Our Future: The Growing Reach of Industrial Symbiosis

Prof. Marian Chertow

Director, Center for Industrial Ecology, Yale School of the Environment

June 7, 2023

- Industrial Ecology
  - Industrial Ecosystem
    - Eco-Industrial Park/Estate
      - Industrial Symbiosis

      - **10^{th} International Sustainable Industrial Areas Conference**

Business Strategy and the Environment

ERP ENVIRONMENT

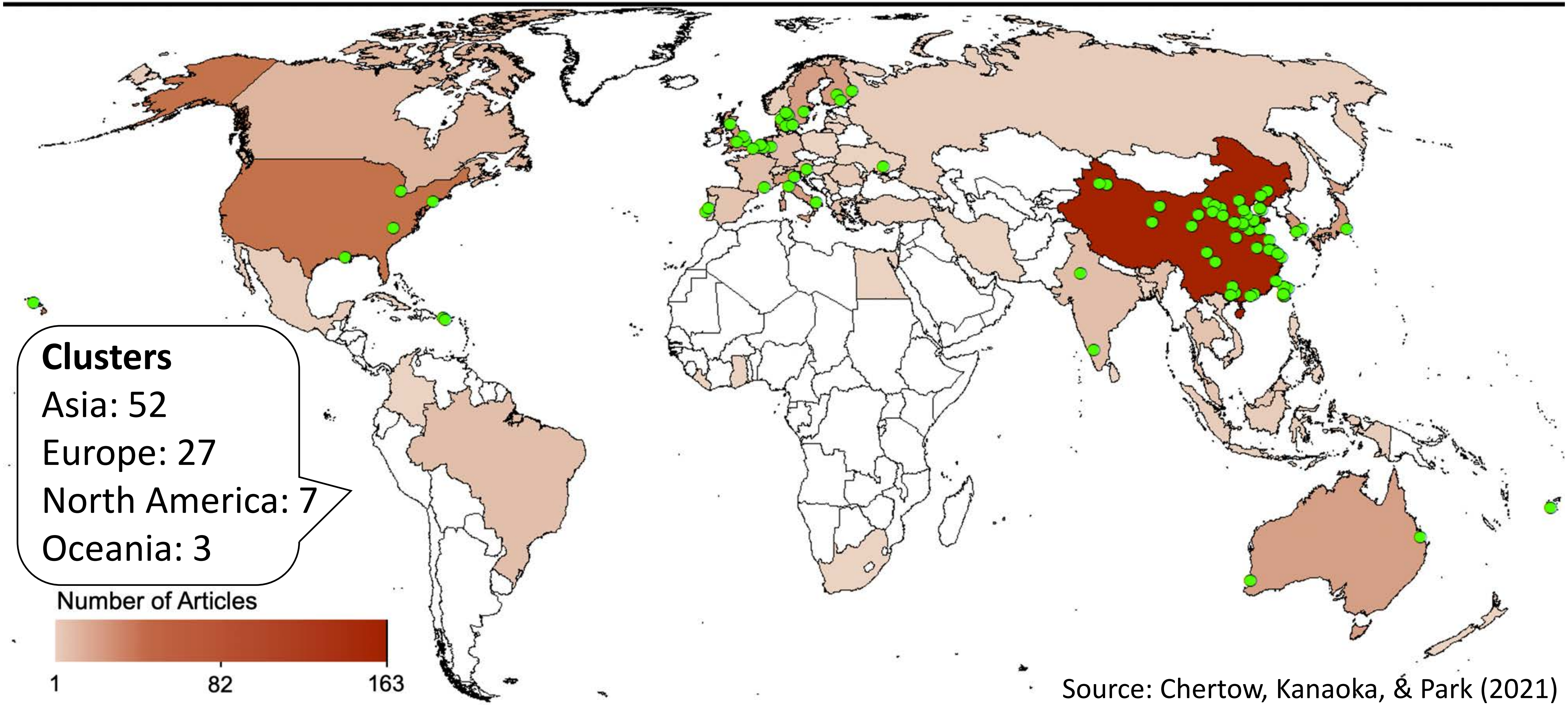
RESEARCH ARTICLE

Industrial symbiosis within eco-industrial parks: Sustainable development for Borg El-Arab in Egypt

Suzanna ElMassah

First published: 01 March 2018 | https://doi.org/10.1002/bse.2039 | Citations: 24

We catalogued 89 industrial clusters in 21 countries that were identified in journal articles on industrial symbiosis (1995–2018)



Source: Chertow, Kanaoka, & Park (2021)

1989 – Roots of Industrial Ecology

“Industrial ecosystem” idea proposed at General Motors

“In an industrial ecosystem, the consumption of energy and materials is optimized, waste generation is minimized, and the effluents from one process serve as the raw material for another” - Frosch & Gallopoulos (1989)

“Industrial symbiosis” is coined in Kalundborg, Denmark

“a cooperation between different industries by which the presence of each...increases the viability of the other(s), and by which the demands [of] society for resource savings and environmental protection are considered.”

