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Energy Digital Twins for Decarbonisation

Brent R. Young
Chemical and Materials Engineering
b.young@Auckland.ac.nz

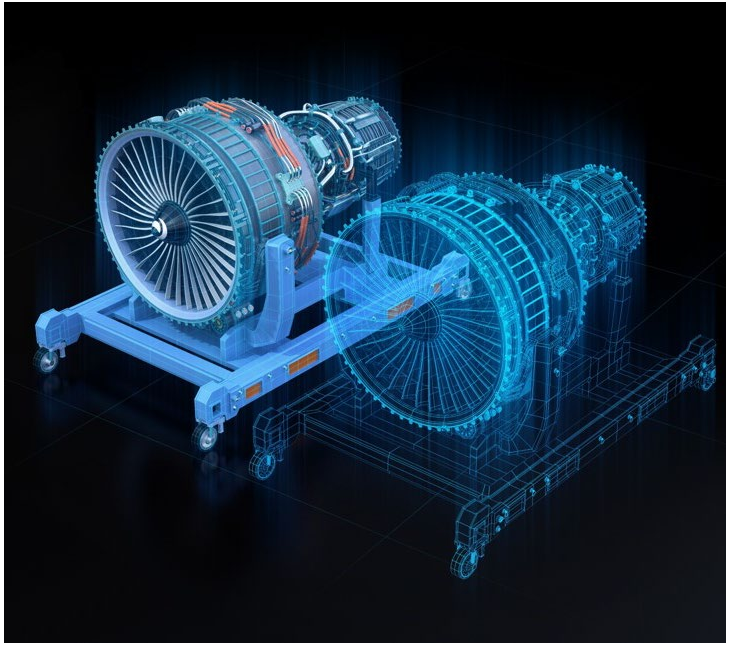
12 April 2024

Agenda

- What are Digital Twins?
- Energy Digital Twins for Decarbonisation
  - Ahuora Research
  - Gaps/Opportunities

Digitalisation word cloud, Chris Hamblin, Keynote, *Advances* 2021

Digital Twins



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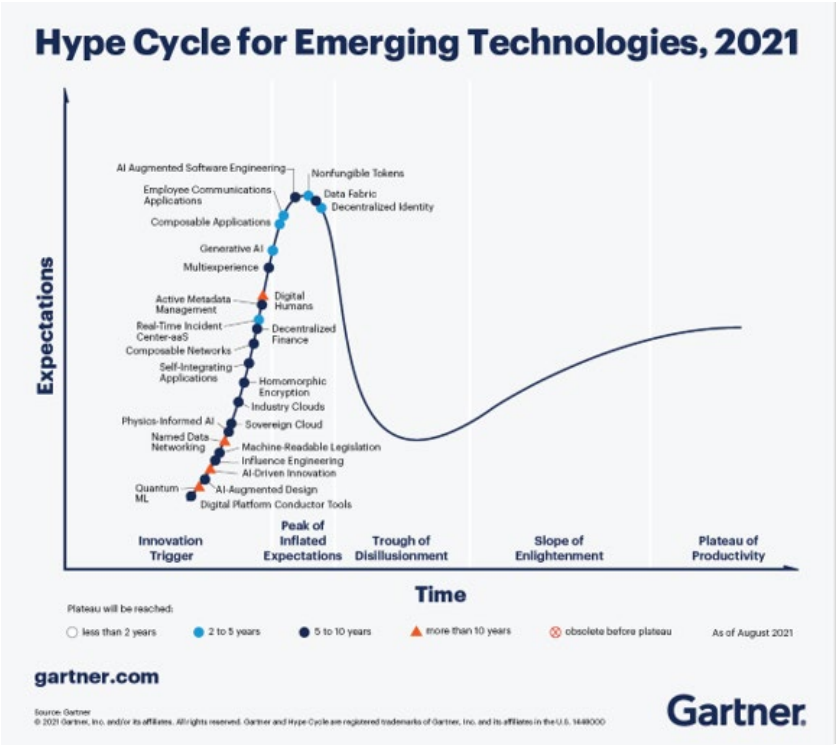
Digital Twins

Hype?

Focus on problem solving

Not just new shiny tech!



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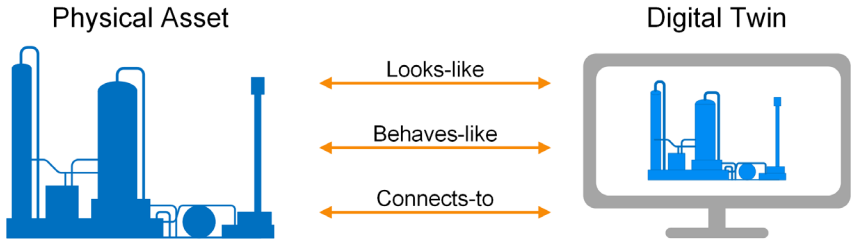
What is a Digital Twin?

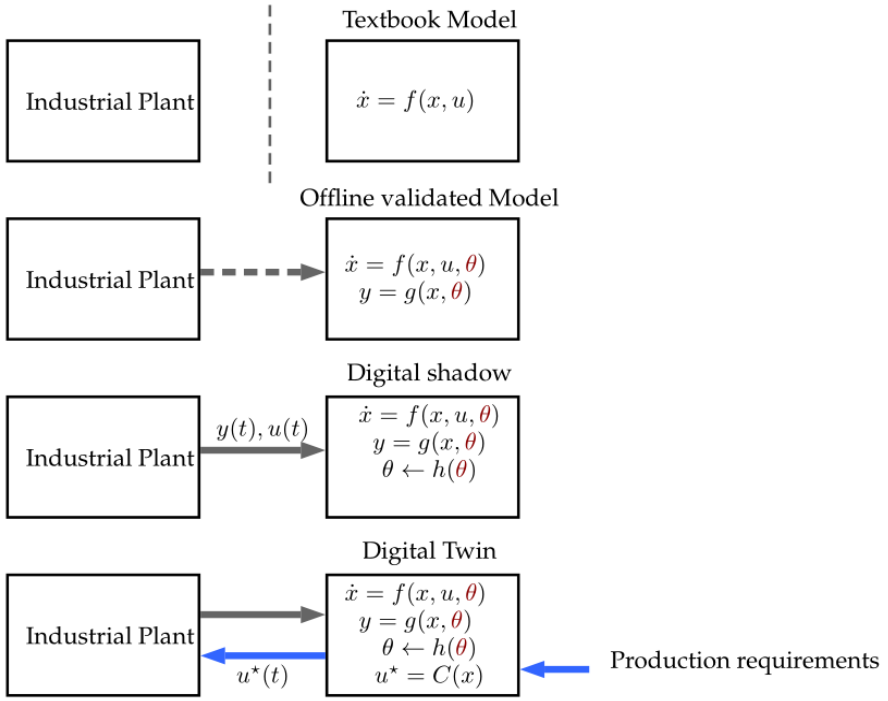
A digital representation that **looks-like**, **behaviours-like**, and **connects-to** a physical system

