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Feasibility Analysis of Recycled-Paper Fueled Agricultural Desalination Process: Design of Recycling and Desalination Processes

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Feasibility Analysis of Recycled-Paper Fueled Agricultural Desalination Process: Design of Recycling and Desalination Processes

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ABSTRACT

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Design of Recycling and Desalination Processes
(Under the direction of Dr. Greg Thoma)

While recycled-paper-briquettes have lower BTU ratings than wood, and fresh water is typically a low cost to agricultural entities, situations exist where economic and/or environmental factors may allow a recycled-paper-fueled desalination process to be viable for some specific agricultural entities. This document begins with a discussion of how water is priced throughout India before analyzing trends in the Maize futures market. By tying the two together, an opportunity is created for solution which the remainder of the document presents. Waste in India makes-up 50% of its solid waste country-wide; however, only a quarter of that waste is recycled - the remainder is land filled or incinerated. As an area where overpopulation and an arid climate elevate the prices of clean water, energy and agricultural commodities, unclaimed paper waste may well be utilized in India to produce clean water from saltwater at an affordable price. This thesis presents a paper-recycling process that aims to couple its energy-dense product with a desalination process for agricultural purposes. In addition to desalination for agricultural purposes, this energy source can be applied to other applications including wastewater treatment, residential heating, power generation and medical device sterilization.

To my mentor *and* my friend, I couldn't have done this without you.

Thank you for all of your support along the way.

PREFACE

Desalination - or removal of Totally Dissolved Solids (TDS) - is a topic of particular interest to me, and I hope my passion is both seen with each stroke of my pen and heard with each word in my presentation. My 5-year goal is to pursue the licensing of water purification processes with international manufacturing and agricultural entities. Ideally, these designs would be scalable in nature to lower the price point of the in-demand process and allow for sustainable philanthropic efforts -- leaving the world better than I found it. In addition to my water-purification efforts, I am also pursuing my Master of Business Administration at the University of Arkansas focusing on entrepreneurship with the desire to gain the following: access to a network of contacts in influential positions within a variety of supply chains; empathy for potential investors; a financial skillset for effectively managing debt and equity; and a refined method of characterizing markets and factors which influence those markets. The University of Arkansas, my friends, colleagues and my family have enabled me to pursue such interests. No amount of thanks shy of success, admiration and philanthropy will substantiate all that has been afforded to me. Thank you for your attention and consideration.

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INTRODUCTION: CLEAN WATER DEMAND, MAIZE DEMAND & PAPER POLLUTION IN INDIA

The proposal presented hereafter was derived in response to the following information presented by UNESCO over the last several years, along with information from a variety of other resources provided by the University of Arkansas and via the internet. "Freshwater and energy are crucial for human well-being and sustainable socio-economic development. Their essential roles in achieving progress under every category of development goal are now widely recognized. Major regional and global crises - of climate, poverty, hunger, health and finance - that threaten the livelihood of many, especially the three billion people living on less than US$2.50 per day, are interconnected through water and energy." [1] Any attempt to further understanding of, and/or innovate processes for a more conservative production of water are in line with urgent needs around the world. "While only 0.5% of the world's available water resources are brackish in nature, brackish-water desalination has found widespread application because it allows the production of freshwater at reasonable low cost and energy expenditures. At present, over 77% of the existing desalination plants in the United States are brackish-water desalination facilities. Approximately 220 brackish-water desalination plants produce freshwater for municipal water supplies in states such as Florida, Texas, California, New Mexico and Virginia. Worldwide, brackish-water desalination also contributes to municipal and agricultural water supplies in many arid regions, such as southern Spain, the Middle East, Australia, South America, and southern Israel." [2] This isn't to say that global demand is being met; on the contrary, it strengthens the argument that desalination processes aren't sufficiently affordable. Aside from higher resultant food, water and sanitation pricing, costly desalination processes drive untenable consumption of renewable water resources. "In an attempt to better capture the relationship between supply and demand, the Millennium Development Goal Water Indicator purports to measure the level of human pressure on water resources, based on the ration between water withdrawal by agriculture, municipalities and industries over total renewable water resources." [3]

