Energy Efficiency Evaluation for Process Aeration Blowers

2011 OWEA Annual Conference

June 22, 2011

MALCOLM PIRNIE | ARCADIS

Agenda

- New Way of Thinking about Energy Efficiency
- Aeration System Energy Considerations
- Introduction to M.E.E. Triangle
- Case Study for Energy Evaluation
  - Town of Greenwich, CT
    Grass Island WWTP

Wastewater Treatment
Today's Buzzword – "Energy Efficiency"

"We're going **GREEN**"

"This is the <u>monthly</u> power bill!"

"Greenhouse gases (GHG) – not from my plant"

"We are an energy *neutral* facility"

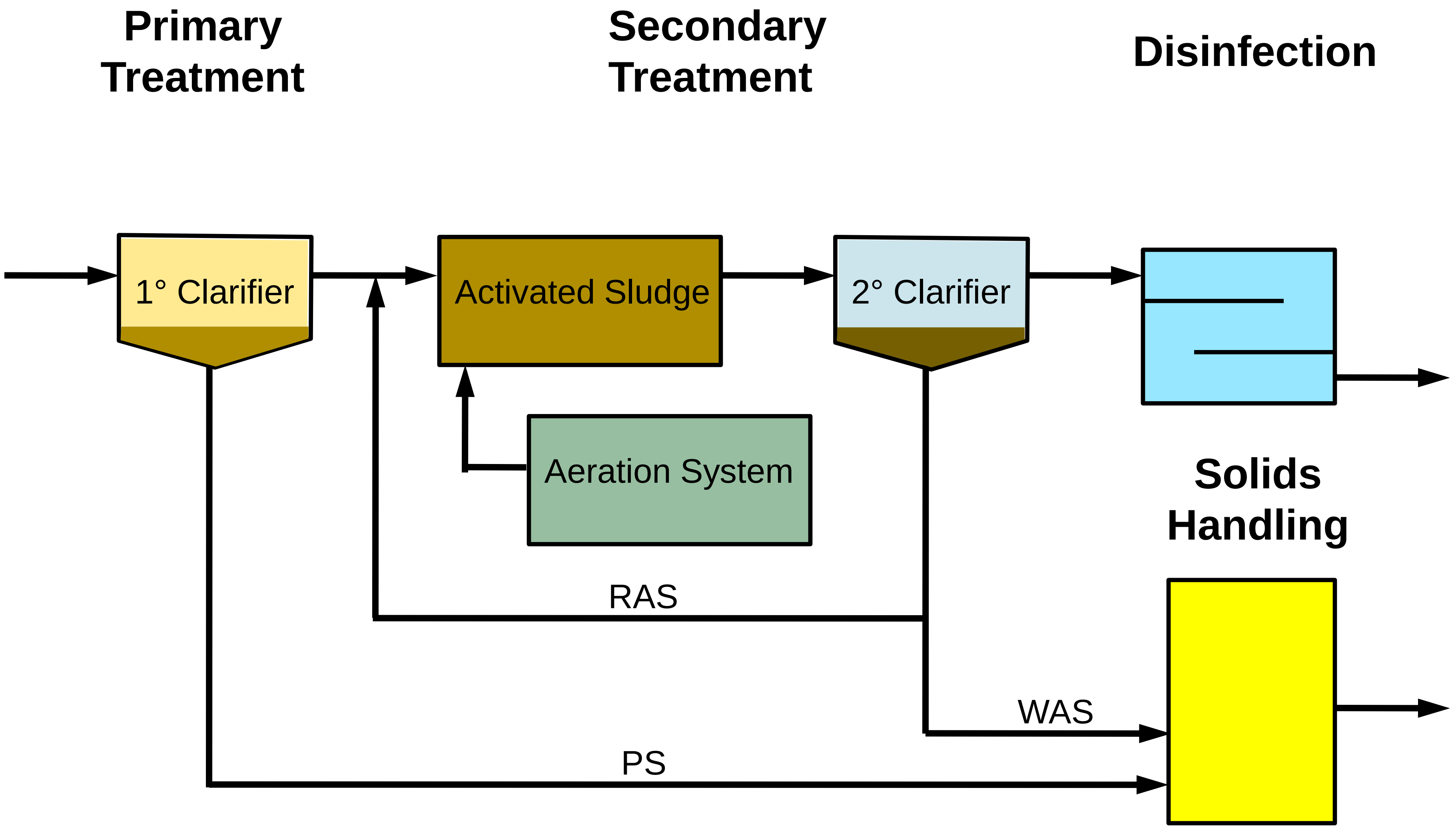
"I don't know the size of my carbon footprint"

Wastewater Treatment
Different Thinking about “Energy”

Yesterday’s Thinking
Energy = Electrical Power

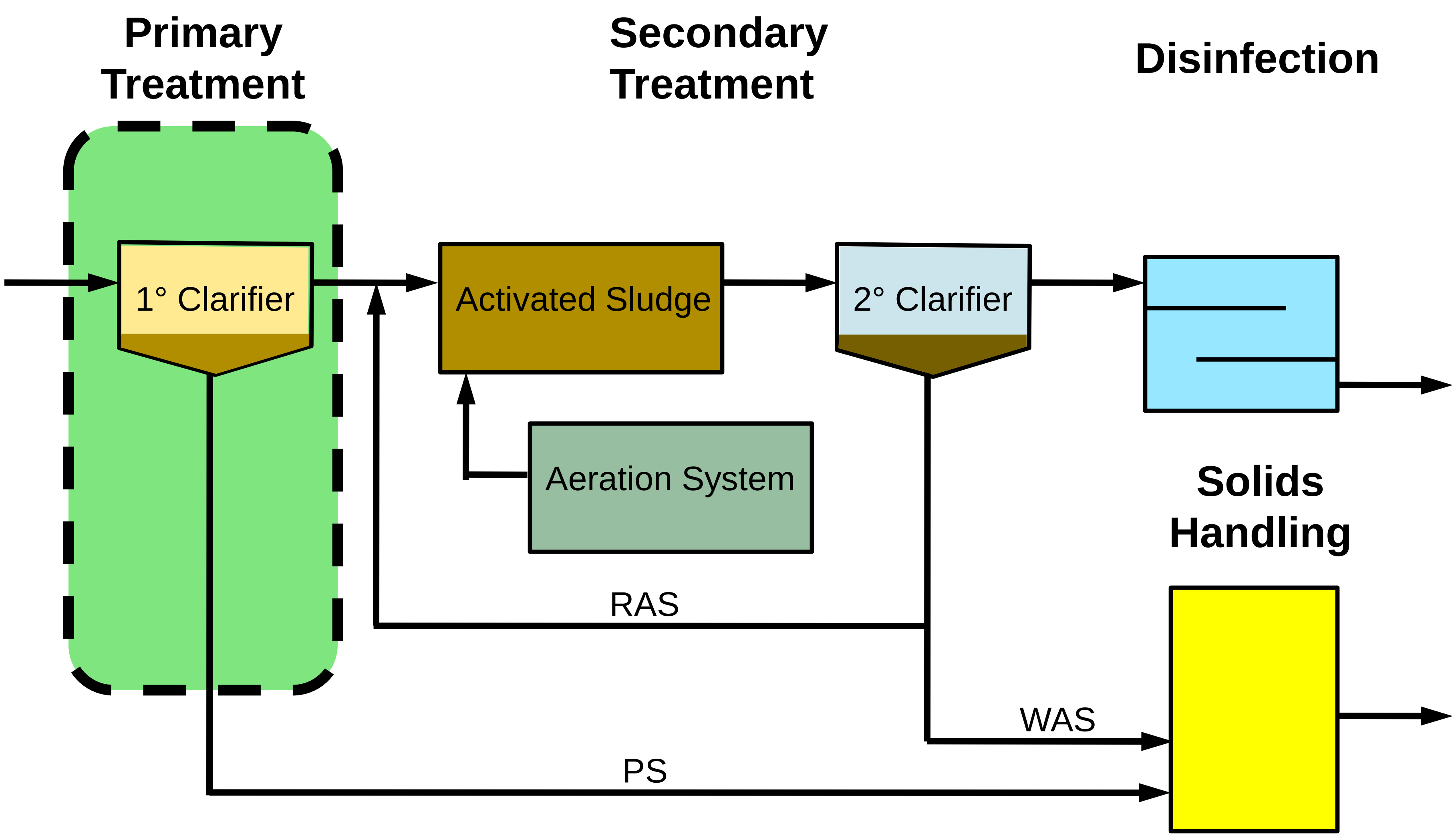
Tomorrow’s Thinking	
Influent Energy	Soluble COD, Denitrification
Energy Sinks	Aeration, Aerobic Digestion
Energy Extraction	Digester Gas

