Closing in on Energy Neutrality at a Wastewater Treatment Works: Modifying Contact Stabilization for 21st Century Drivers

EXCELLENCE IN ENVIRONMENTAL ENGINEERING & SCIENCE
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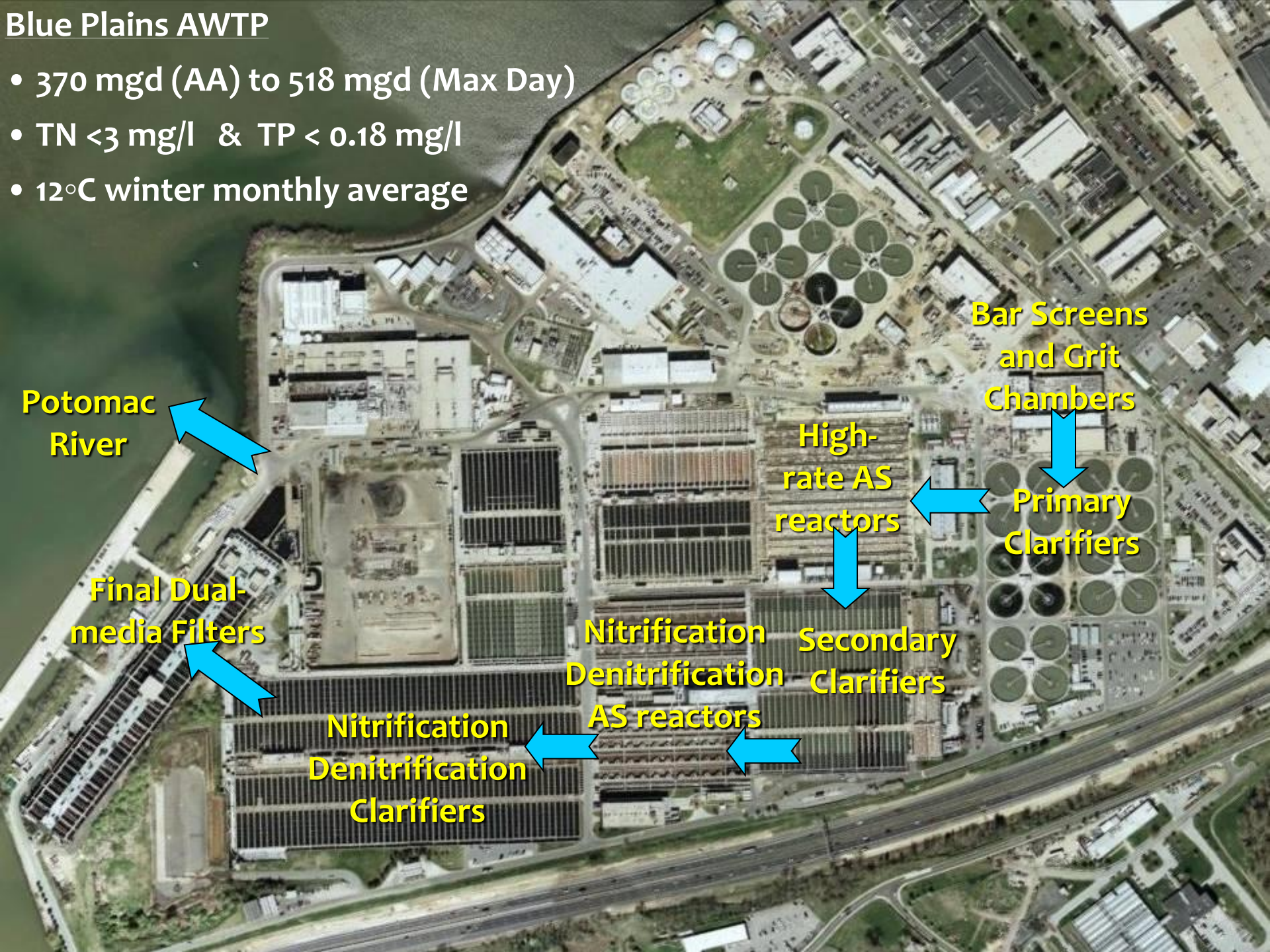

Blue Plains AWTP
• 370 mgd (AA) to 518 mgd (Max Day)
• TN <3 mg/l & TP < 0.18 mg/l
• 12◦C winter monthly average
Potomac River
Final Dual-media Filters
Nitrification Denitrification Clarifiers
Nitrification Denitrification AS reactors
Secondary Clarifiers
High-rate AS reactors
Primary Clarifiers
Bar Screens and Grit Chambers

Challenges Blue Plains Washington, D.C.

DO more

- Growth
- More Stringent Regulations – Now and in the Future
  - Eliminate CSOs (370 – 1076 mgd and higher),
  - Nutrients (TN<3 & TP<0.18),
  - Class A Biosolids (pathogen re-growth / reactivation)
  - Future – PCBs, EDCs, secondary treatment for CSO by-pass

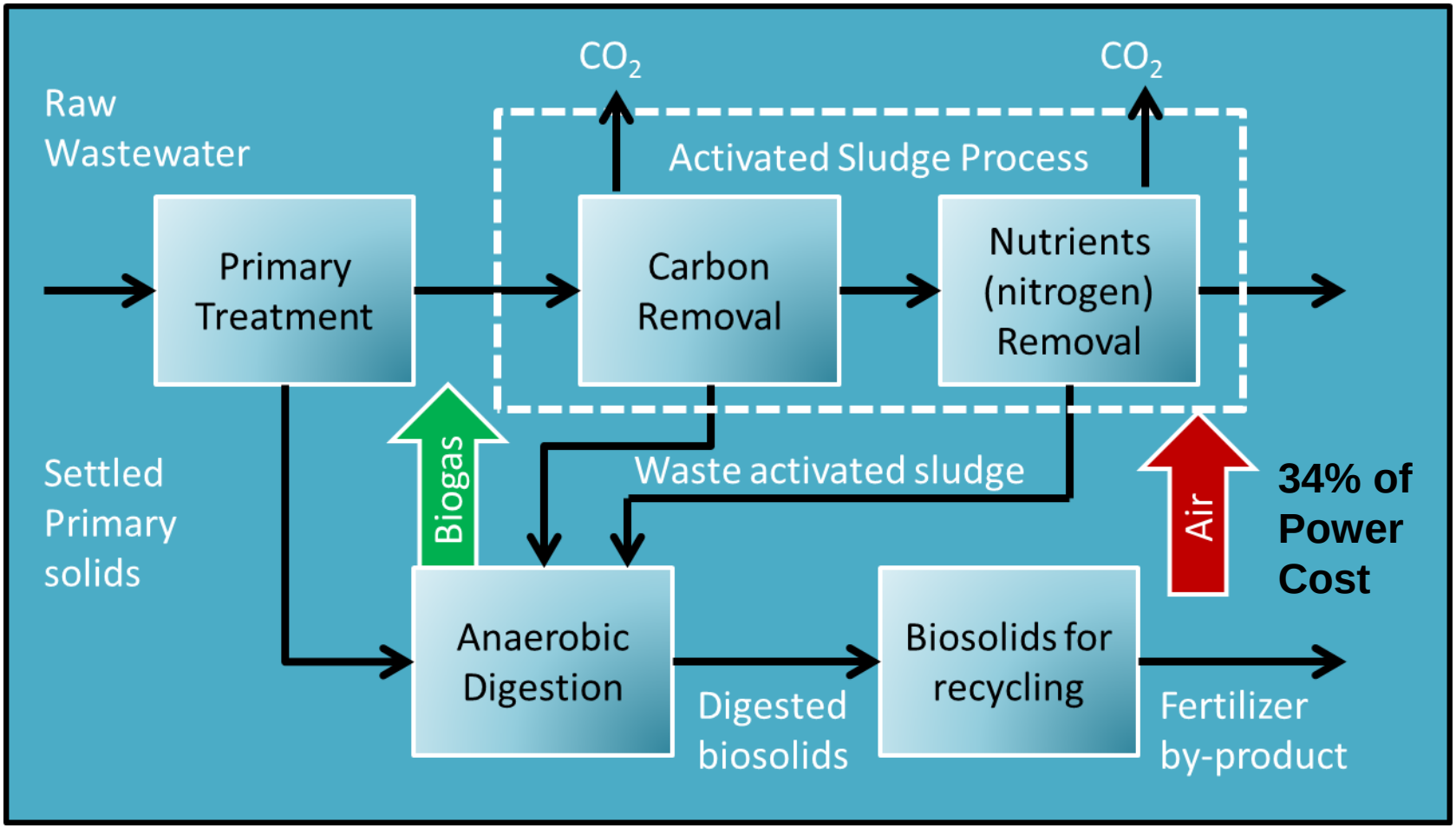
IN less

- Space constraints
- Aging infrastructure
- Urban environment – visual impact, odour, noise

