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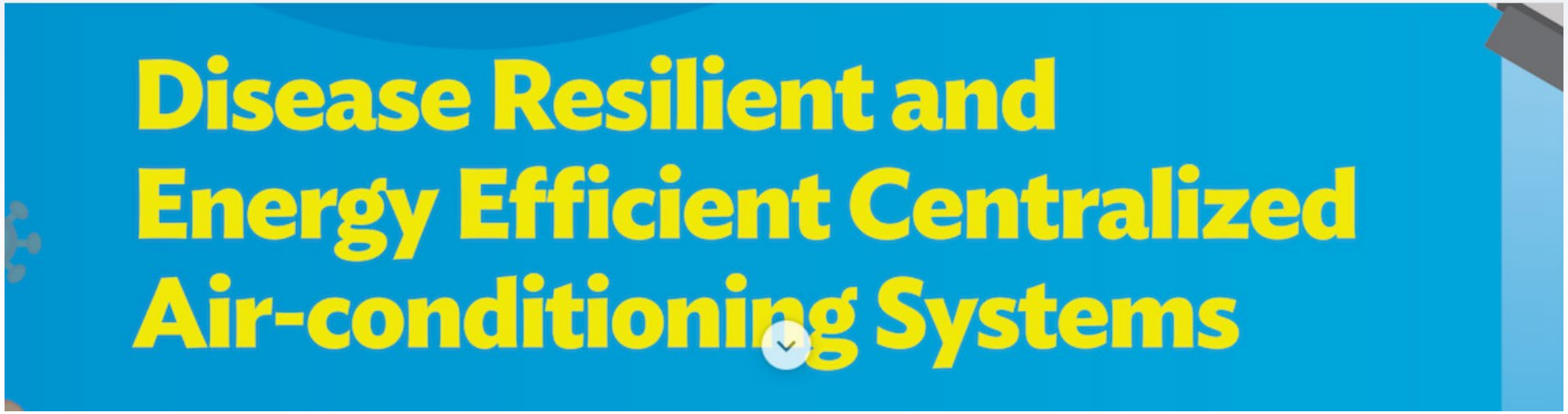
ADB

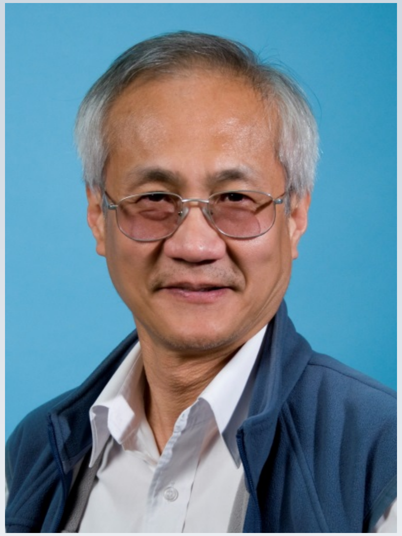
Modelling for Control

Lu Aye

ADB TA-6563 Webinar Series, 15 September 2021



Presenter



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Acknowledgements

"I acknowledge the Traditional Custodians of country throughout Australia and their connections to land, sea and community. I pay my respect to their elders past and present and extend that respect to all Aboriginal and Torres Strait Islander peoples today."

Huang Donglan (Megan), Guangdong Electric Power Design Institute

Jinmiao Xu, Energy Specialist, ADB

Yashkumar Shukla, Executive Director, CARBSE, CEPT University

Outline of the knowledge sharing

HVAC System modelling for control

Why do it?

What should it do?

How it get done?

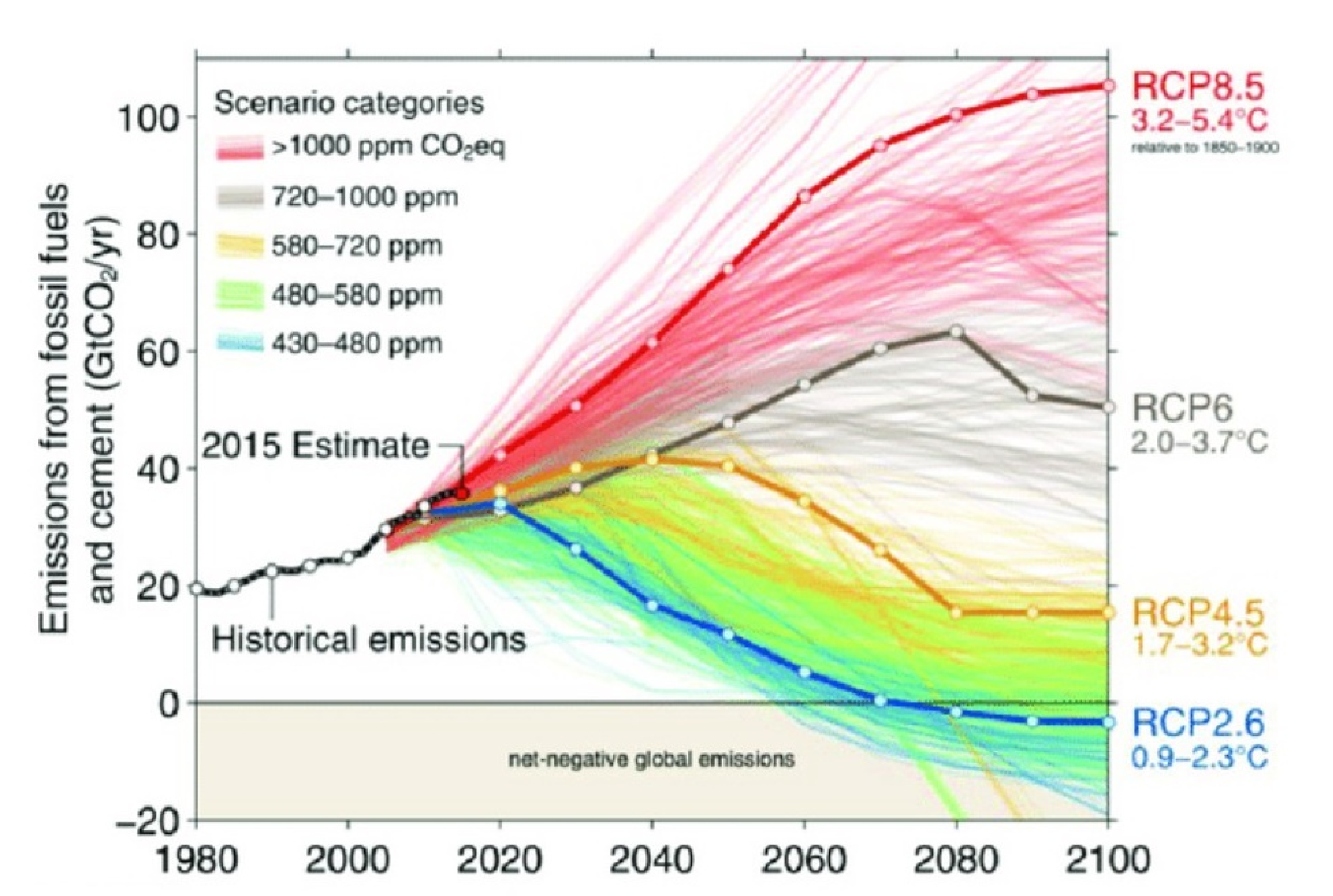
IPCC Representative Concentration Pathways (RCPs)

