



Landfills as a biorefinery to produce biomass and capture biogas

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Walk the talk

- ✓ Landfill for waste management
- ✓ Environmental issues of landfills
- ✓ Revegetation to manage landfill sites
- ✓ Methane generation as a fuel source
- ✓ Landfill biomass for energy production
- ✓ Conclusions
- ✓ Challenges/opportunities

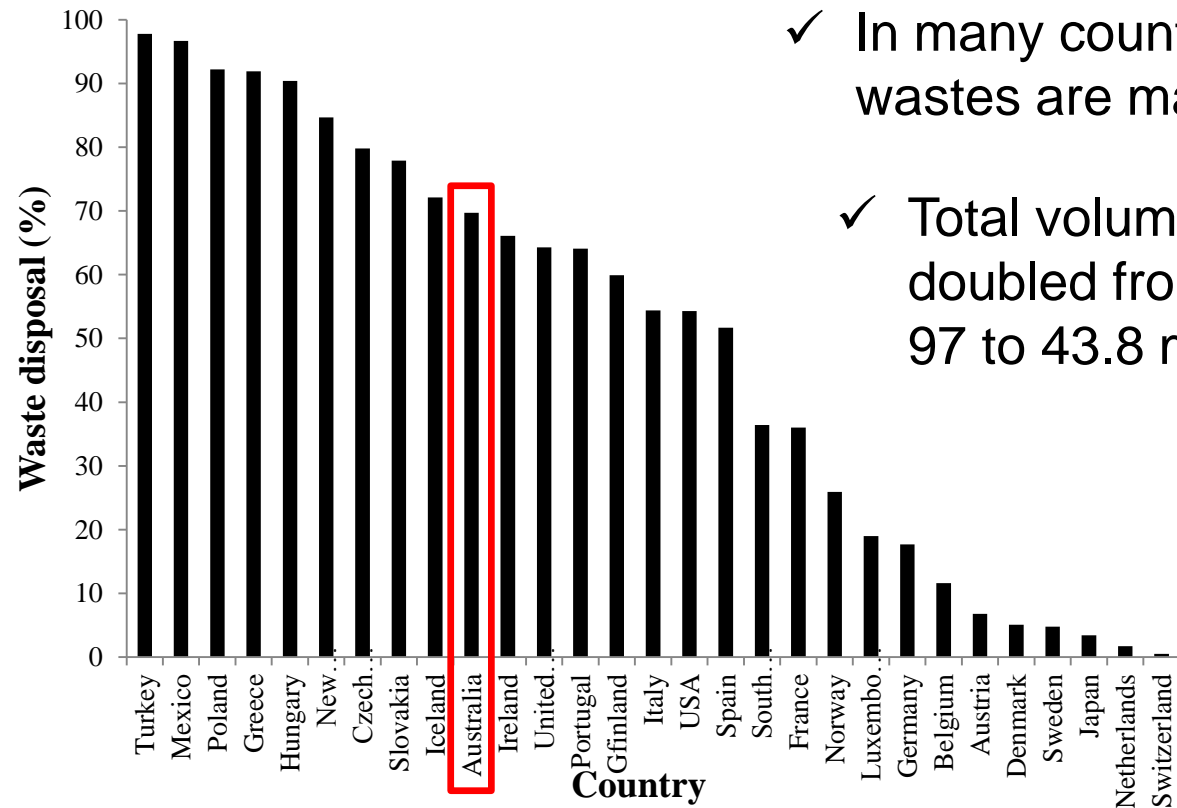


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Landfill for waste management