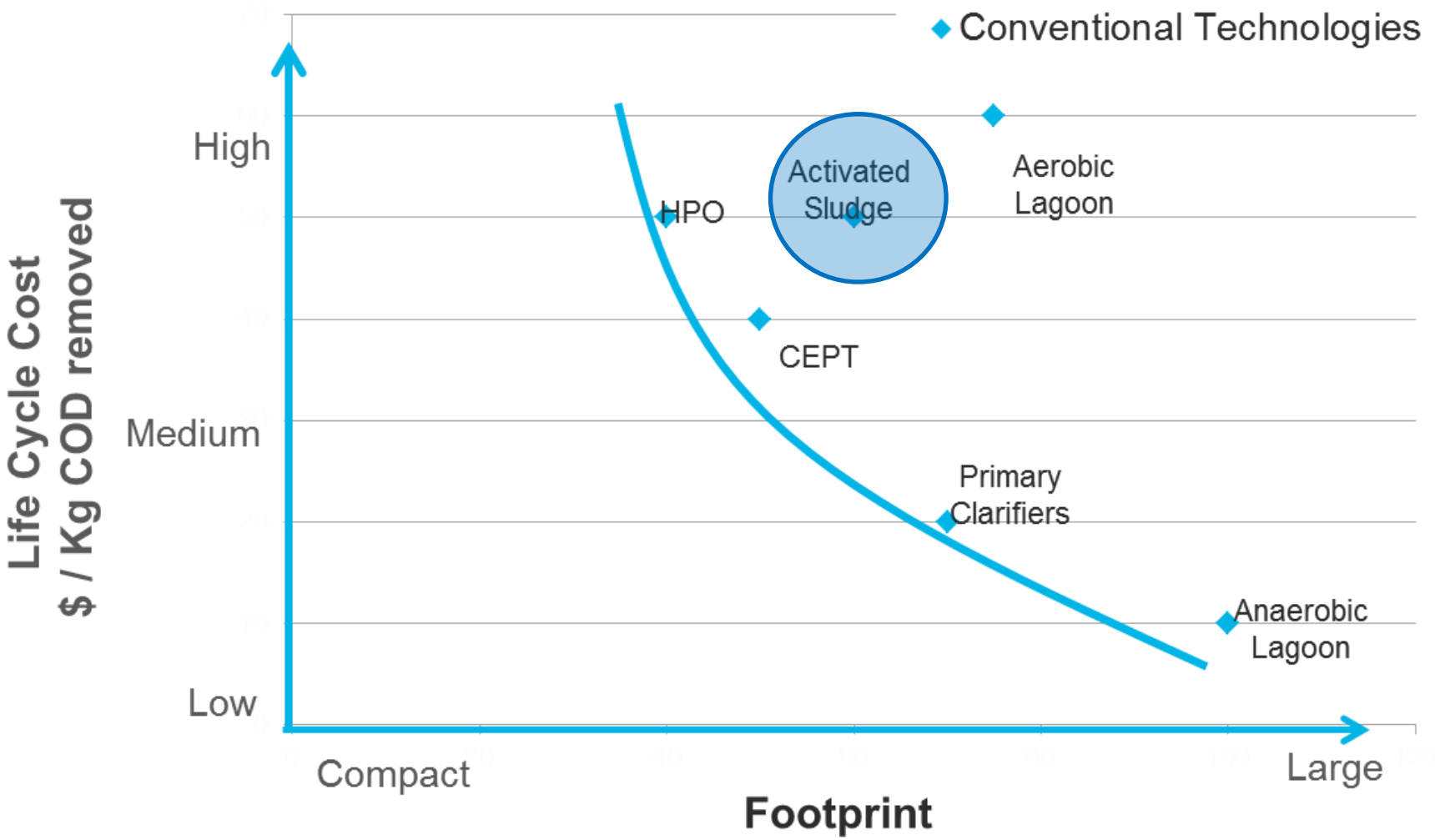
WITH less

- Sustainability Vision
  - Energy Neutrality
  - Resource Recovery – Energy, Biosolids, Nutrients, Water
- Cost – long term rate impacts

