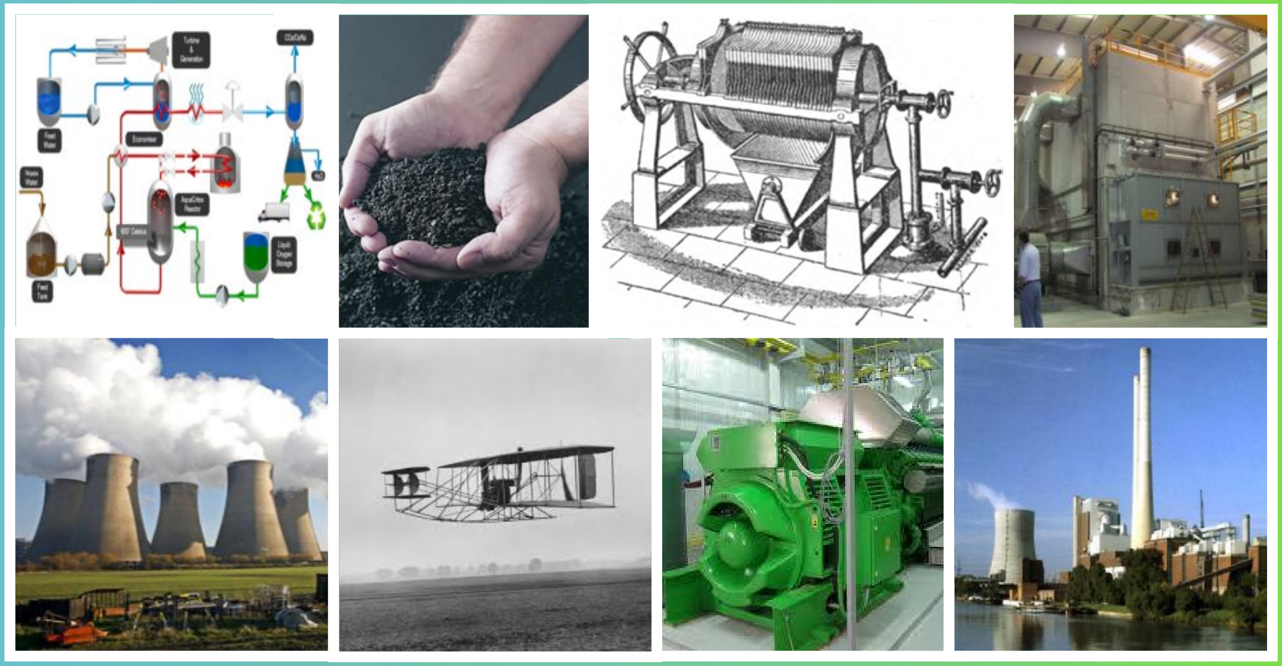
The Wastewater Treatment Plant of tomorrow



Dr Bill Barber

12th June 2012

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Our Current wastewater treatment design

Evolved from 19th Century Drivers

- Public health
  - Removal of disease causing organisms (Cholera, typhoid)
- Pollution (of rivers)
  - Contaminant removal

Consequently most plant is based on mainly 19th Century tech

- Primary settlement
- Activated sludge
- Anaerobic digestion



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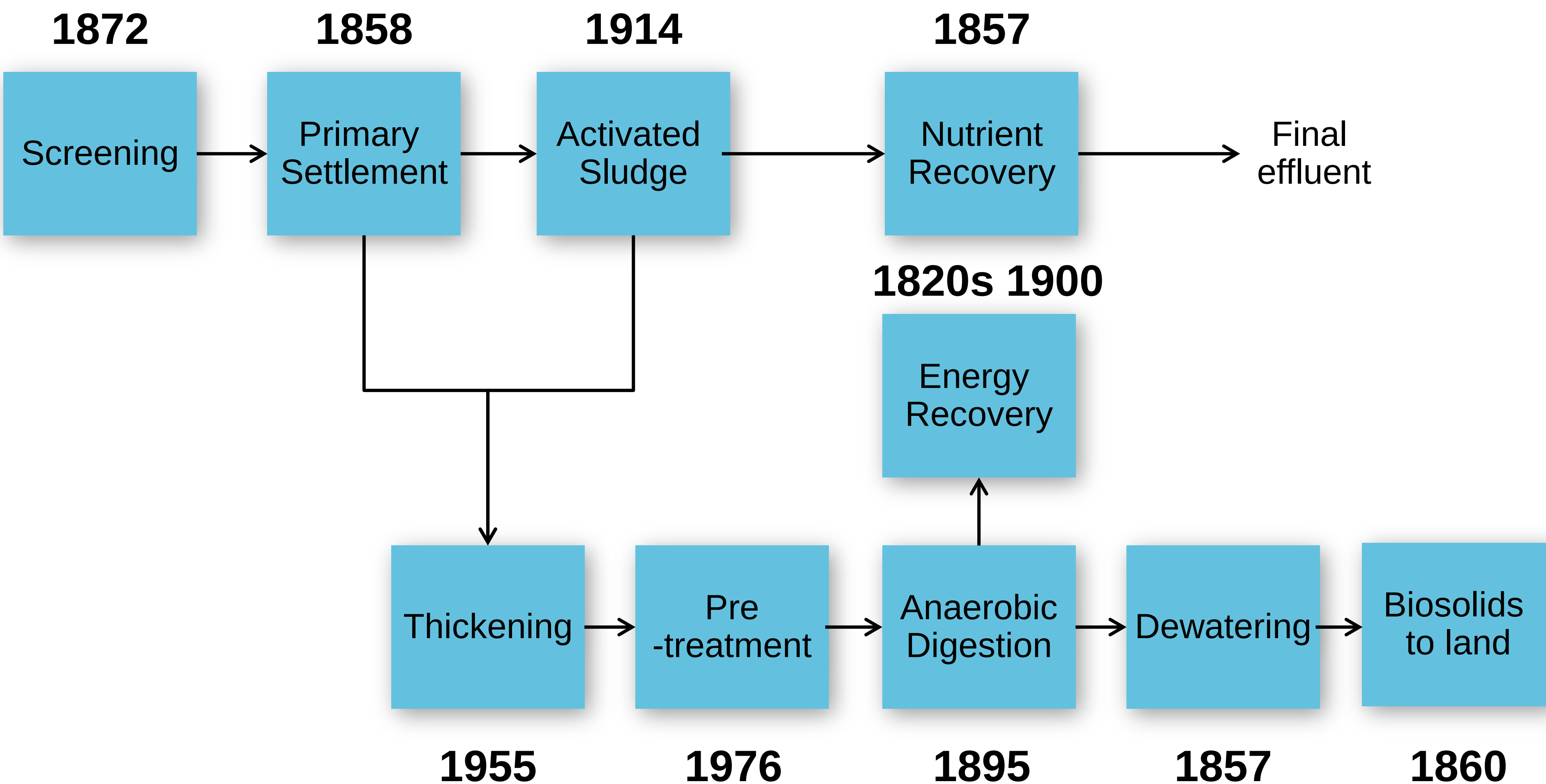
The Wastewater treatment plant of today



1846 Liming

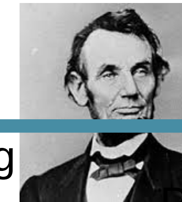
1854 Activated carbon

1857 Filter press dewatering

1858 Primary settlement, electricity

1859 Thermal drying

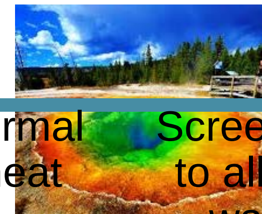
1863 Freezing



1867 Struvite Precipitation

1871 Ammonium recovery by steam stripping

1872 Screening and straining to allow use of sludge water for irrigation



1872 Advanced thermal drying with heat recovery

1880s Interest in fermentative putrefaction (anaerobic digestion)

1887 Anaerobic sand filter

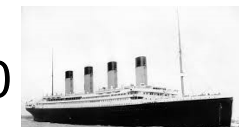
1890 Agricultural products from sludge

1895 Exeter (septic) tank

1902 Staged anaerobic digestion

1906 Theory of AD for biogas prediction

1910 Imhoff tank



1914 Activated sludge

1916 Wet air oxidation of sludge

1935 Microwave pretreatment for AD

1965 Thermal hydrolysis of ligno-cellulosic material

1969 Anaerobic filter

1970s Acid phase AD also with pre-treatment (ultrasound)

Late 1970s Upflow Anaerobic Sludge Blanket

1980 Anaerobic fluidized bed

1990s Anaerobic membrane bioreactor

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Use of technology designed to meet 19th Century Drivers

- We rely on activated sludge and variants
  - High energy consumption
  - Produces secondary sludge which doesn digest well (Rudolfs and Heisig, 1929)

A carbon footprint?
What is one of those?

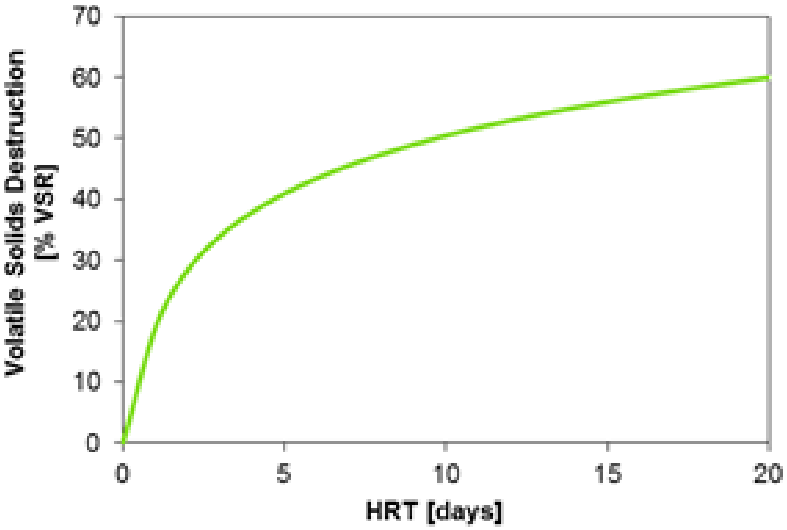
- We still design anaerobic digestion plants which are inherently sub-optimal
  - Current best practice is to build new plants which already need pre-treatment bolt-on to improve performance
  - Design has not evolved in over 120 years
- They are not designed for modern drivers
  - Energy and carbon inefficient
  - Not designed for recovery of value

Why has the design of anaerobic digestion not progressed?

- Energy production was not the primary driver (and in NA, relatively cheap)

- 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

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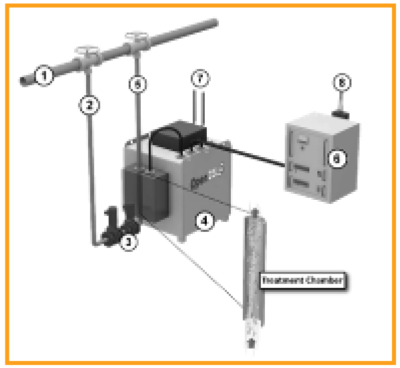
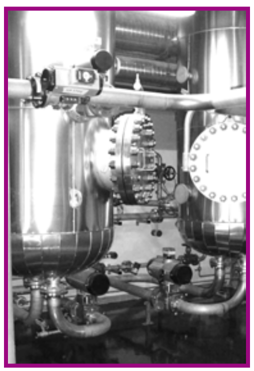
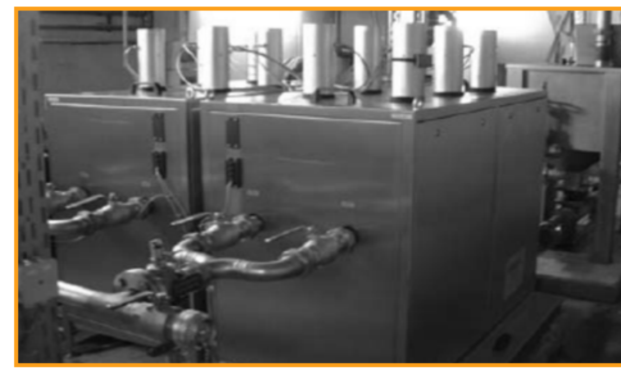
Water Industry
Advanced Anaerobic Digestion

