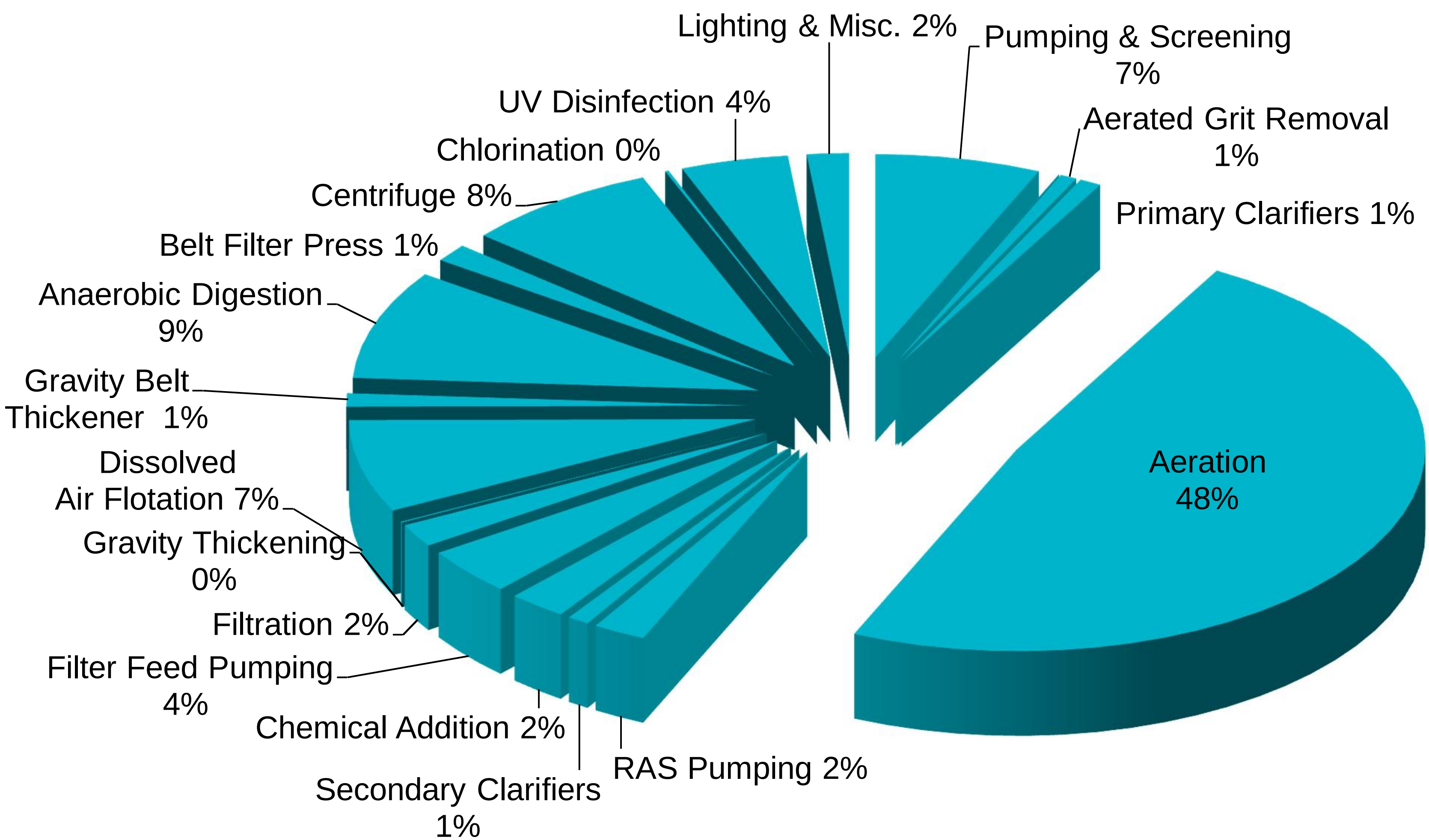
The wastewater treatment plant of tomorrow
Enhancing energy and resource recovery

Thursday 3 September 2015

Distribution of Energy Usage for a Typical WWTP



- Aeration can account for up to 75% of a site's energy demands

Strategy for improving energy balance

- Reduce aeration demand (kWhr/**kg O_2**)
  - Different microbiology, nitrite shunt (SHARON), deammonification
- Reduce power to deliver the oxygen (**kWhr**/kg O_2)
  - FBDA
  - Microbubbles
- Better control
  - Feed Forward and Feedback control based on realtime information
- Eliminate aeration
  - High rate anaerobic treatment (AnMBR, fluidized bed)
- Increase power generation
  - Anaerobic digestion

The question we should ask if we want to optimize energy balance or nutrient recovery is……….

…not **how** we can do things better and more efficiently,

-

Why do we do what we do?

