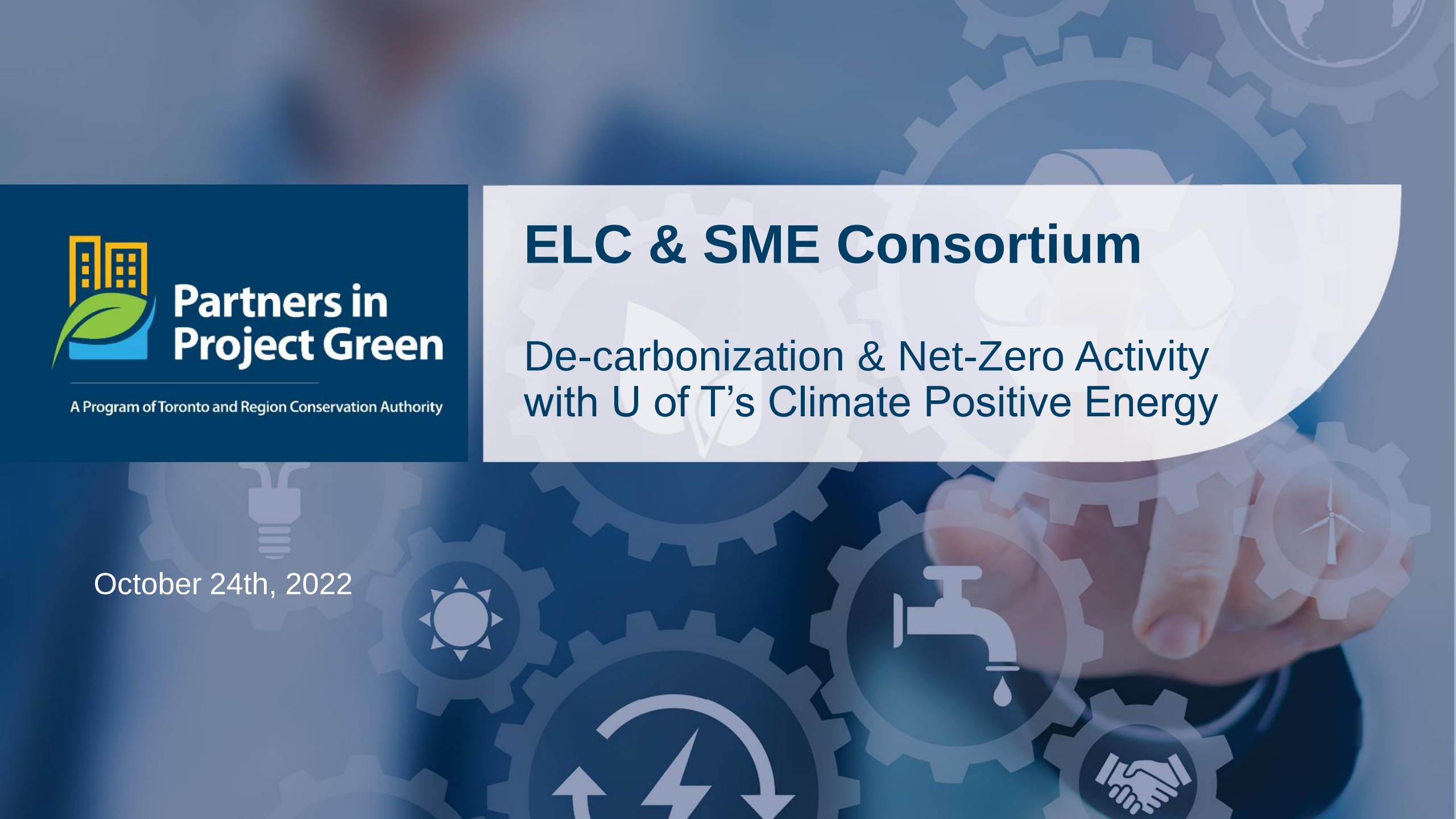
Partners in Project Green

A Program of Toronto and Region Conservation Authority

ELC & SME Consortium

De-carbonization & Net-Zero Activity with U of T's Climate Positive Energy

October 24th, 2022



We respectfully acknowledge that we are situated on the Traditional Territories and Treaty Lands, in particular those of the Mississaugas of the Credit First Nation, as well as the Anishinaabe of the Williams Treaty First Nations, the Huron Wendat, the Haudenosaunee, and the Metis Nation.

As stewards of land and water resources within the Greater Toronto Region, Toronto and Region Conservation Authority appreciates and respects the history and diversity of the land and is grateful to have the opportunity to work and meet on this territory.

Additional Resources

- yrnature.ca/acknowledging_land
- edgeofthebush.ca
- native-land.ca
- Text 1-855-917-5263 with your City and Province to learn whose traditional territory you're on
(standard text messaging rates may apply)

Agenda

Time	Activity	Speakers
1:00-1:10pm	Opening Remarks	Michael Fagan, CPE
1:10-1:30pm	Presentation: Decarbonization & Net-Zero Activity	U of T Sustainability
2:00-2:10pm	Break	
2:10-2:20pm	Remarks from PPG	Matt Brunette, PPG
2:20-2:40pm	Presentation: Grids, Micogrids, and the Energy Transition	Dr. Hooshyar, U of T
2:40-3:00pm	Presentation: Transforming Engineering Education	Dr. Moore, U of T
3:00-3:15pm	Break	
3:15-3:35pm	Presentation: Building Energy Management	Dr. Lee, U of T
3:35-3:55pm	Presentation: Closing the Carbon Cycle	Dr. Edwards, U of T
3:55-4:00pm	Closing Remarks	Michael Fagan, CPE
4:00-5:00pm	Networking	

Introduction

Upcoming ELC Sessions

Date	Topic
November 16 @ 1pm	***Energy Manager Support Services with Goldfin*** *(Virtual)*
December 1 @ 1pm	*Member Roundtable (In-Person/ Virtual)*

**Please contact Matt Brunette if you are interested in hosting an ELC Site Visits this year or next year

Resiliency and Regeneration:
The Next Stage in Business Sustainability

Register today: https://partnersinprojectgreen.com/partners-in-project-green-fall-forum/

Updates and Reminders

- ELC member reporting coming soon!
  - Start collecting consumption metrics related to your energy, natural gas, and water use
  - Consumption metrics must be related to projects or upgrades that were made in 2022
  - Matt will send a tracking form in November 2022 so that you can enter and submit the information for PPG
  - Tracking project metrics on an annual basis helps us celebrate our impact as a consortium of energy leaders!

Updates and Reminders

- ELC member reporting coming soon!

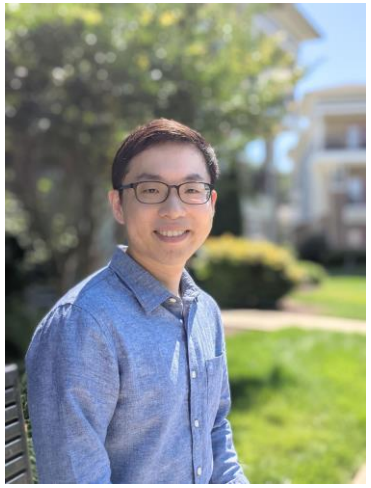
Energy Conservation Measure Description	Utility	Annual Consumption Savings		Monetary Savings ($)
			kWh	
			m3	
			L	
			kW	

Updates and Reminders

Attention Food & Beverage Members: Bioenterprise Canada is now accepting new applications on rolling basis for FoodShift Program ($50K in non-repayable, project-based, matching funding for cleantech projects).

On-farm Maple Syrup Processor	Purchase and installation of a high-brix reverse osmosis (RO) system. RO is a process that removes water from a solution producing a concentrated solution and clean water. This process saves a large amount of energy as the water would otherwise be removed by boiling. **Project Budget: $106,000**
On-farm Egg processor	Purchase and installation of a high-volume egg sorting equipment to lower emissions, which allows this company to lower its energy consumption from motors, conveyors and forklifts; lower water usage from washdowns; and lower food waste due to a more consistent grading system. **Project Budget: $130,000**
Consumer Packaged Goods Food Processor	Purchase and installation of rooftop solar panels and energy storage system. **Project Budget: $1M**
Consumer Packaged Goods Food Processor	Retrofit of freezer floors by repurposing the heat generated from the refrigeration compressors to heat glycol that is circulated below the freezer floor. This eliminates the use of natural gas to heat the boiler. **Project Budget: $100,000**

Today’s Speakers



Seungjae Lee,

Assistant Professor

Building Energy Management

Emily Moore,

Professor

Transforming Engineering Education

Ali Hooshyar,

Professor

Grids, Microgrids, and the Energy Transition

Jonathan Edwards,

PhD

Closing the Carbon Cycle

Presentations

U of T Sustainability Office Presentation

Beyond Carbon Neutral – Our Path to Climate Positive

Partners in Project Green – Presentation & Tour

UNIVERSITY OF TORONTO | CLIMATE POSITIVE ENERGY

Ron Saporta

Chief Operating Officer

cpe.utoronto.ca

LAND ACKNOWLEDGEMENT

We wish to acknowledge this land on which the University of Toronto operates. For thousands of years it has been the traditional land of the Huron-Wendat, the Seneca, and the Mississaugas of the Credit. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.

UNIVERSITY OF TORONTO

CLIMATE POSITIVE CAMPUS

ST. GEORGE CAMPUS
CARBON AND ENERGY
MASTER PLAN

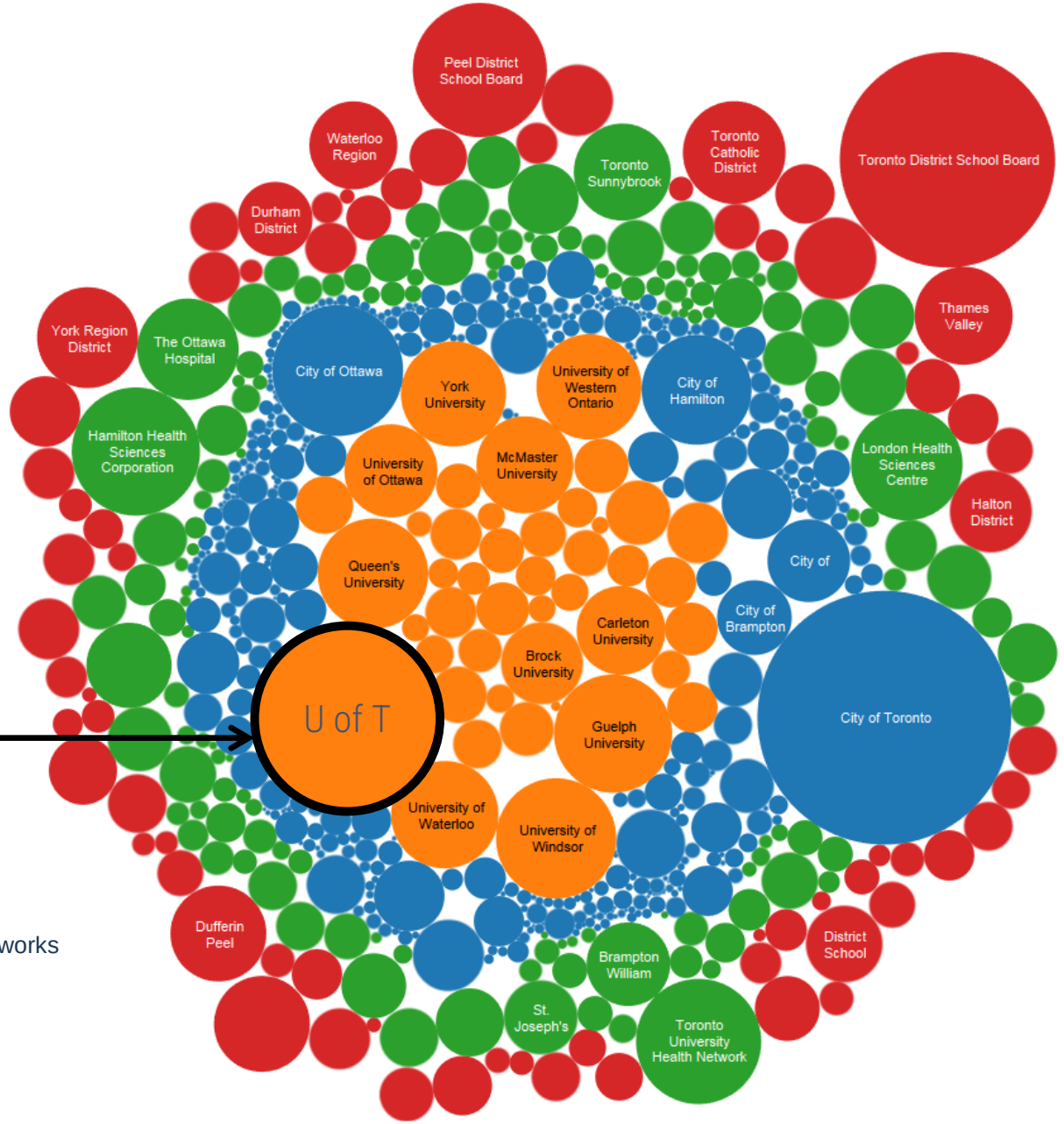
UNIVERSITY OF TORONTO


THE UNIVERSITY OF TORONTO ST. GEORGE CAMPUS
WILL BECOME CLIMATE POSITIVE BY 2050.
UNIVERSITY OF
TORONTO

HOW U OF T'S GREENHOUSE GAS FOOTPRINT COMPARES

- U of T is the 3rd largest greenhouse gas emitter among institutions within Ontario's broader public sector:

  1. City of Toronto
  2. Toronto District School Board
  3. University of Toronto



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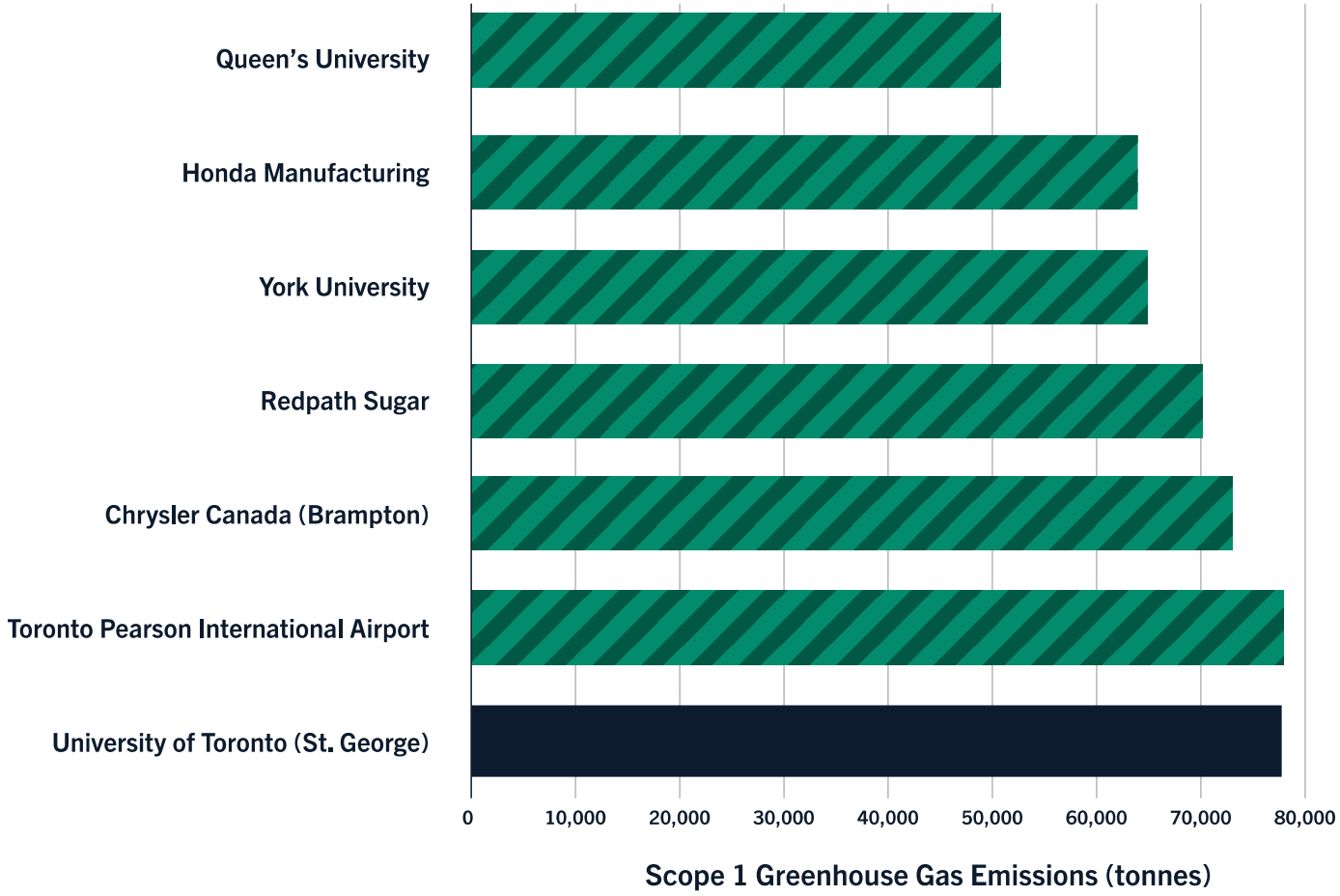
HOW U OF T'S GREENHOUSE GAS FOOTPRINT COMPARES

- The St. George campus produces more greenhouse gas emissions than any other Ontario university and the entire provincial colleges sector
- While we are efficient, we still have a significant footprint - comparable to many local auto manufacturing plants and other significant industry players



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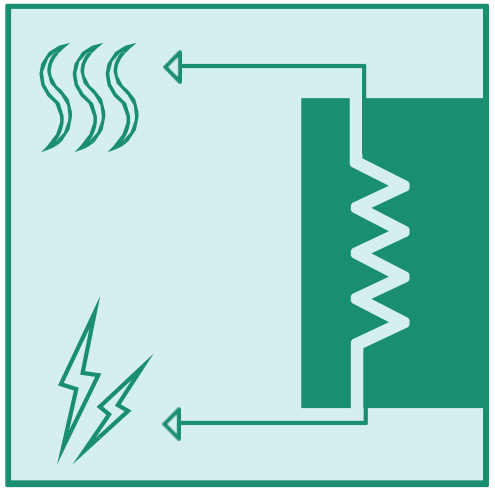
WE WILL OPTIMIZE HOW WE PRODUCE, DISTRIBUTE, AND CONSUME ELECTRICITY AND NATURAL GAS

PRODUCE

Clean Energy & Carbon Capture

DISTRIBUTE



Efficient Distribution

CONSUME

Reduced Consumption

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PRINCIPLE 1:
FOCUS ON REDUCTION

Our strategy's primary focus should be **reduction** of the energy we consume.

*The cleanest and cheapest energy is the energy we **do not** consume*

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PRINCIPLE 2:
BALANCE CARBON WITH COST

We could address our carbon issue by switching to electricity because **electricity is ~5x cleaner than gas**

however,

electricity costs are **~10x more expensive** on an equivalent energy basis.

	Commodity Rate ($ / ekWh)	GHG Emissions (kg / ekWh)
Natural Gas	$0.015	0.1776 kg (n/a)
Electricity	$0.158	0.0370 kg

Note: 2022-2023 data

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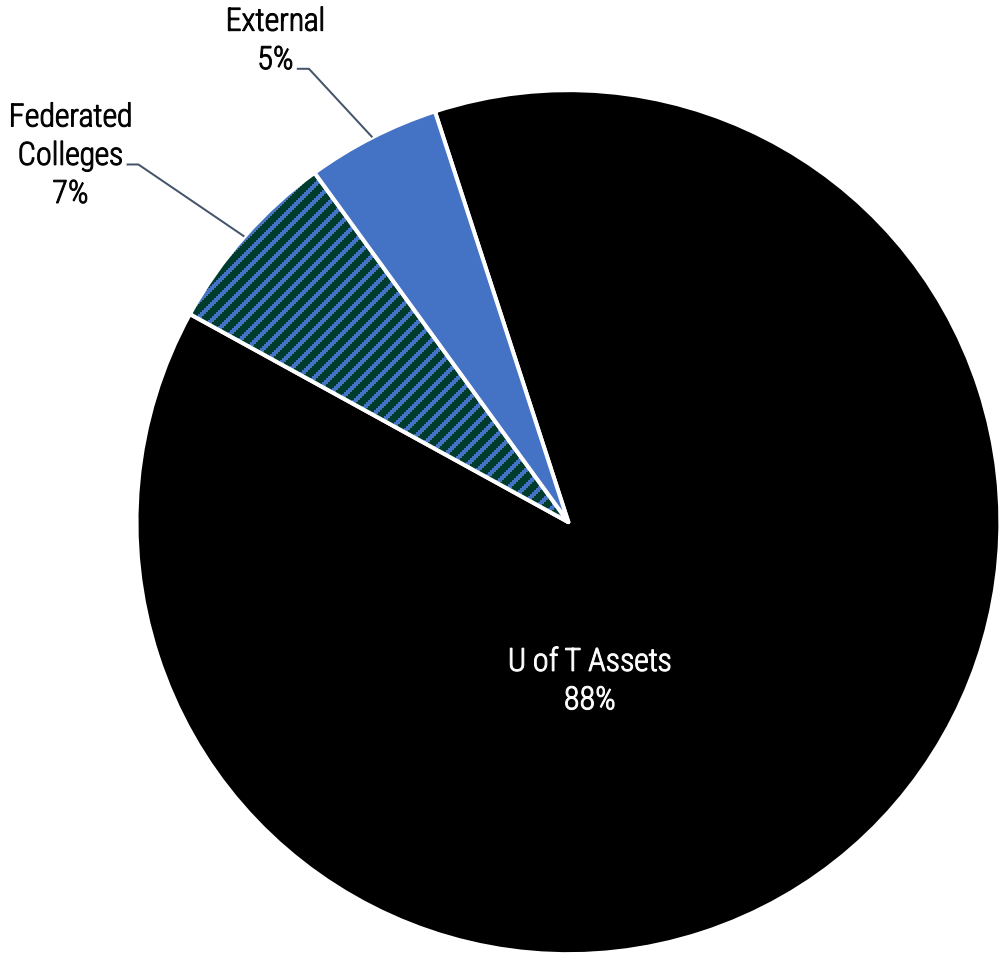
PRINCIPLE 3:
REACH BEYOND OUR OWN ASSETS

On the St. George campus, approximately **12%** of our emissions come from assets we do not directly own or influence.

Our carbon plan must incorporate reductions of these emissions.

We can partner with these organizations to reduce emissions

St. George Greenhouse Gas Emissions



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PRINCIPLE 4:
FOSTERING INNOVATIVE SOLUTIONS

Leverage the campus as a living lab model to foster partnerships with our academic community to achieve carbon reductions

Develop external partnerships to implement innovative solutions to our carbon challenges

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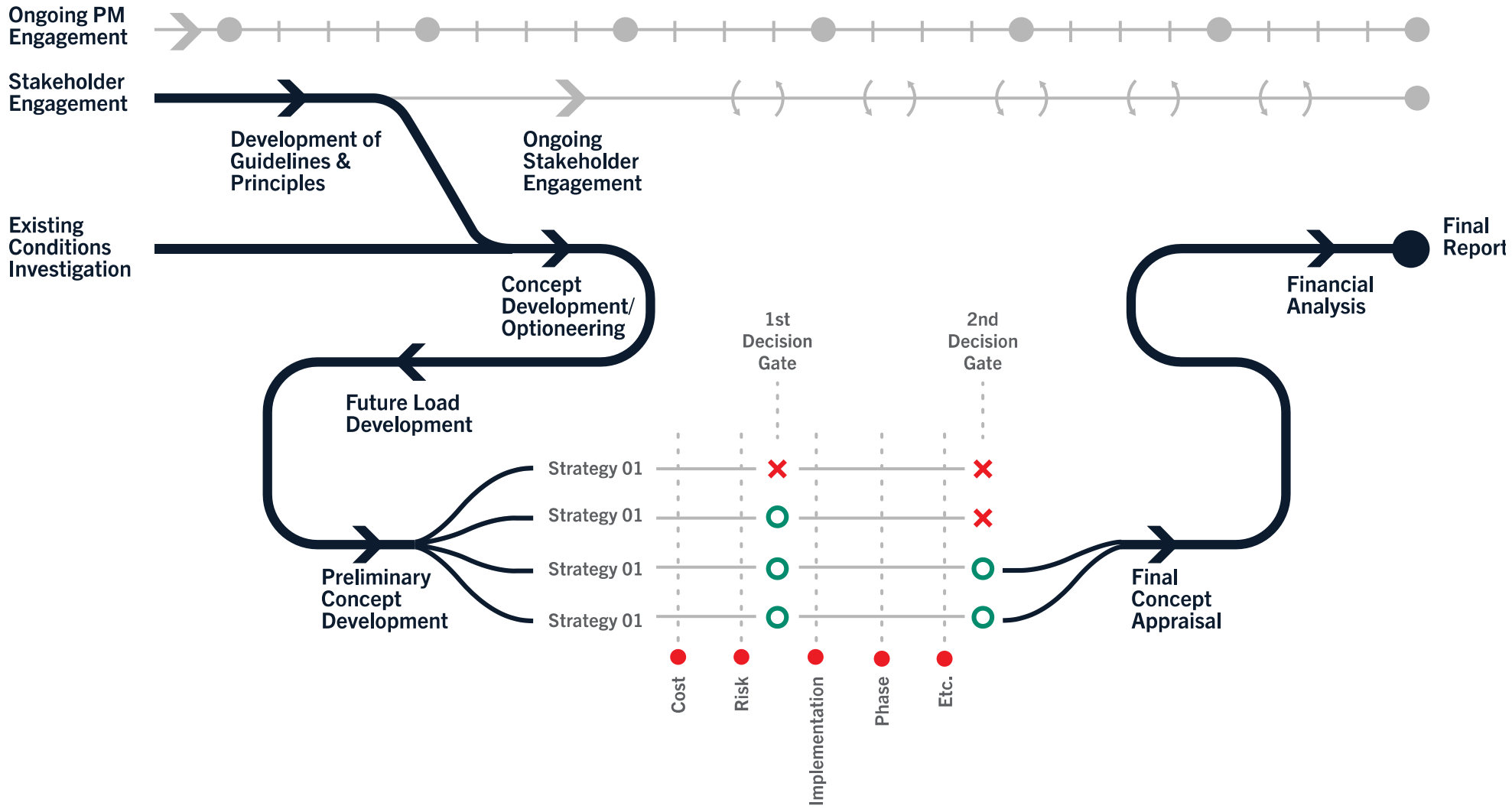
CLIMATE POSITIVE ENERGY

