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Industrial-Urban-Symbiosis
Practical examples from the Industrial Park Höchst

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Content

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Dual challenge:
Industrial parks in Germany must remain competitive today and prepare for CO_2 neutrality

TODAY

- Competitive **energy supply**
- Safe, reliable, high-quality, internationally competitive **production**
- Adaptation to **volatile business** and environmental influences
- **Skills shortage**

PREPARING for a climate-neutral future

- Access to competitive **renewable energies** and raw materials (electricity, heat, hydrogen, CO_2 and other raw materials) and, if necessary, preparation for CCS
- Development of **new business potential** (e.g. chemical recycling, CCU)
- **Industrial symbiosis** with the region (industrial waste heat for the district heating network, location of data centers)

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Industriepark Höchst
A lively cluster for chemical and pharmaceutical companies

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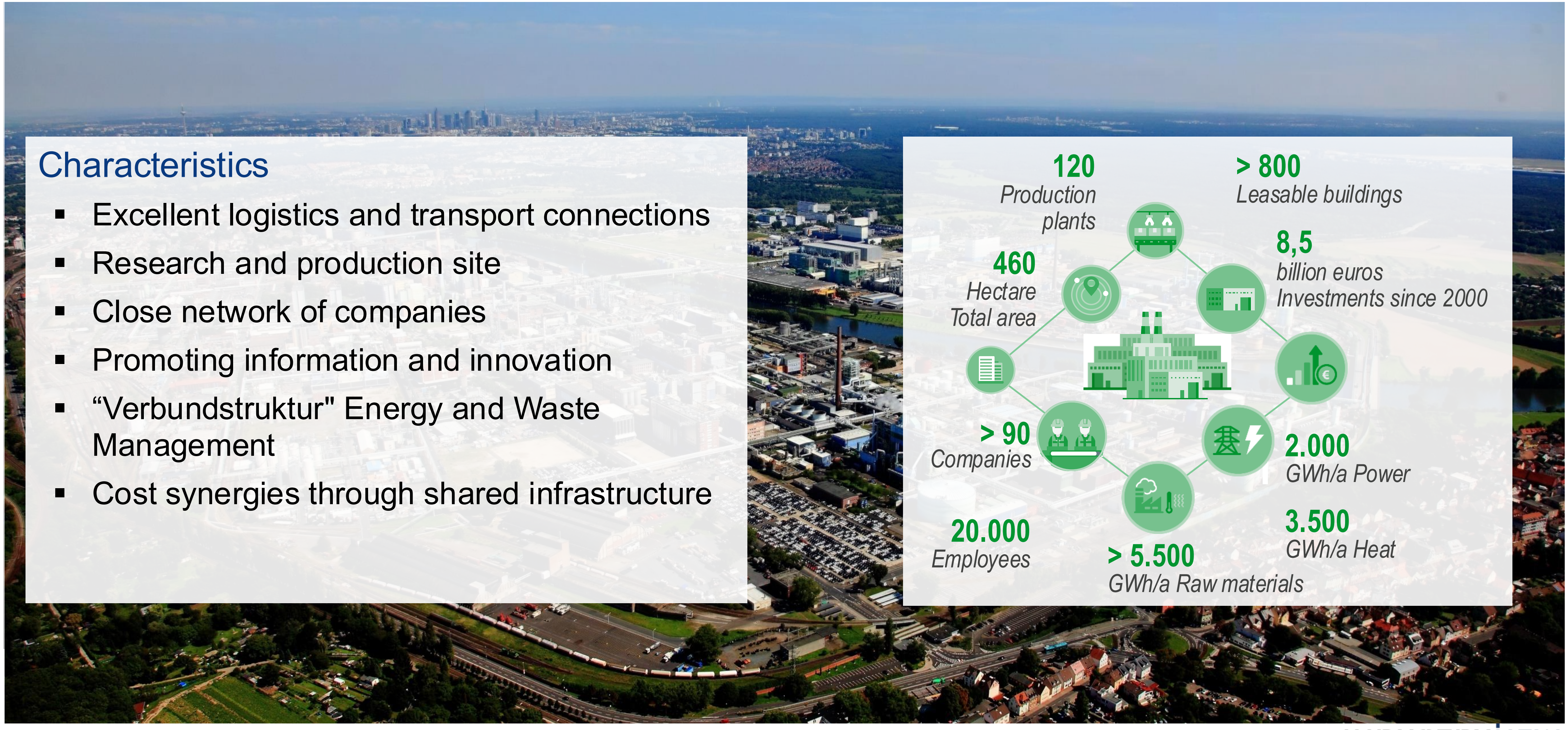

Characteristics

- Excellent logistics and transport connections
- Research and production site
- Close network of companies
- Promoting information and innovation
- “Verbundstruktur" Energy and Waste Management
- Cost synergies through shared infrastructure

INDUSTRYNEW

Center for Industry and Sustainability (ZIN)
Think and do tank for sustainable industry at Industriepark Höchst

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Mission:
We support the industry in its sustainable development

