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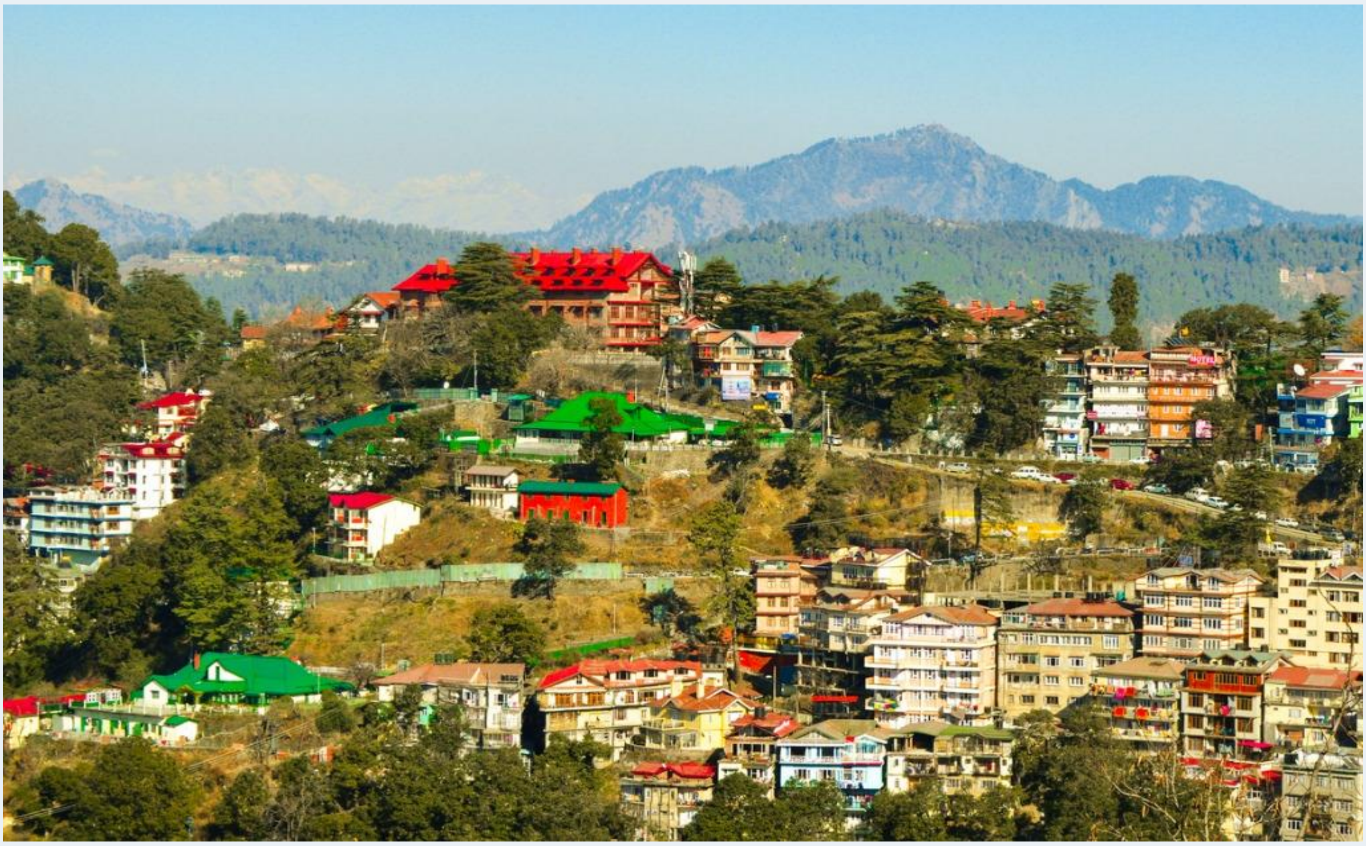
Sub-project – Baseline study for solid waste management in Shimla

Deliverable – Final report



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Acknowledgments

The baseline study for the solid waste management (SWM) project has been commissioned as part of the Shimla (India) – Wolverhampton (UK) strategic collaboration under the European Union (EU's) International Urban Cooperation (IUC) – India programme. The study represents the key deliverable of the Urban Cooperation Action Plan for SWM in the city of Shimla.

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1 List of acronyms and abbreviations

Abbreviation	Full form
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
APCr	Air Pollution Control residue
BMW	Biomedical waste
CAA	Constitutional Amendment Act
CBWTF	Common biomedical waste treatment facilities
CERC	Central Electricity Regulatory Commission
CHP	Combined Heat and Power
EEPL	Elephant Energy Pvt Limited
EfW	Energy from waste
EU	European Union
HPSEB	Himachal Pradesh State Electricity Board
IBA	Incinerator bottom ash
IUC	International Urban Cooperation
MC Shimla	Municipal Corporation of Shimla
MoEF & CC	Ministry of Environment, Forests and Climate Change
MSW	Municipal solid waste
MT	Metric tonne
MW	Megawatts
NGO	Non-government organisation
PPA	Power purchase agreement
PPE	Personal protection equipment
PPP	Public private partnership
RDF	Refuse derived fuel
SEHB	Shimla Environment, Heritage, Conservation and Beautification
SWM	Solid waste management
ULB	Urban local body
UK	United Kingdom
WHO	World Health Organisation
WMBC	Wolverhampton Metropolitan Borough Council

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3 Executive summary

This chapter is the executive summary of the baseline study. It briefly covers the assignment background and the objectives of the study, the district profile of Shimla, existing status of SWM, and the waste to energy (WTE) plant in the city, learning from international best practices, challenges, corresponding solutions, and next steps.

Assignment background

Preparation of study and problem statement: The SWM project's baseline study was commissioned as part of the Shimla-Wolverhampton strategic collaboration under the IUC–India programme. The study is the key deliverable of the Urban Cooperation Action Plan for SWM in Shimla, with additional focus on WTE plants. The assignment's objective is to provide baseline information for SWM in Shimla by analysing the current status of SWM, waste treatment, WTE plants, disposal facilities in Shimla, and identifying best practices across SWM value chain – segregation, composting, WTE, being followed by Wolverhampton.

Strategic cooperation between Shimla and Wolverhampton: Shimla and Wolverhampton signed partnership agreements with IUC-India on September 24, 2018, and October 24, 2019, respectively, and later on jointly agreed on the topic of cooperation, i.e. SWM with additional focus on WTE plants. The two cities were paired because of their common interests as well as specific features such as size. IUC-India is supporting the Shimla-Wolverhampton city pairing through the support for exchange visits, workshops and the development of this report.

Methodology: The study aims to provide a detailed analysis of the existing SWM scenario in Shimla, including the collection, transportation and treatment of waste at the WTE plant, while also identifying challenges being faced by the city related to the SWM value chain and potential solutions for the same. The report also analyses the best practices being followed by the city of Wolverhampton in addition to some other European cities (such as Vienna, Ljubljana and Copenhagen) in terms of their SWM value chain. The study is based on: a) secondary research through reports, web links and data shared by the IUC-India team and officials of municipalities/ city councils of Wolverhampton and Shimla; and b) stakeholder consultations with the officials of the Municipal Corporation of Shimla, City of Wolverhampton Council, and IUC-India.

Existing status of SWM in Shimla

Shimla district profile: The former summer capital of British India and the present capital of Himachal Pradesh, Shimla lies in the south-western ranges of the Himalayas, and is situated at an average altitude of 2,206 metres (7,238 ft.) above mean sea level. It is bounded by Mandi and Kullu districts in the north, Kinnaur in the east, Sirmaur in the west and the state of Uttrakhand in the south. The district having an area of 5,131 sq.km consists of 3,347 villages and is sub-divided into eight sub-divisions: Shimla Urban, Shimla Rural, Theog, Rampur, Rohru, Chopal, Dodra Kwar, and Kumarsain. The total population of the Shimla district as per the 2011 census was 814,010, of which 425,039 were male and 388,971 were female. The 2020 population estimates pegged the district's population at 927,971[1]. The majority of the population is Hindu (approximately 97%), followed by Muslims (1%), and others (approximately 2%). The population of Shimla city was 169,578 as per the 2011 census, of which 93,152 were males and 76,426 were females. The estimated population of Shimla in 2019 was 206,575[2].

Solid waste generation and collection: Based on per capita generation of waste, it is estimated that the city's 34 wards generate approximately 84.5 tonne of solid waste per day. Of the total waste generated, 70 tonnes of

[1] *Himachal Pradesh population*
[2] *Population of Shimla*

waste per day is collected through door to door collection, resulting in a waste collection rate of 83%. Shimla Environment, Heritage, Conservation and Beautification (SEHB) Society was formed to undertake door to door collection of municipal solid waste. As on date, 100% households and commercial establishments in Shimla have been covered under the door-to-door waste collection scheme. Although the waste collection coverage is 100%, the waste collection rate is only 83% on account of factors like segregation of recyclables by rag pickers/ the door to door garbage collectors after collecting waste from various sources, open dumping and illegal burning of waste. The SEHB Society has deployed 457 workers for undertaking door-to-door waste collection. Furthermore, the 202 dumpers which were earlier used for secondary waste collection have now been removed by the Municipal Corporation of Shimla. There are no transfer stations in Shimla city. Users are divided into different categories, with charges differing for each category based on the polluter pays principle. Residential households are charged Rs 88/month (€ 1.03/month) while commercial properties like hotels are charged Rs 16,000/month (€ 178/month). These charges are revised every year at a rate of 10%.

Solid waste transportation: A total of 42 hydraulic vehicles have been procured and deployed to facilitate waste transportation to the WTE plant in Bhariyal. The SEHB Society workers carry waste from areas that are not accessible by roads in gunny bags and deposit them in tippers stationed at accessible roads. Recently, the Municipal Corporation of Shimla procured a compactor, which is used as a stationary compactor/transfer station on a trial basis and placed on the by-pass road. Pick-up vehicles/tippers from far flung areas are allowed to deposit the collected garbage directly into this compactor. During the trial, the compactor was able to accept waste from 19-20 pick-up vehicles/tippers and then the same was transported to the WTE plant. In short, the compactor works as a temporary transfer station. The ward-level routing and loading plan has been developed by the Municipal Corporation of Shimla with the help of The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ).

Solid waste treatment and disposal: A WTE plant was commissioned at Bhariyal, located on the outskirts of Shimla, in August 2017. The plant, which was built at a cost of Rs 42 crore (€ 4.9 million), can produce up to 2.5 megawatt-hours (MWh) of green energy using refuse derived fuel. The plant processes 70 tonne of waste per day on average, and converts it into refuse derived fuel (RDF) averaging 40 tonnes per day[3], which can be used for electricity generation. Given that RDF process reduces the moisture content in the waste, 100% conversion of MSW into RDF is not achieved. Of the remaining waste, 4 tonne of segregated waste consists of recyclable waste and 6-8 tonne is disposed of at the landfill adjoining the waste treatment plant site, which is covered with soil/construction debris on a daily basis. Currently, there are no scientific landfills in Shimla; however, the Municipal Corporation of Shimla is planning to initiate the process of tendering for the same.

SWM best practices in Wolverhampton and other European cities

Shimla, under the IUC-India programme, has entered into a strategic collaboration with Wolverhampton. This study analyses the WTE technology that has been deployed at the waste to energy plant in Wolverhampton along with various waste collection and waste segregation processes employed by the council. The study also analyses some of the best practices across the SWM value chain for few other European cities such as Vienna, Copenhagen and Ljubljana.

Wolverhampton, UK: Waste is segregated into mixed (food waste, textiles, nappies, miscellaneous waste, etc.) and recyclable waste (glass, plastic, mixed paper, card, newsprint and pamphlets, ferrous and aluminium cans) at the household level. The city provides black and green wheel-fitted waste bins to residents for dry mixed recycling and general waste, respectively. The city is now also experimenting with shifting from providing waste bins for each household to placing waste bins at the end of each house lane. Additionally, the city is

[3] *Source: Potential Utilization of RDF as an Alternative Fuel to be used in Cement Industry in Jordan, MDPI, October 20, 2019, by Safwat Hemidat, Motasem Saidan, Salam Al-Zu`bi, Mahmoud Irshidat, Abdallah Nassour and Michael Nelles.*

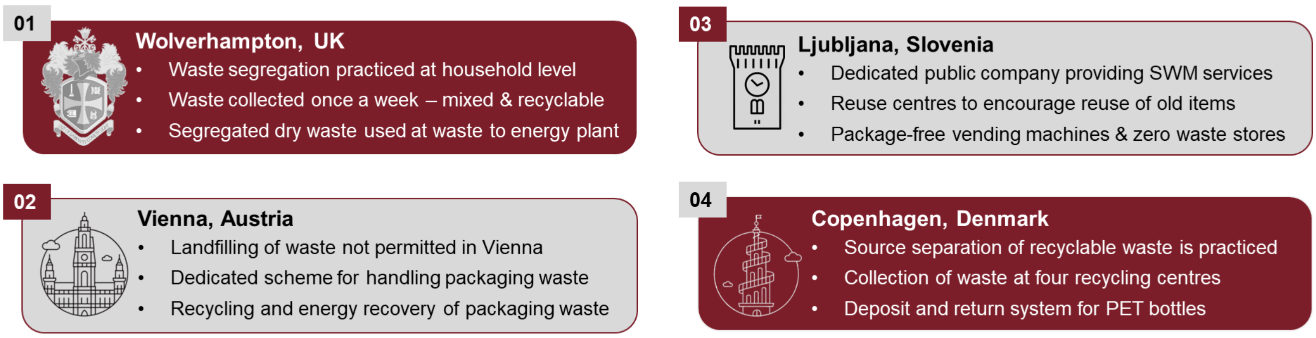
exploring the possibility of setting up underground waste bins. The city has two transfer stations, where waste from various households and institutions is brought after collection. The waste is segregated using manual and technological interventions at these transfer stations. The segregation process ensures that the outgoing waste has uniform quality and calorific value. This ensures that the WTE plant in the city operates at an optimal level. The waste collection activities in the city are well-calibrated. The waste generated in households is collected once a week for each waste type – general and recyclable. The city also collects garden waste from households and charges a fee of GBP 40 per month (Rs. 3,989 per month) from users for this type of collection. Garden waste is further used to generate biogas. The city has 140 employees that handle waste collection. It has a fleet of 17 refuse collection vehicles for the waste collection process. The council directly delivers the collected general waste to the WTE plant, with each truck typically tipping off 2-3 times per day.

Vienna, Austria: Vienna has been successful in managing its plastic waste. In Vienna, packaging waste generated from households and businesses is either recycled or incinerated with energy recovery at municipal incinerators. Landfilling is not allowed as it is banned in Austria. Altstoff Recycling Austria AG (ARA) is Austria's leading collection and recovery scheme for packaging waste in the country. Sorting of plastic packaging waste, collected in the ARA system, takes place at sorting plants to separate the packaging from other types of waste, and also to sort the packaging into 20 different plastic types. Under the ARA system, after sorting and removing other types of waste, the lightweight packaging material is either sent for energy recovery through incineration, or for recycling. The lightweight packaging material collected from households, as described above, is sorted into recyclable and non-recyclable fractions, and the non-recyclable but combustible fraction is sent for energy recovery through incineration. The energy, thus, recovered is used in public buildings and district heating networks. The recyclable fraction of lightweight packaging as well as PET bottles are recycled. For recycling, the plastic waste is shredded, washed, dried, melted, and then processed into granules, which is used as raw material for manufacturing new products.

