Energy Use Optimization and Recovery Strategies to Strive for Energy Neutrality

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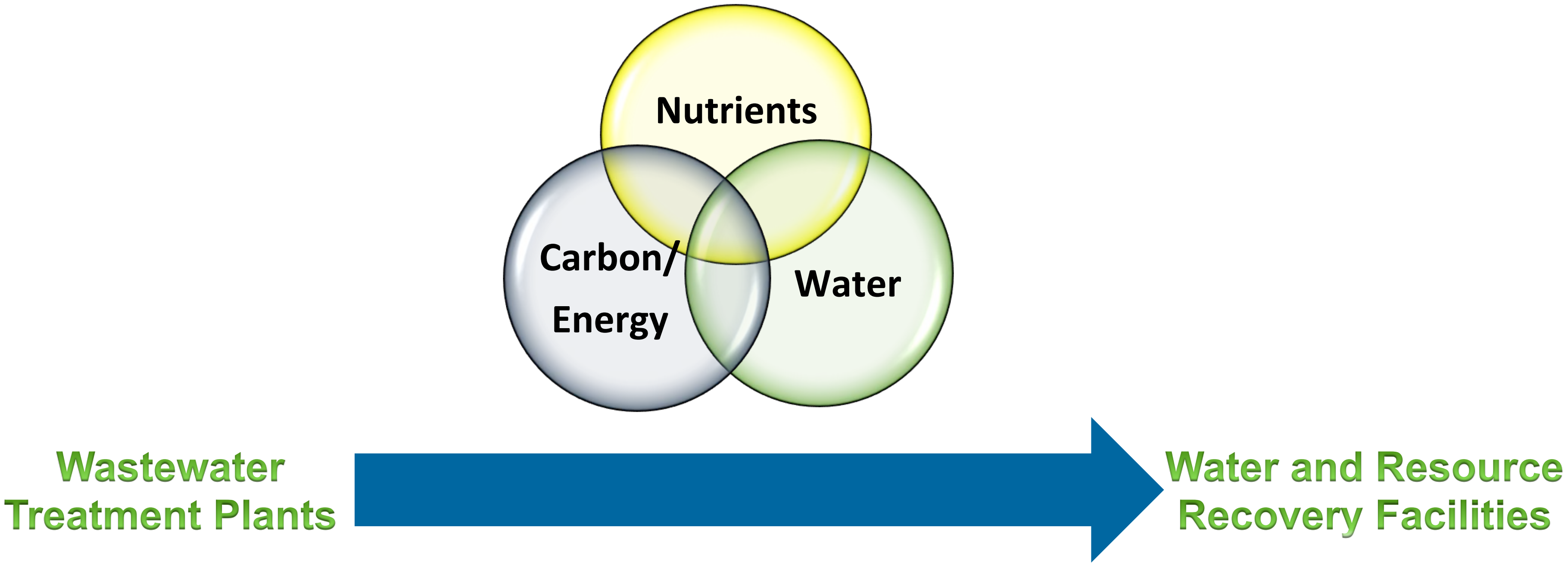
The "N.E.W." Paradigm



Energy Management Drivers

- Increase in energy costs
  - Water and wastewater treatment typically accounts for 30 to 60 percent of municipal government energy usage
- Reduce O&M costs and financial burden on end users
- Stricter regulations
  - Nutrient removal
  - Complex and energy intensive treatment processes
  - Biosolids land application challenges
- Climate change adaption
- Resiliency

Energy Management Focus Areas

Energy Management

Energy Use Baseline

- Energy benchmarking e.g. kWh/MG, kWh/lb BOD treated, kWh/lb N treated.
- Electrical sub-metering
- Utility billing rate structure
- Current and future energy costs

Non-Process Energy Use Optimization and Generation

- Lighting, building and HVAC Improvements
- Renewable energy such as solar, wind and/or hydroelectric

Process Optimization

- Process control optimization and improvements
- Process modifications or upgrades (low metabolic pathway)
- Energy efficient equipment

Process (Calorific) Energy Recovery

- Biochemical processes
- Thermochemical processes
- Treatment of other high energy dense waste materials e.g. FOG

Can WRRF's be Net Zero Energy?

Experimental Determination of Energy Content of Unknown Organics in Municipal Wastewater Streams

Ioannis Shizas[1] and David M. Bagley, M.ASCE[2]

Abstract: A bomb calorimetry method has been used for the first time to measure the energy content of raw municipal wastewater. The method was first validated using standard compounds (arginine, glucose, and propionic acid) and then tested with municipal sludge samples, with the results compared to previously published values. By drying a large enough sample to yield approximately 0.5 g of solid residue and using benzoic acid in a 1:1 ratio as a combustion aid, an accurate and precise measurement of the energy content of raw municipal wastewater can be made. The energy content measurements indicate that for the full-scale treatment facility examined, the potential energy available in the raw wastewater exceeds the electricity requirements of the treatment process by a factor of 9.3.

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CE Database subject headings: Organic matter; Energy measurement; Municipal wastes; Wastewater management.

Introduction

Anaerobic waste treatment requires less energy input than aerobic treatment while also producing potentially renewable energy sources such as hydrogen and methane. To determine the feasibility of energy recovery, the energy content of the organic fraction of the waste should be known.

