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Energy Neutral Opportunities

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MDEQ - Michigan Water Resource Recovery Leadership Summit

AGENDA

- Definition of energy neutrality at WRRFs
- Energy types, use, and recovery potential in the U.S. WRRF sector
- Overview of the WERF research project “Net Zero Energy Solutions for WRRFS” (WERF ENER1C12)
- BNR Example
- Concluding remarks / Q&A

DEFINITION OF ENERGY NEUTRALITY

- **A WRRF that generates 100% or more of the energy it needs for its operation solely from the energy embedded in the water and wastes it treats**

- **On the road to energy neutrality, the metrics can be:**
  - Site electrical energy; kWh/MG
  - Site total energy (electricity, embedded energy in fuels, chemicals, imported waste); MJ/MG
  - Primary energy; MJ/MG

At 100% energy neutrality, the metrics are equivalent. On the road to energy neutrality, they are not.

WHAT IS PRIMARY ENERGY?

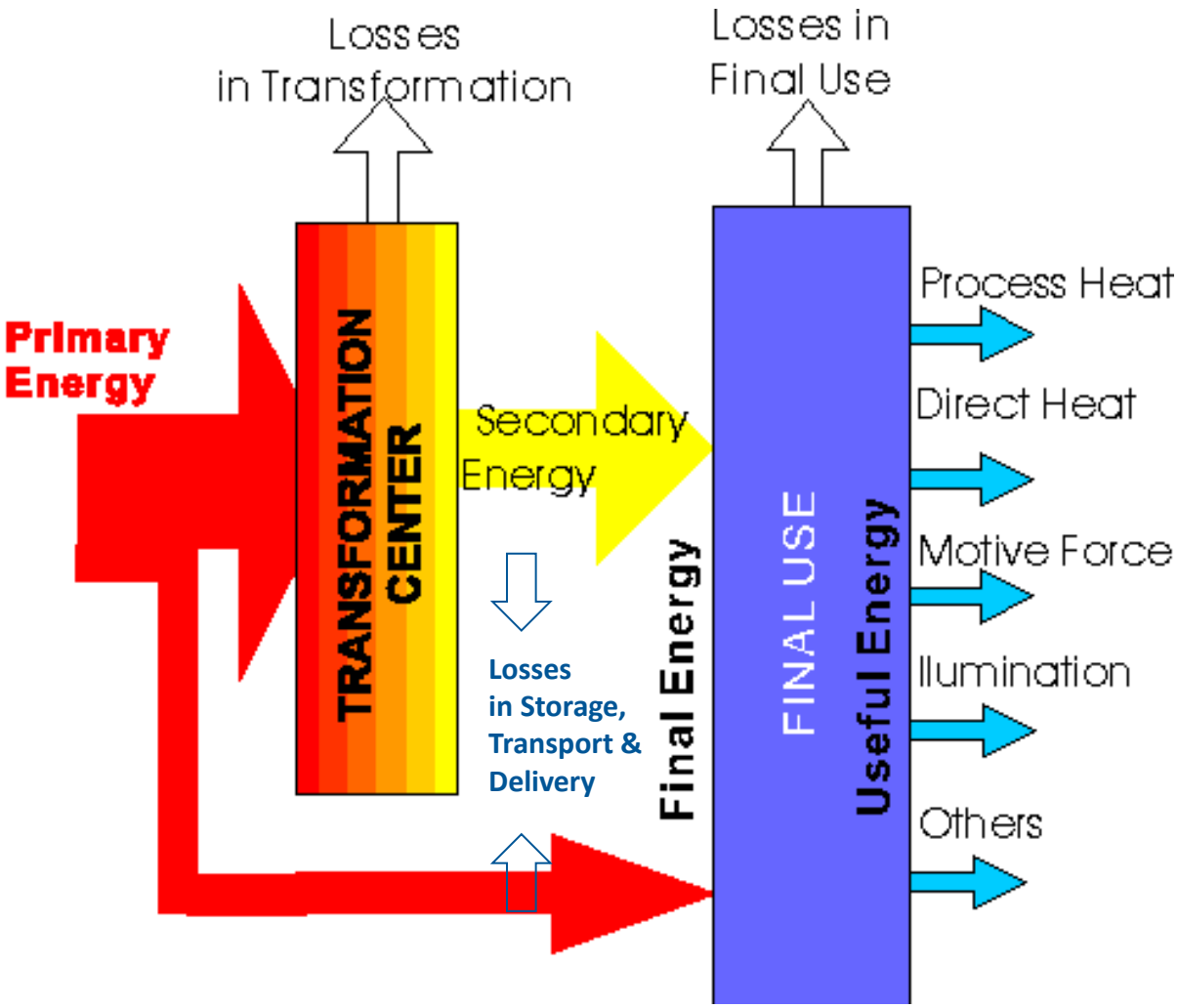
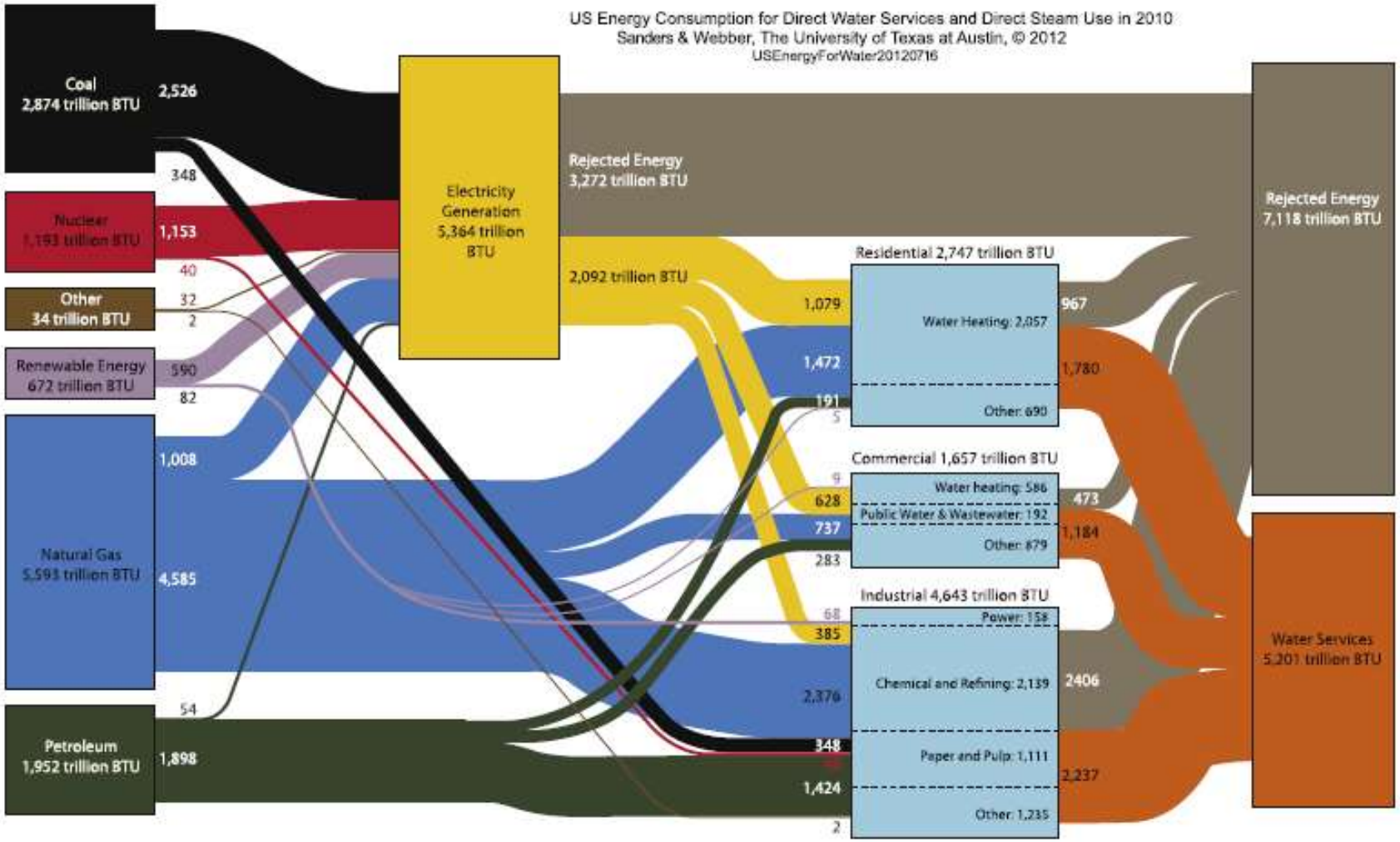


