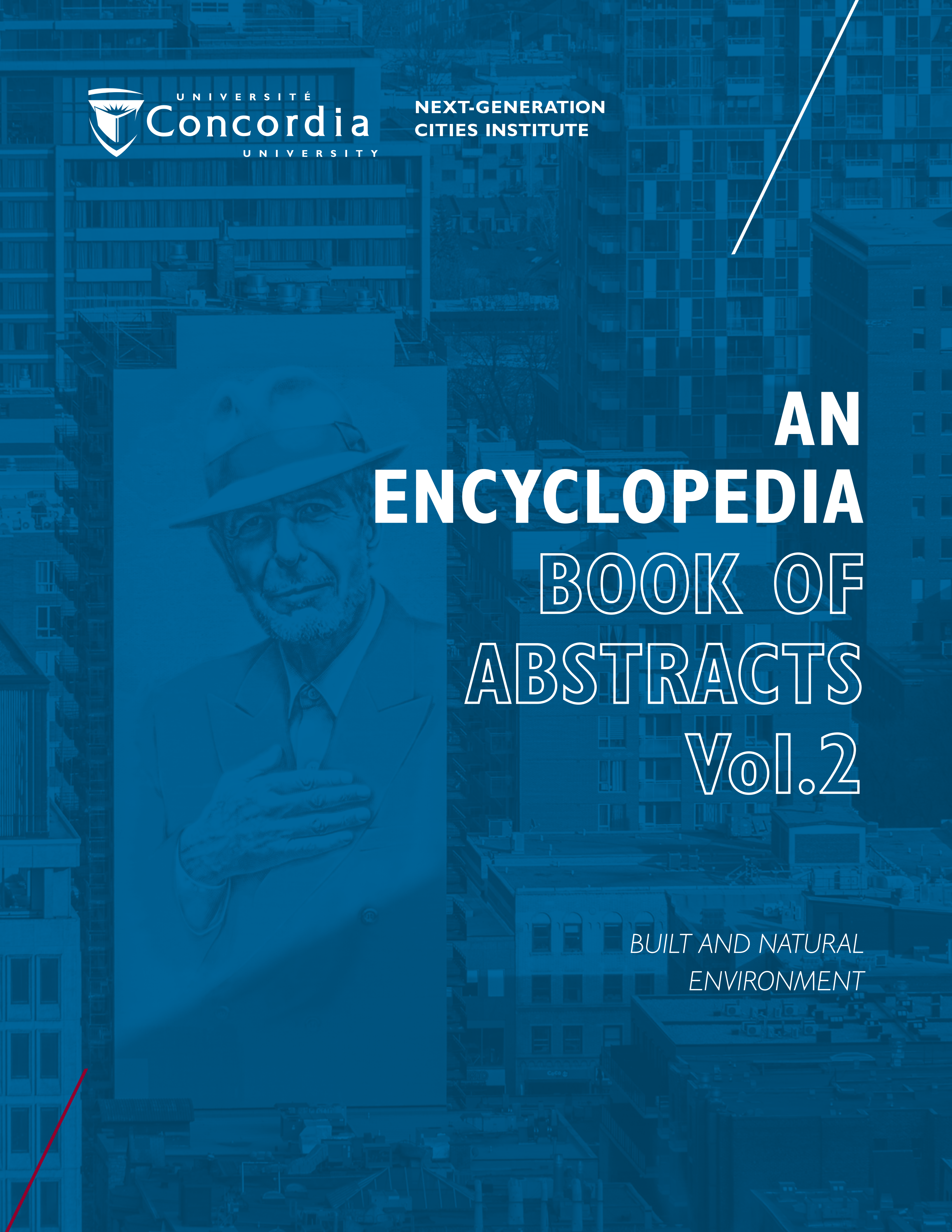


Université Concordia University

NEXT-GENERATION CITIES INSTITUTE


# AN ENCYCLOPEDIA BOOK OF ABSTRACTS Vol.2

*BUILT AND NATURAL ENVIRONMENT*

**BOOK OF ABSTRACTS / VOL. 2**
**FOR NEXT-GENERATION CITIES: AN ENCYCLOPEDIA**

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## *“THE HARDWARE OF THE CITY”*

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## INTRODUCTION



## PART 1

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# INTRODUCTION
# BUILDING SUSTAINABLE CITIES: EVOLUTION AND LIVABILITY

Human settlements are a fascinating object of inquiry. Their evolution testifies to the extraordinary inventiveness of human populations in adapting to varying geographical and environmental conditions, often achieving high levels of technical sophistication and bioclimatic adaptation. The development of cities has been coextensive with that of agriculture. Their construction and the gradual introduction of biocrops entailed a profound transformation of the natural landscape. Yet the impacts had long remained localized and limited by the slow pace of transformations, anchored in vernacular building traditions and the use of locally available resources. Said conditions would evidently change drastically from the dawn of the Industrial Revolution onward, as key technological advances and reliance on fossil energy triggered massive industrialization and urbanization supported by ever-expanding energy and transportation systems. Cities played a central role in such developments while contributing significantly more to the negative outcomes for the environment than their demographic share. In addition to the environmental costs that can be imparted to the production of goods and services are those associated by the forms assumed by urbanization itself since the turn of the 20th century. This is notably the case in the Global North, where the generalization of the automobile is associated with so-called urban sprawl. In sprawled cities, direct and indirect costs are incurred by the spatial distribution of populations and activities. They translate in higher levels of energy consumption and GHG emissions, while land coverage changes entail biomass losses and natural systems degradation. Furthermore, said urbanization patterns affect the social, natural, and built systems' capacity to resist to the unfolding impacts of climate change. Urbanization entails a concentration of populations and activities, which significantly and inevitably disturbs the natural systems. Yet, unsustainable urbanization is not a fatality, if concentration can be leveraged against the artificialization of large peripheral areas comprised of croplands, forest, prairies and wetlands, and if the retrofitting of built infrastructures and systems can reduce the cities' overall footprint.

The built and natural environments set the frame for how people can live, work, play, move, and communicate in cities. Community building and participation in city transformation processes, as discussed in Volume 1, is strongly influenced by the design of the built infrastructure. A diversity of public spaces, urban green infrastructure, sustainable mobility options, and accessible building layouts can increase the options for citizens to meet and contribute to change. The built environment defines the hardware of a city, whereas the natural environment and urban ecosystems provide the living elements that are crucial for human wellbeing and for the upkeep of increasingly threatened biodiversity.

Urban density and intensity and land-use are defining indicators of urban sustainability as urban sprawl continues to increase impervious surface covers and adds to the congestion caused by individual car use that still dominates most contemporary cities. Urban heat islands can be reduced by adding green spaces and trees for shading, showing the close linkage of the built and natural environments. Sustainable urban transportation is closely linked to urban densities and land-uses, especially when dealing with public transit infrastructure. But there is no unique answer to optimize urban densities and land-use composition and distribution which depend on climate, active and public transit mobility options, and of course on the community specific needs and preferences.

Infrastructure in an urban context encompasses a wide range of activities, including the built environment, roads and bridges, energy systems and distribution networks, water supply, and waste management services. Next generation cities need to find circular economy solutions to close existing loops in resource use, especially in the construction industry, an industry with a high carbon emission foot- print and a large contribution to landfilling. Low embodied carbon of construction materials, but also material re-use strategies and recycling concepts, should become the standard for future urban infrastructure. Landfills are so full that waste reduction and efficient separation will become essential.

The energy systems of the future need to become fully renewable to enable a zero-emission future. At the same time, efficiency in the operational phase of buildings should bring down consumption to reduce the needed additional capacity of the energy supply system.

With ever increasing urban population, fresh water supply becomes a challenge in many regions, where groundwater levels drop, and climate change increases the risks of draughts. High quality wastewater treatment and water re-use can provide solutions.

To make cities more livable while minimizing their ecological footprint is a huge challenge of the next decades. It requires the mobilization of a wide variety of stakeholders and specialists while recognizing and making sense of the complexities of intertwined natural and artificial urban systems. Equity and inclusion of diverse population, social justice and ample participation as discussed in Volume 1, are key elements for next generation city transformations.

# PART 1

# OPPORTUNITIES AND CHALLENGES OF CITY BUILDING

## Pierre GAUTHIER

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Dr. Gauthier trained in architecture (BArch Université de Montréal, MArch Université Laval) and urban planning (PhD McGill University). His research, graduate supervision, and teaching revolve around urban morphogenesis - the evolution of urban forms, physical planning and the relations between urban forms, transportation, and the environment. Since 2001, he has trained hundreds of urban planning students, and has taught an advanced urban planning studio centered on urban retrofitting in inner city and suburban contexts in favor of sustainable development and environmental transition. Pierre Gauthier served the broader Montreal community in various capacities: as member and president of the Board of the RESO, a non-profit local economic and social development corporation (2008-2018), as member and vice-president on the Montreal Heritage Council (2011-2015) and as commissioner at the Office de consultation publique de Montréal OCPM since April 2021.

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Qiu holds a BA and a MSc in Urban Studies & Urban Planning. Her research interests are related to urban morphology, the delicates of urban form, the actual dynamics or differing conditions within sprawling environments, the possibilities and potentials of retrofitting sprawled environments, the sustainable urban form, etc. Using Montreal as a case study, her PhD studies urban form entailed by different modes of transportation, especially motorized transportation, through a morphological perspective. Her research wishes to shed some light on the initiatives aimed at reducing automobile dependence and encouraging non-motorized travel, which is vital importance to fight against climate change and other environmental problems.

## KEYWORDS

#URBAN SPRAWL #COMPACT CITYCLIMATE CHANGE
#NATURAL SYSTEMS CRISES #URBAN MORPHOLOGY

## ON SPRAWL AND COMPROMISED URBAN FUTURE

This chapter aims to answer two seemingly simple questions: “what is sprawl?” and “why does it matter in relation to urban sustainability?” Sprawl is often portrayed in the planning literature as the epitome of unsustainable development. Though definitions of urban sprawl are profuse, no consensual conceptualization emerges in the literature. Definitions usually refer to three intertwined sets of conditions: low residential densities, low intensity and segregated land-uses, as well as a generalized dependence to the automobile. Those can be deemed the physical planning drivers of sprawl. The environmental toll associated with such conditions, either considered separately or in combination, has been documented abundantly. Sprawl is often compared to and contrasted with its polar opposite, the more environmentally sound compact city. While evocative, these notions remain elusive. This chapter posits that such lack of clarity is impeding our ability to understand more fully the articulations between urban development models and environmental crises, and to address the associated perils more effectively.

Stemming from a two-pronged literature review dedicated first to surveying definitions and characterizations of urban sprawl, and then to surveying research probing the links between different facets of urban sprawl on climate change and other environmental crises, this chapter problematizes sprawl. It argues that the sprawled city cannot be uncoupled from its broader built, natural, and historical local contexts. A new definition of sprawl is put forth, which synthesizes previous formulations while addressing some of their shortcomings. A conceptual diagram is also proposed to bring some conceptual clarity on the intertwined dynamics between physical planning drivers and environmental crises. Beyond the strict question of GHG emission levels, such dynamics pertain to compromised natural systems and increased vulnerabilities related to the unfolding impacts of climate change. The diagram is meant to facilitate the interpretation of the multifaceted research effort that investigates the environmental footprint of various urban settings configurations, while helping to frame appropriate responses for the future.

## Jochen A.G. JAEGER

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Dr. Jochen Jaeger teaches in the Department of Geography, Planning and Environment at Concordia University, Montreal, and is affiliated with the Department of Biology and the Loyola Sustainability Research Centre. He received his PhD from ETH Zurich in 2000 and has held positions at the Centre of Technology Assessment in Stuttgart, the University of Stuttgart, and Carleton University, Ottawa. Important research areas in his lab include landscape fragmentation, road ecology, urban sprawl, and environmental assessment. His team received the IENE Project Award in 2011, and Dr. Jaeger received a Sustainable Champion Award from Concordia University in 2022.

## Christian Schwick

Christian Schwick earned a Geography degree from the University of Bern, focusing on Swiss waterfalls. He worked as a researcher at the Swiss Federal Institute for Forest, Snow and Landscape Research and the Chair of Nature and Landscape Conservation at ETH Zurich. Since 2004, he has co-owned the environmental consultancy Die Geographen schwick + spichtig, publishing works on urban sprawl and landscape fragmentation in Switzerland and Europe.

## Naghmeh Nazarnia

Naghmeh is a senior consultant and environmental planner with over a decade of experience in environmental planning, permitting, and impact assessment. She specializes in renewable energy, mining, and infrastructure projects, combining regulatory expertise with a strong research background. She has advanced methods for measuring urban sprawl and their application in land-use planning. She holds an MSc from Concordia University.

## Parnian Pourtaherian

Parnian Pourtaherian is a consultant with CPCS's Infrastructure Analytics team, specializing in spatial analytics and data-driven decision-making. She uses quantitative analysis and modeling to optimize transportation systems and infrastructure projects. Parnian holds a Master's degree in Geography, Urban and Environmental Studies from Concordia University and a Bachelor's degree in Urban Planning from the University of Tehran.

## Sepideh Mosharafian

Sepideh Mosharafian is an Environmental Planner and Data Analyst specializing in urban planning and spatial data analysis. She holds an M.Sc. from Concordia University, Montreal, focusing on urban sprawl and greenbelt strategies. Proficient in Esri software and QGIS, she specializes in data management, spatial analysis, and GIS-driven decision-making. She currently works as a Master Data Analyst, analyzing complex data to develop actionable insights.

## Martin Behnisch

Professor Martin Behnisch heads the 'Spatial Information and Modelling' research area at the Leibniz Institute of Ecological Urban and Regional Development (IOER) in Dresden and holds a professorship at Dresden University of Technology (TUD). He has organized the International Land Use Symposium (ILUS) since 2015. His expertise includes spatial data science, built-environment, and land-system science, with extensive experience in leading collaborative research projects. He received his PhD from the Karlsruhe Institute of Technology and undertook postdocs at ETH Zurich, Concordia University Montréal, Yonsei University, and Tianjin University.

## Tobias Krüger

Dr.-Ing. Tobias Krüger is a research associate at the Leibniz Institute of Ecological Urban and Regional Development (IOER) in Dresden, specializing in land use, urban development dynamics, and geospatial data analysis. He studied cartography at Dresden Technical University and completed his doctorate there. He is a member of the International Association for Landscape Ecology (IALE) and the German Society for Cartography (DGfK).

## Yves Maurer

Yves Maurer Weisbrod, a landscape architect with a Master's in Geoinformation, supports the Geoinformation Unit at the Swiss Federal Office for Spatial Development (ARE) in Bern, Switzerland. His interests include site evaluation for renewable energy, statistics, inventories, crop-rotation areas, and second homes. He has promoted the WUP metric of urban sprawl in administration and authored a geomatic method for capturing settlement areas as geospatial information.

## KEYWORDS

#URBAN SPRAWL #URBAN SUSTAINABILITY #PLANETARY BOUNDARIES #RESOURCE-EFFICIENCY #LAND USE #WEIGHTED URBAN PROLIFERATION

## MEASURING AND MONITORING URBAN SPRAWL: NECESSARY STEPS TOWARDS MORE EFFECTIVE ANTI-SPRAWL POLICIES

Urban sprawl has many detrimental consequences including the loss of areas for food production, the loss of recreational areas, a higher demand for mobility, higher energy consumption, increased landscape fragmentation, air pollution, the spread of invasive species, the degeneration of many ecological soil functions, reduced resilience of ecosystems, the separation of areas in which people live and work, and a reduction in landscape aesthetics, among others. Unrestricted urban sprawl disregards the needs of future generations and is an example of the tragedy of the commons. Current trends in land uptake for built-up areas in most parts of the world contradict the spirit and the principles of sustainability. Humanity needs to pay attention to planetary boundaries explicitly, and effective limits to environmental impacts need to be established for harmful human activities. The measurement of urban sprawl is a first step in this direction and serves several objectives. This chapter provides an overview of definitions of urban sprawl and methods available for measuring it. It summarizes the objectives that are served by measuring urban sprawl, followed by a discussion of a set of concrete measures to use land in a more resource-efficient way and to control urban sprawl. Particular attention will be given to the need for establishing targets and limits to curtail urban sprawl, similar to limits and standards that have been established in other environmental sectors, such as noise limits and limits to water pollution. For example, such targets and limits have recently been proposed for Switzerland, based on the method of Weighted Urban Proliferation (WUP), which uses a combination of the number of built-up areas, their dispersion, and land-uptake per person. The method has also been applied to Europe and to Montreal, but no such targets and limits exist yet for these regions. Without rigorous measures, scenarios of future urban sprawl show that sprawl will continue to increase strongly, but some encouraging examples exist that demonstrate that sprawl can be reduced. For example, as a consequence of intense public discussion, the Swiss Spatial Planning Act was revised in March 2013 to make it tighter. The new WUP method has recently been implemented in Switzerland's landscape monitoring system MONET. Banks can help avoid urban sprawl, such as the Alternative Bank of Switzer- land (ABS) has done since 2012, by not giving loans to projects that would strongly contribute to urban sprawl, i.e., a divestment from urban sprawl. The measurement of urban sprawl is suitable for performance control of targets and limits to urban sprawl once they will be implemented as a part of future of de-sprawling strategies.

