Enhancing the Way, We Make Decisions in Energy Planning with Mathematical Models

A Perspective on Important Tools for the Future

Viknesh Andiappan, PhD CEng MIChemE
Assistant Professor
Heriot-Watt University, Putrajaya, Malaysia

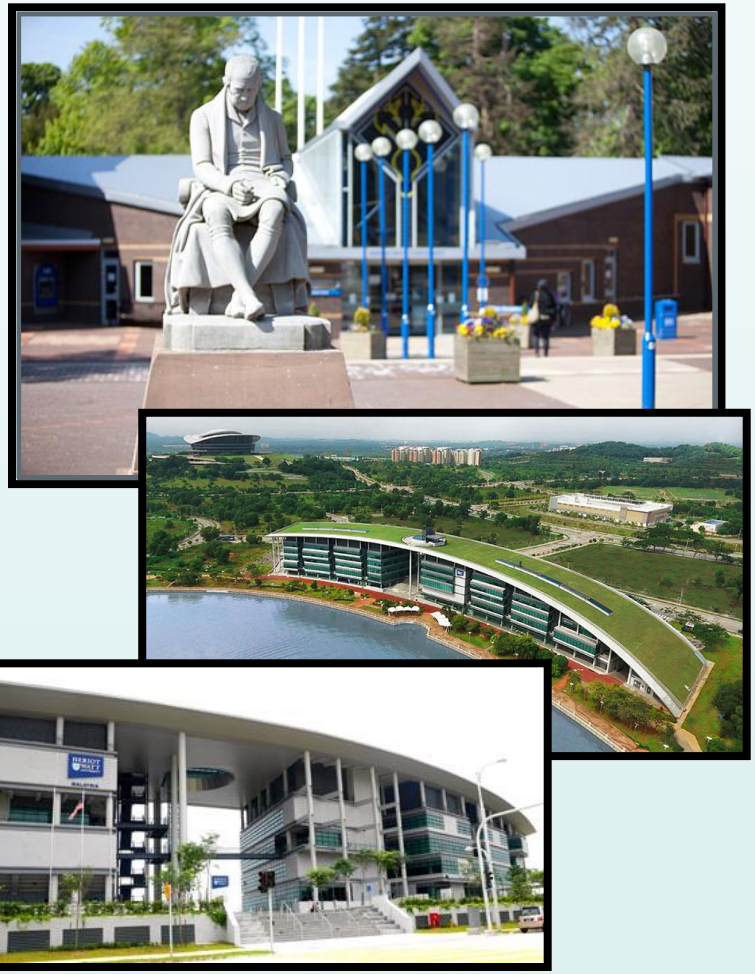
IChemE Webinar,
May 19, 2021, Heriot-Watt University Malaysia

About the Speaker

Career highlights

- Assistant Professor (Chemical Engineering)
- MEng Chem Eng, PhD Eng (Uni of Nott. Malaysia)
- 50+ publications and *h*-index = 13 (Scopus)
- CEng (Engineering Council UK), MIChemE (IChemE)
- IBAE Young Research of the Year 2020 (Engineering)
- Finalist for IChemE Young Researcher Awards Malaysia 2018, 2019.
- Member of Editorial Board for *Process Integration & Optimization for Sustainability* (Springer Nature)
- Guest Editor for Special Issue in *Process Integration & Optimization for Sustainability* (Springer Nature) - *Process Systems Engineering for Decarbonisation Strategies and Systems*
- Review editor for *Frontiers in Sustainability, Sustainable Chemical Process Design* (Frontiers)

Heriot-Watt University
Putrajaya, Malaysia



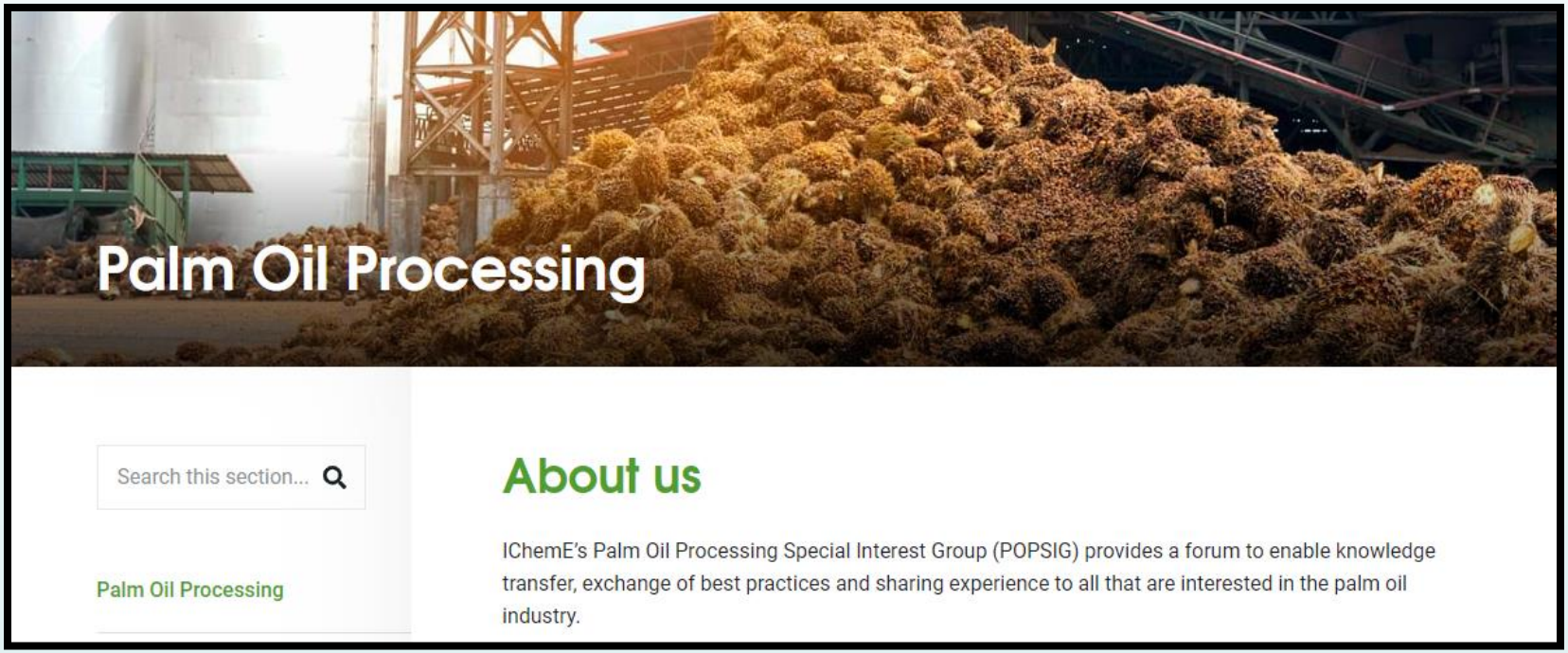
"Founded in 1821, Heriot-Watt has a rich heritage and is valued for its pioneering research informed by the global needs of business and industry"

- Founded in 1821 – as School of Arts of Edinburgh and world's first mechanics' institute
- Granted university status in 1966
- Dubai campus 2005
- Malaysia campus 2014
- THE World Ranking **Top 300**
- QS World Ranking **Top 300**
- QS Subject Ranking (Chem. Eng.) **150+**
- THE Golden Age University Rankings **60+**
- **Top 10** universities in UK (Chem. & Eng.)
- **Ranked 1st in Scotland** for research impact

About the Speaker

Career highlights

- Deputy Chair, IChemE Palm Oil Processing Special Interest Group (POPSIG)
- Former University Roadshow Director, IChemE Palm Oil Processing Special Interest Group (POPSIG)



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About the Speaker

Research Area

- Process systems engineering (PSE) and process integration (PI) – develop **mathematical models** for optimising processes, systems and supply chains

Speaker

Viknesh Andiappan, Heriot-Watt University Malaysia

Dr Viknesh Andiappan is an Assistant Professor at Heriot-Watt University, Malaysia. He is currently working on developing systematic supply chain and design models for biomass utilisation. He completed his Ph.D from the University of Nottingham, Malaysia Campus within two and half years.

Outline of Presentation

- Objective
- Current Issues
- What are Mathematical Models?
- How can Mathematical Models help?
- Are Models Reliable and Trusted?
- Opportunities for Mathematical Models
- Conclusions

Outline of Presentation

- Objective
- Current Issues
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Objective

- To understand:
  - What mathematical models are
  - How mathematical models can be used for decision-making in the energy sector.
  - The opportunities for mathematical models in energy planning and decision-making.

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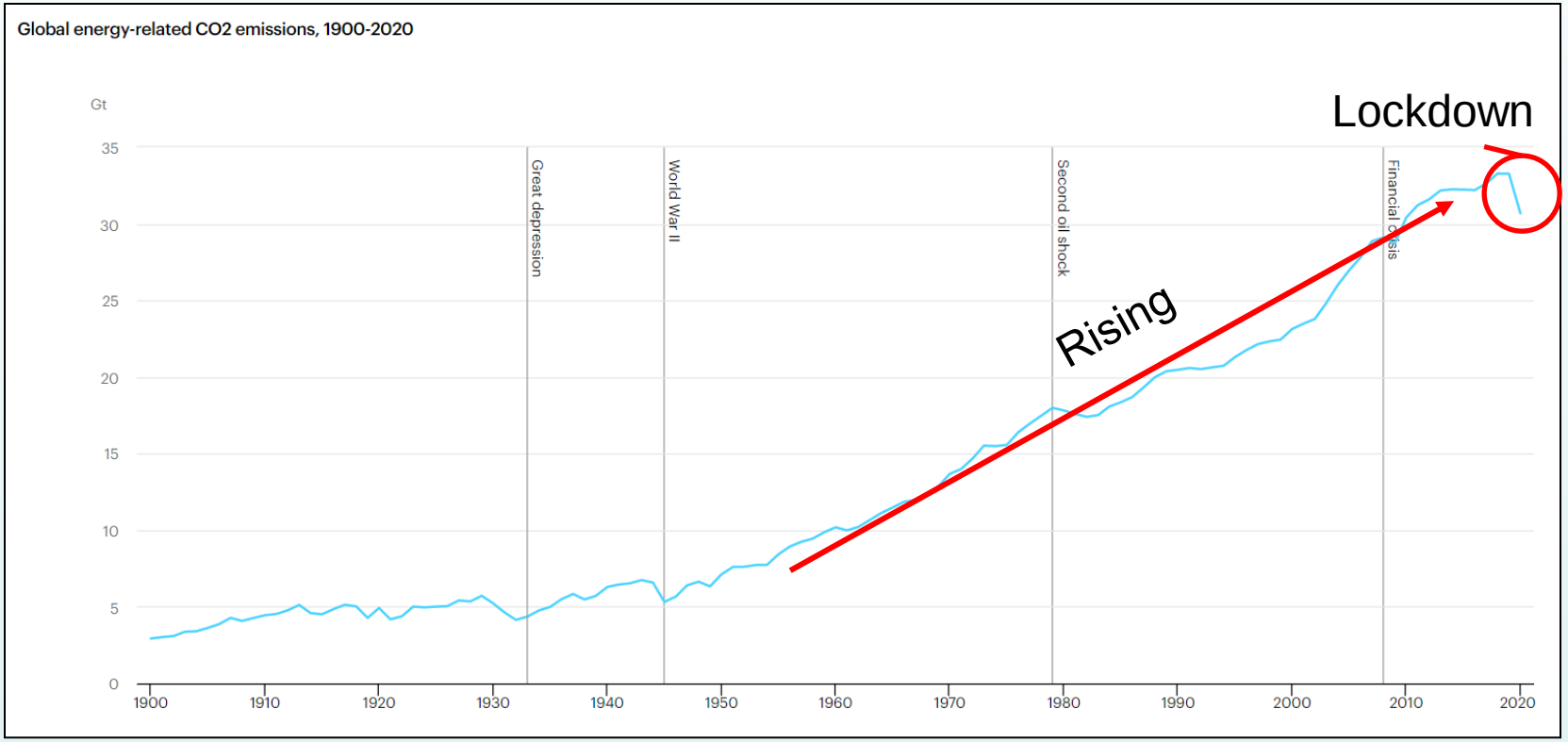
Current Issues