The energy content of the organic matter in a waste stream can be determined by combusting a sample in an oxygen bomb calorimeter. Previous studies have

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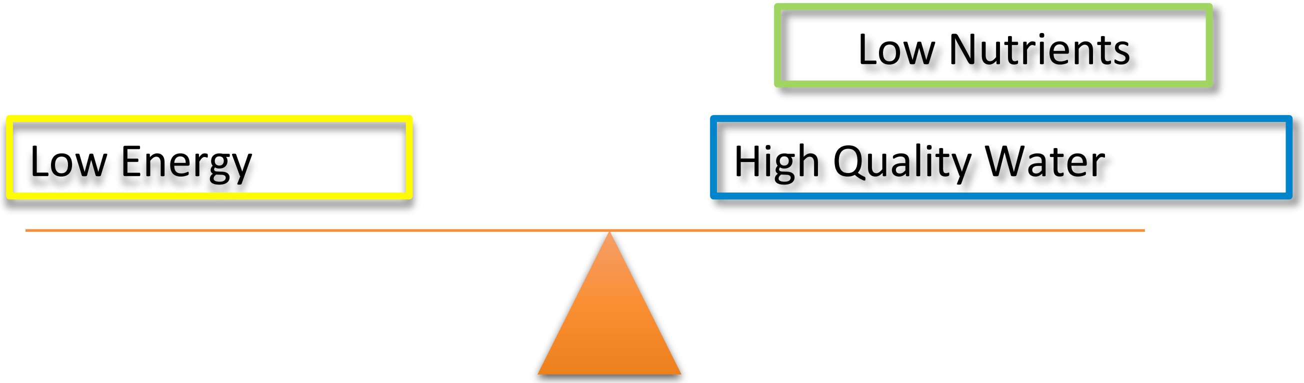
Note. Discussion open until January 1, 2005. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on June 26, 2003; approved on December 19, 2003. This paper is part of the *Journal of Energy Engineering*, Vol. 130, No. 2, August 1, 2004. ©ASCE, ISSN 0733-9453/2004/2-45–53/$18.00.

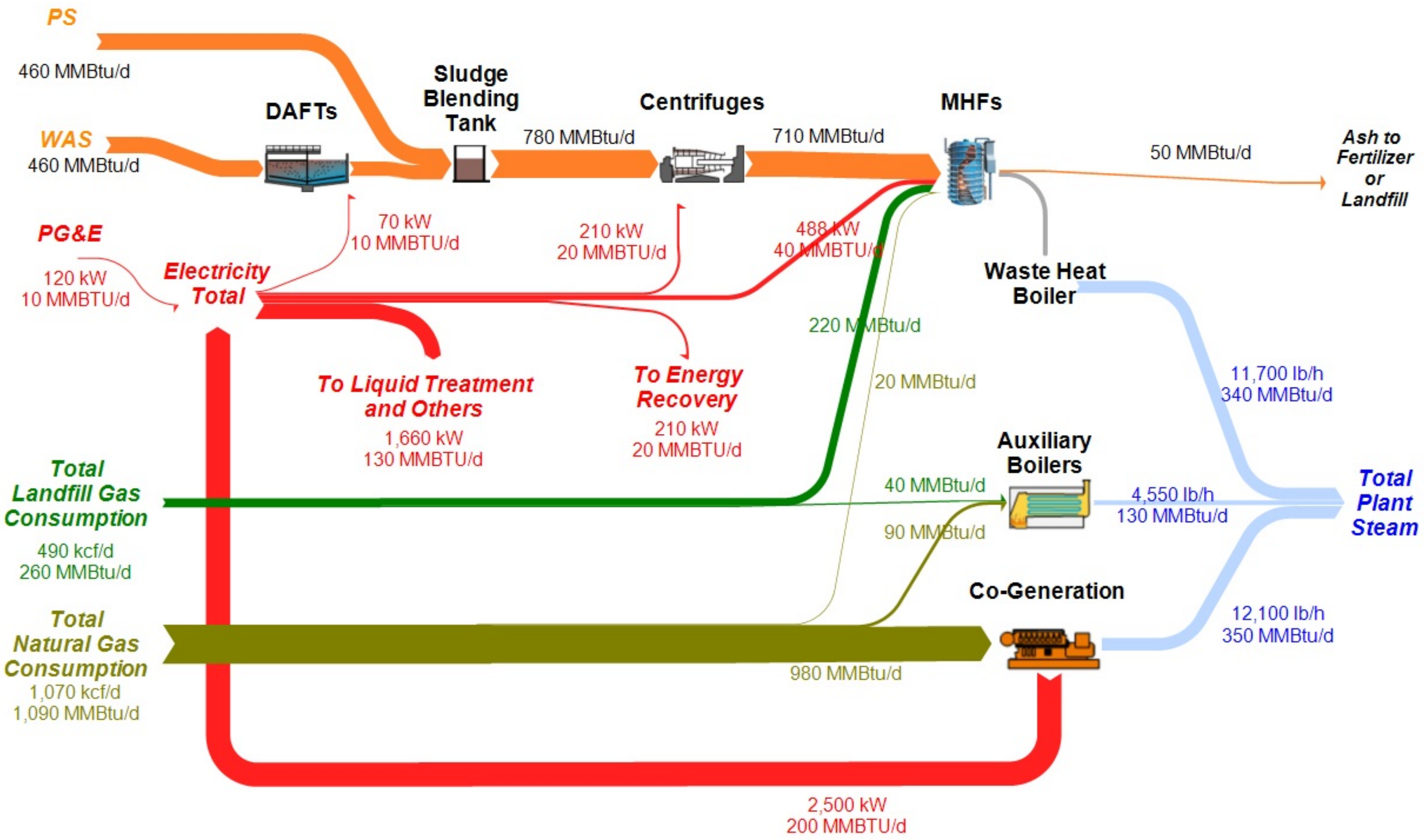
- Research by David Bagley at U of Toronto (North Toronto TP) in 2001:
  - Electricity consumed: 0.2 kWh/m^3
  - Potential Energy of Raw Wastewater: 1.8 kWh/m^3
  - WW contains ~10 times the energy needed for conventional treatment
  - In theory we only need to be 10% efficient at converting BOD to electricity