- Valdemar Christensen (in Engberg, 1993)

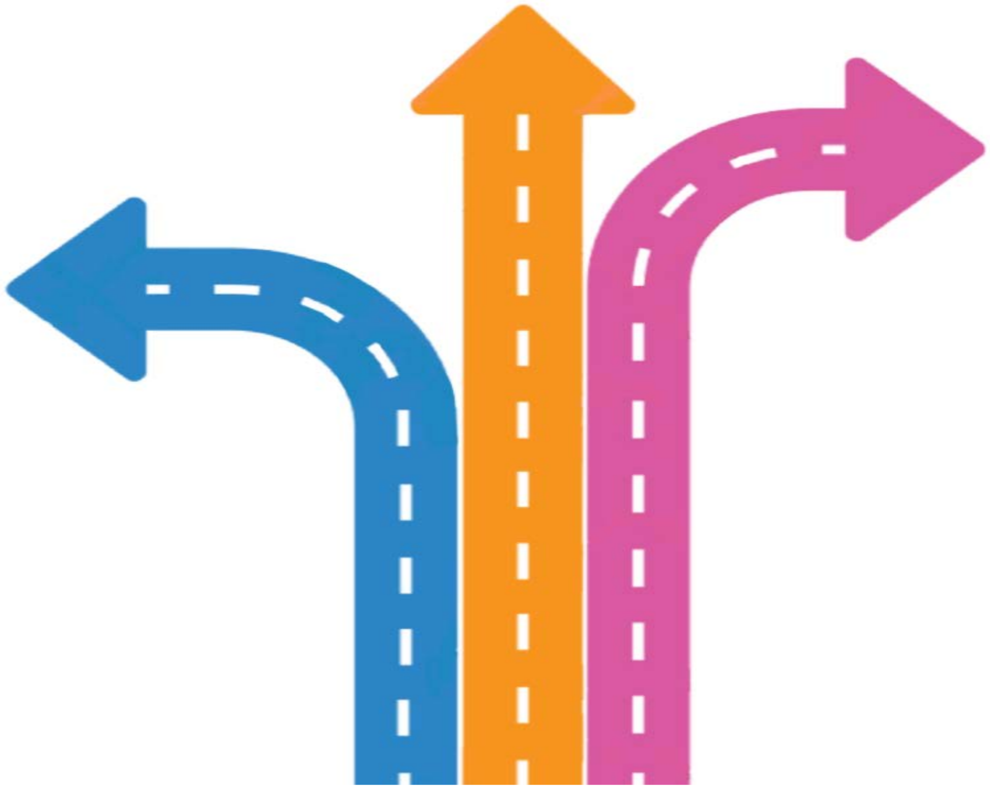
Industrial Symbiosis Dynamics:
A framework for categorizing cases

- The problem of equivalence: the difficulty of comparing instances of industrial symbiosis across different cultural and institutional contexts

- Interest in our research group: to take on the challenge of comparative analysis at the near-global level by (1) identifying different varieties of symbiosis and (2) by organizing a typology of them

- Establishing IS dynamics: the typology of typical pathways of industrial symbiosis is expressed as a set of six dynamics

Boons, Chertow, Park, Spekkink, & Shi (2017)



Six dynamics currently identified

1. Self-organization
2. Organizational boundary change

3a. Facilitation - brokerage

3b. Facilitation - collective learning

4. Pilot facilitation and dissemination
5. Government planning
6. Eco-cluster Development

Focus on 3 of 6 dynamics of industrial symbiosis

- **Organizational Boundary Change** –symbiotic linkages evolve from exchanges that used to take place within the organizational boundaries of one company

