Implications of Circular Economy on Sustainable Development:
A Decade on and the Road Ahead

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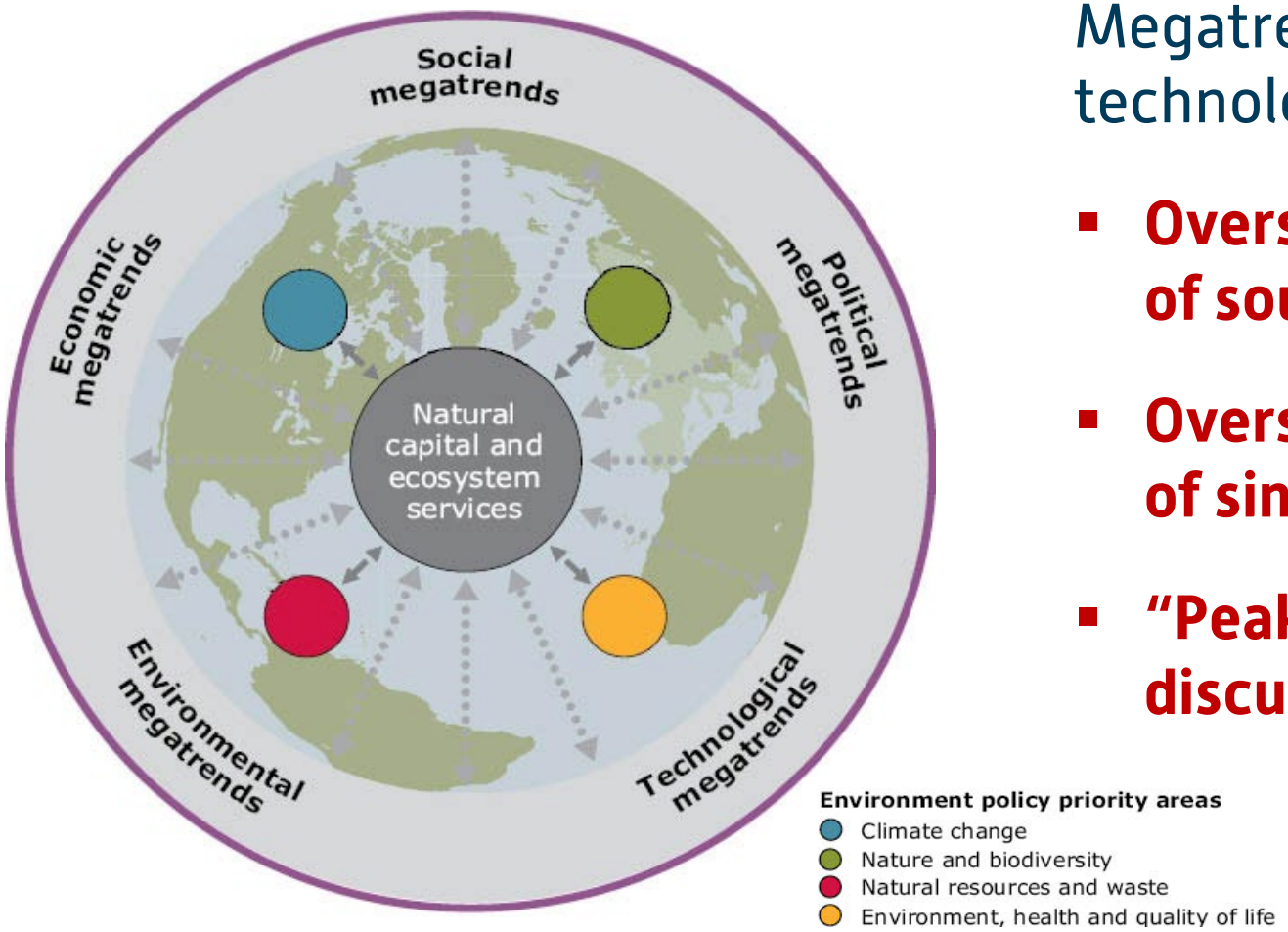
Prof. Dr. Peter Heck, Managing Director of IfaS

ECB, 23rd of October 2019

IfaS Institut für angewandtes Stoffstrommanagement

IMAT INTERNATIONAL MATERIAL FLOW MANAGEMENT

Megatrends of the last two decades

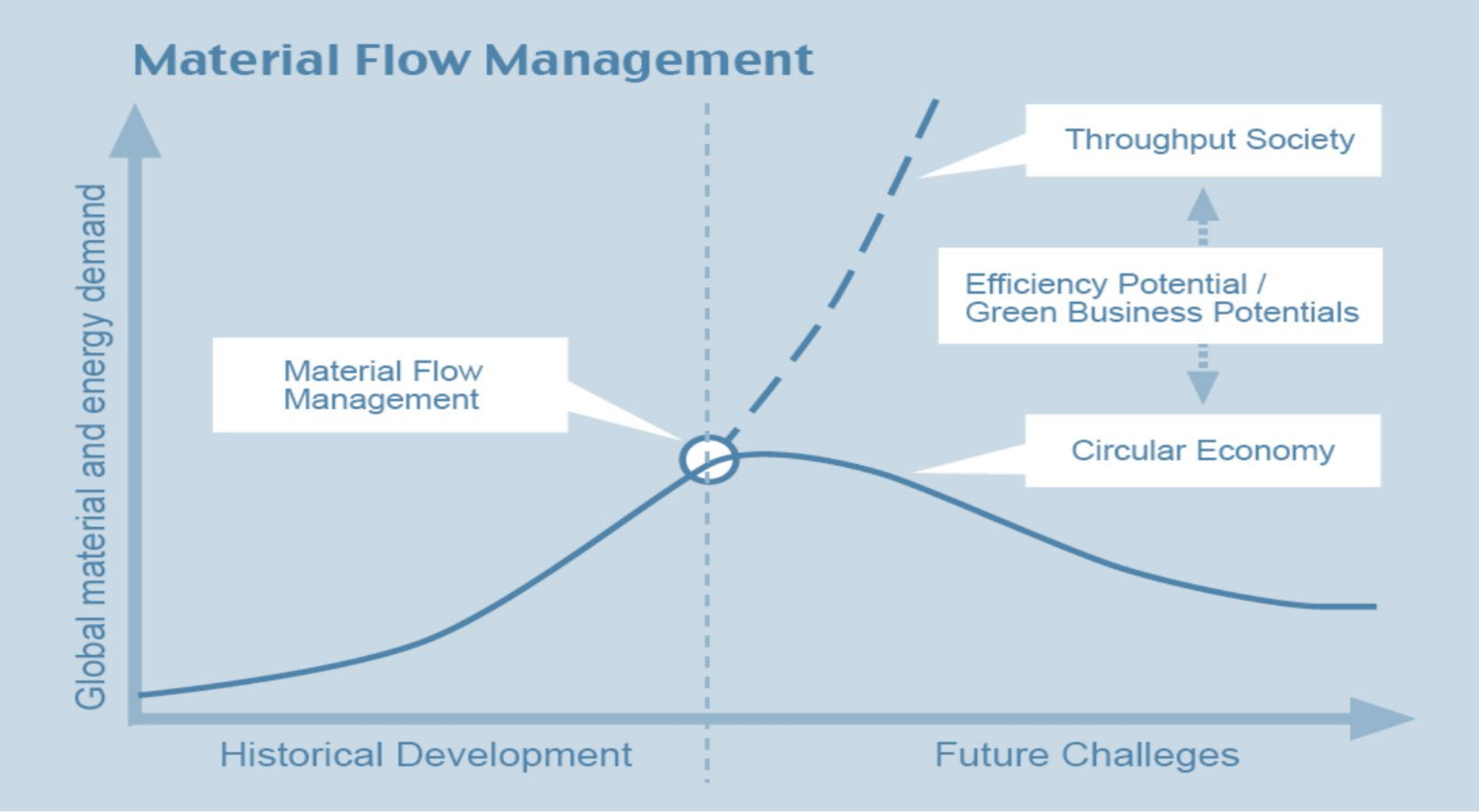


Megatrends have not changed much (despite technology progress)

- **Overshoot on resource extraction (limitation of source)**
- **Overshoot "unwanted production" (limitation of sinks)**
- **"Peak" on climate change (sustainability) discussion in 1994 and now!**

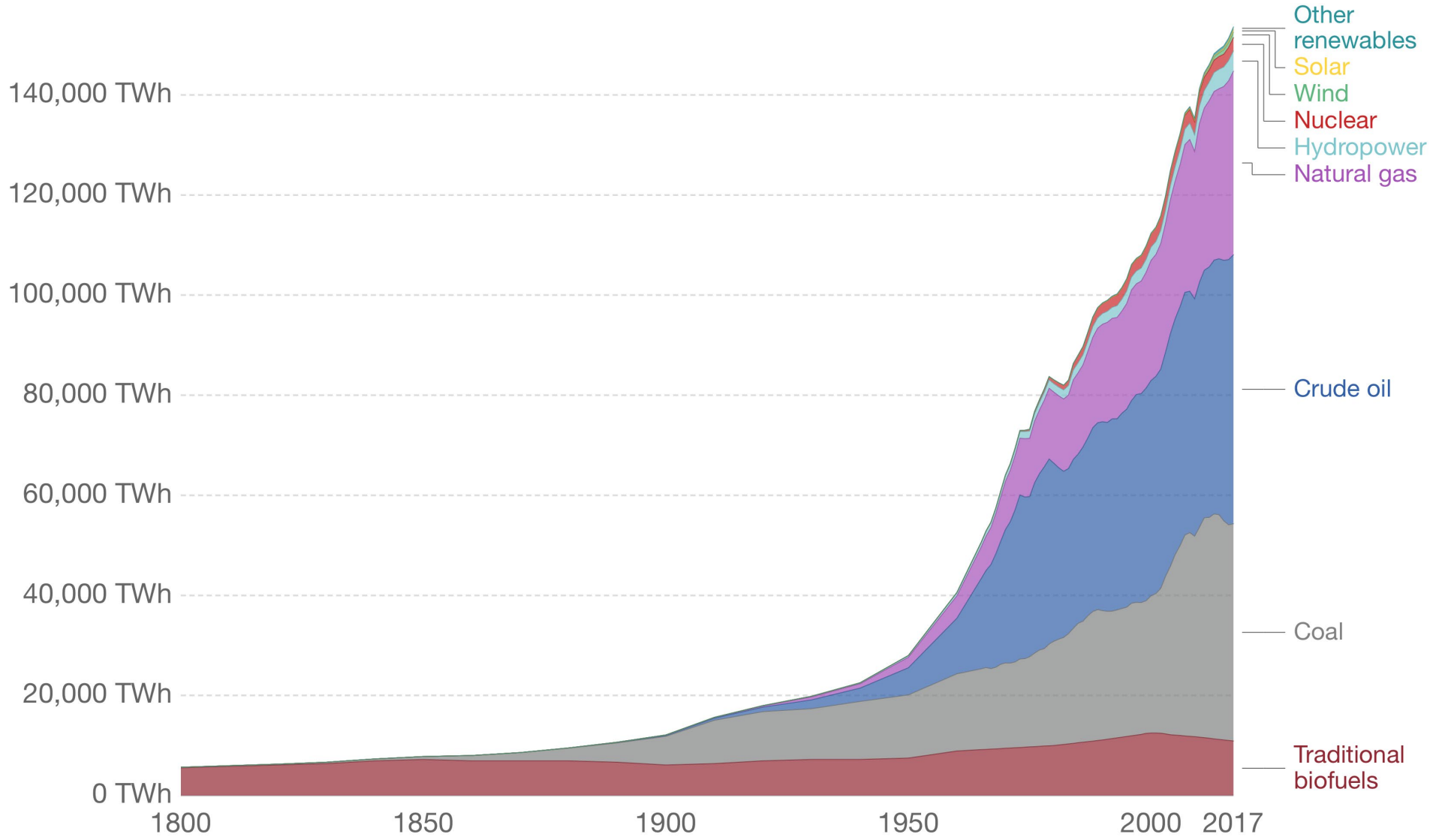
SOURCE: https://www.eea.europa.eu/soer/synthesis/synthesis/chapter7.xhtml. Accessed 10 April 2019

Consumption based growth patterns



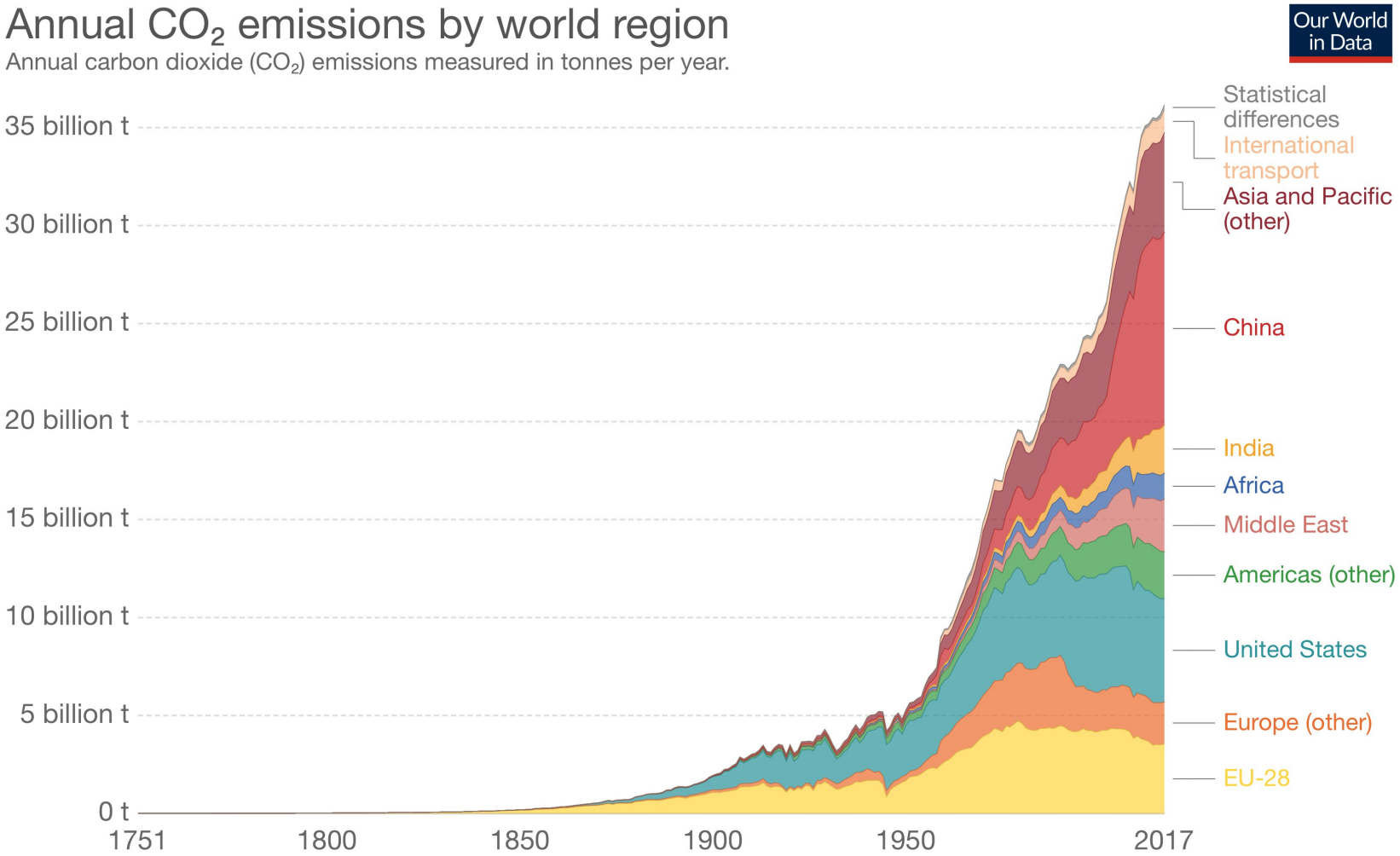
SOURCE: OECD (2019). Global Material Resources Outlook to 2060 Economic Drivers and Environmental Consequences. https://www.oecd.org/environment/global-material-resources-outlook-to-2060-9789264307452-en.htm. *Accessed June 20, 2019*

