Industrial Symbiosis: Networking for Improved Environmental Performance

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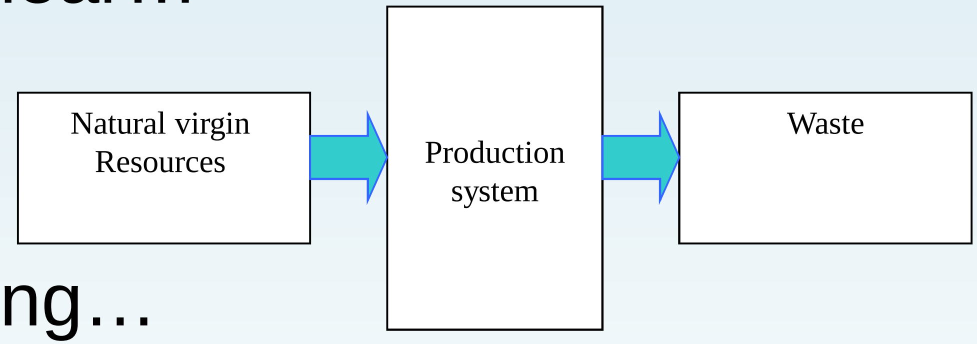
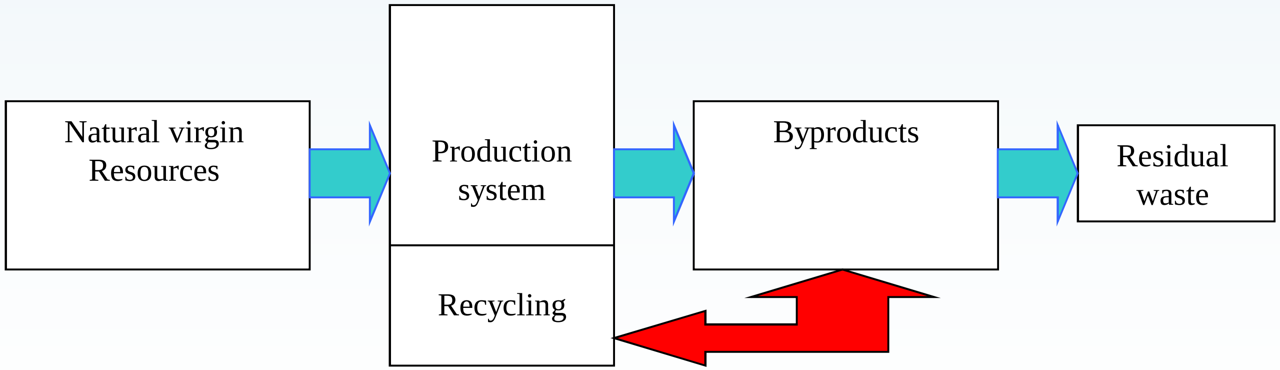
From a linear to a circular industrial system