  EXAMPLE – British Sugar

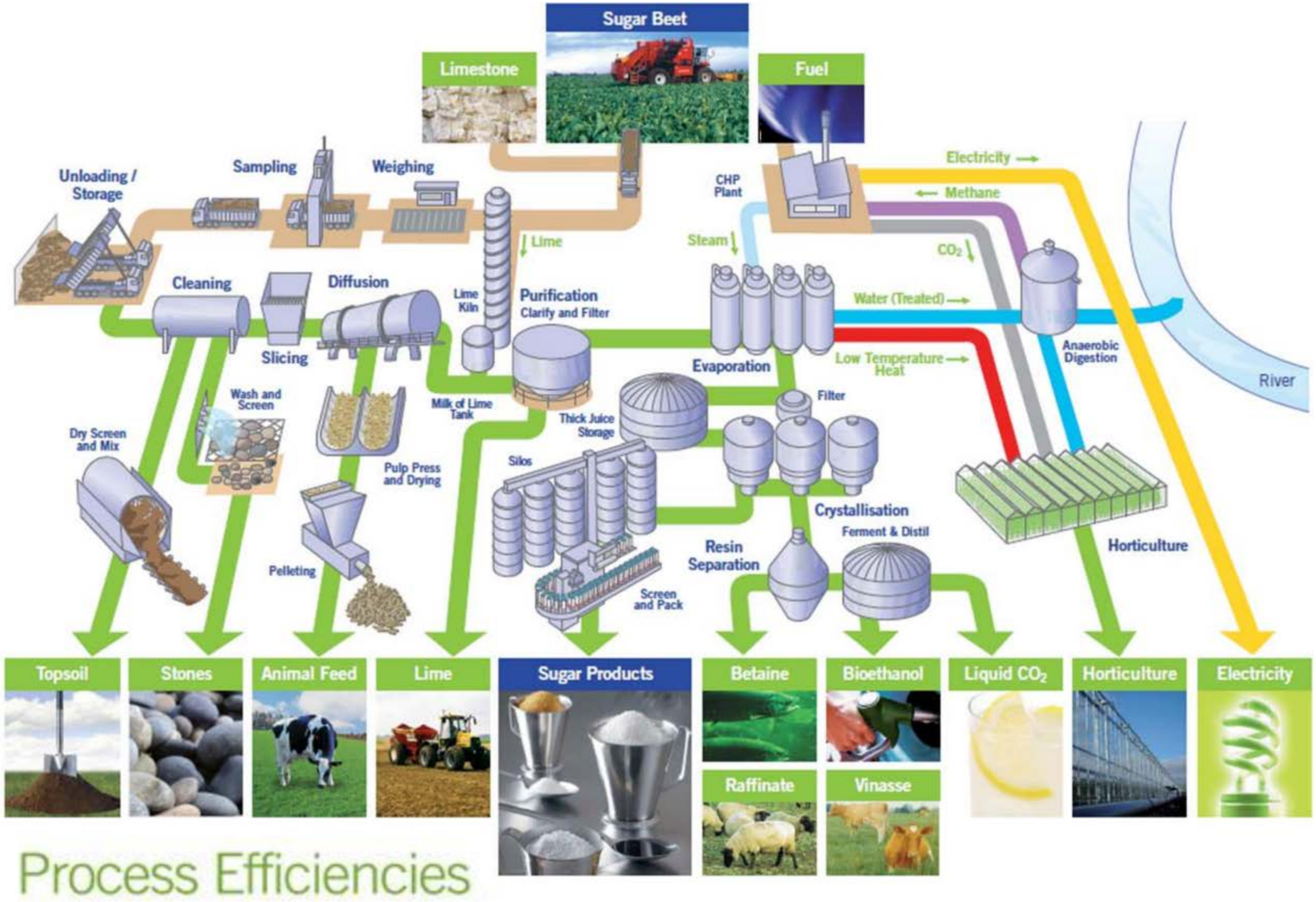
- **Facilitation** - an actor(s) enables the development of symbiotic linkages among multiple industrial actors

  EXAMPLE – Cape Town, South Africa

- **Self-Organization –** development of symbiotic activities as a result of self-motivated strategies of industrial actors

