Energy from waste: Regional Sustainability Workshop Series

Workshop Report

IEA Bioenergy: Task 36: March 2024

Authors: Fionnuala Murphy and Egle Gusciute (University College Dublin)

Edited by: Mar Edo (RISE) and Cristina Trois (Stellenbosch University)

INTRODUCTION

In some places such as South Africa, the US and Ireland, there is still a poor public perception of Energy- from-Waste systems. Lack of transparency during the decision-making process or not inviting residents and stakeholders to be part of the project as well as lack of information exchange between the operators and the clients may lead to poor public acceptance. Developing scientifically based sustainability metrics to give a sound basis for the discussions might also facilitate greater acceptance. Further, a proper decision framework integrating all the main aspects of sustainability (economy, environment and social) is an enabler to ensure that the developed strategies are not sub-optimized in favour of short-term solutions. This workshop series combines informative workshops on regionally relevant waste management systems with the participation of stakeholders in development of a life cycle sustainability framework to consider the most relevant sustainability indicators. The workshop series will identify sustainability indicators to be considered in the IEA Bioenergy Task 36 work programme including a Case Study on Environmental performance of different waste management strategies and a Report on Sustainability that will be published during 2024.

Three Regional Sustainability Workshops were held, with each workshop focusing on different sectors facing challenges for sustainability:

1. Waste-to-energy in South Africa (30 November 2022)
2. Organic and plastic waste resource recovery in North America (25 July 2023)
3. Food waste in Ireland (18 October 2023)

WORKSHOP 1 - LIFE CYCLE SUSTAINABILITY ASSESSMENT (LCSA) FOR WASTE MANAGEMENT: STAKEHOLDER PARTICIPATION FOR THE IDENTIFICATION OF KEY INDICATORS.

This workshop focussed on the use of life cycle assessment methods in the analysis of the sustainability of waste management systems. It was a hybrid workshop which took place in Durban, South Africa on 30th November 2022. The workshop agenda is shown in Table 1[1].

Table 1: Workshop 1 Agenda

Speaker	Presentation Topic
Fionnuala Murphy (University College Dublin)	Life cycle sustainability assessment of waste management systems in the context of South Africa and Ireland
Cristina Trois (University of KwaZulu-Natal)	The WROSE Model: A Decision-Making Tool for Sustained Waste and Carbon Emissions Reduction in South Africa
Charlotte Nell (Aquila Environmental)	Development of South Africa's Waste-to-Energy Roadmap - Findings from Stakeholder Engagements

The workshop began with an overview of the life cycle sustainability methodology delivered by Dr Fionnuala Murphy. Focus has shifted from final disposal towards developing a circular economy emphasising resource and energy recovery, with new technologies and processes being developed to generate value from waste. Novel techniques have not been achieved owing to technical and economic issues, and their advantages and drawbacks should be considered before advancing their commercial and industrial application. Hence, scientifically based assessment to determine the best waste management strategy is required. Environmental impacts are then most frequently assessed when considering the sustainability of waste management, and social impacts are often excluded. There are several social impacts that are relevant for waste management processes, for example contribution to local employment, occupational health, and safety (health risks for workers). However, these impacts are often region specific and need to be assessed qualitatively and cannot always summarise this information adequately per functional unit to complement the environmental life cycle assessment (LCA). Finally, inclusion of locally and regionally relevant sustainability information is needed to better inform decisions regarding the implementation of new waste management systems.

Prof Cristina Trois (University of Kwazulu-Natal, UKZN) gave an overview of the waste management system and its environmental impacts in the South African context. South Africa faces a number of challenges in mitigating such emissions; the challenge of meeting high standards in service delivery with limited resources, limited know-how, and lack of reliable data on waste streams and greenhouse gas (GHG) emissions indicators. The Waste to Resource Optimization and Scenario Evaluation (WROSE)[2] model has been developed by the SARChI Chair in Waste and Climate Change at UKZN. The initial goal of WROSE™ was to compare several treatment methods with the current baseline scenario, depending on the preliminary determination of context-appropriate strategies and the quantity and quality of waste, considering environmental, economic and social impacts.

[1] Workshop announcement: https://task36.ieabioenergy.com/ieaevent/join-us-for-a-series-workshop-about-decarbonization-of-the-waste-sector/

[2] https://wrose.co.za/resource

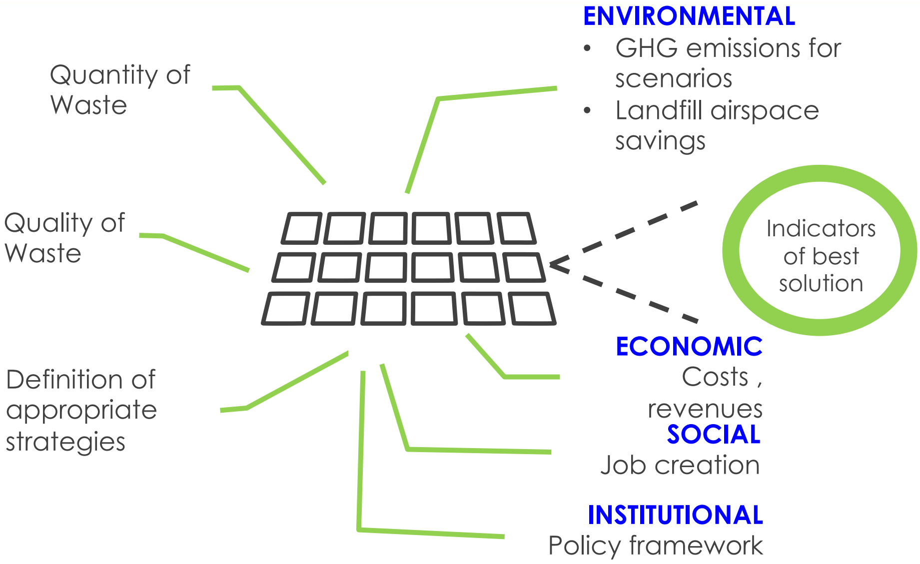


Figure 2: Simulation using the WROSE Model

The WROSE model allows determination of GHG emissions, energy use, techno-economic feasibility, monetary and landfill airspace savings, job creation potential and policy framework. Based on the priority given to each set of indicators, the model can predict the best waste management strategy or pathway for the introduction into an Integrated Waste Management Plan. The WROSE Model has been applied to several municipalities in South Africa, providing reliable data on the impacts of different waste management approaches.

Ms Charlotte Nell (Aquila Environmental) presented on the development of the Waste-to-Energy Roadmap for South Africa[3,4] which was mandated in 2021. Stakeholder engagement is key in the development of the roadmap, ensuring that input is received from key stakeholders during the development, thematically analysing and incorporating these inputs to ultimately develop a roadmap that is relevant and useful.

Stakeholders in the development of the roadmap included regulatory stakeholders, project implementers, financial institutions, industry, research institutions, and media. The stakeholder engagement enabled discussion of themes such as drivers, barriers and opportunities for waste-to-energy implementation, and technology related discissions. Discussions found that it is very important to align the Waste-to-Energy Roadmap with national mandates and policies already in place and accepted. Stakeholders overall agree that the valorization of the organic fraction of waste through anaerobic digestion and gas to energy is important.

The workshop ended with a Panel Discussion chaired by Cristina Trois with panelists Fionnuala Murphy, Catherina Schenck, Takunda Chitaka, Charlotte Nell, and Sameera Kissoon. The discussion focused on social impacts and the importance of the regional context as waste management practices and systems can vary widely from region to region.

---

[3] Nell, CM and Trois, C. (2022). The development of Waste-to-Energy roadmap for South Africa - findings from stakeholder engagements. Wastecon South Africa 2022.

[4] Review of Waste-to-energy policies in South Africa and international comparisons, Grewan, K, and Trois, C.; 2023. Link to the publication: [Task-36-Waste-to-Energy-Policy-Review_2023final-2.pdf (ieabioenergy.com)] (March, 2024).