Global primary energy demand



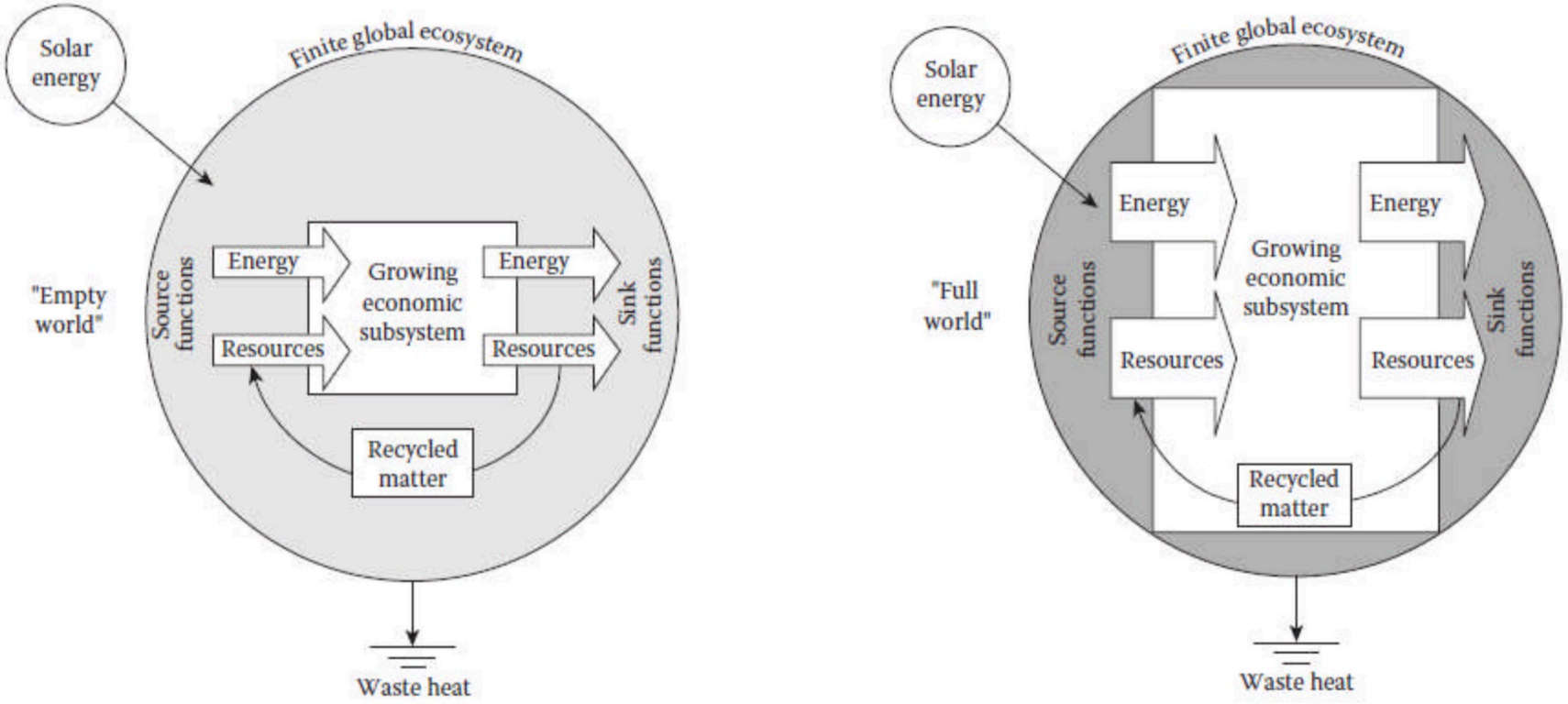
Source: Vaclav Smil (2017) and BP Statistical Review of World Energy

Paris Accord



Source: Carbon Dioxide Information Analysis Center (CDIAC); Global Carbon Project (GCP)
Note: "Statistical differences" notes the discrepancy between estimated global emissions and the sum of all national and international transport emissions.
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

capacity)

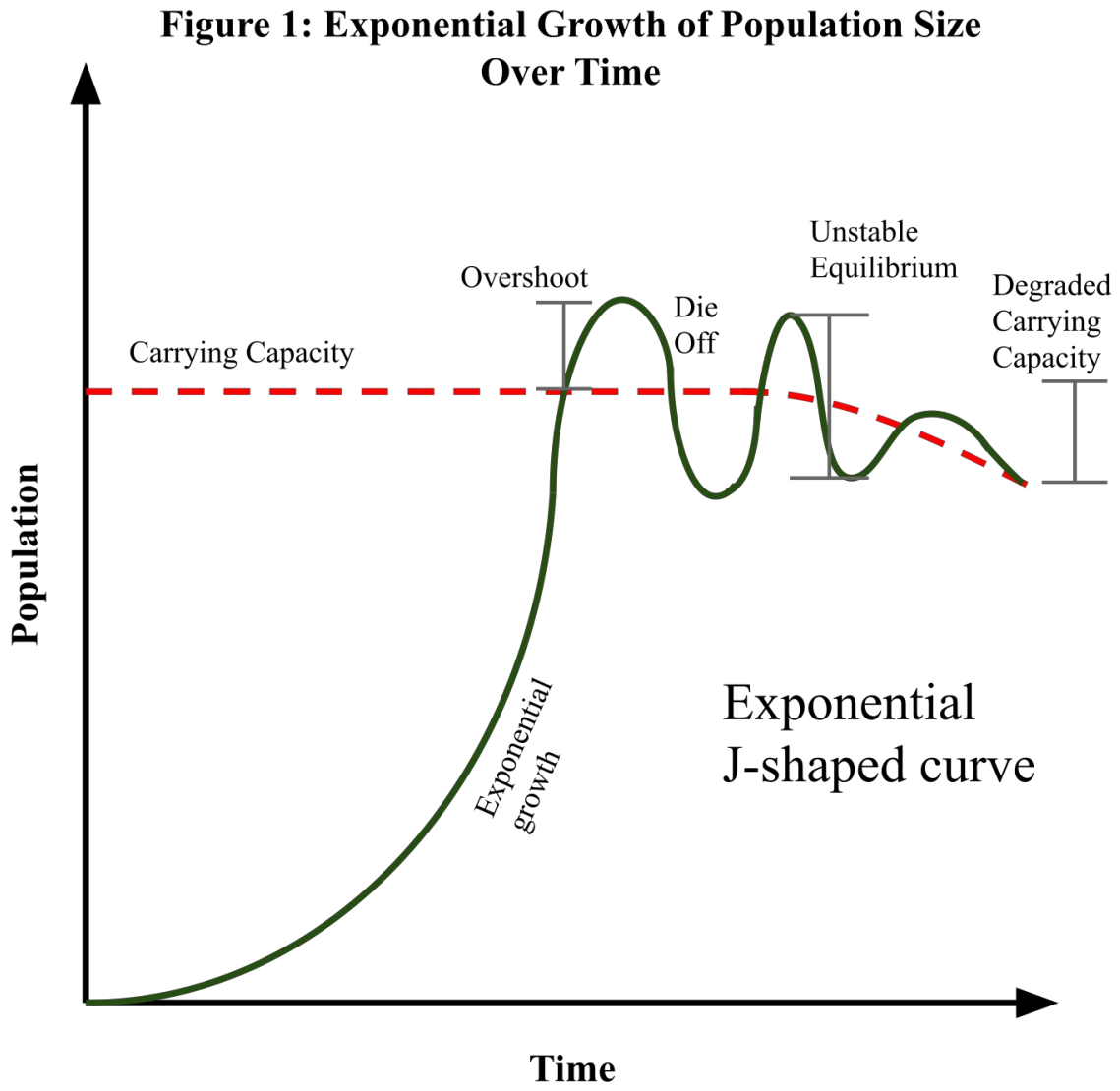


Current (and last decades´) growth model is not sustainable

- **But how far do we overshoot the edges???**

SOURCE: Costanza, R., Cumberland, J.H., Daly, H.E., Goodland, R., Norgaard, R.B., Kubiszewski, I., Franco, C., 2015. An Introduction to Ecological Economics, 2nd ed. CRC Press, London and New York. ; http://etheses.whiterose.ac.uk/22895/1/0_Phd_final.pdf

What are the consequences?



In biology/nature an overshoot leads to extinction

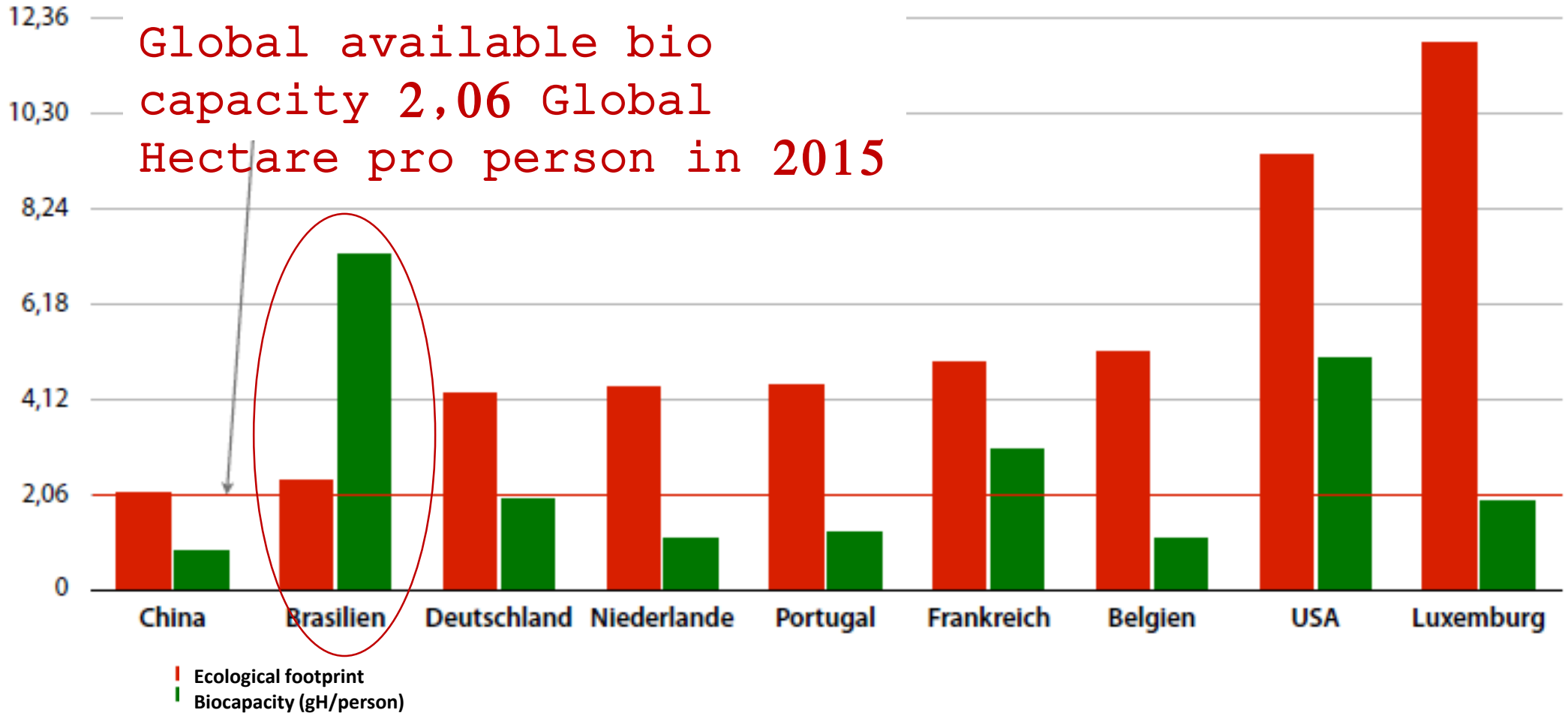
- **Didn´t we see that in man-made systems as well?**
- **What happened to the high culture of the past centuries (e.g. Maya culture)**
- **Why should we be different in 21st century?**

SOURCE: https://en.wikipedia.org/wiki/Carrying_capacity#/media/File:Exponential_Carrying_Capacity.svg

SOURCE: google.com/images, (2019.): accessed 02.APR.2019

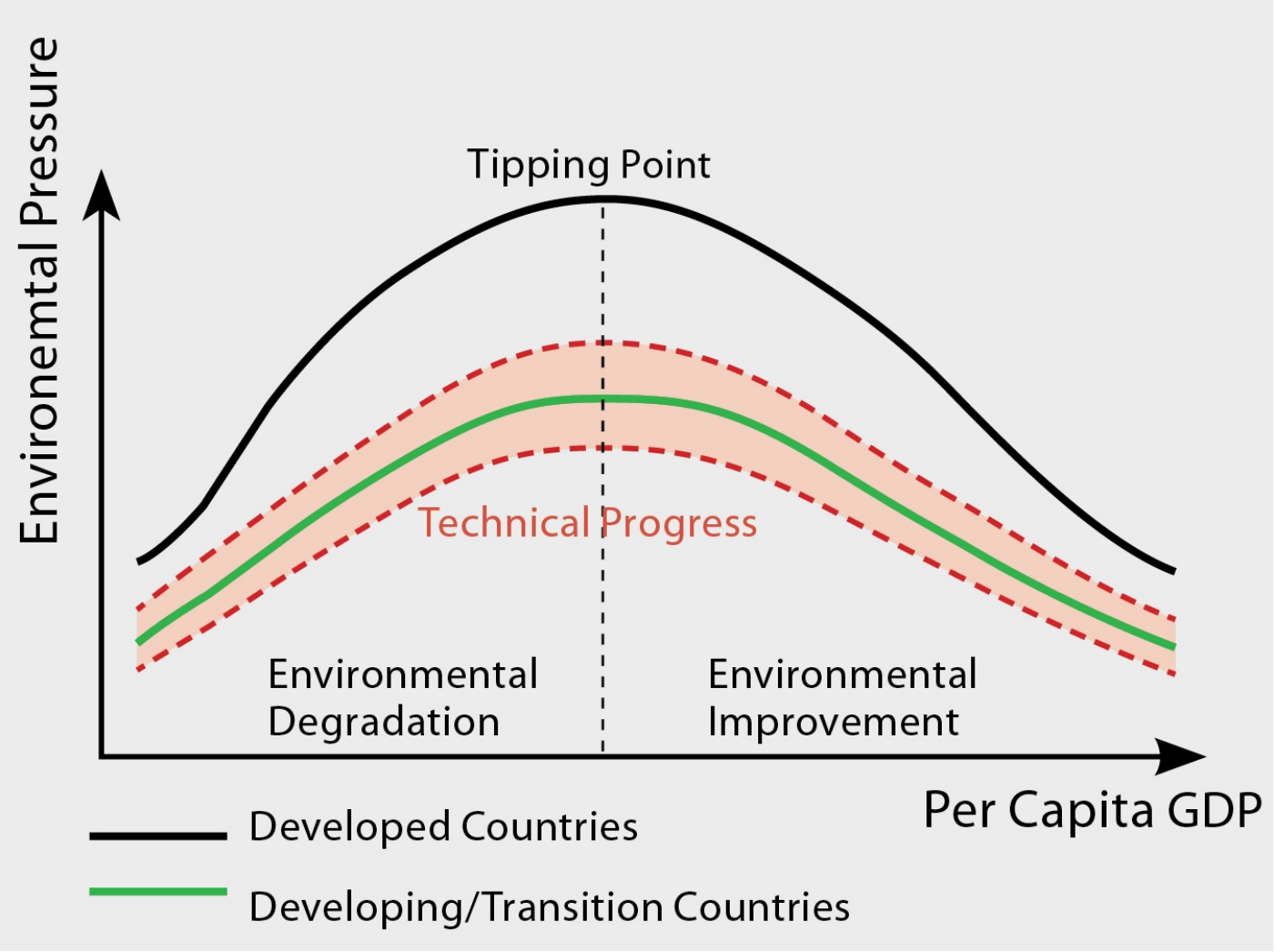
SOURCE: google.com/images, (2019.); accessed 25.AUG.2019

National Biocapacity and Ecological Footprint



SOURCE: https://en.wikipedia.org/wiki/European_migrant_crisis

New Circular Economy Models needed!



- **New development models for LD Countries and developing/transition countries needed.**
- **Decoupling economic growth from source and sink stress**
- **Zero Emission as guiding principle**
- **MFM as operational tool kit**

