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Chapter 2

Systems thinking

We find a shift in metaphors – a change from seeing the world as a machine to understanding it as a network.
Capra and Luigi Luisi (2019).

Complex problems cannot be solved by simple solutions. It is becoming more and more evident that major problems of today – global warming, climate change, water scarcity, clean energy availability for all, food for everybody, and economic inequality[55] – cannot be understood and solved in isolation. So, how do we approach this?

- Listen to and trust the scientists? A good idea, but it not sufficient. We also need to translate the messages in to actions.
- Make the politicians act right now? Great, but it does not solve the problem. We also need to act personally and do what we can do.
- Transforming our food systems to care for the planet? Yes, but far from sufficient. How can we from the wealthy part of the world support less fortunate populations to relieve their hunger?

Each one of the approaches is insufficient if it is done in isolation. Only together they are effective. In other words: *interdisciplinarity is using good general knowledge of many disciplines to solve issues that deep knowledge of one discipline cannot solve.*

The global problems that we face are systemic problems, which means that they are interconnected and interdependent. There are solutions to many of these complex problems, but they require a radical shift in our perceptions, our thinking, and our values. There is a formidable challenge: leaders and decision makers at all levels should see that many of the complexities are interrelated. We must 'connect the dots'. Our solutions today will influence future generations.

Systems thinking= everything is connected

Climate change and all its consequences are truly complex. Various aspects of it are studied by different disciplines. Consequently, they come to isolated conclusions. When each academic discipline, action group, industry, or political leader talks about 'climate change' they could be referring to drastically different things. A marine ecologist worries about increasing ocean temperature, while a power generation engineer talks about increasing hydropower limitation. They address the same issue. However, if they do not listen to each other, they think that their problem is the dominating challenge. By listening to perspectives from different disciplines our minds can be truly extended. It also means that to solve extremely complex problems, we must rely on and trust others. This includes not only so-called experts, but also *everyday people*. The latter often know more than many scientists about consequences of climate change and scarcity of water, energy, or food.

In Figure 1.4 we illustrated that each of the components climate, water, energy, food, economy, and lifestyle has to be understood from a systems perspective, but the complex system must be approached with detailed knowledge of the components. Systems thinking involves connectedness, relationships, and context. The global problems must be understood from the interactions and relationships between the parts. We have to develop many more cross-sectoral interactions, from academic curricula to research, development, financing, and politics. The essence of systems thinking is captured in the phrase, 'the whole is more than the sum of its parts'. The idea is not new: the origin of this phrase is to be found in Aristotle's *Metaphysics,* more than 2,300 years ago.

2.1 SYSTEMIC APPROACH

Integration is the core of systems thinking. The same underlying idea of 'systems' can denote technical, social, economic, and living systems. The meaning of systems derives from the Greek *syn+histanai*, meaning 'to place together'. To understand things systemically literally means to put them together to establish the nature of their relationships.

A fundamental principle of systems thinking is that everything is interconnected. Humans need food, air, and water to sustain our bodies. Trees need CO_2 and sunlight to thrive. Everything needs something else, often a complex array of other things, to survive. The systems thinking perspective defines a fundamental principle of life. We need to change our way of seeing the world as consisting of a huge number of system components to viewing it as a dynamic, interconnected array of relationships and feedback loops. The limits to growth discussions in the 1970s, as described in the prologue, had the systemic view that everything is connected. Even if the detailed calculations were only partially correct, the approach showed the importance of interconnections. It also reminds that systems thinking must be combined with deep knowledge of the components.

> Essential to understand relations and patterns

Systems thinking deals a lot with relationships and patterns, and how various components interact with each other. Therefore, we cannot deal with environment, technology, people and their priorities and ambitions, as independent issues. All of them are interconnected. Sometimes we need a component view and other times we need a systems perspective, like looking at objects from the ground or from a helicopter. The true challenge is to understand the component and process aspects from a systems perspective and to comprehend the system aspects from a component perspective.

Analysis means taking something apart to understand it; *systems thinking* means putting it into the context of a larger whole.