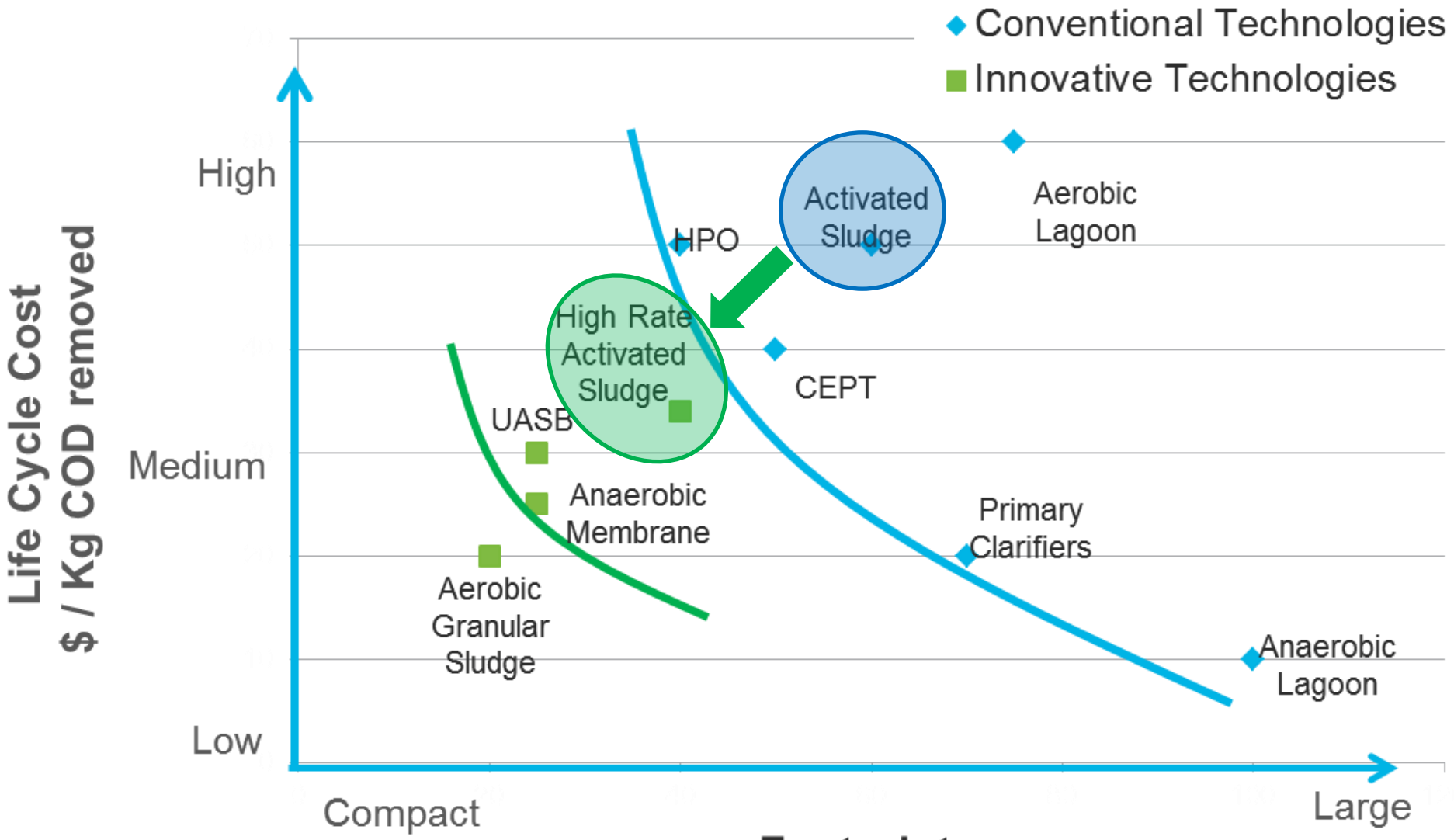
water is life



Conventional Intensification

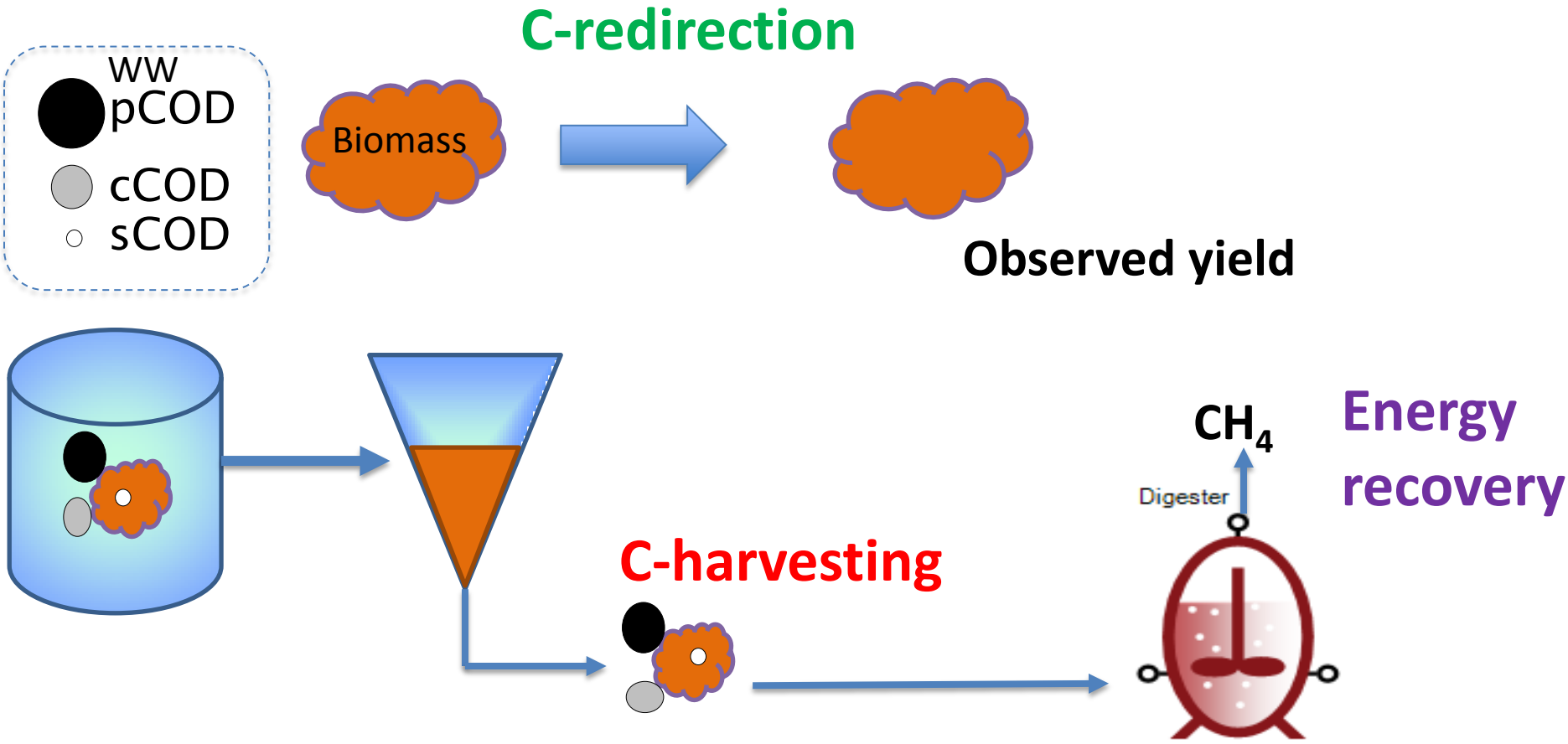


Disruptive technologies



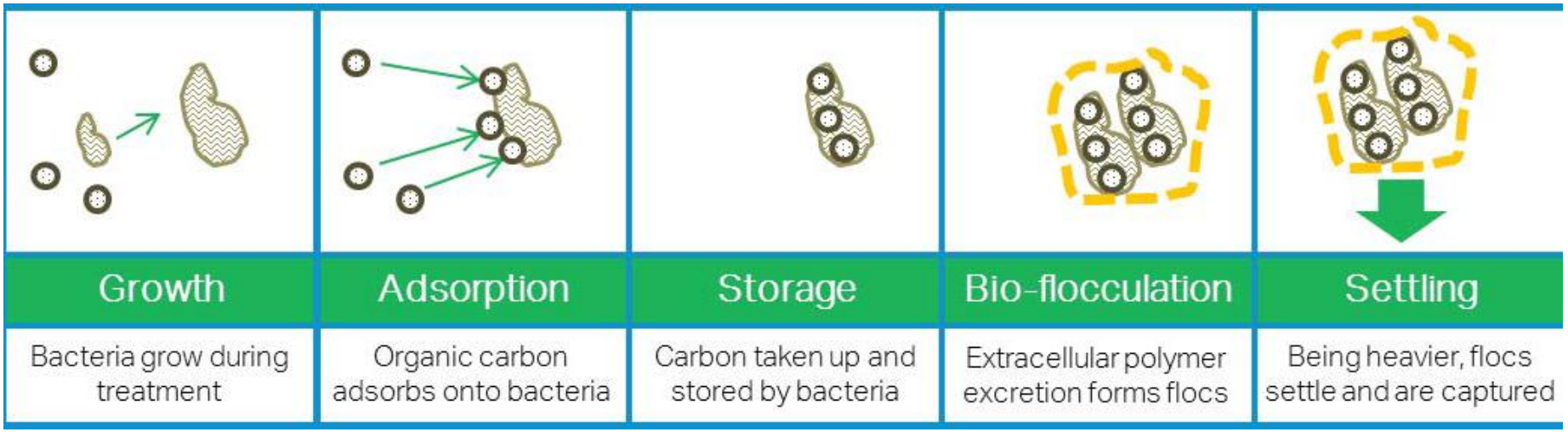
C-harvesting vs C-redirection

water is life



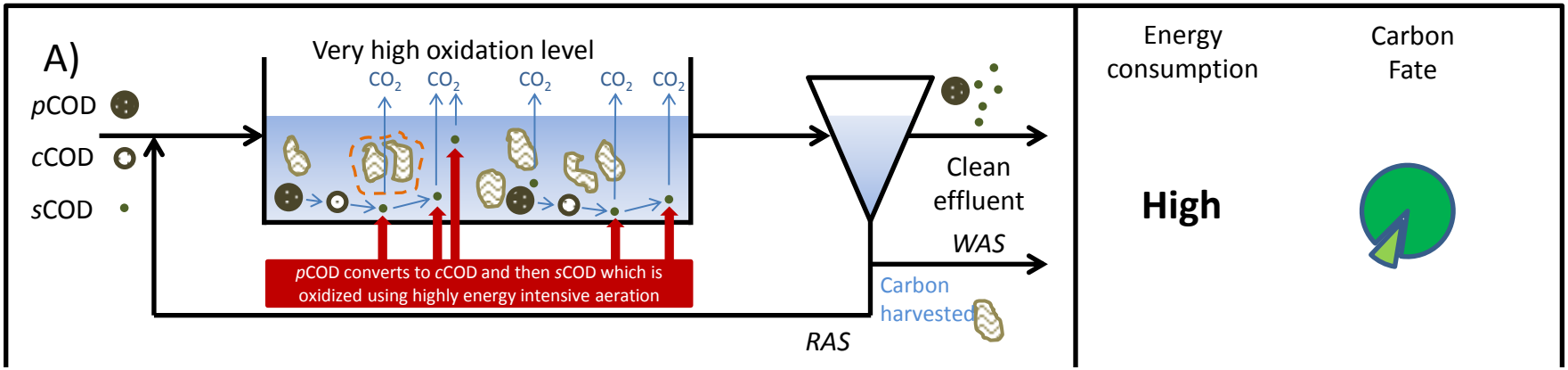
Mechanisms

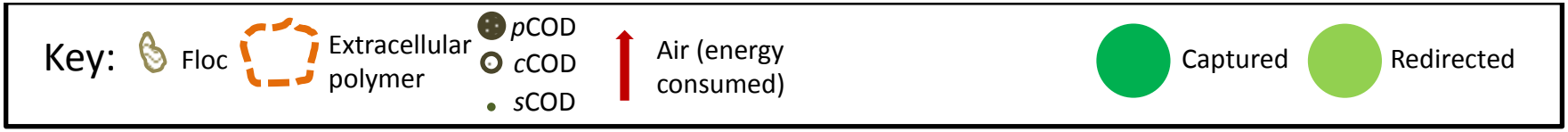
C redirection mechanims

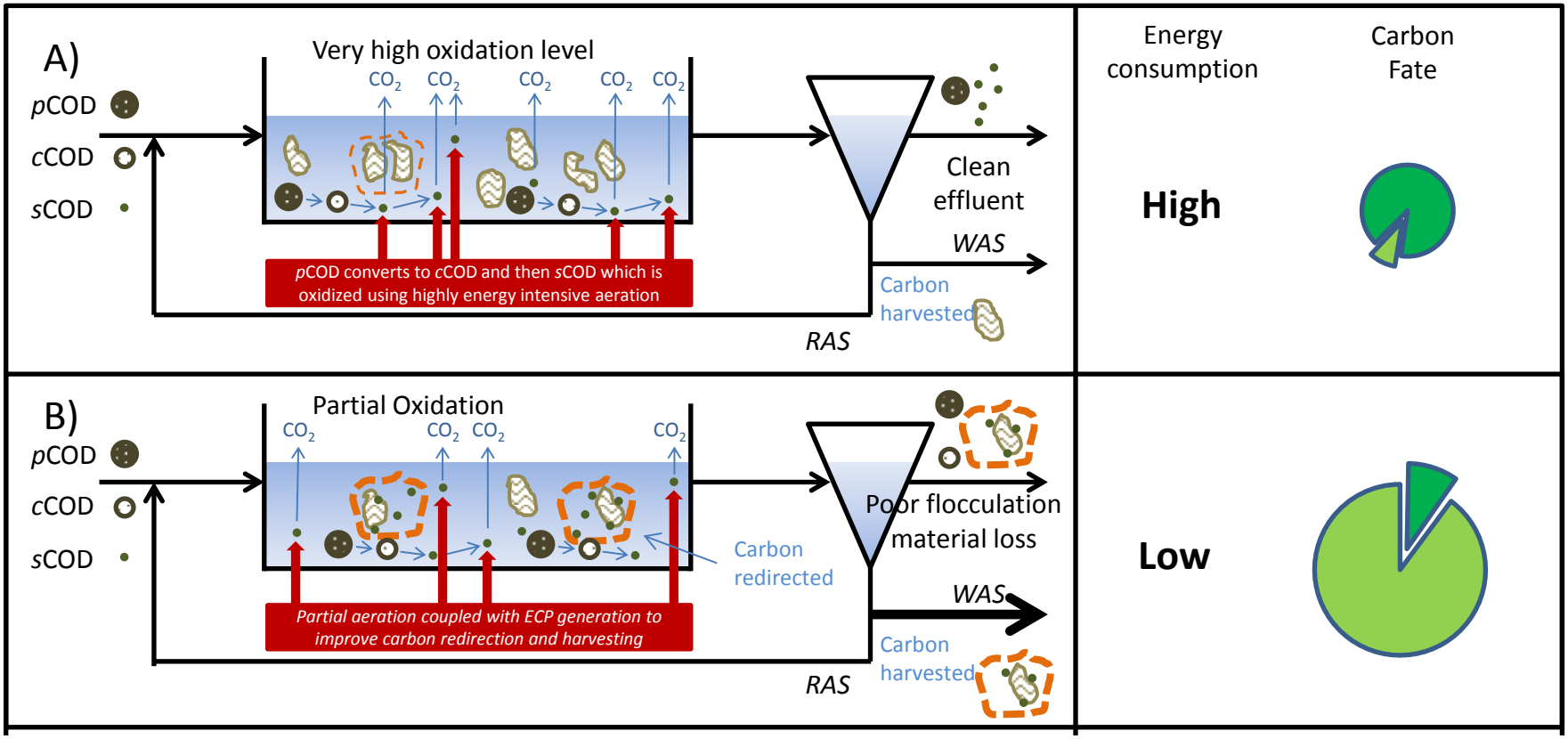


C oxidation

C harvest


A)
pCOD
cCOD
sCOD
Very high oxidation level
CO2
CO2
CO2
CO2
CO2
pCOD converts to cCOD and then sCOD which is oxidized using highly energy intensive aeration
Clean effluent
WAS
Carbon harvested
RAS
Energy consumption
Carbon Fate
High