(https://climatenexus.org/climate-change-news/rcp-8-5-business-as-usual-or-a-worst-case-scenario/)

8.5 worst case

4.5 intermediate

2.6 very stringent



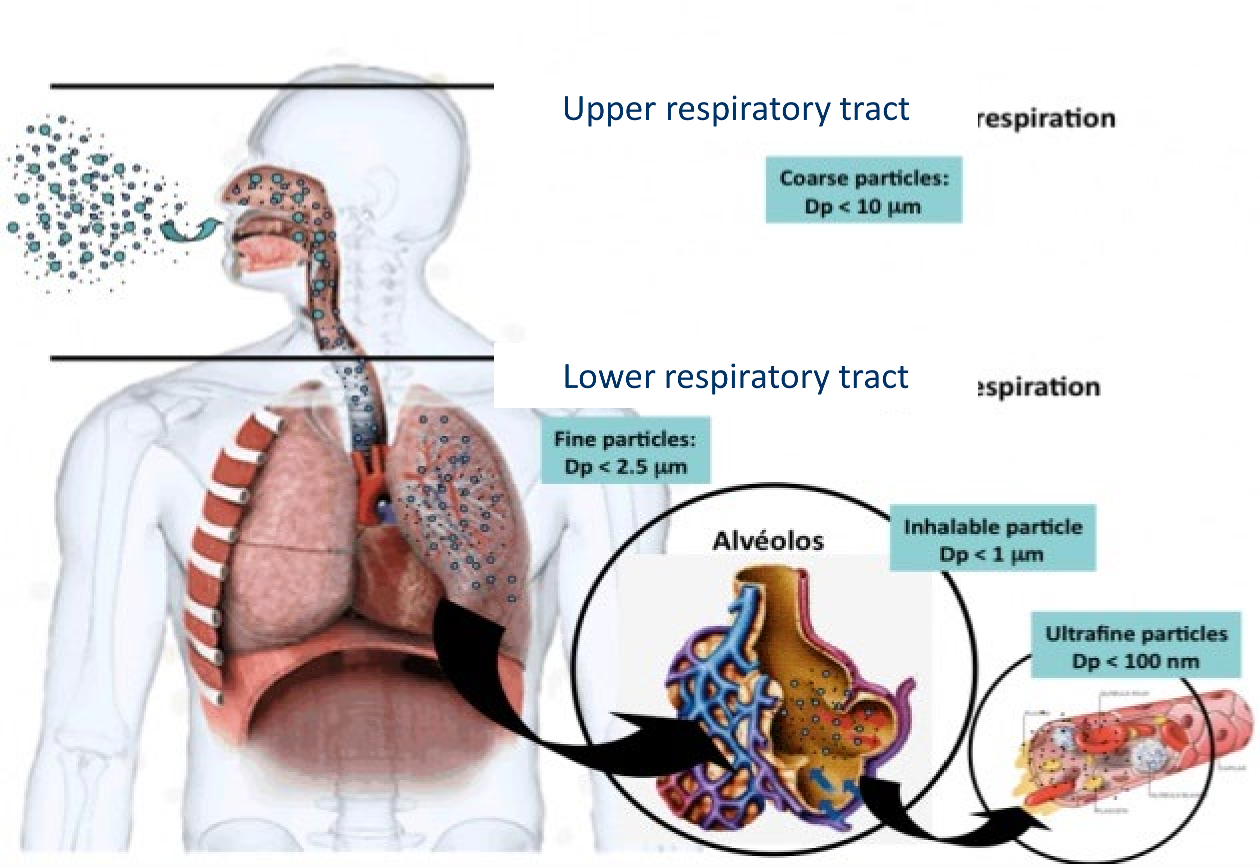
Conditioning air

- Air conditioning provides closely controlled indoor environment necessary for the comfort, working efficiency and well being of a building's occupants.
  - All year round: Ventilating (air movement for odour control)
  - Winter: Heating and Humidification
  - Summer: Cooling and Dehumidification