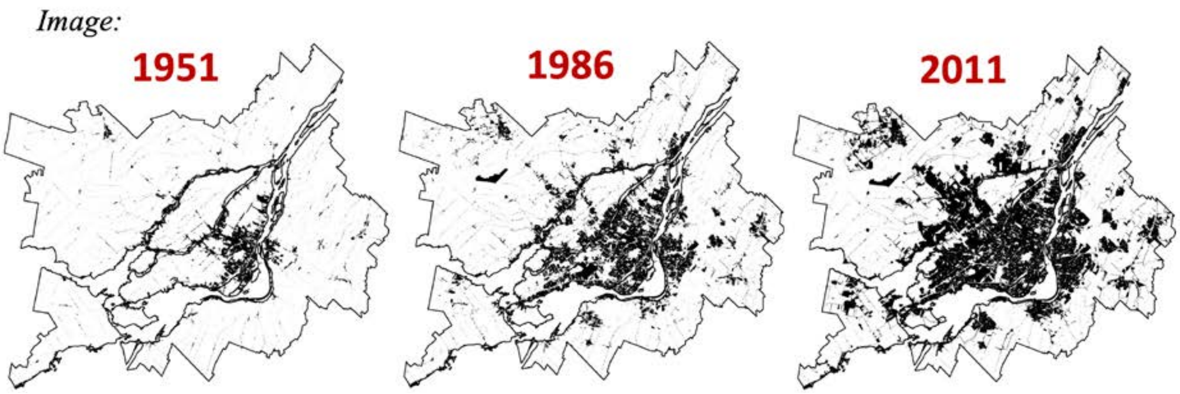


Fig. 1: Rapid growth of built-up areas in the Montreal Census Metropolitan Area between 1951 and 2011 (source: Nazarnia et al. 2016).

## Pierre GAUTHIER

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Dr. Gauthier trained in architecture (BArch. Université de Montréal, MArch Université Laval) and urban planning (PhD McGill University). His research, graduate supervision, and teaching revolve around urban morphogenesis - the evolution of urban forms, physical planning and the relations between urban forms, transportation, and the environment. Since 2001, he has trained hundreds of urban planning students, and has taught an advanced urban planning studio centered on urban retrofitting in inner city and suburban contexts in favor of sustainable development and environmental transition. Pierre Gauthier served the broader Montreal community in various capacities: as member and president of the Board of the RESO, a non-profit local economic and social development corporation (2008-2018), as member and vice-president on the Montreal Heritage Council (2011-2015) and as commissioner at the Office de consultation publique de Montréal OCPM since April 2021.

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## KEYWORDS

#URBAN PLANNING #TRANSPORTATION PLANNING
#TRANSPORTATION-LAND-USE ANALYSIS
#URBAN INTEGRATION OF PUBLIC TRANSPORTATION SYSTEMS

# RETROFITTING THE CITY OF THE AUTOMOBILE: ON CHALLENGES AND OPPORTUNITIES OF AN INTEGRATED APPROACH TO MASS TRANSIT AND PHYSICAL PLANNING

There is a general consensus in the planning literature on the necessity to reduce the dependance to the automobile and, in particular, to curtail urban sprawl in order to fight climate change and foster a more sustainable future. The impacts on natural systems and GHG emissions of the spatial distribution of populations and activities and its associated transportation dynamics have been extensively documented. Cities and other jurisdictions try to address the issue by investing massively in public transportation infrastructures while reforming their approach to land-use. Such efforts have produced mixed results. A survey of the literature on the urban integration of public transportation infrastructures points to significant conceptual and methodological shortcomings in the midst of persistent calls for better analytical, operational, and management tools to address such a central planning question. Difficulties stem in particular from the diversity of academic and professional contexts and disciplines mobilized around the issue (urban planning, transportation planning, engineering, architecture, real-estate, public policy, etc.) as well as from the wide epistemological spectrum of the contributions from interested parties (which range from fundamental and applied science to normative planning "theories" and public policy formulations).

Stemming from a study commissioned by the City of Montréal's Direction des projets de mobilité durable, this chapter maps different scientific and applied approaches to the integration of public transportation systems within the urban contexts that they serve at different scales. While highlighting important shortcomings and a general bias towards the transportation system's requirements and performance, the exercise points to some promising methods. Further, it helps clarify some of the issues at hand by identifying six analytical and operational contexts in which the notion of urban integration of public transportation systems is specifically addressed. The chapter proposes a conceptual diagram which details the main parameters considered as well as the approaches, methods, and tools mobilized in each of those contexts. A contrasted portrait emerges that speaks both of dispersed efforts and of potentials for a better coordination. We argue that a limited understanding of the relations between the different contexts and of each other's methods and prerogatives undermines the ability of stakeholders to collaborate effectively. The conceptual diagram is meant as a preliminary step to clarify these circumstances and highlight some of the gaps, aiming in particular to foster fruitful discussions between interested parties.

## Elaine VARELA

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Elaine Varela has a Ph.D. in Environmental Engineering from UPC - Universitat Politècnica de Catalunya (2012) and is a civil engineer who graduated from UFBA - Federal University of Bahia (2001). She is a member of the Board of Directors and Research at UNESCO Chair on Sustainability (UPC/Barcelona Tech), a professor of the Polytechnic School of UFBA; a leading researcher of GETEC (Group on Construction Technology and Management), and Former Director of BÁKÓ (Community Office on Engineering and Architecture). She was also a visiting professor at Concordia University (Montreal - Canada) between September 2021 and September 2022. With more than 20 years of experience strategizing, securing funds, executing, and overseeing collaborative projects across Brazil, Kenya, Spain, and Canada, she works in sustainability, social responsibility, and innovation for the Built Environment. Her work encompasses a broad range of cutting-edge projects and research on circular economy, sustainable and resilient urban development, digital transformation, social development and inclusion, climate change mitigation and adaptation, and waste management.

## Ursula EICKER

**Canada Excellence Research Chair (CERC) in Smart, Sustainable and Resilient Communities and Cities, Director of Concordia University's NEXT-GENERATION CITIES INSTITUTE, Professor in the Building, Civil and Environmental Engineering (BCEE) Department at Concordia University, Canada**

Dr. Eicker is a German physicist who received her PhD in Solid State Physics from Heriot-Watt University and her Habilitation in Renewable Energy Systems and Building Technology from the Technical University Berlin. She has led numerous international research projects in renewable energy supply systems and building energy efficiency at Stuttgart University of Applied Sciences. A central focus of her research is zero-emission, smart and sustainable cities, integrating renewable energy sources and increasing city livability. A team of over 50 graduate students and software developers worked on numerous eco-district projects in Canada and created the urban modeling, data analytics and stakeholder engagement platform Tools4Cities. Dr. Eicker founded the Next-Generation Cities Institute in November 2020 and addresses the challenges of urban transformation with a transdisciplinary approach and develops tools and strategies for a sustainable future. As a member of the Canadian Green Municipal Fund (GMF) council since 2024, Prof. Eicker supports environmental sustainability and community development. She is a member of several advisory boards, including the Catalonian Energy Research Institute IREC, the Ireland Research Centre for Energy, Climate and Marine Research MaREI, Unibail-Rodamco-Westfield head-quartered in Paris and others.


## KEYWORDS

#URBAN DEVELOPMENT #URBAN RESILIENCE #RESILIENT CITIES
#GLOBAL SOUTH #AGENT-BASED MODEL #ABM

## UNDERSTANDING FUTURE URBAN DEVELOPMENT, RESILIENCE, AND SUSTAINABILITY OF CITIES IN THE GLOBAL SOUTH USING AGENT-BASED MODEL APPROACHES

Next-generation cities are resilient, prosperous, and equitable urban centers that prioritize residents' quality of life and relationships in sustainable zero-carbon infrastructure. The search for more resilient and sustainable cities and a better quality of life for the population became the subject of many studies.

On the one hand, the search for such features calls for a multidisciplinary effort across multiple scales and methodologies. Understanding the relationship and trade-offs between commuting, residential choice, and migration is crucial for establishing aspects related to sustainable urban development, such as transportation, housing policy, and community. From housing and transport to healthcare, education, and job prospects, resource allocation and distribution should depend on where people live. On the other hand, Global South cities deserve higher attention due to their social complexity. Their unsystematic, rapid, and unplanned urbanization, characterized by the emergence and growth of slums, has impacted the population changes and sustainable city development. Urban interventions in Global South cities must consider these aspects to achieve a sustainable, resilient, and participative approach.

Comprehending the complexity of cities' resilience, especially the informality of the built environment in developing countries, is one of the significant urban challenges of our time. It is essential to understand the dynamics that drive adaptation and change in slums, as they can help explain how the population responds to policy interventions, external disturbances, or natural disasters.

Because of their ability to describe and comprehend the complexity of informal urban regions in a bottom-up approach, agent-based models (ABM) stand out as an intriguing decision-making tool for these concerns. In recent years, the agent-based model method has been used as an adaptive tool for dissecting the resilience behavior of complex networks, as it may provide relevant analysis to tackle these urban challenges. Research related to urban development should rely more on urban simulation models such as ABM to aid decision-making in formal and informal settlements. ABM studies allow a comparative analysis of the impacts of various scenarios without the need to carry out real-world experiments, avoiding questions related to the ethics of these studies. In this way, ABMs are characterized by being a transparent and economical option to study the effects of urban improvement measures on people's lives.

Based on a recent and comprehensive literature review, this chapter analyses the current scenario on agent-based modeling to study cities' urban development, resilience, and sustainability in the Global South. It examines this technique's methodological and theoretical challenges in the contemporary Global South, arguing that such research can yield theoretical insights that are useful to urban planners. It analyzes theoretical and empirical models to identify the potential analytic benefits of such an approach.

The discussion presented here does not intend to exhaust the theme but to consolidate it and guide and promote the use of agent-based models to support research on next-generation cities in the Global South. Our findings provide insights related to the current scenario of modeling complex systems based on agents in the area. They identify existing challenges, gaps, and opportunities and present recommendations for the evolution of research in the area, bringing the importance of a multidisciplinary approach and aligning the UN's 2030 Agenda and its Sustainable Development Goals. The chapter highlights that a clearer view of the strengths, weaknesses and available resources of ABM can guide users and developers interested in this area, to improve existing models in the search for solutions for the promotion of resilient, prosperous, and equitable urban centers in the Global South.

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## KEYWORDS

#CONSTRUCTION AUTOMATION #DIGITAL TWINS #NET ZERO
#ENERGY COMMUNITIES #ENVIRONMENTAL POLICY
#ENERGY TRANSITION #ENERGY POVERTY #CLIMATE-CHANGE
#URBAN PLANNING #ENERGY #RENEWABLES #SUSTAINABILITY
#REGIONAL COOPERATION

## CHALLENGES AND OPPORTUNITIES FOR INCREASING THE SUSTAINABILITY OF MARGINALIZED COMMUNITIES: THE CASE OF THE BEDOUIN IN SOUTHERN ISRAEL

This chapter will focus on the Bedouin communities in the Negev desert in southern Israel to illustrate the challenges that marginalized societies face in meeting their energy-related needs.

The first part of the chapter will discuss the general situation of Bedouins in southern Israel. It will start with an explanation of the difference between Bedouin towns that are officially established and are connected to utilities and informal villages that do not receive electricity from the grid and lack other basic services such as sewage treatment and garbage collection. Next, demographic and socio-economic trends will be discussed. The Negev Bedouin have one of the highest rates of natural growth in the world (at 4–5% per year), and socio-economically the established Bedouin towns are ranked lowest among all municipalities in Israel (the situation in informal villages can be assumed to be even worse). The spatial structure and location of many Bedouin communities are based on tribal affiliations. The sedentarization of the Bedouins, as they transition from a nomadic pastoral lifestyle to a stationary urban one, coupled with high poverty levels as the result of years of neglect from the government, have brought many needs and challenges. This chapter will focus on those that are related to energy and sustainability.

The second part of the chapter will describe the current challenges faced by Bedouins in the context of energy and sustainability. These include energy poverty and insecurity, where the Bedouin communities generally display minimum levels of energy consumption, which often fail to meet their basic needs. In terms of the reliance on renewable energy systems (RES) there are marked differences between informal and established settlements. During the last decade, off-grid energy systems based on PV panels have become the main electricity source in informal villages, which consequently can be considered highly sustainable in that respect. On the other hand, the penetration of RES in established Bedouin towns is especially low, even when compared with more prosperous cities in Israel. The impact of conventional power plants is also relevant since some informal villages suffer from a high exposure to pollutants due to their proximity to industrial plants and gas turbines, and at the same time do not benefit from the electricity these plants produce. This provides an additional incentive to replace them with solar-energy plants, while simultaneously ensuring the electricity supply in informal villages. In terms of energy security, a significant negative association has been found between energy insecurity and perceived resilience and health in Bedouin communities.

The third and final part of the chapter will discuss technological and policy-based opportunities for improving the energy security and sustainability of Bedouin communities within the current socio-political constraints, and explore whether these can also be relevant for other types of communities. Community-level solutions and microgrids are highly relevant for these informal settlements, as they would allow enlarging the current installed photovoltaic systems and replacing with batteries the diesel generators that are still often used, by families with no access to PV or as a backup for times in the day when the PV systems are not producing energy. However, to realize these solutions, legal and regulatory hurdles will have to be removed. Increasing the penetration of RES in established towns by adopting some of the solutions that are already prevalent in informal villages is also of immediate relevance. It might be enabled, among other things, through financial mechanisms, a reduction of regulatory hurdles and collaboration with local authorities and the communities.

The chapter will conclude with a brief discussion of the relevance of this topic for other marginalized communities in the world, such as the Roma in Europe or the urban slums in Africa.

## James MILLER

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James is a Kanaka Maoli scholar, architect, and urbanist, James runs a design lab, ʼIke Honua, centering Indigenous knowledge in building resilient communities through architectural and planning frameworks. James Miller's research investigates the role of Indigenous Design Knowledge in the creation of culturally supportive environments. James is currently investigating the application of Indigenous, place-based models for building community resilience in response to the housing crises and rising socio-environmental issues in Hawai'i. Miller's scholarship provides a space for Indigenous knowledge systems tied to the production of the built-environment to be recognized within fields dominated by western-centric world views. Miller holds a PhD in Sustainable Architecture from the University of Oregon with specializations in cultural sustainability and Indigenous design knowledge.

**KEYWORDS**

#REINDIGENIZING #DECOLONIZE #URBAN
#BUILT ENVIRONMENT #PLACEMAKING

## THE INDIGENOUS URBANISM: RECENTERING OCEANIA WITHIN PACIFIC URBAN FUTURES

Urbanization is happening rapidly in the Pacific, yet little attention is given to Pacific Island cities. Urbanization in pacific island cities reflects colonial urban agendas that continue to inform urban development decisions today. Pacific urbanism is not reflective of Pacific Islander epistemes, and because of its incongruity with pacific island ecologies, these colonial city forms are detrimentally impacting Pacific Islander communities. This chapter will examine the historical development of cities in Hawai'i and the Marshall Islands to demonstrate the contemporary urban ramifications of colonial urbanities that are incongruent with island ecologies. While the implications of colonial structures on the city will be presented, the focus will be on ways in which we can re-indigenize the city.

The impetus for this chapter began with a question. How can Kānaka Maoli practices reshape the city? The question is in response to the publication of Konia Frietas and Annie Koh's (2018) article, "Is Honolulu a Hawaiian Place?" Learning through the case studies of bottom-up, Indigenous urban practices and processes in Hawai'i and the Marshall Islands, the chapter will provide answers to the following questions: How do we re-indigenize Pacific Island cities? How do we, as Indigenous Pacific Islanders, see ourselves within our urban centers? The chapter also provides a provocation for future study of Indigenous urbanism in the Pacific. Drawing from Sean Connelly's (2020) work, "Our City as Ahupua'a," and Hawai'i Non-linear, I propose that Pacific Island cities reflect the land-based ethical frameworks of their Indigenous people. Majuro, Republic of the Marshall Islands and Honolulu, O'ahu, Hawai'i will provide urban profiles in which to explore these concepts.

