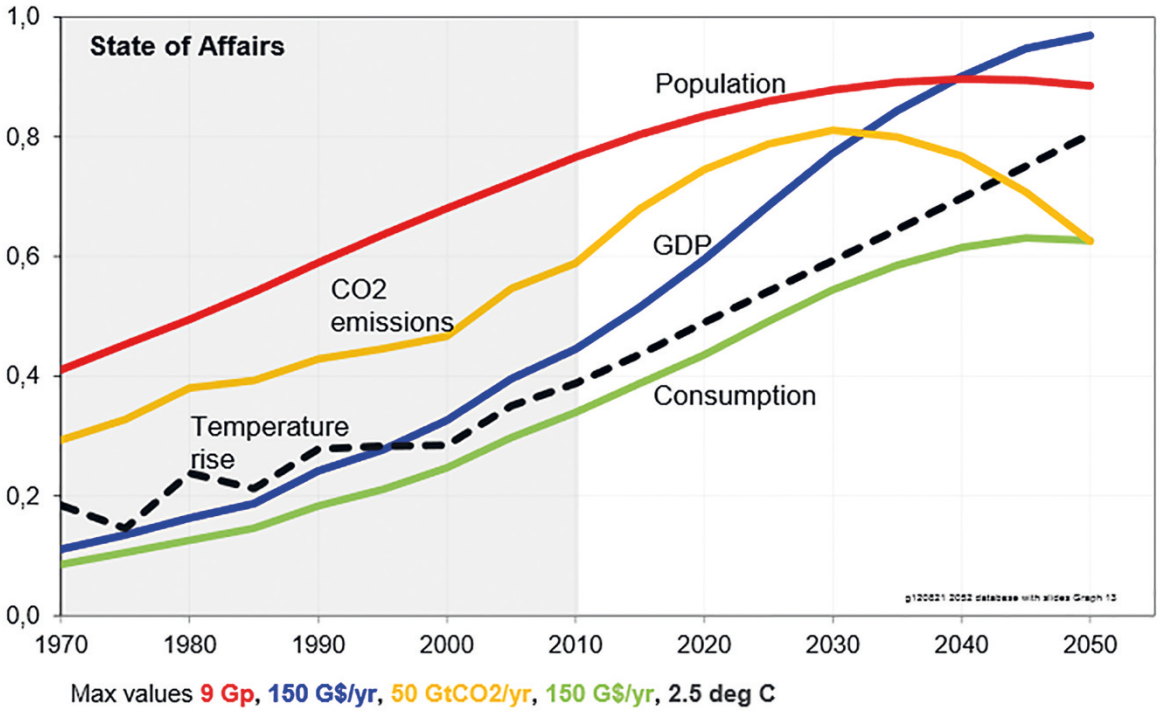
Important elements in the 'non-material future' include stronger government, and urbanization that leads to megacities and the omnipresence of the Internet. The 'zeitgeist' will, according to Randers, focus on fragmentation, local solutions, slum urbanization, and the Internet providing fertile ground for human creativity.

The general forecast is followed by forecasts for five regions (US, OECD minus US, China, BRISE[18] (the fourteen largest 'emerging' economies), and ROW (the *rest of the world*). The maybe most striking feature of these regional forecasts is their diversity. This underlines the large differences that will be experienced in the different regions of the world—not only because 30-cm sea level rise will have very different impacts on society depending on whether one lives on a low Pacific island or on the top of a rugged cliff, but also because the forecast describes some states that will become stronger (but have to invest more to cope with the effects of climate change), and other states that will remain unstable, unable to provide poor inhabitants with basic security and resources.

The language and style in the 2052 book is even more personal and direct than in the LTG series. The big picture depicted in 2052 is a world that is less bad than the author had feared before starting the forecasting work. It is far from his 'ideal' world, and it is a world where people are poorer than he (together

18 Please explain BRISE here.

Figure 16.3: World State of Affairs, 1970–2050. **Source:** Randers (2012: 232). Permission to use this figure was granted by the author.



with many economists) originally expected, but it is also a world where no major collapse will occur before the end-date of the forecast.

Randers closes his book with a list of twenty 'pieces of personal advice'. It is impossible to quote them all here, so here is a selection:

- Focus on satisfaction rather than income
- Invest in great electronic entertainment and learn to prefer it
- Live in a place that is not overly exposed to climate change
- Stop believing that all growth is good
- Remember that your fossil-based assets—suddenly one day—will lose their value
- In politics, remember that the future will be dominated by physical limits.

