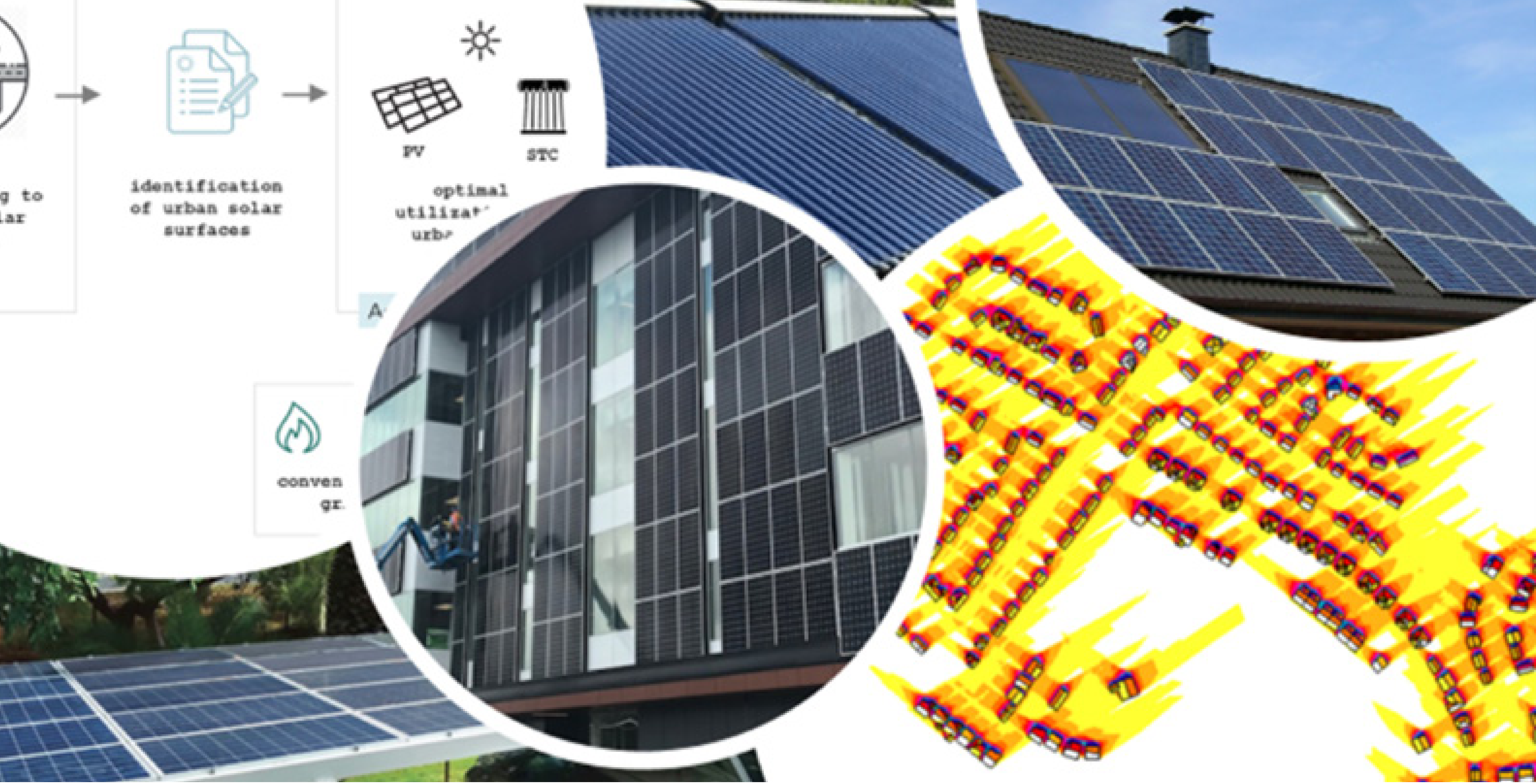


SEPTEMBER 6 - 22, 2022

PLANNING SOLAR NEIGHBORHOODS: STRATEGIES, TOOLS, AND PERSPECTIVES

FALL SCHOOL

IEA SHC Task 63
Solar Neighborhood Planning

Organized by
Caroline Hachem-Vermette, PhD
Subtask A Leader

Edited by
Caroline Hachem-Vermette, PhD
Maria Wall, PhD
Karly Do

The Fall School is organized by Dr. Hachem-Vermette, Subtask A leader, as part of STA deliverables.

University of Calgary
School of Architecture, Planning, and Landscape

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

UNIVERSITY OF CALGARY
Solar Energy and Community Design Lab (SECDL)

SECDL

ABOUT FALL SCHOOL

The main objective of the Fall School (September 2022) is to introduce and discuss various solar strategies, and methods employed to assess and evaluate these solar strategies and concepts, from various perspectives and standpoints. Presentations and discussions will be carried to enhance the comprehension of various perspectives that should be considered in selecting solar strategies, passive and active, for neighborhood application. These perspectives can encompass life cycle analysis, solar technologies integration, techno-economic aspects, simulations and multi-objective solutions, impact on energy goals and sustainable developments, in addition to other practical, social and technical aspects.

The Fall School includes theoretical/lecture-based parts, where prominent people in various fields of solar energy applications (including simulations) are invited to talk about aspects of solar energy, and role of solar energy technologies in sustainable buildings and neighborhoods.

Selected topics of presentations and discussions encompass:

- Status of solar technologies deployment and 100% renewables
- Life cycle of solar technologies and impact
- Socio/economic aspects
- PV and STC integration in buildings
- Simulations of neighborhoods, to analyze different solar strategies
- Overview of various strategies and applications
- Technologies and sustainable developments - case study from industry perspective.

CONTENTS

Dr. Maria Wall

Dr. Maria Wall is associate professor at the Division of Energy and Building Design, Lund University, Sweden. Energy aspects related to buildings have always fascinated her. She has a MSc in Architecture and a PhD in Engineering. Her research includes different aspects related to energy-efficient buildings as well as solar energy strategies. She is presently leader of the international research project IEA SHC Task 63 on Solar Neighborhood Planning (2019-2023), including both passive and active solar energy strategies. She was leader of the SHC Task 41 on Solar Energy and Architecture (2009-2012), and then leader for the SHC Task 51 on Solar Energy in Urban Planning (2013-2018).

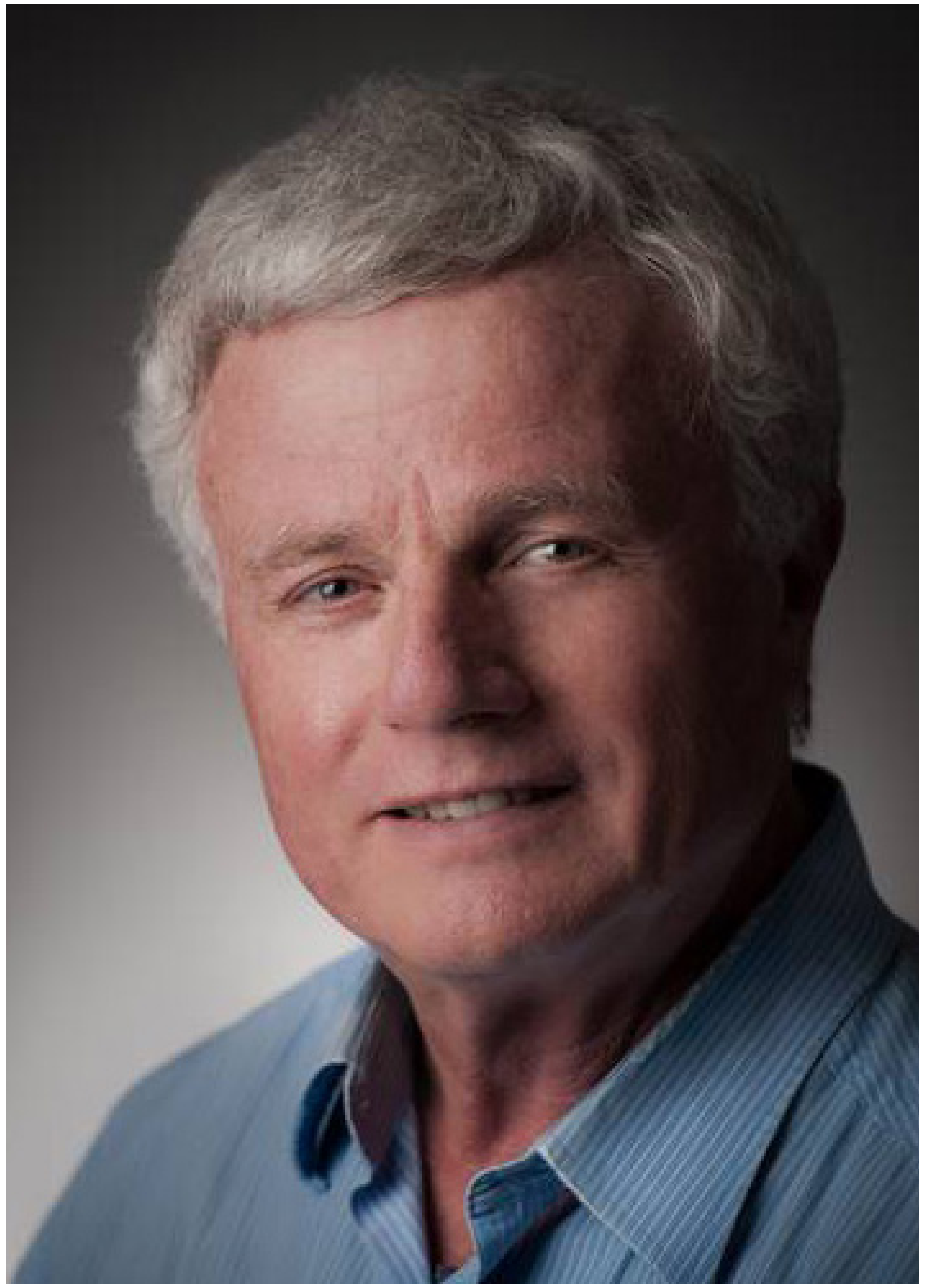
She was the main initiator and developer, and was the Director of the 2-year Master's Programme in Energy-efficient and Environmental Building Design at Lund University, during 2012-2022. This programme is enrolling international students from different backgrounds, both in architecture and in engineering, since interdisciplinary teamwork is needed when designing sustainable buildings and neighbourhoods.

Dr. Caroline Hachem-Vermette

An architect by training and by profession, Dr. Caroline Hachem-Vermette has two master's degrees in architecture, and an additional master's, and PhD degrees in Building Engineering from Concordia University. Dr. Hachem-Vermette research program is highly multidisciplinary, involving such diverse disciplines as architecture, urban planning, and building engineering.

Her research area includes the investigations of multifunctional energy-efficient, resilient neighborhood patterns, solar potential and energy implications of building shapes, building envelope design, developing multifunctional facades for multistory buildings, and others. Her research is multidisciplinary, it plays a bridging role between building engineering and architectural and urban design. Her current research program aims at developing concepts and strategies for the design of sustainable and climate resilient, self-sufficient, smart communities and urban developments. A part of this research program concentrates on the design of urban green infrastructure that aims at improving the health and wellbeing of urban inhabitants, especially in times of stresses (including pandemics).

She is currently leading a subtask on developing strategies for net-zero energy solar communities, within the International Agency Energy Task (IEA) 63 - Planning Solar Neighborhoods. She was also an expert on 2 other IEA SHC tasks on solar energy in architecture and urban planning. She is widely published on the topic of energy efficiency and solar energy, including a book (with Springer) on designing solar buildings and neighborhoods. Dr. Hachem-Vermette is a recipient of a number of awards including the 2019 Peak Scholar Award, 2016 sustainability award, e-sim/ IBPSA award for innovation in modelling, and Hangai prize for young researchers.



Dr. David Renne

Dr. Renné has worked on renewable energy R&D programs for over 45 years. After graduating from Colorado State University (Fort Collins, Colorado, USA) with a Masters in Atmospheric Sciences and a PhD in Earth Resources in 1975 he launched his career at the Pacific Northwest National Laboratory (Richland, Washington USA) where he worked primarily on wind resource assessment programs, both in the U.S. and internationally. In 1991 he moved to the U.S. National Renewable Energy Laboratory (Golden, Colorado USA) to manage NREL's solar resource assessment activities and to work on several international renewable energy programs. After retiring from NREL in 2012 he formed his consultancy, Dave Renné Renewables.

He is currently a Senior Consultant to Clean Power Research, and has consulted with the World Bank, the International Renewable Energy Agency (IRENA), the Asian Development Bank, and several private-sector organizations.

From 2010 – 2019 he served as President of the International Solar Energy Society and continues to serve on their Executive Committee. He also represents on the Board of the Global Solar Council. In 2019 and 2020 he served as co-Chair of the International Renewable Energy Agency's Coalition for Action "Towards 100% Renewable Energy" Group and remains heavily involved with this working group. For over 18 years he was an Associate Editor of the Solar Energy Journal in the topical area of Solar Resource and Energy Meteorology.

SPEAKERS

Dr. Francesco Guarino

Francesco Guarino is Assistant Professor at the University of Palermo, department of Engineering. He completed his M.Sc in Energy engineering in 2011 and got his Ph.D. in Energy in 2015, working on “Building integrated phase change materials energy storage: experimental studies, modelling and parametric analysis”. He participated to multiple International Energy Agency workgroups since 2012 from both the “Solar Heating and Cooling” and “Energy in Buildings and communities” programmes, notably IEA SHC Task 40/ECBCS Annex 52 “Towards net zero energy solar buildings” and is currently Operating agent of Annex 83 “Positive Energy Districts”.

Author of more than 100 among papers in national and international journals and conferences, book chapters or technical reports, he is reviewer consulted among several international energy and environmental journals. Recipient of several research awards and best paper awards. His work is oriented towards sustainability in the building and energy sector, through research in the fields of Life Cycle Assessment of buildings and energy technologies, building physics and building simulation, low-carbon and renewable energy technologies.

Dr. Maurizio Cellura

Full professor of Building Physics and Building Energy Systems since 2011 at the University of Palermo, his scientific activity is mainly oriented towards energy and environmental topics, with focus on energy efficiency in buildings, technologies powered by renewable energy technologies and decarbonization strategies of systems and processes. Director of the Centre for Sustainability and Ecological transition of the University of Palermo since March 2022. Representative for the University of Palermo to the "Sustainable Solutions Development Network – a global initiative for the United Nations" since 2014, he was national vice president of the "Italian Life Cycle Assessment Network" since 2012, becoming president in October 2015.

He is member of the Italian consultation board of the Italian Ministry for Education for the challenge "Secure, Cleaner and Efficient Energy" of the EU program Horizon 2020 (from October 2013). He is national representative of the SETPLAN IWG 5 "Energy Efficiency in Buildings". He is Italian representative member of the Bureau of Research and Innovation of the Union for Mediterranean. He authored more than 380 scientific publications.

Dr. Steven Strong

Steven studied engineering at Northeastern University and then went on to study architecture at the Boston Architectural Center where he established their 1st curriculum on sustainable design. He has taught courses in renewable energy systems engineering and design studios in 'Net-Zero' / sustainable building design and has lectured on these subjects at Arizona State University, Harvard's GSD, University of Oregon, Georgia Tech, Worcester Polytechnic Institute, Pace University, New Jersey Institute of Technology, Rhode Island School of Design, Carnegie Mellon University, Savannah College of Art and Design, Simon Fraser University, MIT, the New School of Architecture, Swiss Federal Institute of Technology, University of Massachusetts, University of California, Southern California Institute of Architecture, Oxford, Tufts University, York University, Roger Williams University, University of Aachen, Yale, Olin College of Engineering, Princeton, Murdoch University, and the Frank Lloyd Wright School of Architecture. He is a Fellow of the American Solar Energy Society.

He is the author of The Solar Electric House and Solar Electric Buildings, an Overview of Today's Applications; contributing author of Photovoltaics in the Built Environment, a Design Guide for Architects and Engineers as well as contributing author to Photovoltaics in Buildings, Building with Photovoltaics and, Green Design – From Theory to Practice with noted architect Ken Yeang. Articles about him and his work have appeared in some 100 publications including TIME, Architecture, Architectural Record, Environmental Design and Construction, World Architecture, Popular Science, IEEE Spectrum, Wired, Forbes, New Age, Sun and Wind Energy (Germany), Fortune and Business Week¨ as well as radio and television interviews and energy and environmental documentaries.

Steven has received numerous awards and citations for his work. In 1993, he received the 1st 'Inherit the Earth' award from Connecticut College for his pioneering work in sustainable design. In 1999, he was named an 'Environmental Hero for the Planet' by TIME magazine. He's the recipient of the Northeast Sustainable Energy Association's Professional Leadership award and the Charles Greeley Abbot Award from the American Solar Energy Society. In 2007 TIME magazine again recognized him as "An innovator building a greener world" in their special issue on responding to Climate Change. The Massachusetts Institute of Technology recently recognized the 1st all-solar, Net-Zero-Energy residence he designed in the late 1970s in their chronicle of the major technological innovations achieved over the last 150 years.

Dr. Costa Kapsis

Costa's research lies at the interface between science, engineering, and architectural design with an emphasis on energy in buildings and communities. His research is focused on questions of energy efficiency, solar energy generation and energy transaction in the built environment. These research efforts aim towards the evolution of (i) building envelope technologies, (ii) climate-resilient cities and communities, and (iii) energy integration between the building and transportation sectors.

Costa serves as an associate editor of the ASCE Journal of Architectural Engineering, chair of ASHRAE TC 6.7 Solar Energy and Other Renewables and, subtask co-leader of the IEA PVPS Task 15 Enabling Framework for the Acceleration of BIPV.

Dr. Kuljeet Singh

Dr. Kuljeet S. Grewal is currently working as Assistant Professor in the Faculty of Sustainable Design Engineering, University of Prince Edward Island (UPEI). Before joining UPEI he worked as a Postdoctoral Researcher at the School of Architecture, Planning, and Landscape (SAPL), the University of Calgary from 2018 to 2021. Dr. Grewal earned his Doctorate from the Indian Institute of Technology (IIT) Ropar, India in Mechanical Engineering in 2018. Currently, his transdisciplinary research focus is on sustainable neighborhood and energy design that also involves the planning of clean energy resources. Upon joining UPEI in September 2021, he established Future Urban Energy Lab for Sustainability (FUEL-S). The area of work involves energy-efficient urban design and energy systems including their planning and optimization promoting long-term sustainability, technological, economic, and environmental adaption.

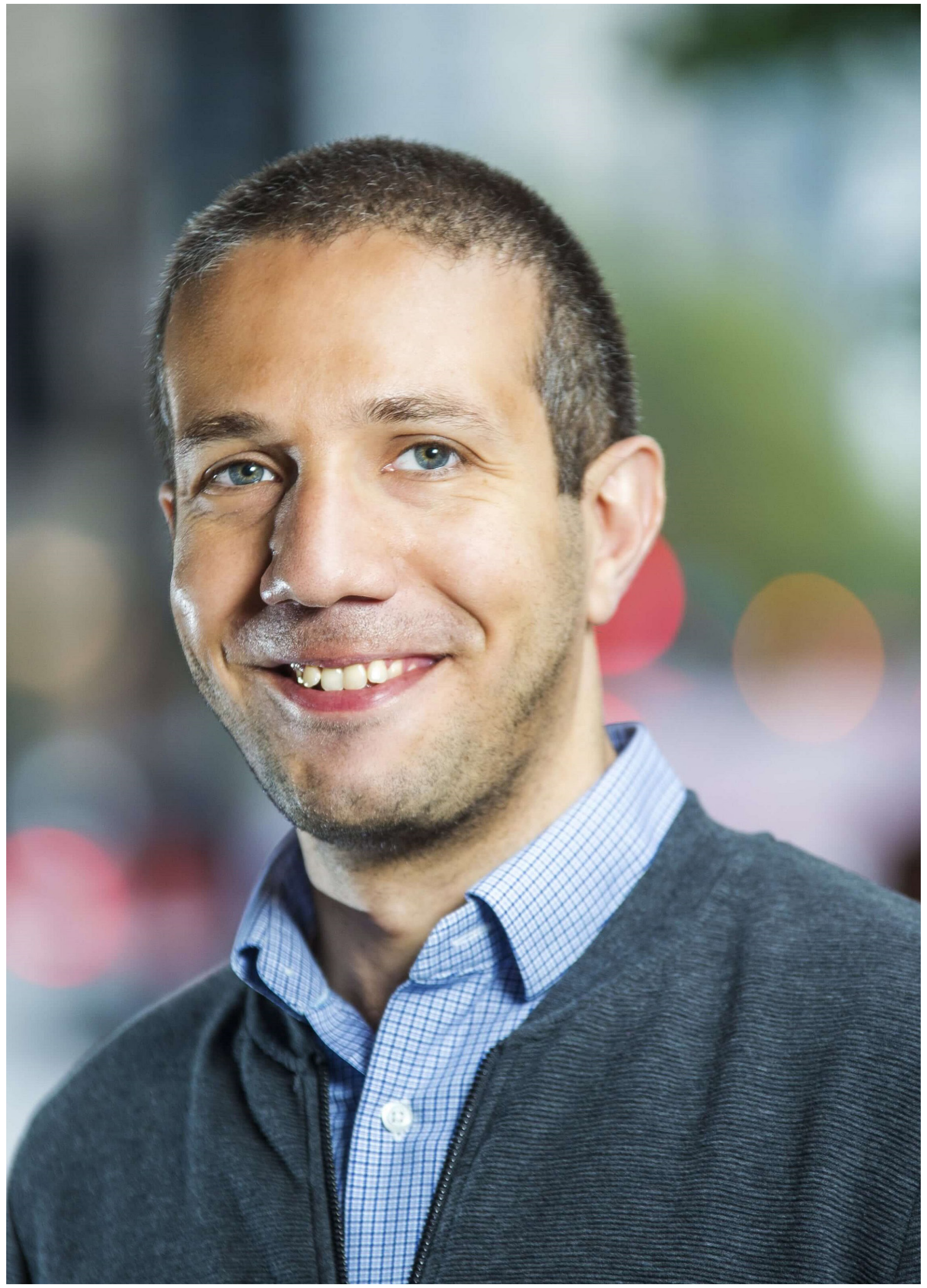
He is currently working as a principal investigator on several funded research projects from the Natural Sciences and Engineering Research Council (NSERC), Natural Resources Canada (NRC), MITACS, and a couple of industrial partners. Dr. Grewal is contributing as a Design Expert in Task 63: Solar Neighborhood Planning of the International Energy Agency (IEA). He is also acting as Guest Editor for a special issues on Advances in Energy-Efficient Buildings in Energies Journal. To date, he has several highly reputed peer-reviewed journal and conference articles.

SPEAKERS

Eric Wilczynski

Eric Wilczynski is a PhD candidate working jointly with the Urban and Regional Energy Systems group at Eurac Research, the Copernicus Institute of Sustainable Development at Utrecht University, and the Energy Efficiency group at the University of Geneva where he is investigating energy flexibility and demand response potential in building and urban energy systems.

He holds a B.A. majoring in both Economics and Environmental Analysis & Policy from Boston University and an M.S. in Energy and Earth Resources from the University of Texas at Austin where he also conducted research for the UT Austin Energy Institute on electric utility business models. Prior to his move to Europe, he gained experience in the utilities industry in southern California.



Dr. Mohamed Ouf

Mohamed Ouf, Ph.D., P.Eng. is an Assistant Professor at Concordia University's Building, Civil and Environmental Engineering Department. He is the principal investigator of the Intelligent Buildings and Cities Lab (IBCL) and is affiliated with Concordia's Centre for Zero Energy Building Studies (CZEBS) as well as the newly established Next-Generation Cities Institute (NGCI). His research focuses on using data-driven approaches to investigate occupant-building interactions at multiple scales, ranging from zone- to building- and up to urban-scales. As an early career researcher, he published over 50 peer-reviewed journal and conference papers and received several prestigious awards in the past couple of years, while establishing collaborations with multiple industry and government partners. He currently supervises a team of more than 10 graduate students at IBCL with expertise in multiple disciplines ranging from mechanical, civil and building engineering to architecture and data science.

Dr. Ouf is actively involved in several academic and professional organizations. He currently 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 International Energy Agency; Energy in Buildings and Communities (IEA–EBC) Annex 79 on "Occupant-Centric Building Design and Operation", as well as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), multi-disciplinary task group on occupant behaviour in buildings (MTG. OBB). Beside his involvement in these organizations, he is an active reviewer for multiple leading journals in the field, and serves on the Editorial Board of ASHRAE's Science and Technology for the Built Environment Journal.

Ashley Hammerbacher

Ashley is a Managing Director for the US division of S2E Technologies and is the EVE Park Project Lead. She is currently living and breathing everything EVE Park. Ashley is coordinating and advising on EVE Park where we are reimagining neighbourhoods for green energy along with the future of autonomous vehicles. Ashley holds a Bachelors in Bioengineering and a Masters in Civil and Environmental Engineering from Stanford University, and has accumulated a breadth of experience in green technology and intelligent mobility.

Seungyeon Hong

Seung is a Modelling and Data Specialist at s2e. His role includes providing technical analysis on all matters related to buildings. This includes developing physics-based computer simulations to study a building's behaviour and estimate the associated energy use, which helps guide design decisions and achieve net-zero energy design. Seung had earned a Bachelor's and Master's degrees in Civil Engineering at Carleton University, apprenticed as a timber-framer in South Korea, worked as structural inspector, wrote a thesis on BIM-BEM interoperability, and co-led a team of graduate students to win a national Hackathon.

Dr. Ursula Eicker

Prof. Ursula Eicker is the Canada Excellence Research Chair (CERC) in Smart, Sustainable and Resilient Cities and Communities at Concordia University Montréal. A German physicist, Eicker has held leadership positions at the Stuttgart University of Applied Sciences and its Centre for Sustainable Energy Technologies. She coordinated many international research projects in the fields of building energy efficiency, renewable energy systems and urban scale simulation.

Since June 2019, she leads an ambitious research program to establish transformation strategies toward zero-carbon cities. Around 50 graduate students work on decarbonisation pathways in the domains of the built environment, renewable energy systems, sustainable transport and circular economy. An urban data analysis and modeling framework integrates the multidisciplinary work. The 7 year research program received 10 million CAD government funding and is supported by a further 10 million Dollars by Concordia University.

In November 2020, Prof. Eicker founded Concordia's Next Generation Cities Institute, which groups 14 university research centers and 200 researchers from all faculties. Three interdisciplinary research clusters deal with Built and Natural Environments as the hardware, Mobile, Secure and Sharing Cities as the software and Design, Arts, Culture and Community as the experience of the city. The Institute addresses the challenges of the urban transformation with a transdisciplinary approach and develops tools and strategies for a sustainable future. Prof. Eicker has published 7 Books, 24 book contributions, 100 Peer Reviewed Papers and 330 Conference Papers.

SPEAKERS

Overview of IEA SHC Task 63 - Planning Solar Neighborhoods
Maria Wall

This presentation provides a background on previous IEA SHC Tasks and outlines the objective for Task 63: Solar Neighborhood Planning (2019-2023). Finally, the introduction to Fall School identifies current subtasks, leadership, and participating countries.

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA SHC Task 63
Solar Neighborhood Planning

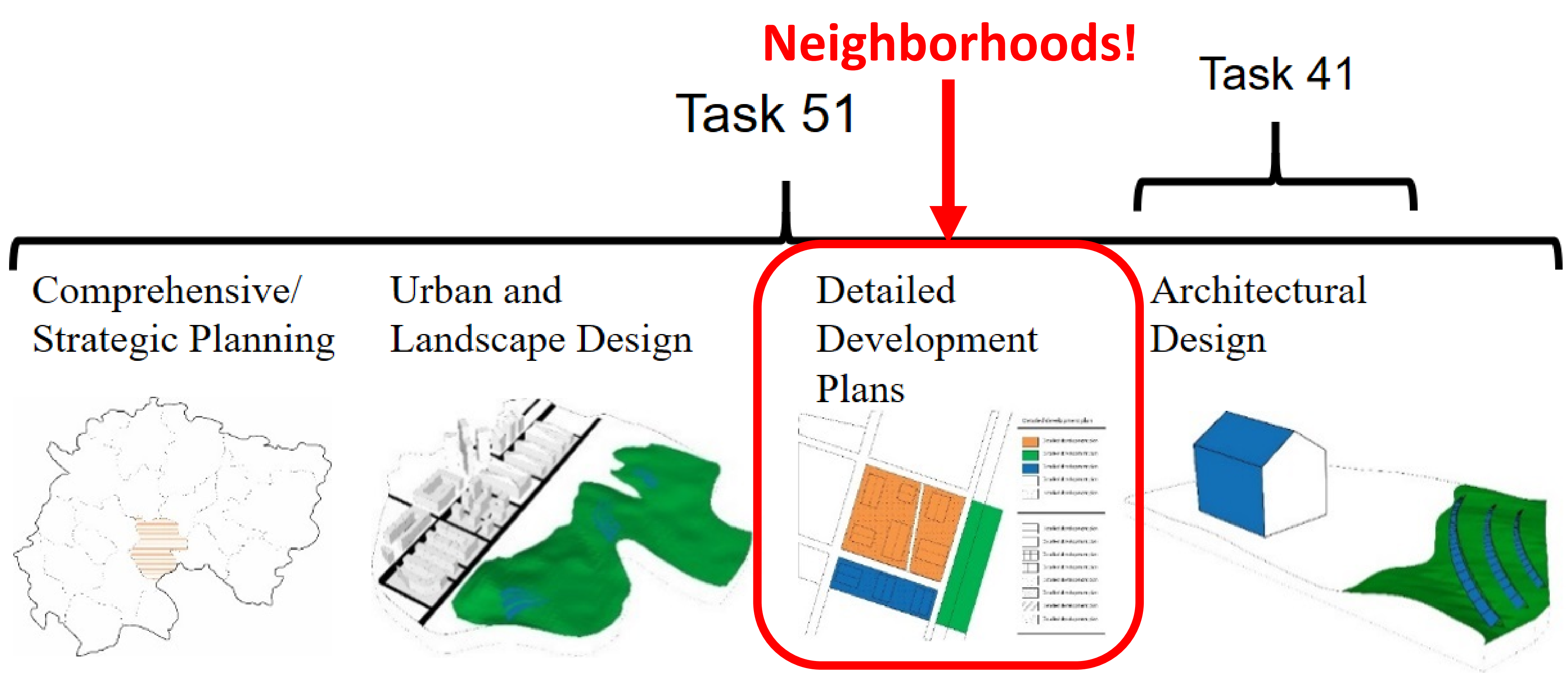
Maria Wall, Task Manager
Fall School, September 6, 2022

Background

IEA SHC Task 41: Solar Energy and Architecture, 2009-2012

IEA SHC Task 51: Solar Energy in Urban Planning, 2013-2018

Conclusion: More developments on a city district level are needed to improve and develop new strategies and methods/tools – cooperation between research and practice!



Solar Contributions

- **Passive solar energy**: indoors and outdoors to reduce heating demand and improve thermal comfort and health
- **Daylighting** buildings and outdoor areas, to reduce electricity for lighting and improve visual comfort and health
- **Local renewable energy production** using Photovoltaics (electricity) and Solar Thermal Systems, to help create energy/resource self-sufficient environments and not rely on energy imports, and to create resilience to energy price fluctuations
- **Local food production** and use of **green areas** for improved air quality and reducing storm water (roofs, facades, outdoor areas)

Task 63: Solar Neighborhood Planning: 2019- 2023

Objective

The main objective is to support key players to achieve solar neighborhoods that facilitate long-term solar access for energy production and for daylighting buildings and outdoor environments – resulting in sustainable and healthy environments.

Scope

The scope of the Task includes solar energy aspects related to

1. New neighborhood development
2. Existing neighborhood renovation and development

Solar energy aspects include active solar systems (solar thermal and photovoltaics) and passive strategies. Passive solar strategies include passive solar heating and cooling, daylighting, and thermal/visual comfort in indoor and outdoor environments.

The role of solar aspects related to energy, environment, economy and inhabitants' comfort and health is in focus

Definition - neighborhood

A neighborhood is defined as a group of buildings, a district/precinct. It is a spatially defined specific geographic area, often including different types of buildings and functions, open space and infrastructure.

A neighborhood can be part of a larger city or a smaller village. It can be part of an urban area, a rural development or represent an isolated community.

- Connected to a district heating/cooling network or outside, giving different boundary conditions

Subtasks and leaderships

A. Solar Planning Strategies and Concepts

Leader: Caroline Hachem-Vermette, University of Calgary, Canada

B. Economic Strategies and Stakeholder Engagement

Leader: Silvia Croce & Daniele Vettorato, EURAC Research, Italy

C. Solar Planning Tools

Leader: Jouri Kanters, Lund University, Sweden &
Martin Thebault, University Savoie Mont-Blanc – INES, France

D. Case Studies

Leader: Gabriele Lobaccaro & Mattia Manni,
Norwegian University of Science and Technology NTNU, Norway, jointly with all leaders

Project leader (Task Manager): Maria Wall, Lund University, Sweden

Participating countries

- Australia
- Canada
- China
- Denmark
- France
- Italy
- Norway
- Sweden
- Switzerland

Thank you!

For more information about IEA SHC projects, see e.g.

Task 63: Solar Neighborhood Planning (2019-2023): https://task63.iea-shc.org/

Task 51: Solar Energy in Urban Planning (2013-2018): https://task51.iea-shc.org/

Task 41: Solar Energy and Architecture (2009-2012): https://task41.iea-shc.org/

LUND UNIVERSITY

Maria Wall / Energy and Building Design, Lund University

The Significant Role of Solar Energy to Mitigate Climate Change

David Renne

This presentation provides background information on the status of Greenhouses Gas emissions and concentrations, as well as renewable energy technologies as of 2022. The discussion of cost considerations in new power installations favors solar and other renewable technologies, and highlights that utility-scale solar is consistently the lowest cost option. A more distributed system will improve flexibility and achievement of climate goals. The presentation recognizes that financing the energy transformation will require a rapid shift away from fossil fuels.

The Significant Role of Solar Energy to Mitigate Climate Change

Dr. David Renné

Dave Renné Renewables
Board Member: International Solar Energy Society
Senior Consultant: Clean Power Research

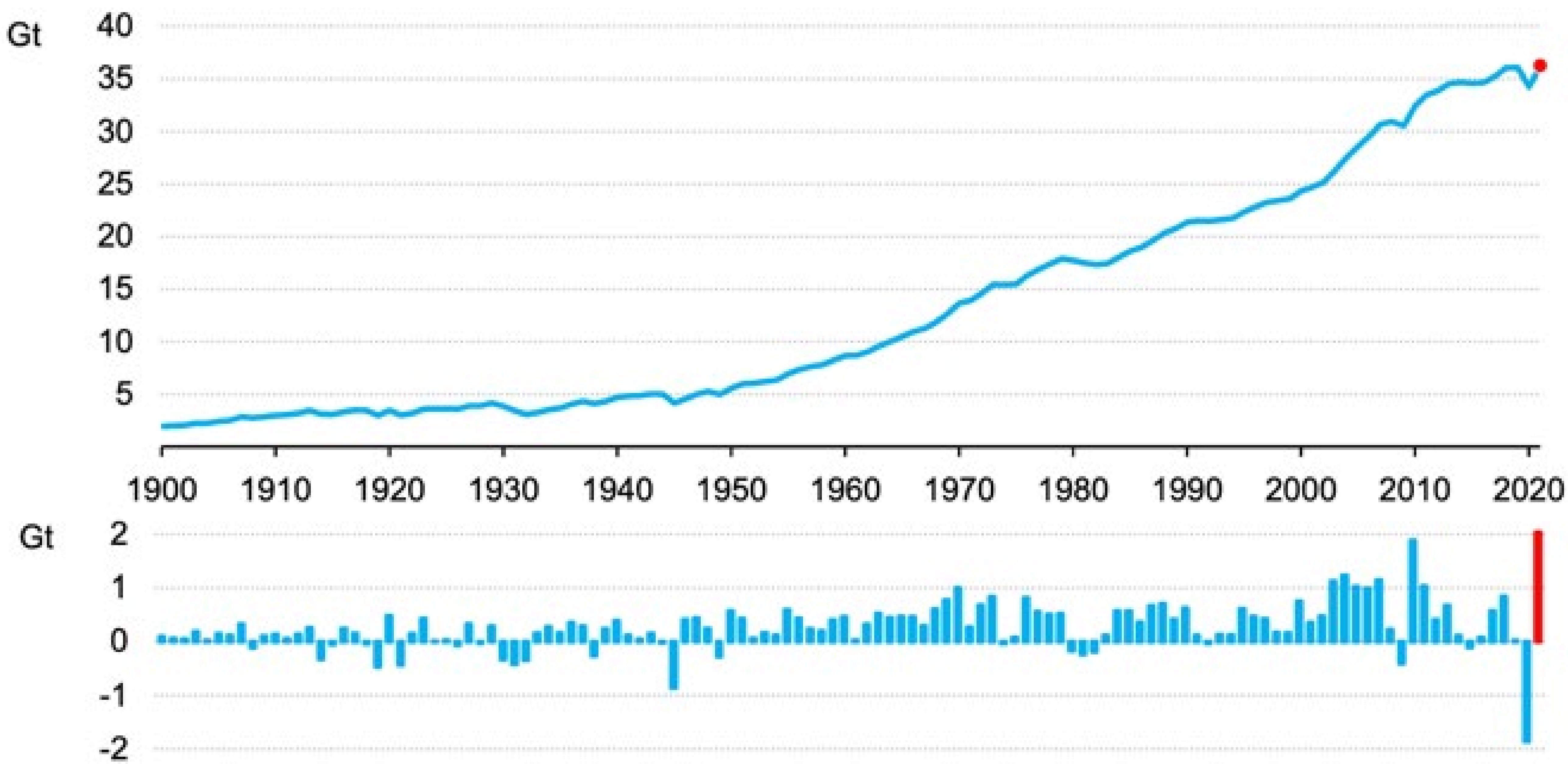
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Fall School: **Solar Neighborhood Planning**
University of Calgary School of Architecture, Planning and Landscape
September 6, 2022

The Big Picture - 2022

- Record high CO_2 atmospheric emissions and concentrations
- Fossil fuel prices at new highs; demand on the rise
- Record high global RE installations
- RE (especially wind and solar) plus enabling technologies lowest cost power solution
- Government ambitions still inadequate to achieve Paris Climate goals

Recent CO_2 Emission Results from the IEA



36.2 GT in 2021

Source: IEA Global Energy Review 2021

June 3, 2022 Headline from NOAA

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Search NOAA sites

Home / News & Features

Carbon dioxide now more than 50% higher than pre-industrial levels

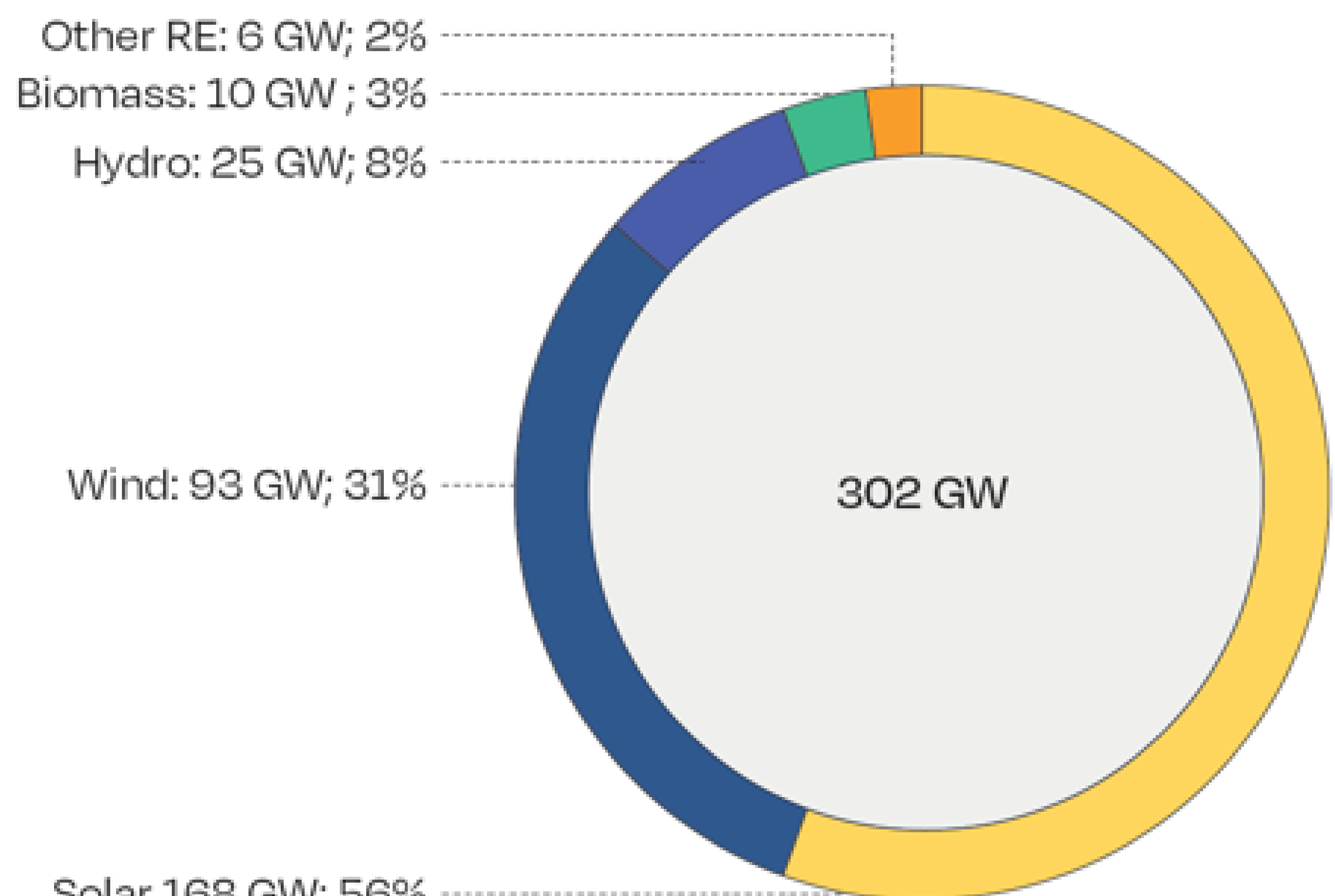
Focus areas: Research **Topics:** climate change , carbon dioxide **Share:**

June 3, 2022

420.99 ppm

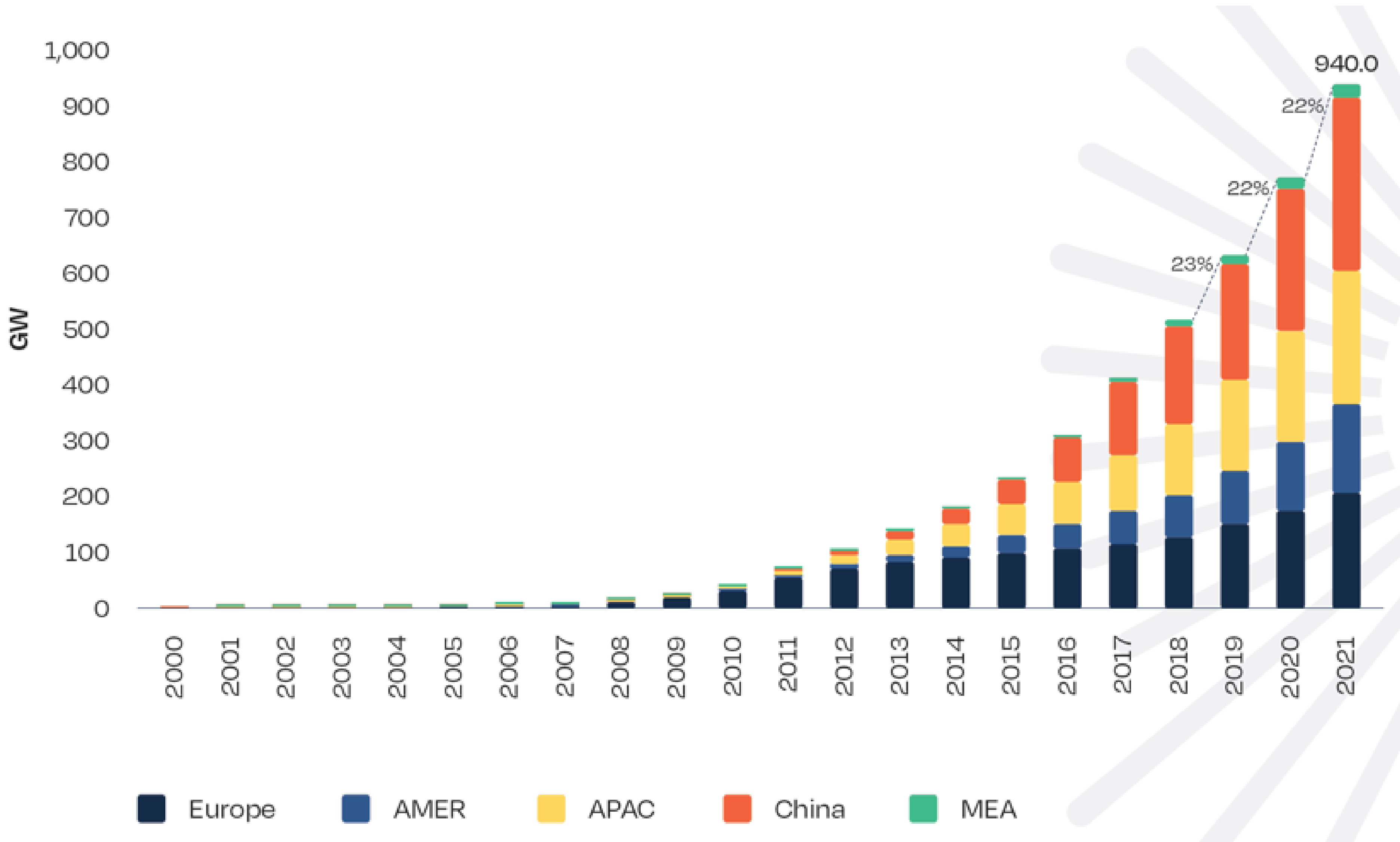
Source: NOAA

The RE Transformation Remained Robust in 2021



Source: SPE GMO 2022

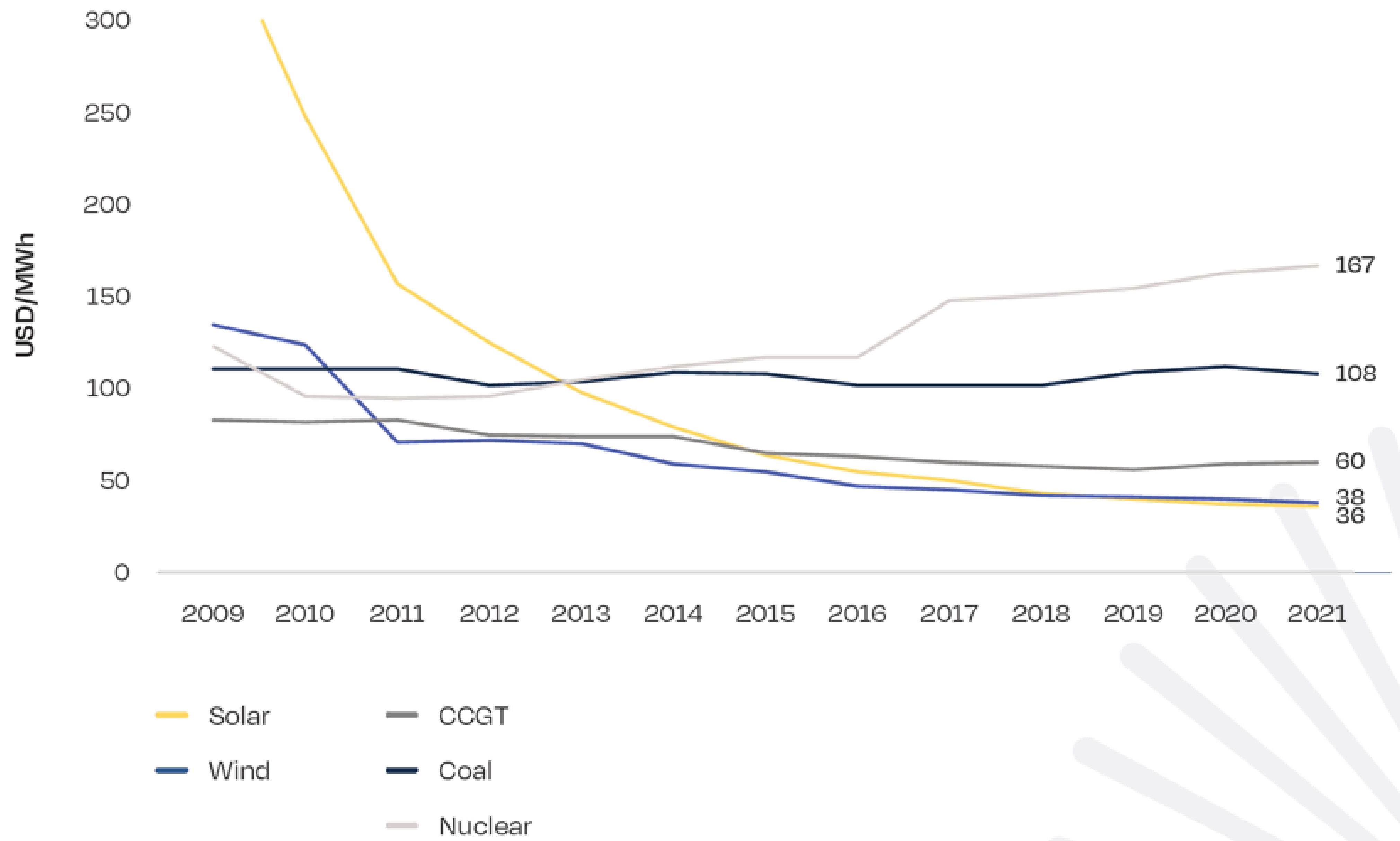
Globally, Installed PV Capacity Has Likely Passed 1 TW



Source: Solar Power Europe
GMO 2022

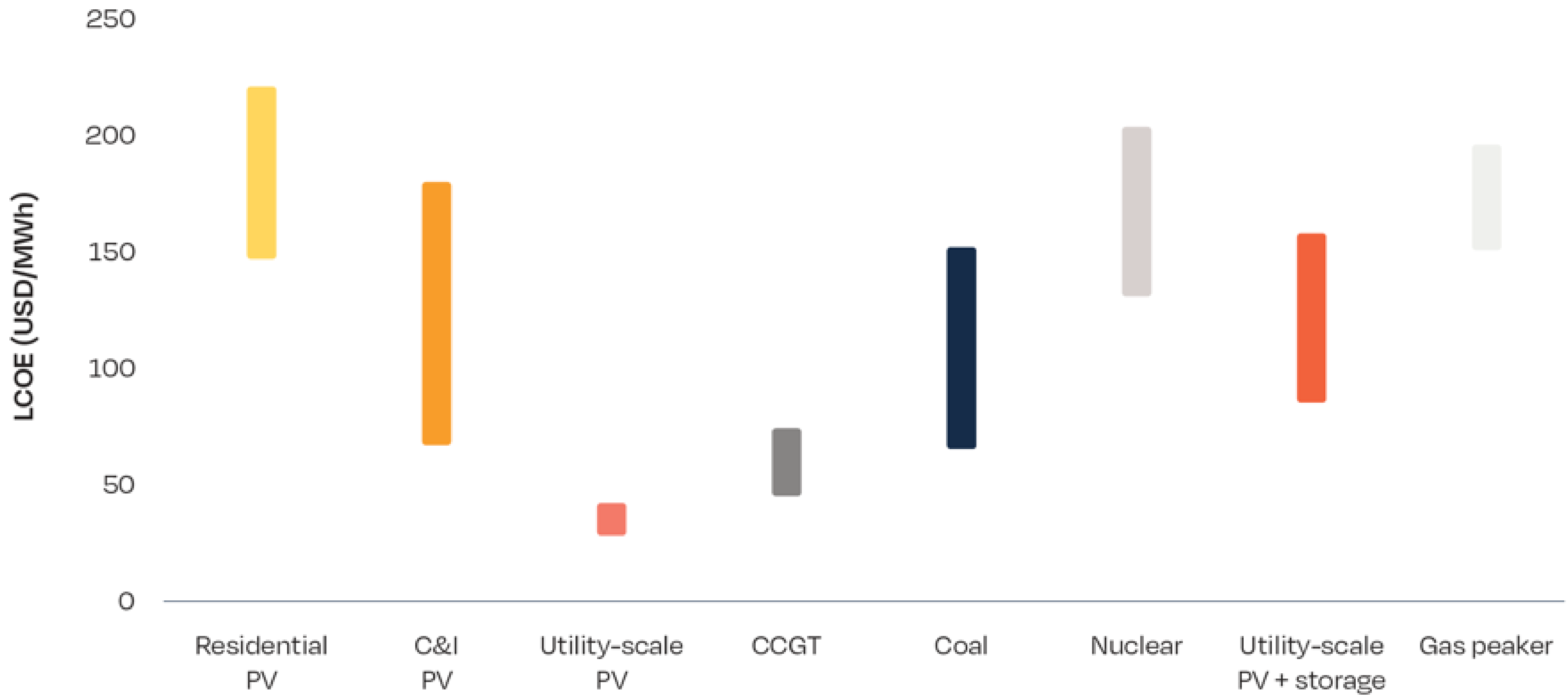
Annual Capacity Growth Rate ~39%
Annual Market Growth Rate ~30%

Solar Costs Declined 90% in 12 Years



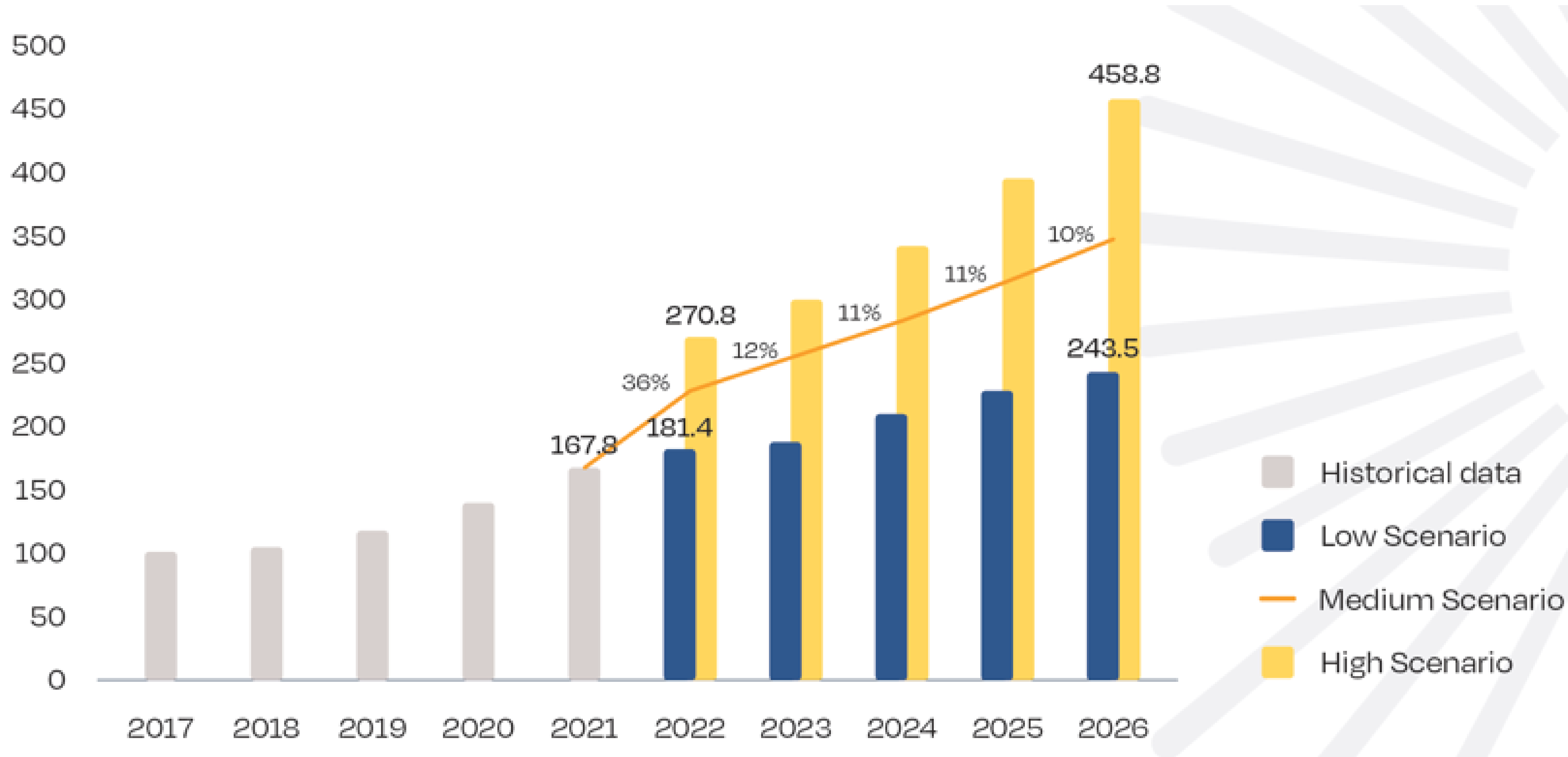
Source: Solar Power Europe GMO 2022

Utility-scale solar is consistently the lowest cost option



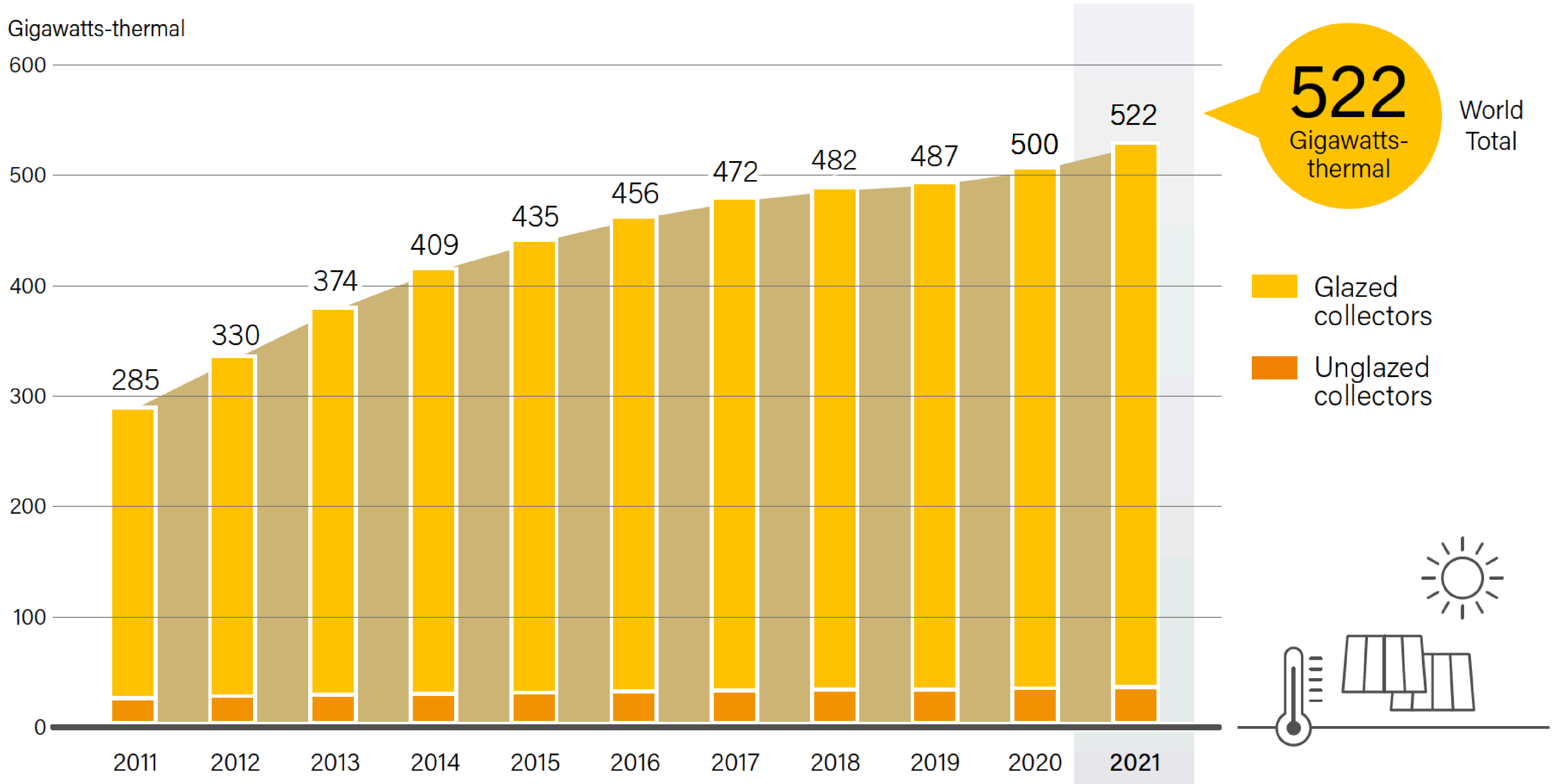
Source: Solar Power Europe GMO 2022

Projected Annual PV Capacity Additions



Source: Solar Power Europe GMO 2022

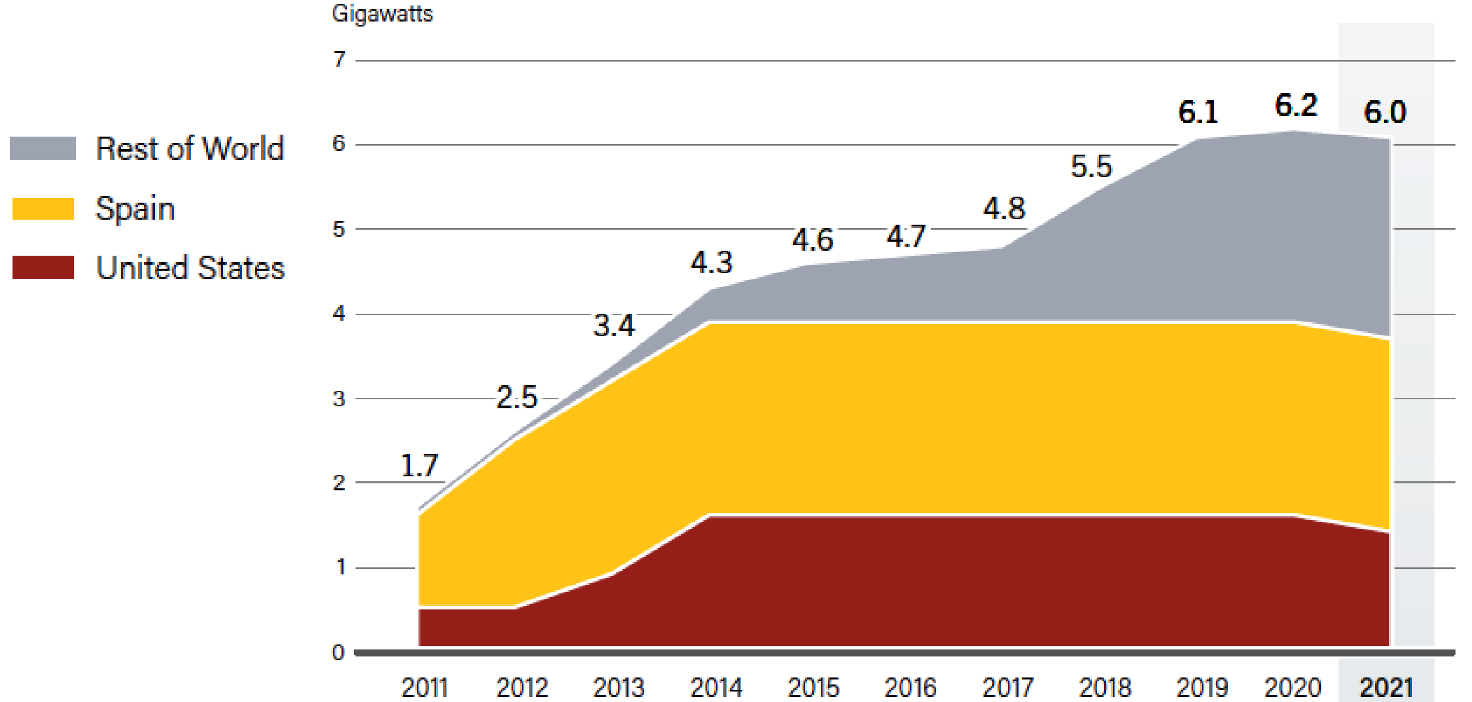
Status of Solar Thermal Capacity Additions



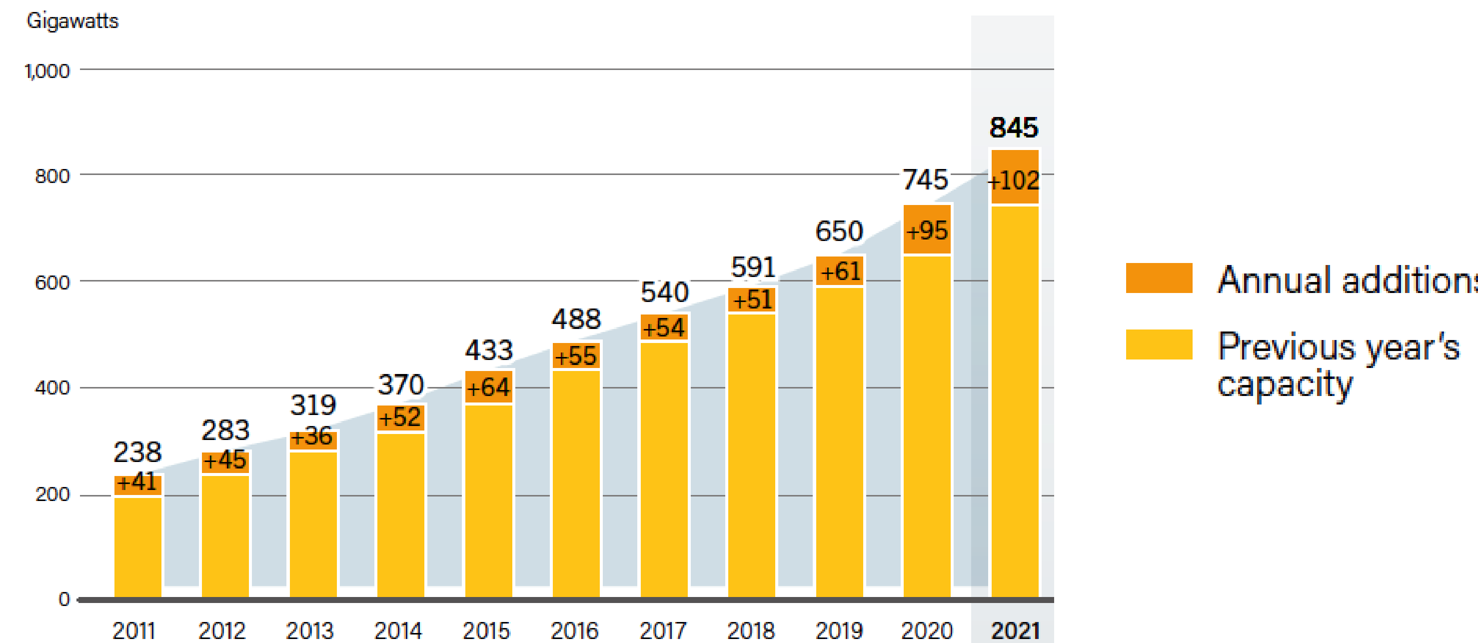
Source: REN21 GSR 2022

Status of Other Renewable Power Systems – 2021

CSP



Wind Power

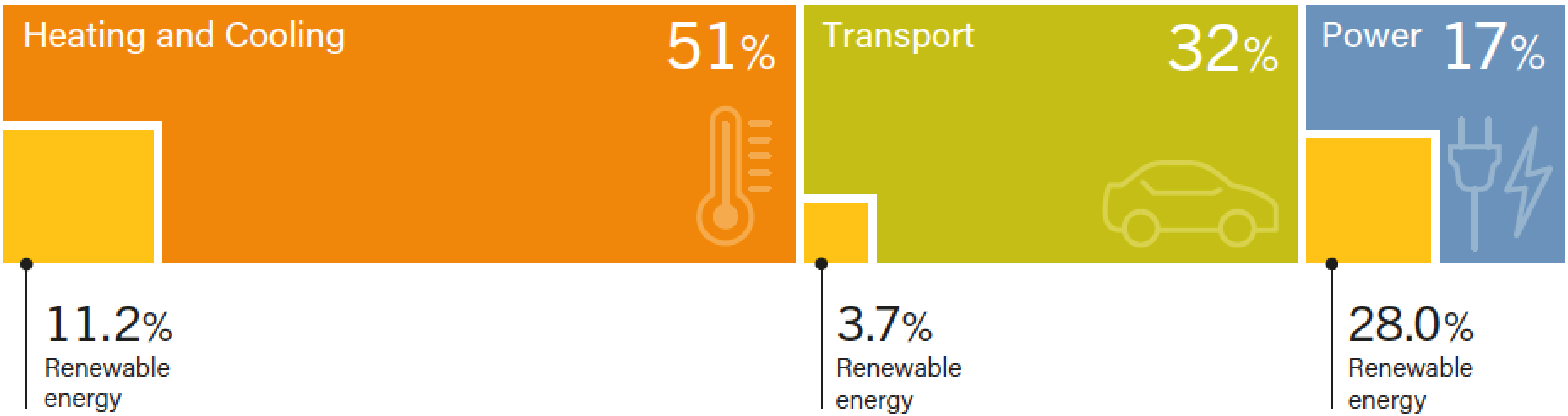


Also at end of 2021:

Hydropower = 1,197 GW
Biopower ~ 158 GW
Geothermal Power = 14.5 GW
Ocean Power = 0.524 GW

Source: REN21 GSR 2022

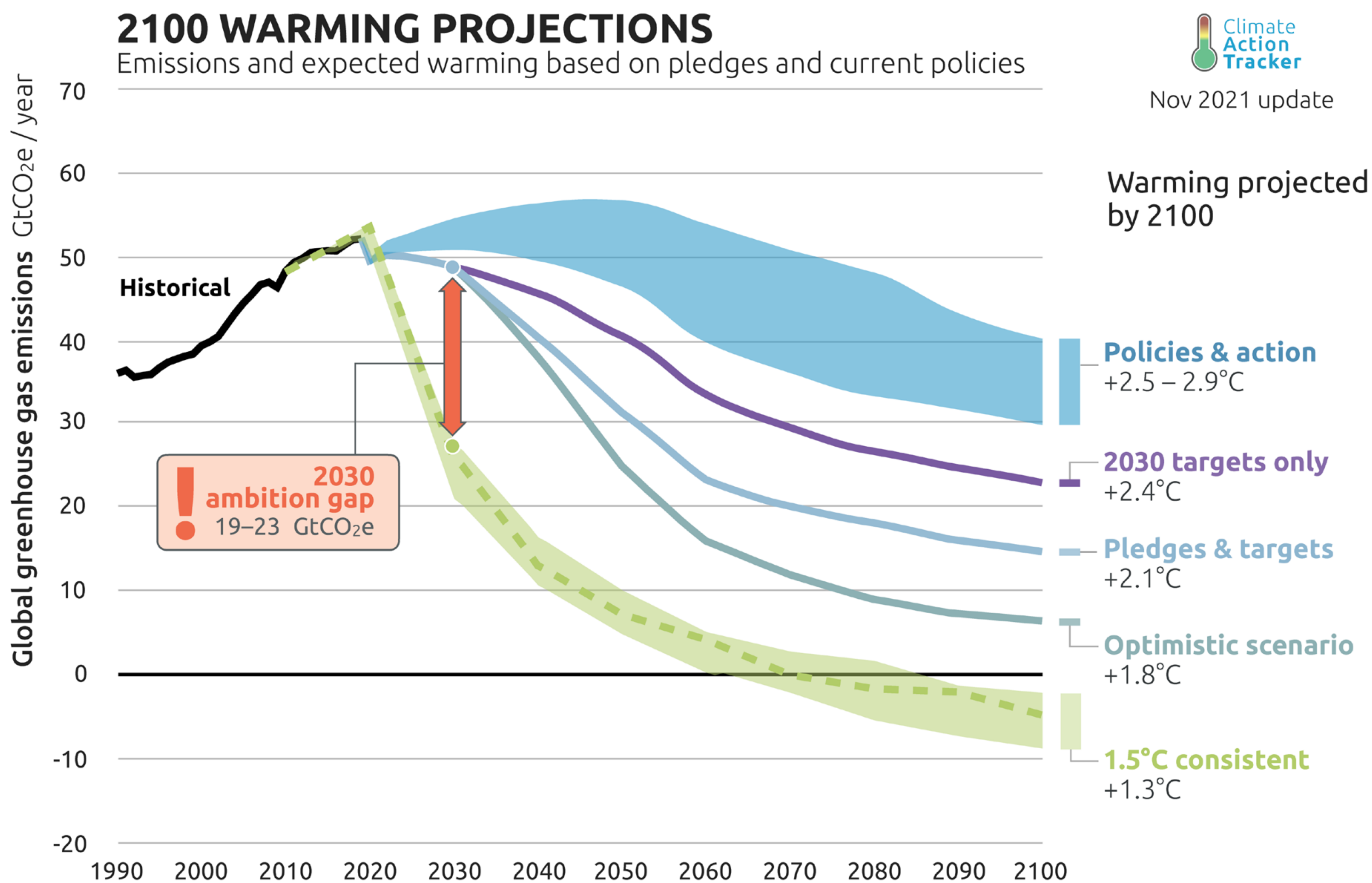
RE in Total Final Energy Consumption, 2019



Source: REN21 GSR, 2022

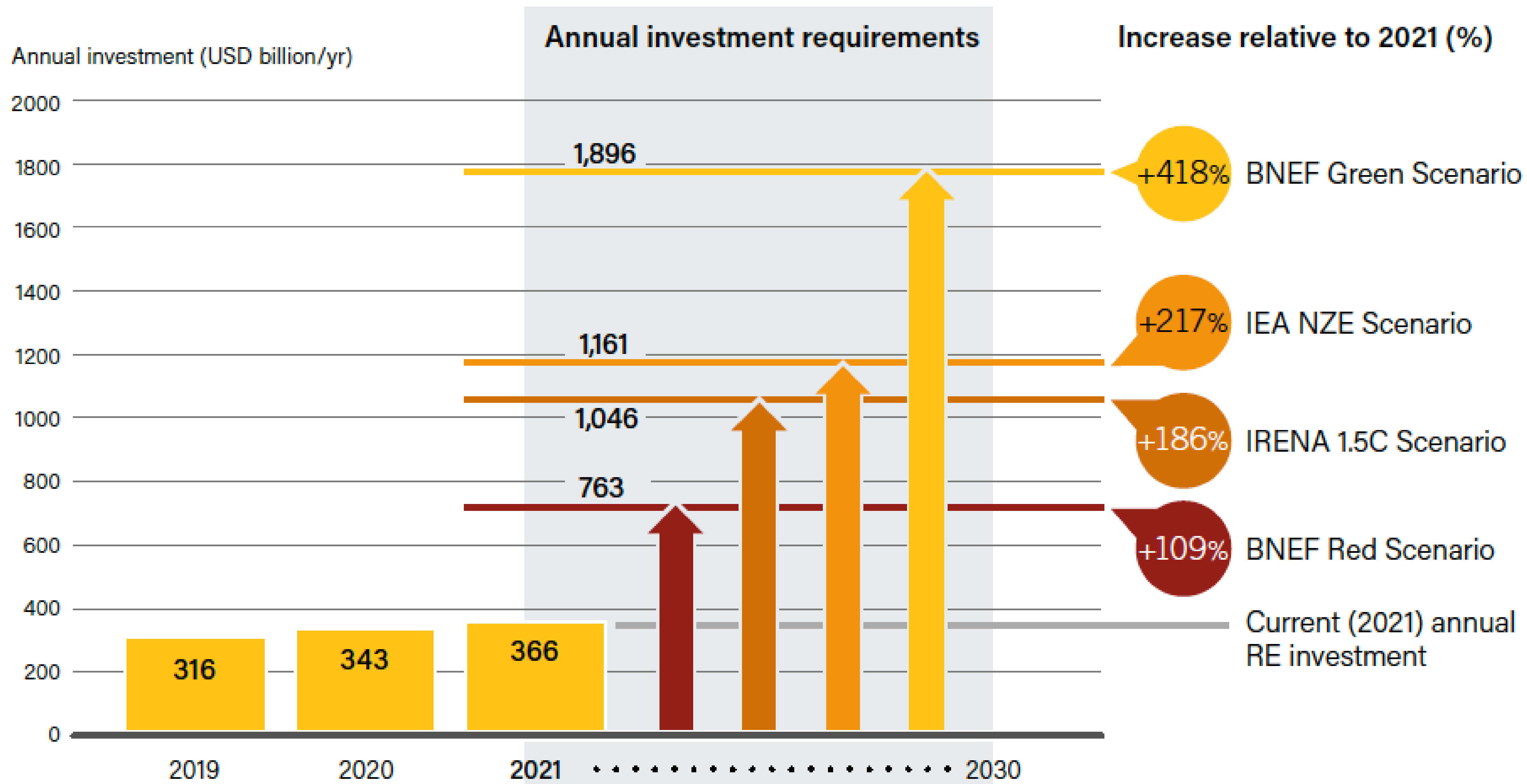
Overall, the share of modern renewables in TFEC has remained at around 20% for over a decade

To Limit Warming to 1.5 ⁰C, the “Ambition Gap” must be closed



Source: Climate Action Tracker

Required Global Investments for the Energy Transformation



Source: REN21 GSR 2022

Fossil Fuel Subsidies Totaled $5.9T in 2020

Fossil fuel industry gets subsidies of $11m a minute, IMF finds

Trillions of dollars a year are 'adding fuel to the fire' of the climate crisis, experts say

A state-owned coal-fired power plant i in Huainan, Anhui province, China. Photograph: Kevin Frayer/Getty Images

Source: https://www.theguardian.com/environment/2021/oct/06/fossil-fuel-industry-subsidies-of-11m-dollars-a-minute-imf-finds

Closing the Gap Requires Total Energy System Decarbonization

- Improved efficiencies in supply, demand and delivery
- Significantly-expanded electrification (direct and indirect)
- Electrification based largely on VRE (solar and wind)
- Grid flexibility and reliability; smart grids, AI
- Sector Coupling
- Hard-to-abate sectors relying on thermal RE and P-to-X technologies

Working Definition of “100% Renewable Energy”

One hundred percent renewable energy means that all sources of energy to meet all end-use energy needs in a certain location, region or country are derived from renewable energy resources 24 hours per day, every day of the year. Renewable energy can either be produced locally ***to meet all local end-use energy needs (power, heating and cooling, and transport)*** *or can be imported from outside of the region using supportive technologies and installations such as electrical grids, hydrogen or heated water. Any storage facilities to help balance the energy supply must also use energy derived only from renewable resources.*

Zero (not net-Zero) Energy-Related Carbon Emissions!