Carbon – A Limited Resource with Competing Demands

- Tradeoffs between achieving low energy and low nutrients
  - Carbon demand to drive biological nutrient removal vs. methane production to generate electricity
- Need for balancing competing aspects of nutrient removal, net energy usage, and high quality effluent water goals



Knowing the Carbon and Energy Flow



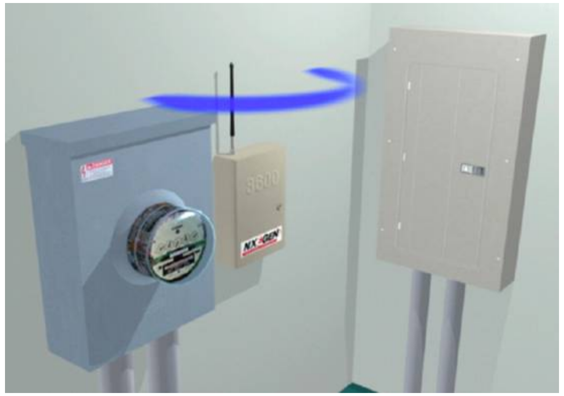
CS 1 – Greater New Haven WPCF

- 60 mgd facility
  - Nutrient Removal: 5 mg/L TN annual average

Energy audit led to optimization and process control enhancements!

CS 1 - Power Mapping and Energy Model

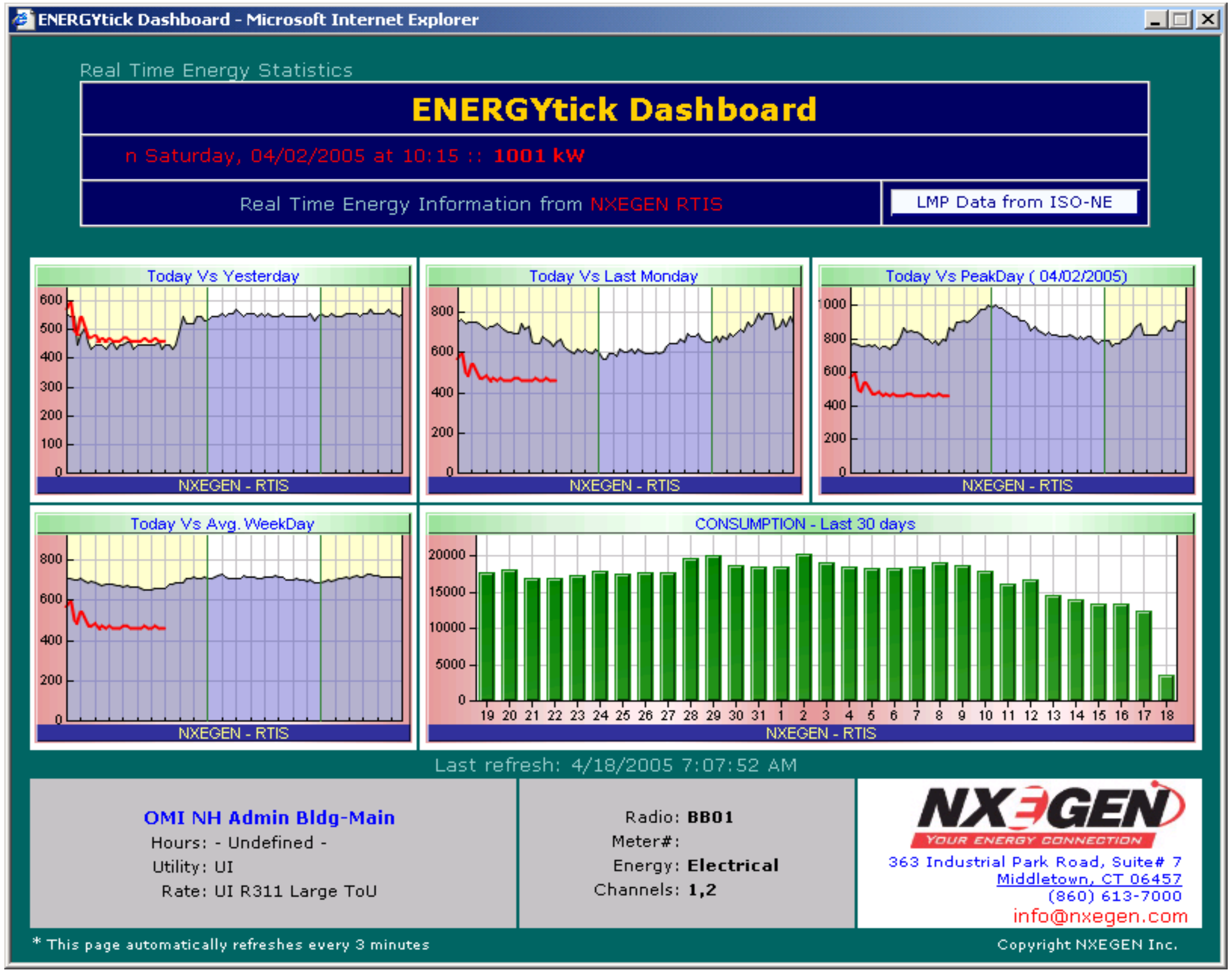
- Detailed mapping of power systems and MCCs
- Static energy model to account for unit process energy consumption
- Model calibration through online power monitoring of key load centers



