FULL SCALE DEMONSTRATION OF ENERGY POSITIVE SEWAGE TREATMENT PLANT CONCEPTS TOWARDS MARKET PENETRATION

Loderer Christian

Kompetenzzentrum Wasser Berlin gGmbH

10.2-12.2016 , 14. Symposium der Energieinnovation, (Graz)

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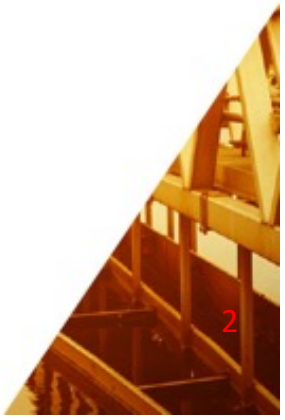

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15 Jahre Kompetenzzentrum Wasser Berlin

- Gründung 2001 als gemeinnützige Gesellschaft (gGmbH) Konsortialvertrag Land Berlin und Veolia
- 25 Mitarbeiterinnen und Mitarbeiter
- Über 70 Forschungsvorhaben
- Zukunft: Berliner Forschungszentrum für angewandte Wasserforschung als Teil der „Berliner Landesfamilie“

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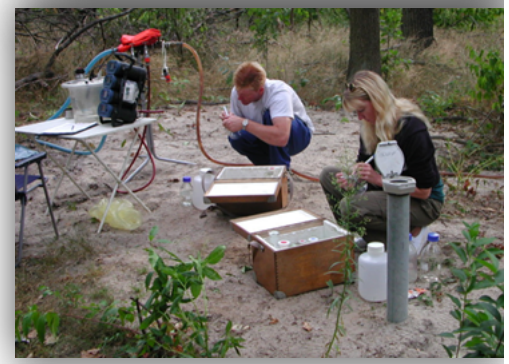
Zertifiziert nach
EN DIN ISO 9001:2008

Was wir tun

- Entwicklung und Durchführung von praxisnahe Forschungsvorhaben
- Entwicklung und Leitung von nationalen und internationalen Forschungsverbünden
- Lieferung von Kontinuität durch festen Mitarbeiterstab
- Veröffentlichung von sämtlichen Forschungsergebnisse
- Kommunikation von Wissenschaft in die Öffentlichkeit
- Qualitätsmanagement nach DIN EN ISO 9001:2008



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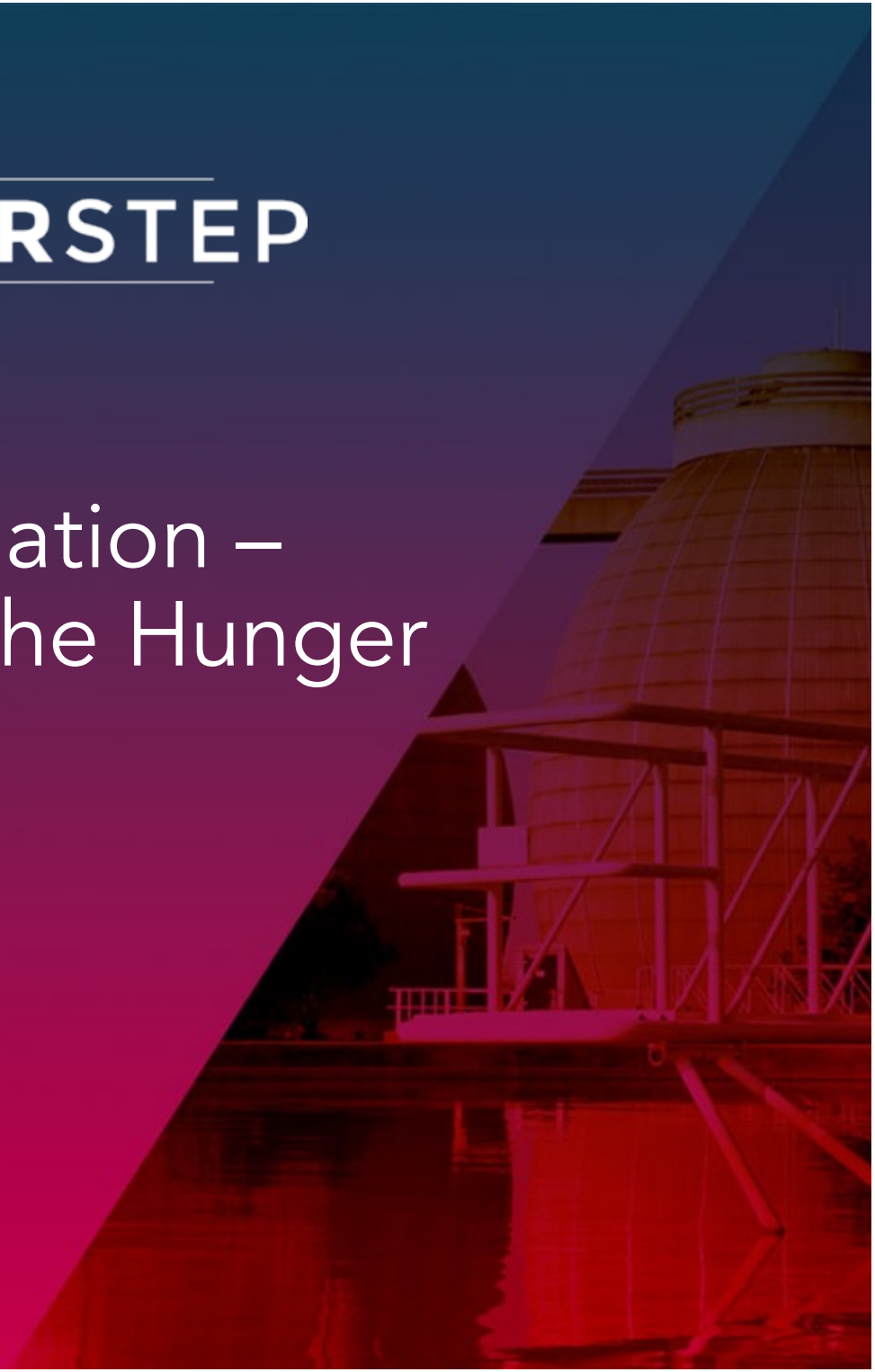
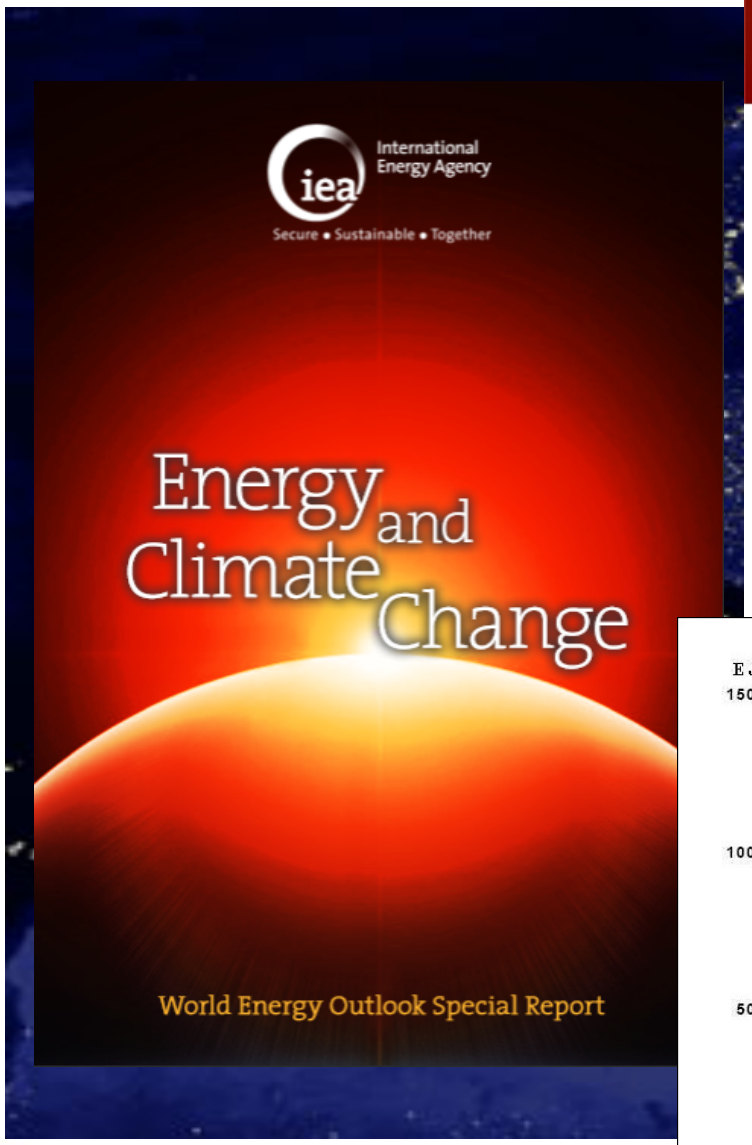
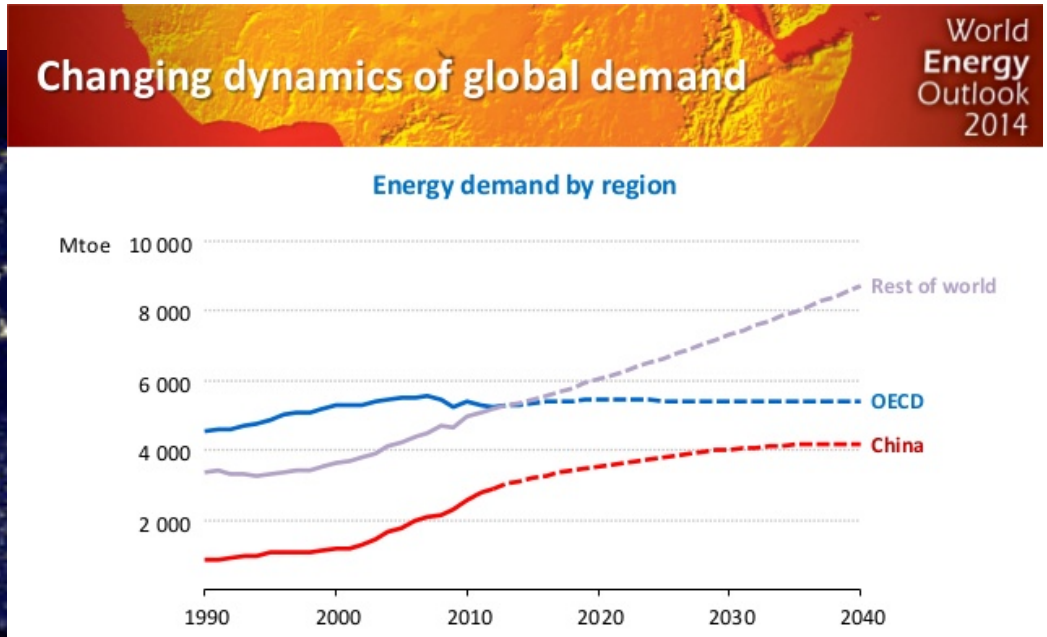
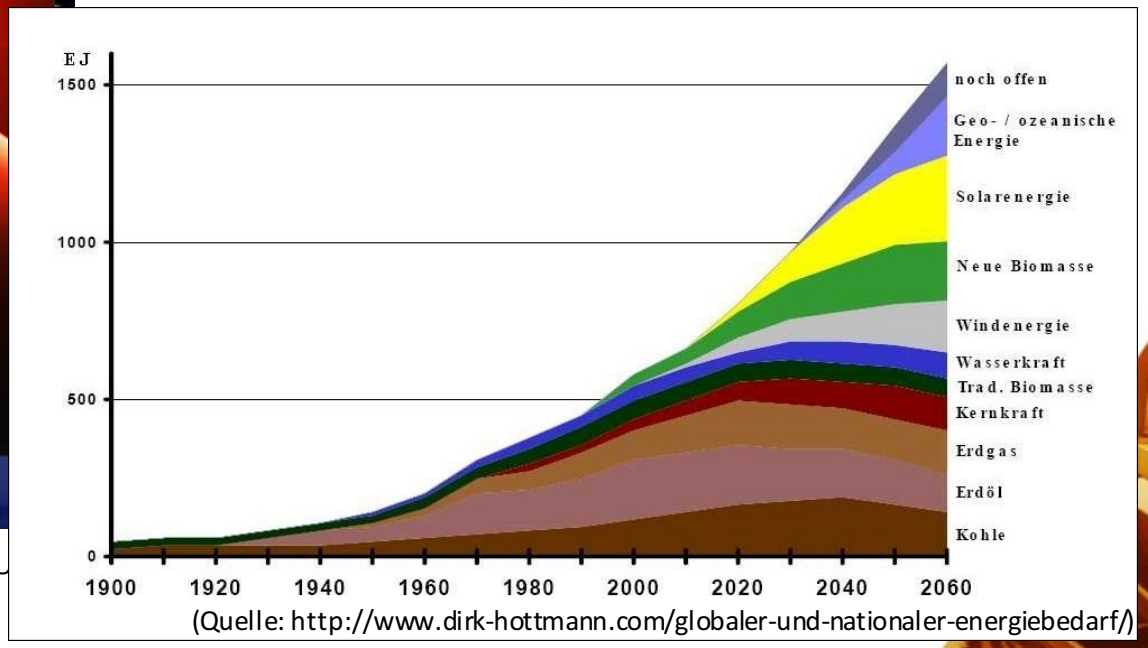
Energiesituation – Der unersättliche Hunger