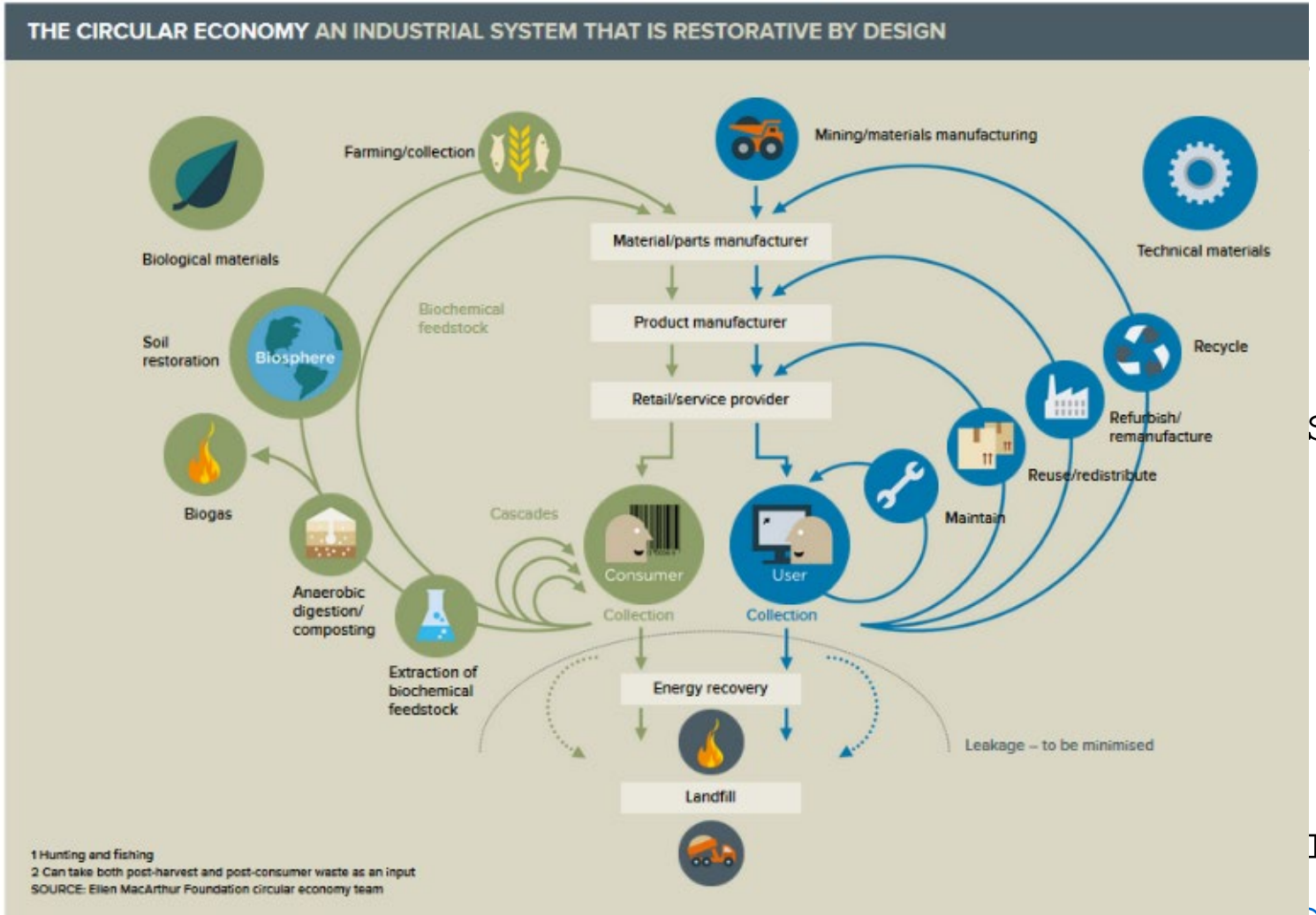
Circular Economy

Energy from non-renewable/finite resources

Energy from renewable resources

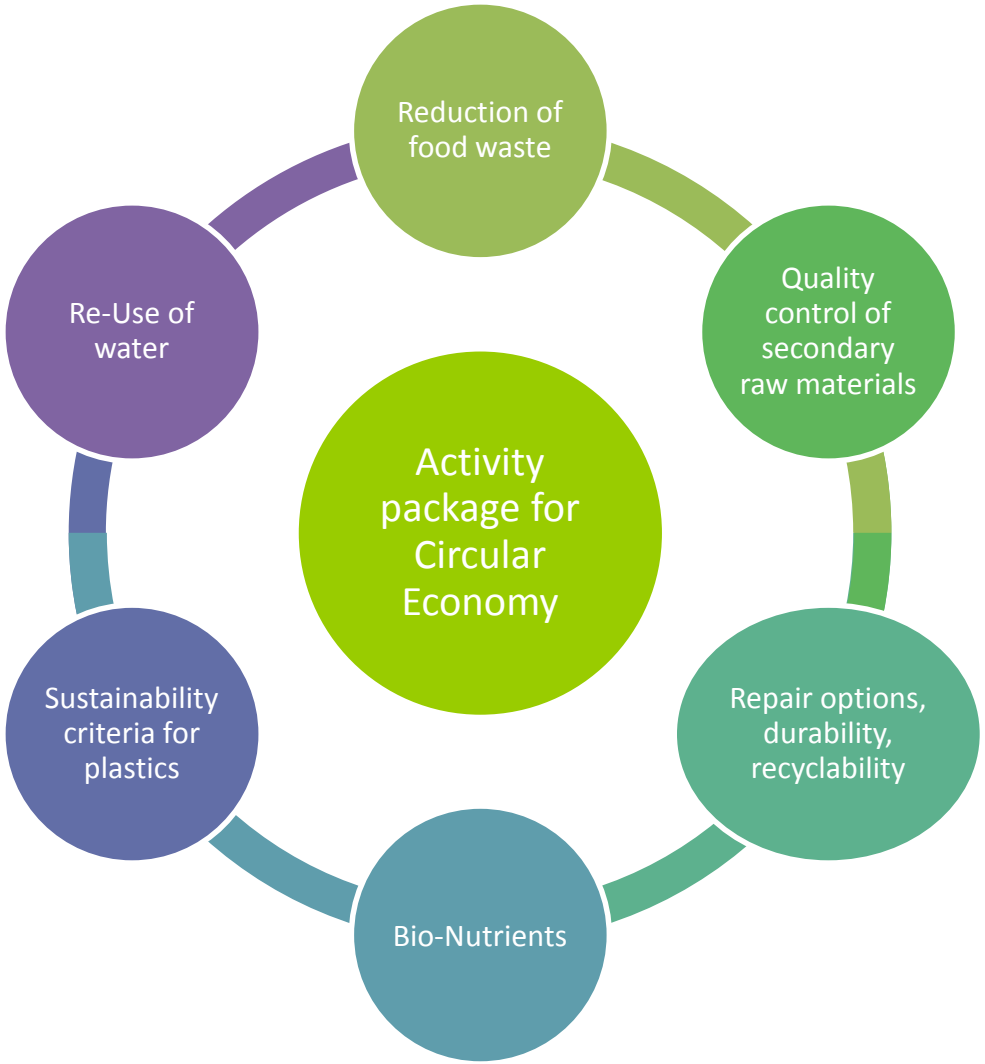
Circular Economy

- Circula… del that **decouple… from the consumpt…**
- "managi…
  - break… spose" model
  - → ideal…
- Princip…
  - Desig…
  - Build…
  - Work t… rces
  - Think in "systems" (→ Material Flow Management!)
  - Think in cascades



Source: http://www.ellenmacarthurfoundation.org/circular-economy/circular-economy/the-circular-model-an-overview

Circular Economy as a European Policy Target



Targets till bis 2030

- 65% Recycling of Waste
- 75% Recycling of packaging material
- Max. 10% to landfill

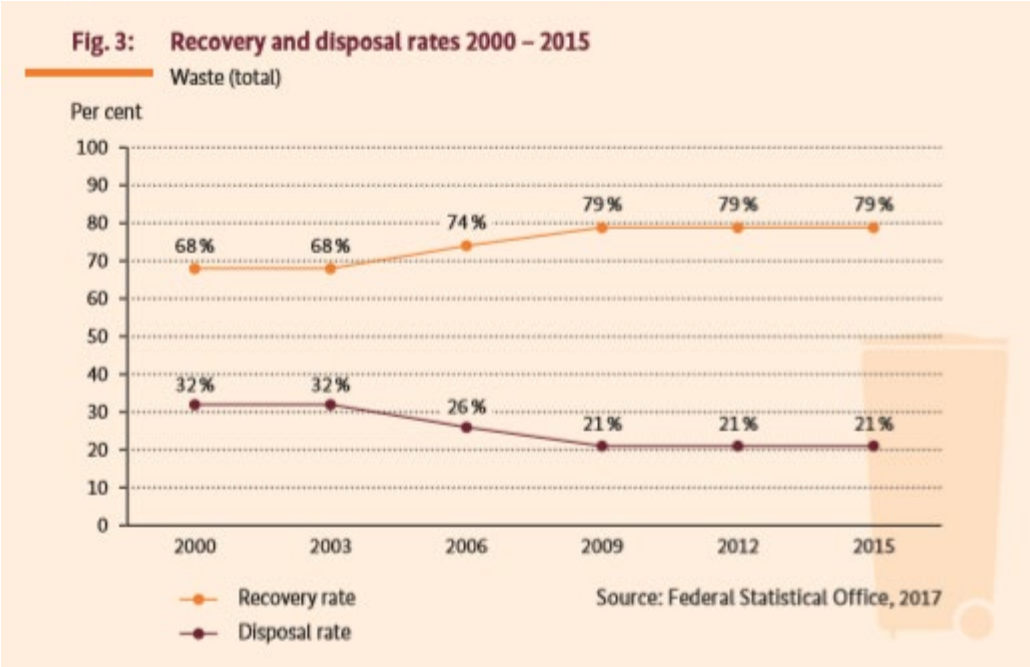
Action proposals:

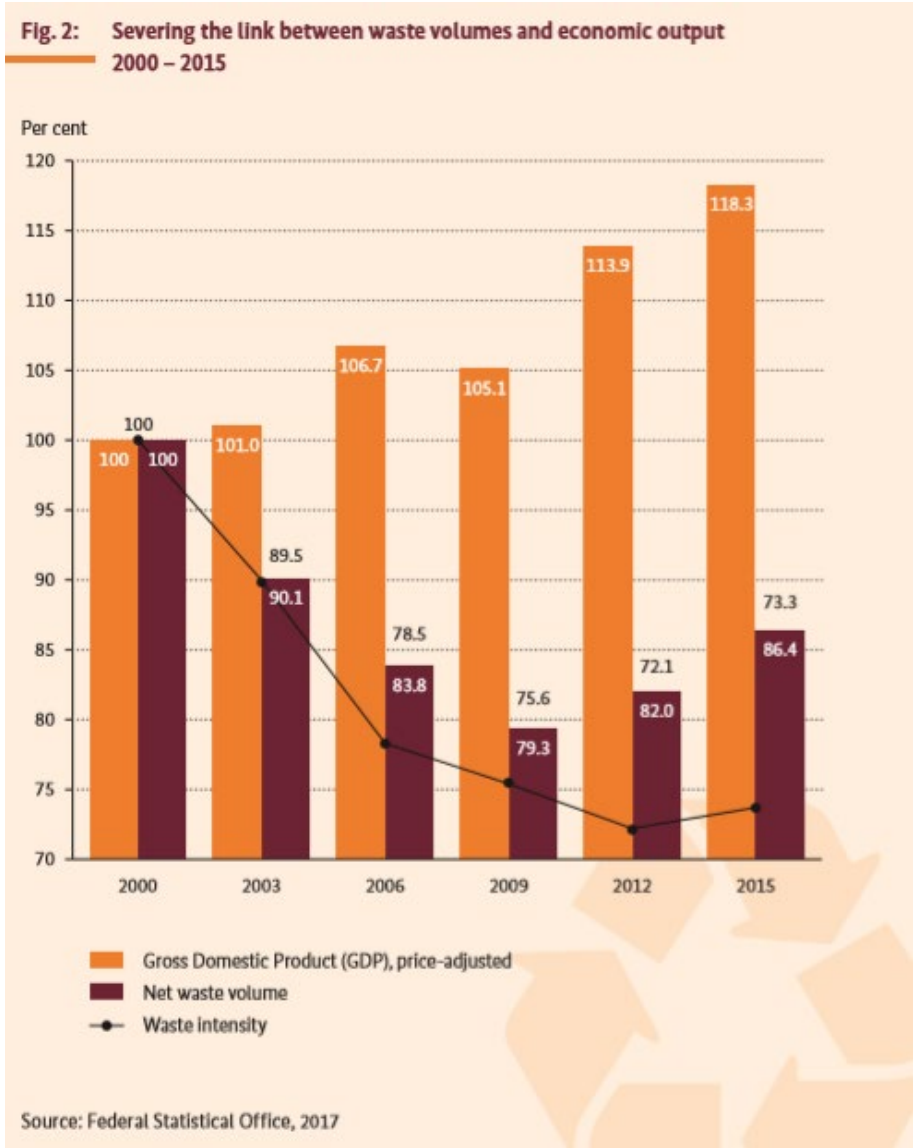
- Support of industrial symbiosis
- Incentives for environmental friendly products and support of re-use and re-recycling systems

Quelle: http://europa.eu/rapid/press-release_IP-15-6203_de.htm

Circular Economy in Germany is still waste management

- CE started – by terminology – in the waste management sector
- GHG abatement in Waste Management sector developed from + 21 mio t CO2e (1990) towards – 6 mio tCO2e in 2018





ENVIRONMENTAL CAMPUS BIRKENFELD

Zero-Emission Campus:

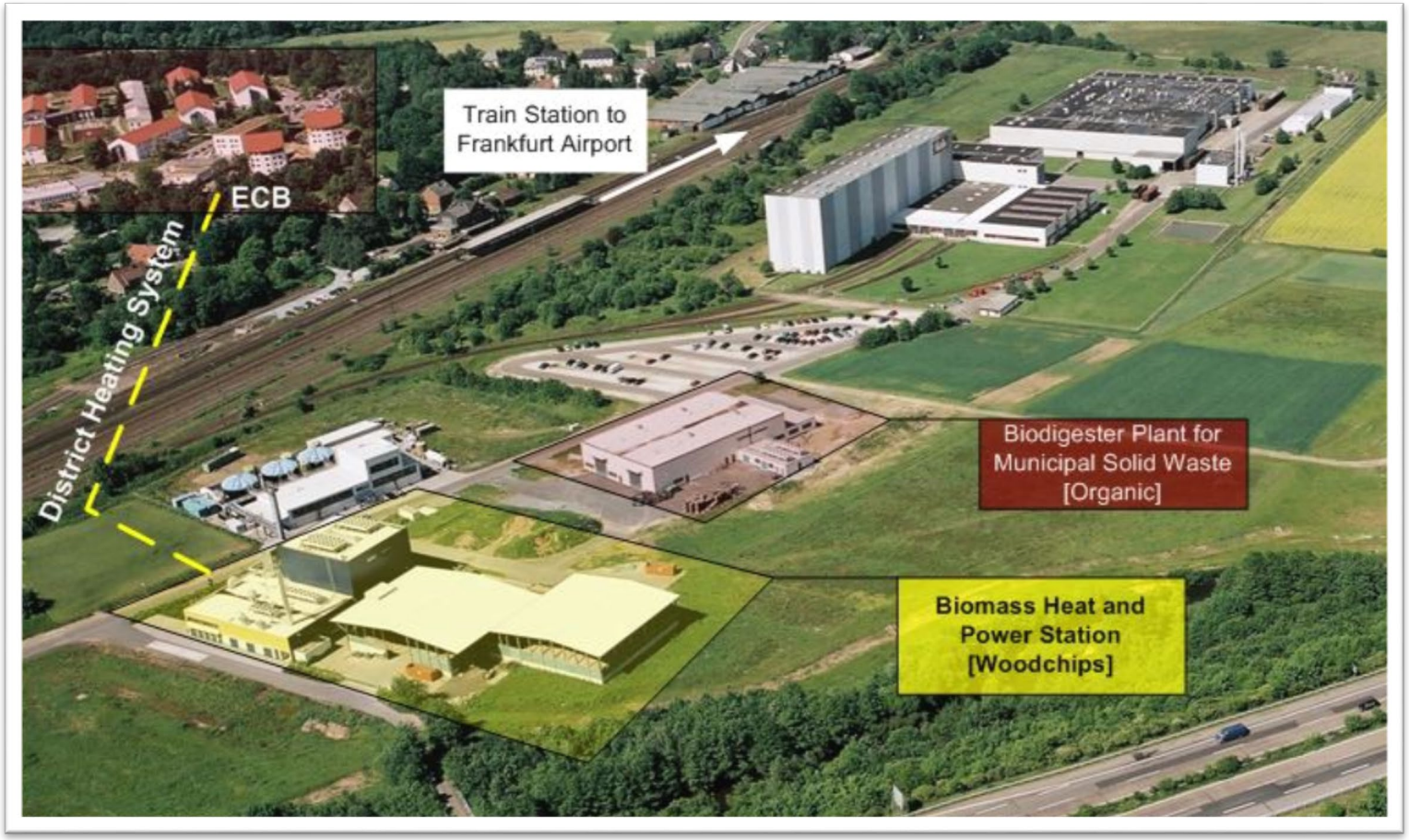
One of the greenest universities of the World!

Zero Emission Campus – Concept

IfaS Institut für angewandtes Stoffstrommanagement

- **100%** renewable heat supply based on waste wood, biogas (co-generation) and solar thermal
- **100%** renewable electricity based on cogeneration & PV
- **100%** renewable cooling supply based on geothermal, biomass and solar adsorption
- **100%** Energy Efficiency

Eco-Industrial Park (Waste-to-Energy)



- **100%** Private company investments (40 Mio. EUR CAPEX) in Public-Private-Partnership
- **100%** Regional Added Value (35 new jobs, GHG abatement, long-term affordable energy security)
- **100%** waste problems solved without second pollutions

Charged by the sun – Sustainable Mobility

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- Carport with 100kWp installed capacity
- Integrated Battery storage [80 kWh]

Zero Emission Building (Energy^{+} - Building)

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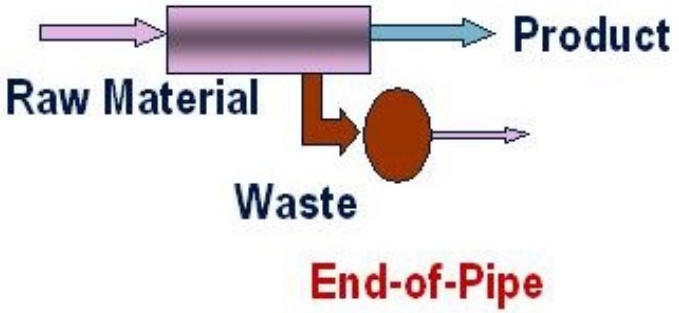
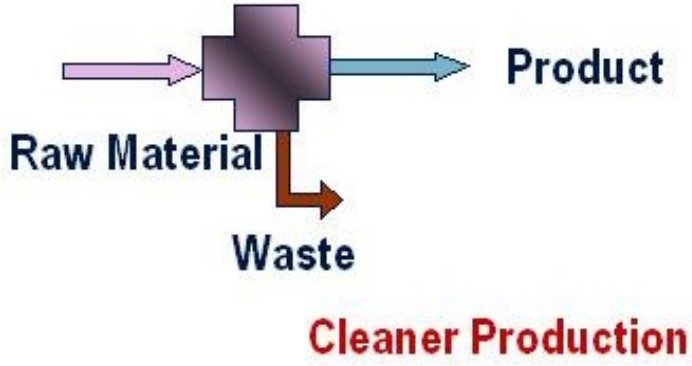
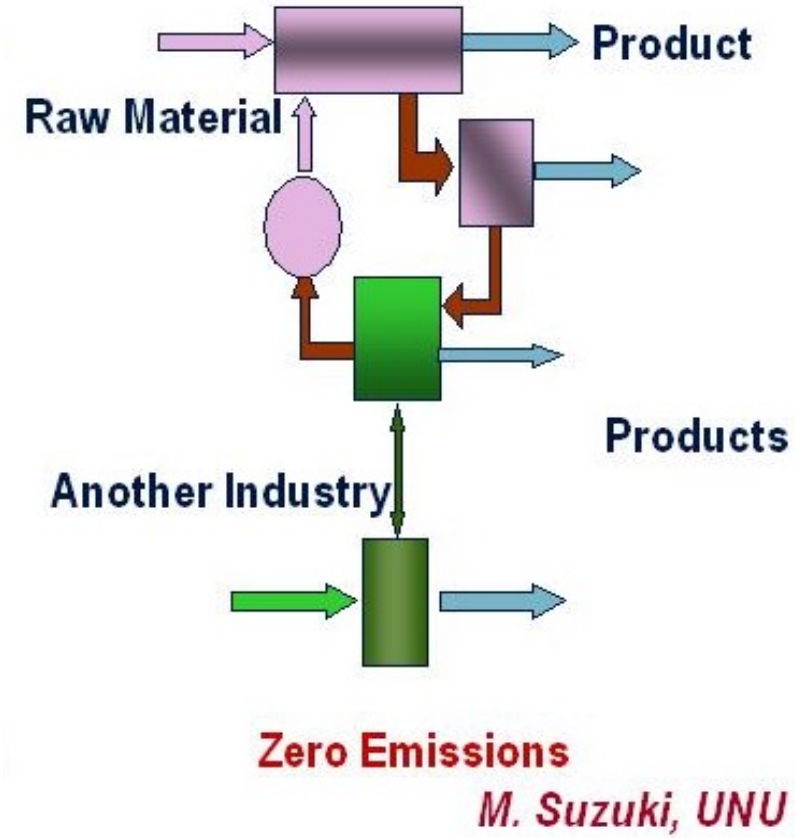
- PV-installation with an installed capacity of 40 kWp
- 40 cm exterior insulation and triple-glazed windows
- HVAC with 80 % heat recovery and high efficient electric motors

Zero Emission & Material Flow Management

Developed in 1994 as well….

