Techno-economic evaluation for energy production from the landfill in Heraklion, Greece

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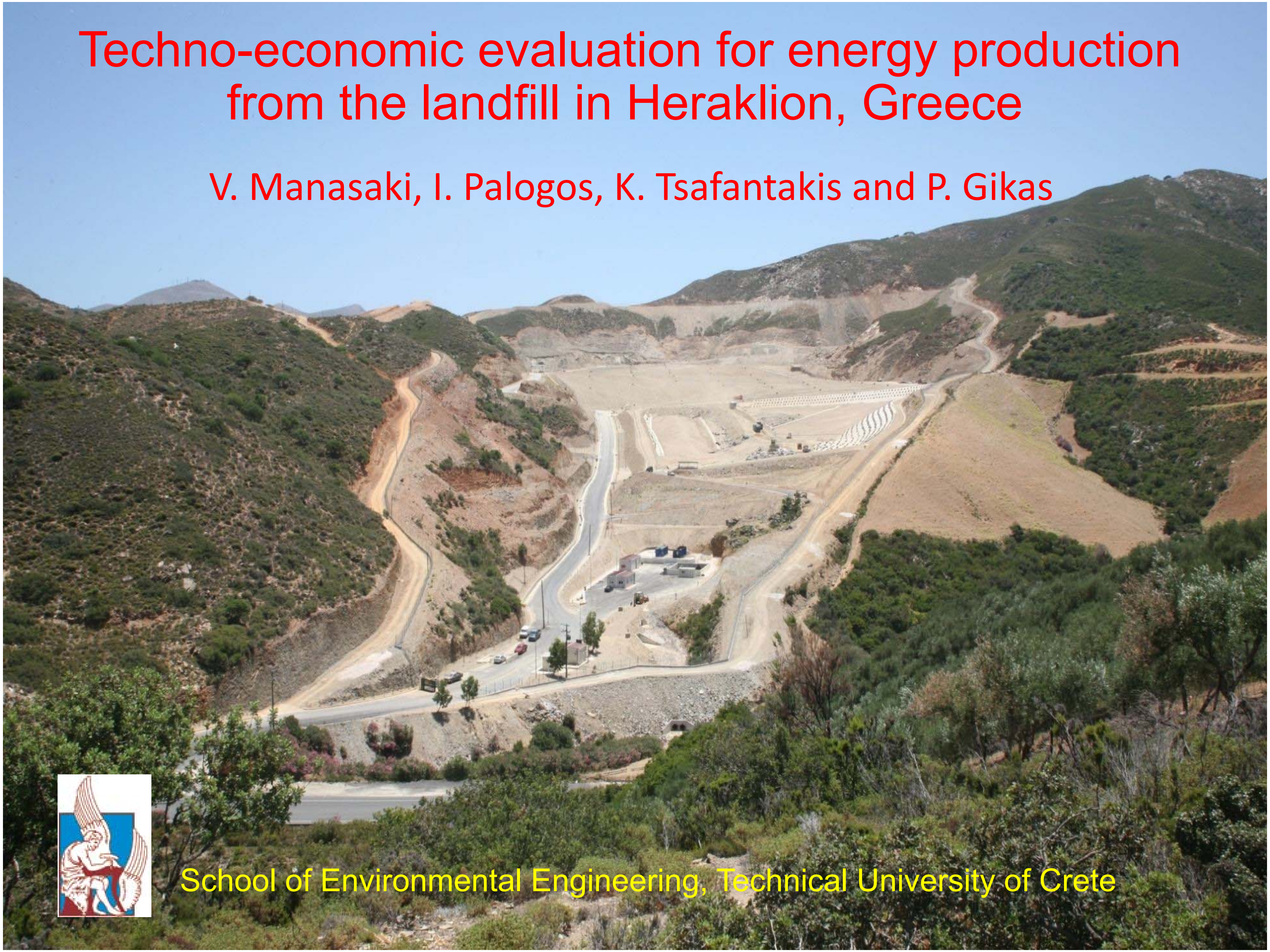