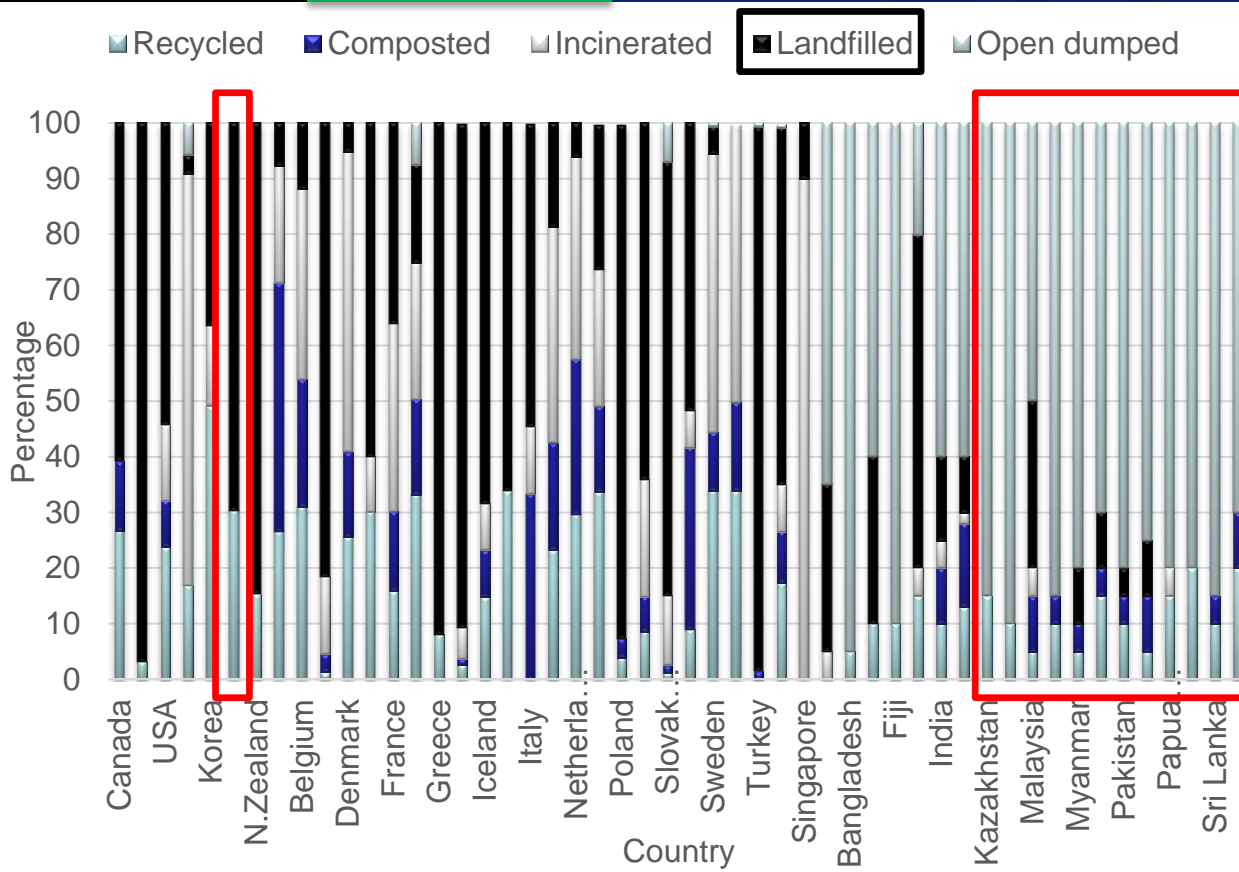


✓ In many countries, domestic and industrial wastes are managed mainly using landfills.

✓ Total volume of waste in Australia nearly doubled from 22.7 million tonnes in 1996-97 to 43.8 million tonnes in 2006-07.

✓ More than 70% of waste produced is disposed off using > 2000 landfills

Landfill for waste management



✓ Although there has been an increase in the recycling of waste, disposal to landfill is most widely used.



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Environmental issues of landfill sites



Landfill sites	Waste source	Issue
South Fremantle, WA	Domestic and Industrial	Methane explosion leachate, groundwater contamination
Wright-Patterson Air Force Base, USA	Industry and municipal	Explosion hazard of methane gas
Normandy Landfill, USA	Municipal waste	Methane explosion leachate, groundwater contamination
Islington Landfill, Australia	Industrial waste	Hydrocarbons, Heavy metals, Friable asbestos, leachate groundwater contamination
Firminy landfill site, France	Iron and steel foundry wastes	Methane explosion, leachate heavy metals

Landfills and methane emission



- ✓ Decomposition of organic matter in landfill can lead to leachate production and methane release.
- ✓ Through gas recovery systems, landfills provide methane as a fuel source.

Landfills and leachate emission

Landfill Leachate: high Cu, Zn, Pb, Cd, As, Cr



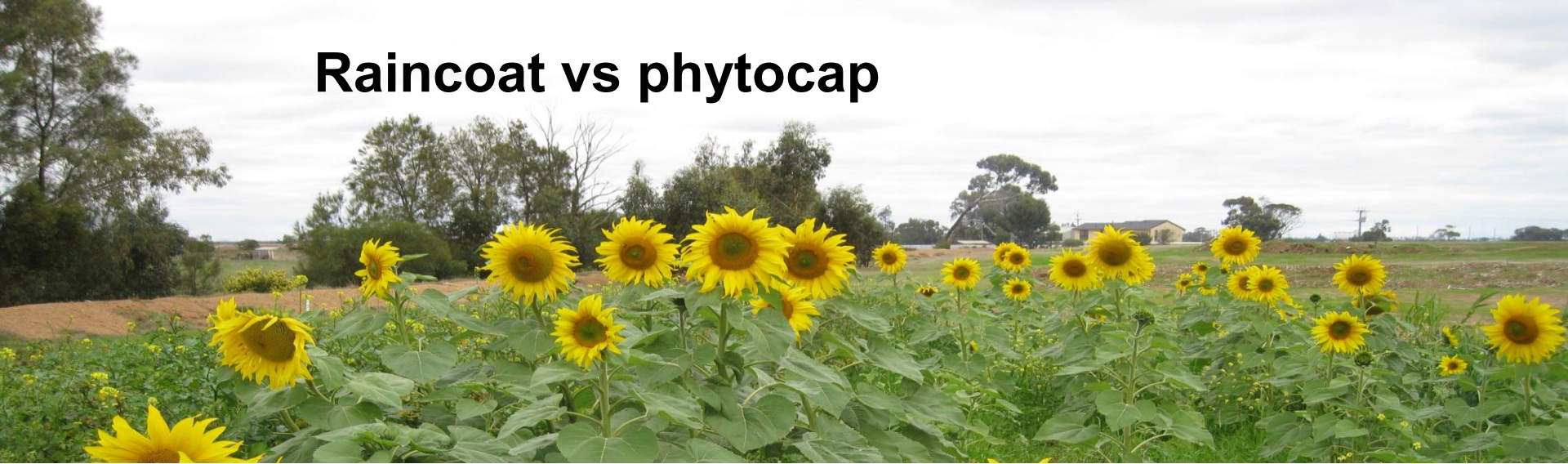
- ✓ Landfill leachates contain a range of contaminants, including dissolved gases, heavy metal(oids) and pesticides.

