



# Introduction to: SDU Life Cycle Engineering

Henrik Wenzel, [henrik.wenzel@kbm.sdu.dk](mailto:henrik.wenzel@kbm.sdu.dk), [www.sdu.dk/lifecycle](http://www.sdu.dk/lifecycle)

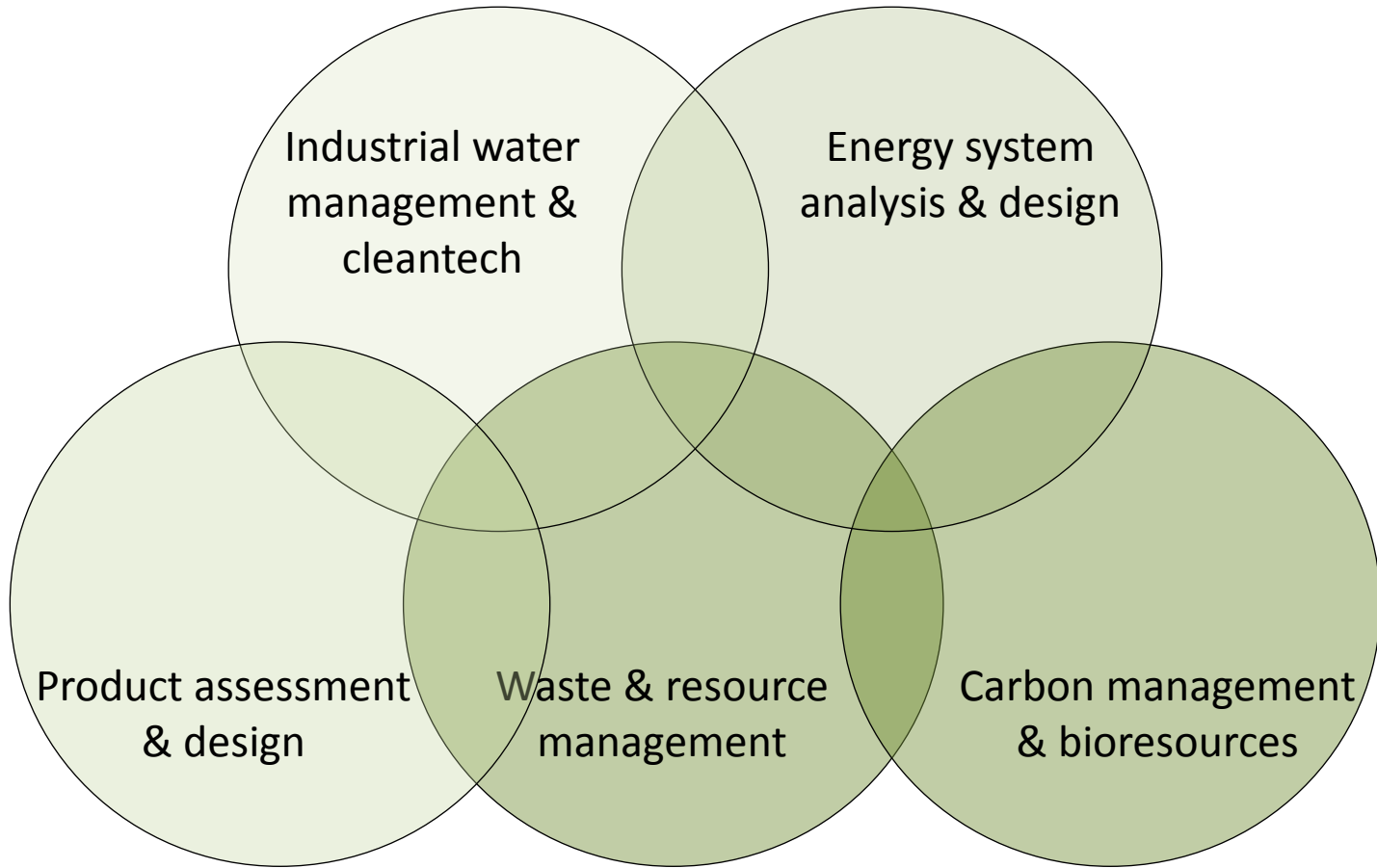
Workshop on Characterizing the built environment stocks: methods and case studies  
SDU, Odense, Denmark, August 11<sup>th</sup>, 2016

# Main research topic

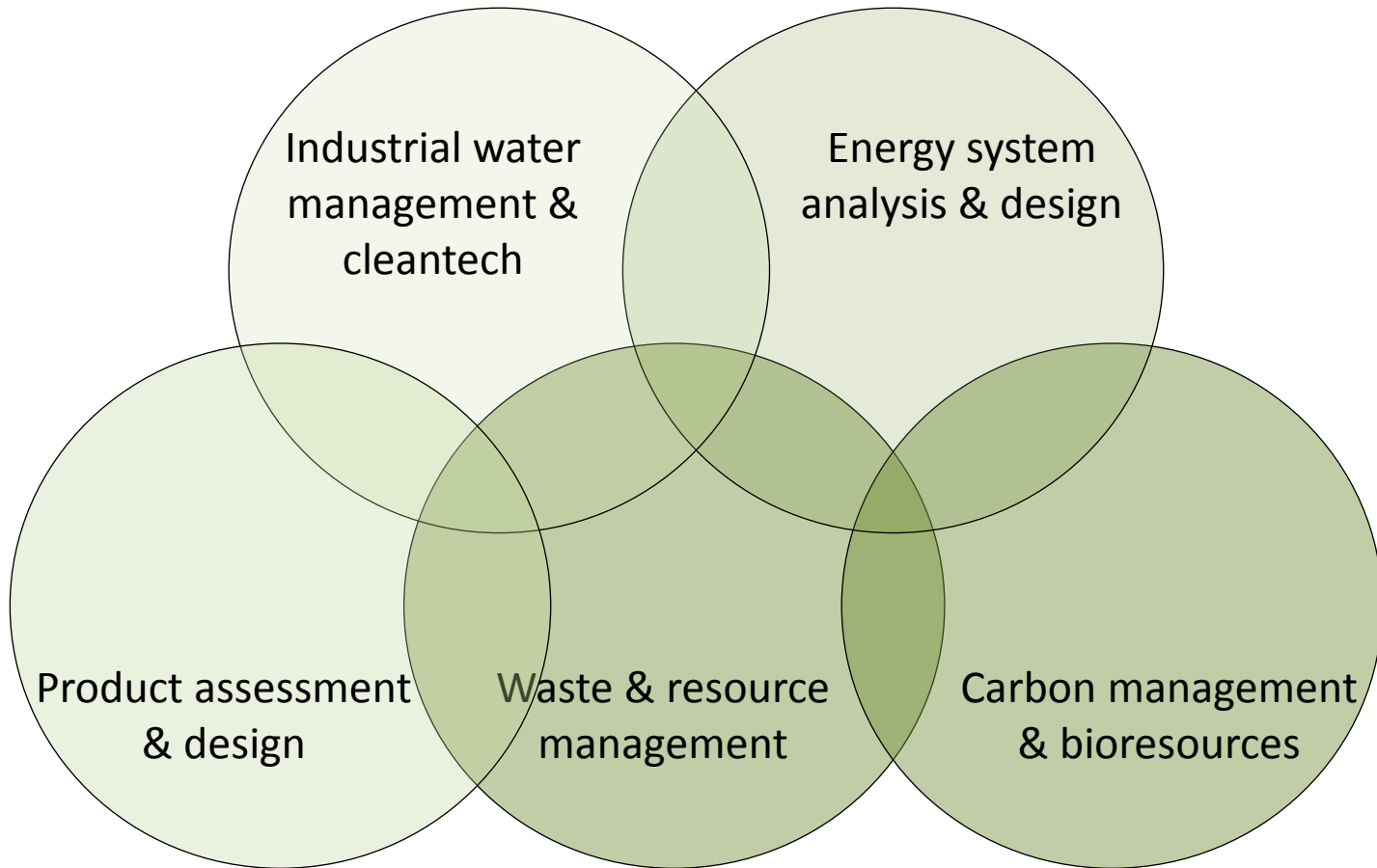
**Life Cycle Engineering and systems integration for environmental optimization of techno-sphere**