Der weltweite Hunger nach Energie







(Quelle: http://www.dirk-hottmann.com/globaler-und-nationaler-energiebedarf/)

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Die Geschichte ist auch nicht NEU in Deutschland

(Quelle: Wikipedia.de)

„Der Himmel über dem Ruhrgebiet muss wieder blau werden“

(Willi Brandt, 1961)

(Quelle: Wikipedia.de)

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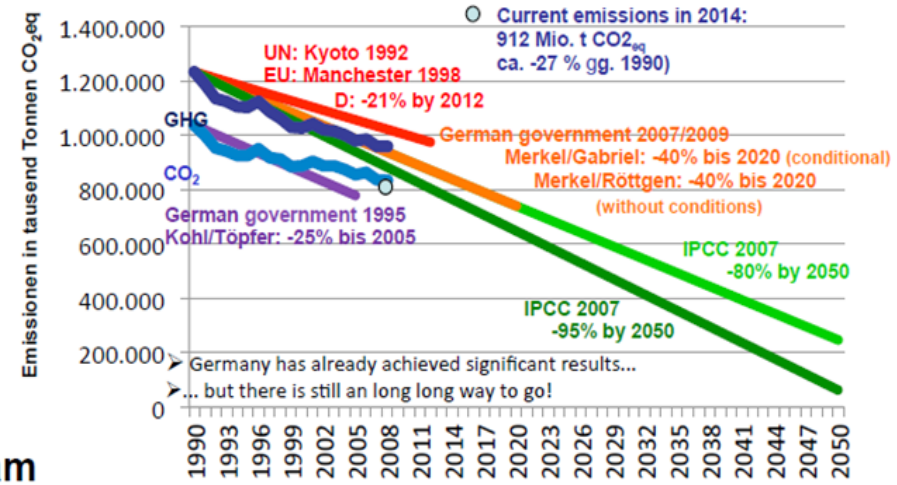
Energiewende in Deutschland – ambitionierte aber notwendige Ziele



- **THG-Emissionsreduktion:**
  80-95% bis 2050
- **Anteil Erneuerbarer Energien am Bruttoendenergieverbrauch:**
  60% bis 2050
- **Anteil der Stromerzeugung aus EE:**
  80% bis 2050
- **Senkung des Energiebedarfs gg. 2008**
  - Bruttoendenergiebedarf um 50% bis 2050
  - Bruttostrombedarf um 25% bis 2050
- **Ausstieg aus der Kernenergie**
  Abschaltung aller Kernkraftwerke bis Ende 2022

Quelle: Prof. Manfred Fischedick, Vizepäsident Wuppertal Institut für Klima, Umwelt und Energie