Source: IRENA Coalition for Action, Working Group on “Towards 100% Renewable Energy”

Grid Flexibility

Grid's ability to manage variability and volatility to balance energy supply and demand

Supply Side: Storage solutions, smart inverters, V-2-G, Green H_2

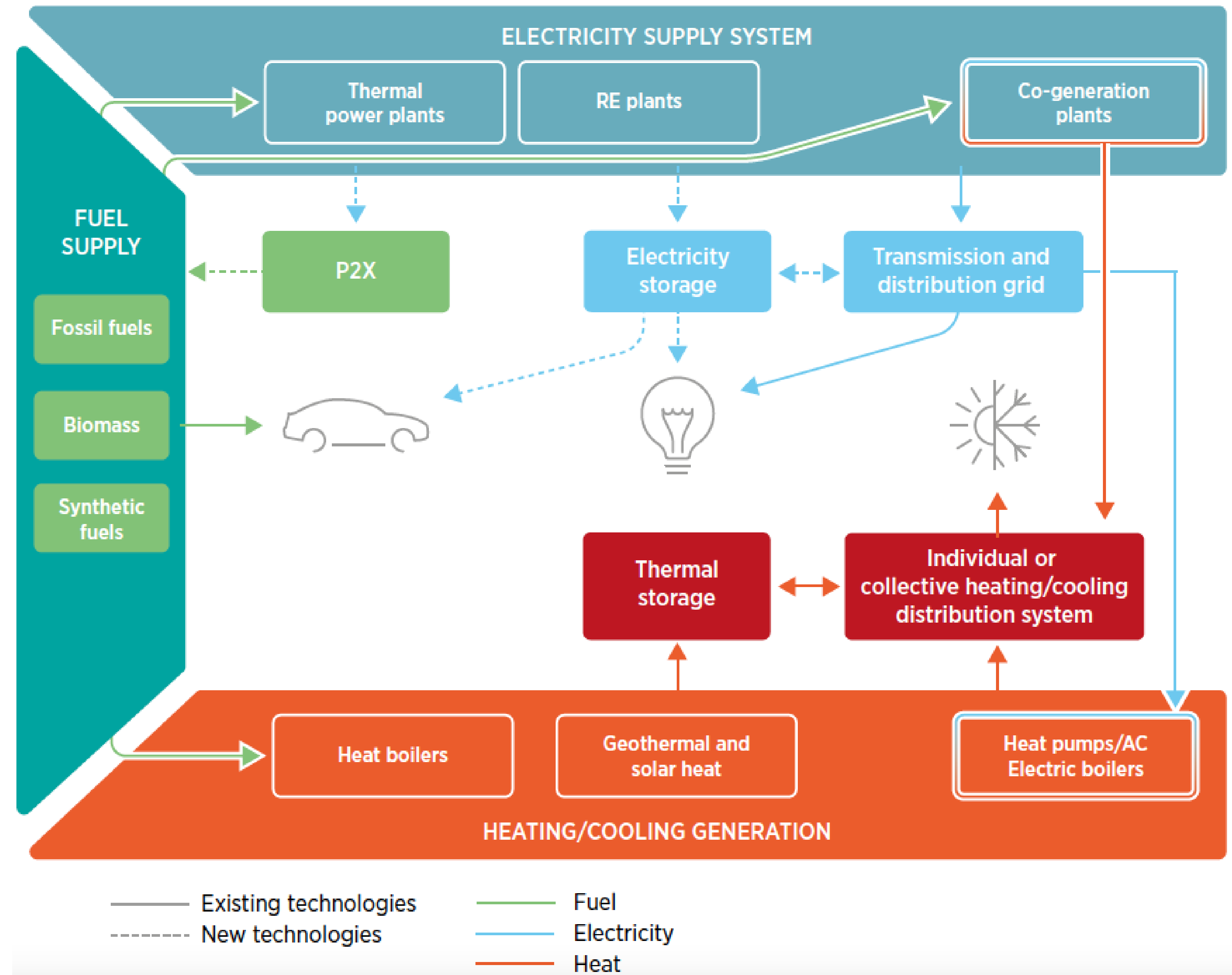
Transmission and Distribution: Pooling generation commitments, storage, balancing, "islanding"

Demand Side: Self-consumption and behind-the-meter storage, demand response, smart charging, sector coupling

Source: Accenture, https://www.accenture.com/us-en/insights/utilities/capturing-value-managing-energy-flexibility

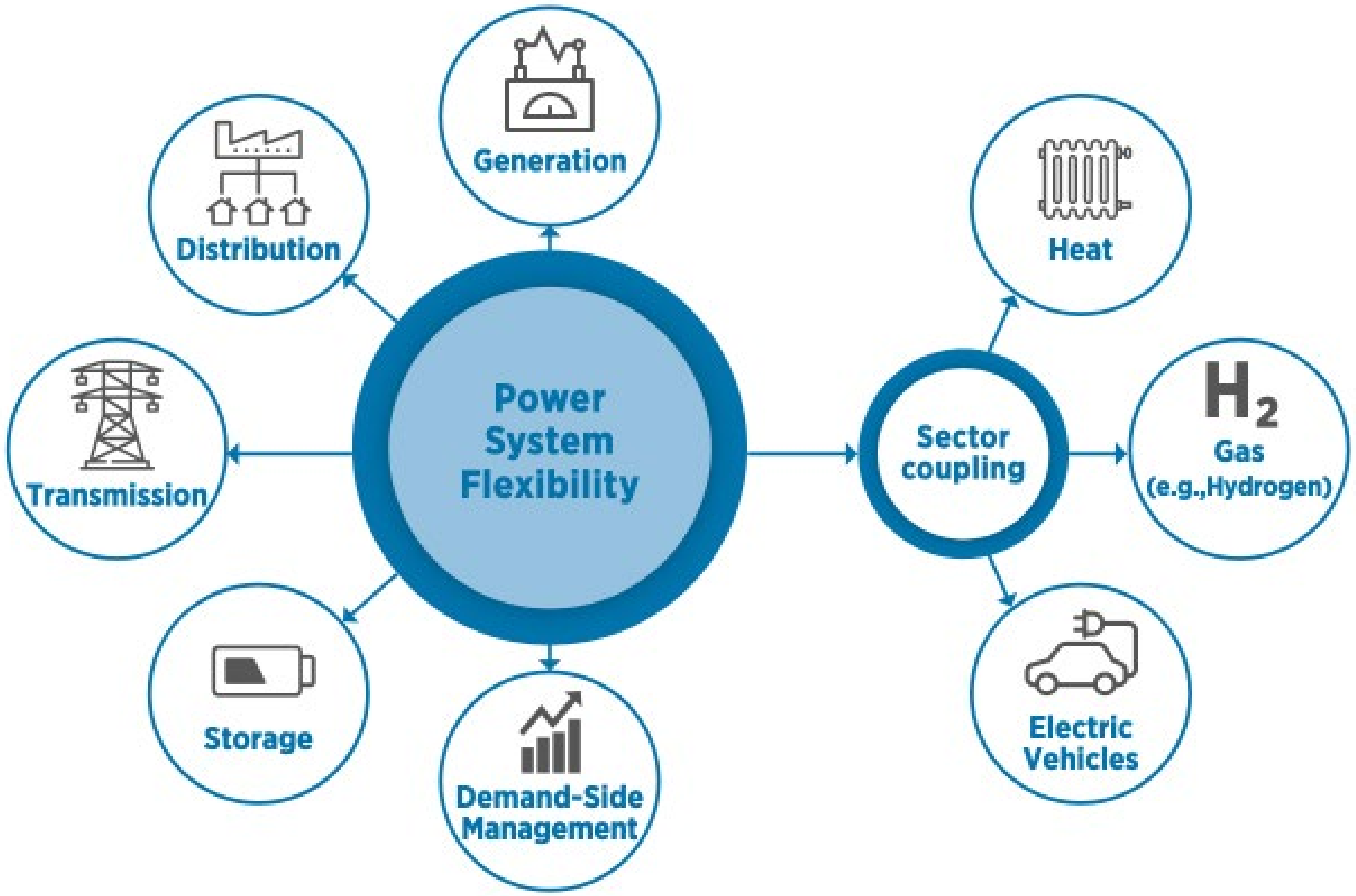
"Sector Coupling" Supports Felxibility

- Combines at least two of the different production and demand sectors (electricity, heating & cooling, transport, industrial processes)
- Provides power system flexibility that leads to a fully RE-based system
- Results in significantly higher levels of direct and indirect electrification



Source: IRENA, IEA, and REN 21, 2018: Renewable energy policies in a time of transition

Summary Overview of “Flexibility Enablers”



Source: IRENA, 2018.

What do 100% RE and even NZE ”Pathway” Studies Tell Us?

- Rapid shift towards clean energy and away from fossil investments
- Significant electrification of end use energy (50 - 90% of TFEC)
  - Transport (EV’s, railways, shipping)
  - Buildings (Heating and cooling, cooking)
- Electricity primarily from renewables (driven by costs)
  - Wind and solar will be primary supply
  - Major grid upgrades and storage will provide flexibility and resource adequacy
- Major growth in use of green hydrogen
- Total final energy consumption decreases
  - Energy efficiency measures
  - Lower per-capita energy intensity while still meeting end use energy requirements

Scenarios Show Major Market Potential for Solar PV

Source	Scenario	Electricity in TFEC	Electricity Supplied by PV	2050 PV Capacity, GW
IRENA (2021)	1.5^0C Scenario	51%	~37%	>14,000
IEA (2021)	NZE by 2050	49%	43%	14,458
BNEF NEO (2021)	Green (NZE by 2050)	49%	32%	24,010
University Technology Sydney (2019)	1.5^0C Target Increase Scenario	57%	49%	12,684
Energy Watch Group/LUT (2019)	100% RE by 2050	90%	76%	57,600

Source: D. Renné in "Solar Compass" (https://www.sciencedirect.com/science/article/pii/S2772940022000017?via%3Dihub.)

Key Take-Away Messages

- The energy transformation, where all energy supply and end use consumption is decarbonized needs to be greatly accelerated
- Cost considerations favor solar and other renewable technologies to dominate new power installations
- Solar will also play key role in many thermal application markets
- Financing the transformation requires rapid shifting of resources away from fossils and toward renewables
- A more distributed system will improve flexibility and achievement of climate goals

Thank You!

Dave Renné
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Positive Energy Districts

Francesco Guarino

The presentation presents an overview of IEA EBC Annex 83 “Positive Energy Districts” by identifying subtasks, objectives, and leadership. The discussion on Positive Energy Districts is prefaced with several definitions related to “net,” “nearly,” “zero carbon,” and “positive”. The presentation highlights the path towards energy positive districts, and concludes with the risks and challenges of Positive Energy Districts, which range from regulatory frameworks to financing structures.

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Positive Energy Districts

Francesco Guarino, IEA EBC Annex 83 Operating Agent
University of Palermo
IEA SHC Task 63 Fall School, Zoom, September 6th, 2022

About me

- Assistant Professor at the University of Palermo, department of Engineering
- M.Sc in Energy engineering in 2011 and Ph.D. in Energy in 2015 on “Building integrated phase change materials energy storage: experimental studies, modelling and parametric analysis”
- Operating agent (Previously Subtask C leader) of IEA EBC Annex 83 “Positive Energy Districts”
- Research interests: sustainability in the building and energy sector, Life Cycle Assessment of buildings and energy technologies, building physics and building simulation, low-carbon and renewable energy technologies.

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EBC
Energy in Buildings and Communities Programme

About IEA EBC Annex 83 “Positive Energy Districts”

HOME NEWS MEETINGS PUBLICATIONS SPECIAL ISSUES VIDEOS ABOUT MEMBER AREA

IEA EBC - Annex 83 - Positive Energy Districts

What are Positive Energy Districts?

The basic principle of Positive Energy Districts (PEDs) is to create an area within the city boundaries, capable of generating more energy than consumed and agile/flexible enough to respond to the variation of the energy market because a PED should not only aim to achieving an annual surplus of net energy. Rather, it should also support minimizing the impact on the connected centralized energy networks by offering options for increasing onsite load-matching and self-consumption, technologies for short and long term storages, and providing energy flexibility with smart control.

Annex 83 Positive Energy Districts

The aim of Annex 83 is developing an in-depth definition of PED and the technologies, planning tools and planning and the decision-making process related to positive energy districts. Experience and data to be used in the Annex will be gained from demonstration cases.

https://annex83.iea-ebc.org

ANNEX INFO & CONTACT

Status: Ongoing (2020 - 2024)

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About IEA EBC Annex 83 “Positive Energy Districts”

- **Organization and SubTasks**

- **Subtask A**: Definition and contest
- **Subtask B**: Methods, Tools and Technologies for Realizing Positive Energy Districts
- **Subtask C**: Organizing principles and impact assessment
- **Subtask D**: Demos, implementation and dissemination

About IEA EBC Annex 83 “Positive Energy Districts”

- **Objectives**
- **Objective 1. Mapping stakeholders and their needs and role.** Building owners and users, city planners, service providers, developers, investors, R&D organizations, policymakers, technology providers, local authorities, etc.
- **Objective 2. Create a shared in – depth definition of PED** by means of mutlistakeholder governance model (Policymakers, local authorities, R&D organizations, energy utilities, etc.)
- **Objective 3. Mapping emerging technical solutions and taxonomy of technologies:** Energy utilities, service providers, developers, designers and planners, technology providers, R&D organizations, energy entrepreneurs and prosumers, etc.
- **Objective 4. Monitoring solutions and data related technical and service opportunities:** Energy utilities, grid operators, service providers, developers, designers and planners, technology providers, R&D organizations, energy entrepreneurs and prosumers, etc.
- **Objective 5. Planning and implementation methodology:** Local authorities, designers, grid operators and planners, developers etc.

IEA EBC ANNEX 83 – Ph.D. Summer school

"Positive Energy Districts: Towards a holistic approach to modeling and performance assessment"

- AIM: Generate a professional network among the Ph.D. Students within Annex 83, help them create work relationships and international contacts.
- Dates: 4th- 8th of July (some preliminary lectures online)
- Where: Concordia University,
- What: Lectures / class & group activities; class presentations on the advancements of the group assignments; social activities (e.g. Ph.D. Project presentations to encourage networking),
- Who: International and Concordia students

Net, nearly, zero carbon, positive
What does ZERO mean?

About the definitions

1. Low energy house
2. High performance buildings
3. Energy saving house
4. Ultra low energy house
5. Zero energy house
6. Zero energy buildings
7. Passive house
8. Zero heating energy house
9. Plus energy house
10. Zero carbon house
11. Emission free house
12. Carbon free house
13. Energy self sufficient
14. BREEAM building
15. EQuilibrium house
16. Green building
17. Very low energy house
18. Climatic active house

- Although these terms have different meaning and are poorly understood, several IEA countries have adopted this vision as a long-term goal of their building energy policies

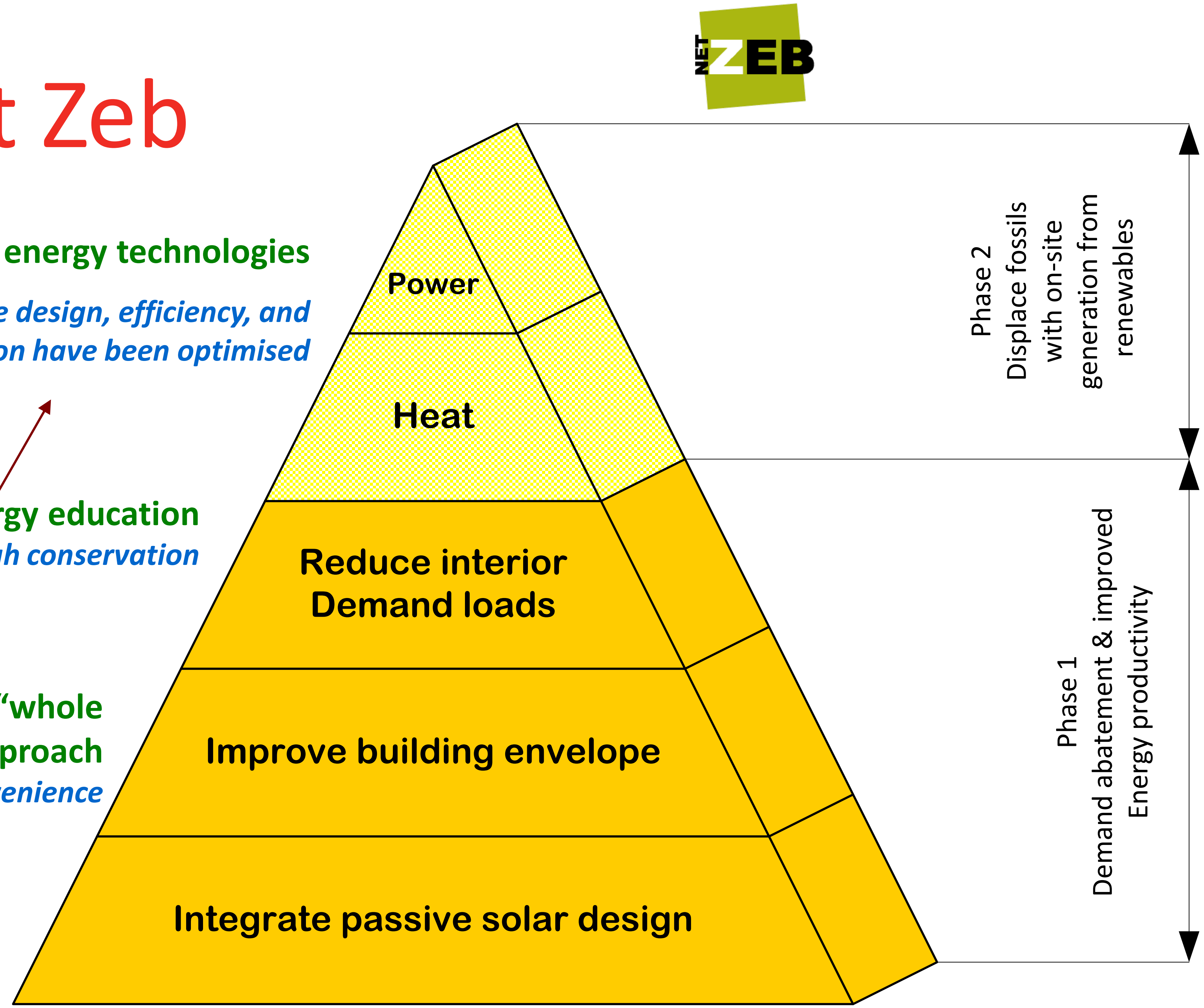
Path to Net Zeb

Emerging green energy technologies
First consideration before design, efficiency, and conservation have been optimised

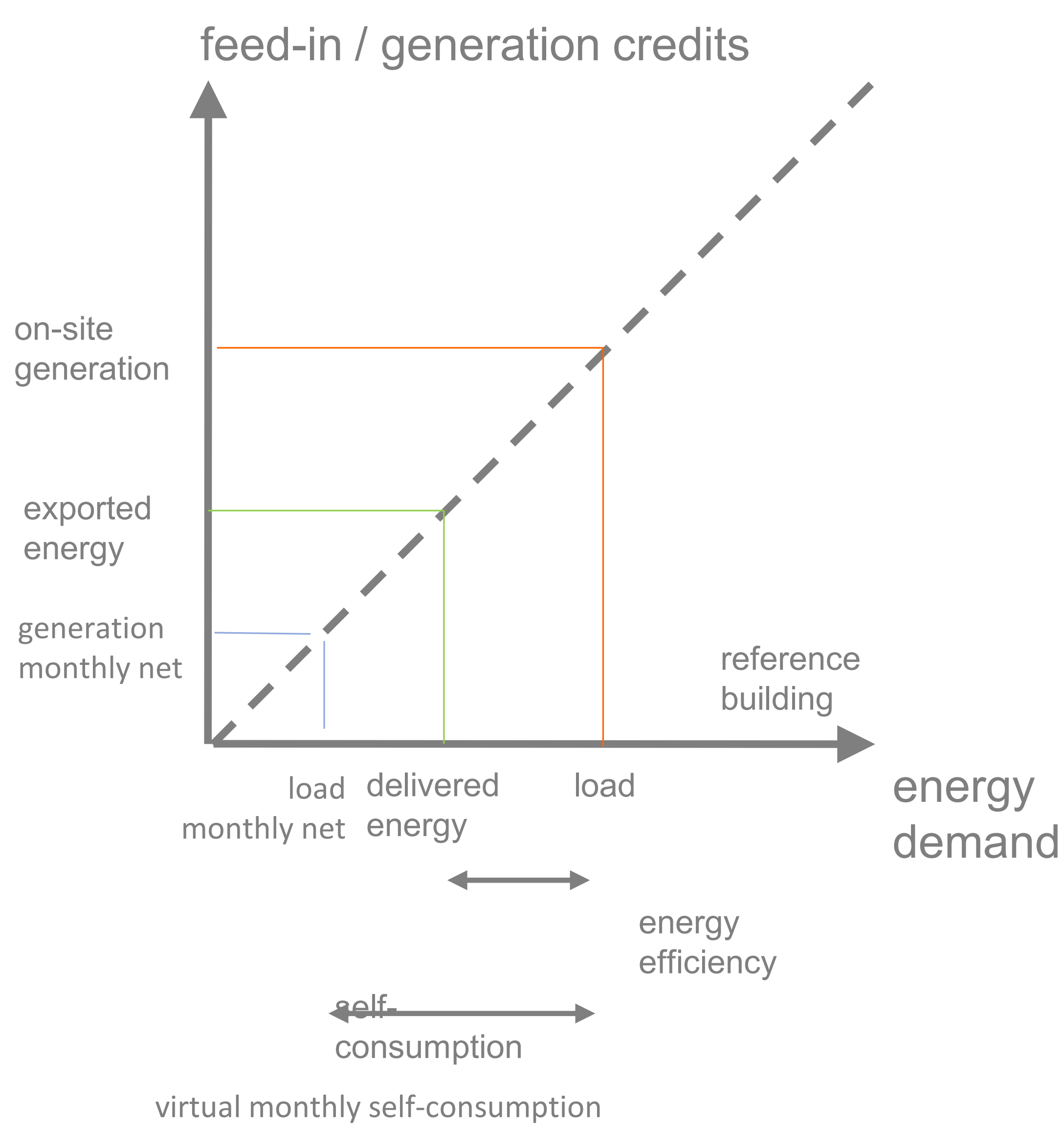
An energy education
Reduce energy use through conservation

Dispelling the cost myth – "whole building" approach
Deliver efficiency W/O inconvenience

The value of good design
Invest in doing it right!



Net ZEB Energy Balance



Planning: 1.Generation/Load

- **Independent** calculation of on-site energy generation (PV, CHP,...) and building total energy demand

Operation: 2.Export/Delivered

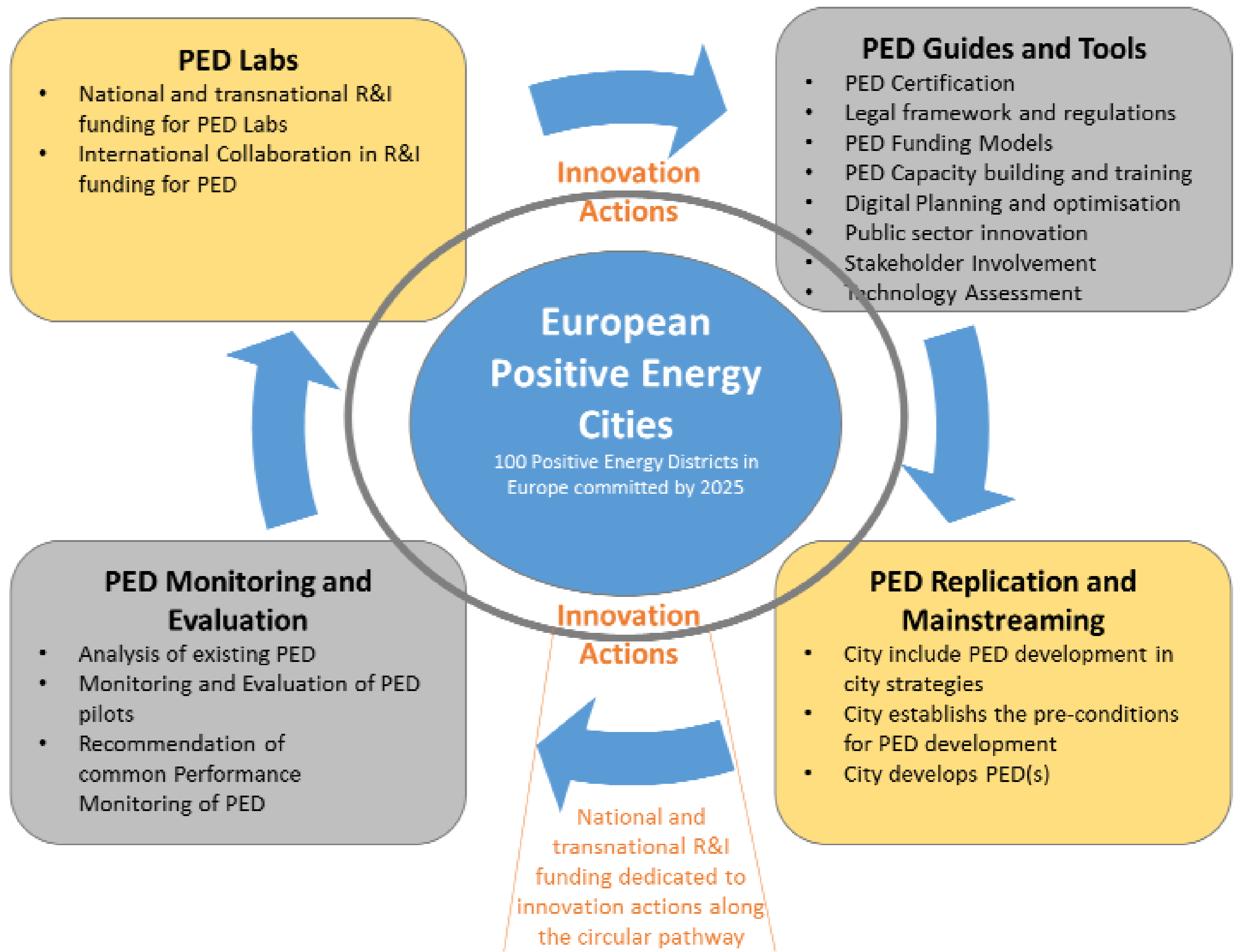
- monitoring of net energy flow at the point of grid interaction considering **internal load match.**

Mixed : 3."Virtual" Load Match

- Independent calculation of on-site energy generation and demand plus **monthly based balance**.

Is the building scale **enough**?
If the aim is to decarbonize the building sector, what is missing?

About Positive Energy Districts



SET-Plan ACTION n°3.2

Implementation Plan

- "[...] a PED* is seen as a district with annual net zero energy import, and net zero CO_2 emission working towards an annual local surplus production of renewable energy. "

*https://jpi-urbaneurope.eu/wp-content/uploads/2021/10/setplan_smartcities_implementationplan-2.pdf

About Positive Energy Districts

MISSION: to bring about 100 PEDs in EU by 2025

IMPLEMENTATION:

- Funding of R&I for methodologies, technologies and solutions in support of those stakeholders, who decide upon urban investments including city administrations, utilities, real state investors;

- Mainstreaming PEDs through a shared definition which reflects their position in the future energy system:

1) A share of renewable energy to be provided by the national-regional system
2) System compatibility (through energy flexibility, energy storage, sector coupling) reflecting the responisibility of urban areas as the largest energy consumers in the system
3) Energy efficiency balanced with on – site generation of renewable energy

SET-Plan ACTION n°3.2

Implementation Plan

About Positive Energy Districts

Main objectives of defining PEDs:

- Motivation and support for city administrations and the real estate sector to transform urban areas & their built environment towards climate-neutrality;
- Accounting for the framework conditions in Europe (climate zones, national energy systems, RE- potential)
- Forward – looking: «100% renewable energy» scenario of 2050 as a baseline
- **The goal:** a realistic target for optimal support by (nationally) generated Renewable energy to achieve climate-neutrality in urban areas
- In this perspective «Positive energy» does not only mean to «go beyond the net-zero balance»

SET-Plan ACTION n°3.2
Implementation Plan

What is a PED?

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Demo neighbourhood Barcelona

38 Housing units

- District heating network
- Energy sharing with the neighbour buildings
- Energy manager and visualisation
- Renewable energy generation is beyond the requirements of building code
- Innovative public procurement with sustainable and environmental requirements

syn.ikia

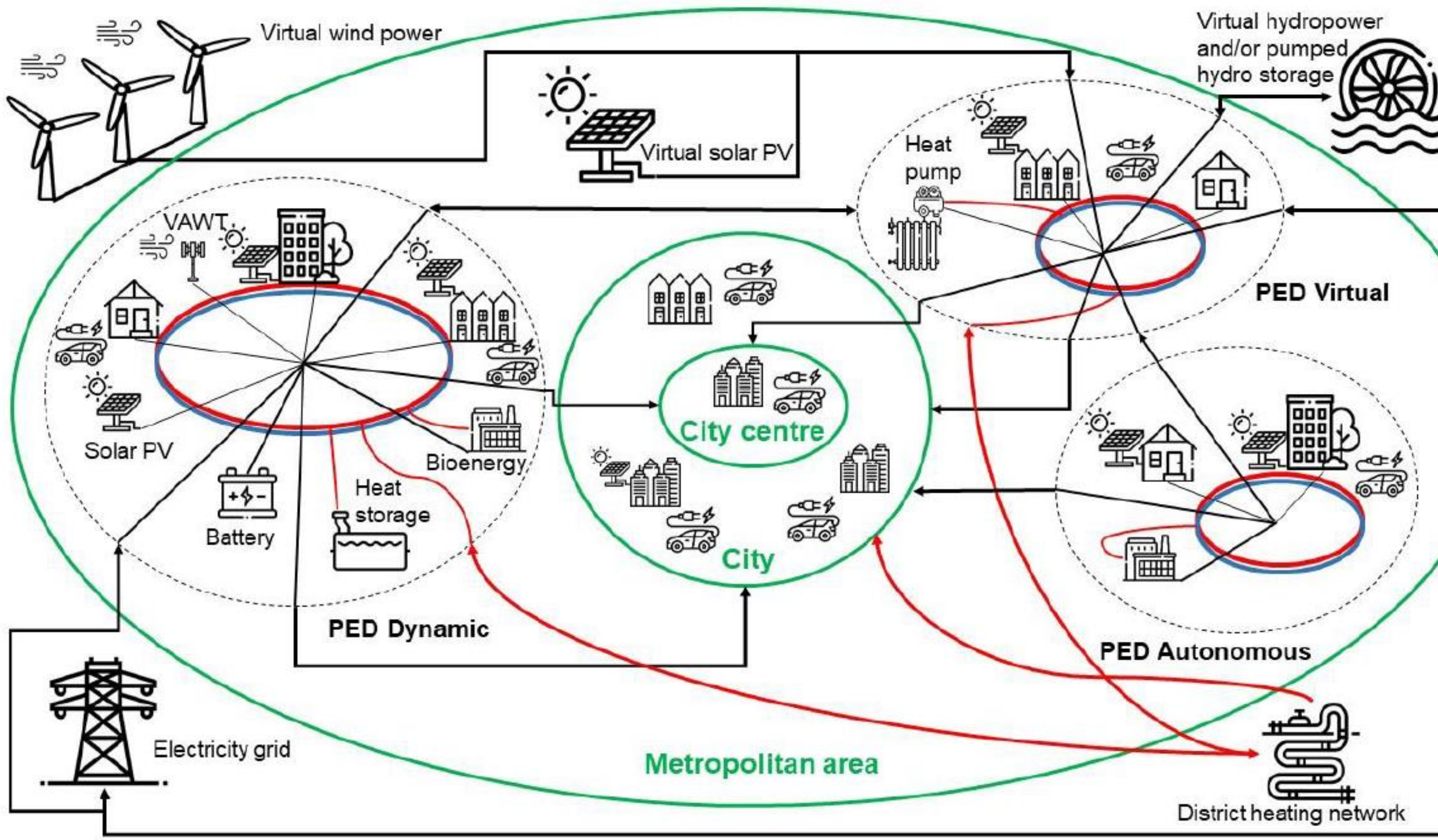
Demo neighbourhood Oslo

154 Housing units

- Smart house technology
- Low carbon design
- Recycled materials in construction
- Shared spaces
- Technical IT platform to initiate activities to create a vibrant neighbourhood
- Smart charging of electric vehicles

syn.ikia

About Positive Energy Districts



Definitions

$PED_{autonomous}$

'Plus Autarkic' net positive yearly energy balance within the geographical boundaries of the PED and internal energy balance at any moment in time (no imports from the hinterland (thus considering any energy carrier) not even helping to balance the wider grid outside)

$PED_{dynamic}$

Net positive yearly energy balance within the geographical boundaries of the PED but dynamic exchanges with the hinterland to compensate for momentary surpluses and shortages

$PED_{virtual}$

Net positive yearly energy balance within the virtual boundaries of the PED but dynamic exchanges with the hinterland to compensate for momentary surpluses and shortages

Pre-PED

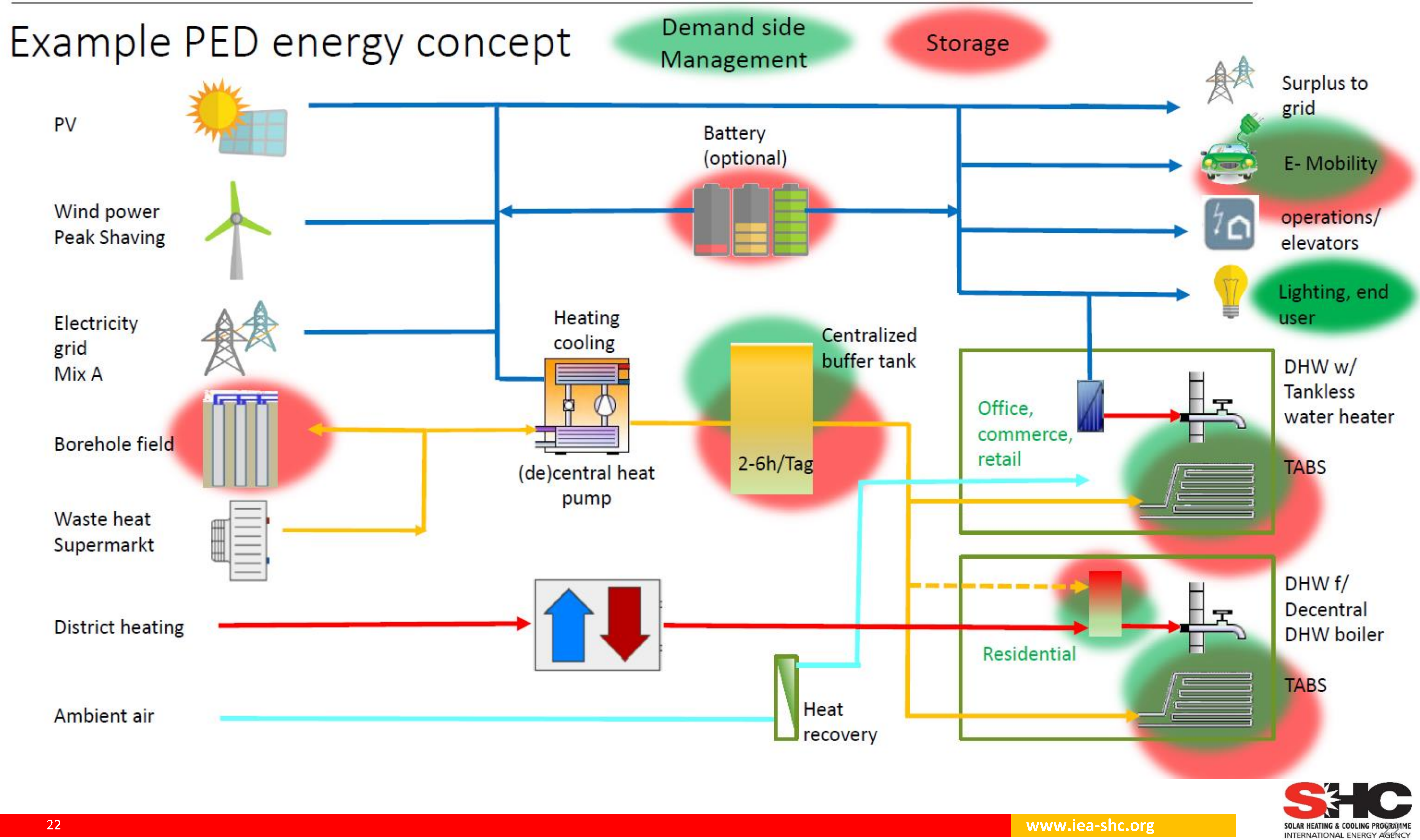
No net positive yearly energy balance within the geographical boundaries of the PED but energy different acquired on the market by importing certified green energy (i.e. realizing a zero carbon district)

Definitions and system boundaries

PED $_{alpha}$
A PED Alpha is a district that has a positive annual primary energy balance, based on all energy services and monthly conversion factors. This includes **operational energy** and user electricity.

PED $_{alpha+mobility}$
This definition of PED meets the above criteria with the inclusion of private **everyday mobility**.

PED $_{Omega}$
A PED Omega covers all of the above as well as the **embodied energy** for structural, technical building and everyday mobility. This can be further expanded in order to included individual emissions of comsumption, nutrition to connect to individual carbon budgets.



Example PED energy concept
Demand side Management
Storage
PV
Wind power Peak Shaving
Electricity grid Mix A
Borehole field
Waste heat Supermarkt
District heating
Ambient air
Battery (optional)
Heating cooling
(de)central heat pump
Centralized buffer tank
2-6h/Tag
Heat recovery
Surplus to grid
E- Mobility
operations/ elevators
Lighting, end user
Office, commerce, retail
DHW w/ Tankless water heater
TABS
Residential
DHW f/ Decentral DHW boiler
TABS
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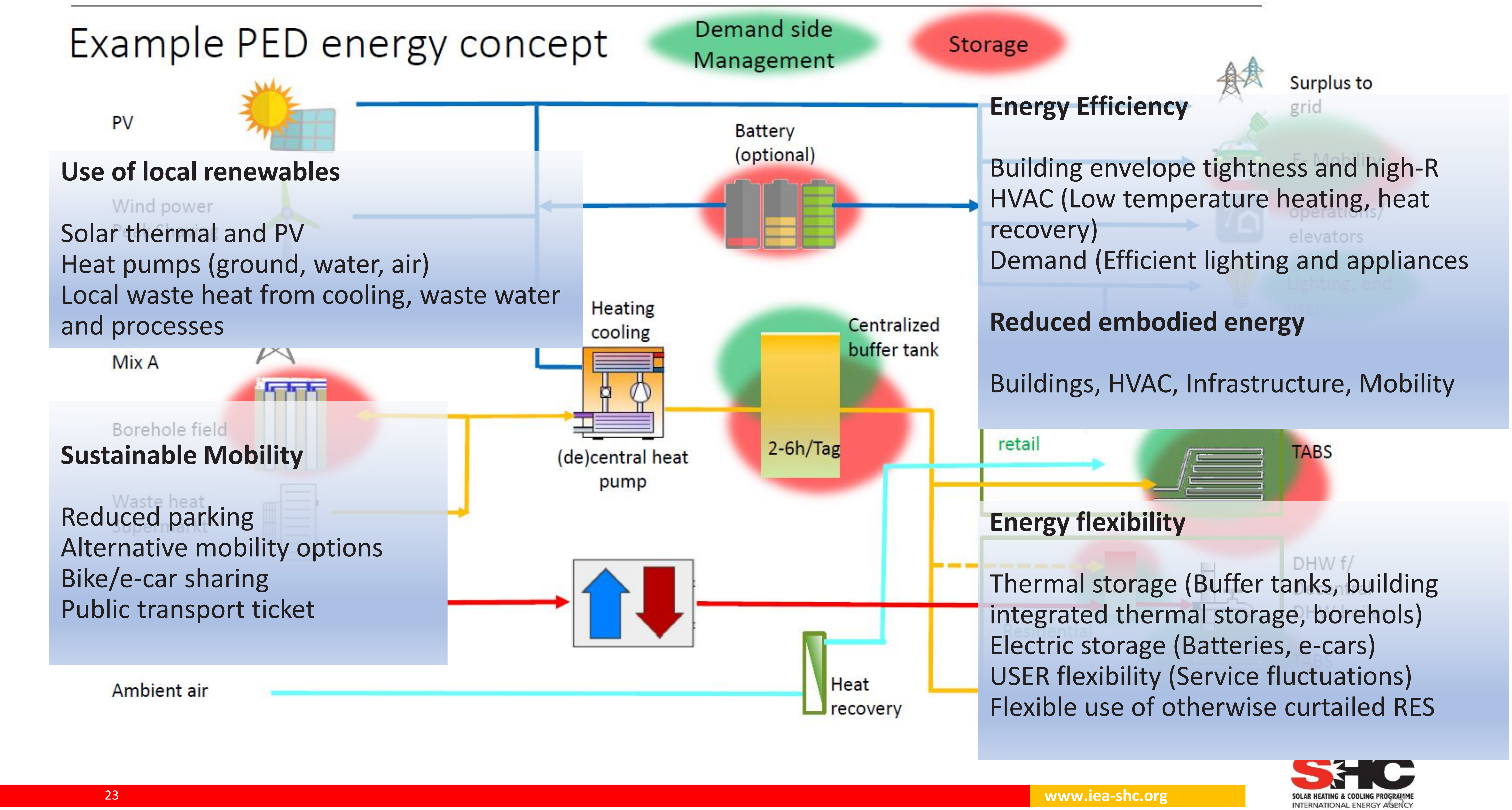

Example PED energy concept
Demand side Management
Storage
PV
Surplus to grid
Battery (optional)
Use of local renewables
Solar thermal and PV
Heat pumps (ground, water, air)
Local waste heat from cooling, waste water and processes
Heating cooling
Centralized buffer tank
Mix A
Borehole field
(de)central heat pump
2-6h/Tag
Sustainable Mobility
Reduced parking
Alternative mobility options
Bike/e-car sharing
Public transport ticket
Heat recovery
Ambient air
Energy Efficiency
Building envelope tightness and high-R
HVAC (Low temperature heating, heat recovery)
Demand (Efficient lighting and appliances
Reduced embodied energy
Buildings, HVAC, Infrastructure, Mobility
retail
TABS
Energy flexibility
Thermal storage (Buffer tanks, building integrated thermal storage, borehols)
Electric storage (Batteries, e-cars)
USER flexibility (Service fluctuations)
Flexible use of otherwise curtailed RES
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Qualitative features of PEDs

- **Holistic** approach towards sustainable, liveable neighborhoods/integrative perspective (integrating technological, spatial, regulatory, financial, legal, economic, social, cultural and governance aspects)
- Synergetically connected to the **wider energy/mobility/infrastructure**. Sometimes the **circular** economy/sustainable urban metabolism is put forward
- **Mixed use & functions**, strong public spaces, integrating green and blue networks
- **Social inclusiveness – accesibility, acceptability and diversity**
- High and affordable **quality of living** – environmental quality (air, noise, security – architectural, urban & landscape quality – affordability
- **Citizen centered** – added value and incentives for the consumer – interested and engaged users, citizen involvement from the outset, role of community ambassadors and emotional buy-in
- Context-sensitive, **co-created with local community,** embedded in local community, culture& patrimony, urban tissue – ‘location, location, location’
- **Exemplary & education role** including up to eco-tourism; scalable and replicable character

System boundaries

Different possibilities and geographic limitation

Primary energy / final energy

The EC seems to point towards final energy

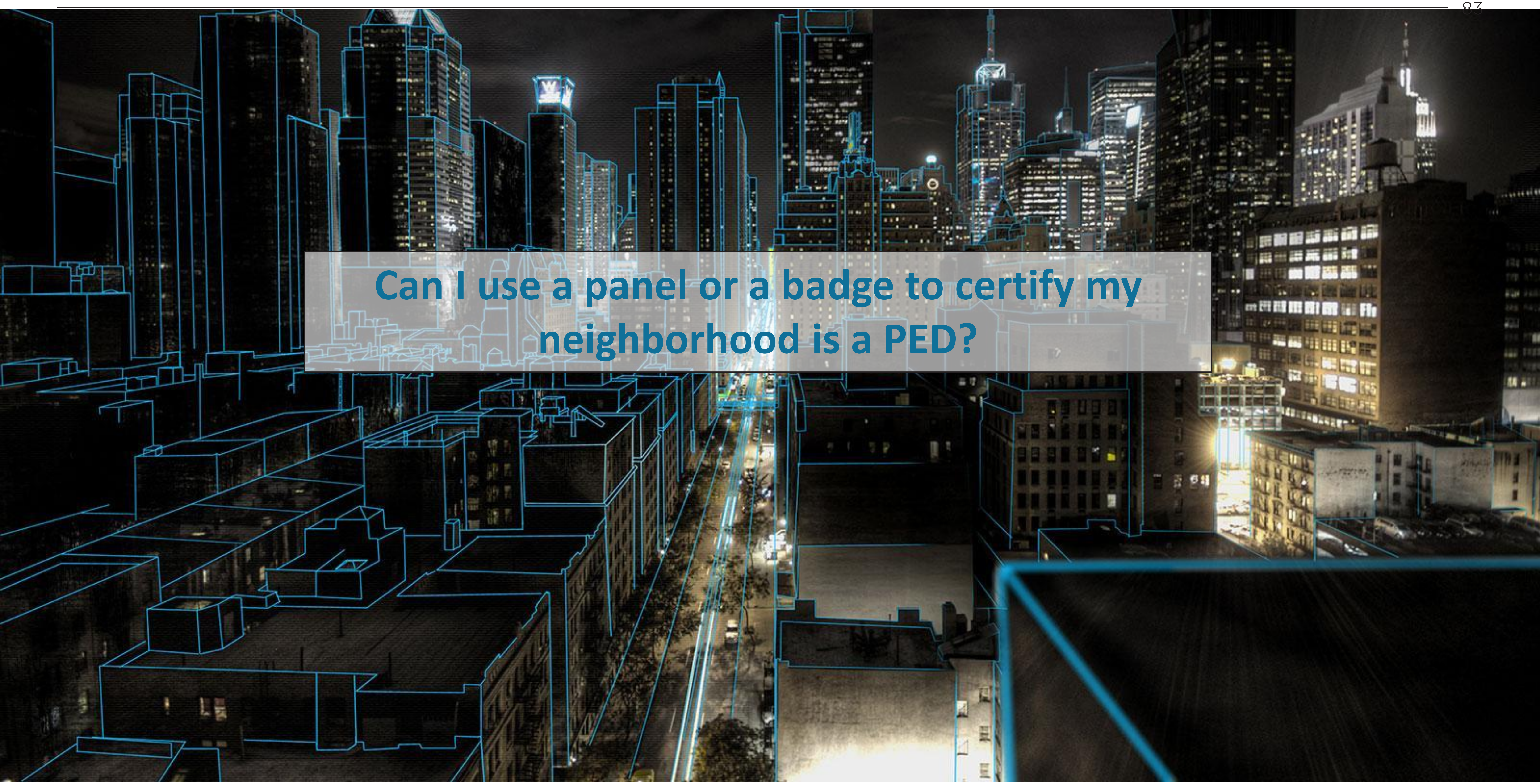
Mobility

How to include mobility in PED balances?

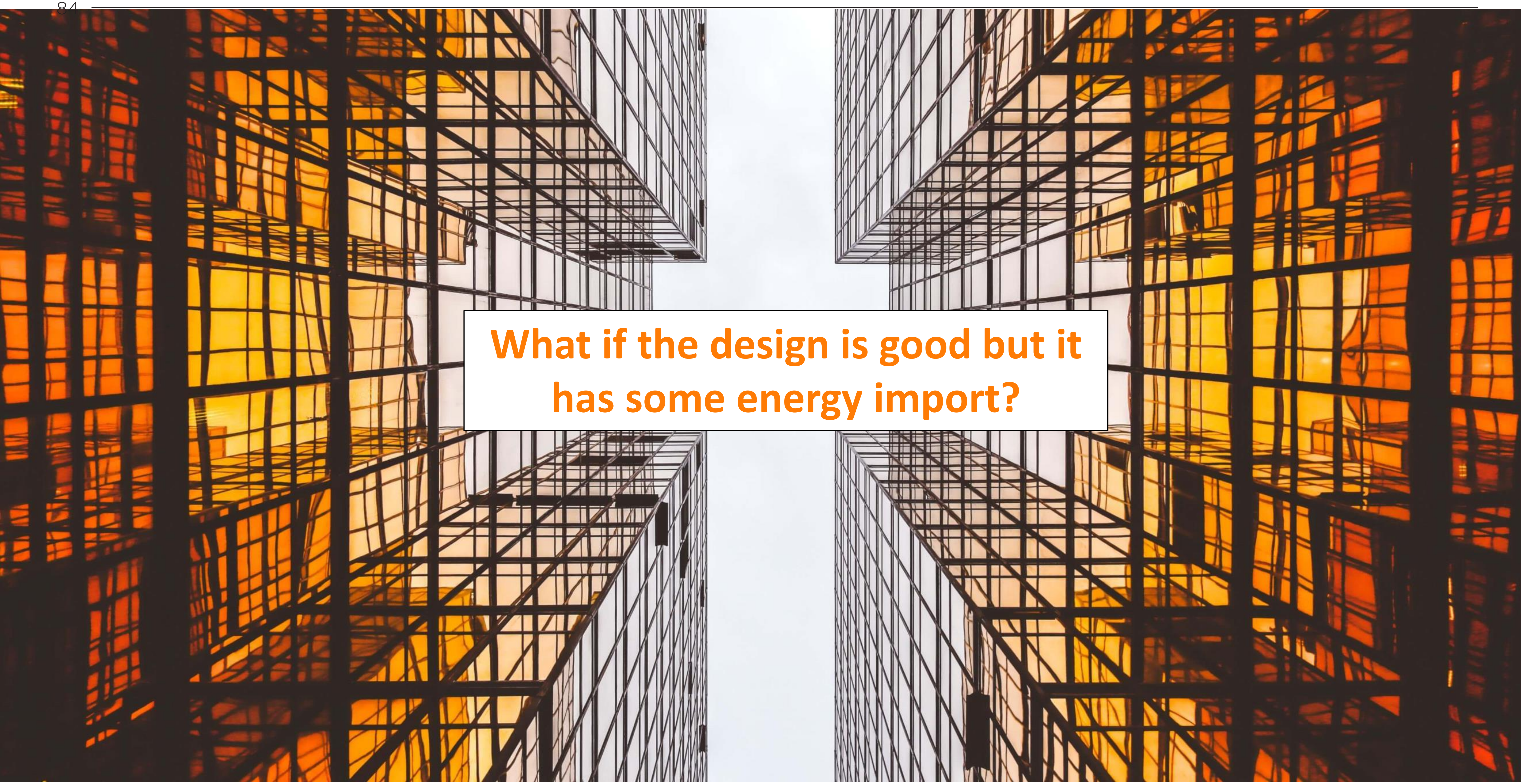
Are we considering the appropriate scale level?

?

Open, inclusive and qualitative definition
versus
Closed, exclusive and quantitative certification



Can I use a panel or a badge to certify my neighborhood is a PED?


What if the design is good but it has some energy import?

Risks and challenges

- **Regulatory frameworks:** urban planning regulations, energy market rules, prescriptions, fiscal and financial regulations, public budget and tendering regulations
- Need for competent planners (knowhow, tools, communication, talent and creativity) & proper capacity at all levels (local authorities, solutions providers, developers) 'planning for change', need for integrated planning capacity
- Data privacy vs value-added tailored services, effective and optimized energy & mobility maagement
- Financing structures: mixed funding models, role of public investment for realising long-term infrastructures, identifying suitable business models. Ownership structures and financing beyond the common short & mid term horizons, sharing models for costs & benefits across actors/investors
- Cross sectoral and cross-silo collaboration in order to acquire integrated solutions and maximizing secondary benefits.

Positive Energy Districts

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IEA Solar Heating and Cooling Programme (group 4230381)

Technology Collaboration Programme by iea

Environmental Performances and Sustainability Assessment in the Building Sector
Maurizio Cellura

The presentation discusses first the differences between embodied energy and operational energy, then posits that decarbonizing the building sector relies on more than just assessment at the building scale. Life Cycle Assessment (LCA) is presented in details, followed by the identification of gaps in current LCA research. The qualitative and quantitave environmental impacts assessment of positive energy disctict are introduced and discussed, as well. A key takeaway from the presentation is the need for a standardized approach to assessing environmental impacts at the district scale.

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Environmental performances and sustainability assessment in the building sector

Maurizio Cellura, Environmental performances and sustainability assessment in the building sector
IEA SHC TASK 63: Solar Neighborhood Planning Fall school, September 8th, 2022

Technology Collaboration Programme
by iea

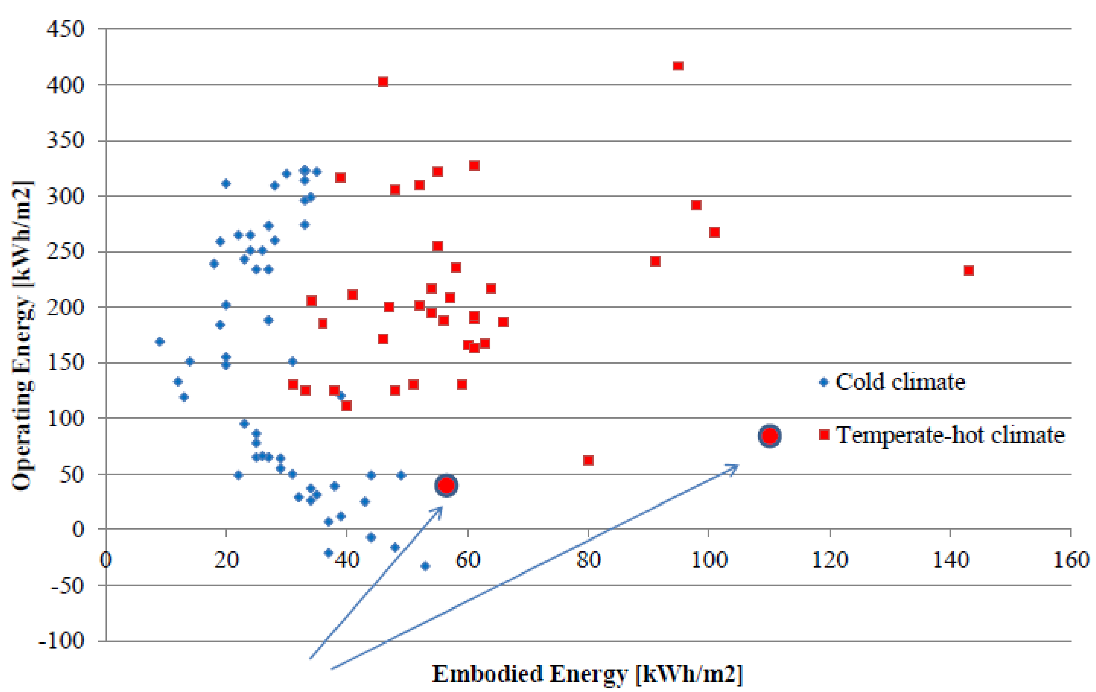
Embodied energy vs operation energy

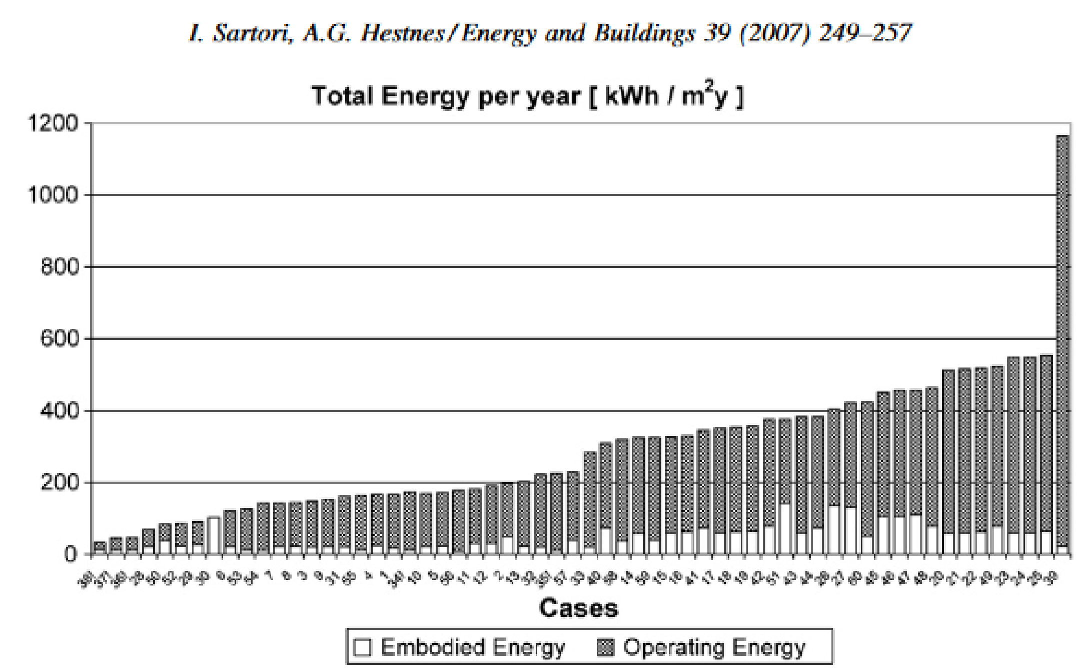
Embodied energy a key issues to assess the energy demand of low energy buildings

- Design of low energy buildings addresses the target of reducing the operating energy, by improving the thermal insulation of the building envelope, reducing infiltration losses, recovering heat from ventilation air and/or waste water, installing renewable energy technologies for heating, domestic hot water and electricity generation. However, the reduction of the operating energy demand involves as increase in embodied energy of the building due to energy intensive materials used in the building shell and technical equipment.

- When shifting from standard houses to low energy buildings and to Net ZEBs the relative share of operating energy decreases, while the relative share of embodied energy increases.

- Therefore, the lower the operating energy, the more important it is to adopt a life cycle approach to compare the energy saving achieved in the building operation with respect to the overall life-cycle energy consumption.





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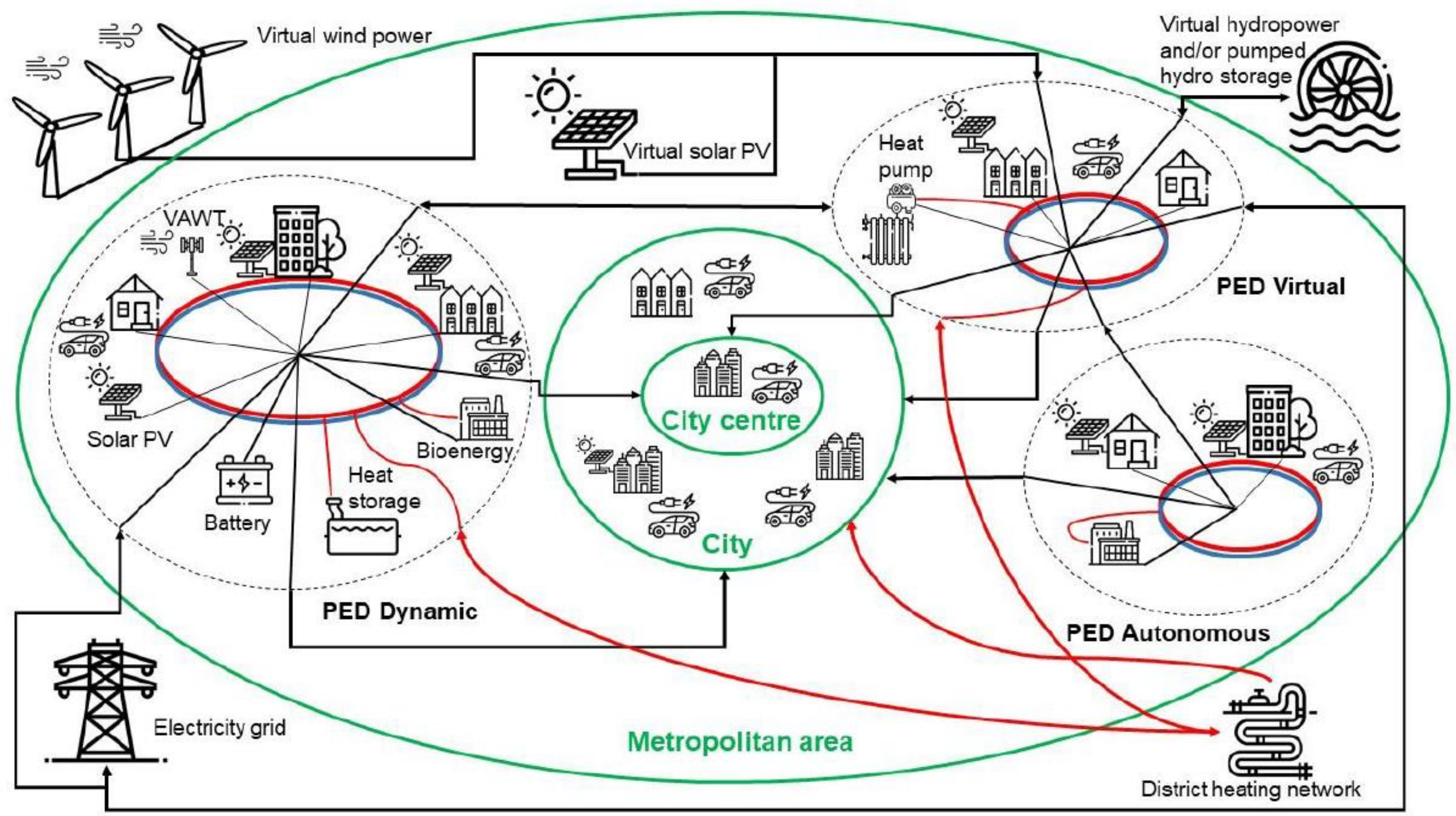
Is the building scale **enough**?
If the aim is to decarbonize the building sector, what are we overlooking?

Positive Energy Districts



[…] In this context, a PED is seen as a district with annual net zero energy import, and net zero CO_2 emission working towards an annual local surplus production of renewable energy. […]

JPI URBAN EUROPE – SET PLAN Action n.3.2 Implementation plan

And the environmental aspects?

The Life Cycle Assessment (LCA)

The Life Cycle Thinking

The LCA is a way of thinking, an approach to get an overview of the energy and environmental performances of products and services.

We talk about the LIFE CYCLE THINKING approach.

Life Cycle Thinking (LCT) goes beyond the traditional productive goals and includes environmental, social and economic impacts of a product over its entire life cycle.

The main goals of LCT are to reduce a products resource use and emissions to the environment as well as improve its socio-economic performance through its life cycle.

The Life Cycle Assessment

The Life Cycle Assessment (LCA) is a *"compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle"* (Source: ISO 14040)

The LCA is an "objective procedure for assessing the energy and environmental loads related to a process or activity, carried out by identifying the energy and materials used and the waste released into the environment" (Source: SETAC)

Life Cycle Assessment

Why the Life Cycle Assessment?

- **It prevents to move the problems from one life-cycle step to another;**
- **It prevents to move the problems from an impact category to another;**
- **It captures the complexity hidden behind a product;**
- **It is a useful tool to compare products and services on a scientific basis.**

LCA allows to have a global overview of the product throughout its life cycle, also including some impacts normally ignored or neglected (such as those related to the final disposal).

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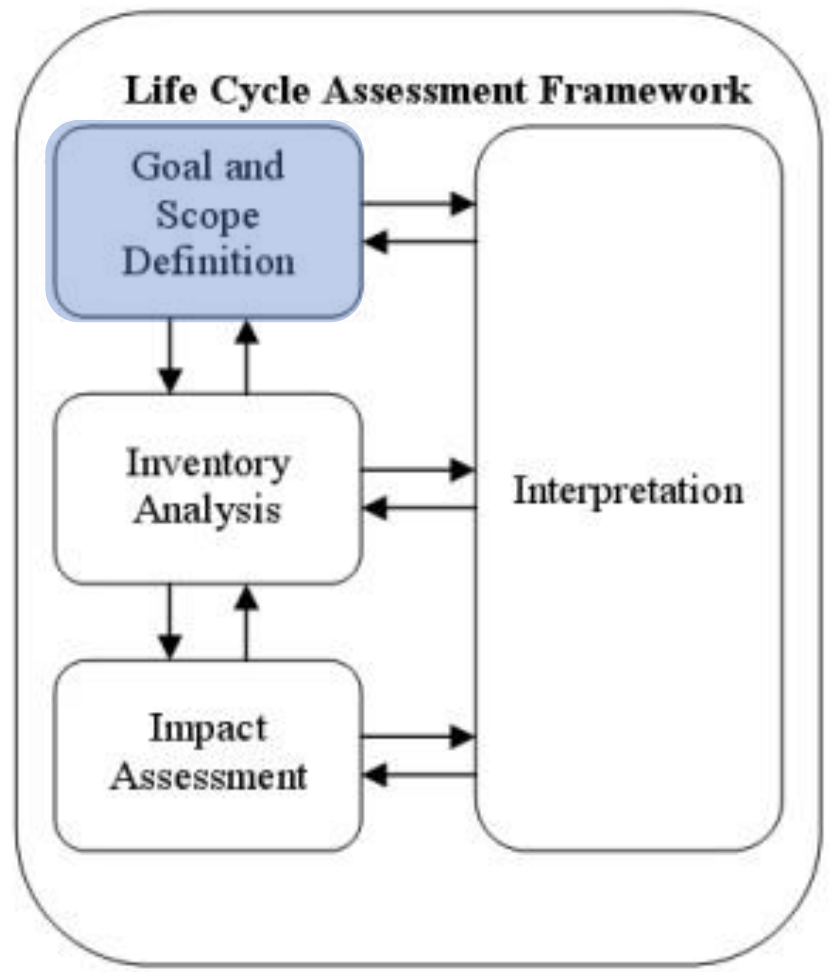
The Life Cycle Assessment

The Life Cycle Assessment Framework

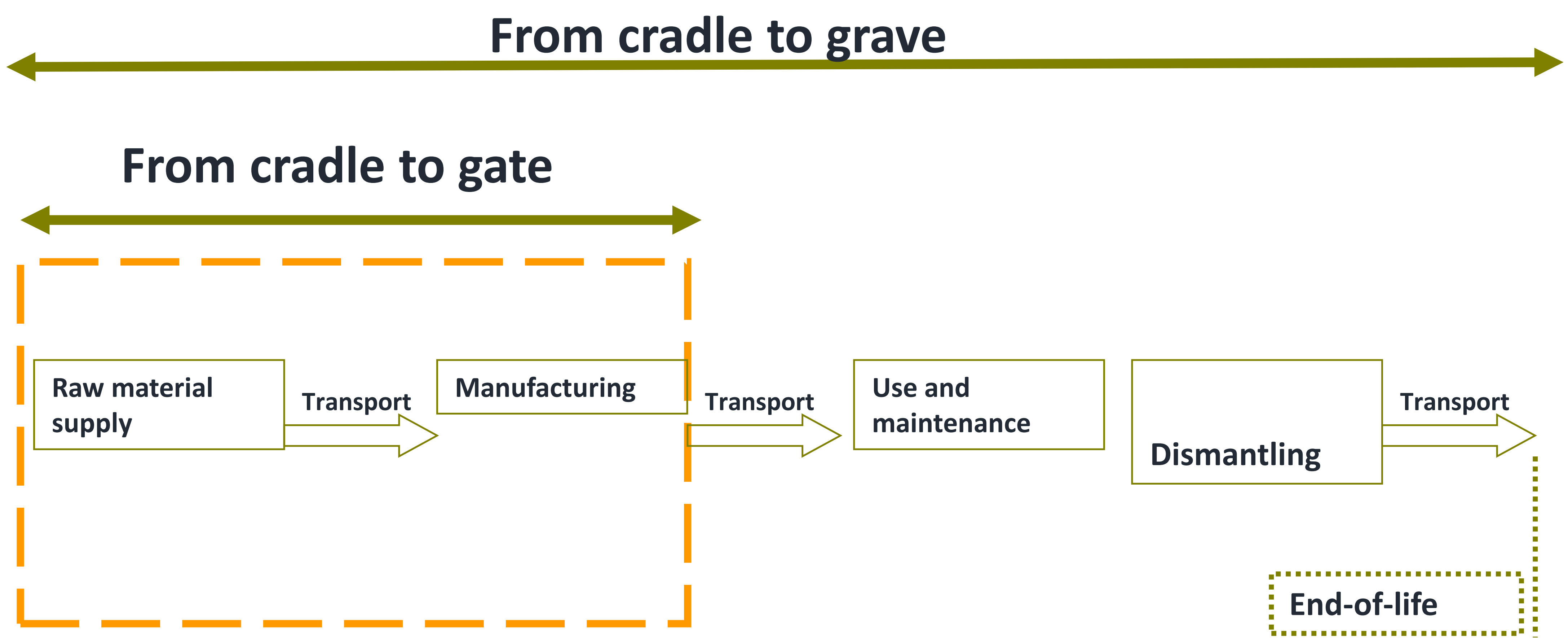
There are four phases in a LCA study.

The scope, including the system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA.



Life Cycle Assessment

System boundaries

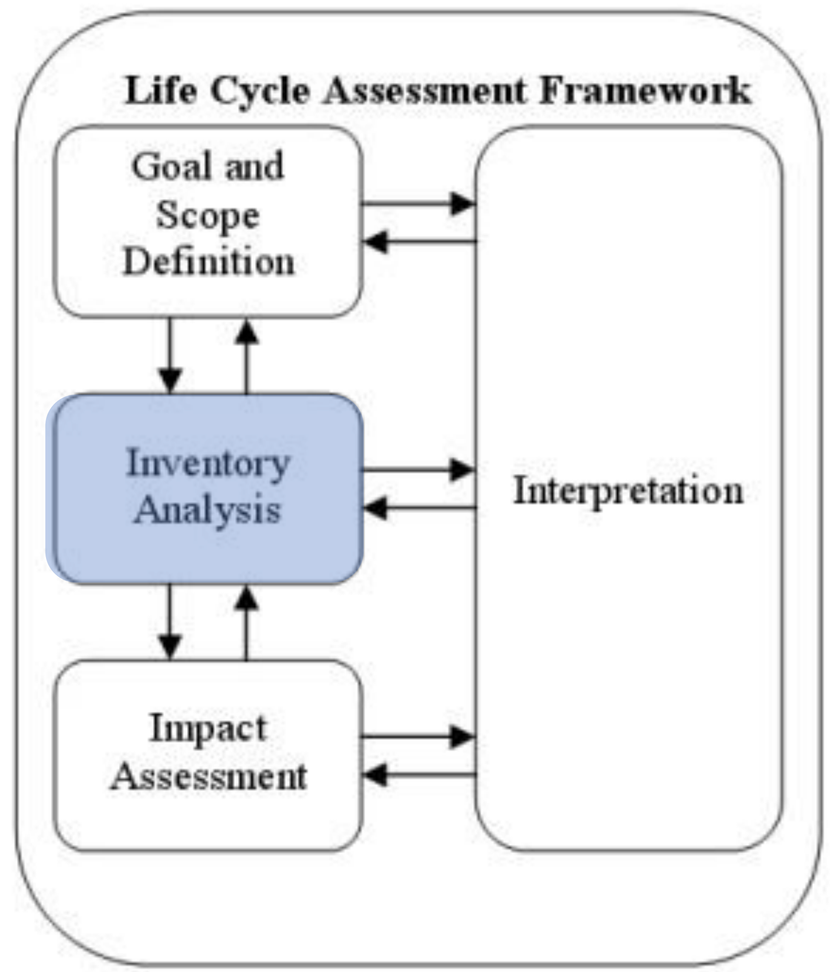


The Life Cycle Assessment

The Life Cycle Assessment Framework

There are four phases in a LCA study.

The life cycle inventory analysis phase (LCI phase) is the second phase of LCA. It is an inventory of input/output data with regard to the system being studied. It involves collection of the data necessary to meet the goals of the defined study.



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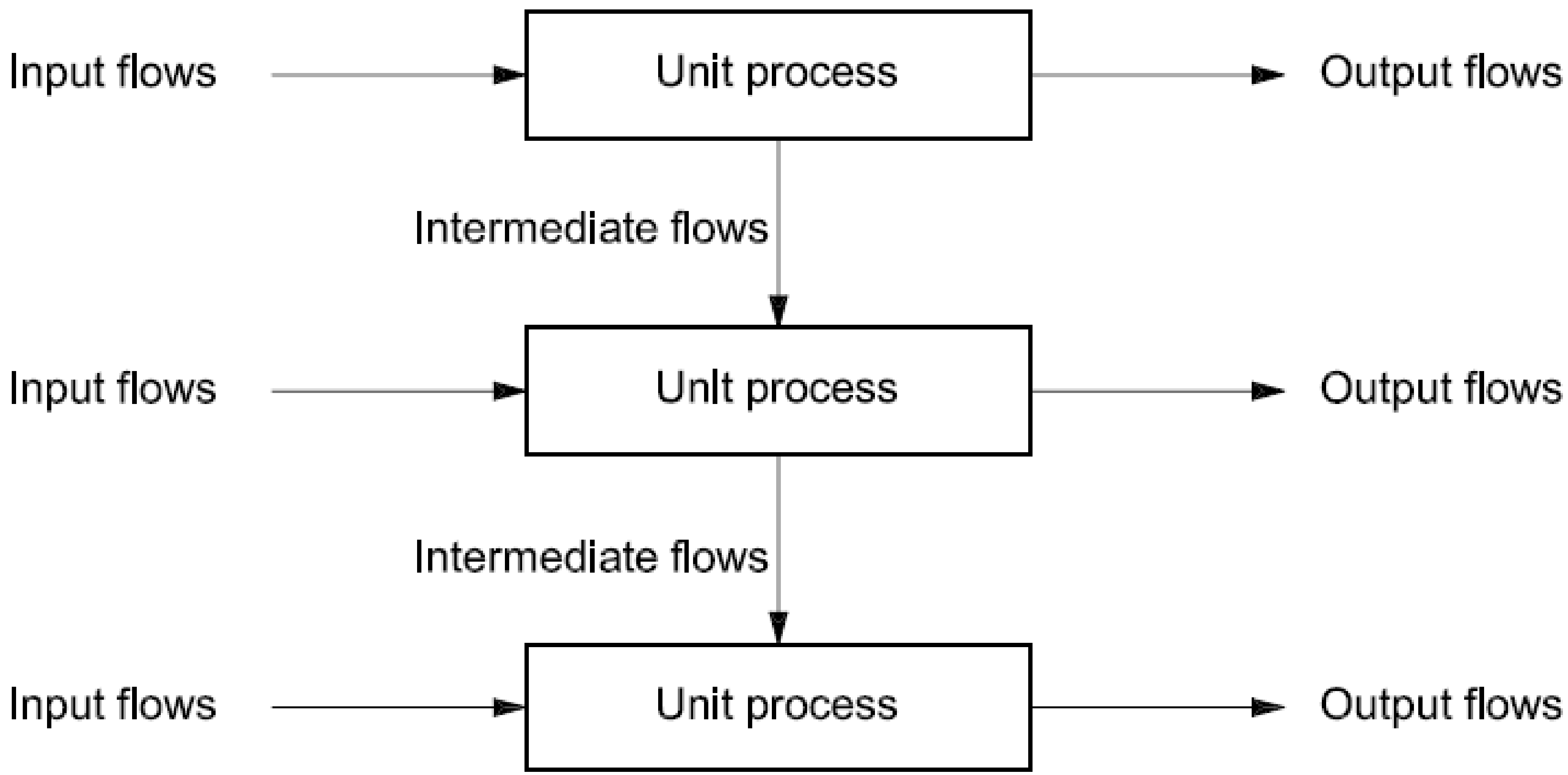
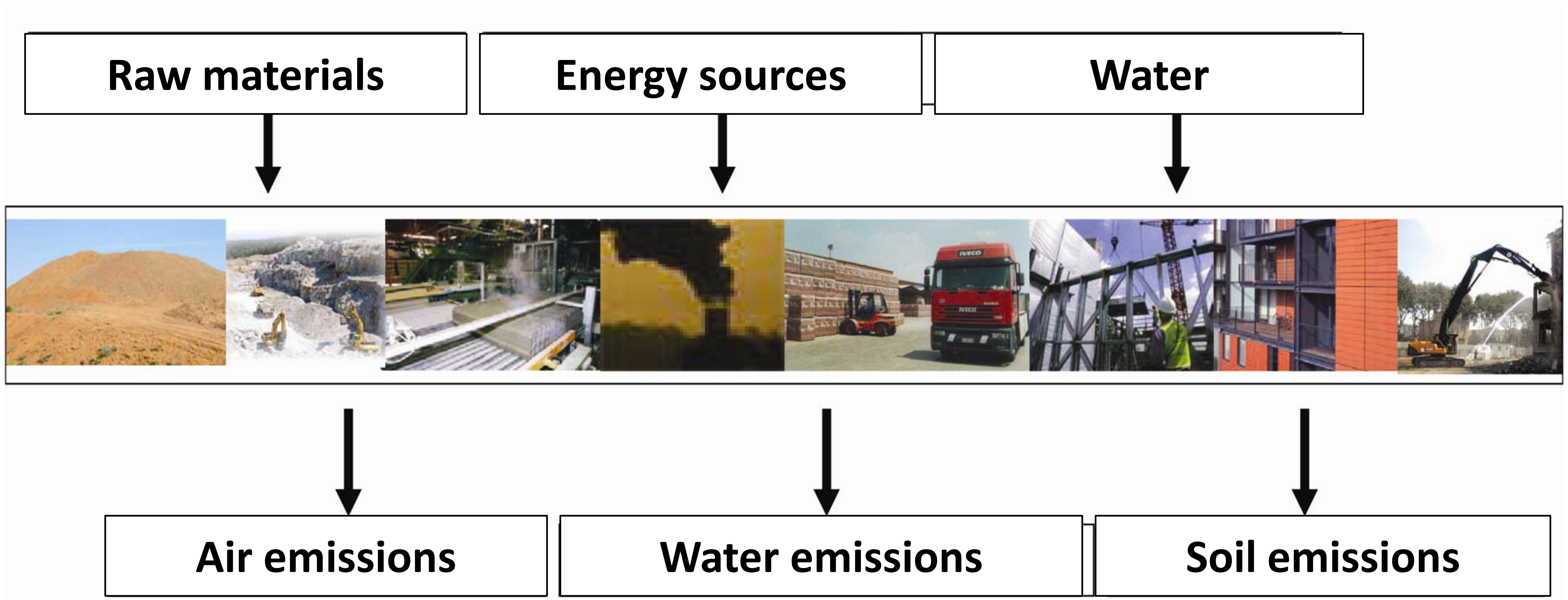
Life Cycle Assessment



Life Cycle Assessment

Input: raw materials (including water), energy sources

Output: waste, air emissions, water emissions, soil emissions

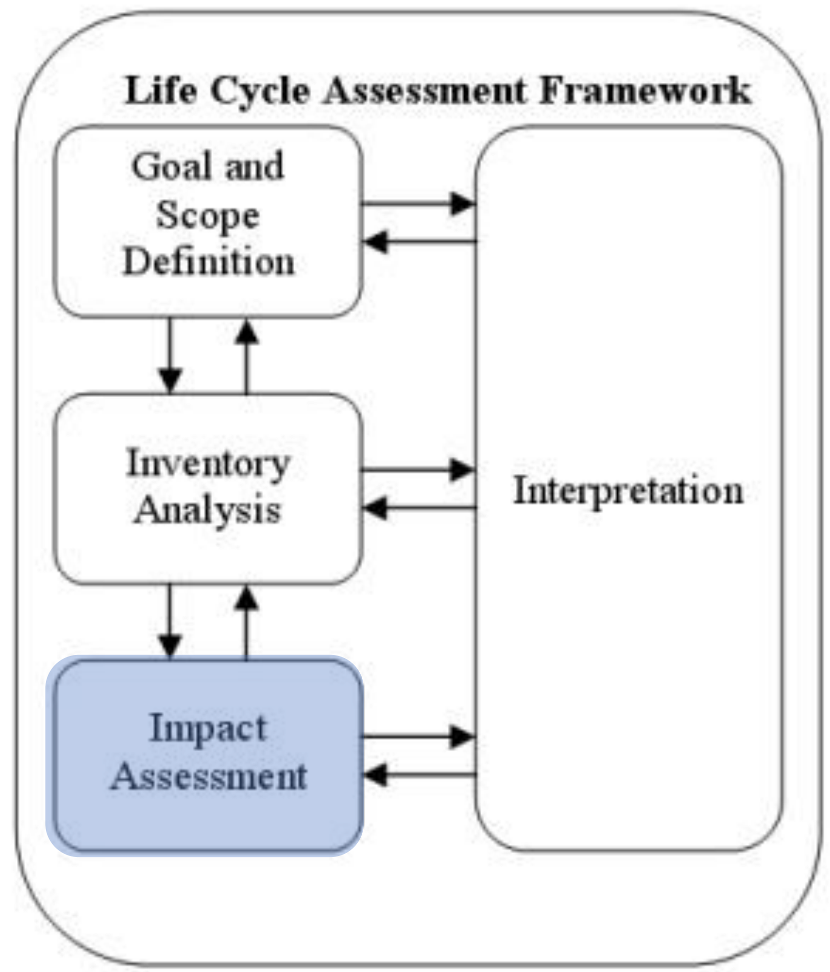


Life Cycle Assessment

The Life Cycle Assessment Framework

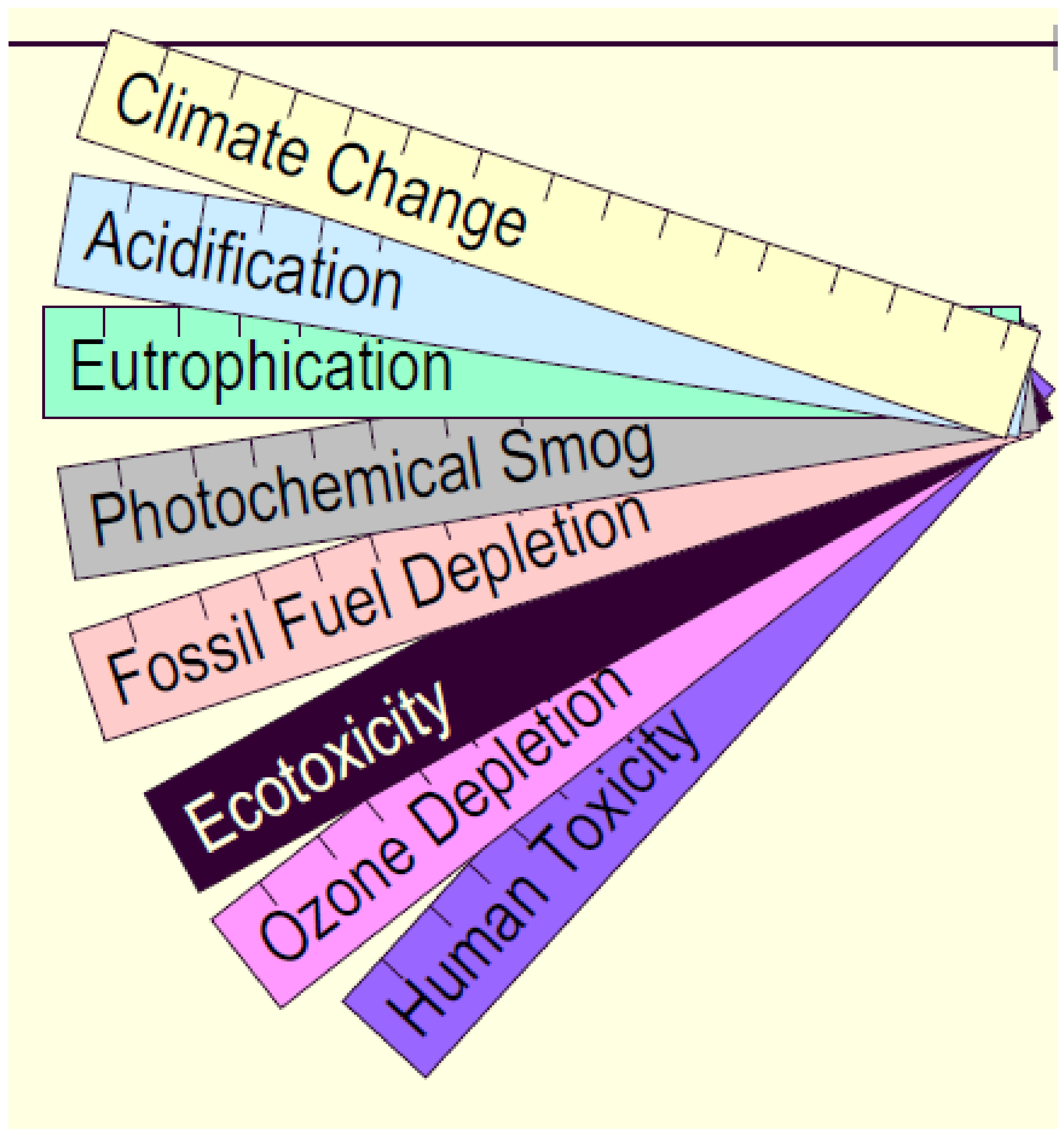
There are four phases in a LCA study.