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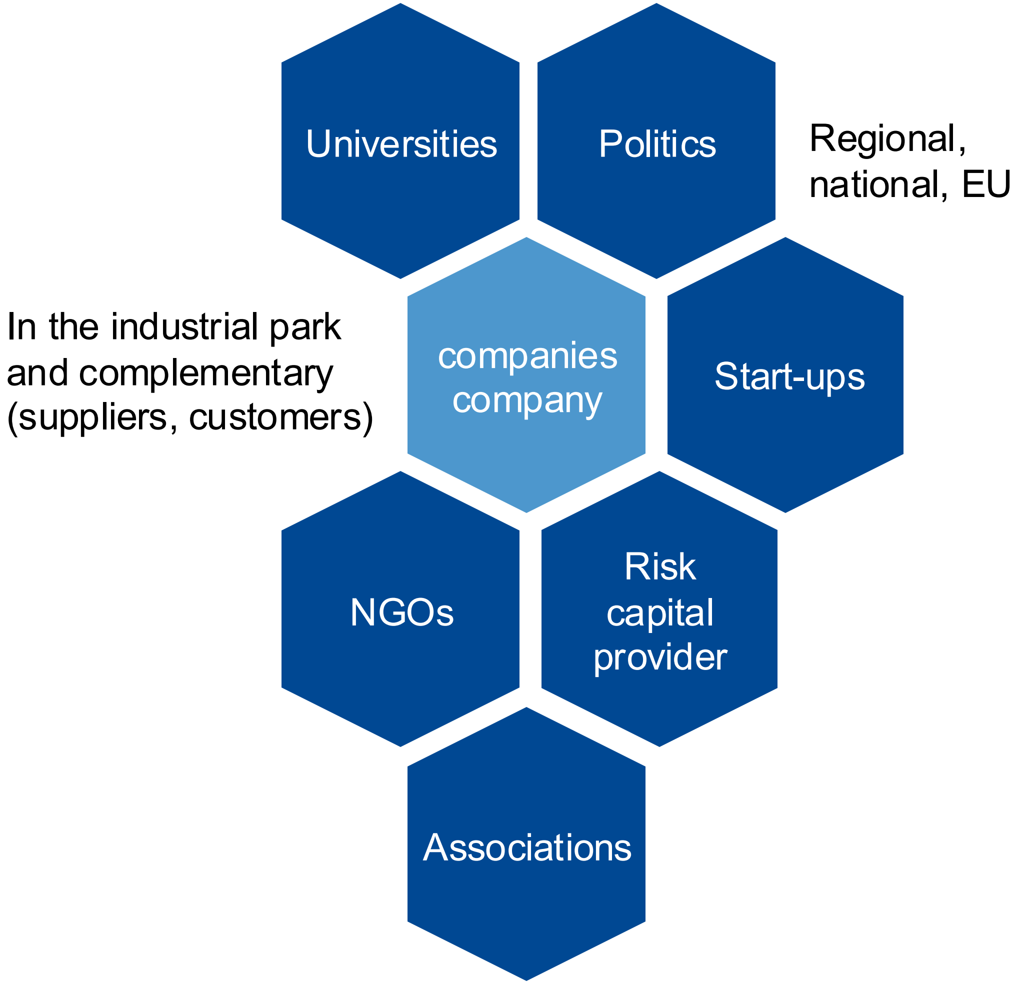
An innovative ecosystem comprises various complementary players.

Innovative ecosystem (MIT stakeholder model)



Value creation in the system

→ Realize new ideas

→ Access to know-how

→ Access to finance

Management approach: Objectives, content, financing, governance

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Industrial Park Höchst
Industrial Symbiosis and Industrial Urban Symbiosis

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We define IS as cooperation at the inter-firm level that involves:

- the optimisation of energy, waste, and by-product use;
- the sharing of utilities and infrastructure;
- the joint provision of services and the joint purchase of energy and resources;
- the transfer of experience and joint learning

Industrial symbiosis as enabler and barrier for defossilization: The case of Höchst Industrial Park

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Industrial Symbiosis and urban-industrial symbiosis in FrankfurtRheinMain: selected examples

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	Industrial Symbiosis at the industrial park	Urban-industrial symbiosis
1 Optimization of energy, waste and by-product use	– Combined heat and power generation (cogeneration) – Use of waste heat in production and disposal facilities	– Currently explored: Options for district heating
2 Sharing of utilities and infrastructure	– Buses inside the park are fuelled with hydrogen	– Utilisation of H_2 (by-product of chlor-alkali electrolysis) – Hydrogen filling station outside the park – Fuel cell trains in public transport refuelled at the park
3 Joint provision of services and the joint purchase of energy and resources	– Residue incineration (production residues) – CO_2 from biogas	Cascade utilisation of sewage sludge – Phosphorus recycling – Sewage sludge incineration – Commercial and municipal waste is thermically recovered
4 Transfer of experience and joint learning	– Cluster Process4Sustainability	Eg. Expert Panel Climate at the city of Frankfurt

Industrial symbiosis as enabler and barrier for defossilization: The case of Höchst Industrial Park

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Industrial Symbiosis: Industriepark Höchst has benefited from a reliable hydrogen supply for over 100 years.

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Hydrogen infrastructure

- Processing of 50 million scm of hydrogen per year
- Several compressors
- Gasometer 10,000 m³ & storage at 200, 300 and 500 bar
- H_2 grid > 20 km at 1, 7, 200 and 850 bar

H_2 Innovation Campus

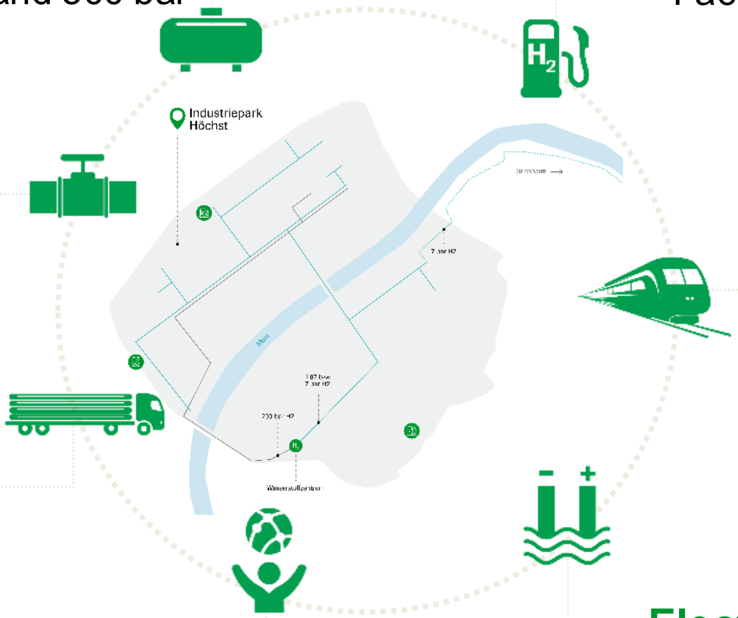
- Settlement of start-ups and funded R&D projects
- Projects in the fields of sustainability, H_2, CO_2, PtL, PtG

H2 Trailer filling

- 200, 300 and 500 bar

Consulting

- Concepts, infrastructure assessment, market research and analysis, studies, technology consulting
- Support in planning and approval process



Public hydrogen refueling station since 2006

- Supply via 1,000-bar pipeline from Industriepark Höchst
- Refueling cars, trucks and buses at 350 and 700 bar
- Factory buses in Industriepark Höchst run on hydrogen