## Rebecca DZIEDZIC

Assistant Professor, Building, Civil, and Environmental Engineering, Concordia University, Canada

Dr. Rebecca Dziedzic is an Assistant Professor at the University of Concordia's Building, Civil and Environmental Engineering Department. Her research expertise lies in developing decision support methods for sustainable infrastructure, particularly water systems. As part of her doctoral studies, she developed energy metrics to assess the efficiency of water distribution systems. These have been applied to five cities and a tool is currently being developed in collaboration with the Canadian Urban Institute to further facilitate their application.

Prior to joining Concordia, Dr. Dziedzic worked as an asset management consultant and now continues to collaborate with industry professionals to better respond to current urban challenges. She is currently working with 14 cities across Canada as part of a project to develop water main failure prediction models.

## KEYWORDS

#URBAN INFRASTRUCTURE #CONSEQUENCE OF FAILURE
#SYSTEMIC UNDERFUNDING

## ASSET MANAGEMENT FOR SUSTAINABLE CITIES

Infrastructure ages. And, similar to us, regular check-ups and preventive treatments extend their lives. However, in many cities, the health of our urban infrastructure has fallen through the cracks. This is evident in recurring national reports, such as the American Society of Civil Engineers' Infrastructure Report Card and the Canadian Infrastructure Report Card. The construction of municipal infrastructure, i.e. transportation, water, wastewater, stormwater systems, and solid waste systems, as well as civic facilities, is generally aligned with local development. And as the focus of urban development shifts, so does private and public investment. Municipalities are still left with the responsibility to maintain these assets and provide expected levels of service to the population.

Asset management practices have spread across cities to formalize the process of managing essential assets and to develop transparent solutions to funding lifecycle infrastructure costs. The general steps for asset management are six: assess state of assets; determine lifecycle costs; define required levels of service; determine asset failure risk; select the best capital and operations and maintenance investment strategies; and determine the best funding strategy. Investment decisions are, thus, based on historical costs and available condition data, which are biased.

This chapter explores strategies for implementing a sustainable and holistic approach to asset management by considering the triple bottom line, i.e. economic, social, and environmental impacts. Although the risks of asset failure should generally include all three spheres, urban areas that have been historically underfunded may still not receive as much funding as other areas. This is because the consequence of asset failure in areas with less public transit, fewer major roads, hospitals, fire stations, police stations, etc., is considered lower. Therefore, one of the proposed strategies is to integrate municipal master planning and asset management.

## Erkan YÖNDER

**Associate Professor at Department of Finance, John Molson School of Business and Cluster Co-Director Built and Natural Environments at the Next Generation Cites Institute, Concordia University, Canada**

With a primary focus on real estate finance, Dr. Yönder's expertise lies in sustainable real estate, commercial real estate, and mortgages. His recent works mainly focus on the critical intersection of climate issues in the real estate industry. Erkan's research has found its way into esteemed academic journals, including publications in the Review of Finance, Journal of Business Ethics, Journal of Banking and Finance, and Real Estate Economics.

His projects have secured multiple grants from renowned institutions such as the National Pension Hub (NPH) in Canada, Real Estate Research Institute (RERI), and the European Public Real Estate Association (EPRA). Notably, his research earned him the Nick Tyrrell Real Estate Research Prize in the UK and the distinguished Best Published Article Award from Principles for Responsible Investment (PRI), a United Nations-supported initiative. Erkan has had the privilege of presenting his scholarly work at some of the world's leading universities, including MIT, Yale University, UCLA, and Cornell University. Dr. Yönder is also actively engaging with the real estate industry as a public speaker. Dr. Yönder received his PhD degree in Finance and Real Estate at Maastricht University in 2013. He also holds a second PhD degree in Economics.

## KEYWORDS

#SUSTAINABLE FINANCE # CLIMATE RESILIENCE
# CLIMATE RISK MITIGATION #LEED CERTIFICATION
#BREEAM CERTIFICATION

## BUILDING CLIMATE RESILIENCE: FINANCIAL INTERVENTIONS IN REAL ESTATE MARKETS

Climate change poses a growing threat to economies, societies, and the built environment, with increasing occurrences of extreme weather events such as hurricanes, wildfires, and heatwaves. The real estate sector, which is both a contributor to carbon emissions and highly vulnerable to climate risks, faces mounting challenges as climate-related disasters disrupt markets, reduce property values, and raise risk premiums for investors. Addressing these risks requires a multifaceted approach that integrates financial markets, policy interventions, and investment in climate-resilient infrastructure. This chapter examines the role of financial tools in both climate adaptation—safeguarding assets from immediate climate risks—and climate mitigation—reducing the carbon footprint of real estate assets.

A key aspect of climate adaptation in real estate involves retrofitting projects aimed at increasing the resilience of properties. Infrastructure improvements, such as flood defense systems, fire-resistant construction, and stormproofing, can mitigate damage and economic losses in climate-vulnerable regions. While these projects generate financial benefits by reducing future losses, quantifying their return on investment remains complex due to uncertainties in climate risk forecasting. On the mitigation side, energy efficiency upgrades such as solar panels, heat pumps, and insulation lower carbon emissions and operating costs. The financial feasibility of these retrofits depends on energy prices and policy incentives, making financial modeling essential in assessing long-term value.

Financial markets play a crucial role in enabling climate resilience through various instruments. Green building certifications, such as LEED and BREEAM, align sustainability goals with financial incentives, attracting ESG-conscious investors and providing a competitive advantage for certified properties. Additionally, policy-driven mechanisms like resilience bonds, tax credits, and sustainability-linked loans enhance the viability of climate-adaptive investments. Green bonds, in particular, have emerged as a key financial tool for funding large-scale sustainable real estate initiatives, with studies demonstrating that green bond issuance reduces borrowing costs and strengthens the financial standing of real estate investment trusts (REITs).

Despite the progress in integrating climate finance into real estate markets, significant challenges remain. The unpredictability of climate disasters complicates risk assessments, regulatory inconsistencies create barriers to widespread adoption of resilience measures, and financial disparities limit access to adaptation strategies in vulnerable communities. Institutional investors are increasingly incorporating climate risk factors into investment decisions, yet the development of standardized climate risk disclosures and harmonized regulatory frameworks is essential for scaling climate resilience investments.

By fostering collaboration between financial institutions, policymakers, and industry leaders, the real estate sector can transition toward a more sustainable and resilient future. Financial innovations, regulatory incentives, and market-based solutions must align to drive investments in climate-resilient real estate. As climate risks continue to escalate, the integration of sustainability into financial decision-making will be a defining factor in securing long-term stability and value in real estate markets.

## Andreas K. ATHIENITIS

**Fellow of ASHRAE, IBPSA and CAE NSERC/Hydro Quebec Industrial Chair & Concordia Research Chair / Professor and Director, Centre for Zero Energy Building Studies at Concordia University, Canada**

Dr. Andreas K. Athienitis is a Professor of Building Engineering at Concordia University and holds a Senior NSERC/Hydro Quebec Industrial Research Chair and a Concordia University Research Chair, Tier I. He obtained a BSc in Mechanical Engineering (1981) from the University of New Brunswick and a PhD in Mechanical Engineering from the University of Waterloo (1985). He is a Fellow of the Canadian Academy of Engineering, a Fellow of ASHRAE and a Fellow of IBPSA. He served as Scientific Director and Principal Investigator of two Natural Sciences and Engineering Research Council of Canada (NSERC) strategic networks on Smart Solar and Net-zero Energy Buildings (2005 – 2017) that included about 30 Canadian researchers from 15 universities and about 30 industrial and other partners. He is founder and Director of the Concordia University Centre for Zero Energy Building Studies. He is the author of more than 300 refereed papers, the Mathcad electronic book "Building Thermal Analysis" and the graduate level book "Thermal Analysis and Design of Passive Solar Buildings". He is a recipient of seven best paper awards, including ASHRAE Willis H. Carrier award. He is a contributing author of the Inter- governmental Panel for Climate Change (IPCC), and was profiled as one of 25 top innovators in Quebec by Actualité Magazine.

## Caroline HACHEM - VERMETTE

**Associate Professor, Building, Civil, and Environmental Engineering at Concordia University, Canada**

Dr. Hachem-Vermette's training combines Architecture, Town Planning, and Building Engineering disciplines. Her research program bridges the gaps between architecture and urban design and building engineering. She develops concepts and strategies for sustainable and resilient built environments. In her work, she integrates buildings, infrastructure, landscape, and ecosystems in a holistic way. Her research attempts to balance between the technical aspects of sustainable built environment and the economic and social dimensions of sustainability aiming at enhancing quality of life.

Among her research interests are energy-efficient, resilient neighborhood patterns, renewable energy potential, energy implications of building and neighborhood designs, high-performance building envelope design, and multifunctional facades for multistory buildings.

She is leading the International Agency Energy Task 63- Planning Solar Neighbor- hoods' subtask on developing strategies for net-zero energy solar communities. She has published extensively on energy efficiency and solar energy, including a book (with Springer) on designing solar buildings. Her awards include the 2019 Peak Scholar Award, the 2016 sustainability award, the e-sim/IBPSA award for innovation in modelling, and the international Hangai prize for young researchers (for her research on deployable structures).


## KEYWORDS

#DESIGN FOR SUSTAINABILITY #ENERGY EFFICIENCY #RENEWABLE ENERGY #SMART CITIES #SMART INFRASTRUCTURES
#GREEN BUILDINGS #CLEAN ENERGY #BUILDING MATERIALS
#SOLAR ENERGY #NET-ZERO ENERGY SYSTEMS
#LOW ENERGY BUILDINGS #INTEGRATED PHOTOVOLTAIC/THERMAL
#HVAC SYSTEMS #HEAT AND MASS TRANSFER

## PATHWAYS TO RESILIENT SOLAR BUILDINGS AND COMMUNITIES

This chapter first overviews major principles for the modelling and design of advanced solar buildings and communities that are optimized to capture solar energy through building-integrated solar systems for the simultaneous production of electricity and useful heat, optimally designed windows for capturing passive solar heat gains and daylight, and efficient techniques of building-integrated energy storage. Results from a Canadian high-performance demonstration net-zero energy building and a solar community are presented with emphasis on their design and operation. The development of building-integrated solar systems and predictive control strategies is overviewed with application to the Varennes Library, a smart solar net-zero energy institutional building completed in Canada in 2016 and currently being monitored and studied. The term “Smart” is used to describe two major expected characteristics of such buildings: 1. A building that optimally controls its indoor environment and is responsive to occupant needs so as to provide good indoor comfort for work, leisure activities, and rest. 2. A building that optimizes its operation so as to substantially reduce energy consumption costs while optimally interacting with energy grids – both electrical and thermal, including the possibility of electric vehicle integration and bi-directional electricity flow. Broader design and policy issues for the built environment are discussed with focus on resilient buildings and communities interacting in an optimal way with smart energy grids so as to shift and reduce peak demand for electricity by optimizing production, storage, and utilization of energy from renewable energy sources. The development of such buildings and communities poses major challenges and requires significant innovations in design, construction, and operation. Some of these innovations will be briefly discussed, including configurations with heat pumps connected to building-integrated solar systems and energy storage. Finally, design and operation for energy resilience is discussed.

## Mohamed OUF

**Assistant Professor, Building, Civil, and Environmental Engineering and faculty member of the interdisciplinary cluster for Smart, Sustainable, and Resilient Cities and Communities at Concordia University, Canada**

Prof. Ouf, is the principal investigator of the Intelligent Buildings and Communities Lab (IBCL) and a member of Concordia's Next-Generation Cities Institute and the Centre for Zero Energy Building Studies (CZEBS). He currently supervises a team of eight graduate students at IBCL with diverse expertise in multiple engineering disciplines and in data science. His research focuses on using data-driven approaches to investigate occupant-building interactions at multiple scales, ranging from zone- to building-level and up to urban scales. As an early career researcher, Prof. Ouf published over thirty peer-reviewed journal and conference papers, and received several prestigious awards, such as the Best Paper Award at the 7th International Building Physics Conference. Prior to joining the Concordia University in 2019, he was a Post-doctoral Research Fellow at Carleton University's Human-Building Inter- action Lab, and previously worked for the Provincial Government of Manitoba on their Green Building Policy.

Dr. Ouf has been actively involved in several academic and professional organizations. He serves on the board of directors of the Canadian chapter of the International Building Performance Simulation Association (IBPSA). He is also a member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and the Canadian Society of Civil Engineers (CSCE).

## KEYWORDS

#BUILDING SIMULATION  #OCCUPANT BEHAVIOUR MODELLING #OCCUPANT COMFORT #DATA SCIENCE #ENERGY MODELLING #ENERGY BENCHMARKING #BUILDING CONTROLS #HVAC SYSTEMS #URBAN-SCALE MODELLING

## OCCUPANT-CENTRIC BUILDINGS

Building energy demand is subject to several sources of uncertainty, among which occupant-related parameters are among the least understood and accounted for. To address such uncertainty, data-driven approaches can be used to investigate the factors that influence occupant behavior. These approaches rely on using multiple data sources that exist within the built environment, ranging from building automation systems, stand-alone sensors, as well as surveys, interviews, and observational studies. The advent of smart metering infrastructure and the internet of things (IoT) has also generated numerous data streams that can be leveraged to better understand occupant behavior and occupancy patterns, which can improve both the design of new buildings and the operation of existing ones.

In this context, the first section of this chapter will provide an overview of occupant-building interaction research and the multiple data sources used to represent both occupancy patterns and occupants' energy related behavior. This section will focus on the potential for new data sources to provide information on building occupants at multiple scales. In addition, the different approaches in which occupant data can be used to model occupant behavior and represent occupant-related uncertainty in building operations will be presented.

The second section of this chapter will focus on the integration of occupant modelling in building design processes. Performance quantification through modelling and simulation has been particularly advantageous to building design, as it can be applied to non-existent buildings in the design process. It allows for testing design variants under identical conditions, and demands much less resources compared to physical measurements. To this end, an overview of simulation-aided design methods to capture occupants' interactions with building systems and accommodate their needs will be presented. The extent to which these design methods can establish and verify design performance, screen and optimize design parameters, and study design robustness, adaptability and resilience will be discussed. Finally, the need to account for the effect of occupant behavior on spatial and temporal energy demand patterns at the urban scale will be highlighted, especially for the design of urban energy systems (e.g. district heating/cooling, micro grids with distributed renewable energy generation).

The last section of this chapter will focus on identifying the different approaches to incorporate occupant-related information in building operations. Specifically, it will introduce the concept of Occupant-centric building controls (OCC), which is a novel approach for indoor climate control in which occupant preferences are directly measured or indirectly inferred from various sensors or control interfaces. It aims to deliver building services only when and where they are needed, in the amount that they are needed. Many researchers suggested that OCC can achieve consider- able energy savings up to 60%. This section will provide an overview of the methodological approaches used in OCC, specifically focusing on the data requirements, the learning algorithms, and control approaches used in this field. It will also identify the multi-dimensional aspects related to the implementation of OCC in actual buildings such as privacy issues, measurement, and verification approaches.

## Osama MOSELHI

**Professor, Building, Civil, and Environmental Engineering at Concordia University, Canada**

Dr. Moselhi is Professor and Director of the Centre for Innovation in Construction and Infrastructure Engineering and Management (CICIEM), Department of Building, Civil and Environmental Engineering at Concordia University. He has over 50 years of professional and academic experience. His industry experience spans tall buildings, bridges, nuclear power plants, harbors, and offshore facilities. His research interest encompasses two major areas. The first is optimized value driven asset management for sustainable and resilient civil infrastructure, including non-invasive and non-destructive condition assessment and rating, deterioration modeling, reliability and vulnerability assessment, resilience measurement and evaluation, and optimized budget allocation for intervention and recovery plans. The second is optimized delivery of engineering, procurement and construction projects, including project delivery systems, planning, procurement, resource allocation, tracking and control for efficient management of construction projects, with a focus on risk management, productivity analysis, management of construction claims and development of decision support systems embracing information technology, remote sensing, web-enabling and spatial technologies.

Dr. Moselhi is Fellow of the Association for Advancement in Cost Engineering (AACE International), the American Society of Civil Engineers (ASCE), the Canadian Society for Civil Engineering (CSCE), and the Canadian Academy for Engineering (CAE). He is recipient of numerous honors and awards, and is member of the Provost's Circle of Distinction at Concordia University.

