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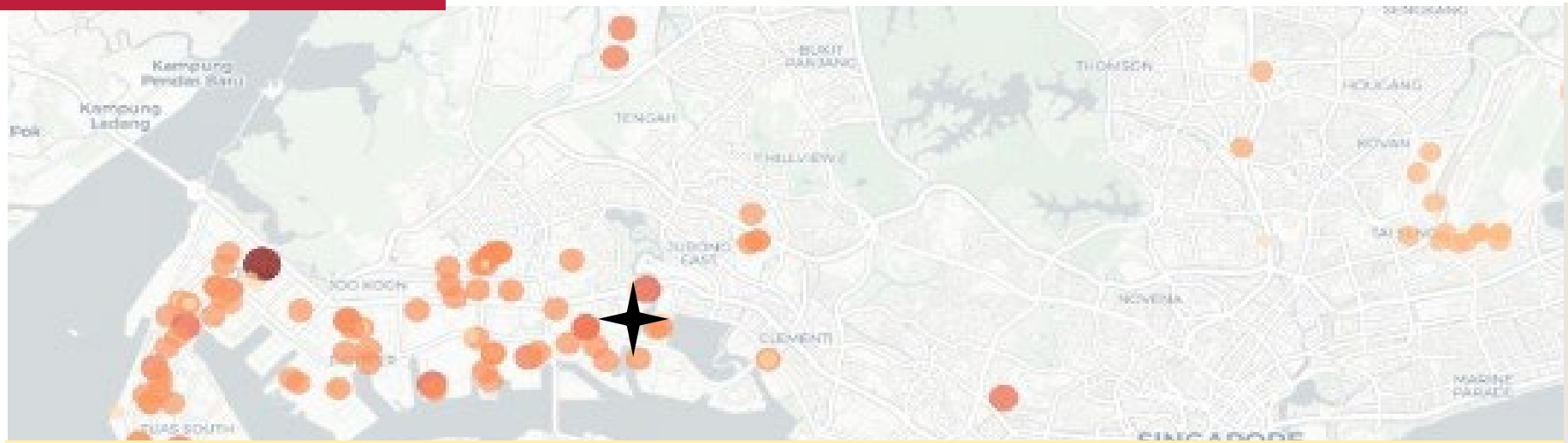

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Graph-Based Recommender System for Urban Industrial Symbiosis: Supporting the Circular Economy

Lorong AI Community Talk

Philipp Grimmel, Chair of Sustainable Manufacturing & Life Cycle Engineering, Institute of Machine Tools and Production Technology (IWF), Technische Universität Braunschweig

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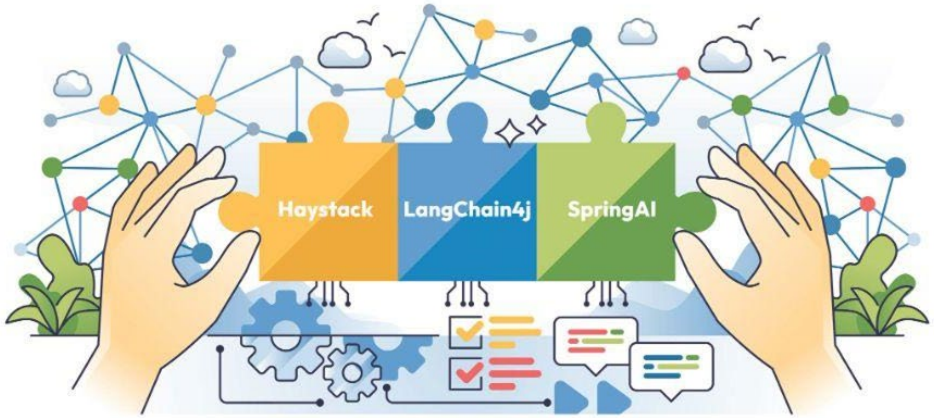
EXPERT INSIGHT

Building Neo4j-Powered Applications with LLMs



Create LLM-driven search and recommendations applications with Haystack, LangChain4j, and Spring AI

Forewords by
Dr. Jim Webber
Chief Scientist, Neo4j
Dr. Julian Risch
Team Lead (Open Source Engineering), deepset

Ravindranatha Anthapu | Siddhant Agarwal

packt

Graph-Based Recommender System for Urban Industrial Symbiosis: Supporting the Circular Economy

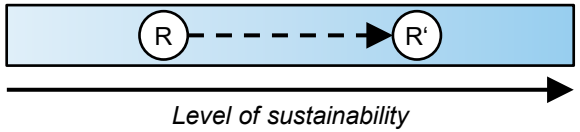
- Motivation
- Sustainable Production and Recommender Systems
- Industrial Symbiosis Recommender Systems
- A Case Study of Wood Wastes in Singapore
- Summery and outlook

Towards Sustainability

From Relative Sustainability …

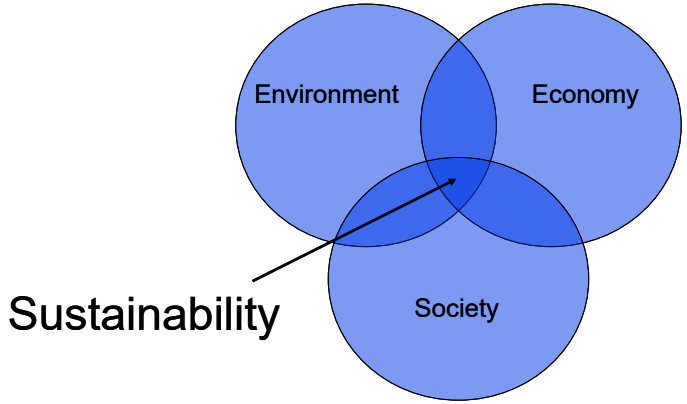
Relative Sustainability

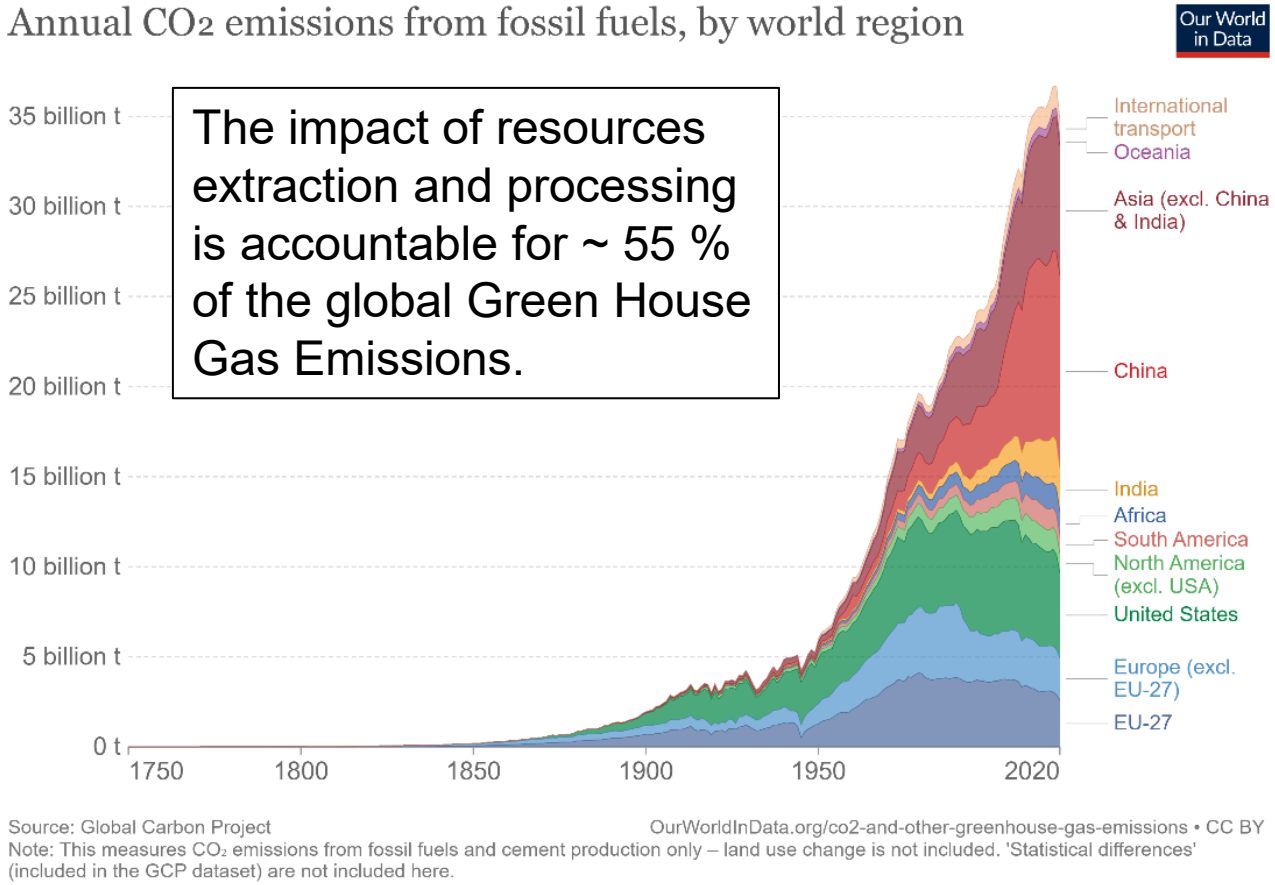
Sustainability is a process (Sustainable Development): R is sustainable. R can be improved to being more sustainable resulting in a situation R‘.