- From linear…



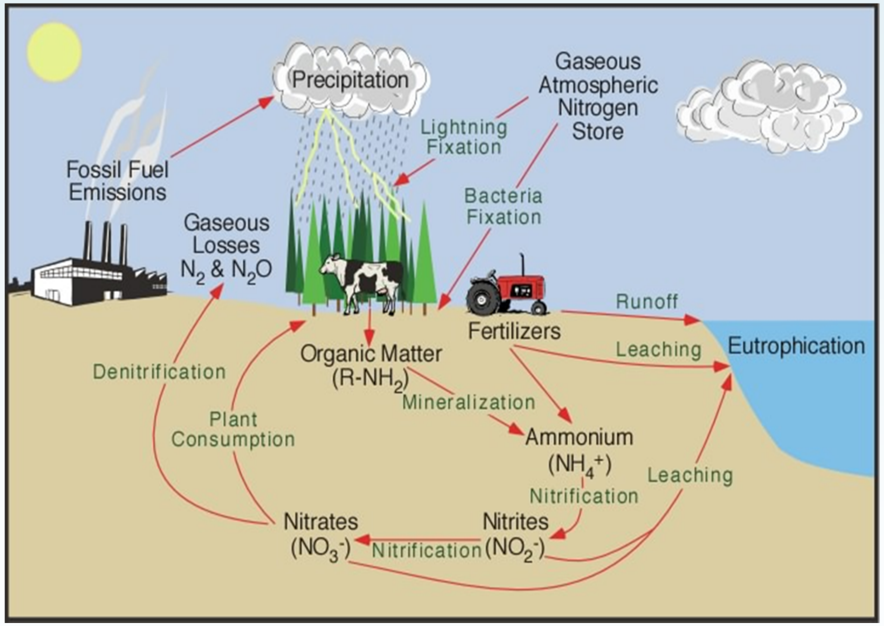
- To cycling…

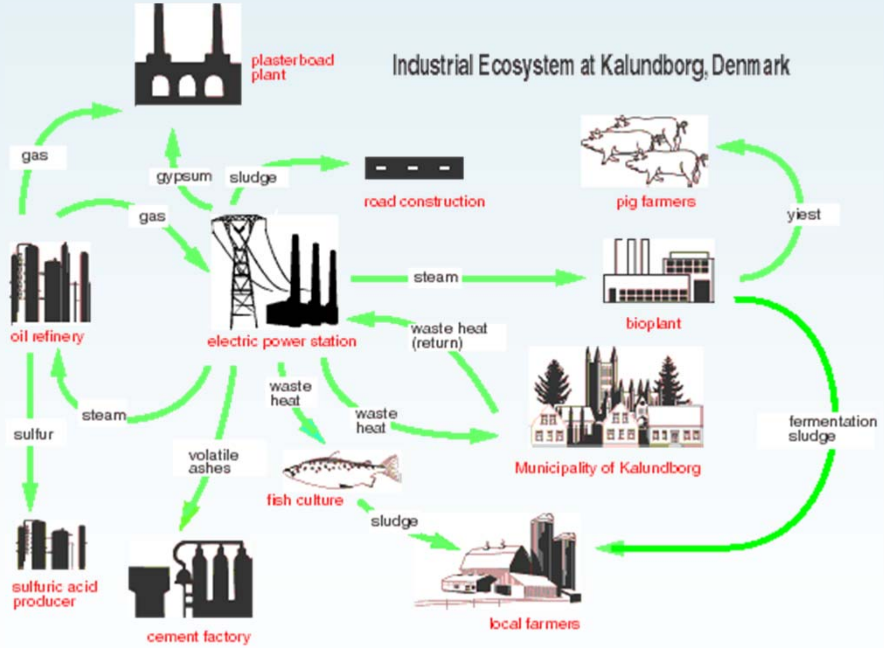


Defining industrial ecology

"It is a system view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product and to ultimate disposal" by emulating the efficient functioning of natural ecosystems, where "effluents and waste from one process serve as the input materials for other processes or are recycled for further production". (Graedel, 1996-Gibbs, 2003)

The Ecological Metaphor





Dimension of Industrial ecology (Chertow, 2001)

Within a company	Intercompany level	Material cycles
• Improvement of eco-efficiency • Reuse and recycle of materials • Cascading of water and energy	• Exchange of waste flow between different processes and activities • Recycle from waste materials and use as input materials • Cascading of water and energy	• Analysis of the material cycles of different substances and components at the whole economy level

Industrial symbiosis networks

- Industrial symbiosis focuses on the cooperative relationship between industries to reduce the material and energy “loses” of the industrial system as a whole by promoting the exchange of by-products and “wastes”
- Two main approaches:

❑ Eco-industrial parks - Spatial-centred approach

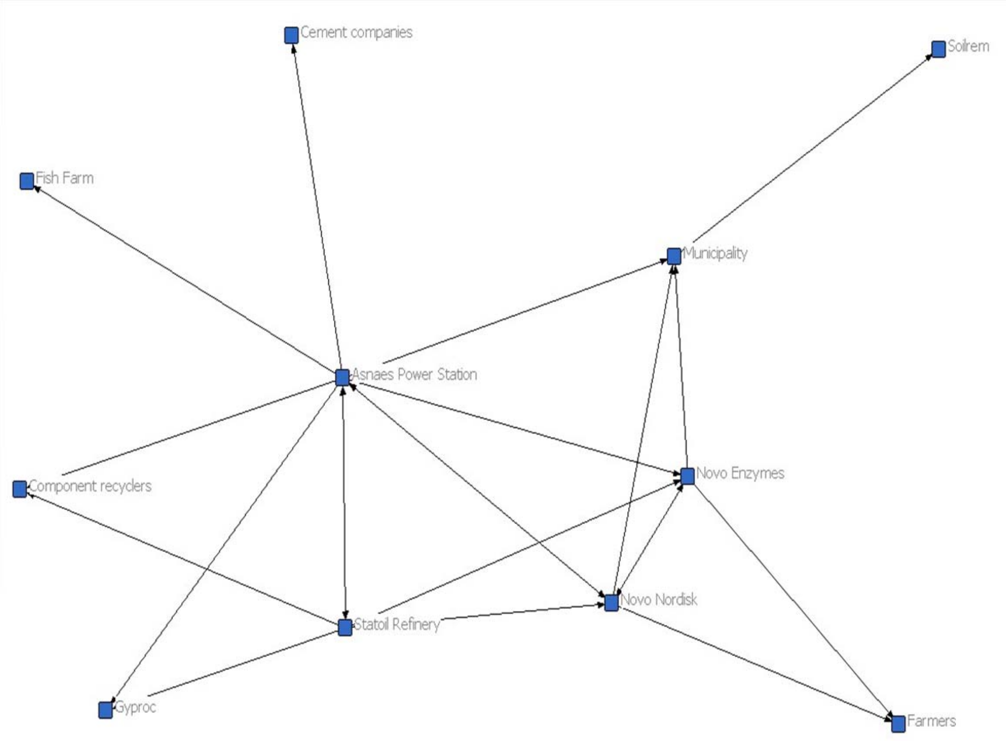
❑ Eco-industrial networks (virtual eco-industrial parks) – Information-centred approach

