Der Wasserkreislauf als Energielieferant, am 02.06.2015 im Klärwerk Buchenhofen

Entwicklung und Erprobung eines Energie Online Management Tool zur Verbesserung der Energieeffizienz von Kläranlagen

Gerd Kolisch, Inka Hobus, Jo Hansen, Alex Cornelissen, Georges Schutz

Inhalt

Introduction
Einführung

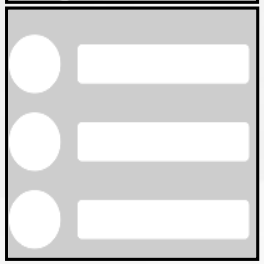
Treatment Plants Monitored
Überwachte Kläranlage

EOS Setup and Structure
EOS Aufbau und Struktur

EOS Outputs
EOS Ergebnisse

Obstacles and Solutions
Hindernisse und Lösungen

Current Work:
Aktuelle Arbeiten:
Decision Support Systems



Conclusions
Schlussfolgerungen

Investing in Opportunities
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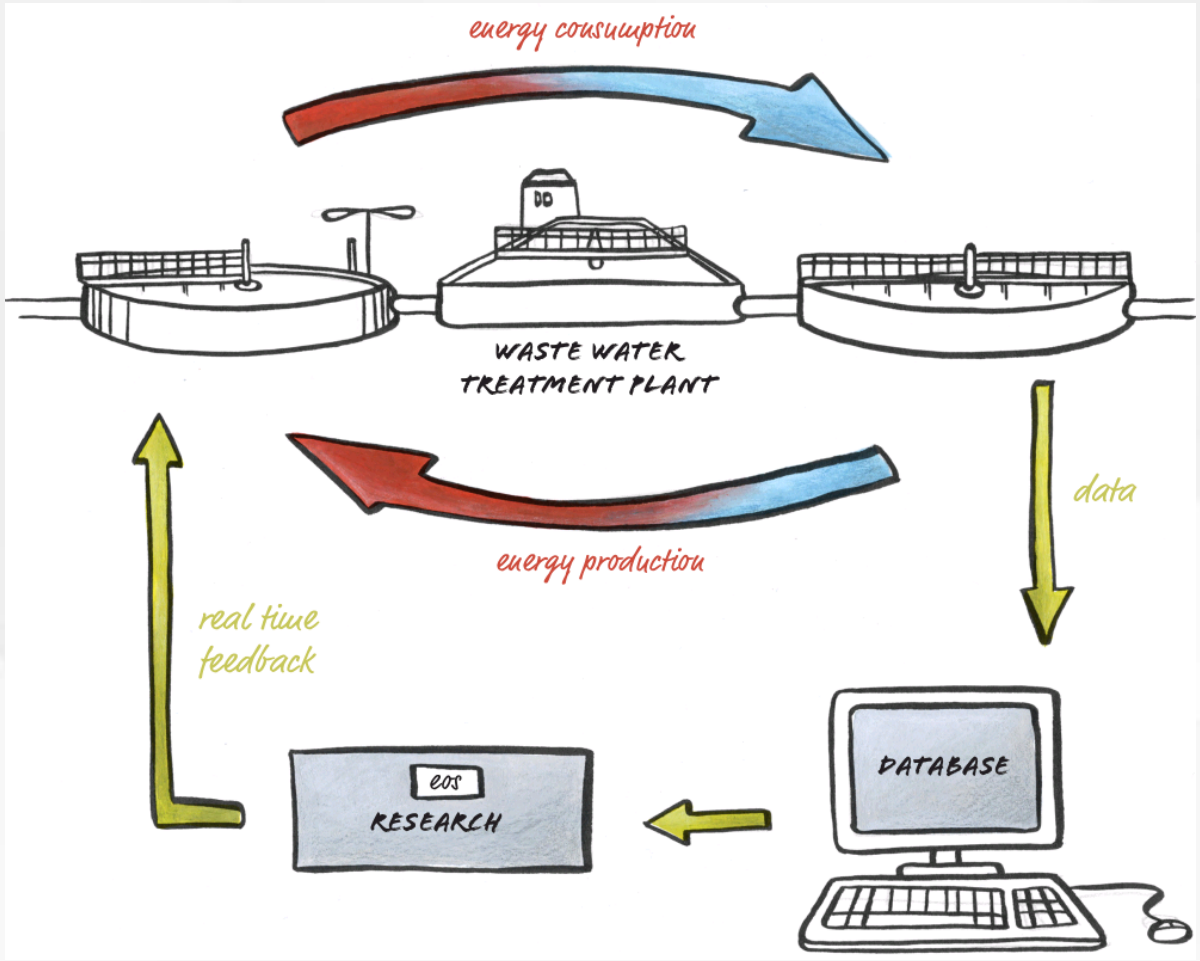
Wupperverband, University of Luxembourg, the Syndicate SIDEN and the Luxembourg Institute for Science and Technology (LIST)

inners

Development and testing of an Energy Online Service tool (EOS)

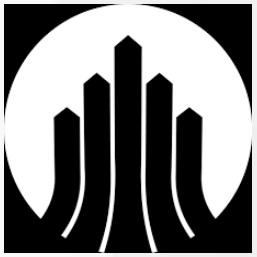
Entwicklung und Erprobung eines Energie Online Service Tool (EOS)