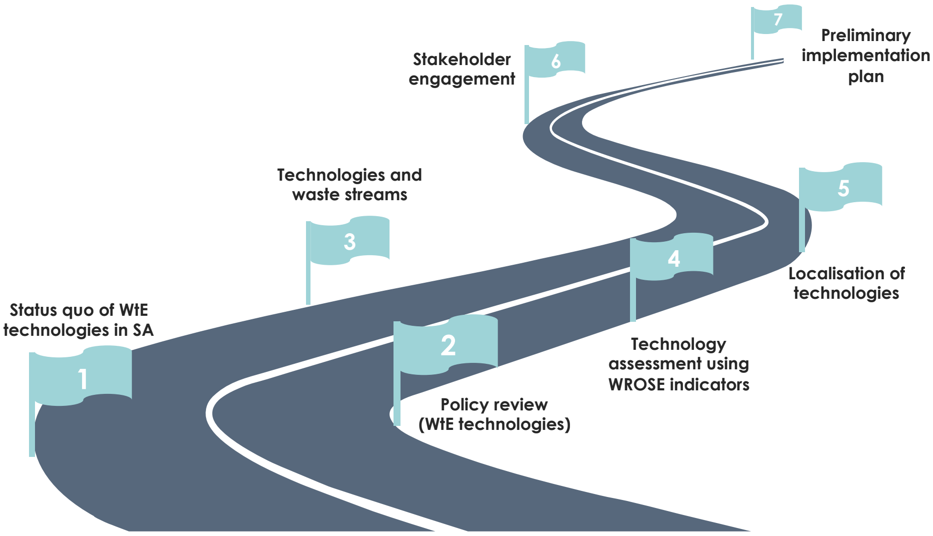


Figure 2: Milestones on the Waste-to-Energy Roadmap

Workshop 1 Survey

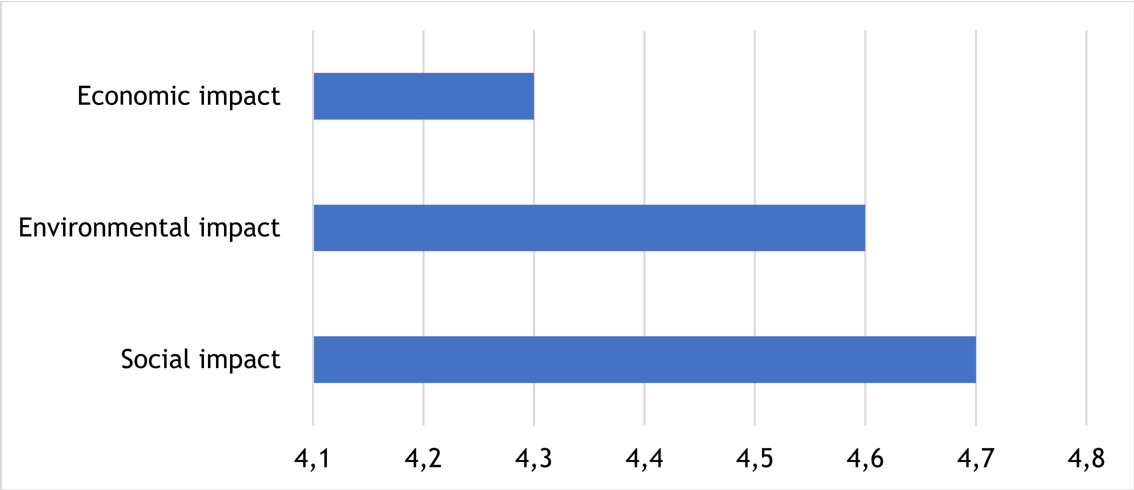
At the IEA Bioenergy Task 36 Sustainability workshop in Durban, South Africa, 18 participants responded to the workshop survey[i]. The survey was conducted via Slido. Table 2 provides an overview of the composition of the stakeholders who participated in the survey in Durban. The majority of stakeholders were from society at large (39%).

Table 2: Composition of Survey Stakeholders in Workshop 1 South Africa

Stakeholder Group	%
Society at large	39
Consumers	11
Value chain actors	11
Local community	11
Other	28

Stakeholders were asked to rate the importance of environmental, economic and social impacts when deciding on a new waste management infrastructure on a 1-5 scale (1 = not important and 5= most important). All 3 impacts were ranked as important, with social impact ranking as the most important impact, followed by environmental and economic impacts, respectively. Chart 1 indicates the ranking of different impacts.

Chart 1: Importance of different impacts when deciding on new waste management infrastructure (South Africa)



Stakeholders were also asked to consider specific environmental, economic and social impacts and their relative importance when deciding on a new waste management infrastructure. Table 3 details the ranking for different environmental impacts. Global warming potential was the most important environmental impact (mean 4.6) closely followed by human toxicity (4.5) and heavy metals (4.4). Stratospheric ozone depletion was ranked as the least important environmental impact when deciding on a new waste management infrastructure.

Table 3: Importance of different environmental indicators when deciding on new waste management infrastructure (South Africa)

Environmental impact	Mean
Global warming potential	4.6
Human toxicity	4.5
Heavy metals	4.4
Land use	4.2
Eutrophication potential	4.1
Ecotoxicity	4.0
Acidification potential	3.8
Resource consumption	3.8
Photochemical oxidants or ozone	3.6
Stratospheric ozone	2.8

Note: *1= not important; 5= very important.*

All of the economic impacts in deciding on new waste management infrastructure were ranked as important; with total investment cost given the highest ranking (4.5) followed by net present value and profit, both given a score of 4.1.

Table 4 details the importance of social impact indicators considered in the survey. The social impact indicators are divided into the following sub-categories: human rights, working conditions, cultural heritage, socio-economic repercussion, and governance. Free from forced labour was the most important social indicator within the human rights dimension (4.9). Occupational health and safety was the most important indicator within working conditions category (4.4) while community engagement was ranked the highest within cultural heritage indicators (4.8). Food security was ranked the most important within the socio-economic repercussions category (4.7) while free from corruption was the most important indicator within the governance indicators (4.9). Overall free from forced labour (human rights) and free from corruption (governance) were considered the most important social indicators when deciding on new waste management infrastructure. Land acquisition, delocalisation, migration, and access to non-material resources (cultural heritage) were ranked as the least important social impacts overall (3.5) in the decision making of a new waste management infrastructure.

Table 4: Importance of different social indicators when deciding on new waste management infrastructure

Social impact sub-category	Social impact indicator	Mean
Human rights	Free from forced labour	4.9
	Free from discrimination (equal opportunities)	4.8
	Free from child labour	4.7
Working conditions	Occupational health and safety	4.4
	Freedom of association and of collective bargaining	4.1
	Decent working hours	4.1
	Fair salary	4.0
	Social benefits	3.9
Cultural heritage	Community engagement	4.8
	Safe and healthy living condition	4.7
	Transparency on social/environmental issues	4.6
	Respect on cultural heritage and local wisdom	4.3
	Respect on customary right of indigenous people	4.3
	Access to material resources	4.1
	Land acquisition, delocalisation, migration	3.5
	Access to non-material resources	3.5
Socio-economic repercussion	Food security	4.7
	Contribution to local employment	4.5
	Contribution to economic development	4.5
	Transfer of technology and knowledge	4.1
	Horizontal conflict	3.6
Governance	Free from corruption	4.9
	Public commitments to sustainability	4.2
	Fair competition	4.2

WORKSHOP 2 - ORGANIC AND PLASTIC WASTE RESOURCE AND ENERGY RECOVERY

This workshop focussed on the use of life cycle assessment methods in the analysis of the sustainability of systems for organic and plastic waste resources and energy recovery. It was an online workshop held on 25th July 2023 with a focus on North America. The workshop agenda is shown in Table 5[5,6].