Tomorrow's Thinking
Energy Management

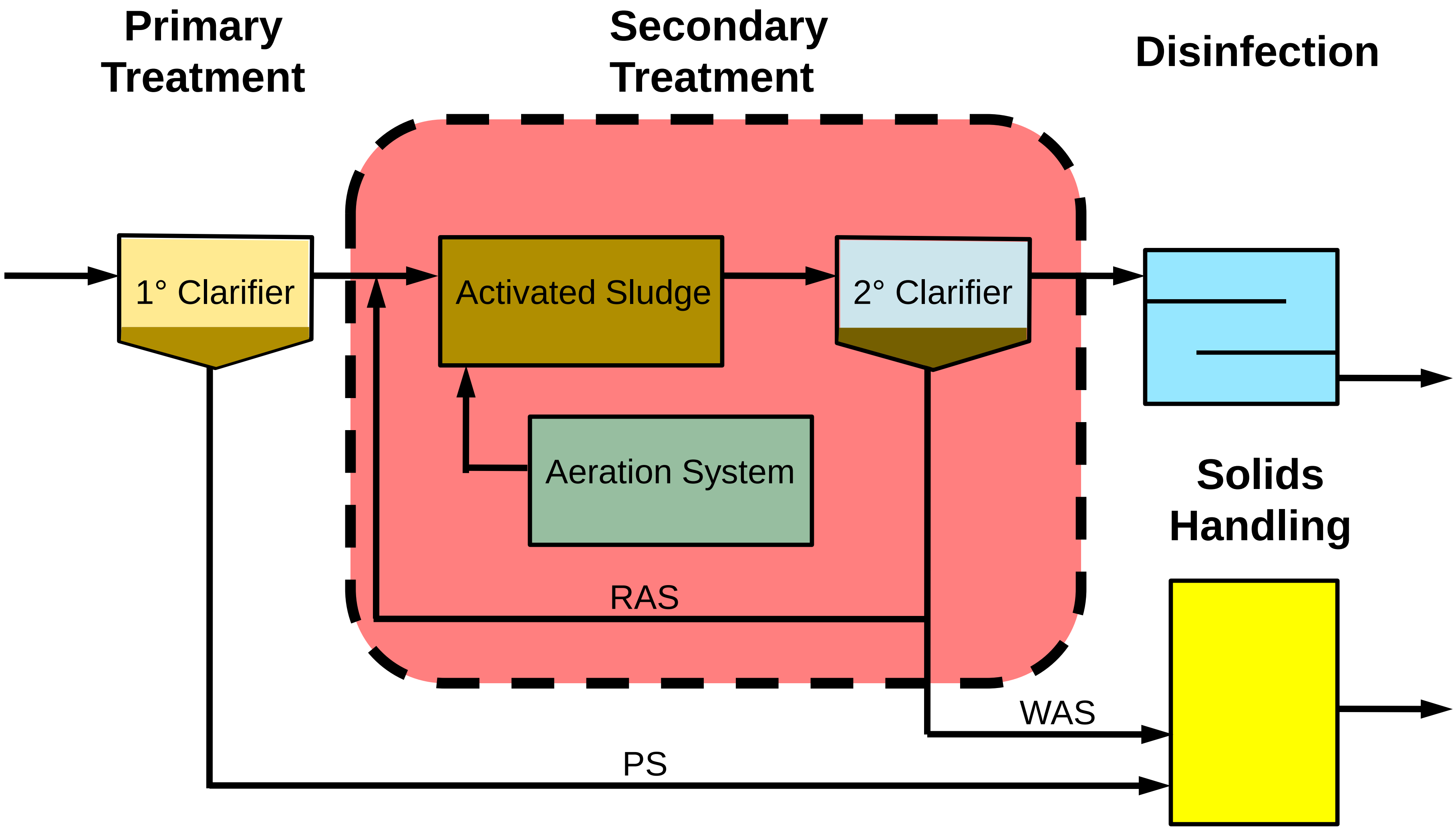


Influent Energy

"It's Free" – Use to Treatment's Advantage

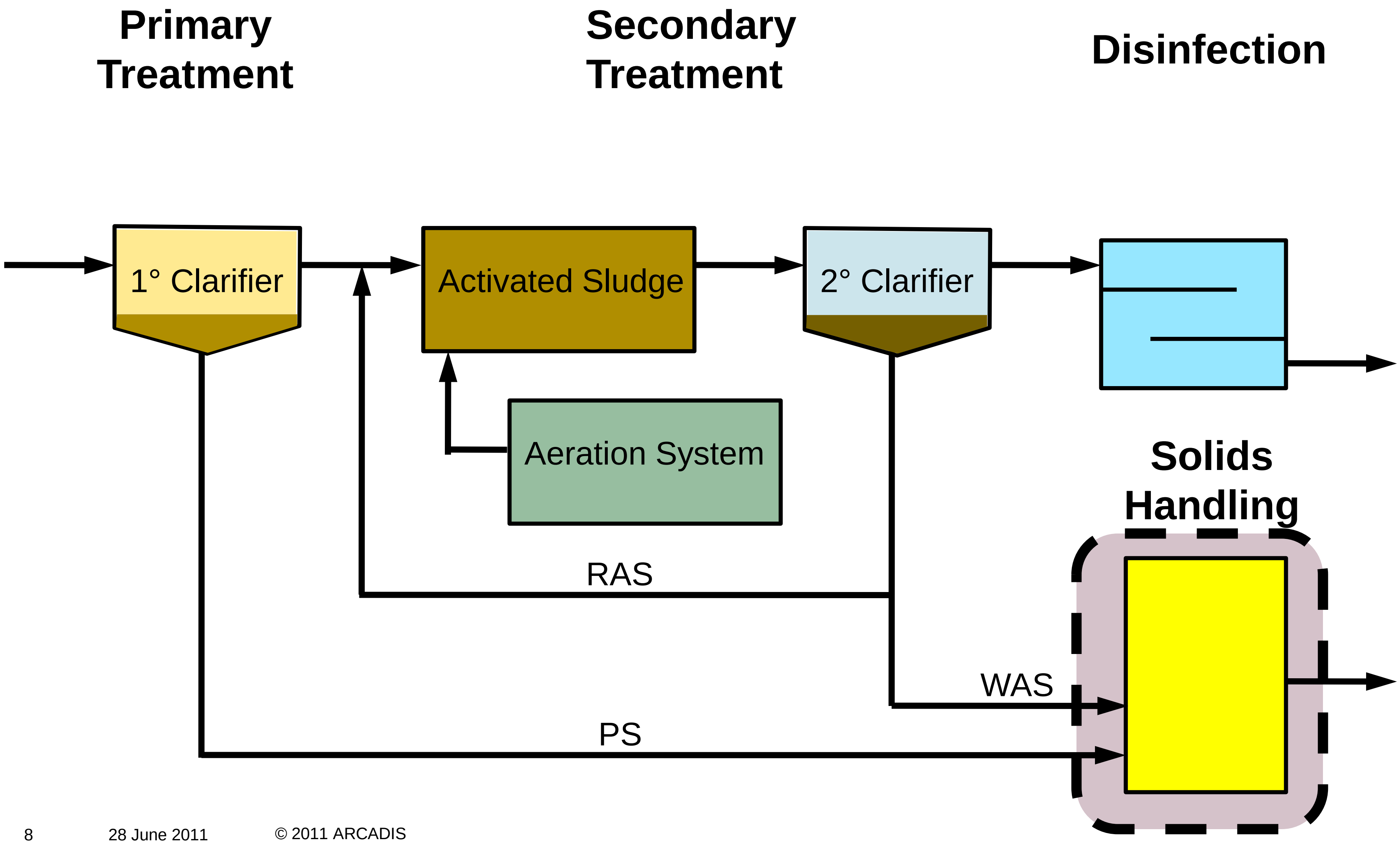


Energy Sinks
Minimize Energy to Reduce Operating Costs

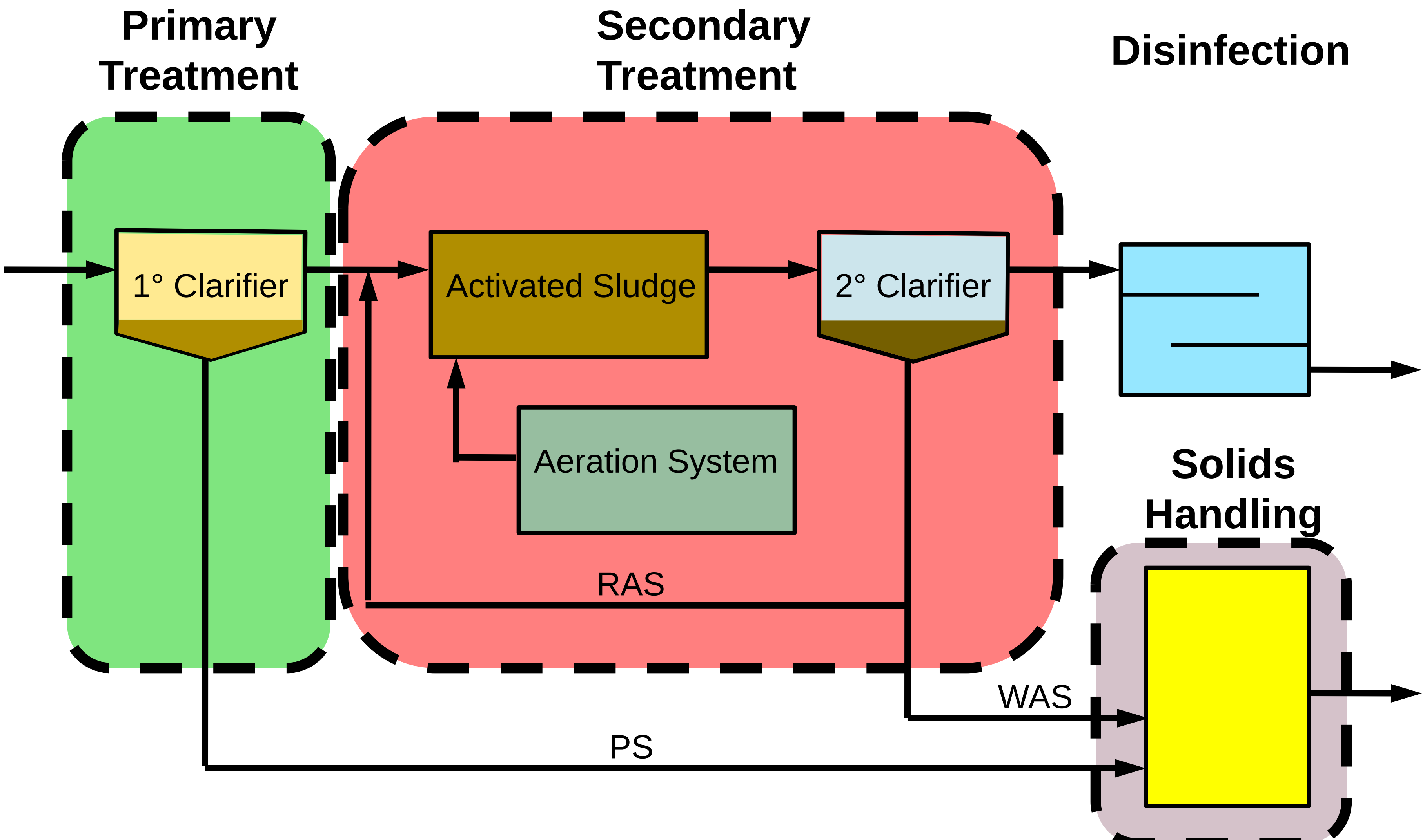


Energy Extraction

Energy Production > Energy Required



Tomorrow's Thinking
Energy Management

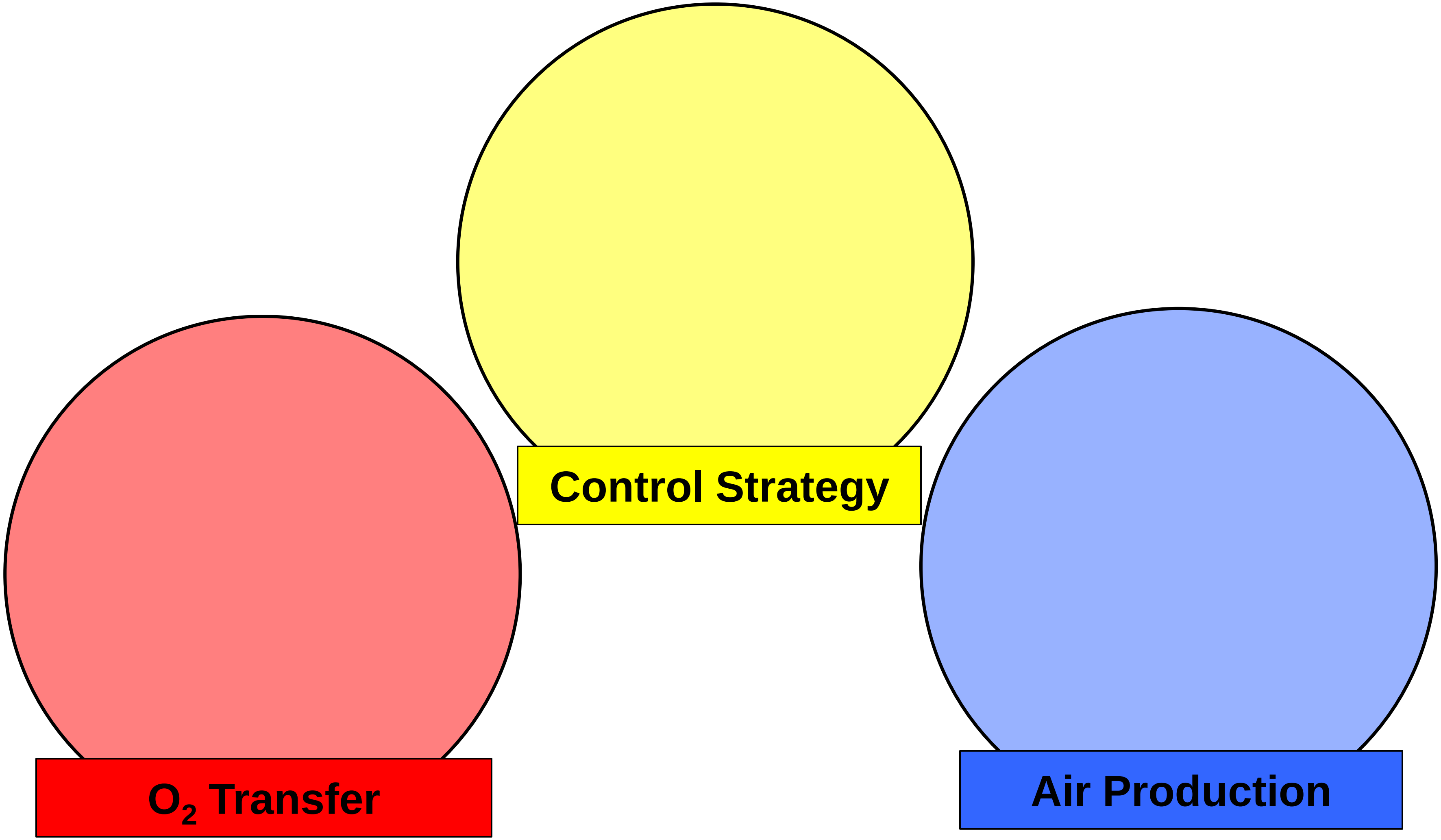


