WORKPLACE OF THE FUTURE

MULTIDISCIPLINARY RESEARCH CATALYST FUND (MRCF)

Carleton UNIVERSITY

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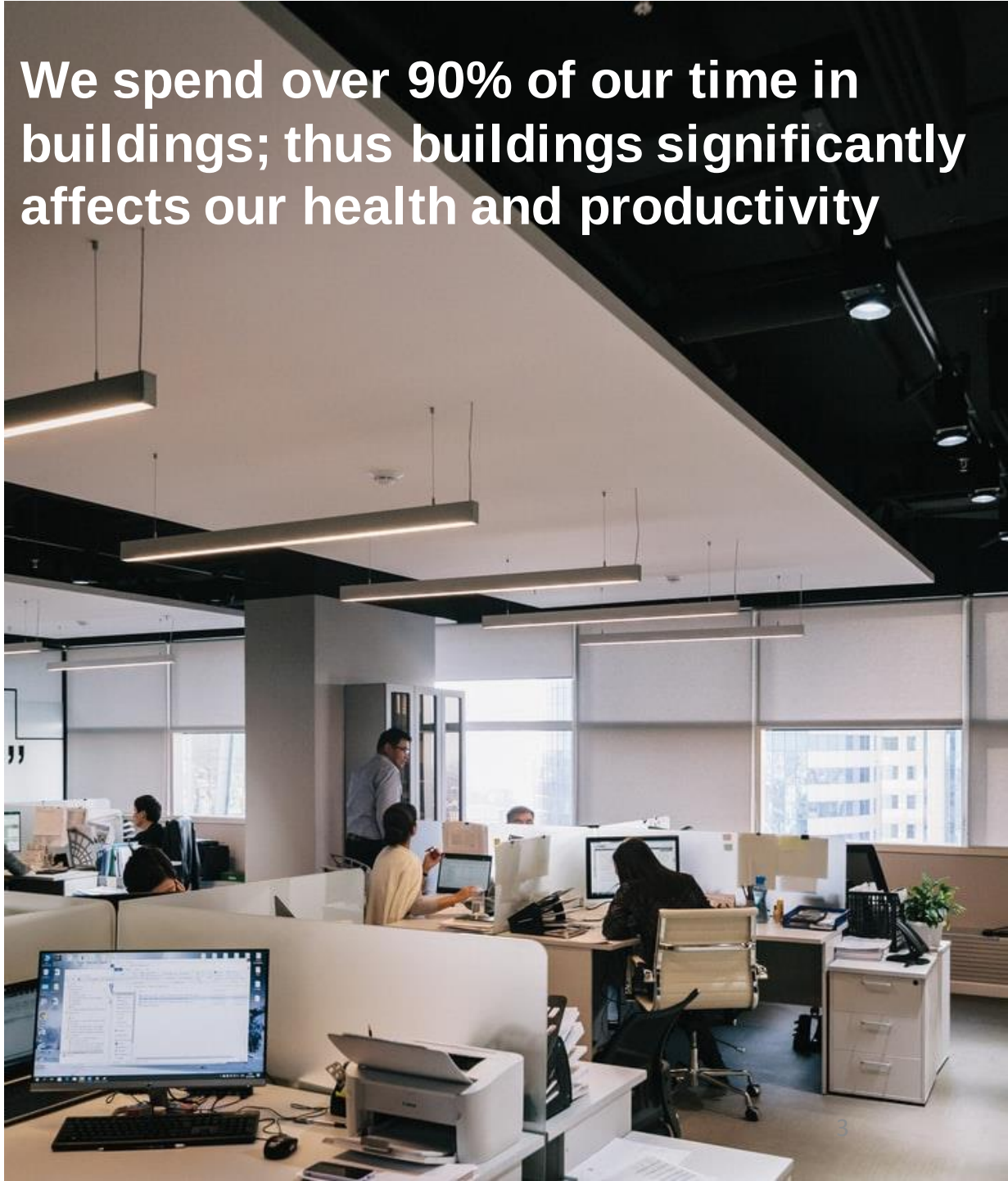
MOTIVATION

Despite ever-increasing design tools, expertise, scientific knowledge, and technologies, new workplaces and office buildings remain far from optimal from an environmental, economic, and social perspective throughout their life cycle (design, construction, operation).

The lack of collaboration between experts during the building design process –and later during operations– results in missed opportunities to achieve workspaces that are: comfortable, healthy, productive, usable and accessible (including for people with disabilities), low in environmental impact, and resilient to challenges occurring due to climate change-induced severe conditions.

Societal trends, environmental pressures, and new knowledge necessitate workplaces transition with respect to the way they are designed, operated, and managed.



