RETHINKING WASTEWATER TREATMENT FROM AN ENERGY PERSPECTIVE

PARTNERING FOR IMPACT IN CALIFORNIA

A CWEA-CASA Webinar

May 5, 2021

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OVERVIEW OF PRESENTATION

- Take Home Ideas
- Energy Available in Wastewater
- Energy Use in Wastewater Treatment
- Heat Recovery from Wastewater
- Energy Recovery from Wastewater Constituents
- Energy Savings Through Process Design
- Codigestion with Organic Fraction of MSW
- Energy Management Through Satellite WWT
- Southern California: A Case Study
- Closing Thoughts

TAKE HOME IDEAS

- New technology is now available to allow wastewater treatment plants to become energy independent
- New technologies under development will result in further energy savings
- Bold new thinking is required
- Must change mindset: *Wastewater is a renewable recoverable source of potable water, energy, and nutrients*

ENERGY AVAILABLE IN WASTEWATER

ENERGY CONTENT OF WASTEWATER, 1

Heat energy

Specific heat of water = 4.1816 J/g•°C at 20°C

Organic fraction of raw wastewater

$C_{7.9}H_{13}O_{3.7}NS_{0.04}$ (typical of possible formulations)

Chemical energy (Channiwala,1992)

$$\text{HHV (MJ/kg)} = 0.3491\,C + 1.1783\,H - 0.1034\,O - 0.0151\,N + 0.1005\,S - 0.0211A$$

C = carbon, % by weight; H = hydrogen, %;
O = oxygen, %; N = nitrogen,%; S = sulfur, %;
A = ash, %

ENERGY CONTENT OF WASTEWATER, 2

Component	Coefficient	mw	Molecular mass	Weight fraction, %
Carbon	7.9	12	94.8	48.9[a]
Hydrogen	13	1	13.0	6.7
Oxygen	3.7	16	59.2	30.5
Nitrogen	1	14	14.0	7.2
Sulfur	0.04	32.07	1.3	0.7
Ash	–	–	–	6.0
			182.3	100.0

[a] [(94.8/182.3) x 0.94]100 = 48.9

HHV, MJ/kg = 0.3491 (48.9) + 1.1783 (6.7) – 0.1034 (30.5) - 0.0151 (7.2) + 0.1005 (0.7) – 0.0211 (6.0)

HHV, MJ/kg = 17.07 + 7.89 – 3.15 – 0.109 + 0.070 – 0.127 = 21.6

LHV, MJ/kg = 21.6 x 0.92 = 19.9

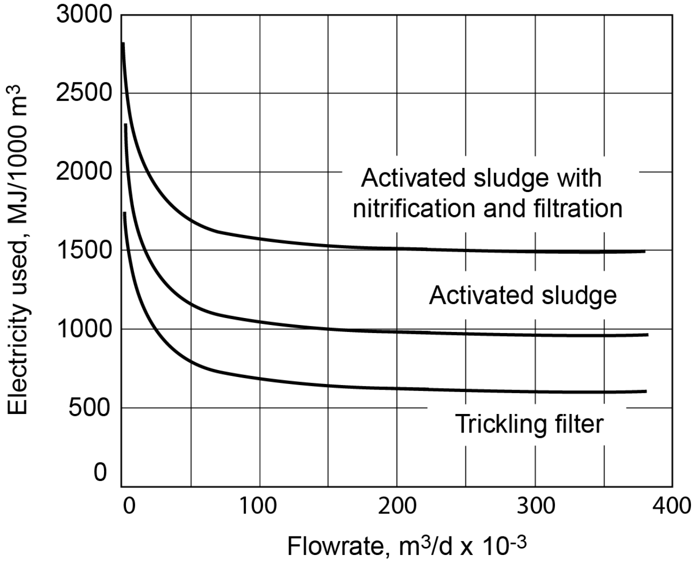
ENERGY CONTENT OF WASTEWATER AND WASTEWATER CONSTITUENTS

Constituent	Unit	Value
Wastewater, heat basis	$MJ/10°C \cdot 10^3 m^3$	41,900
Wastewater, $C_{7.9}H_{13}O_{3.7}NS_{0.04}$	MJ/kg (HHV)	21.6
Wastewater, COD basis	MJ/kg COD	12 - 15
Primary sludge, dry	MJ/kg TSS	15 – 15.9
Biosolids, dry	MJ/kg TSS	12.4 – 13.5

