TALLINN UNIVERSITY OF TECHNOLOGY

SCHOOL OF ENGINEERING

Department of Materials and Environmental Technology

WASTE TO ENERGY POSSIBILITIES IN LADAKH, INDIA

PRÜGI ENERGEETILISE KASUTAMISE VÕIMALUSED LADAKHIS, INDIA

MASTER THESIS

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AUTHOR’S DECLARATION

Hereby I declare that I have written this thesis independently.

No academic degree has been applied for based on this material. All works, major viewpoints and data of the other authors used in this thesis have been referenced.

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MATERIALS AND ENVIRONMENTAL TECHNOLOGY

THESIS TASK

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1.Comparison of waste to energy technologies.

2.Calculation of internal rate of return of district heating.

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PREFACE

Primarily, I would like to thank my supervisor Dr. Eduard latosov who has provided support, advice and recommendation during whole thesis work. I am extremely indebted for the constant feedback of my supervisor during the whole tenure.

My special thanks to the family members especially for keeping me motivated throughout the process. I am grateful for my sister for sending out the important and recent updates about the Ladakh region and providing with the current political changes.

The aim of this research is to provide an in-depth waste scenario in Ladakh, India which is currently facing with lack of disposal methods of waste. Different waste to energy process has been discussed with different costs. Preliminary estimation is made, and a concept of District Heating is proposed to ensure that this can be a possibility. As a result, after calculating investment cost, opportunity cost, cash flows and internal rate of return, there was a possibility of establishing a heating network in the region.

Keywords: Solid waste, incineration, district heating

List of abbreviations and symbols

LREDA	Ladakh Renewable Energy Development Agency
JKPDD	Jammu and Kashmir Power Development Department
LAHDC	Ladakh Autonomous Hill Development Council
CFB	Circulating Fluidized Bed
RDF	Refuse Derived Fuel
A.D.	Anaerobic Digester
CCGT	Combined Cycle Gas turbine
FBG+GE	Fluidized Bed Gasification combined with gas engine
FBC+ST	Fluidized Bed Combustion Systems

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INTRODUCTION

Ladakh is one of the most attractive tourism destinations in India. Situated just below Himalayas at 3500m altitude, the environmental management in the state is of vital significance for the sustainability of Indian subcontinent. With a population roughly around 30thousand, contributing over 4000 households. The capital town Leh is at the extreme north of the Himalayan mountains. The annual waste generation contributes to around 4716 metric tons in Leh while in Ladakh 96000 metric tons. Leh being the capital region has gained an immense penetration of the tourists. To primarily manage the region environmentally is of utmost importance for the development of Indian subcontinent [1].

Municipal solid wastes are the constituent of urbanization, luxurious lifestyle and the tremendous influx of the tourists. The mean waste constituents enshroud food items, cardboard paper, plastic and polythene, wooden items, paper, metals, rubber and leather, bones and shells, glass. The moisture content is around 45percent in the food items since most of the tourists consume processes foods. The wastes primarily are dumped into landfill which has affected the environment of the region drastically. The low supply of oxygen ensures the slow decomposition of the wastes in the landfill [2].

A meticulous analysis shows the rapid tourist accommodation units in Leh town from the 1990 to 2015 contributing it to one of the admired tourist destinations in the Trans Himalayas. This has aggravated anthropogenic pressure on the environment. With the unavailability of proper sewerage and solid waste management, the development of hotspots around urban center leads to the damage of the ecology. The consumption of huge amount of solid waste, untreated sewerage and extraction of excess amount of ground is a concern for the sustainability of town [3].

About 20-30 years have witnessed two types of adverse changes in the generation and disposal of waste. The disposal of night soil in Leh town and other tourist places including Nubira valley, Pangong lake is being disposed off into the Indus river leading to pollution of water and soil pollution taking place due to increasing use of chemical fertilizers [4].

The valley suffers from insufficient water supply and frequent power backouts. On an average there are only five public taps serving over a thousand people. There is no drainage system functioning properly leading to accumulation of water in puddles. According to the locals the region prominently faces two major threats namely pollution (plastic bags and non-degradable waste), depletion of scarce resources (flush toilets and warm showers for tourists) [5,6].

The thesis investigates implementation of waste to energy in the valley from the environmental and economic aspect. Possibilities to increase total efficiency by implementing district heating is also estimated. The preliminary cost with investment opportunities, operation and maintenance cost, net return value and internal rate of return is calculated.

1. DESCRIPTION OF CURRENT SITUATION

Unlike garbage dumping in the plains, in Leh there are no boundaries to the dumping ground. The garbage flies in whichever direction the wind takes. It is estimated during summertime as many as 30,000 plastic bottles are dumped. The municipality is taking steps to introduce waste segregation method for home and a new landfill site will be functional soon.

1.1 Waste management

In one of the findings over the assessment of municipal solid wastes the moisture content accounted over 52.42% and energy content to be 26289 KJ/Kg. The composition of organic waste during the summer period attributed over 93%. During the springtime, most of the construction consist of lead and other hazardous material with improper management of disposal of waste. The carbon content in the waste comprised of 48% by mass referring to the higher calorific value of waste which may be used as fuel and energy can be derived from it. While the oxygen content consisted of 41% and the pH level within range between 6-8 [7].