## Ahmed ASSAD

**Postdoctoral fellow at the University of Alberta, Canada**

Assad holds a PhD in Construction Engineering and Asset Management. Assad has more than six years of professional and academic experience in construction management. He has served as an instructor at the Australian College of Kuwait and as a Seasonal Lecturer at Concordia University, Canada. Assad's main interests include applying simulation tools, machine learning, and stochastic optimization algorithms to develop decision support systems that maintain resilience and sustainability of urban infrastructure systems. Assad's work has is featured in multiple scientific journals and prestigious conferences.


## KEYWORDS

#INFRASTRUCTURAL RESILIENCE #PUBLIC SAFETY #MANAGEMENT OF PUBLIC ASSETS # WATER DISTRIBUTION NETWORKS

## RESILIENCE MANAGEMENT: TOOLS AND APPLICATIONS

This chapter first presents widely used definitions for resilience pertinent to civil infrastructure and introduces a set of management tools for its efficient utilization in preserving the value of infrastructure assets, protecting public and private property, and improving public safety and welfare. The ASCE Policy Statement 518 on unified definitions for critical infrastructure resilience states: "Resilience refers to the capability to mitigate against significant all-hazards risks and incidents and to expeditiously recover and reconstitute critical services with minimum damage to public safety and health, the economy, and national security." The common aspects of resilience can be summarized in two requirements: (1) the ability to absorb or avoid damage arising from extreme adverse conditions without experiencing complete failure, and (2) the ability to recover rapidly from these adverse conditions.

Resilience management for civil infrastructure encompasses methods that establish and/or account for the measurement of resilience levels, condition assessment of infrastructure assets, uncertainty and risk assessment, reliability assessment, multi-attributed criticality assessment, lifecycle cost, zoning and clustering, multi-attributed decisions support, resource allocation, evaluation of recovery strategies, and optimization. It also considers a wide range of economic, environmental, social, levels of service, and public safety and wellbeing. In essence, it is a vehicle that assists management teams in achieving the desired resilience objectives of damage avoidance and rapid recovery within available resources via a set of timely actions in an integrated strategy. These management methods should support what-if scenarios for a set of recovery strategies and their respective improvement of resilience levels. Example applications will be presented on resilience management for water distribution networks.

We consider here a section of the water distribution network of the City of London, Ontario. The section, referred to here as network, is composed of 186 pipe segments that amount to approximately 13.1 km of length and has 143 demand nodes. Firstly, the resilience level for that network is estimated utilizing a newly developed multi-attribute resilience metric that integrates robustness and redundancy of the network. The resilience of the network was found to be 0.467 on a scale from 0-1, where 1 indicates the highest resilience level. Next, we considered a disruptive event that caused failure of 30 pipe segments in the form of small and big breaks, and determine the optimum restoration strategy for that event. Here we consider five repair crews would respond to this event. Several factors were considered in specifying the set of possible restoration methods such as the failure type, pipe characteristics, soil type, and other factors. In addition, the model accounts for the time and cost of repairing crews considering their movements from one location to another. Each restoration strategy defines the sequence and type of restoration activity for each failed pipe segment. The average time, cost, and resilience improvement realized as per the obtained solution were found to be 17.54 days, $1.6 million, and 0.106 (i.e., raising the network resilience from 0.467 to 0.573), respectively.

We also considered a larger section of the London City water network, composed of 369 pipe segments of diameters ranging from 40mm to 450 mm, with an average age of 40 years. The condition of the pipe segments in the selected network were extracted from the GIS record and utilized in the subsequent analysis. The selected section amounts to approximately 34 km of length and consists of three sub-networks covering a wide variation of land use, serviced facilities, and road types. Each sub-network is assumed to have a different minimum acceptable resilience level, reflecting its importance to the decision-makers. A developed optimization model is used to minimize the cost of enhancement actions, maximize resilience improvement, and minimize associated carbon emissions. The model encompasses two phases where the intervention actions are firstly determined along with their timing in the form of a Pareto front that offers a set of optimal enhancement strategies for the City managers to select from based on cost, time, and expected resilience improvement level along with conditions of executing these strategies. The second phase focuses primarily on executing the selected enhancement strategies from the first phase, leading to an optimal schedule of rehabilitation work. The resilience of the example network increased by 20% at a cost of 1.65 million CAD.

# PART 2

# BIODIVERSITY AND ECOSYSTEM SERVICES IN URBAN ENVIRONMENTS

## Carly ZITER

**Assistant Professor, Biology at Concordia University, Canada**

Dr. Ziter is an urban ecologist and assistant professor in the Biology Department of Concordia University, and a faculty member of Concordia's interdisciplinary cluster for Smart, Sustainable, and Resilient Cities and Communities. She completed an MSc in biology and natural resources sciences at McGill, and a PhD in landscape ecology at the University of Wisconsin-Madison (2014-2018). As a landscape and ecosystem ecologist, her research asks how landscape structure, land-use history, and biodiversity impact multiple ecosystem services and their relationships in urban and urbanizing landscapes. Her research program centers on the ecosystem services concept as a lens through which to ask ecological questions related to sustainability, policy, and practice. Ziter holds active research grants as a principal applicant or co-applicant from NSERC, SSHRC, and private foundations, and consistently publishes in high impact journals such as PNAS, Nature Sustainability, and Ecological Applications. In 2016, she conducted the first global meta-analysis focused explicitly on the underlying ecology of urban ecosystem services, centered on the role of biodiversity in service provision. Her recent and ongoing work includes quantifying how variation in impervious surfaces and canopy cover interact to affect urban air temperature at fine scales, developing community science approaches to urban biodiversity monitoring, and contributions to city-scale assessments of wild bee conservation and management.

## Jochen A.G. JAEGER

**Associate Professor, Geography, Planning and Environment at Concordia University, Canada**

Dr. Jaeger received his PhD from the Department of Environmental Sciences at the ETH Zurich (Swiss Federal Institute of Technology). He held a position at the Centre of Technology Assessment in Baden-Württemberg in Stuttgart, Germany, and lectured at the University of Stuttgart. In 2001, he went to Canada as a postdoctoral fellow with Dr. Lenore Fahrig in the Landscape Ecology Laboratory at Carleton University, Ottawa, funded by the German Academy of Natural Scientists Leopoldina. From 2003 to 2007 he was back in Zurich at the ETH as a research associate and was funded by the German Research Foundation DFG, the Swiss National Science Foundation, the Swiss Federal Roads Authority, and the Swiss Federal Office for the Environment. His two last larger projects in Zurich were on the degree of landscape fragmentation and the degree of urban sprawl in Switzerland as indicators for the Swiss Monitoring System of Sustainable Development (MONET). He joined Concordia University in July 2007. In October 2010, he received the Dean's 2009-2010 New Scholar Award for outstanding achievement by a tenure-track faculty member. His research team received the IENE Project Award in 2011 for their project "Landscape Fragmentation in Europe" from the Infra Eco Network Europe. He is also an affiliated member of the Department of Biology and a member of the Loyola Sustainability Research Centre (LSRC).


## KEYWORDS

#BIODIVERSITY LOSS #CITY BIODIVERSITY INDEX
#WILDLIFE MONITORING #URBAN SUSTAINABILITY

## THE CITY BIODIVERSITY INDEX (CBI), OR SINGAPORE INDEX ON CITIES' BIODIVERSITY

The City Biodiversity Index (CBI), or Singapore Index on Cities' Biodiversity, serves as a tool to evaluate and monitor the state of biodiversity in cities and to provide insights for improving conservation efforts. It was developed in response to increasing rates of biodiversity loss in cities. Because the world's population will continue to grow and live predominantly in urban areas, cities need to be involved in efforts to halt, and eventually reverse global biodiversity loss.

Development of the CBI was proposed by the Minister of National Development in Singapore at the 9th Meeting of the Conference of the Parties (COP-9) to the Convention on Biological Diversity (CBD) in May 2008, and was endorsed by the Convention on Biological Diversity in 2009. The CBI was established by the National Parks Board of Singapore and the Secretariat of the CBD in collaboration with the Global Partnership on Cities and Biodiversity from 2009 to 2011. In 2019, a fourth workshop was convened to update the Index by drawing on the experiences that were accrued with the application of the Index by cities, academics, and consultancies and to align it with discussions on the post- 2020 Global Biodiversity Framework.

The Index comprises two parts: First, the "Profile of the City" provides background information on the city; and second, 28 indicators are reported, organized in three groups that characterize (a) native biodiversity in the city, (b) ecosystem services provided by biodiversity, and (c) governance and management of biodiversity in the city. Each indicator is assigned a score ranging between zero and four points, with a maximum score of 112 points. Cities should use the CBI in their first application to make an initial baseline measurement; identify policy priorities based on their measurements and then monitor again at periodic intervals every 3–5 years to allow sufficient time between applications for the results of biodiversity conservation efforts to materialize. The Index is supposed to serve as a public platform upon which biodiversity awareness raising exercises can be launched, and it can act as a portal among various departments within city governance, academics, NGOs, businesses, schools, and the public. This entry provides an overview of the history of the development of the CBI, briefly discusses the 28 indicators, and presents examples of its use by cities and lessons learned.

Reference: City Biodiversity Index (or Singapore Index)


## Lingshan LI

PhD candidate, Geography, Department of Geography, Planning and Environment, Concordia University, Canada


Lingshan is studying the effects of vegetation and the built environment on the urban microclimate in Montreal, using a combination of remote sensing and field-based approaches. She is most interested in the effect of landscape patterns on the intensity of the ecosystem services (urban heat island mitigation, air quality regulation, etc.) provided by urban greening. Her research contributes to the work of the Next Generation Cities cluster co-supervised by Concordia colleagues and collaborators Ursula Eicker, Carly Ziter, and Angela Kross.


## KEYWORDS

#URBAN GREEN INFRASTRUCTURE #SPATIAL PATTERN #COMPOSITION, CONFIGURATION #ENVIRONMENTAL JUSTICE

## URBAN GREEN INGRASTRUCTURE (UGI) AND THEIR ECOSYSTEM SERVICES: HOW TO BETTER MANAGE UGI?

This chapter considers the urban green infrastructure concept, which focuses on the holistic ecosystem vision of urban environments and considers the scale dependent relationships of ecological processes. The adverse effects of urbanization are closely related with human health and wellbeing. Improving urban green infrastructure is an effective strategy to help mitigate the environmental problems such as urban heat island effect and air pollution. The urban greening mainly cools the urban environment by intercepting the solar radiation from reaching the ground and the process of evapotranspiration. They could also reduce the air pollutant concentration by dispersion, interception, deposition, absorption, etc.

When thinking of the urban green infrastructure, environmental justice is a non-negligible aspect to consider. The environmental injustice is part of the concept of social inequality and inequity, which is among the 17 sustainability goals promoted by the United Unions. Urban social inequality stems from historical and contemporary power imbalances and produces deleterious effects that are often intersectional, involving race, economic class, gender, language, sexuality, nationality, ability, religion, and age. Those factors have an impact on the quantity, quality, and accessibility of green spaces that every person possesses in the cities. The uneven distribution of urban green infrastructure also leads to the uneven risk of exposure to the environmental problems. Urban green space area and plant diversity are usually found to be positively correlated with neighborhood wealth, and the ethnic minority people also usually have access to less ecosystem services compared to the white people.

Current studies also reported the spatial pattern of green spaces can potentially influence the magnitude of ecosystem services. The two fundamental aspects of land cover pattern are composition and configuration. Composition refers to the abundance and variety of land cover features without considering their spatial character or arrangement; configuration, in contrast, refers to the spatial arrangement or distribution of land cover features. Due to limited availability of land for green spaces in cities, the optimization of the spatial composition and configuration of green spaces for more ecosystem benefits is a significant issue for urban planners.

## Angela KROSS

**Assistant professor, Geography, Planning and Environment at Concordia University, Canada**

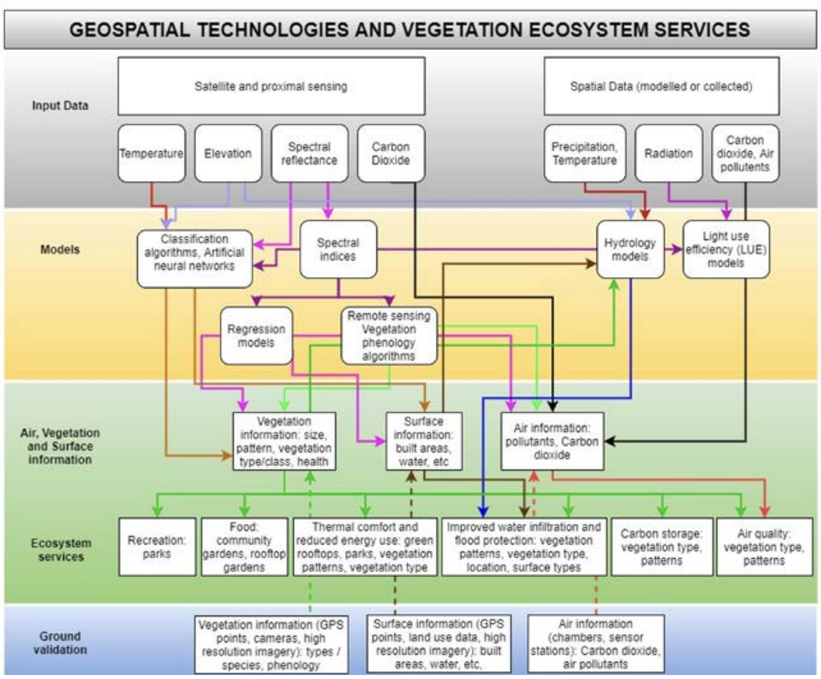
Dr. Kross's academic training (BSc in Agronomic engineering, MSc in Geo-information science and remote sensing, PhD in Geography – remote sensing) and the research she pursues are at the intersection of geospatial technologies, environmental sciences, and ecology. Her research focuses on vegetation: how it responds to environmental change and how vegetation change in turn shapes the broader environment. Vegetation plays a key role in ecosystem processes, regulating water, carbon and energy cycles, global climate, and food systems. Angela's main goal as a scientist is to advance our knowledge of the interactions between terrestrial ecosystems (vegetation) and environmental variables, with a major focus on natural and anthropogenic drivers of vegetation change such as deforestation, increased agriculture, mining, reduced arctic ecosystems, increased temperatures, increased extreme weather events, increased population and urban growth. Geospatial technologies (remote sensing and geo-information systems –GIS) are at the core of her research and methods, as well as developing remote sensing models based on the principles of electromagnetic radiation. Angela uses GIS and Remote Sensing in combination with ground measurements and models to answer research questions like: "how do terrestrial ecosystems respond (in terms of carbon uptake, health) to changes in environmental and climate conditions (due to natural or anthropogenic factors), how can we use vegetation – radiation interaction based indices and models to estimate carbon uptake in different ecosystems?"

## KEYWORDS

#REMOTE SENSING #GIS #VEGETATION DYNAMICS
#VEGETATION PHENOLOGY #LAND COVER CHANGE
#LAND SURFACE PHENOLOGY #ECOSYSTEM SERVICES

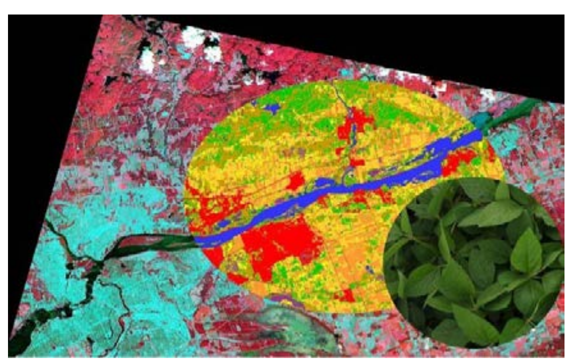
## EARTH OBSERVATION IN SUPPORT OF THE ASSESSMENT AND MONITORING OF URBAN GREEN SPACES AND THE ECOSYSTEM SERVICES THEY SUPPLY

A Next-generation city will nurture sustainability. It will be a city where vegetation greenness will be planned strategically to maximize the sustainable use of its ecosystem services such as recreation, food, improved air quality, thermal comfort and reduced energy use, improved water infiltration and flood protection, and carbon storage. The effective incorporation of these benefits in urban planning and climate adaptation strategies requires a comprehensive understanding of the variability of the vegetation ecosystem services and their responses to environmental and climate change. This chapter will first analyze and discuss the use of geospatial technologies (e.g. remote sensing and geo-information systems) in combination with ground measurements and models to address this requirement. Geospatial technologies can provide continuous information (e.g. daily, weekly, monthly, and annually) over multiple study scales (e.g. plot, city, region) related to vegetation greenness, atmospheric carbon dioxide, carbon uptake by plants, temperature, air quality, land cover, and precipitation. Based on such data, we can ask questions like: how much green space is there in the city and how does it vary? Which plant types or species are most effective for carbon storage? And which ones for improved air quality? Which species are more drought-resistant? Which are the optimal locations for urban roof food production? Where are green roofs needed to increase thermal comfort? Based on the analysis, a framework will be developed and proposed for the use of geospatial technologies in support of the strategic planning of vegetation greenness in next-generation cities, allowing us to answer these questions. The following is a draft conceptual model of the scope of this work.



