CHAPTER SAMPLER

Sustainability in Engineering by Some of our Female Authors

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Implementation of Sustainable Engineering Practices

8.1 Introduction

Sustainability has gained significant attention in the past decades, particularly by engineers. The definition of sustainability by the Brundtland Commission in the 1970s, however, is quite vague and difficult to implement. More recently, tools have been developed to assist in integrating sustainability into design, particularly for buildings and infrastructure. None of these has been adapted universally. In the 1970s, environmental considerations became important. Now, aspects such as resource conservation, societal acceptability, energy minimization, use of renewable energies, and mitigation of climate change, among others, must be included in project/process/system considerations. This chapter will provide examples of sustainable engineering practices and challenges and needs for the future education and research.

8.2 Integration of Sustainability Concepts into Engineering Practices

According to the Association of Consulting Engineering Companies (ACEC)—Canada report on consulting engineering and sustainability (Boyd 2016), conservation, preservation, prediction, and consultation are four main aspects to be included in engineering design. Conservation includes minimization of water, energy, and materials by recycling or use of renewable energies. Durability and site restoration after decommissioning must all be included in the planning. Environmental laws must be followed for biodiversity preservation and health and safety. Human rights must be respected and climate change impacts must be considered. Cultural considerations are also becoming more important. Prediction involves designing for resilience in a changing environment mainly due to climate change. Affected communities must be consulted, as they are important stakeholders in projects.

Climate change is another very important challenge for sustainability. There are two main approaches, mitigation and adaptation. Mitigation involves the reduction in carbon dioxide emissions, in particular. This can be related to reducing energy use, using cleaner fuels, and possible carbon capture. This applies to transportation, buildings, industry, and environmental remediation such as waste management. Adaptation involves new design for projects, as historical data will not apply. Greater uncertainty and thus large factors of safety will be needed.

Clients are becoming more interested in sustainability. Many companies are now participating and producing sustainability reports using the Global Reporting Initiative (GRI) as seen in Chapter 6. Many government agencies also have committed to sustainability. Public participation has been mainly during the environmental assessment phase of a project. This is usually late. They need to be included from the concept of the projects to uncover issues and to communicate progress to the stakeholders.

Procurement also needs to be included in sustainability. This includes no sweatshop labor or unfair labor practices or corruption, use of fair trade products, and support of local development. Engineers must improve sustainability of projects and processes for the future. Determination of indicators at an early stage of the project in consultation with stakeholders is essential. The engineer has the most influence in the early stage of the project. However, there are opportunities during commissioning, operation, and decommissioning to improve sustainability. Climate change is also causing more uncertainty in designs. New tools can help. Traditionally, projects have to meet the client and regulator's requirements. The society is adding new requirements for the project in terms of sustainability. Engineers have an ethical requirement to face these new requirements. New tools are being developed to assist in the assessment but none is perfect. For example, LEED and BREEAM are restricted to buildings.

Innovation is a key aspect for sustainable engineering. These projects are riskier and require more time initially. However, payoffs will be in the future with reduced operating costs. According to the World Federation of Engineering Organizations (WFEO 2015), engineers can contribute to sustainable practices in many ways. Some of these include harvesting renewable resources in ways to ensure continuous supply, minimization of nonrenewable resources, processing resources with little to no wastes, designing and building of infrastructure and processes with minimal waste and environmental impact throughout the life cycle, and development of clean renewable energy sources. Human needs must be met for ensuring adequate living and health standards. In other words, sustainable engineering involves the use of natural resources in a cost-effective way for the support of the human and natural environments. The approach should be as close to a closed loop as possible as proposed in the circular economy. In Chapter 5, various sustainable practices for resources, environmental restoration, and energy production and use were discussed. The next section will demonstrate some case studies of sustainable engineering practices.

8.3 Examples of Sustainable Practices

8.3.1 Industrial Park in Haiti

In Haiti, the construction of the Caracol Industrial Park was to take place. This was to be one of the most important infrastructure projects in the country. When it came to the production of a drinking and industrial water production facility, the mandate for the turnkey project was removed. At this moment, the engineering consulting company SNC-Lavalin took the initiative to design the plant.

Initially, a designer with little experience in working in developing countries, proposed a reverse osmosis system to remove components from the groundwater such as manganese. However, this option was very energy intensive, particularly for a country that gets 95% of their energy from diesel or fuel oil. In addition, the maintenance and operation of the system would be very difficult. The proposed solution was an ion exchange system. The resins would eliminate water hardness and other elements such as manganese that gives color, bad taste, and toxicity, if the water is consumed over a long period of time.

The advantages of the system included:

- The process consumed 98% less pumping energy than reverse osmosis that requires high pressures. The process did not include any mechanical parts such as motors or gears that would have to be replaced due to use.
- The process included the local community in the village of Caracol that already had a salt production system from sea water (Figure 8.1) that was necessary for the recharging of the anionic resins; in other words, the village found a new market for their salt for the system that would require 4 metric tons/day for the production of the water.

When the plant was designed, all equipment was selected so that it could be mounted or moved by an overhead crane of 5 metric tons. In other words, the bridge was able to accommodate the 19 pumps and 10 reservoirs for the softening as well as the 1 metric ton bag of salt for the plant and move them directly by a truck of van without the need of a crane or other equipment. The project was started in 2011 and inaugurated in 2012.

FIGURE 8.1
Production of salt in the village of Caracol (satellite view).

The project consisted of:

- A 400 m^2 building
- Water treatment for drinking (6,000 m^3/day)
- Water for industry (6,000 m^3/day)
- Water for firefighting (2,160 m^3/h)

The system consisted of a phase 1 water treatment reservoir (drinking) of 500 m^3 and one for industrial water of 1,500 m^3. The disinfection was by chlorination (available locally with two peristaltic pumps for 24 h use). The cost was US $3,000,000 for the drinking water production. The design period was 50 h for the preliminary design and 200 h for the detailed design.

8.3.1.1 Environmental Aspects

The process conformed to the rules and regulations of the World Development Bank. An environmental assessment, environmental management plan, and management of greenhouse gases (GHGs) were all according to the norms of the World Development Bank.

The technology used 98% less electricity from heating oil generators, 2–5 MWh of energy for 500 m^3/h of water. This reduced the production of GHGs. The pumps have their own frequency regulator that reduced their energy at start-up and optimized their continuous operation. Translucent panels were used for the panels of the building, thus reducing lighting requirements.

Ventilation and temperature control were ensured by 10 cm (4 in.) vertical spaces between the panels. All wash water was recuperated and sent to the treatment. None was sent to the stormwater drainage system. The water from the softening systems was high in hardness. This was beneficial for the industrial plant that required high alkalinity for its coagulation/flocculation process. A landfill according to the norms of the World Development Bank was built and all buildings had their own septic system along with infiltration fields.

The process did not produce any dangerous wastes. Disinfection was by chlorination. The peristaltic pumps were able to pass ten times higher concentrations of chlorine than regular dosage pumps and thus lower volumes of stored solution and less handling were needed. They did not produce noise.

8.3.1.2 Social Aspects

Salt was purchased from the local community at a rate of 4 metric tons/day. A social impact study was performed according to the norms of the World Development Bank. Six offices of the six neighboring communities were organized to manage the hiring of personnel and favored hiring from the local region. Twenty percent of the construction workers were female, which was a first in Haiti, where normally 0.5% is female. Efforts were also made for deploying social responsibility, conserving cultural sites, avoiding negative social impacts, and supporting the neighboring communities as performed by the World Development Bank and client.

8.3.1.3 Economic Aspects

The plant was to employ 3–5 local people as technicians and chemists. The salt production needed up to 50 employees. Others were needed to transport the salt. Therefore, all created employment opportunities for the local community. In addition, the reduction in energy will save energy costs.

8.3.1.4 Ethics

The project was designed with the concept of sustainability. The building was well lit and ventilated, local salt was used in the production, a crane was used to move the equipment, and the project produced essential water for drinking, industry, and firefighting.

8.3.2 Case Study of the London 2012 Olympics

The London 2012 Olympics was proposed to ensure sustainability in the design, building, operation, decommissioning, and reinstatement of infrastructure (ODA 2013). Sustainability was integrated into the design, procurement and contract management, planning, building, and operation phase along the lines of biodiversity, energy, environmental impact, materials, water, and waste.

Strategy development was the first phase. The vision can be seen in Figure 8.2 along the lines that leave no trace (no environmental damage), zero waste to landfill (reducing waste and maximizing reuse/recycling), zero harm (no accidents, injury, or incidents), and leave a positive legacy (environmental, social, and economic).

The infrastructure was quite unique in that it was temporary so there were no other examples to base the procedures on. Table 8.1 shows the priority targets and outcomes. Success factors were identified such as securing committed leadership, embedding sustainability in procurement and contracts, establishing, monitoring and reporting key performance indicators, and reviewing all audit processes such as environmental management plans.

To deliver the strategic vision and targets, four areas were identified. These included sustainable design, procurement and contract management, town planning, and building and operations.

Sustainable design procedures and results included:

- Establishing a working group for design
- Developing guidance for technical specifications
- Working with suppliers to review products and materials

FIGURE 8.2
Strategy and vision for sustainability for London 2012. (Adapted from Aukett [2012].)

TABLE 8.1

Priority Targets in Sustainability Planning for the London 2012 Olympic and Paraolympic Games

Objective	Final Outcome
Reduction of carbon emissions and minimization of carbon footprint through hiring 85% of commodities to reduce embodied carbon	86% reached
Reduction of venue footprint by 25% to reduce need for materials, air conditioning, lighting, etc.	47% reached
Reduction of heating, ventilation, and air conditioning (HVAC) cooling by 70% and maximization of natural cooling to reduce energy, carbon and GHG emissions	82% reached
Minimization of particulate matter by 80% to improve air quality	90% reached at 47 generator sites
Purchase of at least 20% of materials that are recycled or from a secondary target to reduce material and carbon impacts	Could not be determined
Reuse and recycling of 90% of materials from installation and deconstruction of facilities to reduce wastes	99% reached

Source: Adapted from Aukett (2012).

- Reducing need for extra ventilation and cooling
- Designing standard modules to reduce waste

Procurement and contract management steps consisted of:

- Introducing sustainability ambitions to suppliers in the expression of interest phase
- Pre-ITT (invitation to tender), initial discussion on sustainability considerations at meeting
- ITT phase 10 sustainability questions required responses
- ITT review, Sustainability Procurement Check Sheet completed
- Contract award, sustainability credential needed by suppliers.
- Contract development, sustainability policies, and procedures embedded in the contracts
- Contract management framework and audit tool used to track sustainability

Communications and negotiations were essential to address challenges, particularly of technical versus sustainability, and time issues. Sustainability requirements were often overwhelming for suppliers. Lack of information on the suppliers' own products required training.

Town planning required environmental impact, protection, and management plans to be implemented. Environmental Impact Assessment

(EIA), surveys, and impact assessments had to be performed in consultation with regulators, stakeholders, and planners. Keeping track was essential, all had to be done for a short-term event that presented special challenges. Regular meetings were required. Many surveys were available for land already.

The process for managing impacts and risk at the operations phase included management of environmental risks (air and water quality, noise, ecological preservation), management of waste and resources for reduction, reuse and recycling, and contractors were required to operate sustainably. Stakeholders engagement was ensured at different levels (close engagement, consultation, and information, or information only). Compliance auditing was undertaken on a regular basis; issues and incidents were managed and reporting from all suppliers was required.

Some of the overall conclusions and accomplishments included:

- Clear vision and approach on technical information, such as presence of carbon footprint, are needed.
- Strategic approach needed to be developed for all aspects.
- Budget and resource needed to be addressed early.
- Targets needed to be prioritized and reviewed.
- Design teams and suppliers should be engaged and challenged to improve performance.
- Support is needed for many suppliers and many now have new skills in sustainable practices.
- These lessons although taken for a unique event can be used for many projects.

Various microreports are also available online providing more detail on the sustainability of various aspects of the Olympic Games. For example, an evaluation (ODA 2011) was performed by the design teams to determine which type of pavement would be more sustainable. Asphalt, poured concrete, permeable asphalt, block paving, and porous gravel were some of the options considered. The unit for comparison was one square meter of paving.

The criteria for comparison based on the Building Research Establishment Green Guide Specification included:

- Embodied carbon dioxide
- Recycled content
- Recyclability at end of life
- Weight of materials to reduce handling risks
- Avoided carbon dioxide by recycling

- Urban heat island effect
- Pavement depth
- Olympic Delivery Authority (ODA) green guide specification rating

Other aspects included aesthetics, buildability, cost, wet weather performance, and vehicle loading. Conclusions were reached that despite the high-embodied carbon dioxide content, asphalt was more sustainable due to the requirement for less material. Less depths were needed that reduced the material requirement. The tool CEEQUAL was useful for optimizing material use and energy. Increasing the content of recycled material increased sustainability. It provided a central location for information for discussion by stakeholders and enabled maximization of sustainability using several elements.

Under a contract from the ODA, all the civil engineering, landscaping, and public realm works at the Olympic Park were assessed and verified using CEEQUAL in 17 separate package assessments, all achieving 'Excellent' rated awards. These individual assessments included the Enabling Works (North and South Areas), the Landscaping and Public Realm in the South and North Parks, the District Heating and Cooling Network, Overbridges and Stadium Bridges, and the Primary Foul Sewer and Pumping Station. The scores from the individual assessments were aggregated on a construction value-weighted basis, giving an overall weighted 'Excellent' CEEQUAL score of 93.8%. Furthermore, two of the 17 Olympic Park projects achieved very high scores of 98.3% for the CEEQUAL Assessment: Olympic Park North Park Structures, Bridges and Highways (SBH Lot 1) and Olympic Park Wetland Area Bridges.

8.3.2.1 Economic Activity

Overall, in creating the Park, 2.8 million U.K. construction professionals were involved and over 4,000 long-term jobs were created for the new technology, design, and research center. They generated due to the 4 million visitors during the summer and another 800,000 visitors per year will visit the swimming center. A total of 8,000 new homes, 12 new schools and nurseries, 3 health centers, and a new library were planned after the Games. Two million metric tons of heavily contaminated earth was remediated in addition to the regeneration of the River Lea through the Park. More than 6.5 km of waterways will be monitored in the park. Efforts toward enhancing wildlife habitats incorporated bat roosts, frog ponds, kingfisher walls, otter holts, and planting of wild flowers. Features such as LED lighting, photocell switches, efficient fixtures, and the irrigation system fittings were employed for reduction of energy requirements. Renewable energy production onto the grid included wind turbines and photovoltaic cells for the lighting columns. Overall, 98% of Olympic Park demolition work materials were reclaimed for reuse and recycling, and greater than 650 bird and bat boxes were installed across the Olympic Park (ODA 2013).

London 2012 was the first Summer Olympic and Paralympic Games to measure the carbon footprint over the entire project (CEEQUAL 2013). It showed that by using an independent sustainability assessment tool like CEEQUAL planning, executing of projects and maintenance work during operation can be influenced to enhance sustainability practices.

8.3.3 Sustainable Remediation Using GOLDSET

Various tools can be used such as carbon footprint, ecological footprint, energy efficiency, and life cycle assessment (LCA) but these cover only the environmental aspects. Some multicriteria analytical ranking or scoring systems such as GOLDSET (Golder Associates 2018) are available that cover all three aspects. An example of this is provided as follows:

The GOLDSET-CN approach includes project description and determination of alternatives. Selection of the appropriate indicators, evaluation of the options by data entry and selecting scoring and weighting and finally interpreting the results and recommendations as shown in Figure 8.3. The process can be done across the project life cycle as shown in Figure 8.4.

FIGURE 8.3
Five-step process using GOLDSET (Golder Associates 2018).

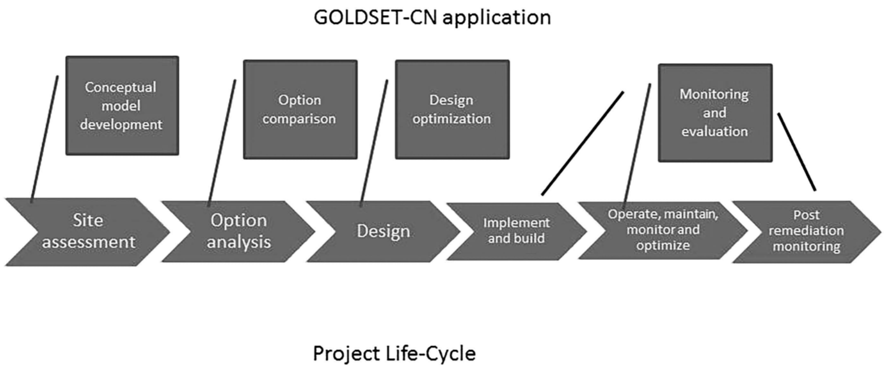

FIGURE 8.4
Application of GOLDSET-CN across the project life cycle (Golder Associates 2018).

A case study was undertaken on the derailment of a train in a peat bog in the province of Quebec in Canada. About 280,000 L of petroleum, which was mainly diesel, spilled and impacted 12,000 m^3 of peat and soil in a ca. 7,000 m^2 area that was 2.4 m in depth. An emergency pumping of the fuel from the water was performed, the train cars were removed, and a confinement trench was installed. The bog was ecologically sensitive and the local community considered it to be an ecological reserve. Three options were evaluated: natural attenuation, partial excavation with risk management, and complete excavation. Indicators were then selected. Estimates of energy and emissions of GHG were calculated in the GOLDSET module as shown in Table 8.2. Scoring and weighting were then performed, as shown in Table 8.3.

Stakeholder involvement was a key part of this sustainable remediation framework. University research leaders as well as members of the regulating

TABLE 8.2

Sample Indicators and Benchmarks Set for the Case Study

Indicator	Unit	Period 6	Period 7	Planned at Completion	Accepted Variation (%)
Soil quality	m^3	0	0	600	10
GHG emissions	total CO_2 eq.	0.18	0.54	47.17	25
Energy consumption	GJ PFE	2.68	8.22	647.7	25
Hazardous waste	kg	0	400	5,730	50
Impacts on biodiversity	—	45	45	90	
Energy consumption per cubic meter excavated soil	GJ PFE/m^3	0	0	0.83	15
GHG emissions per cubic meter excavated soil	Total CO_2 eq./m^3	0	0	0.06	15

TABLE 8.3

Sample Indicators Scoring and Weighting (Golder Associates 2018)

Economic Indicator	Natural Attenuation	Partial Excavation and Risk Management	Total Excavation
Remediation Option			
Net present value	0	100	100
Potential litigation	90	90	100
Financial recoveries	75	50	25
Environmental reserve	100	100	100
Economic advantages for local community	0	50	50
Technological uncertainty	0	50	100
Logistics	100	50	0

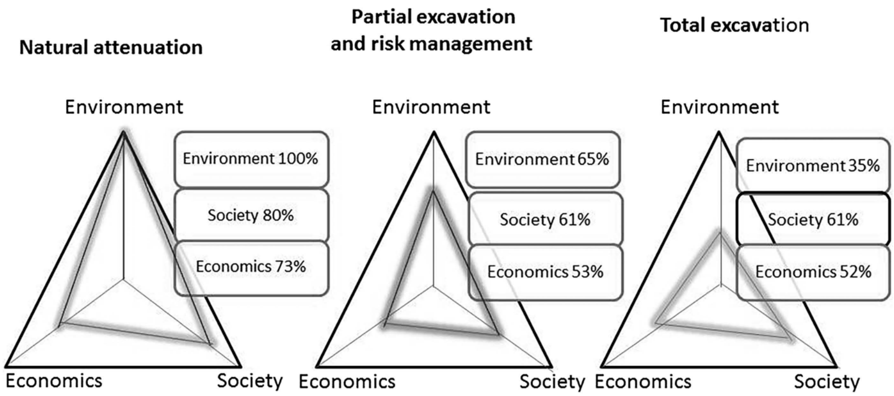

FIGURE 8.5
Comparison of remediation options using Goldset-CN for derailment in a peat bog. The most balanced shadowed triangle indicates the most sustainable option.

agencies were invited to contribute to weigh in on the issues at hand, and provide pertinent comments and questions. These key stakeholders contributed to the composition and procedural design of expert reviews, which helped ensure that all stakeholders found the results of this process credible.

The remediation scheme chosen involved partial excavation and *in situ* remediation. Despite the sustainability of natural attenuation, the regulators did not accept this option. Special floating walkways were installed to access the pilot plots to minimize impact on the vegetation. Solar panels were used to reduce GHG emissions for the blower. Truck-mounted equipment was replaced by tripod mounted or manual augers to reduce vegetation damage. The local university provided expertise to restore the peat bog. Excavation and transport were reduced which in turn reduced 250 metric tons of carbon dioxide emissions. Local landowners were kept informed which enabled participation and acceptance.

GOLDSET provided a transparent communication tool (results shown in Figure 8.5), and enabled the evaluation and tracking of sustainability indicators over the life cycle of the project. Environmental, social, and economic performance can be enhanced by this process.

8.4 Future Needs

8.4.1 Role of Education

Education programs have introduced the sustainable development concepts in to courses to undergraduate engineering students. An industrial survey in 2013 indicated that energy use and efficiency, recycling and reuse, life cycle analysis and corporate social responsibility are key educational needs (Fergus et al. 2013). Special courses have been developed and sustainability has been integrated into course material. Specialization in sustainable development in new degrees may also be another option. Integration of sustainable practices in courses has been difficult as some lecturers are opposed and others are not trained how to do them. Environmental aspects are more easily integrated than social and equity issues. Real-world cases (Steiner and Posch 2006) are required to demonstrate the interdisciplinarity and transdisciplinarity in a complex problem-solving environment. This approach provides a better, dynamic, and more sustainable learning environment.

Sustainability has also become a requirement of engineering program accreditation. In the United States, Accreditation Board for Engineering and Technology (ABET) indicates that students must be prepared for aspects of professional practice that includes sustainability among other aspects. Graduate attribute mapping where learning outcomes are determined and tracked is becoming more popular internationally. Guidance to integrate sustainability in course curriculum is still lacking. Sustainability goes beyond the environmental aspects currently in many courses. In Canada also, Engineers Canada, the national organization of the 12 engineering regulators that licenses Canadian members of the profession, expects graduates to have various skills. This includes understanding of the interactions and the uncertainty of engineering on the economic, social, health, safety, legal, and cultural aspects of society. Some organizations such as Engineers without Borders USA (www.ewb-usa.org) exist in various countries (almost 50) and involve professionals and students for executing projects in developing countries to ensure that the water, sanitation, energy, and infrastructure needs for the communities are met.

Education is key to training future engineers in sustainability. This trend toward interdisciplinarity in engineering education is reflected by an increasing number of interdisciplinary sustainability initiatives at universities and research institutions (CAGS 2012; De Graaff and Ravesteijn 2001). In Canada, a prime example is the University of Victoria that has been the recipient of funding for its *Training Program in Interdisciplinary Climate Science* (University of Victoria 2017). The University of Toronto has applied an interdisciplinary approach to identifying the role of engineers in solving complex global problems—including those related to sustainable development—at the *Centre for Global Engineering* (CGEN) (University of Toronto 2009). In its *Cinbiose* interdisciplinary environmental research centre, *L'université du Québec à Montréal* (UQAM) has collaborated with the World Health Organization since 1998 on problems in several fields such as health care, ecosystem dynamics, urban ecosystem governance, and climate change (UQAM 2017). Western University offers graduate-level courses on interdisciplinary approaches to sustainability studies, and also maintains a standing research faculty contributing to sustainability research across 33 different academic disciplines (Western University 2017).

In the United States of America, initiatives in multidisciplinary environmental research are well established. Stanford University's *Precourt Energy Efficiency* Center (Stanford University 2016) is an example. Universities by setting curriculum standards have the moral responsibility to educate their graduates to play a crucial role in developing a socially just, ecologically aware, and economically responsible society. At the same time, engineers have the obligation to develop and implement design, construct, and manage techniques that minimize environmental and energy footprints. In addition, engineers must also be able to work in multidisciplinary teams that incorporate perspectives from public policy, economics, and social responsibility. These demands place a unique burden on engineering educators to design programs that will train engineers for future challenges.

Engineers must be able to work in multidisciplinary teams incorporating public policy, economics, and social responsibility (Figure 8.6). In light of the above, Concordia University has established the Concordia Institute for Water, Energy, and Sustainability Engineering (CIWESS) that provides a unique interdisciplinary training in water, energy, and sustainability engineering (concordia.ca/ciwess). The specific objectives of this training program are: to catalyze through collaboration, internships, enhanced research opportunities in sustainability; to train highly qualified personnel in an interdisciplinary manner for public, parapublic, and industrial sectors; to maintain and enhance interdisciplinary areas of teaching and research; and to attract external research funding and foster relationships with external researchers and internal Concordia researchers with similar interests.

The training program (Mulligan 2017) is producing trainees with unique knowledge and skills related to sustainable water and energy systems through a combination of multiple programmatic pathways, such as undergraduate minors, graduate degrees and courses, capstone courses, research seminars, internships, conferences, and public outreach.

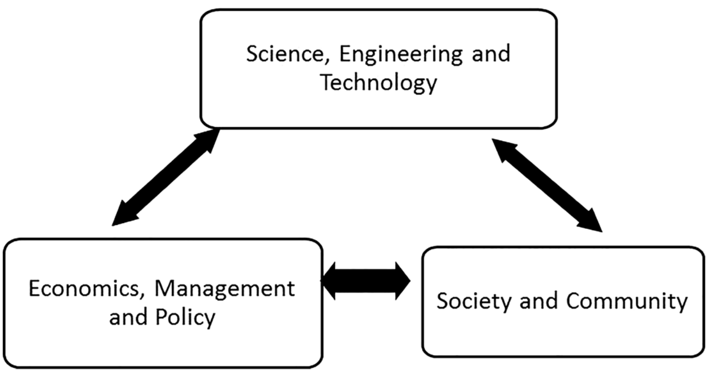

FIGURE 8.6
Interdisciplinary aspects of the training program.

Since interdisciplinarity is an essential prerequisite of any type of research related to sustainability, this program incorporates it at the level of content and program. The underlying philosophy of interdisciplinarity of the program is revealed in the schematic representation in Figure 8.7. All research content while being grounded in scientific and technological aspects nevertheless incorporates economic/policy and society/community aspects. A key mechanism to facilitate interdisciplinarity in research content is through the constitution of supervisory committees that will include members from all aspects.

Since environmental and social issues are by their very nature complex and interrelated, students are required to cross disciplinary boundaries in order to collaborate with those in other disciplines. Interdisciplinary collaboration requires skills that demand modifying traditional ways of thinking and being open to novel means of cross-disciplinary communication. Internships are provided to allow trainees to work in the modern collaborative workplace to improve their academic and professional strengths

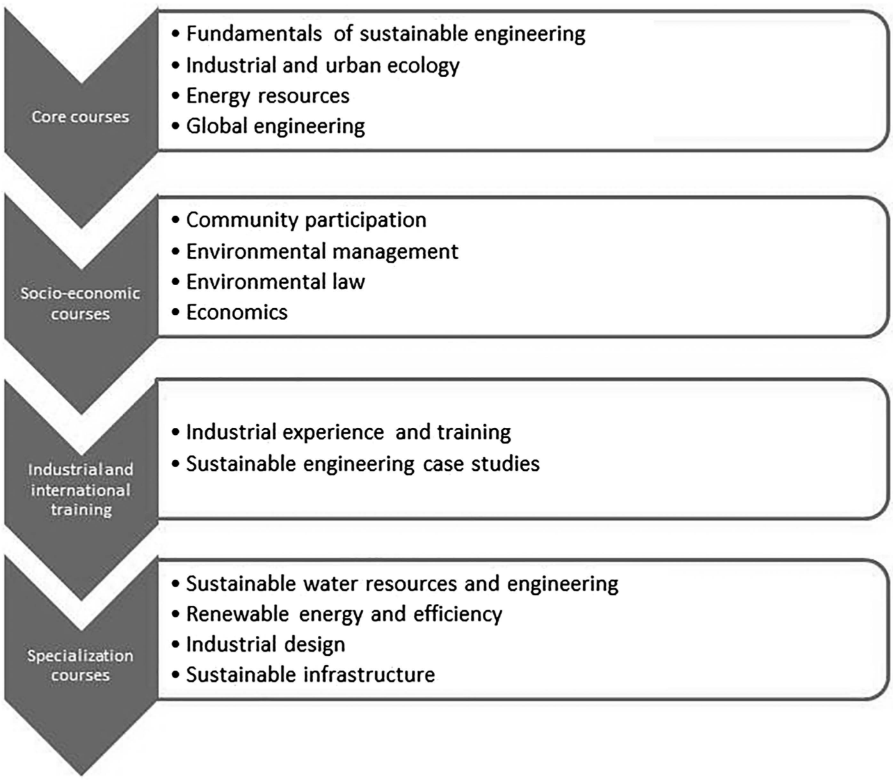

FIGURE 8.7
Components of sustainable engineering graduate programs.

and acquire program-relevant work experience. They gain important soft skills (communications, teamwork, interpersonal cooperation) essential in today's work environment, learn more about the expectations and needs of employers, develop independence and maturity, and take advantage of networking opportunities. The skills obtained enable students to work in policy development, governmental agencies, international organizations, industry, and nongovernmental organizations (NGOs). An internship is a required element of every trainee's program. An annual research event showcasing the achievements of the program provides a venue for trainees to present and discuss their work.

The program facilitates these collaborations by integrating opportunities that arise from these research exchanges into training. In addition, by enhancing international exposure these collaborations will foster globally sustainable work practices in trainees. For example, trainees develop international expertise through these collaborations in water-related disciplines as water engineering and management, land use planning, or water environmental studies.

Trainees are required to attend workshops and professional skills training. These workshops enhance the ability of trainees to write and present effectively, to plan and manage projects, to study abroad during exchanges, to understand ethical practices, and to speak in another language. Another integral component is an internship completed under the supervision of an experienced engineer/computer scientist in the facilities of the participating company. In addition, the university allows trainees to work full time for 4 months at the industry. This structure allows students to maximize the experience of working in teams, develop presentation skills, and the ability to prepare written reports and other information.

Training and education programs are essential for increasing the ability of engineers to address the Sustainable Development Goals (SDG) targets. Innovative initiatives across educational institutes should be shared. Industry, government agencies, and academia need to work together developing and promoting innovation and new ways of thinking.

Informing the public is also an essential element that universities need to include, particularly in their research programs. For example, in a research project in CIWESS, residents involved in lake associations are consulted and information of the development of technologies to maintain and improve lake quality to enhance engagement is provided on a regular basis. Solutions for waste management also must involve the public to incorporate, adopt, and maintain new technologies. Training programs for operators and other personnel are essential.

In a workshop hosted at Concordia University (Montreal, Canada June 9, 2016) with Polar Knowledge on waste management and waste to energy solutions for northern communities, there were discussions of the feasibility of different waste to energy (W2E) solutions for communities of different sizes. Community size was an important factor. Namely, the solutions for waste management and W2E are different for small communities [<500 residents] compared to medium [500–2,000 residents] and large communities [>2,000 residents] in the North. For medium and large communities, landfilling best practices, compaction, composting, incineration or gasification with heat recovery, or refuse-derived fuel (RDF) boiler. For small communities, options include landfilling best practices, compaction, and incineration with heat recovery.

Key aspects for waste management solutions include education, training, buy-in from the community, and to keep trained the community members in the community. Availability of parts and maintenance can be major challenges in remote communities. Community engagement with project planning/design is essential.

8.4.2 Role of Engineering Organizations

Various engineering organizations have formed sustainable development committees to inform their members regarding sustainable engineering and have formed guidance documents. Some of these are by the American Society of Civil Engineers (ASCE) and the U.K. Institute of Civil Engineers (ICE) and the Canadian Society for Civil Engineering (CSCE). The Committee on Engineering and the Environment enables WFEO and the global engineering profession to support the achievement of the UN Millennium Development Goals through the development, application, promotion, and communication of:

- Environmentally sustainable engineering practices and technologies
- Adaptation of infrastructures to the impacts of a changing climate
- Assessment and promotion of clean technologies and engineering practices to mitigate climate change
- The engineering perspectives on the international elements of the agricultural supply chain to United Nations agencies and commissions, national members of the Federation, and other international NGOs
- Development of guidelines for practicing engineers on responsible environmental stewardship and sustainable practices in various areas of practice including mining

The WFEO represents more than 20 million engineers with extensive expertise to contribute to the achievement of the UN Sustainable Development 2030 Goals (WFEO 2015). Engineers must work with organizations, other experts, governmental organizations, and the communities to develop technologies, policies, and frameworks. Engineering societies in many disciplines must also work together toward sustainable engineering. Sharing of case studies can assist in promoting and understanding sustainable practices and implementation. The WFEO Model Code of Practice for Sustainable Development and Environmental Stewardship (WFEO 2013) was developed and adopted at the September 2013 General Assembly.

The ten principles of the Code of Practice include:

1. Maintaining and continuously improving awareness and understanding of environmental stewardship, sustainability principles, and issues related to the field of practice.
2. If knowledge is not adequate to address environmental and sustainability issues, consult with others with the required expertise.
3. Global, regional, and local societal values should be incorporated to include local and community concerns, quality of life, and other social concerns related to environmental impact. Traditional and cultural values must be included.
4. Sustainability aspects should be incorporated at the earliest possible stage and employ applicable standards and criteria.
5. Costs and benefits of environmental protection, ecosystem components, climate change and extreme events, and sustainability should be incorporated in the economic viability of the work.
6. Environmental stewardship and sustainability planning should be over the life cycle for planning and management activities and efficient, sustainable solutions should be employed.
7. A balance between environmental, social, and economic factors should be achieved to contribute to healthy surroundings in the built and natural environment.
8. An open, timely, and transparent engagement process for both external and internal stakeholders should solicit input in and respond to economic, social, and environmental concerns.
9. Regulatory and legal requirements must be met and exceeded by applying best available, economically viable technologies and procedures.
10. In the cases where there are threats of serious or irreversible damage and scientific uncertainty, risk mitigation measures should be implemented in a timely fashion to minimize environmental degradation.