Headline Objectives
Leitziele

Online provision of energy information to operators

Online-Bereitstellung von Energie Informationen an Betreibern

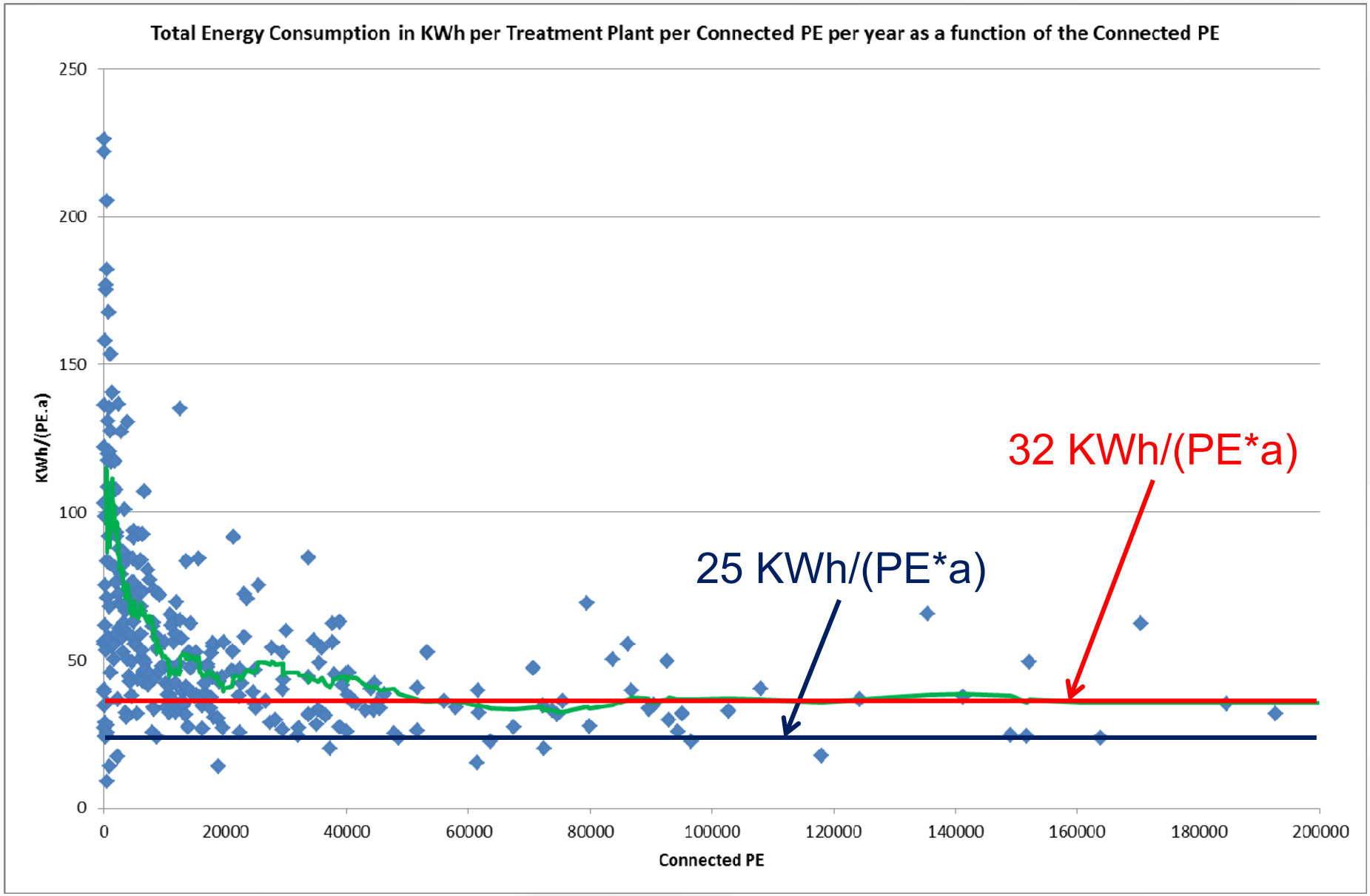


Benchmarking

Energy-efficient operation of municipal sewage plants

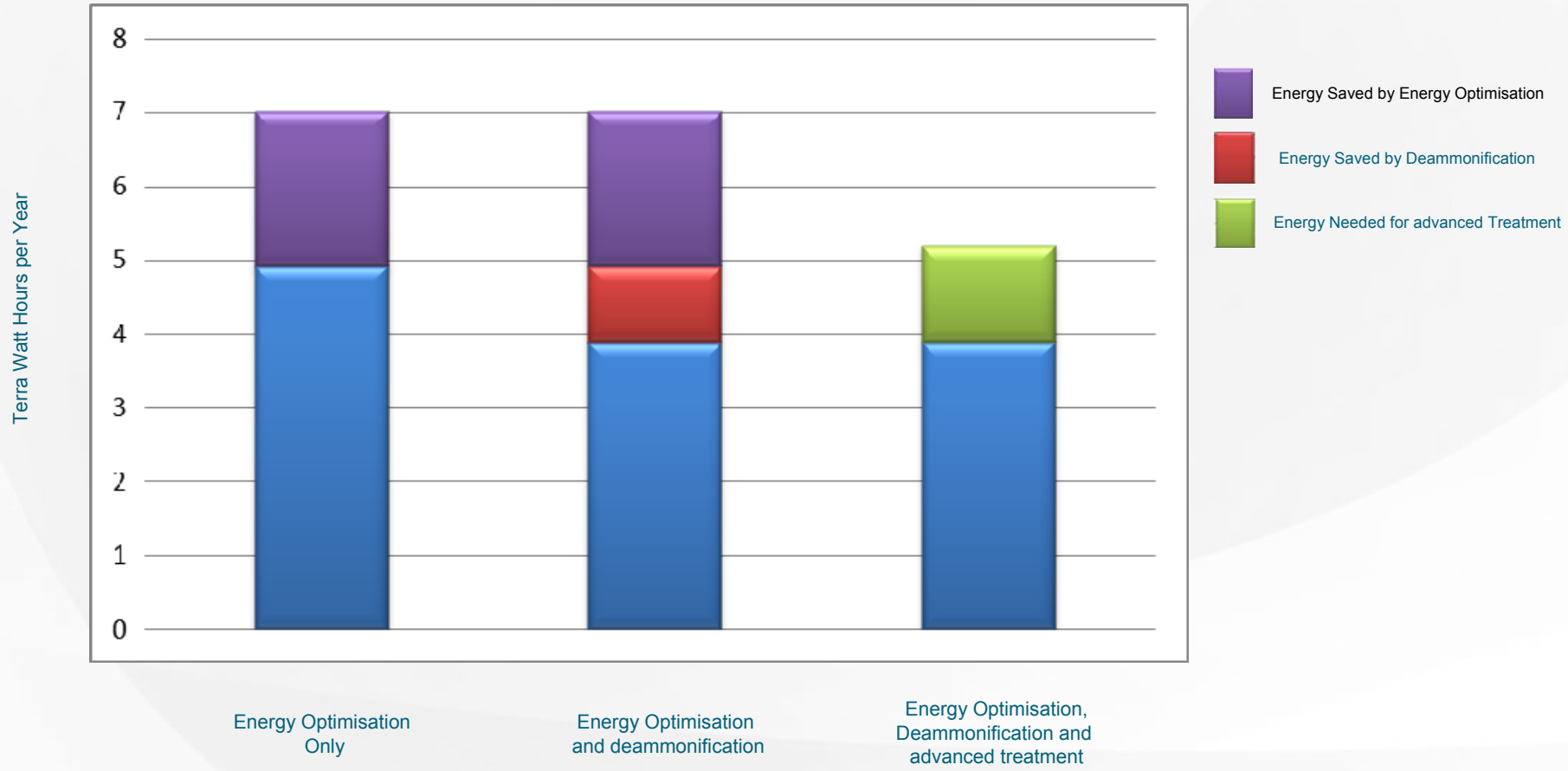
Energieeffizientes Betrieb von kommunalen Kläranlagen

Conventional Benchmarking



Estimation Energy Saving potential for WWTPs: INNERS Estimation

INNERS Schätzung: Energiesparpotenzial für Kläranlagen

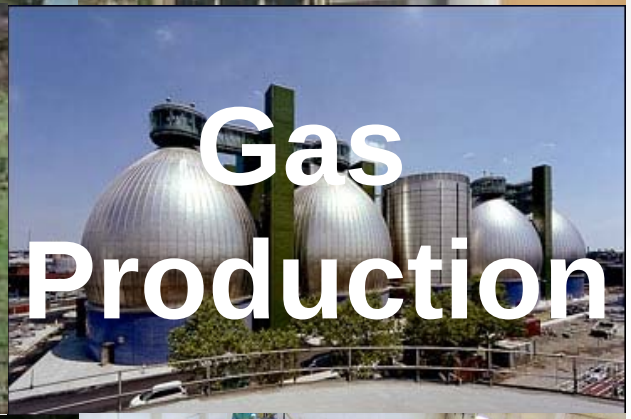


Our estimation shows that Northwest European countries currently consume 7,02 Terra Watt hours per year (TWh/a) on waste water treatment. If all these plants conform to the benchmarks, the achievable value is 4,91 TWh/a, a saving of 30%. If subsequently all plants above 50.000 PE would also implement a deammonification system, this value would be further reduced to 3,88 TWh/a, an overall saving of 3,14 TWh/a or 45%.

However, there is also, possibly, a need to further treat our waste water to remove micro-pollutants, such as pharmaceuticals and personal care products (a subject of other INTERREG NWE projects, such as the NoPILLS project). This would likely increase the energy consumption of all plants larger than 10000 PE by 8Kwh/(PE*a). The resulting impact would be to raise the overall consumption back up to 5,19 TWh/a, which would still be an overall improvement of 1,83 TWh/a, or 26%.

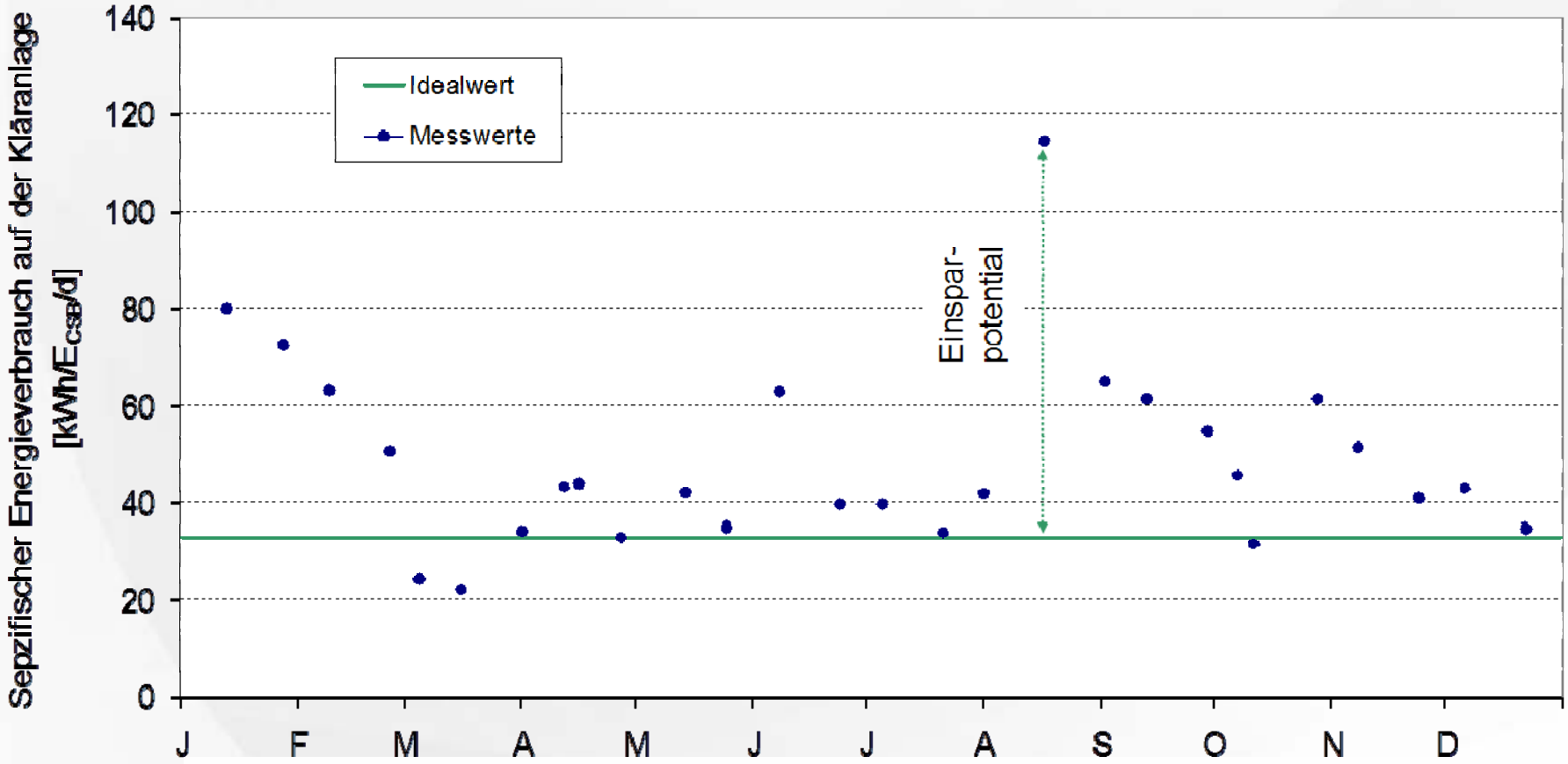
But….What do we Compare?