Current Policy and Required Targets

(IEA, 2020; IPCC, 2018)

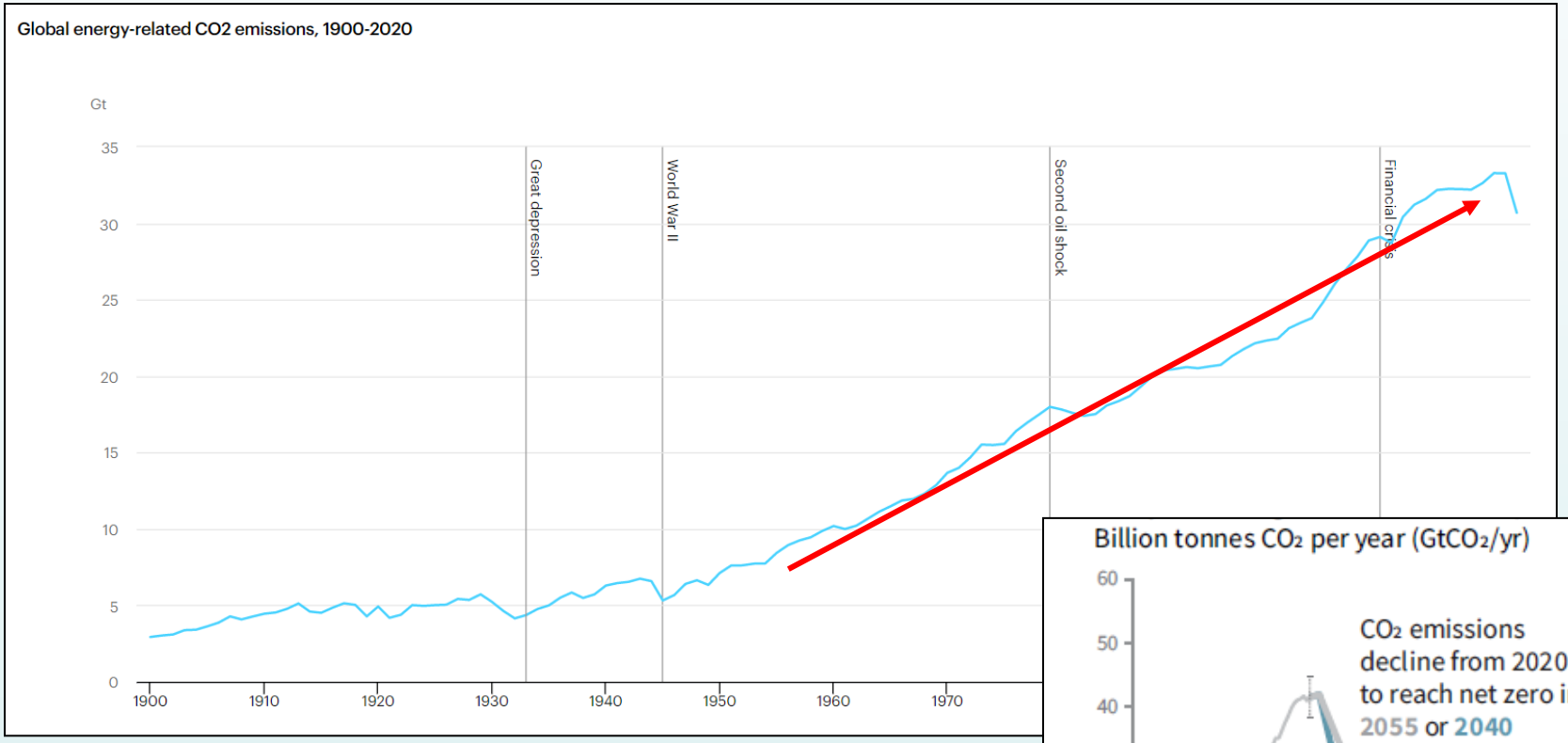


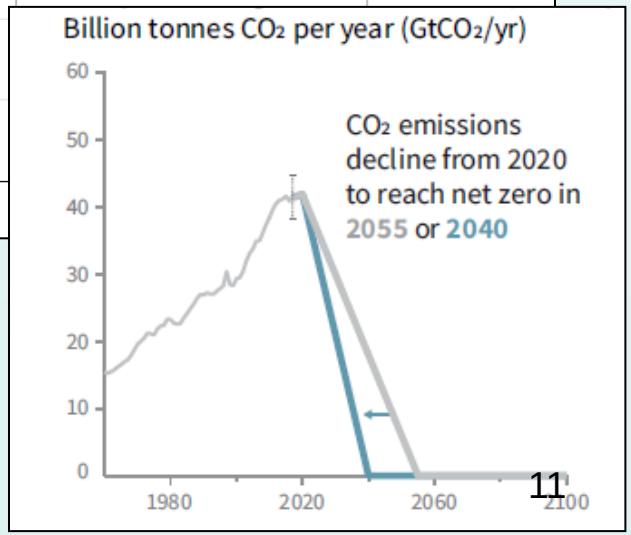
- CO_2 emissions still rising
- Need for effective carbon reduction strategies

Background Problem

Current Policy and Required Targets

(IEA, 2020; IPCC, 2018)





- IPCC - Net zero by 2055 required
- Large scale deployment of renewables required

Current Issues

Current Policy and Required Targets

Chemical engineers are needed!

Engineers have a role to play in minimizing climate change

Engineering plays crucial role in climate change

In a bid to highlight the importance of engineering in sustainable development and climate change, the Institute of Engineers in Singapore has launched a competition to recognise the most innovative engineering achievements in the city-state.

Call for engineers to act on climate change

by University of Leeds

Credit: University of Leeds

Discussion around limiting climate change primarily focusses on whether the best results can be gained by individuals changing how they act, or governments introducing new legislation.

Current Issues

Current Policy and Required Targets

Major Push towards Sustainability/ Sustainable Development

SDGs 7 and 13 directly link to the energy sector

Current Issues

Potential Solution and its Challenges

Potential Solution:

- Integrate renewables and low carbon energy resources into energy sector

BIOMASS ENERGY

SOLAR ENERGY

HYDROGEN ENERGY

- Improve energy efficiency

ENERGY DEMAND MANAGEMENT

ENERGY STORAGE

Current Issues

Potential Solution and its Challenges

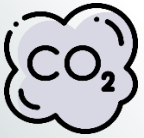
High Investment Costs
Burden to Developing Countries

Need Policy Support
Incentivise decarbonisation

Operational Issues
Intermittency to meet demands

Finite Resources
Land, feedstock, transportation

Clear Targets
Set reduction target of CO_2 emission



Decision-making
Complex large-scale problem

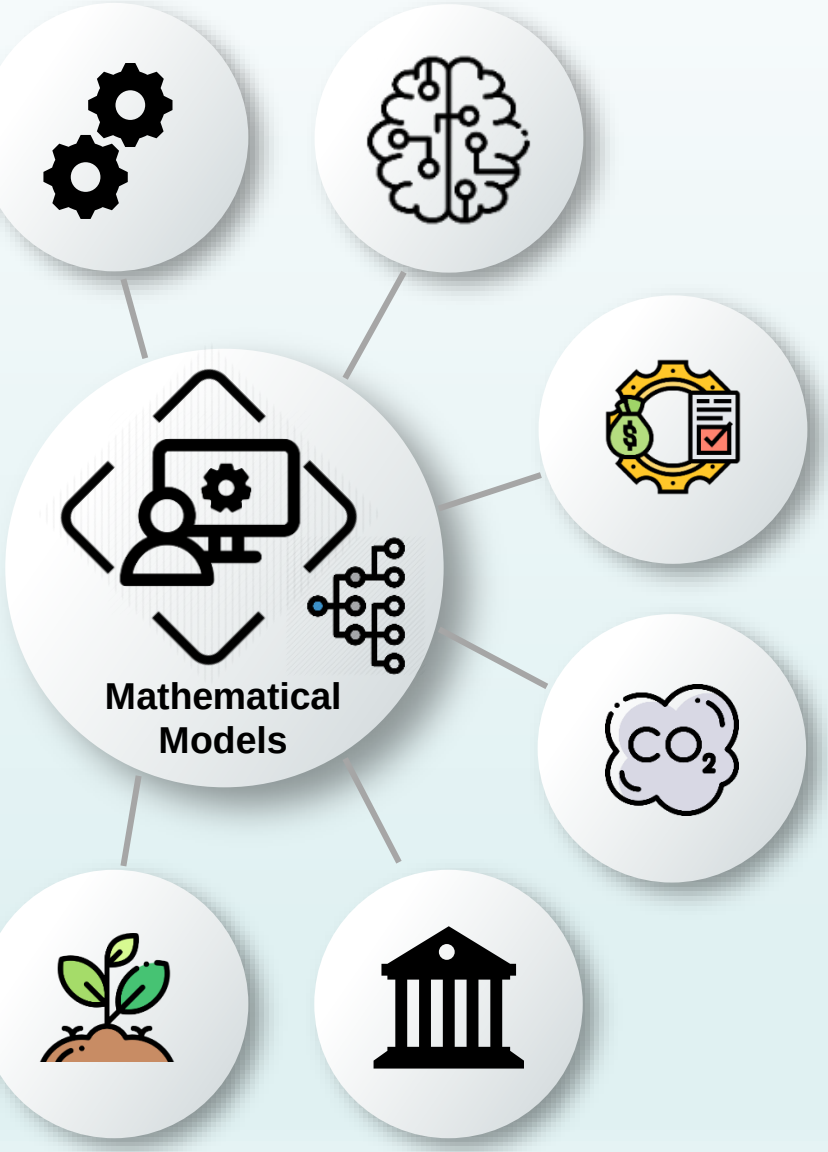
Current Issues

Potential Solution and its Challenges

Current Issues

Potential Solution and its Challenges

How can we solve these issues?



Outline of Presentation

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What are Mathematical Models?