Engineers of all disciplines are involved in the development of technologies to improve life but must assure that impacts (social, economic, and environmental) are minimized. For example, Johnston (2016) indicated that process, civil, mechanical, electrical, instrumentation, and control engineers should work together with economists and scientists to ensure sustainable wastewater treatment and management solutions. Conferences such as STS Forum in Japan (held annually), Engineering for Sustainability (held in Denver, CO, February 18–19, 2016), and the 2015 Engineering Triennial Summit of the ICE/ASCE/

CSCE held in London, United Kingdom, are excellent examples of efforts to establishing collaborations between various societies. Climate change is also creating challenges. Engineering is essential in achieving the UN Sustainability Goals. Figure 8.8 shows some engineering actions for each of the selected goals according to the WFEO. Rating systems such as Envision or CEEQUAL can assist in the assessment of infrastructure project through goals and indicators and are a step in the right direction. Continual development of these and other tools is needed for other types of projects and processes.

An example of Envision ratings is the Platinum Award given to the New Champlain Bridge Corridor project in Montreal, Canada (Infrastructure Canada 2018). The bridge was designed to last 125 years. Some of the features of the project included:

- Design of the stormwater drainage system to take climate change into consideration
- Offset of GHG emissions by carbon credits
- Use of LED lights to reduce light pollution effects on migratory birds and energy requirements
- Recycling of 45% of the construction waste onsite and of the other 54% that was recycled, only 1% was sent to landfill
- Marshlands restoration and creation of new spawning habitats to offset loss of fish habitats, wetlands, and bird sanctuaries during construction of the bridge

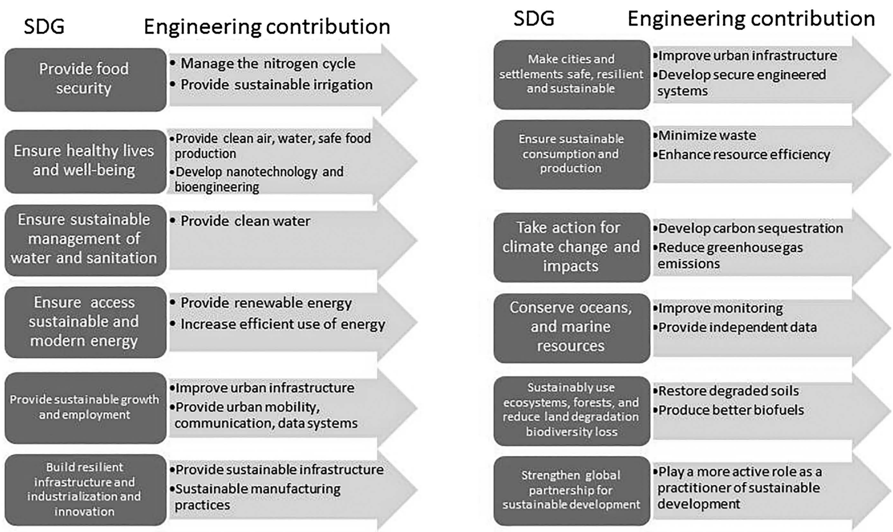

FIGURE 8.8
WFEO contributions toward selected UN Sustainable Development goals (WFEO 2015).

LCA can be complicated and difficult to implement. A life cycle approach, however, is essential. Life cycle sustainability assessment approaches are being developed which may be more appropriate than LCA due to inclusion of the social and economic aspects. Policies and incentives are needed to promote incorporation of sustainability in projects. Industries have made efforts to reduce wastes, emissions, energy uses, and report their progress through GRI standards.

8.4.3 Innovation for Sustainable Engineering

Bugliarello (2010) has identified various challenges for innovation for engineering, in the areas of materials, water and energy, IT, and bioengineering. Resources conservation and waste management are particularly relevant. Standards and regulations should not restrict innovation needed to advance sustainable practices. Nanotechnology, composite materials (especially with natural materials will improve material function and resource protection. The linkages of water and energy need to be addressed by considering both together not separately as is the current practice. Therefore, engineers and professional societies need position papers, metrics, and methodologies for guiding decisions, case studies, and data for enabling new ways of thinking in devising more effective water and wastewater treatment systems, reducing leakage for distribution systems, collection of energy from solar and wind power systems, and replacement of hydrocarbon fuels.

Materials that can be reused or recycled are highly desirable. Reuse and recycling of metals such as metals are essential. This includes aluminum, cobalt, copper, nickel, rare earth and platinum, iridium, gold and silver. Linear practices of waste management should be replaced by a more circular approach of disassembly, reuse, and recyclability. New products will need to be developed, in addition to new cans, car, airplane, and bicycle parts, rebar, etc. that is currently practiced. This requires thinking about the end of the life of a product from the beginning. This is a major challenge in addition to the complexity of the products. Metal sorting and separation are also part of the process. Research and development from the laboratory to pilot industrial scale are essential and supported by adequate funding.

Fenner and Ainger (2016) have indicated that water infrastructure should be monitored for water use and treatment. Harmful substances should be avoided and natural systems adopted such as wetlands and ponds for water management and restoring ecosystems. Water reuse in industry should be encouraged instead of water wasting. Indicators such as water footprinting can assist in promoting water resource conservation and smart water use.

Water is very connected to human activity with a high social and political nature; its availability is not equally distributed worldwide and can vary significantly seasonally and annually. Water use by industry can create significant public protests particularly when there is scarcity of water.

Water management is thus highly important and can drive innovation. As was recently addressed at the Civil Engineering Triennial Summit in London, climate change must be addressed now due to the increased risk of poverty, social inequity, terrorism, and conflict (Perks 2015).

The Innovation for Cool Earth Forum (2017) formulated a statement from the steering committee to further innovations toward net-zero emission of carbon dioxide in light of the Paris Agreement at the COP21. The statement is based on the forum of over 100 experts from many fields from 80 countries.

Some of the key points include:

- A peak of carbon dioxide emissions must be in the near future.
- Technological innovation is essential through zero emission technologies (renewables and nuclear energy), low carbon products, low carbon infrastructures, international cooperation, and financial and social innovation.
- Industrial sector participation in innovation and its diffusion.
- Utilization of a systems approach for diffusion of market-ready technologies (wind and solar power).

Perks et al. (2017) have provided some suggestions on what civil engineers can do. These include making sure existing infrastructure is working in an optimal manner. Leakage, for example, in water systems is a major problem due to water and energy wastage. Low cost, easy to operate, and socially acceptable solutions also must be identified instead of going with the usual practice. Consultation with stakeholders with "fresh eyes" through all stages of the project planning can bring new alternatives for consideration. Carbon neutral approaches for new infrastructures should be adopted. For example, as water pumping is a major user of energy, the use of gravity should be optimized. Future designs must be economically efficient to be affordable for the public and reduce poverty and must reduce and avoid energy consumption as much as possible to mitigate climate change. Key performance indicators are needed to measure progress.

8.5 Conclusions

There are presently many challenges for engineers. Education programs need to be expanded for engineers to include sustainable practices not as a special course but integrated into existing courses. Improved tools are needed. Envision and other tools are a good start but they are complex, hard to address over the life cycle of a project or process and many aspects are lacking, particularly regarding social equity and cultural issues. More partnerships are needed between social scientists, physical science, health and engineering professionals, education, governance and society. In summary, technology, education, regulation, and standards are all essential to promote and implement sustainable engineering practices. Interdisciplinary programs are necessary for training engineers in the circular economy.

Engineers need to work together and be more involved in decision-making at all stages of the project. They should become more involved in local or regional activities to assist in the decision-making. They need to consult with stakeholders for input regarding concerns and to adapt to local conditions. Even during the construction and/or operation phases, engineering should be able to address concerns and provide advice on the sustainability of a project. Research is needed to develop innovative solutions to this changing world under the influence of climate change and increasing uncertainty, deteriorating infrastructure, introduction of new chemicals into the environment, centralization and lock-in of technologies, and growing population to name a few. Engineers have an ethical requirement to rise to this challenge. They have indicated that they want to be involved in sustainable engineering practices. The role of engineers in sustainable development has been undervalued but it is critical. However, action is needed now.

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3

(Re)Think (Re)Design for Resilience

Nina-Marie Lister

CONTENTS

The summer of 2017 was one of the worst on record for flooding anywhere. From North America to Europe to South East Asia, record flood events were posted in coastal and inland areas alike. Torrential rainstorms, record-setting hurricanes, and surging Great Lakes levels combined to raise insurance premiums, public awareness, and political promises for flood protection and stormwater strategies. At a time of unprecedented global urbanization, both in scale and population, urban and urbanizing regions suffer disproportionate effects of flooding: in hard-surfaced cities, with more built form than vegetation, from rainfall to snowmelt, urban stormwater declines rapidly in quality and often has nowhere to flow but overland, bringing urban contaminants into swelling lakes, rising rivers, and subsiding coasts. In the transition to an urban world, the Anthropocene has ushered in a triple-threat: it's becoming clear that the profound social, technological, and built-form changes of urbanization are being exacerbated, tied inexorably through positive feedback to large-scale ecosystem and climate change. In short, the urban world is in urgent need of new modes of planning and design for resilience.

In the face of a changing climate, increasing vulnerability to extreme weather takes many forms. On December 21, 2013, for example, the city of Toronto and its metropolitan area of 5,000,000 inhabitants—along with a sizeable portion of southern Ontario and northern New York—experienced an unseasonably warm winter storm. The storm dropped more than 30 millimeters of freezing rain on the city. Temperatures hovered around freezing for almost 36 hours and then rapidly plummeted to −25°C and stayed there, locking the city under a blanket of ice for almost two weeks and leaving more than half a million residents in the frozen dark following the Winter Solstice. Under the weight of the ice, more than 20% of the city's 10,000,000 trees were felled, bringing down power lines and cables in the process and leaving thousands of homes without power, heat, or light through Christmas and the holiday season. With an estimated cost of CDN$106,000,000 to the city of Toronto alone in clean-up and emergency services, the eastern North American ice storm of 2013 is recorded as one of the worst natural disasters in Canadian history.[1] Yet, notably, this figure does not account for the loss of the green infrastructural value and the attendant ecosystem services of the loss of one-fifth of the city's mature tree canopy. The city will continue to suffer long-term related impacts of the ice storm through increased soil erosion, decreased flood protection, carbon sequestration, urban heat mitigation, and so on.

The ice storm, however, was not an isolated incident. In February 1998, a similar ice storm caused a massive power outage throughout Québec that lasted more than two weeks, affecting more than 50,000 homes in the middle of a deep freeze. The Red River floods of 1998 and 2012 crippled the cities of Winnipeg, Minneapolis, and St. Paul, while Alberta's Bow River flood of 2012 virtually shut down the city of Calgary and the Trans-Canada highway for more than a month. These are but a few of many recent, locally catastrophic storm events. The better-known "monster storms," such as Hurricane Katrina which devastated New Orleans in 2005, and Superstorm Sandy in 2011, which left half of midtown Manhattan without power for more than a week, are globally significant events. By virtue of their reach and effect in major urban centers, these storms have catalyzed a new wave of research into urban environmental planning, coastal defense, urban vulnerability, and related policy responses that link urbanism, planning, and ecology.

In addition to the economic, social, and environmental costs of such storms, there is growing recognition that these events pose significant challenges to the world's urbanizing areas and their largely outdated systems of governance and planning. Cities across the globe are facing the reality that the increasing magnitude and frequency of major storm events are evidence of human-induced global climate change, and with this reality has come a range of increasing challenges to our systems of survival, including a need for new design approaches to cope with ecological change and vulnerability.[2] Identified as a global threat by the *Intergovernmental Panel on Climate Change* (IPCC) and grounded in a wide range of policy-related research linked to long-term sustainability, climate change is now an accepted phenomenon for which adaptation strategies must be developed and implemented from municipal to national scales.[3]

Long-term environmental sustainability demands the capacity for resilience—the ability to recover from a disturbance, to accommodate change, and to function in a state of health. In this sense, sustainability refers to the inherent and dynamic balance between social-cultural, economic, and ecological domains of human behavior that is necessary for humankind's long-term surviving and thriving. Ann Dale has described this dynamic balance as a necessary act of reconciliation between personal, economic, and ecological imperatives that underlie the primordial natural and cultural capitals on Earth.[4] With this departure from conventional "sustainable development," Dale has set the responsibility for long-term sustainability squarely in the domain of human activity and appropriately removed it from the ultimately impossible realm of managing "the environment" as an object separate from human action.

A growing response to the increasing prevalence of major storm events has been the development of political rhetoric around the need for long-term sustainability and, specifically, resilience in the face of vulnerability. As a heuristic concept, resilience refers to the ability of an ecosystem to withstand and absorb change to prevailing environmental conditions. In an empirical sense, resilience is the amount of change or disruption an ecosystem can absorb, by which, following these change-inducing events, there is a return to a recognizable steady state in which the system retains most of its structures, functions, and feedbacks.[5] In both contexts, resilience is a well-established concept in ecological systems research, with a robust literature related to resource management, governance, and strategic planning. Yet, despite more than two decades of this research, the development of policy strategies and planning applications related to resilience is relatively recent. While there was a significant political call for resilience planning following Superstorm Sandy in 2011 and the ice storm of 2013, there remains a widespread lack of coordinated governance, established benchmarks, implemented policy applications, and few (if any) empirical measures of success related to climate change adaptation.[6] In this context, there has been little critical analysis of and reflection on the need to understand, unpack, and cultivate resilience beyond the rhetoric. In this essay, I argue that concomitant with the language of resilience is the need to develop nuanced, contextual, and critical analyses coupled with a scientific, evidence-based understanding of resilience; that is, we need an evidence-based approach that contributes to adaptive and ecologically responsive design in the face of complexity, uncertainty, and vulnerability. Put simply: What does a resilient world *look* like, how does it *behave*, and how do we plan and design for resilience in an urban world?

Why Resilience? Why Now?

The emergence of resilience as a rhetorical idea is tied not only to the emerging reality of climate change, but to an important and growing synergy between research and policy responses in the fields of ecology, landscape architecture, and urbanism—a synergy that is powerfully influenced by several remarkable and coincidental shifts since the turn of the second millennium. Most notable is the global population shift, in which our contemporary patterns of settlement are tending toward large-scale urbanization, a hallmark of the Anthropocene. The last century has been characterized by mass migration to ever-larger urban regions, resulting in the rise of the "megacity" and its attendant forms of suburbia, exurbia, and associated phenomena of the modern metropolitan landscape.[7] For most of the world's population, the city is fast becoming the singular landscape experience.[8]

In North America, and the United States in particular, this shift in urbanism has come, paradoxically, with a widespread decline in the quality and performance of the physical infrastructure of the city. The roads, bridges, tunnels, and sewers that were built during the late nineteenth and early twentieth centuries to service major urban centers are now aging and crumbling, in some cases, while both the political will and the public funds to rebuild this outdated but essential public infrastructure are disappearing. More significantly, these infrastructures continue to decay, and they are increasingly vulnerable to catastrophic failure in the face of more frequent and severe storm events, thus compounding the cost of their loss and the extent of impact (Figure 3.1).

The emergence of a new direction and emphasis in ecology represents another significant and concomitant shift with the change in urbanism and the reality of climate change. During the last few decades, the field of ecology has moved from a classical, reductionist concern with stability, certainty, predictability, and order, in favor of more contemporary understandings of dynamic, systemic change and the related phenomena of uncertainty, adaptability, and resilience. Increasingly, these concepts in ecological theory and complex systems research are found useful as heuristics for decision making generally and, with empirical evidence, for landscape design in particular.[9] This offers a powerful new disciplinary and practical space; one that is informed by ecological knowledge both as an applied science and as a construct for managing change within the context of sustainability. As a practice of planning *for and with* change, resilience is, in itself, a conceptual model for design.[10]

With this new ecological approach has come another important shift in creating the synergy necessary for resilience-thinking: the renaissance of landscape as both a discipline and praxis throughout the last two decades and its (re)integration with planning and architecture in both academic and applied professional domains. Landscape scholars have identified the rise of post-industrial urban landscapes coupled with a focus on indeterminacy and ecological processes as catalysts for the reemergence in landscape

FIGURE 3.1
Four views of a washed-out section of a major arterial roadway in Toronto after heavy rain and flooding of the Don River followed Hurricane Katrina, which was downgraded to a tropical storm when it hit Toronto on August 29, 2005. (Photo collage by Carmela Liggio and Nina-Marie Lister, 2005.)

theory and praxis.[11] Understood today as an interdisciplinary field, linking art, design, and the material science of ecology, landscape scholarship, and application now includes a renewed professional field of practice within the space of the city.[12]

Considered together in the era of climate change and vulnerability, these shifts in our collective understanding of urbanism, landscape, and ecology have created a powerful synergy for new approaches in planning and design to the contemporary metropolitan region. This synergy has been an important catalyst for the emergence of resilience as a rhetorical idea, but much work remains to be done to move toward evidence-based implementation of strategies, plans, and designs for resilience. The scale and impact of North American megastorms, such as Hurricane Katrina in 2005 and Superstorm Sandy in 2011 have been effective triggers for a new breed of policy and planning, initiatives in disaster preparedness in general, and flood management plans in particular. Conventional policy and planning approaches to natural disasters have long been rooted in the language of *resistance* and *control*, referencing coastal defense strategies, such as fortification, armoring, and "shoring up" by using brute-force engineering responses designed to do battle with natural forces.[13] By contrast, emerging approaches in design and planning reference the language of *resilience* and *adaptive management*, terms associated with elasticity and flexibility, leading to the use of hybrid engineering of constructed and ecological materials that adapt to dynamic conditions and natural forces.[14] Recent coastal management policies and flood management plans following the major storm events abound in this language of resilience, including New Orleans's *Water Management Strategy*, Louisiana's *Coastal Management Plan*, New York City's *Rebuild by Design* program, and Toronto's *Wet Weather Flow Master Plan*. These examples are notable as responses (reactive and proactive) to catalytic storm events and climate change, yet they remain, for the most part, speculative, untested, and unimplemented, relying on a language of resilience that is heuristic and conceptual rather than experiential, contextual, or scientifically derived.

The general concept of resilience has origins across at least four disciplines of research and application: psychology, disaster relief and military defense, engineering, and ecology. A scan of resilience policies reveals that the concept is widely and generally defined with reference to several of the original fields and is universally focused on the psychological trait of being flexible and adaptable. Examples are having the capacity to deal with pressure and the ability to "bounce back" to a known normal condition following periods of stress, maintaining well-being under stress, and being adaptable when faced with change or challenges.[15] The use of resilience in this generalized context, however, begs important operational questions of how much change is tolerable, which state of "normal" is desirable and achievable, and under what conditions is it possible to return to a known "normal" state. In policies that hinge on these broadly defined, psychosocial aspects of resilience, there is little or no explicit recognition that adaptation and flexibility may result in transformation and, thus, require the *transformative capacity* that is ultimately necessary at some scale in the face of radical, large-scale, and sudden systemic change. Using sea level as an example, if we accept that waters naturally rise and fall within a range of seasonal norms, we might be better off to embrace a gradient of acceptable "normal" conditions rather than a single static, and ultimately brittle, state that is unsustainable (Figure 3.2). A more critical and robust systems-oriented discussion of resilience will force all concerned to confront a difficult but

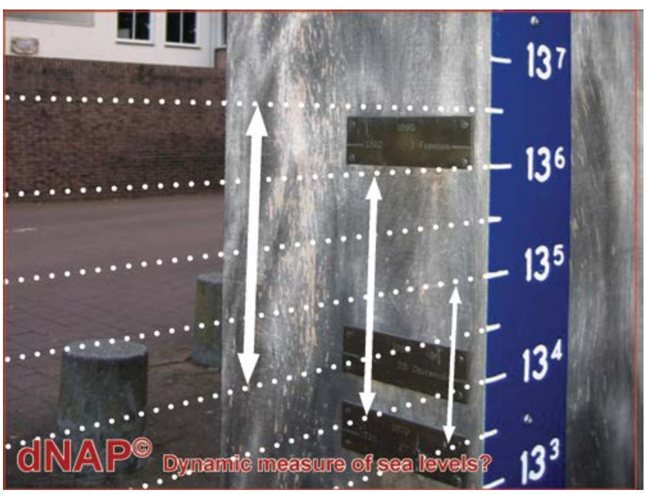

FIGURE 3.2
The Normaal Amsterdams Peil (NAP) is a measure used to gauge the rise in sea level and to establish national policies, laws, and regulations on the basis of a fixed, "normal" water level. In contrast, the Dynamic Normaal Amsterdams Peil or d(NAP), shown here, is a proposed measure of sea level for the Netherlands Delta Region that acknowledges dynamic water levels to address better changing hydrological regimes; for example, to reflect seasonal flooding. (Diagram courtesy of Kimberly Garza and Sarah Thomas, 2010.)

essential question: How much can a person, a community, or an ecosystem change before it becomes something unrecognizable and functions as an altogether different entity?[16] If resilience is to be a useful concept in application and, in particular, to inform design and planning strategies, it must ultimately instruct us *how* to change safely rather than how to resist change completely. Current policies and eventual design strategies will risk the potential power of resilience by emphasizing a misguided focus on "bouncing back" to a normal state that is, ultimately, impossible to sustain.

Unpacking Resilience

Before one can implement applied strategies and associated indicators for resilience in design and planning, it is useful and, arguably, necessary to unpack the history, theory, and conceptual development of resilience as it emerged in ecology. We can do so critically with reference to a well-established social-scientific literature derived principally from ecosystem ecology and, in particular, with research applications in natural resource management. Decades of research related to complex systems ecology, and thinking about and practice of social-ecological systems offers both broad heuristic and empirical contexts for the study and application of resilience. As such, both the construct and measures of resilience are important to embed, apply, and test within policies and designs for long-term sustainability. As an essential capacity for sustainability, applications of resilience are derived from research in complex systems ecology, first published by the American ecologist Howard T. Odum and later developed by the Canadian ecologist, Crawford Stanley ("Buzz") Holling.[17] Yet it should be noted that the foundations of resilience thinking were laid much earlier. Well before the language of complex systems was embraced within ecological science, the early twentieth century conservation movement was already concerned with the health of natural systems, which was conceptualized variously, from self-renewal to healing and balance, with implications for management practices. For example, Aldo Leopold used the concept of "land health" to refer to the land's capacity for self-renewal—essentially resilience—which he saw as threatened by and at odds with unchecked exploitation of land and resources for economic growth.[18] Similarly, Gifford Pinchot's perspectives on the need for cautious resource extraction, however utilitarian, gave rise to an early version of adaptive management to accommodate changes in nature and the landscape.[19] By the 1960s, with the birth of modern environmentalism, there were more urgent calls for caution. Notable among these was Rachel Carson's characterization of nature as resilient, changeable, and unpredictable: "… the fabric of life … on the one hand delicate and destructible, on the other miraculously tough and resilient, capable of striking back in unexpected ways."[20]

The late 1970s and early 1980s marked the beginning of a significant theoretical shift in the evolving discipline of ecology. In general, ecological research at all scales has moved toward a more organic model of open-endedness, indeterminacy, flexibility, adaptation, and resilience and away from a deterministic and predictive model of stability and control, based on engineering models for closed (usually mechanical) systems. Ecosystems are now understood to be open, self-organizing systems that are inherently diverse and complex and behave in ways that are, to some extent, unpredictable.

This shift, influenced by the early ecosystem analyses of the Odum brothers (Eugene P. and Howard T.), followed the rise in complexity science and the groundbreaking work of Ilya Prigogine, Ludwig von Bertalanffy, C. West Churchman, Peter Checkland, and other systems scholars throughout the latter half of the twentieth century. Ecological research came into its own discipline, distinct from biology and zoology, by focusing on large-scale and cross-scale (connected) functions and processes of an ecosystem. As an outgrowth of research in complex systems coupled with the emerging new discipline of landscape ecology and associated spatial analyses—made possible by new tools, such as high-resolution satellite imagery—ecosystem ecology led to multi-scaled, cross-disciplinary, and integrated approaches in land use planning. Beginning in the 1970s with F. Herbert Bormann's and Gene Likens' first ecosystem-based study of the Hubbard Brook watershed, long-term ecological research programs (known as LTERPs) became established, influencing, throughout the 1980s and 1990s, a growing recognition of the dynamic processes inherent and essential to living, layered landscapes, and the understanding of ecosystems as open, complex systems within which structure and function are interrelated and scale-dependent.[21]

The dynamic ecosystem model has been an important development in ecology and a significant departure from the conventional, linear model of ecosystems that dominated scholarly twentieth-century thought. Resilience is an important concept that emerged from this development. Defined by the process of ecological succession, the linear model held that ecosystems gradually and steadily succeed into stable climax states from which they will not routinely move unless disturbed by a force external to that system.[22] An old-growth forest is the typical example, in which a forest matures and then remains in that state permanently such that any disturbance from that state is considered an aberration. Yet we now know that not only is change built into these systems, but, in some cases, ecosystems are dependent on change for growth and renewal. For example, fire-dependent forests contain tree species that require the extreme heat of fire to release and disperse seeds and to facilitate a forest's renewal and, sometimes, a shift in the complement of a species following a major fire. The dynamic ecosystem model, based on long-term research in a variety of global contexts, asserts that all ecosystems go through recurring cycles with four common phases: rapid growth, conservation, release, and reorganization. Known as the adaptive cycle, or the Holling Figure Eight, this generalized pattern is a useful conceptual description of how ecosystems organize themselves over time and respond to change.[23] The adaptive cycle of every ecosystem is different and contextual; how each system behaves from one phase to the next depends on the scale, context, internal connections, flexibility, and resilience of that system (Figure 3.3).

Ecosystems are constantly evolving, often in ways that are discontinuous and uneven, with slow and fast changes at small and large scales. While some ecosystem states appear to be stable, stability is not equated in a mathematical sense but rather in a human-scale or time-limited perception of stasis. C. S. Holling pioneered this concept in application to resource management, in which he described ecosystems as "shifting steady-state mosaics," implying that stability is patchy and scale-dependent and is neither a constant nor a phenomenon that defines a whole system at any one point in time or space.[24] The key point is that ecosystems operate at many scales, some of which are loosely and others tightly connected, but all subject to change at different rates and under different conditions. An ecosystem we perceive as stable in a human lifetime may, at a longer scale, be ephemeral, and this realization has profound implications for how we choose to manage, plan, or design for that system (Figure 3.4).

There is an important connection between stability, change, and resilience—a property internal to any living system and a function of the unique adaptive cycle of that system. Resilience has both heuristic and empirical dimensions, arising from its origins in psychology, ecology, and engineering. As a heuristic or guiding concept, resilience refers to the *ability* of an ecosystem to withstand and absorb change to prevailing environmental conditions and, following these change events, to return to a recognizable steady state (or

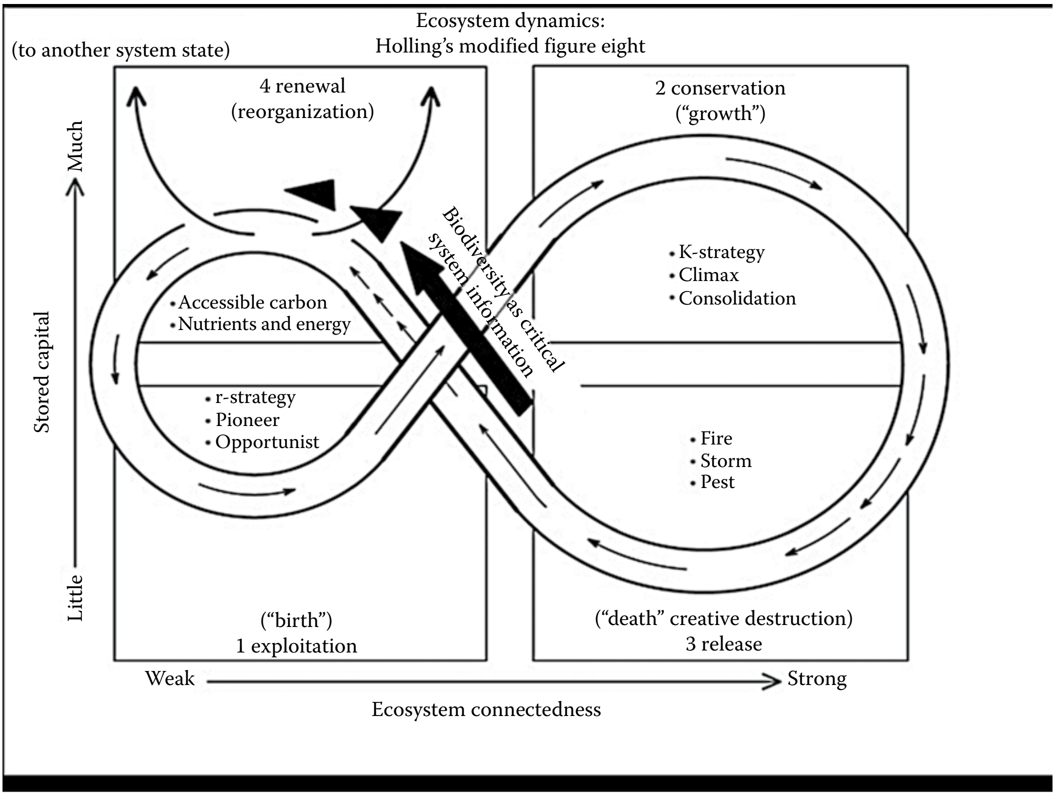

FIGURE 3.3
Ecosystem Dynamics and the Adaptive Cycle: Holling's Modified Figure Eight. Ecologist C. S. Holling's dynamic cycle of ecosystem development is the foundation of a complex systems perspective in ecology. (Diagram courtesy of Waltner-Toews, David, James J. Kay, and Nina-Marie E. Lister, eds. 2008. *The Ecosystem Approach: Complexity, Uncertainty, and Managing for Sustainability*. New York, NY: Columbia University Press. 97; modified from Holling, C. S. 2001. "Understanding the Complexity of Economic, Ecological, and Social Systems." *Ecosystems* 4(5): (August 2001): 390–405.)

a routinely cyclic set of states) in which the system retains most of its structures, functions, and feedbacks. As an empirical construct in engineering, resilience is the *rate* at which an ecosystem (usually at a small scale, with known variables) returns to a known and recognizable state, including its structures and functions, following change events. Such events, considered disturbances—which C. S. Holling strategically referred to in the vernacular as "surprises"—are usually part of normal ecosystem dynamics, yet they are also unpredictable, in that they cause sudden disruption to a system.[25] These can include, for example, forest fires, floods, pest outbreaks, and seasonal storm events.

The ability of a system to withstand sudden change at one scale assumes that the behavior of the system remains within a stable regime that contains this steady state in the first place. However, when an ecosystem suddenly shifts from one stable regime to another (in the reorganization phase, via a flip between system states or what is called a "regime shift"), a more specific assessment of ecosystem dynamics is needed. In this context, *ecological resilience* is a measure of the *amount of change* or disruption that is required to move a system from one state to another and, thus, to a different state of being maintained by a different set of functions and structures than the former (Figures 3.5 through 3.7).[26] Each of

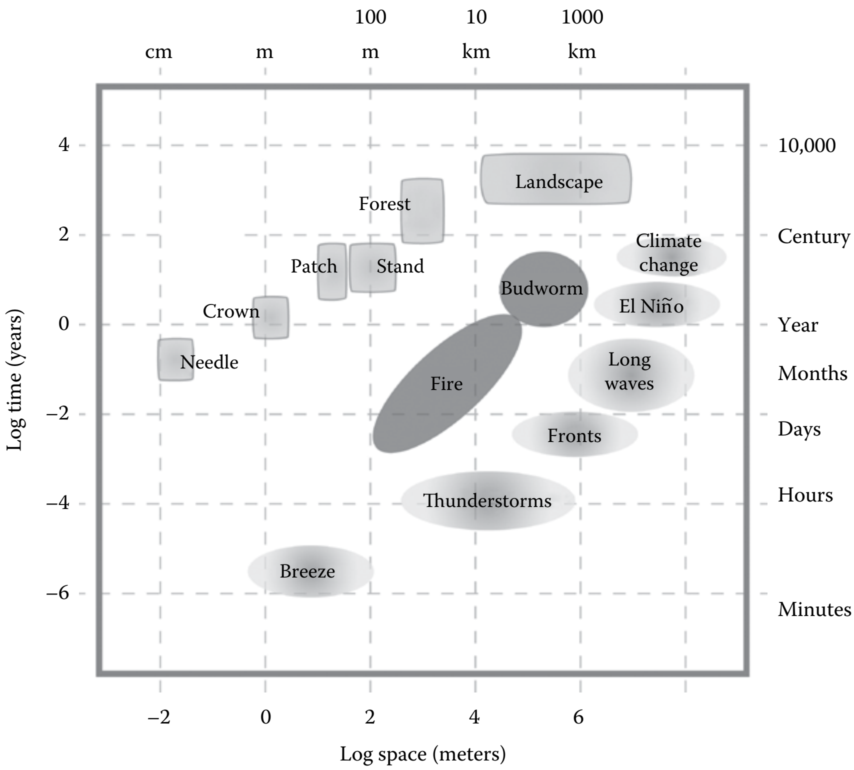

FIGURE 3.4
Ecosystem dynamics are observed here across multiple scales of time and space. (Redrawn by Marta Brocki and adapted from Holling, C. S. 2001. "Understanding the Complexity of Economic, Ecological, and Social Systems." *Ecosystems* 4(5): (August 2001): 390–405 [393].)

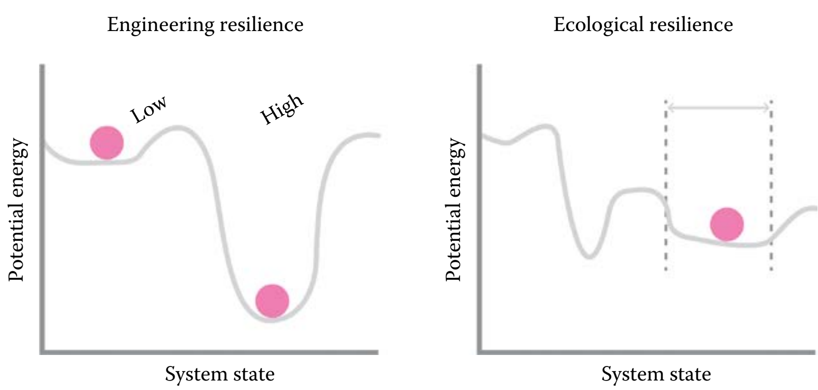

FIGURE 3.5
Shown here are two contrasting perspectives on resilience: (left) Engineering Resilience in closed systems (limited uncertainty and known variables) versus (right) Ecological Resilience in open systems (inherent uncertainty and infinite variables). (Redrawn by Nina-Marie Lister and Marta Brocki and adapted from Holling, C. S. 1996. "Engineering Resilience versus Ecological Resilience." In Schulze, P. C., ed. *Engineering within Ecological Constraints*. 31–44 [35]. Washington, DC: National Academy Press.)

