AUTH

LHTEE

A technical assessment of different food waste treatment technologies in campus dining hall from the perspective of global warming and resource recovery: An implementation in the Aristotle University Thessaloniki

G. Perkoulidis, C. Karkanias, A. Malamakis, S. Kontogianni and N. Moussiopoulos

Laboratory of Heat Transfer and Environmental Engineering

Department of Mechanical Engineering

Aristotle University Thessaloniki

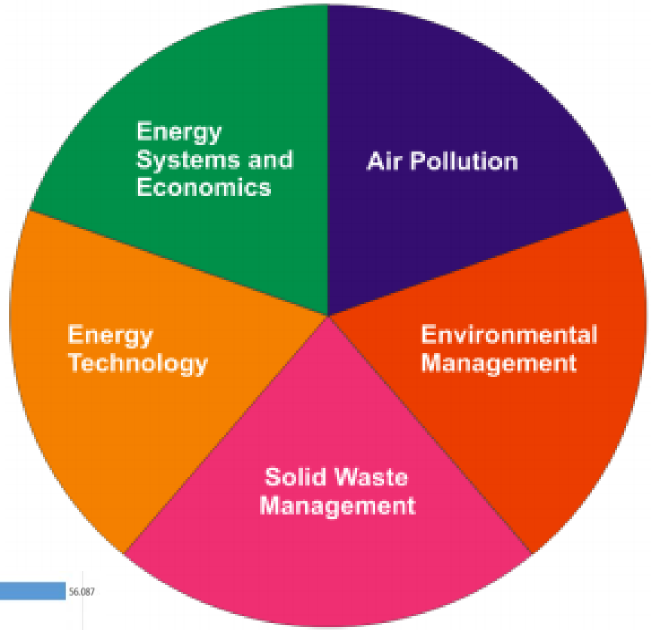
Laboratory of Heat Transfer and Environmental Engineering (LHTEE)

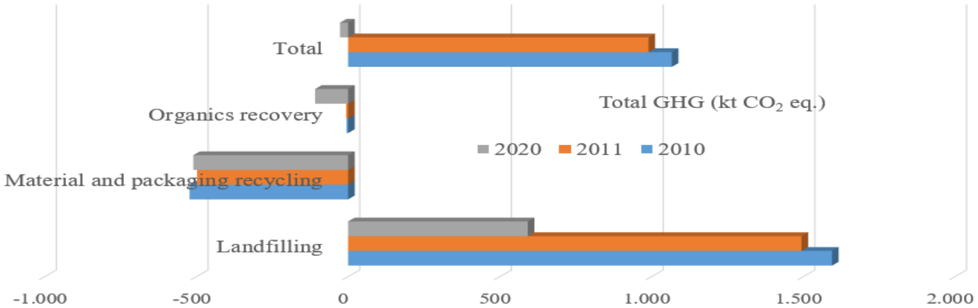
Laboratory address
8th floor, Building D
School of Engineering
Phone: +30 2310 996011
Fax: +30 2310 996012

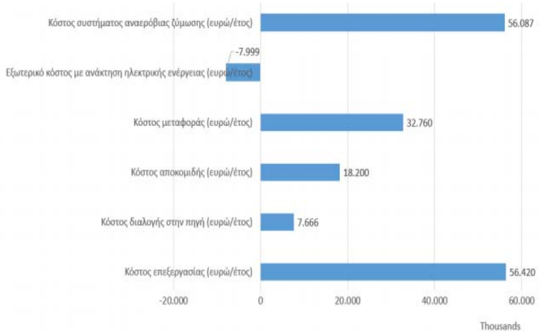
Mail address
Box 483
Aristotle University Thessaloniki
GR-54124 Thessaloniki, Greece
info_lhtee@aix.meng.auth.gr
URL: http://aix.meng.auth.gr

