An organic landfill’s life cycle

Pollux Consulting

Piet Wens

24/05/2017

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1. Introduction

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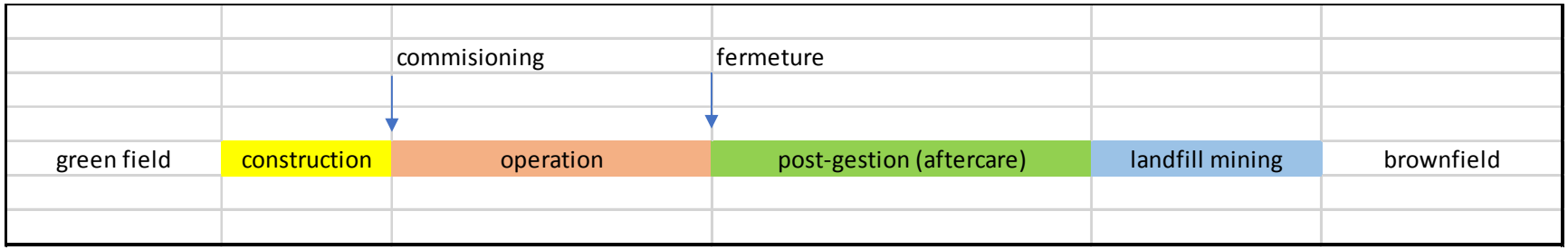
An organic landfill's life cycle



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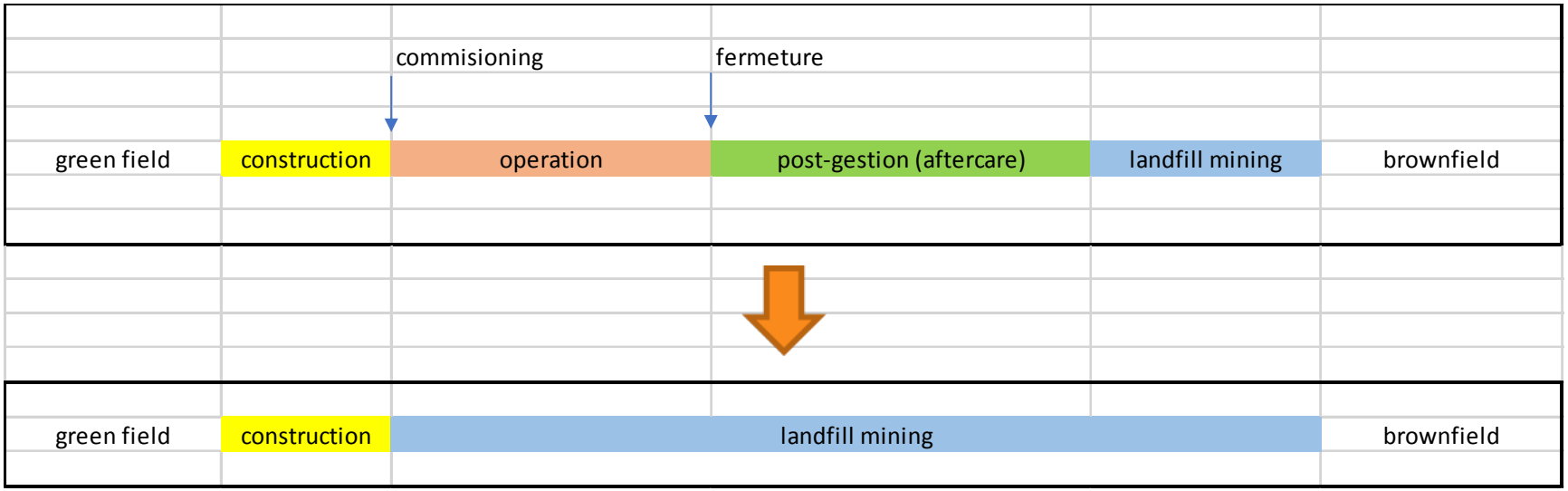

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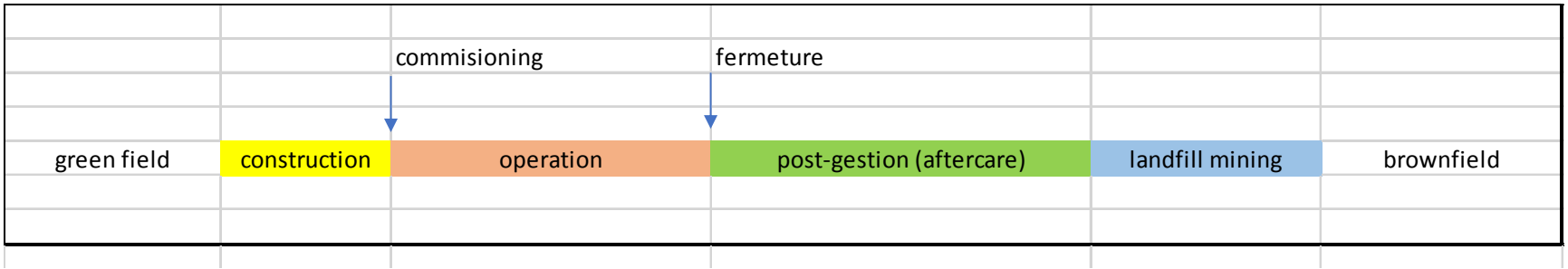
An organic landfill's life cycle



- Old school: view from the outside
- waste is dangerous: We don't want anything coming out
    - Valid for hazardous waste landfills: eternal storage + potential mining
    - Not for organic waste

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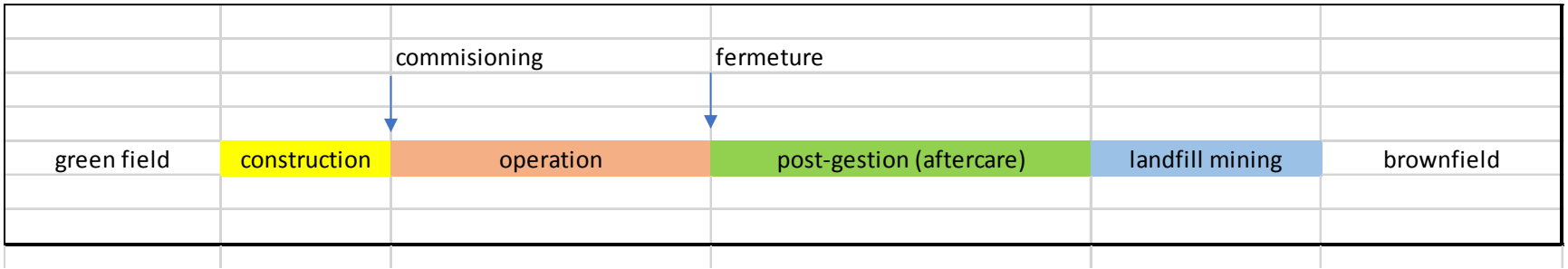
An organic landfill's life cycle



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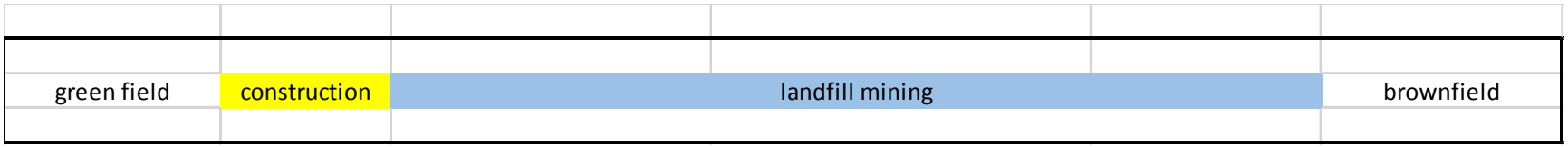

- Municipal solid waste:
  - MSW production per year: 1.300.000.000 ton
  - To double by 2025
  - 80 % of all domestic waste will be dumped or landfilled
  - a lot of valuables in there
- Landfilling will be most important waste treatment technique next 50 years
- Keep developing technology around it
- We don't want anything left inside: view from the inside

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Pollux Consulting

- Pollux Consulting is an engineering company specialised in landfill engineering and management
  - Since 2004
  - Currently +/- 40 landfill projects in more than 15 countries on 4 continents
    - Construction and stability
    - Capping
    - Surface- and groundwater management
    - Leachate and biogas management
    - Operation and aftercare
    - In other words: Landfill mining

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index

1. Introduction
2. Current status of landfills
3. Future of organic landfills
   - Landfill mining
   - Opportunities
   - Gaps in legislation
4. Conclusions

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2. Current status on organic landfills

Waste treatment and electricity generation

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2.1 Organic landfills are a waste treatment technique

- Municipal solid waste landfilling:
  - Composition
    - Rapidly biodegradable: $C_{40}H_{65}O_{27}N$
    - Slowly biodegradable: $C_{20}H_{29}O_8N$
  - Waste treatment: Convert waste to inert molecules

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2.1 Organic landfills are a waste treatment technique

Incineration

C_{org}

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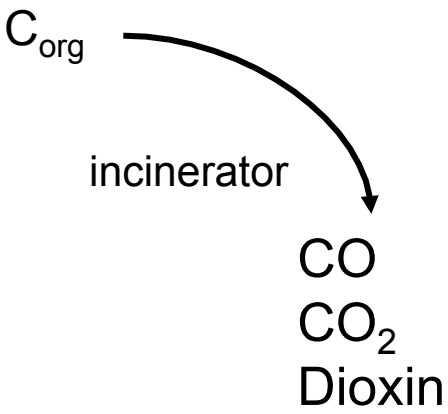
2.1 Organic landfills are a waste treatment technique

Incineration



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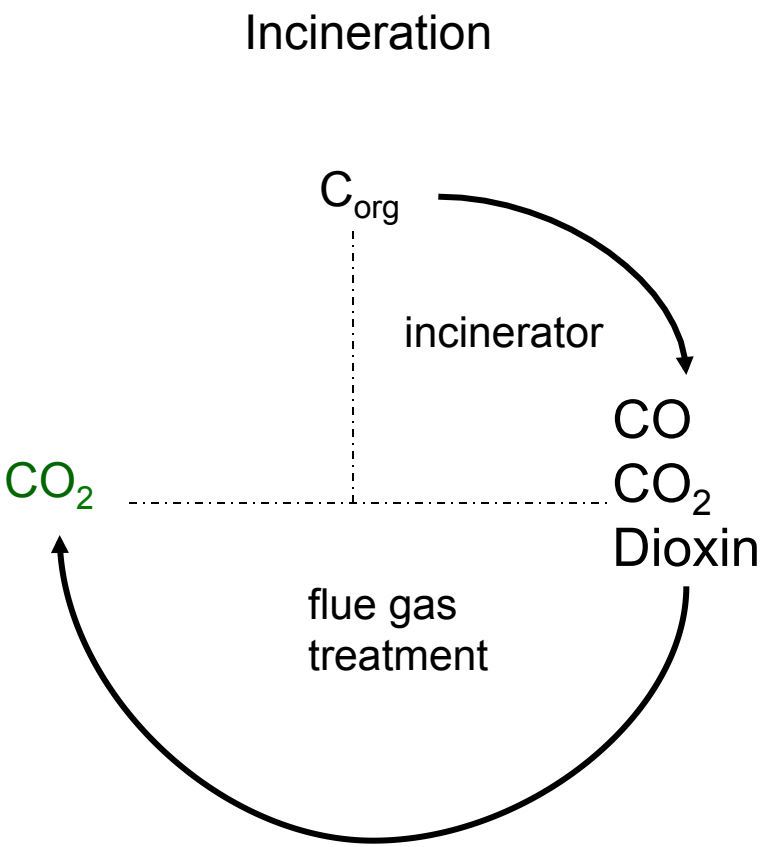

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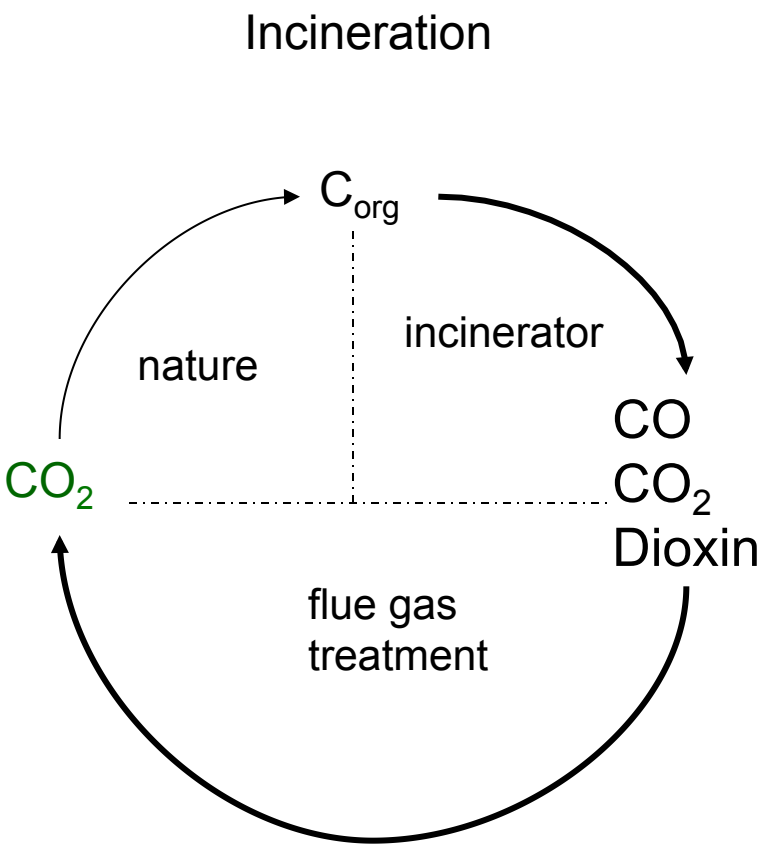

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Landfilling

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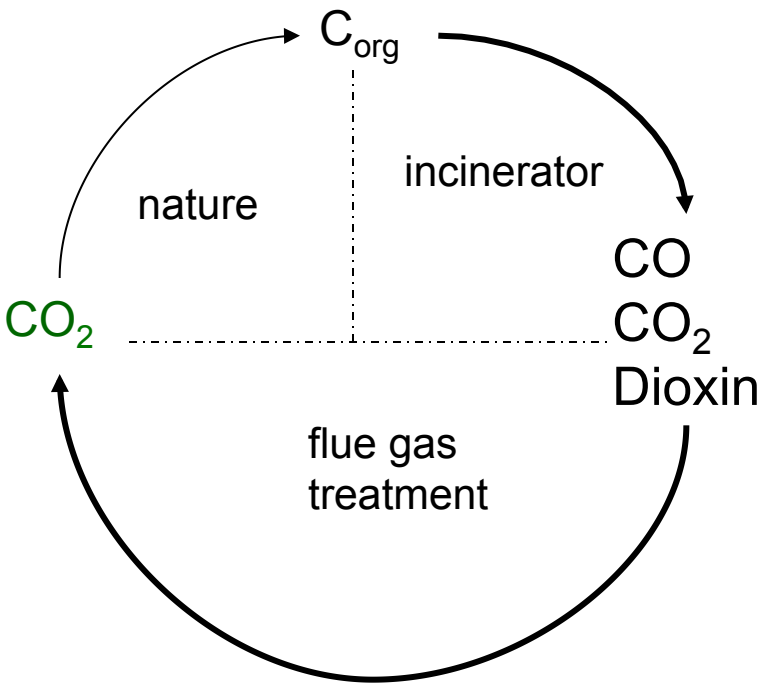

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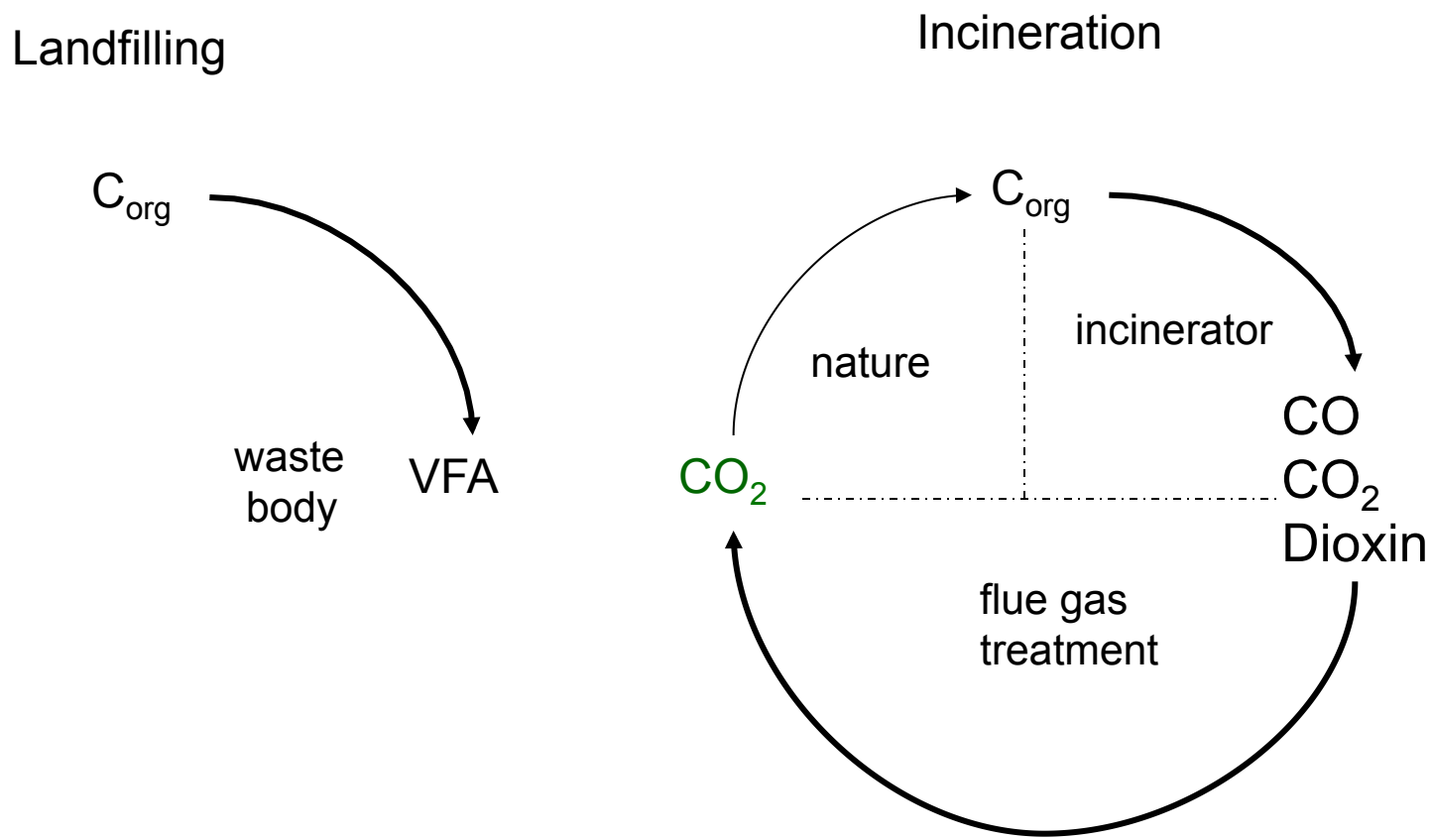