Draft conceptual model of scope of this study


Urban remote sensing


Vegetation remote sensing: from a pretty picture to spectral classes to land cover classes to photosynthesis!

## Catherine MULLIGAN

**Professor, Building, Civil, and Environmental Engineering and Director, Concordia Institute of Water, Energy and Sustainable Systems, Concordia University, Canada**

Dr. Mulligan obtained her BEng and MEng in chemical engineering and PhD in geoenvironmental engineering from McGill University. She worked for the Biotechnology Research Institute of the National Research Council of Canada and SNC Research Corp. Of SNC Lavalin before joining Concordia University in 1999. She held a Concordia Research Chair in Geoenvironmental Sustainability (Tier I) and is a full professor in the Dept. of Bldg., Civil, and Environmental Engineering. She has authored more than 130 refereed papers in various journals, co-authored or edited 8 books, holds 3 patents and has supervised to completion more than 70 graduate students. She is the founder and director of the Concordia Institute of Water, Energy, and Sustainable Systems. The Institute trains students in sustainable development practices and performs research in new systems, technologies and solutions for sustainability. Her research is on the treatment of contaminated soils, water, sediment, and mining residues with biosurfactants and other treatment techniques, in addition to energy production via anaerobic treatment and pressure-reduced osmosis. She is a Fellow of the Canadian Society for Civil Engineering (CSCE) and its current Past President and currently the chair of the Sustainable Geotechnics Committee for the CGS. She is also a Fellow of the Engineering Institute of Canada (EIC), the Canadian Academy of Engineering (CAE), and Royal Society of Canada and was a winner of the John B. Sterling Medal of the EIC.

## KEYWORDS

#CONTAMINATED SITES #REMEDIATION #BIOSURFACTANTS
#SUSTAINABLE MANAGEMENT #ENVIRONMENTAL APPLICATIONS

## APPLICATION OF SUSTAINABLE ENVIRONMENTAL REMEDIATION FOR URBAN SITES

An evaluation of the management options must be made for contaminated sites. In particular, various techniques must be considered for the remediation of soils, mining residues, water and sediments when the release of hazardous materials becomes a serious problem. The options can include physical, biological, and/or chemical treatments. Sustainable management options for contaminated sediments are required and will be evaluated. In situ remediation could be beneficial over ex situ technologies due to a reduction in costs and lack of solid disposal requirements.

Selection of the most appropriate remediation technology must coincide with the environmental characteristics of the site and the ongoing sediment fate and transport processes. To be sustainable, the risk to human health and the environment at the site must be reduced, and not be transferred to another site. Cost-effectiveness and sustainable solutions are significant factors in determining the treatment. Both in situ and ex situ treatment approaches are available but decisions must be made based on the information available. The application of biosurfactants has been evaluated as alternatives to chemical reagents due to their surface active and emulsifying properties, low toxicity, biodegradability, unlimited applicability, and relative low production cost for sustainable remediation. Studies showed that for effective application of biosurfactants, they should be selected based on pollutant characteristics and properties, treatment capacity, costs, regulatory requirements, and time constraints. Moreover, understanding of the mechanisms of interaction between biosurfactants and heavy metal and hydrocarbon contaminants or the contaminated environment can assist in selection of the appropriate biosurfactants for sustainable remediation. This chapter will include research on various environmental applications of biosurfactants. Natural processes for remediation of sediments will also be discussed.

## Fatemeh IZADI

PhD Individualized Program (INDI) candidate at Concordia University, Canada

Fatemeh is using her background in architecture and urban design to integrate knowledge from the fields of urban ecology, engineering, and design in order to understand how built and green elements of cities can enhance urban "walkability," with a focus on thermal comfort. As a member of the CERC Team headed by Professor Ursula Eicker, as well as the IDEAS-BE Team headed by Professor Carmela Cucuzzella, Fatemeh strives to maximize the well-being of communities, protect the environment, and invest in the future. The topic of her research falls within the Next Generation Cities cluster, and her thesis is titled Towards Comfortable, Walkable and Green Streets: Walkability Assessment with a focus on street-level greenery and thermal comfort.

## Rushikesh PADSALA

PhD candidate in the Building Engineering program at Concordia University, Canada

Rushikesh is specializing in geospatial technology. His primary research interests lie in Geodata Management, Urban Digital Twins, and Semantic 3D City Modeling. During his doctoral studies, Rushikesh is actively engaged in exploring the application of urban digital twins for consumption-based carbon accounting within neighborhoods. In addition to his academic pursuits, Rushikesh serves as a researcher in geomatics at the Stuttgart University of Applied Sciences - HFT Stuttgart in Germany. With over 6 years of professional experience, he has successfully collaborated with clients from India, UAE, Germany, Canada, and the USA. His expertise lies in delivering end-to-end solutions for 2D and 3D geospatial projects across various do- mains, including urban energy planning, real estate, urban design, transportation,and AEC.

## Rabeeh HOSSEINI

Professional Sustainable Building at CIMA+, Vancouver, Canada

Combining her background in Architectural Engineering and Urban Design from Shiraz University (Iran) with Building Engineering at Concordia University (Canada), Rabeeh engaged in several studies to develop smart and systematic methods for evaluating urban design performance and creating resilient planning models. For her thesis, she utilized geographic information systems, urban data analysis, and building energy modeling to create a digital twin of a real case study neighborhood, showcasing net zero strategies and scenarios. Her interest in resilient city design led to collaborations in various CERC projects, including developing thermal comfort analysis methods for urban areas in 2020, cleaning and analyzing urban data for the city energy end use (CEE) mapping project with Natural Resources Canada in 2021, and acquiring and modeling building construction data library to support the urban building energy software being developed at Concordia University from 2020 to 2021.


## KEYWORDS

#3D CITY MODELS #SPATIAL DESIGN
#OUTDOOR THERMAL COMFORT #MEAN RADIANT TEMPERATURE

## USING CLIMATE-SENSITIVE 3D CITY MODELING TO ANALYZE OUTDOOR THERMAL COMFORT IN URBAN AREAS

In the context of escalating urbanization, climate change emerges as a critical challenge, necessitating new and advanced approaches to managing cities in a way that considers climate. Addressing this issue requires implementing advanced tools and techniques in urban design. The ongoing evolution of geospatial technologies, notably the transition from traditional 2D to 3D spatial design, holds promise for informed, climate-responsive, urban decision-making. This study uses 3D city models to calculate the mean radiant temperature (Tmrt), a crucial indicator of outdoor thermal comfort. The objective is to assess the spatiotemporal distribution of heat stress at the district scale, with the city of Montreal, Canada, serving as a case study for potential planning scenarios. The research employs a systematic workflow, incorporating advanced geospatial tools such as ArcGIS CityEngine for 3D city modeling and the open-source SOLWEIG outdoor thermal comfort assessment model. We tested our approach on an upcoming urban redevelopment site in the borough of Lachine, west of downtown Montreal. A statistically downscaled weather profile for the projected warmest year before 2050 (2047) was used to showcase the workflow's efficacy in identifying areas under heat stress. The outcome shows the workflow capacity for a structured recognition of hotspots under heat stress alongside supporting the efficient intervention of tree placements as a passive strategy for heat mitigation. The workflow's success underscores its potential for addressing technical challenges urban designers face in decision-making and action planning, particularly regarding the sustainability of urban designs even under climate change conditions.

# PART 3
# URBAN INFRASTRUCTURE AND METABOLISM

## Osama MOSELHI

**Professor and Director of the Centre for Innovation in Construction and Infrastructure Engineering and Management (CICIEM), Department of Building, Civil and Environmental Engineering Concordia University, Canada**

Dr. Moselhi is Professor and Director of the Centre for Innovation in Construction and Infrastructure Engineering and Management (CICIEM), Department of Building, Civil and Environmental Engineering at Concordia University. He has over 50 years of professional and academic experience. His industry experience spans tall buildings, bridges, nuclear power plants, harbors, and offshore facilities. His research interest encompasses two major areas. The first is optimized value driven asset management for sustainable and resilient civil infrastructure, including non-invasive and non-destructive condition assessment and rating, deterioration modeling, reliability and vulnerability assessment, resilience measurement and evaluation, and optimized budget allocation for intervention and recovery plans. The second is optimized delivery of engineering, procurement and construction projects, including project delivery systems, planning, procurement, resource allocation, tracking and control for efficient management of construction projects, with a focus on risk management, productivity analysis, management of construction claims and development of decision support systems embracing information technology, remote sensing, web-enabling and spatial technologies.

Dr. Moselhi is Fellow of the Association for Advancement in Cost Engineering (AACE International), the American Society of Civil Engineers (ASCE), the Canadian Society for Civil Engineering (CSCE), and the Canadian Academy for Engineering (CAE). He is recipient of numerous honors and awards, and is member of the Provost's Circle of Distinction at Concordia University.

## INTRODUCTION TO CIRCULAR ECONOMY: A WAY TO GO FOR SUSTAINABILITY

In this brief introduction, we intend to provide an overview of circular economy and its benefits with emphasis on built facilities in cities and urban developments. Recent challenges arising from climate change and protection of the environment, among other things, made communities, governments, and stakeholders rethink alternatives to the current linear economic model. Indeed, we are witnessing considerable energy and drive to replace the current “material-consume” linear economy of take-make-use-dispose model by a progressive “material-use” circular economy of generate-use-recover-reuse model. Transitioning here from linearity to circulatory provides unmatched opportunities for innovation to meet the challenges of that transition.

The generally recognized arching 4R principles (reduce, reuse, recycle, remove) of the circular economy can help achieve realization of society and governments goals in economic growth, protection of the environment, and sustainability of built facilities. These principles embrace the reduction of waste, the use of renewable energy, resilience for prolonged service life, and rethinking the way we deliver built facilities. It is in this context that one can see a circular economy as a drive to design for sustainability. Circular economies call for integrated systemic solutions in an enabling framework. Clearly, that framework should have the capacity to address on one hand global issues such as deforestation, regeneration of used resources and climate change on planet earth and on the other hand addresses domain specific issues such as resilience and sustainability in the delivery and operation of built facilities in cities and urban developments. While both are interrelated, in this part of the volume, we shall focus on the latter.

## Chunjiang AN

**Associate Professor, Building, Civil, and Environmental Engineering, Research Chair in Spill Response and Remediation at Concordia University, Canada**

Dr. An obtained his PhD degree in Environmental Systems Engineering from the University of Regina in 2013, an MSc degree in Environmental Engineering from Xi'an Jiaotong University, China, in 2006, and a BEng degree in Environmental Engineering from Nanjing University of Science and Technology, China, in 2002. Before joining the department, Dr. An was a research scientist at the Institute for Energy, Environment and Sustainable Communities and an Adjunct Professor at the Faculty of Engineering and Applied Science at the University of Regina. His research interests include a broad range of topics related to pollution control, risk assessment and systems analysis. Dr. An is a licensed Professional Engineer, Associate Editor of the Journal of Environmental Informatics (ISSN: 1726-2135), Managing Editor of Environmental Systems Research (ISSN: 2193-2697), and editorial board member of the Journal of Hazardous Materials (ISSN: 0304-3894), Environmental Advances (ISSN: 2666-7657), BMC Chemistry (ISSN: 2661-801X), Sustainability (ISSN: 2071-1050), Processes (ISSN 2227-9717), and Challenges (ISSN 2078-1547). He is also the Guest Editor for six special issues in some international journals. Dr. An has published over 100 peer-reviewed journal articles, including seven highly cited ESI papers. Dr. An's interdisciplinary activities have been supported by significant research grants from NSERC, DFO, ECCC, etc.

## KEYWORDS

#WASTE MANAGEMENT SORTING AND COLLECTION
#RECYCLING AND TREATMENT

## WASTE MANAGEMENT INFRASTRUCTURE FOR A CIRCULAR ECONOMY

Population explosion and rapid urbanization accompanied by industrialization have led to an increasing amount of waste generation worldwide. The World Bank estimates that waste generation will increase from 2.01 billion tons in 2016 to 3.40 billion tons in 2050. The traditional waste disposal method is landfilling. A large proportion of generated waste is also disposed of through open dumping and burning. The increasing municipal waste generation rate is putting enormous pressure on municipal waste management systems and government budgets. The high cost can also further exacerbate the improper management of municipal solid waste, which can cause problems such as public health impacts, land resource depletion, and greenhouse gas emissions. Effective waste management strategies and technology are required by industry, academia, and government.

Effective and sustainable waste management system is the key to achieve circular economy in cities. The principle of waste management is the familiar '3R' strategy — reduce, reuse, and recycle. Although different techniques can be used in a waste management system, there are some common essential components, including waste sorting and collection schemes, waste recycling equipment and facilities, economic viability, and appropriate policy.

The first step for waste recycling is waste sorting and collection. However, the waste collection rate varies a lot by country. Upper-middle- and high-income countries can collect nearly all generated waste but only 39% of waste can be collected in low-income countries. This low waste collection rate keeps large amounts of waste out of the municipal waste stream and forces it towards open dumping or open burning. In addition, the following waste recycling stage highly depends on the quality of waste sorting. Valuable materials should be separated from the waste flow and transferred to recovery facilities. The high-quality sorting and waste separation require the effective waste collection programs, adequate personnel and equipment, and waste sorting facilities.

Technology is critical for achieving a circular economy by properly disposing of and treating municipal solid waste. In past decades, many waste recycling and disposal techniques have been developed and put into practice including, waste-to-energy (WTE) incineration, composting, landfill gas collection, waste sorting, and recycling. Although these technologies have their own limitations, their development provides more options for sustainable waste management. Appropriate reuse and recycling could also help reduce the use of landfills and mitigate the rapid depletion of natural resources.

Another factor that is critical to sustainable waste management is government policy. The government needs to propose the cost-effective waste management program to increase the capacity of waste collection, recycling, and disposal. In addition, the sustainable waste management system should have economic viability, which means that it cannot only enhance the material recovery but also create job opportunities. This requires the government to integrate the various components of the municipal waste stream, including waste generator, waste disposal and recycling facilities.

This chapter will focus on the three basic common components for a sustainable municipal waste management including waste sorting and collection scheme, waste recycling technologies, and government policy. The information in this chapter aims to provide a guide to achieve a circular economy in waste management.

## Amin HAMMAD

**Full Professor at the Concordia Institute for Information Systems Engineering (CIISE) at Concordia University, Canada**

Dr. Hammad's current research interests are in the areas of automation in construction and infrastructure systems. The research aims to improve productivity and safety on construction sites and the sustainability of infrastructure systems by developing new methods using artificial intelligence, distributed sensing, real-time simulation and resource optimization. He edited one book and published six book chapters and more than 250 papers in peer-reviewed journals and conferences.

## Tersoo K. GENGER

**PhD student at Institute for Information Systems Engineering (CIISE) at Concordia University, Canada**

Tersoo obtained his MSc in Information systems at the Robert Gordon University, Aberdeen, Scotland, UK. He works as a lecturer at the Department of Electrical Electronic Engineering, Federal University of Agriculture, Nigeria. He is currently doing his PhD at Concordia University, Canada, focusing on decision making for the sustainable placement of underground utility infrastructure assets. He has authored and co-authored several international journal articles and he is the recipient of several awards and grants.

## Ali ALAGHBANDRAD

**Former PhD student of Building Engineering in the Department of Building, Civil, and Environmental Engineering at Concordia University, Canada**

Dr. Alaghbandrad completed his PhD in Building Engineering from Concordia University, Canada, in 2020. His PhD thesis is entitled "Economic Analysis and Information Modeling of Smart Multi-purpose Utility Tunnels (MUTs)". He received two Master's degree from École de Technologie Supérieure, Canada, and Azad University, Iran, in 2015 and 2011, respectively. He received his Bachelor's degree in Civil Engineering from Zanjan University, Iran, in 2008. He has authored/co-authored several journal and conference papers.

## Yisha LUO

**Researcher at Terra Info Tech (Beijing) Co., Ltd China**

Yisha Luo is a researcher interested in applying geomatics skills in various fields, including public infrastructure and public health. With a bachelor's degree in Geomatics and a master's degree in Civil Engineering, and some years of work experience, Yisha is combining GIS and other types of data for better decision-making.

