

# An organic landfill's life cycle

Pollux Consulting

Piet Wens

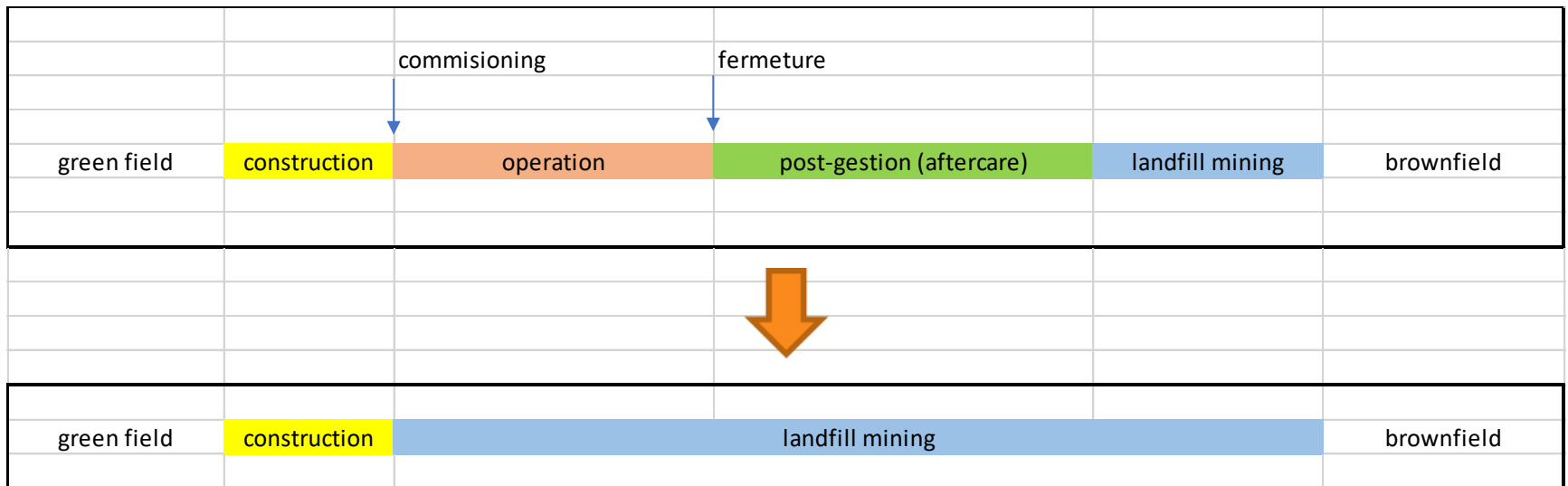
24/05/2017

# 1. Introduction

# My first landfill mining expertise

- 2004 Lebanon
  - Landfill excavation and soil reuse in fancy urban area
  - During rainfall: Biogas bubbles in the villa gardens
- The trial
  - Expensive lawyers from New York
  - Meetings in a 5 star hotel in London
  - Trial in Paris
- Risky business
  - If you don't know the whole story

# An organic landfill's life cycle



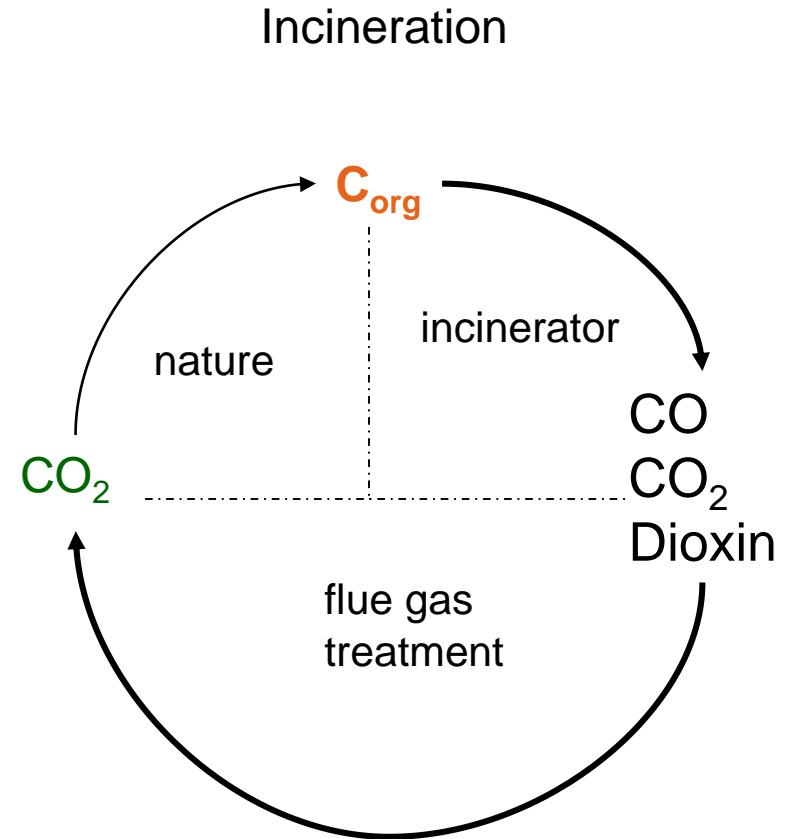
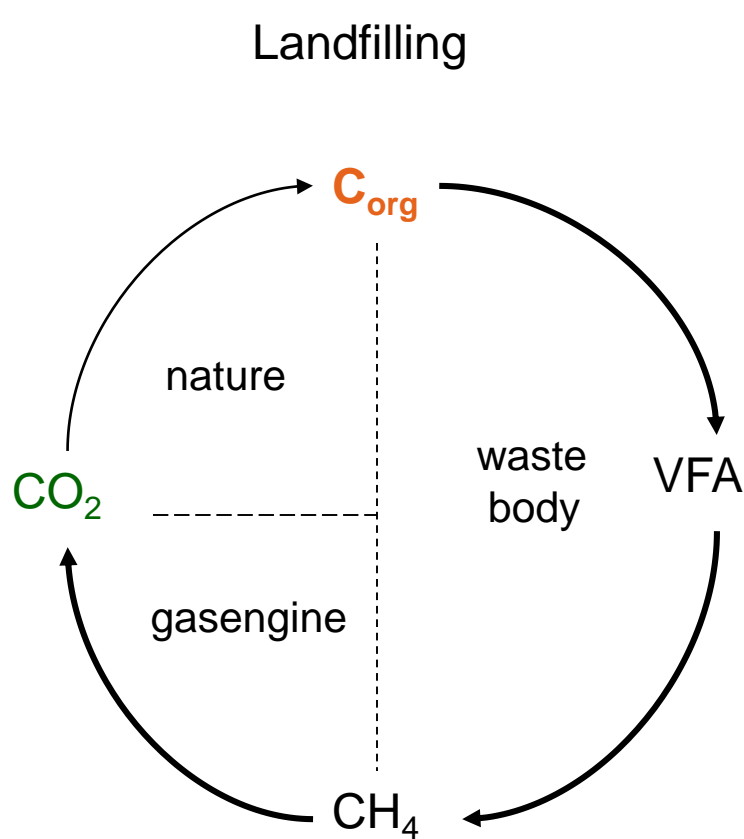
## 2. Current status on organic landfills

Waste treatment and electricity generation

## 2.1 Organic landfills are a waste treatment technique

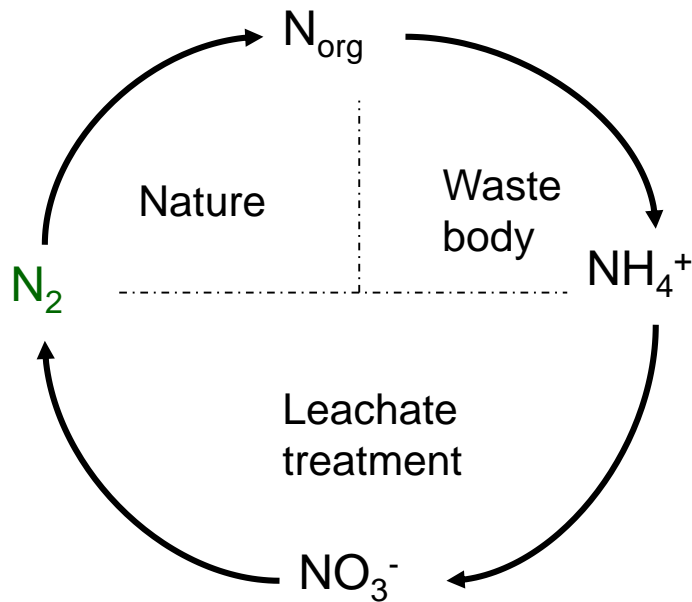
- Municipal solid waste landfilling: Temporary storage + treatment
  - Composition
    - Rapidly biodegradable:  $C_{40}H_{65}O_{27}N$
    - Slowly biodegradable:  $C_{20}H_{29}O_8N$
  - Waste treatment: Convert waste to inert molecules
  - Flushing bioreactor: focus on C and N

## 2.1 Organic landfills are a waste treatment technique



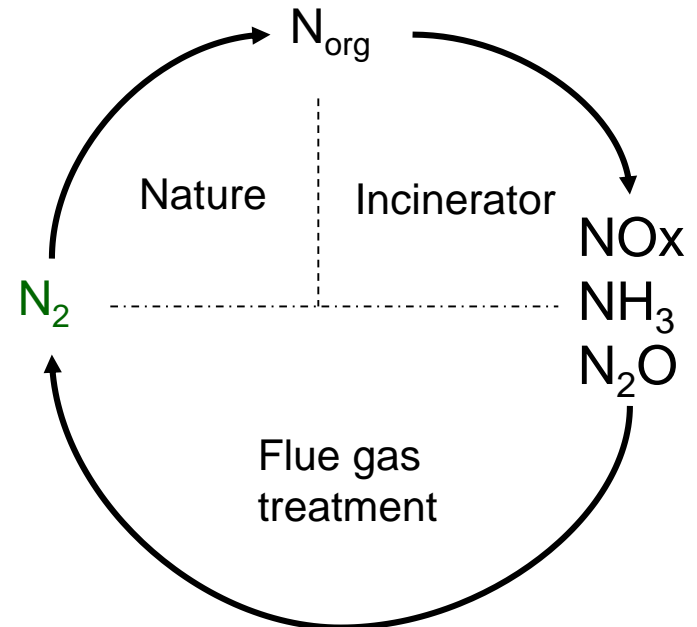
## 2.1 Organic landfills are a waste treatment technique

Landfilling



Flushing bio-reactor

incineration



Chemical reactor



## 2.1 Organic landfills are a waste treatment technique

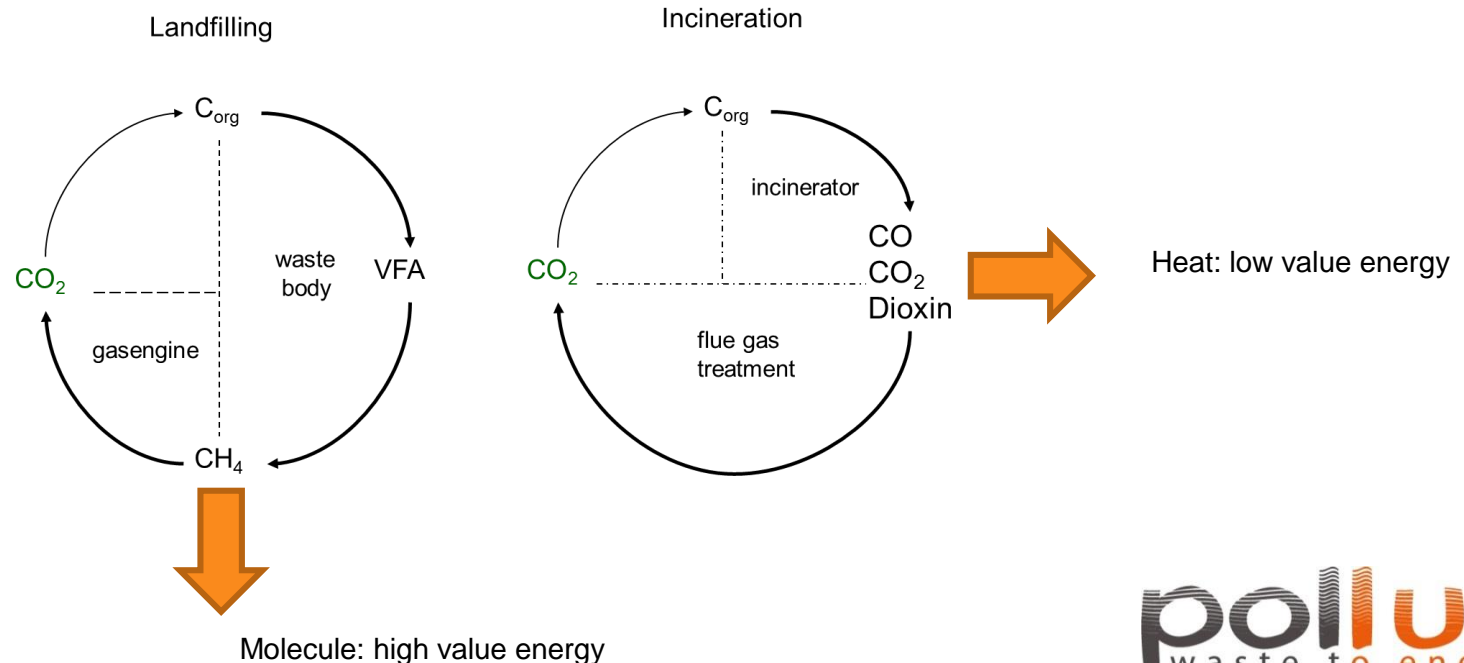
- Sanitary landfilling
- Sustainable waste treatment if
  - landfill
  - + leachate treatment
  - + incineration
- Incineration
- Sustainable waste treatment if
  - Incineration + FGT
  - + landfill
  - + leachate treatment

## 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
  - Non destructive
  - Valuable end products
  - High technology
  - Low technique
- Incineration
  - Sustainable waste treatment if
    - Incineration + FGT
    - + landfill
    - + leachate treatment
  - Short term: 20 minutes
  - High temperature
  - Chemical
  - Destructive
  - Low value end products
  - Low technology
  - High technique