Figure Modified from www.ecen.com

PRIMARY ENERGY USE FOR WATER SERVICES
(TWOMEY AND WEBER, 2010)



WASTEWATER SECTOR ENERGY USE ESTIMATES (FROM WERF ENER6C13)

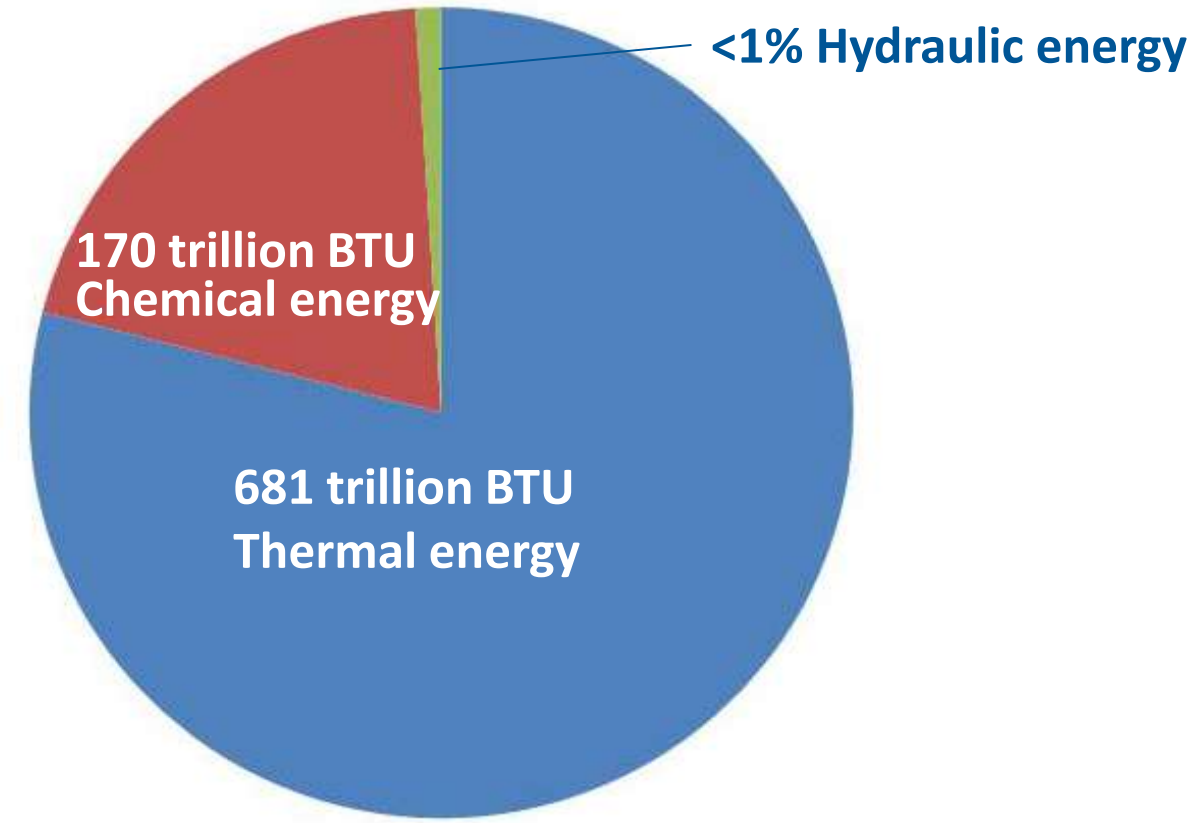
22.3 TWh/year electricity used

0.6% from wastewater

Top Electric Power Using Sectors	Percentage
Chemicals	5.21
Forest products	3.74
Food and beverage	2.26
Water and Wastewater combined	**2.0**
Iron and Steel	1.66
Transportation equipment	1.50
Petroleum refining	1.47
Plastics	1.40