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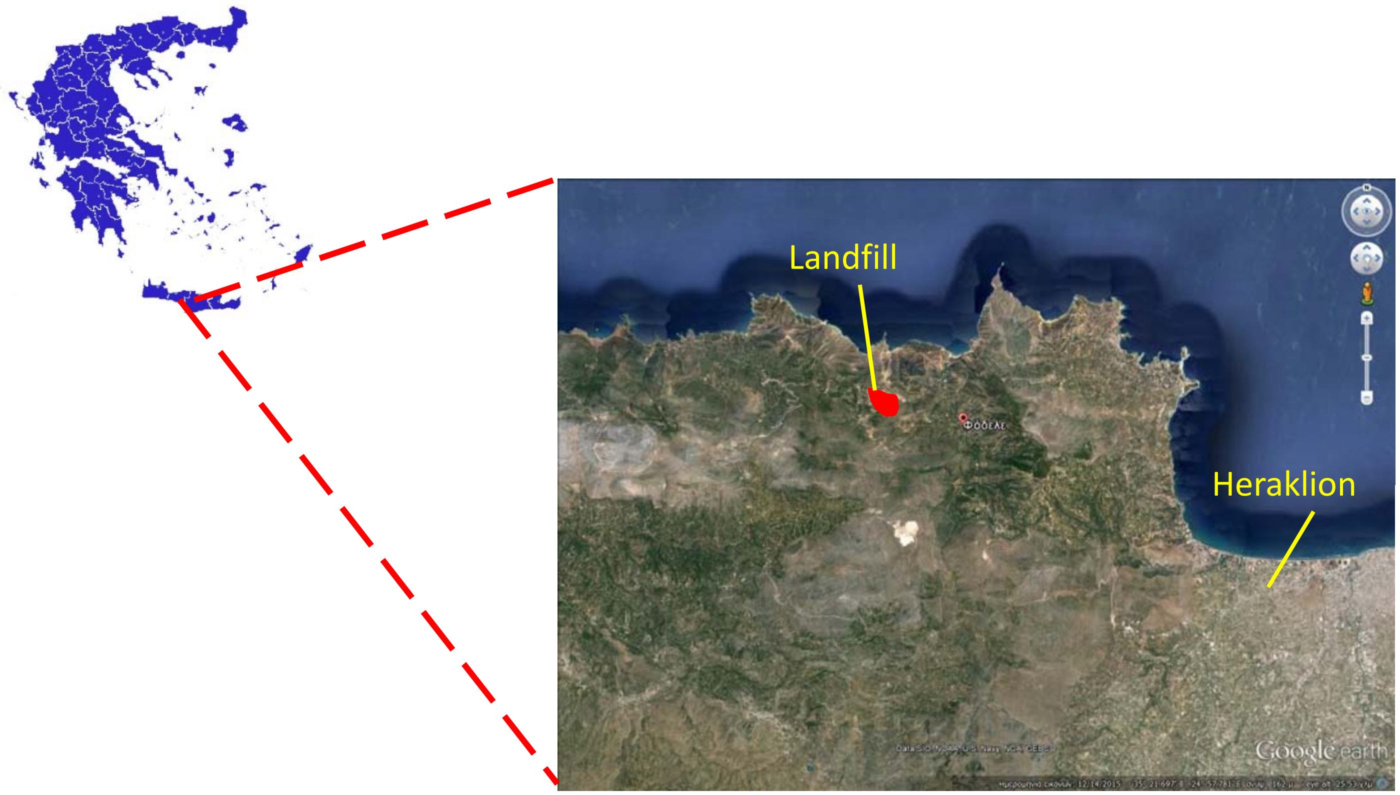
Landfill Gas (LFG) to electric energy

- Landfill Gas (LFG) is inevitably produced in any landfill
- LFG production is often calculated by models
- Most models assume constant methane content, which is not the case in landfills after more than 20 years of operation
- The situation is more complicated if multiple cells have been established

- Internal combustion Engines ((ICE) have a yield of about 40%, but require minimum methane content of approx. 40% in LFG
- Gradual Oxidezers (GO) have a yield of about 29%, but may operate at methane concentrations in LFG as low as 1.5%