Mathematical Models

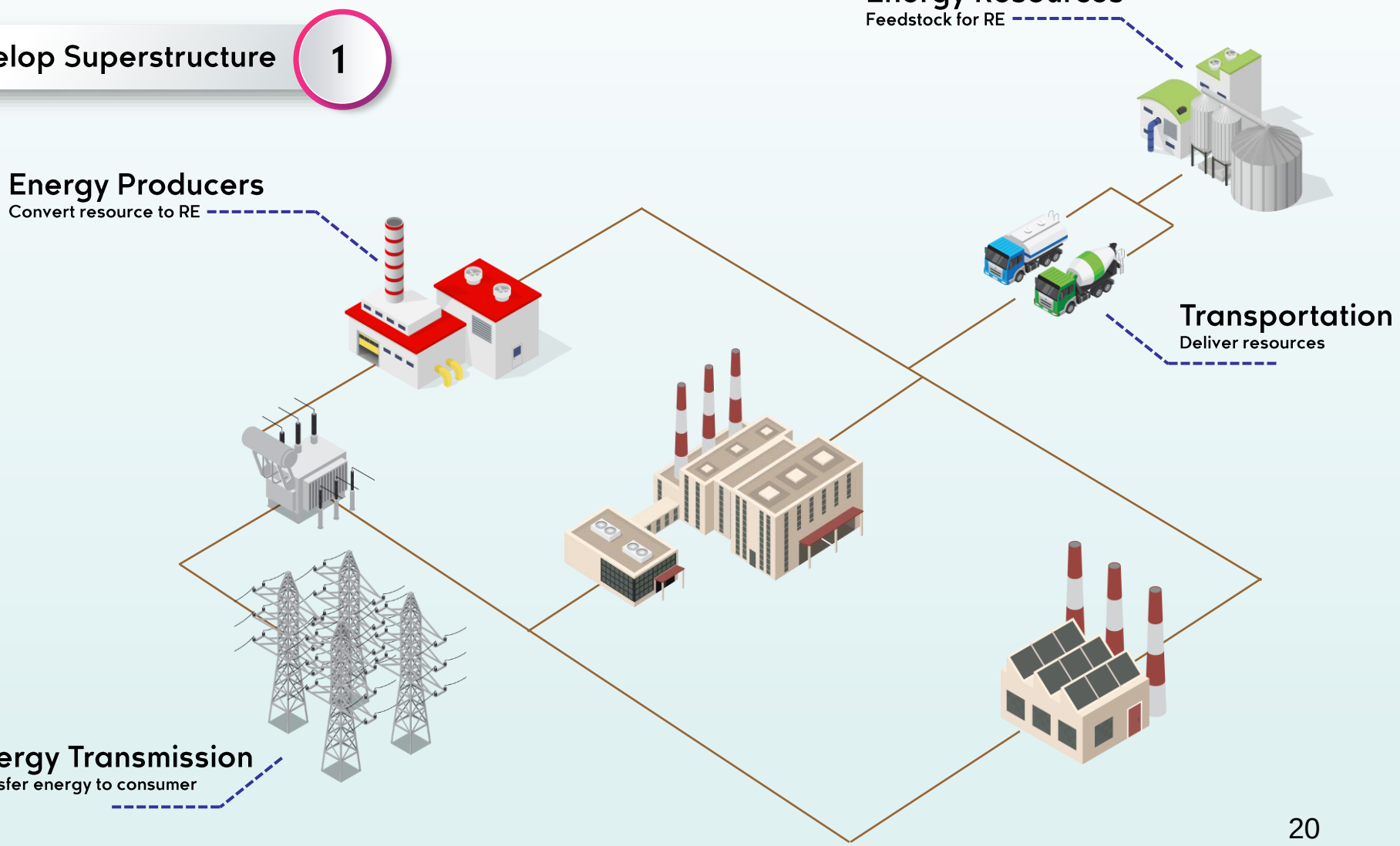
- Describe/represent the behaviour of a system for
  - Further analysis and optimisation
  - Supporting decision-making

- Optimisation - *"Identification of the best solution from among a set of candidate solutions"* (El-Halwagi, 2011)

Let's see how models are developed to understand them further

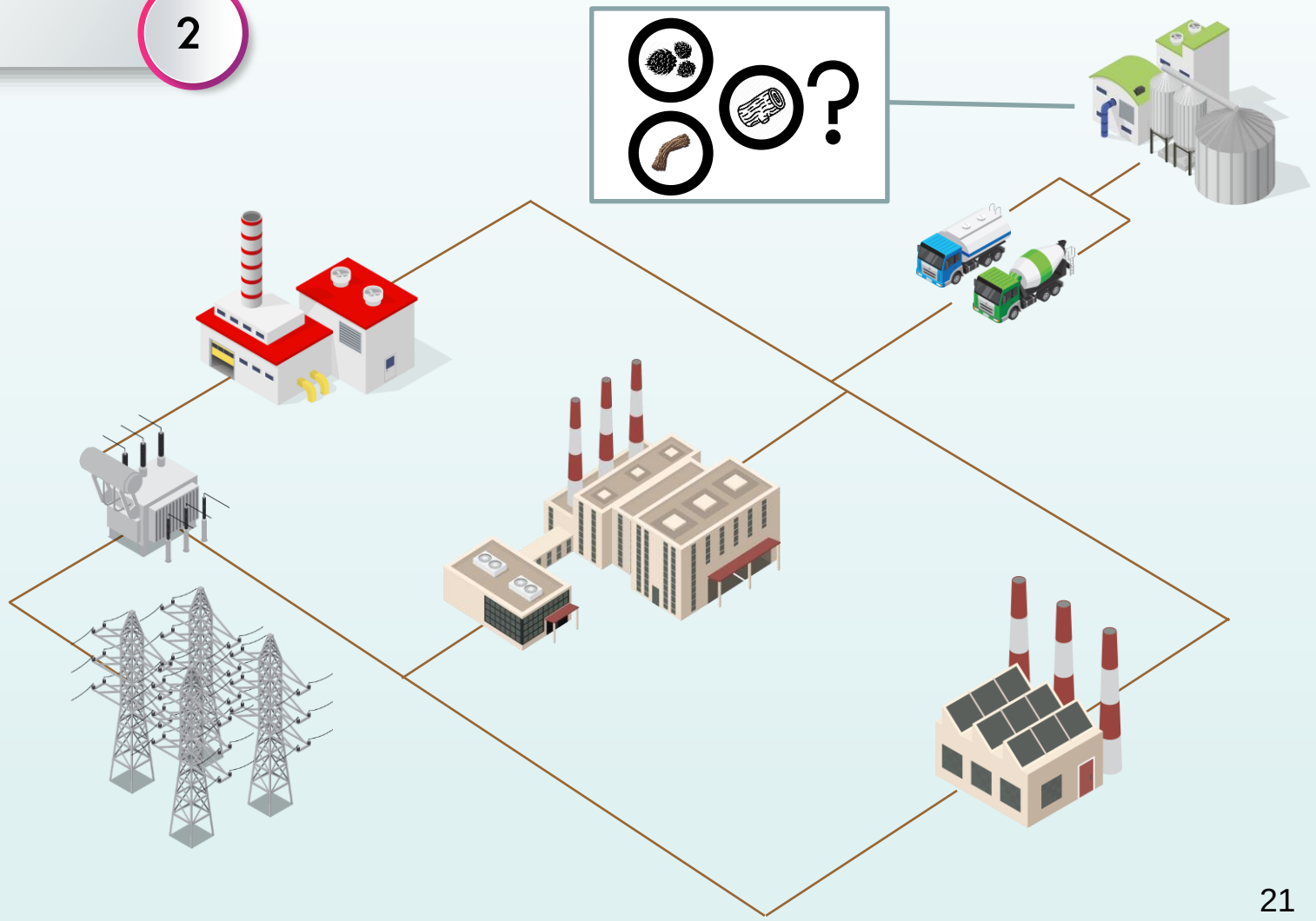
What are Mathematical Models?

Develop Superstructure 1



What are Mathematical Models?

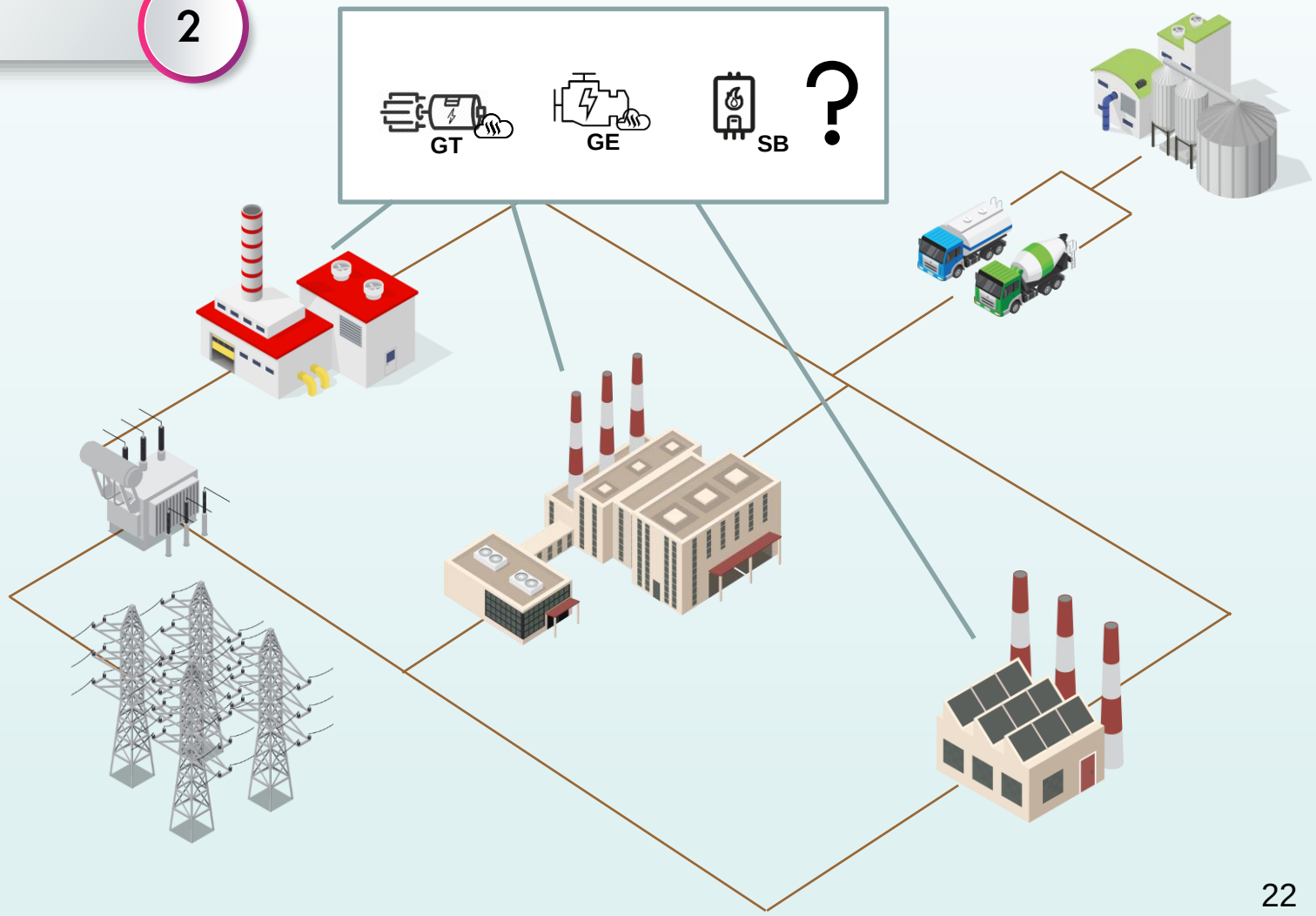
Collect Data 2



What are Mathematical Models?