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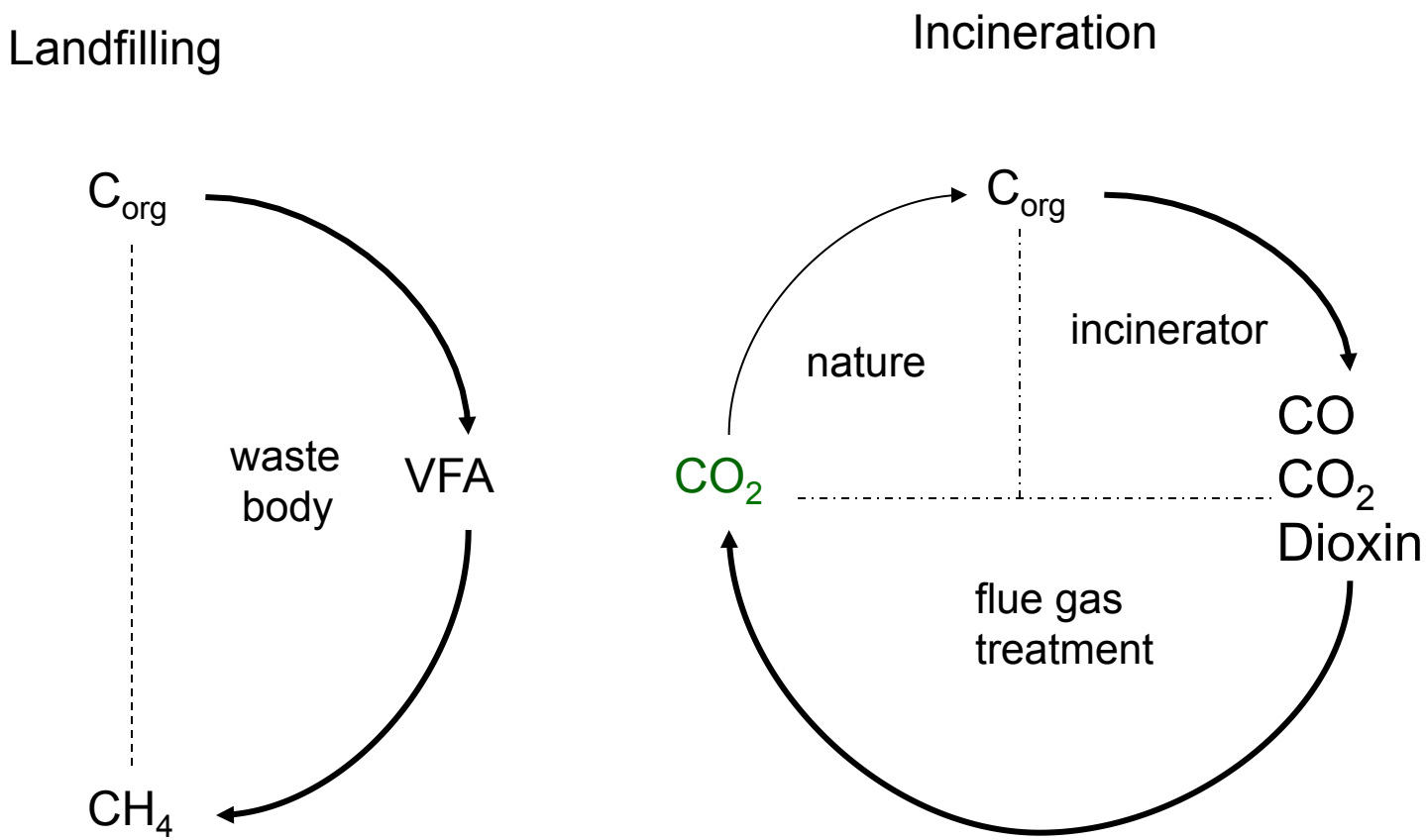

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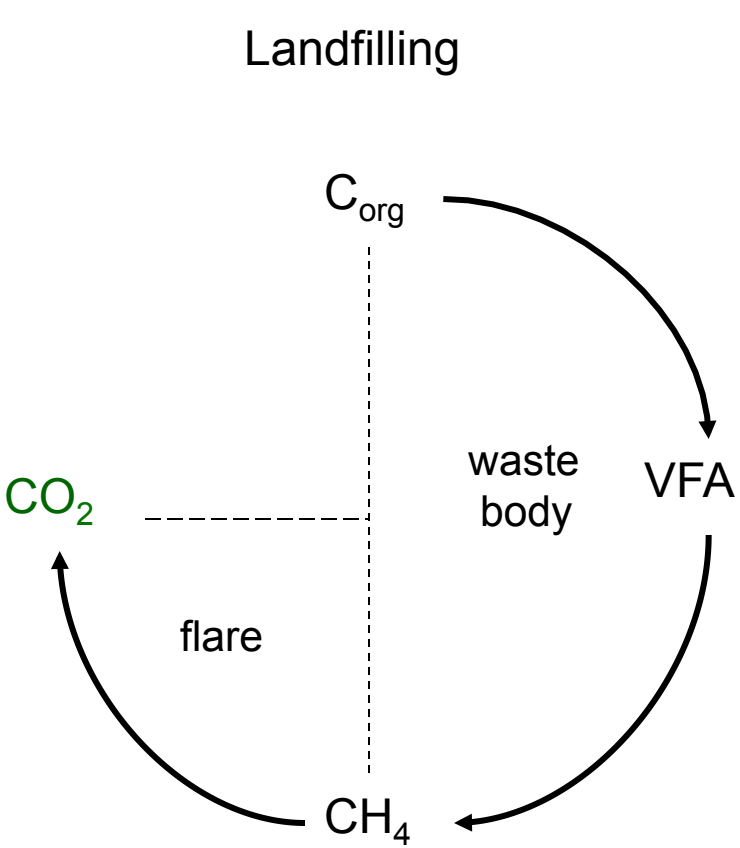

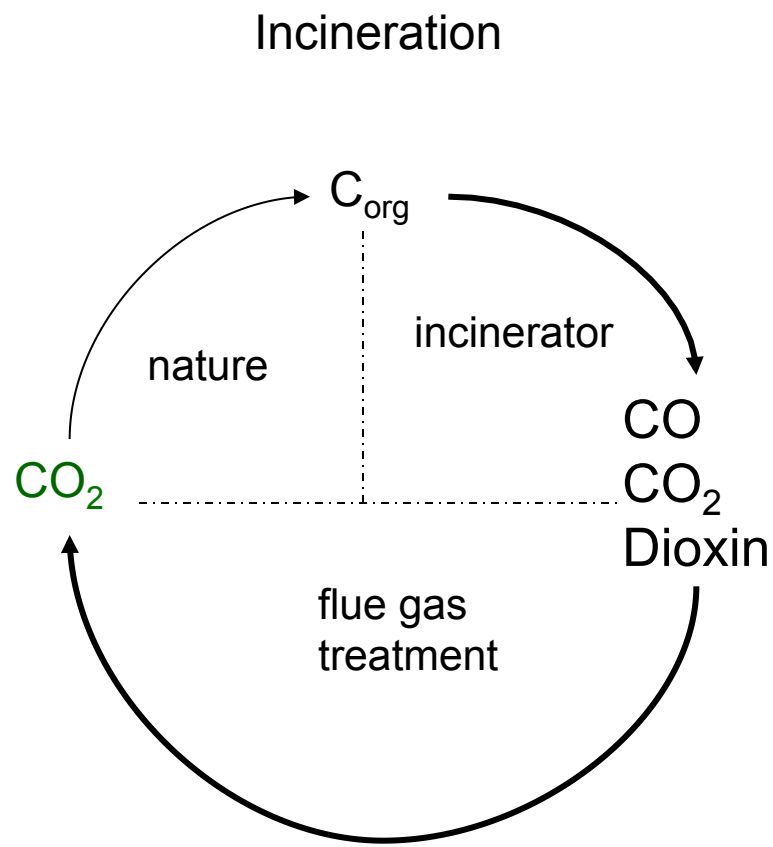

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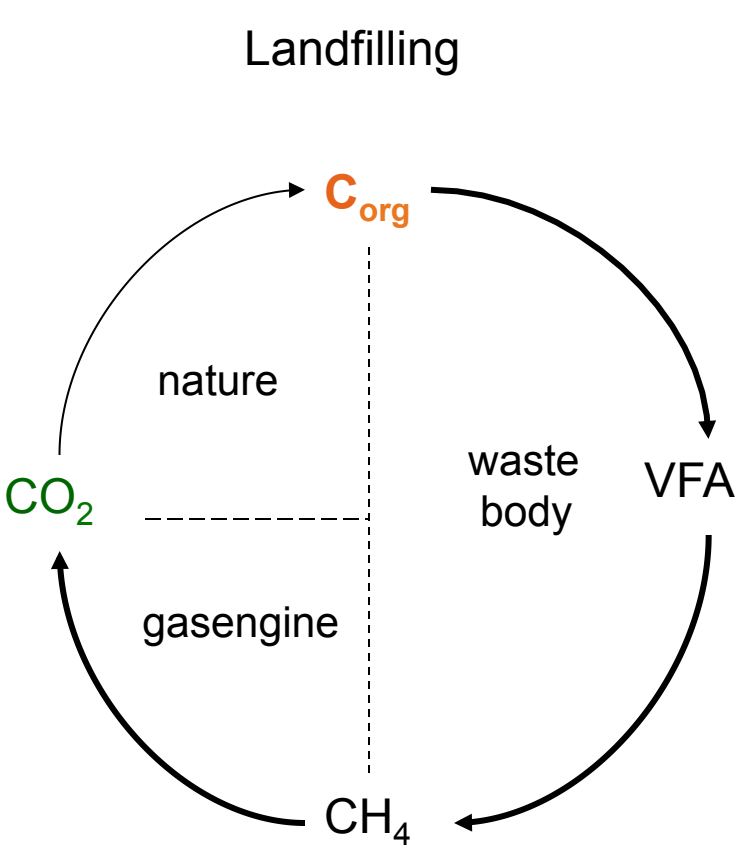

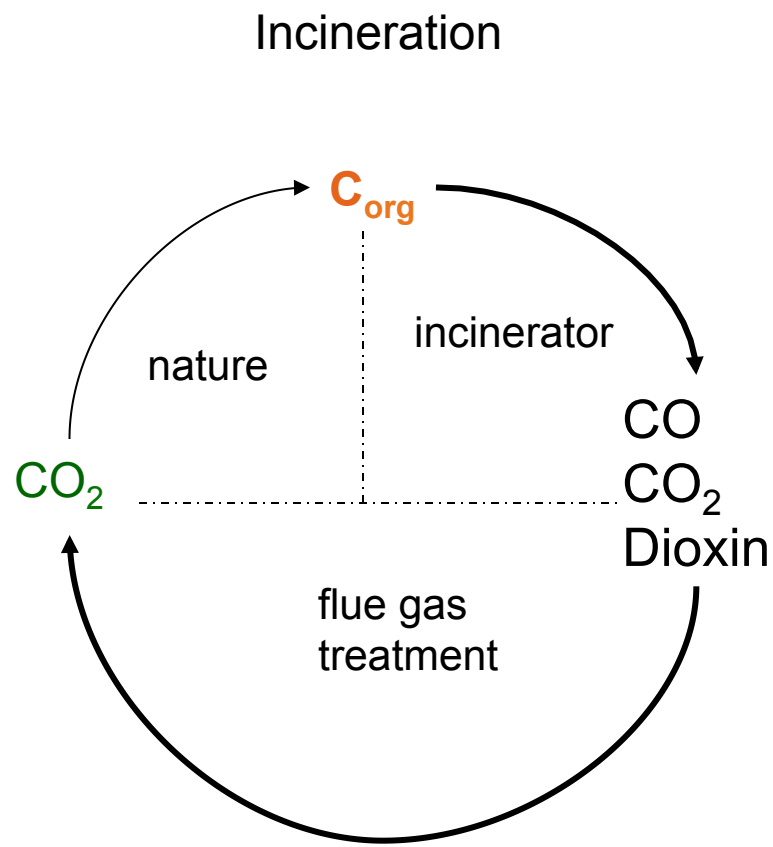

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Incineration

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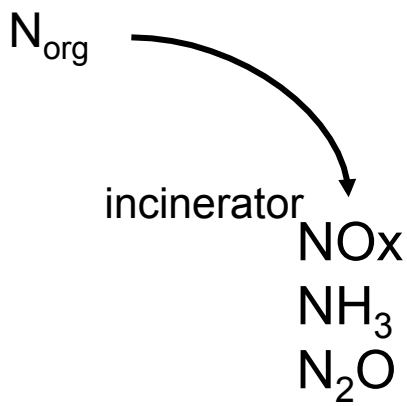

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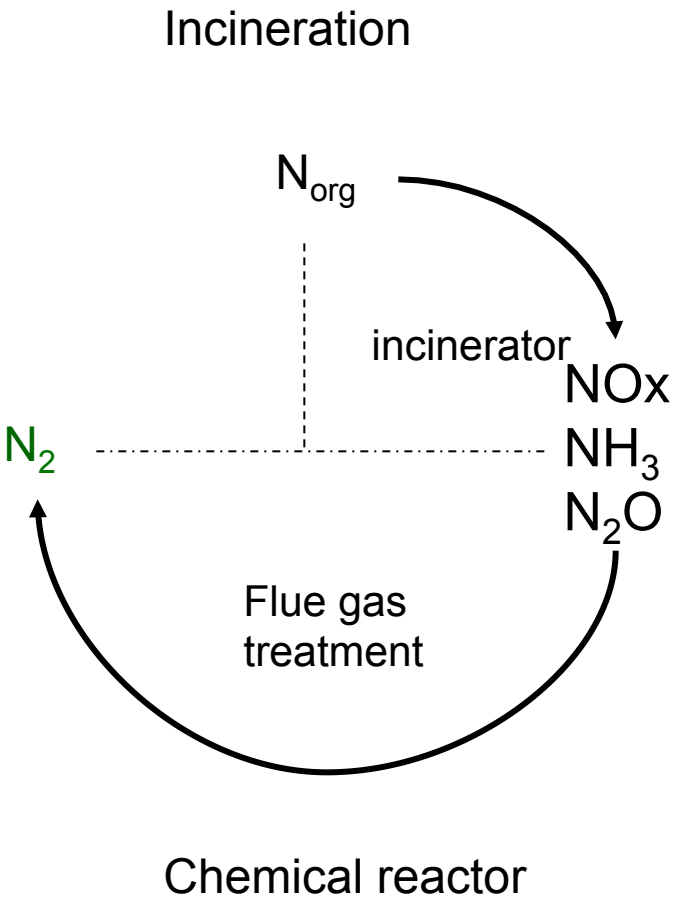

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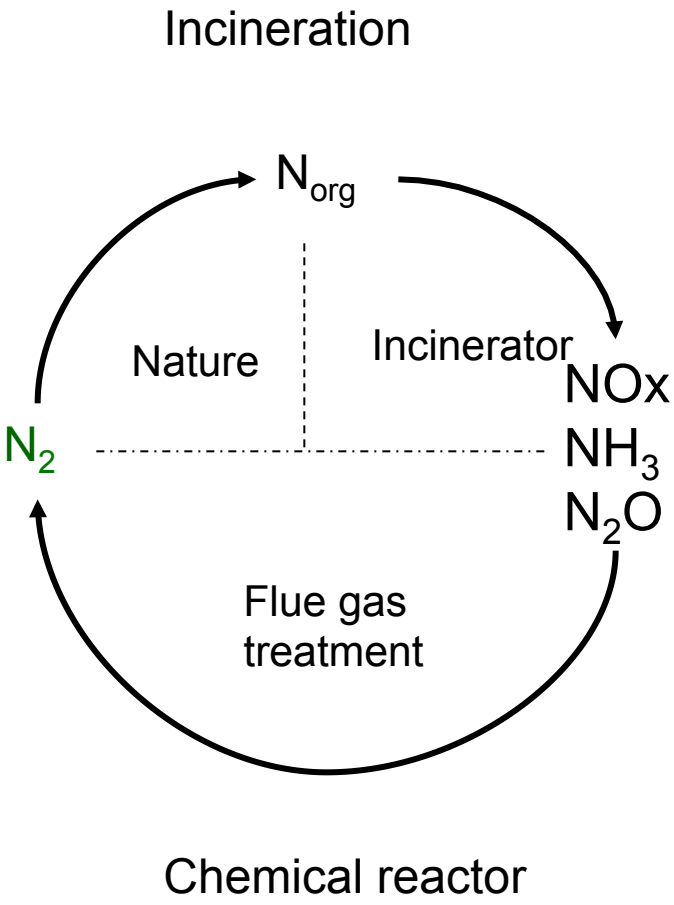

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2.1 Organic landfills are a waste treatment technique