Primary Settlement

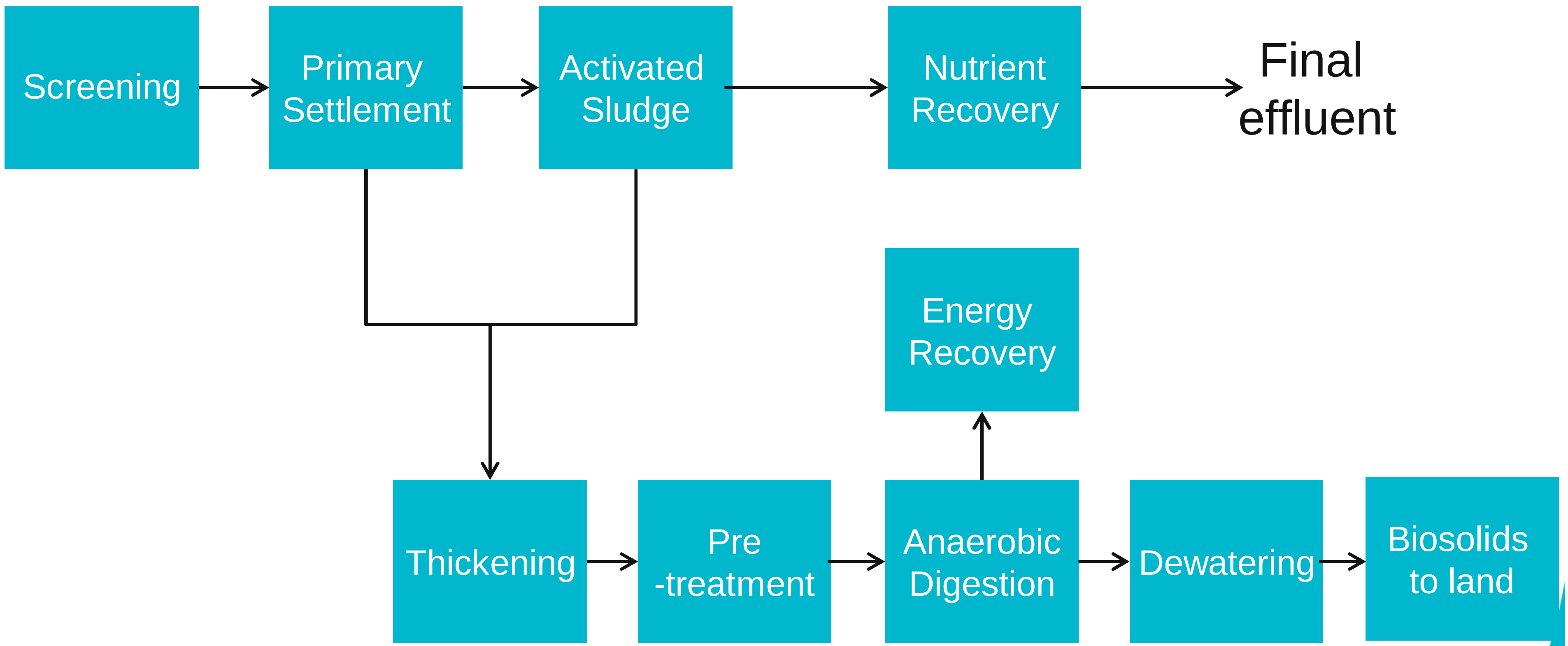
Treat wastewater

Anaerobically digest

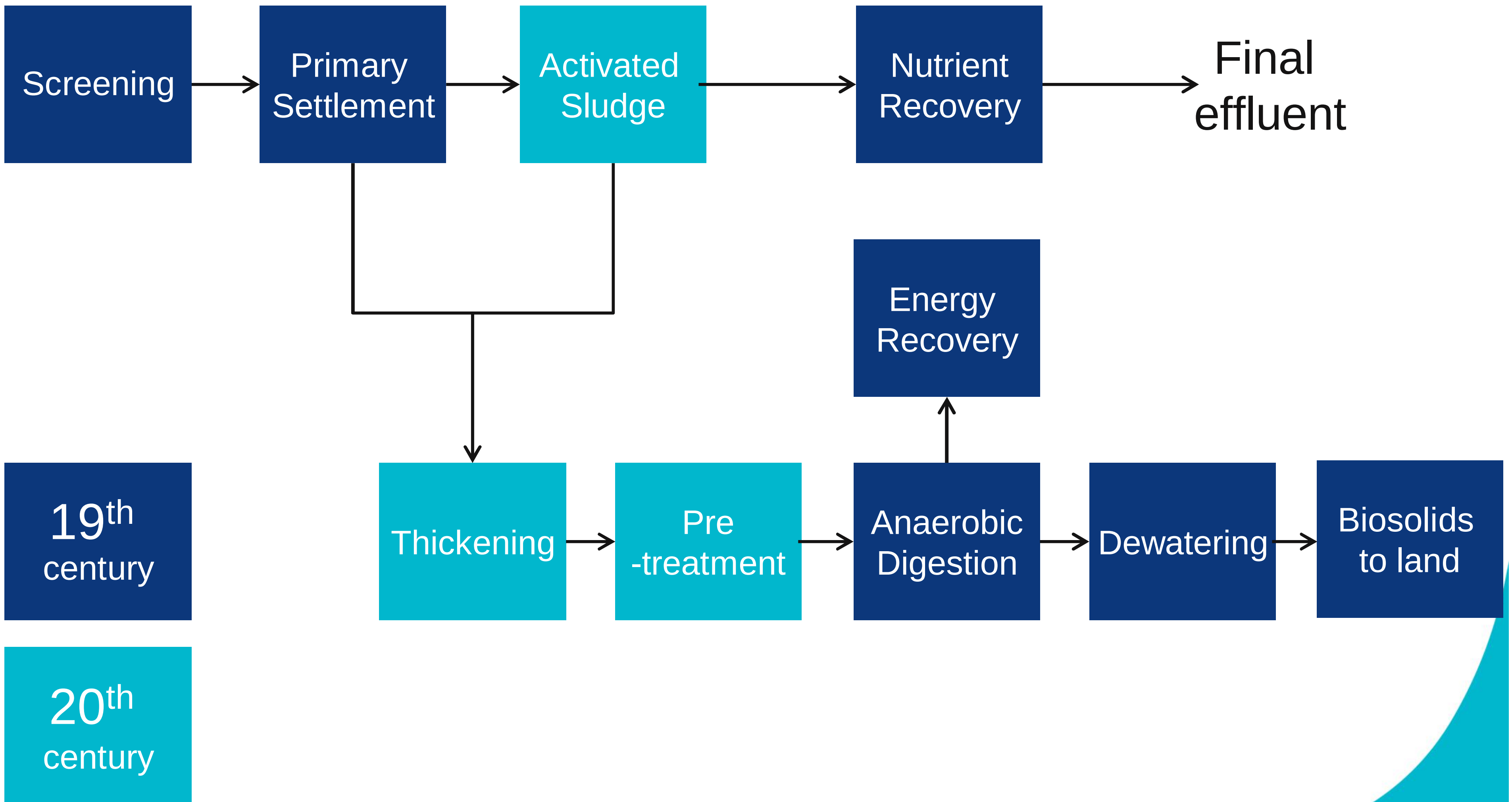
It's what engineers did in the 19th century based on 19th century drivers

Subsequently our plants and technology are largely based on 19th century developments

The Wastewater treatment plant of today



The Wastewater treatment plant of today

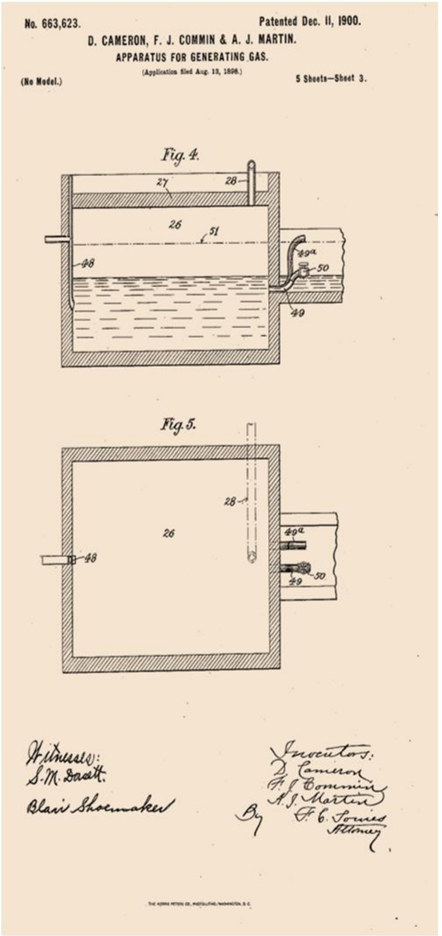


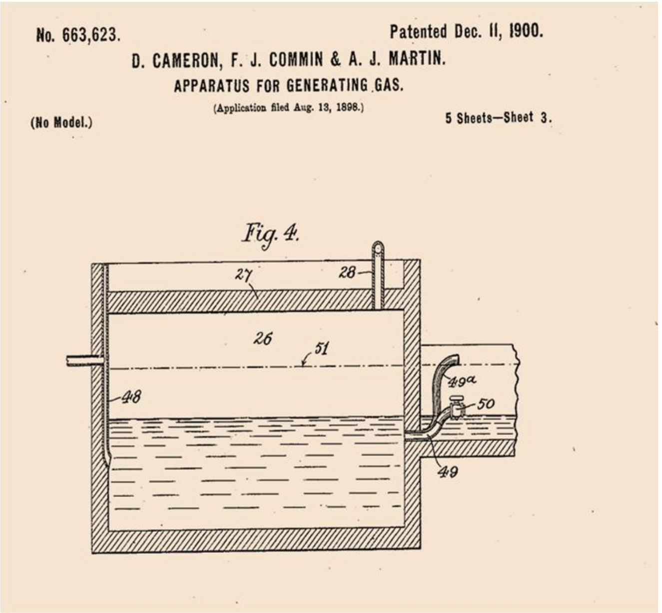
Issues with use of technology designed to meet 19th Century Drivers

- We rely on activated sludge and variants
    - High energy consumption
- Produces secondary sludge which doesn't digest well (Rudolfs and Heisig, 1929)
- We still design anaerobic digestion plants which are inherently sub-optimal
- Current best practice is to build new plants which already need pre-treatment bolt-on to improve performance
    - Design has not evolved in over 120 years
- They are not designed for modern drivers
- Energy and carbon inefficient
- Not designed for recovery of value

A carbon footprint?
What is one of those?

Anaerobic Digestion





In cases where sewage is enclosed in covered tanks we have found that gases will be generated which may be beneficially and economically employed for the purpose of illumination or heating or for obtaining motive power in explosive-motors.

portant results of the work carried on by and stimulated by DeVries will be to show another way in which partial segregation may be secured, and the theory of natural selection needs all the help it can get from segregation.

It should hardly be necessary to urge that, in understanding the development of the conditions which prevail to-day among organisms, the problem of the origin of species seems of very secondary importance in comparison with the problem of the perfection of adaptation.

Maynard M. Metcalf.
The Woman's College of Baltimore.

WILBUR WRIGHT'S SUCCESSFUL FLIGHT IN A MOTOR-DRIVEN AEROPLANE.

The newspapers of December 18 contained the announcement that Wilbur Wright had flown a distance of three miles with an aeroplane propelled by a 16-horse power, four-cylinder, gasoline motor, the whole weighing more than 700 pounds. To the average newspaper reader this meant no more than similar statements previously made in the newspapers that men had flown in New York, or St. Louis, or San Francisco. But to the student of aeronautics, and particularly to those who had followed the careful scientific experiments with aeroplanes which were being made by Orville and Wilbur Wright, it meant an epoch in the progress of invention and achievement, perhaps as great as that when Stevenson first drove a locomotive along a railroad.