[adapted from Petersen (2017)]

“less bad”
(Focus: efficiency, product, process)





The impact of resources extraction and processing is accountable for ~ 55 % of the global Green House Gas Emissions.

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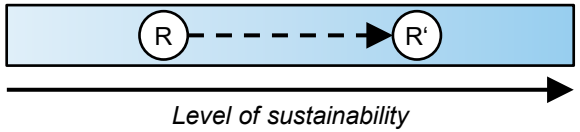

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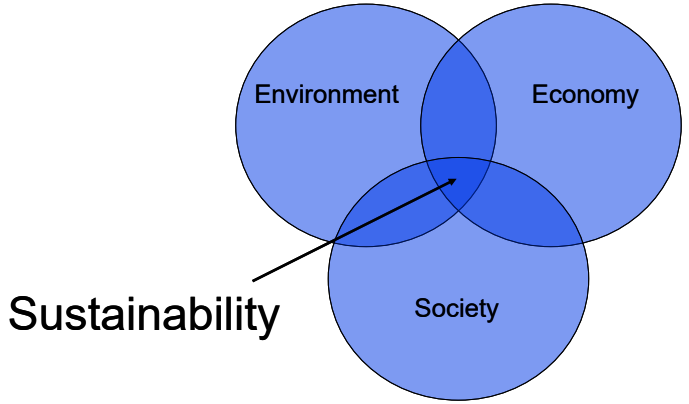
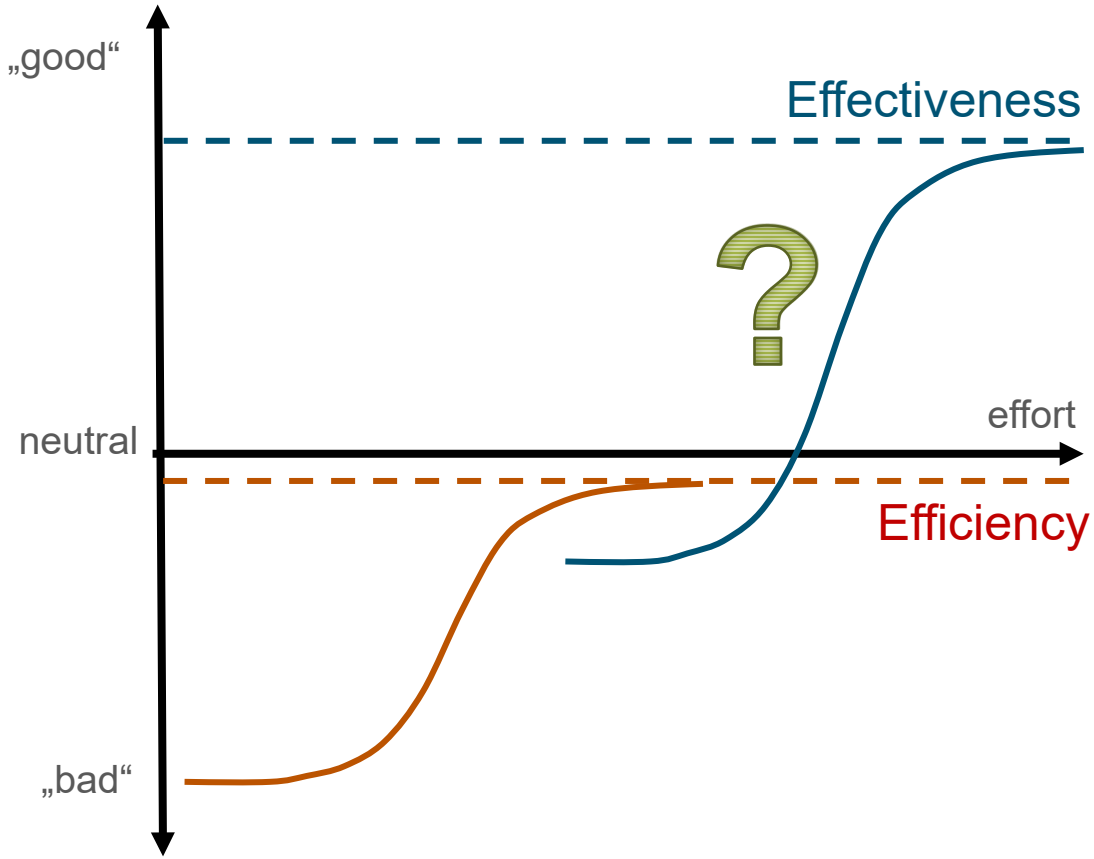


S-curve concept acc. to Foster (1986)



Towards Sustainability
… to absolute sustainability

Absolute Sustainability

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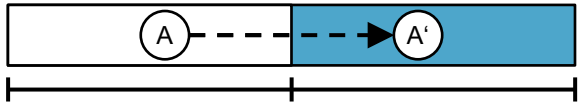

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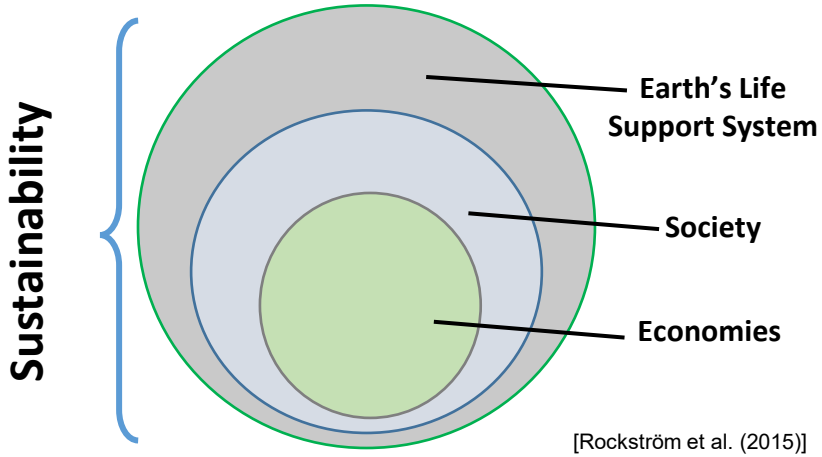
“good”
(focus: effectiveness, system)



[Rockström et al. (2015)]