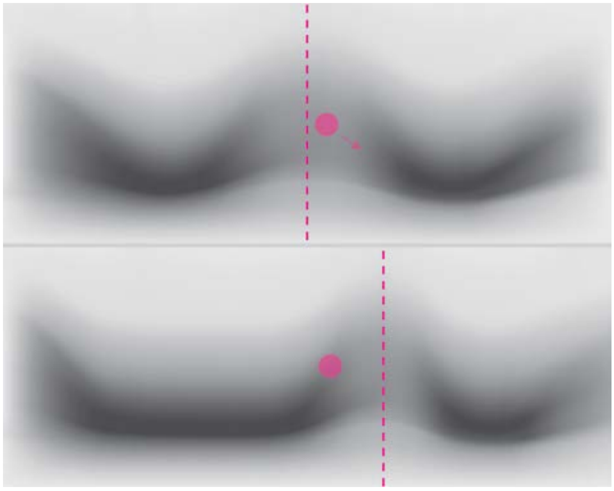

FIGURE 3.6
Resilience, seen here as a function of social-ecological system conditions, is described metaphorically as a ball in a changing basin. The basin represents a set of states that share similar functions, structures, and feedbacks. Though the location of the ball remains the same, changes in the surrounding conditions bring about a shift in state. (Redrawn by Marta Brocki and adapted from Walker, Brian, C. S. Holling, Stephen R. Carpenter, and Ann Kinzig. 2004. "Resilience, Adaptability and Transformability in Social–ecological Systems." *Ecology and Society* 9(2): (December 2004): 4. http://www.ecologyandsociety.org/vol9/iss2/art5.)

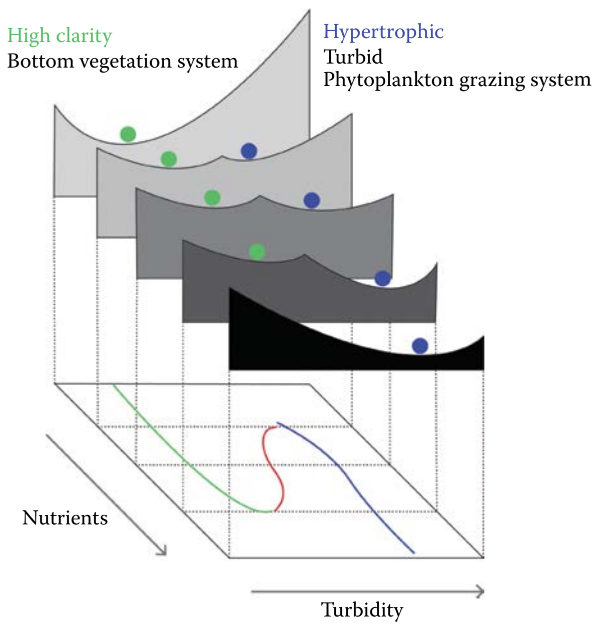

FIGURE 3.7
In this early schematic of a complex systems perspective in ecology, we visualize multiple states—all possible—in a freshwater ecosystem. (Courtesy of James J. Kay, as sketched in lectures from a course, "Systems Design Engineering," at the University of Waterloo, 1994, in which the author was a student. Redrawn by Marta Brocki and adapted from Kay, James J., and Eric Schneider. 1994. "Embracing Complexity: The Challenge of the Ecosystem Approach." *Alternatives Journal* 20(3):(July 1994): 32.)

these nuanced aspects of resilience is important. They underscore the social-cultural and economic challenges inherent in defining what "normal" conditions are and, in turn, how much change is acceptable at what scale.

It becomes critical to understand the ecological systems in which we live, and, given their inherent uncertainty, we ought to do so through a combination of ways of knowing: experiential, observational, and empirical. Indeed, if there are multiple possible states for any ecosystem, there can be no single "correct" state—only those we choose to encourage or discourage. Notably, these are not questions of science but of social, cultural, economic, and political dimensions—they are also questions of design and planning. The trajectory of research in resilience has been instrumental in exploring the paradoxes inherent within living systems—the tensions between stability and perturbation, constancy and change, predictability and unpredictability—and the implications of these for management, planning, and design of the land. Resilience, in short, as Brian Walker declares, "is largely about learning *how* to change in order not to *be* changed."[27]

From Rhetoric to Tactic: Toward Resilient Design

More recently, applied ecology has been focused on trying to understand what the ecosystem states are that we perceive to be stable, at what scales they operate, and how they are useful to us. It is important to recognize that stability can be positive or negative, just as change is neither universally good nor bad. Thus, while designers want to encourage a desirable stability (such as access to affordable food or a state of health for a majority of citizens), they also wish to avoid pathological stability (such as chronic unemployment, a state of war, or a dictatorship). This approach has significant implications for management, planning, and design, as it rests on the recognition that humans are not outsiders to any ecosystem but, rather, participants in its unfolding and agents of its design.

In this context, the sub-science of urban ecology developed during the 1990s has created a new niche for resilience.[28] Related practices of urban design, environmental planning, and landscape architecture have cross-pollinated in the service of design and planning for healthier cities within which connected vestiges of natural landscapes might thrive. The work of environmental scholars (such as William Cronin, Carolyn Merchant, and David Orr), together with the practice of landscape architects (such as Anne Whiston Spirn, Frederick R. Steiner, and James Corner) effectively brought nature into the embrace of the city, challenging the hierarchical dualism of humans versus nature.[29] The once-discrete concepts of "city" and "country" grew tangled and hybridized and the boundaries between the urban and the wild blurred. This blurring of boundaries, coupled with the contemporary ecological paradigm of nature as a complex, dynamic open system in which diversity is essential and uncertainty the norm, represented a significant break from ecological determinism and its slavish pursuit of perpetual stability underpinned by the illusion of the balance of nature.[30] The increasing hybridization of cultural and natural ecologies has created a powerful aperture for the development of resilience in thought and practice—and with it a new realm for design developed formatively through the interdisciplinary study of social-ecological systems science, in which coupled systems of humans *within* nature are the norm.[31]

What does design for resilience look like? What tactics do urban planners and designers need to engage in for attaining resilience? To activate such a model for design, one can summarize key principles of adaptive complex systems, generally, and of resilience, specifically.[32] First, change can be slow and fast, at multiple scales. This means that it is essential to look beyond one scale in both space and time and to use various tools to understand the ecological system. Slow variables are arguably more important to understand than fast ones, as they provide necessary stability from which to study change at a safe distance. Yet there can be no universal point of access or ideal vantage point. Mapping, describing, and analyzing the system from multiple perspectives, using different ways of knowing and with a diversity of tools, is critical. If uncertainty is irreducible and predictability is limited, then the role of the traditional expert is also limited—and the role of designer is more akin to a facilitator or curator.

Second, some connectedness or modularity across scales is important, and feedback loops should be both tight and loose. Resilient systems are not so tightly coupled that they can't survive a shock throughout the system that moves rapidly and destructively. For example, children need some limited exposure to viruses to develop immunities but at not too large a scale of impact so as to endanger long-term health. In the same way, design strategies for resilience must consider novelty and redundancy in terms of structures and functions. A useful example is a trail system in a park, which is somewhat connected using a hierarchy of paths that is legible and efficient and yet not so tightly connected that it compromises habitat, folds in on itself, or prohibits spontaneous exploration.

Third, even as there are multiple states in which an ecosystem can function, there is no single correct state. It is important to determine where, in the adaptive cycle, the system of interest is, such that decision makers and designers can learn patterns and anticipate change (if not predict it). Eventually, perceived stability in any phase will end, and the system will move to a new phase in its adaptive cycle. A non-linear approach to design that encompasses oscillating or changing states within various phases of a system's development will help facilitate change. For example, it may be desirable to design for seasonally flooded landscapes or along a gradient of water that changes rapidly in a short period of time.

Finally, resilient systems are defined by diversity and by inherent but irreducible uncertainty. Successful strategies for resilient design should use a diversity of tactics through *in situ* experimental and ecologically responsive approaches that are safe-to-fail, while avoiding those erroneously assumed to be fail-safe.[33] This distinction is important, for conventional engineering relies on prediction and certainty to assume an idealized condition of fail-safe design. Yet this is impossible under dynamic conditions of ecological and social complexity in which predictability is limited at best to one scale of focus. Even knowing one scale exhaustively and managing for it specifically and exclusively may compromise a system's overall function and resilience. The reductionist caveat of "scaling up," using knowledge gained at one scale and applying it to the whole system, cannot work in complex systems in which scales are nested. Design strategies that support and facilitate resilience should, for example, model its attributes, using living infrastructures that mimic ecological structures and their functions, and to design them to be tested and monitored, from which learning and adaptation to changing conditions are built into the design. When design experiments fail, they should fail safely, at a scale small enough not to compromise long-term health.

These and other emerging approaches to design for resilience tend to reflect the characteristics of the theoretical paradigm shifts that have laid its foundation. They are often interdisciplinary, integrating architecture, engineering, and ecology, specifically, and art and science, broadly. They cross-pollinate freely across scales and hybridize in surprisingly novel ways.[34] The growing use of living "blue" and "green" infrastructures[35] to soften seawalls, anchor soils, provide rooftop habitats, clean stormwater, soak and hold floodwater, and move animals safely across highways[36] are a collective and optimistic testament to the emergence of a new breed of urban and landscape designers whose creative work mimics, models, and manifests the living systems that inspire and sustain us. Yet activating resilience requires a subtle and careful approach to design: one that is contextual, legible, nuanced, and responsive, one that is small in scale but large in cumulative impact. In (re)thinking design, and in (re)designing for change with this sensibility, we have begun to cultivate a culture of resilience and the adaptive, transformative capacity for long-term sustainability—thriving beyond merely surviving—with change in the urbanizing landscapes that now define us.

Acknowledgments

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Endnotes

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6. See, for example, *The Post-Sandy Initiative: Building Better, Building Smarter—Opportunities for Design and Development* (May 2013), initiated and undertaken by the American Institute of Architects, New York Chapter (AIANY), and the AIANY's Design for Risk and Reconstruction Committee (DfRR), available at http://postsandyinitiative.org.
7. The United Nations projects that, in 2030, there will be 5,000,000,000 urbanites with three-quarters of them in the world's poorest countries. See United Nations. 2011. *World Urbanization Prospects: 2011 Revision*. http://esa.un.org. In 1950, only New York City and London had more

than 8,000,000 residents, yet today there are more than 20 megalopoli, most in Asia. See Chandler, Tetrius. 1987. *Four Thousand Years of Urban Growth: An Historical Census*. Lewiston, NY: St. David's University Press; and Yvonne Rydin and Karolina Kendall-Bush. 2009. *Megalopolises and Sustainability*. London, UK: University College London Environment Institute. http://www.ucl.ac.uk/btg/downloads/Megalopolises_and_Sustainability_Report.pdf.

8. According to the World Health Organization, the percentage of people living in cities is expected to increase from less than 40% in 1990 to 70% in 2050. See "Global Health Observatory: Urban Population Growth," World Health Organization, available at http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/.
9. Lister, Nina-Marie. 2008. "Sustainable Large Parks: Ecological Design or Designer Ecology?" In Czerniak, Julia, and George Hargreaves, eds., *Large Parks*. 31–51. Princeton, NJ: Princeton Architectural Press.
10. See, for example, Reed, Chris, and Nina-Marie Lister, eds., 2014. *Projective Ecologies*. New York, NY: Actar, in association with the Harvard University Graduate School of Design.
11. As articulated and elaborated in Corner, James. 1997. "Ecology and Landscape as Agents of Creativity." In Thompson, George F., and Frederick R. Steiner, eds., *Ecological Design and Planning* 80–108. New York, NY: John Wiley & Sons; Corner, James. 1999. "Recovering Landscape as a Critical Cultural Practice." In Corner, James, ed., *Recovering Landscape* 1–26. Princeton, NJ: Princeton Architectural Press; and Waldheim, Charles. ed., 2006. *The Landscape Urbanism Reader*. Princeton, NJ: Princeton Architectural Press.
12. Reed and Lister, *Projective Ecologies*.
13. This phenomenon is well articulated by Mathur, Anuradha, and Dilip da Cunha. 2009. *Soak: Mumbai in an Estuary*. Mumbai, India: Rupa & Co.
14. See, for example, Lister, Nina-Marie. 2009. "*Water/Front*," *Places*. Design Observer Online. http://places.designobserver.com/feature/water-front/10227/.
15. See, for example, a variety of North American and international examples of resilience policies at http://resilient-cities.iclei.org/resilient-cities-hub-site/resilience-resource-point/resilience-library/examples-of-urban-adaptation-strategies/. The U.S. Department of State's *Deployment Stress Management Program* (http://www.state.gov/m/med/dsmp/c44950.htm) defines resilience in a psychosocial context, and the same language of resilience is often used in policy documents referencing resilience.
16. Brian Walker, Chair of the Resilience Alliance and research fellow at the Stockholm Resilience Centre, provides an excellent overview of this aspect of resilience in https://www.project-syndicate.org/commentary/what-is-resilience-by-brian-walker (accessed July 5, 2013).
17. Seminal references are Odum, Howard T. 1983. *Systems Ecology: An Introduction*. New York, NY: John Wiley & Sons; and Holling, "Resilience and Stability of Ecological Systems."
18. Discussed in F. Berkes, N. C. Doubleday, and G. S. Cumming. 2012. "Aldo Leopold's Land Health from a Resilience Point of View: Self-Renewal Capacity of Social–Ecological Systems." *Eco Health* 9(3):278–287.
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23. The adaptive cycle was first described by C. S. Holling. 1986. In "Resilience of Ecosystems: Local Surprise and Global Change," in Clark, W. C., and Edward (Ted) Munn, eds., *Sustainable Development of the Biosphere*. Cambridge, UK: Cambridge University Press; modified in Gunderson, Lance, and C. S. Holling, eds. 2002. *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington, DC: Island Press; and, more recently, by Reed and Lister. In *Projective Ecologies*.

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31. The development of social-ecological systems science, supported by case study analyses, can be followed in: Gunderson and Holling, *Panarchy*; Berkes, Fikret, Johan Colding, and Carl Folke, eds. 2002. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. New York, NY: Cambridge University Press; and Waltner-Toews, David, James J. Kay, and Nina-Marie Lister, eds. 2008. *The Ecosystem Approach: Complexity, Uncertainty, and Managing for Sustainability*. New York, NY: Columbia University Press.
32. Related versions of these principles—described variously as system attributes, tenets, and characteristics—are elaborated in Gunderson and Holling, ibid.; Waltner-Toews, Kay, and Lister, ibid.; and, more recently, in Walker, Brian, and David Salt. 2012. *Resilience Practice: Building Capacity to Absorb Disturbance and Maintain Function*. Washington, DC: Island Press.
33. Lister. "Sustainable Large Parks."
34. See a variety of designed examples in Steiner, Frederick, George Thomson and Armando Carbonell (eds). 2016. *Nature and Cities: The Ecological Imperative in Urban Design and Planning*. Cambridge, MA: Lincoln Institute of Land Policy.
35. See for example Green, Jared. 2015. *Designed for the Future: 80 Practical Ideas for a Sustainable World*. New York, NY: Princeton Architectural Press.
36. A diversity of examples of wildlife crossing infrastructure is available at https://arc-solutions.org/.

2

Sustainable Development and Climate Change

2.1 The Concept and Objectives of Sustainable Development

By analysing the historical development of the concept of sustainable development, the stages of the historical development of the relationship between humanity and the natural environment are often distinguished. The first stage covers the period before the Industrial Revolution and is often treated as a period of human life in harmony with nature by scientists. In fact, at this stage in the evolution of the relationship between the individual and nature, nature dictated its conditions to the human, while the human became awed by nature, often deified it, and tried to accommodate to it as much as possible. In this case, Pagan traditions – sacred groves, sacred rivers, and lakes – well reflect the essence of this approach.

The second stage in the historical dimension of human–nature relations is associated with rapid advances in science and technology, which have led to the formation of a worldview of the conquest of nature, focusing on the fact that humans can conquer nature by changing it according to their own needs and discretion. Constantly accelerating economic development and increasing production volumes have enhanced the growth of the population and increased demand for natural resources, while the increasing use of natural resources has enlarged environmental pollution, which from local or regional has grown to the global level. At this stage, the environment is seen by humans as the building material for creating a more perfect, better world; thus, the humanistic paradigm is displaced by the technocratic paradigm. The core of this stage is the formation of a long-lasting confrontation between the human and nature, which has allowed humans to feel independent from the surrounding nature.

The third stage, explaining the relationship between the human and nature, is often referred to as the stage of human–nature harmonisation with the main aim of reducing the negative effects of economic development on the environment. It emerged by questioning whether the humankind is indeed on the path to full advancement, whether the social and natural environment will be continually improved, and whether material prosperity, regardless of exploitable natural resources, will be achieved without harming the society and the surrounding environment. Precisely in the third stage, environmental problems have been viewed not as negative changes in nature, but as social problems caused by people in their daily lives (Čiegis 2004). In order to solve these problems, it is necessary to use not only the latest tools of scientific and technical progress, but also the inclinations of society, their culture of consumption, their habits, and attitudes established over time.

As a result of these historical stages of the relationship between humanity and the natural environment, the necessity of assessing the responsibility of humanity for their actions arose, as it became evident that further uncontrolled expansion of the technosphere threatens to completely destroy the vital elements. At the same time, not the question "Can the biosphere adapt to change?" but another one arose: "Can the biosphere adapt to change so quickly?" The question of speed arose because the pace of human development surpassed all expectations. At the same time, a new approach to economic growth formed and the understanding and meaning of these concepts began to change, as it became clear that the growth process could be destructive (Čiegis 2004, 2006).

Many postulates on harmony development between humans and environment, in particular the living part of it (flora, fauna), are also easy to find in various religions, especially Buddhism, where a human is considered an integral part of nature. On the other hand, we have to admit that Christianity, which has elevated the human as the perfect and God-like creature above the living nature, is far less favourable to the harmonious relationship between humans and nature. Thus, it is no coincidence that as the civilisation evolves, first and foremost, the deep problems of human–environment relations emerge namely in Christian countries.

The discussions on the relationship between economic growth and the environment are long-standing, complex, and fundamentally unresolvable to this day. The origins of these disputes, though linked to Adam Smith's work An Inquiry into the Nature and Causes of the Wealth of Nations, published in 1776, are often traced back to the ideas of Thomas Robert Malthus outlined in his famous work An Essay on the Principle of Population As It Affects the Future Improvement of Society. The ideas of Malthus were in stark contrast with the ideas about the need to ensure a continuous process of economic growth expressed by Adam Smith in The Wealth of Nations. Thomas Robert Malthus, who developed his own population theory, stating that population dynamics are limited by declining efficiency of the resources, claimed that the population grows in geometric progression, while means of subsistence only in arithmetic progression at best. Thomas Malthus was right in speculating that the population will grow geometrically but was wrong in claiming that food production will increase arithmetically, because he did not foresee humanity's ability to geometrically improve the technology used in agriculture, and did not realise that the economic law of diminishing results is valid only under the immutable status of technologies. Consequently, although Thomas Malthus presented a strong model, its simplicity limited its relevance to political decision-making (Čiegis 2004).

It is worth noting that the problems (overpopulation) raised by Thomas Malthus, Karl Marx's teachings on misallocation, and John Maynard Keynes's doctrine of obligatory labour, all had one common solution to their problems – economic growth. Growth was the general response to all problems. Thus, this expansionist view of the world – a panacea for unmanageable and unbridled economic growth – is also one of the threats to the development of the modern world. Talks over environmentally balanced development to eliminate and prevent (current) consequences of unrestricted economic growth began only in 1983.

The modern version of the neo-Malthus theory was studied by Ehrlich (1989) and Hardin (1968, 1993). They extended pessimistic ideas and stated that uncontrolled population growth would undermine life-sustaining functions and lead to environmental, social, and economic disasters. The identification of a set of such problems can be seen as the beginning of the formalisation of the sustainable development process.

Subsequent ideas focusing on the interpretation of the optimal relationship between humanity and resources were explored in Daly's works Toward a Steady-State Economy (Daly 1980) and Steady-State Economics (Daly 1991). Other classical economists, such as David Ricardo and James Mill, also understood the limitations of natural resources available to humanity and their impact on the scale of economic activity and, therefore, considered long–term economic growth difficult to achieve. Land constraints caused the main concern for resource scarcity. David Ricardo predicted that with the growth of population, land shortages would increase and society would be forced to cultivate increasingly poorer land and, as a result, the price of agricultural products would rise. However, David Ricardo believed that human resources and technological development would help to delay the period when humanity's needs would exceed the possibilities of natural resources (Čiegis 2006).

For a long time, in the discussions about the relationship between economic growth and the environment, a pessimistic attitude prevailed, which is best reflected in the famous report The Limits to Growth written to the Club of Rome by Donella Meadows et al. (1972). The report aimed to clarify the limits of production expansion and population growth, while the starting point was the frightening exponential growth of the population and the economy. The conclusions reached by the scientists were disappointing: the contradictions between nature's limitations and the extremely rapid growth pace of its use, the increasing environmental pollution and the rapid population growth in the mid-21st century could lead to a global ecological crisis. The Limits to Growth and the subsequent projects developed on the initiative of the Club of Rome, such as Beyond the Age of Waste, Goals for Mankind, formed a new mentality and brought the need to ensure global equilibrium to the forefront (Čiegis 2006).

Around 1935, when, through the millennia, the mankind had already been well adapted to the local ecological systems, the English scientist Arthur Tansley introduced the concept of "ecosystem" as a scientific category, which was defined as a dynamic complex of living organisms (plants, animals, and micro-organisms) and non-living environment (soil, water, and air). While the scale of humanity's economic growth was relatively small, it was possible to ignore the fact that the human economy was involved and dependent on the ecosystems of our planet (Čiegis 2004). However, in the long run, there was no area of nature left untouched by a human and without a proper assessment of the ecosystem's condition for a long time, humankind faced ecological problems.

In 1969, at the session of the UN Council, global crisis was brought up since, through continued economic growth and the waste of natural resources at excessively fast rates, it equally threatened both developed and developing countries.

In 1972, at the United Nations Conference on the Human Environment in Stockholm, the connection between economic development and environmental impact was recognised, and the term "ecological development" was proposed. In the Declaration, adopted during the Conference, the key principles were expressed, which must be followed by states in rationally harmonising the relations between development and environment. The first principle of the Declaration proclaimed that "Man has the fundamental right to freedom, equality and adequate conditions of life". The other articles of the document outlined the policy principles and guidelines on rational use and protection of renewable and non-renewable natural resources, relations of economic development and environment as well as scientific and technical progress. The Conference also developed a comprehensive plan of measures with 109 recommendations that covered the most pressing questions of the environmental benefits of that period (Report of the United Nations Conference on the Human Environment 1972).

This concept of global resource management gave Western countries hope for a comprehensive solution to the problems of environmental pollution. However, developing countries made it clear that their objectives and development policies (or, more specifically, economic growth) of that period were a much higher priority than environmental concerns. And yet, notwithstanding all the contradictions that had arisen among countries of different development levels, for the first time, environmental issues were reviewed in a global context, and the idea of the necessity to link ecological problems and their solution to economic and social development was expressed at the Stockholm Conference (Čiegis 2006).

The origins of the current concept of sustainable development date back to 1980, when a vital document – World Conservation Strategy – was published on behalf of the International Union for Conservation of Nature (IUCN), the United Nations Environment Programme, and the World Wildlife Fund. This document completely abandoned the opposition between nature conservation and economic development, postulated in the concept of human survival, and explicitly declared that development and protection were not contradictory, while the rational use of natural resources was an integral part of social development and nature protection. This was the path towards the widely recognised concept of sustainable development (World Conservation Strategy 1980).

As the concept of sustainability was being developed, a significant role was played by the 1986 Ottawa Conference on Conservation and Development organised by IUCN and held to assess the World Conservation Strategy and set out guidelines for its review; moreover, justice and social legitimacy were considered such significant aspects that even the phrase "sustainable and equitable development" was used in the Conference. In the documents of the Conference, the need for a radical change of the old development model is indicated, noting that we need an alternative society, another type of development associated with structural change (Čiegis 2006).

In 1987, the sustainable development philosophy was formalised with the report Our Common Future by the UN World Commission on Environment and Development that had an infinitely noble goal to make the world prosper and be generous to all (Our Common Future 1987). In this report, for the first time in the history of the evolution of the concept of sustainable development, a qualitatively new notion of economic growth has been defined: it is rapid and, at the same time, socially and environmentally sustainable (responsible) economic growth. From this point on, it was agreed that sustainable development encompasses three dimensions – economic, social, and environmental – and that all economic growth shall be achieved by considering the remaining two aspects of economic growth (social and environmental).

Thus far, sustainable development issues have been fundamental and insignificant in the international climate change policy: they have been fundamental in the sense that the reduction of greenhouse gas (GHG) emissions and economic development have often been seen as contradictory. Over the years, policymakers have repeatedly expressed their concerns that ambitious climate policies are limiting development, reducing the number of jobs, damaging the industry, and lowering the standard of living.

At the same time, the link between climate change and sustainable development has hardly been studied. In climate policy, the risk of "carbon leakage" is discussed in detail: this ambitious climate policy can stimulate the relocation of industrial production to other countries; however, the discussions have traditionally focused on calculating GHG emissions and discounting the wider social and economic impacts of climate change actions such as benefits and costs (Ürge-Vorsatz et al. 2014).

Policymakers often do not take climate change into account when planning their economic development. This is clearly illustrated by the current state of the energy sector where coal combustion is still used, and the state of the transport sector, which is reflected by the transport infrastructure that does not consider climate change. This is due to the fact that different ministries have different approaches and due to a lack of policy coherence. The situation is expected to change and improve significantly with the implementation of two milestones: The Paris Agreement and the 2030 Agenda.

The Paris Agreement is the first global agreement on sustainable development based on data assessment and analysis. The legally binding provisions for information flows are aimed at a civilisational transformation and transition of individuals from rural poverty to the urban middle class, while maintaining a global level of well-being and not crossing ecological boundaries.

Key elements of the Paris Agreement:

- Long-term target: Governments have agreed to ensure that the global average temperature increase is well below 2°C compared to pre-industrial temperature while making efforts to keep it below 1.5°C.
- Actions: Before and during the Paris Conference, countries presented comprehensive national climate action plans that aim to reduce their emissions.
- Ambition: Governments have agreed to report on their actions every 5 years, in this way setting even more ambitious targets.
- Transparency: They also agreed to inform each other and the public of their progress in achieving their goals to ensure transparency and observation.
- Solidarity: The European Union and other developed countries will continue to provide financing to developing countries in order to fight climate change by helping them to reduce emissions and increase their resilience to the effects of climate change.

In 2015, the General Assembly of the United Nations adopted the resolution Transforming our World: the 2030 Agenda for Sustainable Development.

2.1.1 Sustainable Development Goals

The resolution Transforming our World: The 2030 Agenda for Sustainable Development signed by the President of the Republic of Lithuania and heads of other 192 countries at the General Assembly of the United Nations officially came into force at the beginning of 2016, introducing Sustainable Development Goals to governmental authorities. This resolution is the result of thorough and comprehensive 3-year negotiations that involved international, national, and regional players from intergovernmental, governmental, and regional institutions, public and private sectors, and the civil society. These goals are important at both global and national levels and encompass both global and national actions with the aim of making our planet more sustainable. The 2030 Agenda is much more ambitious than the Millennium Development Goals and covers a bigger number of issues, and it shall be implemented by developing and developed countries. In the Agenda, 17 Sustainable Development Goals, based on the achievements of the Millennium Development Goals, and including new ones – climate change, economic inequality, innovations, sustainable consumption, peace and justice as well as other priorities – are established. In order to accomplish these goals, a system of 99 indicators has been established, which may fundamentally differ from the system of indicators for assessing sustainable development formed by the United Nations.

The Sustainable Development Goals set out in the Agenda:

Goal 1: End poverty in all its forms everywhere. This goal is ambitious, but it is believed to be possible. In 2000, the world had committed to half the number of people living in absolute poverty by 2015, and this goal was achieved. However, more than 800 million people around the world still live on less than USD 1.25 a day – that corresponds to the total number of Europeans living in extreme poverty. The time to completely eradicate all forms of poverty is now.

Goal 2: End hunger, ensure food security and improved nutrition, promote sustainable agriculture. Malnutrition causes almost half (45%) of deaths of children before reaching age five; that is up to 3.1 million children each year. Across the developing world, 66 million primary school-age children attend classes hungry with 23 million of them being in Africa alone. However, in the past 20 years, hunger has dropped by almost half. Many countries that have suffered hunger and poverty in the past are able to satisfy the nutritional needs of the most vulnerable people. This is an incredible achievement. The time to end poverty and hunger as well as to take care of a healthy diet of the population is now. This requires the support for the development of sustainable agriculture and promotion of small and medium farmers, who supply high-quality food for the locals.

Goal 3: Ensure healthy lives and promote well-being for all at all ages. Everybody knows that the most important thing in the life of all individuals is their health. It has the greatest impact on our quality of life and on what we create and what we can create. Therefore, the realisation of this goal will ensure that every individual has access to the healthcare system of good quality, effective medication, and vaccines. By the time the already mentioned goal was set, children and maternal mortality rate had plunged by more than half in 25 years, which means that this goal can be achieved. However, some problems still need to be tackled such as AIDS, which is the leading cause of death among adolescents in sub-Saharan Africa.

Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Poverty, armed conflicts, and other extreme situations have forced many children around the world to stop going to school. There are many regions around the globe where children do not even have access to primary education and many vulnerable households where children do not have the opportunity to go to school. However, since the year 2000, the significant progress towards primary education for all children worldwide has been made: the overall education level in developing regions has reached 91%.

Goal 5: Achieve gender equality and empower all women and girls. The progress that the world has made in the area of gender equality is commendable, but not all problems have been solved. Girls and women still face discrimination not only in public life but also in the labour market. Significant pay gaps still exist today as well as many unpaid "female jobs", e.g., childcare and work at home. The examples of women discrimination in public decision-making and political participation have also been observed.

Goal 6: Ensure availability and sustainable management of water and sanitation for all. Every individual on Earth should have access to drinking water. This is the goal of the year 2030. Although many people take clean drinking water and sanitation for granted, it should be kept in mind that water scarcity directly affects more than 40% of the world's population. To put it in other words, more than 3 billion people suffer from the lack of drinking water and unsanitary conditions in which they have to live. It is believed that this number is going to soar on account of climate change. If we continue along this path we are on now and not make any changes, by the year 2050 at least one in four people will experience the shortage of drinking water. The new path is more focused on international cooperation in protecting swamps and rivers as well as sharing water treatment technologies that lead to the goal accomplishment.

Goal 7: Ensure access to affordable, reliable, sustainable, and modern energy for all. From 1990 to 2010, the number of people with access to electricity increased by 1.7 billion. This is a gratifying achievement. However, as the world's population continues to grow, more and more people will need cheap electricity to light up their homes and streets, use their phones and computers, and work every day. We generate energy by burning fossil fuels and, thus, increasing GHG emissions, which has a direct impact on climate change and causes many problems in every part of the world. Hence, we have to become a more energy-efficient society and make larger investments into more clean energy sources, e.g. solar or wind energy. By these means, we will meet electricity demand and protect the environment.

Goal 8: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. A significant part of economic growth is a sufficient salary, which ensures the quality of life. The good news is that the middle class is growing all over the world: it has almost tripled in developing countries over the past 25 years. Today, however, job growth is lagging behind the growing workforce. Therefore, entrepreneurship must be encouraged to ensure new workplaces by eliminating forced labour, child exploitation, and human trafficking.

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation. Technological progress helps to deal with great global challenges, e.g. create jobs and use electricity more efficiently. For instance, the world is becoming more and more interrelated and thriving because of the common interest that results from the globalisation processes. Opportunities to take advantage of knowledge management, wisdom, and benefits of the virtual world are increasing. However, 4 billion people, most of whom are from developing countries, do not have access to the Internet. Narrowing the digital divide, promoting sustainable industrial development, and investing in research and innovation are important ways to promote sustainable development.

Goal 10: Reduce inequality within and among countries. We must approve the policy that creates an opportunity for everyone, regardless of who they are or where they come from. Income inequality is a global issue that requires global solutions. This implies that the following steps need to be taken: improving regulation of financial markets and institutions, sending official development assistance where it is most needed, and helping people to migrate safely so that they can take advantage of the opportunities of the global world. Together we can now change the direction of inequality from the old history.

Goal 11: Make cities and human settlements inclusive, safe, resilient, and sustainable. Currently, more than half of the world's population does live in cities, and this number will account for about two-thirds of humanity by the year 2050. Cities are getting bigger. In 1990, ten "big cities" with a population of 10 million or more existed in the world; in 2014, 28 million cities with 453 million people were counted. Many people prefer living in cities due to their cultural centres that exist there; however, at the same time, they are gradually becoming centres of poverty. In order to make cities sustainable for all, we can create good, affordable public housing. We can invest in public transport, create green spaces, and get a wider range of people involved in urban planning. By doing so, we can keep things that we like as they are and change the ones that we disfavour or that are just harmful.

Goal 12: Ensure sustainable consumption and production patterns. The level of consumption of some people is particularly high while others consume very little. There is a considerable difference or so-called consumption inequality that manifests itself in a very small proportion of the population, whose consumption is particularly high, and in the majority of the population that consume very little, often even too little to meet their essential needs. Our aspiration should be the world in which everyone has access to the things they need in order to survive and prosper. The consumption level should be maintained in a way that preserves natural resources so that our children would be able to use them as well as their children. The most onerous part is how to achieve this goal. We can manage our natural resources more efficiently and handle waste correctly.