## 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

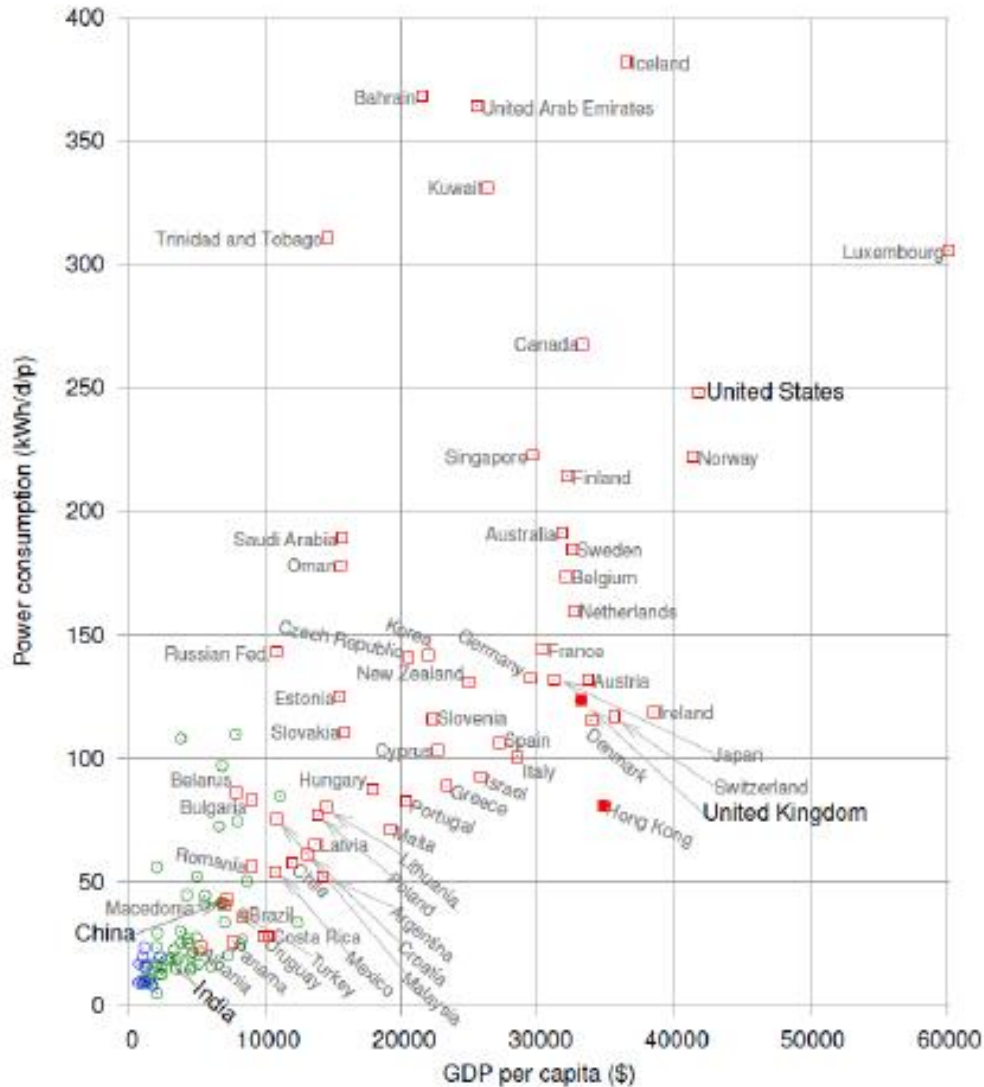


### 3. Future of organic landfills:

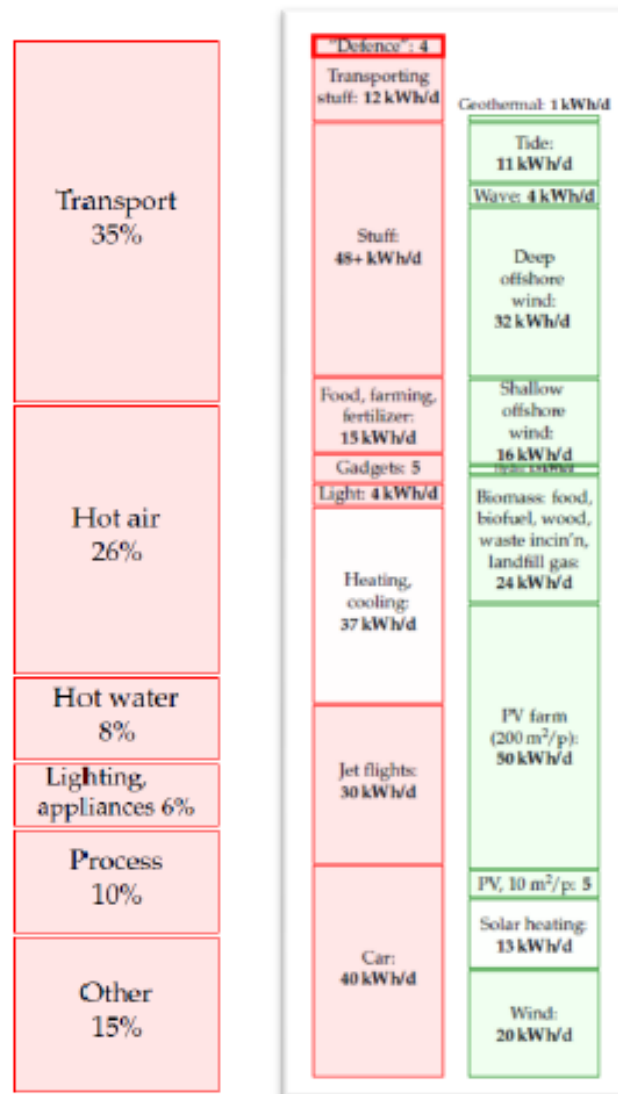
Circular economy and Landfill mining

# 3.1 Energy consumption

“Renewable energy without the hot air”




# 3.1 Energy consumption



“Renewable energy without the hot air”

## 3.2 Paradigm shift

- In the past:
  - Need for electricity
  - Fuel used for electricity production
  - Green electricity

The past:      Fuel            Electricity

- The future
  - Cheaper electricity
    - Due to renewable (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 → electricity used for fuel production
  - H<sub>2</sub>
  - Green fuel
- Impact on landfill
  - Past: green electrons
  - Future: green molecules: production and storage
  - Pollution potential vs mining potential

The future      Fuel            Electricity

# 3.3 Circular economy

## WASTE HIERARCHY - LANSINK'S LADDER



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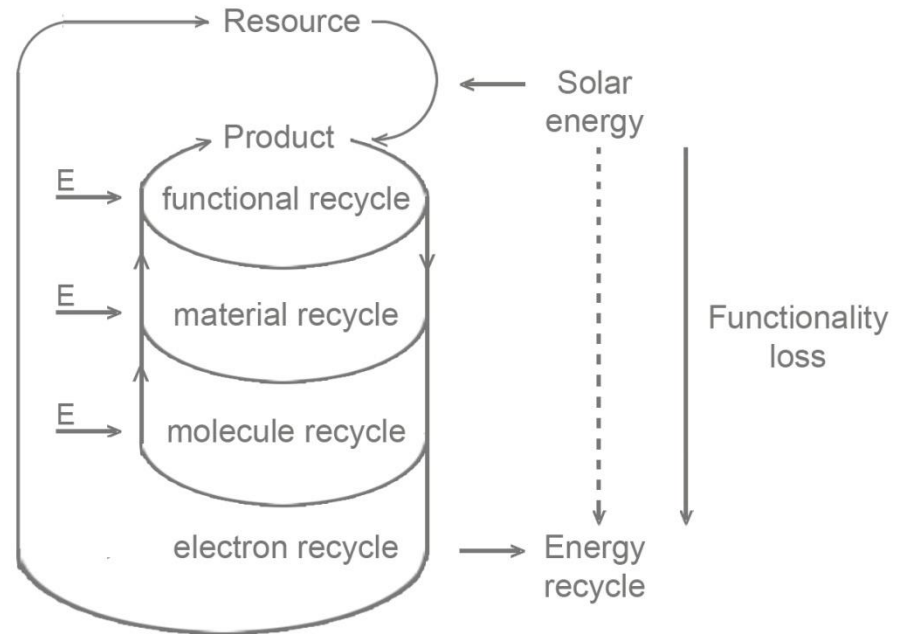


# 3.3 Circular economy

WASTE HIERARCHY - LANSINK'S LADDER



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## 3.5 landfill mining



13 steps



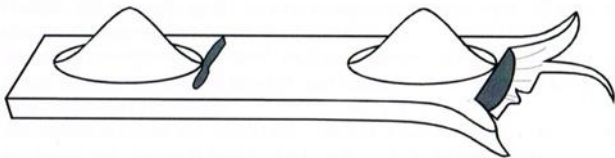
green field	construction	landfill mining			brownfield
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield

# Step 1: Isolate

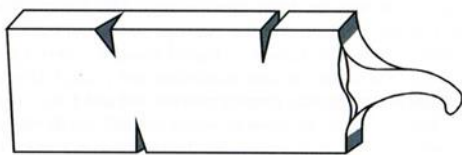
- The better your landfill isolation, the more time you have for mining
- Isolation:
  - Clay as mineral barrier:
    - Eternal lifetime
    - Beware of  $\text{Ca}^{2+}$  : Na-bentonite → Ca-bentonite : K value drops
    - Check your waste and leachate

# Step 1: Isolate

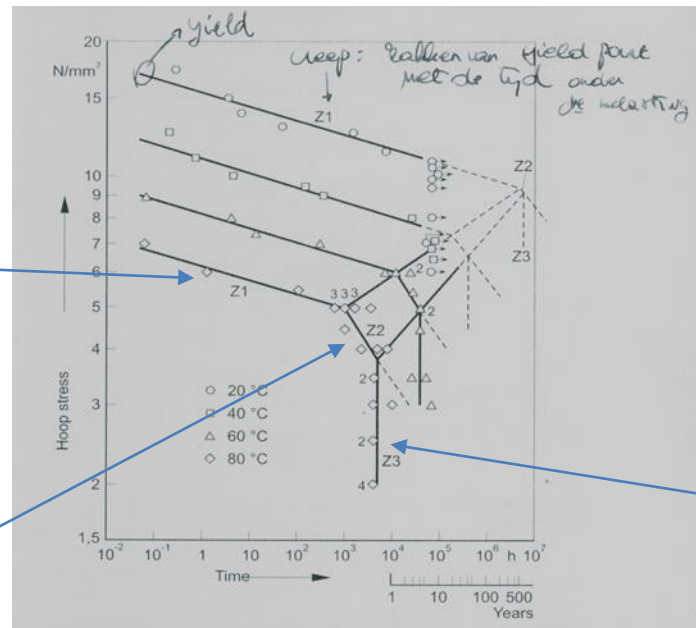
- The better your landfill isolation, the more time you have for mining
- Isolation:
  - HDPE: lifetime up to 500 years
    - Proper installation: Internal stress < 10 N/mm<sup>2</sup> : Elongation < 3 %