According to the study carried out in Sonam Norbu hospital, taken into the total average per day patient considered is 127.2. With the hospital being a 20-bed clinic further elaboration can be done stating monthly biomedical waste generated is 465g. The ministry of Environment and Forest and climate change has amended and brought into action the biomedical waste management rule on 28 March 2016. These rules include to collect, receive, store, transport, treat, dispose or handle biomedical waste in any form with taking into account nursing home clinics, dispensaries, pathological lab, health camp, blood donation camp, research laboratories, clinical establishment excluding the radioactive waste as covered under the provision of the atomic energy act 1962, lead acid batteries management and handling rule 2001,waste covered under e-waste 2011. Biomedical waste from this hospital is loaded manually without any facilities of trolley and covered wheelbarrow. The waste is transported manually from one ward to another exposing the infection risk [8].

Trekking and camping in the valley trails have impacted the region a lot. With over 3000 trekkers per Season in Markha and in the regions Darcha, Digar, Hunder, Sham, Rupsho and the estimated amount of waste disposal during the tourist season is about 100 days long. The type of waste is mostly solid waste related with campsites. The waste accumulated at the dumping sites range within 10kilogram to 446 kilogram per season with the number of visitors ranging within 100 visitors per season to 10000 visitors per season and the number of vehicles accounting to 3000 vehicles per season to 10000 vehicles per season [9].

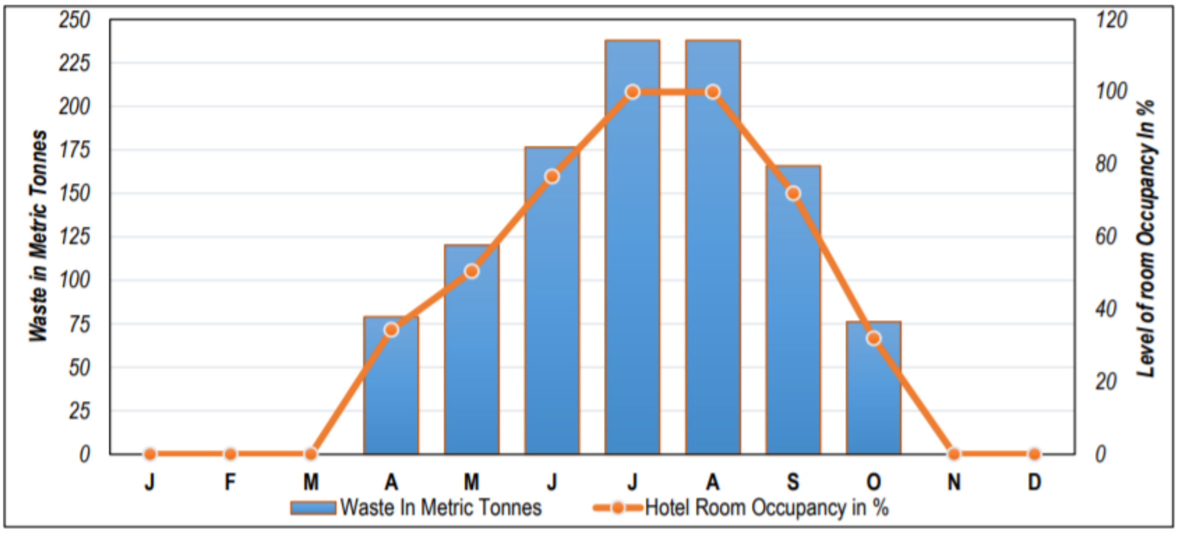

Fig 1.1.1 Seasonal variation of waste generation tourist accommodation units and level of room occupancy [10]

The following figure illustrates the solid waste generation from the tourist accommodation sector to seasonal variations. It is clear from the graph that there is no waste generation during the winter months November, December, January and February. In summers there is a sudden increase of waste up to the month of July i.e. about 237.97 metric tons of solid waste because the accommodation unit experience maximum room occupancy levels. It can be further noticed that waste generation plummets down with respect to the onset of cold season in the valley [10].

Besides the low production of home-grown agricultural products and declining agricultural practices, the people are more dependent on packaged foods. The huge accumulation of non-biodegradable solid wastes like plastic bottles, wrappers, plastic cans contribute to choking of water streams and drainage systems. Currently the solid wastes and garbage disposals problems scenario has worsened to great extend particularly in Leh and Kargil towns extending up to Pangong lake, Tsomoriri lake and also passes like khardung-la [11].

1.2 Heat demand and production

Currently region is supplied power from diesel generators (about 12MW) of the army and paramilitary forces and micro hydroelectricity units (about 14MW). Therefore, a large amount of diesel is still being used for supplying the daily demands of the region. This amount is estimated currently at 8000litres of diesel a day to cover the power needs of the valley. Due to geographical location and climatic condition temperature in winter plummets down to -35℃, diesel is being used for space heating during winter months contributing to additional carbon-dioxide emissions. The air temperature in the valley varies from 30℃ to 35℃ in summer and in winter it is -30℃. The cost of government subsidized power is around 14 US cents per kWh since the diesel is air lifted from New Delhi [12,13,14].