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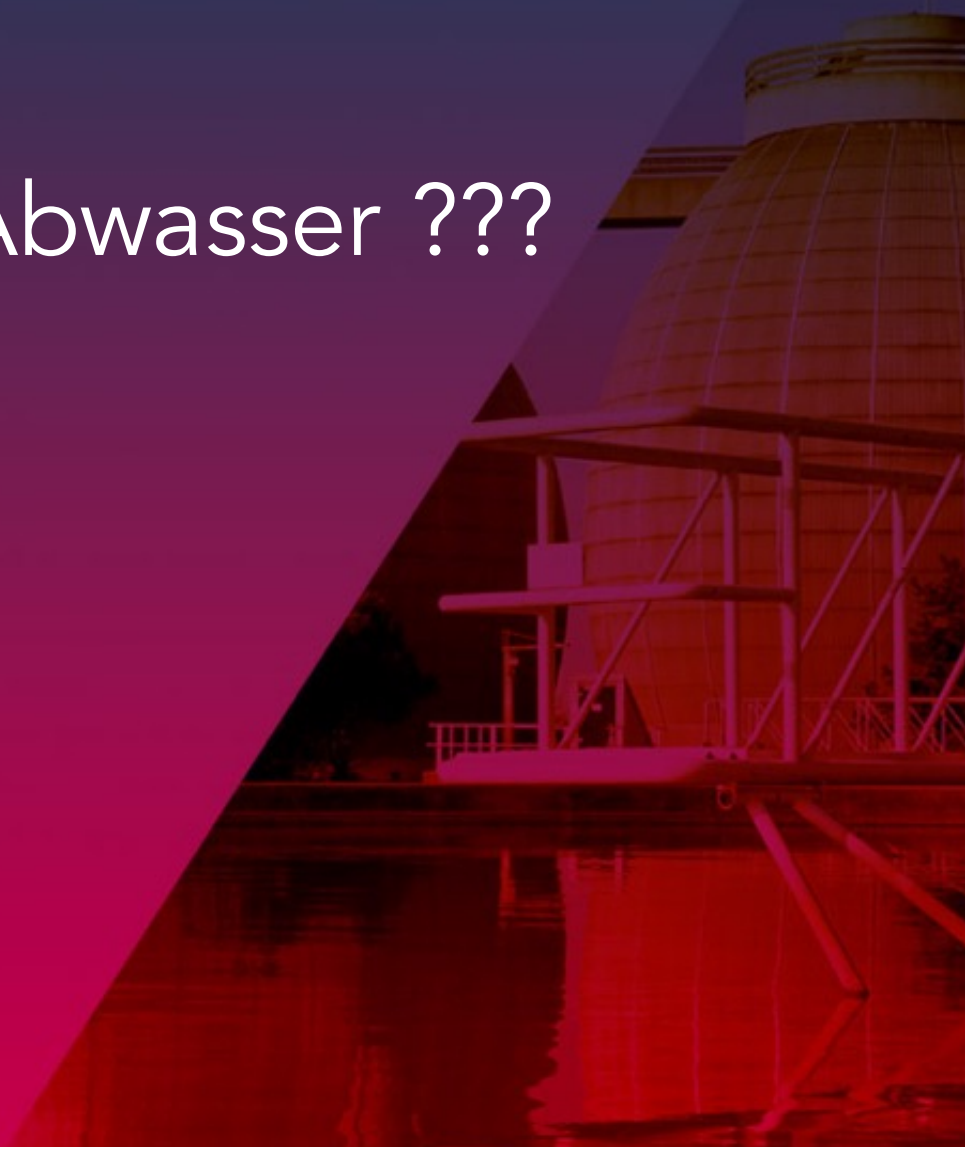
Energie und Abwasser ???



Energie & Abwasser??

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Energie & Abwasser??

Calculation thoughts by Prof. Helmut Kroiss (TU Vienna)

Assumption:

Population 2030: ~ 8,4 Bil. People of which ~ 65% in urban settlements

Goal:

New wastewater infrastructure for 40% of global population in 2030 to meet all the requirements of Goal 6:

Result:

Every day *treatment facilities for* ***600.000*** *inhabitants will have to go into operation*

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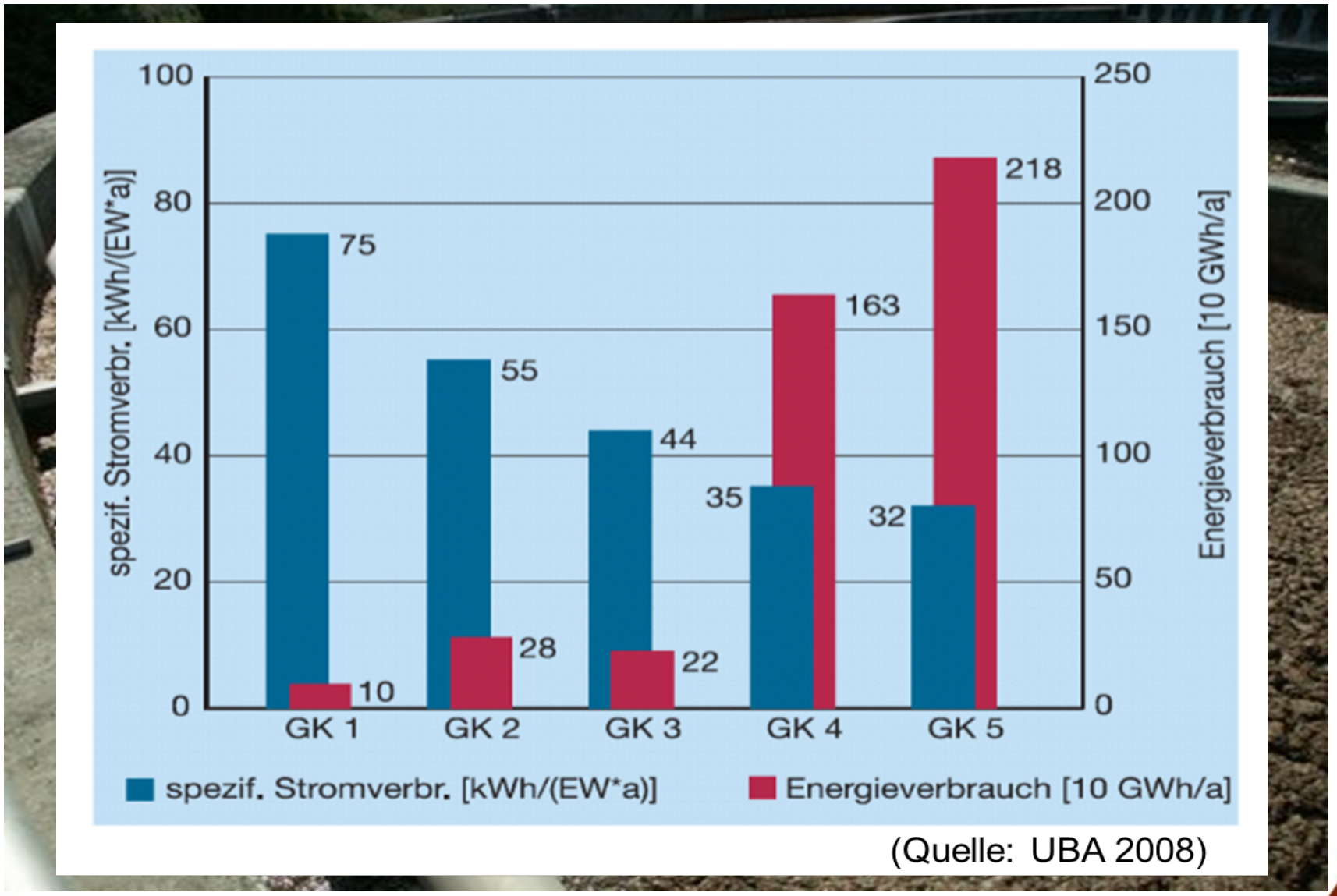
Energie & Abwasser??



(Quelle: UBA 2008)

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Energie & Abwasser??

Calculation thoughts by POWERSTEP

Assumption:

Electricity demand 32 kWh / person *year

European population: ~500 – 750 Millions

Result:

Electricity consumption per year for wastewater treatment services (Large plants)

16,000 – 24,000 GWh / year

= the annual power generation of 2-3 (1 GW power plants)

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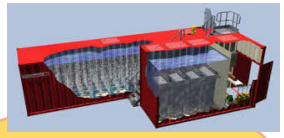
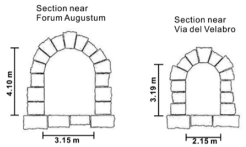
Evolution der Abwasserreinigung



NEUE Konezpte

Reinigungs-optimierung

Abwasser-reinigung



Abwasser-sammlung

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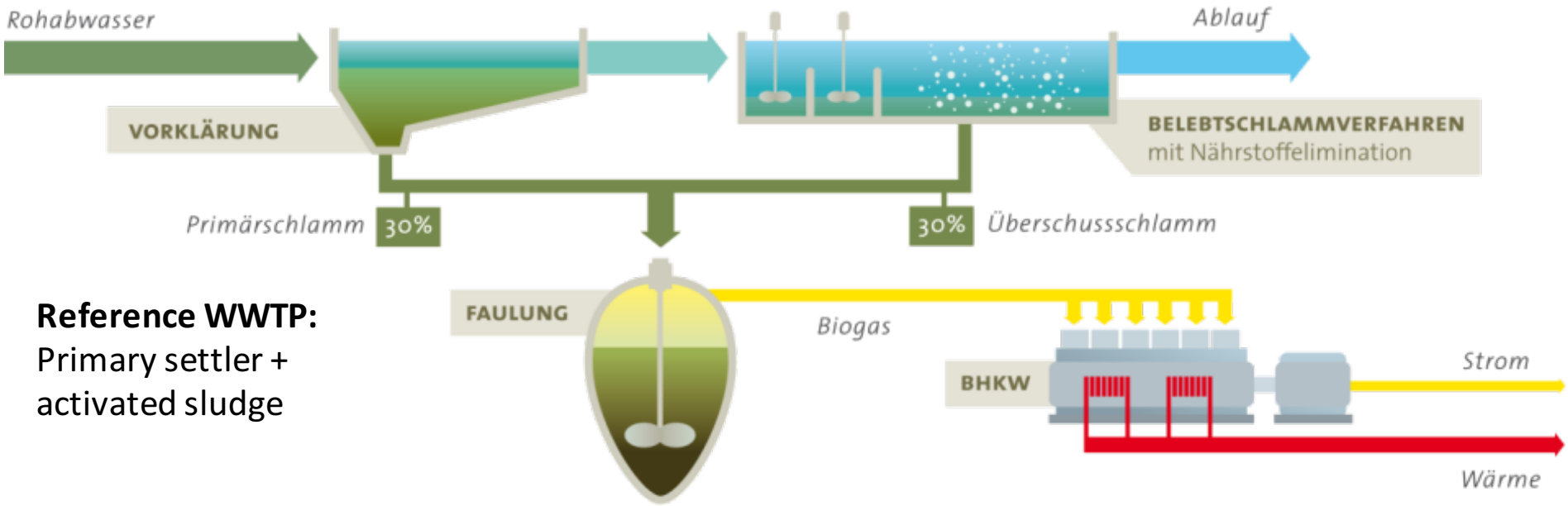
Abwasserreinigung – State-of-the-art