## KEYWORDS

#MULTI-PURPOSE UTILITY TUNNELS # SUSTAINABILITY
#RESILIENCE #BIM #LOCATION SELECTION AND EVALUATION

## SMART MULTI-PURPOSE UTILITY TUNNELS

The traditional way of burying utilities under road segments is a practice that has proven unsustainable, as several deficiencies have been attributed to this method of utility placement. Multi-purpose utility tunnels (MUTs) provide a sustainable and long-term solution to the problems associated with utility placement, inspection, maintenance, and upgrade. An added advantage of MUTs is the ease with which decision-making and technologies such as the Internet of Things can be easily integrated into the management of utility networks. This is in the form of Smart MUTs. MUT planning is a key factor of urban underground space planning, which is an important part of urban planning. This chapter reviews issues related to MUT planning and construction, operation, and maintenance using Building Information Modeling (BIM). Also, this research provides a general method for MUT location selection using Geographic Information System (GIS) spatial analysis. Multi-criteria decision-making (MCDM) is used in this research to select potential MUT locations. The weights of the criteria are calculated using the Analytic Hierarchy Process (AHP) method. A case study is used to demonstrate the feasibility of the proposed method. The specific objectives of the research are: 1) Review the history and recent development of MUTs in the world; 2) Review the application of BIM in MUT design, construction, and lifecycle management; 3) Provide a general method for MUT location selection based on GIS spatial analysis.

## Rebecca DZIEDZIC

**Assistant Professor, Building, Civil, and Environmental Engineering Department at Concordia University, Canada**

Dr. Dziedzic's research expertise lies in developing decision-support methods for sustainable infrastructure, particularly water systems. As part of her doctoral studies, she developed energy metrics to assess the efficiency of water distribution systems. These have been applied to five cities and a tool is currently being developed in collaboration with the Canadian Urban Institute to further facilitate their application. Prior to joining Concordia, Dr. Dziedzic worked as an asset management consultant and now continues to collaborate with industry professionals to better respond to current urban challenges. She is currently working with 14 cities across Canada as part of a project to develop water main failure prediction models.

## Geneva STARR

**Social Worker at Ottawa Hospital, Canada**

Geneva completed her Bachelor of Engineering in Water Resources Engineering at the University of Guelph in 2014. She is a previous project manager at the Canadian Urban Institute and Purpose Building, with expertise in driving sustainable low-carbon communities. She has over 5 years of experience leading projects on municipal energy management, smart city planning, and environmental stewardship. Geneva has worked with national and international communities, promoting sustainable urban development through applied research, stakeholder engagement, and technical tool development. Geneva holds a degree in Water Resources Engineering with Distinction and a Master of Social Work.

## KEYWORDS

#ENERGY METRICS #WATER SYSTEMS #HYDRAULIC MODELING

## ENERGY EFFICIENT WATER DISTRIBUTION

Water distribution systems deliver an essential service to billions of urban dwellers. Water conveyed in pipes is used for drinking, cleaning, fighting fires, and other commercial, industrial, and institutional applications. And moving water across cities and over hills requires a significant amount of energy. For certain cities, water systems are the number one municipal energy user. Around 80% of municipal water processing and distribution costs stem from electricity use.

In addition to representing a commodity and potential environmental impact, energy can also be a framework for analyzing efficiency, viability, and other system characteristics. Additionally, because energy is conserved and can be accounted for throughout the system, similar to currency, it has the potential to be used as a measure of a service's value. Specifically in water distribution, energy is proportional to the product of pressure and flow, the two most important measures in hydraulic systems. Thus, energy has the additional capacity of integrating the two primary products of the system, which control design: water flow and pressure.

The present chapter describes the application of energy metrics to assess the energy efficiency of water distribution systems, identify opportunities for improvement, and compare scenarios. The energy metrics describe how energy is supplied, delivered, and dissipated throughout the system. Their aim is to reconceive the definition of system efficiency; to quantify and then manage energy embedded in each component of a water distribution system.

Results from case study systems highlight how these energy metrics provide a lens that facilitates the identification of energy efficient opportunities. Because metrics are calculated by network component they can be mapped, and inefficient hotspots identified. Since a daily hydraulic model is the only input to this analysis, it is a low-cost solution. Nevertheless, it can lead to significant energy savings of around 6 to 8%, depending on the system.

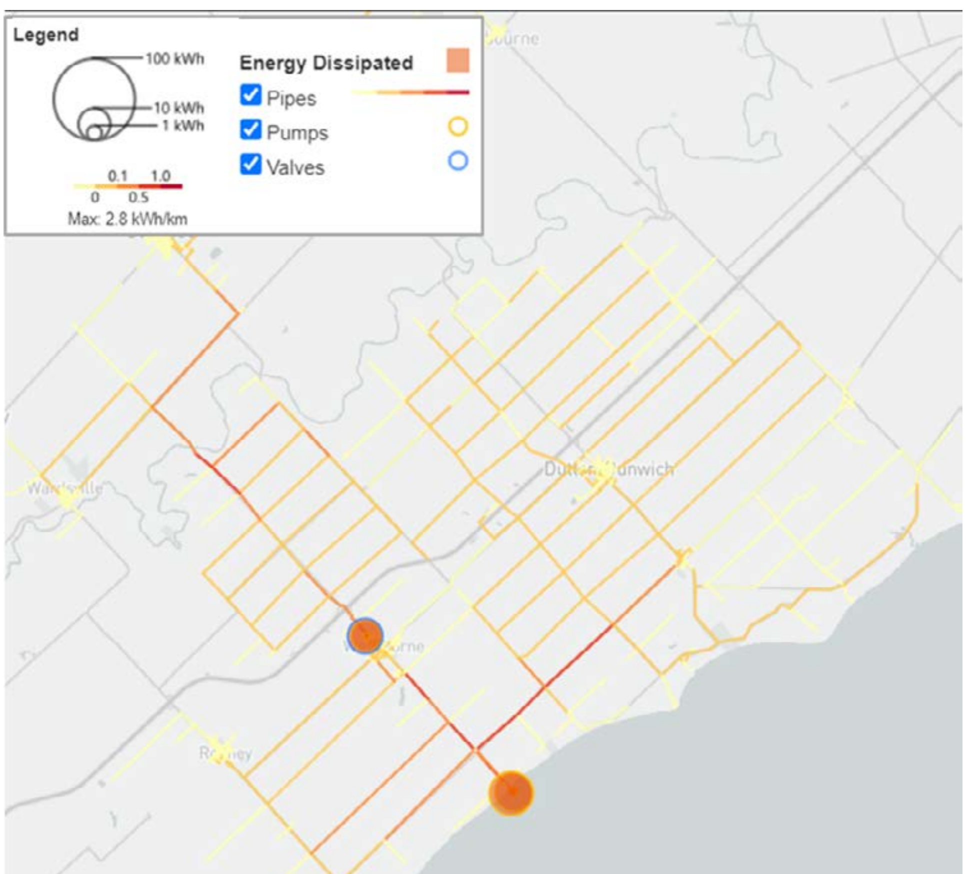



Figure 1: Map of energy dissipated at pipes, pumps and valves for Case Study System A Average Day Demand at 0 hours.

## Matthew COTTON

Matthew hails from Judique Cape Breton in Nova Scotia Canada and is a MASc. Civil-Environmental Engineering student currently researching the use of ANAMMOX for the remediation of tailings produced by the gold mining industry. He also holds a BEng in Civil Engineering, Specialization: Environmental Engineering, a BA in Geography, Specialization: Human Environment, along with a Minor in Biology all received from Concordia University in Montreal Canada.

## Farhad M. MOGHADAM

Farhad is an experienced environmental engineer with dual master's degrees in Water Resources Management from K.N.T. University of Technology and Environmental Engineering from Concordia University (Canada). With over five years in the water and wastewater treatment field, he currently serves as a wastewater and quality technician at Crofter's Organic Jam Company in Ontario in order to manage and recover the water used for making products, ensuring sustainable and environmentally friendly production processes. Farhad excels in coordinating water quality testing, maintaining plant systems, and optimizing processes through meticulous attention to detail and strong organizational skills. He has contributed to wastewater treatment projects, focusing on regulatory compliance and environmental sustainability by reducing energy consumption and solid waste generation.

## Catherine MULLIGAN

**Professor, Building, Civil and Environmental Engineering and Director, Concordia Institute of Water, Energy and Sustainable Systems, Concordia University, Canada**

Dr. Mulligan obtained her BEng and MEng in chemical engineering and PhD in geoenvironmental engineering from McGill University. She worked for the Biotechnology Research Institute of the National Research Council of Canada and SNC Research Corp. Of SNC Lavalin before joining Concordia University in 1999. She held a Concordia Research Chair in Geoenvironmental Sustainability (Tier I) and is a full professor in the Dept. of Bldg., Civil Environmental Engineering. She has authored more than 135 refereed papers in various journals, co-authored or edited 8 books, holds 3 patents and has supervised to completion more than 75 graduate students. Her research is on the treatment of contaminated soils, water, sediment, and mining residues with biosurfactants and other treatment techniques including anaerobic treatment. She is the founder and director of the Concordia Institute of Water, Energy and Sustainable Systems. She is a Fellow of the Canadian Society for Civil Engineering (CSCE) and its current Past President and currently the chair of the Sustainable Geotechnics Committee for the CGS. She is also a Fellow of the Engineering Institute of Canada (EIC), the Canadian Academy of Engineering (CAE), and Royal Society of Canada and was a winner of the John B. Sterling Medal of the EIC.


## KEYWORDS

#WASTEWATER TREATMENT #PRIMARY TREATMENT
#SECONDARY TREATMENT# TERTIARY TREATMENT
#PATHOGEN REMOVAL #SLUDGE DEWATERING

## WASTEWATER IN MODERN CITIES: A BRIEF OVERVIEW

According to the International Panel on Climate Change (IPCC), water scarcity is an issue faced by approximately half of the world's population at some point each year, with at least two billion affected individuals not having access to safe drinking water. As our population continues to grow, and the effects of climate change are expected to further exasperate the issue, it is imperative that we begin to look at the way water is currently used and treated in our most densely populated areas. In that regard, this chapter will examine the current methods of wastewater collection and treatment in the modern city. Focusing on the steps involved in collection and treatment, it will also outline some of the expected constituents of the wastewater, physical, chemical, and biological, how to test for them, and some of the methodologies involved in their removal. The chapter also offers a generalized discussion of wastewater and its constituents as resources to be recovered and reused as opposed to treated and disposed of. This idea is inherent to the concept of integrated water planning and the importance of protecting our water sources and the environments, industrial, societal, and ecological, that rely on them.

## Alex DE VISSCHER

**Professor and Chair, Chemical and Materials Engineering at Concordia University, Canada**

Professor De Visscher Is founding Chair of the Department of Chemical and Materials Engineering at Concordia University. He has a broad range of research interests in chemical engineering fundamentals such as chemical thermodynamics and kinetics, transport phenomena, solubility phenomena, and molecular modeling, with applications in chemical engineering. He published over 60 articles in a wide range of scholarly journals and was editor and main author of the 95th volume of the IUPAC-NIST Solubility Data Series, on alkaline earth carbonates. His first book, Air Dispersion Modeling: Foundations and Applications was published in 2013 by J. Wiley & Sons, Hoboken, NJ.

Dr. De Visscher obtained his PhD at Ghent University, Belgium, in 2001. He moved to Canada in 2005 to take on a Canada Research Chair in Air Quality and Pollution Control Engineering at the University of Calgary. He moved to Montreal in 2017 to join Concordia University.

## Yaser KHOJASTEH SALKUYEH

**Assistant Professor at the Department of Chemical and Materials Engineering at Concordia University, Canada**

Prof. Khojasten's research focuses on the creation and optimization of environmentally friendly processes for the production of chemicals, fuels, and electricity. Dr. Khojasteh received his PhD in 2015 from McMaster University (McMaster Advanced Control Consortium group). His study focused on the development of sustainable energy generation and the production of liquid fuels. He then became a postdoctoral scholar at the University of Toronto (BioZone group), where he conducted research on the creation and life-cycle assessment of bio-based processes. He has also worked at CanmetENERGY Varennes as a research scientist prior to joining Concordia.

## KEYWORDS

#RENEWABLE ENERGY #ELECTRIFICATION #HEAT INTEGRATION #CARBON MANAGEMENT

## TOWARDS A GREEN INDUSTRY

The creation of smart and sustainable cities will be unachievable without a full decarbonization of the economy. While energy use in transportation and buildings (residential and commercial) accounts for around 33% of global GHG emissions, the industrial sectors, directly and indirectly, account for about 30% of global carbon emissions. While incorporating renewable energy greatly decreases the carbon footprint of residential sectors, a similar problem must be addressed in industrial sectors, particularly energy-intensive businesses, in order to further reduce the total carbon footprint. As a result, we must identify a variety of solutions for each sector's challenges to achieve a green industry. This chapter examines the following key points in this regard:

**• Smart Cities to Fuel Industry: Hybrid Renewable Micro-Generation Systems**
The energy demand is much higher than our current electricity generation capacity. For example, while Canada consumed more than 11,500 petajoules of energy in 2018, it generated only around 2300 petajoules of electricity (20% of demand). Hence, a drastic increase in renewable electricity production must go hand in hand with the electrification of industry. The development of renewable micro-energy generating units (using solar or wind energy) in cities coupled with battery or thermal storage systems is not only a critical component of cities' efforts to reduce their energy use but also an opportunity to support industrial sectors with their energy requirements. Although the vast majority of electricity production in Canada is renewable or nuclear, only about 5 % currently comes from solar and wind energy.

**• Low and Medium-Temperature Energy Demand**
In addition to boosting the production rate of renewable electricity and its penetration into the industrial sectors, it is critical to improve the energy efficiency of industrial operations. The majority of industries with low-temperature energy demands, such as food, pulp and paper, chemical, and some petrochemical units, will be outfitted with high-temperature heat pumps and thermal storage systems. Heat integration between low-temperature heat sources (below 100°C) and heat sinks (above 100 °C) will be accomplished employing efficient heat pumps in these heating systems. Current industrial heat pumps are capable of meeting energy demand at temperatures up to 200°C, making them suitable for a variety of industries and applications. Additionally, Mechanical Vapor Recompression (MVR) systems will be integrated into a broader range of applications to meet industry's demand for high-pressure steam (HPS). MVRs are similar to heat pumps except that they utilize process streams rather than a circulating fluid.

**• High-Temperature Energy Demand**
Electrification of high-temperature energy-intensive sectors, such as steel, cement, and process units in chemical and petrochemical complexes, is a critical component of our economy's profound decarbonization. While such energy demand is now fulfilled mostly by the combustion of fossil fuels, electric boilers capable of reaching temperatures of 1000°C are theoretically achievable and will be commercially accessible fairly soon. Electrically driven furnaces and boilers are more energy efficient on average than conventional ones, with lower capital and operating costs. As a result, the electrification of such industries will become financially viable if renewable energy becomes widely available and inexpensive.

**• Carbon Management in Industry**
CO2 utilization provides an opportunity to reduce CO2 emissions that are not the result of energy consumption. Examples are combustion of oil-based chemicals and cement production (calcination of limestone to lime and CO2). As deep decarbonization of energy production becomes a reality, these emissions will increasingly become the main residual sources of CO2 emissions. While some processes exist to reduce CO2 to chemical feedstocks (e.g., reverse water-gas shift, methanol and Fischer-Tropsch synthesis) new processes, such as electrocatalysis and photocatalysis, are expected to broaden the industry's tool set to move to a fully carbon-neutral world.

## Tobias POPOVIC

**Professor of Corporate & Sustainable Finance, Financial Markets and Services at Stuttgart University of Applied Sciences (HFT Stuttgart), Germany**

Before joining HFT Stuttgart, Tobias worked as an equity analyst and senior investor relations manager at DZ BANK. He also served as a board member of Banco Coopera- tivo Español (BCE) in Madrid between 2007 and 2009.

He is also the scientific co-director of HFT Stuttgart's Center of Sustainable Economics and Management (CSEM) and represents the sustainable finance cluster. His research interests include sustainable finance and investments, sustainable insurance, sustainable innovation & entrepreneurship, and ecosystems for sustain- able innovation. In recent years, he has worked on transdisciplinary research projects focused on sustainable finance (e.g. EnViSaGe, Ensign, NATIVE, IEA, DH2050, and REWARDHeat), funded by ministries and the EU.

As well as serving as HFT's ethics officer since 2011, he served as their sustainability officer between 2011 and 2017. During that time, he developed HFT's sustainability strategy and implemented EMAS' environmental management system. As a startup mentor, he contributed to the development of the digital tool "EMAS-App", which served as the basis for BuildingScout.

