INDIA's GOLD

Identification and development of a waste treatment business in India

The Technical University of Denmark
Design & Innovation

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Abstract

The municipal solid waste (MSW) generation in India has rapidly increased and breached the capacity of the current waste management system leading to an extreme degree of unsanitary landfilling. This practice has a severe negative impact on the environment as well as the local society. The governmental initiatives are not solving the problem in the required pace and there is a need for a stepping stone solution with an immediate effect. This favors the cost effective waste-to-energy technology, Pyrolysis, which is able to significantly reduce the physical size of the waste while recovering energy.

This paper investigates the business opportunities for applying pyrolysis technology to the solid waste scene in India. The project has been facilitated by an entrepreneurial approach, which has promoted a flexible process and the development of a detailed solution. Exploration of the complex system has been conducted through a literature review as well as a fact finding mission in the cities Bengaluru, Coimbatore, Hyderabad and Trivandrum. The project has delved into the theoretical domain of entrepreneurship and questioned the background for reliable decision making. This has led to modification and combination of theoretical frameworks to ensure a holistic evaluation of potential business ventures.

The project presents a business venture in Vellalore, Coimbatore, targeting the rejects of a compost treatment plant operated by the company Tatva Global. The plant has a low efficiency (7-10% compost yield) while 40% of its input is screened as refused derived fuel (RDF) which contains a high energy level but a shortage in market demand. This fraction can be utilized to produce and sell biofuel while unloading 25% of the 800 TPD that Coimbatore is currently generating. The business will be economically feasible and is projected to produce an accumulated result of 24 million DKK after 4 years of operation. A positive cash flow will be obtained within two years and break even shortly after.

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Technical University of Denmark

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Preface

India is a country in growth. Their GDP is rapidly increasing and the urban population has doubled in less than 20 years. These two factors are directly correlated with an increased waste generation per capita and the municipal solid waste (MSW) management of urban India is not adapting fast enough. The growth is steady and a three times increase in the waste generation has been projected by 2050. This has in the majority of the urban India led to unsanitary landfilling of 90% of the waste generation. This is polluting the ground water, increasing the health risk and emitting large portions of green house gases into the atmosphere. The scale of the problem is a well-known fact and there is no doubt that the municipalities are eager to find a solution. Unfortunately they are not keeping pace with improvements due to major flaws in their current approach and vision.

This paper covers the development of a business from the understanding of the current waste situation to a detailed business proposal for a potential solution to the problem. It targets the above mentioned waste management issues and aims to establish an economically feasible start-up that can recover the energy from the unutilized waste. The business development revolves around the pyrolysis technology that has the potential to add the required flexibility to the waste scene. It is a technology that is getting more traction in the field of treating waste but has not yet been commercialized in India. A more detailed justification of why pyrolysis technology is believed to be a potential solution for the Indian waste system will be elaborated on throughout the report.

This paper presents the work that has been executed in the compilation of the master thesis project in the program Design and Innovation from the Technical University of Denmark, Lyngby. The paper represents the written part of the exam but will be assisted by an oral exam on the 1st of August 2017.

Scope of project

The objective of this project is to identify and develop a business that by the use of existing pyrolysis technology can ease the environmental, societal and economical impact of the current municipal solid waste issues in India. This business should promote a small pilot setup and strive for a positive cash flow within three years.

This main objective is supported by a number of sub-objectives that have guided and structured the process towards the end goal.

1. Obtain an overview of existing data in the literature concerning the current MSW issues and suggested practice.
2. Investigate the possibilities and limitations of pyrolysis technology.
3. Select a number of Indian cities to conduct a case study to validate the data from the literature and identify specific business opportunities.
4. Establish a network that can be exploited in the initiation and pursuing of a business.
5. Explore different business ventures and systemize the findings of the complex MSW scene.
6. Conduct a holistic evaluation of business opportunities that articulates both objective and contextual parameters.
7. Develop a business plan with a four years launch strategy for the most suitable business opportunity.
8. Become familiar with existing entrepreneurial theory to guide the process and to avoid pitfalls.

How to achieve the objective

This project follows an entrepreneurial approach and focuses on the practical development a business rather than having an academic viewpoint. It emphasizes the importance of first-hand observations and well grounded arguments in the entrepreneurial decision making. This will be assisted by combining an effectual and predictive reasoning from the entrepreneurial domain in order to promote a holistic evaluation of identified business opportunities. The process of the project will be described in the methodology which will also elaborate on the extension of existing theoretical frameworks.

A core element of developing a successful business is the evaluation of identified business opportunities. Where traditional business evaluation mainly focus on the economical projection, this project will emphasize the importance of a contextual assessment. This will ensure that the uncertainty and complexity of India's waste system is not neglected and assist the assessment of how likely a business opportunity is to succeed. That being said, such contextual parameters could not be determined from the beginning of the project as the understanding of the Indian environment was limited. The selection of these criteria is therefore postponed to later in the report and based on the findings from investigating the MSW system. Both the economical and contextual opportunity evaluation parameters are listed below but they will not be further elaborated at this point.

Objective parameters: Pay back period // Operational margin // Operational profit // Capital investments

Contextual parameters: Network strength // Alignment with current strategies // Entanglement // Partners incentives // Personal relation // Implementation time/bureaucracy // Feedstock homogeneity // Feedstock scalability // Span of focus area // Competition

Limitations/boundaries

The focus of this project concerns the development of a business concept and allocates little attention to the technology involved. In fact, the technological development will not be touched upon in this project since it falls out of the project scope. This decision is based on the lack of chemistry competency that would be required in the analysis of a successful pyrolysis output. That being said, the project strives to obtain a thorough understanding of the technology in order to assess the applicability in different scenarios.

The project is furthermore limited by the distance and related costs to travel to India which has made recurrent visits impossible. This fact emphasizes the importance of collecting as much information as possible during the one visit to India. The distance is also an obstacle for the effectual approach that is usually characterized by executing multiple field activities and learning from the results. This has led to a reduced agility in the project which has made it necessary to address existing methods in new ways to ensure a well grounded decision making.

Reading manual

The structure of this paper corresponds to the four phases of the project: *Discovery, opportunity identification, opportunity evaluation and detailing*. The first two phases will be oriented towards creating an overview of India's MSWM system. They will present general aspects in the system to give an overall understanding followed by a focus on four case studies which will elaborate on specific business opportunities. The third phase will be process oriented and present how the project has executed the evaluation of opportunities while ensuring a substantiated selection.

The fourth phase is the detailing which will focus on the development of a final business concept and how it should be executed. The report will have a conclusion and reflection in the end that will sum up the project.

The report outlines the steps of the project and the concluding results. A methodology chapter is placed before the four phases and elaborates on the process of the project and the applied theoretical framework.

In general the report is augmented by an appendix that documents and elaborates on different aspects of the project. The appendix contains essential information presented in the form of worksheets which should be look up when referenced. A reference to the appendix will be illustrated as *WS* [*number*]: [*name of worksheet*] while citation references will be based on a in-text style, illustrated as: ([Author/s] [Year]).

Abbreviations:

MSWM : Municipal solid waste management

STP: Sewage treatment plat

ULB: Urban local bodies

MBT: Mechanical and biological treatment

WTE: Waste To Energy

GDP: Gross Domestic Product

Names:

BBMP: Bruhat Bengaluru Mahanagara Palike (Municipal corporation)

CCMC: Coimbatore City Municipal Corporation

GHMC: Greater Hyderabad Municipal Corporation

MNRE: Ministry of New and Renewable Energy

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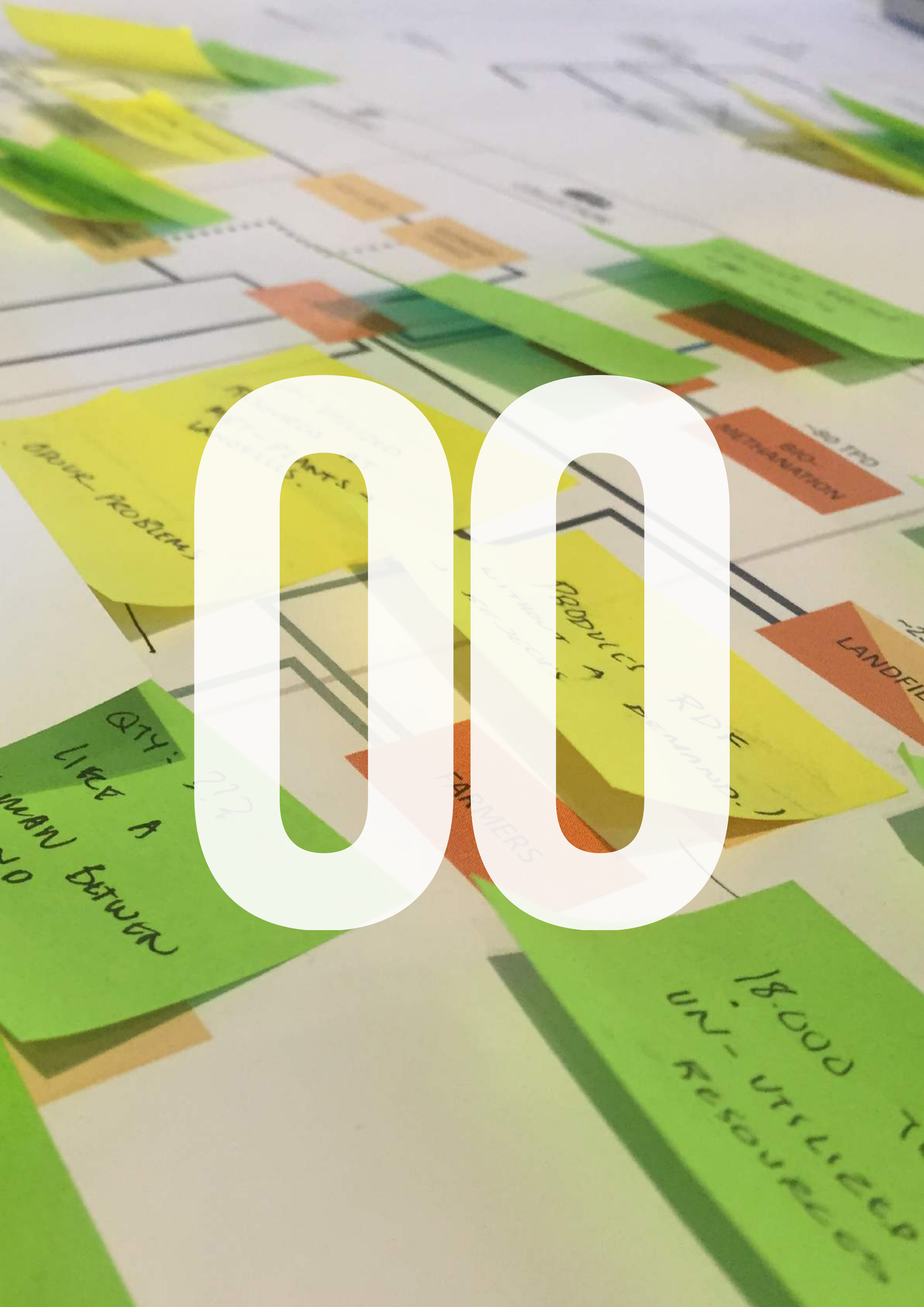

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Methodology

This project sets out with the objective to explore, exploit, evaluate and detail pyrolysis business opportunities in India. Activities that all fall into the entrepreneurial domain (Fuduric 2008). It is therefore natural that this project has been driven by an entrepreneurial approach where the traditional research questions have been substituted with a set of broadly formulated objectives. This allowed the project to diverge in different directions and identify various business opportunities instead of being stuck to one single path towards a predefined business. This agility was facilitated by the entrepreneurial approach: *effectual reasoning* that is commonly cherished by entrepreneurs since it allows adaption to contingencies and flexibility to change direction throughout the development of a start-up. This is particular beneficial in the front-end of a project where high uncertainty and limited knowledge creates the need to explore a wide span of areas (Sarasvathy 2005). This can be summed up as: " …effectual strategies are useful when the future is unpredictable, goals are unclear and the environment is driven by human action" (Sarasvathy 2008; cited by Batley and Omarsson 2014). Aspects that are particuar enhanced when exploring business opportunities in a foreign culture with an unfamiliar code of behavior.

Effectuation is, however, not the only mindset that cast its shadow on this project. Predictive or causal reasoning is often thought of as the inverse principle to effectual reasoning. It is in comparison revolving around an end-goal and uses quantitative parameters to evaluate and select potential paths (Soh and Maine 2013). This approach have been applied in the project to promote a more objective converging of the scope. It is not rare to combine these two approaches as it is acknowledged to have a valuable effect even though the approaches are considered as counter reasonings (Sarasvathy 2005).

The combination of the two aspects has assisted to make well-founded evaluations of future business opportunities, based on both economical and contextual parameters. How this was executed will be further elaborated in this chapter.

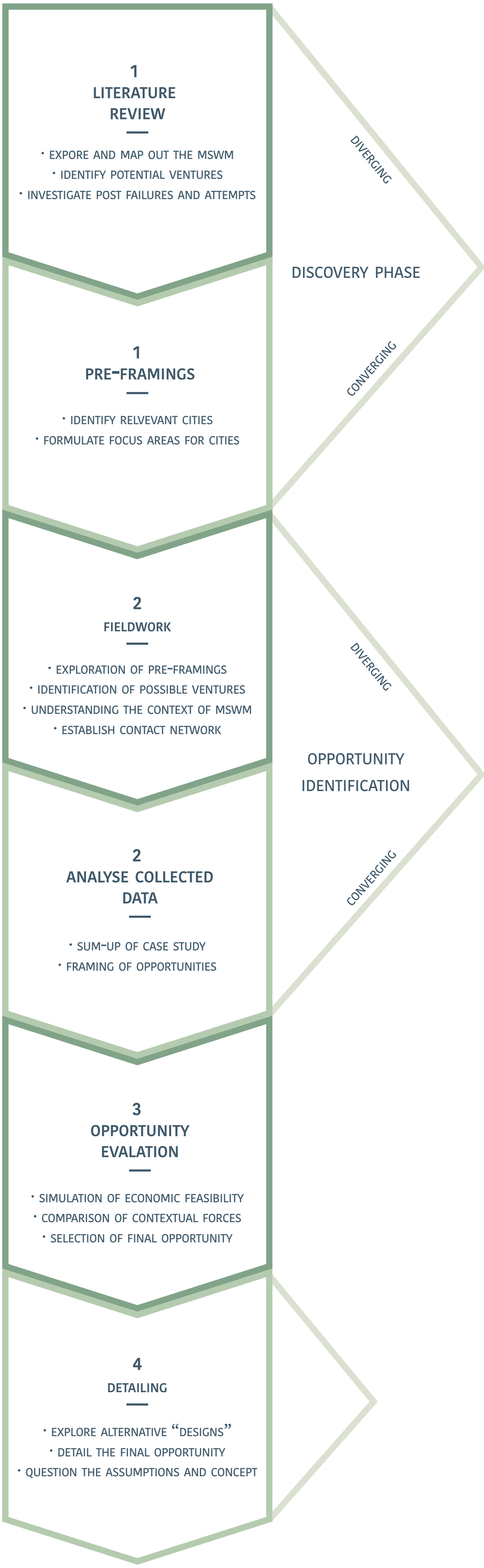

FIGURE 1: The process of this project shifted between diverging and converging phases in order to promote a thorough investigation of both the problem space and solution space.

0.1 Project phases

This project was initiated with an idea of combining a pyrolysis technology with the MSW scene in India. At this point the knowledge of pyrolysis technology was basic while the understanding of the Indian environment was close to nonexistant. This fact emphasized the need for a theoretical framework that would ensure a holistic exploration of the MSW system in order to decrease the risk of missing crucial elements. It was considered essential to investigate the contextual aspects of the MSW system and outline its system architecture. A term that is defined as a:"description of entities of a system and the relationship between those entities" by Crawley, Cameron & Selva (2016). It initiated a broad mapping of the MSW system which later made it possible to base the opportunity evaluations on a holistic understanding.

The project has been divided into different phases with the following focus areas: Discovery, Opportunity Identification, Opportunity Evaluation and Detailing. These divisions have structured the developing process and ensured multiple shifts between diverging and converging practice as it is also known from the double diamond model (Design Council 2005). The four phases are illustrated in Figure 1 together with the respective key activities.

Even though the model is illustrated as linear, it is important to note that the project process did not follow a clear stage gate structure. The discovery, opportunity identification and opportunity evaluation phases in particular were in reality more fluid with several iterations. The specific execution together with the applied theory and methods will be elaborated upon in the sections that follow.

0.1.1 Discovery

The discovery phase was in broad terms a literature study that created a holistic overview of the waste management systems and applied technologies together with the identification of potential business opportunities (pre-framings). It was mainly driven by an effectual approach which allowed the investigation pattern to spread out without being constrained to one particular area - new clues and findings launched new exploration paths that expanded the scope of the project. The exploration of pre-framings revolved around the effectual principle, bird-in-hand (Sarasvathy 2001); but rather than basing the driving force on personal means, it focused on the possibilities of pyrolysis. The end of the discovery phase was characterized by a selection of four cities that shared the potential of offering good conditions for a future business. Four case studies should explore the pre-framings and identify new ventures in the cities.

The discovery phase was based on journal articles, newspaper articles, reports and knowledge sharing with MASH Biotech. Furthermore, actor-network theory (Latour 2005), sequence model (Beyer & Holtzblatt 1998), arenas of development (Jørgensen & Sørensen 2002) and affinity diagram (Spool 2004) were used to create an overview, articulate, discuss and collate the information.

The discovery phase had the purpose of creating a broad understanding of the MSW system including its inherent challenges and opportunities. It has therefore been decided to include findings from the fieldwork that concerns the broad framing in the Discovery chapter as well. This should ease the reading.

SOURCE: PRIVATE - COLLECTION AND SEGREGATION FROM BULK GENERATORS IN COIMBATORE

0.1.2 Opportunity identification

Beyer & Holtblatt (1998) emphasizes the need for a proper understanding of user behavior when designing in complex systems. For the same reason it has been important to conduct a fieldwork in India to personally engage with stakeholders and observe their behavior in the surrounding system. The project phase opportunity identification was based on case studies of four Indian cities with the aim of mapping waste related activities, breakdowns, validate the pre-framings and identify new opportunities. The fieldwork was in other words a fact-finding mission conducted over three week period.

The municipal corporations were targeted as a good entry point since they are the accountable entity in the system. Contact was made directly with the people in charge via LinkedIn as it was impossible to get a reply through the official email and telephone channels. From there the snowball was rolling. A few connections from LinkedIn fostered new relationships and the investigations continued from there. This opened doors that otherwise were shut and it meant that meetings were often spontaneous and required a quick response and adaptability to maximize the opportunity. This approach, by its nature, made it very difficult to conduct full scientific documentation of the case studies. It was, however, the only way to proceed considering the context. The information collected was based on meetings, guided tours, observations, demonstrations and numerous discussions.

This phase targeted both the contextual and technological aspect of future opportunities. The contextual investigation manifested itself by identifying potential partners, new waste streams and reflecting upon the reliability of involved people. The technological aspect focussed on the characteristics of the feedstock and available amount. This aspect were supported by a sampling from relevant sites that were brought home for testing. The test rig was, however, not suitable for the types of feedstocks that had been collected as the max temperature was too low. This is elaborated together with a description of the experiment and the results in *WS 1: Test of samples*.

Sum up method

The collected data was noted daily in a log book. This ensured observations and findings were not lost during the three weeks of fieldwork. Additionally, pictures were used to document the status of practices and facilities in the waste system e.g. landfills, treatment plants etc. However these data formats were too constrained and unmanageable to get the required overview of such a complex system. There was a need for collating the raw data into one flexible medium that would allow a full understanding of the system - a boundary object from which e.g. leverages in the system could be identified and relevant data could be articulated.

This was achieved by merging aspects from three frameworks; sequential model (Beyer & Holtzblatt 1998), Actor Network Theory (Latour 2005) and Life Cycle Assessment (Olsen et. al. 1996). The merger, referred to as the sum up method, had the purpose of facilitating the debrief of each city with regards to identifying breakdowns, unfulfilled needs, and potential opportunities. This was possible since the sum up method illustrated the current waste related activities in the cities, the responsible stakeholders and where different waste streams are present. It structured the data from a fluctuating exploration and enabled the required overview of the MSW system. It is acknowledged by Andreasen, Hansen and Cash (2015) that boundary objects are commonly used in design thinking to articulate and communicate information, which in reality was the main goal here. Due to the diverging nature of this phase the majority of the collected data was included in the sum up and opportunities were brought forward without any filter.

The output of the sum up method was 28 opportunities across three cities since one of the cities were found unsuitable for launching a business. The specific results from the sum up method and the identified opportunities will be further explained in section *2.2 Case studies*. The specific execution steps of the sum up method is illustrated in *WS 2: Sum up method*.

0.1.3 Opportunity evaluation

The opportunity evaluation is the main converging part of this project. The overall purpose of this phase was to narrow the scope and frame one final business opportunity. This framing was executed in two main steps; the first being a quantitative simulation of the economic feasibility of the different opportunities; and the second being a qualitative evaluation of the related contextual environment. The two evaluation steps functioned as stage gates that dismissed unsuitable opportunities and narrowed the opportunity pool down to one. The specifics of the evaluations will be clarified in the following sections.

Simulation of the economical feasibility

The evaluation of economic feasibility aims to stop developing paths which do not have the financial characteristics to succeed. The evaluation balances the cost of required operations with an expected revenue based on the characteristics of the feedstock as it is illustrated in Figure 2. A predictive approach that allowed the isolation of a future financial structure and thereby facilitated a tangible comparison of the opportunities. This kind of reasoning was chosen since the involved parameters represent limited uncertainty which is favored by causal reasoning. "Causal strategies are useful when the future is predictable, goals are clear and the environment is independent of our actions" (Sarasvathy 2008; cited by Batley and Omarsson 2014). The output of the calculations presented an economical conclusion that was used to make a relative comparison of the opportunities. The conclusion consisted of the economical metrics pay back period, operating profit, operating margin and capital investment. All these parameters are appropriate to use when assessing the economical potential of new entrepreneurial ventures. It was decided to identify opportunities that are suitable as pilot projects, which made it essential to have a threshold value that dismissed opportunities with a pay back period that exceeded one year.

An important note regarding the simulation is that even though the uncertainty is low the input values are still estimates. The economical output should therefore be thought of as an indicator of the opportunity's potential rather than the exact value. The feedstocks need to be characterized and tested in a pyrolysis reactor in order to get an exact modelling of the business potential.

Another approach for estimating the potential of an opportunity is to find the lower limit value for when a feedstock contains a suitable amount of energy to facilitate a feasible business. This was, however, discouraged due to the reasoning that opportunities represent diverse needs of processing steps that would not justify an assessment that is based merely on feedstock energy content.

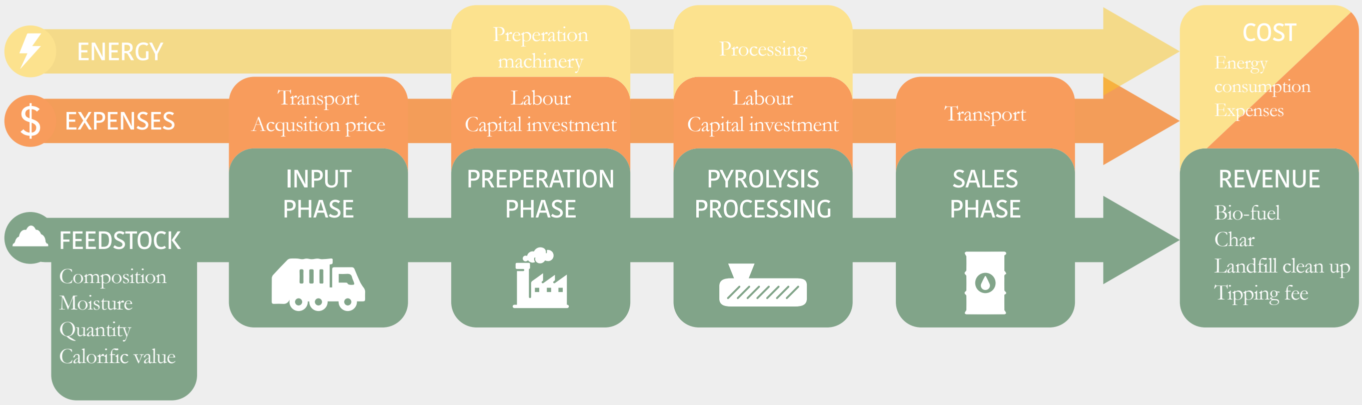

FIGURE 2: The simulation of the economic feasibility was an essential part of evaluating the potential of new business opportunities.

Contextual evaluation

The contextual evaluation aimed to assess the probability of success for the economical feasible opportunities. The assessment is dependent on the environment and emphasizes the importance of a well founded understanding for stakeholder incentives, current activities and relations. It can be argued that these parameters should be included in the aspirations that Soh and Maine (2013) describes when they state that:"The criteria to evaluate future impacts of effectual actions do not rest on economic rationalization but on the entrepreneur who possesses convictions and aspirations for the future". It is suggested that the uncertainty of these aspirations and convictions increases as the system gets more complex. Daniel Kahneman illustrates in his book *thinking fast and slow* (2011) the flaws in human decision making as a results of our reasoning being dictated by intuition which promotes errors. In short, these errors are a product of manipulated focus on relevant data and simplified evaluation patterns. This perspective raises a red flag in relation to effectual decision making since it is based on the "gut-feeling" of the entrepreneur. The flaws of the human decision making only enhances as the number of relevant data to include are increased. That being said, the effectual reasoning is not dismissed from this project but it is instead argued that there is a need for a safety net to ensure the consideration of all critical elements.

The contextual evaluation targeted a transparent decision making that enabled a holistic evaluation of the environment. This was executed by identifying stakeholder risks, environmental practicalities, strategic alignment and market potential, as the critical contextual areas. Each area covered several parameters that were used to rate and compare the opportunities. The parameters were in general qualitative but the rating facilitated the required discussion that articulated crucial risks and connections. This allowed e.g. an understanding of how a strategic partner is influenced by a municipal strategy. This realization would not be possible if the parameters were evaluated individually.

The contextual rating uses a spiderweb layout which is illustrated in Figure 3. The execution steps of the method is illustrated in *WS 3: Contextual evaluation* while the selection of relevant contextual criteria and result of the evaluation will be elaborated in chapter 3: *Opportunity evaluation.* The contextual evaluation was supported by a stakeholder analysis (Attrup and Olson 2008) that rated the credibility and influence for each contact person in India. This was a pre-step to the contextual evaluation and will be further described in the section: *3.2.1 Credibility/influence analysis.*

The output from the contextual evaluation was the selection of a final business opportunity based on the comparison of opportunities.

FIGURE 3: The contextual evaluation criteria articulated relevant aspect related to the contextual part of a new business venture

0.1.4 Detailing

The final phase of this project covers the development and detailing of a business concept. It delves into the selected business opportunity and elaborates on areas such as partners, market and competition. Furthermore, it covers the business conceptualization and the development of an action plan. This phase was mainly guided by the dimensions suggested by Venture Cup in their business plan template to ensure a thorough description (Venture Cup).

Business conceptualization

The end of the *opportunity evaluation* phase presented an opportunity with a potential but the details of how to turn that into a successful business were still to be explored. This exploration was initiated by ideating within the boundaries of the business model canvas (Osterwalder and Pigneur 2010). The ideation produced six different business concepts that mainly differentiated in terms of allocation of activities and the financial structure. Six business concepts had to be cut down to one and was guided by a main concern of partnership satisfaction. It is important to have a fair balance of risk, gain, involvement and competencies as it increases the chance of a healthy partnership and thereby business (Kuzniatsou 2015 and Ostrom, et. al. 1993; cited by Mytty 2015). These four parameters were combined in two rating parameter being *shared incentives* and *balance of competencies.* The specifics for the selection will be elaborated in chapter: *4 Detailing.*

The selection of a business concept enabled the initiation of the next step - the actual business plan. This formulation follows the dimensions from the Venture Cup template (Venture cup) and will elaborate on strategic partners, customers, market, competition, advantages, action plan and the financial structure.

The budgeting furthermore allowed a sensitivity analysis based on a NPV calculation to assess the influence of different parameters in the business concept (Ulrich and Eppinger 2012). This identified potential pitfalls which can be acted upon if cost structure should evolve in a certain direction. The specifics for the action plan, budget and business plan in general will be elaborated in section: *4.3 The business strategy - 1. pin.*

SOURCE: PRIVATE - DISCUSSION WITH MR. MALAR ABOUT THE PRACTICE OF TATVA GLOBAL'S MBT PLANT IN VELLALORE, COIMBATORE

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Discovery

The discovery phase was the first stage of this project and was characterized by an exploration of the current MSWM system. It served the purpose of achieving a broad understanding of the activities in the Indian waste management, the issues, the impact, the previous experiences, the involved stakeholders and the potential of the waste. It should furthermore identify a number of pre-framings that would ease the execution of the case studies in the next phase.

This chapter will elaborate on the above mentioned areas which will be based on a combination of finding from a literature review and first-hand observations.

1.1 Introduction to India's MSW problem

Since the introduction of a new investment and trade regime, in 1991, India has experienced rapid economic growth, currently making it the world's fastest growing economy (Kaka & Madgavkar 2016). This growth is however not restricted to India's financial situation as the urban population is increasing at an alarming rate as well (Bloom, Canning, & Fink, 2008; cited in Tumbe et. al. 2016). The increasing GDP per capita and urban population is a pattern that represents national progress but unfortunately also an increasing waste generation per capita. The municipal corporations are currently struggling to cope with the 62-68M tons of solid waste generated per year (Press Information Bureau 2016; Annepu 2012). This struggle will only become more severe as the rapid pace of growth is not projected to slow down, thus creating a significant threat to the wellbeing of the urban population.

India is the world's second largest population with 1.3 billion inhabitants (United Nations Population Division) and is currently beginning to realize their enormous economical potential. The urban population is projected to maintain its steady growth and exceed the 800M mark by 2050 - thereby accounting for more than 50% of India's total population. In absolute terms, India, with 404 million, is projected to be the biggest provider of urban settlers between 2014-2050 (*World Urbanization Prospects*, United Nations, 2014).

The GDP per capita is increasing at a much faster pace and has in the past 15 years more than tripled, to reach 1500 USD. By 2050 it has been projected that this number will exceed 50.000 USD, which will put India on the same level of relative wealth as Norway and Switzerland (Merchant 2011). With the increasing urban population, along with a strong growth in GDP per capita, the Indian economy has been projected to overtake Japan's place as the world's third largest in 2028 (India Times 2013). In contrast to Japan, India will at that time have a population of 1.6 bn. and the potential of becoming a superpower (Sanghoee 2015; Merchant 2011). These optimistic projections share the fact that they assume India will find a solution to the problems they will encounter during their growth. Complex problems as an undereducated working-age population which is not able to support their elders (Campion and Odayar 2015), corruption in all layers of the society (Goswami 2017) and their cities being unable to adapt to the rapid expansion (Sankhe et. al. 2010). The cities need to build infrastructure and systems for various municipal chores, including municipal solid waste management (MSWM). Future issues regarding MSWM is highlighted as one of the main parameters threatening national growth due to its impact on livability and productivity (Sankhe et. al. 2010). Following a status quo scenario, India will triple their annual waste generation by 2031 and quadruple the number by 2051 (Joshi & Ahmed 2016). This scenario, assuming the current system and practices, will lead to an escalation in the number and size of landfills. Put in perspective, the area required to dispose the waste by 2051 will be equivalent to around 200.000 football fields at a height of 10 m.

The gravity of the problem is well known and there is little doubt that the municipal corporations are eager to find a solution that can reduce the impact of the current practice. However, they are not keeping up due to issues with bureaucracy, corruption and narrow-minded strategies (Ahmed & Ali 2004; Sankhe et. al. 2010).

1.2 Waste management practice today

Municipal solid waste management is one of the main problems that India has to target in order to maintain their current growth. The problem partly originates from a clash between a former culture and todays urban society - a transition from moderate dumping of organic waste in open fields to an exploding waste amount where the introduction of plastics and toxins prohibits clean decomposing. The solid waste management has not adapted swiftly enough and India is now experiencing the drastic consequences. Today the former lack of political action and sufficient attention has led to a MSW system that is inconsistent and managed in an ad hoc manner. This has promoted differing practices across India (Kumar et. al. 2009) which has made it difficult to outline a detailed overview of the current national MSWM system. Nevertheless, Figure 4 illustrates main practices in the system based on literature studies and fieldwork and gives an idea of the status quo. It also elaborates on some of the efficiency values that the literature presents.

