A MATERIAL FLOW ANALYSIS FOR SINT MAARTEN: MATERIAL AND BUSINESS OPPORTUNITIES ON SYSTEM LEVEL INTERVENTIONS

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ABSTRACT

This paper revolves around finding material and business opportunities for resilient reconstruction methods on Sint Maarten, a Caribbean island that was struck by hurricane Irma in 2017. It uses a Material Flow Analysis (MFA) as a tool to find the size of the islands material management, disaster debris management and solutions to loop for the most common material flows on the island. It argues that there is an abundance of physical solutions reusing and repurposing physical material flows. It describes a business model that can both create an incentive to recycle and be financially beneficial to the local community with a decentralized waste management program.

Keywords: *circular economy, Material Flow Analysis, Sint Maarten, business opportunities, material opportunities.*

1. INTRODUCTION

1.1 Background and motive

The 7th of September 2017 hurricane Irma hit Sint Maarten with a force 5+ causing tremendous amount of damage to the island. On Sint Maarten a direct hurricane hit appears every 6 years and around every 20 years a force 5 hurricane hits the island (Gibbs, 2017). After Irma 91% of the built environment suffered damages of which 8% was heavily damaged and 31% was completely destroyed.

An estimated $2.3 billion will be required for recovery and resilience interventions over the next seven years according to the World Bank (World Bank Group, 2018). The sectors with the largest needs are Housing (22.8%), Tourism and Commerce (19.0%), Governance and Public Financial Management (9.4%), Sanitation and Solid Waste Management (8.3%). The focus for this research lies in solutions for housing and waste management. The aim is integrating both to generate economic diversification as well as a more resilient build environment.

The main issue is the absence of a certain material awareness within disaster management and in construction activities in general. Therefore, the ambition of my graduation, which this report is part of, aims to stimulate improved material awareness in the building process. To do so I build on the principles of circular economy. The earth is a closed system that has limited resources. We have to use those as efficiently as possible, reuse where we can, grow new materials where we can. In line with this I take an urban metabolism approach (Rau & Oberhuber, 2016) and the Material Flow Analysis as the main tool for my research (Brunner & Rechberger, 2016).

On a more personal note I want to create awareness for this subject and learn about the potential of waste streams in the construction of buildings and their economic opportunities. The next 5 paragraphs give a more in-depth background on the specific problems around this topic for Sint Maarten. A graphic overview of the pains is given in figure 1.

Figure 1: Map of pains

1.2 Communal Resilience

Resilience: "The capacity to recover quickly from difficulties; toughness (Oxford Dictionaries, 2019)"

Around $550 million on Dutch donations will be invested by the trust fund of the World bank. This is meant for the reconstruction to build back stronger, with better rules and together with the people of Sint Maarten to be better prepared for coming disasters (World Bank Group, 2018). However, a lot of inhabitants and institutions still rely on themselves to reconstruct their property as there is a lack of trust in the local government. Also, the allocation is a bureaucratic and complicated process that only the most well organized can afford (Algemene Rekenkamer, 2018). As most of the build environment is constructed informally, reconstruction progresses slowly and lacks quality due to a lack of building knowledge. The number of skilled carpenters and building materials is limited and the pressure on the market leads to malpractice. Contractors overprice their service or don't finish the jobs. The construction aid provided by the Red cross, for instance, is not sufficient for tackling the problem (Vaes, 2019). To improve the resilience of the community, projects should be **community based, bottom up initiatives.** They should also improve **the self build ability of** the community.

1.3 Economic resilience

Tourism is the main source of income for the community of Sint Maarten as it makes up 81,3% of the economic activity (Theodora, 2019). On a daily basis, thousands of tourists arrive on the island by plane, cruise ship and yacht, generating revenues of about $800 million annually. Irma damaged the build environment: hotels, houses and other vital buildings. From sunken 750,000 liters of fuel is being discharged into the bays; 90 % of the vegetation was damaged and 30% of all coral reefs disappeared. It doesn't come as a surprise that the tourism industry collapsed and the economy contracted 12% in 2018 (Worldbank, 2019). There is little opportunity for local initiatives as trade is monopolized by a few big companies.

Sint Maarten is clearly a single pillar economy that is vulnerable to natural disaster.

Different interviews with restaurants indicated that only 5% of the food production is happening locally. Almost all goods (food and building products and others) are imported (mainly from the US and Europe). The port of Sint Maarten acts as a trade hub, also for surrounding islands. The official unemployment rate is around 10% and about 27% of the population lives under the poverty line of $850 per month (Worldbank, 2019). The reality is that about 30.000 people live on Sint Maarten without a passport. They are not in the statistics and struggle to find jobs after Irma (Koch, 2017).

So, the objective for an intervention is to stimulate local production and, by doing so, **adding to the diversification of the economy** of Sint Maarten.

1.4 Material resilience

It is estimated that the build environment in this region contains about 112,4 tons of material per capita (Symmes et al., 2019). The way materials are treated on Sint Maarten contributes to the loss of their identity. The main issue here is a typical linear economy. Goods are imported, consumed and thrown away without thinking about their value and its reuse. This has resulted in a waste island that is still growing and causing major environmental damage. The growing dump increases the flooding risk of surrounding neighborhoods as it takes up volume of the buffer pond that it lies in. It also creates public health issues because of fires, toxic fumes from disintegrating organic waste, and leaching of toxins in ground water. A lot of valuable material is evaporated as Irma caused a separate landfill of 100.000 m3 only with hurricane debris and domestic waste (*Meeting VROMI*, 2019). Once material ends up in the landfill the chance of it ever returning to society is very slim. Aim for an intervention is **to show the value of now valueless materials by increasing reuse**, and pose a **decentral solution** to the central waste management system.

Summarizing the above, the main issues on the island revolve around finding new economic opportunities. They should create new value for materials and do so with a bottom up decentralized intervention, that the people can set up themselves. This results in the following research question: How can an urban metabolism strategy be used to decrease organic- and inorganic material flows while creating new (circular) business opportunities through a programmatic intervention?

Sub questions

1 How big are the flows of organic and inorganic material on Sint Maarten?
2 What are business opportunities looking at material flows on Sint Maarten?
3 What is the impact of proposed program on the urban metabolism?
4 What physical solutions can be made with the researched material flows?

2. METHODOLOGY

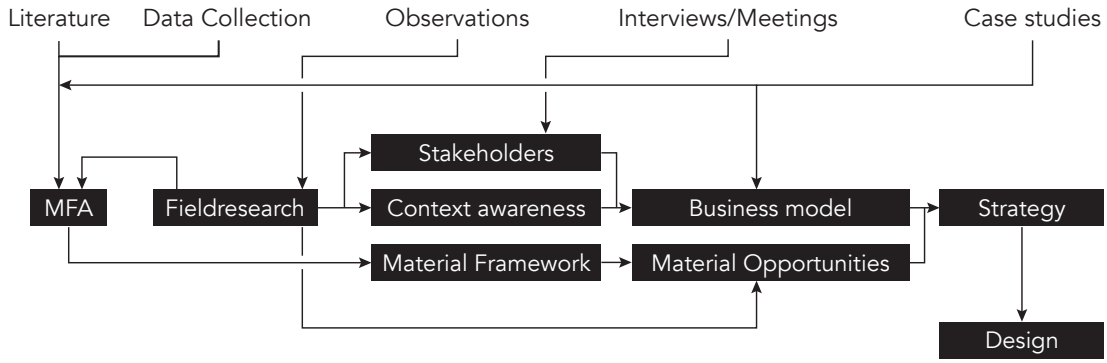

Figure 2: Overview research methods

It is shown that a Material Flow Analysis (MFA) can be used as a starting point to develop realistic and radical engineering solutions (Hunt et al., 2014). During this research, the metabolism of Sint Maarten is studied. For this a MFA analysis is developed to generate input for programmatic interventions that can decrease the flows of material through looping them locally (Brunner & Rechberger, 2016). The research builds on making a Material Flow Analysis for the whole island focusing on materials, water, energy and money flows. From this material- and business opportunities are extracted. If there are any synergies to be found with the water and energy cycle they will be noted. The research is supplemented with three weeks of field research in which surveys and interviews are conducted amongst various stakeholders: inhabitants, businesses, government, NGO's. The field research allows a deeper understanding of the islands context, its nature, the drivers of the local community, material limits and opportunities, business opportunities and building culture. Methods used for the research are: literature studies, data collection, interviews, surveys, meetings, observations and case studies. In figure 2 a graphic overview can be found of the methods used.