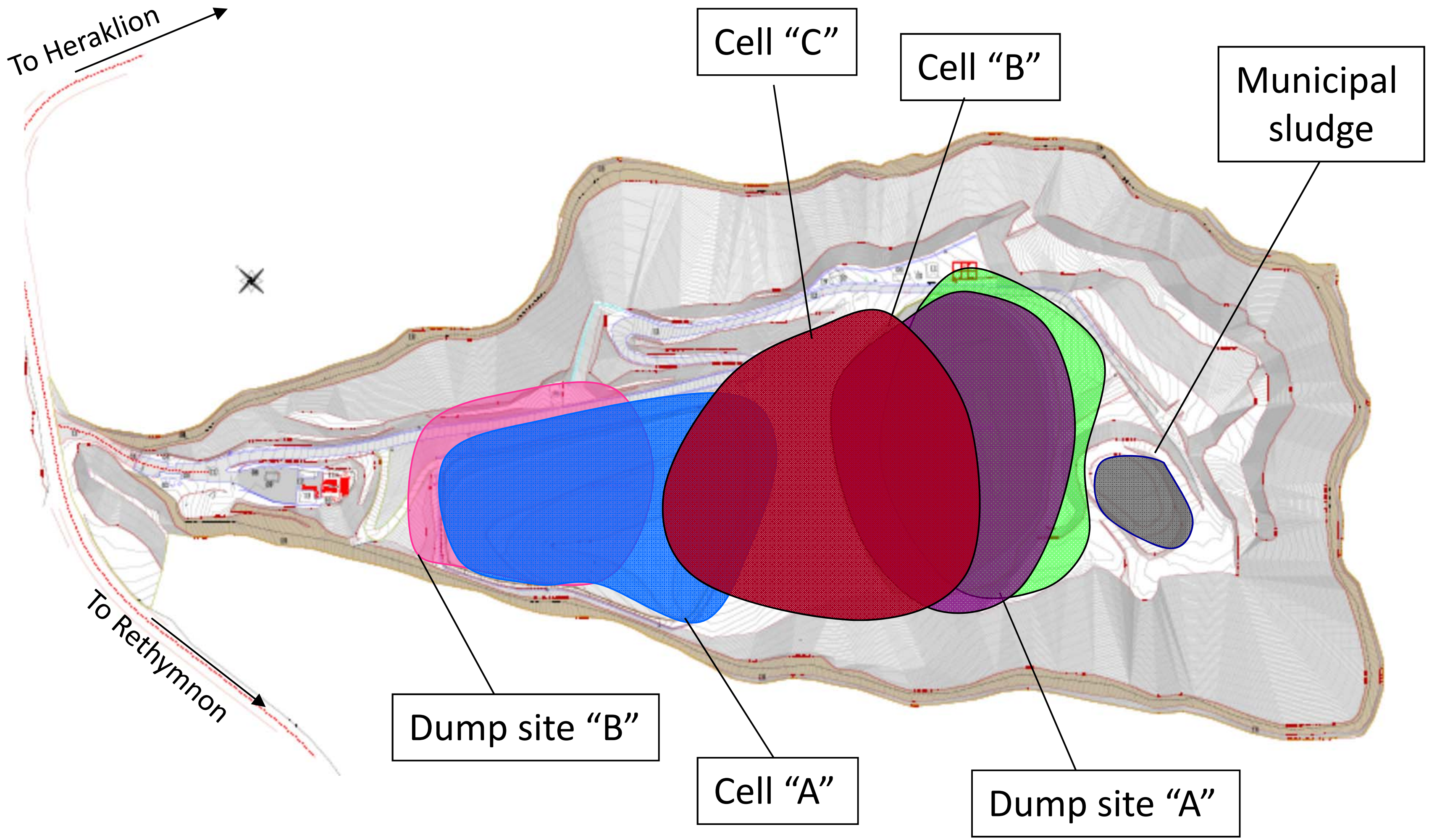
What is the best technology for efficient exploitation of LFG?