SOURCE: PRIVATE - RAGPICKERS SCAVENGING FOR VALUABLES IN BELLAHALLI LANDFILL, BENGALURU

1.2.1 Generation/generators

The MSWM system is supposed to be restricted to only account for municipal waste, meaning mainly domestic and some commercial waste. This is however not the case. The waste streams include some industrial operations, as these stakeholders are avoiding the fee from collection. Instead, they litter the waste in the streets or dump it in public bins and this contributes to an overload of the public system (Kumar et. al. 2009; Sandhya 2017; Sanjeev 2017).

The domestic generators are mainly burdening the system with mixed solid waste (Gupta et al., 2015) but new initiatives across India promote a two bin system or segregation of dry and wet waste. This will increase the segregation efficiency but it is, however, still in the implementation phase (Lekeshmanaswamy 2014; Niloufer & Swamy 2015). Joshi and Ahmed (2016) declare the lack of segregation between inert, recyclable and organic waste as one of the most significant obstacles to developing a sustainable MSW system. It is of highest priority that people start to segregate and consider waste a resource, as it is insufficient to utilize unsegregated waste. This is especially important since it could boost an already financial restricted system and allow a healthy development to speed up.

1.2.2 Collection

High inefficiency in the collection of MSW makes this the largest cost in the system. The main contributor is the sweeping and collection of littered waste from the streets - an activity that is maintaining a damaging behavior by the public. 30-50% of the generated waste is estimated to be littered in the streets which makes the sweeping activity alone account for approximately 70% of the total MSWM budget (Pandey & Malik, 2015). This poses an issue as the large cost inhibits allocation of resources into other phases of the system e.g. treatment and disposal (Pandey and Malik 2015). The collection method varies across India's cities. It is however commonly executed as door-to-door collection with pushcarts that distributes the waste to a secondary storage (Kumar et. al. 2009) – see Figure 4.

1.2.3 Transport

The secondary storage has the purpose of accumulating larger quantities of waste before it is heading for treatment or disposal. These places can in some cases function as a segregation station where valuable recyclables are screened. The efficiency and devotion does however correlate to the composition of the input. Meaning that the dry waste collection center, that only gets dry waste fraction (Sandhya 2017), is more thorough to extract different fractions compared to mixed waste station that only executes a rough segregation (Shyam 2017). The main way of transporting the waste is by truck.

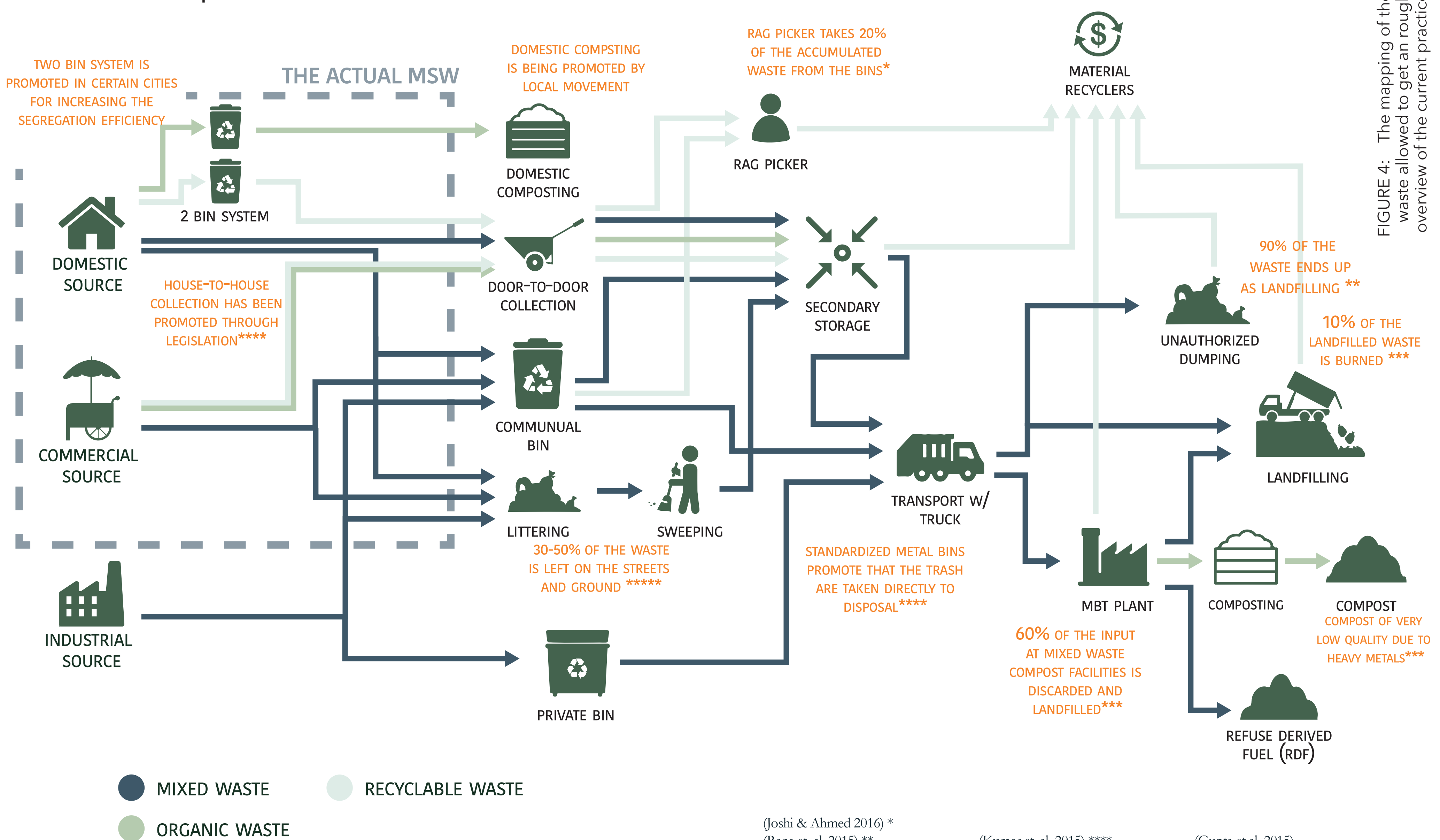
1.2.4 Treatment

Treatment is allocated little resources and concern. Pandey and Malik (2015) states that between 0-5% of the MSW budget is spent on treatment and disposal of waste. It is therefore not surprising that less than 10% of the total generated waste is currently treated (Gupta, Yadav & Kumar 2015). The main treatment method in India is composting which processes approximately 6% of the generated waste (Annepu 2012). These facilities are defined as mechanical and biological treatment plant or MBT plants. The specifics for the MBT plant and alternative treatment facilities will be presented in section: *1.7 Waste processing facilities in India today*.

1.2.5 Disposal

Only 10% of the waste is being processed and the remaining 90% is either landfilled or dumped in an unauthorized manner (Gupta, Yadav & Kumar 2015; Rana, Ganguly & Gupta 2015). This is one of the major concerns of the current MSWM practice and the activity that directly displays the consequences of their system.

Current waste practices



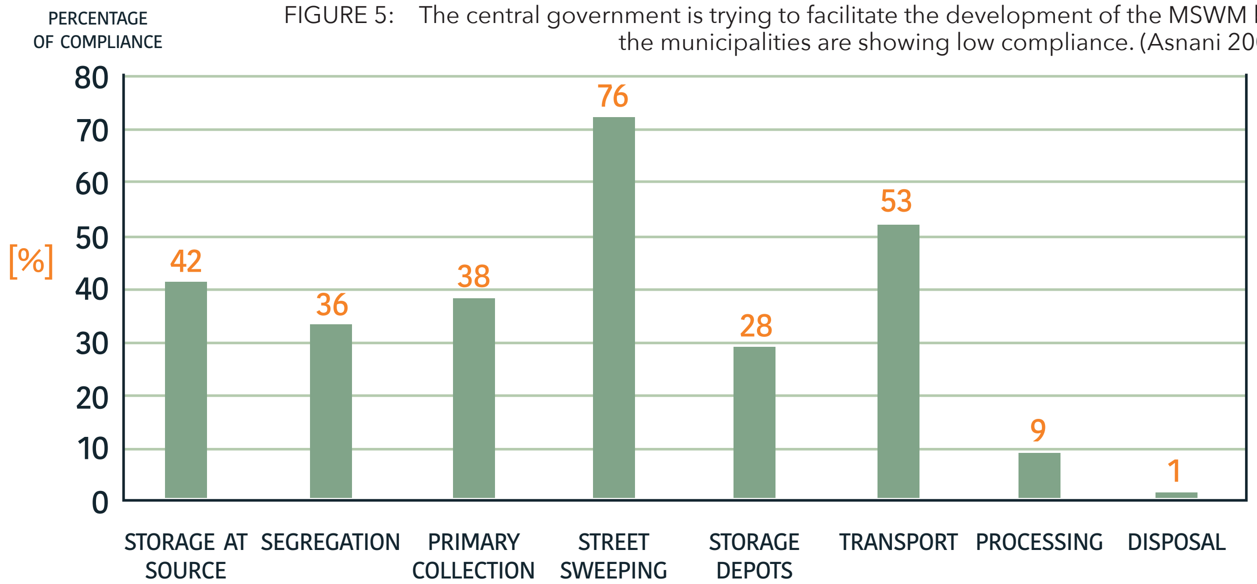
(Joshi & Ahmed 2016) *
(Rana et. al. 2015) **
(Annepu 2012) ***
(Kumar et. al. 2015) ****
(Pandey & Malik, 2015) *****
(Gupta et al. 2015)
(The World Bank 2014)

FIGURE 4: The mapping of the waste allowed to get an rough overview of the current practice

1.3 Governmental initiatives

Back in 2000, India's Supreme Court assigned the responsibility of aligning the national MSWM to the Ministry of Environment and Forest. Later that year, the same ministry published a set of rules (referred to as Rules 2000) that directs, guide and monitors the implementation of a sufficient MSWM system across India. The Rules 2000 made the municipal authorities responsible for MSW collection, storage, transportation, segregation, treatment and disposal with a brief suggestion of methods that could be pursued. The municipalities were demanded to follow certain implementation deadlines with the application of fees if they were delayed (Ministries of Environment and Forests 2000). The deadlines that were supposed to pace the development in reality illustrated that this kind of incentive did not have an effective influence on the majority of the municipalities. Zhu et. al. (2008) explains the lack of commitment to the new rules as a result of apathy authorities, lack of community involvement, lack of technical know-how and inadequate financial resources.

FIGURE 5: The central government is trying to facilitate the development of the MSWM but the municipalities are showing low compliance. (Asnani 2006)



These rules have however been modified since and in 2016 a few additions made (Press Information Bureau, 2016). The responsibility of segregation was allocated to the waste generators with a fine applied if they did not comply. It emphasized that the local bodies are obligated to construct processing facilities in cities where the population exceeds 1M people. Furthermore, the Ministry of Environment and Forest recommended to involve ragpickers into the formal system and engage them as official MSW staff - however without a suggested plan as to how this should be managed or implemented.

The literature is acknowledging that the municipalities are commonly not complying with the rules laid out by the central government. This low compliance is illustrated in Figure 5 and can be traced back to financial issues, lack of public willingness, poor technological knowledge and lack of alignment of strategies (Zhu et. al. 2008; Annepu 2012; Yedla 2016; Mytty 2015). The governmental rules present ideal milestones that are too far ahead of the current situation and they lack proper guidelines of how to reach the goals. It is an attempt to facilitate the MSW development top down but with poor effect as the individuality of the cities is neglected. The guidelines thus appear superficial and are missing the perspective of current status in the individual cities.

1.3.1 Subsidy programs

Despite the poor attempt of changing the MSW development, new initiatives have emerged from the government. A funding program was recently launched with the mission of boosting the implementation of a "treat the waste at the source" campaign. The vision is to facilitate the change by offering a 90% subsidy of domestic composting units in order to make it affordable for residents and municipalities. The initiative is motivated by an economical perspective as it can cut down the cost of transporting the waste (Cherian 2017; Chaitanya 2017; Sandhya, 2017). The government has additionally started to boost the construction of WTE plants (Pandey & Malik 2015; Sardar 2017). This has been implemented by introducing a tariff that ensures WTE plants get a minimum price of 7.9 INR per kWh. This was introduced together with legislation that makes it mandatory for State Distribution Licensees to purchase WTE power (The Standing Committee of Energy, 2016).

Not all subsidies are however promoting the development directly. The government is currently subsidizing larger compost productions from MBT plants as it is a necessity to keep the plants in operation and avoid adding more waste to the landfills. The need for this subsidy originates from the competitiveness of artificial fertilizer that outmatches the compost from the MBT plants. This fact has forced the government to subsidize the MBT plants with 1500 INR/ton produced compost (Sardar 2017; Raghuaram 2017; Malar 2017; The Standing Committee of Energy 2016).

These subsidy programs imply that the government strategy is changing towards them having more direct involvement instead of allocating everything to the municipalities. It is likely that they have realized the need of a larger budget to promote the change and more national coordination.

1.4 Stakeholders and functions in MSWM

The MSW system can be considered to consist of two parts, a contextual and technological. These two fields encapsulate the MSW system and should equally be understood in order to identify good solutions (Andreasen, Hansen and Cash 2015, chapter 2). This section focuses on the contextual part which is characterized by the functions, routines and incentives of different stakeholders. This aspect will unfold as the political system together with risks and potentials proposed by certain stakeholders is examined. These insights assist the understanding of how a future business can be affected by other entities and stakeholders.

1.4.1 The political system

The MSWM is of national concern and it is therefore natural that the system is tightly linked to a political hierarchy as its backbone. The formal sector has in a broad perspective four levels of political engagement which is illustrated in *WS 4: Political Hierarchy*. The different political levels ensure that the MSWM is targeted at a national, state and municipal level. All levels of government that have a role to play in the system.

The legislative power mainly lies within the central government but it can be tweaked and customized by state governments to a certain extent. These entities affect the MSW management top-down by laws and guidelines as described in the section: *1.3 Governmental initiatives*. Beneath the state government is the municipal authorities, also known as urban local bodies (ULBs). They are responsible for the implementation of MSW activities and daily operation which makes them a key stakeholder in India's waste management system. It is therefore important to examine exactly this entity more thoroughly in order to understand the levels of decision making, the power allocation and their responsibilities. It should be mentioned as a side note that the ULB in some cases can cover cities within the 20 million range which emphasizes the size of this organization.

1.4.2 Institutional structure of ULBs

The specific institutional structure of the ULBs are likely to change according to the city under examination. The edition of the hierarchy in Figure 6 is based on an illustration by Sandhya (2017) and observations throughout the field trip. The illustration has incorporated the private and informal sector to illustrate the current connection between these parties. This will be commented on later in this section.

The ULBs is constructed as a ladder of officials that have different responsibilities and focus areas. The JC of health and MSW is the overall responsible of the MSWM. This person is in charge of the strategic decision making as he/she is accountable for enacting the governmental rules and additionally reporting the progress up through the political system. The responsibility of the practical management and development is allocated to the Executive Engineer or in other words the daily management. Zhu et. al. (2008) however argues that the decisive responsibility of waste management is often placed at the sanitary inspector, as the higher positioned stakeholders have other interests.

The ULBs emphasizes the hierarchical structure and it was observed that decisions often pass by a higher ranked person with no other purpose than getting a signature. Due to the hierarchy, inconsistent roles and time consuming bureaucracy the municipal authorities appear rather entangled - implying that they should be engaged with caution.

The ULBs are the executive power in regard to the MSW system, but other stakeholders are also influencing the system. The MSWM is directly engaged by the private sector as the ULBs outsources particular tasks of the MSW system to increase the efficiency and ensure that the available funds are present. These collaborations are in some cases structured as public-private-partnerships which will be further described later in the report. The private sector often has a close connection to the formal MSWM and often solves the task of collection and waste treatment.

Another influential grouping is the *informal sector*. This group mainly consist of ragpickers, material buyers and recyclers that are acting for their own benefit without any alignment with the ULBs. The informal sector is however an important part of the system as it is commonly acknowledged that ragpickers are unloading the system with 20% (Joshi & Ahmed 2016). This reduction in waste saves transport cost, reduces the environmental impact and supports recycling of valuable materials. It is argued that rag pickers are the most important and overlooked asset of the MSW system why it is argued that they should be integrated into the MSWM system (Joshi & Ahmed 2016; Annepu 2012). Both stakeholder groupings represent opportunities and it is essential to consider them as valuable assets. The opportunity potential and the risks of ragpicker behavior and positions will be highlighted in the section: *1.4.3 Key stakeholder groupings and potential partnerships*.

The ULB will from this point in the report be referred to as one entity, municipality, for simplicity. The structure of the ULB institution is however important to understand as it emphasizes the entanglement of the public sector.

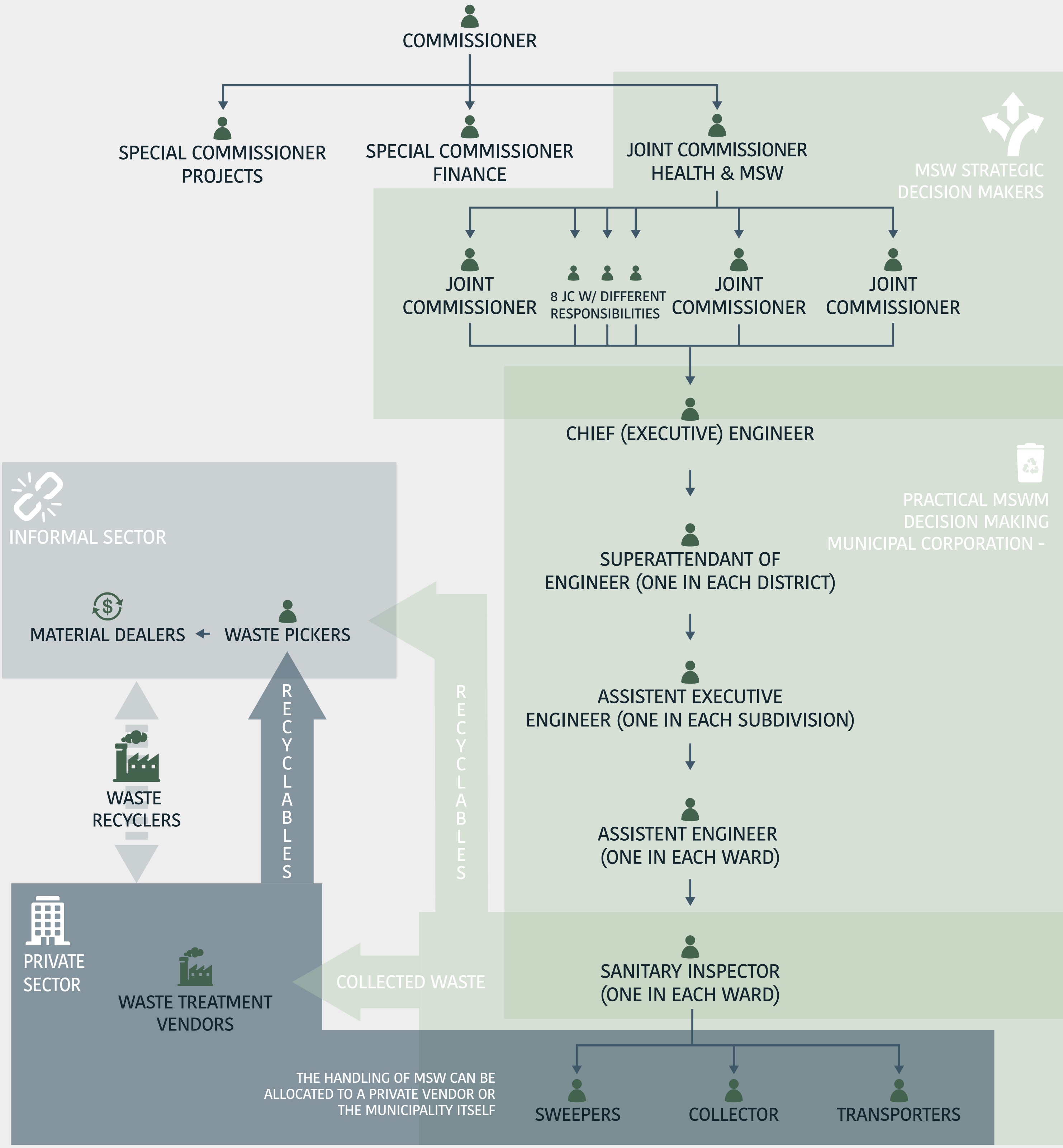


FIGURE 6: The institutional structure of the public sector in India represents a high degree of entanglement illustrated by approvals and general decision making has to follow a strict top-down hierarchy.

1.4.3 Key stakeholder groupings and potential partnerships

The understanding of the contextual environment is an important aspect of the effectual reasoning. Strategic partnerships can increase the affordable loss and decrease the uncertainties related to establishing a new business venture (Soh and Maine 2013). Collaborating with relevant stakeholders can introduce new means, which enhances possibilities and opens up doors for new ventures (Soh and Maine 2013). However, the social context posses threats and challenges as well. It is especially important to evaluate how a partnership or social connection can allocate the control to other stakeholders. Such decisions can reduce the uncertainty of a strategy but at the same time constrain the development to one path (Soh and Maine 2013). It is therefore important to balance the effectual principles *affordable loss* and *pilot-in-the-plane* (*WS 5: Effectual theory and principles*) to make sure that the project does not take an unforeseen turn.

Beyond these two parameters there exists other traditional criteria that are worth consideration. Criteria such as: added competencies, gains, shared risks, incentives, goal compatibility and organizational structure are all acknowledged to be of importance when evaluating potential partners and involved stakeholders (Kuzniatsou 2015 and Ostrom, et. al. 1993; cited by Mytty 2015). It is thus necessary to investigate these aspects for relevant stakeholder groupings as a future evaluation of stakeholder involvement will be based on these insights.

Municipalities

The municipalities are the entity responsible for the practical management of the MSW and are an important part of the political system. This makes them a highly influential stakeholder but with certain limitations as they have to follow official procedures. Among others, the municipality is obliged to put out public tenders if any municipal activity should be contracted to a private company. This practice basically has the purpose of ensuring that the best match is assigned the task and it reduces the risk of corruption (OECD 2016). This is an understandable goal and proven procedure but it can also kill the pace of progress. It was stated during the fieldwork that tender processes often stretch over a two year period (Uppaluri 2017; Hemalatha 2017; Sandhya 2017; Reddy 2017). The escalating projection of India's waste problem requires immediate action which is not aligned with the time consuming bureaucracy that tenders impose. During the procurement of the tender the waste amount is increasing and accumulating without any precautions. This has in hindsight led to the overloading of plants which has resulted in shut downs (Sanjeev 2017). Uppaluri (2017) had additionally experienced that tenders were still affected by corruption. His company had been turned down for the favoring of a smaller local company even though they were lacking resources and know-how. The smaller company shut down two years after the tender selection.

The tenders are usually used to create public-private-partnerships (PPP) between the municipality and private companies with a contract that spans over a number of years. The PPPs are an approach that allows the municipalities to boost the development of the MSW system by introducing capital and enhance the incentive of a feasible business (Joshi & Ahmed, 2016). The model is working in some cities where the private partners handle collection, transport and waste processing. Collaborating with the municipality in a PPP model poses however certain risks (Nema 2009). The idea with the PPPs is that both partners benefit from the collaboration, but Joshi and Ahmed (2016) argue that the partnerships can suffer due to several factors. They highlight that the sociological, economical and the level of involvement should be balanced fairly in order to get an equal partnership.

This is rarely achieved since the municipality often treats PPPs as „… single-responsibility contracts … "(The Standing Committee of Energy 2016). In reality this means that the two partners do not have a shared vision or a fair risk allocation. This misalignment is likely to originate from the fact that municipalities have a changing nature as representatives are replaced and departments have their own agendas (Nema 2009). It was observed in the fieldwork that the municipality in Hyderabad was pushing for a change of direction that actually discouraged the work of the tendered partner (Reddy 2017).

These aspects makes the municipality a volatile stakeholder that in most cases should be avoided in relation to direct partnership. It would reduce the risk of potentially unpleasant contingencies if the municipality was bypassed.

Private companies

Engaging with private companies is evaluated as a more stable relationship compared to the municipality. However, a partnership with an Indian company cannot be directly compared to a common partnership within Europe. The way of doing business in India follows a different code of conduct and it is therefore necessary to be cautious when engaging with a potential partner. It is perceived that deception is not uncommon in India's business world and that social and professional connections are suddenly severed to serve their own good. Gopalakrishnan (2017) and Sanjeev (2017) support this perception as they presented former cases of middlemen cutting out western companies with the help of the authorities. This emphasizes the importance of the personal trust in a partner and implies that the culture and reputation of a company should be considered before engaging. Such a consideration could be based on studying the current partnership that the company already is a part of or by testing their willingness to actually act as promised. It was experienced in both the public and private sector that there exists a fair distance between a promised action to actually getting something done.

A private company is considered a stable partner that can allow entry to the MSW streams while bypassing the municipality. However, it is acknowledged that the foreign business culture increases the risk of being scammed thus it is relevant to "test" potential partners to assess how well they are performing as partners and to ensure a fit in terms of shared values.

Citizens

The citizens of the urban India are the largest and most heterogeneous stakeholder group within the MSW system. They are the main waste generators in the MSW system and it is basically due to their discourse: *waste management being the municipality's problem;* that the MSW issues originate (The Indians abroad 2010). It as a group that represents diversity as they have different agendas, visions, wealth, interests, incentives, etc. It is a group that is influenced by decades of routines and culture which make it difficult to change their perspective and behavior. This manifests itself as low willingness to segregate and in some instances opposition towards waste treatment facilities being located close to their home - Not-In-My-Back-Yard syndrome (NIMBY). A term that is defined as "a person who objects to the siting of something perceived as unpleasant or hazardous in their own neighborhood, especially while raising no such objections to similar developments elsewhere" (Oxford Dictionary of English

2016). In India the syndrome has provided significant resistance towards the construction of new plants in city areas and has led to the shut down of plants as well (Kumar 2014).

That being said, not all the citizens are opposed to a changing MSW system. The case studies revealed grass roots movements consisting of environmentalists that are fostering the change on ground level. These groups are often in direct dialogue with the local authorities and function as managers or promoters of a de-centralized MSW system, e.g. domestic composting. They are a part of the development and they should be considered a valuable asset. They are passionate and can make things happen as long as it is aligned with their course, visions and goals. This could potentially represent an open door into the MSW system and the means to quick adoption by the local community.

The citizens have the largest influence but are at the same time difficult to manage or change. This is the case in all major transformations. A business that targets the citizens as a key stakeholder should be aware of an increased implementation time as well as dependency on the citizens activities. These dependencies represent a risk in the form of a reduced control of the business if not appropriately accounted for and planned for as part of an effective business plan.

Informal sector

The informal sector is a differentiating group, but nonetheless important. They are significantly unloading the amount of waste in the MSW system but without any direct involvement or recognition (Joshi & Ahmed, 2016). However, it is acknowledged that the MSW system could benefit if the informal sector was incorporated into a business. They are independent and they are relatively easy to motivate due to their current living standards and economic situation. This has already showed promising results (Asnani 2006) and it has been elaborated that the introduction of the informal sector system promotes an economical and environmental sustainable system (Pandey and Malik 2015). This is supported by an observation in Coimbatore where an NGO was engaging the informal sector. The NGO was facilitating better working conditions, saving money on salaries while achieving 100% segregation.

An important note to the informal sector is the size. Mytty (2015) roughly estimate that 1-2% of the total urban population are connected to the informal sector which makes them a significant working force.

The informal sector could be a potential entry point for a business strategy, if managed in a proper manner. The engagement would promote trust and local anchoring in the community by helping the rag pickers and improving the system. That being said, it is necessary to emphasize the uncertainty of this group despite their potential. An uncertainty that is illustrated by rumors of ragpickers being affiliated with different ”mafias” (Chakravarty 2017; Cherian 2017). Regardless of that being true or not, it is risky to base the core of a business on the informal sector with little information. If the informal sector is to be engaged it is preferential to identify a local partner that can be responsible for the navigation in the nuances of the culture and the establishment of a reliable working force.

1.5 Impact of the current practice

The current MSW practice is having large impacts on the urban cities in India. They are currently treating less than 10% of the MSW (Gupta, Yadav & Kumar 2015) which has made landfilling their desperate choice for the remaining 90%. This choice impacts the environment as well as the society, both globally and locally. The main sources contributing to this impact are emission of polluters and greenhouse gasses, unsanitary handling and the presence of toxins and heavy metals.

These aspects emphasizes the importance of immediate action and that the municipalities do not have the required capability. The municipalities need outsiders that can reduce these impacts. A fact, that should be incorporated in a future business strategy.

1.5.1 Health risks

The waste is piling up and the improper management is creating unsanitary conditions as high moisture contents makes the heap function as a breeding ground for insects and bacteria (Annepu 2012). This scenario is especially affecting the MSW employees and ragpickers as they are directly exposed to an increased health risk when handling the waste - illustrated in Figure 7 Health risk for pickers (Annepu 2012).

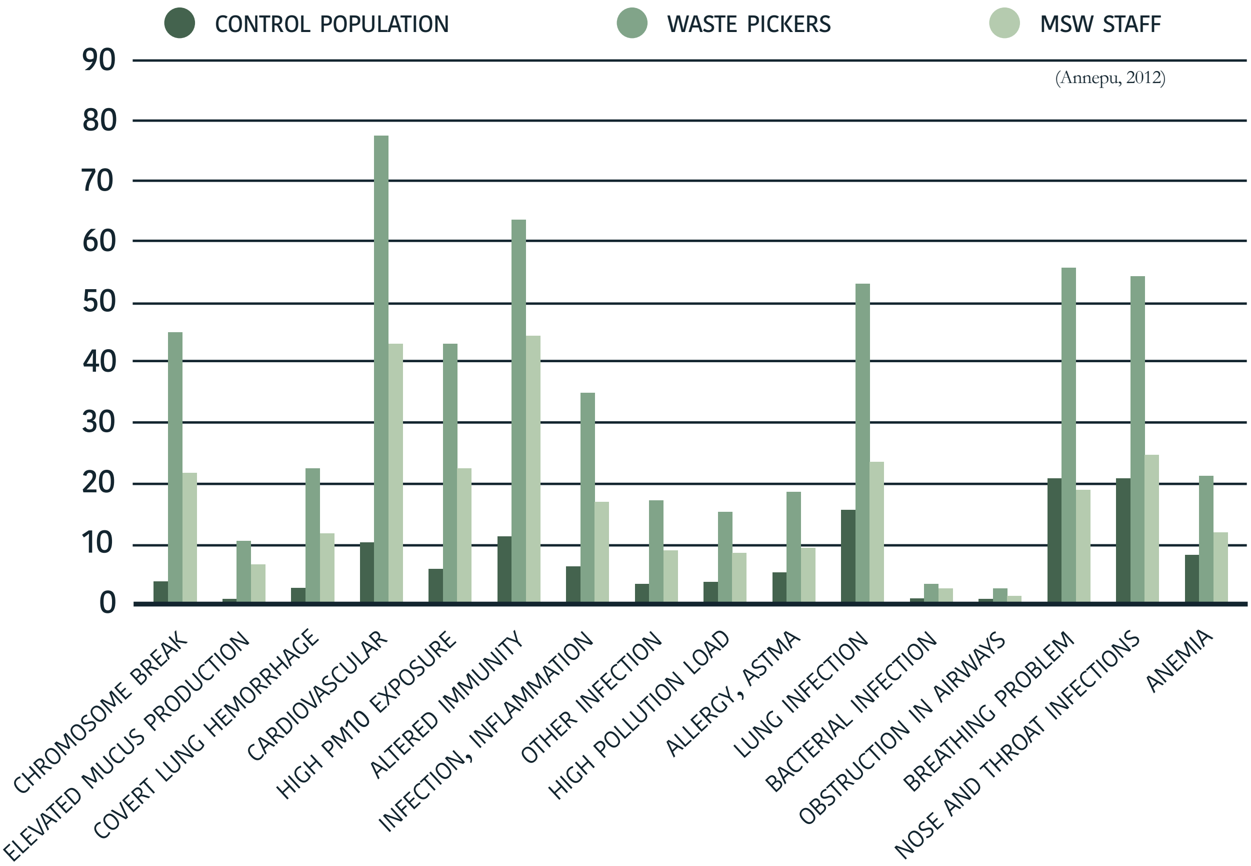


FIGURE 7: The current MSW practice expose the lowest social group in the society for an increased health risk. This is occuring without any recognintion of either their involvement or the health issue.

Figure 7 concludes that ragpickers and waste handling staff are exposed to a higher risk of contracting numerous diseases when compared to “the normal population”. It should be noted, that simple equipment such as gloves, could reduce this risk significantly but it is simply not a possibility for the ragpickers because of the relatively high cost and lack of ready access to such equipment (Annepu, 2012).