Aeration System

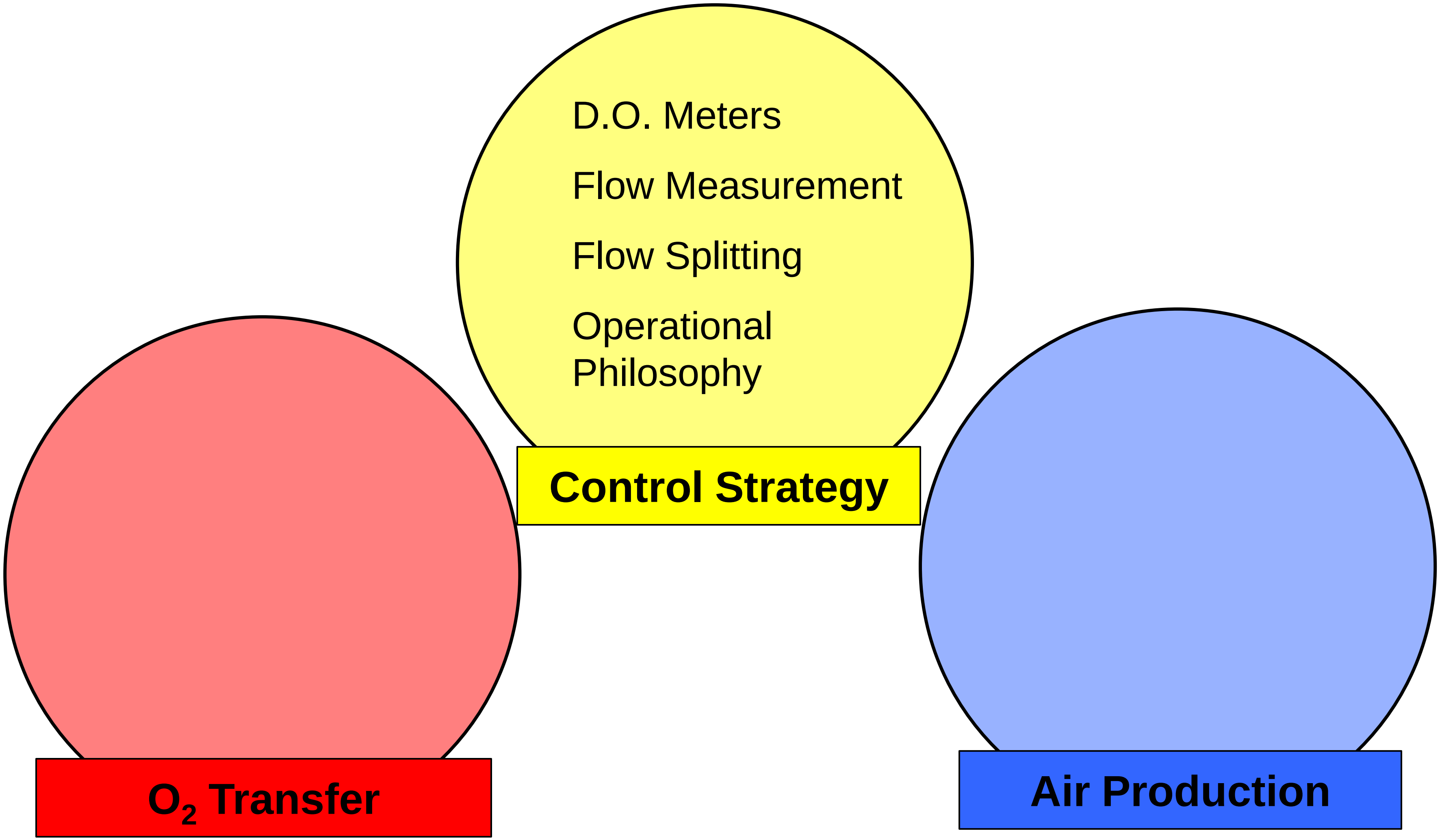
Wastewater Treatment Biggest Energy "Sink"

- Typically, 45 – 75% of total energy costs
- Why necessary?
  - Conversion of particulate to soluble material
  - Oxidation of soluble organic material (i.e. sCOD)
  - Nitrification
- Typical components
  - Oxygen control strategy
  - Oxygen transfer system (i.e. diffusers)
  - Air production (i.e. blowers, aerators, etc.)