Landfill of greater Heraklion in Fodele



Receives approx. 13,000-14,000 tn/year

Development phases of Heraklion landfill in Fodele



MSW management of greater Heraklion

Collection

Landfilling

TMP process

Compaction

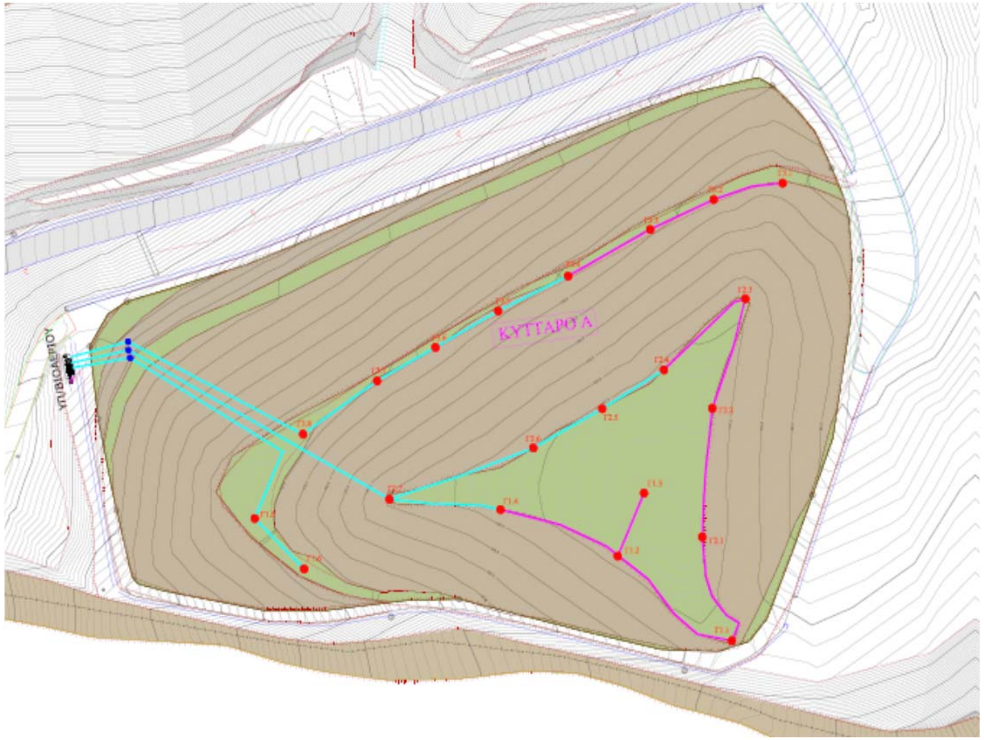
MSW fractions in Fodele landfill

Type of MSW	Fraction (%)
Food residues	39
Paper	20
Plastics	17.5
Wood-fabric-tires	4.7
Glass	4.25
Metals	6
Inert materials	3
Non-classified materials	5.55

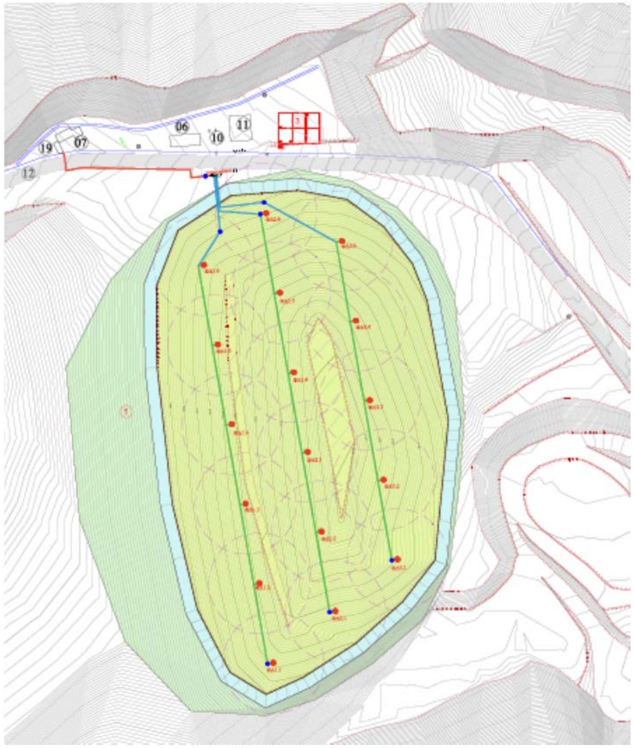
Heraklion landfill – MSW loading

	Dump site "A"	Dump site "B"	Cell "A"	Cell "B"
Operational period	1992-1997	1998-2008	2009-2012	2012-2016
Approx. volume ($10^3 m^3$)	353	719	480	442

LFG collection system



Cell "A"



Cell "B"

LFG collection and combustion system

✓LFG is currently collected only from dump sites “A” and “B” and cell “A”