1.5.2 Open burnings

Another health and environmental issue related to the waste management system is the open burnings of waste in the streets and at the landfills. Open burning is often the easiest way for the public to get rid of the waste but it exposes them and the atmosphere to pollution. This pollution is characterized by the emission of carbon monooxide, particulate matter and hydrocarbons. It is so severe that a study conducted in Mumbai estimated that open burning and landfill fires account for 19% of the air pollution in Mumbai. Because the burning is located at ground level, it pollutes the breathing zone of the atmosphere which increases the chance of people suffering from health issues related to pollution (Annepu 2012). - see *WS 6: Emission from open burnings*. A noticeable fact is that the open burnings are the largest polluter that does not provide any economic value.

1.5.3 Toxins and contamination

The open burnings are not the only source of pollution that affects the public. The high moisture content in the mixed waste and rainy days leads to large productions of leachate which percolates into ground water. This is not a problem by itself, but as the majority of the landfill dispose mixed waste it allow different chemicals to be dissolved by the leachate and transported into the ground water. This creates a contamination of the ground that can spread out to an area that is 300 times larger than the landfill itself (Uppaluri 2017).

The mixed waste is not only a problem at the landfills. The MBT plants are also suffering from this issue since heavy metals from the mixed waste contaminates the organic fraction. Annepu (2012) reports that the amount of heavy metals in the mixed MSW exceeds the control limits for what can be used as composting. He elaborates on this by estimating that if all the waste that is dumped at landfills in the next decade were composted, then 73,000 tons of heavy metals would contaminate the agricultural soil and end up in food products. This will affect all citizens that consume vegetables grown on these fields.

1.6 Potential of the waste

By now it should come as no surprise that India is facing a severe waste management problem with too large quantities for them to cope with. That being said, large quantities of waste is not necessarily a bad thing. A reframing of this problem to be viewed as an opportunity is key. When managed correctly, the large amounts of waste has the potential to become a resource for energy harvesting which could boost the development of the system. The appropriate treatment and the efficiency of such an energy extraction is however dependent on the characteristics of the waste. This perspective will be examined in the following section: *1.6.1 Composition and amount of waste*.

1.6.1 Composition and amount of waste

In order to understand the energy potential of the waste it is important to know what the mixed waste actually consists of. Previous studies conclude that the waste composition of developing countries contains low amounts of plastic and high amounts of inert material and moisture; a combination that has proven unsuitable for waste-to-energy (WTE) projects (Zhu et. al. 2008). The waste composition has however undergone an interesting development over the past 25 years, where combustible matter, such as plastics and paper, has increased significantly while inert material has decreased. The Ministry of New and Renewable Energy in India (MNRE) expressed the development as expressed in the citation on the opposite page:

„As per the Task Force Report on Waste to Energy (WTE), the waste composition has changed rapidly during 1996-2011 and there is over 380% and 1650% increase in paper and plastic waste, respectively, which calls for serious effort to utilize compostable as well as burnable waste, adopting both compostable and waste to energy technologies. the proportion of high calorific value waste is increasing as shown in the table below."

(The Standing Committee of Energy 2016)

The changed composition has, as the MNRE expresses, increased the calorific value of MSW which basically means that the waste gets more suitable to be utilized as an energy resource. This represents a pivotal stage as the calorific value formerly has been on the edge of what was economically feasible (Sebastian & Alappat 2016).

In order to understand the actual value of utilizing the waste in India it is important to understand the equivalent energy in the waste, which is currently put to no use. There are many factors affecting the estimate of potential energy in the generated waste e.g. calorific value, amount of waste put in to WTE processing and efficiency of the WTE process. One estimate, which realistically takes the factors in to account, is the one from the MNRE which states the following:

"The solid waste generated from the cities/towns in India has present potential to generate power of approximately 500 MW, which can be enhanced to 1,075 MW by 2031 and further to 2,780 MW by 2050." (The Standing Committee of Energy 2016)

That means that the current waste contains the energy to generate the power consumed by 591,484 Indian citizens for a whole year. As a comparison to the MNRE estimate, a best case scenario can be found by assuming that all the generated waste is processed at a functioning WTE plant in, for example, Denmark. When referring to Amager Resource Centers production of power they produce 0.8 MWh (Amager Resource Center 2017) per ton of waste, meaning the 62 million tons of waste India generated in 2016 could produce 5,662 MW. This calculation is assuming a similar composition and calorific value, which unfortunately is not the case. But with the development in waste composition, caused by urbanization and economical growth, some cities have already breached the limit for autogenous incineration at 2400 kcal/kg (Sebastian & Alappat 2016).

Annepu (2012) furthermore estimates the total amount of energy landfilled in 2011 to be equivalent of 58 million barrels of oil - which holds a market value of 2.8 Bn US$ (Nasdaq 2017).

FIGURE 8: The current MSW practice in India is neglecting the large energy potential that the waste represents.

The composition of the waste is changing and the calorific value is increasing. This fact is most likely to increase the number of WTE projects in the coming years which implies that it is important to consider this in a future business expansion plan. It could be a market change that if exploited correctly would boost a business but on the other hand could be fatal if executed improperly.

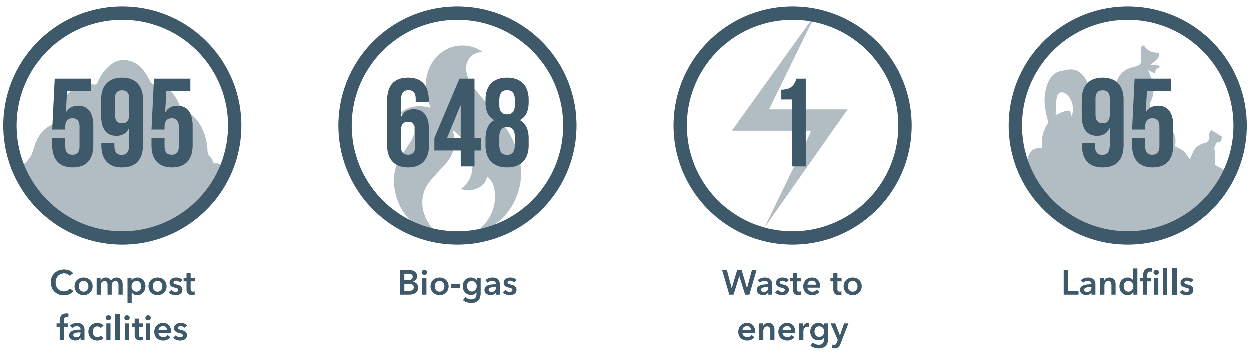
SOURCE: PRIVATE - CLEANING UP LEACHATE, BELLAHALLI LANDFILL, BENGALURU

1.7 Waste processing facilities in India today

MSW consists of various waste fractions that require different processing methods to achieve proper treatment. The MSW Rules 2000 defines these methods as:

- biodegradable waste has to be decomposed through biomethanation, composting, vermi composting or any other biological treatment
- segregated recyclable waste has to be moved to the recycle industry through formal- or informal channels
- residual combustible matter has to be utilized to produce RDF or direct power generation by the use of a Central Pollution Control Board approved method where emission standards are obeyed.

Currently, India has a number of different facilities but the exact overview is difficult to grasp due to the inconsistency in data and definitions. It is rarely obvious whether plants are operational, commissioned or shut down. The distribution between different waste treatment practices is illustrated in the numbers below (The Central Pollution Control Board 2016) with the conclusion that the majority of plants are mechanical biological treatment (MBT) plants, bio-gas plants are mainly small scale handling less than 5 TPD and there is currently only one WTE plant in operation nationwide (The Standing Committee of Energy 2016).



The specifics of the most popular treatment facilities will be elaborated in the following sections and provide an understanding of the current treatment practice and the efficiency of these processes. This allows an assessment of where pyrolysis fits in so that a future business does not misalign with the already executed strategies. These sections gives an overview of how different treatment methods is implemented in India which is supported by a technical description in *WS 7: Waste treatment practice*.

1.7.1 MBT/RDF plant

Mechanical Biological Treatment (MBT) plants are large scale aerobic composting plants, typically based on windrow composting. A method that is commonly is applied for large quantities of organic matter which are placed in rows and frequently turned. Refuse Derived Fuel (RDF) plants have the purpose of preparing non-biodegradable material in to pellets, fluff or raw RDF suitable for either combustion in a WTE plants or as a substitute for coal in industrial establishments. In theory the two plants differ because they are processing different feedstocks. In reality, however, these two functions fall under one roof mainly because the input waste contains mixed fractions of biodegradable and high calorific material. For the remaining of this report these two-functions plants will be referred to as a MBT plants.

MBT plants are the most popular waste processing method throughout India (Annepu 2012). The concept is to cure the organic waste in order for it to decompose into compost. The compost is then yielded with a particle size screening, that sorts out the residual fraction which are either landfilled or turned in to RDF. Annepu (2012) elaborates on the efficiency of this process and states that a MBT plant only yields 7-10% into compost - a number that was confirmed in the fieldwork (Malar 2017; Shyam 2017; Raghuaram 2017). The exact fractions of residues and RDF varies, but it is common that 60% of the input is being rejected (Annepu 2012). The generic process of a MBT plant is illustrated in Figure 9. The MBT plant is designed to handle segregated organic waste, but is usually handling mixed solid waste. The fractions created are compost, rejects, refuse derived fuel (RDF) and leachate.

The RDF and reject outputs from the MBT plant is worth considering as a future feedstock for pyrolysis. These fraction are currently killing the efficiency of the plants as they represents 60% of the output and the plants have no other option other than disposing it. The suitability for utilizing this material in a pyrolysis process will be further elaborated in the section: *1.9.2 Feedstock and added complexity.*

PROS & CONS

- MBT plants are cheaper than WTE-plants as they are simple to install, operate and maintain.

- Environmental leverage: The waste management hierarchy rates composting as a more sustainable solution than any combustion based process, which means that a composting facility theoretically has an environmental edge to any other process other than reuse/recycle (Annepu 2012). This is mainly regarding the organic fraction since the plastic residues are characterized as end-of-life plastics, which currently are not suitable for recycling (Almeida & Marques, 2016).

- Low yield. The process only yields 7-10% of compost (Annepu 2012) which poses a problem as it is the output creating revenue. This fact makes them dependent on government subsidies.

- There is a limited demand for compost due to contamination and a relatively high price compared to artificial fertilizer. This limited demand contributes to an unstable revenue stream.

- Differing decomposition times of organic material combined with a permanent curing time means that plenty of organics get rejected from landfills.

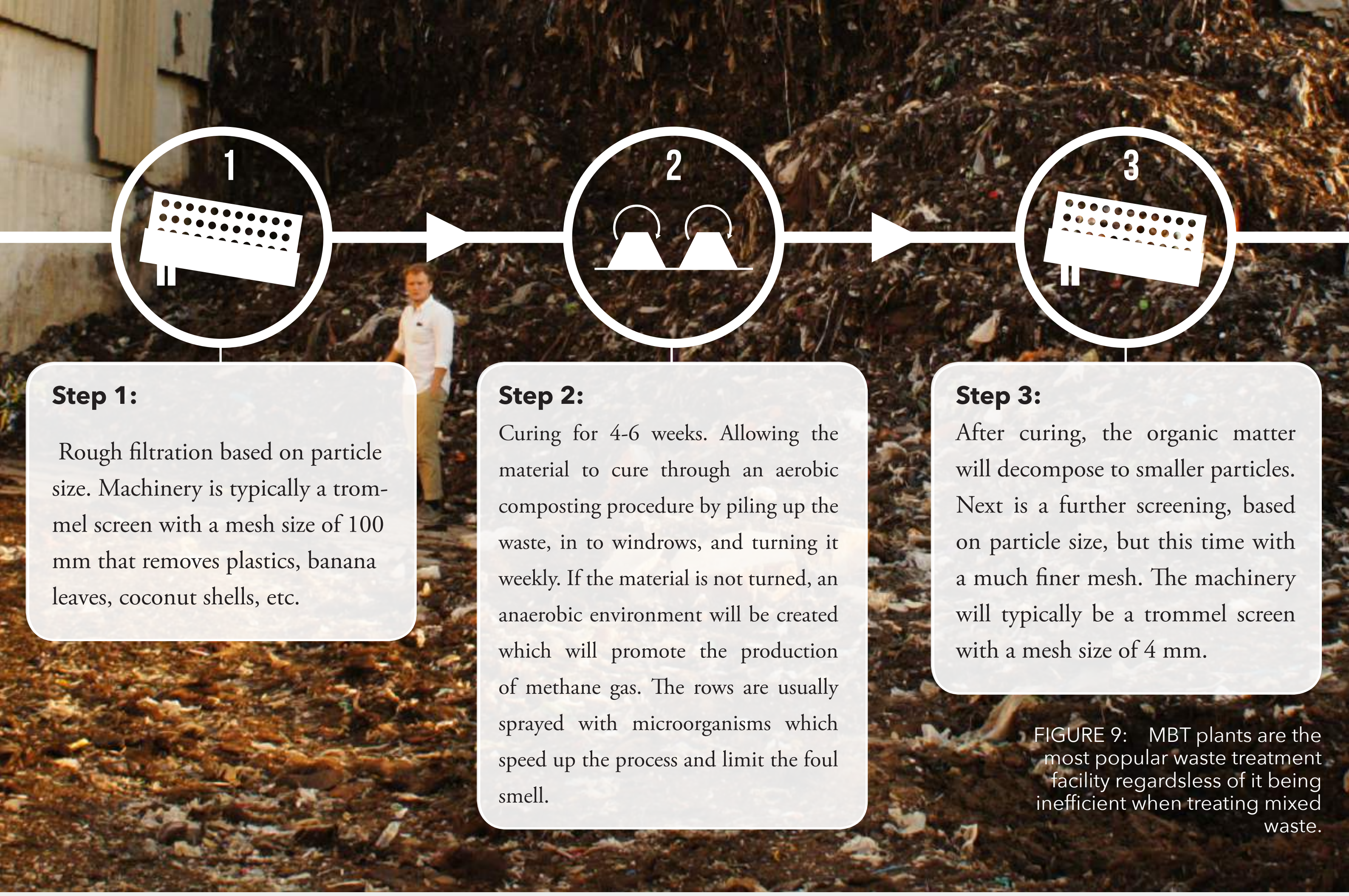


FIGURE 9: MBT plants are the most popular waste treatment facility regardsless of it being inefficient when treating mixed waste.

Outputs from the MBT plant

RDF

RDF is defined as a segregated waste fraction with a high calorific value that makes it a potential substitute for coal. However high calorific value can be obtained from various sources meaning that the composition of RDF varies from pure plastic to a mix of plastic and organics. The organic fraction tends to be fiber rich components such as stems, leaves and coconut shells which has a slow decomposing process. The RDF is extracted with the purpose of being sold to coal based establishments, such as cement kilns. This has however failed for a large number of MBT plants due to high transportation costs and an inconsistent composition (Malar 2017; Raghuaram 2017; Sardar 2017). This is the case despite the calorific value being as high as 11.6 MJ/kg which is above the threshold for feasible WTE feedstock (Annepu 2012).

Rejects

The ***rejects,*** in principle, constitute the waste that cannot be decomposed and which is not suitable for burning. This fraction is usually materials which tend to absorb contaminating molecules e.g. silica or dust which clusters to mud (Malar 2017). A tendency that makes the rejects the fraction with the highest contamination. The rejects are usually separated from the process in the 35 and 16 mm trommel screens, but the characteristics can vary as the differentiation between rejects and RDF can be blurry. It was experienced that improper management at the plants led to a landfilling of energy rich materials like plastics and fiber rich material that were not given the time to decompose (Malar 2017; Shyam 2017; Raghuaram 2017).

Compost

The ***compost*** is the final output of the MBT process and consists of particles that pass through the <4 mm trommel screen. High amounts of organic matter leads to a higher yield of compost, but the compost made from mixed waste tends to be of a lower value compared to artificial fertilizers. This fact has led to a lack of market demand for MBT compost (Nema 2009).

Leachate

Finally, the composting process creates a liquid reject called ***leachate***. It is created from the moisture in the waste and is characterized by a pungent smell. If the leachate is not managed properly it can, in worst cases, assist contaminated substance to percolate the groundwater and contaminate the ground. It is, however, easily contained by evaporation if the windrows are turned often.

1.7.2 Landfills

Landfill or landfilling is an imprecise term since the term in reality covers a wide variety of practices and designs. The intentional use of scientific landfills is for material, which cannot be reused, recycled, composted or combusted and thus only laid out for nature to degrade it (Hierarchy of Sustainable Waste Management). However the actual use case, in India, varies from uncontrolled dump sites to scientific landfills with leachate control and gas recovery (See *WS 7: Waste treatment practice* for further description of the technicalities). Dumping of untreated waste should be the last option when everything else fails (OPUS International 2002) - yet it is the most commonly practiced waste disposal solution, both globally as well as in India (Hoornweg & Bhada-Tata 2012). It is so severe that around 90% of the total waste generated in India is landfilled without any other treatment (Rana, Ganguly & Gupta 2015; Gupta, Yadav & Kumar 2015).

The number of disposal sites is difficult to determine due to the lack of monitoring. It is however reported that the amount of sanitary landfills is generally increasing - reaching 95 constructed sites in 2016 with 242 under implementation (The Central Pollution Control Board 2016). This implies that the MSWM is developing in a positive direction as the criteria for being a sanitary landfill requires the segregation of useful waste. That being said, landfills still represent large quantities of accumulated waste that consists of some level of energy thus making them an unutilized resource that potentially could be recovered. It is, however, important to keep in mind that the waste may have been there for a while and long disposal time could affect the characteristics of the waste, thus limiting its potential as a valuable energy source.

PROS & CONS

PROS	CONS
Inexpensive	Space consuming
Flexible	Contaminating the ground and ground water
	Polluting the atmosphere
	Difficult to control - low engagement/motivation
	Minimal revenue

SOURCE: PRIVATE - BELLAHALLI LANDFILL, BENGALURU

1.7.3 Incineration plants (WTE/RDF plants)

The literature categorizes the energy harvesting waste processing methods as waste-to-energy (WTE). This term covers facilities such as gasification, pyrolysis and mass burn incineration. In reality the vast majority of WTE plants are mass burn incinerators (Pandey & Malik 2015).

Incineration plants is an effective way of reducing the volume of the MSW while extracting energy from the process. The primary problem with incineration plants in developing countries is the low calorific value of the waste, which tends to be much higher in developed countries where the proportion of plastic is significantly higher (Sebastian & Alappat 2016). Asnani (2006) supports this by stating that the revenue created by power sales in India is not sufficient to make WTE operations economically feasible. They would highly depend on tipping fees, which, in 2006, was not present (Asnani 2006). It is worth mentioning that the definition of incineration plants differs, since not all are made with the purpose of harvesting energy but some have the purpose of deconstructing hazardous waste such as unsanitary waste.

Incineration plants have previously been met with resistance and barriers related to the lack of financial and logistical planning which has been difficult to overcome. (Kalyani & Pandey 2013). This is mainly due to the required size of the plant, as economy of scale favors large scale plants with capacity ranging from 500-5000 TPD (Asnani 2006). Such a capacity creates large emissions and even though these are cleansed they still contains hazardous fractions which promotes the NIMBY syndrome (Kalyani & Pandey 2013). However, in recent years the progression in emission cleaning technology has surged worldwide. This is supported by a comprehensive literature review by National Research Council that found no correlation between WTE plants and public health impacts (National Research Council 2000; cited by Annepu 2012). The latest report from the The Central Pollution Control Board describes the presence of 6 power plants, where only one in Okhla, New Delhi is known to be in operation (The Central Pollution Control Board 2016; Raghuaram 2017).

As the field of WTE most likely are to develop in the coming years, incineration plants will represents a large competitor. It is a well known technology that especially is implemented in developed countries that has a stronger financial backbone. This fact implies that resourceful western companies are likely to step into the market as the calorific value reaches an appropriate level. A risk that needs to be considered in the business concept as a stronger financial foundation gives more power – especially in a country like India.

PROS & CONS

PROS	CONS
Effective	Expensive
Harvesting energy	Complex operation and maintenance
Reducing the volume of waste entering landfills	Agitating
	Creating incentives to burn recyclables

SOURCE: HTTP://VIRIDISPERUNDING.COM/SERVICES/RENEWABLE-ENERGY-POWER-PLANTS/WASTE-TO-ENERGY-POWER-PLANTS/

1.7.4 Local composting schemes

The waste hierarchy states that composting is the most sustainable way of treating organic waste. This vision has caught on in the national MSW strategy and facilitated a trend that promotes domestic and semi-decentralized composting. This allocates the responsibility of treating the organic waste fraction to the public which creates the opportunity for a significant saving in transport (Pandey & Malik 2015). Local composting schemes are working with the principle of aerobic composting. Aldrich and Bonhotal (2006) defines aerobic composting as: ”the controlled decomposition of organic materials by microbes in the presence of oxygen”. In other words, microbes turn organic material into a useful manure which can be used in agricultural productions and domestic gardening. In urban environments the small-scale composting schemes consist of a container with an appropriate size to the amount organic waste that the people in the community generates.

The introduction of de-centralized composting is promoting an early stage segregation that represents a potential for obtaining the end-of-life plastic fraction without further fragmentation. The implementation rate of this concept is, however, progressing slowly due to the fact that the public is missing an incentive to purchase the required equipment and treat their own waste. This represents a possible business case since utilization of the end-of-life plastic has the potential to boost the composting schemes financial viability.

PROS & CONS

PROS	CONS
Allowing people to be self sufficient	Dependent on the engagement of the public
Cost saving in terms of transport	
Providing local communities with free energy	
Suitable for all organic matter	

SOURCE: PRIVATE - DAILY DUMP COMPOST CONTAINERS OWNED BY A LARGE APARTMENT COMPOUND, BENGALURU

1.7.5 Biomethanation

The high amount of organics in developing countries, and the ranging complexity, makes biogas plants very suitable as a waste processing method but it requires that a clean source of organics is obtained. The method is categorized to be suitable for different scales of operation, covering household level, community level and commercial establishments (Rajiv Gandhi National Drinking Water Mission; UNICEF 2007). The household level processes kitchen- and garden waste; the domestic level processes cattle dung; and the community sized plant processes cattle dung, roadside garden waste and human waste. All plants work for the purpose of serving the nearby community with combustible gas along with the digestate for direct use as composting manure. The commercial establishments process waste from bulk generators such as hotels, restaurants and vegetable- or meat markets, with the purpose of utilizing the gas and manure commercially (Rajiv Gandhi National Drinking Water Mission; UNICEF 2007).

Biomethanation, as a commercial establishment, is gaining traction in European countries and up until 2014 there were 244 installments of plants processing close to 8 million tons of organic waste per year. Similar to the proposition of designing for appropriate capacity, the plants in Europe differ in average capacity of 10.000 TPY, in Sweden, to 56.134 TPY, in France, which is due to the country's geographical parameters and varying policies. Baere and Mattheeuws (2012) states that the capacity of a commercial plant should be at least 30.000 TPY, and preferably 40-50.000 TPY in order to be economically sustainable.

The current status in India depends on regional popularity and the vast majority of installed plants are small scale facilities (household level). The Central Pollution Control Board (2016) reports the current number of operational plants to be 648, where 600 are installed as domestic units in Kerala.

Biomethanation is a promising treatment method, both centralized and de-centralized. It is, however, struggling with the same issues as composting as it needs the waste stream to be segregated. Biomethanation can be fairly simple constructed which lower the price and makes it an affordable investment for supporting the local community. It could furthermore be incorporated in a long term strategy as the waste streams obtain a more efficient segregation.

PROS & CONS

Usage for all outputs (Gas and manure)

Production of a clean natural gas reduces health risk related to cooking due to no particle pollution from burning organic material

More expensive and complex setup than aerobic compost schemes

Does not function well with acids from example onions and fresh fruit

SOURCE: PRIVATE - SMALL BIO-GAS FACILITY CONNECTED TO A 16 TPD MBT PLANT, TRIVANDRUM

1.8 Ideal waste management

In order to understand the ideal management of solid waste it is important to understand its boundaries and dependencies. Solid waste refers to all non liquid material which does not hold any value to the person responsible for it (Zhu et. al. 2008). Solid waste management includes activities that seek to minimize the impact that waste generation inevitably has on health, the environment and aesthetics in our world. The ideal waste management system is however difficult to define as it is largely dependent on specific contextual parameters e.g. amount, composition, infrastructure, legislation, public awareness and attitudes (Zhu et. al. 2008).

Nevertheless, it is viable to observe and categorize waste management solutions from an environmental perspective. The Hierarchy of Sustainable Waste Management developed by the Earth Engineering Center at Columbia University is commonly used to prioritize waste management processes. Annepu (2012) has further developed this waste hierarchy to include unsanitary landfills and open burning in order to assess the situation in India - see Figure 10. Noticeable about the hierarchy is the need for segregation in order to utilize the benefits of both anaerobic- and aerobic composting. This need has either been neglected or miscalculated by the Indian government since the Rules 2000 promoted the construction of composting plants and segregation at source - but failed to achieve the latter. This implies that governmental initiatives towards handling the waste has been based on naive assumptions without recognizing the challenge of changing public behavior. This fact makes the current processing system an inefficient and unsuitable way of handling the enormous amount of solid waste.

The environmentally ideal waste management solution should aim for maximum resource recovery, which, with regards to the hierarchy of sustainable waste management, is only viable with 100% segregation. Organics should be handled through biomethanation where maximum resource recovery is ensured and residues are directly recirculated in the carbon cycle. The future waste management solution should furthermore aim to recycle as much of the dry fraction as possible. Remaining fractions should processed by relevant WTE processes and finally the residue should be landfilled if not suitable for other applications e.g. stabilizing road construction.

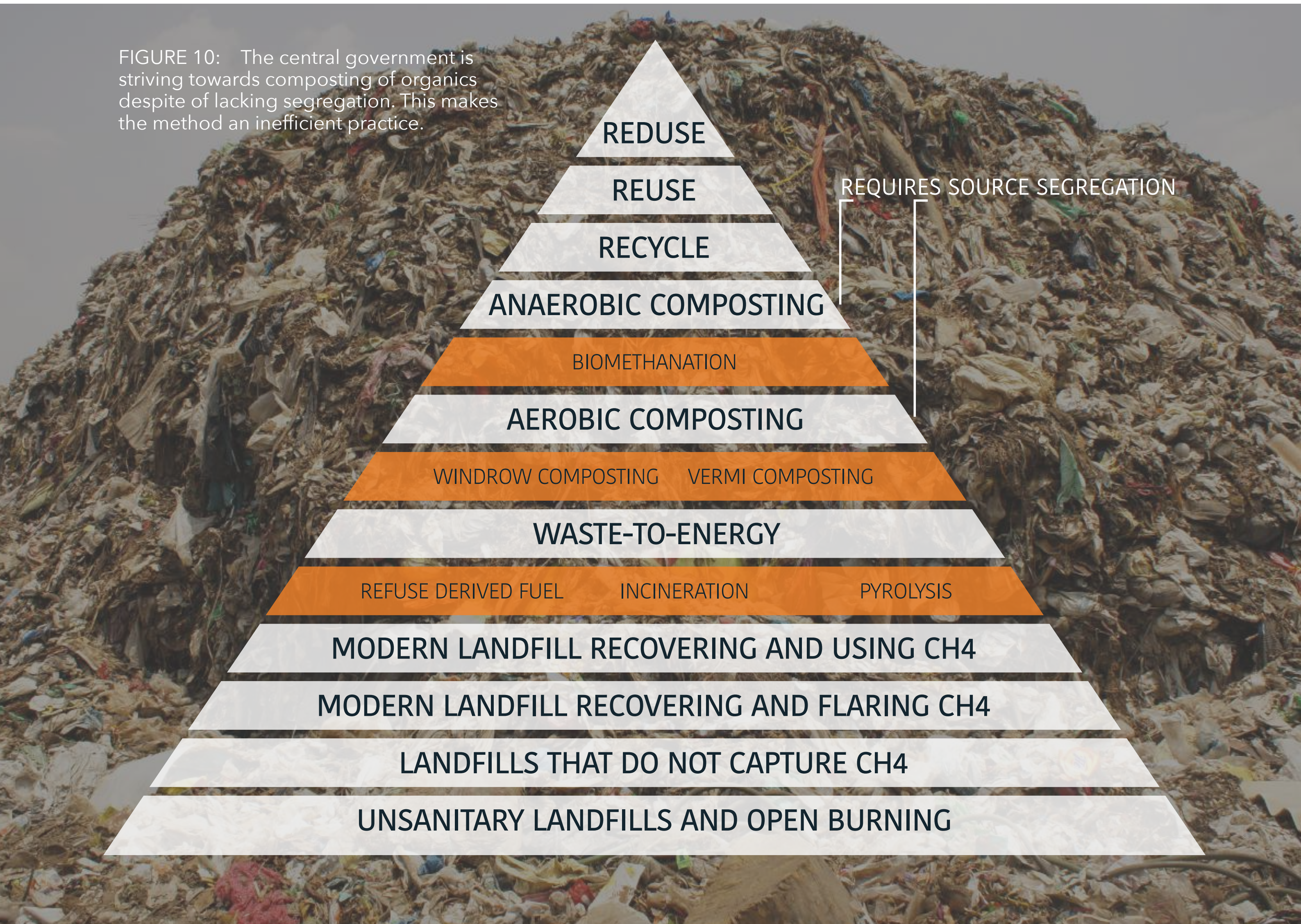
1.8.1 The need for an immediate solution

It is likely that India cannot transform from its current state directly to this ideal solution. There exists a need for a stepping stone solution with the capability of reducing the physical size of the problem as well as the environmental impact of the current state of affairs. The use of composting facilities fits the governments plan in the sense that it is ideal when/if the waste is segregated. This is, however, not the case which implies the need for solutions that target the incremental steps toward “the perfect system”. Joshi & Ahmed (2016) articulates the need for economical feasibility and proven waste-to-energy technologies. Annepu (2012) specifies the need for utilizing the current production of RDF with a combustion based WTE technology. So from a pragmatic viewpoint the benefits from establishing WTE services are a obvious. For example, physical reduction of the waste as well as energy recovery, provide a source of revenue with an actual demand (Annepu 2012).

With regards to conflicting challenges for WTE systems, it is important to acknowledge the need for increased segregation and recycling, which means a decrease in feedstock applicable for WTE. Such a change takes time and the early awareness of this trend should be seen as an opportunity to promote the movement and adapt the associated business accordingly. Another future challenge could be a change in the demand for WTE energy if any revolutionizing discoveries are made in the field of renewable energy. This would limit the value creation, from a combustion- or biomethanation solution, to the physical reduction of solid dry waste. Finally, a waste management system handling mixed waste is not compatible with the aim of the environmental ideal solution mentioned in the previous paragraph. A mixed waste solution could be interpreted as a step backwards compared to the current promotion of composting as well as decreasing the incentive to segregate.

As mentioned in section: *1.7 Waste processing facilities in India today* WTE often refers to incineration. This is a processing method widely used in the developed world but which has had little to no success in India. According to Sebastian & Alappat (2016) one of the reasons for failure is the mismatch between the cost intensive process, the need for skilled labour and the inconsistencies in MSW composition. Annepu (2012) elaborated on this by referring to poor logistics and financial planning as one of the main reasons behind WTE failures. These elements, along with a high capital investment, makes it very difficult to create a financially balanced business and thereby a sustainable endeavor as defined by Osberg & Martin (2015). It has however been concluded in section: *1.8.1 The need for an immediate solution* that there exist a need for stepping stone solution that can assist the large quantities of generated waste. A solution that is more adaptable to different feedstocks and that can be implemented in smaller scale to avoid all-or-nothing solutions. Characteristics that might be possible to achieve with pyrolysis.

FIGURE 10: The central government is striving towards composting of organics despite of lacking segregation. This makes the method an inefficient practice.



1.9 Pyrolysis

Pyrolysis has up to this point been mentioned as a WTE technology that differentiates in certain ways which gives it an advantage. One thing that needs to be made clear at the outset is that pyrolysis is not newly discovered technology. It is a technology that has formerly been used in India to turn rubber waste from car tires into oil. It is a principle that dates back thousands of years. The modern methods known today were first systematically explored in the 1950's by Bell Laboratories together with various universities (Magnum Group International). Pyrolysis, in its essence, means heating (pyro) and decomposition (lysis). This is also the basic principle of the technology. In the modern era the technology has mainly been developed to target energy production through gasification.

The following sections will dig into the technical specification of pyrolysis, elaborate on the utilization of different feedstocks and discuss the current use of pyrolysis in India.

1.9.1 Principle of Pyrolysis

Pyrolysis is a thermal degradation of a given feedstock. The heat is used to break organic compounds (chains of carbon, hydrogen and oxygen) into smaller molecules that transforms into a gaseous form. The gases commonly consist of damp and biogas, but it can contain various components depending on the feedstock. The target of the pyrolysis is to utilize the biofuel which can either happen directly by transforming the gas into energy or condensing it into bio-oil. A bi-product from the pyrolysis process is a solid residue that contains the elements that could not be gasified. The residue is referred to as char or coke and it mainly consist of carbon as the heating is facilitating a carbonization. The char can be utilized as fertilizer in the case of a non-contaminated bio-feedstock due to the large levels of phosphorous and carbon. The different flows of the pyrolysis process is illustrated in Figure 11.