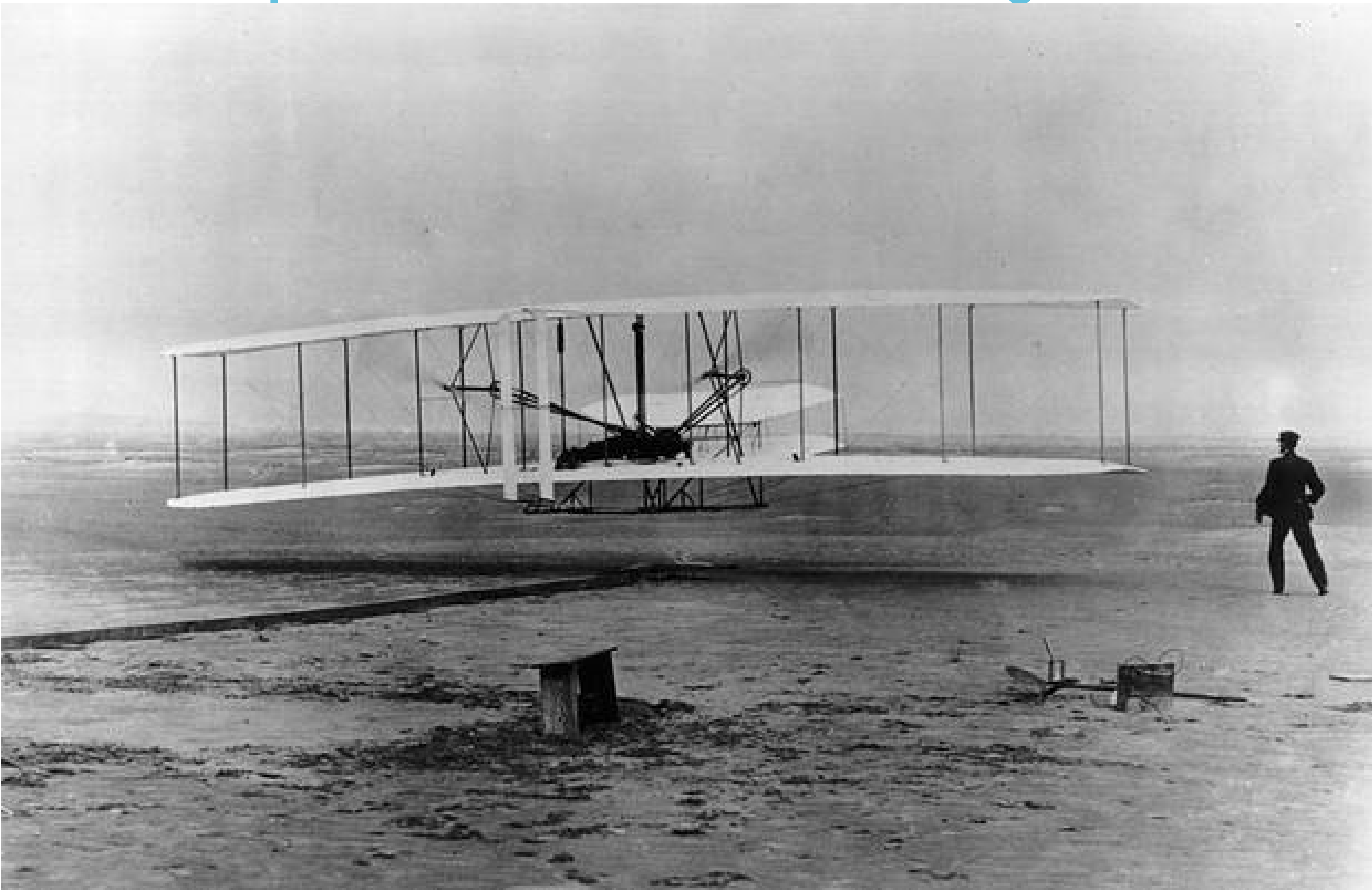



Ultrasonics High Pressure Shear Electric Pulse

Chemical Lysis Medium Pressure Maceration Rapid Decompression

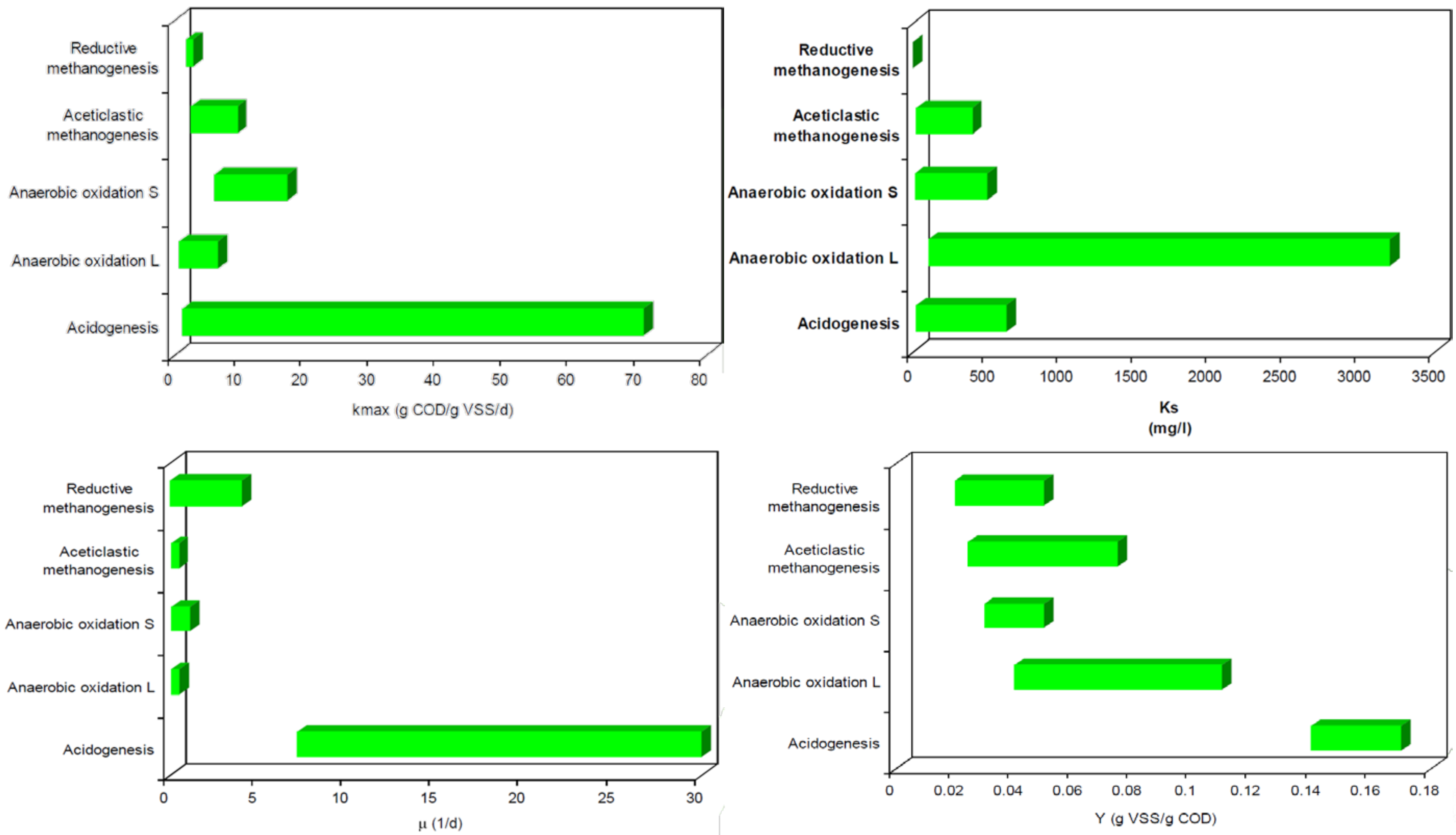
Thermal Hydrolysis Acid Phase Biological Hydrolysis