GOAL

A multidisciplinary approach **involving all five Carleton faculties** to develop robust solutions, knowledge, tools and technologies, policies, and processes needed for the workplace of the future.

We aspire to develop new knowledge, technologies, and workflows to support workplace of the future, and meanwhile build a living lab for:

1) Housing the cluster of researchers, providing space for experiments, and serving as a catalyst for multidisciplinary research, and

2) Serving as a highly-instrumented flexible space to design, implement, and test energy, comfort, and health benefits of technologies for the building sector.

OUR HOLISTIC VISION FOR THE WORKPLACE

We seek to draw knowledge from the following disciplines:

Productivity & Health

As architects do not always get the opportunity to occupy and use the buildings they design, the assumptions they make about the performance of buildings may be inaccurate.
As such, our expert psychologists together with engineers are seeking to establish a stronger evidence base examining the impact of workplace design upon users' satisfaction and productivity.

Occupant-centric building design and controls

Understand the two-way interaction between workplace and their occupants to maximize comfort, well-being while minimizing environmental impacts.

Optimizing workplace design and operation process for comfort and energy use through building automation systems, computerized maintenance, and occupancy monitoring.

Building energy performance

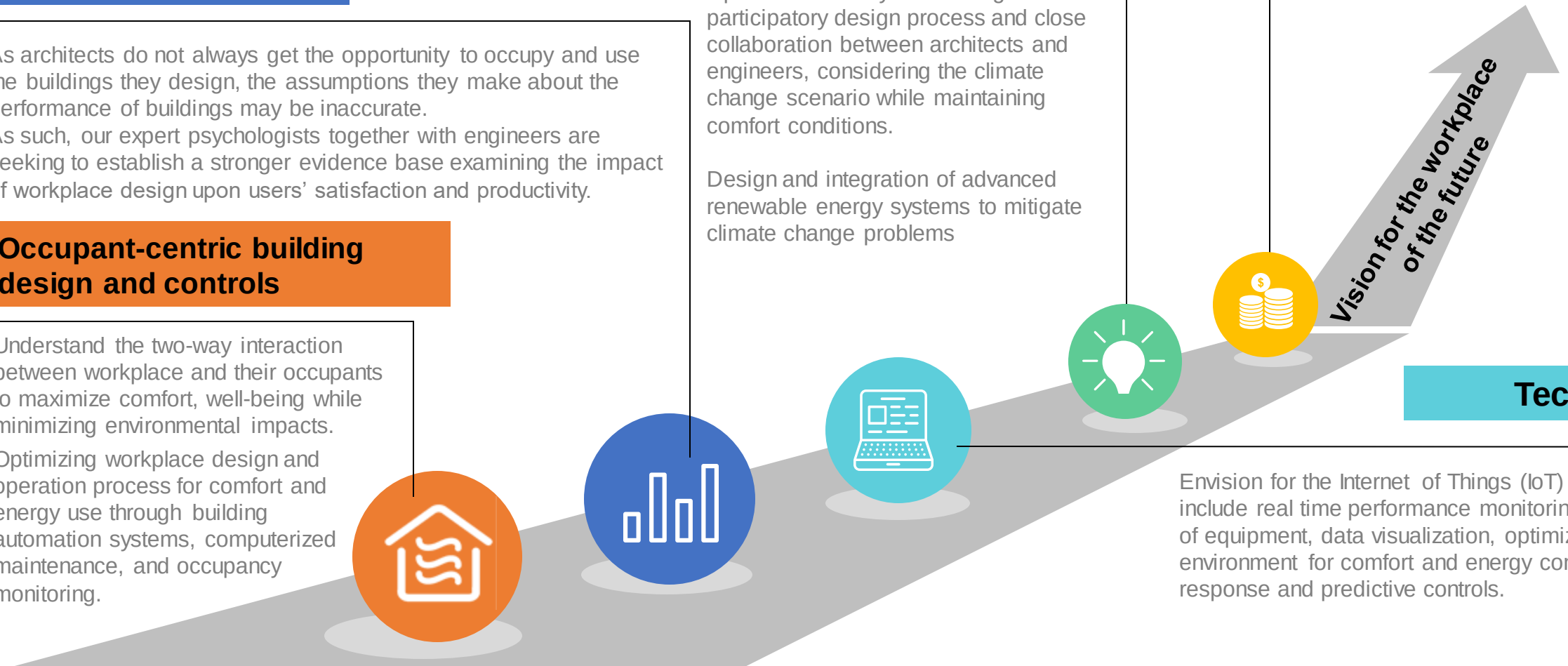
Develop new approaches to constructing building envelopes that are thinner, cheaper, durable, high performance

Optimize HVAC system through participatory design process and close collaboration between architects and engineers, considering the climate change scenario while maintaining comfort conditions.