http://aix.meng.auth.gr /lhtee/index.html

Main Research Topics

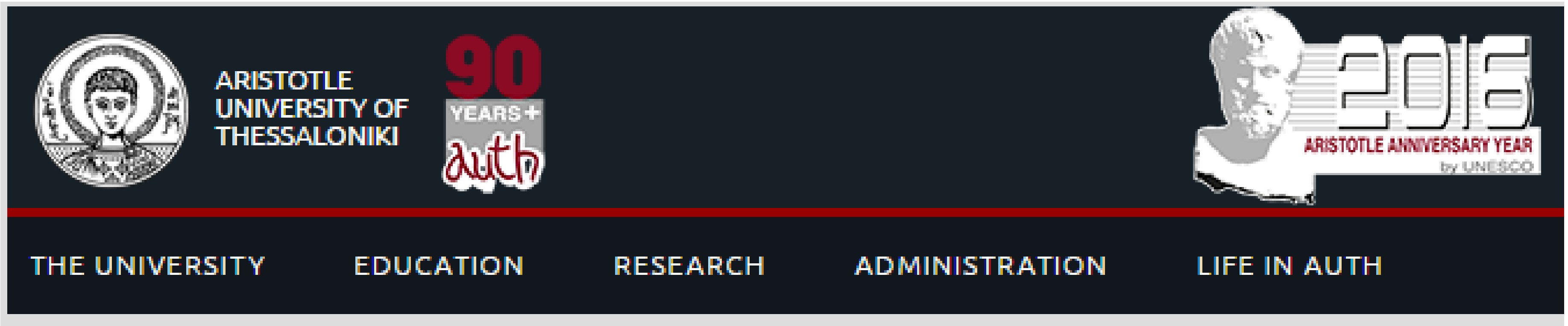






Κριτήριο Διεργασία	Φαινόμενο θερμοκηπίου (kg CO_2/t)	Ανάκτηση ενέργειας (kWh/t)	Ανάκτηση υλικών (kg/t)	Κόστος επεξεργασίας (€/t)
Waasa	216	730	300	90
Valorga	228	700	320	68
Dranco	226	760	260	62
Kompogas	208	585	250	63
BTA	212	700	280	95

Aristotle University Thessaloniki

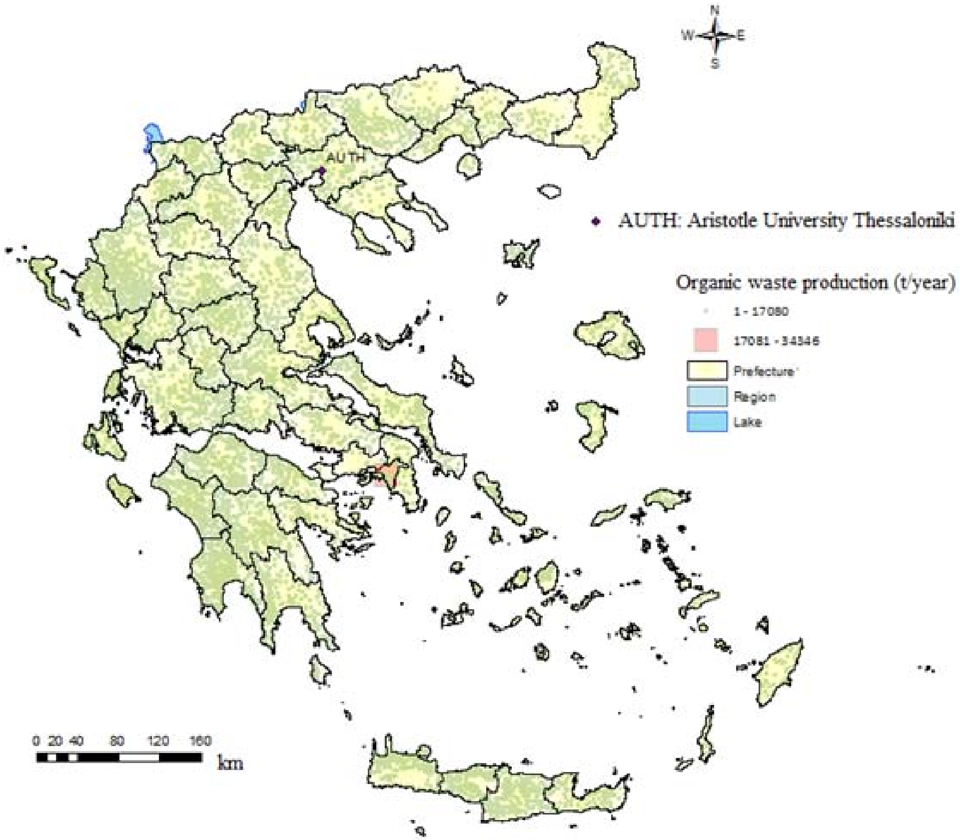


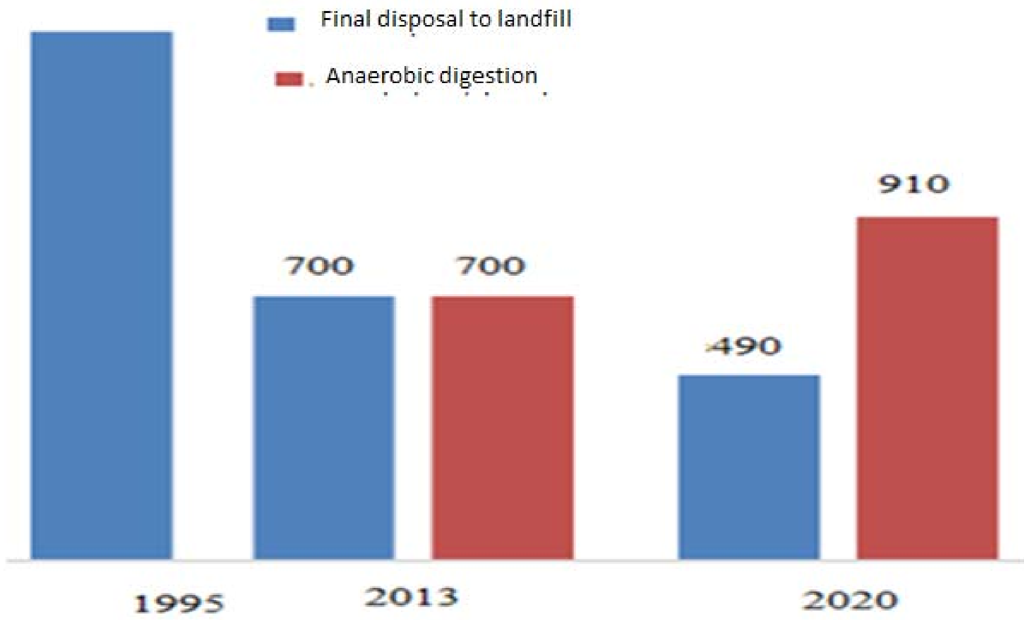
http://auth.esngreece.gr/aristotle-university-thessaloniki

https://www.auth.gr/en/faculties

http://www.eng.auth.gr/en/home.html

Biowaste production in Greece (2016)