OMI Electricity Baseline End Use Budget
East Shore Facility
Month: December 31

	No. of Motors	Operating Motors	Power Factor	Motor H.P.	KW per Motor	Run Hours per Day	Billed KW	Monthly KWh
Large Motors:								
Influent Pumps	3	0.0	90%	250.0	186.5	24.0	0.00	0
Influent Pumps	2	1.8	90%	125.0	93.3	24.0	151.07	112,392
Centrifugal Blowers	5	1.5	90%	700.0	522.2	24.0	704.97	524,498
Totals								636,890
Small Motors:								
Bar Screens	2	1	90%	2.0	1.5	24.0	1.61	1,199
Primary Clarifiers	3	3	90%	1.0	0.7	24.0	2.01	1,499
Secondary Clarifiers	8	8	90%	1.0	0.7	24.0	5.37	3,996
RAS (NRCY)Pumps	8	8	90%	25.0	18.7	24.0	134.28	99,904
Secondary Scum pumps	4	4	90%	5.0	3.7	12.0	13.43	4,995
Primary sludge pumps	6	3	90%	30.0	22.4	12.0	60.43	22,478
Thknd Primary sldg pmps	2	1	90%	5.0	3.7	12.0	3.36	1,249
Primary sludge thickeners	2	2	90%	1.0	0.7	24.0	1.34	999
WAS Pumps	10	5	90%	15.0	11.2	24.0	50.36	37,464
BLEND TANK	4	4	90%	7.5	5.6	24.0	20.14	14,986
Totals								744,071
Total Motor Loads								**1,380,961**
Other Loads:								
					KW Load	Run Hours per Day		
Lighting					207.2	20.0	207.20	128,464
Lighting Upgrade					(75.0)	20.0		
	# of Tons				KW Load	Run Hours per Day		
Air Conditioning	65				78.0	0.0	78.00	0
					KW Load	Run Hours per Day		
Heating					32.6	14.0	32.60	14,148
	# of Work Stations	KW per Work Station	Power Factor			Run Hours per Day		
Computer Loads	30	0.5	95%			18.0	14.25	7,952
		KW per Sq. Ft.	Sq. Ft.			Run Hours per Day		
Miscellaneous Receptacles		1.5	32000			24.0	48.00	35,712
Totals								186,276
Total Baseline Electricity Loads								1,567,237