Climate Positive Campus

Developing the Plan

DEVELOPING OUR PLAN



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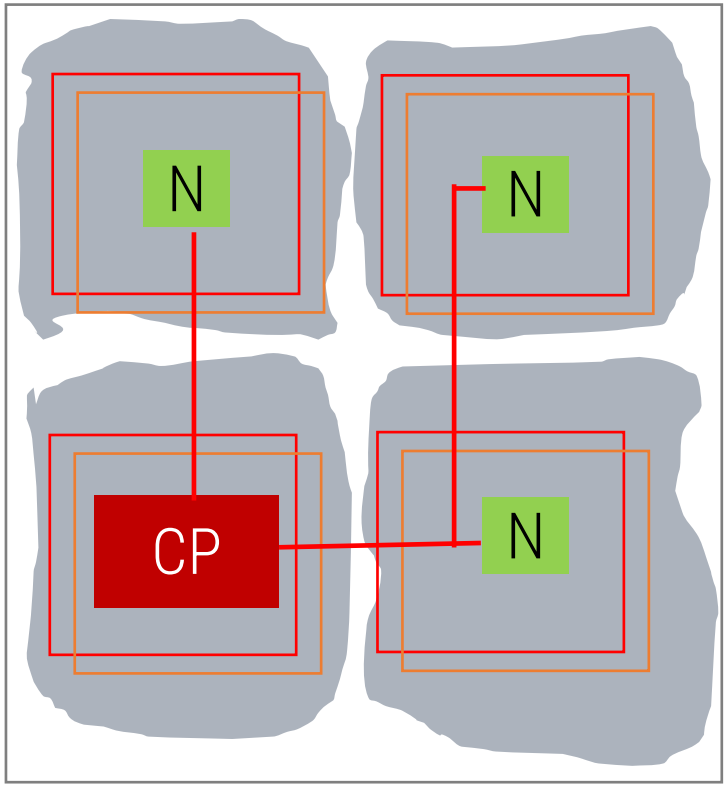
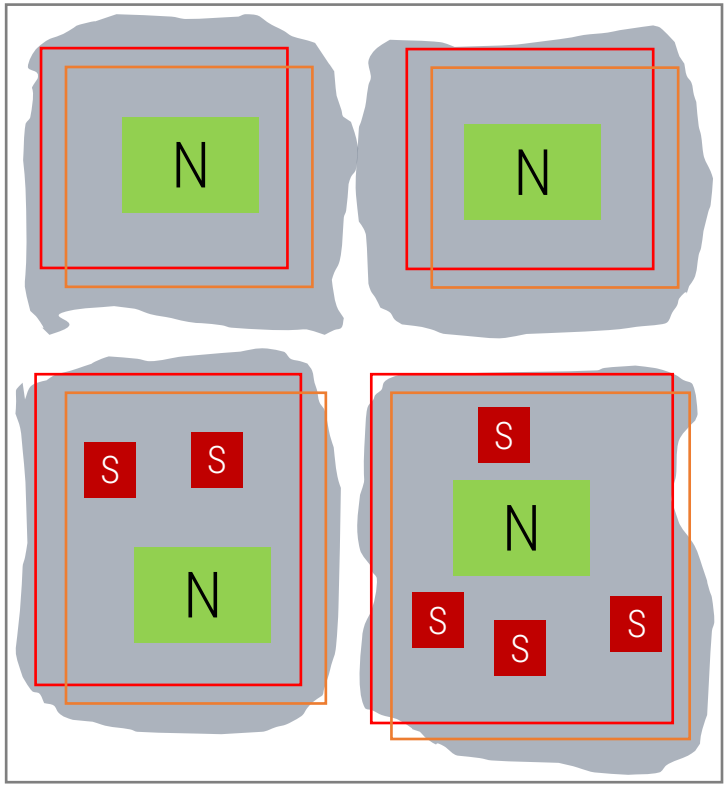
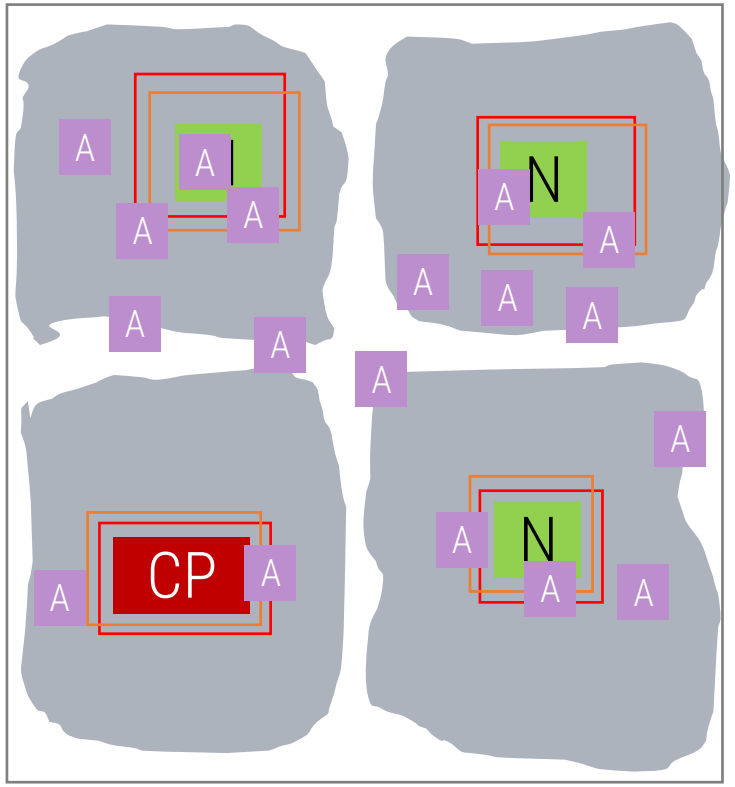
TOP 3 STRATEGIES: OVERVIEW



Alt. 1
Central Generation



Alt. 2
Nodal Generation



Alt. 3
Local Generation

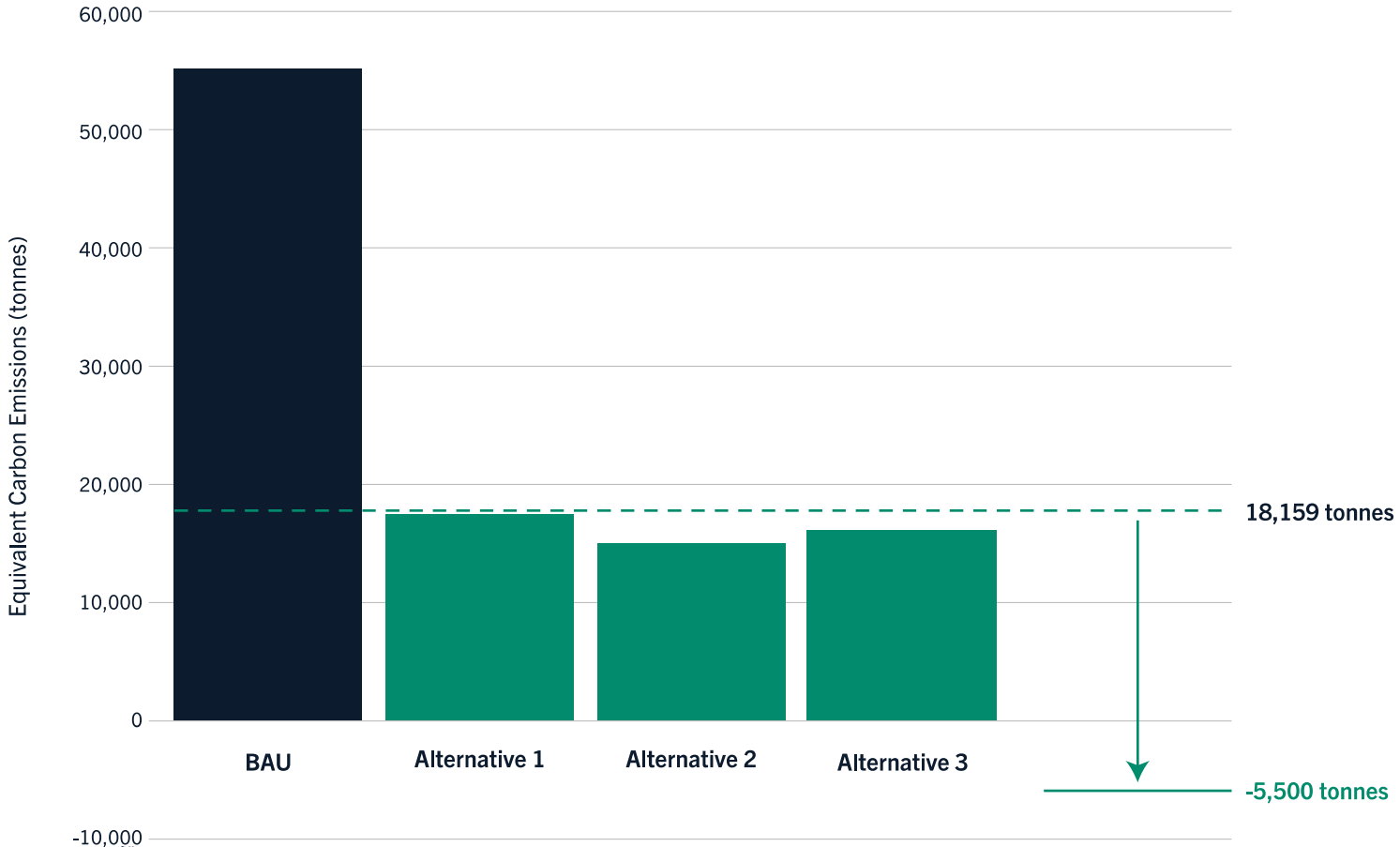
CP Central Steam/Hot Water Plant

N Nodal Plant

S Local Steam Boiler

A Local Air-Source Heat Pump

EQUIVALENT CARBON EMISSIONS - 2050



Emissions offset from a large-scale, University-owned solar farm

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EVALUATION MATRIX

Category	Weight	Criteria	Alternative 1	Alternative 2	Alternative 3
Environmental	30%	Decarbonization, efficiency, environmental impact	18	21	15
Resiliency	**15%**	Flexibility, and future proofing, space	12	9	9
Operational	**20%**	Digitization, operation, compatibility	18	14	15
Social	**5%**	Human impact , campus, culture	3	3	3
Economic	**30%**	Capital, O&M, Risk	19	15	15
		TOTAL	69	62	56

Multi-divisional steering committee, consisting of faculty and administrative leadership evaluated the alternatives

Note: Weighted score are shown as rounded numbers

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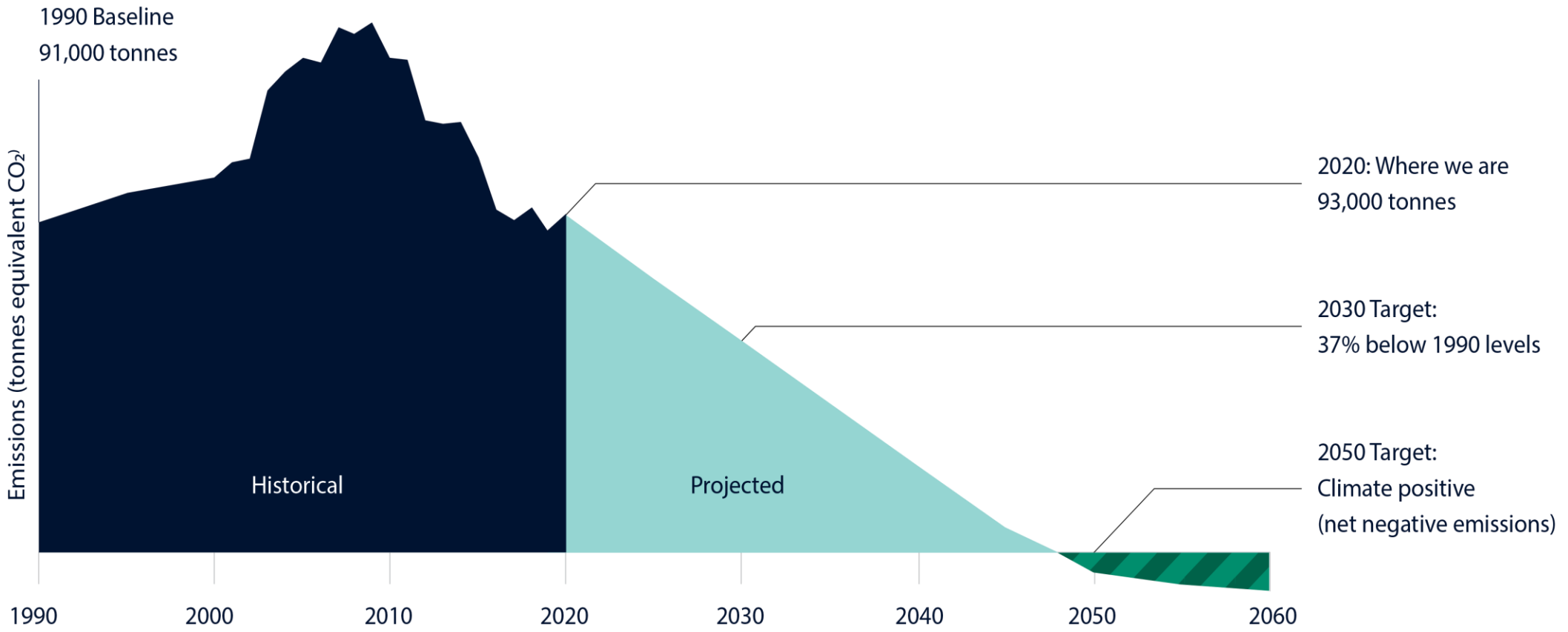
2050 CLIMATE POSITIVE TARGET
ST. GEORGE CAMPUS



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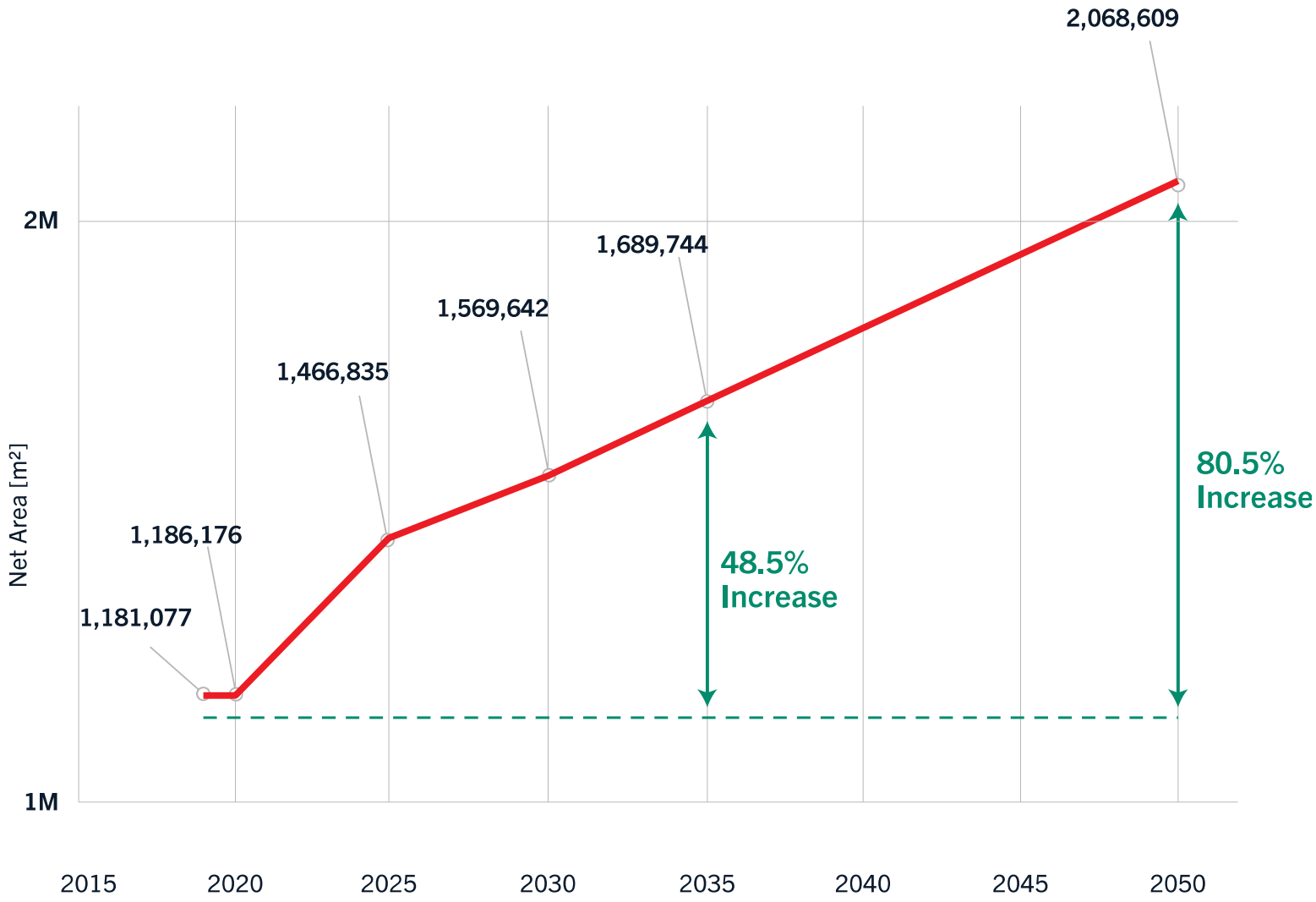
OUR CAMPUS WILL NEARLY DOUBLE IN SIZE BY 2050

Current and Planned Developments



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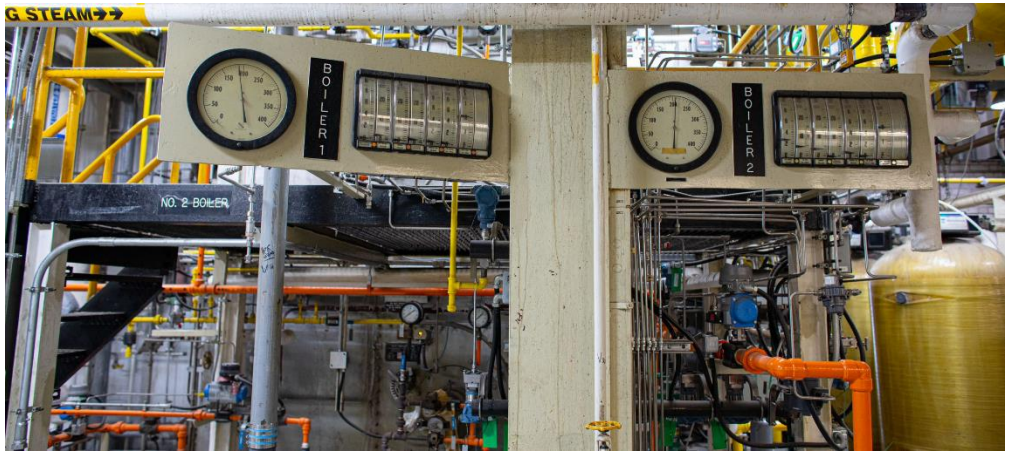
WE HAVE AGING INFRASTRUCTURE

Including a 120-year-old district energy system



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OUR GOALS

1. Responsibly manage the growth of our campus to mitigate the environmental impacts of more space and activity

2. Renew existing and aged utility infrastructure to ensure future performance that supports academic and research excellence

3. Build resilient systems to support our carbon reduction targets with reliable infrastructure by changing how our campus produces, distributes, and consumes energy.

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WE WILL RESPONSIBLY MANAGE OUR GROWTH

Implement carbon and energy budgets for new buildings

Extend our district energy system to all new buildings

Increase use of renewable energy, including a large off-campus solar farm

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WE WILL RENEW OUR INFRASTRUCTURE

Eliminate fossil fuel-based heating as a primary source

Eliminate steam distribution

Renewal and electrification of our central power plant

Significantly reduce existing building energy use through deep energy retrofits

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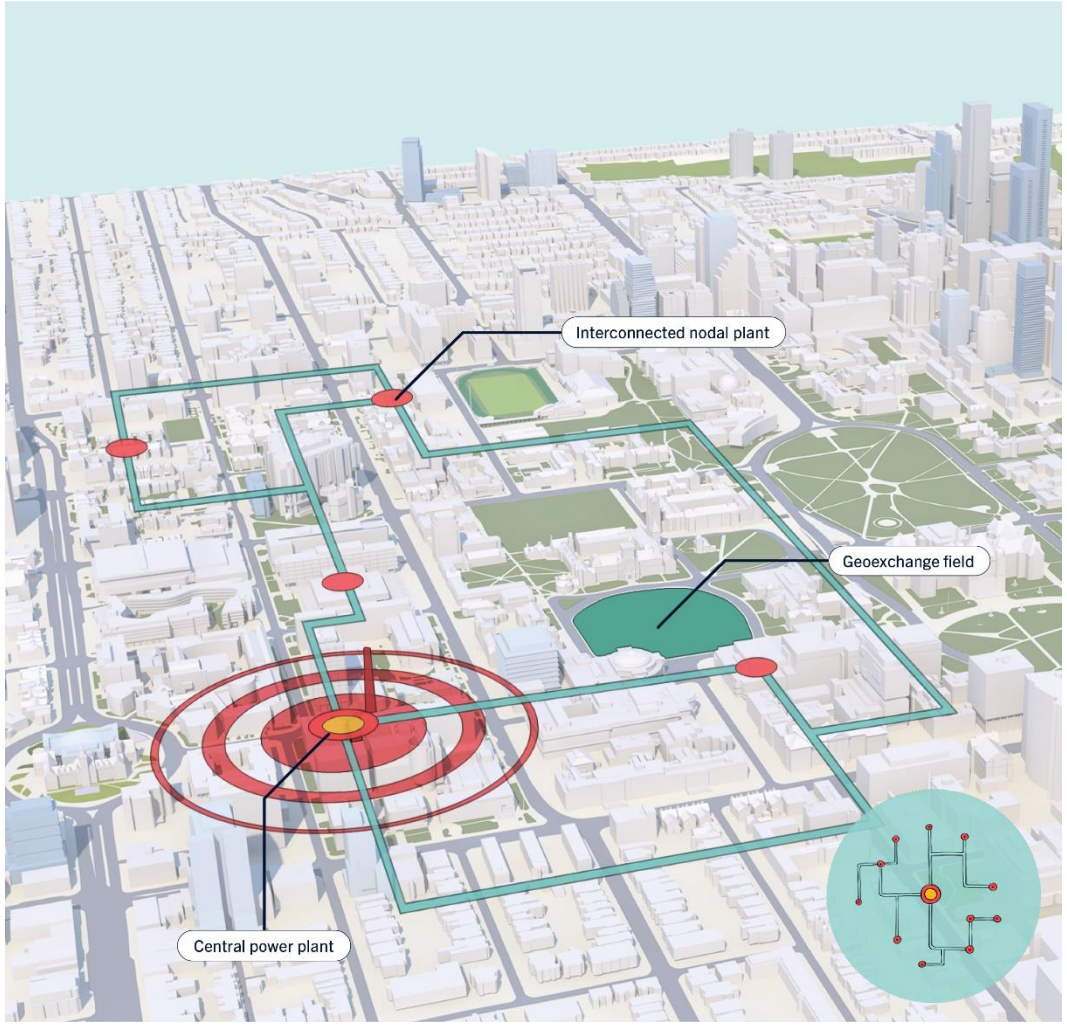
WE WILL BUILD RESILIENT SYSTEMS

Increase use of electricity to heat our campus, using technologies such as geoexchange

Create inter-connected nodal plants to increase redundancy and resiliency

Introduce new inter-connected electricity feeds to increase reliability



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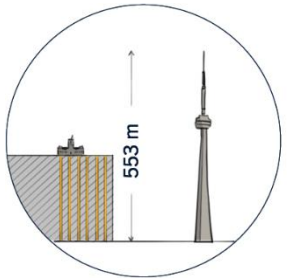
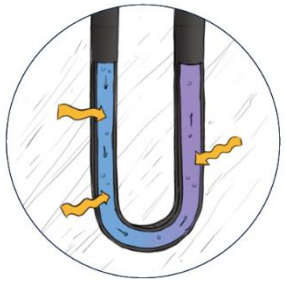
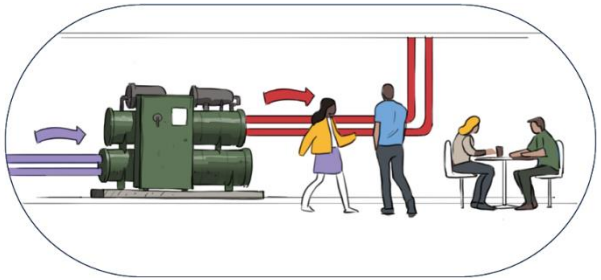
CANADA'S LARGEST URBAN GEO-EXCHANGE SYSTEM







1 — Over 370 boreholes have been drilled 250 metres deep under front campus, nearly half the height of the CN Tower.

2 – U-shaped pipes are inserted into each borehole. Water is circulated through this system, taking excess heat from buildings in the summer and storing it underground for use in the winter.

3 – Heat pumps circulate the water, transferring heat to or from the University's building ventilation systems. This installation will feature an underground display and serve as an applied learning classroom to showcase how the system works for visitors and students.