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Raincoat vs phytocap

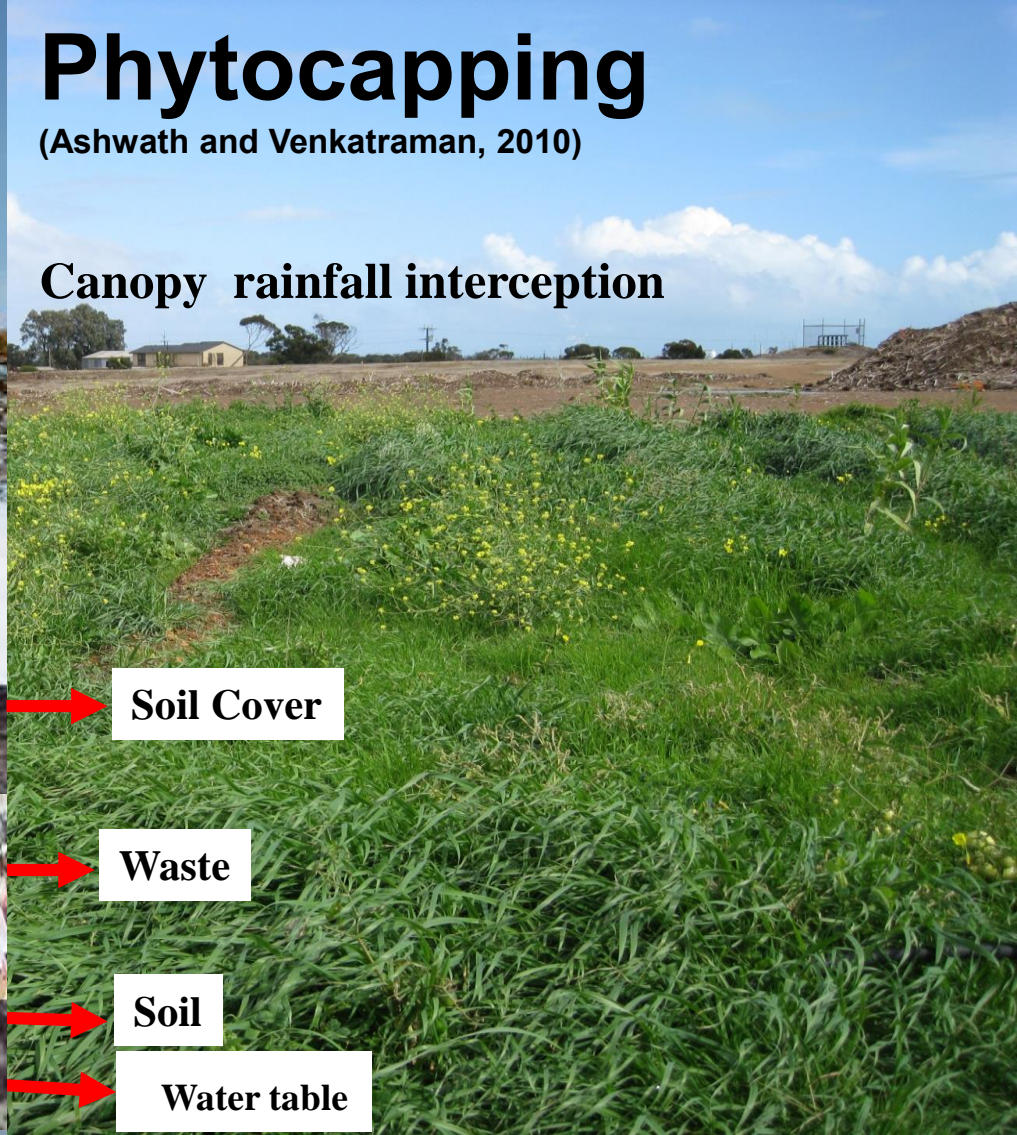
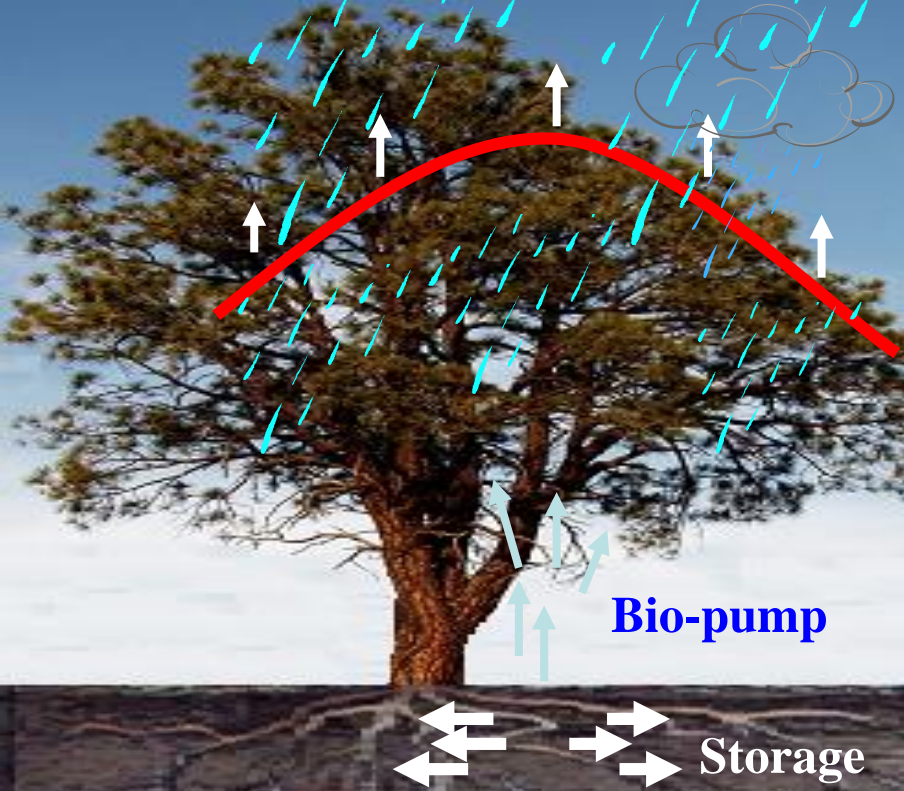


