

# **Holistic Sludge Management Strategies of the Future – Energy and Phosphorus**

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# Outline

## ► Introduction

- Sewage sludge: Pollutant vs. recyclable material

## ► Resource sewage sludge

- Energy
- Phosphorus
- Components of a prospective sewage sludge treatment

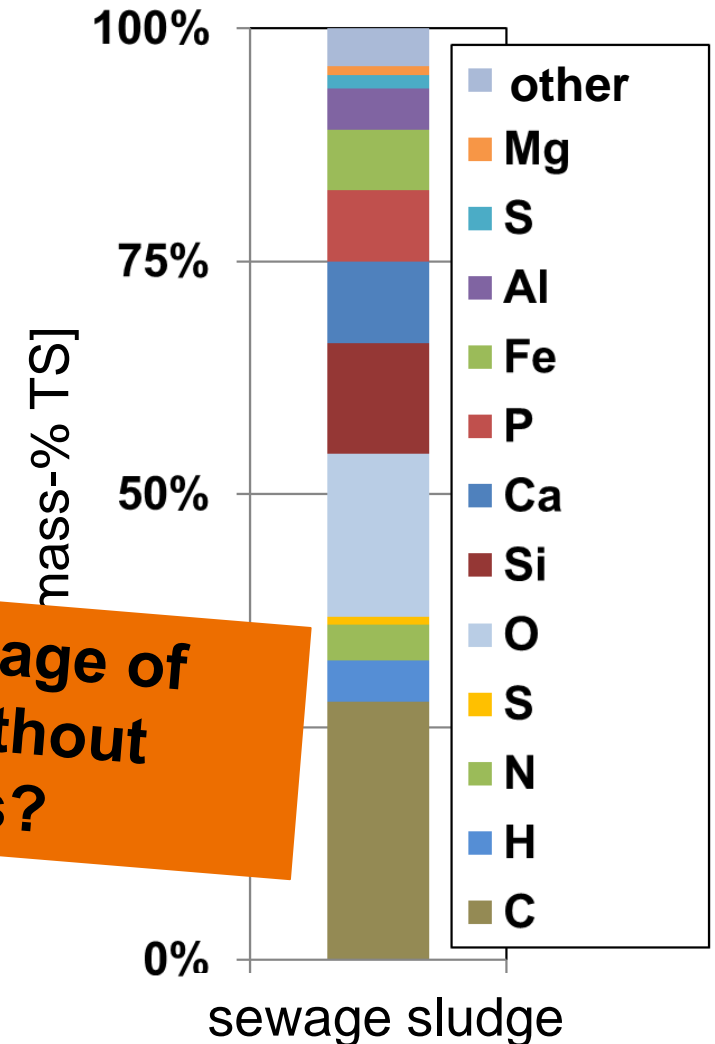
## ► Summary and outlook



# Sewage sludge: Pollutant vs. recyclable material

- ▶ **Mass balance apply for WWTP, means all incorporated substances remain in**
  - effluent of the WWTP
  - exhaust air ( $N_2$ ,  $CO_2$ )
  - sewage sludge
- ▶ **Ambivalent sewage sludge**
  - Nutrients (N, P, K, ...)
  - Energy
  - Raw materials (metals, ...)
  - Pollutants (heavy metals, organic substances, ...)

**How can we take advantage of recyclable materials without spreading pollutants?**



- ▶ **Westerhoff et al. (2015):**  
Theoretical economic value of sewage sludge  
about 280 US\$/Mg TS (regarding 13 diverse elements)
  
- ▶ **Current focus on resource:**
  - Energy
  - Phosphorus
  - In future
    - Metals (?)
    - Organic substances (?)
    - ...