Key:
Floc
Extracellular polymer
pCOD
cCOD
sCOD
Air (energy consumed)
Captured
Redirected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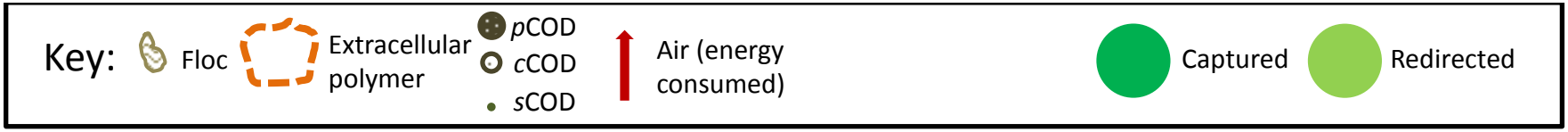
B)
Partial Oxidation
Carbon redirected
Poor flocculation material loss
Partial aeration coupled with ECP generation to improve carbon redirection and harvesting
Low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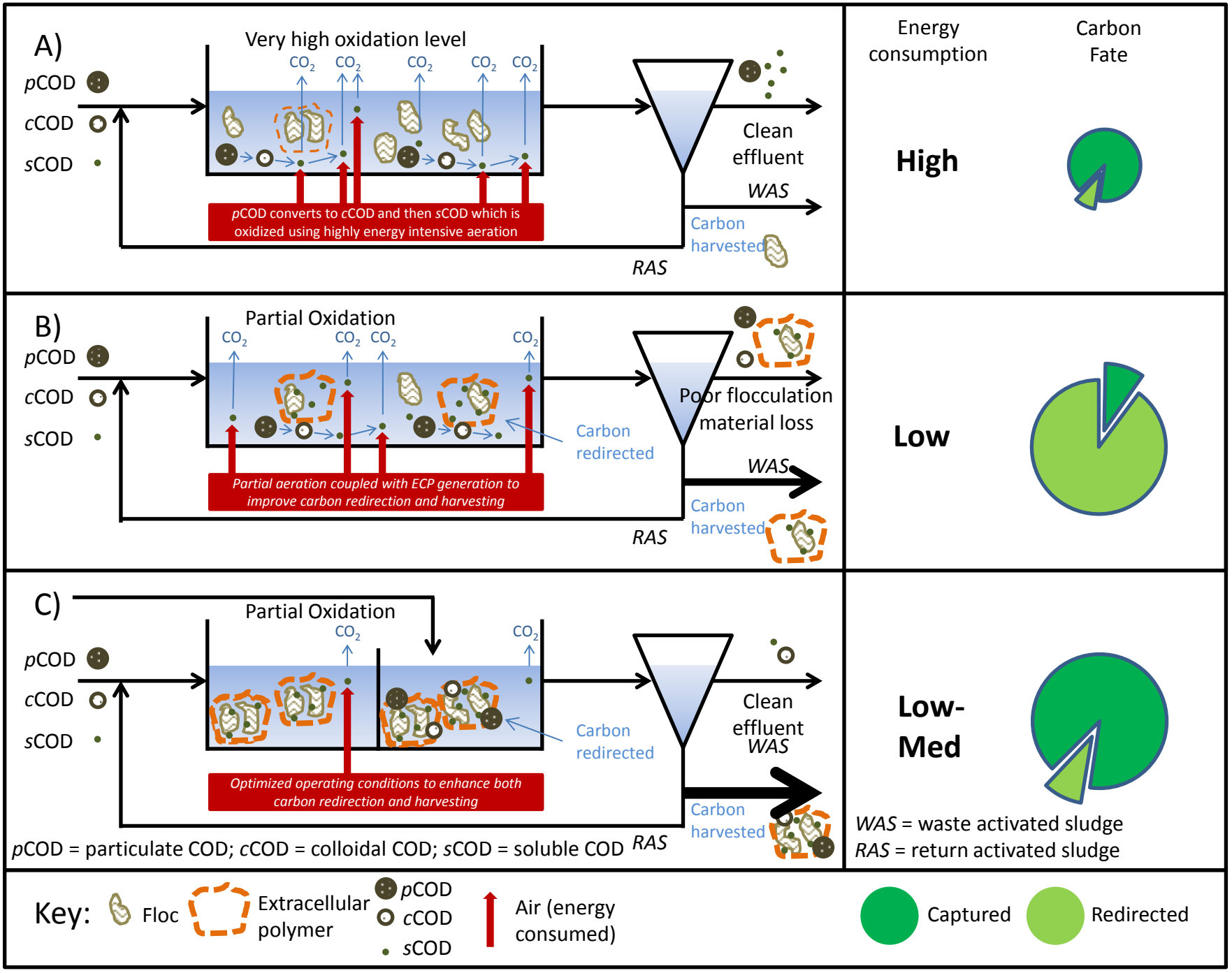
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Poor flocculation material loss
Carbon redirected
Partial aeration coupled with ECP generation to improve carbon redirection and harvesting
Low
C)
Optimized operating conditions to enhance both carbon redirection and harvesting
Low-Med
pCOD = particulate COD; cCOD = colloidal COD; sCOD = soluble COD
WAS = waste activated sludge
RAS = return activated sludge
Key:
Floc
Extracellular polymer
Air (energy consumed)
Captured
Redirected

Experimental setup

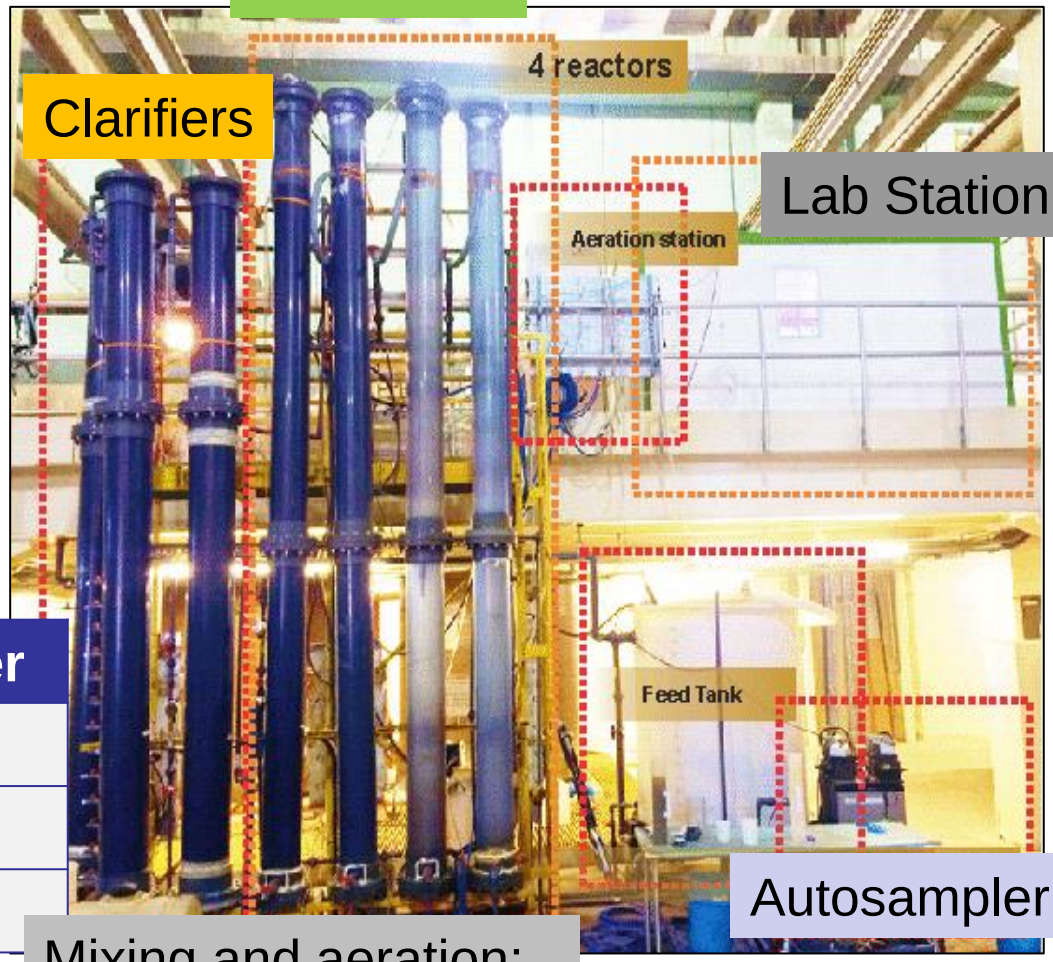
The pilot WWTP is consisting of 3 major components:

1. Four reactors (R1-R4)

2. Three Clarifiers (C1-C3)

3. One RAS tank

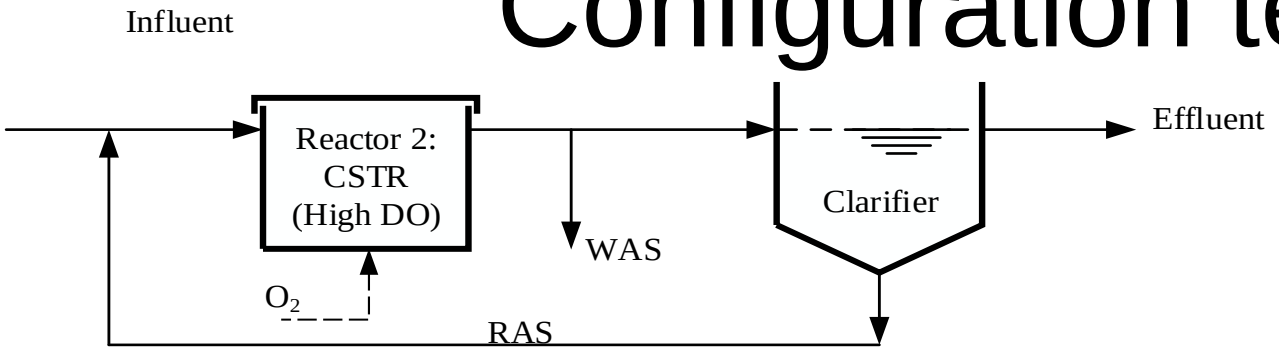
Parameter	Reactor	Clarifier
Diameter	10 in	12 in
Depth	15 ft	12 ft
Volume	227 L	306 L



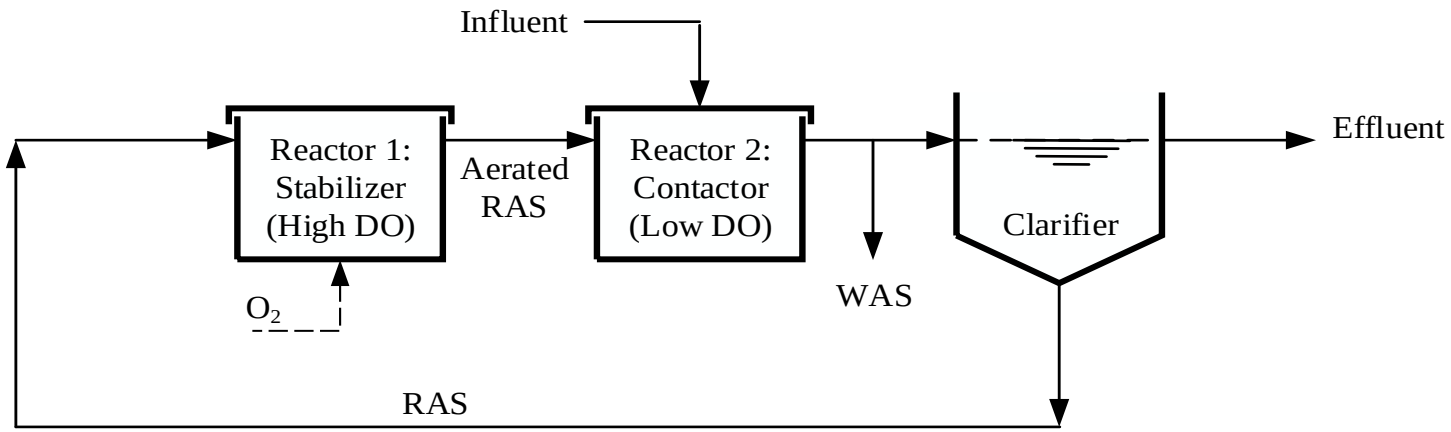
Mixing and aeration:
1. Fine bubble
2. Coarse bubble

Configuration tested

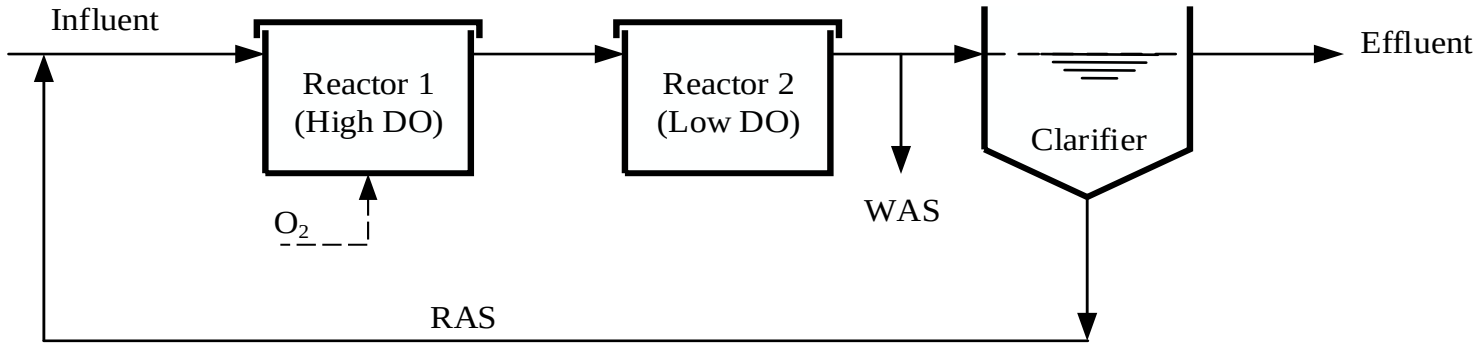
(a)



(b)



(c)



Experimental setup

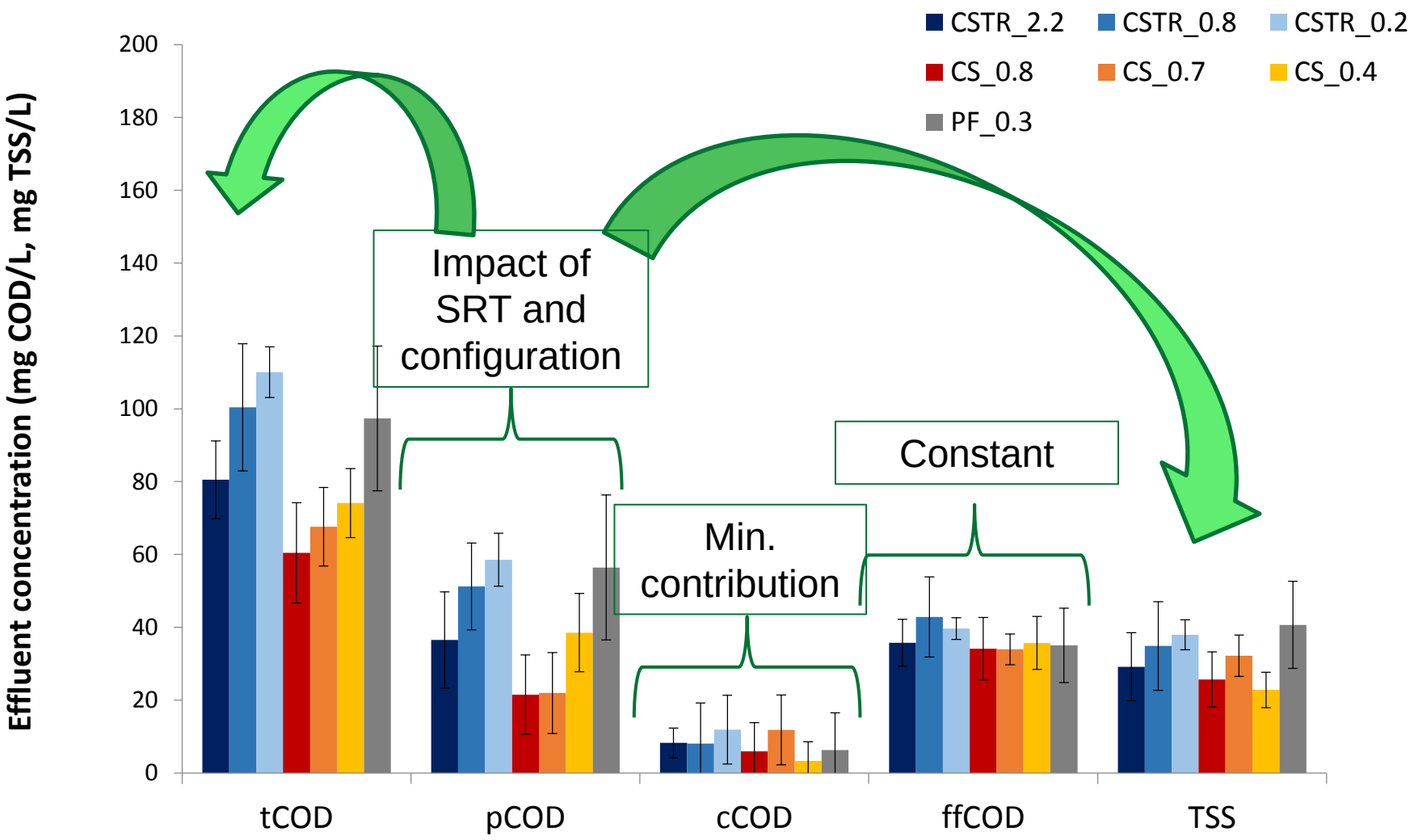
Constant process setting:

Parameter	Unit	Pilot	WEST (1 reactor in operation)
Total reactor volume	m3	0.220 or 2*0.220	23,000
Clarifier volume	m3	0.306	79,000
SOR	m3/m2/h	1.9	0.8
Qin	m3/d	6.3	450,000
Recycle ratio	%	53-65	>80

Controlled parameters: aeration (mixing or to reach certain min. DO)
+ waste flow rate