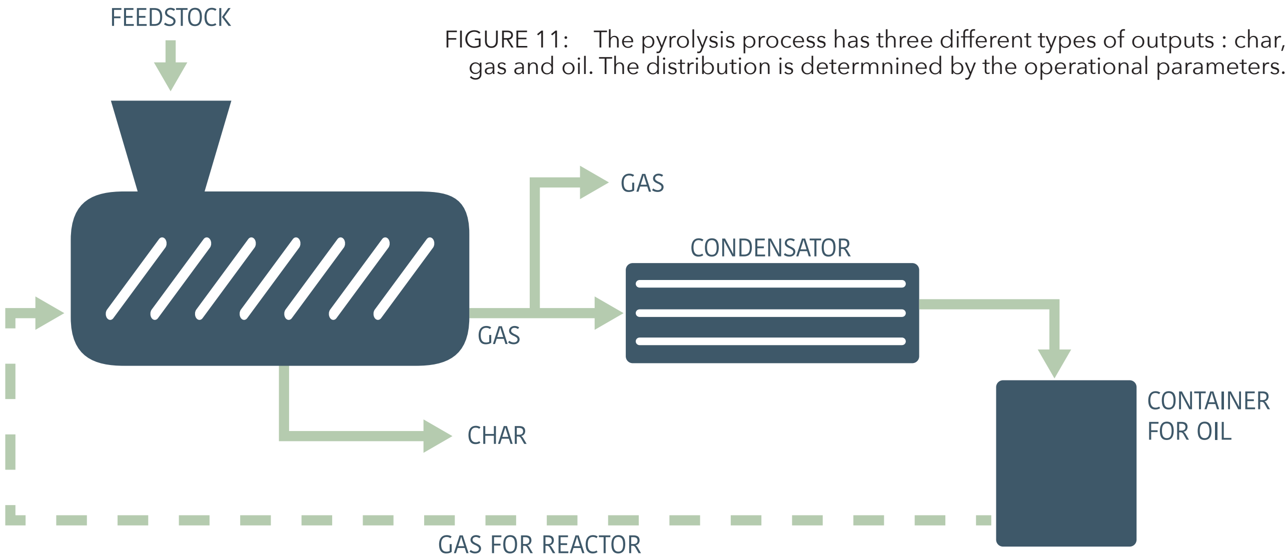


FIGURE 11: The pyrolysis process has three different types of outputs : char, gas and oil. The distribution is determnined by the operational parameters.

The process can by principle appear simple but a heterogeneous chemical composition in the feedstock enables a complex reaction behavior. This can lead to undesired outputs as the feedstock is being thermally degraded. Pyrolysis is therefore not just dependent on the heating process but it relies on the feedstock reacting in the right way at the same time. This is however promoted by performing the process in an anaerobe environment as it eliminates the risk of oxidation and combustion of the feedstock. The control of the reactions is furthermore enhanced by calibrating the operational parameters to the specific feedstock. The main parameters are max temperature, heating rate, pressure, heating time and cooling time (Jahirul et. al. 2012). These parameters can furthermore assist to control the distribution between the three output types (Chen et. al. 2014).

Types of pyrolysis

Pyrolysis can be divided into three different types *conventional pyrolysis, fast pyrolysis* and *flash pyrolysis,* , which are characterized by different processing parameters:. The most common temperature range for pyrolysis spans between 300-1000°C but can exceed 1000°C in the case of flash pyrolysis (Jahirul et. al. 2012). The following table presents the differences in the parameters of the three types in the following table (Bulat et. al. 2009; Bridgwater 2007; cited by Jahirul et. al. 2012):

TYPES OF PYROLYSIS	RESIDENCE TIME [S]	HEATING RATE [K/S]	PARTICLE SIZE [MM]	MAX TEMP. [K]	OUTPUT DISTRIBUTION OIL	OUTPUT DISTRIBUTION CHAR	OUTPUT DISTRIBUTION GAS
CONVENTIONAL PYROLYSIS	450-550	0.1-1	5-50	550-950	30%	35%	35%
FAST PYROLYSIS	0.5-10	10-200	< 1	850-1250	50%	20%	30%
FLASH PYROLYSIS	< 0.5	> 1000	< 0.2	1050-1300	75%	12%	13%

The three pyrolysis types suits different feedstock profiles and promotes certain output distributions. Radlein & Quignard (2013) elaborates on this as they argue that high heating rate and quick cooling promotes higher yields of condensable gasses - in other words, oil. To see a more detailed explanation of the pyrolysis operation, the characteristics of the outputs and how the operational parameters in details affects the process, have a look at *WS 8: Pyrolysis operations.*

1.9.2 Feedstock and added complexity

The number of possible reactions can as a rule of thumb be considered to increase corresponding to the level of heterogeneity in the feedstock (Chakravarty 2017). Thus variation in the feedstock promotes reactions to occur at different temperature levels and with undesired chemical outputs. Most feedstock have some level of heterogeneity which makes it difficult to estimate the ideal parameters for a feedstock and why it is often determined experimental (Chen et. al. 2014). This practice has collated a base of knowledge from which potential feedstocks in the MSW system can be evaluated.

Biomass or organic matter can be defined as any given material that comes from nature. It often contains a large portion of energy and it does, in many developing countries, account for up to 50% of the energy usage. In these cases it is often used as fuel in the production of electricity or directly to heat and cook food (Jahirul et. al. 2012).

Biomass is considered a renewable source of energy in the sense that it does not add carbondioxide to the atmosphere like fossil fuels do (Kumar, Kumar & Mohapatra 2016). It mainly consists of cellulose, hemicellulose and lignin which in the right composition can be suitable for pyrolysis. The three components have different molecular structure which dictates different reaction behavior. This means that the components react at different temperatures and favors different end-products. Jahirul et. al. (2012) states that biomass with a high fraction of lignin fosters bio-char while high fractions of volatile matter promotes the production of bio-oil. The production of bio-oil should be further enhanced by feedstocks with low nitrogen and mineral content (Jahirul et. al. 2012).

One of the issues with pyrolysis is to achieve a high heat transfer in the feedstock. This is especially present in biomass feedstocks since they in general are characterized by having a low thermal conductivity. This affects the yield of bio-oil since a slower heating rate promotes secondary cracking; thus increasing the production of low molecule gasses and char (Radlein & Quignard 2013). Furthermore, biomass contains large amounts of moisture which needs to be removed in order to produce an efficient heating. This fact makes Chen et. al (2014) discourage the inclusion of food waste in the feedstock.

One important aspect of the processing of pure organics is the value of the bio char, which can be used as a soil booster to enhance the effect of fertilizers (Chakravarty 2017; Cherian 2017). This however requires that the feedstock is not contaminated with any toxins or heavy metals.

Plastic waste

Plastics are everywhere and it is a material produced, either partly or fully, from oil. It is not a renewable material which makes recycling of plastic the preferred processing option as it enhances the lifespan of the material (Annepu 2012). However, this is not possible with all types of plastics. Some plastic waste consists of multiple resins that makes them unsuitable for recycling. These plastics still represent a value as they contain a high level of energy which can be utilized by pyrolysis (Almeida & Marques 2016).

The pyrolysis process of plastic waste does not differ significantly from the processing of biomass. The organic compounds of the plastic is being gasified by the thermal degradation and afterwards condensed into a liquid fuel or recovered as a gaseous fuel. The remaining fraction of the plastic is solid and can be recycled later on.

Plastics contain different kinds of additives which in some cases can be contaminating. A lot of these contaminants will remain in the solid residue but unfortunately not all. It is especially the presence of PVC that poses a risk as it introduces chlorine into the feedstock. The problem occurs as the pyrolysis reaction promotes the formation of hydrogen chlorine (HCl) and dioxins (Cho, Jung & Kim 2009) - both of which are severe polluters and pose serious health issues (Almeida & Marques 2016). HCl is also a compound that has corrosive properties which is not only damaging for the pyrolysis reactor but also for the machinery that is powered by the pyrolysis fuel in the end. It is therefore critical to consider the specific composition of a plastic feedstock and evaluate if segregation is needed or if the use of filters can be a sufficient abatement. Studies shows that the HCl can be absorbed into, for example, crushed oyster shells, Ca-C or by the process of de-halogenation (Cho, Jung & Kim 2009; Chen et. al. 2014). Chen et. al. (2014) emphasize the importance of analyzing any given plastic feedstock to determine relevant precautions.

The cracking of plastics in a pyrolysis process often requires higher temperatures than biomass due to the characteristic of the volatile matter. High temperatures and a low thermal conductivity of polymers promotes the unwanted creation of low value gas due to secondary cracking (Efika, Onwudili & Williams 2015). That being said, Almeida and Marques (2016) elaborate that the addition of a catalyst can lower the required temperature and thereby enhance the quality of the end product while decreasing the energy consumption of the process. The influence of the catalyst varies accordingly to its properties, but research suggests that most catalyst enhances the gas production. However, the use of expanded perlite have shown to increase the oil yield from 60% to 65% in a case study of catalytic pyrolysis of scrap tires (Rowhani & Rainey 2016).

Mixed municipal solid waste

Mixed MSW is a type of feedstock that represents a heterogeneous feedstock since it consists of organics, plastics, metals, inert materials etc. This composition, despite its variance, contains fractions with high levels of energy that potentially could be suitable for pyrolysis. The first problem with the feedstock is the high moisture level that is added by the food waste, which needs to be removed in order to get a proper heating efficiency (Chen et. al. 2014). The remaining fraction will still be heterogeneous and the challenge is therefore to estimate the necessary level of segregation. This step will be followed by a calibration phase, as with every other feedstock, to identify the parameters that allows a feasible production of pyrolysis-fuel.

Chen et. al. (2014) did a review study on pyrolysis of MSW and elaborates on the different feedstocks that can be extracted from MSW. It is evaluated that the plastic fraction represents the largest energy potential for pyrolysis and it would be beneficial to treat this fraction separately. This suggestion is based on the characteristics of a high energy concentration with a low level heterogeneity in the feedstock. A segregation of the plastic would not only make the feedstock more homogeneous but it reduces the amount of contamination at the same time. The impurities that can contaminate the end product when processing mixed MSW are S, P, Cl, Ca, Zn, Fe, Cr, Br and Sb. However the levels of S, Cl, Ca, Zn, Br, and Sb is significantly lowered when only treating the plastic from the MSW (Miskolczi et al. 2013); cited by Chen et. al., 2014).

Refused derived fuels

RDF has a composition that reminds of a combination between mixed plastic waste and MSW. It consists of mixed plastic waste, fiber rich biomass and inert material with a varying distribution determined by the MSW characteristic and process steps of the MBT plants. This implies a certain heterogeneity in the RDF but Chen et. al. (2014) presents a study showing that the different fractions in the RDF can have separate reaction behavior. That being said, it is not evident that it will be same for the RDF in India, but it implies that there exists a potential.

Contamination is a general concern when considering pyrolysis with any given feedstock. However, this should be of higher priority if the feedstock contains mixed plastics or other contaminating sources. It is important to consider this fact and implement some sort of emission abatement device to cope with the problem. This has already been elaborated in the section *plastic waste*.

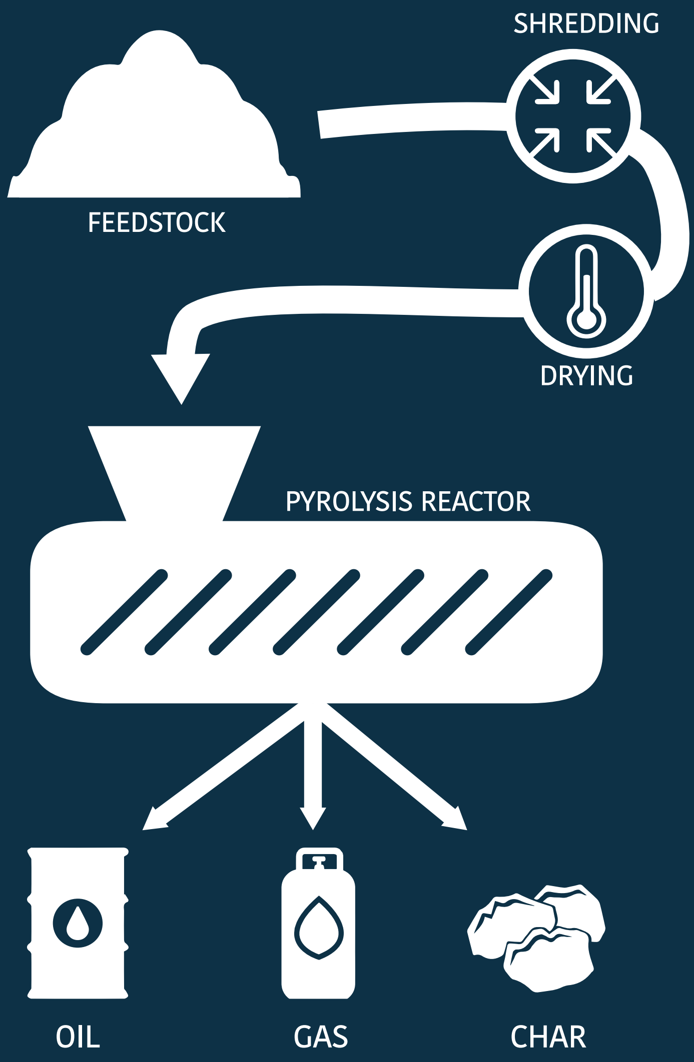
1.9.3 Pyrolysis in India

As previously pointed out, pyrolysis has formerly been used in the recycling of scrap tires and general rubber waste in India. This practice has experienced opposition in the past due to poor processing that resulted in pollution and foul odor. This has mainly been attributed to cheap and smaller units produced in China that did not follow the official regulations which led to the closing of 45 plants in 2011 (Times of India). The industry has evolved since then and a reconsideration by the government has allowed the importation of scrap tires from outside of India since 2016. It is predicted that this change will make the tire-to-oil industry flourish (Rubber Asia).

That being said, pyrolysis has not been adopted by the MSW system in India even though it has been suggested (Annepu 2012; Efika, Onwudili & Williams 2015; Al-Salem, Lettieri, & Baeyens 2010). There has been scepticism to invest in pyrolysis technology because limited MSW projects have been commercialized in a global perspective. One of the remarks given at the initiation of a pyrolysis project in Trivandrum targeted the need for more thorough research of the technology and feedstock. It were at the same time advised to investigate rejects from composting facilities as feedstock since these fractions were acknowledged to be suitable for pyrolysis (The Hindu).

Pyrolysis poses a large potential in terms of extracting unutilized energy from the current waste scene in India. It has been clarified that the pyrolysis technology has the flexibility to adapt to different feedstock characteristics and deliver outputs that can be used in various applications. It is furthermore a technology that is adjustable in scale which is considered an advantage based on the experience of former "make it or break it" incineration solutions that have shown a high failure rate (Sebastian & Alappat 2016; Annepu 2012; Osberg & Martin 2015). This supports the need of a pyrolysis technology which can be launched as a small scale pilot project, have a low cost adaption phase and be scaled to fulfill its full potential later.

The required design for a business that handles MSW will be put aside for now, as it is dependent on the characteristics of the exact feedstock. This will be reconsidered when approaching the detailing of a final business opportunity. For now the perspective will zoom out and focus on the actual feedstocks than can be obtained in the MSW system. This will be elaborated in the next chapter as the case studies and opportunity identification is initiated.


SHREDDING
FEEDSTOCK
DRYING
PYROLYSIS REACTOR
OIL
GAS
CHAR

02

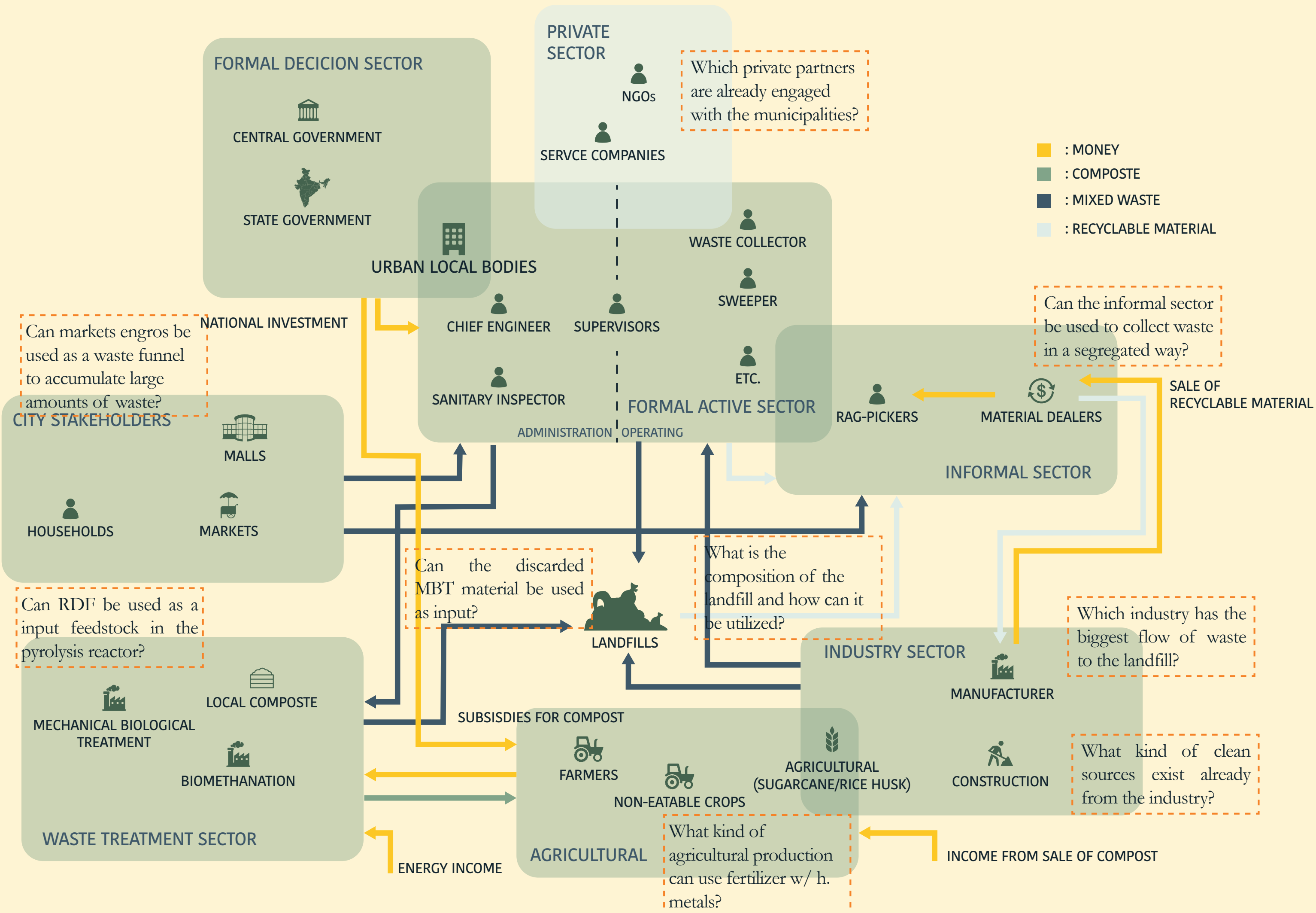
Opportunity identification

The opportunity identification is defined as a fact-finding mission in India where the desktop is replaced with first-hand impressions. It has the purpose of validating findings from the literature, establishing a network and identifying specific opportunities. The opportunity identification was initiated with a scoping of relevant areas that were either emphasized in the literature or identified in a general discussion. These scopes functioned as a starting point for the fieldwork and was investigated during the fact finding mission in India. This chapter will presents the pre-framings followed by a presentation of the case studies in Bengaluru, Coimbatore, Hyderabad and Trivandrum which clarifies identified breakdowns and opportunities.

2.1 Pre-framings

The review of the literature was a way of creating an overview of the MSW system in India. It made it possible to exploit post research and get an initial idea of potential scopes that could be relevant for investigation in the fieldwork. The scopes are illustrated in Figure 12 (*WS 9: Actor network* for larger illustration) placed on an Actor network that has been used to create an overview of relevant stakeholders, relevant waste streams and the location of the pre-framings. The stakeholders are clustered in simplified groupings/arenas in order to simplify the illustration.

FIGURE 12: The pre-framings formulated the initial focus areas of the case studies and were based on experience and suggestions from the litterature.



2.1.1 Waste treatment facilities

The few number of waste treatment facilities as well as their inefficiency made the investigation of existing MBT plants an obvious place to start. Annepu (2012) estimates that the compost yield from MBT plants are only 7-10% which leaves 60% of the input as reject after removal of moisture. These rejects supposedly have a calorific value that are suitable for pyrolysis processing. An exploration of this field is further supported by the lack of demand of the RDF fraction of the rejects which should lower the acquisition rate.

The focus points for this framing are a validation of the scenario together with a characterization of the feedstock and amount.

2.1.2 Landfill composition and value

It has already been clarified that India's landfills could be considered as sources of energy. The waste is continuously dumped which forms large mountains. It pollutes the environment, poses a severe health risk while representing a waste of resources. It is an obvious scope but it is also a field that needs to be thoroughly investigated in order to make a realistic and practical evaluation of the potential. The effect of years of degradation needs to be determined in order to appropriately evaluate the true potential.

The task of this investigation is to understand the real situation of landfilling and furthermore explore the variation of the waste that is being dumped. For consideration is whether the waste trucks that dump the waste can be screened to redirect the dumping of high energy content. It is also important to consider alternative revenue streams aside from the production of oil and evaluated whether tipping fees or the sale of cleaned land could represent possible revenue.

2.1.3 Industrial and commercial waste sources

The data on the waste streams from industrial and commercial sources are limited in the literature. However, a discussion in the discovery phase fostered a hypothesis: industrial sources rarely produce an equal amount of various components as industrial businesses are in many cases considered to be specialized in one field which makes their waste composition correspond to the profession. For example, construction companies will produce construction waste while food exporting companies will have an organic waste generation.

The focus of this pre-framing is to identify cases which can either confirm or decline the hypothesis. If confirmed it would represent a clean source of waste which lowers operational costs.

2.1.4 Agricultural residues

A particular relevant industrial waste source is different agricultural industries. The production of agricultural products includes the generation of residues from stems, branches, leaves, etc. In sugarcane and cotton productions the residues represent a huge resource with calorific value for cotton residues around 17 MJ/kg and for sugarcane bagasse around 16 MJ/kg (Kumar, Kumar & Mohapatra 2016). It is furthermore estimated that the annual surplus residue from agricultural production is around 127 million tons (Dubey et. al. 2004). The utilization of agricultural residues falls a bit out of the boundaries of the MSW but still poses a potential opportunity.

The investigation of this area will set out to identify existing agricultural practices that have a certain required amount of residues with an appropriate energy content. It is important to ensure that an utilization of agricultural waste does not outperform less economical attractive but important applications like using edible oils for fuel which could lead to the undesirable consequence of food scarcity.

2.1.5 Waste funnels

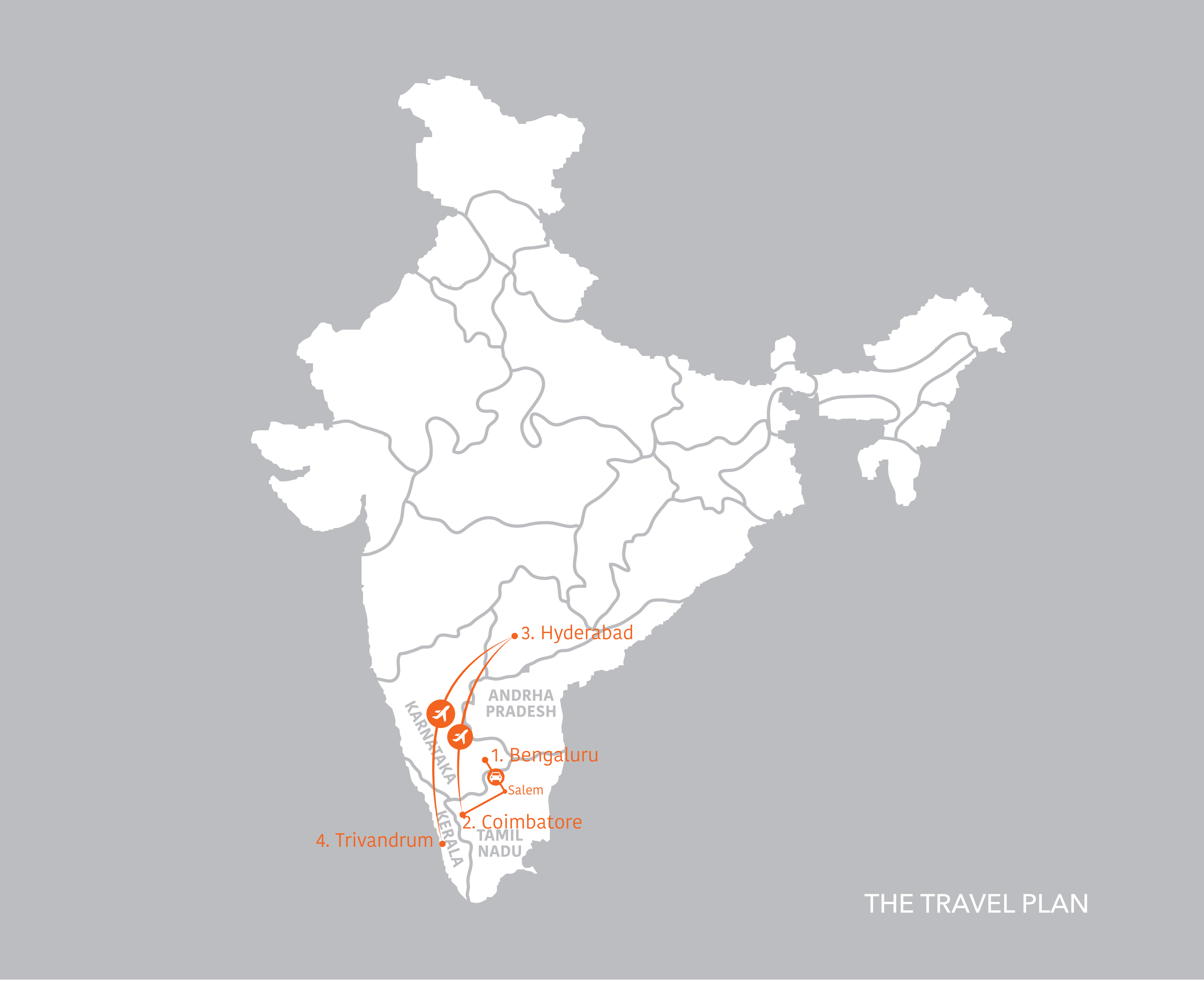
Various waste streams are most likely to find their way to certain meeting points which can be considered as waste funnels. It has been evaluated that a significant amount of waste is likely to occur at places like vegetable and meat markets, as well as engross supermarkets. These places represent large quantities of sales of food and thereby also the production of large amounts of waste.

Few collection points increase the certainty and simplicity in a business venture. Focus points in the further investigation of these funnels would be the chemical and physical composition of the waste gatherings together with present management.

2.1.6 Local schemes and PPP arrangements

The literature states that local schemes and movements has begun to promote a proper MSWM in a bottom up approach. Mytty (2015) describes how a local NGO is assisting the involvement of ragpickers into the formal system. This has created a constellation where the NGO and volunteers are working independently but with a close relationship to the municipality. This poses an opportunity as it could enable the bypassing of the municipality but still obtaining the required feedstock. The PPP arrangements allows for the same possibility.

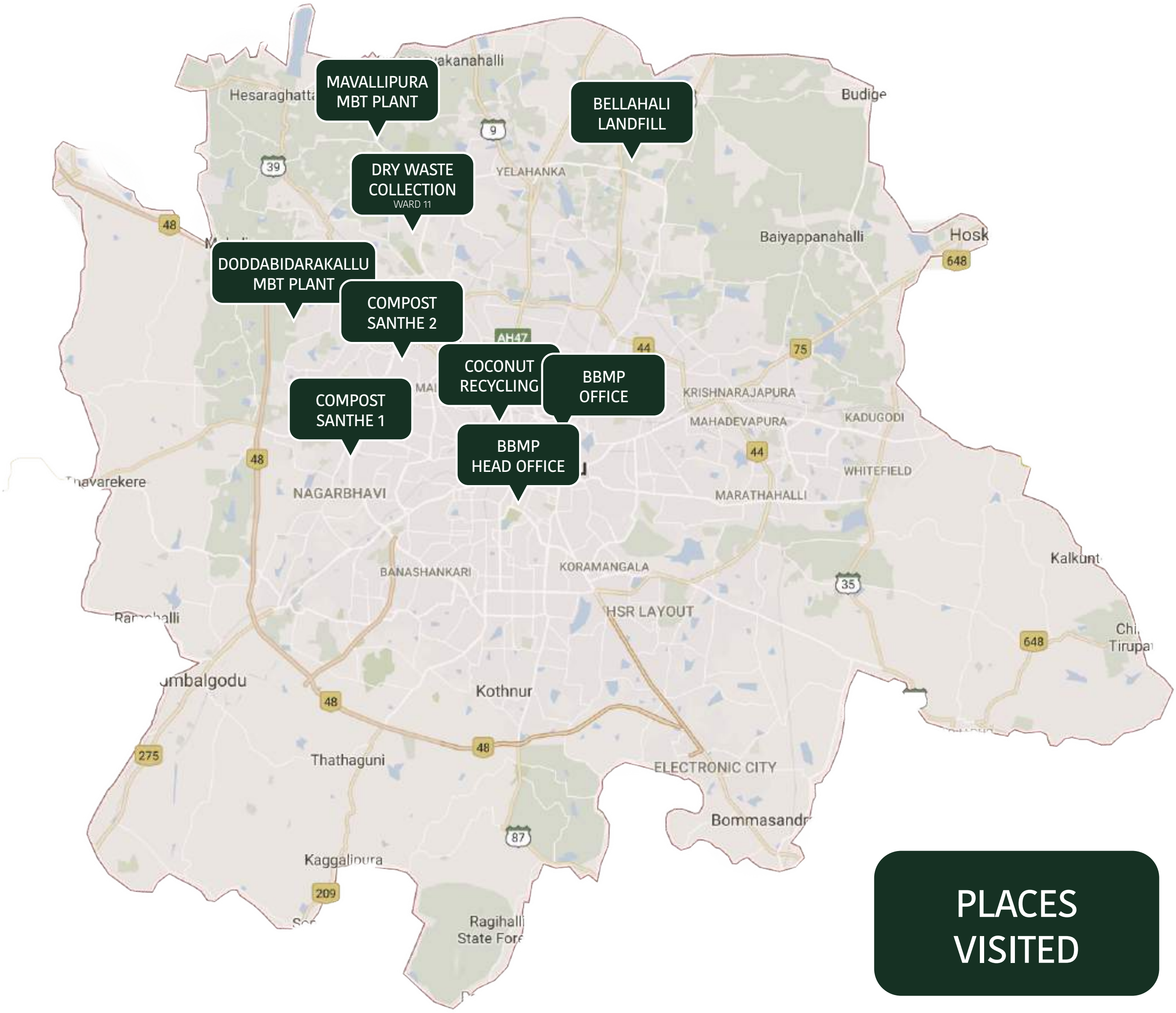
The focus point of this framing is to identify specific stakeholder that can establish an indirect connection to the municipality and allow a reduced implementation time.



2.2 Case studies

The opportunity identification was conducted in four Indian cities: Bengaluru, Coimbatore, Hyderabad and Trivandrum over a three week period. The cities vary in population, climate and level of MSWM efficiency but share the characteristic of having MSW with a high calorific value (The Standing Committee of Energy 2016). The following pages will briefly present the cities along with a visualization of their current waste system, breakdowns in the system and potential opportunities. A detailed outline of the case studies is presented in *WS: 10, 11, 12* and *13*. The practice of the different MBT plants that were visited is illustrated in *WS 14: MBT plants*.

Bengaluru



PLACES VISITED

10.1 Million

709 km^2

5000 TPD

2386 kcal/kg

(The Standing Committee on Energy 2016; World Population Review 2017a; Sandhya 2017)

2.2.1 Case study: Bengaluru

Bengaluru, formerly known as Bangalore, is the state capital of Karnataka. Its population has increased from five million to over 10 over the past 15 years (World Population Review 2017). This urbanization has left their waste system broken as the municipality has been unable to facilitate the expansion (Naveen, Sivapullaiah & Sitharam 2013).