Refueling station for rail vehicles

- Hydrogen supply for 27 Alstom "Coradia iLint" fuel cell trains
- Hydrogen requirement 2,000 - 2,400 kg per day
- replacement for diesel commuter trains

Electrolysis from 2022

- Construction of a PEM electrolysis plant with 5 MW
- Test facility for PEM electrolyser in MW scale

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Industrial Symbiosis and urban-industrial symbiosis
Innovation Campus

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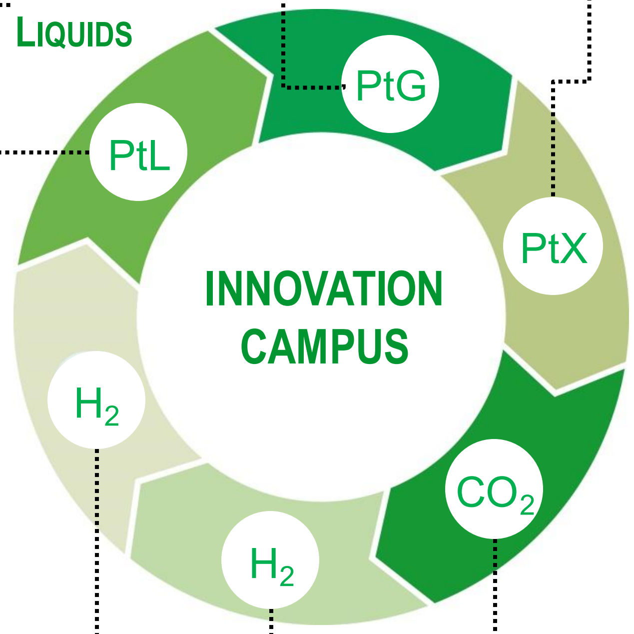
POWER TO LIQUIDS (INERATEC)

POWER TO GAS (CAPHENIA)

POWER TO CHEMICALS (CO2BIOCLEAN, ICO2CHEM)

- Carbon dioxide
- Biogenic waste
- Hydrogen
- Biogas
- Energies



- **Fuels** – Gasoline, Diesel, Kerosene
- **Methane** – Raw material, fuel, energy carrier
- **Chemicals** – Sustainable Chemical Raw Materials
- **Hydrogen** – Energy carrier, raw material for hydrocarbons
- **Energy control power** – Primary and secondary balancing power

ELECTROLYSIS OF WATER (METHQUEST – Bundesministerium für Wirtschaft und Energie)

H2BZ-TRAINS (RMV – Bundesministerium für Verkehr und digitale Infrastruktur)

CO_2 AS RAW MATERIAL (BioBall – Bioökonomie im Ballungsraum)

KOPERNIKUS PROJEKTE – SynErgie – Die Zukunft unserer Energie

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

Industrial Symbiosis[2] Hubs 4 Circularity

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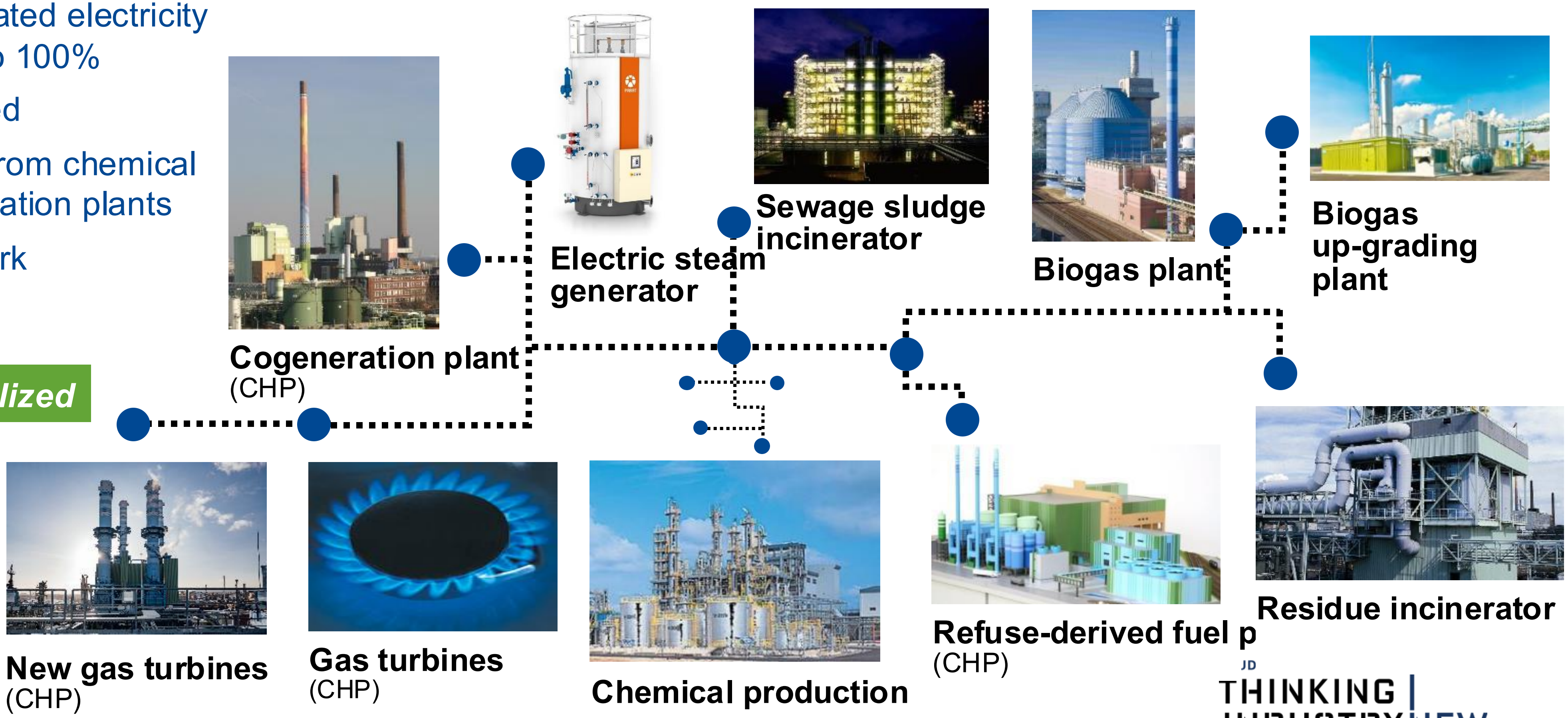
Starting Point:
Integrated Heat and Electricity Network