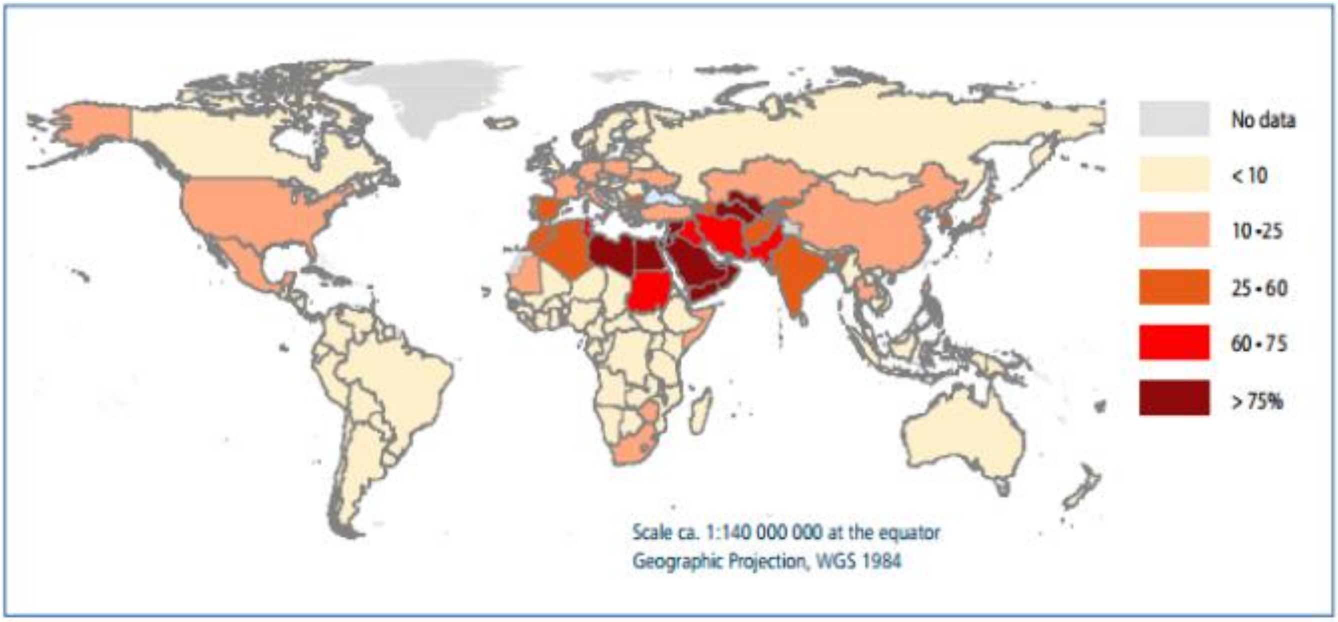

Figure 1: Percentage of Renewable Water Resources Withdrawn [3]

"Agriculture accounts for roughly 70% of total freshwater withdrawals globally and for over 90% in the majority of Least Developed Countries (LDCs). Without improved efficiency measures, agricultural water consumption is expected to increase by about 20% globally by 2050." [3] Agricultural demand exists for desalination processes which both take advantage of readily available biomass and are not capital intensive. The mission of this thesis is to aid in the development of such technologies. The remainder of this introduction investigates and presents India's demand for water, demand for maize and its supply of newspaper waste. By analyzing market trends and pollution statistics, a rational individual can justify investing his/her time and effort into developing technologies that have the potential to reduce prices of commodities and other resources while also converting waste into stored energy.