## Kristina LYGNERUD

**Chair at the European Platform of District Energy Research at the Swedish Environment Research Institute**

Kristina holds the position of Chair at the European Platform of District Energy Re- search and is a Senior Energy Expert at Svenska Miljöinstitutet, IVL. She has extensive experience in business model innovation in district heating and has led several national and international projects, including an EU project on low-temperature waste heat recovery. Kristina supervises three PhD candidates and supports the strategic development of the unit at the University of Lund where she is a professor. She has also worked as an Associate Professor at the University of Halmstad, mentored two PhD candidates, and lectured master level students on the topic of energy system policies. Kristina has a PhD in Industrial and Financial Economics from Göteborg University and has previously worked as a business and strategy developer, a risk manager, and a financial analyst in various organizations.

## Sebastian SCHULTZE

**Research Staff at Stuttgart University of Applied Science (HFT Stuttgart), Germany**

Sebastian is a research staff member at Stuttgart University of Applied Science, where he is involved in researching sustainable finance. He is currently working on two research projects about business models and financing for new generations of district heating networks, one of which is an EU project (H2020 called REWARD- Heat) and the other is funded by the IEA (called DH 2050). Prior to his current position, he worked as a financial consultant for three years at tecis Finanzdienstle- istungen AG, where he advised clients on their investments and was in constant contact with investors, fund managers and financial experts. He holds a Master's degree in technical business administration from the University of Stuttgart, where his thesis was on decarbonization and its impact on asset portfolios. He also has a Bachelor's degree in technical business administration from the same university and his thesis was on material aspects - a key element in the GRI-G4 guidelines for sustainability reporting.

## KEYWORDS

#DISTRICT HEATING AND COOLING NETWORKS (DHCN)
#SUSTAINABLE INFRASTRUCTURE FINANCE
#BUSINESS MODEL INVESTMENT CASES #BLENDED FINANCE

## SUSTAINABLE INFRASTRUCTURE FINANCE IN A NEXT GENERATION CITIES' CONTEXT: THE CASE OF DISTRICT HEATING AND COOLING NETWORKS

Accelerating climate change as well as further "Grand Challenges" (such as e.g., biodiversity loss, water shortages) increase the urgent need for a "Great Transformation" of our societies and economies. As this Great Transformation exists of different kinds of transitions (e.g., an energy transition, urban transitions, etc.) today's – mostly unsustainable – metropolitan areas need to undergo a fundamental transformation into Next Generation Cities. By undergoing these transformational processes, over time, Next Generation Cities should create an increasing impact on as many as possible UN Sustainable Development Goals (SDGs). Due you to related path dependencies infrastructure are a crucial element of this transformation, offering challenges and opportunities at the same time. In addition, over the next 20 years or so, trillions of investments are needed to transform existing infrastructures into more sustainable ones or to install sustainable infrastructures right away. Of particular importance are in this context are District Heating and Cooling Networks (DHCN) with respect to decarbonizing the building sector as it is responsible for approximately 1/3 of carbon emissions.

Against the background of the high public debt levels, governments probably will not be able to provide the funding for these investments. All the more important it is therefore to access financial markets in order to attract institutional investors to DHCN-projects. In this paper we will discuss the different approaches and possibilities the relatively young field of research Sustainable Infrastructure Finance is offering to potentially bridge the funding gap for DHCN. We will also show that it is necessary to develop – based on the technical infrastructure – a business model, which then will be transformed into an investment case to be presented to investors as the basis for their investment decision making. Furthermore, we will discuss different groups of investors potentially willing to provide the required funding. Also, we will provide an overview of a variety of financing instruments, e.g., green bonds, ESG-linked-instruments, blended finance-instruments, etc. In order to illustrate, which kinds of investors are using which types of financing instruments we will outline a matrix combining these two dimensions.

## Thomas BAUMGÄRTLER

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Thomas Baumgärtler has been Professor of International Economics, Banking and Cooperatives at the Offenburg University of Applied Sciences (OUAS) in Germany since 2009. Previously, he held various positions in the cooperative finance group. From 2000 to 2004, he worked on business policy issues for the cooperative banking group in Bavaria as a member of the executive board staff of the Bavarian Cooperative Association. He then moved to the number two in the German insurance market, the cooperative R+V insurance group, where he was a senior executive responsible for sales and coordination of the network.

In addition to teaching at OUAS, he is involved in practical projects on cooperatives and sustainability. These include workshops and consulting activities on sustainability reporting in banks and small and medium-sized companies. He also conducts research on cooperative innovation ecosystems that can provide innovative solutions to regional problems. He also focuses his research on circular economy models. In a recent publication, he analyzed the impact on sustainable development. The circular economy model is seen as having great potential in realizing sustainable development. In this research he examines the impact of the circular economy on the three dimensions of sustainable development, economy, ecology and social. His research-related publications can be found at https://bw.hs-offenburg.de/fakultaet-wirtschaft.

He also teaches as a visiting lecturer at the University of Burgos (UBU) in Spain, where he has most recently contributed to a project and two book chapters on combating fraud and corruption in EU funds (EUMODFRAUD) under the European Union  Union's Hercule III funding program."

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He is also the scientific co-director of HFT Stuttgart's Center of Sustainable Economics and Management (CSEM) and represents the sustainable finance cluster. His research interests include sustainable finance and investments, sustainable insurance, sustainable innovation & entrepreneurship, and ecosystems for sustain- able innovation. In recent years, he has worked on transdisciplinary research projects focused on sustainable finance (e.g. EnViSaGe, Ensign, NATIVE, IEA, DH2050, and REWARDHeat), funded by ministries and the EU.

As well as serving as HFT's ethics officer since 2011, he served as their sustainability officer between 2011 and 2017. During that time, he developed HFT's sustainability strategy and implemented EMAS' environmental management system. As a startup mentor, he contributed to the development of the digital tool "EMAS-App", which served as the basis for BuildingScout.

## KEYWORDS

#SUSTAINABLE INNOVATION AND ENTREPRENEURSHIP #SUSTAINABLE FINANCE #COOPERATIVES #VUCA #UN SDGS #COOPERATIVE BUSINESS MODELS #ECOSYSTEMS FOR SUSTAINABLE INNOVATIONS #STAKEHOLDER NETWORKS #TRANSDISCIPLINARY LIVING LABS # COOPERATIVE MODELS AND COOPERATIVE BANKS, SUSTAINABLE DEVELOPMENT, SUSTAINABILITY MANAGEMENT, INTERNATIONAL ECONOMICS

## COOPERATIVE BUSINESS MODELS IN A NEXT-GENERATION CITIES' CONTEXT – THE CASE OF DISTRICT HEATING AND COOLING NETWORKS

Societies as a whole but next-generation cities in particular are facing a variety of so-called "Grand Challenges" such as demographic change, climate change, etc. At the same time, they are exposed to trends like urbanisation and digital transformation, just to name a few. The resulting complexity leads to a "VUCA"-environment, marked by volatility, uncertainty, complexity and ambiguity, making it difficult for citizens and decision-makers alike to find orientation and a clear vision about how next-generation studies should be designed and implemented. One framework that could be used as a means of orientation in order to transform today's municipalities and cities or city districts could be the United Nations sustainable development goals (SDGs). In addition, a metropolitan region, a municipality or a city district could be considered as an ecosystem for sustainable innovations, consisting of a hub in the centre of the system, which is coordinating a network of relevant stakeholders (e.g., citizens, administration, schools, universities). As a theoretical basis for this ecosystem for sustainable innovations, transdisciplinary living labs with the "Quintuple Innovation Helix" serve as its core principle. In order to develop impactful solutions along the SDGs in response to the "Grand Challenges", all stakeholders should follow further principles such as co-definition, co-construction, collaboration, co-creation and co-production during the entire innovation process.

The objective of this chapter is to show that the potential of cooperatives to develop sustainable innovations in a next-generation cities' context has been largely neglected so far. It will also be outlined in what way cooperatives could effectively contribute to the sustainable transformation of society, cities and the economy. Cooperatives are associations of people that unite on a voluntary basis in order to meet their common primarily economic, but also social and cultural needs by cooperatively developing solutions to existing challenges. It is argued that due to their grassroot democratic structure (e.g., expressed by the one-member-one-vote-principle), their specific set of values and their governance structure cooperatives bear the potential to mobilize civic commitment. Due to the cooperatives' awareness that – as Raiffeisen, one as their founding fathers, put it 200 years ago – the many can achieve what one person alone cannot achieve, it will be argued that cooperatives are well suited to unlock the creativity, the intelligence and the innovation potential of the crowd. Since a cooperative's members are its most important customers and its owners at the same time – in the light of the principal agent theory – strong incentives exist to develop and to offer the best possible products and services (double-market-mechanism). This provides the basis for intensive stakeholder participation and integration in different fields of the sustainable transformation in a next-generation cities' context, such as housing, energy (producing, storing, sharing, selling), data (blockchain as technology that links energy, mobility, payments), mobility, etc. This chapter will also discuss what the most important principles, methods and formats are and what success factors can support cooperatives in effectively contributing to a future oriented transformation of municipalities, cities and districts driven by sustainable innovations along the SDGs.


## Fuzhan NASIRI

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Dr. Nasiri is also affiliated with Institut Nordique du Québec (INQ). Before joining Concordia, he worked at University College London (UCL) as a faculty member (2011-2014), at Yale University as a research scientist (2009-2011), and at GERAD research group as a postdoctoral fellow (2007-2009). Dr. Nasiri holds a PhD in Environmental Systems Engineering from the University of Regina, and MSc and BSc in Industrial Systems Engineering from Sharif University of Technology.


## Mohammad Javad BORDBARI

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Mohammad is a member of CORS, obtained his BSc in electrical engineering from Shiraz University of Technology in 2015, and followed it with an MSc in electrical engineering from Shiraz University in 2018. His research focuses on the resilience and reliability analysis of power systems, along with the configuration and control of networked microgrids, leveraging artificial intelligence and machine learning. He holds a keen interest in sustainable power systems and the incorporation of renewable energy resources.


## KEYWORDS

#POWER SYSTEMS RESILIENCE #NETWORKED MICROGRIDS
#RESILIENCE ENHANCHEMENT
#CONFIGURATION OF NETWORKED MICROGRIDS

## DYNAMIC NETWORKED MICRO-GRIDS FOR URBAN ENERGY RESILIENCE

The escalating impact of climate change and the increasing frequency of natural disasters pose significant challenges to power systems. Enhancing resilience against these rare yet severe events is paramount. The proposal to transform conventional power systems into dynamic networked microgrids (DNMGs) emerges as a promising strategy. Consequently, a growing body of research has concentrated on techniques based on networked microgrids to enhance the resilience of power systems. This paper conducts a comprehensive and current analysis of literature, specifically concentrating on the essential components and configuration of networked microgrids. It explores vital aspects of DNMG configurations, such as formation and power distribution, assessing each through problem modeling, distinctive features, and limitations. The review examines outcomes, highlighting research gaps, with a focus on critical aspects like frequency and voltage stability, reliability, costs related to remote switches and communication technologies, and the overall resilience of the network. The study concludes by outlining potential future trends, providing valuable insights for researchers in this domain.

## Navid SHIRZADI

Research Scientist at Natural Resources Canada

Dr. Shirzadi is a Research Scientist with a Ph.D. in Civil Engineering from Concordia University (2023). His research expertise spans computational problem-solving in the fields of buildings and energy systems, with a focus on the optimal design and management of energy systems in urban areas and microgrids. He applies mathematical programming, optimization techniques, and data science and AI to tackle challenges in the energy sector.


## KEYWORDS

#RENEWABLE ENERGY #URBAN WIND TURBINES
#URBAN WIND FLOW PATTERNS #WIND FORECASTING

## URBAN WIND RESOURCES

Due to numerous reasons such as fossil fuel depletion, environmental issues, and the ongoing rapid transition toward smart cities, urban areas are attracted more than ever before to distributed renewable generation. According to the global wind energy council (GWEC), up to 2019, wind turbines with the production capacity of nearly 650 GW of power have already been installed, and an additional capacity of 355 GW is expected to be added in the years 2020–2024. Admittedly, a large majority of them are expected to be onshore and offshore wind turbines. However, urban wind energy has been identified as one of the renewable resources with high potential for modern cities. Recent studies show three distinct possibilities for integration of wind energy generation in urban environments: (1) stand-alone wind turbines in urban locations; (2) addition of wind turbines onto existing buildings; and (3) full integration of wind turbines together with building architecture. This is owing to various reasons such as the multiplication factor of wind speeds around buildings and convenience offered by proximity of the turbines to consumption points.

However, the aerodynamic performance of wind turbines is heavily dependent on conditions influencing inflow making it an important factor to study. Characterizing this potential in urban areas is complicated due to factors such as obstacles and building structures that impact the air flow, decrease wind speed, and create high turbulence at the top of and around the buildings. Therefore, understanding the wind flow pattern at the lowest urban architectural/ building layers, and analysis of vertical roughness and inertial sublayers is essential. As a result, generation of wind power on-site (or off-site) has often proven to be challenging compared to other renewable technologies. But it is still a very viable and appropriate option in areas with high wind potential.

Due to the intermittency of renewable resources, especially wind, there is a significant tendency towards integrating multiple renewable technologies together to increase the reliability and reduce the initial investment and operational costs of the energy systems. Optimal control of the integrated energy system, especially in urban areas where the system is grid-connected, is vital. To develop a robust model for unit commitment and load dispatching, forecasting the generation of renewable resources is mandatory.

The intermittent nature and unexpected wind speed behavior pose different operational challenges that make wind resource forecasting a vital part of any future urban renewable energy system's control strategy.

Evaluation of the wind speed across different time horizons such as minutes, hours, days, and even a year has been found to be useful for different applications and objectives. For example, a yearly resolution is important for feasibility studies and initial energy system design analyses that validate the system's feasibility, while other horizons could prove to be helpful for grid and energy management practices such as load following, unit commitment, and day-ahead scheduling.

One common wind forecasting approach typically uses historical time series of wind speed data as a dependent variable against some other independent variables (such as temperature, humidity, or pressure) correlated with the wind speed seasonality and trend to predict the future wind speeds. Other new methods such as stochastic methods, statistical methods, and/or machine learning methods for wind speed time series forecasting, also provide interesting new opportunities to improve the wind forecasting capabilities in the urban setting.

The chapter discusses the potential for wind power in urban areas, the importance of wind forecasting, and offers a discussion of the different forecasting methods that would make it possible to maximize use of the urban wind resources.


## Saeed RANJBAR

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Saeed completed his undergraduate studies in Mechanical Engineering and obtained his M.Sc. degree in Renewable Energy Engineering. He is mainly focused on energy system sizing, thermal energy storage, and positive energy districts. To date, he has a number of publications in the fields of thermal energy storage, solar thermal energy systems, life cycle assessment, and energy system sizing. His work is about designing an automatic workflow for implementation of thermal energy storage in urban energy systems.


## KEYWORDS

#RENEWABLE ENERGY #HEAT PUMPS #DECARBONIZING ENERGY SYSTEMS #BUILDING-INTEGRATED ENERGY SOURCES #POWER TO HEAT (P2H)

## RENEWABLE ELECTRICITY WITH REVERSIBLE HEAT PUMPS AND THERMAL STORAGE

Electrification of heating and cooling systems using power to heat (P2H) technologies is one of the most promising methods for decarbonizing urban energy systems. As the most mature among the P2H technologies, heat pumps (HPs) stand out as a viable and ready-to-use option to replace conventional heating systems while simultaneously increasing the share of renewable sources in urban areas.

In countries like Canada, where a large share of the electricity demand is supplied through renewable hydropower, utilizing heat pumps could further reduce greenhouse gas emissions (GHGs). More importantly, heat pumps offer a high level of flexibility by allowing for dephasing of the thermal demand satisfaction and electric power consumption. This makes HPs an ideal candidate for contribution to the creation of demand-side management strategies, especially when integrated with Thermal Energy Storage (TES). Coupling TES with HPs enhances the building energy system's thermal inertia, which leads to higher flexibility. During off-peak hours, the TES unit could be fully charged by the heat pump, and the stored energy will be used later at peak hours. Therefore, the peak demand, as well as the CO2 emissions, will be reduced.

Integrating TES with HPs could further enhance the renewable energy source (RES) share in urban energy sources (UES) by maximising the usage of distributed wind and solar energy technologies. The electricity produced from these building-integrated renewable sources can be used to make the buildings less dependent on the electricity grid during periods of high demand/grid congestion, thus making end-users self-sufficient while also reducing their expenses. At the same time, when used alongside optimal control strategies, RES powered HPs could be scheduled to improve grid security and robustness.