  EXAMPLE – Kalundborg, Denmark; Nanjangud Industrial Area, India

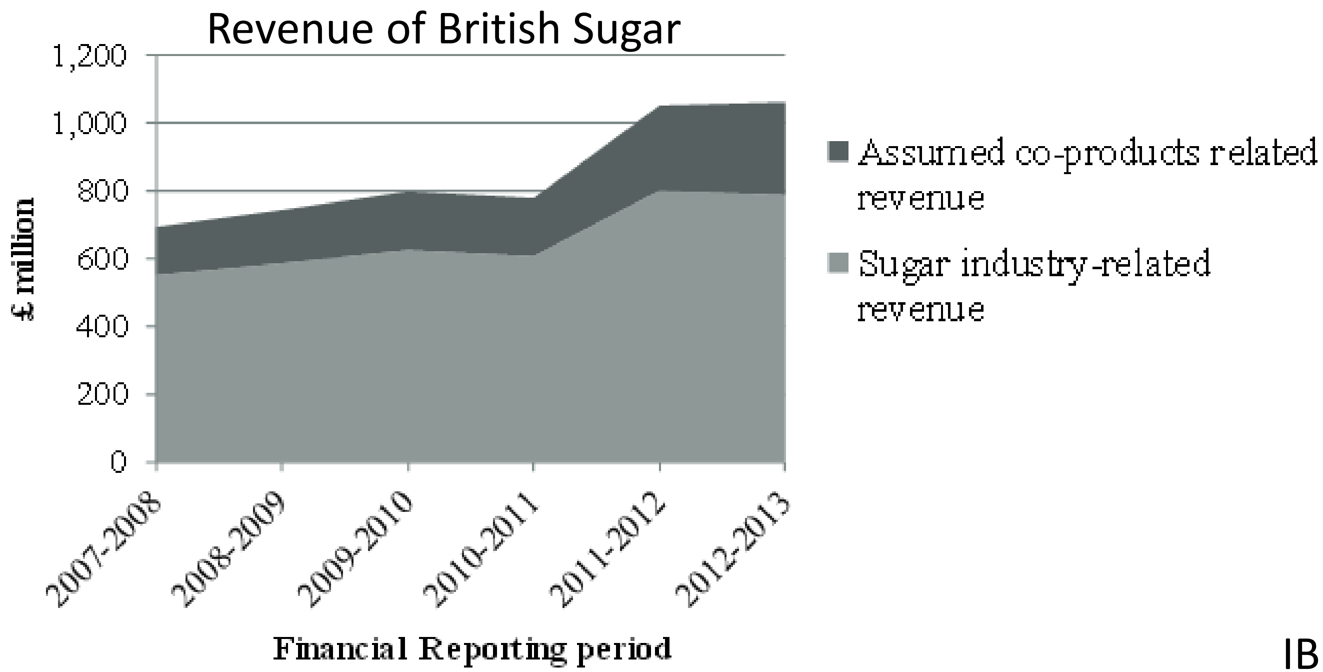
Organizational Boundary Change at British Sugar
What could be "symbiotic" at a sugar beet plant?



Wissington site: See www.britishsugar.co.uk

British Sugar's risk management with by-products

SUGAR	
Bulk granulated	220kt
Bulk liquid	50kt
Liquid blends	10kt
Granulated bags	100kt
Caster bags	40kt



CO-PRODUCTS	
Animal feed	140,000 tonnes
Betaine	6,000 tonnes
Bioethanol	55,000 tonnes
CO2	40,000 tonnes
Electricity	500,000 MWh
LimeX	120,000 tonnes
Tomatoes	15,000 tonnes
TOPSOIL	150,000 tonnes
Aggregate	9,000 tonnes

IBISWorld (2013); Short, Bocken, Barlow, & Chertow (2014)

“We don’t grow tomatoes just because it feels good to make effective use of our waste carbon-dioxide streams. We do it because we think we can make a return on the investment. It’s a good example of how sustainability can be used to drive a business forward.”

- Mark Carr, Former Group Chief Executive, AB Sugar

CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

GreenCape

Facilitation of Industrial Symbiosis in Cape Town

Tiered Government System

Population: 4.6 million (7.7%)

Growth rate: 2-3%

Population Density: 1,600/km2

GDP per capita: US$7,063

GDP Growth: 4%

% of National GDP: 9.9%

Unemployment: 29.6%

RSA Gini Coefficient: 0.64

Industrial Symbiosis facilitators connect companies so that they can exchange under-utilized resources, this leads to increased resource efficiency, environmental savings, job creation and business benefits like cost savings, and increased profits.

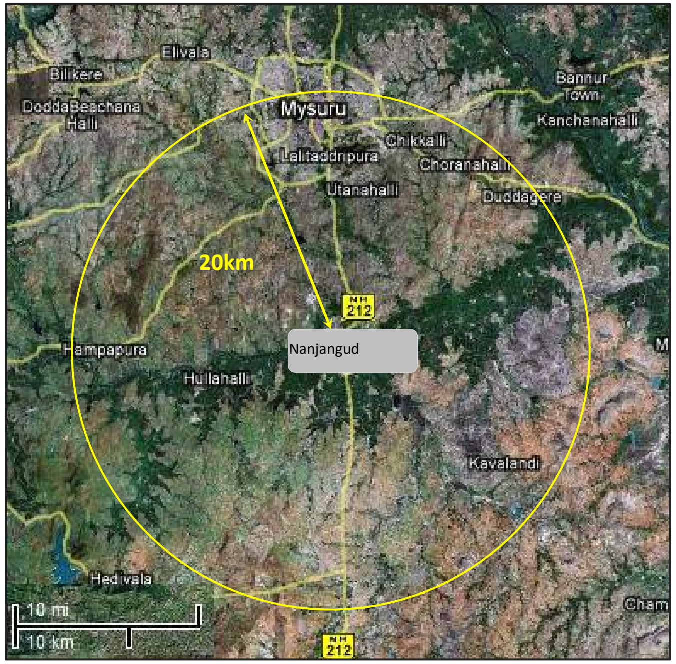
WISP
Western Cape Industrial Symbiosis Programme

Example of Facilitation Dynamic

Core of the program has been the “Business Opportunity Workshops” (networking lunch meetings) and SYNERGie database

