Recovering values from water industry by-products

Ziye DAI

stream
The Industrial Doctorate Centre for the Water Sector

Scottish Water
Always serving Scotland

NORTHUMBRIAN WATER

Newcastle University

Content

- Introduction
- Nutrient Recovery
- Carbon and Energy Recovery
- Conclusion

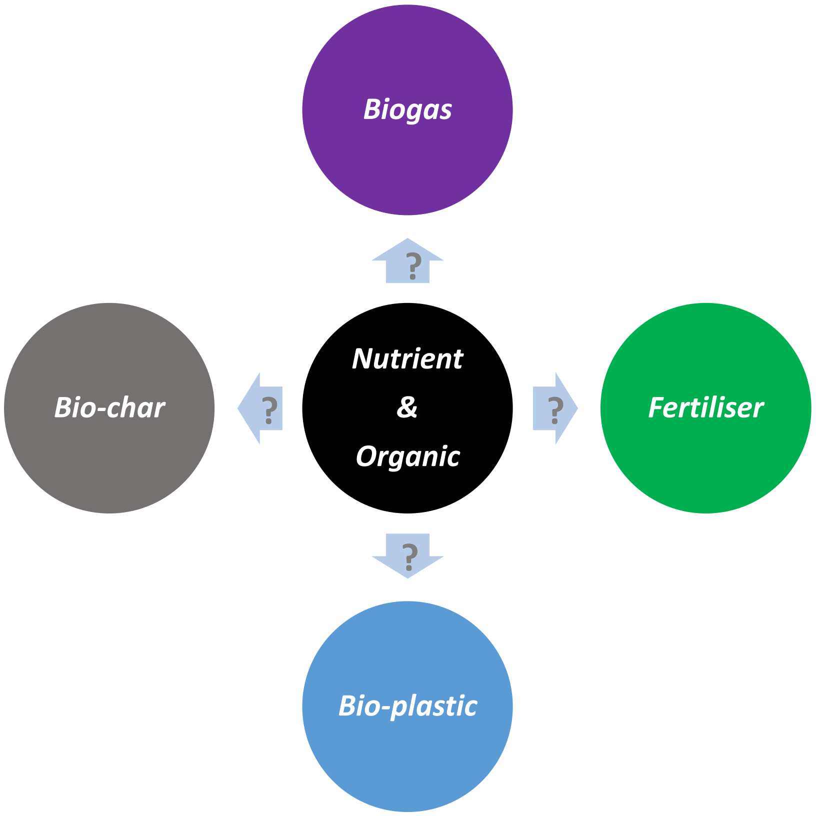
Project Brief

Research Question:

- *How much valuables flow in?*
- *Where and How they get removed or captured?*
- *Where and how to recover them?*
- *Is the mass loading of the recoverable valuables big enough to create **impacts** on **treatment performance**, **sustainability** and **economics**?*

Approach:

Mass and Energy Balance



Mass and Energy Balance Investigation

- **Actual Wastewater Treatment Work**

  Howdon, Hendon, Allers and Laighpark

- **Composite Sample of Every Stream**
  - *Wastewater : Inlet, Settled, Final Effluent, Return Liquor, etc.*
  - *Sludge: Primary, Secondary, Digested, etc.*

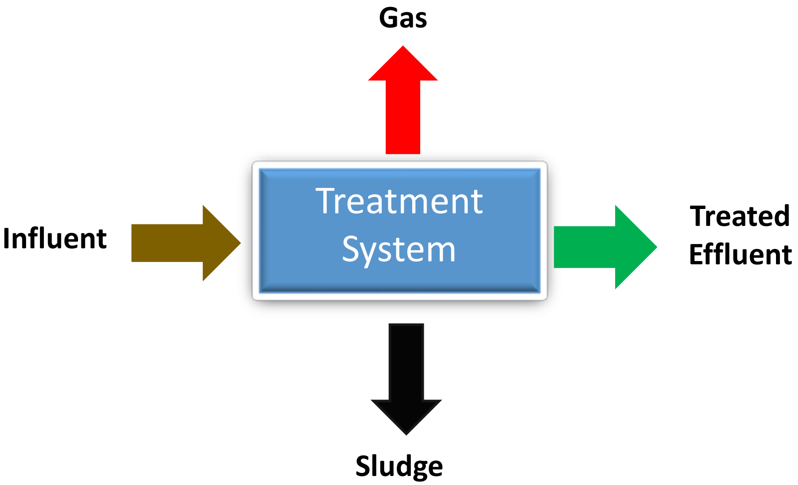
- **Parameters**

  Wastewater
  - *COD, sCOD, TOC, DOC*
  - *AmmN, TKN,O-PO_4*
  - *TS*
  - *Energy*