Ljubljana, Slovenia: Ljubljana is the largest city and the capital of Slovenia. The public company, Voka Snaga, is the biggest waste management company in Slovenia, providing waste management facilities in Ljubljana and in 10 other municipalities. Among other waste management services, Voka Snaga is also responsible for waste collection. Ljubljana is the first European capital committed to being a zero waste city. The waste management reform in Ljubljana began in 2002, with introduction of waste segregation. In 2008, separate collection of biodegradable waste was introduced on a door-to-door basis, and in 2013, bins were provided to all households for collecting packaging and paper waste, both of which were collected door-to-door. After achieving efficient segregation, Voka Snaga refocussed its efforts from raising awareness on segregation to encouraging residents to reduce waste generation, raise awareness on waste reduction, promote reuse, and ensure responsible and sustainable consumption. A reuse centre has been opened in Ljubljana that consisted of a shop, workshop and collection centre. The objective of the reuse centre is to provide work to the elderly, disabled and other disadvantaged people, along with encouraging reuse of old, redundant but reusable items. Voka Snaga, runs its packaging-free vending machines, at the reuse centres for sale of basic household items such as cleaning supplies, shampoos, vinegar, oil and other household items to customers who bring their own reusable packaging. Further, there are zero waste retail stores Ljubljana. One such store is called Rifuzl, which is a plastic-free grocery store, focussing on living with less plastic and shopping sustainably. Shoppers bring their own glass jars and fill these with grocery products at Rifuzl

Copenhagen, Denmark: Copenhagen is the capital, the largest and the most populous city in Denmark. Source separation of recyclable waste fractions is a major part of Copenhagen's waste management process. Household waste is collected by the municipality in line with specific waste regulations and collection schemes. The residual plastic waste generated from households, apart from rigid plastic and bulky plastic waste, is collected either directly from households, or through curbside collection. Flexible and rigid plastic waste and bulky plastic waste are collected at Copenhagen's four recycling centres or at the manned waste collection centres. The waste collection centres are smaller than recycling centres, and accept only certain types of plastic waste and are accessible by foot only. Departing from the general rule in the EU, Denmark has no packaging producer responsibility scheme for plastic packaging. However, in Copenhagen as well as the rest of Denmark, a deposit and return system exists for bottles having carbonated drinks, mineral water, beer and other beverages etc. While selling beverages in Copenhagen, the producer charges the price of the product as well as a deposit related to beverage containers and the return system. Non-recyclable and non-combustible plastic waste is landfilled. All landfilled material has very low plastic content. Flexible PVC is the only plastic waste that is sent to the landfill site. It is difficult to recycle plastic waste as it contains a mixture of different types of plastics that contain different additives and are often contaminated with non-plastics or food residues. To counterbalance this, a CO_2 tax on fossil content in the waste has been implemented that creates incentives for owners of waste incineration facilities to avoid plastics in the waste being incinerated. Figure 1 summarises the above-mentioned cities' SWM best practices.

Figure 1: Snapshot of SWM best practices in European cities



Key challenges related to SWM and WTE in Shimla

Some of the key challenges being faced by the city of Shimla across its SWM value chain have been provided below. Challenges were identified in the areas of waste segregation, collection, transportation, disposal and treatment.

Solid waste segregation, collection and transportation

- Low segregation rate: The issue of prime concern is the mixed waste being received by the waste to energy plant. Given that only 50-60% of municipal waste is segregated, waste reaching the plant has low calorific value and high moisture content (because of the large share of organic waste). Consequently, the plant is unable to operate at its full potential as the RDF produced is of low quality.
- Difficult terrain and weather: Effective SWM, including waste collection is a challenge in hilly terrains because of landform variations, rugged terrains and a scarcity of flat land. Only 25% of the city is connected by road. Hence, waste collectors have to tackle the city's hilly terrains and travel from each household to accessible roads, from where hydraulic vehicles/ tippers transfer waste to the WTE plant. Furthermore, Shimla's predominantly cold weather poses a challenge for waste composting.
- Inefficient use of waste collection trucks: 50-60% of MSW is segregated in Shimla; however, the WTE plant continues to receive mixed waste. Although separate compartments for different types of waste have been provided in the waste collection trucks, due to lack of awareness the segregated waste is getting mixed while loading into the trucks. This practice is leading to inefficient use of waste collection trucks in addition to the WTE plant receiving mixed waste.

Solid waste treatment

- Difficulty in composting: Composting requires segregating into bio-degradable and non-biodegradable waste. Shimla faces many problems with respect to composting of its MSW. First, there are no dedicated composting plants in the city to process biodegradable waste. Second, even if there was a composting plant, the unsegregated waste would pose technological challenges at the plant as composting plants are designed to handle only biodegradable waste. Last, Shimla's predominantly cold weather poses a challenge for the process of composting.
- Presence of pollutants in syngas at the WTE plant: Due to the unsegregated waste, the syngas produced as a result of the gasification technology has a high proportion of tar containing sulphates and nitrates. Hence, the unfiltered syngas cannot be passed through the turbines in order to generate electricity. Deploying additional filtration mechanisms would remove tar from syngas, thereby enabling the WTE plant to operate at full capacity.
- Absence of scientific landfill and legacy waste: Currently, there are no scientific landfills present in Shimla. Although the majority of the waste being generated is processed at the WTE plant and converted into RDF, the residue/by-product from this operation is dumped in an unscientific way at the open space adjacent to the WTE facility and then covered with soil/ construction debris. This is an unsustainable method of waste dumping and could lead to various environmental challenges in the near future.

Besides the above challenges, the lack of enabling policies at the state and city level, inadequate funds to implement projects, as well as lack of awareness and technical know-how may also be contributing to the suboptimal management of waste in Shimla.

Solutions for challenges across the SWM value chain

The following solutions have been proposed while considering the existing conditions in Shimla, discussions held with the officials of the City Council of Wolverhampton and the Municipal Corporation of Shimla, best practices followed in various European cities, including Wolverhampton, Vienna, Copenhagen and Ljubljana, and secondary research.

Solid waste segregation, collection and transportation

- Fines and incentives to ensure segregation**:** The Municipal Corporation of Shimla should impose monetary fines on waste generators for not providing segregated waste to the SEHB Society's waste collectors. The Municipal Corporation of Shimla should ensure strict imposition of fines on those not providing segregated waste. Additionally, the Municipal Corporation of Shimla could tie some incentives/rewards for those who provide segregated waste. For example, offering a 10-20% discount in waste collection fee for providing segregated waste regularly for a month.
- Setting up waste transfer stations: The Municipal Corporation of Shimla can consider setting up waste transfer stations in the city. This would allow the waste collected throughout the city to be tipped at a single place, which can then be sorted and bundled for onward processing. This shall enable the city to supply uniform quality of waste to the WTE plant, which has a better calorific value and allows for a longer burn and improved energy production. Transfer stations can be setup at the outskirts of the city to alleviate land availability challenges due to steep slopes. Furthermore, setting up transfer stations at the city outskirts will not hinder the city's aesthetic appeal.
- Decentralised waste segregation**:** Waste segregation should be encouraged at the community level. Local communities/resident welfare associations (RWA) should be provided with waste bins designated to hold different type of solid waste. A leader should be selected for each local community/RWA to oversee waste segregation for his/her designated area. Penalties/fines or rewards should also be assigned at the local community level. For commercial areas, 4-5 restaurants/hotels/shops can be clubbed together to form a

single unit and provided with proper waste segregation equipment. As restaurants/hotels contribute extensively to wet waste generation, they can be rewarded for sincerely undertaking waste segregation through a reduction in monthly waste collection fee.

- Efficient use of waste collection truck: In order to utilise the waste collection trucks to their full potential, there is a need to create awareness amongst the masses for proper loading of waste in the waste collection trucks. IEC programmes which teach the proper use of separate compartments for different types of waste will help in this effect. Further, Municipal Corporation of Shimla could assign different days for collection of different types of waste such as three days of the week can be assigned for collection of wet waste while the remaining days can be assigned for collection of dry waste. This will lead to only dry waste reaching the WTE plant, thereby improving its efficiency.

Solid waste treatment

- Composting of waste in colder regions: MSW composting can be a year-long activity and does not have to face hindrances due to inclement weather conditions. For the new composting plant proposed by the Municipal Corporation of Shimla, the operator will have to ensure suitable conditions inside the facility. The facility will need to ensure ambient average day temperature from 20-25 degree Celsius and during the night between 8-12 degree Celsius even when temperature outside the facility dips below zero[4]. The composting bins can be fully isolated using 150mm–20mm thick layer of Styrofoam to prevent heat loss, thus aiding the process of composting. The Municipal Corporation of Shimla should also encourage residents to undertake composting wet waste at their homes. The practice is already followed by the City of Wolverhampton, where it has tied up with select operators that provide home composting equipment at discounted prices. This initiative can also be undertaken at a collective level if few households can be encouraged to undertake composting wet waste. This will reduce the quantity of solid waste to be collected and treated.
- Effective functioning of WTE plant: The contamination in the syngas being produced from the gasification process can be reduced by feeding the plant with segregated waste. Once only dry waste is being processed at the WTE plant, the quality of RDF generated will improve significantly, which will in turn lead to production of cleaner syngas. Dry waste has better calorific content and hence allows for longer burn and improved energy production. Syngas which is free from large quantities of sulphates and nitrates can be passed through the engines and turbines directly without requiring an additional step of filtration, thus improving the efficiency of the WTE plant.
- Alternate site with higher capacity for landfill: The SWM rules, 2016 require construction of landfill on hills to be avoided, with plain, level land being required for construction of scientific landfills within a distance of 25 km from the city. Municipal Corporation of Shimla should find a suitable site for the landfill that has a relatively flat topography and has adequate capacity to accept the waste coming from the waste-to-energy plant in addition to fulfilling any future requirements of the city. Municipal Corporation of Shimla should get in touch with municipal corporations of similar cities that have established suitable landfill sites, to get references of trusted operators. Figure 2 summarises the challenges in Shimla across its SWM value chain, along with suggested solutions.

[4] *Composting Manual for Cold Climate Countries, ACF International – USTB, December 2015, by Roman Ryndin and Enkhgal Tuuguu*

Figure 2: Summary of key challenges and corresponding solutions

Key challenges	Solutions
Waste segregation, collection and transportation	
• Low segregation rate • Difficult terrain and weather • Inefficient use of waste collection truck	• Fines and incentives for waste generators to ensure segregation • Awareness programs to promote waste segregation • Setting-up transfer station at outskirts of the city • Decentralized waste segregation at local community level • Separate days for collection of dry and wet waste
Waste disposal and treatment	
• Difficulty in composting • Presence of pollutants in syngas at WTE plant • Absence of sanitary landfill and legacy waste	• Maintaining ambient temperature inside composting facility • Encouraging residents to practice home composting • Using only dry waste at the WTE plant to improve efficiency • Identify an alternate site with higher capacity for landfill

Next steps

Having established the need for an efficient SWM system in Shimla and the requirement to implement decentralised waste segregation process so as to increase the efficiency of the waste-to-energy plant, the Municipal Corporation of Shimla should first divide the recommendations provided in the previous sections in to short and medium term goals. This would help the local administration in prioritising the recommendations as required. Once the goals are set, the administration should look at preparing project reports which would define the broad goals of the project. The administration can then look at arranging for funding of the project which can be secured from state funds earmarked for development actives or through national level schemes such as the smart city project.

4 Introduction

This chapter contains the background of the assignment, city profile of Shimla and the objectives of this baseline study. It also briefly explains the methodology followed in the study's preparation and the exercise's limitations.

4.1 Assignment background

Program objectives: The IUC programme's overall objective is to contribute to improved international urban policy diplomacy and increased decentralised cooperation on sustainable urban development and climate change. The programme has two components: a) City/sub-national cooperation on sustainable urban development to strengthen EU-India cooperation among city/sub-national governments and at the national level on sustainable urban development while contributing to India's Smart Cities Mission, AMRUT and other national and international sustainable urbanisation processes; and b) cooperation on sustainable energy and climate adaptation and mitigation, and access to clean and affordable energy, through building upon the Global Covenant of Mayors (GCoM) initiative in line with existing India-EU commitments.

Baseline study: The baseline study for the SWM project with a focus on the WTE plant has been commissioned as part of the Shimla–Wolverhampton strategic collaboration under the IUC–India programme. The study is the key deliverable of the Urban Cooperation Action Plan for SWM in Shimla with additional focus on WTE plant. The objective of the assignment is to provide baseline information for SWM value chain in Shimla by analysing the current status of SWM and WTE facilities in Shimla, along with identifying challenges and providing recommendations. The study also identifies SWM best practices particularly related to WTE technologies and waste segregation, which are currently being followed in the city of Wolverhampton.

4.2 Shimla – district profile

Introduction: The former summer capital of the British India and the present capital of Himachal Pradesh, Shimla lies in the south-western ranges of the Himalayas and is situated at an average altitude of 2,206 metres (7,238 ft.) above mean sea level. It is bounded by Mandi and Kullu district in the north, Kinnaur in the east, Sirmaur in the west and the state of Uttrakhand in the south. The district having an area of 5,131 sq.km consists of 3,347 villages and is sub-divided into eight sub-divisions: Shimla Urban, Shimla Rural, Theog, Rampur, Rohru, Chopal, Dodra Kwar, and Kumarsain. The district's total population as per the 2011 census was 814,010, of which 425,039 were male and 388,971 were female. 2020 estimates of population peg the district's population at 927,971[5]. The majority of the population is Hindu (approximately 97%), followed by Muslims (1%), and others (approximately 2%). The population of Shimla city was 169,578 as per the 2011 census, of which 93,152 were males and 76,426 were females. The estimated population of Shimla city in 2019 was 206,575[6].