The life cycle impact assessment phase (LCIA) is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system's LCI results so as to better understand their environmental significance.

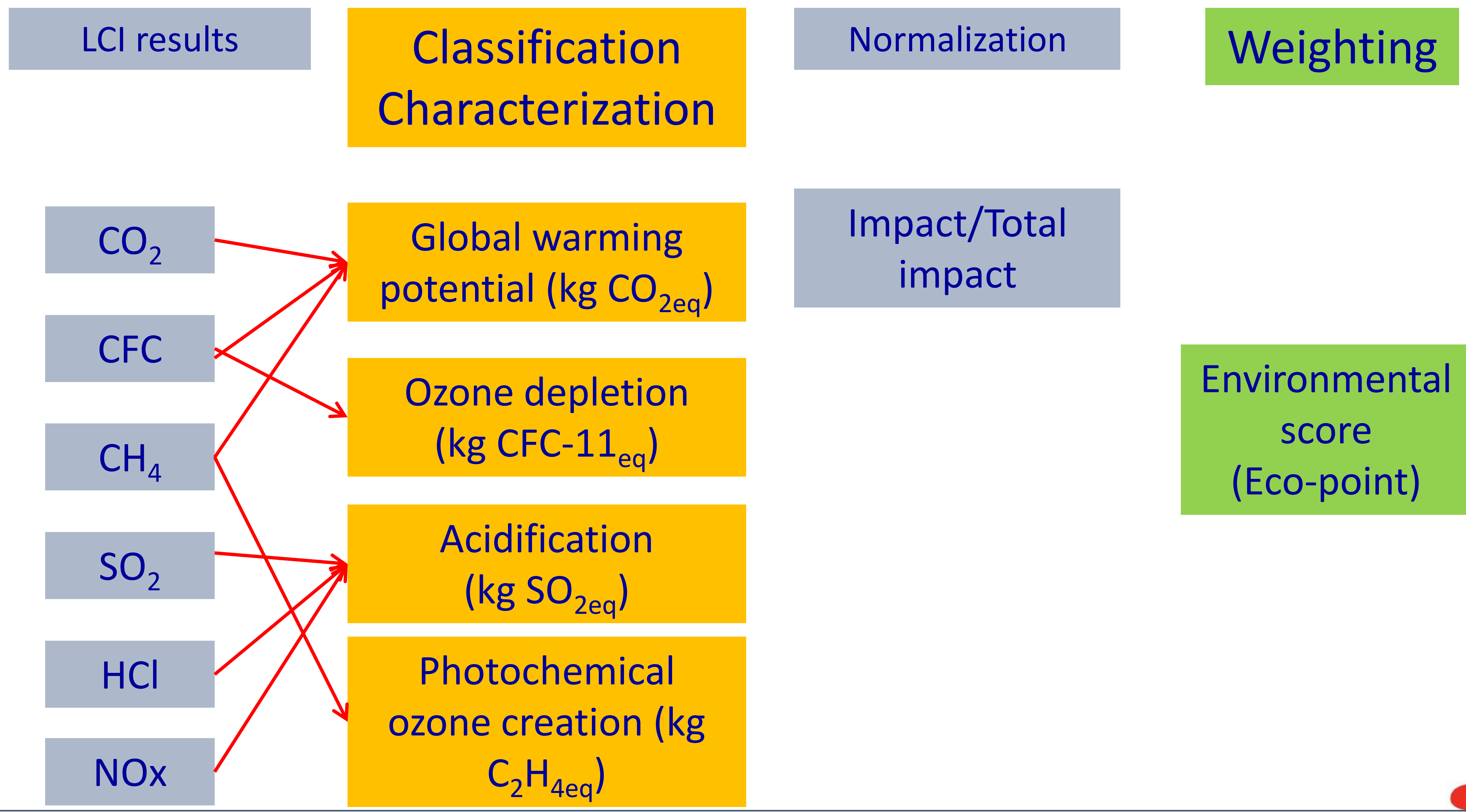


Life Cycle Assessment

Some impact category indicators



Life Cycle Assessment

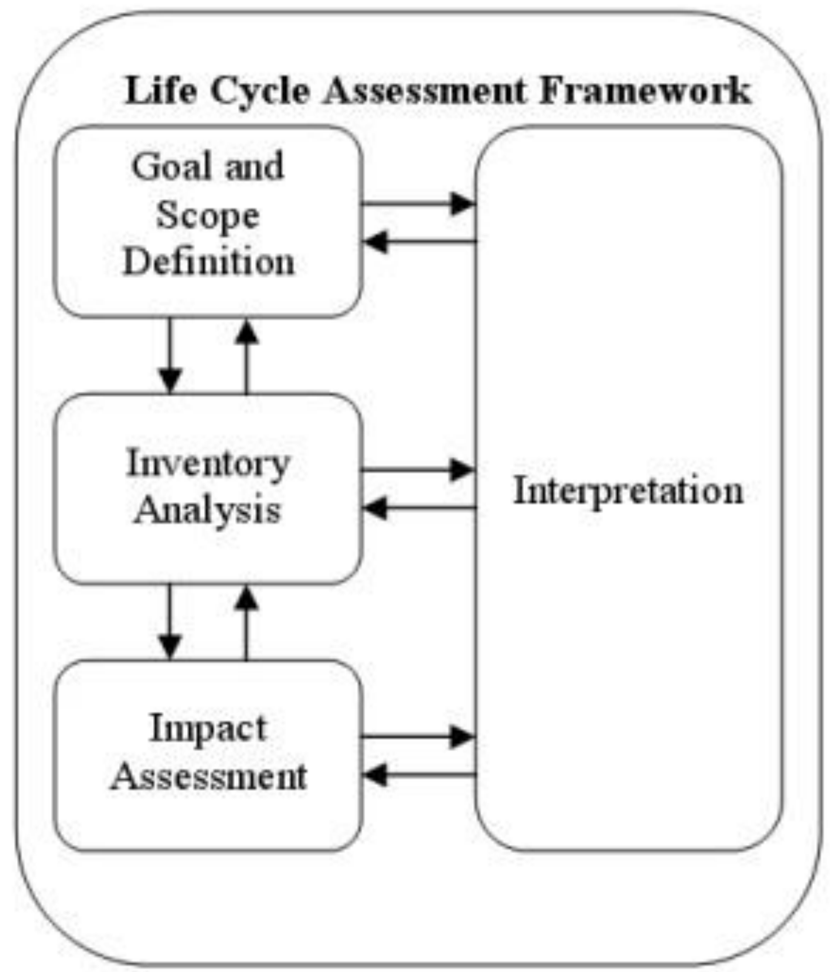


Life Cycle Assessment

The Life Cycle Assessment Framework

There are four phases in a LCA study.

Life cycle interpretation is the final phase of the LCA procedure, in which the results of an LCI and/or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.



Environmental impacts assessment of Positive Energy Districts: Quantitative results analysis

- Studies available in literature use very diverse system boundaries and methodological assumptions
- In some cases the quantitative metric evaluated corresponds to the area of district, in others to the walkable area of the built environment, sometimes being annualized or merely reported as a lump-sum emissions
- The system boundaries are also variable with distinction to the facilities and aspects of the district (e.g. onsite energy supply systems, buildings, mobility, impacts allocation) as well as to the life cycle stages to be included

- Results are VERY diverse and variable

Environmental impacts assessment of Positive Energy Districts: Quantitative results analysis: Dynamic GWP

Method:

- Inventory flow shouldn't be omitted from an assessment;
- All impacts of all substances contributing to an impact category should have the same **Time Horizon of the Impact** (*THI*) in the indicator used for that impact category;
- The THI has no reason to change as a function of time.

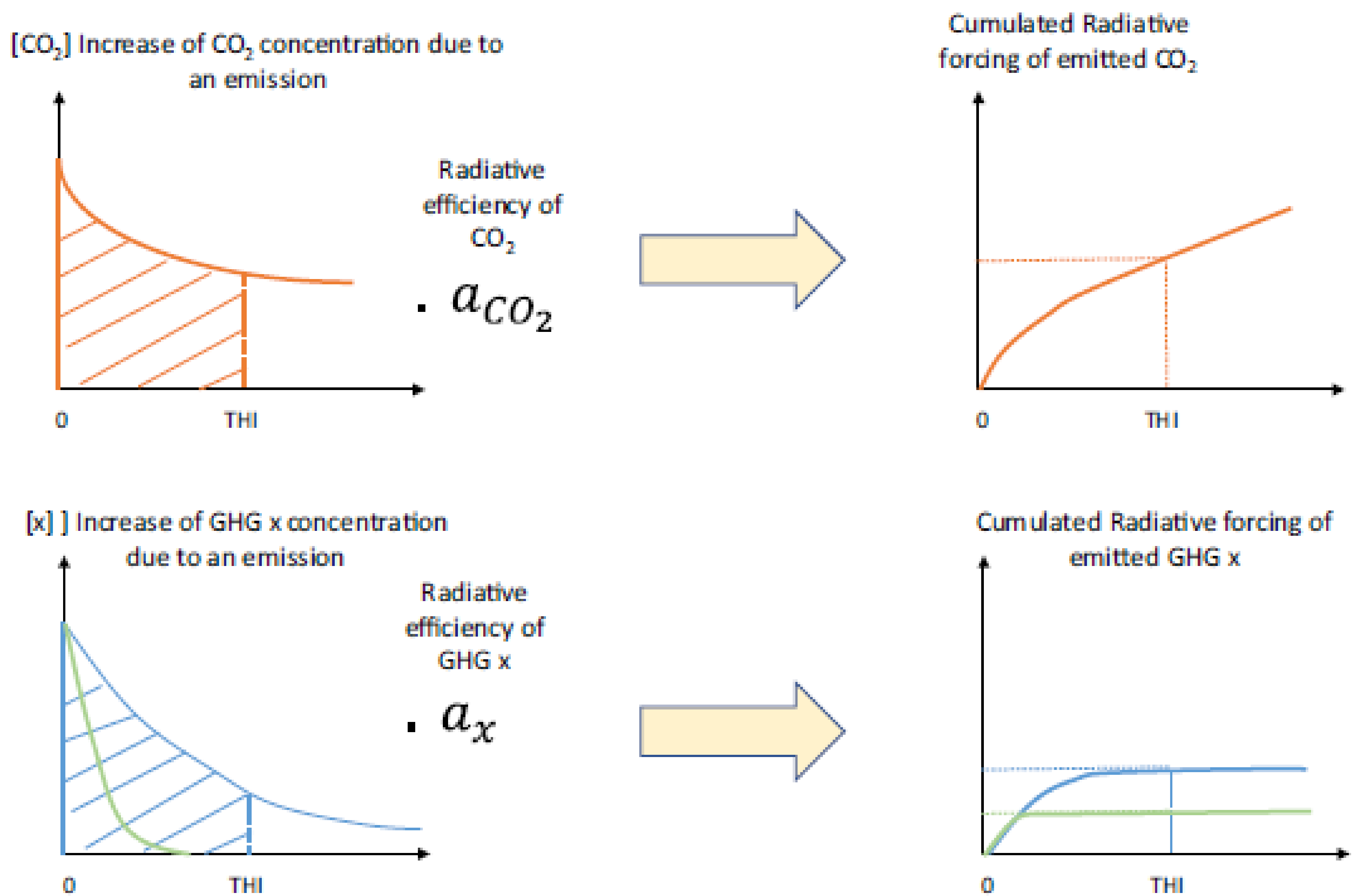
Results

Thus, the **total observation duration** (*TOD*) to consider for any dynamic approach is *TOD* = *LCD* + *THI*, where LCD is life cycle duration.

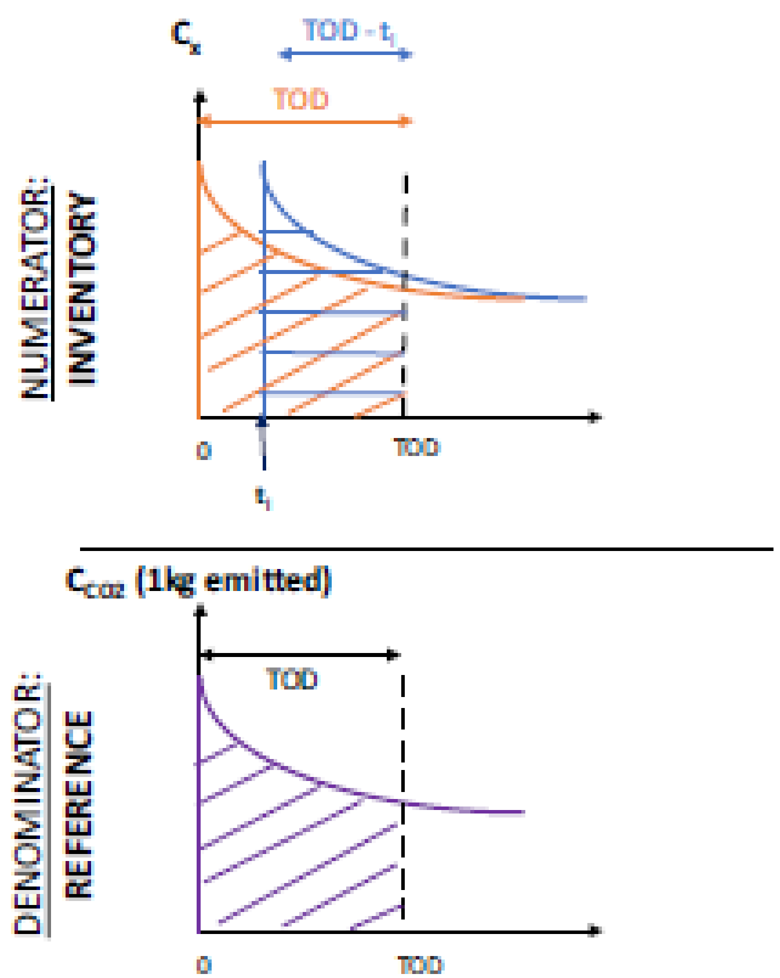
Conclusions

At a time when the dynamic GWP indicator is being considered as a regulatory tool on a French or even European scale, it seems crucial to consider its scientific relevance, because using the wrong method could lead to an overestimation of the possible beneficial effects of temporary carbon storage in the construction sector as a whole.

Environmental impacts assessment of Positive Energy Districts: Quantitative results analysis: Dynamic GWP



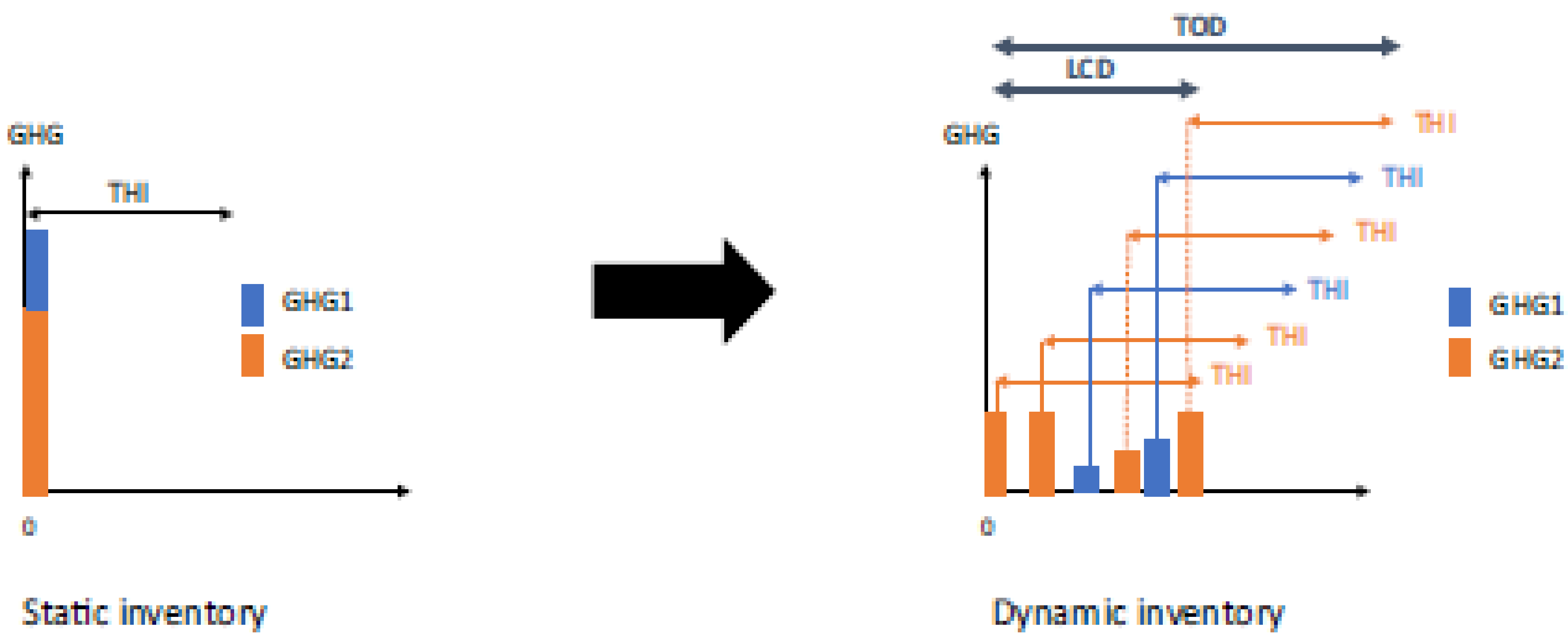
Environmental impacts assessment of Positive Energy Districts: Quantitative results analysis: Dynamic GWP



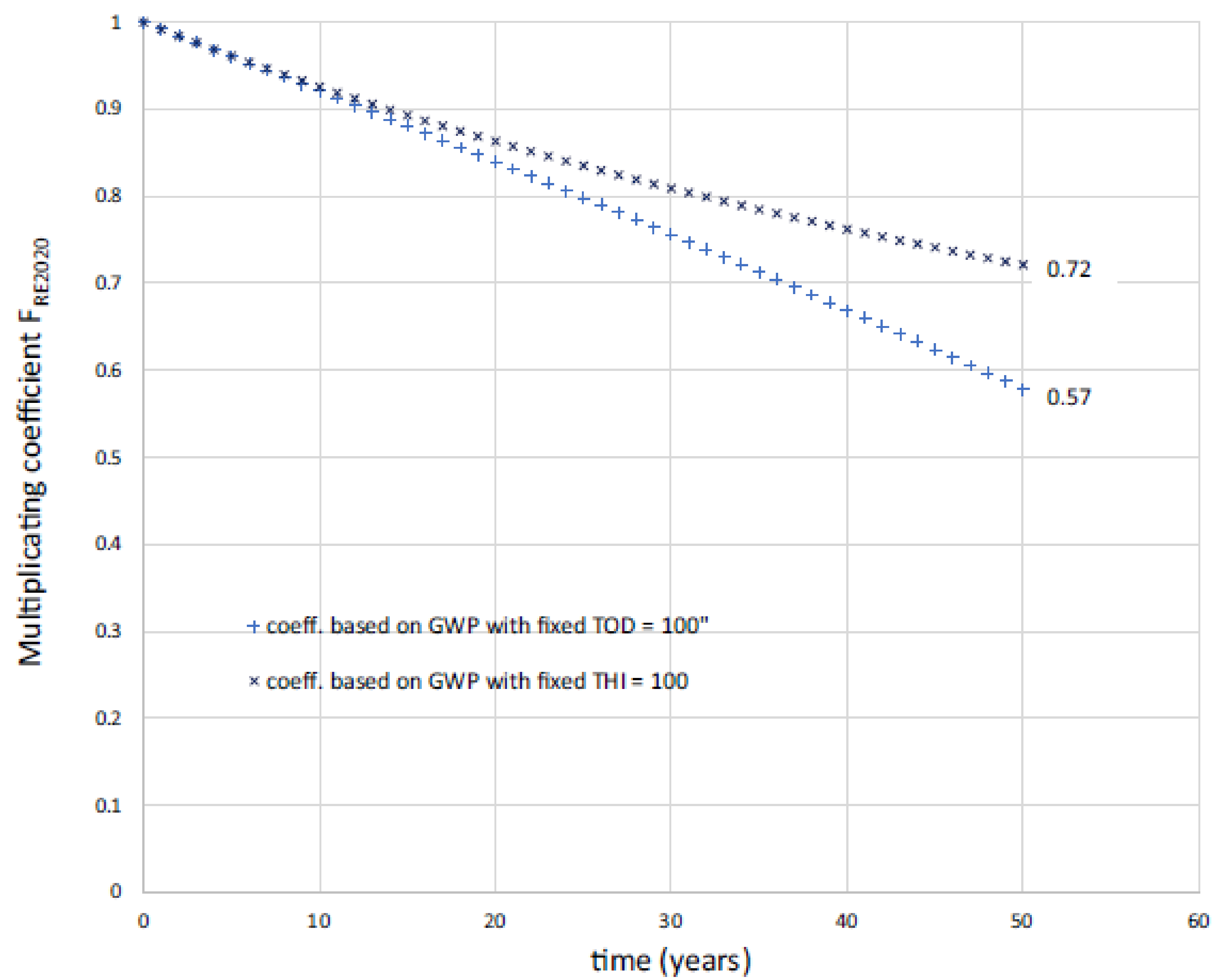
$$= \frac{\sum_{x}\sum_{i}\int_{t_i}^{TOD} a_x . C_x(t-t_i) . dt}{\int_{0}^{TOD} a_{CO2} . C_{CO2}(t) . dt}$$

i: index for each moment of an emission of a substance *x* during the time considered
x: index for each GHG
t_i: moment of an emission (years)
TOD: Total Observation Duration (years)
a_x: radiative efficiency of *x* ($W.m^{-2}.kg^{-1}$ of *x*)
a_{CO2}: radiative efficiency of CO_2 ($W.m^{-2}.kg^{-1}$ of CO_2)
C_x: degradation curve of GHG *x* ($ppb.kg^{-1}$)
C_{CO2}: degradation curve of CO_2 ($ppb.kg^{-1}$)

Environmental impacts assessment of Positive Energy Districts: Quantitative results analysis: Dynamic GWP



Environmental impacts assessment of Positive Energy Districts: Quantitative results analysis: Dynamic GWP



Environmental impacts assessment of Positive Energy Districts: Research Gaps

Complexity of the domain for LCA applications:

- Functional unit definition (PED Definition);
- Methodological uncertainty and lack of homogenous approaches (Territorial LCA / integration with GIS);
- Other uncertainties: Inclusion of transports, industry, Street lighting, Residential (unpredictable) behaviour (energy use, products use, transports), urban metabolism data;
- Data quality and limits of the available inventory datasets.

Environmental impacts assessment of Positive Energy Districts: Research Gaps (Data quality)

Research on LCA for technological applications of NZEBs can be extended also to the district level* . Some specific examples:

- Datasets for modelling specific air-water heat pumps are not available. Proxy are usually used in the practice;
- Pumps, expansion vessels, heat storage tanks, ion-exchanger, flat solar thermal collectors (and all specific technical equipment) are usually modelled by scaling up or down the available LCI on the Ecoinvent 3.6 (specific to the Swiss case);

* Maria Anna Cusenza, Francesco Guarino, Sonia Longo, , An integrated energy simulation and life cycle assessment to measure the operational and embodied energy of a Mediterranean net zero energy building, Energy and Buildings, Volume 254, 2022, 111558, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2021.111558.

Environmental impacts assessment of Positive Energy Districts: Research Gaps (Data quality)

Research on LCA for technological applications of NZEBs can be extended also to the district level* . Some specific examples:

- When enough information is available, datasets are modified while being used as proxies;
- When the information is not available for products and technical systems: only the materials of the main bodies of each device is considered. In the case of e.g. manifolds or valves in the specific case and based on the CAD drawings, it was estimated that the 95% of the total weight was connected to the main body. **Assumptions are developed case by case;**

* Maria Anna Cusenza, Francesco Guarino, Sonia Longo, , An integrated energy simulation and life cycle assessment to measure the operational and embodied energy of a Mediterranean net zero energy building, Energy and Buildings, Volume 254, 2022, 111558, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2021.111558.

Environmental impacts assessment of Positive Energy Districts: Research Gaps (Data quality)

Research on LCA for technological applications of NZEBs can be extended also to the district level* . Some specific examples:

- When assumptions are not reasonably performable, datasets are **excluded** from the analysis. This was the case in * for thermometers and pressure gauges and other sensor equipments.

* Maria Anna Cusenza, Francesco Guarino, Sonia Longo, , An integrated energy simulation and life cycle assessment to measure the operational and embodied energy of a Mediterranean net zero energy building, Energy and Buildings, Volume 254, 2022, 111558, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2021.111558.

Environmental impacts assessment of Positive Energy Districts: Research Gaps (Data quality)

These considerations have been formulated for the single buildings scale.
Similar consideration (of a much wider spectrum) can be formulated for the district scale

A framework for application of Life Cycle Assessment to Positive Energy Districts is being discussed and developed within IEAEBC ANNEX 83 – Subtask C.

* Maria Anna Cusenza, Francesco Guarino, Sonia Longo, , An integrated energy simulation and life cycle assessment to measure the operational and embodied energy of a Mediterranean net zero energy building, Energy and Buildings, Volume 254, 2022, 111558, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2021.111558.

Environmental impacts assessment of Positive Energy Districts: Research Gaps (Data quality)

Energy Generation mixes can also impact severely the results: they are usually based on average calculations extended to a whole year, taking in considerations:

- Technological considerations on the energy generation systems;
- Energy flows at the local level (macro-areas of interest);
- Energy import/export at the national level (e.g. Nuclear energy in Italy);
- All significant environmental impacts are considered per kWh of electricity generated.

Environmental impacts assessment of Positive Energy Districts: Research Gaps (Data quality)

Average electricity mixes are usually used in the common LCA practice.

What happens if the focus becomes **DYNAMIC** (electricity generation mix variable with a hourly detail) rather than staying **STATIC** (average annual national value)?

Environmental impacts assessment of Positive Energy Districts: Conclusions

1. There is a specific **need for a standardized approach** when assessing environmental impacts at district scale, with different scopes and indicators. Since assessment methods have major impacts on the results and their validity, transparent approaches are needed to avoid misleading results that may lead to inaccurate decisions.
2. It is very common to merely mention and calculate KPIs without investigating **trade-offs** between design alternatives. Integrated and systematic analyses to address this aspect should be favored and further investigated;
3. The focus of assessment **should not only be on the operation**, but also on other life cycle stages. For example, **for greenhouse gas emissions, this means not only direct emissions should be considered, but also the indirect emissions** caused by the buildings, infrastructures and activities within the district.

Environmental impacts assessment of Positive Energy Districts: Conclusions

4. In order to avoid shifting burdens between environmental impacts, they should be considered as far as possible in a holistic and integrated manner. **Therefore, the spectrum of indicators for Life Cycle Impact Assessment should not be limited to GWP and/or cumulative energy demand only, but extended to other impact categories** relevant for district planning, such as resource depletion and air-pollution related impacts along the supply chain of materials;

5. **More research is required in the field of LCA at the district level** (Urban metabolism, territorial LCA, system boundaries, temporal horizon, application for **early design**)

6. **Uncertainty and sensitivity analyses are rarely performed** (although highly suggested) and should be therefore addressed with proper methods.

7. Need to take into account for **long-term developments** in technologies and improvements in production processes for the replacement materials, more dynamic approaches, systematic and transparent integration with other modeling scenarios (e.g. energy scenarios) should be investigated (e.g**. dynamic LCA)**

8. **Potential to include spatial constraints and hotspots identification** (GIS integration)

9. Linkage between the **assessment result of PEDs with higher-level environmental targets** (e.g. climate goals at city and national levels/ sustainable development goals) are current missing and should be better addressed.

Thanks

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Electrification of the Built Environment: Designing Future Buildings and Communities
Costa Kapsis

A primary objective of this presentation is to establish an understanding of: smart grid technologies; design and implementation challenges; and effective technical solutions. Another objective is to provide insights into the deployment of smart distributed energy resources (DER) in heat pumps, building integrated photovoltaics, and electric vehicles. The presentation concludes with two case studies: the Evolv1 Office Building (Waterloo, ON) and the Varennes Public Library (Varennes, QC).

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IEA PVPS

Electrification of the Built Environment:

Designing Future Buildings and Communities

Costa Kapsis, PhD, CEE, University of Waterloo

Fall School, September 8th, 2022

UNIVERSITY OF WATERLOO

Learning Objectives

- **Gain an understanding of:**
  1. smart grid technologies
  2. design and implementation challenges, and
  3. effective technical solutions.

- **Provide insights to the deployment of smart distributed energy resources (DER):**
  1. heat pumps (HP)
  2. building-integrated photovoltaics (BIPV), and
  3. electric vehicles (EV)

Acknowledgements

- Natural Sciences and Engineering Research Council of Canada (NSERC)
- International Energy Agency (IEA) Photovoltaic Power Systems Programme (PVPS) Task 15: Enabling Framework for the Development of BIPV
- Waterloo Institute for Sustainable Energy (WISE)
- Centre for Zero Energy Building Studies (CZEBS) – Concordia University
- City of Varennes (case study)
- Cora Group (case study)

Outline

- Electrification Imperatives
- Enabling Demand Flexibility
- Distributed Energy Resources (DER)
  - Heat Pumps
  - Building-Integrated Photovoltaics
  - Electric Vehicles
- Case Studies

Global Building Sector

- **Globally, buildings and construction sector accounts for:**
  - 36% of global final energy use
  - 39% of energy-related Greenhouse Gas (GHG) emissions
- **World's fastest growing energy demand sector (annual growth of 2%)**
- **Towards Carbon Neutral Buildings (NetZCB)**
  - Combustion-free buildings that produce as much energy (from renewable energy sources) as they consume, in an average year
  - Path to success: energy conservation, energy efficiency, renewable energy generation
  - Integration of energy, building and transportation sectors

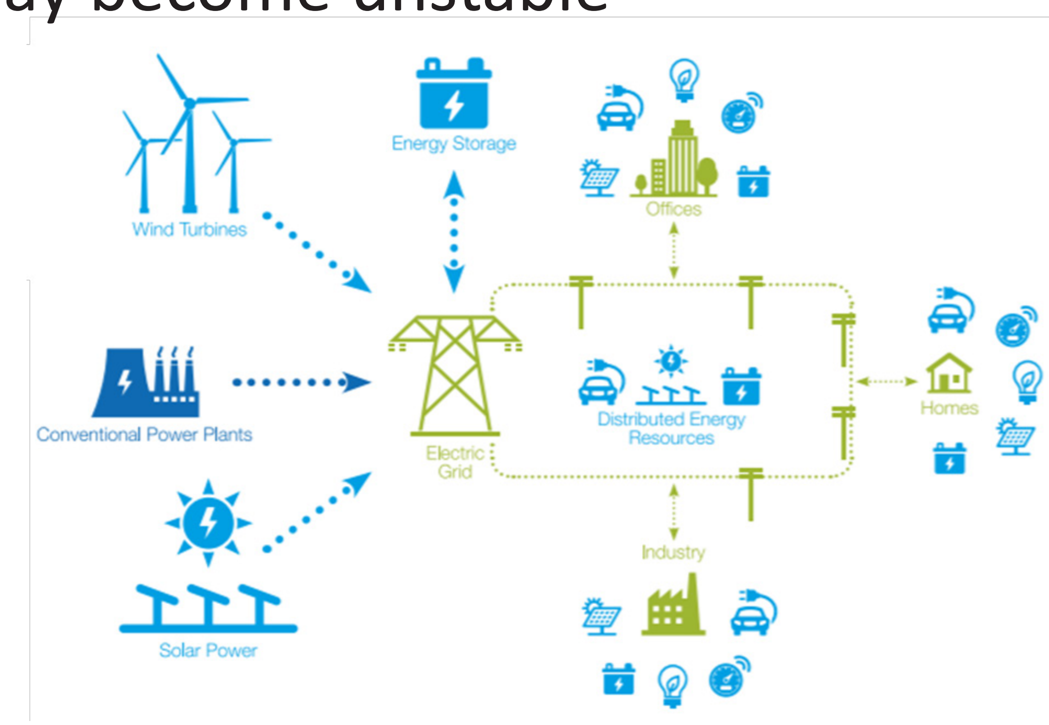
e.g., Canada

- **In Canada, the building sector accounts for:**
  - 28% of secondary energy use
  - 22% of GHG emissions
- **The passenger vehicles account for:**
  - 7% of secondary energy use
  - 6% of GHG emissions
- **Mitigation of climate change**
  - by 2030: Net Zero Energy Ready Buildings (NetZER)
  - by 2040: 100% electric passenger vehicles (EV)
  - by 2050: Net Zero Carbon Buildings (NetZCB)

A smart grid enables the electrification and decarbonization of the building, transportation and energy sectors

Electrification Imperatives

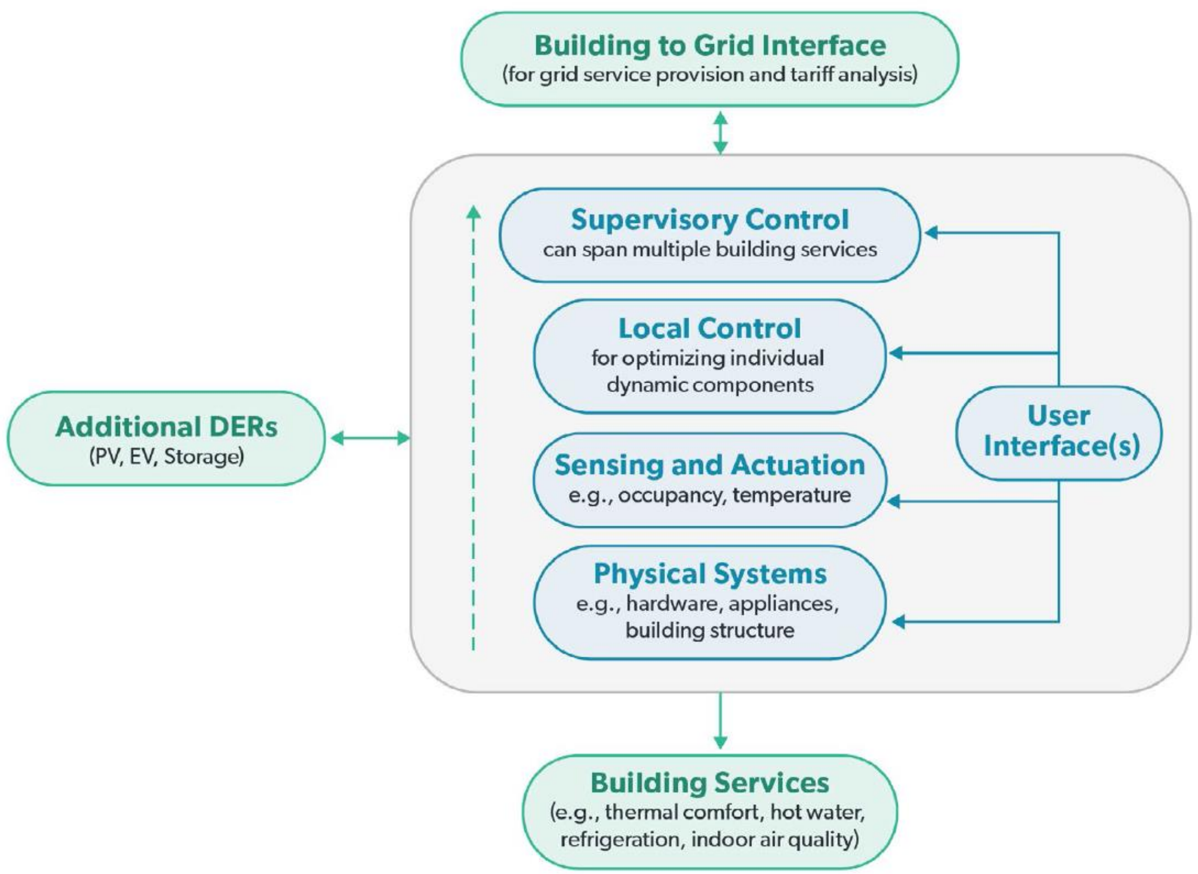
- Switch to cleaner forms of energy as part of a climate change mitigation plan
  (environmental imperative)
- Maintain electricity affordable for all
  (financial imperative)
- Balance electricity generation with load otherwise the grid may become unstable
  (technical imperative)
- Enable integration and interoperability of Distributed Energy Resources (DER) for resilience
  (technological imperative)
- Support the electrification of the transportation sector
  (transportation sector imperative)

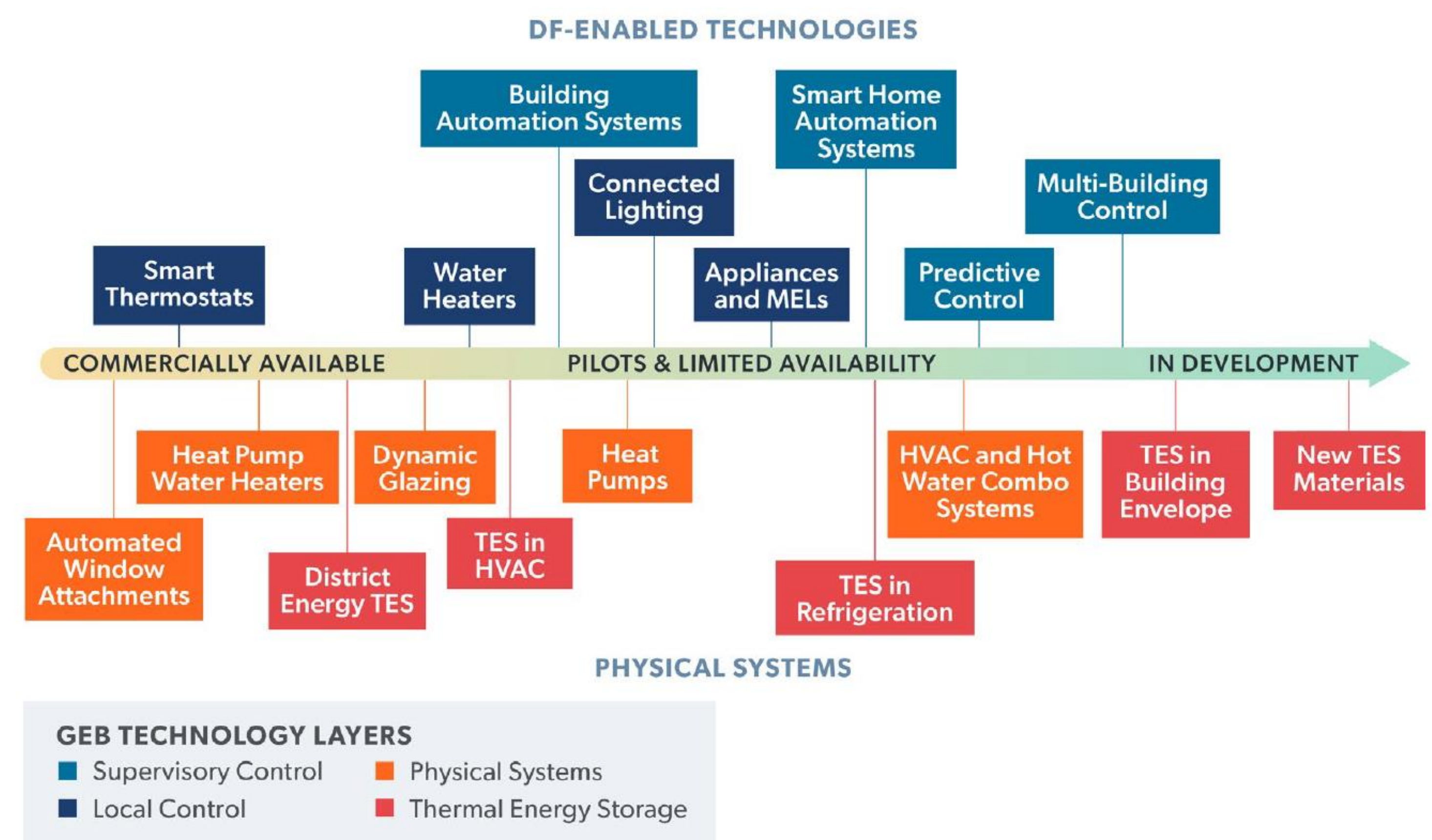


REFERENCE:IEA EBC ANNEX 82, 2020.

Enabling Demand Flexibility

Enabling Demand Flexibility

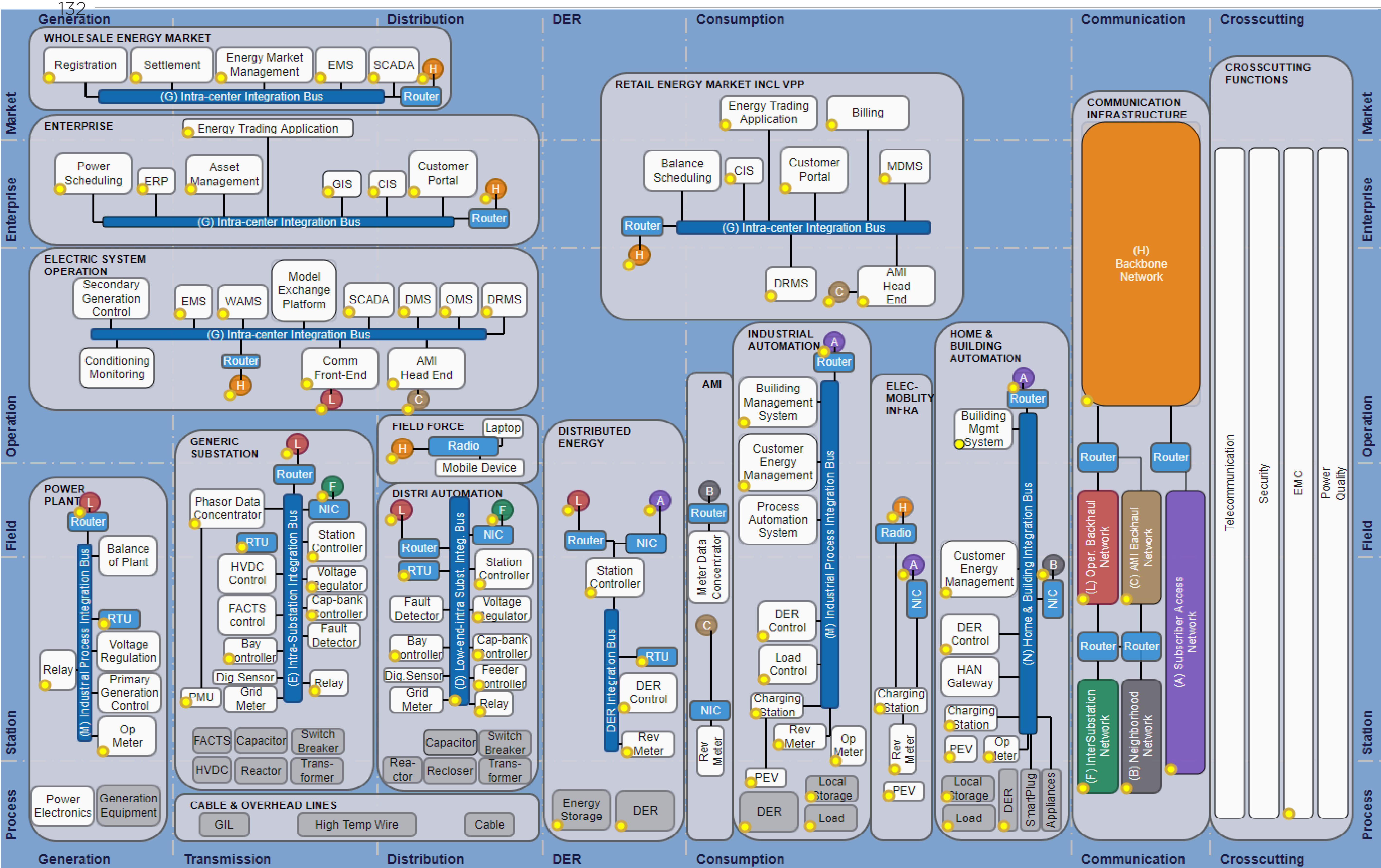




REFERENCE: U.S. DOE, 2021.

- Development of standard metrics and methods to measure and verify demand flexibility and resilience is necessary
- Various layers are required to capture the full potential for demand flexibility
- Connectivity and interoperability between layers and across the grid are essential

IEC Smart Grid Standards Map



REFERENCE: N. PARWAL. 2020. IEC.

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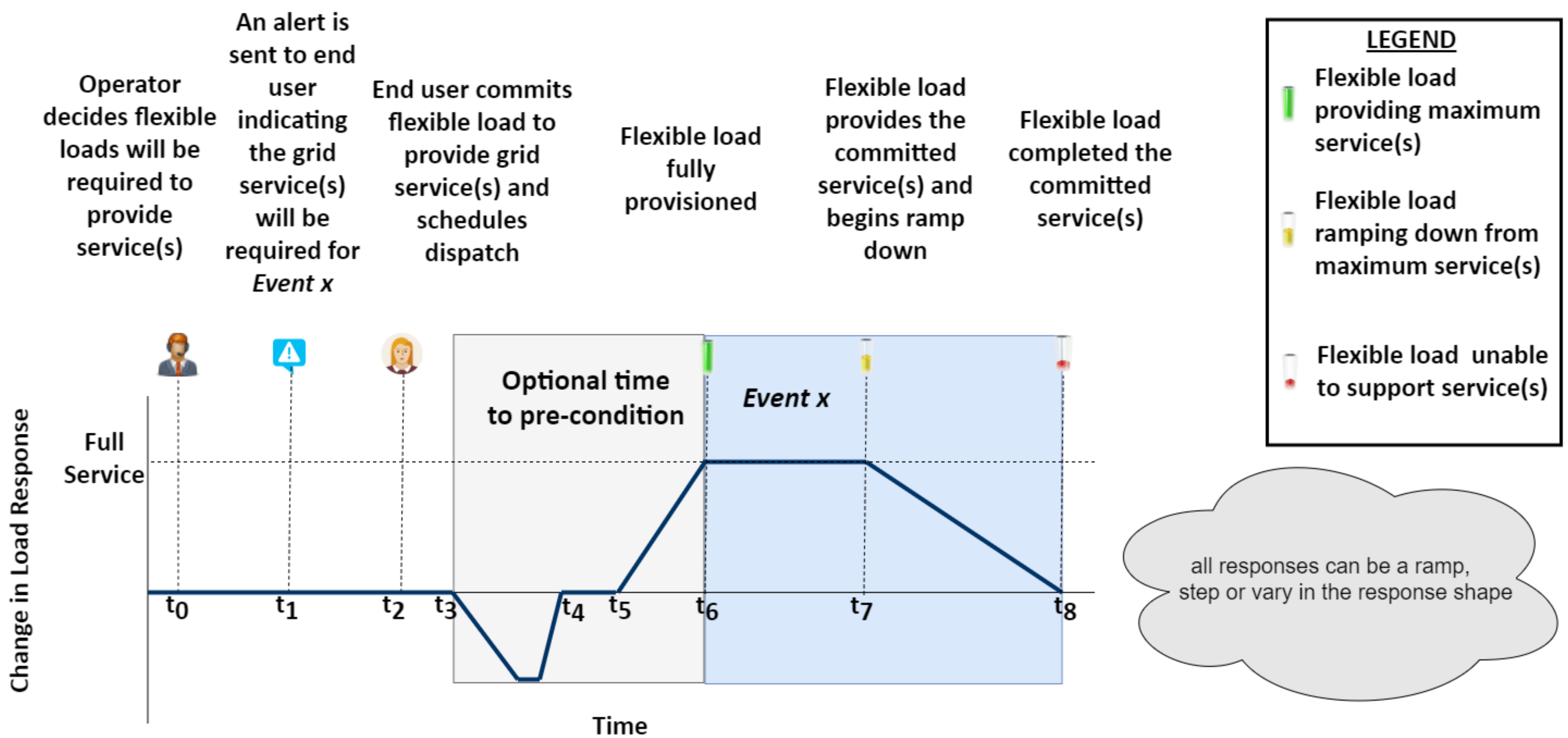
Distributed Energy Resources

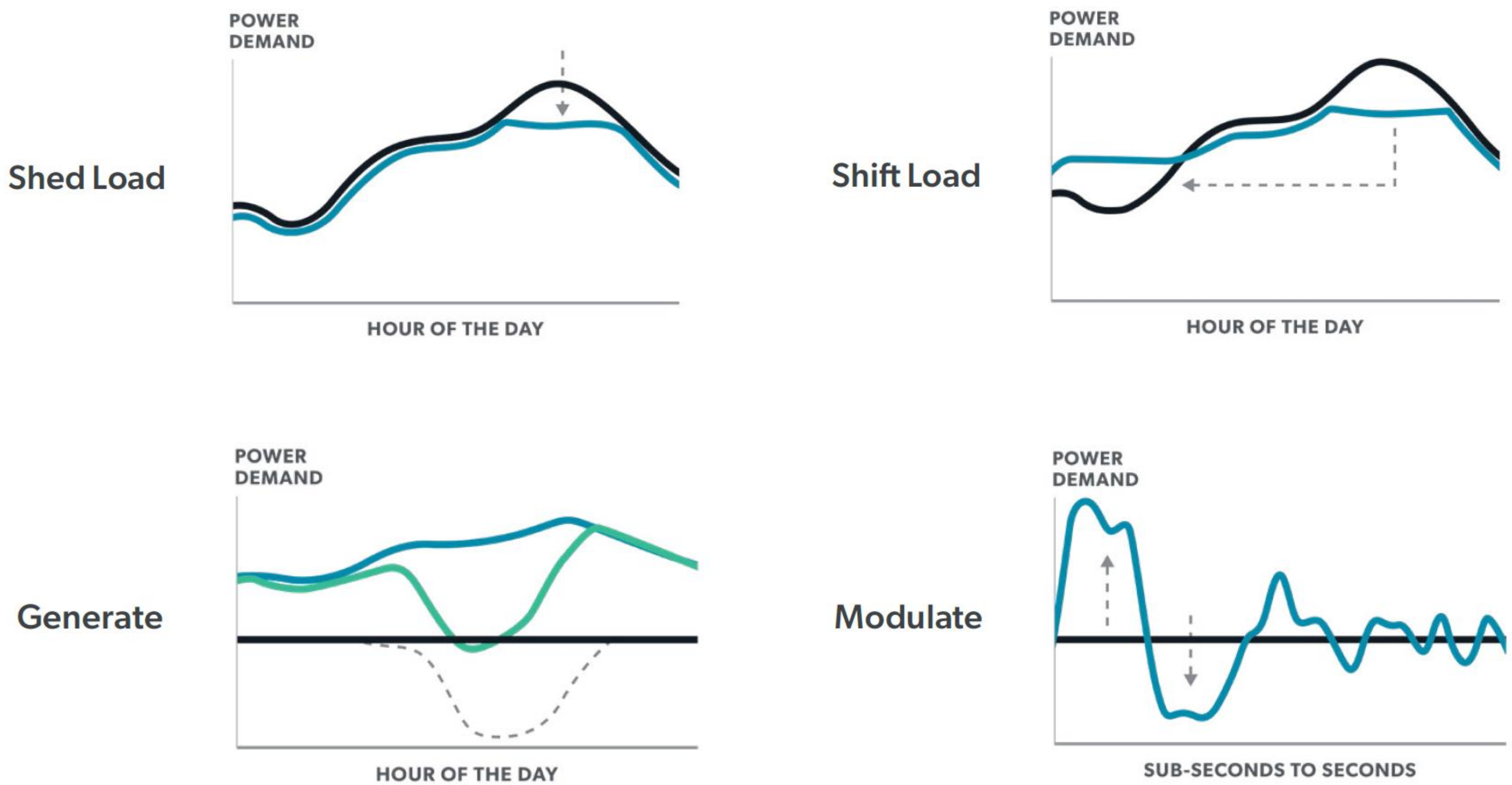
Distributed Energy Resources (DER)



ADAPTED FROM A PRESENTATION BY D. TURCOTTE, NRCAN.

- Simply put, DER is a source or sink of power that is interconnected with the grid, in front or behind a customer meter. These resources may include, but are not limited to, HVAC, thermal and electrical storage, distributed generation and electric vehicles
- From a centralized one-directional energy model to a decentralized bidirectional one

Distributed Energy Resources (DER)

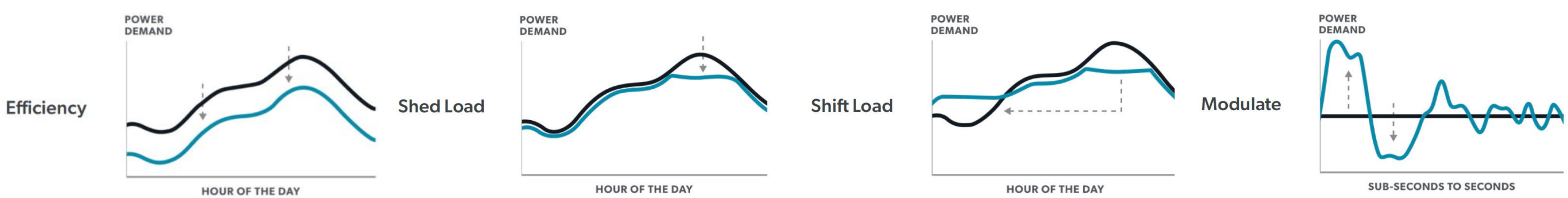


- Depending on the DER, various services to the grid can be provided
- Distributed means (climate and energy) resilient
- NOTE: Energy efficiency measures (e.g., upgrade of the building envelope) continue to be the most cost (and energy) effective action

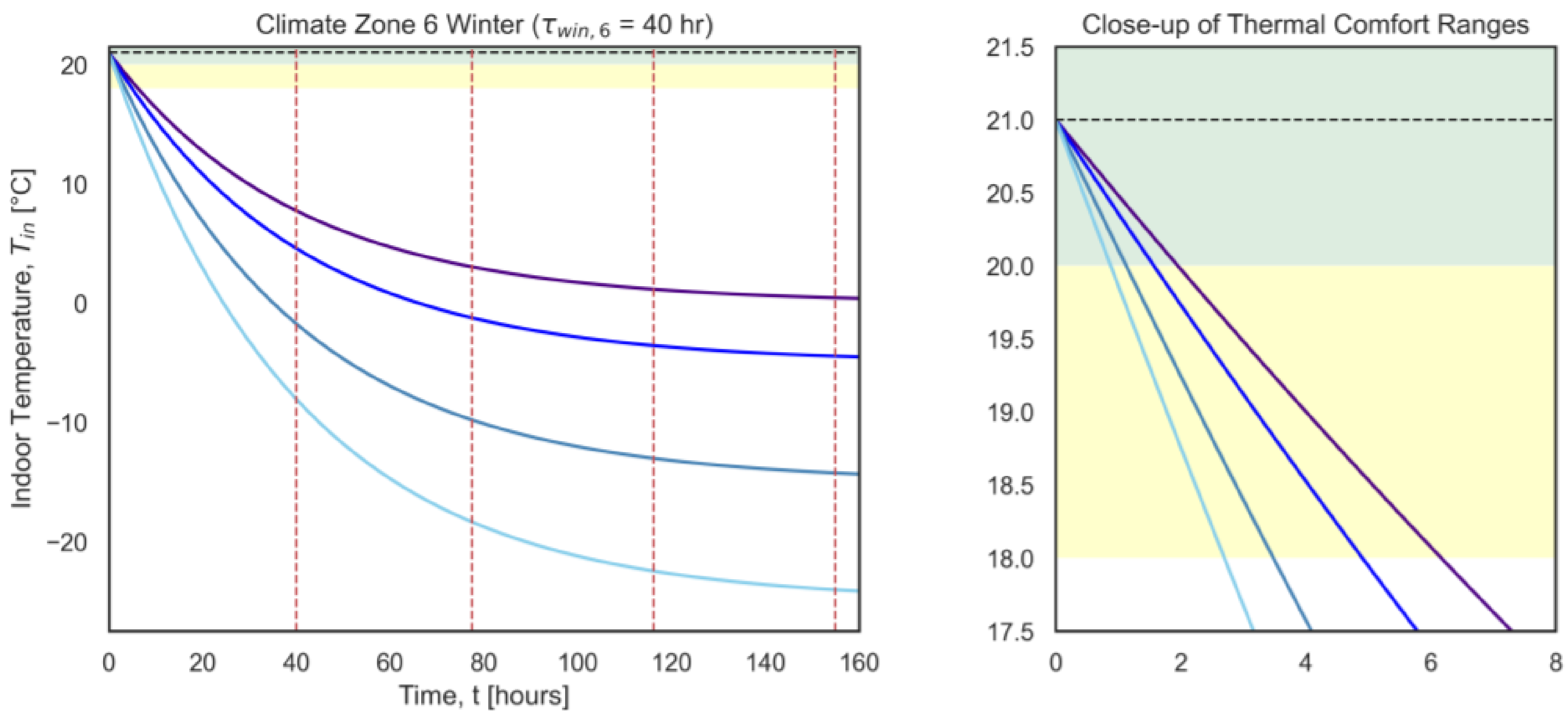
Heat Pumps (HP)

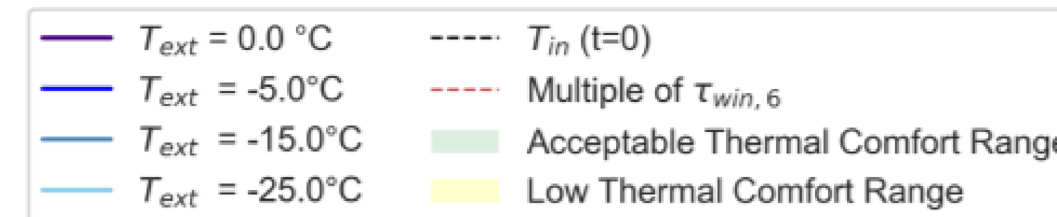
- CO_2 refrigerant HPs: highly efficient systems for space conditioning (heating + cooling), ideal for cold climates with insignificant global warming impact if leaked
- Ground-source HPs: ideal for new commercial, institutional, retail buildings
- Variable Refrigerant Flow (VRF) HPs: ideal for new and retrofit buildings where space for ducting is limited
- Ductless mini-split HPs: ideal for new and retrofit residential applications
- HPs have proven to be a cost-effective solution for new (and occasionally retrofit) applications, enabling electrification, and demand flexibility.

In E.U., HPs are treated (regulatory) as renewable energy resources



Model-Predictive Controls





Inputs

τ_{win}: thermal time constant (winter)

Climate Zone 4 ($\tau_{win,4}$ = 19 hr)
Climate Zone 5 ($\tau_{win,5}$ = 28 hr)
Climate Zone 6 ($\tau_{win,6}$ = 40 hr)
Climate Zone 7 ($\tau_{win,7}$ = 47 hr)

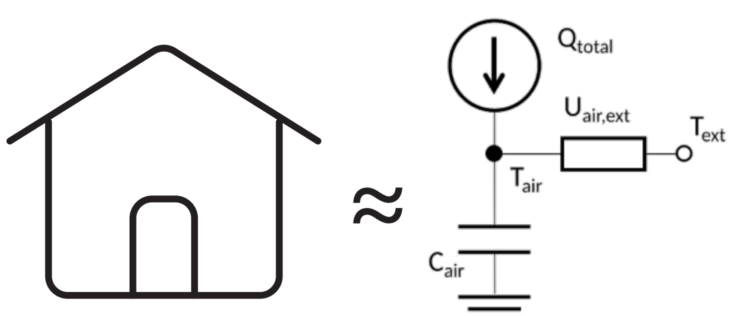
T_{in,t_d}: target temperature (e.g., 18°C)

$T_{in,0}$: initial indoor temperature (e.g., 21°C)

T_{ext}: exterior ambient temperature

Output

t_d: thermal delay (AKA time required for indoor temperature to passively drop from $T_{in,0}$ to T_{in,t_d})



$$= t_d = -\tau_{win} \cdot \ln\left(1 - \frac{T_{in,t_d} - T_{in,0}}{T_{in,0} - T_{ext}}\right)$$

REFERENCE: C. JOHN, 2021, A STUDY OF BUILDING THERMAL DYNAMICS FROM LARGE DATA SETS: AN APPLICATION FOR RESIDENTIAL SMART THERMOSTATS.

Building-Integrated Photovoltaics (generation)





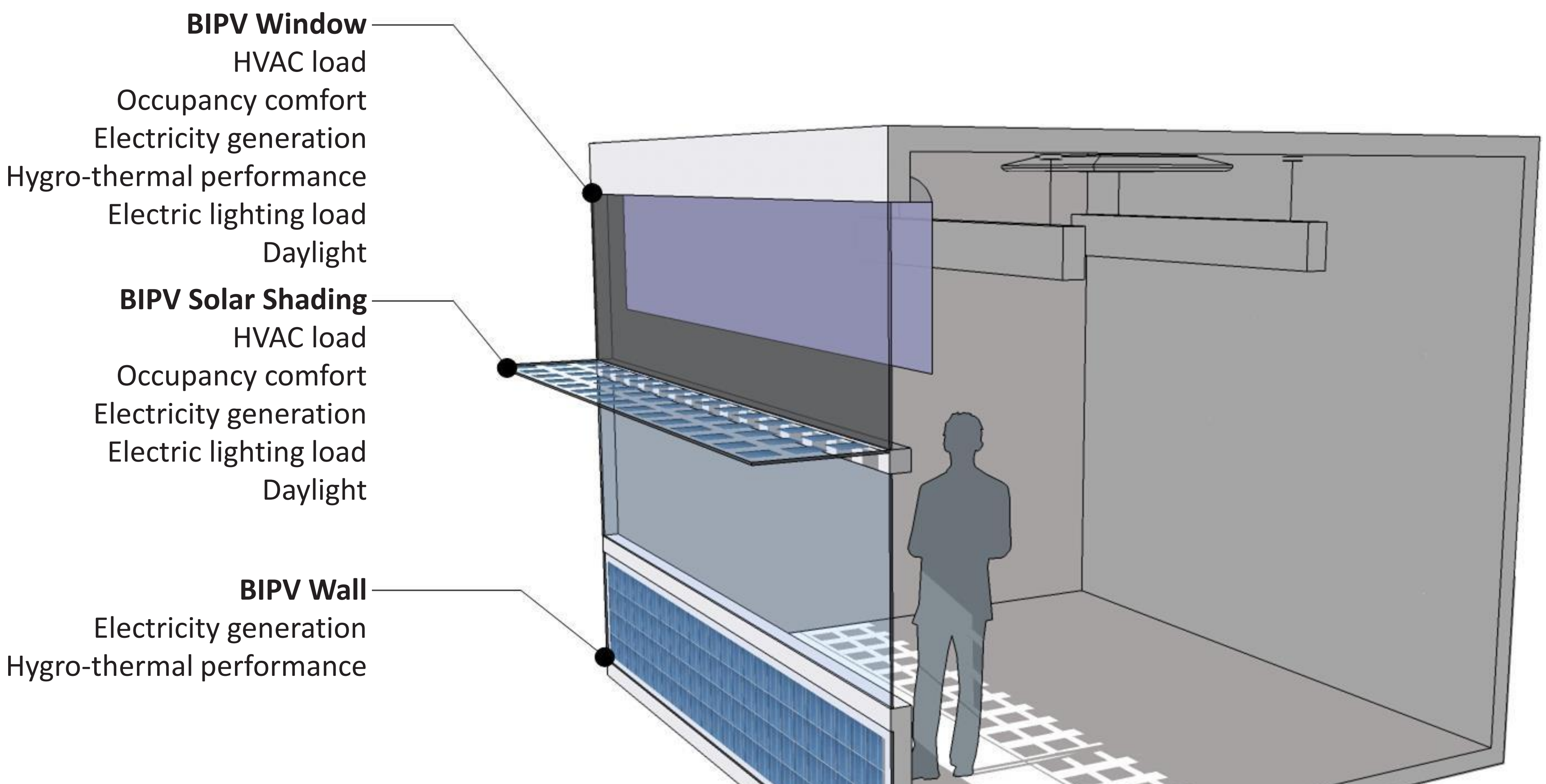


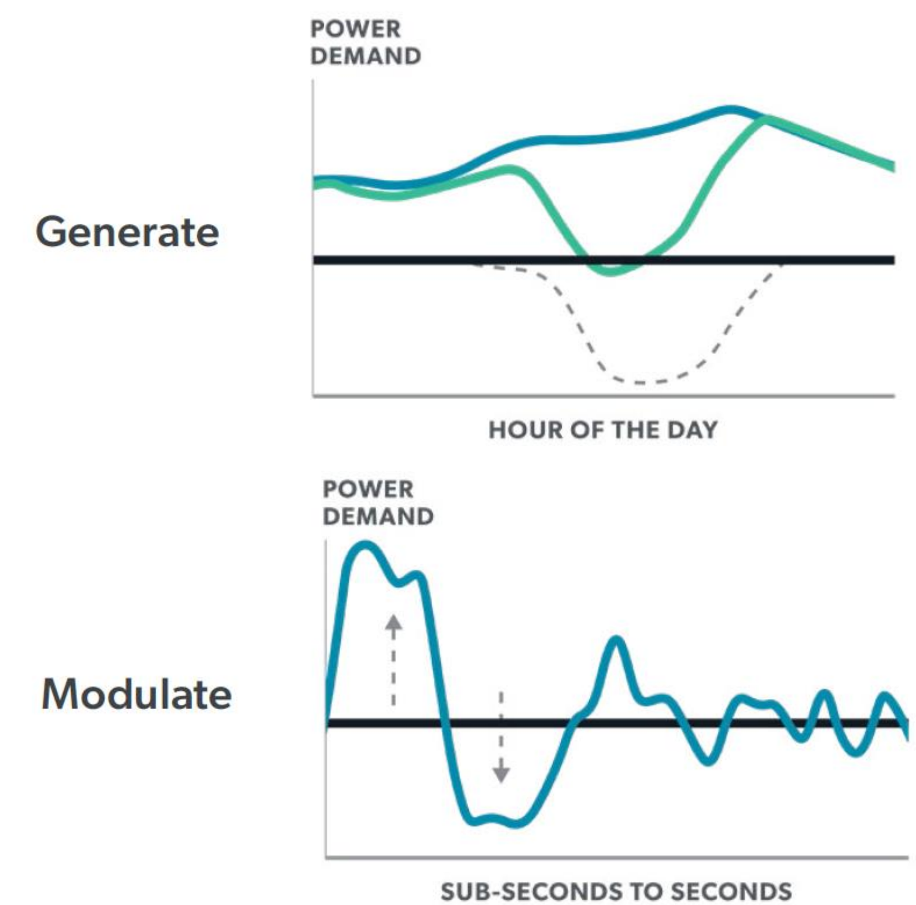






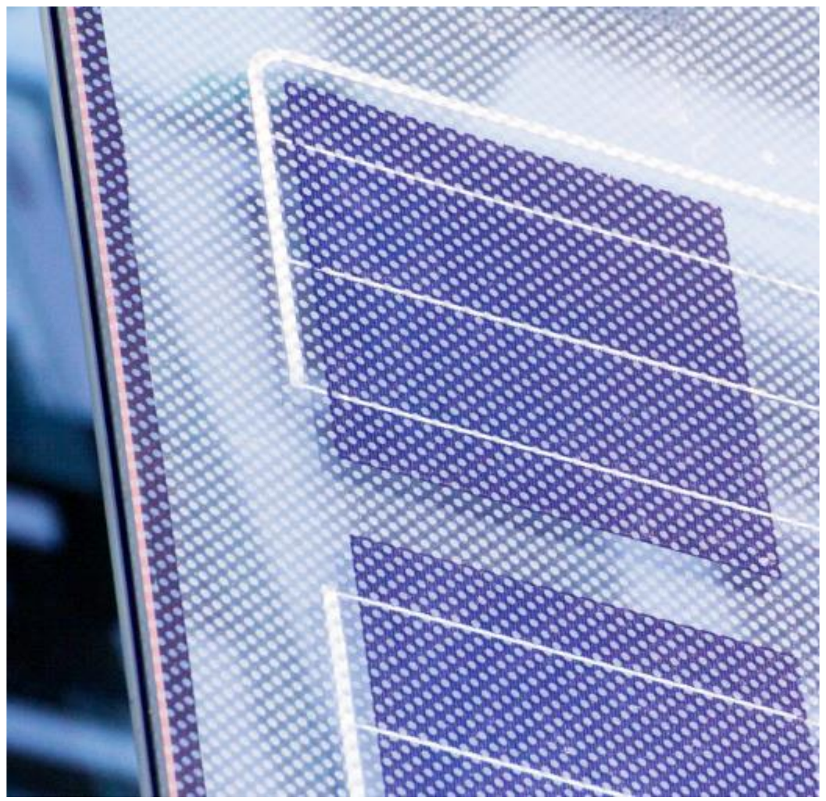
BIPV/Building/Grid Interactions

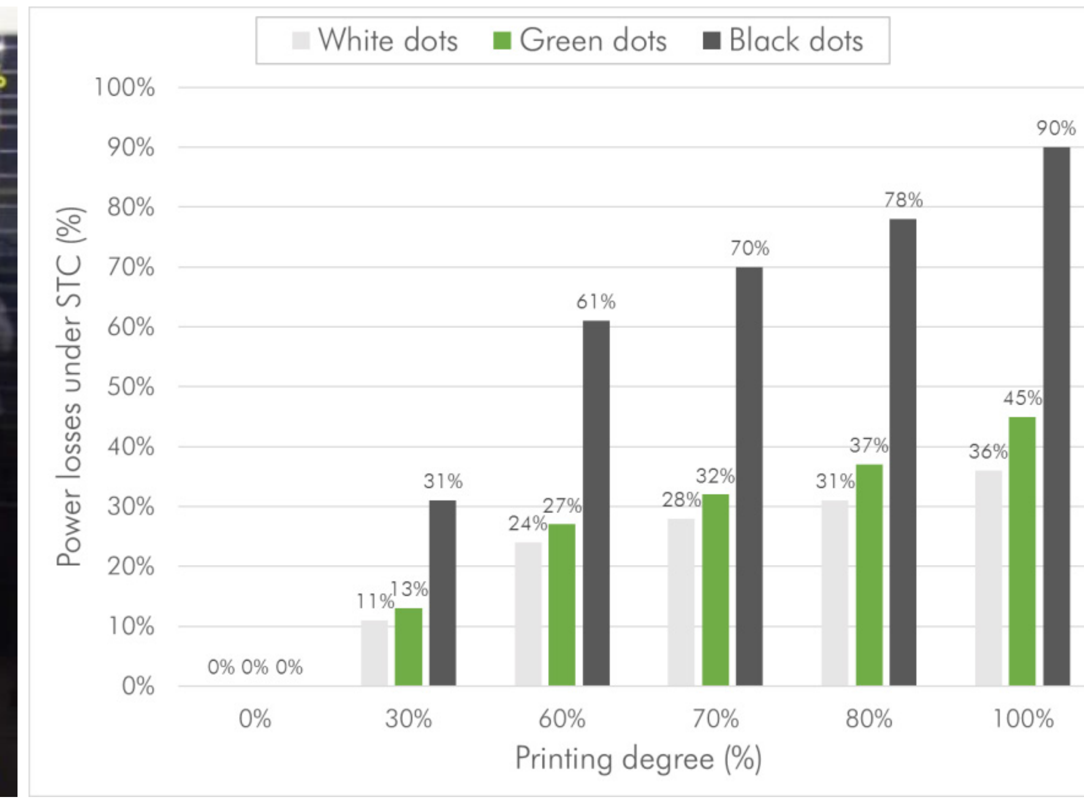




BIPV modules and systems shall comply with building, electrical and fire safety codes.

Photovoltaic Technologies: Colour and Texture



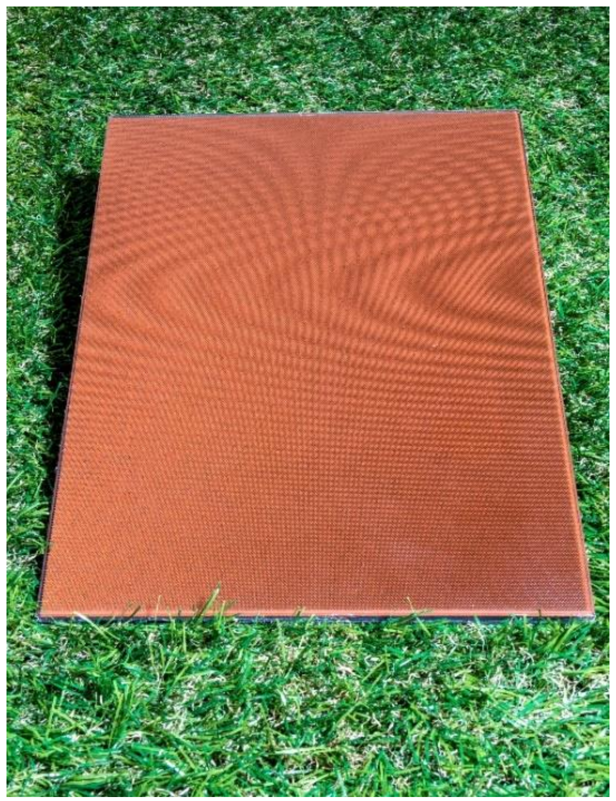


ADAPTED FROM A PRESENTATION BY DR. P. BONOMO, SUPSI.