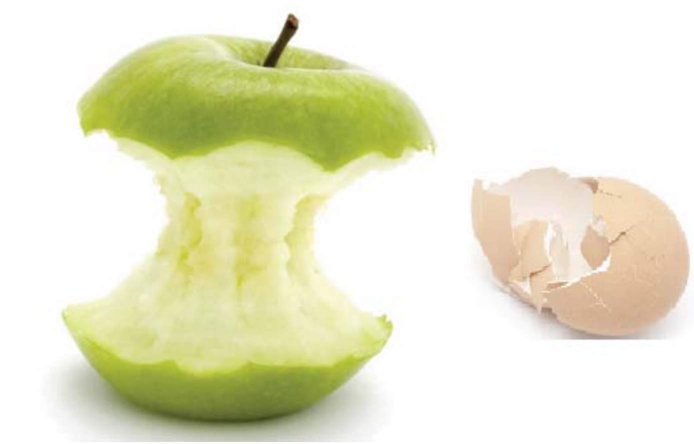




Source: Perkoulidis et al., 2016

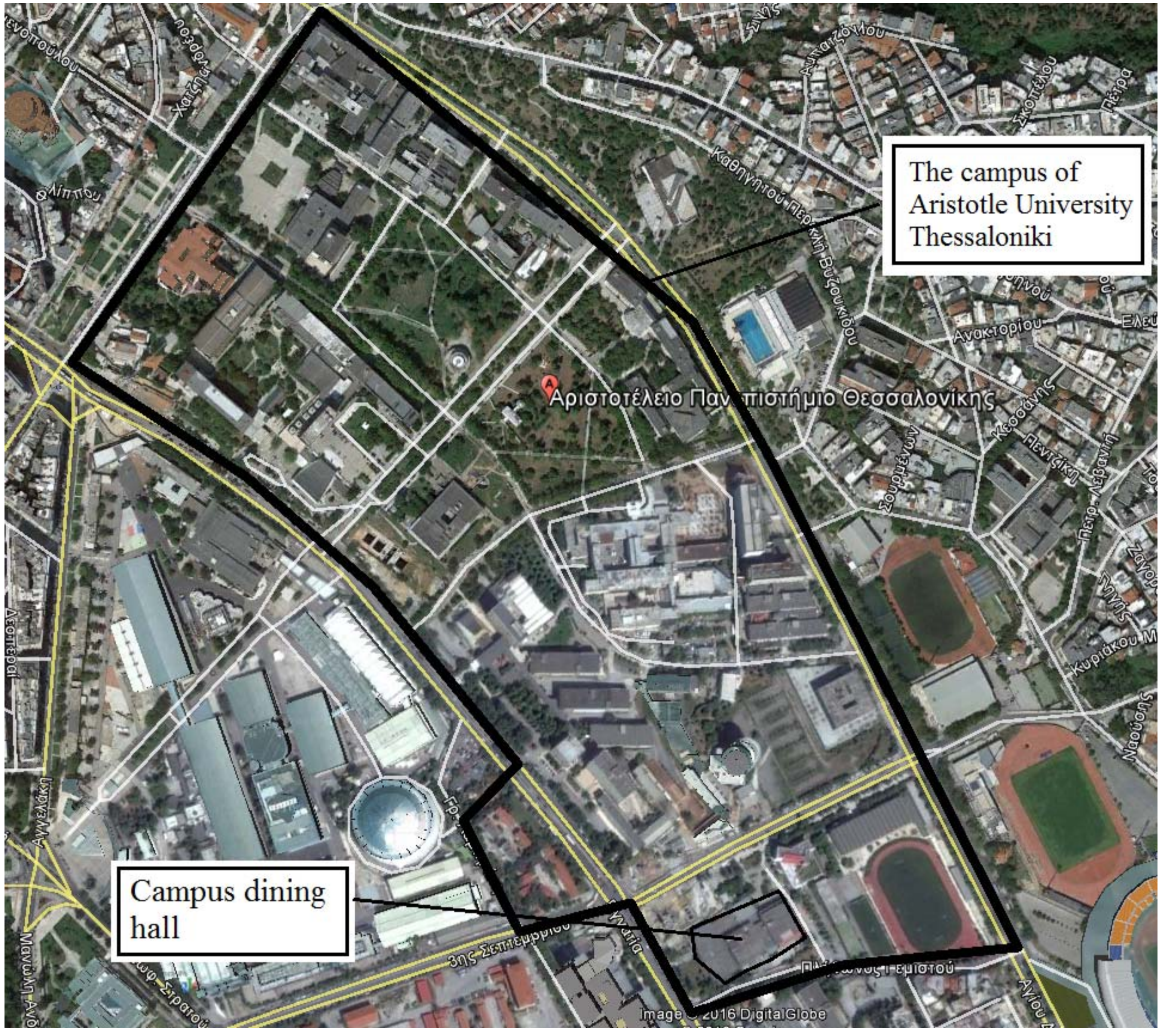
Food waste management in universities

- Exploring Food Waste Reduction in Campus Dining Halls (Merrow et al., 2012)
- Penn – Green Campus Partnership
- University of Washington - Food Waste Composting
- Boston University – sustainability
- University of Leeds - Maximising Opportunities