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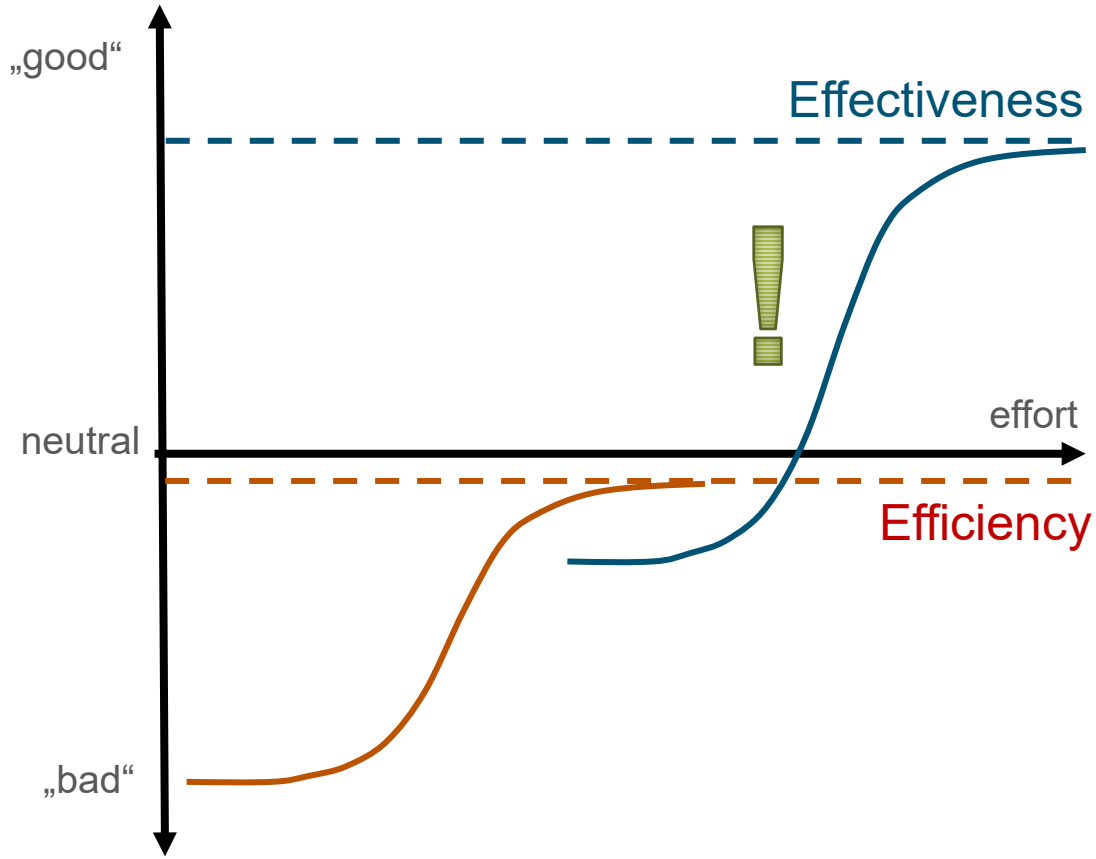

Towards Sustainable Manufacturing

Holistic (Factory) Understanding

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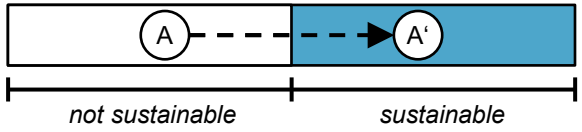

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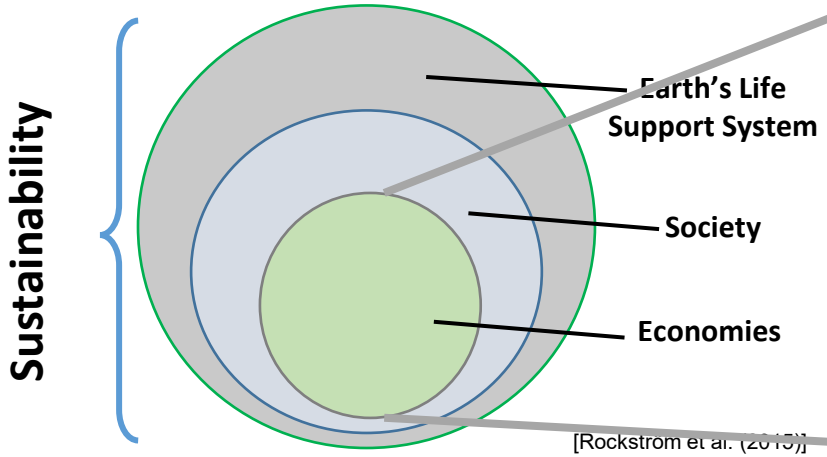

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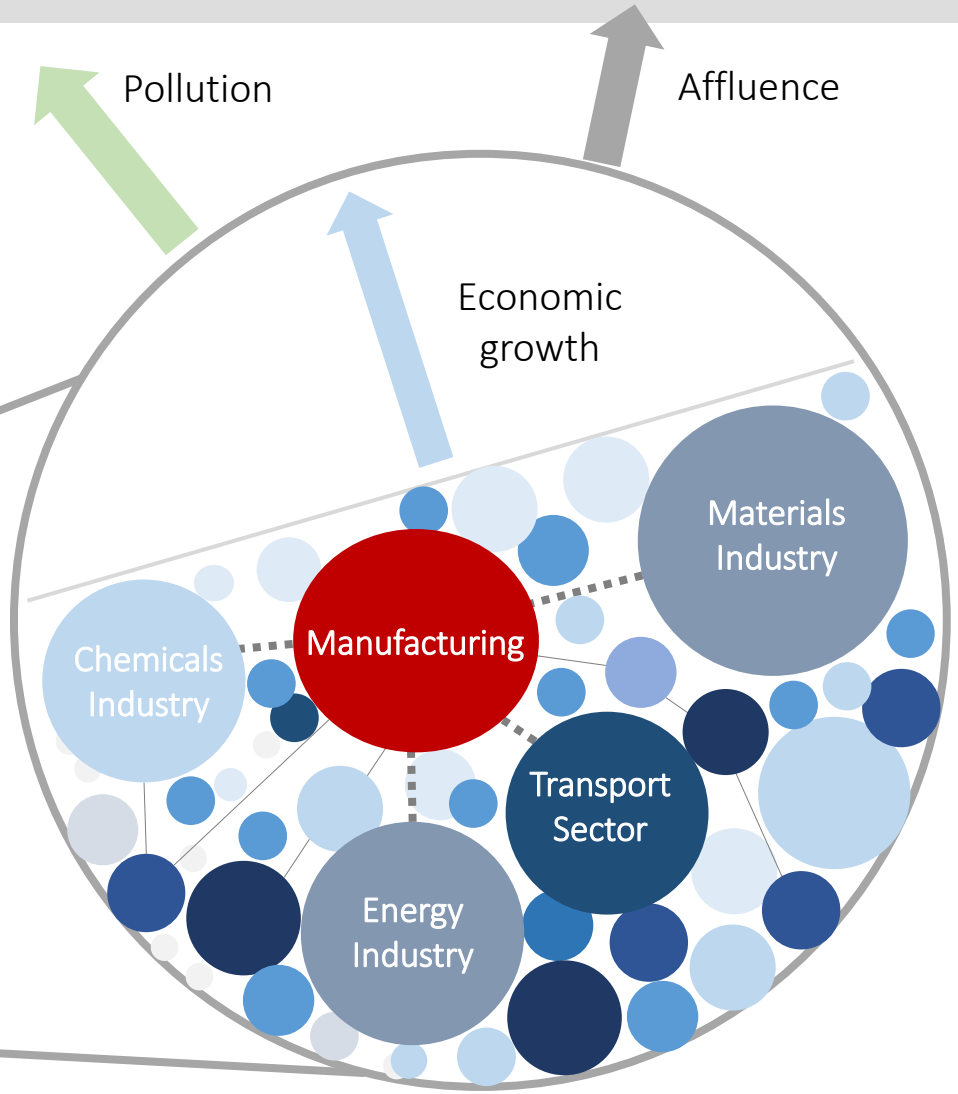