Aeration System
Three Areas of Consideration



Aeration System
Major Design Considerations



Aeration System

Major Design Considerations

Control Strategy

- D.O. Meters
- Flow Measurement
- Flow Splitting
- Operational Philosophy

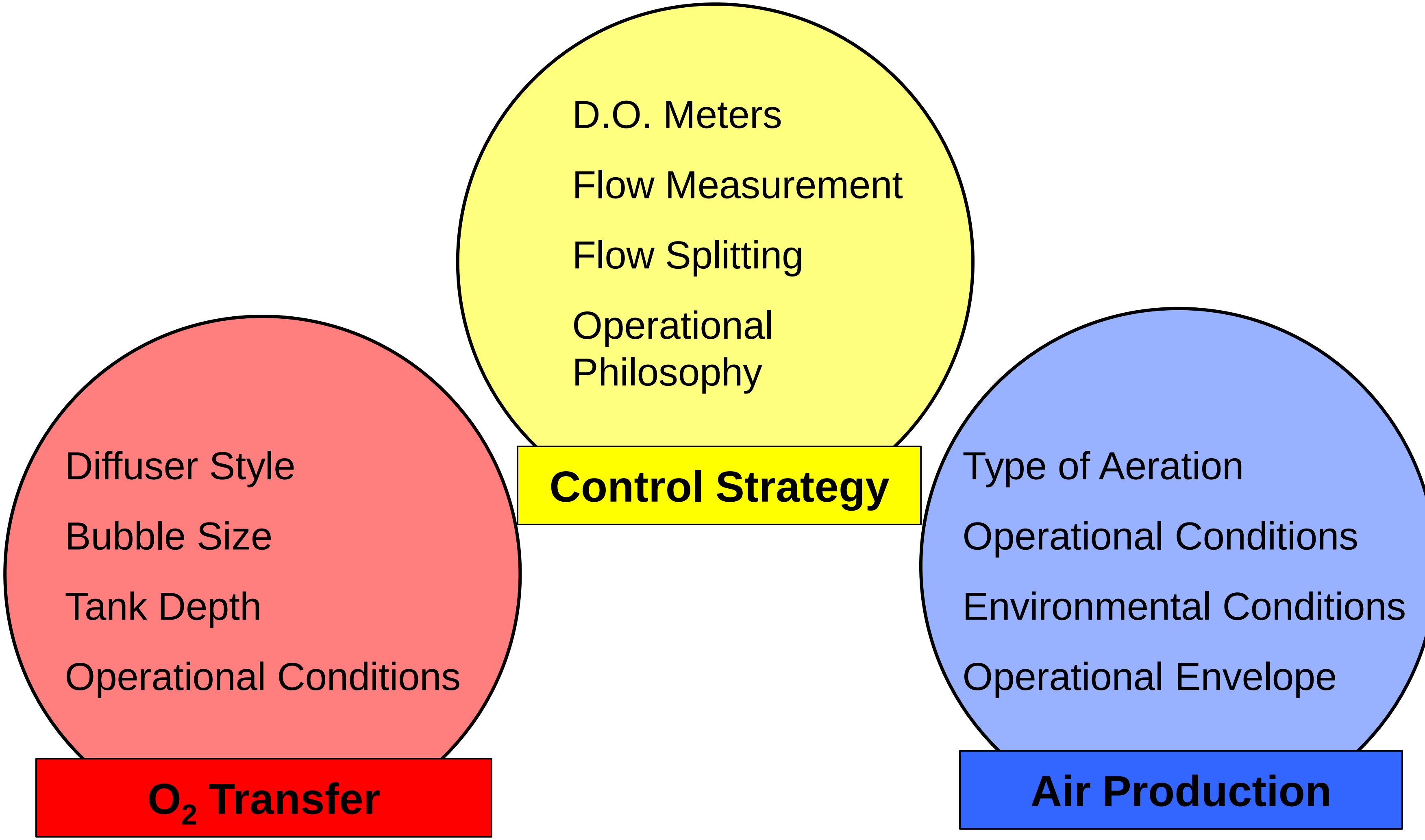
O_2 Transfer

- Diffuser Style
- Bubble Size
- Tank Depth
- Operational Conditions

Air Production

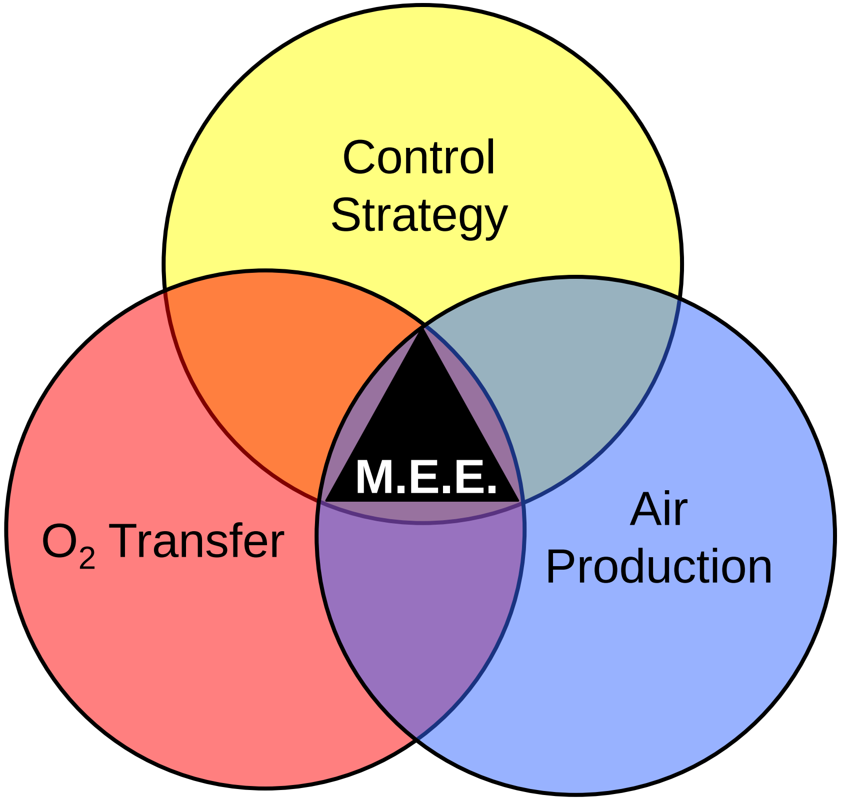
Aeration System

Major Design Considerations



Aeration System
Most Energy Efficient (M.E.E.) Triangle

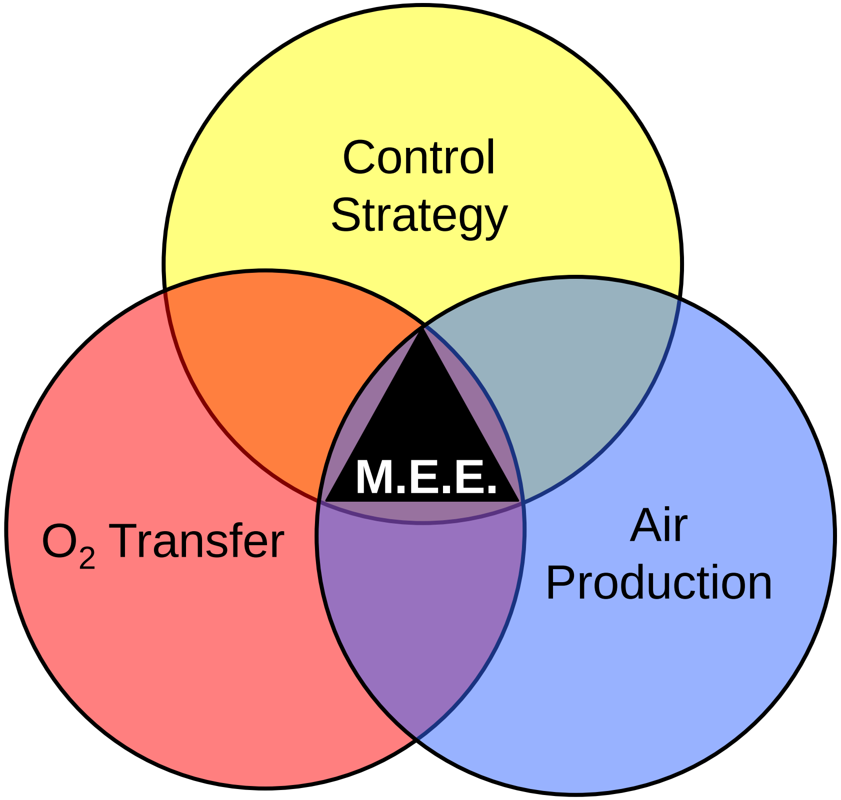