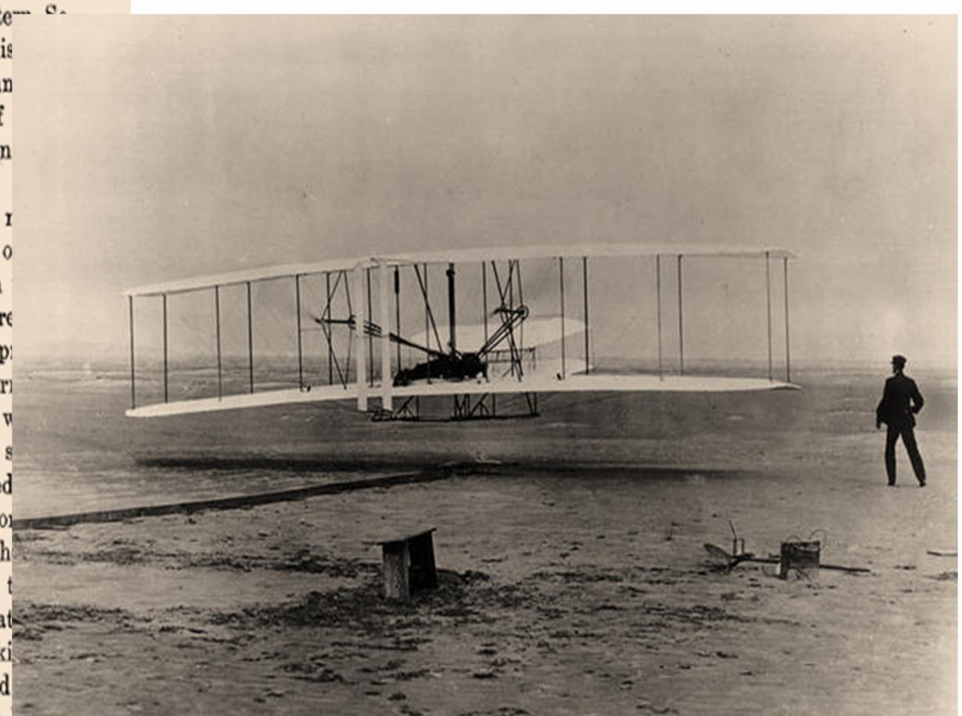
is said to have risen from a level. The reported distance of three miles was probably relative to the wind.

The earlier work of the Wright brothers is described in the reports of the Weste
ciety of Engineers and in part republis
the Annual Report of the Smithsonian
tution for 1902. Their invention of
ward rudder has contributed to the fin
cess.

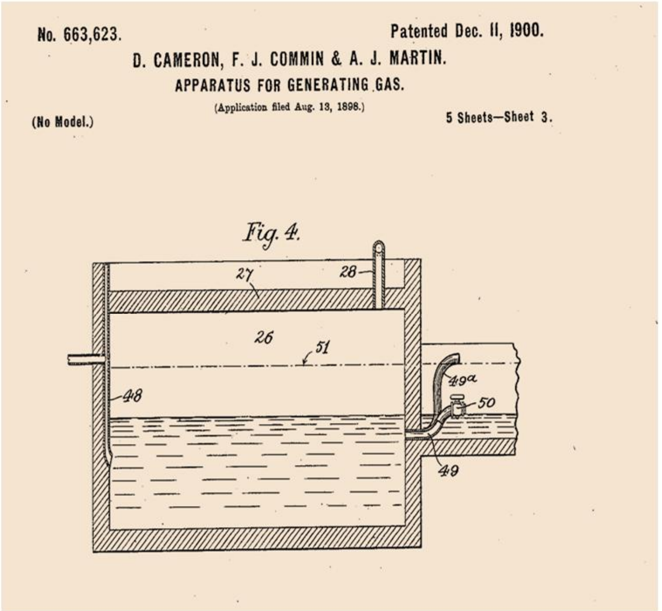
The modern success in aeronautics
said, I think, to date from the feat o
Lilienthal in 1891 in gliding down an
in an aeroplane. These glides were r
with much success and with an imp
aeroplane by Mr. Chanute and Mr. Her
our own country. Mr. Herring even
far as to carry with him 50 pounds of
his aeroplane which weight he computed
be that of an engine sufficient to suppo

Mr. Pilcher, in England, repeated th
periments on a level by rising into
in his machine when drawn by a horse a
to a rope, the machine rising like a ki
then gliding forward. Mr. Whitehead
scribed in the *Scientific American* as
repeated this experiment recently in Connecticut with a motor on board the aeroplane.

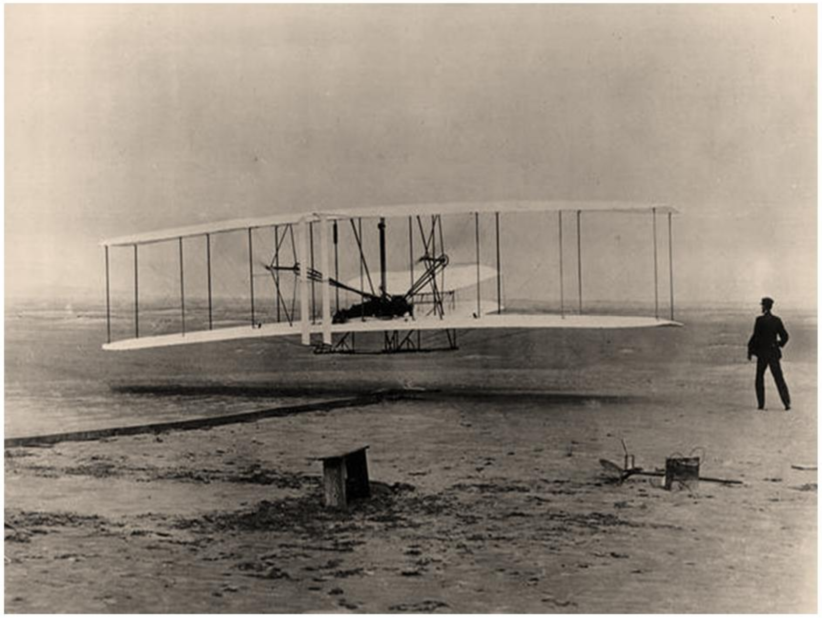
In the meantime, in 1896, Dr. Langley had driven a model weighing about 25 pounds through the air with a small steam-engine, and Sir Hiram Maxim had performed the wonderful feat of lifting 7,000 pounds into the air



Then

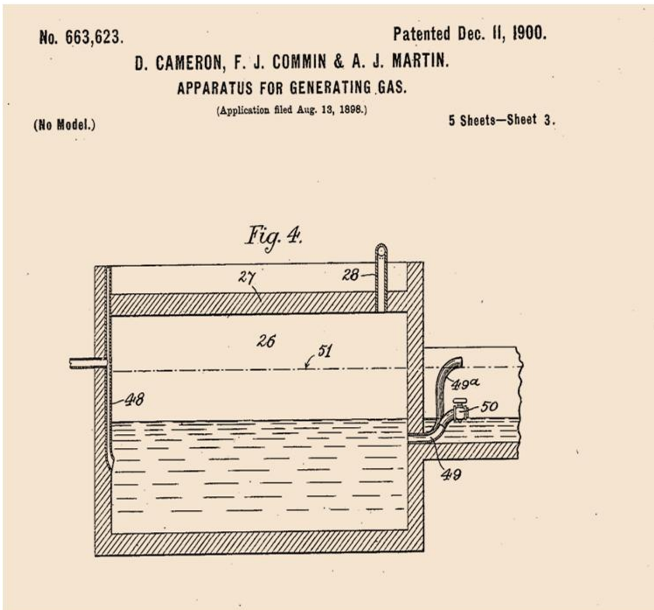


1900



1903

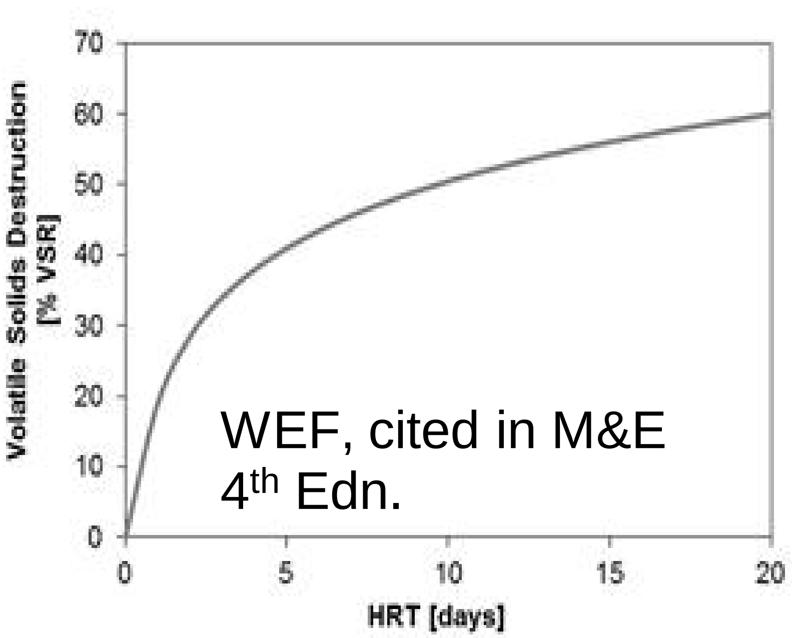
Now


No. 663,623.
Patented Dec. 11, 1900.
D. CAMERON, F. J. COMMIN & A. J. MARTIN.
APPARATUS FOR GENERATING GAS.
(Application filed Aug. 13, 1898.)
(No Model.)
5 Sheets—Sheet 3.
Fig. 4.
27
28
26
51
48
49a
50
49


A380
A380 AIRBUS

Why has the design of anaerobic digestion not progressed?