- under present and future framework conditions

# Main research domains

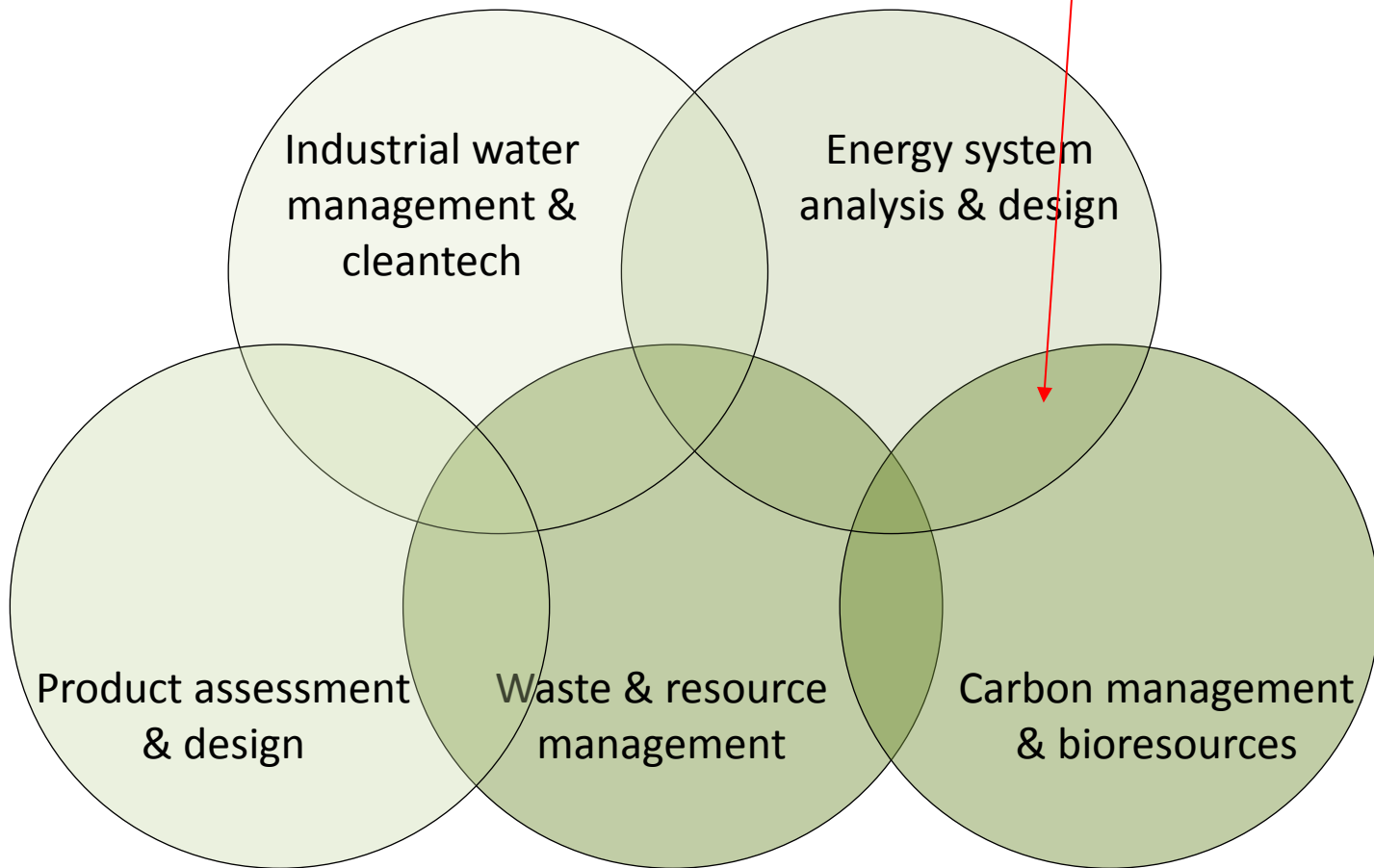


# Research project examples



# Research project examples

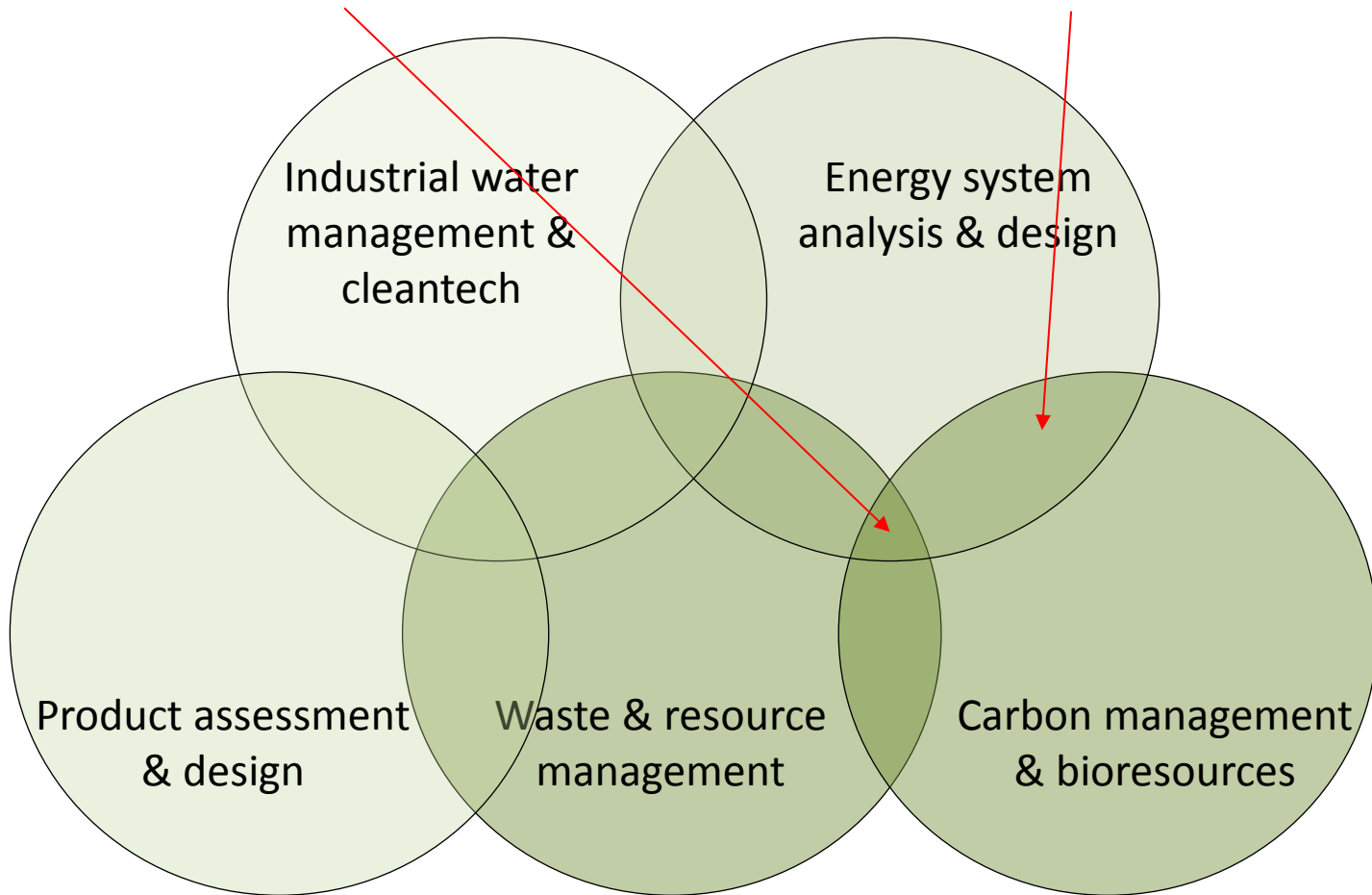
EASI – Energy and Agricultural  
System Integration