Goal 13: Take urgent action to combat climate change and its impacts. Every country in the world is facing drastic consequences of climate change. Direct loss due to earthquakes, tsunamis, tropical cyclones, and floods is estimated at hundreds of billions of dollars per year. We can reduce the damage of property and losses of life by helping more vulnerable regions, e.g. inland countries and island countries which have to become more resistant to the consequences of climate change. By taking into account political will and technological measures, it is still possible to limit the increase of average temperature on a global scale to 2°C compared with the pre-industrial level. Thus, the catastrophic consequences of climate change may be avoided.

Goal 14: Conserve and sustainably use the oceans, seas, and marine resources for sustainable development. Ocean temperatures, chemistry, and their life forms are incredibly important components of our planet. Survival of over 3 billion people depends on the diversity of seas and coasts. Oceans absorb about 30% of carbon dioxide emitted by humans during manufacturing processes, but emissions have been going up recently, and consequently, oceans become more acidic – since the beginning of the Industrial Revolution, the acidity has increased by 26%. According to the latest estimates, on average 13,000 pieces of plastic litter float on every square kilometre of the ocean.

Goal 15: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss. Vegetable oil constitutes 80% of total human nutrition. Forests, which cover 30% of the world's land surface, help to keep air and water clean. However, earth and life on it are in danger. Arable land is disappearing 30–35 times faster than in the past. Deserts are expanding. Animal breeds are becoming extinct. This Sustainable Development Goal is aimed at preserving and restoring dryland ecosystems by 2030.

Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels. No country develops without peace and justice in it, without human rights or government based on the rule of law. Yet, in some parts of the world, relative peace and justice dominate, and individual countries suffer from armed conflicts, crimes, torture, and exploitation that hinder their development. Peace and justice are the goals for all the world's countries. The aim of this Sustainable Development Goal is to reduce all forms of violence and to suggest governments and communities finding long-term solutions to the conflicts and insecurities. This means strengthening the rule of law, reducing the illegal flow of arms trafficking, and involving developing countries in institutions of global governance.

Goal 17: Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development. Today, more than ever before, the world is interrelated due to possibly accessible new information technologies, travels, and global institutions. There is a growing consensus that we need to work together in order to halt the consequences of climate change.

767 million people on the planet still live on less than USD 1.90 a day, whereas 793 million people face a shortage of food and drinking water on

a daily basis (United Nations 2017). Our planet needs a more resolute policy to reduce maternal mortality, achieve sustainable energy goals and larger investments in sustainable infrastructure as well as ensure the rights of every child to quality education. It is estimated that if all children, eligible for learning, graduates from high school by 2030, per capita income will rise by 75% till the year 2050, we may win the fight against poverty in a decade (United Nations 2017).

Almost all the Sustainable Development Goals are related to climate change to some extent. This issue has even been marked out by a separate point, namely, Goal 13. Measures to halt climate change are envisaged and, in the cases, when it is impossible to do so, to apply effective adaptation measures.

However, at first glance, in the Sustainable Development Goals, very little attention is paid to the element of culture and the role of culture while forming a sustainable and smart society. The cultural issue is closely related to the issue of climate change, and this possibly new component of sustainable development can be used effectively to achieve the Sustainable Development Goals that are, as already mentioned, either literary or figuratively related to climate change.

Modern society is transforming into a new, sustainable, and environmentally friendly society with the aim of providing humanity opportunities to build safer, healthier, and richer world where all the people have access to constant teaching and learning, new knowledge, and values and the need to know, understand, and make meaningful and responsible actions (Chakori 2017). None of the Sustainable Development Goals is directly culture oriented, i.e. definitions do not use the concept of culture directly. Despite this, it is worth paying attention to several aspects. The fourth Sustainable Development Goal aims to ensure all-encompassing and equal quality education, which can be implemented by acquiring new and relevant knowledge that would help to promote sustainable development. In order to achieve this goal, already existing and possible measurements that encourage citizenship in society and accessibility to cultural diversity by assessing the contribution of culture to sustainable development shall be used.

Another Sustainable Development Goal, which may promote sustainable, inclusive, and sustained economic growth, is oriented towards a comprehensive development policy of the countries with the goal of creating and forming a sustainable economy, which is possible only by supporting productive activities, using innovations as well as personal or group creativity and other related activities.

Goals 9 and 10 refer to the implementation of a concept of sustainable tourism. The sustainable tourism stimulates resilient infrastructure building, promotes inclusive and sustainable industrialisation, and increases opportunities for innovations and their successful implementation not only in large cities as it provides the evaluation of local elements of culture in creating necessary monitoring tools.

2.1.2 Integration of Culture to Achieve the Sustainable Development Goals

Cultural participation has a significant impact on people's quality of life: it contributes to their well-being and promotes a sense of belonging to a society.

The eleventh Sustainable Development Goal, the main objective of which is inclusive, safe, and sustainable cities and settlements, is of particular importance culturally. The achievement of this goal can be realised by the implementation of programmes and strategies that directly oblige countries to protect cultural and natural heritage.

Consequently, cultural aspects play a significant role in achieving the Sustainable Development Goals. Table 2.1 shows links between the Sustainable Development Goals and culture.

The cultural aspect of sustainability creates strong relations and is compatible with the other three dimensions of sustainable development. The conceptualisation of culture as the fourth component of the sustainable development, along with the ecological, social, and economic components, is based on a well-established and simple approach. Such an approach has its own dangers because culture can be viewed in a rather limited way as an artistic and cultural-creative sector (Hawkes 2001). This narrows down the definition of culture. It is important to note that this concept allows culture to be understood both qualitatively and quantitatively. Nevertheless, the role of the fourth component offers many opportunities. In this way, culture can be connected to the overall concept of sustainable development. The introduction of culture as the fourth dimension of sustainable development makes it possible to define the characteristics of sustainable development in the sector of arts and culture. Cultural values can be used in policymaking and sustainable development strategies and are practically applicable in artistic and cultural organisations and businesses. Artistic and creative values can be used, for example, in defining the criteria for assessing the sustainability of a particular policy, organisation, or company and in defining criteria that make it possible to evaluate the contribution of culture to the process of sustainable development and creation of product or image.

Depending on the circumstances and goals, all three cultural roles are important as everything depends on the context. The presented roles are not an evolutionary path to follow, but in this three-role system, certain trends, dynamics, and trajectories can be seen. Policies are becoming more diverse and multilayered, requiring a broader understanding of the sustainable development process, a dialogue, and ongoing interdisciplinary cooperation. It is clear that conceptualising culture as an equivalent component of sustainable development expands the definition of culture, which requires a systemic approach encompassing both natural and human-made worlds.

TABLE 2.1

Links between the Sustainable Development Goals and Culture

SD Goal No	Sustainable Development Goal	The role of culture in implementing the Sustainable Development Goal
Goal 1	End poverty in all its forms everywhere. Indicators: 1. The access to use chosen infrastructures of the cultural community (museums, libraries, media resource centres, exhibition venues for performing arts) compared to the distributions of the country population in administrative units below the state level. 2. Men and women with the ability to reach the main cultural services and resources (libraries, community centres, art centres, museums, local heritage conservation centres, etc.) in 30 minutes by foot.	Cultural services are services that shall be accessible to all, ensuring equal access to them by paying particular attention to poor and vulnerable individuals. The creation of cultural expression, services, goods, and heritage sites may contribute to inclusive and sustainable economic development.
Goal 2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.	Traditional knowledge that allows preserving the existing genetic resources should be recognised and maintained in each area. In this way, it is possible to reduce the threat of famine and improve local population nutrition opportunities by using genetic seed diversity and promoting fair payments in agriculture. The sustainable development of agriculture can be promoted by using traditions of cultivation, livestock farming, and horticulture.
Goal 3	Ensure healthy lives and promote well-being for all at all ages.	New health policies and healthy lifestyle promoting programmes must be culturally relevant. Local customs, which can be integrated into traditional healthcare systems, play an important role here. Individual participation in the cultural life of the country can also improve their health and overall well-being.

(*Continued*)

TABLE 2.1 (*Continued*)

Links between the Sustainable Development Goals and Culture

SD Goal No	Sustainable Development Goal	The role of culture in implementing the Sustainable Development Goal
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Indicators: 1. The percentage of teaching hours for art education, taking into account the total amount of teaching hours in the first two years of secondary school (grades 7–8). 2. The percentage of workers in primary and secondary education with special training in artistic and cultural disciplines. 3. The percentage of primary and secondary schools with a library. 4. The percentage of the population who have participated in cultural activities at least once in the last 12 months. 5. Global Cultural Engagement Index (and related indicators).	Aspects of cultural diversity, art education, languages, and culture that play an important role in sustainable development should be integrated into education programmes of all levels. Cultural approach, including the recognition of local languages and local level skills, and participation of interested cultural parties must be prevailing in creating education programmes at all levels: it complies with human rights and can contribute to the educational objectives, including student motivation and community relations. This goal can be achieved by ensuring that all learners acquire the knowledge and skills needed to promote sustainable development. It requires the use of assessment of the sustainable development and sustainable lifestyle, human rights, gender equality, peace and non-governmental cultural promotion priorities as well as the assessment potential for global citizenship development, cultural diversity, and contribution of culture to the sustainable development.
Goal 5	Achieve gender equality and empower all women and girls.	Gender equality should be achieved in cultural life as well. It requires widening the opportunities for women and girls to take an active part in cultural life and manage their projects and organisations in this field. Cultural practice, which is mainly run by women and girls, must be more visible and acknowledged. Narratives that talk about gender discrimination or show the importance of the role of women and girls in cultural life are necessary.

(*Continued*)

TABLE 2.1 (*Continued*)

Links between the Sustainable Development Goals and Culture

SD Goal No	Sustainable Development Goal	The role of culture in implementing the Sustainable Development Goal
Goal 6	Ensure availability and sustainable management of water and sanitation for all.	Traditional knowledge, values, and customs can provide an opportunity to learn how to use ecosystems properly, which is directly related to clean water availability and sanitation.
Goal 7	Ensure access to affordable, reliable, sustainable, and modern energy for all.	Certain cultural factors can be used as models for energy generation and consumption. By employing traditional businesses and cultural heritage knowledge, creative people can participate in creating educational and awareness-raising activities related to energy generation and consumption, especially in the field of energy efficiency.
Goal 8	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. Indicators: 1. The percentage of people employed in the cultural sector of the total working population. 2. The percentage of UN development assistance systems, national development plans, and local development plans integrating culture. 3. Contribution of creative and cultural activities to the gross domestic product. 4. Index of interface and coverage of technical and vocational training and higher education systems in the field of art and culture. 5. The percentage of countries that implemented/adopted social security and tax laws and regulations for self-employed artists according to 1980 UNESCO recommendation on the status of an artist.	Cultural and creative sectors can become areas of inclusive, sustainable, and fair employment if decent working conditions, which are in line with international human rights, are ensured. Cultural aspects can be integrated into tourism strategies. It is essential to ensure that cultural identities, as well as related activities and assets, would not be deco-desexualised and that the benefits would be reinvested into cultural activities. This goal can be achieved by supporting productive activities, job creation, entrepreneurship, creativity, and innovations in the development of small- and medium-sized enterprises, taking advantage of local access, human resources in the regions and isolated areas, and adequate funding. Sustainable tourism promotes local culture, which, in turn, creates jobs and culturally promotes the development of valuable products.

(*Continued*)

TABLE 2.1 (*Continued*)

Links between the Sustainable Development Goals and Culture

SD Goal No	Sustainable Development Goal	The role of culture in implementing the Sustainable Development Goal
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation. Indicators: 1. The number of countries that implement the national strategy of creative industry development.	If the cultural infrastructure is properly designed, it ensures affordable and equal access to cultural life as a part of the high-quality, reliable, sustainable, and resilient infrastructure that should be accessible to all. Artists and creative individuals can participate in processes of research, development, and innovations in various industrial areas.
Goal 10	Reduce inequality within and among countries.	The participation of individuals in cultural life contributes to reducing inequality since the participation must not be restricted by age, gender, disability, race, ethnicity, religion, economic, or another status. Artists and creative individuals have the opportunity to participate in the process of creating and presenting narratives that give an exclusive status to developing countries. All approaches to migration should include the cultural aspect and intercultural dialogue.

(*Continued*)

TABLE 2.1 (*Continued*)

Links between the Sustainable Development Goals and Culture

SD Goal No	Sustainable Development Goal	The role of culture in implementing the Sustainable Development Goal
Goal 11	Make cities and human settlements inclusive, safe, resilient, and sustainable. Indicators: 1. The percentage of national and local urban development plans that include a specific "cultural impact assessment". 2. The number of identified cultural and natural heritage objects (objects and artefacts). 3. The number of dangerous natural and cultural heritage objects. 4. The number of public libraries per 1,000 inhabitants. 5. The percentage of the budget allocated to the preservation of cultural and natural resources. 6. Multidimensional system development index of heritage sustainability. 7. The part of cities with the integrated urban policy that protects cultural and natural heritage. 8. The part of urban land for open public spaces (streets, squares, gardens, parks, etc.). 9. The part of urban land for public protected premises (libraries, museums, etc.).	Many important objects and elements of tangible and intangible cultural heritage are located in cities and play an important role in sustainable local development; indeed, cultural aspects are essential in promoting sustainable local development. Green and public spaces can contribute to the development of local cultural activities and must be accessible to all. Traditional construction methods, knowledge, and local materials can provide information on the renovation of existing buildings and the design of new buildings. Cultural factors inform about behaviour in cities, including transport and mobility, usage of environment, etc. The implementation of this goal enables the strengthening of efforts in the area of global cultural and natural heritage protection by ensuring universal access to safe, inclusive, and accessible green and public spaces, particularly for women and children, the elderly and the disabled.
Goal 12	Ensure sustainable consumption and production patterns. Indicator: 1. The percentage of national and local sustainable tourism development strategies involving the culture section.	Local and traditional products that are suitable for promoting sustainable consumption must be recognised and valued in order to achieve the goal.

(*Continued*)

TABLE 2.1 (*Continued*)

Links between the Sustainable Development Goals and Culture

SD Goal No	Sustainable Development Goal	The role of culture in implementing the Sustainable Development Goal
Goal 13	Take urgent action to combat climate change and its impacts. Indicator: 1. The percentage of national and local climate change strategies that consider the role of the cultural aspect of promoting environmental sustainability.	Intercultural activities and traditional knowledge of environment-friendly practices must be explored and promoted. Cultural professionals have the opportunity to inform the public about climate change and its consequences through cultural activities.
Goal 14	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.	The goal can be implemented by identifying and strengthening certain cultures that maintain traditions related to the preservation of marine and coastal ecosystems.
Goal 15	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation as well as halt biodiversity loss.	Cultural factors related to the preservation of terrestrial ecosystems including relevant local and traditional knowledge must be included in the preparation, implementation, and evaluation of policies and programmes in this field.
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable and inclusive institutions at all levels. Indicators: 1. Laws ensuring the right to receive information from public institutions, based on international standards. 2. Legal regimes ensuring compliance with international standards on freedom of expression, association, and assembly. 3. The percentage of libraries regularly providing specific training on media and information literacy competences in order to help users access and use information.	In order to implement this Sustainable Development Goal, nationalised and otherwise expropriated cultural objects should be returned to the concerned communities. Citizens should be able to participate in the preparation, implementation, and assessment of cultural policies and programmes. Cultural objects, including libraries and media centres, promote access to the information. Strategies that condemn violence and promote peace shall also include a cultural component.

(*Continued*)

TABLE 2.1 (*Continued*)

Links between the Sustainable Development Goals and Culture

SD Goal No	Sustainable Development Goal	The role of culture in implementing the Sustainable Development Goal
Goal 17	Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development.	The cultural aspect should be integrated into international, national, and local sustainable development strategies seeking to implement the 2030 Agenda. The capacity of cultural stakeholders to address the challenges of sustainable development should be strengthened, whereas capacity building should also enable other sustainable development groups to understand the importance of cultural aspects. The capacity of cultural stakeholders to produce and distribute cultural goods and services, particularly those representing lesser-known cultural expressions, should be increased.

Source: Created by authors.

2.2 The Link between Sustainable Development and Climate Change

A close link exists between sustainable development and climate change. Since their main connection is energy, it is necessary to examine how policies of sustainable development and climate change can be identified and implemented together. A system of indicators is necessary to establish a link among the Millennium Development Goals (which are the key targets of sustainable development policy), national development, and climate change mitigation programmes.

In the Third Assessment Report by the Intergovernmental Panel on Climate Change (IPCC), a chart linking climate change, natural systems, people, and opportunities for socio-economic development was introduced.

In Figure 2.1, the interaction between the climate change mitigation policy and adaptation efforts is presented.

Figure 2.1 vividly illustrates how paths of socio-economic development affect GHG emissions as well as climate change, which leads to changes in human and natural systems.

Following the IPCC report, several studies had emerged that addressed climate change and sustainable development in a comprehensive manner. These studies aimed to establish a clear divide between natural processes

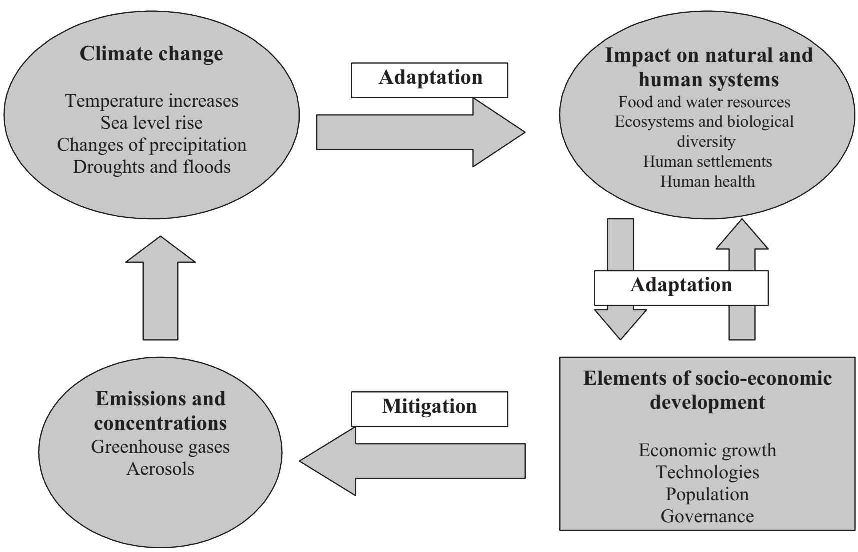

FIGURE 2.1
Interaction among policies of sustainable development, adaptation, and climate change mitigation.

Source: Created by authors.

with their outcomes and their relation to human and social activity outcomes, which are determined by the implementation of policy provisions. These policies include direct climate change mitigation measures as well as more general policies that impact vulnerability due to climate change together with adaptation and mitigation capabilities.

Furthermore, we will examine the options for sustainable development, climate change, adaptation, and mitigation as well as their links in more detail. When it comes to climate change mitigation and adaptation, it must be recognised that these processes are influenced by the trajectory of development together with institutions implementing it and by the specific options available for climate change mitigation and adaptation. This means that policy-driven development trajectory and institutions implementing it, despite their broader development targets, have an indirect impact on climate change adaptation and mitigation.

This impact can be both positive and negative. Several studies had been developed that proposed integrating climate change mitigation and adaptation into development policies to ensure more sustainable development (Munasinghe 1991).

Kenneth Joseph Arrow proposed a method to assess alternative options for consumption growth in the long run from a sustainable development perspective. Intermediate consumption and usefulness are used as criteria for assessing sustainable development. One of the determinants of consumption and usefulness is the productive base of society, which consists of capital (productive, human, natural) and institutions. Institutions can be understood as a part of the capital as well as a guide for resource (and capital) distribution. Institutions cover the legislative framework, formal and informal markets, various state agencies, interpersonal networks, and the rules of conduct and the norms on which they base their activities (Arrow et al. 2012).

From the perspective of sustainable development, it is important how and to what extent policies can affect the productive base of society, while ensuring that the development trajectory is more sustainable when implementing certain adaptation and mitigation policies.

Policy on climate change mitigation or adaptation can be considered as a starting point, while sustainable development can be seen as a result of the indirect influence of this policy. This approach is focused on more specific sectoral policies or climate change policy instruments that ensure adaptation and mitigation targets but are not necessary for all dimensions (social, economic, and environmental) of sustainable development. This shows that climate change policy will be held back by the compatibility of development goals with the global environment. Besides, policies that fail to assess the economic and social consequences may remain unsustainable for a long time.

The next figure presents a chart of interaction among climate, natural systems, and society as well as the impact of policies among themselves.

Figure 2.2 shows three systems represented by ellipses: climate change, natural system, and socio-economic system. GHG emissions affect the climate

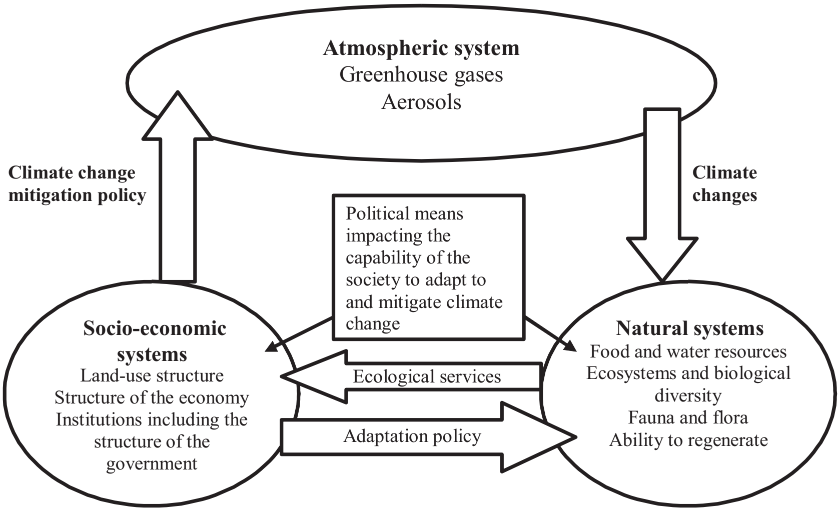

FIGURE 2.2
Interaction among climate, natural, and socio-economic systems and their connection with climate change adaptation and mitigation.

Source: Created by authors.

system and cause climate change, which impacts the natural system again. The impact of climate change on the natural system depends on the vulnerability of the system and its ability to resist those impacts. As a result, ecological services are provided to the public such as agricultural land, fishery resources, water resources, etc. It should be stressed that the mutual influence of all systems is complex and non-linear, making it difficult to assess all aspects of the links among them.

The response to climate change depends on the productive base of society, which includes capital, institutions, and adaptation and mitigation capabilities. Policies aimed at ensuring the productive base of society and the capacity for adaptation and mitigation are presented in Figure 2.2 and grouped in one division. In addition, the policies that are divided here have many synergistic effects, which together affect the natural system and the achievement of Sustainable Development Goals.

In this conceptual framework, adaptation and mitigation policies are treated as more isolated policy efforts such as investments in protective measures (dams, new types of crops, technologies to reduce GHG emissions, carbon taxes, etc.), which only affect the marginal response of the production base of society. The factual outcome of specific mitigation and adaptation policies depends on adaptation and mitigation capacities that are part of the social, economic, and natural state of systems. Together, the results of adaptation and mitigation policies depend on the propulsion of social and economic development such as investments, technologies, population, governance, and environmental priorities.

> Dual-link: climate change → sustainable development and sustainable development → climate change

There is a dual-link between climate change and sustainable development. On the one hand, climate change affects the main natural and living conditions together with the social and economic development foundations, but, on the other hand, society's sustainable development priorities impact both vulnerability and GHG emissions.

Many discussions on the links between sustainable development and climate change were initiated in the IPCC Third Assessment Report. The synthesis report stressed the importance of understanding the links between climate change and sustainable development and concluded that climate change issues are a part of the broader challenges of sustainable development. As a consequence, climate change policy can be much more effective if it is consistently integrated into the wider regional and national sustainable development strategies since the climatic diversity and changes, the response to climate change policies and the related socio-economic development will affect the country's capacity to implement Sustainable Development Goals. And vice versa, the realisation of the Sustainable Development Goals will impact the potential of climate change policies and the success of their implementation. The socio-economic and technological characteristics of different development trajectories will have a huge impact on GHG emissions, climate change and its influence, and the capacity to adapt and mitigate climate change.

The key findings of the IPCC are more conceptual and confirm that sustainable development can serve as a framework for understanding society's ability to respond to climate change.

Climate change will also affect sustainable development: due to the negative impact of climate change on ecosystem services, human health, agricultural production, and many other areas, it will be more difficult to implement Sustainable Development Goals. The impact of climate change on development perspectives has been described as a comprehensive poverty reduction and climate change mitigation project "Climate change will complement existing poverty". The negative effects of climate change will be stronger in developing countries, as the latter have limited capacity to adapt to climate change. In these countries, the poorest sections of society with the least resources and the least capabilities to adapt will be the most vulnerable. Predicted changes of extreme climate events in their frequency, power, and intensity as well as average climate changes will mainly affect their quality of life and continue to increase inequalities between the developing and developed world. Thus, it can be stated that climate change is a strong source of poverty growth.

By recognising the dual-link between sustainable development and climate change, it must be stressed that policies shall simultaneously cover both sustainable development and climate change mitigation and adaptation targets.

2.2.1 Development Targets and Sustainable Development Tasks

The concept of sustainable development had been long discussed in the theoretical literature until it became the most significant target in economic, social, and environmental development of Agenda 21, UN institutions, national governments, and private individuals. There are many definitions of sustainable development, but here we will use a significantly pragmatic perception of sustainable development as the goal of human well-being both from a short- and long-term perspective.

The simplest concept of sustainable development is defined as co-development ensuring economic, social, and environmental development targets. These targets can be expressed by a number of economic, environmental, human, and social indicators, while the impact of the implemented policies on sustainable development can be assessed both quantitatively and qualitatively. Table 2.2 provides examples of the main dimensions of sustainable development.

As a starting point for the links between sustainable development and climate change, basic Sustainable Development Goals such as health, education and energy, food, and access to water can be achieved through good governance and without impacts of climate change. Thus, the Sustainable Development Goals are addressed together with the current development targets and the challenges of achieving them.

Using such a pragmatic approach to the concept of sustainable development requires the acknowledgement that the main conceptual assumptions are based on the key development paradigms and analytical approaches which are used in many sustainable development studies. The perception of development goals and the discovery of a compromise among different policy targets depend on the applied development paradigm. Therefore,

TABLE 2.2

Examples of Economic, Environmental, Human, and Social Dimensions of Sustainable Development

Economic Dimensions	Human Dimensions
Economic growth	Training and education
Investments	Health
Technological changes	Gender
Revenue in specific areas	
Environmental dimensions	**Social dimensions**
Atmospheric pollution	Governance
Water pollution	Income distribution
Waste	Participation
Biodiversity	Justice
Depleting resources	

Source: Created by authors.

in this chapter, we will show how policy recommendations on sustainable development and climate change depend on alternative approaches to the development itself.

A system of sustainable development indicators aimed to measure policy decisions at the lowest and highest levels, called Action Impact Matrix (AIM), was developed by Mohan Munasinhge. AIM links national development targets and programmes with the assessment of sustainable development indicators and the involvement process of governmental authorities, academic and civil society as well as the private sector.

Alternative development paradigms: The development targets of different paradigms, as well as different scientific disciplines, are treated differently. The development approach in paradigms is the basis on which the key elements, necessary to be evaluated in order to establish the link between development and climate change and its dynamics, are determined. Further, we will examine many development paradigms and their impact on climate change mitigation studies.

Paradigms based on economic theories usually define a number of goals that are important contributions to the well-being of people. In this case, development goals can be perceived as functional elements of a certain value. The value function reflects the results of individual utility by using various goods and services.

Some economic paradigms rely on the economic welfare function, where efficient resource allocation is approached as in neoclassical economics, while deviations from this state and ways of overcoming these deviations are not addressed. From the point of view of these paradigms, the link between sustainable development and climate change is approached as a simple statement that climate change mitigation only leads to additional costs for optimal status.

Meanwhile, other economic-based paradigms, such as institutional economics, are more focused on formulating a question: how do markets or other information-sharing mechanisms provide the basis for economic interaction? In this context, the main idea is how mitigation policies can be integrated into the institutional framework of the economy. Thus, the institutional approach to climate change analysis involves the assessment of the work of existing institutions and making proposals on improving their work by assessing market weaknesses and limited capacity. Furthermore, institutions include governance and political systems that are the main factors for determining development trajectories.

For example, Partha Dasgupta recommends studying the allocation of resources as a counterpoint to the effects that can be measured by parameters of well-being. Possibility to get an income and meet basic needs (education, food, energy, medical services) is considered the basis of the human being (Dasgupta 2000, 2003).

In the context of climate change mitigation policies, it should be examined whether and to what extent, policies may impede or facilitate access of individuals to specific resources and freedoms. In some cases, mitigation policies may prove to be too expensive if more expensive types of energy carriers are introduced, while, in other cases, they may increase the access to energy if energy conservation measures are introduced and energy becomes more affordable.

This approach is close to the paradigms of social sciences, which are based on the ethics of liberalism or equalisation and emphasise the rights of individuals to participate in decision-making and goal achievement processes. These theories shape the assurance of individual freedoms, so issues such as the link of risk and justice with climate change will be addressed by studying the local participatory process.

Development trajectories: When analysing possible development trajectories, it is very important to recognise that several different definitions of sustainable development exist based on the concept of sustainable development established by the Brundtland Commission.

If we regard sustainable development as the policy target, then the important question is how policies can ensure a more sustainable development trajectory. Society's development trajectory is exposed to many important decisions relating to investments, use of natural resources, lifestyle and consumption, selection of technologies as well as the institutional structure, which leads to the base conditions of these choices. All of this can be achieved through sustainable development policies.

Sustainable development policies cannot be strictly separated from other policies; however, a variety of policy recommendations, which cover different components, can still be discussed. They include many policies related to nature conservation, laws regulating access to resources, environmental taxes, promotion of organic agriculture, the increasement of human and institutional capital, research and development, financial schemes, and technology transfers. These policies are usually not implemented as a part of the general sustainable development policies package, but as policies, dedicated to addressing specific policy targets such as air pollution standards, organic food and health issues, GHG emission reduction, income generation for specific groups of people, or the development of green technology industry. In this way, the development trajectory is obtained as a result of many economic and social transactions initiated by governmental policies, private sector initiatives, and choices of consumers.

There are a great number of scientific studies, which are based on economic theories and complex systemic methodology, ecological science, as well as other methodologies and determine the conditions under which the development of the trajectory meets the sustainable development requirements. Arrow summarised the controversy of discussions between economists and ecologists concerning the nature of current development and its compliance with the criteria of sustainable development. Economists are looking into the ability of the economy to maintain an adequate standard of living and state that welfare should be optimised to ensure that current consumption is not excessive. However, it is difficult to determine the optimal level of current consumption; thus, the theoretical debate revolves solely around the factors leading to development that is not sustainable. Those factors include the link between market return on investment and social discount rates and the link between market prices for goods and their social costs.

2.3 Implementation of Sustainable Development and Climate Change Policies

The impact of climate change policy on development policies: Studies aimed at evaluating the impact of sustainable development on climate change and vice versa explore a number of current development challenges. Here, we will overview international policy initiatives and solutions that include development goals as well as discuss how climate change issues can be addressed in conjunction with development goals. We will also look at many examples of how countries that have formulated development goals also consider mitigation aspects of sustainable development.

Many international initiatives, including the World Summit on Sustainable Development 2002 (WSSD) and the actions of the Commission on Sustainable Development, have set many different goals for different sectors related to climate change mitigation policies. We will take a look at these initiatives below.

The main decision of the World Summit on Sustainable Development was the confirmation of the Water, Energy, Health, Agriculture, and Biodiversity (WEHAB) initiative's connection with sustainable development (World Summit on Sustainable Development 2002). The WEHAB sectors reflect the main areas in which WSSD countries consider it necessary to establish policies in order to implement Agenda 21. The justification document prepared for the WEHAB presents numerous policy measures in different sectors that relate to climate change issues. Below a description of the main sectors and policies is presented.

Water: Ensuring safe water supply, water management, agricultural efficiency, human health, disaster preparedness, financial resources, institutional and technical capacity, and protection of water systems.

Energy: Accessibility, efficiency, renewable energy, advanced organic fuels, and transportation.

Health: Reduction of poverty and malnutrition, access to health services, reduced infant, child and maternal mortality, control and eradication of major diseases, planning, link with the environment, risk management capacity, and crisis preparedness.

Agriculture: Increasing productivity and sustaining the natural foundation, knowledge generation and information transferring, partnerships between public and private sectors, and political and institutional reforms.

Biodiversity: Integrating sustainable development into economic and sectoral development plans, and restoring and protecting biodiversity.

Aspects of climate change policy can be linked to the Millennium Development Goals (MDGs). Commission on Sustainable Development stressed that climate change could only worsen the situation of the poor and hinder the implementation of the Millennium Development Goals. SDS has proposed to complement the MDGs with energy development tasks to strengthen the connection between the MDGs and climate change mitigation.

MDGs could be linked to energy, food, water access, and climate change impacts as well as vulnerability and adaptation (Table 2.3).

The basis for the joint implementation of sustainable development and climate change policies is illustrated in Figure 2.3. It consists of the general state of the natural environment, the socio-economic system, and policy priorities. The latest international trends in sustainable development and management of climate change are the increasing involvement in these processes by various institutions and other stakeholders. These stakeholders include international agencies, global forums, private companies, and non-governmental organisations. The involvement of various stakeholders in this process creates new opportunities to combine international agreements and commitments with voluntary action and market-driven processes. Several new initiatives by private efforts are to combine green business, sustainable development, and climate change mitigation.

Many companies have included voluntary commitments in their development strategy reflecting their social responsibilities and environmental goals that go beyond their traditional responsibilities. The majority of companies voluntarily commit to reducing GHG emissions. Several international networks are promoting these initiatives: World Business Council for Sustainable Development (WBCSD), The Climate Group, etc. These initiatives serve as platforms for collaboration among companies, non-governmental organisations, governments, and other stakeholders.

WBCSD has identified the following main targets for private companies in order to mitigate energy and climate change:

- to ensure long-term success in a competitive business environment;
- to achieve the objectives of national and regional climate change mitigation policies;
- to assess risks and economically effective options for reducing pollution; and
- to participate in the innovation process of processes and products.