Aber ... was vergleichen wir?

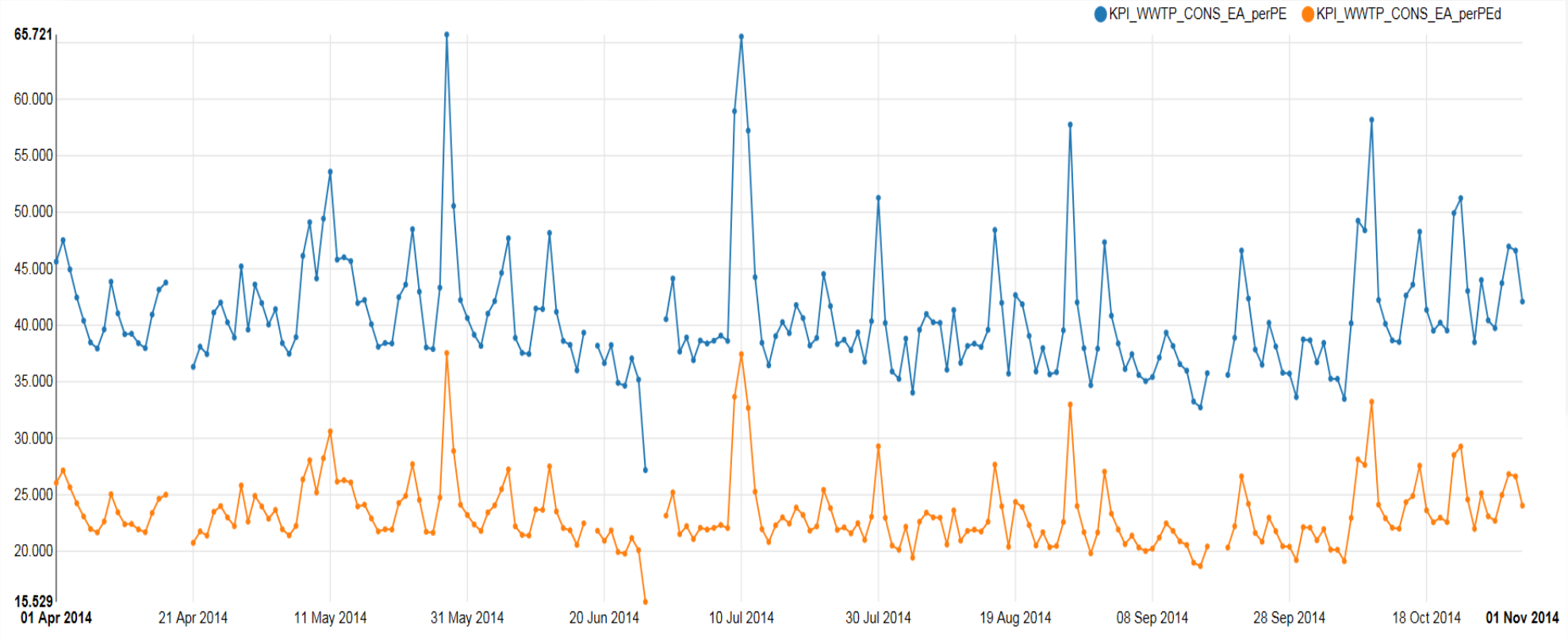


What is the internal variation in the data?

Was sind die interne Schwankung in der Daten?



Consider the Daily variation
Betrachtung von die Tagesschwankung



KPI_WWTP_CONS_EA_perPEd	Total Energy Consumption per PE design
KPI_WWTP_CONS_EA_perPE	Total Energy Consumption per PE

It is difficult to compare plants performance by total energy consumption alone because of:

Es ist schwierig, die Leistung von Kläranlagen allein aufgrund Gesamtenergieverbrauch zu vergleichen:

1. Variation between wastewater treatment plants

   Unterschieden zwischen Kläranlangen

2. Internal variation of a wastewater treatment plant

   Interne Variabilitait in der Kläranlage

It is important to use measures that are comparable

Es ist wichtig, Maßnahmen, die vergleichbar sind zu verwenden

☛ Key Performance Indicators (KPIs)

 Total Energy use, Energy use per day

 Energy use per person equivalent

 Energy use per m^3

Inhalt

Introduction
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Treatment Plants Monitored
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EOS Outputs
EOS Ergebnisse

Obstacles and Solutions
Hindernisse und Lösungen

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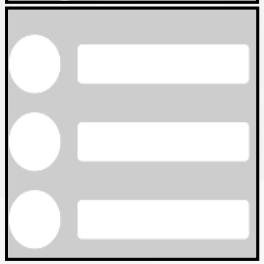

Conclusions
Schlussfolgerungen

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Installation of EOS at Burg

WUPPERVERBAND
für Wasser, Mensch und Umwelt

Power measurements

- Phoenix Contact, EEM-MA 600
- Current transformers MBS 50/5A
- Connection via Profibus / Interbus
- PCS: Schraml Aquasys 6

Inflow load

- Ultrasonic measurement (Nivus OCMpro)
- NH_4-N-online measurement (WTW Varion)
- S:CAN-measurement (Spectro:lyser)