**Energy**

**Phosphorus**

Westerhoff, P.; Lee, S.; Yang, Y.; Gordon, G. W.; Hristovski, K.; Halden, R. U.; Herckes, P. (2015):  
Characterization, Recovery Opportunities, and Valuation of Metals in Municipal Sludges from  
U.S. Wastewater Treatment Plants Nationwide, *Environmental Science & Technology*

# Demands for a prospective power supply in Germany

- ▶ **Changeover from fossil energy supply and nuclear fuel to renewable energy**
- ▶ **Increasing the energy efficiency**
  - Reducing consumption of energy
- ▶ **Expansion of renewable energies**
  - Significantly fluctuating power generation
  - Grid stability requires balance between power generation and consumption
  - “cellular approach” is relevant in future,  
means balance between power generation and consumption at local level



# Demands for a prospective power supply in Germany

## Contribution of WWTP?

► Changeover from fossil energy to renewable energy

► Increase of efficiency

- Reduction of energy consumption

► Expansion of capacity

- Significantly fluctuating power generation
- Grid stability between production and consumption
- “cellular approach” for energy generation and consumption

**Energy analysis  
and efficiency**

**Renewable energy**

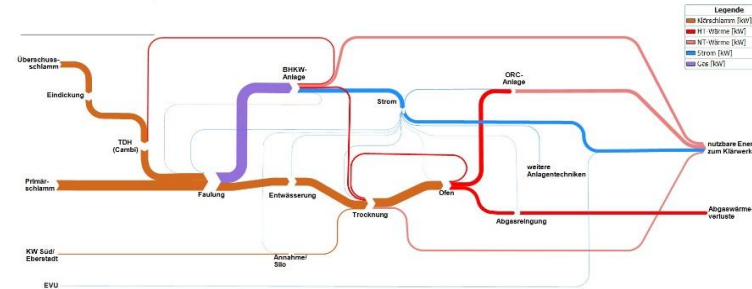
**Energy storage  
and flexibility**  
load management  
control energy



# Holistic approach

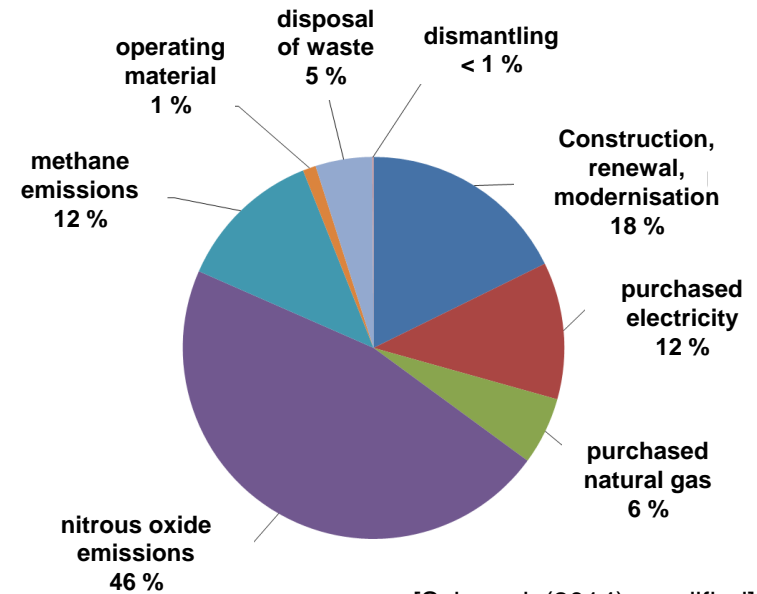
## ► Concept for power without heat?

- Development of heat management



## ► Emissions?

- Consider methane and nitrous oxide emissions
- Reduction of waste disposal
- Recovery within recycling economy



[Schmuck (2014), modified]



