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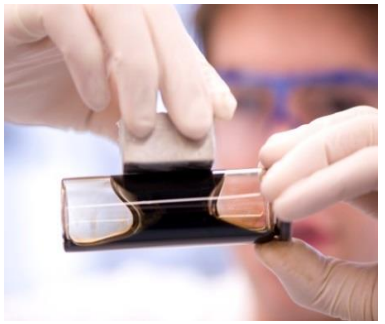
PROJEKTGRUPPE IWKS

Innovative circular approaches on the recycling of phosphorus

Dr. Carsten Gellermann

CONTENT

- State of the art of P
- Its role as fertilizer
- Available technologies for P recycling
- Approaches of Fraunhofer IWKS
- Possibilities for biomass



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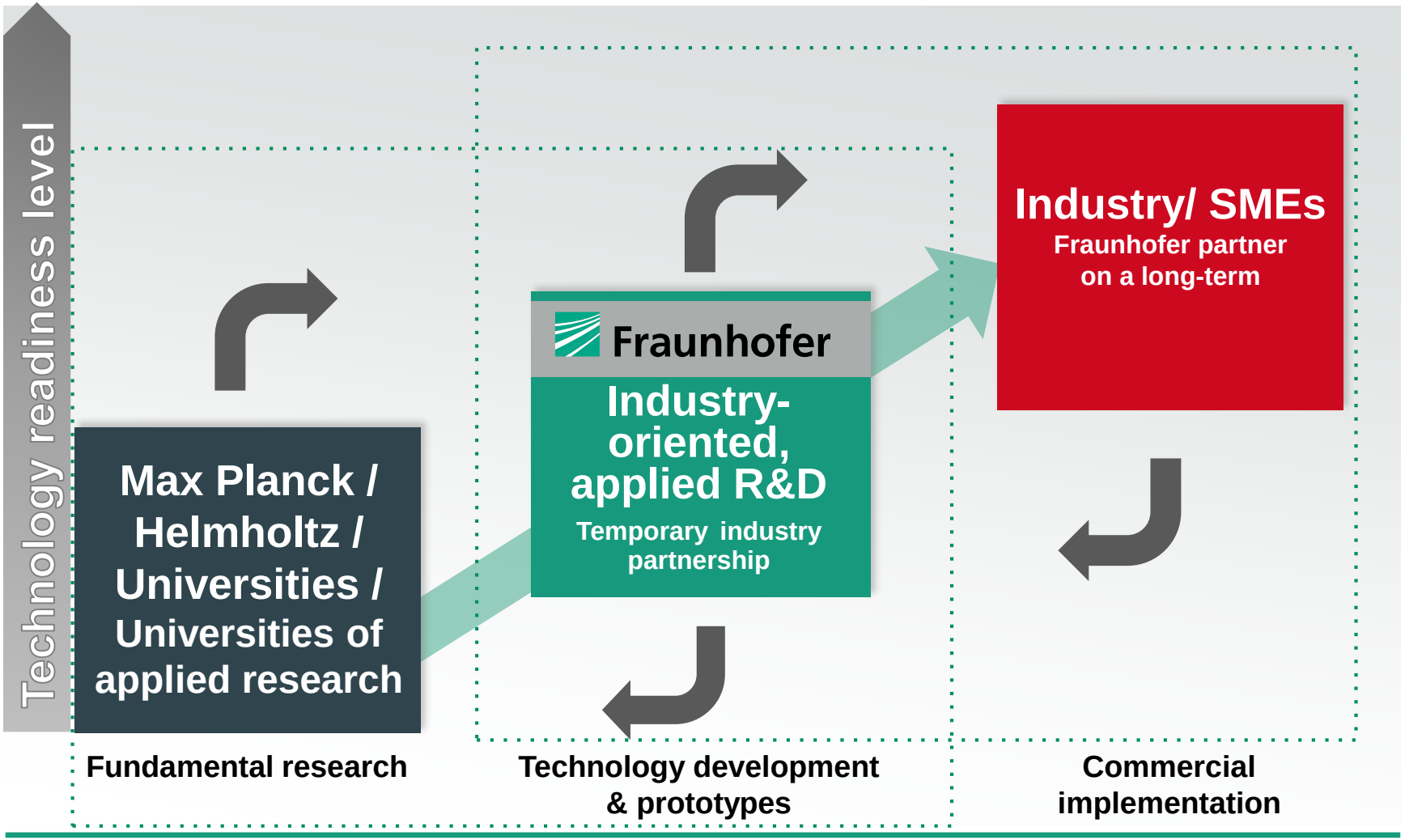
Fraunhofer Gesellschaft
R&D-Partner for Industry: On Demand and Long-Term



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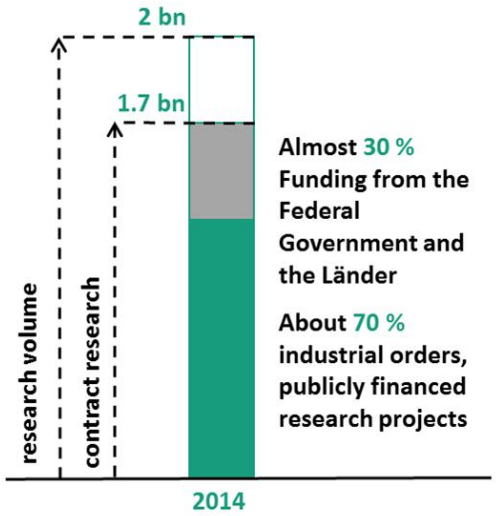
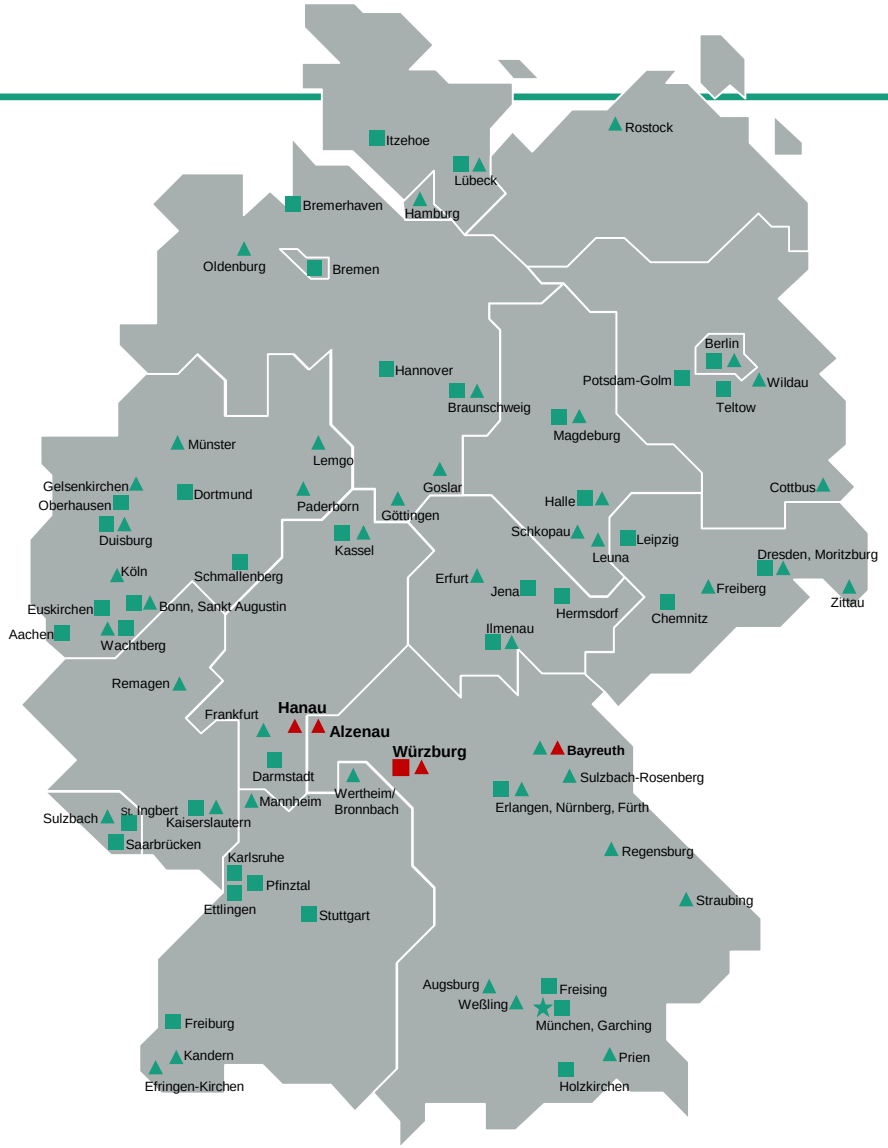
FRAUNHOFER GERMANY