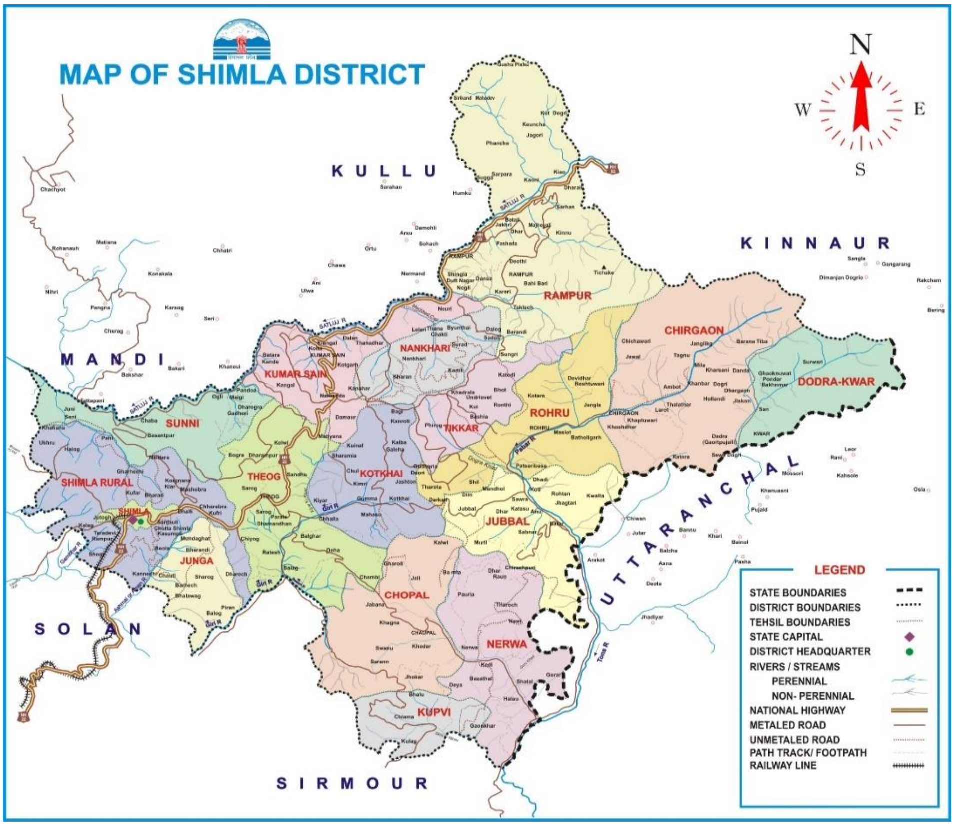
History: The history of Shimla dates back to the 19th century when it was founded by the British in the year 1819 after the Gorkha war. During that period, it was popular because of the temple of Hindu Goddess Shyamala Devi. In 1822, the first British summer home was constructed by Scottish civil servant Charles Pratt Kennedy. Shimla became the summer capital of the British Raj during the latter half of the 19th century. Shimla has seen many important historical events such as the famous Shimla Pact between India and Pakistan. Another remarkable event that took place in the history of Shimla was when the Kalka-Shimla railway line was constructed in 1906, which improved accessibility and resulted in immense popularity. Apart from this, Shimla was declared as capital of the undivided state of Punjab in 1871 and remained so until Chandigarh (the present-

[5] *Himachal Pradesh population*
[6] *Population of Shimla*

day capital of Punjab) was given the status of the region's capital. Himachal Pradesh got separated from Punjab in 1971, with Shimla becoming its capital.

Geographical location: Shimla is situated at a distance of 88 km northeast of Kalka, 116 km northeast of Chandigarh, 247 km south of Manali and 350 km northeast of Delhi. The city of Shimla stretches nearly 9.2 km from east to west and it was built on top of seven hills: Inverarm Hill, Observatory Hill, Prospect Hill, Summer Hill, Bantony Hill, Elysium Hill and Jakhoo Hill. There are no water bodies near the main city and the closest river, the Sutlej, is about 21 km away. Other rivers that flow through the Shimla district are the Giri and Pabbar (tributaries of Yamuna). Figure 3 provides maps of the Shimla district.

Figure 3: Shimla district map



Source: [Brief Geography of District Shimla]– Himachal Pradesh General Studies, May 19, 2020, by HP General Studies.

4.3 Objective of the study

Establish a baseline of the current practices to handle solid waste: The study has been prepared by undertaking extensive secondary research and multiple stakeholder consultations. The study highlights the amount and nature of solid waste generated in Shimla, and encapsulates current SWM practices with respect to collection, transportation, handling, disposal and treatment of waste in the city, along with highlighting policies and legal framework that influence SWM in Shimla, and overview and status of WTE plant set-up in Shimla.

Study on existing WTE plants: The study also analyses the current situation with regards to the operation of the existing WTE plants in Shimla. The study undertakes an assessment and description of technologies being used by these plants, describes the process of their operations and maintenance, highlights any challenges being faced by these plants and subsequently proposes potential solutions for those problems.

Present international experience on similar processes: This report covers case studies from Wolverhampton (UK) and some other European cities to identify efficient SWM value chains, and best practices regarding WTE technologies followed internationally. The study also encapsulates the key challenges and learnings from Wolverhampton in the SWM and WTE domain, which can be tailored, adapted and implemented in Shimla.

4.4 Methodology employed

The study is based on: a) secondary research through documents and reports shared by IUC-India and Municipal Corporation of Shimla, web search and case studies on SWM and WTE plants; and b) stakeholder consultations with officials of the IUC-India team, Municipal Corporation of Shimla and City of Wolverhampton Council.

Secondary research: Extensive secondary research was carried out during the preparation of this baseline study, which included summarising, collating and synthesising the existing research pertaining to the city of Shimla through reports shared by IUC-India and MC Shimla, and web search. Case study from Wolverhampton and best practices from other European cities provided additional information:

- <u>Documents shared by City of Wolverhampton Council and MC Shimla</u>: The officials of both the councils, i.e., City Council of Wolverhampton and Municipal Corporation of Shimla, provided documents and information that was used to data gaps and eventually complete the report. The officials of MC Shimla provided a status note on the current situation relating to the WTE plant commissioned in the city. The officials from Wolverhampton provided a PPT describing the solid waste management value chain in the city of Wolverhampton. They further shared their suggestion on improving the waste management cycle of Shimla based on a number of exchanges, which have been included in this report.
- <u>Documents shared by IUC-India</u>*:* The documents shared by the IUC-India team were imperative in the preparation of this baseline study and included several reports and research papers describing the state of SWM and the WTE plant in Shimla along with the draft local action plan being prepared as part of this cooperation. These documents provided a comprehensive overview of the current situation in the city related to the SWM value chain, including solid-waste generation, segregation, collection, transportation, treatment and disposal.
- <u>Documents procured through web search</u>: Various reports and articles related to urban infrastructure in Shimla and current condition related to SWM were referred to while preparing this study. Some of these reports included the City Development Plan, District Environment Plan for Shimla, Municipal Corporation of Shimla quarterly e-newsletter, a paper from a scientific journal titled, "Current status of solid waste management of Shimla", a case study sponsored by GIZ titled, "Effective Municipal Solid Waste Management Practices", Himachal Pradesh state byelaws, and some reports related to SWM as obtained from MC Shimla website. Various news articles and research report related to SWM and the WTE plant in Shimla were also reviewed during the course of this study.
- <u>Case study</u>: As a part of an extensive secondary research, case studies were analysed from various European cities, including Wolverhampton, Vienna, Copenhagen etc. The cases focused on efficient SWM systems, as well as best practices related to WTE technologies being adopted. Key learnings from these cities in the SWM domain as well as the WTE facility, which can be tailored, adapted and implemented in Shimla, have been detailed along with the case studies.

Stakeholder consultations: Stakeholder consultations were organised through video conferencing and conference calls. Discussions were held with various stakeholders – such as Ross Cook, Director, City of Wolverhampton Council, Dr. DP Singh, Project Coordinator, Municipal Corporation of Shimla, Mr. James Newman, Executive Chairman of EEPL, Mr. Dinesh, Project Manager of EEPL – and officials of IUC India, such as Dr Panagiotis Karamanos, Team Leader, IUC. Discussions were held to analyse the study's objectives, role of Municipal Corporation of Shimla, background of SWM in Shimla with a focus on WTE facilities, challenges being faced as well as to understand the key points to be captured in the baseline study. Inputs and insights provided by these experts/officials were of great importance in the preparation of this study and these have been further included in relevant chapters of this study.

4.5 Limitations of the exercise

The study aims to provide a comprehensive analysis of the current SWM scenario in Shimla, including an analysis on the existing WTE facilities in the city and to highlight the best SWM practices followed internationally. However, the study is limited in the sense that it is only a baseline study to assess the as-is situation of the SWM lifecycle in Shimla, in addition to the assessment of existing WTE facilities and the challenges being faced. Additionally, this study relies heavily on secondary sources of information and data collection through stakeholder consultations. In the wake of Covid-19 and the subsequent restrictions laid out by the Government of India, on-ground verification of data and site visits were not feasible.

5 Existing solid-waste management

This chapter captures the existing arrangement of SWM, including WTE facilities in Shimla, covering the entire SWM value chain, including waste generation, segregation, collection, transportation, disposal and waste-treatment processes and technologies. The coverage of SWM activities within the city, prevailing waste types and sources of waste have been further explained. It also covers the roles and responsibilities of key stakeholders of the SWM system, and the policy and legal framework applicable to SWM in Shimla.

5.1 Solid waste generated in Shimla

Amount of solid waste generated in Shimla: As per the officials of MC Shimla, no formal studies are available on the amount of solid waste generated in Shimla. However, based on per-capita generation of waste, it is estimated that all the 34 wards of the city combined generate about 84.5 tonne of municipal solid waste per day. Of the total waste generated, 70 tonnes of waste per day are collected through door-to-door collection, resulting in a waste collection rate of 83%. Although the waste collection coverage is 100%, the waste collection rate is only 83% on account of factors like segregation of recyclables by rag pickers/ the door to door garbage collectors after collecting waste from various sources, open dumping and illegal burning of waste.The collected waste is transferred to the WTE plant located at the outskirts of the city in Bhariyal. The plant converts municipal solid waste into RDF, which is sold to cement companies. The segregated waste and residue coming from the WTE process is disposed of at a site adjacent to the plant and covered with soil and construction debris.

Physical characteristics of municipal solid waste: A paper published in the Journal of Civil Engineering and Environmental Technology in 2016, titled “Current Status of Solid Waste Management of Shimla”, analysed waste samples collected from different parts of the cities, including residential zones, commercial zones and mixed zones. It determined the amount of various physical components (metal, glass, food and paper) in the samples collected. While the major component in the sample collected from the residential zone was food (42.6%), the major component in the sample collected from the commercial zones was paper (32.8%). Table 1 provides a detailed breakdown of various samples of solid waste collected from different zones in terms of their physical characteristics:

Table 1: Physical characteristics of municipal solid waste in Shimla, 2016

#	Component	Residential zone		Commercial zone		Mixed zone	
		Weight (kg)	%	Weight (kg)	%	Weight (kg)	%
1.	Metal	3	0.3	0.5	0.1	11	0.9
2.	Glass	15	1.5	3.5	0.7	19	1.7
3.	Food	435	42.6	96	18.8	295	26
4.	Paper	162	15.9	167	32.8	205	18.1
5.	Textile	56	5.5	16	3.1	78	6.8
6.	Plastic	84	8.2	87	17.1	164	14.5
7.	Rubber	9	0.9	14	2.7	55	4.8
8.	Inert	84	8.2	31	6.1	129	11.4
9.	Misc. combustible	75	7.4	22	4.3	54	4.8
10.	Misc. incombustible	97	9.5	73	14.3	125	11.0
Total sample size		**1,020 kg**	**-**	**510 kg**	**-**	**1,135 kg**	-

Source: Current Status of Solid Waste Management of Shimla, Journal of Civil Engineering and Environmental Technology, Volume 3, Issue 9; October-December, 2016, pp. 793-795, by Mudit Mishra, Bhawani Singh Meena and Nitin Rana

Chemical characteristics of municipal solid waste: The same study also analysed the chemical composition of waste samples collected from different parts of the cities, including residential zones, commercial zones and mixed zones. The analysis focused on determining the pH values of the three samples and the amount (in %) of moisture, nitrogen, phosphorous, potassium, total carbon and organic matter present in the waste samples. Table 2 highlights the chemical characteristics of the MSW that was analysed for the city of Shimla.

Table 2: Chemical characteristics of municipal solid waste in Shimla, 2016

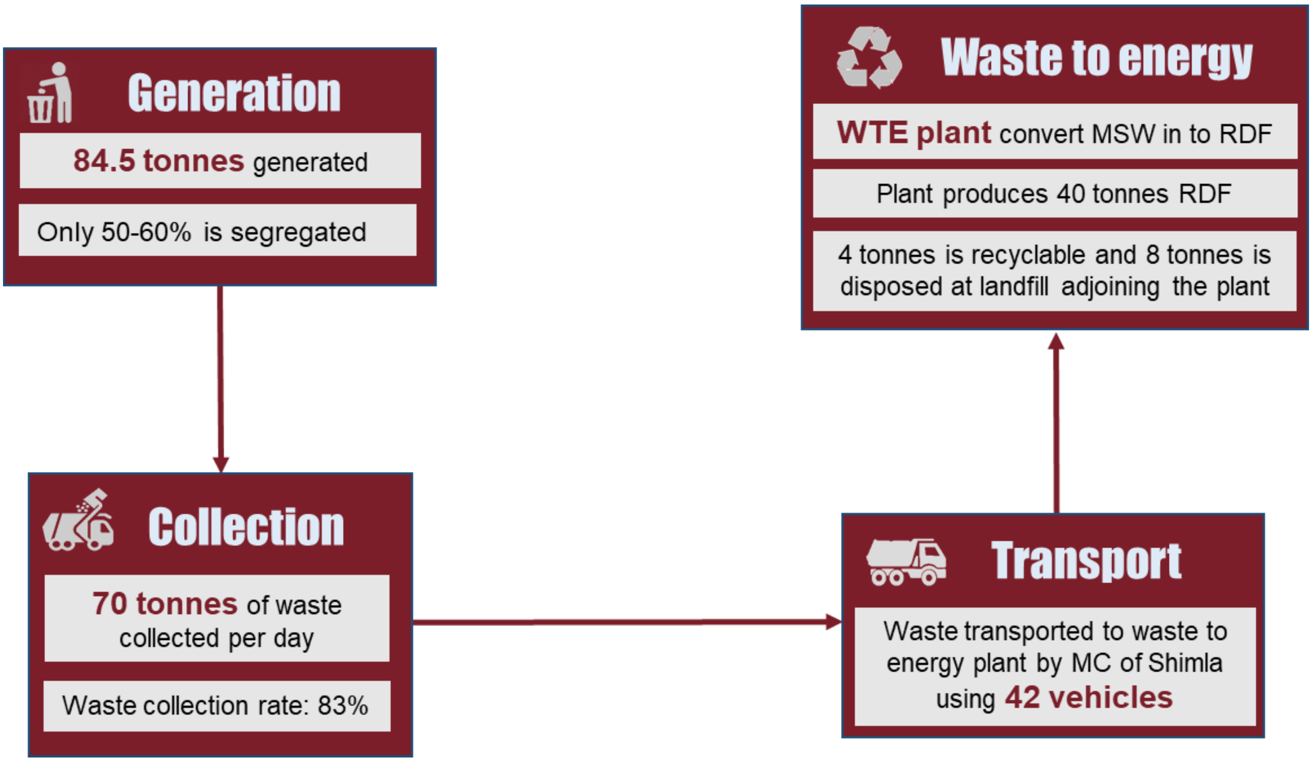
#	Component	Residential zone	Commercial zone	Mixed zone
1.	pH	6.48	6.84	6.23
2.	Moisture (%)	58.2	40.7	52.5
3.	Nitrogen (%)	0.9	0.7	0.7
4.	Phosphorous (%)	0.4	0.2	0.2
5.	Potassium (%)	0.3	0.3	0.6
6.	Total carbon (%)	35.5	25.0	37.0
7.	C/N ratio (%)	40.8	36.8	52.0
8.	Calorific value (kcal/kg)	2,840	2,480	2,950
9.	Temperature (°C)	13.5	10.5	12.5
10.	Organic matter (%)	41.7	30.0	47.5

Source: Current Status of Solid Waste Management of Shimla, Journal of Civil Engineering and Environmental Technology, Volume 3, Issue 9; October-December, 2016, pp. 793-795, by Mudit Mishra, Bhawani Singh Meena and Nitin Rana

5.2 Solid waste collection, transportation and treatment

Solid-waste management responsibility and coverage: The SWM division is under the administrative control of the health officer of the Municipal Corporation Shimla. The officer is assisted by project coordinator, chief sanitary inspector, sanitary inspectors, and other sanitary staff. The Himachal Pradesh State Environment Protection and Pollution Control Board being a regulatory body acts in an advisory role in matters related to SWM. Shimla is divided into 34 wards for providing SWM services. Each ward is further divided into beats for street sweeping and is supervised by sanitary inspectors. Sanitary Inspectors are also responsible for monitoring of door-to-door garbage collection scheme, which is undertaken by SEHB Society workers. The duties and responsibilities of various stakeholders include door-to-door collection of municipal solid waste, segregated storage of the waste at secondary storage and collection points, and treatment and disposal of municipal solid waste. Figure 4 presents the SWM cycle in Shimla.