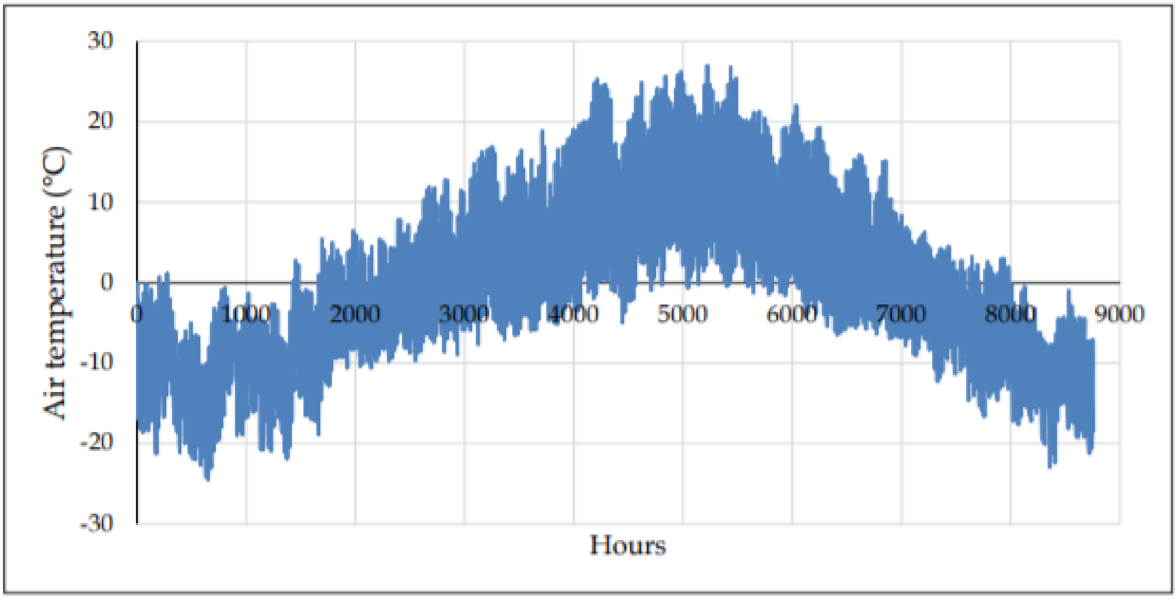

Fig.1.2.1 Average hourly temperature [12]

The ambient temperature in Leh remains subzero for most period in a year and reaches to a low of about -28℃ during January-February. The above figure illustrates the average hourly variation of temperature in Leh. During winters it is difficult to provide power access to remote areas and impossible using transmission lines from a centralized grid which is neither a technically feasible nor an economically viable option [12].

1.3 Electricity scenario

Leh gets its electricity from 6 diesel generators that generate 8 Mw (49056 MW hr.) burning 3 million liters of diesel and emitting about $41*10^6$ kg CO_2 (817kg CO_2 /MW hr. for oil).The current installed capacity in Leh district is 23.14MW with hydro and solar attributing to 7.8MW and 140KW respectively. According to LREDA, the power demand of Leh district was 58.53MW in 2005 and grew at an average rate of 7 percent a year. Considering the same growth rate for subsequent years, current demand for energy is in the range of 93.6MW and expected to grow 140.5MW by 2025. The following table explains out the energy deficiencies in villages of Leh. The JKPDD estimates household power demand at 500watts(W), however according to Ladakh Ecological Development Group, the current average connected load per household is approximately 160W. In addition to the household demand, there is a high demand for commercial loads in several blocks which is estimated at 2kW per commercial customer [15,16].

Table1.3.1 Electricity Demand in Leh [16]

Table 1: BLOCK-WISE DISTRIBUTION OF ENERGY REQUIREMENTS Serial No.	Block	Number of Households (source: 2001 census)	Average Connected Load Per Household (W) (source: survey conducted by LEDeG in 2004)	Required Connected Load Per Household (W)	Peak Energy Requirement for Domestic Use as Per Required Load (kW)
1	Diskit	2,305	115	500	1,153
2	Panamik	1,067	115	500	534
3	Chuchot	2,671	186	500	1,336
4	Durbuk	951	78	500	476
5	Khaltsi	2,641	115	500	1,321
6	Kharu	1,566	98	500	783
7	Leh	3,350	140	500	1,675
8	Nyoma	2,082	137	500	1,041
9	Saspol	934	186	500	467
10	Leh Town	6,580	432	1,000	6,580
TOTAL		**24,147**		**15,166 (15.16 MW)**	

According to Ladakh Renewable Energy Development Agency, it is estimated the household power demand at 500 watts(W) in several blocks. In addition to the household demand, there is a high demand for commercial loads in several blocks, which is estimated at 2kW per commercial customer. The Power grid Cooperation of India has proposed for 220KV transmission line should be laid from Srinagar to Leh which is estimated to provide 160MW of electricity to the district [17].

2 WASTE ENERGY TECHNOLOGIES

2.1 Overview about waste energy technologies

The following section discuss the main available thermochemical technologies for calorific waste treatment namely incineration, gasification, pyrolysis, plasma-based technologies.