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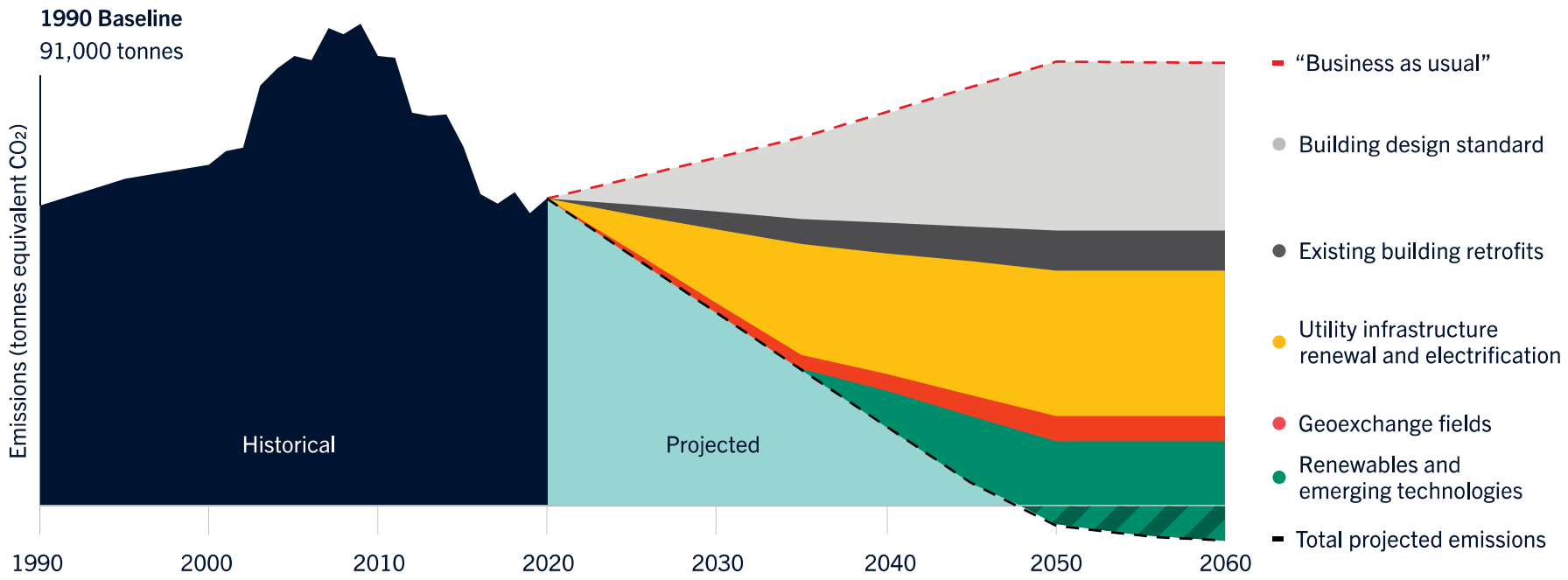
2050 CLIMATE POSITIVE TARGET
ST. GEORGE CAMPUS



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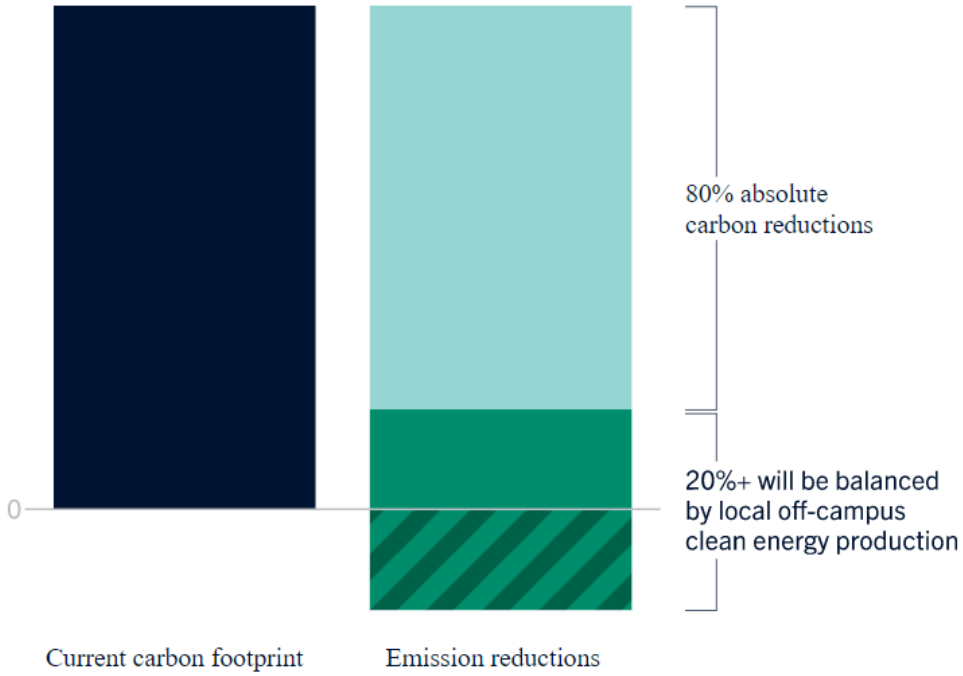
LEVERAGING OFFSITE GENERATION

By leveraging offsite generation, UofT would be able to offset the remaining +20% of carbon emissions

UofT has an opportunity at several sites across southern Ontario to install larger scale Solar installations to meet this need

Virtual Net Metering with our main accounts on the St George campus help to ensure that the projects are financially feasible



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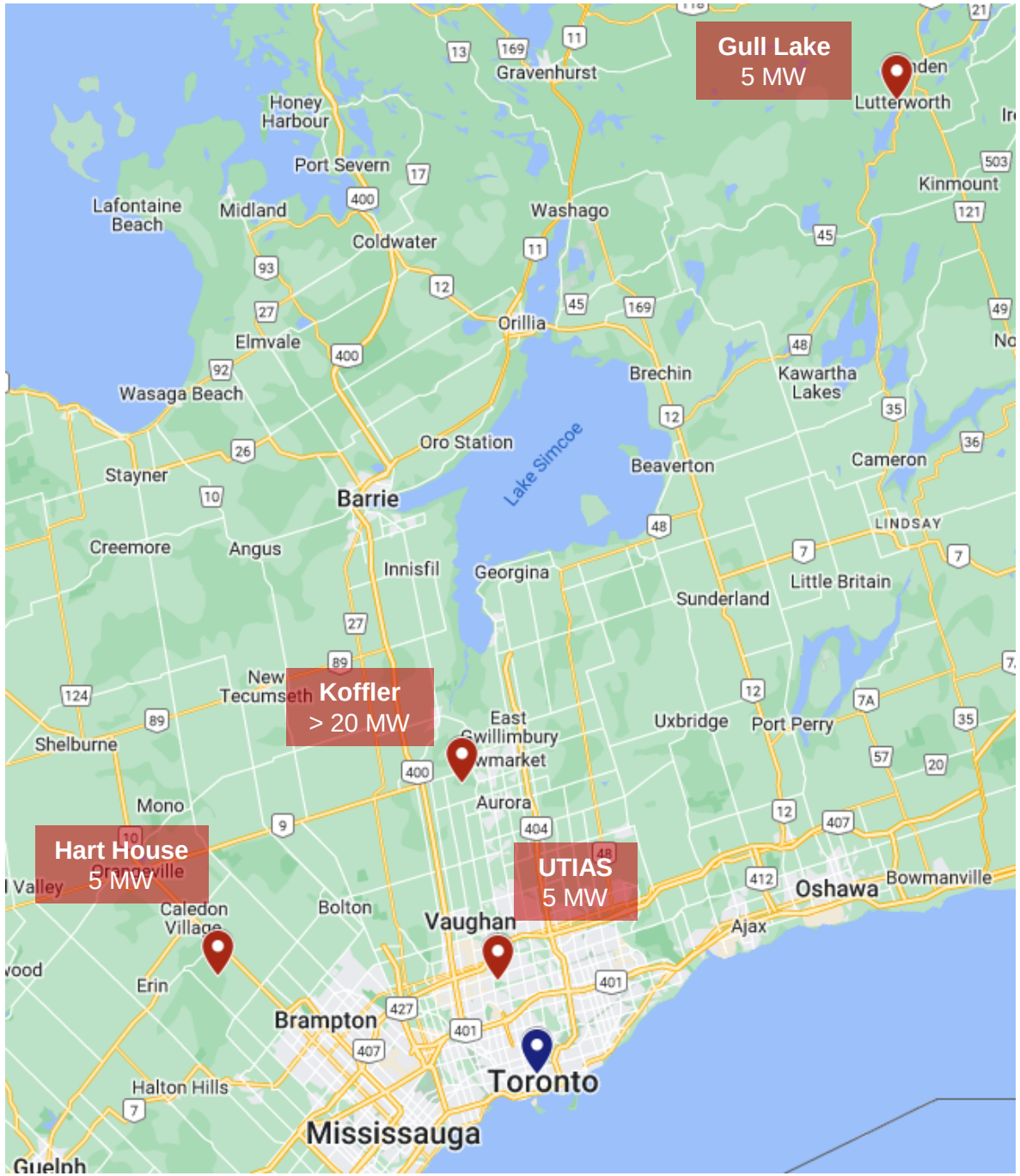
POTENTIAL LOCATIONS



CLIMATE POSITIVE ENERGY

Climate Positive Campus

Project LEAP: The first (BIG) step in our plan

ONE PROJECT THAT ADDRESSES 50% OF OUR EMISSIONS

PROJECT LEAP - HIGHLIGHTS

Project highlights:

- Reduction of emissions by over 50%, or 46,000 metric tonnes
- Introduces electric boilers to start transition away from fossil fuels
- Utility and demand reduction strategies
- Savings from reduced carbon taxes
- Significant mitigation of deferred maintenance risk

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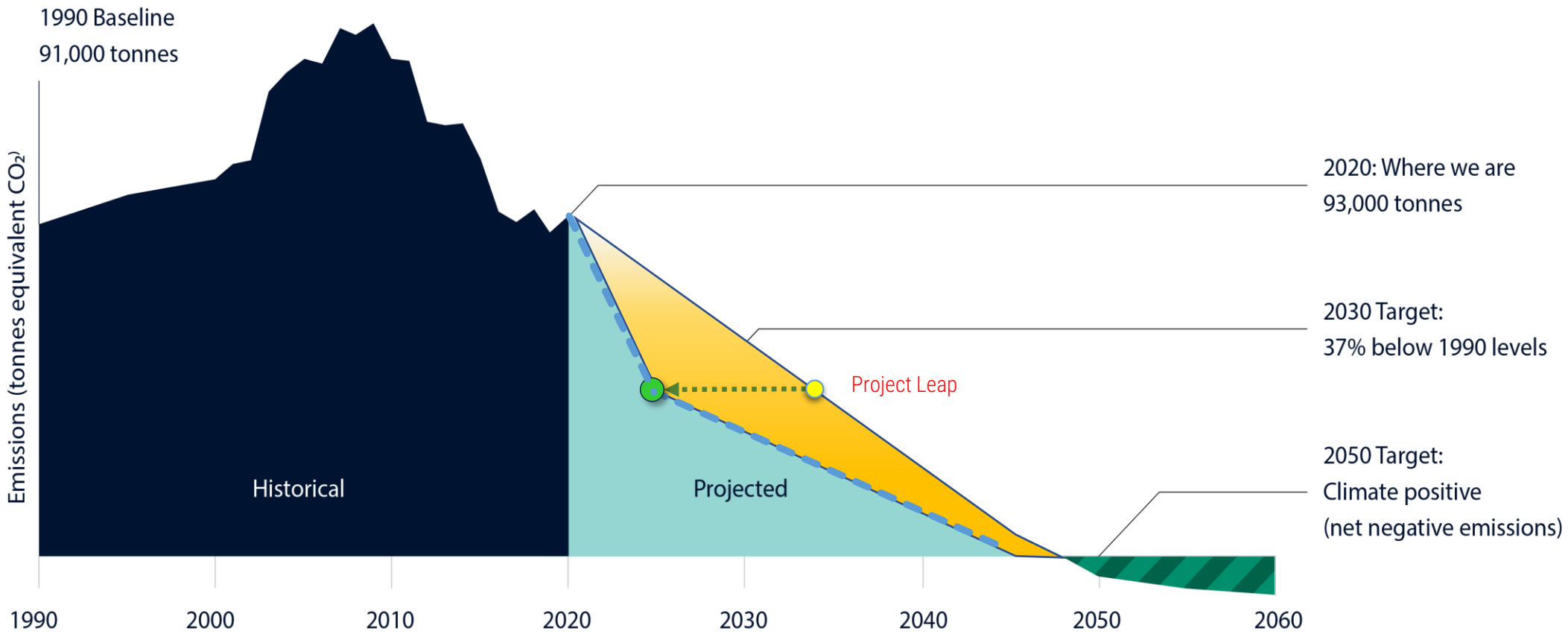
ONE PROJECT THAT ADDRESSES 50% OF OUR EMISSIONS

PROJECT LEAP



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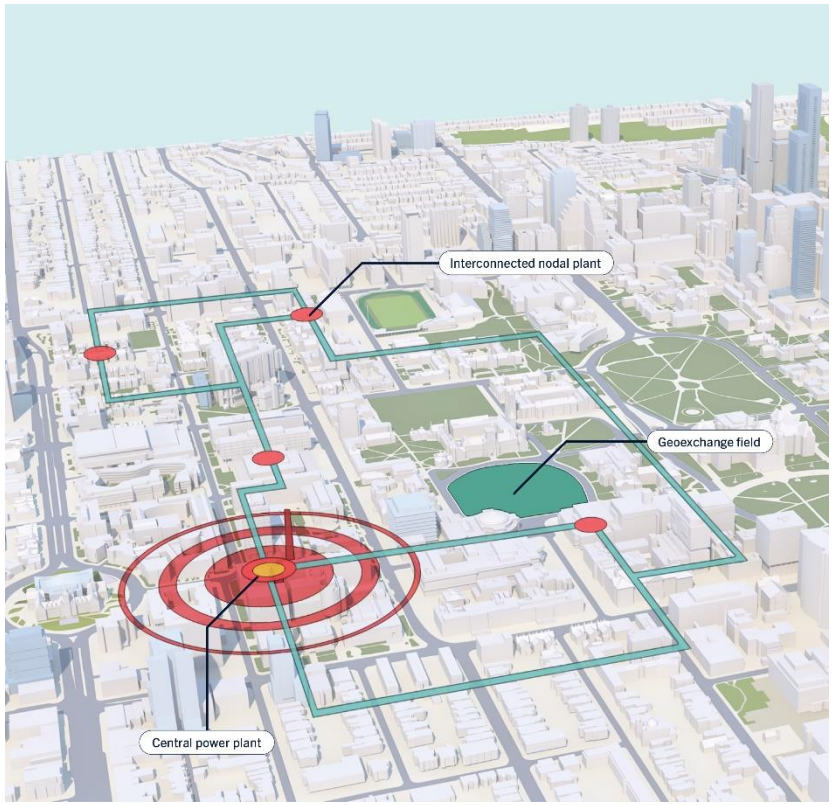
ONE PROJECT THAT ADDRESSES 50% OF OUR EMISSIONS

PROJECT LEAP – SUMMARY

District Energy



Partial electrification of the central heating plant

- Added resiliency and fuel diversity
- Battery energy storage
- Address deferred maintenance on existing boilers

Address deferred maintenance at main chilled water plants

- Addition of thermal storage for resilience and load shifting
- Replacement of a chiller in each plant

Demonstration / Innovation

- Carbon capture and conversion to ethylene
- Various demand response technologies

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PROJECT LEAP – SUMMARY

Building Retrofits

Demand reduction with active heat recovery
and demand control ventilation

Deep retro-commissioning of building control systems

LED lighting control systems

Conversion to low temperature hot water heating and humidification

Energy Storage (battery & ice) for resiliency and load shifting

Targeting > 40% EUI reduction

ONE PROJECT THAT ADDRESSES 50% OF OUR EMISSIONS

PROJECT LEAP – SUMMARY

Low Carbon Node

Demand reduction with active heat recovery

Disconnect from 3rd party steam

LED lighting retrofit

Conversion to low temperature hot water heating and humidification

Energy storage (battery & ice) for resiliency and load shifting

Renewable energy
- Solar PV
- CO2 air source heat pump

Targeting > 35% EUI reduction

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PROJECT LEAP - FINANCIALS

Feasibility study completed with independent 3rd party costing and technical peer reviewed

Deferred maintenance funding can support a portion of the project

Exploring the use of the Low Carbon Economy Challenge

Avoided carbon tax savings will be leveraged for project loan payments

Several funding avenues have been explored..

ONE PROJECT THAT ADDRESSES 50% OF OUR EMISSIONS

PROJECT LEAP - CIB PARTNERSHIP

CIB BIC | Canada Infrastructure Bank

GREEN INFRASTRUCTURE
Jul 19, 2022

CIB Commits Up to $56 million for Energy Retrofits at University of Toronto

U of T News

FOLLOW U OF T NEWS

U of T partners with Canada Infrastructure Bank to boost climate positive efforts

Ehren Cory, the chief executive officer of the Canada Infrastructure Bank, speaks at an event to announce a $56-million financing partnership with U of T to complete deep energy retrofit projects on campus (photo by Johnny Guatto)

July 19, 2022

The University of Toronto will receive $56 million in financing from the Canada Infrastructure Bank

"It's driving all of us to get to that climate positive goal as fast as we can."

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Thank you.

Contact us: info@cpe.utoronto.ca

ron.saporta@utoronto.ca

scott.hendershot@utoronto.ca

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RE-ENVISIONING ENERGY SYSTEMS

Grids, Microgrids, and the Energy Transition

Ali Hooshyar

Grids, Microgrids, and the Energy Transition

Climate Positive Energy, Oct. 2022

UNIVERSITY OF TORONTO

CLIMATE POSITIVE ENERGY

Ali Hooshyar

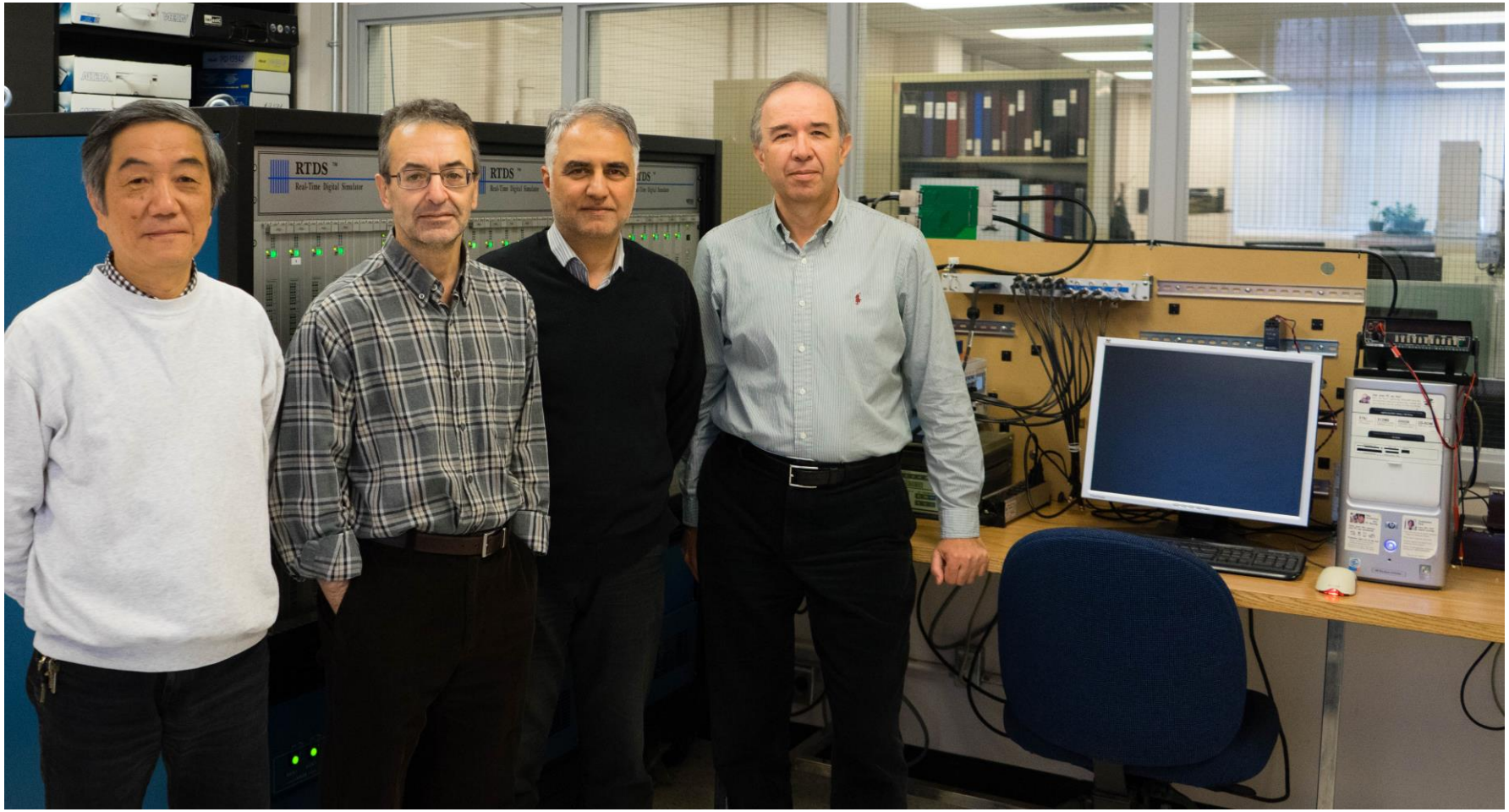
Professor

cpe.utoronto.ca

Outline

- Transformation of electric energy systems
- State-of-the-art modeling tools for energy systems
- Case study: Protection of net-zero microgrids

Centre for Applied Power Electronics



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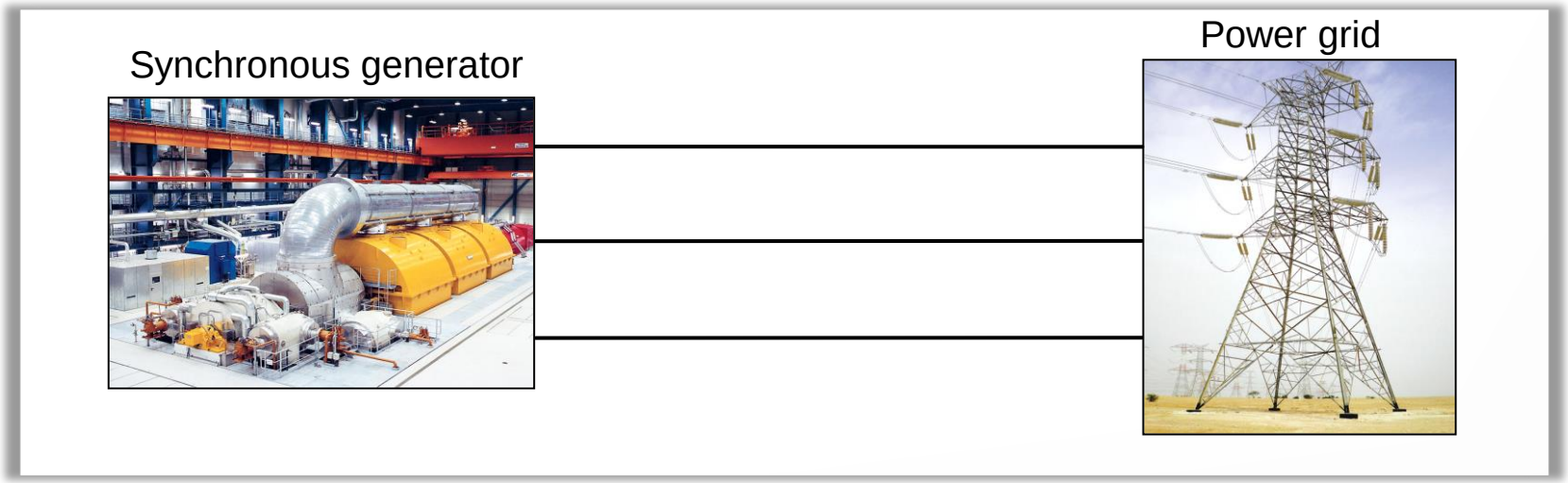
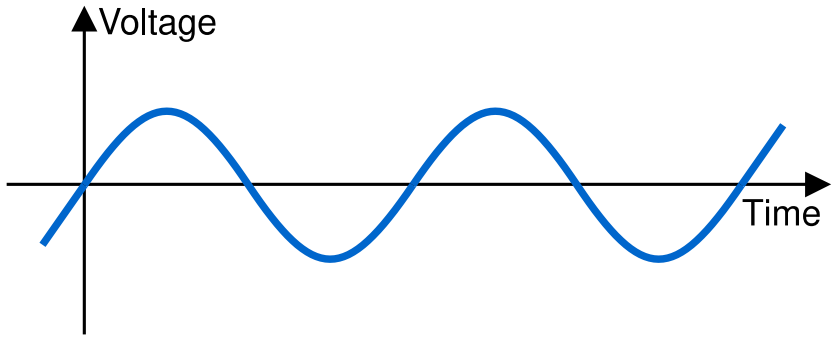
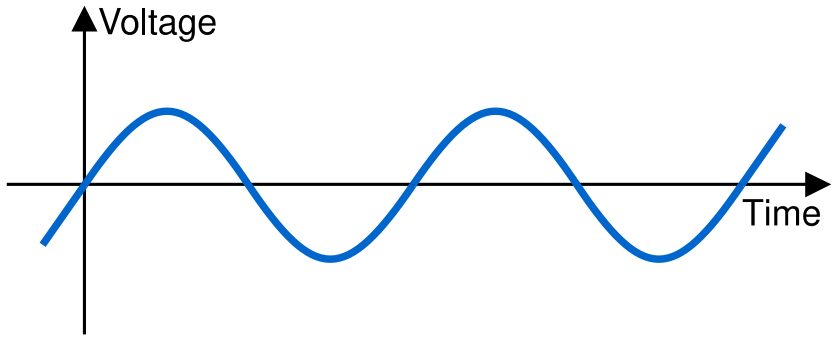
CLIMATE POSITIVE ENERGY