Creep



Stress crack



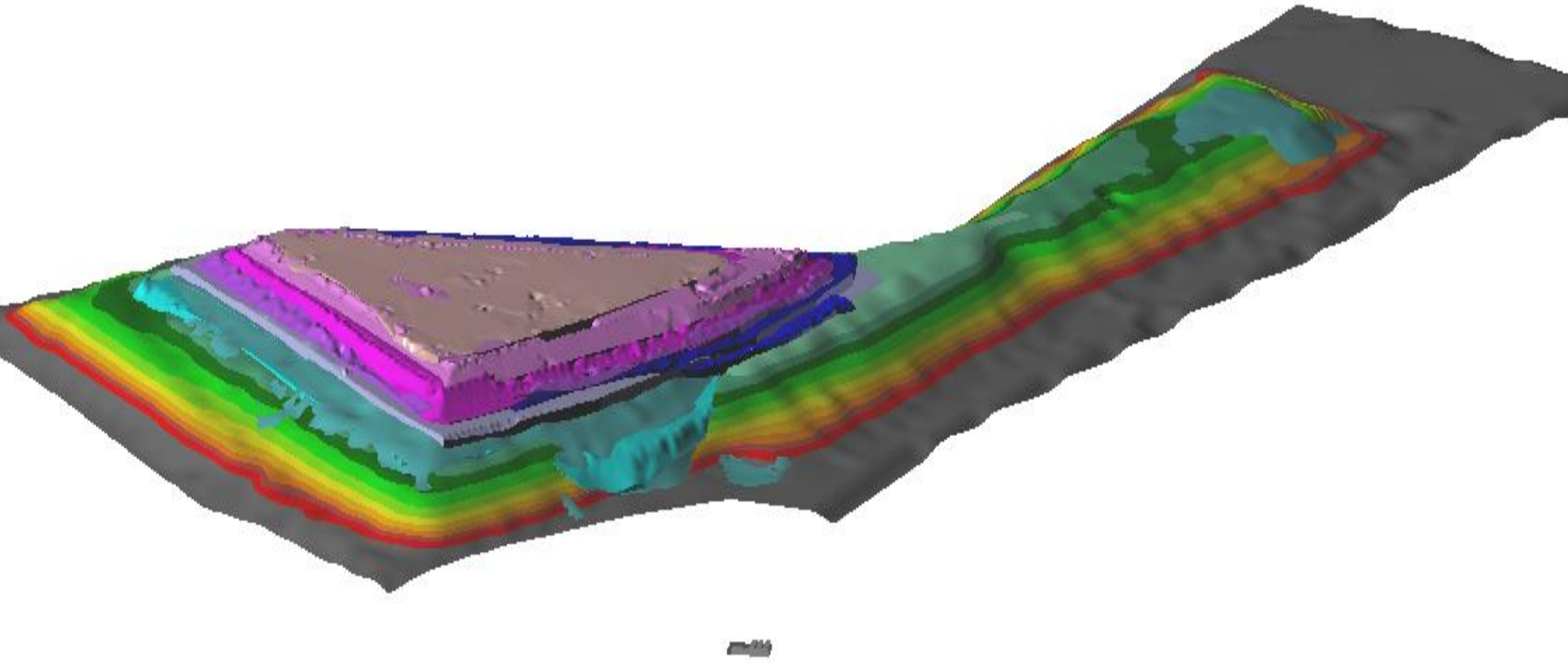
Oxydation

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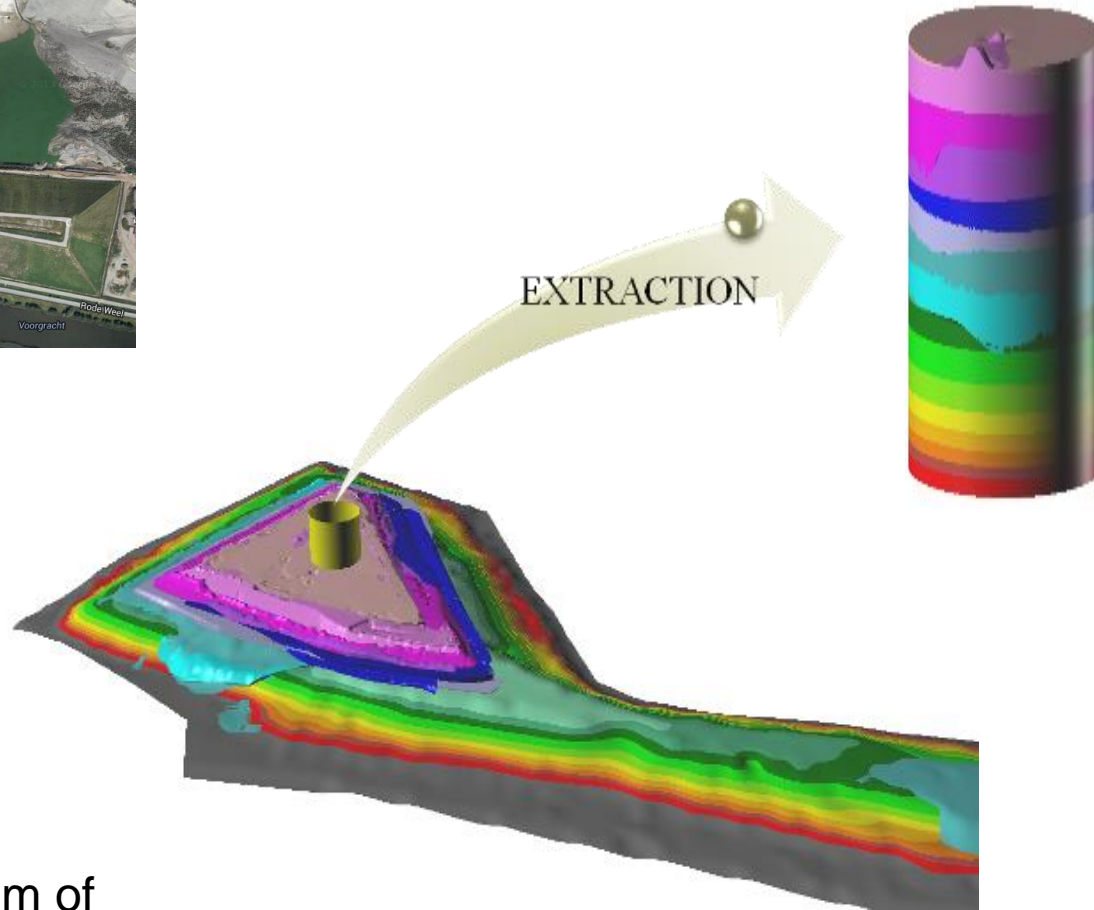
## Step 2 Make an inventory

- 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

## Step 2 Make an inventory



# Step 2 Make an inventory



Do it for a maximum of  
components



# Step 3



Tanger, Marokko





# Step 3



Marrakech, Marokko



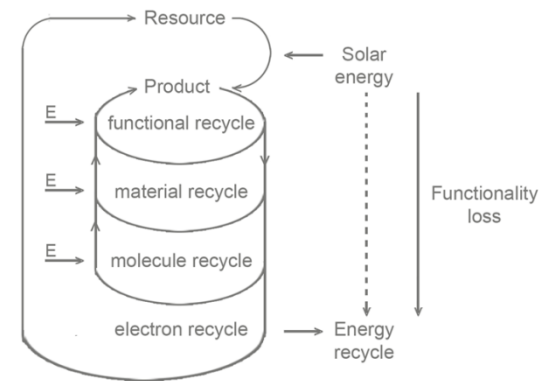
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## Step 3: “Front door” mining

- Selective collection (change the front door):
  - From “landfill door” to “house door”



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



- Keep checking waste composition at the landfill
- Make sure you can reuse what you keep out
  - Pet recycle and the plastic soup



Step 4:

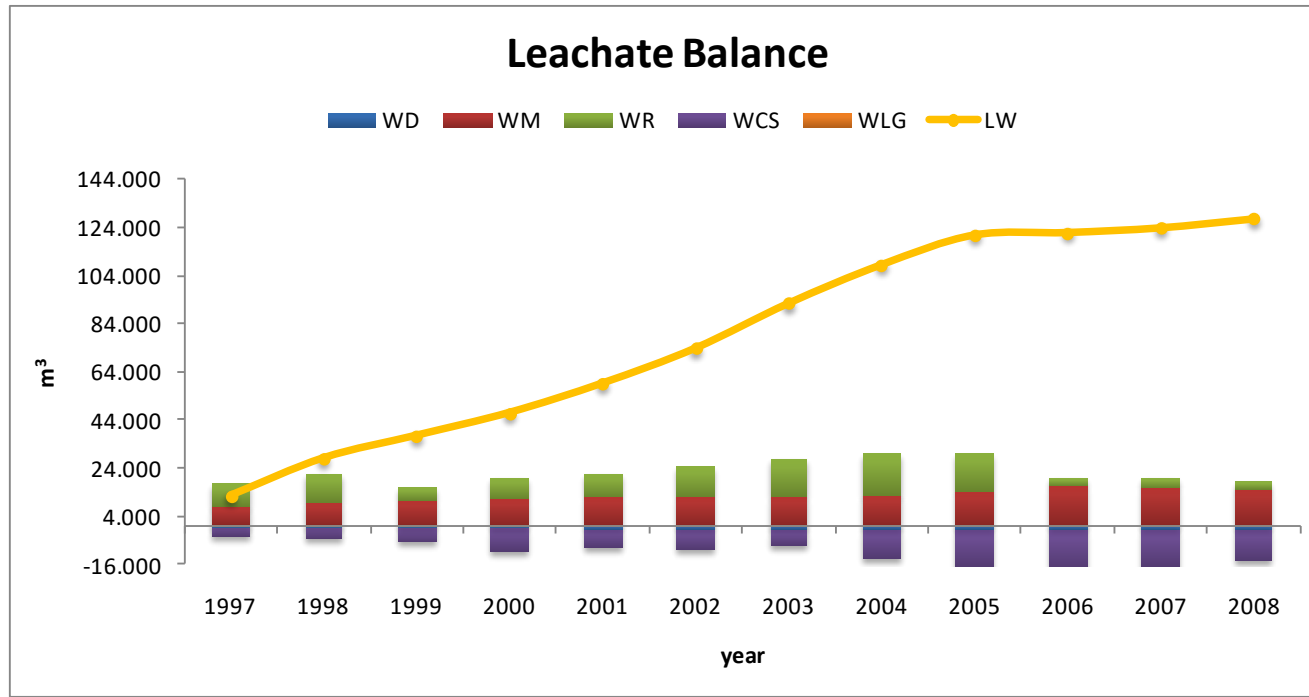


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## Step 4: Provide water

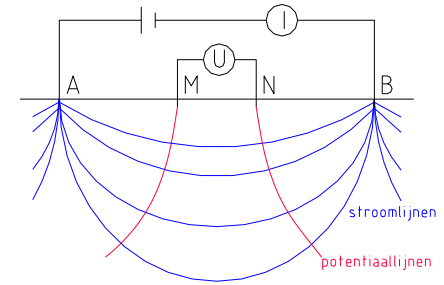
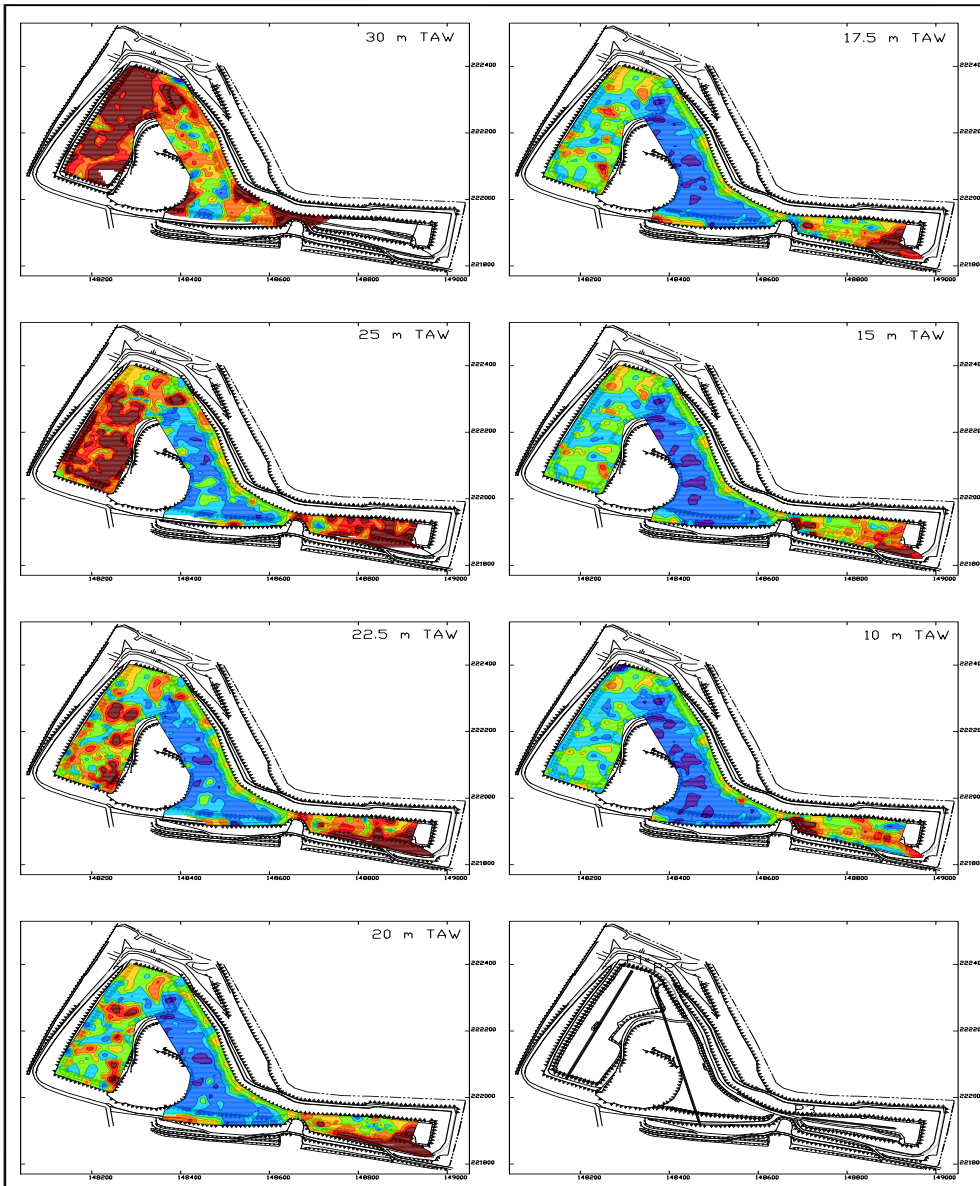
- Start up of hydrolysis
  - 100-200 l water/m<sup>3</sup> in situ waste on top of moisture content
  - Rainfall
- Cut waste in elementary molecules and dissolve in the liquid phase:
  - C
  - N
  - P
  - S
  - Salts
- Ready for mining:
  - Direct: via liquid phase: flushing
    - 1-2 m<sup>3</sup> water/ m<sup>3</sup> in situ waste
    - Water injection
  - Indirect: via gaseous phase: biodegradation

# Step 4: Provide water



- Keep humidity at the right level
- Water balance:
  - WR: Input of rain into the waste body
  - WM: Waste humidity released from the waste during degradation
  - WD: Water consumption during hydrolysis of the waste
  - WLG: Water contained in the LFG in the form of water vapour
  - WCS: Leachate extraction from the landfill

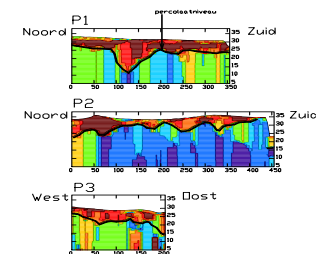
# Step 4: Provide water



Legende

- < 2 Dhmm
- 2 - 4 Dhmm
- 4 - 6 Dhmm
- 6 - 8 Dhmm
- 8 - 10 Dhmm
- 10 - 15 Dhmm
- 15 - 20 Dhmm
- > 20 Dhmm

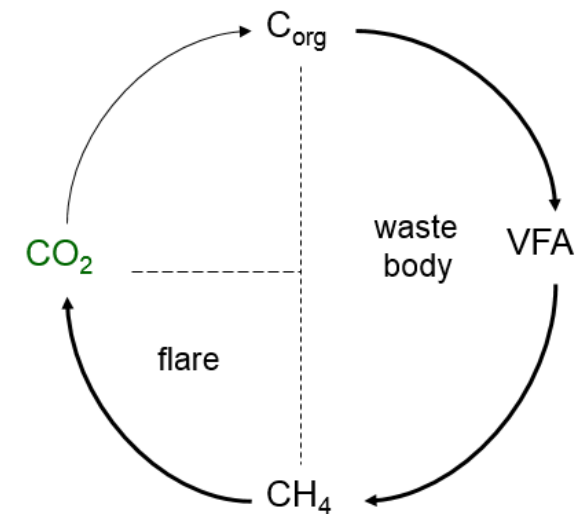
Belgische Lambertcoördinaten



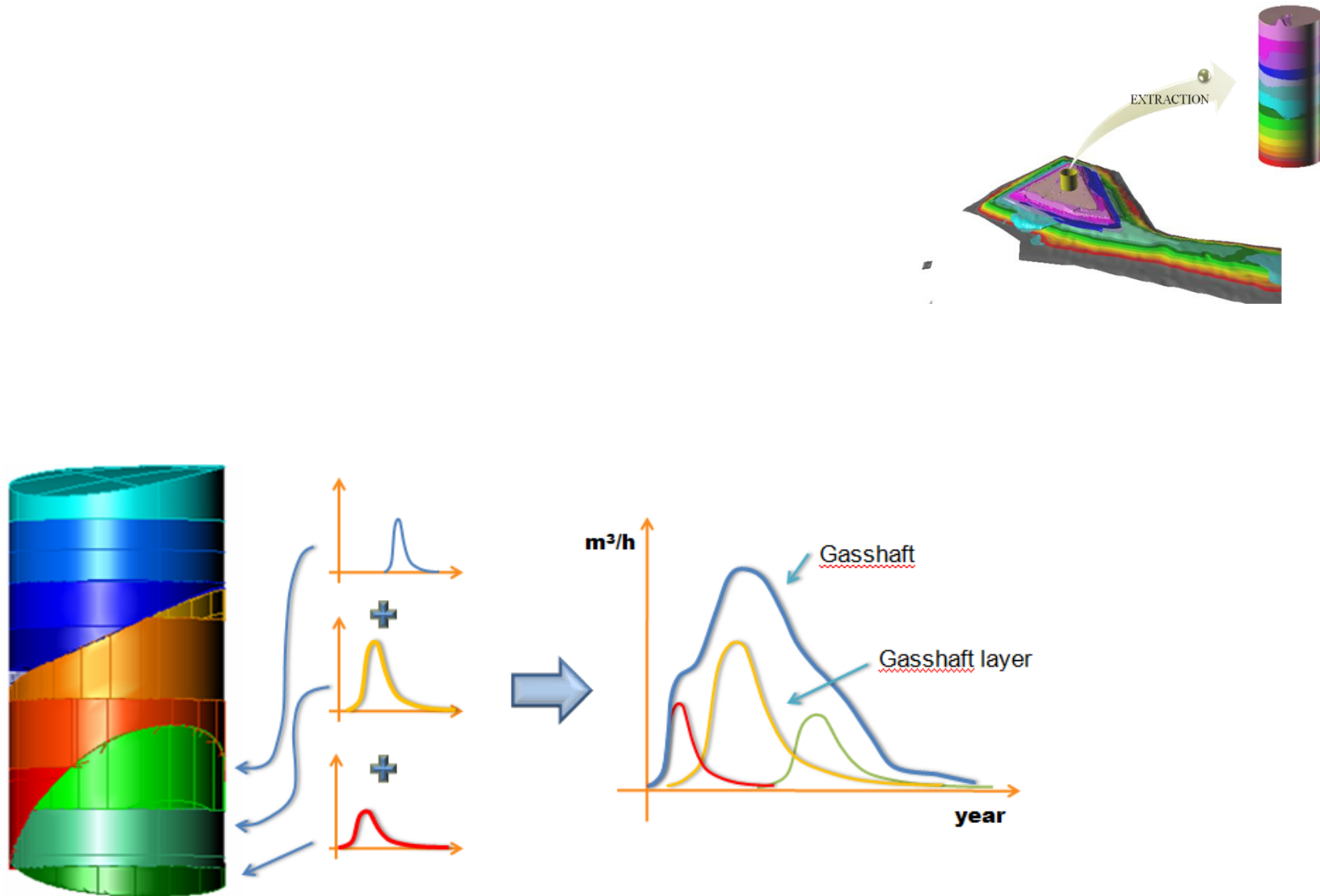
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# Step 5 C-mining