- Most coatings and printing methods developed for laminated glass can be applied on BIPV
- Applying coatings, prints or etching on BIPV laminated glass reduces electrical efficiency

REFERENCE: IEA PVPS TASK 15. COLOURED BIPV : MARKET, RESEARCH AND DEVELOPMENT

Photovoltaic Technologies: Colour and Texture

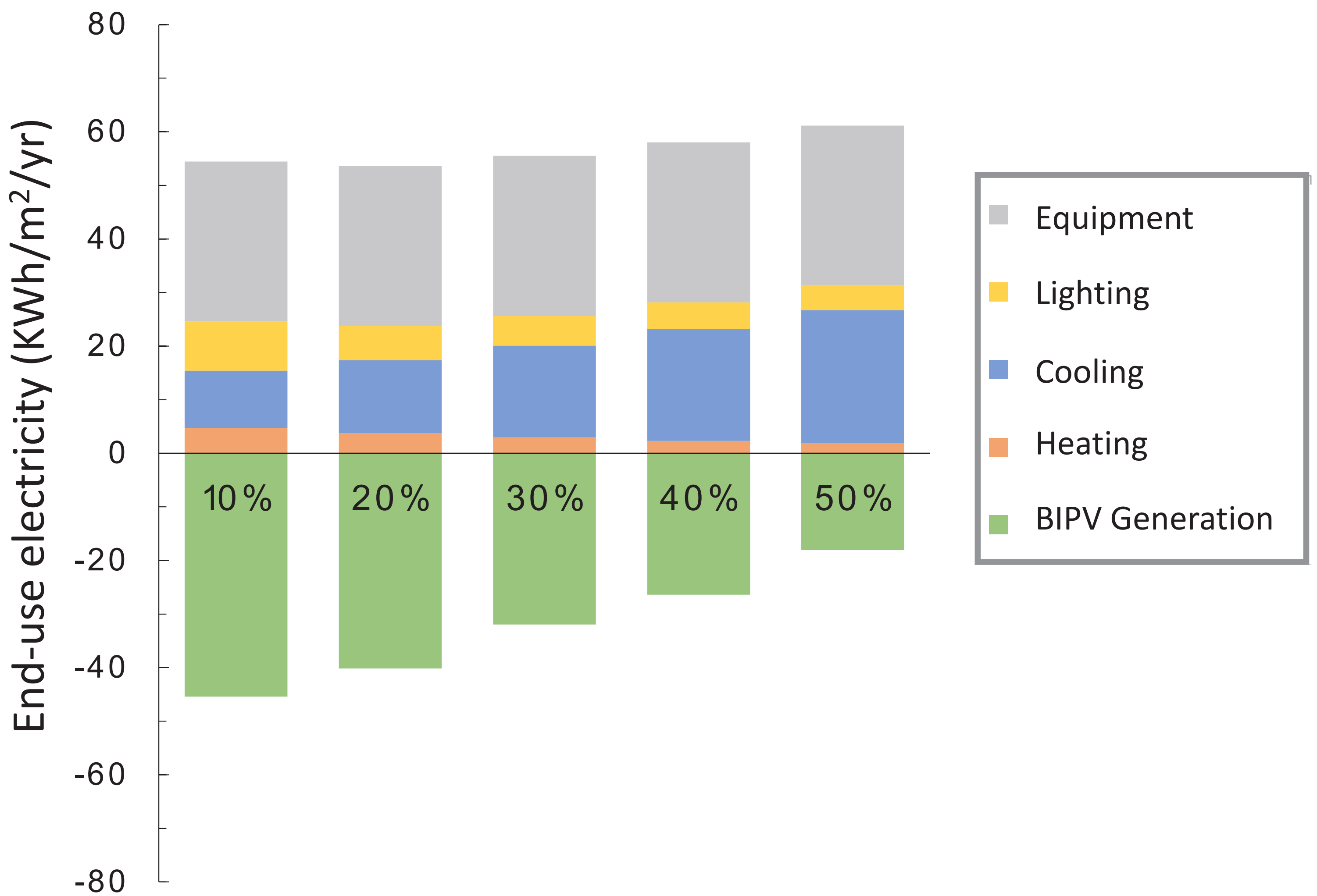



- For glass-based PV solutions, any colour, shape and texture is virtually possible
- Like any building material, customization strongly impacts module prices (per m^2)

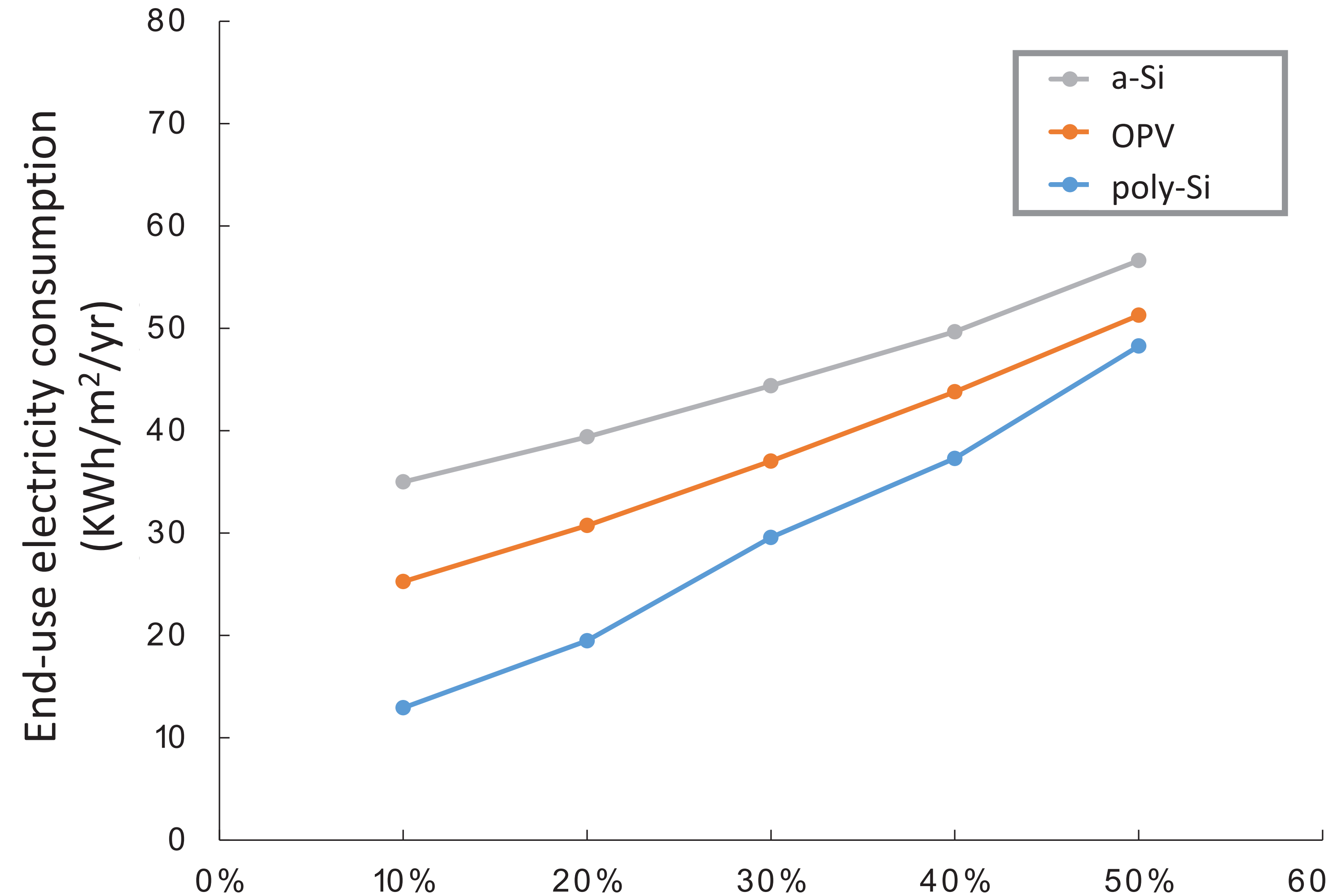
REFERENCE: IEA PVPS TASK 15. COLOURED BIPV : MARKET, RESEARCH AND DEVELOPMENT

Energy Impact Assessment

Analysis for an Office Building in Toronto

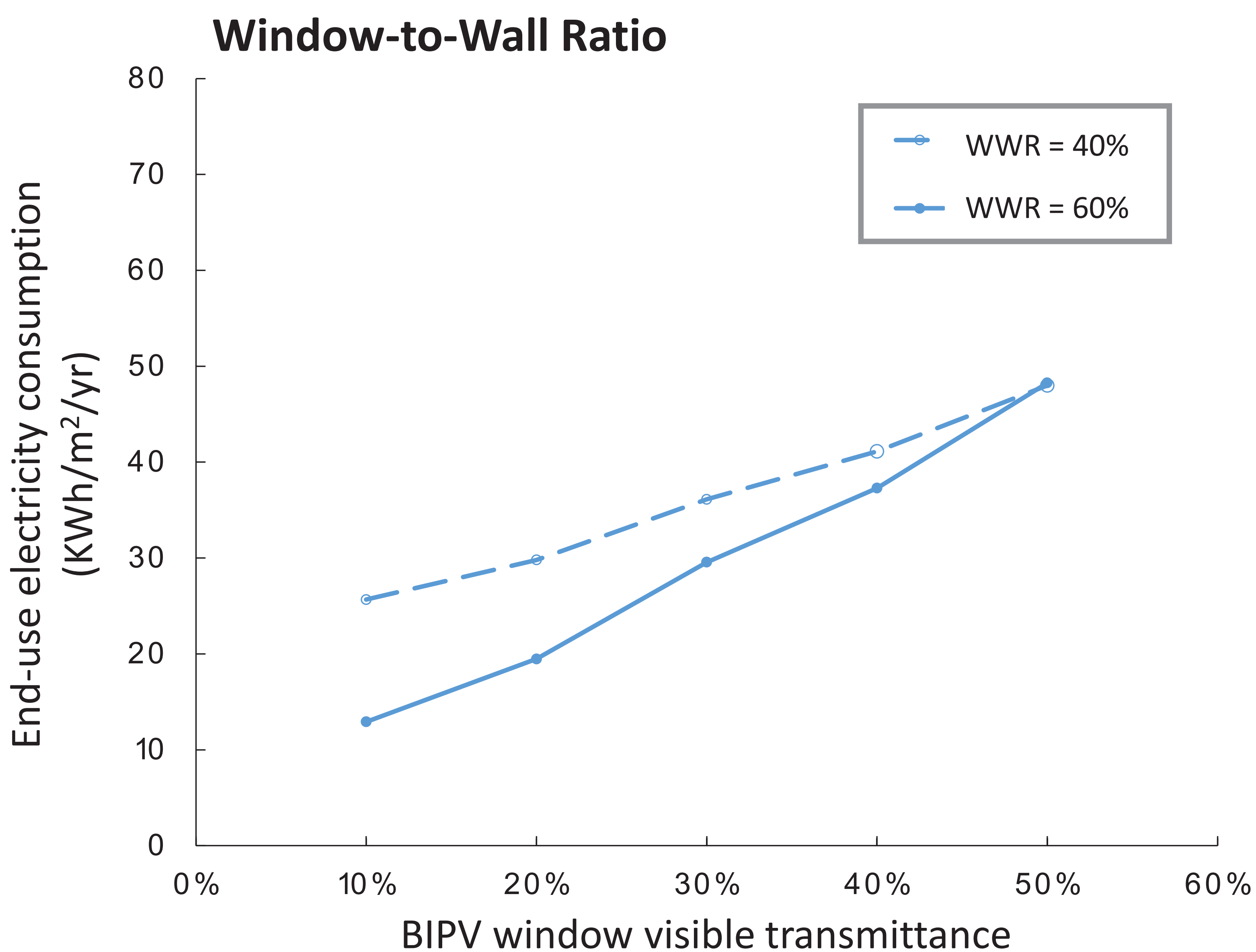


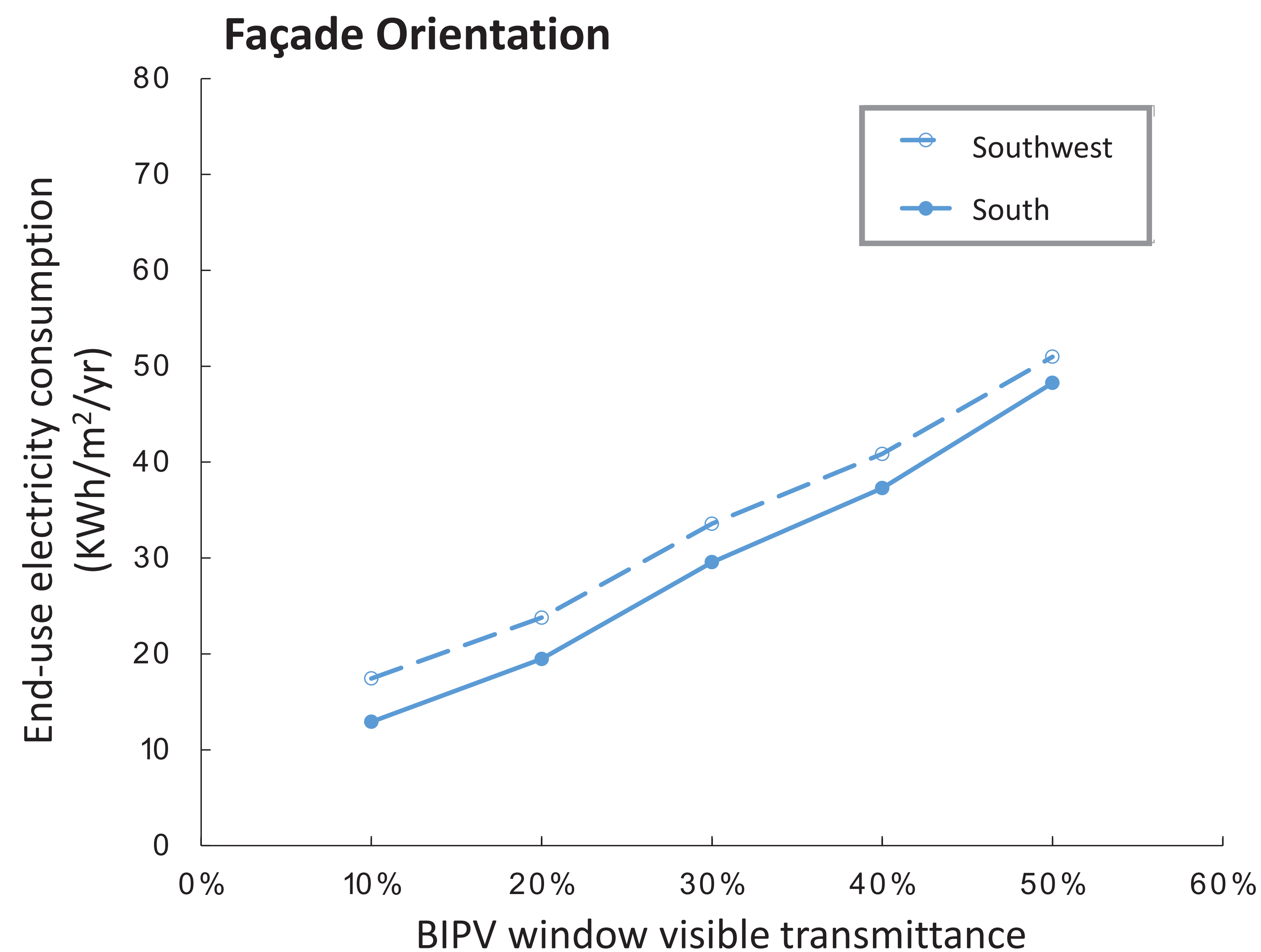
Photovoltaic Technologies



REFERENCE: KAPSIS, K., & ATHIENITIS, A. K. (2015). A STUDY OF THE POTENTIAL BENEFITS OF SEMI-TRANSPARENT PHOTOVOLTAICS IN COMMERCIAL BUILDINGS. SOLAR ENERGY, 115, 120-132.

Energy Impact Assessment

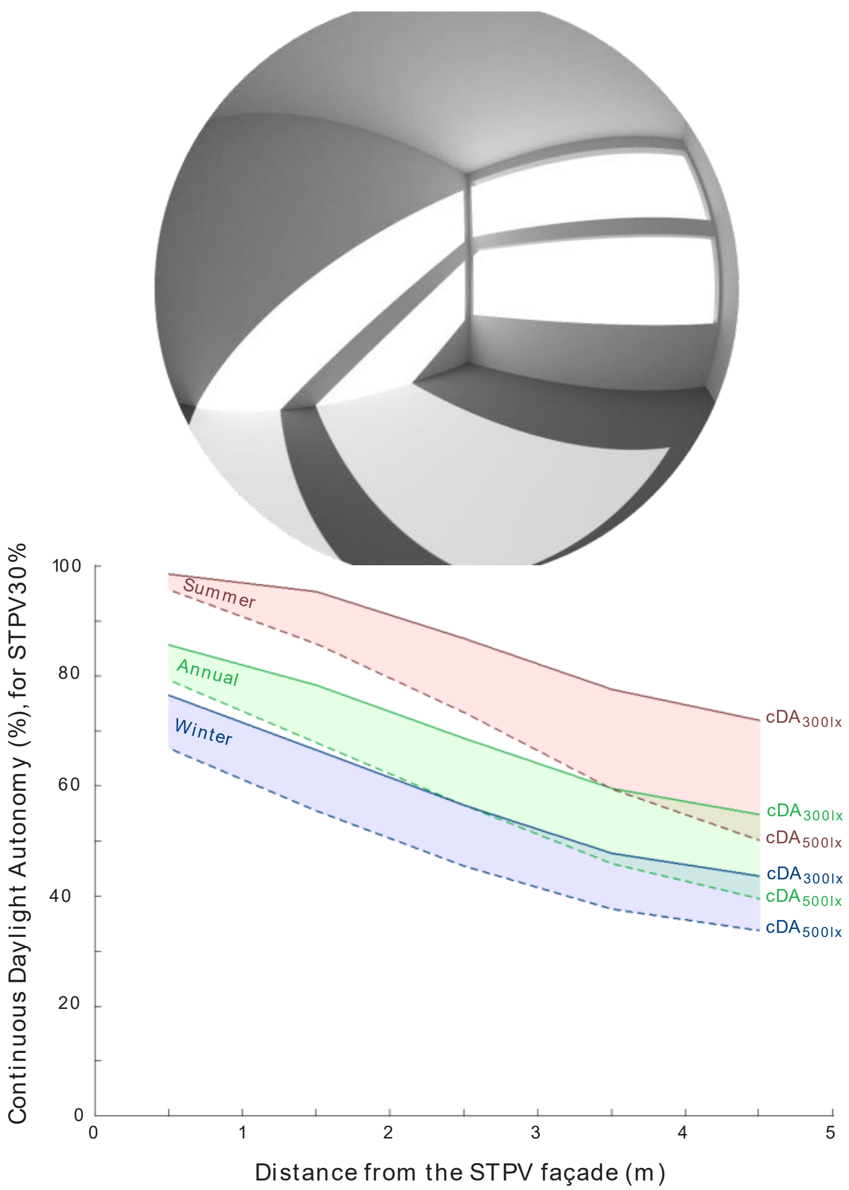




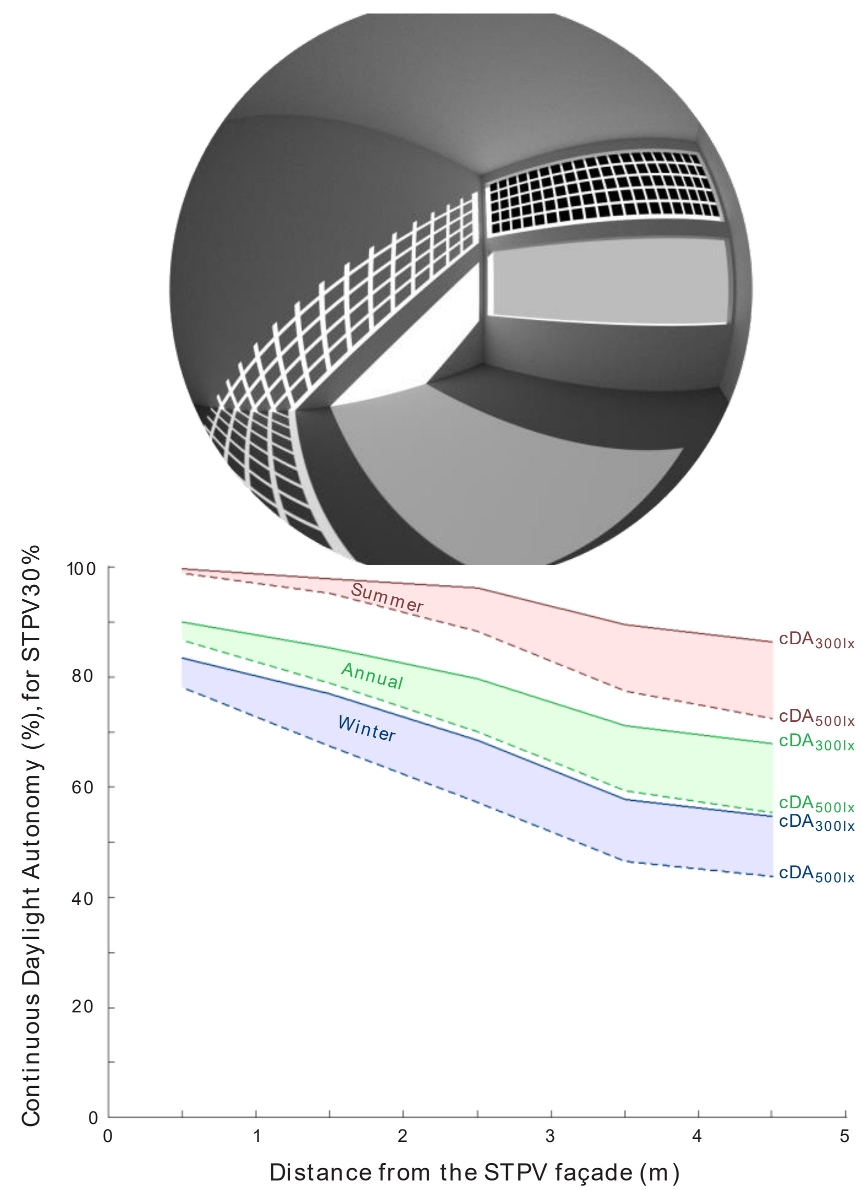
REFERENCE: KAPSIS, K., & ATHIENITIS, A. K. (2015). A STUDY OF THE POTENTIAL BENEFITS OF SEMI-TRANSPARENT PHOTOVOLTAICS IN COMMERCIAL BUILDINGS. SOLAR ENERGY, 115, 120-132.

Daylighting Optimization

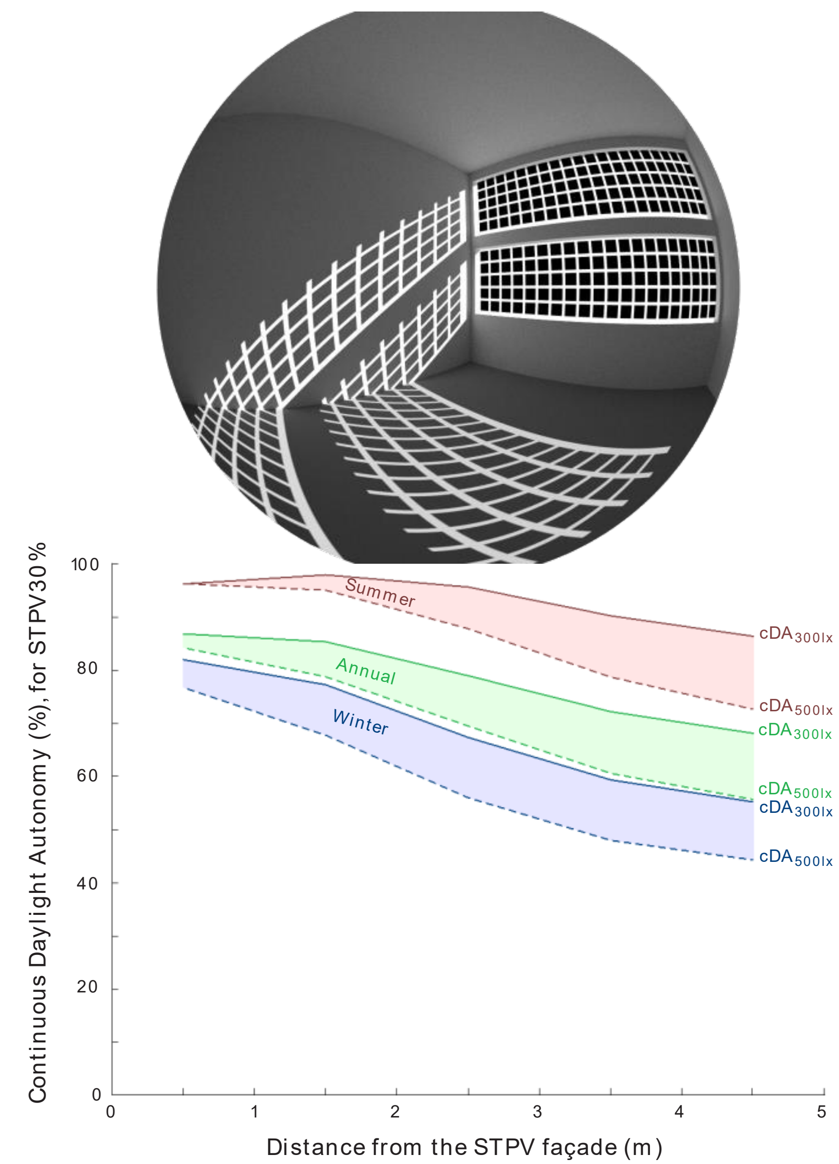
Thin Film



Thin Film & Poly-Si

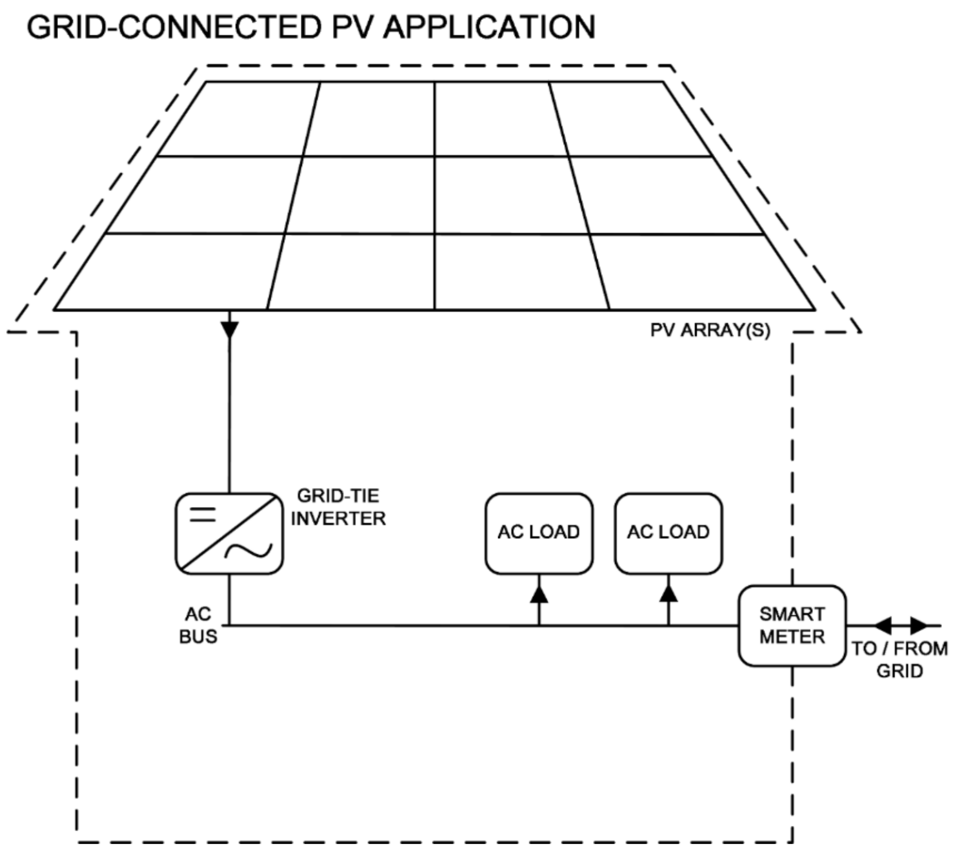


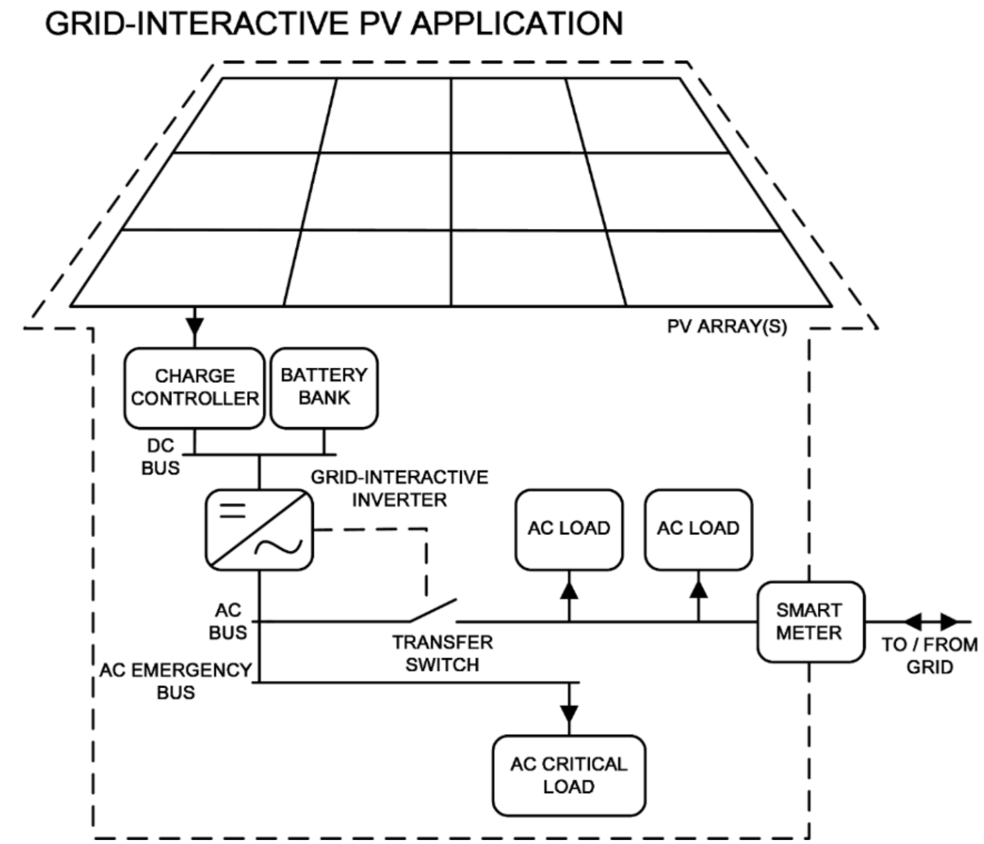
Poly-Si



REFERENCE: KAPSIS, K., DERMARDIROS, V., & ATHIENITIS, A. K. (2015). DAYLIGHT PERFORMANCE OF PERIMETER OFFICE FAÇADES UTILIZING SEMI-TRANSPARENT PHOTOVOLTAIC WINDOWS: A SIMULATION STUDY. ENERGY PROCEDIA, 78, 334-339.

Grid-Connected Photovoltaic Systems

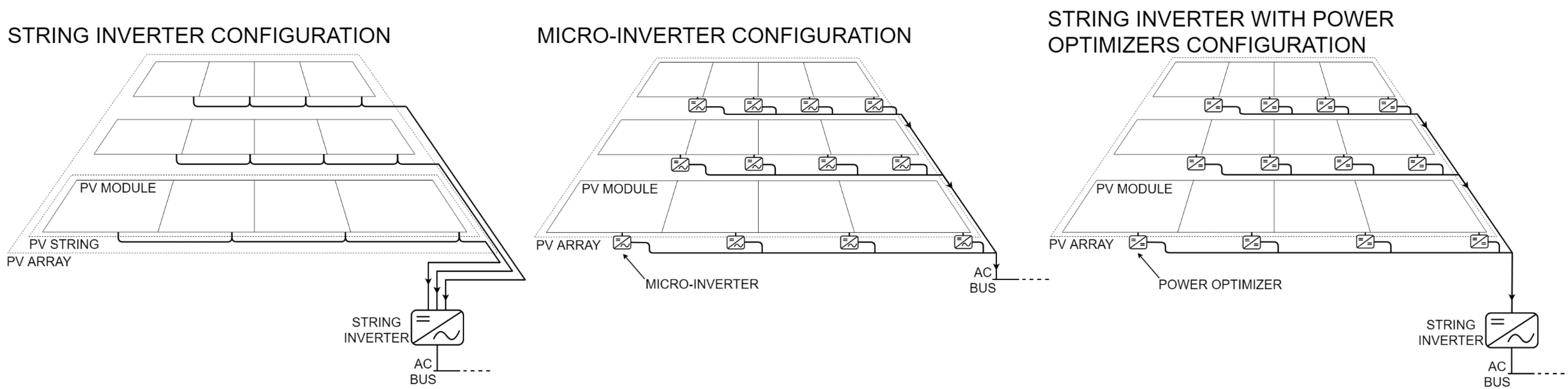




- AKA grid-tie systems (usually no battery storage)
- During a power outage, the system will shut down
- Typically used to reduce energy consumption from the grid (and reduce peak power demand if battery storage is used)

- It can function in an isolated mode (when the grid is down) or in a parallel-to-the-grid mode
- Typically used to reduce energy consumption from the grid, reduce peak power demand and enhance energy resiliency
- Recommended for areas vulnerable to earthquakes, hurricanes, heat waves, ice storms, etc.

Grid-Connected Photovoltaic Systems



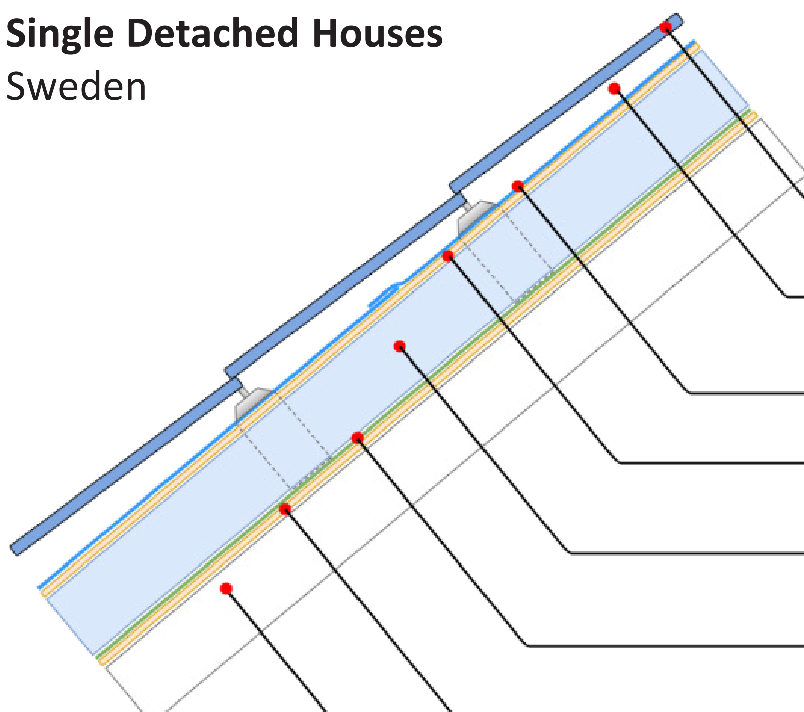
Inverter Configurations

- In the case of a string inverter, several modules are connected in the form of PV strings or arrays
- In the case of microinverters, each individual PV module has its own microinverter
- Occasionally, power optimizers are connected to individual modules, able to optimize the power output of each module

Optimized BIPV Envelope Solutions

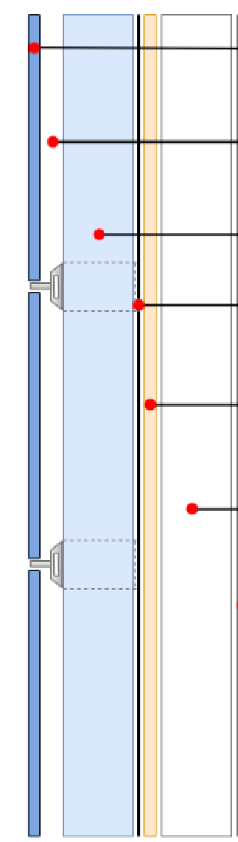
Roof Assembly

Single Detached Houses
Sweden



Wall Assembly

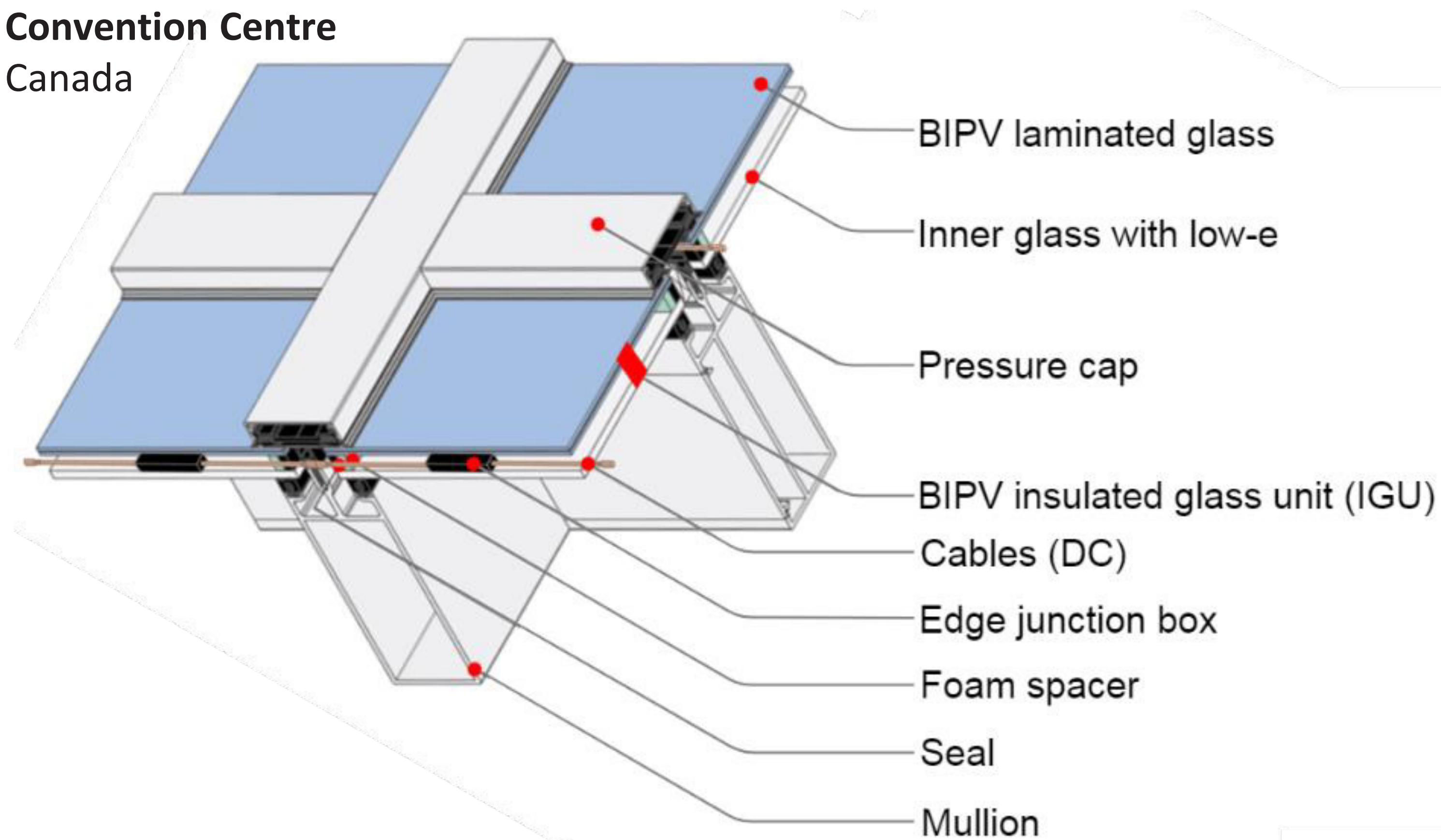
MURB
Switzerland



Optimized BIPV Envelope Solutions

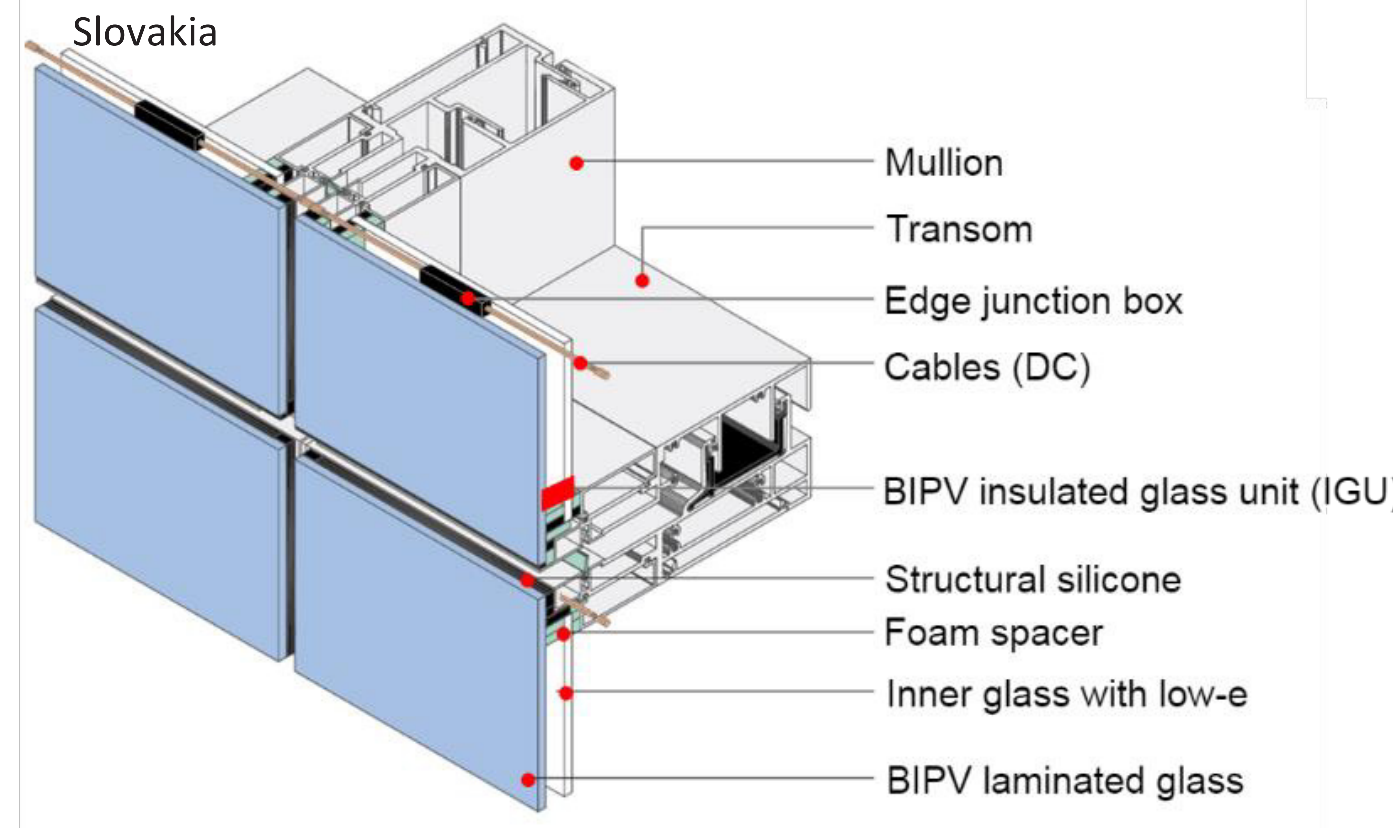
Stick-in Curtain Wall

Convention Centre
Canada



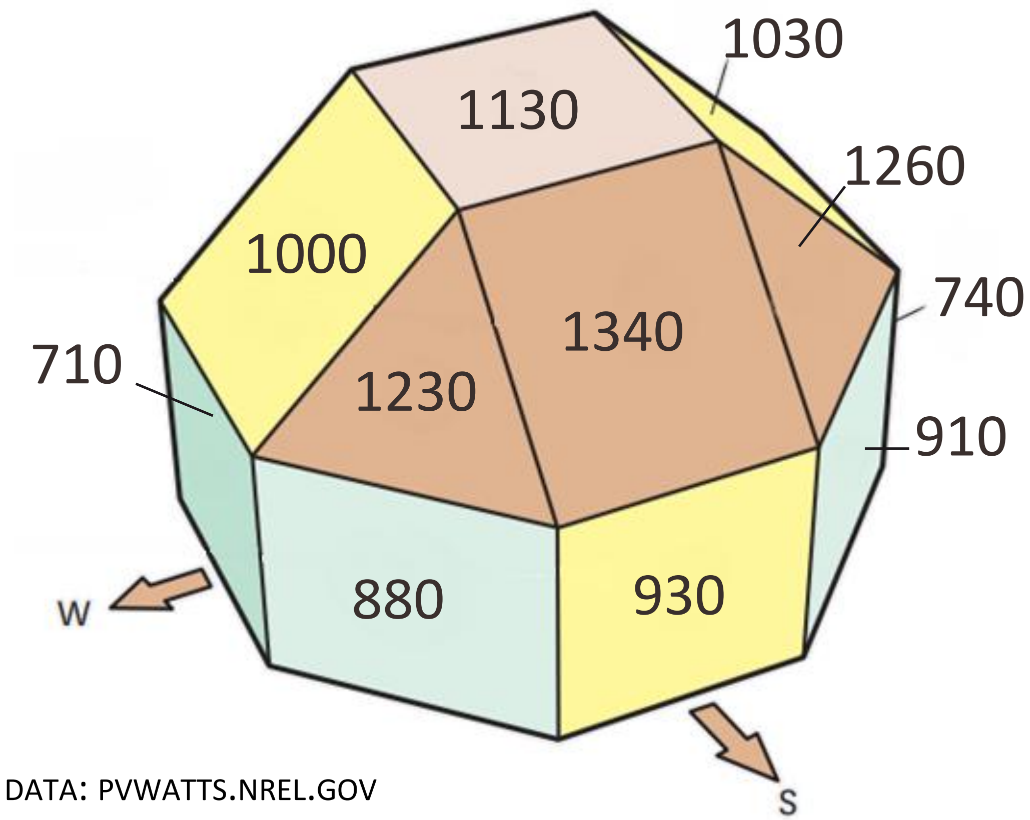
Unitized Curtain Wall

Office Building
Slovakia



Solar Availability Study

Annual Electricity Generation for Toronto (kWh_{AC} / kW_p)



DATA: PVWATTS.NREL.GOV

- Account routine shading (e.g., self-shading, shading due to surrounding buildings and topography
- When possible, also account for temporary shading (e.g., shading due to vegetation, snow, soiling)

Solar Availability Study

From manufacturer's specsheet

- Module electrical efficiency (η)
- Power temperature coefficient (μ)

From typical meteorological weather file

- Ambient air temperature (T_o)
- Incident solar irradiance (S)
- Wind speed at standard 33 ft height (WS)

Operating PV temperature in °C

$$T_{PV} = T_o + S \cdot \exp(a + b \cdot WS) + (S/1000) \cdot \Delta T$$

Solar power generated in W

$$P_{PV} = 0.85 \cdot \eta \cdot [1 + \mu \cdot (T_{PV} - 25)] \cdot S \cdot A_{PV}$$

REFERENCE: 2019 ASHRAE HANDBOOK – HVAC APPLICATIONS

Type of PV Application	a	b	Δt
Open rack PV, BAPV or BIPV with good rear ventilation	−3.47	−0.0594	3
BAPV or BIPV with medium rear ventilation	−2.98	−0.0471	1
BAPV or BIPV with poor rear ventilation	−2.81	−0.0455	0
Double glazing BIPV window with low-e coating	−2.85	−0.0351	9
Triple glazing BIPV window with low-e coatings	−2.88	−0.0319	11

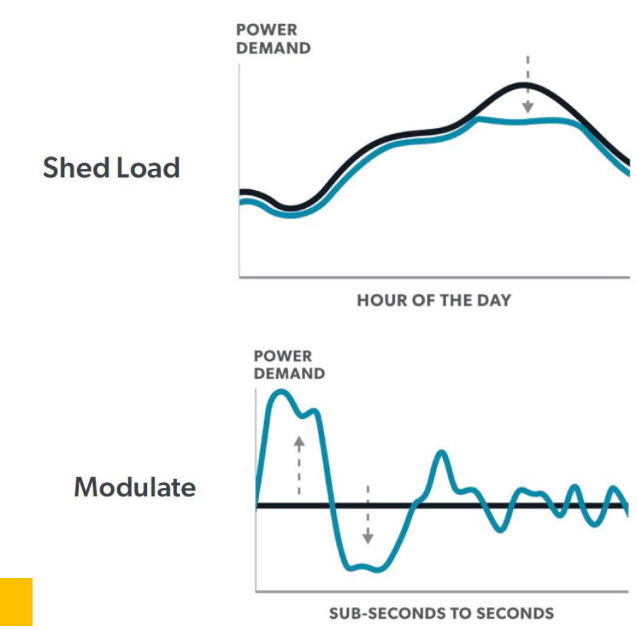
Electric Vehicles (demand + storage)

Electric Vehicles (unidirectional)

- EV is likely to increase the evening peak loads due to residential charging
- if EV are treated as DER, they create a demand-side opportunity whose full potential is yet to be realized
- EV can provide load balancing by charging when grid is underutilized
- Despite regulatory and infrastructure gaps charging networks have moved beyond pilot stage
- Charging Levels
  - AC Level 1: up to 1.92 kW (residential applications)
  - AC Level 2: up to 19.2 kW (residential and commercial applications)
  - DC Level 1 : up to 80 kW (transportation corridor)
  - DC Level 2: up to 400 kW (transportation corridor)

Electric Vehicles (unidirectional)

- Typical driving mileage per day is ~45 km (~28 miles)
- Average EV range is ~380 km (~240 miles)
- If EV regulations allow bidirectional flow
- Prediction scenarios: By 2040, 1/3 vehicles on the road to be EV
- Research indicates that even without vehicle-to-grid power flow, EV have the potential to:
  - Reduce GHG emissions by replacing conventional vehicles
  - Enable greater integration of renewables – including BIPV – by reducing curtailment of renewable production
  - Flatten the daily electricity demand profile in buildings.



Case Studies

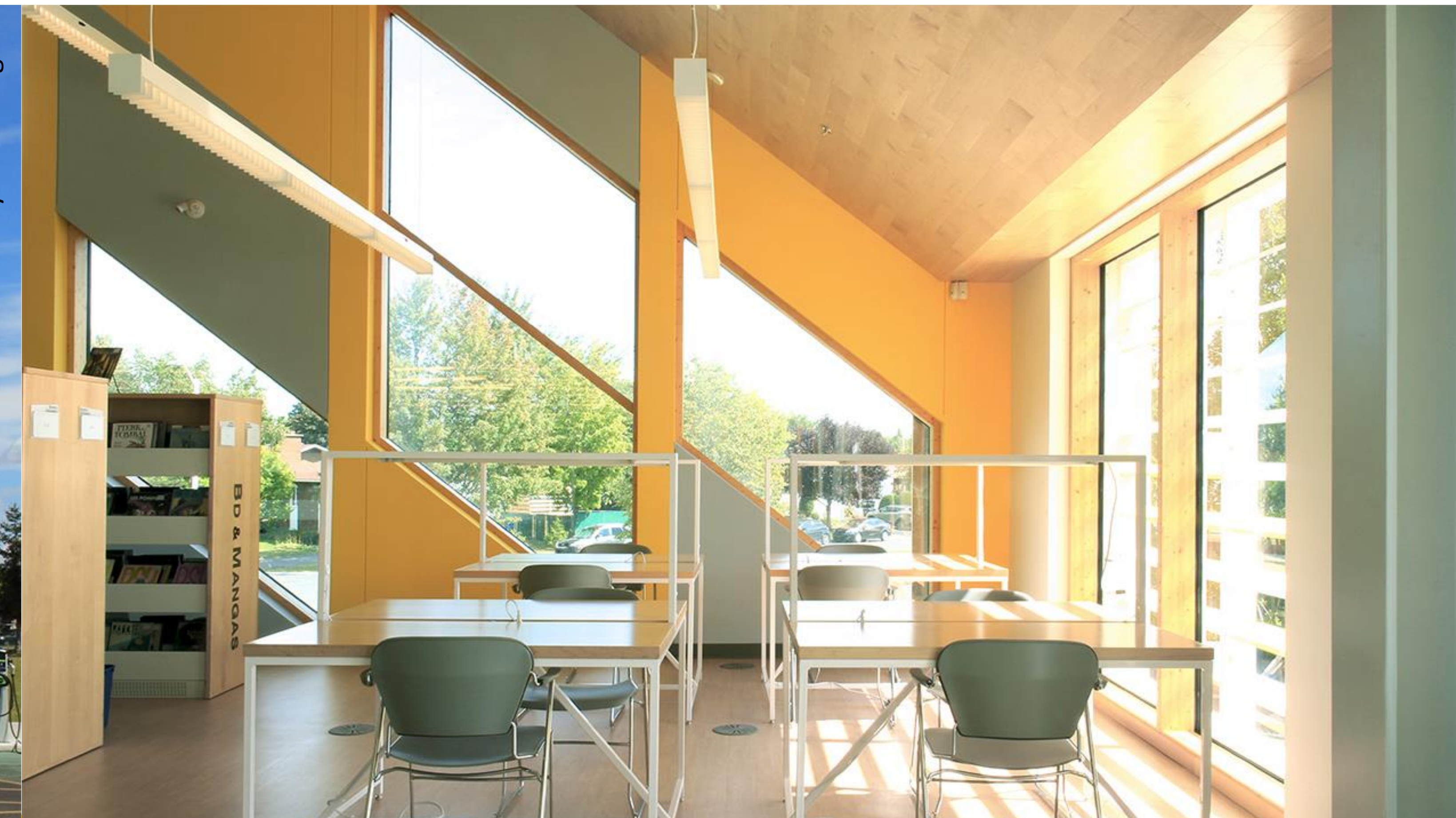
Evolv1 Office Building, Waterloo, ON


Courtesy of: Cora Group

- R-30 walls, R-40 roof, WWR~37% with exterior solar shading
- Operable windows for natural ventilation
- Space conditioning through water-cooled VRF heat pumps
- Open-loop geo-exchange system
- Building-integrated solar collector for preheated fresh air

- 770 kWp PV parking canopy & rooftop PV
- EV charging
- **EUI:** 81 kWh/m^2/year
- **TEDI:** 24 kWh/m^2/year
- **Peak Demand:** 389 kW (winter)

Varennes Public Library, Varennes, QC

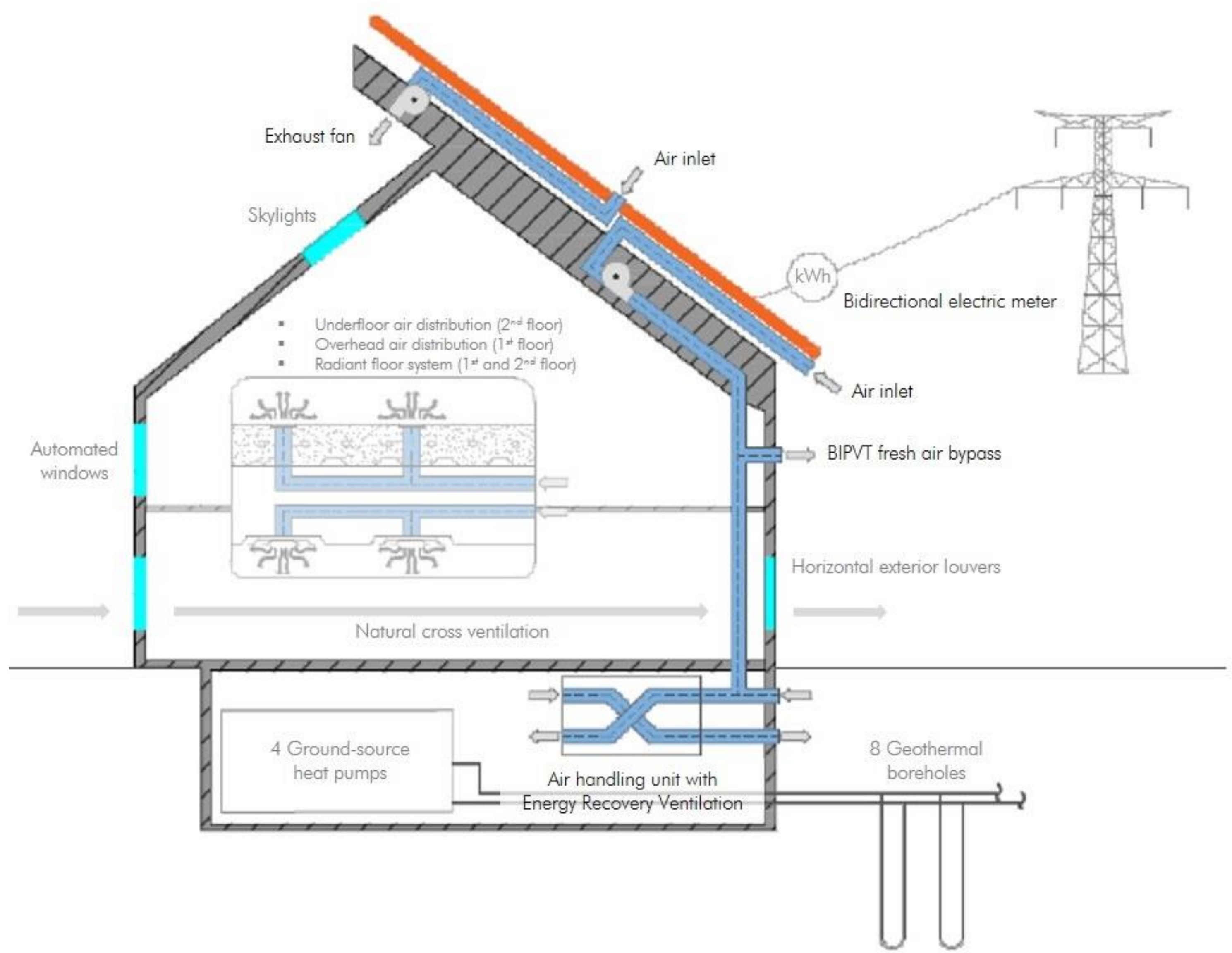


- R-30 walls, R-48 roof, WWR~30% with exterior solar shading
- Operable windows for natural ventilation
- Ground-source heat pumps with a total capacity of 40 tons
- Primary space conditioning through a hydronic radiant slab
- Solar heat recovery from the BIPV roof for preheated fresh air

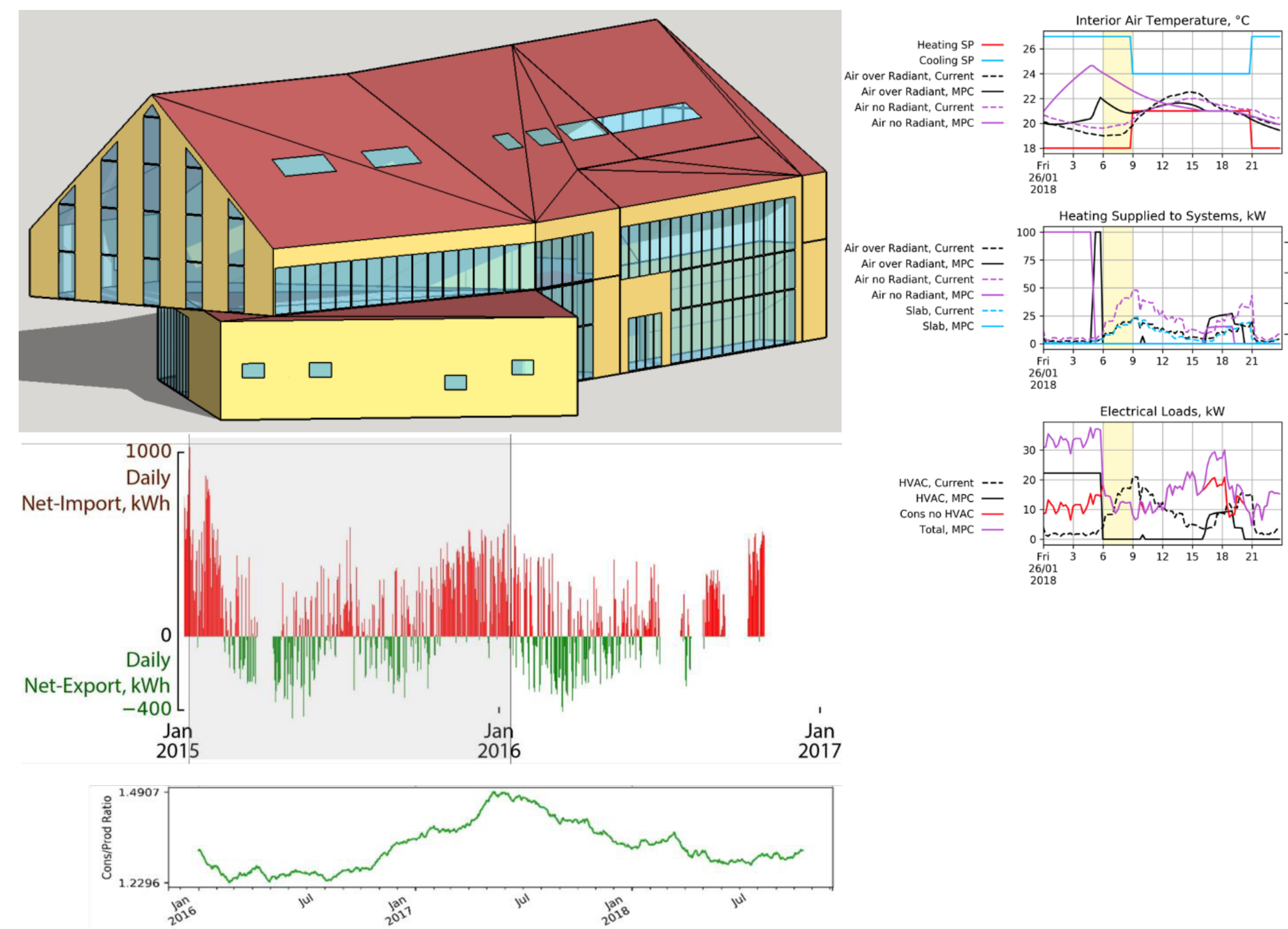
- 120 kWp BIPV/Thermal roof
- EV charging
- **EUI:** 70 kWh/m^2/year
- **TEDI:** 20 kWh/m^2/year
- **Peak Demand:** 80 kW (summer)

Varennes Public Library, Varennes, QC

Conceptual Design



Building Performance Simulations



REFERENCE: V. DERMARDIROS, 2020, DATA-DRIVEN OPTIMIZED OPERATION OF BUILDINGS WITH INTERMITTENT RENEWABLES AND APPLICATION TO A NET-ZERO ENERGY LIBRARY.

Questions?

email: costa.kapsis@uwaterloo.ca

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA PVPS

Economics of Solar Neighborhoods and Evaluation Techniques
Kuljeet Grewal

This presentation is comprised of five parts. It begins with an introduction to solar strategies and technologies, identifying and comparing different types of solar panels. This is followed by a discussion of the concept of energy payback time (EPBT), then an examination of economic analysis methods. The presentation introduces HOMER Pro before demonstrating the software through an exercise.

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Economics of solar neighborhoods and evaluation techniques

FUTURE URBAN ENERGY LAB FOR SUSTAINABILITY

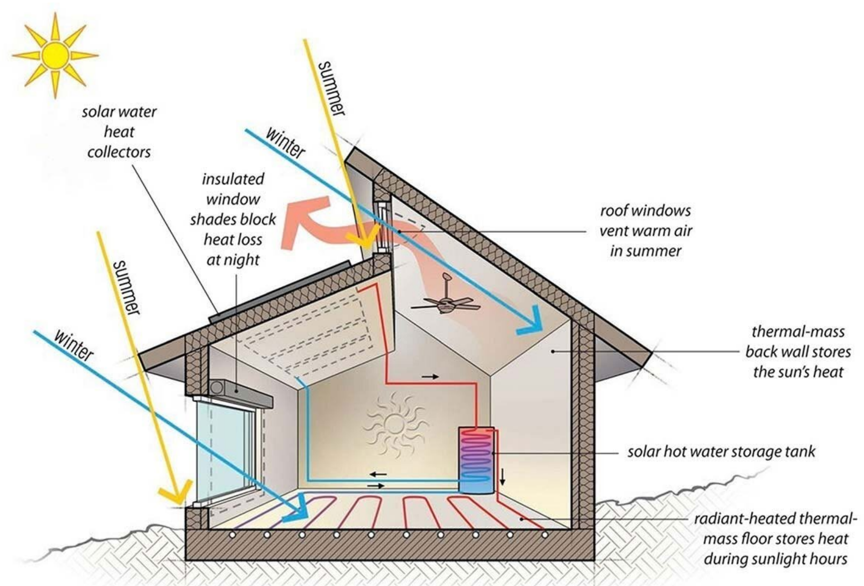
Kuljeet S. Grewal (Ph.D.), Assistant Professor, University of Prince Edward Island, Canada
IEA Task 63, Fall School, Canada, Sep 13, 2022

Content

- Solar strategies and technologies
- Energy payback time (EPBT)
- Economic analysis methods
- Introduction to HOMER Pro
- Exercise

FUEL-S

Solar Strategies



Passive: cheap, efficient design; block summer rays; allow winter

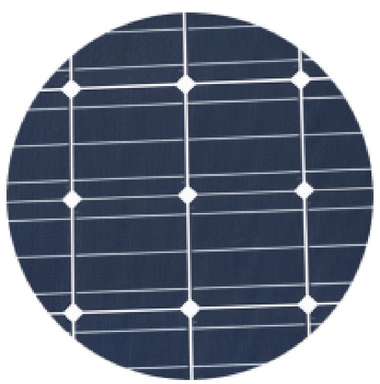
Photovoltaic (PV): direct electricity; 15%-20% efficient; $5 per Watt to install without rebates/incentives; small fraction of roof covers demand of typ. home

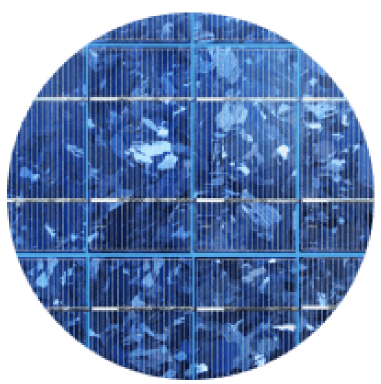
Solar hot water: up to 50% efficient; several $k to install; usually keep conventional backup; freeze protection vital

Solar Thermal: ~30% efficient; cost-competitive; requires direct sun; heats fluid in pipes that then boils water to drive steam turbine

Types of Solar Panels

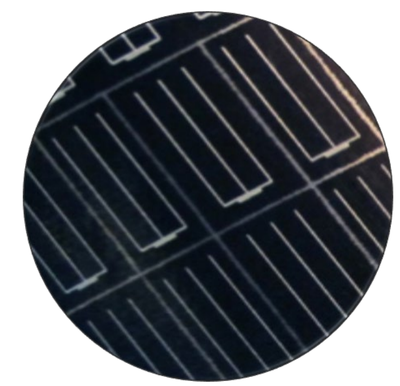
1st Generation





2nd Generation

3rd Generation



Pocket calculators

Biohybrid Solar Cell

Comparison of Panels

Solar Cell Type	Efficiency Rate	Advantages	Disadvantages	Rate (per Watt)
Monocrystalline Solar Panels (Mono-SI)	~20%	High efficiency rate; optimized for commercial use; high life-time value	Expensive	$1.00 - $1.50
Polycrystalline Solar Panels (p-Si)	~15%	Lower price; made by melting raw silicon	Sensitive to high temperatures; lower lifespan & slightly less space efficiency	$0.90 - $1.00
Thin-Film: Amorphous Silicon Solar Panels (A-SI)	~7-10%	Relatively low costs; easy to produce & flexible	Shorter warranties & lifespan	$1.00 - $1.50
Cadmium Telluride Solar Cell (CdTe)	~16% (22%: First Solar)	Cd is abundant; Te is rare but limited use (recyclable); low cost	Cd is toxic	$0.75 - $1.25
Concentrated PV Cell (CVP)	~41%	Very high performance & efficiency rate	Solar tracker & cooling system needed (to reach high efficiency rate)	$0.80 - $1.10

Source: https://www.greenmatch.co.uk/blog/2015/09/types-of-solar-panels

Energy-Payback Time

- Energy-payback time (EPBT) of a PV module is the amount of time a module must produce power to recover the energy it took to produce the module initially

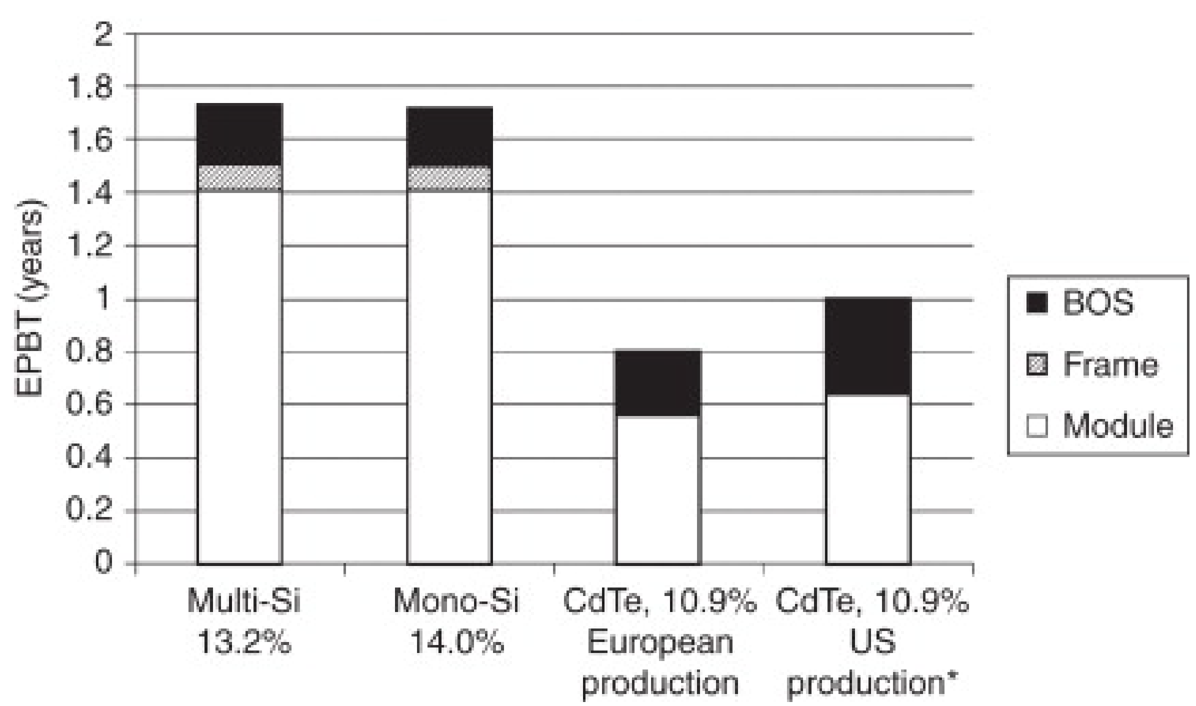
Energy-Payback Time, $$\text{EPBT} = \frac{E_{\text{mat}} + E_{\text{manuf}} + E_{\text{trans}} + E_{\text{inst}} + E_{\text{EOL}}}{E_{\text{agen}} - E_{\text{aoper}}}$$

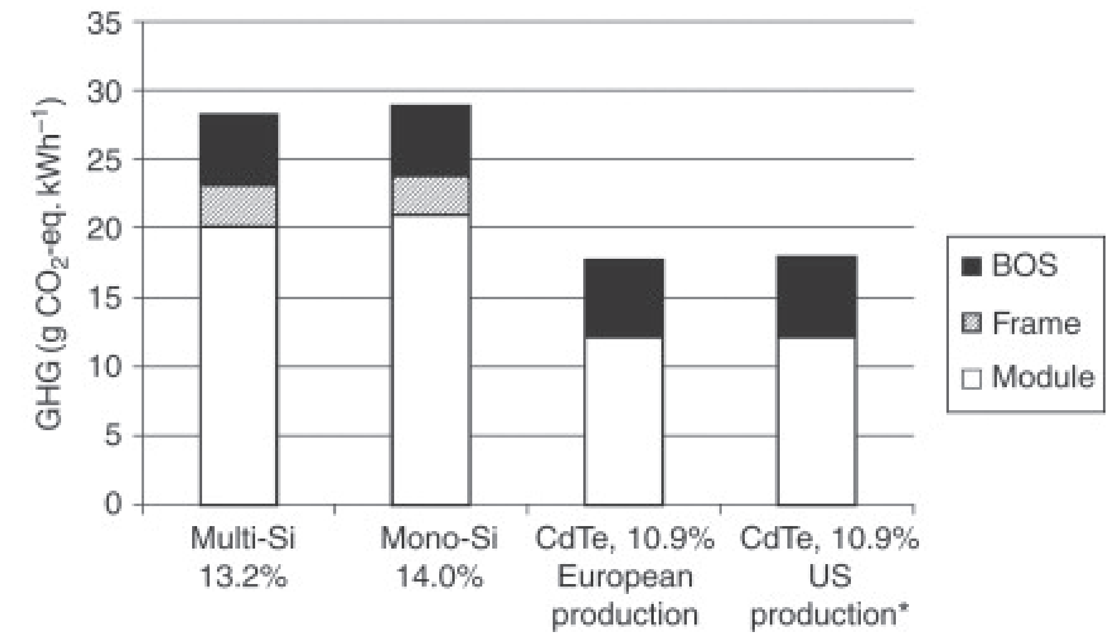
E_{mat} = primary energy demand to produce materials of PV system
E_{manuf} = energy demand to manufacture PV system
E_{trans} = primary energy demand to transport materials used during the life cycle
E_{inst} = primary energy demand to install the system
E_{EOL} = primary energy demand for end-of-life management

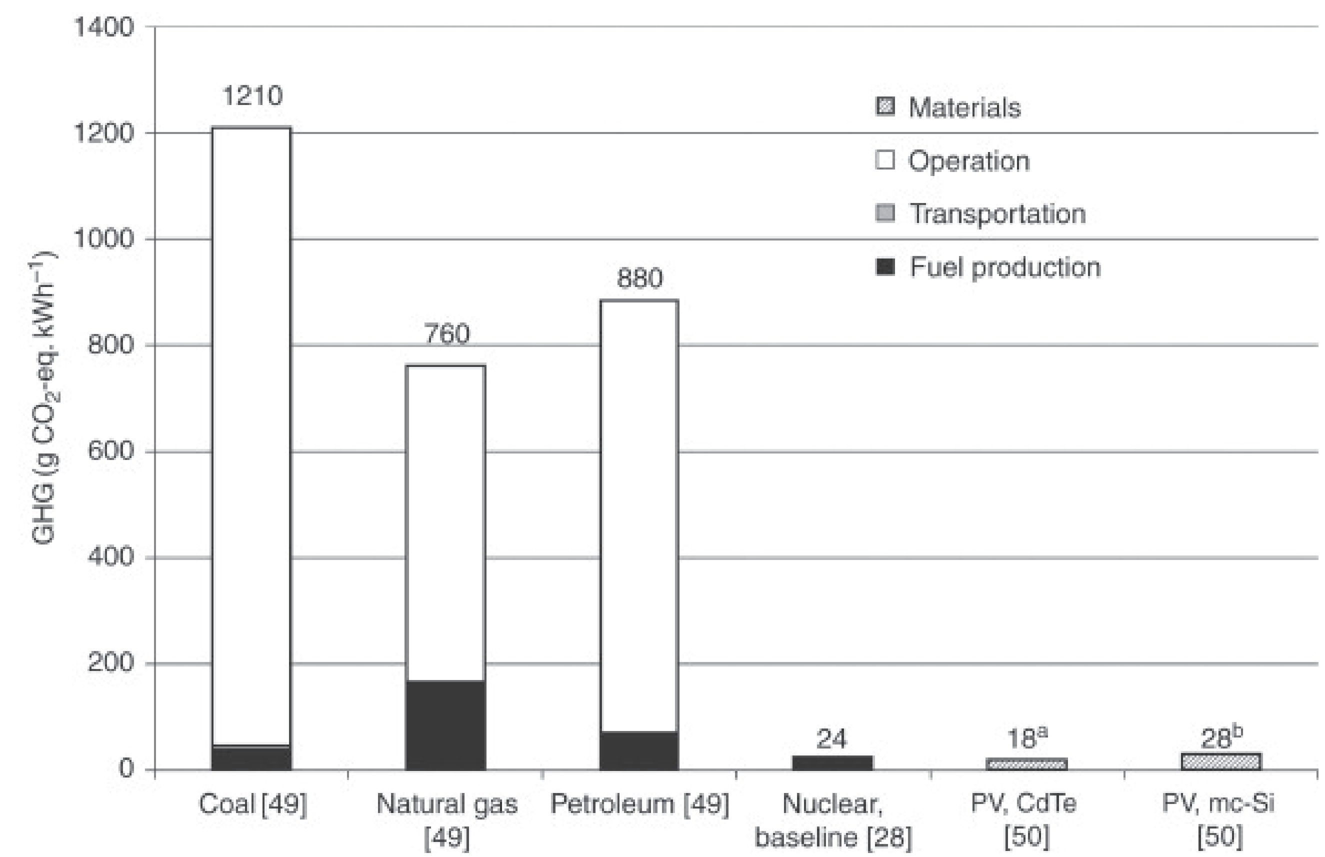
E_{agen} = annual electricity generation in primary energy term
E_{aoper} = annual energy demand for operation and maintenance in primary energy term

FUEL-S

EPBT and Emissions







BOS (balance of system): module supports, cabling, and power conditioning

Source: https://www.sciencedirect.com/topics/engineering/energy-payback-time

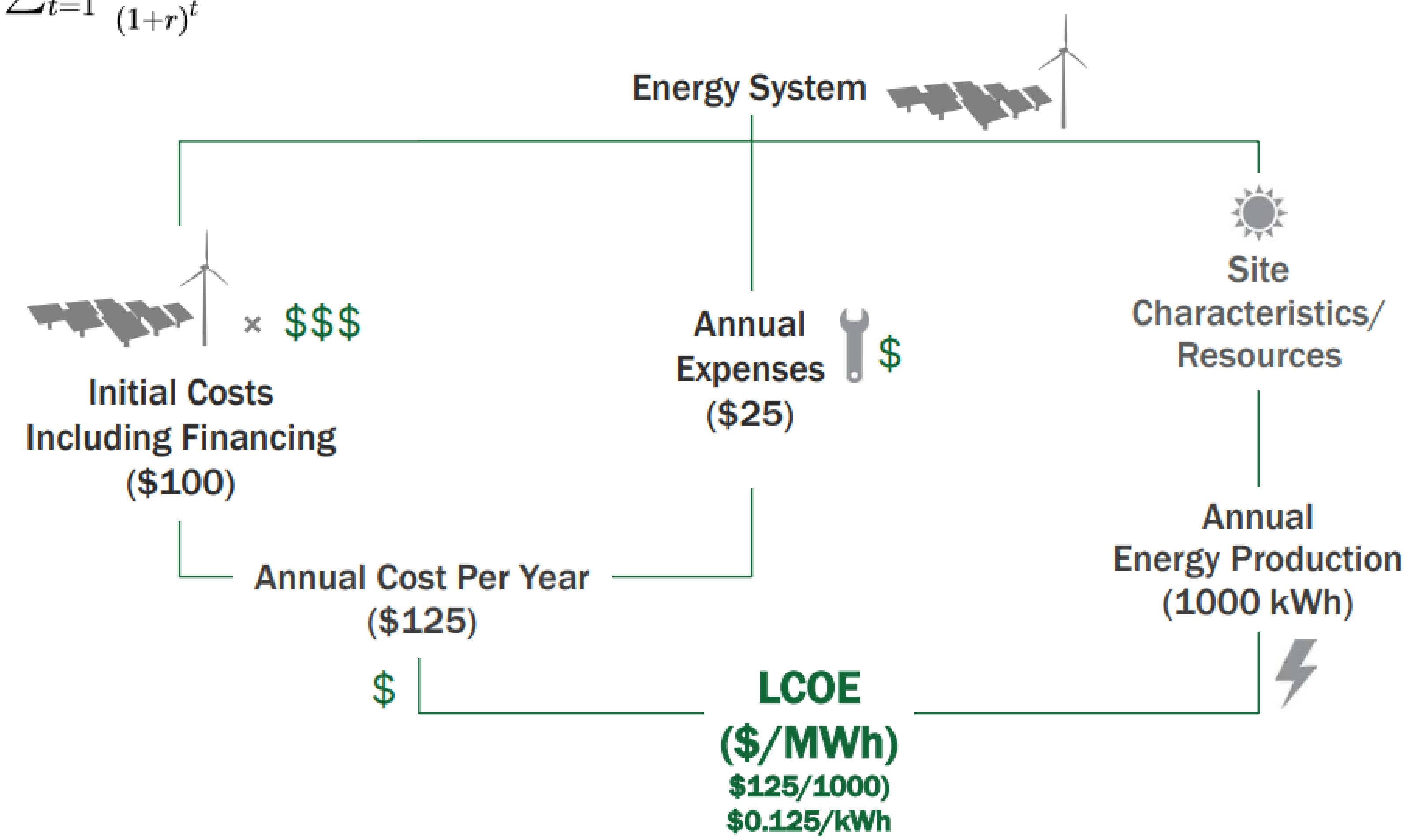
FUEL-S

Levelized Cost of Energy (LCOE)

$$\text{LCOE} = \frac{\text{sum of costs over lifetime}}{\text{sum of electrical energy produced over lifetime}} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

I_t = investment expenditures in the year t
M_t = operations and maintenance expenditures in the year t
F_t = fuel expenditures in the year t
E_t = electrical energy generated in the year t
r = discount rate
(present value of a cash flow that occurs in any year of the project lifetime)

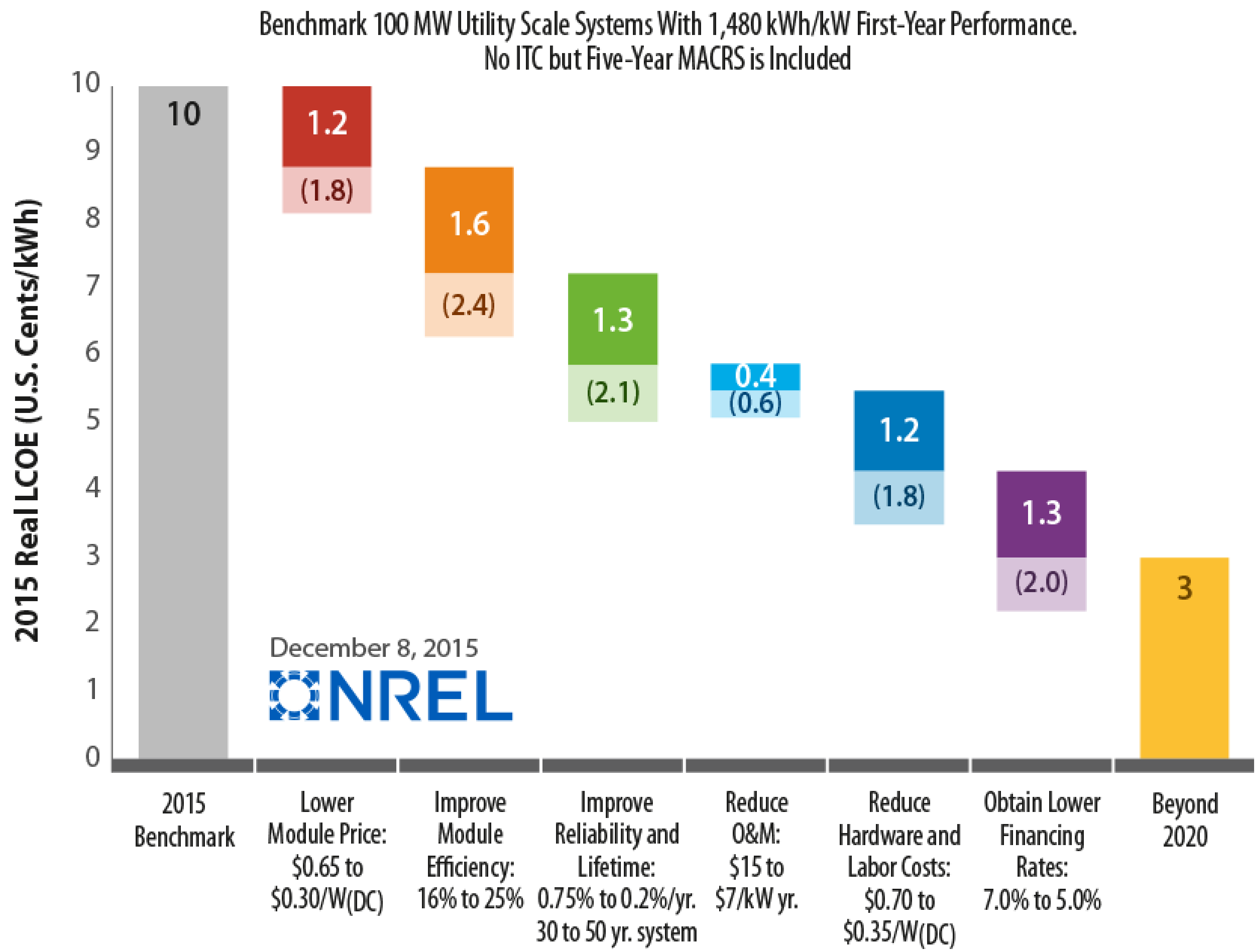
n = expected lifetime of system or power station



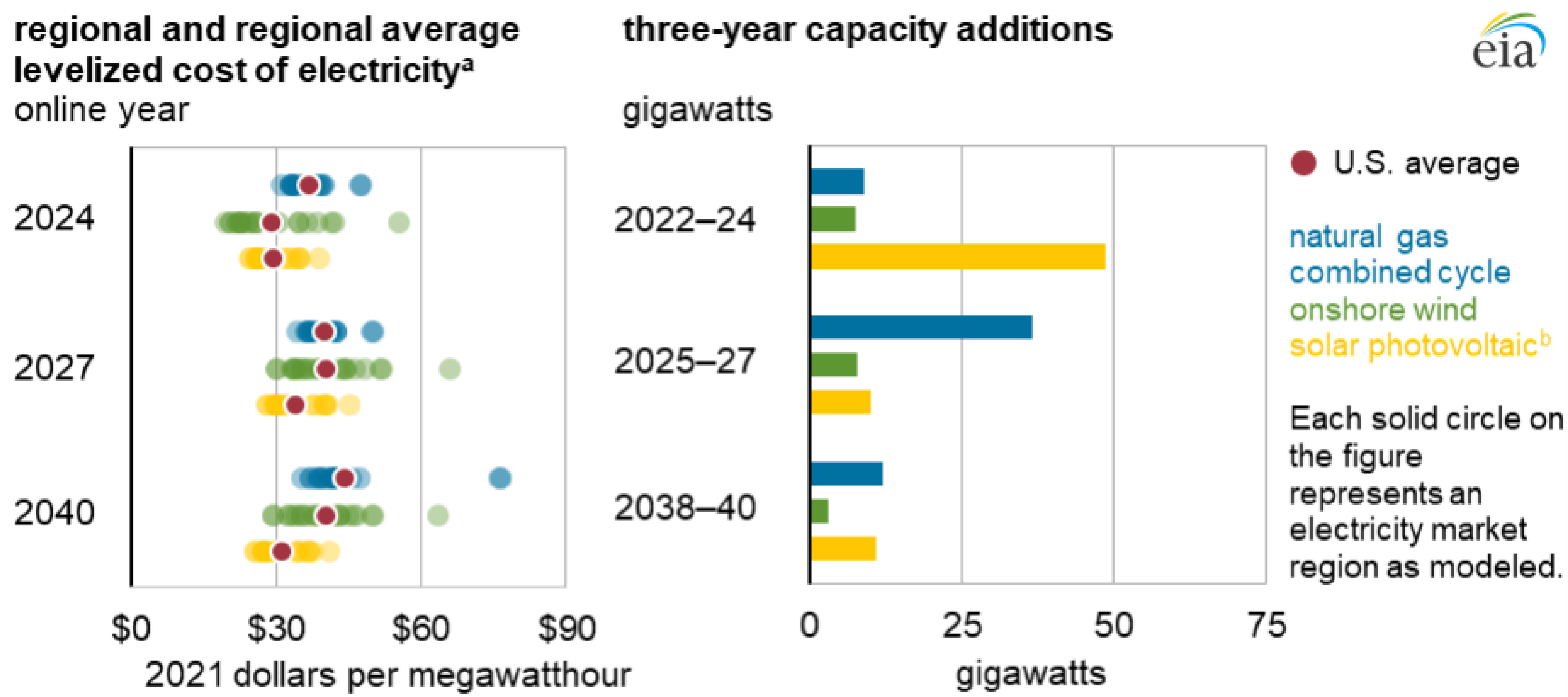
Adapted from European Wind Energy Association, "Economics of Wind Energy," http://www.ewea.org/fileadmin/ewea_documents/documents/00_POLICY_document/Economics_of_Wind_Energy__March_2009_.pdf

Source: Lai, Chun Sing, et al. "Levelized cost of electricity for photovoltaic/biogas power plant hybrid system with electrical energy storage degradation costs." *Energy conversion and management* 153 (2017): 34-47.
https://www.energy.gov/sites/prod/files/2015/08/f25/LCOE.pdf

Pathway to 3 Cents per kWh



LCOE Projections

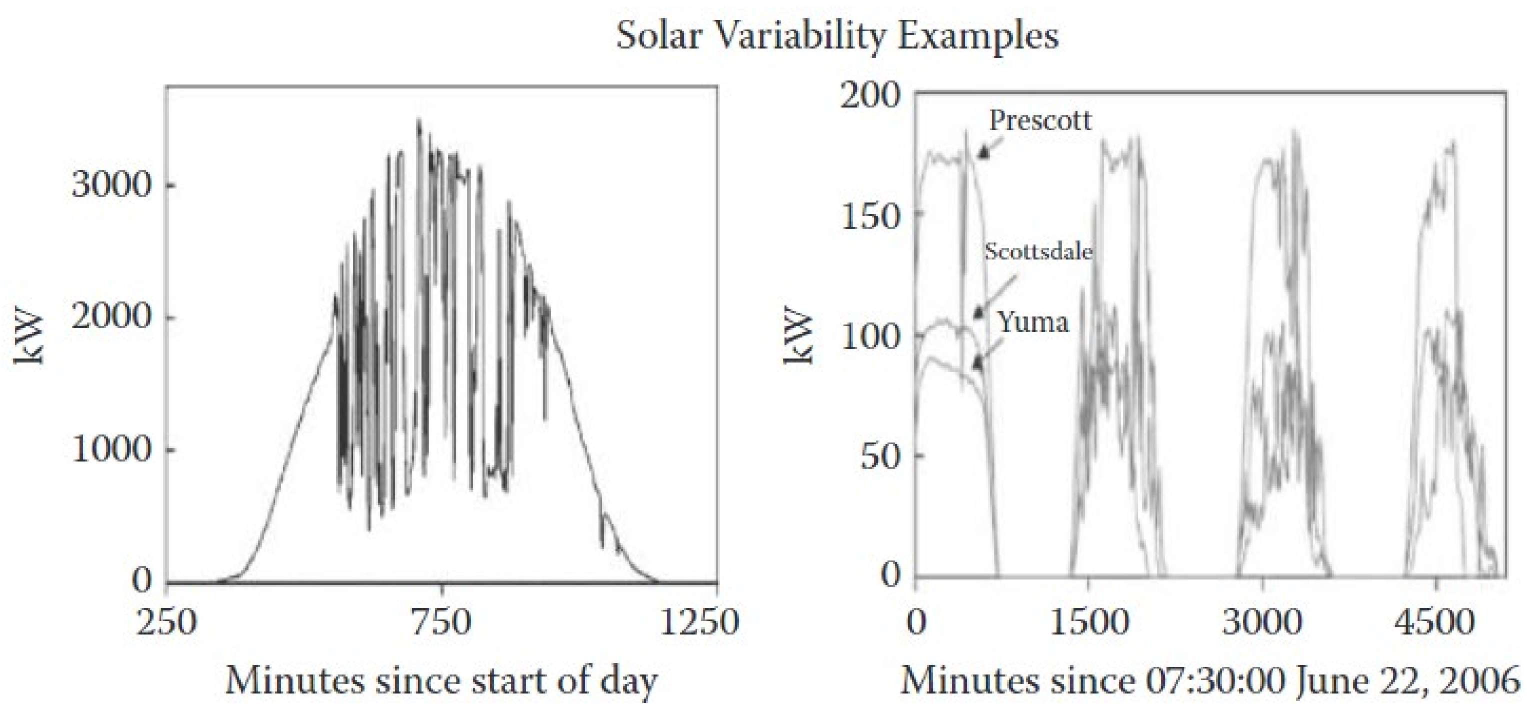


Source: U.S. Energy Information Administration, *Annual Energy Outlook 2022*

[a] Levelized cost includes tax credits available for plants entering service during the projection period.
[b] Technology is assumed to be photovoltaic with single-axis tracking. Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

Source: https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

Variability of Solar



Courtesy of AzRise

Lack of solar energy availability at certain times cause two types of problem:

- Short term variability: Need to smooth the rapid variations: i.e., small clouds pass overhead
- Long term variability: Continuing need for power at nights and on cloudy days

Prominent challenges when variable power exceeds more than 10 to 15% of the total power

For low renewable energy and high demand, the multiple approaches to solve the problem include:

- energy storage (essential for net-zero)
- demand response (i.e., bringing gas-fired generators online)
- reducing demand by turning off loads (smart grid)

Source: Barnes, F., and J. Levine. "Large energy storage systems." *NY: Taylor & Francis Group* (2011).