Figure 4: SWM cycle in Shimla



Source: Effective Municipal Solid Waste Management Practices: A Case study of Shimla, Himachal Pradesh, India; Omesh Bharti, Amarjeet Singh, D P Singh, Vibhor Sood; Waste Management & Resource Utilisation (2014), International Society of Waste Management, Air and Water (ISWMAW);

Waste segregation: Waste segregation at the source, i.e., households/commercial establishments, is encouraged by the Municipal Corporation of Shimla. SEHB has provided two bins, coloured yellow and green, to households / commercial establishments / institutions for collection and segregation of garbage. The yellow bins are for non-biodegradable waste and green bins are for biodegradable waste collections within the establishments. This segregated waste in the respective bins is to be given to the representative of the SEHB Society, as per the collection schedule fixed for each locality. At a broad level, three days each in a week are allocated for collection of dry and wet waste. Municipal Corporation of Shimla also runs various information, education and communication programmes to sensitise the general population with the benefits of segregation waste. However, the waste-segregation initiative has not met with the intended success and only 50-60% waste is segregated in the city. Figure 5 depicts the segregation bins provided to residential/commercial establishments, along with an example of primary collection of waste in Shimla.

Figure 5: Primary segregation and collection in Shimla

Source: Himachal Initiates Waste Management, by Disha Singh Sharma, April 30, 2010; Municipal Solid Waste Management Plan for Municipal Corporation Shimla, 2012

Solid waste collection: The SEHB Society was formed to undertake door-to-door collection of municipal solid waste. Currently, 100% households and commercial establishments in all the 34 wards of Shimla have been covered under the door-to-door waste collection scheme. SEHB Society has deployed 457 workers for undertaking door-to-door waste collection. SEHB Society has made significant efforts in management of its human resources – garbage collectors are provided personal protective equipment, while woman workers are assigned with clusters close to their homes. Married couples are kept in the same ward operations. Vaccination drives are conducted from time to time for workers. Further, all the 202 dumpers, which were used for secondary collection of waste, have now been removed by Municipal Corporation of Shimla. Only 17 dumper containers remain in the city; they are located at the premises of large organisations, such as ISBT Shimla, Himachal Pradesh University, schools and colleges. There are no transfer stations in the Shimla city. Apart from this, Municipal Corporation of Shimla has also placed litter bins at all the major public places to promote cleanliness in the city. Users have been divided into different categories and each category is charged differently based on the polluter-pays principle; for example, residential households are charged Rs 88 per month (€ 1.03 per month) while commercial properties like hotels are charged Rs 16,000/month (€ 178/month). These charges are revised every year at a rate of 10%.

Solid waste transportation: A total of 42 hydraulic vehicles have been procured and deployed to facilitate the transportation of waste to the WTE plant at Bhariyal. Each of the 34 wards have at least one pick-up vehicle/ tipper at their disposal. The SEHB Society workers carry waste from areas that are not accessible by roads in gunny bags and deposit the waste in these pick-up vehicles / tippers stationed at accessible roads. Recently, Municipal Corporation of Shimla has procured a compactor, which is being used as a stationary compactor/ transfer station on trial basis and has been placed on the by-pass road. Pick-up vehicles / tippers from far-flung areas are allowed to deposit the collected garbage directly into this compactor. During the trial, it was found that the compactor was able to accept waste from 19-20 pick-up vehicles / tippers and then it was transported to the WTE plant. In short, the compactor is working as a temporary transfer station. Municipal Corporation of Shimla plans to buy four more of these compactors. The ward-level routing and loading plan has been developed by Municipal Corporation of Shimla with help of GIZ. The ward-level route and waste-collection point are plotted at the ward-level map. Additional information such as the domain of the garbage collector, street-sweeping beat, collection timings, frequency, road category, landmarks and land use is compiled at the ward level. The collection vehicles run on a predefined and optimised route. The routing and loading plan for waste transportation is shared with each vehicle and exercised in coherence with door-to-door garbage collection.

Solid-waste treatment and disposal: A WTE plant was commissioned at Bhariyal, located on the outskirts of Shimla, in August 2017. Built at a cost of Rs 42 crore (€ 4.9 million), the plant can produce up to 2.5 MWh of green energy using RDF. The collected waste is transported to the WTE plant through hydraulic vehicles and compactors. The plant processes 70 tonne per day of waste on an average. The amount of waste processed by the plant can be up to 80 tonne per day or more in summer. Of the 70 tonnes per day of waste received, the plant converts 40 tonnes into RDF daily[7], which can be used for electricity generation. Given that RDF process reduces the moisture content in the waste, 100% conversion of MSW into RDF is not achieved. Of the remaining waste, 4 tonne of segregated waste is recyclable waste and 6-8 tonne is disposed of at the landfill adjoining the waste-treatment plant site, which is covered with soil / construction debris on a daily basis. Currently, there are no scientific landfills in Shimla, but Municipal Corporation of Shimla is planning to initiate the tendering process for a scientific landfill.

Composting and biogas plant: Municipal Corporation of Shimla has commissioned one tonne per day of biogas plant, which uses organic waste as an input. The plant was established under a European Union-funded project with a total project cost of Rs 36 lakh (€ 42,024). The biogas produced from the plant is used by the laborers, working at the plant, for domestic purposes. Municipal Corporation of Shimla also identifies composting as an option to tackle bio-degradable waste. Hence, it has floated tenders for setting up a composting plant with a capacity of processing 5 tonne per day of wet waste. If successful, the composting plant will help in increasing the efficiency of the WTE plant by accepting considerable amount of organic waste being produced in the city, especially from bulk-waste generators / vegetable market, leaving the dry waste for the WTE plant.

5.3 Organisational set-up of the city

Overview: The administrative responsibilities of the city of Shimla reside with Municipal Corporation of Shimla. Municipal Corporation of Shimla is one of the oldest municipalities of India and has passed through many slings and arrows during its last 170 years of existence. It was first constituted as Municipal Committee in December 1851, and became Class I Municipality in 1871. In 1874, it was brought under the Punjab Municipal Act (IV of 1873). As a result of re-organisation of Punjab, Shimla became a part of Himachal Pradesh. Pursuant to Himachal Pradesh Development and Regulation Act, 1968 (Act No.22 of 1969), Shimla Municipal Committee was converted into a corporation in 1969.

Elected body: The elected body of Municipal Corporation of Shimla has 39 councillors, of which 34 are directly elected and five are nominated by the Government of Himachal Pradesh. The tenure of the corporation is five years. The elected councillors elect the mayor and deputy mayor among themselves for a tenure of two-and-a-half years. The house, comprising the elected and nominated members, takes all policy decisions. The house meets at least once every month. The corporation has several statutory and non-statutory functional committees, represented by councillors to set out the obligatory and discretionary functions bestowed upon the corporation by the 74th Constitutional Amendment Act (CAA). Each committee consists of not less than three and not more than five councilors, including mayor or deputy mayor.

Administrative set-up: The commissioner of Municipal Corporation of Shimla is the administrative head of the corporation. All executive and administrative powers for the purpose of carrying out day-to-day functions are vested in him. He is appointed by the state government for a particular time. He is assisted by a joint/assistant commissioner, who is also appointed by the state government. Additionally, Municipal Corporation of Shimla has its own permanent cadre of officers, who look after independent branches. The head of the branches are also deputed with Municipal Corporation of Shimla on deputation basis for a particular period by the Government

[7] *Source: Potential Utilization of RDF as an Alternative Fuel to be used in Cement Industry in Jordan, MDPI, October 20, 2019, by Safwat Hemidat, Motasem Saidan, Salam Al-Zu`bi, Mahmoud Irshidat, Abdallah Nassour and Michael Nelles.*

of Himachal Pradesh. Municipal Corporation of Shimla is entrusted with the development-related matters of the municipal corporation areas and providing basic civic amenities.

5.4 Policy and legal framework

Various national policies and by-laws related to SWM are described below. These are: solid Waste Management Rules, 2016; Construction and Demolition Waste Management Rules, 2016; e-Waste Management Rules, 2016, Plastic Waste Management Rules, 2016; Bio-Medical Waste Management Rules, 2016; and Hazardous Waste Management Rules, 2016.

- **Solid Waste Management Rules, 2016:** The Ministry of Environment, Forests & Climate Change (MoEF & CC) revised the Municipal Solid Waste (Management and Handling) Rules, 2000, as Solid Waste Management Rules, 2016. With the introduction of the Solid Waste Management Rules, 2016, a wider range of stakeholders have been held accountable for the efficient management of the SWM system. The new set of protocols define the responsibilities of each member in the value chain and also introduce awareness initiatives, incentives and penalties around the SWM process. They also introduce the criteria for setting up a waste-treatment facility, criteria for a WTE process, specifications of sanitary landfills, and monitoring for their implementation. The policy explains the roles and responsibilities of stakeholders, and explain the power of ULBs to enforce user charges for SWM services. The policy also allows for incentives, such as capital subsidy, co-marketing of fertilisers for WTE plants. Additionally, the policy mandates that non-recyclable waste, having a calorific value of 1,500 kcal/kg or more, shall not be disposed of on landfills and shall only be utilised for generating energy either or through RDF or by giving away as feedstock for preparing RDF.
- **Construction and Demolition Waste Management Rules, 2016:** The MoEF & CC notified the Construction and Demolition Waste Management Rules in 2016. The rules are an initiative to effectively tackle the issues of pollution and waste management. The construction and demolition waste generated nationally is about 530 million tonne annually. The Construction and Demolition Waste Management Rules, 2016, defines construction and demolition waste; The rules apply to every waste resulting from construction, re-modelling, repair and demolition of any civil structure of individual, organisation or authority, who generates construction and demolition waste, such as building materials, debris and rubble. Additionally, the rules mandate that the local authority shall get the collected waste transported to appropriate sites for processing and disposal, either through own resources or by appointing private operators. Additionally, Himachal Pradesh state policy and strategy on management of construction and demolition waste has been notified by Govt. of Himachal Pradesh[8].
- **E-Waste (Management) Rules, 2016:** The MoEF & CC notified the E-Waste Management Rules, 2016, in supersession of the E-Waste (Management and Handling) Rules, 2011. The policy applies to every consumer, producer, manufacturer, collection centers, dealers, refurbishes, dismantlers and recyclers involved in manufacture, sale, transfer, purchase, storage, collection, and processing of e-waste or electronic and electrical equipment, which is listed in Schedule I. It also include parts, components and spares that make the product operational. The protocols superseded the E-Waste Management Rules, 2011. In E-Waste (Management) Rules, 2016, e-waste has been defined as a whole or in parts of an electrical and electronic equipment discarded as waste by consumers as well as the rejected material from refurbishment, manufacturing and repair. As per these rules, it is the responsibility of the manufacturer, producer or dismantler to collect the e-waste generated during manufacture/production/dismantling and channelise it for recycling/disposal.

[8] *(http://ud.hp.gov.in/sites/default/files/documents/Himachal%20C%26D%20Waste%20Policy.pdf)*

- **Plastic Waste Management Rules, 2016:** The MoEF & CC notified the Plastic Waste Management Rules, 2016, which will now supersede the Plastic Waste Management Rules, 2011. The policy defines plastic, compostable plastics, carry bags, virgin plastics, multilayered packaging and all types of plastic waste. It also lists the categories of plastics, the roles and responsibilities of prescribed authorities for plastic waste management, as well as the roles and responsibilities of plastic waste generators and producers. The set of protocols explain the modalities of plastic waste management, environmental issues and challenges related to plastic waste and to promote the use of plastic waste in various tasks, such as road construction and energy recovery. Recently, Govt. of Himachal Pradesh has notified a policy regarding Buy-back of Non-recyclable and Single Use Plastic Waste including plastic bags in the Himachal Pradesh from Rag pickers and households, providing Minimum Support Price of Rs. 75/- only per kilogram, for its collection and deposit in the collection centers of the Urban Local Bodies[9].
- **Bio-Medical Waste Management Rules, 2016:** The MoEF & CC notified the bio-medical waste management rules, 2016, to replace the earlier rules of 1998. These protocols define the types of waste, which is categorised as bio-medical waste such as human and anatomical waste, treatment equipment, such as needles, syringes and other material used in healthcare and in the process of treatment and research. They also explain the waste categories for bio-medical waste and define the ambit of bio-medical waste generators, such as blood banks, treatment or immunisation processes in hospitals and nursing homes, as well as scientific disposal of such waste for effective disposal by hospitals and other waste generators. The roles and responsibilities of waste generators and producers as well as standards for incinerators and other bio-medical waste handlers are also explained.
- **Hazardous and other Waste (Management and Transboundary Movement) Rules, 2016:** The MoEF & CC has issued its revised Hazardous and Other Waste (Management and Transboundary Movement) Rules, 2016. The policy explains the type of waste, which, by reason of its characteristics, would be classified as hazardous waste and helps to distinguish between hazardous and other wastes. Classification of hazardous waste, identification as well as storage and labelling requirements of hazardous waste are explained. Management of such waste, problems associated and importance of proper hazardous waste management are also illustrated. The roles, responsibilities and duties of waste generator and various stakeholders as well as environmentally sound management, management hierarchy, co-processing, disposal and recycling of hazardous waste are also explained.

Policies and by-laws applicable to SWM and waste-treatment facilities in Shimla, as prescribed by Municipal Corporation of Shimla and the Government of Himachal Pradesh, have been described below.

- **Himachal Pradesh Non-Bio-Degradable Garbage (Control) Act, 1995:** An Act to prevent throwing or depositing non-biodegradable garbage in public drains, roads and places open to public view and to regulate the use of non-biodegradable material in the state of Himachal Pradesh and for matters connected therewith or incidental thereto. Some salient features covered under this Act include: (i) prohibition to throw non-degradable garbage in public drains and sewage; (ii) restriction or prohibition on use of certain things manufactured from non-biodegradable material; (iii) provision for placement of receptacles and places for deposit of non-biodegradable garbage; (iv) duty of owners and occupiers to collect and deposit non-biodegradable garbage; and (v) power of local authority or competent authority for the removal of non-biodegradable garbage or non-biodegradable material from private properties.
- **Door-to-Door Garbage Collection Bye-Laws (MC Shimla), 2006:** Under the Himachal Pradesh Municipal Act, 1994, Municipal Corporation of Shimla had adopted the Door-to-Door Garbage Collection Bye-laws in 2006, which state that each household / commercial establishment / educational institute and other institutes will handover garbage to the agency authorised by Municipal Corporation of Shimla. This led to the

[9] *http://ud.hp.gov.in/solid-waste-managementngt/plastic-waste-buy-back-policy*

establishment of SEHB Society, registered under the Himachal Pradesh Societies Registration Act, 2006, in 2009. The municipal commissioner heads the SEHB Society's waste-collection initiative and is responsible for overall supervision, along with the corporation health officer as a member secretary of the society. The SEHB Society staff, which is supervised by the chief sanitary inspector, looks after collection and transportation services. A dedicated team is allocated for smooth functioning of the system. There are two coordinators for SEHB Society. All the wards have a dedicated supervisor and assistant supervisor reporting to the coordinators, who, in turn, reports to the sanitary inspectors. A mechanism for collection is defined through physical verification of households and communities. Optimisation of routing of each vehicle and provision of a substitution plan for any breakdown in vehicles has been established. Centralised complaint redressal system within Municipal Corporation of Shimla and dedicated telephone lines at the SEHB Society office have been established to resolve the complaints of users.

