



Institute for Advanced Study  
(IAS)

# Analysis of production networks for policy

Presenter: Dr. Carolina Mattsson

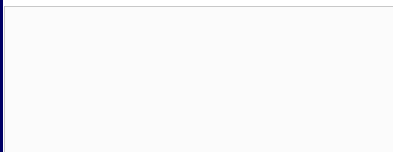


# Multi-institutional collaboration



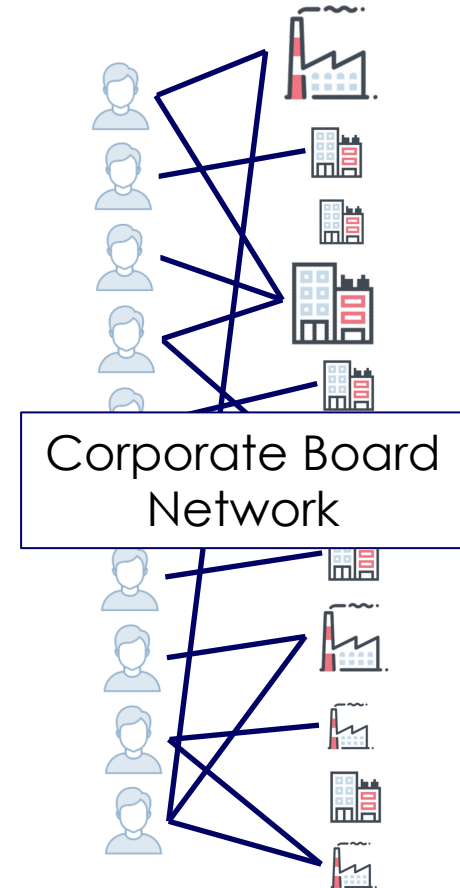
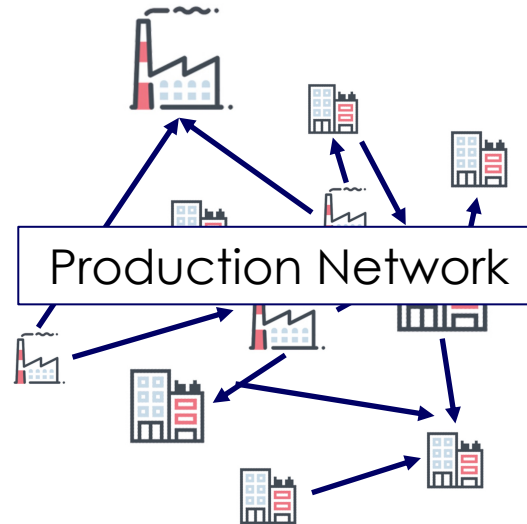
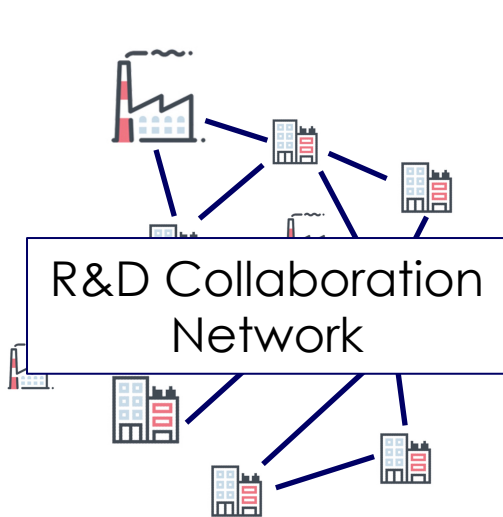
Carolina Mattsson  
Frank Takes  
Gert Buiten  
Eelke Heemskerk  
Cees Diks  
Peter M.A. Sloot  
Albert Faber

Leiden University  
Leiden University  
Statistics Netherlands  
University of Amsterdam  
University of Amsterdam  
University of Amsterdam  
Ministry of Economic Affairs & Climate