- Biggest organization in Europe for applied research and development
- 69 Fraunhofer Institutes, at more than 80 locations
- about 25.000 employees (focus: scientists and engineers)





- Institute/independent research unit
- Other research unit
- Headquarter

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Fraunhofer Materials Recycling and Resource Strategies IWKS

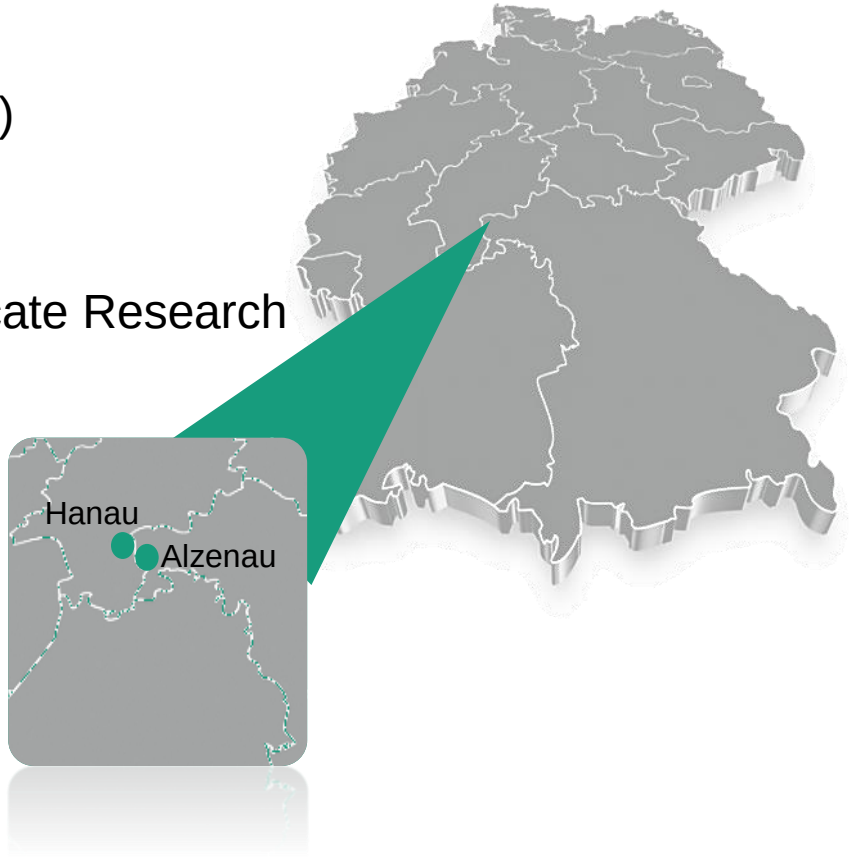
- Founded 2011
- More than 90 employees (5 in 2011)
- Parent Institute:

  Fraunhofer ISC - Institut for Silicate Research in Würzburg

- Locations:

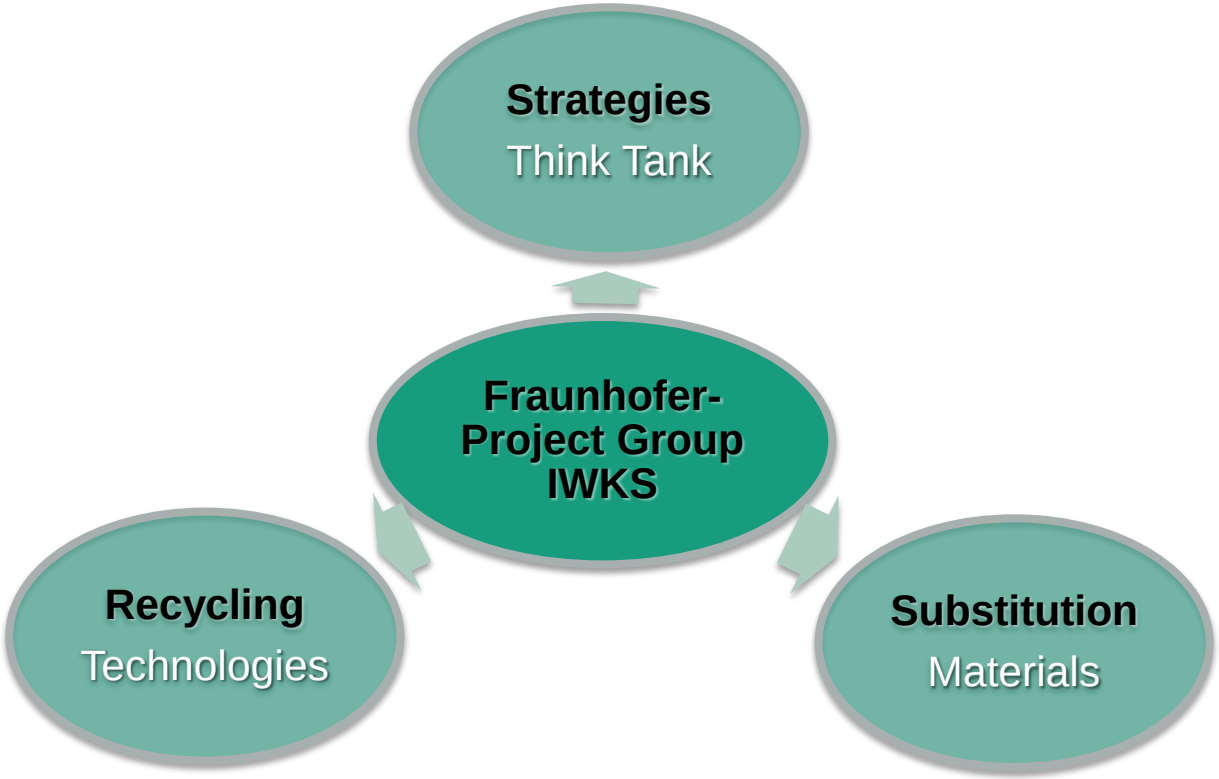
  Hanau (Hesse)

  Alzenau (Bavaria)



Research Approach of Fraunhofer Materials Recycling and Resource Strategies IWKS

Development of efficient resource strategies



Development and implementation of economic resource concepts

Increasement of chances through substitution

DEUTSCHE PHOSPHOR-PLATTFORM DPP E.V.