Levelized Cost of Solar-Plus Storage (LCOSS)

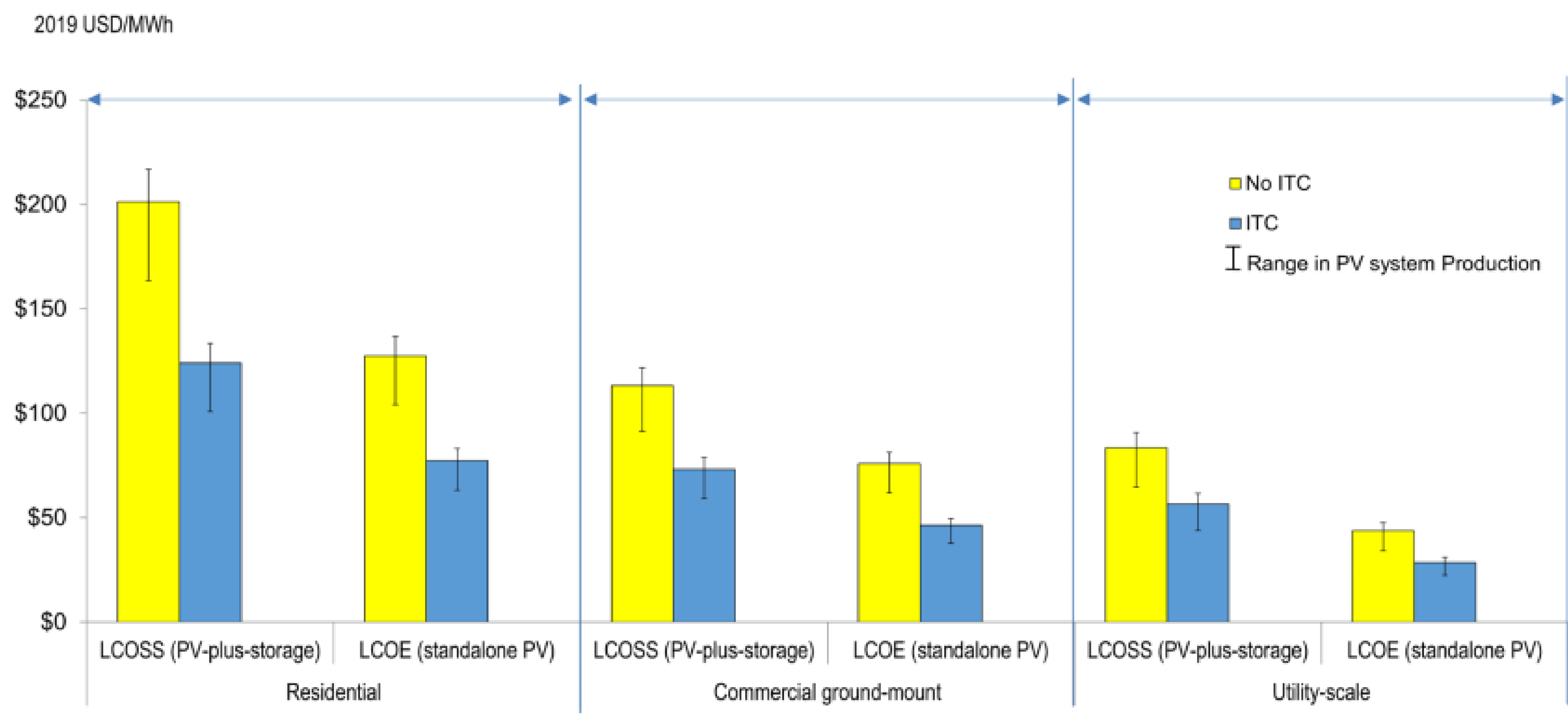
$$LCOSS = \frac{\overset{\text{Initial CAPEX}}{I} + \overbrace{\frac{F^n}{(1+R)^n}}^{\text{Follow-on CAPEX}} - \overbrace{\sum_{n-1}^{N}\frac{(D+DF)^n}{(1+R)^n}\times(T)}^{\text{Depreciation}} + \overbrace{\sum_{n-1}^{N}\frac{(O+C)^n}{(1+R)^n}\times(1-T)}^{\text{O\&M costs \& cost of electricity bought from electric grid}} - \overbrace{\frac{Rv^n}{(1+R)^n}\times(1-T)}^{\text{Residual value}}}{\underbrace{\sum_{n-1}^{N}\frac{P\times(1-Dr)^n}{(1+R)^n}\times(1-B)}_{\text{Electricity produced by PV system and fed to grid/demand}} + \underbrace{\sum_{n-1}^{N}\frac{P\times(1-Dr)^n}{(1+R)^n}\times(B)\times(1-Lp)}_{\text{Electricity produced by PV system and fed to battery (accounting for losses)}} + \underbrace{\sum_{n-1}^{N}\frac{G}{(1+R)^n}\times(1-Lg)}_{\text{Electricity fed from the grid to battery and back again (accounting for losses)}}}$$

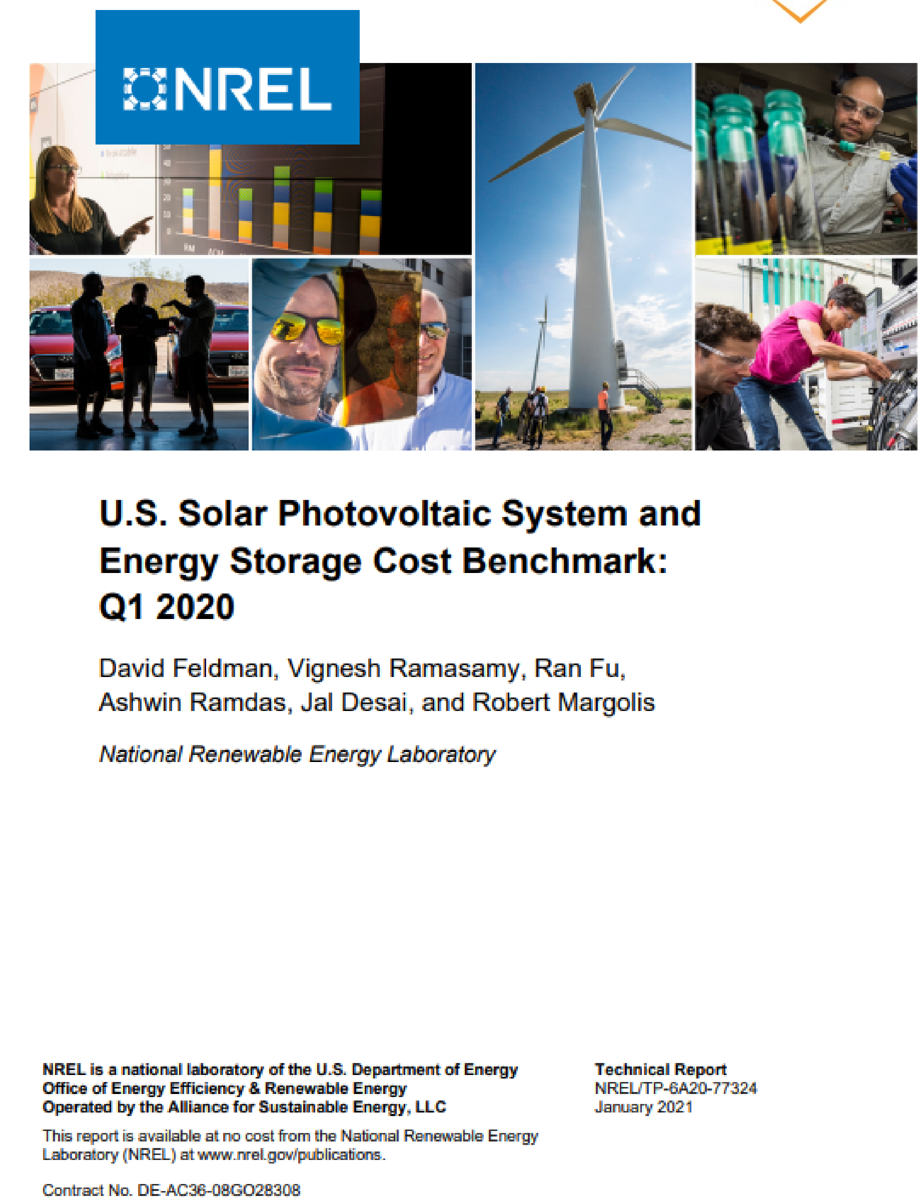
I = initial investment
C = charging cost
F = follow on investment (replacements)
D = depreciation
R = discount rate
T = tax rate
O = O &M

Dr = Degradation PV
Rv = residual
B = percent of generated solar energy fed to battery
Lp = roundtrip energy losses from PV-storage-grid
Ln = losses from grid-storage-grid
G = annual electricity purchased from grid

Source: https://www.nrel.gov/solar/market-research-analysis/solar-levelized-cost.html

Economics Insight





NREL

U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020

David Feldman, Vignesh Ramasamy, Ran Fu, Ashwin Ramdas, Jal Desai, and Robert Margolis

National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

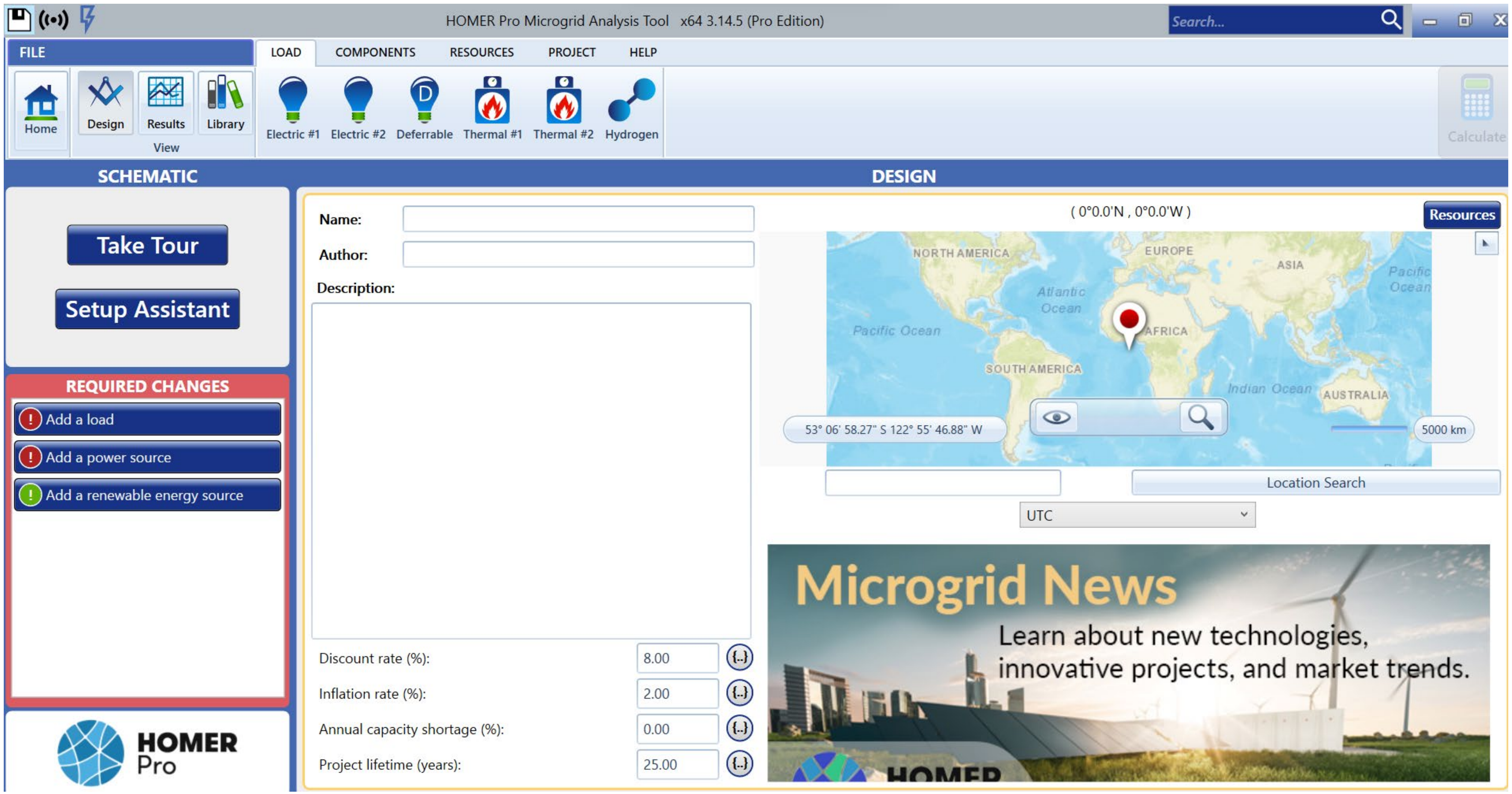
This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

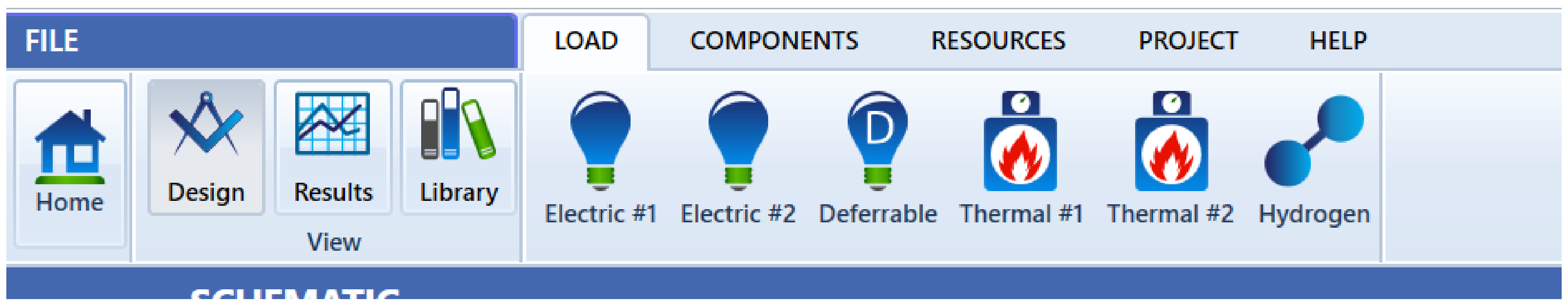
Technical Report
NREL/TP-6A20-77324
January 2021

LCOSS: levelized cost of solar-plus storage
LCOE: levelized cost of energy
ITC: investment tax credit

Evaluation Techniques: HOMER Pro



HOMER Pro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Electric #2
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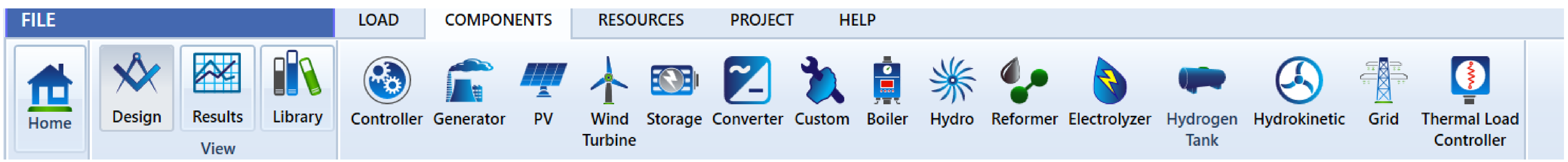
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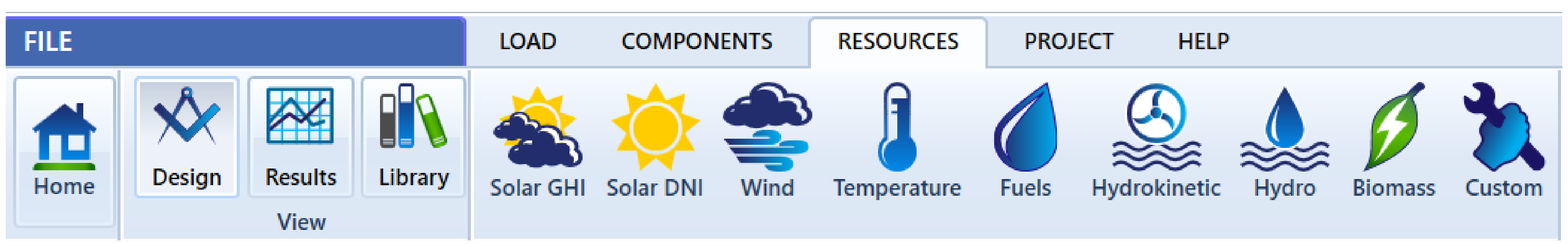
Hydrogen Tank
Hydrokinetic
Grid
Thermal Load Controller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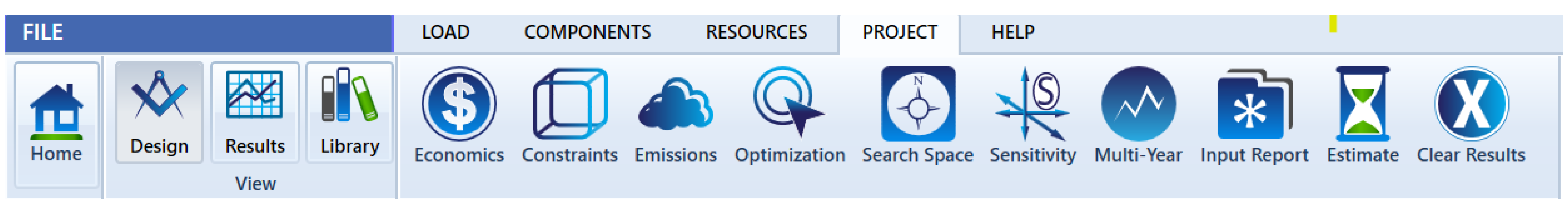
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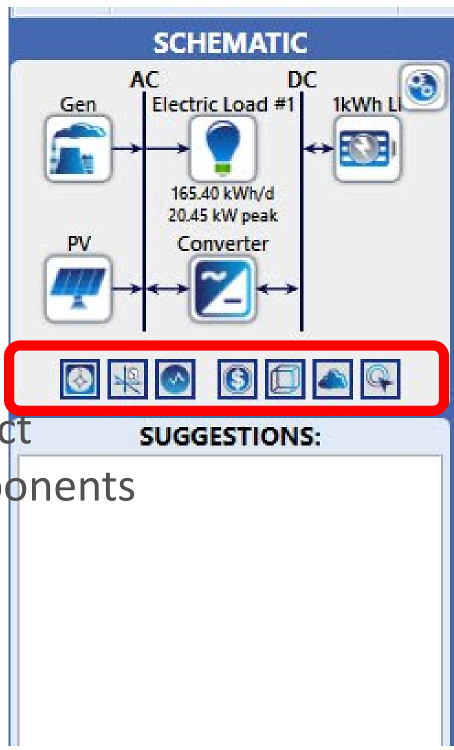
Constraints
Emissions
Optimization
Search Space
Sensitivity
Multi-Year
Input Report
Estimate
Clear Results

Community Applications: HOMER Pro



Project components

DESIGN

Name: Sample_CommunityMiniGridWithMultiYear

Author: John Glassmire

Description:

This model demonstrates the Multi-Year capability of the HOMER model. A Multi-Year analysis simulates the system for every timestep for every year of the project lifetime. Without the Multi-Year analysis, HOMER simulates the system for one-year and extrapolates the results to the other years to calculate the economics. Enabling Multi-Year allows the system to model capture year-to-year changes. In this model, that captures the battery storage level from year-to-year, PV performance degradation, and diesel cost escalation above the inflation rate. The trade-off for this is that the model is more precise, but the calculation takes longer. For this reason, I recommend that you model first without Multi-Year and then refine the design with it.

First, we ran this model with Multi-Year turned off, and used the Optimizer to find the optimal system design. The optimal system for the single-year model had 25.1 kW of PV and 65 kWh of li-ion storage. The COE for that system was $0.412/kWh.

Then, we ran the model with slightly refined sizes and Multi-Year turned on to model the performance of this design over 20 years of project life.

Modules required to run this model:
* Multi-Year

Unnamed Road, Tanzania (6°22.1'S , 34°53.3'E)

Export...

Optimization Results

Left Double Click on a particular system to see its detailed Simulation Results.

Categorized Overall

Architecture					Cost				System		Gen					PV		1kWh LI			
PV (kW)	Gen (kW)	1kWh LI	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&M Cost ($/yr)	Fuel Cost ($/yr)	Capital Cost ($)	Production (kWh/yr)	Autonomy (hr)	Annual Throughput (kWh/yr)	Nominal Capacity (kWh)	Usable Nomi (kW
25.0	23.0	65	12.0	CC	$330,326	$0.473	$17,377	$129,100	44.7	10,186	1,803	33,384	10,186	1,240	11,887	75,000	41,187	7.55	22,125	65.0	52.0
	23.0	65	12.0	CC	$444,995	$0.637	$33,755	$54,100	0	21,516	4,513	67,711	21,516	3,125	25,187			7.55	19,004	65.0	52.0
25.0	23.0			LF	$470,359	$0.673	$33,148	$86,500	15.8	19,805	7,052	50,810	19,805	4,852	23,141	75,000	41,187				
	23.0			LF	$509,086	$0.728	$42,968	$11,500	0	26,191	8,760	69,443	26,191	6,044	30,658						

Optimal System Configuration

Summary | Tables | Graphs

Calculation Report

Simulation Details

Winning System Architecture

- HOMER Cycle Charging
- Gen - 23.0 kW
- PV - 25.0 kW
- 1kWh LI - 65.0
- Converter - 12.0 kW

Base Case Architecture

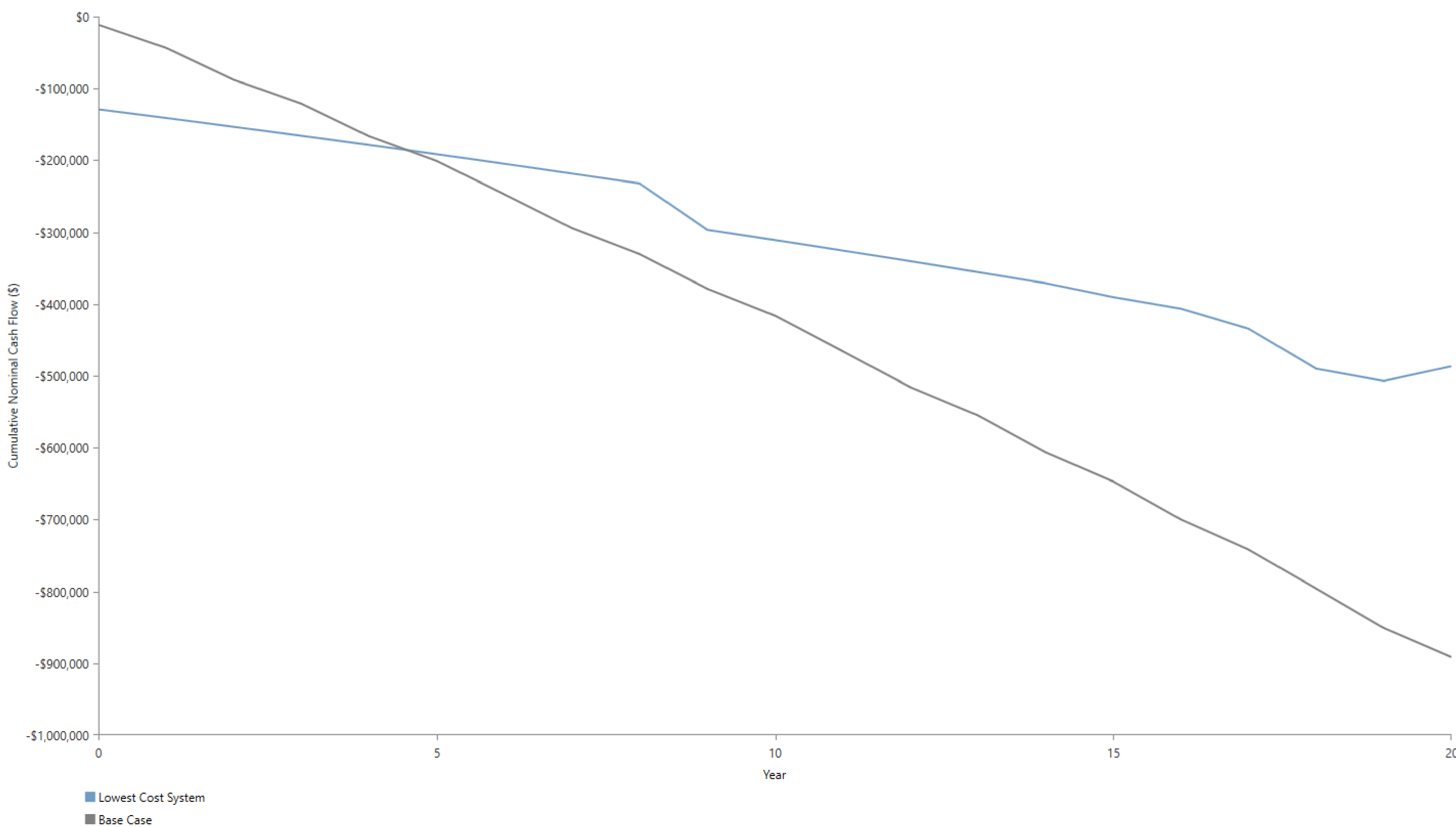
- HOMER Load Following
- Gen - 23.0 kW

Change Base Case

Economic Metrics

IRR	21%
ROI	17%
Simple Payback	4.6 yr

Here's how the hybrid system saves money over the project lifetime.

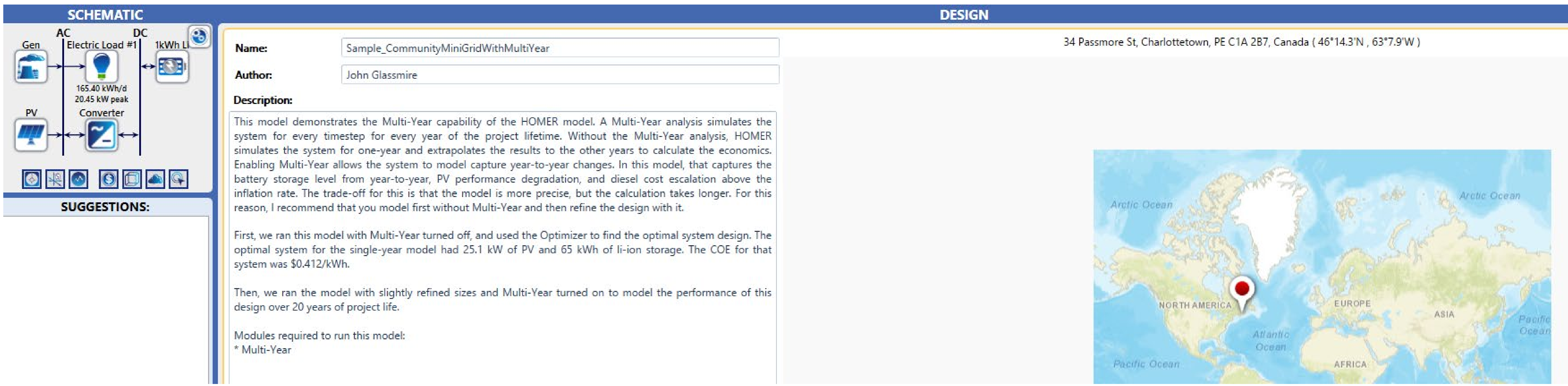


Cost Summary

	Base Case	Lowest Cost System
NPC	$509,086	$330,326
Initial Capital	$11,500	$129,100
O&M	$42,968/yr	$17,377/yr
LCOE	$0.728/kWh	$0.473/kWh

Exercise

Update location and see changes



Have questions or interested in working together for real-world impact!

Kuljeet S. Grewal, Ph.D.
Assistant Professor,
Faculty Sustainable Design Engineering (FSDE),
University of Prince Edward Island
kgrewal@upei.ca

FUEL-S

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IEA Solar Heating and Cooling Programme (group 4230381)

Technology Collaboration Programme by iea

Economics of Neighborhood Solar Development
Eric Wilczynski

The presentation begins with an introduction to the concepts of neighborhood solar and a comparison of solar development. This is followed by a discussion about economics, by examining market potential, LCOE, and local economic benefits. The presentation continues with a discussion of different business models and financing mechanisms before concluding with a PVWatts demonstration.

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Economics of neighborhood solar development

IEA Task 63 Fall School, Calgary (CA)
September 13, 2022

Eric Wilczynski
Researcher at the Institute for Renewable Energy, Eurac Research (IT)
PhD Candidate at the University of Geneva (CH) & Utrecht University (NL)

Outline

I. Introduction
   I. Defining neighborhood solar
   II. Solar development comparison
II. Economics basics
   I. Market potential
   II. LCOE
   III. Local economic benefits
   IV. Summary of economic benefits
III. Business models
   I. Typical business models
   II. Financing mechanisms
   III. PVWatts demo

I. Defining neighborhood solar

Neighborhood solar is a solar development servicing a group of buildings or a district within a spatially defined, specific geographic area (IEA SHC Task 63)

Image source: Getty images

I. Solar development comparison

	Rooftop system	Neighborhood-scale systems	Utility-scale system
Typical capacity	<1 MW	1 to 5 MW	>5 MW
DER potential	Yes	Yes	No
Available technology	Low	Medium	High
Ownership	Private ownership/lease	Shared/subscription based	Private or utility ownership

Image sources: Wikimedia Commons

II. Economics basics

Content:

- Market potential
- LCOE
- Local economic benefits
- Summary of economic benefits

II. Market potential

Which consumers are unique to neighborhood/community solar?

II. Market potential

- Defining and identifying potential customers
  - Typical:
    - Homeowners/building owners
    - Neighborhood organisations
  - Unique:
    - Renters
    - Residents in MFHs
    - Occupants of buildings with inadequate roof for solar
    - Low/moderate income consumers

Numbers: Canada

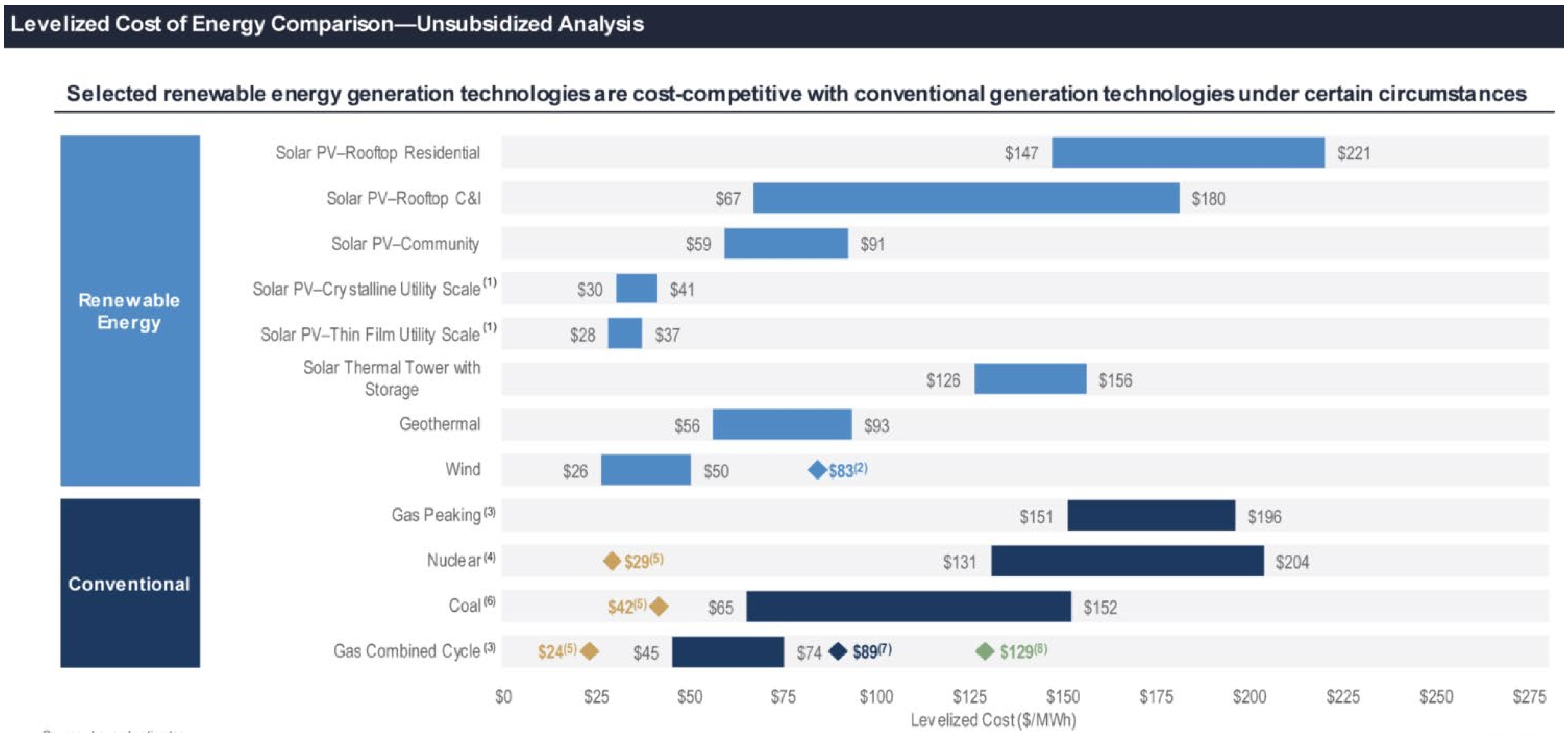
30% renters

>40% dwellings are multi-family buildings or mobile homes

>50% middle income (7% low income)

Source: StatCan, OECD

II. LCOE



www.iea-shc.org
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Source: Lazard Ltd.

II. Local economic benefits

- Local labour market growth
- Increased tax revenue
- Positive land repurposing
- Sale of power generation

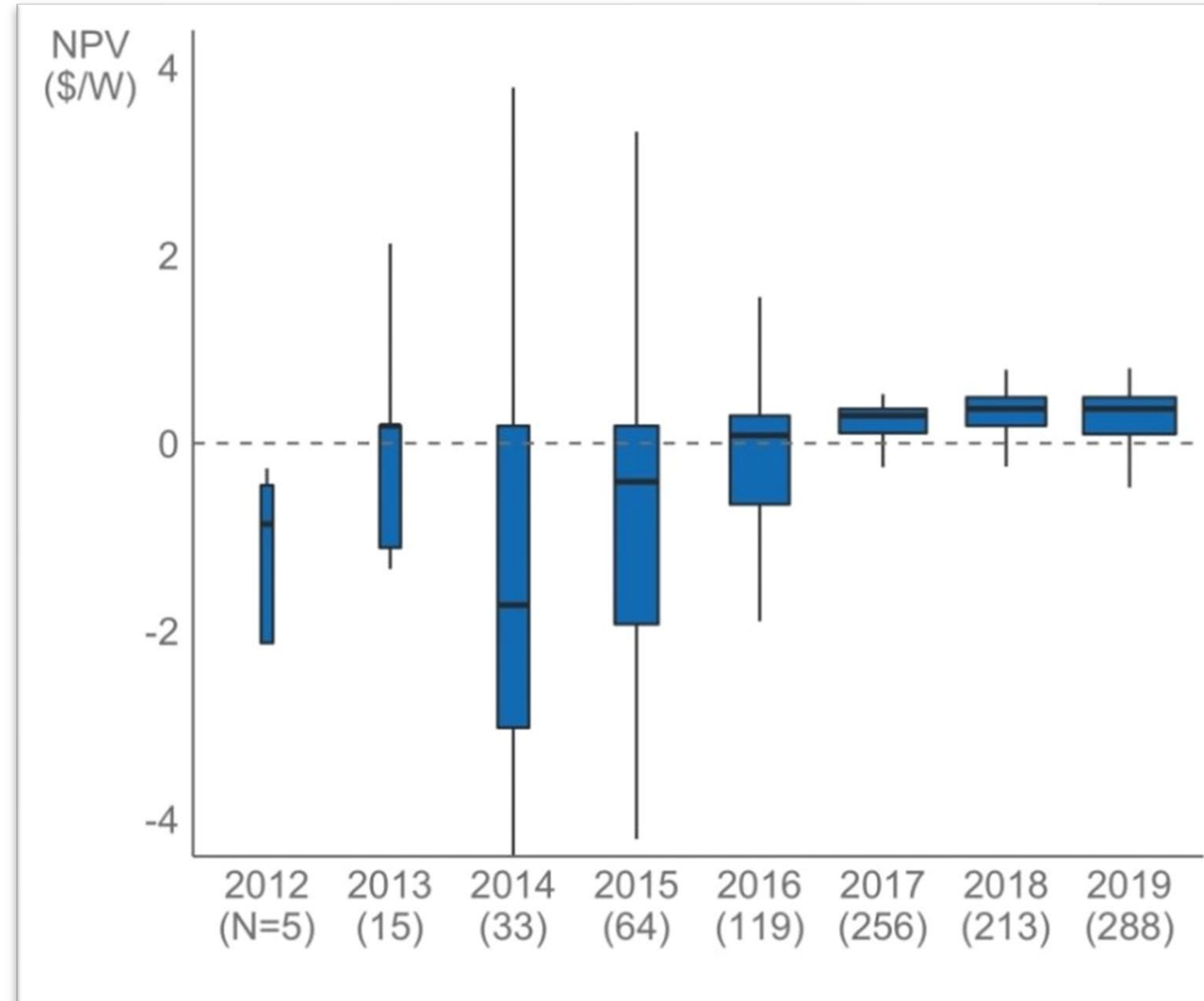
Community solar development in Beverly, MA on capped landfill

Image source: Beverly, MA official website

II. Summary of economic benefits

Consumers (individual)	Neighborhood/society	Developers
• No need for property ownership (renters can participate) • No rooftop space necessary • Lower risk • Opportunities for lower income consumers • No upfront costs • Save on bill costs	• Land use reappropriation • Increased energy independence • Increase property values • Landowner benefits • Job creation	• Lower operating costs • Additional technology options • Land use/solar incentives

NPV of community solar subscription (US)



Source: US DoE

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III. Business models

Content:

- Typical business models
- Financing mechanisms
- PVWatts demo

III. Typical business models

	Utility model	SPE model	Developer model
Who sponsors and owns the project?	Utility (or 3rd party)	Special purpose entity members	Developer
Who pays for the project?	Utility, grants, ratepayer subscriptions	Member investments, grants, incentives	Developer investments, grants, incentives
Who builds the project?	3rd party developer	3rd party developer	Developer
Who hosts the project?	Utility (or 3rd party)	3rd party	3rd party

Source: NREL Community Solar Guide

III. Financing mechanisms

- Typical schemes:
  - Bank financing (loans, bonds)
  - Equity-based financing
  - Power Purchase Agreement (PPA)
- Innovative/alternative schemes:
  - Crowdfunding
  - Peer to peer electricity trading (P2P)
  - Feed-in Premium (FiP)
  - Solar bonds
  - Development trust
  - Charity development

Image source: European Commission

III. PVWatts demo: Subscription model

https://sam.nrel.gov/

Steps:

1. Select location
2. Define system design
3. Set grid limits (optional)
4. Set annual AC output degradation
5. Input overhead costs
6. Input operating costs
7. Define subscriber parameters
8. Define financial parameters
9. Enter any incentives
10. Set depreciation
11. Run simulation and view results

Source: NREL

Thank you

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IEA Solar Heating and Cooling Programme
(group 4230381)

The Role of Occupant Behaviour in Energy Efficient Buildings and Solar Neighborhoods Planning
Mohamed Ouf

This presentation opens introduces first the effect of Occupant Behavior (OB) on energy consumption and efficiency, identifying the challenges of modelling OB and discussing how to account for OB in planning solar neighborhoods. The next section of the presentation is focused on how occupant behavior can be modelled and integrated in building performance simulations. The presentation concludes with a discussion about how to integrate occupant behaviour in building operations.

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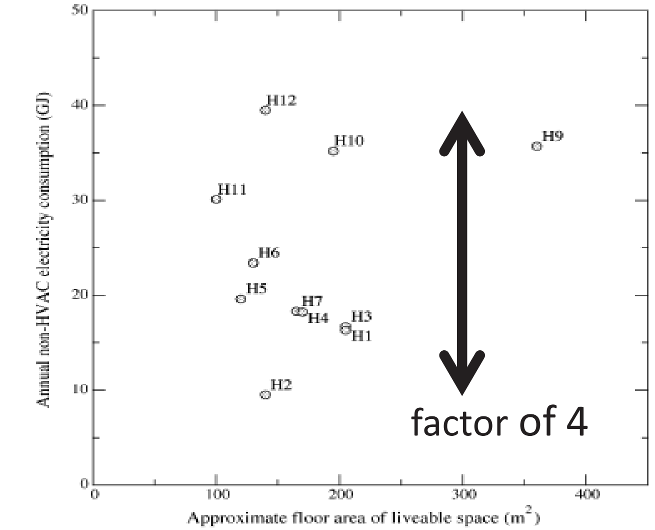
The role of occupant behaviour in energy efficient buildings and solar neighborhoods planning

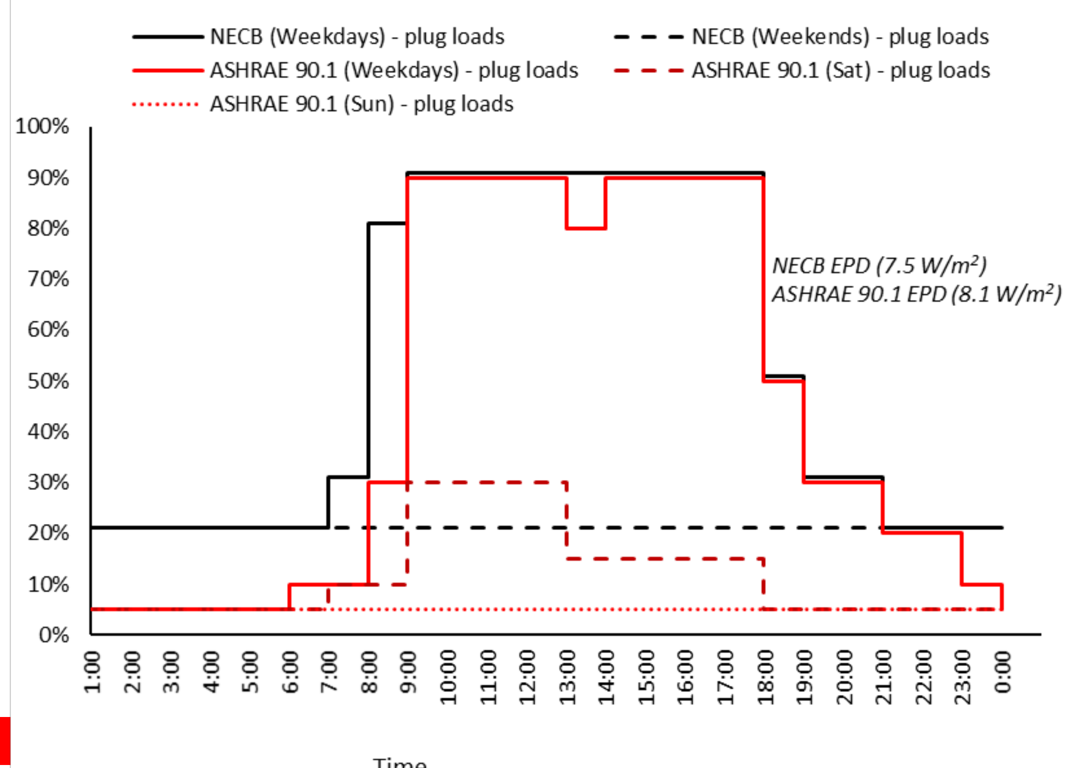
Mohamed Ouf, Assistant Professor, Concordia University
IEA SHC TASK 63 Fall school, September 6th-22nd, 2022

Introduction

- Evidence for the effect of Occupant Behavior (OB) on energy consumption; efficiency
- Challenges
  1. Oversimplification of occupant assumptions when sizing / designing various systems
  2. Effect on peak demand / demand response is not well understood



(Saldanha and Beausoleil-Morrison, 2012)

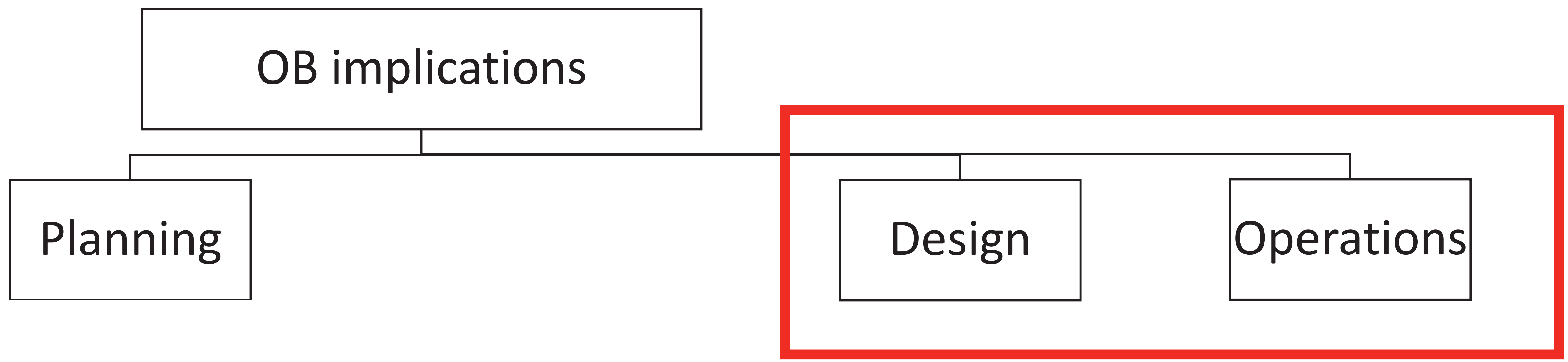


ASHRAE

NECB National Energy Code of Canada For Buildings

Introduction

- How to account for OB in Planning solar neighborhoods?



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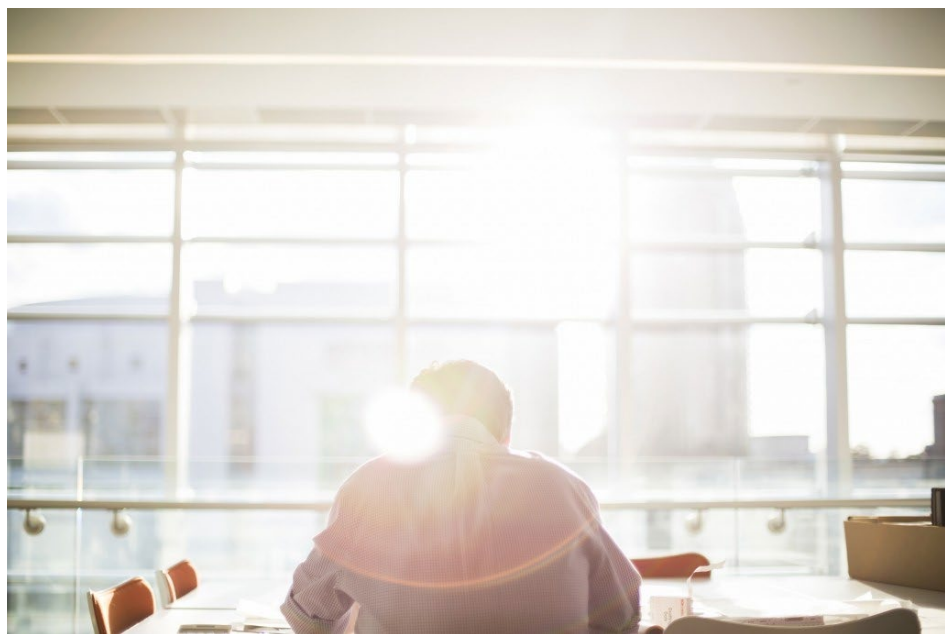
Occupant Behaviour (OB) in Design

Consider this example



Office designed to maximize daylight harvesting

Occupants close blinds due to excessive glare (design flaws)

Occupants use electric lighting instead of daylight harvesting

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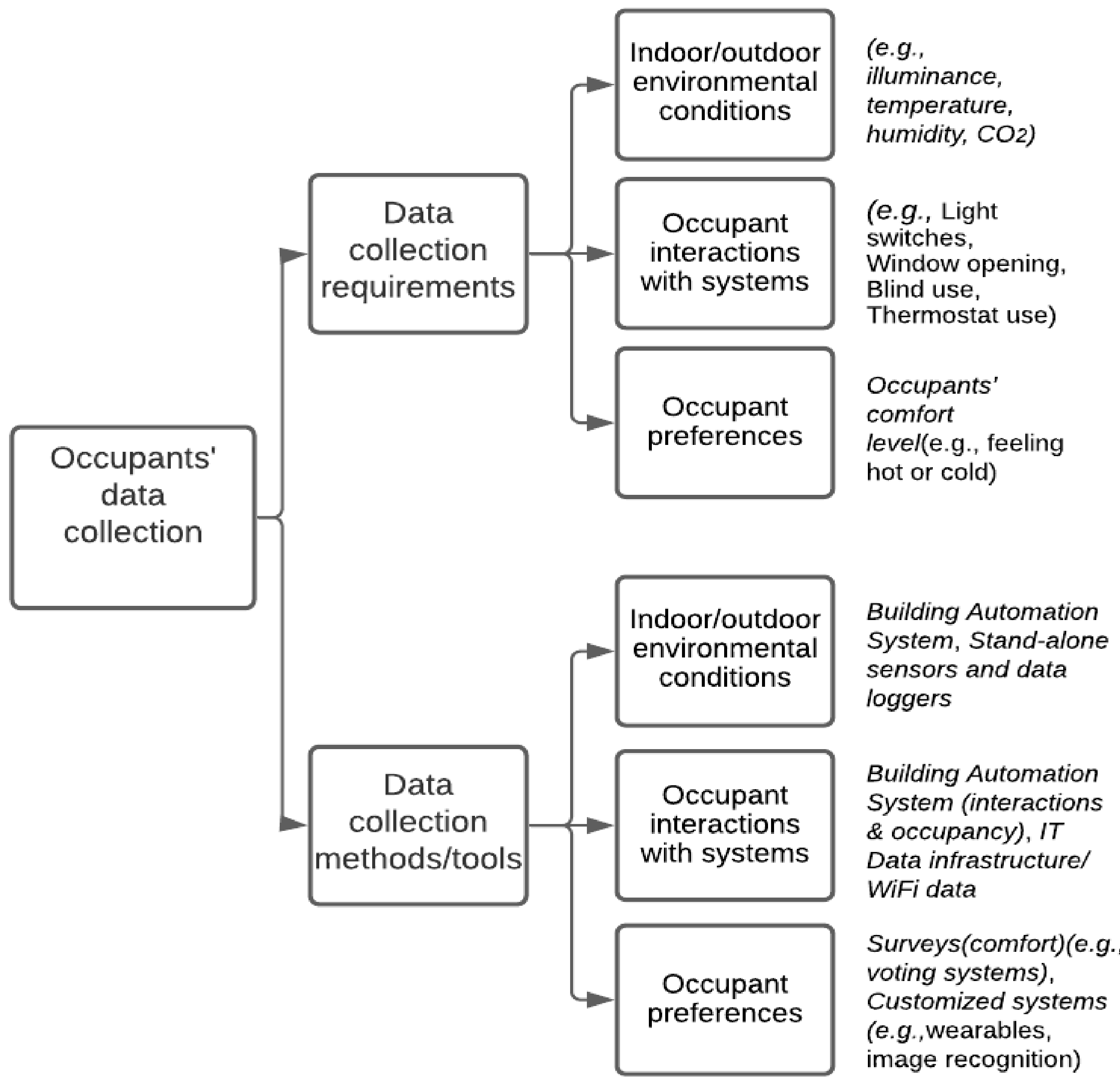
How can we address OB during design?

- Building Performance Simulations
  - Integrating a more detailed representation of OB

		Level of Randomness	
		Deterministic Model	Stochastic Model
Level of Complexity	Static Model	Static Deterministic model	Static stochastic model
	Dynamic Model	Dynamic deterministic model	Dynamic stochastic model

- Data collection of occupant-related information

What are occupant-related information?



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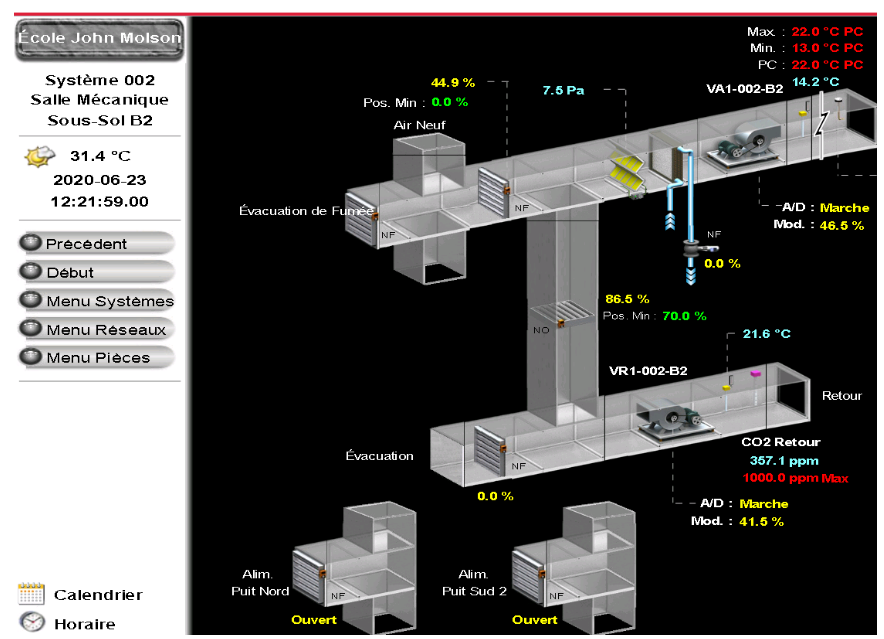
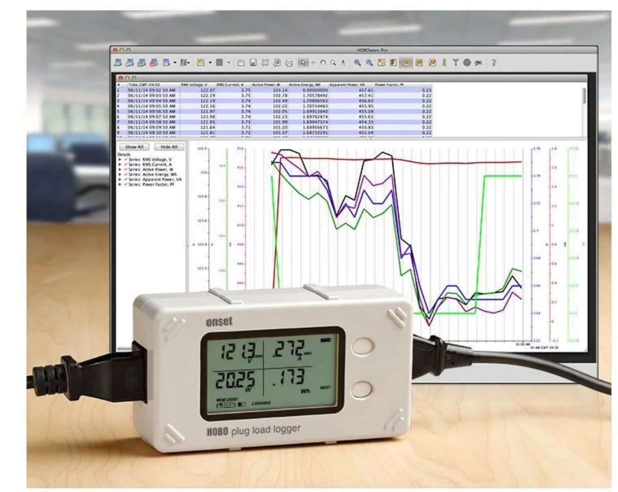
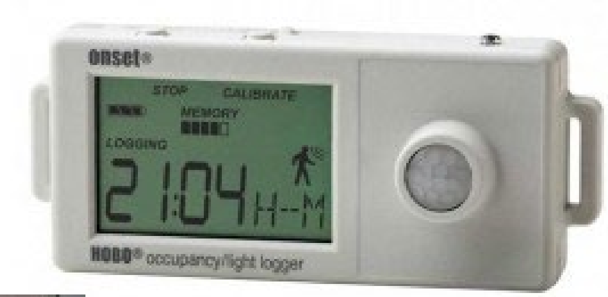
Data Collection

Common data sources

Building Automation Systems



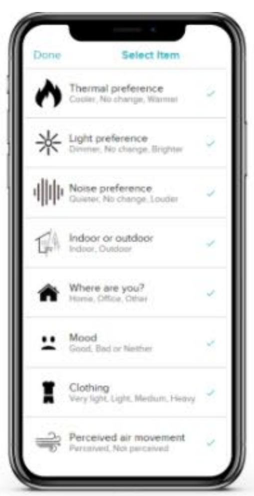




Installing stand-alone sensors / monitors

Data Collection

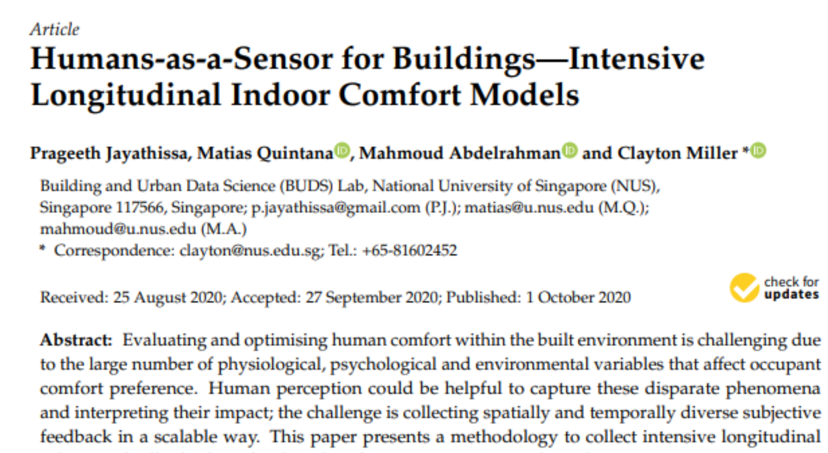
Other data sources



cozie

Tailor your experiment via the Fitbit mobile app

and design your flow



Article

Humans-as-a-Sensor for Buildings—Intensive Longitudinal Indoor Comfort Models

Prageeth Jayathissa, Matias Quintana, Mahmoud Abdelrahman and Clayton Miller *

Building and Urban Data Science (BUDS) Lab, National University of Singapore (NUS), Singapore 117566, Singapore; p.jayathissa@gmail.com (P.J.); matias@u.nus.edu (M.Q.); mahmoud@u.nus.edu (M.A.)
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Received: 25 August 2020; Accepted: 27 September 2020; Published: 1 October 2020

check for updates

Abstract: Evaluating and optimising human comfort within the built environment is challenging due to the large number of physiological, psychological and environmental variables that affect occupant comfort preference. Human perception could be helpful to capture these disparate phenomena and interpreting their impact; the challenge is collecting spatially and temporally diverse subjective feedback in a scalable way. This paper presents a methodology to collect intensive longitudinal subjective feedback of comfort-based preference using micro ecological momentary assessments on a

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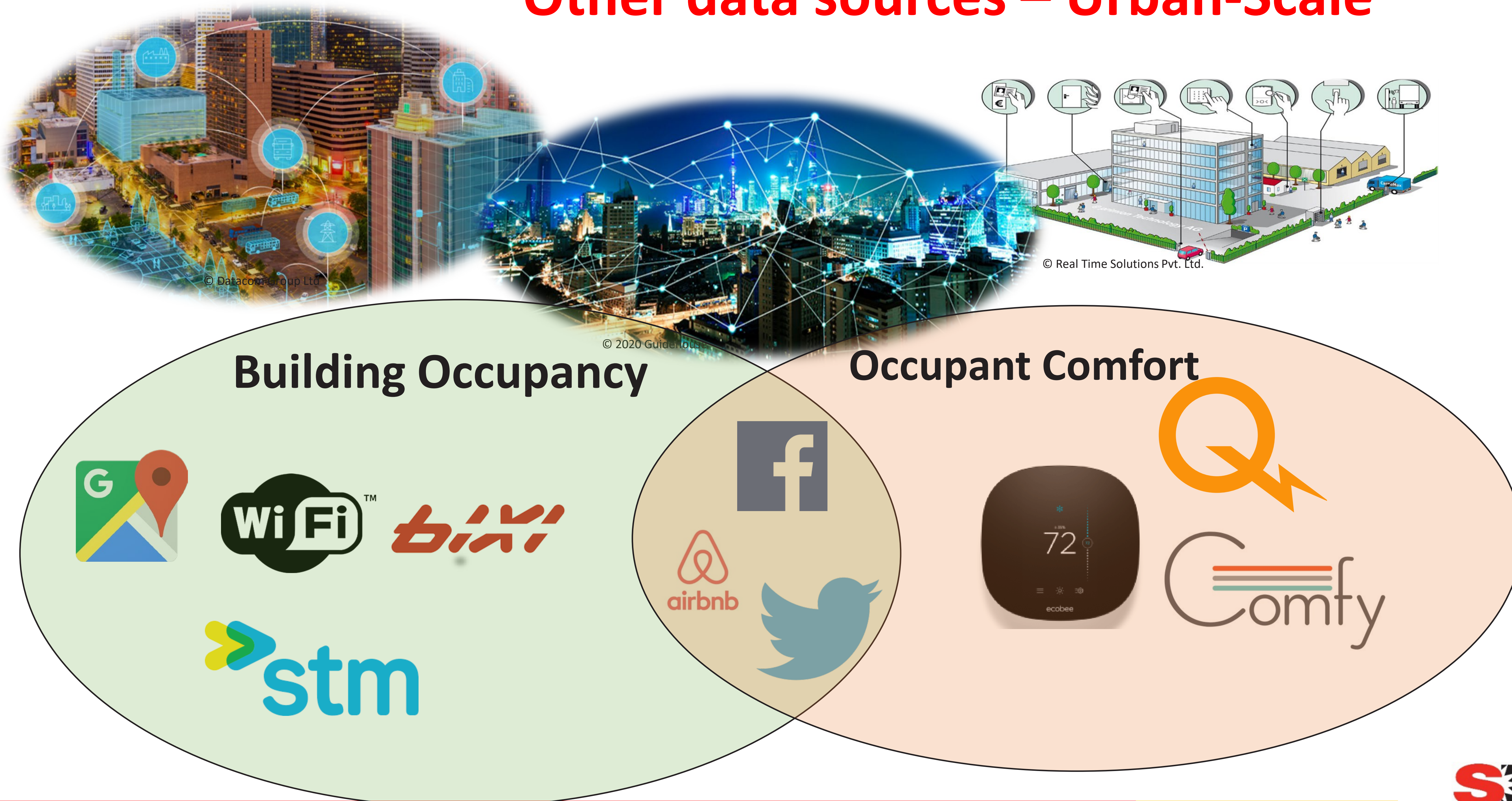
Data Collection

Other data sources – Urban-Scale



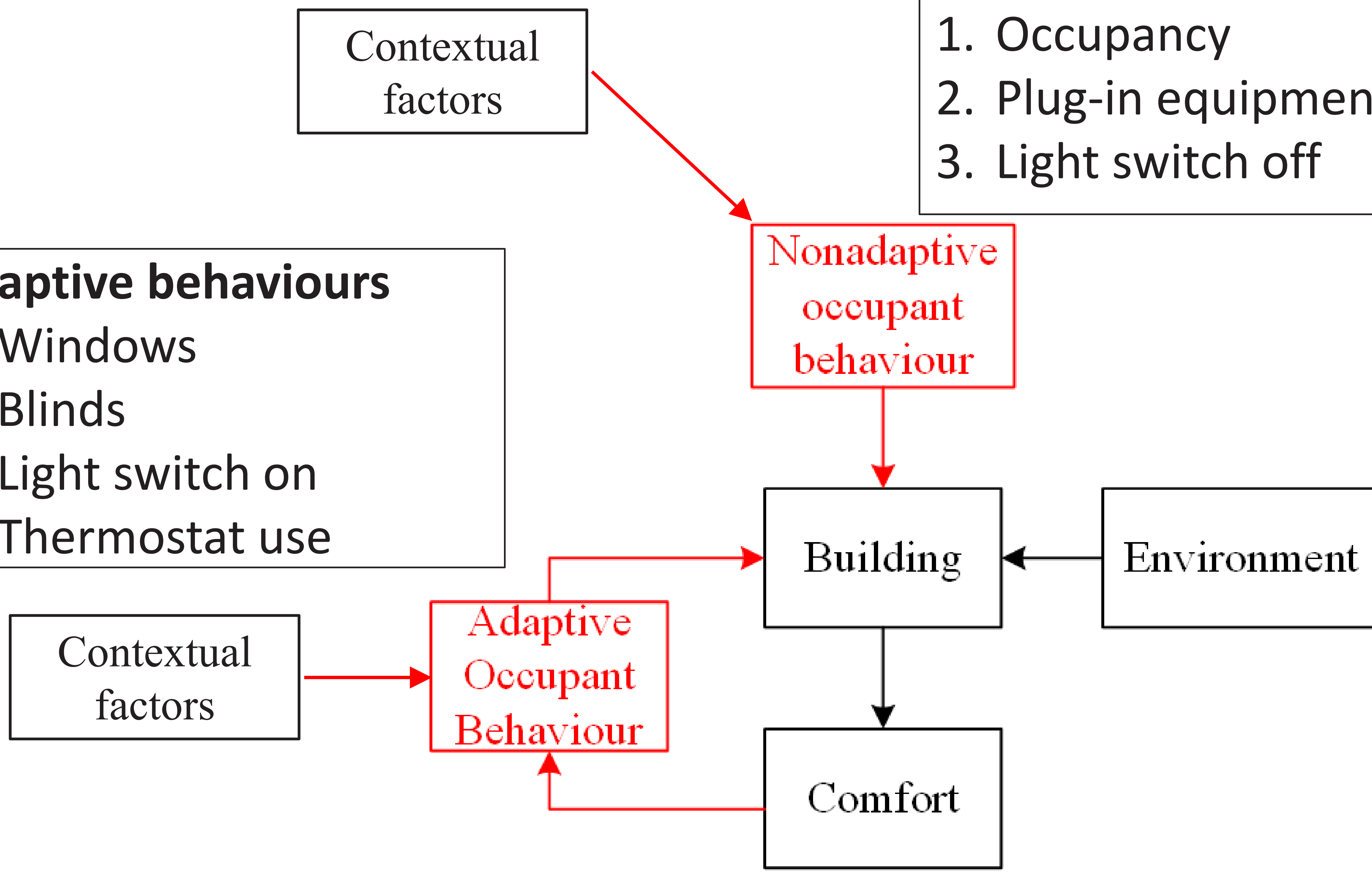
Modelling Occupant Behaviour

OB Model Formalism

- Occupant Behaviour types

Non-adaptive behaviours
1. Occupancy
2. Plug-in equipment
3. Light switch off

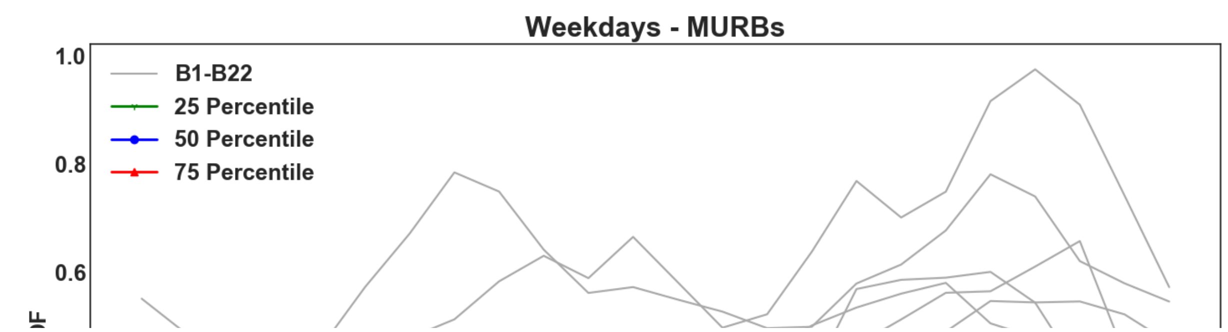
Adaptive behaviours
1. Windows
2. Blinds
3. Light switch on
4. Thermostat use



OB Model Formalism

Each sub-category can be modelled using different approaches:

- Inter-quartile ranges
- Monte-Carlo methods
- **Bernoulli random processes**
- **Discrete-time Markov Chains**
- Discrete-event Markov Chains
- Survival Analysis
- Generalized Linear Regression
- **Logistic Regression**