# Research project examples

SYMBIO - Integration of biomass and wind power for biogas upgrading via hydrogen

EASI – Energy and Agricultural System Integration

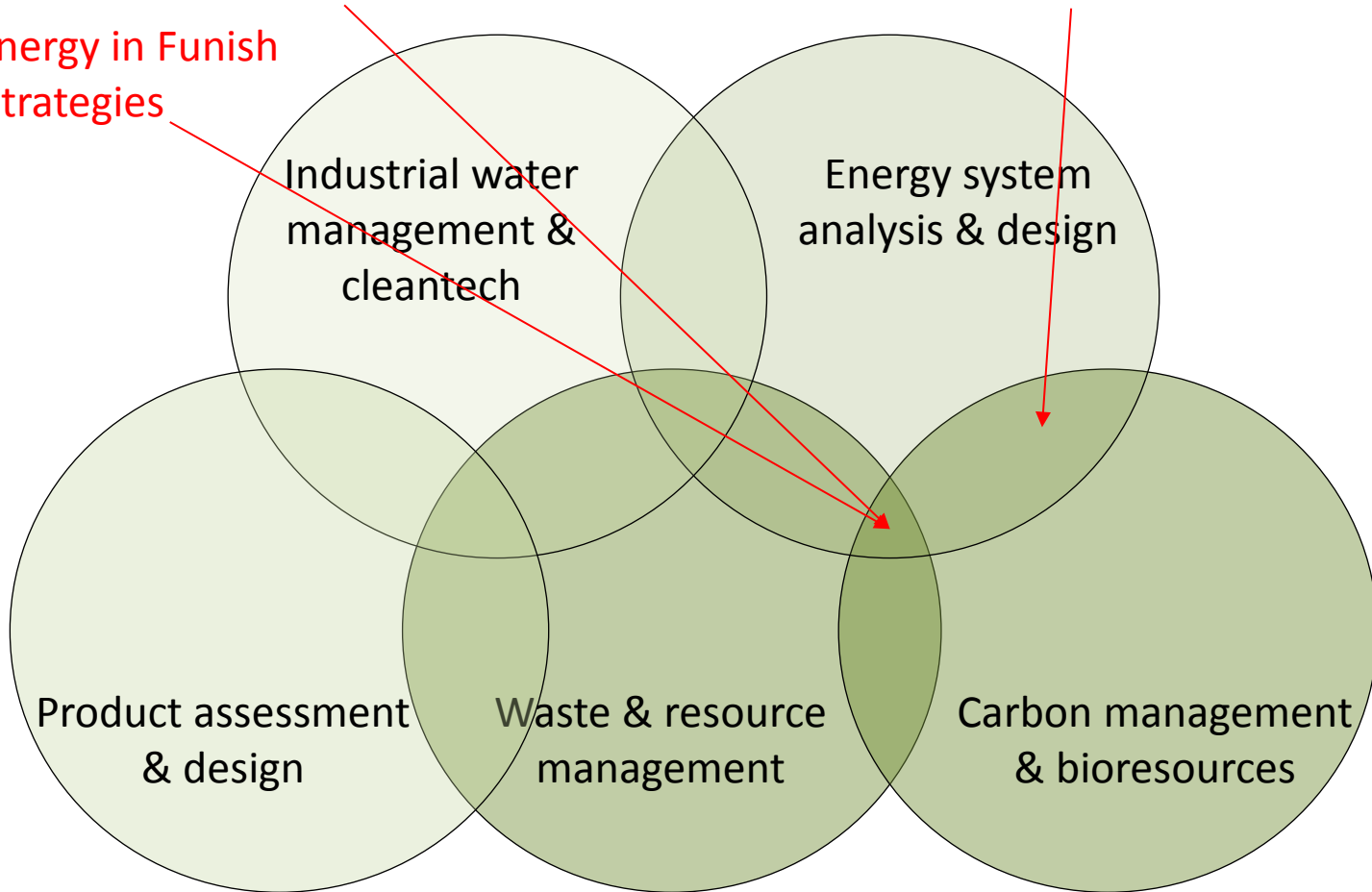


# Research project examples

SYMBIO - Integration of biomass and wind power for biogas upgrading via hydrogen

EASI – Energy and Agricultural System Integration

SYFRE – Synergy in Finnish Resource Strategies



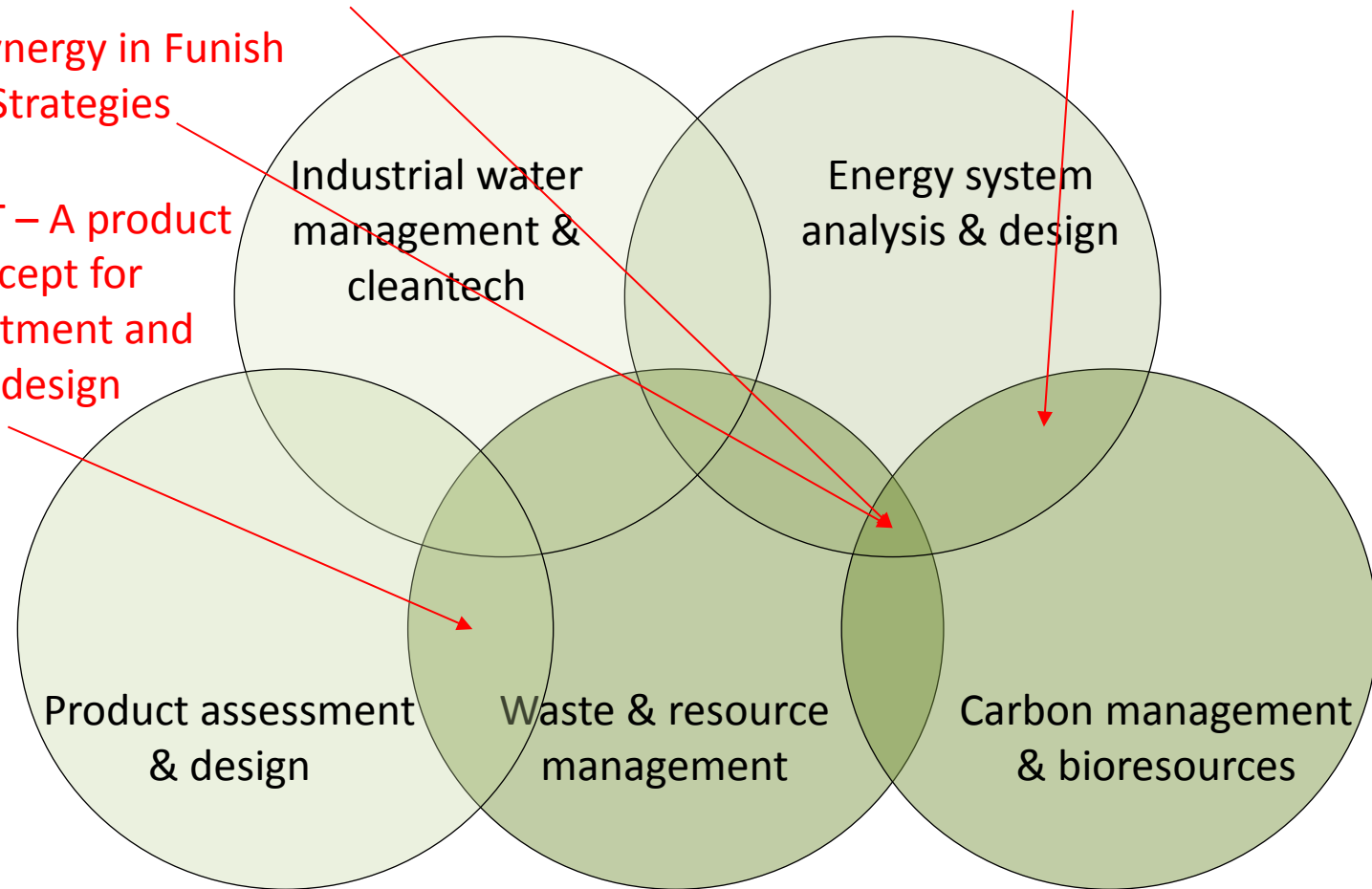
# Research project examples

SYMBIO - Integration of biomass and wind power for biogas upgrading via hydrogen

EASI – Energy and Agricultural System Integration

SYFRE – Synergy in Finnish Resource Strategies

INNOSORT – A product family concept for WEEE treatment and e-product design





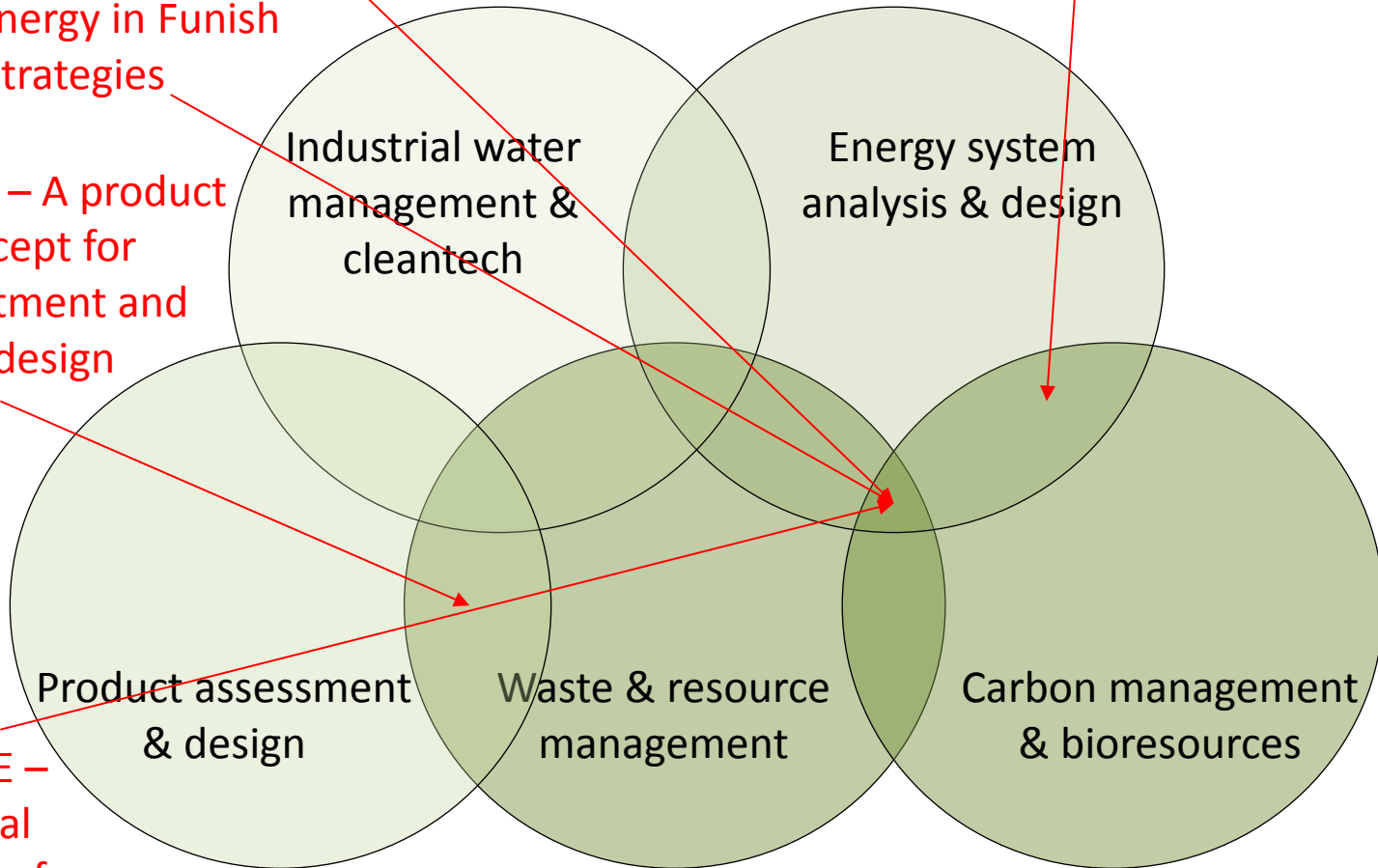
# Research project examples

SYMBIO - Integration of biomass and wind power for biogas upgrading via hydrogen

EASI – Energy and Agricultural System Integration

SYFRE – Synergy in Finnish Resource Strategies

INNOSORT – A product family concept for WEEE treatment and e-product design



TOPWASTE – The optimal treatment of waste

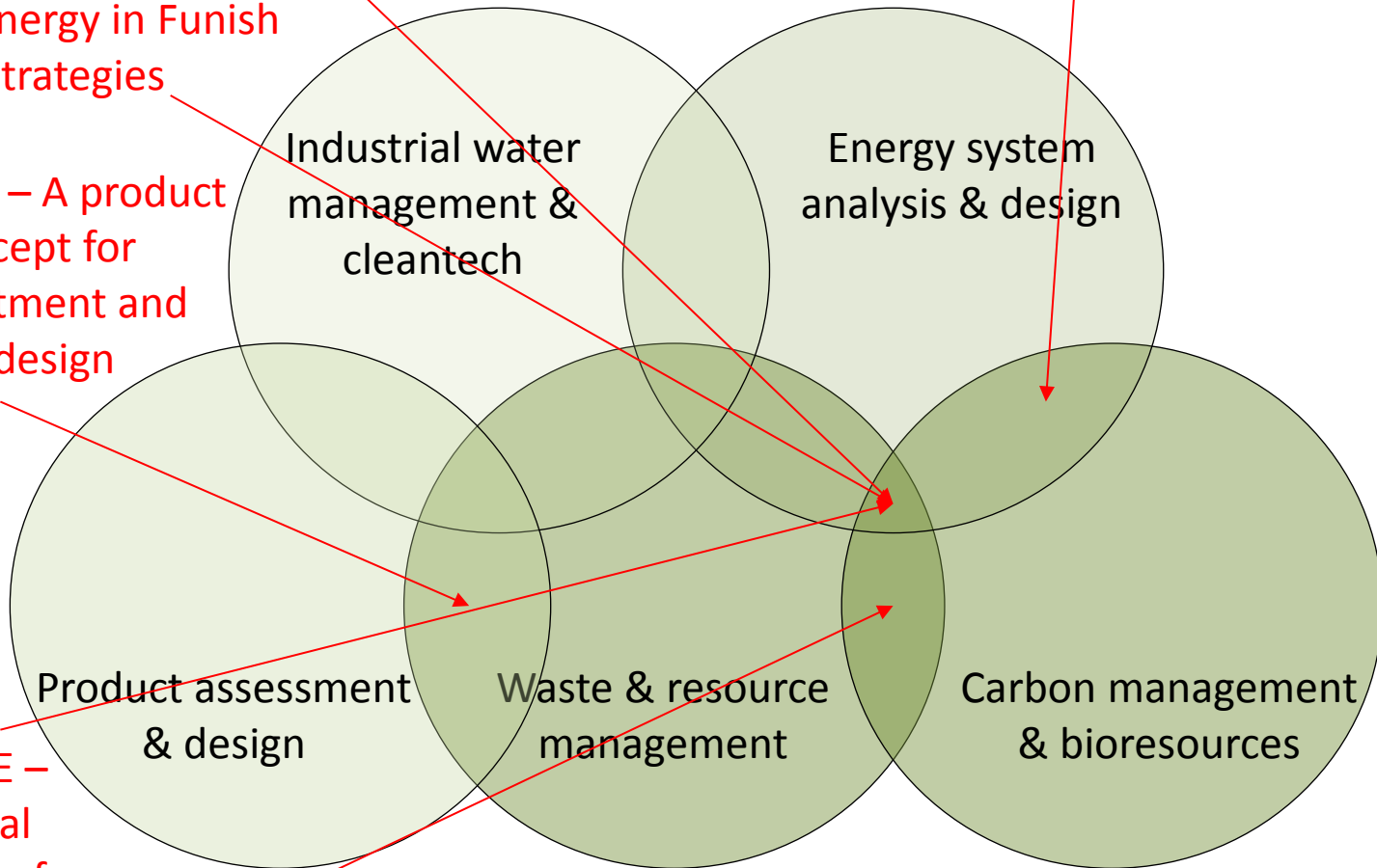
# Research project examples

SYMBIO - Integration of biomass and wind power for biogas upgrading via hydrogen