- Established in 2013
- Office located in Alzenau
- Association since 2015

DEUTSCHE PHOSPHOR PLATTFORM

- Tasks:
  - **Support networking** of phosphorus related stakeholders from agriculture, engineering, science, policy and municipalities
  - **Create interdisciplinary understanding**, knowledge- and technology transfer
  - **Develop recommendations** on best practices for policy makers

- Key note: improvement in efficiency - recycling - substitution

www.deutsche-phosphor-plattform.de

European Sustainable Phosphorus Platform (ESPP)

ESPP is a non-profit organisation, funded by its members, which brings together industry, knowledge institutes and public establishments, alongside national nutrient platforms, to promote and implement phosphorus sustainability in Europe:

- **Dialogue & networking** of expertise and experience
- **Collaboration** of industry, R&D, public authorities, stakeholders for sustainable phosphorus management in Europe
- **Awareness building**
- Access to **policy & regulatory developments**
- **Dissemination of innovation**, business cases, value chain

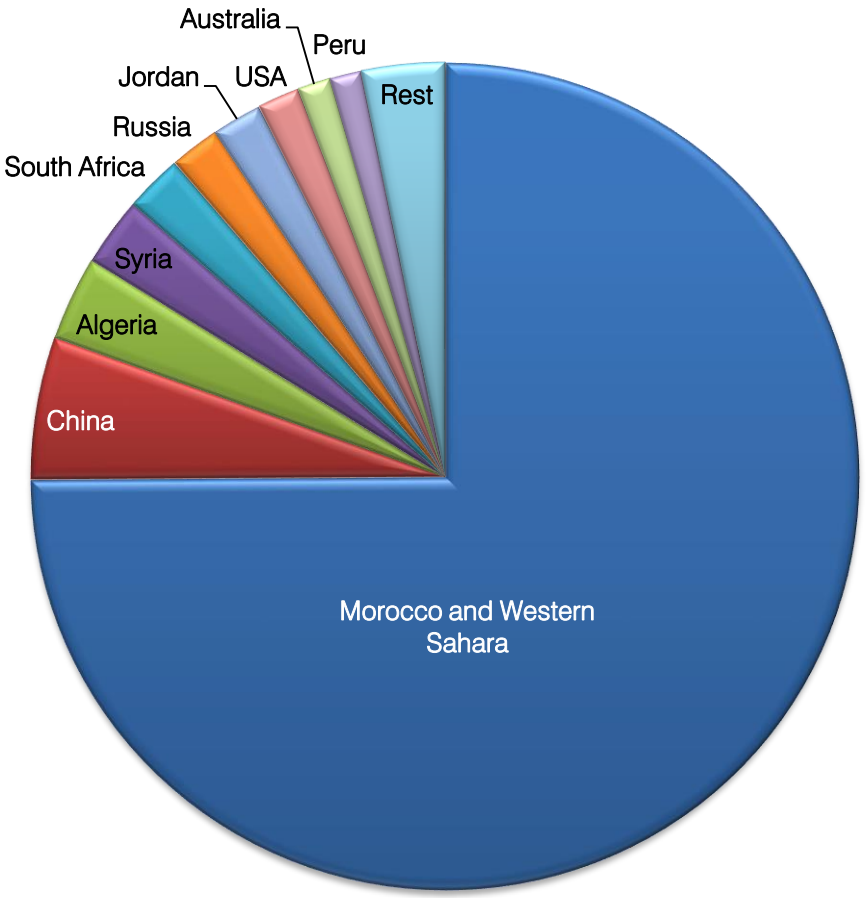
www.phosphorusplatform.eu

PHOSPHORUS (P)

- As a core element of DNA and bones → essential for all living matter
- Main use in the agricultural sector as fertilizer (80 - 90 %)
- Important element in many technological applications such as batteries, fluorescent materials, foodstuffs, pharmaceuticals, flame retardants, etc.
- Germany/Europe imports 100 % of P
- 75 % of P is located in Marocco / Western Sahara

Motivation for the Recycling of Phosphorus

World Reserves of Phosphate Rock



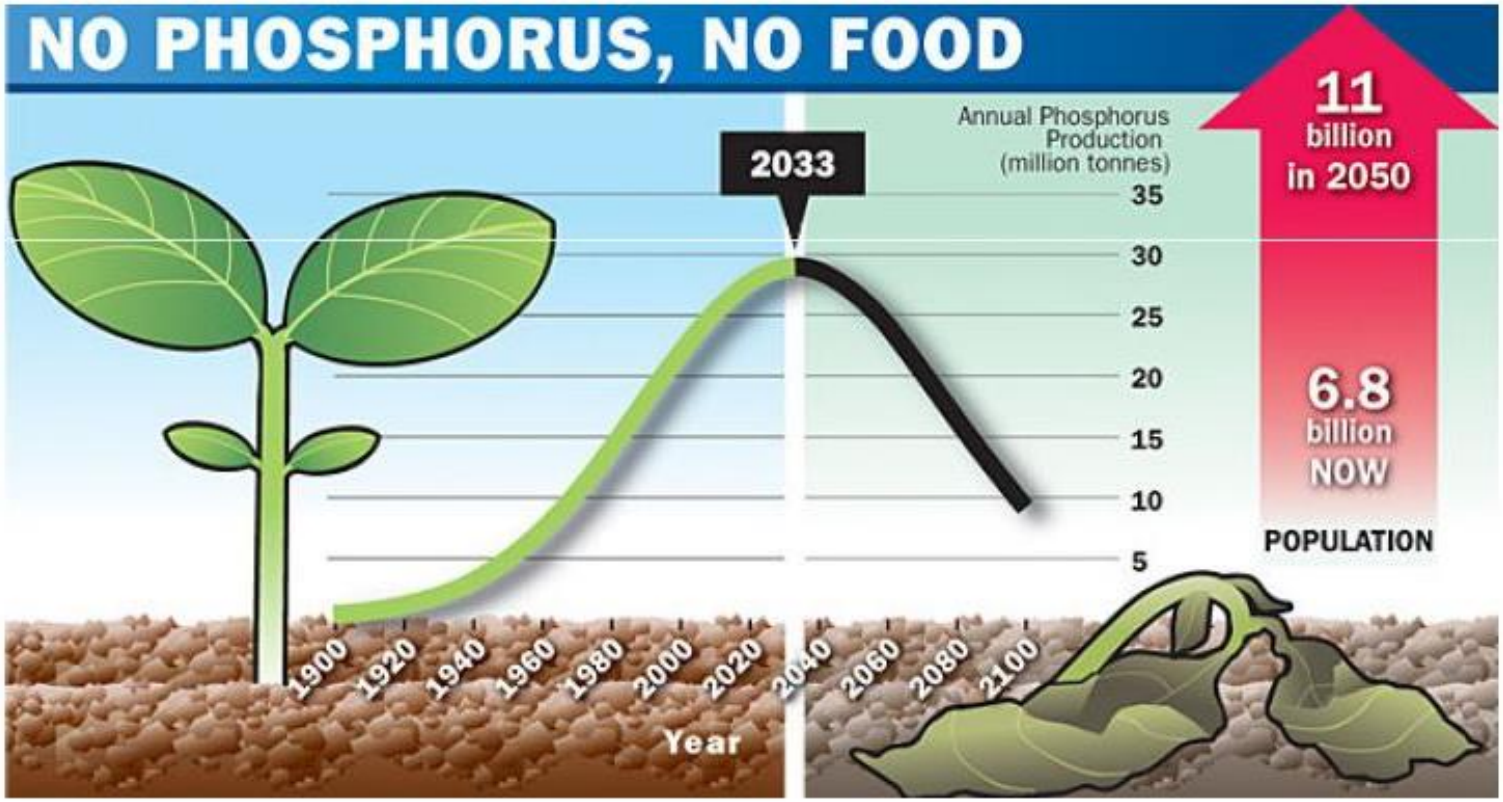
Increase in fertilizer demand 2012-2016

South Asia	34 %
East Asia	37 %
Latin America	16 %
North America	2.5 %
Western Europe	2.0 %
Africa	1.5 %