Current performance – Anaerobic Digestion

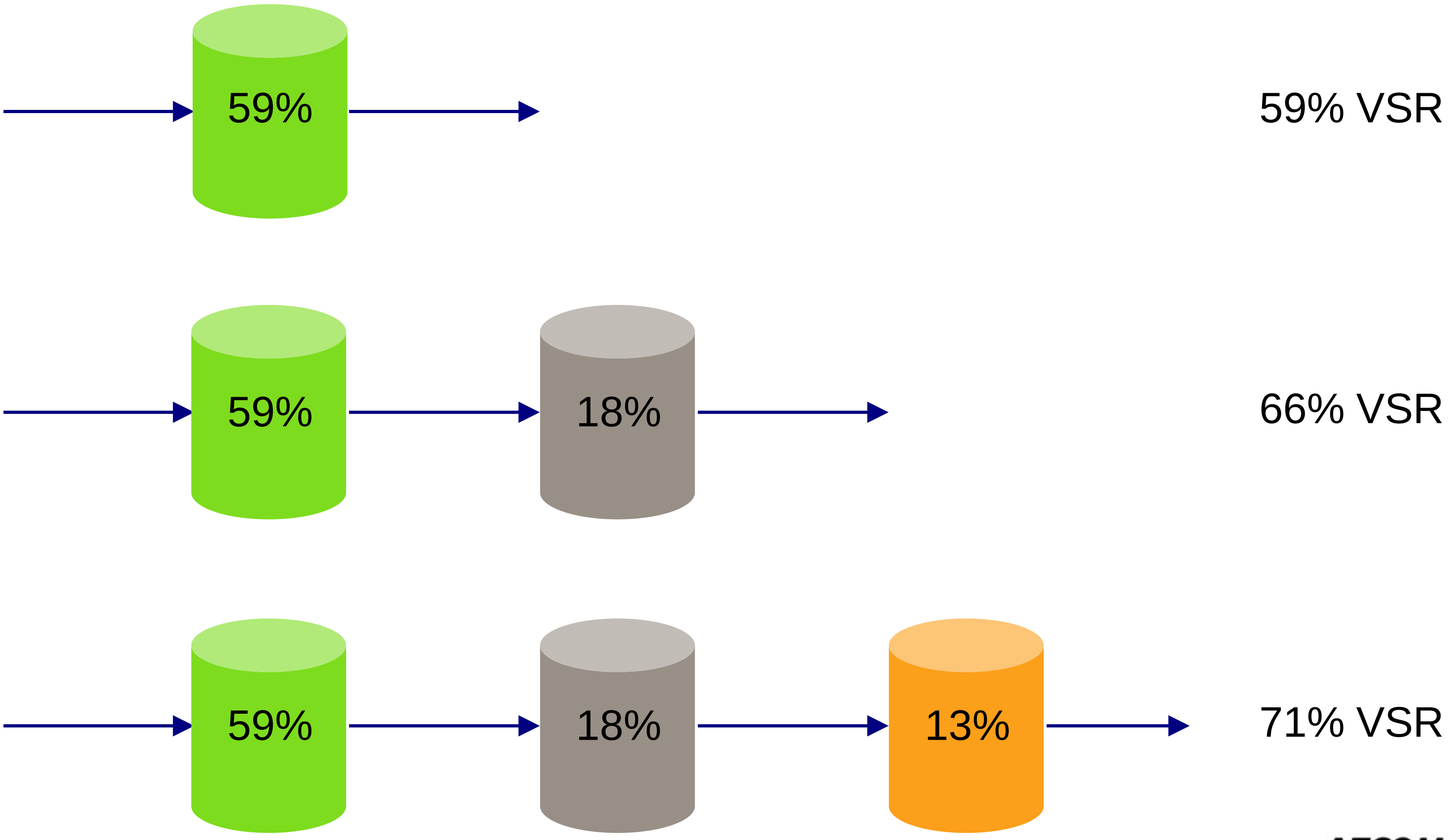


Issues with current design of anaerobic digestion

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



In Practice – Tacoma Central, USA



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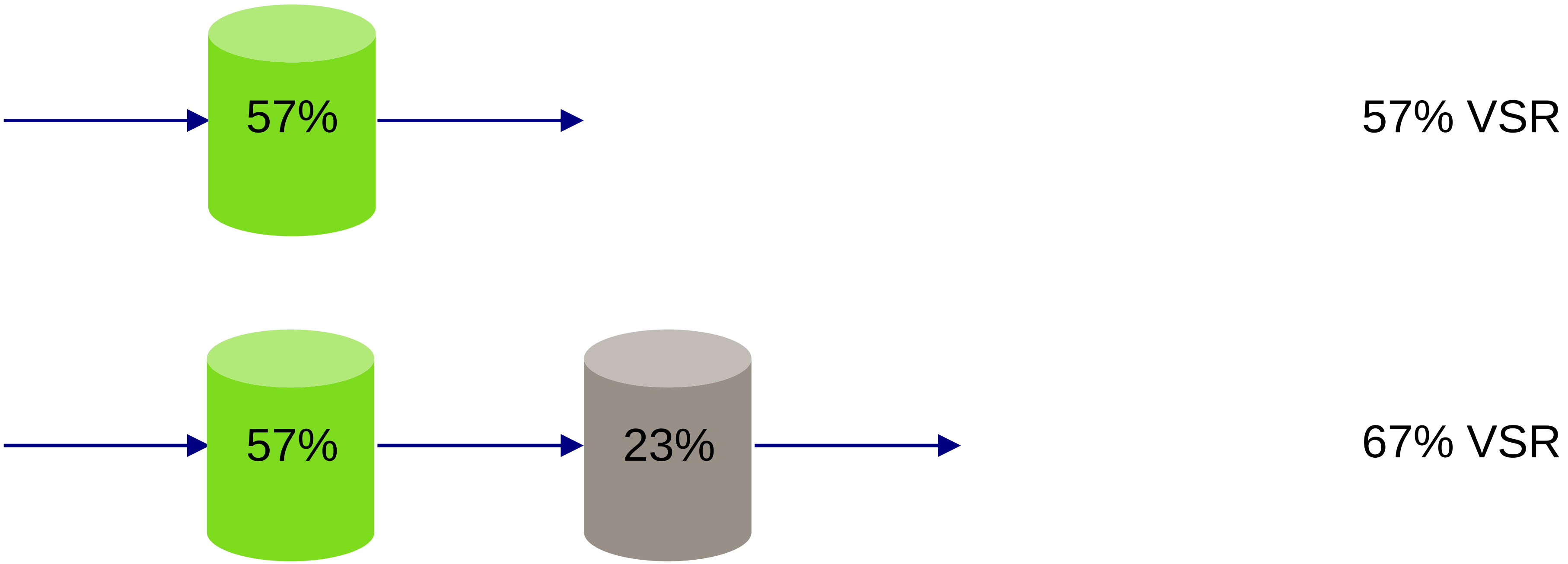
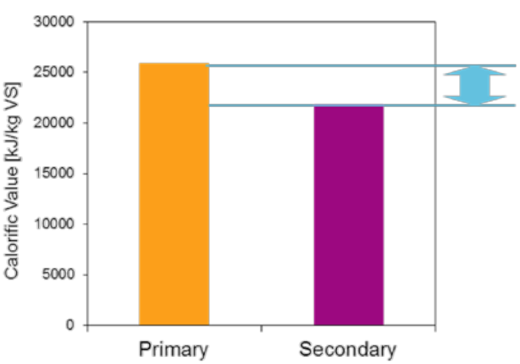
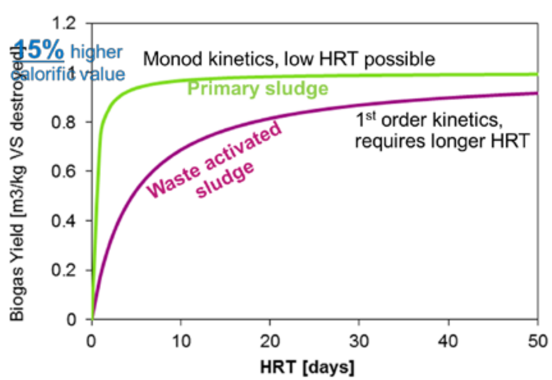
In Practice – Budd Inlet, USA

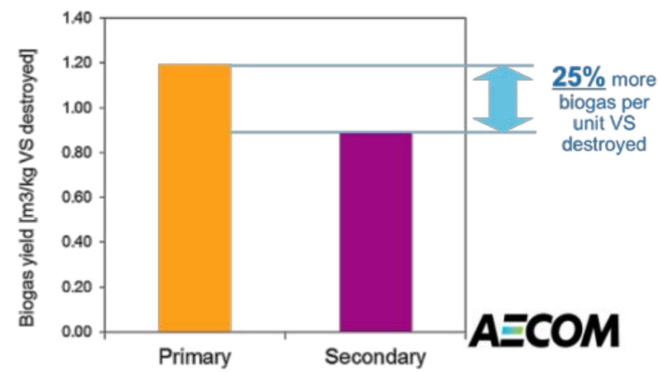


Issues with current design of anaerobic digestion

- 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
  - Work has shown when primary and secondary sludge are digested separately, biogas production is higher than when an equivalent mixture of the sludge is digested together







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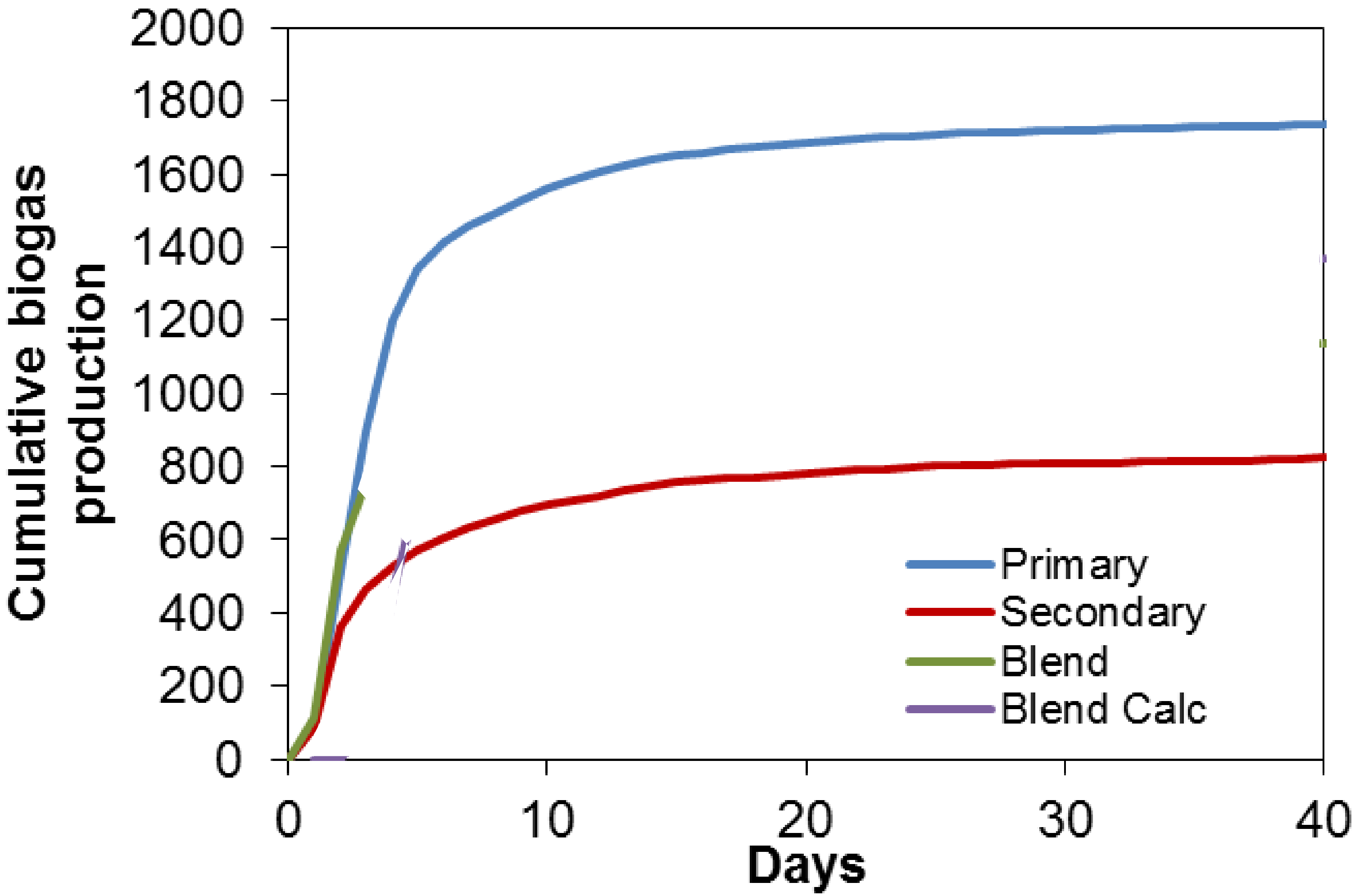
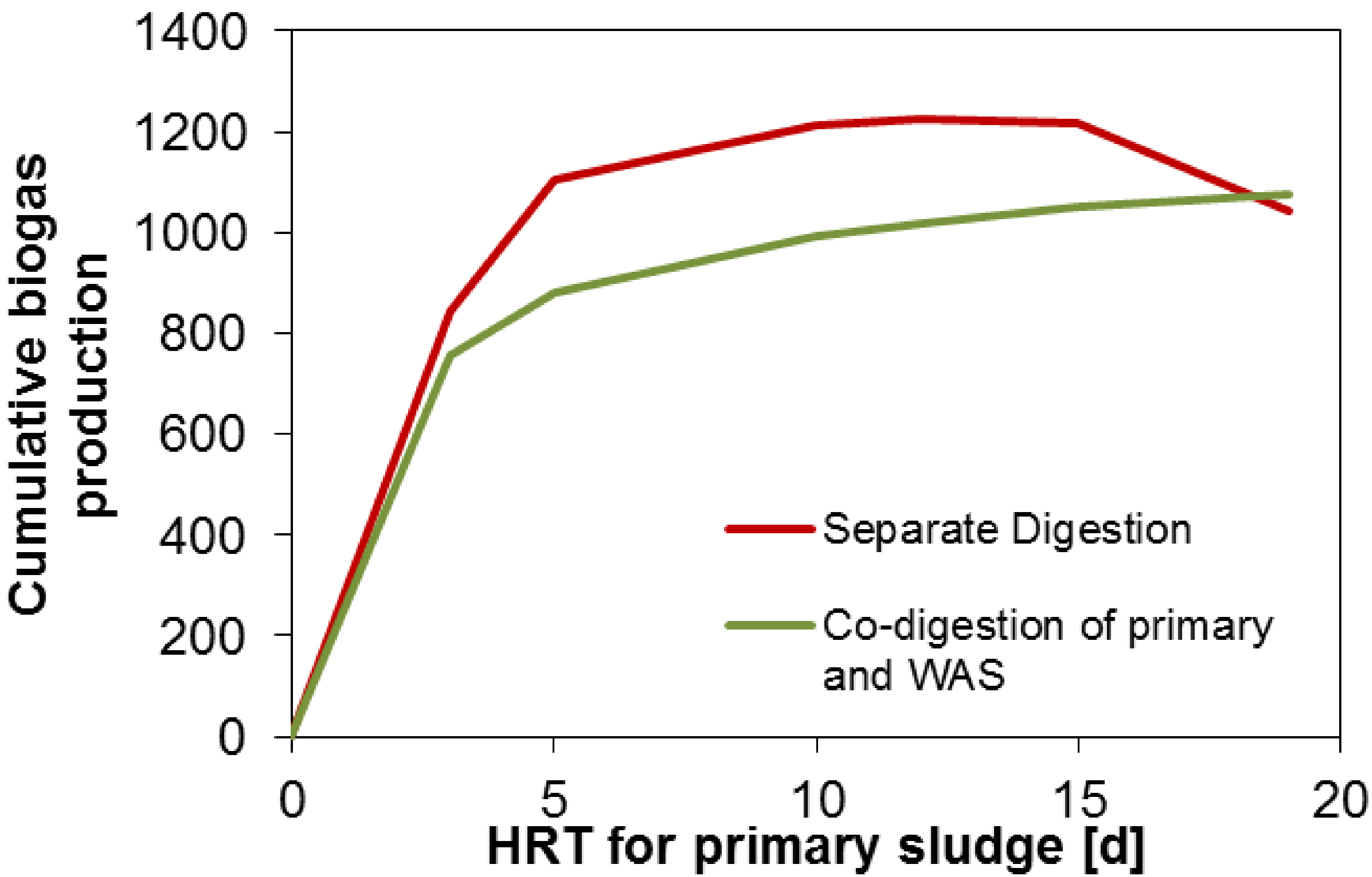
Separate Primary and WAS digestion