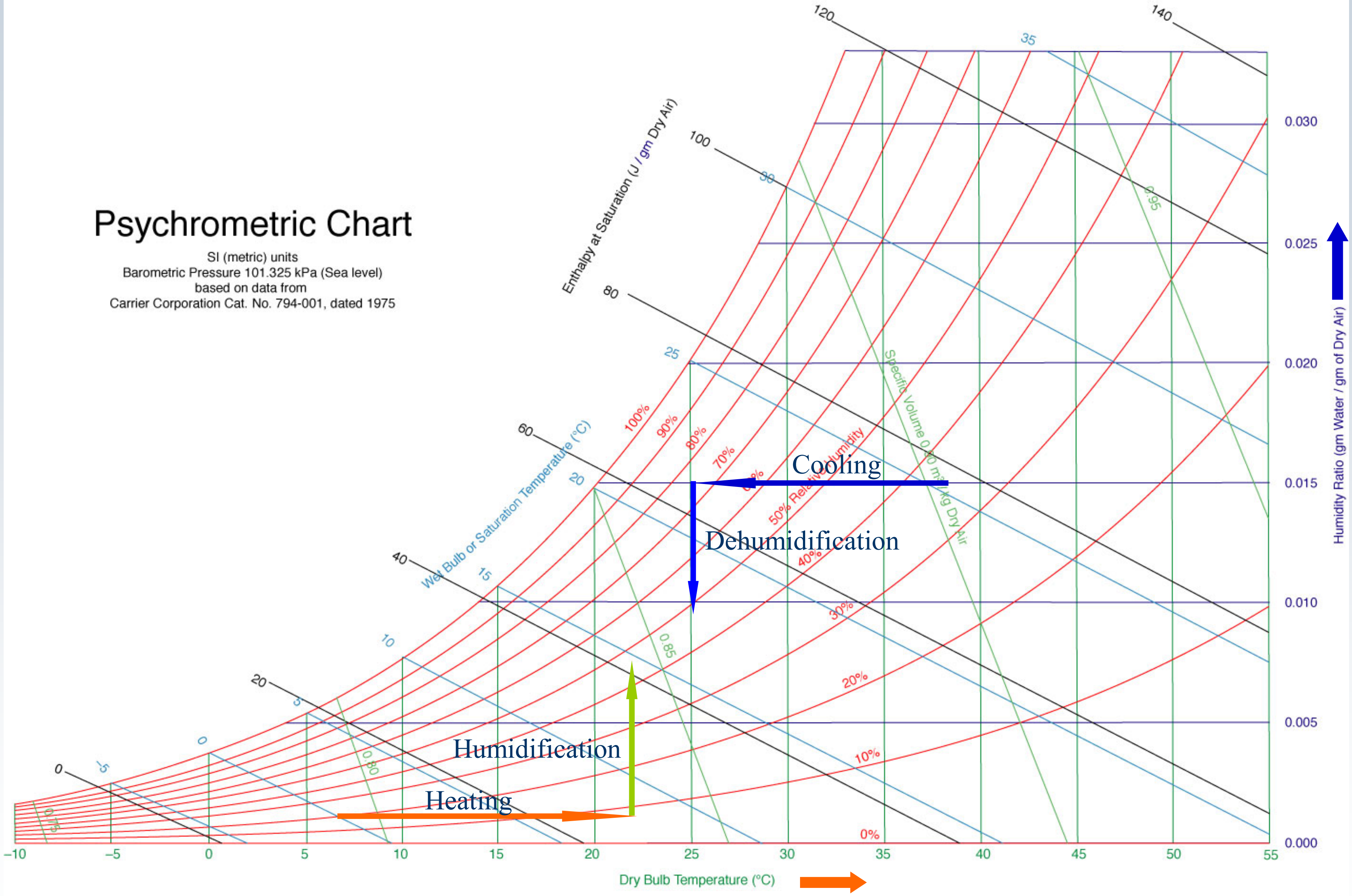
Ventilating

- Ventilating is defined as the supplying or removing of air from a space by mechanical or/and natural means.
- It serves two purposes:
  - Addition or removal of heat and/or humidity from occupied spaces
  - Supply of fresh air to meet health requirements

Deposition of inhaled aerosols in human lung



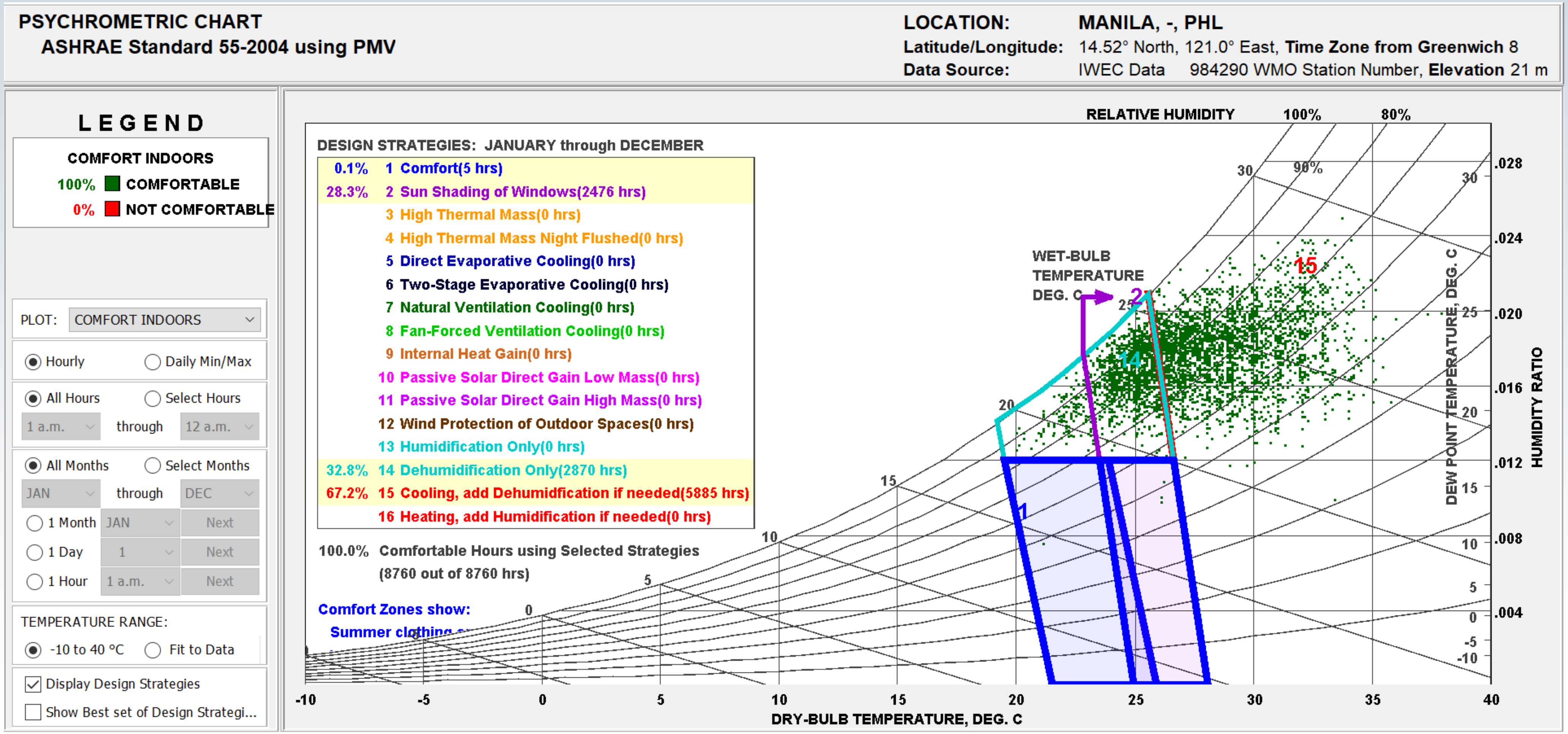
(http://static.bitlanders.com/users/galleries//285465/image4_fa_rszd.jpg)