CS 1 – Energy Monitoring Dashboard



CS 1 – The Energy Management Improvements

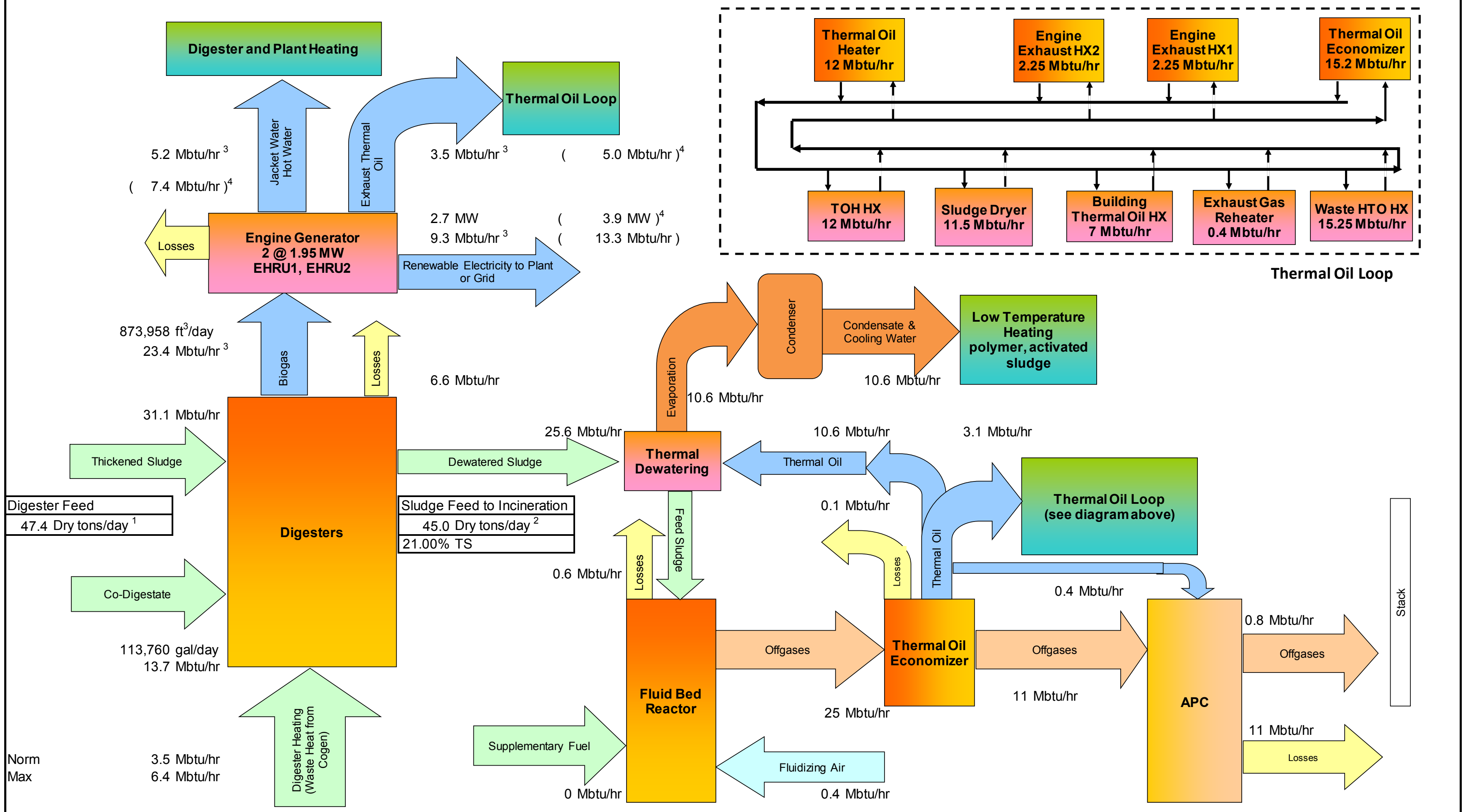
- Mapping, Modeling & Monitoring Outcomes
  - Found 0.6 million kWh/year of power used by 3rd party contractor
  - Identified weaknesses in emergency power supply
  - Found discrepancies between utility bills and on-line metering
- Energy management improvements
  - Aeration: 1 million kWh/yr
  - Lighting: 0.66 million kWh/yr
  - Instituted ISO NE demand response program to generate revenue and reduce power load by 1.7 MW

CS 2 - Green Bay Metropolitan Sewerage District (GBMSD)

- Formed in 1931 owns and operates:
  - GBF, designed to treat 49.2 mgd through secondary treatment