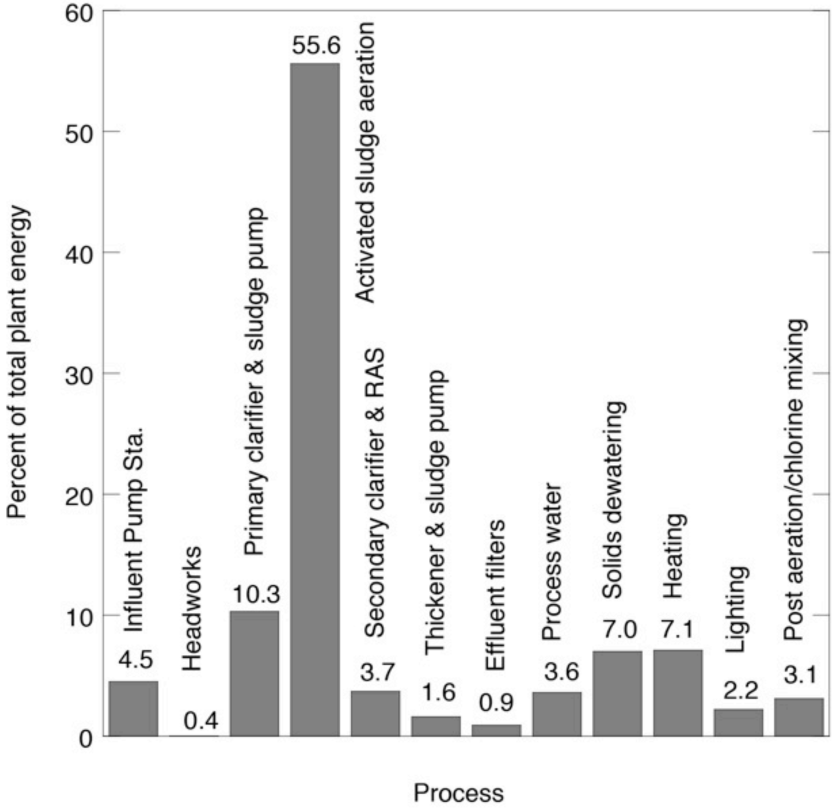
kWh x 3.6 = MJ; LHV = HHV x 0.92

ENERGY USE IN WASTEWATER TREATMENT

TOTAL AND UNIT PROCESS ENERGY USAGE IN WASTEWATER TREATMENT



Note: $m^3/d \times 2.6417 \times 10^{-4} = 1.0$ Mgal/d



REQUIRED AND AVAILABLE ENERGY FOR WASTEWATER TREATMENT, EXCLUSIVE OF HEAT ENERGY

Energy required for secondary wastewater treatment

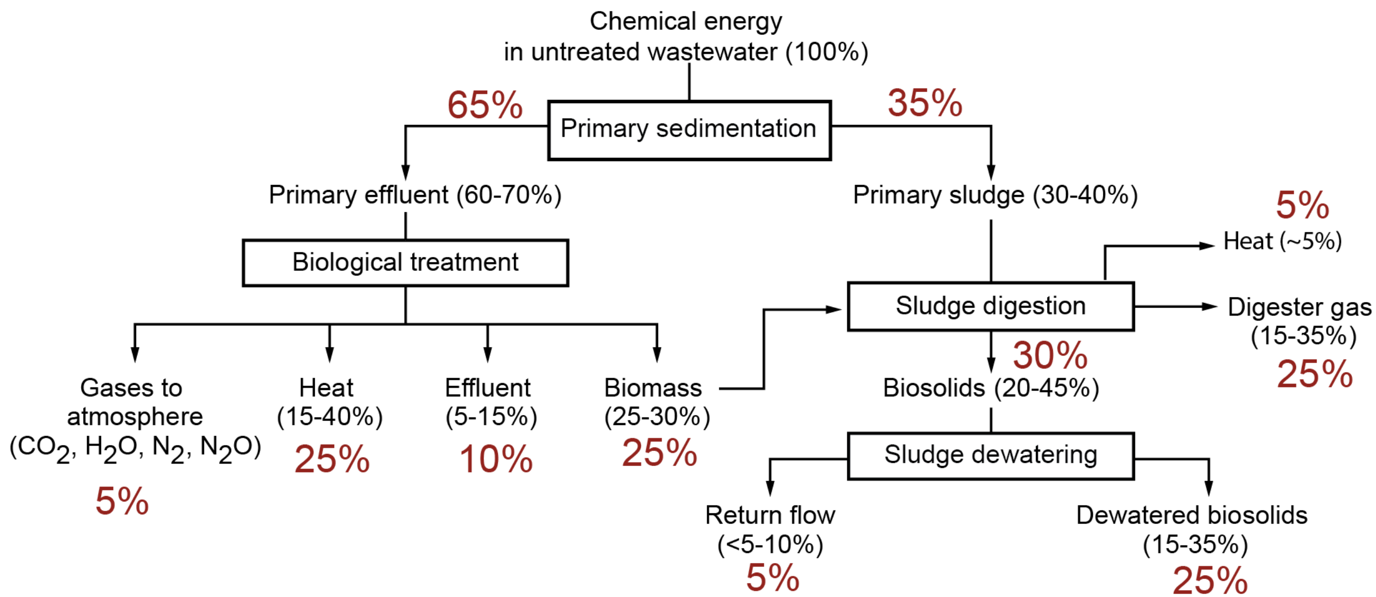
1,500 MJ/1,000 m^3 (> 25 Mgal/d) to
2,200 MJ/1,000 m^3 (~ 5 Mgal/d)

Energy available in wastewater for treatment (assume COD = 500 g/m^3 = 500 kg/1000 m^3)

$$E = (500 \text{ kg COD}/1{,}000 \text{ m}^3)(13 \text{ MJ/ kg COD})$$
$$= 6{,}500 \text{ MJ}/1000 \text{ m}^3$$

Energy available in wastewater is about 2 to 4 times the amount required for treatment