Table 5: Workshop 2 Agenda

Speaker	Presentation Topic
Xavi Fonoll Almansa and John Norton Jr. (Great Lakes Water Authority)	Organic and Plastic Waste Resource and Energy Recovery
Pahola Thathiana Benavides and Ulises R. Gracida Alvarez (Argonne National Laboratory)	Environmental Sustainability
Corinne D. Scown (Lawrence Berkeley National Laboratory)	Social Sustainability & Siting Considerations

The workshop opened with a brief introduction by Dr Fionnuala Murphy which focused on the stakeholder engagement through the workshop survey.

Dr Xavi Fonoll Almansa and Dr John W. Norton, both of Great Lakes Water Authority, gave an overview of the organic waste resource and energy in the Tri-State region in Chicago. The Great Lakes Water Authority (GLWA) services a population of 2.9 million, with a 1.7 billion gallons per day peak primary treatment capacity and 930 million gallons per day peak secondary treatment capacity through a network of more than 24,000 miles of connected sewers. Most of the generated biosolids are dried and then land applied (300 dry tons/day), approximately 100 dry tons/day are incinerated with the ash landfilled, however the incinerator that manages 25% of the sludge produced (80 dry ton/day) has a remaining lifespan of 8 to 10 years. The cost of upgrading is prohibitively high so GLWA are exploring alternative waste-to-energy technologies; anaerobic digestion, hydrothermal liquefaction and pyrolysis.

[5]Workshop announcemnet: IEA Bioenergy Task 36 Workshop on sustainability indicators pertaining to waste resource and energy recovery

[6]Recording of the event: https://www.youtube.com/watch?v=_1xez4MylKo&feature=youtu.be

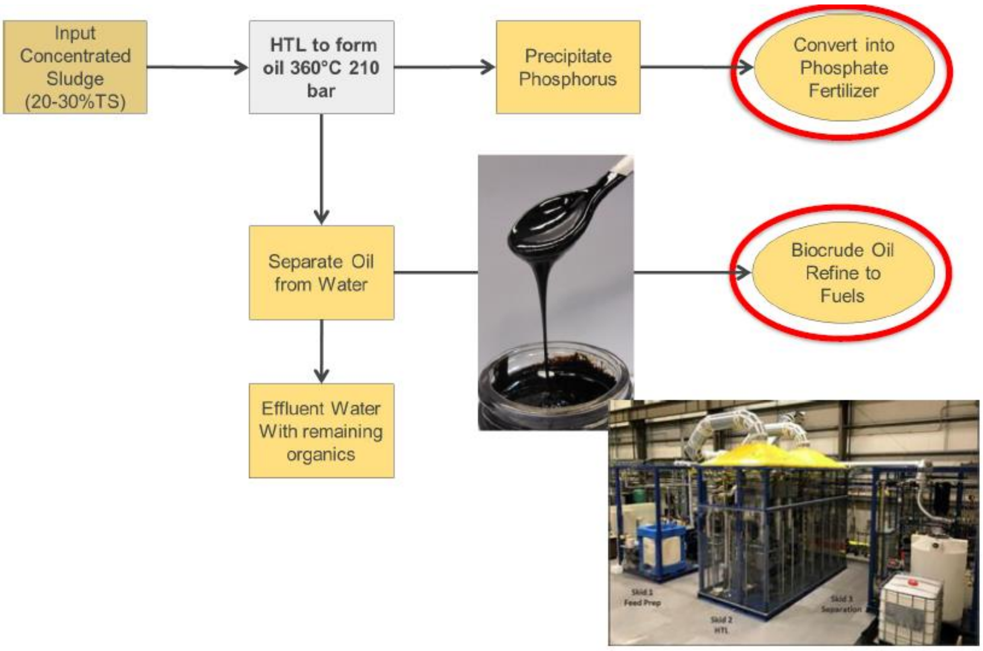


Figure 3: Hydrothermal liquefaction has the potential to advance resource recovery in GLWA[7,8].

Dr Pahola Thathiana Benavides and Dr Ulises R. Gracida Alvarez, both of Argonne National Laboratory, gave a presentation on environmentally sustainable solutions for organic and plastic waste, illustrating scale of plastic waste generation and the environmental problems caused, including the significant impact on the marine environment. The environmental impacts of a range of treatment methods including mechanical recycling, an advanced/chemical recycling technologies such as pyrolysis, gasification, methanolysis, solvent based, enzymatic hydrolysis, etc. have been assessed using the GREET LCA tool towards alleviating the environmental concern of plastics. Their research has found that greenhouse gas emissions benefits of waste plastic recycling depend on the waste resources used, conversion or separation technologies employed, and the credits that apply due to displaced products in a circular economy context. For example, the research showed that implementation of advanced recycling technologies does not always result in GHG emissions reduction on a systems level perspective when compared to virgin materials (see figure 4). Further research on waste-to-energy pathways for organic waste feedstocks has shown significant GHG emission reduction benefits through anaerobic digestion.

---

[7] Cronin, D., Schmidt, A.J., Billing, J., Hart, T.R., Fox, S.P., Fonoll, X., Norton, J., and Michael R. Thorson, M.R. (2022) Comparative Study on the Continuous Flow Hydrothermal Liquefaction of Various Wet-Waste Feedstock Types, ACS Sustainable Chemistry & Engineering, 10, 3, 1256–1266. DOI: 10.1021/acssuschemeng.1c07214.

[8] Snowden-Swan, L.J., Li, S., Jiang, Y., Thorson, M.R., Schmidt, A.J., Seiple, T.E., Billing, J.M., Santosa, D.M., Hart, T.R., Fox, S.P., Cronin, D., Kallupalayam Ramasamy, K., Anderson, D.B., Hallen, R.T., Fonoll-Almansa, X., and Norton, J (2022) Wet Waste Hydrothermal Liquefaction and Biocrude Upgrading to Hydrocarbon Fuels: 2021 State of Technology. United States: N. p., 2022. Web. doi:10.2172/1863608.