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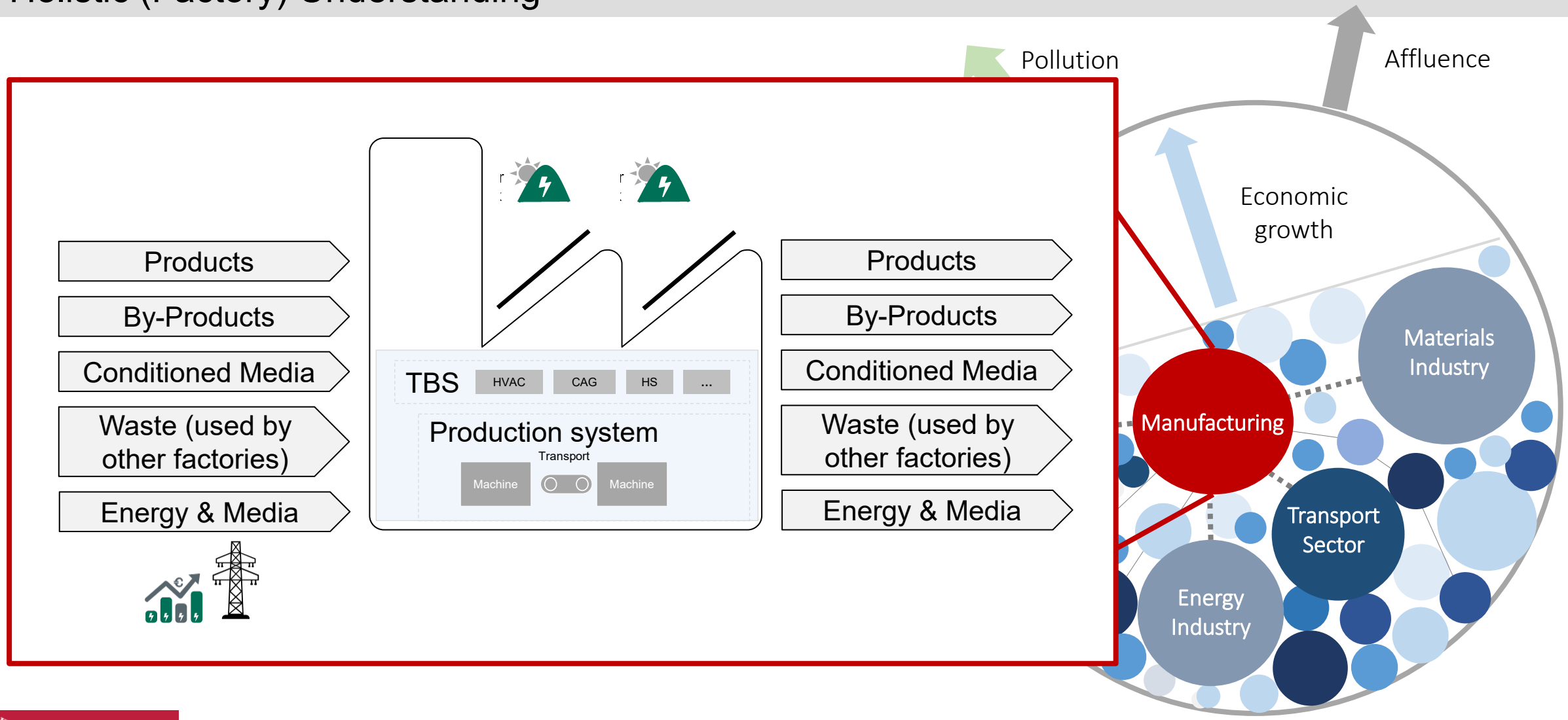
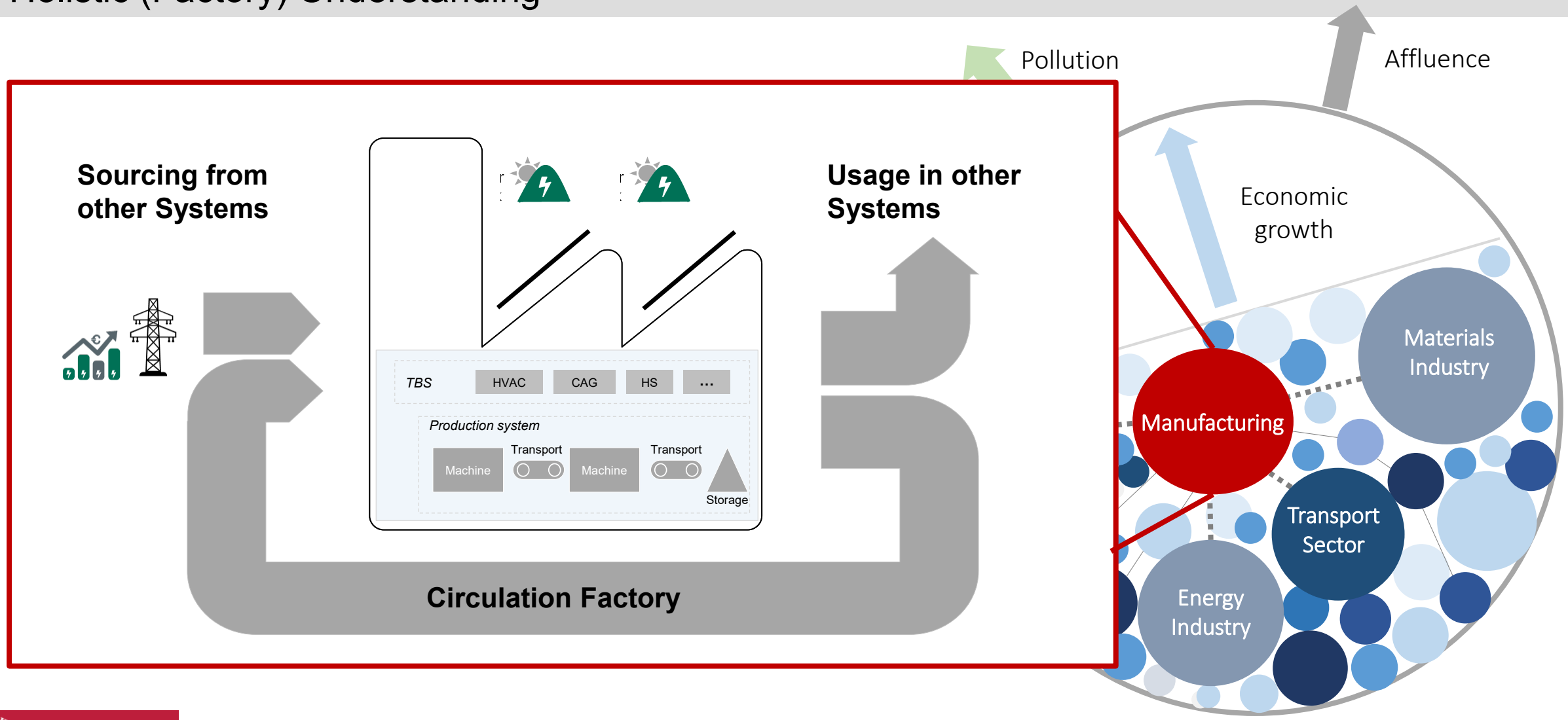