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Energy

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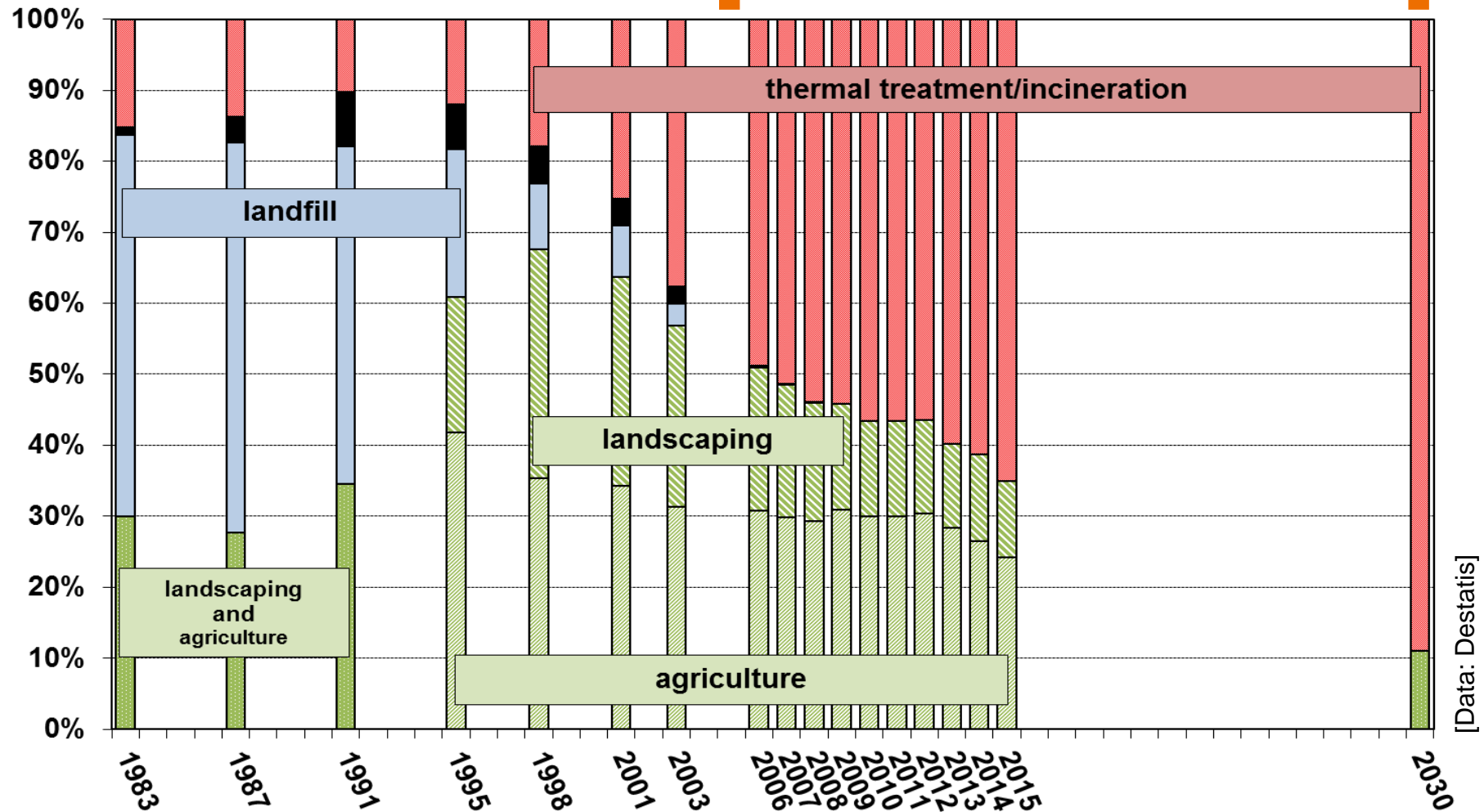