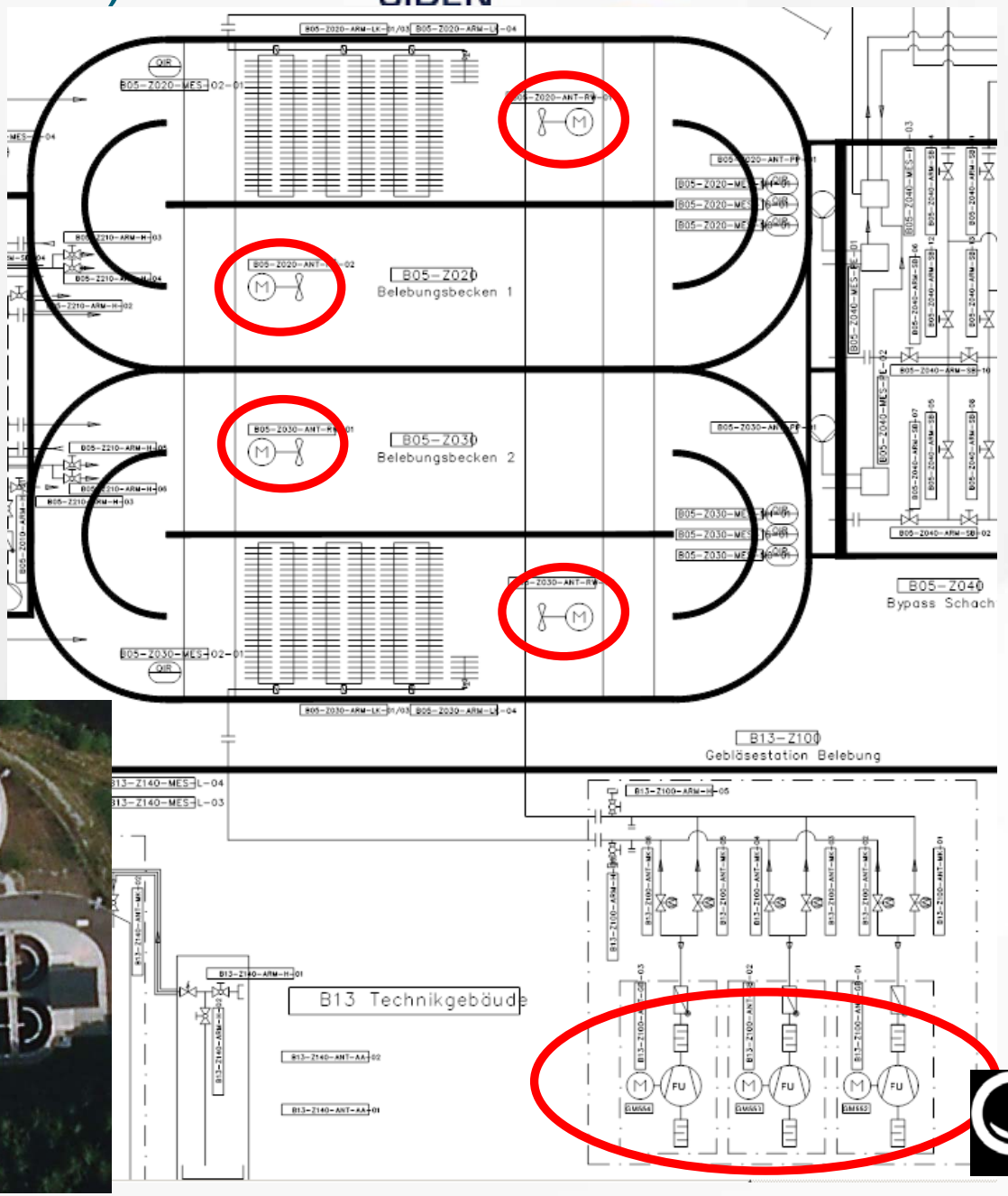
Installation of EOS at Heiderscheidergrund (HSG)

Power measurements

- Phoenix Contact, EEM-MA 250
- Current transformers ASR 21.5 50/5A

Inflow load

- NH_4-N-online measurement
- No reliable measurement of COD



It is possible to fit a plant with energy meters:
1. At a very low cost (<<1500 €/measurement)
2. But care should be taken to size equipment properly

Clearly it is better to fit a plant with energy meters during construction

Es ist durchaus möglich, eine Anlage mit Energiezählern auszustatten:
1. Zu sehr tiefen Kosten (<< 1500 € / Messung)
2. Aber Vorsicht ist geboten die richtige Grosse zu wahlen

Es ist naturlich besser eine Kläranlage wahrend der Konstruction mit Energiezählern auszustatten

Inhalt

Introduction
Einführung

Treatment Plants Monitored
Überwachte Kläranlage

EOS Setup and Structure
EOS Aufbau und Struktur

EOS Outputs
EOS Ergebnisse

Obstacles and Solutions
Hindernisse und Lösungen

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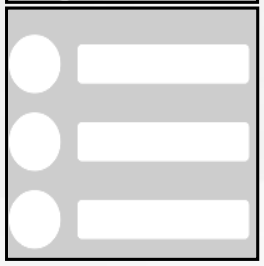

Conclusions
Schlussfolgerungen

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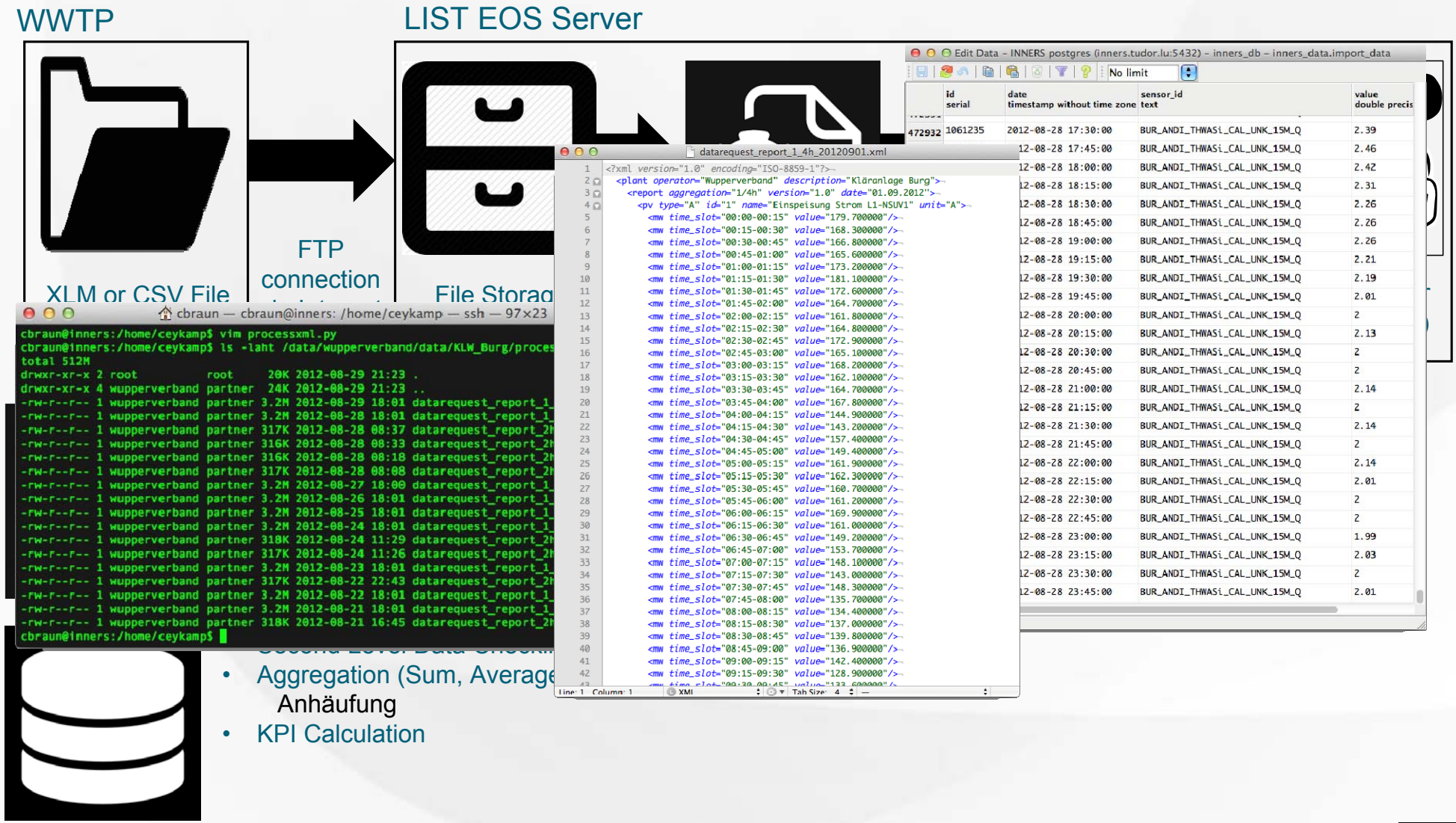
Data Transfer and Logistic
Datenübertragung und Logistik