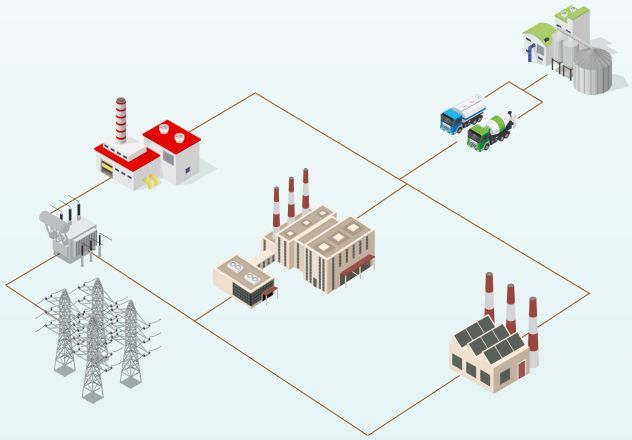
Collect Data

2

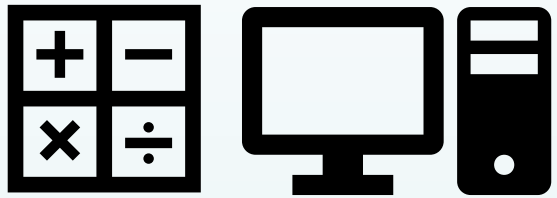


What are Mathematical Models?

Developing Model 3



Understand operations/behaviour of technologies



Develop equations based on behaviour of technologies

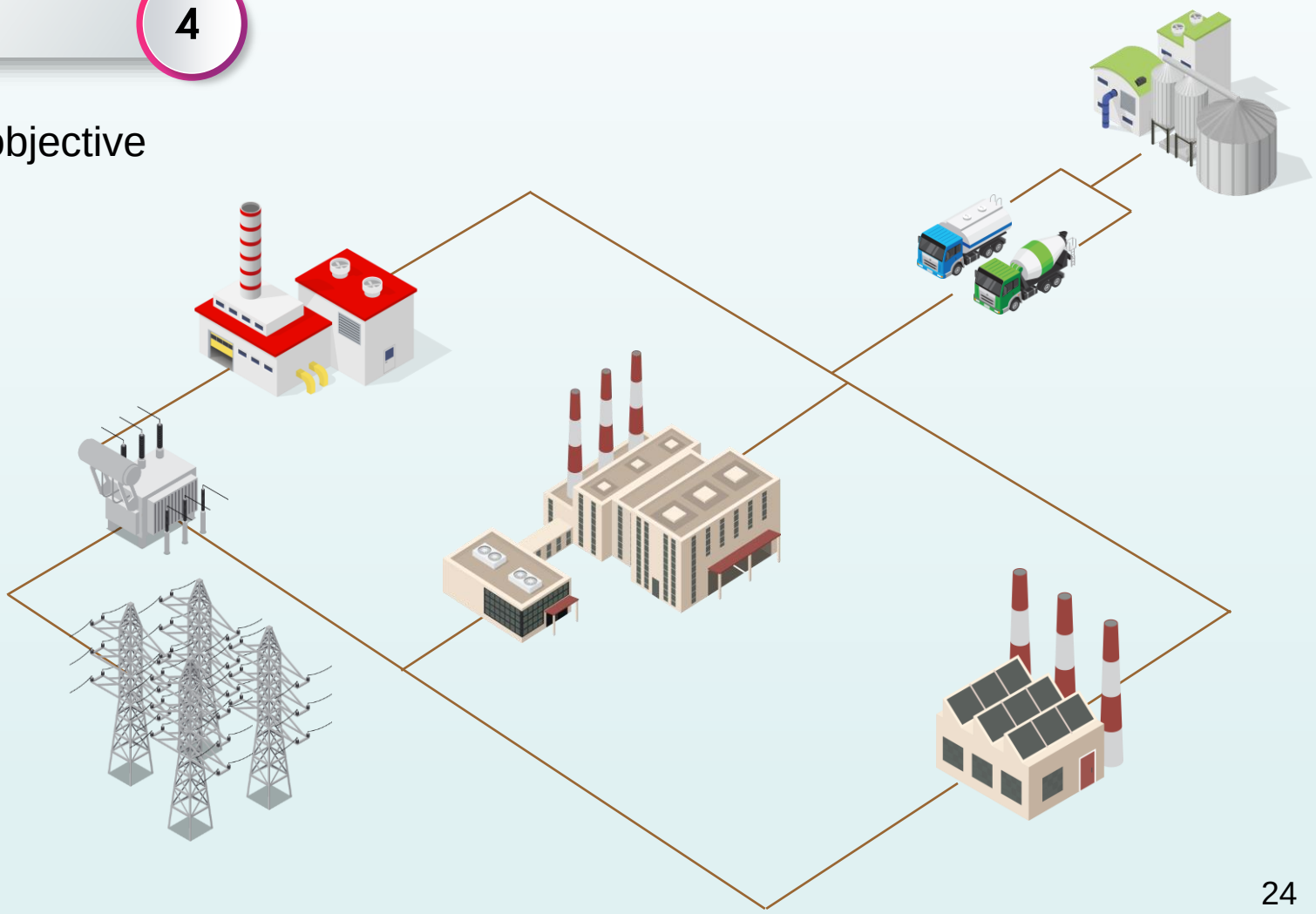
GAMS MATLAB LINGO AIMMS

Coded on various commercial software platforms

What are Mathematical Models?

Solve Model 4

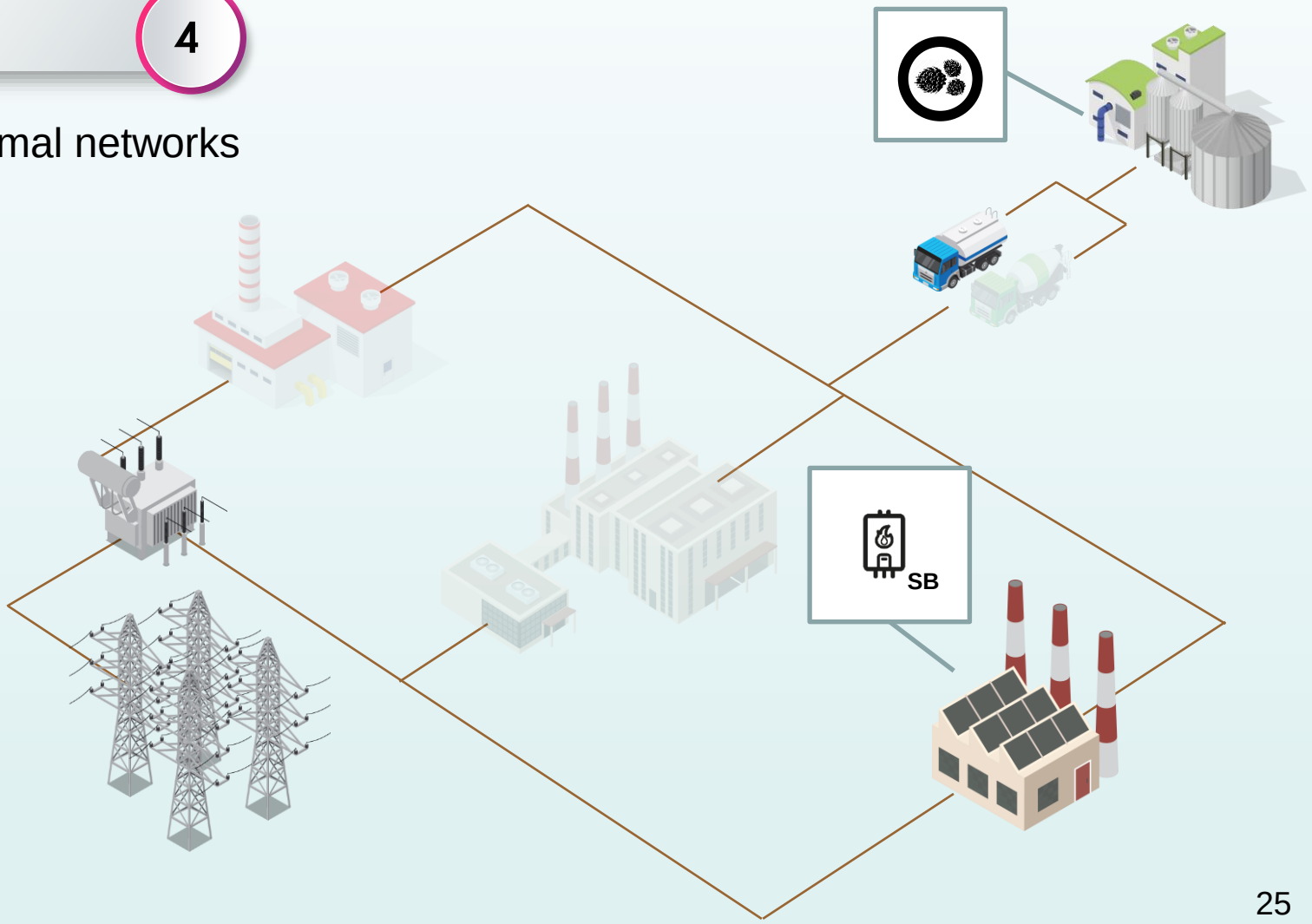
Based on a objective



What are Mathematical Models?

Solve Model 4

Generate optimal networks



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How can Mathematical Models help?