✓Cell “B” will close shortly and LFG will be colelcted

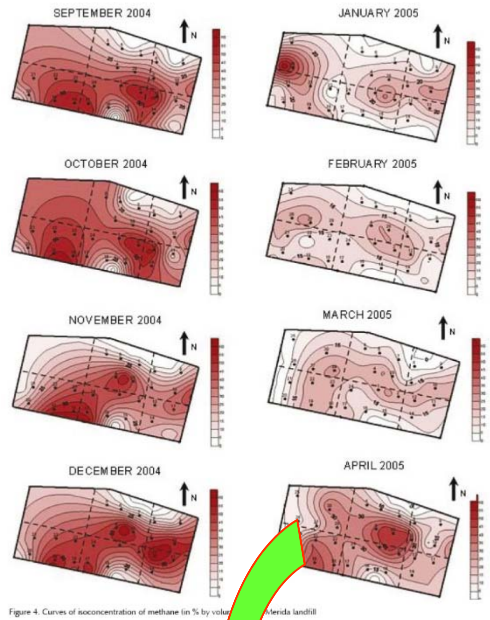
✓LFG is currently flared out

Estimation of LFG production

Experimentally

It shows only a picture of the current situation

By modelling



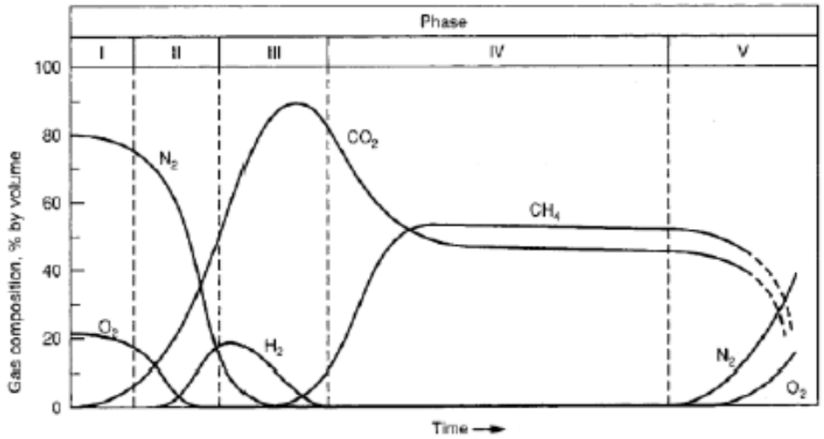
It involves a large degree of uncertainty

Modelling LFG production

- Various models can predict the LGF production in landfills
- Landgem (a free software by EPA) is widely used
- Landgem calculates the volume of LFG based on the filling pattern and MSW quality
- Landgem does not distinguish between normal and pressurized MWS during landfilling
- Landgem assumes that LFG consists of 50% CH_4 and 50% CO_2 – No other gases are considered

Methane concentration in LFG

However, after about 15-20 years after the landfill has been closed, methane concentration is usually reduced, due to the intrusion of atmospheric air.



Khalil et al, Int. J. Eng. Techn. Res., 2014

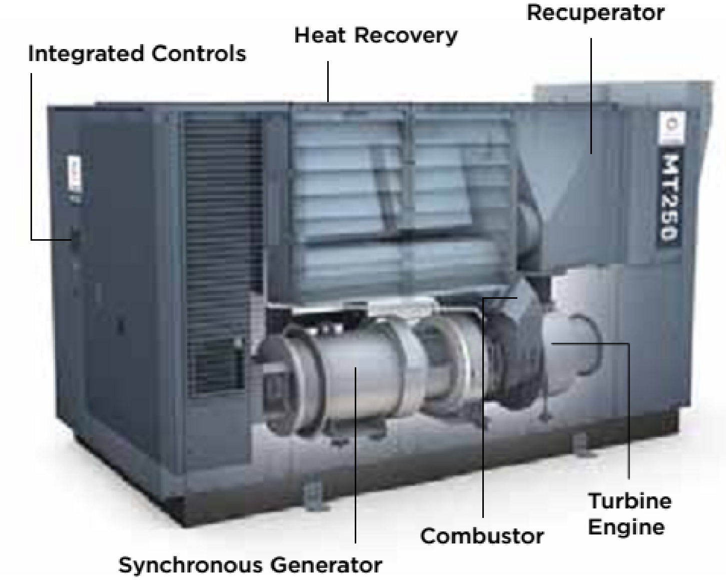
…But the concentration of methane is decisive for the selection of the process for the production of electric energy.