- The driver was sanitation not biogas production
  - Conservative industry led by meeting regulatory requirements. Energy production is/was not core business
  - Text book rule of thumb based on previous conservative designs



WEF, cited in M&E 4th Edn.

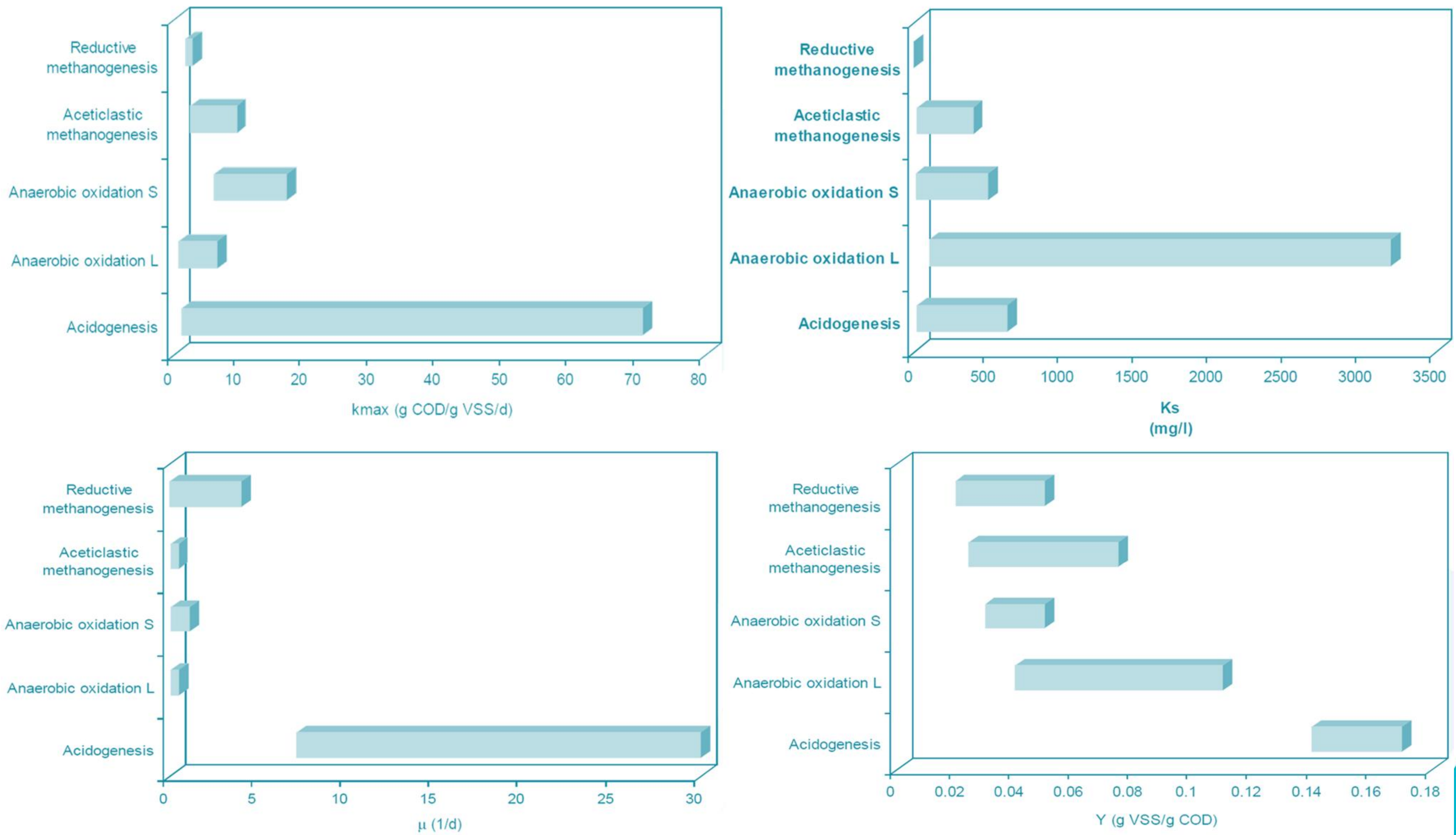
- Not due to lack of understanding of microbiology