Separate Primary and WAS digestion



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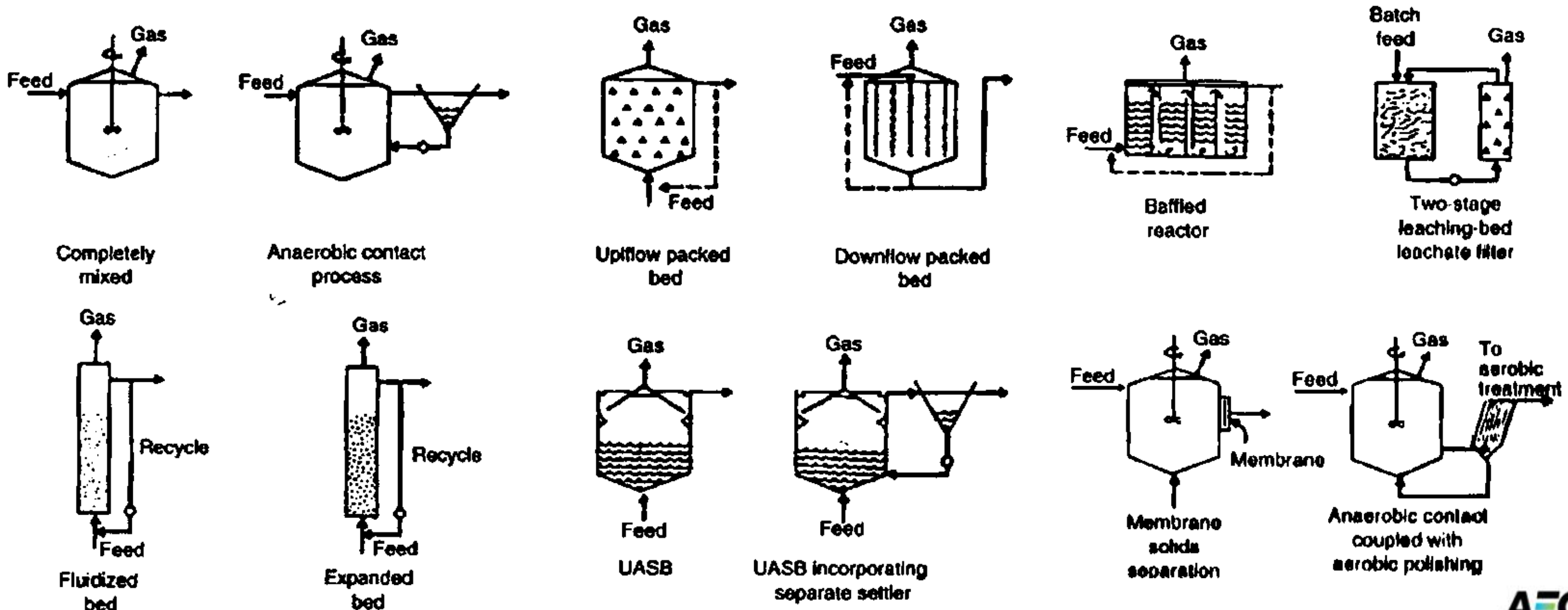
Issues with current design of anaerobic digestion

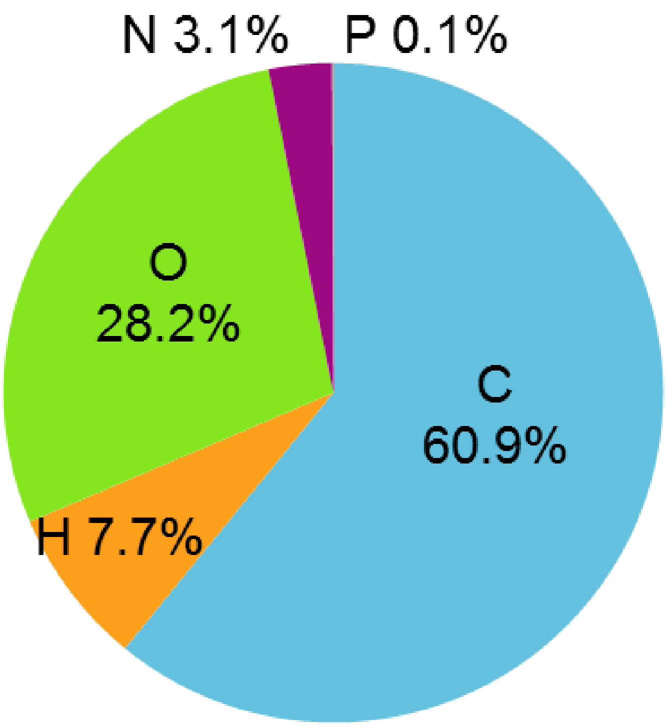
- We don’t keep the biomass in the digesters
  - The biogas producing organisms are known to be slow growing
  - We do this for activated sludge treatment
  - Recuperative thickening attempts to address this
  - Loading rates are low and therefore digestion plants are unnecessarily large

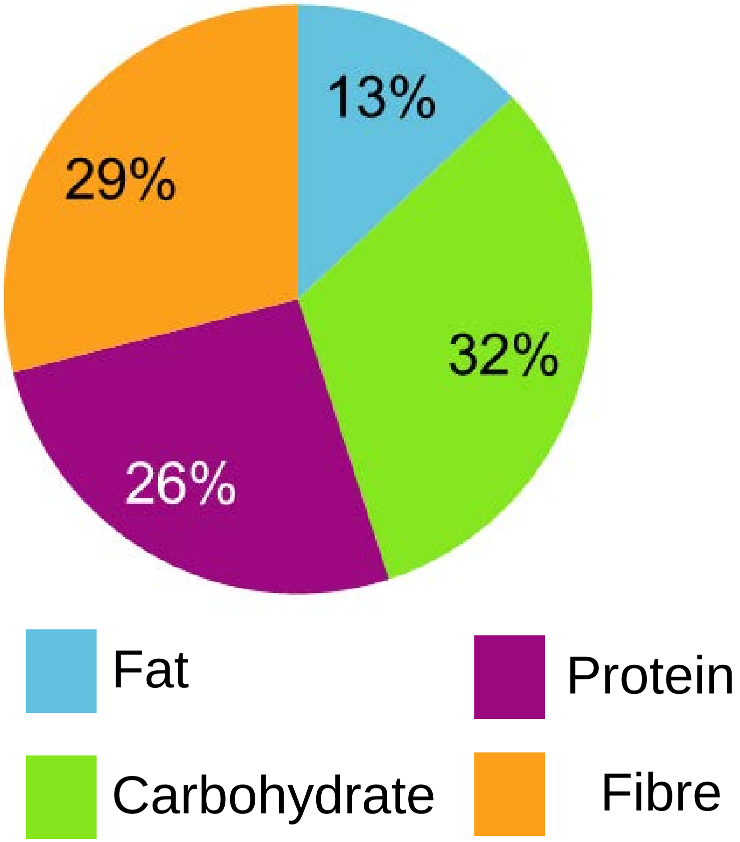


Speece, 1983

Primary Sludge

$C_{23}H_{35}O_8N$





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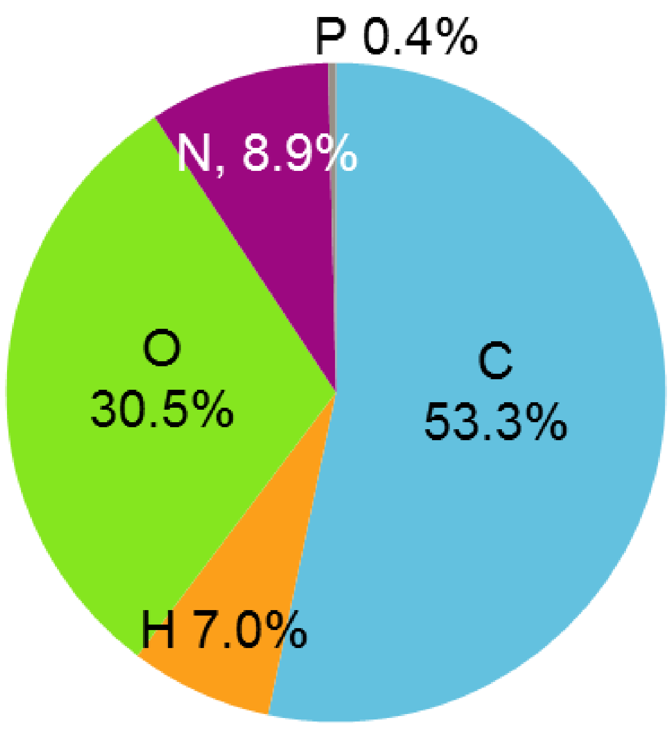
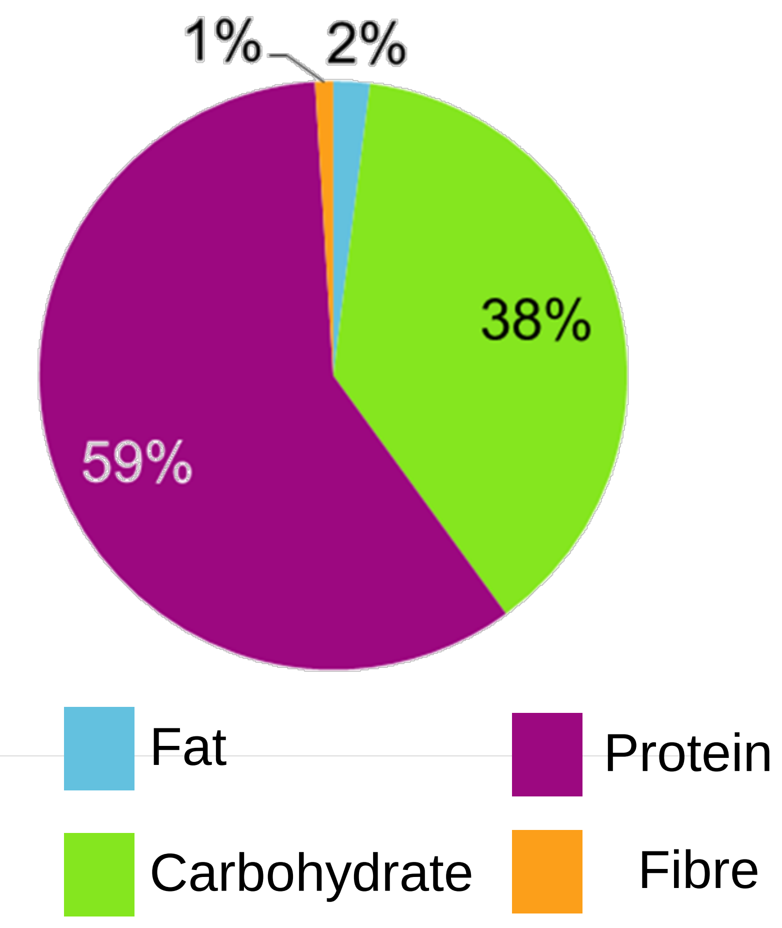
Waste Activated Sludge

$C_7H_{11}O_3N$





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Digestion and burning of primary sludge