Although there are various guidelines for treatment of biomedical waste, these guidelines lack guidance on adapting the existing waste management practices for a pandemic. Keeping this in mind, United Nations Human Settlement Programme has developed a ten point strategy for solid waste management in the context of Covid-19. These guidelines have been presented below:

- **Map sources of waste generation to identify changes in generation amounts and flows:** Places such as hospitals, home care units, testing labs, and quarantine camps should be identified as they will generate hazardous waste. Additionally, places such as schools commercial units etc. which will see decreased waste generation shall also be identified. The mapping of such sources will enable efficient resource allocation

- **Separate infectious waste in households:** All potentially infectious waste should be put in clearly identifiable colored bags, ensuring double coverage if possible. If identification of or separation of infectious waste is not possible then all waste from the household should be sealed and handles as residual waste. Waste bags should be distributed to households' especially low income and informal settlements.

- **Maintain and expand waste collection services:** Human as well as financial resources should be allocated efficiently as per the mapping exercise undertaken by the authorities. Increased and regular waste collection services should be provided to the identified biomedical waste sources, informal settlement and high population density areas. The authorities should promote reduced contact between people especially during door to door collection of waste.

- **Ensure safe waste treatment and disposal:** On site temporary storage and thermal treatment of infectious waste from identified sources in the city must be ensured. If thermal facilities are not available, adequate and safe sanitary landfill measures must be ensured.

- **Protect waste workers, formal and informal:** All workers either formal or informal must be properly trained to follow basic hygiene measures. Safe work practices including PPE shall be made available for these workers. The authorities should also consider support for livelihood loss of informal waste workers.

- **Regularly communicate with citizens and stakeholders:** The new collection schedule and other changes must be effectively communicated to through radio, newspapers, social media and other channels. Citizens should ensure proper disposal of waste in line with guidelines.

- **Engage with stakeholders:** The authorities must engage with waste stream stakeholders both formal and informal to identify roles and responsibilities. Coordination and collaboration with informal workers, NGOs and waste management operations should be undertaken to strengthen and expand service and coverage.

- **Accelerate procurement procedures:** The procurement of safety equipment, additional storage bins, collection trucks, should be expedited. A review of central and state funds should be undertaken to review possibility of fund diversion from existing programmes to push Covid-19 related activities
- **Application of national and international guidelines for healthcare and medical waste:** The guidelines laid out by the respective government shall be followed. In case of absence of government guidelines, the WHO guidelines should be followed.
- **Design scenarios and contingency plans:** The lesson learned from other countries should be considered and implemented in each phase of planning. The authorities should also conduct risk assessments associated with failure of continued service for instance staff and equipment shortage, closure of recycling, waste treatment and disposal units.

6 Waste-to-energy plant

This chapter analyses the WTE plant at the outskirts of Shimla. It examines the different types of technology used at the plant, and agreements between the private operator and government authorities. It also provides the current status of the plant along with operational data for fiscal 2020.

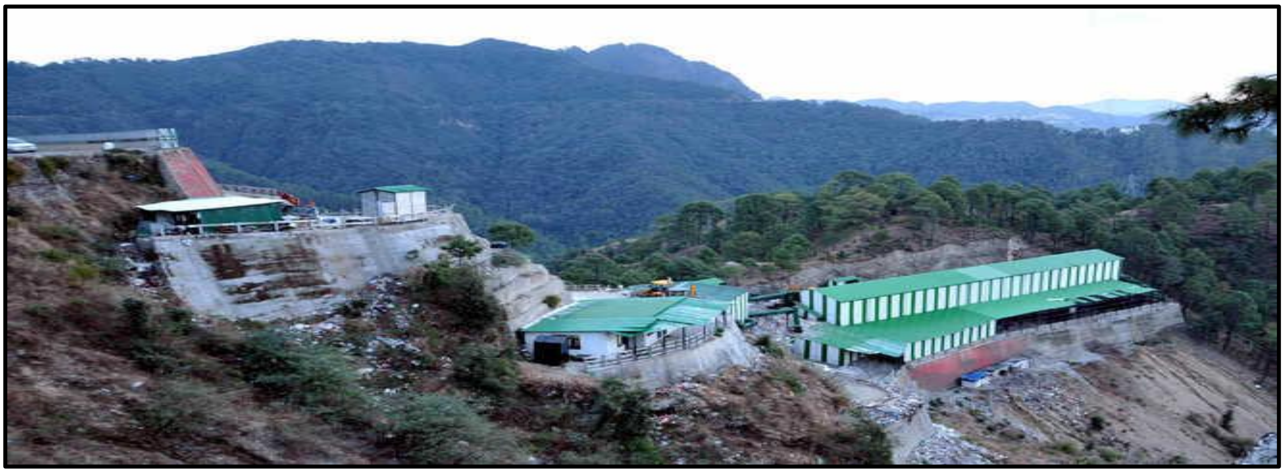
6.1 Introduction

Overview: Municipal Corporation of Shimla signed a waste concession and land access agreement with M/s Elephant Energy Pvt Ltd (EEPL) on March 29, 2016, for setting up the WTE plant. Further, a power purchase agreement (PPA) between EEPL and Himachal Pradesh State Electricity Board Ltd (HPSEB) was signed on May 16, 2016. After the signing of these agreements, a 2.5 MWh WTE plant based on “refuse derived fuel” (RDF) technology using “gasification technology” was commissioned based on PPP mode. The plant, commissioned in August 2017, has been set up in the outskirts of Shimla, at a cost of Rs 42 crore (€ 4.9 million). It has a capacity to handle 100 tonnes of waste per day and can generate up to 2.5 MWh of electricity. Two RDF lines have been made functional for processing municipal solid waste and converting it into RDF for generation of electricity. Other equipment such as engines and turbines have been installed and the machinery has been tested by EEPL. The grid connectivity has been done through HPSEB. Though solid waste is being processed at the WTE plant daily, it is yet to generate electricity to its full potential. As per recent reports, trials for generating electricity from municipal waste have started at the plant. Around 2 KWh power is being produced during the trials every day, and 1.7 MWh of electricity is expected to be generated by processing 70 tonnes/day of municipal solid waste.

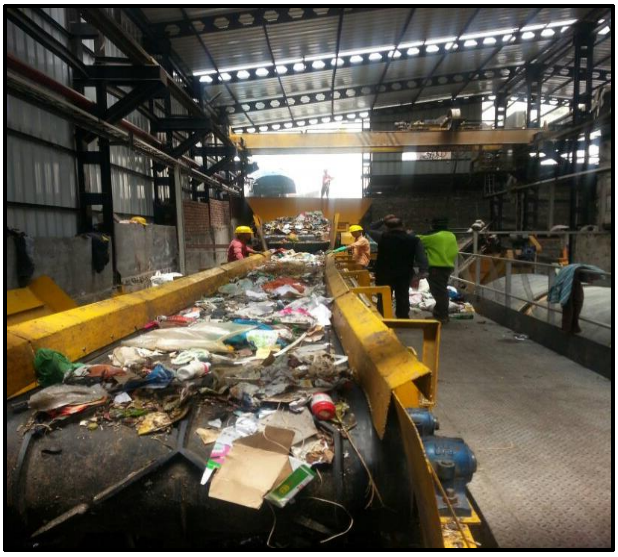
Details of PPP concession agreement: The WTE plant in Shimla was commissioned on a PPP mode with a concession period of 20 years. The land has been provided by Municipal Corporation of Shimla, while all the capex related to RDF processing and deployment of gasification technology has been undertaken by EEPL. As per the PPP agreement signed between the corporation and EEPL, the former is mandated to deliver 70 tonnes of waste per day to the plant. Failing to do so may lead to monetary penalties on the corporation by EEPL. However, so far, the corporation has been able to deliver on its mandate. It provides 70 tonnes of waste to the plant daily, which increases to 80 tonnes during the tourist season. Figure 6 presents few images of the waste to energy in Shimla.

Details of agreements signed: As per the waste concession and land concession agreement signed between EEPL and Municipal Corporation Shimla, EEPL has to accept mixed waste at the WTE plant and the corporation does not have to pay tipping fee to the private operator. Waste rejects from the gasification technology are expected to be less than 10%, which can be used for preparation of tiles, etc. Thus, it will reduce the burden on the landfill site and the tipping fee to be paid to the operator of the scientific landfill site will be saved. The PPA has been executed as per Central Electricity Regulatory Commission (CERC) notification at the rate of Rs 7.90/unit (€ 0.09/unit).

Figure 6: Waste to energy plant, Shimla



Waste to energy plant, Shimla



Refuse derived fuel section

Gasification section

Source: Delhi firm to generate power from solid waste in Shimla – The Tribune, February 9, 2016, Kuldeep Chauhan; Municipal Corporation of Shimla.

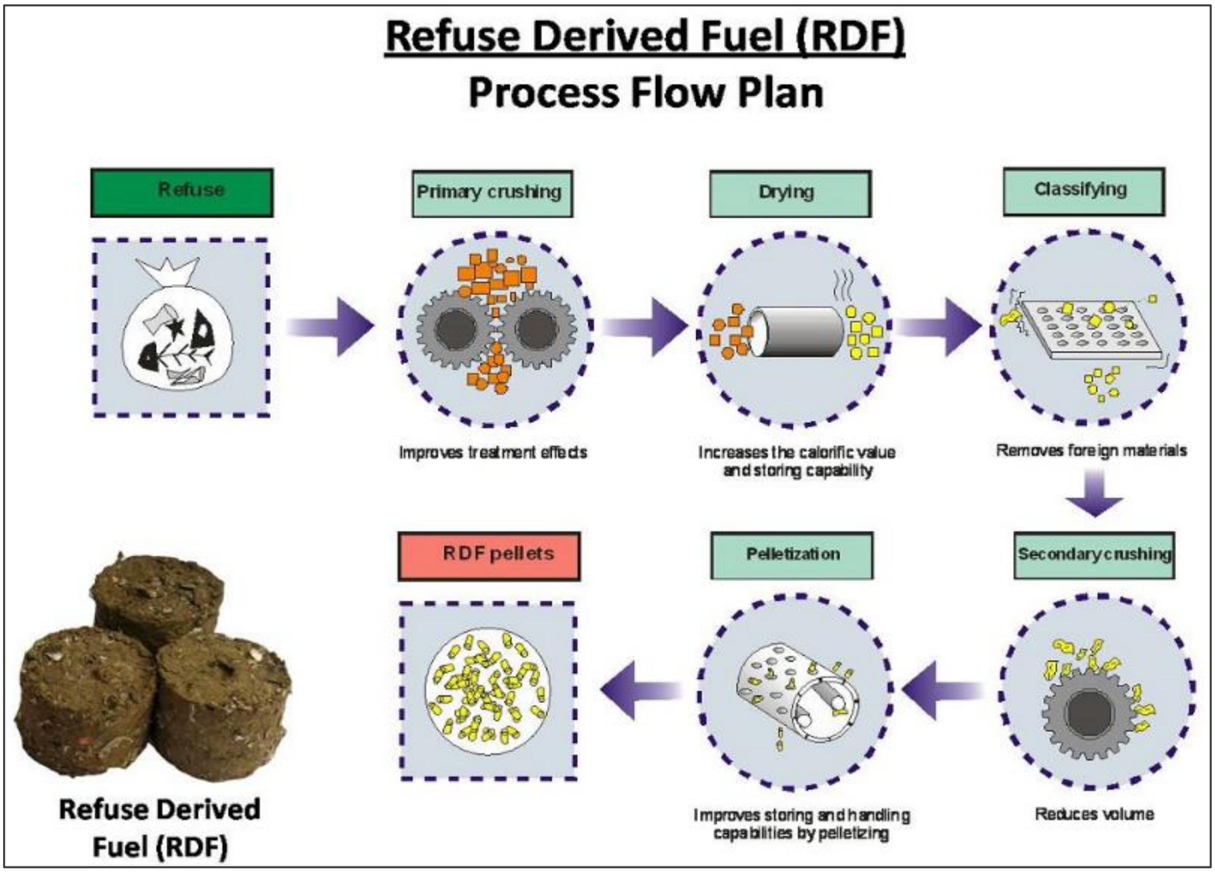
Current status of the WTE plant: Although the trial run for the generation of electricity was carried out successfully, problems related to excessive oxygen content were noted inside the gasifiers installed by the private operator, which could have led to explosion inside the machinery. In order to rectify the same, the gasifier was sent to Germany and thereafter Australia. A modified gasifier was installed at the Bhariyal plant and the private operator added a plasma torch. However, commercial production of electricity is yet to start. EEPL has proposed to install a gasifier with enhanced capacity. Commercial generation of electricity is expected to commence in July 2021. The main hindrance faced by the WTE plant is the cleaning of synthetic gas (syngas), which is being produced by the gasifier and is fed to the turbines to generate electricity. At present, all the waste is converted into RDF and, on average, 40 tonnes/day of RDF is produced. On average, 27-30 tonnes/day RDF is transported to cement industries for further processing and the rest is stored at the plant for use during the lean period.

6.2 Technology description

Solid waste generated by Shimla is processed at the WTE plant to extract RDF, which is used as a feedstock in the gasifier to produce syngas. This gas can be used in engines or turbines to generate electricity or further processed to produce hydrogen, substitute natural gas, chemicals, or fertilisers. Detailed description of RDF and gasification technology is as follows:

RDF: Within municipal SWM, processing of several fractions that are combustible in nature but not recyclable (such as soiled paper, soiled cloth, contaminated plastics, multilayer, packaging materials, other packaging materials, pieces of leather, rubber, tyres, polystyrene, and wood) has remained a challenge and these fractions end up at landfill sites. These fractions can be processed and converted to RDF, which carries significant calorific value, and can be utilised as alternative fuel in various industries in line with the principle of waste to wealth. RDF is produced in a four-step process. First, waste is crushed to an appropriate size for drying. The crushed refuse is then dried and deodorized under high temperature blasts. Then waste is sorted and non-combustible materials (such as glass and metal) are removed. Waste items are then separated according to their weight. Heavy materials are discarded as they have a lower calorific value. Lighter material with high calorific value are used as RDF. These materials are processed into pellets, bricks or logs to be used as RDF. Figure 7 briefly illustrates the process of extracting RDF from municipal solid waste.