270 trillion BTU/year primary energy

851 TRILLION BTU OF ENERGY IS FLOWING THROUGH U.S. SEWER PIPES EVERY YEAR



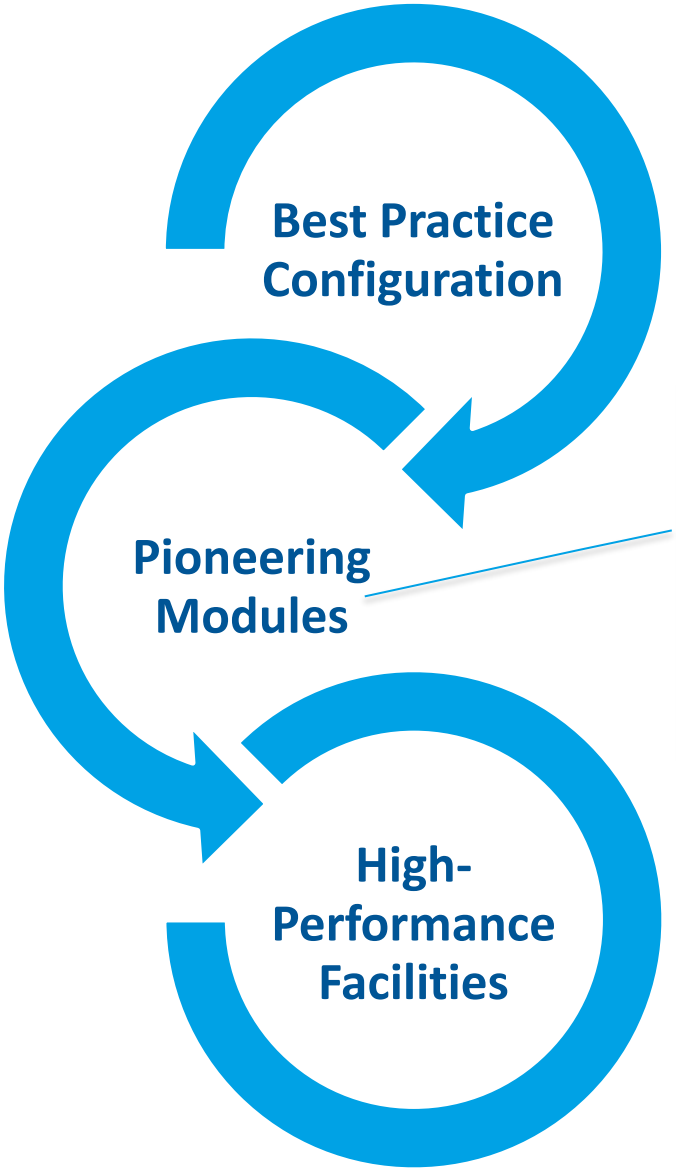
OVERVIEW OF WERF ENER1C12

NET ZERO ENERGY SOLUTIONS FOR WATER RESOURCE RECOVERY FACILITIES

ENERGY MODELING

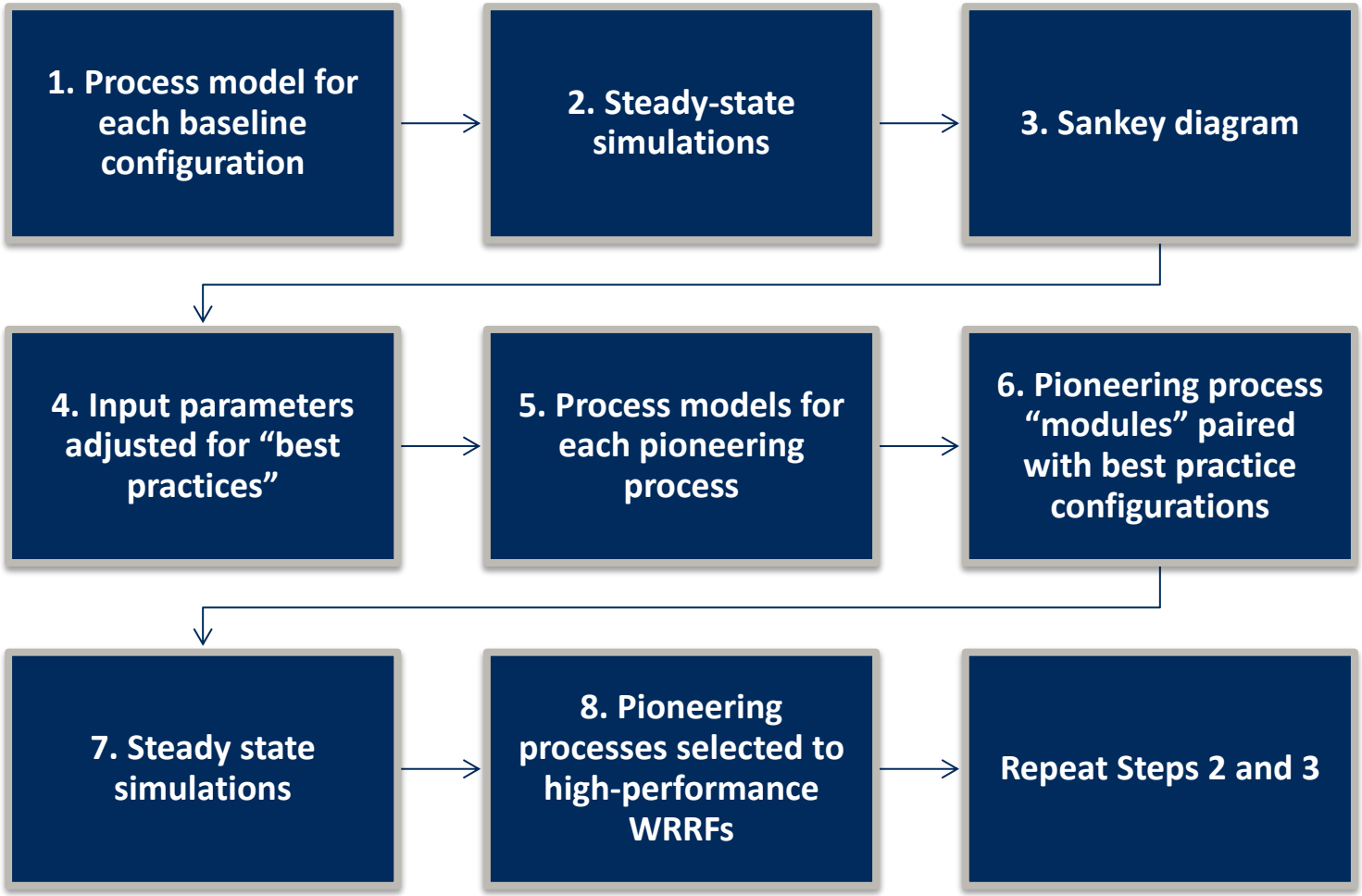
- **50 baseline energy models of common WRRF configurations**
  - 25 “typical”
  - 25 “best practices”
- **Software**
  - GPS-X (for process and energy modeling)
  - E-Sankey (for energy flow diagrams)
- **18 “pioneering” process modules**
  - Potential for significant step towards energy neutrality
  - Applied to specific best practice configurations to develop 10 model facilities