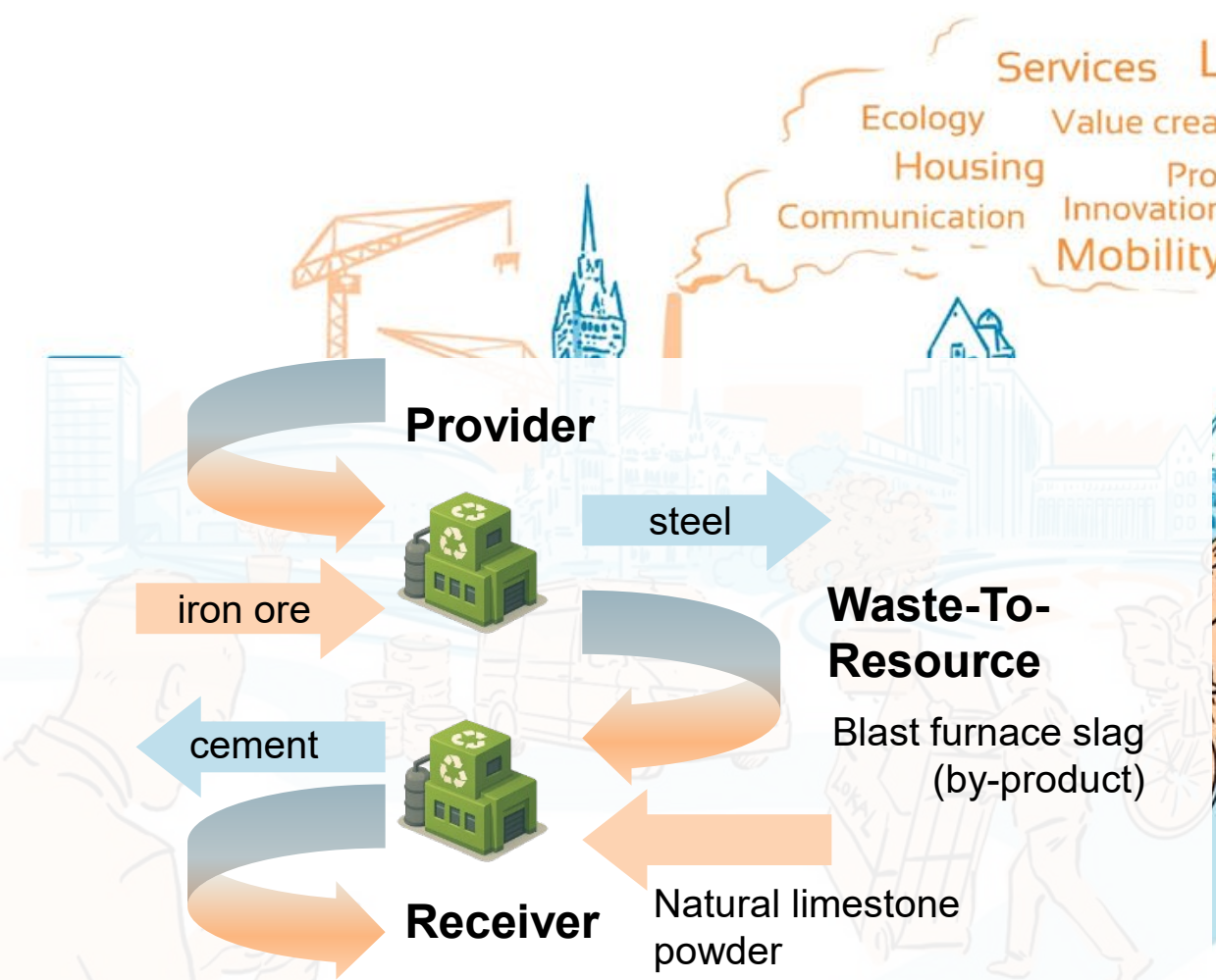
Towards Sustainable Manufacturing

Holistic (Factory) Understanding



Motivation

Urban industrial challenges and material demands can be addressed by Industrial Symbiosis



Factories are **embedded into urban systems**
Leading to several **complex interfaces**

How to identify best exchanges?

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Recommender Systems and Impact Assessment

Enabling the discovery and matching of IS

Bottom Up Design

IS Network

Top Down Design

Industrial Perspective

Resource substitution

By-Product and Waste valorization

…

Urban Perspective

Economic Development

Urban Infrastructures

…

Recommender System for Urban Industrial Symbiosis

Knowledge Base

Historic cases
User preferences
Local value chain information

Cased Based Reasoning

Filter on industry class and material

Feature Based Ranking

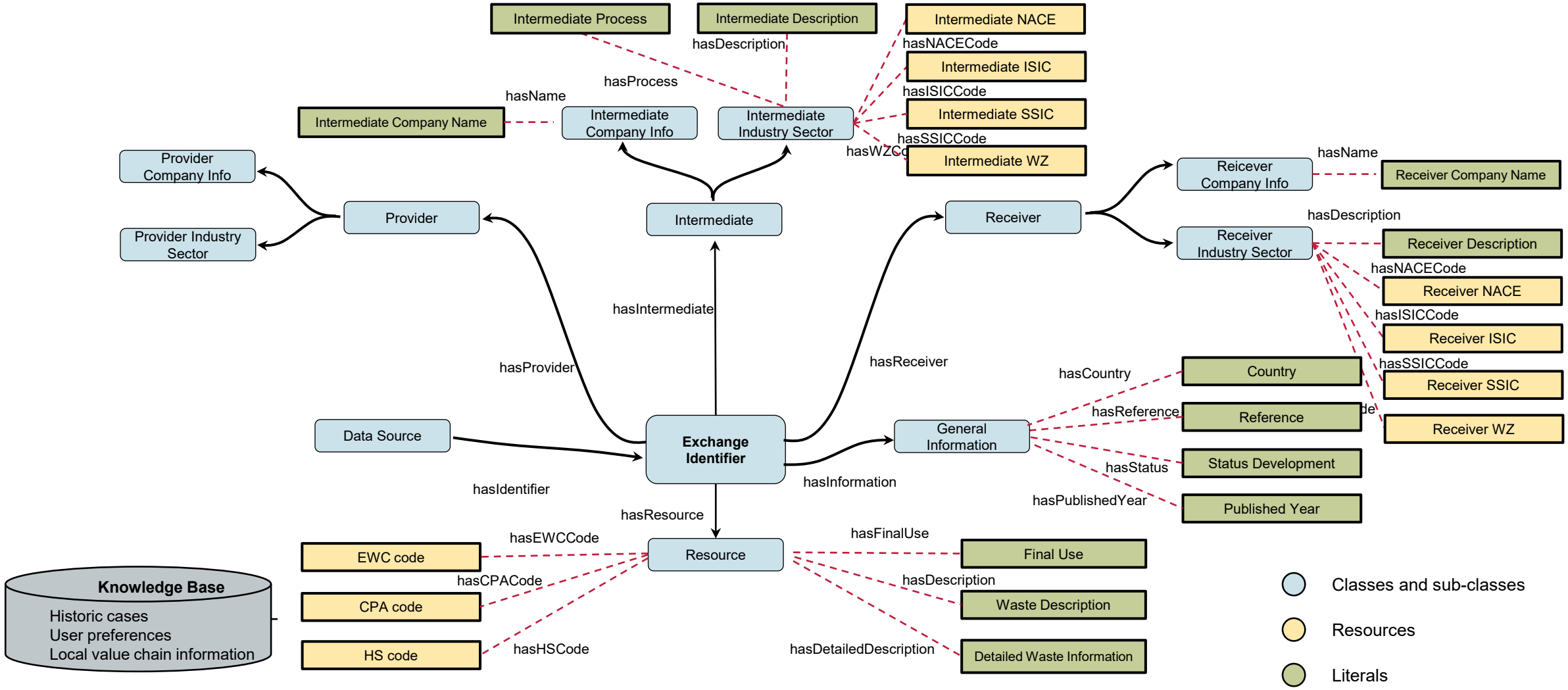
K-Nearest Neighbor to ideal case

Recommendations

Inform on best approaches for new synergies

Recommender Systems and Impact Assessment

Enabling the discovery and matching of IS



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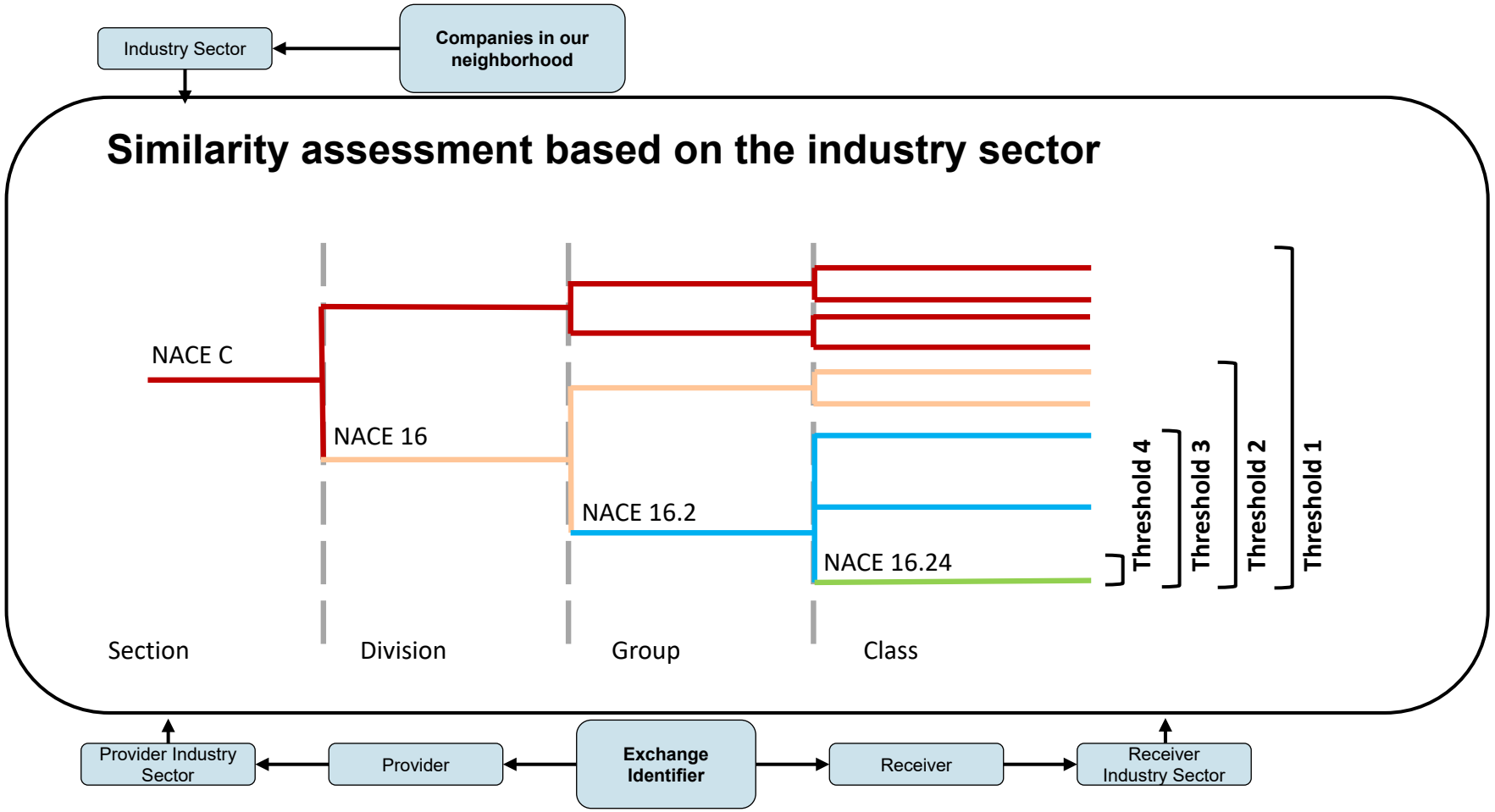
Recommender Systems and Impact Assessment