# How can network analysis help economic policy makers?





# Policy challenge





# Energy transition in industrial clusters

- Our climate is changing at an alarming rate due to the greenhouse gasses released during economic activity
- Policymakers are tasked with facilitating the transition to a carbon-neutral economy
- One focus is to decarbonize regional industrial clusters that rely on energy-intensive production processes

**What is the structure of production in industrial clusters?**

**How do we use this to accelerate the Energy Transition?**

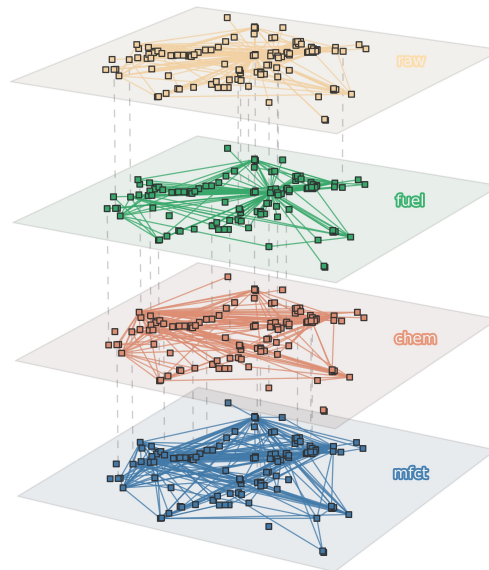


# Dutch production network



# Inferred customer-supplier ties

National	Supply BEID	Use BEID	Comm group
Edges	A	B	27
	A	C	27
	A	D	27
	A	E	345
	A	F	543
	B	D	27
	B	G	273



Hooijmaaijers, S. and Buiten, G. (2019). A methodology for estimating the Dutch interfirm trade network, including a breakdown by commodity. Tech. rep., Statistics Netherlands.

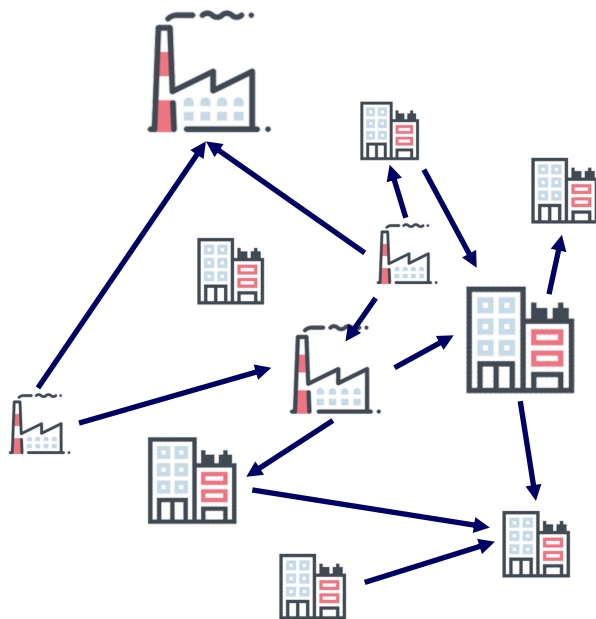
Product groups, e.g.:

- Electricity
- Fertilizer
- Shipping services
- Accounting & tax administration

Dutch implementation European CPA (2008)



# Reconstructed production network



	Nodes	Simple edges
<b>Netherlands:</b>		
All	875,222	195,903,806
5+	102,461	50,930,077
<b>Zeeland:</b>		
All	18,398	2,143,412
5+	2,497	334,334

Hooijmaaijers, S. and Buiten, G. (2019). A methodology for estimating the Dutch interfirm trade network, including a breakdown by commodity. Tech. rep., Statistics Netherlands.