With the **goal to optimise** decision-making across all time horizons



Digital Twin Classification

- Digital Model
  - Non-automatic data flow
- Digital Shadow
  - One-way automatic data flow
- Digital Twin / Digital Manager
  - Two-way automatic data flow



Digital Twin Classification

Renewable and Sustainable Energy Reviews 161 (2022) 112407

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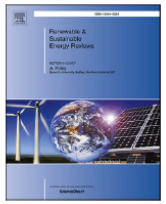
journal homepage: www.elsevier.com/locate/rser

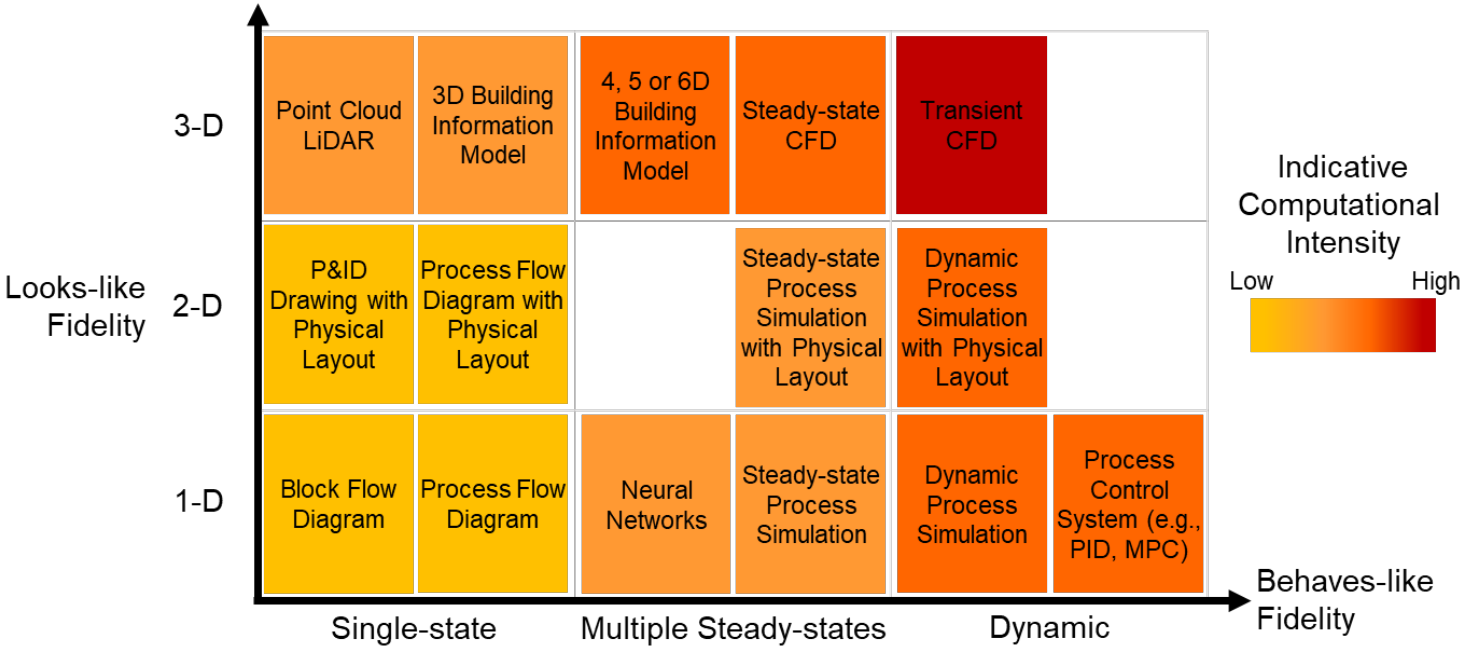


Energy digital twin technology for industrial energy management: Classification, challenges and future

Wei Yu [a], Panos Patros [b], Brent Young [a], Elsa Klinac [c], Timothy Gordon Walmsley [c,*]

[a] Industrial Information and Control Centre, Department of Chemical & Materials Engineering, The University of Auckland, Auckland, 1010, New Zealand
[b] ORKA – Cloud and Adaptive Systems Lab & Ahuora – Centre for Smart Energy Systems, Department of Software Engineering, University of Waikato, Hamilton, 3240, New Zealand
[c] Ahuora – Centre for Smart Energy Systems, School of Engineering, University of Waikato, Hamilton, 3240, New Zealand

Digital Twin Classification



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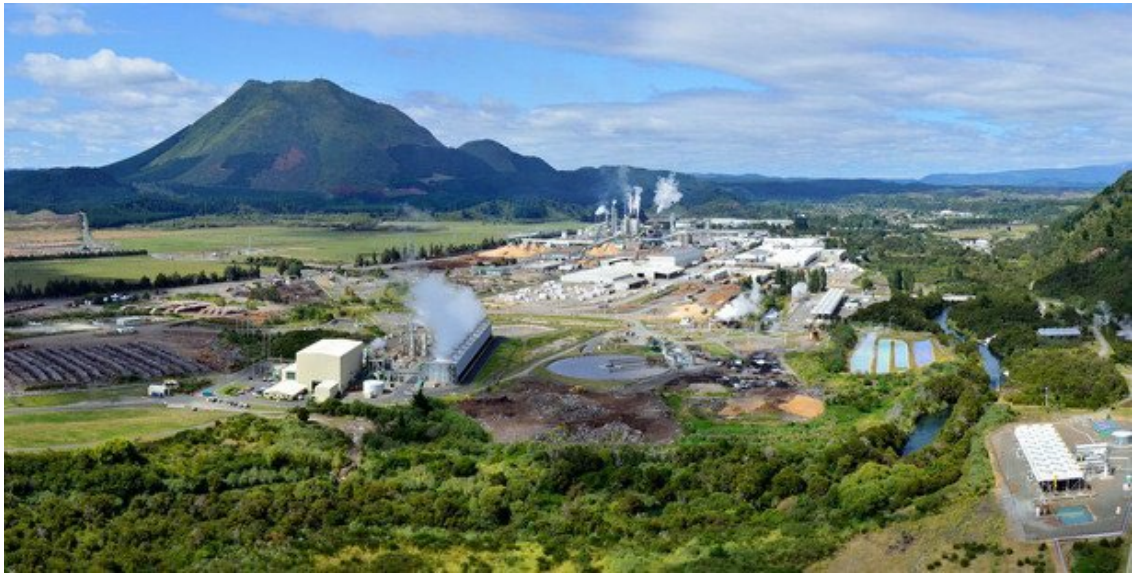
Energy DTs



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Energy Digital Twins

AHUORA
CENTRE FOR SMART ENERGY SYSTEMS

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Advanced Energy Technology Platform

Govt funded, industry support
$12.5 Million / 7 years
12 initial industry partners
rep >50% of NZ process industry
Started October 2020

11 Academics
3 Post Docs
12 PG students
15 UG students

Ahuora Research

- **Energy Digital Twins for Process Heat Decarbonisation**
- Re-engineer the way we **use**, **convert**, and **provision** energy for process heat using a smart systems approach