$$4C_8H_{13}N_2O_3 + 14H_2O = 4N_2 + 19CH_4 + 13CO_2 + 2H_2$$

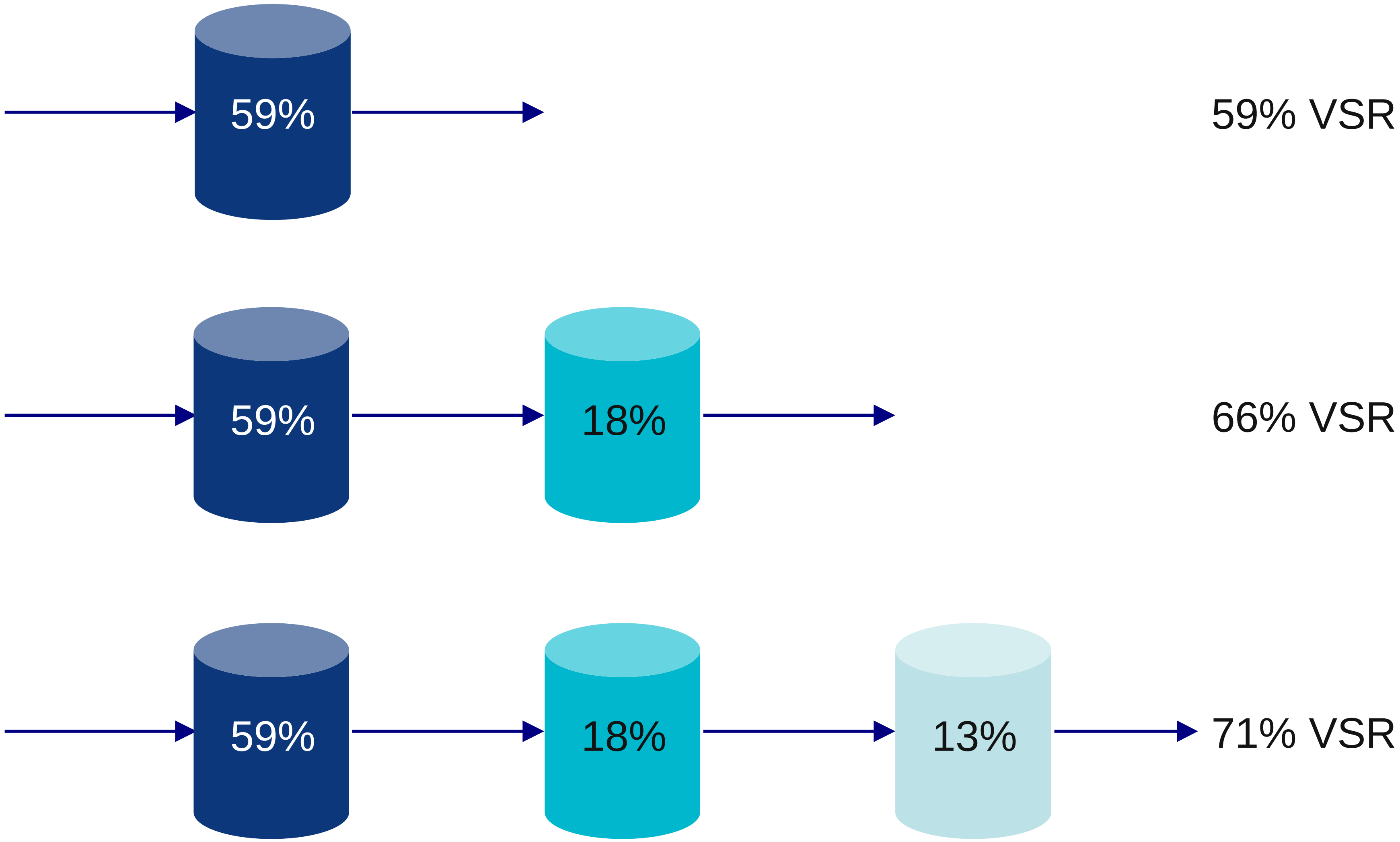
Rideal, 1906

Issues with current design of anaerobic digestion

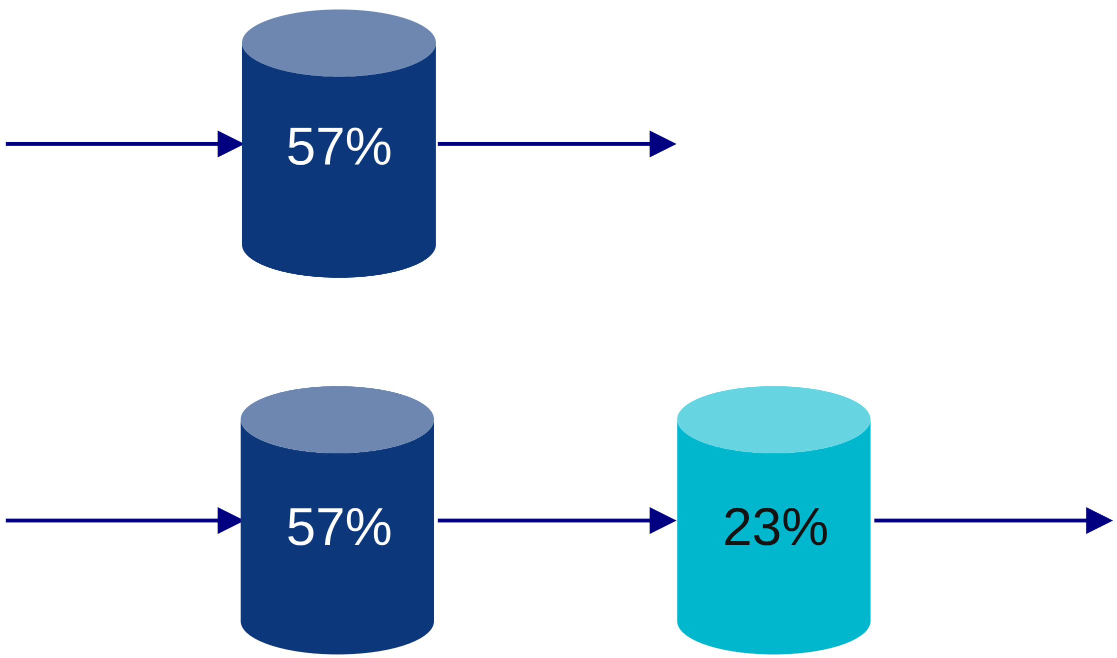
- We (almost always) digest in parallel
- But microbiology of anaerobic digestion is a series of reactions



In Practice – Tacoma Central, USA



In Practice – Budd Inlet, USA

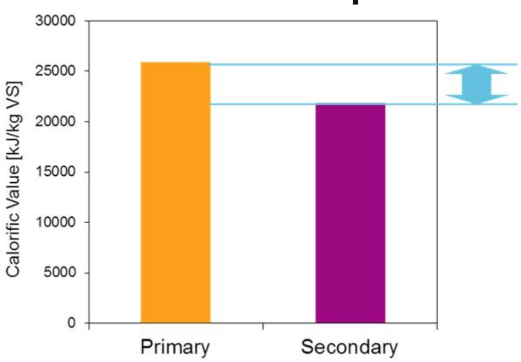


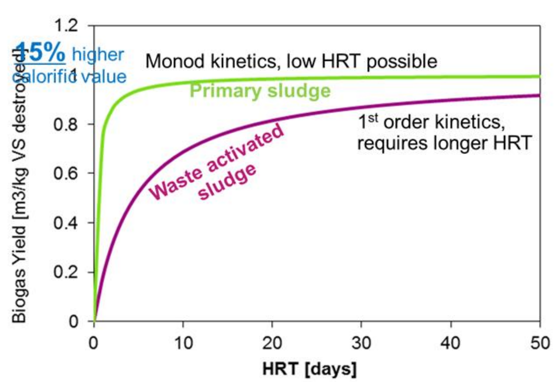
57% VSR

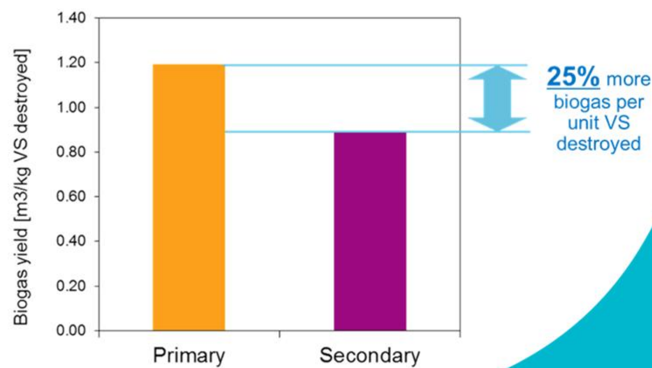
67% VSR

Issues with current design of anaerobic digestion

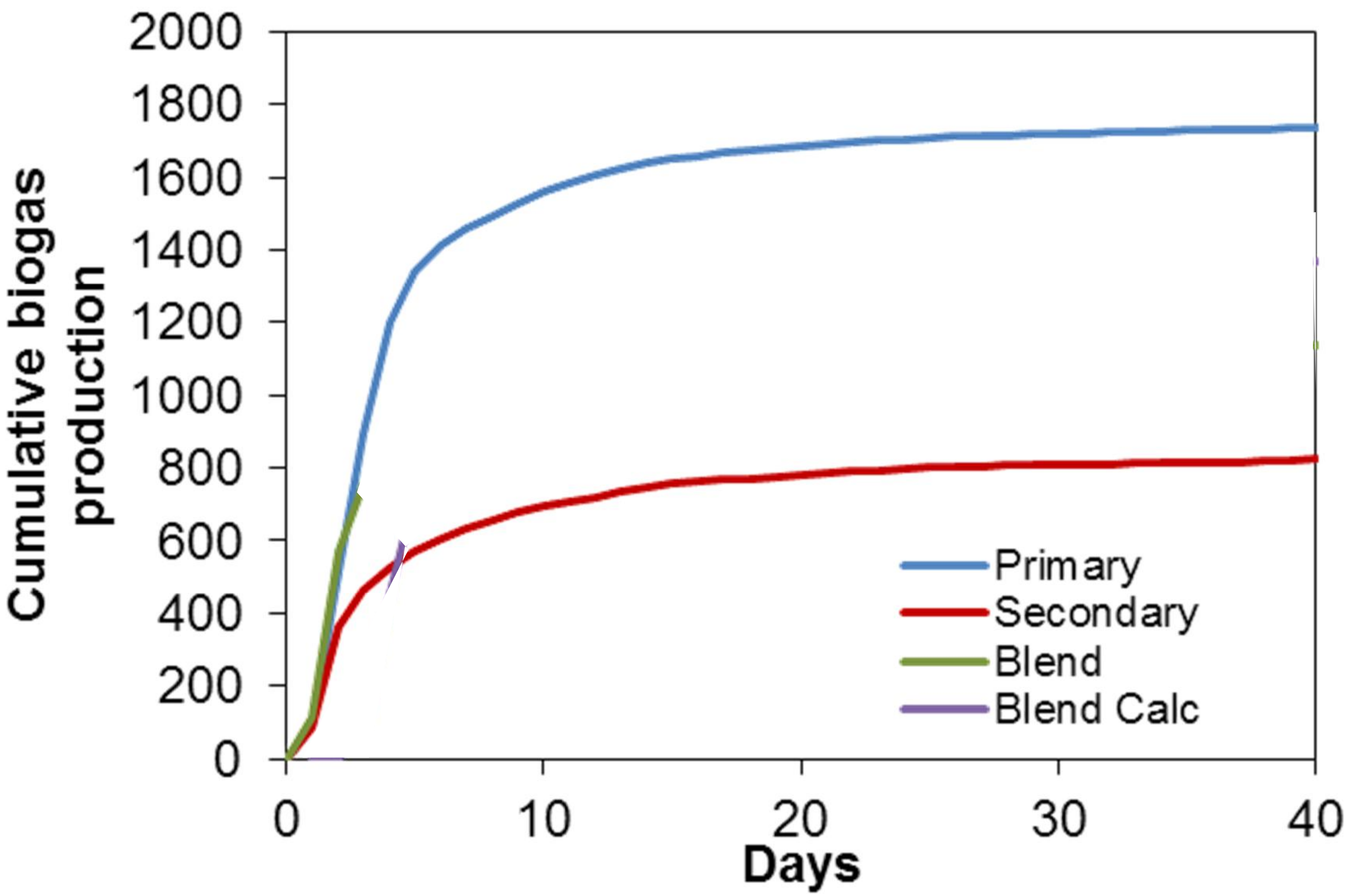
- We co-digest primary and waste activated sludge but they are fundamentally different materials with:
  - Very different C:N ratios
  - Different calorific values
  - Different kinetics governing their degradation
  - Different biogas yield per kg destroyed
  - Different biogas composition
  - Different temperature optima
  - Biogas production is higher when primary and WAS digested separately