Today, Bengaluru Municipality (Bruhat Bengaluru Mahanagara Palike, BBMP) is pushing a new strategy that promotes de-centralized composting schemes in order to reduce transport expenses and avoid large quantities of accumulated waste that they are incapable of handling. This change is driven by a realization that their current MBT plants do not have the proper capacity. They are mainly engaging idealists and children in order to create awareness and willingness. The Joint Commissioner for Health and MSW expressed concerns for the centralized production of compost due to the lack of demand and did not find it feasible that this method was dependent on governmental subsidies (Sardar 2017). The MBT plants are, however, the main processing method used in Bengaluru while direct landfilling comes second. The BBMP put a tender in 2017 for a new MBT plant that in addition to the composting facility will have an incorporated WTE module.

The de-centralized composting trend is facilitated by a collaborative movement between the BBMP and volunteering environmentalists. The movement arranges composting events (Santhe) in public spaces with a twofold agenda; one is to create awareness of the impact of the waste issues and secondary promoting domestic composting products targeting individual households and communities. Their vision is to treat all organic waste at the source and use the produced manure in home gardening or distribute it to farmers. In the cases where the manure goes to the farmers, it is sold for 800-1300 INR per ton. This price is lower than the acquisition cost of the required composting micro-organisms which makes the composting schemes uneconomical. That being said, the wheels keep on turning due to the volunteers that have persuaded the residents to pursue this positive course.

The fieldwork in Bengaluru was mainly conducted with assistance of Dr. Sandhya who is a sanitary inspector in Yelehanka - one of the eight districts in Bengaluru. She is a part of the de-centralized composting movement and is an idealist that spends her time pursuing this path outside work hours. She is a main contact in Bengaluru and has enabled the establishment of a large network that are connected to the MSWM. This network is reliable and there exist a handful of people that would be willing to help if they were engaged appropriately.

SEE *WS 11: CASE STUDY: BENGALURU* FOR MORE PICTURES AND DESCRIPTIONS

SOURCE: PRIVATE

B1 CLEAN OUT LANDFILL, BELLAHALLI
Landfill takes up a lot of space which can be cleared out. This will free valuable land. Residential areas in the Bellahalli area is sold for between 6,000 - 80,000 INR/sq.yard[1]. The amount of waste gathered over the years accumulates to 950,000 T

B2 MIXED WASTE BELLAHALLI
Bellahalli is a landfilled own by the BBMP where 1300 TPD of mixed waste is dumped. The composition is estimated to be 50% plastics and 50% organics. (high moisture)

B3 REJECTS FROM MAVALLIPURA
Mavallipura is a MBT plant operated by Ramky. They landfill 30% of the input as a reject. This fraction represents a large part of organics which is not suitable for compoting.

B4 RDF FROM MAVALLIPURA
Another bi-product from the MBT process is the production of RDF. The RDF from Mavallipura is a mixture of plastic and large organics (coconuts etc.). The plant is producing 80 TPD which is sold for 3000 INR/ton. The manager estimated the caloric value to be 3000 kcal/kg.

B5 REJECTS FROM DODDABIRADAKULLA
Doddabiradakulla is BBMP own and operated MBT plants. They are treating partly segregated waste (mostly organics). They produce approximately 60 TPD and have 5000 tons accumulated on the premise.

B6 RDF FROM DODDABIRADAKULLA
Doddabiradakulla has besides the rejects a bi-product of RDF. The RDF from Doddabiradakulla is pure plastic a batched together in cubes of waste plastic. They are producing approximately 20 TPD. Plastic waste contains a calorific value between 4000-10,000 kcal/kg.

B7 18,000 TON RDF DEPOT
BBMP has accumulatd 18,000 tons of RDF that is posing issues for the municipality. Among others, there is no demand for the RDF and due to high caloric value can it catch fire. Furthermore the BBMP is mainly interesting in freeing the space as it is more valuable than the RDF itself.

B8 COCONUT RESIDUES FROM RECYCLERS
Bengaluru houses a coconut recycle center They produce between 5-40 TPD of coco peat. Coconuts in general contains 15% moisture and has a calorific value of between 5-40 TPD.

B9 DRY WASTE COLLECTION CENTERS
There exist 174 dry waste collection centers that is funded by different NGOs. They collect and separate dry waste in order to sell it for recycling. However the low value plastic does not pose a value for recyclers.

B10 APARTMENT COMPOUNDS
Several compounds has taken the SWM into their own hands. One example has 1000 residents with who produced around 165 kg per week (13% of their recyclables. Used to be paid 1 INR/kg - however no goverment support at the moment. They have to pay for transport.

B11 PUBLIC BIN SYSTEM
OUT OF SCOPE

Bengaluru is (almost) a bin free city which opens up for a opportunity of saving the municipality of the high cost for street sweeping. High entry barier, no incentive to get mixed waste, municipal responsibility.

B12 BULK GENERATOR SW COLLECTION
NO DATE

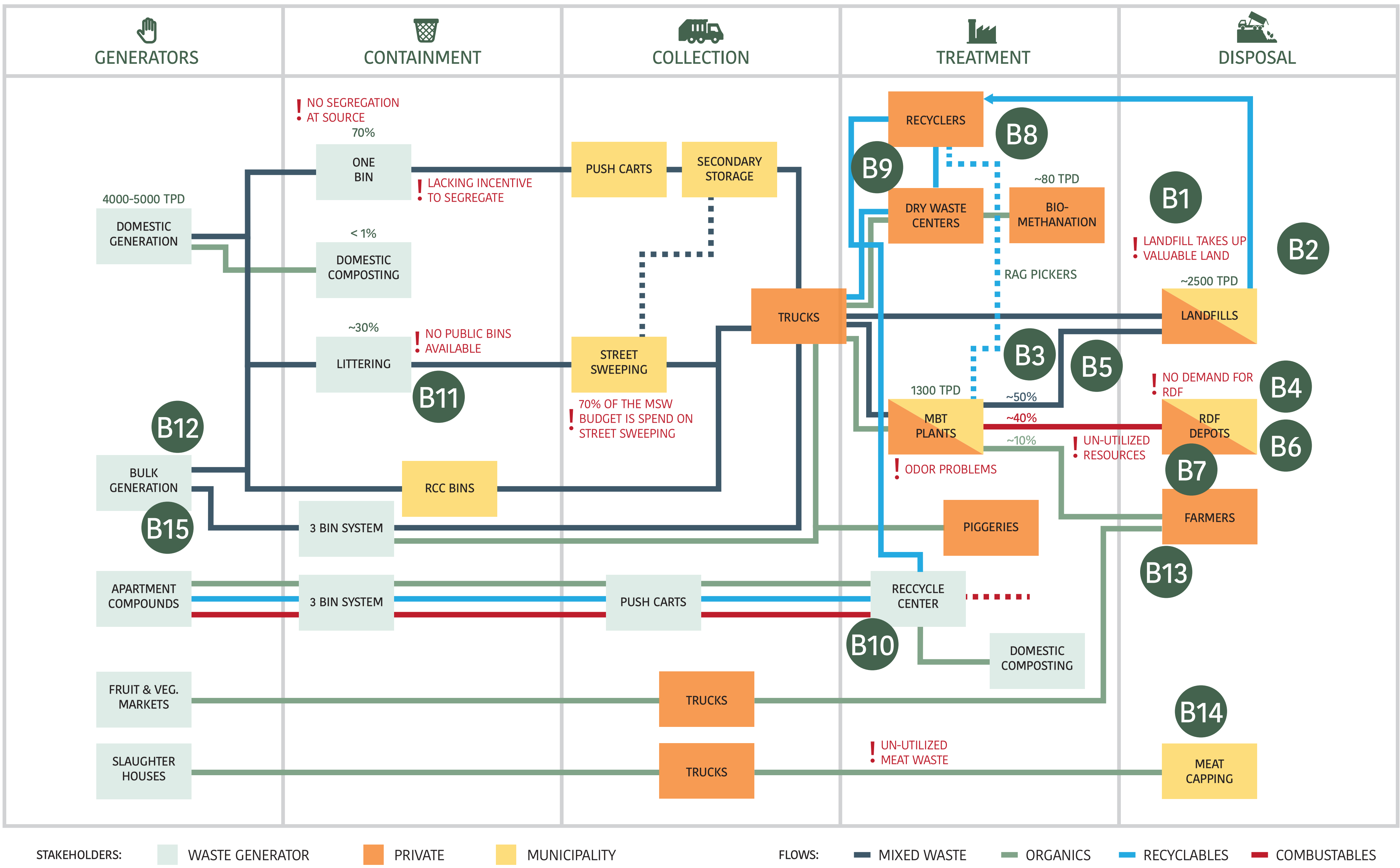
Offer a cheaper collection option for bulk generators. Create an incentive for segregation - maybe money driven. The current tipping fee for waste management cost 22 INR/kg

B13 FARMERS AND MARKETS
The farmers uses residues from fruit and vegetables markets as a fertilizer. However pyrolysis can offer the same fertilizing characteristics while utilizing oil as well. The waste from the markets is mainly organics which contains a large fraction of moisture.

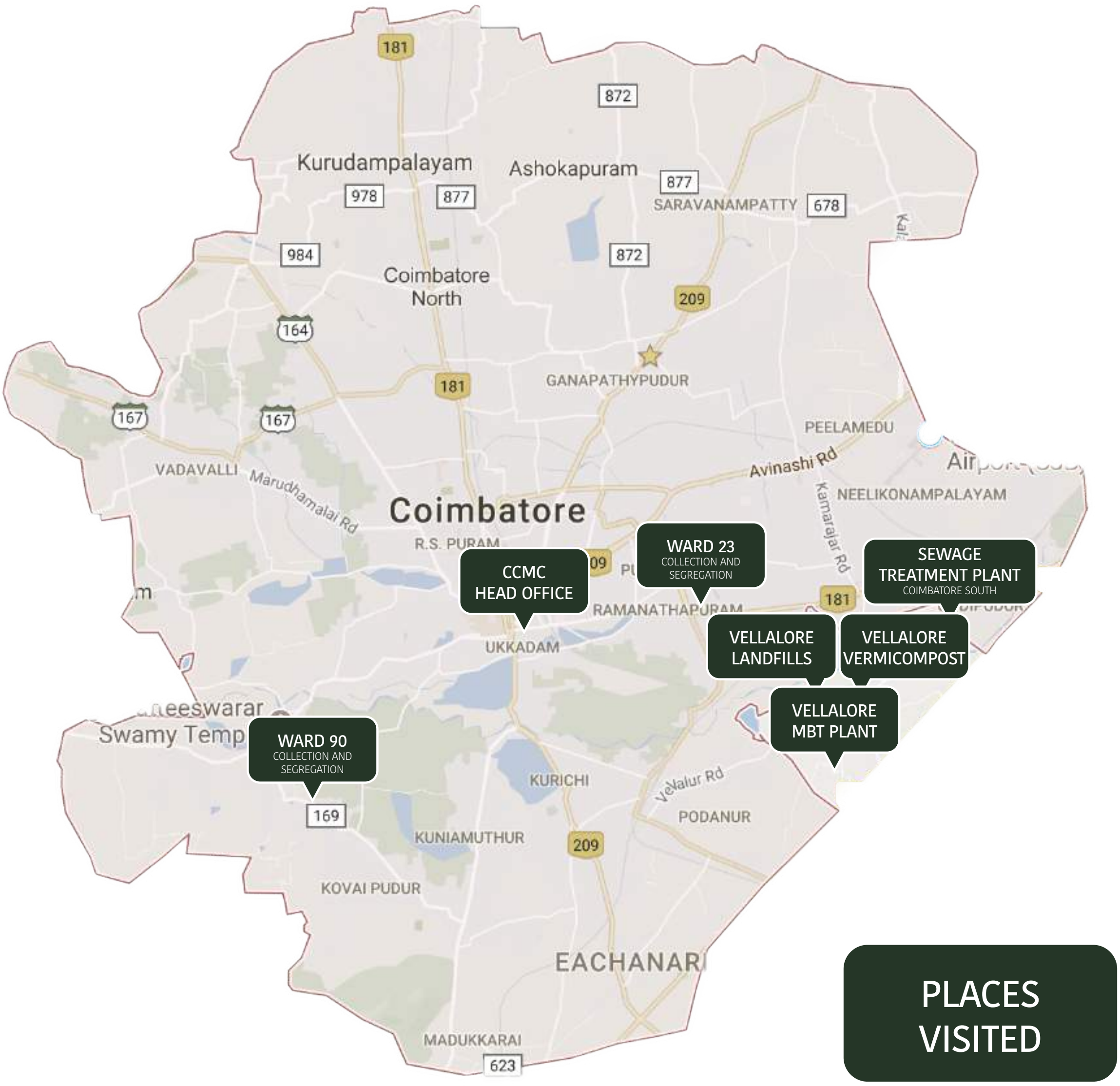
B14 MEAT WASTE
Bengaluru houses several slaughter houses which produced approximately 80 TPD. Currently the meat waste is being capped in a separate landfill. This meat waste contains manily of waste from poultry.

B15 FAST FOOD CHAINS
Utilize food waste from food chains that serves high calorific value food, such as burger joints etc. This can also apply to food courts.

Sum up: Bengaluru



Coimbatore


Kurudampalayam
Ashokapuram
SARAVANAMPATTY
Coimbatore North
GANAPATHYPUDUR
PEELAMEDU
Avinashi Rd
NEELIKONAMPALAYAM
VADAVALLI
Marudhamalai Rd
Coimbatore
R.S. PURAM
Kamarajar Rd
RAMANATHAPURAM
UKKADAM
KURICHI
Velalur Rd
PODANUR
KUNIAMUTHUR
KOVAI PUDUR
EACHANARI
MADUKKARAI
WARD 23
COLLECTION AND SEGREGATION
CCMC
HEAD OFFICE
SEWAGE TREATMENT PLANT
COIMBATORE SOUTH
VELLALORE LANDFILLS
VELLALORE VERMICOMPOST
VELLALORE MBT PLANT
WARD 90
COLLECTION AND SEGREGATION
PLACES VISITED

1 Million

257 km^2

850 TPD

2391 kcal/kg

(The Standing Committee of Energy 2016; Census 2011a; Naidu 2017)

2.2.2 Case study: Coimbatore

Coimbatore is the second largest city in the state of Tamil Nadu and a rapidly expanding tier II city (Ministry of Urban Development 2016). It serves as a major textile, industrial, commercial, educational, information technology, healthcare and manufacturing hub of Tamil Nadu. Coimbatore is constituted by five zones with 20 wards in each. The Coimbatore Municipal Corporation (CCMC) is passionate about solving their MSW issues and consider the awareness and willingness of the public as the biggest obstacle. They are well aware of the chaos that a fast expanding city promotes and the executive engineer defined their management style as "crisis management" (Naidu 2017). That has resulted in a trial and error approach where they pursue different methods and pilot projects at the same time - e.g. by outsourcing particulate tasks to young entrepreneurs.

One of the projects target instant segregation at source which is facilitated in collaboration with a NGO called *No Dumping*. The instant segregation is achieved by pushcarts managed by two sanitary workers using a shallow bucket, shaped like a wok, to manually separate the waste into more than 10 different fractions. They are motivated by a commission from sales of recyclable material, which allow them to raise their salary from 9,000 INR/month to 13-15,000 INR/month. They are currently operating 14 pushcarts, each capable of collecting around 3-400 kg/day from 260 houses.

The executive engineer in Coimbatore is a man that is eager to try new things in order to promote change. He was however not the only promising candidate in Coimbatore. The technical manager from the Tatva Global MBT plant at Vellalore seems reliable and interested to do business. The local NGO, No Dumping, seemed idealistic and helpful in Coimbatore. Unfortunately, it has been difficult to maintain this relationship after leaving the city.

SEE *WS 11: CASE STUDY: COIMBATORE* FOR MORE PICTURES AND DESCRIPTIONS

SOURCE: PRIVATE

C1 NO DUMPING - DOMESTIC COLLECTION

FUTURE TREND

The NGO No Dumping currently collects, and segregates, mixed waste from ward 90. A business could revolve around value creation from the residue fractions - low value plastic and high fibre organics - at a small to not existing acquisition price. They currently collect 84 kg/day/ward of high fibre organics and 210-280 kg/day/ward of low value plastics.

C2 UTILIZE SEGREGATED GARDEN WASTE

OUT OF SCOPE

A number of wards segregate garden waste for collection in push carts. This contains a high fibre content and are badly composted - which makes it suitable for pyrolysis and combustion. The amount of garden waste and its immediate suitability for composting puts it out our scope.

C3 VELLALORE RDF

The MBT in plant in Vellalore produces around 200 TPD of RDF aimed at reselling to cement kilns or similar industrial usage. They are however lacking demand. Their sales prices is 350 INR/Ton and it is estimated to contain a calorific value of 2500-3000 kcal/kg.

C4 VELLALORE REJECTS

In the process of producting compost and RDF the MBT plant rejects around 200 TPD of material based on particle size. It is currently being landfilled, meaning an acqusition price of 0 INR and it contains a large fraction of plastic. A part of the rejects comes from a 4 mm mesh screening were 15 TPD are produced. This fraction differs by its increased homogenuity.

C5 VELLALORE LANDFILL

The waste generation in Coimbatore exceeds the treatment capacity meaning a constant accumulation of mixed untreated waste. This holds up large areas and could present a substantial resource in oil/char/gas production and/or brown field development.

C6 NO DUMPING - COMPOUNDS

OUT OF SCOPE

No Dumping also operates a number of apartment complexes and compounds. This system will deal with a residue fraction which can't be recycled - but still work in a pyrolysis concept. They currently serve 36 compounds with a waiting list with 50 compounds. They are currently looking to expand at their own revenue provision, which could present an opportunity. Unfortunately the amount of compound residents in Coimbatore limits the economical feasibility of the opportunity.

C7 BULK GENERATION

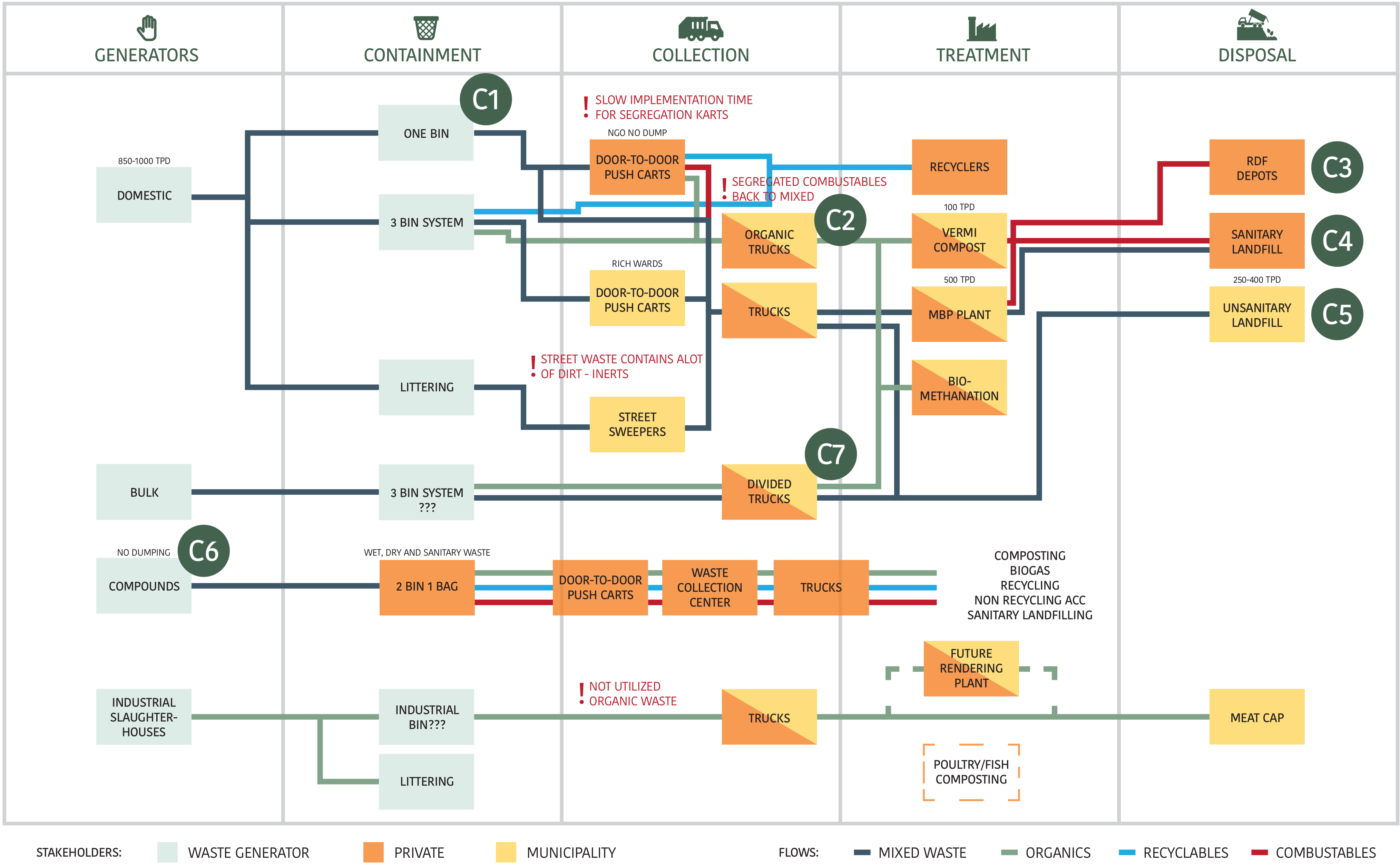
NO DATA

Bulk generators in Coimbatore reaches a segregation efficency of up to 80%. The current system works with a tipping fee payed buy the bulk generator to the collector. This provides a business opportunity where revenue can be generated from tipping fee and sale of pyrolysis outputs.

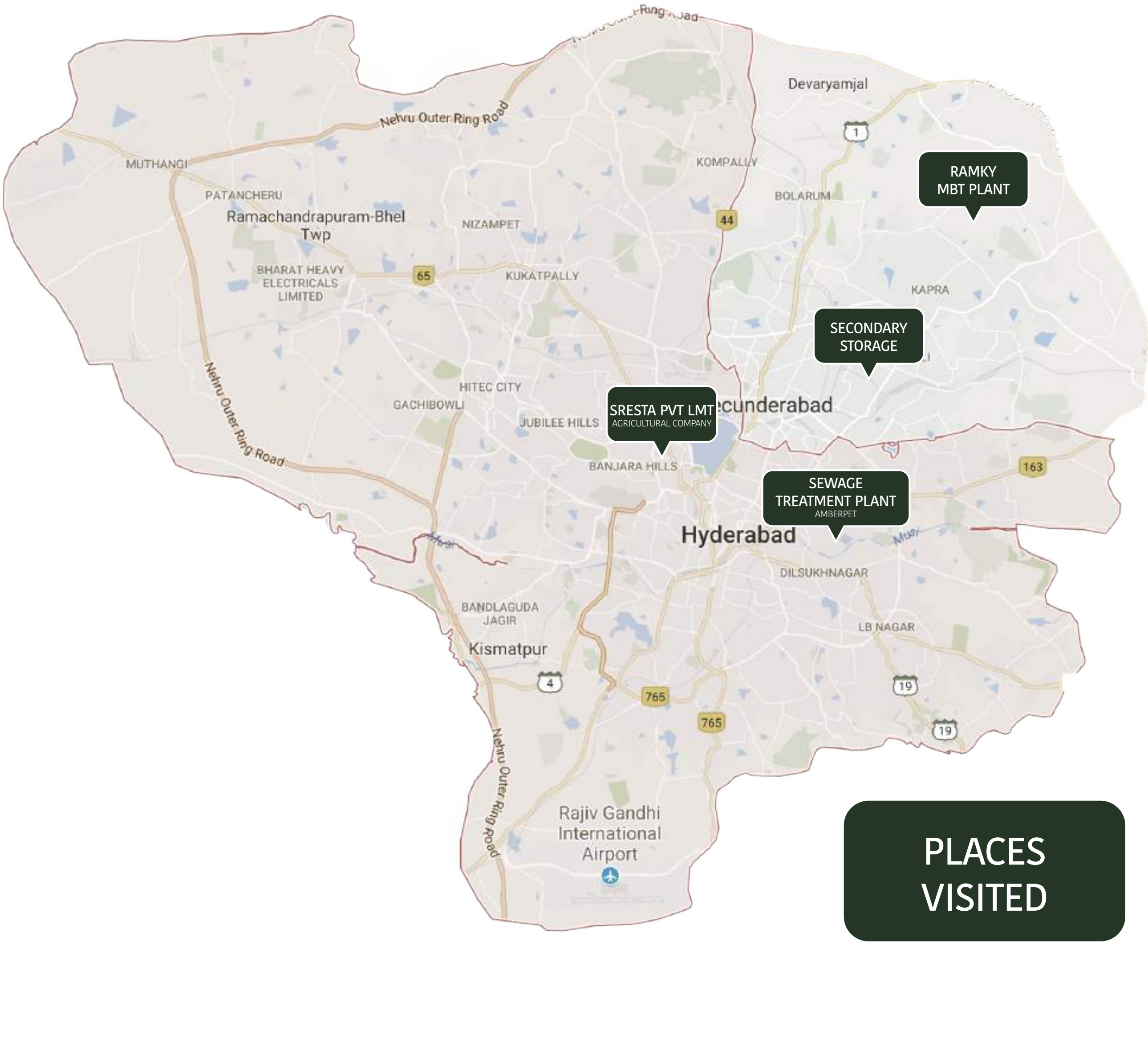
C8 ANIMAL WASTE

Industrial slaughterhouses, and meat markets, currently pays a tipping fee of 65 INR/kg in order to get rid of their waste. Coimbatore produces a total of 5 TPD in weekdays and 10-12 TPD on markets days. The waste contains more than 50% of poultry waste which holds a energy content between 13.1-15.2 MJ/kg.

Sum up: Coimbatore



Hyderabad



PLACES VISITED

8.7 Million

650 km^2

4600 TPD

1969 kcal/kg

(The Standing Committee of Energy 2016; World Population Review 2017b; Reddy 2017)

2.2.3 Case study: Hyderabad

Hyderabad is a shared capital of the states Telangana and Andhra Pradesh. It is home to 220,000 households and is the technological hub of India, sometimes referred to as the ”silicon valley” of India. The MSW is driven by a top-down initiated change and seems well functioning. The municipality has sponsored a two bin system for each household in order to promote 100% segregation of dry and wet waste. This has had a total investment cost of 290M INR. The bin set is the first step of an initiative which is being followed by a purchase of 2000 segregation trucks (tipper vehicles) and several decentralized vermi composting units. The tipper vehicles has proven successful in a few wards and two pilot vermin compost facilities have been constructed. This concept will be implemented across the wards over the next few years. The executive engineer at Hyderabad Municipality, Mr. Srinivasa Reddy (2017) stated that they consider themselves as a ”national pioneer” in waste management. Their MSWM is based on a PPP model with the company Ramky as the main partner. Ramky is currently responsible for 100% of the processing and 70% of the collection, but they will get the entire management as a part of the newly mentioned initiative. Ramky is also constructing a WTE that is supposed to deliver 80MW to the electricity grid.

The setup of one main partner and the size of this partner, makes Hyderabad a very difficult candidate to engage. Ramky has a 20 years tender and their plant in Hyderabad was the most developed system that was observed in the four cities. There is definitely room for improvement but the Ramky cooperation is a tough competitor.

The executive engineer of the municipal cooperation is a man that pushes for change but might not be the most reflective person. He did not consider it an issue or oppositional incentive that Ramky should facilitate the change to 100% segregation even though they receive their main revenue from tipping fees. A revenue that will decrease as the segregation improves.

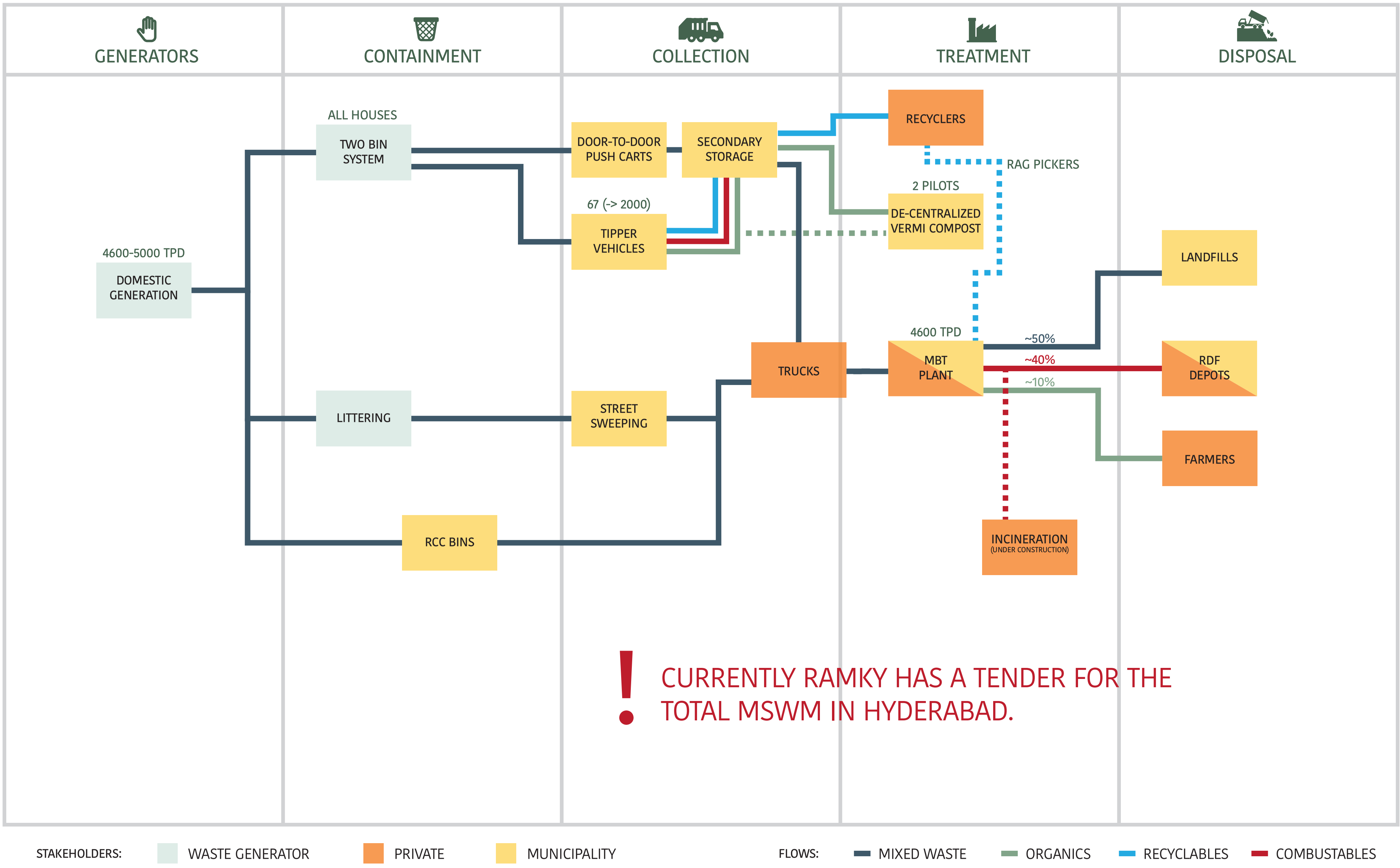
It was decided at this stage that Hyderabad was not a suitable location warranting further investigation.