Plant efficiency **Boilers & Heat pumps** **Renewable energy**

- Produce open-access software tools for NZ industry
- Develop the next generation of **Digital Twin** technology called a **Adaptive Digital Twin**

Smart design and operation

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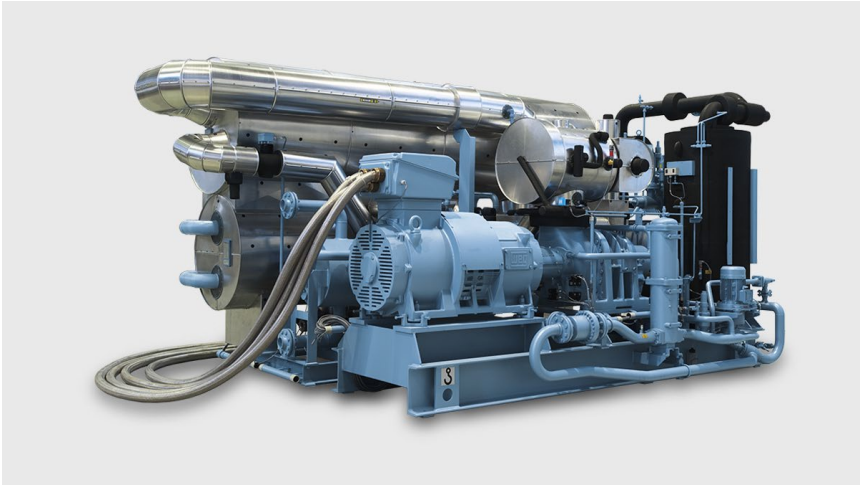
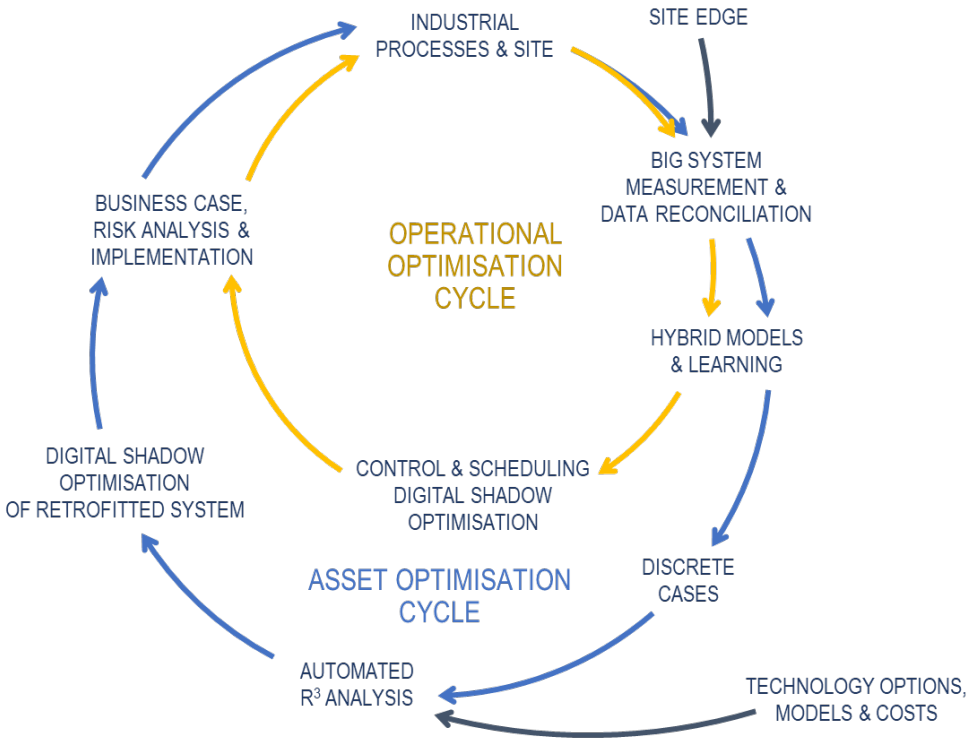
How will Digital Twins help?

- Real time optimisation & control
- Evolve Energy Assets for efficiency
  - Retrofit, Replace, Retire (R3)
- Integration and optimisation of energy
- Energy storage
- Energy procurement
- Emissions management



Example
Industrial Heat Pumps
Design, Integration & Operation

DTs & Improvement Cycles



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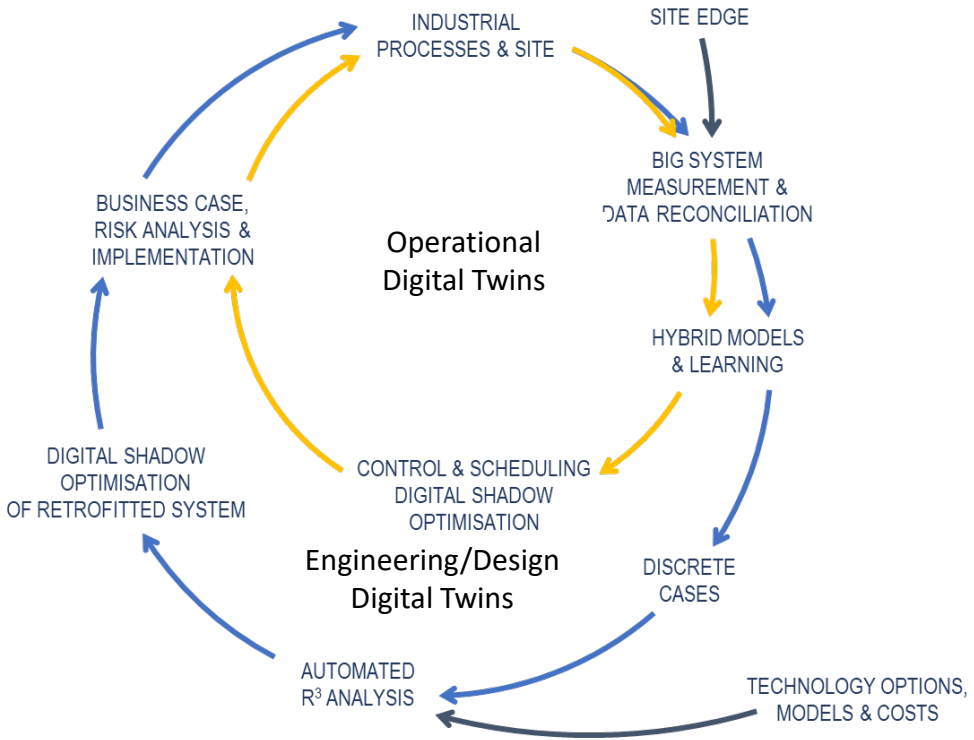
DTs & Improvement Cycles