EASI – Energy and Agricultural System Integration

SYFRE – Synergy in Finnish Resource Strategies

INNOSORT – A product family concept for WEEE treatment and e-product design



TOPWASTE – The optimal treatment of waste

REFRESH – Resource efficient food and drink for the entire supply chain

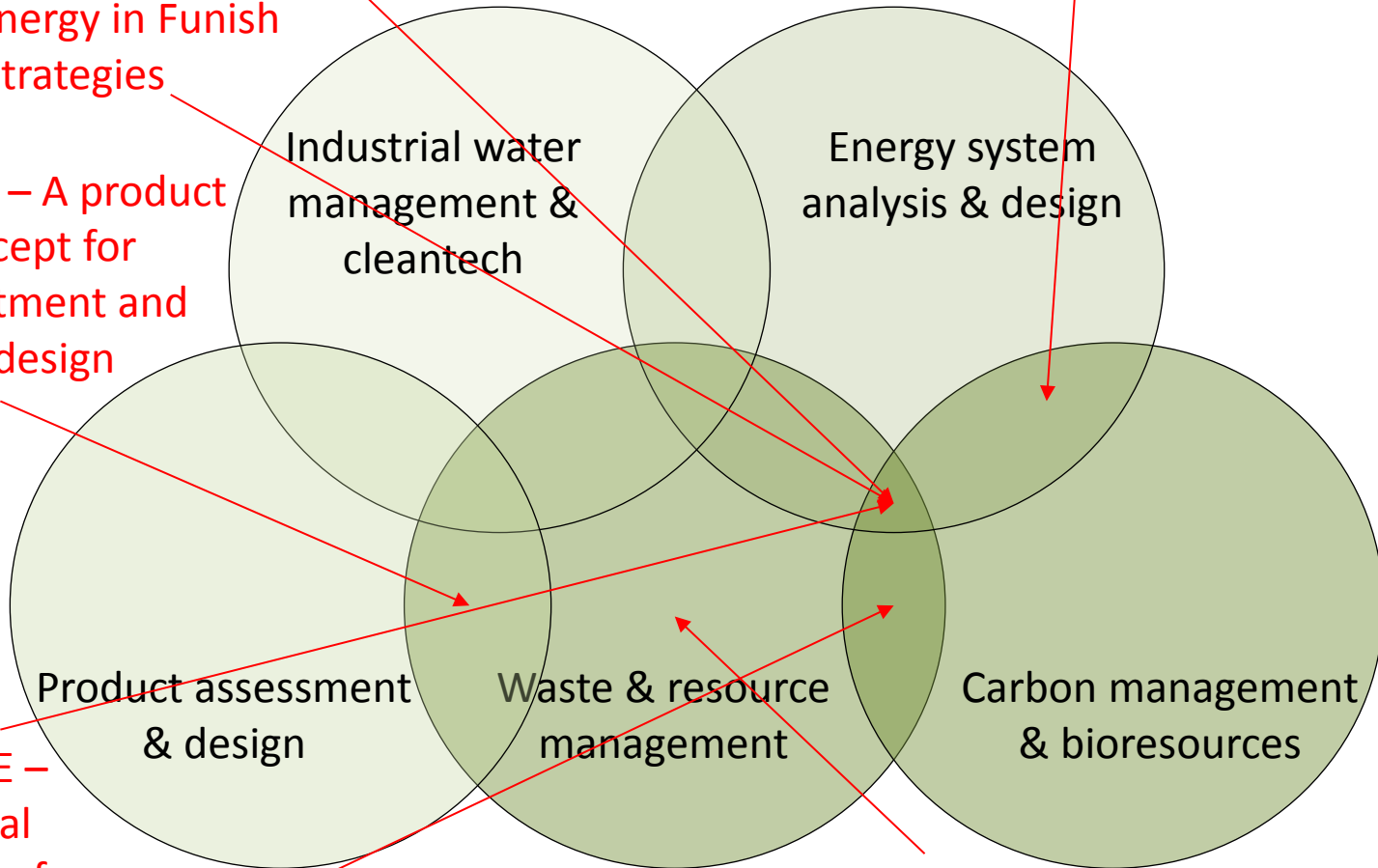
# Research project examples

SYMBIO - Integration of biomass and wind power for biogas upgrading via hydrogen

EASI – Energy and Agricultural System Integration

SYFRE – Synergy in Finnish Resource Strategies

INNOSORT – A product family concept for WEEE treatment and e-product design



TOPWASTE – The optimal treatment of waste

REFRESH – Resource efficient food and drink for the entire supply chain

MinFuture – Global material flows and demand-supply forecasting for mineral strategies

# Research project examples

SYMBIO - Integration of biomass and wind power for biogas upgrading via hydrogen

EASI – Energy and Agricultural System Integration

SYFRE – Synergy in Finnish Resource Strategies

INNOSORT – A product family concept for WEEE treatment and e-product design

Industrial water management & cleantech

Energy system analysis & design

CityWeight – The weight of cities and dematerialization and decarbonization implications