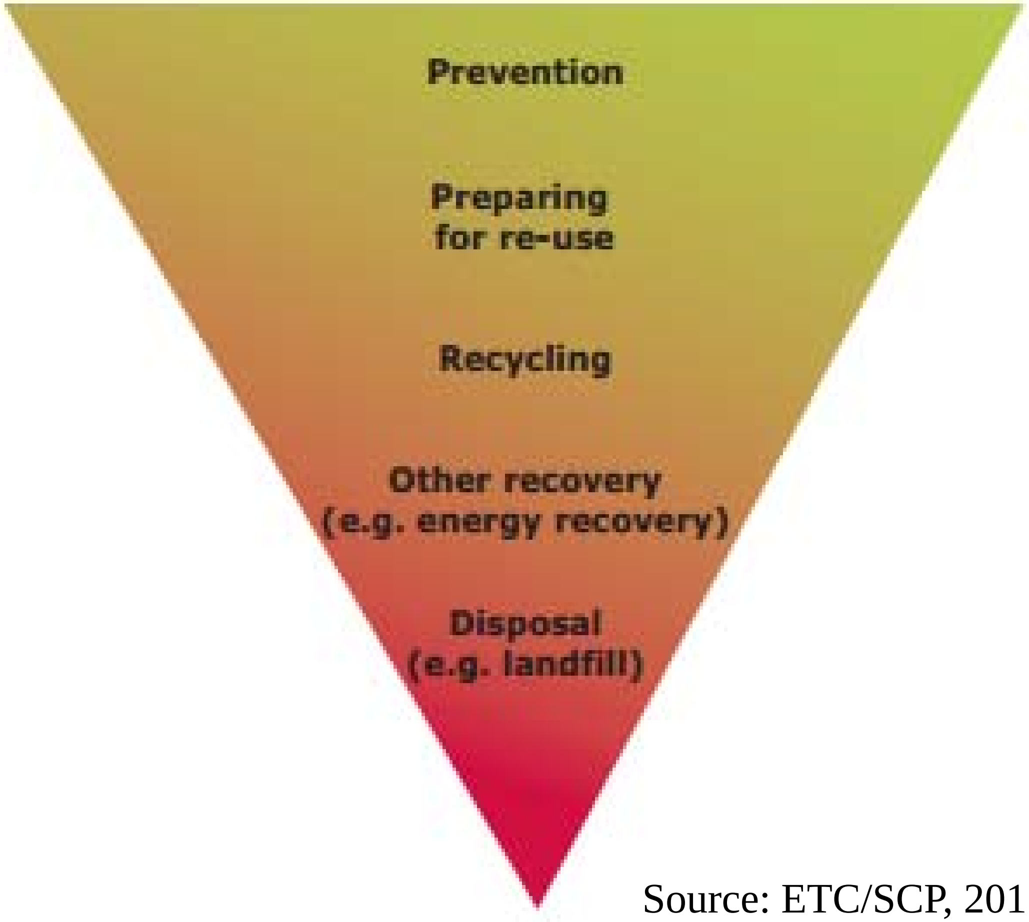
https://wmich.edu/sites/default/files/attachments/ENVS%204100%20Final%20Project%20Report%20-%20Merrow,%20Penzien,%20Dubats.pdf,
http://www.facilities.upenn.edu/sites/default/files/Penn%20Compost%20Poster.pdf,
https://www.washington.edu/facilities/building/recyclingandsolidwaste/procedures/food_waste,
http://www.bu.edu/sustainability/what-were-doing/food/
http://www.see.leeds.ac.uk/misc/ejournal/Issue%207%20files/7;%20201-231.pdf