Mayor DeLille is now the
Minister of Tourism for South Africa

Self-organization - Nanjangud Industrial Area Karnataka, India BEST EVER ON CIRCULARITY

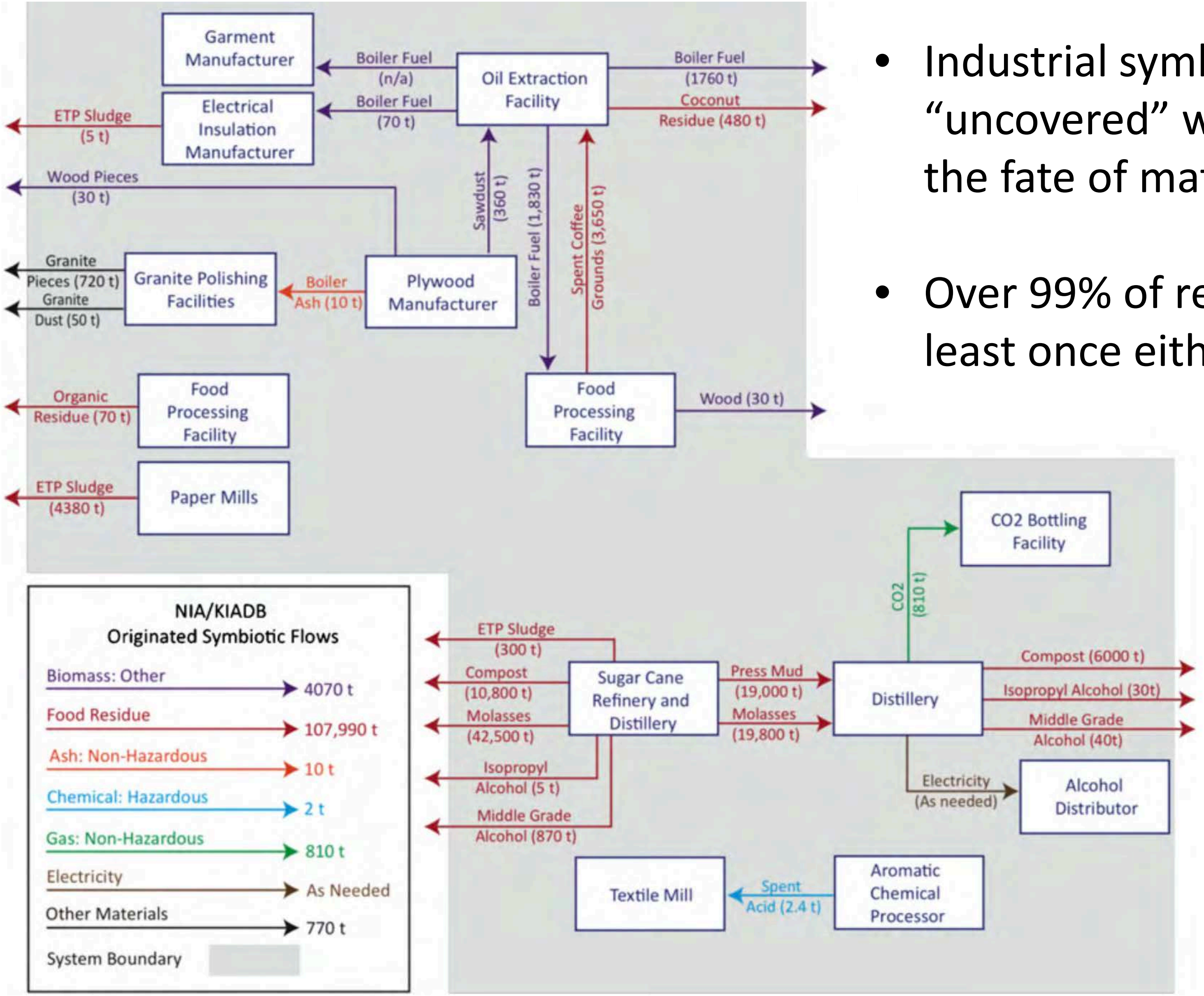


Profile of industrial enterprises in NIA

45 facilities –
900,000 tons/year of potential discards

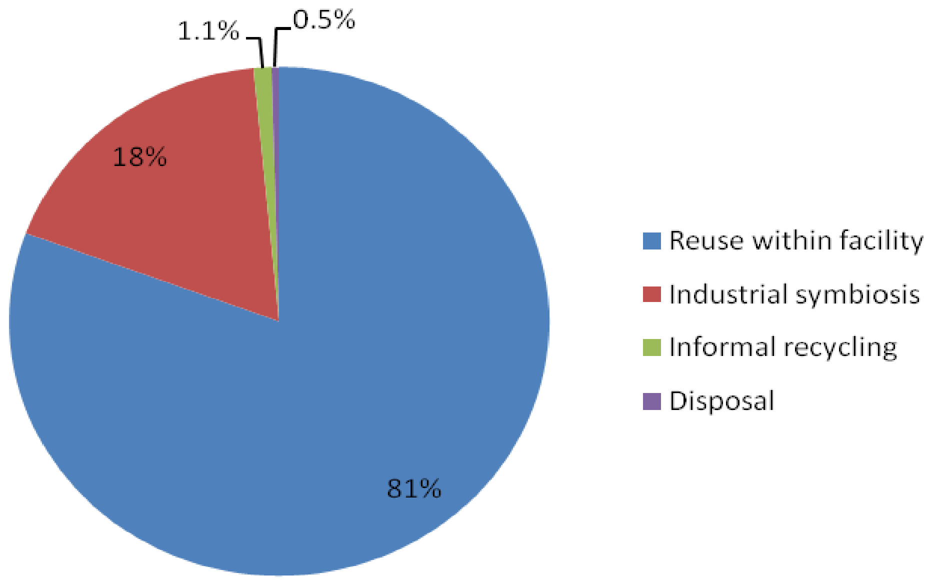
1. A sugar refinery and a coffee/beverage producer account for ~60% production volume
2. Printed circuit boards, paper, textiles, automotive parts, distillery