Increasing energy efficiency and reducing CO_2 emissions in the energy network

- Highly efficient combined heat and power generation
- Increase in self-generated electricity Generation capacity to 100%
- Coal combustion ended
- Waste heat recovery from chemical production and incineration plants
- Flexible system network

Waste-to-Energy realized



Biogas plant as part of infrastructure
Source of of biomethan and biogenic CO_2

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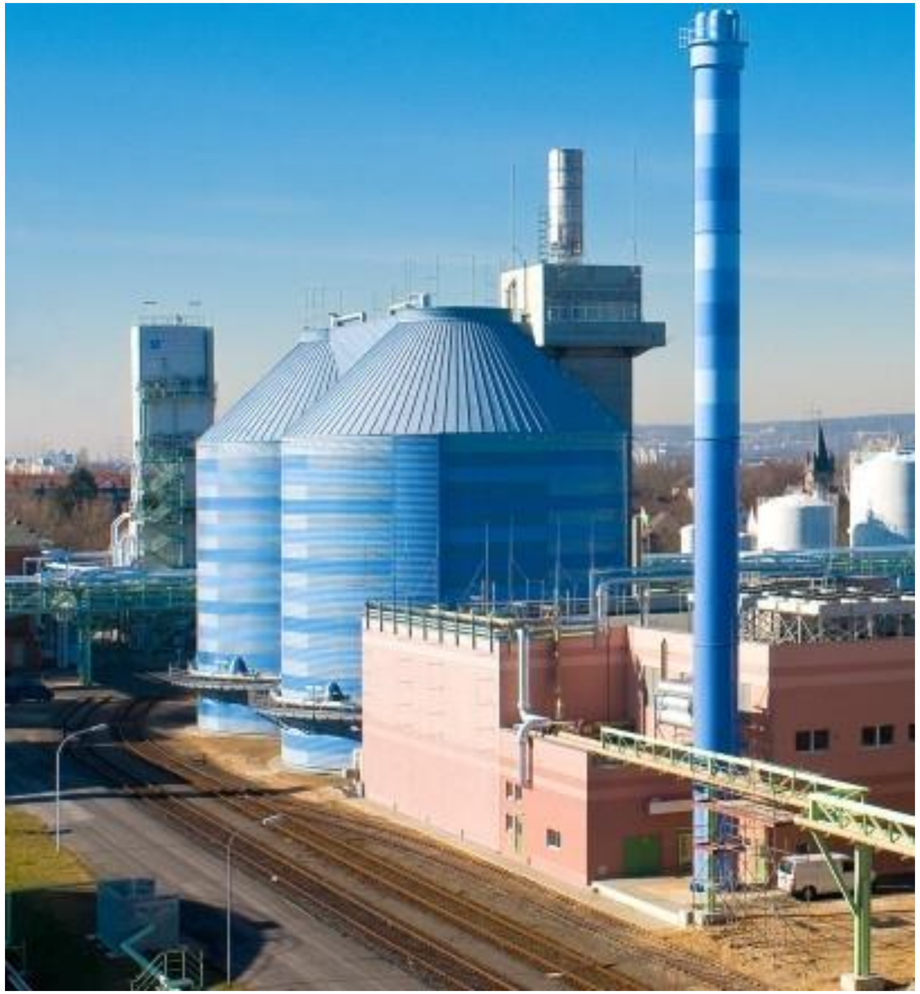
TECHNICAL DATA

- Digester volume:
  2 x 10,800 m³
- Capacity:
  310,000 t/a sewage sludge and about 190,000 t/a co-substrates
- Biogas production:
  approx. 30,000 m³/d
- Output
  electrical 5.1 MW; thermal 3.9 MW; 10 MW Biomethan
- Waste types:
  > 100 types of waste.
  Including: homogenized food waste; pharmaceutical industry waste; oil and grease trap waste; biogenic refuse from biochemical processes or food production; mother liquors or solvent mixtures; slaughterhouse waste such as blood; sewage sludge; alcohols, glycerins, stearate, etc.



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Carbon capture campaign with GEA pilot plant
Project example: From IS2H4C in 2025

- CO_2 capture at a waste incineration plant
- Pilot plant campaign from May-August 2025
- Determine costs of CC
- Further costs for purification, compression, liquefaction, transport ex IPH
- Investigation of heat integration / optimization
- Determine alternative capture processes such as membrane technology incl. test trial

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Example: Hydrocarbons produced from biogenic CO_2 and hydrogen:
Settlement of INERATEC

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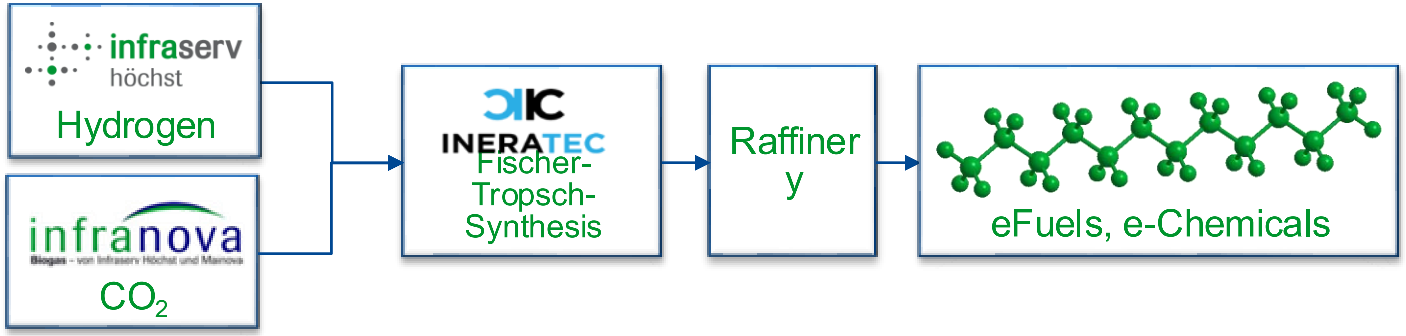
Power-to-Liquid Pioneer plant in Germany

- Raw materials:
  - H_2 from electrolysis with renewable power und CO_2 from biogas up-grading
- Production of 2,500 tonnes of eFuel and e-Chemicals annually by INERATEC