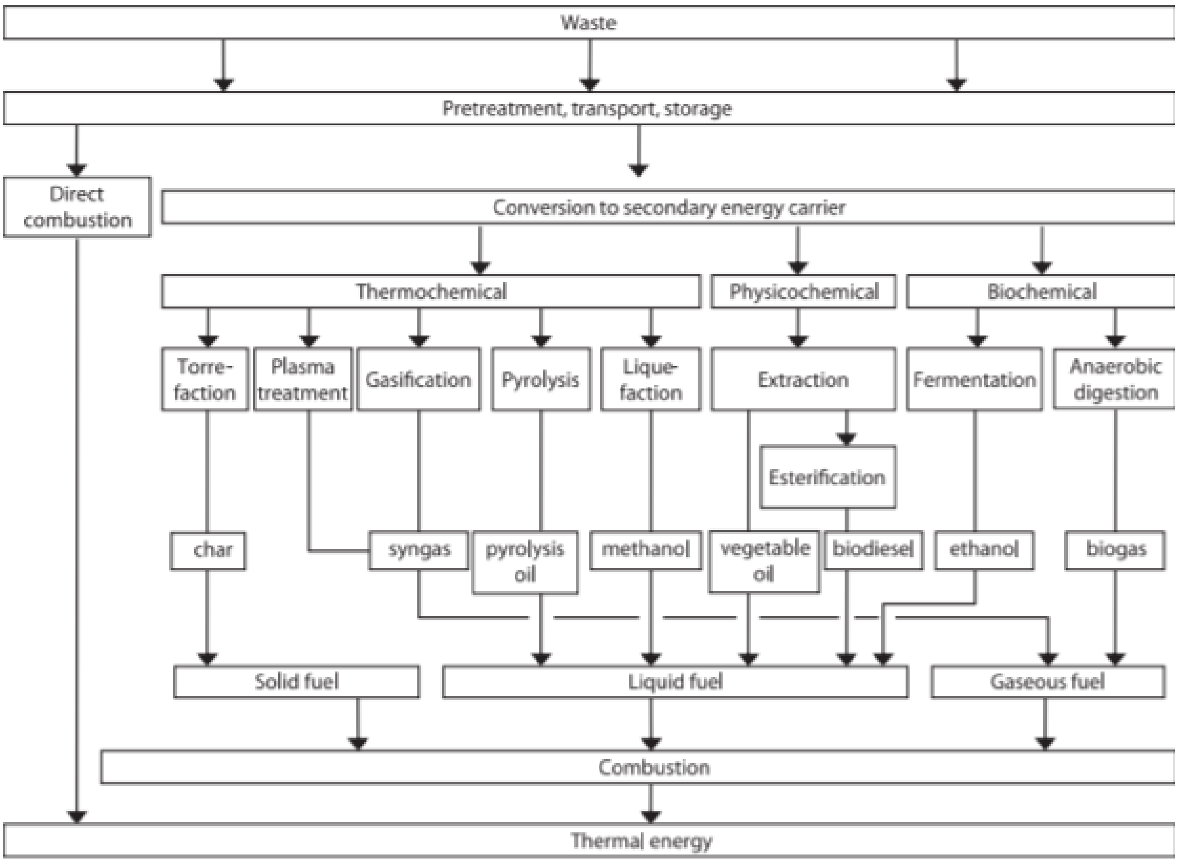

Fig 2.1.1 waste-to-energy technologies mechanism [18]

The following figure illustrates about the conventional method of waste energy mechanism where the waste is converted into secondary energy carrier and then through various thermochemical, physicochemical and biochemical processes are converted into solid, liquid and gaseous fuel respectively. The present study is confined to thermochemical processes such as incineration, gasification, pyrolysis and plasma arc gasification.

2.1.1 INCINERATION

It is the process of oxidizing the combustible materials present in the waste. The waste mostly consists of organic substances, minerals, metals and water. The gases generated during the process namely carbon-dioxide, oxygen and nitrogen which contain most of the available fuel energy as heat. Waste incineration efficiency level is said to be about 25-30%. The waste incinerators are categorized into mass burn and refuse derived fuel (RDF). the major threat with incineration is the greenhouse gas emission, release of fly ash from incineration poses respiratory problems. The cost of operating WTE incineration is high if operated without combined heat power plant. The new age incineration plants are equipped pollution control technologies and flue gas cleaning systems. With the implementation of maximum available control technology regulations in United States have resulted in reduction of toxic elements by over 99% [18].

2.1.2 GASIFICATION

Gasification refers to partial oxidation of organic substances at increased temperature(500-1800 ℃) to produce synthetic gas.The synthesis gas comprises of carbon monoxide,carbon-dioxide,hydrogen,water,methane,small amounts of hydro-carbons such as ethane and propane ,inert gases and contaminants .Good operation of the gasification reactor(high conversion efficiencies and minimal tar formation) requires that the nature(size ,consistency) of the waste input remains within certain predefined limits. The most frequent reactors used are fixed bed gasifier, fluidized bed gasifier and entrained flow gasifier. The salient features of the process include trapping of inorganic residues, smaller gas volume compared to incineration, predominant formation of carbon monoxide rather than carbon dioxide. The gas produced by gasification is combustible and can be combined with gas engines and fuel cells for electricity. In terms of waste treatment benefit, gasification can save between 1.9 and 3.8 MW per ton of waste. This technology in United States, the number of gasification plants has seen more than 100% increase since 2010.While the technology is in nascent stage as compared to incineration. Continuous advancements in the technology hold a great potential to complement modern forms of energy [18].

2.1.3 PYROLYSIS

Pyrolysis is the thermal degradation in the absence of an oxidizing agent or with limited supply to provide the thermal energy required. The three products obtained from this process pyrolysis gas, pyrolysis liquid and solid coke. In addition to the thermal treatment of municipal solid waste and sewage sludge, pyrolysis processes are also used for decontamination of soil, treatment of synthetic waste, metal and plastic compound materials for substance recovery. Pyrolysis gas could be used to power gas engines or gas turbines which generate electricity more efficiently than conventional steam boilers. The process is gaining significant traction in the waste energy technology because of higher efficiency since it has the potential to recover as much as 80% stored energy in carbonaceous wastes [18].

2.1.4 PLASMA BASED TECHNOLOGY

The application of plasma-based systems for waste management is relatively a new concept. The high energy densities and temperature that can be achieved in plasma processes allow to achieve high heat and reactant transfer rates to reduce the size of installation and high melting point temperature. The different categories for waste treatment namely plasma pyrolysis, plasma gasification, plasma compaction and vitrification of solid wastes. For the waste materials with higher calorific value plasma processes offers a viable solution to complete combustion and steam generation as the plasma treatment recovers the energy value of waste in the form of a synthesis gas.