3. Micro-enterprises: granite cutters, oil producer, food processors
4. Surrounded by a large agricultural community

Uncovering Industrial Symbiosis in Nanjangud



- Industrial symbiosis in Nanjangud Industrial Area was "uncovered" when industrial ecology students mapped the fate of materials and energy in this industrial park

- Over 99% of residuals were being reused or recycled at least once either within or across companies

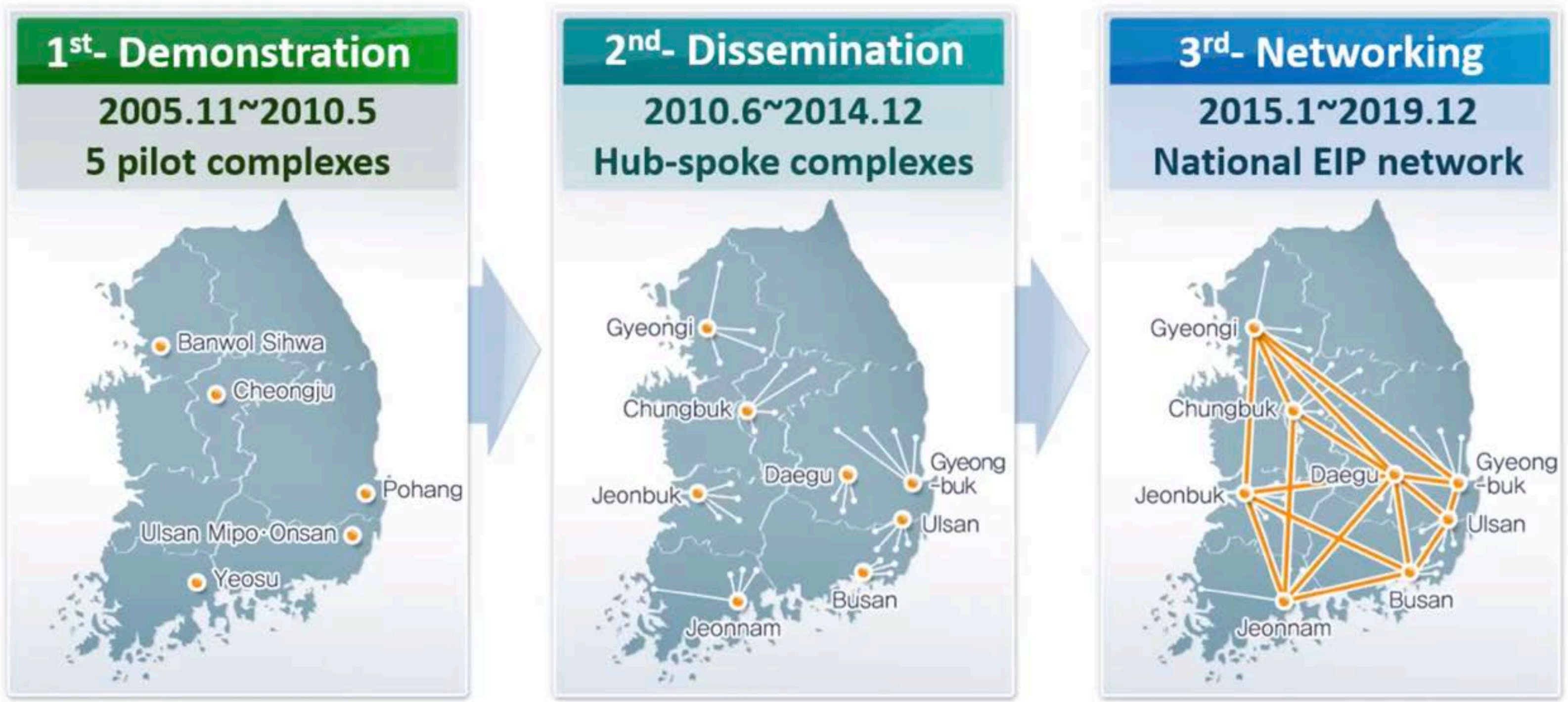


Chertow (2007); Bain et al. (2010)