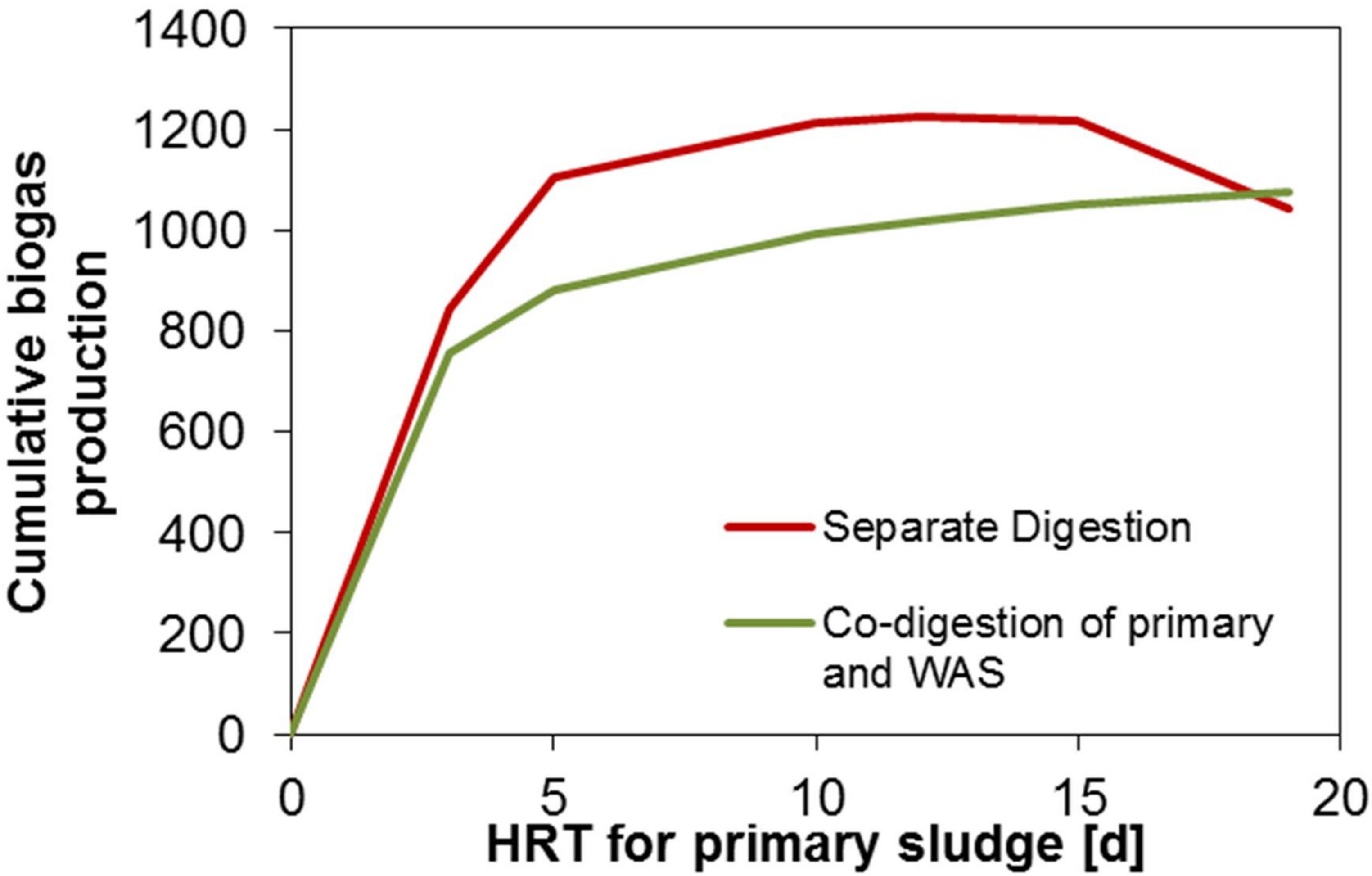




Separate Primary and WAS digestion

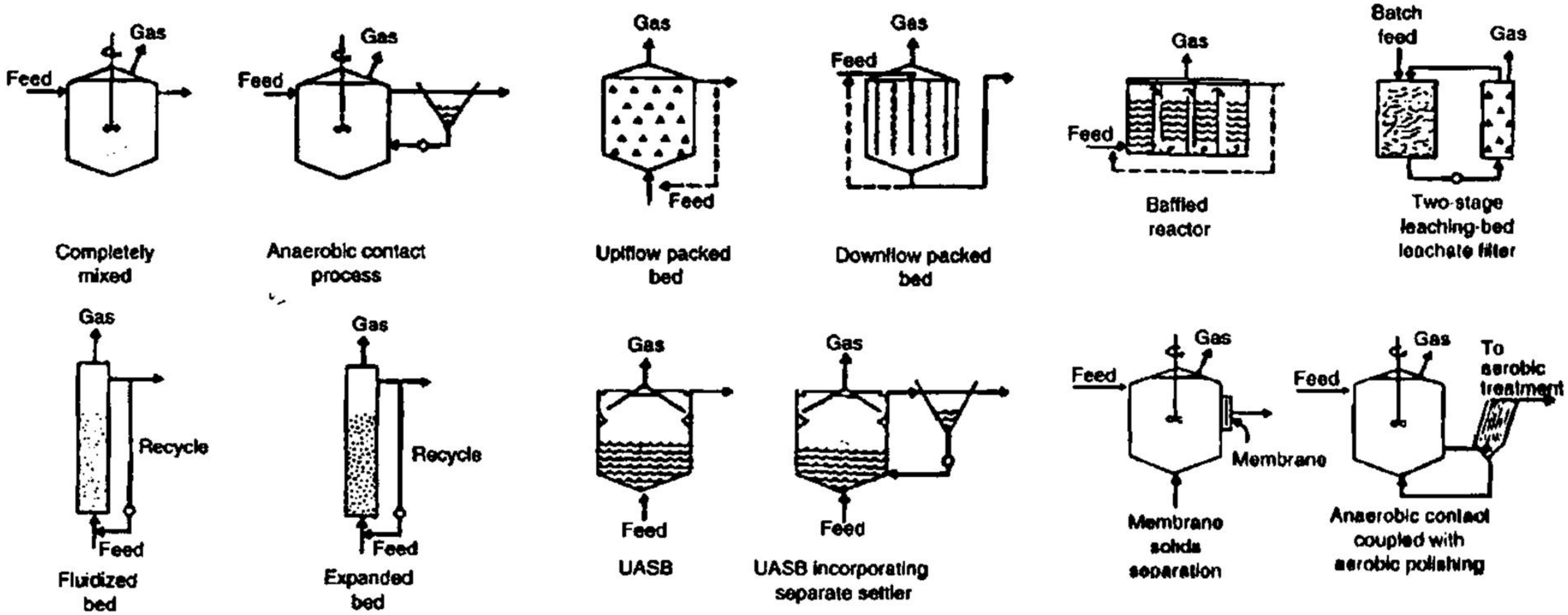


Separate Primary and WAS digestion



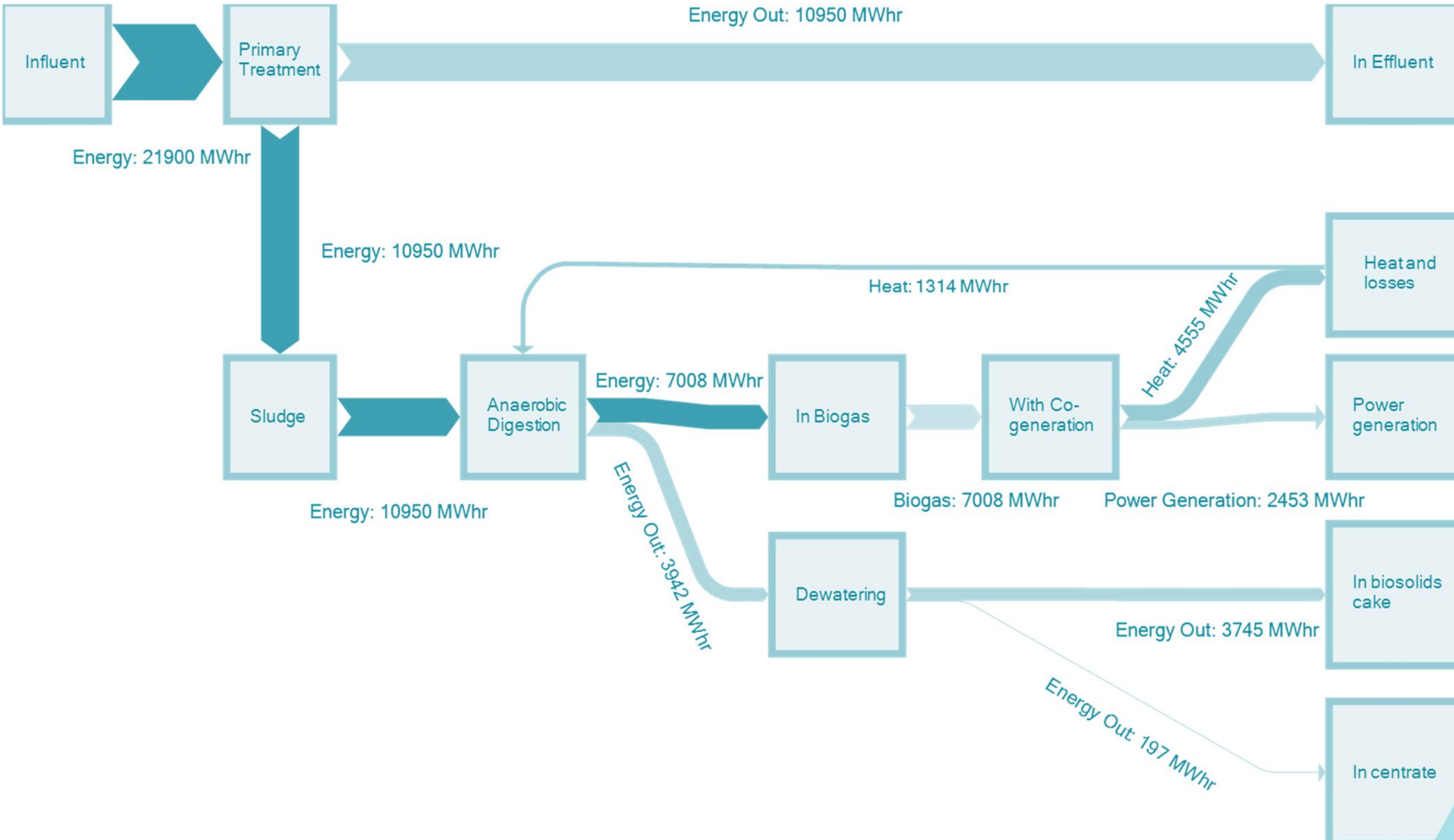
Issues with current design of anaerobic digestion

- We don't keep the biomass in the digesters
- The biogas producing organisms are known to be slow growing
- We do this for activated sludge treatment
- Loading rates are low and therefore digestion plants are unnecessarily large
- Recuperative thickening attempts to address this