Design and integration of advanced renewable energy systems to mitigate climate change problems

Economy

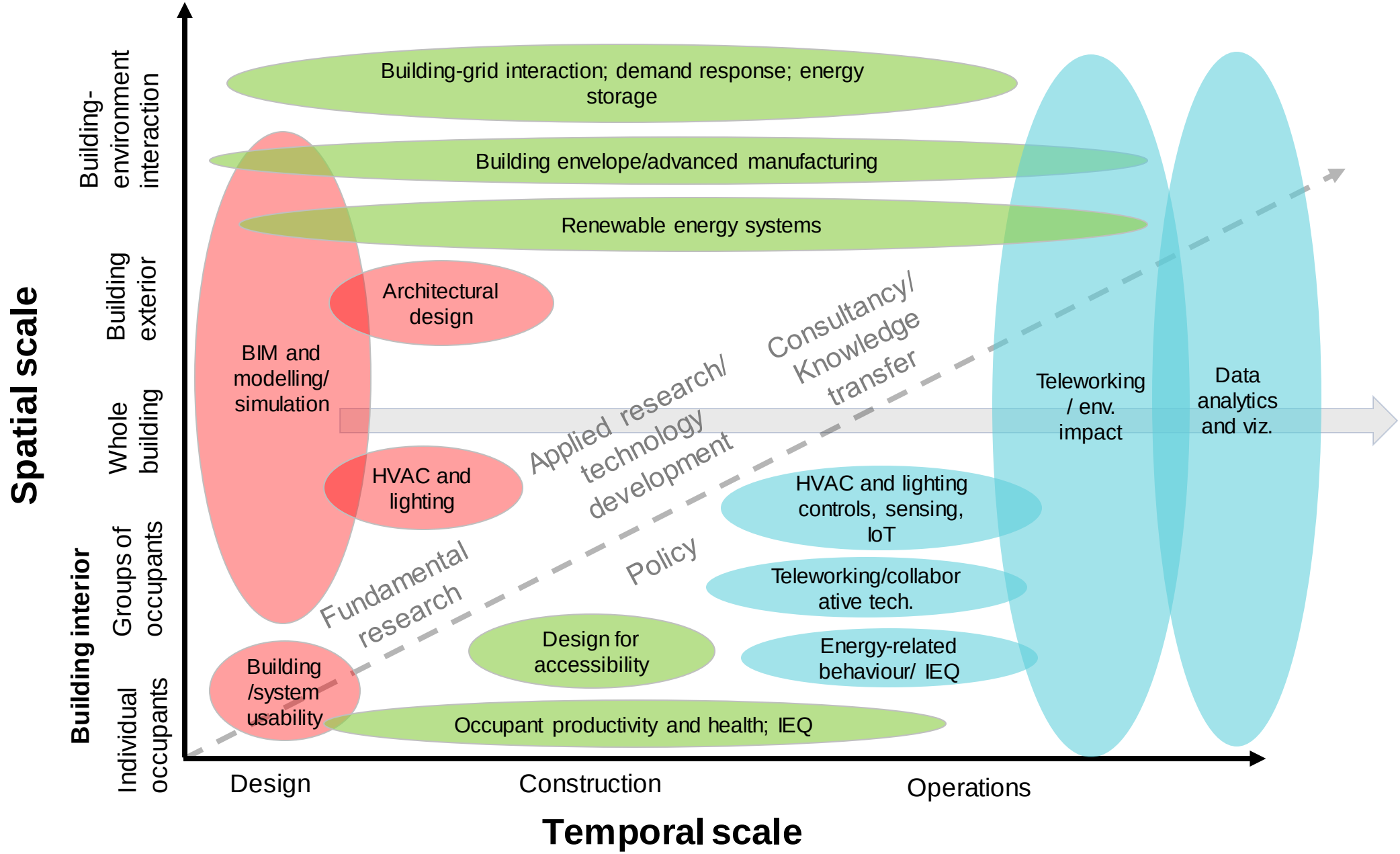
Investigating the potential economic value of integrating all elements together (technology, HVAC, building envelope, work productivity, human costs) into the workplace throughout its life-cycle (design, construction, operation)



Technology

Envision for the Internet of Things (IoT) in workplace, include real time performance monitoring, fault diagnosis of equipment, data visualization, optimization of indoor environment for comfort and energy consumption, demand response and predictive controls.