South Korea's (Lucrative)
National Eco-Industrial Park (EIP) Development Program

Motivation: Retrofit the aging and polluting industrial parks into an "environmentally friendly industrial base"

EIP Initiatives Three-stage Master Plan (2005 – 2019)



Source: Korea Industrial Complex Corporation

Post National EIP Program

- Industrial Symbiosis Technology Development Program (2019–2021), Korea Evaluation Institute of Industrial Technology
- EIP Graduate Program (2019–2023), Korea Institute for Advancement of Technology
- EIP Overseas Market Development Program (2018–present), Korea Energy Agency
- Subsidy for Mitigation and Utilization of Carbon from Industrial Parks (2017–2022), Korea Institute of Industrial Technology
- Ulsan Regional EIP Center privatized

Keit 한국산업기술평가관리원 Korea Evaluation Institute of Industrial Technology

KIAT Korea Institute for Advancement of Technology

KOREA ENERGY AGENCY

KITECH Korea Institute of Industrial Technology

The growing reach of industrial symbiosis

European Commission

CIRCULAR ECONOMY
Closing the loop

UN environment programme

WORLD BANK GROUP

giz
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

United States Business Council for Sustainable Development

UNIDO
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

International Synergies
industrial ecology solutions

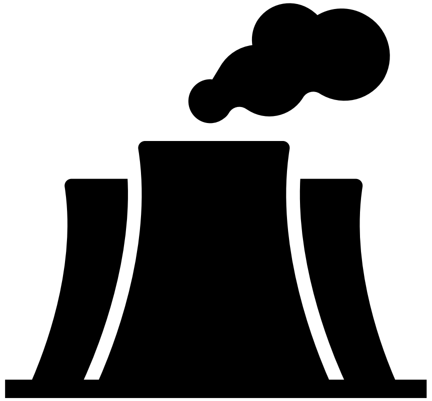
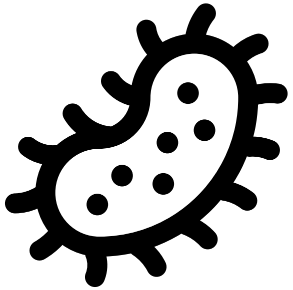
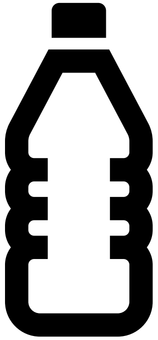
ADB
ASIAN DEVELOPMENT BANK

Chittagong, Bangladesh

Istanbul, Turkey

Peshawar, Pakistan

The Future of Industrial Symbiosis (?)

Waste input		**Process**		**Output**
	>		>	
OFFGAS *STEEL MILL*		MICROBE FERMENTATION		ETHANOL

LanzaTech

Translating knowledge into impact

Yale SCHOOL OF THE ENVIRONMENT
Center for Industrial Ecology

THE WORLD BANK

Collaborations:

- Memorandum of Understanding
- Creating online, open source IS data platform for use by industrial parks
- Advising on IS implementation in Morocco, Bangladesh, and more
- Publication in progress - Angel Hakim, et al. Data-limited industrial symbiosis: Developing methodology and application from Morocco

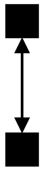
Annual Industrial Symbiosis Research Symposium

Year	Hosting location	Host or contact person
2004	New Haven, Connecticut, **USA**	Marian Chertow
2005	Stockholm, **Sweden**	Noel Jacobsen
2006	Birmingham, **UK**	Peter Laybourn
2007	Toronto, **Canada**	Ray Côté
2008	Devens, Massachusetts, **USA**	Peter Lowitt
2009	Kalundborg, **Denmark**	Jørgen Christensen
2010	Kawasaki, **Japan**	Tsuyoshi Fujita with China, Korea, Japan sponsorship
2011	San Francisco, California, **USA**	Marian Chertow
2012	Tianjin, **China**	Shi Han, Yuyan Song
2013	Ulsan, **South Korea**	Hung-Suck Park
2014	Melbourne, **Australia**	Robin Branson, Biji Kurup
2015	Lausanne, **Switzerland**	Guillaume Massard, Suren Erkman
2016	Devens, Massachusetts, **USA**	Peter Lowitt
2017	Chicago, Illinois, **USA**	Weslynne Ashton
2018	Cartago, **Costa Rica**	Jose Alfaro, Graham Aid
2019	Beijing, **China**	Graham Aid, Chang Yu with China sponsorship
2020–2022	Postponed due to COVID-19	
2023	Leiden, **Netherlands**	TBA

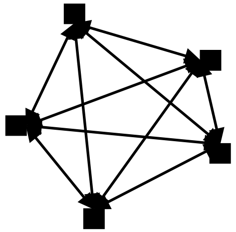
EXTRA SLIDES for SIP Conference

What counts as industrial symbiosis?