Data from USGS, Mineral Year Book 2015, International Fertilizer Industry Association, Bundesforschungsanstalt für Landwirtschaft and UBA

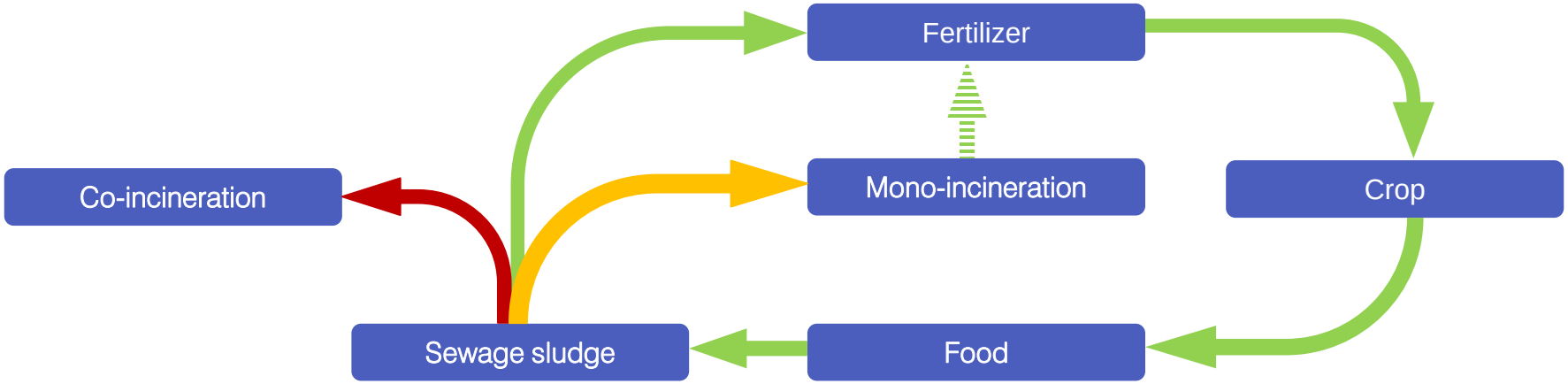
MOTIVATION FOR THE RECYCLING OF PHOSPHORUS

Mineral phosphorus fertilizer is needed for food production, but phosphate rock resources are limited and quality decreases



P cycle with traditional food production

- P is used as fertilizer and finds ist way into the sewage sludge via crops and the resulting food.
- The agricultural utilization or P recovery allows closure of the circulation.
- The current gap is the co-incineration (e.g. waste incineration or cement production), if P is not recovered from sludge.



MOTIVATION FOR THE RECYCLING OF PHOSPHORUS

- No direct application of P-rich **sewage sludge or wastewater on land**, e.g. for food production; this is a **highly controversial issue** in terms of organic and inorganic contaminants, and fertilizing efficiency

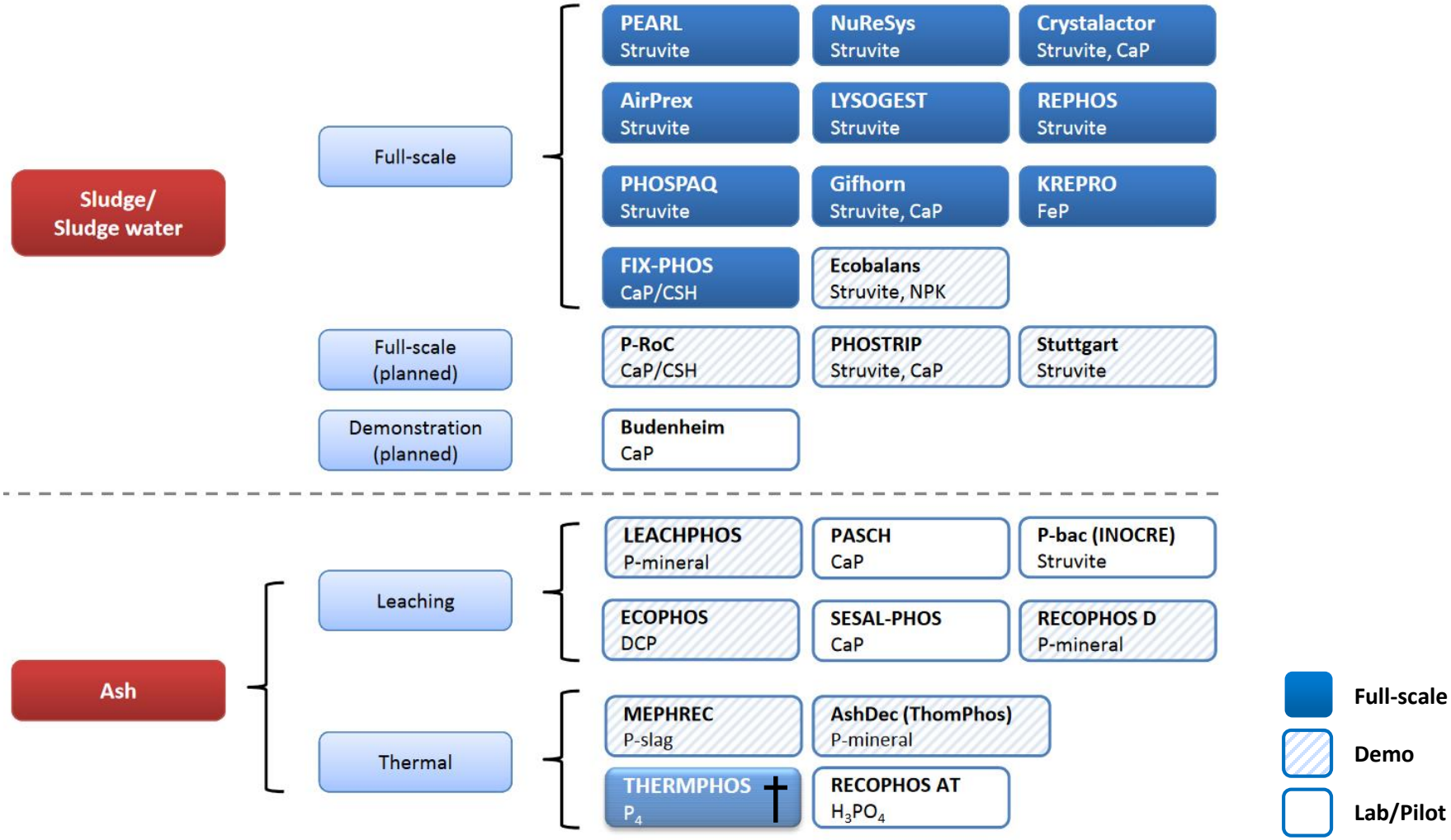
  →Solution: **creation of a pure, unpolluted phosphorus product** from wastewater (removal before or after ash production)

- The highest potential for phosphorus recovery can be found within the municipal wastewater

  In Germany, **up to 50 %** of the „primary phosphorus“ used in fertilizers could be substituted by “secondary phosphorus” recovered from wastewater

  - fertilizer with less contaminants
  - sustainability (no eutrophication and recycling)
  - autarky

Overview on Recent Phosphate Recovery Processes



KABBE, P-Rex, 2015

P-Recovery at Fraunhofer IWKS – Main Topics

Recovery of nutrients (P, N, K) from wastewater, process water, sludge and ash:

- Development of **strategies and technologies** for optimum recovery of nutrients matter
- **Modelling** of processes, statistical experiment design, laboratory experiments, reactor design and scale-up
- Synthesis of **innovative adsorption materials** & particles as magnetic carrier particles, calcium silicate hydrates (CSH), etc.
- Chemical and physical **characterization** of raw materials and residues with regard to their nutrient content
- **Feasibility studies**, including experimentation