Product groups, e.g.:

- Electricity
- Fertilizer
- Shipping services
- Accounting & tax administration

Dutch implementation  
European CPA (2008)





# Local connectivity structure





# What “type” of network is this?

**Social networks**

Two-mode networks

Functional networks

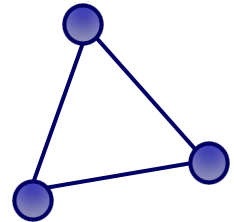
Random networks

Links form between nodes who associate with one another, ex. “friends” or “colleagues”

Example:

R&D collaborations

Lots of *triangles*





# What “type” of network is this?

Social networks

**Two-mode networks**

Functional networks

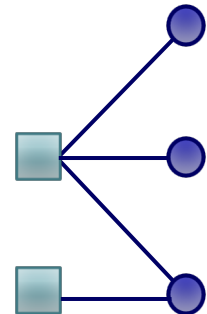
Random networks

Links exist between nodes and specific affiliations, ex. “club membership” or “student at”

Example:

Corporate boards

Bipartite structure





# What “type” of network is this?

Social networks

Two-mode networks

**Functional networks**

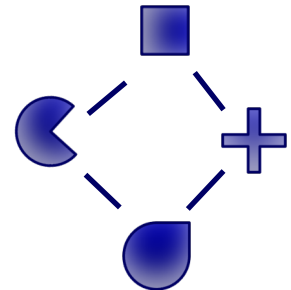
Random networks

Links form between nodes with complementary function, ex. “bind to” or “trade with”

Example:

Customer-supplier ties

Lots of squares





# What “type” of network is this?

Social networks

Two-mode networks

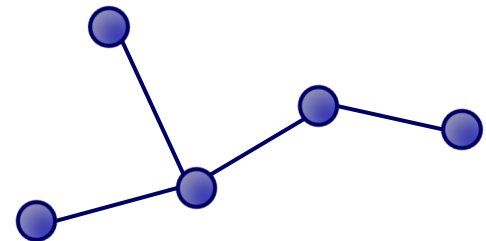
Functional networks

**Random networks**

Links between nodes have come to occur by chance.

Example:  
Randomized comparisons

Random





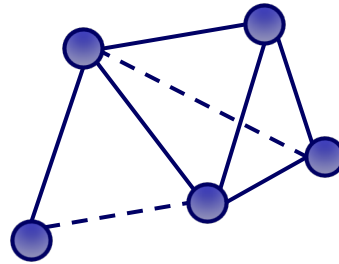
# Social vs. functional structure

**Social networks**

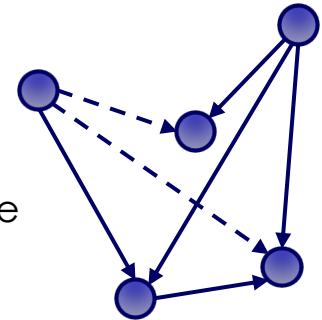
Two-mode networks

**Functional networks**

Random networks



Friends of my friends are likely to also be my friends.



Customers of my competitors are likely to also be my customers.



# Scientific contribution



**ORIGINAL RESEARCH** article

Front. Big Data, 21 May 2021 | <https://doi.org/10.3389/fdata.2021.666712>



## Functional Structure in Production Networks

 Carolina E. S. Mattsson<sup>1,2\*</sup>,  Frank W. Takes<sup>1,3</sup>,  Eelke M. Heemskerk<sup>3,4</sup>,  Cees Diks<sup>5,6</sup>,  Gert Buiten<sup>7</sup>,  Albert Faber<sup>8</sup> and  Peter M. A. Sloot<sup>9,10,11,12,13</sup>



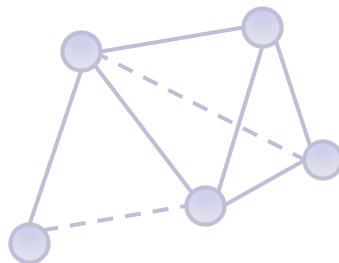
# Company-level production networks have functional structure