TABLE 2.3

The Link among the Millennium Development Goals, Energy, Food, Access to Water, and Climate Change

Goals	Sectoral Subjects	Relations to Climate Change
From 1990 to 2015, to reduce the proportion of people whose income is less than 1 USD a day	Energy: • Energy supply to local businesses • Facilitation of income generation • Energy supply to the equipment • Employment related to energy supply Food/water: • Increment of food production volumes • Improved water supply • Employment	Energy: • GHG emissions • Increased adaptive capacity due to higher incomes and reduced dependence on natural energy sources Food/water • GHG emissions • Increased agricultural productivity can reduce climate change • Better water supply management can help adaptability
From 1990 to 2015, to reduce the proportion of people who suffer from hunger	Energy: • Energy supply for machinery and irrigation equipment in agriculture Food/water: • A more efficient production process which increases production volumes and reduces waste • Land and food distribution	Energy: • GHG emissions Food/water: • Increased GHG emissions from some agricultural activities; however, it is partly offset by better use of agricultural waste • The ability of farmers to adapt depends on the income and the form of land ownership

(*Continued*)

TABLE 2.3 (*Continued*)

The Link among the Millennium Development Goals, Energy, Food, Access to Water, and Climate Change

Goals	Sectoral Subjects	Relations to Climate Change
To ensure that by 2015 children will have access to primary education everywhere	Energy: • Reduced time to provide energy • Electricity for reading • Electricity for educational information means, including TV and computers Food/water: • Shorter time in this sector allows devoting more time for education • Better health increases children's ability to read	Energy: • Education can strengthen the ability to mitigate climate change Food/water: • Education can strengthen the ability to mitigate climate change
To ensure that girls and boys have equal access to primary and secondary education by 2005 and to the education of any level by 2015 at the latest.	Energy: • Due to modern energy services young women or girls no longer need to provide themselves with energy and they have more free time • New electronic educational tools are making it easier for girls to access information at home Food/water: • Modern agricultural production technologies and improved water supply	Energy: • Education can strengthen the ability to mitigate climate change Food/water: Education can strengthen the ability to mitigate climate change

(*Continued*)

TABLE 2.3 (*Continued*)

The Link among the Millennium Development Goals, Energy, Food, Access to Water, and Climate Change

Goals	Sectoral Subjects	Relations to Climate Change
From 1990 to 2015, to reduce the mortality rate of children under five by two-thirds	Energy: • Energy supply can speed up the development of healthcare facilities • Reduced air pollution from sources that use traditional fuel for combustion • Reduced time spent on collecting fuel may increase time spent on children's healthcare Food/water: • Improved health due to increased supply of high-quality food and clean water • Reduced time spent on providing food and water can increase the time spent on children's healthcare	Energy: • GHG emissions Food/water: • Improved health increases the ability of adaptation
From 1990 to 2015, to reduce maternal mortality by three quarters	Energy: • Electricity supply to health clinics • Reduced air pollution from sources that use traditional fuel for combustion and other health improvements Food/water: • Improved health due to increased supply of high-quality food and clean water • Reduced time spent on providing food and water can increase the time spent on children's healthcare	Energy: • GHG emissions Food/water: • Health improvement increases the vulnerability of climate change and the ability of adaptation

(*Continued*)

TABLE 2.3 (*Continued*)

The Link among the Millennium Development Goals, Energy, Food, Access to Water, and Climate Change

Goals	Sectoral Subjects	Relations to Climate Change
AIDS, malaria, and other serious diseases	Energy: • Electricity for health facilities • Cooling of vaccines and medical devices Food/water: • Improved health due to cleaner water supply • Manufacturing technologies of the food industry that reduce the likelihood of malaria	Energy: • GHG emissions from the increased health clinic service; however, health improvements may reduce the need for health clinics Food/water: • Health improvement increases the vulnerability of climate change and the ability of adaptation
To stop the unsupported exploitation of natural resources	Energy: • Deforestation allows waste fuel to be collected • The usage of non-renewable resources Food/water: • The decline in land ownership	Energy: • GHG emissions • Separation of carbon Food/water: • Separation of carbon • Better conditions in agricultural production increase adaptability
From 1990 to 2015, to reduce the proportion of people who cannot access drinking water	Energy: • Electricity for pumping and distribution systems Water: • Better water systems	Energy: • GHG emissions Water: • Increased vulnerability and adaptability
To expand global cooperation in development		

Source: Created by authors.

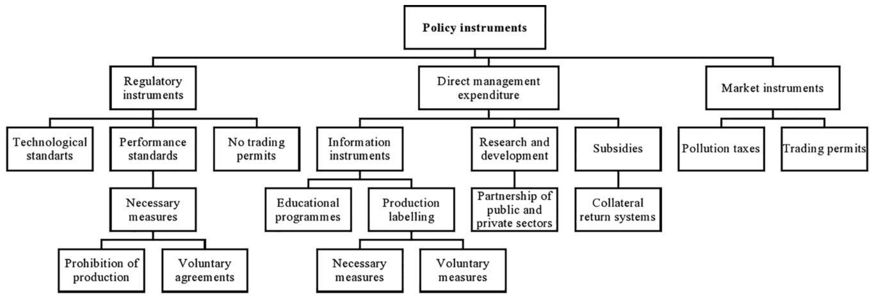

FIGURE 2.3
Measures of the climate change policy.

Source: Created by authors.

The WBCSD has prepared guidelines for monitoring and accounting for GHG emissions under IPCC GHG inventory standards. The WBCSD also emphasised the importance of accounting for GHG emissions in order to demonstrate eco-efficiency and to maintain the company's image of accountability and transparency. In addition, the implementation of this GHG accounting methodology allows companies to participate in emissions trading.

Moreover, insurance companies have their own rules of operation which include activities for ensuring sustainable development and climate change (Munich RE initiative). An example of a non-governmental organisation's initiative combining the goals of sustainable development and climate change mitigation is The Gold Standard prepared by the WWF. The Gold Standard is designed to assess how CDM projects can support the broader Sustainable Development Goals and if they are not included in their GHG reduction tasks.

Climate change mitigation measures: Each country chooses individual climate change mitigation measures. On the basis of the IPCC Third Assessment Report, the following chart of all the climate change mitigation measures is drawn up. Thus, the main climate change mitigation policies can be grouped as follows:

- market-based mechanisms (pollution taxes, emission allowances, subsidies, and collateral return systems);
- regulatory instruments (emission permits, operating and product standards, and prohibitions);
- voluntary agreements; and
- direct government expenditure on research and development (or subsidies/financing of information tools, including educational programs and eco-labelling schemes).

Each of these climate change mitigation measures has its own disadvantages and advantages when comparing with others. The IPCC Third Assessment

Report indicates that various policies that are not related to climate change could influence the dynamics of GHG emissions. These may include structural reforms, for example, the pollution control in the energy sector that is trying to reduce the negative impacts on human health and afforestation for economic or biodiversity's preservation reasons or for salinity control reasons.

The main feature of market-based instruments is that they apply economic incentives to pollution control through pollution taxes and emissions trading allowances. They encourage polluters to adjust to market prices or pollution levels.

Regulatory instruments form the technological and performance standards and project the fuel that is used or the fuel that cannot be used. These types of instruments are applied at a national, sectoral, or company level. They are typically introduced before the market-based instruments and create opportunities for institutional capabilities in the spheres of policy evaluation, monitoring, and enforced implementation.

Voluntary agreements are agreements between a governmental body and a private company, or a unilateral agreement recognised by a public authority. They differ from the regulatory instruments because they are not mandatory and there are no penalties for non-compliance. They demonstrate a mutual responsibility of the contracting parties and are applicable internationally and nationally; they also have low transaction costs and flexibility in implementation.

Information instruments help to overcome the market disadvantage related to the asymmetry of information. Two main information instruments can be used both nationally and internationally: educational programs and eco-labelling. Educational programs are designed to fill knowledge gaps that hinder climate change risk assessment. They also introduce pollution reduction actions such as energy-saving initiatives.

Environmental labelling programs, whether mandatory or voluntary, send signals to users about the characteristics of the equipment (energy efficiency of the equipment). An example of voluntary labelling is the labelling of organic products or ethical trademarks.

The third group of information instruments has recently been identified – informing the industry of long-term indicative goals of the government. For example, the long-term goals for reducing GHG emissions or the tasks of renewable energy sources in the primary energy structure.

An alternative way to tax pollution is the subsidisation of less polluting fuels or energy efficiency improvement measures. Both methods have an impact on energy prices and are favourable for technologies that emit less GHG emissions as well as for clean fuels. Subsidies and pollution taxes are sometimes combined when the taxes for the sold energy are used to subsidise renewable energy.

The following criteria shall be met to select appropriate climate change mitigation measures:

- environmental effectiveness looking from a long-term perspective;
- environmental effectiveness in terms of transaction, information, and forced implementation costs;
- impact on resource redistribution;
- the possibility of administrative and political implementation;
- the dynamic effect related to the learning, innovation, and technological development processes;
- the other economic effect (income redistribution); and
- the other environmental impact (the assurance of ambient air quality).

Countries can select several policies or use them in succession, for example, to introduce technological standards first and then – performance standards. Finally, they could introduce market-based instruments.

Promotion of the spread of innovations and new technologies is a very important means of climate change mitigation. Usually, the government uses subsidies, research funding programs, green purchasing of environmentally friendly technologies as well as a complex of climate change mitigation measures. That way the strengths of the various instruments can be combined, and their negative impact reduced.

Climate change mitigation policy and associated costs include a range of measures used for market development and broader institutional policies (Table 2.4).

When defining climate change mitigation policies, certain assumptions are made in the energy sector (Table 2.5). These assumptions are very important when choosing climate change mitigation policies and justifying the expediency of using the proposed instruments. The most important assumptions are based on population, economy, energy demand growth forecasts, the elasticity of prices and services, discount rate, etc.

Table 2.6 shows the relation between climate change policy and the different dimensions of sustainable development. As can be seen, climate change also has a direct impact on economic growth opportunities and many important social factors as well as political and social issues. In addition, the effects of climate change can be identified domestically and globally.

The most significant thing when selecting the climate change policy and measures for its implementation is to take into account its impact on sustainable development and to harmonise climate change policies with those of sustainable development; otherwise, the climate change mitigation can have even more negative effects than climate change itself. This is particularly the case with developing countries, which are the most vulnerable to climate change but have limited possibilities to adapt to it. Therefore, in these countries, climate change mitigation policies need to be integrated into their country's sustainable development strategies, and their implementation should not hinder the achievement of the MDGs.

TABLE 2.4

Examples of Policy Measure Implementation Related to Climate Change

Market Measures	**An Example of a Policy Measure**
The development of the market during the transitional period, possibly involving the public sector	Temporary support for special demonstration projects
Privatisation with precise identification of property rights and individual requirements	Land ownership rights
Competition regulation by introducing more market players	Information companies, flexible loans for the expansion of technologies that use renewable resources
Environmental taxes	Carbon taxes
Support for efficiency through savings and stimulation of investments	Support by the financing mechanisms
Publishing of technical standards within the relevant period	Standards for the effective use of electrical appliances
Price liberalisation, support for the international competition	Change in the rate of devaluation, elimination of the subsidies
Redirecting Policy towards Flexibility and Constraint of Acknowledged Technical Systems	
Time selection of infrastructure investments	Long-term planning of energy production and transmission
Subsidies for capital turnover projects	Special capital grants
Subsidised credits for research development	Demonstrations and research programmes
Coordination of specific climate change mitigation measures and their integration into the common investment policy	Information, subsidies
Established (Institutional) Policy Measures	
Establishment of monitoring and the enforced implementation systems	Reporting systems
Established and imposed property rights	Land reforms
A structure to mitigate the risk and/or to reduce the accumulated risk (especially in the capital market) is established	A balanced market
Establishment of specialised organisations to reduce uncertainty and transfer information	Insurance schemes
To implement an international mechanism for technology "transfers"	Clean Development Mechanism
Policy Measures Concerning Human Opportunities	
Learning and educational activities	Opportunity development programmes
The improvement of decision-making processes	Participation, local government
Educational programmes	Providing energy and transport for schools

Source: Created by authors.

TABLE 2.5

Assumptions for the Climate Change Mitigation Policy in the Energy Sector

Assumptions Are Introduced	Meaning and Relevance
Population	Growing population increases GHG emissions
Economic growth	A growing economy increases energy consumption and makes it possible to increase investments, which accelerate the growth of the energy-using equipment
Energy needs • Structural change • Technological change • Lifestyle	Different sectors have different levels of energy consumption intensity; structural changes have a major impact on overall energy consumption Different assumptions in the areas of the intensity of GHG emissions and the use of resources can be used for alternative scenarios
Energy supply • Presence of technology and prices • New technologies • Learning	Possibility for fuel and technology replacement Electricity prices that make alternative electricity supply possible Technology costs related to time, market scale, and institutional competence Opportunities for the introduction of new technologies
Elasticity of prices and revenue	Relative changes in the energy needs due to the changes in prices or revenue; higher elasticity results due to larger changes when energy is used
Implementation and contractual prices	The scope of implementation, regulatory framework, institutional competence, administration
Discount rate	Time The potential price of the capital Assumptions of risk Uncertainty
Policy instruments and regulation • Instruments • Obstacles	Economy against the regulatory measures Implementation costs including the cost of overcoming obstacles, the form of institutional aspects or market trends, including building opportunities and institutional reforms; functioning assumptions
Existing tax system and tax refund	Carbon tax refunds; replacement of distorting taxes
Additional benefit	Integration of local and regional policy measures into many production cases Secondary benefit Targets of social policy: income distribution and employment

Source: Created by authors.

TABLE 2.6

The Impact of Climate Change on Different Dimensions of Sustainable Development

Dimensions of Sustainable Development	Impact of Climate Change	
	Domestically	**Outside the Country**
Economy	Increased vulnerability of agricultural technologies enhances inequality	As the negative effects of climate change in developing countries increase, inequality increases as well
Health	The poorer people suffer from lower general health standards and reduced access to healthcare	Effects of floods and diseases are more important in developing countries
Social security	All sectors are affected but those that depend mainly on natural resources are affected the most	Greater impact in developing countries
Gender	As the main users of natural resources, women are individually affected by climate change	Economic gender inequality increases
Access to the welfare of society	Government cost-sharing to mitigate the effects of climate change impacts everyone, but it will mostly affect the poor	Adaptation costs are higher in poor countries
Political and social freedoms	With the possibility of social destruction, freedoms can be ruined	The impact of migration can be felt in all countries

Source: Created by authors.

2.4 Sustainability Assessment Methods

Sustainability assessment methods can be divided into four key groups: indicators and indices, sustainability assessment means at the level of products (production methods) as well as at project, and country levels. All these means can be further subdivided based on their sustainable development dimensions (environmental, social, economic, integrated, and including all sustainable development dimensions) (Table 2.7).

2.4.1 Indicators and Indices

The first group for sustainability assessment consists of *indicators*. Indicators are a simple tool that allows assessing the economic, social, and environmental development goals of a country. If environmental, social, and economic indicators are integrated into a single indicator, they make an *index*. Indicators must show the following features: simplicity, wide coverage, and an ability to perform a quantitative assessment that helps to determine tendencies. Tendency assessment allows you to make short-term forecasts.

TABLE 2.7

Sustainability Assessment Methods

	Indicators/Indices	Products, Technology Assessment	Project Assessment	Sectoral, Country Assessment
Environmental dimension	Environmental pressure indicators Ecological footprint	Life-cycle assessment Material input per unit of service Material flow analysis Energy flow analysis Exergy analysis Emergy analysis	Environmental impact assessment Ecological risk analysis	Environmental extended inter-branch balance Inter-branch energy balance Strategic environmental impact assessment Regional emergy analysis Regional exergy analysis
Economic dimension	General national production volume	Life-cycle costs	Accounting of all life-cycle costs	Economic material flow analysis Economic flow analysis Economic inter-branch balance
Social dimension	Social indicators		Social impact assessment	Social inter-branch balance
Integrated method	Human Development Index Environmental Sustainability Index Welfare Index Sustainable national income Genuine progress indicator Genuine savings indicator		Cost–benefit analysis Risk analysis	Multi-criteria analysis Vulnerability analysis
Sustainable development	UN Sustainable Development Goal indicators Sustainable energy development indicators			Conceptual framework System dynamics Sustainability impact assessment Integrated sustainability assessment

Source: Created by authors.

All the tools and indicators of this category can be grouped into non-integrated and integrated indicators (indices). Regional flow indicators make a different class.

Environmental Pressure Indicators (EPIs), prepared by the European Union Statistical Office EUROSTAT (European Commission and Eurostat 1999, 2001), are an example of non-integrated indicators. EUROSTAT collects these indicators for EU member states and regions, in co-operation with the statistical departments of these countries. EPI consists of 60 indicators, 6 indicators for each political sphere, set by the Fifth Environmental Action Programme (Lammers and Gilbert 1999). In each political area, these six indicators may be aggregated into indices, which, in turn, make up ten environmental pressure indices. The entirety of these indicators, which consist of, e.g. damage to forests, the intensity of tourism, and polluted soil, is dedicated to assessing the environmental protection sustainability of EU member states. These indicators allow the comparison of countries and the assessment of their tendencies.

Another example of non-integrated indicators is the collection of 58 indicators, used by the United Nations Conference on Sustainable Development (UNCSD 2001). These indicators include not only the economic, environmental, and social dimensions but also the institutional dimension. Such an indicator system is not integrated. Examples may include water quality level, national literacy rate, population growth rate, gross domestic product (GDP) per capita, and a number of ratified international agreements. Since 1994, based on these indicators, countries have been preparing reports to the European Commission and accounting for their results of meeting sustainable development goals (United Nations 2002).

Sustainable Energy Development Indicators include social, economic, and environmental energy sector dimensions. The indicator system was created by the International Atomic Energy Agency, EUROSTAT, and United Nations. These indicators are not integrated and are used for the sustainability assessment of the country's energy sector. By using these indicators, it is possible to assess the sustainable energy development tendencies and take proper actions to change or promote these tendencies.

Material and Energy Flow Analysis allows analysing the resource flow structure and finding inefficient manifestations in the system. This indicator class can be used for historical reconstruction of flows and emissions as well as decision-making. Material Flow Analysis (MFA) analyses physical metabolism of the society in order to support dematerialisation processes and to reduce the negative impact on the environment, related to wasteful resource usage (Kleijn and Adding 2001). MFA studies have been performed in many countries and regions (Fischer-Kowalski and Hüttler 1998). In addition, the number of MFA has significantly increased in recent decades. This indicator class is non-integrated; these indicators include only physical flows, so they analyse the environmental dimension. MFA of all economy, calculated by EUROSTAT (2001), is a standard MFA tool for the EU countries.

World Resources Institute MFA studies for the developed world countries were the initial tool to standardise MFA in the European Union. EUROSTAT has prepared guidelines for the MFA economy assessment. In the EUROSTAT guidelines, material flow indicators are divided into three categories: input, outflow, and consumption. Each category includes different levels based on whether it involves local, foreign, or hidden flows. Hidden flows are the flows that are not included in the economic system, i.e. excavation, soil erosion, etc. (Matthews et al. 2000).

Material Input Indicators show material inflow into the economy through local production and consumption. *Material Outflow Indicators* measure all material outflow back to the environment or pollutants disposed of to the environment during the production or consumption processes. *Material Consumption Indicators* measure all material consumption in the economy.

Substance Flow Analysis (SFA) involves the regional flows of certain chemical materials and environmental losses related to them (Lindqvist and von Malmborg 2004). The goal of the SFA is to reduce the pressure of certain materials to the environment. The SFA is carried out at a regional or country level to identify problematic areas. It is useful for planning and managing an environmental policy.

Energy Flow Analysis covers energy flows in the economy. It is based on the first law of thermodynamics or energy persistence, which states that the amount of energy is constant, cannot be created or destroyed, and can only transfer from one form to another. Energy analysis of a country or a region is performed by using the *input–output energy analysis,* based on Wassily Leontief's economic input–output matrix, which analyses flows among different industry branches in the economy. In the case of energy flow analysis, among industry branches or sectors, sale flows are changed to energy flows (Finnveden and Moberg 2005).

In addition, energy analysis can be performed by using *exergy and emergy analysis*. This analysis is advanced because both the quality of energy and its quantity are considered during it (Rosen and Dincer 2001; Herendeen 2004). System exergy is the maximum amount of mechanical work that can be generated. Exergy analysis shows the efficiency of material usage and where losses form as well as where technological upgrades can be made in order to increase the efficiency of energy. The results of regional exergy analysis, conducted in Sweden, Japan, and the United States, allowed preparing the methodology of regional emergy analysis, the base of which is constituted of the expression of all resources and goods in a single unit of measurement – solar emjoules, i.e. the amount of solar energy needed to produce them.

There are many efforts to integrate sustainable development indicators in order to create one index that reflects the achievements of sustainable development (Gerlagh et al. 2002). The first efforts were directed towards supplementing new indices of national report systems such as GDP and net national income, which are meant for general welfare assessment. The latter sent false signals about the level of the achieved welfare since the achievements of sustainable development such as income distribution inequality, public safety, material overexploitation, or non-evaluation of external costs had not been assessed.

A larger variety of GDP modifications were proposed because of its limitedness in assessing environmental dimensions and willing to set an adequate life quality indicator. All of them were meant for the performance assessment of sustainable development.

Sustainable National Income (SNI) is an index created in the Netherlands. The main point of this index is GDP modification that includes sustainable resource consumption into the national income report. SNI does not directly assess social factors. It is a comparison of national income, calculated by principles of sustainability, and traditionally calculated national income. The difference between these two values shows the dependency of a country on production resource consumption that exceeds sustainable resource consumption calculated by logistic growth models (Gerlagh et al. 2002).

Index of Sustainable Economic Welfare (ISEW), created by Herman Daly and John Cobb, as well as the *Genuine Progress Indicator* (GPI), created by the organisation Redefining Progress, involves economic, social, and environmental dimensions. All these indicators are GDP modifications by adjusting national account modifications in order to include a larger number of welfare determinants such as military expenditure, environmental degradation, and natural capital depreciation. They have been calculated for many countries.

Genuine Savings Indicator (GSI) is meant for national-level sustainability assessment. This indicator is applied in the studies and reviews of the World Bank. It includes resource decay and environmental degradation indicators as well as technological changes, human resources, the export of depleting natural resources, resource discovery, and critical natural capital. Economic and environmental components are emphasised the most, but it also covers investments and education. The positive indicator value shows positive movement towards sustainability, while the negative indicator presents the movement in the opposite direction. Its advantage is that it gives a clear signal to a country about the direction of its sustainability.

Ecological Footprint is an indicator which rates resource consumption and waste formation for a certain area of land and is calculated on a country or regional scale. Ecological footprint calculation consists of a few steps. First, the average yearly food, living space, transport, product, and service consumption per capita are calculated. The land plot required to make each of the consumption needs is calculated after that, and its environmental impact based on the needed land plot is assessed. Then, after adding those land plots, a land plot required to fulfil yearly needs per capita is derived. It has been calculated for many countries and regions and is dedicated to assess the sustainability of the country; however, it can also be applied to a city or a region.

Aggregated indices are also calculated. *Welfare Index* (WI) was used in order to rate the progress of Parties of the Johannesburg Earth Summit 2002 in their sustainable development. It was calculated for 180 countries. This index consists of two indices: the *Human Welfare Index* (HWI) and the *Ecosystem Welfare Index* (EWI), which includes more than 60 aggregated indicators. HWI involves human and health parameters, wealth indicators as well as indicators of knowledge, culture, community, and equality. EWI involves dimensions of the earth, water, and atmosphere, indicators of biodiversity, and resource consumption. When they are connected to WI, these indices are given equal weight. The Barometer of Sustainability is applied for the procedure of connecting these indicators to WI.

Environmental Sustainability Index was formed in order to rate the progress achieved in sustainable development. It consists of 68 indicators that involve five different categories: the condition of environmental systems (air, water, soil, ecosystems, etc.), reduction of stress on environmental systems, reduction of human vulnerability due to environmental changes, social and institutional abilities to deal with environmental challenges, and strengthening of international standards and requirements. Even though this index assesses environmental sustainability, it also involves social and institutional dimensions. Its goal is to compare countries based on their ability to make environmental decisions.

Since 1975, the *United Nations Development Programme (UNDP)* prepares annual global reports on social human development. *Human Development Index (HDI)* of 175 countries is calculated in the report; according to it, Lithuania takes the 45th rank. HDI is a composite unit of human development.

HDI *measures the average achievements of a country based on three key components of social human development*:

- long and healthy life, which is testified by the future average life expectancy;
- knowledge and education, as measured by the adult literacy rate (two-thirds of the component weight), and the combined coefficient of those who are trying to get primary, secondary, and tertiary education (one-third of the component weight); and
- good standard of living, as indicated by the GDP.

Before calculating HDI, the indicator of each aforementioned component has to be determined, and then the HDI is calculated, which is a simple average of the three component indicators. The first UNDP report on human development was presented in 1990 for the sole goal of placing humans in the centre of the developmental process when there are economic debates, the policy is being formed, and a propagating work is performed. Each report is dedicated to the significantly relevant development discussion topic and presents an innovative analysis together with policy recommendations.

In order to make decisions on a global, country, or regional scale, policy measure analysis methods are applied, whereas local assessment methods are applied on a project scale.

In the context of sustainability assessment, integrated methods of assessment are mostly *ex ante* methods that are applied in the form of possible scenario analysis. Many of these integrated assessment means rely on system analysis and involve aspects of nature and society (Gough et al. 1998). Integrated assessments consist of many different means. Integrated environmental problem assessments are performed by using such means as multi-criteria analysis, risk analysis, vulnerability analysis, and cost/benefit analysis.

2.4.2 Conceptual Framework and System Dynamics

Conceptual framework analyses quantitative (causative) relations and applies flow diagrams, flow maps, etc. A conceptual framework can be applied in order to visualise and determine changes in the system, which positively impact sustainability, or to apply powerful computerised models for relation conceptualisation. System dynamics is the creation of computerised models to depict complex systems and experiment with them as well as monitor the long-term operation of these models and analyse various possible scenarios. General and partial balance models are an example of models applied for sustainability assessment: GEMINI, RAINS, TIMES, BALANCE, etc. IMAGE model is meant for monitoring and analysing social, biosphere, and climate system dynamics.

2.4.3 Multi-Criteria Analysis

Multi-criteria analysis is applied to assess the impact of a project or policy means based on opposing criteria. Multi-criteria analysis sets targets and tasks and seeks to weigh them and set an optimal policy tool based on all targets and tasks. This method allows rating both quantitative and qualitative data. This methodology was used to select the policy for energy and environment (Greening and Bernow 2004).

2.4.4 Vulnerability Analysis

Vulnerability analysis assesses the vulnerability of human–natural system in order to determine how sensitive a system is to changes and how it is able to deal with those changes. If it is determined that a human system or a natural system is vulnerable, a risk analysis is performed. Vulnerability analysis was performed on society and ecosystems while studying the impact of climate change (Kann and Weyant 2000).

Having analysed the sustainability assessment methods based on their ability to integrate nature and society and involve long-term periods and different area levels, it can be stated that only some of them integrate nature and society or all three dimensions of sustainability. As seen from the provided grouping of methods, only integrated methods and methods of sustainable development involve all sustainable development dimensions. Many methods involve only the environmental dimensions, especially on a product scale. Only the life-cycle costs assessment involves economic and environmental costs of the product.

In order to expand the analysis, it is aimed to integrate or join sustainable development assessment methods. For example, *life-cycle assessment* (environmental impact assessment method) was joined with *life-cycle costs assessment* (economic method) and *social life-cycle assessment*. Even though many methods involve the national level, they can also be applied at lower levels. Product level sustainability assessment methods are not related to the location; however, the efforts are made to improve these means, in order to bind them with the influence in a particular area. Forecasting methods are useful to determine the impact on sustainability on a long-term perspective. Sustainability assessment methods should be more standardised and provide more transparent results because the abundance and variety of the latter provide much confusion when rating the sustainability of policy means, projects, or products and choosing from alternative options.

In order to select proper climate change mitigation means in the energy sector, it is very important that they would be able to ensure other energy policy goals as well. Sustainability assessment of climate change mitigation means or the impact of climate change mitigation policy means on the assessment of sustainable development indicators plays an important role here.

For the purpose of comparing climate change mitigation means, the integrated indicator based on the sustainable energy development indicator system could be calculated; however, multi-criteria decision-making models allow maintaining the principle of interconnectedness among sustainable energy development indicator systems, while the calculation of integrated sustainable development indicators is the sum of the deviation of sustainable energy development indicators from the average.

4

Waste or Savior? Two Cases of Emerging Wastewater Irrigation in Urbanizing Kathmandu Valley

Silvia Quarta, Dik Roth, Robert Dongol, Anushiya Shrestha, and Saroj Yakami

CONTENTS

4.1 Introduction

Nepal is an extremely water-rich country, but at the same time suffering from water stress due to increasingly intensive water use, high seasonal rainfall variability, and the growing impact of climate change (Shrestha and Sada 2013; Shrestha et al. 2014). In Kathmandu Valley, the most urbanized and most rapidly urbanizing area of Nepal and the location of the capital Kathmandu, water stress levels are rising. Ninety percent of its 1,868 mm of annual rainfall is between June and September (Raschid-Sally et al. 2008). The main river in the valley, Bagmati, is subject to seasonal fluctuations.

Its basin collects 2 percent of the surface water available in the country but serves 8 percent of Nepal's population, causing a potential mismatch of supply and demand (WECS 2011). Annual groundwater consumption in the valley is now exceeding twice the amount of groundwater recharge (Shukla et al. 2011).

As a result of population increase in the valley, rapid changes in land and water use are taking place both in more urbanized and in peri-urban areas. Concurring with other authors on peri-urbanity (e.g., Iaquinta and Drescher 2000; for South Asia, see Narain 2009, 2014; Narain and Prakash 2016), we approach the peri-urban in terms of processes and flows rather than fixed and clearly bounded and governed spaces. What are often referred to as peri-urban areas are actually highly dynamic, evolving, constantly expanding, and shifting intermediate zones between cities and rural areas that are better understood in their processual dynamics—in terms of interconnections and flows of people, natural resources, goods and services, knowledge, capital—than as fixed states (Iaquinta and Drescher 2000, 18). Typically, peri-urban areas have both urban and rural characteristics, visible in a patchwork landscape of housing plots and high-rise buildings, agricultural fields, industries, and other land uses.

In this chapter, we explore these interconnections and flows between the urban and the rural (Narain 2016). Our focus in these explorations is the changing water uses and the growing role of polluted or wastewater for irrigation in these hybrid, peri-urban waterscapes (Swyngedouw 1999), which are increasingly also wastewaterscapes (Karpouzoglou and Zimmer 2016). In Kathmandu Valley, they manipulate and divert myriad flows of water, then access and use the water for production, consumption, and disposal of waste. Water flows interconnect the urban, peri-urban, and rural through rivers and canals, sewers, bottles, and water tankers, conveying surface and groundwater, fresh or polluted with waste and other forms of contamination, but also crucial for drinking and other domestic uses, and for agriculture, brick-making, and other purposes.

These processes are not neutral: they may create new opportunities and access for some but insecurity and exclusion for others, change the realities of water rights and access to water, and lead to conflicts between competing uses, users, and claimants of water (Swyngedouw et al. 2002). Poor and marginal groups with little bargaining power but highly dependent on land and water for their livelihoods, such as peri-urban farmers, tend to be at the losing end (Narain et al. 2013; Narain and Prakash 2016). With the economy of Nepal largely based on agriculture (Bartlett et al. 2010; Water and Energy Commission Secretariat 2011), the primary livelihood source for more than two-third of the population (Dhakal 2011), changes in access to land and water can deeply influence the lives of peri-urban farmers who may experience greater water insecurity.

Little is known of how farmers experience and perceive such changes nor how they cope with them in a materially, socially, and institutionally complex and changing environment (Iaquinta and Drescher 2000; Narain and Prakash 2016). This knowledge is also lacking for irrigation practices in peri-urban environments. Many studies focus on wastewater irrigation practices, related water quality and health issues, and farmers' awareness and perceptions of these from a more normative perspective (Rutkowski et al. 2007; de Leeuw 2014). This chapter, on the contrary, aims to develop a different understanding of these changing water uses. Rather than normatively labeling emerging irrigation practices as either good or bad or gathering evidence on water quality, we intend to bring forward the perceptions, motives, and choices (or lack of them) behind these practices as they are developing in specific water use contexts of Kathmandu Valley. This approach can help us gain a better understanding of these changes and can point us to new ways of dealing with peri-urban inequalities in access and water insecurities in the future.

We structured this chapter as follows. After this introduction, we present the research approach, methods, and case study locations. We then give a short overview of the development of wastewater irrigation in Kathmandu Valley. In the fourth section, we present the two cases: first, the Bhaktapur case (wastewater irrigation from a sewage system); and, second, the Dadhikot case (the pumping of highly polluted water from Hanumante river). After an analysis of the cases we provide the conclusion to this chapter.

4.2 Research Approach, Methods, and Locations

Political ecology of water and urban political ecology of water, interdisciplinary and socio-technical approaches in irrigation studies, actor-network and assemblage theory, and the anthropology of law conceptually and theoretically inspired the research for this chapter. The political ecology of water contributed important ideas about the hybrid, co-constituted character of nature, technology, and society, approaching them as socio-natures, hydro-social, and social-environmental networks, relationships, and processes (Swyngedouw 1999; Budds 2009). The urban political ecology of water (Swyngedouw et al. 2002) stresses the political, power-laden, and contradictory character of these processes. Seeing urbanization as a "historically specific accumulation of socio-environmental processes as well as the arena through which these transformations take place" (Swyngedouw 2002, 126), Swyngedouw notes that these transformations are never socially or environmentally neutral. Power relations shape them and they shape power relations that create differences in access and control, and inclusion and exclusion.