  - DPF, designed to treat 14.2 mgd through secondary treatment
- NEW Water – Water Conservation & Stewardship

Gain flexibility by tapping energy in wastewater solids!

Energy Summary for 2035 - Annual Average Flows (Revised: October 09 2015)



Notes:
1 24/7 Operation
2 24/5 Operation
3 LHV basis
4 Full Load Output with 2 Engine Generator units operating

Legend:

APC	Air Pollution Control Equipment
LHV	Lower Heating Value
Mbtu/hr	Million British Thermal Units per Hour
MW	Megawatts

Digester Performance with thickened sludge only

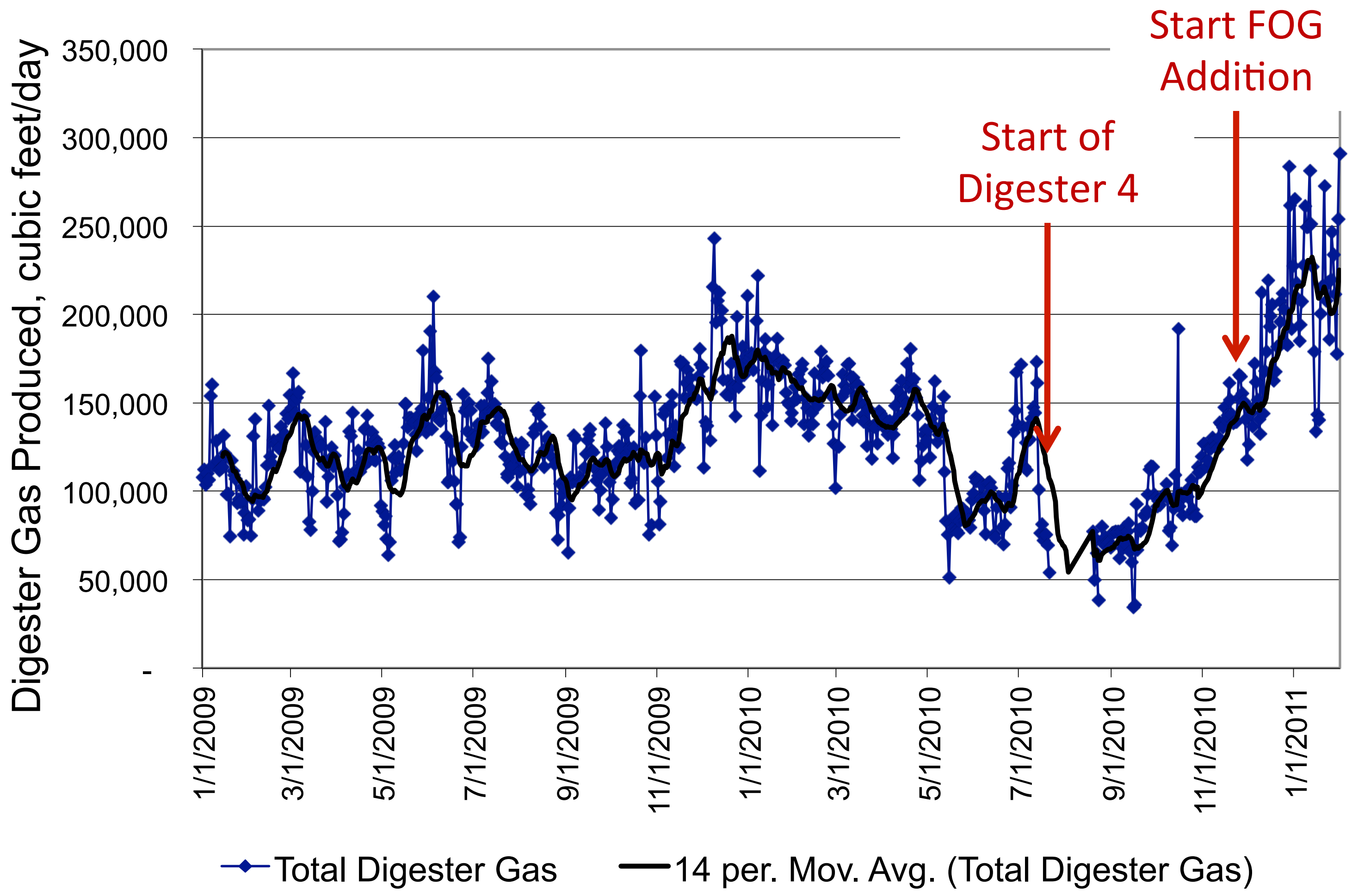
Biogas Production	494,834 ft^3/day
Biogas Energy	12.4 Mbtu/hr