**Social networks**

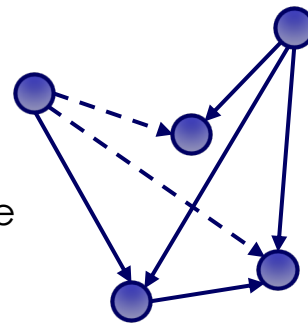
**Two-mode networks**

**Functional networks**

**Random networks**



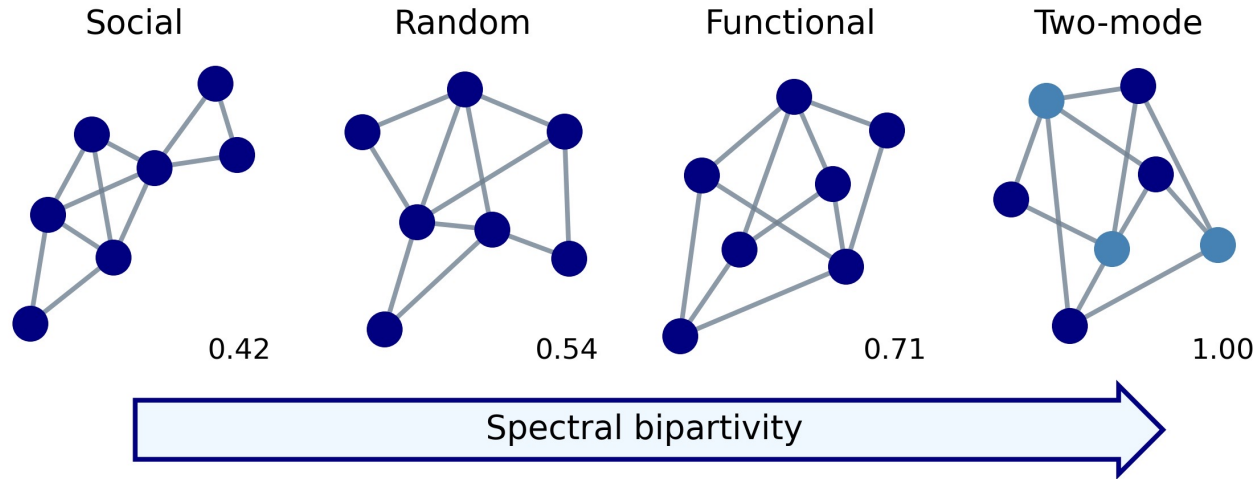
Friends of my friends are likely to also be my friends.



Customers of my competitors are likely to also be my customers.