FATE OF CHEMICAL ENERGY DURING CONVENTIONAL WASTEWATER TREATMENT



Energy available 6,500 MJ/1,000 m^3 x (0.25 x 0.7) = 1,170 MJ/1,000 m^3

versus

1,500 (large > 10 x 10^4 m^3/d) to 2,200 MJ/1,000 m^3 needed for treatment

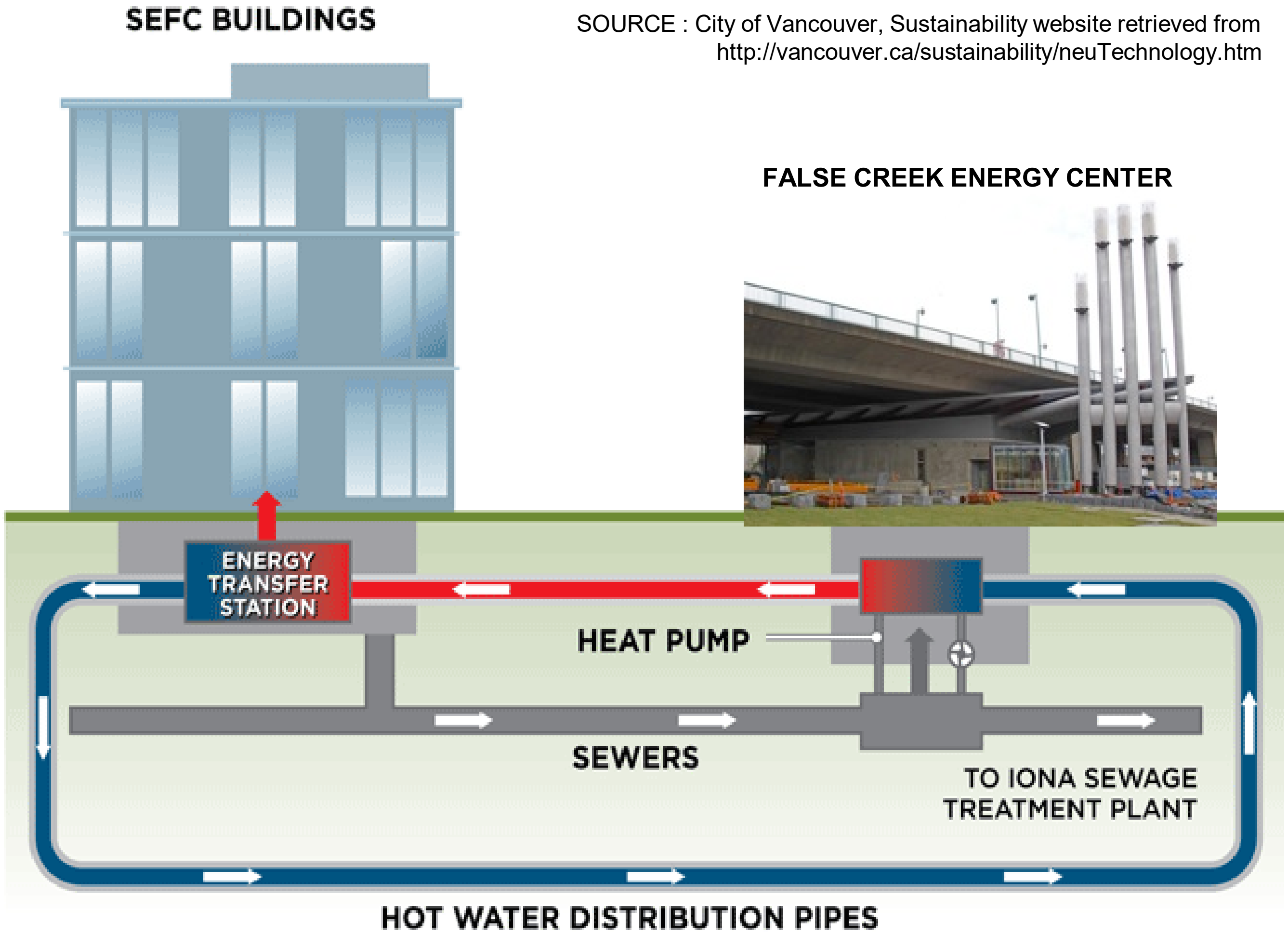
conclusion

Energy self sufficiency is easier to achieve with large plants

HEAT RECOVERY FROM WASTEWATER

HEAT RECOVERY FROM WASTEWATER

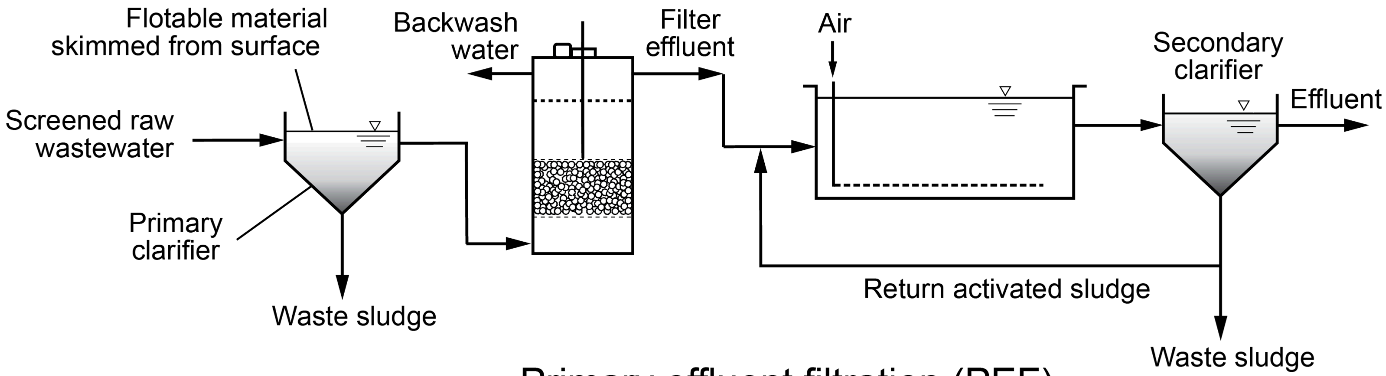
SOURCE : City of Vancouver, Sustainability website retrieved from http://vancouver.ca/sustainability/neuTechnology.htm



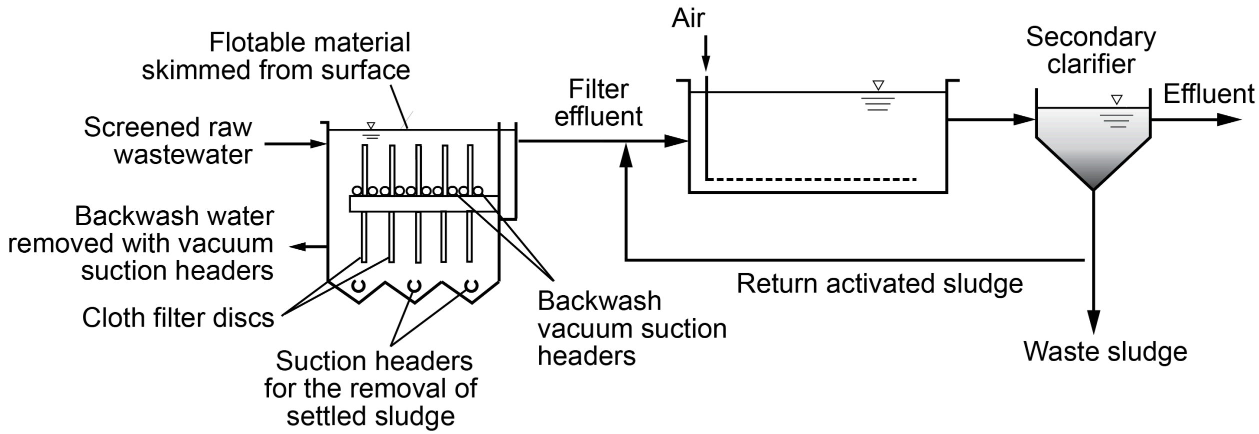
Issue: Must have use for heat year-round

ENERGY RECOVERY FROM WASTEWATER CONSTITUENTS

PEF AND PF FOR ENHANCED ENERGY RECOVERY AND REDUCED ENERGY USAGE FOR TREATMENT

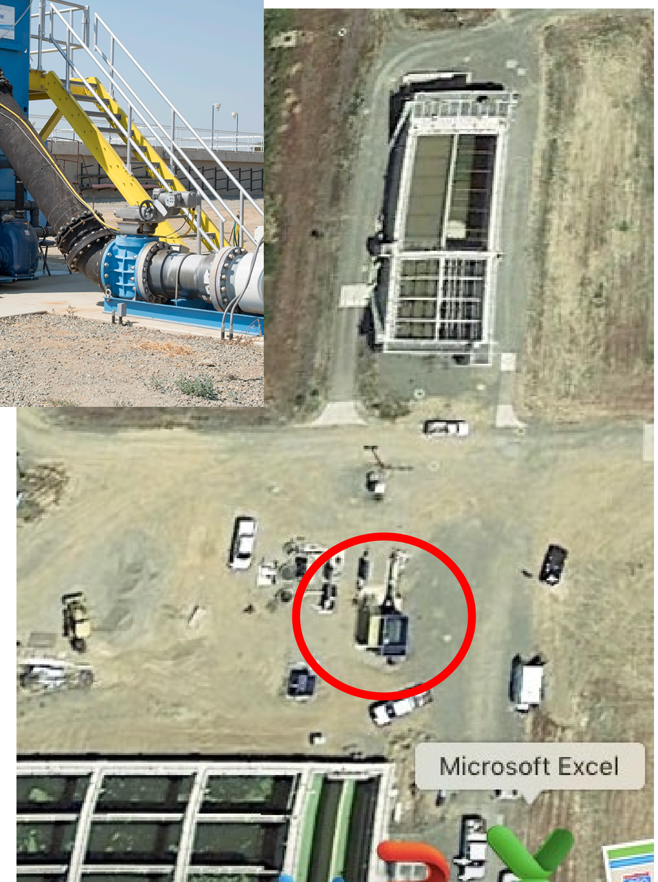


Primary effluent filtration (PEF)