- Intersect of three components defines M.E.E. triangle
- Three components must work together
- Circle size controlled by efficiency of component
- “Larger Circle = More Efficient”
- Environmental & operational conditions control frequency in M.E.E triangle
- Improvements to one +/- impacts other two “circles”



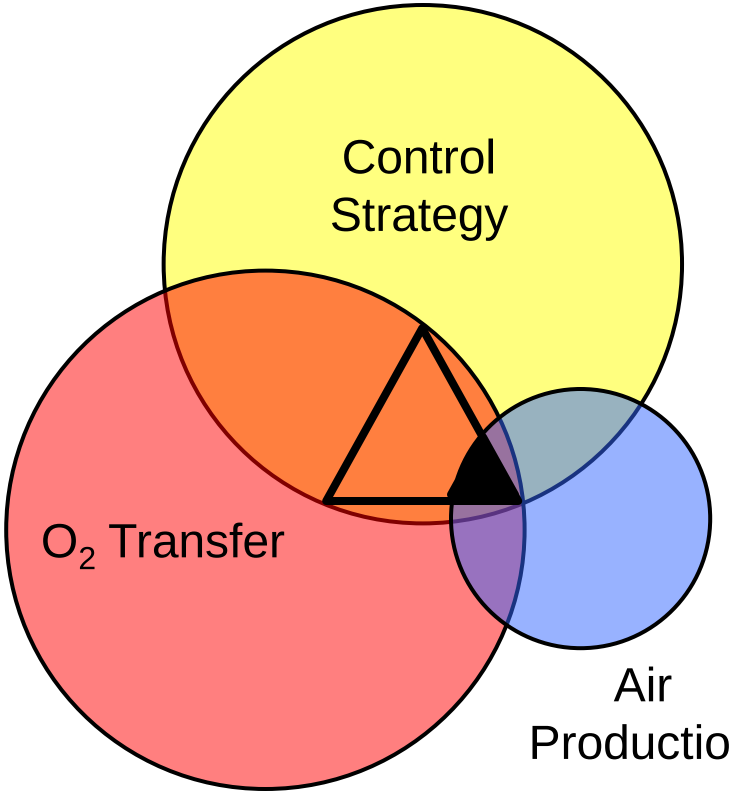
M.E.E. – Most Energy Efficient

Aeration System

Example for M.E.E. Triangle



M.E.E. – Most Energy Efficient



Control Strategy – Most advanced

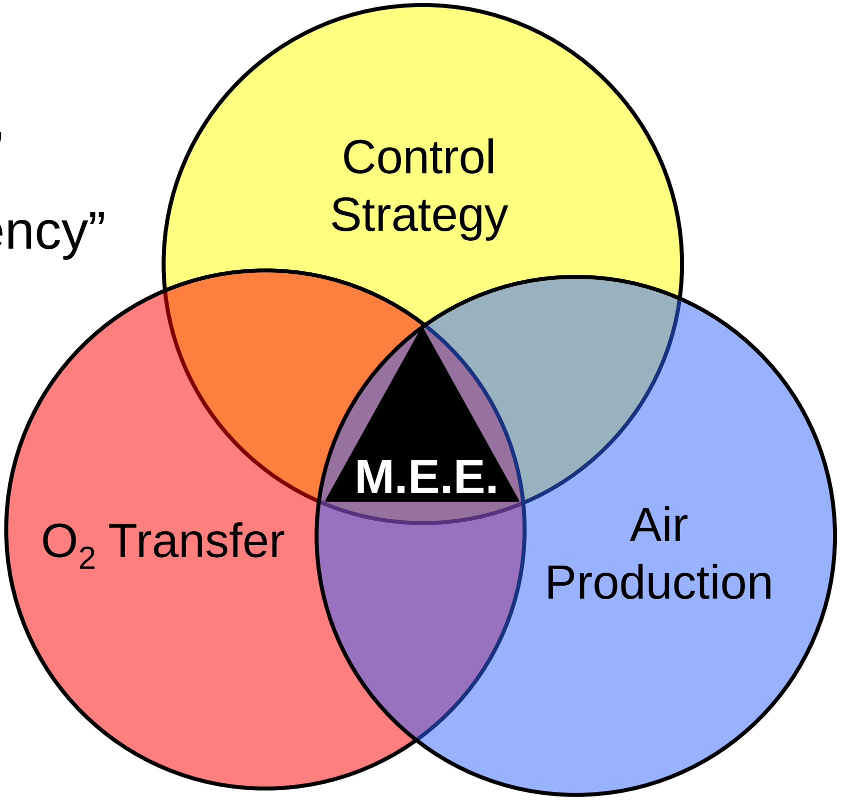
O_2 Transfer - > 35% SOTE

Air Production – “Doesn’t match”