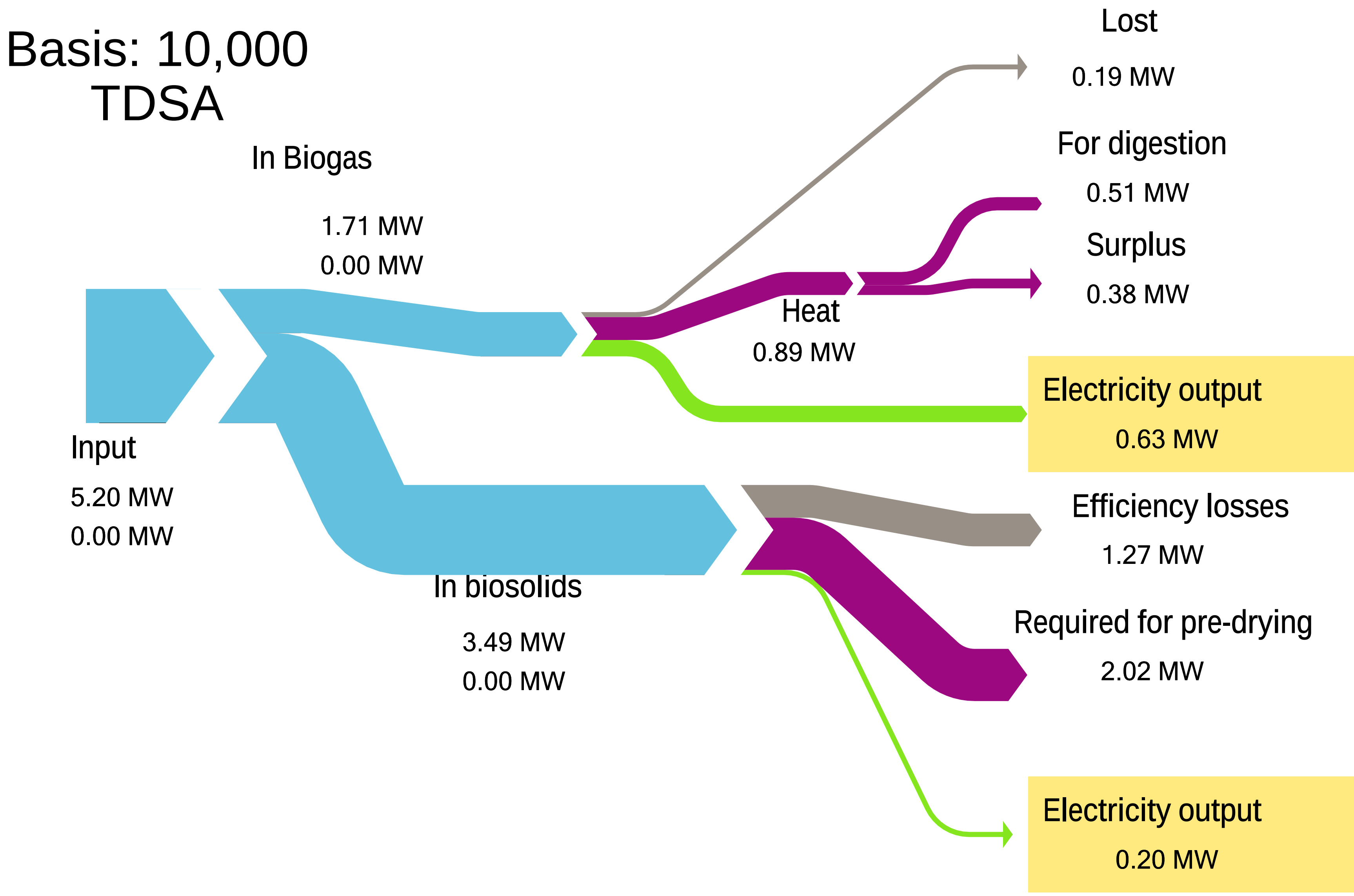
Basis: 10,000
TDSA

Input

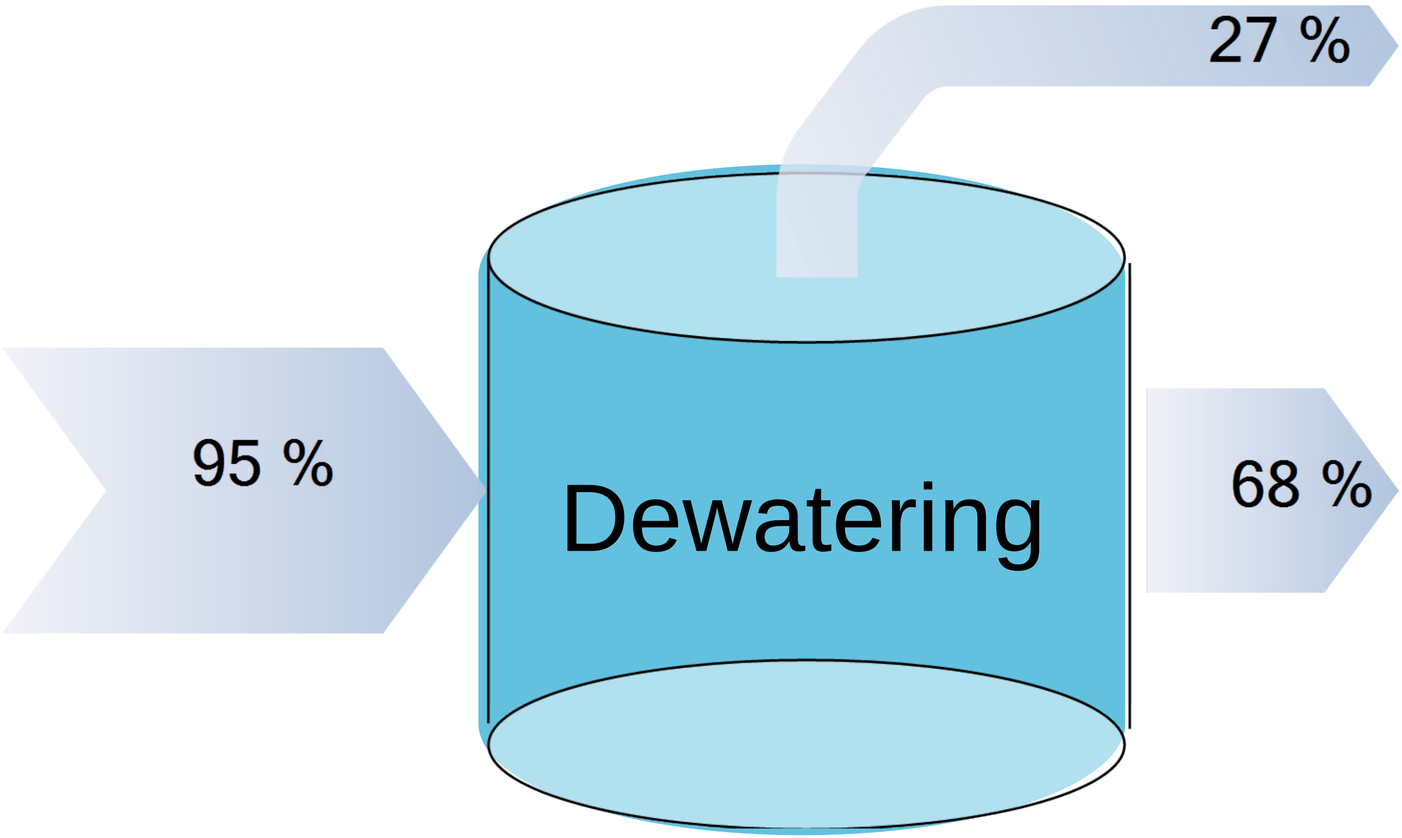
6.16 MW

0.00 MW

Digestion and burning of WAS



Current performance – Dewatering



This is best practice

Where the industry wants to go

- Maximize the value of biosolids application to land as a low-carbon intensive sustainable fertilizer
  - Costing analyses done in 1860s, most turned a profit
  - Patents on sludge use as fertilizer 1890s
- Recover resources
  - But we still rely on secondary treatment which involves the destruction of resources (even deammonification)
    - The world consumes energy to make nitrogen resources for agriculture then wastewater treatment consumes more energy to destroy them
  - Struvite
    - Patented 1857 for extraction of “ammoniaco-magnesian phosphate”
  - Ammonia, as ammonium sulphate
    - From steam stripping, patented in 1871
- Enhance energy recovery
  - As previously mentioned

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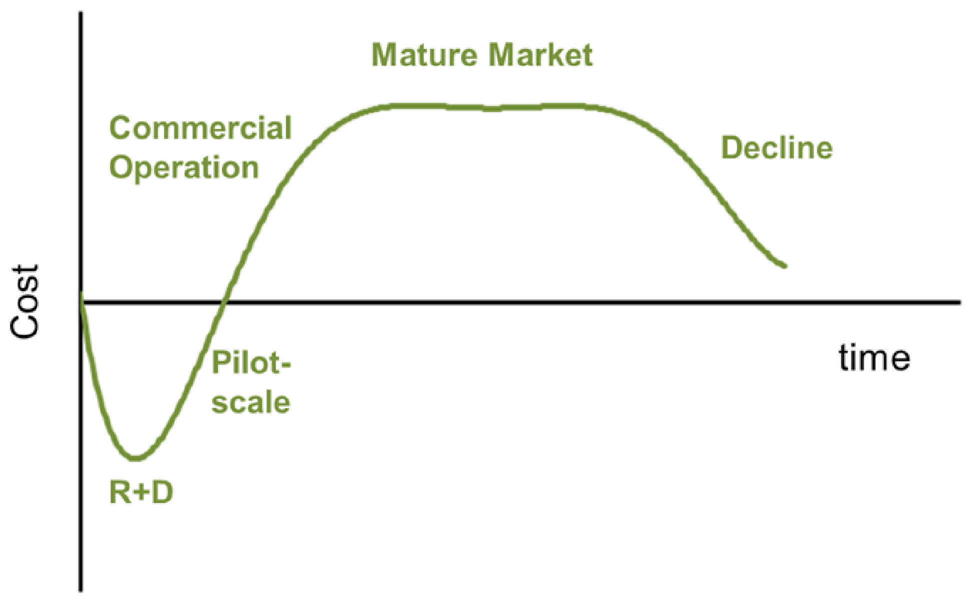
21st Century Drivers

21st century Drivers

- As with the Victorian Sanitation engineers, the wastewater treatment plant of the future will be fundamentally influenced by a number of non-regulatory and regulatory drivers

- It is likely that the technology of the future plants will be based on variations of what currently exists and technology currently at lab- or pilot-scale



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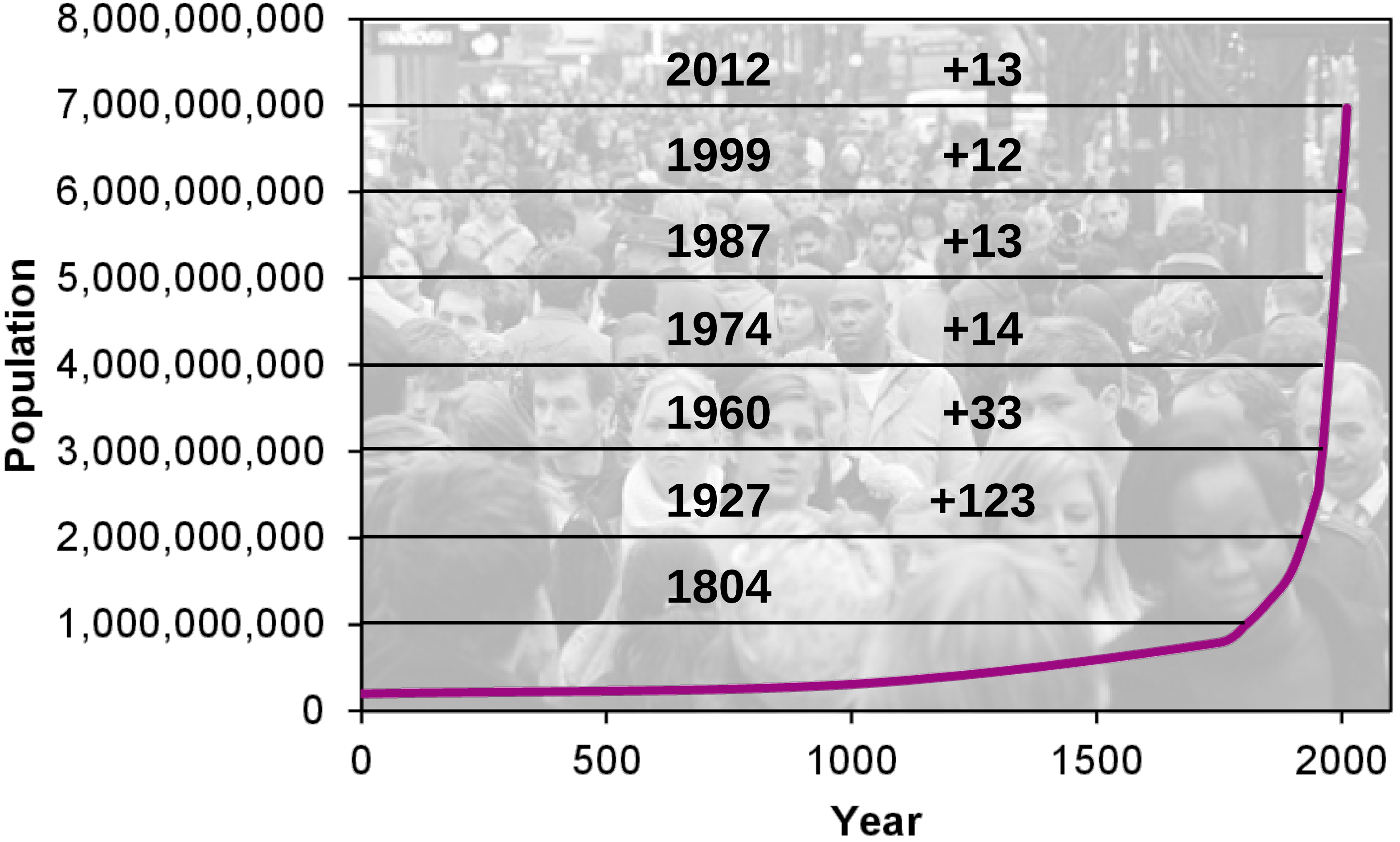
Population Growth



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Higher population which is more affluent

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Increasing affluence – changing eating habits

FOOD & DRINK 3/26/2014 @ 11:10AM | 7,570 views

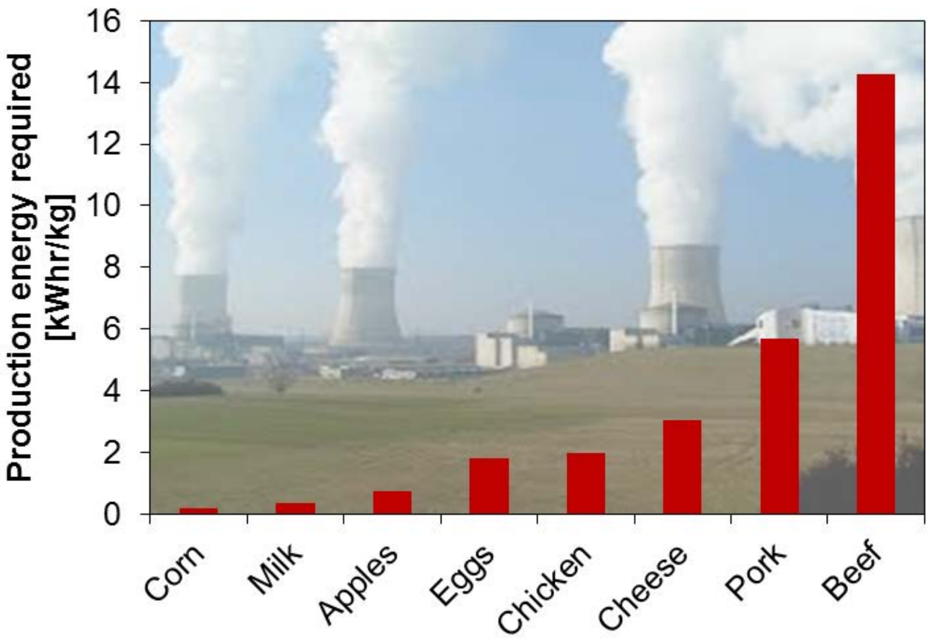
How Increased Meat Consumption In China Changes Landscapes Across The Globe