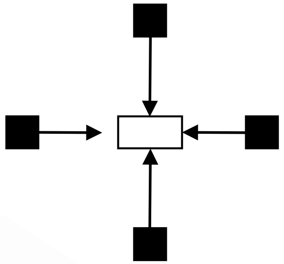
- Byproduct exchanges
  - One company’s waste becomes another’s feedstock



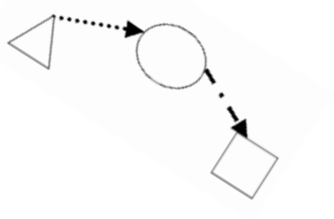
- Utility/infrastructure sharing
  - Shared access/management of utilities (electricity, water, wastewater)



- Service sharing
  - Shared common services with clear environmental savings provided by third parties (recycling, pipelines)



- 3-2 Heuristic for minimum size of system
  - At least 3 entities with at least 2 materials
  - If < 3-2 symbiosis, categorized as “precursor” or “kernel” of symbiosis



Chertow 2007, Ashton 2008, Chertow et al 2008

Industrial Symbiosis & Climate Change

- Industrial symbiosis can reduce carbon emissions.
  - Use of by-products reduces impacts from extraction and processing of virgin materials.
  - For example: industrial district of Ulsan, South Korea saves approximately 200,000 tons of CO_2 per year as a result of reductions in electricity use, fuel combustion, virgin material extraction, and water consumption.
- Symbiosis can reduce climate-change-induced business risk.
  - Local sourcing of by-products provides better supply chain resilience against more frequent natural disasters (depending on location of firms).
  - Replacing virgin materials with by-products protects firms from higher costs of feedstock caused by resource scarcity (e.g., droughts).

Unit characterization factors of material and energy substitutions of the Campbell Industrial Symbiosis

Material	Annual Amount	Avoided or (additional) process	Primary Energy GJ/t	Emissions: Greenhouse kg CO_2eq/t	Acidifying kg SO_2eq/t	Eutrophying kg NO_xeq/t
Mixed ash	60,000 t	Ash disposal [a]	0.3	10.0	0.07	0.09
substitutes for:						
Sand	50,000 t	Sand extraction [a]	0.03	2.4	0.02	0.02
Fly ash	7,000 t	Ash disposal [a]	0.3	10.0	0.07	0.09
substitutes for:						
Portland cement	7,000 t	Cement production [b]	2.7	762	1.22	1.43
		Cement transport [a]	0.6	39.8	0.89	0.66
Sludge (95% wet)	200,000 t	Sludge landfill disposal [a,*]	0.32	647	0.15	0.15
substitutes for:						
Fertilizer	2,500 t	Fertilizer production [a]	36.0	2,630	42.2	16.8
		Fertilizer transport [a]	0.6	39.8	0.89	0.66

Evolving Definition of Industrial Symbiosis

Industrial symbiosis engages traditionally *separate* industries in a *collective approach* to competitive advantage involving *physical exchange* of materials, energy, water, and/or by products.

- Chertow (2000)

HORIZON 2020

Industrial symbiosis (IS) is a systems approach that connects different **industrial stakeholders to leverage underutilised resources in a more integrated and sustainable way.**

- CORALIS project, 2020–2024

Defining Industrial Symbiosis

Industrial symbiosis engages traditionally *separate* industries in a *collective approach* to competitive advantage involving *physical exchange* of materials, energy, water, and/or by products.

The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity.

M. Chertow 2000, Annual Review of Energy and Environment.

Consequence of Too Much Success

"Ironically, Korea's national IS program was discontinued in 2016, owing to its success (Park et al. 2018).

The national government concluded that government funding was unnecessary because…pilot projects were generating significant profits"

- Chertow, Kanaoka, et al. (2020)

Overall Performance (cumulative for 2005–2016)

655 potential synergies assessed (1,831 companies)		355 projects implemented
Economic Benefit	Environmental benefit	Social effect
• $2.4 billion (revenue + cost savings) • $0.8 billion government research funding	• 8.5 million tons CO2-eq avoided (1.2% of national) • 6.7 million tons of waste reduced	• $0.76 billion private investment • 992 direct job creation