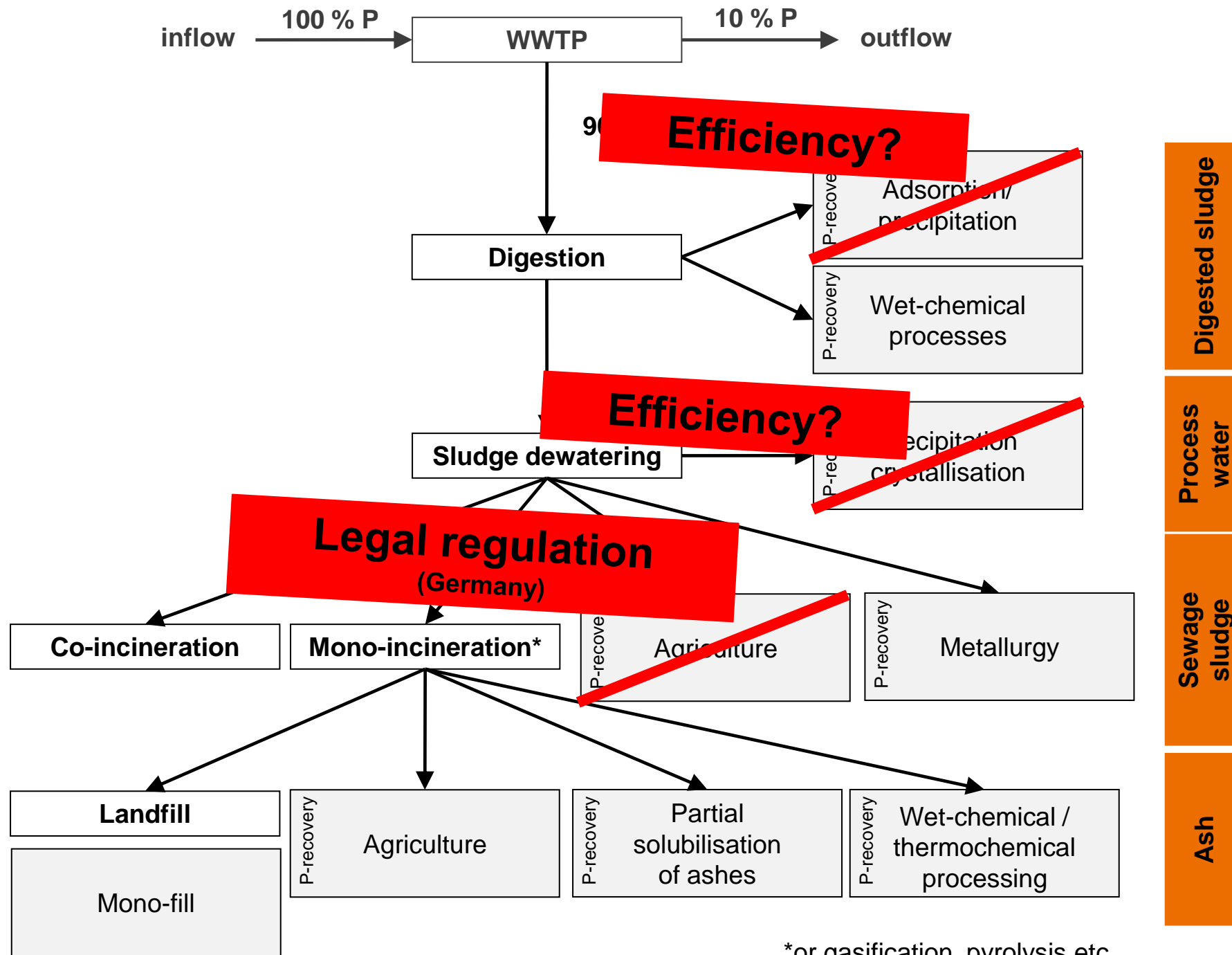
# Resource phosphorus

- ▶ **Phosphorus is indispensable for living organisms (humans, animals, plants)**
- ▶ **Usage of mineral phosphates from finite deposits mainly for agriculture**  
Morocco/Western Sahara (77 %), Iraq (8%), China (6 %), other (9 %)
- ▶ **Critical raw material (supply risk vs. economic importance)**



# Sewage sludge disposal look back and outlook Germany





\*or gasification, pyrolysis etc.

# Technologies for P-Recovery

Waste/process water	Sewage sludge	Sewage sludge ash
<b>Crystallization and precipitation processes</b> <ul style="list-style-type: none"> <li>Phostrip</li> <li>DHV Crystalactor</li> <li>Ostara Pearl</li> <li>Unitika Phoenix</li> <li>Nishi</li> <li>NuRe</li> <li>NuRe</li> <li>Kurita</li> <li>Ebara</li> <li>MAP Kristallisation Treviso</li> <li>CSIR Wirbelschichtreaktor</li> <li>REPHOS</li> <li>P-Ro</li> <li>Sydn</li> <li>PHOSPAQ</li> </ul>	<b>Crystallization processes</b> <ul style="list-style-type: none"> <li>AirPrex</li> <li>NuReSys</li> <li>PECO</li> <li>PRISA</li> </ul>	<b>Wet-chemical fusion</b> <ul style="list-style-type: none"> <li>RÜPA-/PASCH</li> <li>(erweitertes) SEPHOS</li> <li>SESAL-PHOS</li> <li>BioCon</li> <li>LEACHPHOS</li> <li>Ed</li> <li>Ed</li> <li>R</li> </ul>
<b>Ion exchanger processes</b> <ul style="list-style-type: none"> <li>REM NUT</li> <li>PHOSIEDI</li> </ul>	<b>Thermochemical fusion</b> <ul style="list-style-type: none"> <li>Mephrec</li> <li>ATZ-Eisenbadreaktor</li> <li>RecoPhos</li> </ul>	<b>The</b> <ul style="list-style-type: none"> <li>AshDec/Susan</li> <li>Mephrec</li> <li>ATZ-Eisenbadreaktor</li> </ul>
<b>Combination and special processes</b> <ul style="list-style-type: none"> <li>RECYPHOS</li> <li>Magnetseparator</li> </ul>		<b>Bioleaching</b> <ul style="list-style-type: none"> <li>Inocre P-bac</li> </ul>

