Chapter 2
The Story of "The Limits to Growth"

The end of the Second World War brought a period of great prosperity for the Western World. It was the time of suburban housing, of two cars for every family, of a refrigerator in the kitchen, and of air travel which was not any more a privilege for the rich. It was the time of plastics, of antibiotics, of television, and of the first computers. Those were also the years of the start of the exploration of space. The first Sputnik satellite was launched in 1957. Only 12 years later, in 1969, a man set foot for the first time on the Moon.

All this was taking place together with a rapid increase in the use of energy and of raw materials. In the late 1960s, crude oil took the lead from coal as the most important energy source in the world. Cheap fuels obtained from crude oil generated the urban reality that we see today in most of the Western World: large suburban areas inhabited by commuters who use their cars to reach their workplaces in urban centers.

Oil was not just a source of fuels for private cars. Only with the cheap energy that came mostly from oil was it possible to generate the flux of mineral commodities that was indispensable for modern industry. Plastics become an everyday commodity, replacing wood and natural textiles. Steel, once an expensive hallmark of military power, became cheap and commonplace also for civilian uses. Aluminum became a standard material for all kinds of applications, from cooking to the aeronautics industry. The growing hi-tech industry could find exotic and rare elements at reasonable prices for the applications in electronics, aerospace, chemistry, and engineering. Finally, the "green revolution" in agriculture was the result of a combination of mechanization and artificial fertilizers; both were made possible by cheap crude oil and natural gas. It was the great increase in agricultural productivity generated by the green revolution that made it possible to feed the growing world population; a trend that is continuing up to now.

It was known that crude oil – and fossil fuels in general – were a finite resource, but that did not affect the general optimism of the overwhelming majority of scientists, engineers, economists, and other thinkers. Already in the 1950s, new forms of energy were believed to be ready to usher in an even greater abundance than what fossil fuels had brought. The first nuclear reactor designed for the production of electric power went into operation in the US in 1951. It was the start of what was

U. Bardi, *The Limits to Growth Revisited*, SpringerBriefs in Energy: Energy Analysis,
DOI 10.1007/978-1-4419-9416-5_2, © Ugo Bardi 2011

seen as an onrushing wave of reactors that, eventually, would provide humankind with a new era of prosperity; greater than anything experienced before. The finiteness of mineral uranium resources was recognized, but it was believed that it could be overcome by developing "breeder" reactors and, eventually, by fusion reactors that would provide us with energy "too cheap to meter" (Strauss 1954).

With so much prosperity and with growth seeming unstoppable, some outlandish ideas did not seem far-fetched. In the 1950s, people seriously thought of flying cars, of one-use clothes, of atomic planes, and of weekends on the Moon for the whole family. And why not colonizing other planets? What prevented us from exploring the whole Galaxy? The rise of technological progress had convinced most people that human ingenuity could overcome all problems that came from limited resources.

And yet, in the middle of so much optimism, a new consciousness was appearing. If the Western World was experiencing so much prosperity, it was also easy to see that the rest of the world was being left behind. Those regions optimistically defined as "developing countries" were not developing at all and that was true even for parts of the affluent countries (Harrington 1962). True, the green revolution had reduced the frequency of famines in the world but, nevertheless, something prevented the Western prosperity from spilling over to people who could not even dream of two cars per family or of flying to Hawaii for their vacations.

Was it just a question of time? Perhaps, just waiting long enough, the magic of the free market would accomplish the miracle of putting everyone on the development path. Or was it a cultural problem? Perhaps, by diffusing Western ideas, Western culture, and the Western way of life, including hamburger and hot dogs, everyone in the world would learn how to set up a business and be ready for the local industrial revolution.

But, perhaps, the problem was different. Perhaps there just was something wrong in the idea that the earth had sufficient natural resources to provide everyone with the same way of life that had become standard in the Western World. So, it started to appear clear to some that there were limits to human growth on a finite planet.

The concept of limits to growth was nothing new. Even in ancient times, periods of crisis had led people to wonder about what we call today "overpopulation." In modern times, the problem was studied by Thomas Robert Malthus, who published his "An essay on the principle of population" from 1798 to 1826; a work that remains today a milestone in the understanding of the physical limits that humankind faces. But Malthus was misunderstood already in his times, with Thomas Carlyle defining economics as "the dismal science" with a reference to Malthus's work. In later times, Malthus was accused of all sorts of errors, in particular of having predicted a catastrophe that did not occur – a common destiny for all those who predict a not so bright future. But Malthus was not "merely a foreteller of evil to come" (McCleary 1953). Rather, he was the first to understand that biological populations tend to grow until they have reached the limit that their environment can support. He had a profound influence in biology, for instance, where he influenced Darwin's thought, and in economics as well. The classical economists of the eighteenth and nineteenth century, Adam Smith, Ricardo, Mills, Jevons, and others, had a clear view of the limits of the economic system and adapted their thought accordingly.