HYD ERA BAD

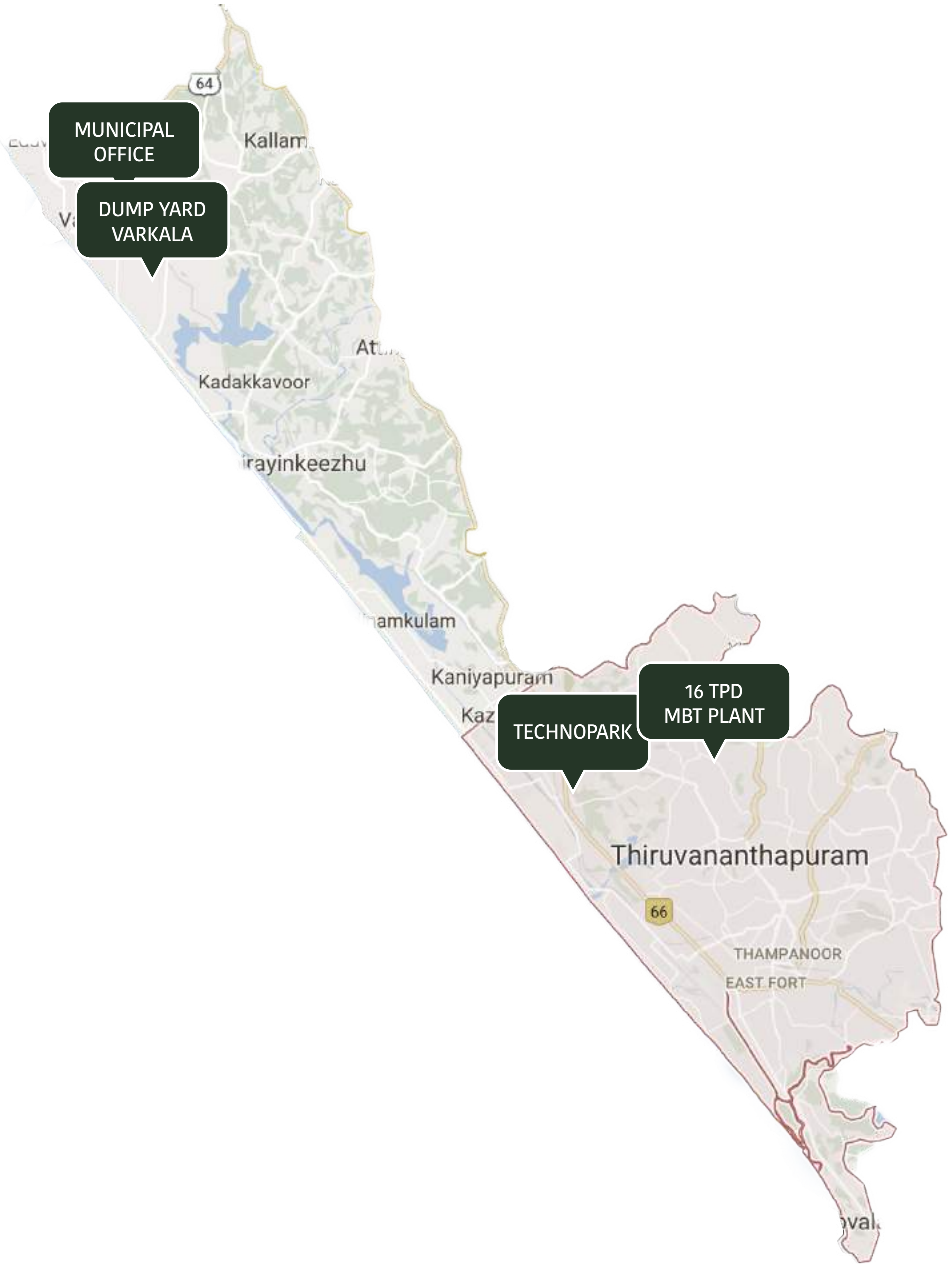
SEE *WS 12: CASE STUDY: HYDERABAD* FOR MORE PICTURES AND DESCRIPTIONS

SOURCE: PRIVATE

Sum up: Hyderabad



Trivandrum



PLACES VISITED

3.3 Million

250 km^2

500 TPD

2378 kcal/kg

(The Standing Committee of Energy 2016; Census 2011b)

2.2.4 Case study: Trivandrum

Trivandrum is the capital and largest city in the state of Kerala. The state is known as "Gods own country" due to its beautiful nature, beautiful beaches and tropical climate. For the same reason the area is very popular to tourists which is having an influence on the appearance of the area as it adapts to a western lifestyle. This in turn affects consumer behavior which introduces more plastic into the society. Trivandrum is facing severe problems in terms of their MSWM since the political engagement is close to non-existent (Sanjeev 2017). Even though numerous articles state that the city has a working MSWM system (Praveen 2015), this is no longer the case. The city used to have a collection system and a waste processing station in the area Villappilsala that closed down in 2012 from opposition in the population who found the leachate and odor totally unacceptable. Ever since, the public has been throwing their garbage along the roads and it is rapidly accumulating in particular spots around the city. The municipality is currently abandoning their responsibility and letting the waste accumulate along the roads where it gets buried when the pile is large enough.

Varkala is one of the nearby tourist destinations that is located around 40 km from the center of Trivandrum. It is a small city with a population of 50,000 that has been granted governmental funding of 500,000,000 INR in order to develop their MSW system (Sanjeev 2017). They are receiving this funding as a reward for good work and progress. The funding is targeting domestic composting where they are appointing five ambassadors for every 100 households whose job it is to educate the residents in proper composting practices. The officials in this area seemed eager to engage in a pyrolysis project but the size of their community limits a potential operation.

The area around Trivandrum has become a popular tourist destination which has accelerated their economical growth. This popularity might not continue, however, if they do not fix their MSW system and maintain the attractiveness of the area. It is unknown how many resources are currently put into the development of the MSW system, but it is clear that a more structured strategy is needed. It might be possible to exploit the fact that they are adapting to a more western image by arguing and demonstrating support for this change.

The awareness and actions towards changing the MSWM is mainly facilitated by a movement of local environmentalists. They are eager to change the system but they are not aligned around any particular solution. The movement is engaged with people on different levels, including municipal officials, which makes it easier to influence the municipality. However, it is unknown how strong this connection is and how easily it can exploited.

SEE *WS13: CASE STUDY: TRIVANDRUM* FOR MORE PICTURES AND DESCRIPTIONS

SOURCE: PRIVATE

T1 TOTAL ENTERPRISE

LACK OF DATA

Crisis breeds opportunity. In this case the city of Trivandrum has no real collection system and the municipality is escaping their responsibility, which provides an opportunity for controling the whole activity chain.

T2 PLASTIC WASTE FROM ROAD USE

LACK OF DATA

From the limited amount of collected waste the low value plastic fraction is shredded and used in building roads. The majority of waste, which is littered at the road sides, is currently being accumulated at the road sides and finally burried when expanding the roads. The opportunity lies in processing the plastic fraction of the accumulated waste at the road sides as well as processing the shredded fraction from various treatment plants. The value of such an opportunity furthermore lies in reducing the amount of microplastics flushed in the ocean.

T3 ACCUMULATED WASTE IN VARKALA

City of Varkala has accumulated its waste from the past 5 years at a land area. If this was to be processed it could provide a profit from selling the pyrolysis output as well as enhancing the value of the land. The information of this site is limited, but it it interesting due to personal contacts in the area.

T4 PYROLYSIS TREATMENT FACILITY

LACK OF DATA

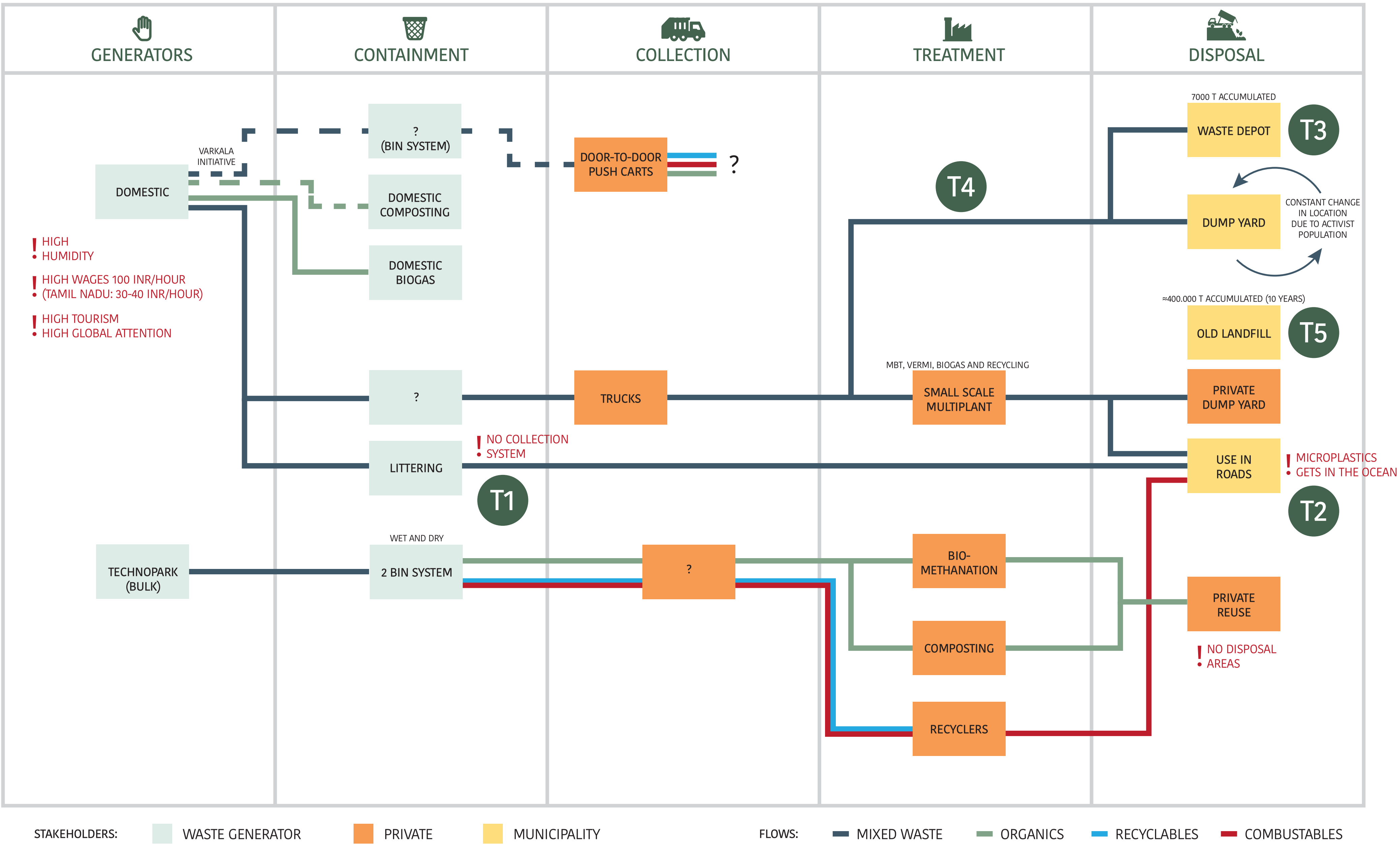
Trivandrum doesn't currently treat their waste at any large scale facility. This provides a need, and an opportunity, for processing mixed waste.

T5 ACCUMULATED WASTE IN VILAPPILSALA

LACK OF DATA

From 2000-2011 a processing plant with a 90 TPD capacity was operating in Vilappilsala on 46 acres. However it received around 200 TPD (with more than 50% biodegradable matter), which resulted in a large accumulation of waste until the plant was closed in 2011. The opportunity lies in the large quantity of ressources currently lying still in the city Vilappilsala.

Sum up: Trivandrum




03

Opportunity evaluation

The third phase of the project was the opportunity evaluation. This phase had the purpose of evaluating the framed opportunities in two aspects, firstly the economic feasibility related to the operation and secondly the strength of the contextual setting. These two steps functioned as stage gates that screened unpromising opportunities and narrowed the opportunity pool down to one final business case.

These two evaluations will be highlighted in this chapter describing the purpose, selected criteria, the underlying assumptions and finally the results.

3.1 Simulation of economical feasibility

The economical feasibility is a common method used in causal reasoning to evaluate the potential of a new venture (Sarasvathy 2008; cited by Batley & Omarsson 2014). The simulation had the purpose of dismissing unfeasible opportunities with a requirement of a pay back period point after one year. This threshold value is based on the aim of creating a pilot project that can be scaled after a low cost adaption phase.

The economical simulation is based on the cost and revenue of operating a pyrolysis business. It has been divided into four phases that combined summarize the total operational cost. Each phase represents various machinery and activities that are required in some opportunities but not in others. The estimates of cost and properties of this machinery are based on existing offerings of machinery and labor in India, see *WS 15: Preparation machinery specifications*. The total operational costs of these activities are balanced with an estimation of the potential revenue based on a specified feedstock. The costs and revenues that the simulation encapsulates is illustrated in Figure 13 and further elaborated in *WS 16: Simulation of economical feasibility* where the calculation process is described.

The values assigned to each opportunity are based on data from the fieldwork, observations and comparison to similar cases. The specific assumptions for estimating the different criteria will be described in the following sections. It is however important to mention that an "at-least-principle" has been used throughout the estimations which means that, when in doubt, the worst case scenario has been chosen.

feedstock characteristics

Calorific value

The calorific value is a key parameter for WTE projects, but can be difficult to estimate for heterogeneous feedstock. The estimations used in the simulations are based on a qualitative evaluation of the composition but with respect to the table values for different types of plastics, fiber rich organics, etc. When available, the estimations have been based on sources affiliated with each opportunity.

Composition

The composition of the feedstock can be divided into various fractions dependent on the purpose. In this case, the relevant categories have been set to combustibles, recyclables and organics and is used to assist the evaluation of the calorific value and the assessment of required preparation machinery.

The inert category is widely used in the literature but due to high uncertainty in its estimation it has been accounted for in the assessment of the calorific value. Combustibles define the category of waste which are suitable for pyrolysis and contains appropriate calorific values. It has also been estimated that the majority of the moisture content in the waste is represented in the organic fractions which means that the combustible part contains little water. The organics category covers mainly food waste with

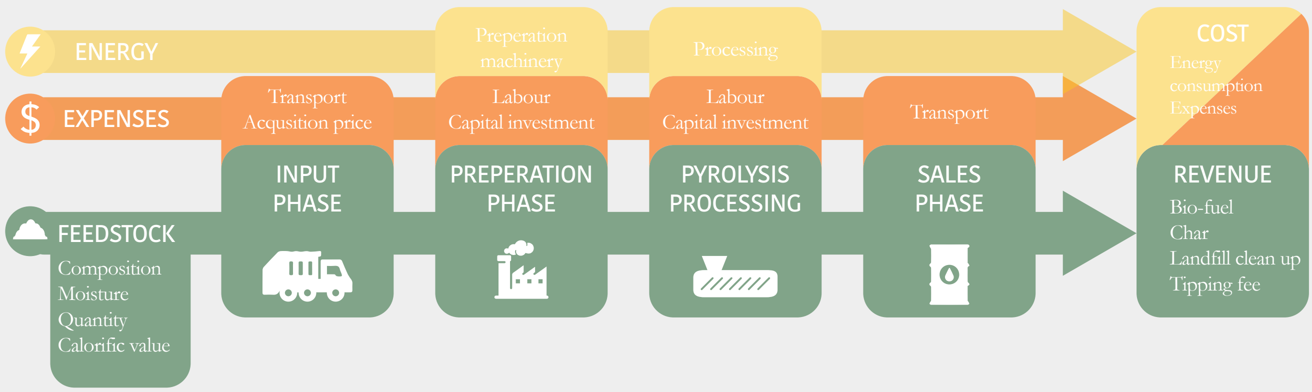


FIGURE 13: The simulation of the economical feasibility balances the operational cost with projected revenue from a oil production. This allow a predictive assessment of the potential.

low energy and high moisture content. The recyclable category is mainly used in the opportunities where the recyclable parts could be used for an alternative revenue stream.

Moisture

Moisture content is assumed to be represented in the organics, which means that a segregation of organics will remove the majority of the moisture. The estimation of the moisture content has been based on the climate in the city, the fraction of organics and samples. The moisture content is used to estimate the total input when accounting for the loss of weight from drying.

Input

Transport

Transportation of feedstock is a cost that Malar 2017 and Sandhya (2017 claims to be underestimated and which represents the main restricting factor for the RDF market (Malar 2017). In this case, the transportation cost has been estimated based on the possibility of acquiring industrial land in close proximity to the waste source, the number of waste sources that needs collection and the amount of waste to be collected. The price has been estimated to approximately one DKK per ton per kilometer based on current logistic pricing in Coimbatore (Malar 2017).

Acquisition price

An obvious cost in the operation is the price of acquiring the feedstock. Some feedstocks represent a nuisance to the MBT plants and can therefore be acquired without cost, while others are produced for selling. The prices for RDF are based on statements from the MBT plants while other prices are estimated on current recycling prices - see *WS 16: Simulation of economical feasibility*.

preparation

Drying

In the case of a very high moisture level, sun drying of the feedstock might not be adequate and a drying mechanism would be needed. The physical parameters of the feedstock defines the best way to dry the material. This was however simplified to one drying mechanism - a rotary dryer (*WS 15: Preparation machinery specifications*). This was decided to promote simplicity in the calculation and with the argument that the cost of different drying mechanisms will not differ significantly.

Shredding

The heating rate of the pyrolysis process is correlated to the particle size and homogeneity of the feedstock, thus the heat rate increases as the particle size reduces. This requires a shredder in most cases but it is dependent on the characteristic of the source.

Segregation methods

A key activity of the feedstock preparation is segregating the useful fraction from the invaluable fractions. Depending on the feedstock this activity requires different thoroughness and machinery.

Manuel segregation

The low-tech method is to manually segregate the feedstock into the desirable fractions. This require a certain number of workers depending on the amount of feedstock accompanied by an appropriate number of conveyor belts to move the material past the workers.

Trommel screens

The core segregation practice at MBT plants is based on particle size screening using trommel screens with different mesh sizes. In this simulation, the required number and types of trommel screens has been based on the amount of mixed input, composition, the flow rates and segregation efficiency of the trommel screens.

Air density separator

While the trommel screen method is based on particle size, an air density separator segregates the fractions based on density. The method is ideal for separating the low density plastic fractions from mixed waste streams. The separation limit can be controlled by adjusting the speed and power of the air flow.

Excavator

Handling large quantities of waste inevitable leads to moving tons of mass. In reality this requires one or several excavators to transport the waste around the premises. The size and amount of the excavator is based on the amount of waste that is being processed.

Conveyor belt

In order to optimize the production line the facility would need conveyor belts to transport the waste between machinery. The appropriate number of conveyor belts is dependent on the number of machines needed for operation.

pyrolysis

System capacity

The capacity of the pyrolysis has been set to 15 TPD to enable a fair comparison of the different opportunities in the same scale. Furthermore, a 15 TPD reactor is considered to be a suitable capacity for a pilot launch.

Operational specifications

The pyrolysis treatment parameters are estimated in collaboration with Chakravarty (2017). In comparison to the literature, the values are set lower than other reported efficiencies (*WS 8: Pyrolysis operations*).

sales

Distribution

The sales phase has not been investigated in depth at this point. It has however been validated that the market for biofuels is present and reliable in India (Chakravarty 2017). The sales phase does thereby not differentiate across the opportunities and are allocated a common distribution cost for the end product. The distribution distance of the biofuel have been set to 100 km in order to promote a more realistic output for the calculations.

3.1.1 Economical feasible opportunities

The opportunities that passed the screening is illustrated in Figure 15 while the result boxes elaborates on the specific calculations. The remaining simulations and the detailed calculation are illustrated in *WS 17: Simulation results*. The threshold value is, as mentioned before, set to a pay back period on one year since the opportunity should be suitable as a pilot launch. Longer break-evens can be relevant in a long term strategy if the economical profile appears appealing. This will, however, not be further discussed here. To review a recap of the opportunities please return to section: *2.2 Case studies*.

FIGURE 14: The simulation of economical feasibility was used as a stage gate to dismiss unpromising opportunities.

B5 REJECTS FROM DODDABIRADAKULLA

Feedstock: Combustables (mainly high fibre organics/ low value plastics) Segregation: Air density seperator and shredder.

Waste amount (wet): 60 TPD	Combustables: 70%	Moisture: 30%
System capacity (wet): 21.5 TPD	Organics: 30%	Transport: 20 km/day
Calorific value (dry): 2200 kcal/kg	Recyclables: -	Price: -

Total cost	**613,000 kr.**	**Total revenue**	**kr.**	**1,270,000**
Total investment	**670,000 kr.**	**Operating margin**		**52%**
Operating profit	**657,000 kr.**	**Pay back period [years]**		**1.02**

C1 NO DUMPING - DOMESTIC COLLECTION

Feedstock: High fiber organics/ low value plastics Segregation: Air density seperator and shredder.

Waste amount (wet): 360 kg/day	Combustables: 100%	Moisture: 15%
System capacity (wet): 16 TPD	Organics: -	Transport: -
Calorific value (dry): 3000 kcal/kg	Recyclables: -	Price: 100 DKK/ton

Total cost	**1,047,000 kr.**	**Total revenue**	**kr.**	**1,990,000**
Total investment	**670,000 kr.**	**Operating margin**		**47%**
Operating profit	**943,000 kr.**	**Pay back period [years]**		**0.71**

C3 RDF FROM MBT - VELLALORE

Feedstock: RDF (mixed). Segregation: Air density seperator and shredder.

Waste amount (wet): 200 TPD	Combustables: 100%	Moisture: 20%
System capacity (wet): 17 TPD	Organics: -	Transport: 5 km/day
Calorific value (dry): 2500 kcal/kg	Recyclables: -	Price: 35 DKK/Ton

Total cost	**794,000 kr.**	**Total revenue**	**kr.**	**1,537,000**
Total investment	**680,000 kr.**	**Operating margin**		**48%**
Operating profit	**743,000 kr.**	**Pay back period [years]**		**0.91**

C5 CLEAN UP VELLALORE LANDFILL

Feedstock: Mixed waste. Segregation: Trommel screens, air density seperator and shredder.

Waste amount (wet): 500,000 T	Combustables: 50%	Moisture: 35%
System capacity (wet): 17.2 TPD	Organics: 50%	Transport: -
Calorific value (dry): 2450 kcal/kg	Recyclables: -	Price: -

Total cost	**507,000 kr.**	**Total revenue**	**kr.**	**1,492,000**
Total investment	**980,000 kr.**	**Operating margin**		**66%**
Operating profit	**985,000 kr.**	**Pay back period [years]**		**0.99**

C4 REJECTS FROM MBT - VELLALORE

Feedstock: High fibre organics and low value plastics. Segregation: Air density seperator and shredder.

Waste amount (wet): 200 TPD	Combustables: 100%	Moisture: 10%
System capacity (wet): 15 TPD	Organics: -	Transport: 5km/day
Calorific value (dry): 2500 kcal/kg	Recyclables: -	Price: -

Total cost	**614,000 kr.**	**Total revenue**	**kr.**	**1,537,000**
Total investment	**680,000 kr.**	**Operating margin**		**60%**
Operating profit	**924,000 kr.**	**Pay back period [years]**		**0.74**

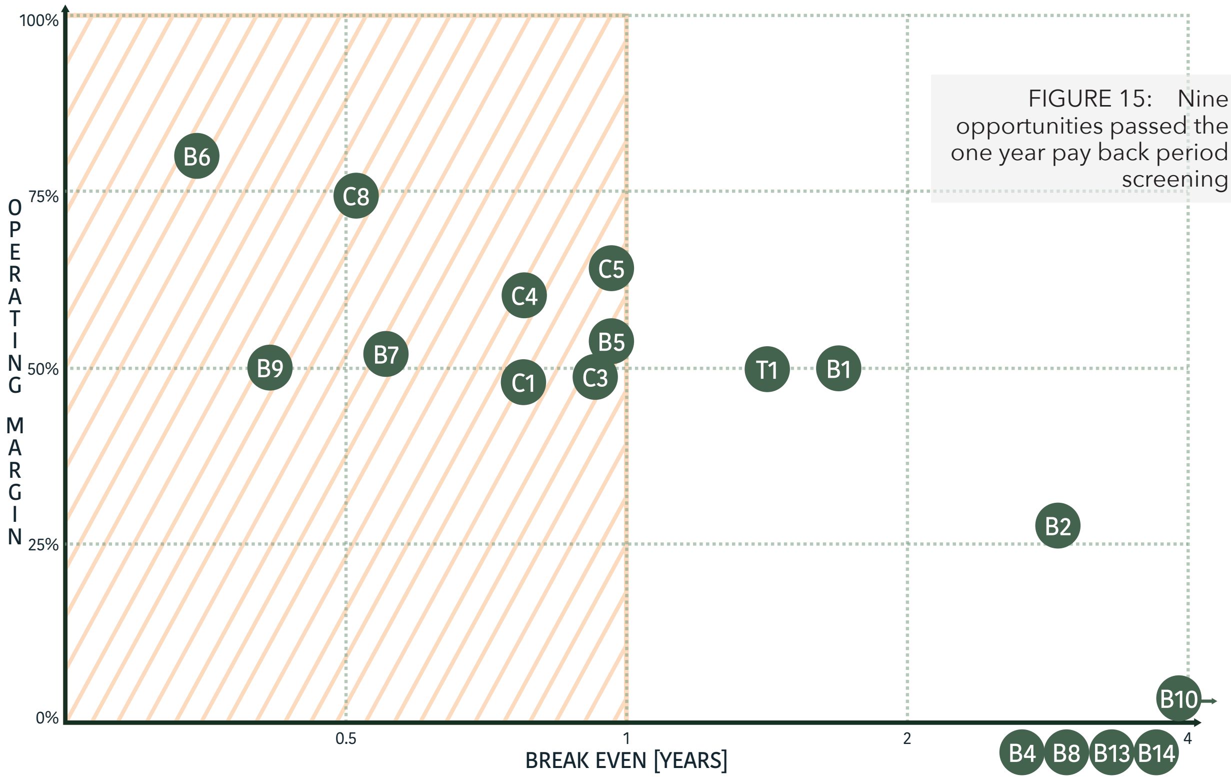


FIGURE 15: Nine opportunities passed the one year pay back period screening

B7 18.000 TON RDF DEPOT

Feedstock: RDF (clean)/ low value plastics. Segregation: Air density seperator and shredder.

Waste amount (wet): 18.000 T	Combustables: 100%	Moisture: 10%
System capacity (wet): 15 TPD	Organics: -	Transport: -
Calorific value (dry): 4000 kcal/kg	Recyclables: -	Price: -

Total cost	**872,000 kr.**	**Total revenue**	**kr. 1,989,000**
Total investment	**670,000 kr.**	**Operating margin**	**56%**
Operating profit	**1,117,000 kr.**	**Pay back period [years]**	**0.60**

B6 RDF FROM DODDABIRADAKULLA

Feedstock: RDF (clean)/ low value plastics. Segregation: Shredder.

Waste amount (wet): 20 TPD	Combustables: 100%	Moisture: 10%
System capacity (wet): 15 TPD	Organics: -	Transport: 20 km/day
Calorific value (dry): 4000 kcal/kg	Recyclables: -	Price: -

Total cost	**616,000 kr.**	**Total revenue**	**kr. 2,892,000**
Total investment	**570,000 kr.**	**Operating margin**	**79%**
Operating profit	**2,276,000 kr.**	**Pay back period [years]**	**0.25**

B9 DRY WASTE COLLECTION CENTERS

Feedstock: Low value plastics. Segregation: Shredder.

Waste amount (wet): 56 TPD	Combustables: 100%	Moisture: 10%
System capacity (wet): 15 TPD	Organics: -	Transport: 100 km/day
Calorific value (dry): 4000 kcal/kg	Recyclables: -	Price: 100 DKK/Ton

Total cost	**1,437,000 kr.**	**Total revenue**	**kr. 2,892,000**
Total investment	**570,000 kr.**	**Operating margin**	**50%**
Operating profit	**1,455,000 kr.**	**Pay back period [years]**	**0.39**

C8 ANIMAL WASTE

Feedstock: Organics. Segregation: Rotary dryer and shredder.

Waste amount (wet): 5-10 TPD	Combustables: -	Moisture: 40%
System capacity (wet): 5 TPD	Organics: 100%	Transport: 20 km/day
Calorific value (dry): 2950 kcal/kg	Recyclables: -	Price: -650 DKK/ton

Total cost	**359,000 kr.**	**Total revenue**	**kr. 1,445,000**
Total investment	**580,000 kr.**	**Operating margin**	**75%**
Operating profit	**1,087,000 kr.**	**Pay back period [years]**	**0.53**

3.2 Contextual evaluation

The simulation of the economical feasibility functioned as the predictive evaluation of the various opportunities with the aim of assessing the more certain parameters. This is, however, not solely sufficient since the contextual environment in a developing country represents a high degree of uncertainty. This creates the need for a qualitative evaluation of opportunities based on specific contextual criteria. It is argued that this approach is more critical to evaluate due to the fact that it is superior in answering the question: How certain are we to succeed?

The selection of specific criteria that facilitated the evaluation will be further elaborated after the analysis of relevant contact persons in India have been presented.

3.2.1 Credibility/influence analysis

Interaction with a breadth of stakeholders is inevitable when establishing a new venture. But how does one know who can be trusted, who has the means to improve the business and who should be avoided? Throughout the fieldwork, various stakeholders have been engaged in the identification and exploration of new business ventures. However, not all of them pose equal potential influence for the further development and not all stakeholders have equal credibility. It has therefore been necessary to evaluate the stakeholder network on the parameters of credibility and influence. C*redibility* encapsulates the characteristics of professionalism, consistency in their communication, personal connection and personal visions. The parameter *influence* includes the width of their network, power and practical control. Relevant stakeholders from the fieldwork have been rated on these two axis in order to evaluate their true potential. The result is presented in Figure 16 and assisted the later evaluation of certain contextual criteria.

The stakeholders are mapped individually but most of them represent a bigger organization in the form of a municipality, a private company or similar – stakeholder groupings that has been examined in section: *1.4.3 Key stakeholders and potential partnerships*. These organizations can have agendas and structures that inevitably influence the individual stakeholder. This aspect is evaluated as a degree of entanglement which describes on which level a given person is reliant to other stakeholders and their incentives. It is an important aspect of the opportunity evaluation and has therefore been formulated as one of the contextual criteria which will be described in section: *3.2.2 Contextual criteria*.

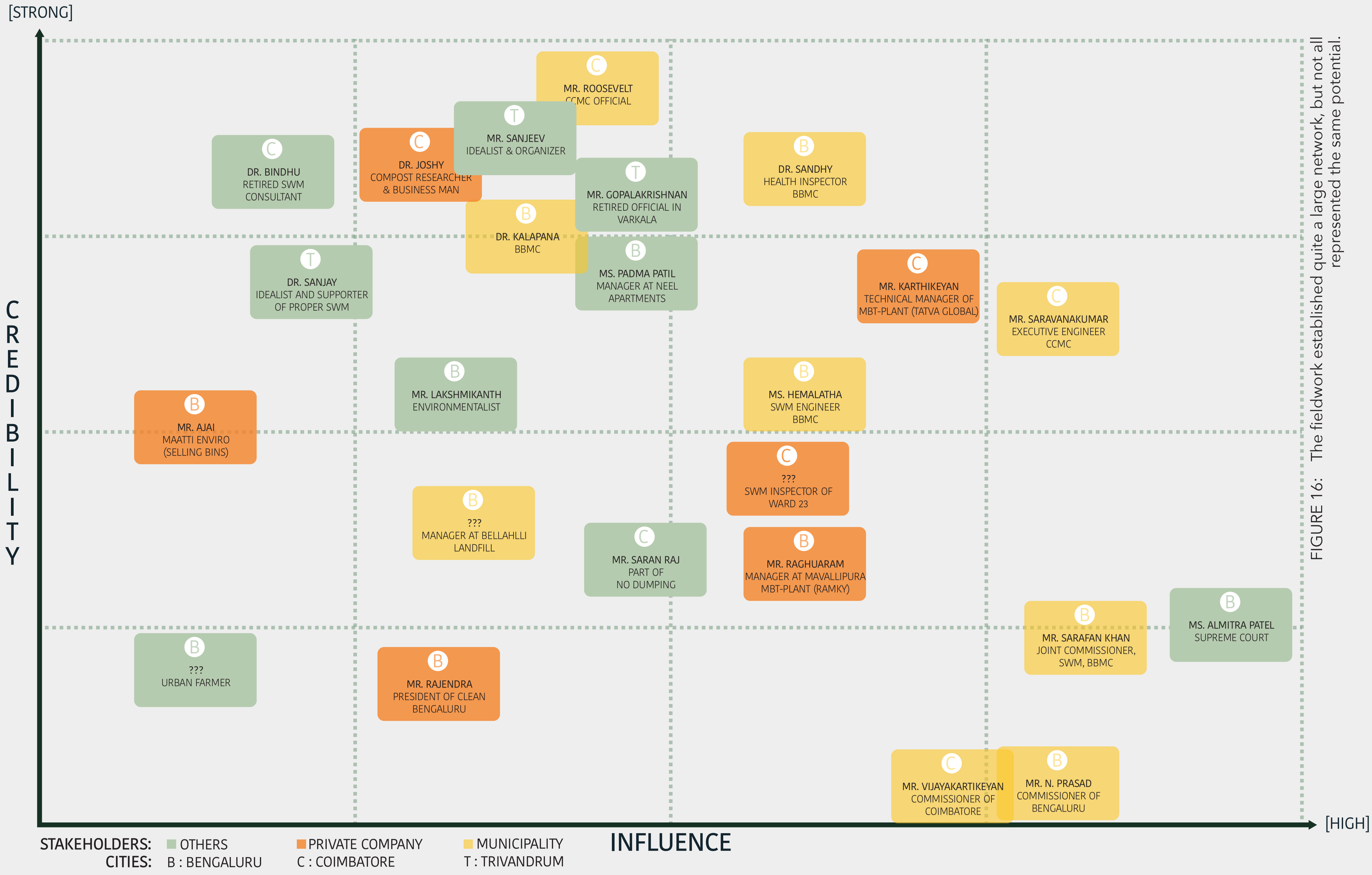


FIGURE 16: The fieldwork established quite a large network, but not all represented the same potential.