Mathematical Models

Used to Optimise and Aid

Decision-making

Processes

Supply Chains

Policy & Economic Systems

As long as there are

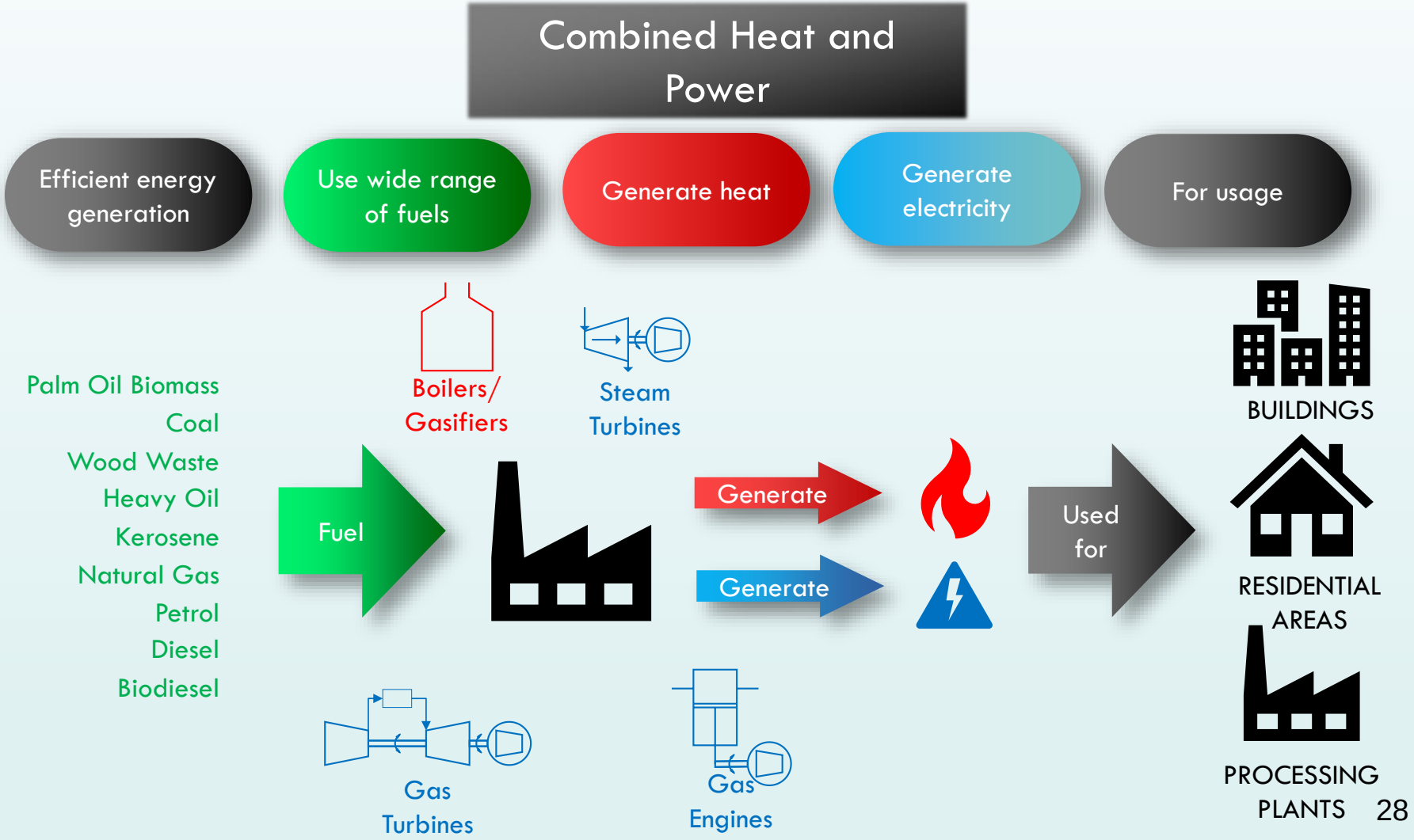
NETWORKS

Processes

How can Mathematical Models help?

Previous Work

(Lok et al, 2020. PSEP. 137)



Processes

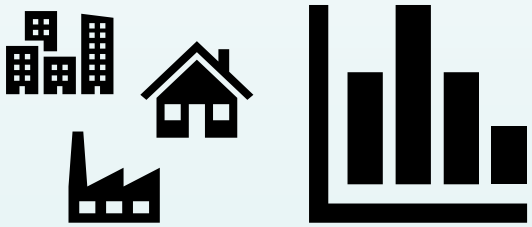
How can Mathematical Models help?

Challenge

Previous Work

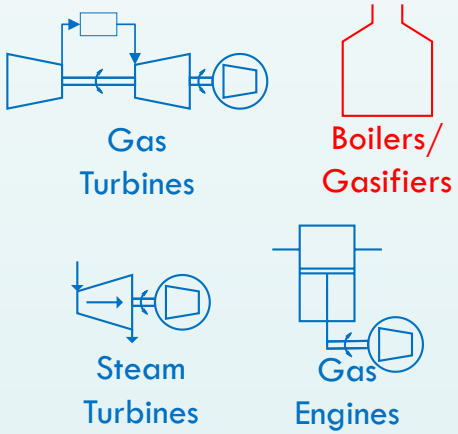
(Lok et al, 2020. PSEP. 137)

Variation in Energy Demands



Affects

Choice of Technology



- ❑ Flexibility in adjusting operations
- ❑ Cost to adjust operations
  - Start-up & shutdown costs
- ❑ Emissions related to fuel choice when adjusting operations

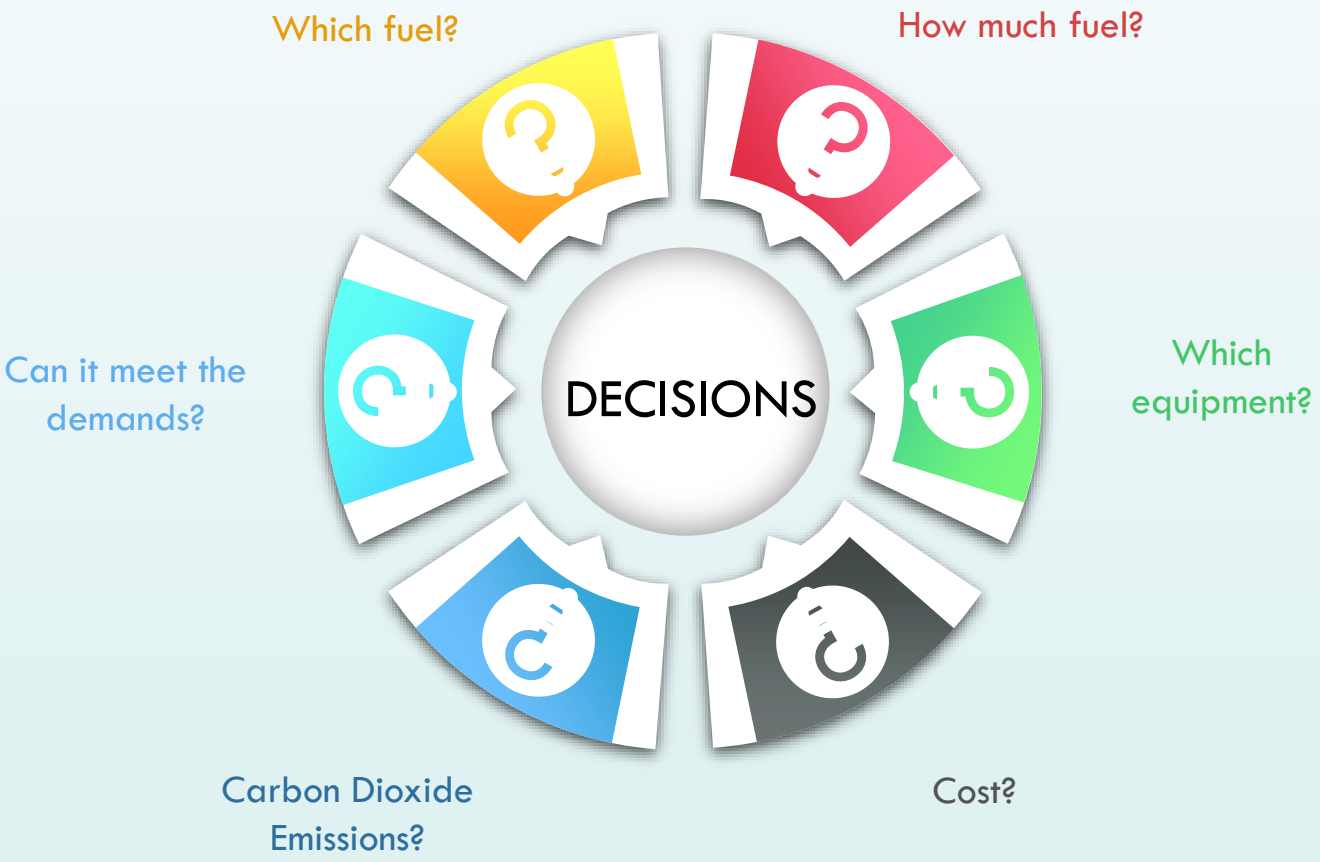
Affects

Processes

How can Mathematical Models help?

Previous Work

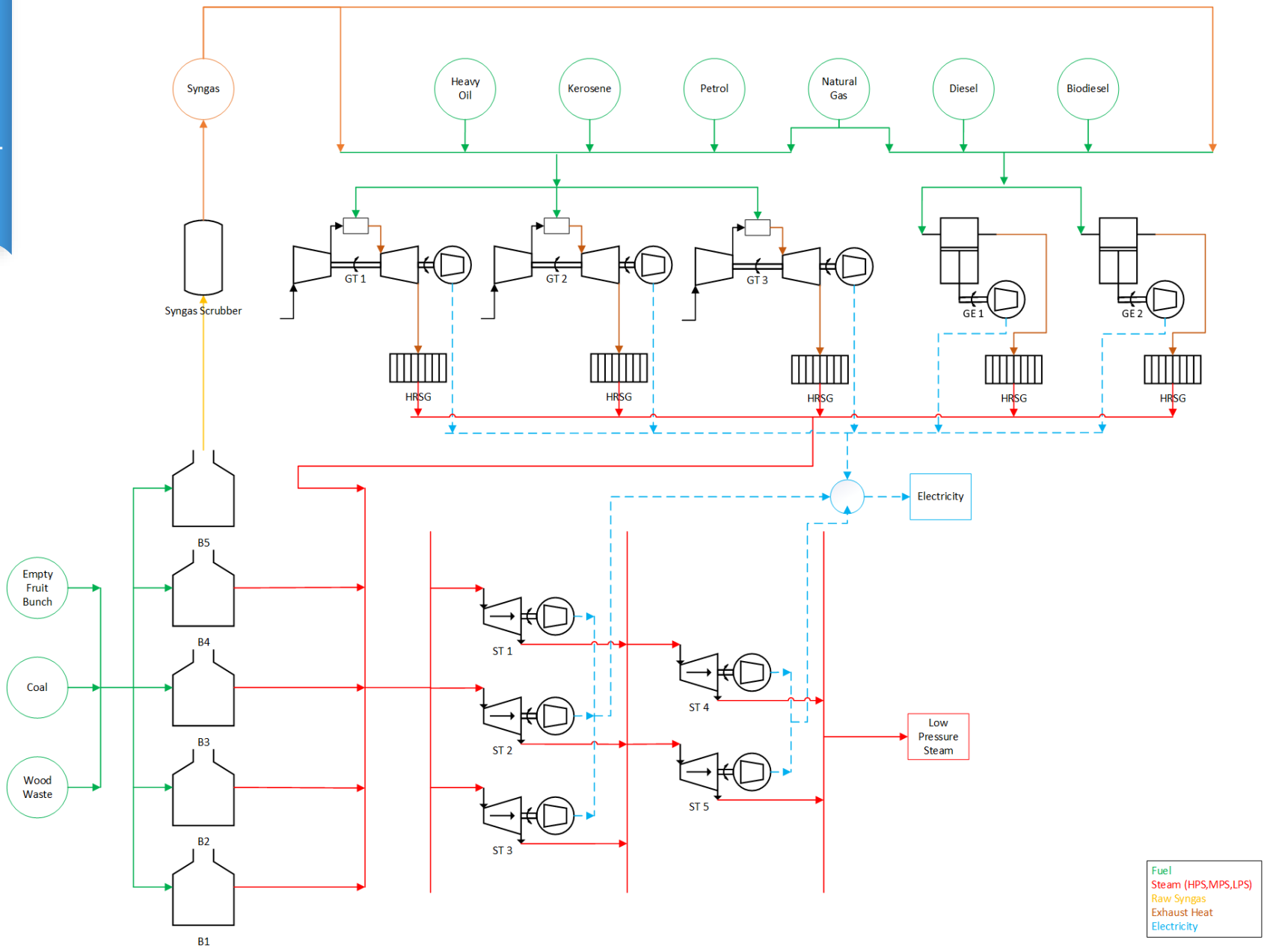
(Lok et al, 2020. PSEP. 137)