The vision of the classical economists became outmoded with the great rush of optimism that started in the second half of the twentieth century. But, even in the midst of what was perhaps the fastest paced phase of economic growth of human history, some people were asking themselves a basic question: how long can it last?

The years after the Second World War were perhaps the first time in history when the physical limits of our planet became clearly recognizable for everybody. It was past the time when maps showed white areas with the writing, "*hic sunt leones*"; "there are lions here." Already in 1953, Edmund Hillary and Tenzing Norgay had climbed to the top of Mount Everest, the highest mountain on Earth; one of the last spots on the planet's surface that had remained untouched by humans. In the 1960s, photos of the earth from space, brought back by the astronauts of the Apollo spaceships, showed images of our planet as a blue-green ball. It was finite, it was limited; everybody could see that. "No man is an island", John Donne had said. It was now easy to understand that we were all living on a small blue island floating in the blackness of space.

The idea that all living beings were part of the same entity goes back to the 1920s, when Vladimir Vernadsky had coined the term "biosphere" (Weart 2003). The concept became widely known in the 1960s, when James Lovelock developed the concept of "Gaia" (Lovelock 1965), borrowing the name of the ancient earth divinity to describe the planetary ecosystem. Gaia embodied the concept that all the creatures of the Earth are linked in a complex system of feedbacks that maintain the temperature of the planet at levels tolerable for life.

In time, Gaia turned out to be far different from the benevolent entity that Lovelock had imagined (Ward 2009). But the concept of Gaia remains a valid metaphor even today for the description of the planetary ecosystem (Karnani and Annila 2009). Then, if life is a single, giant organism, it follows that this organism is tied to the limits of the whole planet. And, if the bounty of the planet is limited, how could we continue forever the rapid growth experienced in the 1950s and 1960s?

In 1968, Garrett Hardin provided more food for thought on this problem with his paper "The Tragedy of the Commons" (Hardin 1968). Hardin described a case in which land is a common good, that is, it is free for all shepherds as pasture. Each shepherd understands that too many animals damage the land. Yet, each shepherd tends to add more animals to his own herd because his individual advantage is larger than the damage caused to him by the collective loss. The result is disaster: with too many animal grazing, the fertile soil is destroyed by erosion and everyone suffers as a consequence. Still, even though the situation is evident to everyone, it remains convenient to each individual shepherd to overexploit even the last patches of pasture remaining.

Hardin's model was schematic and, surely, the real world is much more complex than the hypothetical pastures he had described. Nevertheless, with his analysis, Hardin questioned at its core the concept of the "invisible hand" that Adam Smith had developed almost two centuries before. Whereas neoclassical economists saw the pursuit of self interest as leading to the maximum common good, Hardin saw it as leading to the destruction of the resource being exploited.

While Hardin's qualitative model explained the reasons for the overexploitation of natural resources, in the 1950s, the American geologist Marion King Hubbert developed an empirical model that described how fast resources were exploited. Hubbert proposed that the production curve for crude oil in any large productive region should be "bell shaped." Applying his model to crude oil in the 48 US lower states, he predicted in 1956 that maximum production should have been attained around 1970 and that it should have been declining afterwards. That was what happened, with the peak reached in 1971 (Campbell and Laherrere 1998).

Today, the "bell shaped" production curve has been observed for many minerals other than crude oil (Bardi and Pagani 2007) and even for slowly renewable, nonmineral resources (for instance for whales (Bardi 2007b)). The bell shaped curve is known also as the "Hubbert curve," while the maximum is often called the "Hubbert peak" (Deffeyes 2001, 2005). The worldwide peak of oil production is often called "peak oil" (Campbell and Laherrere 1998).

Crude oil in the US was not the first case of a major mineral resource having reached its production peak. Earlier on, around 1920, British coal production had also peaked and had started its decline (Bardi 2007a). These and other historical production peaks passed largely unreported and, whenever discussed, were normally attributed to market factors. Nevertheless, these data showed that resources, even important ones, were finite and that production could not be kept increasing forever.