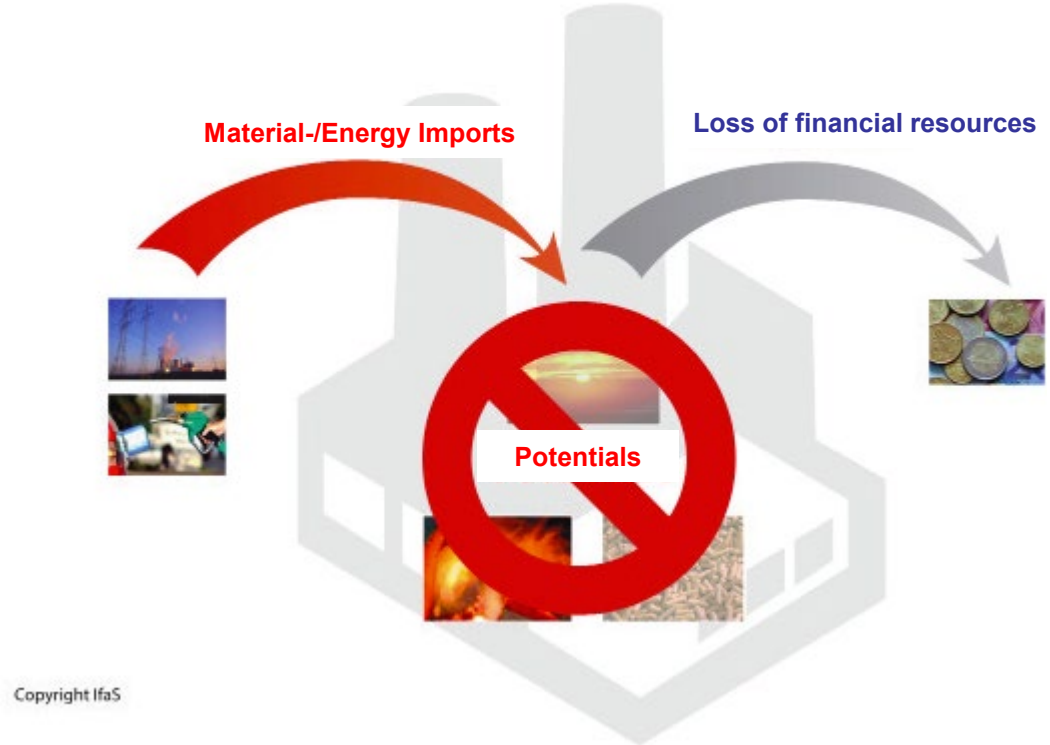


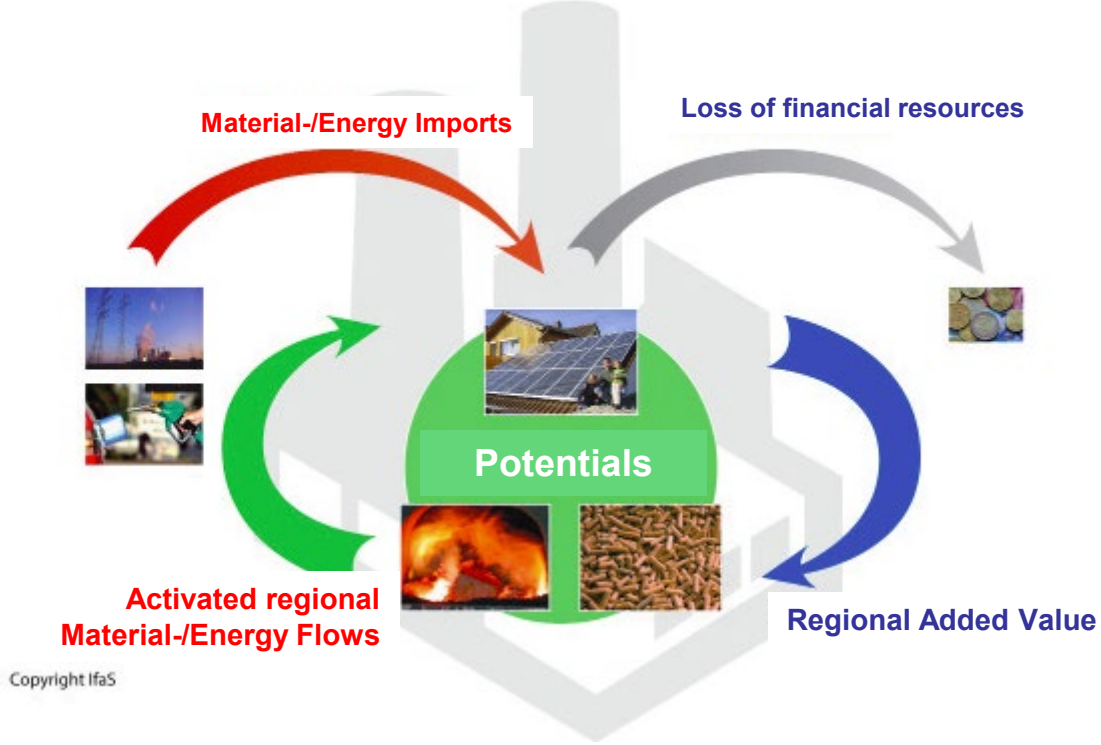




Material Flow Management & Regional Added Value

Nowadays "throughput society" – Vision and Goal – Zero Emiss





- Low CAPEX – High OPEX
- Negative Environmental impact

- High CAPEX but improved Project-IRR
- Environmental Protection and

Negative welfare by fossil fuels – Example Small Village

Assumptions per household:

- Heat demand approx. 30.000 kWh
- Oil price approx. 60 Ct/litre
- Electricity demand approx. 3.000 kWh
- Electricity price approx. 26,6 Ct/kWh

Today´s structural problems*

Heating costs: **540.000 €**
Electricity costs: **240.000 €**

Loss: approx. 780.000 €

- **No regional added value,**
- **No development perspective,**
- **No innovation,**
- **No climate protection,**
- **No resource security etc.**

Tomorrows Opportunities

- Photovoltaic, solar thermal
- Windpower and windgas
- Bioenergy, heat pumps
- Building efficiency
- ….

Regional added value

Negative welfare – Example Rhine-Hunsrück County District

Annual Energy Import & loss of purchase power of 290 Million €

Das bedeutet:

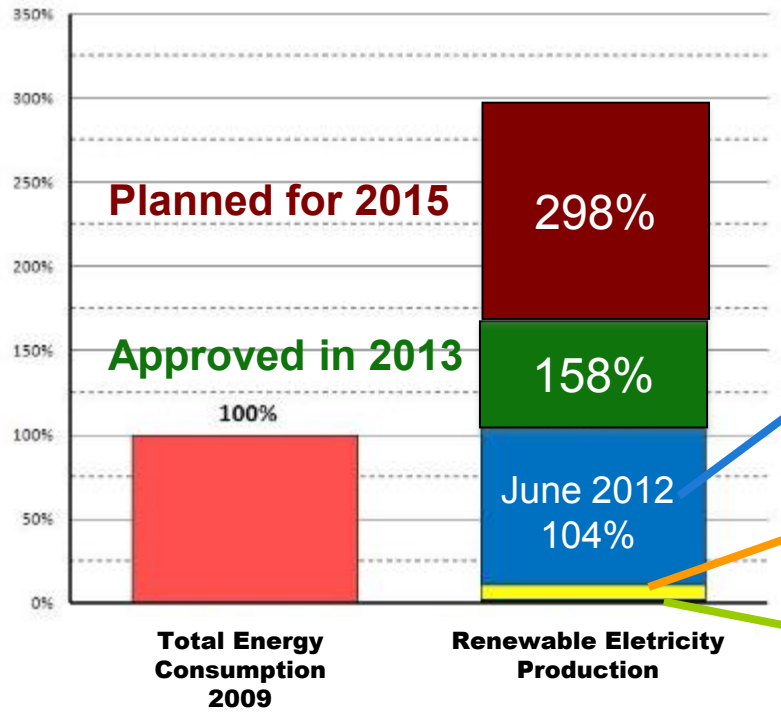
Energy Import & loss of purchase power in Germany of approx. 90 billion EUR (2016)

Objective of Zero Emission:

Through improvements in energy efficiency and introduction of renewable energies we convert energy

Renewable Energy Share (in 2015)

Total electricity demand
473 Million kWh in 2009



149 turbines

2.404 plants

14 plants

Hydropower
Ø national 3,3 %

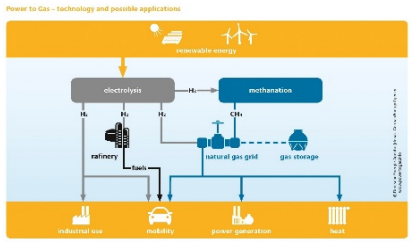
from 2010: Pilot project in the river Rhein close to St. Goar

Wind Energy
June 2012: **93,59 %**
Ø national 7,5 %

Photovoltaics
June 2012: **9,01 %**
Ø national 4,0 %

Biomass
June 2012: **1,86 %**
Ø national 5,5 %

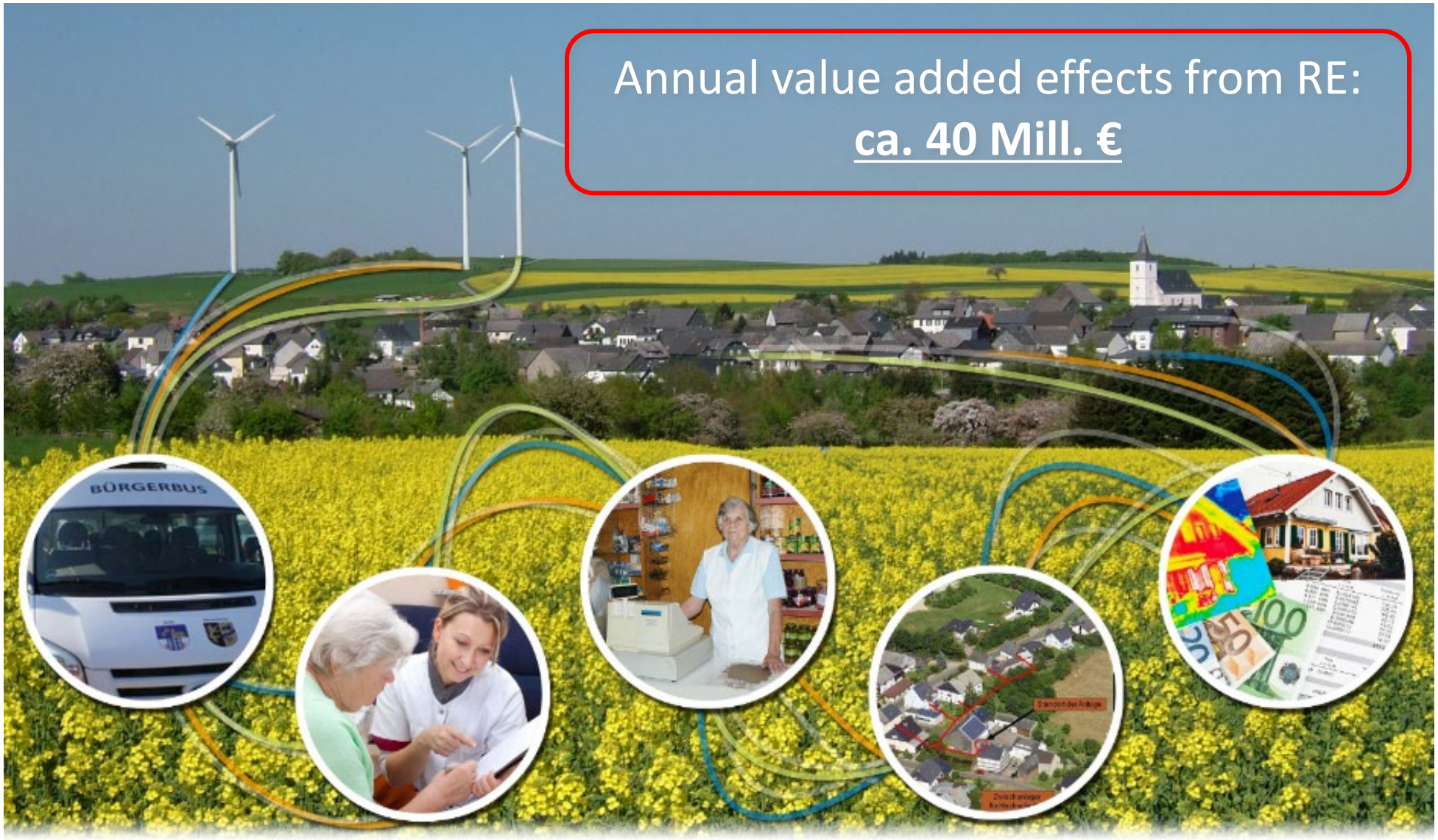
Rural Districts as Energy Exporter for Urban Areas!


Power to Gas – technology and possible applications
renewable energy
electrolysis
methanation
refinery
natural gas grid
gas storage
industrial use
mobility
power generation
heat

Power to gas


Wind energy
Electricity
Electricity
ENERGIE PARK MAINZ
H_2
Research
Hydrogen production through electrolysis and subsequent storage
Industry
Hydrogen
Hydrogen
Electricity
H_2
Households
Public gas Net
BHKW
Gas station
Gas power plant or modular heat and power station

ProjecttiDeee: Renewable energies and energy efficiency as a regional development opportunity



Regional economy has a long tradition!

Friedrich Wilhelm Raiffeisen
(1818 - 1888)

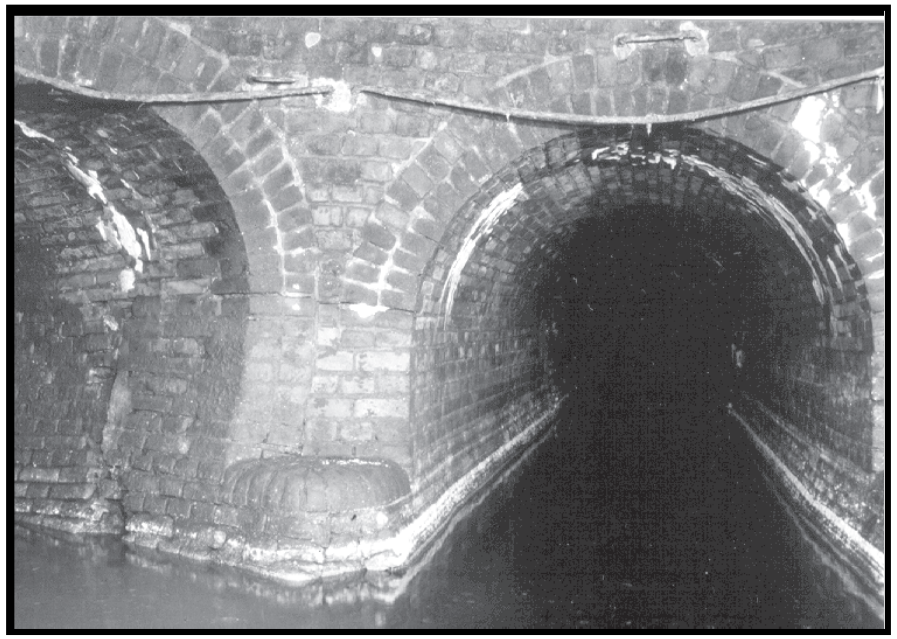
The money
of the
Region
for the
Region

Sustainable Water Resource Management

“Definition” & historical background

The classical comprehension of waste water leads to the following “technical solutions”:

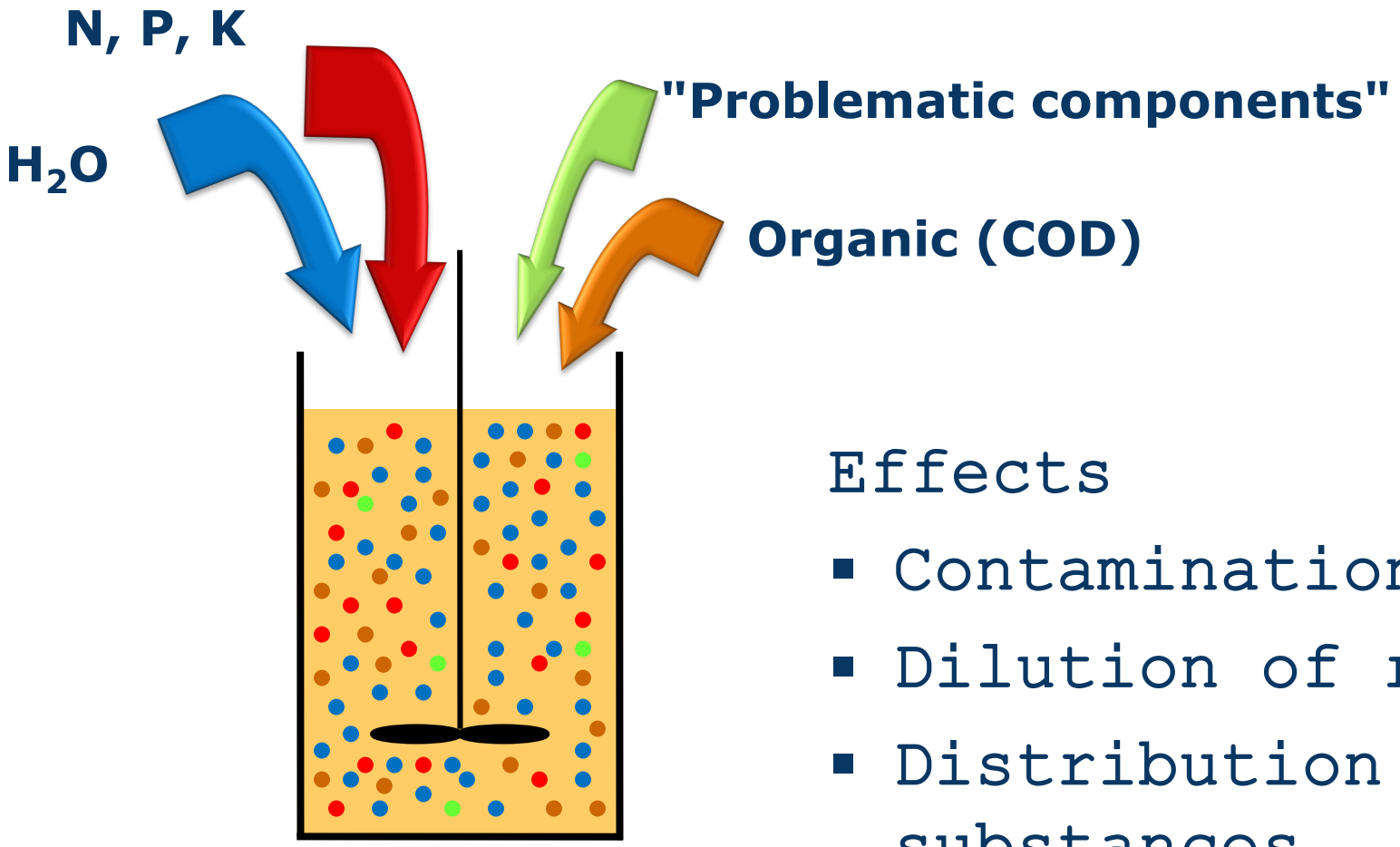
- Collecting waste water in sewers
- To treat the wastewater in centralized treatment plants



Out of sight –

Out of mind!

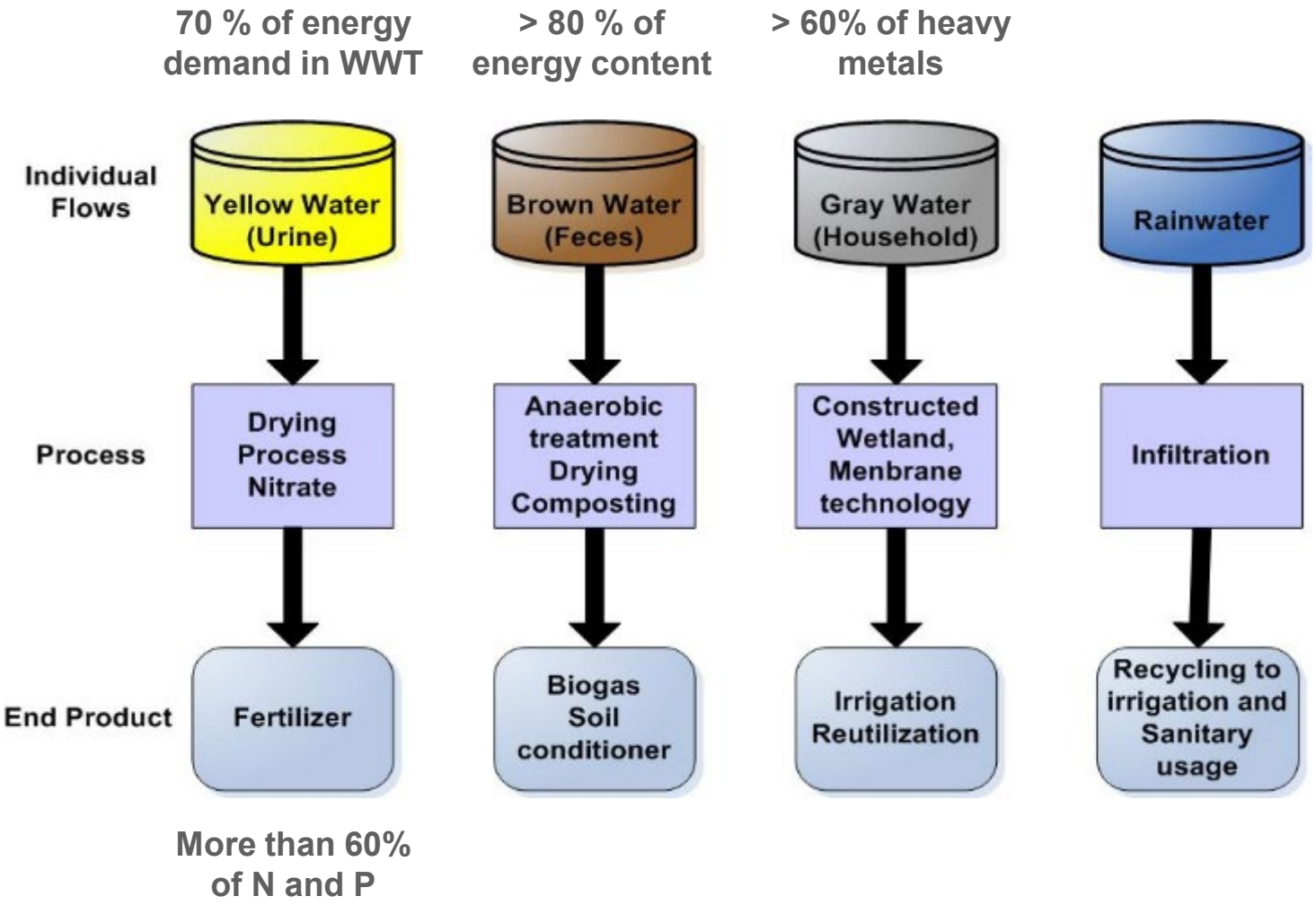
Water Resource | WW as nutrient “cocktail”



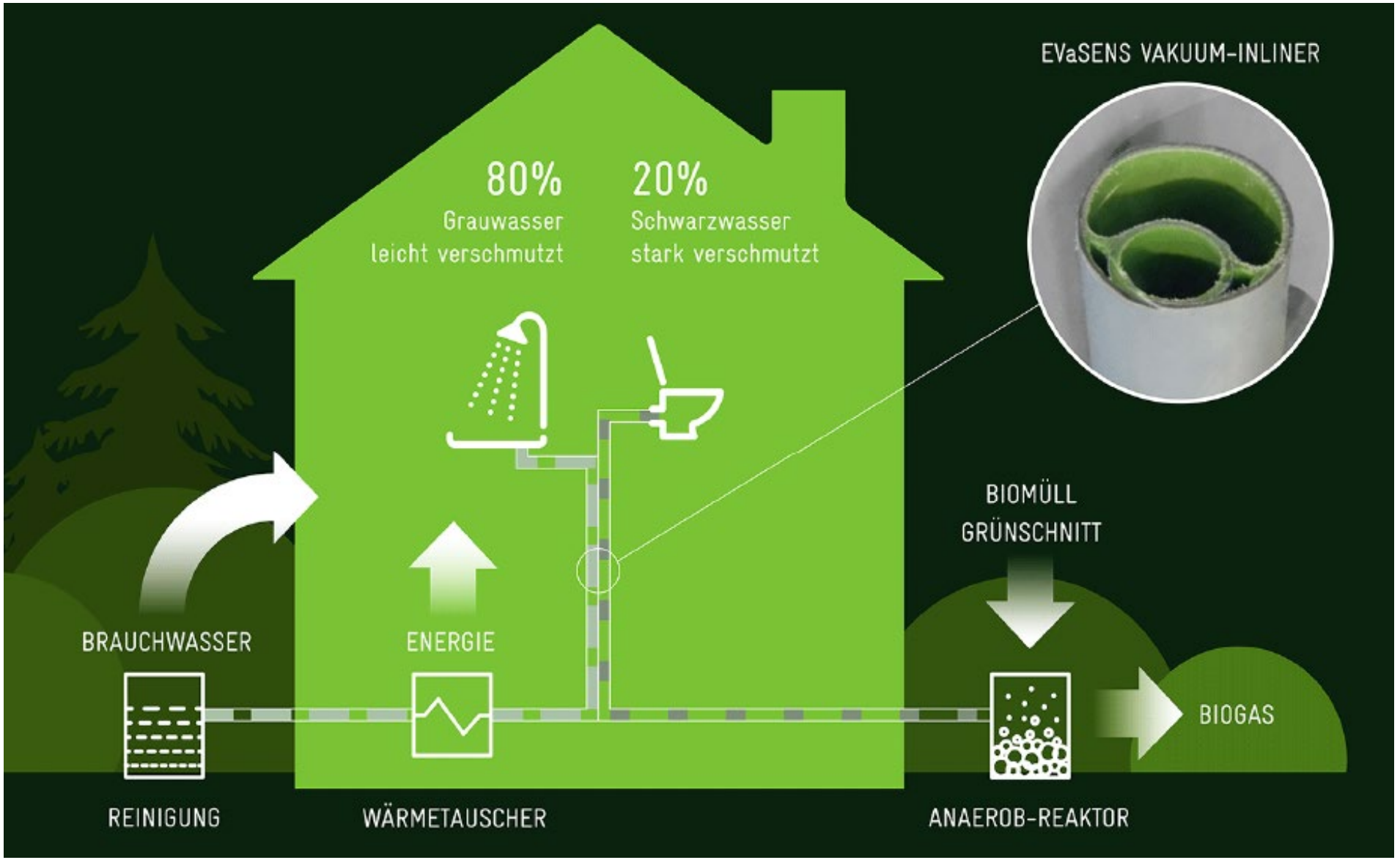
Effects

- Contamination of water
- Dilution of resources
- Distribution of hazardous substances

Water Resource | Separation of water flows

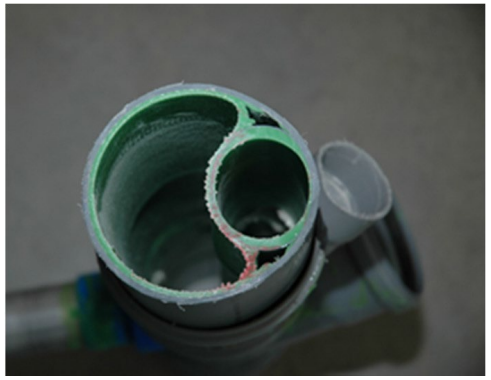


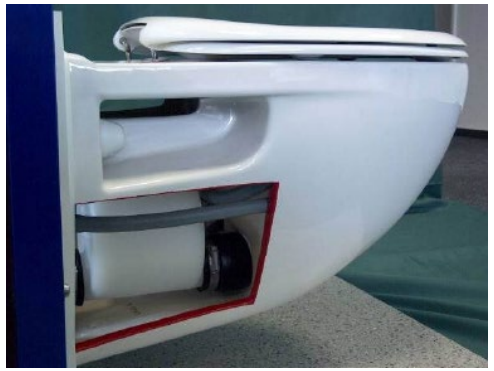
ReLab: Project concept and objective



Quelle: Björnsen Beratende Ingenieure GmbH 2017

ReLab: Project concept and objective





Objective: Development of an overall concept "Wastewater-free Environmental Campus Birkenfeld

- Separate collection and use of wastewater and biomass potentials (household biowaste).
- Integration of a New Sanitation Concept (NASS) into an existing student dorm on the ECB.
- Double inliner system (EVaSENS), Vacuum drainage system and sanitary system

Installation of vacuum pump station

Next potentials | Integrated water resource management

- Intelligent new WWT designs with minimised capacity (and investment)
- Optimisation of existing WWT structures
  - Energy efficiency and energy “autarky” of existing WWTP by anaerobic digestion of raw WW/sewage sludge
  - Re-use of pre-treated water for irrigation (semi and arid area)
  - Production of fertilizer substitute by digestate

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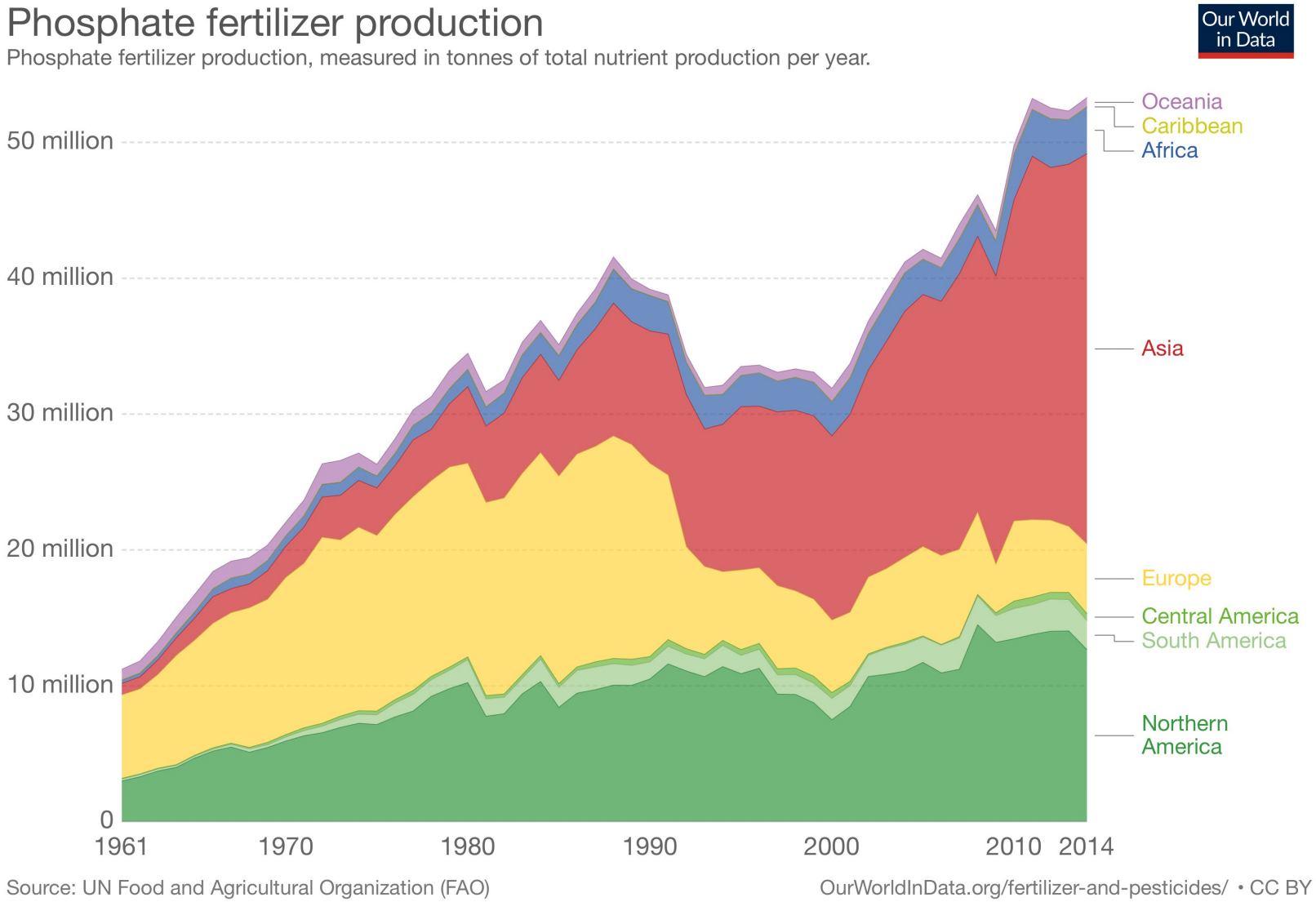
Water Resource | Covering phosphate demand by WW?