- ✓ Conventional landfill covers include compacted clays or plastic – to act as a ‘raincoat’ to keep out of water.
- ✓ **Phytocap** includes a ‘sponge’ layer (growing medium plus plants) that ‘stores’ water.
- ✓ Phytocapping is an alternative ‘lining’; aims to intercept water through ‘phytopumping’ – resulting in less leachate emission.
- ✓ Phytocapping provides additional benefits – biomass for energy production.

Phytocapping

(Ashwath and Venkatraman, 2010)

Canopy rainfall interception



Soil Cover

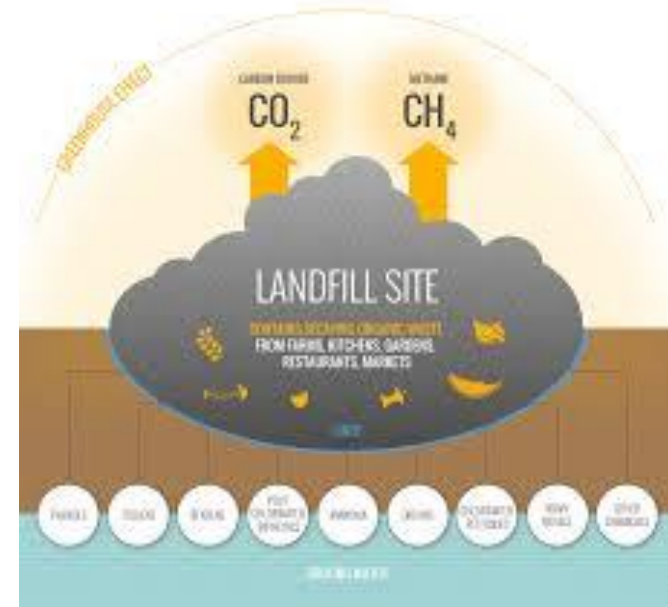
Waste

Soil

Water table

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Methane generation as a fuel source

- ✓ Methane from landfills can be extracted, recovered and used for electricity generation and as a direct fuel source.
- ✓ Methane recovery, although an expensive technology, is being implemented and adopted in many developed countries.