Pictures: © Fraunhofer ISC; © freshidea

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Main Topics at IWKS

Own Key Technologies

- **Process development**
- mechanochemical leaching
- extraction with CO_2
- electrochemical deposition

- **Innovative adsorption materials and particles**
- magnetic carrier particles
- calcium silicate hydrates (CSH)
- other mostly inorganic materials

PROJECT 1: RECYCLING OF PHOSPHORUS – FROM SECONDARY RAW MATERIAL TO A SMART FERTILIZER (PROJECT PRIL)

Phosphor-Recycling – vom Rezyklat zum intelligenten langzeitverfügbaren Düngemittel (PRiL)

- Incineration ashes from thermal utilization of sewage sludge (provided by City of Munich - Münchner Stadtentwässerung)
- P-Recyclate generated by P-bac method and integrated process optimization (Fritzmeier)
- Granulation and creating stable and durable pellets (ICL Fertilizers)
- Scientific support to industrially producable P-fertilizer (Fraunhofer IWKS)

Münchner Stadtentwässerung

FRITZMEIER Umwelttechnik

ICL Fertilizers

Bundesministerium für Ernährung und Landwirtschaft

ptble Projektträger Bundesanstalt für Landwirtschaft und Ernährung

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P-BAC ® PROCESS

Solid material:
i.e. sewage sludge ash

Rich in heavy metals (HM)
& phosphates

Removal of Heavy Metals (HM)