SOURCE: https://ourworldindata.org/fertilizer-and-pesticides

Water Resource | Urine as material source

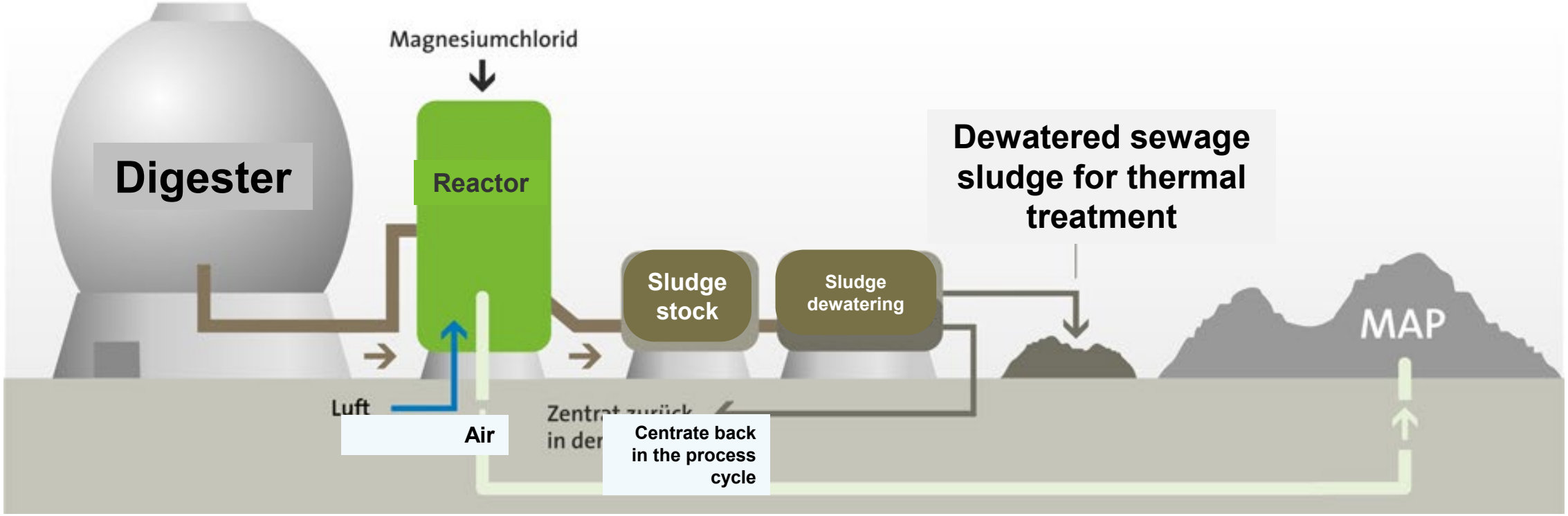
1m3 of Urin contains:

9.2	kg	Nitrogen
1.0	kg	Phosphorous
2.2	kg	Potassium

- Treatment (elimination of nutrients and energy) of 1 m^3 waste water takes on average 0.5 $kWh_{EL.}$
- The Production of 1 kg Nitrogen takes approx. 10 $kWh_{EL.}$
- The Exploration of 1 kg Phosphorous takes approx. 10 $kWh_{EL.}$

Conventional waste water treatment destroys valuable raw materials and energy by using fossil energy and **money!**

Next potentials | Nutrient Recycling (Magnesium, Ammonia, Phospate)



- **Products:**
  - e.g. Berliner Pflanze®
  - 0,5 kg 2.50 EUR
  - 2 kg 4,00 EUR
  - 5 kg 10,00 EUR

Source: Berliner Wasserbetriebe, 2016

Vacuum drainage system for the transport of waste water

Why using precious water for flushing excrements in arid environments?

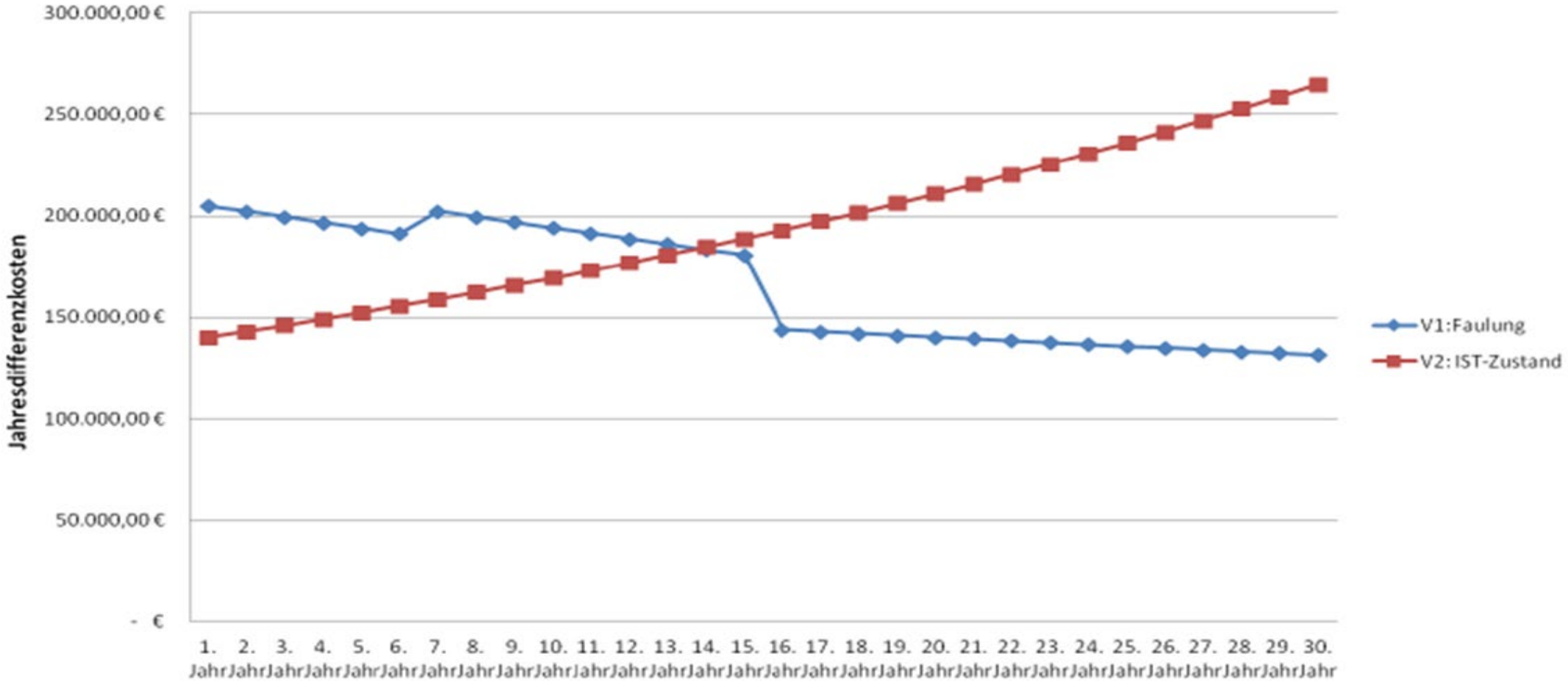
Source: Roediger Vacuum, 2010

SOURCE: google.com/images, (2019.); Accessed 05.MAY.2019

SOURCE:
https://blogs.worldbank.org/water/wastewater-treatment-critical-component-circular-economy

Next CE technologies | Energy positive WWTPs

Economic Evaluation and comparision of anaerobic versus aerobic WWTP



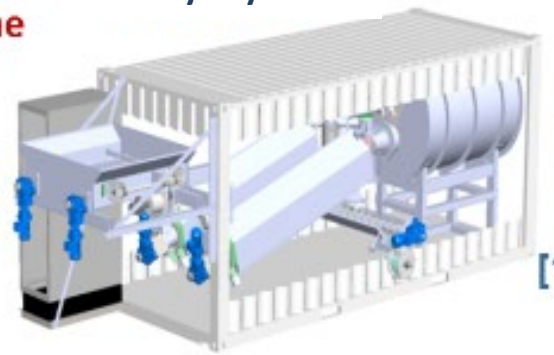
Source: Dipl.-Ing. Stefan Krieger, HYDRO-Ingenieure Energie & Wasser GmbH, 2011

Nutrient Mining | Phosphorus Recovery by PYREG®

1 GWh/a Wärme

Sludge
4,800 t/a
[25%TM]

Pyrolysis



Sludge

Ash
660 t/a
[100%TM]

Schlamm
40,000 t/a
[3%TM]
vgl. Stadt Trier

Avoid fertilizer change
1,730 t CO2/a
2,62 kg CO2 / kg P2O5
Source: ecoinvent

660 t/a

Market preis Phosphate rock
150 €/t (20 – 30% P)
1.000 €/t (100% P2O5)
Current willingness to pay in agriculture for ash-P
10 €/t (10% P2O5)

From Waste to Resource Management

Waste as a management failure
No waste strategy
Ressource Centers

Next CE STRATEGY | From waste to resource management

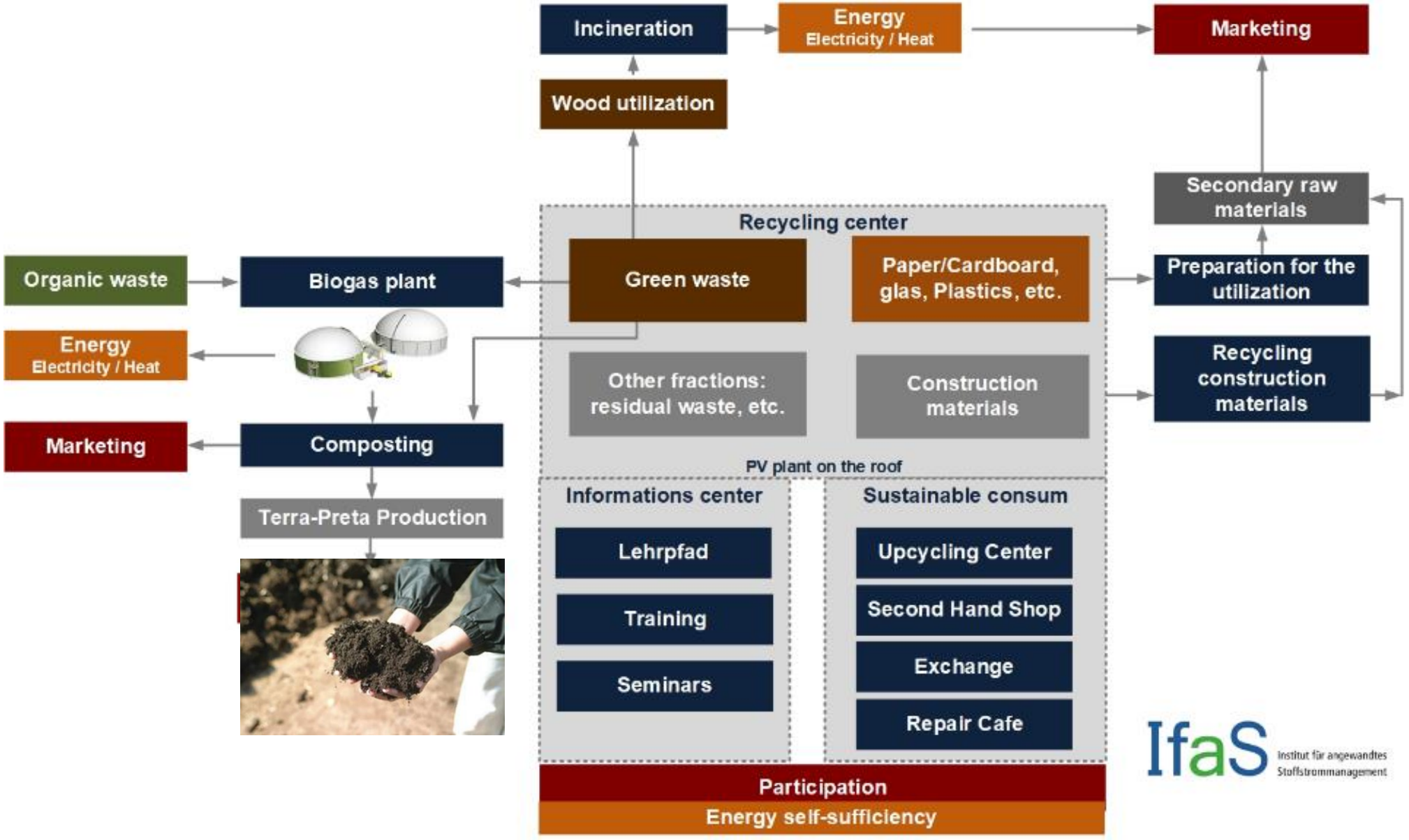
Resource centre instead landfill
No disposal in the future

☑

Next CE technologies | Resource Centre instead of landfills!

- Biowaste is seen and treated as a resource!
- Industrialised (space efficient) design
- Serving as base load power plants

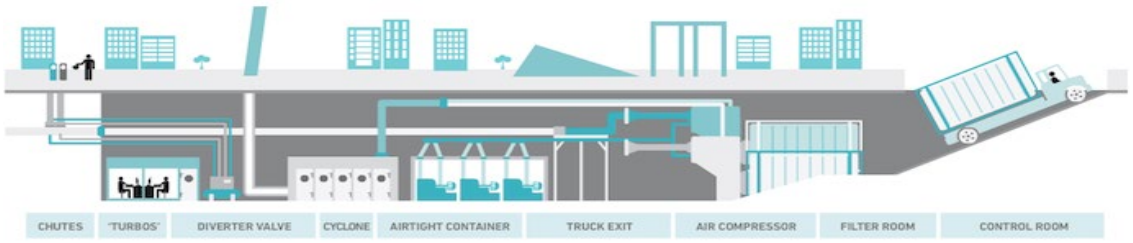
Next CE strategies | BioEnergy and Resource Centres (BERC)



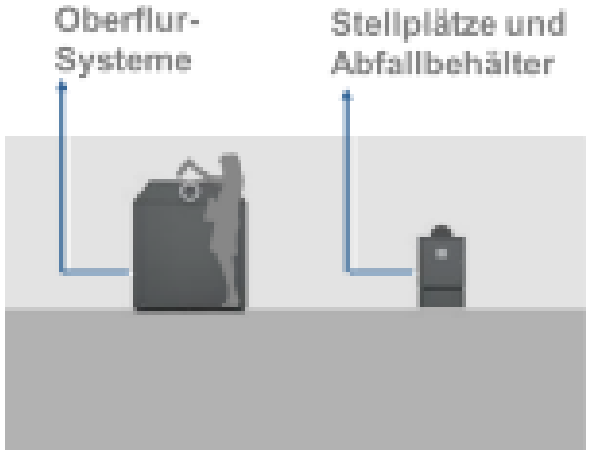
Next CE technologies | Innovative waste collection systems

Stationary and underground disposal system with vacuum technology

Underground Systems

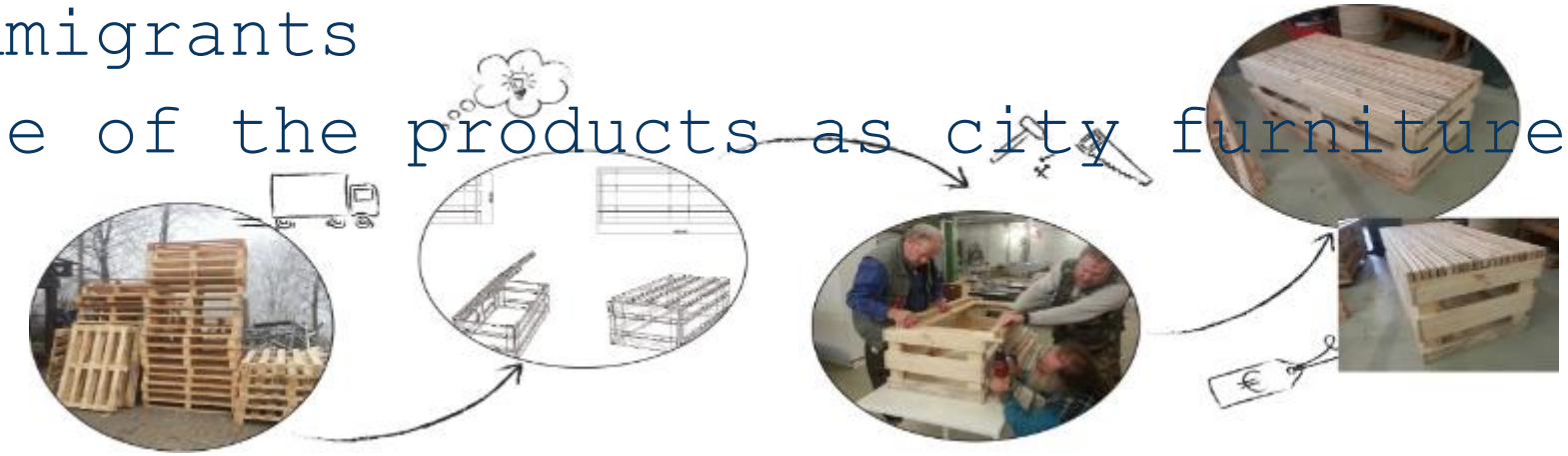


Above ground systems



Next CE strategies | Innovative Upcycling Centres

- Creative upgrade of the residues into new products
- Design of new product lines with artisans and artists
- Integration of jobseekers and immigrants
- Use of the products as city furniture



Selection of available materials → Product development and design process → Production → Marketing

Laayoune| Sustainable biomass production in desert areas

2009

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Marga-Marga| Municipal Waste Managment Centre

Socio-Economic Parameter	Evaluation Results	
	BAT concept	BAU Scenario
Total Investment	25.443.429 €	7.270.470 €
VAC- Net present cost value (in €)	-1,333,364 €	-1,357,258 €
CTT- Treatment costs per unit (in €)	-11,39 €	-11,67 €
Creation of new Jobs	120 - 188	40 - 64
Emission Reduction Potential in t CO_{2e}	2,827,309	Transport Emission
Operating Costs in € per t of MSW including transportation and disposal	10.16 €	18.55 €
Value Added Tax Potential (VAT 19%)	3.346.560 €	+ /- 0

2010

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Antalya| Resource and waste treatment centre Antalya

Regional added value	Total in 20 years of the project	
Emission reductions	10.180.193	t CO_2e
Solid fertilizer production	4.830.148	Tonnen
Liquid fertilizer production	3.037.710	Tonnen
Recyclable materials (papier, plastics, glass and metals)	4.258.758	Tonnen
Net electricity production	1.782.876	MWh_{el}
Net heath production	2.412.915	MWh_{th}
RDF production	2.411.874	Tonnen
Direct jobs	34,4	Average per year in 20 years

2011

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Global| Start of the international IMAT university network