Landfilling

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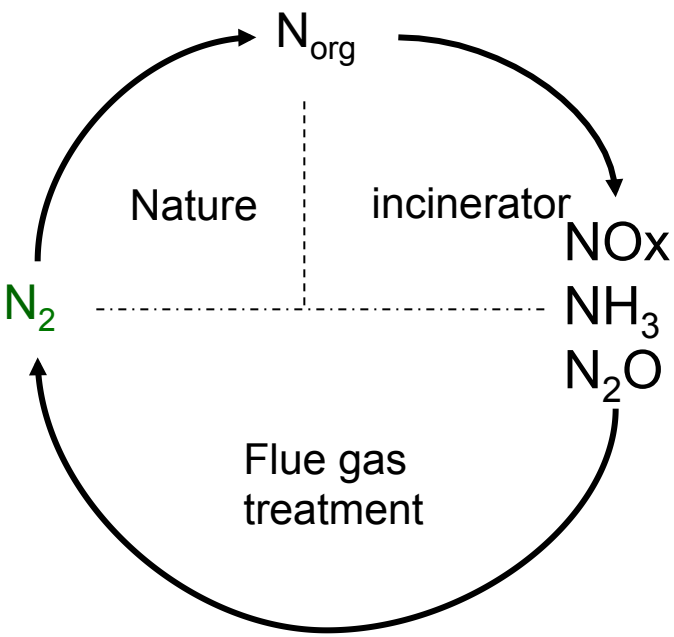
incineration



Chemical reactor

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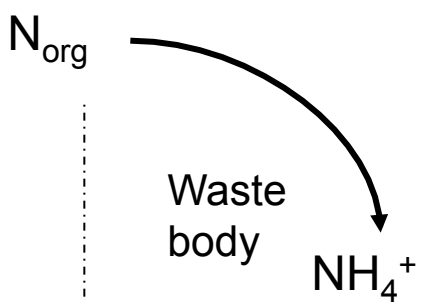
waste to energy

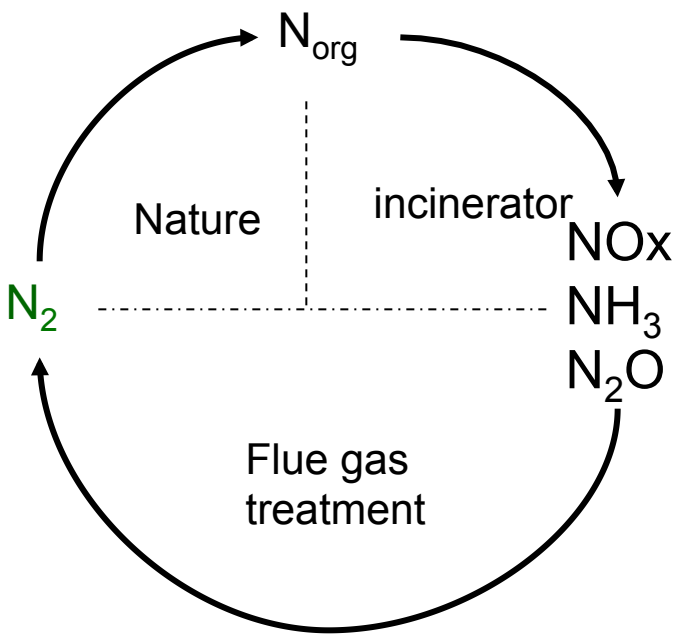
2.1 Organic landfills are a waste treatment technique

Landfilling



bio-reactor

incineration



Chemical reactor

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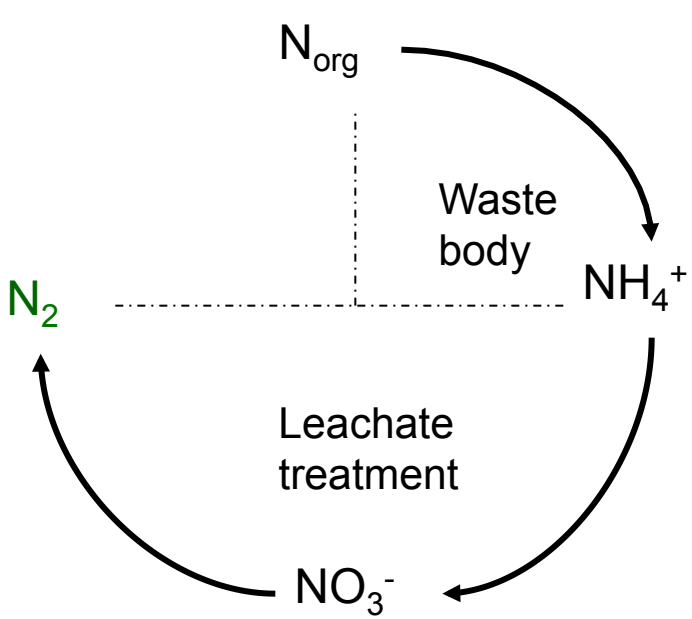
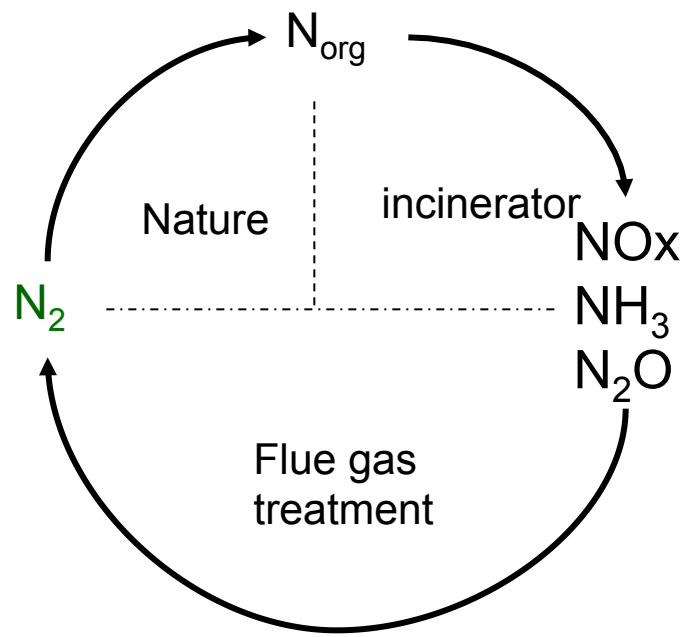
2.1 Organic landfills are a waste treatment technique

Landfilling



Flushing bio-reactor

incineration



Chemical reactor

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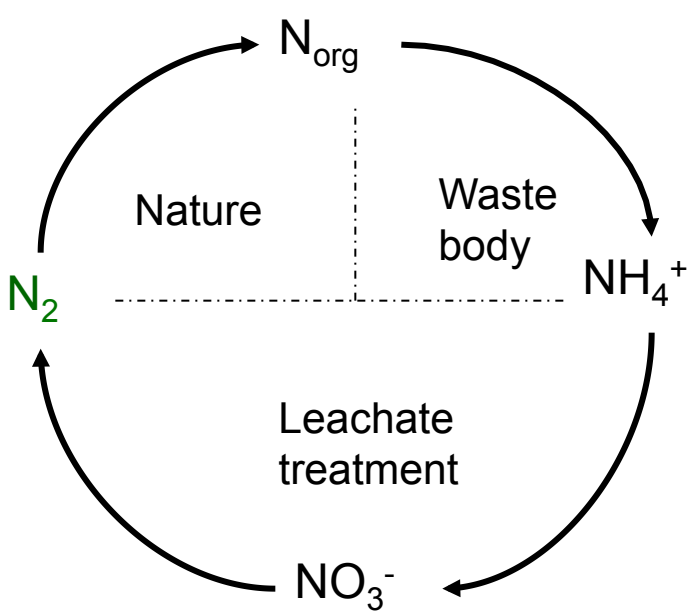
2.1 Organic landfills are a waste treatment technique

Landfilling



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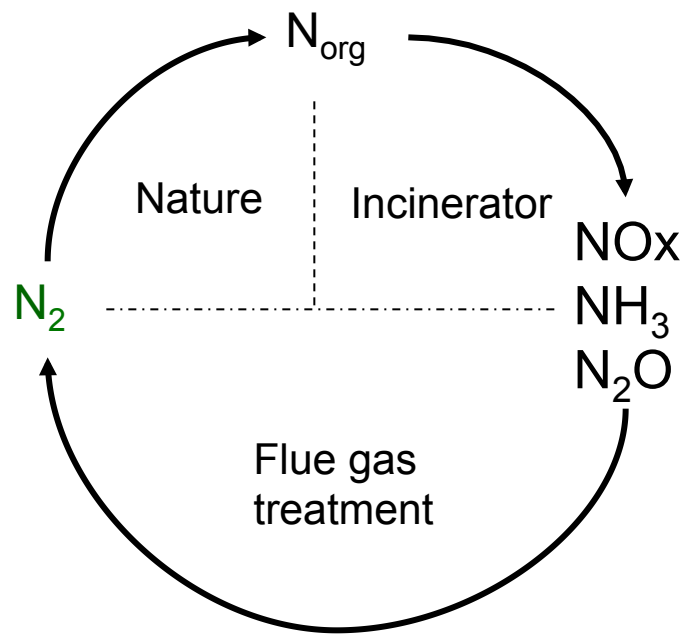

Chemical reactor

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2.1 Organic landfills are a waste treatment technique

- Sanitary landfilling
- Sustainable waste treatment if
  - landfill
  - + leachate treatment
  - + incineration

- Incineration
- Sustainable waste treatment if
  - Incineration + FGT
  - + landfill
  - + leachate treatment

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2.1 Organic landfills are a waste treatment technique

- Sanitary landfilling
- Sustainable waste treatment if
  - landfill
  - + leachate treatment
  - + incineration

- Long term: 20 years
- Low temperature
- Microbial degradation
- Non destructive
- Valuable end products
- Hign technology
- Low technique

- Incineration
- Sustainable waste treatment if
  - Incineration + FGT
  - + landfill
  - + leachate treatment

- Short term: 20 minutes
- High temperature
- Chemical degradation
- Destructive
- Low value end products
- Low technology
- High technique

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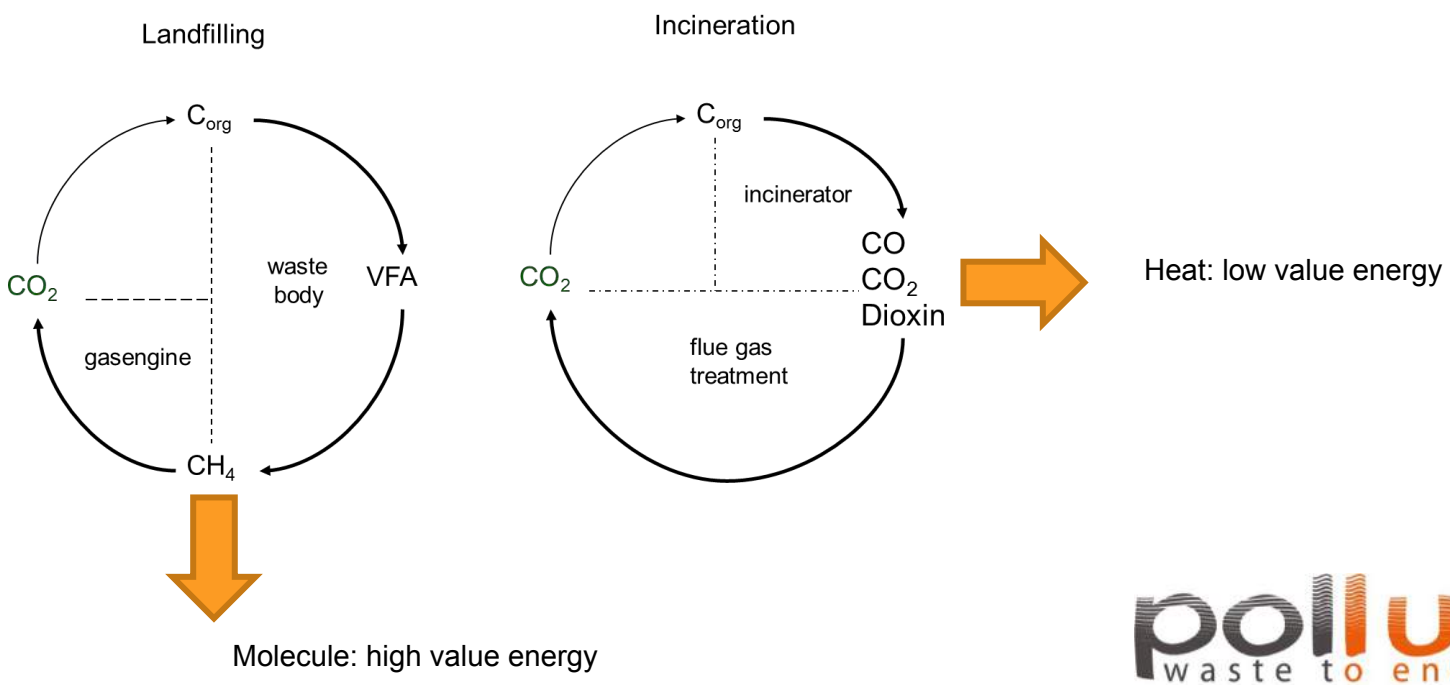
2.2 Waste treatment and electricity generation

- Environment of electricity shortage
  - Fuel to electricity
- Green electricity: waste to energy concept
  - Incineration: steam turbines: heat to electricity
  - Landfill: biogas engines/turbines: molecule to electricity



3. Future of organic landfills

Circular economy and Landfill mining

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3.1 Paradigm shift

The past: Fuel → Electricity

- **In the past: Need for electricity**
  - Abundance of fuel
  - Fuel used for electricity production
  - Green electricity

The future Fuel ← Electricity

- **The future:**
  - **Cheap abundant electricity**
    - Due to renawable (solar, wind, ..)
    - Already now: need for storage during peak production
    - Fight for the grid
    - Search for battery concepts (grid, physical battery, landfill, .)
  - **Scarcity of fuel + climate change ➔** electricity used for fuel production
    - H_2
    - Green fuel

- Impact on landfill
  - Past: green electrons
  - Future: green molecules: production and storage
  - Pollution potential vs mining potential

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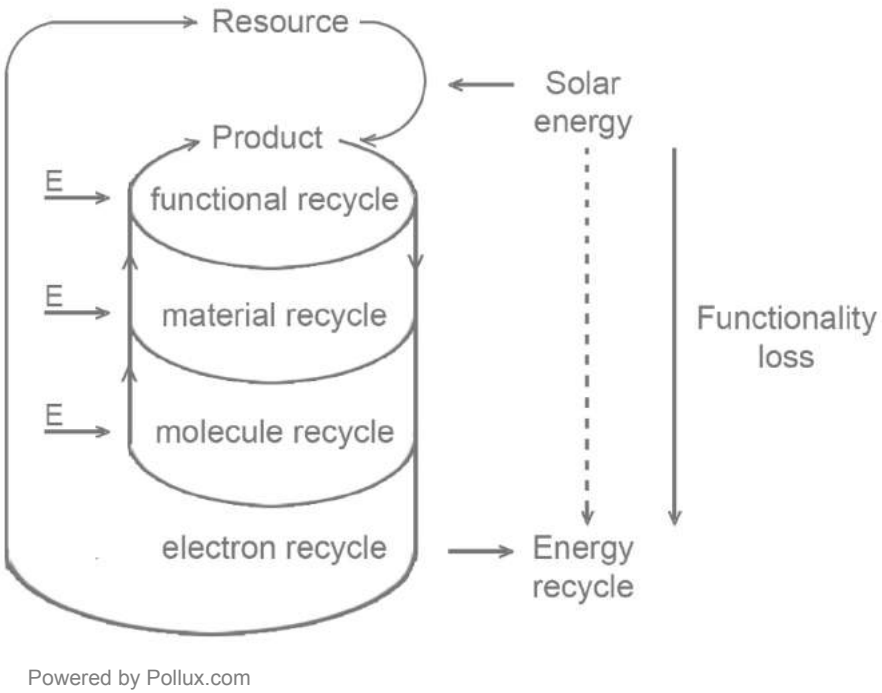
3.3 Circular economy

Treatment view

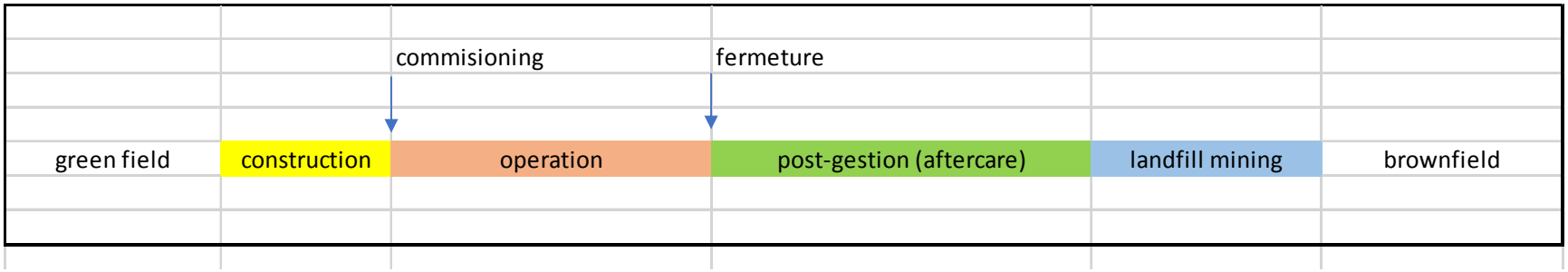
3.3 Circular economy



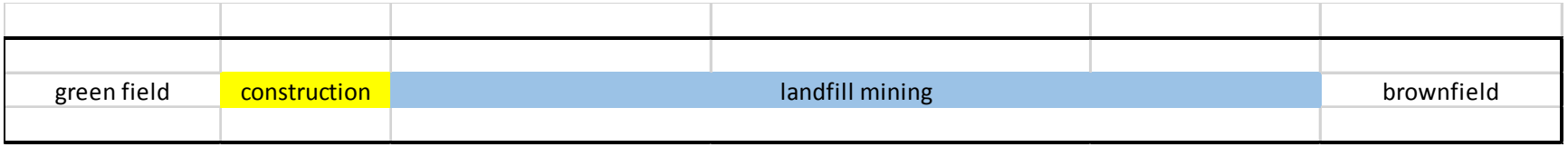
Treatment view

Resource view

3.4 An organic landfill destiny



- 30 years aftercare
- Afterwards: nobody cares



- Landfill mining: you try to take molecules out
- You have time: maybe up to 500 years