The scope of the research focusses on the direct flows of material and their opportunities for reuse. Other lifecycle aspects like embodied energy are not taken into account for this research. The MFA will answer the material aspect of the first two questions. The business model study and qualitative property analysis are separate investigations that derive from the MFA. Conclusions on the three researches done will provide the answers for the remaining research questions.

MATERIAL OPPORTUNITIES FOR CONSTRUCTION

2.1. Improvements on disaster debris management

Hurricane Irma roughly produced 200.000m^3 of debris of which 100.000m^3 is now cleared. After clearing the roads, the emergency response of Irma resulted in more than 20 satellite dumps located on various strategic locations along the main roads on the island. About 10% consists of green, about 20% of car wrecks and the remaining 70% is a mix of household waste and construction/demolition waste (see map of locations in appendix 1). Metals like roofing are sometimes kept separate, but tend to get mixed with the rest of the streams. Clearly the incentive is good however VROMI stated that they were unable to keep the types of waste from Irma separated (*Meeting VROMI*, 2019) while the French side was able to separate and recycle 70% of all the hurricane waste. The boundaries that can be set for disaster debris management are as follows:

- To minimize open dumping, solid waste disposal options must be available immediately.
- Source separation is key to successful recycling.
- Private contractors must be educated regarding recycling.
- Waste management must be well documented and distinguished from non-disaster debris.
- Putrescible wastes must be managed immediately, therefore provisions should be made for back up to conventional landfills should they become unavailable.
- Open burning is quick and inexpensive but will bring complaints. It is environmentally unacceptable and generates an ash that must be managed as a hazardous waste.
- Organic waste must be processed quickly to avoid combustion in temporary dumps or stockpiles (Reinhart & T. McCreanor, 1999).

2.2. Improvements on current material and waste handling system

Well-functioning 'livable' cities, both now and in the future, are dependent upon numerous critical influencing factors, including: the inward movement of natural resources (for example, food, water and energy) in sufficient quantities to meet demand; and, effective mechanisms for disposal of waste (Hunt et al., 2014).
Momentarily there is no incentive to recycle as there is no tipping fee on the Dutch side of the island. Waste management companies are privately owned and generate revenue from picking up waste and rent of containers and dumpsters. Almost all waste streams go to the dump. Recycling of material happens on a small scale only (e.g. backyard composting). Currently there is no market for waste trade.

Disaster debris management	**Household waste**
Source separation at satellite dumps	Decentral collection
Corporation between Dutch and French side	Decentralized recycling

Table 1: Summary of opportunities for improved waste management

2.3. Business opportunities for waste

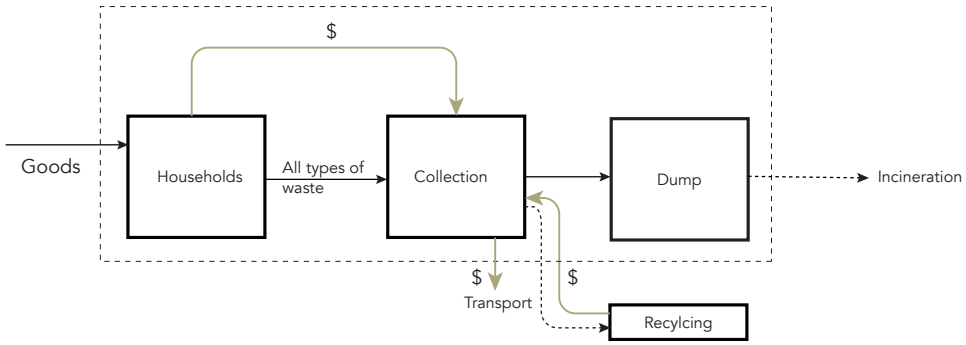

Figure 3: Current business model waste handling

It is also important to reduce waste and move the operations towards efficient and interesting services focusing on increased quantities that are re-used, recycled and upcycled. A key prerequisite for this type of solution lies in the creation and maintenance of sustainable business models (Ladhe, Magnusson, & Nilsson, 2014). Nilson also emphasizes the importance of decentralized collection and recycling facilities and gives some interesting propositions for a physical space:

- Attractive space (attract people inside).
- House events (event space).
- Flexible space (house multiple functions)
- Scalable spaces (allow for growing activity).
- Located within an urban fabric
- Visible waste separation (to generate communal awareness)

On a small-scale, pilots are running. Meadowlands B.V. in combination with Greenbox initiative are collecting plastic bottles, cans, cardboard and paper. If this pilot is successful it will be scaled up (Richardson, 2019). The business model behind this is gathering and selling clean streams to recyclers. On spaces where there is little awareness (most neighborhoods) an alternative business model can also create an incentive to improve waste separation. When collectors receive money on handing in clean separate waste streams and pay money for handing in mixed waste, the incentive for waste separation should improve and it provides entrepreneurs to commence a startup on new products from waste streams. Research shows that allowing communities to sell clean waste streams can both generate an incentive for recycling, as it is financially beneficial (Fetter & Rakes, 2012). With the trade in common waste streams, revenues of about $1000-6000 per shipment should be feasible. Trade in scrap metals and plastics is most lucrative (see appendix 4).

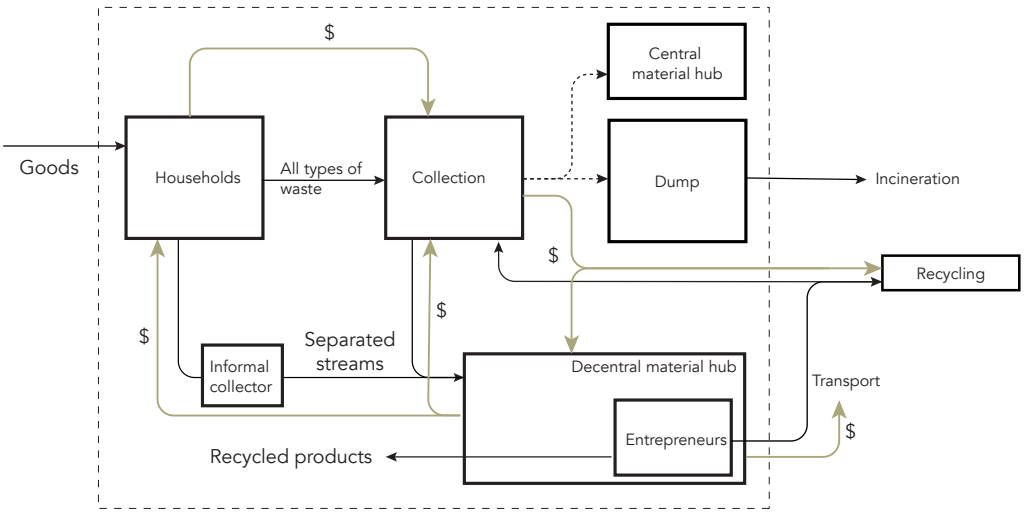

Figure 4: New business model for waste separation

2.4. Material opportunities

The strategy for this chapter is to address the flows of material that have the most impact on the metabolism of Sint Maarten and how a programmatic intervention can improve this. An overview of all organic- and inorganic material flows on the island is given in Figure 4.