# Measure of local connectivity

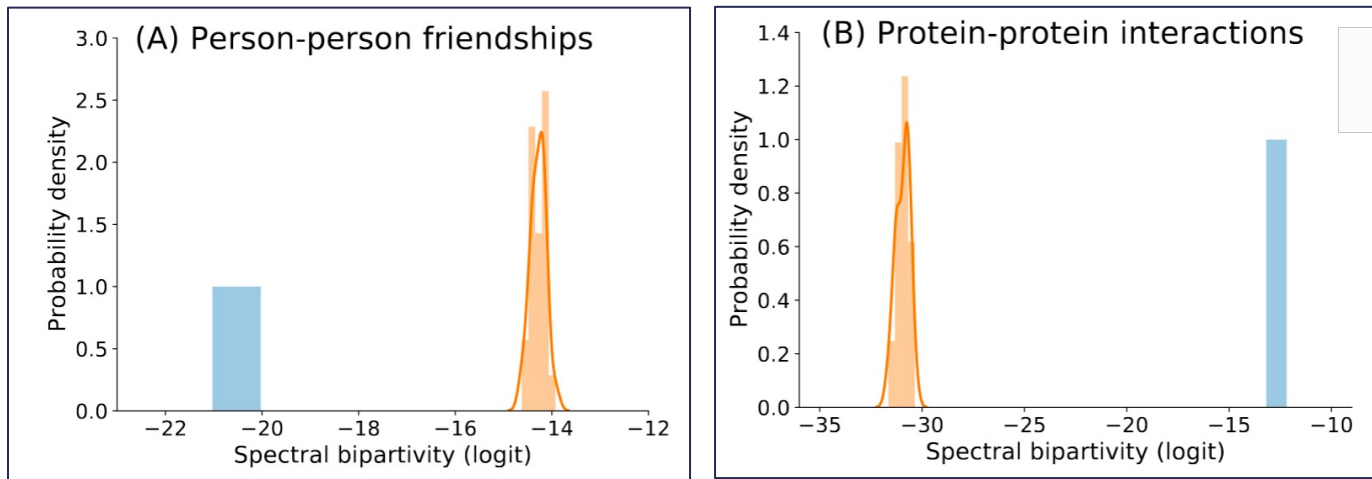


Estrada, E. & Gómez-Gardeñes, J. "Network bipartivity and the transportation efficiency of European passenger airlines". *Physica D: Nonlinear Phenomena* (2016)

$$\begin{aligned}
 b_s(G) &= \frac{\text{tr} \cosh(A) - \text{tr} \sinh(A)}{\text{tr} \cosh(A) + \text{tr} \sinh(A)} \\
 &= \frac{\text{tr} \exp(-A)}{\text{tr} \exp(A)} \\
 &= \frac{\sum_{j=1}^n e^{-\lambda_j}}{\sum_{j=1}^n e^{\lambda_j}}
 \end{aligned}$$



# Spectral bipartivity vs. random



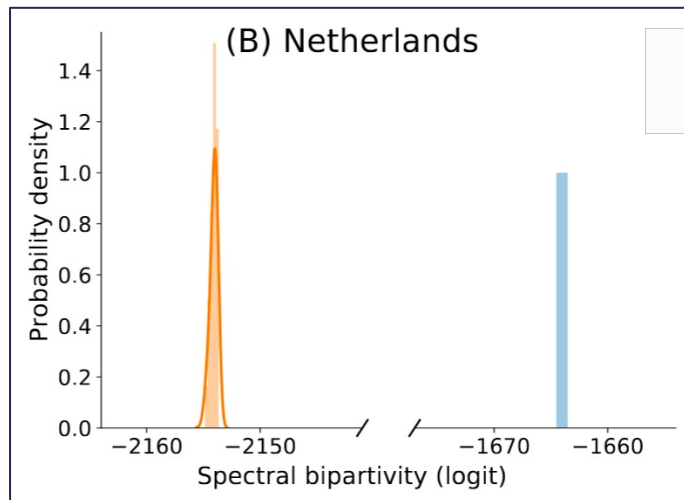
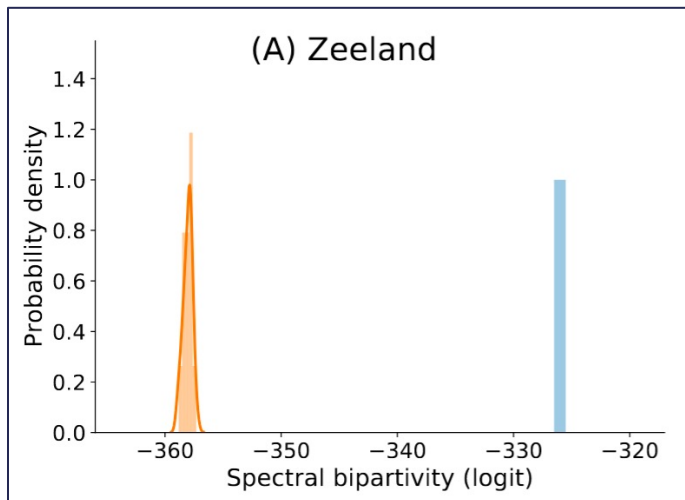
<https://github.com/carolinamattsson/local-connectivity-structure>

Kovács, I. A., Luck, K., Spirohn, K., Wang, Y., Pollis, C., Schlabach, S., et al. (2019). Network-based prediction of protein interactions. *Nature Communications* 10.

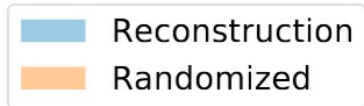
Sapiezynski, P., Stopczynski, A., Lassen, D. D., and Lehmann, S. (2019). Interaction data from the Copenhagen Networks Study. *Scientific Data* 6, 315.