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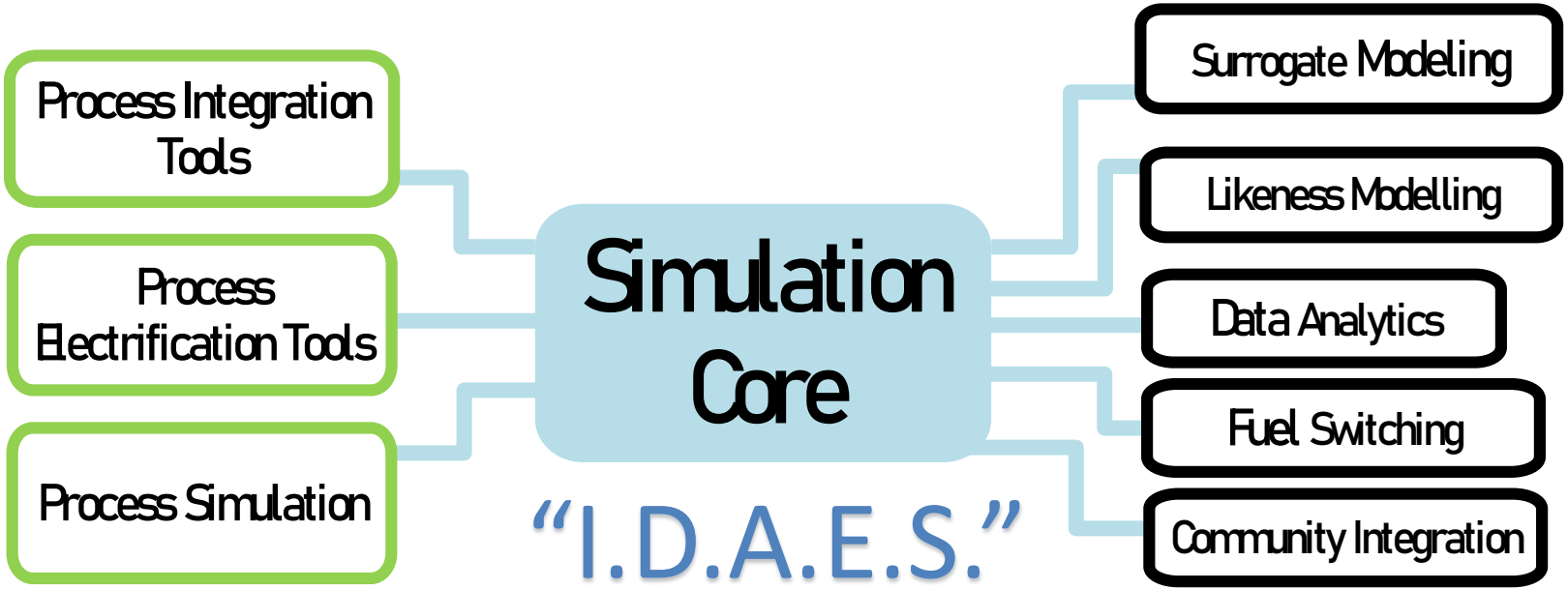
Tool Development

- Tool development necessary
- Existing ones are rebranding
  - e.g. process simulation
- New methods to exploit industry 4.0, IoT, big data, machine learning
- Integration between DTs
  - e.g., energy DT & business DT

Open Source Platform



"I.D.A.E.S."

Institute for Design of Advanced Energy Systems

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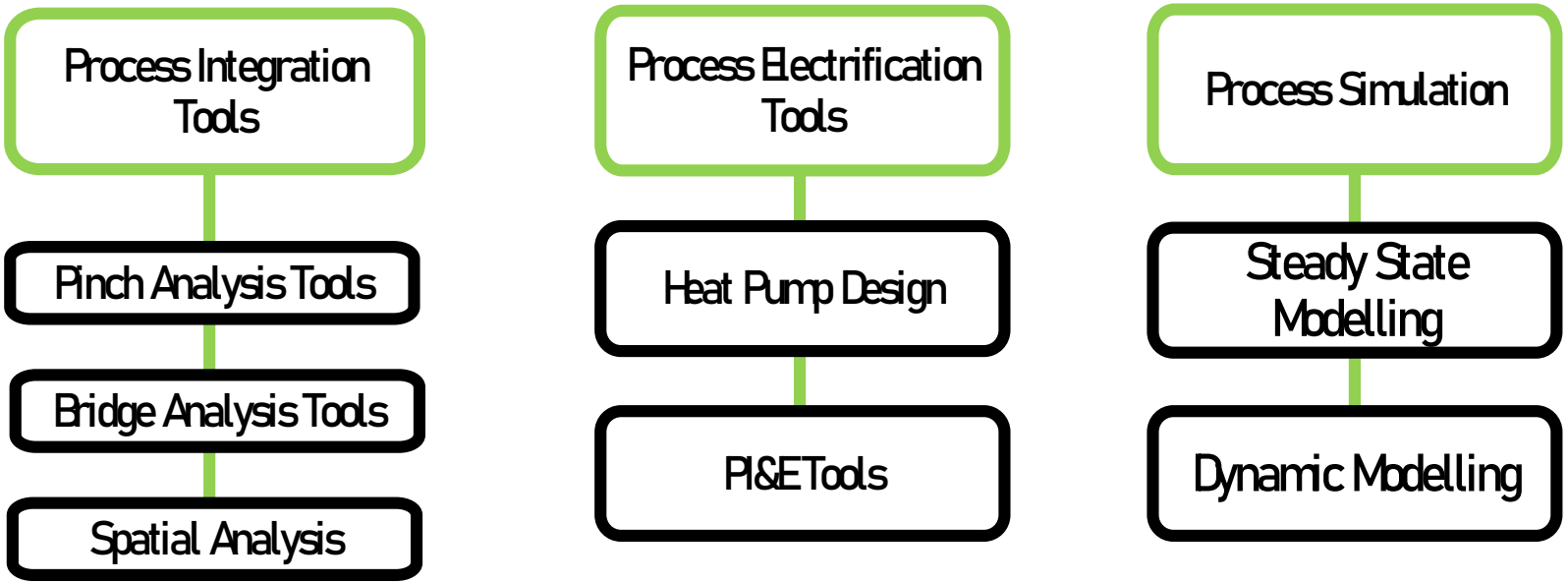
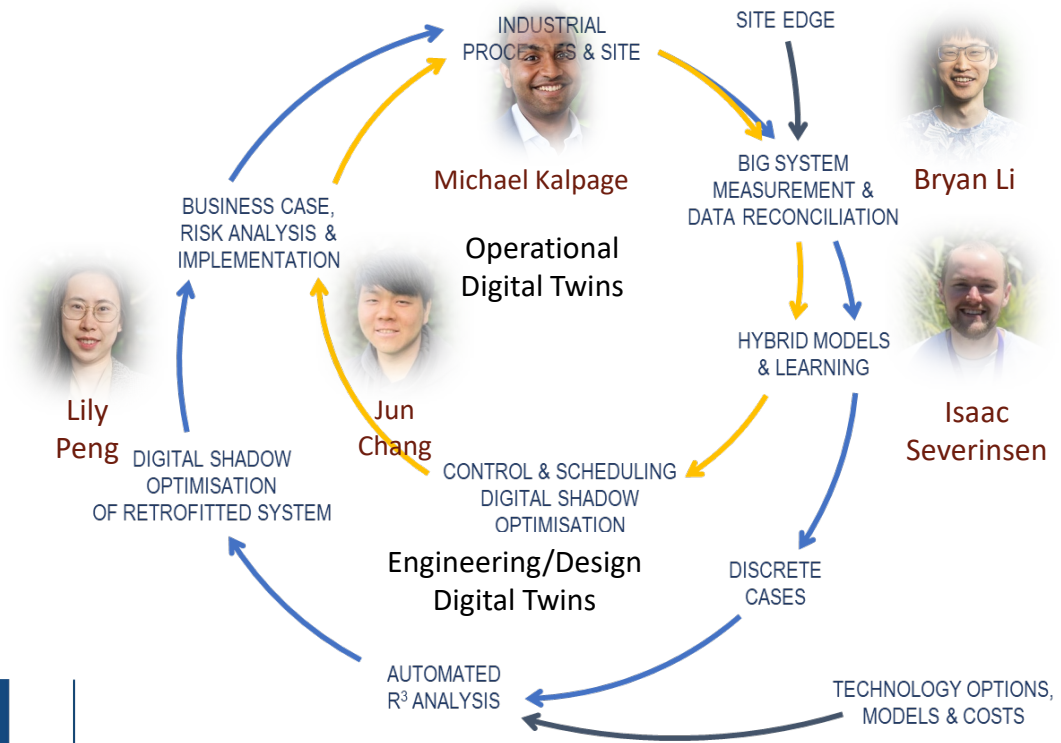
Open Source Platform