Aeration System

Air Production Sensitivity

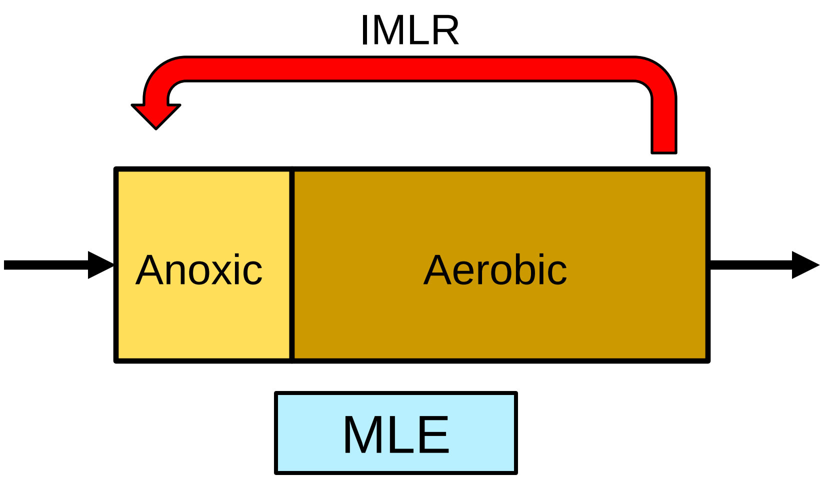
- Air production is most sensitive to conditions and efficiency
- Control strategy – "Defined Efficiency"
- O_2 Transfer – "Partially Defined Efficiency"
  - Tank depth
  - Bubble size
  - Variables: Temp & Op. DO
- Air Production – "Variable Efficiency"
  - Type of equipment
  - Variable influent conditions
  - Diurnal conditions
  - Seasonal conditions
  - Environmental conditions

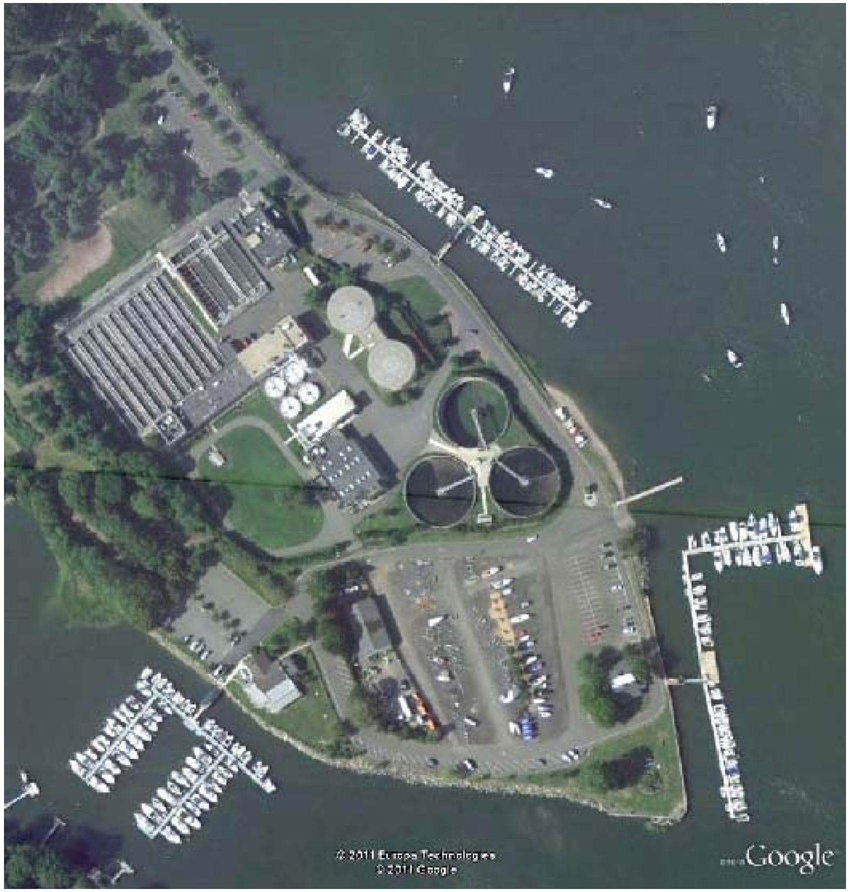


M.E.E. – Most Energy Efficient

Town of Greenwich, CT
Grass Island Wastewater Treatment Plant

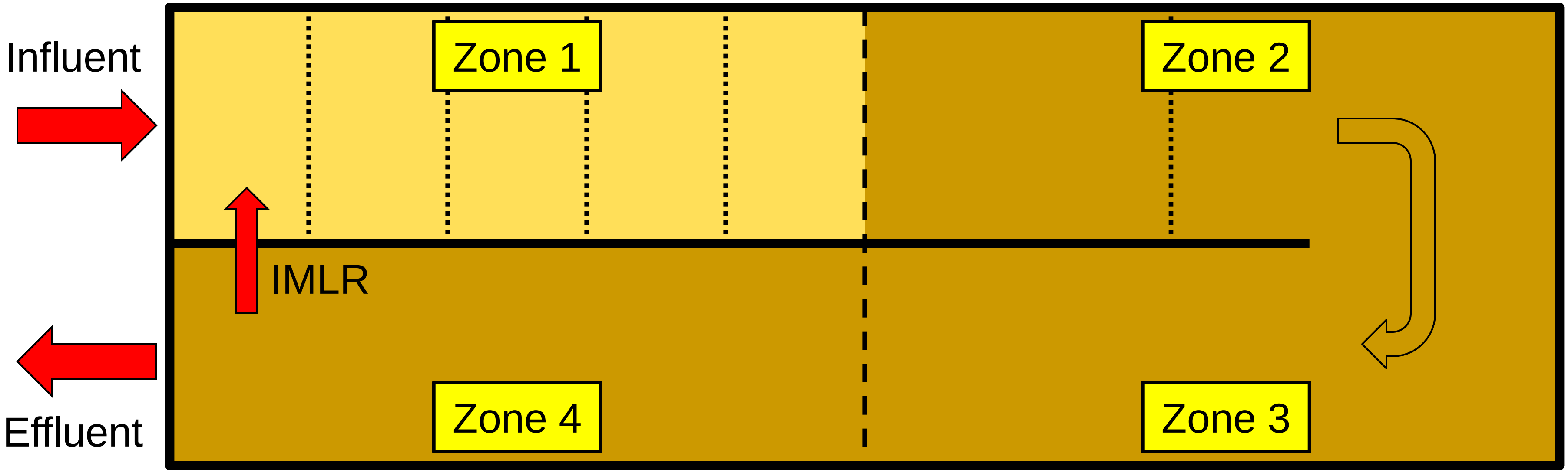
- 12.5 mgd advanced WWTP
- Long Island Sound outfall
- Total nitrogen limit
- Modified Ludzak-Ettinger (MLE) configuration