RESEARCH SPACE TO SUPPORT WORKPLACE OF THE FUTURE



OCCUPANT-CENTRIC BUILDING DESIGN AND CONTROLS

OCCUPANT-BUILDING INTERACTION

Optimize buildings and their systems for usability, comfort, and energy performance

BUILDING AUTOMATION/ CONTROL

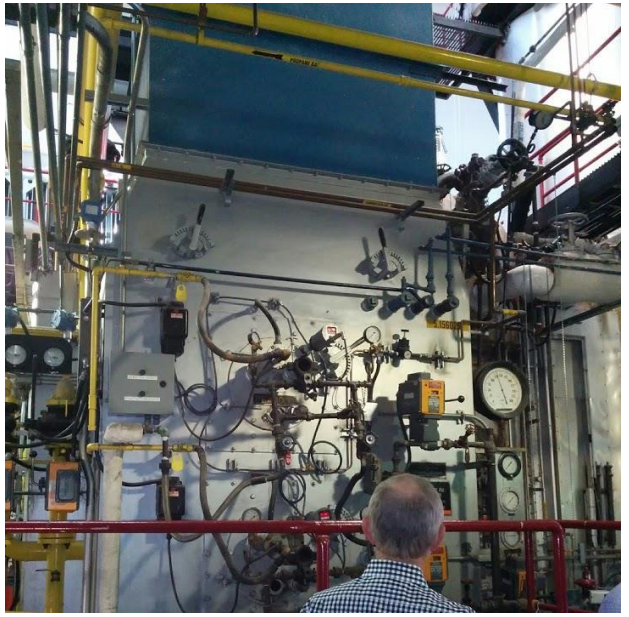
Optimize the operation of a buildings through a network of sensors, actuators, and algorithms to improve comfort, and optimize energy use

OCCUPANT-CENTRIC BUILDING DESIGN AND CONTROLS

FACILITIES

40 highly-instrumented rooms with detailed real-time and historic data about indoor environmental conditions, occupant interaction, and energy

50 campus buildings with open data



Meters for electricity, natural gas, submeters for heating, cooling, lighting, plug loads

Building automation systems for HVAC, lighting, access control

Fully-customizable building interfaces

BUILDING ENERGY PERFORMANCE

BUILDING ENVELOPE

Develop new approaches to constructing building envelopes that are thinner, cheaper, more durable, and higher performance

HVAC SYSTEMS

Optimize HVAC system design and operation for energy and comfort performance, considering individual control and adaptability

RENEWABLE ENERGY

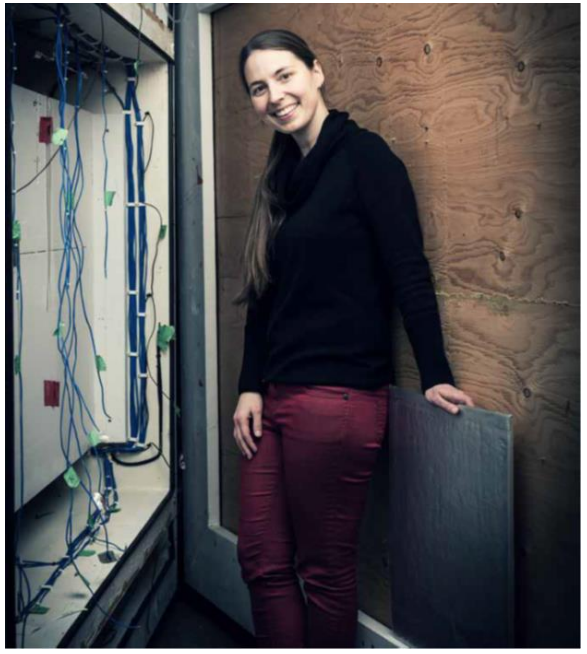
Design and integrate advanced renewable energy systems to reduce reliance on the grid and mitigate climate change

BUILDING ENERGY PERFORMANCE

FACILITIES

A full-scale experimental facility that possesses redundant energy conversion, storage, and distribution systems to enable research on numerous topics with minimal switch-over time required.

Occupant simulation



Guarded hot box for testing innovative wall sections

Two temperature and humidity-controlled climate chambers (top) and a guarded hot plate (bottom) to collect data on new insulation materials and their long-term performance