LFG to electric energy

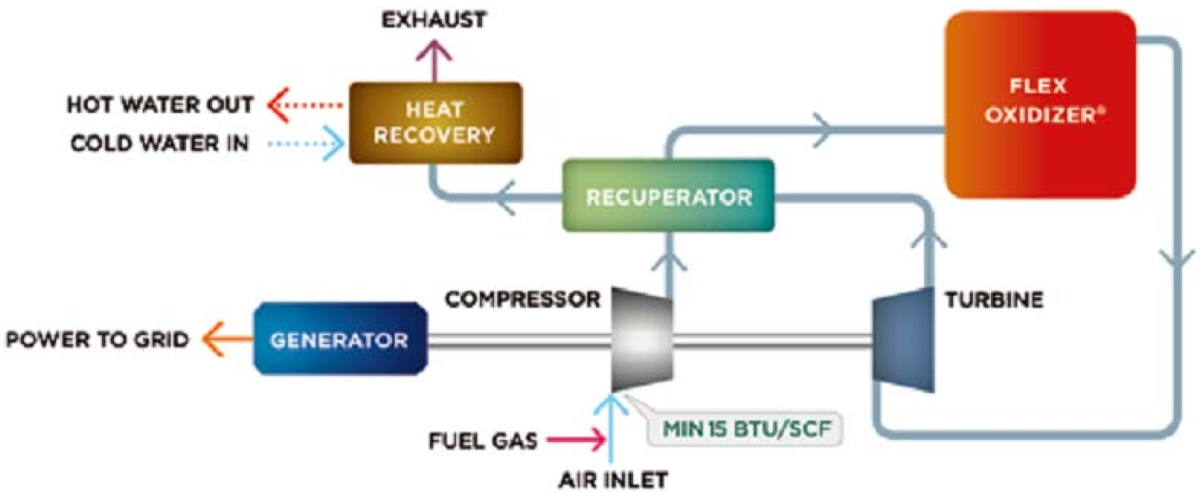
Internal combustion engine (ICE)	Gradual oxidiser (GO)
	
Requires CH_4 concentration > 40%	May operate at CH_4 concentration as low as 1.5%

Which is the best combination of processes for the maximization of profits?