Actor-oriented sociology further inspired our research (Long 2001). Related, but moving beyond human agency, is Actor-Network Theory (ANT), which also considers the agency of material and non-human "actants," thus transcending ontological differences between people and objects (Law 1992; Latour 1999). In ANT, the social refers to "a type of connection between things that are not themselves social" (Latour 2005, 5), and society becomes a heterogeneous network because various materials are social agents interacting with each other (Law 1992). ANT thus provides a valuable tool for analysis, transcending the separation between irrigation technology and the practices and organizational arrangements around it. In peri-urban networks, multiple human actors with conflicting interests, values, framings of reality, and strategies interconnect with resources, technologies, institutions, laws, policies, and discourses and interventions of development. The fluid and scalar nature of these connections, the "labour of assembling and re-assembling socio-material practices that are diffuse, tangled and contingent" (Anderson and McFarlane 2011, 125), the socio-spatial and socio-material transformations that characterize peri-urban irrigation, and issues of agency in tempo-spatial orders (Li 2007; Allen 2011) also point to assemblage theory (Anderson and McFarlane 2011). Finally, to better understand what urbanization and changes in water flows mean for changing practices of claiming and accessing water, we used elements of property rights and access theories (Ribot and Peluso 2003; von Benda-Beckmann et al. 2006).

This chapter is based on fieldwork carried out by the first author of this chapter, Silvia Quarta, in Kathmandu Valley in 2016.[1] In view of the aims of this chapter, the authors designed the research as an ethnographic case study. Using ethnographic approaches yields the most comprehensive and in-depth understanding of the selected cases. Case studies can provide answers to questions like: Why do irrigators change from freshwater into wastewater sources? What does this mean for their water use and organizing practices? What agency do they exert in the complex emerging assemblages of resources, technologies and managing institutions? Case study approaches help to situate researched issues in a specific locale, explore linkages with other issues, and make sense of the emergent assemblages of land uses, water flows, human actors, organizational practices, technologies, and regulations. Providing a context-dependent understanding of processes, relationships, and networks, case studies have the force of example. The often rich and detailed narrative of case studies makes visible the complexities, nuances, and ambiguities of real life, without simplifying such realities (Law 2004; Flyvbjerg 2006).

After a first exploration, we selected two research sites, both located in Bhaktapur District east of Kathmandu (Figure 4.1), for field research to capture various types of hydro-social change related to urbanization, located in various waterscapes and involving various technologies. The first area, Golmadi, is in the Bhaktapur Municipality. On the edge of the old town

[1] The second author (Roth) was involved as research supervisor, while the other authors (Dongol, Shrestha, and Yakami) acted as local resource persons, giving feedback and sometimes joining in field visits and interviews.

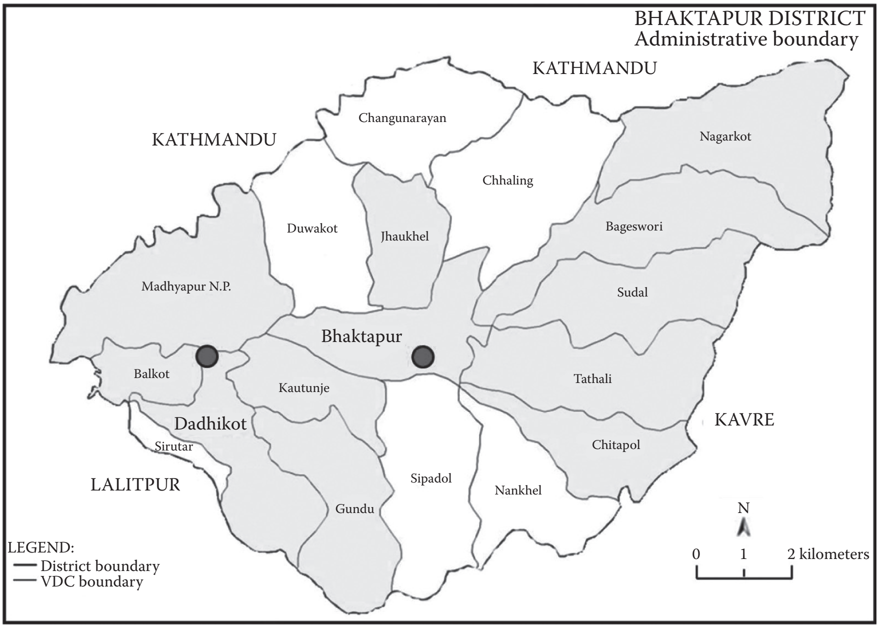

FIGURE 4.1
Map of study locations.

center and enclosed by buildings, the agricultural fields in this area are quite small. Farmers irrigate with water coming directly from a sewage pipe crossing the fields. The extreme condition of this location where raw, completely untreated wastewater serves as irrigation source makes it a very interesting study area. The second area, Dadhikot,[2] is in the Suryabinayak Municipality, established in 2017. It is a bigger area situated along the Hanumante River, rapidly urbanizing but retaining many rural characteristics, especially its land use for (irrigated) agriculture. Farmers rely on more sources here. An irrigation canal serves the farmers closer to its source, a *kulo* (surface irrigation system). Groundwater wells are an alternative or additional source, but do not always provide water due to the declining groundwater table. Finally, farmers pump heavily polluted water from the Hanumante River when the other sources fail (Table 4.1).

Main fieldwork methods were field observations, participant observation, and interviews with farmers, government officials, administrators, and other relevant officials. We held short interviews at both sites with almost all farmers who owned or worked land to get an overall idea of the farmer population and their characteristics. We held in-depth interviews with farmers

[2] Before municipal declaration Dadhikot was part of Dadhikot Village Development Committee (VDC), a separate administrative unit.

TABLE 4.1

Overview of Basic Characteristics of the Selected Study Locations

Indicators	Golmadi (Bhaktapur)	Dadhikot (Suryabinayak)
Household income	Mostly diversified	More than half of households rely on diversified incomes
	Only two households depend completely on agriculture	Almost half of households depend only on agriculture
Plot size	~700 m^2 on average (31–2,000 m^2)	~900 m^2 on average (55–4,000 m^2)
Rent costs (USD/ropani (~500 m^2)/season)	115–140	32
Land tenure	25% households renting land (7)	44% households renting land 35% renting and owning land
Water sources used for irrigation	Sewage pipe	Hanumante River Irrigation canal Wells
Type of wastewater	Concentrated	Diluted
Investments in agriculture	Low (not paying for water, no wells, no pumps)	High (construction of wells, use of pumps)
Agricultural Department	No involvement	Registered groups of farmers get Agricultural Department support

selected for their positions relative to water sources, specific views, experiences with and knowledge of relevant issues, and position in the community, or through snowball sampling. We recorded the interviews in field notes or by audio recordings; photographic material helped in visualizing research choices and experiences. We conducted interviews in Nepali or Newari with the help of translators.[3]

4.3 Development of Wastewater Irrigation in Kathmandu Valley

Kathmandu Valley is among the most productive agricultural areas in Nepal, with rice, wheat, and maize yields significantly higher than national averages (HMG [His Majesty's Government of Nepal] and United States Agency for International Development [USAID] 1986). The ancient canal irrigation systems known as *rajkulo* (royal canal), fed by the Bagmati River or its tributaries,

[3] Thanks are due to the following students of Nepal Engineering College: Sarita Shrestha, Nishant Shrestha, Jyoti Dahal, and Saroj Malakar.

played an important role in enriching this agricultural potential.[4] Since the 1960s the agricultural landscape of the valley started urbanizing.[5] Unplanned urban expansion and influx of people from the 1980s led to a growing production of wastewater. The area introduced four large-scale and centralized wastewater treatment systems in the 1970s and 1980s, and another in the early 2000s.[6] These systems, targeted for treatment of urban sewerage, were unable to deal effectively with the waste of expanding residential, commercial, and industrial establishments, resulting in disposal of untreated waste into the Bagmati River and its tributaries (Shukla et al. 2012; KUKL [Kathmandu Upatyaka Khanepani Limited] 2013; Jha and Bajracharya 2014).

Over the decades, the area constructed few public and private decentralized wastewater treatment systems (DEWATs). Municipal efforts have largely failed in managing the increasing volume of domestic and industrial effluents. For example, the integrated waste management system in Sano Khokana, constructed to use treated effluent in nearby agriculture, fails to treat wastewater (Shrestha 2016). Although the practice of recovering nutrients in wastewater exists in traditional agricultural systems (Shrestha 2011), increasing pollution of traditional irrigation sources left farmers with no option but to use polluted water. Farmers practicing wastewater irrigation get it directly from municipal sewage, from rivers with diluted wastewater, or from wastewater ponds and pools developed in urban, peri-urban, and rural areas (Shukla et al. 2012). Farmers use wastewater especially for cash crops which require frequent and reliable irrigation in this increasingly water-deficit area.[7] A study conducted in Harisiddhi revealed that farmers accept wastewater because of its easy access and year-round availability (Baidya 2016): it has created opportunities for cultivation of high-value crops, even in the dry season, to fulfil the growing need for vegetables in urban areas.

However, high nutrient levels in wastewater can also cause skin and other health problems, and crop damage: effluents in the valley register high turbidity, microbial, and nutrient levels (Baidya 2016), all critical parameters for irrigation water. Although wastewater use is largely informal and unrecognized by the government, it is rapidly spreading (Rutkowski et al. 2007; Sada 2010; Shukla et al. 2012). The area is developing new treatment plants,[8] but untreated wastewater irrigation practices are likely to increase

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[4] The population widely uses the Bagmati River and its tributaries for drinking, irrigation, industrial, and other purposes in the valley (GoN/NTNC 2009).

[5] The urban population in the valley increased six-fold in the last 60 years, from 218,092 people in 1961 to 1,426,641 by 2011. The built-up area increased by 134 percent, from 24.54 square kilometers in 1989 to 57.32 square kilometers in 2006 (Shrestha et al. 2014).

[6] The total theoretical capacity of these plants is 36.3 megaliters per day (Rutkowski et al. 2007).

[7] Water demand has reached 375 megaliter per day while supply is 118 megaliters per day (wet season) and 73 megaliters per day (dry season) (KUKL 2016).

[8] Kathmandu Valley Wastewater Management Project supported by ADB underway since 2013/14.

in the rapidly urbanizing valley (World Health Organization 2006). This situation makes case studies on its emergence and experiences of wastewater users timely and relevant. While most research deals with wastewater from an instrumental perspective, focusing on its role in food and environmental security and poverty alleviation (Raschid-Sally and Jayakody 2009), we need a deeper understanding of the daily practices around wastewater irrigation as a solid ground for policy-makers in their future management of peri-urban waterscapes.

4.4 Two Cases of Wastewater Irrigation

4.4.1 Bhaktapur

4.4.1.1 History of a Sewage Pipe

In Bhaktapur, the sewage pipe there used to be a *rajkulo* that provided potable water for the population of Bhaktapur. The canal was the main source of water for the whole town and stone spouts and ponds distributed the water further. When flowing through farmland, farmers also used the water as a source of irrigation water (Gautam 2015).

Between 1974 and 1986 the Bhaktapur Development Plan (BDP), locally known as the German Project, promoted urbanization and industrial development in the city. The project, arranged between the Government of the Federal Republic of Germany and His Majesty’s Government of Nepal, with the technical support of the (then) German Association for Technical Cooperation (GTZ; Deutsche Gesellschaft für Technische Zusammenarbeit), focused on improving hygienic conditions, boosting public services and economic activities in the city, restoring buildings, and creating institutions to maintain the improvements achieved (Matthaeus 1988). Construction of the sewage network, sewage treatment plants, public toilets, and promotion of installation of private toilets in each household were part of this project (Matthaeus 1988).

After this intervention, sewage water from Bhaktapur started flowing through the *rajkulo*. Now a brick pipe with a diameter of about 3 m, also used as a pedestrian passage, crosses the fields in Golmadi. Eventually it drains into the Hanumante River. The pipe has one manhole to reach the interior of the pipe and other small openings all along it on both sides and close to the ground. Farmers use the water from this pipe to irrigate their fields. The original plan included the construction of two treatment plants in two locations, Sallaghari and Hanumanghat. However, today these are either malfunctioning or not in use anymore (Sada 2010). The centralization of management of the wastewater flowing out of the city caused a higher level of pollution in the canals flowing into the river and the *rajkulos*, disrupting the pre-existing household-level water management systems in the area and deeply affecting the livelihoods of farmers (Sada 2010) because they now depend on it. A farmer said: "*we have never been told not to use the wastewater from the municipality. But even if people were told so, they would not agree*" (Golmadi, January 1, 2016). Although Nepal considers this practice illicit, the municipality, aware of the lack of alternatives for farmers in the area, does not intervene against it.

For government and municipality officials, introduction of the sewage system was a sign of development and its malfunctioning caused by poor maintenance and farmers' irrigation practices from the pipe. According to the farmers it meant an improvement of living conditions, also allowing them to have greater water availability throughout the year. Since its construction, farming in Golmadi has undergone an evolution: the water flow has increased but water quality and access have changed. Farmers have introduced new cropping patterns because year-round water availability allows them to grow vegetables also in the dry season. "*Before the German project in this area we used to cultivate only wheat and paddy* [in the monsoon season], *there was not enough water available* [*for other crops*]" (farmer, Golmadi, January 19, 2016). "*If the pipe hadn't been constructed, this land would not be suitable for cultivation, due to lack of water.* […] *If the sewage had not been built, we would have to pump the water from the river, which is expensive.* […] *We can now irrigate only thanks to the wastewater*" (farmer, Golmadi, January 13, 2016). Thus, thanks to wastewater, farmers can produce crops all year close to markets, their homes, and customers. The new water flows are influencing cropping patterns, market supplies, and income sources, showing once more the interconnectedness between water flows and social and economic changes (Table 4.2).

Most farmers state that during the drier summer months the wastewater is bad both for the soil and crops which become yellow and often die. However, most of them consider the health hazards and poor water quality minor issues that they need to overcome anyway for lack of alternatives: "*for an alternative to wastewater, we have to buy a field somewhere else or dig a well, which are both expensive options.* […] *Everyone would like to dig a well but they cannot afford it*" (farmer, Golmadi, December 29, 2015).

The sewage pipe has also affected access to water for the farmers. With the *rajkulo* they only had to block the open canal to divert the water flow. A young farmer performing this labour: "*I do the blocking of the pipe with three bags of sand. There's no light so I need a torch. It's dangerous, the soil is slippery. It only takes 5 min to do it.* […] *The last one to irrigate will unblock the main sewage pipe*" (Golmadi, January 22, 2016). Men usually do this, as a woman explains: "*I don't like to do it, it is smelly and dirty*" (Golmadi, January 20, 2016). Then, the water flows to the fields through open canals diverted by farmers often walking barefoot or digging the soil with bare hands: some farmers got skin rashes because of the contaminated water.

On the eastern side of the sewage canal the water only serves fields adjacent to the pipe, so each farmer has developed his or her own system, for

TABLE 4.2

Characterization of Farmers in Golmadi, Bhaktapur

Characterization of Farmers in Golmadi, Bhaktapur		
# interviewed farmers	39	
Household size	2–11 members	
Income	Mostly diversified (manufacturing, sales and retail occupations, transport and construction, private businesses, a few professionals and people working abroad)	
Who takes care of the fields	Mostly middle-aged people (parents/grandparents)	
	Mostly female	
Paid farm labour	Only two households. Mostly labour exchange practice	
Home distance	Average 5–10 min' walk	
Land size	~700 m^2 on average (31–2,000 m^2)	
Land ownership	Mostly inherited	
Land tenure	Only six households. Payment in money or 50% output	
Rent prices	USD 1.2–2.2/1 aana (31.8 m^2)	
Production	**Winter**	**Summer**
	Vegetables	Rice
	Potatoes	Wheat
		Chili
		Eggplant
Production purpose	Mostly self-consumption, market	

Year-round agriculture benefit from wastewater usage

example, by connecting a small pipe to the openings in the sewage pipe. When not in use, the farmer closes the pipe with a brick. When the farmer moves the brick the water immediately flows out. Some farmers use buckets to irrigate their plots, taking the water from the open canals that carry the wastewater through the fields. One farmer, whose house is in the fields, irrigates her small plots with water from a newly installed tap. An elderly farmer fetches water at wells and ponds near the house when the wastewater is not enough. Two farmers also pump water from the Hanumante River: "*most people don't use a pump but wastewater, even if its quality is not good. It is difficult for one person alone to bring the pump and apply the water, and on these fields, there is mostly only one person working [per plot]. Additionally, it is expensive, and people don't own pumps here*" (farmer, Golmadi, January 22, 2016).

There are no strict rules that set a specific irrigation order among farmers. Unwritten and even unspoken social agreements to a large extent guide wastewater use practices: "*when you need the water you can just take it, there is no form of organization around it. Usually there is enough for everyone, but you have to wait for your turn, until your neighbour is done with it*" (farmer, Golmadi, December 28, 2017). Some farmers agree in stating that upstream farmers are the first ones to irrigate, and this sometimes causes damage to their crops downstream because they must sow or irrigate their crops too late. A combination of factors, however, makes this imperfect system suitable for farmers in Golmadi. The fact that the area is not too large probably reduces the impact of the upstream-downstream relations. In addition, this method is the only way of accessing irrigation water for many farmers in the area.

Although farmers tend to go for individual water access solutions that best fit their financial and organizational capacities, awareness of each other's interests and forms of cooperation do play a role. Cooperation of farmers in maintenance and cleaning is necessary for retaining access to the sewage water because with time canals and pipes get clogged if not properly maintained. The maintenance takes place twice a year, during the dry season or at the beginning of the rainy season. The system is practical and flexible, tailored to the farmers' needs and the individual requirements of various people. Landownership and seniority are the leading forces behind the system: the most vocal farmers are those who have owned the larger land plots for a longer time. The system does not require the presence of farmers owning smaller plots because they can pay some money depending on their willingness, the amount of land owned or rented, and duration of the maintenance work. The few farmers not contributing in any way are usually not benefiting from the canal system. The existence of a form of social organization around the wastewater irrigation system and the sewage pipe allows many farmers to benefit from this source.

4.4.1.2 Golmadi: Wastewater as an Opportunity

In this dynamic combination of rural and increasingly urban characteristics found in Golmadi, the advancing city is literally enclosing the farmland. Being cut off from their traditional surface irrigation canals increasingly constrains the farmers. Within these constraints, however, construction of the sewage system has also brought new benefits, primarily year-round access to irrigation water. Although water quality is low, it brought new livelihood options. Thus, the farmers keep working their land aided by their connection to wastewater. Awareness of the changes around them does not make farmers less willing to continue farming because it is a necessity for most of them. Even while the city slowly encloses them, they do not seem prone to drop their shovels.

4.4.2 Dadhikot

In Dadhikot a "*drastic land use change in the past 5 or 6 years*" (farmer, Dadhikot, January 26, 2016) has taken place. Buildings, shops, brick kilns, and other enterprises and infrastructure are arising everywhere, and land prices are increasing exponentially. Farmers are seeing land and water encroached by

TABLE 4.3

Characterization of Farmers in Dadhikot

Characterization of Farmers in Dadhikot, Suryabinayak		
# interviewed farmers	51	
Household size	3–16 members	
Income	More than half diversified (transport and construction, work abroad, professionals, manufacturing, office work). Others agriculture only.	
Who takes care of the fields	Mostly husband and wife	
Paid farm labour	Almost half of households have seasonal/yearly employees	
Home distance	On field/bordering municipality	
Land size	~910 m^2 average (55–4,030 m^2)	
Land ownership	More than half farmers own land. Mostly bought.	
Land tenure	Almost half. Payment in money or 50% output	
Rent prices	32 euros/ropani (500 m^2)/6 months	
Production	**Winter**	**Summer**
	Vegetables	Rice
	Potatoes	Wheat
		Chili
		Eggplant
Production purpose	Mostly market	

A declining irrigation source: the *kulo*

new inhabitants. The first and most contested irrigation source in Dadhikot is the *kulo*, the irrigation canal. It comes from a seasonal stream, the Chakhu Khola, that farmers for many years diverted into their fields with a dyke of sandbags. The kulo water availability shows seasonal variations in accordance with the hydrological seasons of the Bagmati River Basin: a dry pre-monsoon season from March to May, the rainy monsoon season from June to September, and the post-monsoon season with little rain from October to February (Sharma and Shakya 2006) (Table 4.3).

Aside from changes in rainfall patterns and reduced source water availability, farmers specifically blame population increase for the reduction of water availability in the *kulo*: "*There are houses everywhere and everyone draws water from the kulo. There used to be enough water every year in Falgun* [*February–March*] *but this year there is no water and there has been no rainfall. It has decreased compared to last year*" (farmer, Dadhikot March 14, 2016). This change is intensifying water distribution inequalities. Farmers closer to the source mostly get enough water; however, those further away get little or no water. Several farmers have lost access to the *kulo* because of buildings among the fields. One farmer says: "*I don't get water anymore … because there* *are houses everywhere, both of people with legal permission to build a house and of people who… have taken the land around the kulo illegally*" (farmer, Dadhikot, February 11, 2016).

After the rainy season, farmers conduct the maintenance around the *kulo*. Around 20 to 30 farmers, mostly men, gather with some of them leading the process. Whoever cannot join pays money to a treasurer, who manages the expenses. One farmer states: "*often the landowners only grow paddy [in the summer season], so the tenant is responsible for maintenance*" (Dadhikot, January 6, 2016). The farmers have decreased the frequency of maintenance over the years. One farmer stated: "*50 or 60 people were participating previously, nowadays only 30. Less people are involved in agriculture, and there are more houses around*" (Dadhikot, February 21, 2016). Although the maintenance system is still active, it is becoming more informal. Reduced access to water for farmers and the decrease of people involved in agriculture are roots of these changes.

The first-come first-served principle seems to be leading in using kulo water, together with mutual understanding, daily agreements between farmers, and respect for each other's turns. Sometimes conflicts arise: "*There are conflicts among farmers but not serious ones, and always solved by talking. Usually upstream - downstream issues* […]. *Upstream people use more water and block the kulo when irrigating, so that people downstream don't get enough*" (farmer, Dadhikot, February 23, 2016). Wide changes in water availability fuel such issues. Downstream users are often looking for alternative water sources or practices, such as irrigating at night or drawing water directly from the kulo source, the Chakhu Khola. Some are hoping for governmental support for repairing the *kulo*.

4.4.2.1 New Irrigation Practices, Technologies, and Problems

The increasing water stress is forcing many farmers to turn to other water sources, such as wells. A few scattered ones are in the fields, built by private owners or with funding of the Agricultural Department. Farmers value well water for its quality and use it mostly for washing vegetables and drinking. Only a few farmers use groundwater for irrigation. One farmer says: "*10 or 12 years ago I used well water to irrigate, but not anymore. It used to take 4 h to irrigate with well water. Now it takes 7 h and too much fuel*" (Dadhikot, February 7, 2016). Although farmers share most wells, groundwater is undergoing a privatization process. Some farmers are not allowing neighbors to benefit from their wells anymore, while new households are constructing wells for their own use. The growing number of wells and increasing water consumption are causing a lowering of the groundwater table. Often in the dry season many wells run dry. The reliance of many new houses on well water deprives farmers of this clean water source which is switching from agricultural to domestic use.

Most farmers are turning to the Hanumante River as main irrigation water source. While farmers have always used the river for this purpose, the

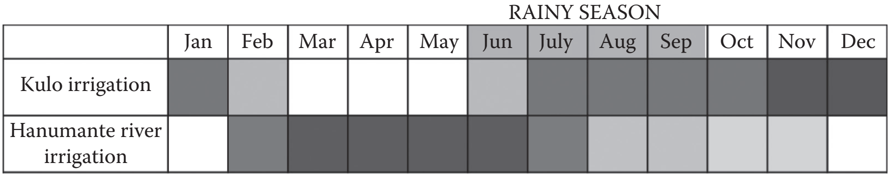

FIGURE 4.2
Irrigation sources calendar.

number of users is increasing. Water quality has changed drastically since the creation of centralized sewage systems that dispose increasing quantities of treated water into the river: "*We used to drink the river water, but now we cannot even touch it*" (farmer, Dadhikot, February 5, 2016). Many farmers incur health problems, mainly skin rashes and itching, from contact with river water while irrigating. Hence, whoever has access to the *kulo* prefers that source: "*in April the smell of the river water is terrible. We only use it when we have no other option. If we use too much diluted wastewater the vegetables become yellow*" (farmer, Dadhikot, January 6, 2016). Figure 4.2 shows the use of different water sources by farmers: darker colors mean higher water availability and more farmers relying on that water source, and so also more competition.

The use of river water and groundwater has introduced new technology: water pumps. Half of the interviewed farmers own a pump and the others rent one. Often, pump-owners help their customers placing the pipes and operating the pump. One farmer states: "*there is no organization for getting the water from there* [*the river*]: *whoever can afford a pump, pumps the water. Others pay the pump owner 250 rupees per hour*" (Dadhikot, December 23, 2015). Thus, with new technology new differences are arising. These differences gain relevance especially in the dry season, when farmers need to irrigate more often. Another farmer said: "*I can't irrigate whenever I want to, as I depend on availability of the pump.* […] *Some people irrigate at night, with nobody around they can use as much water as they want*" (Dadhikot, February 21, 2016).

4.4.2.2 Dadhikot: Growing Pressures on Irrigated Agriculture

Decreasing government support for farmers, an increasing number of young people seeking a future outside agriculture, land use changes, and the weakening of water rights and maintenance mechanisms in the irrigation systems are all signs of urbanization in Dadhikot. Houses and households are increasing, rivers are turning into sewers, and irrigation canals are disappearing from the map. In this rapidly urbanizing landscape, increasingly also influenced by a changing climate, farmers try to uphold their farming-based livelihoods.

4.5 Analysis: Multiple Agencies, Assemblages, and Changing Access to Water

This chapter has taken the changing water flows and water infrastructures of the two case study areas as its point of departure, approaching the irrigated areas as assemblages of a diversity of human and non-human elements, including farmers and farmer organizations, changing land uses and agricultural practices, water flows, spaces, rivers, canals and water infrastructure, technologies, policies and flows of funding, land and water rights, and access to water. This change highlights the peri-urban dynamics in various ways: the provisional and contingent character of the hydro-social (trans-)formations involved, the multiple human and non-human agencies involved in the processes of shaping and reshaping them from heterogeneous elements, and their emergent yet also coherent character (Anderson and McFarlane 2011). It also highlights that these processes of assembling, reassembling, or both shaped by, and re-shaping the ways in which farmers define water rights and hydraulic property, and create access to water (Ribot and Peluso 2003; Roth et al. 2015), which we will clarify in the following analysis.

We can consider the sewage pipe in Bhaktapur as an interface (Long 2001) or as a key material element in an assemblage-involving multiple, human, and non-human agencies. In a chain of agencies, farmers are the actors who reshaped the technology to use it for a purpose not intended. Using the manhole, needed to control the functioning of the pipe, the farmers restored the irrigation system they used when the sewage pipe was an open canal. The clash between multiple values and realities comes into being exactly at the location of the sewage pipe and the area around it. First, conflicting views are emerging concerning the characterization of the peri-urban with farmers on one side and any of the government agencies or municipality officers on the other side. For most farmers, this area is the place where they have always farmed. Their need for water to irrigate the crops they depend on for their livelihoods drove them to use the new water source, despite its new function and, hence, lower water quality. The farmers' motives for holding onto their farmland are stronger than the many changes taking place: livelihoods, family ties, and lack of alternative options. Their priority is not cleanliness of the water, but water availability. It even became an opportunity: a constant water flow even in the dry season. For farmers in Golmadi, these reasons are strong enough to make them stay and continue their agricultural practices using the sewage water and turning this area one of the last agricultural strongholds in the city.

The new water source creates new definitions of water rights and legitimate access. This legal aspect has pushed farmers to participate in the social organization around the sewage-based irrigation system. Strong organizational ties between farmers have developed around the sewage pipe. Labour for maintenance, time, and money invested, materials used, and sticking to the locally developed agreements are necessary conditions for everyone to retain recognized access to wastewater; thus, the system shows characteristics of hydraulic property (Coward 1986, in Roth et al. 2015). Even though the system is based on soft rules, almost everyone participates personally or with monetary support because this way they can benefit from the resource in a way regarded as legitimate locally (Ribot and Peluso 2003; von Benda-Beckmann et al. 2006).

The Dadhikot case involves changing water sources, new water sources, and new actors in the network. The *kulo* is still the basis of farmers' customary water rights. Even though increasingly flexibly organized, the right to use irrigation water continues to be tied to material and labour investments in construction and maintenance, a form of hydraulic property. However, this arrangement is no longer a guarantee of actual water access (Ribot and Peluso 2003; Roth et al. 2015). While less people now are investing in *kulo* maintenance, house owners are increasingly using the system. The latter, however, do not participate in the process that would allow them, according to customary rules, to benefit from the canal. They do not feel tied to the farmers' customary norms and use their ability to directly access the source.

New landowners also claim property rights to groundwater according to the 1992 Water Resources Act gained along with land owned. For them, the well is their own property, not a communal resource. These new water users are carrying with them a whole new set of norms related to the association between land control and the right to use groundwater. As this new rights-based mechanism arises—farmers claiming rights to groundwater because they own the land—some of the structural-relational mechanisms (Ribot and Peluso 2003) through which farmers based their access to water are also affected: the water source is declining or depleted and so farmers need deeper wells and new and increasingly powerful pumping technology to access the groundwater. This situation creates new divisions between those who retain access to groundwater and those who gradually lose their ability to access it.

The increasing number of farmers shifting to river water is changing the nature of the assemblage from one where the whole area served farming purposes and farmers strongly tied to the *kulo*, its organizational arrangements, and system-based water rights, to an assemblage where the kulo is becoming part of a more heterogeneous peri-urban waterscape. In the latter farmers are creating new networks around alternative water sources, using new technologies, infrastructure, and resources (pumps, pipes, money, and fuel), different types of water rights, more flexible and ad-hoc forms of access to water, and a less structured social organization around it. The process creates new discrepancies between farmers. The water flows that bring these changes into being are not socially neutral, as is also stressed in the urban political ecology of water literature (Swyngedouw et al. 2002). Another focal point in political ecology literature is the scalar dimension of these flows between urban and peri-urban areas. The case studies show how urbanization is encroaching on relatively clean peri-urban water sources and creating new flows of polluted water for urban or peri-urban re-uses, such as in peri-urban agriculture in the cases we discussed. The actors affected by this quality shift are those at the margins of urbanization, farmers who do not have other options but to keep on using whatever is available around them.

4.6 Conclusion

Building on insights from the political ecology of water, actor-network theory, assemblage theory, and anthropology of law in this chapter, we have tried to understand farmers' changing irrigation practices that are increasingly based on wastewater or heavily polluted water in the dynamic peri-urban environment of Kathmandu Valley. We brought forward the perceptions, motives, and choices (or lack of them) behind these practices as they are developing in two irrigation water use settings. The two cases of changing irrigation practices—Golmadi, Bhaktapur case (wastewater irrigation from a sewage system) and Dadhikot case (pumping of polluted water from Hanumante river)—mainly differ in the combinations of water sources farmers can still rely on as urbanization is advancing. In both cases, urbanization is attracting new infrastructures and people, introducing new notions of water rights and land rights, and new organizing practices to create, maintain, and control access to water to enhance water security. Fundamental discrepancies in the perception of these changes are emerging, further enhancing the growing peri-urban water stress for some while creating opportunities for others.

The analysis highlights the importance of infrastructure in these shifting peri-urban interfaces, and the central role played by the agency of different human and non-human actors in shaping and reshaping the reality around them. Confronted with growing land and water stress in an urbanizing landscape, farmers re-interpret infrastructure, introduce new technologies, change cultivation and irrigation practices, and find new ways of establishing, maintaining, and strengthening their water rights, water access, and water security. Irrigation practices are constantly changing along with urbanization, water rights are becoming less explicit, and access to water more ad-hoc. The case studies show how unpredictable and context-specific farmers' responses to changes in land and water are. To understand how to deal with these changes, it is essential to start from an analysis of daily farming practices in peri-urban fringes. By looking at changing flows and assemblages, we focus not only on the specific geographical study area, but also on the concept of peri-urban as a process, a constantly evolving network. We followed the changing water flows and relationships, highlighting the relevance of looking at the peri-urban as a waterscape (or wastewaterscape). Such research might give new insights in the changes taking place and expand our knowledge and understanding of peri-urban processes.

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2

*Energy Efficiency Strategies in Urban Planning of Cities**

2.1 Introduction

As discussed in Chapter 1, the world's energy consumption in 2011 was 14,092 Mtoe; about 30 Giga metric tons of CO_2 emissions were released in the atmosphere to meet this energy demand [2]. Greenhouse gas (GHG) emissions and energy demand have risen high on the global environmental agenda—particularly with the Kyoto Protocol and other related global agreements. Consequently, an urgent need has arisen for the incorporation of energy efficiency issues into urban planning and construction [3]. To meet the urban challenges of today, and the challenges to come, appropriate planning strategies and management frameworks must be available, through which cities can apply innovative approaches suitable for their local circumstances. This chapter will review the challenges that cities face and factors that affect new strategies for urban planning where energy efficiency is the core issue shaping the city's future.

2.2 Cities and Energy Consumption: The Macrolevel

The city can be seen as an ecosystem comprising five main sub-systems that interact together. These are population sector, employment sector, housing sector, transport sector and urban land sector [4].

2.2.1 Size

Cities vary in size, starting from only 25,000 inhabitants—the number of city dwellers specified by Egypt's General Organization of Physical Planning (GOPP). In Egypt, population size is the main driving force of urbanisation

* Most of this chapter is derived from Khalil [1].

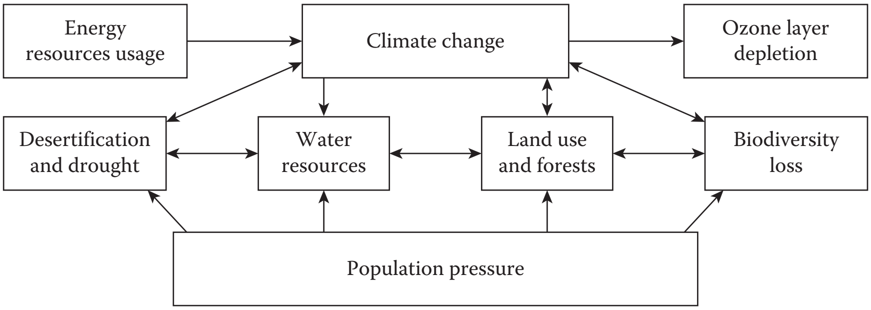

FIGURE 2.1
Relationships among desertification, climate change and biodiversity. (Adapted from The United Nations Economic Commission for Africa (UNECA) and North Africa Office, The fight against desertification and drought in North Africa, *The Eighteenth Meeting of the Intergovernmental Committee of Experts*, United Nations Economic Commission for Africa, Tangiers, Morocco, 2008.)

and in the quest for fulfilling their needs in an urban context. Another dimension related to population pressure in urban contexts is a city's growing size and its impact on climatic change. This is only one part of the environmental chain of energy use, ozone depletion, desertification and biodiversity loss, as shown in Figure 2.1 [5].