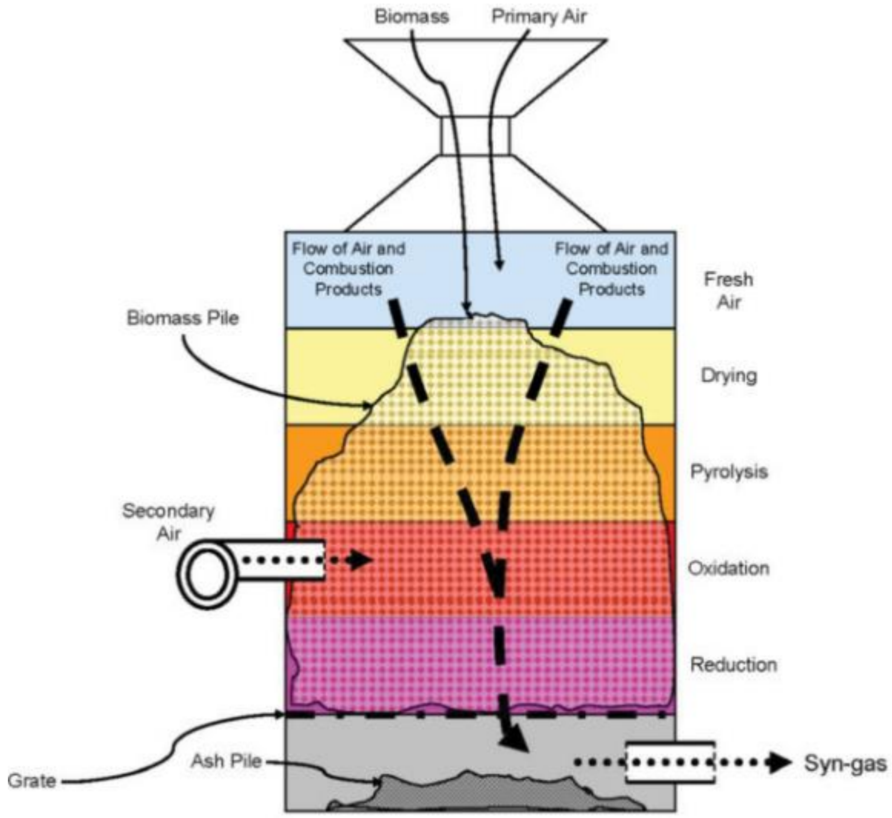
Figure 7: Processing of RDF



Source: [Refuse derived fuel – Waste Busters]

Gasification technology: Gasification is a thermal process which converts organic carbonaceous materials into a combustible gas comprised of carbon monoxide (CO), hydrogen (H) and carbon dioxide (CO_2) by using refuse derived fuel and other materials such as such as wood waste, shells, pellets, agricultural waste, and fraction of municipal solid waste and an input. This is achieved by reacting the material at high temperatures, without fully combusting it, using a controlled oxygen inlet. The resulting gas mixture is called syngas. At temperatures of 600-1000°C, solid biomass undergoes thermal decomposition to form gas-phase products which typically include CO, H, CH_4, CO_2, and H_2O. Gas composition depends on many factors, including the type of feedstock, gasification temperature and the reactor type. Syngas can be used directly for heating or electricity generation or can be used for further processing as chemicals or liquid fuel synthesis. The process is similar to that of combustion, but has lower moisture acceptability (less than 15% of total waste). The gasification process produces gases and ash. The process can also be termed as incomplete combustion or extended pyrolysis in which gas-solid, gas-gas and liquid cracking reactions are required to maximise the gaseous product yield. Figure 8 illustrates the gasification process.

Figure 8: Gasification process



Source: [Biomass gasification for large scale electricity generation]() – EE Publishers, January 30, 2019 by Mike Rycroft, EE Publishers

There are four stages in the gasification process:

- Drying: In the drying zone, moisture in the feedstock is evaporated by heat from the lower zones at a temperature between 150°C and 200°C. Vapours move down and mix with vapours originating in the oxidation zone. A part of the vapour is converted into oxygen with the remainder being retained in the producer gas.
- Thermal decomposition: Thermal decomposition of biomass is undertaken in low oxygen conditions at temperatures ranging 200-600°C. For gasification, there must always be a zone of relatively low temperature where condensable hydrocarbons are generated. This process results in production of solid char, liquid tar, and a mixture of gases. The proportions of these components are influenced by the chemical composition of the biomass and operating conditions of the gasifier, of which reactor temperature is critical. It is generally understood that process involves the breakdown of large molecules (such as cellulose, hemi-cellulose, and lignin) into medium-size molecules and carbon (char). If medium-size molecules remain in

the hot zone long enough, they break down into smaller molecules and, along with the char, forming CO, CO_2, H_2, and CH_4.

- Combustion: Oxidation occurs in the presence of a reactive gas (air or pure oxygen), which affects the calorific value of the gas leaving the gasifier. The use of air as reactive gas is more common. An oxidation zone follows, at which air is introduced at less than stoichiometric oxygen conditions. The principal reactions are highly exothermic and, thus, result in much higher temperatures, leading to the breakdown of medium-size molecules, such as tars and oils generated in the pyrolysis zone, into smaller molecules including CO, H_2, CH_4, etc. Oxidation takes place at temperatures ranging 700-1000°C. In addition to O_2 and water vapour, ambient air contains large amounts of N_2 and small amounts of other inert gases, all of which are considered to be non-reactive with fuel constituents at relatively low pressures and temperatures.
- Reduction: Products of the oxidation zone, hot gases and glowing char, move into the reduction zone. Since there is insufficient O_2 in this high-temperature zone for continued oxidation, a number of reduction reactions take place between hot gases (CO, H_2O, CO_2, and H_2) and char. Principal reduction reactions include CO_2, a water gas, and a water-gas shift reaction. The char produced reacts with water vapour and CO_2, forming hydrogen and carbon monoxide - principal constituents of the combustible gas (syngas).

Syngas from gasification: The main application of produced syngas is generation of power and heat. This can be realised either in standalone combined heat and power (CHP) plants or through co-firing of the product gas in large-scale power plants. Syngas from gasification is a combustible gas and can be used for the production of power in many types of equipment, from steam cycles through gas engines and turbines. While the usage in boilers for steam cycles does not require extensive gas treatment before power generation, gas engines need a higher degree of purification and preparation. Stability and consistency of fuel provided to the internal combustion engine are key factors of this process.

6.3 Description of operations of the plant

The WTE plant at Shimla is divided in to two parts: RDF processing and electricity generation through gasification. Although the RDF processing part is functioning at its full capacity and generates 40 tonne of RDF per day, the gasification plant is yet to operate at its full capacity of 2.5 MW. The plant's operations have been described below:

- RDF: The RDF processing plant consists of two RDF lines, magnetic separators, manual segregation, shredders, and dryers. On average, it produces 40 tonnes of RDF per day. Given that the plant is not generating any electricity, 27-30 tonnes of RDF produced from the plant, on average, is sold to cement companies in proximity (Ambuja Cement and Ultratech Cement) at a nominal price of Rs 500/ tonne (€ 5.9/tonne), while the remaining RDF is stored at the plant for further use during the lean period. The residue from the RDF process (6-8 tonne) is disposed of at the landfill site and covered with soil. The recyclable material (~4 tonne) is sold to third parties. Further, the plant receives mixed waste from Municipal Corporation of Shimla, hence much of the plant's energy is utilised in segregating municipal waste so that it can be converted to RDF. The quality of RDF produced by the plant is also affected given the high moisture content in solid waste.
- Gasification: All the machinery and equipment for generating electricity is in place. However, syngas produced at the plant is contaminated with tar, containing high amounts of sulphates and nitrates. This is due to unsegregated waste being used to produce RDF at the plant. Since syngas is contaminated with tar, it cannot be passed through the turbines to generate electricity. The operator is in the process of upgrading the filtration mechanism to remove excess sulphates and nitrates from syngas, and expects the plant to run at full capacity within the next six months.

6.4 Data provision

Table 3 presents the operational data of the WTE plant for 2020. The plant received 70 tonne of waste per day. The amount of RDF generated averaged 40 tonnes[10], of which, 27-30 tonne was sold to cement plants. Given that RDF process reduces the moisture content in the waste, 100% conversion of MSW into RDF is not achieved. Of the remaining waste, 4 tonne consisted of recyclable material and 6-8 tonne consisted of residue/ by-product from the RDF processing plant. Currently, the plant is not producing electricity due to technological challenges being faced in the filtration of syngas.

Table 3: Operational data – WTE plant, Shimla (2020)

Particulars	Unit	Per day
Amount of waste received	Tonne	**70**
Amount of RDF produced	Tonne	**40**
Amount of recyclables segregated	Tonne	**4**
Amount of residue/ by-products produced	Tonne	**6-8**

Source: Municipal Corporation of Shimla

[10] *Source: Potential Utilization of RDF as an Alternative Fuel to be used in Cement Industry in Jordan, MDPI, October 20, 2019, by Safwat Hemidat, Motasem Saidan, Salam Al-Zu`bi, Mahmoud Irshidat, Abdallah Nassour and Michael Nelles.*

7 International best practices

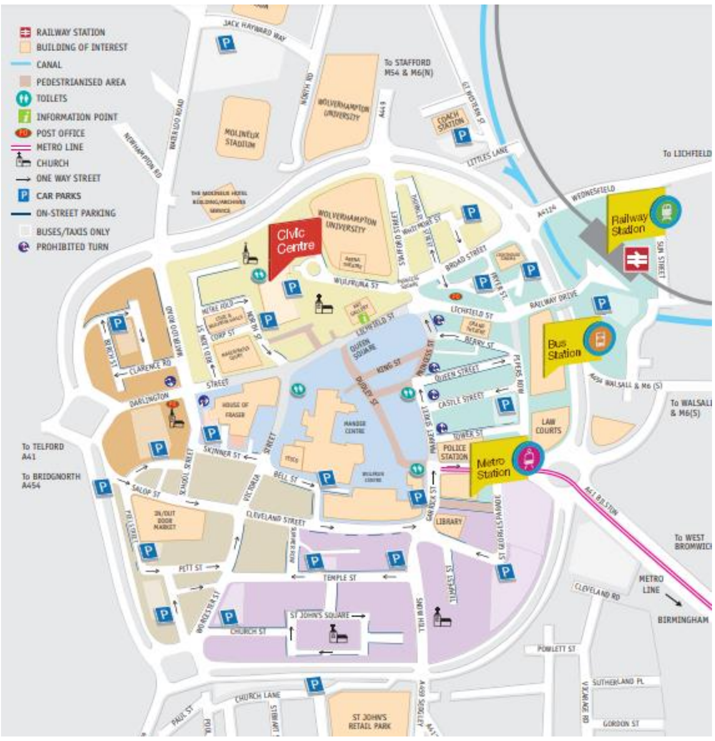
This chapter analyses a case study from Wolverhampton (the UK) and SWM practices followed by other European cities to assess the best practices and processes in SWM and WTE technology. It also explains how international best practices in SWM can be replicated in Shimla.

7.1 Experience from Wolverhampton, the UK

Under the IUC India programme, Shimla has been paired with the city of Wolverhampton in the UK. In an effort to identify potential solutions to some of the challenges faced by Shimla, analysis of the entire SWM value chain in Wolverhampton has been undertaken in this section. It includes waste generation, segregation, transportation, recycling, and generating energy from collected waste.

Wolverhampton – city profile: Wolverhampton is a city, metropolitan borough, and administrative centre in the West Midlands, England, covering an area of 69.4 sq km. The city had a population of 249,470 as per the 2011 census, which, as per the estimates of the local administration, increased to 254,406 by 2015[11]. As per the data provided by the City of Wolverhampton Council, there are 110,750 households in the city. City of Wolverhampton Council is the governing body of the city of Wolverhampton. It was known as Wolverhampton Metropolitan Borough Council (WMBC) prior to the award of city status in 2000, and also as Wolverhampton City Council before adopting the City of Wolverhampton branding in 2015. Local councilors are the elected representatives of City of Wolverhampton Council; 60 councilors represent 20 wards in the city - three councilors per ward. Figure 9 represents an illustrative the map of the city of Wolverhampton.

Figure 9: Map of Wolverhampton



Source: [City of Wolverhampton location map]()

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[11] Wolverhampton city

Waste generation and segregation: The city generates 330 tonnes/day of general waste, i.e. non-hazardous waste that cannot be reused or recycled and needs to be sent for energy recovery including food waste, textiles, nappies, miscellaneous waste, etc. The city further generates 85 tonnes/day of recyclable waste including glass, plastic, mixed paper, card, newspaper, pamphlets, ferrous, and aluminum material and the recycling rate of the city is ~38% (2019-2020). Waste is segregated into general and recyclable categories at the household level. The city provides a black 240-litre wheel-fitted waste bin to residents for dry mixed recycling, a 140-litre or 240-litre green bin for general waste and a larger 360-litre general waste bin is available to households with seven or more residents. The city is also experimenting with doing away household-level bins and providing waste bins at the end of each house lane. Additionally, the city is exploring the possibility of setting up underground waste bins. These bins have a small inlet above the ground but a large capacity beneath the surface. During collection, waste bins are taken out by lorries and waste collected from them. These bins, thus, do not affect the aesthetic value of the city, while preventing issues such as waste spillover, odour, etc. The city has two transfer stations where waste from the various households and institutions is brought after collection. Waste is segregated using manual as well technological interventions at these transfer stations. The segregation process ensures that the outgoing waste is of uniform quality and calorific value. This ensures that the WTE plant in the city operates at an optimal level.

Waste collection and transportation: Waste collection activities in the city are well calibrated. Waste generated in households is collected once a week for each waste type – mixed as well as recyclable. For instance, once a week, the waste collection team collects general waste from 20,000 households and the next week it collects the recyclable waste. This translates to a waste collection cycle of 15 days from each household. The council also operates a residential subscription-based garden waste service which typically runs between late February and early December. It charges GBP 40 per month (Rs. 3,989/month) from the users for this type of collection. Garden waste is used to generate biogas. The council also runs a separate commercial trade waste service. In the past, the city has experimented with collection of food waste for a fee, but most of the households were not keen to avail such services and, thus, it was discontinued. The city operates its own waste collection service and employs 140 people for the entire gamut of waste collection activities including waste collection from all households across the city – both curbside and flats. It has a fleet of 17 refuse collection vehicles to collect waste. Each lorry has three staff – one driver and two waste collectors. The council directly delivers collected general waste to the WTE plant, each truck typically tipping off 2-3 times per day. The city is split into 14 curbside routes for each day operating Monday to Friday; alternating each week between general waste collection and recycling collection. The council also operates four daily rounds for collecting general and recycling waste from flats. In addition, there are four rounds daily for the paid garden waste service. Approximately 11,000 tonne of green waste is collected by this service and composed using open windrows per year.