The pioneering plant is one of the largest of its kind and will pave the way for further PtL projects from INERATEC

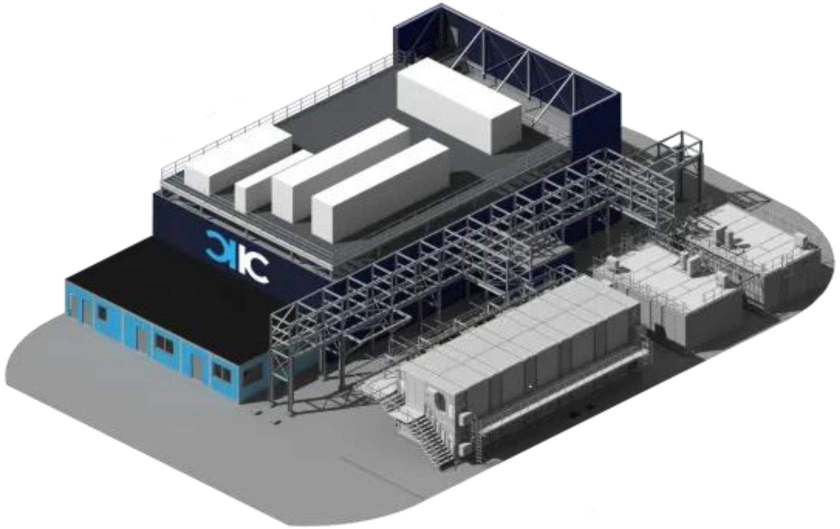


Image sources: INERATEC GmbH

Industrial Symbiosis:
Industrial parks as innovation hubs

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Infrastructure

Energy supply
- Power generation
- Electricity grids
- Heat / Steam
- Hydrogen
- Biogas
- Biomethane
- …

Disposal (Circular economy)
- Wastes
- Phosphate
- CO_2
- …

Sustainable raw materials available

Innovation Campus

Initiation and participation in funded innovation projects

Settlement of innovative start-up companies

Pilot and demonstration plants for PtG, PtL and PtX

First-of-its-kind systems for sustainable processes

Industrial infrastructure in place

Networks

Formation and active participation in networks with chemical companies

Experience has shown that regional clusters offer significant synergies

Close cooperation with universities and research institutions

Entire value chain present

Hubs4Circularity

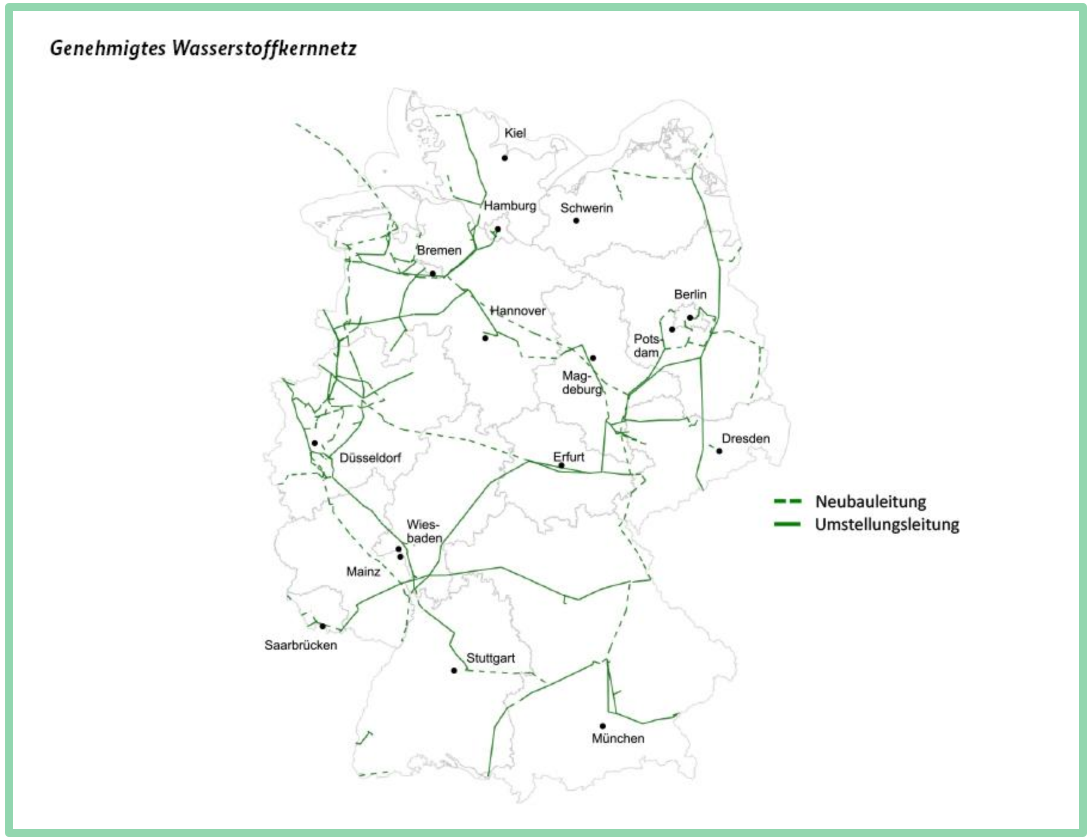
Industrial-Symbiosis
Transfer of experience and joint learning

Process4Sustainability

- Target: Creation of a CO_2-neutral industry by 2045
- Topic: Breaking down CO_2 neutrality to the individual company and making findings usable.
- The cluster supports companies on their way to climate neutrality by:
  - Identification of the levers for CO_2 neutrality (CO$_2$ footprint; Scenarios; Roadmap Development)
  - Identification of technical solutions for CO_2 neutrality (technology assessment, discussion papers, trend radar)
  - Dealing with new business models (circular economy, public-private partnership)
  - Networking with innovation partners and solution providers for CO_2 reduction (innovation and cooperation formats)
  - Project development and public funding, review of support programmes (application and innovation support)

Levers
1. Replacement of natural gas
"Green" electricity Electrification Heat Synthetic methane from CO_2 C-free fuel gas (H_2; Methane pyrolysis) Biogas / Biomethane
2. Substitute for fossil ethylene
"Green" ethylene from ethanol Plastic recycling and cracking
3. Substitute for fossil methanol
Syngas from biomass; CO_2 und H_2
4. Substitute for fossil acetic acid
via "green" methanol
5. Other topics
CCS; Recycling