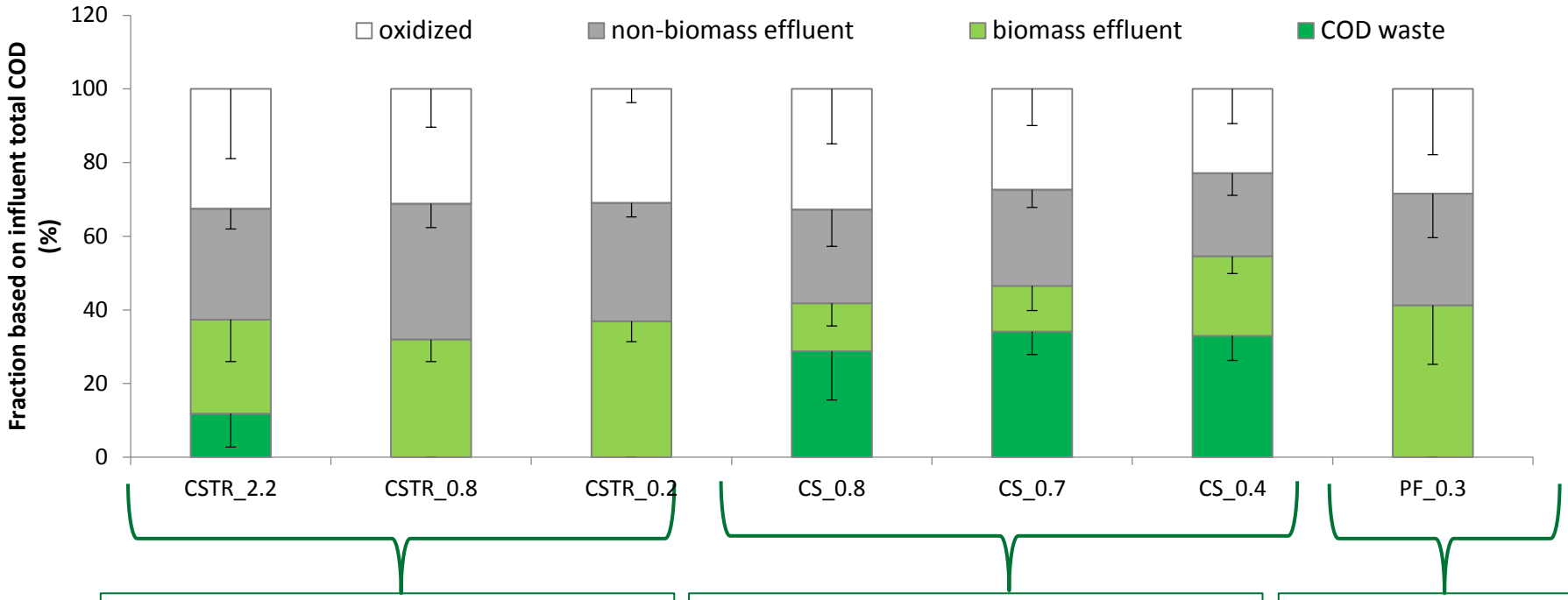
Non-controlled parameters: influent characteristics, temperature

Effluent quality



water is life

Carbon balance

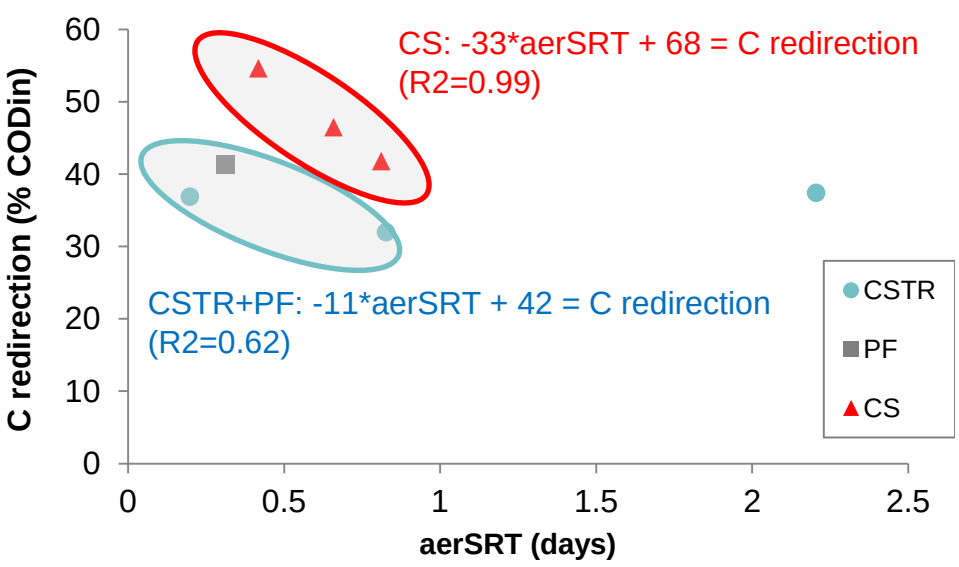


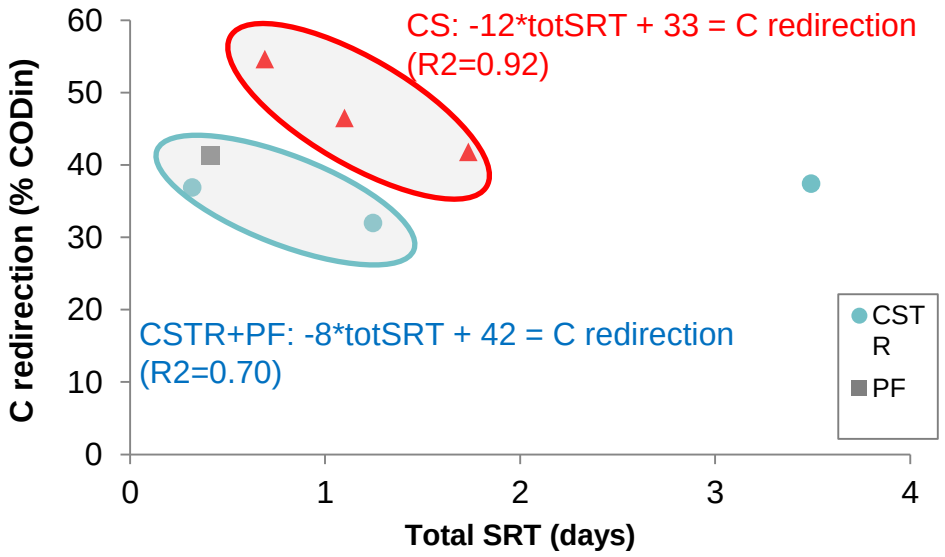
- Increased carbon redirection with decrease in SRT
- Loss of bioflocculation at low SRT
- Minimum oxidation = 30%

- Increased carbon redirection with decrease in SRT
- Improved bioflocculation at similar low aerSRT as CSTR
- Minimum oxidation = 25%

- Loss of bioflocculation under similar operation condition as 1.7d SRT CS

SRT vs configuration





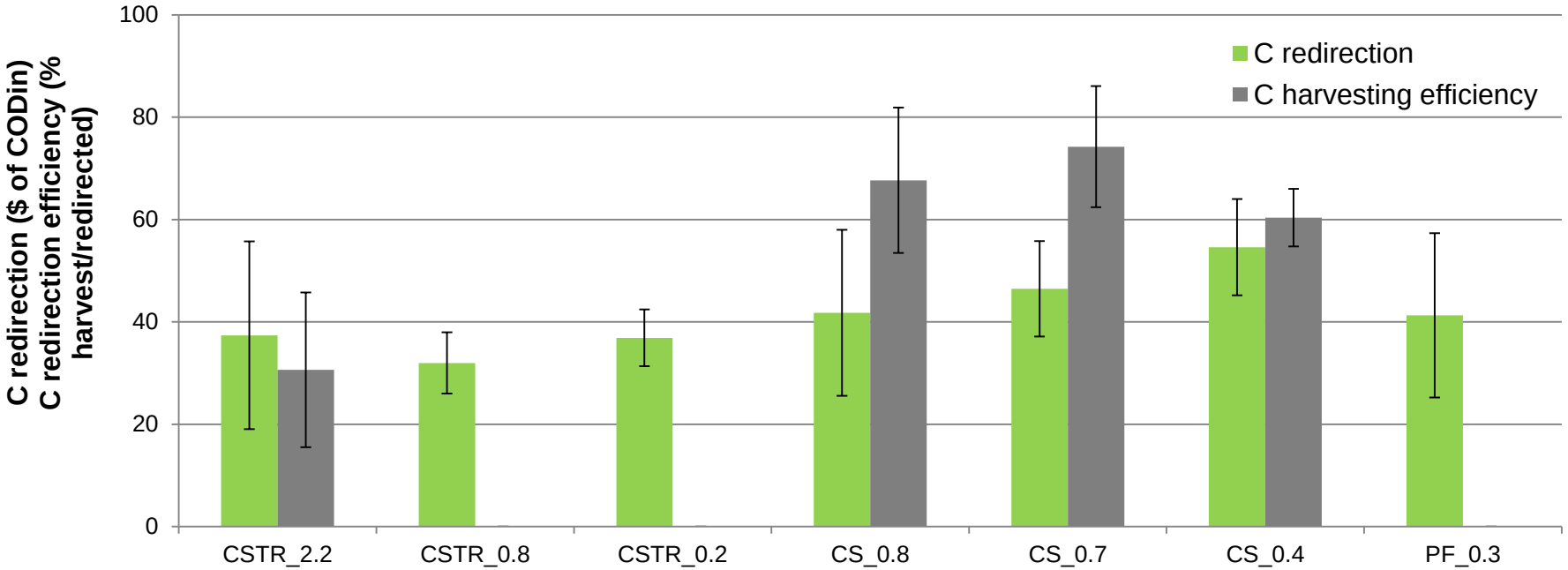
Total SRT:

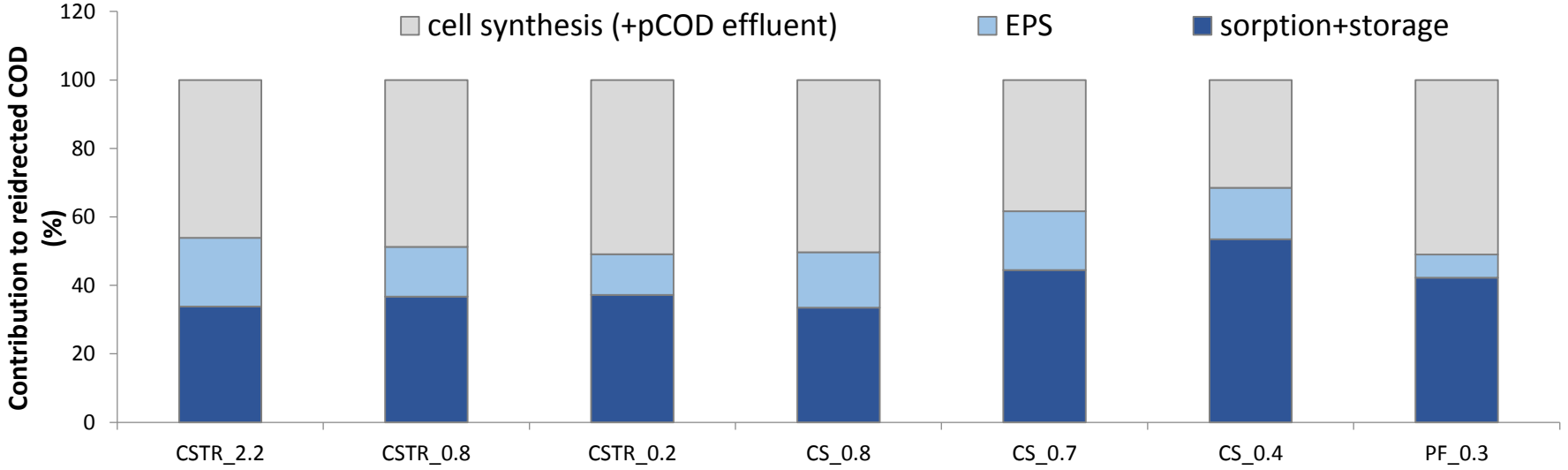
- Relationship more or less similar
- Shift to the left for CS (due to anoxic zoning)
- Higher theoretical C-redirection achievable for CS: 60 vs 40%

Aerobic SRT:

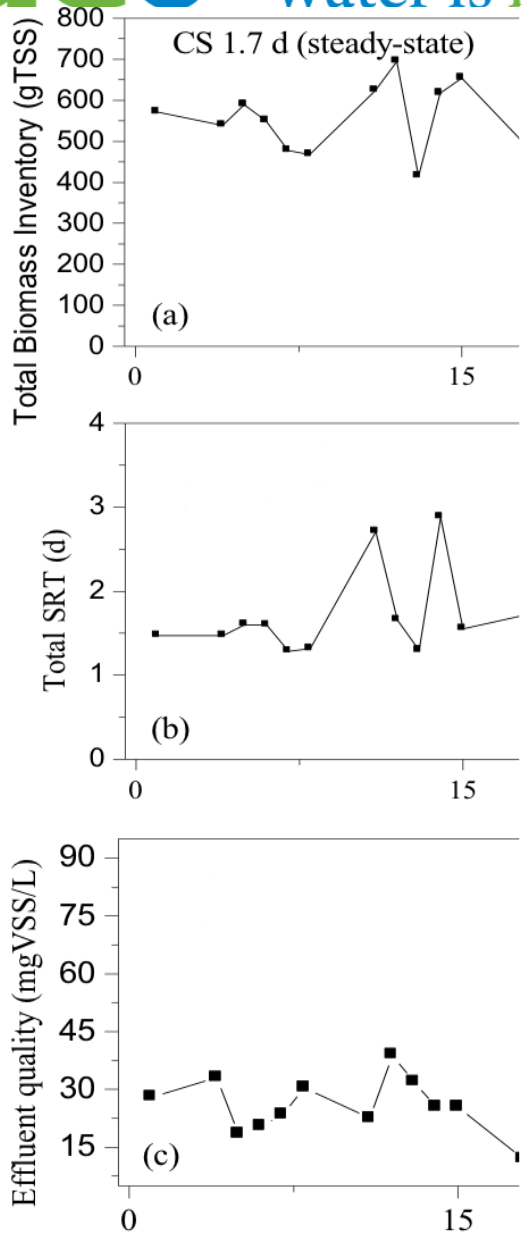
- More mechanistic relationship
- CS increases C-redirection more significantly with change in aerSRT (because bioflocculation control is linked to aerobic SRT in CS)

Capture efficiency





CS vs PF


CS 1.7 d (steady-state)
Total Biomass Inventory (gTSS)
800
700
600
500
400
300
200
100
0
(a)
0
15
Total SRT (d)
4
3
2
1
0
(b)
0
15
Effluent quality (mgVSS/L)
90
75
60
45
30
15
(c)
0
15

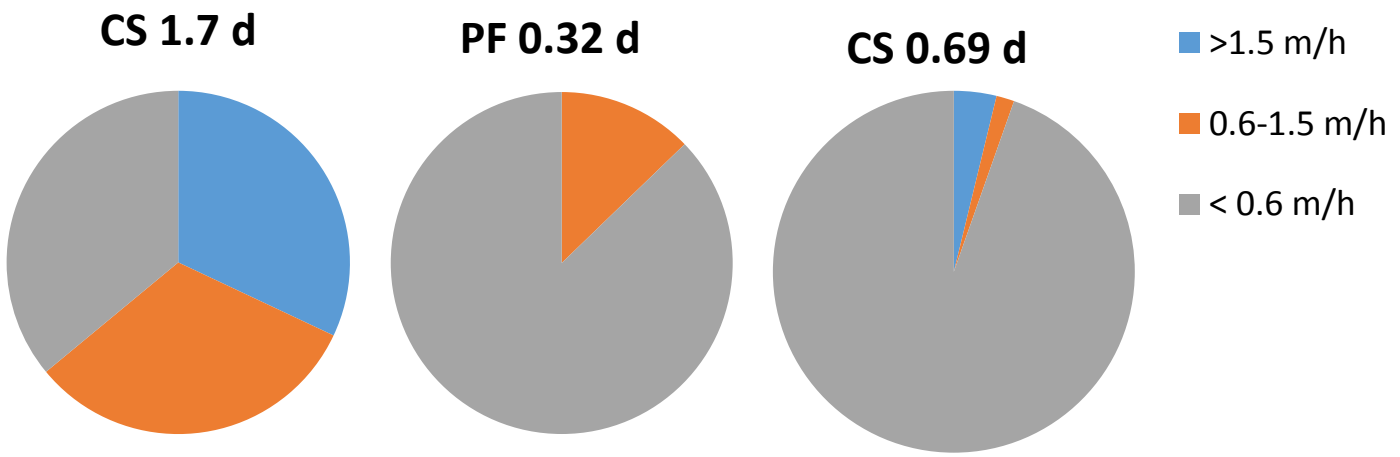
Settleability

Phase	SVI_{30} (mL/gTSS)
CS 1.7d	168 ± 45
PF 0.4 d	859 ± 356
CS 0.69 d	582 ± 113

Phase	TOF (mgTSS/L)
CS 1.7d	156 ± 32
PF 0.4 d	>860
CS 0.69 d	219 ± 58

Phase	Effluent TSS (mgTSS/L)
CS 1.7d	20 ± 6
PF 0.4 d	44 ± 14
CS 0.69 d	21 ± 4

Intrinsic settling classes



Dense fraction (>1.5 m/h) related to storage mechanisms??

Overall pilot conclusions

1. Understand the impact of SRT on C redirection and C capture
   (SRT control based on TSS)
   - *C-redirection increases with decreased aerSRT (linear correlation up to certain point)*
   - *Bioflocculation determines C-capture*
2. Determine the best operational configuration to achieve high C capture efficiency
   - *CS (RAS aeration + feast at low DO) is key to increase bioflocculation*
   - *Switch from stabilizer to contactor: increase EPS production, storage, sorption*
     - *EPS production and storage: dependent on starvation period in stabilizer*
     - *Sorption: depends on fresh EPS, available sorption spots*

Questions???