WHY APPLYING SNA TO IS NETWORKS?

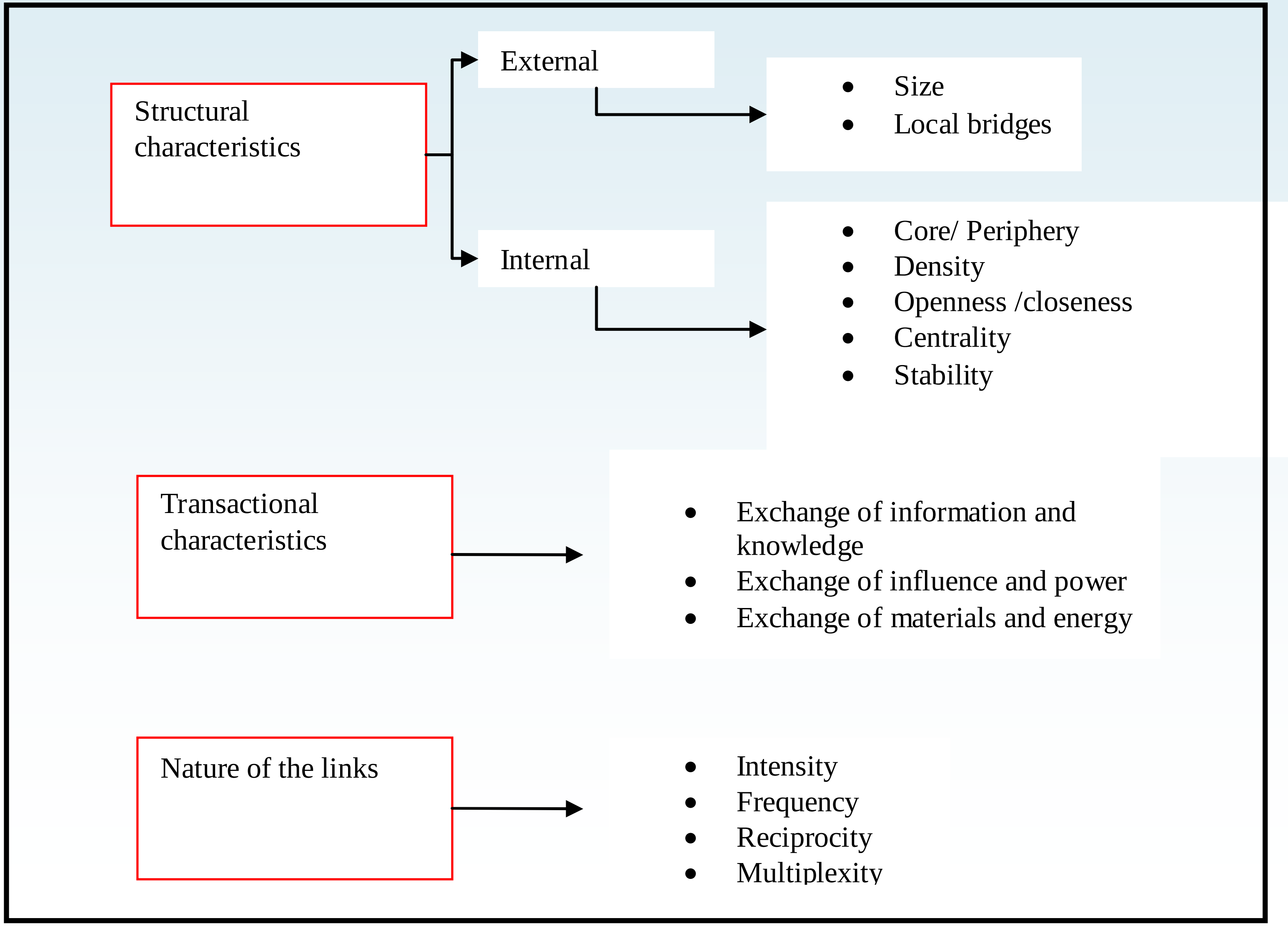
- Identify key actors in the operation of the networks
- Determine what networks structure may provide better outcomes
- Local bridges
- Network position, trust and power/ influence
- Identify structural characteristics that may foster or limit the efficient operation of the network
- Determine potential patterns of development of IS networks
- Identify potential risks of disconnection of the network