P-bac® Process

Phosphate Recovery

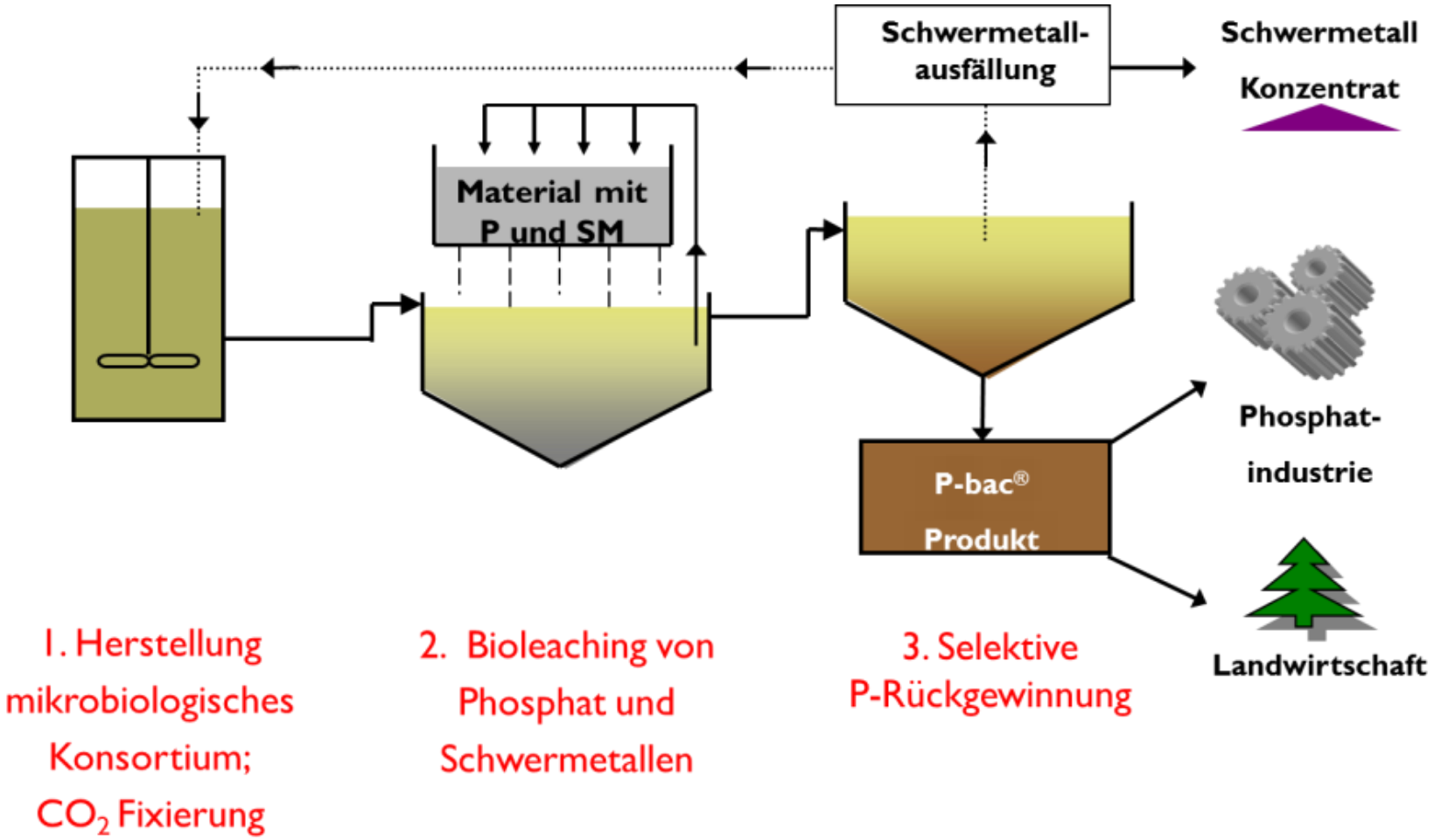
Solid ash:
HM & P reduced

HM concentrate:
further separation possible

Phosphate product:
HM highly reduced

Source: Fritzmeier Umwelttechnik

P-BAC ® PROCESS

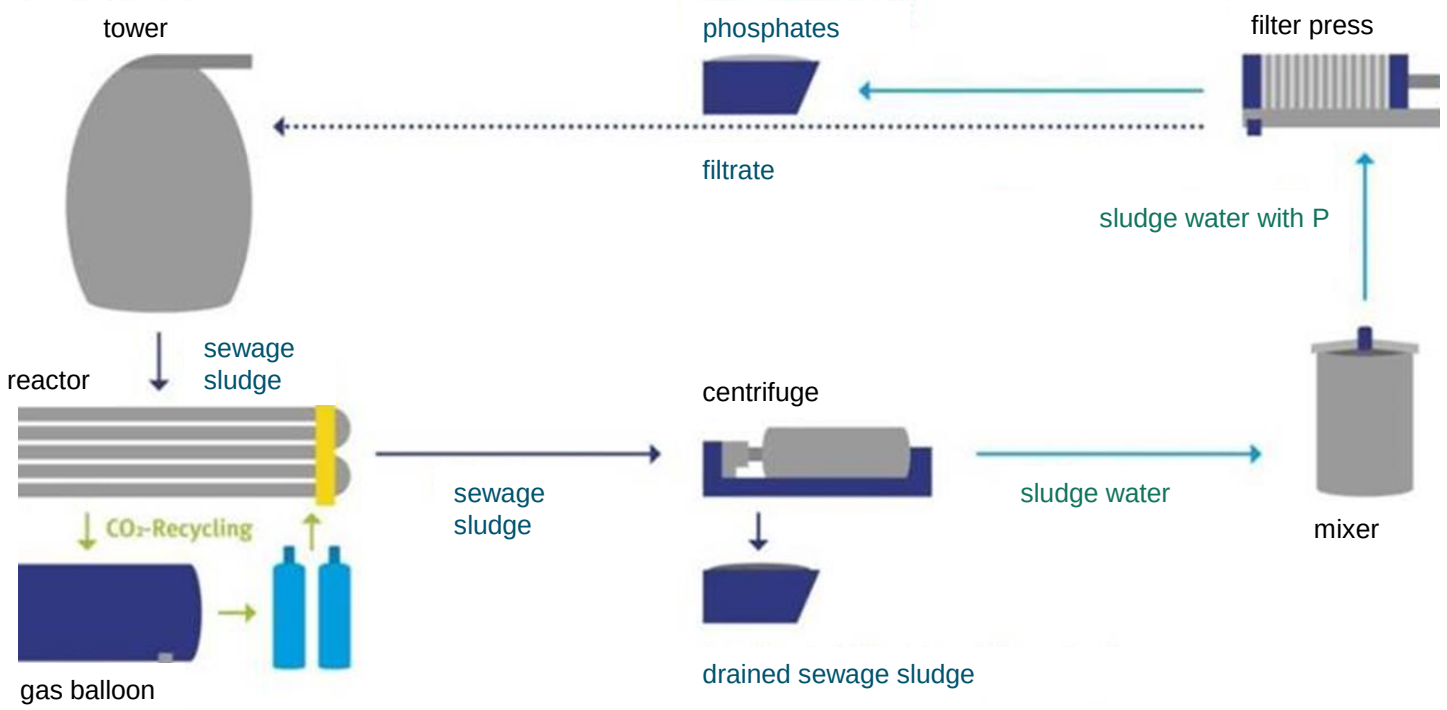


PROJECT 2: EXTRACTION OF PHOSPHORUS BY CO_2 (EXTRAPHOS®) - COOPERATION WITH THE CHEMISCHE FABRIK BUDENHEIM KG -

- Development of the recovery of phosphorus from sewage sludge using carbon dioxide
- Recovery of CO_2 and reuse in the process
- No use of hazardous chemicals
- Low energy consumption compared to incineration
- Possibility to use sludge residue in the cement industry

Extraction of Phosphorus by CO_2 (ExtraPhos®) - Cooperation with the Chemische Fabrik Budenheim KG -

- Status
  - Commissioning of the pilot plant in Mai 2017
  - Location: Mainz-Mombach
  - Scale: 1 m^3



PROJECT 3: RECOVERY OF PHOSPHATE FROM WASTE AND PROCESS WATER BY MAGNETICALLY SEPARABLE ION EXCHANGERS

Rückgewinnung von Phosphat aus Abwasser und Prozesswasser mit Hilfe superparamagnetisch abtrennbarer Ionentauscher im Großversuch (SupaPhos)

- Development of efficient and selective adsorbent for phosphate, combination with magnetic particles, upscaling of synthesis (ISC/IWKS)
- Investigations on efficiency and selectivity of adsorber material, development of suitable desorption solution, performing pilot scale phosphate removal (ISWA)
- Development and dimensioning of efficient magnetic separation equipment for pilot scale application (KIT-IFG)
- Further processing of desorption solution as phosphate source, preparation of phosphate fertilizer via precipitation (KIT-CMM)

Universität Stuttgart | iswa | KIT Karlsruher Institut für Technologie | CMM Competence Center for Material Moisture

Baden-Württemberg Stiftung WIR STIFTEN ZUKUNFT

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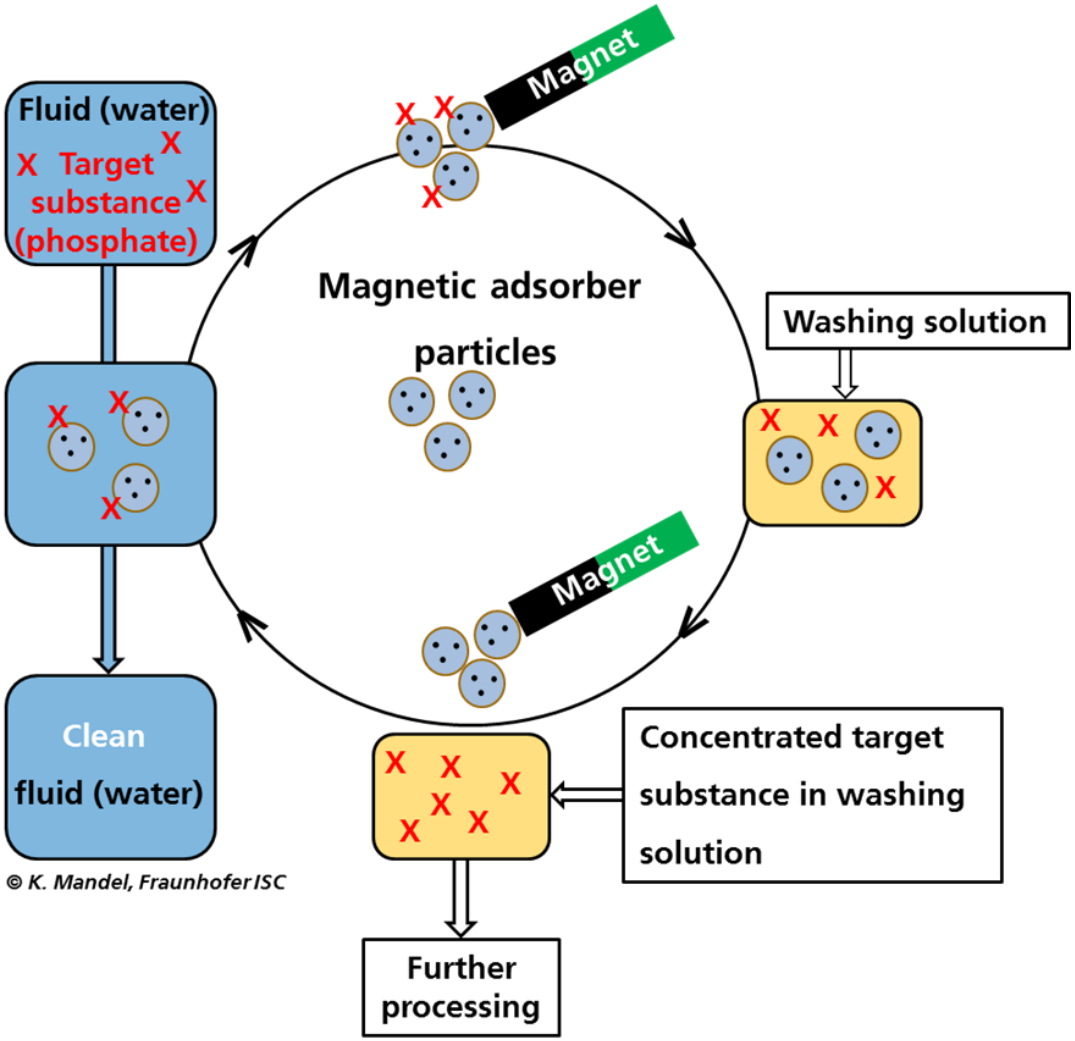
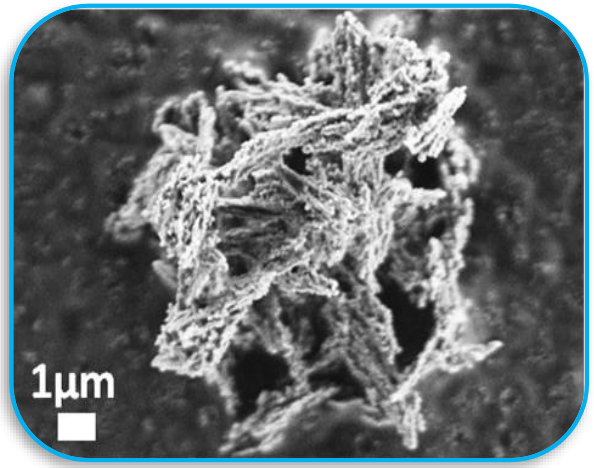
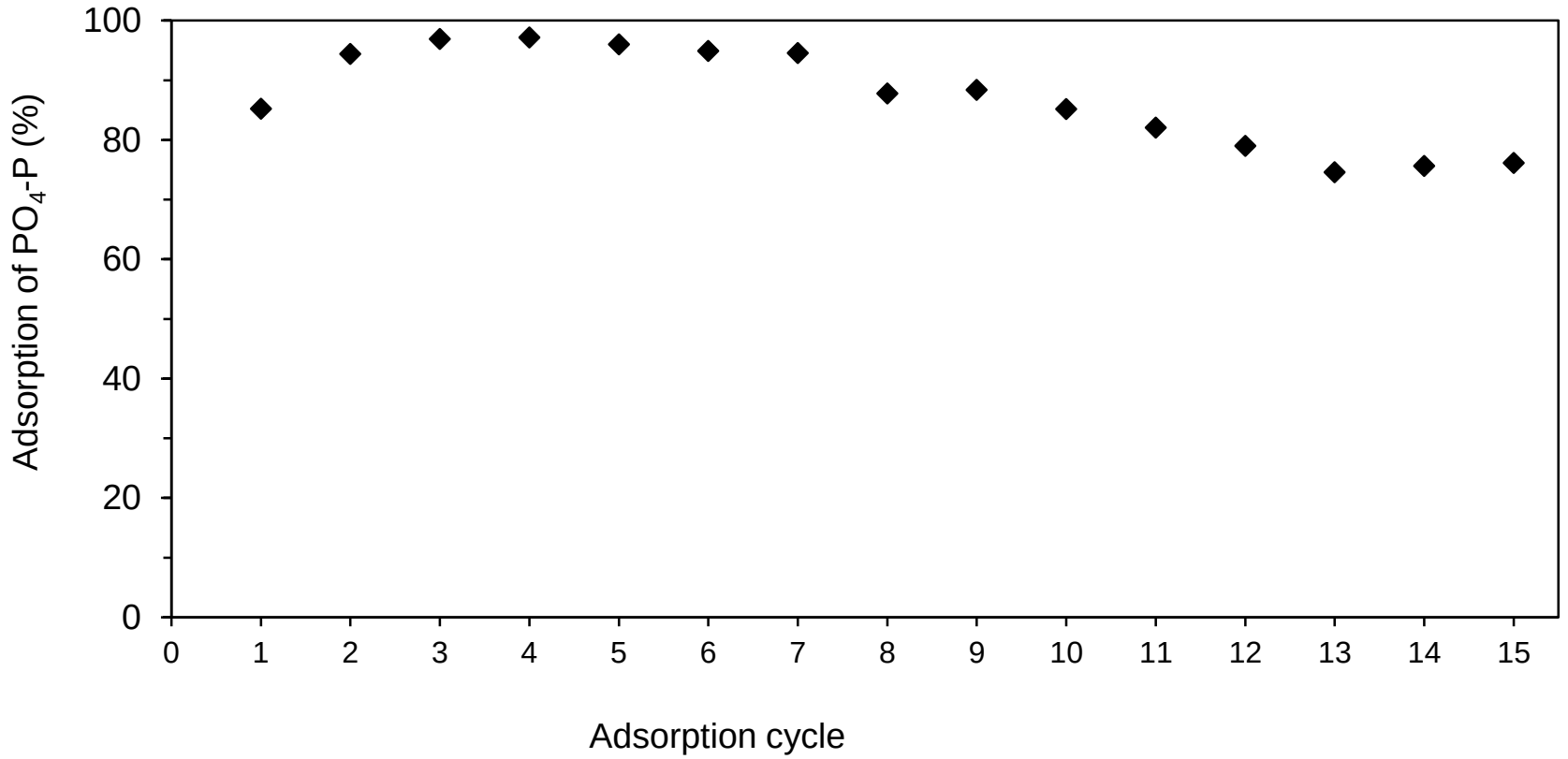
RECOVERY OF PHOSPHATE FROM WASTE AND PROCESS WATER BY MAGNETICALLY SEPARABLE ION EXCHANGERS