Another worry of those times was the growth of human population; a crucial factor of Hardin's "commons" model (Hardin 1968). Up to then, population growth had been always seen as a good thing. More people meant more soldiers for the army, more taxpayers for the state, more peasants for landlords, more workers for factory owners; in short, more wealth for everyone. But, in the 1950s and 1960s, population growth had taken an ominous trend. At the beginning of nineteenth century, the human population had reached one billion. In 1927, it had touched two billions. The three billion mark had been reached in 1960s. Growth seemed to follow an exponential curve and it was a nightmare to extrapolate the trend to future decades. Worries about overpopulation were diffused in a popular book by Paul Ehrlich "The Population Bomb" (1968) where the author predicted widespread famines all over the world.

Finally, the world "pollution," so familiar to us, is recorded to have been used with the meaning of "environmental contaminant" for the first time in the 1950s. Initially, the term was referred mainly to the radioactive waste generated by nuclear explosions but, with time, there started to appear other forms of pollution. "Smog," the fumes resulting from the combustion of coal became a deadly threat. The 1952 London smog episode was especially deadly, with about 4,000 victims (Stegerman and Solow 2002). This event generated legislation against pollution: the Clean Air Act, enacted in Britain in 1956 and the "Air Pollution Control Act" enacted in the United States in the same year. Later on, another, more comprehensive piece of federal legislation in the US, the "Clean Air Act," was enacted in 1963.

Pollution took many forms, often unexpected. One was the effect of pesticides. In 1962, the American biologist Rachel Carson published her book "Silent Spring" (Carson 1962) where she criticized the indiscriminate use of pesticides; that she termed "biocides." Carson's claim was nothing less than revolutionary. Up to that time, an obvious truth had been that living creatures could be divided into "useful" and "noxious" and that it was a good thing to exterminate the latter kind. The concept of "ecosystem," where many species interact with each other, actually need each other, was relatively new in a world dominated by concepts such as "better living through chemistry." Carson was probably the first author to describe these issues in a popular book and the resonance was enormous. She is correctly credited as having started what we call today the "environmental movement."

These years also saw the first hints that human activity was creating an even more worrisome threat to humans: global warming. In 1957, Robert Revelle and Hans Suess (Revelle and Suess 1957) took up earlier work on the effect of greenhouse gases and published a study that evidenced how the observed growth of carbon dioxide resulting from human activities would result in a rise in the planetary temperatures. The evidence of global warming was not to become completely clear before the 1970s but, already in the 1960s, it was another worrisome indication of the effect of humans on ecosystems.

In the 1950s and 1960s, worries about resource depletion, overpopulation, and pollution were not at the top of the daily news, but were slowly making their way inside the consciousness of many people concerned about the fate of humankind. Something was to be done, clearly, but it was not enough to say that, someday, we would have to come to terms with our environment. The point was *when*. Did we have millennia, centuries, or perhaps just decades? And not just that; *how* would the clash of humankind against planetary limits take place and what symptoms could alert us and help us preventing the worst consequences? There was a tremendous need to understand what the future had in store for humankind.

Quantifying this kind of global problems had never been attempted before, but the progress of technology was starting to provide the right kind of tools for such a purpose. In the 1950s and 1960s, digital computers were rapidly developing and in several areas of science they started to be utilized as instruments for forecasting the future.

In the late 1940s, a young professor at the Massachusetts Institute of Technology in Boston, Jay Wright Forrester, had started using a new generation of digital computers to simulate the interactions of different elements of machinery and electronic systems. In time, Forrester moved his interest to management and to the modeling of economic systems. He dubbed the new field "industrial dynamics" (Forrester 1958, 1961) but, later on, the term "system dynamics" became commonplace. The method could be used to simulate business situations (Sterman 2002) and socioeconomic systems such as entire cities (Forrester 1969; Madden 1979; Burdekin 1979). From there, another step forward was clear for Forrester: simulate the world's entire economic system. He developed his first world models in the mid 1960s, when his computers had become powerful enough to carry out simulations involving the main elements of the world's economy and of the ecosystem.

While Forrester was engaged in these studies, others were examining the same problems. In 1968, Aurelio Peccei (1908–1985) and others formed the "Club of Rome," a group of intellectuals from industry and from academia who had gathered together to study and discuss global economic and political issues. At the beginning, the focus of the Club was not specifically on planetary limits. The document titled "The Predicament of Mankind" (Club of Rome 1970) shows that the main concern of the Club at that time was finding practical ways to improve the conditions of life of human beings; in particular by reducing inequality in the distribution of wealth. But the members of the Club rapidly came to the conclusion that they had to find ways to quantify the limits of the world’s resources if they wanted to be able to act on their concerns. In 1968, Aurelio Peccei met Jay Forrester at a conference on urban problems in Italy, on the shores of Lake Como (Forrester 1992). That meeting was the spark that ignited the series of events that would lead to “The Limits to Growth” study.