Social Network Theory

- Two levels of analysis:
  - Complete network
  - Ego-centered network
- Dyads and nodes
- Core/periphery structure
- Centrality
- Connectedness
- Geodesic distance



Social Network Theory: Analysis of industrial symbiosis networks



Industrial symbiosis networks: Conditions of emergence

Exchange Conditions → **Structural Embeddedness** ← Social Mechanisms of control

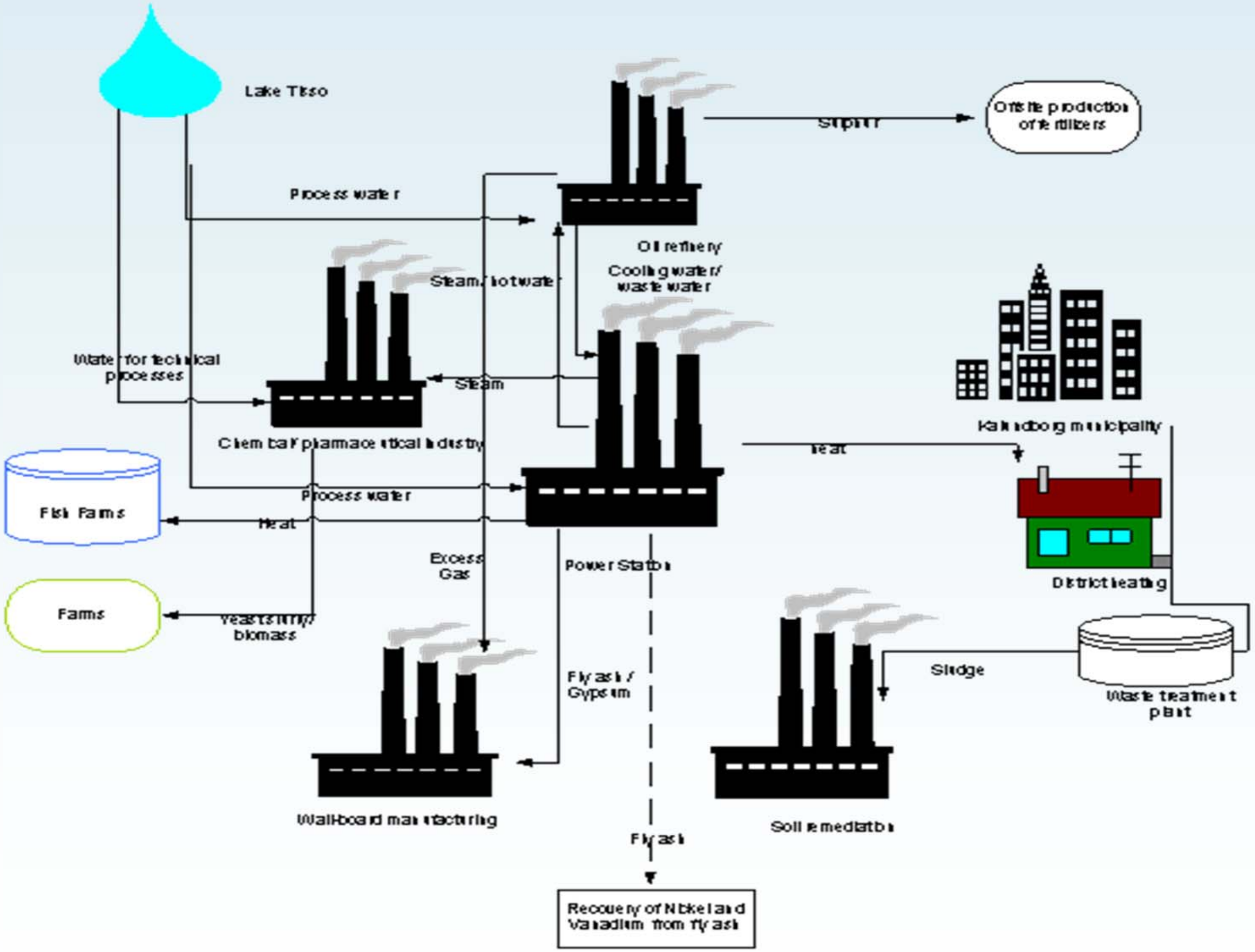
Exchange Conditions:

- Stringent and rapidly evolving regulatory framework
- Shortage of raw materials
- The need of customised, ad-hoc solutions
- Frequent interaction

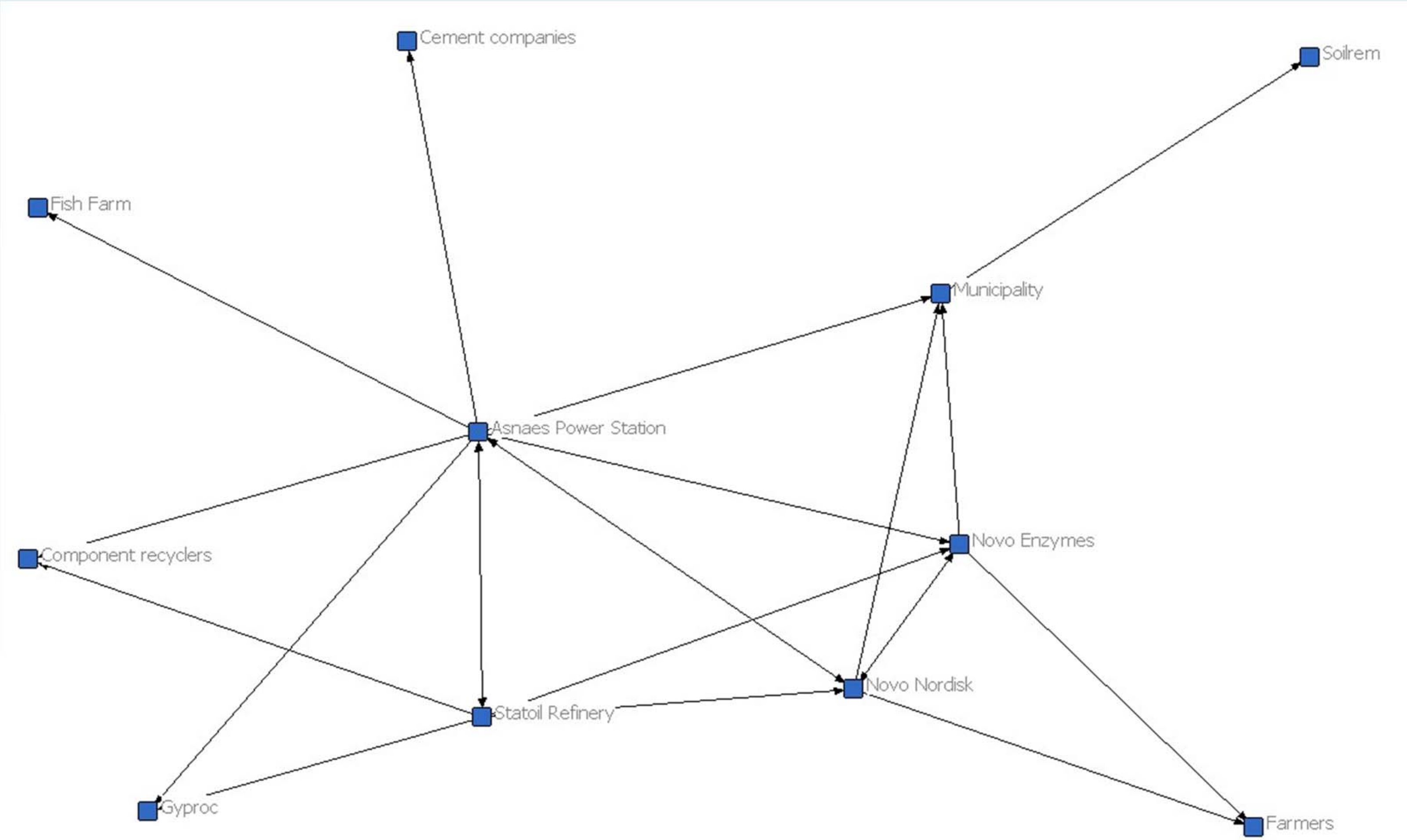
Social Mechanisms of control:

- Collective sanctions
- Reputation
- Macroculture of cooperation

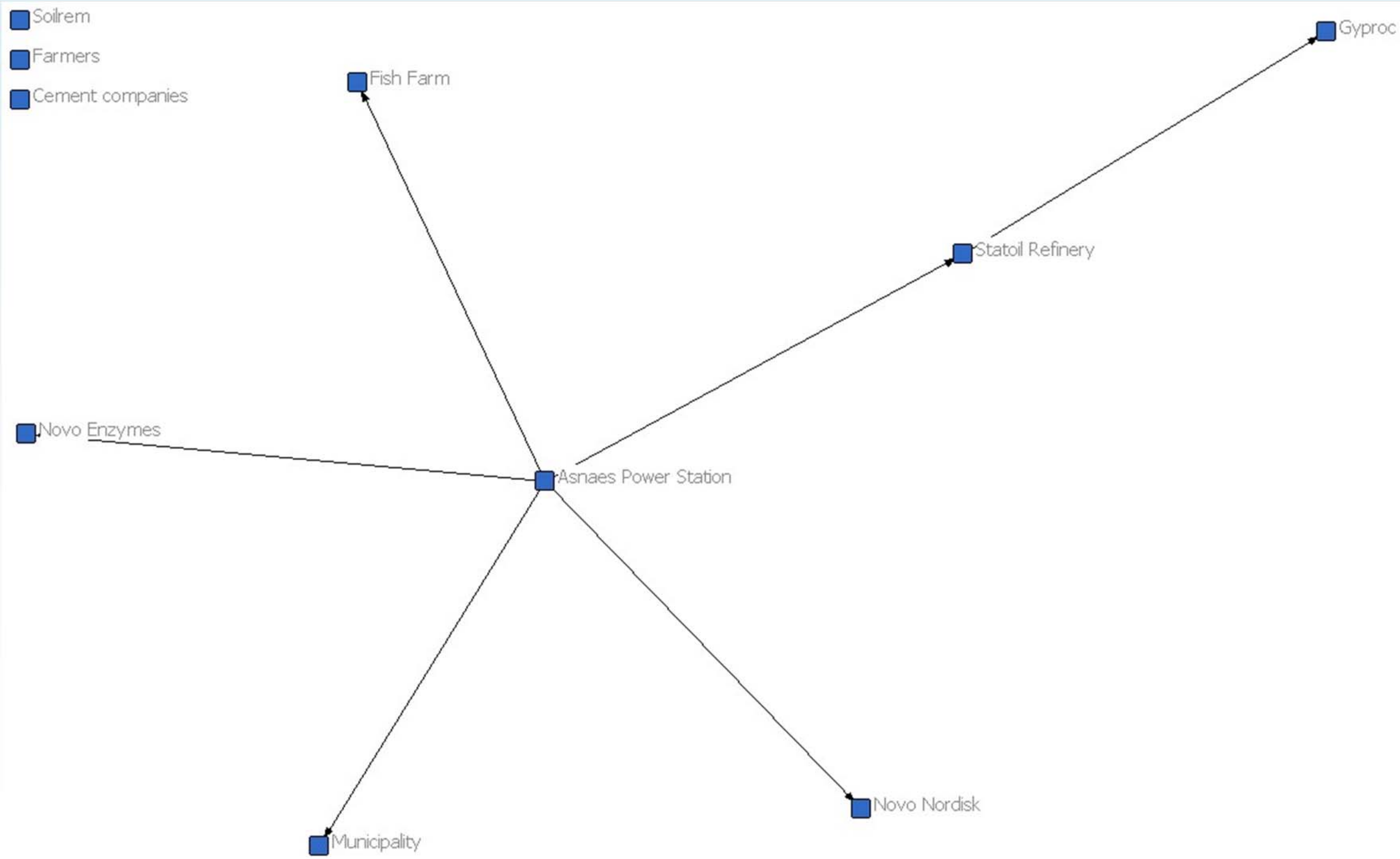
Case study: kalundborg (Denmark)