For this investigation, seawater is proposed as the feed stock for the desalination process, thus coastal regions of India will be the intended target market for this feasibility analysis. To this end, understanding how the Indian government regulates the price of water is critical to the endeavor -- without an understanding of both operating costs and taxation assessments of this nature have no value. As seen in Figure 1, India's rate of fresh water consumption was not sustainable in 1984. The source document for this information was the *United Nations World Water Development Report 2016*, which added that the demand has only increased in response to India's population growth over the last 30 years. This trend has placed the Indian officials in charge of pricing the national water supply in a unique position. On one hand, the government is under intense demand to generate a rational and practical approach to levy Water Rates for both large national operations and small family sized operations. On another hand, the government has the ultimate opportunity to direct social change, economic development, and to promote a more sustainable and diverse supply of commodities for its citizens and its international markets. India's National Water Policy Statement of 1987 highlights the officials' predisposition towards setting Water Rates, stating "Water Rates should be such as to convey the scarcity value of the resource to the users and to foster the motivation for economy in water use. They should be adequate to cover the Maintenance and Operation Charges and a part of the fixed costs of irrigation works. Efforts should be made to reach this ideal over a period of time while ensuring assured and timely supplies of irrigation water. The Water Rates for Surface Water and Ground Water should be rationalized with due regard to the interest of small and marginal farmers." [4] A derivative of this initiative is carried out by the Information System Organization Water Planning & Projects Wing Central Water Commission who publishes a resource called the "Pricing of Water in Public System in India." The March, 2017 edition [5] of this index is used to validate the price of water derived for the subject region of this investigation. Interestingly, the Indian Government sets the price of water in each region of the country in response to the supply and demand associated with each crop planted (i.e. water for under-produced maize will cost more than water for over-produced cotton in the same region). Knowing where and how to enter the Indian coastal-agriculture market is thus dependent on an intuition of agricultural commodity pricing for that market. This thesis focuses on producing maize near Mumbai (the coastal capital of India's Maharashtra state). The water price for maize produced in the Maharashtra state will be derived throughout the remainder of this introduction section in conjunction with an analysis of maize pricing.

Understanding agricultural commodity pricing in Indian markets is a tall task. Ms Supriya (alumna, Dept. of Commerce, Delhi School of Economics, University of Delhi, India) provides some useful insights in his financial-focused analysis of the derivatives market in India - including the following key insight: "trading is fragmented over multiple market venues due to both the lack of free movement of commodities and the differential taxation in different states." [6] In layman's terms, a sufficient infrastructure does not exist in India for the level pricing of commodities across all markets. Additionally, taxation varies based on each state's needs. The result of these phenomena is the dominance of spot markets throughout the country - particularly in the coastal regions. "There are about 25 recognized commodities exchanges. All exchanges have been set up under overall control of the Forward Market Commission (FMC). There are more than 100 commodity derivatives trading on these exchanges." [6] The National Commodity and Derivatives Exchange (NCDEX) [7] is the source of commodity data chosen for this forecast. In addition to insufficient infrastructure dictating commodity prices, weather patterns drive agricultural planning and thus price variance over the course of a given year. These weather patterns force the existence of two types of crops in the Agriculture-sector that were named based upon the season planting occurs -- Kharif crops and Rabi crops. Kharif crops are also known as "monsoon" crops and are harvested from late September through March, whereas Rabi crops are known as "winter" crops and are harvested during April and May. Kharif crops generally include rice, maize, sorghum, pearl millet/bajra, finger millet/ragi (cereals), arhar (pulses), soybean, groundnut (oilseeds), cotton, etc., while Rabi crops primarily include wheat, barley, oats (cereals), chickpea/gram (pulses), linseed, mustard (oilseeds) etc. [8] For an understanding of where and when each commodity is grown and what factors cause commodity values to fluctuate across various markets, any of the applicable recognized commodities exchanges can be utilized. The NCDEX was referred to for this study and offered the following *Commodity Snapshot* for the Indian maize market:

> "Also called corn, maize requires moderate climate for growth, excess or deficient rains adversely affect yields as well as quality. It grows well in loamy soils. Maize in India is grown in both kharif (80%) and rabi (20%) seasons. The major states are Karnataka, Andhra Pradesh, Maharashtra, Madhya Pradesh and Uttar Pradesh. In rabi, maize is grown in Bihar and coastal region of Andhra Pradesh. Maize production and consumption has been rising consistently in India. The feed uses of maize are projected to increase by 10% annually. Starch companies are also in expansion mode with several existing players adding new capacity. Starch derivatives are used in textiles, pharmaceutical industries, confectionery, etc. and all these industries are poised to grow substantially in future. Increased production of maize caters to export markets and offers distinct freight advantage to Indian exporters to Middle East and South East Asian countries. Maize usage is bound to grow as its consumption is linked to economic growth. Maize production and consumption are largely stable, but price volatility is intricately linked to seasonal changes in consumer preferences of poultry products, export demand and demand for starch derivatives." [7]