Plasma pyrolysis is slowly becoming commercially viable proven technology. Currently there are ten plants operating in Australia, Japan, USA and Mexico. There are few small-scale plasma pyrolysis installations for treating polymers, medical waste and low-level radioactive waste. For the solid waste stream plasma gasification and vitrification seems to be preferred. Plasma systems show potential for higher net electrical efficiencies than waste incinerators since gas engines generate electricity more efficiently than steam turbines [18].

2.2 SELECTION OF SUITABLE SOLUTION FOR LADAKH

According to the literature review, most of the waste plants have higher investments or lower investments based on the capacities of the plant whether it is a higher or lower capacity plant. Some of the sources provided operation and maintenance in terms of percentage (ranging from 6 % to 14%). The electrical efficiency from the sources have been within the range of (15% to 21%). On an average whether it is the incineration, gasification, pyrolysis and plasma arc technologies, the price deviation in all is more than (+50%) [20,21,22].

A graphical relation is made up with the investment cost and capacities of incineration plant and with operation and maintenance cost and capacities relation.

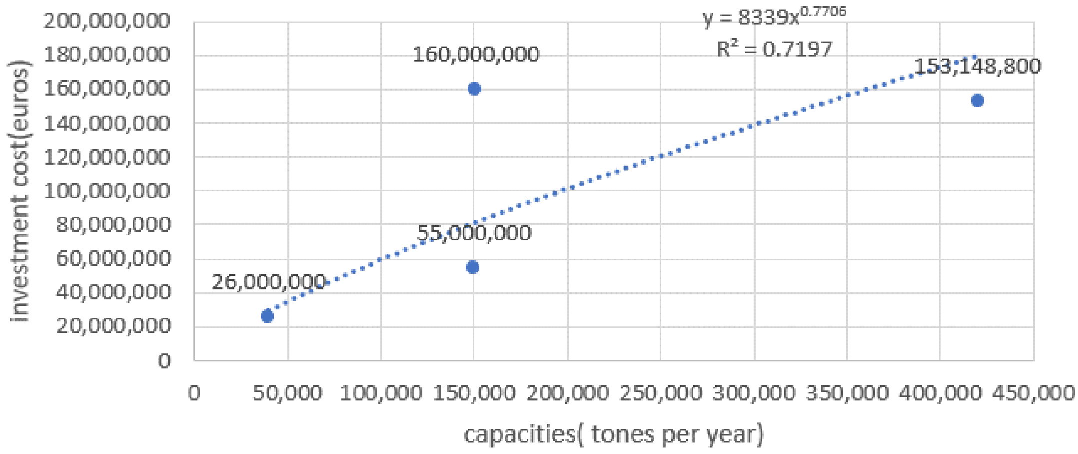

Figure 2.2.1 investment vs capacities of waste incineration

The above figure displays the relation between investment cost and capacities of incineration plant considered from the literature review of different waste to energy technologies. The investment cost includes refer to the costs related to project planning and development, including siting, feasibility studies, design, land, equipment and construction.

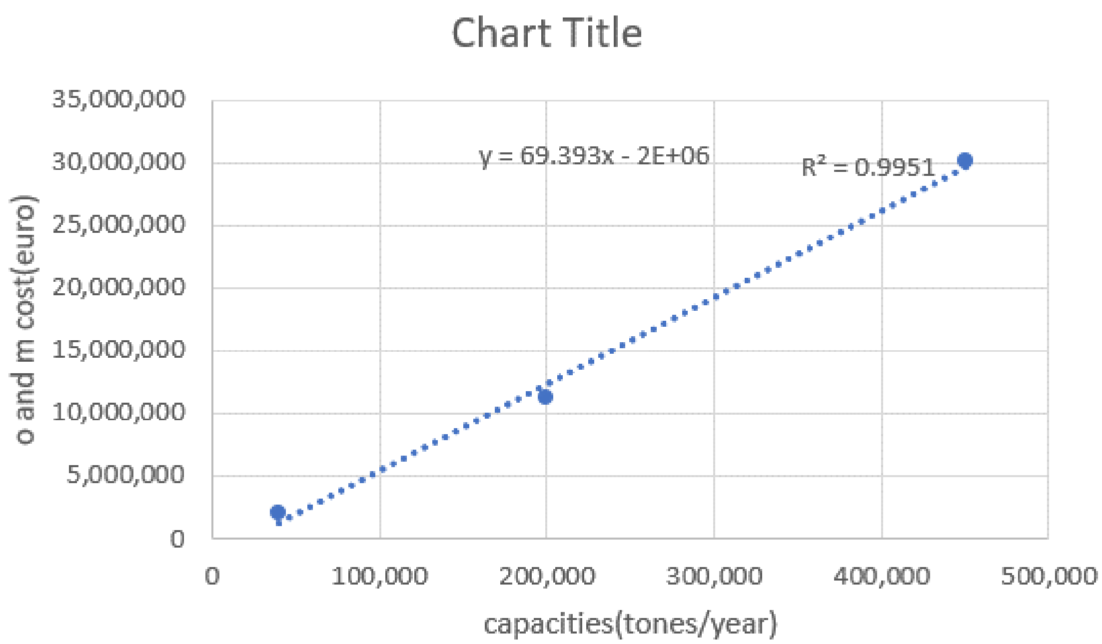

Figure 2.2.2 operation and maintenance cost vs capacities

The following figure displays the relationship between operation and maintenance cost and capacities of the waste incineration plant. Operation costs include the cost of labor, fuel, energy, maintenance and repair, emissions control and monitoring, public management and administration. Although equipment costs for thermal waste to energy plant are difficult to compare since the cost varies from different local conditions and in percentages ranging from (6% to 14%).