> 20  
technologies

> 15  
technologies

> 15  
technologies

In total more than 50 technologies!

[Remy, 2013, Fraunhofer Umsicht, 2012]

# P-Recovery: Just a technical question?

## ► Product use?

- Value depends on:
  - Purity, concentration, usability, demand

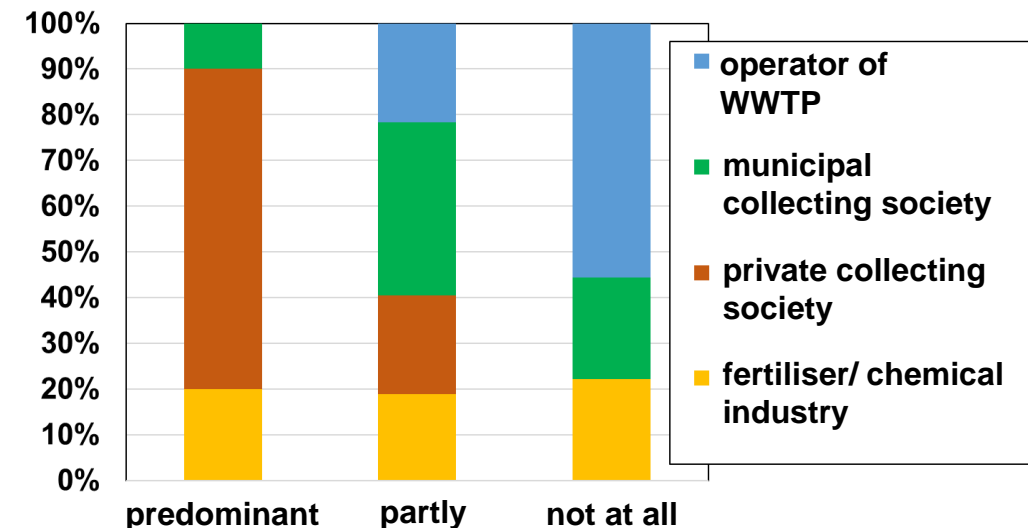
## ► Resource recovery requires a new self-conception

- From disposer to producer
- Quality standards, availability, product acceptance, delivery guarantee, customer focus etc.