  Sludge
  - *TS, VS*
  - *TOC, TN, TP*
  - *Fibre – Hemicellulose, Cellulose and Lignin*
  - *Energy*

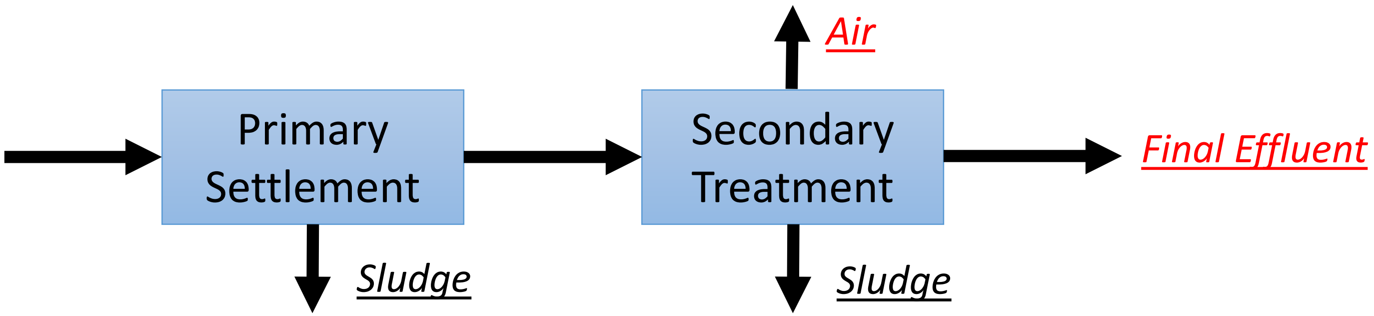
Mass = Flow x Concentration

Principle of Mass and Energy Balance



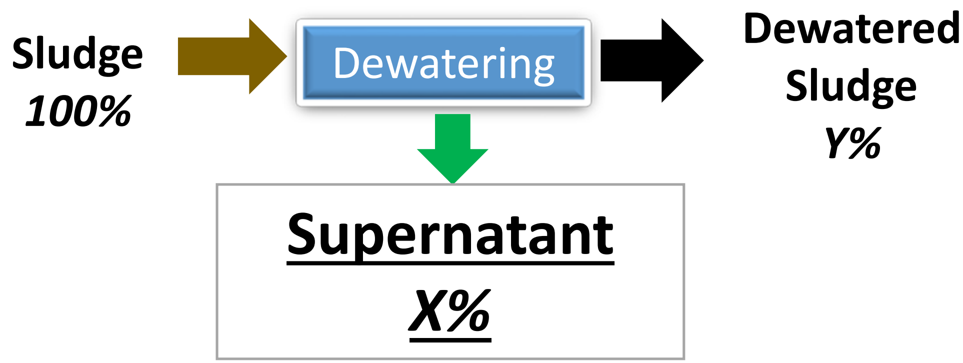
$$m_{(in)} = m_{(out)}$$
$$m_{(Influent)} = m_{(Gas)} + m_{(Sludge)} + m_{(Treated\ Effluent)}$$
$$E_{(in)} = E_{(out)}$$
$$E_{(Influent)} = E_{(Gas)} + E_{(Sludge)} + E_{(Treated\ Effluent}$$

Nutrient in Wastewater Treatment



	N	P
Form of Existence	NH_4^+, Organic N	PO_4^{3-} , Organic P
Treatment	**Biological (Secondary Treatment), Nitrification and Denitrification** *NH_4^+ → NO_3^- (In Effluent)→ N_2 (In Air)* *NH_4^+ → Organic N (In Secondary Sludge) **	**Chemical (Primary Treatment)** *PO_4^{3-} → $FePO_4$ or $AlPO_4$ (In Primary Sludge)* **Biological (Secondary Treatment)** *PO_4^{3-} → Organic P (In Secondary Sludge)**
Capturing Rate	20-30%	30-90%

Nutrient in the Supernatant



	X% N-NH4 in Supernatant	X% P-PO4 in Supernatant
Primary	3-5%	3-6%
Secondary	3-5%	5-10%
Stored Sludge	<u>15-20%</u>	<u>30-40%</u>
Digested Sludge	<u>50-80%</u>	<u>20-40%</u>
Total Recoverable from <u>Sludge</u>	60-90%	50-60%
Total Recoverable from <u>Wastewater</u>	**12-30%**	**15-50%**

Recirculate to head of the work!!