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3.5 landfill mining

green field	construction	landfill mining			brownfield

13 steps

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green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Step 1: Build reactor

- Isolate
  - The better your landfill isolation, the more time you have for mining
- Create internal pathways
  - In a later stage, you want to take out as much molecules as possible
  - Foresee
    - Escape ways (drainage layers) during landfill build up.
    - Water injection systems

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green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Step 2 Make an inventory

- Know your“ potential mining capacity”
- Landfill
  - Don’t drill at the end
  - Make an inventory from the beginning
    - Monitor what you landfill
    - Monitor what you mine
    - Mass balances
- Format:
    - Excel files: how much in and out
    - 3D models: where is it

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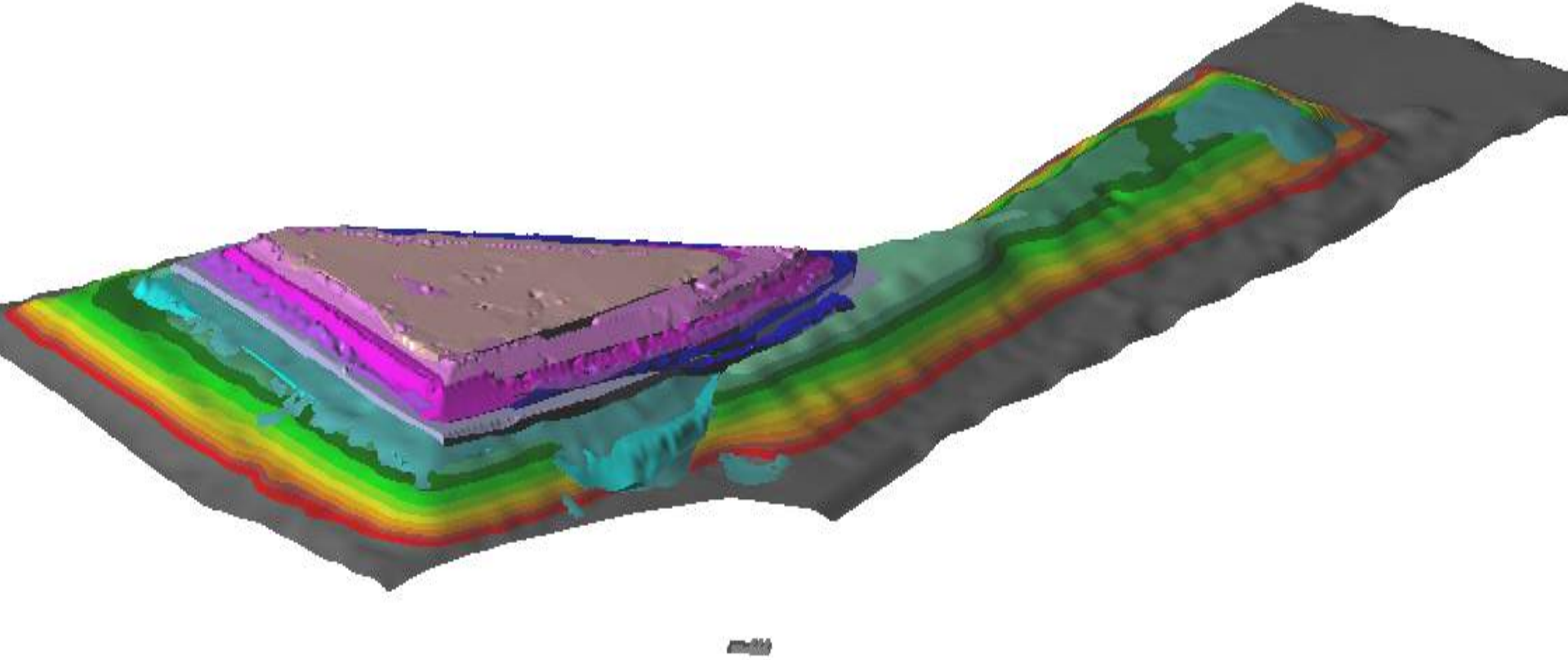
Step 2 Make an inventory



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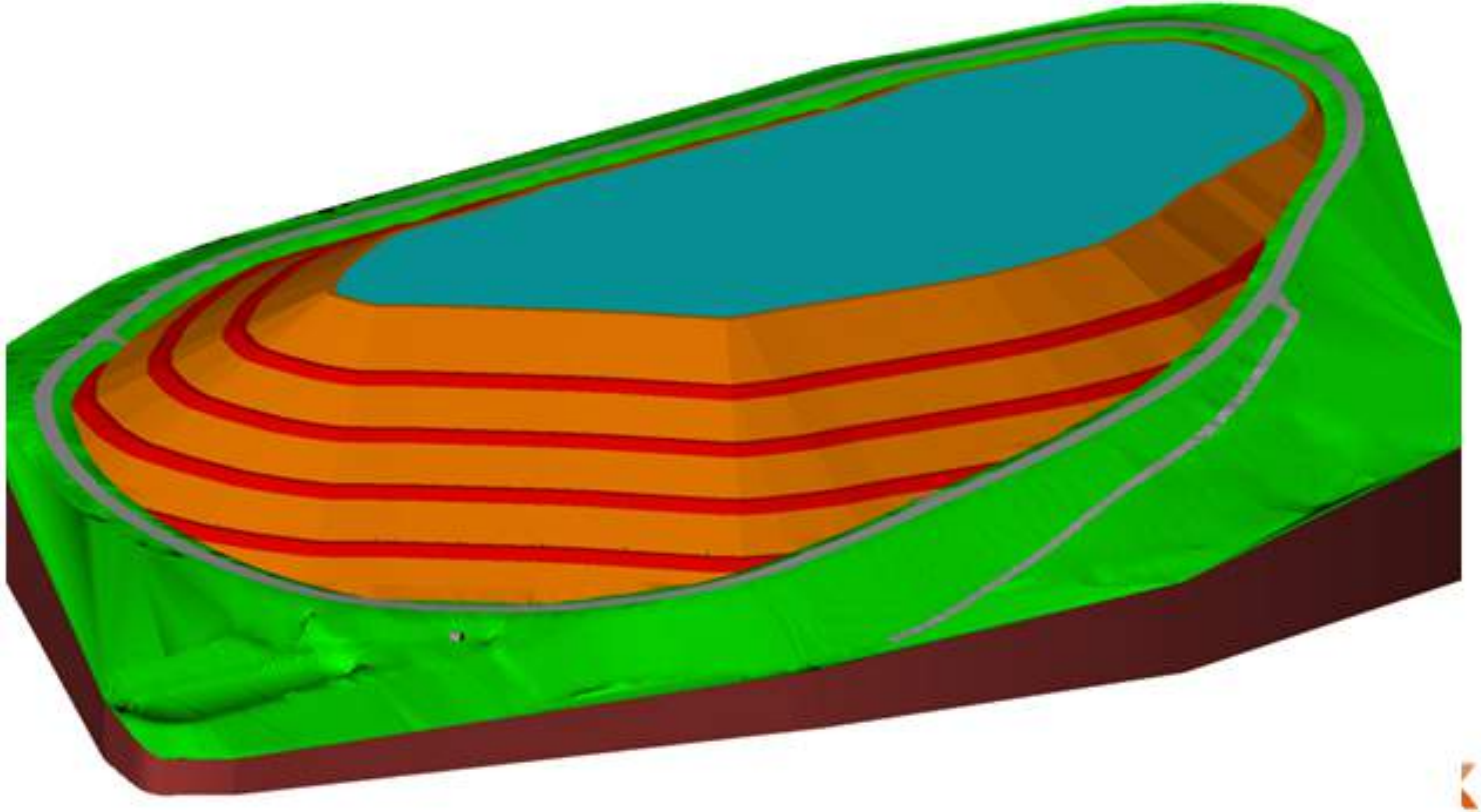
Samsun, Turkey



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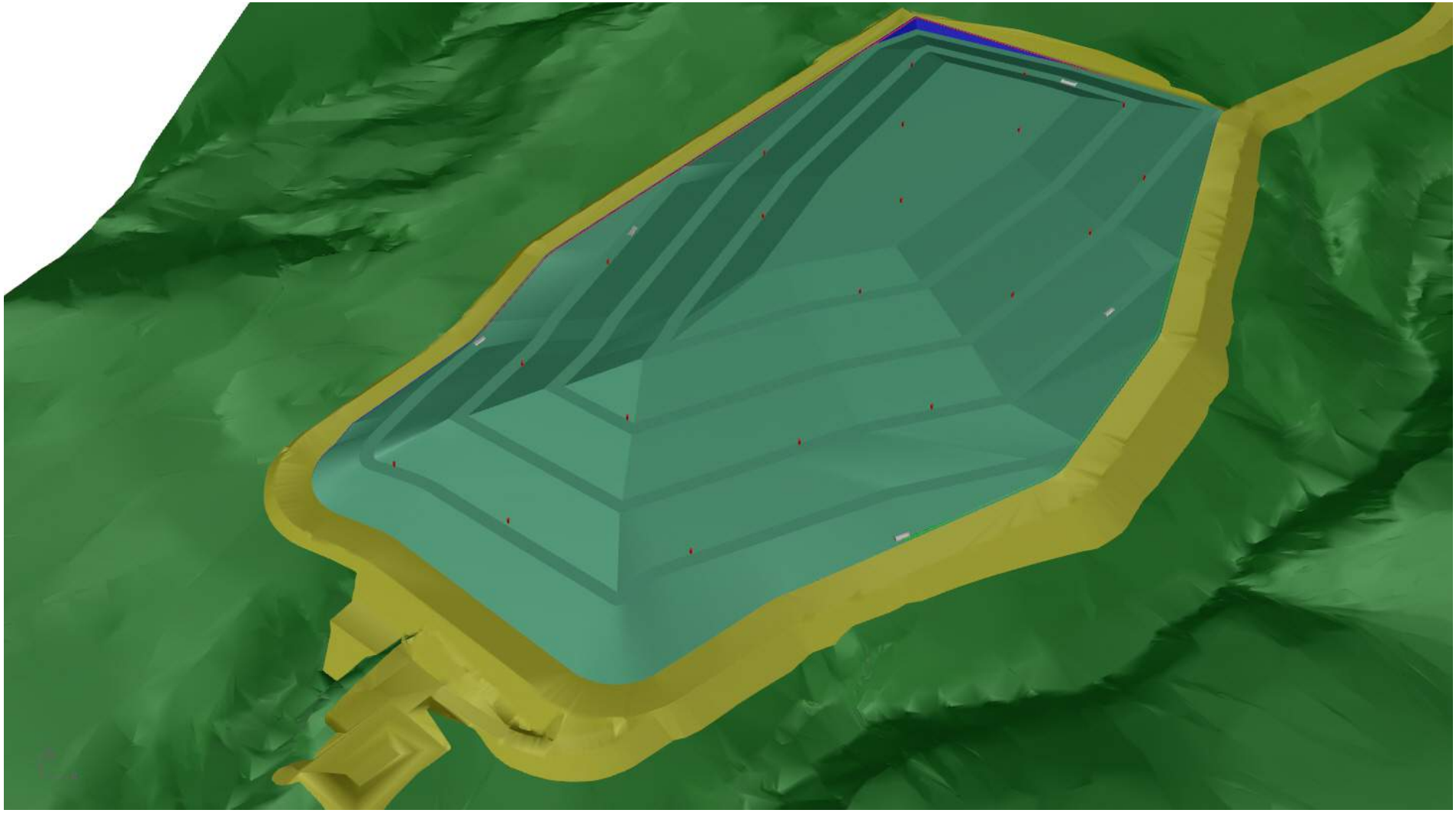
Kostinbrot, Bulgaria



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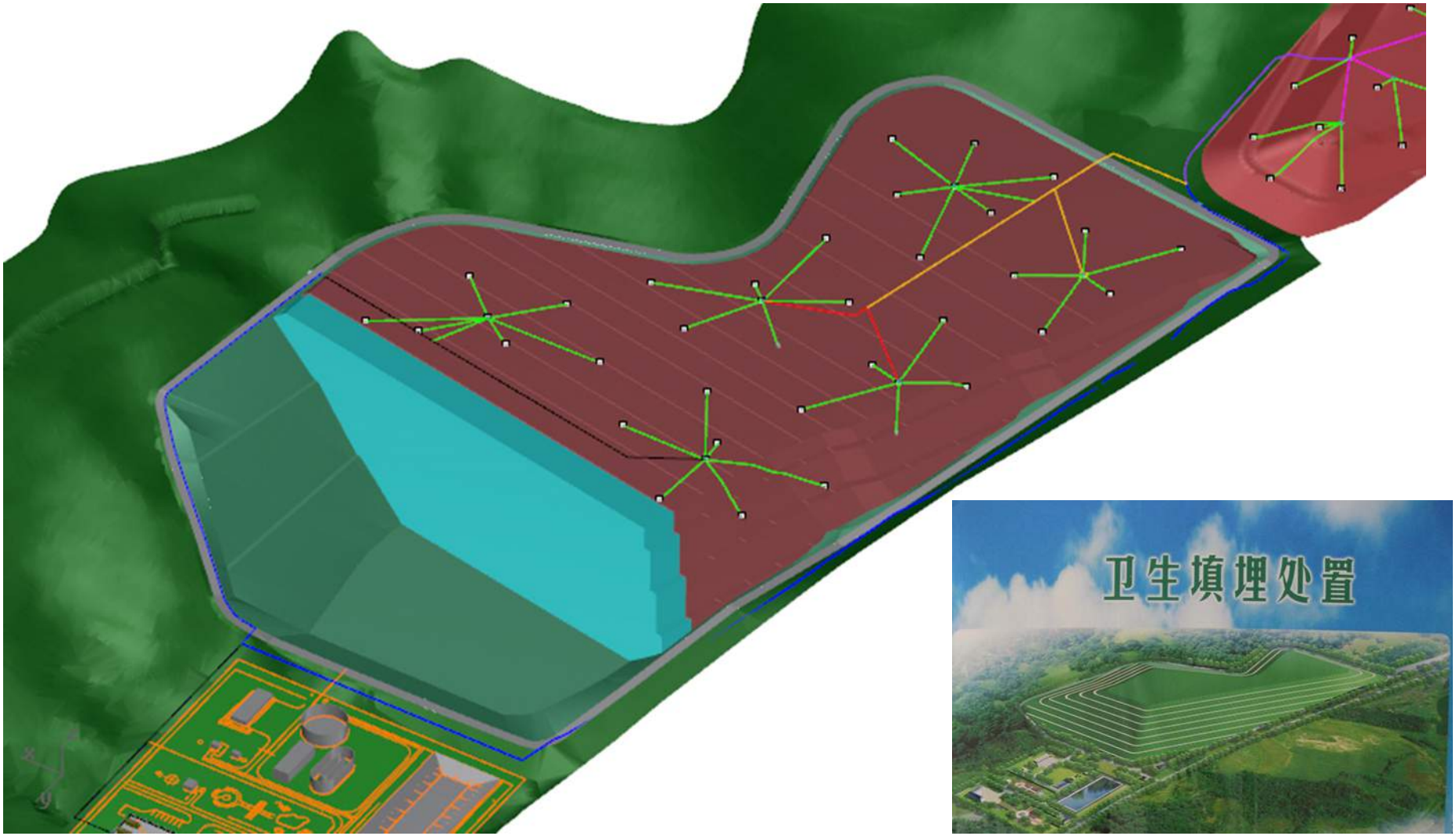
Chaohu, China



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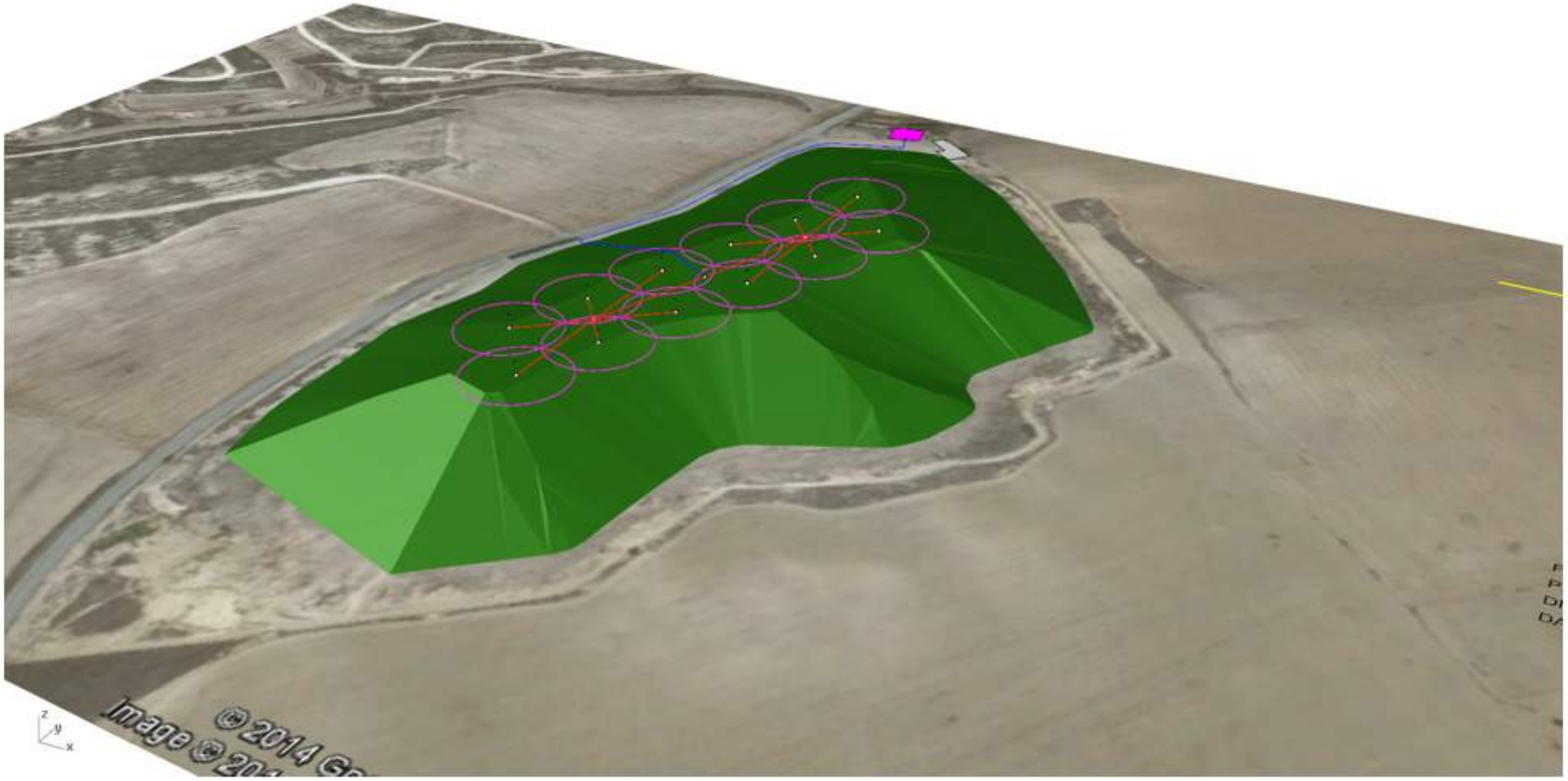
Larnaca, Cyprus