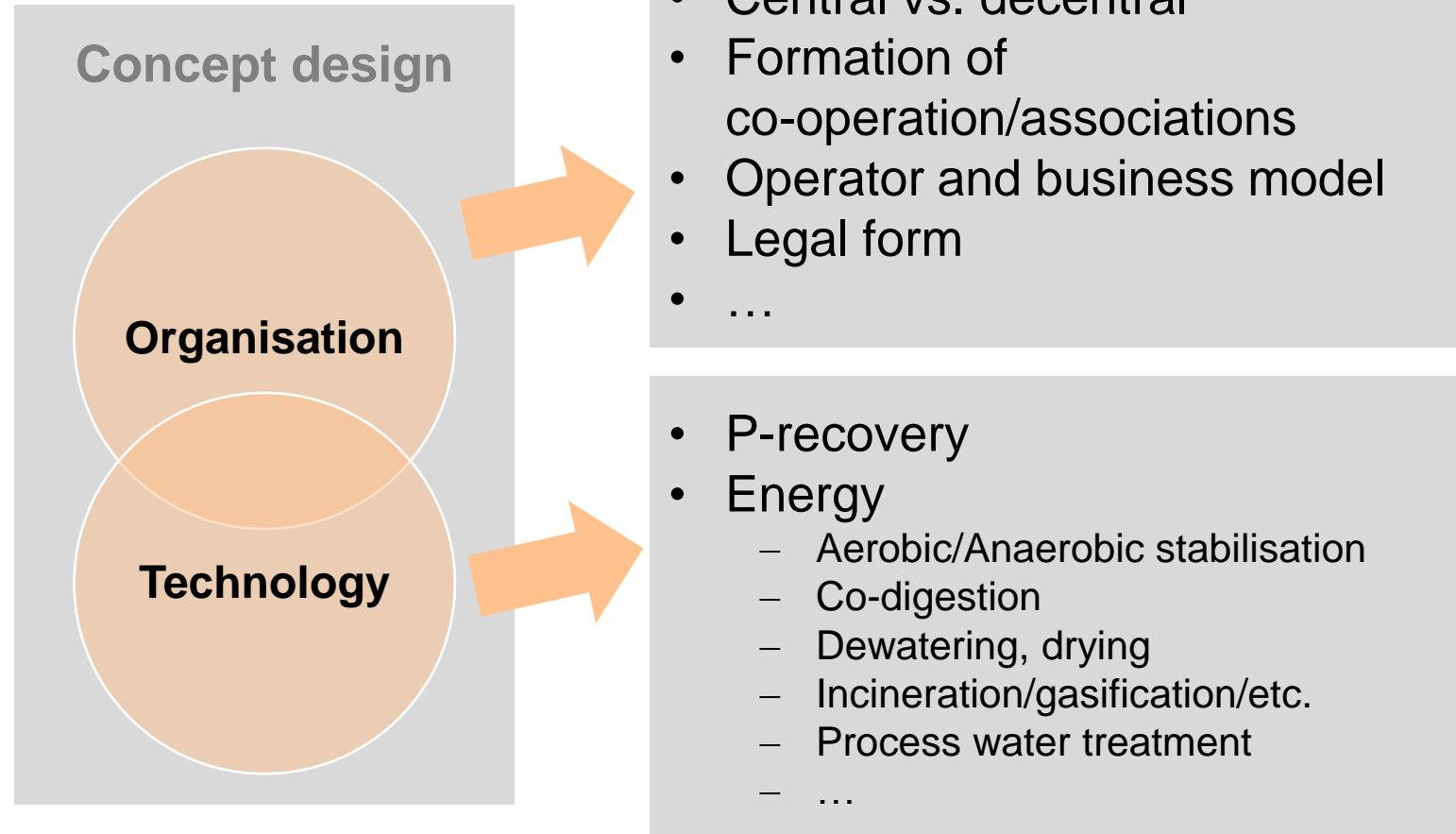
## ► Who operates the technology and markets the product?

- Survey in a workshop in co-operation with DPP in September 2017 in Berlin

From „Push“ to „Pull“



# Components of a prospective sewage sludge treatment





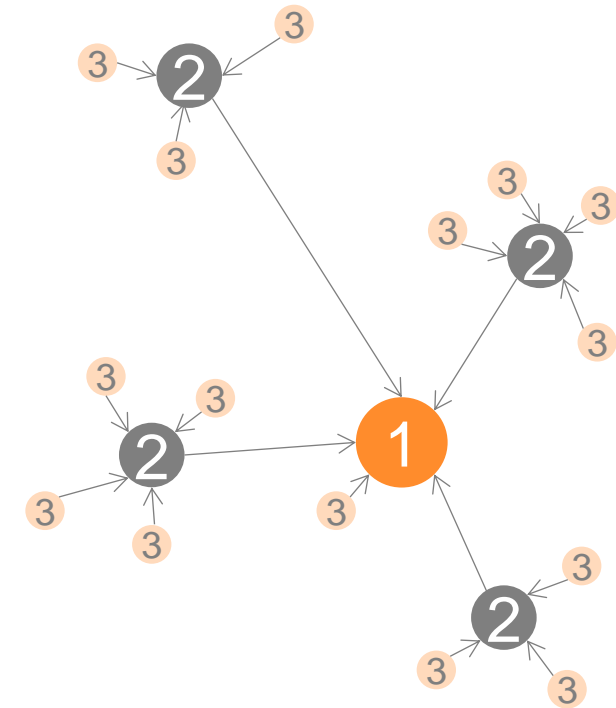
# Formation of co-operations

## ► Formations of associations

- Category 3:  
delivers wet sludge to larger ones nearby
- Category 2:  
wet sludge is digested and dewatered
- Category 1:  
central thermal treatment