'2052' is the work of someone who is clearly disappointed with the world and the lost opportunities for change over the last four decades. The real disappointment is that it has proved impossible to beat short-termism, both in economics and in politics. Solving the climate challenge will mean choosing the slightly more expensive solution in the short term, and making (and keeping) electoral promises about something further than one electoral cycle away does not ensure re-election.

16.4.1 Further Resources

In spring 2014 the book was translated into seven languages. The material and analysis is rendered accessible through a website dedicated to the project (<www.2052.info>), where readers can find some of the experts' glimpses into the future and make their own forecasts based on the model.

'2052' has formed the basis for a long series of lectures and presentations,[19] and has contributed to debate in an impressive number of countries around the world. Among the many themes covered in the debates are population growth and birth control policies, environmental degradation, the future of the energy sector, and short-termism and challenges for democracy.[20]

16.5 Concluding Remarks

In the introduction two questions were raised: firstly, why did the debate about the *Limits to Growth* become so polarized, and secondly what have we

19 See <http://www.2052.info/presentations/>.
20 See <http://www.2052.info/articles/>.

learned about the fundamental questions posed by the LTG team?

The answer to the first question can be found in the interests that felt threatened by the publication. Large industrial interests (in particular producers of fossil energy and other scarce resources) would clearly have a hard time believing that the fundamental credo and the resources from which they had created their wealth and large fortunes were to run out any time soon. Economists and politicians, who believed economic growth to be the panacea for increasing human welfare, found their world view questioned. And the population at large generally wanted and needed work and an income, and saw economic growth as the safest option for meeting these needs.

Criticism is often met with hostility. What now seems a relatively uncontroversial message about planetary boundaries was radical when it first appeared. The authors of the LTG were not prepared for the animosity their message would entail, and despite their attempt at framing their message as one of 'hope' because they presented 'possible futures', the necessary changes to bring the world to a sustainable development path were threatening for many of the established elites, economic, political and industrial.

We should also remember that the LTG was not the only environmental message that was met with hostility. The 1960s and the 1970s were decades of controversy and large societal conflict in many parts of the world, but particularly in the US.

Subsequent updates of the LTG study were also clearly presented in different lights, with more emphasis on 'hope' and 'love' (in 1992), and 'doom and gloom' (in 2004). It seems reasonable to assume that the authors chose different strategies because of their previous experiences, and because they fundamentally wanted to engage the world in a debate about where we are heading.

What has humankind learned over the last four decades?

Graham Turner has shown that the standard run of World3 seemed to be a rather good description of reality as observed thirty years after the scenario's publication.[21] Growth has continued, both in global population, production, and ecological footprint. Humankind is in a situation of overshoot with a current consumption of approximately 1.5 Earths. Every year twice as much CO2 is emitted as is being absorbed in oceans and forests, which will lead to temperature rise. Biodiversity loss and ocean acidification is happening.

The global governance system under the UN has not been able to produce a globally binding *greenhouse gas* (GHG) emission reduction treaty during the past forty years. Whether a comprehensive global agreement will occur in 2015 is still an open question, but it is highly unlikely that it will be sufficient for the world to meet its 2°C target.

This review of the four books has shown that they have all concentrated on the development of the relatively uncontroversial 'physical' variables of human development and its effect on the world around us. Discussions about wider security and social development issues have been largely non-existent. This must be characterized as one of the major shortcomings of these books. The analysis and discussion about the effects of physical changes (lower food production, climate change, biodiversity loss), i.e. how they will be felt by humans and how they will impact on social structures, stability and security, are pivotal to our possibility of grasping the real challenges. In these books it is often assumed that resource shortages may lead to social unrest, but no closer analysis or causal mechanisms are discussed.

The 2052 book only partially puts right this issue. Discussions are included about the importance of focusing on quality of life ('happiness') rather than economic growth, but the analysis is rather superficial. This is also the case for political processes, which, to the extent that they are mentioned, are criticized for not delivering policies that bring about sustainable living. Democracy is particularly vulnerable, whereas the Chinese political system gets a bit more credit for delivering on the necessities of preventing the worst causes of pollution. There is no further discussion about whether or how the political process, democratic or otherwise, can contribute to solving the *social* problems resulting from climate change.

The story of *Limits to Growth* and its aftermath is at least two different stories. One is about how global governance has been unable to take sufficient action to prevent many of the challenges that were highlighted even as early as the early 1970s. This is a story that easily leaves us feeling helpless in face of humanity's destiny. But there is another story that is sometimes forgotten. That is the story about how one slim volume managed to incite debate, raise deep ethical questions, spur a search for deeper knowledge about the world in which we live, and remain relevant for several generations.

21 The real test on the LTG scenarios will come over the next couple of decades, when the scenarios start to deviate.

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