Industrial-urban symbiosis
Industrial transformation requires collective action
Example: Infrastructure H2



Relevant Stakeholders:

- Companies
- Policy makers
- Public administration
- Society incl. NGOs
- Media
- …

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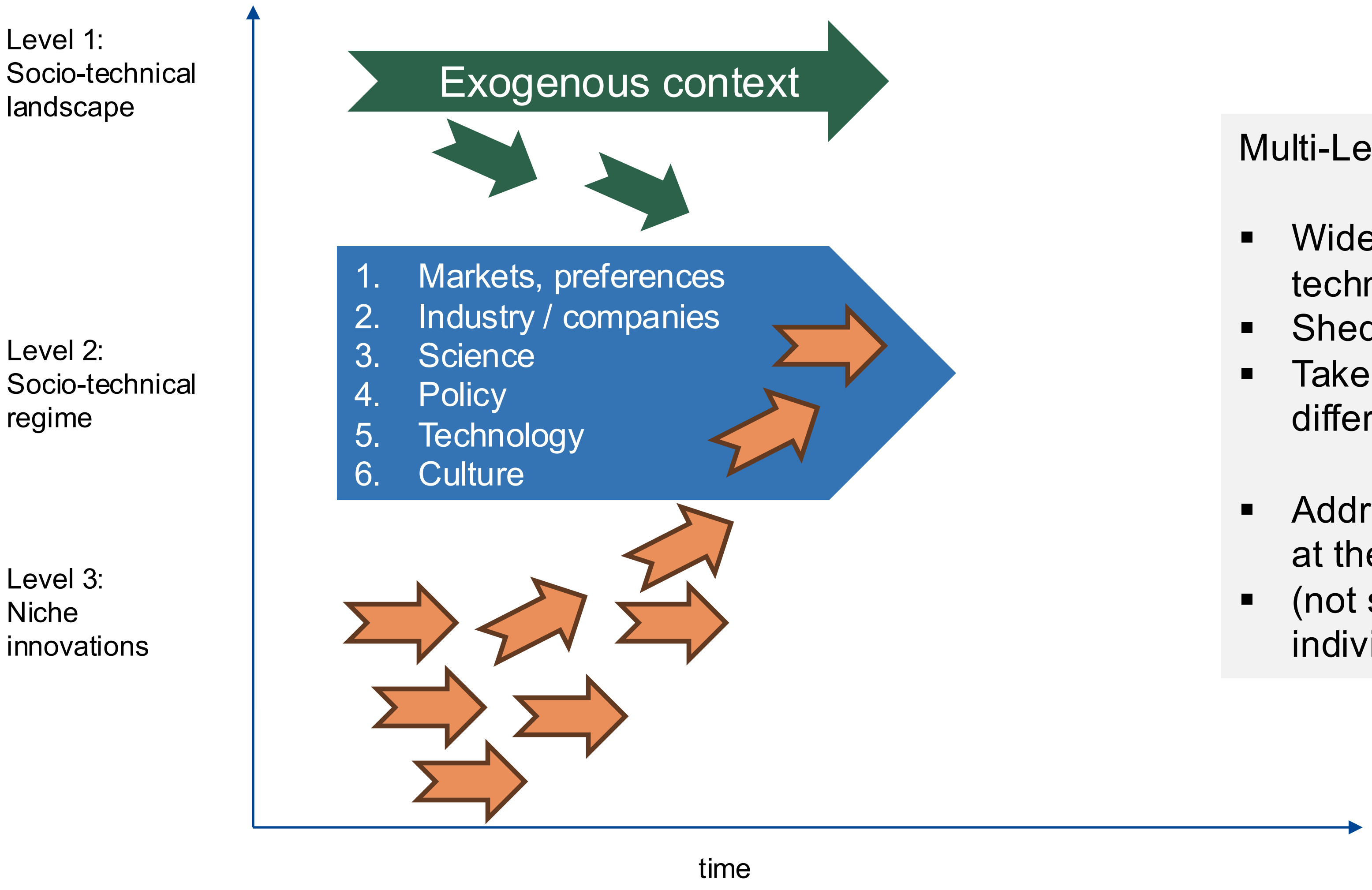
Industrial transformation requires collective action
How do we conceptualize transition processes?



Multi-Level-Perspective, Prof. Geels

- Widely used in the debate on socio-technical change
- Sheds light on systems and actors
- Takes into account findings from different disciplines

- Addresses socio-technical systems at the "meso level"
- (not society as a whole, not individual innovations)

[The multi-level perspective on sustainability transitions: Responses to seven criticisms - ScienceDirect]