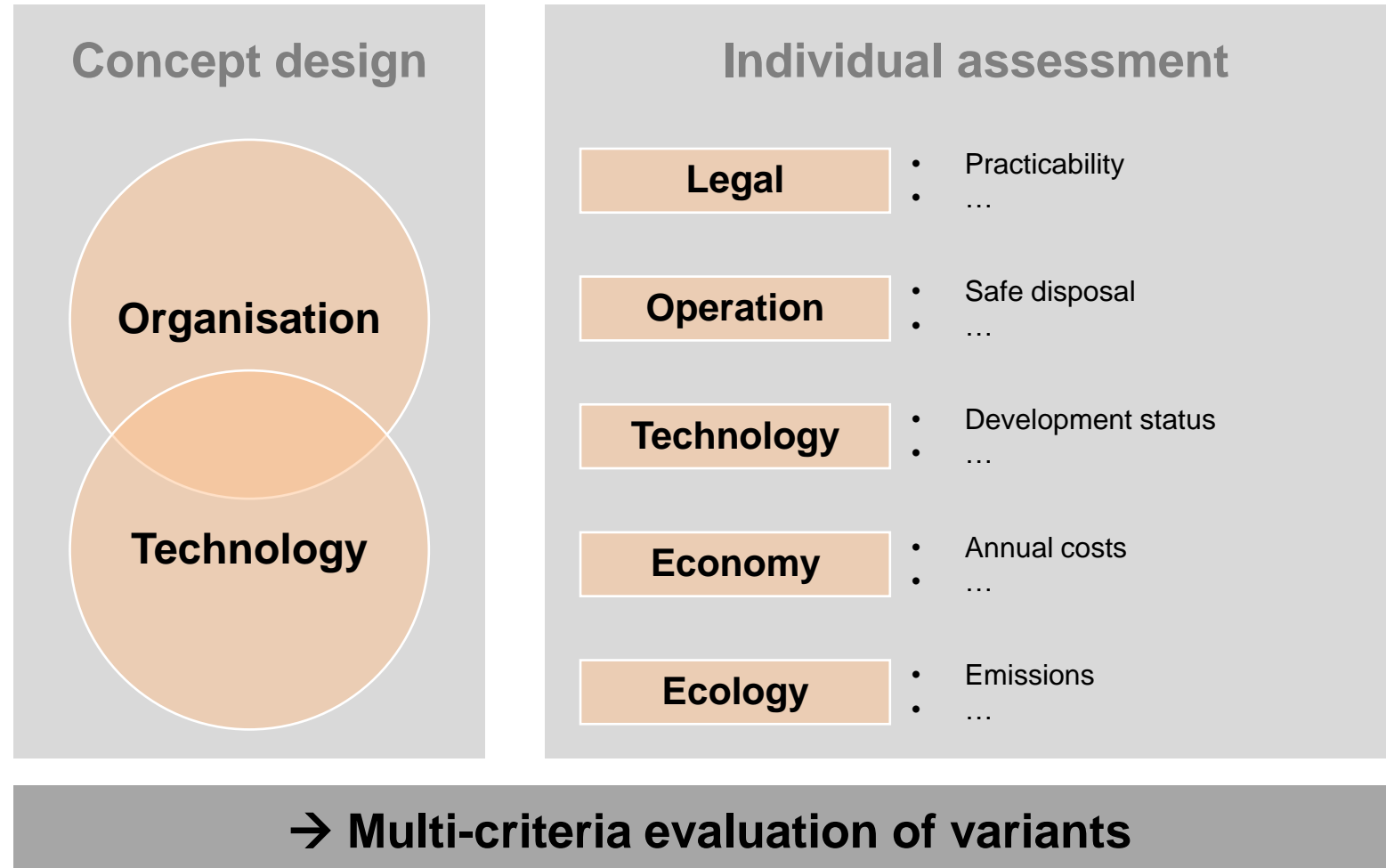
## ► Numerous examples in Germany

- Increasing formation of co-operations/associations



[LfU, 2011]