Peccei was impressed by Forrester’s ideas and he invited him to participate at a meeting that the Club of Rome organized in Bern in 1970. At the meeting, Forrester persuaded the members of the executive committee of the Club to travel to MIT, in Boston, to discuss the possibility of using system dynamics for their purposes. It is said that Forrester jotted down the basic elements of his world model while flying back to Boston.

In Boston, the members of the Club of Rome discussed with Forrester and also with one of his coworkers, Dennis Meadows, then 28 years old. Apparently, Meadows was the only one in Forrester’s group who was not already burdened with other projects. So, he wrote a memo of several pages in which he outlined how a world modeling project based on system dynamics could be run and the members of the Club decided to try to use it. Later on, Meadows, following Peccei’s suggestion, applied to the Volkswagen foundation to provide a grant for the study (Meadows, private communication, 2010). The proposal was accepted and Meadows assembled a team of 16 researchers to work on the project. The team included Dennis Meadows’ wife, Donella Meadows, Jorgen Randers, William Behrens, and others.

In 1971, Forrester published the results of his work on world modeling in a book with the title “World Dynamics” (Forrester 1971). The work of the team headed by Dennis Meadows was published in 1972 as a book with the title of “The Limits to Growth” (LTG) (Meadows et al. 1972).

Forrester and the LTG team had worked independently of each other, but had arrived at the same shocking conclusion that can be summarized as: *The world’s economy tends to stop its growth and collapse as the result of a combination of reduced resource availability, overpopulation, and pollution*. This conclusion was a “robust” feature of the simulations; that is, it changed little when varying the initial assumptions.

Neither Forrester’s calculations nor the LTG ones were meant to determine when exactly the collapse was to start but, using the best available data, both studies indicated that the start of the economic decline could be expected within the first decades of the twenty-first century, that is about 30 or 40 years into the future. In the LTG study, this scenario was referred to as the “Base case” or the “Standard Run” (Fig. 2.1).

Both Forrester and the LTG team performed their simulations for a variety of possible assumptions, including radical technological innovations or that population could be stabilized by policy actions at the global level. In most cases, even for very optimistic assumptions about resource availability and technological progress, collapse could not be avoided but, at best, only delayed. Only a carefully chosen set of world policies designed to stop population growth and stabilize material consumption could avoid collapse and lead the world’s economy to a steady state while maintaining an average level of material consumption not different than it was in the 1970s.

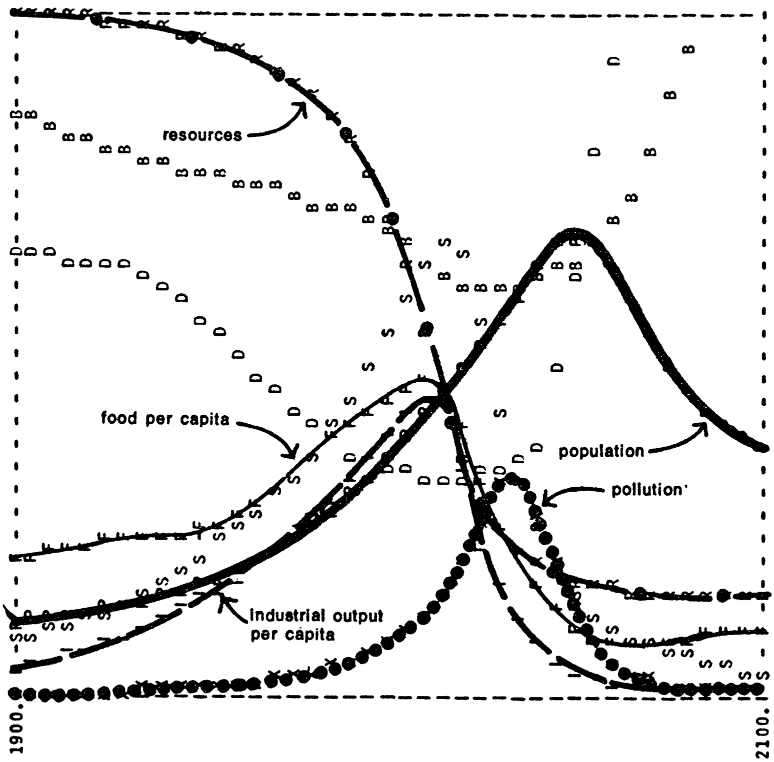

Fig. 2.1 Results of the simulations for the "base case" model from the 1972 edition of "The Limits to Growth." The base case model is the one which assumes as input parameters the values closest to the available data. Image credit: Dennis Meadows

The two books describing these concepts, "World Dynamics" and LTG, both had a considerable success. Forrester's book sold about 100,000 copies, a remarkable result for a book that was conceived as a technical text and that was full of equations and diagrams. But the real impact came with the LTG study, which was aimed from the beginning at the general public.