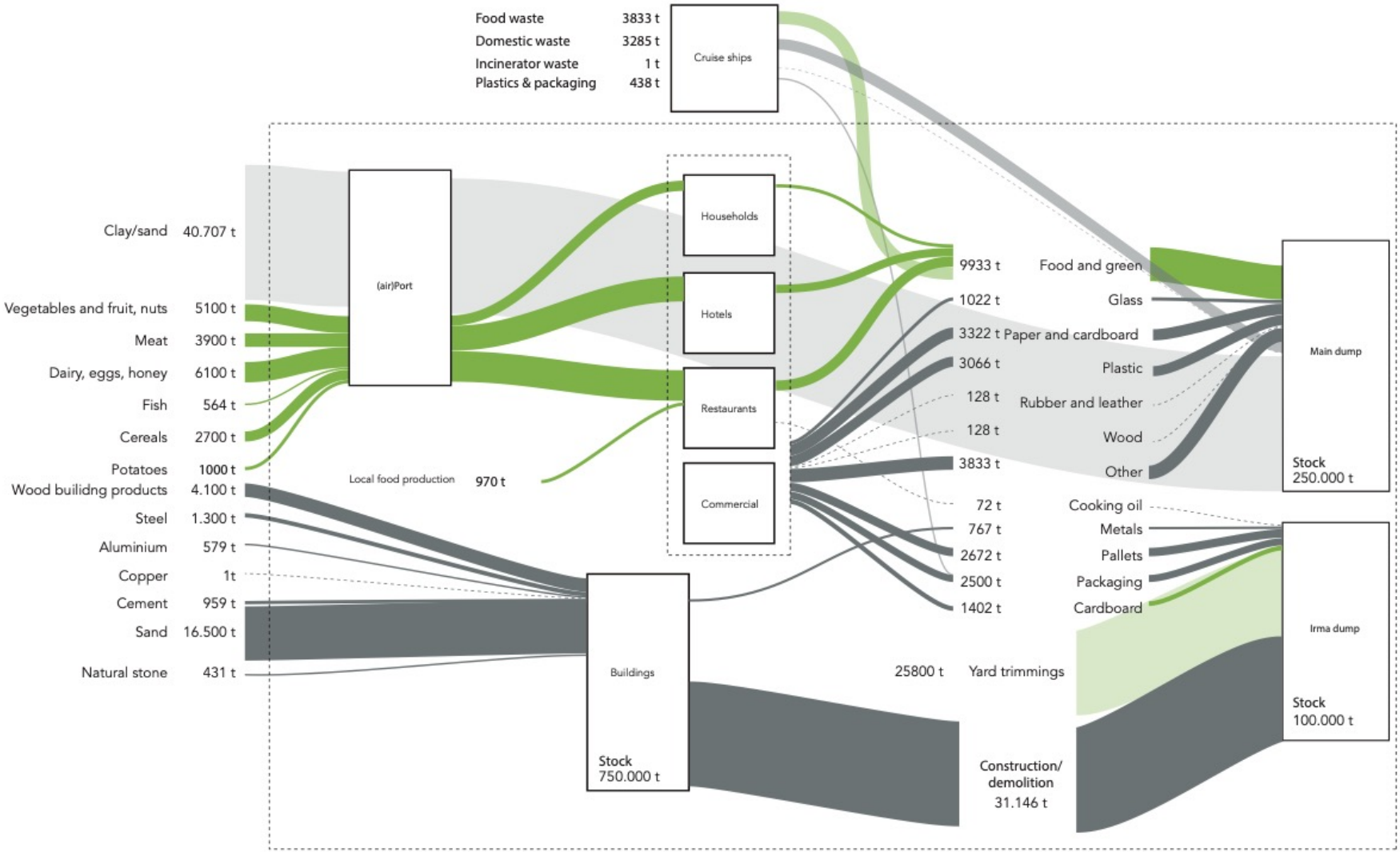

Figure 5: MFA for organic and inorganic materials

2.4.1. Organic materials

The organic material has a big influence on the environment and the community of the island. The organic content in municipal waste causes a lot of health issues and environmental damage (Dwight Wiliams, Richardson, & Social Economical Council, 2016), recycling organics is not so hard, and some composting activity is already been undertaken, however on a small scale (Frye, 2019). With the abundance of material available, the lack of fertile land and the general lack of land, composting and urban agriculture are a big opportunity to improve the urban metabolism. For agriculture hydroponics are preferred as they have a yield of 11 times traditional agriculture and use up to 12 times less water (Lages Barbosa et al., 2015). Also, when the organic content doesn't end up at the dump, 40.700 ton of topping material (28% of the total annual material flow) can be saved annually.

2.4.2. Construction and demolition waste

This is momentarily the second biggest waste stream on the island (22,5% of the total annual material flow). Along with the reconstruction of the island reusing aggregates from stone like materials is a big opportunity along with the reuse of timber. There is a sifting plant on the waste dump, however it is unclear as to which extent the output of this is actually used in construction. As deconstructing wood demolition waste is labor intensive, no recycling of this stream is done. There is however a high demand for all sorts of timber, so there is a big opportunity.

2.4.3. Plastics

Plastic bottles and packaging are abundant on Sint Maarten. The total waste stream (about 5600 ton or 4% annually) however is not big enough for industrial recycling. A proper collection program and small scale informal recycling is the most feasible. Waste2Work, one of the local circular initiatives, experiments on using plastic bottles as an insulator against the heat for a local innovation hub (Perez Izquierdo, 2019). Green SXM does small scale experiments with biodegradable plastic bags (Frye, 2019).

2.4.4. Cooking oil

Sint Maarten houses about 500 restaurants that produce on average 6000 tons of cooking oil annually. Right now, it is collected and returned to the oil companies to be recycled into the crude oil, but this stream could easily be turned to biodiesel.

2.4.5. Discarded containers and Yachts

After Irma, a lot of containers got damaged unusable to the shipping industry. They are easy to build with, and protect against hurricane winds when strapped to a heavy foundation. This is commonly done already on the island for multiple purposes. Also, about 400 yachts got badly damaged during the hurricane. They still have potential for reusing the polyester hulls as a roof, or the whole boat for housing if most of it is intact.

2.5. Opportunities on physical flows

Based on the above and other case studies done (see appendix 6) the conclusions that are made can be found in table 2.

Organics	**Inorganics**
Decentralized composting	Reuse car tires as cladding or retaining walls
Decentralized bio digester	Reuse zinc as wall cladding
Centralized bio digester	Harvest storm wood as lumber
Community gardens	Use C&D waste as aggregates
Biodiesel from cooking oil	Separate wood from C&D waste.
	Well accessible office and workshop space
	Cardboard recycling
	Reuse discarded containers and school busses
	Reuse/repurpose discarded yachts

Table 2: Summary of material opportunities

As for the more industrial materials the following boundaries can be set. Materials that are collected in factories as a waste product from manufacturing processes (such as sawdust and timber off-cuts) are called 'postindustrial' by-products or waste. Given a choice, it is more environmentally beneficial to use post-industrial waste as the material has not progressed as far along the cradle-to-grave life cycle as post-consumer waste. Similarly, it is better from an environmental point of view to reuse components or equipment rather than to use recycled materials that have already progressed further along the material life cycle (Addis, 2006).