Reference WWTP:
Primary settler + activated sludge

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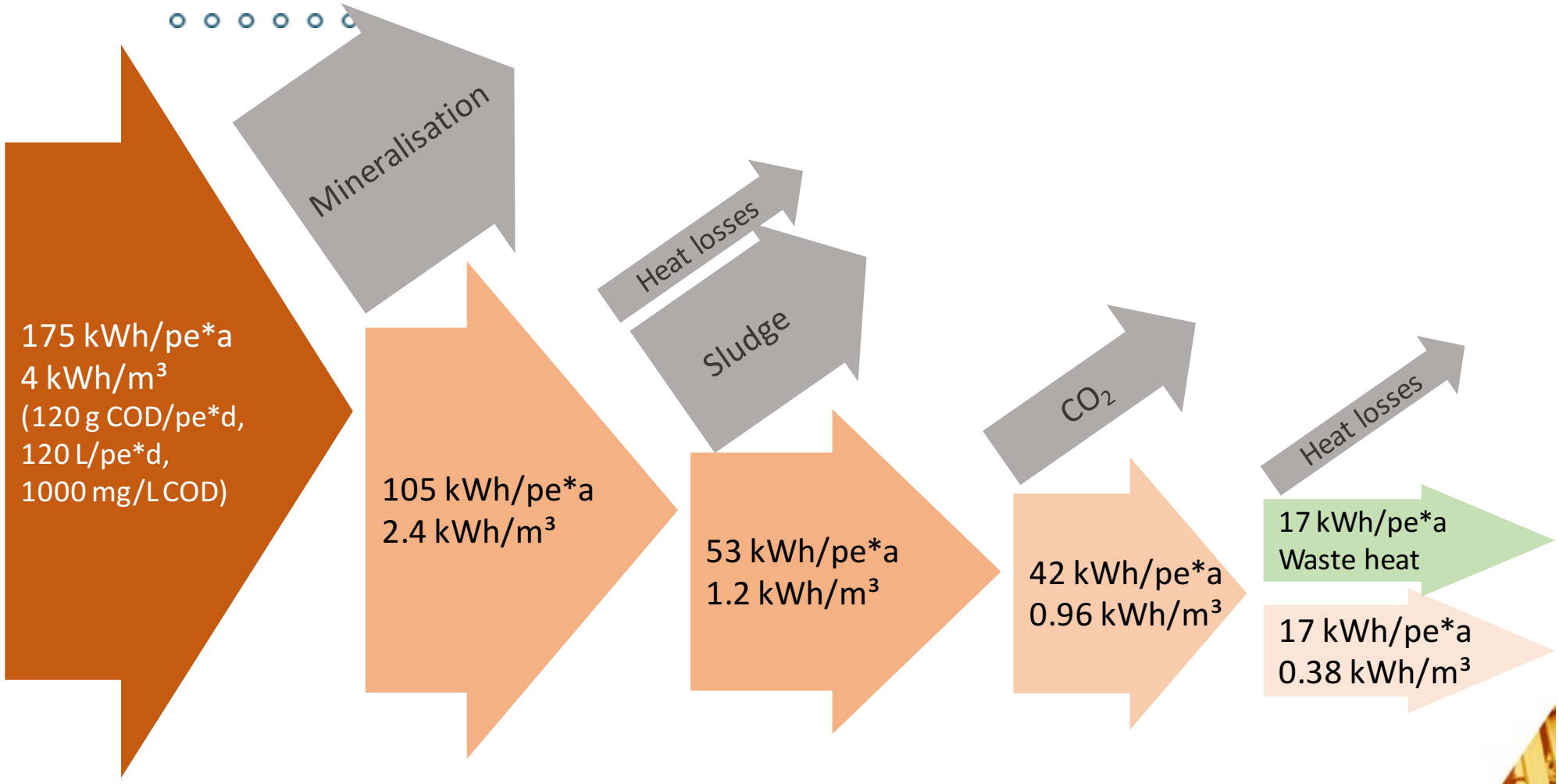
Abwasserreinigung – State of the Art



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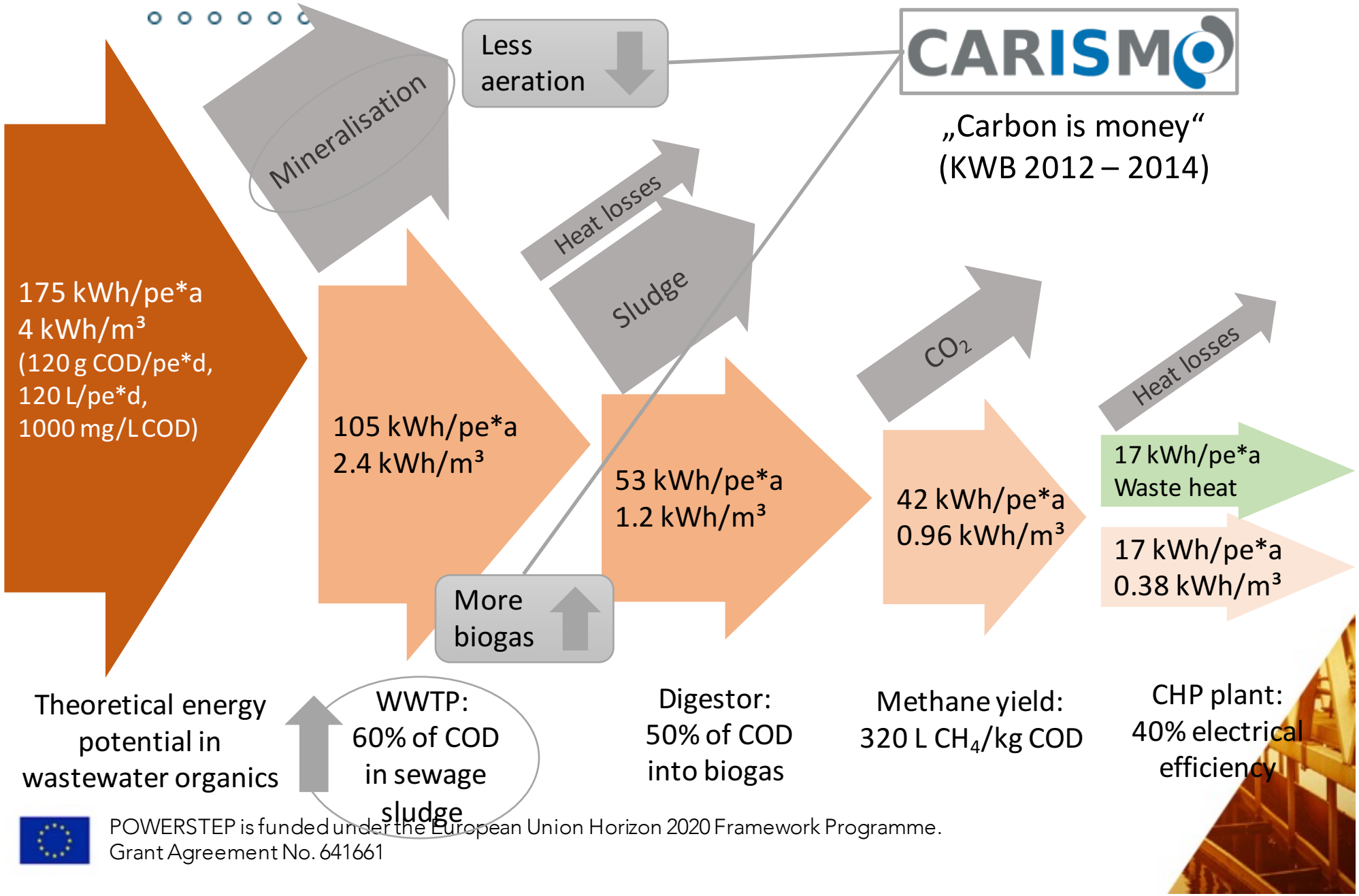
NEUE Konzepte