Grass Island WWTP

Existing MLE Bioreactor Configuration



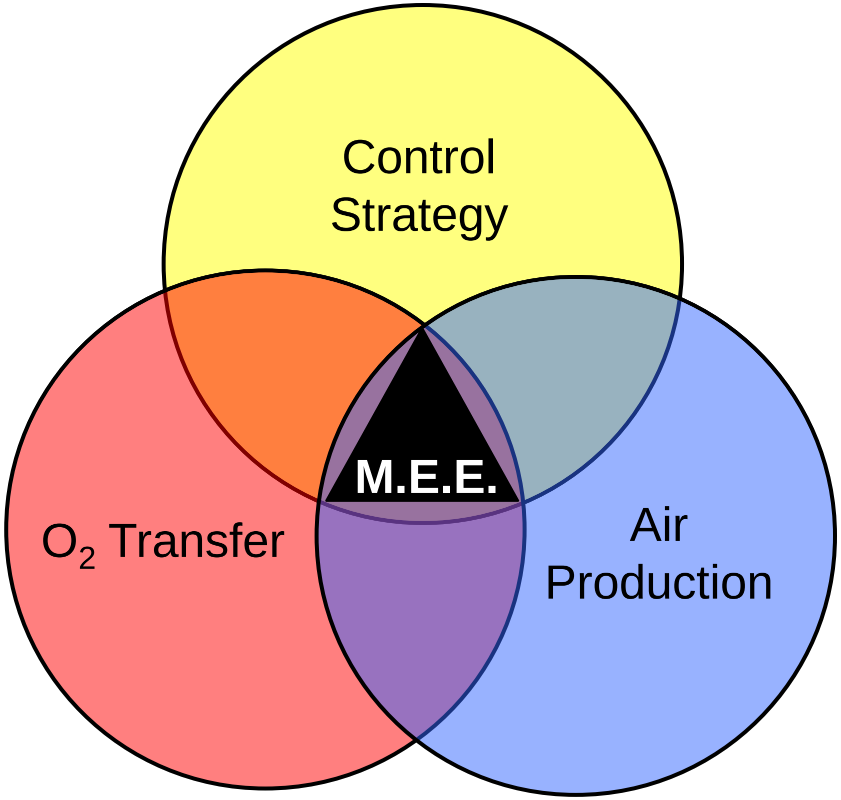
Zone	Operation	Compartments	Diffuser Type & Quantity
1	Anoxic	5	Coarse bubble
2	Aerobic	2	Fine bubble – 750 diffusers
3	Aerobic	1	Fine bubble – 380 diffusers
4	Aerobic	1	Fine bubble – 205 diffusers

Grass Island WWTP
Aeration System Components

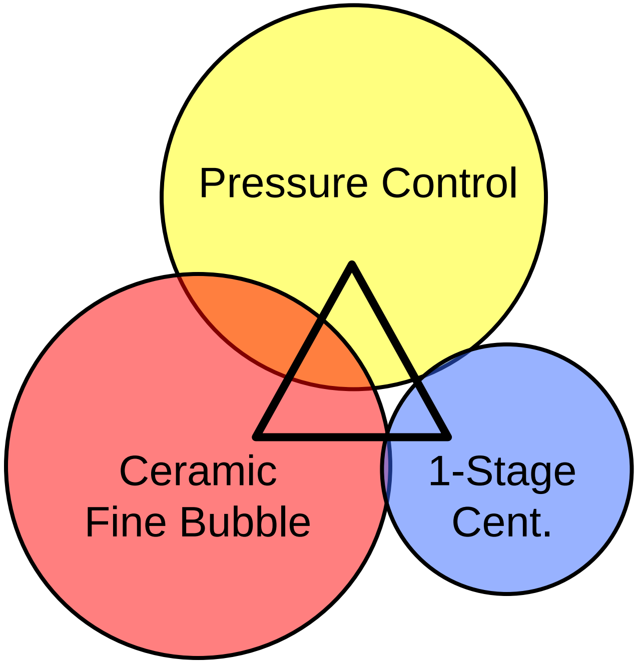
Component	Criteria
DO Control System	Header Pressure Control Multiple zone drop legs DO control in 2 of 5 tanks
O_2 Transfer System	Ceramic Fine Bubble Diffusers Submergence = 11 feet SOTE = 22%
Air Production System	Single-Stage Centrifugal (Gear Driven) Quantity: 3 Capacity: 10,000 ACFM Discharge Pressure: 7.0 psig Horsepower: 400 hp

Grass Island WWTP

Aeration System M.E.E. Triangle



M.E.E. – Most Energy Efficient



Grass Island WWTP

Grass Island WWTP
Air Production System

Design Criteria

Parameter	Design Criteria
Blower Style	Single-Stage Centrifugal
Quantity	3
Inlet Capacity	10,000 ACFM
Capacity Control	Inlet Guide Vanes
Inlet Temperature	100 °F
Inlet Relative Humidity	80%
Discharge Pressure	7.0 psig
Horsepower	400 hp

Operational Criteria

Parameter	Operational Design Criteria
Barometric Pressure	14.4 – 15.1 psia
Inlet Air Temperature	0 – 100 °F
Relative Humidity	30 – 80%
Discharge Pressure	6.0 – 7.0 psig
Maximum Turndown	45% rated capacity

Grass Island WWTP
Air Production System Challenges

- Blower design criteria
  - Only one blower operates
  - Sized in ACFM at highest temp & R.H.
  - Single point capacity control (i.e. inlet guide vanes)
  - Only one blower is on standby power system
- Ancillary air demands
  - Vary with no. of units in service
  - Operating pressures vary among unit processes
- **Insufficient blower turndown**
  - **Average blow-off ~ 1,000 scfm**
  - **Normal operation ~ 25% air vented**