Systems thinking is the opposite of analytical thinking. Analysis means *taking something apart* to understand it; systems thinking means *putting the parts into the context of a larger whole*. A dominating methodology in science has been analysis, where we dissect complex problems into manageable components. This reflects the mechanical and reductionist view, where the complexity is broken down into parts. Synthesis aims to combine two or more things to create something new. It is about understanding the whole and the parts at the same time, along with the relationships and the connections that make up the dynamics of the whole. Systems thinking got a lot of attention from Jay W. Forrester in the early 1970s[56], as we discussed in the Prologue.

There is abundant evidence that the mechanical/reductionist paradigms have had an adverse impact on our ability to address all categories of our challenges. Machine thinking has mindlessly destroyed so much; we need a different mind-set to repair the damage. The degradation of environment has carried us to the boundaries of what Earth can take. We will not be able to fix the damage to the environment using the same paradigm. As we diligently extract non-renewable resources, we are also greatly diminishing and endangering the system that created life on this planet.

We are part of the ecosystem

Systems thinking and a living network paradigm enable us to see ourselves, our communities, and our environment as components of a larger ecosystem, and to recognize the importance of interactions between different systems. Some examples may illustrate the connections:

- Turning production to low-income countries means that they may be blamed for higher emissions that are primarily caused by consumption in higher income countries. This was a key criticism of the Kyoto Protocol.
- Decreasing over-consumption in rich countries will naturally influence production. This in turn depends on material and energy resources.
- Increasing renewable energy production should mean that less fossil fuels would be needed. However, cutting off fossil fuel burning too abruptly will cause transitional problems. This relates to critical minerals or metals, land use for feedstocks for biofuels, and competition with growth of food resources and water.
- Decreasing meat consumption is good both for the climate and for water resources. However, this change will not only affect the cattle industry but also the farmlands producing feed for the cattle. Ultimately, it would mean that the land area required for a certain number of calories will change.

- Public health problems are closely related to the access to clean water and is also related to water storage for energy or irrigation.
- Decreasing urban water consumption means that water age (the time that water remains in the distribution system) will increase. This may influence the ultimate water quality.
- Increasing industrialization in a low-income country will increase the competition for water.

Looking at climate change risks, multiple drivers interact, as do the risks themselves.

We live in a highly networked world. Looking at climate change risks, multiple drivers interact, as do the risks themselves. It is obvious that climate change has wide implications, even if it may be characterized primarily by the CO_2 content and the major emission source, fossil fuels. Climatologists emphasize that real-world experience underscores the complexity of interactions among multiple drivers of climate change risk[57]. Not only the risks have to be assessed, but the interactions that generate the risks must be identified. Potential impacts due to climate change as well as responses to climate change relate to risks. To approach complex systems like these it is crucial to think across sectoral and regional boundaries, and risks are not only related to physical phenomena but also to socio-economic drivers.

Lifestyle has a profound impact on global warming

Climate change has impacts on water resources. Lack of water resources has a great influence on food production. Energy has consequences not only for climate but depends on available water, for example, for cooling thermal plants, for hydropower, and for finding metals for battery production. The priorities of financing institutions have a great impact on climate change or on alternative energy sources. The lifestyle of wealthy people has great significance for energy and water consumption and, consequently, on climate. A measure of success in the western world is mostly related to income and consumption. If happiness is believed to be correlated with capital wealth, it will be too hard to change lifestyle.

Connections between technological, environmental, and socio-economic systems require that we understand how risks are transmitted from one system or sector to another. This in turn creates new risks or amplifies existing ones. Most often it is convenient to break analysis into silos, taking a component-oriented, rather than interaction-oriented, view. This is to some extent done also by the Intergovernmental Panel on Climate Change (IPCC) which divides its assessment into three separate working groups focused on: (1) physical climate change; (2) climate impacts, vulnerability, and adaptation responses; and (3) emissions mitigation. This approach is useful for synthesizing thousands of discipline-specific studies and reflects the largely sectoral approach of

'All things are bound together, all things connect. Whatever befalls the earth, befalls also the children of the earth'.
Oren Lyons

many governments. However, by considering individual sectors, assessments can miss important interactions[58].