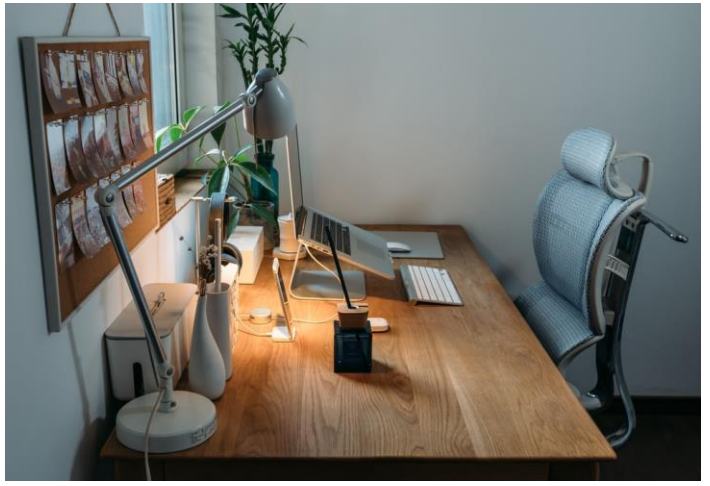
PRODUCTIVITY & HEALTH

Work-life balance

Consideration of work-life/balance, change management, and employee wellbeing in workplace of the future

Human factors/ ergonomics

Design of workplaces for usability, ergonomics, and productivity



Psychology, wellbeing, and perception of time

Design for employee wellbeing and promotion of sustainable behaviours

PRODUCTIVITY & HEALTH

FACILITIES AND INITIATIVES

- **National studies on work-life balance**
  - Balancing work and caregiving in Canada (2012)
  - Work-life experiences of employed caregivers (2013)
- **CU Happiness Lab**
- **Life Tools Lab**

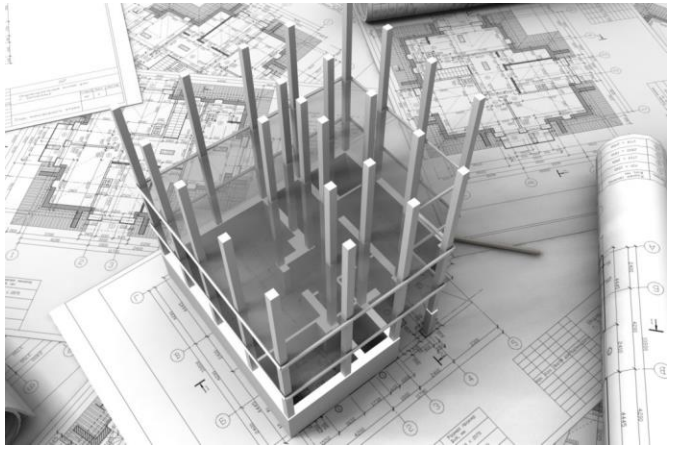
TECHNOLOGY

Advanced user interfaces

Enhanced interfaces for greater employee interactivity

BIM and virtual environments

Utilization of Building information modelling and virtual environments to support office design and operation



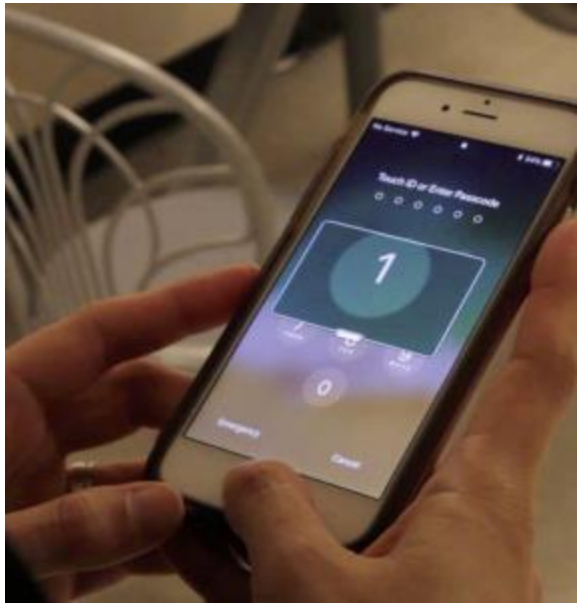
IoT, advanced computing and data analytics