UOA Ahuora Research



Michael Kalpage

Bryan Li


Wei Yu

Lily Peng

Jun Chang

Isaac Severinsen


Tonn Aeowjaroenlap


Brent Young

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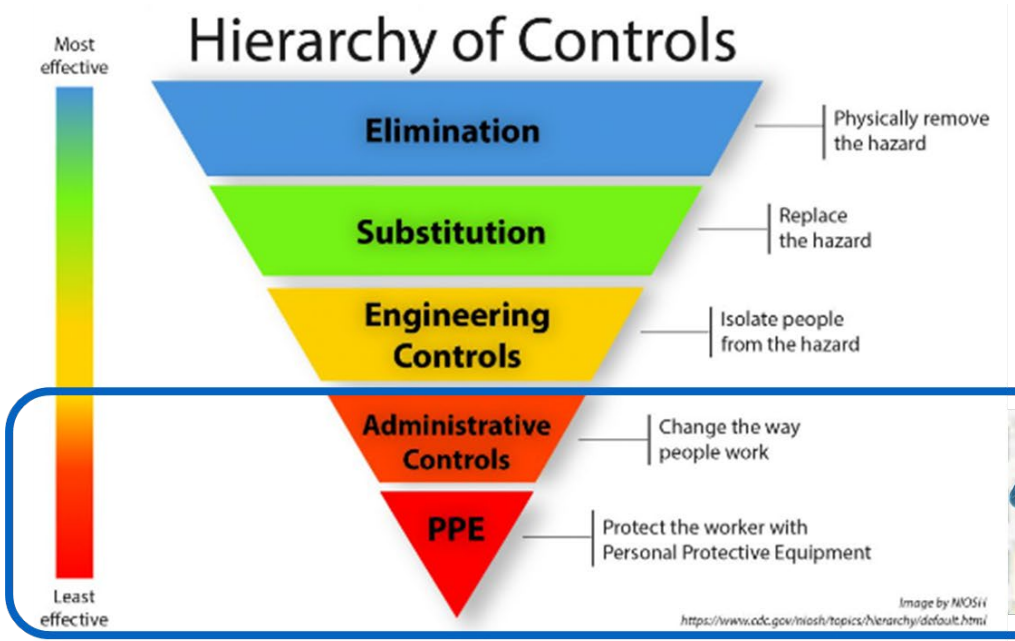
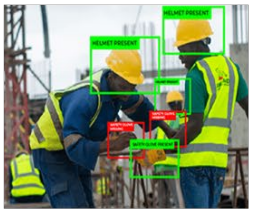
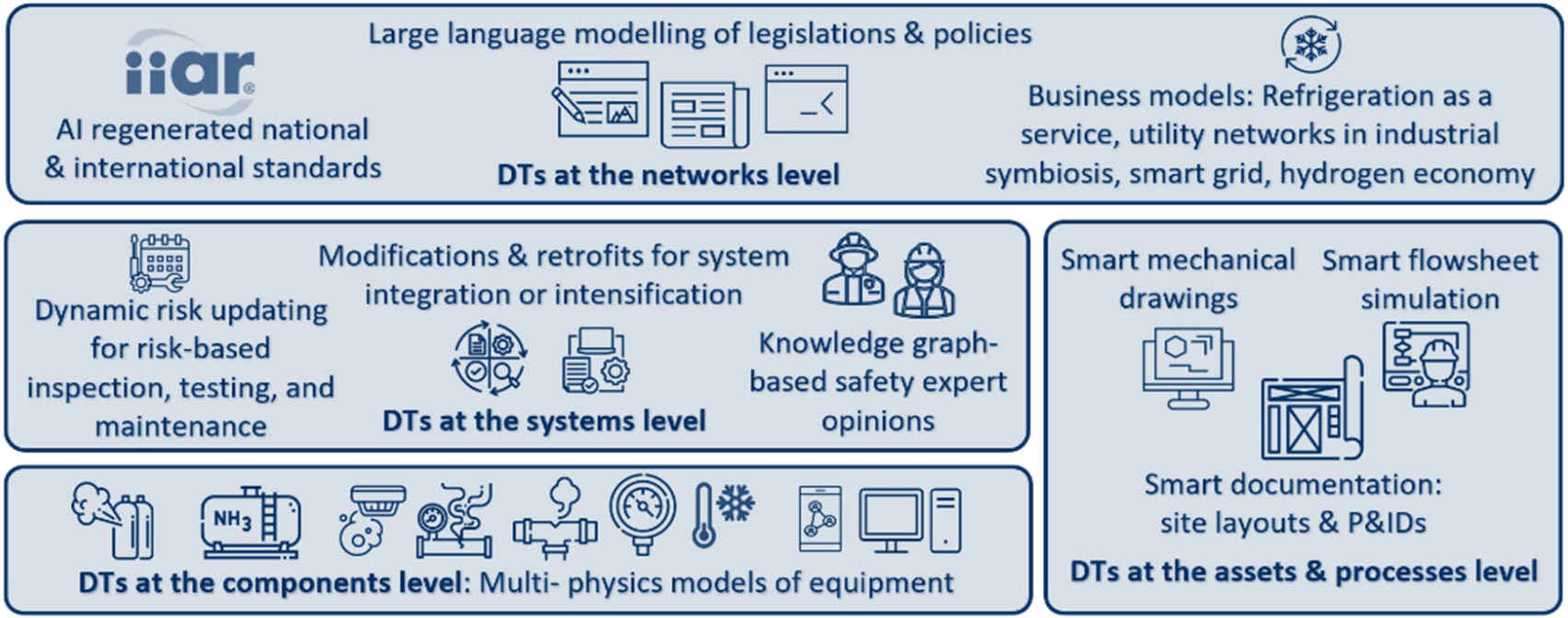
Process Safety DTs