Review

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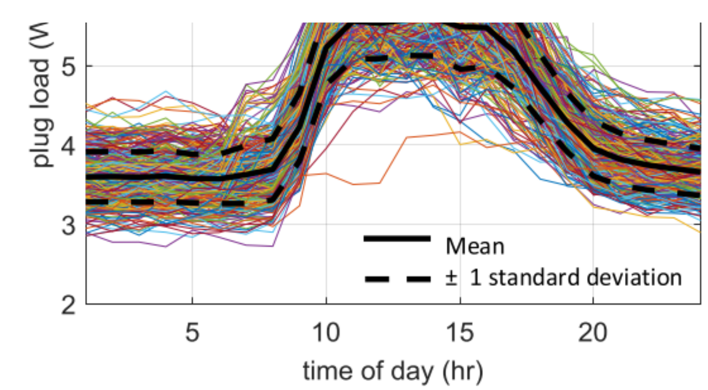
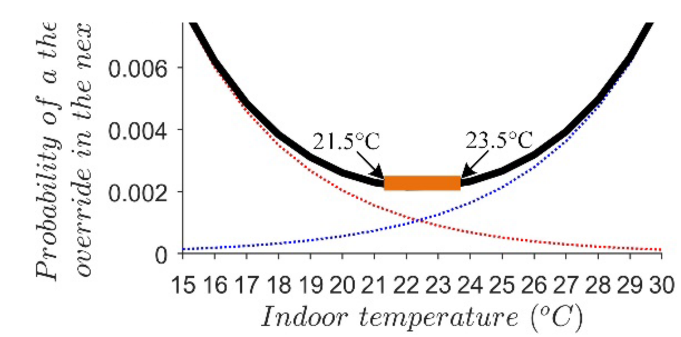
Critical review and illustrative examples of office occupant modelling formalisms

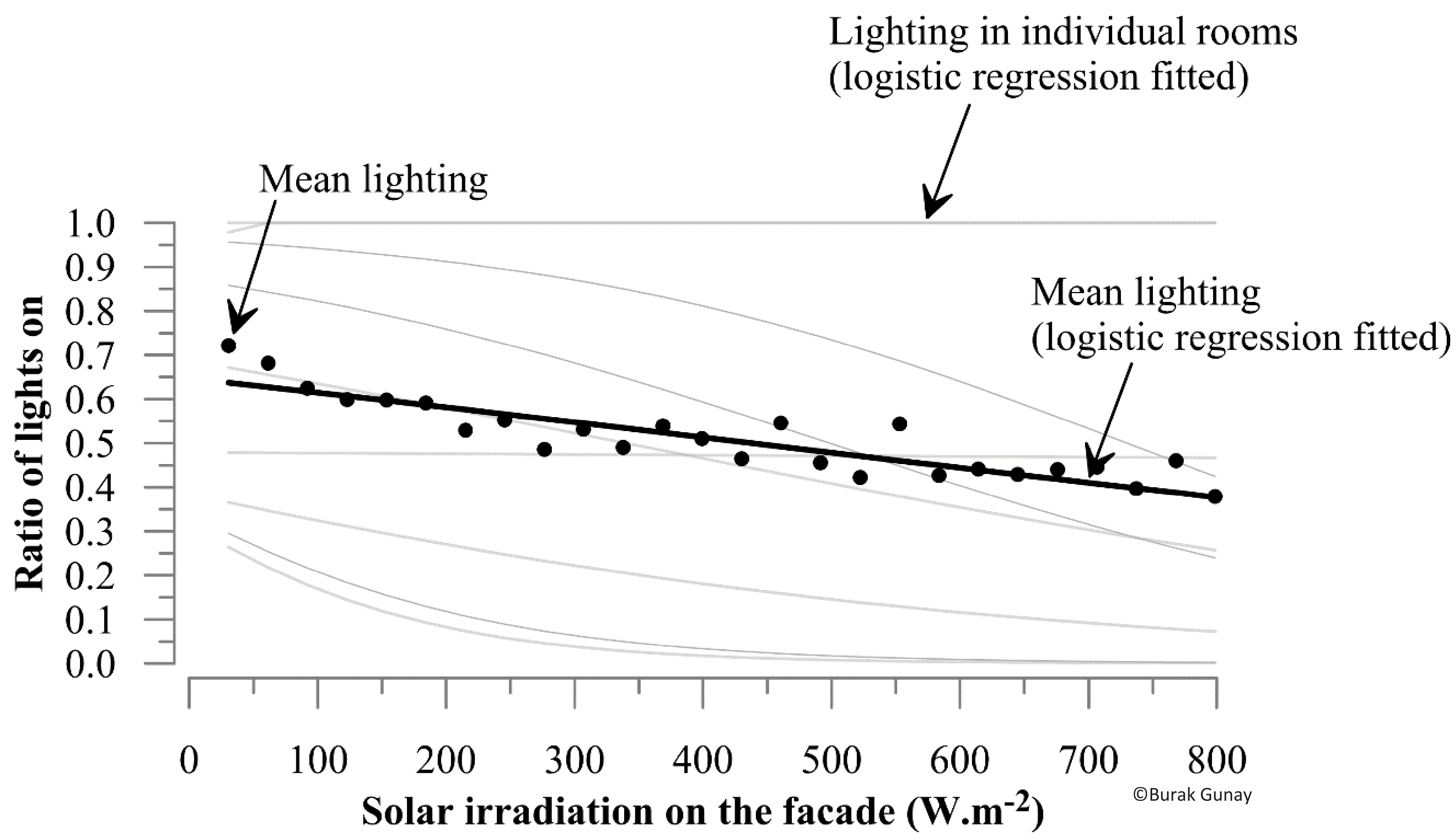
Simona D'Oca[1], H Burak Gunay[2], Sara Gilani[2] and William O'Brien[2]





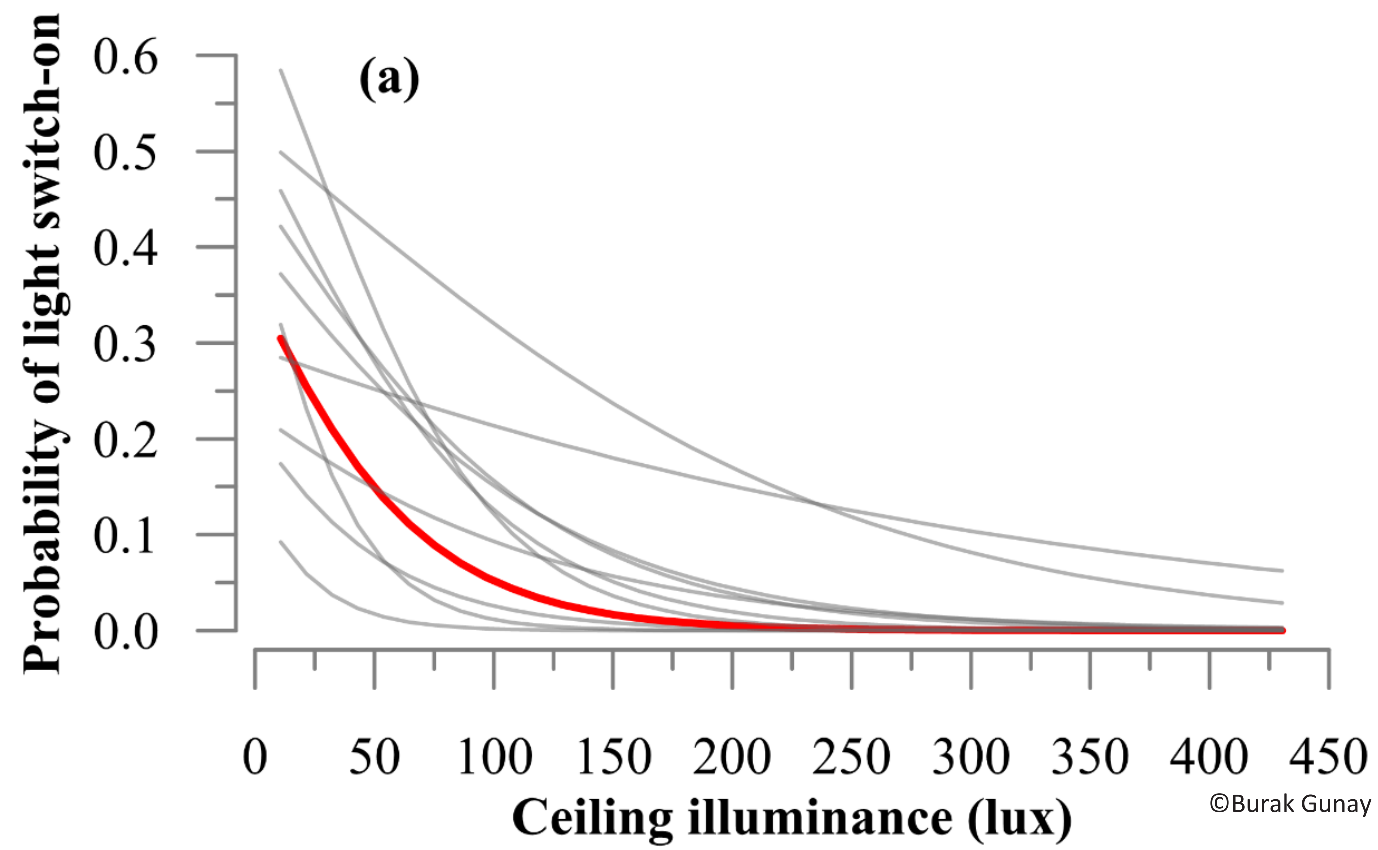
OB Model Formalism

Occupant model forms – Bernoulli



OB Model Formalism

Occupant model forms – Discrete-time Markov



$$p(switch\ on|off) = \frac{Number\ of\ timesteps\ with\ a\ light\ switch\ on}{Number\ of\ occupied\ timestpe\ when\ lights\ were\ off}$$

OB Model Formalism

Occupant model forms – Logistic Regression Models

Indoor workplane illuminance (at sensor)

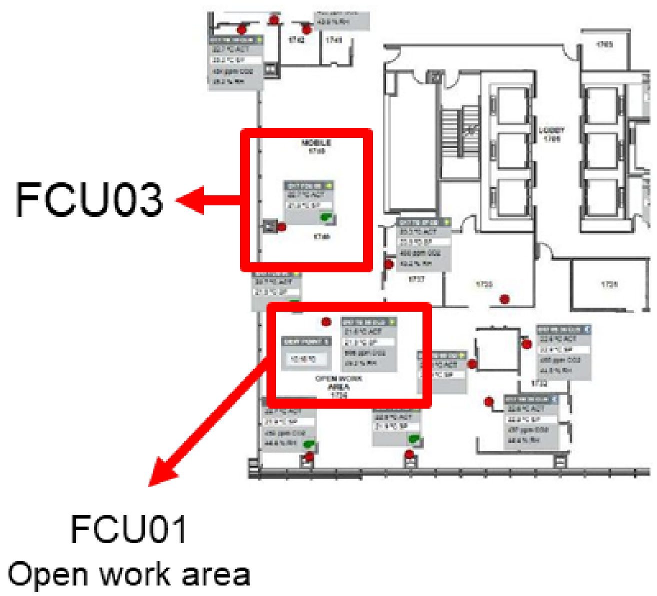
$$P_{switch-on}(E_{in}) = \frac{\exp\,(a + \, b_{in}E_{in})}{1 + \exp\,(a + \, b_{in}E_{in})}$$

Expected duration of absence

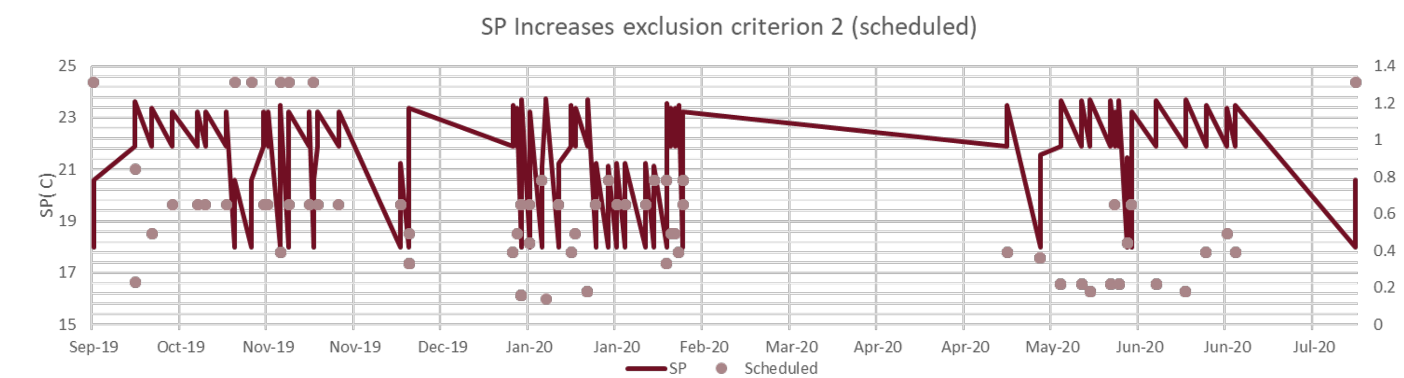
$$P_{switch-off}(T_{abs}) = \frac{\exp\,(a + bT_{abs})}{1 + \exp\,(a + bT_{abs})}$$

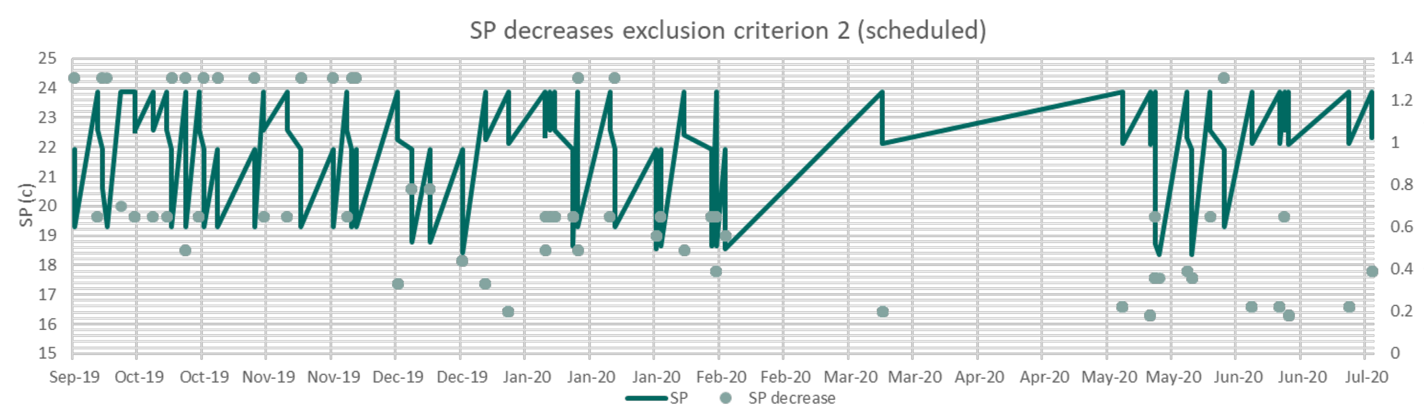
Modelling Occupant Behaviour (OB)

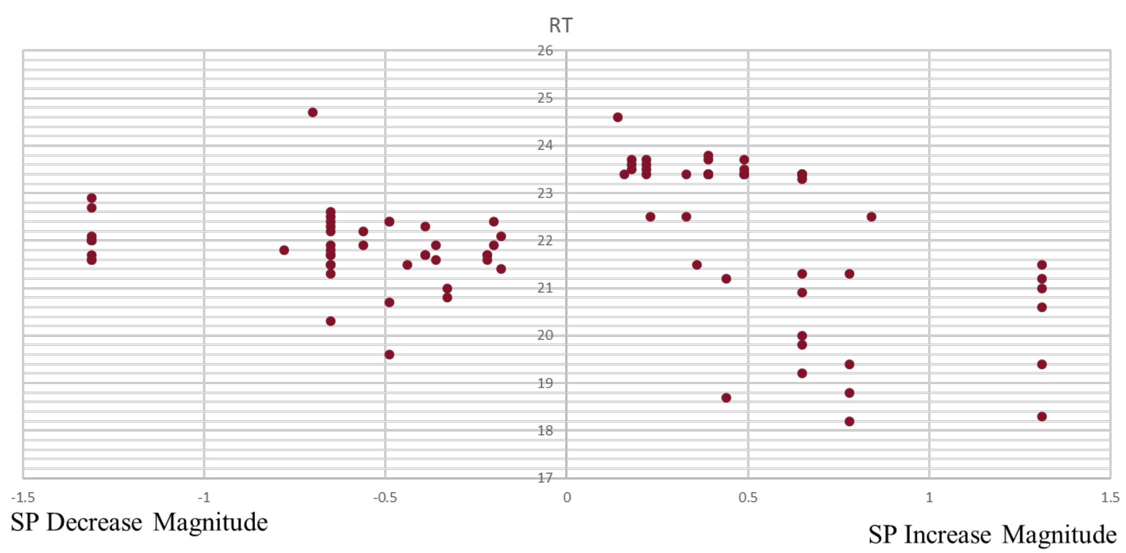
- Estimating the likelihood of occupant-building interactions

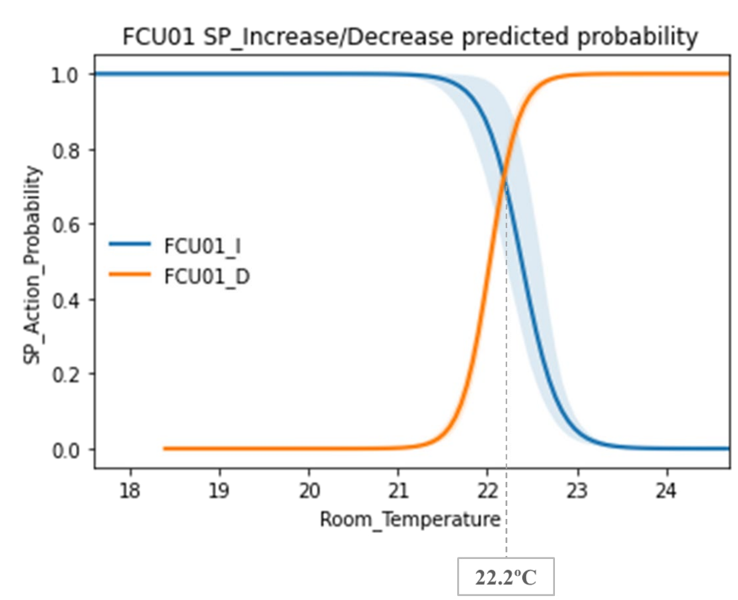


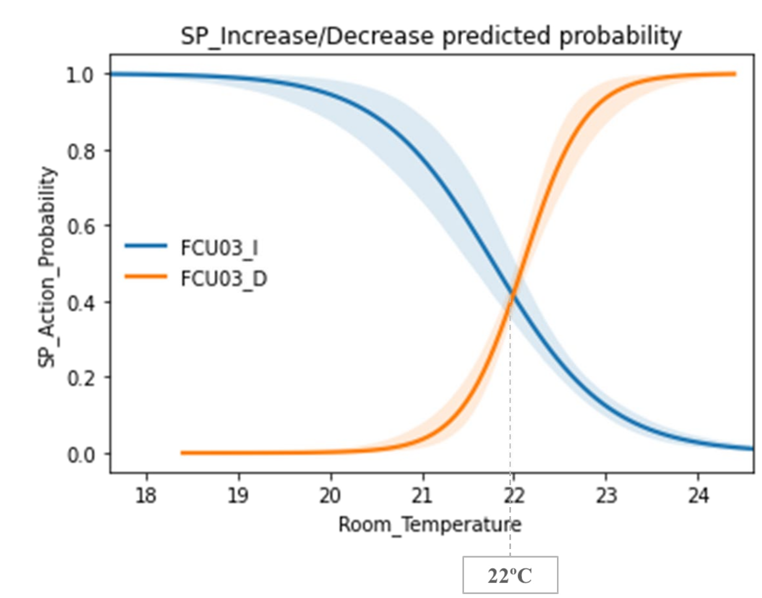
Office Building in Edmonton, AB



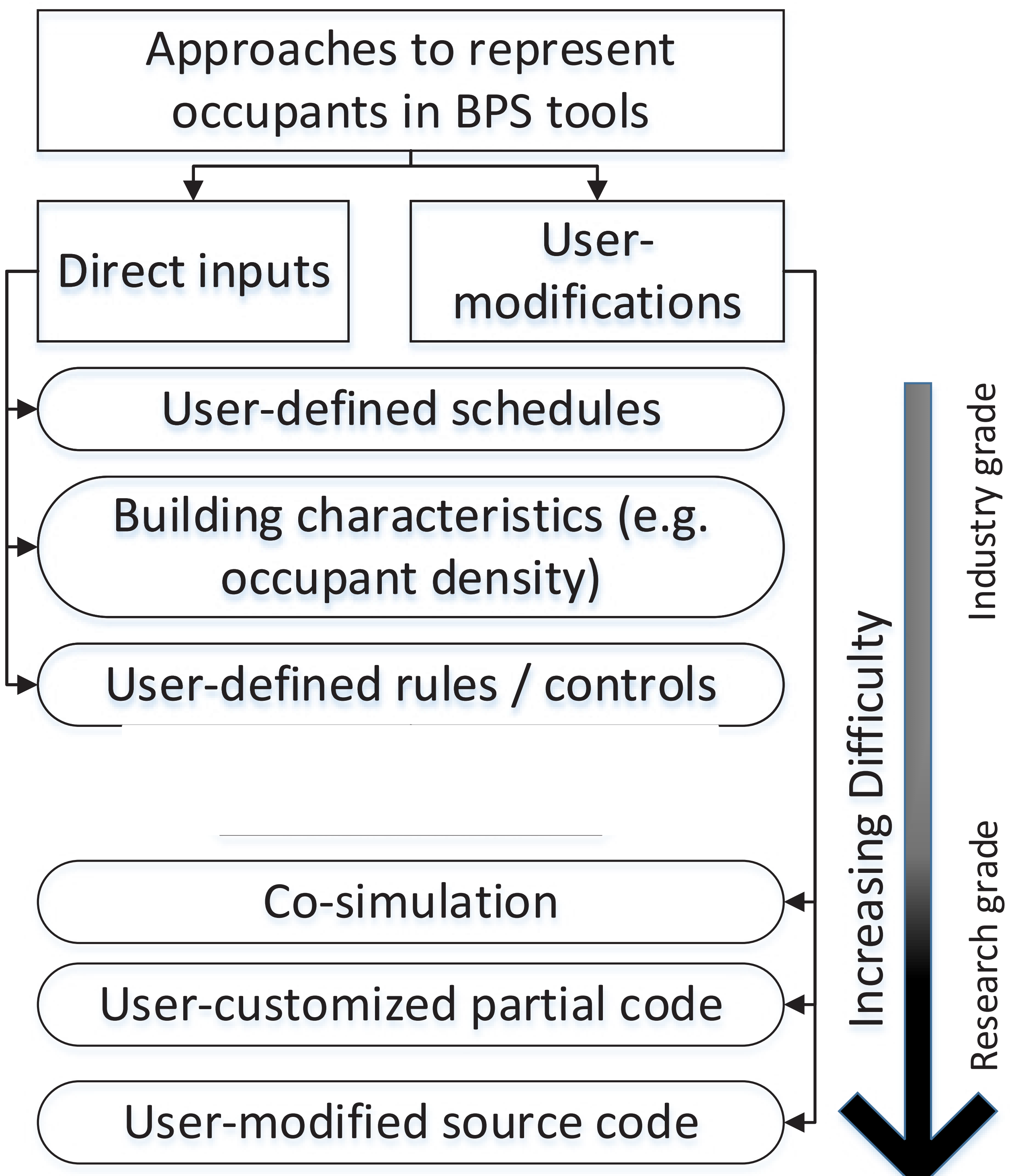








Integrating OB in Building Performance Simulations



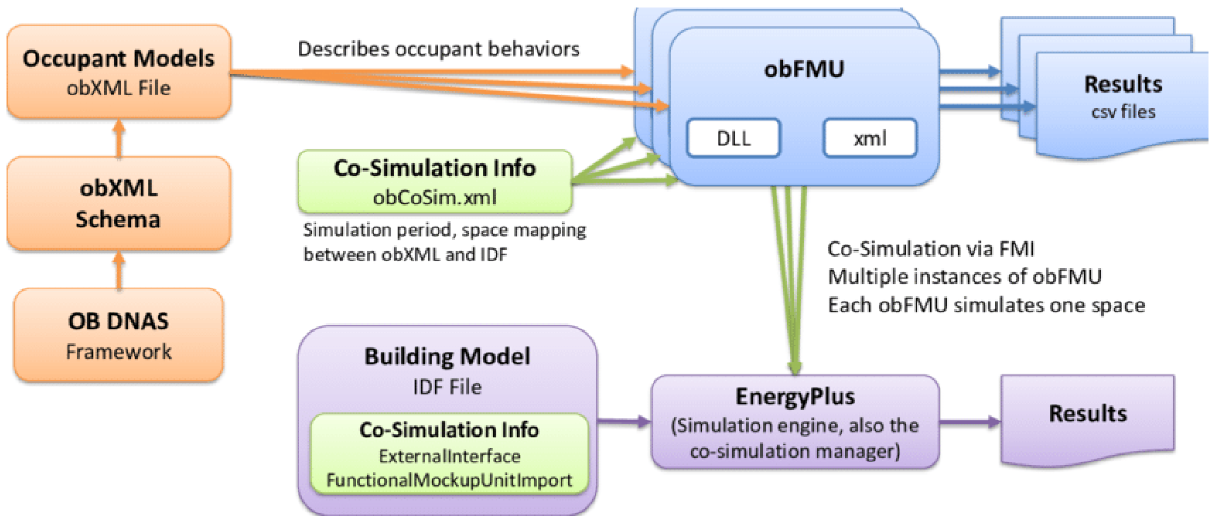
BUILD SIMUL
https://doi.org/10.1007/s12273-018-0443-y

Improving occupant-related features in building performance simulation tools

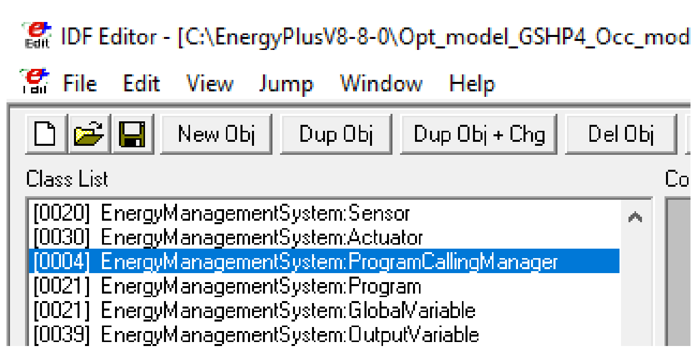
Mohamed M. Ouf (✉), William O'Brien, H. Burak Gunay

Department of Civil Engineering, Carleton University, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada

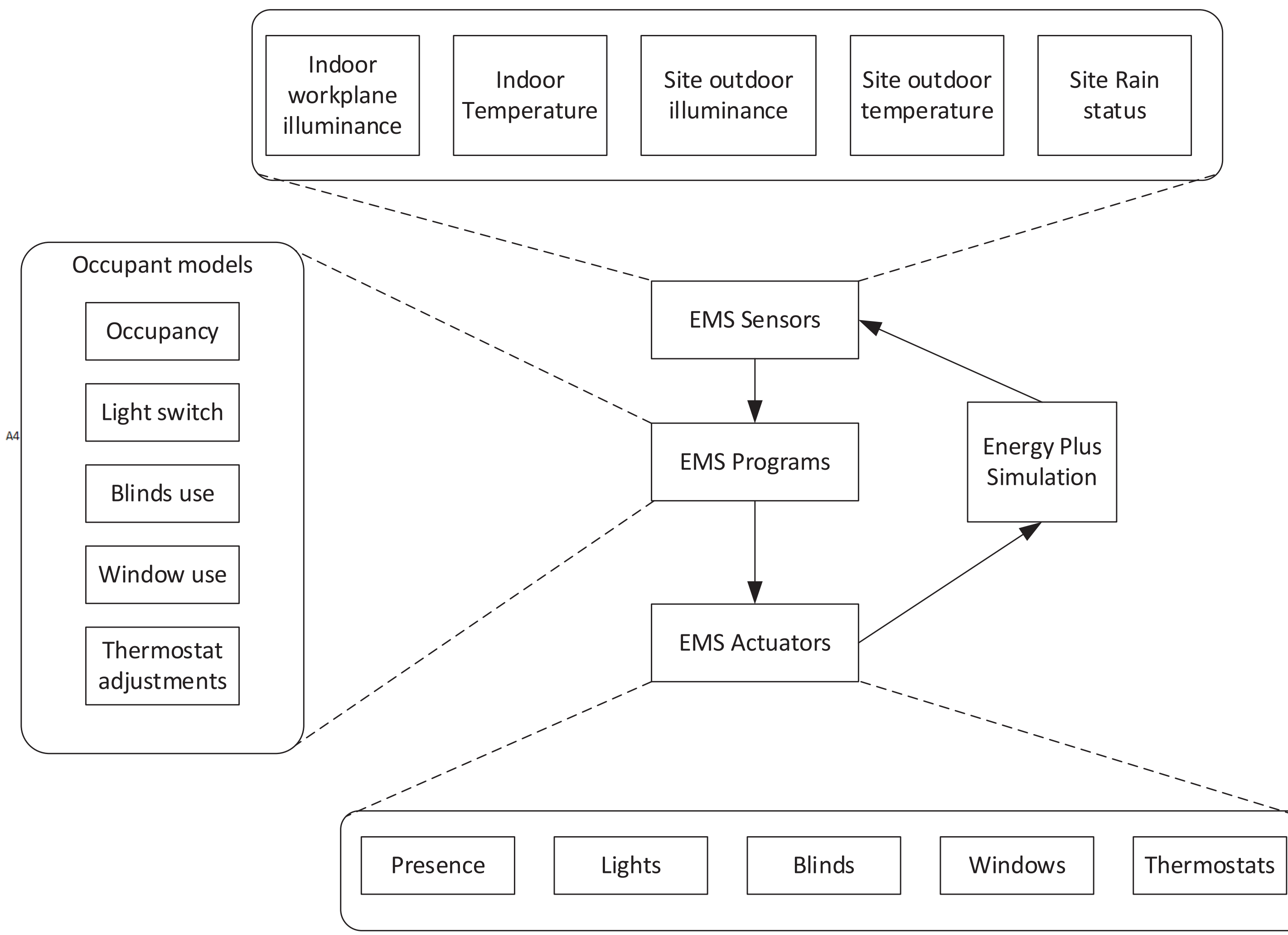
Integrating OB in Building Performance Simulations



Zhe Wang, Tianzhen Hong & Ruoxi Jia (2019) *Buildings.Occupants*: a Modelica package for modelling occupant behaviour in buildings, Journal of Building Performance Simulation, 12:4, 433-444,




```
EnergyManagementSystem:Program,
    Haldi_Blinds,            !- Name
    set alpha=1.708,         !- Program Line 1
    set unshadedfrac=1-Blinds,  !- Program Line 2
    if CurrentTime>Arrival && CurrentTime<Arrival+0.1,  !- A4
    set handle=A26+B31*daylight+B32*unshadedfrac,  !- A5
    set handle=@Exp handle,  !- A6
    set R=@RandomUniform 0 1,!- A7
    set handle=handle/(handle+1),  !- A8
    if handle>R,             !- A9
    set handle=A28+B35*E_glob+B36*unshadedfrac,  !- A10
    set handle = @Max handle 0-19,  !- A11
    set handle = @Min handle 600,  !- A12
    set handle=@Exp handle,  !- A13
    set handle=handle/(handle+1),  !- A14
    set R=@RandomUniform 0 1,!- A15
    if handle>R,             !- A16
    set Blinds=1,            !- A17
    else,                    !- A18
    set lambda=1.522*Blinds-2.294,  !- A19
    set lambda=@Exp lambda,  !- A20
    set db = @RandomUniform 0 1,  !- A21
    set db = @ln (1-db),     !- A22
    set lambda = (lambda^alpha)*(0-1),  !- A23
    set db=db*lambda,        !- A24
    set db=db^(1/alpha),     !- A25
    set db=db*100,           !- A26
    set remainder=@Mod db 25,!- A27
    set db=(db-remainder)/100,  !- A28
    set db=@max 0.25 db,     !- A29
    set Blinds=@min Blinds+db 1,  !- A30
    endif,                   !- A31
    endif,                   !- A32
    endif,                   !- A33
    if Num_People == 1,      !- A34
    set handle=A27+B33*daylight+B34*unshadedfrac,  !- A35
    set handle = @Max handle 0-19,  !- A36
    set handle = @Min handle 600,  !- A37
    set handle=@Exp handle,  !- A38
    set handle=handle/(handle+1),  !- A39
    set R=@RandomUniform 0 1,!- A40
    if handle>R,             !- A41
    set handle=A28+B35*E_glob+B36*unshadedfrac,  !- A42
    set handle = @Max handle 0-19,  !- A43
    set handle = @Min handle 600,  !- A44
    set handle=@Exp handle,  !- A45
    set handle=handle/(handle+1),  !- A46
    set R=@RandomUniform 0 1,!- A47
    if handle>R,             !- A48
    set Blinds=1,            !- A49
```

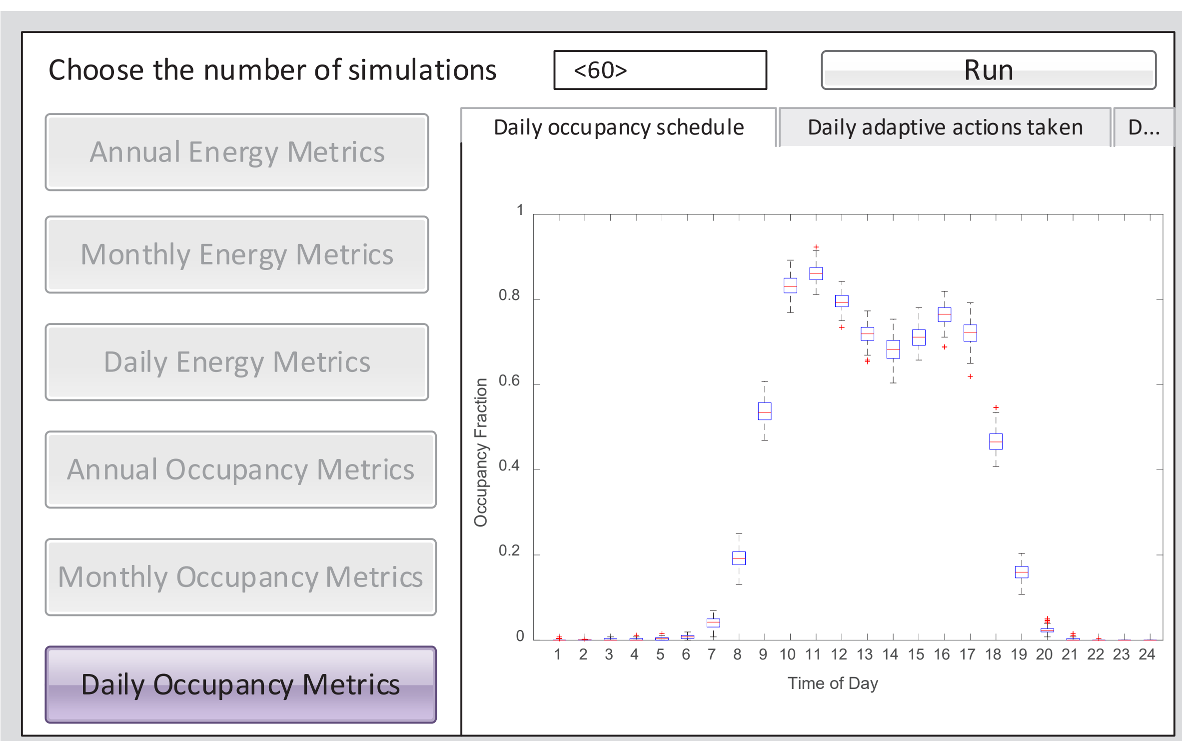


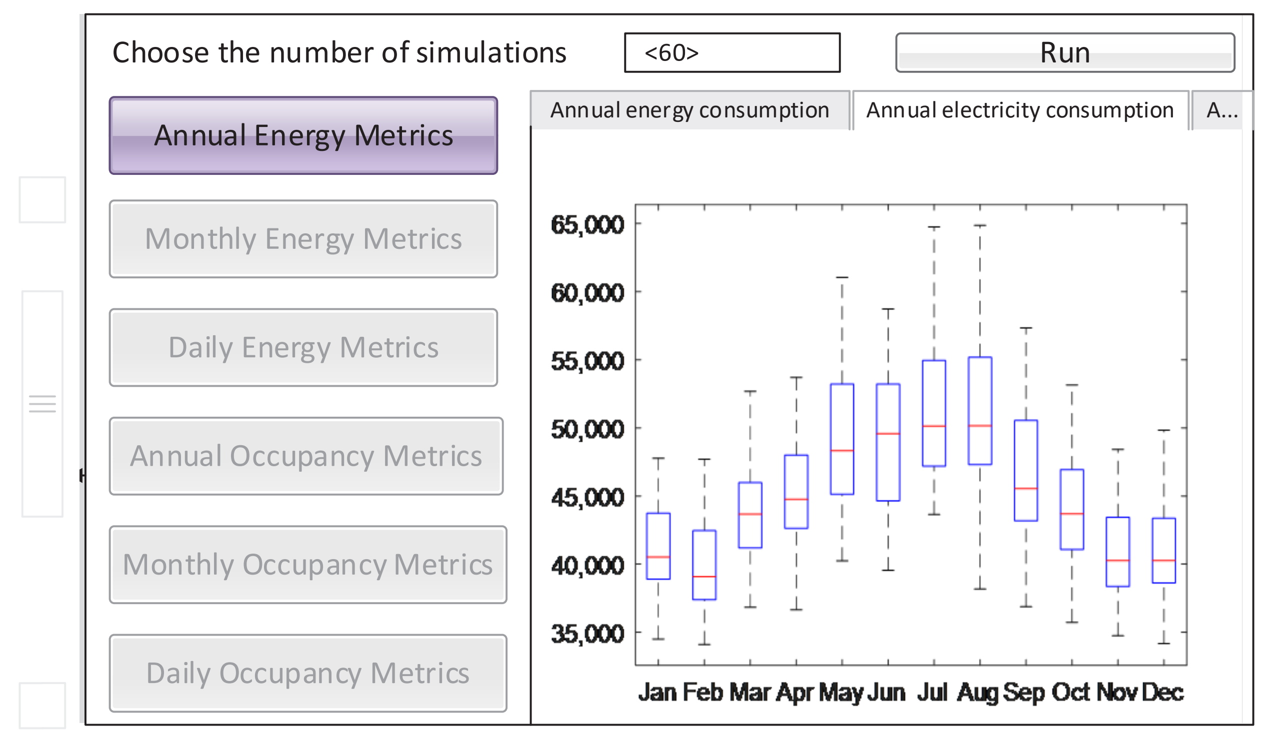
H. Burak Gunay, William O'Brien & Ian Beausoleil-Morrison (2016) Implementation and comparison of existing occupant behaviour models in EnergyPlus, Journal of Building Performance Simulation, 9:6, 567-588

Integrating OB in Building Performance Simulations

Outputs

- A range of building performance values
- Occupant-centric performance metrics
    - e.g., number of interactions with systems

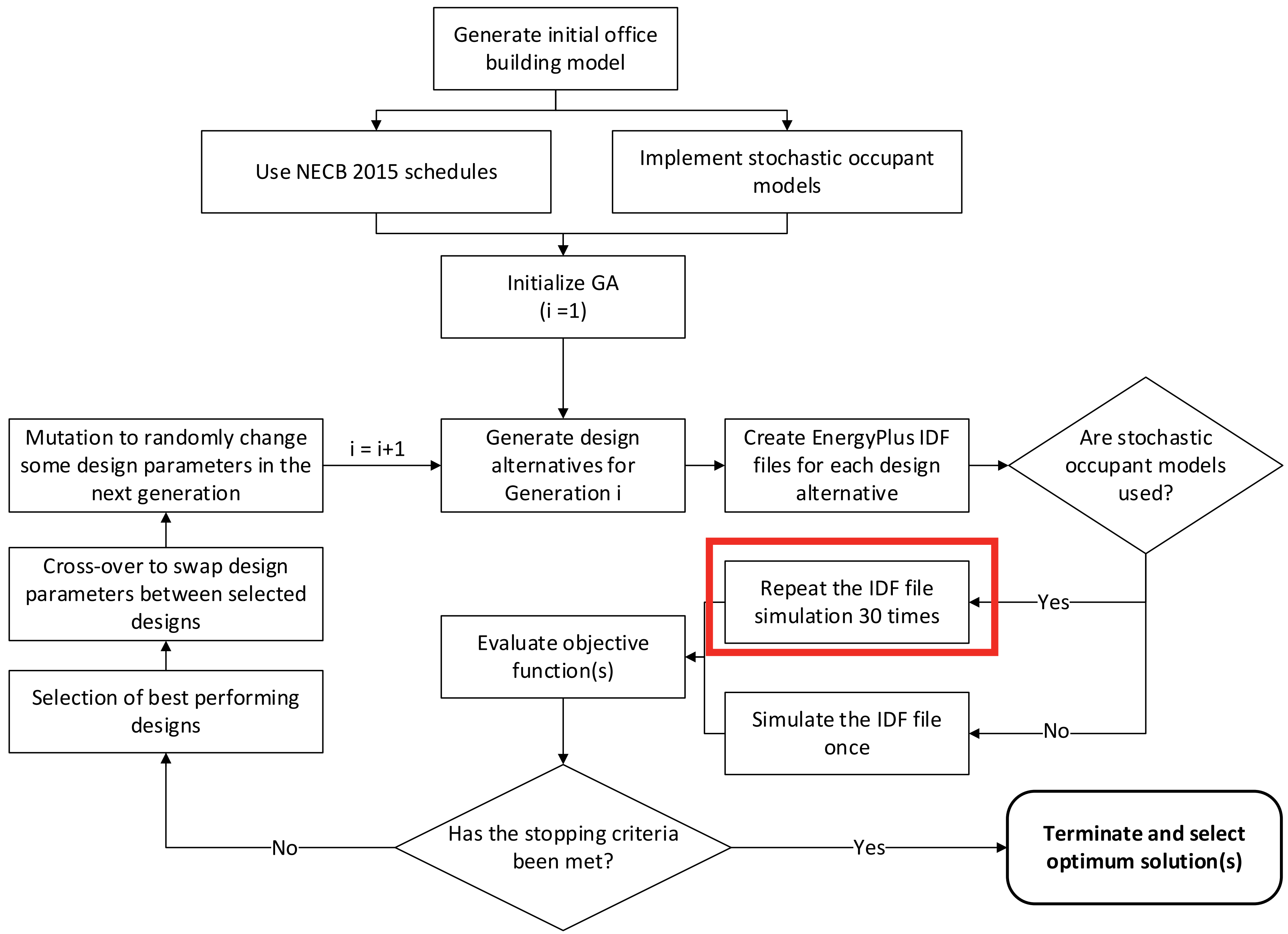




Ouf, M.M., O'Brien, W. & Gunay, H.B. Improving occupant-related features in building performance simulation tools. *Build. Simul.* **11**, 803–817 (2018).

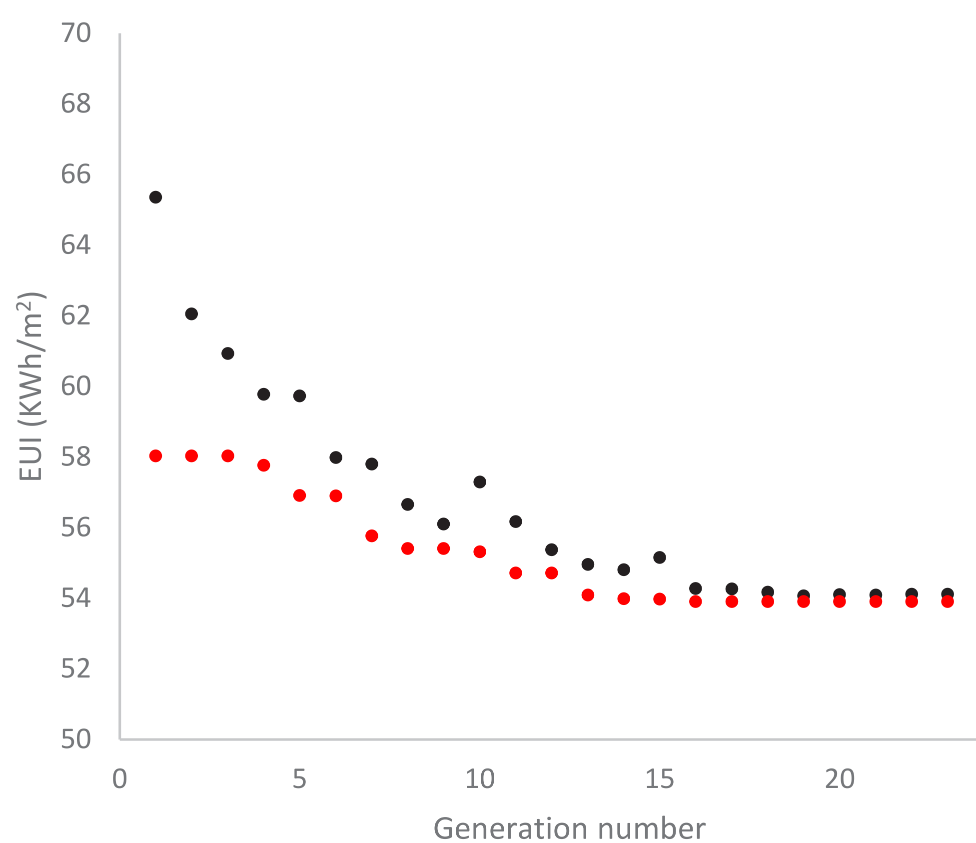
Integrating OB in Building Performance Simulations

Optimization

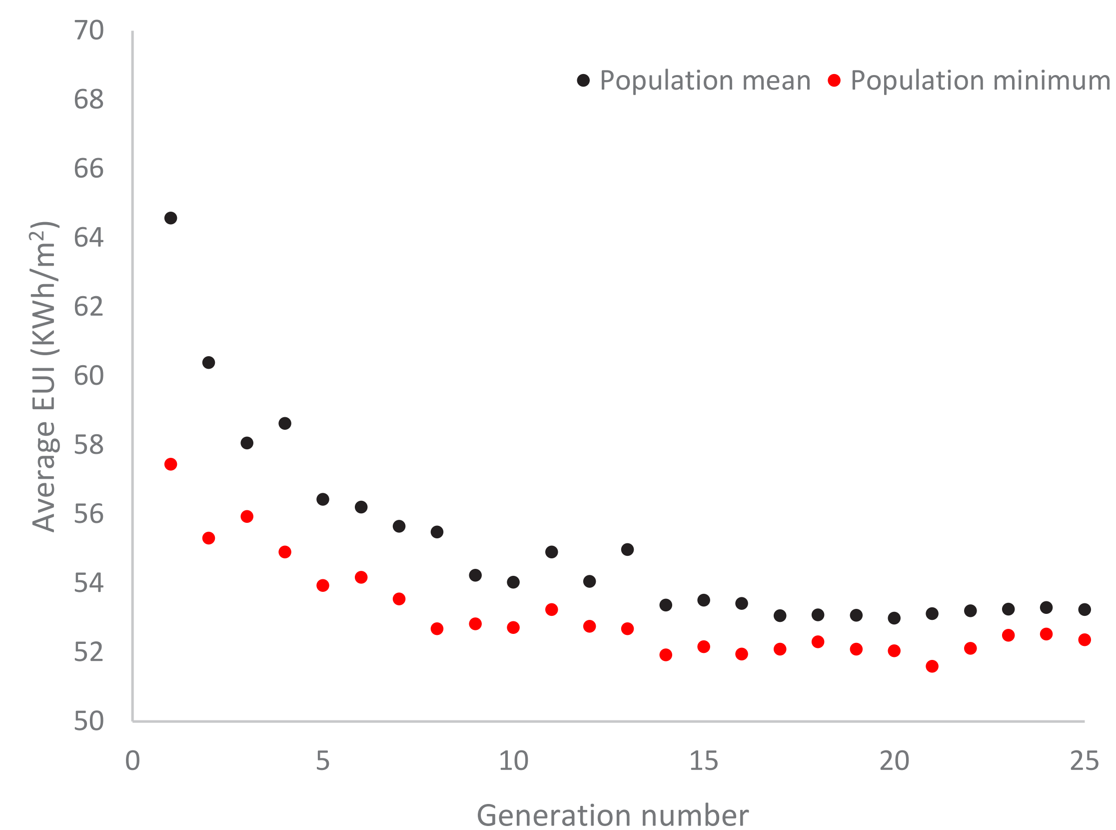


Integrating OB in Building Performance Simulations

Optimization



Standard ASHRAE 90.1 schedules

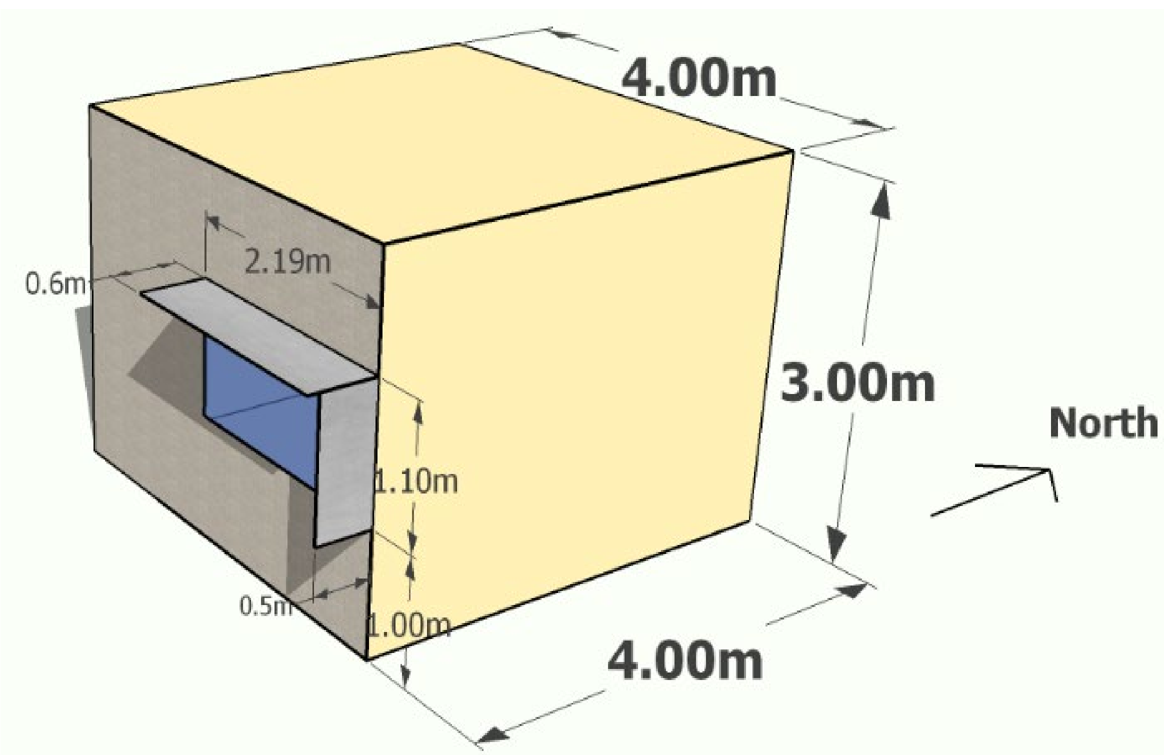


Stochastic occupant models for occupancy, light use, and blinds use

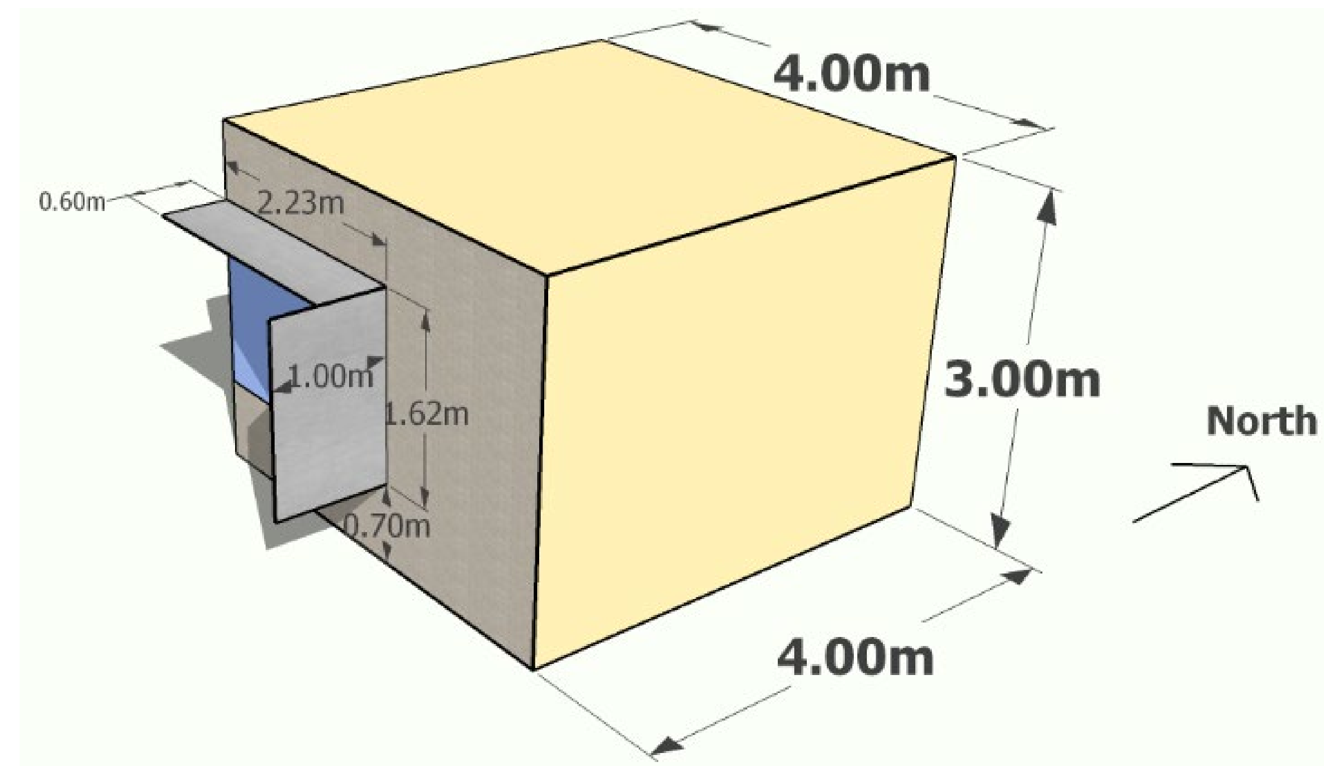
Integrating OB in Building Performance Simulations

Optimization

Identify optimal design variables using the Genetic Algorithm



Standard ASHRAE 90.1 schedules

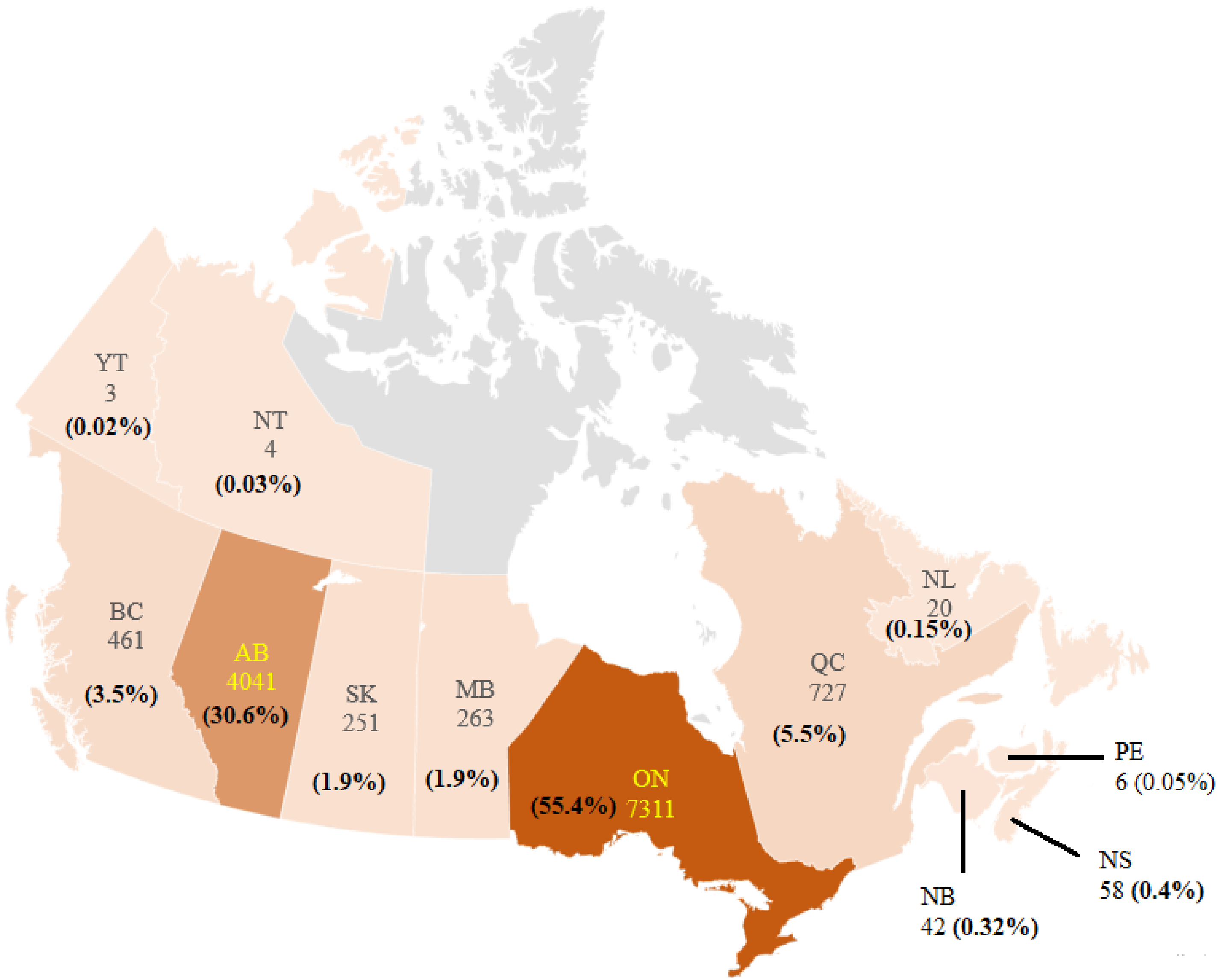


Stochastic occupant models for occupancy, light use, and blinds use

Ouf, Mohamed, William O'Brien, Burak Gunay (2020) Optimization of electricity use in office buildings under occupant uncertainty. **Journal of Building Performance Simulation,** 13:1, 13-25

Modelling OB at the Urban-Scale

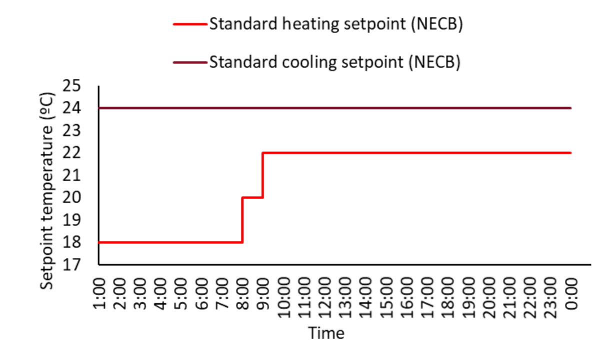
- Rely on big data collected across North America
  - Ecobee smart thermostat data (**~14,000** houses in Canada)



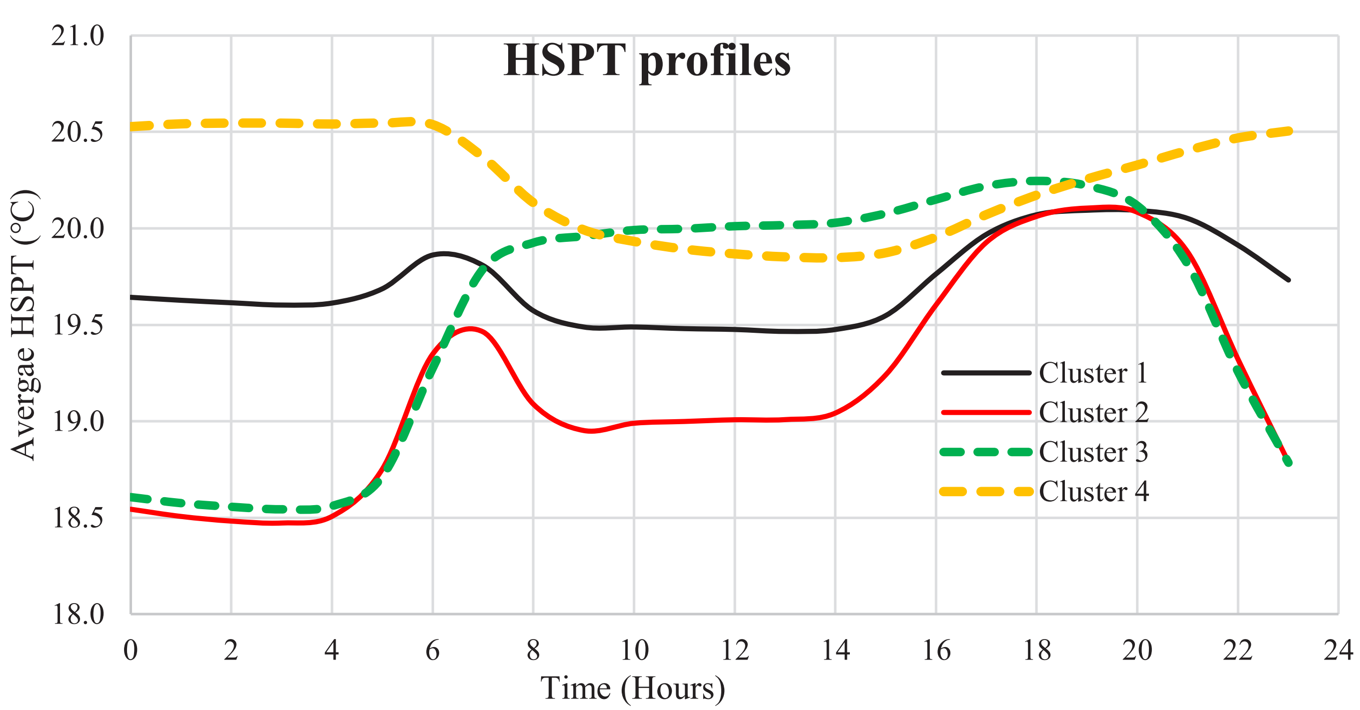
ecobee

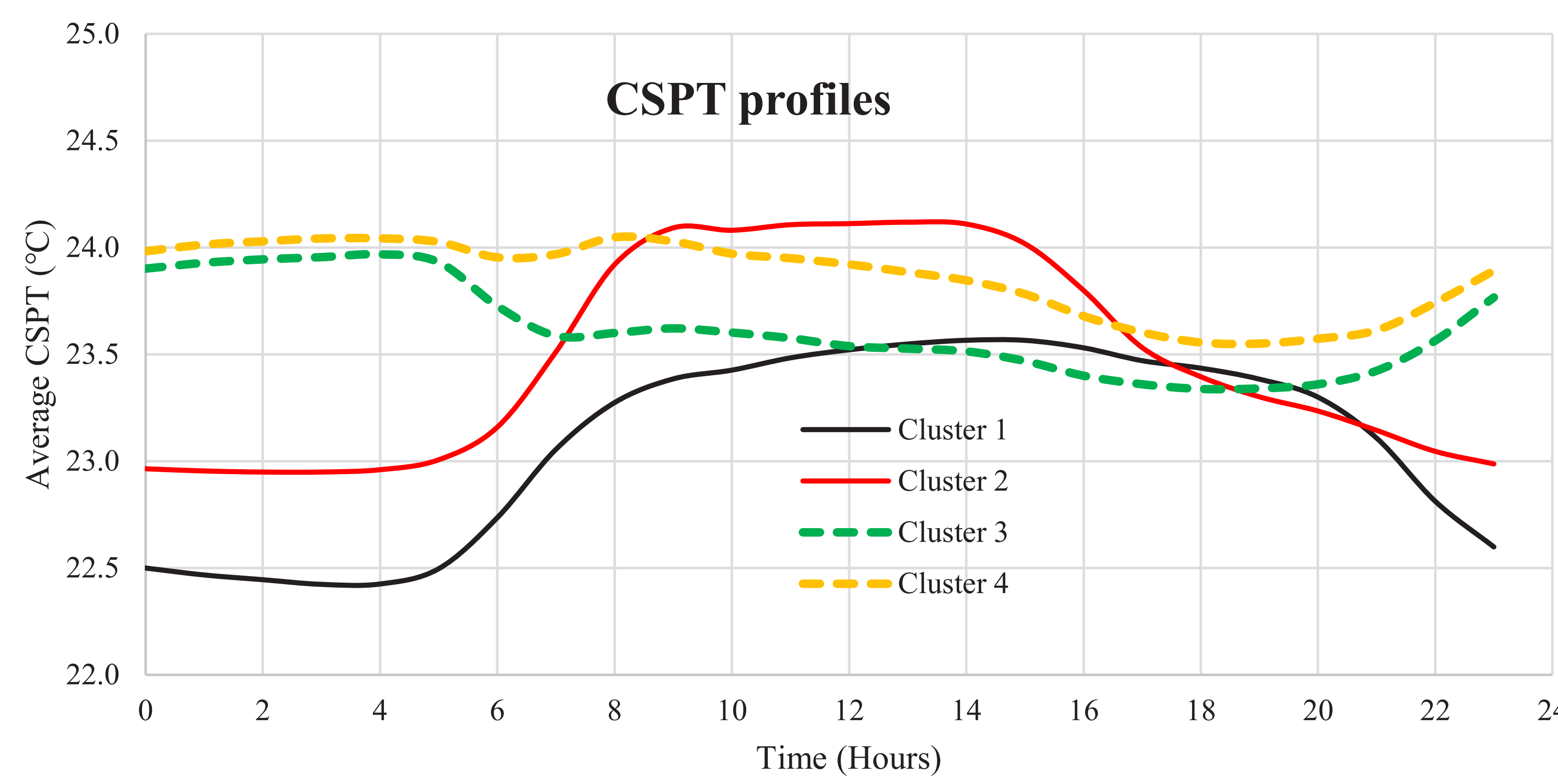
Modelling OB at the Urban-Scale

- Ecobee data shows some level of agreement with statistically sampled data reported in SHEU
- K-shape clustering of average 24-hr heating / cooling profiles
  - The highest Dunn index value was obtained with 4 clusters
- Approximately 60% of houses had a **daytime** heating and cooling **setback**
- Data-driven heating / cooling setpoint profiles do not match Code assumptions
- Code assumptions also do not change based on climate zone, house type or area



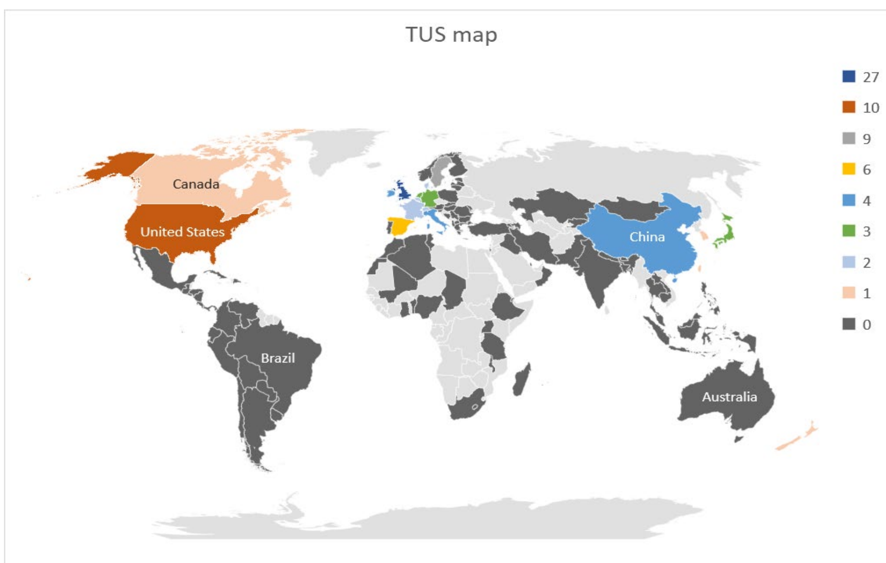
NECB
National Energy Code of Canada For Buildings

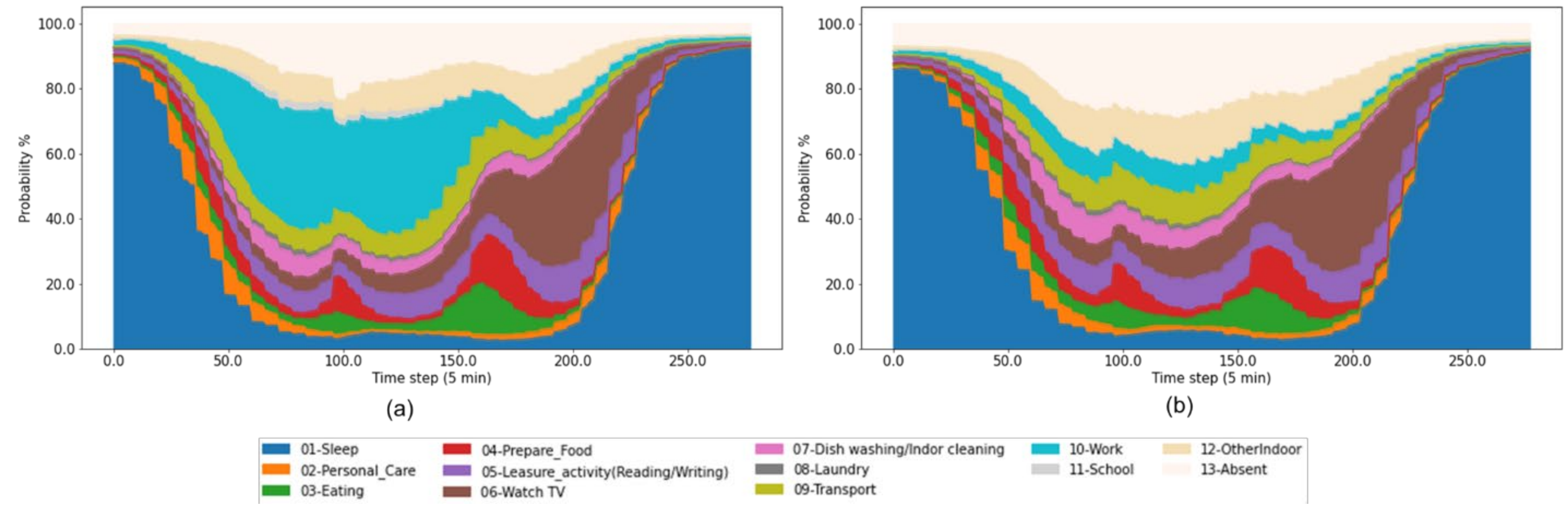




Modelling OB at the Urban-Scale

Time Use Surveys





Cultural and Social
- TUS
- Household travel survey
- Working time survey

Economic and Demographic parameters
- Census data
- Building Stock surveys
- Energy consumption surveys

Human behaviour parameters
- On-site measurments (electricity, setpoint temperature- etc)
- Technology adoption surveys

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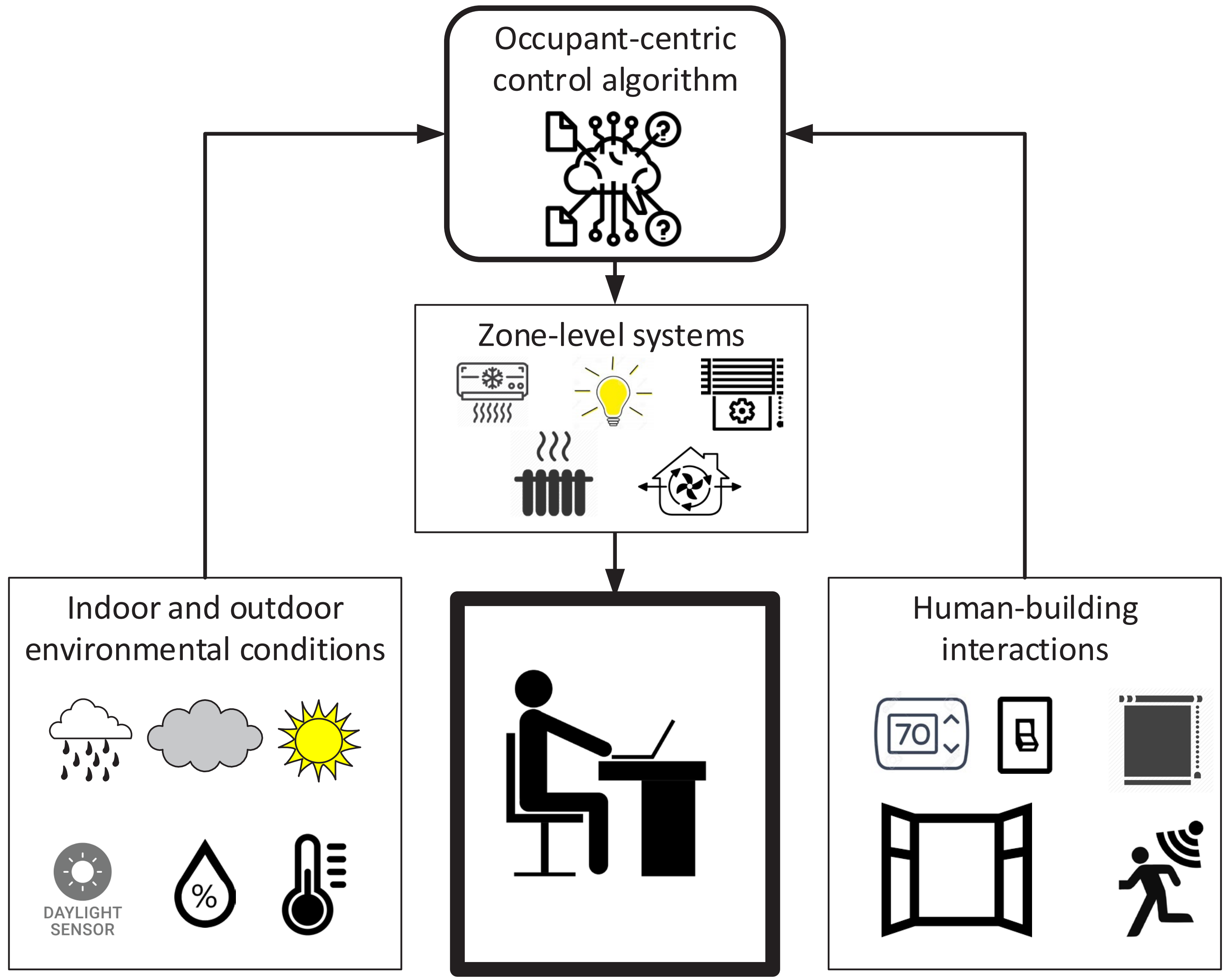
Integrating Occupant Behaviour in Building Operations

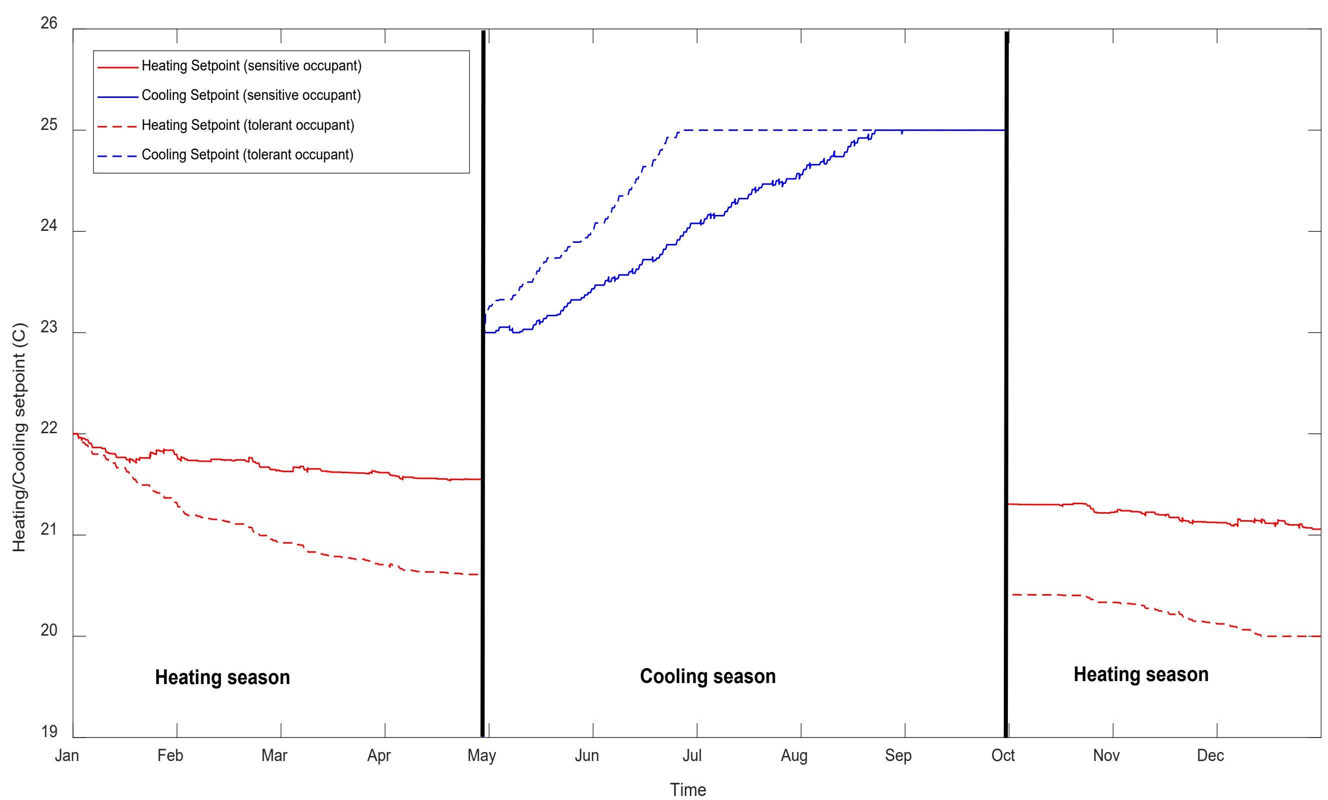
Integrating Occupant Behaviour in Building Operations

Occupant-Centric Control (OCC)