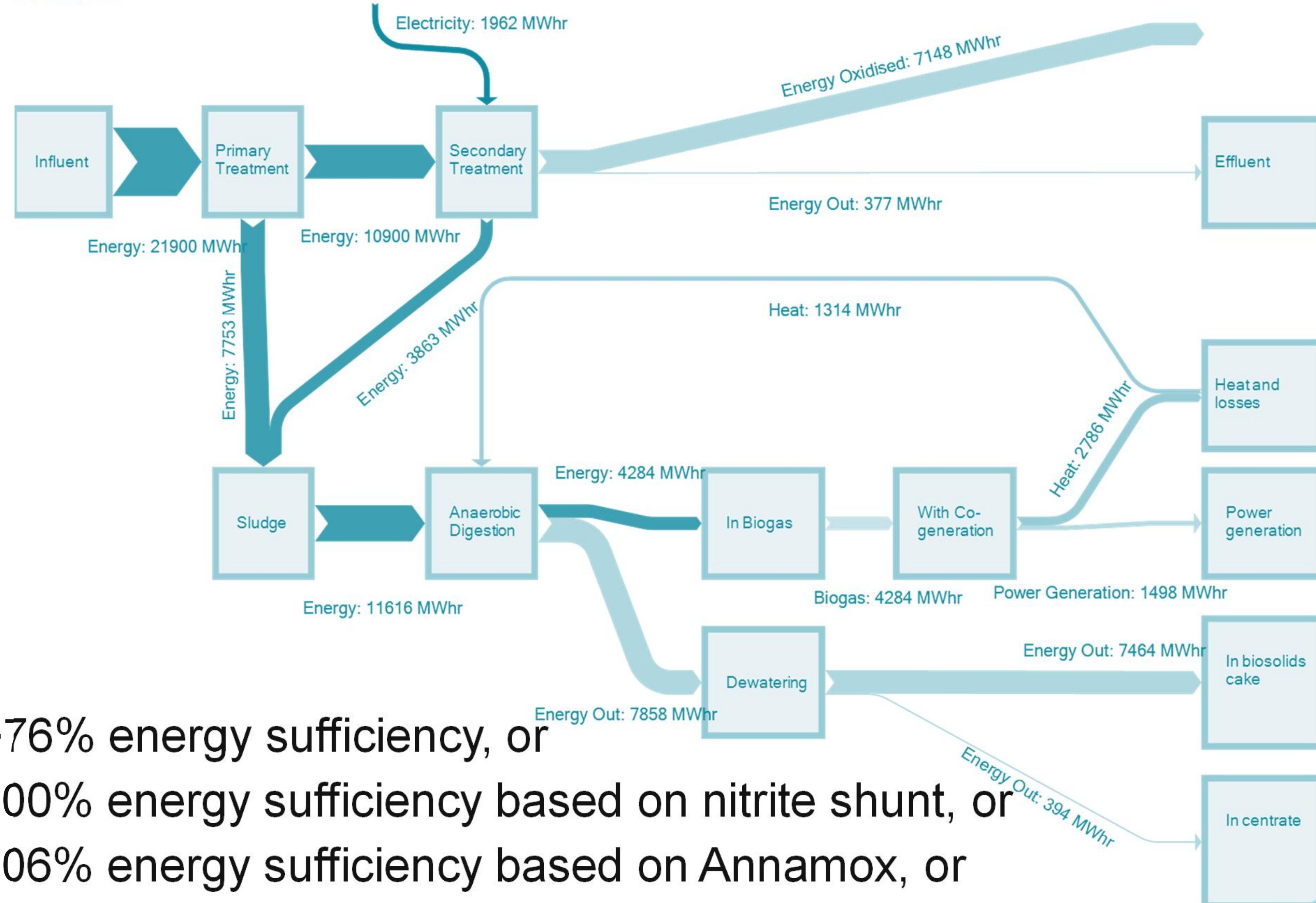
Speece, 1983

Primary Treatment Energy Flows



Primary with Secondary Treatment Energy Flows

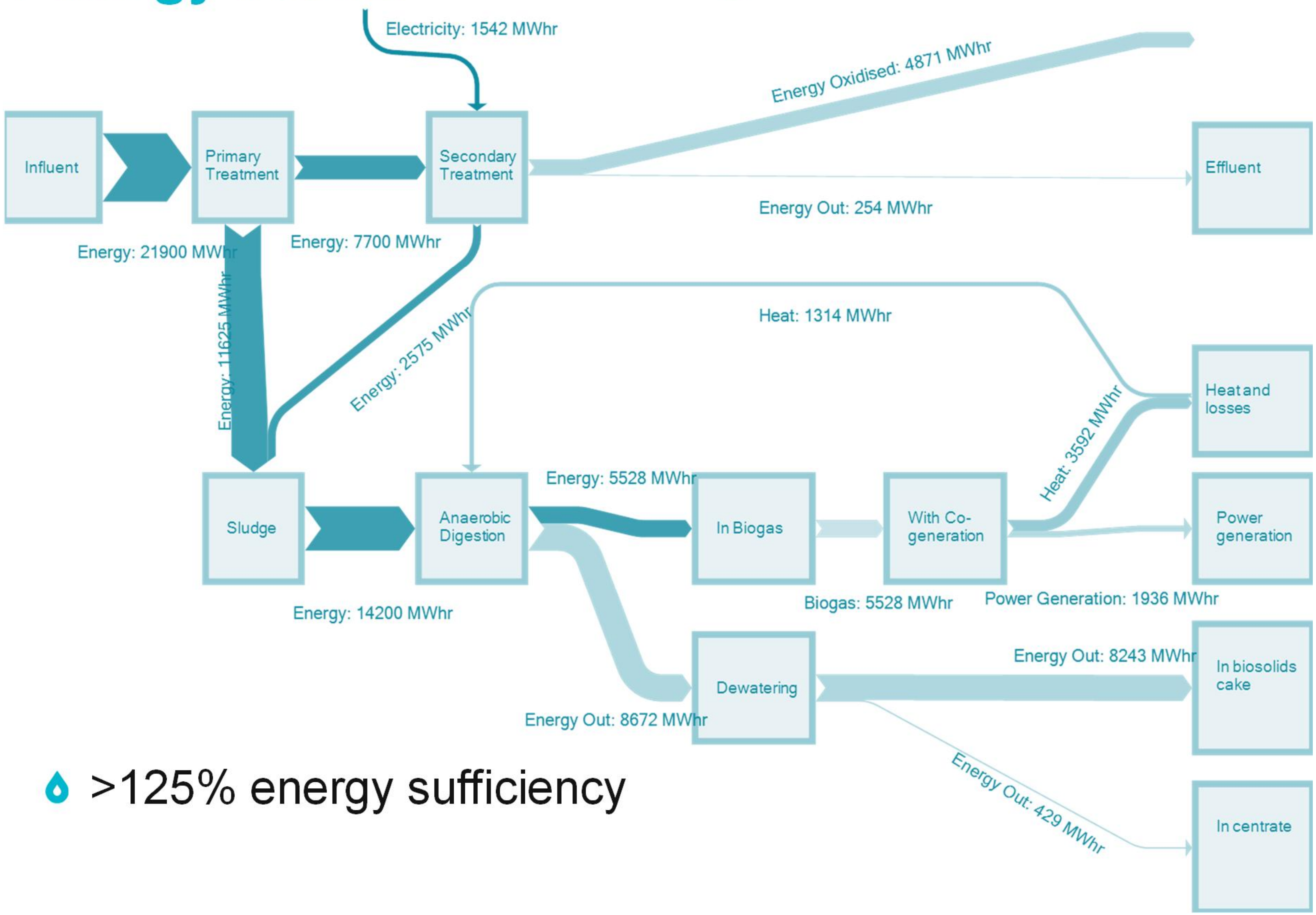
- 0.34 kWhr/m^3 treated



- >76% energy sufficiency, or
- 100% energy sufficiency based on nitrite shunt, or
- 206% energy sufficiency based on Annamox, or
- Generate 30% more biogas

Enhanced Primary with Secondary Treatment Energy Flows

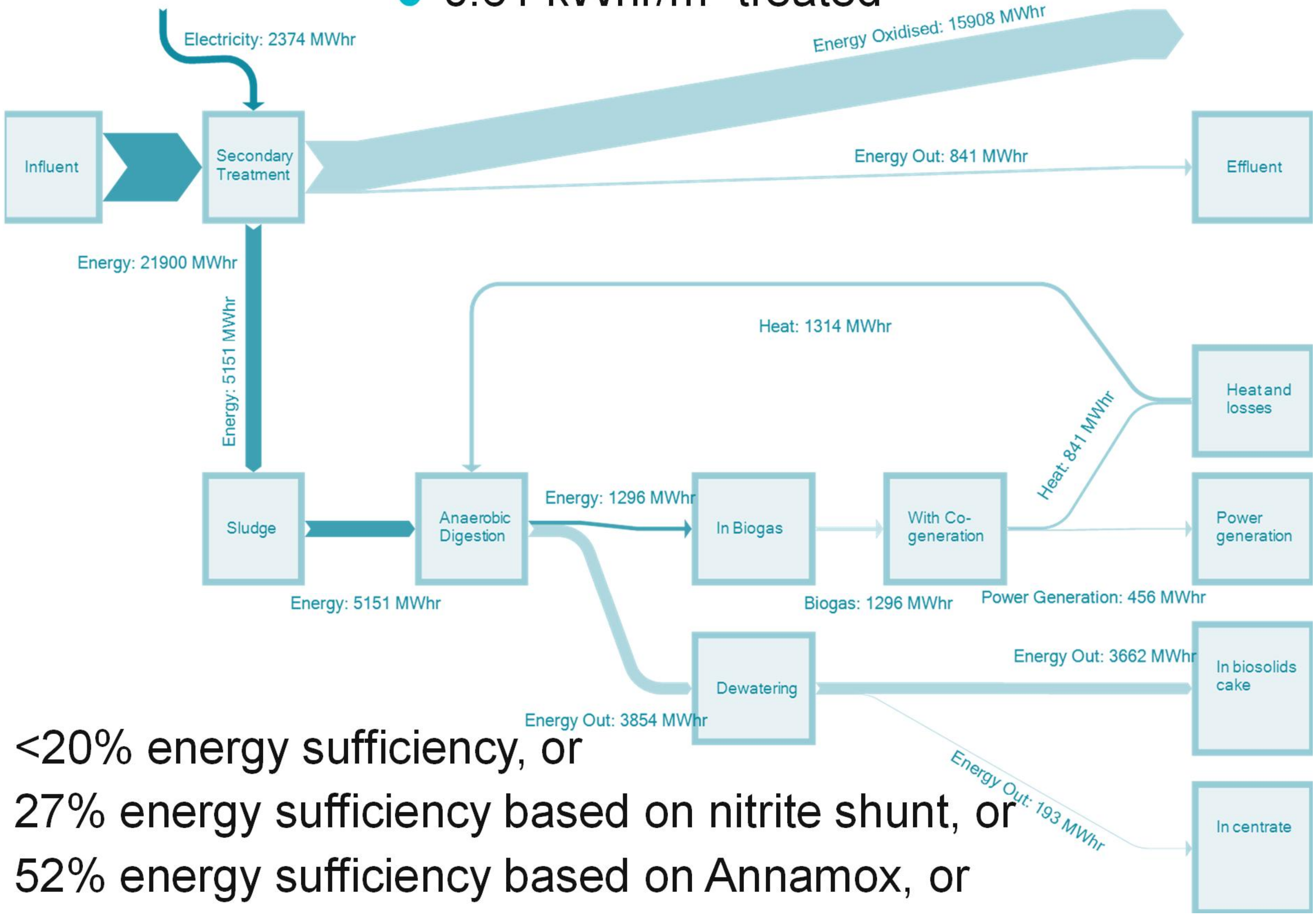
- 0.21 kWhr/m^3 treated



- >125% energy sufficiency

Secondary Treatment Energy Flows

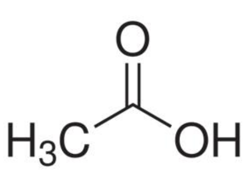
- 0.61 kWhr/m^3 treated



- <20% energy sufficiency, or
- 27% energy sufficiency based on nitrite shunt, or
- 52% energy sufficiency based on Annamox, or
- Generate 5 times more biogas

Biosolids as a resource

1 ton dry solids of biosolids



185 kg

$100+

From purely a financial standpoint, are we recovering the right materials?

Resource Recovery

Water

Currently we throw this away

Energy

Our plants are very inefficient at energy recovery

Nutrients