- Waste C to methane
- Mining option
  1. Biogas engines → electricity
    - Many failures because of lack of inventory
    - Subsidie driven
    - Green electron + green heat

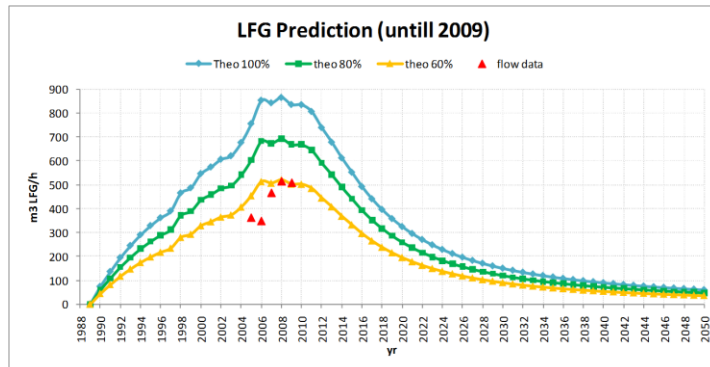
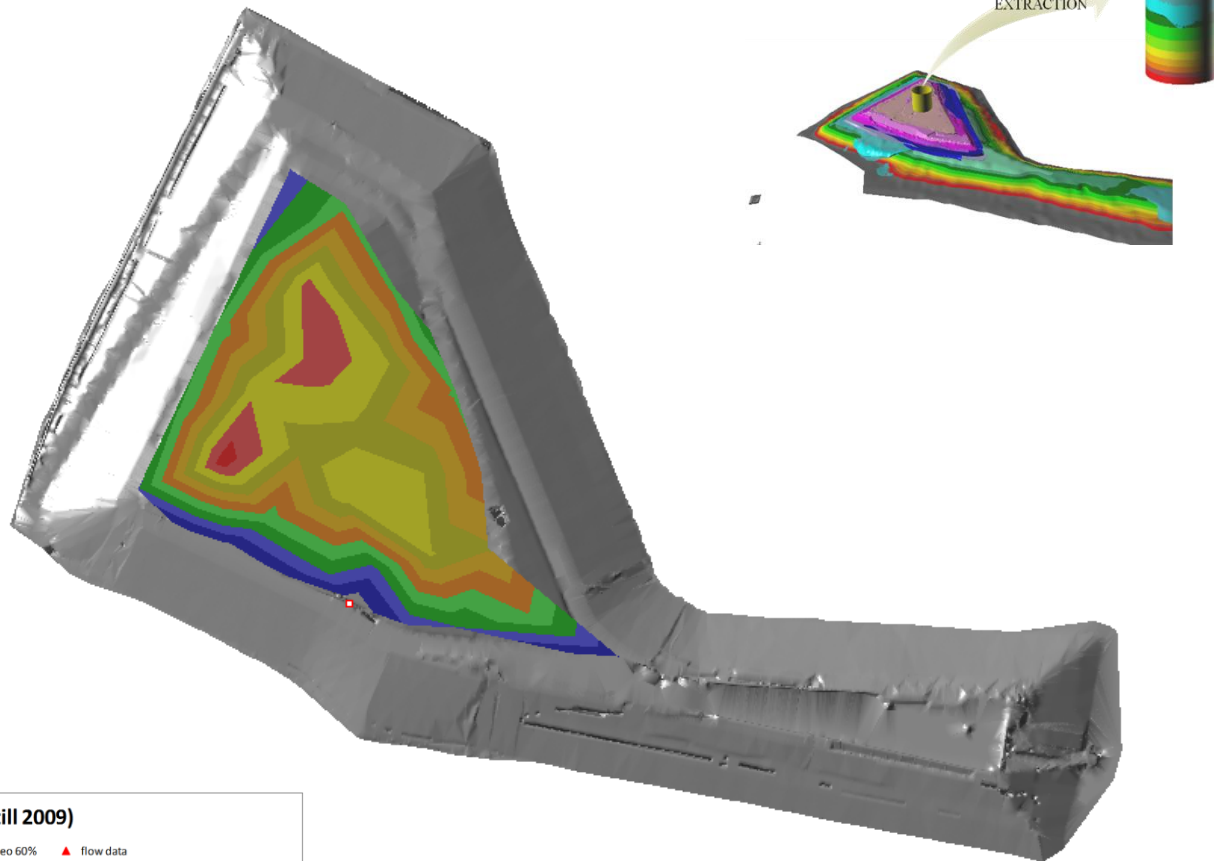
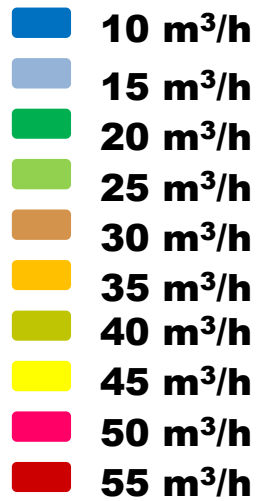


# Step 5 C-mining

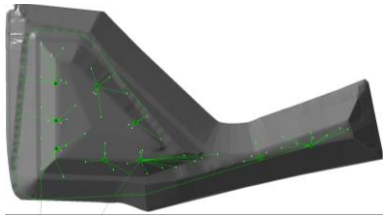




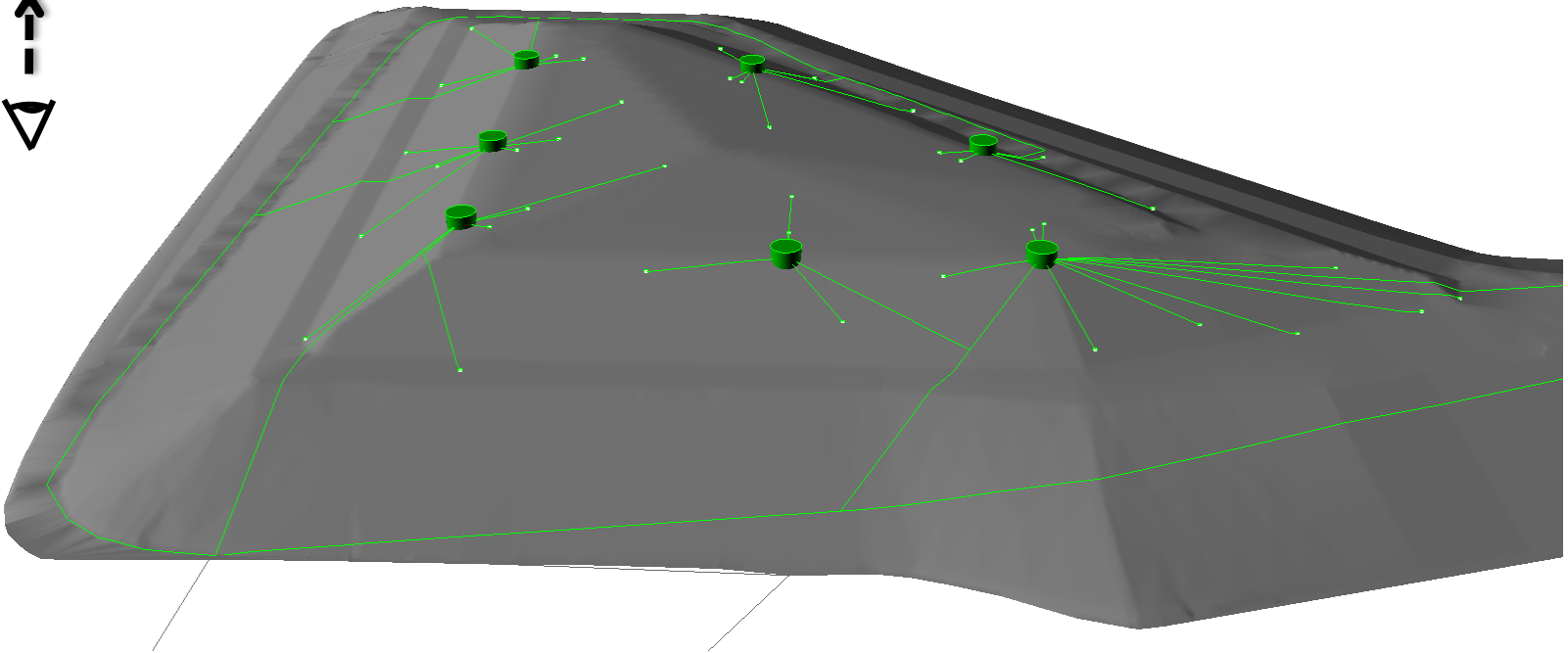
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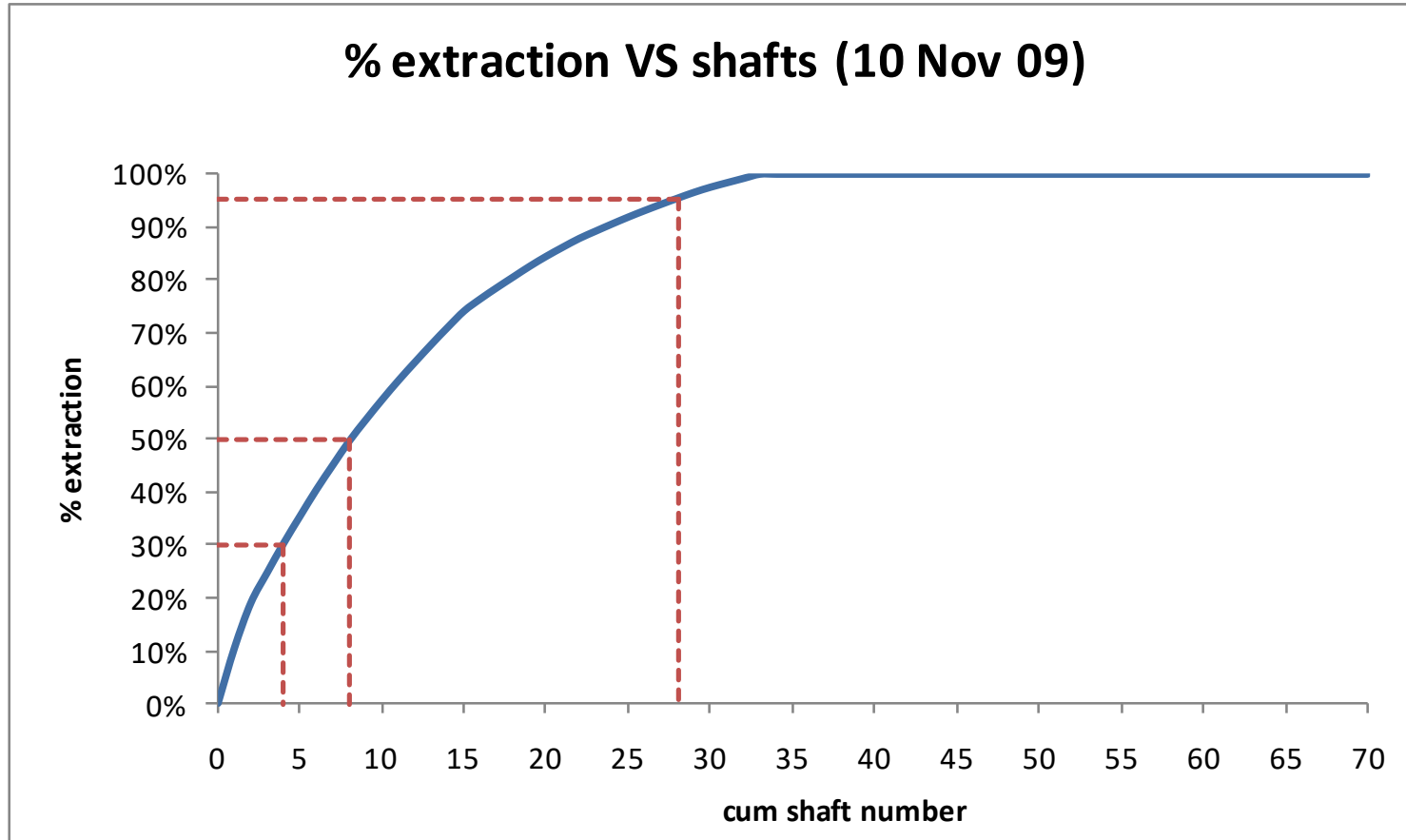