WTE plant: The WTE plant in Wolverhampton was constructed in 1998 by MES Environmental Ltd. The installation provides a sustainable method of waste disposal and recovery, predominantly for the area within the administrative boundary of City of Wolverhampton Council, with smaller quantities of wastes accepted, where capacity and demand exists, from other local authorities within the general vicinity of the plant. All general waste collected from the city is disposed of at the WTE plant. With two combustion lines operating with a combined capacity of up to 14 tonne per hour, the facility is able to process a maximum of around 110,000 tonne of waste per year, providing an effective alternative for sending the waste to landfill. Heat produced during the incineration process is converted into electrical energy by generating steam in high pressure boilers and expanding the steam through a steam turbine. Air-cooled condensers re-circulate condensate back to the boilers. When operating at full load, the plant produces approximately 36,500 MWh of gross electricity per month. In addition to the electricity generated, the WTE plant also generates heat, which is very useful considering the weather conditions in Wolverhampton. The city has started a project around district heating systems wherein the generated heat is used by local institutions such as football stadiums, university, library, etc. Approximately 19%

of the incinerated waste becomes residue of bottom ash or fly ash, which is used as a raw material for an aggregate process. Figure 10 presents the waste to energy plant in Wolverhampton, UK.

Upgradation plans and environmental standards: The city is investing in battery storage for the electricity generated at the plant. This will enable the city to sell the electricity to the grid at times when the cost of electricity is higher. Stored electricity can also be sold to private households, local university, etc via these storage mechanisms. The WTE plant in the city is old and is being constantly upgraded to enhance the emission quality in line with the stricter environmental standards being laid out by the government. The WTE plant in proposed to be carbon neutral by 2025 while the city plans to become carbon neutral by 2041.

Figure 10: Energy from waste plant at Wolverhampton

Source: Wolverhampton EFW – MES Environmental Limited

Summary of operational process and procedures: The incineration processes have been designed against the background of a detailed assessment of the prevailing environmental conditions at the site location, and are based on the best available technology as detailed in the original authorisation application and the application for the permit issued under the Pollution Prevention and Control (England and Wales) Regulations. Some of the operational processes and procedures include: plant developed specifically for incineration of municipal solid waste; efficient, comprehensive process control and monitoring systems to ensure optimum conditions for complete combustion of waste and to minimise emissions from the processes; operations confined within buildings under slight negative pressure in order to contain and minimise dust and odour; multi-stage high efficiency flue gas cleaning systems comprising deNOx selective non-catalytic reduction (SNCR) for the removal of oxides of nitrogen, activated carbon and lime semi-dry acid gas scrubbing for controlling acid gas, dioxins/furans and mercury emissions; final stage flue gas abatement for particulate materials using fabric filtration; residue from the combustion process and from the flue gas cleaning system disposed of by approved means, maximising recycling wherever possible; waste water from the process is neutralised and recycled as far as is practicable to minimise the quantity released to sewers; and provision of bunds or double-skinned vessels for storage of fuel and chemicals in order to prevent accidental and inappropriate discharge to public sewers and watercourse.

Residue handling: Two main sources of residue arise from the operation of the plant: incinerator bottom ash (IBA), which includes ferrous metals discharged within the ash, and residues from the flue gas treatment system - known as air pollution control residue (APCr). Residue from the flue gas treatment process is discharged into an enclosed system which feeds into double-skinned heavy-duty bags prior to removal from site for controlled treatment and disposal. This account for ~5% of the total weight of all refuse processed by the facility. Bottom ash produced by the site represents ~10% of the original volume of the refuse processed and ~20% of its weight. Bottom ash is now widely used in the UK and Europe as a substitute for valuable primary aggregate materials in the construction of roads and embankments. Table 4 - 6 presents the operational data of the plant for the year 2019.

Table 4: Operational data – waste type received (2019)

Waste type	Unit	Q1	Q2	Q3	Q4	Year total	%
Household/ local authority		29,264	29,341	23,161	29,816	**111,582**	97.5%
Commercial and industrial	Tonnes	604	344	376	1,506	**2,830**	2.5%
Total waste received		**29,868**	**29,685**	**23,537**	**31,322**	**114,412**	**100.0%**

Source: Annual Performance Report 2019, Wolverhampton Energy from Waste facility – MES Environmental Ltd, January 31, 2020 by J Purnell

Table 5: Operational data – energy usage/ export (2019)

Particulars	Unit	Q1	Q2	Q3	Q4	Year total
Power generated	MWh	11,470	13,921	9,879	14,189	**49,459**
Power exported	MWh	9,612	11,603	8,199	11,899	**41,313**
Power used at site	MWh	1,858	2,319	1,680	2,290	**8,147**
Power imported	MWh	402	6	131	103	**642**
Parasitic load	%	19.0%	16.7%	18.1%	16.7%	17.5%

Source: Annual Performance Report 2019, Wolverhampton Energy from Waste facility – MES Environmental Ltd, January 31, 2020 by J Purnell

Table 6: Operational data – waste disposal and recovery (2019)

Particulars	Unit	Q1	Q2	Q3	Q4	Year total	% input
APC residues - produced		889	926	659	1,034	**3,508**	3.1%
IBA – produced	Tonnes	4,551	5,144	3,738	4,966	**18,399**	16.1%
Metals recycling		487	395	379	451	**1,712**	**1.5%**

Source: Annual Performance Report 2019, Wolverhampton Energy from Waste facility – MES Environmental Ltd, January 31, 2020 by J Purnell

7.2 SWM best practices in other European cities

In addition to analysing the best practices being adopted by Wolverhampton for its SWM value chain, this sub-section examines some of the established practices in various European cities such as Vienna (Austria), Copenhagen (Denmark) and Ljubljana (Slovenia).

Vienna, Austria: Vienna has been successful in managing its plastic waste. In Vienna, packaging waste generated from households and businesses is either recycled or incinerated with energy recovery at municipal incinerators. Landfilling is not allowed as it is banned in Austria. The packaging waste treatment is specified below:

- Sorting of packaging waste: Alstoff Rescycling Austria (ARA) is a major scheme for collection and recovery of packaging and packaging waste in Austria (including Vienna). The ARA scheme was established by private stakeholders of the packaging production business and the retail industry to handle packaging waste resulting from their day-to-day operations. Sorting of plastic packaging waste, collected in the ARA system, takes place at sorting plants to separate the packaging from other types of waste, and also to sort the packaging into different plastic types. There are sorting plants with manual sorting and/or automatic sorting (using infrared light to sort out different plastic packaging types). The plastic packaging is sorted in over 20 plastic fractions and a mixed plastic fraction

- Energy recovery through incineration: Under the ARA system, after sorting and removing other types of waste, the lightweight packaging material is either sent for energy recovery through incineration, or for recycling. The lightweight packaging material collected from households, as described above, is sorted into recyclable and non-recyclable fractions, and the non-recyclable but combustible fraction is sent for energy recovery through incineration. The energy, thus, recovered is used in public buildings and district heating networks
- Recycling: The recyclable fraction of lightweight packaging as well as PET bottles are recycled. For recycling, the plastic waste is shredded, washed, dried, melted, and then processed into granules, which is used as raw material for manufacturing new products. Plastic packaging needs to be sorted carefully and thoroughly before it can be recycled, as different packaging types have different melting points and do not mix upon melting. Sometimes, it is possible to recycle even unsorted plastic packaging waste; however, it allows manufacturing of only massive products in simple shapes

Ljubljana, Slovenia: Ljubljana is the largest city and the capital of Slovenia. The public company, Voka Snaga, is the biggest waste management company in Slovenia, providing waste management facilities in Ljubljana and in 10 other municipalities. Among other waste management services, Voka Snaga is also responsible for waste collection. While packaging, paper, glass packaging, and bio waste are collected door-to-door or from bring points; hazardous household waste, and bulky waste are disposed free of charge at either the bring points or civic amenity centres. Some of the best practices related to SWM lifecycle in the city are listed below:

- Zero waste city – Ljubljana: Ljubljana is the first European capital committed to being a zero waste city. The waste management reform in Ljubljana began in 2002, with introduction of waste segregation. Paper, glass and packaging was collected separately in roadside container stands. In 2008, separate collection of biodegradable waste was introduced on a door-to-door basis, and in 2013, bins were provided to all households for collecting packaging and paper waste, both of which were collected door-to-door. Between 2004 and 2018, Ljubljana saw a 10-fold increase in separate collection of waste, and the amount of waste sent for disposal reduced by 95% while keeping costs the lowest in Europe. The city currently produces only 115 kg of per capita residual waste annually
- Prevention and reuse: After achieving efficient segregation, Voka Snaga refocussed its efforts from raising awareness on segregation to encouraging residents to reduce waste generation, raise awareness on waste reduction, promote reuse, and ensure responsible and sustainable consumption. The company launched a campaign ‘Get used to reusing’
- Reuse centres: At end-2013, a reuse centre was opened in Ljubljana that consisted of a shop, workshop and collection centre. The objective of the reuse centres is to provide work to the elderly, disabled and other disadvantaged people, along with encouraging reuse of old, redundant but reusable items. It includes technical devices, pieces of furniture, clothing, and plastic items – practically everything that can be found in a flea market. There are eight reuse centres in Slovenia
- Packaging-free vending machines at reuse centres: Voka Snaga, runs its packaging-free vending machines, at the reuse centres for sale of basic household items such as cleaning supplies, shampoos, vinegar, oil and other household items to customers who bring their own reusable packaging. The appearance of the vending machine itself promotes recycling and reuse. All the equipment at the vending machine is made up

of recycled plastic. All the vending machine products are either made from organic ingredients, or are manufactured by local companies (produced through 100% natural processes), and do not contain any artificial ingredient

- Zero plastic waste stores: Zero waste retail stores are on the rise in Slovenia, wherein stores sell environment-friendly products in reusable packaging. Rifuzl is a plastic-free grocery shop in Ljubljana, which focusses on living with less plastic and shopping sustainably. Shoppers bring their own glass jars and fill these with grocery products at Rifuzl
- Recycling in Slovenia: Six different coloured containers are used to separate and collect six different waste fractions. While packaging, glass, paper, and plastics are taken directly to recycling companies, mixed waste and organic (biodegradable) waste are treated at a modern waste management centre known as the Regional Waste Management Centre (RCERO) situated in Ljubljana. It is a modern centre, and one of the largest in Europe. RCERO handles the waste of 58 municipalities and treats more than 170,000 tonne of waste per year. About 98% of the waste is recycled into objects, compost or fuel. In 2017, Slovenia had the fourth highest recycling rate of plastic packaging at 60% (source: Eurostat, 2017)

Copenhagen, Denmark: Copenhagen is the capital and the largest and most populous city in Denmark. According to Denmark's environment protection law, the responsibility for Copenhagen's waste management, including waste collection and assignment, lies solely with the municipalities. The municipalities are in-charge of regulation and control of waste generators, waste carriers, and treatment plants and are responsible for environmentally sound waste handling. The municipalities are also responsible for establishing operations of recycling centres. The responsibility for source separation of waste, as suitable for recycling or recovery rests with the waste generators but under supervision of municipalities. Some of the best practices related to SWM lifecycle in the city are listed below:

- Collection of plastic waste from households**:** The plastic waste collected in Copenhagen is mainly packaging waste and also various types of rigid consumer plastic waste. Source separation of recyclable waste fractions is a major part of Copenhagen's waste management process. Household plastic waste is collected by the respective municipalities, in line with specific waste regulations and collection schemes. The residual plastic waste generated from households, apart from rigid plastic and bulky plastic waste, is collected either directly from households, or through curbside collection. Curbside collection is established in localities having detached households. Plastic waste is also collected from apartment buildings. Collection frequency varies from weekly to bi-weekly
- Nem Affaldsservice: This is a waste service facility in Copenhagen. If residents need more information on garbage collection at their residence, including collection dates, ordering extra bins, ordering collection of bulky waste, reporting problems and issues or giving any kind of message to the municipality of Copenhagen, they can use the Nem Affaldsservice by typing in their address at the website
- Recycling centres and manned waste collection centres: Flexible and rigid plastic waste and bulky plastic waste (such as rigid and flexible PVC, garden furniture, plastic foils etc.) are collected at Copenhagen's four recycling centres (Borgervaenget, Bispeengen, Kulbaneve and Vermlandsgade) or at the manned waste collection centres. The waste collection centres are smaller than recycling centres, and accept only certain types of plastic waste and are accessible by foot only. Both types of centres are manned/staffed and at both these centres, the different plastic waste fractions are collected separately. Most of these centres have a swap stand where one can donate or collect items which are still usable. While flexible and rigid plastic and bulky plastic originating from households is the responsibility of municipalities, wherein municipalities collect this fraction at the recycling centres, the ones originating from businesses is the responsibility of the companies wherein the companies bring the relevant plastic waste fractions to the recycling centres. Flexible plastic waste is collected both from households and is also delivered at the recycling centres. At

these centres the bulky waste is collected, compressed into bales and is sent to the sorting facilities mainly in Germany and Sweden, though a few facilities exist in Denmark as well

- Deposit and return system for PET bottles: Departing from the general rule in the EU, Denmark has no packaging producer responsibility scheme for plastic packaging. However, in Copenhagen as well as the rest of Denmark, a deposit and return system exists for bottles having carbonated drinks, mineral water, beer and other beverages etc. While selling beverages in Copenhagen, the producer charges the price of the product as well as a deposit related to beverage containers and the return system. Danks Retursystem, the operator of the deposit and return system, receives the deposit from the producers, which goes into the system maintenance. In most of the supermarkets, grocery stores, and gas stations there are local reverse vending machines installed wherein the consumer can return their used and deposit marked bottles and cans. The reverse vending machines accept the bottles and cans and scan the deposit mark and barcode and calculate the amount of money to be refunded. The machine then empties the bottles and cans into containers that are transported to the Danks Retursystem centres, wherein the items are registered, counted or sorted. The bottles and cans are then recycled, melted and turned into new bottles and cans. Post this process, the Danks Retursystem pays a refund to the shops and supermarkets, which then refund it back to the end consumer. Danks Retursystem covers the recycling costs of the participating stores. To increase the recycling rates, the Danish government is expanding the deposit and return system, wherein post 2020, consumers will be able to return juice, concentrate bottles and other deposit-marked bottles at their local reverse vending machines
- Treatment/processing of plastic waste: Non-recyclable and non-combustible plastic waste is landfilled. All landfilled material has very low plastic content. Flexible PVC is the only plastic waste that is sent to the landfill site. While 63% of plastic waste from households and businesses is incinerated in Denmark, 36% is recycled. Waste incineration with energy recovery has dominated the Danish waste management system. Waste incineration is a well-organised business and a well-developed district heating system wherein 20% of district heating and 5% of electricity supply in Denmark comes from these plants. It is difficult to recycle plastic waste as it contains a mixture of different types of plastics that contain different additives and are often contaminated with non-plastics or food residues. To counterbalance this, a Co2 tax on fossil content in the waste has been implemented that creates incentives for owners of waste incineration facilities to avoid plastics in the waste being incinerated.

7.3 Key learnings

The sections above highlighted the processes, technologies and best practices used for efficient SWM systems in some of the European cities including Wolverhampton (UK), Vienna (Austria), Ljubljana (Slovakia), and Copenhagen (Denmark). The key learnings from the best practices being followed by these European cities have been listed in Table 7.

Table 7: Comparison of various European cities

City	Innovative practices
Wolverhampton	• Waste segregated at household level, further segregation practiced at transfer station • Waste collected once a week for each typed of waste – general and recyclable • Segregated dry waste of uniform quality transferred to the WtE plant
Vienna	• Landfilling of waste in Vienna is not allowed as it is banned by law • Dedicated ARA scheme for collection and recovery of packaging waste • Treatment of packaging waste by recycling and energy recovery (incineration)
Ljubljana	• Dedicated public company providing waste management facilities

City	Innovative practices
	• Reuse centres to encourage reuse of old, redundant but reusable items • Increasing number of packaging-free vending machines and zero plastic waste stores
Copenhagen	• Source separation of recyclable waste fractions is a major part of city's SWM • Collection of waste at four recycling centres and manned waste collection centres • Deposit and return system for PET bottles used for storing water, beverages etc.