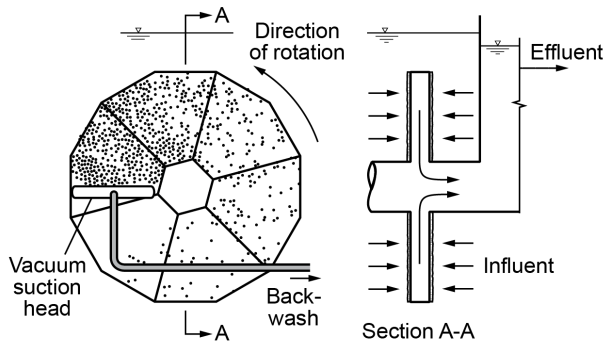


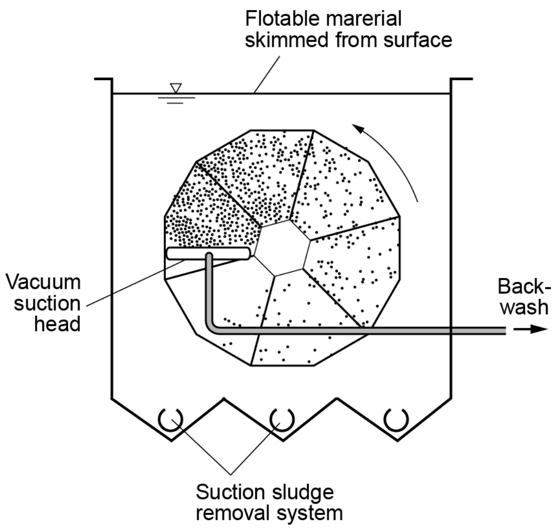
Primary filtration (PF)

PRIMARY FILTRATION WITH CLOTH DISK FILTER AT LINDA WWTP, LINDA, CALIFORNIA



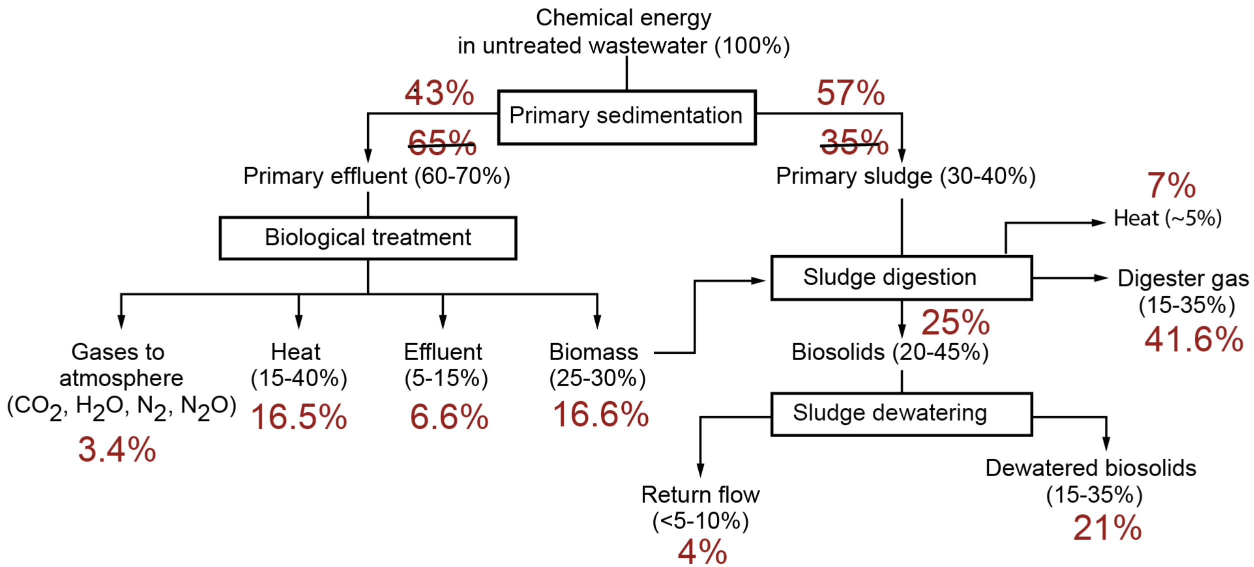
ENHANCED ENERGY DIVERSION WITH PRIMARY TREATMENT: CLOTH DISK FILTER (Pore size 5-10 μm)





Constituent	Average concentration, mg/L		Average removal, %
	Filter influent	Filter effluent	
TSS	301	48	83
COD	605	254	57
BOD_5	305	123	58
TKN	48	39	19

POTENTIAL ENERGY RECOVERY WITH PRIMARY FILTRATION



Energy available 6,500 MJ/1,000 m^3 x (0.416 x 0.7) = 1,893 MJ/1,000 m^3

versus

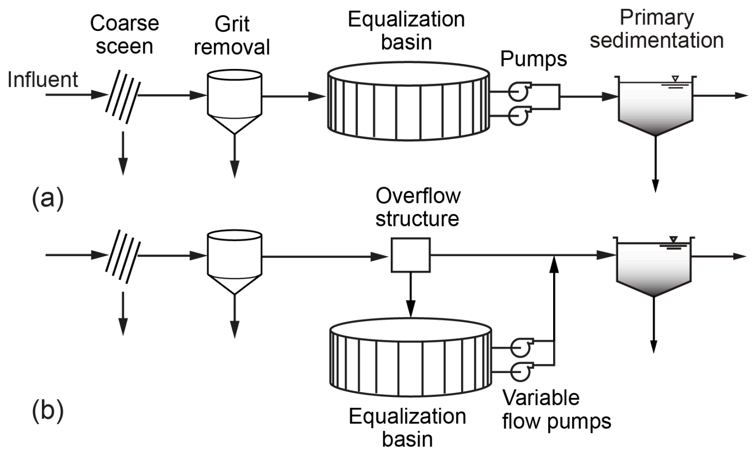
1,335 (large >10 x 10^4 m^3/d) to 1,958 MJ/1,000 m^3 needed for treatment with 20% reduction in aeration energy due to load reduction