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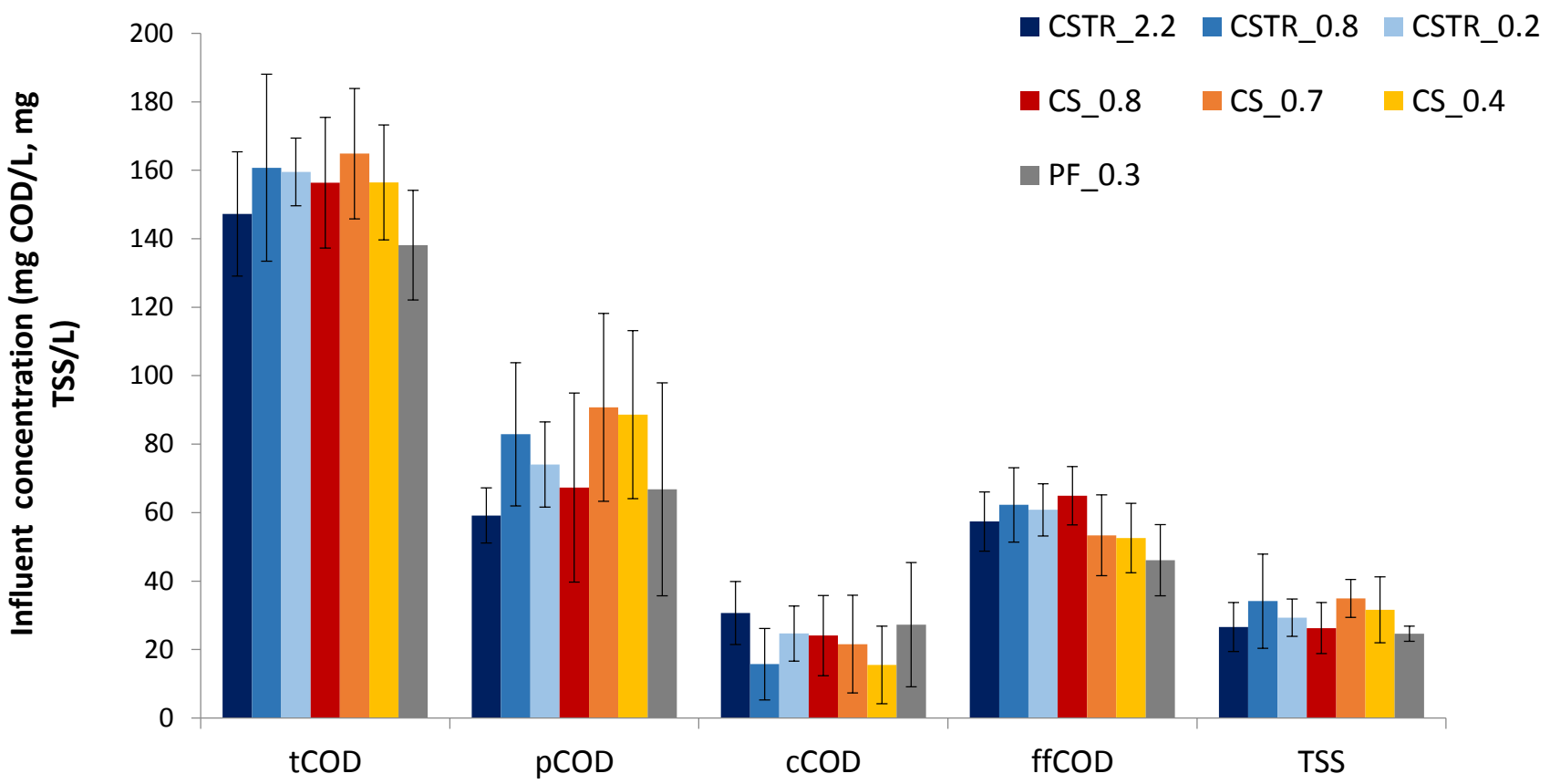
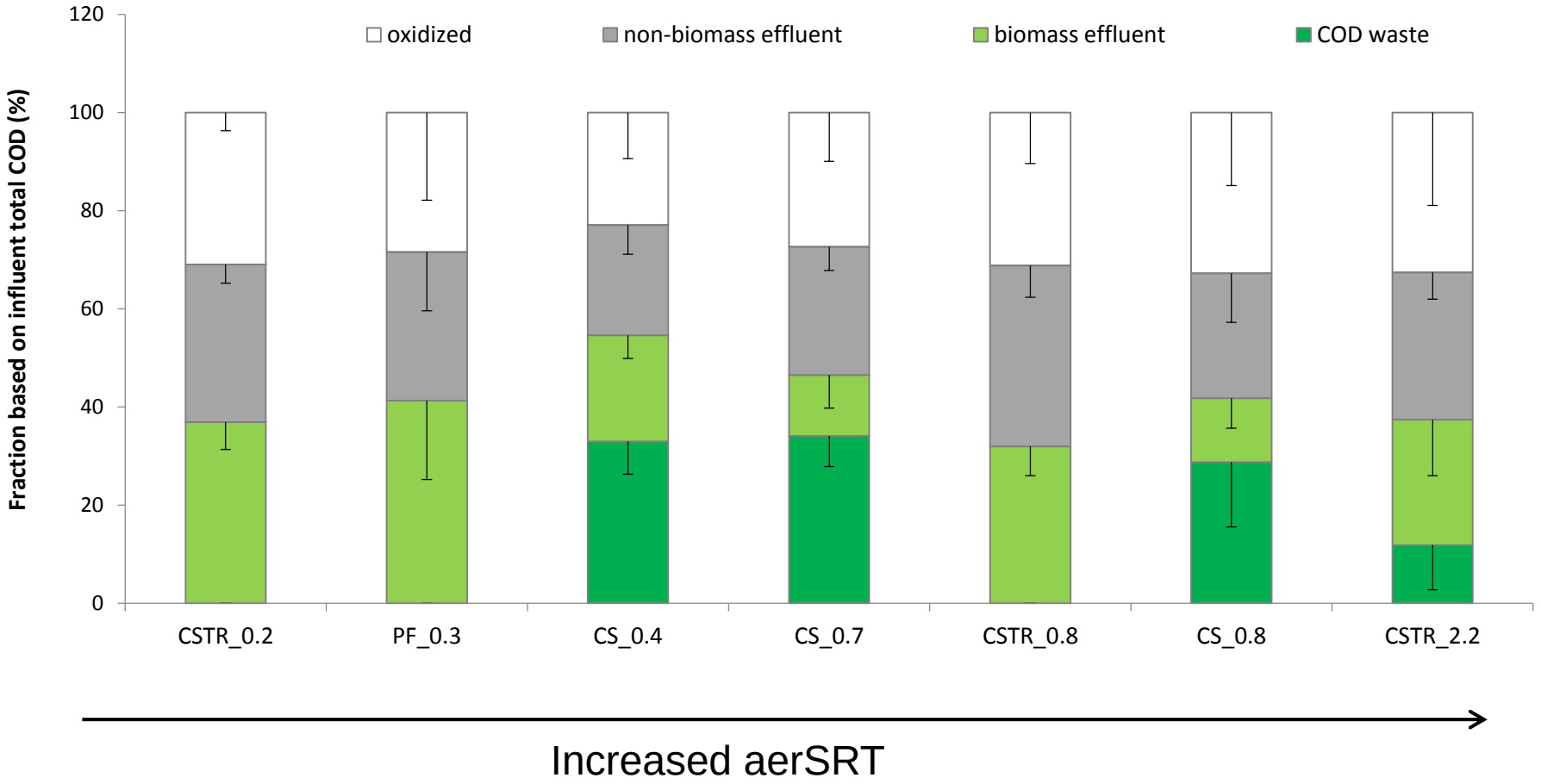
Influent characteristics



OHO fraction in influent: 0.5 - 2 % of influent COD

Inert sCOD: ~ 20 mg COD/L (plant effluent), pilot minimum 35 mg COD/L

SRT vs configuration



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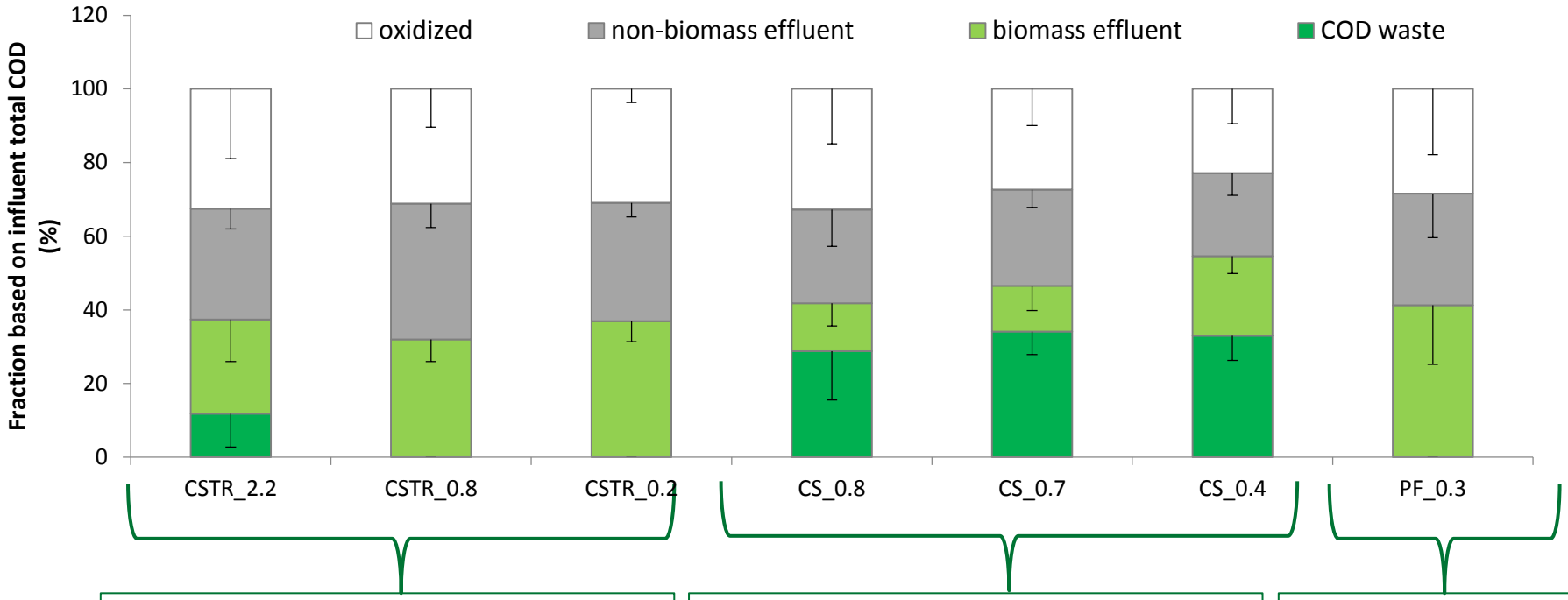

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