The campus and food waste from dining hall



Source: Google earth, 28/8/2015

The European Union waste hierarchy and the anaerobic digestion process

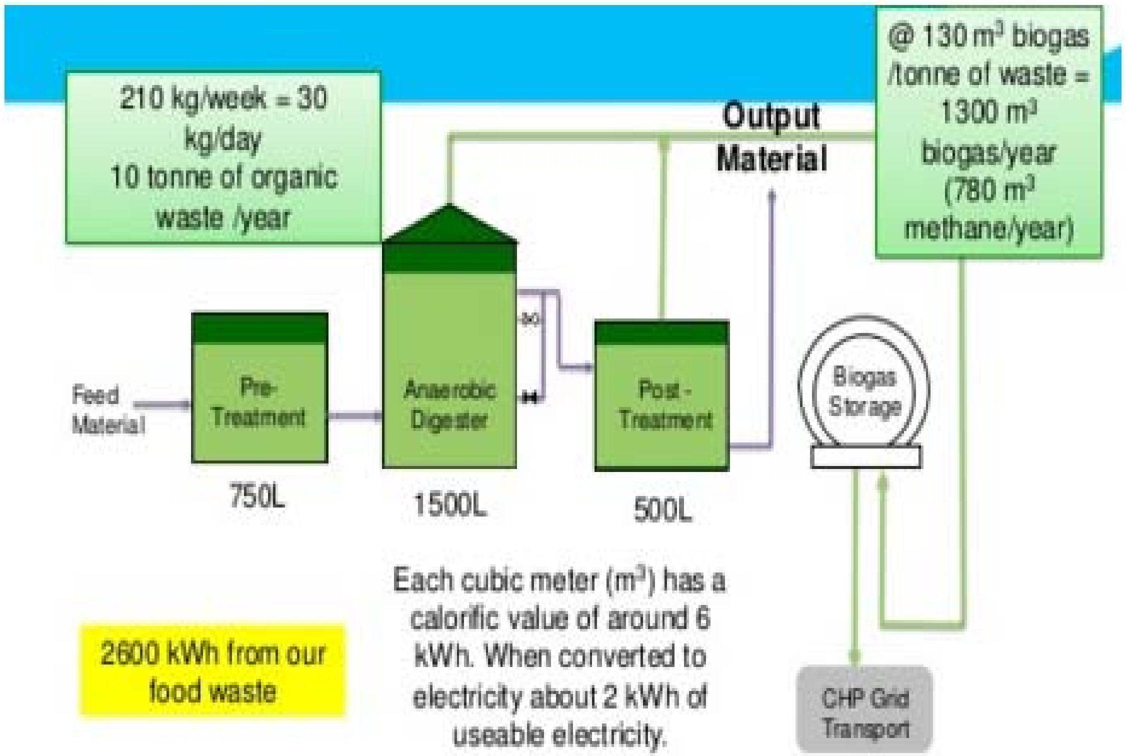


Source: ETC/SCP, 2011

- The anaerobic digestion process degrades organic matter in the absence of oxygen and generates biogas, which typically has a volumetric composition of 65% methane (CH_4) and 35% of CO_2
- Food waste is a suitable feedstock for anaerobic digestion due to its high organic content and moisture level

Cranfield anaerobic digestion

- Opened in 2014
- A plug-and-play facility for research into anaerobic digestion
- Modular construction, mounted on skid-type frame assemblies
- Biogas is collected in a 40 m^3 membrane biogas holder
- Two gas engines