Magnetic Adsorber Particles



ADSORPTION CAPACITY OF PHOSPHORUS



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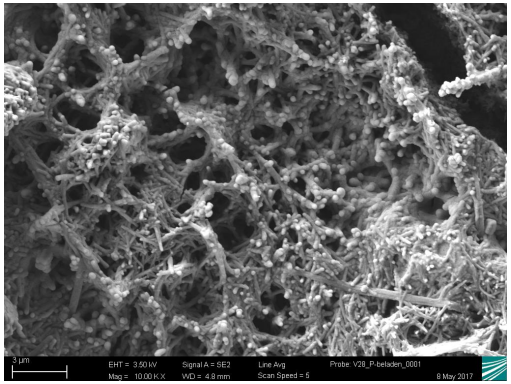
PROJECT 4: CALCIUM SILICATE HYDRATES (CSH) AS ADSORBENTS FOR THE PHOSPHORUS RECOVERY FROM WASTEWATER

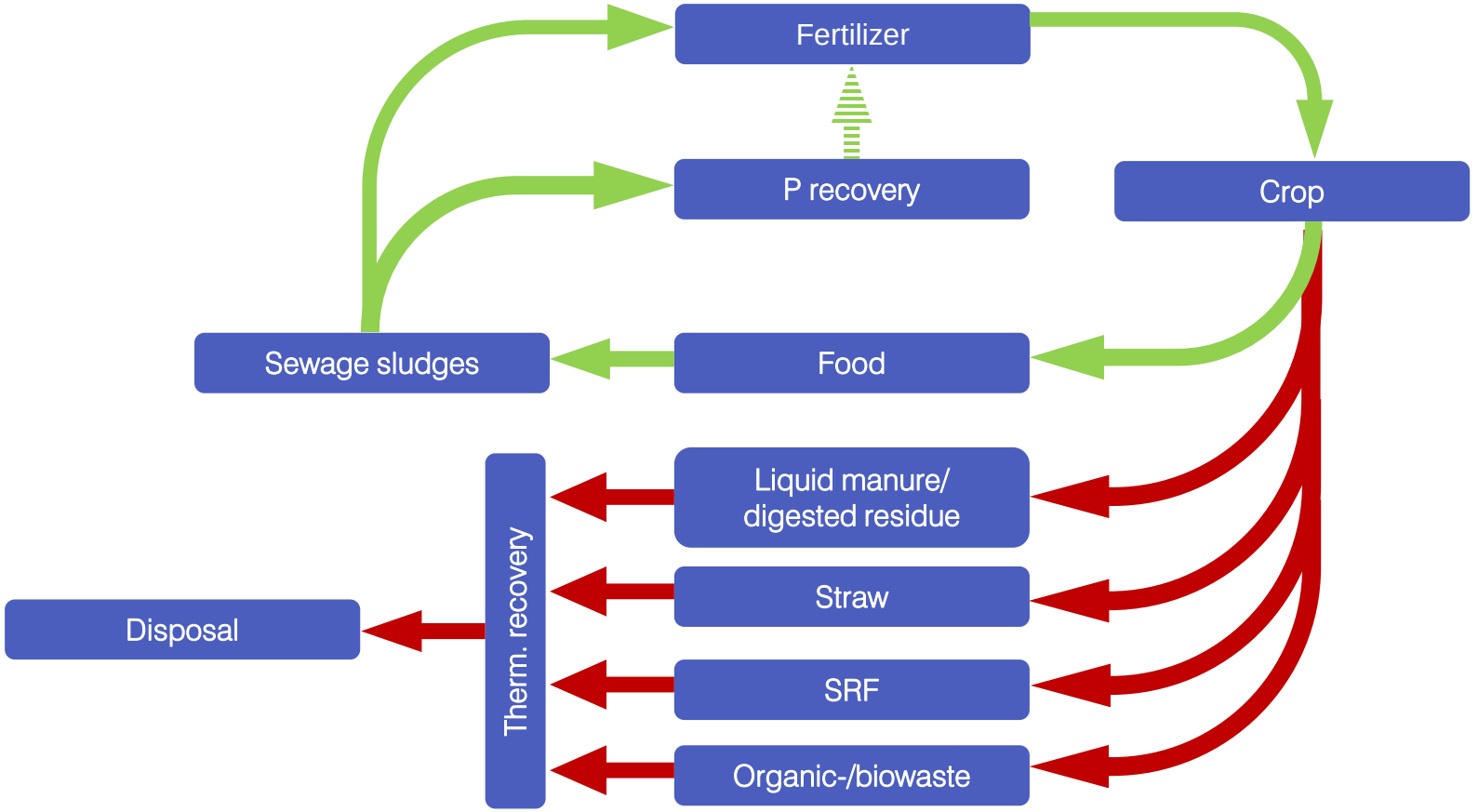
- Calcium silicate hydrates (CSH) are generated from quartz (SiO_2), lime (CaO) and water under hydro-thermal conditions.
- Industrial CSH (Tobermorite) showed already promising results in the use of CSH for a wastewater treatment.
- Realization of novel CSH adsorption systems for the optimized adsorption capacities of phosphates.