Adapted from: http://en.wikipedia.org/wiki/Image:PsychrometricChart-SeaLevel-SI.jpg

Manila

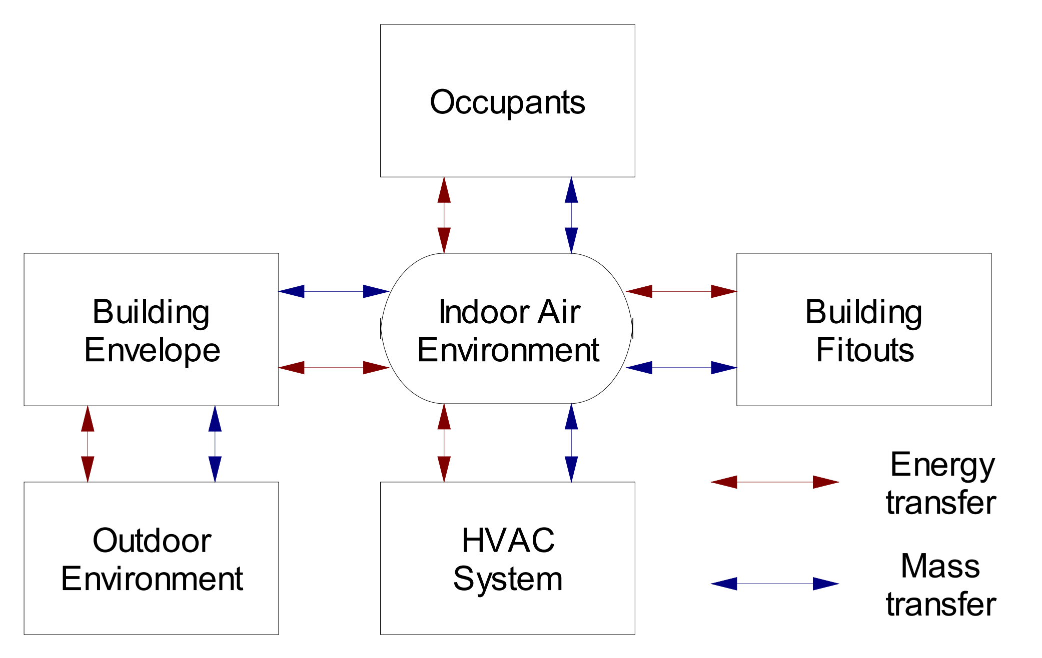
Psychrometric chart plotted using Climate Consultant 6.0.16 (Liggett & Milne 2020)