- International IMAT partner universities:
  - Ritsumeikan Asia Pacific University, Japan
  - Akdeniz University, Turkey
  - Universidade Positivo, Brazil
  - Al Akhawayn University, Morocco
- Vision: Global IMAT University Network

2012



www.imat-master.com

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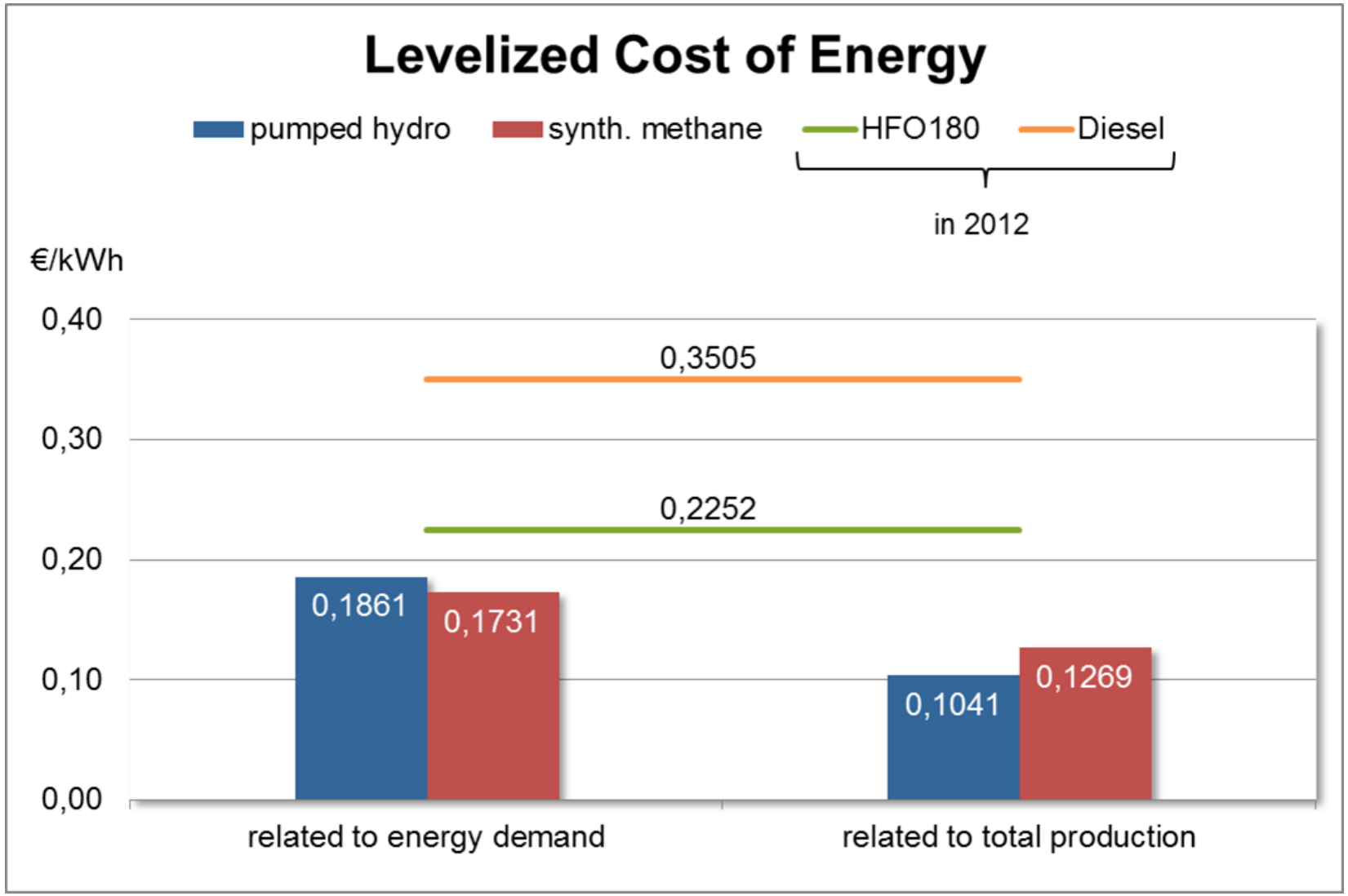
Cape Verde | ZE Concept: 100% RE Cape Verde



2013

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City of Tomorrow | Desert Rose Dubai 2014

Desert Rose = **First** global cutting edge, **Self Sufficient**, **Sustainable and Smart City-** The most **INNOVATIVE** Property development in the World

2014

Desert Rose 300MW SOLAR BANK

Desert Rose ECOPARK

Desert Rose housing and city center SOLAR ROOFTOP INSTALLATIONS

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Guizhou | Development of a strategy for ‘Ecotourism’

Methodology

Status quo assessment
Socio-economic development
Current status and development of the (eco)tourism sector
Assessment of the current (eco)tourism development strategy

Guizhou „ecotourism“ definition
Linking MFM & ecotourism
Criteria & indicators

Clustering of (eco)tourism sites
Definition of clustering criteria
Clustering and mapping

Cluster-specific material flow analysis tool
Material flow analysis tool
MFA → energy/water/waste/carbon „footprints“
Ranking
Gap analysis

Case studies
Circular Economy concepts for different clusters

Strategy for ecotourism in Guizhou Province
Policy recommendations
Novel tourism products

Research for Ecotourism

Human Capital Planning – Training & education

2014

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Dudelange | Energy and water-/ waste water concept

- Planning area: approx. 30 ha and GFA of 200,000 m²
- Energy concept
  - Demand analysis for stock and new construction (building efficiency)
  - Solar urban land-use planning (Revision of land-use plan)
  - and photovoltaic installations
  - RegPotential analysis for biomass, geothermal installations, wind power enerative supply with electricity, heat, cold
  - Development of 15 heat supply options (centralized and decentralized)
- Water-/Waste water concept
  - Water demand and waste water advent analysis
  - Development of water utilization and waste water disposal opportunities
    - Rain water utilization, drainage concept, constructed wetlands
    - Treatment opportunities of separate material flows (e.g. grey water treatment)
    - Semi-central treatment plants, energetic utilization of segment flows

2015

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Europe | LIFE-ZENAPA

Climate Protection
Reduction of greenhouse gas emissions by utilizing regional potentials in large-scale protection areas.

Biodiversity Protection and restoration of ecosystem services

Bioeconomy Increased "value" from a hectare through a sustainable country "economy".

2016

Key Data:

- 16 Partners /4 Co-Financers
- Duration: 2016 until 2024
- **17,168 Million € budget**
- 8,157 Million € contribution of the LIFE Programme of the EU
- Implementation of German and EU climate protection targets (CAP 2020 and CPP 2050) as well as German and EU biodiversity and

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Namibia | Development of Biomass Industrial Parks

Problem

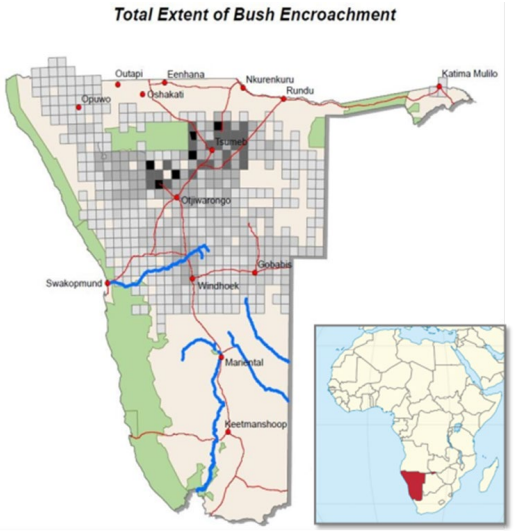
- >30-45 million ha of productive rangeland bush encroached at an annual growth rate of 3-5%
- Severe impact on biodiversity, groundwater recharge and livestock productivity
- Annual agronomic losses of 100 million EUR due to reduced rangeland productivity (2/3 of total productivity)

Opportunity

- >300-450 million tons of standing "unwanted" but valuable biomass with annual growth of 9-18 million tons
- Increasing demand on regional and international markets
- Socio-economic benefits: rangeland restoration, climate

and

2017



"Bush Encroachment is a National Disaster"
Hon. Min. MAWF, National Rangeland Policy 2012

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Namibia | Development of Biomass Industrial Parks

Services

Balancing Unit

Loading & Separation

Logistics & Rental Centre

Workshop

Raw Material Processing

Raw Wood

Field Wood Chips

Fine WC

Shredding

Grinding

Manufacturing

Carbonization

Compressed FW

Briquetting

Charcoal Activation

BtL

Biomass Recycling

Heat & Power

WPC

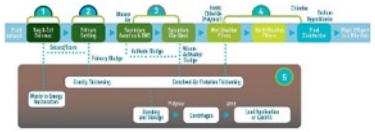
PYREG

Animal Feed

Syncraft

KSW

Solid & Liquid Waste Management

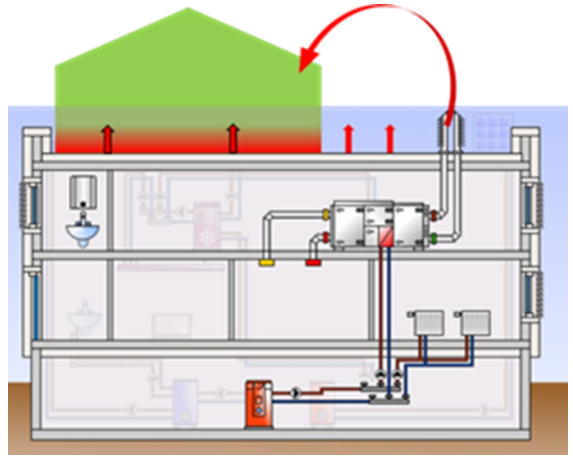


North-West Europe | GROOF Greenhouses to Reduce CO2 on Roofs

- Project title and acronyms — Greenhouses to Reduce CO2 on Roofs (GROOF)
- Project duration: — 48 months (September 2018 – September 2021)
- Budget: — 2,8 Mio. €
- Programme: — INTERREG VB NWE
- Programme priority — Priority Axis 2 Low carbon
- Program priority specific objectives — To facilitate the uptake of low carbon technologies, products, processes and services in sectors with high energy saving potential, to reduce GHG emissions in NWE
- Project Partners: — 11
- Project Leader: — Conseil pour le Développement Economique de la Construction (CDEC)
- Project Area — Luxemburg, Spain, Germany, France and Belgium

Interreg North-West Europe GROOF
European Regional Development Fund

2018



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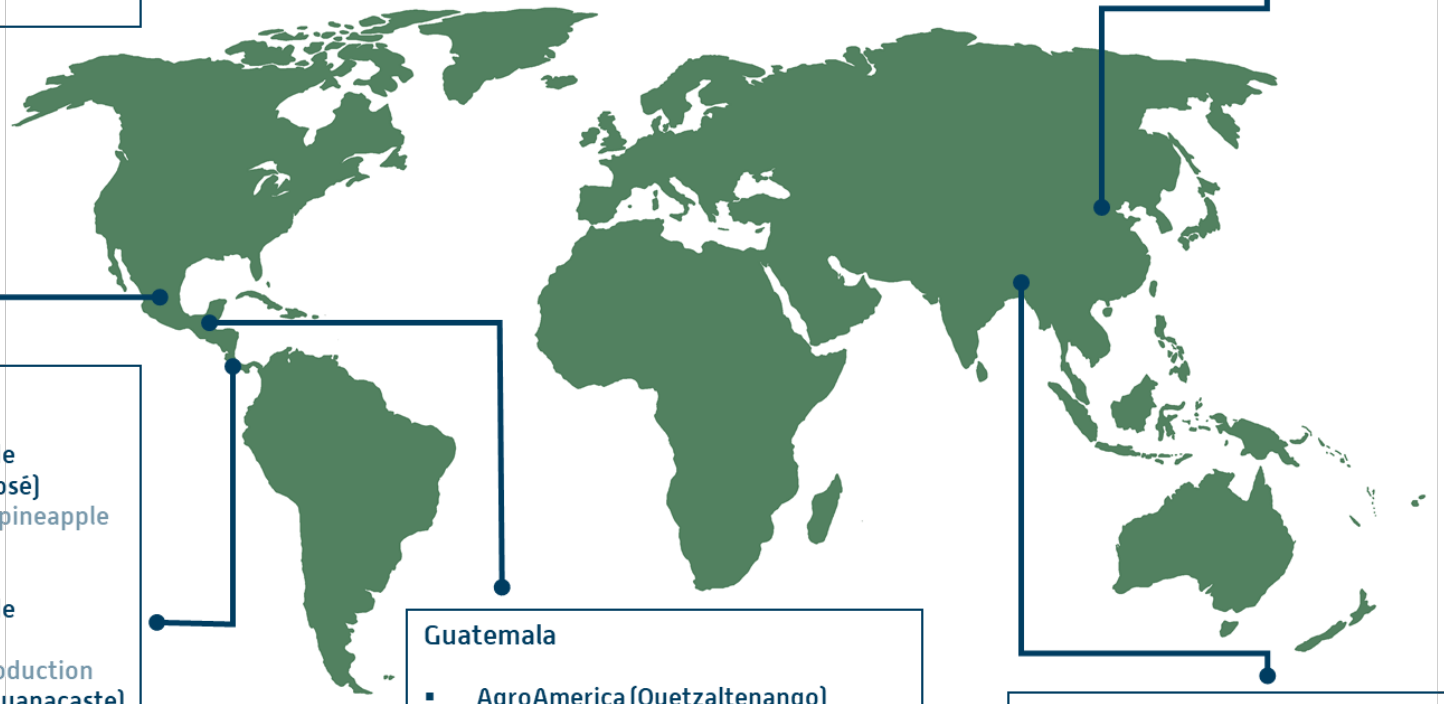
Global | REC – Resource & energy efficiency checks

Mexico

- Tabasco (Beta San Miguel, Santa Rosalia de la Chontalpa)
  Agro-industry: Sugar production
- Quintana Roo Beta (San Miguel, San Rafael de Pucté)
  Agro-industry: Sugar production

Republic of China

- Kempinski Hotel & BLC (Beijing)
  Hotel and food service industry



2019

KFW DEG

Costa Rica

- Ingenio El Viejo (Filadelfia de Guanacaste, Limón & San José)
  Agro-industry: Rice and pineapple production,
  Service industry
- Ingenio El Viejo (Filadelfia de Guanacaste)
  Agro-industry: Sugar production
- Ingenio Taboga (Cañas de Guanacaste)
  Agro-industry: Sugar and alcohol production
- LAICA (Cañas de Guanacaste)
  Agro-industry: Sales & distribution of sugar and liquid sugar

Guatemala

- AgroAmerica (Quetzaltenango)
  Agro-industry: Banana and palm oil production
- IMSA - Ingenio Magdalena (Escuintla)
  Agro-industry: Sugar and alcohol production

Bangladesh

- ANANTA Apparels Ltd. (Dhaka, Bangladesh)
  Textile and apparel industry

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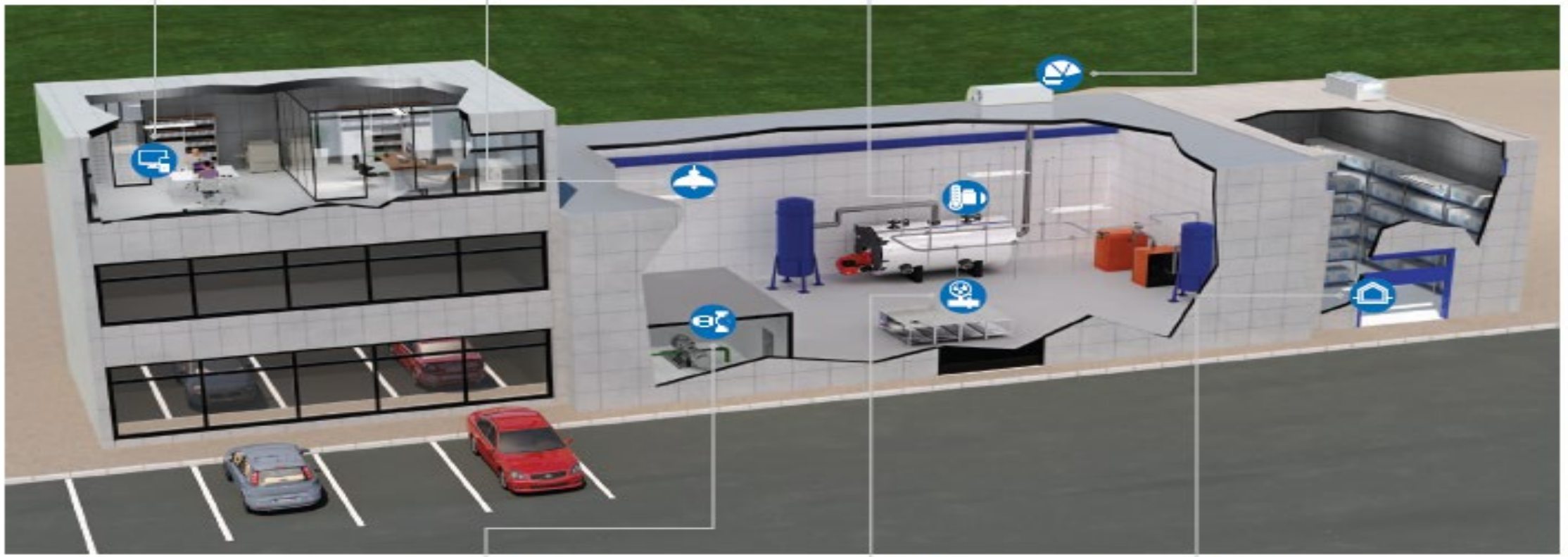
Examples | Energy efficiency potentials