In this section, the role of heat pumps with thermal energy storage in the next generation cities is investigated. The potential benefits and configurations that could maximize the utilization of RES with HPs and TES are studied and different use cases that could make the modern city resilient and efficient are discussed.

## Hadis MONTAZERI NEJAD

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Hadis is a mechanical engineer and is excellent at using programming languages and numerical simulation for modeling technologies, including micro-gas turbines and fuel cells. Hadis's thesis focuses on studies on integrating CHP systems run by renewable fuels in the urban environment. Her research interests include the role of hydrogen and synthetic fuels in future urban energy systems.

## KEYWORDS

#ZERO-CARBON ENERGY SYSTEMS #CHP SYSTEMS #EMISSIONS #HYDROGEN #SYNTHETIC FUELS

# COGENERATION SYSTEMS FOR EFFICIENT ELECTRICITY AND HEAT GENERATION FROM RENEWABLE FUELS

There are many comprehensive studies carried out and solutions proposed to fight global warming and reduce greenhouse gas (GHG) emissions. One of them is the usage of combined heat and power (CHP) technologies to produce heat and electricity simultaneously. These devices offer a unique opportunity to improve the overall fuel-based engine conversion efficiency by using the engines' waste heat within the urban setting.

CHP units can be classified based on the prime mover used, such as internal combustion engines (ICEs), micro-gas turbines (MGTs), Stirling engines, fuel cells (FCs), organic Rankine cycles (ORCs) etc. They can be further categorized based on the energy source used to power the unit. The fuels used today are still mainly fossil fuels such as diesel and natural gas, but a shift to green fuels is ongoing using biogas, solid biomass, and hydrogen produced from renewable energies such as solar and wind. Finally, CHP systems can also be classified based on their generated power. The systems with a nominal output power of lower than 50kWe, between 50kWe to 1MWe, and more than 1MWe are grouped into micro-cogeneration, small scale cogeneration, and medium or large cogeneration, respectively.

When the CHP units only produce heat and electricity, the CHP units are typically characterized as cogeneration units, and if they are also able to be used along with devices such as electrolyzers to produce fuel, they are called polygeneration devices.

Considering the advantages offered by CHP systems (like their adaptability in using a wide range of energy sources and simultaneous production of electricity, heating, and storage of energy in the form of fuel produced), they are already being used in a wide range of sectors such as residential sectors, healthcare, commercial sectors and also in remote locations with only intermittent access to the energy supplied by the grid. In these places, CHP and polygeneration units can offer great benefits in the form of improved reliability and resilience to the consumer in question. They are also able to provide much-needed stability and flexibility when energy supply is not guaranteed, especially in locations where shutdowns can have grave consequences, like hospitals or data centers.

Using hydrogen in cogeneration systems increases efficiencies due to the higher heating value, while syngas performs less well but offers low-cost solutions, and existing infrastructure can be used. Additional cost occurs due to other hydrogen infrastructure, storage, leakage, and flame flashback risk prevention. In conclusion, cogeneration technologies offer ample scope for low emission, reliable and flexible power in future renewable energy systems and need to be carefully chosen depending on the application, power range, and performance goals.

This chapter looks at the role of cogeneration technologies in urban areas and compares them depending on the application, efficiency priorities, and power range.


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## KEYWORDS

#ZERO-CARBON ENERGY SYSTEMS #CHP SYSTEMS #EMISSIONS #HYDROGEN #SYNTHETIC FUELS

## THE ROLE OF HYDROGEN AND SYNTHETIC FUELS IN FUTURE URBAN ENERGY SYSTEMS

More than 80% of the consumed energy in the world is supplied by fossil fuels such as petroleum, coal, and natural gas. Supplying electricity, heating, and cooling demands by fossil fuels is not only a risk to the economy due to the foreseeable depletion of their resources but also damages the environment and human health through greenhouse gases and other pollutant emissions. To address the mentioned challenges, new sustainable, clean, and renewable energy fuels will be increasingly used in the transportation domain as well as in cogeneration systems for urban electricity and heat generation.

One of the most promising carbonless fuels is hydrogen, a fuel that can satisfy green and clean energy requirements. Hydrogen is an energy carrier with high sustainability, is environmentally friendly, and does not produce any pollutants nor toxic wastes. Renewable resources, including hydropower, wind, wave energy, solar, biomass, and geothermal energy, can generate hydrogen as a potential economical, clean fuel for the future economy. If hydrogen is used in urban energy systems, it has no carbon emissions because water vapor is the only by-product of its combustion. Although storing hydrogen is difficult because of its low density, its high stability allows the use in energy storage systems for a long time. Gaseous, liquid, and solid-state systems can be used for hydrogen storage. To distinguish which kinds of vessels are appropriate, safety, performance, cost, weight, and size should be assessed.

From hydrogen, a range of synthetic fuels can be produced to be used in cogeneration systems. In addition, biogas and syngas from biomass or waste sources are available.

While hydrogen has the highest energy content, the operation is more complex due to its high flammability, low explosion temperature, expensive storage, leakage, and flashback risks. On the other hand, biomass or waste-based resources are limited, and the combustion processes produce carbon emissions. In conclusion, switching from fossil fuels to renewable gases for cogeneration applications might result in a performance decrease if low energy content gases such as syngas are used, whereas performance typically improves for hydrogen as a sustainable and non-toxic energy carrier.


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Abolfazl obtained his bachelor's degree in Mechanical Engineering from the Iran University of Science and Technology (IUST), Tehran, Iran, in 2017. He pursued his interest in Mechanical Engineering and joined the IUST Automotive Engineering Research Center for two years as a research assistant to work on developing a model to simulate the hydraulic and thermal behavior of the cooling system in an internal combustion engine. Currently, he is a PhD student in Building Engineering at Concordia University Canada. His main research interests are applied mathematics, heat transfer, and computational fluid dynamics.


## KEYWORDS

#DISTRICT HEATING #RENEWABLE ENERGY
#THERMAL NETWORK STRUCTURE #OPTIMIZATION
#THERMAL NETWORK SIMULATION

## THERMAL DISTRIBUTION NETWORK

Low-temperature networks play an important role in the transition towards sustainable and efficient energy systems due to their efficiency and incorporation of renewable energy sources. Prosumers, which are consumers with the ability to consume and produce heat, such as data centers or buildings with renewable energy systems, and bidirectional energy exchange play a crucial role in this context. On the network side, prosumers have four possible connection configurations: return-to-supply, return-to-return, supply-to-supply, and supply-to-return. To analyze the performance of District Heating Networks (DHNs) with prosumers, a mathematical model is necessary to simulate the behavior of such systems under different operational conditions. Recent studies have focused on developing models to study the thermo-hydraulic behavior of DHNs. These models can be categorized as either physical or statistical. Physical models that examine the steady-state hydraulic and dynamic thermal performance of DHNs have lower computing costs than completely dynamic models and provide more information than fully static ones. These models are the focus of the current report and can be divided into hydraulic and thermal parts. The current study provides a comprehensive review of hydraulic and thermal models used to investigate DHNs in the literature as well as their limitations, followed by a discussion on the study of prosumers in DHNs in terms of the feed-in configuration, number and types of prosumers, and employed models.

## Ramanunni PARAKKAL MENON

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Raman's fields of expertise include Energy Management, Optimization and Operations Research, Optimal Control, Internet-of-Things (IoT) hardware and software, Smart Buildings and Networks, Smart Grids, Machine Learning for Smart grids and Energy system integration and system design for communities and cities. He completed his BE in Chemical Engineering from BITS-Pilani, Goa in India, his MSc in Energy from Heriot-Watt University, Edinburgh in Scotland, and his PhD in Energy from EPFL Lausanne in Switzerland on "Model Predictive Control Strategies for Polygeneration Systems and Microgrids". He worked within the EU Horizon 2020 project "Sim4Blocks" and as a Postdoctoral Fellow at the CERC (Canada Excellence Research Chair in Smart, Sustainable and Resilient Communities and Cities) in Concordia University, Montreal in Canada prior to his current tenure at DLR.

## Ursula EICKER

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Dr. Eicker is a German physicist who received her PhD in Solid State Physics from Heriot-Watt University and her Habilitation in Renewable Energy Systems and Building Technology from the Technical University Berlin. She has led numerous international research projects in renewable energy supply systems and building energy efficiency at Stuttgart University of Applied Sciences. A central focus of her research is zero-emission, smart and sustainable cities, integrating renewable energy sources and increasing city livability. A team of over 50 graduate students and software developers worked on numerous eco-district projects in Canada and created the urban modeling, data analytics and stakeholder engagement platform Tools4Cities. Dr. Eicker founded the Next-Generation Cities Institute in November 2020 and addresses the challenges of urban transformation with a transdisciplinary approach and develops tools and strategies for a sustainable future. As a member of the Canadian Green Municipal Fund (GMF) council since 2024, Prof. Eicker supports environmental sustainability and community development. She is a member of several advisory boards, including the Catalonian Energy Research Institute IREC, the Ireland Research Centre for Energy, Climate and Marine Research MaREI, Unibail-Rodamco-Westfield head-quartered in Paris and others.

## KEYWORDS

#SMART GRIDS #DECENTRALIZED DISTRIBUTION GRIDS
#MICROGRIDS #DISTRIBUTED ENERGY RESOURCES
#BIDIRECTIONAL FLOW

## MICROGRIDS, DISTRIBUTION NETWORKS, SMART GRIDS

Traditionally the electricity grids have been centralized systems with a clear partition between the generators, the transmission and distribution systems and the consumers. The power flowed unidirectionally from the generators to the consumers who are located at the other end of the grid. This made control and management fairly straight-forward. But, the growing demands of the consumers alongside the simultaneous introduction of distributed and renewable energy resources within the grid as a means to tackle climate change and to replace nuclear and other fossil fuel-based power from the electricity grids in many countries, has brought about a need to move away from a centralized unidirectional grid. This change has necessitated the requirement of new solutions to improve the resilience, reliability, and efficiency, and to maintain power quality within the power grid. Smart grids, Active Distribution Networks (ADNs), Virtual Power Plants (VPPs) and microgrids along with Demand Side Management (DSM) and Transactive Energy (TE) Frameworks have been proposed as some of the most suitable and viable solutions for solving the various supply, demand, and congestion problems that may arise from the new decentralized bidirectional grid structure.

Smart grids have been proposed to handle the abovementioned challenges through efficient usage of the power available by integration of advanced communication, intelligence, and control capabilities. Integration of smart meters and monitoring systems for each node in the grid allows for quicker maintenance and efficient management of the grid based on requirements. Smart grids also allow for more modern market models, integration of new storage units, electric vehicles, and distributed energy resources. This, in turn, enables the creation of new concepts such as Virtual Power Plants, Energy Hubs, microgrids, and other solutions proposed.

Microgrids were first introduced in the early 2000s as a solution for better integration of Distributed Energy Resources (DERs), Distributed Energy Storage Systems (DESSs), and controllable and non-controllable loads. Microgrids were thought to be especially suited to isolated areas and regions which have fewer connections to the larger electrical grid, enabling them to be self-sufficient for longer periods. Detailed definitions and rules for interaction and coordination of the different elements within a microgrid have been codified and continues to be codified in technical forums, industrial and academic entities like CIGRE (International Council on Large Electric Systems), NEDO (New Energy and Industrial Technology Development Organization), and CERTS (Consortium for Electric Reliability Technology Solutions).

A smart grid and microgrid still depends on the efficient and optimal use of transmission and distribution networks to ensure satisfaction of the energy demands from the energy source to the location of the demand. Some of the tenets (basic structure and minimum requirements) required for this have been codified within microgrids and enabled by the sensors and intelligence of the smart grids. But, Active Network Management (ANM) by Transmission System Operators (TSOs) and Distribution Network Operators (DNOs) remains essential for the successful amalgamation of the Demand Side strategies, the usage of the energy produced by the Distributed Energy Resources, and the new market models. New proposals for Active Management of Distribution Networks via ADN and ANM technologies is the last piece of the puzzle that brings all of it together preventing network failure, congestion, and customer dissatisfaction, among other problems.

Thus, through the discussion of all the various pieces and solutions pivotal for the future electrical grid, this section will detail the steps required for the move towards a smart decentralized grid with bidirectional flows. The smart grid infrastructure required to make the transition will be detailed upon. Similarly, Active Distribution Networks and microgrids, and their advantages and disadvantages, will be discussed. This will be used to inform and discuss the steps required towards the creation of the modern resilient, reliable, and efficient grid of the future capable, of maximizing the utilization of renewable energy resources.


## Jingdi WANG

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Jingdi received her Bachelor's degree in Engineering from Communication University of China. Her research topic is "Fast Acting and Robust Power Electronics Interfaces for Energy Storage Systems in DC Nanogrid." Her interests focus on modeling, simulation, and control of power electronic interfaces, and hierarchic control of Microgrids/Nanogrids.


## Luiz A. C. LOPES

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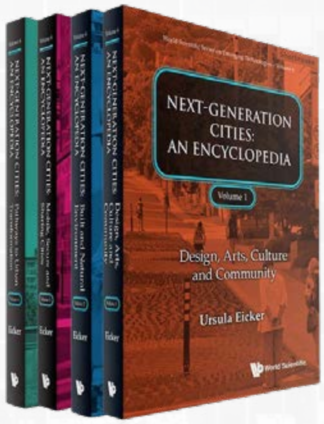
Dr. Lopes obtained his PhD from McGill University in 1996. He was an Associate Professor at Federal University of Para, Brazil, from 1996-2001. In 2002, he joined the Department of Electrical and Computer Engineering in 2002 at the rank of Associate Professor and has been a Professor since 2013. His present research interests are power electronics and distributed power generation. He was a member of the NSERC Solar Buildings Research Network, leading subproject 3.2.a entitled "Development of Interconnection Technologies for Grid-Connected PV Systems". He was a technical representative for Canada in Task 11 "PV Hybrid Systems within Mini-grids" of IEA-PVPS and the lead author of the report "PV Hybrid Mini-grids: Applicable control Methods for Various Situations." Dr. Lopes is a Member of the international advisory board of Efficacity, French Urban Energy Transition Institute, since February 2018. He is also a member of the Administration Board and of the Academic Committee of the Institut en Génie de l'Énergie Électrique (IGEE). Dr. Lopes has supervised to completion 12 PhD students, 35 Master of Applied Science students and 95 Bachelor (final year capstone project) students. He has published about 50 journal papers and more than 130 conference papers. Dr. Lopes is a member of the Ordre des Ingénieurs du Québec (OIQ) and a senior member of the IEEE.


## KEYWORDS

#RENEWABLE ENERGY SOURCE #DISTRIBUTED ENERGY SOURCE #ENERGY STORAGE SYSTEM #MICROGRID #NANOGRID #HIERARCHICAL CONTROL #DROOP CONTROL #STATE OF CHARGE CONTROL #VOLTAGE REGULATION

## USING DC TECHNOLOGY FOR NANO AND MICROGRIDS: BENEFITS AND CHALLENGES

The integration of Renewable Energy Sources (RES) increases the feasibility of Microgrids (MG) and Nanogrids (NG). MGs and NGs can improve the grid's resilience and efficiency and reduce carbon emissions. Power electronics interfaces of Distributed Energy Resources (DER) and hierarchical control can be employed to deal with the fluctuating nature of RESs and the caused low grid inertia. This chapter discusses a case study of an isolated DC NG with two-layer control, including one Photovoltaic (PV) system and two Energy Storage (ES) units. Primary control uses droop control to share load demand among DERs automatically. Secondary control regulates the DC bus voltage and State of Charge (SoC) of ES units.




In conclusion, THE BOOK OF ABSTRACTS / VOL. 2 for the “Next-Generation Cities: An Encyclopedia” series, published by World Scientific Publishing Co Pte Ltd, introduces the diverse and interdisciplinary topics covered in the four volumes. Both publications are co-edited by Prof. Ursula Eicker, Canada Excellence Research Chair (CERC) in Smart, Sustainable, and Resilient Communities and Cities, and founding Director of the Next-Generation Cities Institute (NGCI), along with the team of Co-Directors representing the Institute’s three research clusters: Built and Natural Environment (BAN), Mobile, Secure, and Sharing Cities (MSS), and Design, Arts, Culture, Community (DAC).

The presented abstracts offer the perspectives of authors who are primarily experts in the field of urban studies from Concordia University in Montreal, along with related experts from Canada and around the globe. In this way, this collection creates an international overview. It highlights the multifaceted nature of urban development, integrating insights from various fields to understand the challenges and opportunities facing our cities today. We invite you to explore the subsequent volumes, each offering unique perspectives on next-generation cities. Together, these volumes form a rich resource for shaping the future of urban environments.

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