Potential methane and electricity production from landfills in various countries

Region	Country	Population (million)	Waste disposal in landfills (%)	Landfill methane production (Gg/yr)	Total methane production (%)	Total electricity from methane (GWh/yr)	Percentage of total electricity from methane (%)
Oceania	Australia	17.46	69	81.92	1.35	405	0.16
	N. Zealand	3.519	84	20.06	1.53	99	0.23
America	USA	238.7	54	872.3	3.34	4314	0.10
	Brazil	137.9	85	788.8	4.59	3901	0.84
Europe	UK	54.02	64	233.7	7.46	1156	0.31
	France	63.00	36	152.6	4.15	755	0.14
	Germany	82.51	18	98.27	3.04	486	0.08
	Sweden	9.029	4.8	2.92	0.54	14	0.01
Asia	Vietnam	90.12	4.3	24.27	1.22	112	0.11
	Korea	38.70	36	94.78	6.23	469	0.11
	India	1080	15	1090	3.92	5392	0.60
	China	1313	43	3801	5.99	18801	0.51

- ✓ Methane recovery from landfill provides energy source, although their contribution to total electricity production is not significant.

Landfill methane and electricity production

Name	Location	Landfill area (ha)	Landfill methane produced (Mg/yr)	Net electricity (MWh/yr)
Ruseifeh Landfill	Amman, Jordan	54	1856	9180
Mugga Lane Landfill	Australian Capital Territory	123	1545	7641
Pilsworth Landfill	Pilsworth, North West, UK	76	2592	12821
Rainham Landfill	Runham, East, UK	177	4816	23817
Ano Liossia Landfill	Ano Liossia, Attiki, Greece	45	26629	131698
Plessis-Gassot Landfill	Ile-de-France, France	250	3027	14971
Barycz Landfill	Krakow, Krakow, Poland	36	451	2232
Bradley Landfill	California, United States	69	2737	13536
El Sobrante Landfill	California, United States	200	1546	7648
Rautenweg Landfill	Wien, Austria	58	2461	12172
Siggerwiesen Landfill	Salzburg, Austria	50	1272	6293

- ✓ Methane recovery from landfill and its subsequent use as an energy source is practiced in many countries.

Landfill gas recovery in Australia

Source	Energy Capacity
Werribee Sewage Treatment Plant, VIC	10 MW
Shoalhaven Landfill Gas Abatement Facility (NSW)	1 MW
Woy Woy Landfill Gas Abatement Facility (NSW)	1 MW
The facility is hosted by Gosford City Council, NSW	
Glenorchy Gas Extraction and Generation Facility (TAS)	1.5 MW
Kincumber Landfill Gas Abatement Facility (NSW)	1 MW
The facility is hosted by Gosford City Council, NSW	
Rockingham Landfill Gas Power Generation Facility (WA)	2 MW
McRobies Gully Gas Power Generation Facility (Tas)	1 MW

✓ AGL's 16 M\$ biogas unit at Werribee Plant is the largest in southern hemisphere.



Landfill gas recovery in Hong Kong

Closed Landfills	Gas Collected (M ³ /hr)	Modes of Landfill Gas Utilization	Gas Utilized (M ³ /hr)
Shuen Wan	288	Gas treated and piped to Towngas for use as fuel	288
Tseung Kwan O	1,462	Electricity generation for on-site use; used for heating in the leachate treatment process	963
Gin Drinkers Bay	203	Used for heating in the leachate treatment process	203
Pillar Point Valley	448	Used for heating in the leachate treatment process	444



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Landfill biomass for energy production



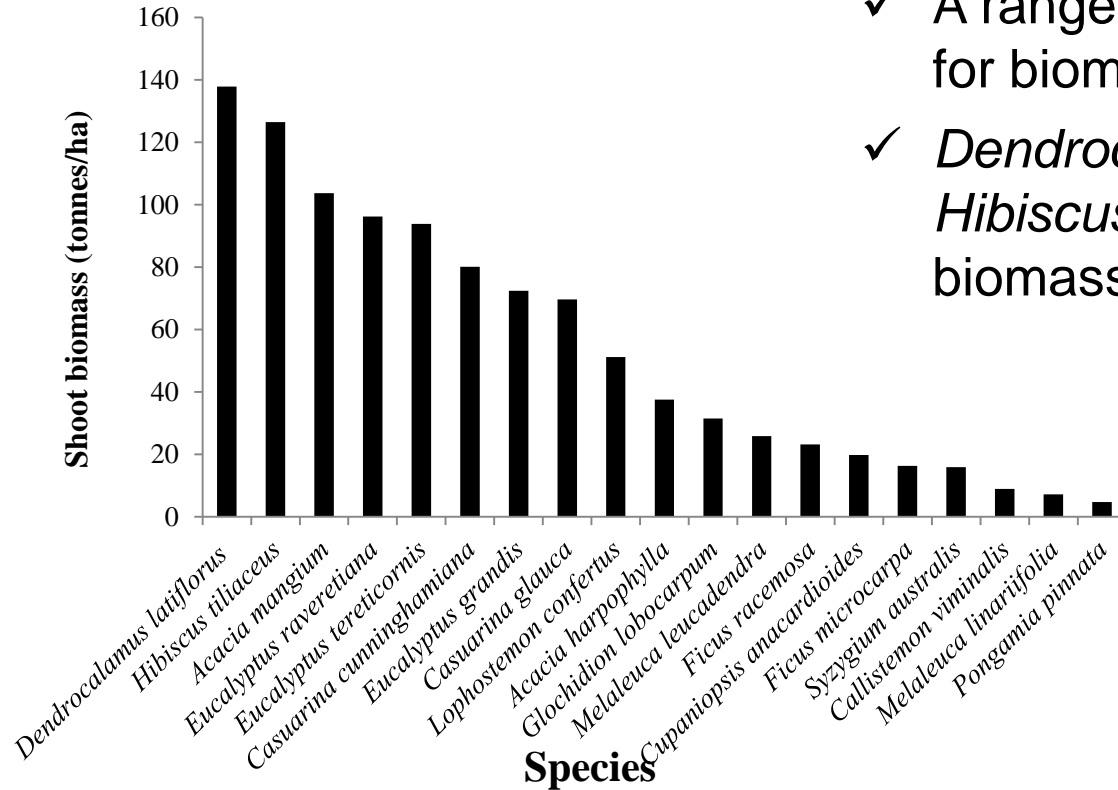
- ✓ The biomass produced from the landfill sites can be used for energy generation and biochar production.
- ✓ Biomass: any renewable source of fixed carbon emerging from wood, wood residues, agricultural crops and their residues.
- ✓ If landfill sites are managed effectively for biomass production, it has wider economic potential and environmental benefits.