Transformation of Electric Energy Systems

Conventional Power Plants



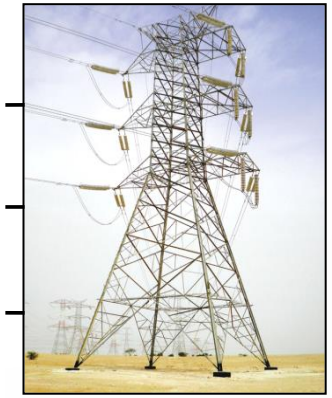


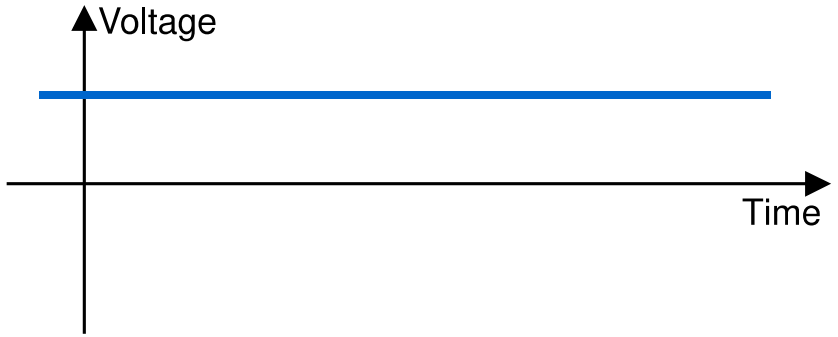


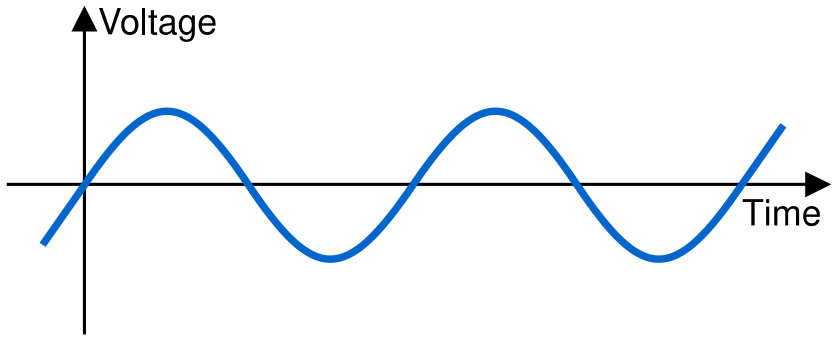
Renewable Energy Sources

Solar panel

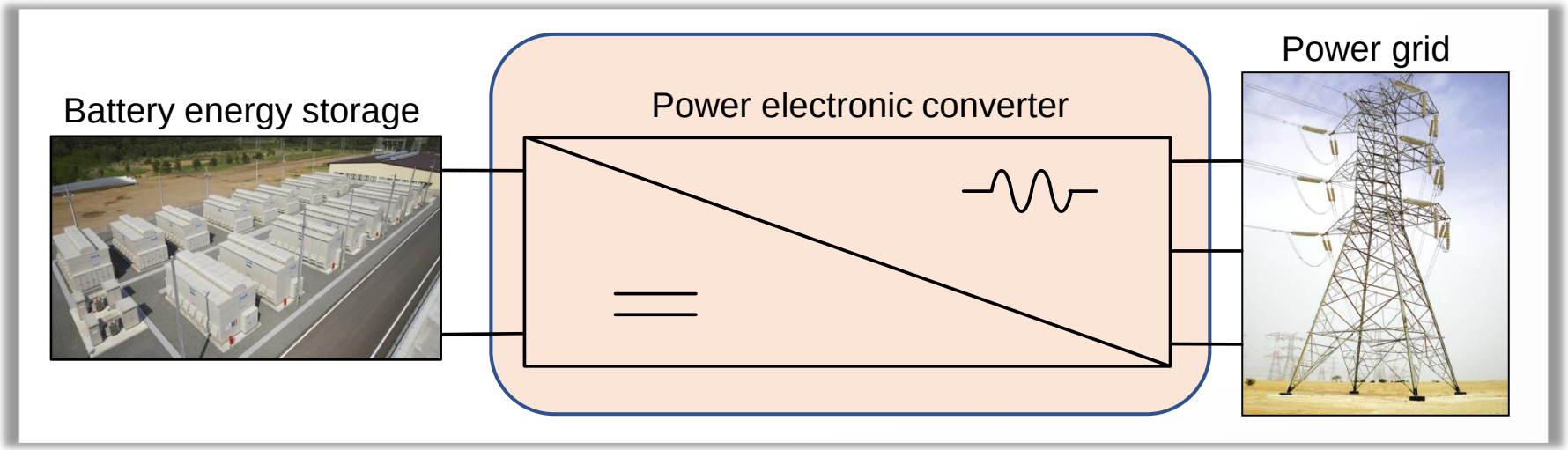
Power grid

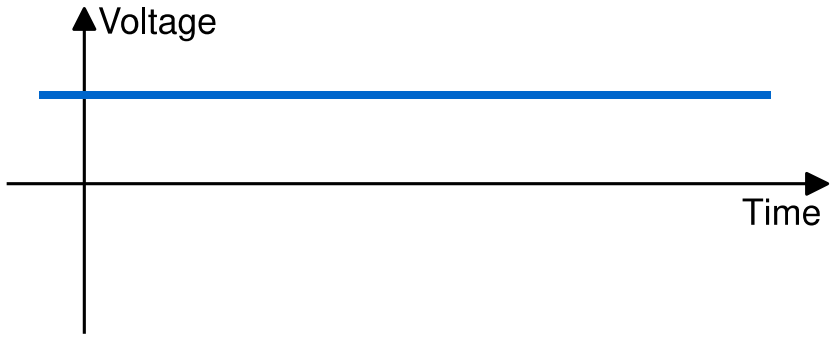


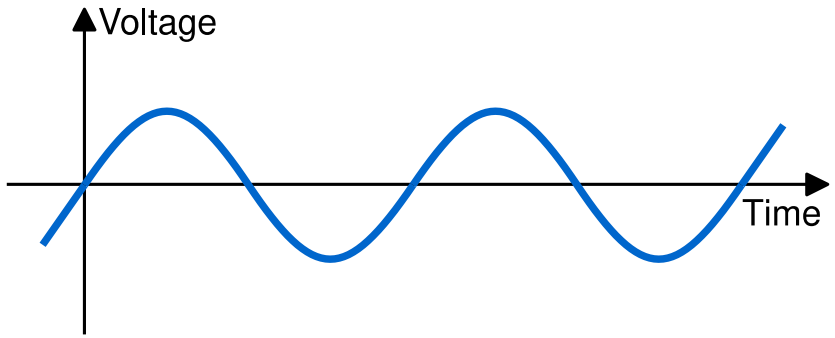




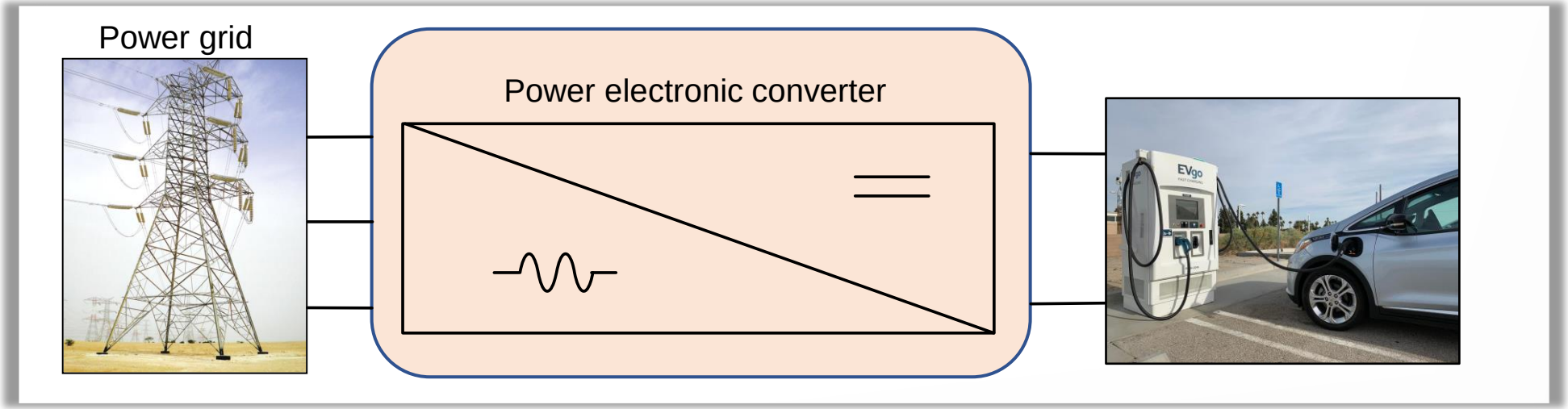
Battery Energy Storage Systems

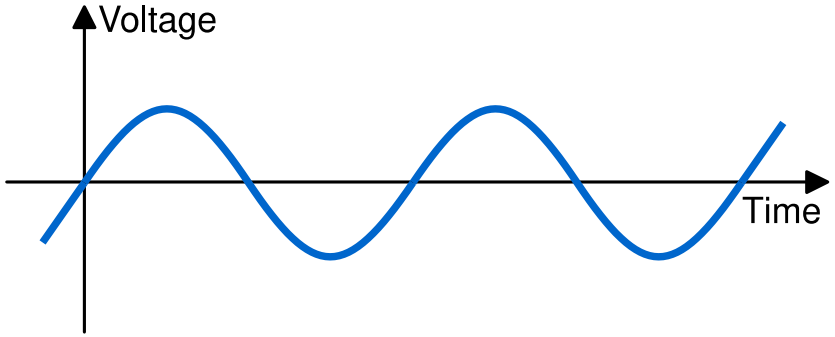




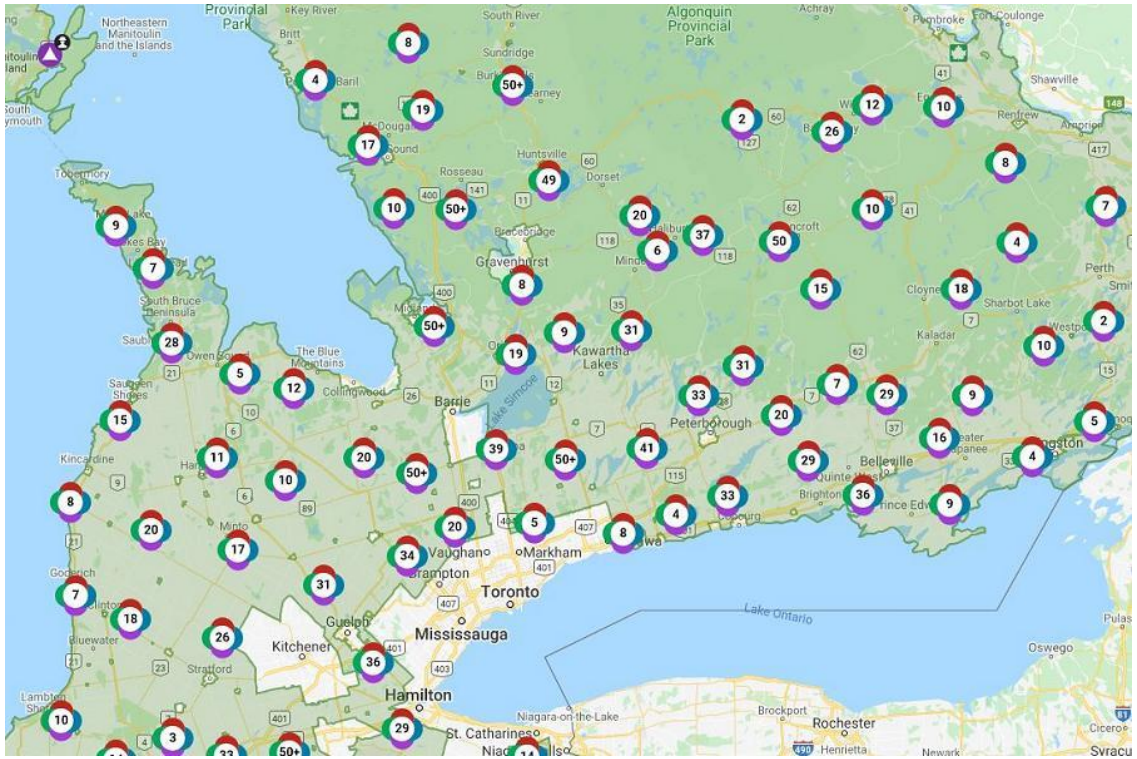


Electric Vehicles

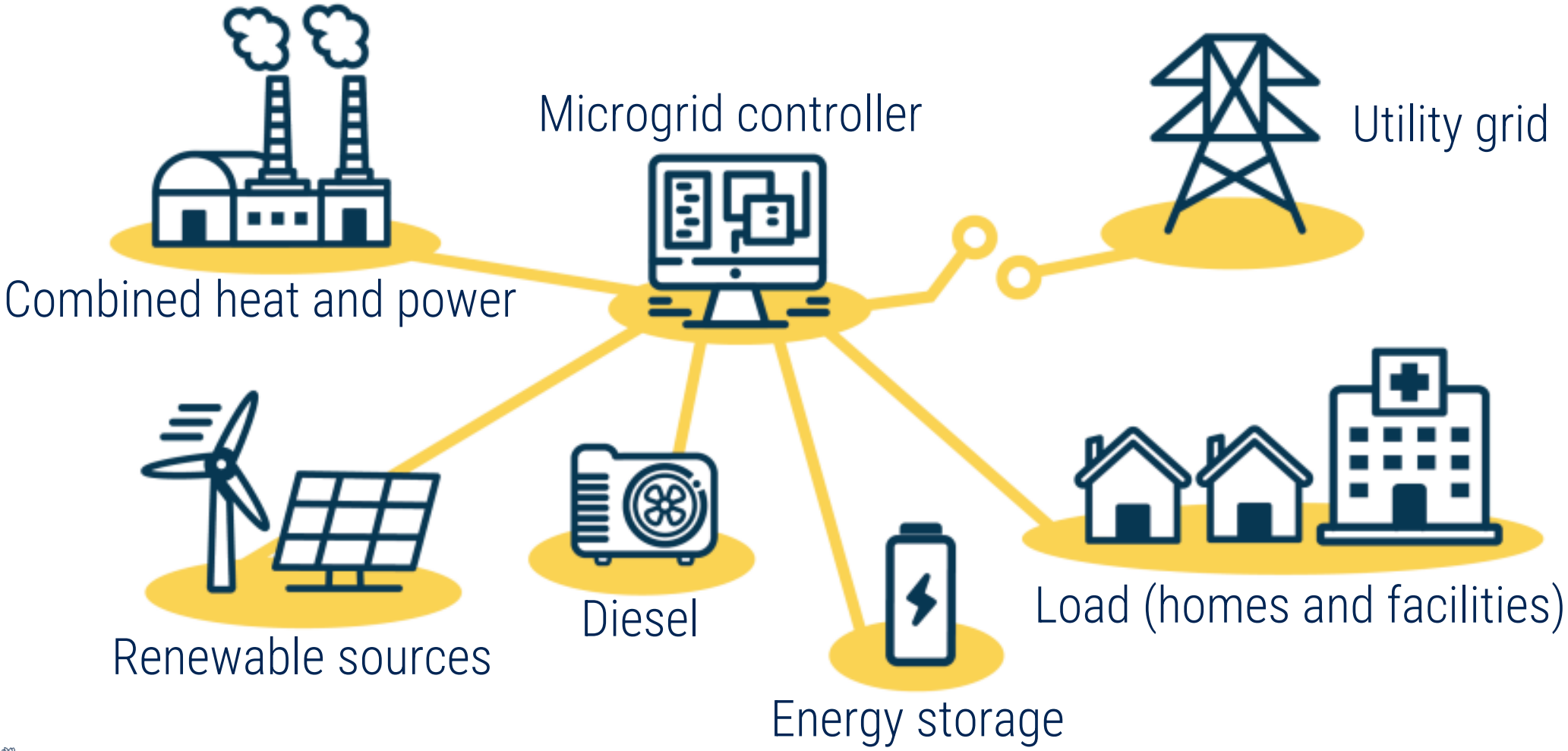




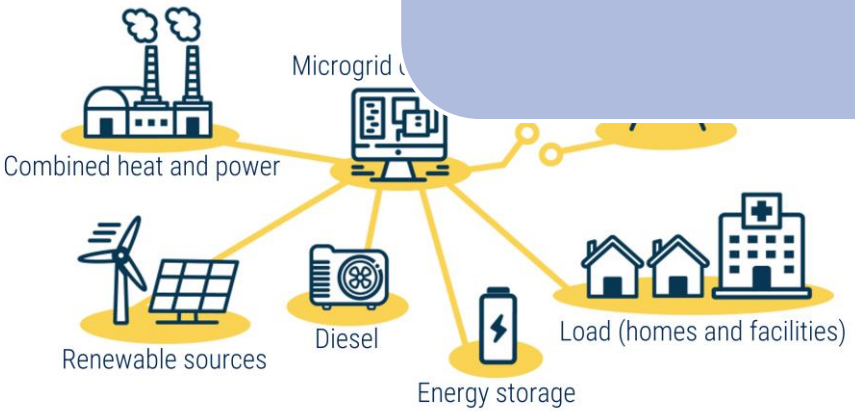
Increasing Frequency of Major Grid Disturbances



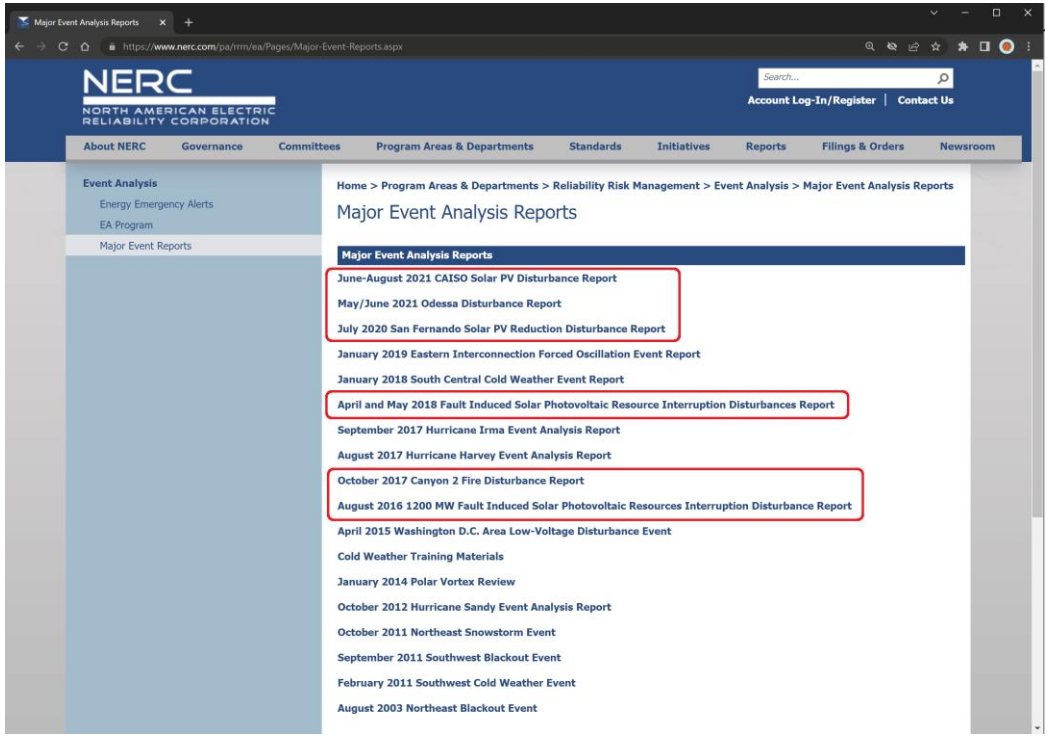
Microgrids to Improve Grid Resilience



Transformation of energy systems



Are We Ready?



Major events in the NERC system

Fire events in battery plants

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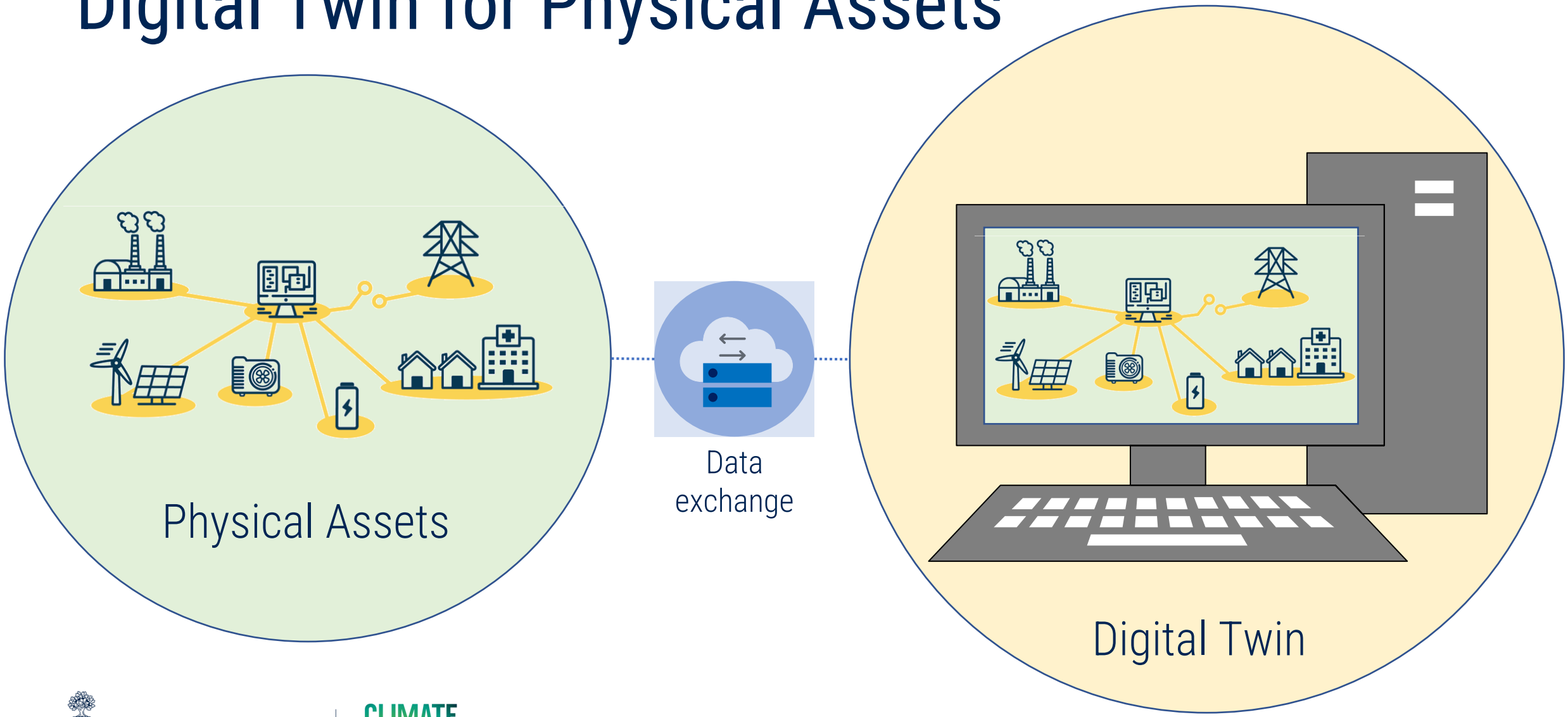
State-of-the-Art Modeling Tools for Energy Systems

Digital Twin for Physical Assets



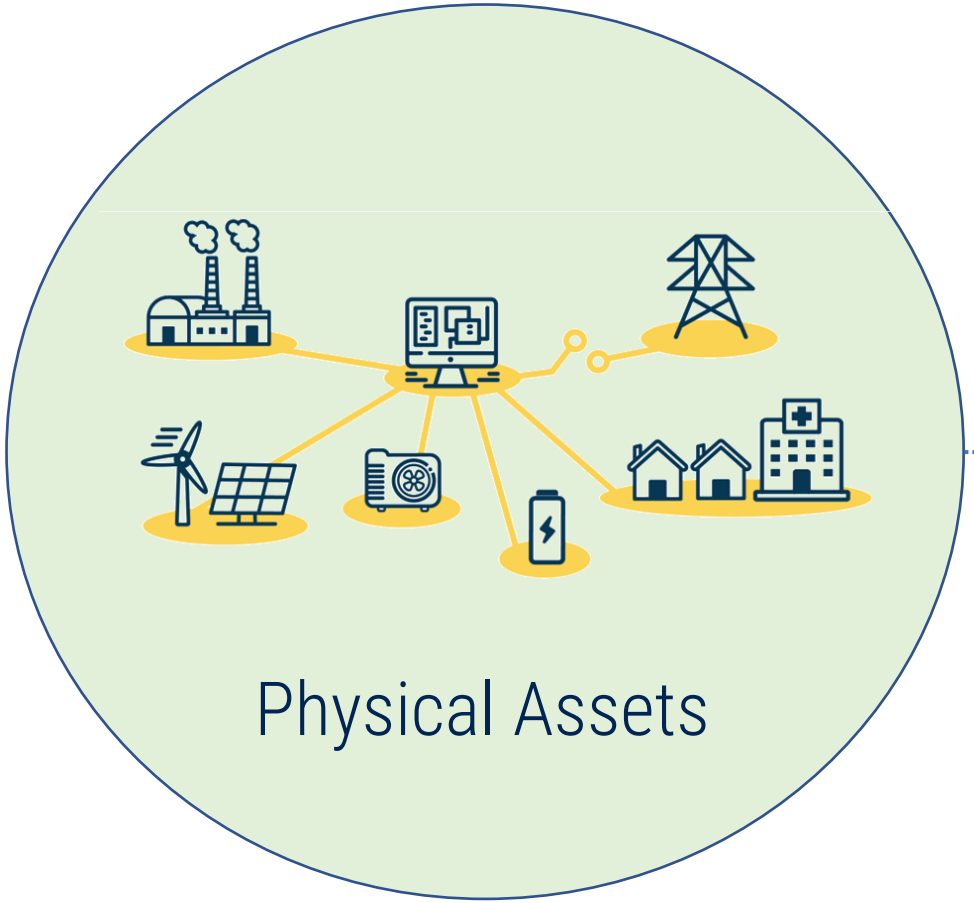
Conventional Modeling Tools

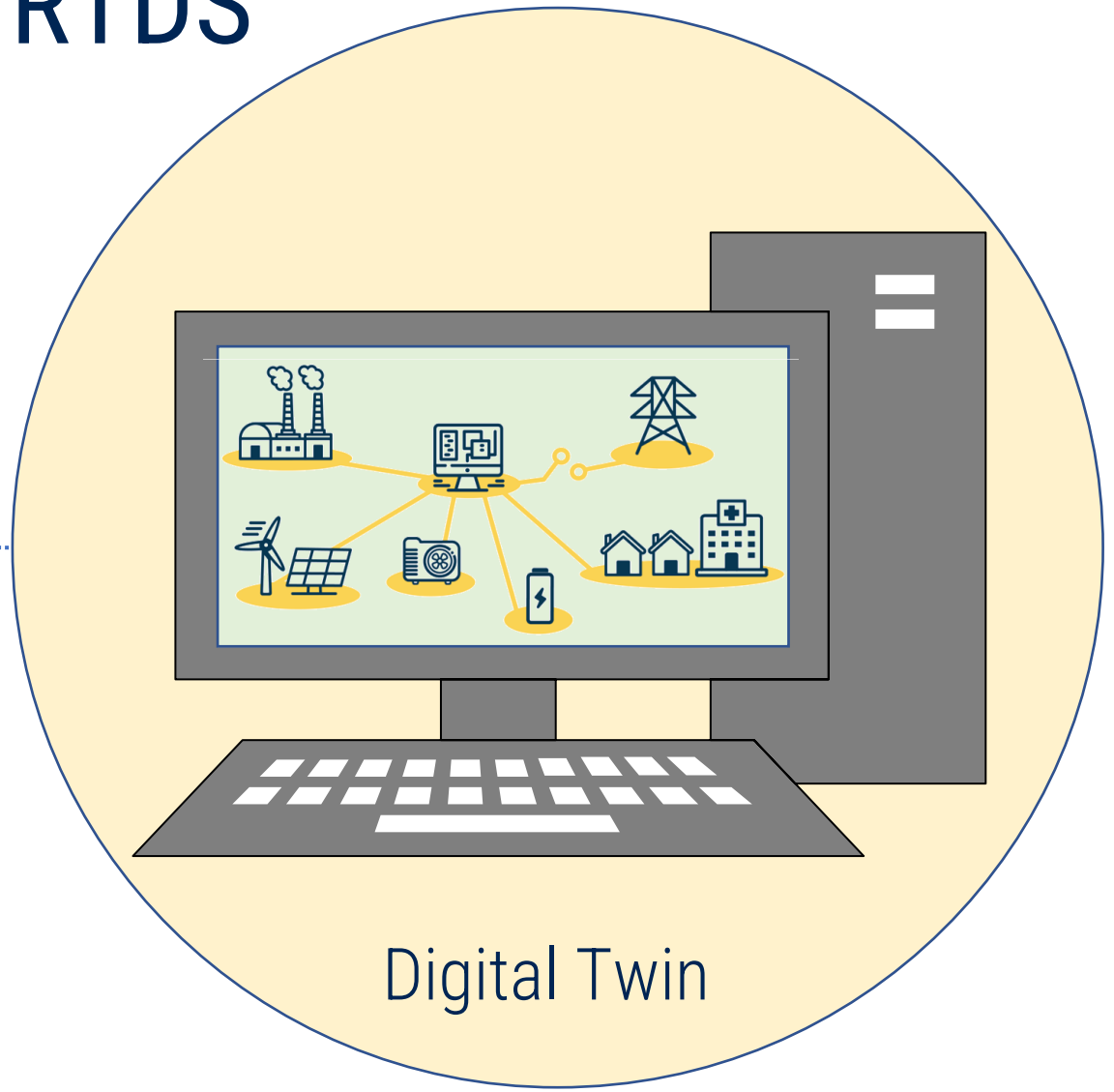
Physical Assets

A twin?!