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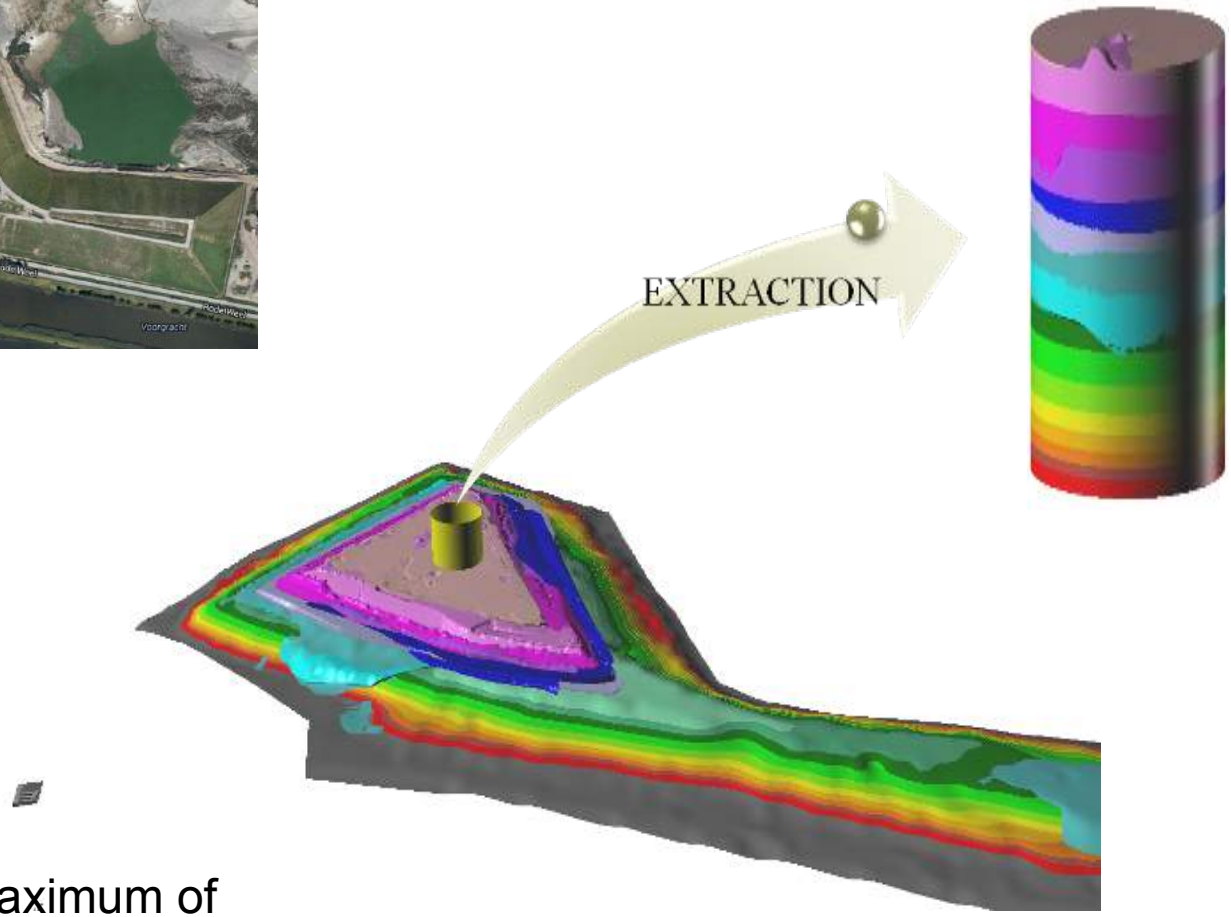

Do it for a maximum of components

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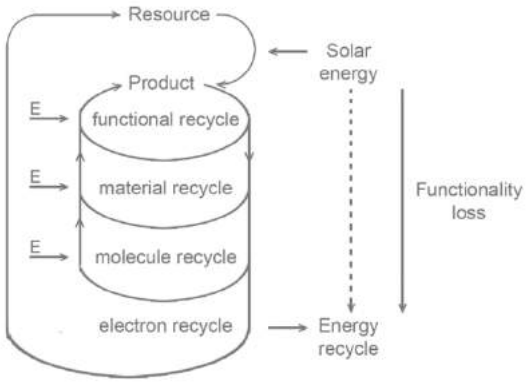
green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Stap 3: “Front door” mining

- Marrakech landfill
  - Selective collection at landfill gate

- Change the front door:
  - From “landfill gate” to “house door”



- Very important step in landfill mining
  - Keep it at material level

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Step 4:

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green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Step 4: Crush the waste and Provide water

- Start up of hydrolyis
- Cut waste in elementary molecules and dissolve in the liquid phase:
  - C
  - N
  - P
  - S
  - Salts
- Ready for mining of molecules:
  - via liquid phase: flushing
  - via gaseous phase: biodegradation

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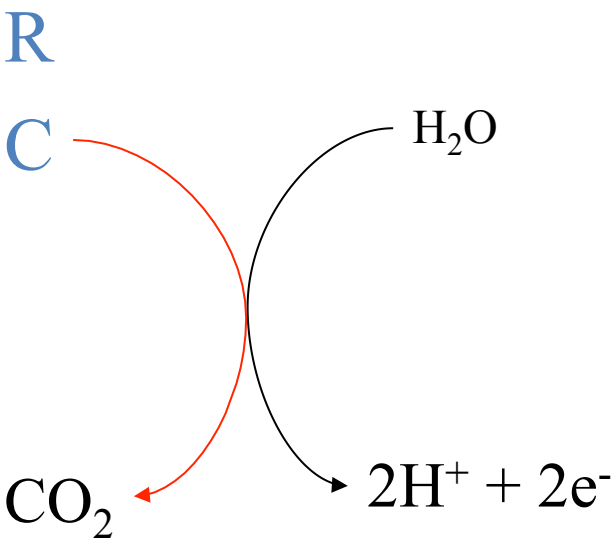
Step 4: Crush and Provide water



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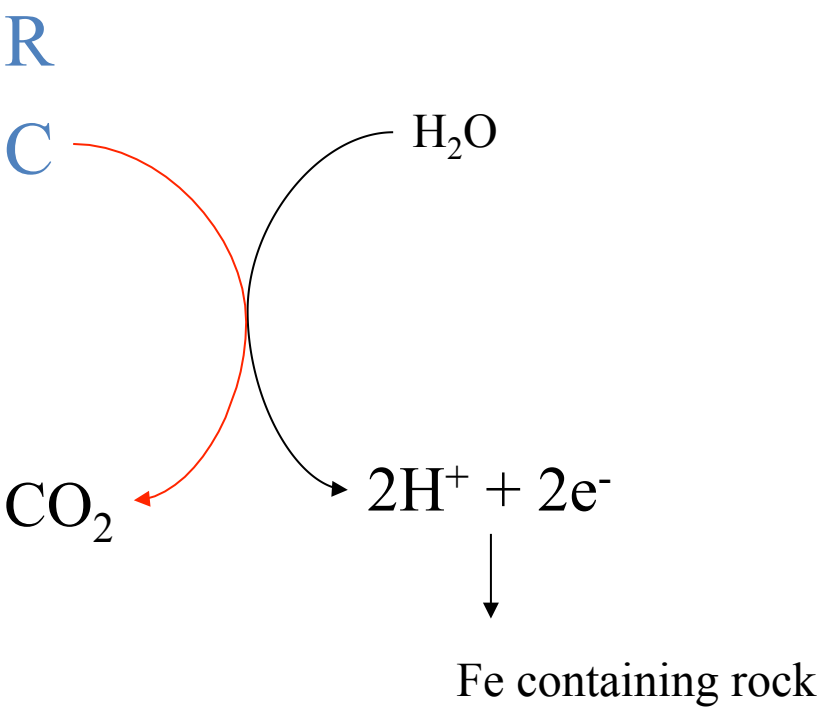

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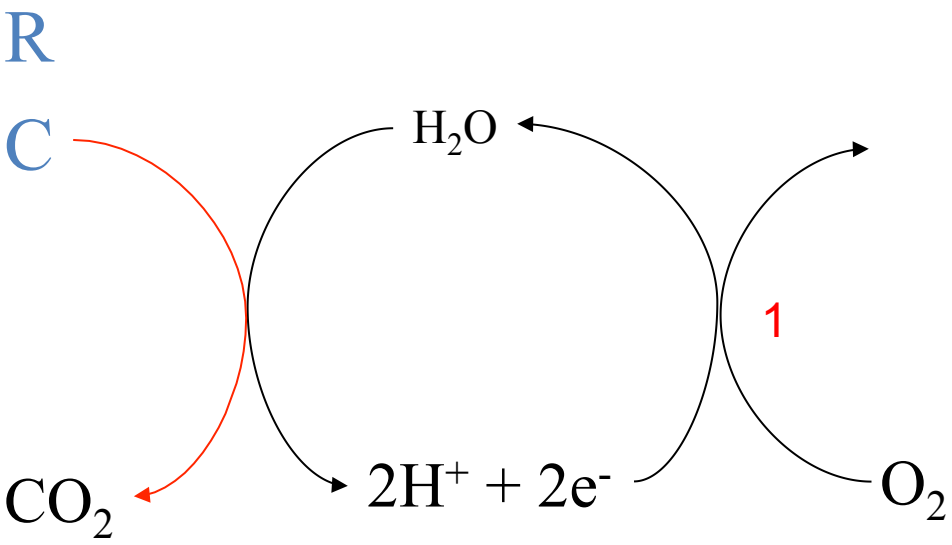

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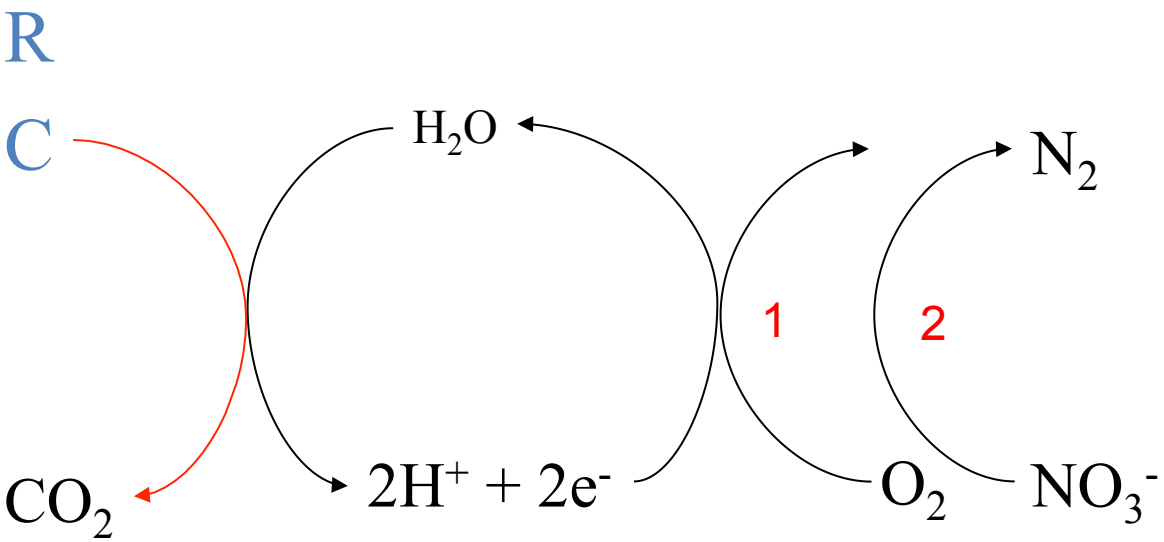

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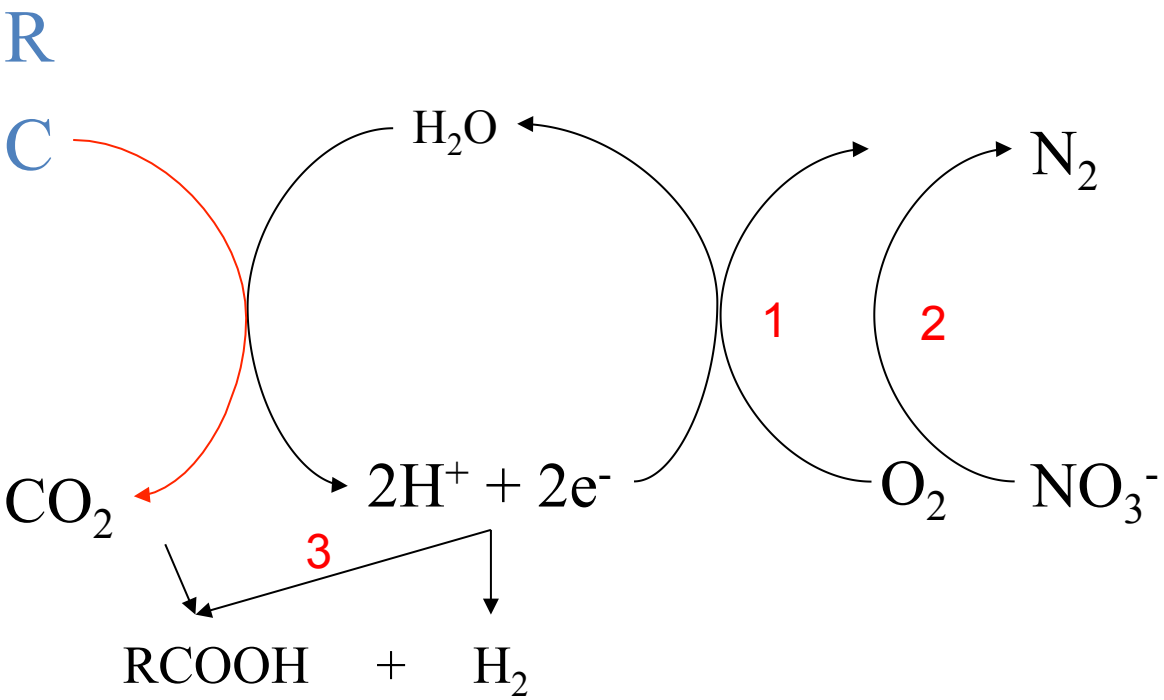

Acetaat:
CH_3COOH

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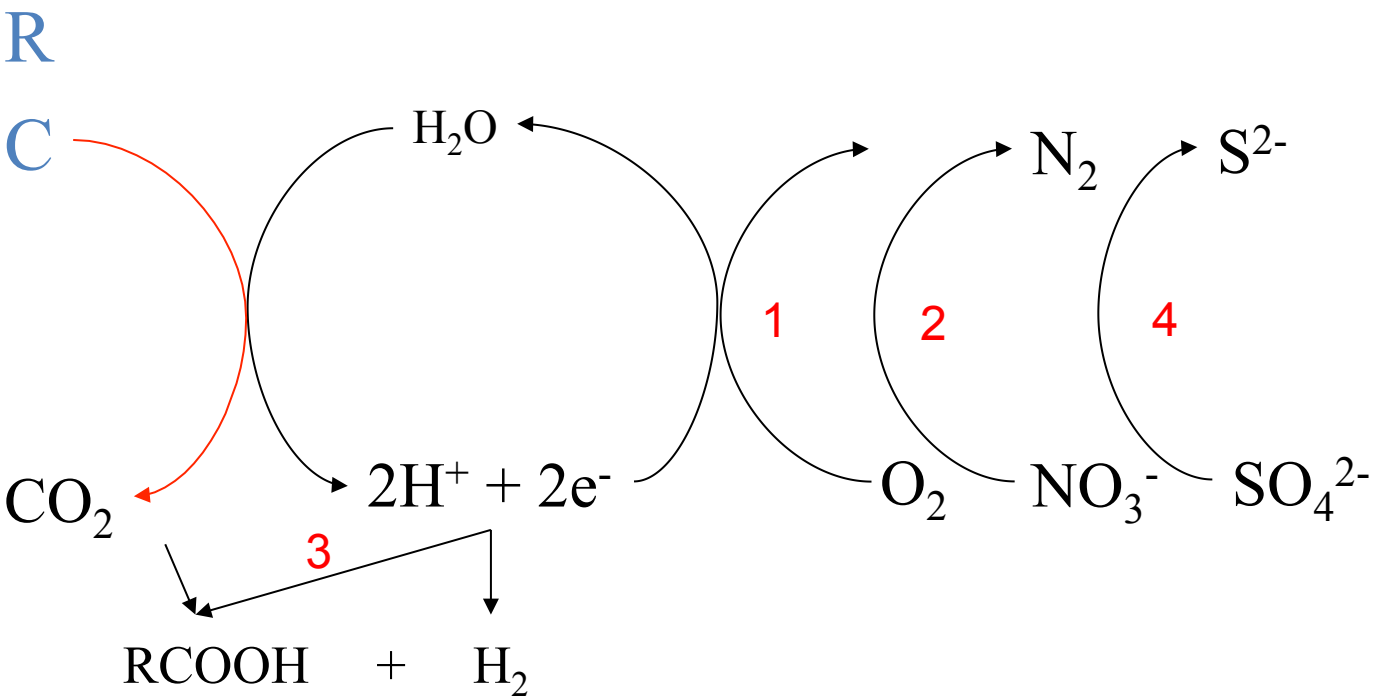
Step 4: Crush and Provide water