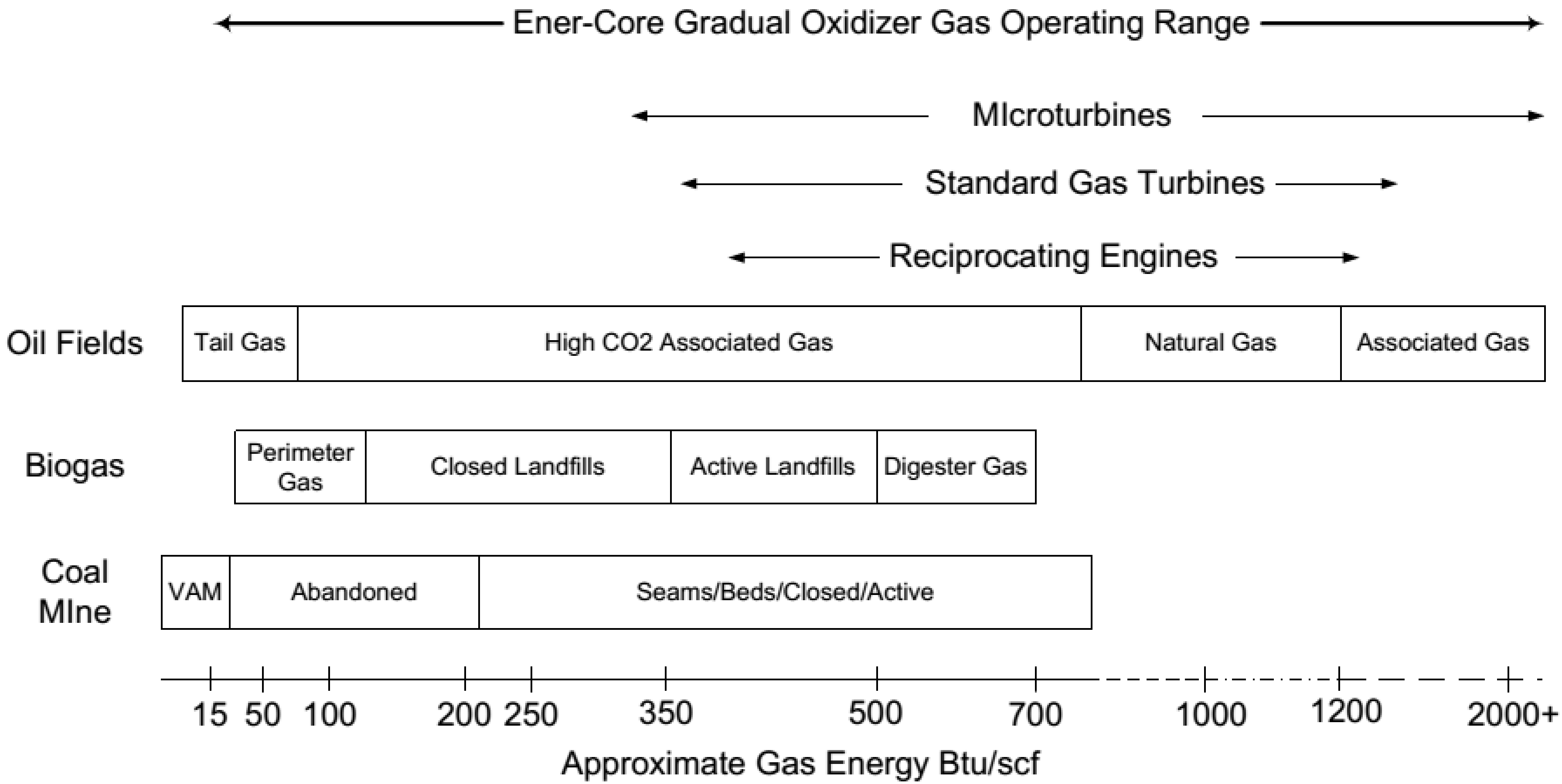
Gradual Oxidizer (GO) configuration



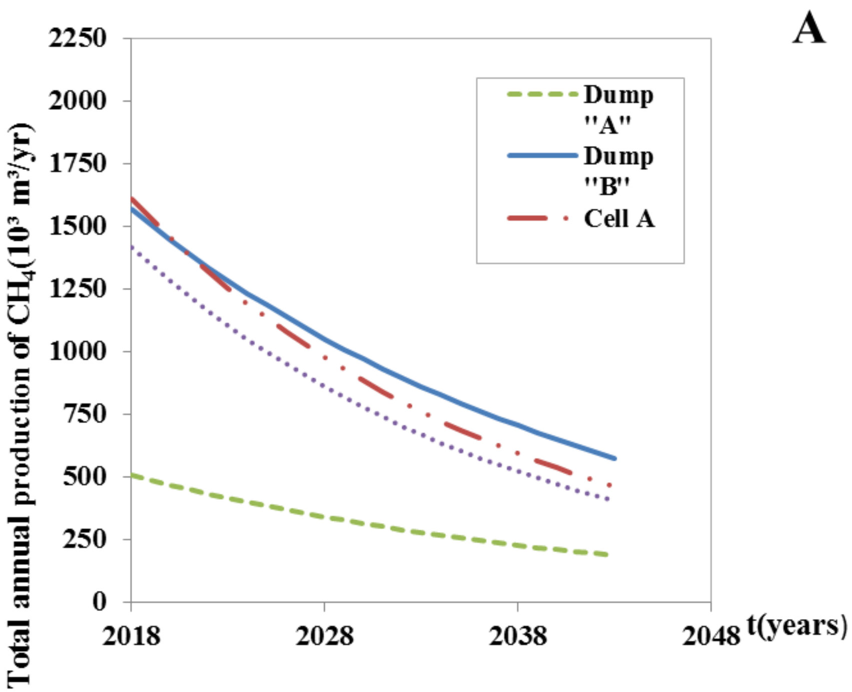
- A gradual oxidizer replaces the combustor and drives the turbine
- Low grade fuels aspirated with air prior to the inlet, at low compression
- Higher grade fuels can be injected at high compression upstream of the oxidiser
- Due to low oxidation temperatures, NOx emissions are kept significantly low