- Aggregation (Sum, Average
  Anhäufung
- KPI Calculation

EOS Structure

EOS System User Interface

EOS Website

Decision Support

Benchmarks

KPI

EOS System Data Management Level

KPI Equations

KPI parts

Static Data

Aggregated Plant Data

Plant Data Table

Transfer Table

Legend:
EOS – Energy Online System
KPI – Key Performance Indicator

WasteWater Treatment Plant

Raw Data From Plant

Some of the KPIs and the Nomenclature

Einige der KPIs und der Nomenklatur

Kpi	Description	Unit
KPI_BIO1_FLOrcir_RATIO	BIO 1 Recirculation ratio	%
KPI_WWTPi_BODTN_RATIO	C:N ratio at inlet	%
KPI_WWTPi_CODM_perCODMd_RATIO	Degree of design capacity utilisation	%
KPI_WWTP_COVel_RATIO	% electric self coverage	%
KPI_WWTP_SEN_NH4NM_ELI	NH4-N elimination rate as measured by sensor	%
KPI_COGE_ETAea	Efficiency of CHP plant	%
KPI_WWTPi_BODCOD_RATIO	BOD/COD ratio at inlet	%
KPI_WWTPi_NH4NTN_RATIO	NH4-N/TN ratio at the inlet	%
KPI_BIO_SLA2	Sludge Age	day
KPI_BIO1_HRT	Hydraulic retention time in Biology 1	day
KPI_PCL_HRT	Hydraulic retention time Primary Clarifier	day
KPI_ANDI_HRT	Hydraulic retention time Anaerobic Digester	day
KPI_WWTP_CODM_ELI	COD elimination rate	kg
KPIp_WWTPi_CODM	Influent COD load	Kg
KPIp_BIOi1_NH4NM	BIO1 NH4-N load	Kg
KPIp_WWTPi_NH4NM	Influent NH4-N load	Kg
KPIp_WWTPi_TNM	Influent TN load	Kg
KPIp_CO2_Emissions	Emission of CO2 [kgCO2eq] (IPCC 2007 method)	Kg
KPI_BIO_SLR	Solid retention time	kg/m2/day
KPI_WWTP_CO2_Emission_perPE	Emission of CO2 per PE	Kg/PE
KPI_WWTP_oDM_perPE	Organic dry matter produced per PE [kgoDM/PE]	Kg/PE
KPI_BIO_BLO_CONS_EA_perOH	Biology blower consumption per operation hour	kW
KPIp_WWTP_PROD_EAren	Electrical work production renewable energies	kWh
KPI_COGE_HEAT_PROD	Heat production CHPP (thermal efficiency assumed to be 0.5)	kWh
KPI_WWTPi_CONS_EA_perTNM	Total energy consumption per kg TN	kWh/kg
KPI_SANF_COMP_CONS_EA_perVOLww	Sandfilter consumption of compressor per m³ water	kWh/m^3
KPI_BIO2_STIR_CONS_EA_perVOLtan	Biology 2 stirrer consumption per m3 tank volume	kWh/m^3
KPI_BIO_BLO_CONS_EA_perVOLww	Biology blower consumption per m3 wastewater	kWh/m^3
KPI_SAND_BLO_CONS_EA_perVOLww	Sandtrap blower consumption per m3 wastewater	kWh/m^3
KPI_UV_UVL_CONS_EA_perVOLww	UV lamps consumption per m³ effluent	kWh/m^3
KPI_WWTP_CONS_EA_perVOLww	Total Energy Consumption per m3 wastewater	kWh/m^3
KPI_BIO_BLO_CONS_EA_perPE	Biology blower consumption per PE	kWh/PE*a
KPI_WWTP_CONS_EA_perPEd	Total Energy Consumption per PE design	kWh/PE/a
KPI_WWTPi_PUM_CONS_EA_perPE	Inlet pump consumption per PE	kWh/PE/a
KPI_WWTP_CONS_EA_perPE	Total Energy Consumption per PE	kWh/PE/a
KPI_ANDI_VOLbiog_peroDM	Volume biogas per organic dry matter in thickened sludge [m³/g]	m^3/kg
KPI_SCL2_SURL	Surface loading Secondary clarifier 2	m^3/m^2
KPI_ANDI_VOLbiog_perPE	Volume biogas produced per PE	m^3/PE
KPI_BIO_F_M_RATIO	(Food-to-Mass Ratio	%

Inhalt

Introduction
Einführung

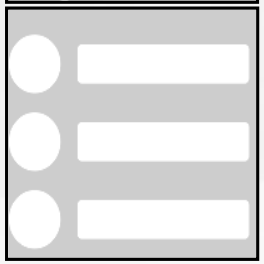
Treatment Plants Monitored
Überwachte Kläranlage

EOS Setup and Structure
EOS Aufbau und Struktur

EOS Outputs
EOS Ergebnisse

Obstacles and Solutions
Hindernisse und Lösungen

Current Work:
Aktuelle Arbeiten:
Decision Support Systems



Conclusions
Schlussfolgerungen

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Energy data in Burg with EOS (215 days/7 months)

Total energy consumption	
Total energy use	1620565 kWh
Energy consumption per day	7537.5 kWh/d
Total Energy consumption per PE	40.2 kWh/(a*PE)
Energy consumption per m3	0.54 kWh/m³
Peak consumption external energy (28/5/2014)	8865.5 kWh

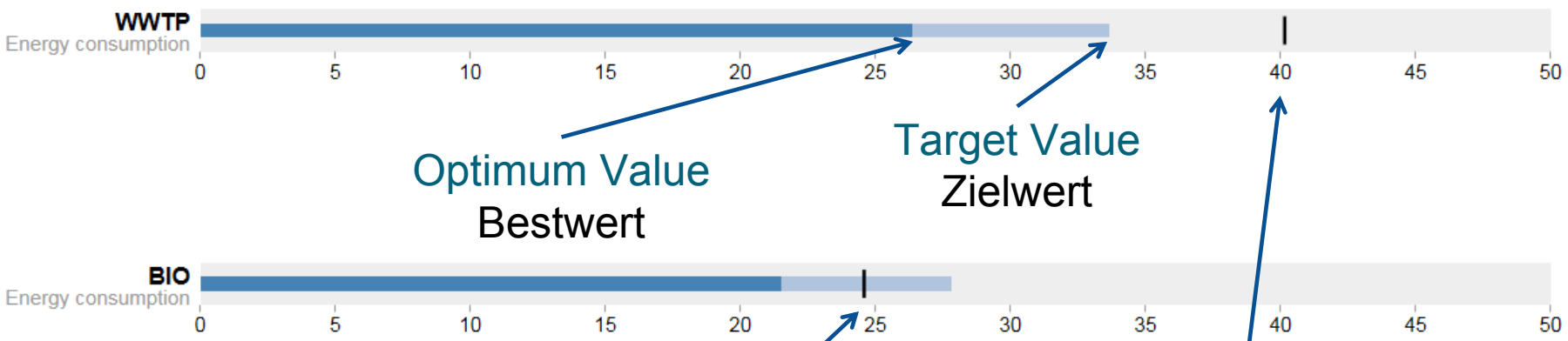
Energy production	
Total electricity production	897737 kWh
Electricity production per day	4175.5 kWh/d
Electricity production per PE	22.2 kWh/(a*PE)
Electric self coverage	54.9 %

Biology energy consumption	
BIO Energy consumption	992148 kWh
BIO Energy consumption per PE	24.6 kWh/(a*PE)
Percentage of total consumption	61.2 %

Operational data quality	
CODin	578.0 mg/L
COD removed	1911822 kg
Calculated Population Equivalents	68547 PE
Design population equivalents	120000 PE
Degree of utilization of plant	57.1 %