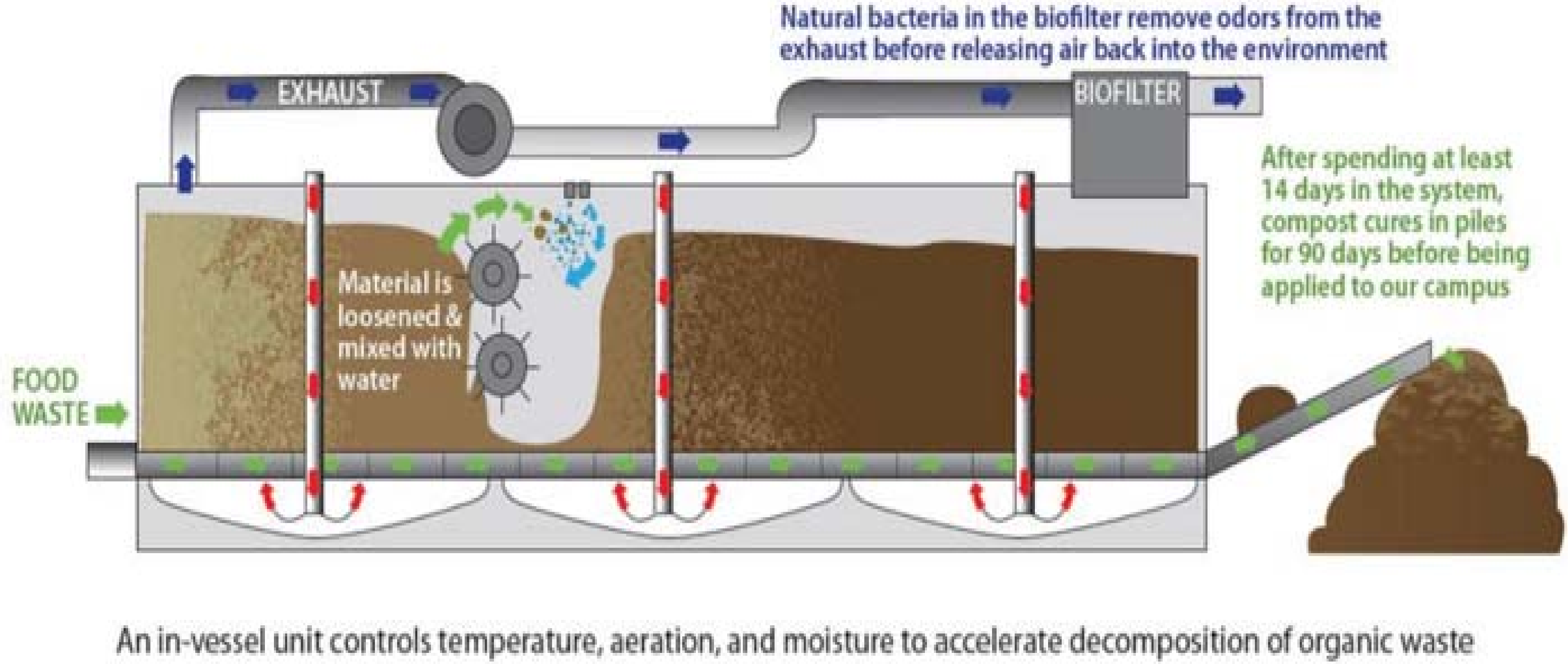


Source: Villa, 2015

Composting

- An effective way to reduce organic solid waste through decomposition of organic debris achieved by microorganisms (bacteria, actinomycetes and fungi) under controlled environmental conditions
- In-vessel composting refers to a group of methods that confine the composting materials within a building, container or vessel:
  - automated compost units usually constructed on a concrete pad with a building covering all or part of the unit and
  - very technologically advanced with computerized continuous feed systems and mechanisms to maintain an optimal composting environment
- Manage residential and commercial food in recent years, as people learn how composting converts food waste into a valuable soil amendment

Ohio University's in-vessel composter



Source: Ohio University, 2015

In-vessel composting equipment

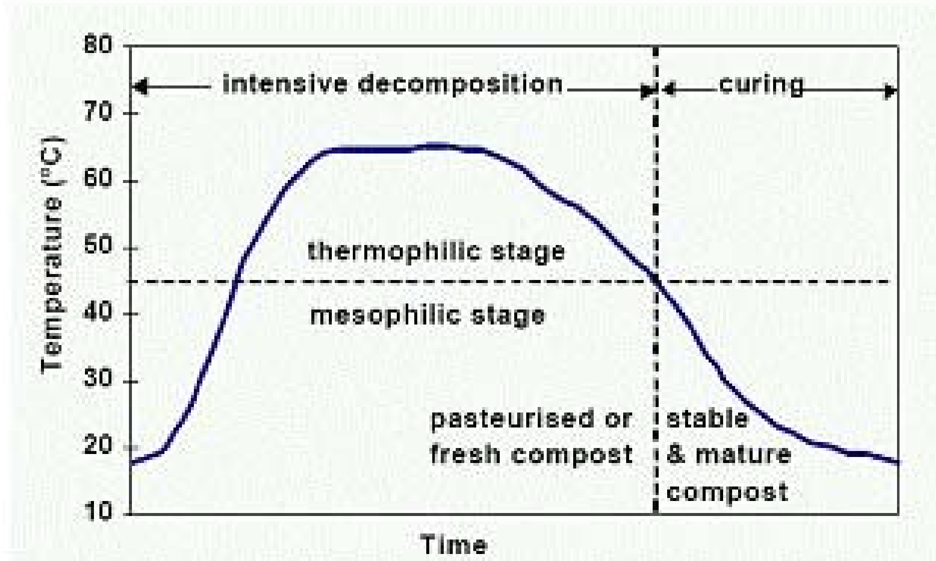
- Drum (vessel):
  - rotates only four revolutions per hour by electrical power only 2 hours on and 10 hours off using very little electrical energy
- Loading conveyors
- Air systems (blowers)
- Temperature monitors
- Electric panels and
- Downloading conveyors

Heat is generated inside the drum by the combination of carbon and nitrogen in the organic waste combined with oxygen (the aerobic process) as the mixture is turned very slowly

Source: xactsystemscomposting.com

Proper composting of food waste

- Results in thermophilic temperatures:
  - generation of microbial metabolic heat which can effectively destroy:
    - pathogens and weed seeds
- Converts biodegradable solid organic matter into a stable humus-like substance which can be:
  - handled,
  - stored, and/or
  - applied to land without adversely affecting environment



Temporary curve of a typical compost process

http://agriculture.vic.gov.au/agriculture/dairy/managing-effluent/composting-spoiled-hay

Universities that have adopted anaerobic digestion

- Ohio State University:
  - initiated the construction of a dry anaerobic digestion process in 2012 with a processing capacity of 30,000 t of agricultural and food waste per year
  - The system was expected to produce 7800 MWh of electricity every year
- Clarkson university:
  - single and two-phase operations were compared at mesophilic operating conditions using a digester system consisting of
  - three 5-m^3 reactors treating food waste generated daily within campus kitchens
  - the operation rate of the anaerobic digester was 2,461 L per day
  - benefits occurred: i) 211 t of waste diverted per semester, ii) 32,367 € saved per semester, iii) 19.7 trips saved to the landfill, iv) 5,704 fewer kilometers were driven per semester

Universities that have adopted aerobic digestion

- Imperial College in London:
  - 18,000 persons (students and personnel) were fed every day.
  - 1 t of food waste was arise weekly and it was aerobically digested in the campus.
  - The composter, which had been created using research from the College’s Department of Civil & Environmental Engineering, would turn the waste from the South Kensington Campus’s food outlets into compost used to enhance campus green spaces. This move contributed towards the College's target of recycling 40% of all College waste during 2010

biogas.ifas.ufl.edu

SWOT analysis - Strengths

- Divert of food waste from landfill
- Easy to use
- Students and personnel feel like they are making a difference
- Students have more recycling options
- Adapting a system that works well, does not require a big change in the habits in the campus
- Successful in another universities