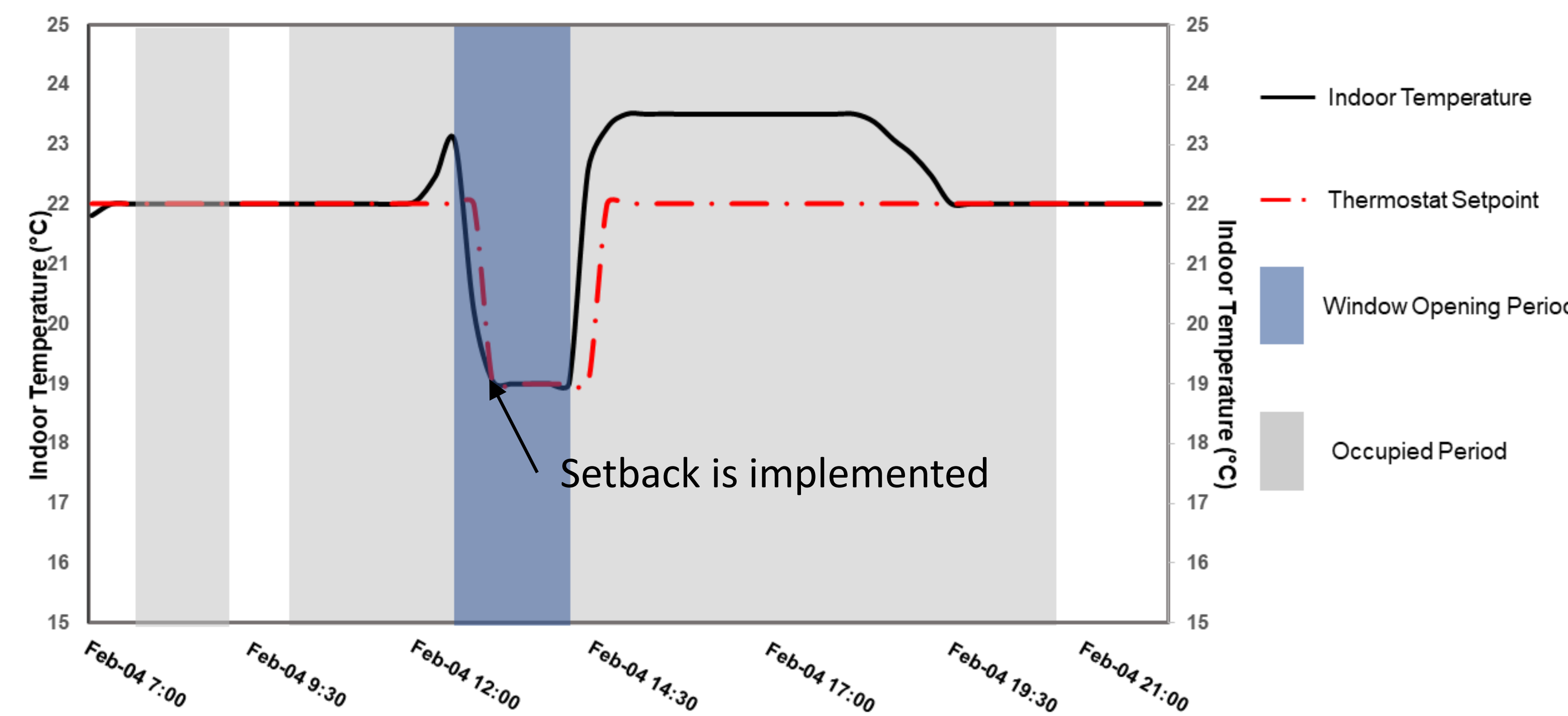


Occupant-Centric Controls (OCC)

Optimize the operation of different systems



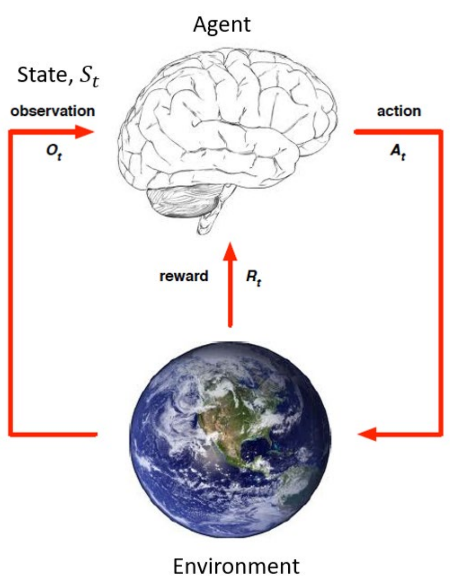
Adjust thermostat setpoints ($1000s in savings)



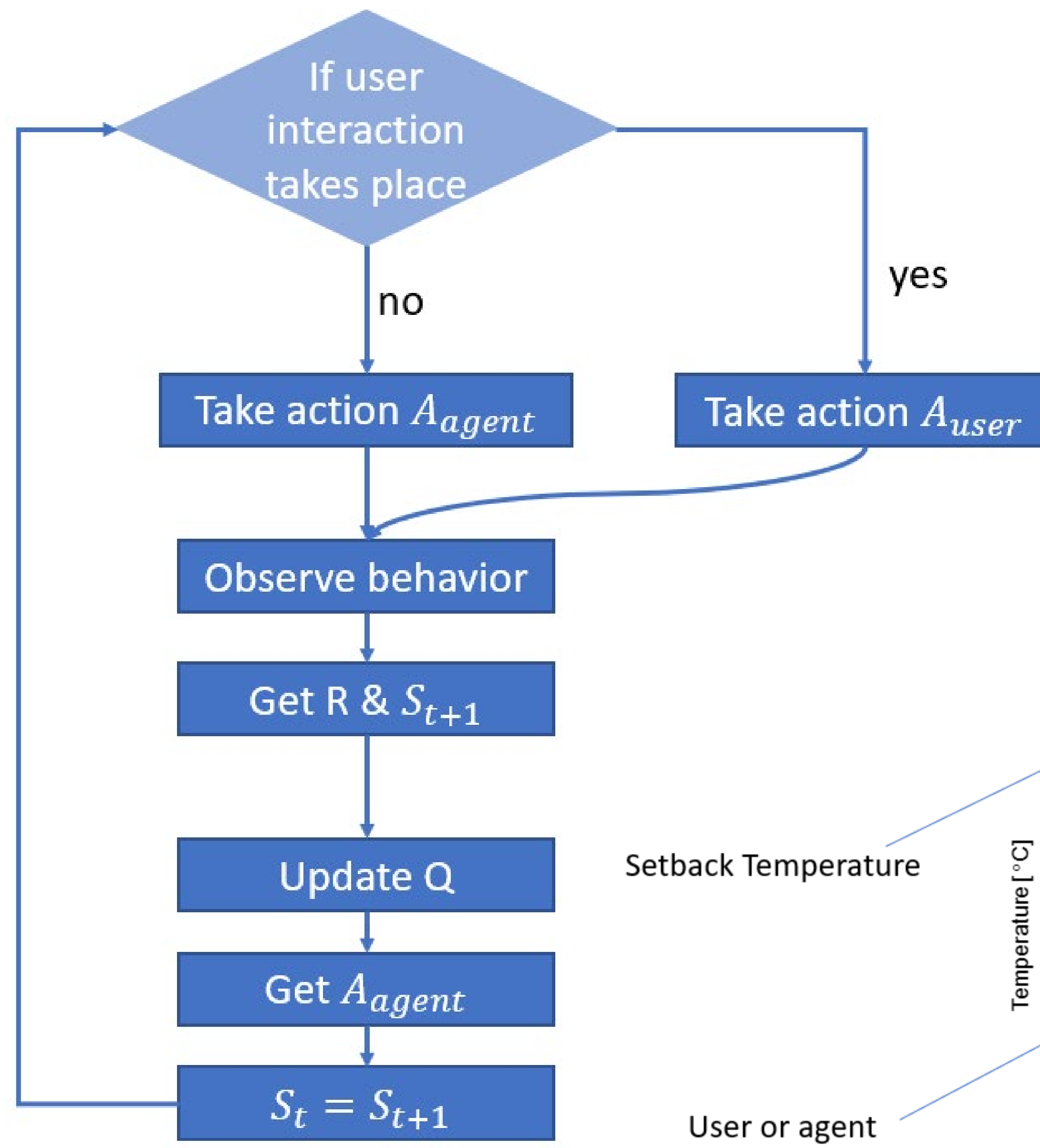
Regulate window operation

Occupant-Centric Controls (OCC)

Use Reinforcement Learning as a model free approach



States/actions	18	20	21	22	23	24	26
1 (T<19)	-1.5	-1.5	-1	-0.5	0	-0.5	-1.5
2 (T=19)	-1.5	-1.5	-1	-0.5	0	-0.5	-1.5
3 (T=20)	-1.5	-1.5	-1	-0.5	0	-0.5	-1.5
4 (T=21)	-1.5	-1	-0.5	0	-0.5	-1	-1.5
5 (T=22)	-1.5	-1	-0.5	0	-0.5	-1	-1.5
6 (T=23)	-1.5	-0.5	0	-0.5	-1	-1.5	-1.5
7 (T=24)	-1.5	-0.5	0	-0.5	-1	-1.5	-1.5
8 (T=25)	-1.5	-0.5	0	-0.5	-1	-1.5	-1.5
9 (T>=26)	-1.5	0	0	-0.5	-1	-1.5	-1.5
10 (occ=0)	-1.5	-1.5	-2.775	-1.5	-1.5	-1.85	0

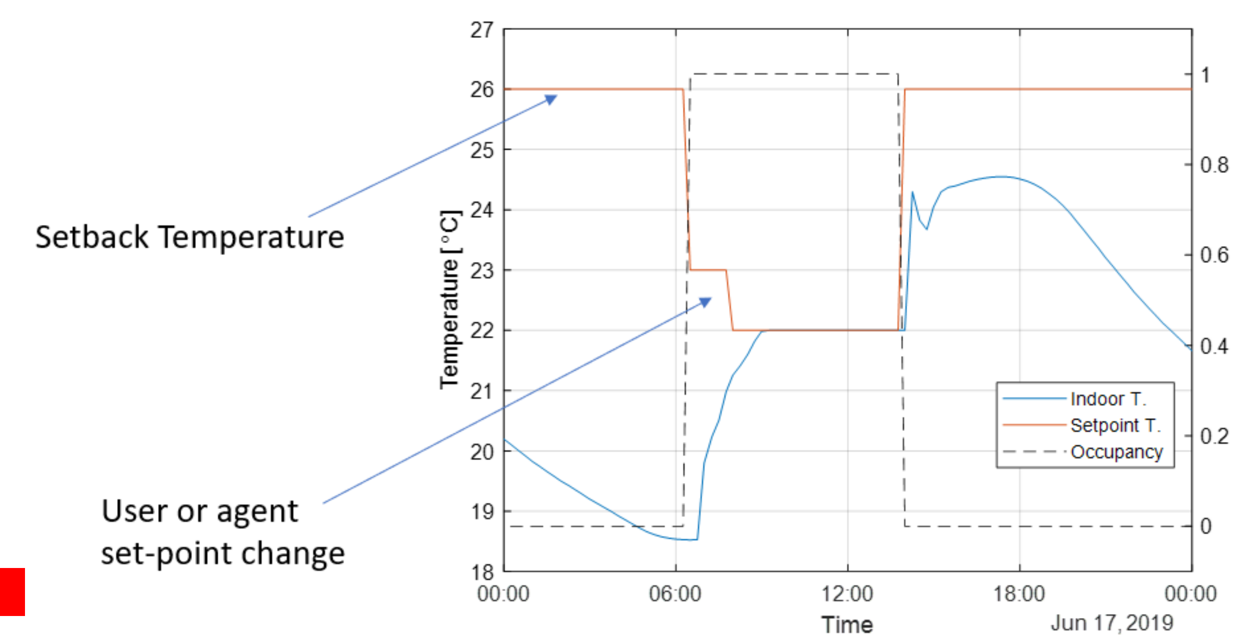


A tabular Q-learning algorithm is used to learn a target policy $\pi(S\_t)$ from the user's behavior (behavior policy $\mu(S\_t)$)

Initially, actions are chosen based on the behavior policy $\mu(S\_t)$

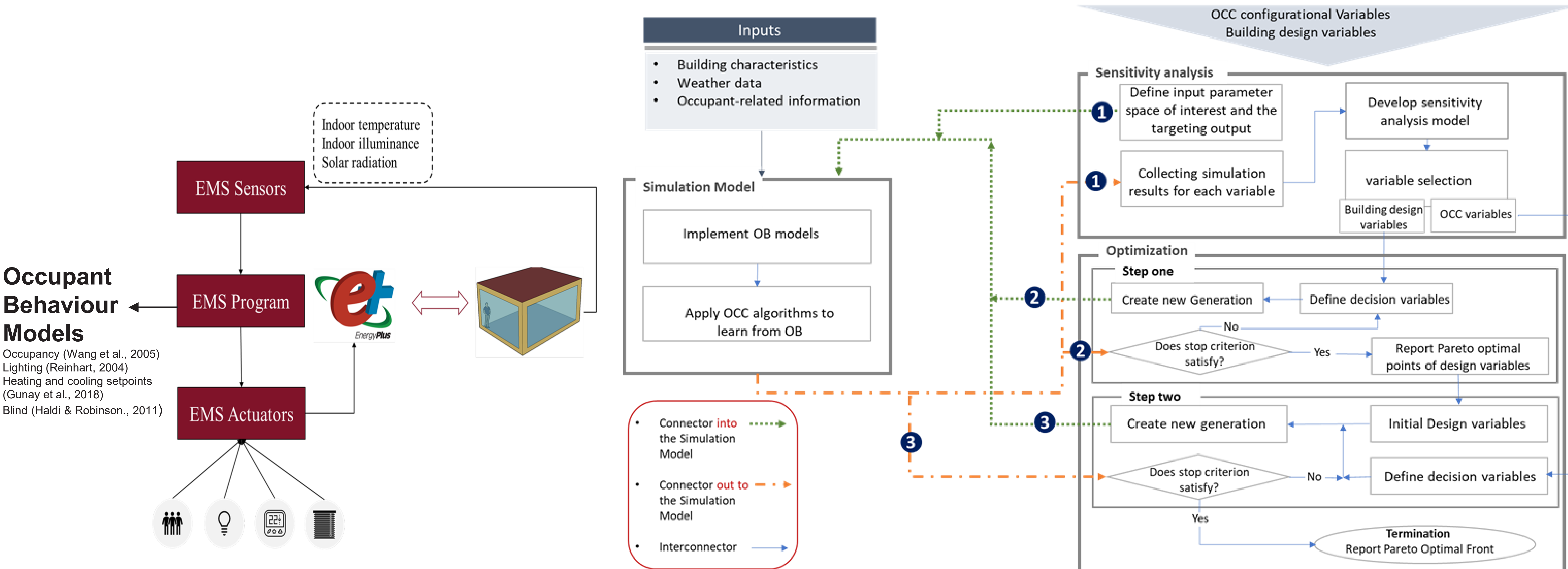
The Q values are updated towards the target policy $\pi(S\_t)$ using:

$$Q(S\_t,A\_t\ )=Q(S\_t,A\_t\ )+\ \alpha(R\_(t+1)+\gamma Q(S\_t,A\_(t+1)\ )-Q(S\_t,A\_t\ ))$$



Occupant-Centric Controls (OCC)

A simulation-based framework to optimize occupant-centric controls



Outlook

- Goal of investigating occupant behaviour
  - More accurate prediction of energy use??
  - Influencing design choices
  - Improving building operation

- Fit for purpose modelling
  - Representing simulation results as a range
  - How does this influence solar neighbourhood planning? What level of detail in modelling OB is needed?

- Large-scale data collection
  - Data-driven approaches to investigate occupant-building interactions at multiple scales

- Potential benefits for demand-response programs, integration of renewables / solar generation, operating building clusters and optimizing their interactions with the grid

Thank You!

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Designing and Building Effective Sustainable Neighorhoods: A Case Study of the EVE Park London Project
Seungyeon Hong and Ashley Hammerbacher

The presentation begins with an introduction to the case studies: the West5 project and the EVE Park project. The West5 case study is focused on system design and the use of a microgrid, and optimization of buildings to achieve net-zero energy. The EVE Park case study combines interesting architectural designs to optimization of PV electricity production. The presentation concludes with a discussion about energy consumption reduction through the design of efficient buildings.

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Designing and Building Effective Sustainable Neighborhoods: A Case Study of the EVE Park London Project

Seungyeon Hong *(Sustainability Engineering, Energy and Civil)* and **Ashley Hammerbacher** *(EVE Park Project Lead)*
IEA SHC Task 63: Solar Neighborhood Planning | University of Calgary | September 15, 2022

Agenda

- Introduction to the West5 Project and EVE Park Project
- System Design - *West5 Microgrid*
- Electricity Production - *Designing EVE Park Solar Array*
- Consumption Reduction- *Designing efficient buildings*
- Q&A

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West 5 – The Most Visionary Sustainable Lifestyle Destination

- First fully inclusive Net Zero Energy Community in North America
  - 2,000 living units
  - Over 32,000 to 46,000 m^2 of commercial and office space
- Master plan designed by s2e for Sifton Properties, acting as the sustainable partner in the development.
- Interconnected walkways, trails and open green spaces. A safe, walkable, pedestrian-centric design with a vision for 100% energy efficiency.
- Electricity Micro Grid
- Under continuous construction:
  - First commercial building in operations since 2015.
  - Second commercial building in operations since 2016.
  - First block of townhomes fully occupied since 2018/4Q.
  - New central mixed-use residential and commercial buildings under construction.

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EVE Park- NZE Community within West5

COMMUNITY

EVE Park is located in a budding new community in West London. The Riverbend neighborhood is developed around the principles of wellness, innovation and sustainability. Solar panels adorn the rooftops, running and biking clubs are abundant, and a network of foot paths weave throughout this naturalized neighborhood. A quick walk to nearby parks and amenities, while just a short drive from central London and the 401 — this area is one of the most sought after in London.

1 The Sifton Center

Backroads London
West 5 Discovery Centre
MedPoint Executive Fitness
Dr. Vicky Martin, Psychologist
West 5 Physiotherapy & Health Centre
MedPoint Executive Services
Sugarbush Spa Inc.
Edward Jones Investments
West 5 Family Dentistry
The Penthouse Salon & Cosmetic Clinic
Sifton Properties Limited
Corporate Office
Sifton Decor Studio
Tesseyman Orthodontics (Coming Soon!)
Oxygen Yoga

2 Mixed Use Office & Retail

Hey, Cupcake!
West Blooms Flowers
Eolos (Coming Soon!)
LBM Partner Services

Existing & Future Development

3 Oak West Animal Clinic
4 Existing Residential
5 Existing Residential
6 Future Recreational Center
7 Retirement Apartments
8 Townhomes
9 Existing Residential
10 Future Grocery
11 Future Office Space
12 Legacy Square

58

COMMUNITY

Note: This map is an approximation of the layout for planned future developments.

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EVE PARK LONDON- Evolved Living

- 84 for-sale condominium homes
- Net Zero energy,
  100% solar electric homes
- Efficient Water Systems
- Superior Indoor Air Quality
- Connection to West 5 Smart Grid for battery backup during power outage
- Automated Parking Tower Integration
- All-electric carshare fleet

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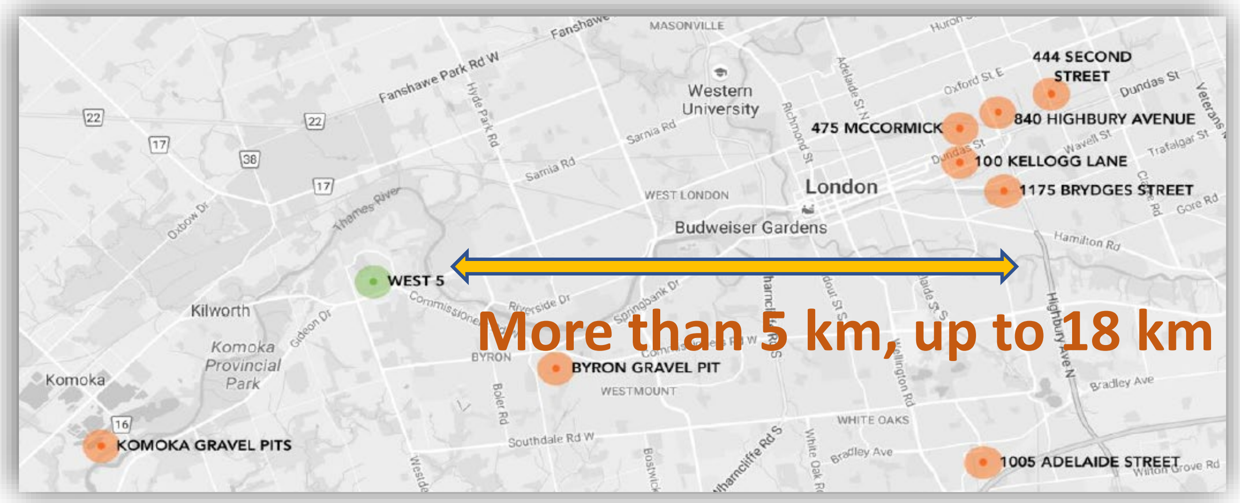
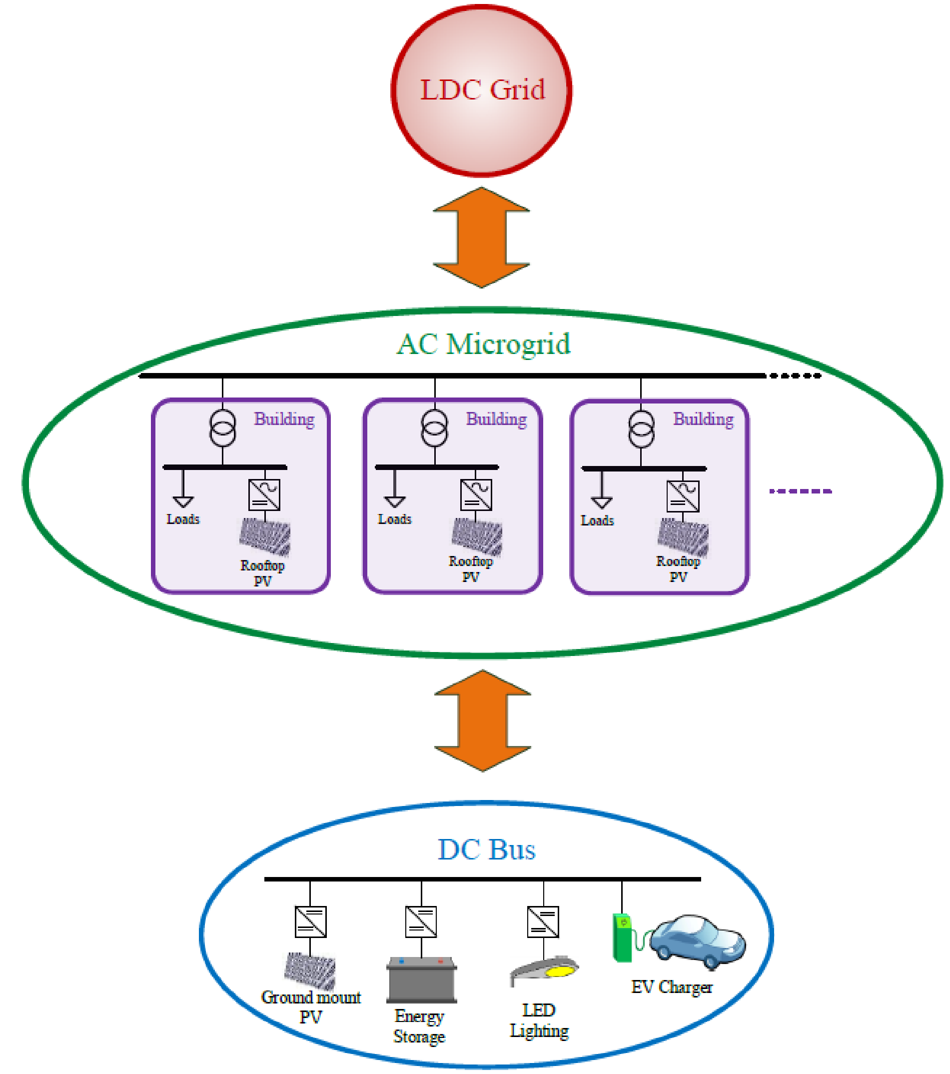
West 5 Microgrid

Problem: Shortage of space for PV (Rooftops, canopies, and façade ~8.5 MW of PV for Community Solar)





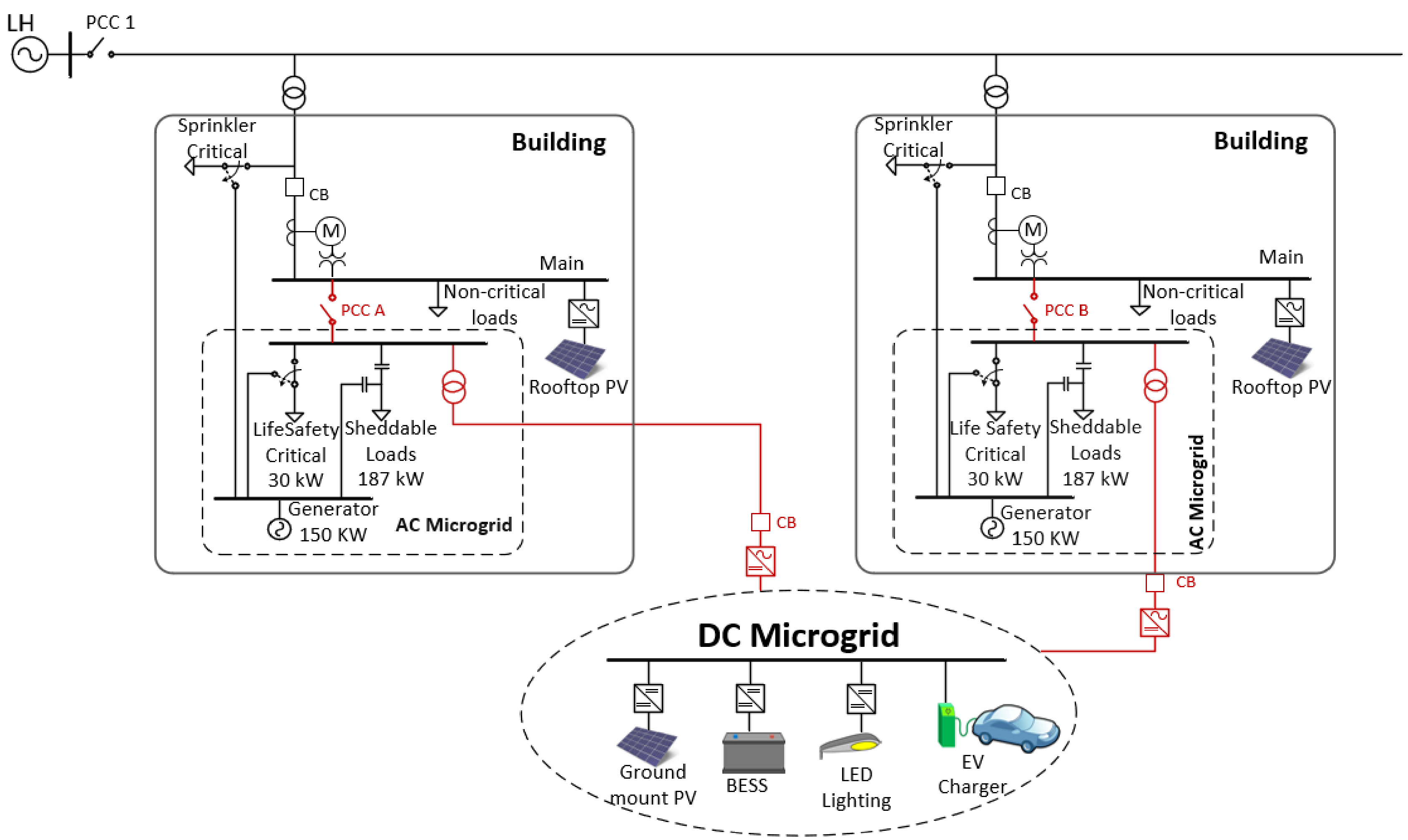
- Assessed alternates (like PV farm on brownfield) with a medium voltage link to downtown. However, the primary concern was the substantial distance between West5 and the possible locations

- Instead, chose to use a hybrid microgrid (combines advantages of AC and DC which decreases investment costs and energy loss)
- DC opportunities included: decreased conversion losses, power quality improvement, extra capacity (avoiding reactive power & cable skin effect), reduction of voltage level & potential for safety) and most excitedly, future proofing with modular design

Microgrid - Multiple topology options

The leading candidate: interfaced to the building mains, with DC-coupled interconnection between buildings

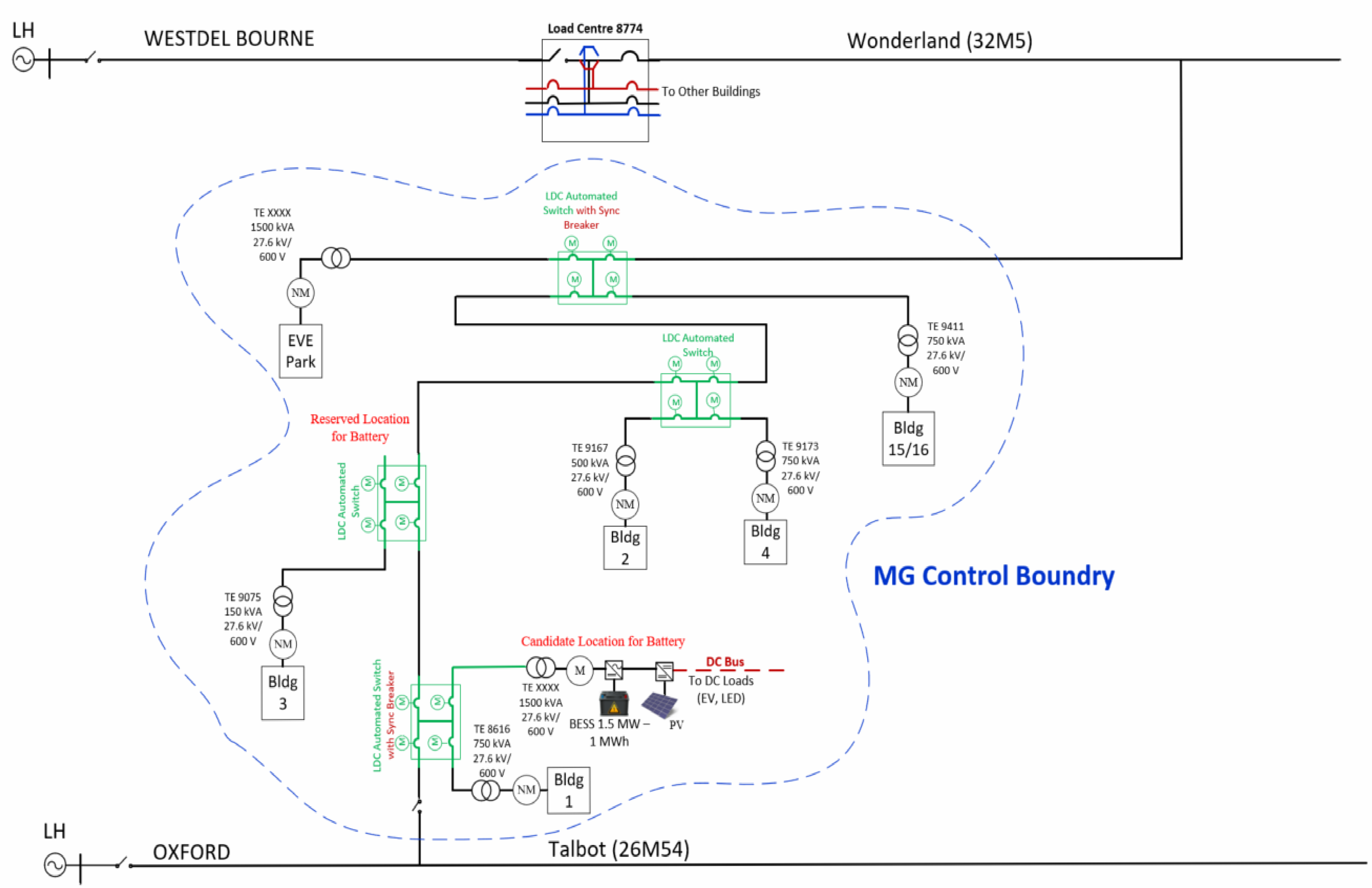
Lesson Learned: Each situation has a unique microgrid solution, depending on the cost/performance/reliability priorities



	Advantages & Limitations					
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
No Need for Fast Load Shedding Inside the Building	X	X	✓	✓	✓	✓
No Voltage Sag Issue	X	X	✓	✓	✓	✓
No MV PCC CB Requirement	X	X	✓	✓	X	✓
No Need MV/LV Transformer	X	✓	✓	✓	X	✓
Extending Islanding Capability by leveraging the building PV	✓	✓	X	X	X	✓
Scalability: New Building	✓ -limited	✓	✓	✓ -limited	✓ -limited	✓ -limited
Scalability: Interconnection inverter (Redundancy)	X	✓	✓	X	X	X
Transactive Energy Possibility	X	✓	✓	X	X	✓
Net Zero Capability	X	✓	✓	✓	✓ -limited	✓
No Power Sharing Issues in Islanded Mode	✓	X	✓	✓	✓	✓
Low Number of Interface Inverter	✓	X	X	✓	✓	✓
Less Control Complication	✓	X	✓	✓	✓	✓
Low Number of LV/LV Transformer	✓	X	X	✓	X	✓
No Voltage Deviation Due Reverse Power Flow in MG	✓	X	✓	✓	✓	✓
Large Number Requirement of LV PCC Inside Building	✓	✓	X	X	✓	✓
No Central Inverter Requirement	X	✓	✓	X	X	X
No VNM Program Requirement	X	✓	✓	✓	✓ -limited	✓
Potential to Support Existing Sheddable Loads than Life Safety	✓	✓	✓	✓	✓	✓

Microgrid Battery Location

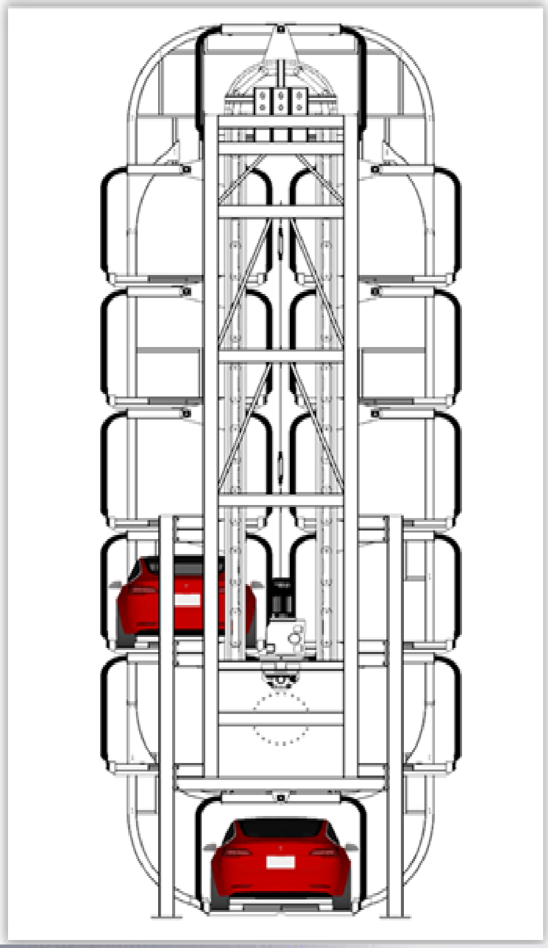
Microgrid – Current Design



Microgrid – Charging

- High density electric vehicle (EV) charging
- Demand Response – approx. 1 hr/ year
- Autonomous vehicle automatic charging system
- Investigate different charging technology (Wireless, DC fast chargers, etc.)
- Parking Tower Microgrid development (PV, Storage, Vehicle-to-Grid Charging)

Robotic Charger- In Development



EVE Park Solar – Original Design Concept

Concept Art – Original Design Intent

Challenges:

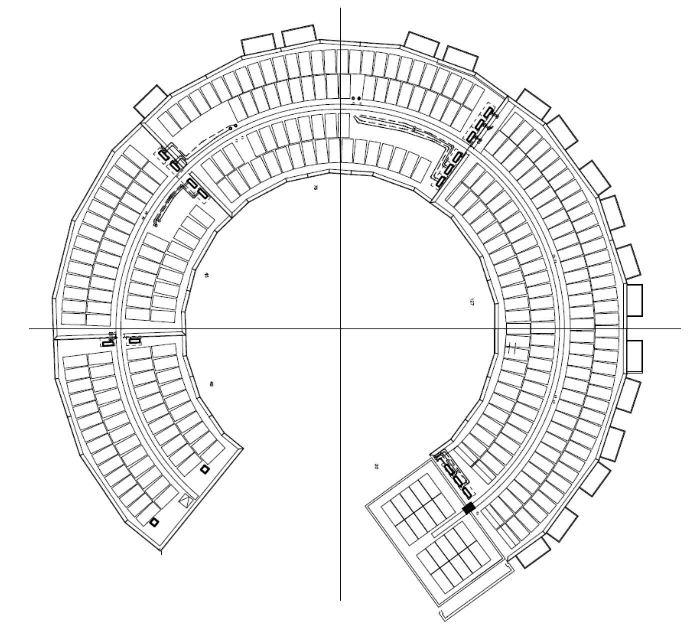
- Complex slope
- Expensive walkway (+ challenges with code compliance)

EVE Park – Optimizing Solar Layout

East-West Design

Challenges:
- Roof anchors end up under solar panels or potentially damage solar panels in use
- Requires expensive roof anchoring system w/ no central walkway for maintenance
- Inefficient use of roof space

Final Design: Radial



Benefits
- Walkway down the middle of the project

EVE Park – Solar Sizing

Kept design under 500 kW

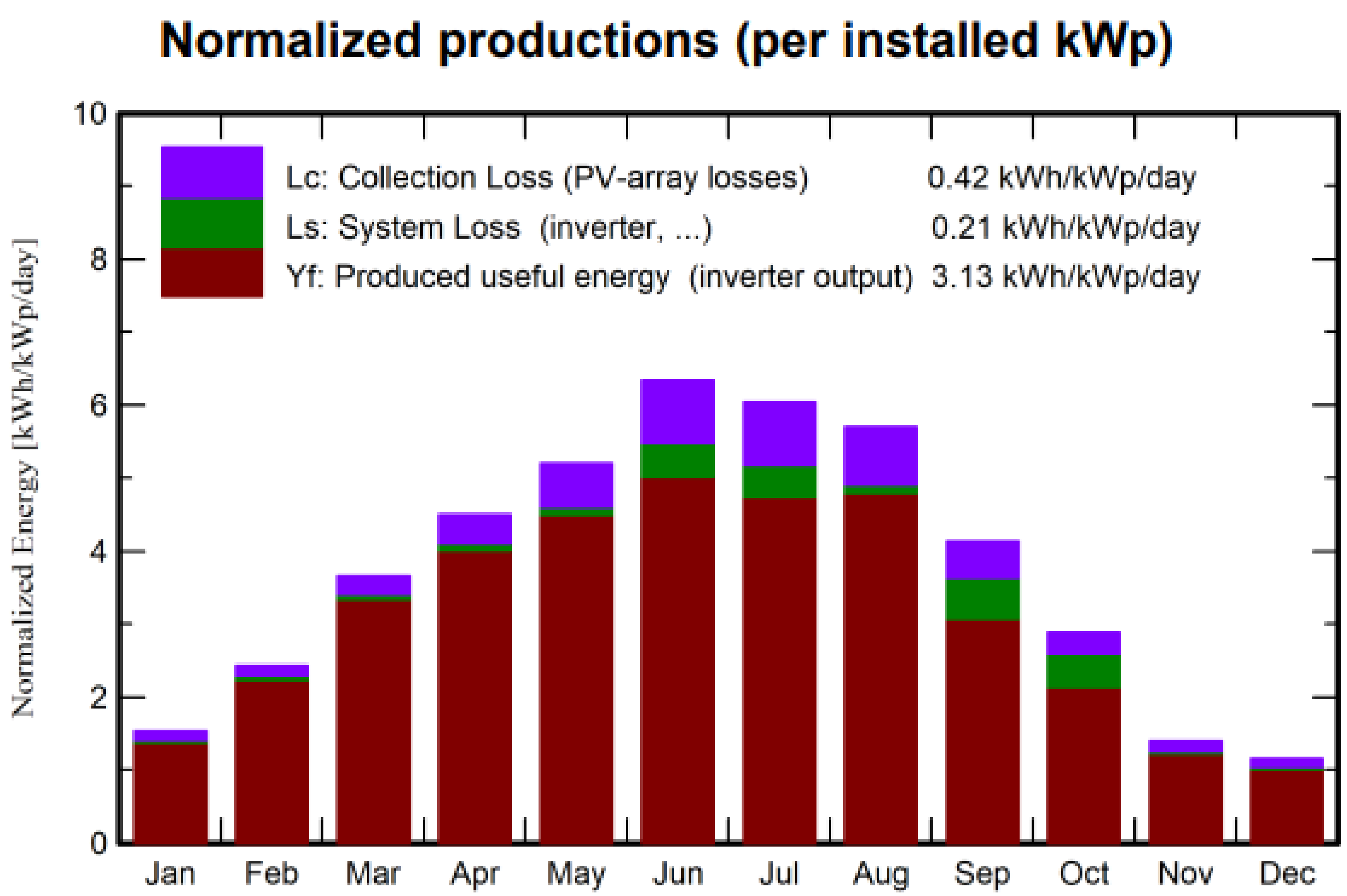
- No transfer trip study required
- Lower tier of connection agreement (CCA) with Local Distribution Company (HydroOne/London Hydro)

Capacity: DC 580kW / AC 480kW
Yield: 1142 kWh/kWp/yr
Total: 662.2 MWh/yr

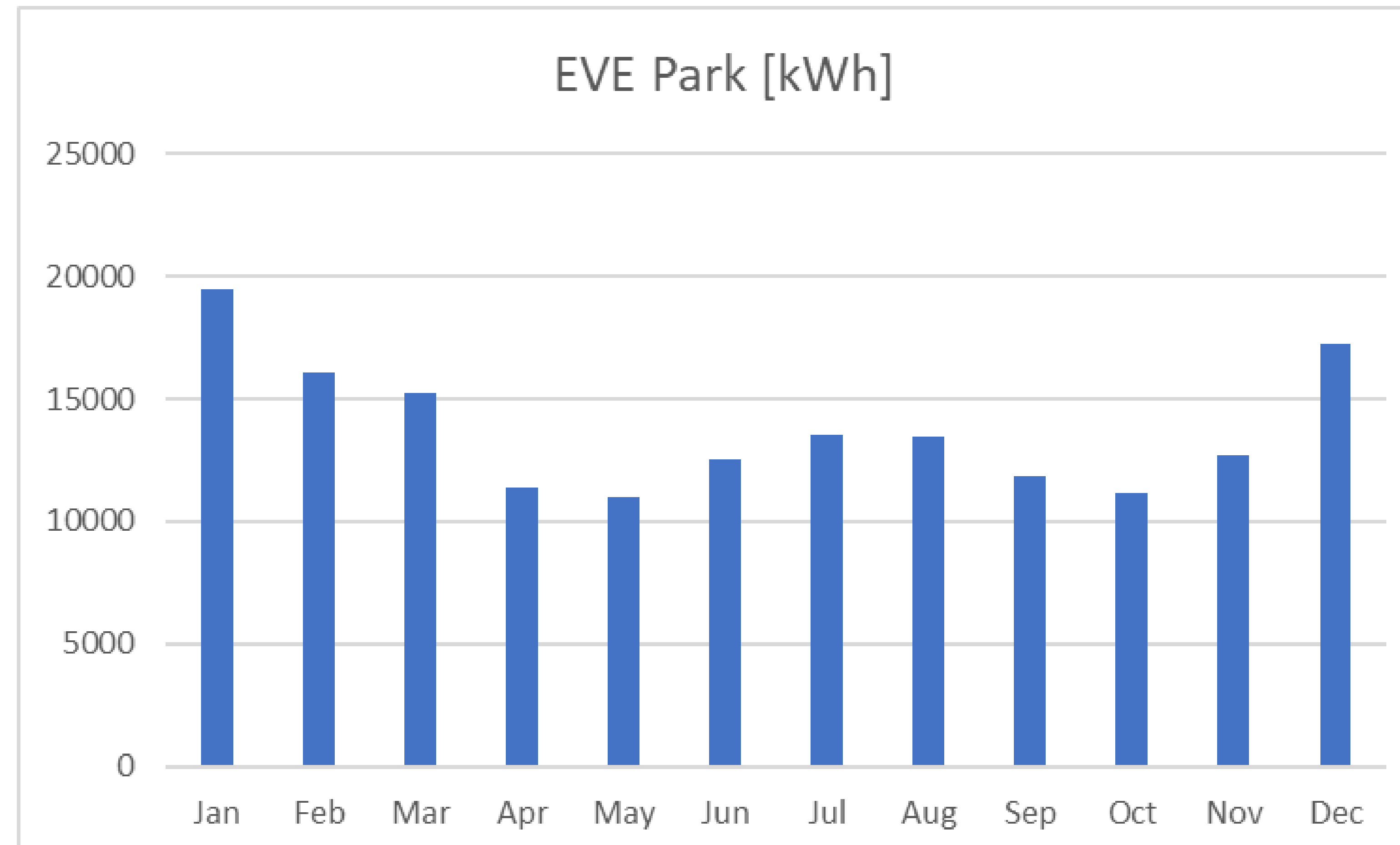
HOW DID WE ACHIEVE NET ZERO ENERGY GIVEN SMALLER PRODUCTION?

EVE Park – Net Zero

PRODUCTION



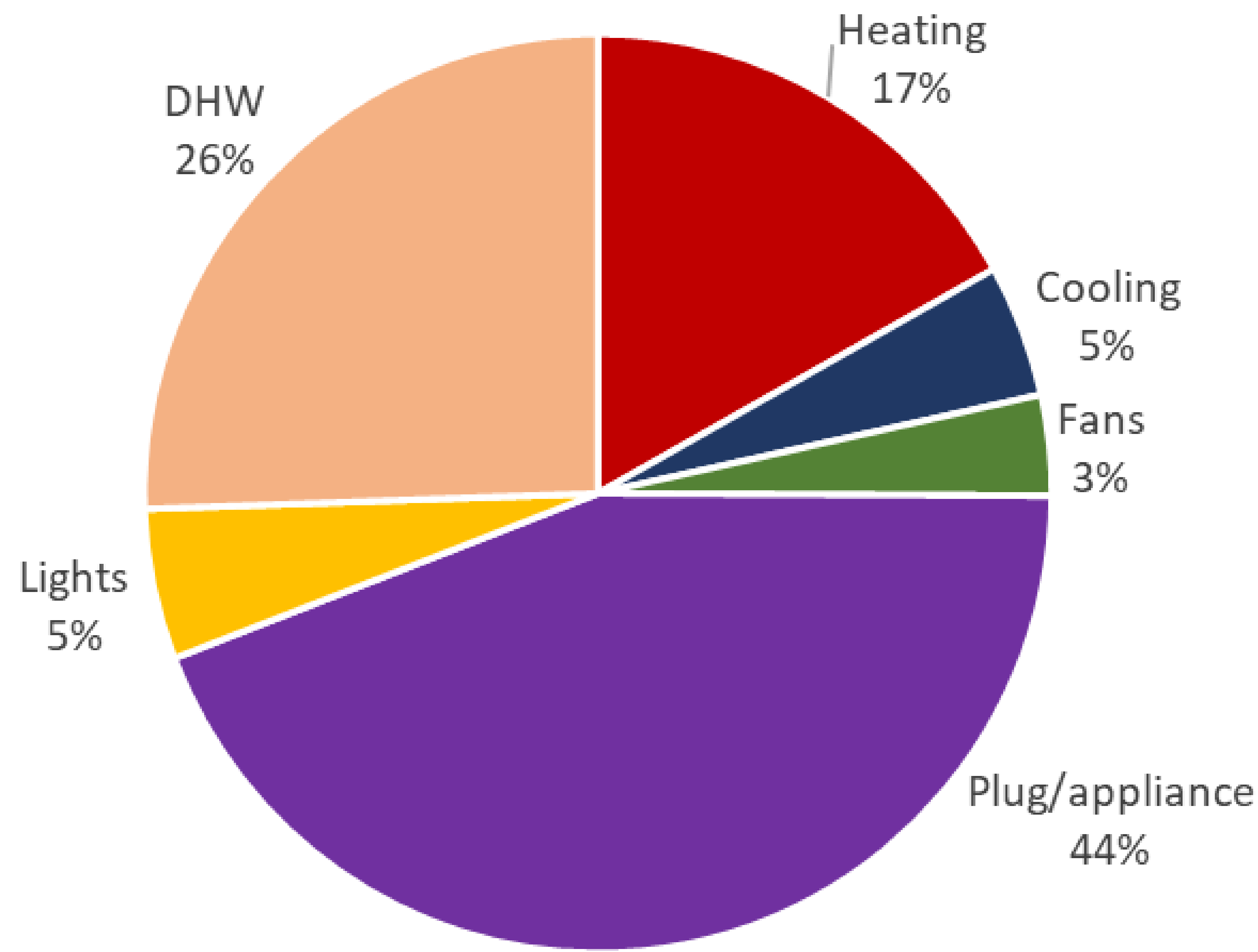
CONSUMPTION



662.2 MWh

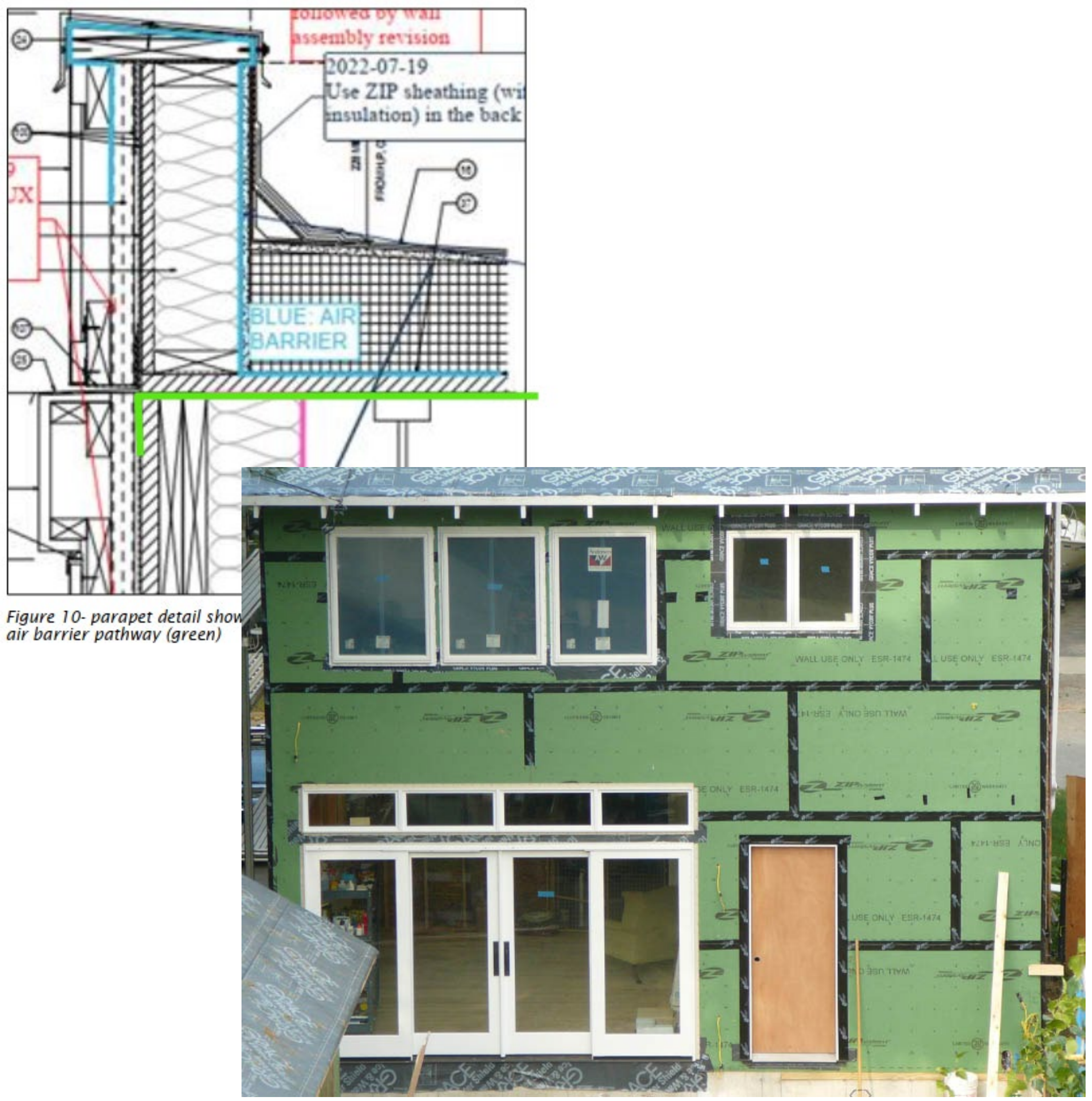
662.0 MWh

EVE Park – Consumption



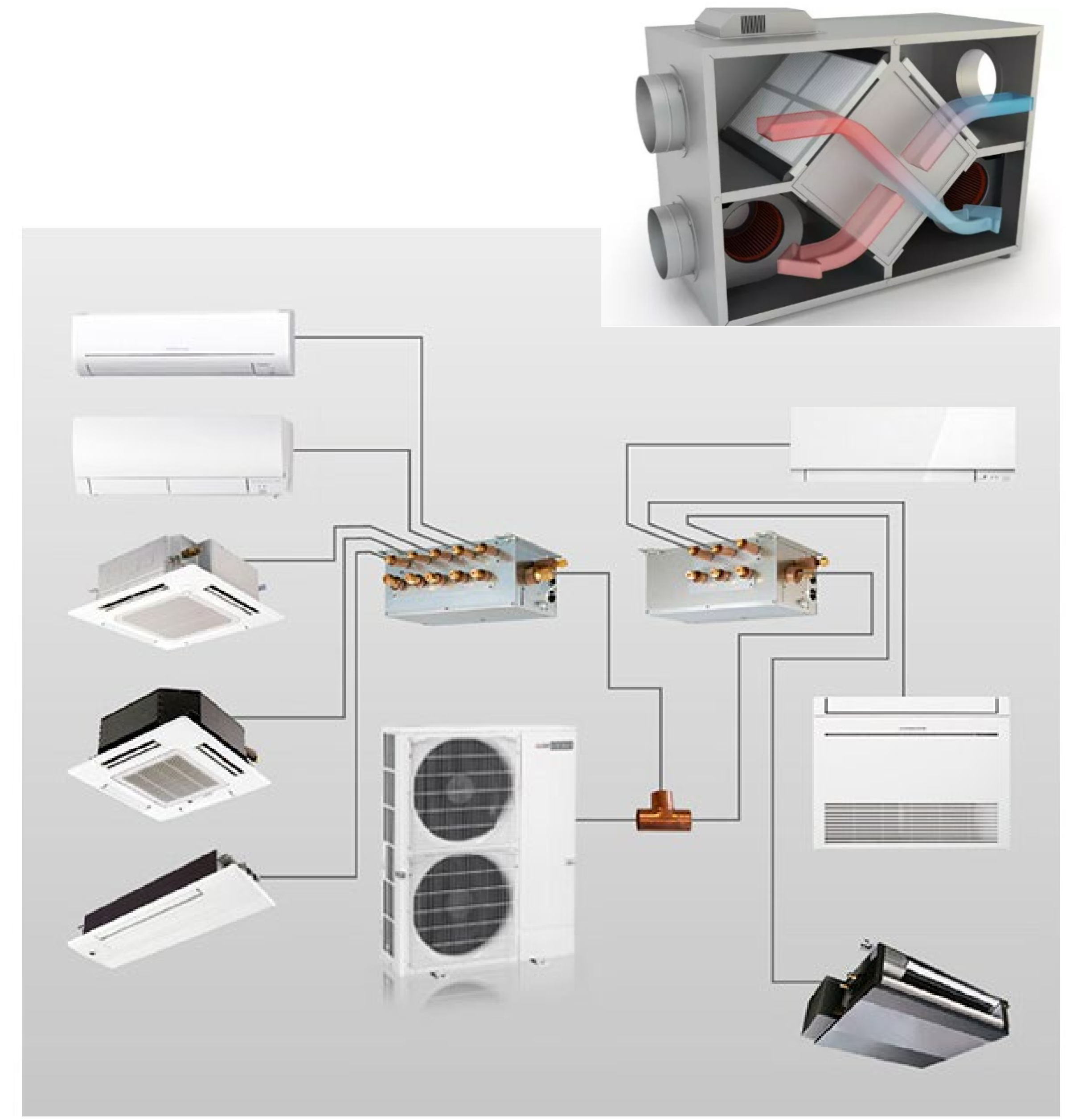
EVE Park – Building

4- Consumption



Tight envelope
(air, bulk water,
condensation, capillary)

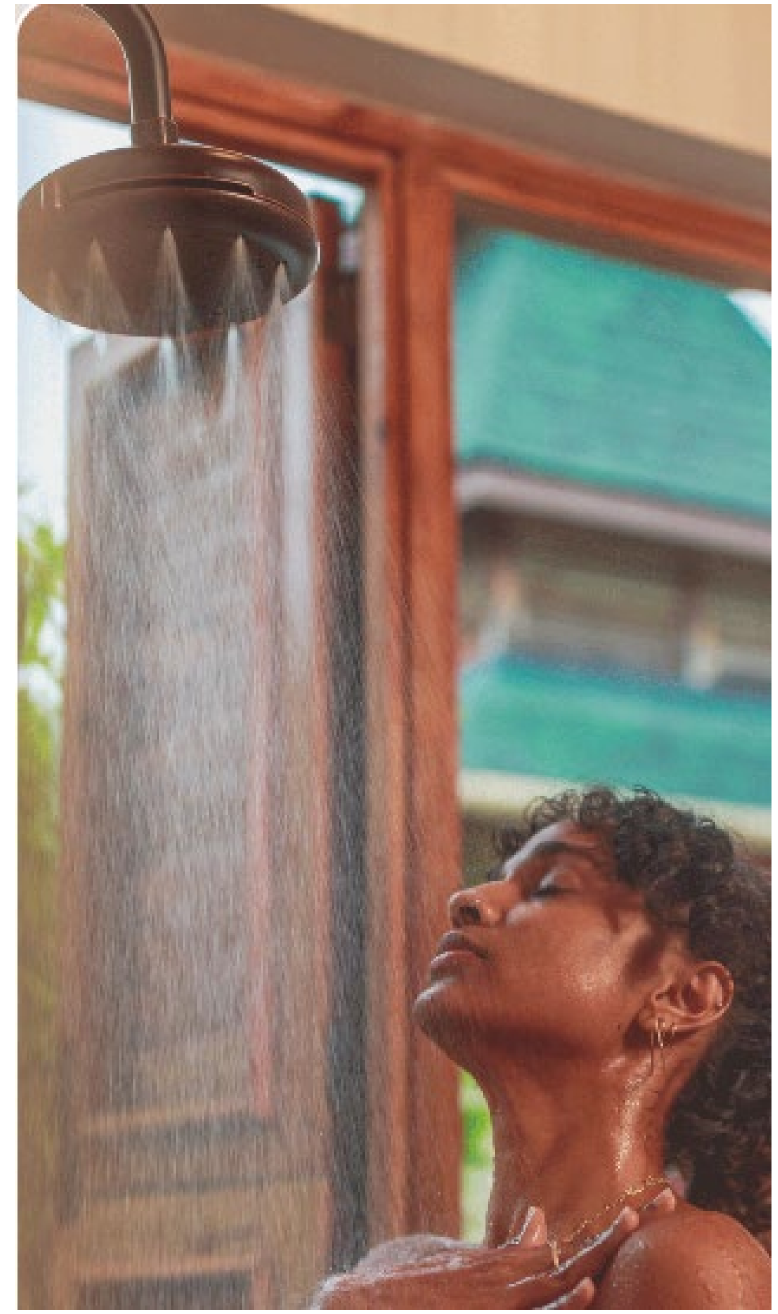
Triple glazing



Efficient HVAC
(VRF heat pump + ERV)

EVE Park – Building

Efficient appliances



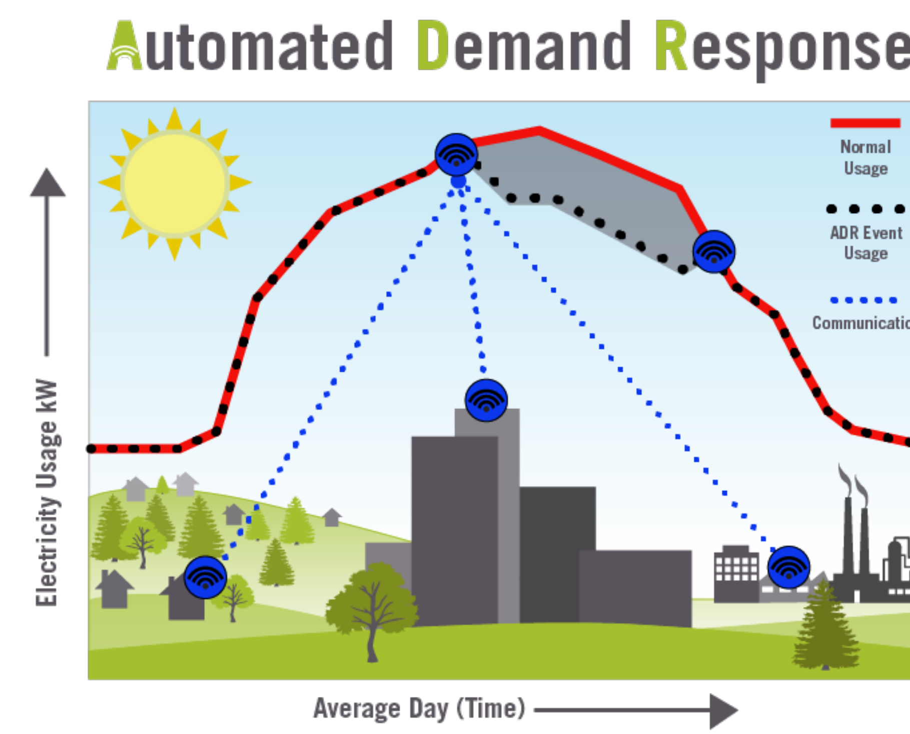
Water saving shower

Energy Monitor

EVE Park – unimplemented

Electrochromic Glazing

Smart water heater controller



Demand Response

Autonomous Features at EVE Park – Future Possibilities

Click picture for video link

Thank you!

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The Impact of Urban Morphology and Construction Standards on the Energy Consumption of Neighborhoods
Ursula Eicker

The objective of the presentation is to study and identify the most important morphological and geometrical parameters that influence a building's energy consumption on a neighborhood scale. This discussion is followed by an evaluation of energy consumption in a neighborhood case study, and an analysis of the impact of certain parameters. The presentation concludes with a discussion of the role of morphology and construction standards on renewable energy generation potential.

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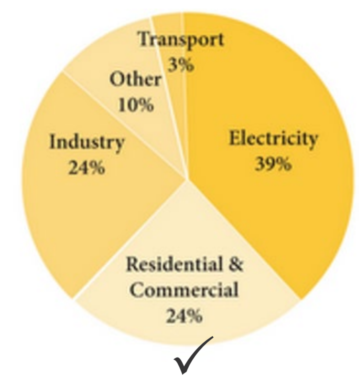
The impact of urban morphology and construction standards on the energy consumption of neighborhoods

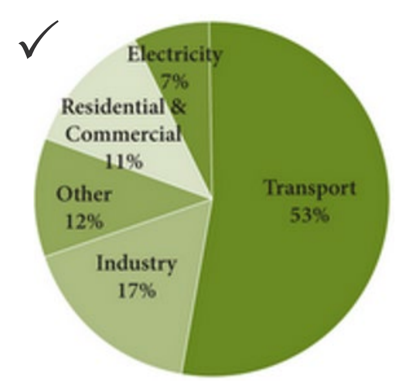
Ursula Eicker, Canada Excellence Research Chair in Smart, Sustainable and Resilient Cities
Azin Sanei, MSc Building Engineering, Concordia University

Introduction

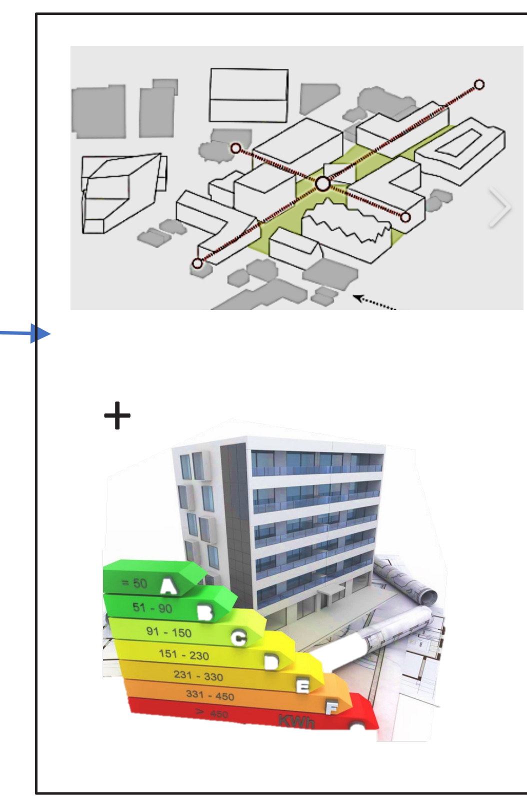
Natural gas



Oil



Urban Design & energy consumption



https://urban.uw.edu/news/new-apps-help-builders-reduce-carbon-footprint
/https://canada.constructconnect.com/joc/news/economic/2020/03/infographic-canadas-urban-population-growth
https://urban.uw.edu/news/new-apps-help-builders-reduce-carbon-footprint/https://www.archdaily.com/371686/new-acadia-retrofitting-urban-decay-winning-proposal-garrett-rock
https://www.houzz.com/for-pros/feature-estimating?&lsd=bing_estimates&lsmr=bing_software&m_refid=olm_bing_372026306_1305120532480009_kwd-81570232988441:loc-32__c_o_cat-grow_o&pos=&device=c&nw=o&matchtype=b&m_kw=construction%20estimate&source=bing&utm_medium=cpc&utm_source=bing&utm_term=kwd-81570232988441:loc-32&msclkid=0fd6c56d8a5116a7b03fa7bd0e7e56db

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Introduction

Objectives

- To study and identify the most important morphological and geometrical parameters that influence buildings' energy consumption on a neighborhood scale.

- To evaluate energy consumption in real case study neighborhoods and analyze the impact of selected spatial parameters. This step helps future energy-efficient urban development and design.

- To study the construction standard's effect on energy consumption on a neighborhood scale and compare it with the geometrical effect.

- To study the role of morphological parameters and construction standards on renewable energy generation potential.

Introduction + Literature

Urban environmental measuring metrics + related parameters

Evaluate environmental performance metrics in City and Neighborhood scale

Environmental performance metrics

in city and neighborhood scale

- Heating load
- Cooling load
- Ventilation Potential
- Urban Heat Island (UHI)
- Lighting load
- Building indoor temperature
- Solar potential
- Life cycle
- Sky view Factor
- Wind airflow

Parameters

in urban or neighborhood scale

The performance metrics will be calculated for urban areas

Morphological Parameters

that define urban scale design

Construction parameters

that apply to building elements:

- Windows
- Roofs
- Walls
- Floors

Introduction + Literature: Morphology

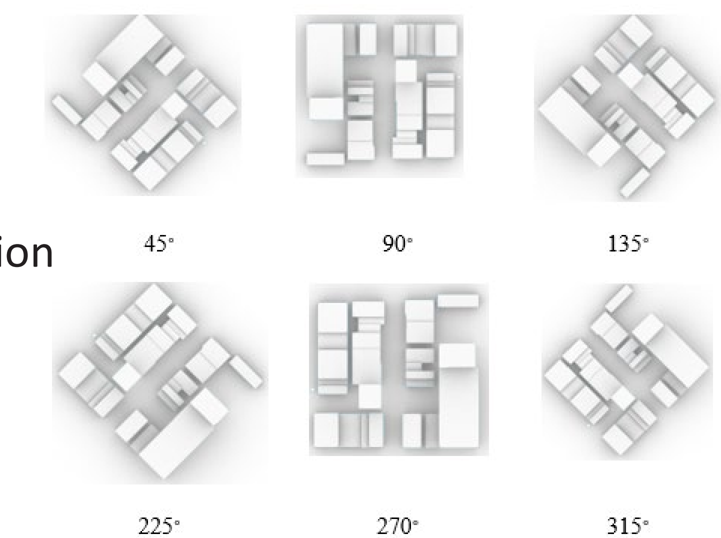
Morphological Parameters

that define urban scale design

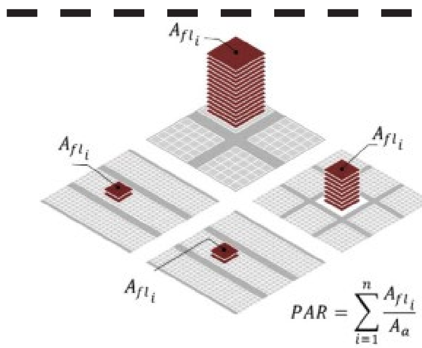
- **Surface to volume ratio (S/V), Compactness**
- **Orientation**
- Ratio of perimeter to the area
- Aspect ratio of the blocks or buildings (length/width)
- Ratio of obstruction height to canyon width (H/W)
- Floor Area Ratio
- Cover Ratio (site coverage)
- Plot area ratio
- Typology
- Volume to Area ratio

Compactness

Orientation



Plot area ratio

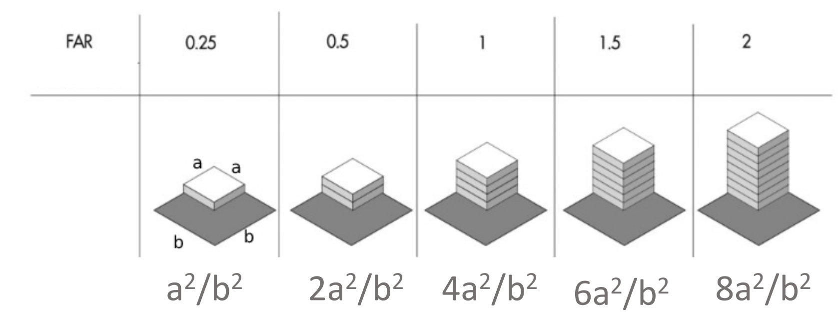


Surface to Volume ratio

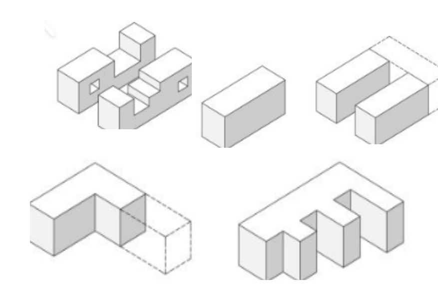
surface-to-volume (S/V) ratio: the ratio of the building envelope (external facades, ground floor and roof) to the entire volume of that building

Floor area

ratio of accumulated built floor areas against the size of a site/plot.



Typology

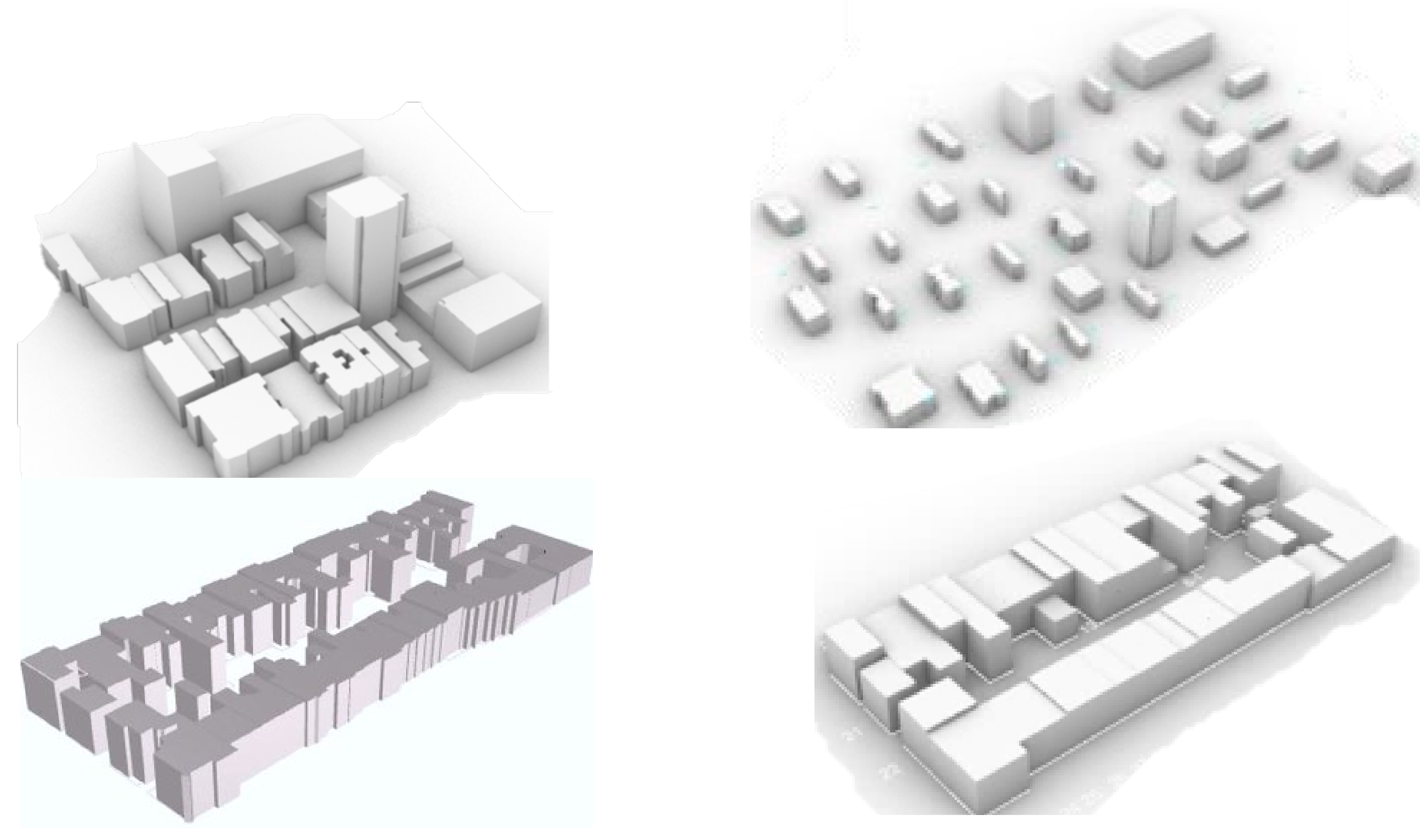


Morphology parameter scenarios

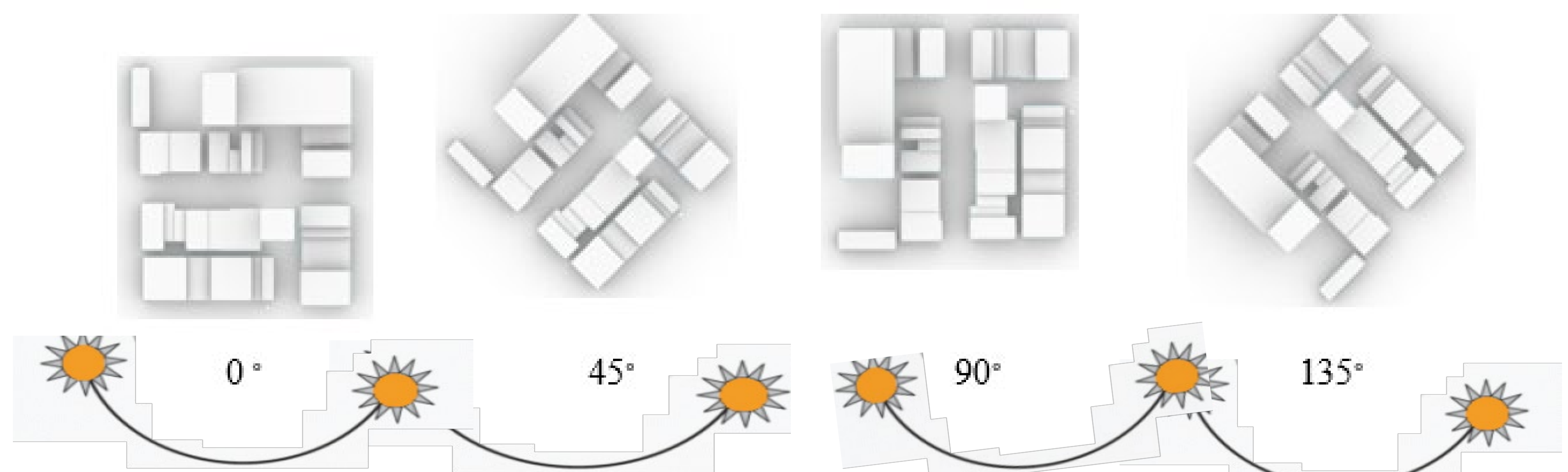
Surface to Volume ratio

Exterior surfaces/Volume

- **Compactness**
- **Simplification**



Orientation



Assumption

Construction standard parameters & building envelope assumption

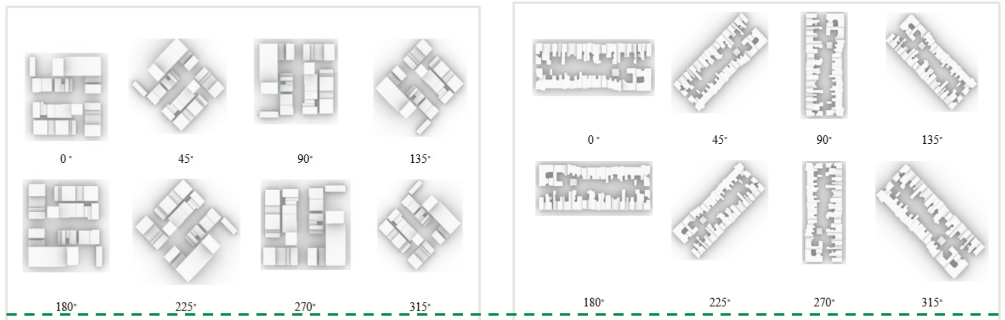
Construction standard parameters

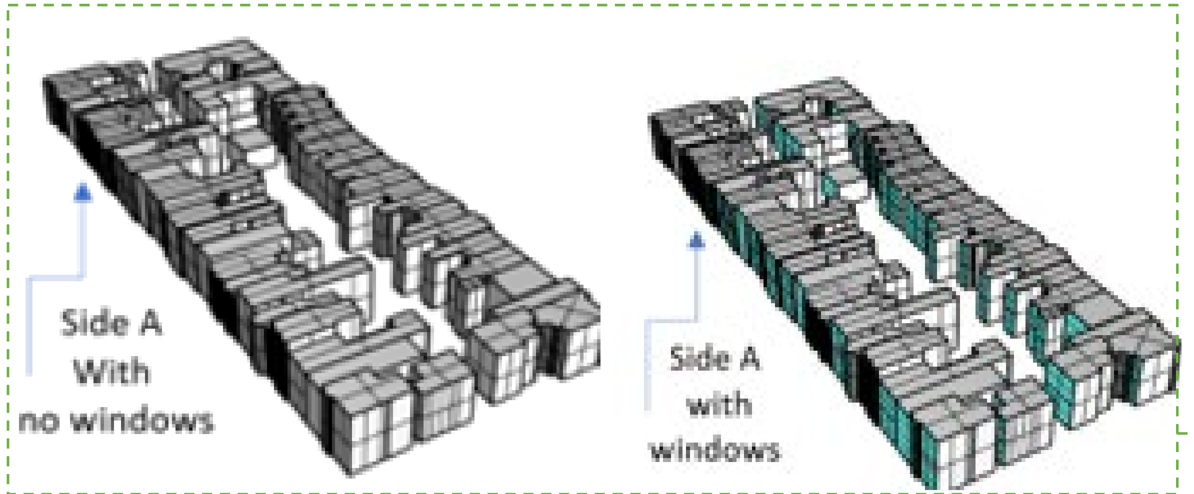
building's construction assumptions			
	R-value		U-value
	Exterior walls m^2K/W	Exposed floor m^2K/W	Windows W/m^2K
Weak	1.13	3.44	5.7
Average	1.8605	3.44	4.68
Good	3.58	5.55	2.68
Very good	10.56	10.66	1.75
Strong	16.12	16.019	1.07
Very Strong	26.58	26.69	0.6

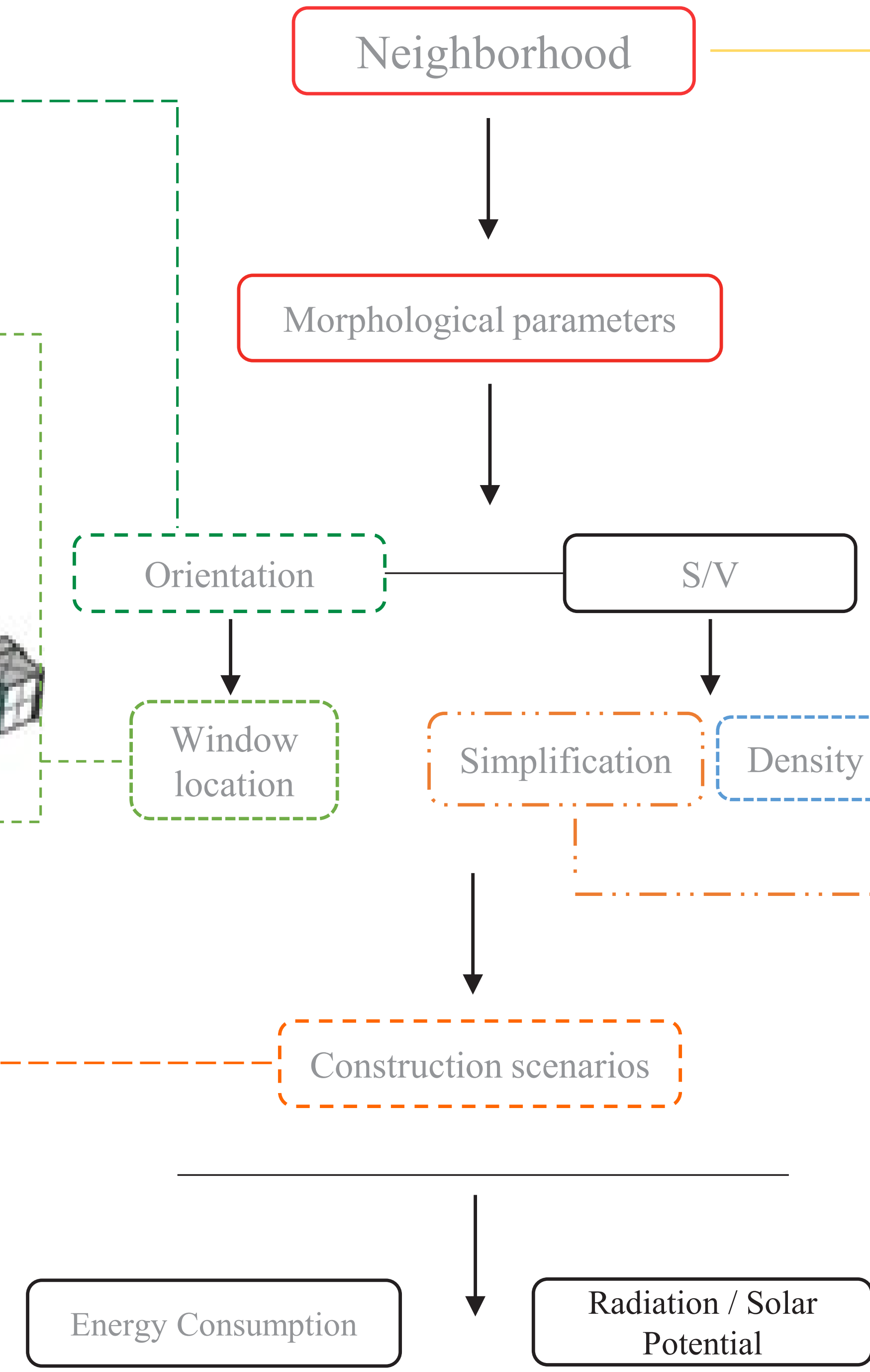
building envelope assumption

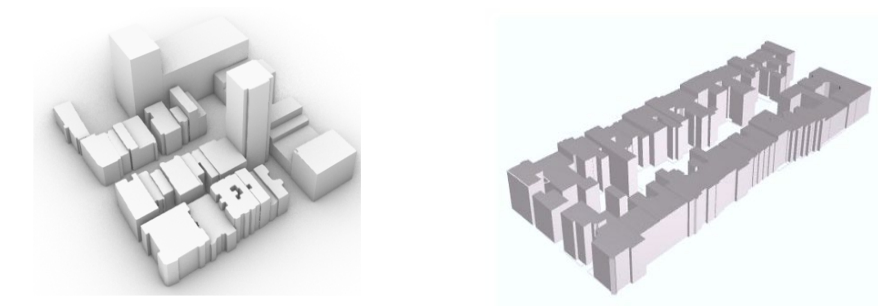
- The same construction, building programs, and schedules are considered for all the buildings in the neighborhood
- Window-to-wall ratio and window properties are considered the same for all the buildings.