Nutze das Potenzial im Abwasser



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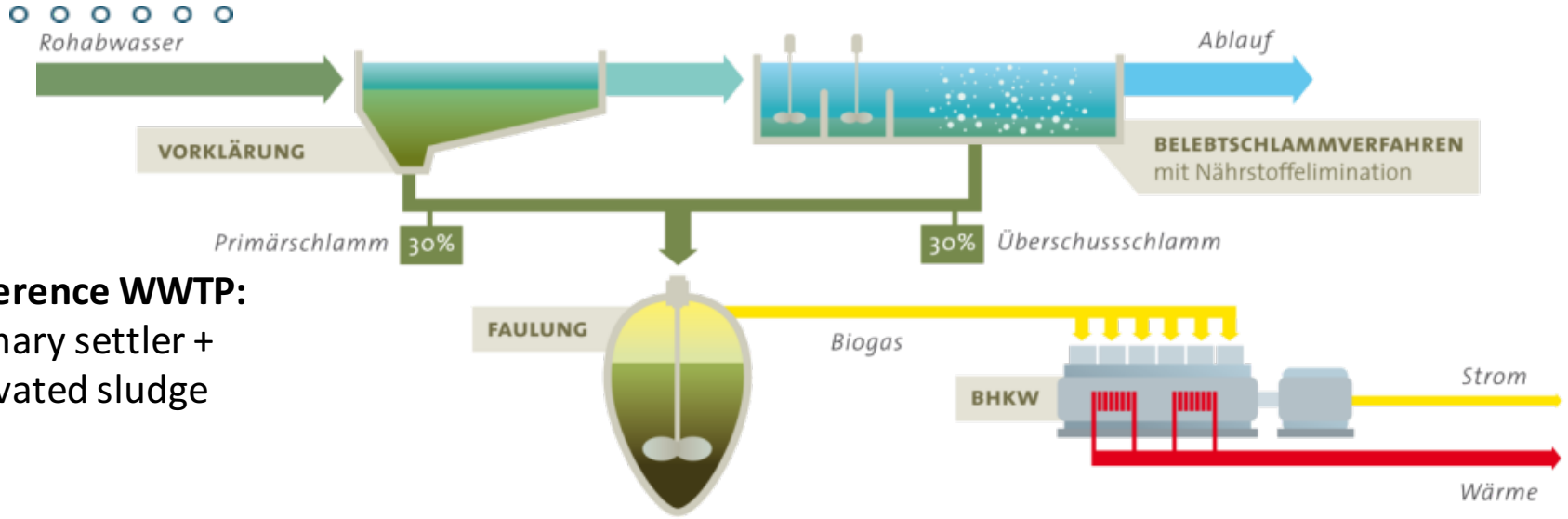
State-of-the-art versus NEUE Konzepte



Reference WWTP:
Primary settler +
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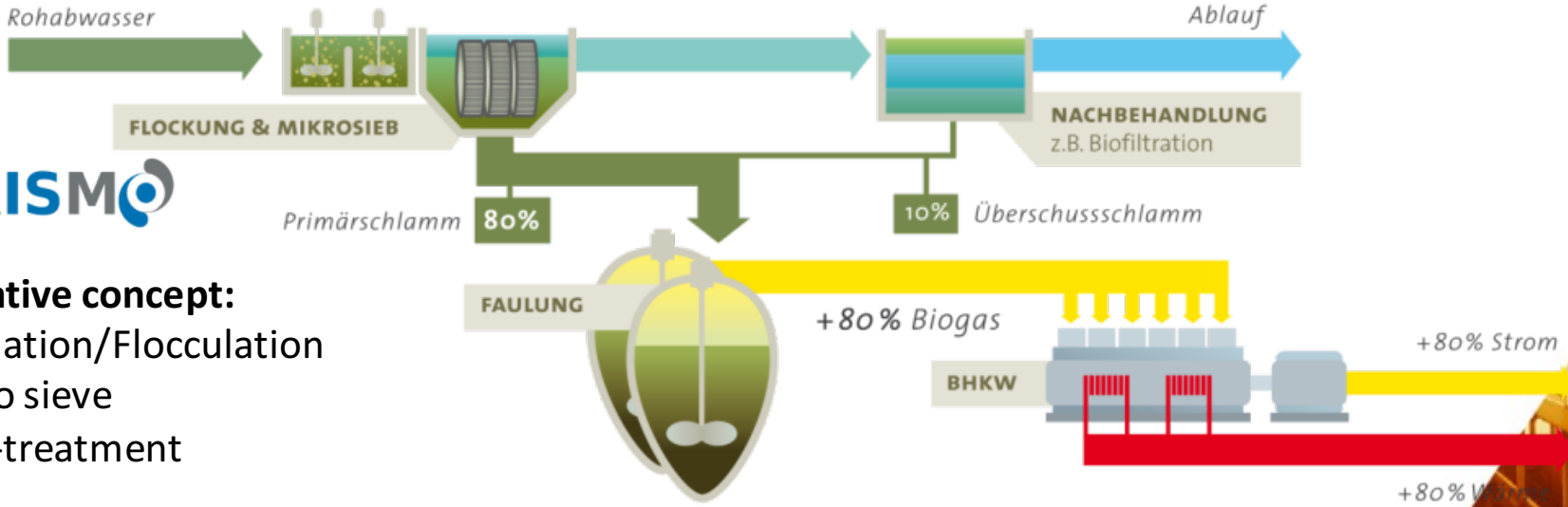

CARISMO

Innovative concept:
Coagulation/Flocculation
+ micro sieve
+ post-treatment

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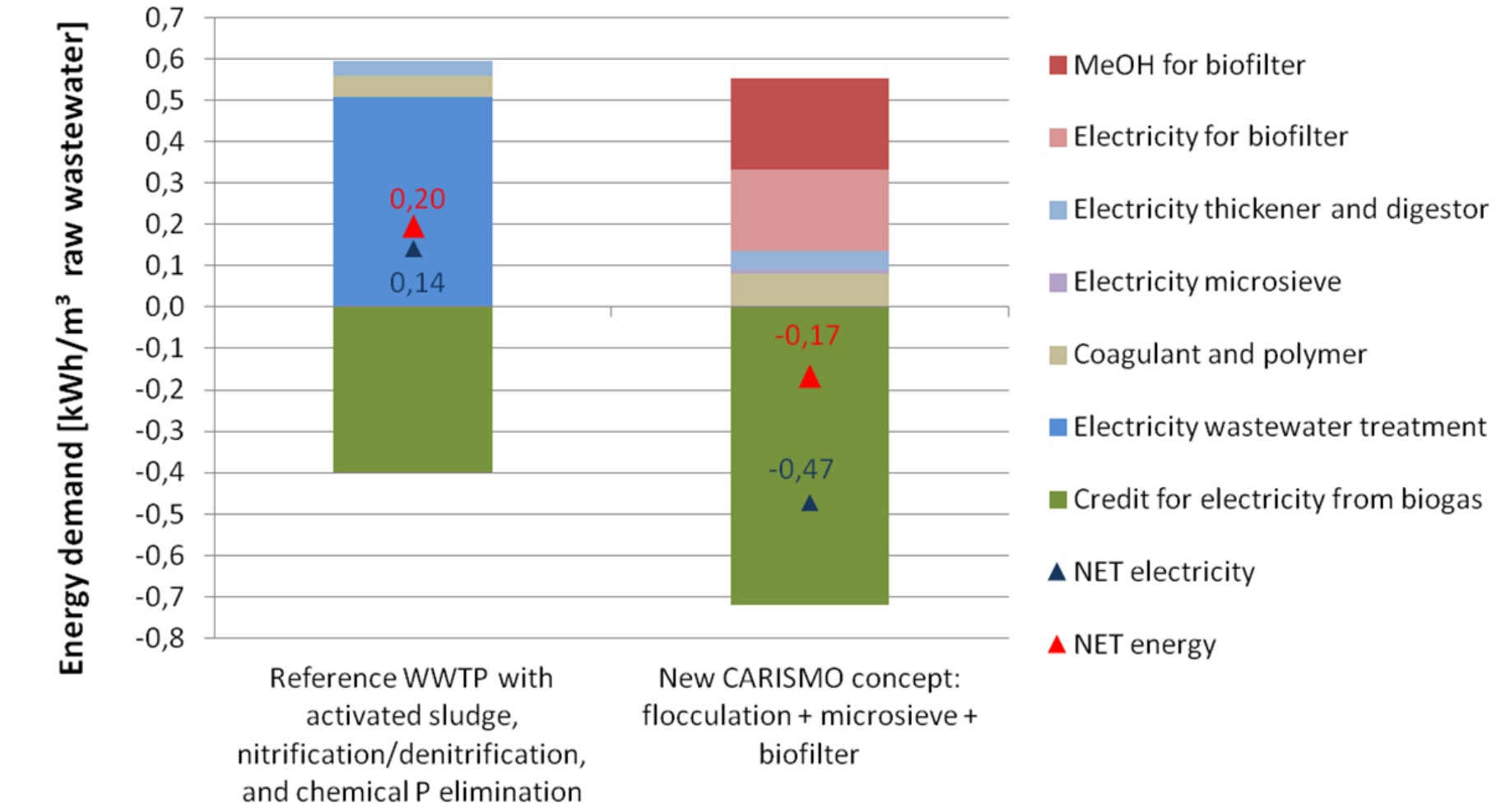
State-of-the-art versus NEUE Konzepte