Real-Time Digital Simulator

Real Digital Twin Given by RTDS





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Applications of RTDS-Based Digital Twins

- Reliability analysis
- Resource adequacy
- Resource utilization
- Effective asset management
- Hardware-in-the-loop analysis

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Case Study: Protection of Net-Zero Microgrids

Short-Circuit Faults

If we do nothing after a fault happens …

Protection System in a Substation

Measurements

Control room of a substation

Protective relay

Circuit Breaker

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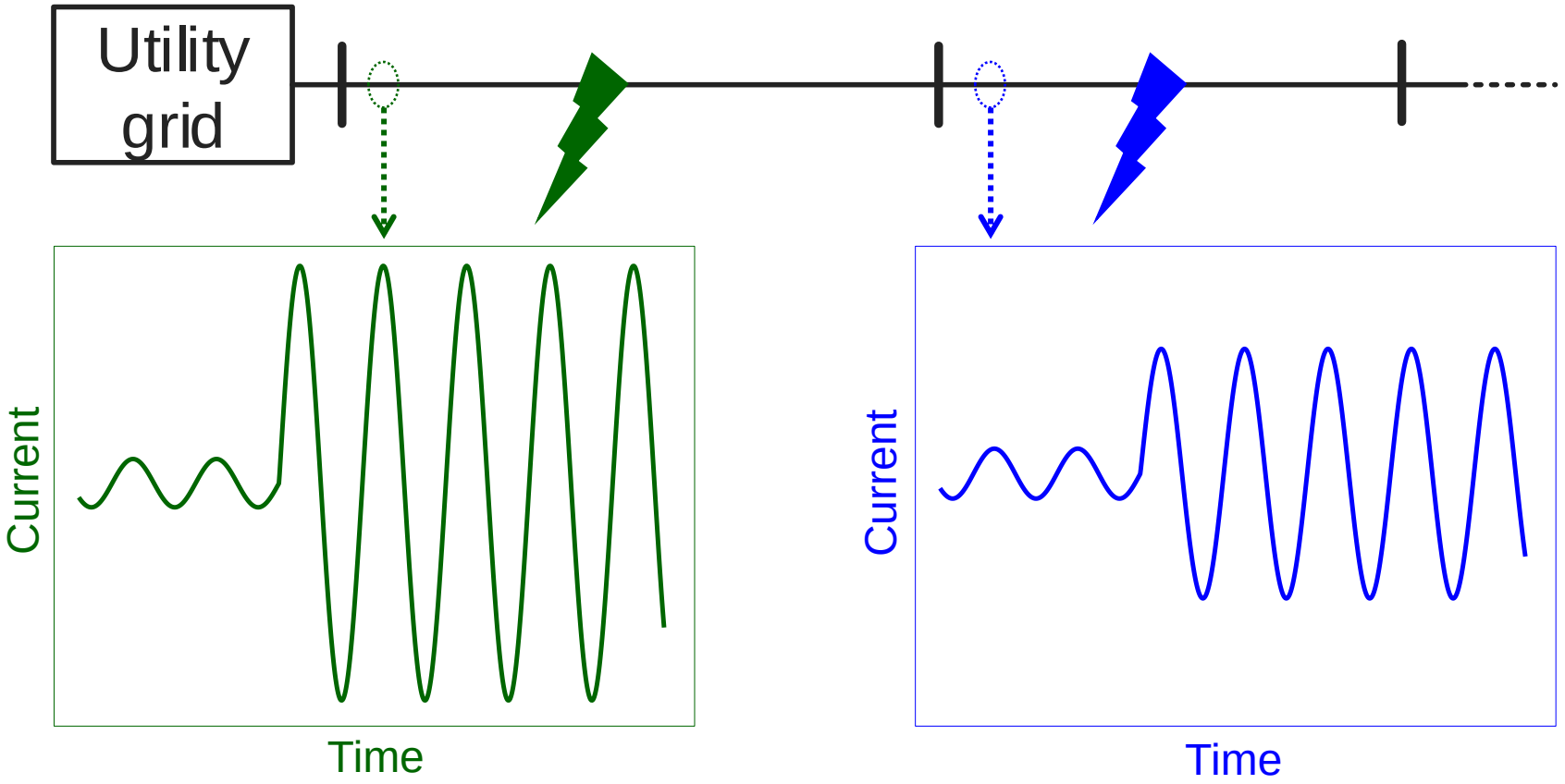
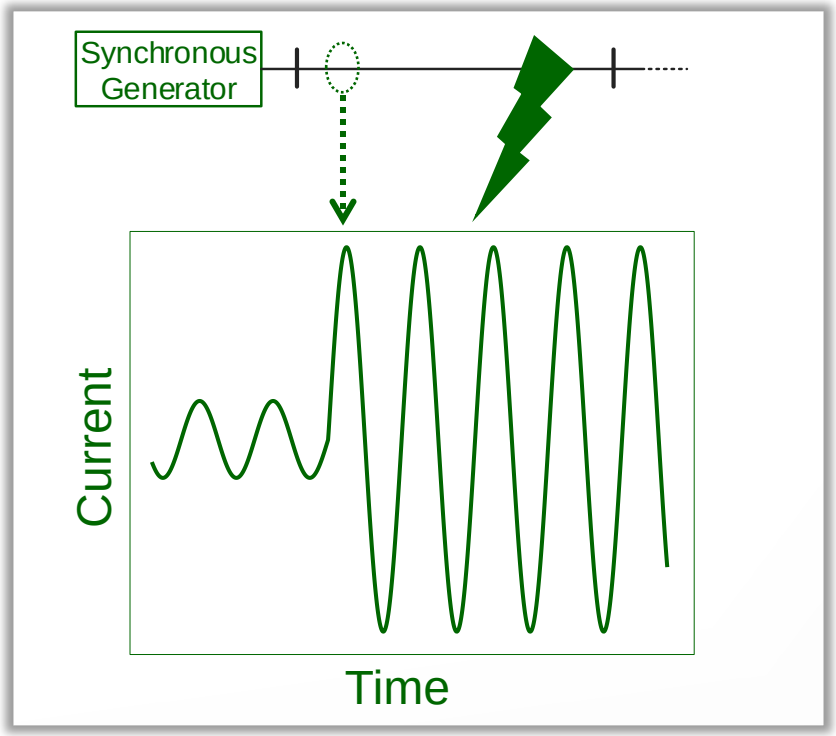
Distribution System Protection

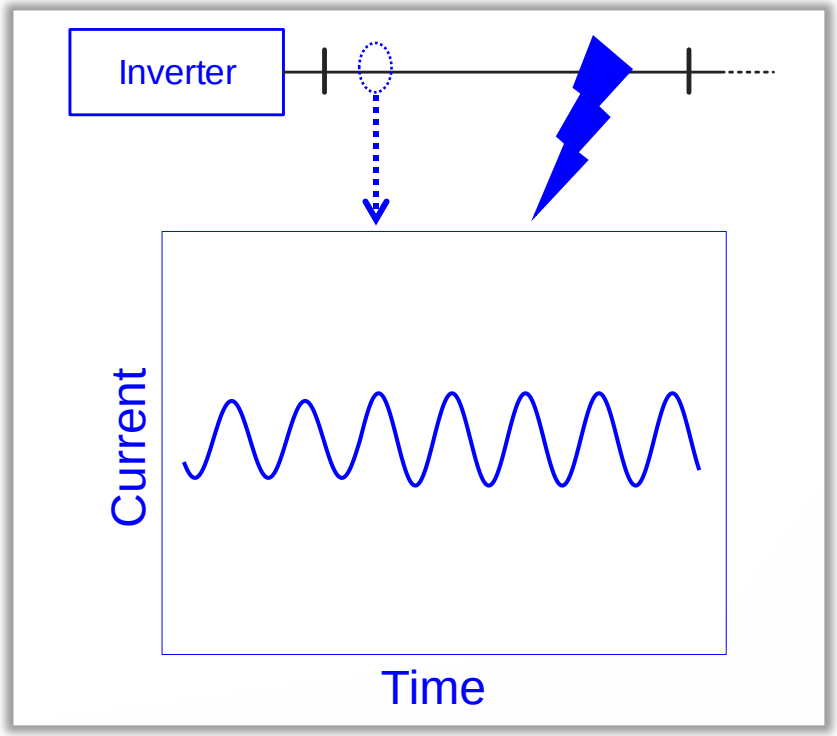
- Overcurrent protection has been historically used in distribution systems



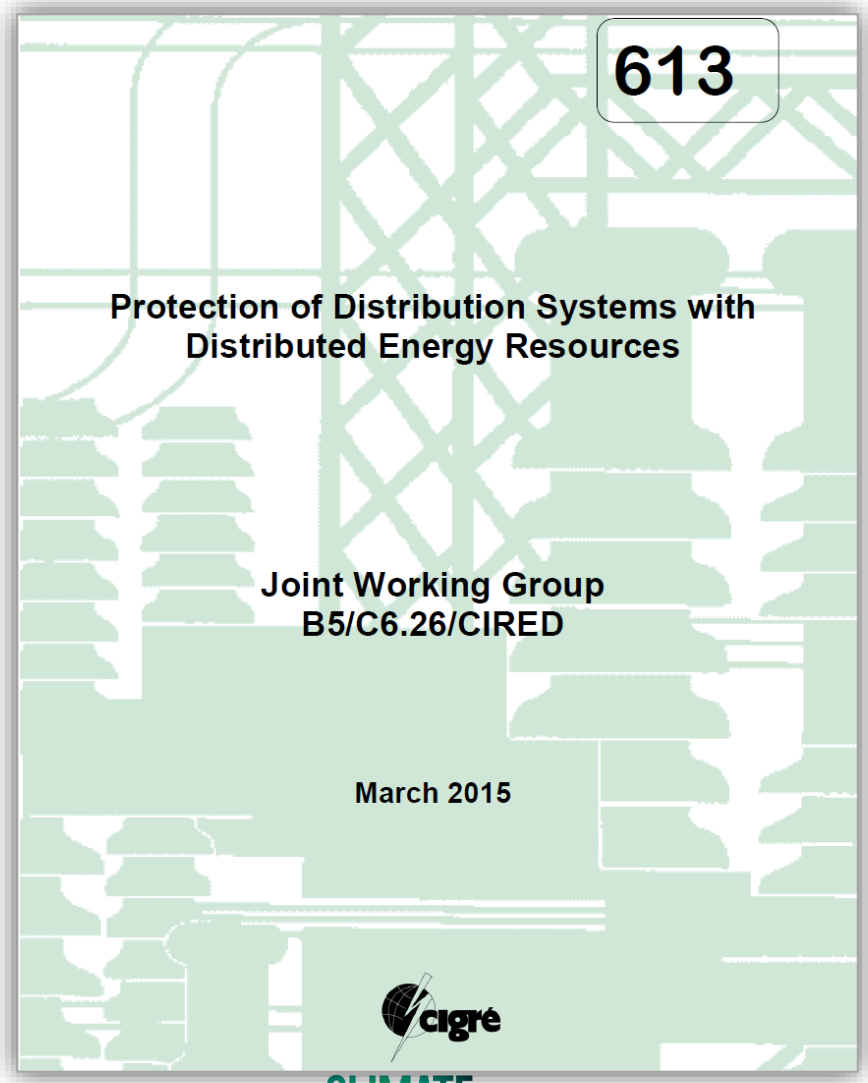
Microgrid Protection Challenges

- Limited fault current of renewable energy sources





CIGRE Working Group on Microgrid Protection



> *"Protection of distribution networks might become more similar to transmission systems, which would solve many of the problems encountered in the distribution networks having greater integration of DER."*
>
> *CIGRE B5/C6.26, Page 15*

CIGRE Working Group on Microgrid Protection

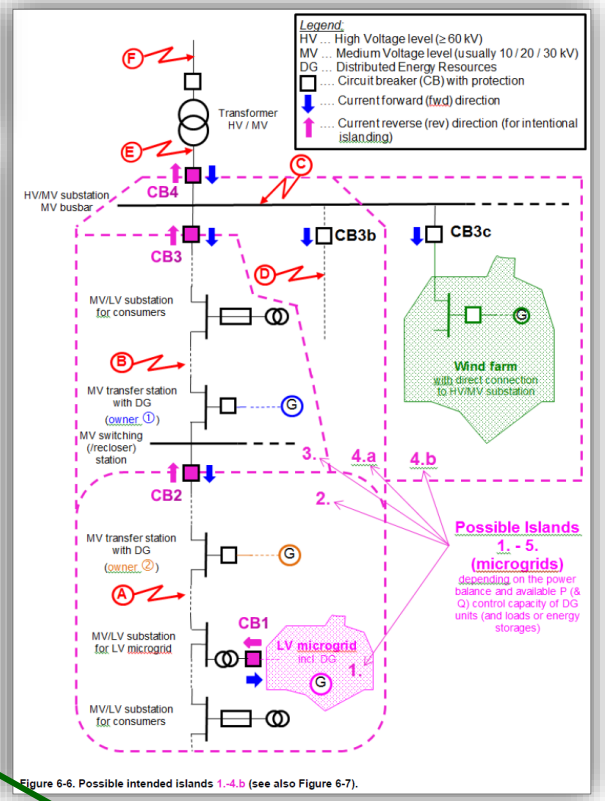
6.2.2 Example Case of CIGRE / CIRED JWG – Protection Needed for Successful Transition to Intended Island Operation

In Figures 6-6 and 6-7 the idea is that the possible operation principles of directional short-circuit protection in forward direction can be

1) Directional overcurrent protection with fixed time delay (and high-stage / low-stage settings)
2) Distance protection with fixed time delay (in forward direction)

Similarly in Figures 6-6 and 6-7 the possible operation principles of directional protection in reverse direction (for intentional islanding) can be

1) Undervoltage with fixed time delay (and high-stage / low-stage settings) AND current direction detection in reverse direction. Function pick-up/start is only based on undervoltage (i.e. not in overcurrent, because fault current levels of inverter-based DER units can be fairly low as discussed in previous chapters)
2) Distance protection with fixed time delay (in reverse direction)



Distance protection

Directional protection

RTDS Test Results for Microgrid Protection

Distance relays ✗

Directional relays ✗

Differential relays ✓

Thank you.

Contact us: info@cpe.utoronto.ca
hooshyar@ece.utoronto.ca

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RE-ENVISIONING ENERGY SYSTEMS

Transforming Engineering Education

Emily Moore

Transforming Engineering Education at U of T

Presented to Partners in Project Green “Energy Leaders Consortium”, October 24, 2022

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Emily Moore

Director, Troost ILead

cpe.utoronto.ca

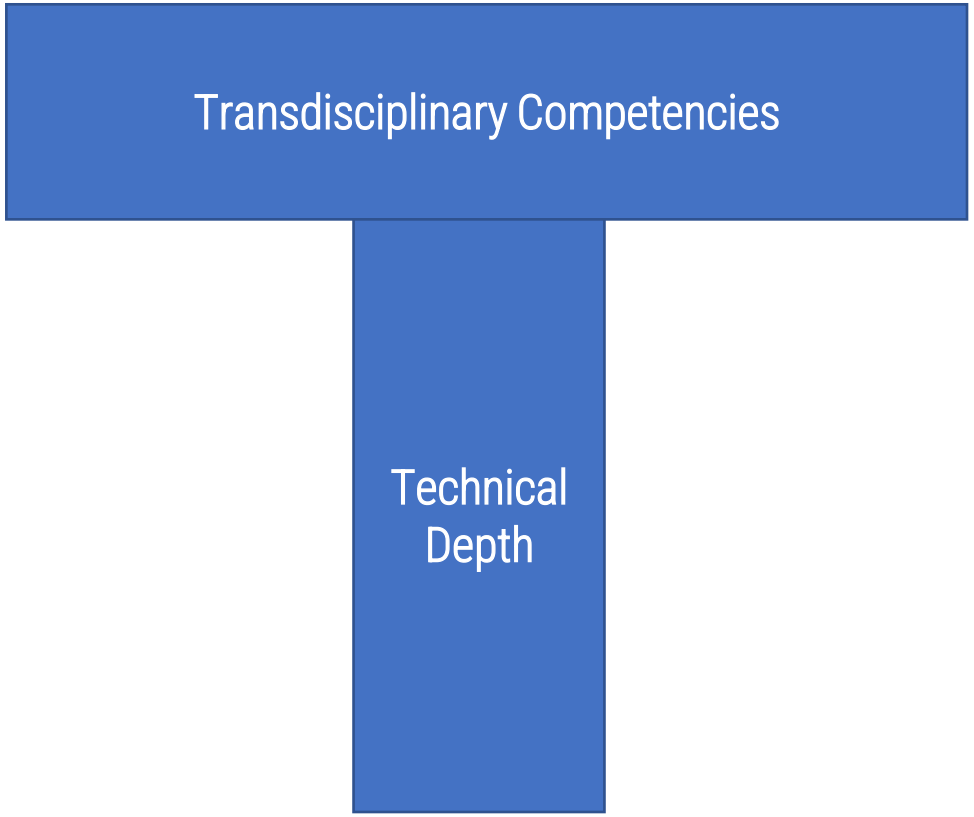
Getting to net-zero requires:

- Technical innovation
- Interdisciplinary collaboration
- Teamwork and Leadership
- Communication
- Continuous learning
- Adaptability and resilience
- Economics and business knowledge
- Entrepreneurial spirit
- Understanding of social and environmental context and impact
- Systems thinking

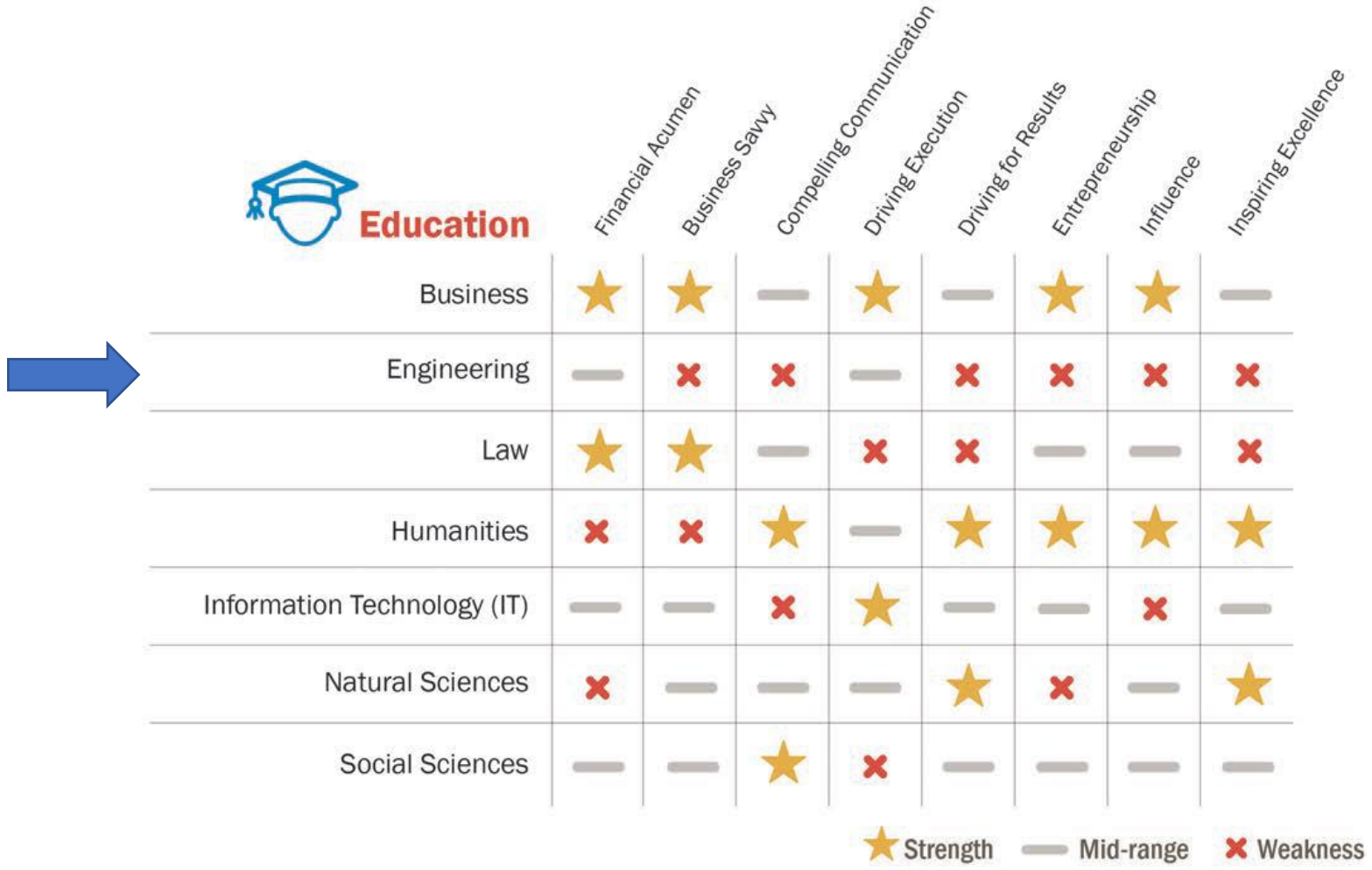
What kinds of engineers do we need?

T-shaped engineer:

an individual who has deep knowledge and skills in a particular area of specialization, along with and the desire and ability to make connections across different disciplines



But… is engineering education delivering?



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High-Resolution Leadership: A Synthesis of 15,000 Assessments into How Leaders Shape the Business Landscape. Development Dimensions International, Inc. 2016

What kinds of problems do engineers face?