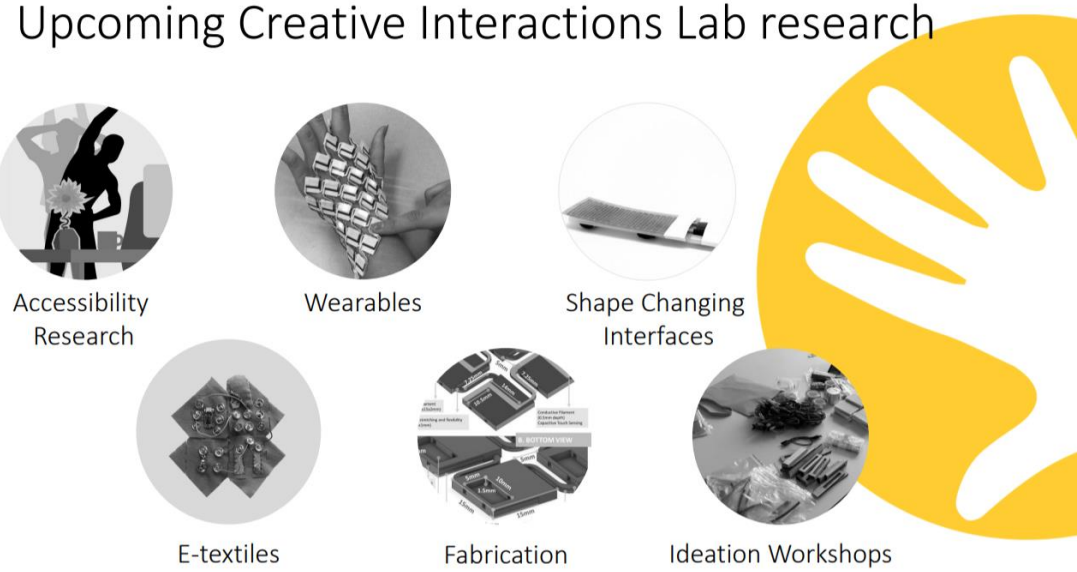
Utilizing cloud computing, resource management, and wireless sensor networks for the workplace

TECHNOLOGY

FACILITIES

- **Creative Interactions Lab**
- **Carleton Immersive Media Studio**
- **Director Real Time and Distributed Systems Research Centre**
- **Research and Education in Accessibility, Design, and Innovation (READi)**





ECONOMY

LIFE CYCLE COST ANALYSIS

Minimizing costs of workplaces –from construction to end of life- while also considering productivity