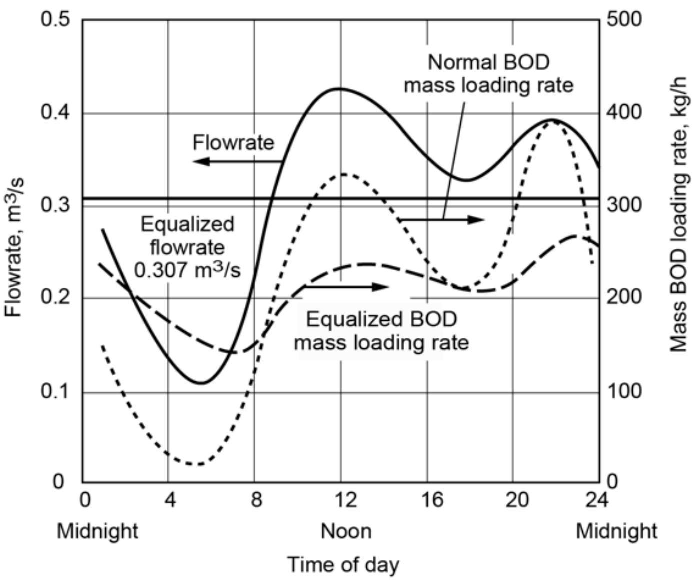
conclusion

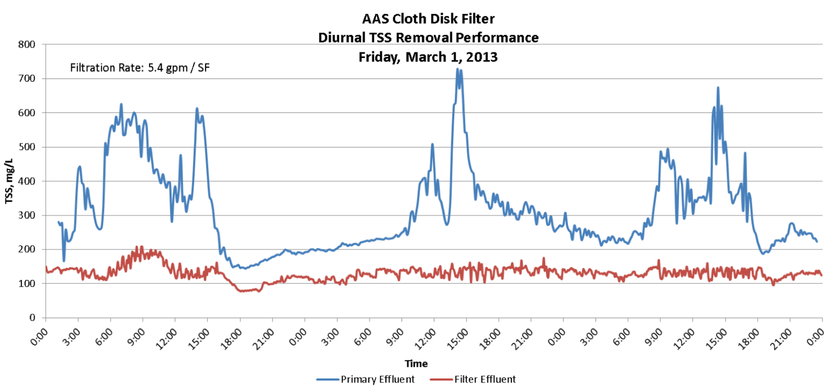
Energy self sufficiency is easier to achieve with large plants

REDUCTION IN PEAK ENERGY USAGE THROUGH FLOW EQUALIZATION AND IMPROVED PROCESS DESIGN

IN-LINE AND OFF-LINE FLOW AND BOD AND TSS MASS LOADING EQUALIZATION FOR ENHANCED TREATMENT PERFORMANCE AND REDUCED ENERY USAGE





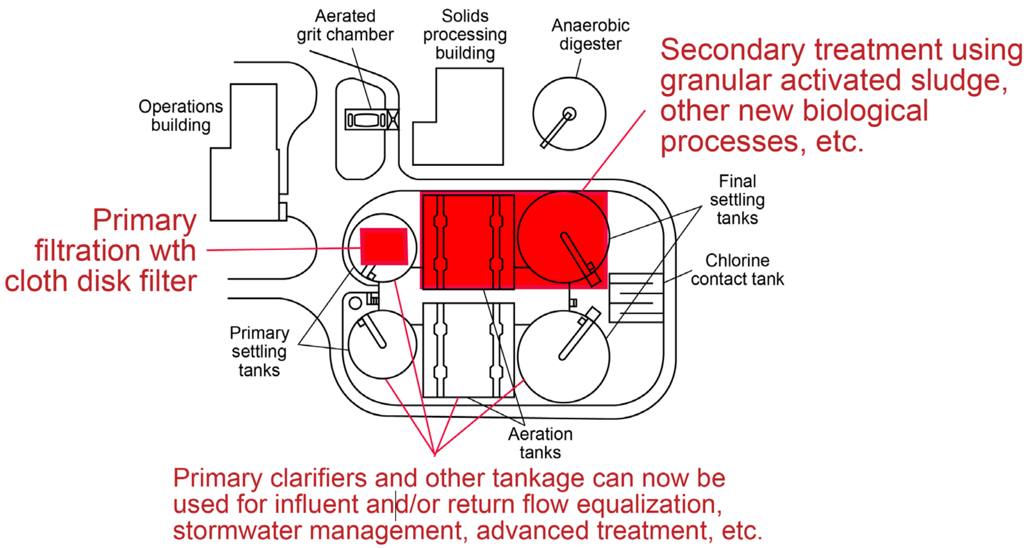


REDUCED ENERY USAGE THROUGH IMPROVED PROCESS DESIGN

At $0.03/kWh energy efficiency was not an Issue.

REDUCTION IN ENERGY USAGE WITH NEW BIOLOGICAL TREATMENT PROCESSES

PLAN FOR FUTURE ENERGY REDUCTION WITH NEW BIOLOGICAL TREATMENT PROCESSES



Anaerobic granular sludge

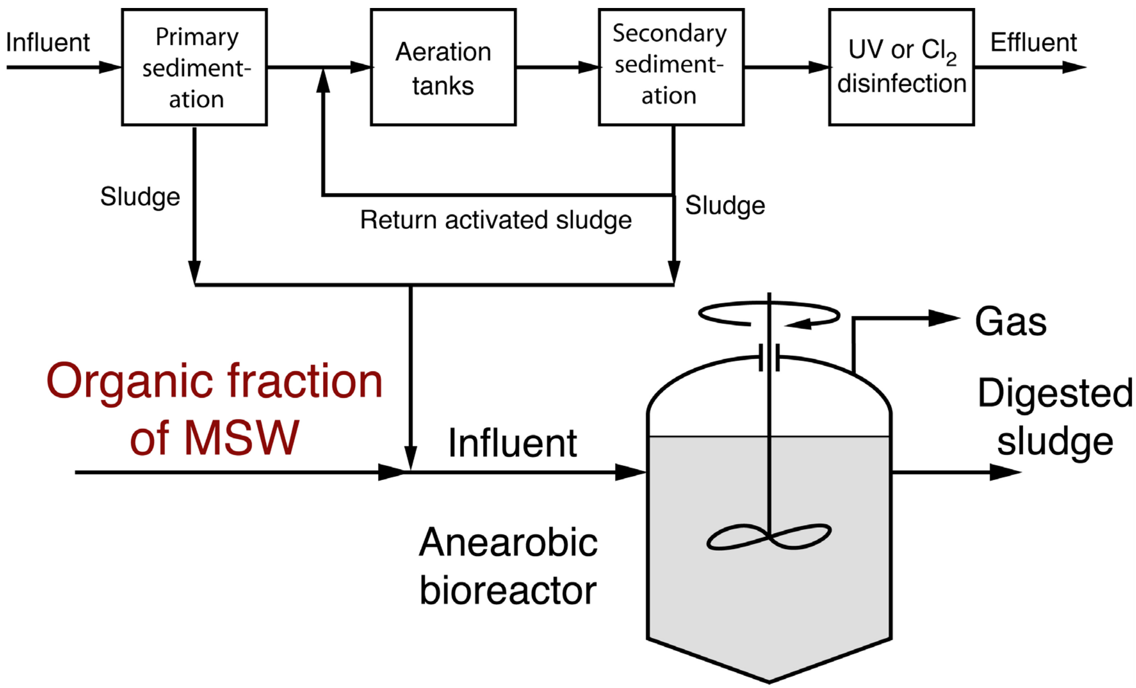
Simultaneous nitrification and denitrification (SND) and phosphate removal with single microorganism (???)
New heterotrophic ammonium oxidation pathway described with reduced oxygen requirements (~ 60%???)