Indoor air environment

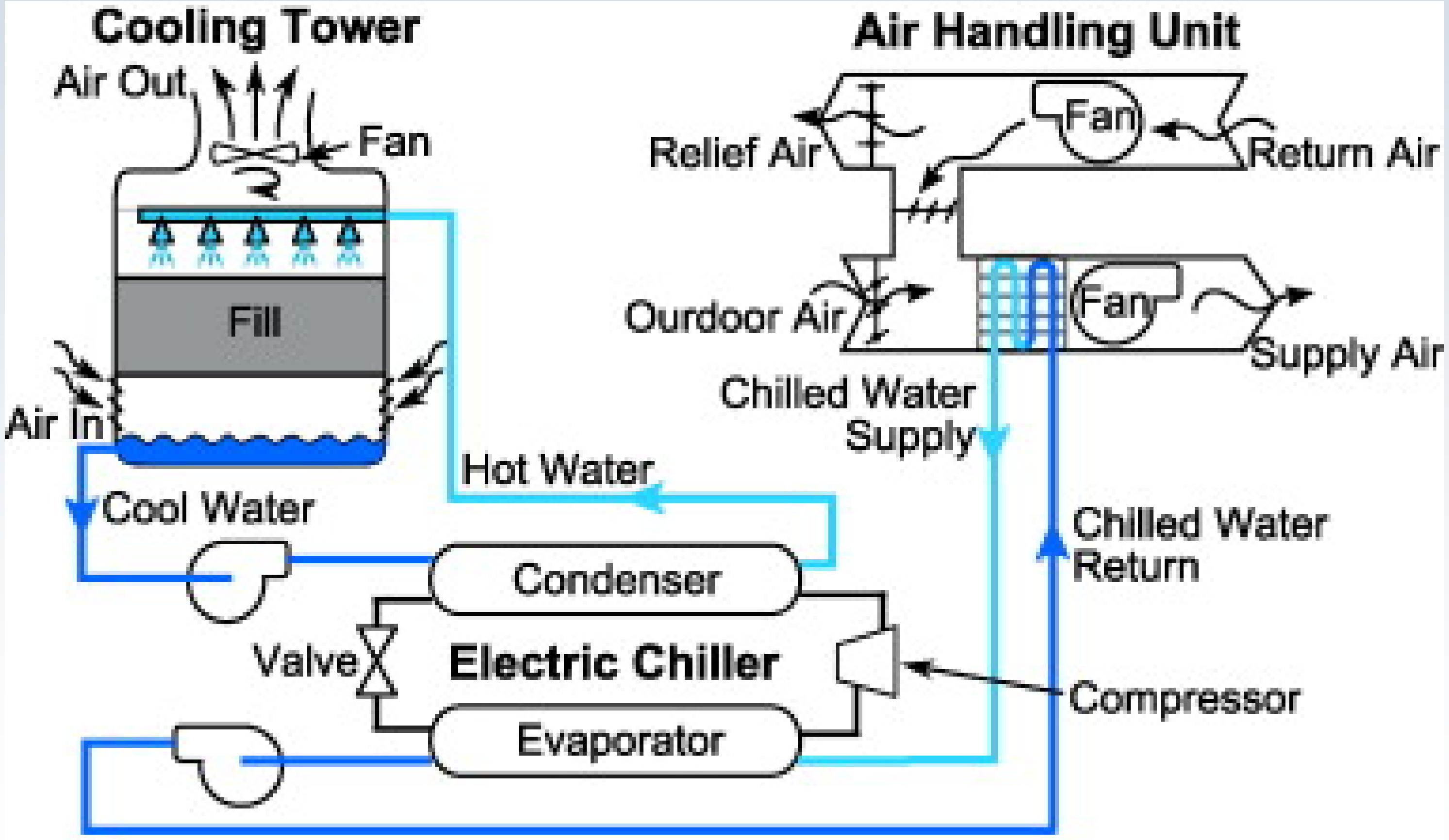
(Aye 2021)

- The indoor air environment is a complex dynamic system
- Main physical transfer phenomena:
  - Heat transfer
  - Mass transfer
  - Momentum transfer (air flow)
- Continuous interaction between outside and indoor environment
- Human intervention or control



- Discrete, non-linear & highly constrained characteristics and parameters

A typical chilled-water HVAC system
(Li et al. 2013)



Why Modelling for Control

- Efficient operation of an HVAC system depends on
  - Control system and
  - Optimisation parameters.
- Control algorithm requires accurate modelling of the system and implementation of appropriate optimisation techniques.

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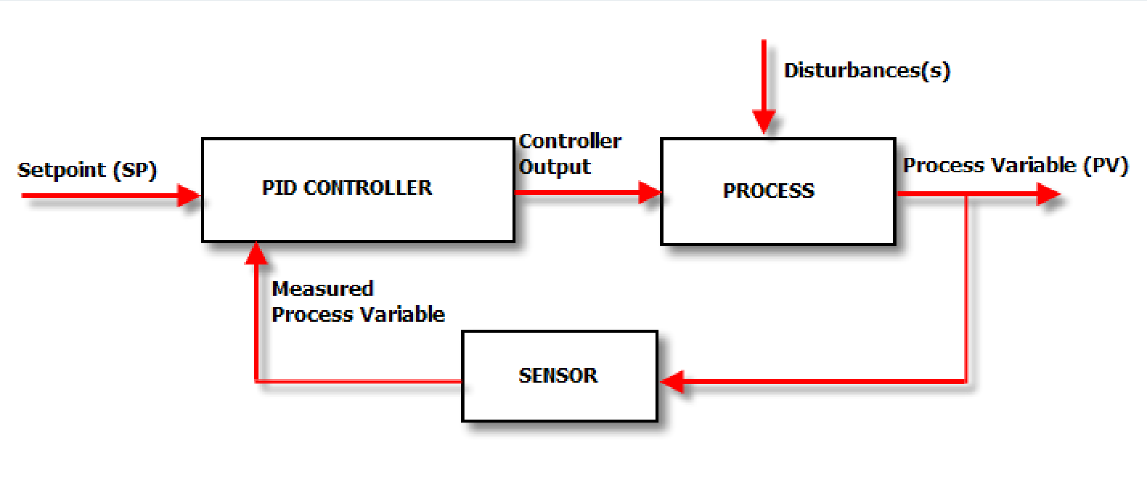
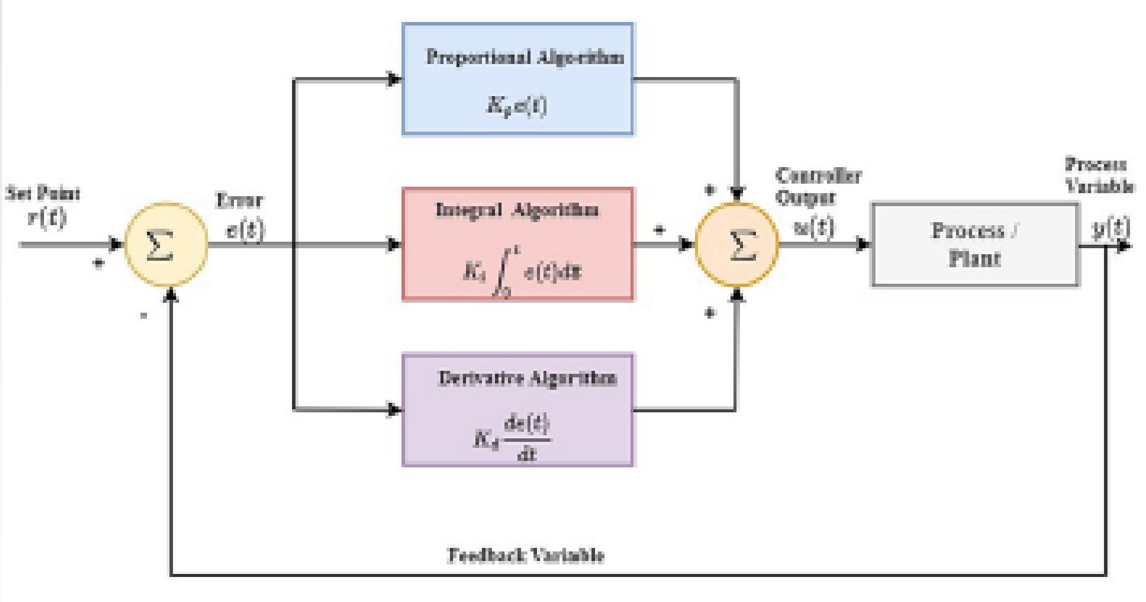
Why is it important?