Another important factor impacting maize market investment profitability is proximity to feed/industrial-grade (FIG) spot market locations. These markets exist year-round and vastly outweigh human-consumption demand for maize. For our analysis of the Maharashtra coastal region, four of the five major spot markets of this nature exist within a 1 state proximity [note: India is comprised of 29 states]. With characteristics affecting maize market investment profitability labelled, NCDEX can now be referred to for the development of annual maize commodity pricing (a.k.a. futures). Figures showing 2016-2017 spot market prices for maize across India can be found in Appendix A (note: the official NCDEX Trading Parameters' unit of trading for maize is 10 metric tons. Some of the markets began capturing data recently - hence they are listed in varied time-scales). Figure A1 presents maize kharif spot prices in Nizamabad which is not in India but remains a potential customer for a maize venture along the western coast of India. Figures A2, A3, A4, and A5 offer maize FIG spot prices for the four FIG spot markets near the State of Maharashtra (Sangli, Karimnagar, Jalgaon, and Davengere, respectively). Figure A6 shows the same trend for the remaining FIG spot market in Delhi while Figure A7 does the same for the maize rabi spot market in Gulabbagh. The spot market trends all show the effect of increased supply - caused by the onset of maize kharif harvests beginning in September - with the large step-change reduction in price. This is the logical conclusion as maize requires a lot of water and other rabi crops require much less - incentivizing the government to allocate water elsewhere during the summer months and charge more for water use for non-economical rabi maize irrigation. These summer months are when the greatest effect can be felt by the technology presented in this thesis. Over the last year - as shown in Appendix A - the spot market prices for maize across each market raised to nearly $1,900 per 10 metric tons (~30% higher than the $1,450 price during the monsoon season) due to the decrease in supply caused by the increased cost of water. Thus, reducing the cost of acquiring freshwater – thereby addressing what has traditionally driven up the price of rabi maize – increases the profitability of the crop and decreases the risk associated with the investment for the time period. In addition to this price, the Government of India recognizes these efforts to invest in alternative sources of water and will work with investors to reduce taxes and other costs. [5] Water pricing is provided in terms of area (per 10,000 m^2) thus an annual spot value for maize generated from the same 10,000 m^2 area must be generated. In determining the annual spot value, the cost of water can be back-calculated, and the design can have a basis from which to improve. Usda.gov reported that the expected yield for 1 acre of corn for 2015 was 168.8 bushels in the US. [9] By assuming a ~10% reduction to 150 bushels per acre - to account for India's potentially less advanced agriculture practices – and converting to SI units, 10,000 m^2 of farmland will produce around 10 tons of maize per year. [10] Therefore, for 70% of the year (rough estimate of kharif maize production using Appendix A), the value of maize is $1,450/10 metric tons, and for the remainder, the value is $1,900/10 metric tons. Thus, the weighted spot market value for 10,000 m^2 of maize crops in Maharashtra is found to be a little more than $1,550 annually without an alternative source of freshwater than the government. If the difference in price between the kharif maize and the rabi maize is assumed to be the cost of supplying fresh water to the maize, then the cost of water for 10,000 m^2 of maize farmland over the course of a year is the kharif value less the weighted average value of the crops – or $450. This is a conservative value as kharif maize futures likely include the possible cost of supplying water when the monsoon season doesn't deliver the required amount of rain; however, for the purposes of this analysis, I will consider $450 as the base cost of water per year per 10,000 m^2 of maize farmland. This note will be included in the discussion of results at the end of the thesis.