2.2 FEEDBACK

Feedback is an essential component of systems thinking. There are several feedback mechanisms related to global warming and climate, such as how global warming causes methane release due to the permafrost thaw. This will in turn amplify the global warming. Such feedback is an example of positive feedback, leading to the growth of its effect and instability. In a drought situation more groundwater may be used for irrigation. This may led to energy waste, which in turn affects climate. Furthermore, unrestricted use of groundwater will lower the water table, increasing irrigation challenges, demanding even more electrical power. Food habits with more meat consumption often leads to more land use, increasing water consumption and other negative impacts. Meeting extreme temperatures with more air conditioning (as suggested by a policy maker) will further amplify climate change.

Receiving data and comparing them with desired outcomes is the basis for feedback and corrections and is an essential part of our decision making and learning. As the few examples above illustrate, water problems or the energy challenges cannot be solved in isolation. Norbert Wiener (1894–1964), the true pioneer of cybernetics (from Greek *kybernetes*, 'steersman') defined cybernetics as the science of 'control and communication in the animal and the machine'. Early on in his work on cybernetics, Wiener was aware that feedback is an important concept for modelling not only living organisms but also social systems. Norbert Wiener's milestone publication from 1948 defines the basic principles of cybernetics that has later developed into control and communication[59]. He wrote: '*It is certainly true, and the social system is an organization like the individual, that is bound together by a system of communication, and that it has a dynamics in which circular processes of a feedback nature play in important role.*'

The principles of feedback control are applicable all the way up to high-level strategic decisions. The framework is always the same, whereas the measurements, the analyses, and the decisions are different. Understanding feedback loops is intimately connected to the concept of causality. One event or dynamical change results in another change in a dynamic and constantly evolving system. Cause and effect are fundamental concepts in physical systems and in life in general. To understand how components in a system influence each other we must practice causality concepts and systems thinking.

> Principles of feedback control are applicable all the way up to high-level strategic decisions

2.3 WICKED PROBLEMS

At planning, strategic, and policy levels, there are numerous complex challenges that have been characterized as 'wicked' problems[60] This is a social, cultural, or organizational problem that is difficult or impossible to solve. Knowledge about it may be incomplete or contradictory. There are many people and opinions involved, or the economy is a major obstacle. Often the problems are interconnected with other problems. Therefore, there is no apparent correct solution.

Handling wicked problem requires wisdom, a process of continuous learning,

We may replace the term wicked with VUCA (volatile, uncertain, complex, ambiguous) problems to address the complex but solvable problems more correctly with a new mindset. To handle VUCA problems requires wisdom, which is a process of continuous learning, a journey rather than a destination.

Conventional problems often have scientific solutions developed by experts. A wicked problem definition depends on stakeholders' views and perspectives. For conventional problems, we can often judge if the outcome is true or false, or if it is successful or unsuccessful. For a wicked problem there is mostly no 'correct' solution. The outcome may be better, worse, or acceptable.

Acquiring wisdom is an incremental process of integrating different types of knowledge, opinions, and interests into a holistic framework.

Dealing with complexity requires wisdom: and acquiring wisdom is an incremental process of integrating different types of knowledge, opinions, and interests into a holistic framework rather than mastering the details of a single aspect of knowledge. Achieving wisdom is a process of learning: a journey rather than the destination. To handle many of the problems described in this book requires that people from many different disciplines, cultures, social status, and economic conditions should cooperate. This is probably the challenge of our time.

2.4 HYPEROBJECTS

Since the nuclear bombs over Hiroshima and Nagasaki, we live in the nuclear age, the time when humans can destroy all life on Earth. We who grew up in the 1940s and 1950s can still remember the arms race, the fear of a nuclear winter and radioactive radiation. At any time, a senseless leader could push the button. This was another kind of fear compared to climate change. The climate threat has a low intensity and has been on-going for many years but is getting less attention. It is difficult to relate to a specific place and to one responsible leader. It is global and appears in many ways. The nuclear bomb threat was highly explosive and could be released at a specific moment.