*Cluster system*



# Step 5 C-mining

- Case studie: gas shaft quality



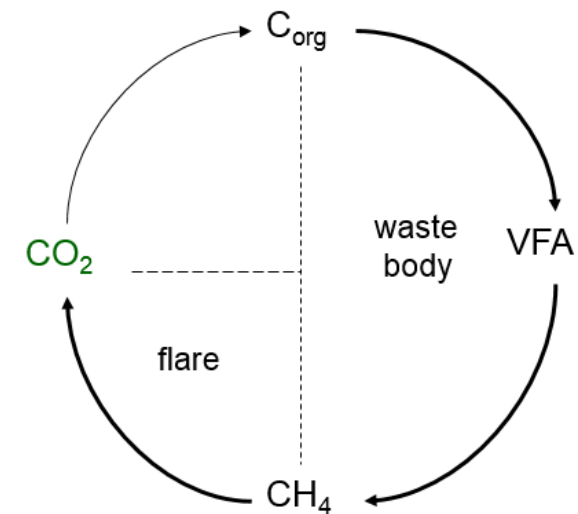
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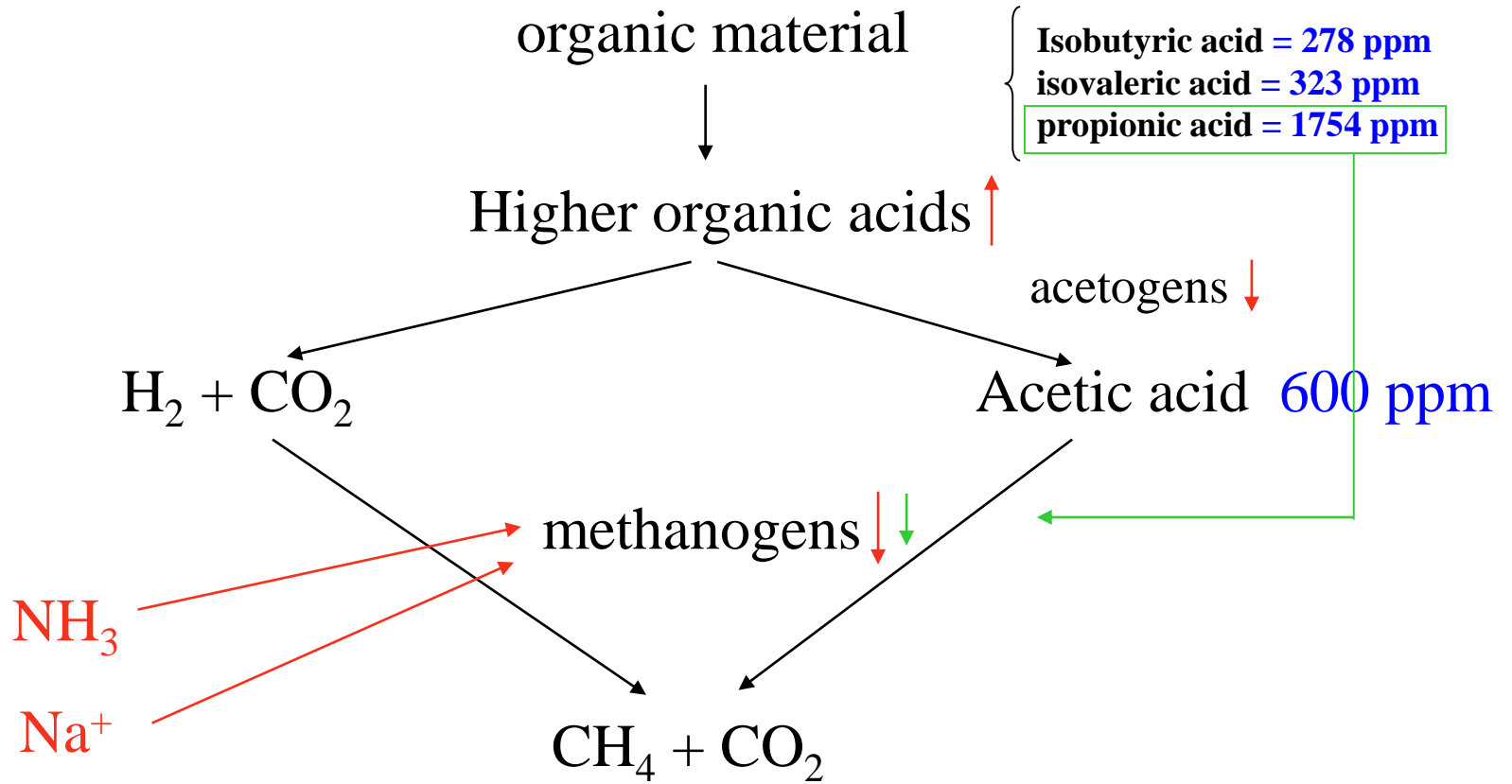
The future      Fuel      ← Electricity

2. Conversion to natural gas
  - Save the molecule
  - Keep in a high energy quality level
  - Green molecule
  - Natural gas (**unfortunately no incentive**)
  - Potential for chain enlargement
    - Go into Chemistry
    - Plasma technology

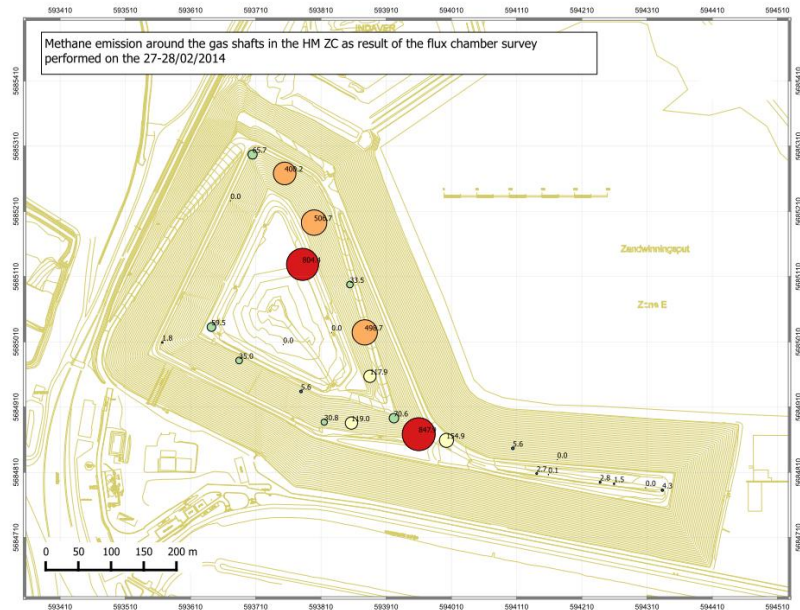


## Step 5 C-mining

## Leachate analysis

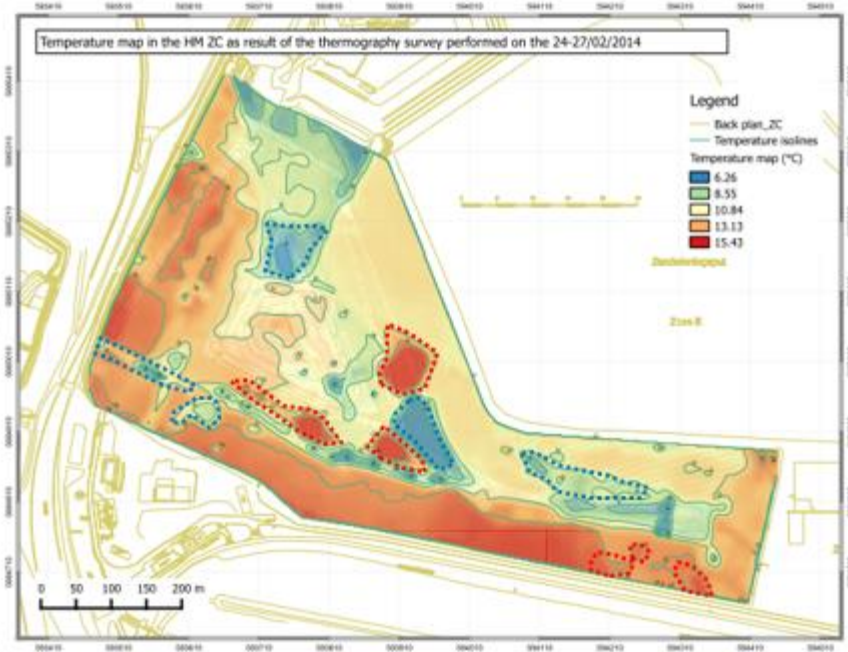


# Step 5 C-mining

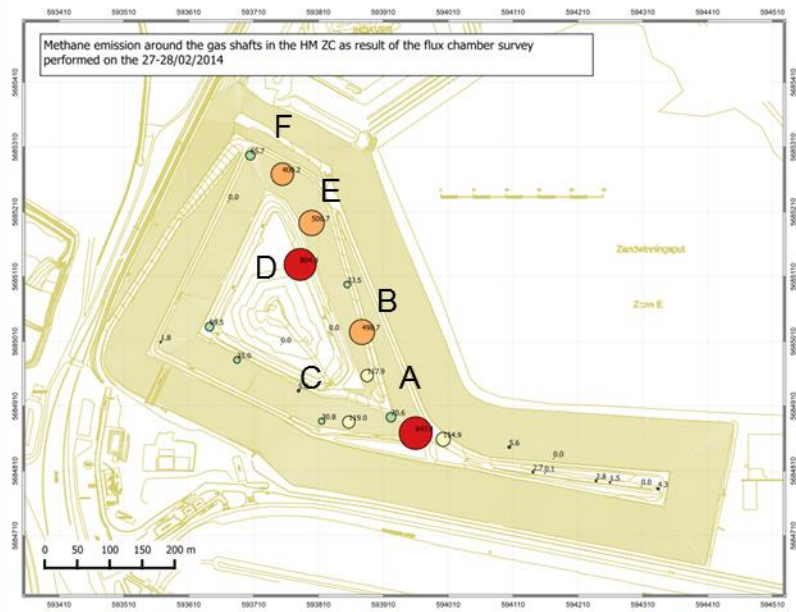




# Step 5 C-mining



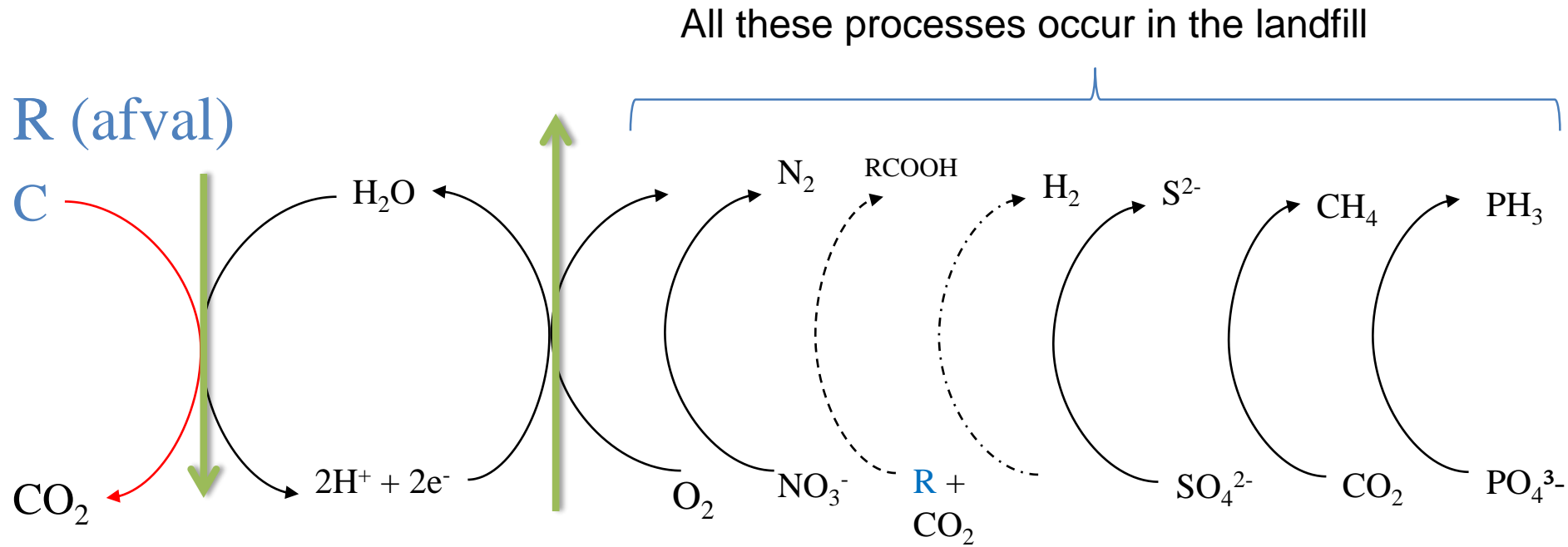
# Step 5 C-mining





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## Step 6 S mining



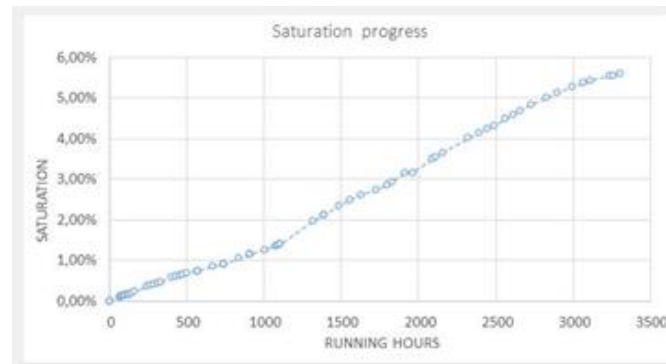
- Landfill: conversion from solid to liquid and gas
- Mining of energy rich molecules:
  - via liquid and gaseous phase
  - Not only C, but also S and P as energy rich molecule
  - No incentive
  - S considered as pollutant of biogas