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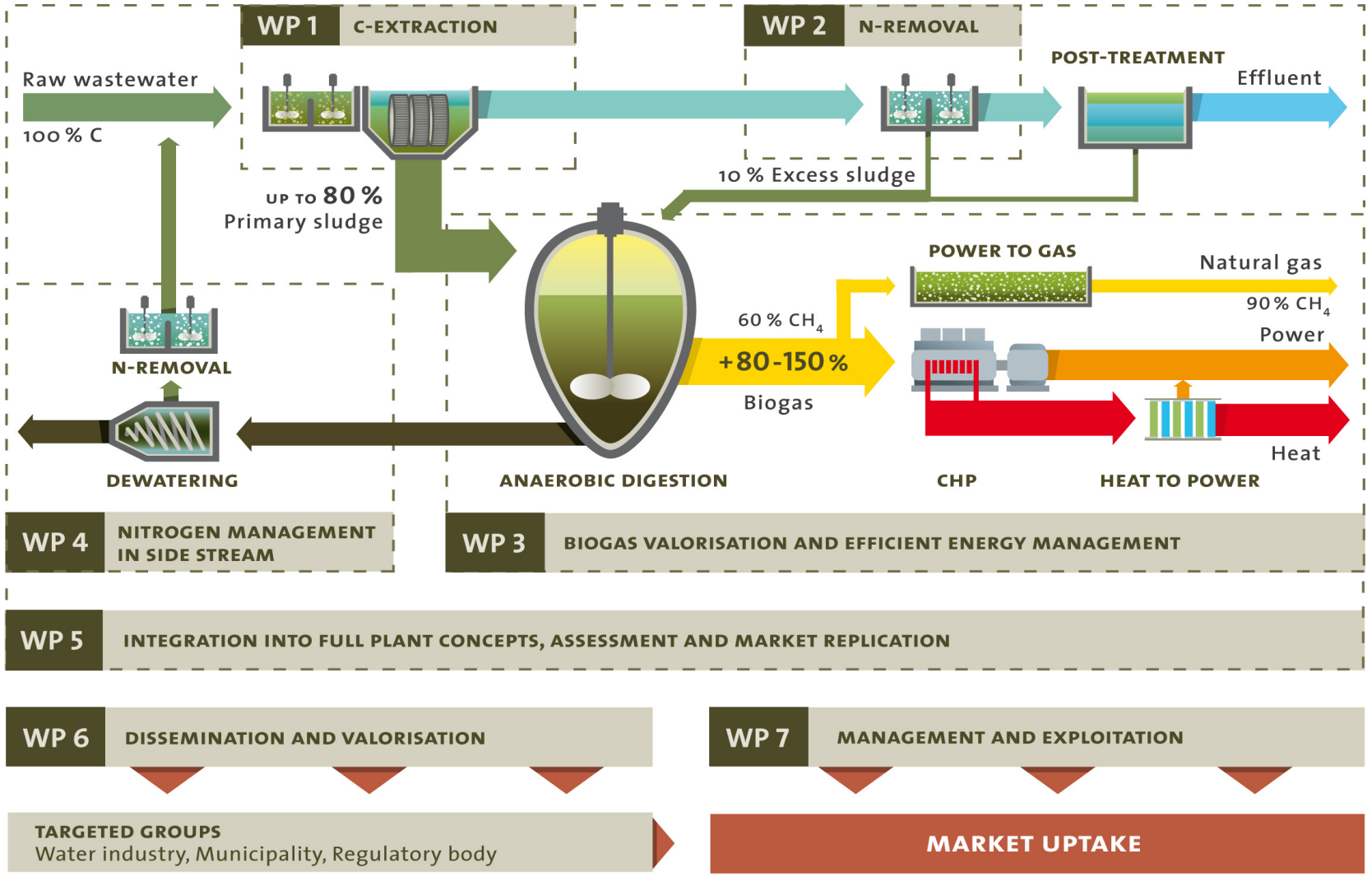
Die Kläranlage aus Kraftwerk „POWERSTEP“

Carismo – Reicht das Konzept?



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Wie kam es dazu?

- **Sept. 2013: first thoughts and contacts ...**
- Dec. 2013: Publication Water 1a Call « Innovation & Demonstration »
- July 2014: First consortium Meeting
- **Sept. 2014: Submission Stage 2 proposal**
- Feb. 2015: Invitation to Grant Preparation phase – **Score 14.5/15**
  (42 submissions, 8 granted projects!)
- Mai 2015: Grant Agreement signed by Commission
- June 2015: Consortium Agreement signed
- **July 2015: Start of project**
- 28 Sept. 2015: Kick-Off meeting

- 2 years of preparation => 3 years of implementation

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Strategische Ziele von POWERSTEP

- Obj. 1: Demonstrate the concepts of **energy producing WWTP based upon full-scale investigations** of individual processes and design elements.
- Obj. 2: Assess **energy balances and operation costs** (compared with conventional treatment schemes), and the dependence on factors such as wastewater constitution, treatment quality target etc.
- Obj. 3: Define potential **design schemes of cost competitive, energy positive and carbon neutral WWTPs for state-of-the-art treatment targets** (at least +150% energy positive WWTP).
- Obj. 4: Provide enough confidence in the design and operation of the overall treatment schemes to enable **replication of solutions and quick deployment of the concept over Europe**.
- Obj. 5: Guarantee a significant contribution of the water sector to the European energy transition while securing **worldwide market shares and job growth in Europe** in this promising field.

+ SMART goals for each work packages

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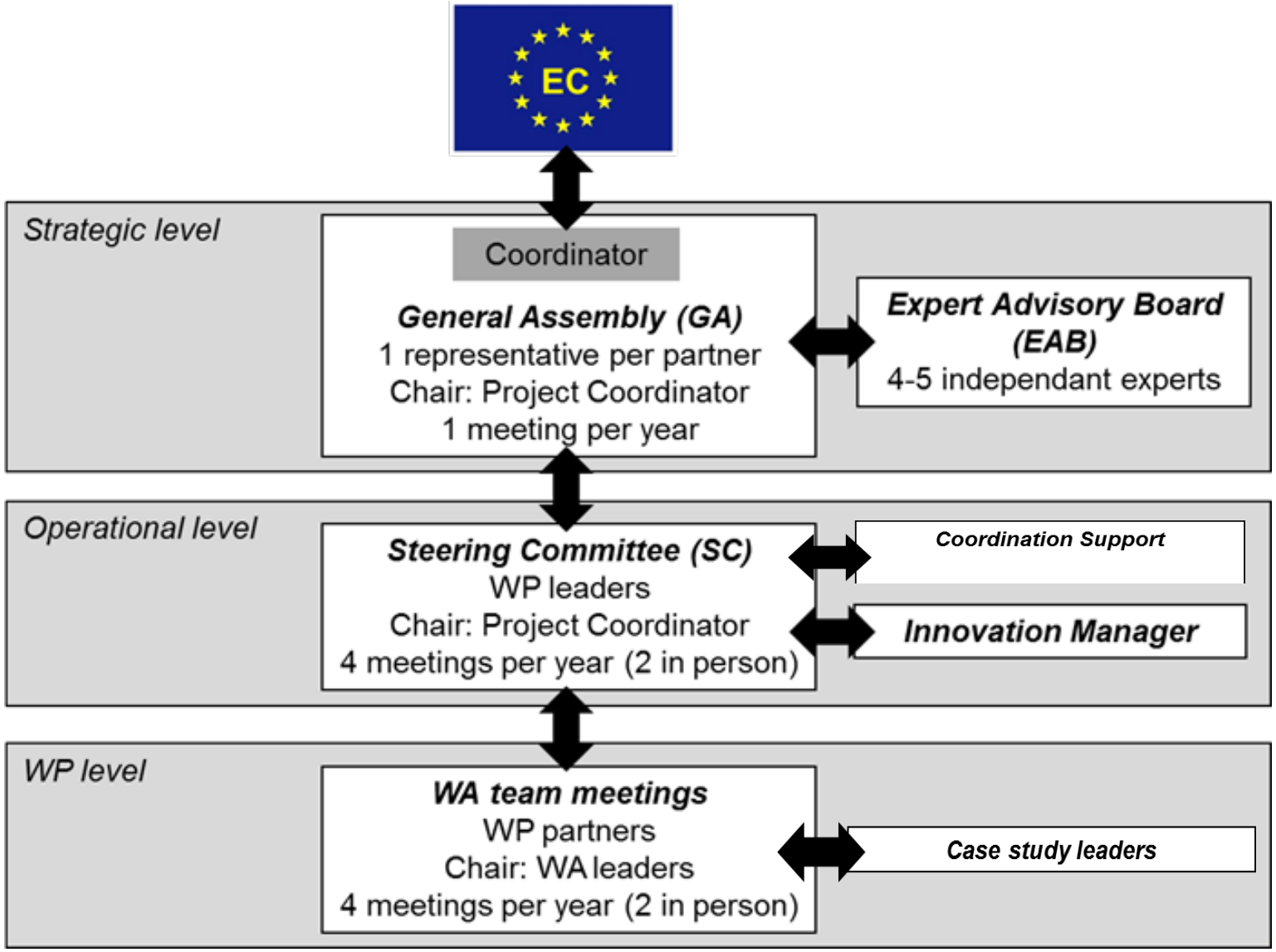
POWERSTEP Managementstruktur