Lilly Peng

Process Safety DTs



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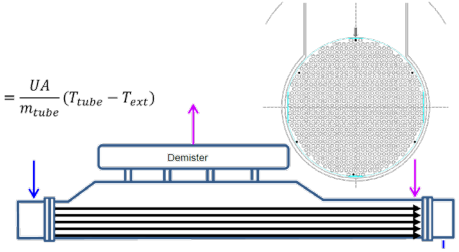
A Case Study: Process Safety **Digital Twins** for Ammonia Refrigeration System

Digital Modelling

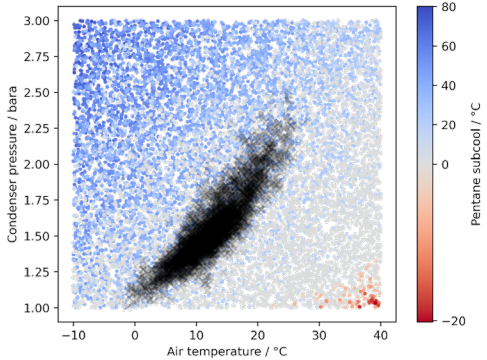
Isaac Severinsen

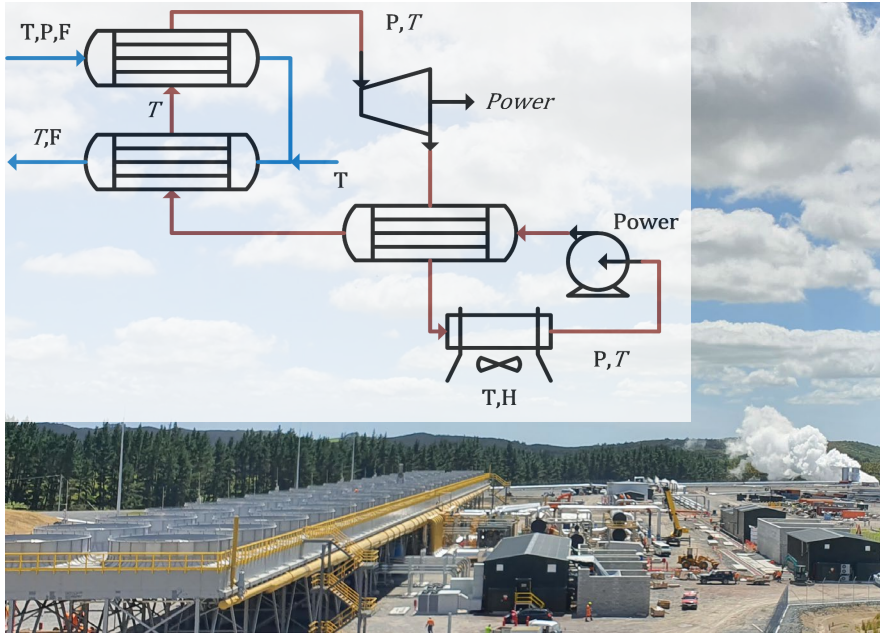
- **Efficient, dynamic, digital twin models** of unit operations using modern regression
- First Principles:

$$\frac{dH}{dz} = \frac{UA}{m_{tube}}(T_{tube} - T_{ext})$$



- Data Driven:





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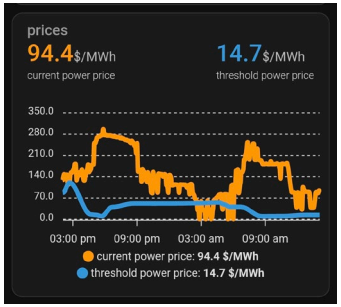
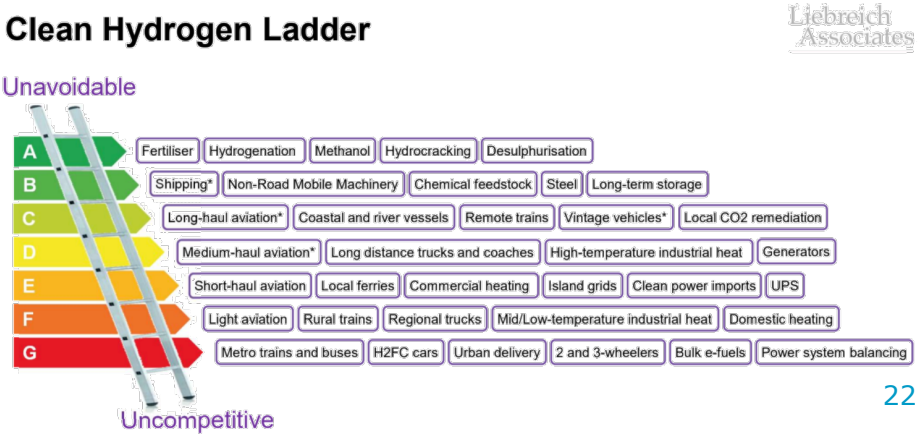
Digital Modelling

- **Demand Response**
  - Residential
    - Hot water
  - Industrial
    - Hydrogen





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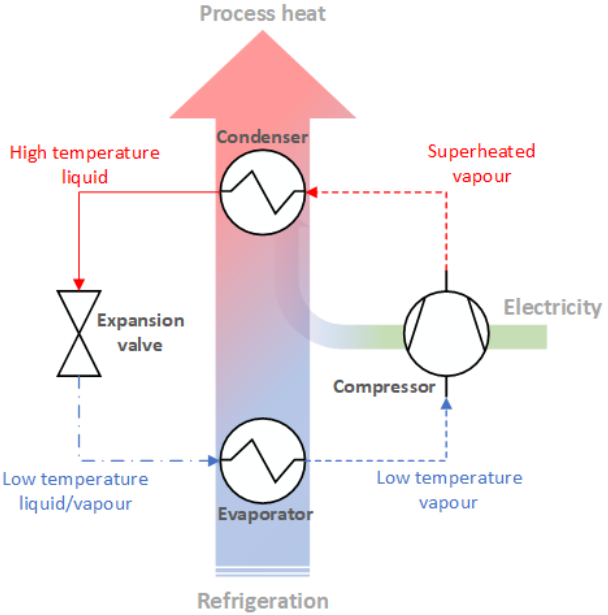
Time Series Forecasting