	Problem: Well Structured/Defined	Problem: Poorly Structured/Defined
Solution: Established or Pre-defined	**Routine Problem** (i.e. standardized, clear process; primarily analytic)	**Process-Oriented Problem** (i.e. translating solutions, products, or services to new domains; analytic and synthetic)
Solution: Complex or not Pre-Defined	**Originative Problem** (i.e. requires innovation, creation, reconceptualization; analytic and synthetic)	**Wicked Problem** (i.e. political, social, ethical, environmental dimensions)

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Source: *Beth-Anne Schuelke-Leech. "The Place of Wicked Problems in Engineering Problem Solving: A Proposed Taxonomy." IEEE International Symposium on Technology and Society, Nov. 12-15, 2020*

Evolution of engineering education at UofT

Introduction of Design Spine

Engineering Communication Program

Troost Institute for Leadership Education in Engineering (Troost ILead)

Continued development of cross-disciplinary programs

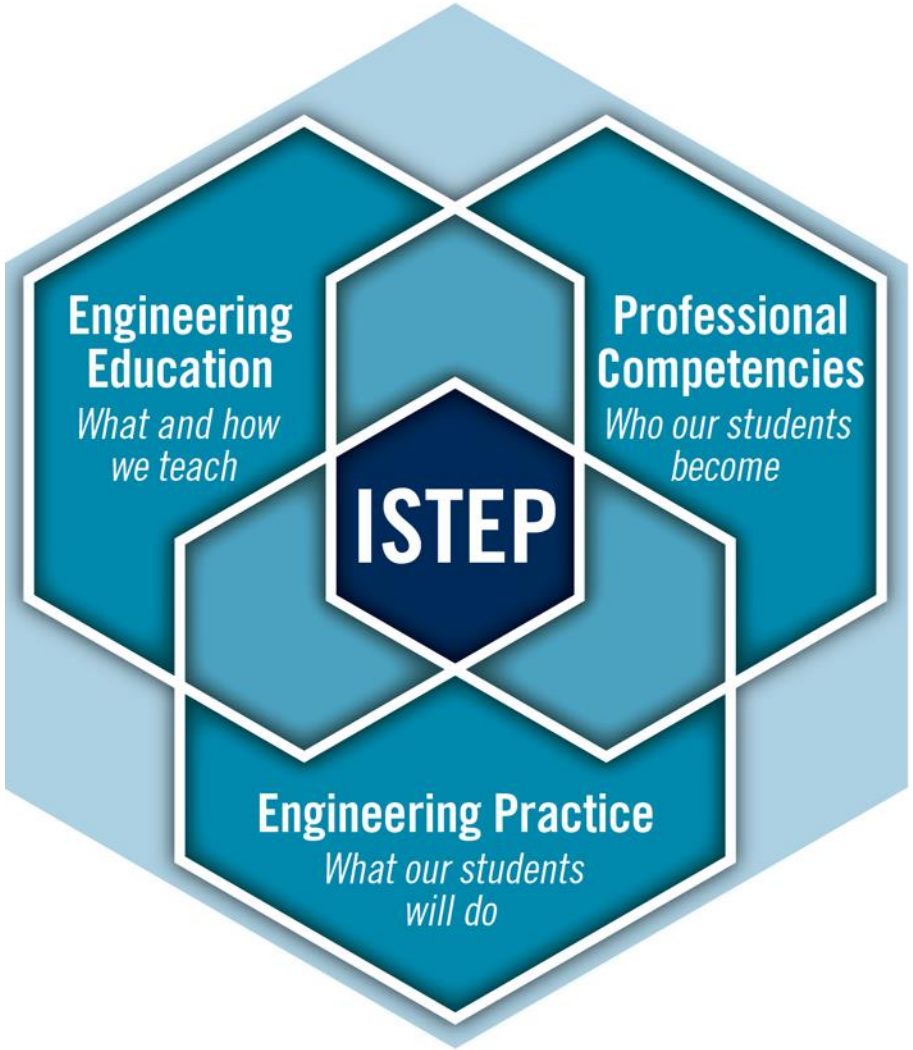
- 20+ minors and certificates currently

Entrepreneurial Programs

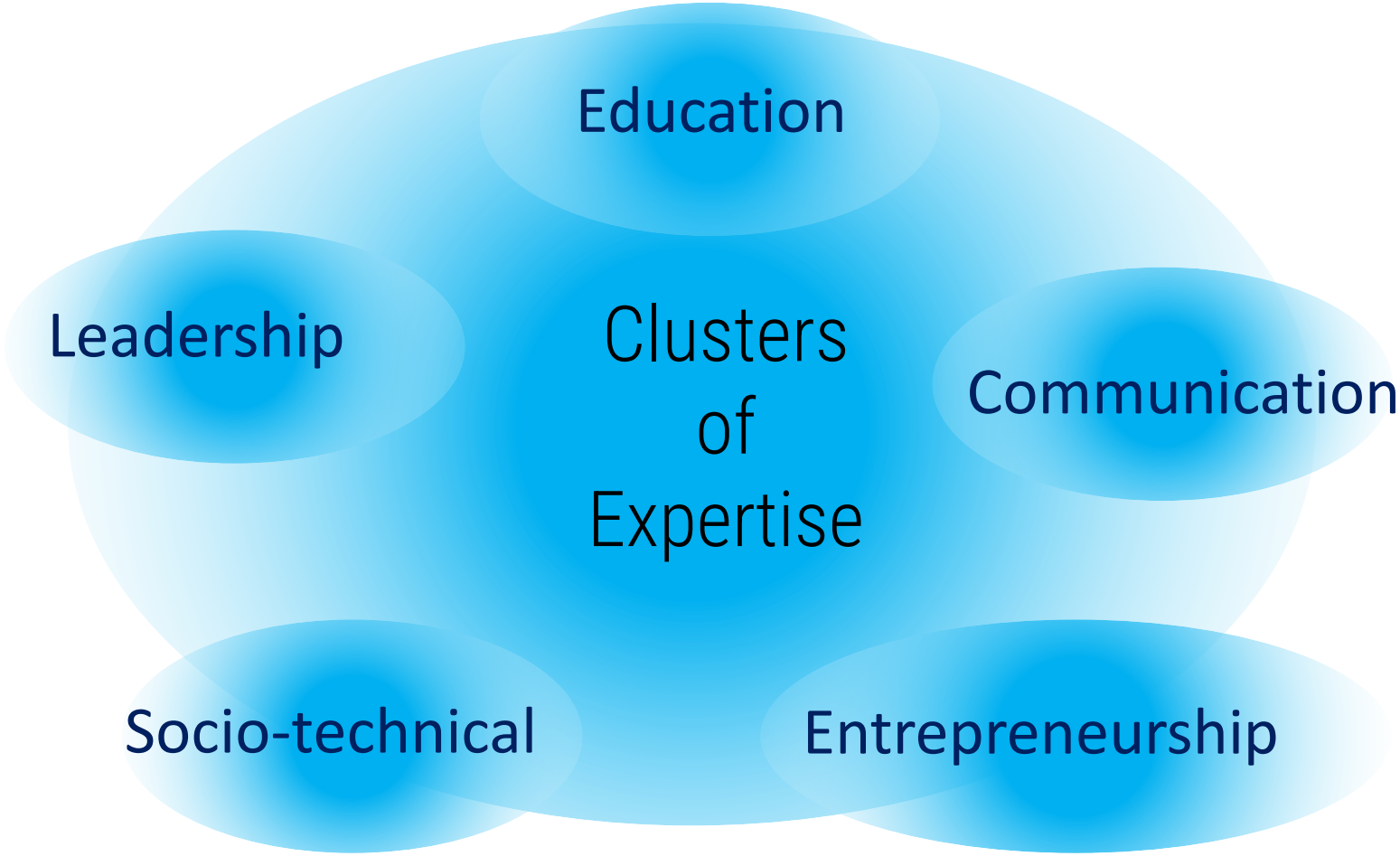
2018 - Creation of ISTEP

UofT Response: Creation of ISTEP

- Institute for Studies in Transdisciplinary Engineering Education & Practice
- Brought together existing initiatives, academic programming, scholarship and people to create a vibrant ecosystem for instructional innovation



ISTEP: Clusters of Expertise



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Lifelong and Lifewide learning

- **Lifelong learning**: Building knowledge
  - Awareness of learning as a process
  - Knowledge foundation accelerates future learning
  - Accessible anchor points rather than buried pockets of knowledge
- **Lifewide learning:** Connecting knowledge
  - Across courses and learning experiences
  - With many jobs along their career
  - With the world around them and themselves

How we deliver

- Emphasis on project based, active and experiential learning
- Integration of transdisciplinary competencies into core courses
- Extension courses to explore competencies more fully and examine socio-technical interfaces
- Augment with co-curricular programs

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Example: Developing Systems Thinking

What is Systems Thinking…

Moving from thinking that

- Focuses on the parts
- Looks for hierarchical structures
- Identifies static categories
- Is Linear and causal
- Looks at structural parts
- Uses bivalent logic
- Thinking based on physical phenomenon

To thinking that

- Considers the whole
- Looks at distributed networks
- Considers part-whole groupings
- Is non-linear, webs of causality
- Looks at dynamic relationships
- Uses multivalent logic
- Thinking that incorporates social phenomenon

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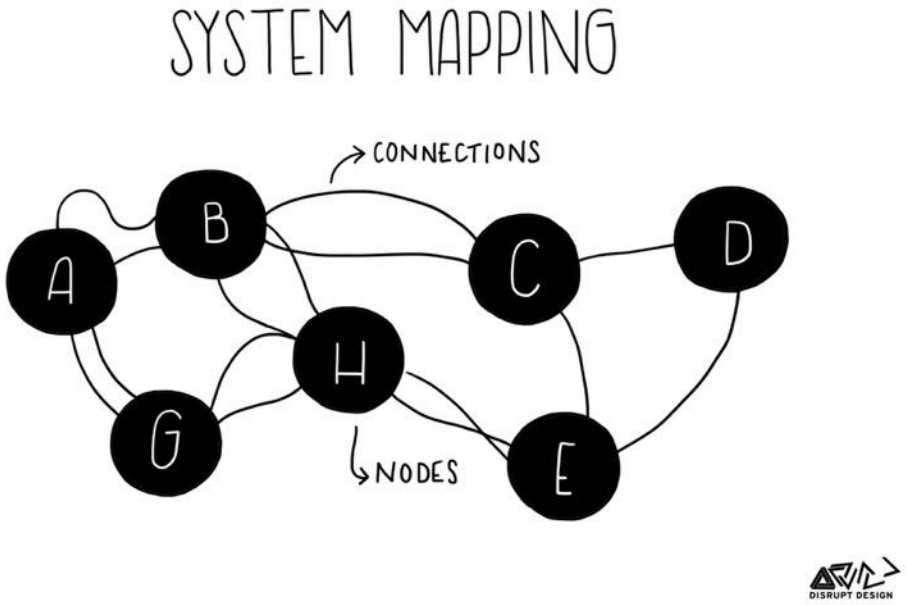
Adapted from Cabrera and Cabrera, Systems Thinking Made Simple

Intervention: System Mapping Course

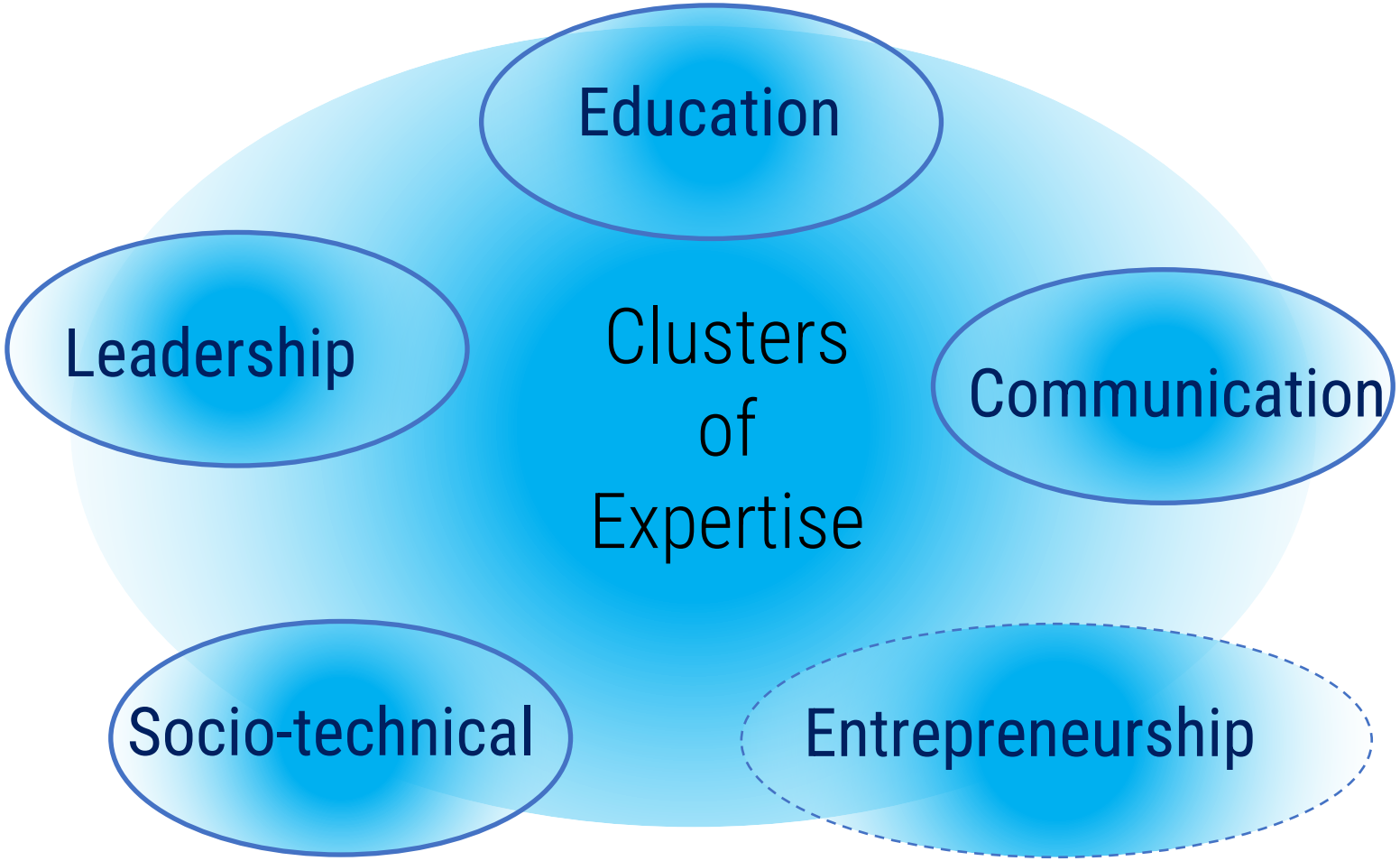
- Create a course focused on understanding problem definition and context rather than designing a solution
- Help students to explore how engineering interfaces with other academic disciplines and to build respect for those disciplines
- Get students more comfortable with ambiguity
- Practice divergent versus convergent thinking

Intervention: System Mapping Course

- Piloted Winter 2022
- 6 self-selected team projects
- Research, expert consultation, guest speakers
- Experimented with various system mapping tools for collaborative visualization
- Sample topics:
  - Reduction of car dependency
  - Improvement of transit access
  - Unlocking the supply chain



Developing Competencies: ISTEP Expertise



Future Opportunities

- Evaluating effectiveness of the course pedagogy
  - Assessment of competency development
  - Application of particular interventions to entrepreneurship and innovation development
- Developing systems maps for innovation challenges
  - Course partnership possibilities
  - Research collaborations
- Exploring systems thinking development in engineering practice

Thank you.

Contact us: info@cpe.utoronto.ca
Emilyl.moore@utoronto.ca

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RE-ENVISIONING ENERGY SYSTEMS

Intelligent and Interactive Buildings

Seungjae Lee

Intelligent and Interactive Buildings

Exploring Net-Zero and Decarbonization: Climate Positive Energy welcomes Partners in Project Green, Oct. 24th, 2022

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Seungjae Lee

Assistant Professor

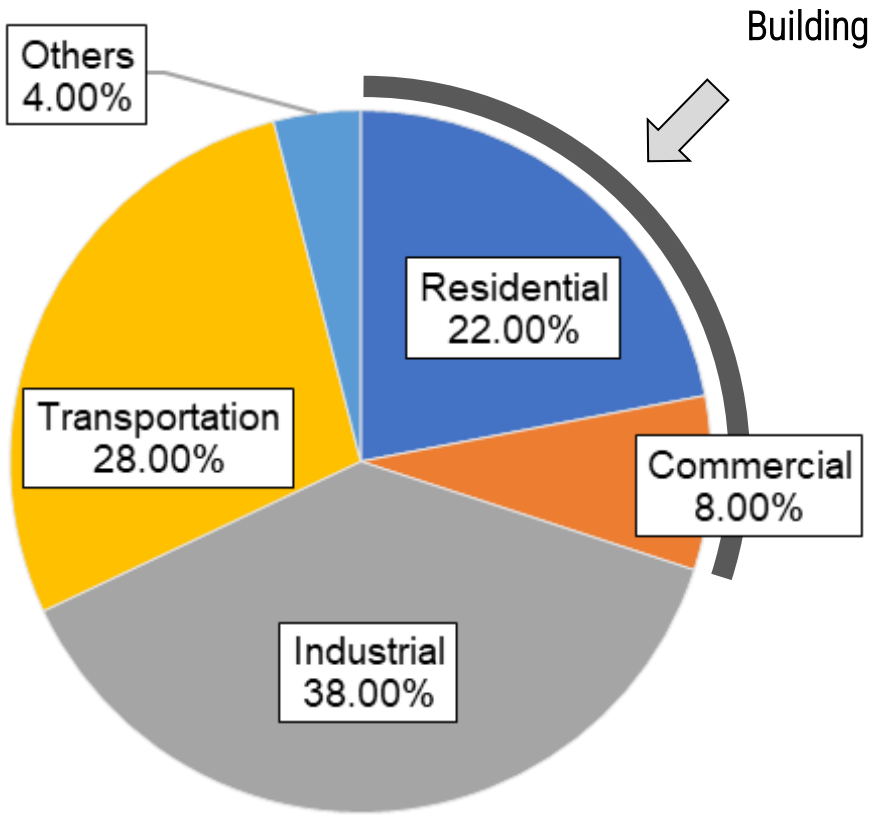
cpe.utoronto.ca

Intelligent and Interactive Buildings Lab

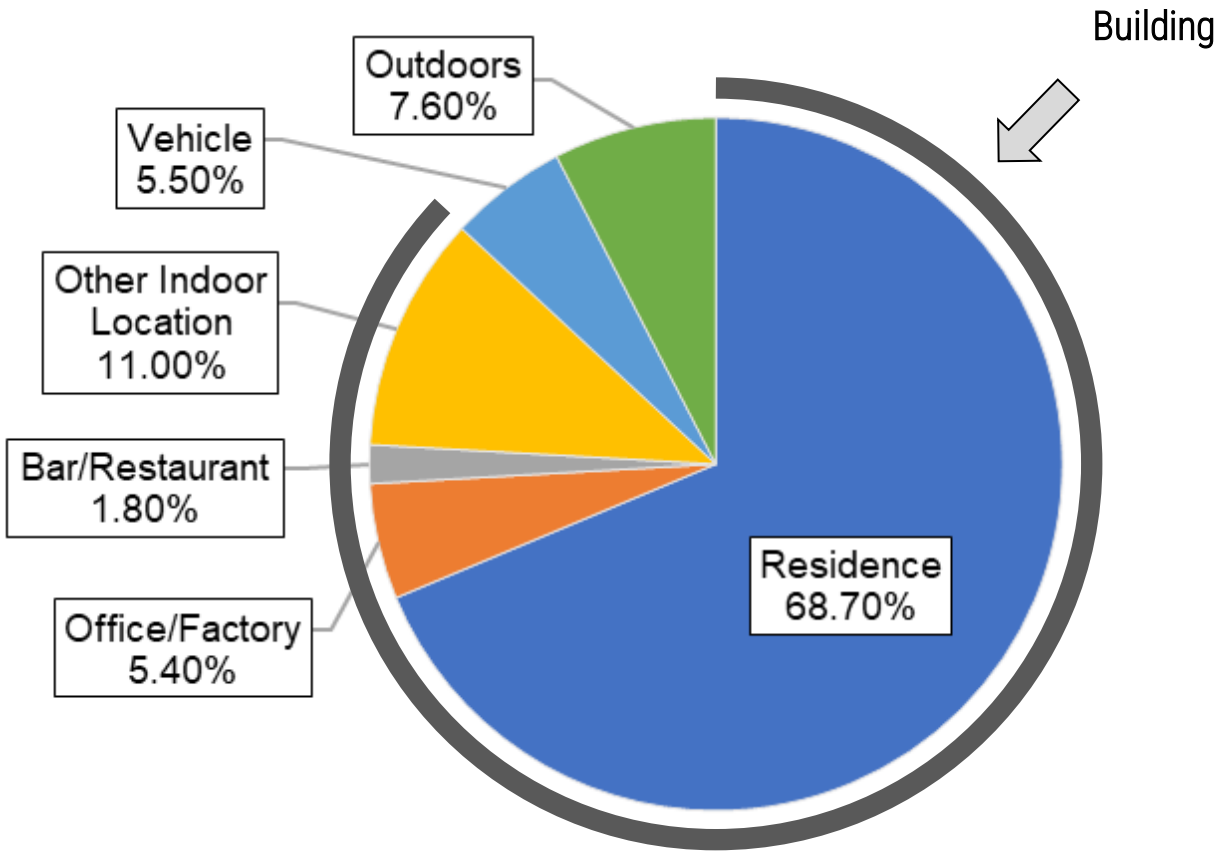
Mitigate climate change and improve the quality of life by realizing intelligent and interactive buildings

- Create advanced AI solutions for buildings to improve energy performance, IEQ, occupant well-being, and grid reliability & resilience.
- Explore uncharted fields of building science research to increase the depth and breadth of knowledge and facilitate engineering innovation.

Background

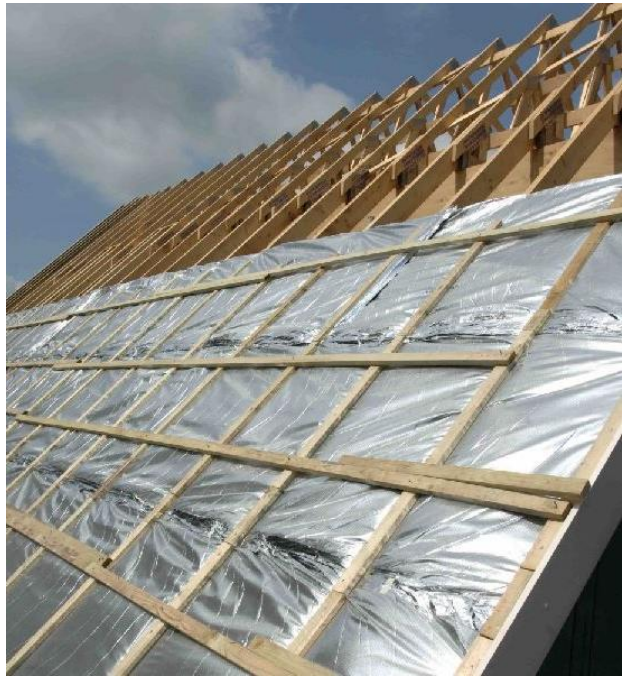
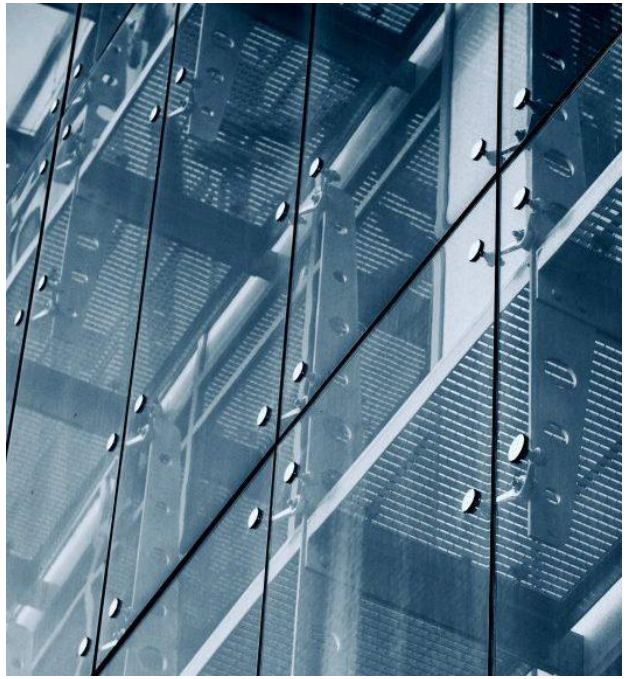
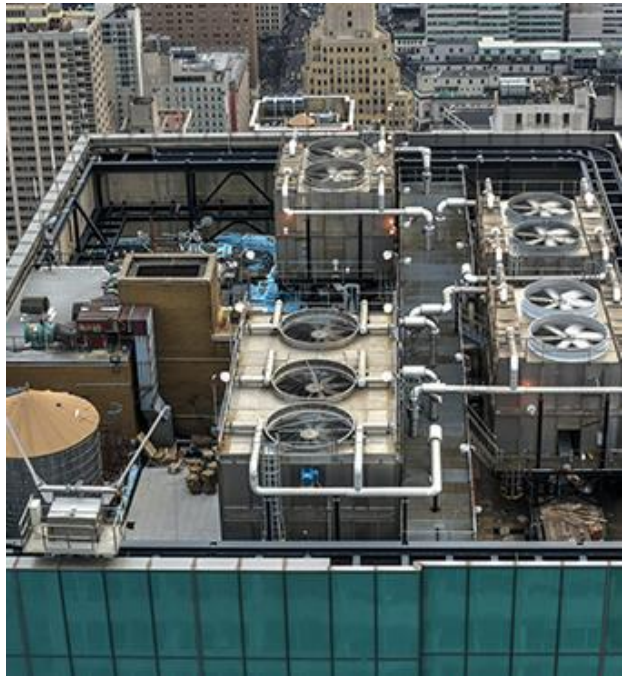


Energy Consumption
by Sector (2018)



Time Spent by Location

Background

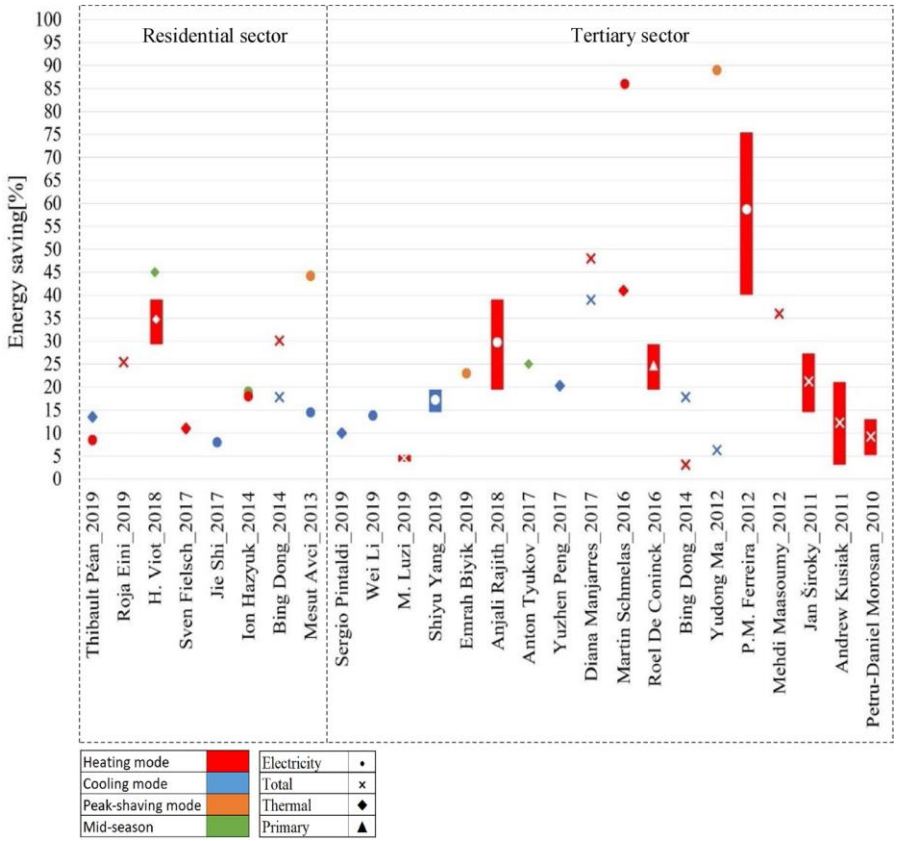





Building integration, operation, and management

Background

AI solutions for buildings can…

- Save 15-50% of energy consumption

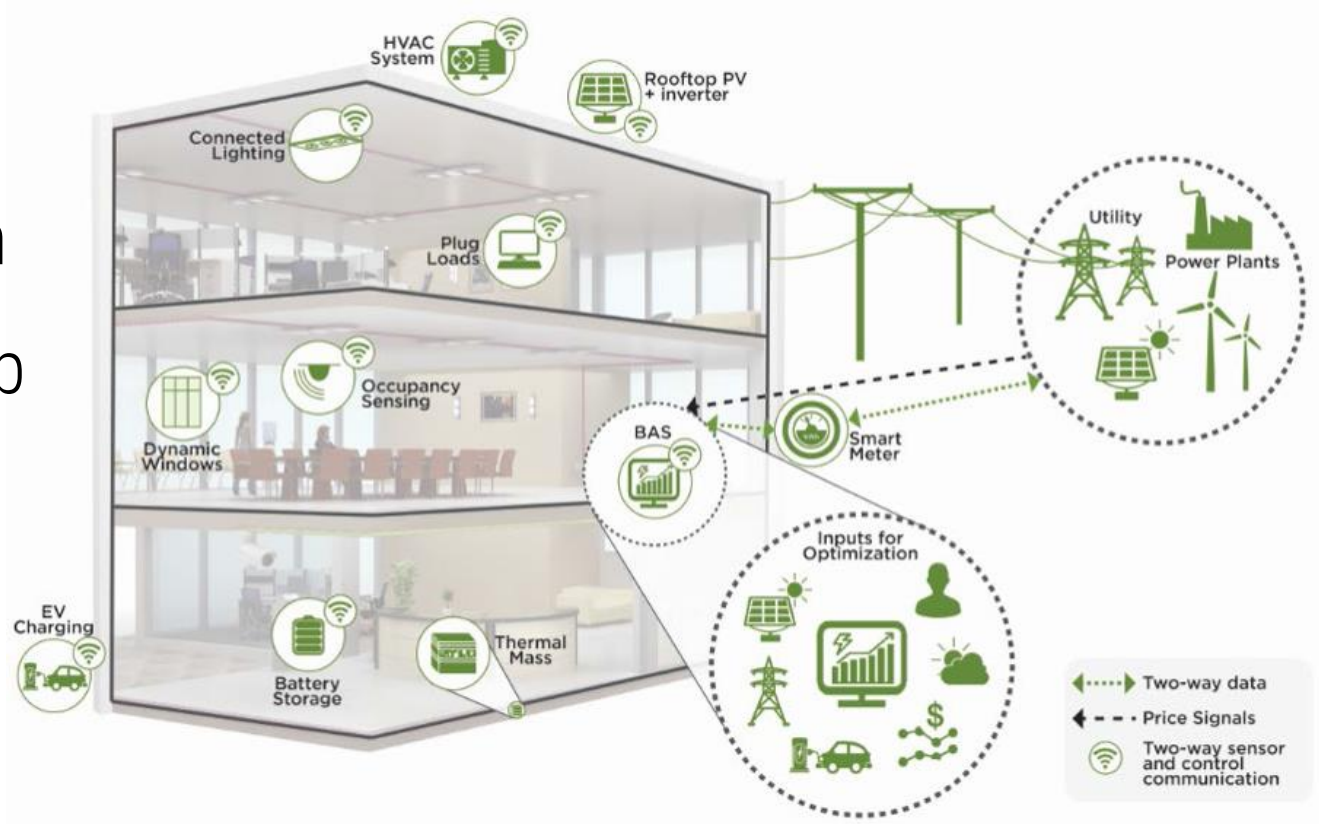


Energy saving potential by application of advanced control strategies in the analyzed literature (M. Gholamzadehmir et al. 2020)