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Wer ist das Team hinter POWERSTEP

KOMPETENZZENTRUM WasserBerlin

TU WIEN TECHNISCHE UNIVERSITÄT WIEN

eawag aquatic research

Fraunhofer IPM

VEOLIA

NEAS ENERGY

BIOFOS

Berliner Wasserbetriebe

Umwelt Bundesamt

Electrochaea Renewable Natural Gas

aps aqua plant solutions

Sustec Consulting Contracting

ATEMIS

Arctik

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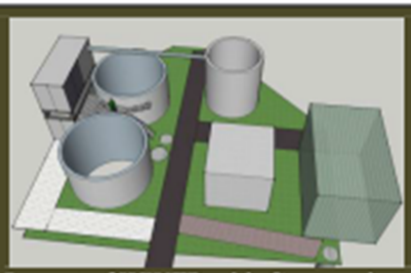
Wie wird POWERSTEP realisiert?

Case Study 1: Westewitz WWTP (Germany)

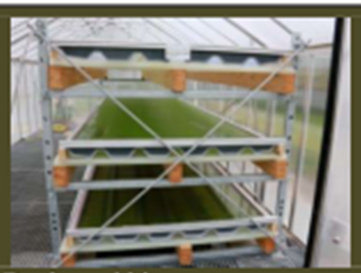
Size: 2,000 pe

Site owner / operator: OEWA and Abwasserzweckverband Döbeln-Jahnatal

Case study leader: KWB



Layout of WWTP with C extraction



Duckweed bioreactor

Context	Small-size WWTP with two sequencing batch reactors, built in 2009, flexible infrastructure enables this plant to serve as demonstration case for energy-positive WWTP concepts, established cooperation between OEWA, Veolia Water Technologies and KWB
Goals	- Full-scale demonstration of energy-positive WWTP with primary microscreen treatment - Full-scale test of advanced control strategies for nitrogen removal - Demonstration of innovative nitrogen removal process based on duckweed
Prerequisite legal obligations	- Health and Safety approval, operating permit has to be adapted

Work package	Technological solution	Description	Partners
WP1 Carbon extraction	Microscreen-based advanced primary treatment (drumfilter)	Low energy microscreen technology plus coagulation and flocculation	KWB VWT
WP2 Nitrogen removal	Nitrogen removal management after advanced carbon extraction in existing infrastructure	Operation conditions will be optimized with existing SBR plant in order to achieve nitrogen removal while minimizing the needs of external carbon source	KWB
WP2 Nitrogen removal	Duckweed bioreactor	Innovative duckweed bioreactor enables nitrogen removal through biomass production in less than 1d contact time	KWB APS (SME)

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Wie wird POWERSTEP realisiert?

Case Study 2: Källby WWTP (Sweden)

Size: 120,000 pe
Site owner / operator: VA SYD
Case study leader: VWT


MBBR reactors for deammonification process


WWTP Källby

Context	This site hosts a research programm on "next generation WWTP", where several processes have been investigated at pilot scale. VWT will operate a large prototype MBBR facility, where a 3-stage concept with BOD-reduction, nitritation and anammox will be applied on main stream water. A flexible design, well equipped with different on-line sensors, makes the facility suitable for full-scale demonstration.
Goals	- Large-scale prototype demonstration of 3-stage BOD, nitritation and anammox in MBBRs for stable nitrogen removal in main stream water with 2 different pre-treatment processes. - Optimisation of N removal capacity in main stream anammox. - Achieve high carbon extraction capacity through pre-filtration with microscreen with minimum chemicals and lowest possible remaining COD for further treatment in nitritation+anammox process
Prerequisite legal obligations	- Health and Safety approval

Work package	Technological solution	Description	Partners
WP1 Carbon extraction	Pre-filtration (discfilter)	Coagulation / flocculation + microscreen	VWT
WP2 Nitrogen removal	Large-scale prototype tests of main stream deammonification (possible supplement by side stream) Feed with high load biology effluent or microscreen effluent	Deammonification in MBBRs, enabling up to 60% savings of O_2 and require no external C source compared to conventional nitrification / denitrification. Increase alternative control options for stable N removal. Tests with fixed biomass on suspended carriers performed for biokinetics, microbial characterisation, microbial structure. Process optimisation with minimum of N_2O production.	VWT

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Wie wird POWERSTEP realisiert?

Case Study 3: Avedøre WWTP (Denmark) **Size:** 350,000 pe **Site owner / operator:** BIOFOS **Case study leader:** BIOFOS	 Gas storage and fermentation tanks at Avedøre WWTP		
Context	Large WWTP with full N&P removal. Primary and secondary sludge is digested and produces biogas. A 1 MW biological methanisation plant will be erected in 2015 to convert biogas CO_2 to methane.		
Goals	- Full-scale demonstration of biological methanisation - Development and full-scale test of advanced control strategies - Optimise the interaction between operation, price of electricity and storage		
Prerequisite legal obligations	- only Health & Safety approval		
Work package	**Technological solution**	**Description**	**Partners**
WP3. Biogas production + energy recovery	Power-to-gas concept and "Smart grid"	1) Gas storage considerations 2) Control strategies for optimal operation 3) Oxygen to aeration tanks 4) Recycling of metabolic by-water in anaerobic digestion 5) Integration of heat systems / process heat management 6) Coordinating control of the units with price of electricity and product quality.	BIOFOS ELEC (SME) NEAS

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Wie wird POWERSTEP realisiert?

Case Study 4: Braunschweig WWTP (Germany)

Size: 325,000 pe
Site owner / operator: AVB and SE|BS
Case study leader: KWB


WWTP Braunschweig


Steam Rankine Cycle unit

Context	Large-size WWTP with nutrient removal and reuse of treated wastewater and sludge in agriculture. Thermophilic sludge digestion with co-substrates and additional biogas from nearby biowaste plant and landfill yields high energy production in CHP units and high self-sufficiency in electricity. Established cooperation between SE|BS, AVB and KWB
Goals	- Pilot testing of thermoelectric generators (TEG) at one CHP unit - Full-scale evaluation of Steam Rankine Cycle (SRC) unit for utilisation of excess heat for electricity production - Comparison of TEG and SRC in cost-benefit assessment - Optimisation of dynamic heat management with storage systems - Optimizing the operation of the plant against energy markets and energy consumption, production and storage
Prerequisite legal obligations	- No special permits required

Work package	Technological solution	Description	Partners
WP3. Biogas production + energy recovery	Steam Rankine Cycle engine, Thermoelectric generators on CHP, Seasonal heat management	Comparative assessment of SRC engine (+15% of heat in electricity) and thermoelectric generators on CHP (+5% electricity generation) Seasonal heat management through heat storage system	KWB IPM NEAS

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Wie wird POWERSTEP realisiert?

Case Study 5: Kirchbichl WWTP (Austria) Size: 100,000 pe (15,000 m³/d) Site owner / operator: AWV Wörgl-Kirchbichl Case study leader: TUV	  Two-stage plant with anaerobic digestion in Kirchbichl (AT)
Context	Medium-size two-stage WWTP (patented HYBRID process), strong seasonal variation due to tourism, with high nitrogen return loads in SDE. Integrated management of SDE targeted with stable and energy-efficient process to maximise energy recovery.
Goals	- Full-scale demonstration of integrated SDE management via nitritation at a HYBRID two-stage WWTP, operational and long-term experience - Investigations on specific factors as e.g. C/N ratio or seasonal impacts - Process optimization by modelling and identification of technical/biological limits - Evaluation of the effects on the WWTP with regard to expected reduced aeration demand and increased biogas yield - Dynamic modelling of biological processes with electricity input/output - Comparison of nitritation with state-of-the-art processes in efficiency/costs
Prerequisite legal obligations	- Only Health and Safety approval

Work package	Technological solution	Description	Partners
WP4. Nitrogen manage-ment in side stream	Integrated management of sludge process water for two-stage activated sludge plants	Nitritation of SDE and dosing into the first stage reduces aeration demand and increases biogas production compared to nitrification/denitrification	TUV

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Wie wird POWERSTEP realisiert?