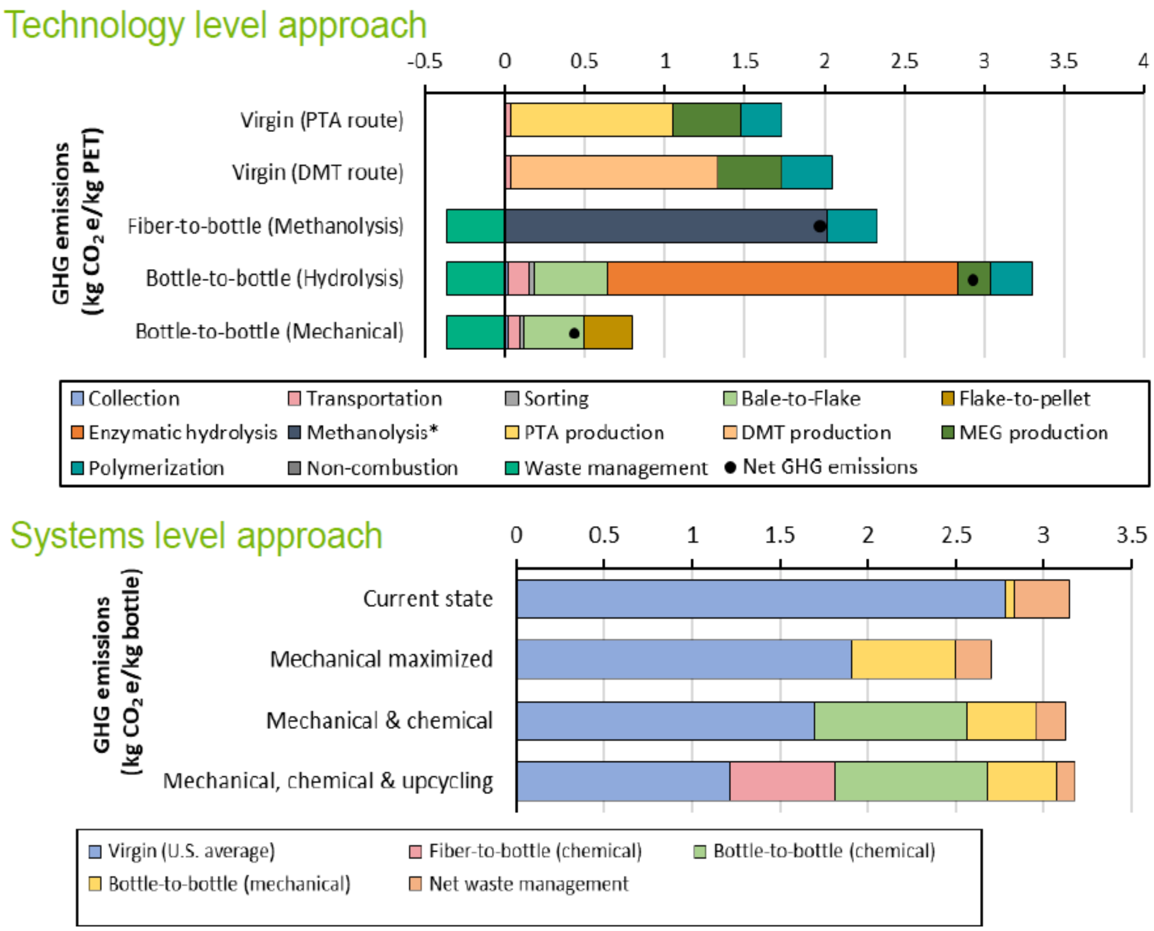


Figure 4: Greenhouse gas emissions for a bottle-to-bottle Circular economy Case study[9]

Dr Corinne D. Scown, of Lawrence Berkeley National Laboratory, concluded the workshop with a presentation on social sustainability and citing considerations relating to waste infrastructure for organic and plastic waste. Dr Scown's research has shown that risks, costs, and benefits of the future bioeconomy and a more circular economy are not shared equally. For example, biorefineries have traditionally been located close to feedstocks, on previously closed facilities or on previously undeveloped land. The risks relating to the biorefinery (e.g. emissions to air and water, freshwater demand, and truck traffic), and the benefits (e.g. reduced wildfire risk, reduced nutrient loading), may not be borne by the same community. In relation to plastic waste, infrastructure is crucial as under-investment in sorting/collection infrastructure can lead to more polluting facilities such as pyrolysis and incineration, rather than lower polluting solvent-assisted, enzyme-based, and mechanical recycling facilities which require adequate sorting infrastructure. Overall, it is crucial to listen to communities to enhance place-based benefits and implement meaningful mitigation measures, while at the macro level checking waste management strategies for blind spots and overall distribution of benefits and costs.

---

[9] Gracida-Alvarez, U.R., Xu, H., Thathiana Benavides, P., Wang, M., and Hawkins, T.R. (2023) Circular Economy Sustainability Analysis Framework for Plastics: Application for Poly-ethylene Terephthalate (PET) ACS Sustainable Chemistry & Engineering 2023 11 (2), 514-524. DOI: 10.1021/acssuschemeng.2c04626

Workshop 2 Survey

At the IEA Bioenergy Task 36 Sustainability workshop in the US, 13 participants responded to the workshop survey. The anonymous survey was conducted via Google forms. Table 6 provides an overview of the composition of the stakeholders who participated in the survey in the US. The majority of stakeholders were consumers and researchers (46% in total, 23% each).

Table 6: Composition of Survey Stakeholders in the US

Stakeholder Group	%
Consumers	23
Researchers	23
Value chain actors	15
Local community	15
Other	15
Society at large	8

Note: *Due to rounding percentages may not add up to 100 per cent.*

Stakeholders were asked to rate the importance of environmental, economic, and social impacts when deciding on a new waste management infrastructure on a 1-5 scale (1 = not important and 5= very important). All three impacts were ranked as either very important or important, with environmental impact ranking as the most important impact (mean 4.8 on a 1-5 scale). Social impact was considered to be the second most important factor (mean 4.5) and economic impact was ranked as third (mean 4.1). Chart 2 provides more detailed information on the ranking of different impacts. 85 per cent of respondents ranked environmental impacts as very important and 15% ranked them as important. 62% of respondents ranked social impacts as very important and 31% ranked them as important. 46% of respondents ranked economic impacts as important and 38% ranked them as important. None of the respondents ranked either of the three indicators as not important.

Chart 2: Importance of different impacts when deciding on new waste management infrastructure (United States)

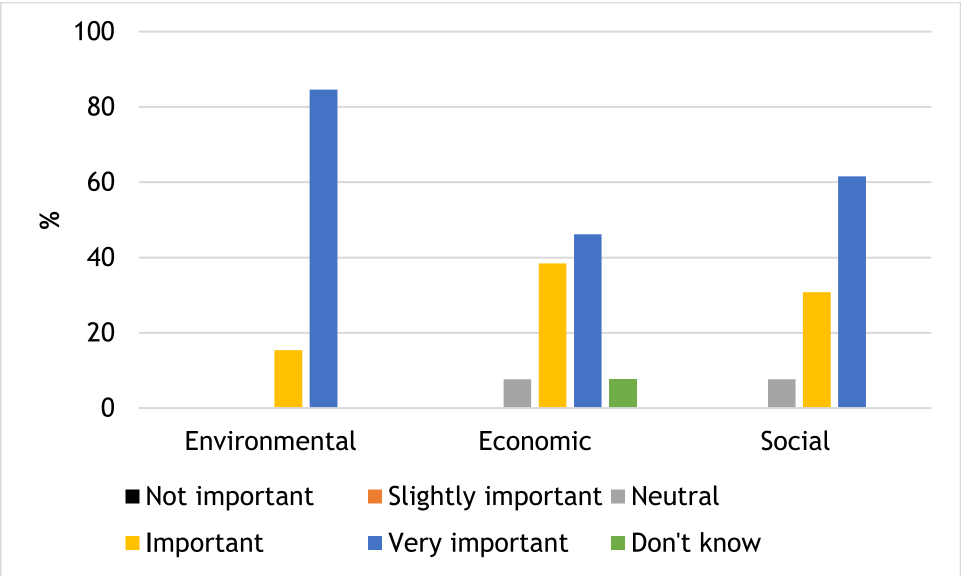


Table 7 details the ranking for different environmental impacts. Land use was ranked by all participants as either very important (46%) or as important (54%) when deciding on new waste management infrastructure. Human toxicity and total nutrients/other resources recovered from wastes (e.g. nitrogen, phosphorus, potassium) were ranked by 64% of respondents as very important. Resource consumption, ecotoxicity and land use were ranked by 54% of respondents as important. Global warming potential was ranked by 85% of respondents as either very important or important (54% and 31%, respectively), but 5% of respondents considered it to be only slightly important. Stratospheric ozone depletion and photochemical oxidants or ozone were considered to be the least important factors by the respondents.

Table 7: Importance of different environmental indicators (%) when deciding on new waste management infrastructure (United States)

	Not important	Slightly important	Neutral	Important	Very important	Don't know
Acidification potential	0	0	8	46	23	23
Global warming potential	0	15	0	31	54	0
Eutrophication potential	0	0	8	31	38	23
Resource consumption	0	0	0	54	46	0
Human toxicity	0	0	15	23	62	0
Photochemical oxidants or ozone	0	8	8	46	31	8
Ecotoxicity	0	0	0	54	31	15
Stratospheric ozone	0	8	15	31	23	23
Heavy metals	0	0	8	38	54	0
Land use	0	0	0	54	46	0
Total energy recovered from wastes (e.g., MJ/ton of waste recovered)	0	0	8	38	54	0
Total nutrients or other resources recovered from wastes (e.g.nitrogen, phosphorus, potassium)	0	0	8	31	62	0

Chart 3 details the rankings for economic impacts in the US. Over 90% of respondents ranked net present value as either very important (62%) or as important (31%). 69% of respondents ranked total investment cost as very important while 15% of respondents ranked profit as not important.