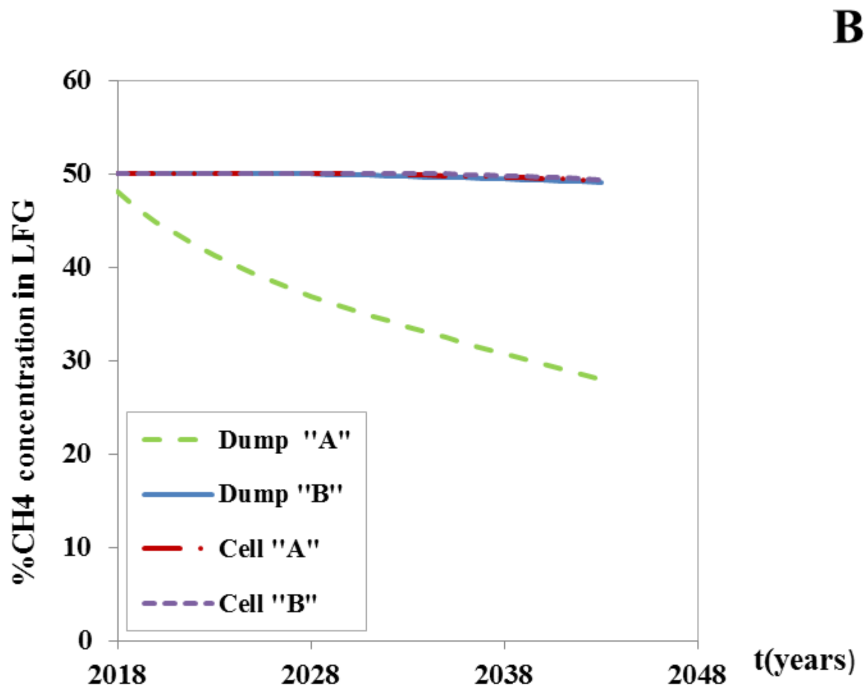


Operational ranges of various processes



Methane production





Internal combustion engines Vs Gradual oxidizers

ICE engine

GO engine

Characteristics			
Technology	Efficiency (%)	Operational time (availability) (%)	Minimum level of CH_4 concentration (%)
ICE	40	85	40
GO	29	95	1.5

Net Present Value (NPV)

$$NPV(n) = \sum_{t=1}^{n} \frac{C(t)}{(1+i)^t} - C_0$$

Techno-economic evaluation

- Installation costs
- Operational and maintenance (O&M) costs
- Costs of major services
- Electric energy production yields of each technology
- Operational time (availability) of each process
- Sale price of electricity (0.1€/kWh)
- Interest rate of 5%
- Period of techno-economic analysis (2018 to 2043)
- Minimum available size of GO in market (250kW)

Technology	Capital cost (€/kW)	O&M (€/kW)	Major service cost (k €)
ICE	2,400	220	250 (every 7 years)
GO	4,150	74	400 (every 9 years)

Calculation of the best scenario

Scenario	LFG to Electricity options
1	One 250kW GO engine for dump site "A" and two 250kW (each) ICE engines for dump site "B" and cells "A" and "B"
2	Three 250kW (each) ICE engines for dump sites "A" and "B" and cells "A" and "B"
3	Two 250kW (each) ICE engines for dump sites "A" and "B" and cells "A" and "B"
4	Two 250kW (each) GO engines for dump sites "A" and "B" and cells "A" and "B"
5	Three 250kW (each) GO engines for dump sites "A" and "B" and cells "A" and "B"
6	One 250kW GO engine for dump sites "A" and "B" and two 250kW (each) ICE engines for cells "A" and "B"

Calculation of the best scenario

Scenario	LFG to Electricity options	NPV (M €)
1	One 250kW GO engine for dump site “A” and two 250kW (each) ICE engines for dump site “B” and cells “A” and “B”	0.8
2	Three 250kW (each) ICE engines for dump sites “A” and “B” and cells “A” and “B”	1.6
3	Two 250kW (each) ICE engines for dump sites “A” and “B” and cells “A” and “B”	2.2
4	Two 250kW (each) GO engines for dump sites “A” and “B” and cells “A” and “B”	1.8
5	Three 250kW (each) GO engines for dump sites “A” and “B” and cells “A” and “B”	0.5
6	One 250kW GO engine for dump sites “A” and “B” and two 250kW (each) ICE engines for cells “A” and “B”	1.1

Conclusions

- LFG production has been estimated based on modified Landgem model concerning the reduction of methane concentration, with time
- The potential for electric energy production and the relative NPV have been calculated for various combinations of ICE and GO engines
- The use of two 250 kW ICE engines, yields the highest NPV, followed by the use of two 250 kW GO engines. GOs yields low NPV due to the absence of commercially available engines with capacities below 250kW
- GO has a definite advantage if environmental issues will also be encountered (such as Nox emissions)
- For better evaluation of the model outputs, experimental verification of LFG flows and qualities should take place, and the expected LFG production of the new cell should also be taken into account

Ευχαριστώ για την προσοχή σας