- Efficient operation of an HVAC system <- depends on its control system.
- System modelling is very important for the control, if you can't accurately model the system, you can't control it well (Huang 2021).

Proportional, Integral, Derivative (PID) Control



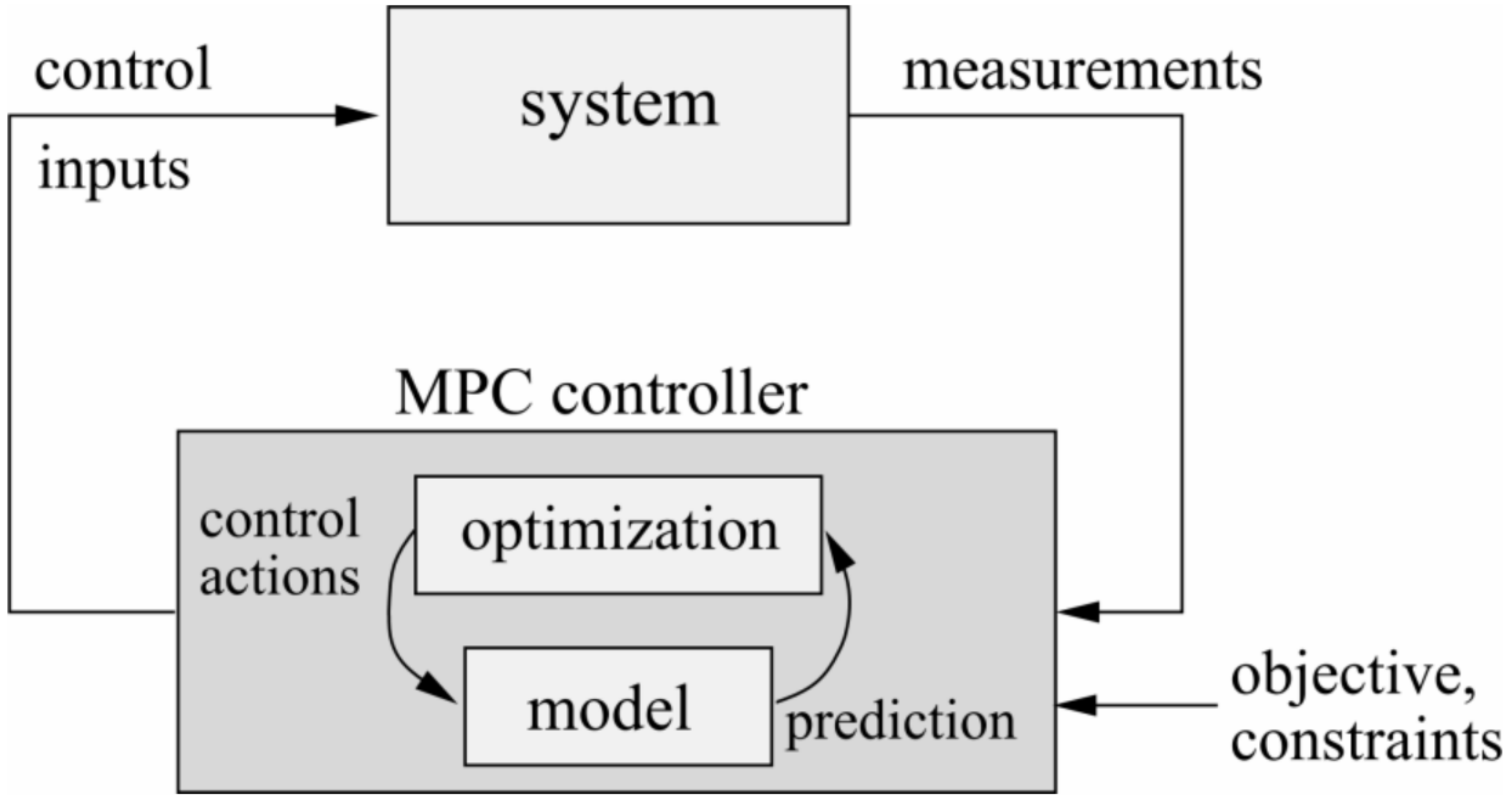
(Peacock 2008)