HIGH-PERFORMANCE FACILITIES

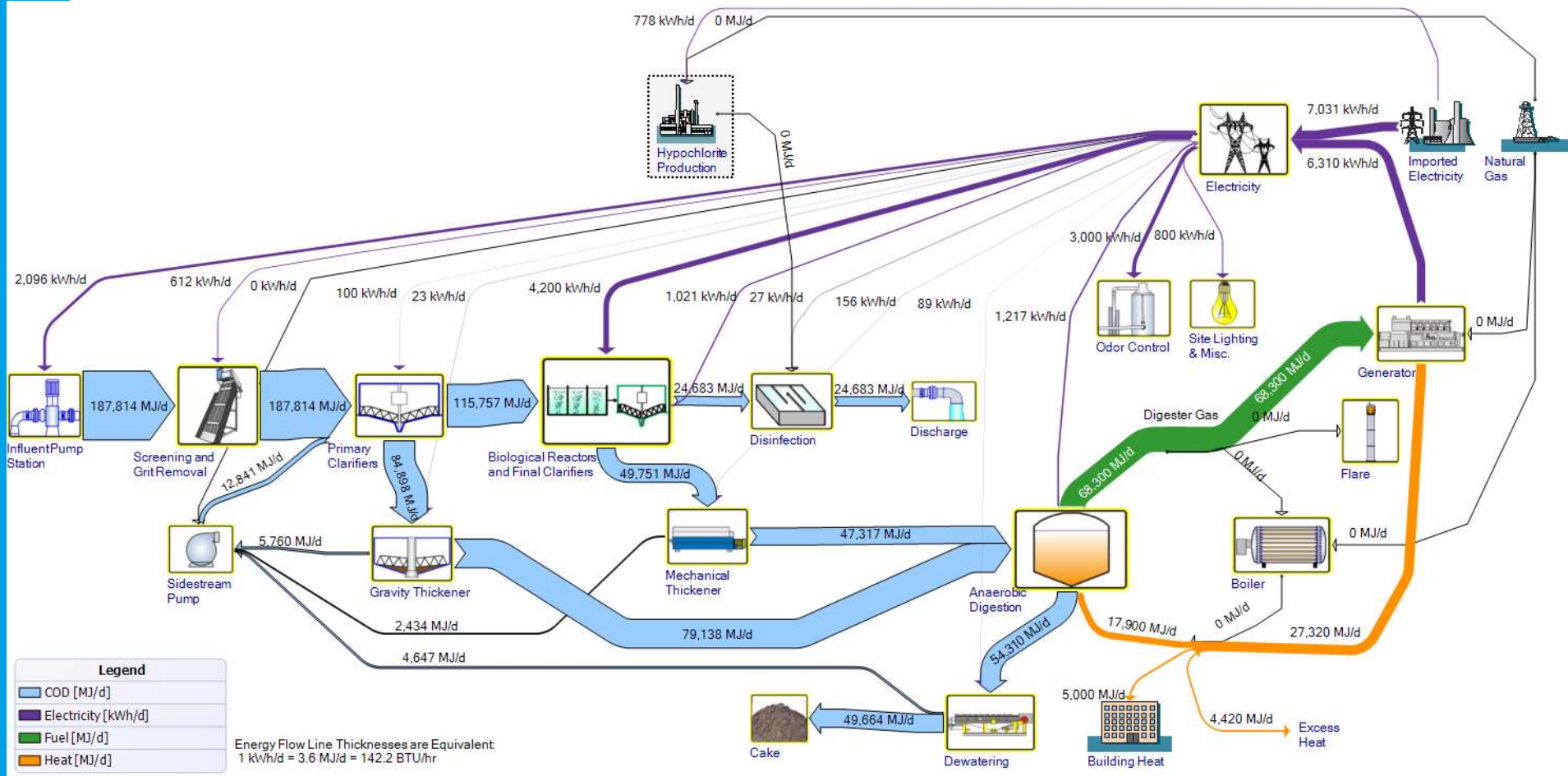


Promising technologies and processes (innovative, but well-demonstrated)

MODELING METHODOLOGY



SANKEY DIAGRAMS SHOW ENERGY FLOWS BETWEEN EACH UNIT PROCESS



INFLUENT WASTEWATER ASSUMPTIONS

Symbol	Description	Selected Value	MOP 8 "Average"	GPS-X Mantis 2 Default
COD	Chemical oxygen demand	358	430	430
BOD	Biochemical oxygen demand (5-day)	190	190	250
TSS	Total suspended solids	210	210	225
VSS	Volatile suspended solids	160	160	168
TKN	Total Kjeldahl nitrogen	40.0	40.0	40.0
NH4-N	Ammonia	25.0	25.0	25.0
TP	Total phosphorus	7.0	7.0	10.0
OP	Orthophosphate	5.0	5.0	8.0