The nutrient loading to the WwTW is increased.

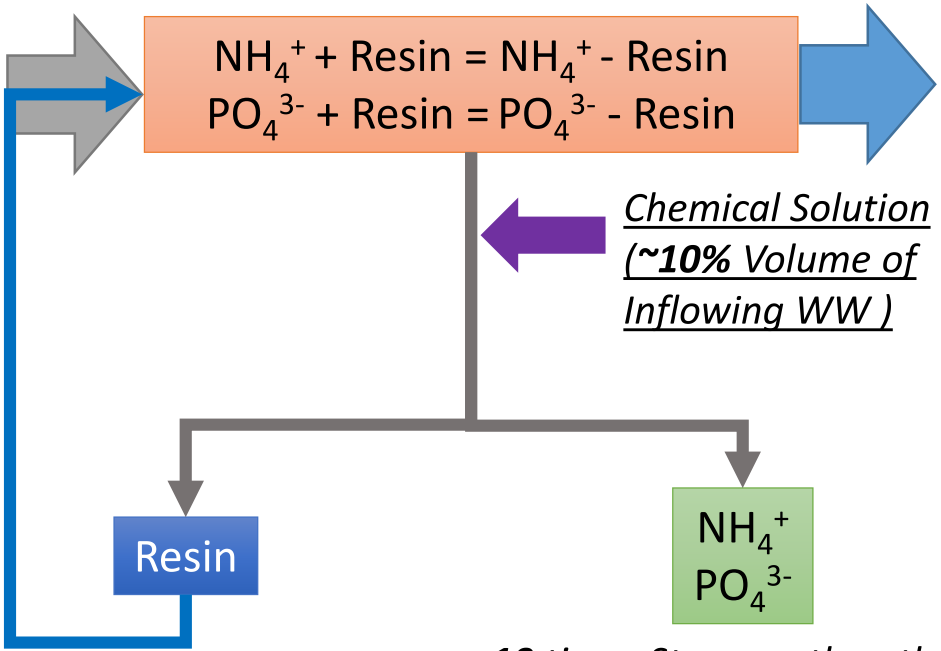
Recovering Nutrient Directly from Wastewater

Loading = Concentration x Flow

	Raw Wastewater	Return Liquor
Flow, m^3	270,000	8,500
AmmN, mg/L	30	211
AmmN, t	**8.0**	1.8
P-PO_4, mg/L	3	70
P-PO_4, t	**0.8**	0.6

- Though the nutrient concentration in the raw wastewater is low, considerable amount of nutrient is lost in ***Air/Final Effluent***, especially the loss of Ammonium in ***nitrification*** and ***denitrification***.