# Reconstructed production network



Mattsson CES, Takes FW, Heemskerk EM, Diks C, Buiten G, Faber A and Sloot PMA (2021) Functional Structure in Production Networks. *Front. Big Data* 4:666712.





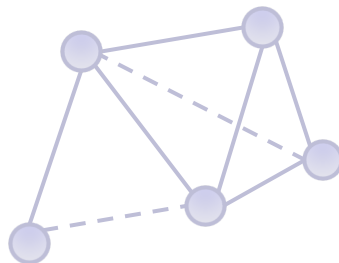
# Company-level production networks have functional structure

**Social networks**

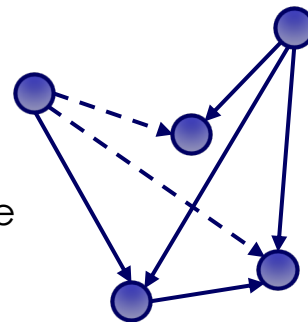
**Two-mode networks**

**Functional networks**

**Random(ized) networks**



Friends of my friends are likely to also be my friends.



Customers of my competitors are likely to also be my customers.



# Suitable intuitions about structure



**What is the structure of production in industrial clusters?**  
How do we use this to accelerate the Energy Transition?



# Structure of industrial clusters

- Disassortativity in degree
  - Relatively little direct trade among large companies
  - Zeeland producers active in different production chains
  - This is an industrial cluster *in terms of opportunities*
- Over-representation of squares
  - Indirect dependence via shared customers and suppliers
- Functional modules
  - Company clusters with a higher-level economic function

“Businesses that establish themselves [in Terneuzen] can make use of the extensive network of reliable contractors and suppliers that Dow has built up in the course of forty years.”

DOW Benelux via Valuepark Terneuzen website (Nov. 2020)



# Basic research synopsis





# Analysis of production networks

- Production network data produced by CBS\*
- Scientific contribution towards identifying local connectivity structure in networks
- Production networks have “functional” structure
- Intuitions about the structure of industrial clusters
  - Relatively little direct trade among large companies
  - Indirect dependence via shared customers and suppliers
  - “Modules” that reflect higher-level capabilities

Mattsson CES, Takes FW, Heemskerk EM, Diks C, Buiten G, Faber A and Sloot PMA (2021) Functional Structure in Production Networks. *Front. Big Data* 4:666712.

\*An improved and more up-to-date data set will be available in the fall of 2021.





# Policy implications



What is the structure of production in industrial clusters?  
**How do we use this to accelerate the Energy Transition?**



# Industrial production in Zeeland

- Vulnerabilities
- Opportunities
- Driving a transition
- Points of attachment for policy



# Disruptions can “echo”

- Major industrial companies are embedded in high-volume production chains that extend far beyond Zeeland
- The bankruptcy or departure of a major player would affect many local, specialized suppliers
- Potentially, such a disruption could begin to “echo”
- Example:

Several Detroit automakers were hit hard by the 2008 financial crisis. As the crisis progressed, we actually saw the CEO of Ford give testimony to the US Govt. in favor of support for his competitors, General Motors and Chrysler. Ford’s CEO argued that “a default by one of the other Detroit carmakers could adversely affect all carmakers, because they shared parts suppliers, which were at risk.”

*What are the key vulnerabilities of major producers?*

Inoue, H. & Todo, Y.  
“Firm-level propagation of shocks through supply-chain networks”. *Nature Sustainability* (2019)

Klier, T., & Rubenstein, J. M. (2013).  
Restructuring of the U.S. Auto Industry in the 2008-2009 Recession. *Economic Development Quarterly*, 27(2), 145.