3.2.2 Contextual criteria

Evaluating business opportunities on contextual criteria assist the transparency of qualitative decision making. The following sections aim to describe each contextual criteria and the parameters that it covers. The rating tool is illustrated in Figure 17.

NETWORK STRENGTH

This criteria aims to evaluate the size and influence of the network related to a specific opportunity. More specifically, it is targeting the number of influential people that are possible to exploit or reach.

COMPETITION

This criteria aims to articulate the level of competitive rivalry that exists in the context of where the business opportunity exists. The evaluation is based on Porter's five forces (Porter 2008) and targets the threat of substitution from other companies and organizations.

SPAN OF FOCUS AREA

The "bird in hand principle" states that one should "do what you know". This could also be interpreted as "don't do what you don't know" (WS ?? Effectual theory and principles). This criteria aims to articulate that a business opportunity should not embrace too large a spectrum of tasks but rather focus on one core element, especially when launching a start-up.

FEEDSTOCK SCALABILITY

The amount of feedstock available is an obvious limitation to the scale of the business. The purpose of the criteria is to evaluate the limit of the business opportunity. This is a measurable criteria and it thereby differs from the other contextual criteria. It was kept out of the economical simulation in order to have a fair comparison of the opportunity potential based on similar scales of operation.

FEEDSTOCK HOMEGENEITY

The feedstock is a vital element of this business. It is also an element with a high amount of uncertainty. It is, therefore, important to evaluate business opportunities based on the homogeneity of the proposed feedstock as well as the level of certainty of the estimation.

PERSONAL RELATION

Another important parameter of a successful business venture is the connection to the people involved or, in other words, the trust and credibility of these people. This has already been evaluated in the stakeholder analysis where the articulated parameters were professionalism, consistency in communication, personal connection and personal visions.

ALIGNMENT WITH CURRENT STRATEGIES

The MSW system in each of the different cities are heading in a specific direction which is critical to take in to account when launching a new business. This criteria compares the alignment of the business opportunity with the current development direction in order to evaluate and articulate potential incentive and stakeholder clashes.

FIGURE 17: The contextual criteria and rating tool are used to evaluate the contextual strength of new business ventures

PARTNERS INCENTIVES

A key element of establishing a successful partnership is the balance of contributing value creation across the partners. This criteria seeks to ensure that a future partnership has a solid foundation based on equal value creation.

ENTANGLEMENT

Large stakeholder entanglement, as mentioned in the end of section *3.2.1 Credibility/influence analysis*, can affect an opportunity in numerious unpredictable ways. This criteria aims to capture this issue by articulating the number of affected stakeholders, the alignment of their agendas, and their incentives.

IMPLEMENTATION TIME/BUREAUCRACY

When launching a proof of concept strategy it important to achieve results as quickly as possible. This also means that you will want to limit the time and energy spent on non-value adding activities e.g. applications, approvals, etc. The amount of control one has over such activities is thus important (Pilot-in-the-plane: WS ?? Effectual theory and principles) which puts time consuming bureaucracy as a negative element in a successful partnership.

3.2.3 Results of the contextual evaluation

The following spiderwebs represent the results from a rating that facilitated a discussion of each opportunity's contextual potential. The reasoning behind the scores is described in *WS 18: Contextual evaluation results*.

B5 - REJECTS FROM DODDABIRADAKULLA

B6 - RDF FROM DODDABIRADAKULLA

B7 - 18,000 T RDF DEPOT

B9 - DRY WASTE COLLECTION CENTERS

C8 - ANIMAL WASTE

C1 - NO DUMPING - DOMESTIC COLLECTION

C4 - REJECTS FROM VELLALORE

C5 - CLEAN UP LANDFILL VELLALORE

C3 - RDF FROM VELLALORE

3.3 Final selection

The contextual evaluation articulated the necessary discussion to select a final business opportunity. The choice fell on a combination of pursuing the RDF and reject fractions from the MBT plant in Vellalore, Coimbatore - C3 and C4. It was evaluated to be the opportunity with the largest potential to succeed as the contextual parameters outperformed the others. The personal relationship established with the contact at Tatva Global is very high and it is a business opportunity that targets the processing of a segregated feedstock which enabled the focus on one core activity - the pyrolysis processing. Finally, Tatva Global is a private company which reduces both the implementation time and the degree of entanglement compared to collaborating with a municipality.

This opportunity will be brought forward into the detailing phase where the assumptions of former evaluations will be tested while the business concept is being developed and detailed.


04

Detailing

The detailing phase had the purpose of taking the business opportuntity to the next level. The potential of the opportunity had to be validated by justifying the market, supplier, competitors and advantageous. It furthermore had to transform the idea into a concrete action plan that targets a long term vision and expansion plan. This chapter will start out by elaborating on the situation in Coimbatore, relevant stakeholders, justify the suppliers market and descibe the specfic business idea. It will be followed by an examination of the market for pyrolysis outputs and a conceptualization of a 1. Pin strategy. The chapter will finally present an action plan that describes the concrete steps to take which is supported by a financial overview that elaborate on the economical potential and the most significant risks.

4.1 The business opportunity in Coimbatore

Coimbatore were evaluated to represent the opportunity with the largest contextual potential to succeed. It is a relatively small city compared to the rest of India with a population of 1 million people (Census 2011a). This size promotes a more stable and less "crowded" MSW system since there is only one processing stakeholder in the city, Tatva Global. Additionally, it is a city where the municipality has realized the immediacy of the inefficient MSW system and they are actively working to minimize the consequences on a daily basis. This means that Coimbatore is not blindfolded by an ideal solution with a 10 year perspective and they are initiating action that is immediately moving the situation forward. This behavior implies that there will be an easier adoption and integration phase with a new business.

The selected opportunity targets bi-products from the MBT plant in Vellalore. It is a plant that process 500 tons of mixed waste daily with a large fraction of rejects and RDF. The exact procedure of the plant is illustrated in Figure 18.

The plant is located in the outskirts of Coimbatore in a designated area for MSW processing and dumping. It is supported by a small vermi-compost facility that on paper is treating the clean organic fraction from the city - the pureness of the feedstock is however questionable. The MBT plant is located with a mixed waste dump site on one side of the plant and a landfill dedicated for MBT rejects on the other. The total premise is spread out on 650 acres of land (Krishnan 2015) which implies the possibility of leasing part of the land for a future processing facility.

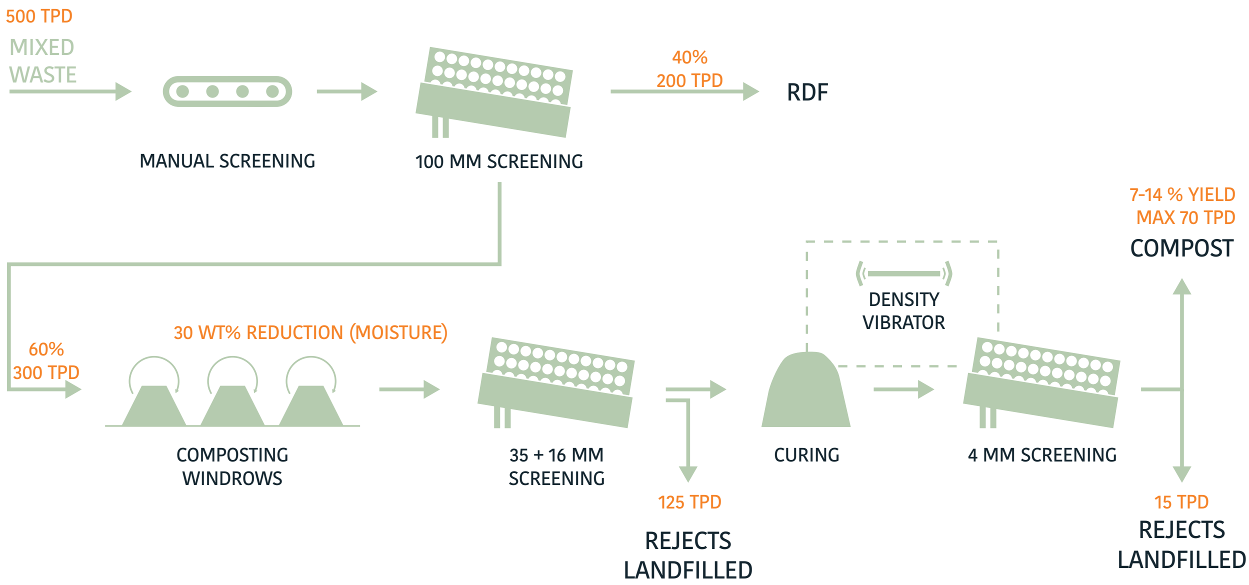


FIGURE 18: Tatva Global is experincing a pain in terms of handling large quantities of material from which they get no value. This pain can be turned into a new revenue stream if combined with a pyrolysis technology.

SOURCE: PRIVATE - END OF LIFE PLASTIC FROM THE MBT PLANT IN VELLALORE, COIMBATORE

4.1.1 Supplier profile - Tatva Global

Tatva Global is one of the largest MSW companies in India and it offers activities in all stages of the MSW system (collection, treatment, disposal etc.). They have nine operating subsidiary companies that mainly operate in the Southern part of India. One of them is located in Coimbatore where they are tendered to treat mixed waste with a financial structure based on tipping fees, subsidies from producing compost and the sale of compost. They are collaborating with a global distributor and producer of fertilizer which emphasizes that their core activity is composting (Malar 2017).

Furthermore, Tatva Global is a company with foreign business connections in Germany and Japan (Tatva Global 2017). A fact, that implies an optimistic perspective on international collaborations and that Tatva Global prefers to outsource specific activities that are not within their field of expertise. This impression is supported by the technical manager's interest in delivering RDF to a future project (Malar 2017). Karthikeyan Malar is the name of the technical manager of the plant. He is in his mid-30s and expressed competence as he explained the processing steps of the plant. He avoided sugarcoating the truth when touring the plant and appeared honest as he pointed out the imperfections of the facility. He has worked with Tatva Global for two years and has been in-charge of two plants in Bengaluru and now Coimbatore. Karthikeyan Malar is perceived to be a reliable and trustworthy contact person but this is mainly based on a gut felling that needs to be tested and validated.

Testing Tatva Global

Tatva Global has already proven to be cooperative since they have supplied a 500 kg sample. They have thus already climbed the first step of the validation ladder. Karthikeyan Malar responded quickly and arranged the pick-up in a few days. This illustrates a promising behavior in the social part of the business and implies that the contextual evaluation was valid. It pre-validates Tatva Global but their consistency in delivering still needs to be verified. The process for this verification will be described in the section: *4.4 Action plan*.

It is however not only the contextual part of the business that needs validation as this only fulfills half of the requirements. The quality of the feedstock needs to be in the appropriate range to ensure the suitability for pyrolysis. This test was initiated by testing a 500kg sample of the RDF in a lab in Chennai, but the results are unfortunately not available yet.

Market for RDF and rejects

The selected opportunity is targeting the bi-products, rejects and RDF, from the MBT plant in Vellalore. RDF is the most suitable for direct use and is by principle considered a valuable resource due to its high calorific value. There is currently a lack of market demand which is mainly due to the absence of RDF applicable facilities (WTE plant) and the price advantage of coal in India. The lack of demand has resulted in large accumulations of the RDF which represents a serious problem. Malar (2017) and Sardar (2017) both reported incidents of RDF depots catching fire which emphasized the risk and increased their willingness to get rid of the material. A combination of the fire risk and lacking demand has ducked the prices on RDF from around 950-5000 INR/ton (Mytty 2015) to less than 500 INR/ton (Malar 2017; Shyam 2017).

These aspects makes RDF an unexploited market that is waiting for a first mover. The widespread existence of MBT plants also makes it a scalable opportunity that exceeds the boundaries of Coimbatore.

Coimbatore

Coimbatore produces approximately 800 TPD of MSW, out of which Tatva Global processes 500. This represent a RDF production of 200 TPD by the estimate of Malar (2017). The RDF in Coimbatore consist of low value plastic, fiber rich organics and unknowns - a conservative estimate would put at least 25%wt in the plastic fraction. This fraction would be ideal for launching a pilot project as it has a high calorific value with a relatively homogeneous composition. In other words it has the potential of enabling a simple pyrolysis process that returns a good output product (Chen et. al. 2014). When succeeding with a pure plastic source, the focus can be shifted towards incorporating the organic fraction.

The 200 TPD of RDF allows to scale the business to a proper size plant after proofing the concept in the pilot launch. In comparison, Pyrocrat's (producer of pyrolysis reactors) largest plastic-to-energy reactor has a capacity of 48 TPD (Pyrocrat), which indicates that 200 TPD is quite a large capacity. It should further be noted that RDF does not represent the only valuable bi-product of the MBT plant. About 40% of the input ends up as rejects from the 35 and 16mm screening which currently is being landfilled. This fraction could potentially increase the amount of available feedstock, which is supported by Malar (2017) who estimated the rejects to contain around 4000 kcal/kg. This number has to be assessed critically and needs to be tested.

In addition, it should be noted that Coimbatore has a dry climate which removes the need for drying machinery.

National RDF projection

MBT plants are the most widespread waste processing method in India. It was earlier suggested that around 6% of the total generation is channeled through a MBT treatment (Annepu 2012). This number might however be outdated since it would conclude that India as a nation only produces 3,000 TPD of RDF while the cities Bengaluru, Coimbatore and Hyderabad alone are responsible for 2400 TPD. Regardless of the exact number, they both implies that the business is expandable in a national perspective. In extension it should be noted that the MBT plant in Doddabiradakallu, Bengaluru would be an obvious place to initiate the expansion since this place is already segregating the end-of-life plastics.

Future RDF market

Former behavior in the Indian MSW system illustrates a high failure rate of new initiatives and unfulfilled strategies (The Standing Committee of Energy 2016; Yedla 2016; Annepu 2012). Retrospectively, that implies that the amount of RDF will increase corresponding to the projections of the waste generation as the improvements of the system would be limited. Section: *1.1 Introduction to India's MSW problem* suggest that the waste will quadruple in 2051 (Joshi & Ahmed 2016) which is equivalent to a production of 68,000T of RDF daily.

That being said, the situation is not that simple. It would be naive to neglect the current changes that point towards increased segregation, de-centralized MSWM and banning of certain packaging (Johnston 2017). This will affect the quantity and composition of the waste streams that end up at MBT plants over time and emphasizes why a future business should adapt to a different waste stream. This should preferably be renewable residues which align with long-term national strategies for MSWM.

4.1.2 The business idea

This business idea aims to recover energy from the unexploited RDF that is currently accumulating in large depots at the MBT plant in Vellalore, Coimbatore. The RDF is lacking market demand as it is outperformed by coal which is more consistent and cheaper. It is, however, believed that it can be turned into a feasible business with the use of pyrolysis technology. This is supported by the presumption that the RDF exceeds the energy limit of 2400 kcal/kg that indicates it is a feedstock suitable for WTE technology. The exact value is currently being tested in a lab in Chennai for a final confirmation, but Malar (2017) estimated it to be above 3000 kcal/kg.

RDF is currently traded like a commodity in Coimbatore with a price tag of 350 INR/ton (approximately 35 DKK/ton). The revenue for this business idea is based on the sale of crude oil which is a reliable commodity with a large market and a global technological momentum that ensures a continuous demand.

Pyrolysis detailing

It has formerly been illustrated that pyrolysis is divided into three different types of reactors with ranging parameters - see section: *1.9.1 Principle of pyrolysis*. Three types of pyrolysis is however not equivalent to three different designs of pyrolysis reactors. Various designs have been proposed in the field with the aim of achieving certain parameter values that makes them appropriate for specific feedstocks - see *WS 19: Pyrolysis designs*. This business case is targeting a heterogeneous feedstock which makes the selection of an optimal design difficult.

The business case is targeting oil as the preferred output but this could change during the testing phase if the components of the feedstock are more ideal for gas production. It is, however, a common characteristic that a high heating rate should be achieved in order to facilitate the production of pyrolysis fuel over char (Li et al. 1999a,b; Yi 2007; Velghe et al. 2011; cited by Chen et. al. 2014). The distribution between the oil and gas products is determined by the residence time and cooling rate (Font et al. 1995a,b; cited by Chen et. al., 2014). These parameters imply the suitability of a flash pyrolysis reactor with an adjusted max temperature. This type of reactor will however not be the first step since the rotary kiln reactor is more widespread and it is available in the lab in Chennai where the 500 kg are tested. The rotary kiln reactor will function as a starting point to test the feedstock more continuously. The results from this testing will determine whether this design is suitable for the pilot launch or if it will be necessary to invest in a fluidized bed or micro wave reactor. These are two promising designs with high heating rates (Chen et. al. 2014) that, despite the results from the rotary kiln, should be researched as part of the business plan. To have a look at the mentioned design look up *WS 19: Pyrolysis designs*.

Another aspect of the specification of the technology targets the segregation of feedstock. The RDF is containing end-of-life plastic which if segregated would represents a homogeneous feedstock and simplify the pyrolysis processing. This would allow processing of the plastic and organic fraction separately and thereby achieving isolated results. The plastic fraction represents the largest energy source and could initially be prioritized in a pilot launch. This would allow the possibility to create immediate revenue while adapting to the organic fraction and optimizing the reactor for this composition.

4.2 Market for pyrolysis fuel

The customer profile of this business opportunity can in reality be a number of different stakeholders, but they do however share a common interest in purchasing fuels for e.g. transport, production, energy generation, etc. The oil market is a globally established venture with a large demand that almost guarantees a buyer. This is the main reason for the end customer not being of bigger concern and why the focus instead has been leaning towards the supplier to enhance the chance of success. The oil market is validated by the global oil price platforms that are presented by sources like Nasdac (2017) and ET Markets (2017). This is further supported by India currently being the third largest consumer of oil but well on its way to becoming the largest in the world (Domm 2017).

4.2.1 Customer profile

The specifics of a customer is unrealistic to determine at this stage since it is difficult to investigate outside of India. That does however not mean that it should not be discussed. The business seeks to establish a relationship with a single customer to decrease distribution costs and logistics planning. This is a goal that is well aligned with the fact that the pyrolysis needs refining which makes an oil refinery an obvious customer. If it were preferred to sell directly to the end-customer it would require larger investments and added team competencies to allow the refining in house. This is not suitable for a pilot launch since it is important at this stage to focus on the pyrolysis technology and reduce the risk that is associated with having more activities and features in the company.

Even though the oil quantity produced is small compared to the national consumption in India, this business idea has an advantage. India does not have oil reserves to meet their needs as they are only covering 22% of their domestic usage which makes them dependent on importing oil from other countries (Ashworth 2014). This presents an advantage because the business model can reduce distribution cost and thereby be more competitive on price. It should, however, not be neglected that there is an option for a favourable price when importing large quantities.

Kochi refineries is the closest refinery to Coimbatore and is approximately 190 km out of town (Bharat Petroleum). This will inevitably add a cost to the business which needs to be incorporated in the economical projection. It is a cost that could be removed over time, however, since it may be possible to move the refining in-house eventually. This would allow the engagement of Petronet, an oil distributor located just outside Coimbatore, which manages a large network of oil pipes with connections in Tamil Nadu and Kerala (Petronet CCK Limited).

The exact implications of these considerations will be pushed to the testing phase of the implementation and thereby not further investigated in this report. The business development will instead focus on Tatva Global and how their needs and challenges can be fulfilled. It is determined that the suppliers and the system around them are of highest priority in this kind of venture. The value proposition should be considered with respect to the “service” that is delivered to Tatva Global, instead of the actual sale of oil.

4.3 The business strategy – 1. Pin

The launching of the business should be initiated with a pilot project. This has been a recurrent aspect of the project as it enables a smoother and smaller start-up that makes it possible to adapt to contingencies. It is now time to think beyond the initial pilot stage in order to align the launching activities with a future business strategy. The future strategy has revolved around creating a robust business, which means that incentives, involvement, competencies, gain and risk should be balanced between the relevant stakeholders.

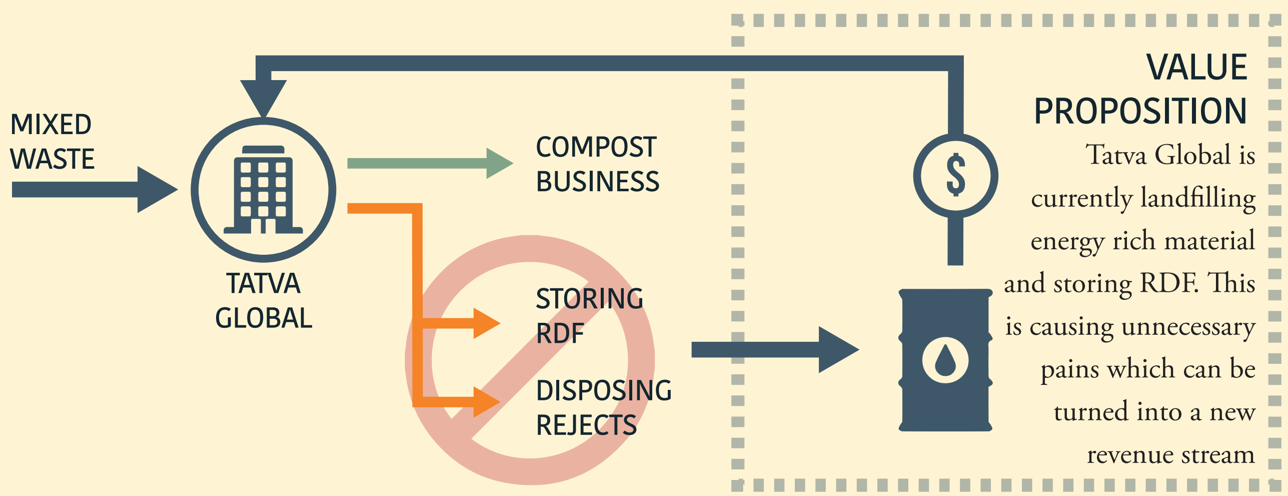
The business development settled on a shared revenue structure that targets Tatva global as a strategic partner. They will be allocated the task of preparing the feedstock which exploits their expertise and does not require any further investment as they already have the required machinery. This start-up company will focus on the pyrolysis processing and thereby ensure the opportunity to leverage their core competency. This way of allocating the activities aligns the incentives to increase the revenue which enhances the quality of the RDF and discourages Tatva Global from initiating a project on their own. The business concept will strive over time to adapt the pyrolysis reactor to the contaminated rejects from the MBT plant that currently is being landfilled. This will lower the operational cost for Tatva Global further and thereby improve the partnership.

The described business structure is defined as a 1. pin business model and will be elaborated in the following sections. The 1. pin strategy was selected from a pool of different business concepts which is illustrated in *WS 20: Business Model Canvas*.

4.3.1 Value proposition

The value proposition in this business concept focuses on the ability of transforming RDF and contaminated rejects into oil. This ability is especially valuable for Tatva Global as they are struggling to get rid of these bi-products today. The processing will save Tatva Global the trouble of storing the RDF and landfilling the rejects as illustrated below. It will furthermore add a new revenue stream without any significant increased operational cost. The collaboration will improve Tatva Global's image by them having a higher processing efficiency.

The business model represents other value propositions but these are subsidiary to the above mentioned. It can, however, be argued, for example, that the minimized environmental impact is of value as it aligns with the Tatva Global's overall strategy and reputational goals.



4.3.2 Strategic partner

Tatva Global is considered to be the best strategic partner in Coimbatore. This is based on the fact that they are the producer of the targeted feedstock. Furthermore, they are a large player on the India MSWM market which in reality makes them a potential competitor if they are not engaged properly. This aspect is crucial to eliminate as it could destroy the foundation for the entire business. Their size and influence is, however, a clear advantage if a partnership is initiated. Tatva Global is already present across India and this can be exploited to expand the concept. They can also vouch for the value of the partnership which will make it easier to enter other cities and ventures.

A stable supplier is, however, not enough for a successful business case. The core team of this start-up is limited in their technological experience regarding pyrolysis processing which emphasized that this competence will have to be acquired from outside. This project was initiated in collaboration with the pyrolysis based company, Mash Biotech, which makes them ideal partners to assist with technological know-how and experience. It is intended that they should function as a permanent consulting organ in the firm with a focus on research and development. The financial structure for this arrangement is to be determined in the testing phase.

Tatva Global and MASH Biotech represent direct partners in this business concept but indirect partners should also be valued in order to increase the chance of success. It has formerly been established that the communities and local movements in Indian cities has a large influence on the practice and strategy. It is therefore important to incorporate this aspect into the business structure. This integration and approval from the public will be based on existing contacts. The plan is also to initiate a supporting program with the NGO, *No Dumping,* and support the investment in new equipment to improve the segregation efficiency of the city. This will promote the current strategy and accelerate the implementation rate of their program. Such a scheme will enhance the image of the start-up but at the same allow access to the low-value plastic that is segregated. Currently, the amount that is collected is too limited to base a business on, but as No Dumping expands so does the amount of low-value plastics.

4.3.3 Competition

Generally speaking, MSWM is no longer neglected in India. The awareness has increased over the past decade to the point that even though the WTE projects is progressing slow, it is expected that this area soon will accelerate. The projection is based on studies reporting an increasing calorific value in the MSW which will make WTE a feasible business (Sebastian & Alappat 2016). New WTE projects are most likely to be driven by existing MSW companies in India that will expand their business area which could involve adaption of pyrolysis technology. This implies that the expansion of this business should be executed relatively quickly after the first location is sustainably established. This is a threat that already is present in Coimbatore as it was recently discovered that Tatva Global has been given license to construct a Japanese-designed incineration plant. The plant is framed to target the deconstruction of MSW and with a capacity limited to 150 TPD. It is furthermore not a project that has been initiated yet. The impression from the technical manager implied that this was not going to happen anytime soon (Malar 2017). It is, however, raising a red flag and the risk should be accounted for when planning the projection of the operations in Coimbatore.

4.3.4 Competitive advantages

Pyrolysis is a technology that is flexible as it allows adaptations to different feedstocks with various outputs. This gives the business a slight advantage compared to other WTE technologies. Pyrolysis is, however, not a new technology and there is a risk of other companies implementing the same technology. This threat should be managed continuously but it is not likely to affect the launch in Coimbatore.

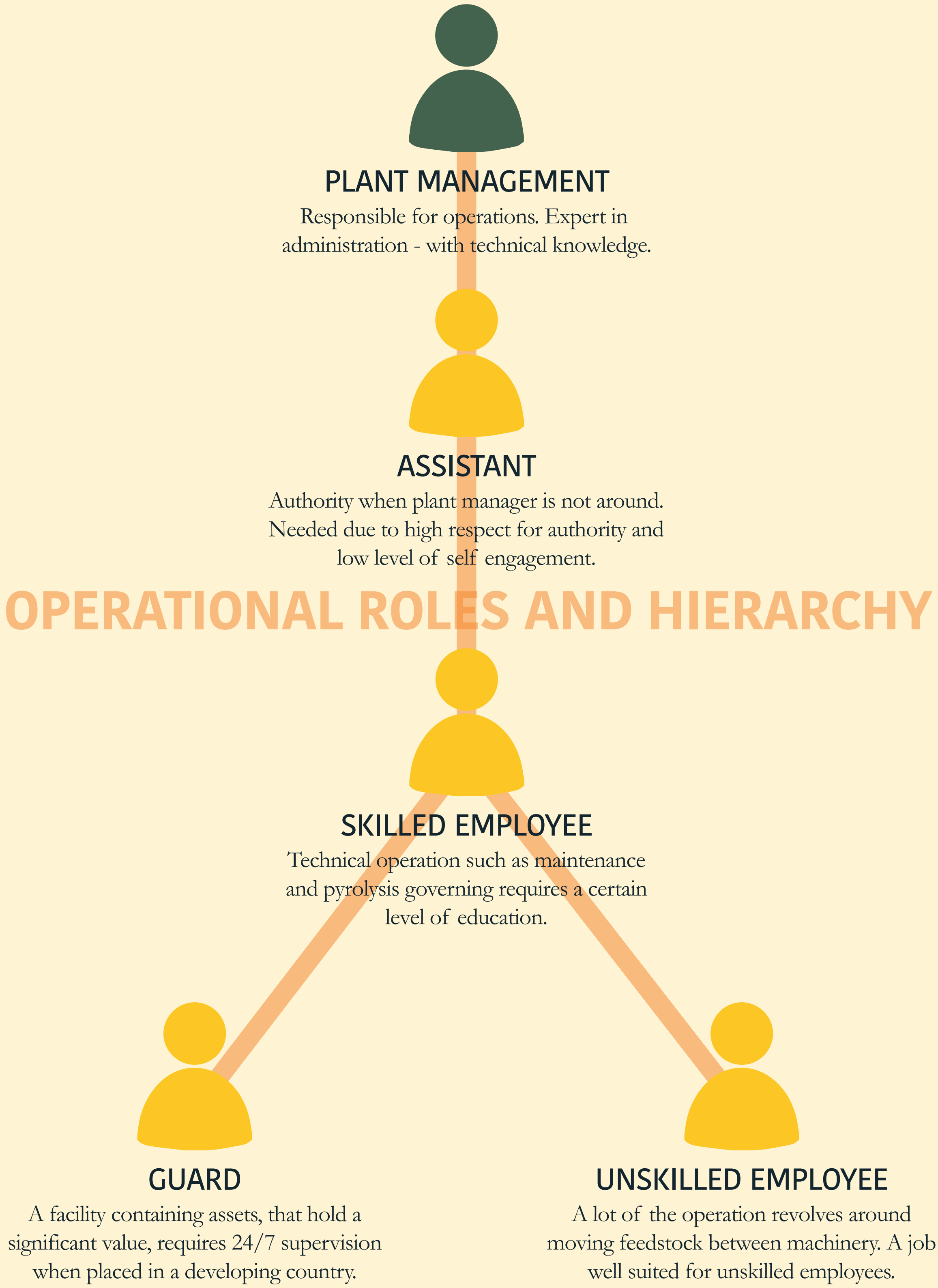


FIGURE 19: The pyrolysis business will require different skillsets when it is up an running. Most activites can be solved by unskilled employees but there is a need for a person with certain technical know-how.

4.4 Action plan

The 1. pin business strategy has at this point been described but has yet to be detailed in a execution plan. This section elaborates on exactly that as it goes through the needed competencies, how to test Tatva Global, the launching plan for the pilot project and the details of an expansion strategy. It will elaborate on which risks that should be kept in mind and how they can be managed.

4.4.1 Team

The team of a business in this venture will need to incorporate the appropriate interdisciplinary profiles to succeed. As for many start-ups the precise delegation of roles can vary and people can share responsibility. Figure 19 and 20 illustrates the hierarchy of the daily operation and categories where expertise is needed.

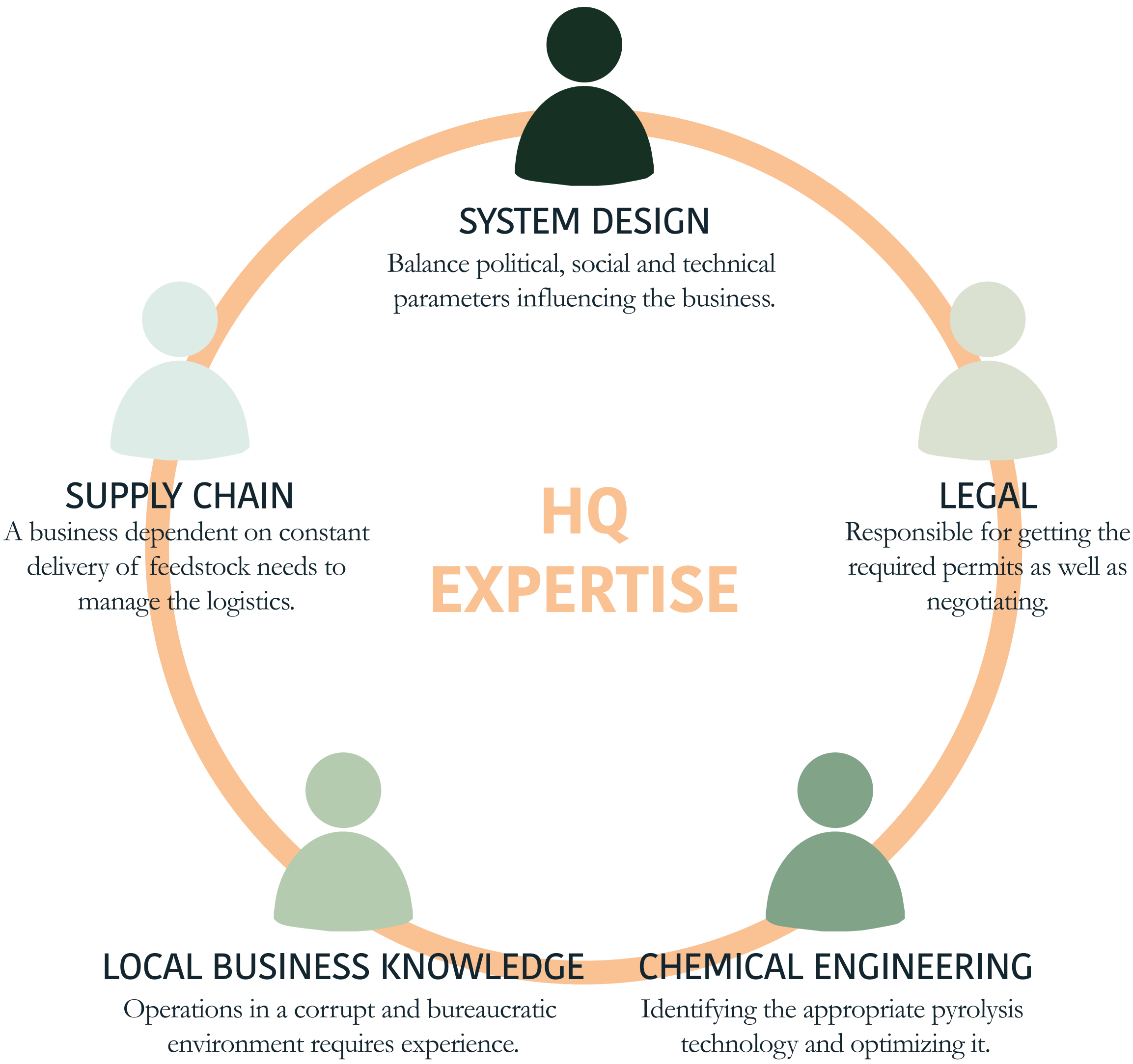


FIGURE 20: The existing team will require support and new competences in order to launch this business. This mainly concerns the technical expertise that is needed to setup and calibrate an pyrolysis reactor.