Product assessment & design

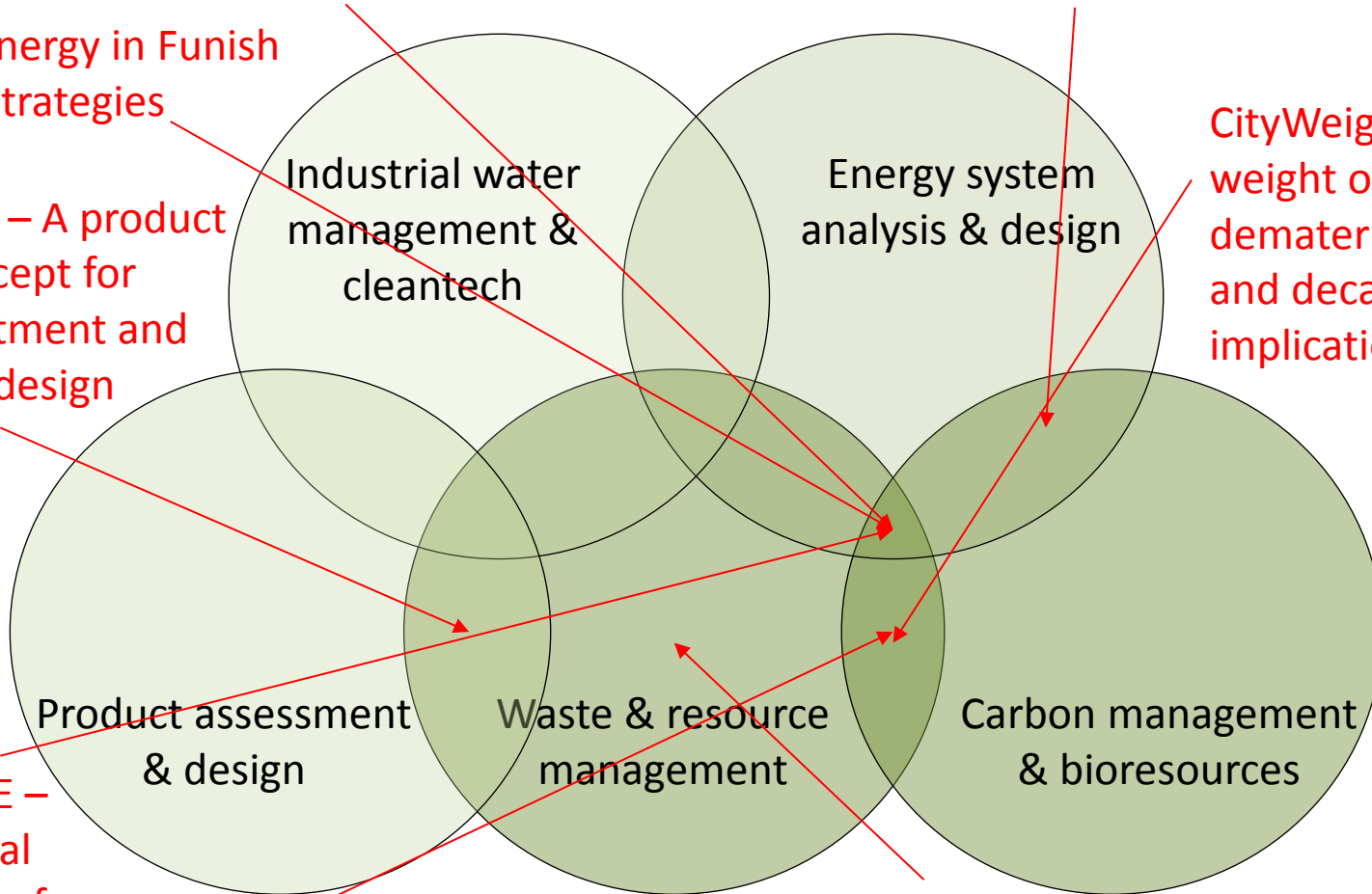
Waste & resource management

Carbon management & bioresources

TOPWASTE – The optimal treatment of waste

REFRESH – Resource efficient food and drink for the entire supply chain

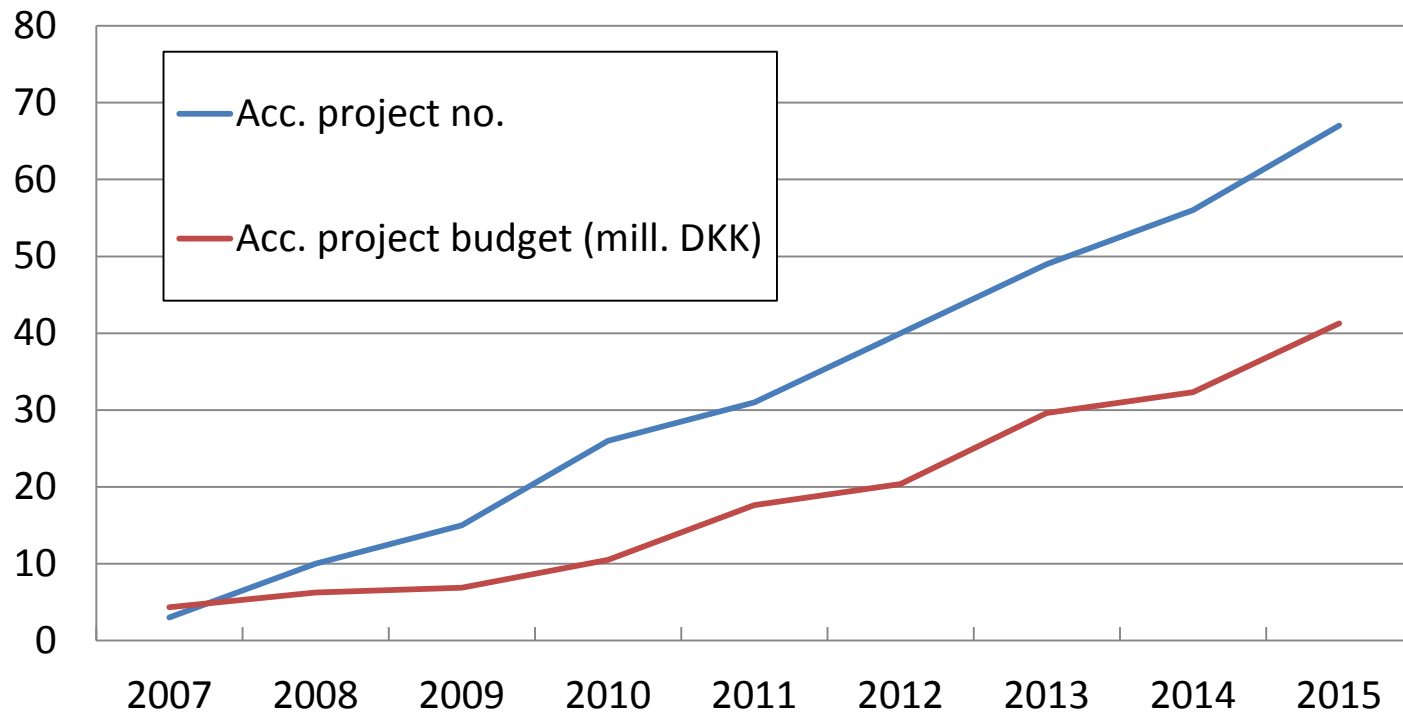
MinFuture – Global material flows and demand-supply forecasting for mineral strategies



# External funding

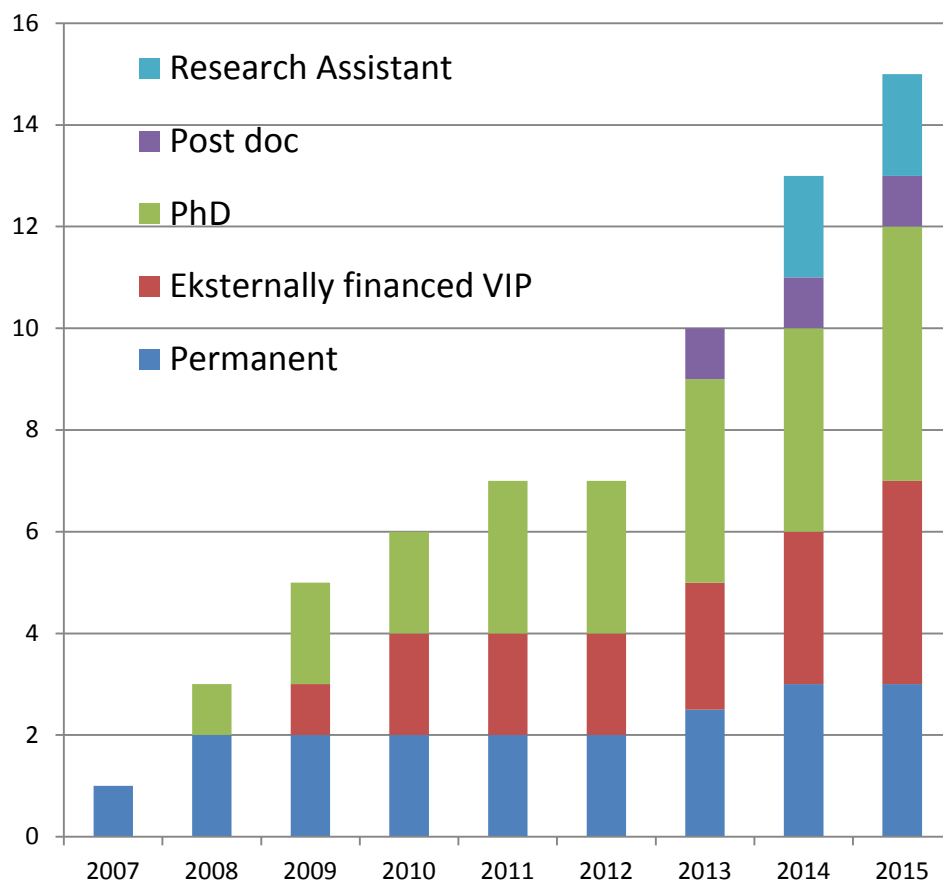
- dynamics

**Project portfolio**



# Staff development

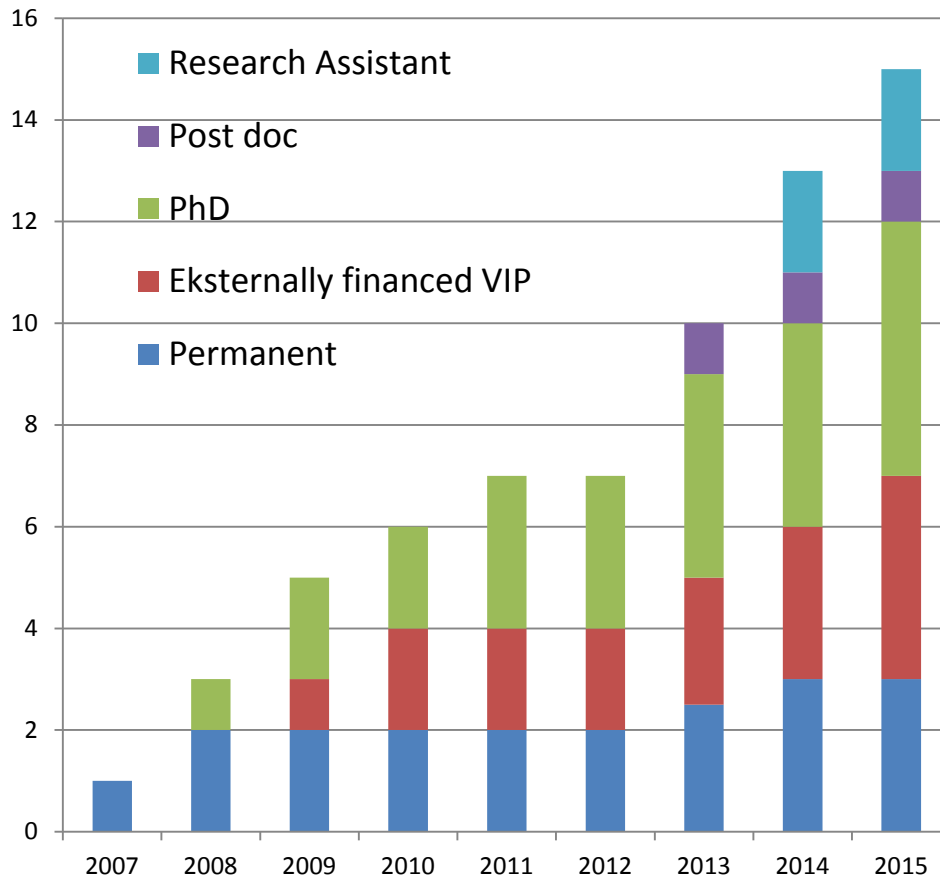
## Research staff ultimo 2015



Position	Name
Research assistant	Peter S Hansen
Research assistant	Agnieszka Glab
PhD student	Julie H Hansen
PhD student	Komal Habib
PhD student	Ciprian Cimpan
PhD student	Keshav Parajuly
PhD student	Christine Dasanayake
Post doc	Abid Rabbani
Assistant professor	Lorie Hamelin
Associate professor	Gang Liu
Senior consultant	Marianne Wesnæs
Senior consultant	Ole Dall
Senior consultant	Henrik Grüttner
Associate professor	Birgitte L Sørensen
Professor mso	Henrik Wenzel

# Staff development

## Research staff ultimo 2015



## Open positions August 2016:

2 assistant/associate prof in LCA and carbon mgt

2 assistant/associate prof in Energy Systems

1 associate prof in MFA, Waste & Resource systems

2 PhD positions in ESA, MFA & LCA of emerging fuels

1 PhD position in Urban Metabolism

1 Vice Center leader

Cf. [www.sdu.dk](http://www.sdu.dk) 'vacant positions'