SEM-picture CSH development with high pore volume and specific surface area

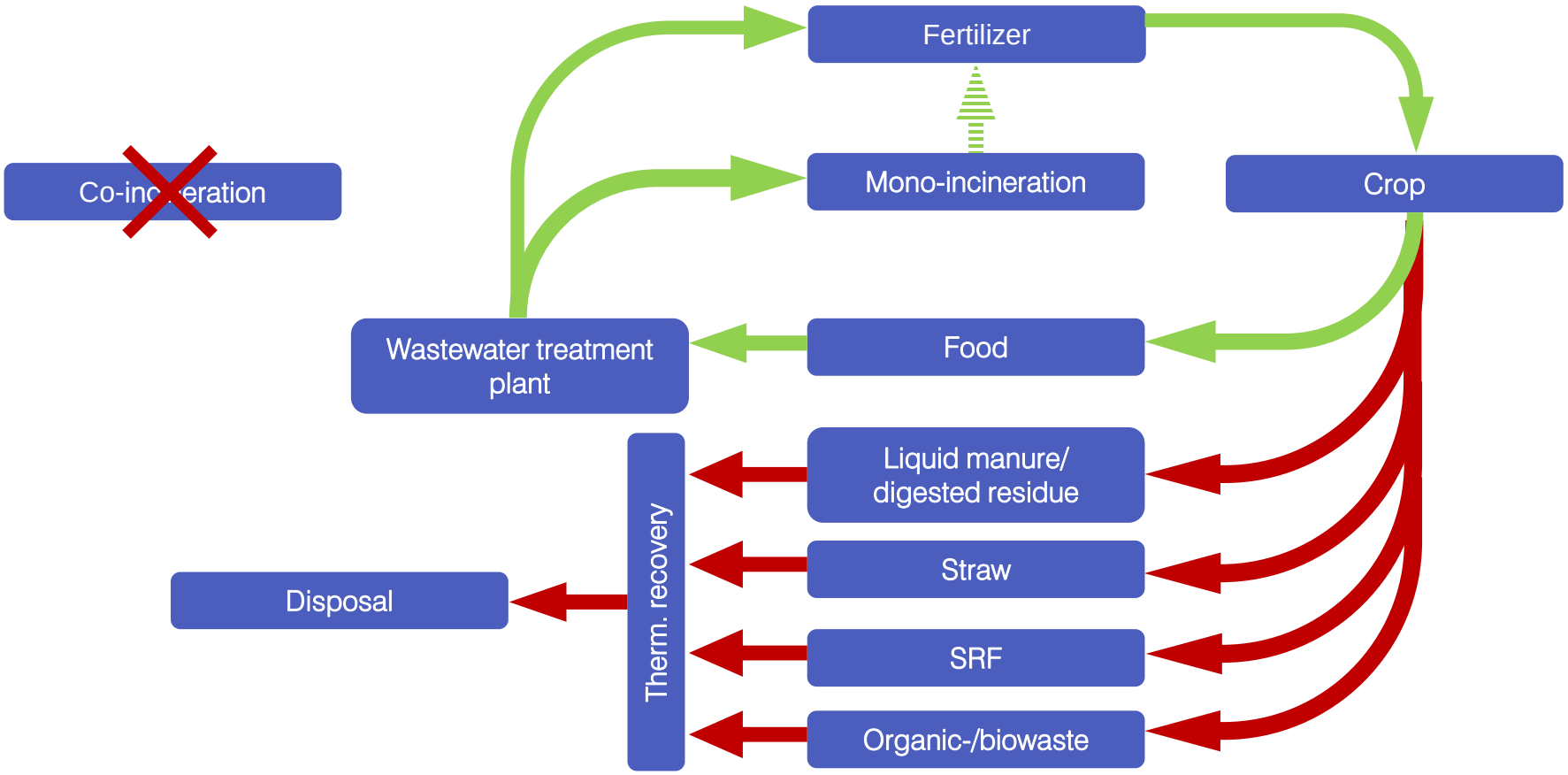
P cycle with creation of energy/industrial crops

- Industrial crops generate new product and waste streams.
- In Future, recovery of nutrients from biomasses will be necessary.



P-cycle with creation of energy/industrial crops

- Thermal recovery of biomass opens new gaps in the P-cycle.
- In Future co-incineration will presumably prohibited unless recovery of nutrients will be done.



Phosphorus levels in biomass ashes

Type of Biomass	P_2O_5-concentration in the ash [%]
horticulture waste	1,8 – 3,4
wood, bark and wood waste	0,7 – 13,1
Poplar wood	2,7
Corn stalks	1,8
Wheat straw	3,0
Rye-/barley straw	3,7 – 3,9
Sunflower stalks	18,5
Rapeseed expeller	41,4
Wheat grains	9,8 – 15,6
Sewage sludge ash	15 – 28

Data converted from Schiemenz, Diss. 2012

Phosphorus potential of biomass ash from wheat straw

Annual amount of wheat straw in Germany.		30 Mio. t
Direct available for thermal treatment:		10 Mio. t
Ash content:	5,7 %	**= 456.000 t Ash**
P_2O_5-content of the ash:	3,0 %	

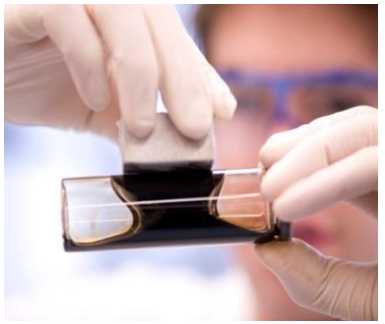
P-Potential of 22.055 t P_2O_5

Prerequisites for the establishment of fertilizer from recycled material

- Compliance with the DüMV (nutrient, pollutant levels, plant availability of the phosphorus …)
- Conditioning (grain size, nutrient balance, machinability)
- Practicality in application
- Economically available quantities
- Long-term guaranteed product quality
- Acceptance of the user

SUMMARY

- P as non-substitutional resource for life
- P is imported mainly for application as fertilizer
- Available technologies for P recycling
- Approaches of Fraunhofer IWKS
- Activities for biomass in future



Source: © Fraunhofer ISC







Thank you!

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