## Step 6 S mining



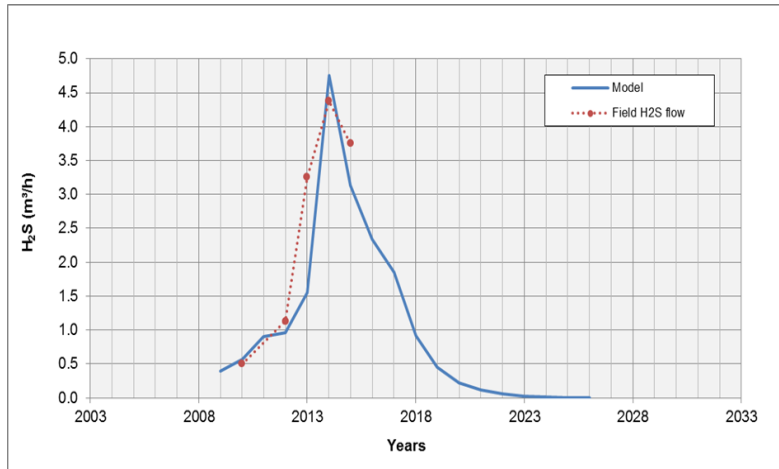
# Step 6 S mining

- Removal by means of bottom ash filter

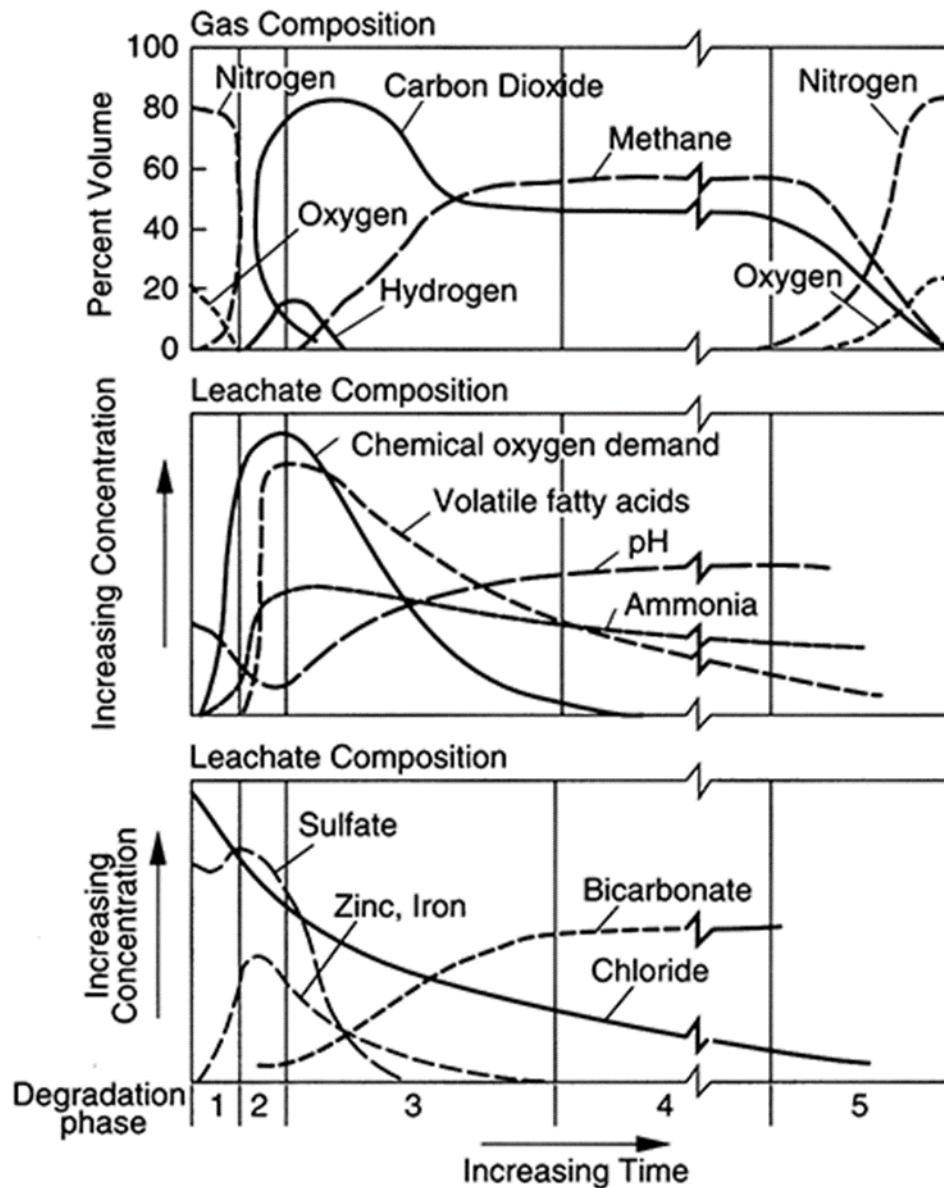


# Step 6 S mining

- Recycle of RO concentrate in the landfill
- $\text{H}_2\text{S}$  stripping and oxydation to S



# Step 6 S mining

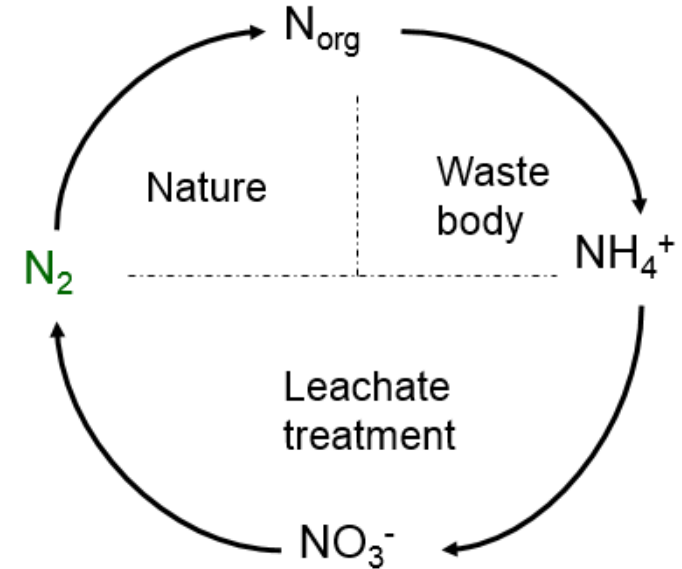




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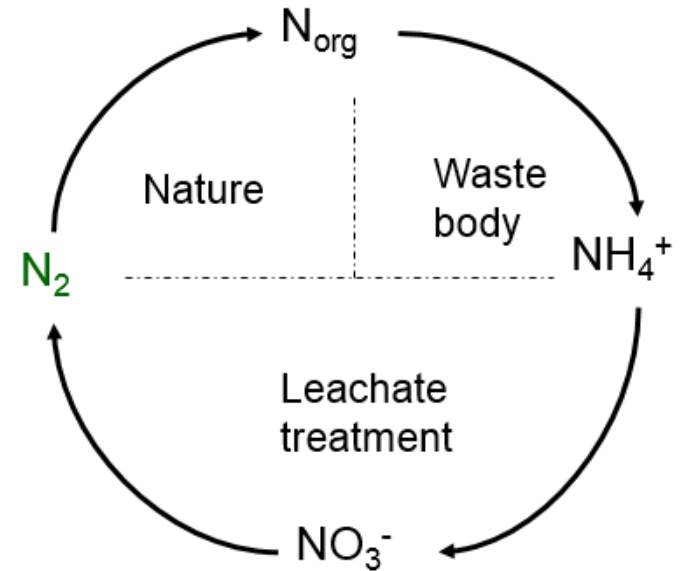
# Step 7 N-mining

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



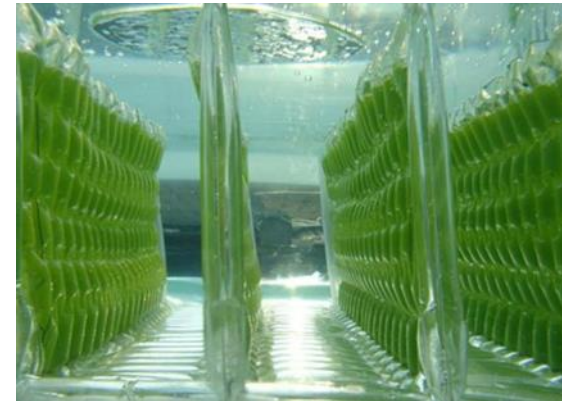
# Step 7 N-mining

- N has a separate microbial pathway:  $\text{NH}_4^+$
- Waterline
- No incentive for green nitrogen
- ➔ costly destruction in leachate treatment
  - Nitrification and denitrification
- Mining option: by adding the other sources
  - $\text{NH}_4^+$
  - $\text{CO}_2$  from the engines
  - Green Electricity ➔ light
  - Green Heat
  - Growth of algae:
    - Biofuel



# Stap 7 N-mining

- N has a seperate microbial pathway:  $\text{NH}_4^+$
- Waterline
- No incentive for green nitrogen
- ➔ costly destruction in leachate treatment
  - Nitrification and denitrification
- Mining option:by adding the other sources
  - Stripping:  $\text{NH}_3$
  - $\text{CO}_2$
  - Electricity
  - Heat
  - Growth of algae:
    - Biofuel
    - Higher molecules
      - Tocopherols (vit E)
      - Facial creme





## 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<sub>2</sub>, 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 energieverbruik 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 ( $\text{NH}_4$ ), als nutriënt kan dienen voor de algen. Deze praktijkervaring komt het onderzoek zeker ten goede.

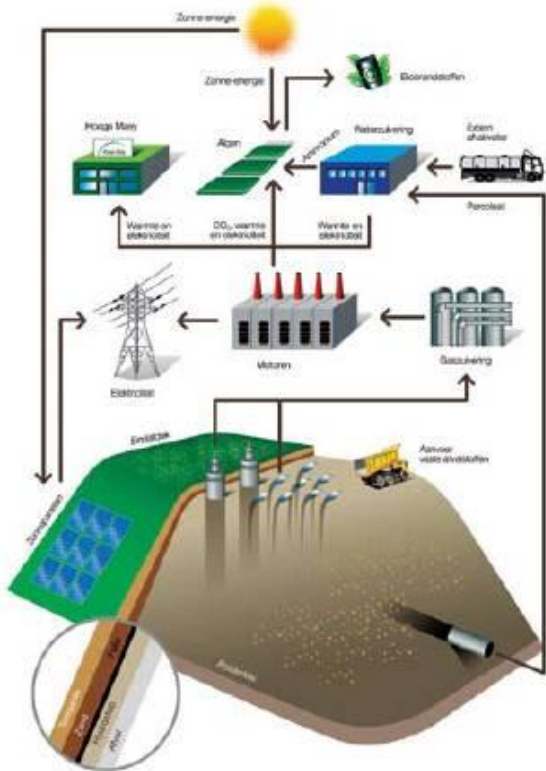
Opstart getoond tijdens  
Openbedrijvendag 2010

Het project ging van start in april 2010. Tijdens de Openbedrijvendag in oktober 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 posteressie een tussentijds verslag gaven van hun onderzoek.



 Meer informatie  
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Directeur Hooge Maey  
daniel.dirickx@indaver.be

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## Step 8 Salts

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

# Step 9



- 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

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## 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
- 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 (waste water)
    - Further flushing of molecules by water (remember step 4)
    - Continuous methane production

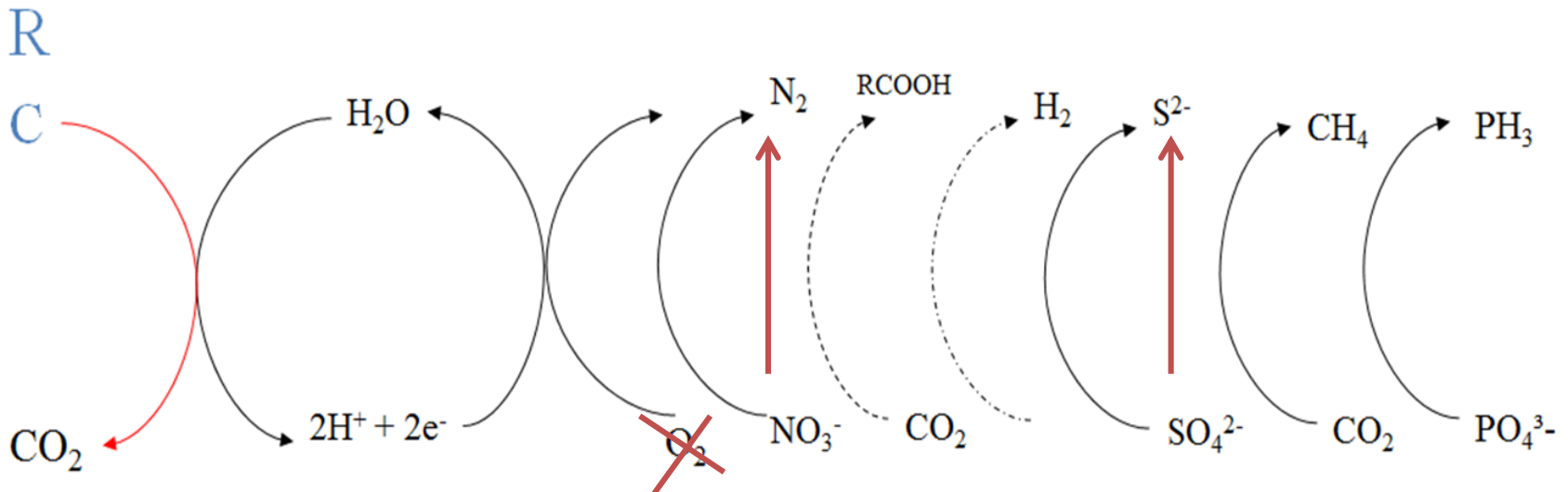
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## Step 10 Heavy metal mining

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

# Step 10 Heavy metal mining

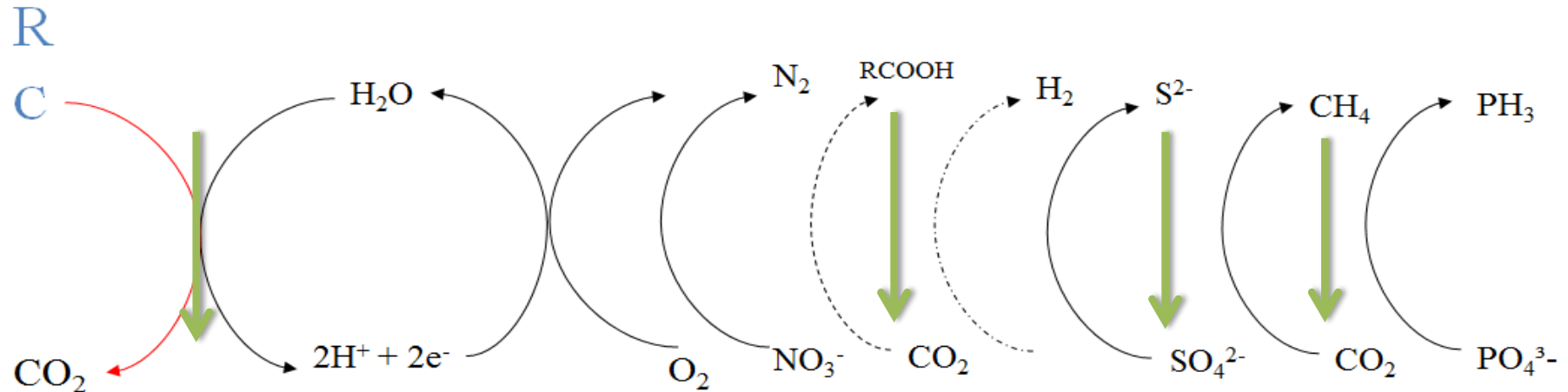
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## Step 10 Heavy metal mining