Chart 3: Importance of different economic indicators (%) when deciding on new waste management infrastructure (United States)

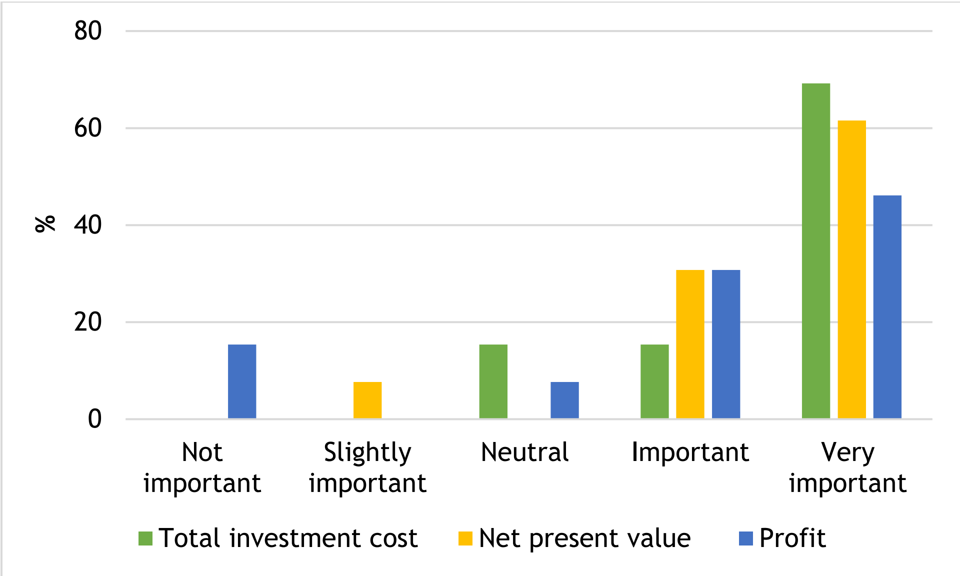


Table 8 details the importance of social impact indicators considered in the survey. The social impact indicators are divided into the following sub-categories: human rights, working conditions, cultural heritage, socio-economic repercussion, and governance. Equal opportunities was the most important social indicator within the human rights dimension with 100% of respondents indicating that it is either very important (62%) or important (38%). Occupational health and safety as well as fair salary were ranked as the most important social indicators within the working conditions sub-category as all participants ranked it as either important (23% for occupational health and safety and 46% for fair salary) or very important (77% and 54% respectively). Community engagement, safe and healthy living condition and transparency on social/environmental issues were ranked as very important or important by 92% of respondents within the cultural heritage indicators. Within the socio-economic repercussions category, contribution to local employment, contribution to economic development and transfer of technology and knowledge were ranked as important or very important by 85% of respondents. Free from corruption was the most important indicator within the governance indicators as all participants ranked it as very important (62%) or important (38%). Overall free from discrimination (human rights) and occupational health and safety (working conditions) were ranked the highest across the social impact indicators, with 77% of respondents rating these as very important. Freedom of association and of collective bargaining, decent working hours (working conditions sub-category); respect on cultural heritage and local wisdom, respect on customary right of indigenous people, land acquisition, delocalisation, migration (cultural heritage); and food security (socio-economic repercussion) were ranked as not important by 8% of respondents. Overall respect on cultural heritage and local wisdom was the least important impact as 16% of respondents ranked it as only slightly important or not important at all in the decision making of a new waste management infrastructure.

Table 8: Importance of different social indicators (%) when deciding on new waste management infrastructure (United States)

Social impact sub-category	Social impact indicator	Not important	Slightly important	Neutral	Important	Very important	Don't know
Human rights	Free from forced labour	0	0	8	31	54	8
	Free from discrimination	0	0	8	15	77	0
	Equal opportunities	0	0	0	38	62	0
	Free from child labour	0	0	8	31	54	8
Working conditions	Occupational health and safety	0	0	0	23	77	0
	Freedom of association and of collective bargaining	8	0	23	31	38	0
	Decent working hours	8	0	8	31	54	0
	Fair salary	0	0	0	46	54	0
	Social benefits	0	0	8	54	38	0
Cultural heritage	Community engagement	0	0	0	31	62	8
	Safe and healthy living condition	0	0	0	38	54	8
	Transparency on social/environmental issues	0	0	8	31	62	0
	Respect on cultural heritage and local wisdom	8	8	0	38	38	8
	Respect on customary right of indigenous people	8	0	8	46	31	8
	Access to material resources	0	8	0	46	31	15
	Land acquisition, delocalisation, migration	8	0	8	38	38	8
	Access to non-material resources	0	0	15	23	46	15

Cont. Table 8: Importance of different social indicators (%) when deciding on new waste management infrastructure (United States).

Social impact sub-category	Social impact indicator	Not important	Slightly important	Neutral	Important	Very important	Don't know
Socio-economic repercussion	Food security	8	0	8	8	62	15
	Contribution to local employment	0	0	15	54	31	0
	Contribution to economic development	0	8	8	38	46	0
	Transfer of technology and knowledge	0	8	8	23	62	0
	Total costs of waste management for the community	0	0	8	23	62	8
	Horizontal conflict	0	0	8	31	15	46
Governance	Free from corruption	0	0	0	38	62	0
	Public commitments to sustainability	0	8	0	46	46	0
	Fair competition	0	8	0	62	31	0

WORKSHOP 3 - A PARTICIPATORY WORKSHOP TO INFORM AND ENGAGE PARTICIPANTS IN A DISCUSSION ABOUT SUSTAINABILITY AND FOOD WASTE.

This workshop explored the issue of food waste and sustainability, considering the impacts and potential solutions. It was a hybrid workshop, with 99 registered attendees, which took place in Dublin, Ireland on 18th October 2023. The workshop agenda is shown in Table[10].

Table 9: Workshop 3 Agenda

Speaker	Presentation Topic
Angela Ruttledge (FoodCloud)	Food Redistribution: A win-win for people and planet
Tracey O'Connor (Munster Technological University)	Value chain impacts of food waste and opportunities for food waste reduction across the value chain
Tamíris da Costa (University College Dublin)	The environmental impacts of food waste and food waste reduction strategies

The workshop opened with a brief introduction by Dr Fionnuala Murphy which focused on the stakeholder engagement through the workshop survey. The Dublin workshop focussed on the topic of food waste and featured presentations from three Irish organisations.

Angela Ruttledge, from FoodCloud[11], began by highlighting the significant climate impact of the food systems which account for 34% of global anthropogenic GHG emissions. With 40% of the food produced being wasted[12], 8-10% Global GHG emissions are related to food waste and efforts are needed to avoid this wastage. A large proportion (60%) of the food that is wasted is fit for human consumption and one of the key strategic pillars of FoodCloud is to reduce this portion of food waste by redistributing as much food as possible. A key issue facing primary producers of food is the lack of market for 'B grade' produce. Foodcloud is leading The Growers' Project, connecting growers who have surplus produce with community groups located around the country, particularly in rural areas (Figure 5). This approach has benefits for many stakeholders; consumers gain access to fresh produce direct from the farm, food producers get paid for previously 'devalued' food, and food waste is avoided leading to environmental benefits.