SWOT analysis - Weaknesses

- Vermin could get into bins
- Odours from bins in hot weather
- Contamination of food waste with plastic
- Only certain technologies can be used to compost
- Large startup costs
- Some composting methods are energy intensive

SWOT analysis - Opportunities

- Compost can be sold to primary producers
- Collected biogas, could supplement power on site
- There is the opportunity to apply for multiple grants in research and development
- The life of landfill will be extended by saving space
- The collection frequency of green waste bins will be reduced

SWOT analysis - Threats

- The competition with other universities for national and international sustainability grant
- Smells generated from plant could cause complaints from locals
- The pretreatment regulations can extend processing time slowing turn over from food waste to compost
- The legislation may prevent sale of compost to farms due to hygiene restrictions

Methodology - Technical analysis

The technical feasibility of the anaerobic and aerobic digestion technologies was evaluated by

- reviewing the process type (reactor type for anaerobic digestion, capacity)
- reviewing the process requirements (e.g., feedstock, material and energy inputs)
- reviewing existing examples at other universities
- performing a material and energy on each process

One main parameter of the technologies was the residence time, which was referring to the length of time for complete degradation of food waste in a digester

Methodology - Economic analysis

- The economic feasibility assessment was conducted by determining:
  - the capital investment and operational costs
  - the savings on utility bills and
  - the repayment period
- The repayment period took into account the investment cost and the net annual revenues

Methodology - Greenhouse gas emissions

- The following steps were considered in the analysis for the anaerobic digestion facility (European Communities, 2001):
  - Treatment. Emissions of short-term carbon dioxide and leakage of methane during the anaerobic digestion process. Energy use to operate the plant was provided by the anaerobic digestion gas
  - Use / Disposal. Carbon sequestered in soil as a result of composted digestate application
  - Displaced emissions. Avoided emissions from energy generation displaced by the heat and power exported by the anaerobic digestion plant. Also avoided emissions from displacement of peat or fertilisers by the composted digestate
- The mobilisation was not taken into account because there wasn’t any kind of transportation of food waste from campus dining facility to the anaerobic digestion plant and transport of products (composted digestate and liquor) to market or landfill

Results and discussion (1/3)

- There were three main steps for selecting the anaerobic digestion facility (Tu et al., 2015):
  - pretreatment of waste such as grinding, shredding, screening and mixing,
  - digestion of the waste including feeding and mixing in the reactor and
  - biogas collection, treatment, storage and utilization
- The food waste generation at Aristotle University Thessaloniki dining hall was estimated to be 60 kt per year and the predicted annual energy generated was 26 MWh

Results and discussion (2/3)

- The fixed cost of the anaerobic digestion facility was depended on:
  - the fermentation time
  - the capacity (L) and
  - number of reactors.
- For 20 days fermentation time and 400 L capacity of the reactor:
  - installation cost of reactor: 31,280 € and
  - cogeneration unit cost: 12,420 €

Results and discussion (3/3)

- Annual cost of aerobic fermentation facility: 1,104 €.
- Required fermentation days: 40
- Capacity: 750 L
- Cost of the reactor: 4,600 €
- Running cost: 4 €/d
- Annual revenues from the marketing of produced compost: 1,800 €.
- Annual expenses of facility: 1,104 €