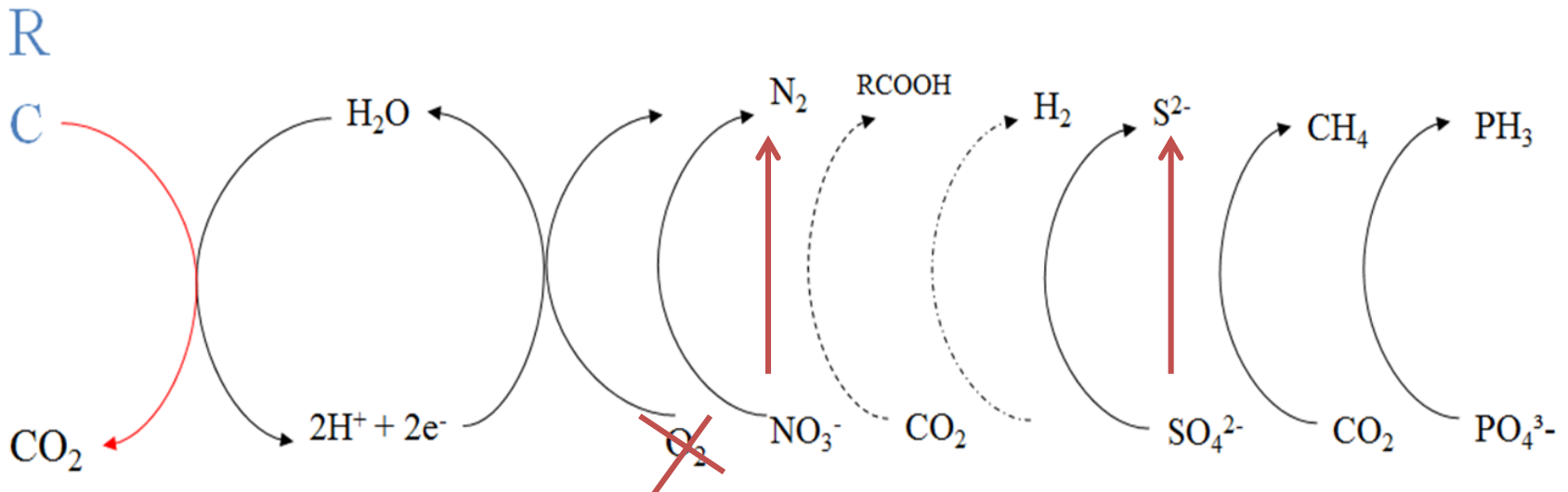


- When everything has been mined, you reverse
- Aeration:
  - Sulfides will be oxidised
  - Heavy metals will be released and can be flushed
  - **Final breakdown of persistent molecules R + ammonium and methane oxydation**
  - ➔ leachate with sulfate, nitrate and heavy metals

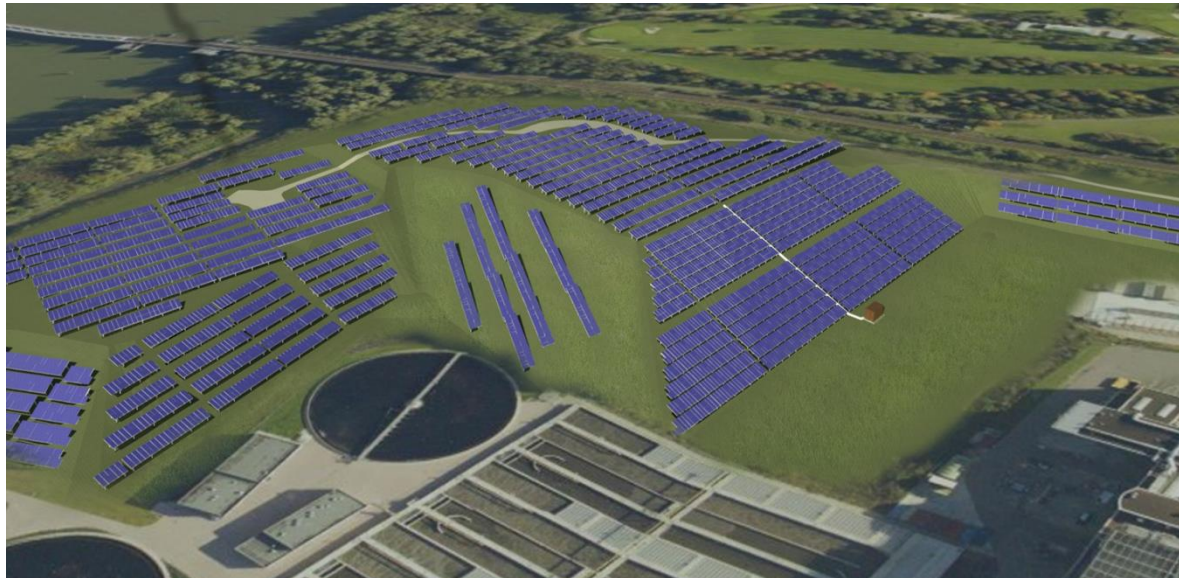


# Step 10 Heavy metal mining

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

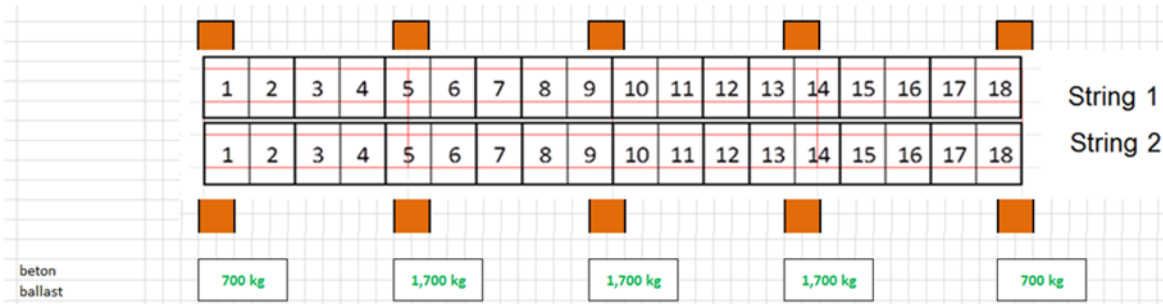
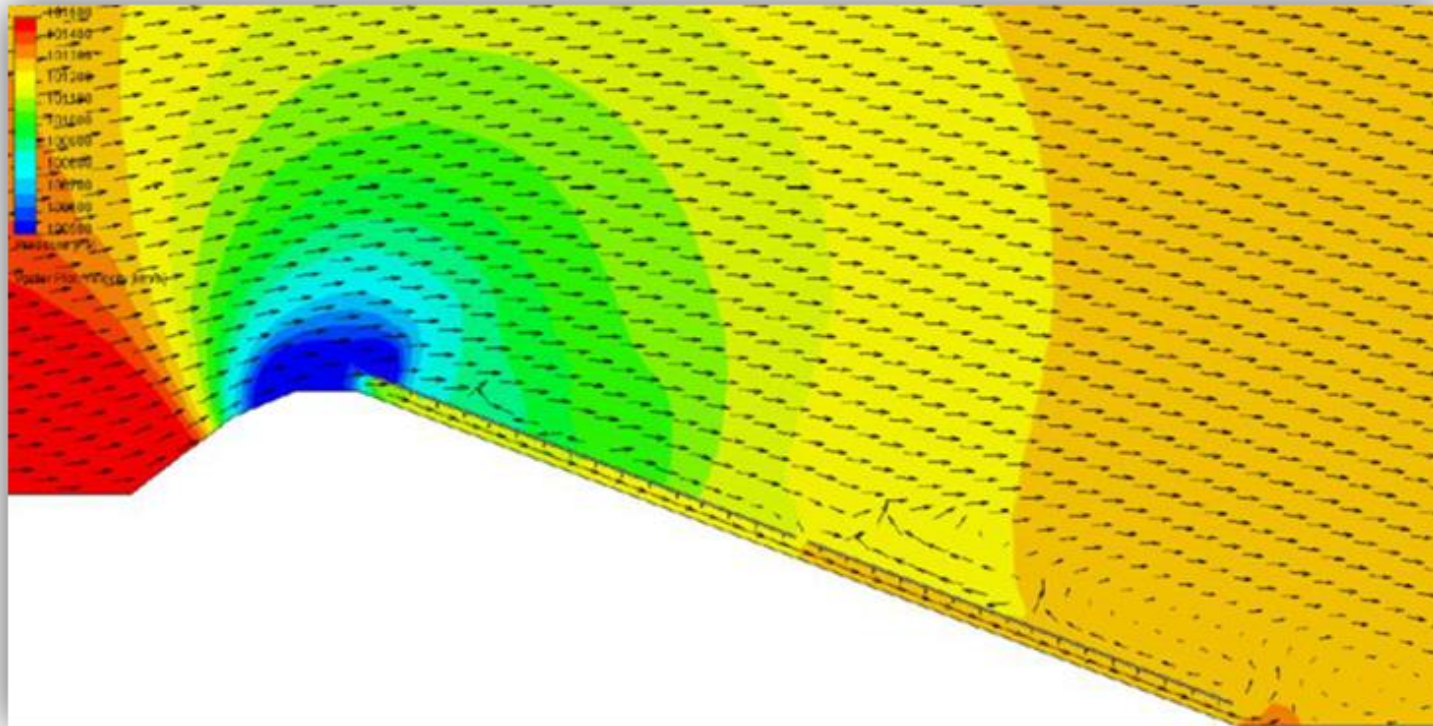


# Step 11

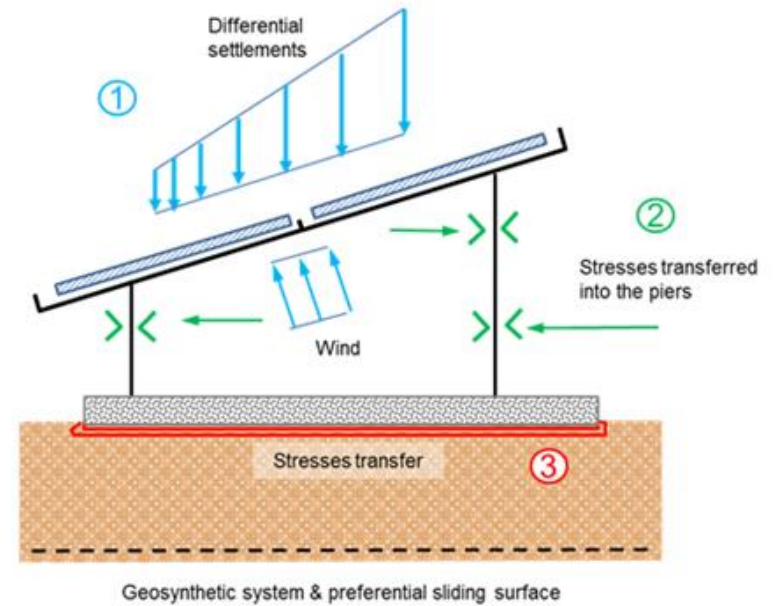
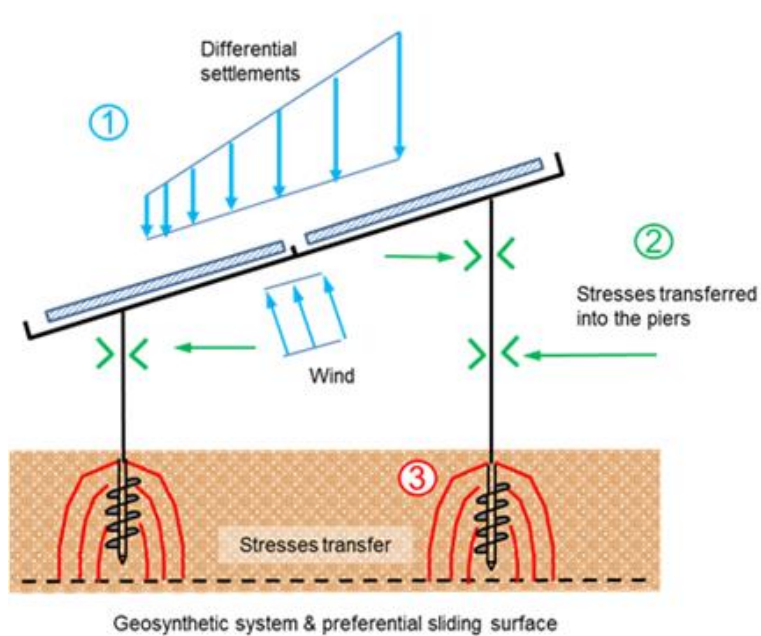




# Step 11



# Step 11





# Step 11

8 incredible parks created from landfills (google it)



# Step 11





# Step 11



## BEKLIM DE HOOGE MAEY PER MOUNTAINBIKE !

Sportieve vroege vogels krijgen een unieke kans om de Hooge Maey van zijn mooiste kant te zien: Een mountainbikeparcours van 35 km met spectaculaire klim tot op de hoogste berg van de provincie Antwerpen ligt voor hen klaar.

Vertrek op zondag 2 oktober tussen 08u00 en 09u00 's ochtends vanuit Berendrecht.



De Hooge Maey, de indrukwekkende heuvel langs de A12, is het hoogste punt van de provincie Antwerpen. Het voormalige stort is nu bedekt met meters grond en gras en lijkt op een Alpenweide. Dit hectaren groot terrein is niet toegankelijk voor het publiek maar ter gelegenheid van open bedrijvendag komt de hemel wat dichterbij. Wie vroeg uit de veren is, kan met de mountainbike deze groene reus bedwingen en bovenop genieten van een geweldig uitzicht over de stad, de haven en de omliggende polders. De aangelegde grindwegen op de Hooge Maey geven de indruk van een bergparcours met haarspeldbochten en steile stukken, echt eens iets anders.

De start van de MTB-tocht en de parking ligt in het naburige Berendrecht, waar er een verplichte registratie is. De Hooge Maey is immers een streng beveiligde omgeving. Vertrekken kan alleen tussen 08u00 en 09u00 !

Na een korte trip door het groen en een stukje haven, gaat de tocht omhoog de berg op. Vervolgens leidt de terugrit door de polderwegen van Stabroek en Berendrecht terug naar de startplaats. De MTB-tocht beslaat 35 km en is een mengeling van kasseistroken, grindwegen, asfalt en onverharde wegen door bos en velden, geïnspireerd door de wielervedstrijd Schaal Sels. Het is een pittig parcours met steile klim en een gedurfde afdaling ... MTB-fiets + helm verplicht ! In het centrum van Berendrecht kan je na afloop even nagenieten van deze onverwachte omgeving in wat, verrassend voor velen, nog grotendeels Stad-Antwerpen is.

Vooraf inschrijven is wenselijk maar niet nodig. Registratie bij het vertrek in Berendrecht (uiterlijk 09u00) is om veiligheidsredenen evenwel verplicht. DEELNAME IS GRATIS.