Potential biomass production from landfills

Region	Country	Landfill area (ha)	Potential biomass yield from landfill site (Mg/yr)					
			Sunflower	Sugarcane	Arundo	Willow	Switch	Miscanthus
Oceania	Australia	296	17265	16456	20992	3706	2550	6286
	N. Zealand	38	2223	2118	2702	477	328	809
America	USA	5146	299635	285587	364317	64321	44253	109089
	Canada	289	16822	16033	20453	3611	2484	6124
	Brazil	1308	76158	72588	92598	16349	11248	27727
Europe	UK	1260	73358	69919	89194	15748	10834	26708
Asia	Japan	1319	76808	73207	93389	16488	11344	27964
	India	788	45866	43716	55767	9846	6774	16699
	China	3398	197843	188567	240551	42470	29219	72029
	Honkong	158	9186	8756	11169	1972	1357	3345
	Vietnam	112	7108	6952	8958	1487	1013	2601
Africa	S. Africa	170	9927	9462	12070	2131	1466	3614

- ✓ Depending on the plant species significant amounts of biomass can be produced from landfill sites.

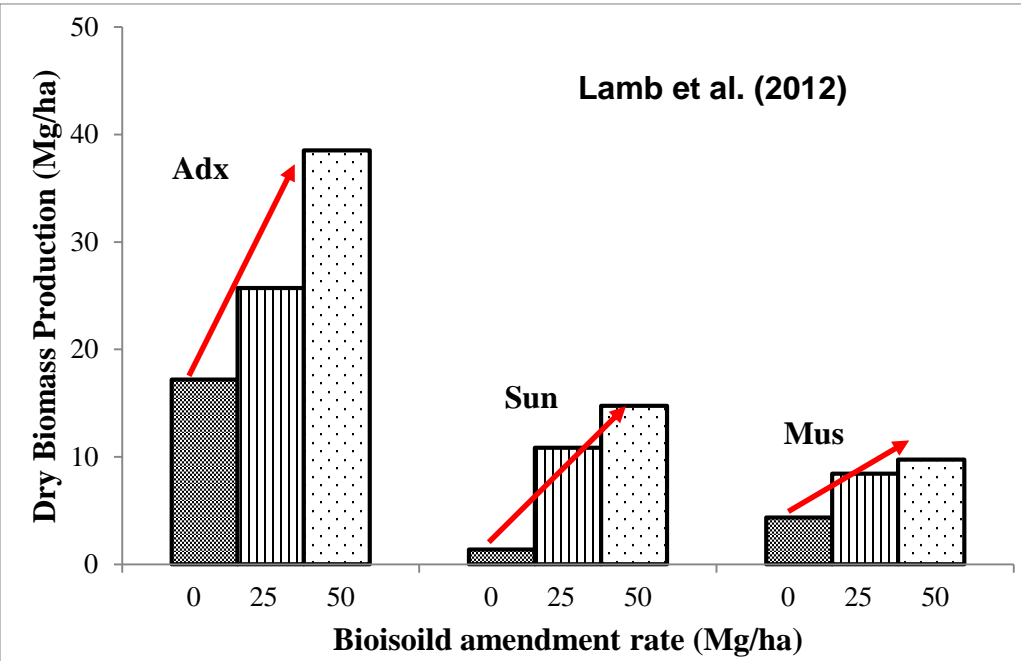
Biomass production



- ✓ A range of plant species can be used for biomass production.
- ✓ *Dendrocalamus latiflorus* (bamboo) and *Hibiscus tiliaceus* produced the highest biomass production (Venkatraman and Ashwath, 2009).