BEHAVIORAL ECONOMICS

Research in decision making and behavioural science

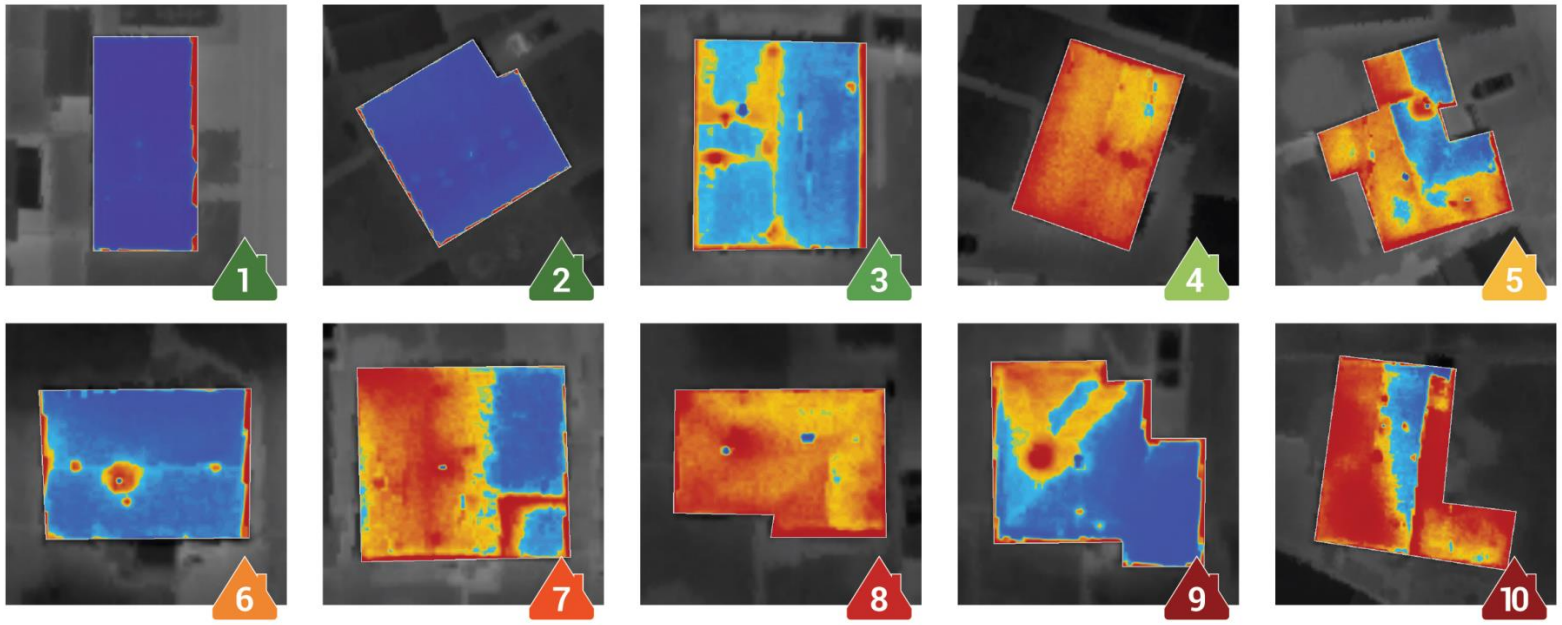
ENERGY/ CLIMATE CHANGE POLICY

Determining optimal policies to reduce energy and GHG emissions of workplaces

ECONOMY

FACILITIES AND APPROACHES

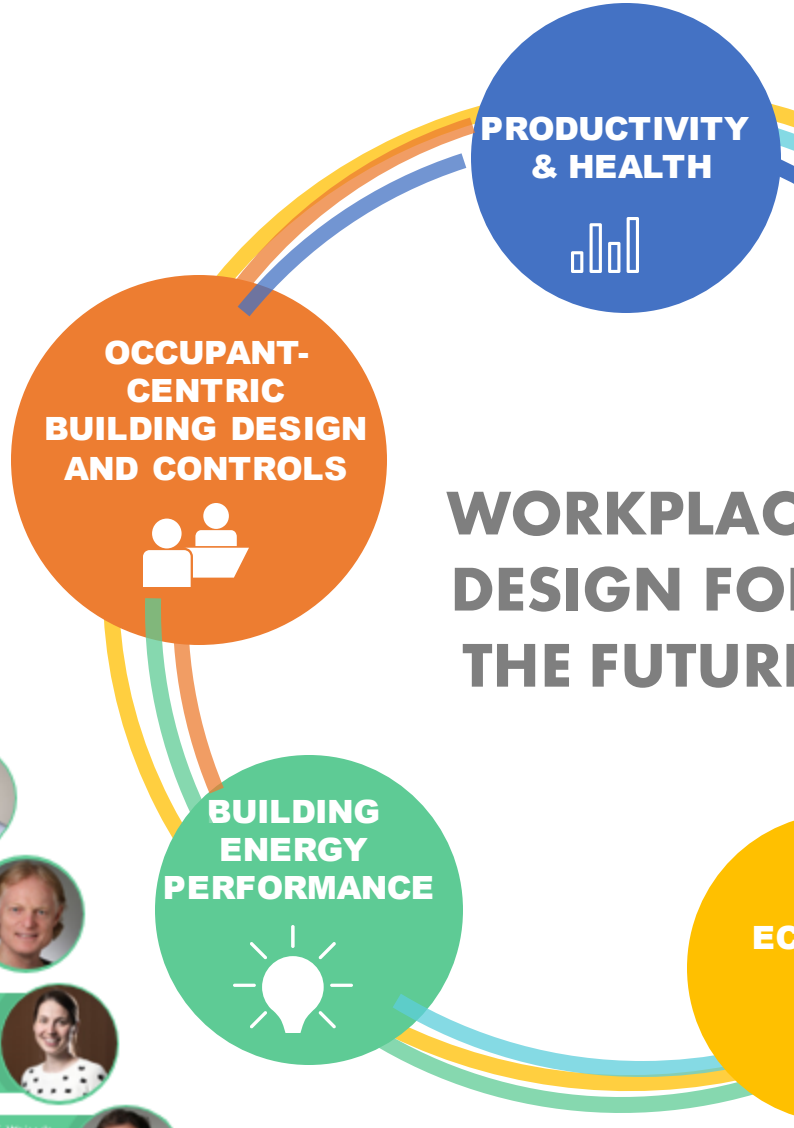
Carleton Economics Laboratory for Behavioural and Experimental
Research: for understanding decision-making and assessing the validity of behavioural theories



Randomized control trials to identify the most cost-effective policies to reach building energy conservation milestones and decarbonization of the commercial buildings sector

TEAM STRENGTH

WHO WE ARE



Prof. Linda Duxbury is a faculty member in the Sprott School of Business. Prof. Duxbury's research involves work-life balance as it relates to work-family conflict, change management, supportive work environments, stress, telework, the use and impact of office technology, managing the new workforce, and supportive management. Prof. Duxbury has received several awards and honors, including the "Canadian Pension and Benefits National Speaker Award" and the "Toastmasters International Communication and Leadership Award." Also, in 2009, she was recognized as one of Deloitte's Women of Influence.

Prof. Chantal Trudel is a faculty member in the School of Industrial Design. Prof. Trudel is interested in the design's role in health, safety, performance and productivity, accessibility, and inclusion. Her work in design of corporate and specialized interiors and workflows such as healthcare environments has been featured in Canadian Interiors and awarded the 2010 Canadian Architecture Award of Excellence and the 2012 International Academy for Design and Health High Commendation in the International Future Health Project Category.