2.2.1.1 Mega Growth, Mega Complexity

The megacity is a relatively new form of urban development. In 1950, there were only two cities with populations of more than 10 million: New York and Tokyo. By 1975, two more locations, Shanghai and Mexico City, joined the club. However, by 2004, the number of megacities had rocketed to 22 and, together, these cities now account for 9% of the world's urban population. It is important to note that:

1. Mega cities' importance in the national and global economy is disproportionately high.
2. City governance has to adapt to the challenge of delivering holistic solutions across vast metropolitan regions.
3. City managers must strike the balance between three overriding concerns: economic competitiveness, environment and quality of life for urban residents.

Urban growth is spread unequally around the world, and the same is true of its largest cities. Most of the megacities in the developed world are growing slowly, if at all. Tokyo remains the largest with 35 million inhabitants, but the fastest growth will be in the developing world (particularly in Asia and Africa), placing huge pressure on infrastructure in those locations. By 2020, Mumbai, Delhi, Mexico City, São Paulo, Dhaka, Jakarta and Lagos will each have populations of more than 20 million. Moreover, it is estimated that between 2010 and 2015 some 200,000 people on average will be added to the world's urban population every day with 91% of this increase expected to take place in developing countries [6]. For many emerging cities, soaring populations are extremely difficult to manage; at current rates of growth, the number of inhabitants in Nigeria's Lagos will double by 2020, mainly through expansion of informal settlements. By contrast, most mature cities (as well as many transitional ones) will need to address a different kind of demographic challenge in the form of population ageing.

There is a continuous debate about megacities. On one level, these super-sized cities are seen as the engines of the global economy, efficiently connecting the flow of goods, people, culture and knowledge. They offer, at least potentially, unprecedented concentrations of skills and technical resources that can bring increased wealth and improved quality of life to vast numbers of people. However, megacities also conjure up an altogether darker vision. Most cities in the developing world face huge challenges ranging from congestion and pollution to security threats and inadequate services groaning under the weight of excessive demand. Those in the developing world also struggle to cope with the rapid growth of informal settlements. In 2006, almost one in three members of the world's urban population lives in slums, without access to good housing or basic services [7].

Today's megacities are not only bigger than the cities of the mid-20th century but also more complex. For one, they are increasingly competing with, and dependent on, relationships with other cities in the global economy. At the same time, we are witnessing the emergence of new city regions—sprawling conurbations that extend far beyond the boundaries of a single city. Examples include the 'BosWash stretch' (extending from Boston, MA, to Washington, DC) in the United States, and Chongqing in China. These huge megacity regions create a new urban dynamic. Commuters travel large distances from densely populated suburbs. Economic activity frequently becomes de-concentrated, dissipating from the centre to the periphery. Often fragmented systems of metropolitan governance have not caught up with this trend, with the result that it is difficult to deliver an efficient, holistic approach to infrastructure challenges at a metro regional level [8]. In addition, other new spatial configurations are increasingly taking place, such as urban corridors and city regions. These large urban configurations, as grouped in networks of cities, amplify the benefits of economies of agglomeration, increasing efficiencies and enhancing connectivity. They also generate economies of scale that are beneficial in terms of labour markets, as well as transport and communication infrastructure, which in turn increase local consumer demand [6].

2.2.2 Role and Competitiveness

In the context of continuous globalisation, there is a focus on competitiveness to attract investments to increase cities' prosperity. In this quest, there is a struggle among economic competitiveness and employment, environment and quality of life.

Megacities prioritise economic competitiveness and employment. In a study of which issues drive decision making in 25 megacities around the world, 81% of stakeholders involved in city management cited the importance of the economy and employment. There is a strong focus on creating jobs, with unemployment emerging as the top economic challenge for survey respondents from emerging and transitional cities. Competitiveness in the global economy is another important consideration. Six in ten stakeholders think that their cities place a high importance on making themselves competitive to attract private investment when deciding infrastructure issues [8].

Despite this inclination towards economic competitiveness, development decisions often involve difficult trade-offs between growth and greenness or growth and quality of life. There are obvious interdependencies among the three concerns. Competitive cities are more likely to have the wealth and resources to invest in high-quality infrastructure and services and to create economic and social opportunities for large numbers of the urban population. All things being equal, environmentally clean, modern cities are more attractive locations for a broad spectrum of business activities than those with heavy pollution. Equally, cities with a healthy, well-educated urban population are better positioned to attract investment than those where deprivation and inequality block a large portion of the population from participating in economic growth. This suggests that, in the long run, focusing on one of these concerns to the detriment of the others will be a recipe for failure (as shown in Figure 2.2) [8].

Therefore, cities need modern, efficient infrastructures, especially transportation networks. Abundant (and preferably skilled) labour together with modern information and communications technologies are also hugely important, as evidenced by the offshoring trend that has itself fuelled the growth of cities such as Bangalore in India. Another crucial factor is the

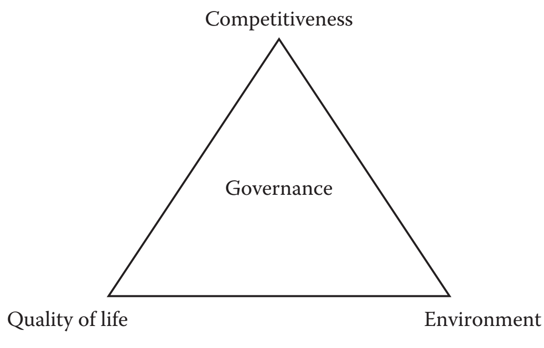

FIGURE 2.2
Striking a balance among quality of life, competitiveness and environment should be the main concern of megacities' governance.

quality of basic services; people with access to quality housing, education and good basic services such as water and electricity are much more likely to fulfil their potential and to contribute to economic growth. The wider business environment is also a key factor; research from the *Economist* intelligence unit indicates that clear, business-friendly policies and regulations are more important factors in attracting international investment than incentives such as subsidies and tax breaks [8].

Whatever their potential, however, many of today's megacities feature a catalogue of environmental problems. Congestion, air and water pollution, waste management and degradation of green areas are familiar issues in most large cities around the world, and they are particularly extreme in the megacities of the developing world. There are also huge inequalities in the distribution of wealth and in economic opportunity among cities. In its recent report on urbanisation trends, UN-Habitat describes cities as 'the new locus of poverty'. World Bank estimates predict that although rural areas are currently home to a majority of the world's poor, by 2035 cities will become the predominant locations of poverty [8].

The consequences of a failure to improve quality of life for the urban poor are huge. The UN-Habitat research indicates that people living in slums, where a large proportion of the urban poor reside, are more likely to be affected by child mortality and acute respiratory illnesses and by waterborne diseases than are their non-slum counterparts. They are also more likely to live near hazardous locations, making them more vulnerable to natural disasters such as floods. Inadequate access to basic services saddles them 'with heavy health and social burdens, which ultimately affect their productivity' [7]. Poverty may be less extreme in the more developed cities, but social problems still abound.

Historically, cities tend to get rich first and then clean up later. Unfortunately, that approach could be disastrous in the context of climate change; this is one reason for the growing focus on sustainable urban development. Sustainable solutions promote greater use of alternative energy sources and more energy-efficient buildings and transport, measures to combat congestion and CO_2 emissions, water and waste recycling, and the use of vegetation to filter pollution and capture carbon dioxide. Although several cities have started implementing at least some of these measures to good effect, there will be a need for more concerted efforts if the environmental cost of urbanisation is to be reduced.

Consequently, it is not growth and economic prosperity that cities should seek; it is rather a more sustainable development that combines efficiency, accountability and environmental responsiveness. This is a goal that comprises the main core of the Sustainable Cities Programme (SCP), a worldwide technical cooperation activity of the United Nations. The SCP works at the city level in collaboration with local partners to strengthen their capabilities for environmental planning and management. Each city-level SCP project is adapted to the particular needs, priorities and circumstances of that city;

nonetheless, all SCP city projects follow the same general approach, and all are implemented through the same series of activities known as the SCP process [9].

The SCP recognises that environmental deterioration is not inevitable. Although many, perhaps even most, cities are still suffering severe environmental and economic damage, there are encouraging signs. Some cities are learning how to better plan and more effectively manage the process of urban development, avoiding or alleviating environmental problems while realising the positive potentials of city growth and change. The SCP aims to support cities in finding—and managing—development paths that are more effectively fitted to their environmental opportunities and constraints.

There is a common approach that is shared by all SCP cities and that holds true across the full range of partner cities [9].

1. Central focus on development–environment interactions
2. Broad-based participation by public, private and community groups
3. Concern for inter-sectoral and inter-organisational aspects
4. Reliance on bottom-up and demand-led responses
5. Focus on process – problem-solving and getting things done
6. Emphasis on local capacity building

More recent initiatives in this field are promoted by various organisations. The Urban Low Emission Development Strategies (LEDS) project, funded by the European Commission and implemented by UN-Habitat and the International Council for Local Environmental Initiatives (ICLEI),* has the objective of enhancing the transition to low emission urban development in emerging economy countries. It offers selected local governments in Brazil, India, Indonesia and South Africa a comprehensive methodological framework (the GreenClimateCities methodology)† to integrate low-carbon strategies into all sectors of urban planning and development. Another initiative is the Cities and Climate Change Initiative (CCCI) that builds on UN-Habitat's long experience in sustainable urban development. The initiative helps counterparts to develop and implement pro-poor and innovative climate change policies and strategies. CCCI also is developing a suite

* ICLEI Local Governments for Sustainability is the world's leading association of more than 1000 metropolises, cities, urban regions and towns representing over 660 million people in 86 countries. ICLEI promotes local action for global sustainability and supports cities to become sustainable, resilient, resource efficient, biodiverse, low carbon; to build a smart infrastructure; and to develop an inclusive, green urban economy with the ultimate aim of achieving healthy and happy communities. Website: http://www.iclei.org

† ICLEI's GreenClimateCities programme offers a process to local governments integrating low emission alternatives into their planning processes and policies. It has a clear methodology, with guidance and/or tools provided for each step. For further information, refer to http://www.iclei.org/our-activities/our-agendas/low-carbon-city/gcc.html

of tools to support city leaders and practitioners in addressing the impact of climate change (adaptation) and to help to reduce greenhouse gas emissions (mitigation) [10].

2.3 Cities and Energy Consumption: The Microlevel

Within planning research, it is commonly assumed that the design and location of residential areas have important consequences for households' energy consumption for housing and transport. It is believed that physical planning and design make it possible to achieve a more sustainable consumption pattern. Mainly there are four distinct consumption categories: energy use for cooling/heating and operating the house; energy use for everyday travel; energy use for long leisure-time travel by plane; and energy use for long leisure-time travel by car.

2.3.1 Urban Pattern

In their study of the relationship between urban planning and energy consumption, Holden and Norland pose the question: Does the change of urban forms tend to reduce the frequency and length of journeys and, hence, energy consumption? To this day, the disagreement persists and the critiques against planning have many different forms, including [11]:

1. Claims that engine technology, taxes on gasoline and driving, and road pricing are more effective measures for reducing energy consumption than urban planning [12,13].
2. The assertion that socioeconomic and attitudinal characteristics of people are far more important determinants of travel behaviour than urban form. Critics in this matter emphasise that the importance of form is highly overestimated in empirical studies [14].
3. Casting doubt on the assumption that proximity to everyday services and workplace will contribute to reduced travel in a highly mobile society [15,16].
4. That the relationship between non-work travel, especially long leisure-time travel, and urban form has been neglected [17].
5. The assertion that travel preferences rather than urban form influence travel behaviour: People live in city centres because they prefer to travel less, and not that they travel less because they live in city centres (the 'self-selection bias') [13].

Even though these aspects should not be taken lightly, there seems to be overwhelming support in the literature for the idea that planning does matter in determining the level of energy consumption in urban areas. This view is based on theory and empirical studies advocating that planning is an important instrument for promoting sustainable development.

2.3.1.1 Compact versus Dispersed Development

When it comes to land-use characteristics that influence energy use for everyday transport, Næss concludes that the following characteristics are favourable for reducing energy use per capita: high population density for the city as a whole; high density within each residential area; centralised settlement within cities and towns (i.e. higher density in the inner part than on the fringe); centralised workplace location; low parking capacity at workplaces; decentralised concentration at the regional level; and a high population for each city [11,18].

The main principle in the compact city theory is high-density development close to or within the city core with a mixture of housing, workplaces and shops. This implies densely and concentrated housing development, which favours semidetached and multifamily housing. Under this theory, development of residential housing areas on (or beyond) the urban fringe, and single-family housing in particular, are banned. Furthermore, central, high-density development supports a number of other attributes that are favourable to sustainable energy use: low energy use for housing and everyday travel, efficient remote heating/cooling systems, proximity to a variety of workplaces and public and private services, as well as a highly developed public transport system.

The supporters of the compact city theory [19–24] believe that the compact city has environmental and energy advantages, as well as social benefits. The list of advantages is remarkably long, including a better environment, affordable public transport, the potential for improving the social mix and a higher quality of life [25]. However, the main justification for the compact city is that it results in the least energy-intensive activity pattern, thereby helping us cope with the issues of global warming. The supporters of the dispersed city suggest that the green city—that is, a more open type of urban structure, where buildings, fields and other green areas form a mosaic-like pattern [11,18].

The list of arguments against the compact city theory is even longer than the list in support of it and includes: that it rejects suburban and semi-rural living, neglects rural communities, affords less green and open space, increases congestion and segregation, reduces environmental quality and lessens the power for making local decisions [11,25].

However, until fairly recently, an international consensus favouring the compact city as a sustainable development approach has dominated the debate [26]. Although there has always been considerable scepticism, the concept of the compact city has been so dominant that it seems inconceivable that anyone would oppose the current tide of opinion towards promoting greater sustainable development and the compact city in particular [27].

Consequently, it is not surprising that the 'move towards the compact city is in the mainstream throughout Europe' [28, p. 275].

The disagreements between the compact city and dispersed city discourses can be summarised to a large extent as a debate about two issues—which form affords the greater energy efficiency, and which aspects of sustainable development are more important?

The relationship between urban form and energy efficiency—especially energy use for travel—is at the core of the sustainable urban form debate. During recent decades, there has been a multitude of empirical studies supporting the relative energy efficiency of the two urban forms. Boarnet and Crane worked through this literature and came to a rather surprising conclusion: 'Very little is known regarding how the built environment influences travel' [13, p. 4]. Although these authors were referring to the United States, we find the same scepticism in Europe. Williams et al. conclude that 'A great deal still needs to be learnt about the complexity of different forms and their impacts' [29, p. 335]. This includes the relationship between urban compactness and travel patterns. A possible relationship between the built form and long leisure-time travel by car and plane is a part of this new knowledge that has to be learned [11].

The possible impacts of urban forms are not limited to travel behaviour. The built form also influences social conditions, economic issues, environmental quality and ecology within the city [29]. All these aspects are also important parts of the sustainable development concept and therefore can be used as criteria for a discussion about sustainable urban form. It should come as no surprise that a study that has minimising energy consumption as an overall goal could easily reach different conclusions from those of a study that aims at using urban form to 'reduce the number of people exposed to fine particles' or to 'promote social equity'. In the end, it will be necessary to balance these impacts because sustainable urban form is ultimately about values [30].

The dispute between the two camps has led to the development of a number of middle positions, which try to combine the best aspects of the compact and the dispersed city discourses, while at the same time trying to avoid the disadvantages of each. Among such alternative middle positions are the urban village [31,32], 'New Urbanism', the sustainable urban matrix [33], transit-oriented development [13], smart growth [34] and decentralised concentration [35–37], and sustainable urbanism [38]. These alternatives all try to combine the energy efficiency gained from a compact urban form with the broader quality-of-life aspects gained from the dispersed city. Still, whether a specific urban form will be more energy efficient is an empirical question [11].

2.3.1.2 Density

Much of the concern with density in planning and other related fields has been over high urban density and its assumed negative effect on the quality of life of urban residents. The city has historically been perceived to be a place of overcrowding, noise, dirt, crime, poverty, disease and so forth [39–41]. The high density existing in cities during the early period of the Industrial Revolution was seen as one of the major culprits of poverty and disease. As a result, planning controls (in Canada and Great Britain, for example) usually specified maximum densities. The planning reaction was a strong movement towards lower density housing outside of the city. In the United States and Canada, this took the form of a move to the suburbs, but in Great Britain and Sweden, it resulted in garden cities [41,42]. Radberg describes the garden city movement as representing decentralised urban growth [39]. The assumption was that these relatively low-density residential areas would not suffer from the ills found in high-density cities and would offer a higher quality of life to residents [43].

More recently, there have been many second thoughts on, and strong criticisms of, these trends. Environmentalists express concern about the environmental implications of low density [44], and urbanists are concerned about the decline of the city [19,40] or of the community [45,46]. Questions about low densities also have been posed by those who are concerned about the efficient use of land and public services [40]; by feminists and researchers who argue that low-density suburbs are hostile to women's lives—especially employed women with children and single parents [47] and by sociologists who criticise the social homogeneity and the social segregation in these low-density areas [46,48]. There are some, of course, who mention all of these problems [43,49].

In 1994, a detailed set of principles were set out in *Sustainable Development: The UK Strategy* (Department of the Environment 1994a), which was subject to further revision in 1999 (*UK Government's Strategy for Sustainable Development* 1999). In this strategy, the land-use planning system was targeted for specific treatment and the foundations laid for more recent policy statements on car usage and urban layouts [50]:

> (24.20) Urban growth should be encouraged in the most sustainable settlement form. The density of towns is important. More compact urban development uses less land …
>
> The scope for reducing travel, especially by car, is dependent on the size, density of development, and range of services on offer …
>
> (24.26) Town and city centres must incorporate the best principles of urban design …

Indeed, the commission recommended that planning guidance should increasingly reflect the growing sustainable agenda and should become much more integrated with other public policy areas, notably economic policy [49].

Hitchcock [51] and Orchard [52] direct attention to the fact that, on the whole, the discussion about increasing density and reducing urban land consumption concentrates almost totally on residential densities. It neglects all of the other land uses that make up a city, even though these land uses represent a significant proportion of a city's total land area. If these non-residential land uses are not taken into account, the reduction in land consumption achieved by increasing residential density will not be as great as initially conceived because services and amenities will have to be augmented to accommodate the increased population [43].

There are a number of advantages from increasing densities, which can be summarised as follows [43]:

1. It can help protect agricultural land from urbanisation.
2. It results in less depletion of the natural resources needed for construction purposes [53].
3. Built forms that facilitate higher net densities may result in significant reductions in energy demands [15,54]. Energy use within buildings can be reduced by passive solar architecture, superior insulation and energy-saving technology [54] or by built forms with low-surface areas and combined heat/cooling and power systems [55]. Owens [15] notes that very different densities (ranging from 37 to 250 dwelling units per hectare) are attainable using combined heat and power systems, depending on discount rates and fuel prices.
4. Decreased pollution from vehicle exhausts can be achieved as a result of a decline in the use of cars, the mixing of land uses, the provision of efficient and accessible public transportation, and walking [15,54]. High densities have been found to be associated with lower gasoline consumption per capita [35,56]; however, this is a controversial issue [28,52,57].
5. Decreased emission of pollutants may result from energy-saving land-use plans and from energy-efficient buildings [53].
6. High density may result in a decrease in the total number of car trips [53]. Nasar found lower automobile dependency scores in high-versus low-density neighbourhoods [58]. These differences were greater for older people, women and households with no children. A decrease in the number of kilometres per trip may also result [54,59–61].
7. High density has been found to be related to a higher proportion of travel on public transit, to greater public transit service provision per person and to transit use by a higher proportion of workers [20,35]. Increased public transit use, in turn, may reduce pollution emissions (an environmental advantage).
8. High density enhances the opportunity to use public transportation because high density brings the development of public transportation systems to the thresholds of profitability and efficiency. The report prepared by Berridge Lewinberg Greenberg, Ltd. adopts several benchmarks for the relationship between residential density and transit use. It suggests that 17–75 dwelling units per net hectare are necessary to sustain significant transit use, and 150 dwelling units result in a modal split of different transportation types in which more than 50% are public transit [62].

9. As a result of an increase in transit use, traffic congestion in residential, work and commercial centres may decrease [62].
10. Public transit can be more energy efficient. Handy highlights that it is the set of choices correlated with density—not density itself—that shapes travel behaviour [63]. In this context, Bannister discusses the interaction between socioeconomic circumstances and people's propensity to travel with different frequencies, trip lengths and transportation modes [59]. Moreover, gender should be added to these intervening variables [64]. Self debates the effect that a change in density would make. He claims, for example, that a 50% increase in the density of Canberra, Australia, would produce only a modest increase in public transit use [65].
11. It offers more opportunities to walk or ride a bicycle to work, service and entertainment facilities [59,60].
12. High densities may result in economies of scale that facilitate the use of better quality and more attractive building materials [51].
13. It enables the use of a building complex as an element of the urban composition. It also allows for a variety of densities and types of construction in a given region. Variation in density and construction, in turn, makes the environment more interesting [51].
14. High-density development in the proximity of public transportation lines can decrease the demand for land located further from these lines [66].
15. High-density development as infill in existing areas can revitalise those areas and can reduce the pressure to develop open spaces [61].

On the other hand, urban density is a major factor that determines the urban ventilation conditions, as well as the urban temperature. Under given circumstances, an urban area with a high density of buildings can experience poor ventilation and strong heat island effect. In warm-humid regions, these features would lead to a high level of thermal stress of the inhabitants and to increased use of energy in air-conditioned buildings. However, it is also possible that a high-density urban area, obtained by a mixture of high and low buildings, could have better ventilation conditions than an area with lower density but with buildings of the same height. Closely spaced or high-rise buildings are also affected by the use of natural lighting, natural ventilation and solar energy. If not properly planned, energy for electric lighting and mechanical cooling/ventilation may be increased and application of solar energy systems will be greatly limited [67].

2.3.2 Land-Use Distribution and Home–Work Trip

The distribution of uses over the city plan is the main driving or restraining force of transportation. It is those trips made to different facilities that shape our daily activities, whether going to work, or using educational, health or other public services, or just for leisure. Housing location influences the distances to different types of facilities, and the spatial location of most of these facilities suggests that average travel distances will be shortest for inner-city residents. However, there are claims that high accessibility to different services might create an increased demand for transport. Moreover, opting for a wider range of jobs, shops and leisure activities might establish the need for more everyday travel.

2.3.2.1 New Urbanism and Transit-Oriented Development

In urban design literature, the development of what is loosely referred to as 'New Urbanism' applies a raft of sustainable objectives to new urban layouts. The evolution of this movement may be traced to the development of urban villages (in the UK) and sustainable growth management projects, also known as New Urbanism (in the United States), that have been 'directed toward creating an alternative to the typical car-dominated suburban sprawl that predominates on the fringe of virtually all western cities and towns' [68, p. 207].

The main design concept in New Urbanism is the creation of a 'module' or 'ped-shed' (walkable urban design and sustainable place making). It is made up of a walkable neighbourhood with a 400-m radius to shops, services and transport nodes in which the fabric creates a series of interconnected pedestrian friendly streets. It does not necessarily ban the private car; however, it serves to 'maximize interaction while minimizing the travel needed to do it' [68, p. 209]. The logic is that there will be a dramatic reduction in car parking provision. It decreases from the predominant post-war patterns of two or three spaces per dwelling to one space or less. Consequently, a link is established between reduced car parking standards and the design of mixed uses, small street blocks and interconnected streets [69]. At a more fundamental level, conventional Western post-war car parking layouts are challenged by the need to raise residential densities to make for greater land-use efficiencies [70] and to foster non-car-based trip generation where a provision of less than one space per dwelling is a desirable objective [71]. Morris and Kaufman acknowledged that this focus on New Urbanism will make a significant contribution to achieving more sustainable cities, yet they voiced concern that 'While the intentions and potential to re-shape cities and towns towards less car dependence is a strong thrust of many practitioners of new urbanism, the evidence of major gains on the ground is limited' [68, p. 208].

The two approaches, New Urbanism and transit-oriented development, do not target increasing densities—any increase in density that is achieved is basically a by-product of a minimal nature. The emphasis of the New Urbanism movement is on small towns. New urbanists envision towns or neighbourhoods that are compact, mixed use and pedestrian friendly [42]. The emphasis of transit-oriented development, whose principal proponent is Calthorpe [49,72], is to plan balanced, mixed-use areas with a simple cluster of housing, retail space and offices within a one-quarter mile walking radius of a light rail system. The motivation for transit-oriented development is to improve the ills brought about by dependence on the automobile and the mismatch that exists between old suburban patterns and the post-industrial culture. The goal is to preserve open space and reduce automobile traffic without necessarily increasing density. Calthorpe [73] defines average net residential densities of urban transit-oriented developments as 44 dwelling units per hectare, with densities of 62–123 units per hectare for up to three-story apartment buildings [43,72].

2.3.2.2 Long-Distance Leisure Time Travel: Compensatory Travel?

An important question that arises from looking at the wider issue of energy use and greenhouse gas emissions is whether, for certain income levels, reduced local everyday travel will be compensated for by increased long-distance leisure travel at other times. Is it the case that—for certain income levels—the sum of 'environmental vices' is constant and that households managing on a small everyday amount of transport create even heavier environmental strain through, for instance, weekend trips to a cottage or long-distance holiday trips by plane? In the professional debate, some [73] have claimed that people living in high-density, inner-city areas will, to a larger extent than their counterparts living in low-density areas, travel out of town on weekends—for instance, to a cottage—in order to compensate for the lack of access to a private garden. In addition to this 'hypothesis of compensation', others, including the Swedish mobility researcher Vilhelmson [74], have launched a 'hypothesis of opportunity', which asserts that the time and money people save due to shorter distance daily travel will probably be used for long-distance leisure-time travel [11].

A study conducted in Norway suggested that the total energy use decreases as density reaches a certain point, although the data indicate that the total energy use increases at higher density levels. This pattern is similar to a pattern in the relationship between energy use and city size found by a number of empirical studies of cities in Norway, Sweden and England [18]. According to these studies, up to a certain point, energy use per capita decreases as density increases, but thereafter energy use starts to increase. Thus, the advantages of 'megacities' or 'extreme density areas' seem to be outweighed by the advantages offered by more modest forms of urban compactness [11].

2.3.3 Road Network and Transportation Network

Transportation is the leading consumer of energy and fuel in the city. The spread of roads among extended urban areas has helped people easily commute within these vast areas, thus making distances irrelevant and promoting more and more dispersion.

2.3.3.1 Road Network

The road network connects the various parts of the city and connects the city with its surrounding context. Thus, it contributes to the efficiency of the city, the flow of people and goods, and consequently to the economic cycle.

However, the emphasis on road network design has created not so lively neighbourhoods. This was expressed by The Prince's Foundation when examining 'Sustainable Urban Extensions' in the UK, in which the problem is summarised thus:

> House builders place a high priority on complying with rules and guidance on highway engineering. They are anxious that their estates' street system should be adopted by the local authority with the minimum of negotiation and delay. Estates are consequently designed around road layouts based on loops, dead-end spines and cul-de-sacs, whose principal aim is to handle road traffic as efficiently and safely as possible. But as well as discouraging travel on foot or by bicycle, these 'roads first–houses second' designs can damage the harmonious grouping of houses and visual quality…. [75, p. 1]

2.3.3.2 Transportation

Because a compact city strategy is recommended to be adopted, an emphasis on the development of rail transport of great accessibility, safety, sustainability and environmental friendliness is the main target. In a study conducted in 25 megacities, the following was found [8]:

1. Transportation is seen as the single biggest infrastructure challenge by a large margin and is a key factor in city competitiveness.
2. With air pollution and congestion emerging as the two top environmental challenges, stakeholders predict a strong emphasis on mass transit solutions.
3. Cities are more likely to focus on incremental improvements to existing infrastructure, rather than on new systems.
4. Demand management is rarely mentioned as a major strategy for addressing the cities' transport problems.

2.3.3.3 Parking

Parking policy is commonly viewed as a complementary measure to reduce car use when combined with other initiatives. Sustainability seeks to establish less reliance than previously existed on private car usage—for example, by promoting compact urban development in areas well served by good public transport. Urban design policy promotes a departure from the 'roads first, houses later' philosophy (as dictated by many highway standards) to give precedence to the relationship among buildings rather than strict adherence to predetermined road design in new residential environments. A new design approach to car parking has emerged where there is a shift from the previously adopted orthodoxy of minimum standards to maximum ceilings (i.e. no more than one space per dwelling). Such a trend towards reduction of parking standards (and thus provision) is at variance with the projected growth in car ownership worldwide [50].

Research studies clearly demonstrate that a trade-off exists between relaxing current car parking standards and raising residential density [70,76]. Urban design commentators and practitioners increasingly lobby in favour of a 'car-free urbanism' in which the sustainable residential neighbourhood is based on radical rethinking of density and parking policy. The avoidance of inflexible standards will yield improved layouts, so that urban design can reclaim the city back from the car [77].

2.3.4 Buildings: Form, Height and Facade Treatment

Globally, buildings are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of lighting, heating, cooling and air conditioning [67].

One way of reducing building energy consumption is to design buildings that are more economical in their use of energy for heating, lighting, cooling, ventilation and hot water supply. Passive measures, particularly natural or hybrid ventilation rather than air conditioning, can dramatically reduce primary energy consumption. However, exploitation of renewable energy in buildings and agricultural greenhouses can also significantly contribute towards reducing dependency on fossil fuels. Therefore, promoting innovative renewable applications and reinforcing the renewable energy market will contribute to preservation of the ecosystem by reducing emissions at local and global levels. This will also contribute to the amelioration of environmental conditions by replacing conventional fuels with renewable energies that produce no air pollution or greenhouse gases. The provision of good indoor environmental quality while achieving energy and cost-efficient operation of the heating, ventilating and air-conditioning (HVAC) plants in buildings represents a multivariant problem. The comfort of building occupants is dependent on many environmental parameters including air speed, temperature, relative humidity and quality in addition to lighting and noise. The overall objective is to provide a high level of building performance (BP), which can be defined as indoor environmental quality (IEQ), energy efficiency (EE) and cost efficiency (CE).

IEQ is the perceived condition of comfort that building occupants experience due to the physical and psychological conditions to which they are exposed by their surroundings. The main physical parameters affecting IEQ are air speed, temperature, relative humidity and quality. EE is related to the provision of the desired environmental conditions while consuming the minimal quantity of energy. CE is the financial expenditure on energy relative to the level of environmental comfort and productivity that the building occupants attained. The overall CE can be increased by improving the IEQ and the EE of a building [67].

Urban planning has a considerable impact on the future EE of buildings, and planners lack useful tools to support their decisions. A study was made presenting a new method based on a genetic algorithm that is able to search for optimum urban forms in mid-latitude climates (35–50°). Here, more energy-efficient urban forms are defined as those that have high building absorptance in winter and low summer building absorptance. These forms can be designed by choosing among regular tridimensional building geometries with fixed floor space indices, which can be parameterised by adjusting the following variables: number of floors, building length ratio, grid azimuth and aspect ratio on both directions. The results obtained show that adequate urban planning, based on the consideration of the local radiation conditions as a function of latitude, may result in significantly better building thermal performance. In particular, it is concluded that the highest latitudes are more restrictive in terms of optimal solutions: pavilions (cross-sectional square blocks) are the best solutions for latitudes of 50° and terraces (blocks infinite in length) are preferred for 45°. For lower latitudes, all urban forms are possible. In terms of grid angle with the cardinal direction, it is concluded that the angle should stay between −15° and +15°, except for the latitude of 50° where it can ranges from −45° to +45°. For slab and terrace urban forms, the spacing between blocks in the north–south direction should be maximised, quantified by a building-height-to-street-width (aspect) ratio that decreases with the increase of latitude, ranging from 0.6 for a latitude of 35°, to 0.4 for a latitude of 45°. For pavilions, the north–south aspect ratio is independent of latitude and should stay close to 0.7. The pavilion is the urban form that allows for a larger number of floors [78].

Arguably, the most successful designs were in fact the simplest. Paying attention to orientation, plan and form can have far greater impact on energy performance than opting for elaborate solutions. However, a design strategy can fail when those responsible for specifying materials, for example, do not implement the passive solar strategy correctly. Similarly, cost-cutting exercises can seriously upset the effectiveness of a design strategy. Therefore, it is imperative that a designer fully informs key personnel, such as the quantity surveyor and client, about their design and be prepared to defend it. Therefore, the designer should have an adequate understanding of how the occupants or processes, such as ventilation, would function within the building. Thinking through such processes in isolation without reference to others can lead to conflicting strategies, which can have a detrimental impact upon performance. Likewise, if the design intent of the building is not communicated to its occupants, there is a risk that they will use it inappropriately, thus compromising its performance. Hence, the designer should communicate in simple terms the actions expected of the occupant to control the building [67].

2.3.5 Renewable Energy

Research into future alternatives has been and is still being conducted to solve today's complex problems such as the rising energy requirements of a rapidly and constantly growing world population and global environmental pollution. Therefore, options for a long-term and environmentally friendly energy supply have to be developed that lead to the use of renewable sources (water, sun, wind, biomass, geothermal, hydrogen) and fuel cells. Renewables could shield a nation from negative effects in the energy supply, pricing and related environmental concerns. For many years, hydrogen (for fuel cells) and the sun [for photovoltaics (PVs)] have been considered as likely and eventual substitutes for oil, gas, coal and uranium. They are the most abundant elements in the universe. The use of solar energy or PVs for everyday electricity needs has distinct advantages: avoiding consuming resources and degrading the environment through polluting emissions, oil spills and toxic by-products. A 1-kW PV system producing 150 kWh each month prevents 75 kg of fossil fuel from being mined. It avoids 150 kg of CO_2 from entering the atmosphere and keeps 473 L of water from being consumed. Electricity from fuel cells can be used in the same way as grid power—to run appliances and light bulbs and even to power cars because each gallon of gasoline produced and used in an internal combustion engine releases roughly 12 kg of CO_2, a greenhouse gas (GHG) that contributes to global warming [67].