[10] Workshop announcement: https://task36.ieabioenergy.com/ieaevent/sustainability-series-workshop-on-food-waste-18th-october/
[11] FoodCloud: Food waste hurts our planet
[12] 2021, Driven to Waste *Global Food Loss on Farms, WWF and Tesco

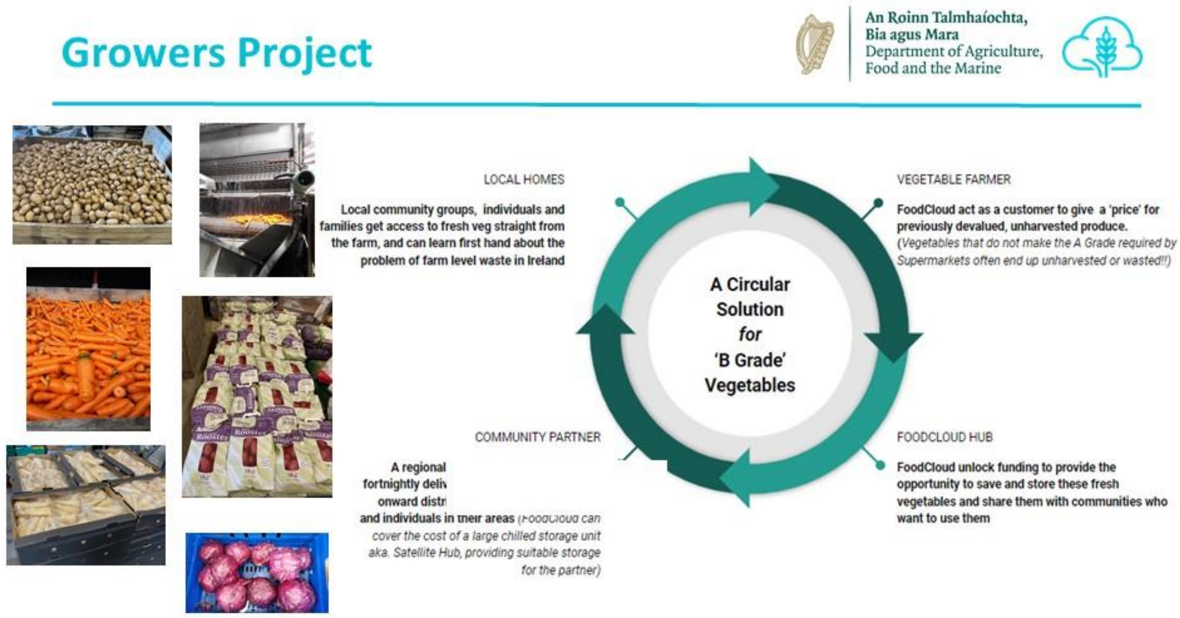


Figure 5: Growers Project – A case study for the use of 'B Grade' Vegetables.

Dr Tracey O'Connor, Munster Technological University, continued the theme of food waste and looked at opportunities for waste reduction across the value chain. Food waste occurs across the supply chain (Figure 6); in primary production, manufacturing and processing, retail and distribution and in consumption (domestic and retail). Opportunities for food waste reduction occur across value chain stages, e.g. enterprise process improvement. Business can reduce food waste through monitoring, staff training, equipment purchasing, packaging & labelling changes, changing food storage, handling, and manufacturing processes.

The final presentation was by Dr Tamiris da Costa, from University College Dublin, who presented on the REAMIT[13] project and the environmental impacts of food waste and food waste reduction strategies. The REAMIT strategy to reduce food waste is to;

- Deploy and adapt IoT sensors to detect and prevent food waste, hence improving resource efficiency of the agribusiness.
- Collect data in the cloud and conduct Big Data analytics to identify sources and patterns of food waste.

A case study in the food processing industry was carried out. The case study aimed at identifying meat waste in an abattoir occurring due to un-uniform temperature distribution. Microbiological growth often occurs on the surface of beef due to fluctuation in temperature in the chill rooms (Figure 7).

[13] https://www.reamit.eu/

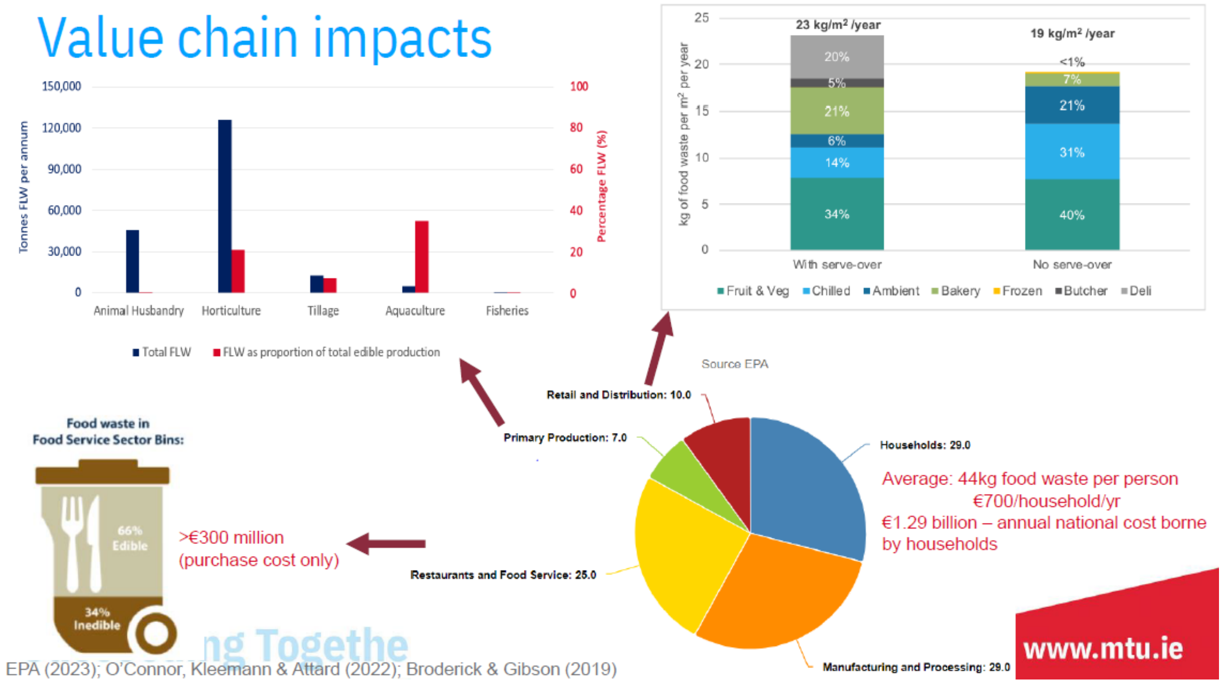


Figure 6: Impacts across the food value chain[14]