$$NH_4^+ \rightarrow NH_2OH \rightarrow N_2$$

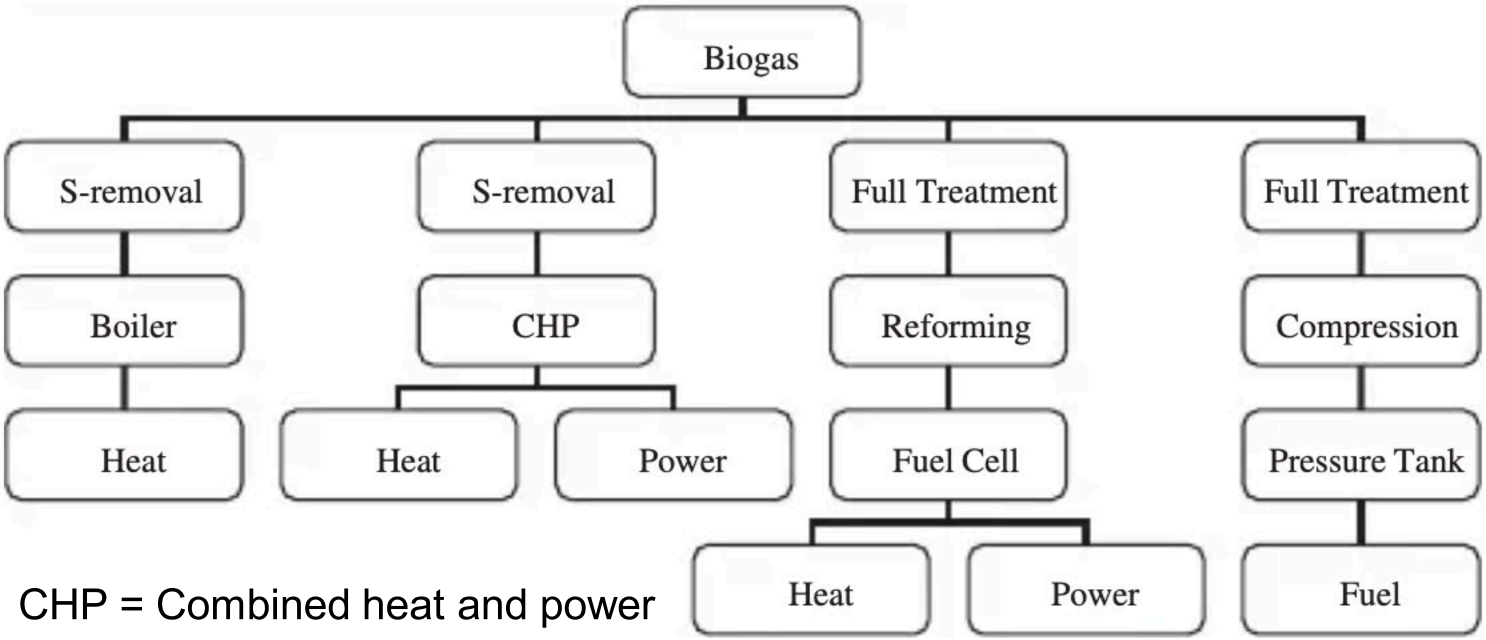
https://doi.org/10.1016/j.waters.2020.116300

ENHANCED ENERGY PRODUCTION THROUGH C0-DIGESTION WITH ORGANIC FRACTION OF MSW

ENERGY AND NUTRIENT RECOVERY FROM CO-DIGESTION OF WASTEWATER SLUDGE AND ORGANIC FRACTION OF MSW



SOME BIOGAS UTILIZATION OPTIONS



CHP = Combined heat and power

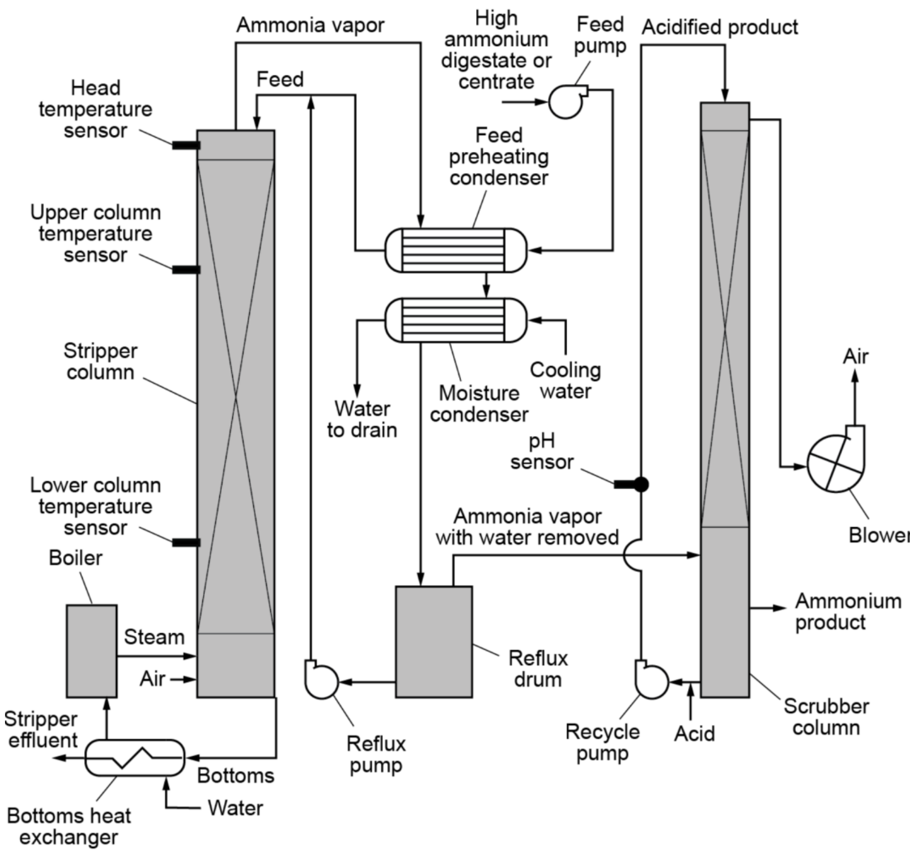
L. Appels, J. Baeyens, J. Degreve, and R. Dewil (2008) "Principles and potential of the anaerobic digestion of waste-activated sludge," *Progress in Energy and Combustion Science*, **34,** 755–781.