Start: Berendrecht, "De Sportduif", Solftplaats 6. Parking: Berendrecht, Oude Papestraat 16  
MTB-fiets + helm verplicht ! Meer info en inschrijvingen: [MTB@schaalsels.be](mailto:MTB@schaalsels.be)

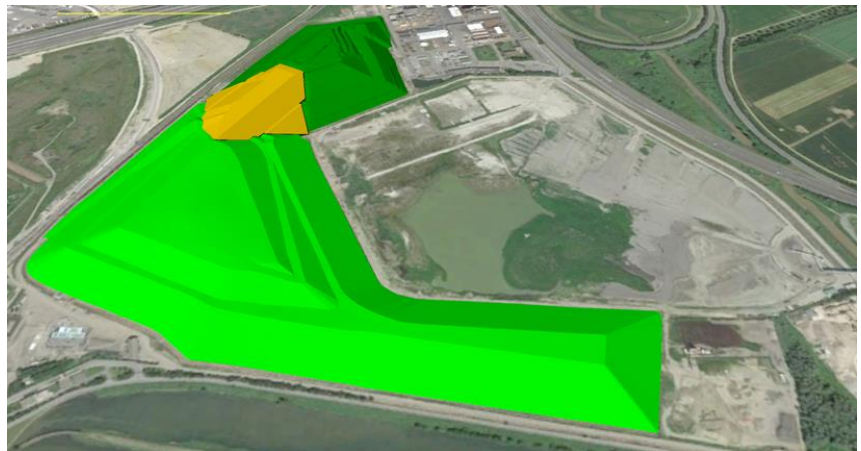


AMORAS

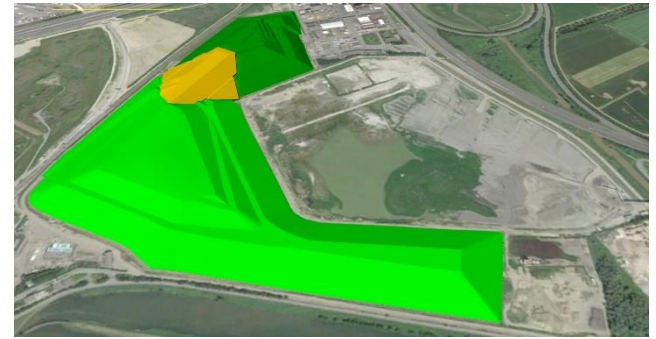




# Step 11

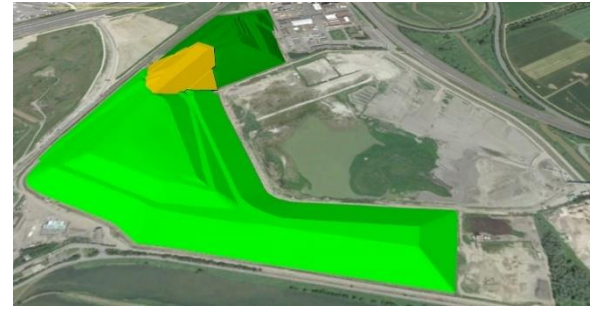


# Step 11





# Step 11



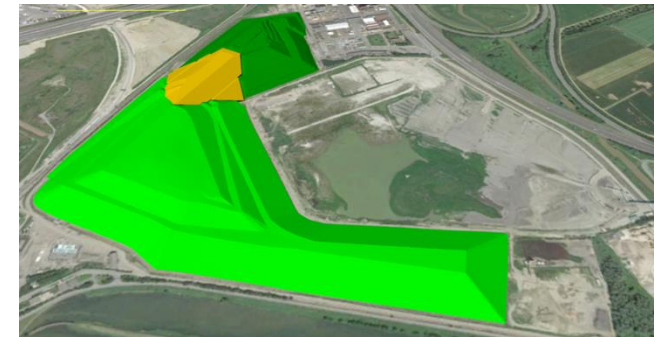
# Step 11



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

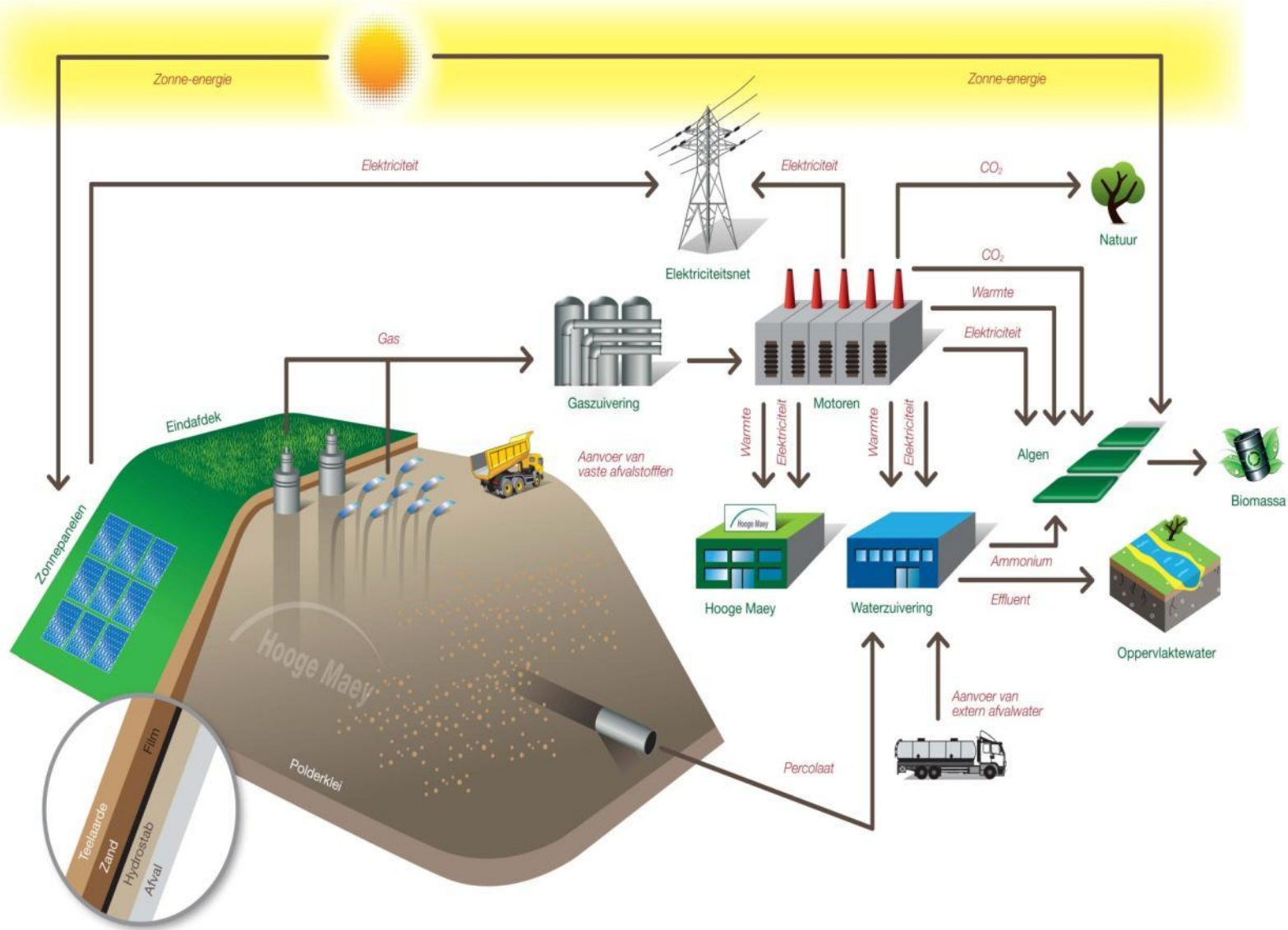
# Step 11 Shape mining

- Landfills have a specific shape
- Use it:
  - Solar parks: ideal inclination
  - Hydro
  - Park
  - New landfill
  - Infrastructure





# Intermezzo



# Intermezzo

- Untill step 11: in situ/on site mining
  - If you don't mine it, take care of it
- After step 11:
  - Landfill to be considered inert
  - Liner may fail: little risk
  - Mineral barrier will take care
- 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		



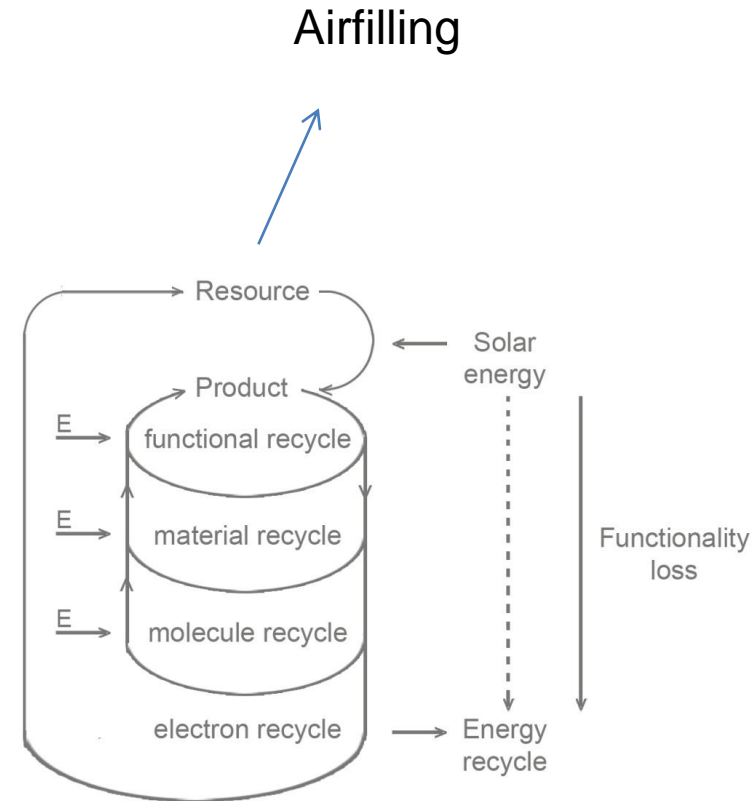
# Intermezzo

		commisioning	fermeture		
		↓	↓		
green field	construction	operation	post-gestion (aftercare)	landfill mining	brownfield
isolate	1				
make inventory	2				
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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		

- What's next?
- What is there still to be found?
  - Plastic
  - Soil
  - Metals
  - Pathogens
  - Asbestos
  - Land area
  - Radio-active waste

# Step 12 Storage: carbon sink

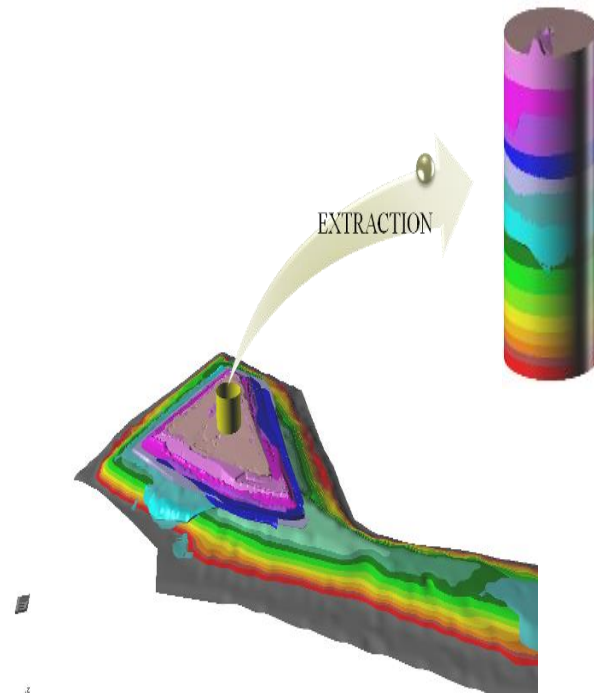
- Plastic recovery: Which destiny?
- Incineration?
  - Waste treatment with energy recovery
- But: incineration
  - Low energy efficiency
  - End product is waste: CO<sub>2</sub>
  - Airfilling



- Maybe better to produce energy from fossil fuel (high efficiency) and leave plastic in the landfill
  - Better carbon balance
  - Landfill is a Carbon sink

# Step 12 Storage

- Isolation and storage:
  - Plastic
  - Pathogens
  - Asbestos
  - Radio-active waste
- What's left:
  - Metals
  - Diamonds
  - Land area
  - Contaminants
    - Non recycled molecules
- Land area

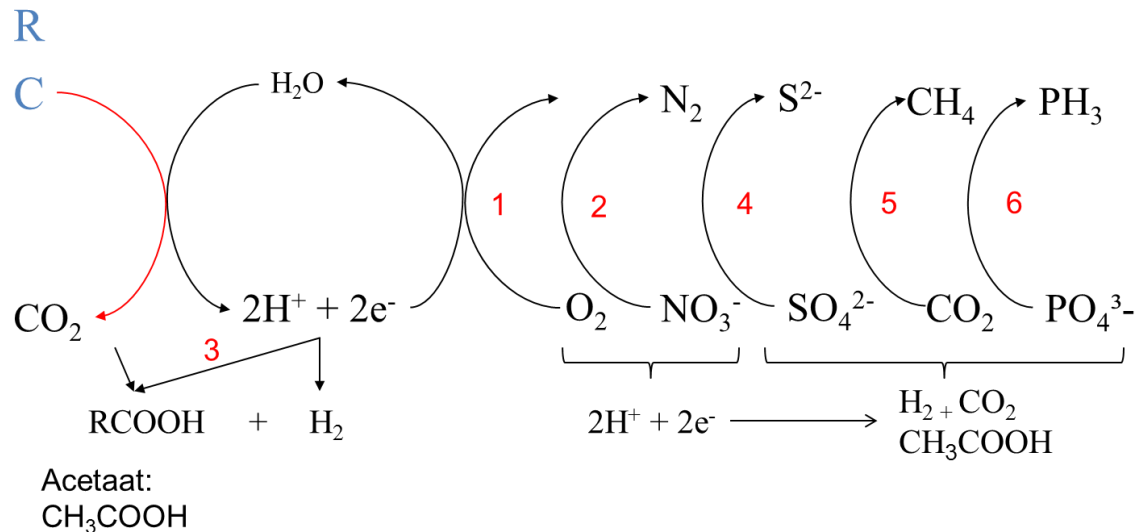


# Step 12 Storage

- When is it safe to let go?
  - Depending on the environment
  - Compare to waste water treatment discharge
  - See next speaker
- Or you start step 13: physical mining:
  - You are still looking for materia of molecules
  - You fear the environmental impact
  - See next speaker

# Step 13 Physical mining

- 2004 Lebanon
  - Landfill excavation and soil reuse in fancy urban area
  - During rainfall: Biogas bubbles in the villa gardens
- The trial
  - Expensive lawyers from New York
  - Meetings in a 5 star hotel in London
  - Trial in Paris
- Risky business
- What went wrong



# Step 13 Physical mining



input

< 30 mm

> 30 mm

Dumpsite in  
Brussels

- All samples:
  - Heavy metals (Pb)
  - PAH (Benzo(a)pyrene)
- 1 sample: PCB
- You might need a new landfill and incineration: then don't





# Step 13 Physical mining



input

Dumpsite in  
Brussels

< 30 mm

> 30 mm



- Or maybe you do
- EFLM: enhanced landfill mining
- See next speakers



## 4. Conclusion

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