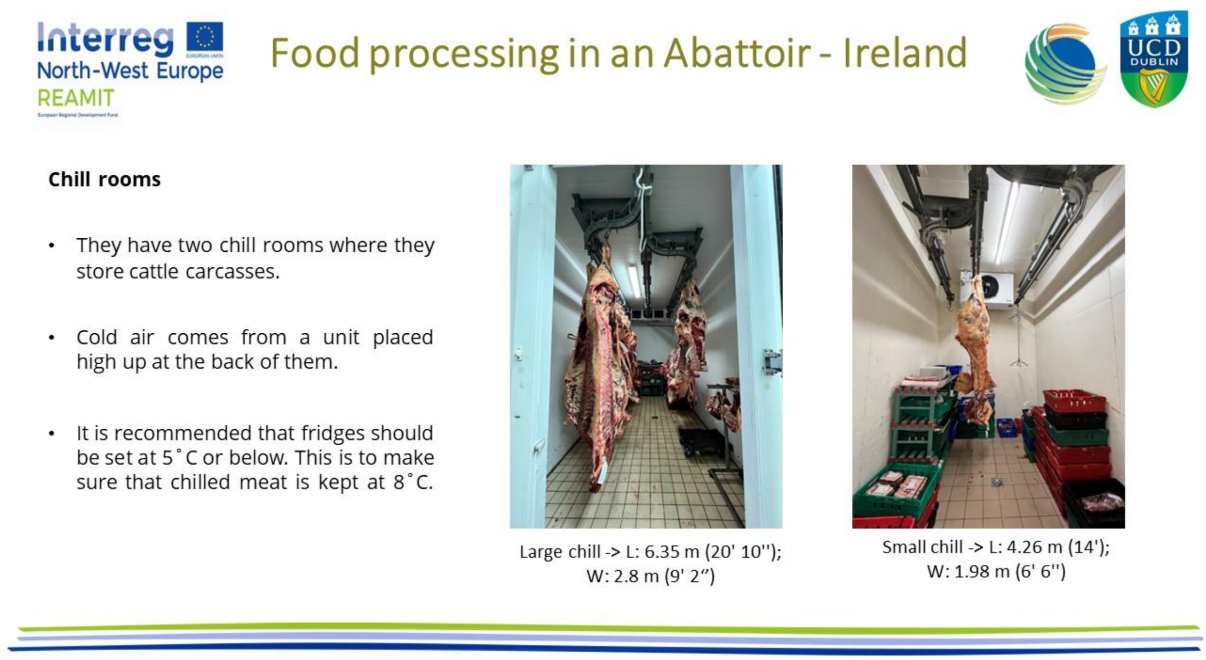


Figure 7: Meat waste reduction case study

[14] EPA (2023) Food waste statistics for Ireland [online] (last accessed: 17/10/2023) https://www.epa.ie/our-services/monitoring--assessment/waste/national-waste-statistics/food/
O'Connor, Kleemann & Attard (2022) Vulnerable vegetables and efficient fishers: A study of primary production food losses and waste in Ireland Journal of Environmental Management 307:114498
Broderick & Gibson (2019) Research 282: Reducing Commercial Food Waste in Ireland. Wexford: EPA pp.32

Temperature and humidity sensors were deployed in the chambers to monitor changes in the atmosphere. Automated algorithms were developed to detecting anomalies and send alerts if the temperature in the cold room rises above 7 °C, promoting action by the operator to reduce the temperature (Figure 8). To avoid false alarms, alerts are only sent after 6 readings, 10 min apart are recorded above the threshold temperatures.

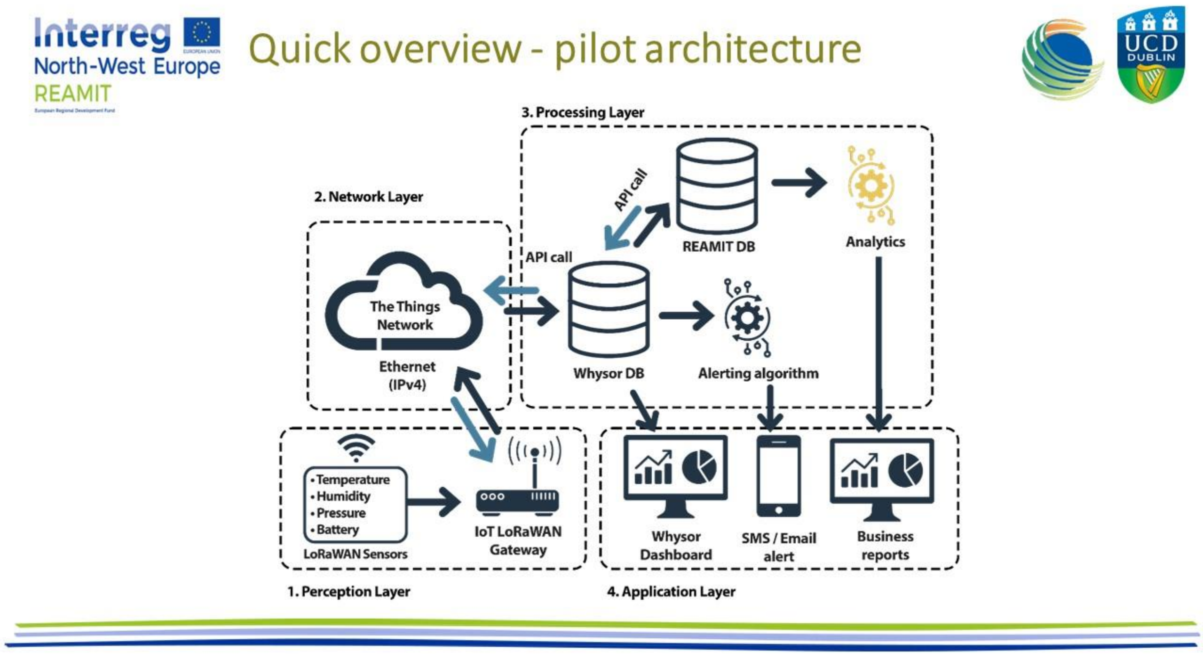


Figure 8: The REAMIT Pilot Approach

The REAMIT approach allowed reduction of food waste generation, resulting in a decrease in GHG emissions of up to 75 tons of CO_2-eq per year.

Workshop 3 Survey

At the IEA Bioenergy Task 36 Sustainability workshop in Dublin, 22 participants responded to the workshop survey. The anonymous survey was conducted via Google forms. Table 10 provides an overview of the composition of the stakeholders who participated in the survey in Dublin. The majority of stakeholders were consumers (46%).

Table 10: Composition of Survey Stakeholders in Dublin

Stakeholder Group	%
Consumers	46
Value chain actors	18
Society at large	14
Researchers	9
Other	9
Local community	5

Stakeholders were asked to rate the importance of environmental, economic, and social impacts when deciding on a new waste management infrastructure on a 1-5 scale (1 = not important and 5= very important). Environmental impact was considered to be the most important (mean 4.9 on a 1.5 scale). Social impacts were considered to be the second most important factors (mean 4.4) and economic impact was ranked as third (mean 4.3). Chart 4 provides more detailed information on the ranking of different impacts. 86% of participants considered environmental impact to be very important while remaining 14% considered it to be important. 59% of respondents ranked social impacts as very important and 27% ranked it as important. 41% of respondents ranked economic impacts as important and 50% ranked it as important. None of the respondents ranked either of three indicators as not important, however 5% of respondents indicated that social impacts are only slightly important.

Chart 4: Importance of different impacts when deciding on new waste management infrastructure (Dublin workshop)

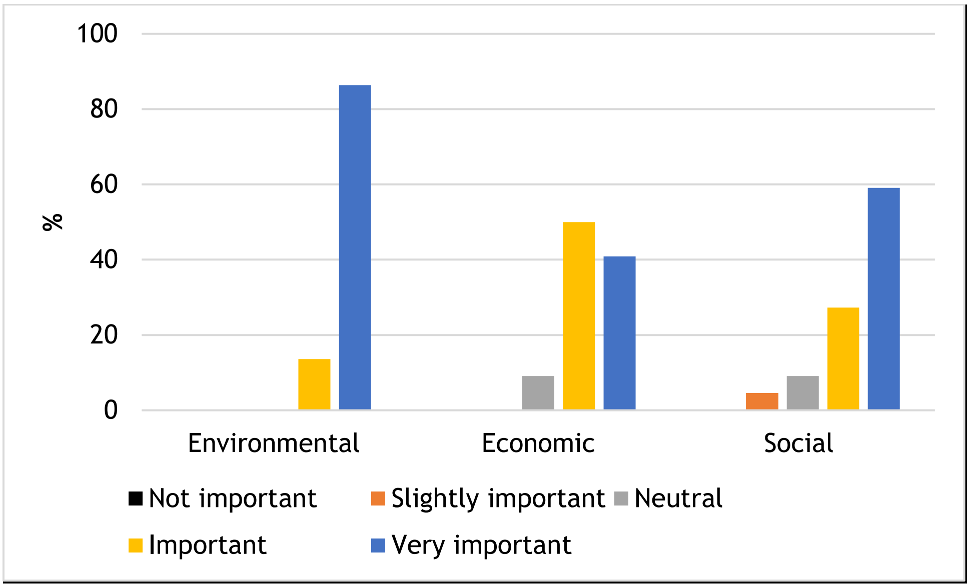


Table 11 details the ranking for different environmental impacts. Global warming potential was ranked by all participants as either very important (77%) or as important (23%) when deciding on new waste management infrastructure. Human toxicity and total nutrients/other resources recovered from wastes (e.g. nitrogen, phosphorus, potassium) were ranked by 64% of respondents as very important and by 36% of participants as important.