Background

AI solutions for buildings can…

- Save 15-50% of energy consumption
- Manage/curtail building peak load up to 20%

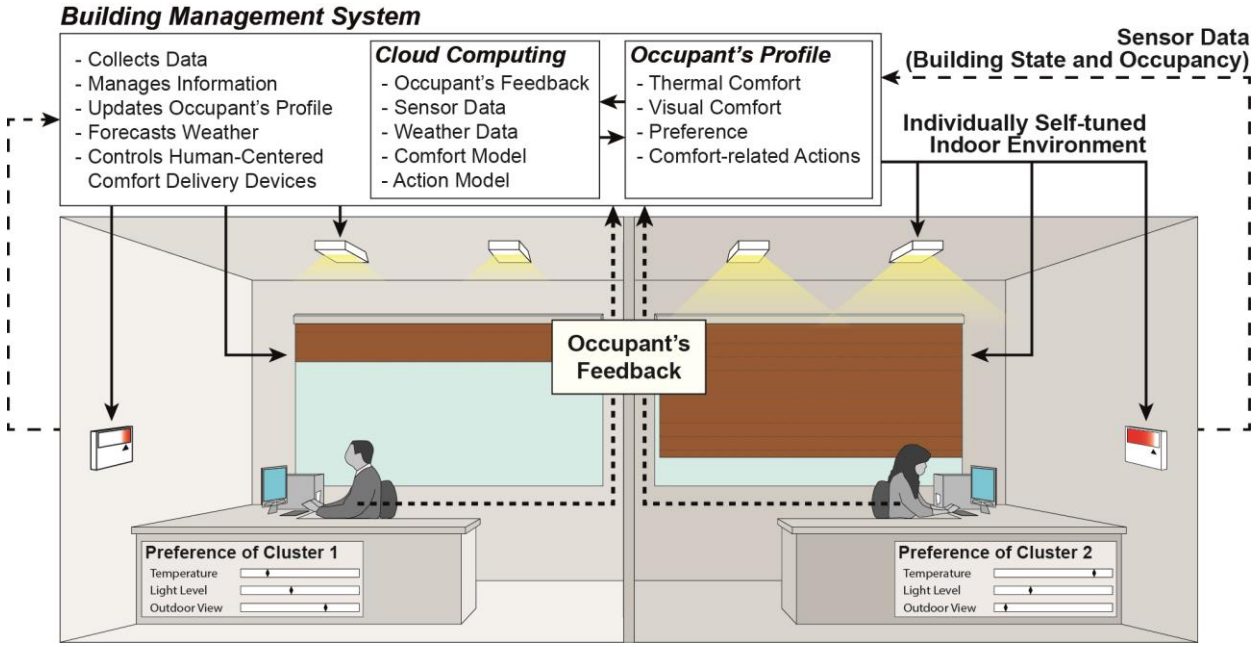


Example Commercial Grid-interactive Efficient Building (US DOE Building Technologies Office, https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings)

Background

AI solutions for buildings can…

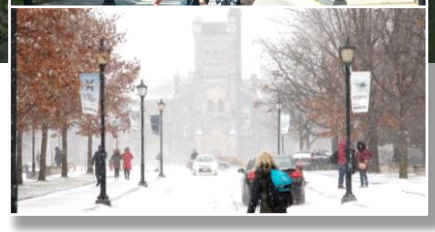
- Save 15-50% of energy consumption
- Manage/curtail building peak load up to 20%
- Improve occupant satisfaction, productivity, and health



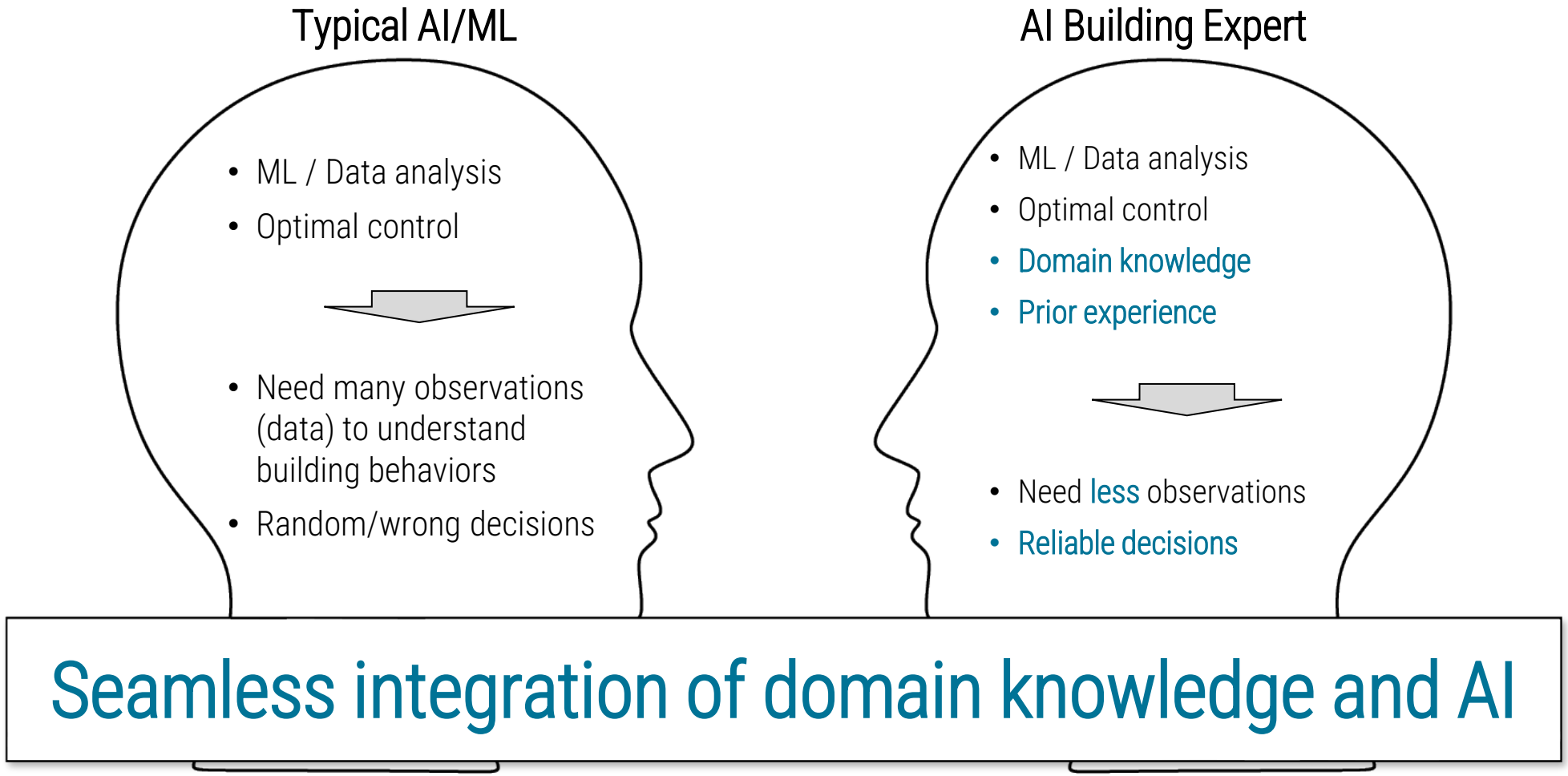
Challenges

Scalability & Reliability issues due to:

- Heterogeneity
- Complexity
- Uncertainty



Challenges


Typical AI/ML
ML / Data analysis
Optimal control
Need many observations (data) to understand building behaviors
Random/wrong decisions
AI Building Expert
ML / Data analysis
Optimal control
Domain knowledge
Prior experience
Need less observations
Reliable decisions
Seamless integration of domain knowledge and AI

Research Topics

Energy System Optimal Control

Grid-Interactive Building Control

Fault Detection & Diagnosis

Human-building Interaction

UofT Campus Projects

Table 4 – Future Demand and Consumption Report – Future Campus Demand and Consumption Summary

		2019	2020	2025	2030	2035	2050
Heating Energy	Annual heating energy [MWh]	331,990	333,547	331,155	322,440	311,708	330,961
Heating Demand	Peak heating demand [MW]	107	108	114	115	113	127
Cooling Energy	Annual cooling energy [MWh]	98,350	99,135	97,371	96,089	105,357	135,932
Cooling Demand	Peak cooling demand [MW]	65	66	72	80	94	135
Electric Energy	Annual electric use [MWh]	216,726	217,642	225,531	237,490	254,675	305,262
Electric Energy	Peak electric demand [MW]	46	46	53	59	66	84

~ 60%

> 70%

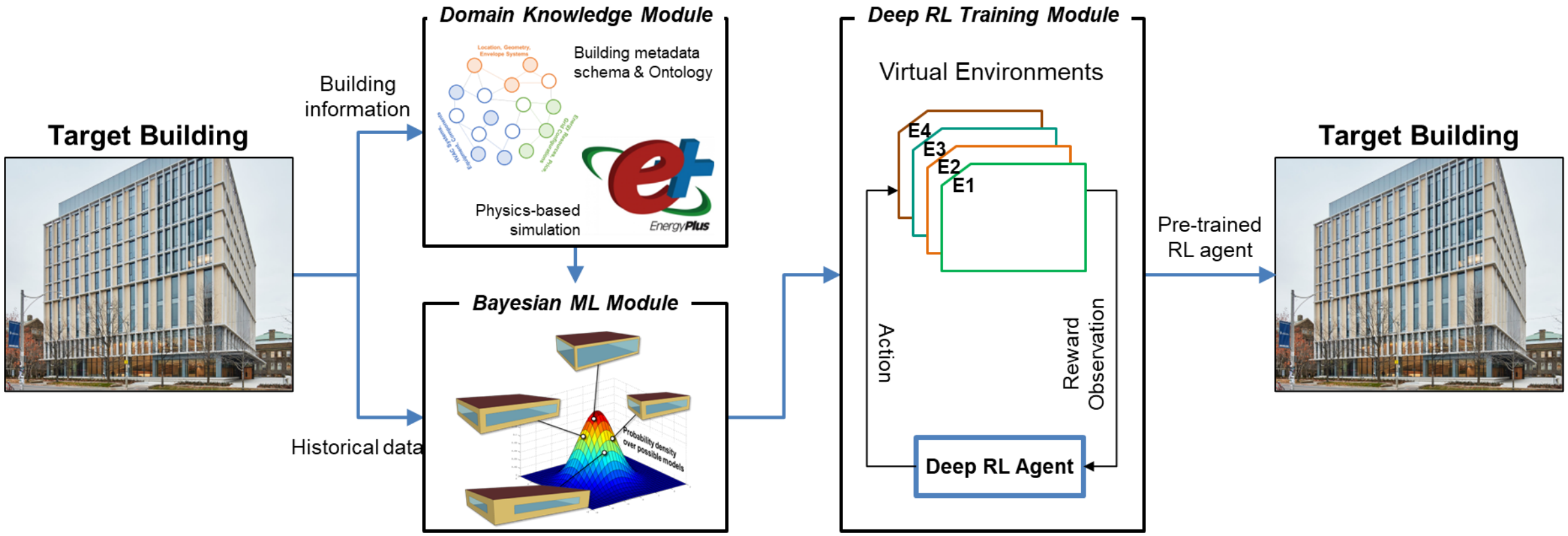
"University of Toronto Carbon and Energy Reduction Master Plan." (https://climatepositive.utoronto.ca/images/Carbon_and_Energy_Reduction_Master_Plan_V1.0.pdf)

Campus Project 1
Grid-Interactive Campus Smart Buildings

- How to optimize HVAC temperature set points to minimize building energy consumption and peak load while satisfying occupant thermal comfort?

Campus Project 1
Grid-Interactive Campus Smart Buildings

Campus Project 1
Grid-Interactive Campus Smart Buildings



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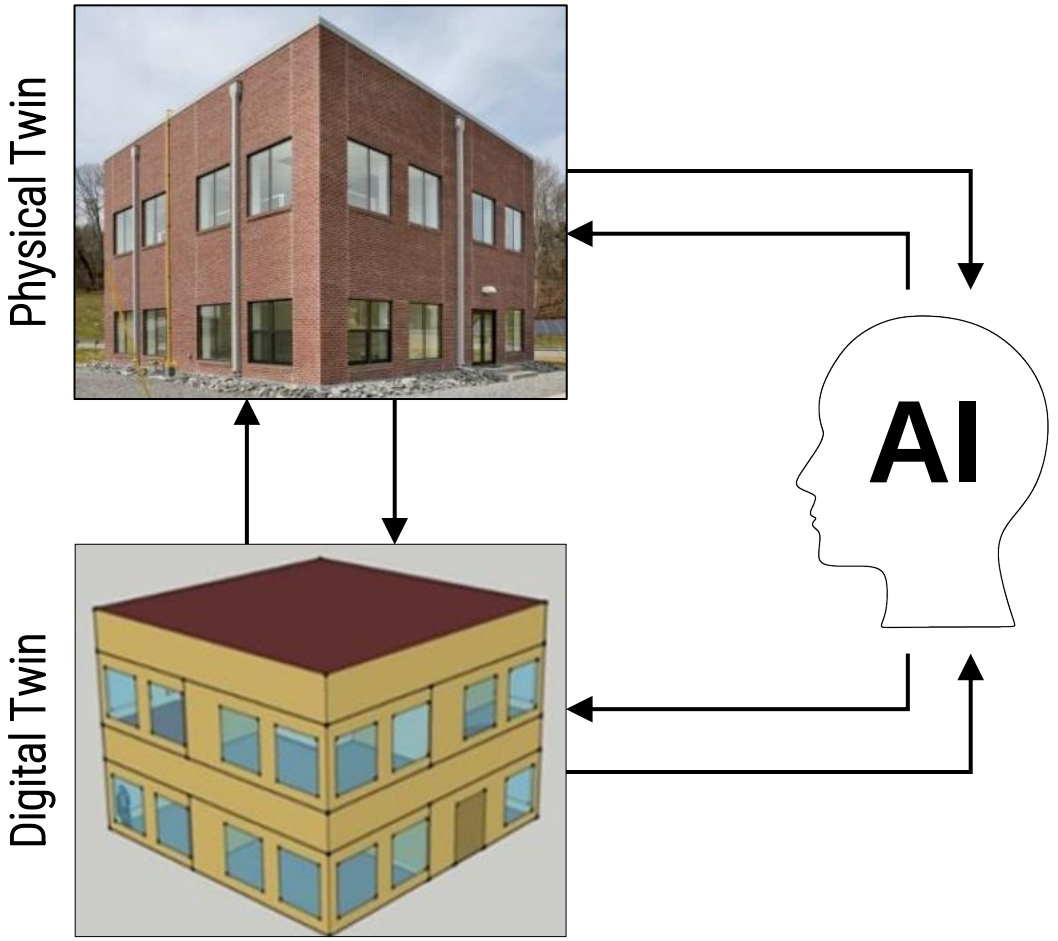
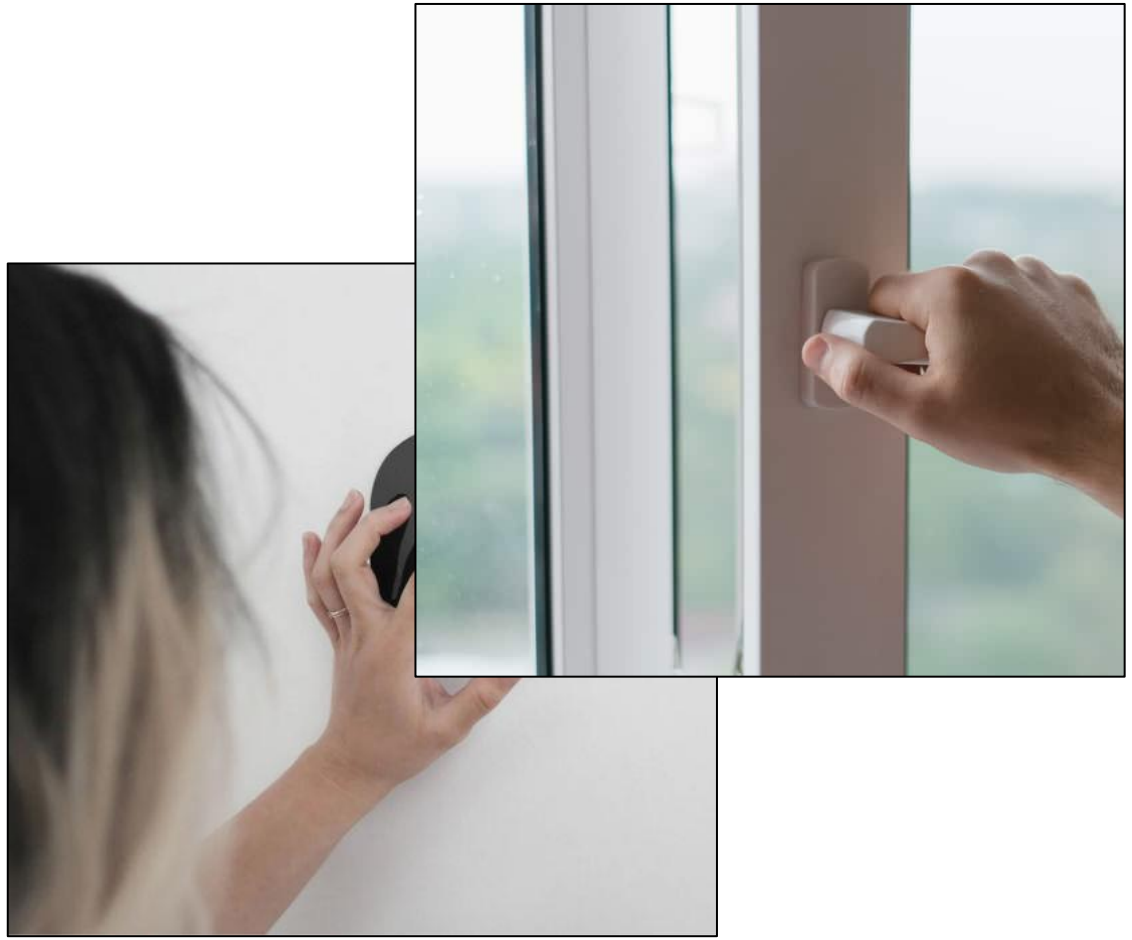
Campus Project 2
Digital Twin Platform for Building Systems

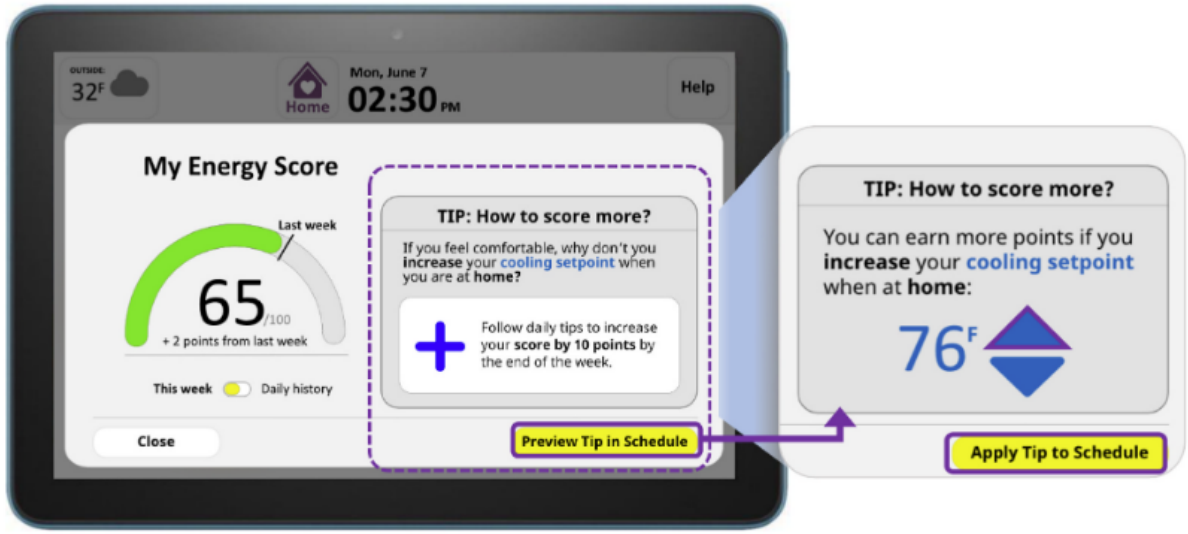
Digital twinning methods for major building systems

- System optimal control
- Fault detection & diagnosis
- Predictive maintenance



Human-Building Interaction Projects





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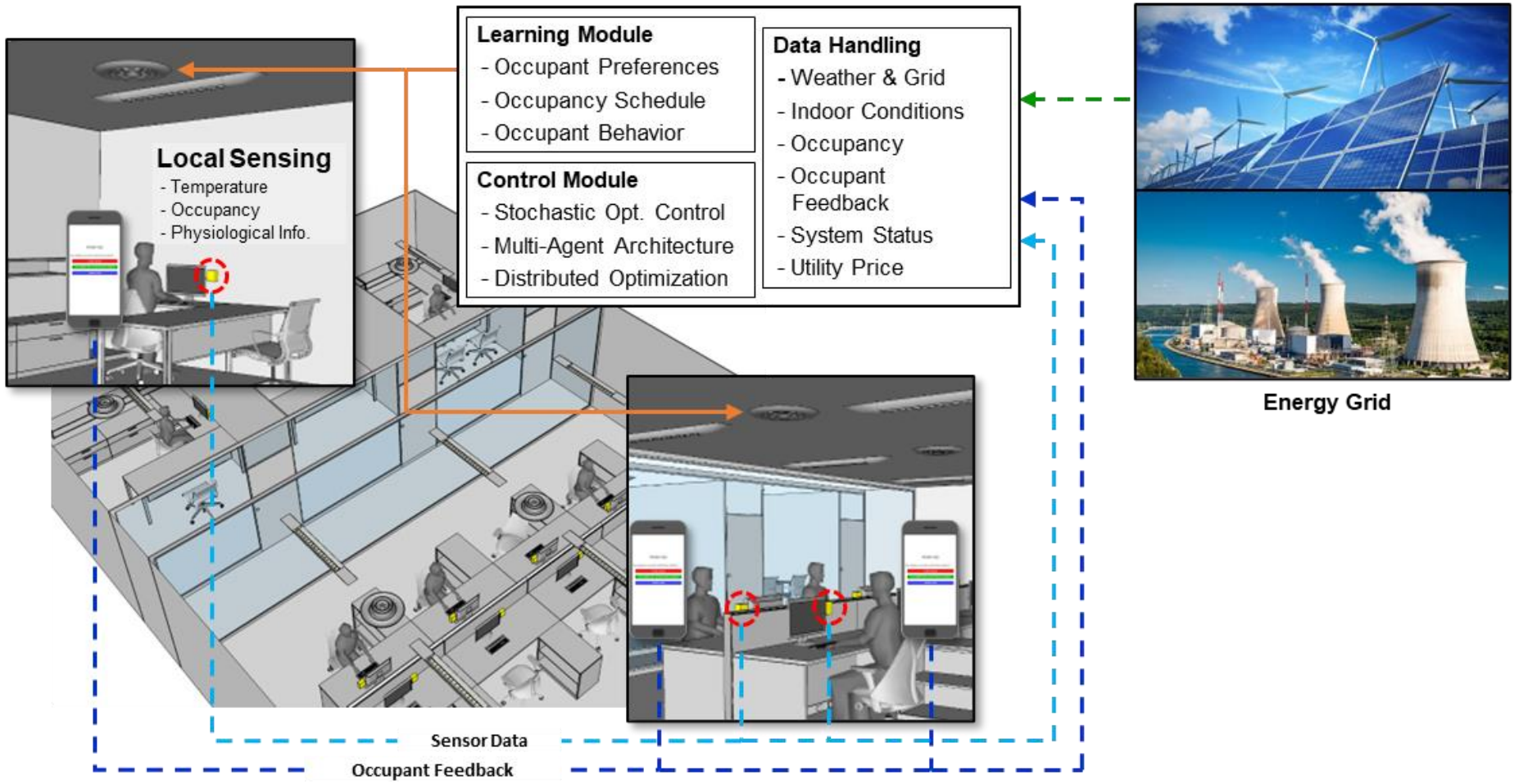
Intelligent and Interactive Buildings



Thank you.