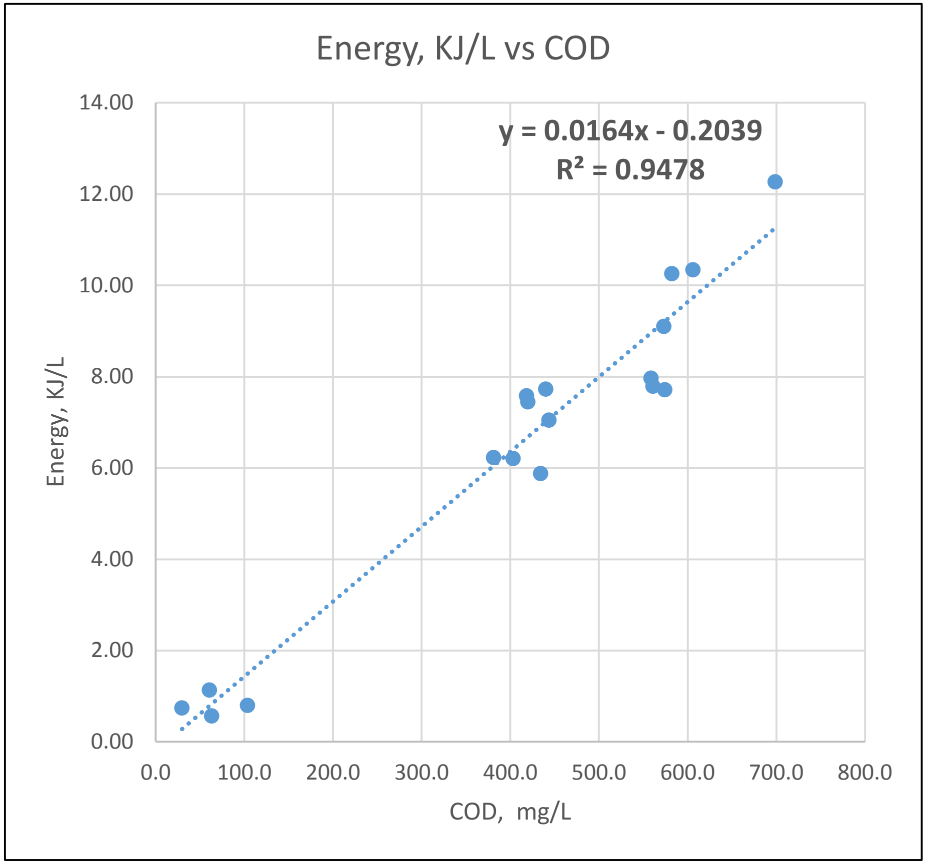
$NH_4^+ \rightarrow NO_3^-$ (In Effluent)$\rightarrow N_2$ (In Air)



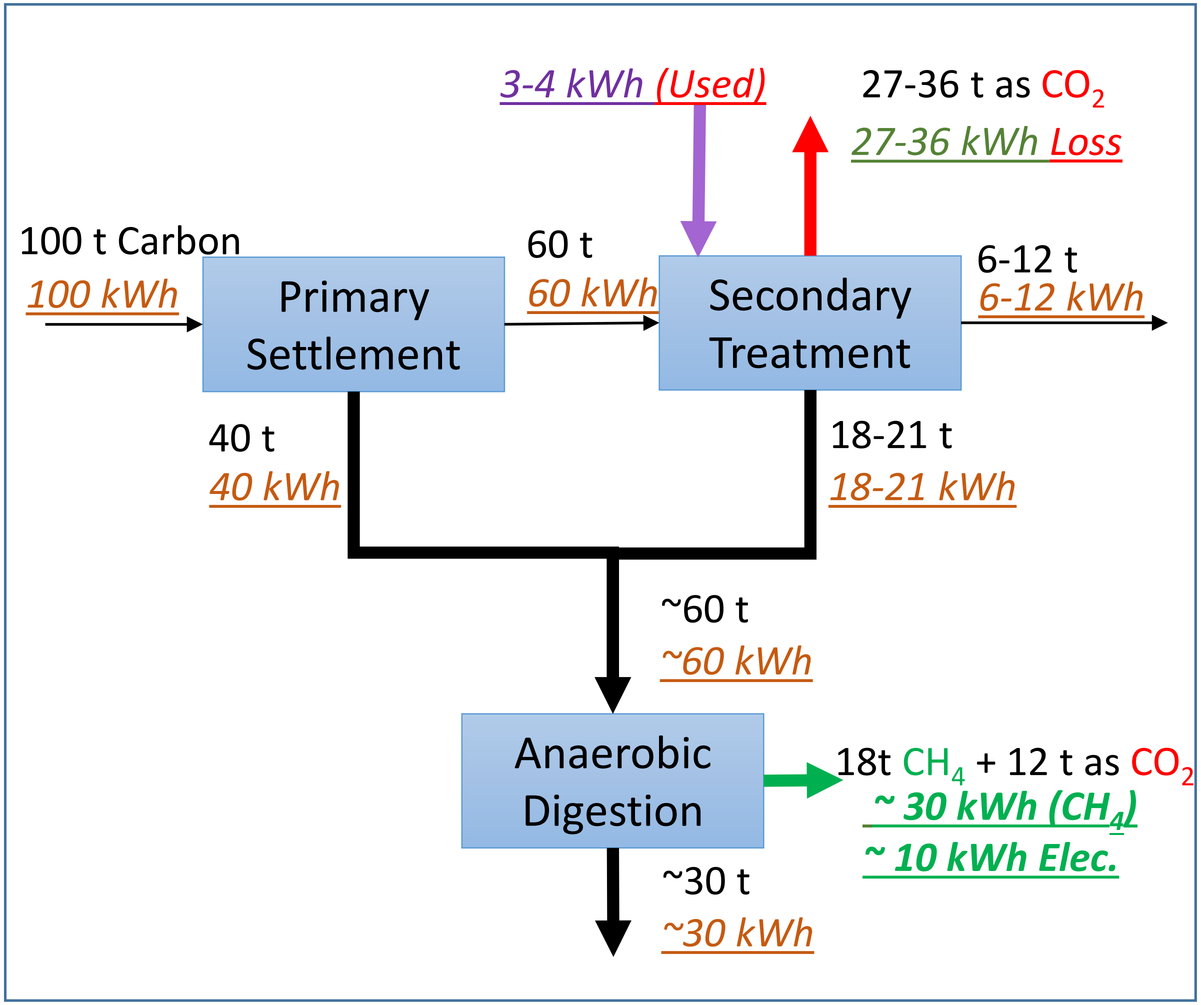
10 times Stronger than the original concentration