The total number of copies of LTG sold is not known with certainty. However, the authors of the study (Meadows, private communication, 2010) estimate that the total sales were surely over one million. The book was also translated into more than 30 languages. Evidently, the book gave voice to something that was deeply felt all over the world: that the limits to the planetary resources could not be ignored for long.

In spite of the success and the interest raised, the work of Forrester and of the LTG team also encountered strong criticism. Economists, for instance, seemed to be unified in rejecting the methods and the findings of these studies as not compatible with economics as it was understood at that time. But where the debate really raged was in political terms. Here, the very success of the LTG book generated a strong reaction.

The reviews by Giorgio Nebbia (1997) and by Mauricio Schoijet (1999) tell us how different political attitudes shaped the worldwide reaction to LTG. In the Soviet Union, the reaction was that the book might have well described the collapse that was in store for Capitalism, but that it had nothing to do with Communist societies which would avoid collapse by means of their planned economies. In many poor countries, local intellectuals often saw LTG as an attempt to perpetuate the dominance of the rich West, a fraud to impose population reductions on the poor or even the harbinger of a return to colonialism. In the Western world, different political orientations often dictated the reaction to LTG and, in many cases, left and right were united in the rejection. The left often saw LTG as an attempt to justify the subordinate position of the working class while the right saw it as a threat to their vision of free markets and economic growth. Positive political reactions to LTG came most often from moderate–liberal positions, which not only saw the threats described in the LTG scenarios as real but also as opportunities to reduce inequality and create a freer world (see, e.g., Peccei and Ikeda 1984).

If, at the beginning, the debate on LTG had seemed to be balanced, gradually the general attitude on the study became more negative. It tilted decisively against the study when, in 1989, Ronald Bailey published a paper in "Forbes" where he accused the authors of having predicted that the world's economy should have already run out of some vital mineral commodities whereas that had not, obviously, occurred.

Bailey's statement was only the result of a flawed reading of the data in a single table of the 1972 edition of LTG. In reality, none of the several scenarios presented in the book showed that the world would be running out of any important commodity before the end of the twentieth century and not even of the twenty-first. However, the concept of the "mistakes of the Club of Rome" caught on. With the 1990s, it became commonplace to state that LTG had been a mistake if not a joke designed to tease the public, or even an attempt to force humankind into a planet-wide dictatorship, as it had been claimed in some earlier appraisals (Golub and Townsend 1977; Larouche 1983). By the end of the twentieth century, the victory of the critics of LTG seemed to be complete. But the debate was far from being settled.

The interest in LTG and, in general, in world modeling, may be returning today as the collapse seen in all the scenarios of LTG may start to manifest itself in terms of crashing markets and economic crisis. With the new century, we are seeing a growing realization that we need new ideas and approaches to address severe economic and environmental problems from resource depletion to global climate change.

Today, we can look back at almost 40 years of the story of "The Limits to Growth" and review the message that we received in 1972. What was the future at that time is now the past and we can recognize the validity of the scenarios presented in the book (Turner 2008; Hall and Day 2009) with the world's economic system having closely followed the LTG "base case" scenario up to now. So, we can say that LTG never was "wrong" in the sense that critics intended. They had badly misunderstood, forgotten, or ignored that the time scale of the base case scenario was such that collapse was not to be expected until a time that was roughly estimated as within the first two decades of the twenty-first century.

There is also a deeper factor in the misunderstanding the LTG message. It was a warning, not a prediction and, as such, it could not be “wrong.” It does not matter whether collapse occurs or not on the specific date that corresponds to a specific scenario of those presented in the book. What matters is that, by ignoring the study for the past four decades, we probably lost the ability to do something to avoid, or at least mitigate, the problems ahead.

The story of “The Limits to Growth” is a continuing one. We can still learn a great deal from the 1972 study and from its more recent versions (Meadows et al. 1992, 2004). So, it is not too late to put into practice some of the methods and recommendations that can be derived from the study.

Springer
http://www.springer.com/978-1-4419-9415-8

The Limits to Growth Revisited
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2011, XIII, 119 p. 22 illus., 6 illus. in color., Softcover
ISBN: 978-1-4419-9415-8