4.4.2 Implementation plan

The implementation plan strives towards a low cost business roll out and avoid all-or-nothing scenarios, such as large capital investments in an unproven setup. The plan furthermore aims to test and control uncertainties in different phases in order to validate the assumptions defining the business model. This approach ensures control of the business development as supported by the effectual principles: Pilot-the-plane and affordable loss (*WS 5: Effectual theory and principles*).

1. Test

The purpose of the testing phase is to eliminate uncertainties affiliated with the technology and the choice of Tatva Global as supplier/partner. Testing the feedstock and identifying the correct type of pyrolysis will be executed in collaboration with a third party, with expertise in pyrolysis. The test phase aims to determine a suitable reactor design for the feedstock together with an identification of the right operational parameters. It furthermore has to be investigated if Tatva Global can live up to the potential they were evaluated to represent. This will be validated by ordering several loads of RDF for pre-runs which will determine their true potential.

2. Pilot launch

After the test phase the project is ready for an initial launch constituting a small scale set-up in Coimbatore. This set-up will ensure that the operating parameters are correct and verify the cost structure before scaling. It will also initiate a small production of oil which can validate the calculated revenue stream. This phase revolves around practical activities such as acquisition/lease of land, solving the bureaucratic issues of setting up a company in India and getting the right permits for handling waste and producing oil. All these practicalities have to fall into place before scaling. The pilot launch will function as a proof of concept for the business but at the same time will allow for adjustments to various unforeseen contingencies. It will also support the establishment of a brand which will be essential for future expansion. This work will not be possible without an investment to allow the purchase of a small scale set-up which requires a reactor, air density separator and a shredder.

3. 1. Pin business strategy

This phase covers the business scaling and refers to the 1. pin of a bowling pin strategy (Dixon 2010). The 1. pin business model illustrates the operations that will be in focus over the coming years. The business model is based on a shared revenue with the purpose of involving Tatva Global in the business in order to promote a shared incentive. This phase will expand the waste treating capacity to 200 TPD as a part of the involvement of Tatva Global. An expansion that will require further investments in order to purchase a larger reactor. Other equipment should not be needed as Tatva Global takes over the preparation phase of the feedstock.

4. Expansion strategy

Once the business model, and full scale operation, has been verified it is time to expand. The complex environment and the unpredictable market increases the uncertainty of the exact actions at this point. The current strategy would be to use the leverage gained from a sustainable business to apply for an operation with the BBMP in Bangalore, where the RDF would be sourced from the MBT plant at Doddabiradakallu. It is, however, important to observe the changes in the environment and reflect upon whether or not other opportunities have become more feasible.

SEPTEMBER 2017

PHASE	ACTIVITY	FOCUS AREAS	
TEST	**EXTERNAL TESTING** Test the feedstock by involving 3rd party with expertise in pyrolysis technology.	**FEEDSTOCK/PYROLYSIS** · Which type of pyrolysis performs the best with the chosen feedstock? · Which operational parameters should be used? · What is the optimal output?	**PARTNER POTENTIAL** · Can they deliver the desired quantity and quality of feedstock? · Are the assumptions regarding personal relation and implementation time correct?

JANUARY 2018

PHASE	ACTIVITY	FOCUS AREAS	
PILOT PROJECT	**SETUP 15 TPD** Launch pilot project at site with an appropriate scalable capacity.	**PROOF OF BUSINESS** · Is the cost structure holding up with the estimates? · Does the revenue, and sales channels, match the expected? · Prove the potential of the business and establish a brand.	**PRACTICALITIES** · Are the practicalities regarding estbalishment of company in India in place? · Are the required permits in place?

SEPTEMBER 2018

PHASE	ACTIVITY	FOCUS AREAS
1.PIN	**TEST OF BM** Apply the *shared revenue* business model.	**BALANCE IN OPERATION** · Is there a match between incentives, rewards and share of operation?

JANUARY 2020

PHASE	ACTIVITY	FOCUS AREAS
EXPANSION	**NEW LOCATION** Use the bowling pin strategy to explore new opportunities.	**OBSERVE MARKET CHANGE** · How has the market changed? Is there still a demand for WTE? Are the previous opportunities still relevant? Has the proof of business presented new options?

FIGURE 21: The action plan consist of four phases that each have the purpose of validating or investigating certain aspects. All activites are aligned towards the 1. pin strategy.

4.4.3 Risk assessment

Technological risk

This report has mainly focused on the contextual dimensions of establishing a pyrolysis waste treatment facility. The actual technical exploration has so far been based upon review of experiments and in lab experience, which implies a significant risk of the technology not performing as expected. The impact of this risk is however relative as there are different ways the technology can act unexpected. The parameters that would impact the business case the most is the quality and quantity of the oil. The initial testing phase will focus on clarifying this risk before moving on to more substantial investments.

Deception

After interviewing different people from the business scene in India the risk of corruption has become clear. Coming from a different culture means that you would be engaging on foreign territory which increases the risk of getting deceived. A business venture will include various agreements between e.g. Tatva Global, fuel customer, logistical company etc. which will represent the risk of deception. A way to approach this risk is to ensure proper balance between incentives around the business. In other words create win-win situation.

Caught up in bureaucracy

The level of bureaucracy in India must not be underestimated. It has been mentioned in the section: *1.4.3 Key stakeholders and potential partnerships* where it is emphasized how it impacts the implementation time of a business. The lack of bureaucracy is one of the major reasons behind choosing a private company as a strategic partner as opposed to working with a municipal corporation. The size and organizational structure (with numerous sister companies) of Tatva Global does however also pose a risk time consuming approvals. This acknowledgement underlines the importance of a strong personal relation with the technical plant manager Karthikeyan Malar, which will be managed by maintaining a continuous communication with Mr. Malar as well as engaging him in the development of the business.

SOURCE: PRIVATE - A GATHERING OF MUNICIPAL OFFICIALS ILLUSTRATING NO DUMPINGS INSTANT SEGREGATION INITIATIVE

SOURCE: PRIVATE - UNSEGREGATED RDF, STORED IN LARGE DEPOTS, VELLALORE, COIMBATORE

4.5 Economical overview

The budget is an important aspect of the detailing as it projects the economical potential of the business and allows the identification of parameters that potentially could destroy the cost structure. This budget projects a four year period starting from September 2017 and follow the structure of the previous described action plan. The following sections will elaborate on the financing strategy and evaluate the benefit from scaling the business. Finally it will present a stress test that identifies the parameters of the business will affect the cost structure the most if changed.

The budget has the purpose of emphasizing the potential which can be used when negotiating with future investors. The economical results and the development of the cost structure are illustrated on the next page. The budget is further elaborated in *WS 22: Budget* where the excel sheet is presented.

4.5.1 Financing strategy

The financing of the project is aimed towards external funding such as venture capital. The leverage of venture capital firms are the fact that they bring the money which allow them to have a strong case when negotiating company shares. This leverage however decreases over time as the uncertainty and risk decreases. The strategy is therefore to clarify uncertainties with minimal funding before drawing in the larger investments.

The investments needed for the 1. pin strategy represents the most uncertainty based on amount and risk of failure and should therefore be rewarded with shares in the companies future profits. The launch of the 1. pin strategy will serve as a large scale proof of concept and thereby reduce the risk and uncertainties when expanding to new locations. This reduction should be reflected in the later investments that solely should get part of the funded plant and not the business as a whole. This will be referred to as project based investments - as opposed to the first two investments rounds that inevitable will demand a large share of the company. It is however difficult to decide the right investment strategy at this point as it could also be beneficial to acquire the money from the bank. This would not allow the same expansion rate but keep more control over the business. The budget is for now based on engaging a bank in the second investment round but should be reconsidered along the way.

4.5.2 Economies of scale

The scalability of the business has a natural capacity limit at 200 TPD of RDF due to the waste generation in Coimbatore, which means that the business have to expand to other locations in order to grow. With regards to economies of scale the business benefits from increase in productivity by dividing fixed cost over more operations. However in this case the only fixed cost to be divided is the management salary (36% of the cost structure affiliated with a 200TPD plant) since the lease of land will increase as new plants are installed. Other benefits may occur as the business grows to other locations, such as improved logistics or shared know-how, but these are difficult to estimate at this time due to uncertainties regarding location, quantity, key partners and more. When considering the operation capacity the business may benefit from economies of scale as the relative energy consumption and the number of employees both decreases. An estimation of returns from different size plants are illustrated in Figure 22.

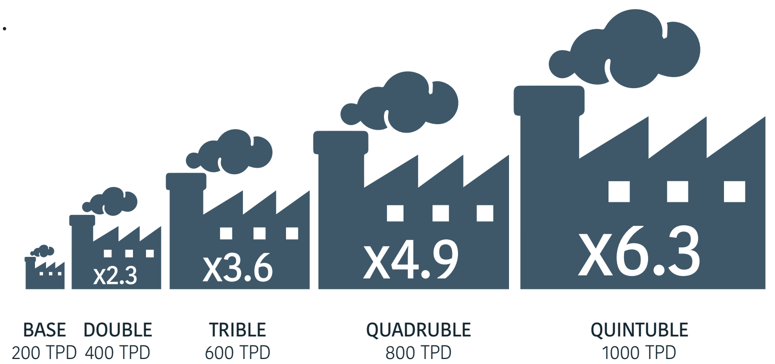


FIGURE 22: The business becomes more efficient as it is scaled. This makes it subject to economies of scale.

ACCUMMULATED RESULT

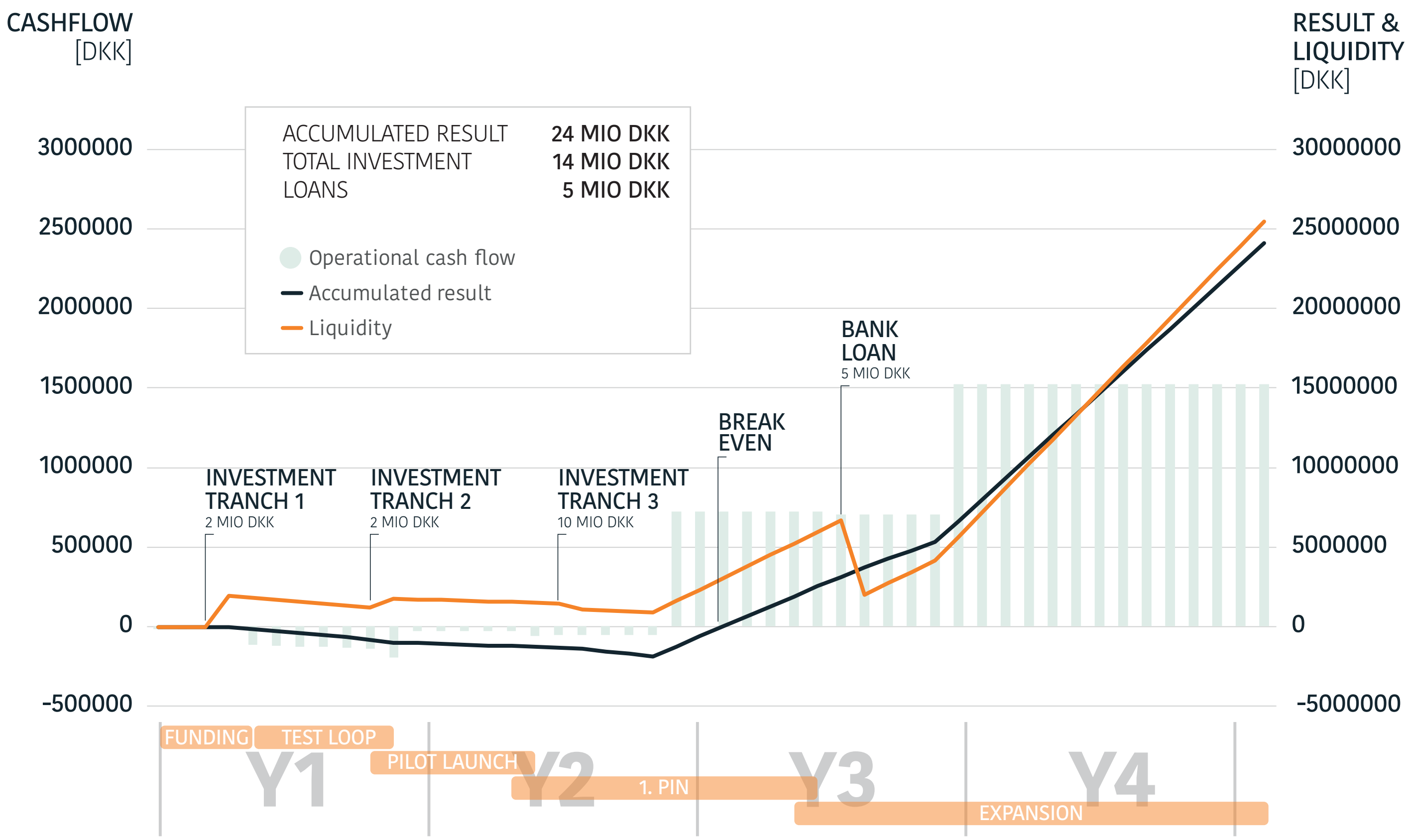


FIGURE 23: External investment will stabilize liquidity until the business model has been proven.

DEVELOPMENT IN COST STRUCTURE
[ILLUSTRATED IN %]

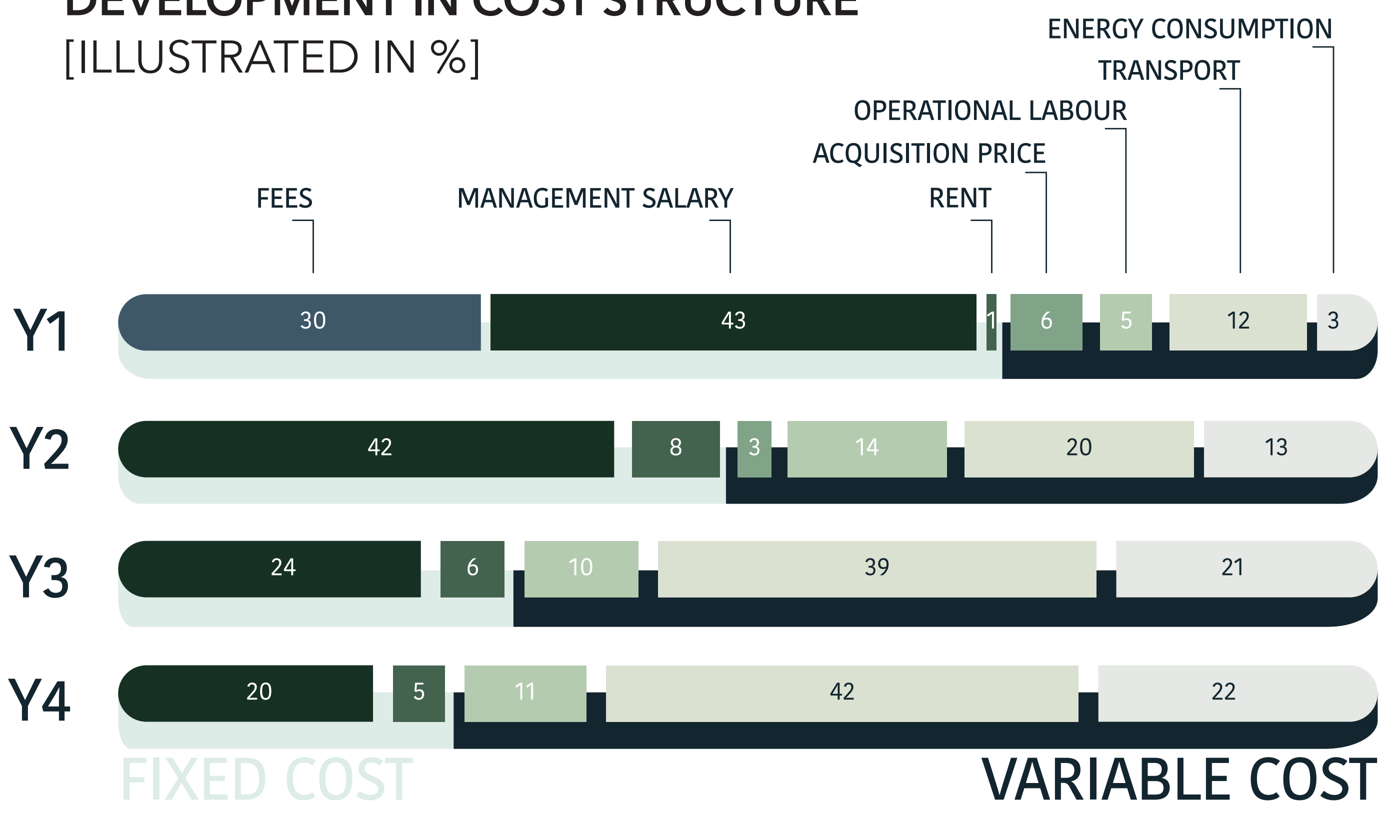
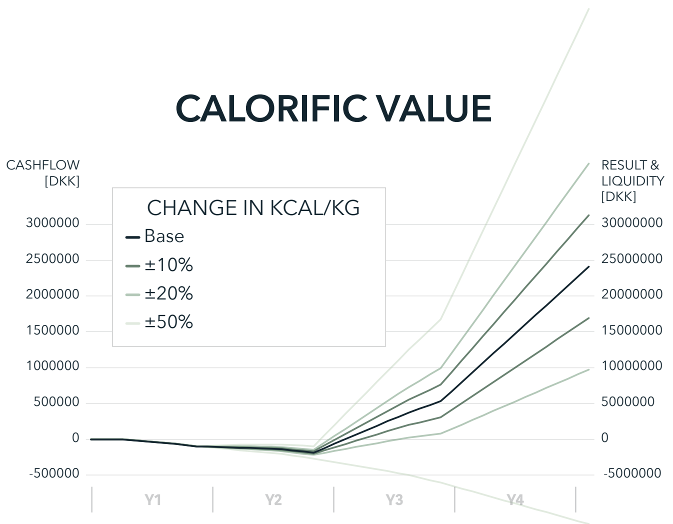


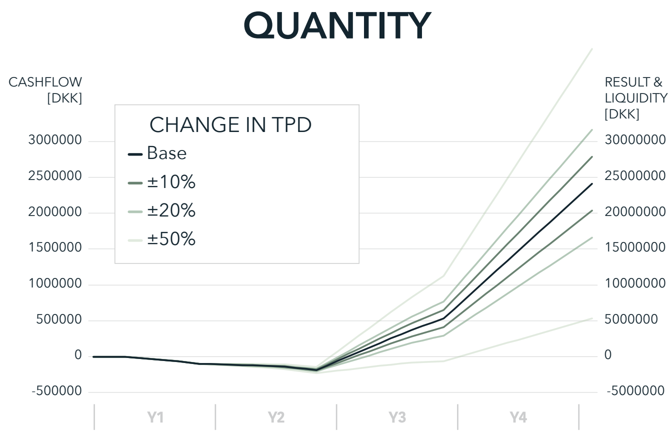
FIGURE 24: The business will become more resistant to market change as the fracion of variable cost increases.

4.5.3 Stress test

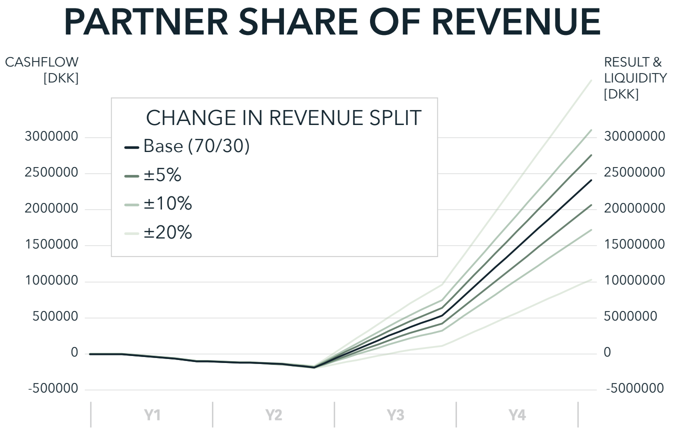
Due to the predictive manner of a budget it often means that the budget posts are based on estimates. These estimates includes different levels of uncertainty. The purpose of this stress/sensitivity analysis is to identify which changes in estimates has the most impact of the business. The change has been measured in the NPV over a four year period as it describes the overall value of the business proposal. The test furthermore reveals relations between budget elements that can be used to evaluate the business model at a later stage. The impact scale below illustrates how the NPV over a four year period is affected by a 50% change of relevant budget estimation. This highlights the sensitivity of these parameters which is further elaborated by the following graphs. To see the full sensitivity analysis please look up *WS 23: Sensitivity analysis*.

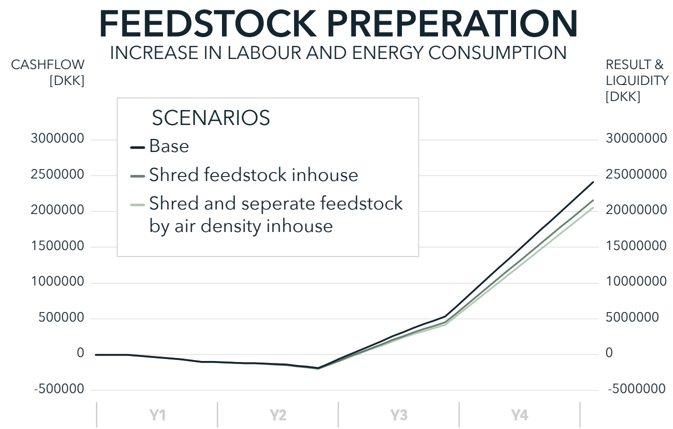
1. 151% CALORIFIC VALUE
2. 103% SALES PRICE
3. 79% QUANTITY
4. 58% PARTNER SHARE
5. 16% TRANSPORT
6. 15% FEEDSTOCK PREPERATION
7. 5% WAGES



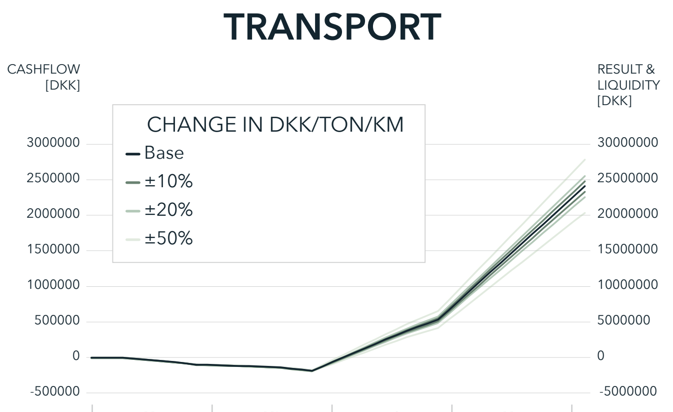


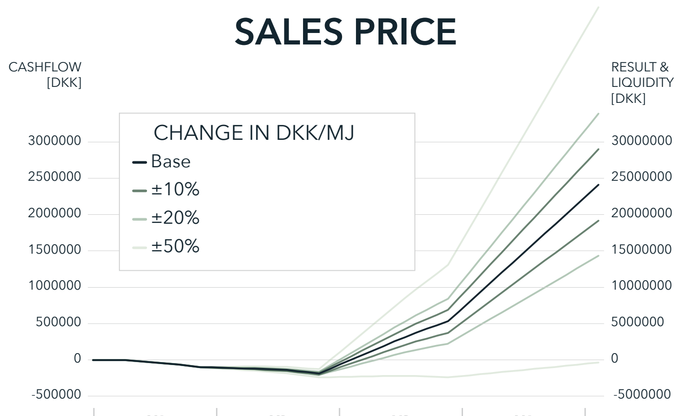
The feedstock properties is vital to the business since both the calorific value and the quantity are vital for profit margin of the business. This recognition emphasizes the need for thorough testing of the feedstock before drawing in large investments.





The difference in sensitivity between the partner share of revenue and the preparation of feedstock shows that sharing the revenue is not due to financial issues but almost exclusively to maintain shared incentives. This acknowledgement is important to keep in mind for future negotiations.





The current estimation of transport cost is based on moving the same quantity to and from the treatment plant. In reality the amount of fuel transported would be much less and the cost accordingly. This overestimation of the cost acts as the required buffer mentioned in the risk assessment. The sensitivity analysis concludes that the an error in the estimation of the transport cost per ton per km has a relatively small impact on the business valuation. A noticeable fact when comparing to previous statements where the transport cost was claimed to be the factor that made the business unfeasible (Malar 2017).

Finally the estimation of sales price has a high impact on the performance of the company. An important factor with regards to possible changes in the future oil market. This is however not a manageable parameter and there is nothing else to do than follow the development of the market.

Conclusion

India has during the past decades been facing the consequences of increasing urbanization and economic growth which has led to exploding waste generation in the urban areas. The government is targeting the issues by different initiatives and legislation to assist the change at municipal level. The effect has however been limited due to unrealistic implementation of visionary solutions. This is illustrated by the fact that 90% of India's urban waste is landfilled and the few treatment facilities in operation are inefficient. MBT plants are the most widespread treatment method across India but these plants are discarding 60% since it is only capable of processing the organic fraction of mixed waste. The construction of this type of facility is based on the vision that people will start to segregate immediately without the recognition that changing public behavior takes time. The system is in desperate need of a stepping stone solution that is able to treat and dispose the mixed waste while the segregation is implemented. Pyrolysis technology represents a good candidate for this purpose since it can add the required flexibility to the Indian waste scene. This flexibility allows the deconstruction of various waste types with an economical feasible trait when processing energy rich material. Furthermore, it is a scalable technology which allows to launch a low cost pilot project that can be expanded when proven feasible. This has been a missing strategy amongst former WTE projects which have demonstrated large failure rates.

This paper identifies the MBT plant in Vellalore, Coimbatore, as a promising entry point from which a start-up can be launched. The business will target the high energy RDF from the MBT plant as a feedstock for a pyrolysis treatment plant to produce pyrolysis oil. This has the potential to create an economically sustainable business that at the same time will increase the efficiency and economy of the MBT plant. It will unload Coimbatore's waste system with 25% of their generated waste and thereby reduce its societal and environmental impact. The operating company, Tatva Global, represents the required potential of a strategic partner, which is why the MBT plant in Vellalore was selected as a promising business venture. The revenue from the oil sale will be shared with Tatva Global in order to align incentives towards an optimized pyrolysis operation while discouraging them to start their own project. The launch of a business in Coimbatore has the purpose of proving the economical feasibility of the business which can later be expanded nationally. It has been projected that this business can achieve an accumulated result of 24 million DKK over a four year period and a positive cash flow within two.

Contribution to theory

This project has focused on practical aspects of developing a business which has promoted a hands-on entrepreneurial approach. This has made it natural to modify methods or models if they were not directly applicable. This adaption has mainly been promoted by the high complexity of India's waste system as it is argued that such an environment requires a holistic understanding to ensure reliable decision making.

One of the main theoretical domains that this paper targets is effectual decision making in a complex context. Effectuate decision making is in general cherished in environments with high uncertainty as it is based on the aspirations of the entrepreneur which makes it flexible. This is often supported by a statement of predictive reasoning being unsuitable in uncertain environments as it promotes errors (Sarasvathy 2008; cited by Batley and Omarsson 2014). This argument does, however, not justify that effectuate sense making should be executed without any guide lines. The risk of such a decision practice could exclude essential aspect that would neglect pitfalls. It was experienced in the comparison between different business opportunities how it was impossible to encapsulate all relevant aspect in a verbal discussion. Thus, a need for a communication platform that would articulate the relevant parameters and enable a holistic evaluation. Soh and Main (2013) defines scenarios with many interfering incentives as constrained effectuation where the entrepreneur has to put himself aside and focus on the means and benefits of others in order to obtain a broad perspective. They do, however, not propose any particular methods to facilitate such a practice. The process of obtaining the required perspective for a reliable opportunity evaluation in a complex environment is therefore considered a contribution to the effectual domain - see section: *3.2 Contextual evaluation*.

Complexity has been a continuous element of this paper which highlighted a missing link in the transition from research and discovery to analysis and synthesis. A link that allows collation and streamlining of the raw data in a way that promotes the identification of relevant focus areas. The solution was the sum up method which has already been described in section: *0.1.2 Opportunity identification* and applied in section: *2.2 Case studies*. It is important to emphasize the significant impact of this model on the project. It would not have been possible to get the same results if the three combined frameworks (sequential model, actor network theory and life cycle assessment) were applied individually. This modified method allowed the possibility to see both activities, responsibilities and flows in one large perspective. This characteristic is argued to be critical when dealing with complex systems.

Reflection

This project has been a diverse journey which has touched upon various aspects related to the project goal and theory as well. The project has been conducted over a period of five months which has led to several reflections on the way. These will elaborated in the following sections.

Inconsistent literature

The projected started out by delving into the existing literature to get an understanding of the Indian MSW system and exploring what former studies have experienced. It quickly became evident that former studies were not in agreement about the reality of India. The literature review suggested conflicting information about the present practice, waste quantities and characteristics of the waste. This was to some extend expected as India is a large country and estimations are based on different parameters. It did however also support the pre-assumption that it is necessary to conduct a field study to proper understand a given situation and to identify specific and realistic opportunities. The literature review created an overview but due to the inconsistency it was necessary to validate each critical step by drawing from the literature and comparing it with first-hand impressions.

Overcome the limitation of the distance

A main limitation from the beginning of the project was the 7000 km distance to India. This was an obstacle to the agility of the project as it was not possible to visit the country several times. This limitation also affected the entrepreneurial approach which is usually associated with continuous iteration and interaction with the market. It was a limitation that was realized at the outset which is why it was overcome by focusing on the establishment of a diverse and broad network during the field study. This allowed keeping connection while being in Denmark which has been beneficial in terms of fact testing and taking the first steps of a business launch. It proved to be the next best thing to being there.

Entrepreneurial approach

The entrepreneurial approach has been the driving force of this project and has opened doors than otherwise would not have been open. It was this approach that dictated the need for traveling to India and this approach that allowed keeping a broad focus when investigating the issues of the MSW system. It limited the required planning and allowed to follow the flow as new people were introduced and ventures identified. It has mainly been the effectual approach that has paced the project as it has allowed for quick decisions in the discovery and opportunity identification. The pace was deliberately slowed down as the project moved into the opportunity evaluation as the decision making would not have been well grounded. This has already been elaborated in the contribution to theory.

Theoretical foundation

Throughout the project certain methods have been suggested in order to make the theory applicable on such a complex environment as the MSWM system. This has been executed in an ad hoc manner that has focused on this project and a desired result or inclusion of certain parameters. These suggestions are thereby questionable in terms of being generic, which means that they need to be further investigated and tested. Such an investigation would have to do a literature review in order to identify alternative methods that are already present. This was not part of this projects scope and has therefore not been executed.

Competencies

The competencies of this team lacks the skills of performing chemical analysis of feedstock and oil samples. This fact was well known from the beginning thus the technological development and testing were excluded from the project. It was, however, possible to get access to these competencies through MASH Biotech and a test facility in Chennai. It was determined that the start-up should be launched preferably with a chemical "expert" in house.

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