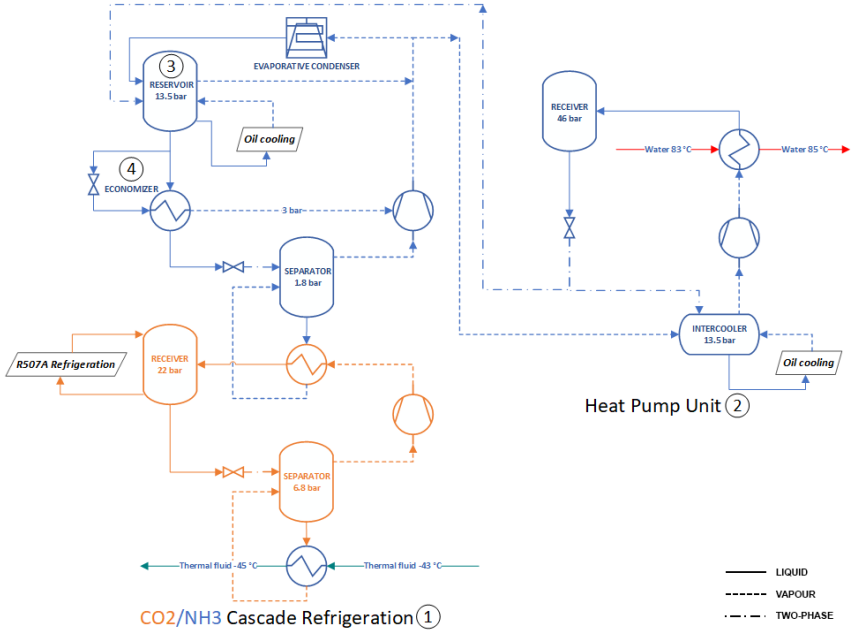
Tonn Aeowjaroenlap

Machine Learning for Time Series Forecasting

- Machine Learning Approach: Trends, Patterns, Fluctuation, Outliers
- Time Series Modelling: e.g., Naïve, ARIMA, ANN
- Applications: Process and Energy Optimization in the Dairy Industry

Refigeration Control





Jun Chang

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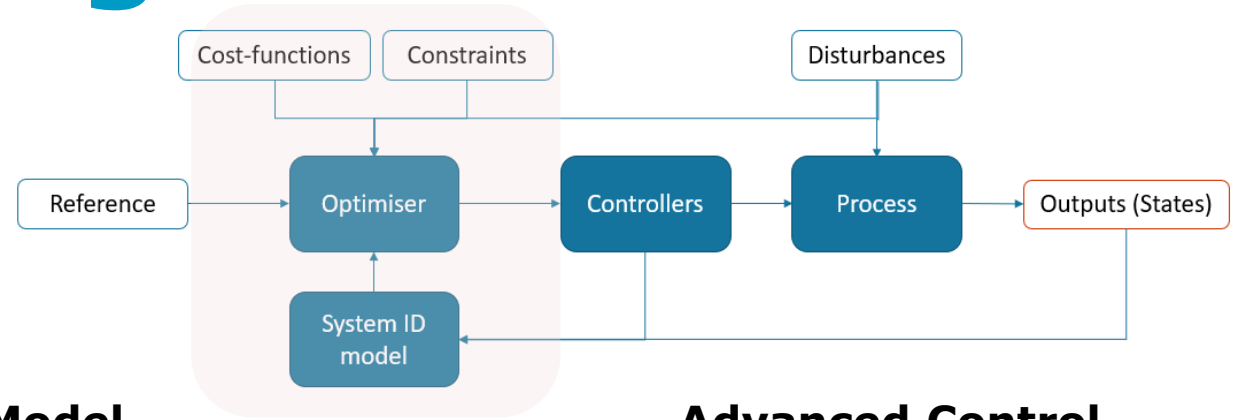
Refrigeration Control



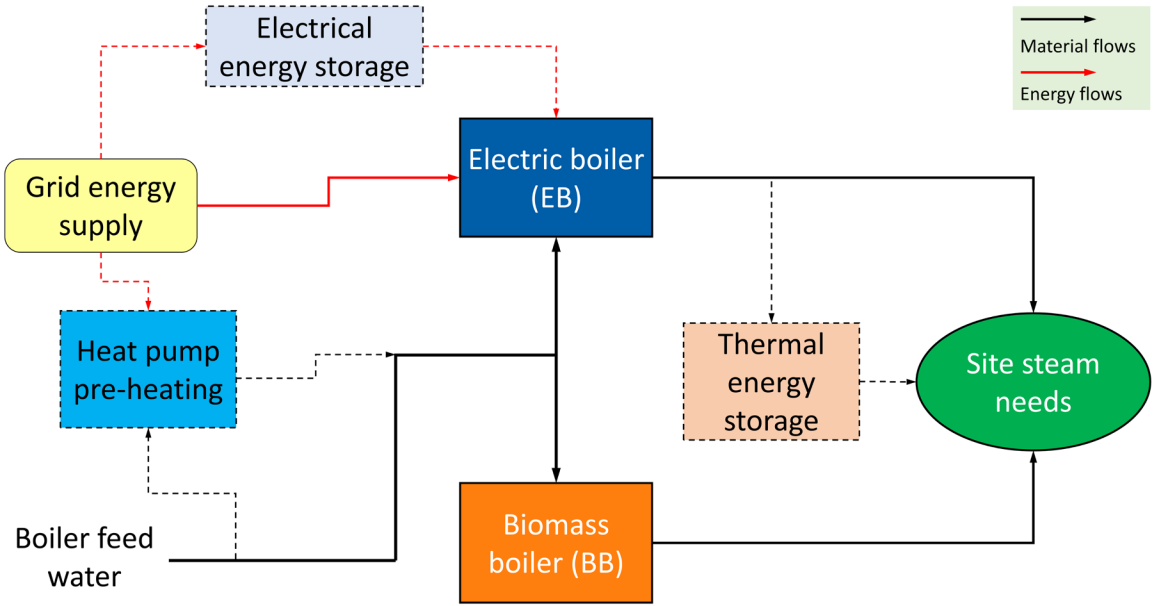
Dynamic Model

- Identifying operational issues and potential improvements
- Developing advanced control methods

Advanced Control

- Stable operation closer to design
- Economic benefit

Industrial energy flexibility

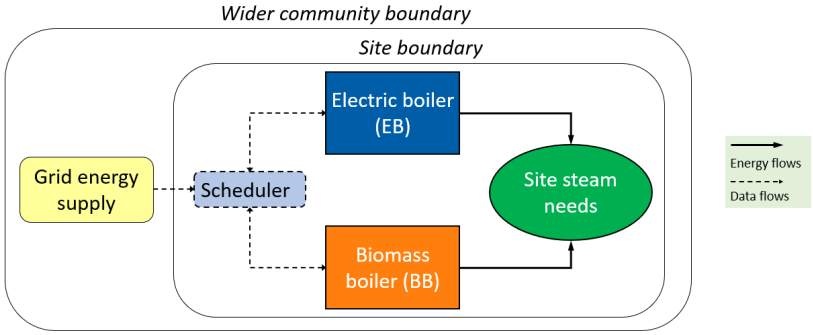


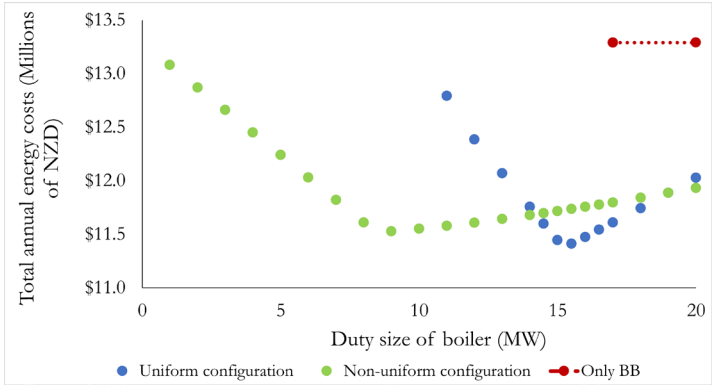
Michael Kalpagé

Industrial energy flexibility

- Simulation approach
  - 30-minute time intervals
- Determining best use of cheap energy