Carbon and Energy

- ***0.25-1 kWh*** **electrical** energy is used to treat 1 m^3 of wastewater
- 1 gram of COD has about 16 KJ of **chemical** energy
- For a medium strength of wastewater with 500 mg/L COD, 1 m^3 of wastewater has ***2.22 kWh*** of **chemical** energy
- If the conversion rate of chemical energy to electrical energy is **35%**, 1 m^3 of wastewater has ***0.77 kWh*** of **electrical** energy
- Potentially, wastewater treatment can be energy neutral or even energy positive



Carbon and Energy Balance of Wastewater Treatment



Carbon Balance

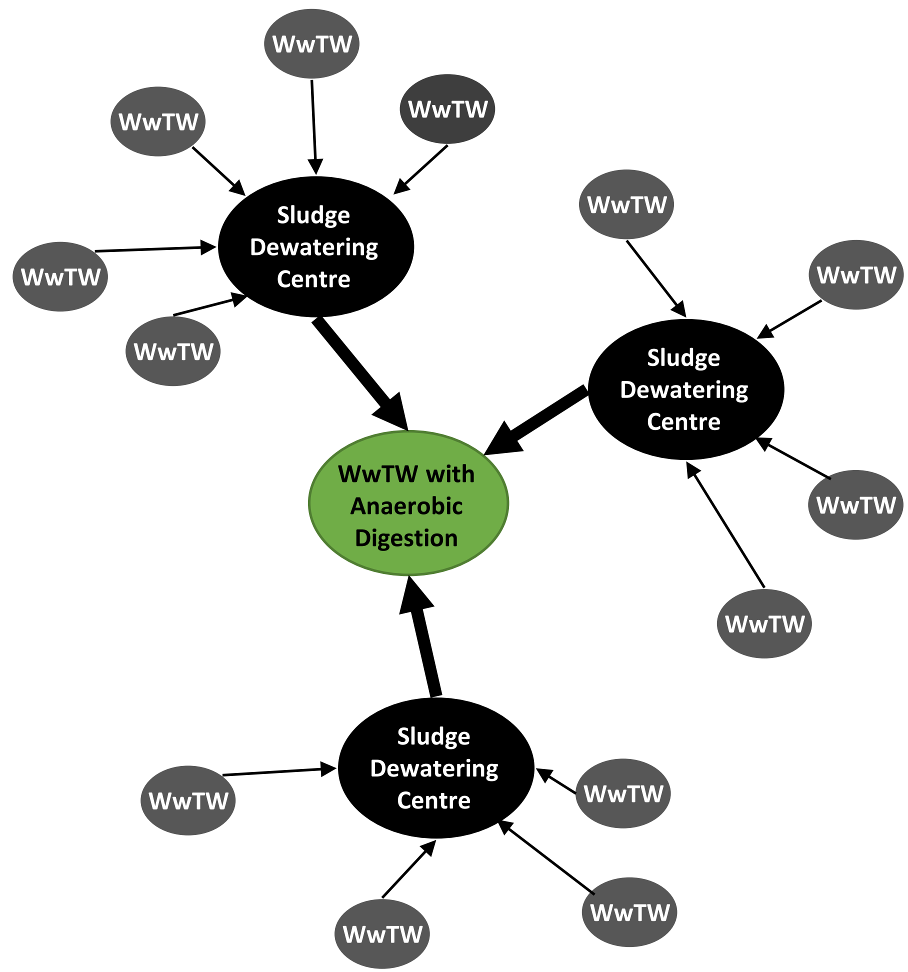
- **18%** is recovered as CH_4
- **60 %** of C is loss
  - 6-12 % in Final Effluent
  - 27-36 % in CO_2 in Aeration
  - 30% in the Digested Sludge