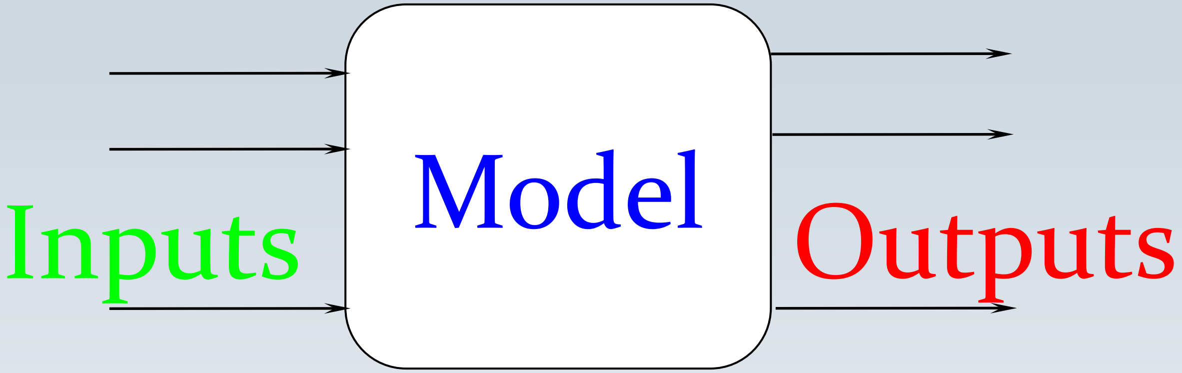
(Borase et al. 2021)

Model Predictive Control (MPC)

(Arnold et al. 2009)



Models



System model = Whole of sub-system and component models

Component model = Series of relationships between output and input variables

Component models

- Chiller, cooling tower, building zone, air handling unit (AHU), mixing box, splitting box, heating coil, cooling coil, humidifier, fan, pump, duct, sensor, damper, valve, etc.

Categories of HVAC system modelling

- Phenomenological or physics-based (or white box/mathematical/forward), deductive, in general continuous and deterministic
- Data-driven (or black box/empirical/inverse), inductive, in general discrete and deterministic or stochastic
- Gray box (or hybrid).

Applications of HVAC system models

- Phenomenological -> developed by applying laws of conservation and primarily use in design stage
- Data-driven -> developed through a process of collecting the system performance data from an existing system; suitable for performance improvements and control
- Gray box (or hybrid).