# Research project examples

## SYMBIO - Integration of biomass and wind power for biogas upgrading via hydrogen

## EASI – Energy and Agricultural System Integration

# SYFRE – Synergy in Finnish Resource Strategies

# INNOSORT – A product family concept for WEEE treatment and e-product design

~~Industrial water  
management &  
cleantech~~

# Energy system analysis & design

## CityWeight – The weight of cities and dematerialization and decarbonization implications

## Product assessment & design

~~Waste & resource management~~

## Carbon management & bioresources

## TOPWASTE – The optimal treatment of waste

REFRESH – Resource efficient food and drink for the entire supply chain

## MinFuture – Global material flows and demand-supply forecasting for mineral strategies

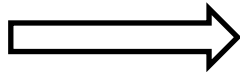


# CRITICAL RESOURCES IN CLEAN ENERGY TECHNOLOGIES AND WASTE FLOWS

*Komal Habib*

*Supervisor: Henrik Wenzel*

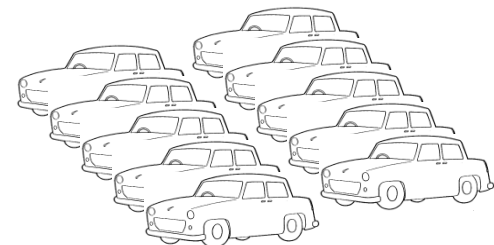
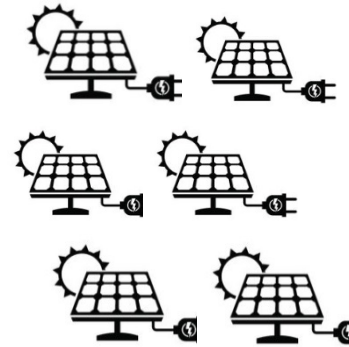
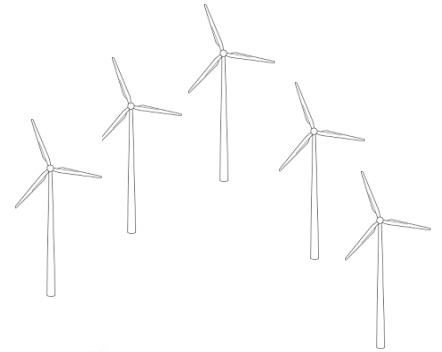
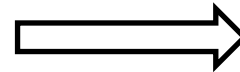
Department of Chemical Engineering, Biotechnology & Environmental Technology,  
Faculty of Engineering, University of Southern Denmark



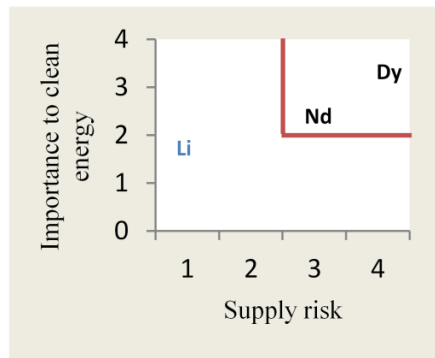
**Depleting resources**



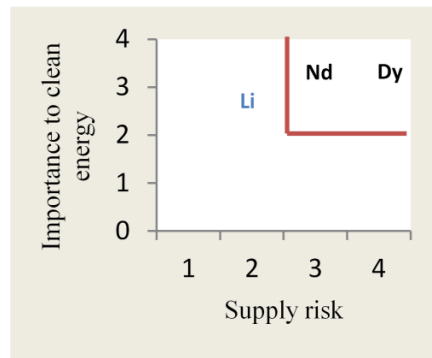
**Climate change**



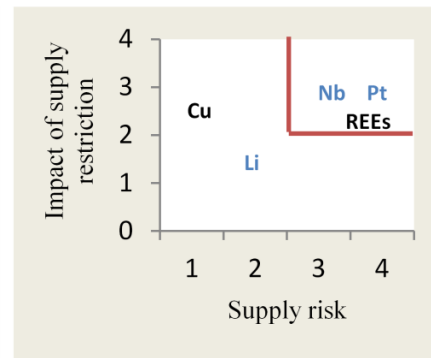
# RESOURCE CRITICALITY ASSESSMENT



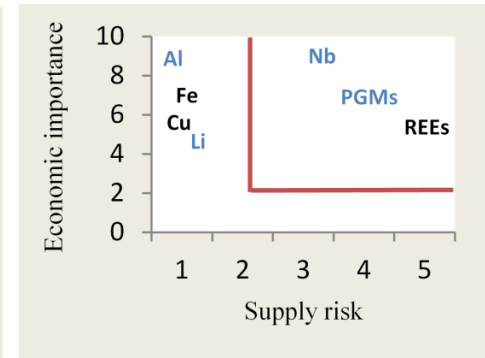
Short-term (Present-2015) Criticality Matrix (Bauer et al., 2011)



Medium-term (2015-2025) Criticality Matrix (Bauer et al., 2011)



Criticality Matrix (U.S. NRC, 2008)

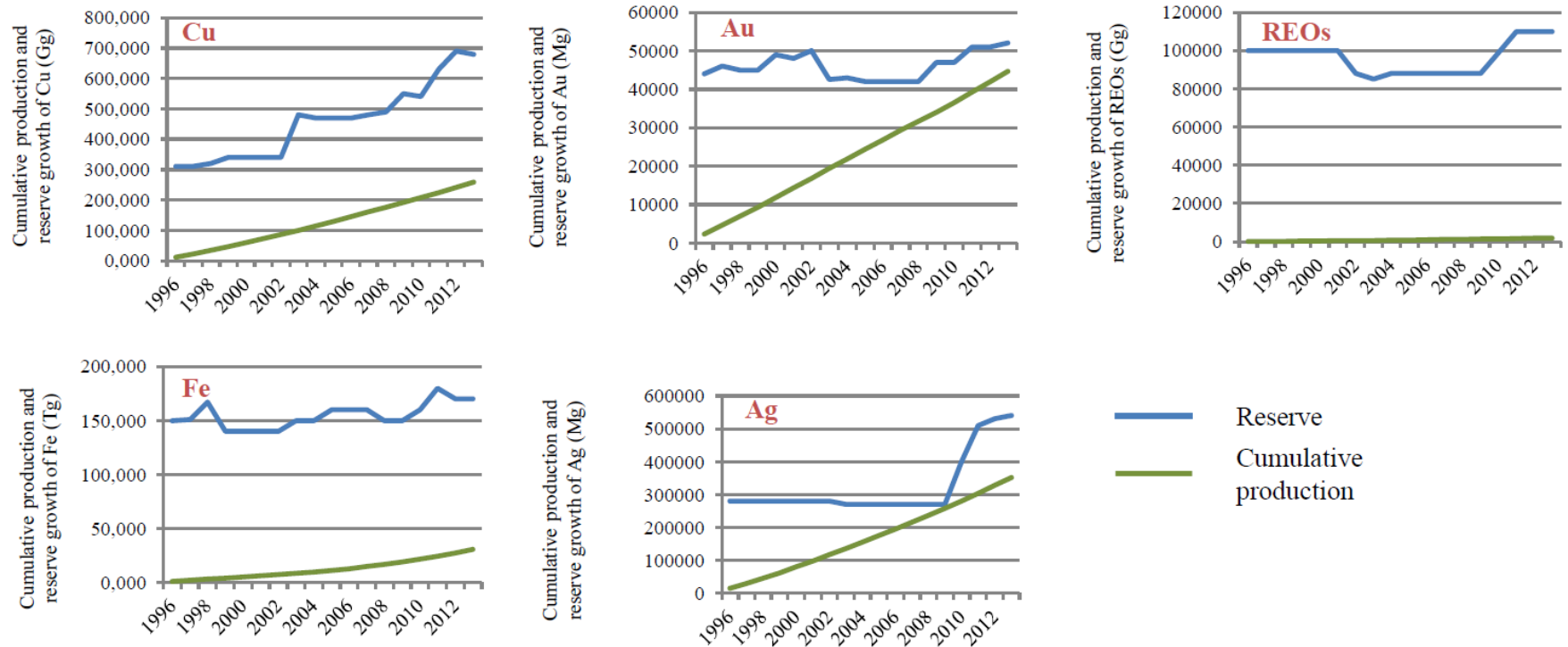


Criticality Matrix (EU Commission, 2010)

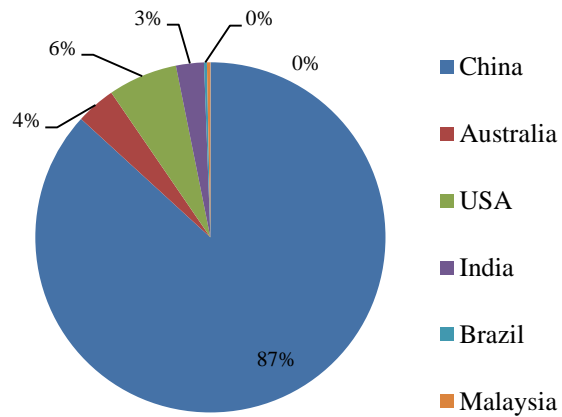
Methodological shortcomings:

1. Supply risk assessment not sufficiently dynamic
2. Importance assessment not sufficiently elaborated on substitutability

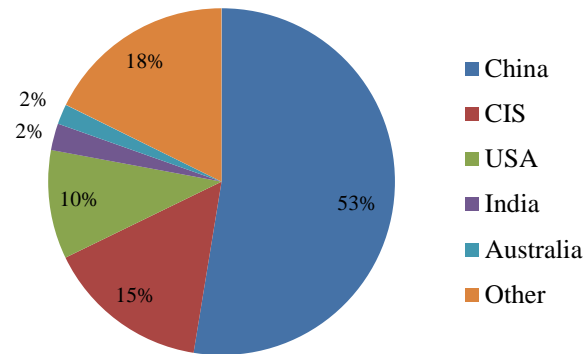
# Dynamic aspect of geological availability