Case Study 6: Altenrhein WWTP (CH)

Design size: 120,000 pe (22,500 m³/d)
Site owner / operator: AVA Altenrhein
Case study leader: EAWAG

Pilot plant for membrane stripping

Application of recovered N fertilizer

Context	Medium-size WWTP with anaerobic sludge digestion, receiving additional 70,000 m³/a of sludge from smaller WWTPs of the region. Consequence is a very high return load of nitrogen from sludge dewatering, making nitrogen recovery attractive. Established cooperation between partners from EU project ROUTES.
Goals	- Full-scale demonstration of membrane ammonia stripping in side stream - Operational and long-term experience + optimisation - Comparison to alternative technologies in costs and efficiency - Evaluation on energy balance of WWTP and economic feasibility
Prerequisite legal obligations	- Health and safety approval

Work package	Technological solution	Description	Partners
WP4 Nitrogen management in side stream	Membrane ammonia stripping	Nitrogen recovery in side stream treatment of sludge process water, competitive to deammonification in costs and efficiency	EAWAG SUSTEC ATEMIS

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Vorreiter sein – um Visionen umzusetzen

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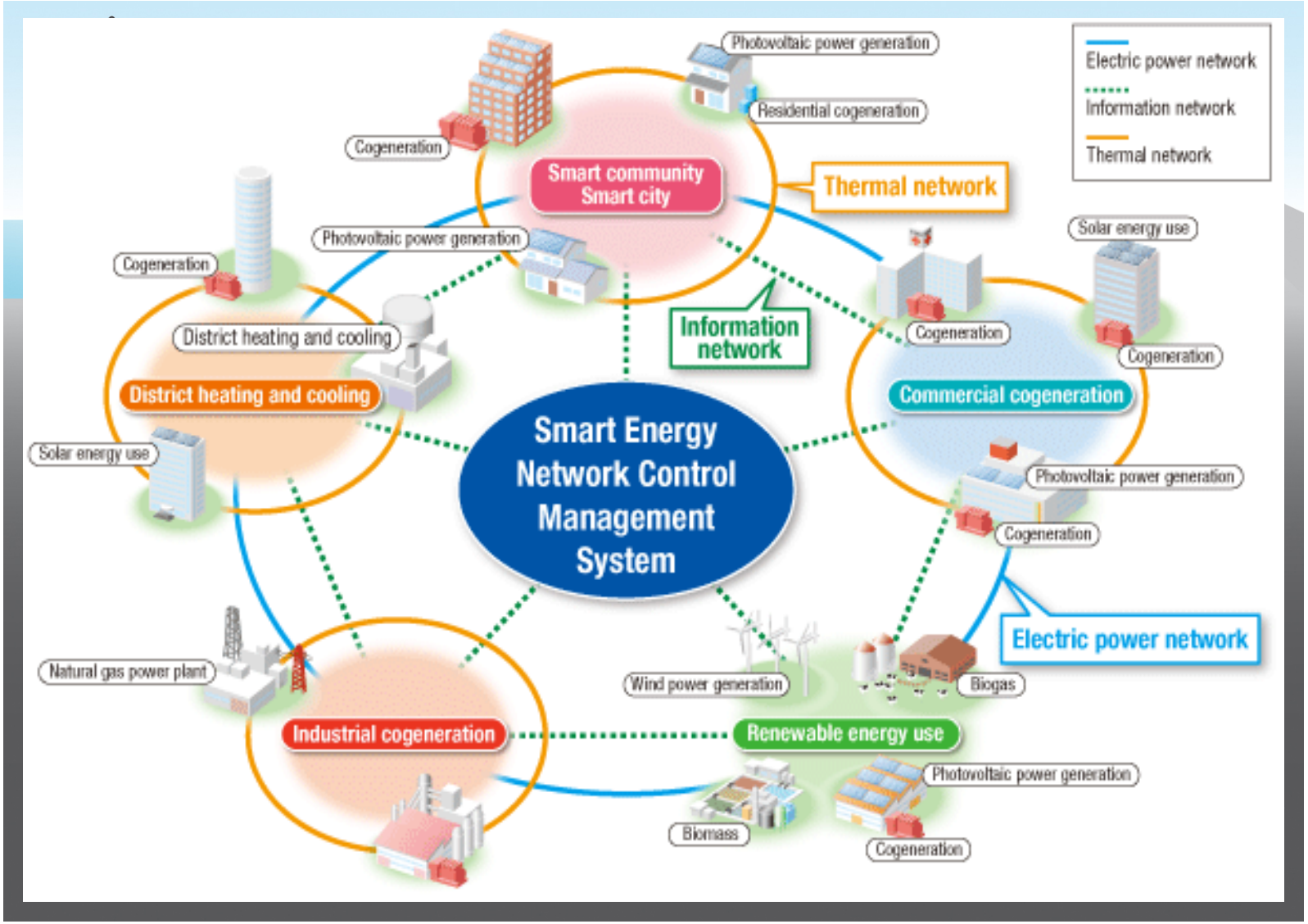
Ausblick



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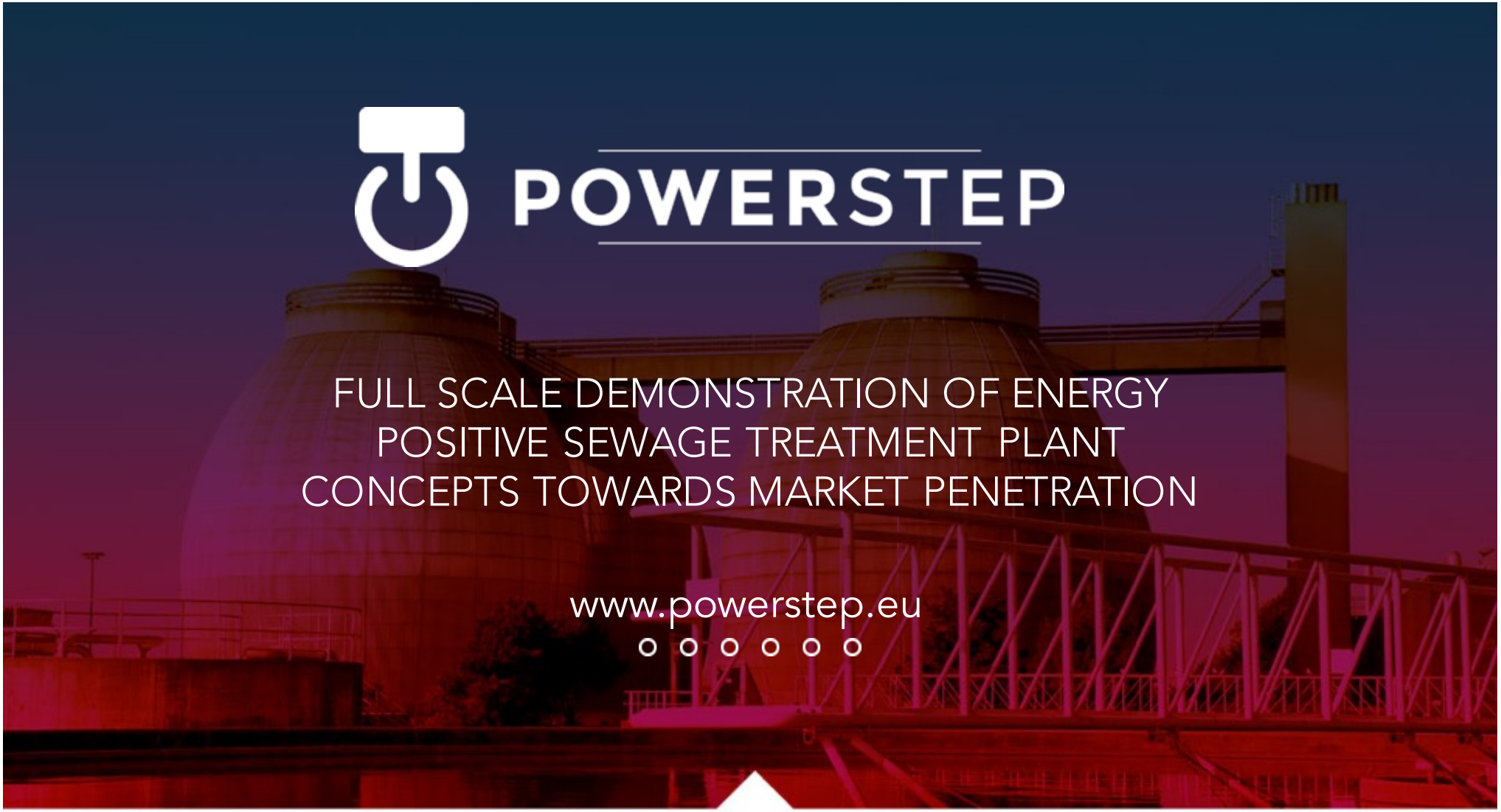
Danksagung

POWERSTEP is an innovation action project supported by the European Union under the Horizon 2020 Framework Programme.

Contract no. 641661

Duration: 1/07/15 – 30/06/18



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www.powerstep.eu

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