Table 2.2.1 potential of the four main thermochemical waste treatment technologies

Technology	Suitable for MSW	Commercially proven
Incineration	++	++
Pyrolysis	--	-
Gasification	+	+
Plasma gasification	++	-

The following table illustrates the potential of four main thermochemical waste treatment technologies suitable for different feedstocks including municipal solid waste (MSW) and the commercial status to be proven.

2.3 TECHNICAL AND ECONOMIC FIGURES

According to the literature study of various waste treatment plants the investment cost, operation and maintenance cost with electrical efficiency and fuel efficiency has been figure out for different waste energy possibilities. These technical and economic cost variables vary according to the capacity of plant, location and different mechanism of waste energy plants including the combination of gasification plants combined heating power, anaerobic digestion, co-combustion, landfill biomass,bio-diesel,palletization,pyrolysis,trans-esterification,incineration,gasification and plasma arc gasification.

Appendix A1

3 EXPECTED SITUATION

3.1 INVESTMENT

Considering the above waste-to-energy technologies incineration is selected for the valley as the main possibility. Leh has been selected as center point for establishment of waste to energy plant. The expected investment for the waste to energy plant incineration is around 45 million euros. The capacity of the incineration around 90 thousand tones per year with calorific value 7.31-megawatt hour per ton. The operating time of the plant is 8000 hours per year. The heat demand in Leh is 32,600-megawatt hour and the selling price of electricity to grid in the region is estimated out 35 euro per megawatt hour [32].

The alternative scenario is also considered with the set-up of district heating. Since the region is deficient in electricity, constructing a district heating network where the consumer can be access with electricity can be a viable solution. Currently the price of fuel is 1euro per liter. The heat density is 2.7 MWh/m. The district heating network is estimated 12,074.07 km. While the district heating network costs 250 euro/m, the district heating investment is 3,018,518.52 euro and addition of the investment cost of waste energy plant which constitutes around 48million euros [33].

3.2 MEASURE FOR INVESTMENT

To calculate the profitability of waste to energy, the measures for investment is calculated. In this study internal rate of return (IRR) is used as main figure and calculate for (I) waste to energy plant and (II) plant with district heating network. The waste to energy plant is in Leh with 100-meter radius and since Leh is a small city with population of nearly 30thousand people the construction of district heating network is in the same region with 200m radius.

Case A Leh (100m radius)- A satellite image is being used up for the valley within 100m radius with nearby areas as tourist areas and mountainous region.