- **Next steps:**
  - Stochasticity
  - Multi-criteria assessment
  - Reinforcement learning(?)
  - Forecasting revisit





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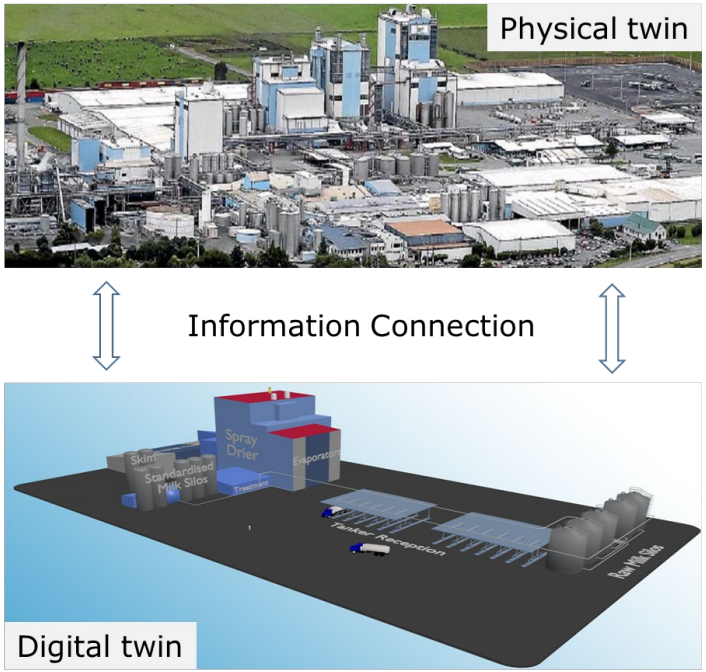
Multi Plant Clusters

Dynamic Large Scale Digital Twin for Optimization of Multi-plant Industrial Clusters

Bryan Li

- To develop a novel digital twin to dynamically simulate and optimize the use of energy and product streams for large-scale multi-plant industrial clusters.
- To ultimately identify the types of new businesses which could join the cluster to bring about mutual benefits.

Energy and Business DTs



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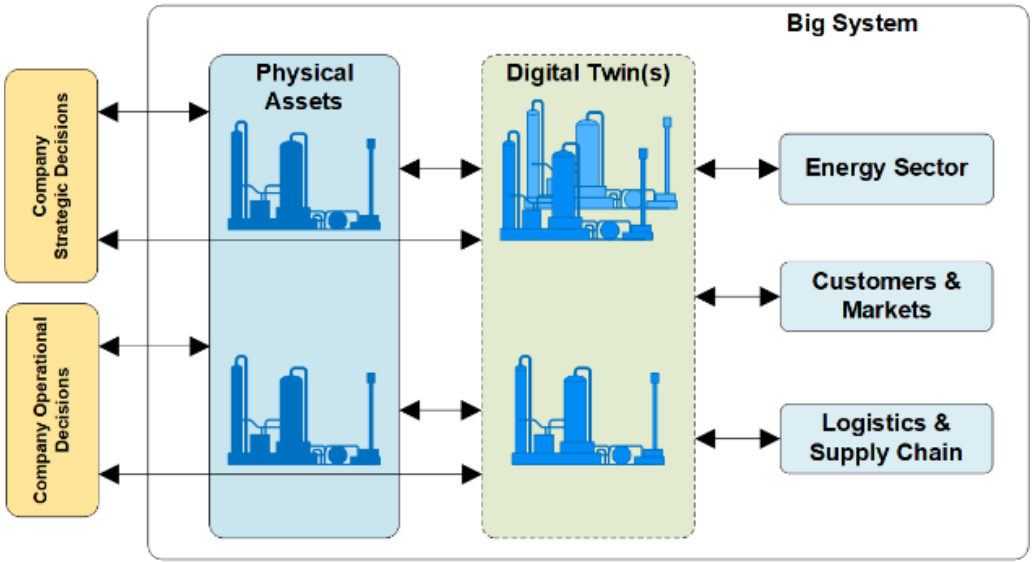
Energy and Business DTs

- In this talk and in our research we have so far focused on company level DTs
- For decarbonization & demand response, DTs **need** to include: The '**Big System**', i.e., the company, the grid, and the community DTs



New research proposed

Energy Demand Response Dynamic Digital Twins

- A system and a framework of dynamic digital models and twins
- That will integrate energy digital twins and business digital twins
- To provide optimal demand response and flexibilization for industry, business and residential

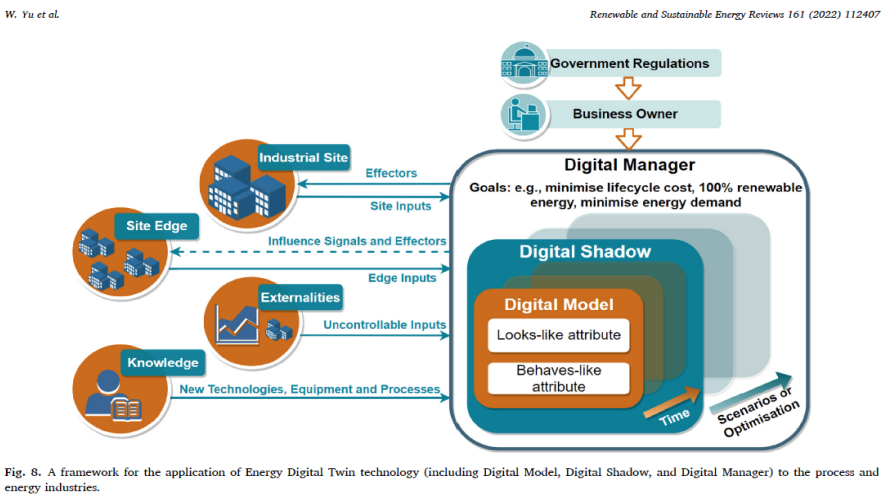


Fig. 8. A framework for the application of Energy Digital Twin technology (including Digital Model, Digital Shadow, and Digital Manager) to the process and energy industries.

Acknowledgments

- MBIE for funding of the Ahuora Advanced Energy Transformation Program
- Colleagues and collaborators at University of Auckland, University of Waikato, Massey University and our industrial partners

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