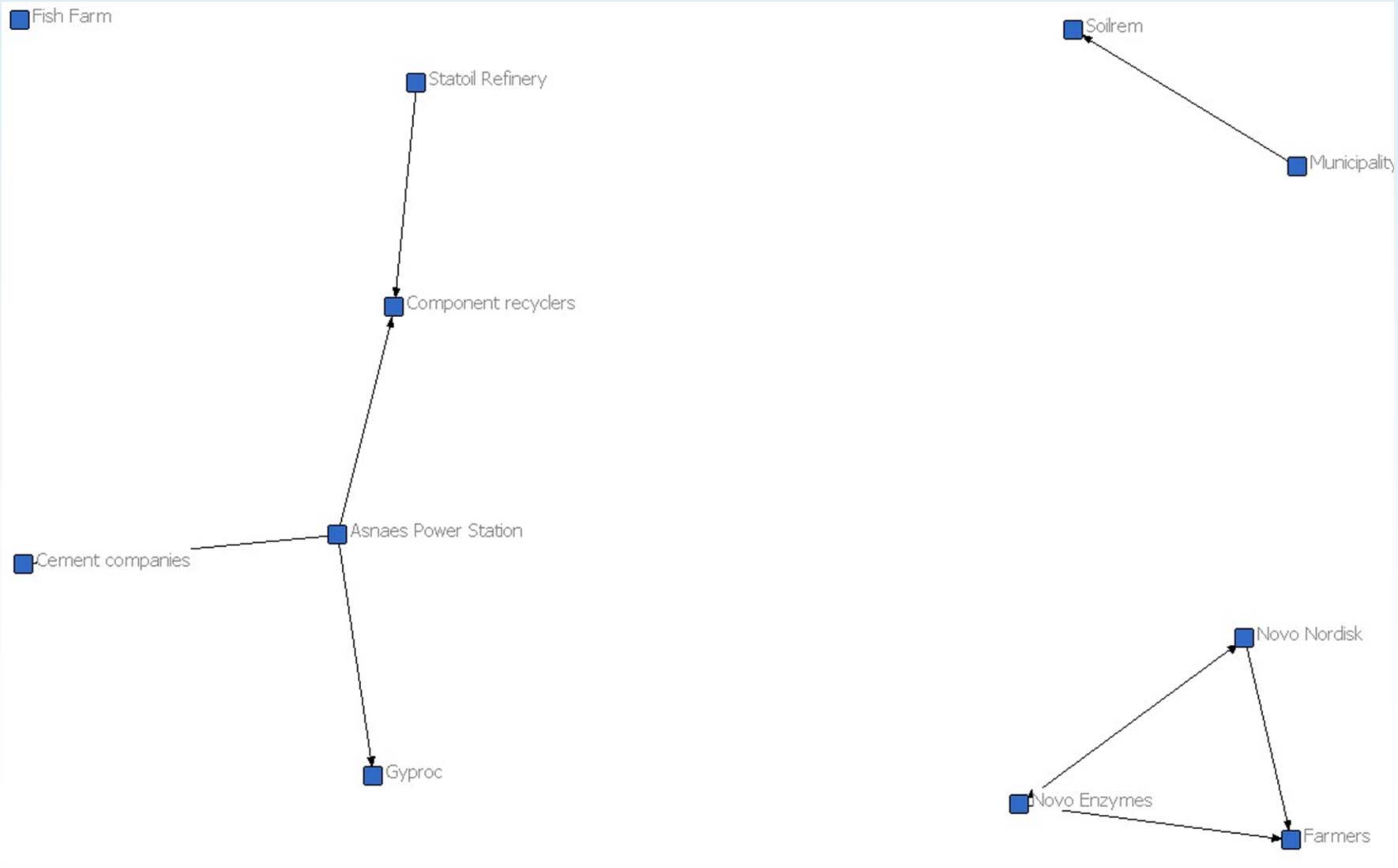
Whole network structure



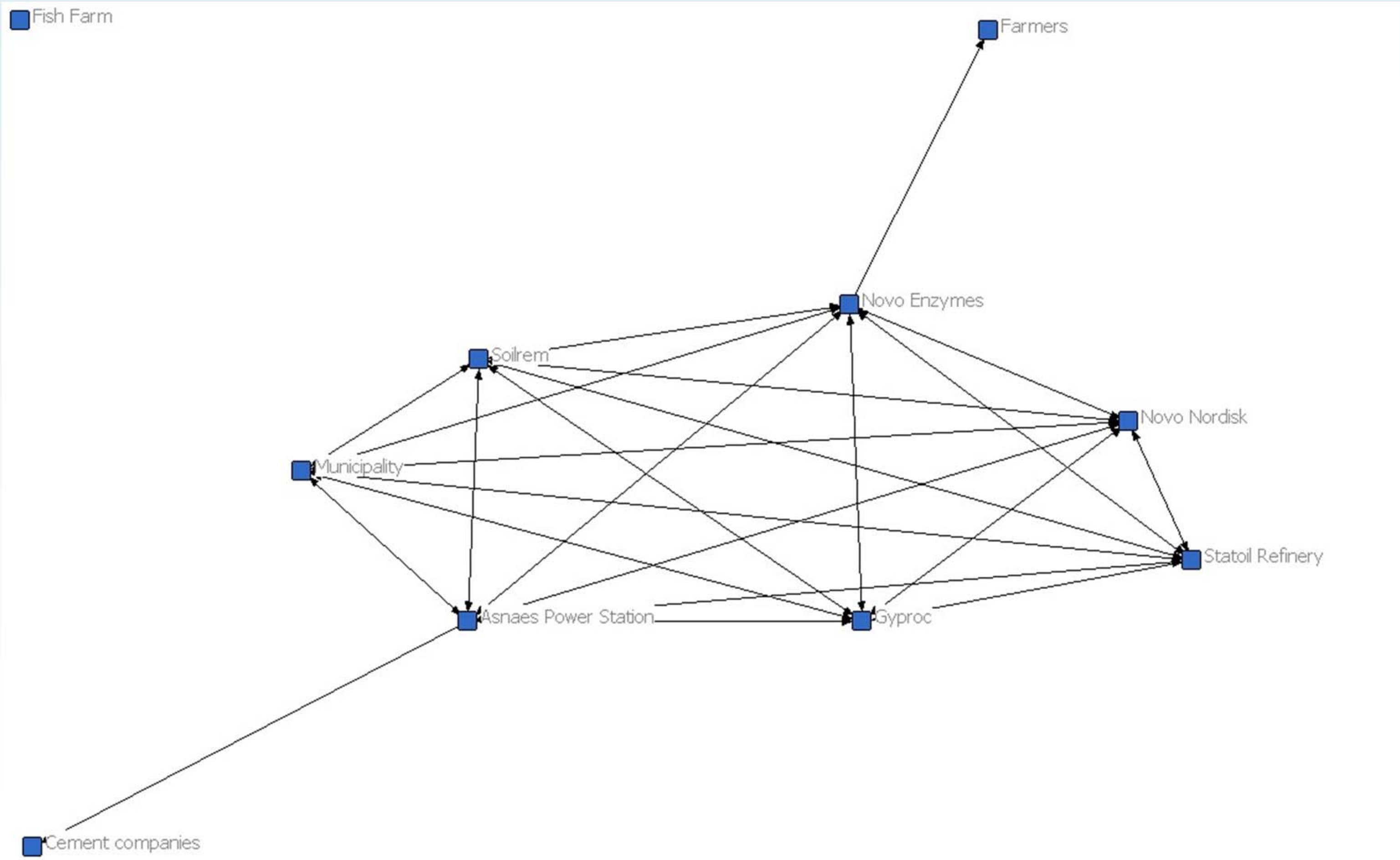
Energy network



Material network



Knowledge network



Structural characteristics

	Whole network		Materials network		Water network		Energy network		Knowledge network	
Number of ties	22		9		14		6		44	
Density	0.2		0.0818		0.1556		0.0667		0.4889	
Network centalisation	57.78%		18.89%		33.33%		52.78%		33.33%	
Ave. Geodistance	1.585		1.000		1.125		1.143		1.214	
Distance-based cohesion "compactness"	0.279		0.082		0.167		0.072		0.556	
Distance-weighted fragmentation "breath"	0.721		0.918		0.833		0.928		0.444	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Degree centrality	3.273	2.178	1.455	0.782	1.600	1.685	1.200	1.400	4.600	2.615
Betweenness centrality	2.182	3.0777999	0.000	0.000	0.200	0.400	0.100	0.300	1.200	2.400
Closeness centrality										
IN	13.407	0.889	9.871	0.713	12.312	2.376	10.788	0.733	23.955	4.737
OUT	29.515	27.922	9.933	1.113	12.606	3.193	11.544	4.273	34.974	16.374

Centrality

CENTRALITY	Degree	Betweenness	Closeness	
NODES			IN	OUT
Asnaes power station	8.000	8.667	12.346	83.333
Novozymes	5.000	1.667	12.500	47.619
Novo Nordisk	5.000	7.667	12.500	66.667
Statoil refinery	5.000	2.000	12.346	62.500
Municipality	4.000	4.000	14.085	10.000
Component recyclers	2.000	0.000	13.699	9.091
Gyproc	2.000	0.000	13.699	9.091
Farmers	2.000	0.000	13.889	9.091
Fish Farm	1.000	0.000	13.514	9.091
Cement companies	1.000	0.000	13.514	9.091
Soilrem	1.000	0.000	15.385	9.091

Main Findings: characteristics of successful networks

- The core is dense and well articulated, favouring the interaction between the members. This morphology favours the rapidly dissemination of ideas and information.
- Due to the small size of the network, the path distance is very small, which has contributed to a) reduce the transaction costs associated with the exchanges b) favour the building of trust and commitment among members.
- Multiplexity of the linkages contributes to increase the density of the network and favours the building of stronger relationships, which could indeed explain the innovation capacity of the network.
- The analysis of the centrality measures point to small number of key players of the networks: central actors are important not only for the number of direct connections they hold with other members of the networks, but also for its capacity to connect other nodes, and therefore, to ensure the cohesion of the network. Hence, the disconnection of any of these nodes will cause an important disturbance to the operation of the network, which could lead to defragmentation.

THANKS FOR YOUR ATTENTION

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