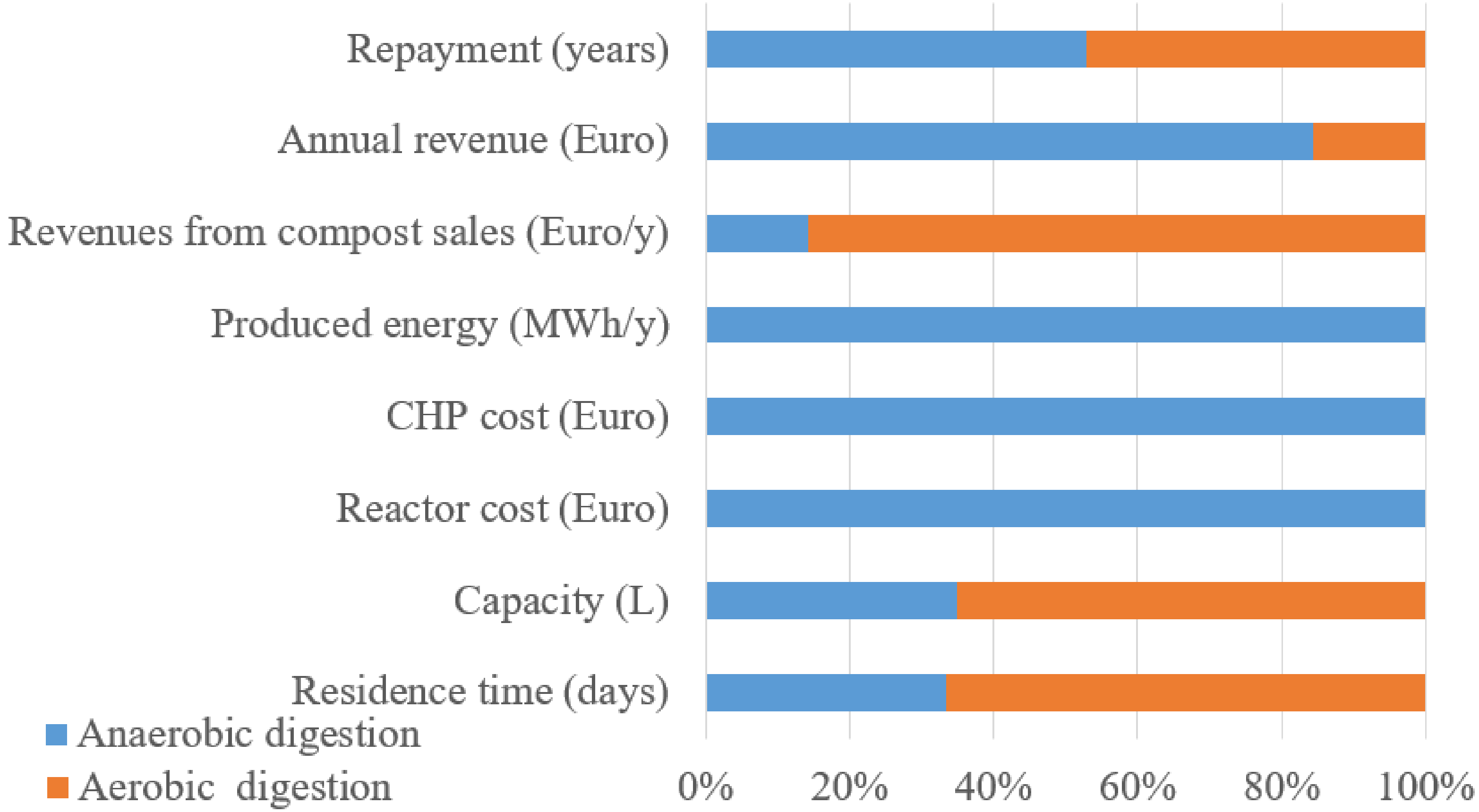
Parameters and values that were used for the management of food waste

	Anaerobic digestion	Aerobic digestion
Residence time (days)	20	40
Capacity (L)	400	750
Reactor cost (€)	31280	0
CHP* cost (€)	12420	

* CHP: Combined Heat and Power

	Anaerobic digestion	Aerobic digestion
Produced energy (MWh/y)	25,55	0
Revenues from compost sales (€/y)	300	1800
Annual revenue (€)	5921	1104
Repayment (years)	7.0	6.6

The percentage of contribution (of each parameter) for the management of food waste



Conclusions

- Payback periods for the two treatment options of meals for 10,000 students and 300 days per year:
  - 6 years and 7 months for aerobic digestion
  - 7 years and 5 months for anaerobic digestion
- Reduction of greenhouse gas emission from the implementation of the two material and energy recovery options:
  - 1.92 t CO_2-eq/y for aerobic digestion
  - 14.76 t CO_2-eq/y for anaerobic digestion
- Future research: biodiesel production from waste cooking oil, refuse derived fuel from plastic and paper and wood residue in boilers

Sources

- http://aix.meng.auth.gr/lhtee/index.html
- PerkoulidisG. , KarkaniasC. , MalamakisA. , Kontogianni S. and Moussiopoulos N. , 2016, A circular economy system for managing and recyvlign bio-waste in Greece, 2nd National Landfill Mining Conference, Athens, 15-16 June.
- https://wmich.edu/sites/default/files/attachments/ENVS%204100%20Final%20Project%20Report%20-%20Merrow,%20Penzien,%20Dubats.pdf
- http://www.facilities.upenn.edu/sites/default/files/Penn%20Compost%20Poster.pdf
- https://www.washington.edu/facilities/building/recyclingandsolidwaste/procedures/food_waste
- http://www.bu.edu/sustainability/what-were-doing/food/
- http://www.see.leeds.ac.uk/misc/ejournal/Issue%207%20files/7;%20201-231.pdf
- http://auth.esngreece.gr/aristotle-university-thessaloniki
- https://www.auth.gr/en/faculties
- http://www.eng.auth.gr/en/home.html
- ETC/SCP: Projections of municipal waste management and greenhouse gases, ETC/SCP working paper, 4/2011. http://scp.eionet.europa.eu/publications/2011WP4 (2011). Accessed 28 April 2016
- Google earth, 28/8/2015
- Villa, R.: RED: Supporting SMEs in anaerobic digestion.). http://www.slideshare.net/adbiogas/raffaella-villa-47283577 (2015). Accessed 12 April 2016
- Ohio University: Compost facility. https://www.ohio.edu/sustainability/programs/compost-facility.cfm (2016). Accessed April 2016
- xactsystemscomposting.com
- http://agriculture.vic.gov.au/agriculture/dairy/managing-effluent/composting-spoiled-hay
- biogas.ifas.ufl.edu

Thank you very much for your attention!

2016

ARISTOTLE ANNIVERSARY YEAR

by UNESCO