IT up to **75%**

Lighting up to 70%

Heat Processes up to **30%**

HVAC up to **65%**



Pump systems up to **30%**

Compressed Air up to **50%**

Building Envelope up to **80%**

Source: DENA

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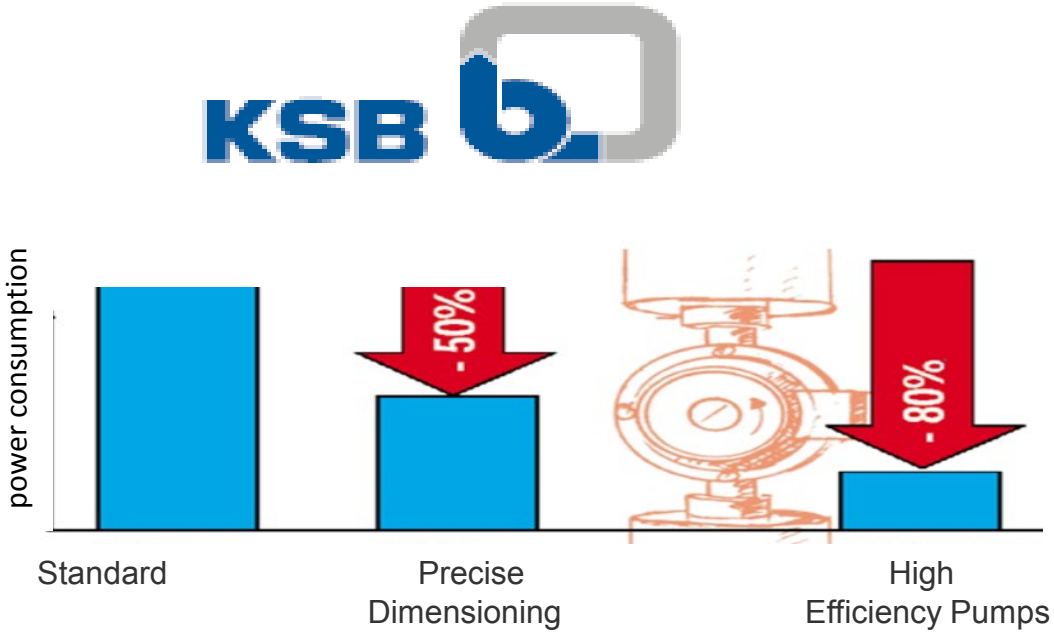
Energy | Energy efficient pump systems

Power, energy cost and GHG reductions by precise dimensioning, frequency inverter, modern high efficiency pumps and motors



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MFA | Business case ”CHWP” College of Agriculture

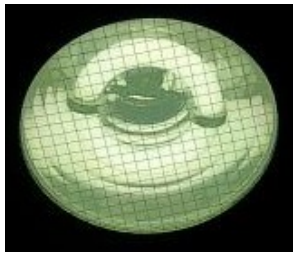
η: 35%

η: 89%

PARAMETER	VALUE [Old]	VALUE [NEW]	[Unit]
Installed Electricity capacity	37	13.65	kW
Electricity demand	213,712	78,842.4	kWh
Electricity Saving		134,869.60	OMR/a
Investment		6,121.38	OMR
Monetary saving		42,534.74	OMR/a
GHG Abatement		114.64	tCO_2e
Payback period		1.8	a
Internal Rate of Return		65	%

Source: KSB Etabloc PumpDrive

Example Lighting | Production hall illumination



Economic Evaluation	
Electricity Demand "Punta"	52.569 kWh/a
Electricity Demand "Valle"	10.514 kWh/a
Electricity Demand "Nocturno"	77.101 kWh/a
Energy saving "Punta"	42.768 kWh/a
Energy saving "Valle"	8.554 kWh/a
Energy saving "Nocturno"	62.726 kWh/a
Cost saving "Punta"	15.950 USD/a
Cost saving "Valle"	7.892 USD/a
Cost saving "Nocturno"	6.717 USD/a
Total Monetary savings	**30.559 USD/a**
Price per Lamp	226 USD
Investment	**44.748 USD**
Payback	**2,81 a**

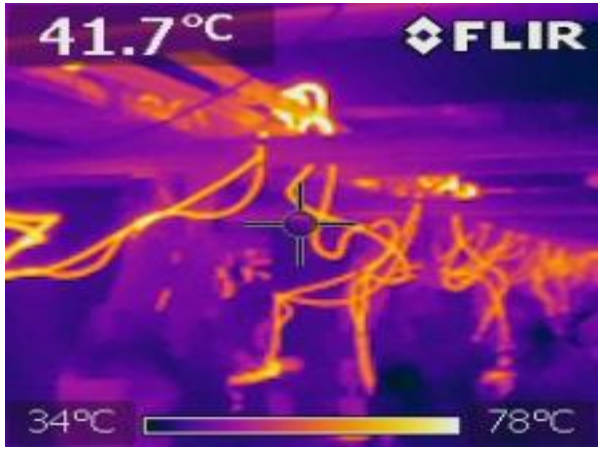
Energy Efficiency Potential of 81%

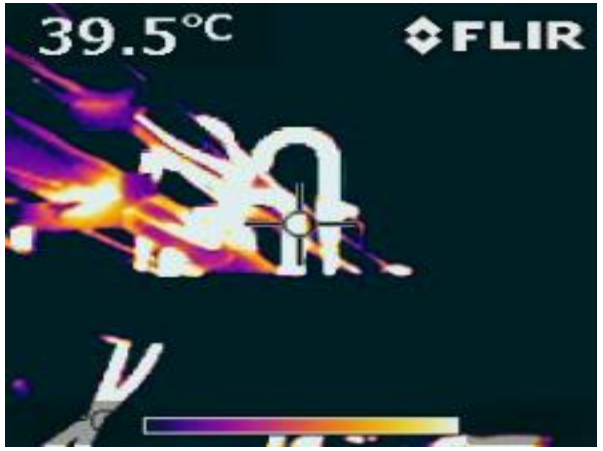
GHG abatement potential of 4,333 $kgCO_2$

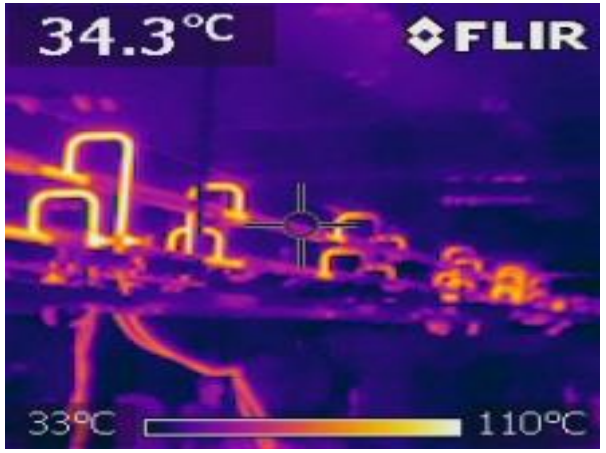
Capacity reduction potential of 47,5kW

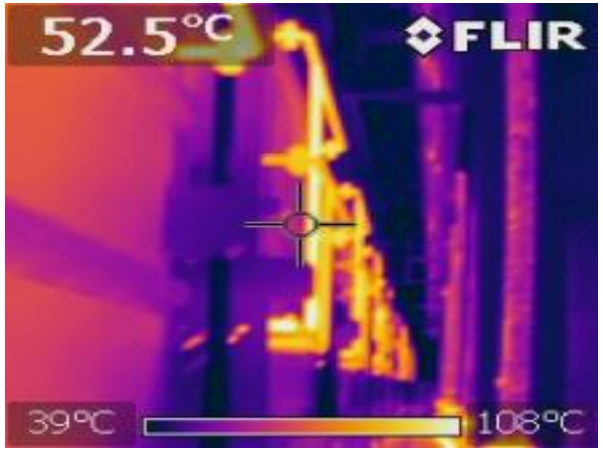
Increasing operating hours

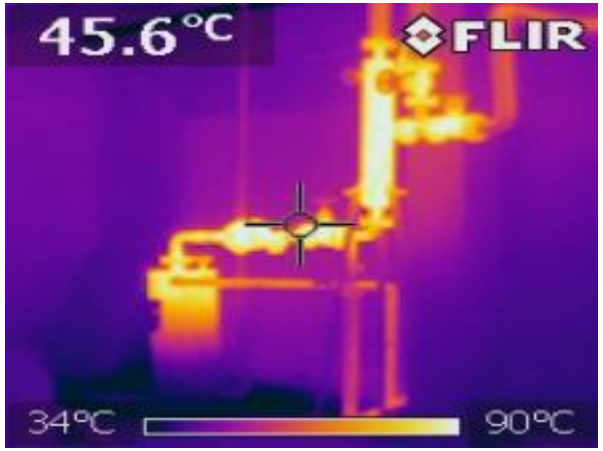
Thermal Energy | Insulation management

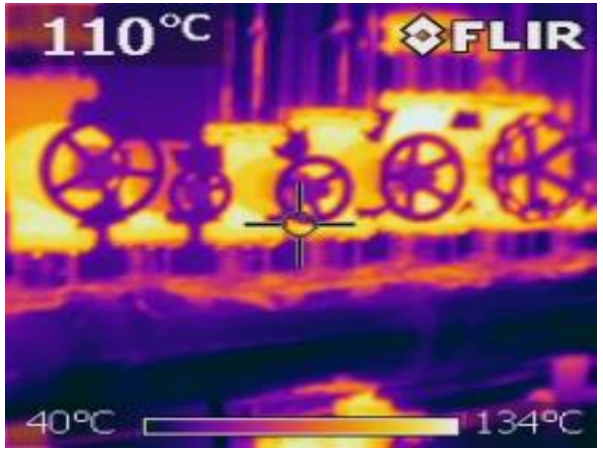


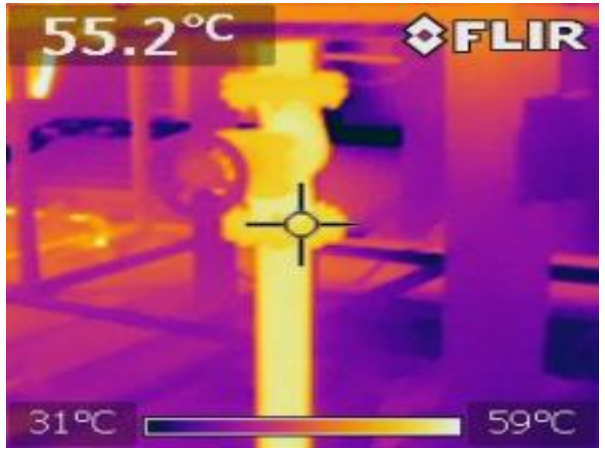


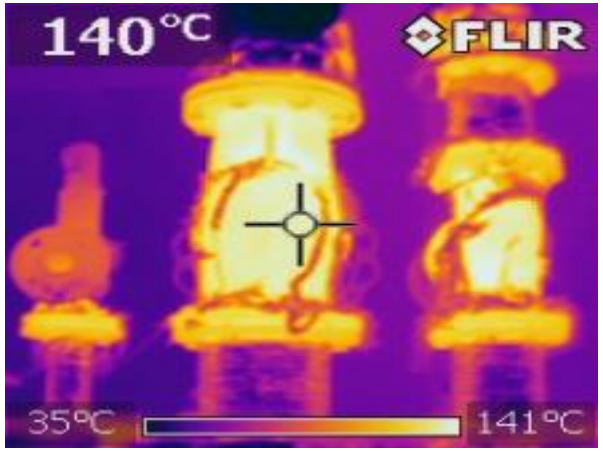






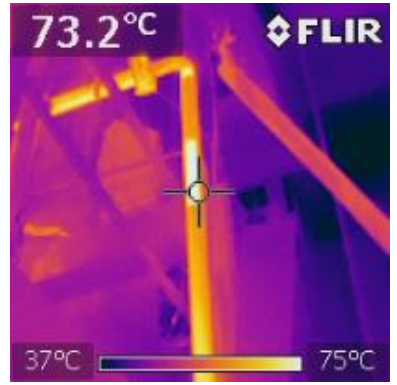






Thermal Energy | Insulation management

Piping Insulation					
	[Unit]	Status Quo (non-insulation)	1.5" insulation	2.0" insulation	3.0" insulation
Total heat energy loss	[kWh/a]	473,612	35,382	30,907	25,643
Heat energy savings	[kWh/a]		438,230	442,705	447,970
Heat energy costs	[USD/a]	18,546	1,386	1,210	1,004
Monetary savings	[USD/a]		17,161	17,336	17,542
Total Invest (after taxes)	**[USD]**		**16,141**	**18,153**	**27,359**
Static PBP	**[a]**		**0.9**	**1.0**	**1.6**
CO_2 mitigation potential	[t CO_2/a]		152	154	155



Water Management | Mapping water potentials

1) Material Flow Analysis of current (waste) water streams
   - Water Mapping, HotSpots Identification, LCoW
2) Evaluation of different efficiency and/ or treatment measurements and/or technologies
   - Process water production, WW avoidance, Sludge-to-Value
3) Economic evaluation
   - Determination of CAPEX
   - Project based key performance indicators (KPI's) [IRR, NPV, Payback]

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Water Mapping | Third Step: Economic evaluation

- Identify treatment/re-use/recycling technologies
- Evaluation of (fresh and/or waste) water saving potentials
- Economic valuation and ranking of measures

Rank	HotSpot	Potential savings [%]	Potential savings [m³/a]	Potential savings [USD/a]	Investment [USD]	Simple Payback [Years]
1	Avocado	50%	52.200,00	4.249,62	25.000,00	5,88
2	Red Pepper Autoclaving	80%	57.456,00	4.677,51	4.000,00	0,86
3	Mango	50%	34.800,00	2.833,08	22.000,00	7,77
4	Artichokes Rosting	0%	-	-	-	-
5	Artichokes Cleaning	50%	25.650,00	2.088,17	14.000,00	6,70

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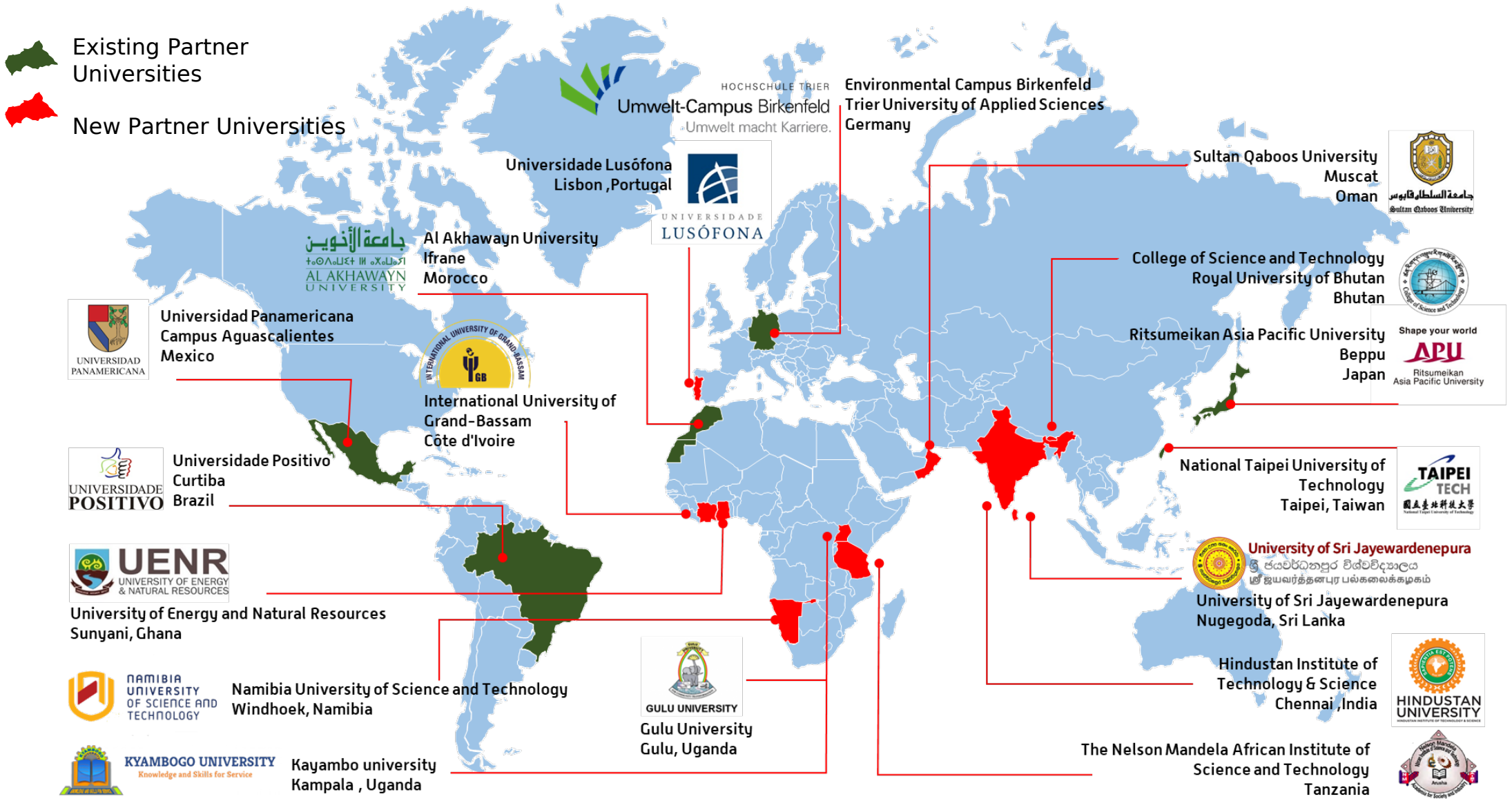
IMAT | Combining Education, Research and Export Promotion



Activate potentials | Just a deeper look!

- Understand your system
- Price the unprized
- Compare to BAT
- Listen to weak signals

➢Communicate!

IfaS Institut für angewandtes Stoffstrommanagement

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