Operational data flows	
Treated volume	3426204 m³
Average volume	664.0 m³/h

High Level Benchmarking: Example Burg



Optimum Value
Bestwert

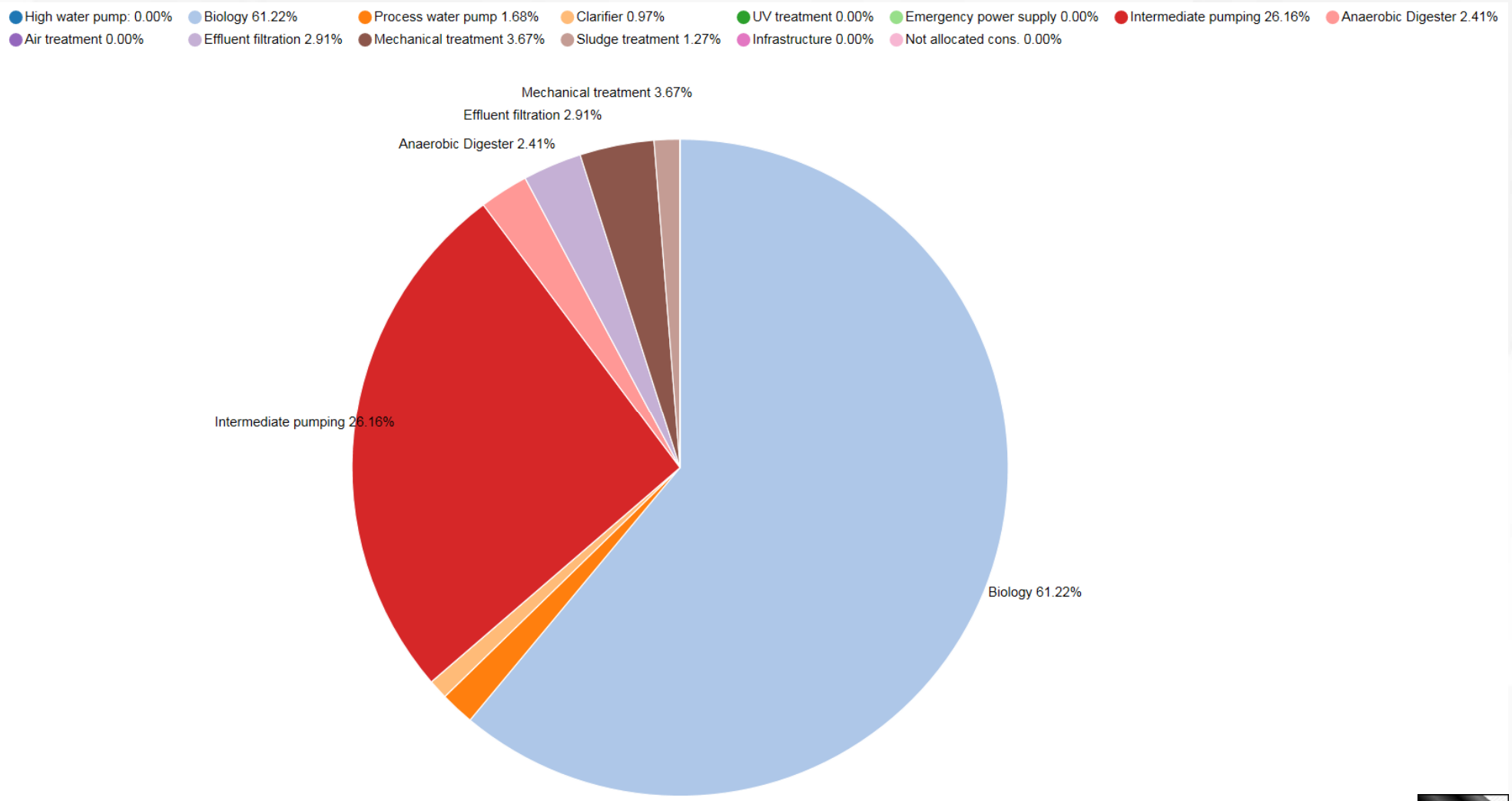
Target Value
Zielwert

But aeration is within the benchmark
Aber Belüftung ist innerhalb des Benchmark

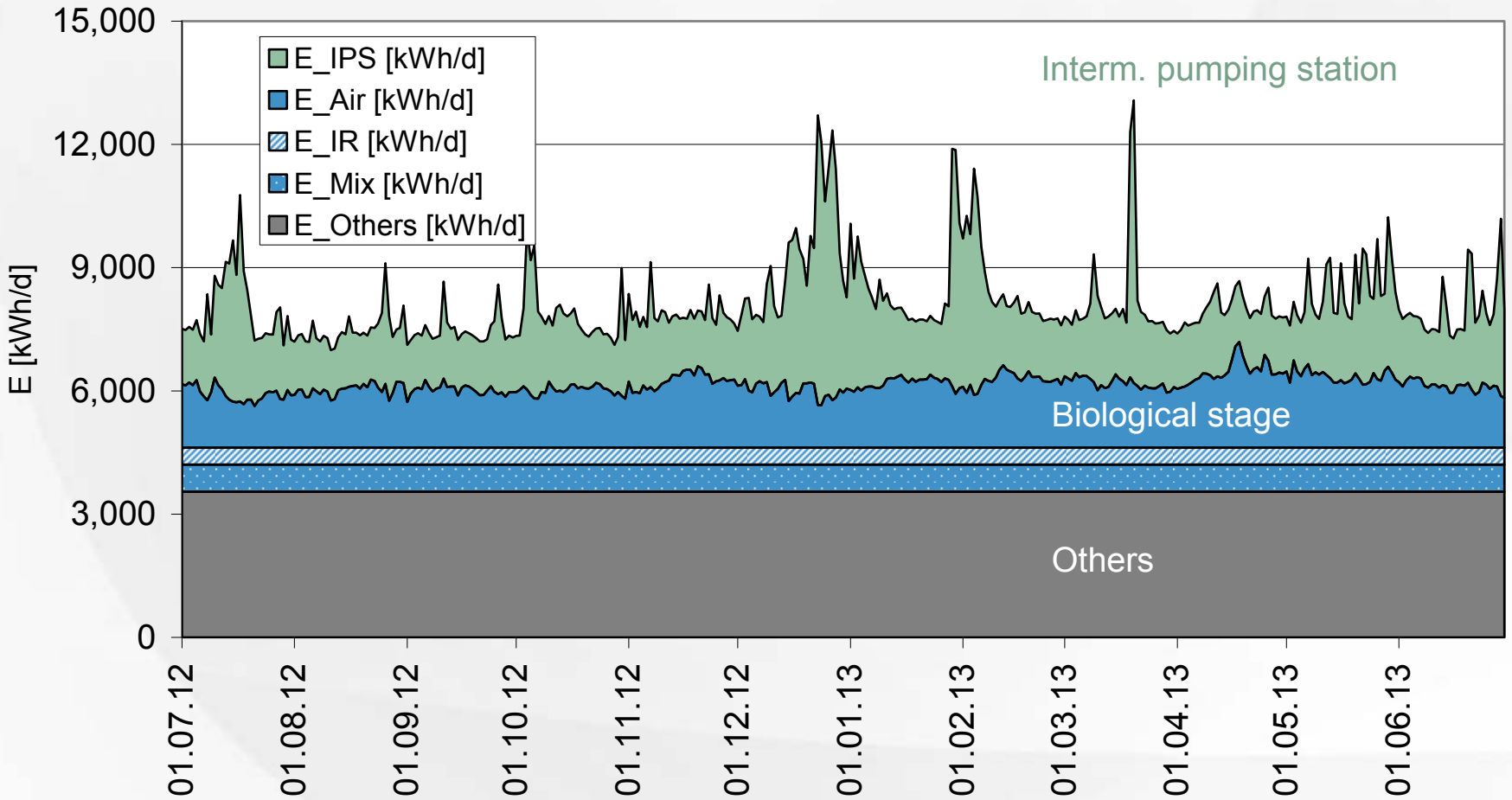
Burg has intermediate pumping =
High overall power consumption
Burg hat ein Zwischenhebewerk =
Hohe Gesamtstromverbrauch

Comparing using percentages

Vergleicht mit Hilfe Prozentsätze



Benchmarking: Example Burg
Build of Energy Consumption



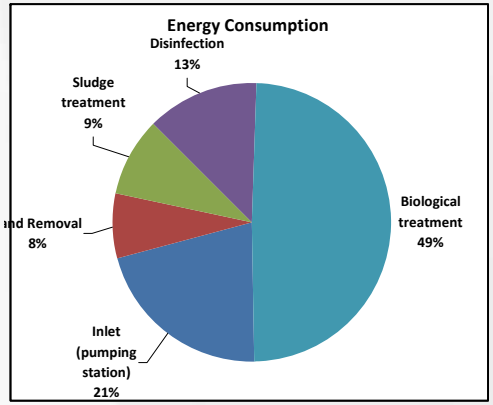
E_IPS= Energy Intermediate Pumping Station, Energie Zwischenhebewerk,
E_Air=Energy Aeration, Energie Beluftung,
E_IR=Internal recirculation, interne Rezirkulation
E_Mix= Energy Stirrers, Energie Ruhrwerk

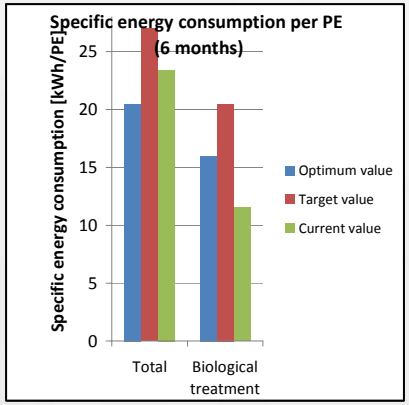
Example HSG:
Individual energy report

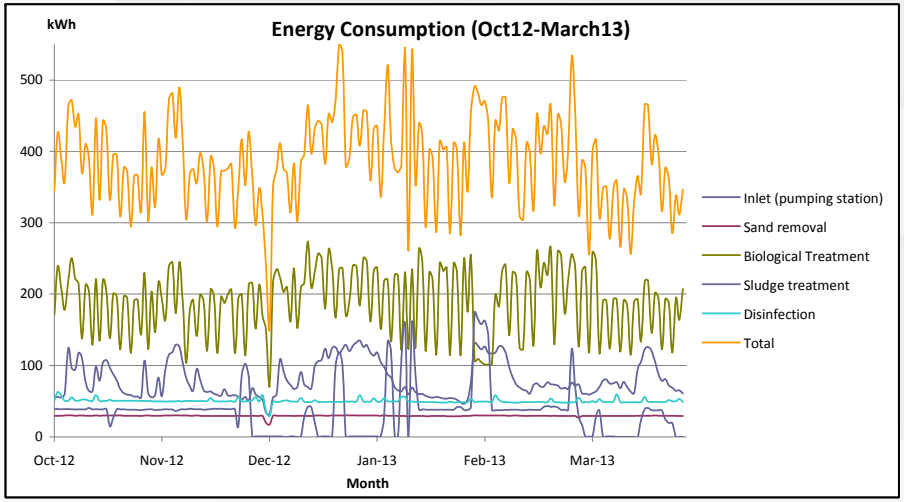
Heiderscheidergrund

Name of the plant	a_plant			***Date of report***	09.04.2013	
	Start	**Finish**		**COD removed/6 months**	114936	Kg COD
Period	01.10.2012	31.03.2013		**PE design**	15000	PE
Treated Volume	325 808	m3		**Pe Actual**	3000	PE
Average Volume	81	m3/h		**Operating hours**	4368	h