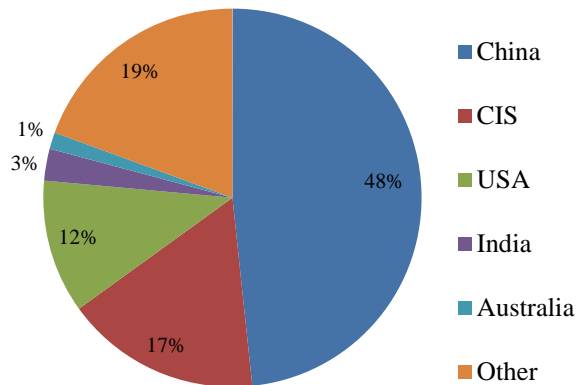
**REOs Production**



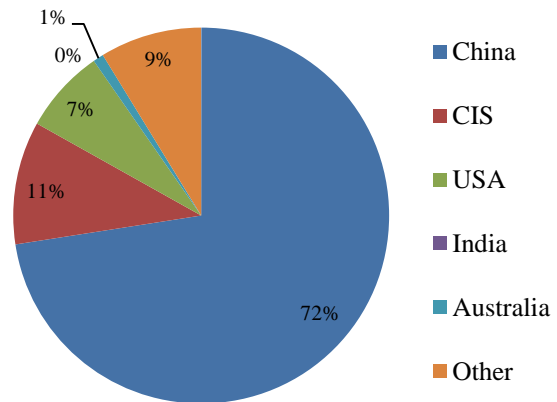
**Nd Reserves**



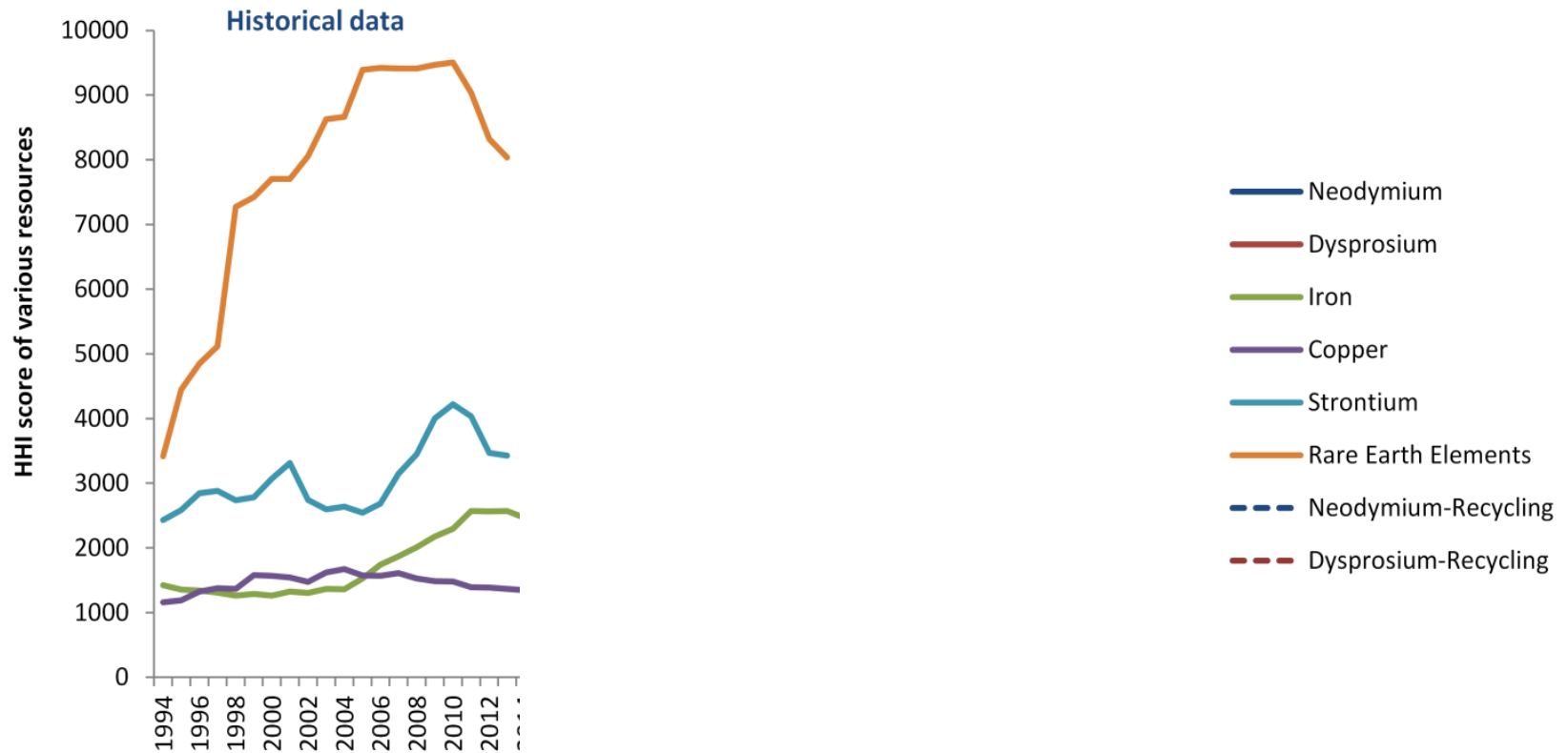
**REOs Reserves**



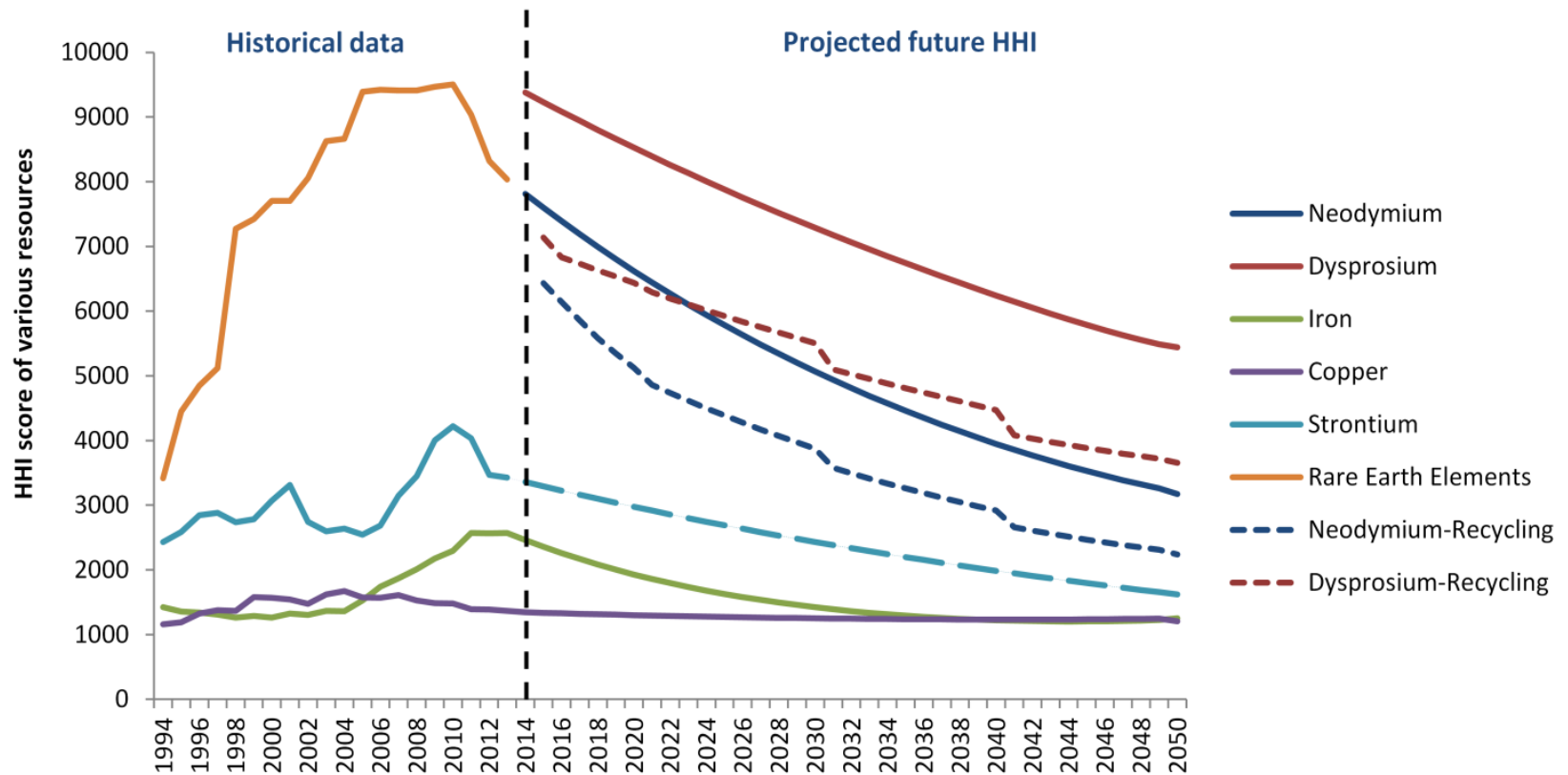
**Dy Reserves**



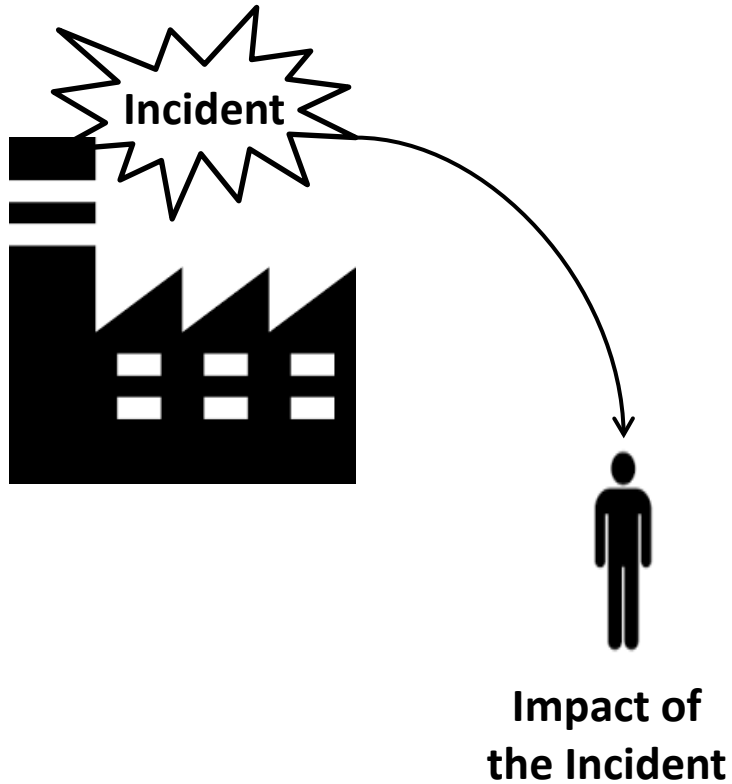
# Geopolitical supply risk



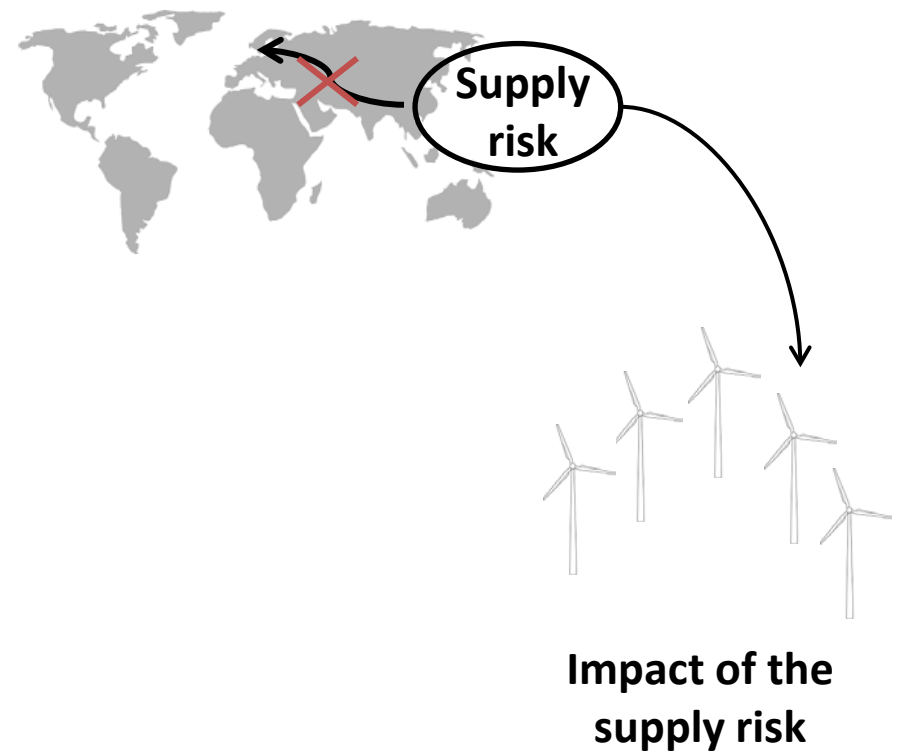
# Geopolitical supply risk



## Risk Assessment



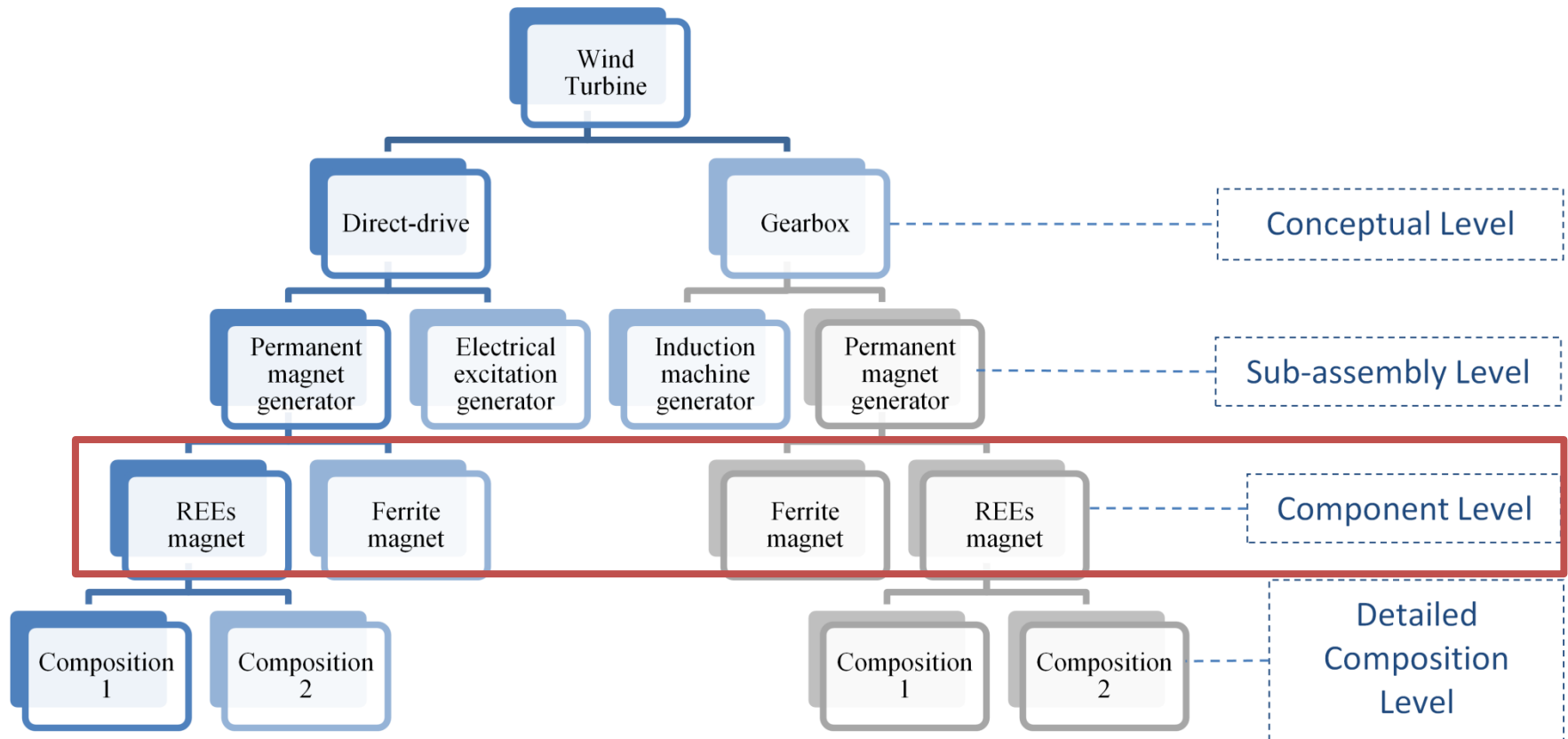
## Resource Criticality Assessment



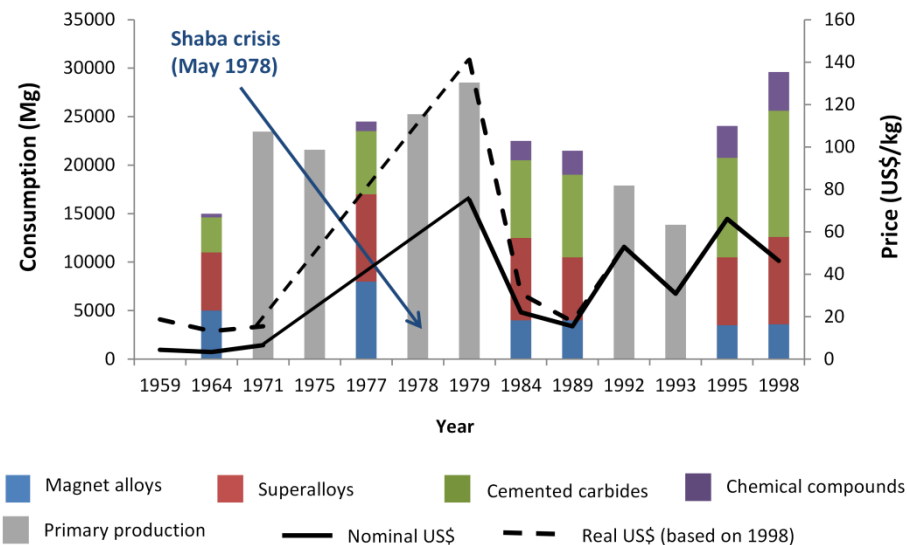