Contact us: info@cpe.utoronto.ca
sjae.lee@utoronto.ca

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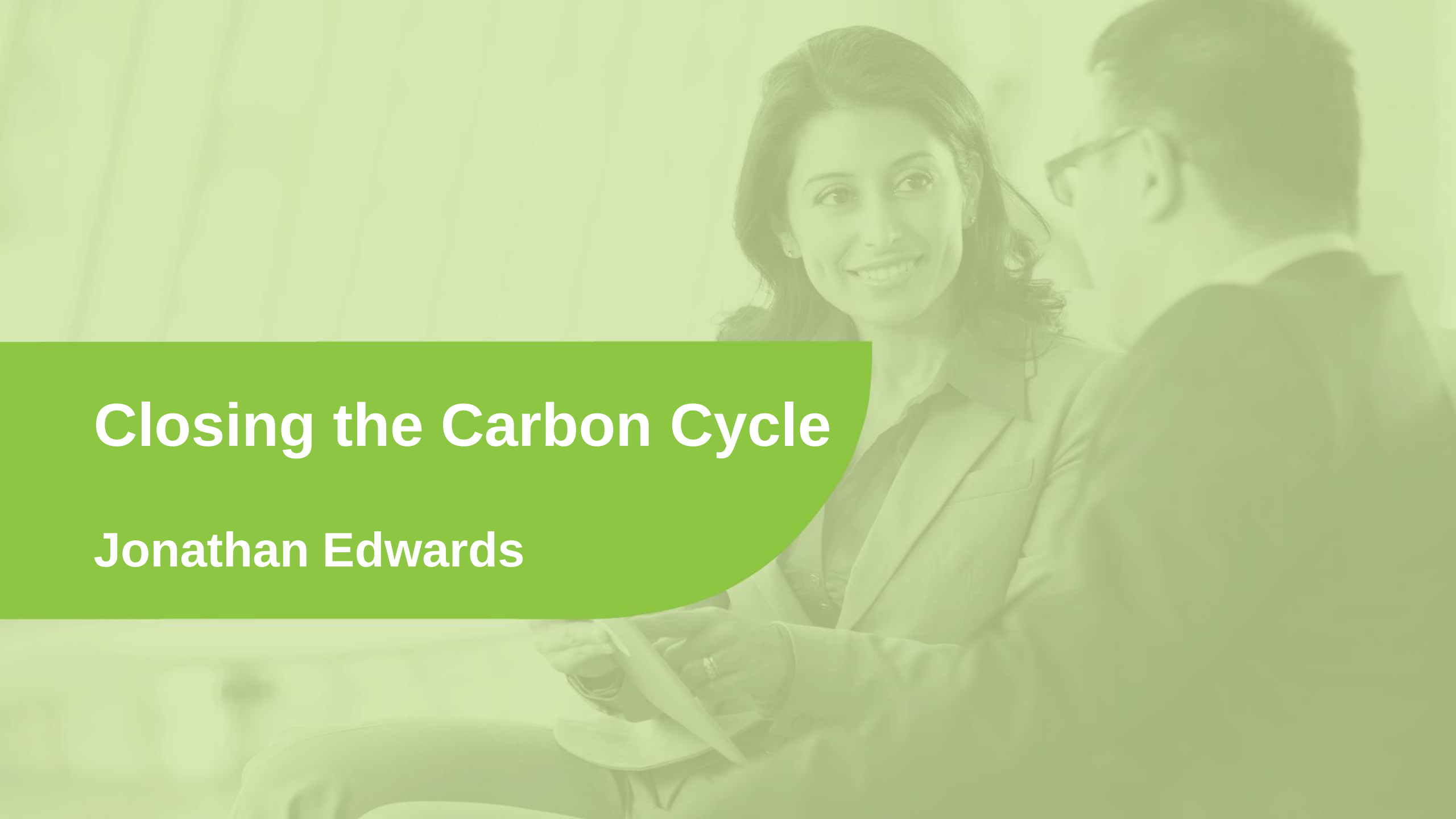
RE-ENVISIONING ENERGY SYSTEMS



Closing the Carbon Cycle

Jonathan Edwards

Closing the Carbon Cycle: Transforming CO_2 into Value at CERT

Energy Leaders Consortium, October 24th, 2022

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Jonathan Edwards, PhD

Principal Research Scientist, CERT Systems Inc.

cpe.utoronto.ca

Rising CO_2 Levels

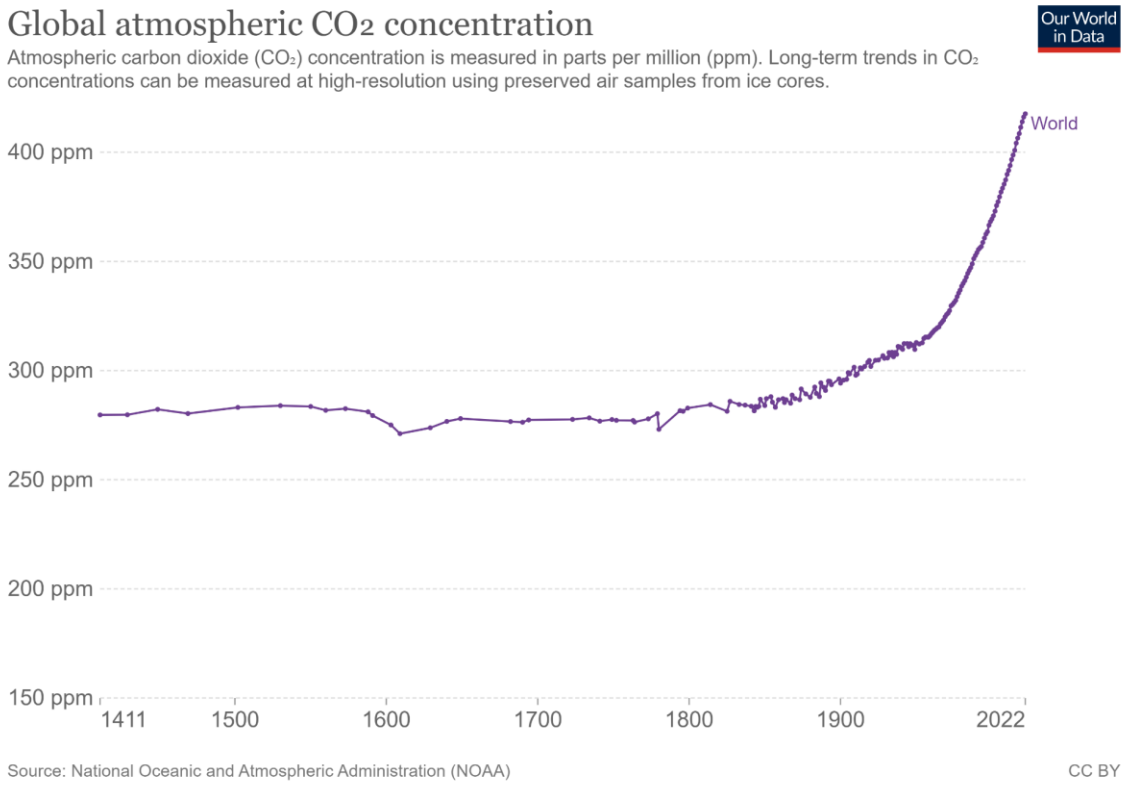
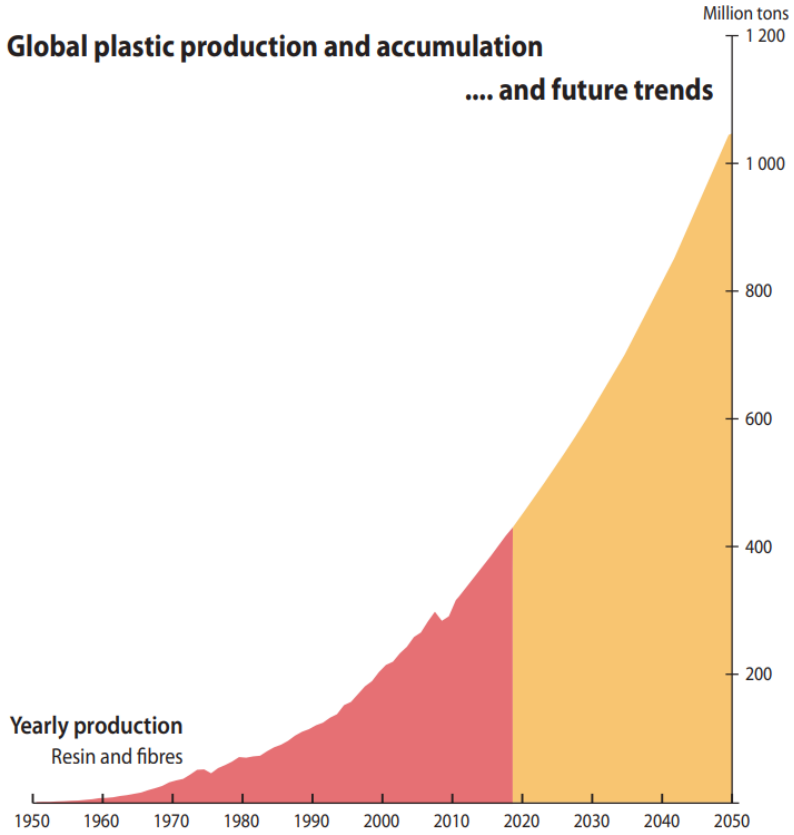


Photo: Felton Davis via Flickr

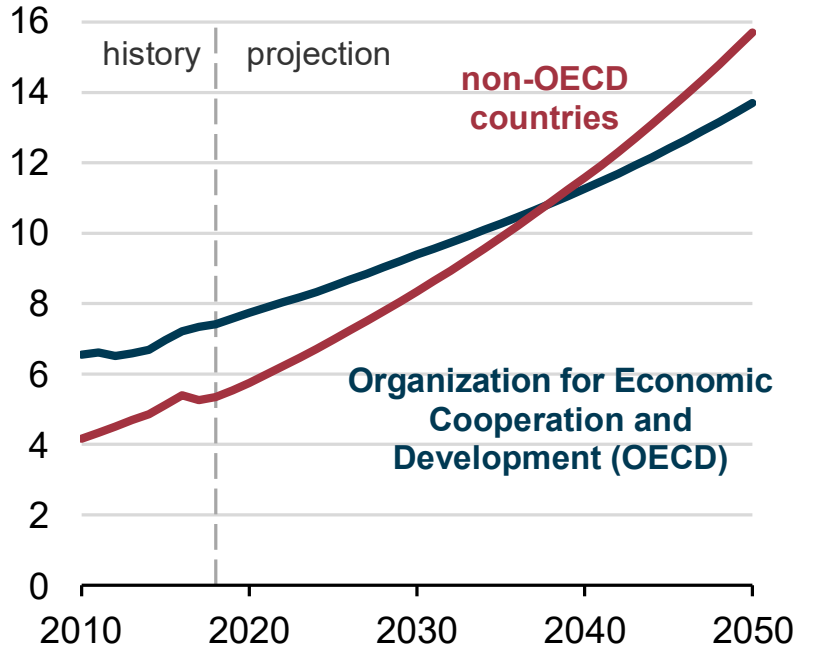
Photo: Patrick Emerson via Flickr

Growing Demand for Chemicals and Fuels



Source: United Nations Environmental Programme, 2021

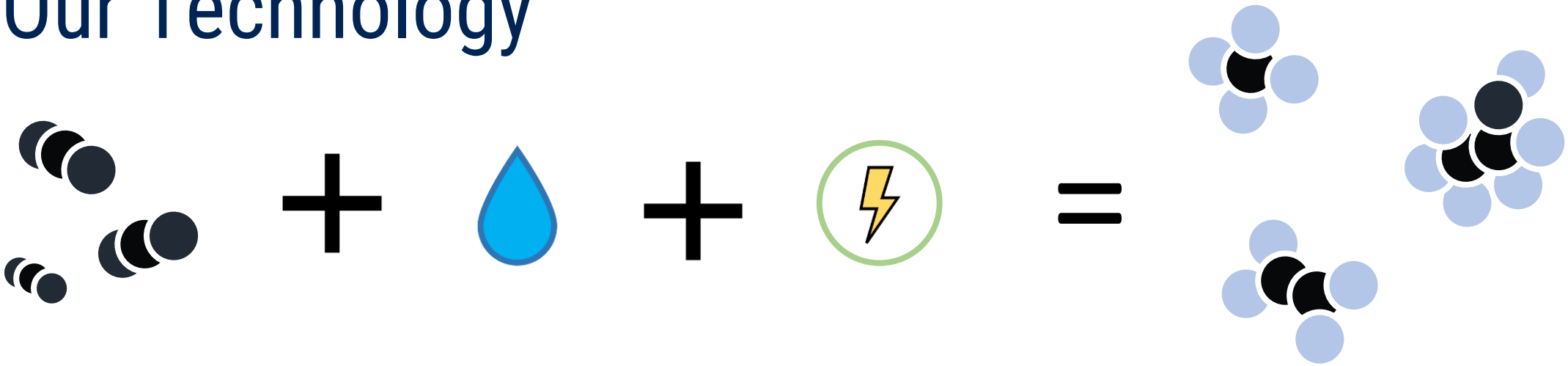
Global jet fuel energy consumption (2010-2050)
quadrillion British thermal units



Source: U.S. Energy Information Administration, International Energy Outlook 2019

Our mission is to transform the way the world's most important chemicals are made.

Our Technology



CO_2 **Water** **Electricity** **Chemical building blocks and fuels**

Gas Products

- Syngas
- Methane
- Ethylene

Liquid Products

- Formic acid
- Ethanol
- Acetate
- Propanol

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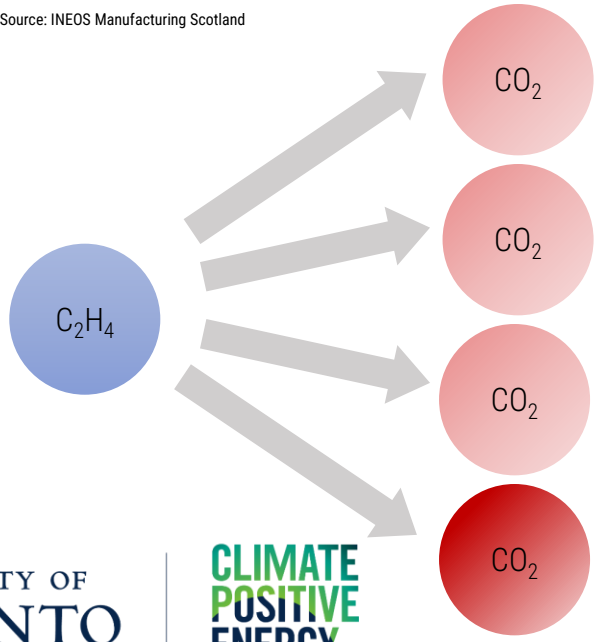
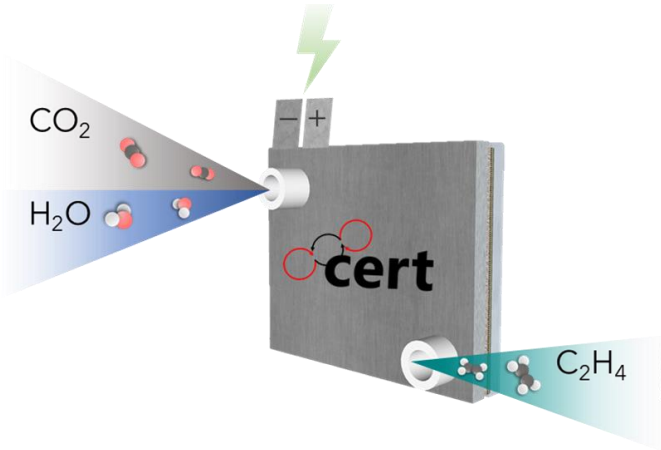
Ethylene Production

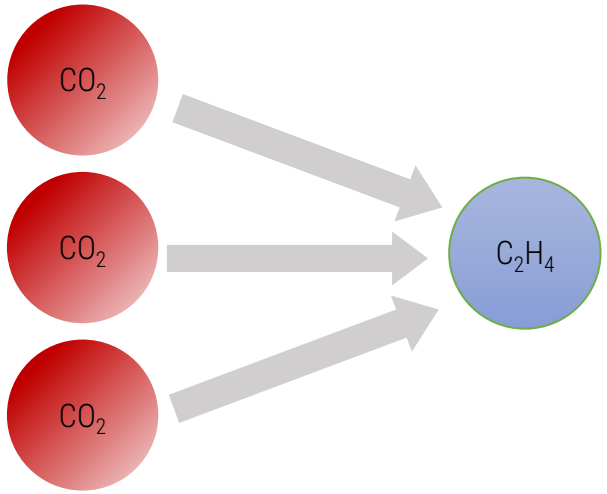
Conventional Steam Cracking

Source: INEOS Manufacturing Scotland



Electrochemical





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cert


XPRIZE
CARBON
nrg
cosia

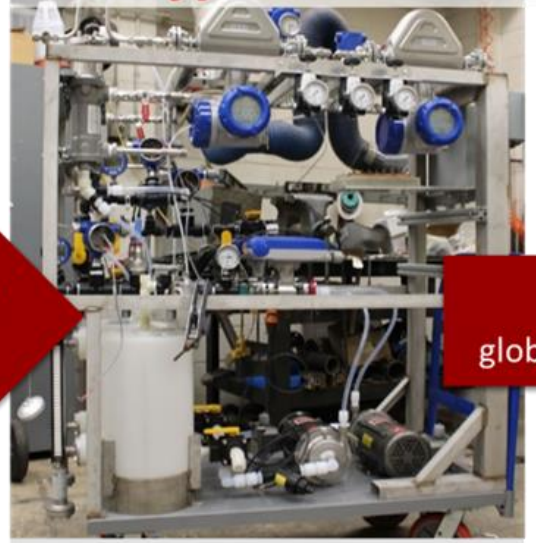
NRG COSIA Carbon XPRIZE Finalist

Lab Scale

Size: Rubik's Cube
Capacity: 1 g/day

10000x scale up
in 5 months

Prototype (Built Dec 2017)



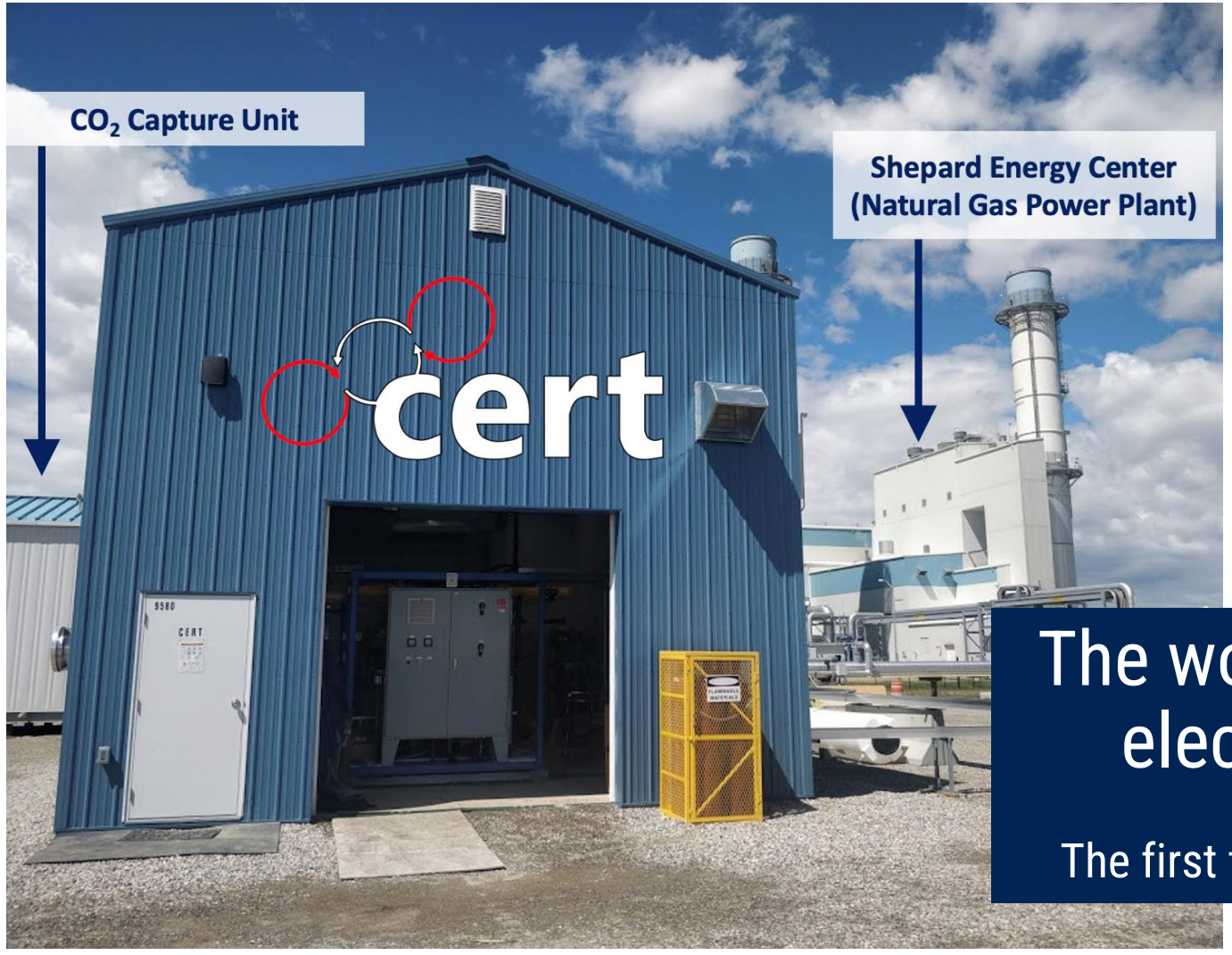
Size: Large Refrigerator (6'x5'x1')
Capacity: ~10 kg/day

1 of 5 finalists
globally to compete in Alberta

Pilot Plant (Built Oct 2019)

Size: Skid (8'x8'x20')
Capacity: ~100s kg/day

CERT's Electrolyzer Skid

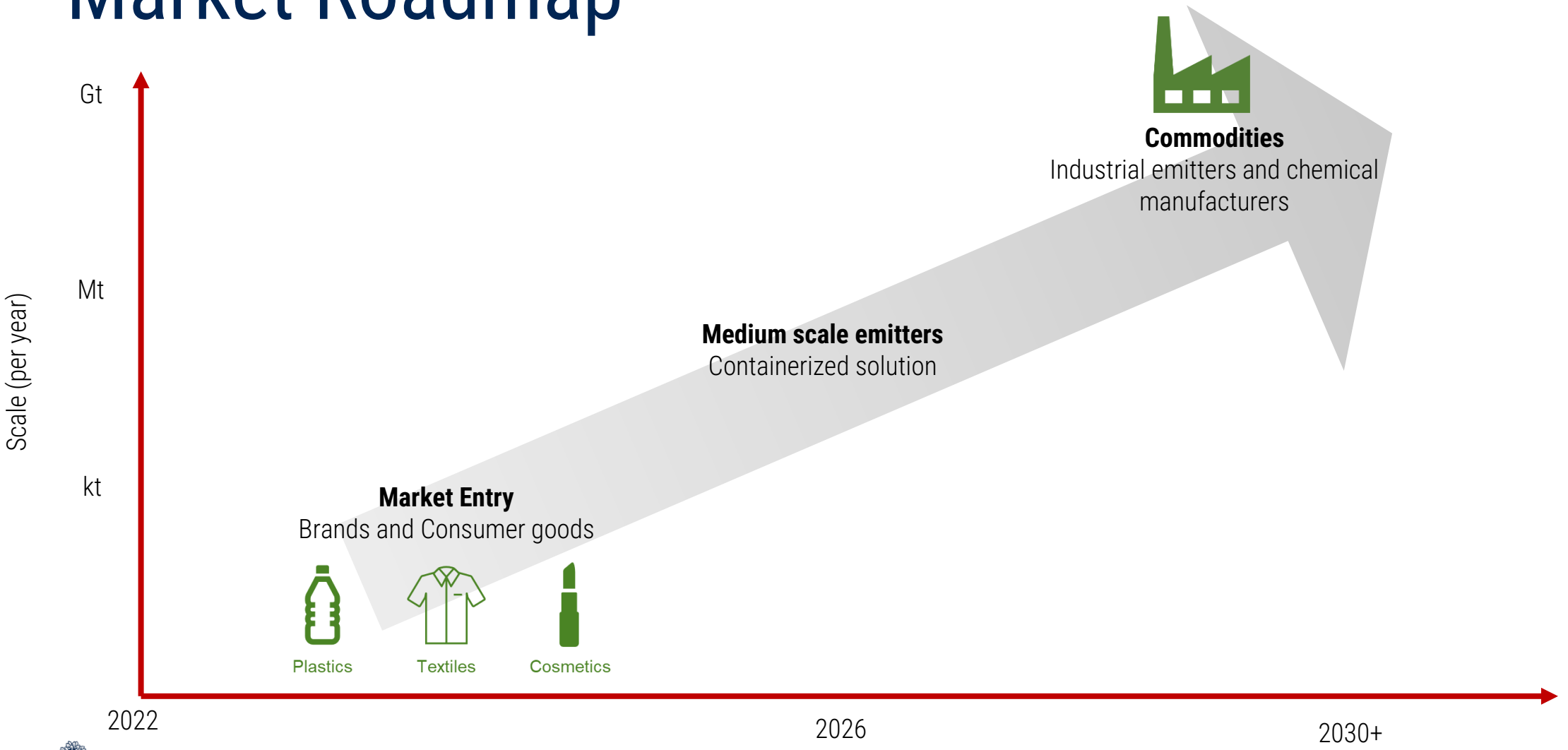


The world's largest CO_2 electrolyzer demo

The first to convert CO_2 to ethylene

Breakthrough Energy Fellows

Market Roadmap



Seeking

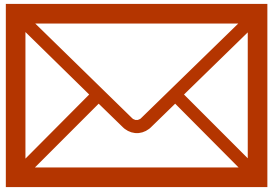
Partnerships and advisors

Scale up

Strategy

Pilot opportunities

End users



Fundraising

We are currently planning a Seed Round for 2022

Thank you.

Contact us: info@cpe.utoronto.ca
jonathan@co2cert.com
co2cert.com

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CLIMATE POSITIVE ENERGY

RE-ENVISIONING ENERGY SYSTEMS


Partners in
Project Green
A Program of Toronto and Region Conservation Authority

Thank you.