TREATMENT LEVEL TARGET VALUES

Treatment Level	Target Effluent Values	
Basic secondary treatment	BOD <10 mg/L	TSS <15 mg/L
Nitrification	Ammonia <2 mg/L BOD <10 mg/L	TSS <15 mg/L
Biological nutrient removal (BNR)	Ammonia < 2 mg/L Total-N < 10 mg/L	Total-P < 2mg/L
Enhanced nutrient removal (ENR)	Total-N < 5 mg/L	Total-P < 1 mg/L

- **Supplemental carbon (acetic acid and/or methanol) needed to meet BNR and ENR limits**
- **Tertiary treatment stage (denitrification filters) with intermediate pumping required to meet ENR limits**
- **Target BNR effluent values for MBR configurations**

TYPICAL AND BEST PRACTICE ASSUMPTIONS

Process	Parameter	Units	Typical	Best-Practice
Multiple	Pump efficiency	%	60	85
Grit removal	Energy use	hp	33.5	4.6
Primary clarifiers	Removal efficiency	%	60	70
Biological reactor	Fouling constant	-	0.6	0.95
Biological reactor	Combined blower/motor efficiency	%	70	80
Biological reactor	Standard oxygen transfer efficiency (SOTE)	%/ft	2	*As Typical*
Gravity thickener	Thickened sludge concentration[1]	%TS	5	7
Gravity thickener	Removal efficiency	%	90	92
Mechanical thickener	Thickened sludge concentration	%TS	5	6
Mechanical thickener	Removal efficiency	%	95	98
Anaerobic digester	Mixing power use	hp/1000 cf	0.2	0.05
CHP	Electric efficiency	%	33	40
CHP	Thermal efficiency	%	40	45

BASELINE CONFIGURATIONS
TYPICAL VS. BEST PRACTICE COMPARISONS

(AVERAGE ELECTRICAL INTENSITY FOR DIFFERENT TREATMENT LEVELS)

	Typical	Best-Practice	Comparison
Trickling filter	1058	793	81%
Carbon only	1412	973	**100%**
Nitrification	1934	1249	128%
BNR	2070	1241	128%
ENR	1955	1202	123%
MBR	5676	2815	289%
Two-Sludge (A/B)	1981	1277	131%