Enabling the discovery and matching of IS



Cased Based Reasoning

Filter on industry class and material

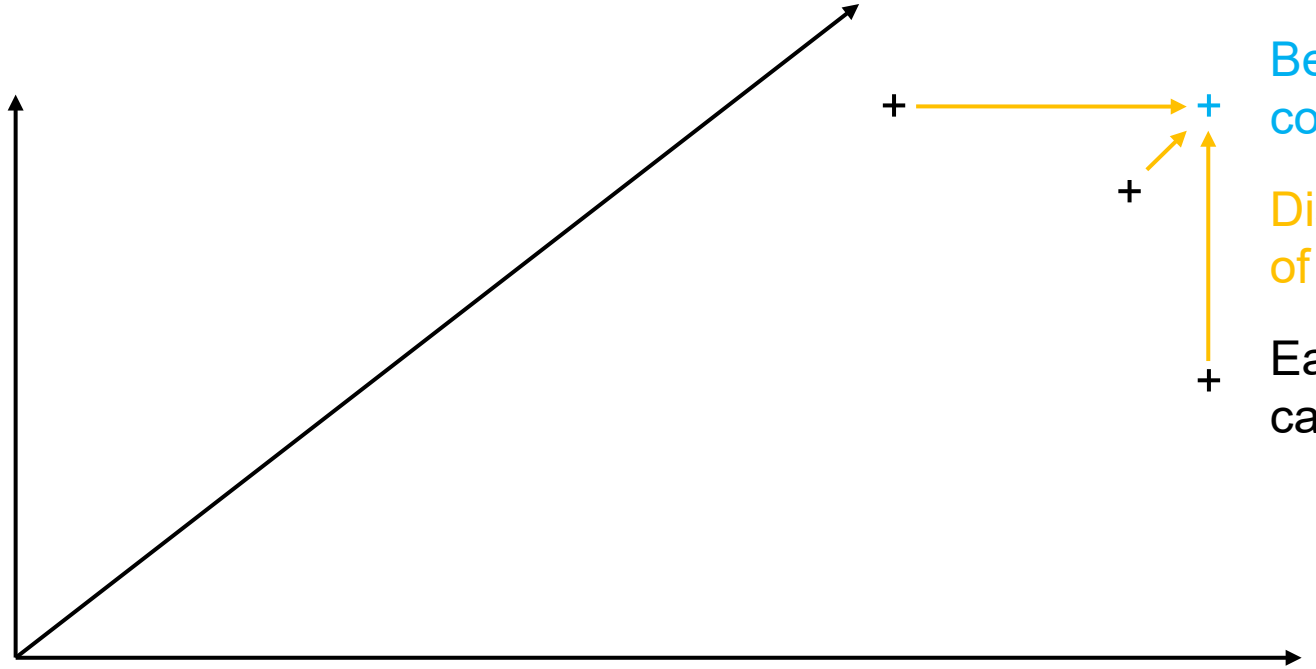
Grimmel, P., Niemeyer, J. F., Tan, C. F., Sun, Y., Zhao, Y., Schöling, N., Yeo, Z., Mennenga, M., Carlow, V. M., & Herrmann, C. (2025). Urban–industrial symbiosis recommendation platform for urban factories: Leveraging historical exchange patterns through feature analysis for real-world applications. *Journal of Industrial Ecology*. Advance online publication. https://doi.org/10.1111/jiec.70015

Recommender Systems and Impact Assessment

Enabling the discovery and matching of IS

Feature x: Expendable

Feature 1:
e.g. industry
similarity



Best possible recommendation considering all features

Distances describe the suitability of each recommdendation

Each recommendation can be mapped

Feature 2: e.g. expected environmental benfit of historic cases

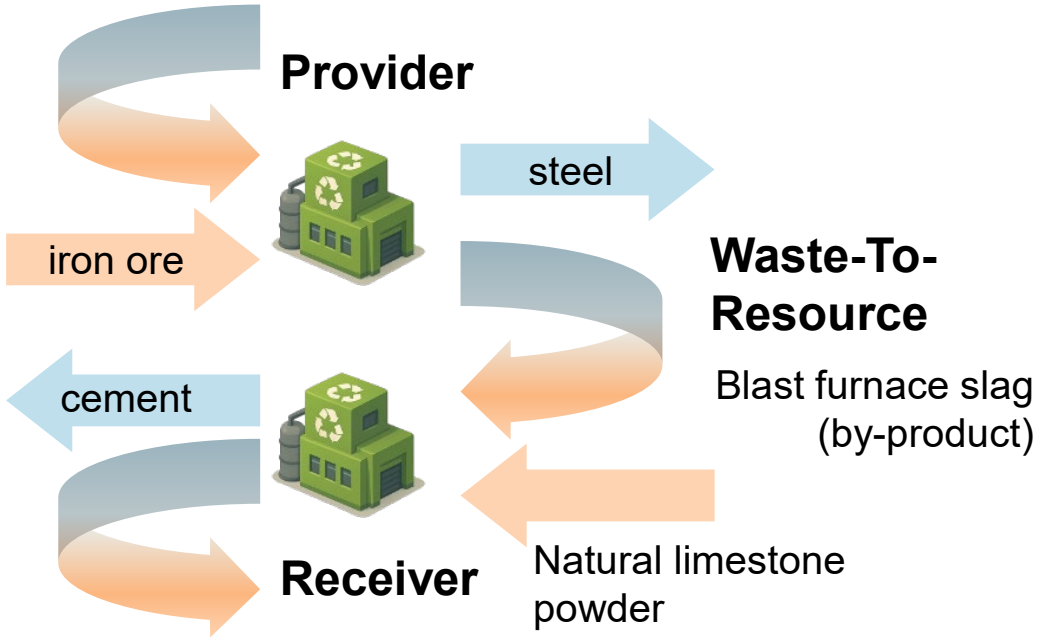
Feature Based Ranking

K-Nearest Neighbor to ideal case

Recommender Systems and Impact Assessment

Enabling the discovery and matching of IS

Each recommendation reflects a
potential new provider or receiver for a specific material or company



How to identify best exchanges?