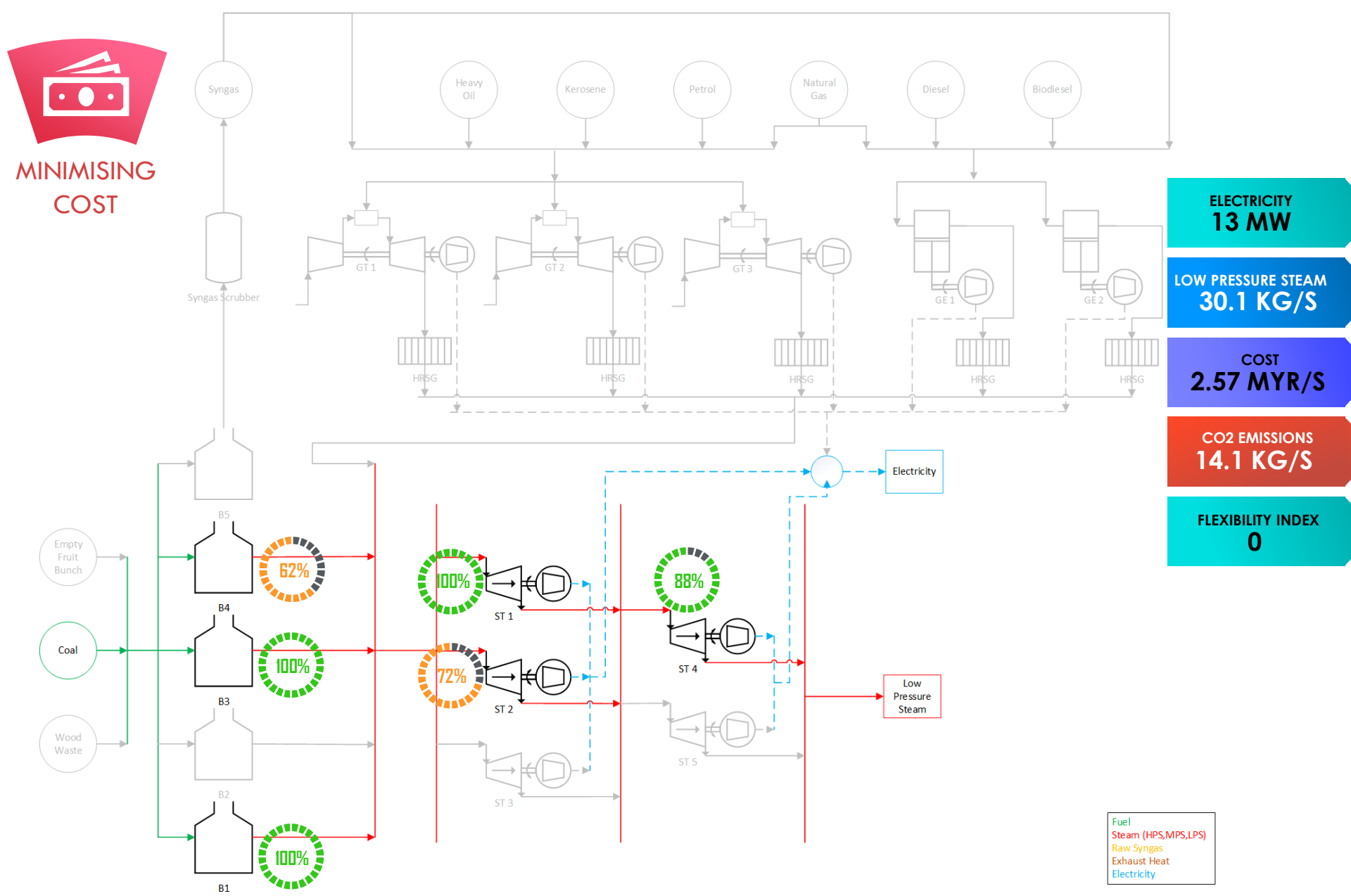


How can Mathematical Models help?

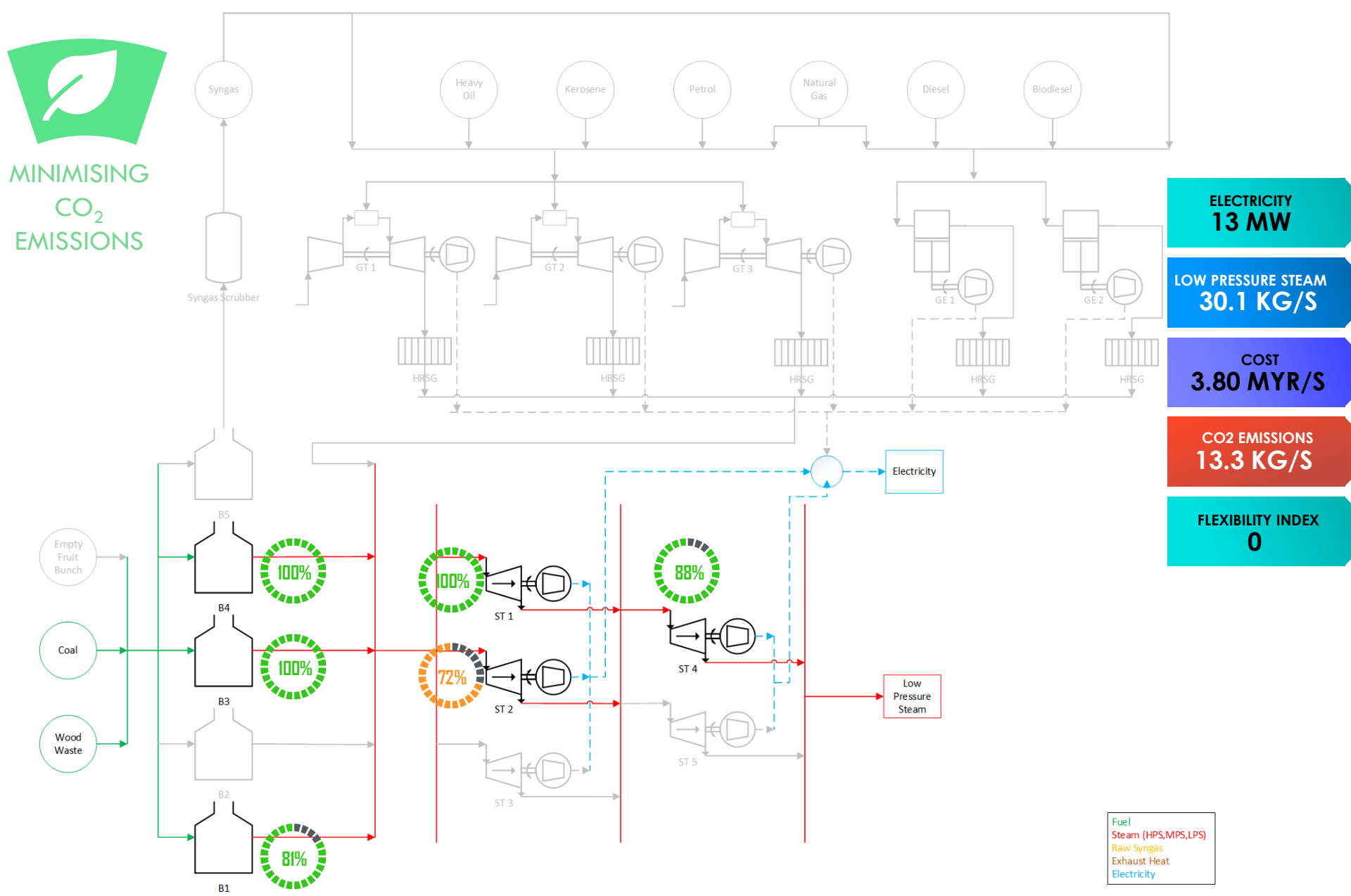
Previous Work

(Lok et al, 2020. PSEP. 137)


Syngas
Heavy Oil
Kerosene
Petrol
Natural Gas
Diesel
Biodiesel
Syngas Scrubber
GT 1
GT 2
GT 3
GE 1
GE 2
HRSG
HRSG
HRSG
HRSG
HRSG
Electricity
B5
B4
B3
B2
B1
Empty Fruit Bunch
Coal
Wood Waste
ST 1
ST 2
ST 3
ST 4
ST 5
Low Pressure Steam
Fuel
Steam (HPS,MPS,LPS)
Raw Syngas
Exhaust Heat
Electricity


MINIMISING COST
Syngas
Heavy Oil
Kerosene
Petrol
Natural Gas
Diesel
Biodiesel
Syngas Scrubber
GT 1
GT 2
GT 3
GE 1
GE 2
HRSG
HRSG
HRSG
HRSG
HRSG
Electricity
B5
B4
B3
B2
B1
62%
100%
100%
100%
Empty Fruit Bunch
Coal
Wood Waste
100%
72%
88%
ST 1
ST 2
ST 3
ST 4
ST 5
Low Pressure Steam
ELECTRICITY
13 MW
LOW PRESSURE STEAM
30.1 KG/S
COST
2.57 MYR/S
CO2 EMISSIONS
14.1 KG/S
FLEXIBILITY INDEX
0
Fuel
Steam (HPS,MPS,LPS)
Raw Syngas
Exhaust Heat
Electricity