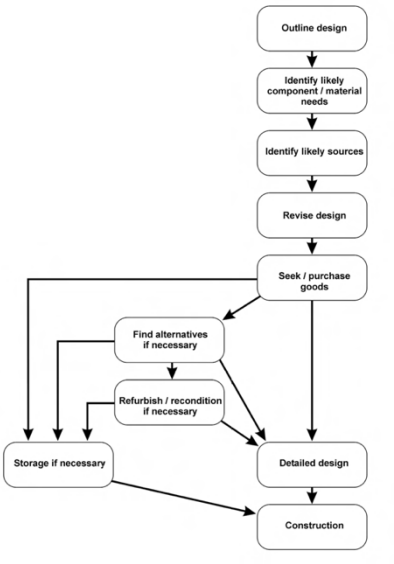

Figure 6: Reclamation, reuse and recycling: The design team and client view

Addis also describes the most valuable parameters to keep in mind:

- Easily removed or dismantled without damage?
- Are they inherently valuable (based on original cost)?
- Are they valuable due to their scarcity?
- Does there already exist an infrastructure dealing in the goods (e.g. architectural salvage)?
- Easy to transport and store without damage until a buyer can be found?
- Are the goods in demand? Likeliness of useful life remaining after demolition?
- Are they available in the quantities that people may require?
- Ease of assessment of the condition for **potential reuse**, and **useful life remaining**?
- Ease of refurbishment to restore their condition sufficiently for reuse?
- Can a suitable organization be identified that will test a product and provide a warranty adequate to meet the building designer/contractor's needs (both technical performance and for insurance purposes)?

2.6. Programmatic interventions

Summarizing Sint Maarten needs a programmatic intervention that improves the urban metabolism. Key features for this intervention are improvement of the organic chain, generating financial benefits and attracting business activity. As the scale is too small for big central interventions decentralized neighborhood scale interventions will work best. An intervention should be located central in the neighborhood, be well accessible and should be attractive to the public. In table 3 a summary of the programmatic proposal is outlined. This provides a solution for about 1000 households. A more detailed description of the programmatic requirements can be found in appendix 5.

Program	**m2**
Separation station: Separation, storage, office space, event space, baling machines	1420 (1630 incl circulation)
Urban farm: Hydroponics, Bio digester, composting and cistern	1150 (1320 incl circulation)
Commercial spaces: Office for entrepreneurs, workshops, restaurant	550 (630 incl circulation)
Apartments: 50 apartments, with shared facilities and waste collection points integrated	2010 (2310 incl circulation)
Total	5890

Table 3: Summary of the programmatic proposal

3. RESULTS

Summarizing the MFA made, the size and specifics of Sint Maartens metabolic system is as follows. The imports, on a yearly basis are about 20.000 tons of food and 24.000 tons of construction materials. A 7.500 tons (5,3%) of waste derives from the cruise ship industry. Last year 57.000 tons (40%)f hurricane debris was processed on Sint Maarten. Roughly 40.000 tons (28%) of the annual flow consists of topping material for the dump. The other 37.000 tons (26,7%) is domestic waste. The biggest and most problematic stream within the domestic waste is organic waste which is 13.000 tons (9%) annually.

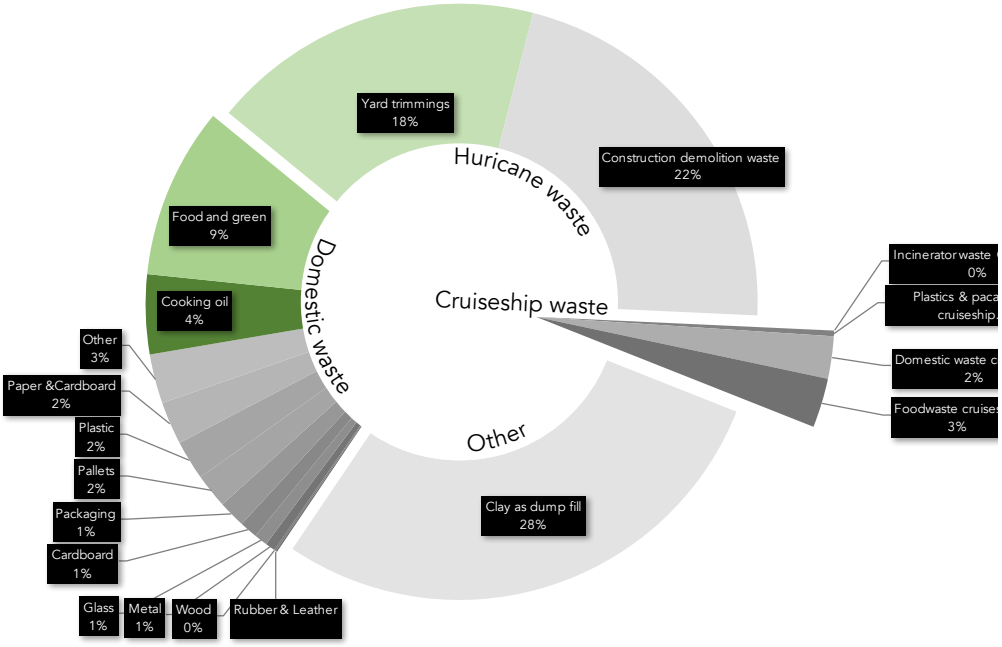

Figure 7: Pie diagram showing the annual flows towards the dump

Cruise ship waste has a limited impact on the annual flows of the island. If organics are taken out of the stream, also the 40.000 tons of topping material doesn't have to be imported. The local food production needs to be increased as only 5% of the food production is local. Urban farming with hydroponics is the most effective and economically feasible solutions to this issue.
The potential of the 750.000 tons of damaged building stock needs to be addressed. There is of potential for reusing waste as construction material (see appendix 6). The main conditions for the use of those products are: market for reuse, ease of reuse and quality control.
Finally, the programmatic proposal leads towards three types of interventions: a decentral separation station, workshop space, an urban farm and improved waste separation facilities for housing. The total need for this program is about 6000m2. It houses the facilities to accommodate the improvement of the urban metabolism of 1000 households (about 7% of the whole community).

4. CONCLUSION

How can an urban metabolism strategy be used to decrease organic- and inorganic material flows while creating new (circular) business opportunities through a programmatic intervention?

An MFA is a good instrument that can lead to system level interventions to create material and business opportunities. However, it needs another set of research methods like interviews, site visits, ethnographic research, photographing, case study analysis to come to valuable conclusions on opportunities of material flows. Therefore, both quantitative and qualitative analysis of the system were done for the research. The methods used are applicable to every type of context that the urban metabolism needs to be improved in.

The main conclusion on the MFA done is that the organic waste streams should be addressed better. To do so, four types of program should be introduced on a neighborhood scale: a decentral separation station, workshop space, an urban farm and waste separation facilities for housing. There is a big stock of material in damaged buildings, that can be utilized for this intervention.

The most effective solutions to improve the urban metabolism lie in decentralized productive programs. As for the business opportunities, trade in metals and plastics is most lucrative. The main condition is generating well separated, clean streams. The research shows that payment for clean waste streams can generate waste separation incentives and be financially beneficial for the community. To do so two new actors need to be introduced: the informal collector and the entrepreneur. The focus lies on waste trade and urban agriculture. It can be used for variety of business opportunities however.

The proposed program directly impacts one neighborhood (about 1000 households) and solves the metabolism on the same scale. Similar interventions are needed in other neighborhoods to create an impact on the islands scale.