$$\text{Risk} = \text{likelihood} * \text{vulnerability}$$



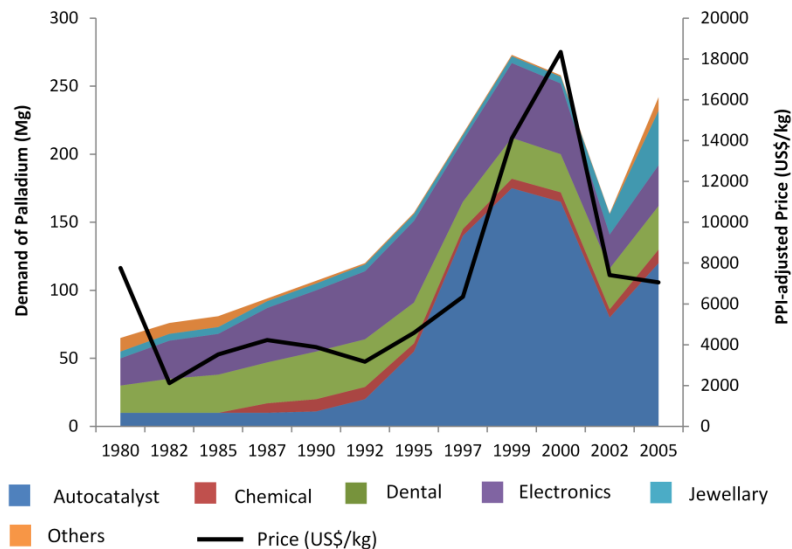
# VULNERABILITY (SUBSTITUTABILITY)



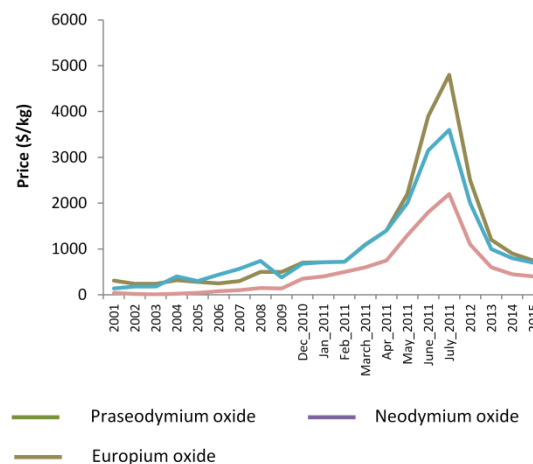
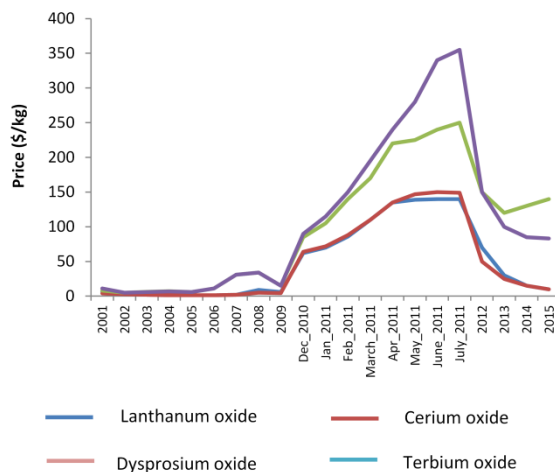
## Cobalt



## Palladium



## Rare Earths



For more details:

**Habib K. (2015)** Critical resources in clean energy technologies and waste flows. PhD Thesis, University of Southern Denmark, Odense, Denmark. Find at [www.sdu.dk/lifecycle](http://www.sdu.dk/lifecycle) (under PhD projects)