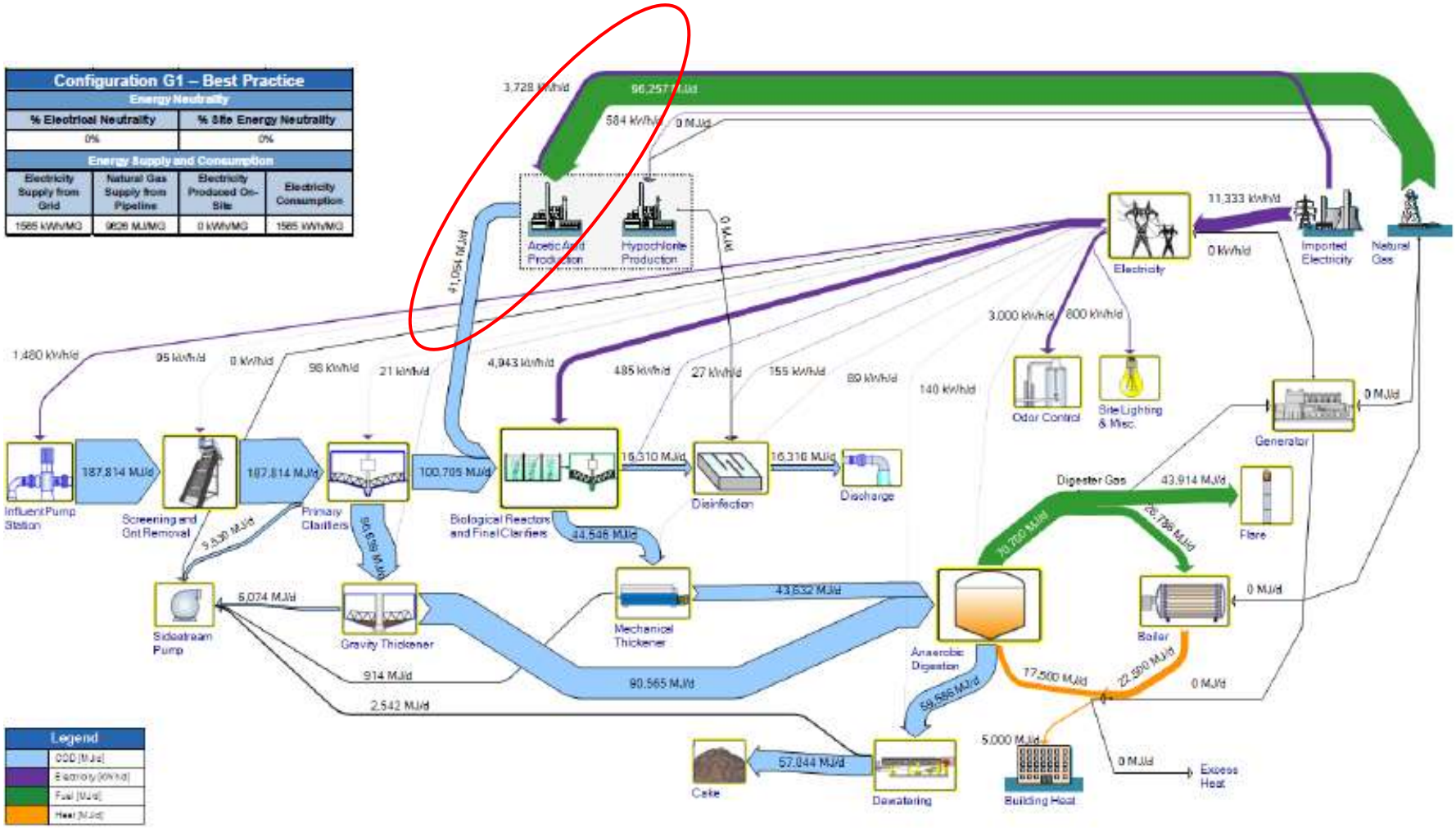
REVIEW OF SELECT ENERGY FLOW DIAGRAMS

BASELINE CONFIGURATION G1

- Activated sludge, BNR
  - With primary treatment
  - Hypochlorite disinfection
  - Primary sludge thickening in gravity thickeners
  - WAS thickening in mechanical thickeners
  - Anaerobic digestion
  - CHP biogas energy recovery for “G1E”
  - Belt filter press dewatering

BEST PRACTICE CONFIGURATION G1

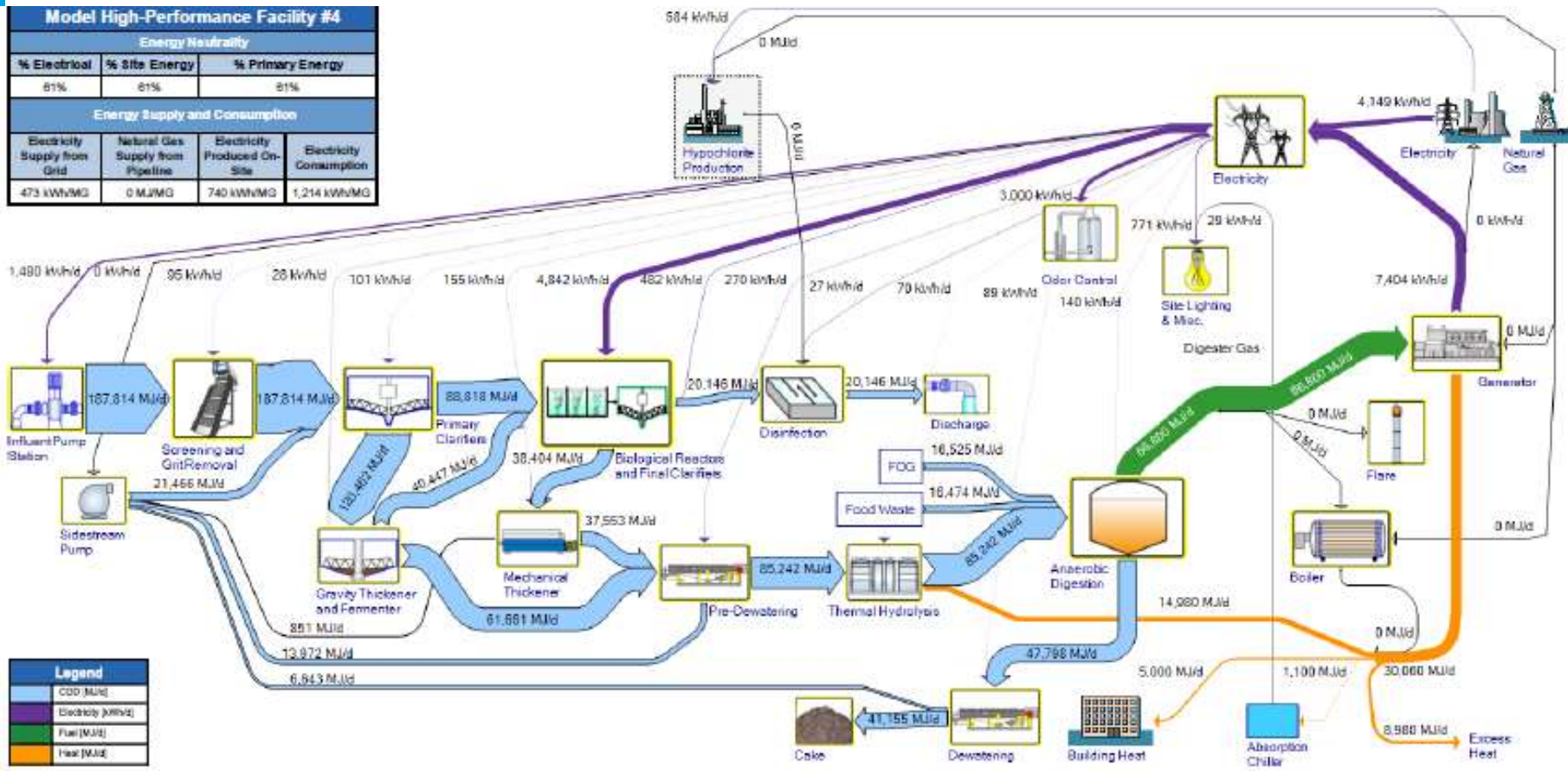
Configuration G1 – Best Practice			
Energy Neutrality			
% Electrical Neutrality		% Site Energy Neutrality	
0%		0%	
Energy Supply and Consumption			
Electricity Supply from Grid	Natural Gas Supply from Pipeline	Electricity Produced On-Site	Electricity Consumption
1565 kWh/MG	9626 MJ/MG	0 kWh/MG	1565 kWh/MG