How do we conceptualize transition processes?
Level 2: socio-technical regime

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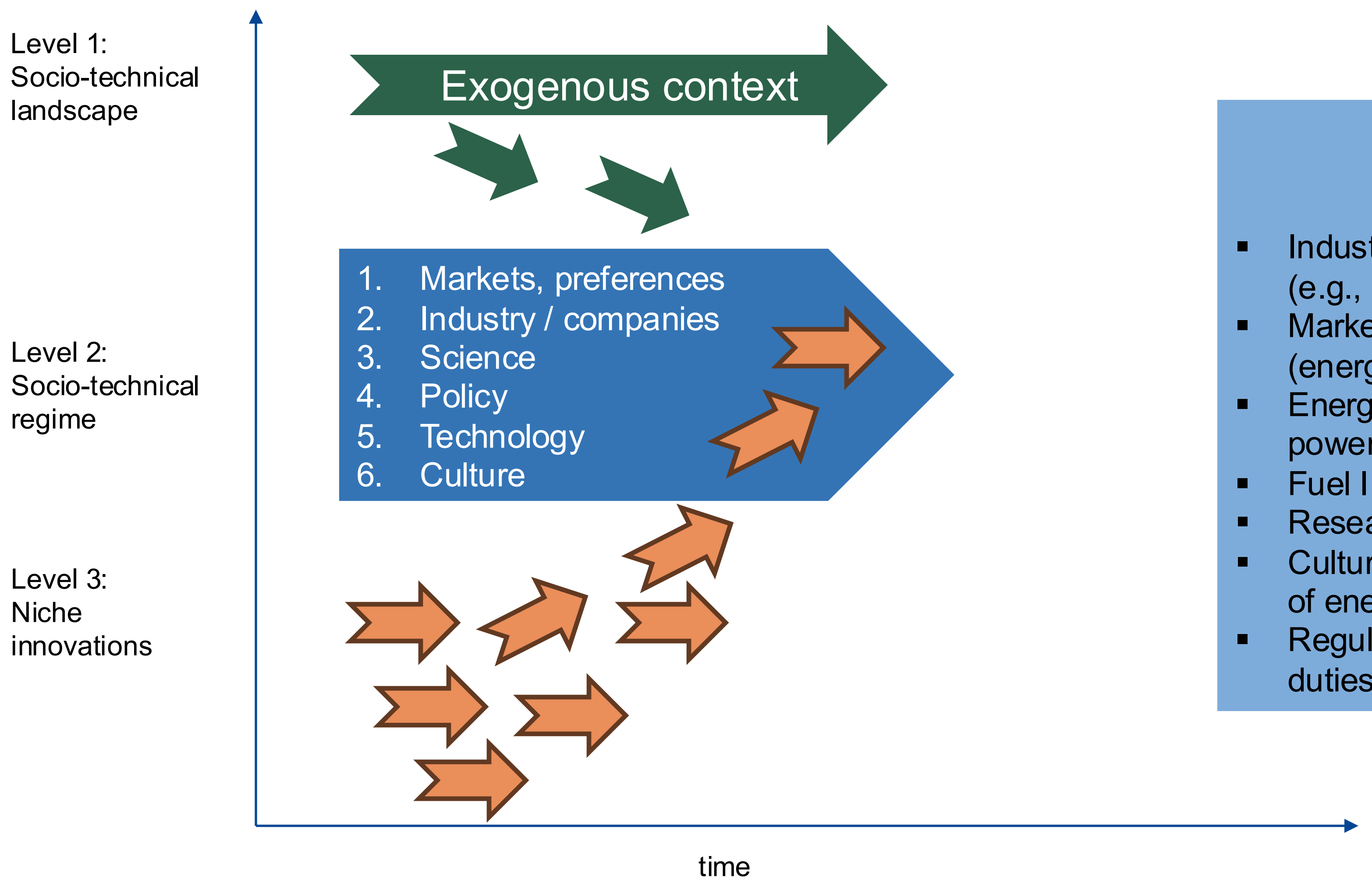

Interconnected sub-systems

Socio-technical system for energy production/use

- Industry structure (e.g., energy producers; suppliers)
- Markets (energy-markets; CO_2-markets)
- Energy infrastructure(e.g., existing coal-fired power plants)
- Fuel Infrastructure (companies, gas stations)
- Research & Development institutions
- Culture and symbolic meaning (e.g., importance of energy for a self-determined life)
- Regulations and guidelines (e.g., taxes and duties)

The multi-level perspective on sustainability transitions: Responses to seven criticisms - ScienceDirect

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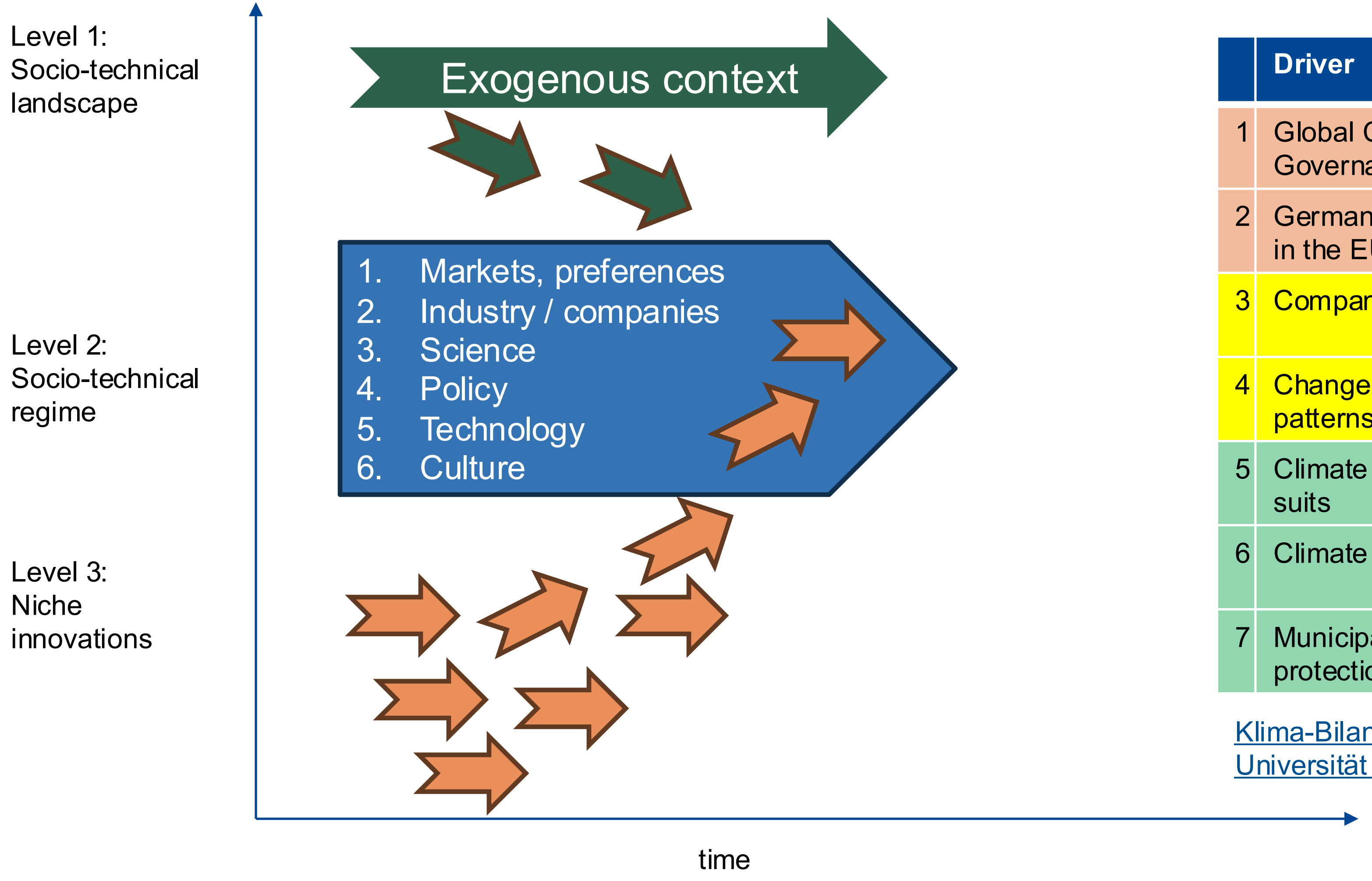
How do we conceptualize transition processes?
Germany: Status Quo Climate Change Transition 2025