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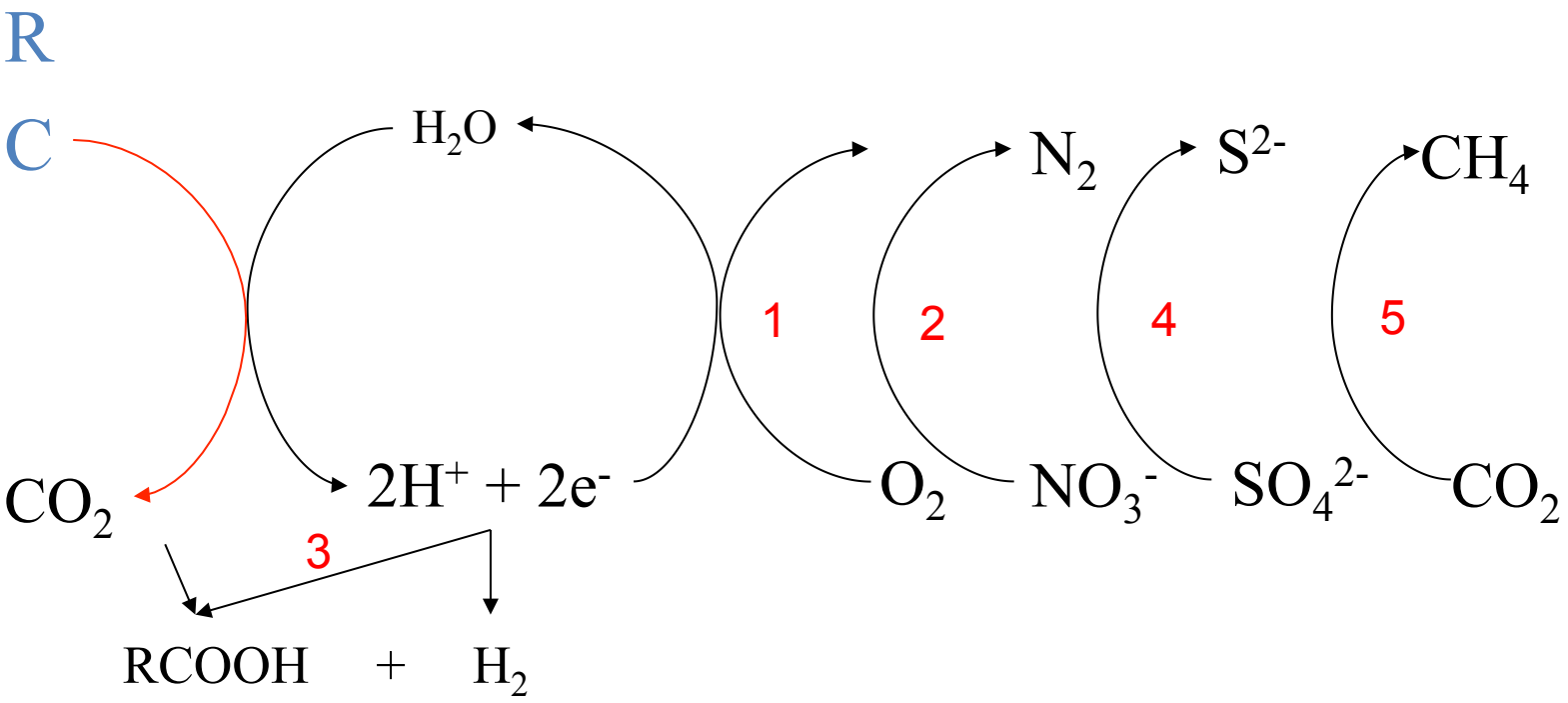

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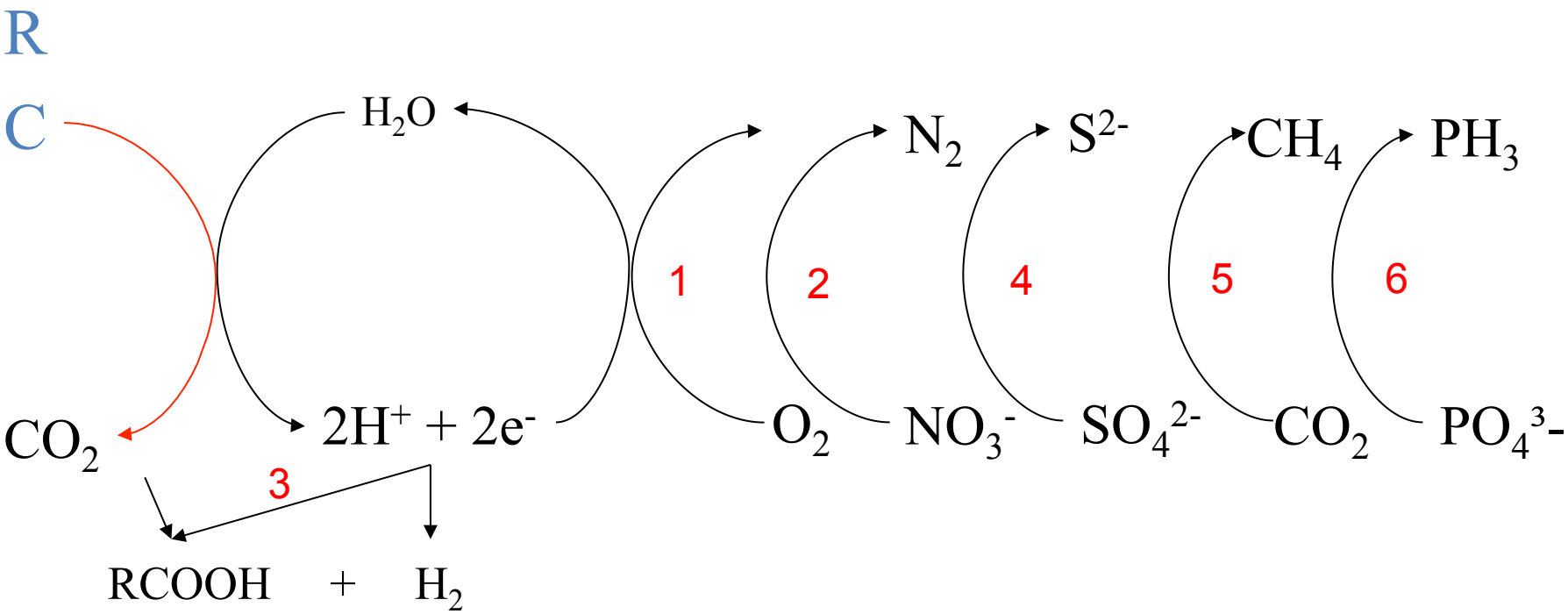
CH_3COOH

Step 4: Crush and Provide water

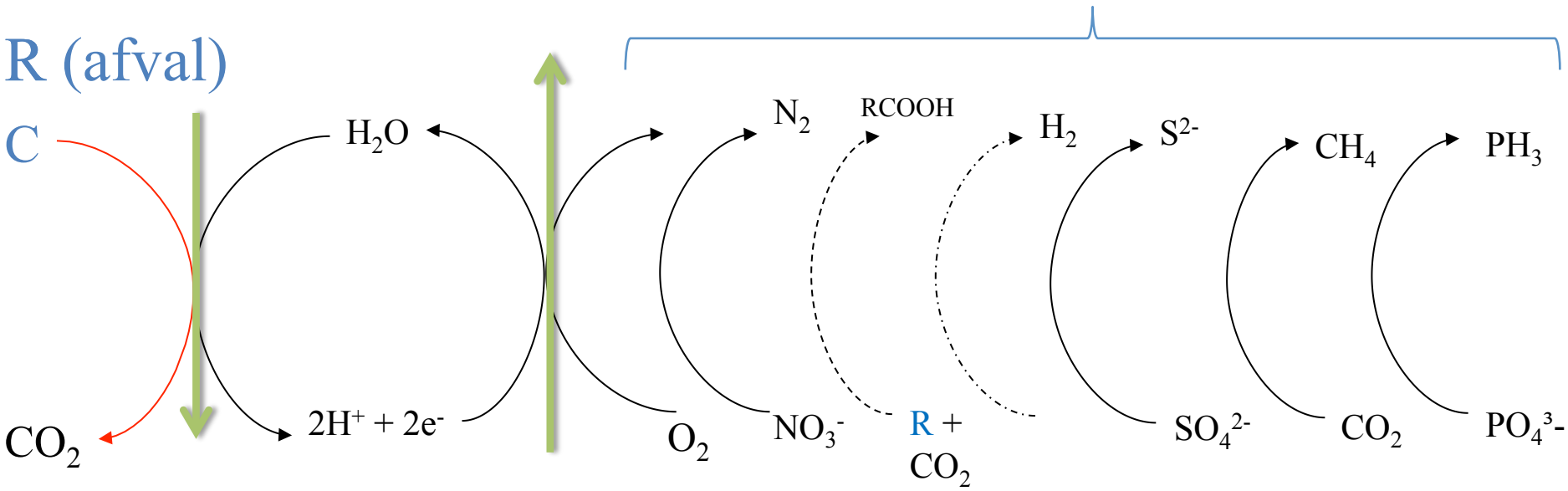


Acetaat:
CH_3COOH

green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Step 4: Crush and Provide water

All these processes occur in the landfill



- Landfill: conversion from solid to liquid and gas
- Mining of energy rich molecules:
  - via liquid and gaseous phase
  - Not only C, but also S and P as energy rich molecule
  - No incentive
  - S considered as pollutant of biogas

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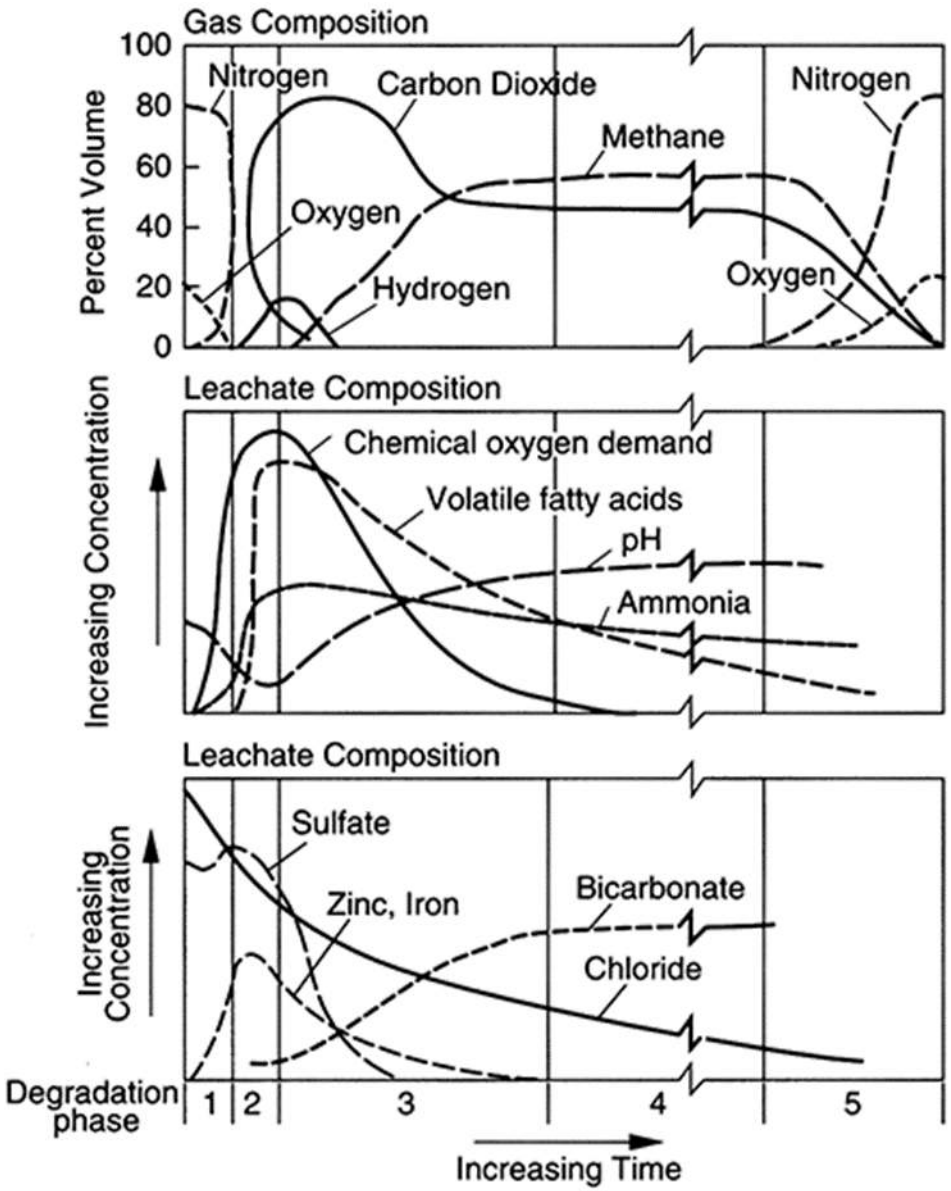
Step 4: Crush and Provide water



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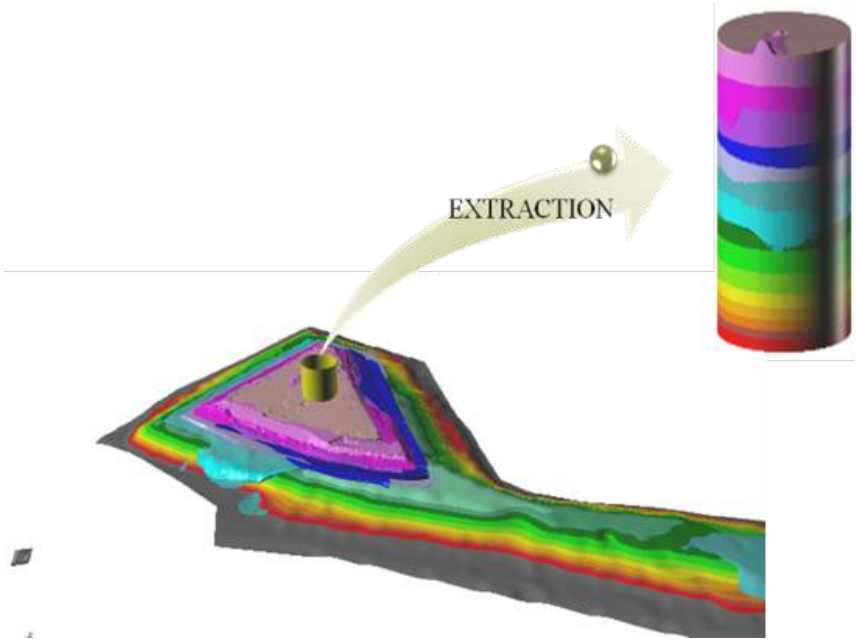
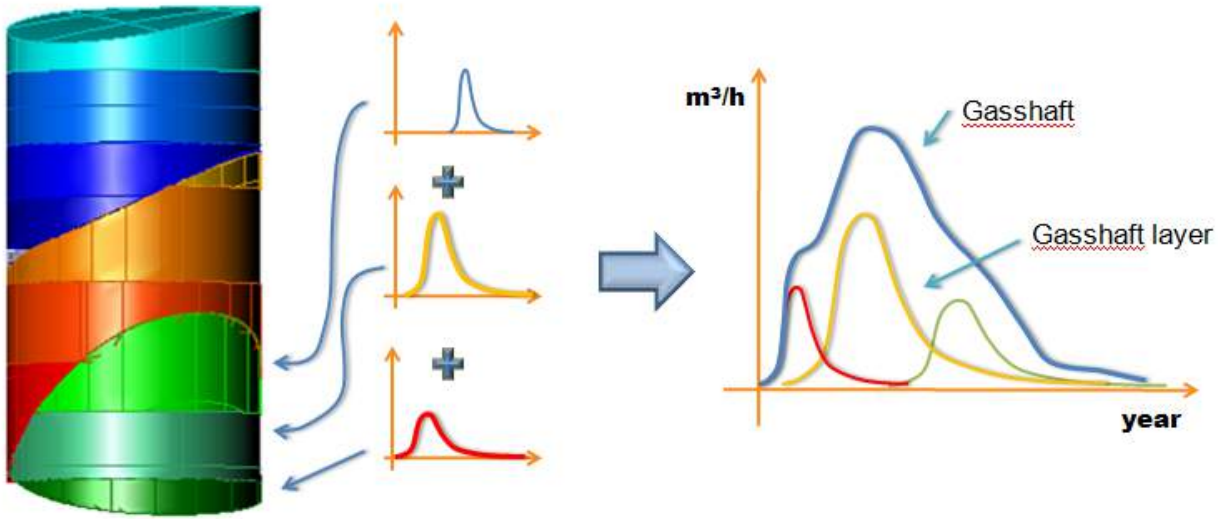
Step 5 C-mining