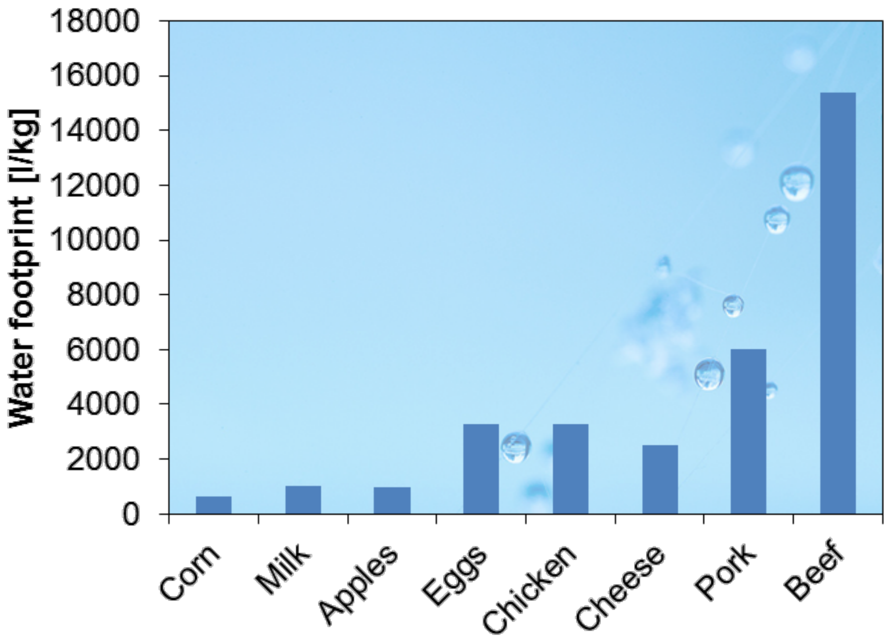
+ Comment Now + Follow Comments

Americans eat 235 pounds of meat annually. That's the equivalent of roughly 470 big hamburgers a year – more than a burger a day.

The Chinese on the other hand consume a mere 120 pounds of meat per person each year. Yet with 1.35 billion people in the country, China now consumes double the amount of meat we do in the U.S..

Changing eating habits





Production of beef requires > 70 times the energy and 25 times the water than an equivalent weight of corn

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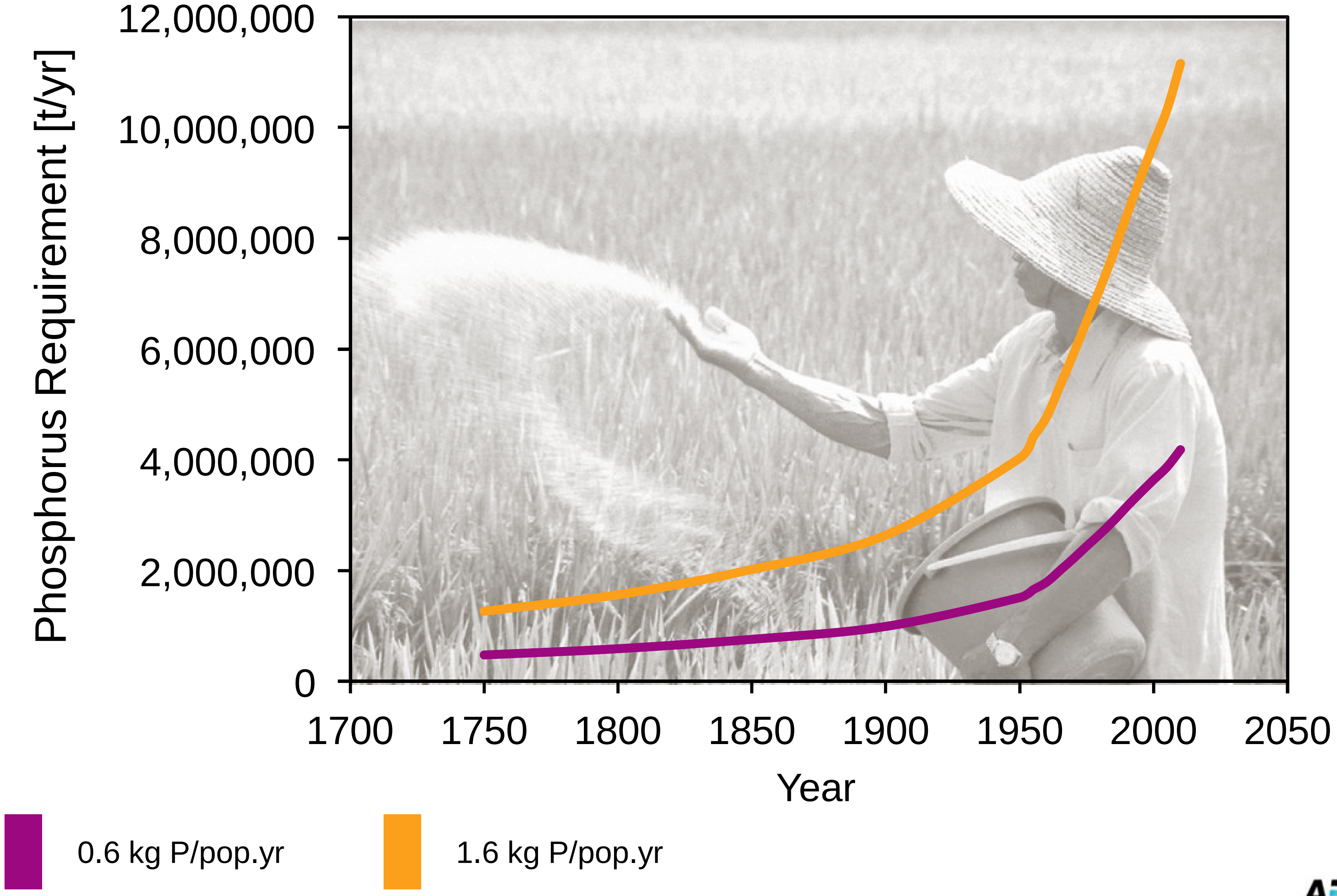
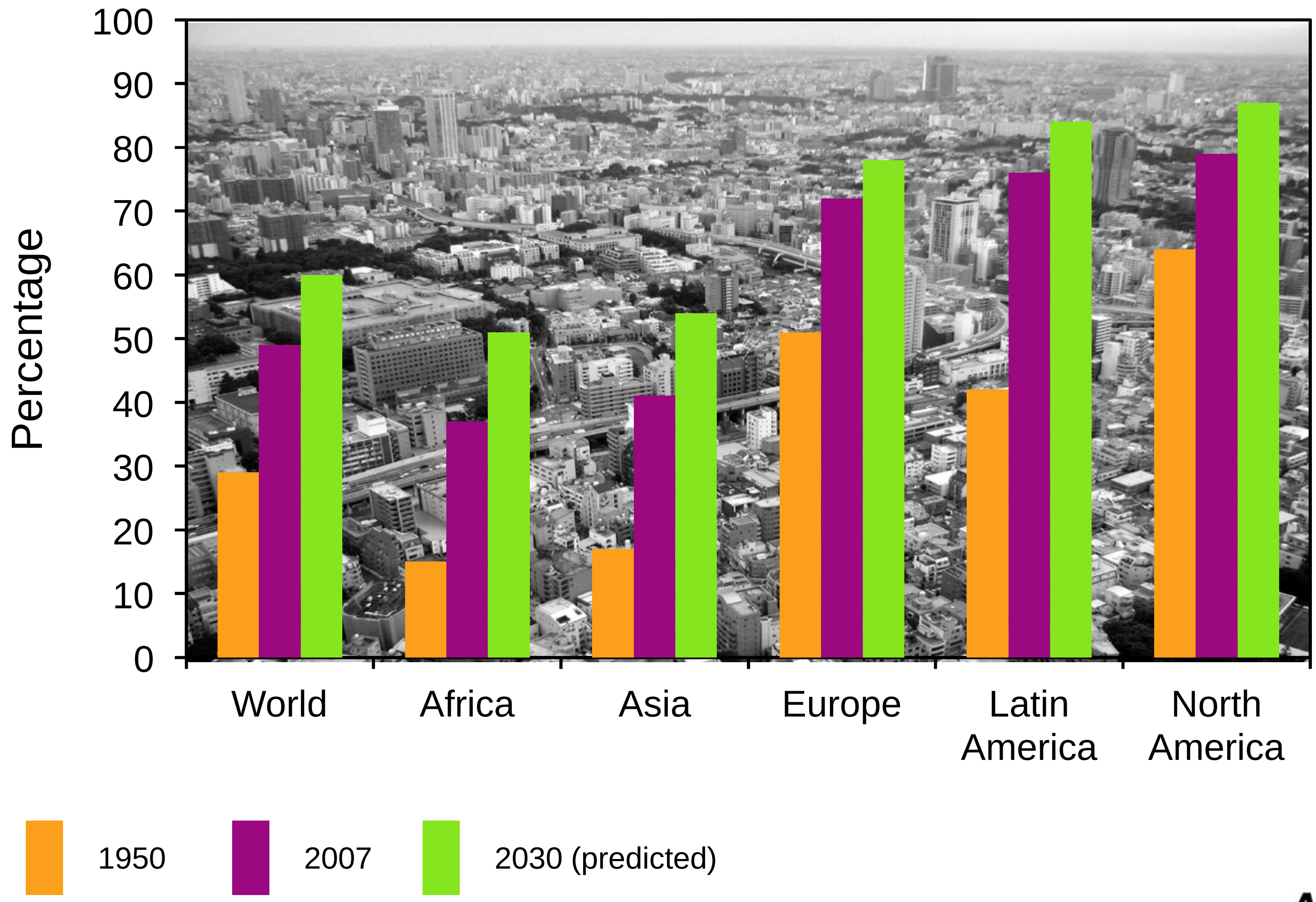
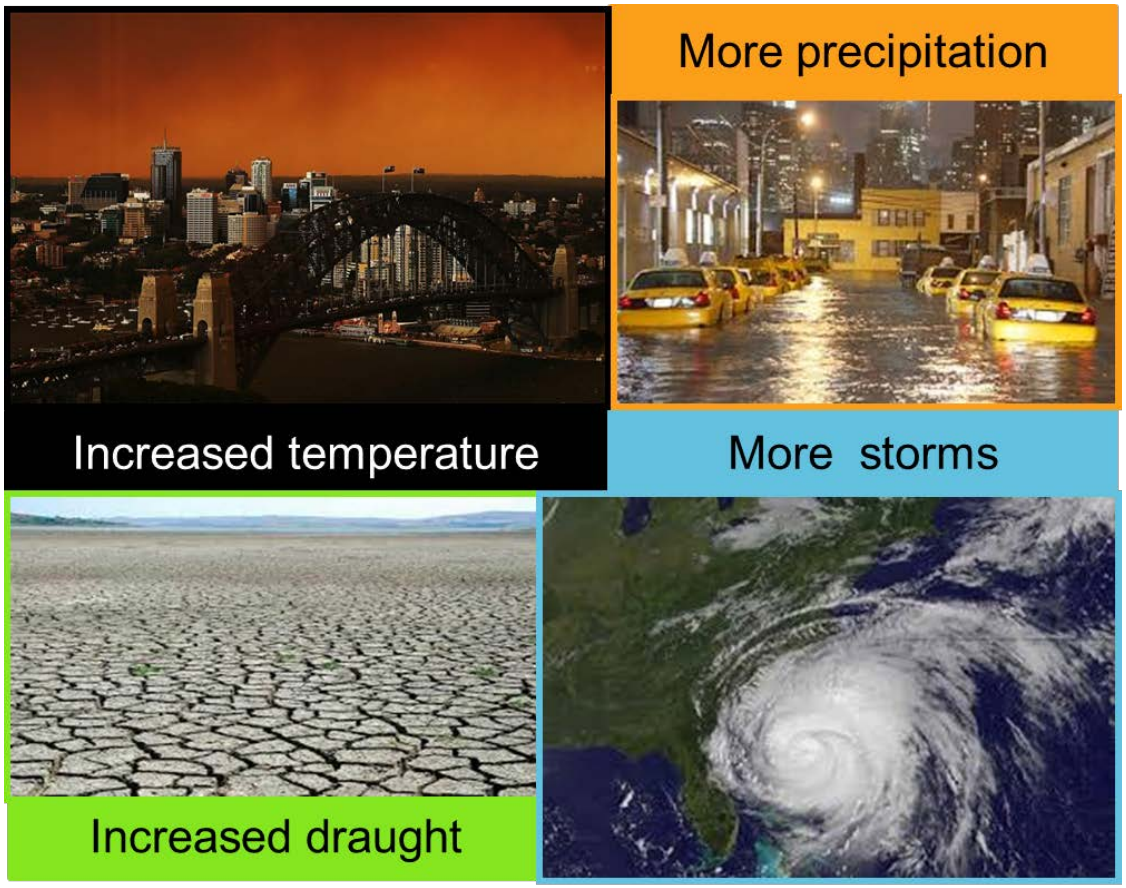
Changing food habits