Stratospheric ozone depletion and photochemical oxidants or ozone were considered least important by the respondents.

Chart 5 details the rankings for economic impacts by respondents at the Dublin workshop. Total investment cost was considered as important by 55% of respondents and very important by 36% of respondents, and overall, the most important indicator within the economic impacts. Net present value was considered as important by 68% of respondents and very important by 5% of respondents. Profit was considered as very important by 18% of respondents and not important by 9% of participants.

Table 11: Importance of different environmental indicators (%) when deciding on new waste management infrastructure (Dublin workshop)

	Not important	Slightly important	Neutral	Important	Very important	Don't know
Acidification potential	0	0	8	46	23	23
Global warming potential	0	15	0	31	54	0
Eutrophication potential	0	0	8	31	38	23
Resource consumption	0	0	0	54	46	0
Human toxicity	0	0	15	23	62	0
Photochemical oxidants or ozone	0	8	8	46	31	8
Ecotoxicity	0	0	0	54	31	15
Stratospheric ozone	0	8	15	31	23	23
Heavy metals	0	0	8	38	54	0
Land use	0	0	0	54	46	0
Total energy recovered from wastes (e.g., MJ/ton of waste recovered)	0	0	8	38	54	0
Total nutrients or other resources recovered from wastes (nitrogen, phosphorus, potassium as examples)	0	0	8	31	62	0

Chart 5: Importance of different economic indicators (%) when deciding on new waste management infrastructure (Dublin workshop)

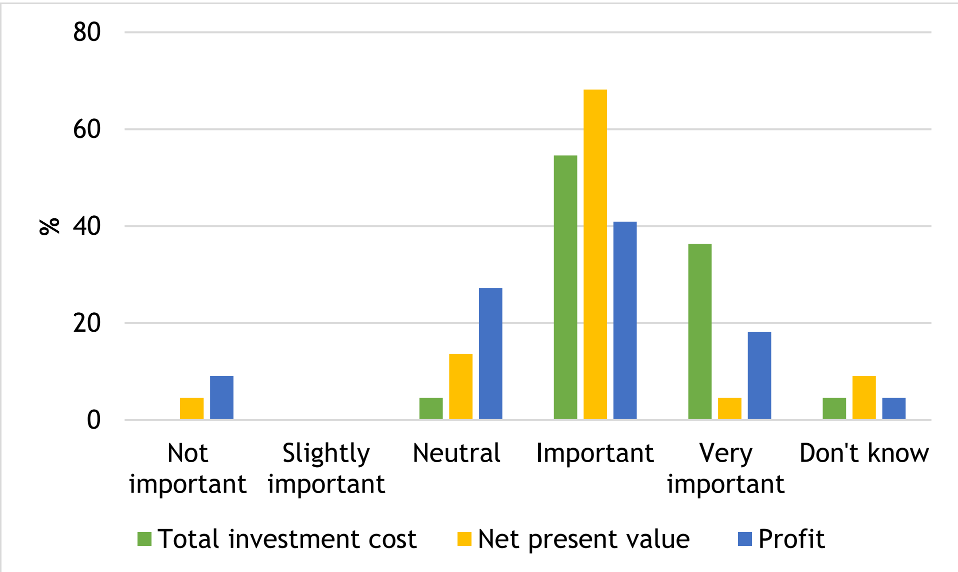


Table 12 details the importance of social impact indicators considered in the survey during the Dublin workshop. The social impact indicators are divided into the following sub-categories: human rights, working conditions, cultural heritage, socio-economic repercussion, and governance. Free from child labour was the most important social indicator within the human rights dimension with 95% of respondents indicating that it is very important and 5% indicating it is important. Occupational health and safety was ranked as the most important social indicators within the working conditions sub-category as 91% of respondents ranked it as very important and 9 indicated it is important. Safe and healthy living condition was ranked as very important by 91% of participants and as important by 9% of participants within the cultural heritage indicators. Within the socio-economic repercussions category, food security was ranked as very important by 86% of respondents. Free from corruption and public commitments to sustainability were ranked as either very important (77% and 64%, respectively) or important (18% and 32%, respectively) by 95% of respondents within the governance indicators. Overall, 19 out of 26 of the social indicators were ranked as very important or important by at least 90% of respondents. Free from forced labour, Free from discrimination, Free from child labour, Occupational health and safety, Safe and healthy living condition, Total costs of waste management for the community were ranked as either very important or important by all participants. Horizontal conflict (socio-economic repercussion) was the least important social indicator with 55% of respondents ranking it as very important or important, 18% as neutral and 27% expressing no opinion through the 'don't know' option.

Table 12: Importance of different social indicators (%) when deciding on new waste management infrastructure (Dublin workshop)

Social impact sub-category	Social impact indicator	Not important	Slightly important	Neutral	Important	Very important	Don't know
Human rights	Free from forced labour	0	0	0	9	91	0
	Free from discrimination	0	0	0	27	73	0
	Equal opportunities	0	0	5	32	64	0
	Free from child labour	0	0	0	5	95	0
Working conditions	Occupational health and safety	0	0	0	9	91	0
	Freedom of association and of collective bargaining	0	0	0	50	41	9
	Decent working hours	0	0	5	32	64	0
	Fair salary	0	0	5	32	64	0
	Social benefits	0	9	0	41	50	0

*Cont. **Table 12: Importance of different social indicators (%) when deciding on new waste management infrastructure (Dublin workshop).***

Social impact sub-category	Social impact indicator	Not important	Slightly important	Neutral	Important	Very important	Don't know
Cultural heritage	Community engagement	0	0	5	50	45	0
	Safe and healthy living condition	0	0	0	9	91	0
	Transparency on social/environmental issues	0	0	5	23	73	0
	Respect on cultural heritage and local wisdom	0	0	5	32	64	0
	Respect on customary right of indigenous people	0	5	5	32	59	0
	Access to material resources	0	0	0	55	41	5
	Land acquisition, delocalisation, migration	0	0	14	41	41	5
	Access to non-material resources	0	0	9	55	32	5
Socio-economic repercussion	Food security	0	0	5	9	86	0
	Contribution to local employment	0	0	18	55	27	0
	Contribution to economic development	0	0	18	41	41	0
	Transfer of technology and knowledge	0	5	18	50	27	0
	Total costs of waste management for the community	0	0	0	64	36	0
	Horizontal conflict	0	0	18	45	9	27
Governance	Free from corruption	0	0	5	18	77	0
	Public commitments to sustainability	0	0	5	32	64	0
	Fair competition	0	0	23	27	50	0

CONCLUDING REMARKS

The result from the three workshops, held in South Africa, the US and Ireland, indicate that stakeholders consider a holistic approach which considers social, environmental and economic factors to be necessary in the decision-making process relating to new waste management infrastructure. In all three workshops, social impacts were considered as either the most important impact or the second most important impact, highlighting the growing awareness of the need to include social factors in sustainability frameworks and metrics. The results from the workshops also highlight the importance of considering a range of social impacts within a specific context as their importance varied in different countries. For example, in South Africa, 'free from forced labour' and 'free from corruption' were considered the most important social impacts in while in the US 'free from discrimination' and 'occupational health and safety' were ranked the highest by stakeholders. In the case of Ireland, a wide range of social indicators (19 out of 26 social impacts) were considered as either important or very important. Inclusion of stakeholders in the decision making is necessary to ensure a successful adoption of new sustainable systems and infrastructure while consideration of social impacts is essential to ensure social acceptance.