Energy Balance

- **30%** of Chemical Energy is recovered
- Excluding Pumping, Dewatering, the electrical energy consumption is equivalent to 3-4% of the inflowing energy
- If the produced chemical energy is converted into **electrical** energy, the **NET electrical** energy production (6-7 kWh) is equivalent to 6-7 % of the inflowing **chemical** energy

Achieve Energy Neutral/Positive

- Not every wastewater treatment work has Anaerobic Digestion
- Transportation of the sludge requires energy
- Besides, Pumping, Screening, Sludge Dewatering, etc. require energy
- For achieving energy neutral/energy positive:
    - **Produce more energy**
    - **Reduce treatment related energy consumption**

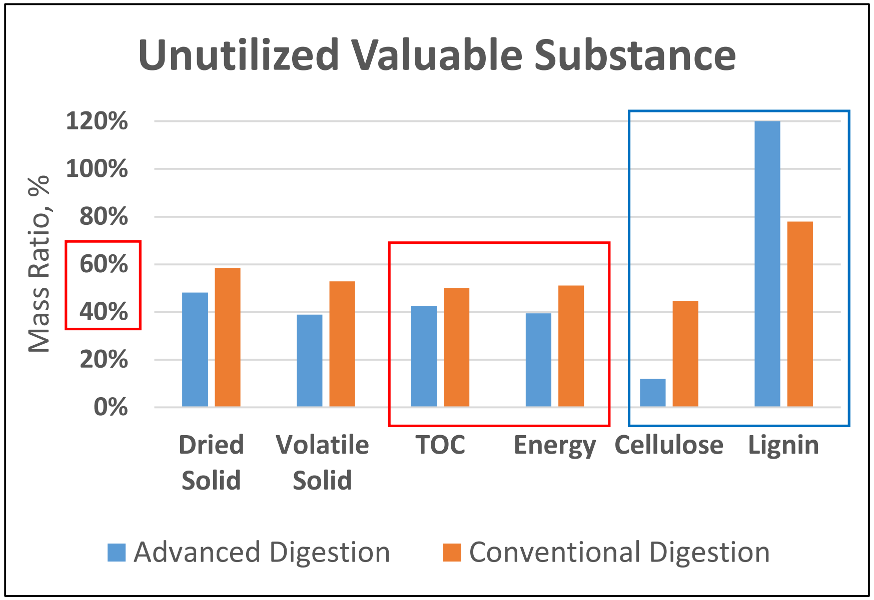


Producing More Energy

Improve Primary Settlement

- *Increase AD feed*
  - ❑ *Improve Primary Settlement for capturing more COD/TOC and preventing* ***loss in Secondary Treatment***

With conventional coagulant
COD Removal: 40% → 70%
pCOD Removal: 50% → 90%



Recovery from Digested Sludge

- *Further recover energy from digested sludge (15 KJ/g)*
  - ❑ *Hydrolysing leftover* ***cellulose*** *and feed back to Digester*
  - ❑ *Pyrolysis, Gasification, Hydro-carbonization*

Reducing Energy Consumption in Secondary

Advantages:

- Robust treatment performance
- Capable of removing Nutrient

Disadvantages:

- **Energy intensive (Aeration)**
- Oxidize part of TOC (~30%)

Current Approaches

Activated Sludge and Trickling Filter

- TOC + Energy = CO_2 + ***Biomass***

Possible Alternative Technology

Microbial Fuel/Electrolysis Cell

- MEC: TOC + Energy = CO_2 + $\boldsymbol{H_2}$
- MFC: TOC = CO_2 + ***Electricity***