TOTAL ENERGY USE	70315	kWh/6 months	**Energy per day**	386	kWh/day
Energy per m³	0,20	kWh/m³	**Energy per PE (Design)**	5	kWh/PE
Energy per Kg COD rem	0,61	kWh/Kg COD	**Energy per PE (Actual)**	23	kWh/PE







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Inhalt

Introduction
Einführung

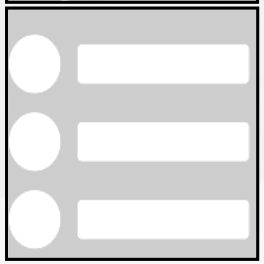
Treatment Plants
Monitored
Überwachte Kläranlage

EOS Setup
and Structure
EOS Aufbau und Struktur

EOS Outputs
EOS Ergebnisse

Obstacles
and Solutions
Hindernisse und Lösungen

Current Work:
Aktuelle Arbeiten:
Decision Support Systems



Conclusions
Schlussfolgerungen

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Obstacles and Solutions

Data Import
Process Quality

Missing values due to mismatching in tranfer-table
•Data transfer fails due to changes on the plant. ➲Smart data Input routines
Intelligente Dateneingaberoutinen
•Missing value due to fault in device➲ Logging and tracking implemented
Protokollierung und Rückverfolgung implementiert

Lab Quality Data

•No online quality data: Lab data arrives every 15 days, no complete dataset for each day. ➲ Software sensors, Predictive approaches Software-Sensoren, Predictive Ansätze ➲ Inclusion of the sewer system Einbeziehung der Kanalisation

Missing Data

•Missing Data: no KPI calculation ➲ More than one way to calculate KPI Mehr als einen Weg KPI zu berechnen
•Too much missing data: EOS calculates monthly or weekly aggregation without meaning ➲Replacement strategies: use mean values or time series analysis
Ersatz-Strategien: Nutzung Mittelwerte oder Zeitreihenanalyse

Visualization

•How to present the data? ➲ Work with experts and operators Arbeit mit Experten und Betreiber

Inhalt

Introduction
Einführung

Treatment Plants Monitored
Überwachte Kläranlage

EOS Setup and Structure
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EOS Outputs
EOS Ergebnisse

Obstacles and Solutions
Hindernisse und Lösungen

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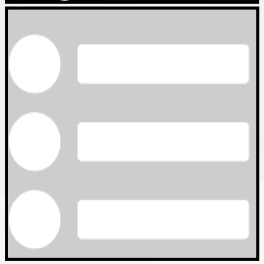

Conclusions
Schlussfolgerungen

Investing in Opportunities
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Why a Decision Support System?

- We do/did not know exactly what we want to achieve. We want to energetically optimise the plant…..What exactly does this mean?
  Wir wissen / wussten nicht genau was wir erreichen wollen. Wir wollen die Anlage energetisch optimieren…..Was genau bedeutet das?
- We have much missing, bad or unclear data.

Wir haben viel fehlerhafte, schlechte oder unklare Daten

- We are dealing with a complex system we do not fully understand

Wir haben einem komplexen System, das wir nicht vollständig verstehen

- We want a system that works for ALL WWTPs
  Wir wollen ein System, das für ALLE Kläranlagen funktioniert

- Direct control is currently not possible. We can only give advice to operators

Direkte Steuerung ist derzeit nicht möglich. Wir können nur Betreiber beraten

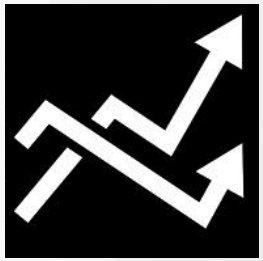
- Our DSS approaches are mostly flexible enough to work with different WWTPs

Unsere DSS Ansätze sind meistens flexibel genug, um mit unterschiedlichen Kläranlagen zu arbeiten

Decision Support System (DSS)
Main Features

WWTP Status Identification Kläranlage Zustand Identifizierung

- Fault Finding Fehlersuche
- Benchmarking



WWTP Status Forecasting Kläranlage Zustand Vorhersagen

- Let operator see future performance with current set-points
- Optimise set-points to achieve maximum performance (Future: RTC)

Data Management

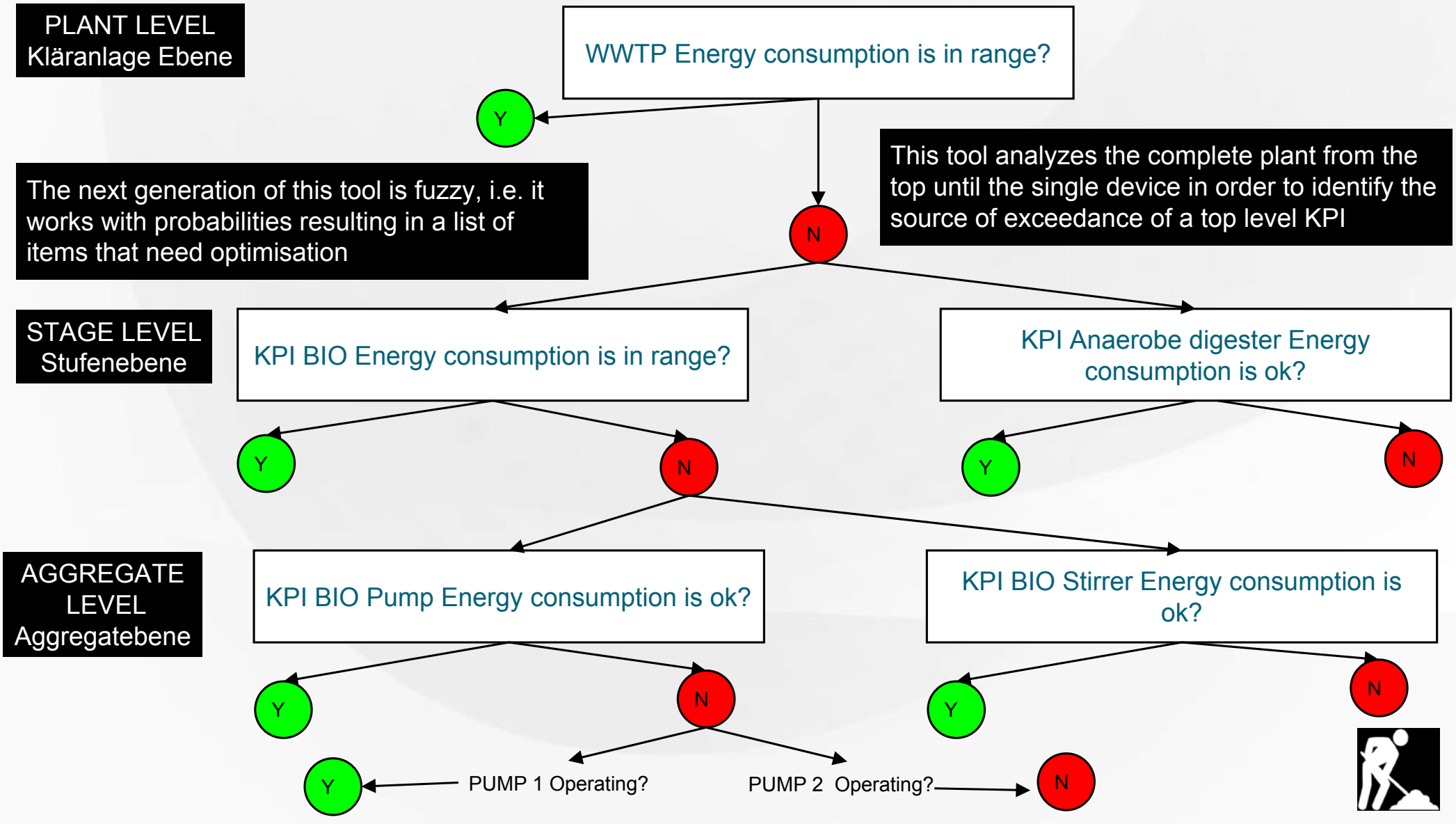
- Eliminate missing data Beseitigen fehlende Daten
- Provide Quality information