TYPICAL DIGESTATE PHYSICAL AND CHEMICAL PROPERTIES

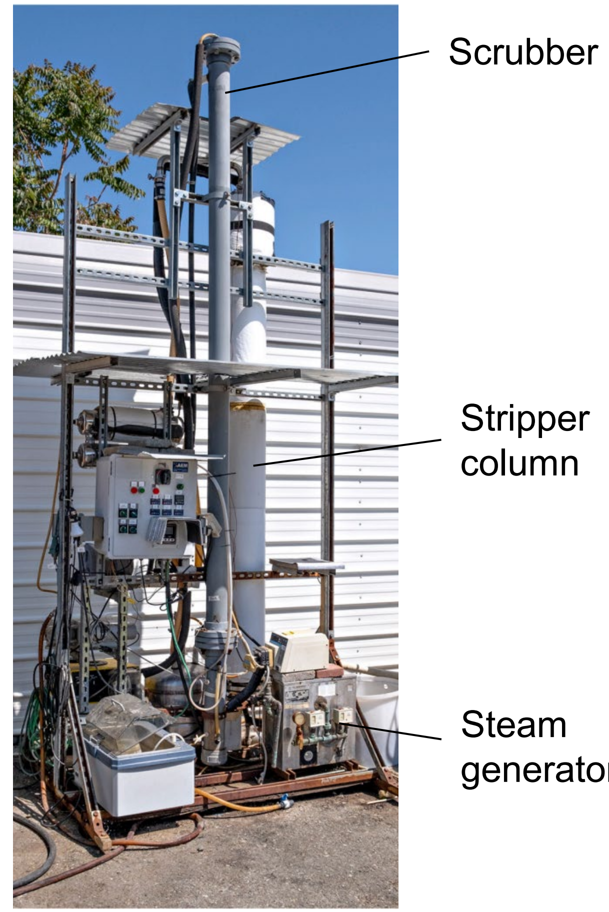
Parameter	Unit	Type of digestion		
		Themophilic	Mesophilic	
		Food waste	Co-digestion	Co-digestion centrate
BOD, soluble	mg/L	3500	500	500
Alkalinity	mg $CaCO_3$/L	20,000	8400	4200
Ammonium, N	mg N/L	4000	1500	950
Phosphate, P	mg P/L	100	270	200
Sodium, Na	mg/L	700	100	100
pH	-	8.2	7.8	8.3
TS	%	2 - 4	4.4	0.5

Major issue with digestate is the nitrogen

AMMONIUM RECOVERY SYSTEM
(Pilot plant flowrate = 0.7 L/min)