OR

Anaerobic Treatment

- TOC = CO_2 + $\boldsymbol{CH_4}$

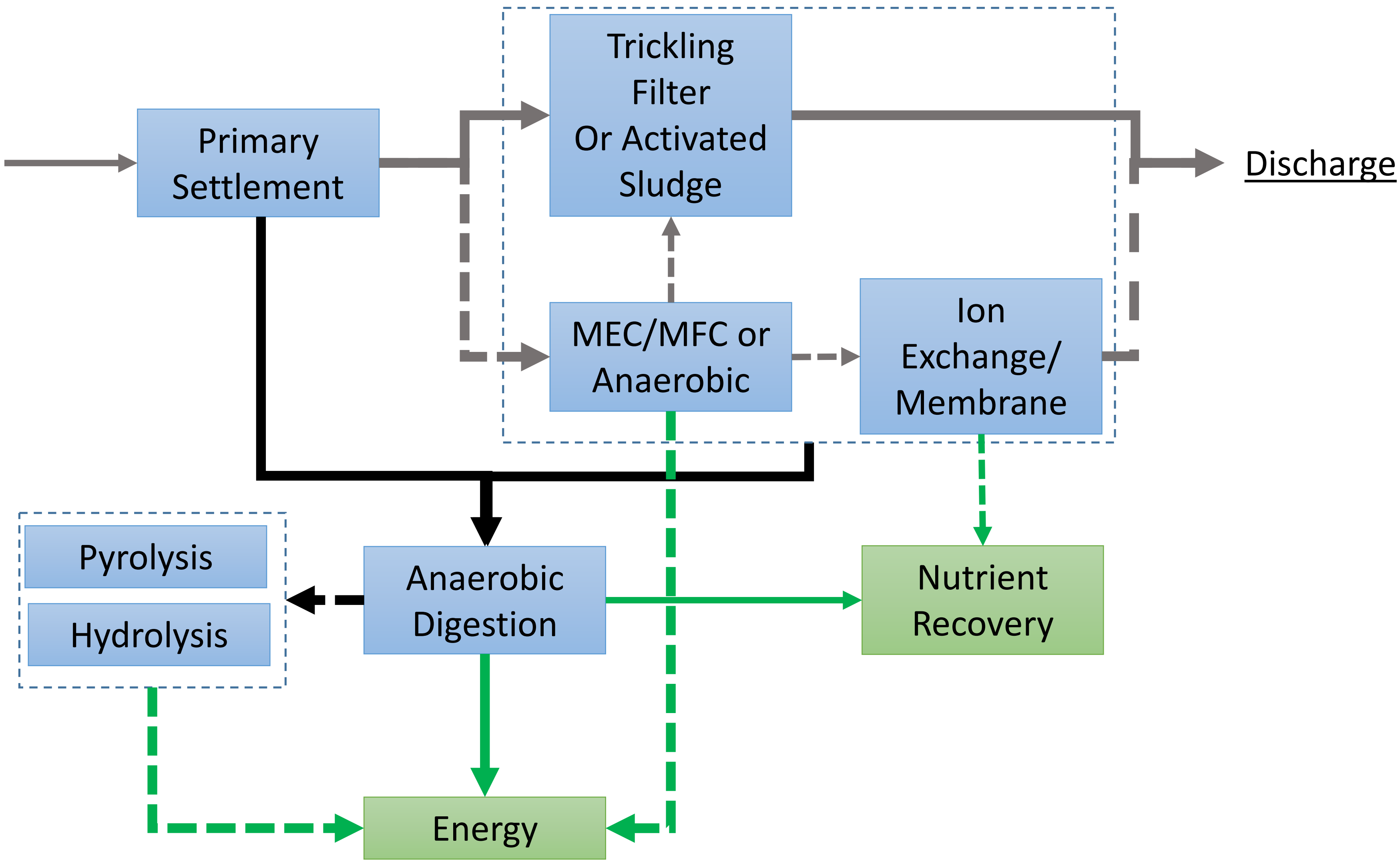
Advantages:

- Generate energy in the treatment process
- Less sludge production
- Less energy consumption

Disadvantages:

- **Incapable** of removing Nutrient
- Nutrient has to be removed by further biological or chemical treatment

Future Wastewater Treatment



Conclusion

- Supernatant of sludge dewatering process, which may contains about **12-30% of inflowing N** and **15-50% inflowing P**, is a good place to recover nutrient

- Recovering nutrient directly from wastewater can prevent considerable amount of nutrient lost in the wastewater treatment process.

- Wastewater treatment can be **energy neutral/positive**.

- For achieving energy neutral/positive, it is better to
  - *Improve Primary Settlement for **capturing** more COD/TOC and for **preventing** carbon/energy loss in Secondary Treatment*

  - ***Further recover** energy from sludge*

  - ***Reduce** energy consumption of secondary treatment, or even **generate** energy in the secondary treatment*

Thanks