Based on a historic evidence and a suitability index

Recommendations

Inform on best approaches for new synergies

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A Case Study of Wood Wastes in Singapore

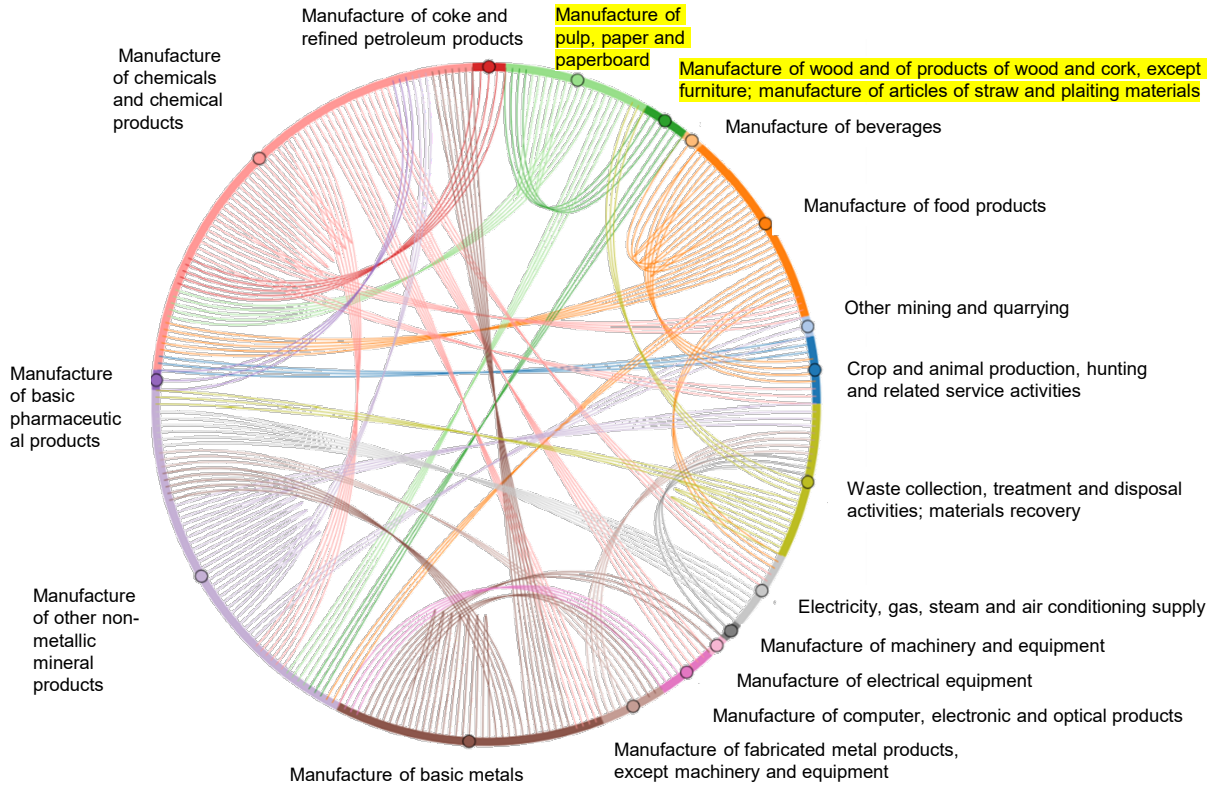
Ranking Industrial Symbiosis Opportunities in Singapore

Setting of case study

- A factory in Singapore generates a wood by-product suitable for industrial symbiosis.
- Over 140 factories in the region show high potential to incorporate this by-product into their production processes.

How to identify best exchanges?

Historic exchange patterns include manufacturer of wood products and paper products



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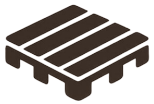
A Case Study of Wood Wastes in Singapore

The impacts depend on the final use

Historic Cases

- In history four different end uses have been established for the wood waste from similar factories
- With different similarities to the historic cases
- At different locations across Singapore

Wood pellet

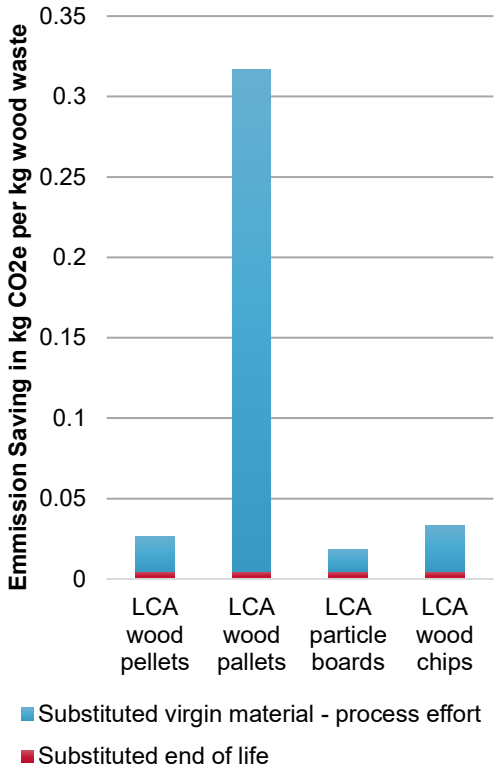


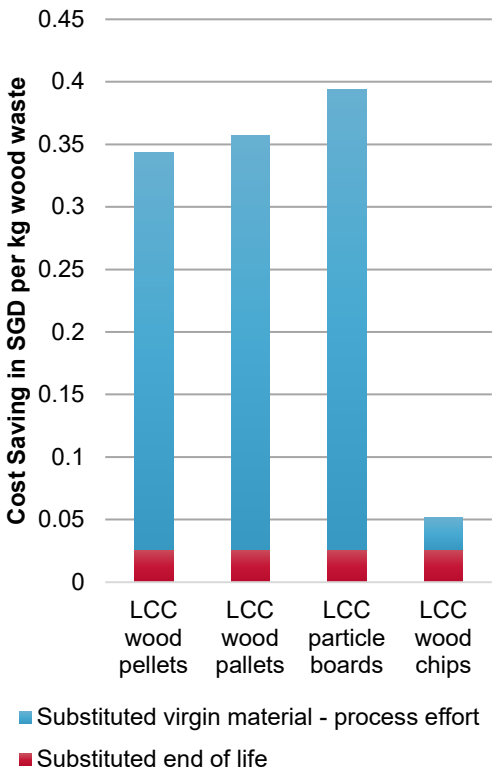
Wood pallet

Wood chips

Particle board

Features





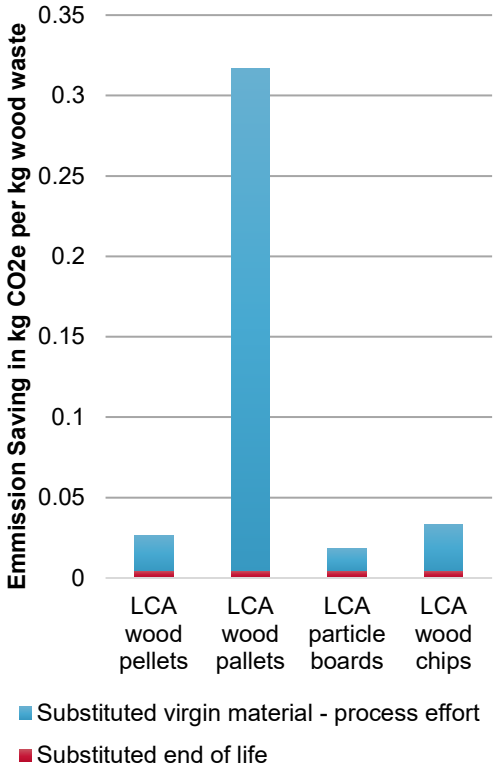
Further Features:

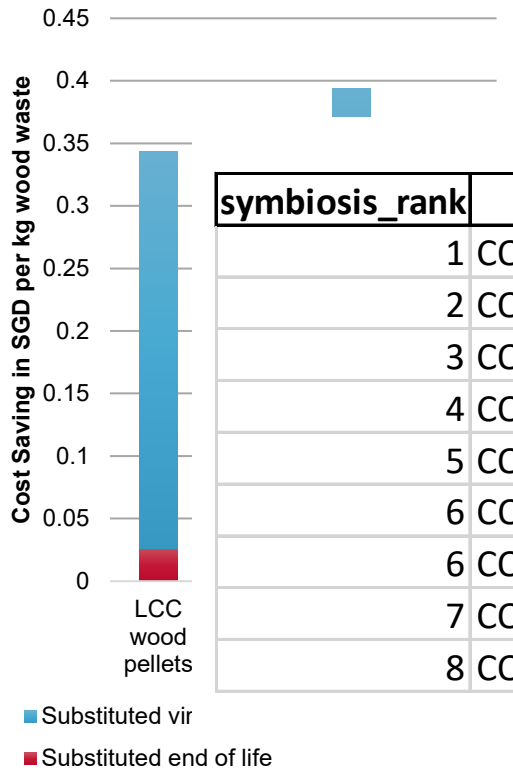
- Technical Feasibility
- Physical Distance that effect also LCA and LCC of individual recommendations