Sunlight is not only inexhaustible but also only energy source that is completely non-polluting. The World Summit on Sustainable Development held in Johannesburg in 2002 committed itself to 'encourage and promote the development of renewable energy sources to accelerate the shift towards sustainable consumption and production'. Accordingly, it aimed at breaking the link between resource use and productivity. This can be achieved by the following:

1. Trying to ensure economic growth does not cause environmental pollution
2. Improving resource efficiency
3. Examining the whole life cycle of a product
4. Enabling consumers to receive more information on products and services
5. Examining how taxes, voluntary agreements, subsidies and regulation and information campaigns can best stimulate innovation and investment to provide cleaner technology

Until 2002, renewable energy contributed as much as 20% of the global energy supply worldwide [79]. More than two-thirds of this came from biomass use, mostly in developing countries, some of it unsustainable. Yet, the potential for energy from sustainable technologies is huge. On the technological side, renewables have an obvious role to play. In general, there is no problem in terms of the technical potential of renewables to deliver energy. Moreover, there are very good opportunities for Renewable Energy Targets (RETs) to play an important role in reducing emissions of GHGs into the atmosphere, certainly far more than have been exploited so far. However, there are still some technical issues to address in order to cope with the intermittency of some renewables, particularly wind and solar. Yet, the biggest problem with relying on renewables to deliver the necessary cuts in GHG emissions is more to do with politics and policy issues than with technical ones [79]. For example, the single most important step governments could take to promote and increase the use of renewables is to improve access for renewables to the energy market. This access to the market needs to be under favourable conditions and, possibly, under favourable economic rates as well. One move that could help, or at least justify, better market access would be to acknowledge that there are environmental costs associated with other energy supply options and that these costs are not currently internalised within the market price of electricity or fuels [67].

Renewables are generally weather dependent and as such their likely output can be predicted but not controlled. The only control possible is to reduce the output below that available from the resource at any given time. Therefore, to safeguard system stability and security, renewables must be used in conjunction with other, controllable, generation and with large-scale energy storage. There is a substantial cost associated with this provision.

The recent REN21* report (2014) states that renewables have entered the mainstream as we begin the Decade of Sustainable Energy for All (SE4ALL),† mobilising towards universal access to modern energy services, improved rates of EE and expanded use of renewable energy sources by 2030. In 2012, renewable energy provided an estimated 19% of global final energy consumption, and it continued to grow in 2013. Of this total share in 2012, modern renewables accounted for approximately 10%, with the remainder (estimated at just over 9%) coming from traditional biomass. Heat energy from modern renewable sources accounted for an estimated 4.2% of total final energy use; hydropower made up about 3.8%, and an estimated 2% was provided by power from wind, solar, geothermal and biomass, as well as by biofuels. The combined modern and traditional renewable energy share

* REN21 is the global renewable energy policy multi-stakeholder network that connects a wide range of key actors. REN21's goal is to facilitate knowledge exchange, policy development and joint action towards a rapid global transition to renewable energy.

† The UN Secretary-General's initiative Sustainable Energy for All mobilises global action to achieve universal access to modern energy services, double the global rate of EE and double the share of renewable energy in the global energy mix by 2030. As the newly launched Decade for Sustainable Energy for All (2014–2024) unfolds, REN21 will work closely with the SE4ALL Initiative towards achieving its three objectives.

remained about level with 2011, even as the share of modern renewables increased. This is because the rapid growth in modern renewable energy is tempered by a slow migration away from traditional biomass and a continued rise in total global energy demand [80].

It is useful to codify all aspects of sustainability, thus ensuring that all factors are taken into account for each and every development proposal. Therefore, with the intention of promoting debate, the following considerations are proposed [67]:

1. Long-term availability of the energy source or fuel
2. Price stability of energy source or fuel
3. Acceptability or otherwise of by-products of the generation process
4. Grid services, particularly controllability of real and reactive power output
5. Technological stability, likelihood of rapid technical obsolescence
6. Knowledge base of applying the technology
7. Life of the installation—a dam may last more than 100 years, but a gas turbine probably will not
8. Maintenance requirement of the plant

However, the improved energy performance of cities from these kinds of initiatives is usually being outweighed by the increases in the use of fossil fuels by private transports that have occurred in recent years. This is the case all over the developed world, and particularly in the United States and Australia, where low-density urban sprawl has made it very difficult to introduce energy-efficient public transport systems. In cities with low-density sprawl where most people rely on private cars, it will be particularly important to introduce new transport propulsion such as fuel cell technology to make private transport and public transport less polluting and more energy efficient [81].

Really significant breakthroughs in urban EE and introduction of sustainable energy systems in cities will emerge only as a result of major changes in national energy policy. We have seen some significant breakthroughs in some countries, but far more needs to be done to transform our cities from fossil fuel junkies to sustainable, future-proof systems [81].

Thus, in order to reach a sustainable environment, a combination of policies and actions is essential (as proposed in Figure 2.3). These policies include sustainable energy production and renewable energy production as considerations for city planning regarding EE. When these policies are combined with trends in users' consumption patterns, a sustainable environment can be reached.

It is important to note that the know-how exists to decrease urban energy use by 50% or more without significantly affecting living standards, while

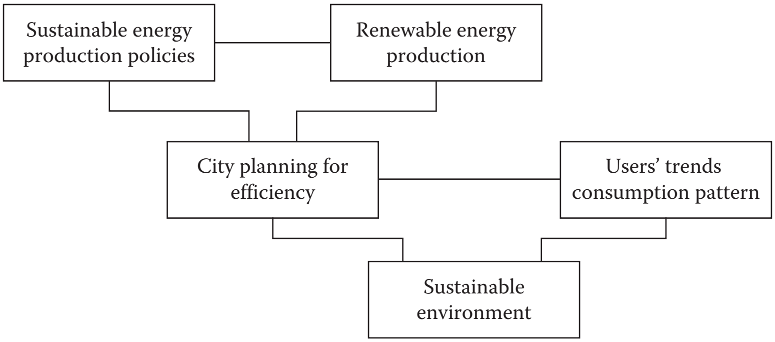

FIGURE 2.3
The relationship among policies for achieving a sustainable environment.

creating many new local jobs at the same time. There are some initiatives to improve the EE of cities—for example, The Cities for Climate Protection Program of the ICLEI. This is a performance-oriented campaign, started in 1993, offering a framework for local authorities to reduce global warming and waste gas emissions all over the world. This framework includes five performance milestones (which were implemented by 500 local governments participating in the campaign in 2004) [82]:

1. Conduct an energy and emissions inventory and forecast
2. Establish an emission target
3. Develop and obtain approval for the local action plan
4. Implement policies and measures
5. Monitor and verify results

2.4 City Consumption and City Impact

2.4.1 Ecological Footprint

In order to measure a city's impact versus its consumption, a more sophisticated analysis has been developed by Rees that can calculate a city's ecological footprint (EF) [83]. As previously mentioned in Chapter 1, it is based on an ecological understanding of how a city extracts food, water, energy and land from a bioregion (and beyond) and what ecosystem services it requires to absorb its wastes. The total resource use of a city is figured relative to its population, and the resulting calculation allows a per capita footprint of land to be compared to that of other cities [84].

The EF, as previously explained, translates consumption of various types into a common metric—the total area of productive land and water ecosystems required to produce the resources that the population consumes and to assimilate the wastes that the population produces, wherever on Earth that land and water may be located [85]. In calculating the footprint of nations or regions, the different bioproductivities of various land types are taken into account; this is achieved by incorporating equivalency factors, such that the calculated EF is expressed as standardised acres of world-average productivity. EFs quantify humans' overall impact on nature in relation to carrying capacity [86]. In 2000, the average global footprint was 6.25 acres per capita, but there were only 4.8 acres available per person based on the biologically productive area divided by the world population. Hence, we were in a deficit of 1.45 acres per person [86], depleting Earth's natural capital rather than living off nature's interest [87]. According to the Global Footprint Network for 2007, these numbers are 6.7 acres per person as EF per capita worldwide, while the biocapacity for Earth is only 4.4 acres per capita. Thus, the deficit has increased to 2.3 acres [88].

The concept of an EF is now firmly ensconced in the environmental literature and, despite its limitations [89–95], there is considerable support among researchers and environmentalists for the footprint as a clear, unambiguous indicator of human impact on nature that is easily applied [85,93,94,96].

One of the important linkages, that is not often drawn, is between EF, urban density and transport energy. Some commentators have criticised the use of per capita car use and per capita land use as confounding the statistics because population is in both denominators [97,98]. However, if the population factor is removed, then it is possible to look at whether land area (the direct footprint of a city) relates to transport [84].

One inherent weakness of using the EF is that it, like other inventory tools, is intended to measure impact. The EF is not designed look at cause and effect. However, where qualitative data provide insight into decision-making processes and choices, the EF becomes a useful tool for understanding the pathways to different outcomes. Also, the raw data assembled for its calculation could be used for specific questions of importance in planning practice.

In addition, the EF could be used by policy makers as part of the approval process for proposed developments. Rather than restricting development according to standard urban design codes, developments could be classified by a maximum EF. It would be up to developers and designers to plan communities that fall within the assigned EF. Rather than crippling innovation and creativity in urban design through legislation, a maximum assigned EF would foster new ideas and designs to tackle the sustainability challenge [87].

A study on the EF in EcoVillage at Ithaca, New York (United States), found that consumption, not built form, contributes most to the overall footprint;

therefore, the link between design and behaviour is of critical importance. The experiences at EcoVillage at Ithaca suggest that physical design may be a catalyst or facilitator of some changes in consumption, especially as they relate to utilities and possibly also to transportation, but no overall conclusion on the interaction between design and behaviour can be drawn from this study [87].

2.4.2 Sustainability Assessment

The EF helps when assessing development on the global scale, but on the local scale there is a need for a much more comprehensive tool. A key aspect to sustainability assessment is the assistance it provides to complex, controversial urban policy issues. One example is the density of cities and planned developments—a very controversial policy area in some urban settings. There is a strong global economic rationale for redeveloping car-dependent cities into focused centres and corridors to make better use of infrastructure at the scale required to provide such local services as public transport, shops and community services within walking distance. The lesser need for transport, the reduced urban sprawl and EF, the far greater opportunities for housing diversity, and other equity issues all provide additional justification at local and global levels. However, those local residents in the area where redevelopment is planned often perceive it as a threat to their local environment and social amenity. Sustainability assessment of such development can ensure there are real global economic, environmental and social benefits (often regional benefits but they may as well be global for many local people), but it can also ensure that developers include real local economic, social and environmental benefits. It can be used to ensure that there is a clear rationale for any development in terms of local environmental benefit (enhancing the local sense of place) and of local socioeconomic benefit (clear provision of better services). With these in place, the local and global issues can be seen to be resolved and a net benefit provided [84].

'Good' planning begins with an assessment of users' needs [99]. For example, transit stops are located in a way that is sensitive to demand. However, planning may also help to shape demand. Indeed, the very existence of planning reveals some general level of acceptance that land markets require guidance to ensure the provision of needs but in a sustainable manner. There are a number of arguments against sprawl; in some cases, suburban development has devoured many wetlands, with consequences for future water quality and supply [100,101], while in other parts of the world it has engulfed arable land. Auto-dependence and associated air pollution have severe implications for those with respiratory problems, and carbon dioxide emissions may contribute to climate change with unforeseeable consequences [87].

Cities will always be centres of consumerism. However, we can change the way they utilise resources. This can be done by conceptualising cities as sustainable ecotechnical systems, which requires converting their largely linear resource throughput into circular resource flows. EE, resource productivity, and urban and industrial ecology are key terms in this context [78].

2.5 Roles of Stakeholders in Planning for EE

2.5.1 Legislations and Laws Addressing Environmental Issues

In order to achieve more energy-efficient cities, where development is sustainable and environmentally responsive, laws and legislations should play a vital role. In 2000, the city of Barcelona introduced its mandatory 'solar ordinance'. All new housing, offices, restaurants, and public buildings have to install solar hot water systems if they use substantial amounts of hot water. Old buildings also have to be fitted with solar hot water systems when they are refurbished. Around the Mediterranean, use of solar hot water systems has become commonplace. In Japan, about 10% of all dwellings have their own solar hot water systems [81].

In German cities, solar PV panels are becoming commonplace, despite the country's relatively cloudy skies. This is primarily due to the German government's 'feed-in' legislation, which has fixed subsidies and favourable tariffs for owners of PV roofs. They used to be paid about 50 cents/kWh for selling their electricity back to the electricity grid, which is about four times the price paid to conventional electricity generators. The policy has led to a massive growth in demand for solar PV technology across the country. Similar policies have been introduced in Austria, France and Spain [81].

2.5.2 Governance

Better governance is a vital step towards better cities. With so many areas crying out for investment in better infrastructure, it is not surprising that funding emerges as a big issue for many stakeholders in a study survey done on megacities.* However, for those involved in city management, it is improvements to governance—rather than just money—that are the top

* A unique global research project undertaken by two independent research organisations, GlobeScan and MRC McLean Hazel, with the support of Siemens, the infrastructure provider. The goal of the project was to carry out research at the individual megacity level to gather objective data as well as perspectives from mayors, city administrators and other experts on local infrastructure challenges. The findings are based on an in-depth survey of over 500 megacity stakeholders, including elected officials, public- and private-sector employees, and influencers such as academics, NGOs and media. This survey was supplemented with extensive secondary research, to enable the team to shed light on the key challenges faced by global cities at various stages of development.

priority going forward. More than half of respondents with knowledge of urban management see improved planning as the priority for solving city problems, compared with only 12% that prioritise increased funding. In addition to more strategic planning, there is also a strong focus on managing infrastructure and services more efficiently. Both these goals will require cities to make the step from passive administration of existing services to a more active style of managing systems that focuses on improved efficiency and more measurable outcomes [8].

There is also a relationship between the scale of the environmental burdens and the appropriate roles of different levels of government. Some governance failures can be traced to a mismatch between the scale of the problem and the scale at which the response has been articulated. Local governance should not be expected to reduce carbon emissions voluntarily, although it can be a very appropriate level for driving local water and sanitation improvements. Global governance, on the other hand, is clearly needed to help develop institutional mechanisms to reduce contributions to global climate change, but it is inappropriate for developing institutional mechanisms for managing local water and sanitation systems. On the other hand, reducing local environmental burdens often requires support (or at least the absence of opposition) from global processes and institutions, while responses to global burdens often need to be rooted in local agency [102,103]. Moreover, cities and their needs are complex, and the traditional, departmentally organised approach to city governance needs to be rethought to enable more holistic solutions on the one hand and more responsiveness and accountability to citizens at a local level on the other [8].

The search for improved efficiency may require megacities to contract out the management of more services to the private sector. One of the more surprising findings in the survey is the fact that the main perceived advantage of private sector operation is improved efficiency (more than access to funding). Where cities do increase private sector involvement, they will need to create the right framework for success. There is a variety of models available, where ownership and operation of services can be shared. But when entering into partnerships with the private sector, the consequences must be well thought through, and success will require a 'context-sensitive' approach to privatisation, with overall control (and responsibility) resting with the public sector. If comprehensive governance models and efficient management structures are put in place, economic attractiveness, environmental protection, and quality of life for all citizens need not be contradictory goals [8].

Today, there is almost universal recognition in governments at all levels that it is essential to incorporate environmental considerations into urban planning and management. This provides significant benefits in every area of urban life, cutting across issues such as health, poverty, security, and economic development. Moreover, there is an essential call for better communication within the government and with other stakeholders involved in city planning and operation.

2.6 The Middle East Context

2.6.1 The Gulf Area

The Gulf area as an arid zone provides a challenge for architects and urban planners to build urban settlements that respond to the needs of inhabitants for climatic comfort and in the same time be sensitive to energy use and its consequences of climate change. This section reviews two approaches to tackle this issue and provide a climatic responsive built environment that is energy efficient.

2.6.1.1 A Return to Compact Cities

Over centuries, the climate in Arabia has become a major factor that shaped the daily life of local societies and, thus, the form of their cities. Old cities were characterised by their compactness, which stemmed from the need for protection from the harsh environment. Urban fabric has been dominated by the building masses, the limited number of enclosed public and outdoor spaces, and the inward-looking architecture. Besides its environmental utility, compactness also provided a physical support to the local community, reflecting its strong social structure and complex network of kinships. Nowadays, Gulf cities that are mostly shaped by the modern movement and American lifestyle are in complete negation with their past. An unprecedented sprawl effect is taking place all over the Gulf countries due to the heavy reliance on private transportation, high building technology, powerful air-conditioning systems and private housing [104].

A study by Ben-Hamouche on cities in Arabia recognised two historical shifts in the form of the city. The first one occurred during the industrialisation era from the old compact city to the modern dispersed city, and the second shift is expected to occur in the information age from the modern dispersed city back to the post-modern compact city through the combination of the concepts of sustainability and IT. He refers to the New Urbanism movement and its principles in his call for referral to compact cities as a remedy to the cancerous sprawl and suburbia [104].

Although this study claims that the information age will make the city more compact, due to the diminishing need for mechanical mobility, this increased accessibility might not lead to compactness. The sprawling may continue; only car usage might decrease but not necessarily increasing density.

2.6.1.2 Masdar City: Innovative Technologies [105]

As the geographical core of the Masdar sustainable energy initiative, Masdar City has been one of the elements to move forward the most quickly. The concept is simple but radical: zero-carbon and zero-waste. This involves a radical rethink of everything about the way that the city will function.

The 7 km^2 site selected is near the airport and about 17 km from the city of Abu Dhabi, and were it not in the desert, it would be classified as a 'green-field' site. The fundamentals of the plan have been agreed, ground has been broken and phase one is underway. Initially, more than $300 million of procurement is in place, and an additional $1 billion was expected to be committed by the end of 2009. The city was due to be built in 7 years, at a total cost of $22 billion. The first $4 billion of this was coming from the Masdar Initiative, with the remaining $18 billion being raised through direct investments and other financial instruments. In 2013, the Abu Dhabi government has committed $15 billion to Masdar city. Moreover, more than $1 billion of equity has been invested across renewable energy projects with a total value of over $6.9 billion [106].

Sir Norman Foster, the British architect, is behind the design of the city, and detailed planning and preparation has been done by a range of international consultants and experts, including Pooran Desai from BioRegional, the UK consultancy WSP, Canada and United States-based CH2M Hill.

2.6.1.2.1 Building Design

Much of the design will adopt local, vernacular architectural principles, but this will also be mixed with a lot of cutting edge technology, some of it still in the experimental phase. The city will incorporate traditional medinas, souks and wind towers and will make use of open, public squares and narrow shaded walkways to connect homes, schools, restaurants and shops. The buildings themselves will then adopt a wide range of passive measures, and they should consume well under a quarter of the energy used by comparable buildings elsewhere in the region.

2.6.1.2.2 Transportation

There will be no cars in Masdar City—indeed, no internal combustion engines of any type. Instead, there will be a network of electric trams (a light rail transit or LRT system, which will also link to the planned Abu Dhabi LRT system) and smaller, 'personal rapid transit' vehicles, effectively an automatic, driverless system of electric taxis controlled by a central computer. These will be programmed so that, once occupied, the passenger has privacy and no other passenger can board along the route.

2.6.1.2.3 Renewable Energy

All the energy used in Masdar will be renewably generated, not only the electrical power but also that for heating, cooling and transport. The bulk of this is likely to come from one solar form or another. There will be power generation for a smart grid from solar thermal power and concentrating PV and also distributed PV throughout the city. The wind resource in Abu Dhabi is generally poor and will contribute little to the overall mix, but some geothermal and waste-to-energy, particularly from bio waste, are also likely to be significant contributors.

As well as providing a regional location, there are also numerous partnership opportunities for companies with technologies that may be used at Masdar. Among the energy technologies expected to be sourced are PV and solar thermal power generation (concentrating PV, parabolic trough and parabolic dish generation); advanced thermal waste treatment plants; geothermal systems that can be used for district cooling; and smart grid management systems. A range of other district cooling systems are also being considered, together with water desalination and grey-water treatment plants, and waste handling systems, including plasma and pyrolysis. More widely, procurement is also underway for IT systems, the transport infrastructure and facilities management and services.

The Arabic word 'Masdar' was chosen as the name of the project because one definition of the word is 'source'—in the sense of the root or spring from which things originate. For years, many good renewable energy projects have suffered through lack of access to sources of funding. The Masdar Initiative demonstrates that the combination of good projects and a plentiful source of funding can result in very rapid development of even the most ambitious plans. As such, it may also be a beacon for other places that are contemplating whether large-scale investment in renewables really can pay off.

2.6.2 Egypt

There is a growing awareness in Egypt about the change in climate since 1982 when that country established the Egyptian Environmental Affairs Agency (EEAA). Egypt was also one of the first Arab countries to sign the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. Egypt has participated in and undertaken several actions that deal with climate change and environmental issues [107].

1. Ratification of the UNFCCC, the issuance of Law 4/1994 for the Protection of the Environment, and participation in various international workshops and conferences related to climate change to avoid having any international obligations on developing countries, including Egypt.
2. The Ministry of Electricity and Energy has established several projects in the field of new and renewable energy (wind, solar, hydro and bio) and has encouraged EE projects.
3. The Ministry of State for Environmental Affairs has established guidelines for the private sector to encourage investments in the field of clean energy projects, waste recycling and afforestation.
4. With the restructuring of the National Committee of Climate Change in 2007, as the coordinator on the national level related to climate change issues, by putting a visionary for needed policies and

strategies to deal with these issues, and by suggesting mechanisms required for implementation.
5. Maximising the benefit from Kyoto Protocol Mechanisms through implementing Clean Development Mechanism Projects.

An energy code for BP was established by the Housing and Building Research Center (HBRC) in 2006. It specifies the energy consumption of buildings according to their use and typology. This was an initiative to make buildings more energy efficient; however, this code has not been yet implemented.

2.6.2.1 Strategic Planning for Cities Programme

On the urban planning level, since 2008, there have been a lot of efforts made to upgrade more than 200 Egyptian cities. The programme, conducted by the GOPP, started strategic planning of cities under the auspices of the Ministry of Housing. A parallel programme is run and funded by the UN-Habitat concerning small cities (i.e. 25,000–50,000 inhabitants).

It is important to note that continuous urbanisation of rural areas in Egypt has created a unique case. One can find cities that are just villages in their structure, plan, network and physical and social infrastructure. These cities comprise most of the Egyptian urban context. This is primarily due to the way a city is defined by the government (according to population size). Typically, a city is defined as a settlement with more than 25,000 inhabitants. In other words, a village could become a city when its population exceeds this limit; however, it will still hold its rural characteristics, way of life, function and physical features.

In the context of the strategic planning of cities, three main sectors are studied: shelter and informal areas, infrastructure and local economic development. Three other sub-crosscutting sectors are investigated: local governance; environment; and poverty, women & vulnerability. Its main activities include preparing a city profile for the sectors investigated, a list of projects that are required by the city that represent its priorities, and a strategic plan with these projects situated in the appropriate locations that shows the road network, land uses and city limits. All processes are conducted with a participatory approach where all the city stakeholders are involved in the process of planning, prioritising and decision making. The final product is the strategic plan for the city.

The environment sector is mainly concerned with environmental hazards, pollution, noise and solid waste management and recycling. There is no mentioning of energy responsiveness or planning for maximising efficiency of energy use. However, these issues might be tackled depending on the environment consultant concept and the local context of the city under study.

Despite the programme's negligence related to energy responsive strategies, it provides a unique opportunity to really make our cities green and energy responsive. There are a number of ideas and actions that, if gathered and formulated into a strategy, could present a pioneer example within local contexts of the developing world.

In the progress of strategically planning the city of Ashmun in the governorate of Menoufia, Egypt, a number of ideas and requests were submitted by the local community that are energy responsive in essence (Figure 2.4) [108].

1. Preserving city boundaries with minimal increase just to accommodate future needed services and the preservation of agricultural land.
2. The need to build a ring road to increase transportation efficiency and decrease energy consumption and pollution.
3. Increasing the heights to double the street width (law specifies max building height = 1.5 street width) in structurally fit buildings to become four floors instead of only three floors. Thus dandifying existing urban areas instead of horizontal spread of the city.
4. Non-inclusion of sprawling houses in city limits in order to prevent or minimise future expansion on agricultural land.
5. Wise location of needed services, appropriate rates per capita of services and facilities, and their concentration in single location central to community.
6. Advocating mixed uses as commercial/residential uses.

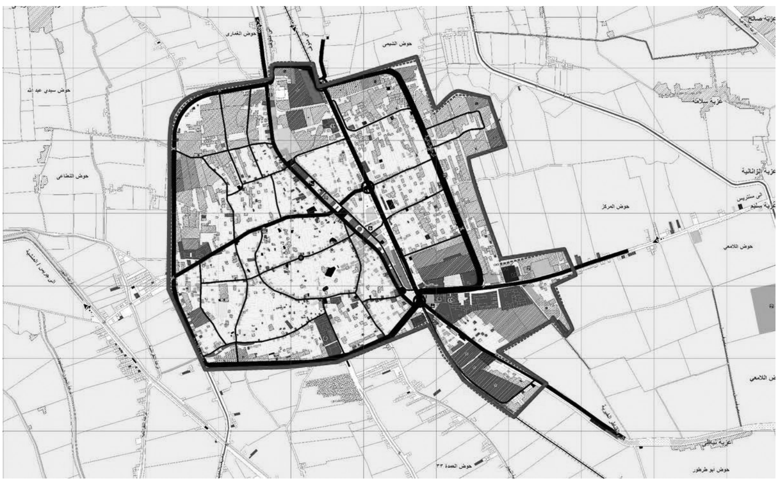

FIGURE 2.4
Keeping Ashmun city boundaries to the minimum and preserving surrounding agricultural land. (From Associated Consultants. (2008). *Strategic Planning for Ashmun City, Menoufia, Egypt*, Ministry of Housing, Utilities & Urban Communities and The General Organization of Physical Planning (GOPP), Cairo, Egypt.)

7. Locating workshops in a special area outside the residential mass, increasing efficiency of operation, management and transportation to other cities for further manufacturing.
8. The need to replace old deteriorated water supply asbestos pipes to prevent leakages and minimise health problems.
9. Better road network linkage with surrounding settlements for better and efficient transportation. Proposing a bridge to decrease travelling distance to neighbouring industrial zone (Sadat city). Thus providing jobs, preventing agricultural land loss and advocating more efficient industrial centres.

These ideas were required and enforced by the local community and the elected leaders, which shows awareness of the pressing issues of energy responsiveness and conventional resources depletion, despite the fact that a direct correlation to EE was not explicit. But this subtle concern can provide a solid base for more action to provide strategies for planning for EE in Egyptian cities.

2.6.2.2 Cairo

The megacity of Cairo is rated second worldwide for its pollution rate (Figure 2.5) [8]. There are approximately 18 million people living in the Greater Cairo region, which consists of five governorates. Expansion has caused many problems related to the environment, quality of life and infrastructure. Cairo is denser than many other cities because the law specifies an allowed maximum density of 150 person/feddan (357 persons/ha); it does not need to become any denser. However, there is a need to revise the current development strategies concerning the sprawling communities around the city. These gated communities are a replica of the American image of the perfect housing environment, where a villa exists on a private piece of land with a front lawn and a back garden. The building density is as low as 25% (downtown can reach 60%–70%) to accommodate for the extended open spaces. These communities were originally part of the green belt designated to surround Greater Cairo. However, there was a shift towards transforming it into dwelling areas, but with low densities, as an attempt to preserve the concept of the green belt.

Although there is a growing demand for these communities, they are far from environmentally friendly. The extension towards the new cities of Sheikh Zaied and 6th of October on one side of Cairo and the cities of Obour, Elshorouk and New Cairo on the other defies the original concept of establishing these as separate cities and transforms them into parts or districts of ever-growing Greater Cairo (see Figure 2.6).

This has really affected energy consumption trends, especially in increasing car dependency. The lack of an adequate transportation system that

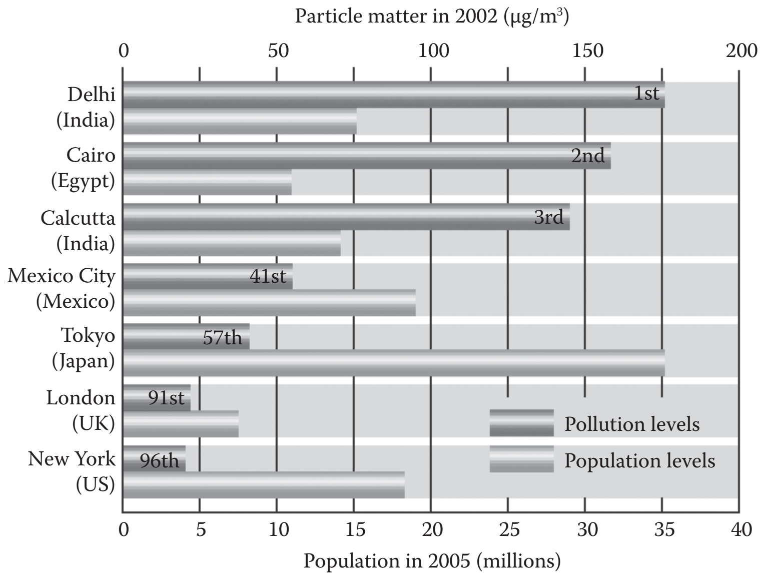

FIGURE 2.5
World's most polluted cities. (From The World Bank as cited in GlobeScan and MRC McLean Hazel, *Megacity Challenges: A Stakeholder Perspective*, Siemens AG, Munich, 2007.)

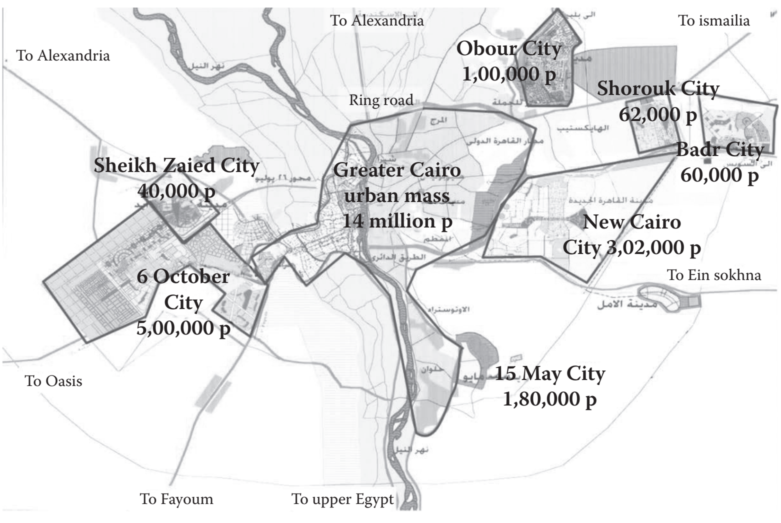

FIGURE 2.6
Greater Cairo with the surrounding new cities.

links all spread-out areas increases car dependency and fuel consumption. The home–work trip is becoming a daily nightmare resulting in congested traffic with a continuous peak hour.

Moreover, these gated communities and nearby new cities lack sub-centres that provide adequate services or businesses. Thus a trip to downtown Cairo is essential for obtaining services.

2.7 Conclusions

In November 2007, UN-Habitat held an Expert Group Meeting on 'Cities in Climate Change' in Nairobi, Kenya, bringing together participants from UN agencies, research institutions, local authorities and the private sector. The experts discussed the role of UN-Habitat regarding climate change and worked out basic elements for the agency's strategy on cities in climate change. The main outcomes of the Expert Group Meeting are that UN-Habitat has a clear role to play in dealing with climate change at the local level with a special focus on urban areas in developing countries. Furthermore, climate change should be regarded as a cross-cutting issue and integrated into UN-Habitat's existing initiatives and programmes [109].

The experts underlined the importance of immediate action—for example:

1. Launching of the Sustainable Urban Development Network (SUDNet) in 2008 for strengthening the performance of local governments to enhance climate change mitigation and adaptation measures in developing countries through existing and new partnerships
2. Promoting city-to-city cooperation
3. Conducting vulnerability assessments and risk mapping at the local level and providing guidelines for adaptive local planning
4. Collecting and sharing case studies on good practice
5. Developing mechanisms to assist cities in preventing land-use conflicts arising from relocation of human settlements
6. Assisting governments in translating National Adaptation Plans of Action to Local Adaptation Plans of Action together with adequate transfer of resources

This is in line with the experience gained from the Strategic Planning for Cities Program in Egypt because the actions required by the experts are what the programme in Egypt lacks on the broad level.

Much can be done in the developing countries. In the Egyptian context, there is a need for more awareness and action with regard to energy-efficient

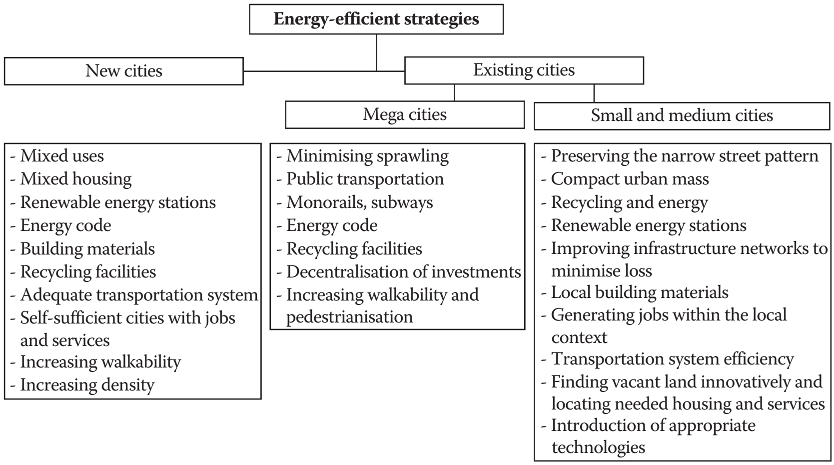

FIGURE 2.7
Energy efficiency strategies in cities.

strategies and to integrating them in urban planning. These strategies are summarised in Figure 2.7. On the personal level, it is recommended to try to use one's car less and separate his garbage as the former mayor of Curitiba, Brazil, advises [81].

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