CS 3 – Douglas L. Smith Middle Basin WWTP

- 14.5 mgd
- Project Components:
  - Anaerobic digestion facilities expansion
  - FOG and HSW receiving facility
  - Two 1060 kW co-generation units
- Results
  - Tipping fee: $300,000/yr
  - Electricity savings :$400,000/ year

Increased solids handling capacity while decreasing carbon footprint!

CS 3 - Digester Gas Production Increased with Addition of FOG Waste

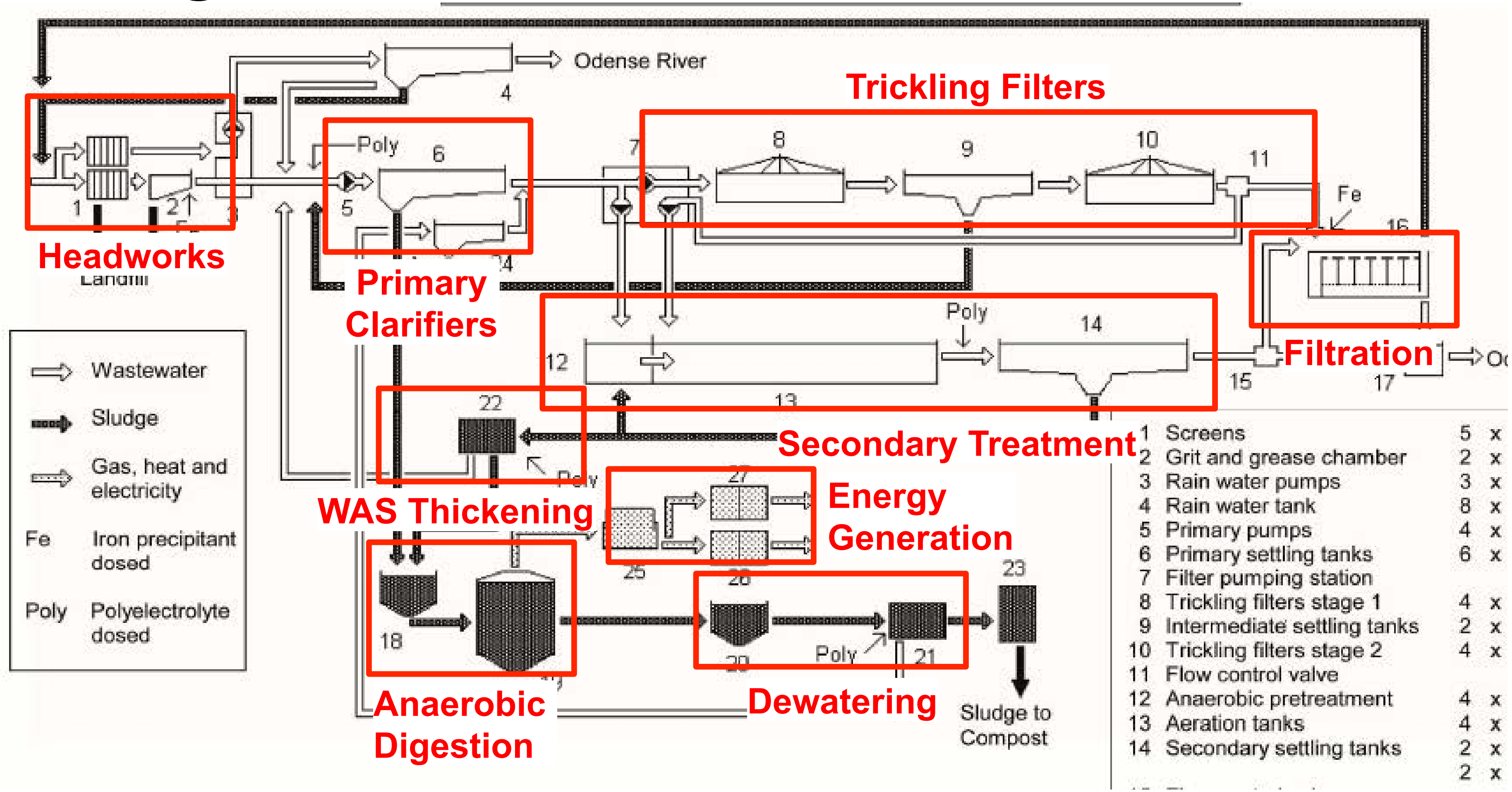


CS 4 - VandCenter Syd (VCS)

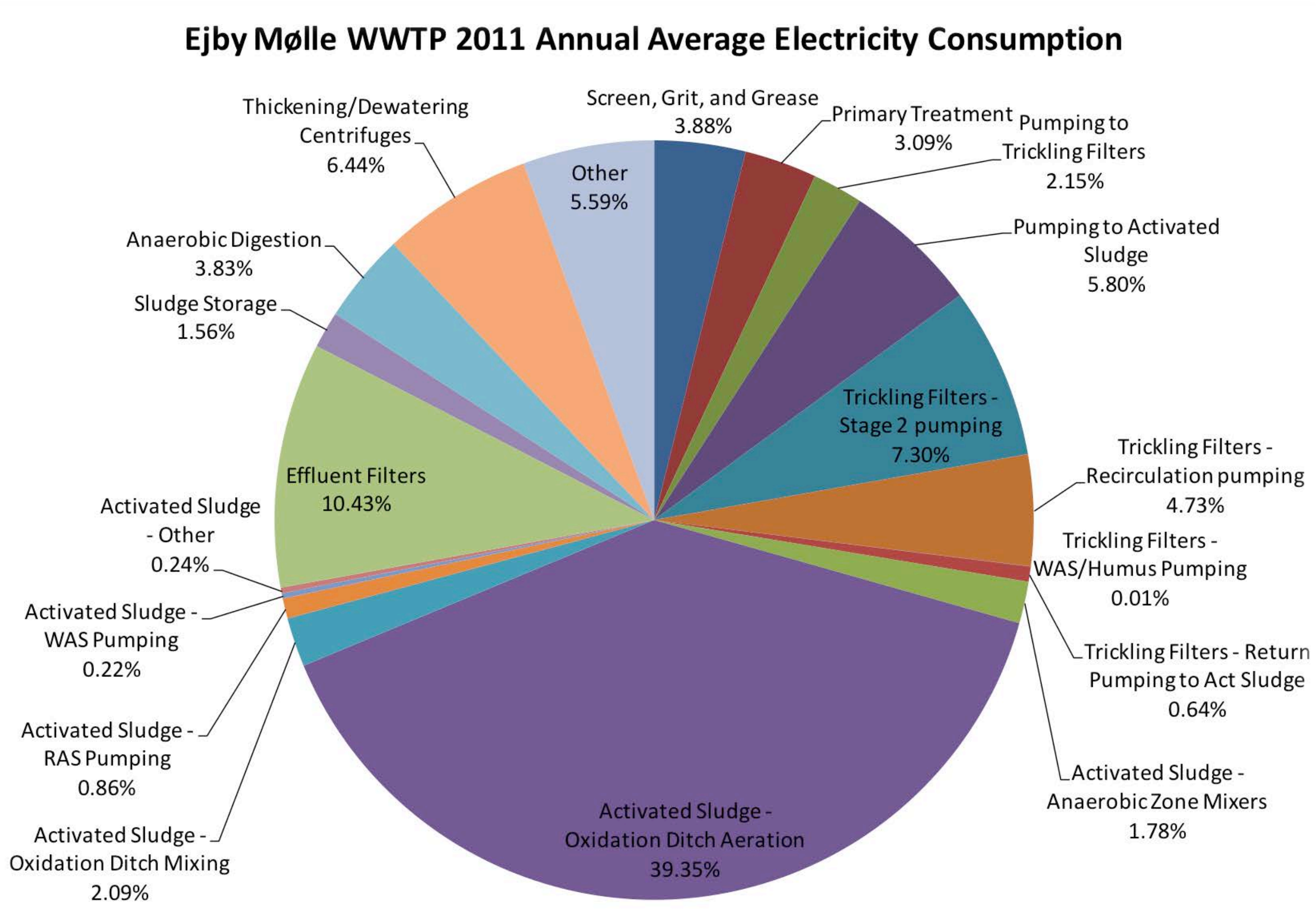
- 3rd largest water and wastewater company in Denmark. Headquartered in Odense.
- Ejby Mølle WWTP
  - 385,000 PE BNR facility
  - 76 percent self-sufficient in 2011

Achieving Energy Self-Sufficiency in a Nutrient Removal Facility Through Operational Optimization!