MINIMISING CO_2 EMISSIONS



ELECTRICITY
13 MW

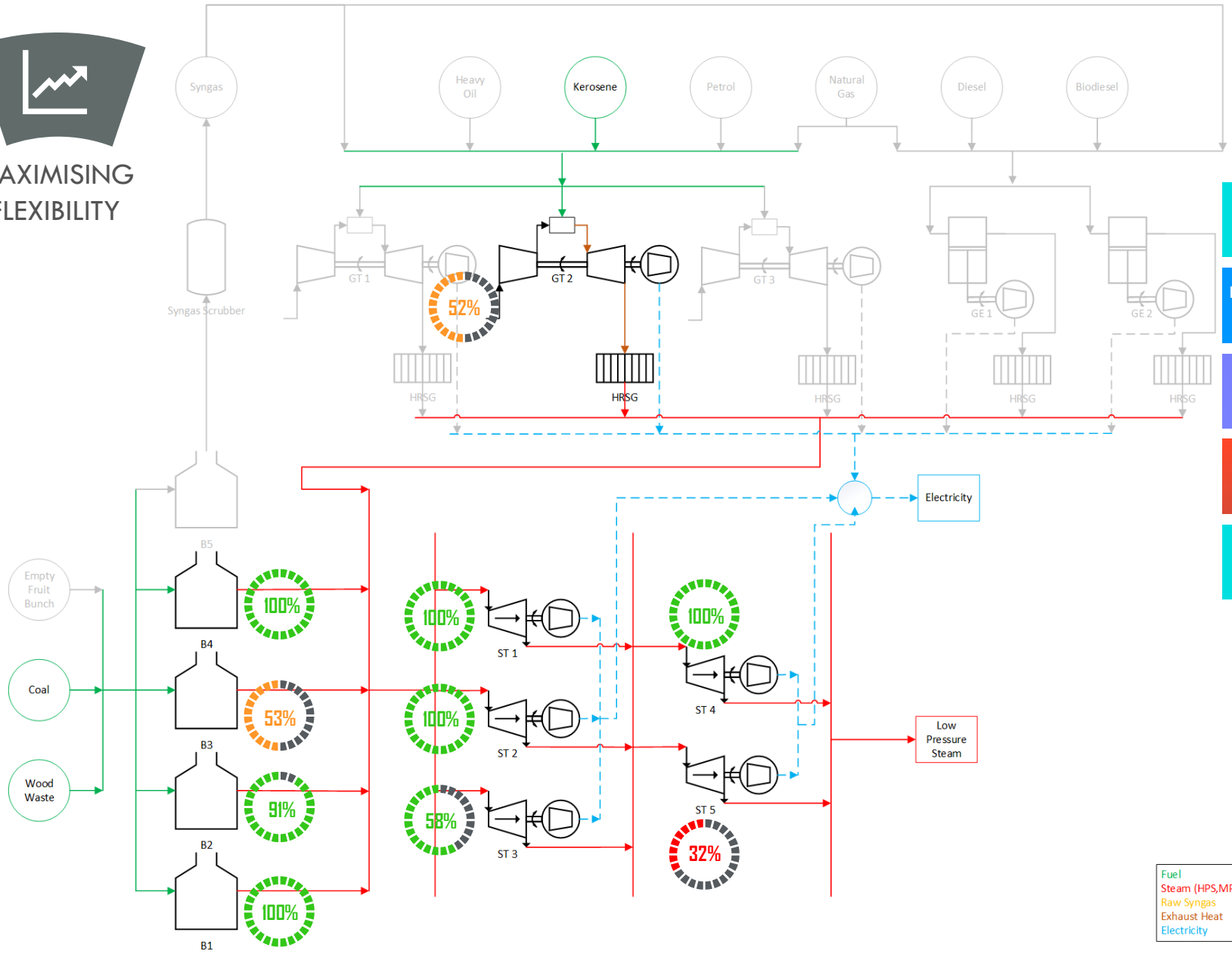
LOW PRESSURE STEAM
30.1 KG/S

COST
3.80 MYR/S

CO2 EMISSIONS
13.3 KG/S

FLEXIBILITY INDEX
0

MAXIMISING FLEXIBILITY



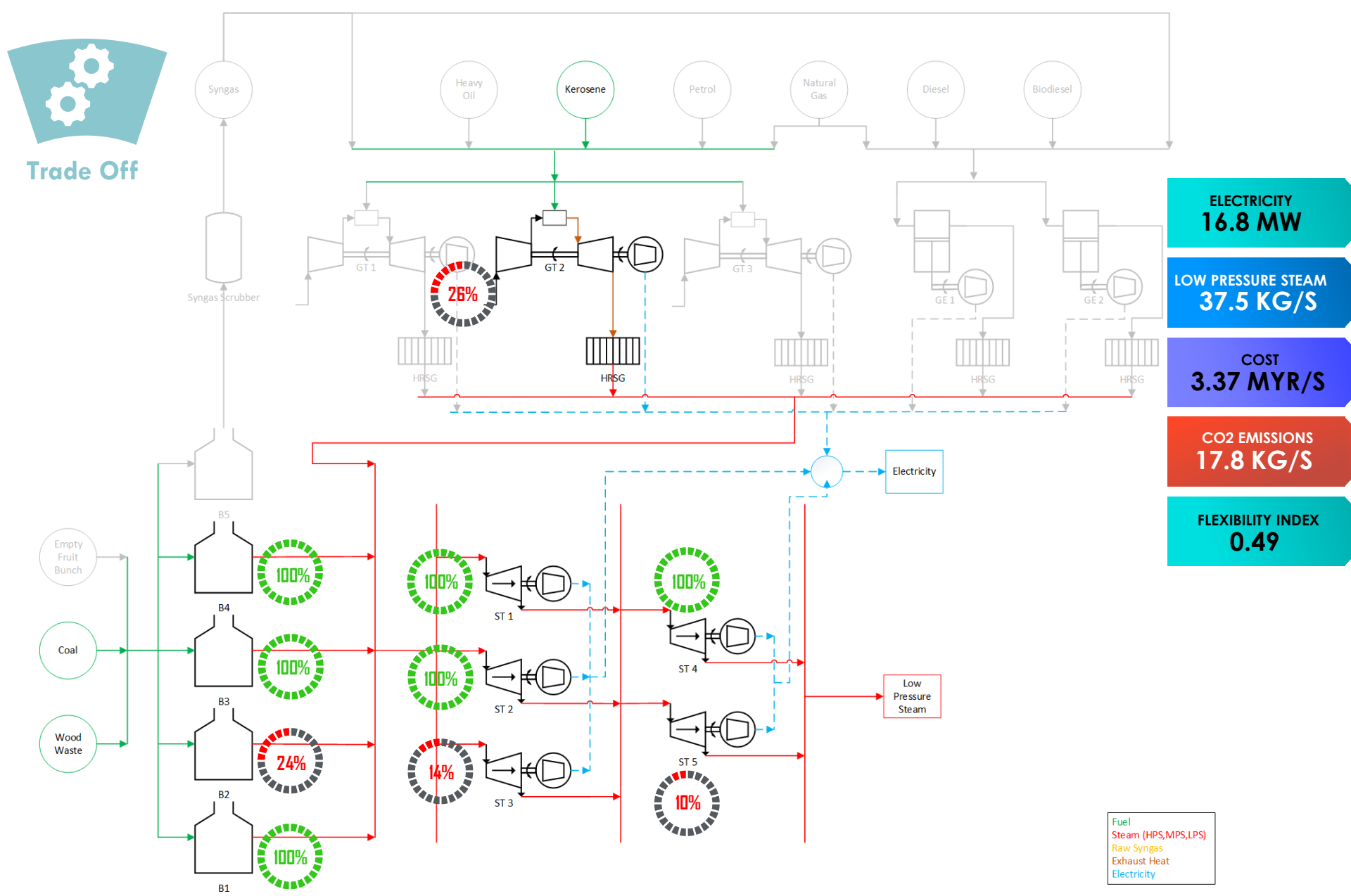
ELECTRICITY
20.8 MW

LOW PRESSURE STEAM
45.2 KG/S

COST
4.15 MYR/S

CO2 EMISSIONS
22.1 KG/S

FLEXIBILITY INDEX
1


Trade Off
Syngas
Heavy Oil
Kerosene
Petrol
Natural Gas
Diesel
Biodiesel
Syngas Scrubber
GT 1
GT 2
GT 3
26%
GE 1
GE 2
HRSG
HRSG
HRSG
HRSG
HRSG
Electricity
B5
B4
B3
B2
B1
Empty Fruit Bunch
Coal
Wood Waste
100%
100%
24%
100%
100%
100%
14%
ST 1
ST 2
ST 3
100%
100%
10%
ST 4
ST 5
Low Pressure Steam
ELECTRICITY
16.8 MW
LOW PRESSURE STEAM
37.5 KG/S
COST
3.37 MYR/S
CO2 EMISSIONS
17.8 KG/S
FLEXIBILITY INDEX
0.49
Fuel
Steam (HPS,MPS,LPS)
Raw Syngas
Exhaust Heat
Electricity

Supply Chains

How can Mathematical Models help?

Previous Work

(Ling et al, 2019. Energy. 178: 554)

Contents lists available at ScienceDirect

Energy

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

An integrated mathematical optimisation approach to synthesise and analyse a bioelectricity supply chain network

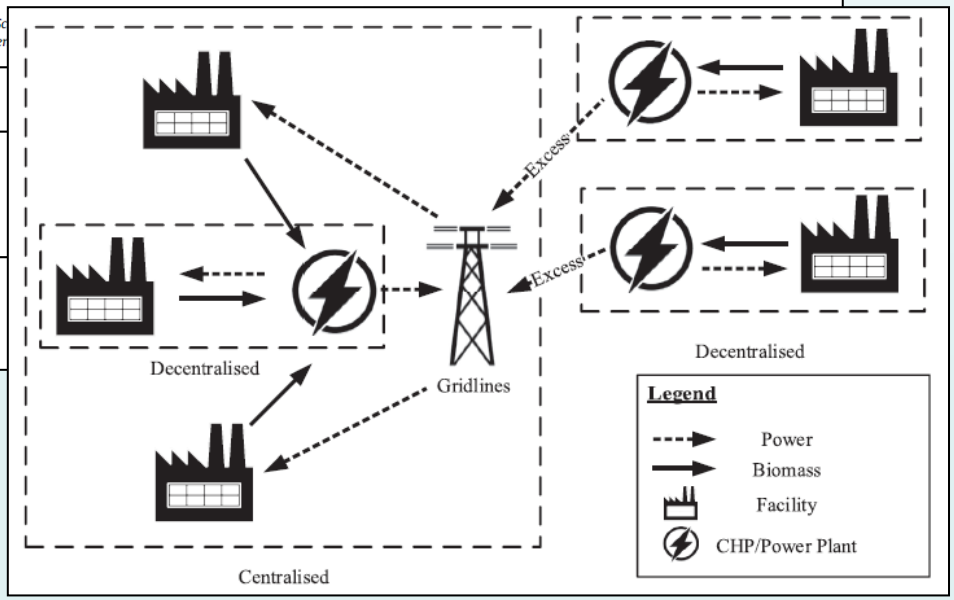
Wen Choong Ling [a], Arati Banu Verasingham [b], Viknesh Andiappan [c], Yoke Kin Wan [d], Irene M.L. Chew [a], Denny K.S. Ng [b, c, *]

[a] School of Engineering, Monash University Malaysia, Jalan Lagoon Selatan, 47500, Bandar Sunway, Selangor, Malaysia
[b] Department of Chemical and Environmental Engineering/Centre of Sustainable Palm Oil Research (CESPOR), University of Nottingham, Malaysia, Broga Road, Semenyih, 43500, Malaysia
[c] School of Engineering and Physical Sc
[d] School of Engineering, Taylor's Univer

ARTICLE INFO

Article history:
Received 13 November 2018
Received in revised form
13 April 2019
Accepted 21 April 2019
Available online 26 April 2019

Keywords:
Bioelectricity supply chain network
Palm oil
Feasible operating range analysis
Input-output modelling



- Mathematical prog. determines optimal:
  - Transport routes
  - Processing routes
  - Locations
- Advantages:
  - Detailed account of supply chain
  - Determine centralised or decentralised

Supply Chains

How can Mathematical Models help?