The two global threats are seldom connected, but neverthless, both are real. The Anthropocene age is changing the Earth. The concept of *hyperobjects* provides one potentially useful way of seeing, comprehending, and adapting to these grand problems. The idea of hyperobjects has been conceived by Timothy Morton, Professor of Contemporary Philosophy at Rice University, Houston, Texas[61]. Global warming is the hyperobject par excellence. Global warming is not a traditional object, because it cannot be seen directly but only through data about it. And even so it cannot be perceived as one whole object. As Morton expresses it: '*The panic and denial and right-wing absurdity about global warming are understandable. Hyperobjects pose numerous threats to individualism, nationalism, anti-intellectualism, racism, speciesism, anthropocentrism, you name it. Possibly even capitalism itself.*'

Global warming is not a traditional object. It cannot be seen directly but only through data. It is a hyperobject.

Morton explains that the problem with hyperobjects is that you cannot experience one, not completely. You also can't *not* experience one. They bump into you, or you bump into them; they bug you, but they are also so massive and complex that you can never fully comprehend what's bugging you. This oscillation between experiencing and not experiencing cannot be resolved. It's just the way hyperobjects are.

In the 1950s the fear of nuclear war was raised also via movies. Today, sea level rise, loss of biodiversity, or carbon footprint are not understood in the same way. Our language is too meagre to describe what is happening around us. At the same time, it is remarkable that we believe that we will never experience a nuclear war, even though there are around 14 000 nuclear warheads ready to be fired. In July 1946, as the USA planned to test the first hydrogen bomb at the Marshall Islands the American military leaders explained for the local residents: '*We are testing these bombs for the good of mankind and to end all wars*.'

Do we see the correlation between the attitude to the Marshall Islands citizens and our disrespect for the poorest in the world that are now affected by our lifestyle and consumption?

2.5 THE UN SUSTAINABLE DEVELOPMENT GOALS

The 17 UN Sustainable Development Goals (SDGs) were adopted in 2015 by the international community as part of the 2030 agenda for sustainable development[62]. It should be recognized that there are a lot of interlinkages between the various SDGs. Therefore, it is important to adopt an integrated approach towards their implementation.

Nearly all the development goals depend on sufficient energy and water being available. There are strong couplings between water and energy. SDG 6 – 'Ensure availability and sustainable management of water and sanitation for all' – relies on available and affordable energy. This links to SDG7 – 'Ensure access to affordable and reliable, sustainable, and modern energy for all'. Conventional energy like thermal power plants and hydropower depend heavily on water availability. This reliance can be significantly decreased using solar photo-voltaic and wind power system. The strong dependency between SGD6 and SDG7 are increasingly recognized[63]. The role of renewable energy and

Without clean water and affordable energy none of the SDGs can be fulfilled.

water solutions will directly and indirectly contribute to all the other 15 SDGs. This has been elaborated in a previous book by the author[64].

> Making renewable energy and water solutions available will directly and indirectly contribute to all the other 15 UN Sustainable Development Goals.

2.6 GLOBAL RISKS

The Global Risks Report 2020, published by the World Economic Forum[65], presents a detailed and sobering account of global risks, estimated for the next 10 years. The risk assessment is based on an annual Global Risks Perception Survey, completed by approximately 800 members of the Forum's diverse communities (called the *Multistakeholders*). For the first time the report also presents a survey among around 200 people, representing the younger generation of emerging global social entrepreneurs and leaders (the *Global Shapers Community*).

As illustrated in Table 2.1, all the top five global risks for *both* categories, in terms of *likelihood,* are in the environmental category. In the *impact* group three out of the five are categorized as environmental. Not surprisingly, the Forum's younger constituents show even more concern, ranking environmental issues at the top in both the short and long term, and they see the existential risks not only to their generation but to the wider global community. The water crises are naturally connected to environmental as well as society and conflict risks.

Table 2.1 Long-term risk outlook according to World Economic Forum (2020).

		Multistakeholders	**Global Shapers**
Likelihood	1	Extreme weather	Extreme weather
	2	Climate action failure	Biodiversity loss
	3	Natural disasters	Climate action failure
	4	Biodiversity loss	Natural disasters
	5	Human-made environmental disasters	Human-made environmental disasters
Impact	1	Climate action failure	Biodiversity loss
	2	Weapons of mass destruction	Climate action failure
	3	Biodiversity loss	Water crises
	4	Extreme weather	Human-made environmental disasters
	5	Water crises	Extreme weather