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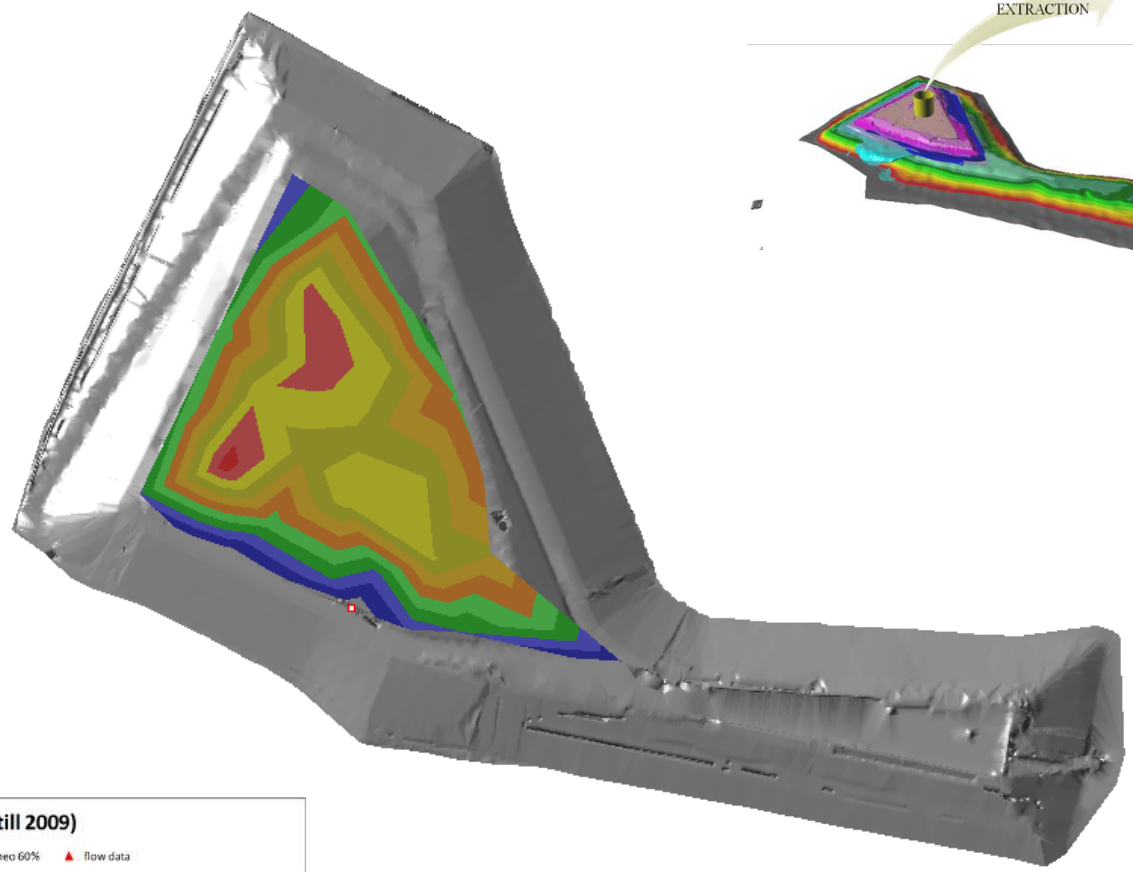
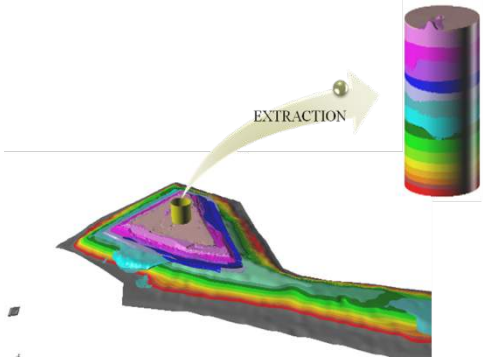
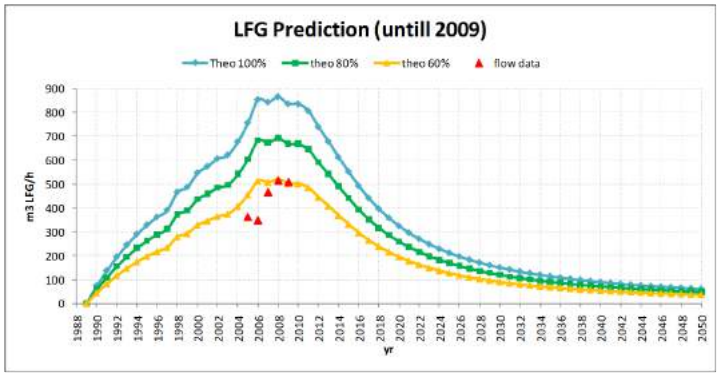
Step 5 C-mining

- 10 m³/h
- 15 m³/h
- 20 m³/h
- 25 m³/h
- 30 m³/h
- 35 m³/h
- 40 m³/h
- 45 m³/h
- 50 m³/h
- 55 m³/h







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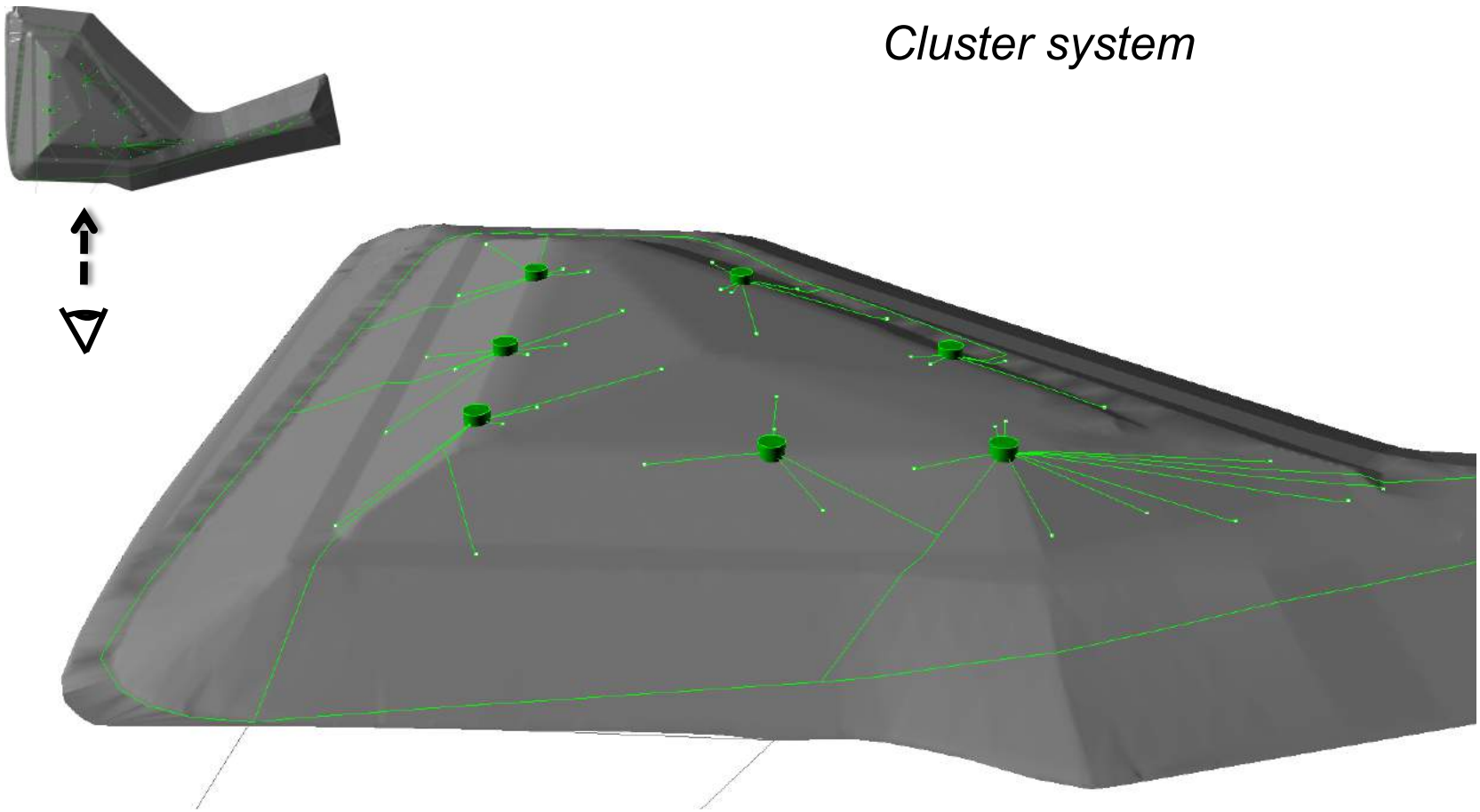
Step 5 C-mining



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Step 5: C mining

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Step 6 S mining

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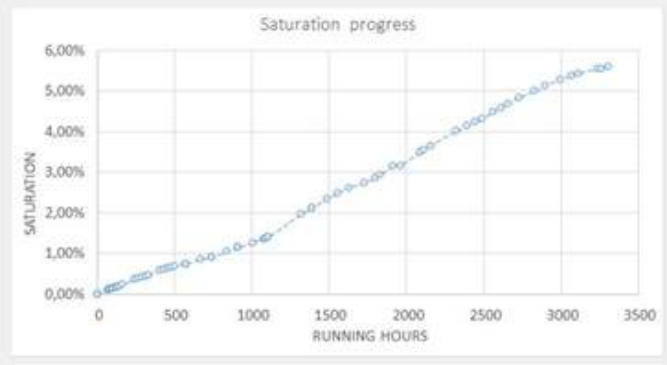
Step 6 S mining

- Removal by means of bottom ash filter



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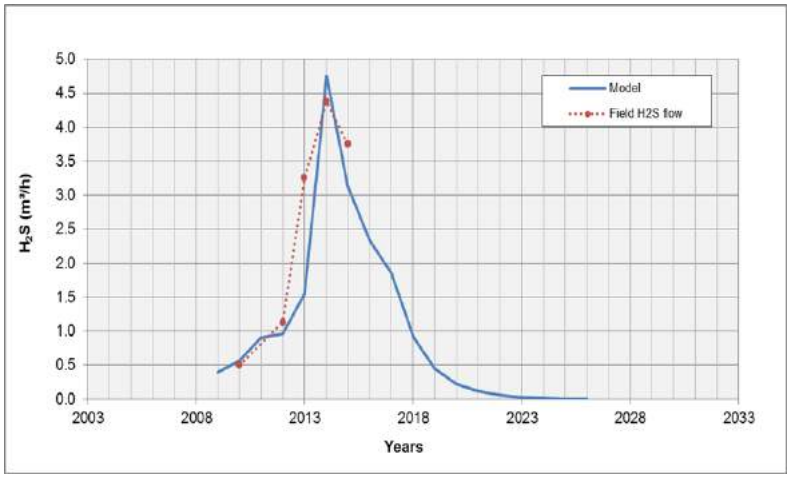
Step 6 S mining

- Recycle of RO concentrate in the landfill
- H_2S stripping and oxydation to S



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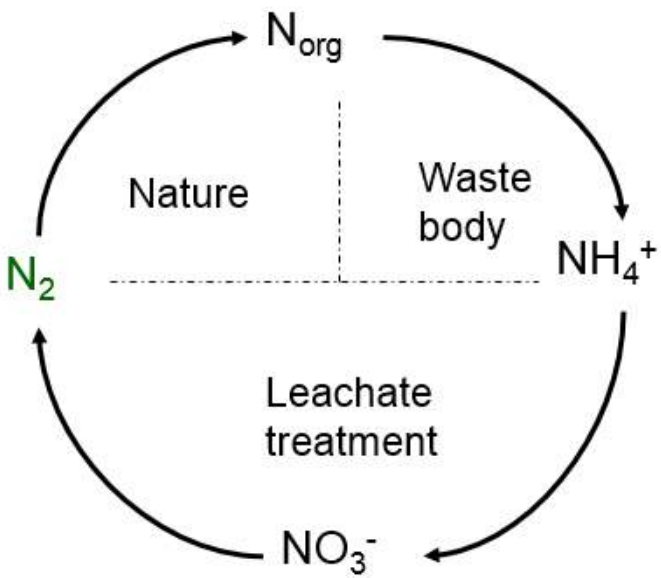
waste to energy

green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Step 7 N-mining

- N has a separate microbial pathway
- Waterline
- No incentive for green nitrogen
- ➔ costly destruction in leachate treatment
  - Nitrification and denitrification



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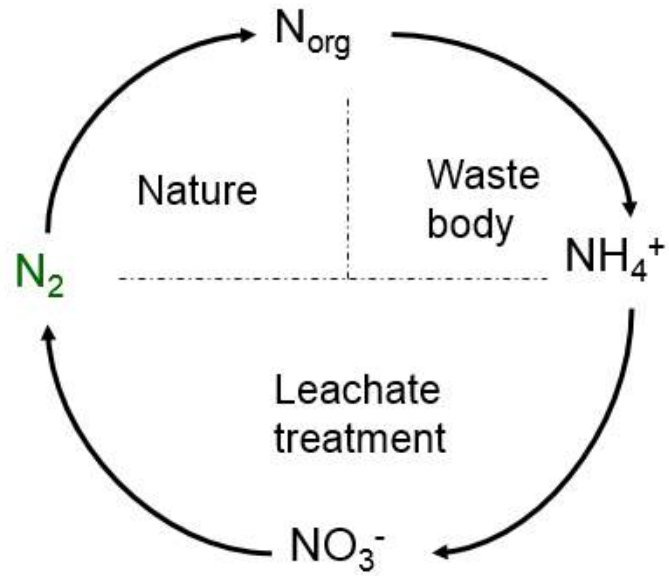
Step 7 N-mining

- N has a separate microbial pathway: NH_4^+
- Waterline
- No incentive for green nitrogen
- ➔ costly destruction in leachate treatment
  - Nitrification and denitrification

- Mining option: by adding the other sources
  - NH_4^+ from leachate
  - CO_2 from the biogas engines
  - Green Electricity ➔ light
  - Green Heat
  - Growth of algae:
    - Biofuel



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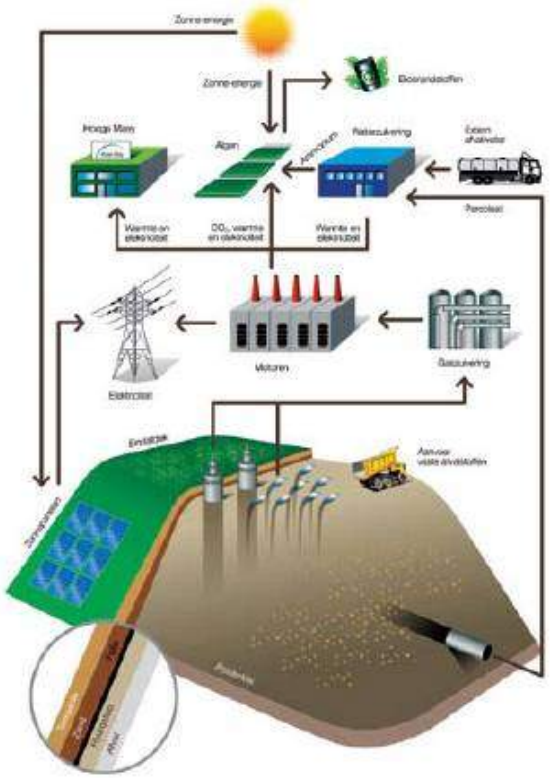
Step 7 N-mining

Algenproject Hooge Maey door Cleantech verkozen tot beste MIP2-project



Sedert iets meer dan een jaar bevindt zich op de Hooge Maey een algenplantage. Die maakt deel uit van het 'Alchemis'-project dat onderzoekt hoe algen als alternatieve grondstof kunnen ingezet worden in de (chemische) industrie. Het percolaat van de stortplaats doet dienst als voedingsbron en de stortgasmotoren leveren CO_2, elektriciteit en warmte. Het project is een samenwerking tussen diverse partners en geniet de steun van MIP2. Op 20 oktober werd het tijdens het Cleantech-festival Vlaanderen in aanwezigheid van Minister Lieten verkozen tot 'beste MIP2 project'.

Algen als oplossing voor schaarste van fossiele grondstoffen?

Schaarsheid van fossiele grondstoffen en de noodzaak om iets te ondernemen naar klimaatverandering dwingen de chemische sector om alternatieve grondstoffen te zoeken en de broeikasgassen te verminderen. Een potentiële oplossing voor beide problemen wordt geboden door algen. In een traditionele algenplantage zou het energie-verbruik en het gebruik van nutriënten op basis van fossiele brandstoffen de kosten de hoogte injagen. Ook zou men de duurzaamheid van een dergelijk project moeten in vraag stellen. Vandaar dat de Hooge Maey met haar randinfrastructuur een ideale oplossing bood om dit probleem te verhelpen. Immers, de eigen waterzuiveringsinstallatie, de stortgasmotoren én de beschikbare ruimte komen tegemoet aan nagenoeg alle noden van een algenplantage. De Hooge Maey is dan ook een belangrijke partner in dit MIP2-project. Bovendien bouwde de Hooge Maey in de loop der jaren heel wat knowhow op met betrekking tot de samenstelling van percolaat. Zo is gebleken dat het ammonium dat erin aanwezig is (NH_4), als nutriënt kan dienen voor de algen. Deze praktijkervaring komt het onderzoek zeker ten goede.

Opstart getoond tijdens Openbedrijvendag 2010

Het project ging van start in april 2010. Tijdens de Openbedrijvendag in okober 2010 kon een eerste opstelling getoond worden aan de 2 000 bezoekers van de Hooge Maey. Intussen werd al heel wat knowhow uitgewisseld op diverse wetenschappelijke fora.

Erkenning door Cleantech - oktober 2011

Recent kreeg het project een mooie erkenning door Cleantech. Tijdens het Cleantech-festival werd het bekroond met de prijs van beste MIP2-project. Naast de waardering voor de bijdrage die het onderzoek levert inzake eco-innovatie, houdt de prijs in dat Alchemis een promotiefilm ter waarde van 2 000 euro mag laten maken door een professionele cameraploeg.
Minister Ingrid Lieten, viceminister-president van de Vlaamse regering en tevens bevoegd voor onder andere innovatie bezocht de diverse projecten die tijdens een postersessie een tussentijds verslag gaven van hun onderzoek.