Urbanization



Impacts of climate change



- Sewer flooding
- Environmental impact of intermittent discharges
- Environmental and regulatory threat from pollution incidents
- Security of supply
- Water quality
- Increasing flood risk
- Indirect, socio-economic risks

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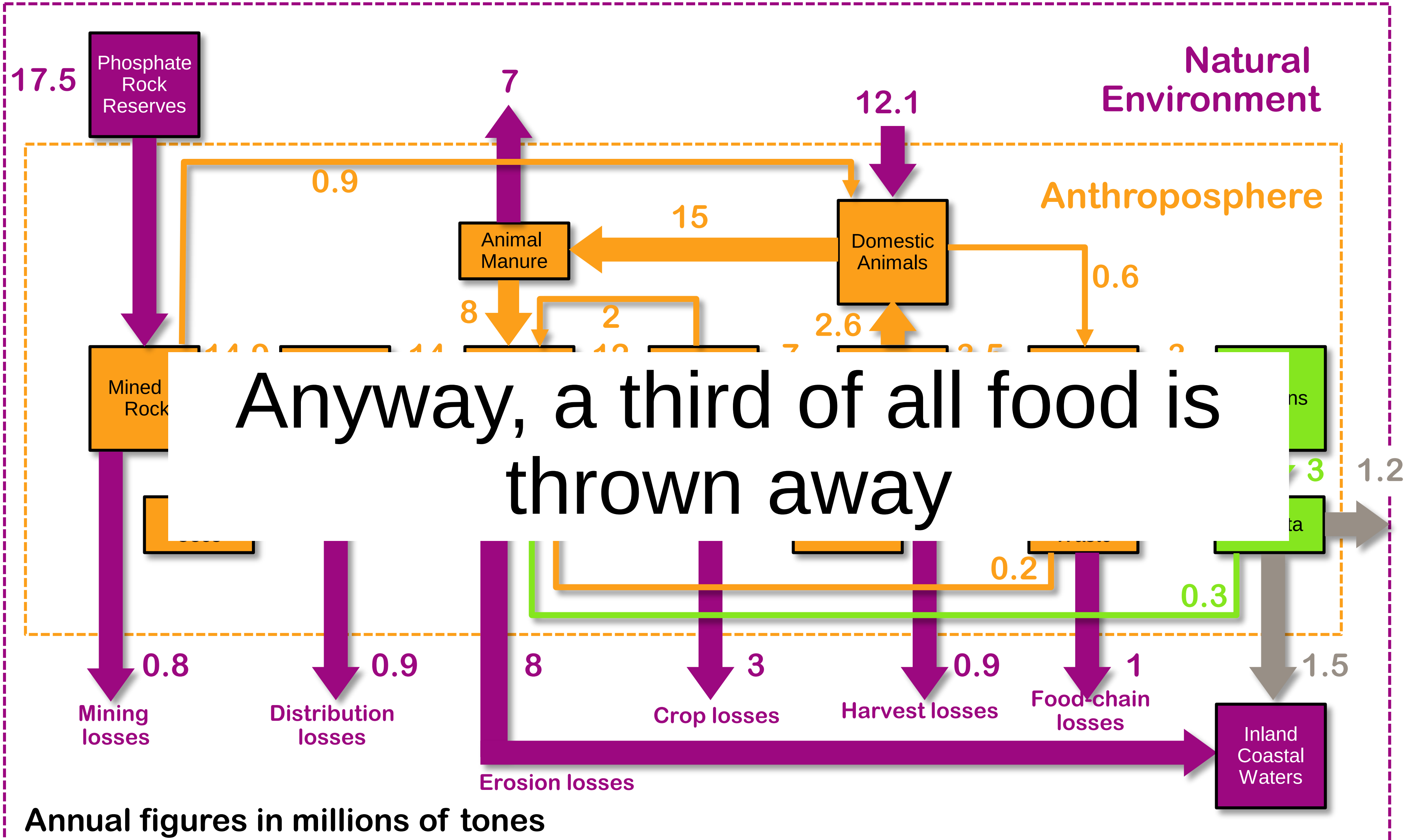
Recovery of phosphorus? Phosphorus Balance



Anyway, a third of all food is thrown away

Annual figures in millions of tones

Adapted from Cordell *et al*., 2009. The story of phosphorus: Global food security and food for thought

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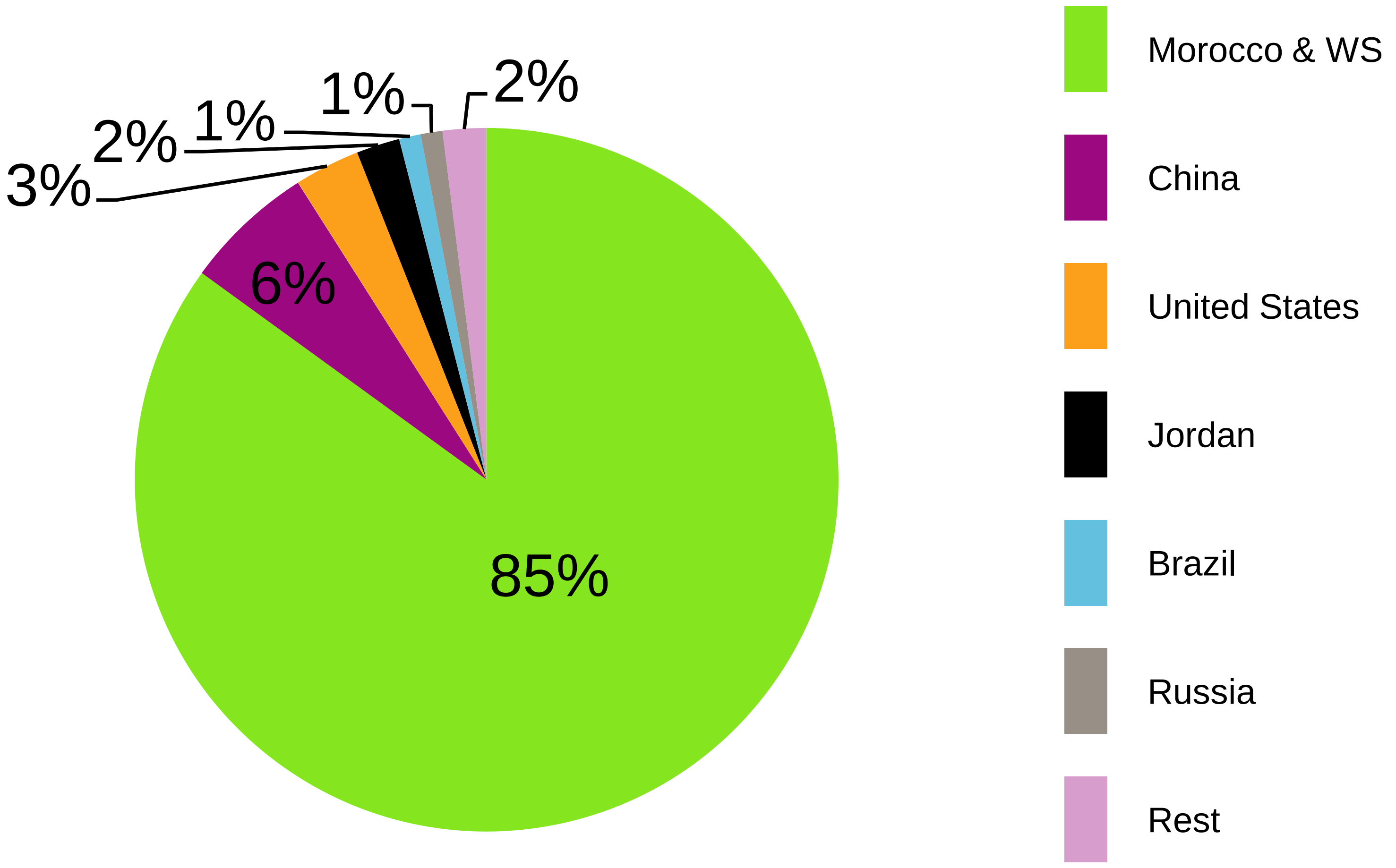
Phosphate Reserves (65,000 million tonnes)



Source: Van Kauwenburgh (2010) World Phosphate reserves and resources, IFDC

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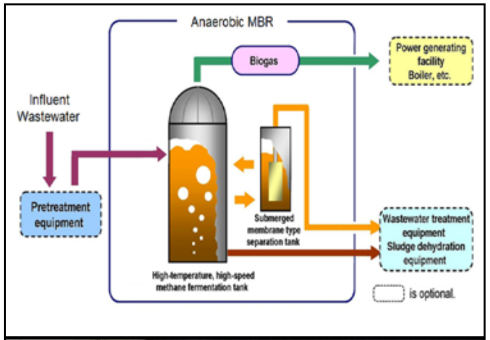
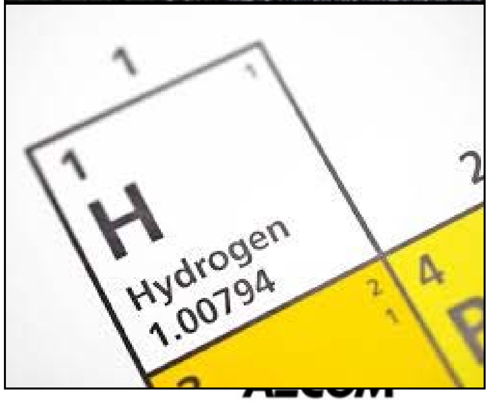
Where could we go from here

- Improve anaerobic digestion
  - As we have seen, many options exist, starting with series digestion and solids retention
  - Hydrolysis technology will always improve any anaerobic digestion configuration
  - AnFB + AnMBR gives effluent equivalent to activated sludge treatment at under 50F for influent wastewater



- Improve dewatering
  - It is not the dewatering equipment or the polymers which are limiting performance but, it is the sludge itself
  - As for anaerobic digestion, employ pre-dewatering technology to change biosolids properties

- Is biogas the answer?
  - It is the natural endpoint of fermentation



Minimize energy consumption at a wastewater treatment works

- We know that diverting carbon away from secondary treatment towards anaerobic digestion is highly beneficial regarding site-wide energy balance
  - Less load to secondary requires less aeration energy
  - More sludge is produced so there is more biogas
  - Higher proportion of primary sludge
    - Which has higher calorific value
    - Generates a higher biogas yield
    - Is more biodegradable

- What is the logical endpoint of this approach?