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6. APPENDIX

Appendix 1: Map of satellite dumps found

Appendix 2: MFA on organic and inorganic materials

IN

Source	Buildign Materials import	Amount	Unit	<-- source	Price/ton	Amount (ton)	<--Source
	Hurricane waste (2017)					355.000,00	VROMI meeting
	Wood builidng products	$ 1.600.000,00	$			4.100,00	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
France/US: 65/35	Steel	$ 1.500.000,00	$			1.300,00	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
USA/NL: 50/50	Aluminium	$ 1.800.000,00	$			579,00	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
USA	Coper	$ 18.000,00				1,00	
USA	Cement	$ 88.200,00	$			959,00	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
France	Sand	$ 317.000,00	$			16.500,00	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
St Barths	Clay/sand	?					
Neatherlands	Natural stone	$ 125.000,00				431,00	
	Oil	$ 4.750.000,00	$			7.700,00	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
	Gas (LPG)	$ 525.000,00	$			1.300,00	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
	Coal	$ 45.600,00				140	

	Food import	Amount	Unit			Amount (ton)	Source
USA: $44,3M	Vegetables and fruit, nuts	$ 11.900.000,00	$	https://atlas.media.mit.edu/nl/profile/country/maf/		5100	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
NL: $4,8M	Meats	$ 13.100.000,00	$			3900	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
FR: $3,3M	Dairy, eggs, honey	$ 20.600.000,00	$	https://atlas.media.mit.edu/nl/profile/country/maf/		6100	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
CANADA: 0,8M	Fish	$ 4.200.000,00	$			564	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
Jamaica: 0,5M	Cereals	$ 2.300.000,00	$	https://atlas.media.mit.edu/nl/profile/country/maf/		2700	https://resourcetrade.earth/data?year=2017&importer=534&category=1&units=weight
NL	Potatoes	$ 633.000,00	$			1000	
Local food production						968,2	intervieuws
Food waste						6099,66	

OUT

Cruise ship waste	Amount	Unit			Amount (ton)	Source
Amount of passengers per cruise	3000	persons				https://www.cruisemapper.com/wiki/761-cruise-ship-passenger-capacity-ratings
Ships piloting for SXM (average 348)	1	/day				http://crew-center.com/philipsburg-st-maarten-cruise-ship-schedule-january-june-2019
Average docking period	1	day				Observation
Days before docking	1	day				http://crew-center.com/celebrity-reflection-itinerary
Plastics & pacakging	0,001 and 0,008	m3/person.day				Report:The Management of Ship-Generated Waste On-board Ships - EMSA-OP-02-2016.pdf
Plastics & pacakging cruiseship	1200	kg/day			438	Report:The Management of Ship-Generated Waste On-board Ships - EMSA-OP-02-2016.pdf
Food waste per ship	12	m3/week	EPA, 2008			Report:The Management of Ship-Generated Waste On-board Ships - EMSA-OP-02-2016.pdf
Foodwaste cruiseship	3,5	kg/day.pp	(HPTI, 2007)		3832,5	Report:The Management of Ship-Generated Waste On-board Ships - EMSA-OP-02-2016.pdf
	18 to 32	kg/week	ASCI, 2000)			Report:The Management of Ship-Generated Waste On-board Ships - EMSA-OP-02-2016.pdf
Domestic waste cruiseships	3	kg/person/day			3285	Calculation
Incinerator waste Cruiseships	0,05	m3/month			0,72	Report:The Management of Ship-Generated Waste On-board Ships - EMSA-OP-02-2016.pdf

Domestic waste	Amount	Unit				Source
Total waste	130000	tons/year			130000	VROMI
General (NL side)	1	kg/ppd			25550	Assumption
General FR side	1,71	kg/ppd				
Composition						
Food and green	52%				13286	Report: What a waste 2.0 - A Global Snapshot of Solid Waste Management to 2050 (world bank group
Glass	4%				1022	Report: What a waste 2.0 - A Global Snapshot of Solid Waste Management to 2050 (world bank group
Metal	3%				767	Report: What a waste 2.0 - A Global Snapshot of Solid Waste Management to 2050 (world bank group
Paper &Cardboard	13%				3322	Report: What a waste 2.0 - A Global Snapshot of Solid Waste Management to 2050 (world bank group
Plastic	12%				3066	Report: What a waste 2.0 - A Global Snapshot of Solid Waste Management to 2050 (world bank group
Rubber & Leather	1%				128	Report: What a waste 2.0 - A Global Snapshot of Solid Waste Management to 2050 (world bank group
Wood	1%				128	Report: What a waste 2.0 - A Global Snapshot of Solid Waste Management to 2050 (world bank group
Other	15%				3833	Report: What a waste 2.0 - A Global Snapshot of Solid Waste Management to 2050 (world bank group

Company Waste						
Pallets	1,83	ton/3h			2672	Observations + Calculation
Packaging	1,44	ton/3h			2102	Observations + Calculation
Cardboard	0,96	ton/3h			1402	Observations + Calculation
Cooking oil					6176	

Others	Amount	Unit				Source
Yard trimmings	17,7	Ton/3h			25842	Observations
Carwrecks	8	wrecks/3h			11680	Observations
Illegal dumping from French side	?				?	
Clay as dump fill	281				40707	Estimation + calculation
Construction demolition waste	215				31146	Observations + calculaton
					129421	
Dump 4	290	ton/3h			423400	73047
Dump 1	346	ton/3h			505160	70106
Total flow annually					143153	

Appendix 4: calculations on business models for decentral waste separation

Shipping costs	20 ft (1TEU)	40 ft (2TEU)	1TUE = 6,1*2,44*2,59 = 38,5 m3
USA	930,00	1.200,00	
Netherlands	1.800,00	2.340,00	
Puerto rico	100,00	130,00	Paper mill,
Domunican republic	225,00	295,00	
Cuba	510,00	660,00	

Scrap values (EU)	Glass	Paper	Plastics	Metal scrap	Alu Cans	Alu scrap
Average €/t (2004-2015)	46,27	121,13	329,63			
Average $/t	50,90	133,25	362,60	362,87	1.360,78	3.447,30