A Case Study of Wood Wastes in Singapore

The impacts depends on the final use

Features





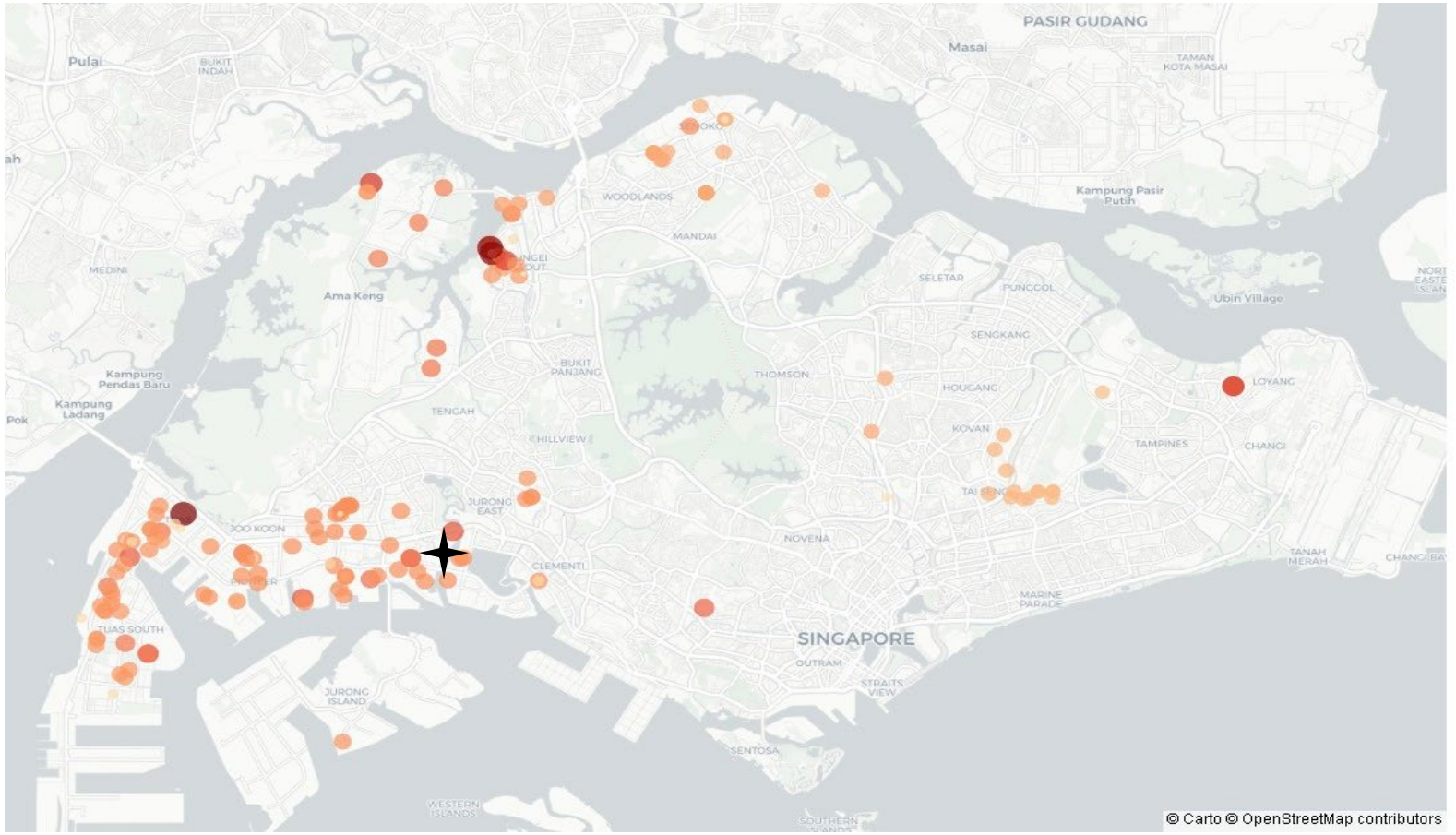
Rank the recommendations

1. Weight each feature (i) w_i
2. Calculate a distance between each

symbiosis_rank	company_id	company_industry	suitability_overall	fa
1	COM:Company/30	ISIC4:1702	1	
2	COM:Company/53	ISIC4:1701	0.98	
3	COM:Company/117	ISIC4:1702	0.98	
4	COM:Company/69	ISIC4:2399	0.8	
5	COM:Company/93	ISIC4:2395	0.8	
6	COM:Company/146	ISIC4:1702	0.75	
6	COM:Company/61	ISIC4:1702	0.7	
7	COM:Company/54	ISIC4:2029		
8	COM:Company/56	ISIC4:2029		

A Case Study of Wood Wastes in Singapore

Ranking Industrial Symbiosis Opportunities in Singapore



- Most suitable wood waste recipients highlighted in red based on suitability.
- Key suitability factors: end use and technical feasibility (exchange likelihood).
- High synergy potential for a single material indicates strong scalability in urban setting

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Discussion and outlook

Enabling systematic identification and ranking of high-potential Industrial Symbiosis opportunities

Graph Approach

- Provide suitable recommendation for industrial symbiosis in complex environment
- Highly flexible system to add further data and decision criteria into the graph

Further Demands

- Expand the knowledge graph with unstructured data by knowledge extraction e.g. from literature and CSRD reports
- Refine the suitably assessment based in a model based approach considering network effects.

Further Applications

Identification synergies in industrial parks

Identification of synergies in urban settlement units

Cooperation models and contact

- Strategic research cooperation
- Development partnership
- Project based cooperation
  - Publicly funded projects
  - Bilateral contract projects
- Student exchange

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Sustainability and Informatics Cycle Engineering

Acknowledgement

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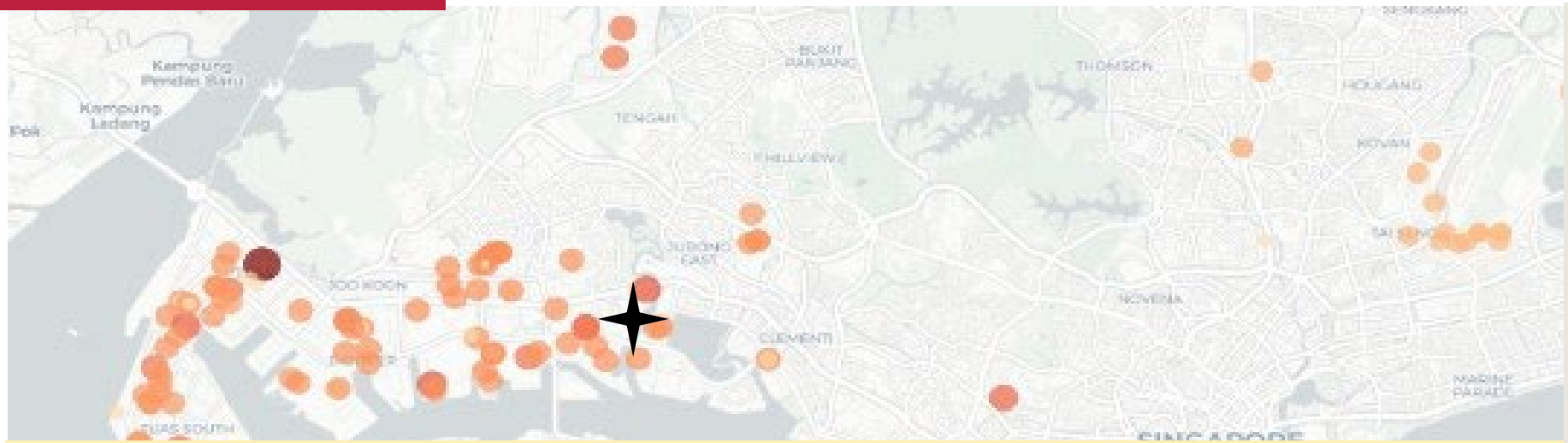

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