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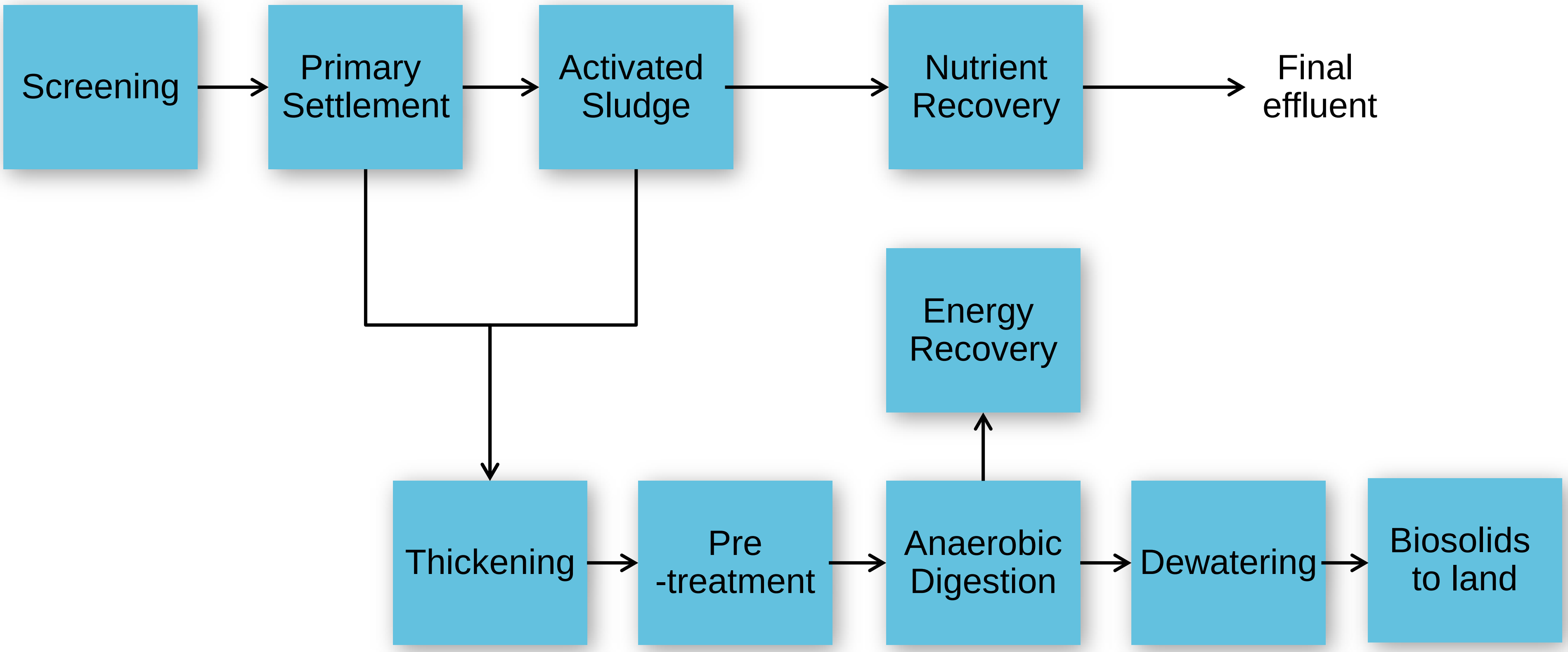
The Wastewater treatment plant of today



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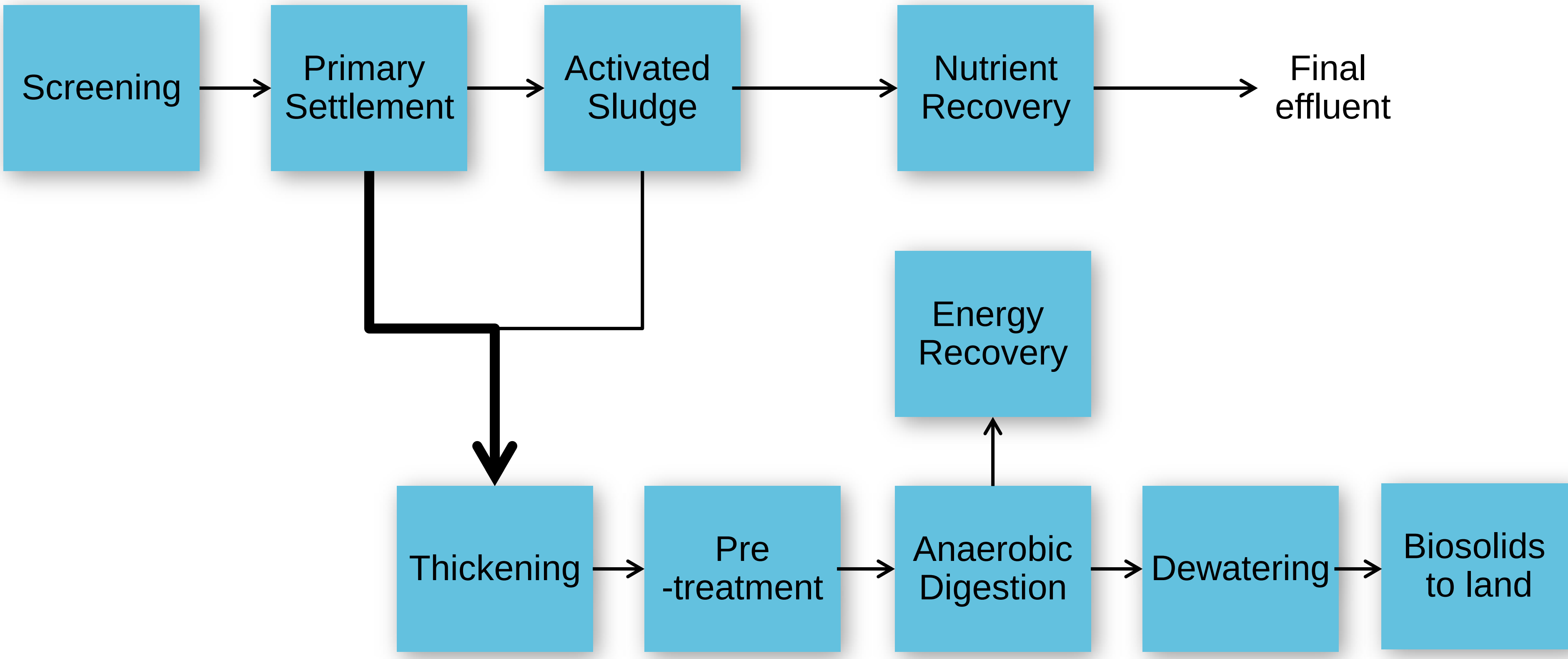
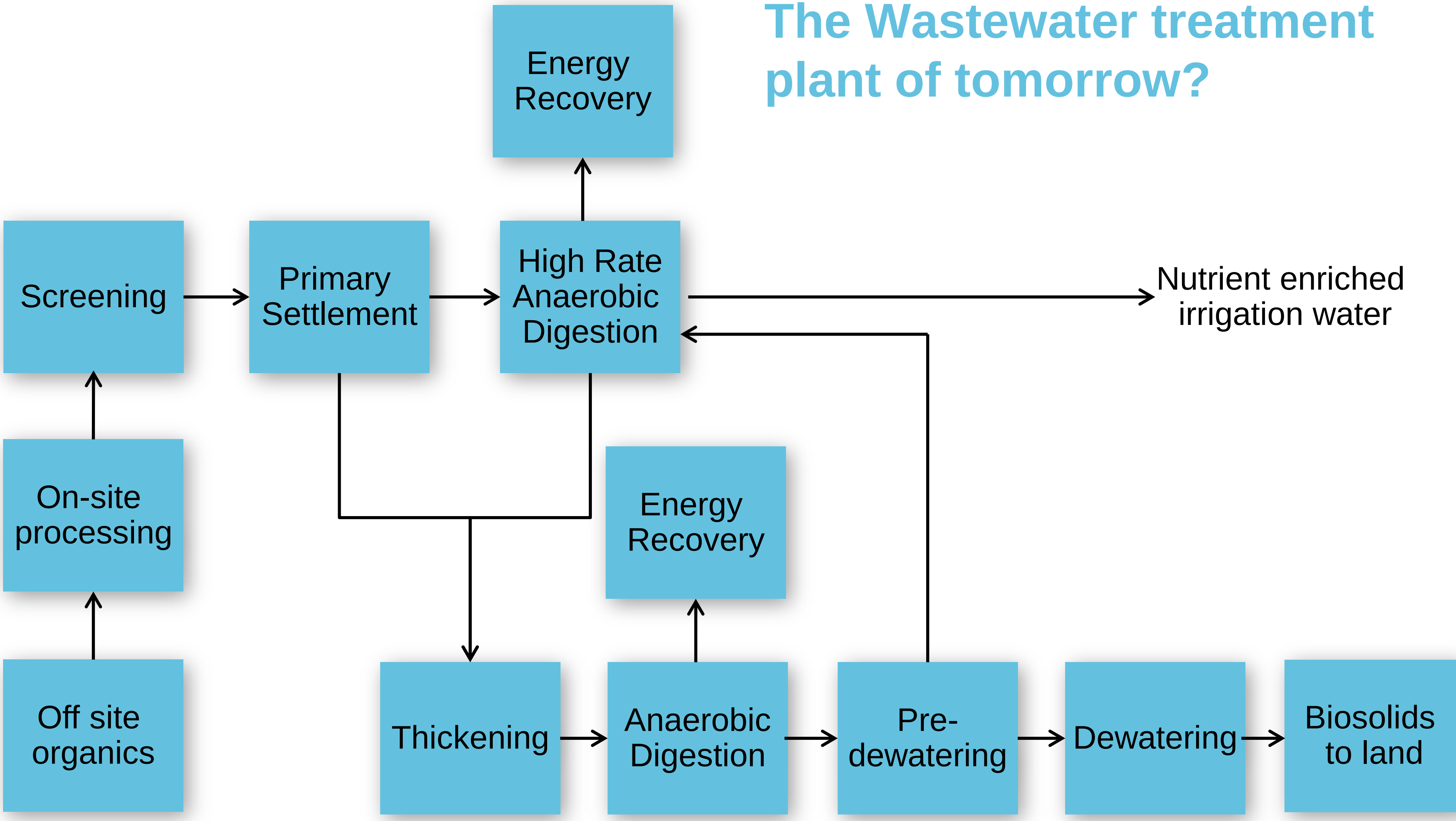
The Wastewater treatment plant of today



The Wastewater treatment plant of tomorrow?



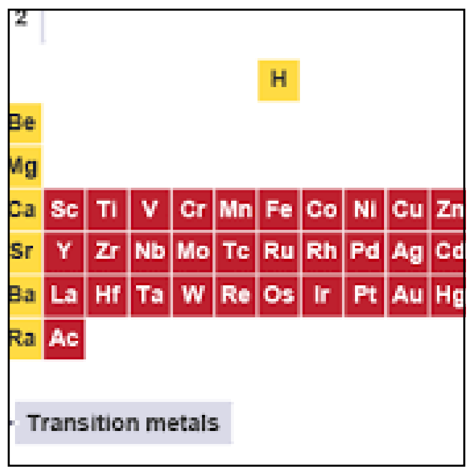
Start with anaerobic digestion first?

honour which is due to them, is more creditable to their courage than to their intelligence. No one, however, would have been more pleased than Pasteur himself, had he lived, to see the developments which there is every reason to believe will soon lead to the successful solution of the problem of sewage disposal by means of putrefactive fermentation, followed by nitrification of the organic matters under highly aërobic conditions.

W. D. Scott-Moncrieff.

Victoria Street, Westminster, S.W., July 26th.

Extracting value from biosolids



Metals

"There are metals everywhere," Dr. Kathleen Smith of the US Geological Survey (USGS) said in a statement, noting that they are "in your hair care products, detergents, even nanoparticles that are put in socks to prevent bad odors."

SMARTNEWS *Keeping you current*

Millions of Dollars Worth of Gold And Silver Lurk in Sewage

A city with one million people could have $13 million worth of metals in sewage sludge

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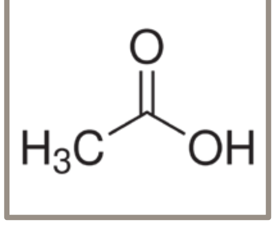
Biosolids as a resource

1 ton dry solids of biosolids



185 kg

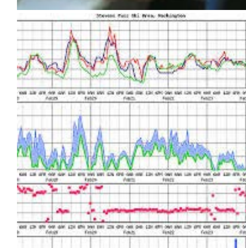
$100+

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

Operation of tomorrows wastewater treatment plant

- Data and online monitoring
- High level of automation
- Remote (unmanned) operation
- Advanced telemetry
  - Intelligent unit operations
- Smart metering
- Self correction in real-time
- Communication between sites



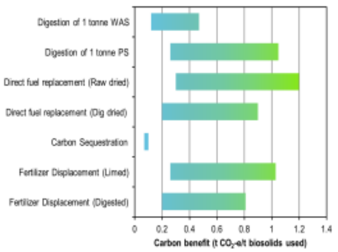




Conclusions

Our wastewater treatment plants of today are based on drivers from the 19th century and are therefore inefficient at meeting the desires of modern operators

As for 19th the century, a variety of modern drivers, which may be regulatory or non-regulatory, will shape the development of 21st century wastewater treatment plants

Modern facilities will have to adapt to climate change, increasing demands on water, energy and resources



The treatment plant of tomorrow may comprise a combination of optimised variants of what we have today and new technology and will use highly advanced data management and control systems, assuming drivers encourage change

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Thank you

Dr Bill Barber

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