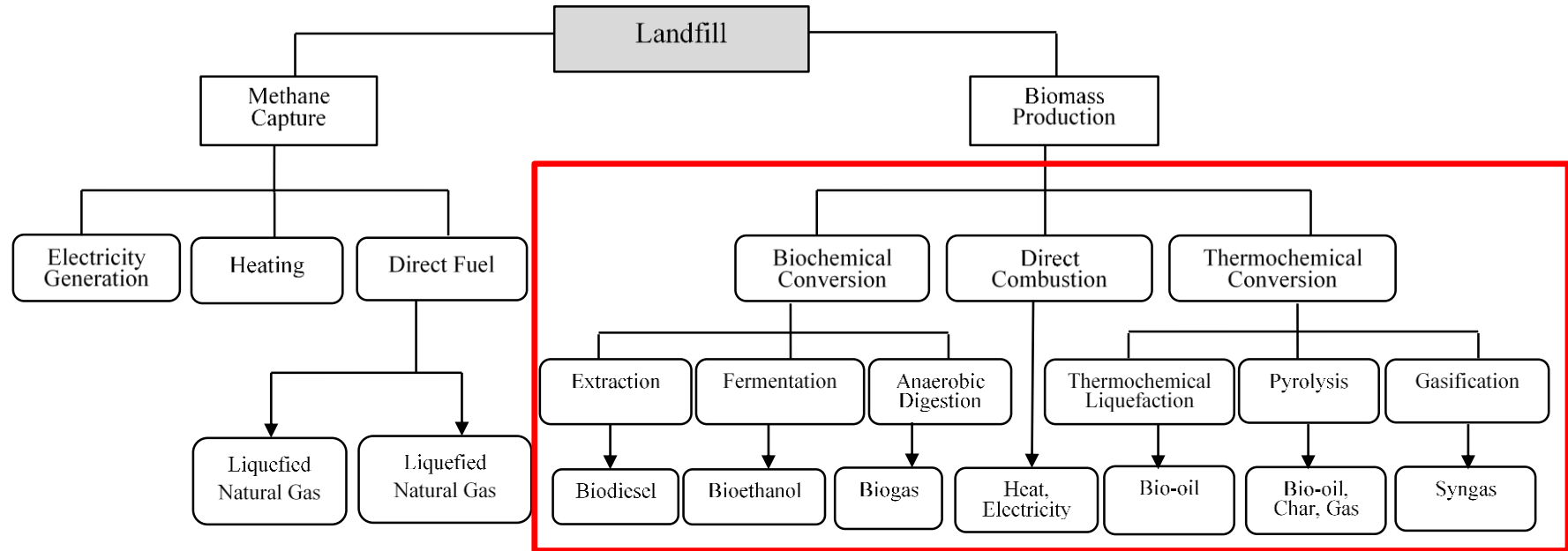
Biomass production



- ✓ Landfills with clay caps have high bulk density and low nutrient supply.
- ✓ Application of amendments can improve soil properties, thereby increasing biomass yield.