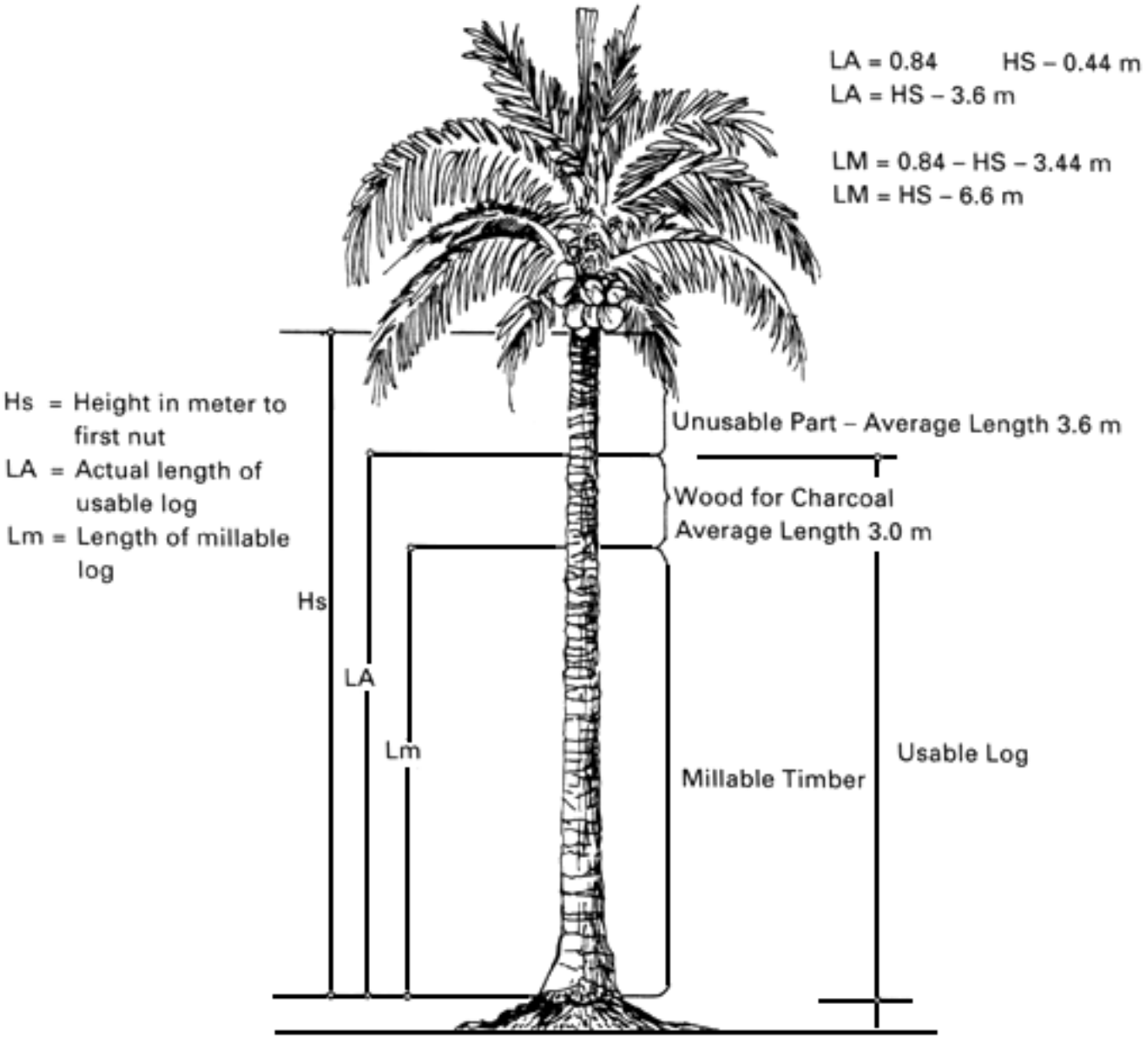
Type of Material	Loose	Av (lbs/cy)	1TUE (ton)	Revenu 1TUE	Baled	Av (lbs/cy)	1TUE (ton)	Revenu 1TUE
Cardboard	50 – 100 lbs/cy	75,00	2	$ 225,30	600 – 1100 lbs	800	18	$ 2.403,16
PET (Soda bottles, food packaging etc)	30 – 40 lbs / cy	35,00	1	$ 9.064,89	200–500 lbs /	350	8	$ 2.861,09
HDPE (Milk Jugs, Detergent Containers etc)	22 – 25 lbs / cy	23,00	1	$ 9.064,89	200 – 500 lbs /	350	8	$ 2.861,09
Aluminum Cans	50 – 75 lbs / cy	60,00	1	$ 34.019,40	150–500 lbs /	300	7	$ 9.203,41
Steel Cans	150 – 175 lbs / cy	160,00	4	$ -	500 – 1,000 lb	750	17	$ 6.135,60
Paper	500– 600 lbs / cy	550,00	12	$ 9.064,89	1,000 – 1,200	1100	25	$ 3.304,35
Newspaper	350 – 500 lbs / cy	400,00	9	$ 9.064,89	750 – 1,000 lb	900	20	$ 2.703,56
Glass	500 – 600 lbs / cy	550,00	12	$ 1.272,53	1,800 – 2,500	2100	47	$ 2.409,83

Conversion factor (lbs/cy to kg/m3)	1,69
1TUE (m3)	38,00
Max load 1TUE (ton)	25,00
lb to ton	4.535,92

Appendix 5: Program of requirements for decentral waste station

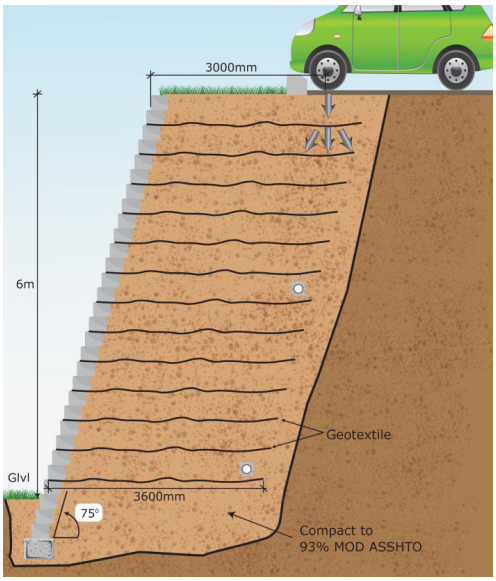
Separation station	**Specifics**	**m2**
Office space		50
Event/expo/experiment space	Flexible, public	300
Storage space		500
Separation space	2000/y	500
3 balers (Paper, plastic, alu)	Paper: 67 ton/y Plastics: 73 ton/y Alu: 3 ton/y	50
Metal baler	11 ton/y	20
Urban farm		
Bio digester	75 ton/y	50
Composting facility (1000HH)	75 ton/y (67m3)	100
Hydroponics farm	Output:40kg/m2.y Demand: 40kg/p.y	1000
Water storage hydroponics	20L/kg.y = 14.000/m	14m3
Rainwater catchment	Min 45mm/month	Min 311
Commercial space		
Office space 15 entrepreneurs	20m2 pp	300
Workshop space	Metals: Wood Plastics	100 100 50
Kitchen/restaurant		300
Apartments	**Specifics**	**Needs (m2)**
50 apartments	50 x 25m2	1000
Shared space with kitchen and toilets		200
Community garden (supporting 50HH)		500
Septic tank		20
Cistern		20
Shared hygienic facilities (toilets showers)		200
Waste collection point		50
Composting facility		20

Harvesting storm wood



Car tires

Car tires on the dump of Sint Maarten (own picture)