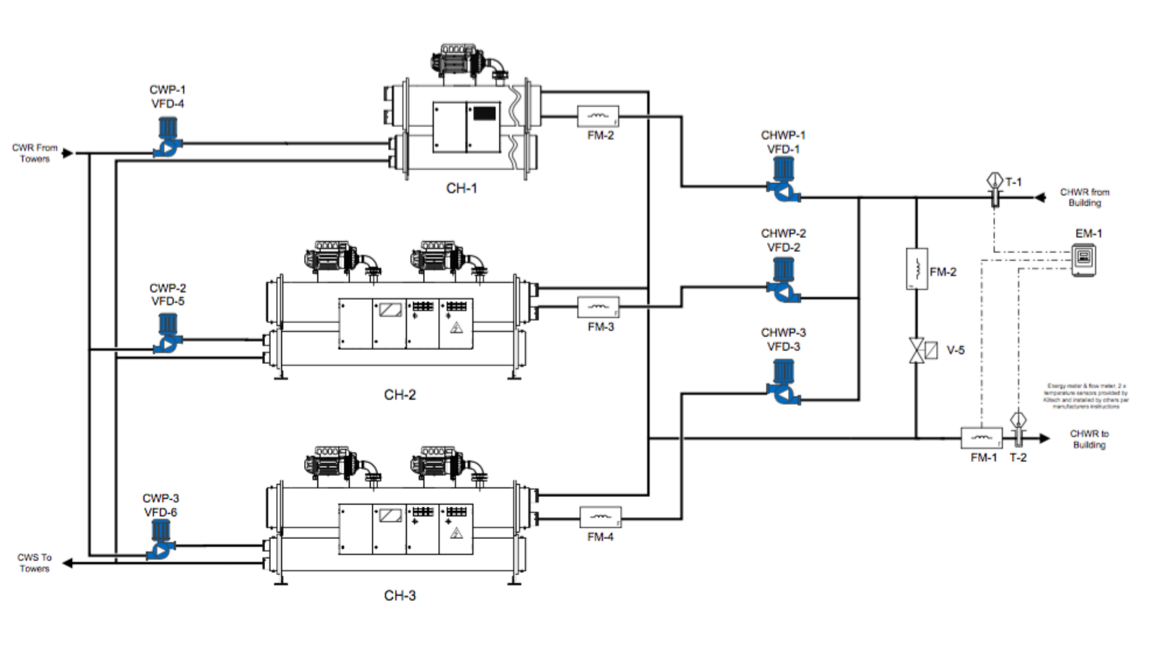
Strengths and Limitations

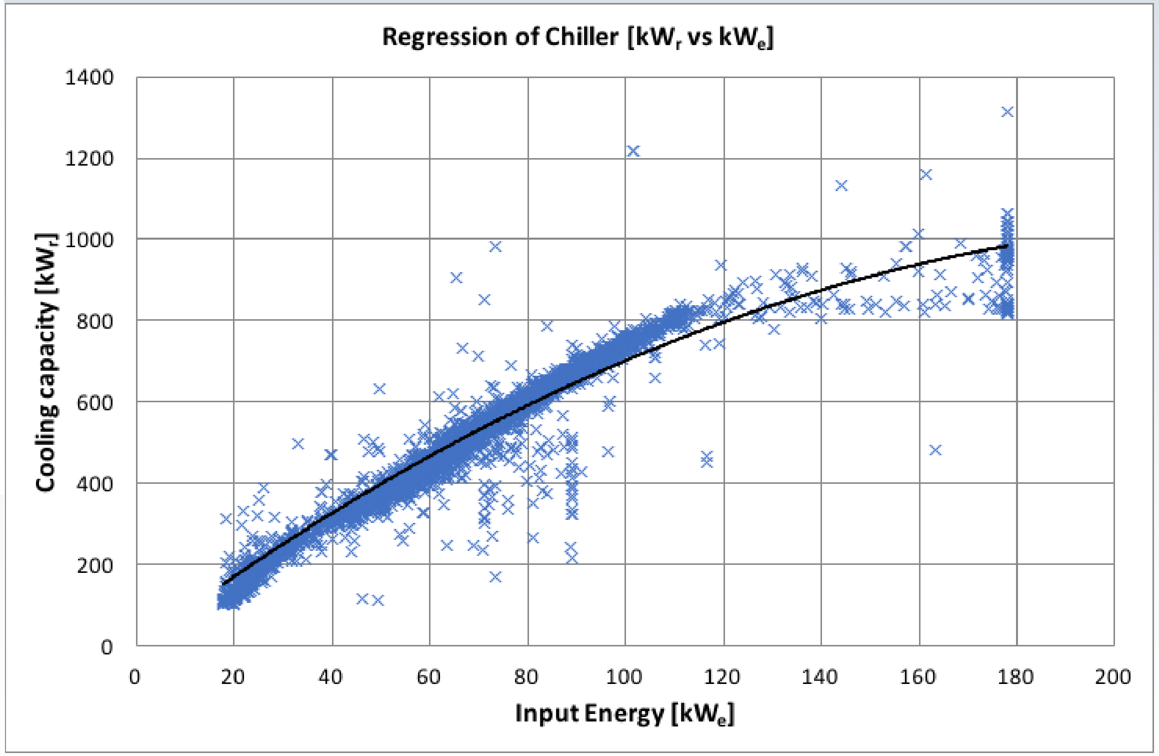
(Extracts from Afroz et al. 2018)

Model	Strenghts	Limitations
Phenomenological	Ease of analysis, Robust generalisation capability, Less training data required,	Uses many mathematical equations, Detailed modelling is very complex to implement in real time, Large number of assumptions reduces accuracies,
Data-driven	High accuracy, simple structure -> applicable for real-time operation and control, No need to have a good understanding of the system physics,	Training data requirement, Poor generalization capability, Some key parameters or may not be considered, Some models lack validation,
Gray box	High accuracy, Easy generalization capability, Less complexity and low computational cost, Can deliver good control performance.	Involves the implementation of both governing equations and a large amount of training data, Large number of assumptions reduces accuracies,

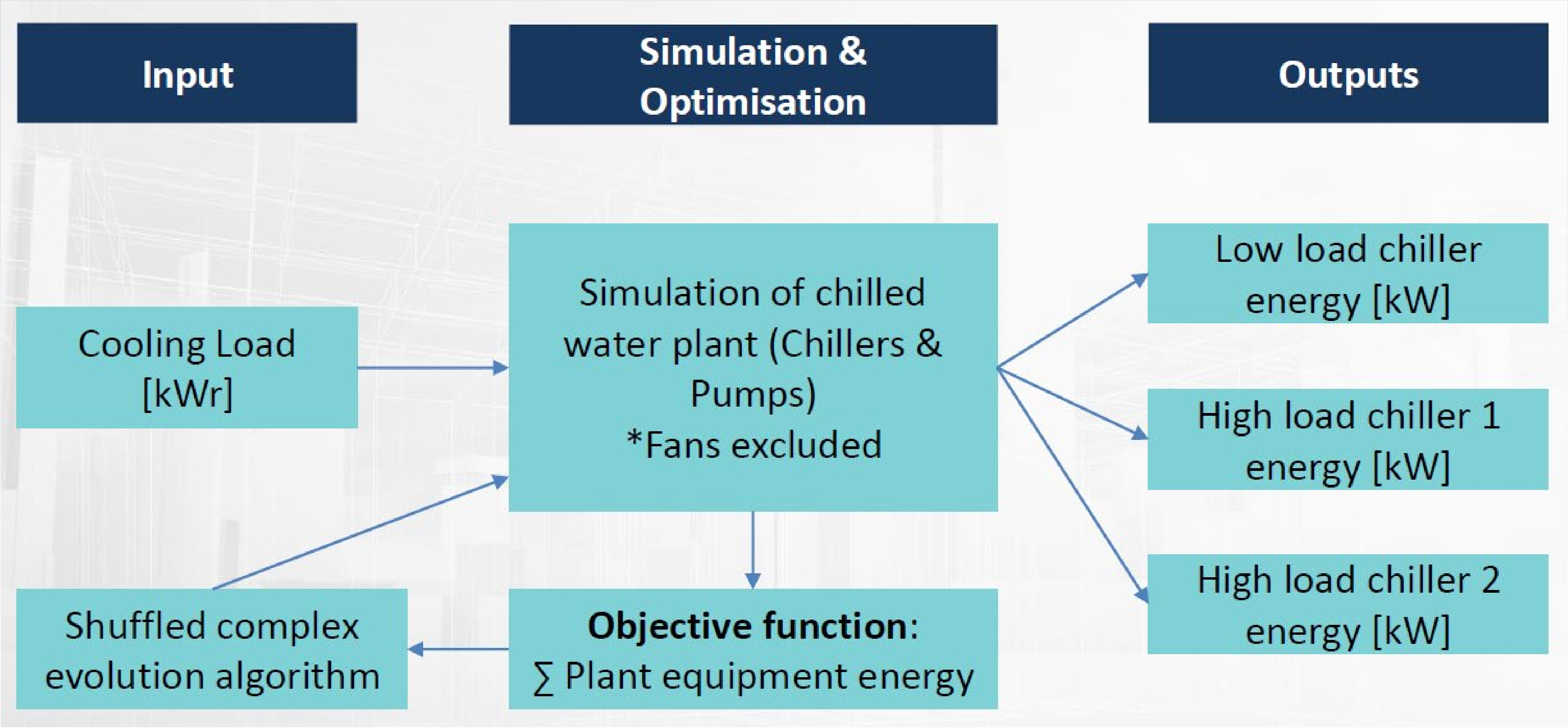
A data-driven model example

(Stewart et al. 2017)





Model structure
(Stewart et al. 2017)



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The End.

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