Meer informatie
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daniel.dirickx@indaver.be

pollux waste to energy

green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Step 8 Salts

- Na, K, Cl, fosfates, etc
- Just walk out via the waterline
- Again no financial incentive: so discharge
- Salt mining would be possible
    - Reversed osmosis
    - Evaporation

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Step 9 Functionality mining

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Step 9 Functionality mining

- Biological waste water treatment sludge:

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Step 9 Functionality mining

- Biological waste water treatment sludge:
  - Activated sludge

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Step 9 Functionality mining

- Biological waste water treatment sludge:
  - Activated sludge: for free (you pay for the truck)

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Step 9 Functionality mining

- Biological waste water treatment sludge:
  - Activated sludge: for free
  - Nitrifying sludge:

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Step 9 Functionality mining

- Biological waste water treatment sludge:
  - Activated sludge: for free
  - Nitrifying sludge: for free, if you are lucky

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Step 9 Functionality mining

- Biological waste water treatment sludge:
  - Activated sludge: for free
  - Nitrifying sludge: for free, if you are lucky
  - Anaerobic sludge:

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Step 9 Functionality mining

- Biological waste water treatment sludge:
  - Activated sludge: for free
  - Nitrifying sludge: for free, if you are lucky
  - Anaerobic sludge: 3.000 €/truck
    - 1.500 € ton/DM of anaerobic sludge

pollux waste to energy

green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Step 9 Functionality mining

- Anaerobic sludge: 3.000 €/truck:
  - 1.500 € ton DM of anaerobic sludge
- The landfill is full of anaerobic bacteria: enormous potential as
  - anaerobic waste water treatment plant
  - Anaerobic waste gas treatment plant
- Landfill:
  - It is a reactor (remember step 1)
  - Anaerobic (remember step 5)
  - During operation:
    - input of solids
    - Input of acetogenic leachate from new phase
  - After closure: input of organic liquid and organic or inorganic gas
    - Further flushing of molecules by water (remember step 4)
    - Continuous methane production

pollux waste to energy

green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Step 9 Functionality mining

- New project development starting subsidie phase
- Landfill body:
  - Conversion of waste ➔ CO_2 and H_2 ➔ CH_4
    - 60 % CH_4
    - 40 % CO_2
  - What if we inject H2 in the waste body: will react with 40 % CO2
    - ➔ 100 % CH_4: natural gas
- Eventually we run out of waste and CO_2 and H_2
- What if we inject:
  - CO_2 from the adjacent incineration
  - H_2 produce from solar farm on the slopes of the landfill:
    - Waste CO_2 + green H_2 ➔ CH_4 ➔ green natural gas

pollux waste to energy

Step 9 Functionality mining

- Integrated projects:
- Combination of:
    - Cement production
    - Landfill
    - Sewage treatment plant
- Aftercare periods might take a long time, without any income except for the build up funds
  - Might get short at low intrest rates
  - Functionality mining allows revenues during aftercare

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green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

Step 10 Heavy metal mining

- During operation no problems with heavy metals
- Precipitation under the form of sulfides
    - FeS: black colour
    - CdS, ZnS, PbS, CuS, etc

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Step 10 Heavy metal mining

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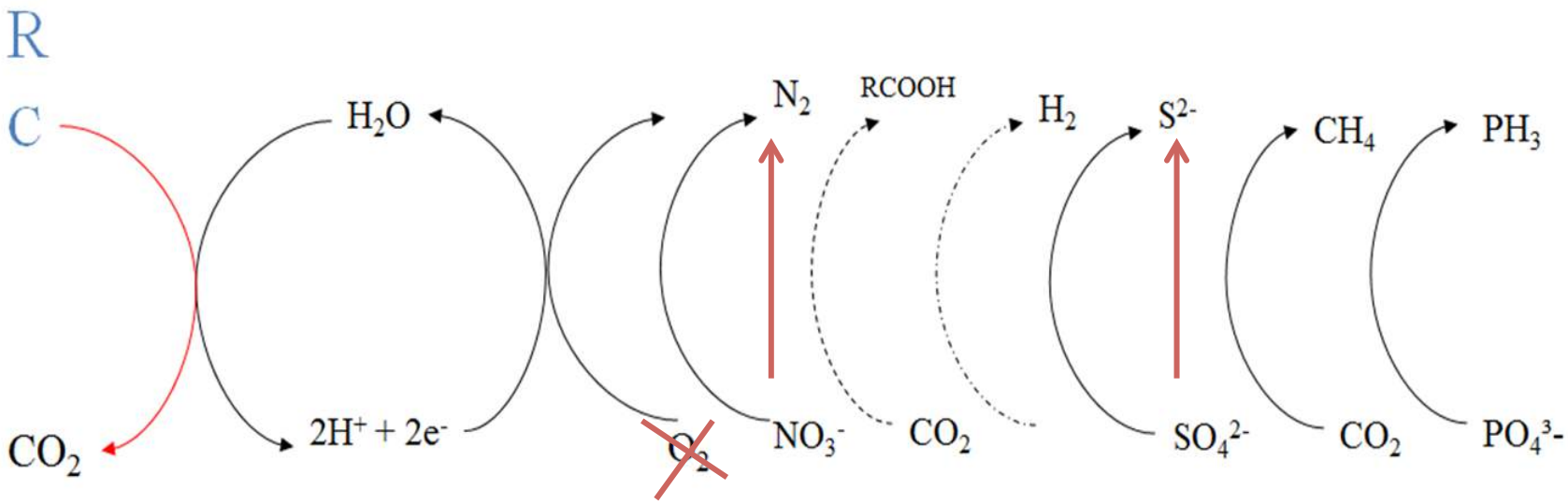

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green field	construction	landfill mining			brownfield
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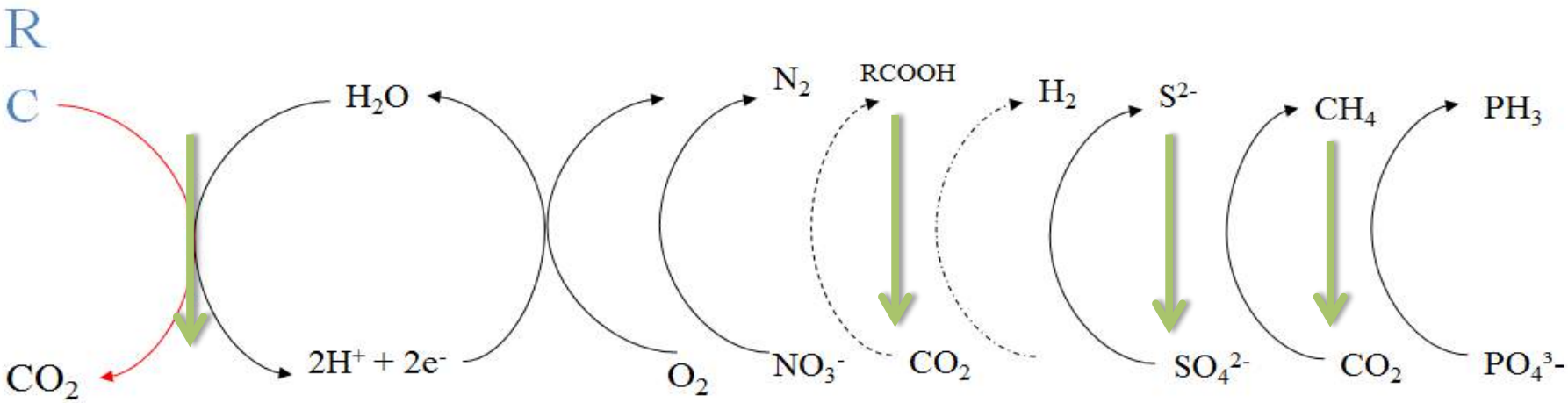
Step 10 Heavy metal mining



- When everything has been mined, you reverse
- Aeration:
  - Sulfides will be oxidised
  - Heavy metals will be released and can be flushed
  - Final breakdown of persistent molecules R + ammonium and methane oxydation
  - ➔ leachate with sulfate, nitrate and heavy metals

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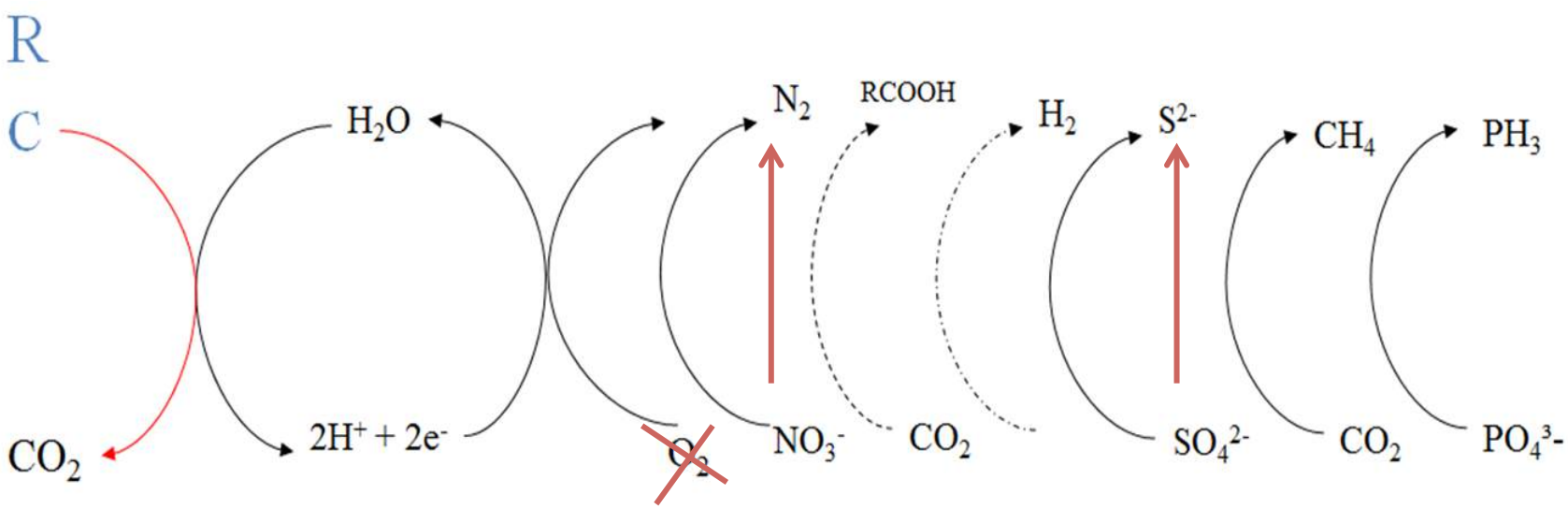
Step 10 Heavy metal mining

- ➔ leachate with sulfate, nitrate and heavy metals
- Anaerobic waste water treatment
  - Add carbon source
  - Nitrate reduction + sulfate reduction
  - Heavy metal recovery



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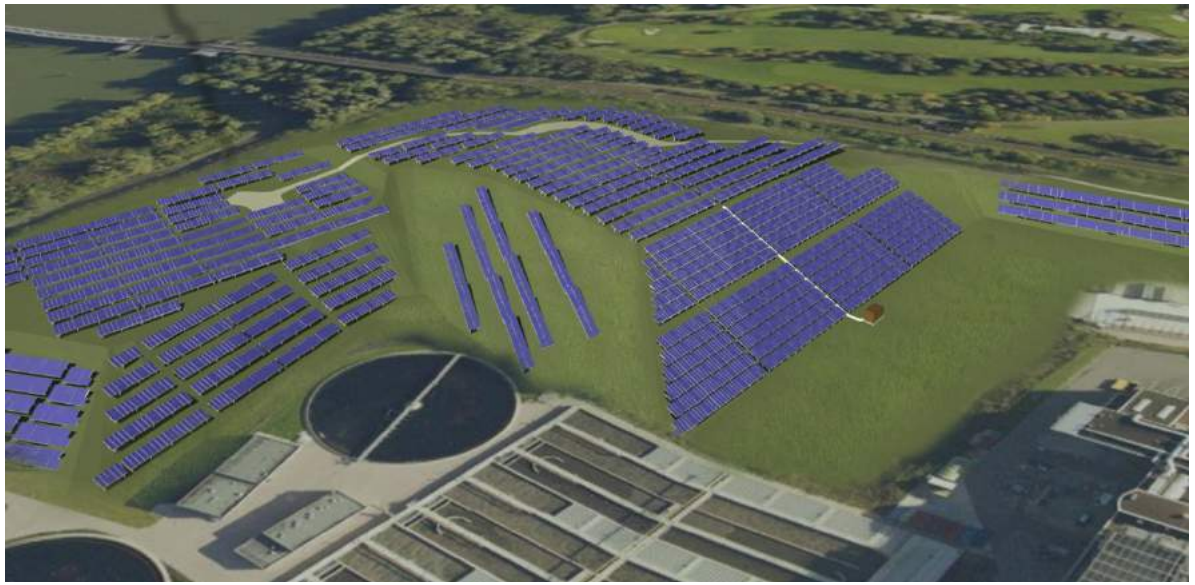
Step 11 Shape mining



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Step 11 Shape mining

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Step 11 Shape mining

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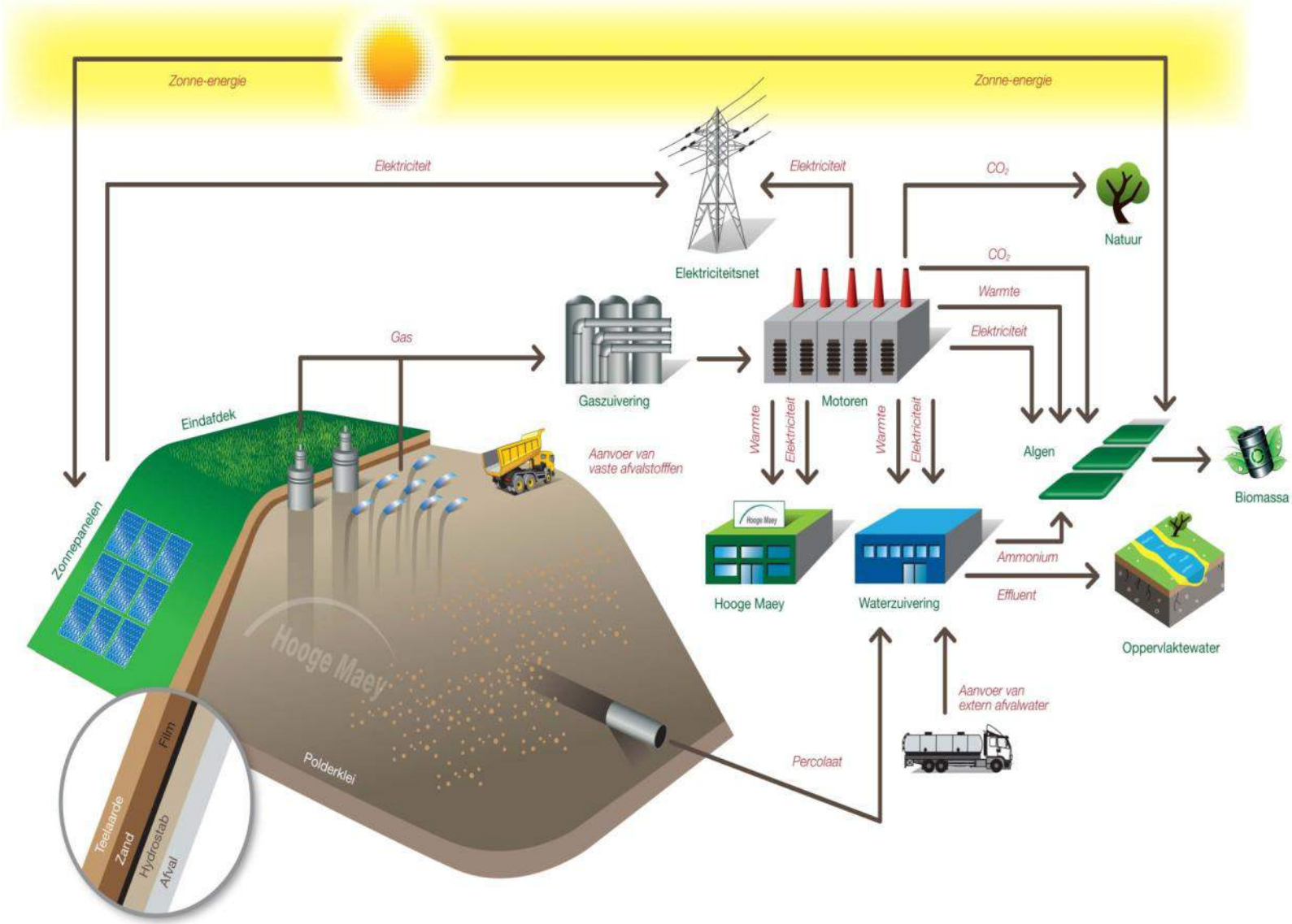
Intermezzo



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Intermezzo

- Untill step 11: in situ/on site mining
- Timeline

		commisioning	fermeture		
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield
isolate	1				
make inventory	2				
front door mining		3			
water input		4	4		
C-mining		5	5		
S mining		6	6		
N-mining		7	7		
salt mining		8	8		
functionality mining			9		
heavy metal mining			10		
shape mining			11		
physical mining				12	

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4. Conclusion

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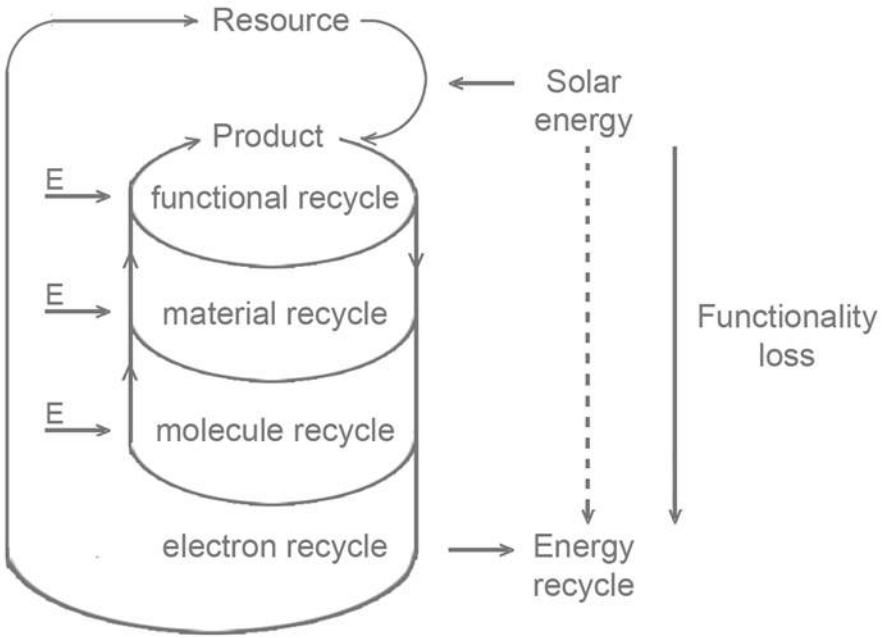
4. Conclusion

- 2.600.000.000 ton MSW/year to be produced by 2025 (World bank)
  - 20 % C
  - 1 % N

- 80 % or more to be landfilled
- Landfilling is sustainable and mining steps allow recycle at different levels
  - Functional
  - Material
  - Molecule
  - Electron
  - Heath



- Landfill mining: Technology and legislation should move away from electron focus to higher levels in the recycle chain
- Molecules

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