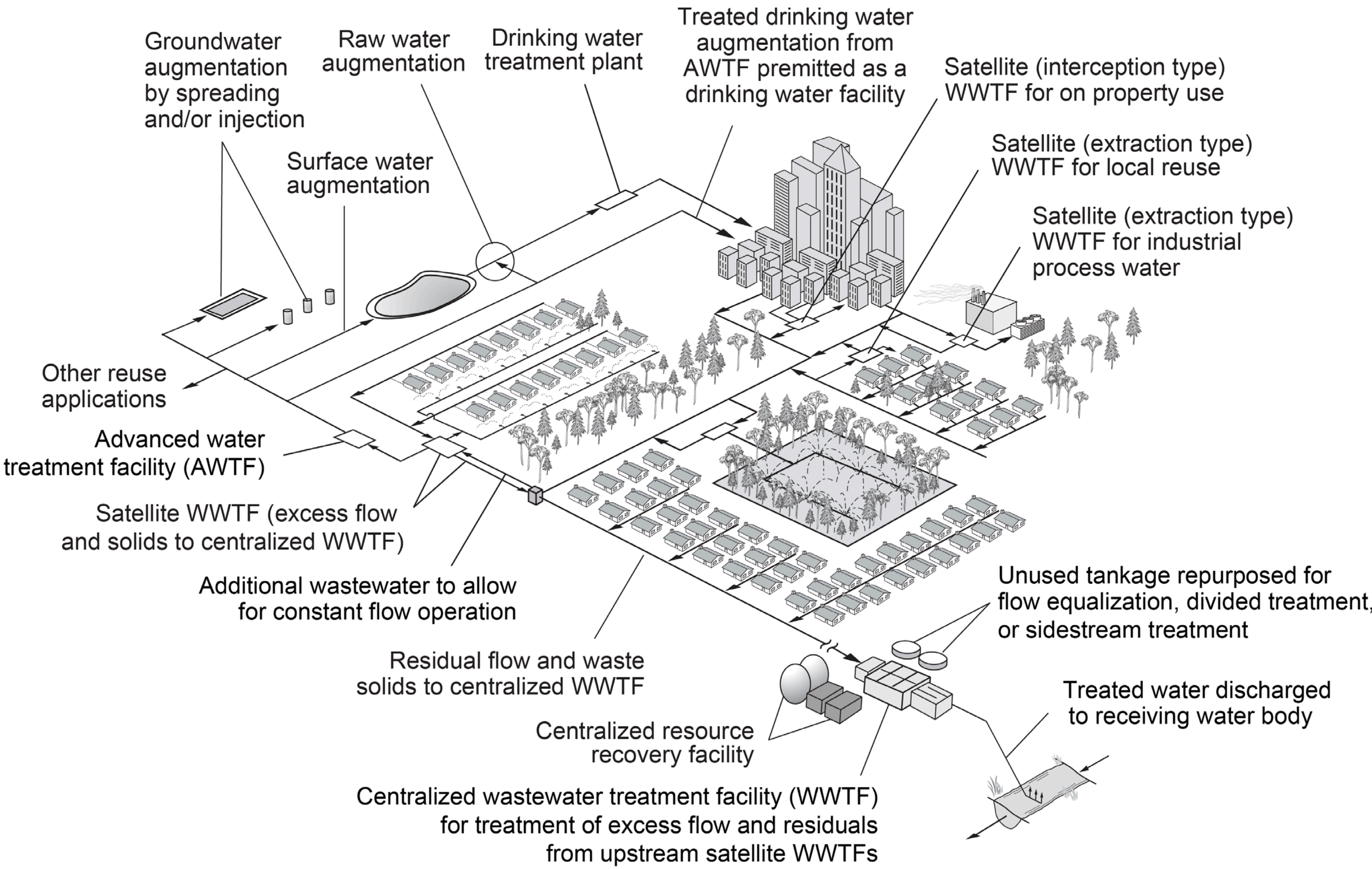


Courtesy: Advanced Environmental Methods, Dunnigan, CA

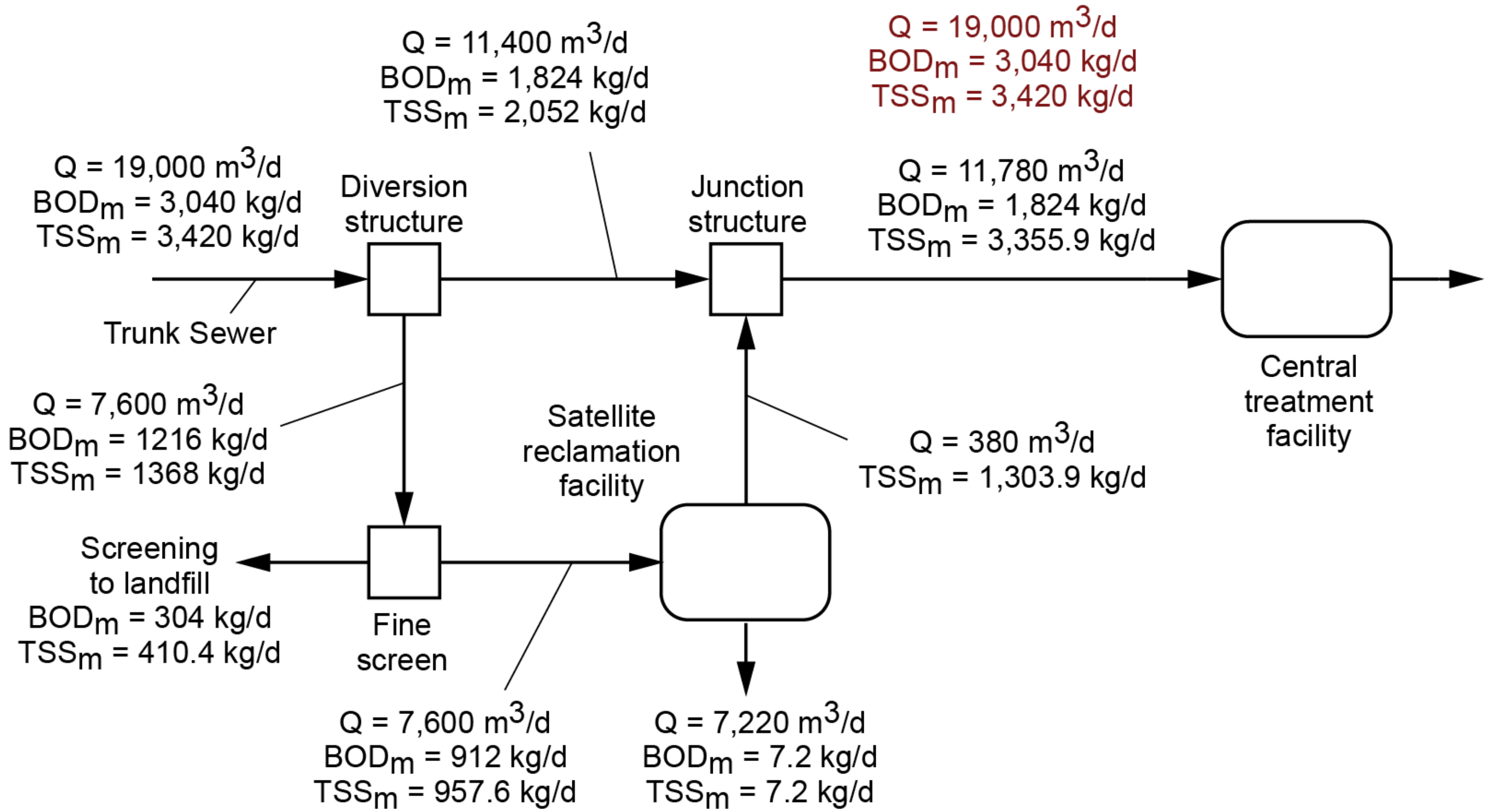


REDUCTION IN PEAK ENERGY USAGE THROUGH SATELLITE TREATMENT

ENERGY SAVINGS THROUGH INTEGRATED WASTEWATER MANAGEMENT



MASS BALANCE FOR EXTRACTION TYPE SATELLITE WATER REUSE TREATMENT SYSTEM



A DPR CASE STUDY: SOUTHERN CALIFORNIA

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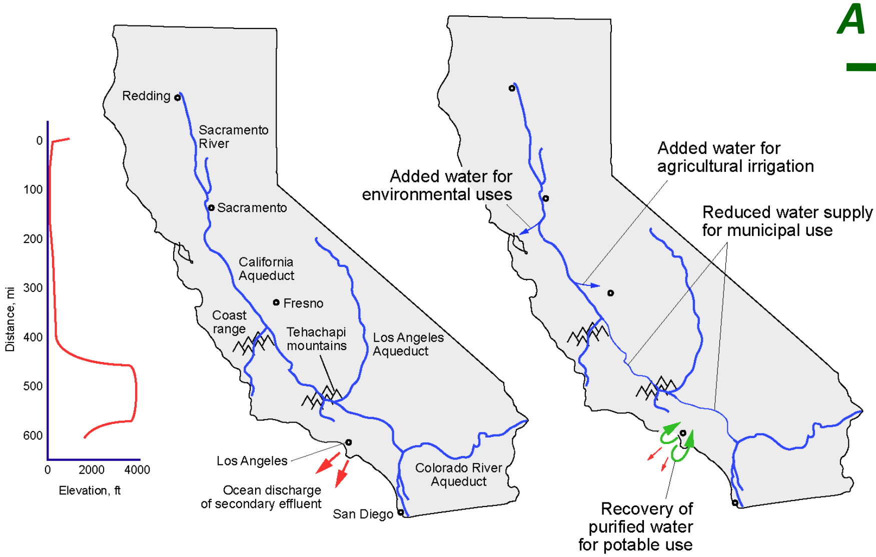
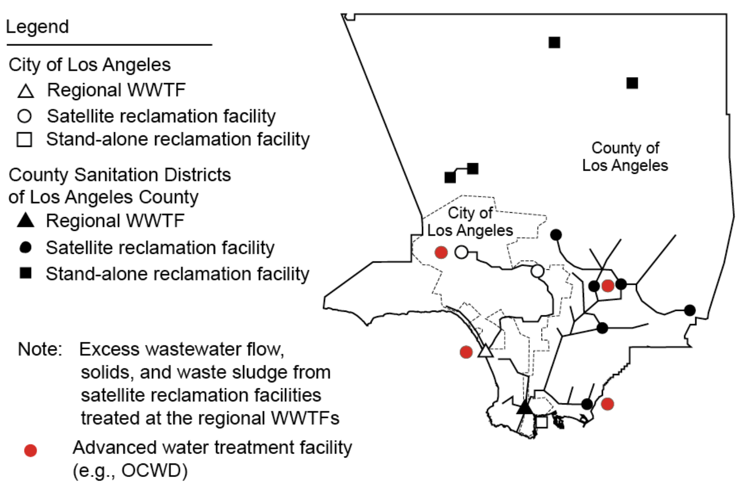


System	Power Consumption, kWh/Mgal	
	Northern California	Southern California
Supply and Conveyance	150	8,900
Treatment	100	100
Distribution	1,200	1,200
Wastewater treatment	2,500	2,500
Total	3,950	12,700



DPR Benefits to Southern California

- Reliable alternative water source
- Lower cost and energy usage
- Upstream agricultural use and benefits
- Upstream environmental benefits

CLOSING THOUGHTS

- It is now possible for wastewater treatment plants to become energy independent, to produce effluent suitable for processing into potable water, and to recovery nutrients
- New technologies under development will result in further energy savings
- *Must plan now for a future where wastewater is considered a renewable recoverable source of POTABLE WATER, ENERGY, and NUTRIENTS*

THANK YOU

FOR LISTENING