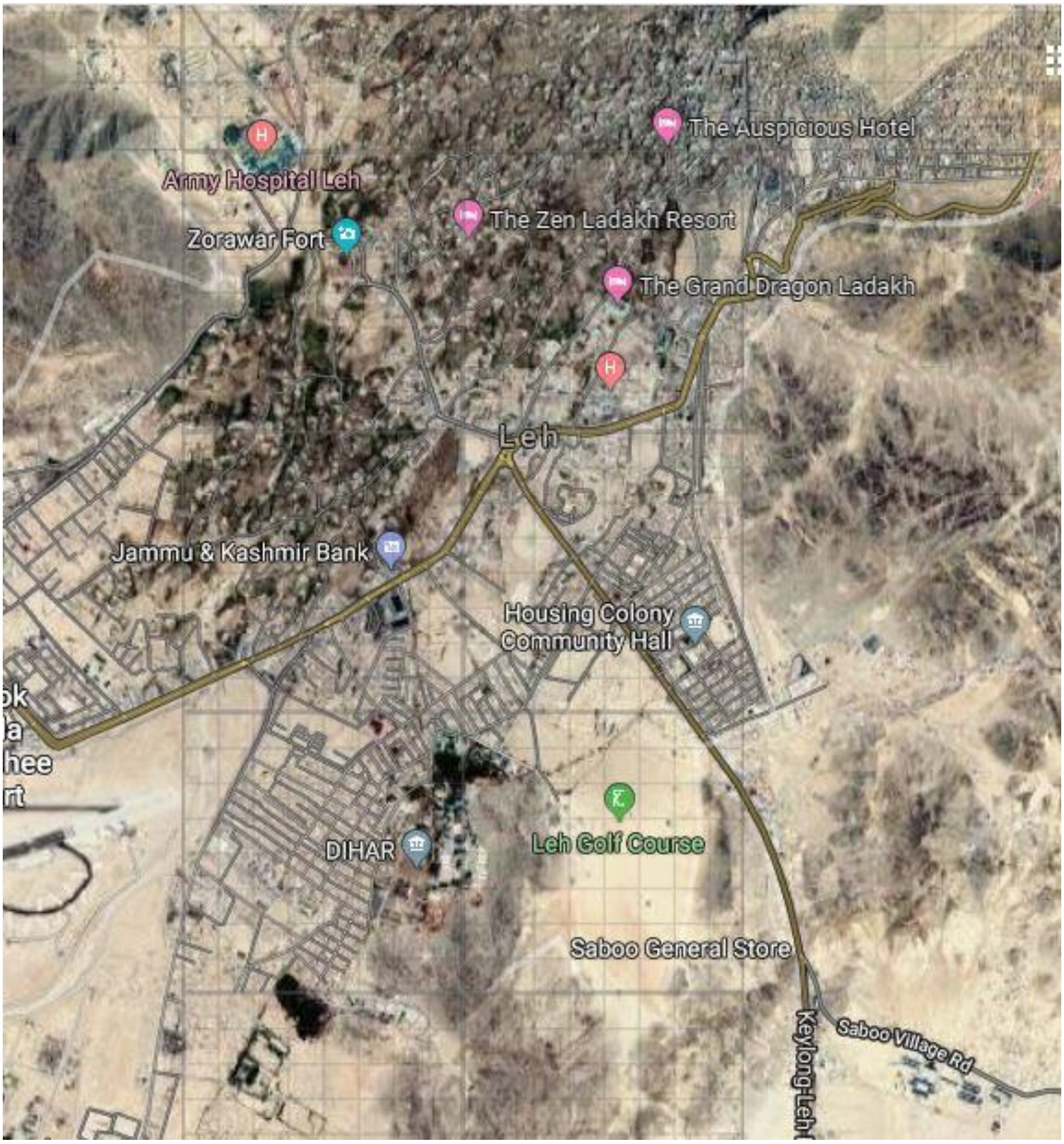

Fig 3.2.1 Satellite image of Leh (100m radius)

Table 3.2.1 Description of attributes in Leh (100m radius)

Capacity	90,000tones per year
Calorific value	7.31MWh/tone
Annual fuel energy content	657,900MWh
Electric efficiency	25%
Heat efficiency	55%
Operating time	8000hours/year
Electricity production	164,475MWh
Heat from WTE plant	361,845MWh

	IRR		-5%														
case A	Leh (100km) radius																
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	investment(WTE)	-45000000															
	o and m		-3780000	-3780000	-3780000	-3780000	-3780000	-3780000	-3780000	-3780000	-3780000	-3780000	-3780000	-3780000	-3780000	-3780000	-3780000
	electricity sells		5756625	5756625	5756625	5756625	5756625	5756625	5756625	5756625	5756625	5756625	5756625	5756625	5756625	5756625	5756625
	heat sells		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	cash flows	-45000000	1976625	1976625	1976625	1976625	1976625	1976625	1976625	1976625	1976625	1976625	1976625	1976625	1976625	1976625	1976625
	cumulative cash flo	-45000000	-4.3E+07	-41046750	-39070125	-37093500	-35116875	-33140250	-31163625	-29187000	-27210375	-25233750	-23257125	-21280500	-19303875	-17327250	-15350625

Figure 3.2.2 internal rate of return for waste incineration plant in Leh

The investment cost is based upon 45 million euro with electricity selling price to the grid as 35 euro/MWh. The cash flows and annual cash flows have been analyzed for the span of 15 years. However, the internal rate of return when calculated turns out to be negative (-5%).

Case 2: Leh (200m radius) with District heating network establishment.

Fig 3.2.3 Satellite image of Leh(200m) radius with possibility of district heating pipe network

Considering the alternative case in the valley, based upon the preliminary estimation second analysis has been analyzed with the district heating network possibilities.

Table 3.2.2 description of attribute with district heating network

Calorific value of fuel	10.00818KWh$_{fuel}$/liter
Price of fuel in Leh	1 euro/liter
Heat price	105.1771eur/MWh $_{heat}$
Heat density	2.7MWh/m
District Heating network	12,074km
District heating network costs	250euro/m
District Heating investment	3018518 euro
Efficiency	95%

Since the main residential area is near Leh, the highlighted places suggest the possibility of implementing district heating network. With the assumption of heat density, the cash flows and annual cash flows have been analyzed over the span of 15 years. The internal rate of return when calculated showed the positive value (6%) which proves the possibility of burning wastes with the help of cogeneration.

Case B	Leh with district heating																
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	investment(WTE+DH)	-48,018,519.00															
	o and m		-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000	-3,780,000
	electricity sells		5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84	5,753,124.84
	heat sells		3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897	3,085,897
	cash flows	-48,018,519.00	5059021.63	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84	5059021.84
	cumulative cash flows	-48,018,519.00	-42,959,497.37	-37,900,475.53	-32,841,453.69	-27,782,431.85	-22,723,410.01	-17,664,388.17	-12,605,366.33	-7,546,344.49	-2,487,322.65	2,571,699.19	7,630,721.03	12,689,742.87	17,748,764.71	22,807,786.55	27,866,808.39
	IRR	6%															

Figure 3.2.4 internal rate of return for Leh with district heating network possibility.

CONCLUSION

Different types of waste to energy plant such as incineration, pyrolysis, gasification and plasma arc gasification is discussed based on the investment cost, operation and maintenance cost, electrical efficiency and the capacities and a graphical correlation is done.

The key features of the research are mentioned below:

A. Out of the four waste to energy technologies, incineration has been considered the suitable solution for Ladakh considering the moisture content and the type of waste produced in the valley.

B. The graphical correlation for the capacity and investment cost, operation and maintenance cost and capacity of the waste incineration according to the literature review of the waste thermal technologies is generated.

C. The electrical efficiency of the incineration plant has been in the range of (15 percent up to 21 percent).

D. With this preliminary estimation waste to energy technology and district heating network scenario is discussed in Ladakh region. As a measure of profitability internal rate of return is calculated for the span of 15 years.

E. For the valley Leh waste incineration is considered with the capacity of 90,000tones annually and with 45million euros investment.

F. While considering the region Leh with a certain radius(100m), the internal rate of return while calculated seems a negative value significantly showing that the region is lacking in electricity.

G. Establishing a district heating network with the investment of 48million euros for the same capacity of plant is based in the (200m) radius.

H. The internal rate of return when calculated for the district heating network accrues for the positive value (6%).

India being the tropical country where there is no approach of district heating, by analyzing the positive internal rate of return there is a probability of establishing the district heating network in the valley. To invest around 48 million euros for the project for s span of 15 years is a feasible solution for Leh region.