We consume energy to destroy these

Because our plants address 19th century drivers

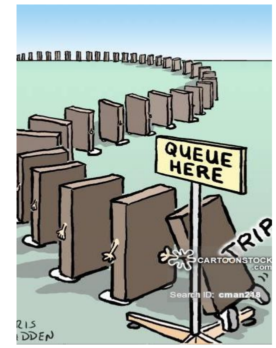
Utilities and recovery of energy and resources

- Large existing infrastructure base
- Retrofit technology
  - Use existing plants in more efficient ways
  - E.g. variations of anaerobic digestion
  - Energy recovery from waste stream emitted to oceans on coastal plants
- Activated sludge
  - Better control systems
  - Alternative biology
  - Replace with high rate anaerobic digestion
- Question resources which are required?

Pressure on energy, water and nutrient resources will increase in the future

Need to adapt to 21st Century needs and pressures

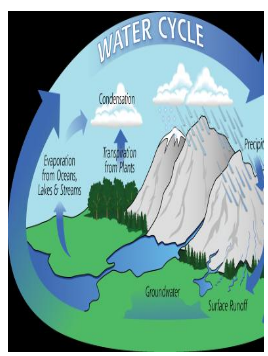
There will be consequences



There is no single or straightforward solution

Most technology will have a place

Re-evaluate what resources we want or need to recover



Review/challenge the regulations

Those who do not learn history are doomed to repeat it

Thank you

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