# Mutually reinforcing opportunities

- There is a natural, ecological pattern of development:
  - Smaller companies emerge to meet specialized demand
  - Large companies with similar needs see opportunity
  - New entrants also bring new specialized demand
- Example:

Oatly is an entrepreneurial company whose key product has a climate-mitigating impact: oat-based milk. They established a factory in Vlissingen, Zeeland in 2019 in large part because of the existing supporting industries (packaging & distribution). They note: “The new production facility will also generate excess capacity, which offers opportunities to develop and introduce new innovations.” [\[Press Release\]](#)

*How can carbon-mitigating specialization be accelerated?*

Neffke, F., & Henning, M. (2013). Skill relatedness and firm diversification. *Strategic Management Journal*, 34(3), 297–316.

Relevant: “related diversification”



# New capabilities as “modules”

The energy transition is a major change, by definition

- We know that **major change can happen quickly**
- Regions *can* develop entirely new economic capabilities and policy measures *can* accelerate such progress
- Higher-level capabilities are “modules” of companies
- Example:

The North Sea Port is more than its physical infrastructure. There is a diverse collection of smaller companies that operate, maintain, and provide supporting services for the port; for profit, of course. This capability is a “module”.

*How can new, decarbonizing “modules” be established?*

Boschma, R., Coenen, L., Frenken, K., & Truffer, B. (2017). Towards a theory of regional diversification: Combining insights from Evolutionary Economic Geography and Transition Studies. *Regional Studies*, 51 (1), 31–45.

Relevant: “unrelated diversification”

Relates to: “Thinking in terms of ecosystems”



# Attract key intermediate players

- Those driving change in networks are **intermediate players**
- Major players are too embedded; peripheral are too small
- Those who introduce structural change to regional economies tend to be **companies from elsewhere**
- Example:

Yara and Ørsted have announced possible plans to build a supply chain for carbon-free “green” ammonia in Zeeland. The expected investment is a 100MW electrolyser that would produce enough renewable hydrogen to decarbonize “10% of the capacity of the largest of the ammonia plants in Sluiskil”. [\[Statement\]](#)

*What group(s) of companies would jump at the chance to make this 90%? How can policymakers make it happen?*

Sloot, P. M. A., Kamps, G., & Gulyás, L. (2013). Advances in dynamic temporal networks: Understanding the temporal dynamics of complex adaptive networks. *The European Physical Journal Special Topics*, 222(6), 1287–1293.

Neffke, F., Hartog, M., Boschma, R., & Henning, M. (2014). Agents of structural change. The role of firms and entrepreneurs in regional diversification. In *Papers in Evolutionary Economic Geography (PEEG)*



# Major change can happen quickly

## EPZ proposes to build two new nuclear reactors at Borssele in the Netherlands

7 Dec 2020

The construction of a new reactor at Borssele would require an investment of €8bn to €10bn and would take **8 years**.

[\[Industry News\]](#)

The costs of nuclear energy would be comparable to wind and solar.

[\[Report for EZK\]](#)

&Flux																				
ABB	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
ABC-Techniek B.V.			.	.	.					.	.	.	.	.	.	.	.	.	.	.
AEG Power Solutions B.V.	.	.	.										.	.	.	.	.	.	.	.
Alles over waterstof																				
AMF Bakery Systems -																				
Ansaldo Thomassen B																				
Antonius																				
AquaBattery B.V.																				
Battolyser B.V.																				
Berenschot																				
Bosch Rexroth B.V.																				
Bredenoord																				
BrigH2																				
Bronkhorst Nederland																				
Bürkert Fluid control s																				
Stichting Cenex Neder																				
Connectr - Energy inn																				
ConPackSys B.V.																				
Corre Energy Storage																	.			
De Boer SPS		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

*Work has started on the Netherlands' first Gigawatt electrolyser to be operational by 2030.*

[\[RVO Report\]](#)



# Policy research synopsis







# Analysis of production networks for policy

- **Vulnerabilities**

- Large disruptions to major producers could “echo”

- **Opportunities**

- Mutually reinforcing dynamics of development

- **Driving a transition**

- New capabilities are new “modules” of many companies

- **Points of attachment for policy**

- Attract intermediate players to the region from elsewhere



Institute for Advanced Study  
(IAS)

# Analysis of production networks for policy

Presenter: Dr. Carolina Mattsson