CS 4 – Ejby Mølle WWTP Process Flow Diagram



CS 4 — Availability of detailed historic energy consumption and generation data was key in the evaluation of optimization opportunities

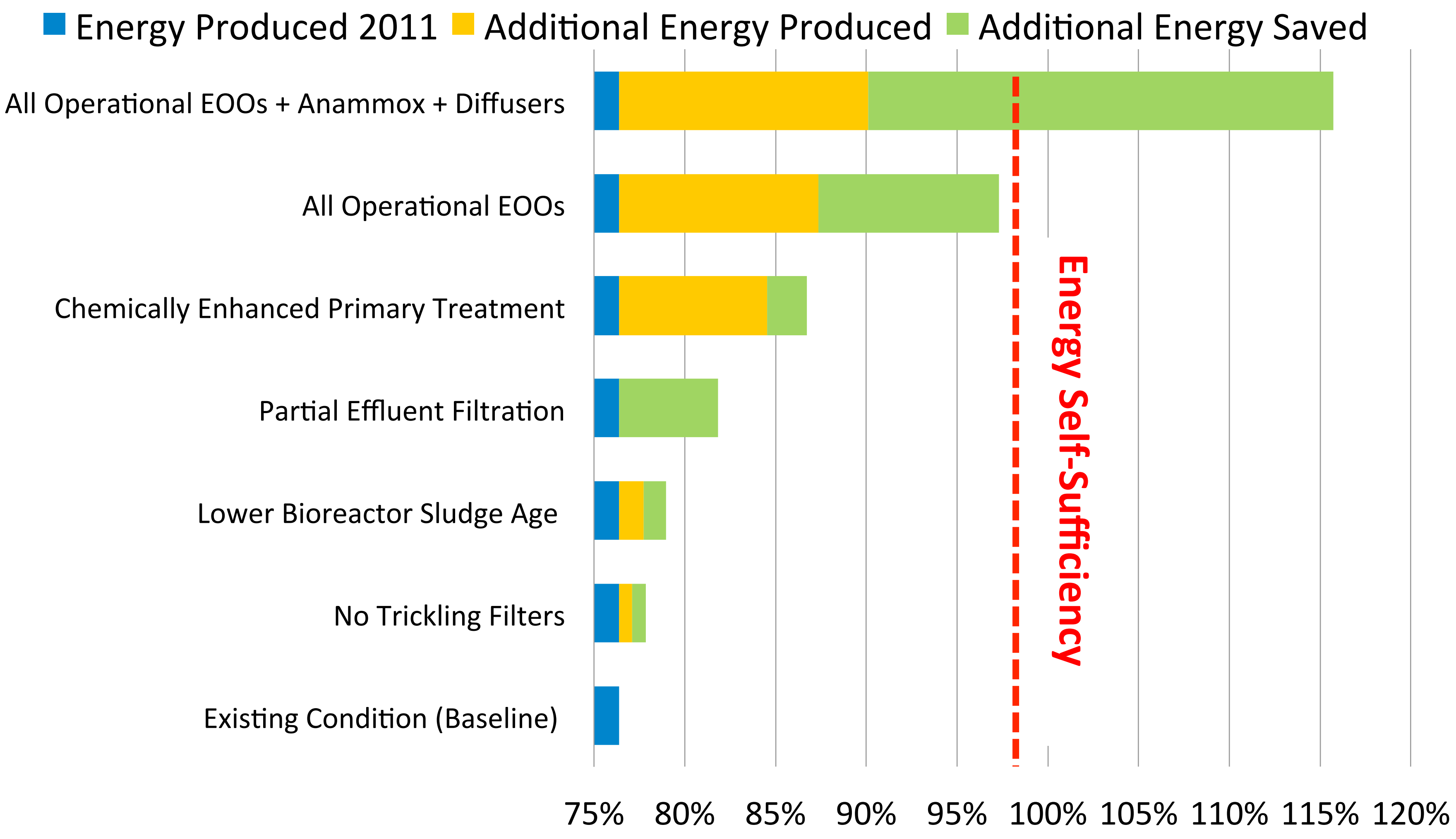


CS 4 - Facility Level Mass and Energy Balance to Identify EOOs

- Adopted screening criteria
  - Readily implementable; primarily process modifications
  - Significant impact on energy profile
  - Proven process
- Short Listed EOOs
  - Implement chemical enhanced primary treatment (CEPT)
  - Nitrify centrate in trickling filters (TFs)
  - Decommission TFs and convert TF clarifiers to CEPT for wet weather treatment
  - Shorter BNR system solids retention time (SRT)
  - Reduce effluent filtration operation to 12 hours per day

- Long Term EOOs
  - Implement deammonification for nitrogen removal in recycle returns (sidestreams)
  - Replace oxidation ditch mechanical aerators with fine bubble diffused aeration

CS 4 – Path to Energy Self Sufficiency



Conclusions

- Typical municipal wastewater theoretically has more energy in wastewater solids compared to energy required for its treatment
- Energy benchmarking and monitoring is essential to evaluate potential improvement scenarios
- Two pronged holistic approach to energy management and self sufficiency
  - Energy use optimization
  - Energy recovery
- Net energy-positive condition achievable with external carbon (codigestion)
- Balancing nutrient removal, carbon management and water reclamation requirements are key to striving for energy neutrality

Thank You

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