Previous Work

(Leong et al, 2019. SPC. 18)

Contents lists available at ScienceDirect

Sustainable Production and Consumption

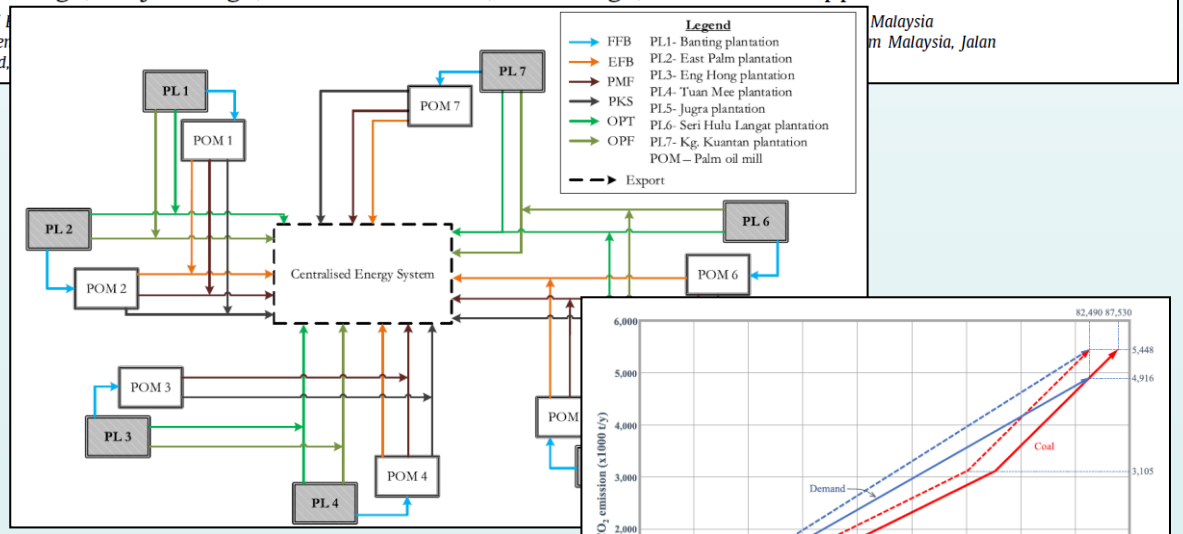
journal homepage: www.elsevier.com/locate/spc

Research article

Hybrid approach for carbon-constrained planning of bioenergy supply chain network

Huini Leong [a], Huiyi Leong [a], Dominic C.Y. Foo [b], Lik Yin Ng [a], Viknesh Andiappan [a,*]

[a] School of ... Malaysia
[b] Departmer... m Malaysia, Jalan Broga Road,



- Mathematical prog. determines optimal:
  - Transport routes
  - Processing routes
  - Locations
  - Plant Capacity
- Advantages:
  - Detailed account of supply chain
  - Determine practicality of carbon reduction targets

Supply Chains

How can Mathematical Models help?

Previous Work

(Ong et al, 2020. CTEP)

Biochar

Fine-grained Charcoal

Supply Chains

How can Mathematical Models help?

Previous Work

(Ong et al, 2020. CTEP)

Store Carbon at Stable Form

As Soil Amendment

Biochar

Carbon Storage

Supply Chains

How can Mathematical Models help?

Previous Work

(Ong et al, 2020. CTEP)

Store Carbon at Stable Form

As Soil Amendment

Retention
Plant Growth

Nutrients

Water

Supply Chains

How can Mathematical Models help?

Previous Work

(Ong et al, 2020. CTEP)

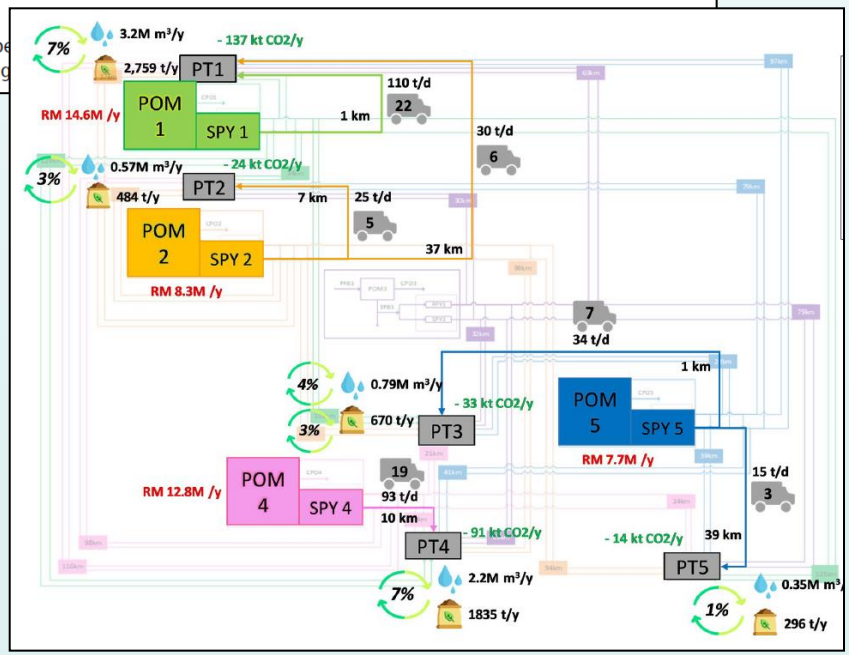
Clean Technologies and Environmental Policy
https://doi.org/10.1007/s10098-020-01990-0

ORIGINAL PAPER

Optimisation of biochar-based supply chains for negative emissions and resource savings in carbon management networks

Shi Hui Ong[1] · Raymond R. Tan[2] · Viknesh Andiappan[1]

Received: 7 August 2020 / Accepted: 10 Novembe



- Mathematical prog. determines optimal:
  - Transport routes
  - Processing routes
  - Locations
- Advantages:
  - Detailed account of supply chain
  - Determine practicality of carbon reduction targets

Policy & Economic Systems

How can Mathematical Models help?

Previous Work

UK > News > Noticeboard >

Malaysia team lead GCRF project for recovery of agro-industry in Malaysia and the Philippines

Published: 17 Jun 2020

The COVID-19 pandemic has pushed governments and policymakers worldwide, including Malaysia and the Philippines, to implement drastic lockdown periods since 18 March 2020 and 15 March 2020 respectively. The shocks caused by the pandemic have led to several disruptions to agro-industry supply chains in Malaysia and the Philippines. In order to maintain the stability of the agriculture sector, it is essential to develop strategies for post-pandemic recovery. Such “exit strategies” need to be calibrated to allow maximum economic gain from minimal inputs. Both governments will need to be shrewd in allocating limited resources for such purposes.

In view of this, a research team led by Assistant Professor Dr Viknesh Andiappan and Professor Ir. Denny Ng at the School of Engineering and Physical Sciences in Malaysia, were recently awarded Heriot-Watt's Global Challenge Research Fund (GCRF) for a project titled ‘Post-Pandemic Recovery Strategies for the Agro-Industry Sector in Malaysia and the Philippines’.

The project team consists of well-established researchers from Malaysia and the Philippines. The team is working to identify critical sectors impacted by the reduction in the revenue, specially affecting the agriculture sector in Malaysia and Philippines. The project is expected to provide insights on strategies to efficiently allocate government resources such as incentives, subsidies, financial aid and manpower, for post-pandemic recovery. The team includes Associate Professor Dr Nishanth Chemmangattuvalappil from the University of Nottingham, Malaysia, and Professor Raymond Tan, Professor Kathleen Aviso and Associate Professor Dr Krista Danielle Yu from De La Salle University, Philippines.

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DE LA SALLE UNIVERSITY MANILA

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University of Nottingham UK | CHINA | MALAYSIA

YouTube

Policy & Economic Systems

How can Mathematical Models help?

Previous Work

MANUFACTURING AND WHOLESALE-RETAIL TRADE ARE CRITICAL SECTORS DURING PANDEMIC, STUDY SAYS

PRINT

Published: 26 September 2020 Hits: 782

The other manufacturing, retail-wholesale trade, and government services are the top three economic sectors th
"Mitigating Economic Loss
Analysis,"which was prese
Where We Want To Be." T
the Philippines.

Analyzing the five facto
multiplier, and employme
economies of both count
network effects, where c
sectors of the economy.

The Manila Times®

Home › Public Square › Manufacturing, wholesale-retail sectors critical during pandemic

Manufacturing, wholesale-retail sectors critical during pandemic

By The Manila Times October 5, 2020

Like 12

THE manufacturing, retail-wholesale trade and government services are the top three economic sectors that are critical during the pandemic, based on a study on "Mitigating economic losses

How can Mathematical Models help?

- Design of processes, supply chains, policies – basically anything that has a network!

- Avoids pilot-scale testing experiments that cost large sums of funding – catastrophic if done wrong!

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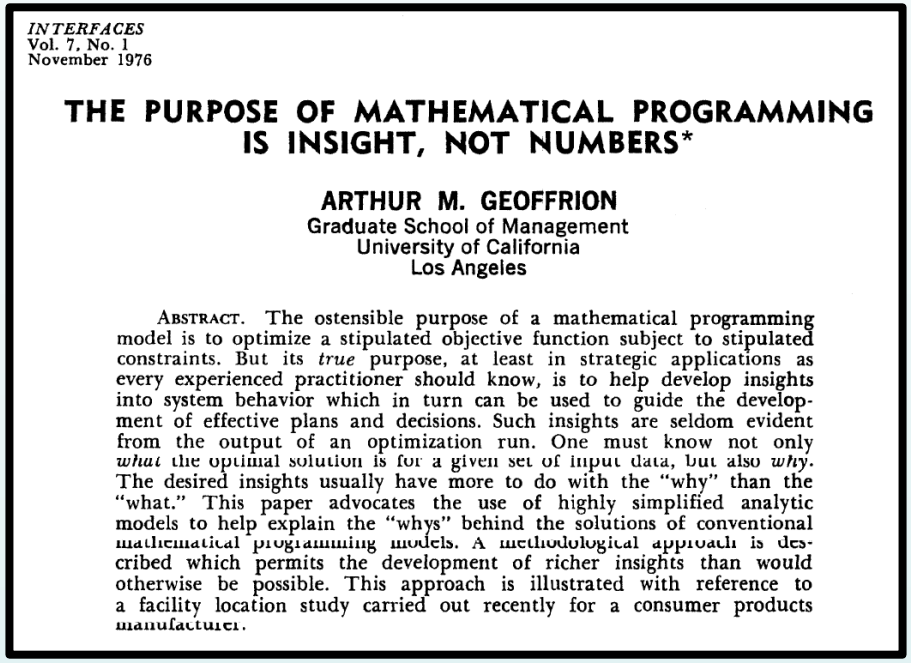
Are Models Reliable and Trusted?

Important Principles:

- Not Numbers, But Insights (Geoffrion, 1976)



INTERFACES
Vol. 7, No. 1
November 1976

THE PURPOSE OF MATHEMATICAL PROGRAMMING IS INSIGHT, NOT NUMBERS*

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ABSTRACT. The ostensible purpose of a mathematical programming model is to optimize a stipulated objective function subject to stipulated constraints. But its *true* purpose, at least in strategic applications as every experienced practitioner should know, is to help develop insights into system behavior which in turn can be used to guide the development of effective plans and decisions. Such insights are seldom evident from the output of an optimization run. One must know not only *what* the optimal solution is for a given set of input data, but also *why*. The desired insights usually have more to do with the "why" than the "what." This paper advocates the use of highly simplified analytic models to help explain the "whys" behind the solutions of conventional mathematical programming models. A methodological approach is described which permits the development of richer insights than would otherwise be possible. This approach is illustrated with reference to a facility location study carried out recently for a consumer products manufacturer.

- Look for the estimates, understand trends, impacts of changes, patterns and behaviour
- Aids decision-making, BUT *does not make the decision for you*

Outline of Presentation

- Objective
- Current Issues
- What are Mathematical Models?
- How can Mathematical Models help?
- Are Models Reliable and Trusted?
- Opportunities for Mathematical Models
- Conclusions

Opportunities

- Set and analyse targets for carbon emission reductions
- Determine subsidies and incentives required to encourage buy-in
- Develop strategies for deployment
- Analyse impact of technology learning rates (i.e., cost and maturity)

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Conclusion

- What are Mathematical Models
- How can Mathematical Models help
- Are Models Reliable and Trusted
  - Insights – aid decision-making
  - Estimates, understand trends, impacts of changes, patterns and behaviour
- Opportunities for Mathematical Models

Thanks for your attention

Comments and questions are welcomed

Like to know more? Or Collaborate?

Just get in touch!

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