Methodology



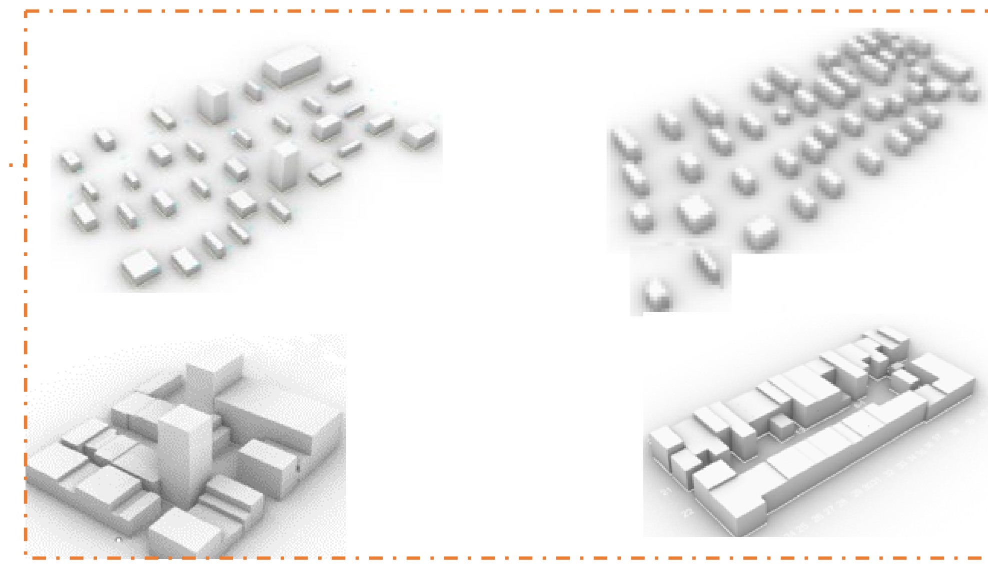






Case Study two, SC2-r, Montreal downtown

Case Study one, SC1-r, Plateau Montreal



	R-value		U-value
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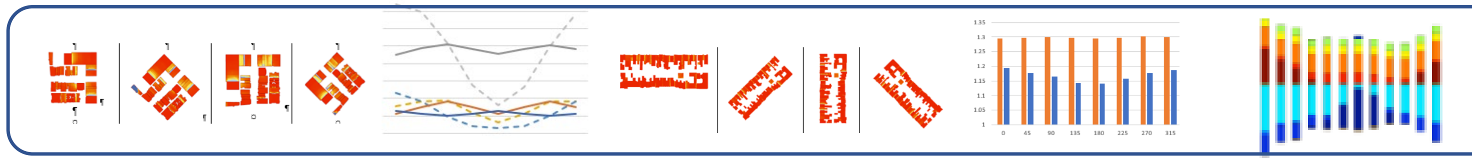
Good	3.58	5.55	2.68
Very good	10.56	10.66	1.75
Strong	16.12	16.019	1.07
Very Strong	26.58	26.69	0.6

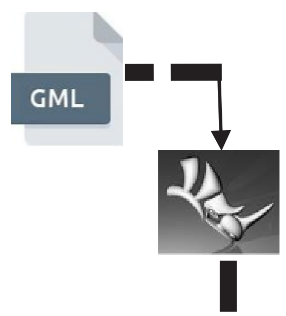
Methodology: Software workflow

URBAN GEOMETRY

Bâtiment 3D 2013. Manually added Windows and openings. Construction standards selected based on available standards

Urban scale energy & radiation calculations



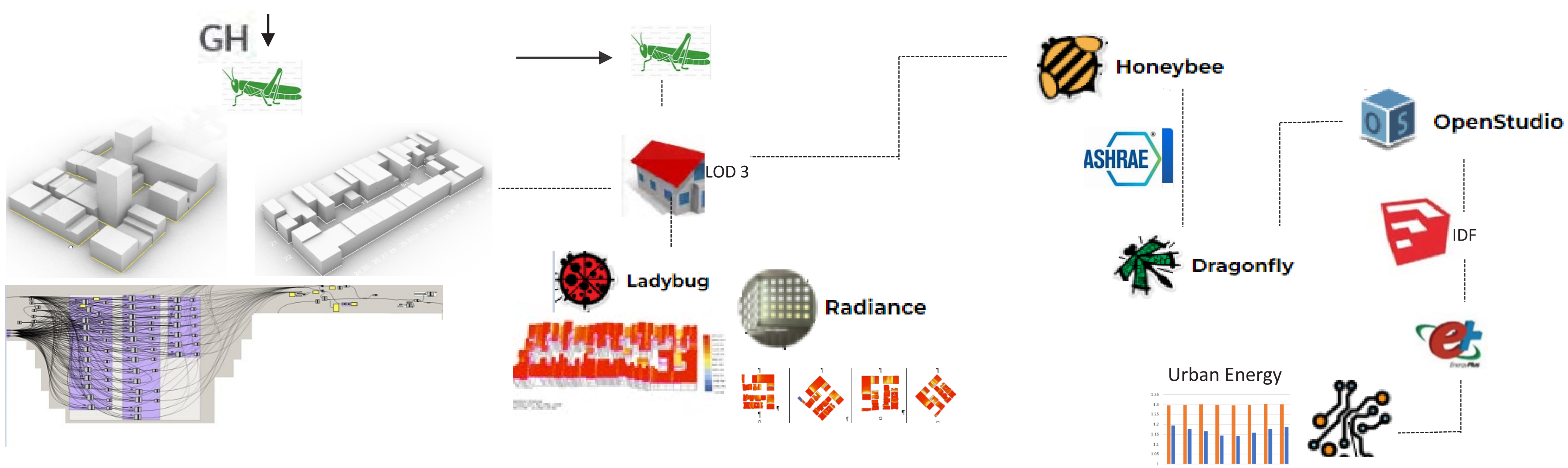


Radiation

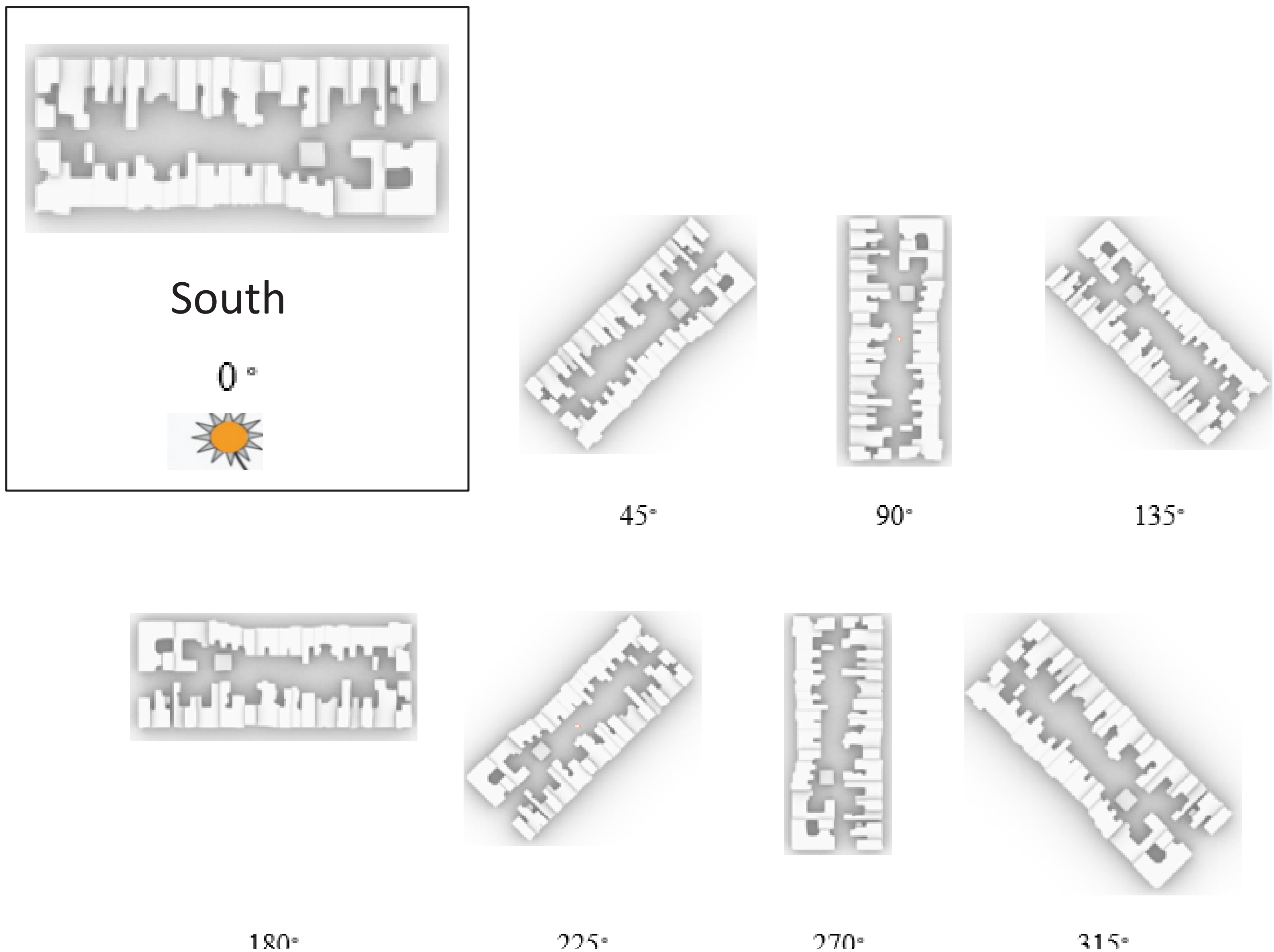
Radiation calculation considering shading effects, in urban scale
Calculating radiation on windows and roofs

Load calculations

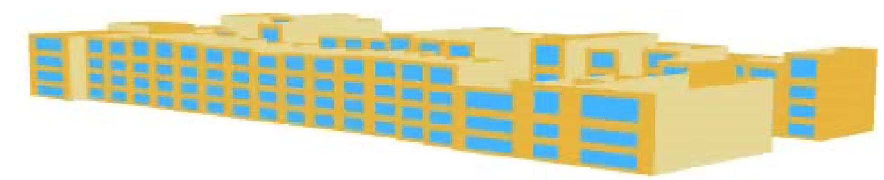
Construction & standards are defined
Infiltration, occupancy, lighting, ventilation and etc.



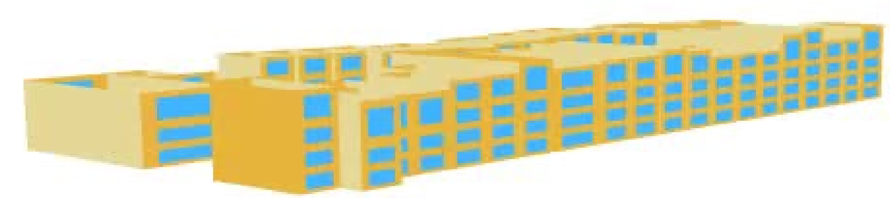
Simulation & results: window location & radiation



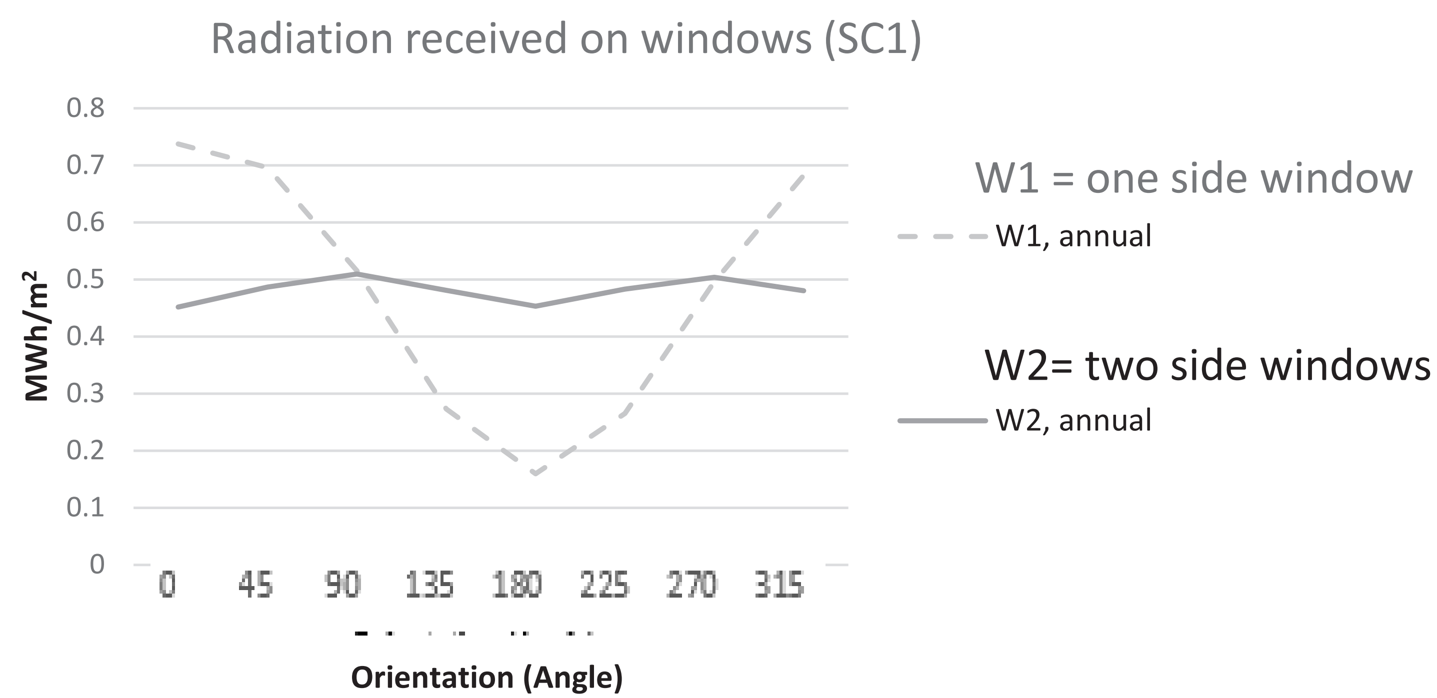
One side window
(W1)

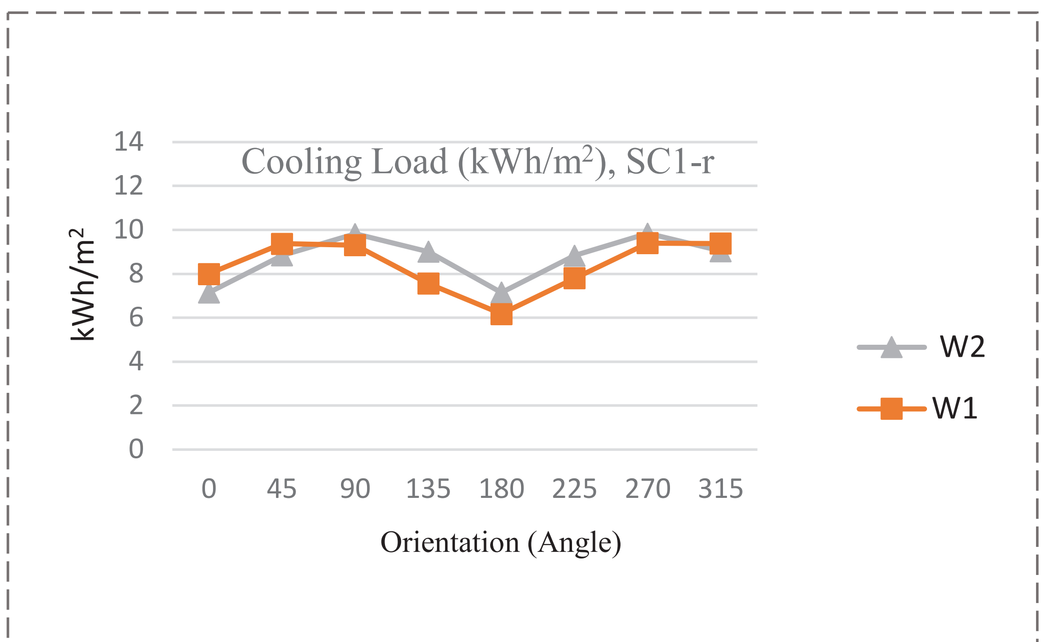


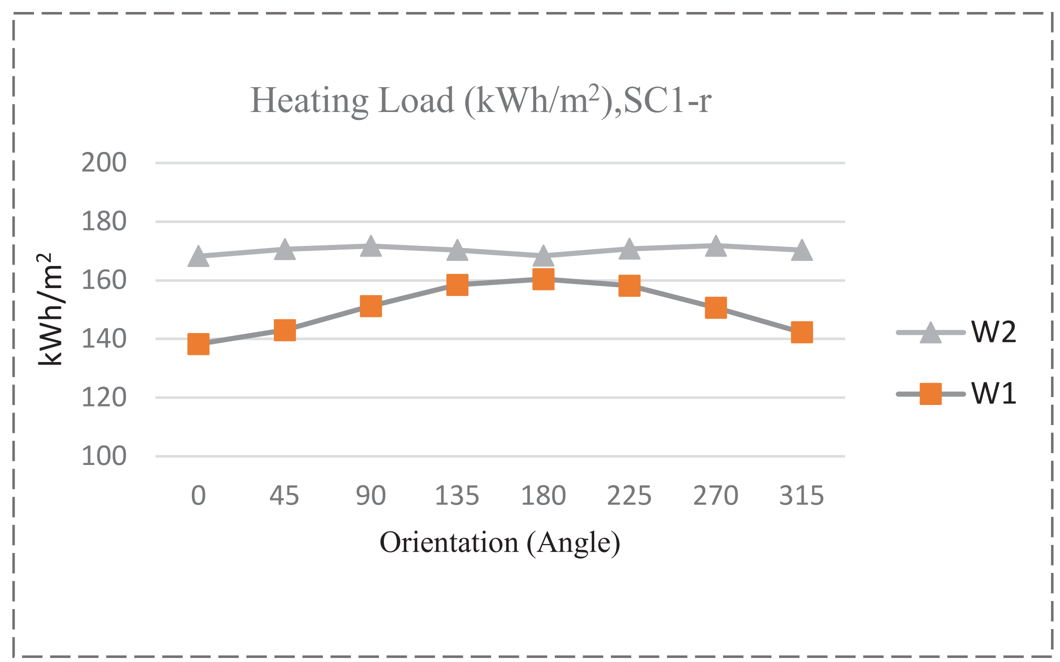
two side window
(W2)



Simulation & results: window location & radiation





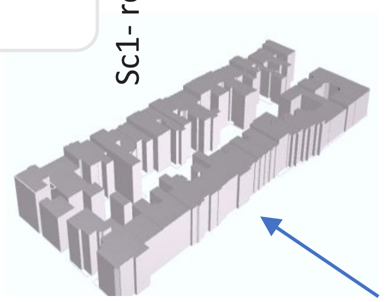


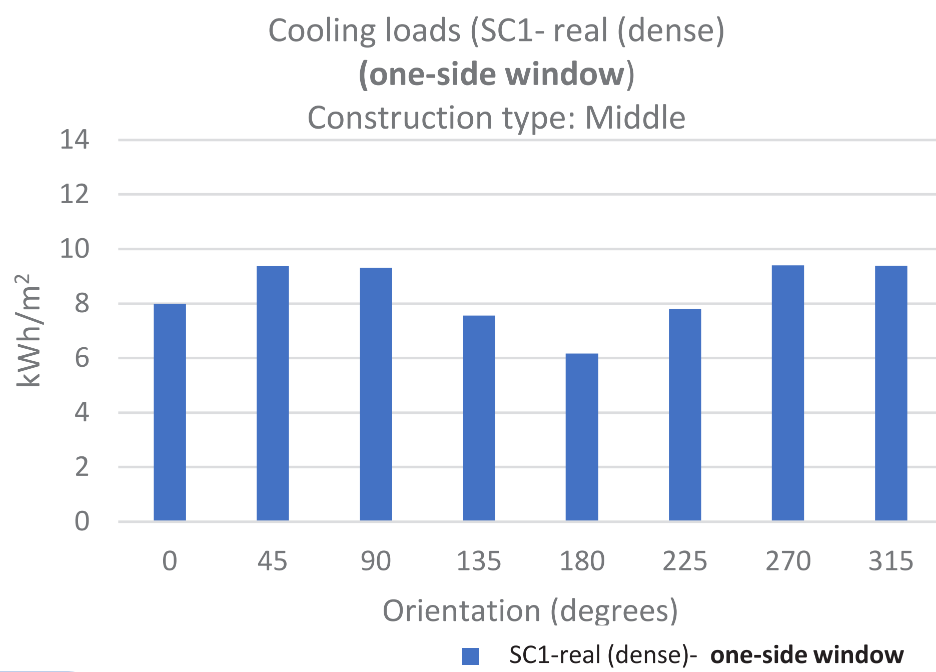
Parameters: Orientation

comparison of one side window and two side window

SC1-r-W1

Sc1- real (dense) one side window



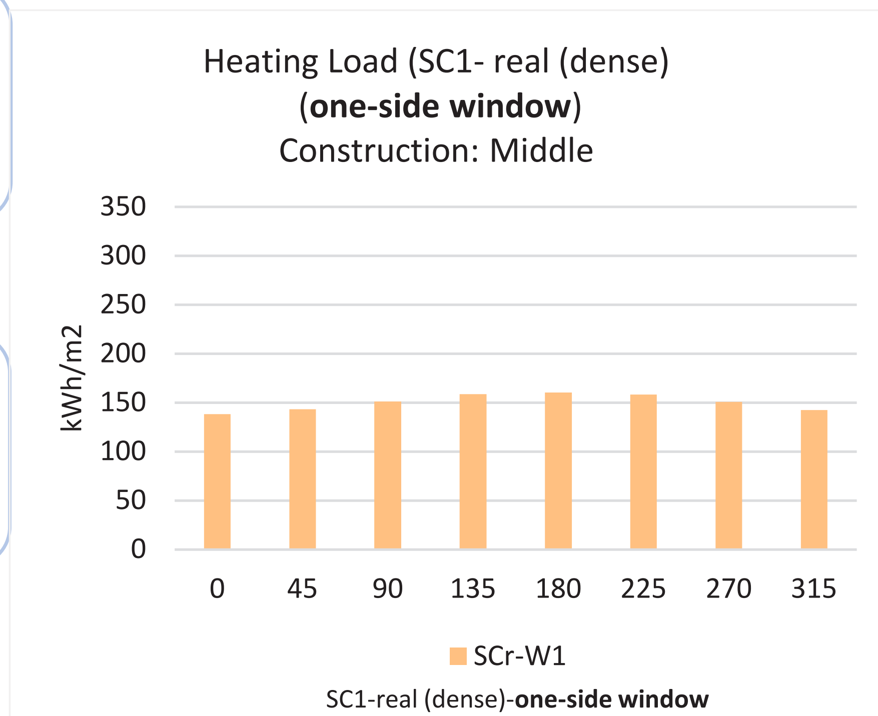


Cooling demand difference in different orientations

34%

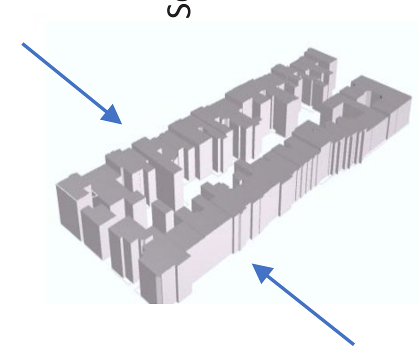
Heating demand difference in different orientation

13%



SC1-r-W2

Sc1- real (dense) two side window

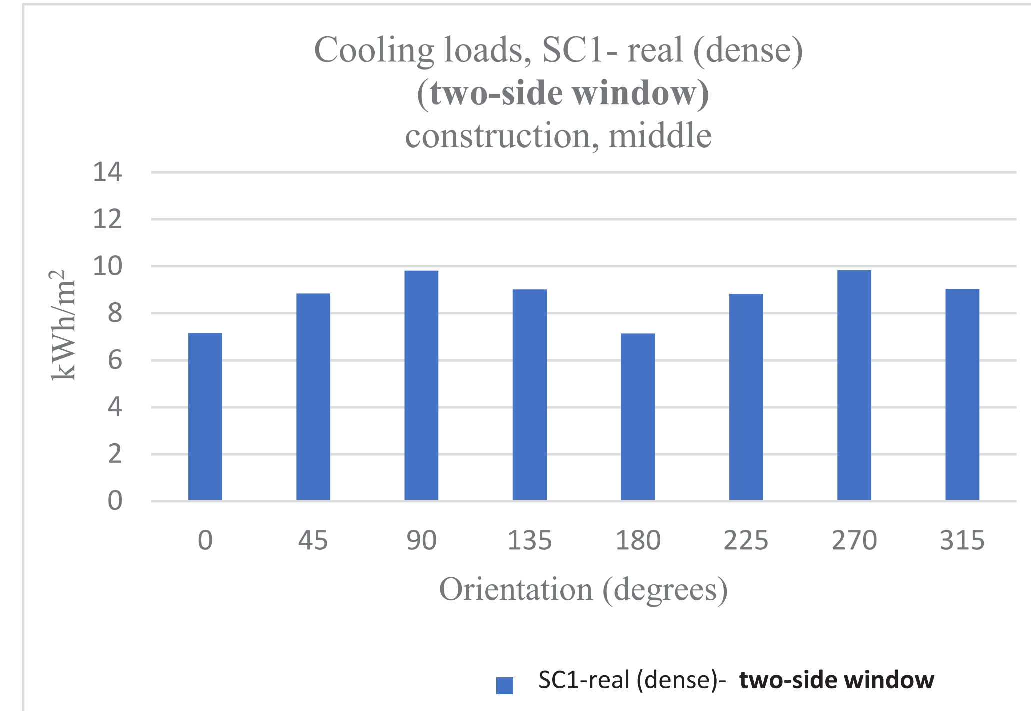


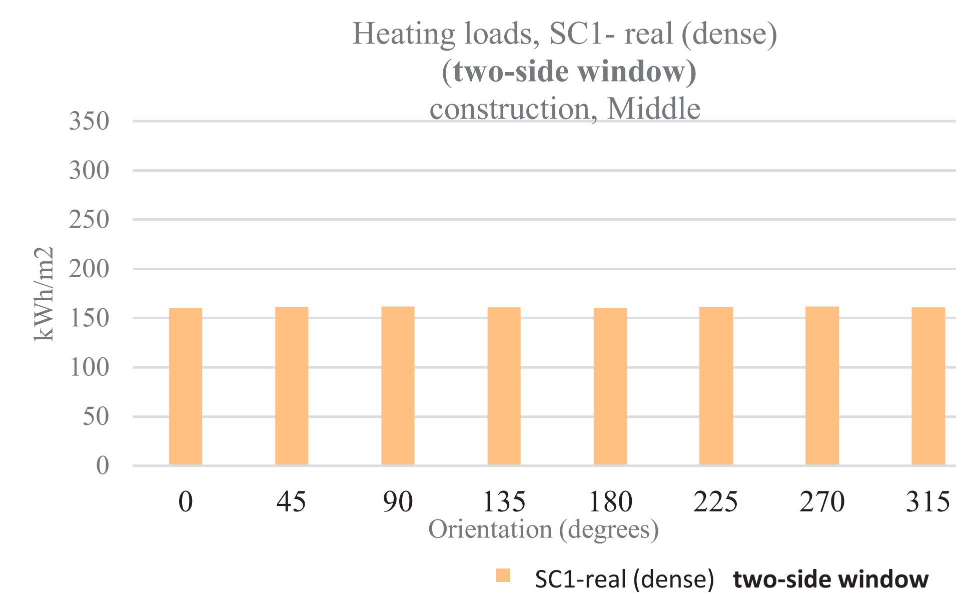
Cooling demand difference in different orientations

27%

Heating demand difference in different orientation

1%





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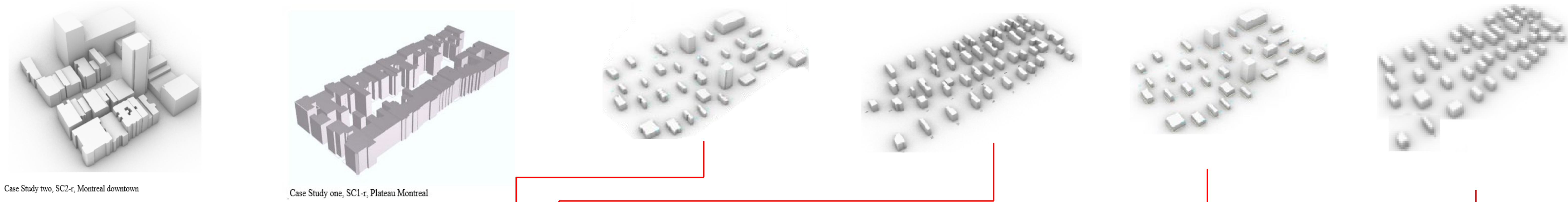
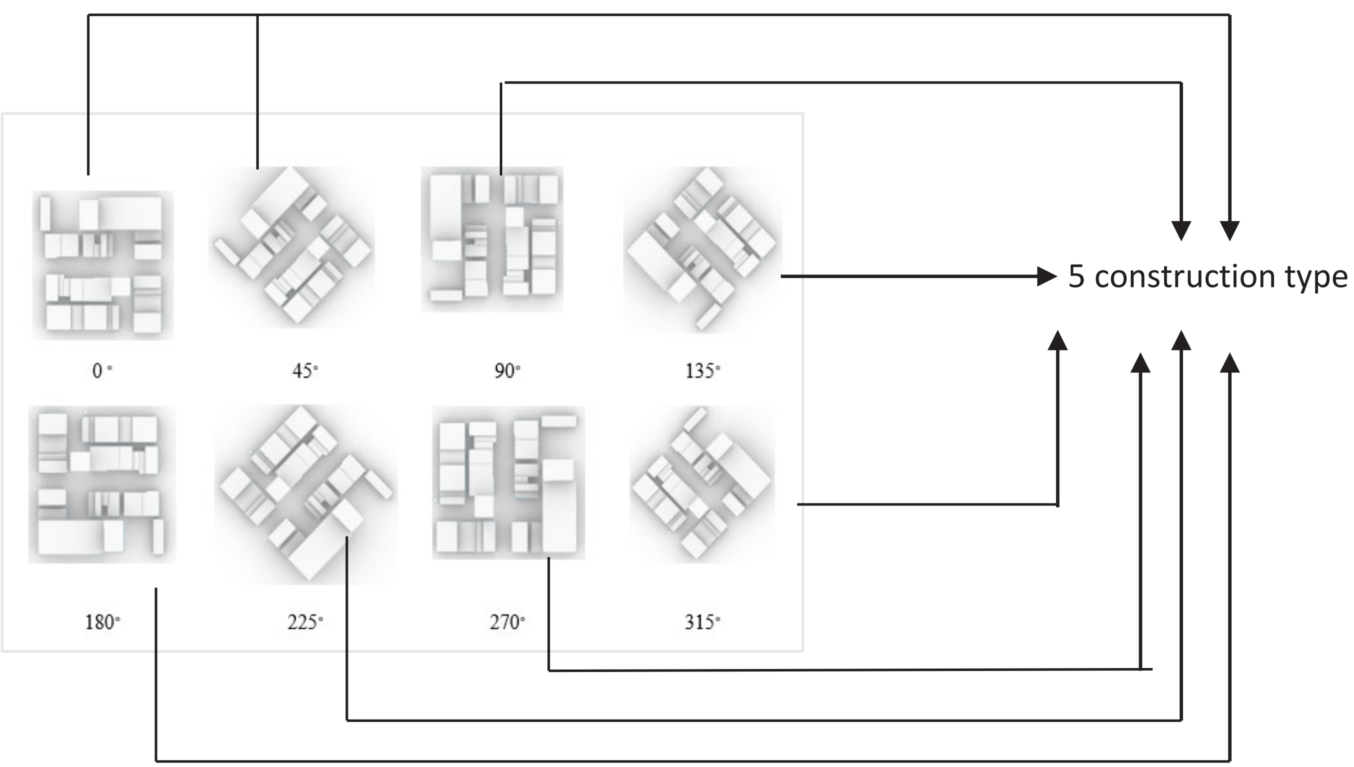
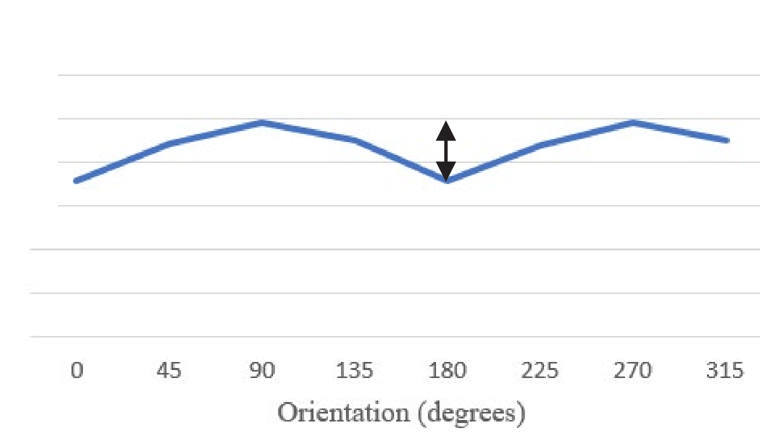
Parameters: Orientation

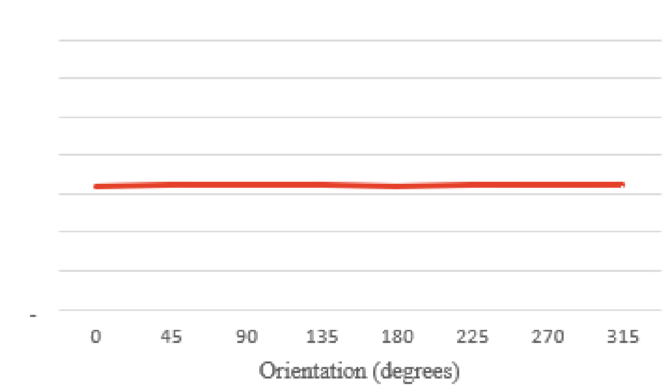
comparison of one side window and two side window





The pattern of changing
heating load and cooling loads
in different orientations (two-sided windows)
for all morphology scenarios and construction standards



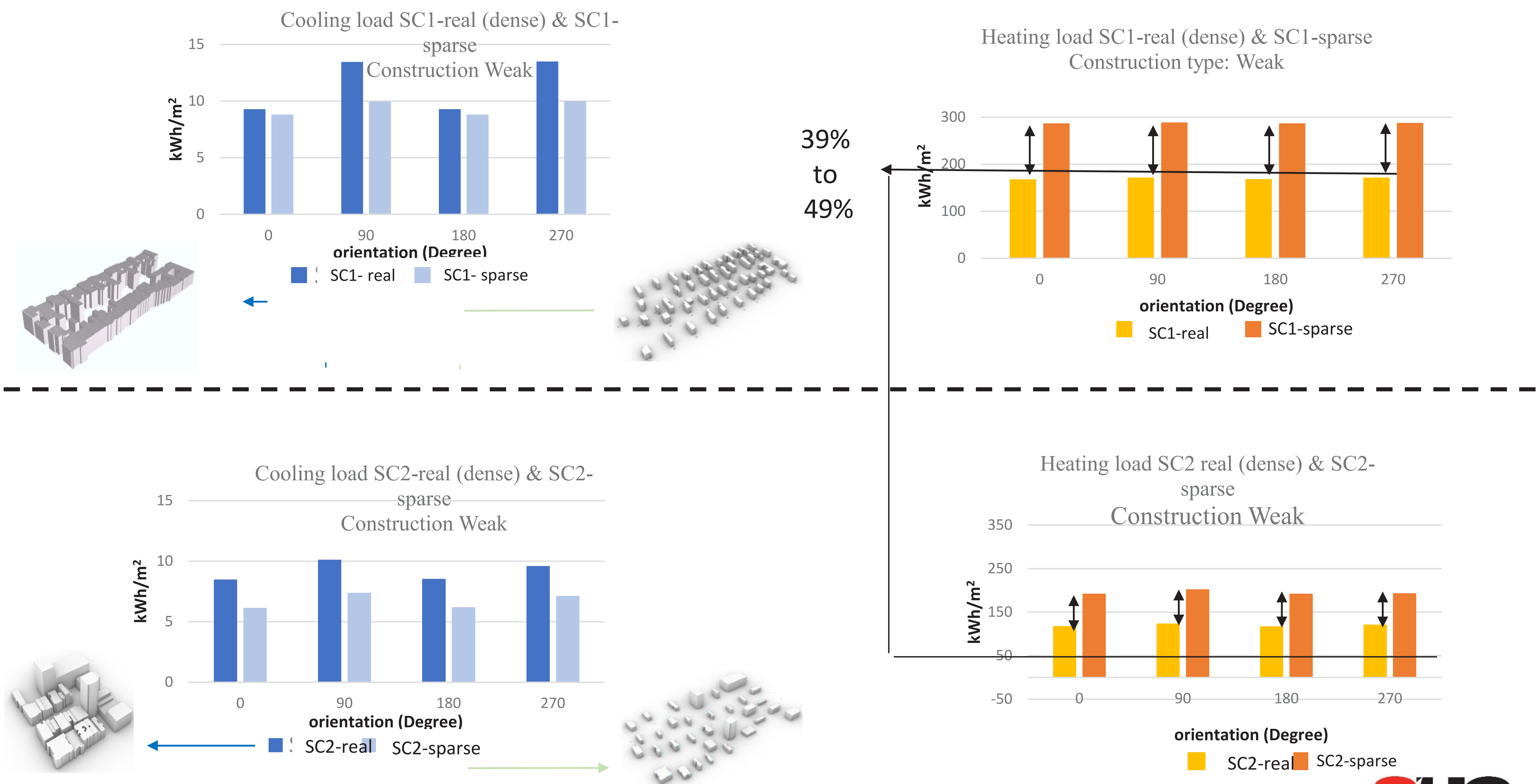


27% Cooling demand difference in different orientation

1% Heating

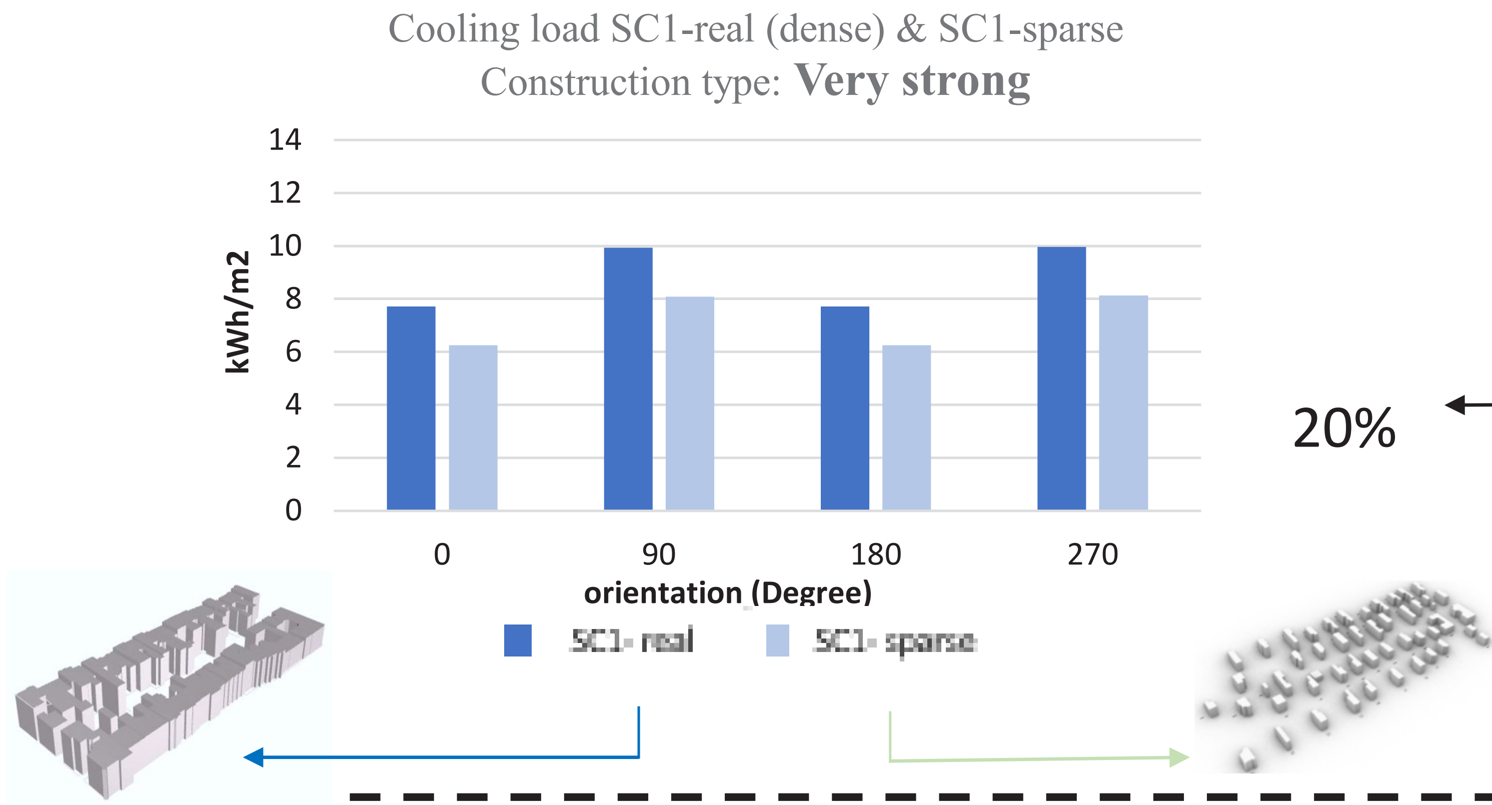
Slide 13

Parameters: Compactness
comparison of real dense scenarios to the sparse scenarios

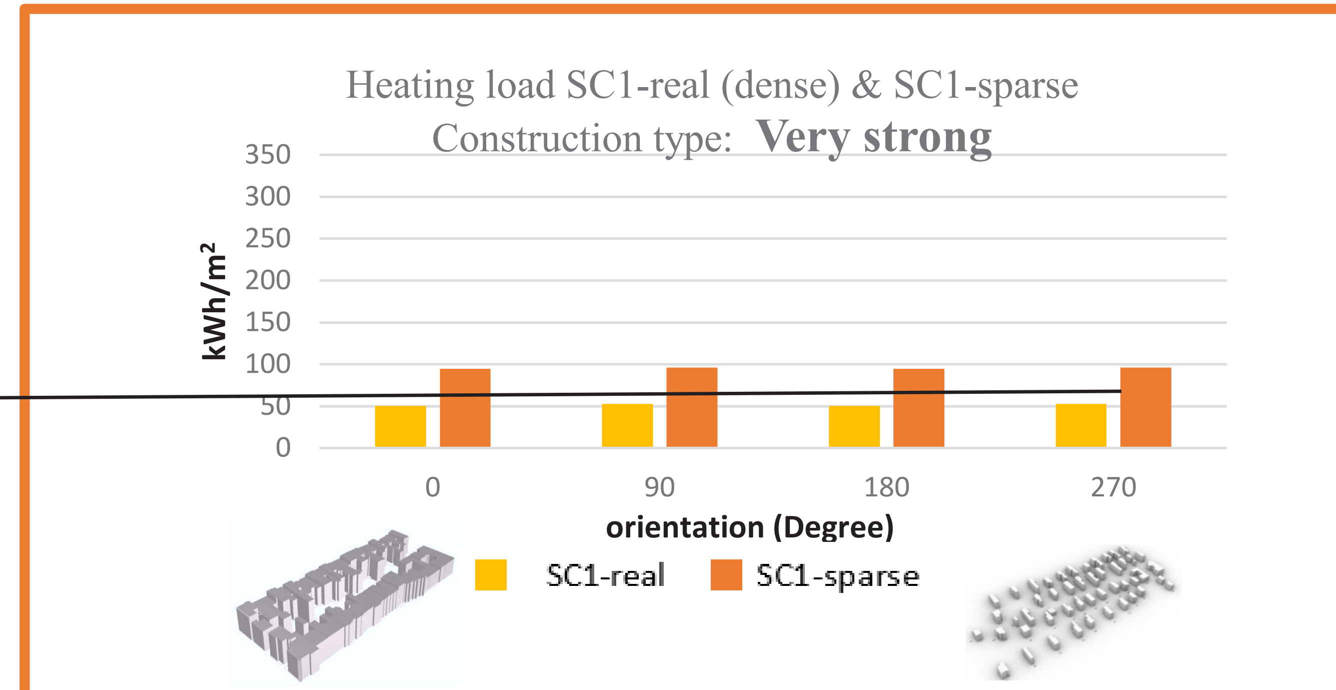


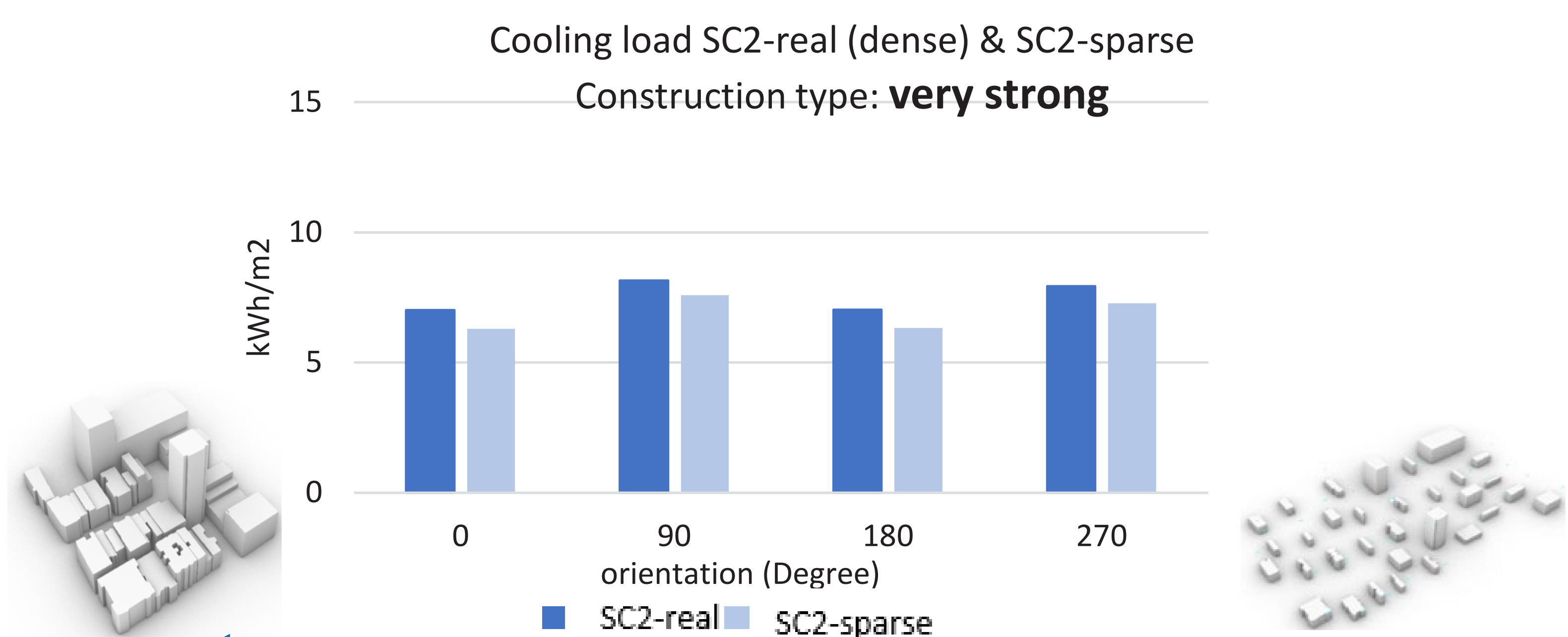
Parameters: Compactness

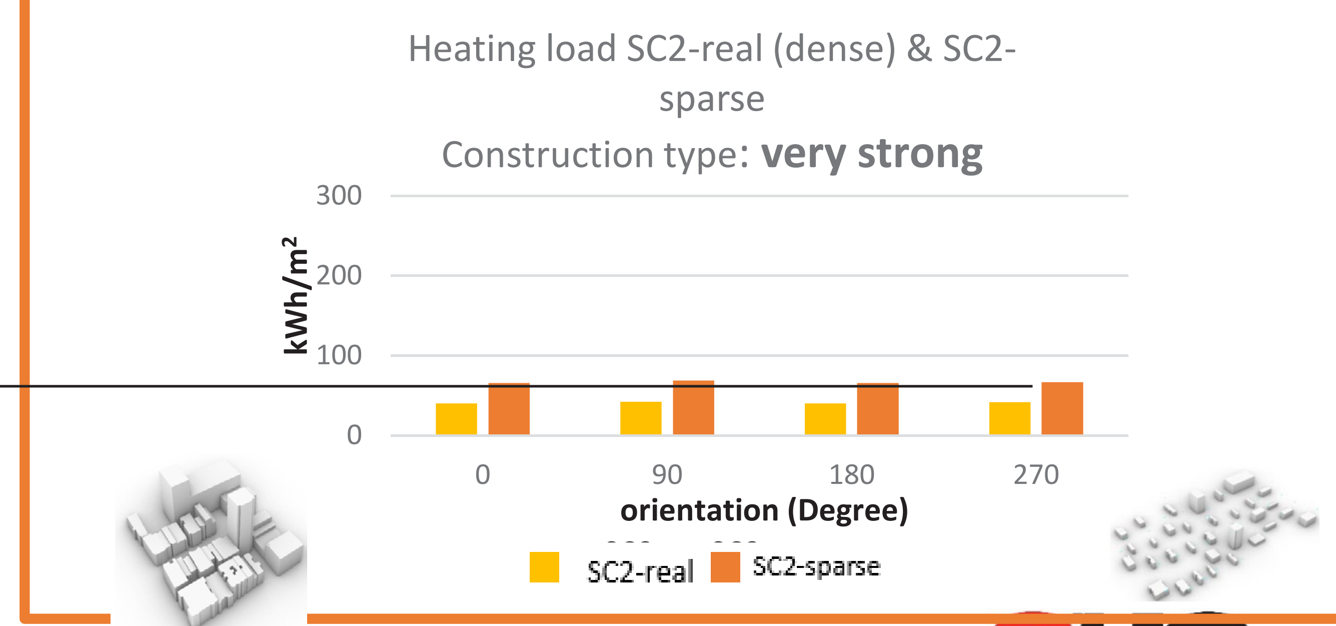
comparison of real dense scenarios to the sparse scenarios



20%

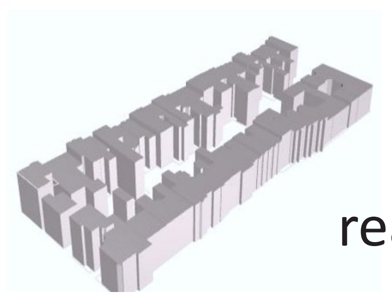




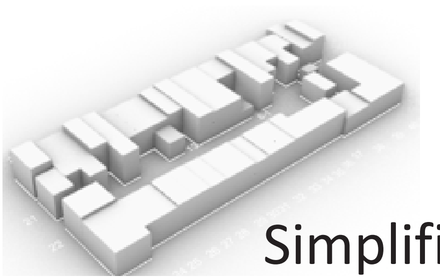


Parameters: Simplification

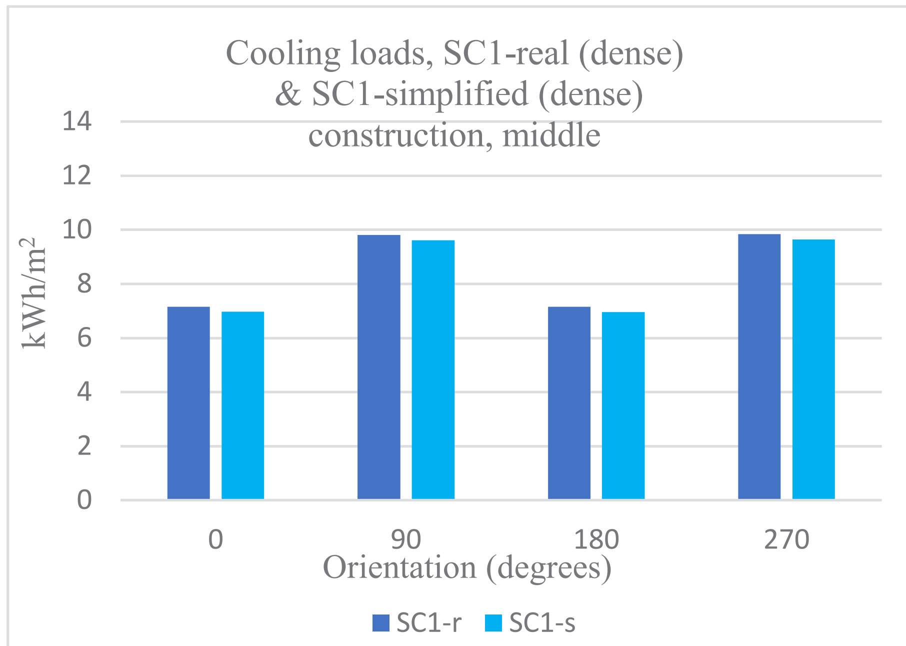
comparison of **real** (dense) scenarios to the **simplified** (dense) scenarios

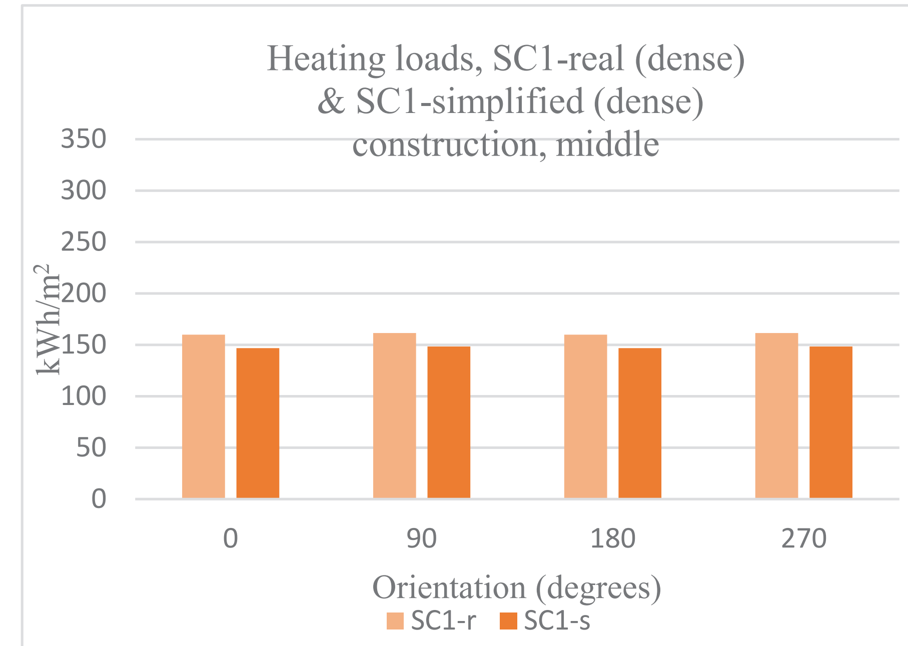


real

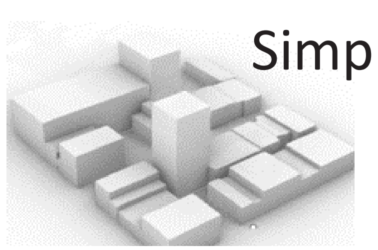


Simplified

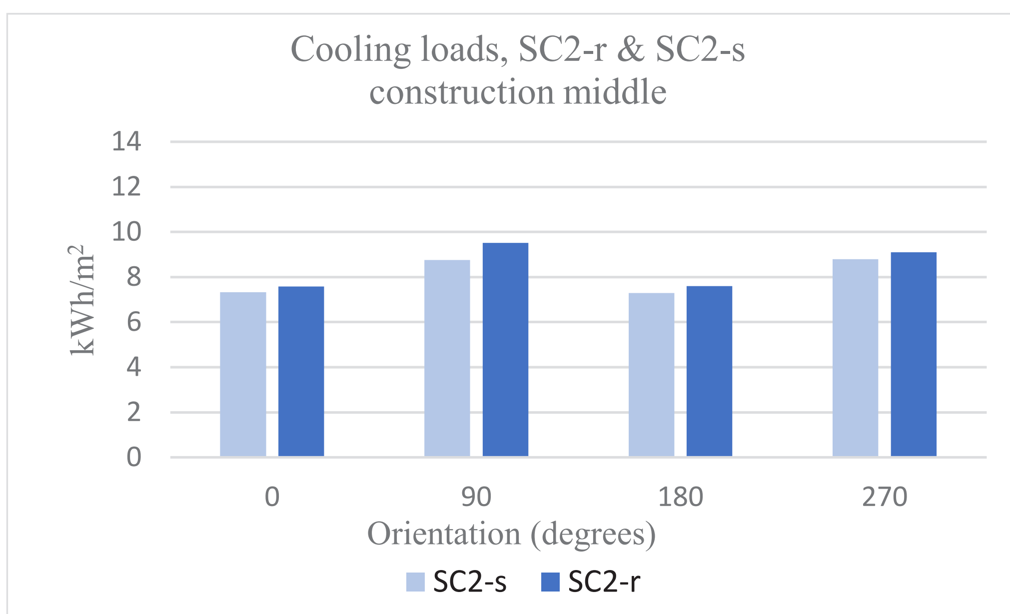


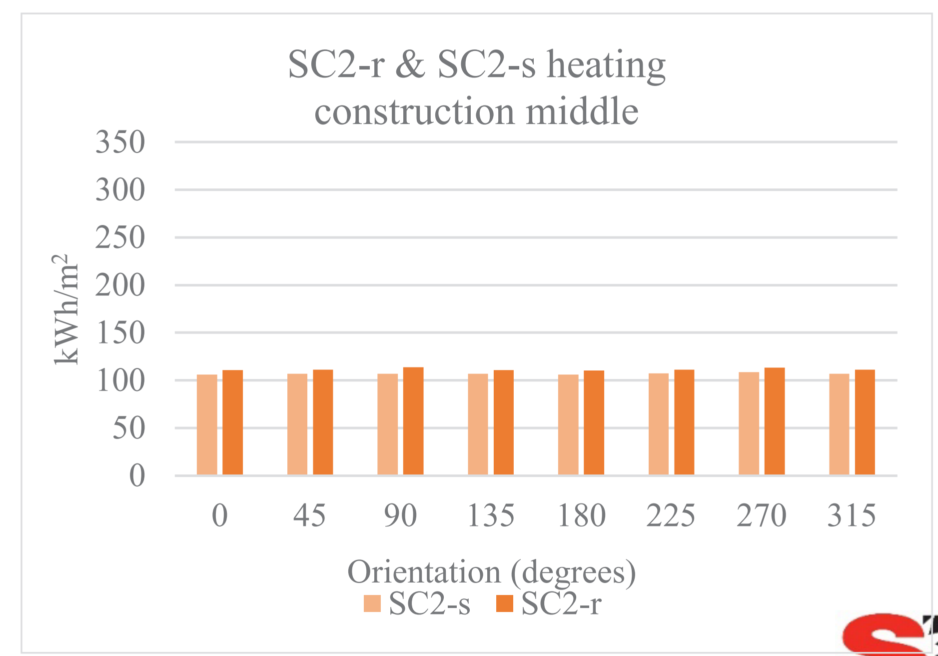


real



Simplified





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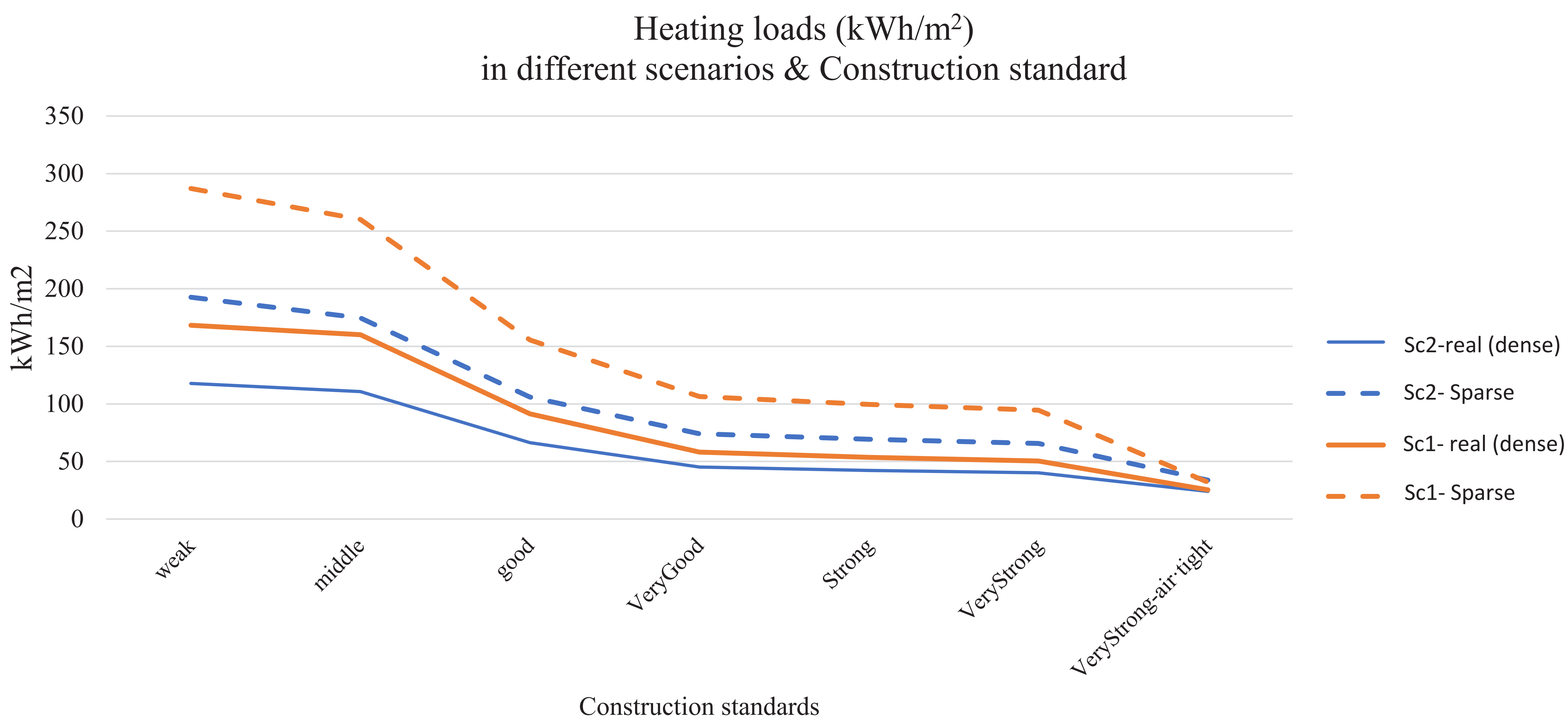
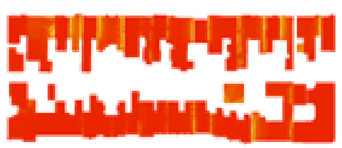
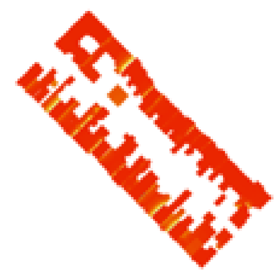
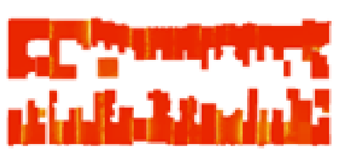
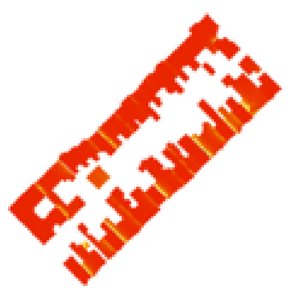
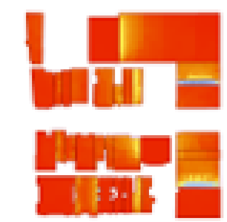
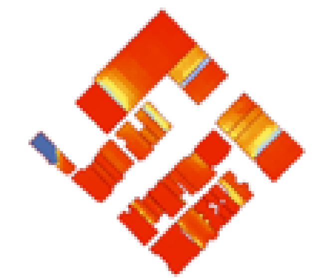
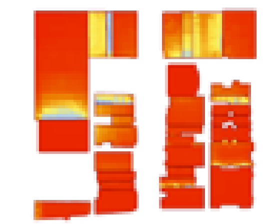
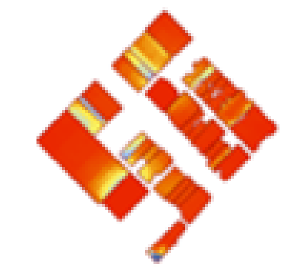
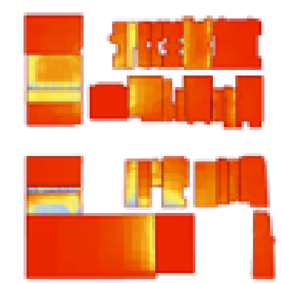
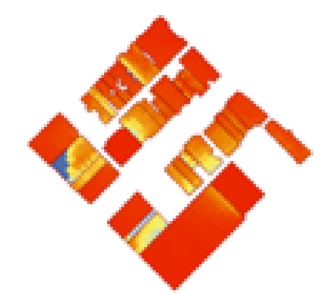
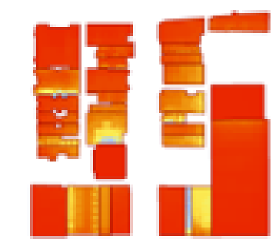
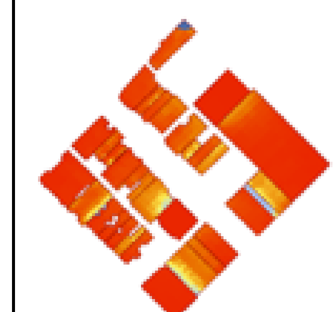
Parameters: Construction standards



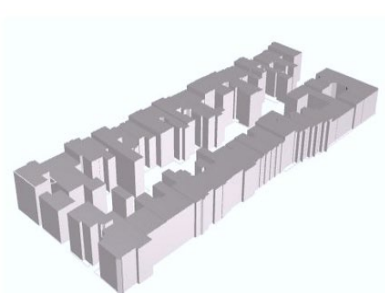
Radiation calculations:
Roofs

			
0 °	45°	90°	135°
9436.2 MWh	9454.9 MWh	9471.8 MWh	9447.3 MWh
			
180°	225°	270°	315°
9429.9 MWh	9452.7 MWh	9478.5 MWh	9456.1 MWh

Radiation received on roofs in different orientations, SC1-r

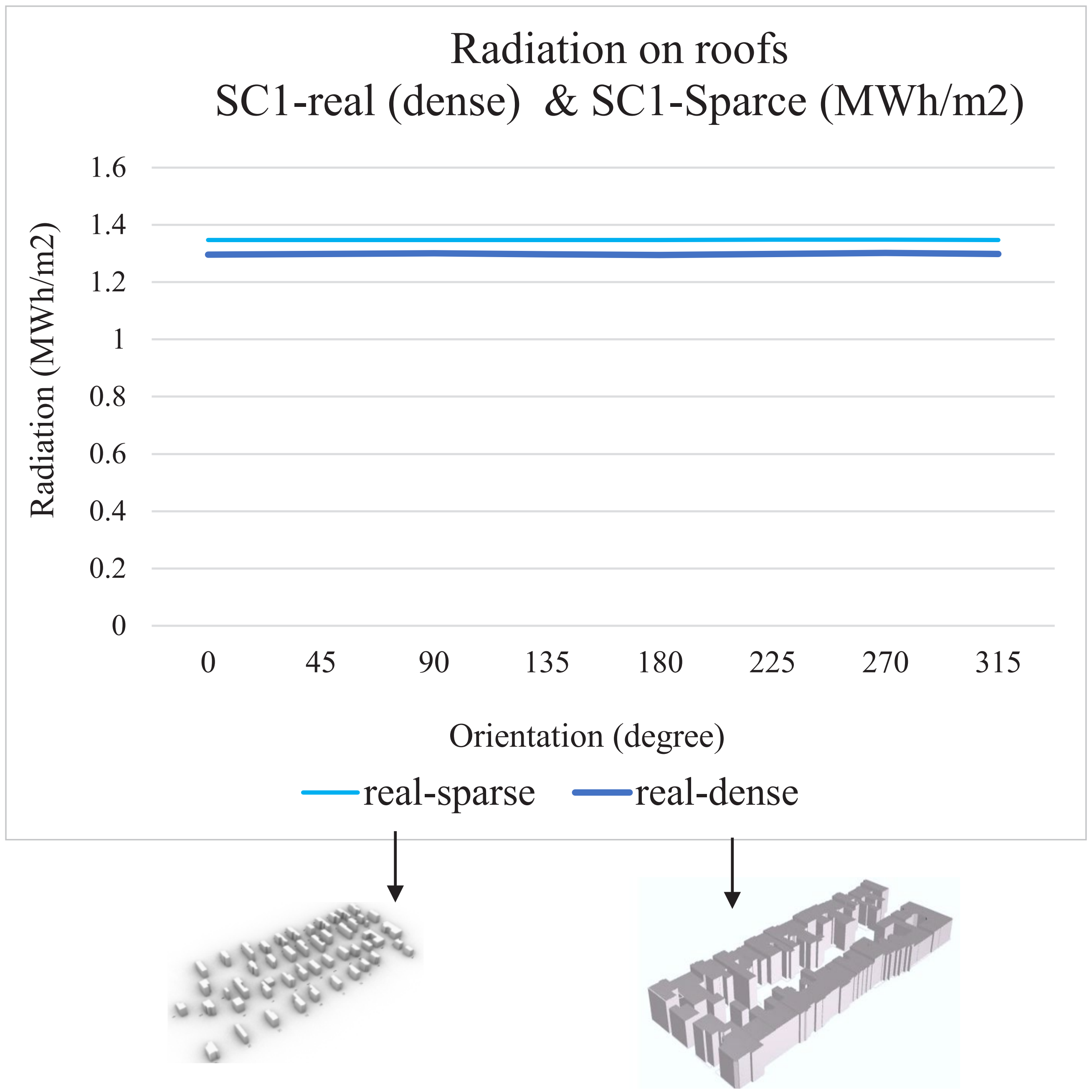
			
0 °	45°	90°	135°
18287 MWh	17628 MWh	17814 MWh	17381 MWh
			
180°	225°	270°	315°
17410 MWh	17464 MWh	17464 MWh	18095 MWh

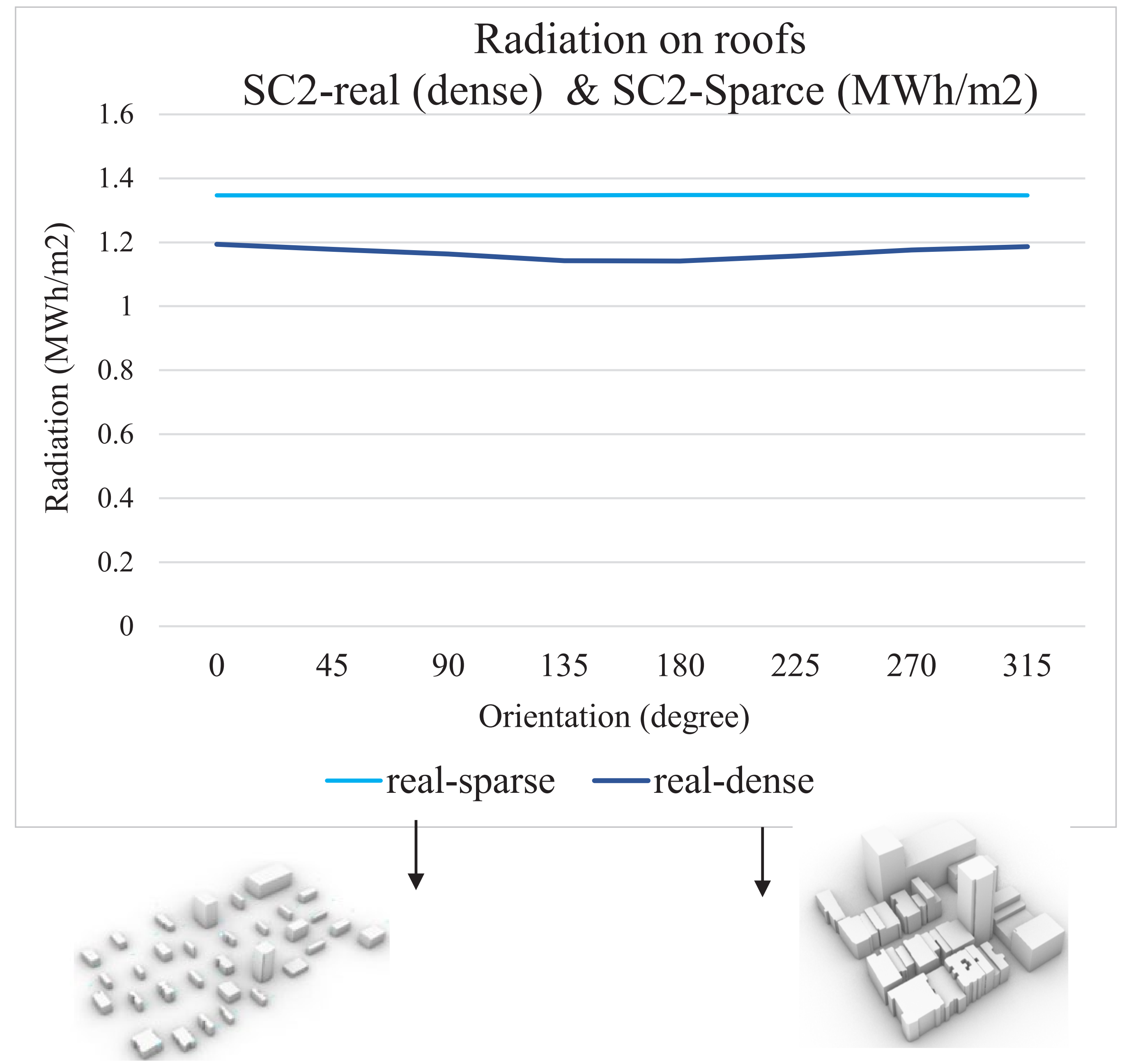
Radiation received on roofs in different orientations, SC2



Radiation calculations

Roofs





Renewable energy calculations

Scenario	SC1: Solar electricity generation / Electrical energy needed	SC2: Solar electricity generation / Electrical energy needed
Worst orientation + Dense+ worst construction	0.66	0.58
Worst orientation +Dense + Best construction	1.34	0.94
Best orientation +Sparse + worst construction	0.45	0.44
Best orientation + Sparse + Best construction	0.99	0.80
Best orientation + Dense + Best construction + airtight	1.67	1.00
Best orientation + Sparse + Best construction + airtight	1.56	0.99

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Conclusion and discussion

- Orientation is only important when windows are only one-side of the buildings (Maximum difference in heating loads is 13% compared to 2% on both sided scenario)
- Higher surface-to-volume ratios (sparse scenario) increase the heating demand significantly by up to 50% when buildings are detached.
- If the buildings are highly insulated, the heating only increases by 20% when the buildings are detached. This means that high insulation standards reduce the impact of urban morphology changes.
- Simplifying the geometries does not have significant impacts.
- Construction standards can bring down energy consumption by 85%.
- In all cases cooling loads are significantly lower than heating loads (within the range of 8kWh/m2 to 14 kWh/m2 compared to heating loads 300 to 30kWh/m2).
- Even with the worst orientation, and less solar potential (Dense scenario), with good construction standards we can have a positive energy district if there is not much height difference in the neighborhood.

Thank you!

Any questions?

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