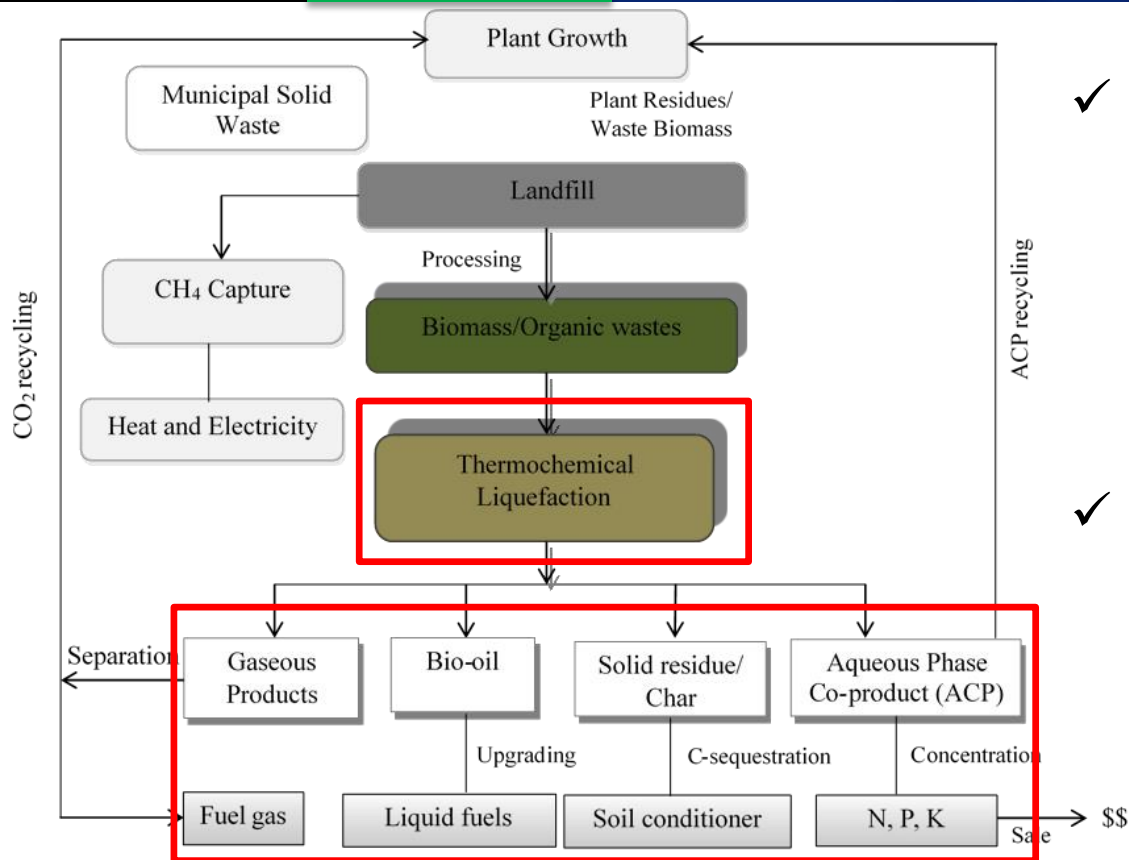


Technologies for biomass conversion



- ✓ Biomass can be converted into fuels and carbon-based products by biochemical and thermochemical methods.

Thermochemical biomass conversion



- ✓ Thermochemical conversion leads to higher productivity, complete utilization of feed stocks, and better control over the process relative to biological processes.
- ✓ A range of by-products are produced during the thermochemical conversion of biomass.

Pyrolysis

Type	Conditions	Yields (%)		
		Liquid	Char	Gas
Slow (carbonization)	Low temperature (300-700°C), Long solids and vapour residence time (600-6000 s), Particle size: 5-50 mm	30	35	35
Intermediate	Moderate temperature (around 500°C), moderate vapour residence time ~10-20 s	50	20	30
Fast	Moderate to high temperature 500- 1000°C), moderate vapour residence time ~1 s, particle size (< 1 mm)	75	12	13

- ✓ Pyrolysis: thermal decomposition of biomass to liquid (bio-oil), solid (char) and gaseous products in the absence of oxygen at 350-700°C.
- ✓ Pyrolysis results in biochar, bio-oil and bio-gas end products.



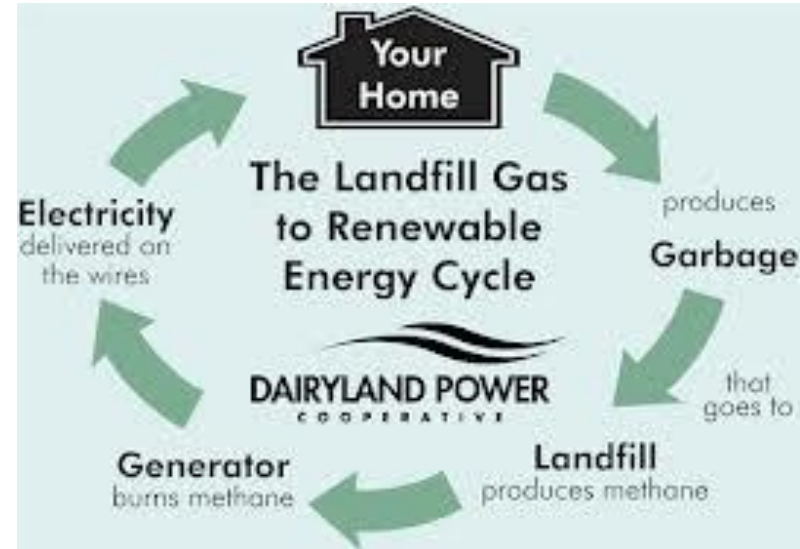
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Conclusions

- ✓ While landfilling provides a pathway for waste disposal, it causes leachate generation and GHG emissions.
- ✓ Landfills with gas recovery systems can be used to capture methane as a fuel source.
- ✓ Revegetation (i.e., phytocapping) to manage leachate generation provides a source of biomass for energy production.
- ✓ Biomass from landfill sites can be converted to energy through pyrolysis, gasification and co-generation.



Conclusions

- ✓ Landfill gas capture and revegetation (i.e., phytocapping) contribute to environmental and social benefits including improved groundwater and air quality, and local employment and community programs.



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*“There are **known knowns**;
known unknowns;
unknown unknowns”*



Challenges/Opportunities

- ✓ Phytocapping landfills with endemic plant species for the creation of a natural ecosystem and high biomass for energy production.
- ✓ Although the potential landfill area is relatively less compared to other degraded lands, landfill sites are readily accessible for biomass production.
- ✓ To maximize the benefits of biomass for energy production, plant species for local market or end-use should be selected.
- ✓ Methane recovery and biomass production from small-scale landfills at rural regions are critical in sustainable management.

Chasing for marijuana at landfills sites.



THANKS

Perhaps in Bioenergy Research and Technology, there are more
“unknown unknowns”



*“There are **known knowns**; **known unknowns**; **unknown unknowns**”*