	Driver	Evaluation 2025
1	Global Climate Governance	contributing less to coordination than before.
2	German Climate Policy in the EU context	not strong enough to meet climate targets.
3	Companies	contradictory dynamics: + energy sector, other sectors -
4	Change of consumer patterns	no significant shifts to climate-friendly consumption patterns
5	Climate related law suits	Climate lawsuits have a countercyclical effect
6	Climate activists	supportive, but significantly less so than a few years ago.
7	Municipal climate protection measures	predominantly supportive of climate change,

Klima-Bilanz: Wo es in Deutschland hakt : CLICCS : Universität Hamburg

The multi-level perspective on sustainability transitions: Responses to seven criticisms - ScienceDirect

Textbook world: Cooperation between politics, business, and society
But why does this interaction not work in real-life?

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Policy Mix	1. Fragmented and inconsistent transition policy mix Transformation processes require coherent sets of instruments. Reality shows fragmentation and a lack of coherence
Multi-Level	2. Multi-level governance :Too many veto players lead to compromise solutions and long coordination processes. As a result, companies increasingly lose track of responsibilities and decision-making logic.
Poly-centric	3. Polycentric governance: In a complex system such as the energy transition, many levels of actors emerge. Without coordination, the overview is lost – for politics, business, and society alike.
Wait-see	4. Lack of credible commitment: Political uncertainty prevents investment. Companies do not recognize the long-term reliability of political commitments.
Mind-set	5. Cultural change needed: Social change can only succeed if technological, economic, and cultural dimensions are linked. The ability to shape change in a co-creative way is needed.

Industrial-urban symbiosis
Governance Models

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IS Model	What can be found in the Frankfurt area? (own impression)
Self-organised	▪ If complementary actors identify joint economic interests (e.g. construction industry and landfill operator)
Facilitated	▪ Some funded initiatives e.g. Bioball ▪ Process4sustainability.eu network
ICT enabled	▪ ? (data on CO_2 or biomass in the region as a challenge)
Strategic or planned	▪ Initiatives within the industrial park Höchst and between the park and the district (if significant economic benefits are identified)

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Societal readiness level

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In addition to the Technology Readiness Level, the Societal Readiness Level describes society's readiness to accept, understand, and use new technologies. This approach calls for the parallel development of technical and societal innovation pathways.

Societal	Readiness Level	Technology
Successful deployment in real stakeholder context	9	Successful user deployment in real life
Final testing in real stakeholder context	8	Final user testing in real life
Demonstrated in operational stakeholder context	7	Demonstrated in operational user environment
Demonstrated in simulated stakeholder context	6	Demonstrated in simulated user environment
Validated in simulated stakeholder context	5	Validated in simulated user environment
Stakeholder context validated	4	Validated in lab
Stakeholder context proof of concept	3	Experimental proof of concept
Proposed solution in stakeholder context	2	Technology concept
Societal problem in stakeholder context	1	Basic principles

Schraudner, M. et al.: Social innovation: The potential for technology deployment, RTOs and industry

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Summary

- **Redesigning the economy within the planetary boundaries is a <u>large-scale socio-technical transition</u>. In addition to the technical challenge, it includes the redesign of a variety of societal fields (e.g. industries, policies, markets, customer preferences, regulation, science). The multi-level perspective helps to capture the dynamic nature of these transitions.**

- **<u>Real-life-challenges</u> in the transition: 1. inconsistent policy mix; 2. multi-level governance, 3. lack of overview of in polycentric governance, 4. lack of commitment, 5. cultural deficits**

- **<u>Societal acceptance</u> of industrial activities can be understood as a relationship between an accepting subject and an object of acceptance. Social acceptance is developed in a <u>societal discourse process</u> and influenced by project and process characteristics (project: e.g. perceived cost-benefit, risks; process: perceived fairness, perceived social influence and participation).**

- **One way of capturing the societal acceptance of a project are the so-called <u>societal readiness levels</u> which compement the established technological readiness levels.**

Content

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Literature and project references

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zin-publikationen.pdf (provadis-hochschule.de)

Process4 Sustainability

HESSEN Hessisches Ministerium für Wirtschaft, Energie, Verkehr und Wohnen

Sustainable Industrial Area Management

zin-projectlist.pdf (provadis-hochschule.de)

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Center for Industry and Sustainability

Let's create a sustainable industry together

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Transforming Industries

We are supporting the industry to become more sustainable, reduce CO_2 emissions and benefit from digitalization. Through our projects we identify options for industry defossilization and new business development.

Accelerating Sustainable Businesses

We conceptualized the EIT Climate-KIC cleantech accelerator and managed it both regionally and internationally. We offer start-ups mentorship and support with sustainable business model development. For organizations we develop business creation and matchmaking formats.

Educating Change Makers

We create learning opportunities for national and international change makers. Our formats (e.g., workshops, trainings, summer schools) focus on real-life challenges and bring latest knowledge in effect. We make knowledge work!

20+ high-impact projects on regional, national and global scale with partners from academia, industry and public authority.

Key facts since 2016

Cooperations with 50+ companies

350+ start-ups in 13 countries supported

2.500+ participants in our education formats

Activities with a funding of 18 million euros

Selected Projects

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CO_2 -Neutrality: Process4Sustainability cluster

Process4 Sustainability

HESSEN Hessisches Ministerium für Wirtschaft, Energie, Verkehr und Wohnen

Management of European Cleantech Accelerator

eit Climate-KIC

Climate-KIC is supported by the EIT, a body of the European Union

Sustainable Industrial Area (SIA) Management Courses with GIZ

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Sustainable Industrial Area Management

Projects with impact in 30+ countries

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