Provide Support

- Suggestions to fix problems Vorschläge Probleme zu beheben
- Suggestions to improve performance Vorschläge Leistungsverbesserung

Example Status Identification: Forward Chain Analysis

Forward Kettenanalyse



Example Status Forecasting
Trajectory Knowledge discovering

TKD identifies the status of the system using “And/Or” rules and use statistics to forecast the probability to move from a status to another one

TKD identifiziert den Status des Systems mit "und / oder" Regeln und Nutzt Statistik um die Wahrscheinlichkeit von einem Status zu einem anderen zu bewegen vorherzusagen

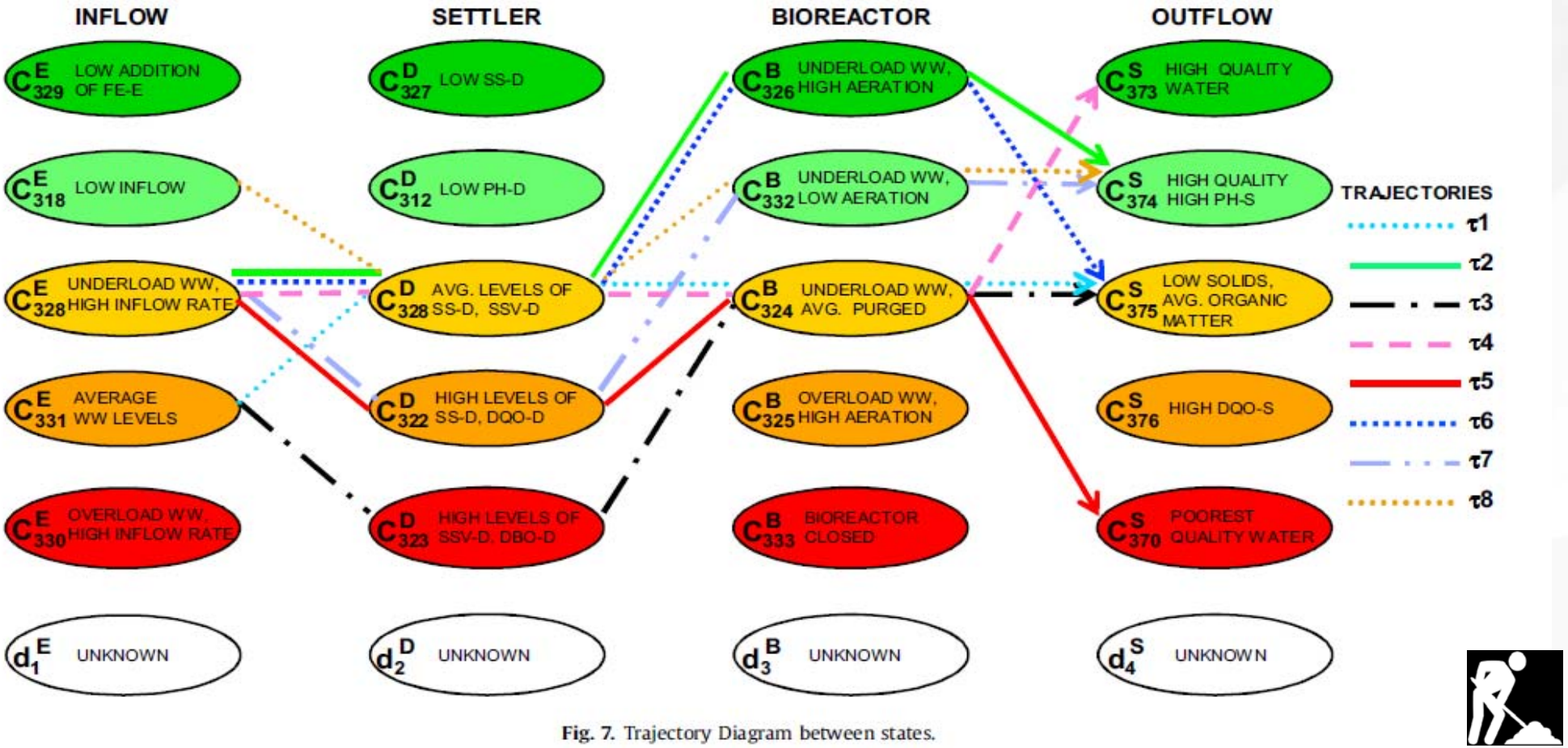


Fig. 7. Trajectory Diagram between states.

Example Data management:
Chemical Oxygen Demand (COD) prediction
Chemischer Sauerstoffbedarf (CSB) Vorhersage

- We would like to have a complete dataset for each day
  Wir wollen einen kompletten Datensatz für jeden Tag haben
- Laboratory analysis are done on periodical basis (1 week / 2 weeks)

Laboranalysen worden auf periodischen Basis durchgeführt (1 Woche / 2 Wochen)

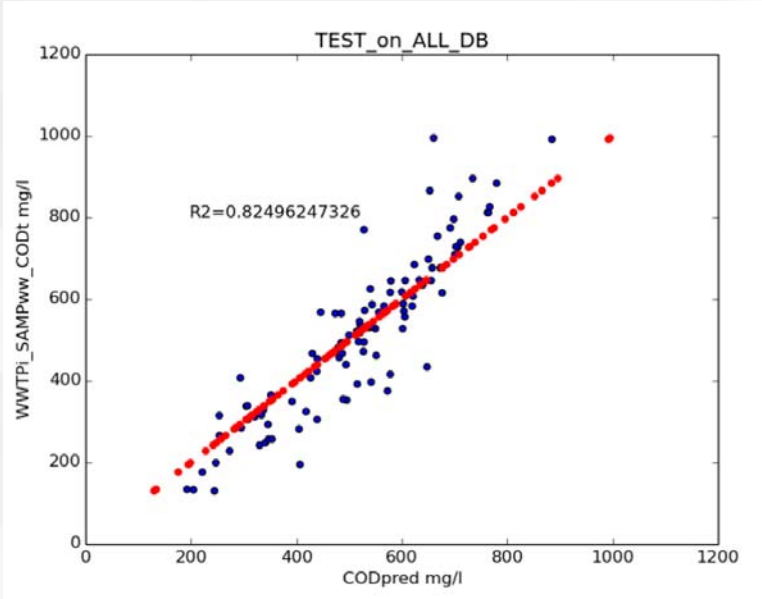
- Especially the measurement of COD at the inlet is important because it is used in more than 60% of KPIs.

Insbesondere die Messung der CSB am Einlass ist wichtig, da es in mehr als 60% der KPIs verwendet wird.

It is possible to generate a software sensor to calculate the COD

Es ist möglich, eine Software-Sensor, um den COD vorherzusagen zu entwickeln

Approach	R^2
Exponential Interpolation	0.48
Multi Linear Regression Analysis	0.61
Neural Network	0.72
Random Forest Regression	0.75 - 0.84



Two Plants are being added

Zwei Anlagen werden in Kürze hinzugefügt

RWZI Amersfoort

RWZI Zwolle

Inhalt

Introduction
Einführung

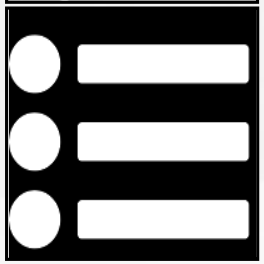
Treatment Plants
Monitored
Überwachte Kläranlage

EOS Setup
and Structure
EOS Aufbau und Struktur

EOS Outputs
EOS Ergebnisse

Obstacles
and Solutions
Hindernisse und Lösungen

Current Work:
Aktuelle Arbeiten:
Decision Support Systems



Conclusions
Schlussfolgerungen

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
INTERREG IVB

Conclusions

- The EOS allows automatic real-time evaluation of energy data at municipal sewage plants Die EOS ermöglicht die automatische Echtzeit-Auswertung von Energiedaten in kommunalen Kläranlagen
- The energy data and calculated performance indicators can be used for energy optimisation as well as for energy reporting/benchmarking Die Energiedaten und berechneten Kennzahlen können zur Energieoptimierung als auch für Energieberichterstattung / Benchmarking verwendet werden
- Further work is ongoing to develop an advanced Decision Support System (DSS) Weitere Arbeit ist im Gange, um eine hochavanciert Decision Support System zu entwickeln (DSS)
- Two plants are in the process of being added Zwei Anlagen werden in Kürze hinzugefügt
- The methodologies developed can assist to reach the optimum performance off all WWTP in NWE Die entwickelten Methoden können helfen, um die optimale Leistung auf alle Abwasserbehandlungsanlage in Nordwesteuropa zu erreichen

Thank you for your attention!

Vielen Dank für Ihre Aufmerksamkeit!

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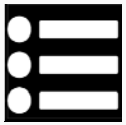

Finished

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