Grass Island WWTP

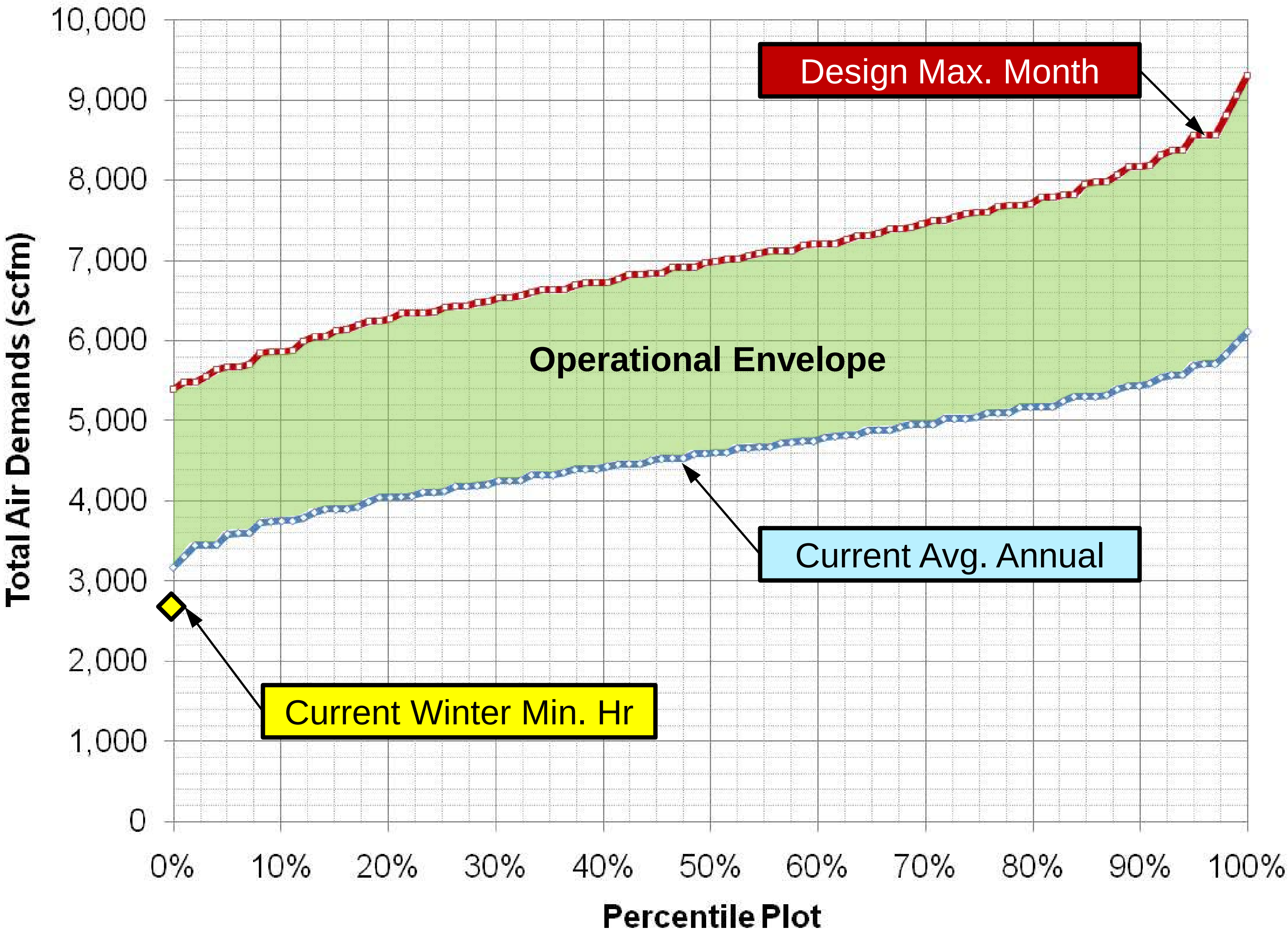
GPS-X Process Modeling Scenarios

Scenario	Description	Flow	Loadings
1	Current Condition	8.3 mgd	Past 3 years
2	Future Condition	10.0 mgd	20% increase over Current
3	Design Condition	12.5 mgd	50% increase over Current

- Influent diurnal flow patterns
- Primary effluent scenarios
  - Variable flow only
  - Variable flow and load
- Seasonal conditions
- Variable unit processes in services

Grass Island WWTP

Blower Operational Envelope



Grass Island WWTP
Aeration Blower Design Criteria

Parameter	Design Criteria
Number of Units	3
Number of Units in Service	1 (Average Conditions) 2 (Peak Conditions)
Nominal Capacity	2,500 – 5,600 scfm
Capacity Turndown	45 – 100%
Discharge Pressure	7.0 psig
Horsepower	250 – 300 hp

- Alternatives
  - Multi-stage centrifugal (eliminated due to turndown)
  - Single-stage gear driven centrifugal
  - Single-stage direct drive centrifugal (i.e. “turbo” blowers)

Grass Island WWTP

Aeration Blower Alternatives

Supplier	Drive	Point Control	Capacity Range	Horsepower
1	Gear	Dual	2,500 – 5,600 scfm	250 hp
2	Direct	Single	3,100 – 5,700 scfm	300 hp
3	Direct	Single	3,150 – 5,650 scfm	300 hp
4	Direct	Single	3,200 – 5,600 scfm	300 hp

- Gear driven configuration met specified turndown
- Direct driven configurations required higher installed horsepower
- Evaluation to determine “wire-to-air” efficiency
  - Estimated efficiency among various components
  - Average ranged between 68 – 72% WAE
- LCC evaluations performed for electricity
  - Direct driven configurations marginally higher WAE
  - Required higher installed horsepower

Grass Island WWTP

Quantitative & Qualitative Evaluations

Quantitative Evaluation		
LCC Criteria	**Gear Drive**	**Direct Drive**
Capital Costs	Marginally Higher	Marginally Lower
Electrical Costs	Same	Same

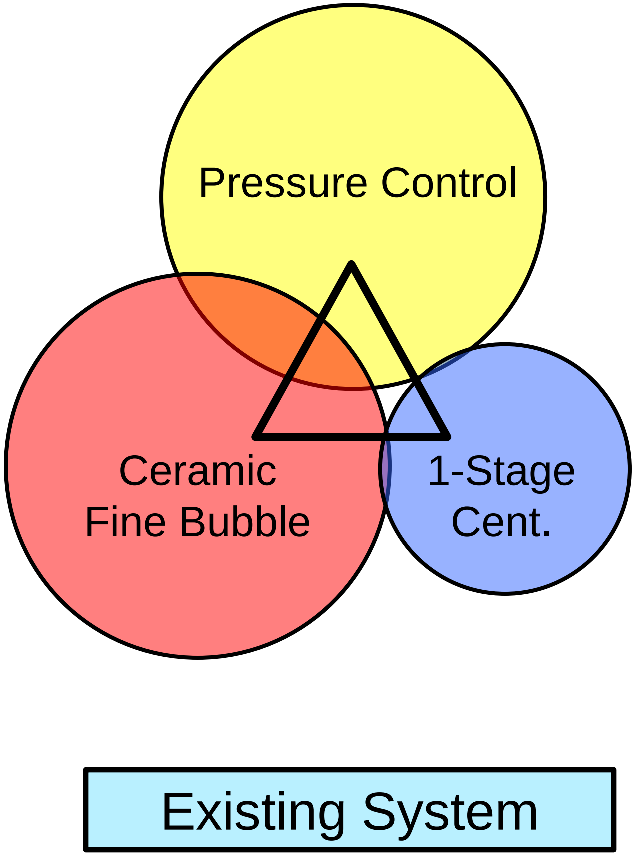
Qualitative Evaluation		
Qual. Criteria	**Gear Drive**	**Direct Drive**
Technology Development	**> 40 years**	< 10 years
Footprint Requirements	Higher	**Lower**
Bearings	Oil	Air or Magnetic
Capacity Control	**Dual Point**	Single Point
Turndown Capability	**Higher**	Lower
Noise Level	Higher	**Lower**
Operator Familiarity	**High**	Minimal

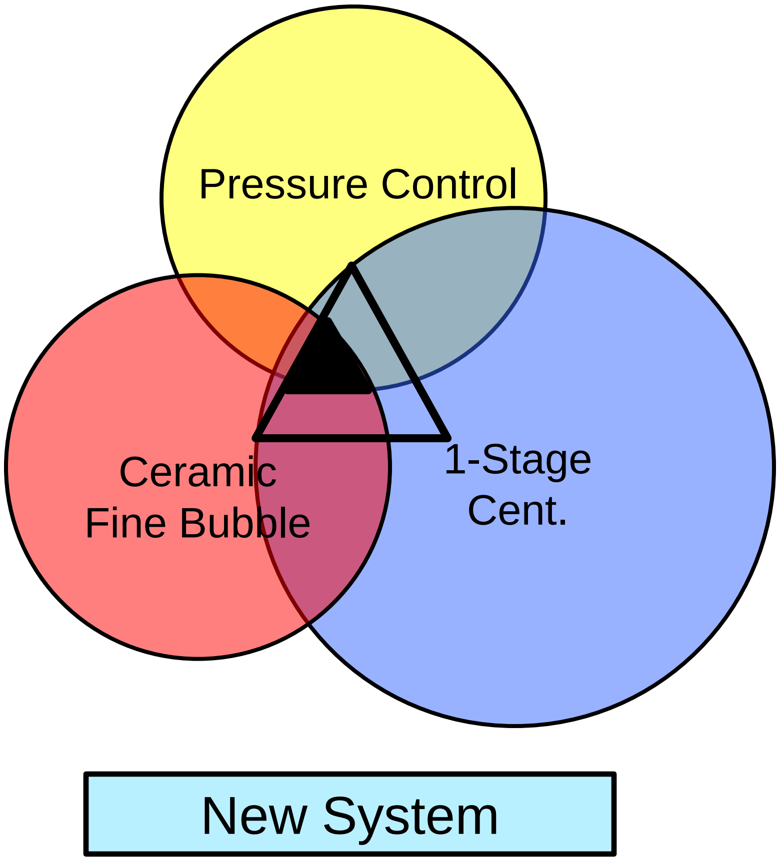
Grass Island WWTP
Aeration System Recommendations

- Control Strategy
  - Maintain existing DO drop leg zones & header pressure control strategy
- Oxygen Transfer System
  - Optimize ceramic fine-bubble diffusers arrangement
- Air Production System
  - Three single-stage gear driven centrifugal blowers
  - 2,500 – 5,600 scfm/each
  - One or two units in service allows > 97% envelope operation
  - Sufficient turndown to eliminate “blow-off”
  - Power requirements permit two blower operation on standby generators

Grass Island WWTP

Aeration System M.E.E. Triangle





Agenda Revisited

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    Grass Island WWTP

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