Energy required to produce external carbon source approximately 2.5x the COD energy needed for BNR

MODEL HIGH PERFORMANCE FACILITY FOR BNR CONFIGURATION G1

Model High-Performance Facility #4			
Energy Neutrality			
% Electrical	% Site Energy	% Primary Energy	
61%	61%	61%	
Energy Supply and Consumption			
Electricity Supply from Grid	Natural Gas Supply from Pipeline	Electricity Produced On-Site	Electricity Consumption
473 kWh/MG	0 MJ/MG	740 kWh/MG	1,214 kWh/MG



Energy neutrality increased to 61

HIGH-PERFORMANCE FACILITY RESULTS SUMMARY

	10 Modeled Facilities	Electric Energy	Primary Energy
1	**BOD removal only** (*CEPT*); **Anaerobic Dig.** (*THP, FOG and FW co-digestion*); **CHP; Dewatering**	**139%**	**139%**
2	**BOD removal only** (*CEPT*); **Dewatering (satellite to #9 or #10)**	0%	0%
3	**Nitrification** (*CEPT, pre-anoxic*); **Anaerobic Dig.** (*THP, FOG and FW co-digestion, sidestream deammonification*); **CHP; Dewatering**	**110%**	**110%**
4	**BNR** (*CEPT, fermenter*); **Anaerobic Dig.** (*THP, FOG and FW co-digestion*); **CHP; Dewatering**	61%	61%
5	**BNR** (*CEPT, fermenter*); **Fluidized Bed Incineration** (*steam turbine energy recovery*)	13%	11%
6	**ENR** (*CEPT, fermenter*); **Anaerobic Dig.** (*THP, FOG and FW co-digestion*); **CHP; Dewatering**	49%	39%
7	**Reuse-MBR** (*CEPT, simultaneous N/DN*); **Anaerobic Dig.** (*THP, FOG and FW co-digestion, sidestream deammonification*); **CHP; Dewatering**	80%	80%
8	**BNR** (*CEPT, fermenter*); **Anaerobic Dig**. (*THP, FOG and FW co-digestion*); **CHP; Dewatering; Fluidized Bed Incineration** (*energy recovery*)	69%	59%
9	**Regional – Anaerobic Dig.** *(Imported solids, THP, FOG and FW co-digestion*); **CHP, Dewatering – System includes #2**	**103%**	99%
10	**Regional – Fluidized Bed Incinerator** (*imported solids, steam turbine energy recovery*) **System includes #2**	52%	41%

PROJECT KEY FINDINGS

- Use of **best practices** to minimize energy use, including:
  - **Clean and properly maintain fine-bubble diffusers**
  - Use high-efficiency motors and generators, **operating near design points**
  - **Maximize solids capture in solids processing**
- **Maximize primary sludge capture** efficiencies
- **Co-digestion of high-strength waste** in anaerobic digesters is a valuable approach to achieving energy neutrality

PROJECT KEY FINDINGS, CONT'D

- Use anoxic zones for energy recovery in nitrification plants
- BOD removal-only and nitrification facilities can be net energy positive
- Mainstream short-cut nitrogen removal is required to push energy neutrality beyond 50-60% for BNR and ENR facilities
- Dewatered biosolids retain a significant portion of influent chemical energy
- Thermal energy in wastewater is a significant resource

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