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Prof. Shikharesh Majumdar is a faculty member in the Department of Systems and Computer Engineering, and the director of the Real-Time and Distributed Systems Research Centre. Prof. Majumdar research interests are in cloud and grid computing, smart systems, operating systems, and performance evaluation. Prof. Majumdar is a fellow of the Institution of Engineering and Technology (IHET), a member of ACM, and a senior member of IEEE.

Prof. Adrian Chan is a faculty member in the Department of Systems and Computer Engineering, director of the NSERC CREATE Research and Education in Accessibility, Design, and Innovation (READI) training program. Prof's Chan's current research interests include biological signal processing, signal quality assessments, gesture recognition, assistive devices, and non-invasive sensor systems. Prof. Chan has been recognized with several honors, including CMBES' Outstanding Biomedical Engineer of the Year and the 3M National Teaching Fellowship.

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Prof. Liam O'Brien is a faculty member in the Department of Civil and Environmental Engineering and the principal investigator of the Human Building Interaction Lab. Prof. O'Brien's research focuses on building energy performance, data analysis and visualization, modeling and simulation, and occupant comfort and behavior. Prof. O'Brien has won several prestigious awards including the Carleton Research Achievement Award, Ontario Building Envelope Council Rising Star Award, the Ontario Early Researcher Award, and the International Building Performance Simulation Association (IBPSA) Outstanding Young Contributor Award.

Prof. Dorsk Gunay is a faculty member in the Department of Civil and Environmental Engineering and leads a Data-driven Building Operation and Maintenance research group. Prof. Gunay's research examines methods to optimize the operation of buildings for comfort and energy use. He uses the operational data gathered inside modern automation and control networks to learn from the occupants' comfort, behavior, and presence patterns. Prof. Gunay has won a Senate Medal and Governor General's Medal for his Ph.D. thesis.

Prof. Jean Duquette is a faculty member in the Department of Mechanical and Aerospace Engineering. Prof. Duquette's research expertise includes numerical modeling and simulation of renewable energy systems (e.g., solar, wind, wave, hydro, etc.), energy storage technologies (e.g., batteries, thermal storage), thermal processes, district energy networks, and low energy buildings.

Prof. Ian Beausoleil-Morrison is a faculty member in the Department of Mechanical and Aerospace Engineering and leads the Sustainable Building Energy Systems group. Prof. Beausoleil-Morrison's research interests include solar housing, micro-cogeneration, seasonal storage of solar thermal energy, and understanding and controlling for occupant behavior. Prof. Beausoleil-Morrison is a Director of the International Building Performance Simulation Association (IBPSA) and was awarded the grade of Fellow of IBPSA in 2015.

Prof. Cynthia Cruickshank is a faculty member in the Department of Mechanical and Aerospace Engineering, and Director of Solar Energy Systems Laboratory and newly established Carleton University Centre for Advanced Building Envelope Research (CABER). Prof. Cruickshank's research focuses on the design and optimization of advanced building energy systems, including research related to high-performance building envelopes, energy-efficient insulation materials, solar-assisted heat pumps, solar absorption cooling, and thermal storage.

Prof. Gabriel Wainer is a faculty member in the Department of Systems and Computer Engineering. Prof. Wainer's research interests include DEVS formalism, real-time modeling, cellular models, modeling and simulation methodologies and tools, and parallel/distributed/web-based simulation. Prof. Wainer has received several awards and honors, including Carleton University's Research Achievement Award, Bernard P. Zeigler DEVS Modeling and Simulation Award, the SCS Outstanding Professional Award, and a recipient of the Nepean's Canada 150 Anniversary Medal.

Prof. Maya Papineau's research interests include environmental and energy economics, causal inference, econometrics, and program evaluation. She has applied econometrics tools to several research questions pertaining to building energy consumption. These include assessing whether commercial real estate markets value energy efficiency in buildings constructed under progressively more stringent energy codes, measuring the realized cost-effectiveness of commercial building energy standards and quantifying tenant-side "split incentives" problem among large commercial sector.

Prof. Stephen Schott is a faculty member in the School of Public Policy and Administration. Prof. Schott's His research currently focuses on alternative energy and sustainable development in the Arctic, the economic impacts of mining on local communities and local business development, food security and Arctic commercial fishery development, wildlife management and knowledge co-evolution, behavioral and experimental lab and field experiments, and energy strategies and carbon emission reduction programmes in North America and Europe.

Prof. Nadovan Vadovič is a faculty member of Economics and a director of Carleton's experimental economics laboratory (CELBER). Prof. Vadovic is an experimental and behavioral economist with broad interests, including studying the shape and formation of beliefs in strategic interactions, examining the behavioral foundations of choice, and exploring the various aspects of legitimacy and social validation.

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