8 Key challenges, solutions and next steps

This chapter provides the challenges being faced by Shimla in terms of its SWM value chain and the waste-to-energy plant, including the processes of waste segregation, collection, transportation, disposal and processing/treatment along with the corresponding solutions. The chapter also discusses the next steps to be undertaken after the successful completion of the baseline study.

8.1 Key challenges

Some of the key challenges being faced by Shimla across its SWM value chain have been provided below. Challenges were identified in waste segregation, collection, transportation, disposal and treatment:

Solid waste segregation, collection and transportation

- Low segregation rate: The issue of prime concern is the mixed waste being received by the waste-to-energy plant. Given that only 50-60% of municipal waste is segregated, the waste reaching the plant is of low calorific value and has high moisture content (due to presence of high amount of organic waste). As a result, the plant is unable to operate at its full potential as the RDF produced is of low quality
- Difficult terrain and weather: Effective SWM including waste collection is a challenge in the hills, due to landform variations, rugged terrain and scarcity of flat land. Only 25% of Shimla is connected through road. Hence, waste collectors have to tackle the hilly terrain of Shimla and physically travel from each household to accessible roads where hydraulic trucks are present to transfer the waste to the waste-to-energy plant. Further, the predominantly colder weather of Shimla makes the composting of waste difficult to undertake
- Inefficient use of waste collection trucks: 50-60% of MSW is segregated in Shimla; however, the WTE plant continues to receive mixed waste. Although separate compartments for different types of waste have been provided in the waste collection trucks, due to lack of awareness the segregated waste is getting mixed while loading into the trucks. This practice is leading to inefficient use of waste collection trucks in addition to the WTE plant receiving mixed waste.

Solid waste treatment

- Difficulty in composting: Composting of waste requires segregation of waste into bio-degradable and non-biodegradable waste. Shimla faces many problems with respect to composting of its municipal solid waste. Firstly, there are no dedicated composting plant in the city to process the bio-degradable waste. Secondly, even if there was a composting plant, the unsegregated waste would pose technological challenge at the plant as composting plants are designed to handle bio-degradable waste only. Lastly, Shimla predominantly has a colder weather due its geographical location, which makes the process of composting all the more difficult
- Presence of pollutants in syngas at the waste-to-energy plant: Due to the unsegregated waste, the syngas produced through the gasification technology has high quantity of tar containing sulphates and nitrates. Hence, the unfiltered syngas cannot be passed through the turbines to generate electricity. Additional filtration mechanisms are in the process of being deployed that should be able to remove the tar from the syngas resulting in the waste-to-energy plant operating at its full capacity
- Absence of scientific landfill and legacy waste: As on date, there are no scientific landfills present in Shimla. Although majority of the waste being generated is processed at the waste-to-energy plant and converted into RDF, the residue/ by-product from this operation is dumped in an unscientific way on the open space in the waste-to-energy facility and then covered with soil. This is an unsustainable way of waste dumping and might lead to various challenges in near future

Besides the above challenges, the lack of enabling policies at the state and city level, inadequate funds to implement projects, as well as lack of awareness and technical know-how may also be contributing to the suboptimal management of waste in Shimla.

8.2 Solutions to challenges being faced by MC Shimla

The following solutions have been proposed while considering the existing conditions in Shimla, discussions held with officials of the City Council of Wolverhampton and MC Shimla, and best practices were identified from various European cities including Wolverhampton, Vienna, Copenhagen and Ljubljana in addition to secondary research.

Solid waste segregation, collection and transportation

- Fines and incentives to ensure segregation**:** MC Shimla should impose monetary fines on waste generators for not providing segregated waste to the SEHB Society's waste collectors. MC Shimla should ensure strict enactment of fines and levy fines on those not providing waste in a segregated manner. Additionally, the council can tie some incentives/rewards for those who provide segregated waste. For example, a waste generator who provides segregated waste regularly for a month may be given a discount of 10-20% in their waste collection fee.
- Awareness programs to promote segregation: Although already being implemented, MC Shimla should continue to conduct its awareness programs on waste segregation through Information, Education and Communication (IEC) activities in order to sensitise the public and other stakeholders about the advantages of waste segregation at source, and how it could lead to efficient functioning of the waste-to-energy plant.
- Setup of transfer stations: MC Shimla can consider setting up waste transfer station in the city. This would allow the waste collected throughout the city to be tipped at a single place, which can then be sorted and bundled for onward processing. This shall enable the city to supply uniform quality of waste to the waste-to-energy plant, which has a better calorific value and allows for a longer burn and improved energy production. The transfer station may be setup on the outskirts of the city to alleviate the challenge of land availability due to steep slopes at the waste-to-energy plant. Further, setting up the transfer station at the city outskirts will not hinder the aesthetic appeal as Shimla is a tourist city.
- Decentralised waste segregation**:** Waste segregation should be encouraged at the community level. Local communities/ resident welfare associations (RWA) should be provided with waste bins designated to hold different type of solid waste. A leader should be selected for each local community/ RWA who would oversee this initiative of waste segregation for his/her designated area. Penalties/ fines or rewards should also be assigned at the local community level. For commercial areas, 4-5 restaurants/hotels/ shops can be clubbed together to form a single unit and provided with proper waste segregation equipment. Since restaurants/ hotels contribute extensively to wet waste generation, they can be rewarded accordingly through a reduction in monthly waste collection fee for sincerely undertaking the waste segregation process.
- Reduce, reuse and recycle to combat challenges created by hilly terrain: To combat the challenges posed by SWM in hilly terrain, it is important to implement the 3Rs of waste management – reduce, reuse and recycle. MC Shimla could support and encourage reduction and reuse of waste at source to enable waste minimisation (reuse carry bags) and promote sustainable/ multi-use of products (packaging jars, etc.). MC Shimla could also promote recycling and processing of inorganic waste to recover commercially valuable material (such as plastic, paper, metal, glass etc.). When majority of the waste is reduced, reused and recycled at source, less of it will need to be collected and transported for treatment, thus combatting challenges posed by hilly terrain. However, it needs to be noted that it might not be possible to recycle the entire segregated waste to zero waste. Many plastics are simply unrecyclable and are perceived as

commercially unattractive. Hence, a large amount of unrecyclable plastic/waste end up at landfills. Waste to energy is an effective way of recycling the unrecyclable waste in to green energy.

- Efficient use of waste collection truck: In order to utilise the waste collection trucks to their full potential, there is a need to create awareness amongst the masses for proper loading of waste in the waste collection trucks. IEC programmes which teach the proper use of separate compartments for different types of waste will help in this effect. Further, Municipal Corporation of Shimla could assign different days for collection of different types of waste such as three days of the week can be assigned for collection of wet waste while the remaining days can be assigned for collection of dry waste. This will lead to only dry waste reaching the WTE plant, thereby improving its efficiency.

Solid waste treatment

- Composting of waste in colder region: Composting of municipal solid waste can be a year-long activity and does not have to face hindrances due to inclement weather conditions. With regards to the new composting plant proposed by MC Shimla, the operator will need to provide suitable environment inside the facility. The facility will need to ensure ambient average day temperature of 20-25 degree Celsius and during the night between 8-12 degree Celsius even when temperature outside the facility dips below zero[12]. The composting bins can be fully isolated using 150mm – 20mm thick layer of Styrofoam to prevent heat loss, thus aiding the composting process.
- Home composting: MC Shimla should encourage residents for composting their wet waste at their premises. Wolverhampton follows the practice, where the city authority has tied up with select operators who provide home composting equipment at discounted prices. This initiative can also be undertaken at a collective level if few households can be encouraged to undertake composting of their wet waste together. This will reduce the amount of solid waste to be collected and treated.
- Effective functioning of waste-to-energy plant: The contamination in the syngas being produced from the gasification process can be reduced by feeding the plant with segregated waste. Once only dry waste is being processed at the waste-to-energy plant, the quality of RDF generated will improve significantly which will in turn lead to cleaner syngas production. Dry waste has better calorific content and hence allows for longer burn and improved energy production. Syngas, which is free from large quantities of sulphates and nitrates, can be passed through the engines and turbines directly without requiring an additional step of filtration, thus improving the waste-to-energy plant's efficiency.
- Alternate site with higher capacity for landfill: The SWM rules, 2016 require construction of landfill on hills to be avoided, with plain, level land being required for construction of scientific landfills within a distance of 25 km from the city. Municipal Corporation of Shimla should find a suitable site for the landfill that has a relatively flat topography and has adequate capacity to accept the waste coming from the waste-to-energy plant in addition to fulfilling any future requirements of the city. Municipal Corporation of Shimla should get in touch with municipal corporations of similar cities that have established suitable landfill sites, to get references of trusted operators. Figure 11 summarises the key challenges being faced by Shimla and the corresponding solutions.

[12] *Composting Manual for Cold Climate Countries, ACF International – USTB, December 2015, by Roman Ryndin and Enkhgal Tuuguu*

Figure 11: Key challenges and corresponding solutions

Key challenges	Solutions
Waste segregation, collection and transportation	
• Low segregation rate • Difficult terrain and weather • Inefficient use of waste collection truck	• Fines and incentives for waste generators to ensure segregation • Awareness programs to promote waste segregation • Setting-up transfer station at outskirts of the city • Decentralized waste segregation at local community level • Separate days for collection of dry and wet waste
Waste disposal and treatment	
• Difficulty in composting • Presence of pollutants in syngas at WTE plant • Absence of sanitary landfill and legacy waste	• Maintaining ambient temperature inside composting facility • Encouraging residents to practice home composting • Using only dry waste at the WTE plant to improve efficiency • Identify an alternate site with higher capacity for landfill

8.3 Next steps

Having established the need for an efficient SWM system in Shimla and the requirement to implement decentralised waste segregation process so as to increase the efficiency of the waste-to-energy plant, the Municipal Corporation of Shimla should first divide the recommendations provided in the previous sections in to short and medium term goals. This would help the local administration in prioritising the recommendations as required. Once the goals are set, the administration should look at preparing project reports which would define the broad goals of the project. The administration can then look at arranging for funding of the project which can be secured from state funds earmarked for development actives or through national level schemes such as the smart city project.

9 References

The chapter lists the documents provided by the IUC, MC Shimla, City of Wolverhampton Council and links to various news articles, publications, policy documents, research papers, company reports, and case studies that were referred to during the preparation of this study.

Table 8: Table of references

Date	Title	Author	Link
Existing reports and studies			
April, 9-12, 2018	City Report, Shimla	MC Shimla	https://www.uncrd.or.jp/content/documents/6365City%20Report_Shimla,%20India.pdf
2014	Effective Municipal Solid Waste Management Practices: A case study of Shimla, HP, India	Omesh Bharti, Amarjeet Singh, DP Singh, Vibhor Sood	http://www.shimlamc.org/file.axd?file=2014%2F7%2FSolid+Waste+Management+in+Shimla.pdf
2016	Current Status of Solid Waste Management of Shimla	Mudit Mishra, Bhawani Singh Meena and Nitin Rana	http://www.krishisanskriti.org/vol_image/06Aug201706084312%20%20%20%20%20%20%20%20%20%20%20%20Mudit%20Mishra%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20793-795.pdf
2012	Municipal Solid Waste Management Plan For Municipal Corporation Shimla	MC Shimla and GIZ	http://www.shimlamc.org/file.axd?file=2012%2F6%2FMSWM+Plan.pdf
-	Management of Urban Solid Waste in Shimla	A.N. Sharma	https://hls-esc.org/documents/2hlsesc/08-2HLS_T1A_UrbanSWMShimla_ANSharma.pdf
-	Management of Municipal Solid Waste In Shimla with Community Participation	Dr. Omesh Kumar Bharti	https://icrier.org/Urbanisation/events/30-5-14/Hilly_Region_Case_Shimla-Dr.%20Omesh%20K.%20Bharti.pdf
August 2006	Solid Waste Management in Urban Himachal	-	http://www.hpccc.gov.in/PDF/Solid_Waste/Solid%20Waste%20.pdf
-	Waste Strategy 2018-2028	City of Wolverhampton Council	https://wolverhampton.moderngov.co.uk/documents/s75571/Appendix%201%20for%20Waste%20Strategy%202018-2028.pdf
June 6 2018	Waste Energy Strategy 2018-2028	City of Wolverhampton Council	https://wolverhampton.moderngov.co.uk/documents/s75570/Waste%20Strategy%202018-2028.pdf
2008	Wolverhampton energy from waste plant	-	https://ukwin.org.uk/files/pdf/wolverhampton2008.pdf
January 31 2020	Annual Performance Report 2010	J Purnell	https://ukwin.org.uk/library/210-AnnualPerformanceReport-2019.pdf
September 2014	Economic Review: Wolverhampton	City of Wolverhampton Council	https://midlandseconomicforum.co.uk/images/uploads/Wolverhampton_The_City_of_Business_Opportunities_September_2014.pdf

Date	Title	Author	Link
News articles and other relevant publications			
April 06, 2019	Two years on, only waste, no energy	Kuldeep Chauhan	https://www.tribuneindia.com/news/archive/himachaltribune/two-years-on-only-waste-no-energy-754214#:~:text=All%20trash%20and%20junk%20produced,the%20periphery%20of%20Shimla%20city.&text=Kuldeep%20Chauhan-,All%20trash%20and%20junk%20produced%20in%20Shimla%20for%20treatment%20goes,the%20periphery%20of%20Shimla%20city.
August 10, 2017	Shimla's cleanliness finally powered by waste	Archana Phull	https://www.thestatesman.com/cities/shimla-s-cleanliness-finally-powered-by-waste-1502372988.html
March 7, 2017	Shimla to become India's first hill station to turn solid waste into electricity	Himachal Watcher	https://himachalwatcher.com/2017/03/07/shimla-to-become-indias-first-hill-station-to-turn-solid-waste-into-electricity/
April 6, 2019	Shimla WtE plant has still not reached its full generation capacity	-	https://solidwasteindia.com/shimla-wte-plant-has-still-not-reached-its-full-energy-generation-capacity/
-	Refuse Derived Fuel	Waste Busters	http://wastebusters.com.pk/refuse-derived-fuel/
-	Syngas: energy-rich gas for power applications	Biogreen	http://www.biogreen-energy.com/syngas/
July 29, 2020	Pyrolysis of Municipal Wastes	Salman Zafar	https://www.bioenergyconsult.com/pyrolysis-of-municipal-waste/
April 30, 2010	Himachal Initiates Waste Management	Disha Singh Sharma	https://hillpost.in/2010/04/himachal-initiates-waste-management/19734/
Official website of stakeholders and government agencies			
-	Shimla Municipal Corporation: Quarterly e-Newsletter	MC Shimla	http://www.shimlamc.org/file.axd?file=2018%2F2%2Fe-News-2017-18.pdf
-	City Development Plan	MC Shimla	http://www.shimlamc.org/MC/admin/Pages/page/City-Development-Plan.aspx
-	Wolverhampton City	-	https://www.wolverhampton.gov.uk/sites/default/files/pdf/Wolverhampton_City.pdf