Retaining walls

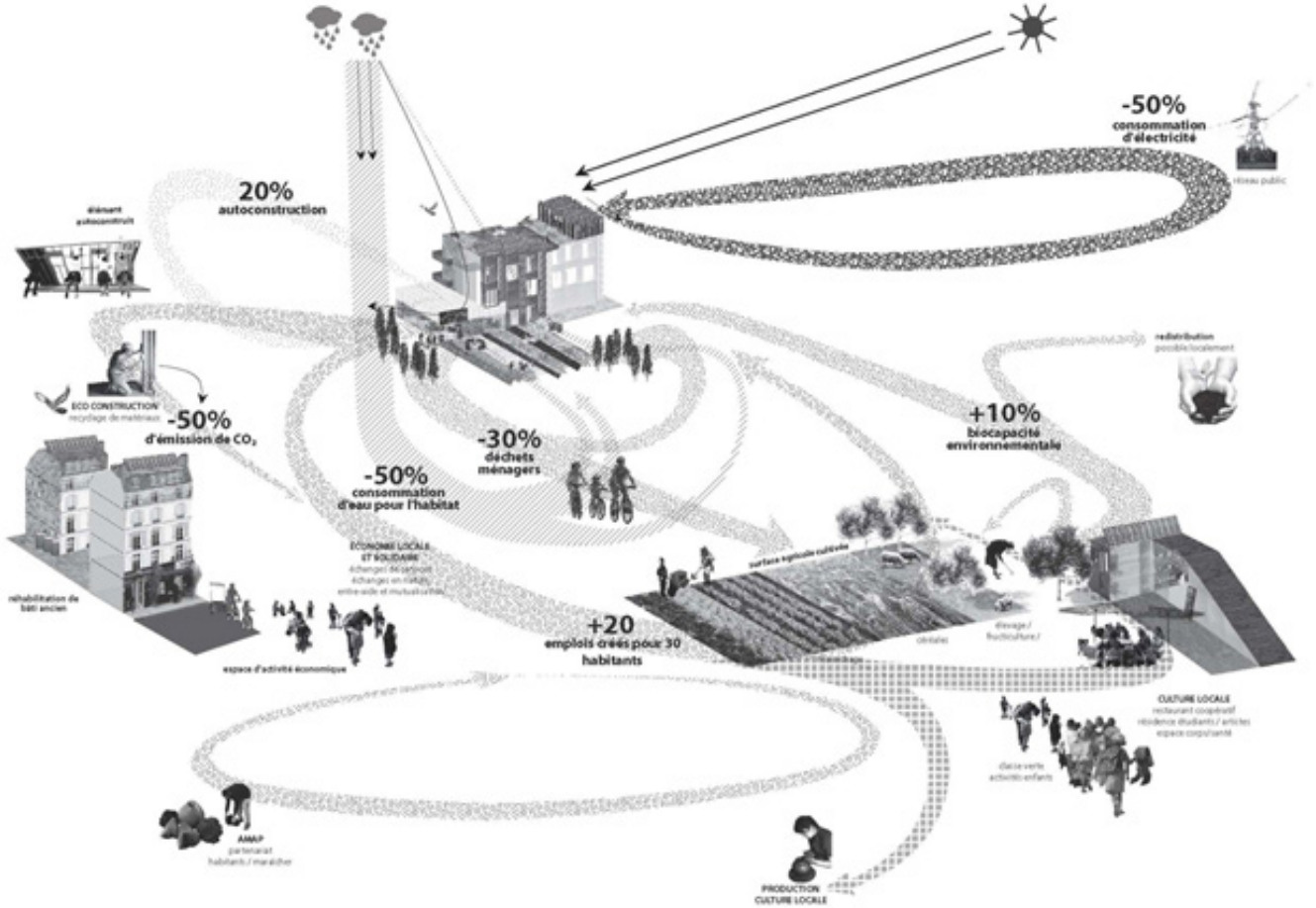
Roof cladding

Zinc

Piles of Zinc after Hurricane Irma (Thomas Proust)

Wood

Organics: Composting



Yachts

Bales

Containers

Appendix 7: Interview waste2Work

May 10, 2019

Union Road 129, Cole Bay, Sint Maarten

Interview waste2work:

AN INNOVATIONHUB FOR SINT MAARTEN

Celia Izquierdo Pérez – Architect, technical

Originally, I'm form Spain. During my studies in architecture, I was working a lot on development however, and within my studies I chose to do projects outside of the European context and stayed in Brazil for a year.

I graduated in 2016 and my final thesis was about informal settlement in Peru. I did a Postgrad on that specific informal settlement. I was working on that project for two years. After my graduation, I worked for the municipality in El Salvador on constructing with bamboo and earth. After that I worked for Habitat for Humanity in Domunica and Jamaica where I did a small guideline on how to build hurricane resilient in a cheap way for local communities. This was part of an assessment on disaster risk reduction. That's how I got acquainted with hurricane resiliency for local communities.

How did you end up at waste to work?

I basically saw the position and I really liked it because it was about designing an innovation hub and actually building it! Also, the part of supporting entrepreneurs I found very interesting. So, I applied and eventually got the job.

What do you do at waste to work and who do you work together with?

At the beginning, I was working by myself and I still do a lot of work individually. Now I get more support for the hands-on work of physical testing of the design by the from the upcycle centre. During the process I collaborated with an interior designer that helped me on developing the interiors of the hub. For the development of the project I work together with an engineer that helps me on the calculations on the foundation. I'm also in contact with a company that provides us solar panels to phase out our connection to the grid within 3 years. We're in contact with them on how to do this in the best way because it is expensive to install all the power we need for the whole hub. It has a lot of facilities that need quite some power. In general for this project we try to innovate on all levels of the building. We're for instance looking to use improved water purification systems for septic tanks and we design the roofs on the containers so they also collect rainwater.

This seems to be an exceptional project on Sint Maarten?

We do see a lot of initiatives on the island. Places where people are composting and growing their own food, even some buildings with solar panels. However, we tend to bring all of this together in the hub. And also, we want to stimulate further innovations within the building as we stimulate experimentation.

How do you think this project will change the mindset of the people here?

We plan to do the whole project very much participatory. We work on different innovation parts that the building is part of so people that visit can see what we're working on. We want to showcase all the topics we're working on physically in the building. Also, the building process is participatory. For these parts, we only work with waste materials. All the construction that can be done with unskilled labour we build together with local people to gain more consciousness on the building process.

We have ideas now how to fill the program of the hub, but we are very much aware that this can change over time. That's why the design is flexible in a sense that the infill of the space (the containers) can be filled with the interests of the partnerships we develop with the community.
Lastly, to get people involved in an early stage we organize volunteering days (with "SXM Doet") where they could build with waste and that was a big success! They were very enthaused about the project. So this is only the start, if we continue this I'm sure more people will join.

May 10, 2019

Union Road 129, Cole Bay, Sint Maarten

How do you source your materials?

We took the material from the demolition site next door. We took wood and metal, cable trays, and cabling. We intend to make more agreements with construction companies that give us debris. Especially wood because it is so easy to reuse. We also approach architects to collaborate with us to get demolition waste. It's hard to collect usable demolition waste since separating is not a priority in the building process here. However, there's much more attention for the subject now were here and people on the island get know us.

Much of the wood we get donated. With "SXM Doet" we also did a scavenger hunt for specific waste materials and that turned out to be a very effective way of collecting specific materials. Even for the trophies of the Heineken regatta we collected the cans through a Facebook campaign. Sometimes however, you can't get the material that you want or you have to work with materials that you have in stock to make something you need. This especially creates new ideas and solutions

How is the circular economy integrated in the innovation hub?

We reuse material so that part of the circular economy is clear. Financially however it is more complicated, because were not a business. We are a foundation that facilitates businesses. The innovation hub provides space that is right now lacking on Sint Maarten: for instance accessible office space and well organized workshop spaces. So, the space definitely provides economic opportunities for the island.

The goal is that the projects within the hub are sustainable over time. So, we don't only provide them with a space and tools to make a business but we will also train them to develop their business in a sustainable way. For every partner, we will do a follow up on circular business models. As for the selection of start-ups we're now already in contact with a lot of interested parties. We hope to attract more waste and socially engaged start-ups, but were also looking into corporations with universities to provide a space for research on the topics that we've developed.

How do you see your role as an architect here?

I don't see myself as a traditional European architect. I don't believe in building anymore. To be more specific I don't think we have to build anymore. You find so many abandoned buildings on the Island. Why don't we start reusing those and innovate in that way? You cannot always do exactly what you want to do in such a project, but I don't think its necessary to build new buildings for the middleclass.

We build more and more and were not focussing on the social aspects of the middle class. In Sint Maarten this is a big problem since these are the people that suffer the most from natural disasters as they don't get aid to rebuild their homes.

As an architect I think my responsibility goes further though. We're not only responsible for the communities, but also for the earth. With building in concrete for the rich, we set a bad example for the middle class. There are so many great alternative building materials and building techniques that get so little attention. Its hard to work with local materials. In my projects I work a lot with waste. Other natural materials like bamboo and earth are not used here. There is no knowledge on how to grow and build with natural them on Sint Maarten.