# Assessment of strategies for sewage sludge treatment



## ► Introduction

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## ► Summary and outlook



- ▶ **... sewage sludge has to be treated in such a way it can be disposed without overall negative ecological influence**
  - Usage of sewage sludge as a resource (energy, phosphorous) with minimal emissions
  
- ▶ **Energy**
  - Sewage sludge → chemical bounded energy;  
Usage as flexible technology with operating strategies (storage, load management, energy industry etc.)
  - WWTP contributes to
    - Proportion of the overall power consumption in Germany < 2 %  
→ though locally high power consumption (“cellular approach”)
    - Total installed capacity of co-generation unit about 145 - 300 MW<sub>el</sub>  
→ relevant for control energy (*energy industry*)

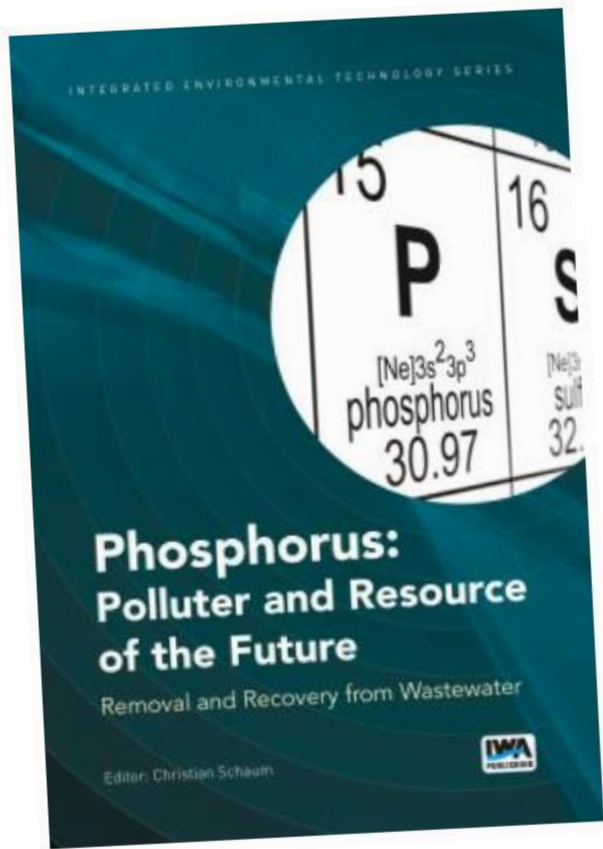
## ► Phosphorus

- Several technologies for recovery from waste water/ sewage sludge available
- Substitution potential about 35 - 45 %  
(referred to consumption of mineral fertilisers in Germany)

## ► Conversion from disposer to producer (From “Push” to “Pull”)

- Quality standards, availability, product acceptance, delivery guarantee, customer focus etc.
- Affecting all sectors of waste water and sewage sludge treatment
  - Health and water protection
  - Energy
  - Phosphorus

# Phosphorus: Polluter and Resource of the Future



- ▶ **Part I: Phosphorus - A Special Element**
  - *P. J. A. Withers, A. M. Farmer, K. M. Udert*
- ▶ **Part II: Elimination of Phosphorus from Wastewater**
  - *S. Krause, J. Bratby, M. Barjenbruch, J. Kopp, M. Beier, P. Baumann, D. Batstone*
- ▶ **Part III: Phosphorus Recovery**
  - **Technology**  
*C. Adam, O. van der Kolk, K. Rabaey, S. Jeyanayagam, M. Takaoka, L. Hermann*
  - **Case Studies**  
*15 different pilot/full scale technologies*
  - **Assessment**  
*J. Krampe, W. Schipper, C. Kappe, T. Ansmann*
- ▶ **Part IV: Outlook**
  - *C. Schaum*



# Holistic Sludge Management Strategies of the Future – Energy and Phosphorus

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