SUMMARY

Ladakh being in the northernmost region of India is not strategically important but also from the environment point of view is fragile. The region being used as an important touristic destination however in the recent decade due to rapid anthropogenic pressure on account of increase in urban population, seasonal tourist inflows and enormous migratory labor force during summer season generating huge amount of waste. Among the recyclable waste glass constitutes 14.95 metric tons during summer season followed by food waste. The region requires a holistic approach to deal with the issues of solid waste management in an environmentally and economically feasible manner.

Waste to energy Incineration is presently used in the metropolitan cities of India and to use in Ladakh would also be feasible solution. Around 1241.17 metric tones in Leh town miscellaneous waste is generated during summer season in Leh town because of low market value. However, among these miscellaneous waste items, wood, non-recyclable paper and low-grade plastics, textile and bones can be diverted for the incineration plant disposal. The waste can then be burned at high temperature up to 600℃ and the resultant heat energy is converted into electric energy. Based on technical and economic figures of the waste energy plant incineration is relative to the price and within electrical efficiency of the plant.

Internal rate of return is used as a measure of profitability for the region with incineration plant and with the advent of district heating. A preliminary estimation is made for 15 years for the incineration plant and district heating considering the heat demand, electricity production, investment cost, operation and maintenance cost and electrical efficiency. While the internal rate of return is negative for the incineration plant but with the district heating network shows the positive value illustrating that there is a possibility of constructing the district heating solution to solve the waste management problem.

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APPENDICES

APPENDIX A1

S.no.	Plant	wte	investment	operation	electricity	electrical	capacities	Sources
			cost(eur)	cost(e/tone)	kwh/tonne	efficiency(	ton/year	
1	MSW	incinerate	16.425	1.2		25		[19]
2		pyrolysis	13.6	1.6		17		
		gasification						
3		plasma arc	15.6	2		32		
		gasification						
4		RDF	6	0.24		18		
5	MSW	anaerobic	76,000,000	36.72	389		406,975	[20]
		digestion						
6		gasification644,305,600		56.92	1530		341,275	
7		plasma arc	81231040	32.8	816		182,500	
		gasification						
8		incineration	153,148,800	24	340		420,000	
9	MSW	incinerate	112,000,000	56		20	200000	[21]
10		gasification	680	68		30	200000	
11		anaerobic	368	22.08		15		
		digestion						
12		waste	58,680	15.64		14		
		incineration						
13		landfill biogas	960,000	76,000	52eur/mwh			
		power plant						
14	British,irish	incineration	560	42			120,000	[22]
	american							
15	Danish	incineration	26,000,000	48.8		15.3	40,000	
16	Dutch	incineration	463,500,000	67		15.3	450,000	
17		gasification	524	60		27.2	500000	
18	Dranco	A.D.	1,000	40	225			
19		waste	2185.5	152.8		19.5		[23]
		incineration						
20	D.E.A	cocombus	120	71		34.4		
21		RDF	2139	85		30		
22		syngas	108,472	17,354		47		
23		biodiesel	8089	80				
24		bioethanol	2721	272				
25	MSW	pyrolysis	13-Jan	1.6	489GWh/y	25		[24]
		RDF	6	0.24	200GWh/y	18		
26		trans-	160	28	244.2GWh	33		
		esterification						
27		A.D.	0.112		164.5GWh	25		
28		A.D.	9,850,005	2.4734457		0.16		
29		incineration	19,342,557	10.79		0.449		
30		occ	174000000	50		0.958		
31	EFW	FBG+GE	560	87	6.8MWe	38.4	50,000	[25]
32		FBG+CCGT5	576	84	7.2	40.9	50,000	
33		FBC+ST	603	82	5.4	24.9	50,000	
34	pretreat	Torre-	6500000	325000		92	3332	[26]
		faction						
35		TOP	7,800,000	390,000		90	3332	
36		pyrolysis	6,200,000	0.248		64	3332	
37		pelletise	6.2	0.31		84	3332	
38	ELM	plasma gas	55	77		30		[27]
39		ification						
40		incineration	45	70		24		
41		incineration	185,000,000.00	180				
42		A.D.	20,000,000	15				
43		landfill	6,000,000	0.8				
44		gasification	120,000,000	40				
45	MSW	composting	3,600,000,000				365,242	[28]
46		A.D.	7,600,000,000		187.5		407,245	
47		gasification	661,600,000		1000		113,956	
48		pyrolysis	6,640,000,000		490		127835	
49		incineration	2,160,000,000		340		189926	
50	biomass	direct	1040eur/kw			20		[29]
		combustion						
51		gasification	1840eur/kw			40		
52		pyrolysis	4960eur/kw			85		
53	medium	gasification	1360eur/kw	10960	56MWe	36		
	plant							
54	2MW	pyrolysis	2880eur/kw		2MW	38		
55	RDF	CFB+CCGT	19	84			100,000	[30]
56	RDF	CFB incin	20	82			100,000	
57	MSW	GB incin	11.9	66			136,000	
58	MSW	GB gas	15.3	52			85,000	
59	MSW	FB+ICE	13.3	58			85,000	
60	MSW	GB inicn	8.9	76			245,000	
61	MSW	plasma+	17.9	130.3			2,250,000	
		CCGT						
62	MSW	FB+CCGT	6.4	57.6			341,000	
63	conven	incin	55,000,000	65,000,000		21	150000	
64	wte-gt	incin	160,000,000	280,000,000		42	150000	
65		A.D.	16,000,000	28,000,000		10.4		
66		gasific	100,000,000	75,000,000		35	250000	