I see a lot of people that don't take the time to consider alternative building methods and building materials. Many people I meet have such a different mind-set here. I think they never got a chance to think differently about what they do and how they build. When you ask them why they do what they do only then they open their eyes and you see they start thinking differently. Hopefully with the work that I do I can make a change into that mind-set. That's why I'm here.

Appendix 8: Interview Green SXM

May 18, 2019

Trumpet Shell Road, Upper princes Quarter, Sint Maarten

Interview Green SXM:

On waste management, recycling and composting on Sint Maarten

Alex Frye – Architect

Worked on the Island bank in Cupecoy. Since Irma she mainly worked on insurance reports and reconstruction. Recently she did a small housing project with apartments and town houses. She had to fight to integrate garbage recycling and separation facilities. She's frustrated that gets little recycling as the dump doesn't charge a dumping fee.

How do you see your role as an architect when it comes to sustainability?

The budget is very limiting it doesn't allow for sustainable development. So, it is a fight to get people to do better than they do now.

For the housing program a green space was planned to accommodate local trees, a safe playground for kids and a meeting space for the inhabitants. However, the developers insisted on placing car parking there. In the end, we achieved to pave with permeable paving, so we don't contribute to increased flooding with the building. We had to fight for that as well however.

How do you see the future of Sint Maarten? Do you think the mind-set will change?

Going back to quality instead of quantity. Improving what we already have instead of building something new improving and building the latest and greatest. It's difficult to achieve because everyone wants to progress and expand. There is a huge pressure on the build environment, the infrastructure, the traffic, the waste dump, education.

Irma has however changed the mind-set of the people. A lot of people changed their interests to help out and make a better future for the island. There is a lot more going on around improving waste management and recycling. People are more aware of the problems on the island. One of the biggest changes I see are in (urban) agriculture. A lot of traditional gardening has come back to the island, having chickens and a vegetable garden used to be rare. Now I see this happening more and more again.

I don't think you can completely change the mind-set of the people, but I think you can give them a gentle push in the right direction. Since I've been writing about composting, I get a lot of interesting responses on people picking up the idea or even telling me that they have been doing this for years already on the island! I think it is important to talk about this as much as you can. For instance, on regenerative agriculture, waste and circular economy, the more people talk about it the more impact it will have on the community. The more people talk about it the more of a difference it will make and the more people benefit from it.

Can you imagine a waste free Sint Maarten?

It would be great. As tourism is the main industry the problem is tourists don't think about sustainability too much when they are on holidays. They don't want a paper straw as they want to be able to drink their cocktails lying down and don't want to sit up having to drink it. Those types of problems make it hard to make Sint Maarten waste free hard. I think the solutions lie in simple regulation minimising single use waste and on what products can't be used. The other half of the waste problem can be tackled if more people start composting.

Do you see a future for ecotourism?

It is possible. People that are looking for a very remote location won't go to Sint Maarten, however there is an opportunity for more cultural tourism. The bigger tourist streams stay at the beaches, but there are some small-scale activities going more into the core of the island to get a more of the beaten track experience. Lottery farm for instance is a good example of a busy and off the beaten track destination. But also, the zip line tour and birdwatching tours give you a close to nature experience. There is a lot of niche markets that Sint Maarten can use. It's important to attract eco conscious tourists because they tend to spend more and stay longer than the average tourist. If Sint Maarten could attract that type of tourist again it would be both beneficial for the economy and the ecology.

Could Sint Maarten become a waste hub for the region?

The cruises ship industry needs an overhaul to make it eco-friendlier. They create a lot of pollution. Think not only about air pollution but also dumping of sewage and food waste over board, weather legal or illegal. There is a lot of gossip about waste problems, however the biggest problem is the lack of concrete evidence on which

streams go where. For instance, on the cruise ship waste their companies claim that most of the waste is processed in the Caribbean, but there is not hard data on where this is done, how much is processed and how it is processed. When it comes to wastewater treatment on Sint Maarten the same thing happens. All the companies and hotels that treat wastewater claim that their waste streams are clean, but again there is no hard data to confirm this.

Solutions on this problem should be handled both top down and bottom up. When you talk about handling waste, within the waste management hierarchy, source reduction is the most important factor. This is something that needs to happen on both a commercial and neighbourhood scale. There is also a lot that we can and must do on an individual level. We need to buy less single use plastics (Styrofoam, plastic bags, packaging etc.), we should compost more and recycle whatever we can recycle. Only the rest goes to the dump. All the levels below that are the responsibility the government. There is a plan for a Waste to Energy plant. This might be the best solution looking into the scale of the problem, however the effectiveness of it really depends on the content of the waste and the scale of the plant. If a plant is too big no proper recycling will be done anymore since all the waste goes to the energy plant. The question is also whether there is an incentive for a proper and clean installation that doesn't emit toxic fumes.

Small scale recycling is probably the most effective on Sint Maarten. The Waste Factory is a good example of this. Making art out of waste. This adds direct value to waste. This is much harder to do if you want to mak an actual product. However, Sint Maarten needs more economic diversity, so increased recycling could pose a solution to the problem.

What is the potential for communal urban agriculture on Sint Maarten?

Lots of people grow their own vegetables because it is a lot cheaper than buying imported goods. The Rastafarian community on Bellevue run an agricultural farm for years already and together with Soualiga farm they are the only farms that provide fresh local food. There is also some regional import some shops import from Guadeloupe and Dominica. And there are some other interesting small-scale initiatives.

Space less gardens, Sint Maarten fisheries, Lilly's permaculture garden, Sint Maarten green soldiers that focusses on hydroponics. There is one guy that has a big setup of hydroponics in a damaged house and is generating a lot of knowledge on doing this and scaling this up.

After a hurricane nature recovers remarkably quick, so within a month you can have fresh lettuce and herbs already. Especially root vegetables stay protected against the winds and are a good post hurricane food crop. So, a lot of people rediscovered the potential of urban agriculture.

There is not a lot of space for agriculture. The limited green space we have left is forest and you don't want to cut down trees for agriculture. Also reclaiming soil is hard because the topsoil has been removed completely for construction and needs to be revitalized before it can be used. The building culture doesn't respect the nature on the plot as they get completely stripped of any natural vegetation and soil before construction starts. With this also the water retaining capacity of the soil had disappeared. So, closed loop systems like hydroponics have a big opportunity on the island since they depend less on those factors. A lot of people love the nature of Sint Maarten, but they don't make the connection that removing top soil doesn't leave any opportunity for plants to grow.

The business model behind communal urban agriculture is also interesting. There is lots of communal space that could be used differently on Sint Maarten. There are lots of successful examples where small-scale agriculture on borrowed land appears to be very lucrative across America. So, this model could also be implemented on Sint Maarten. You would not only have less import and less plastics but also generate income. The setup I have (about a 1m3) can provide 15 households with compost.

When it comes to community it is hard to get more people to recycle. The people that are interested in recycling are already doing it, but the biggest amount of people think it is to much trouble handing in separate streams of waste. Even with a community or neighbourhood there is a difference in willingness to do something with recycling and farming. Some people really like it and some don't. However, if a community adopt it they will also enforce it. I think there is two ways of changing this. The government could give fines to people that don't recycle, which I really don't like. Or you could provide the proper services next to regular garbage pickups and talk a lot and organise events to generate more awareness. Which can be painstaking, but might be much more effective. It's also about the small things. A friend of mine runs an air-bnb and also educates the users how to handle their waste. The very poor communities however do a great job reusing what they have out of financial necessity. It is mainly the middle class that has a complicated relation to waste and that needs to be educated.