This thesis proposes for newspaper waste to be recycled into briquette form and then combusted to fuel a distillation desalination process for the production of fresh water from sea water thereby reducing water-consumption costs for coastal maize-farmers in India. With a basis for both maize demand and clean water pricing established above, the next variable to investigate is the availability of newspaper waste. In Preeti's July 25, 2016 article on paper recycling in *The Hindu*, the following information is presented:

> "As many as 550 mills in India use waste paper as primary fiber-source for paper, paperboard and newsprint production. This waste paper is sourced indigenously as well as through imports. The present recovery and utilization of waste paper by paper mills in India is 3.0 million metric tons annually, which translates to a recovery of 27 per cent of the total paper and paperboard consumed, very low when compared to recovery rates in developed countries like Germany (73 per cent), Sweden (69 per cent), Japan (60 per cent), Western Europe (56 per cent), USA (49 per cent) and Italy (45 per cent)." [11]

So, where does the extra 73% - or 8.1 million metric tons - of the total-paper and paperboard which is consumed end up? "On average, waste paper contributes to about 50% of municipal solid waste, and newspaper alone constitutes 14%. At present, the majority of waste paper is land filled or incinerated." [12] Alright, but where does the 27% end up after it is reproduced into paper, paperboard and newsprint production but before it is sent to landfills or incinerators? "The paper waste can typically be recycled from 5 to 7 times, before papermaking fibers become too short and weak to hold together; each recycling requires de-inking with chemicals processing and by adding virgin wood fibers." [13] In contrast to the intent of most paper-recycling processes in literature, the process proposed here supports a use for the last stage of the paper life-cycle - where it is usually land-filled or incinerated. Another important topic frequently avoided in paper-recycling literature is the topic of motivating paper waste recycling efforts. Mehra points to several developing efforts brought out of India's private sector before providing the following insights about developed nations -- "across most of the developed nations, waste paper recycling is initiated, organized and operated by municipal authorities, supported by suitable national policy normally based on the *polluter-pays* principle. Legislations are formulated in the form of directives, procurement policy guidelines, as well as voluntary agreements." [11] However, addressing the complexity of motivating India's population is both unique and challenging. Western mentalities - simply put - do not work in India. Organizations cannot possibly expect people with no vested interest in the economy to recycle for the sake of improving the economy or helping a company. In all reality, there are many Indian citizens with no significant vested interest in their economy. Worldbank.org reports that 20% of India's 1.3 billion people lived on below $1.90 a day in 2011. [14] These people are struggling to live, eat and stay warm, and cannot possibly be expected to think about anything other than survival. A majority of this fraction is illiterate in addition to being justifiably apathetic. Thus, while 11.1 million metric tons of annual paper waste circulates within India, and is available for reuse, a large portion of it inevitably falls to the fate of man's will to survive and ends up simply discarded without regard to the opportunities that are lost.

An essential process of designing any system is the consideration of how you want people to be impacted by its use. Naturally, it must be investment worthy, however, it must also be user-friendly, safe and "in the best interest" of the parties it purports to effect. By aligning interests, economies are formed and people work together for mutual growth. In deriving the system for this maize market, design priority was given to profitability, scalability and versatility-of-markets-served. Using this design criteria, the solution conceived has the potential to motivate a population of people who need clean and affordable water and food by providing them with a key to the process -- the paper waste which surrounds them. That is not to say that the profitability of the design for the maize market depends on the will of this lower 20% of the population that lives on less than $1.90 per day; instead, it only suggests that the solution is potentially beneficial and motivational to that fraction of the Indian citizenry. The feasibility analysis presented in the remainder of this document highlights this design's scalability and profitability and concludes with a table of expected cash flows, return on investments and capital costs. Although the analysis only investigates one commodity, there would undoubtedly be promising potential effects upon other markets such as wastewater treatment, residential heating, power generation and medical device sterilization.

AGRICULTURAL WATER QUANTITY BASIS JUSTIFICATION

The Food and Agricultural Organization (FAO) of the United Nations' (UN) primary objective is to help eliminate hunger, food insecurity and malnutrition. In line with its primary objective, the organization seeks to make agriculture, forestry and fisheries more productive and sustainable. [15] The FAO's Natural Resources Management and Environment Department provided a series of helpful documents called Irrigation Water Management Training Manuals in the late 80's. [16] The principles and practices established in these manuals are used to determine a basis for irrigation water needs for this investigation. While maize was chosen as the commodity of focus for this analysis, the training manuals offer reference information for all types of crops, soils and environments.

In determining crop water needs, the training manual first assesses the needs for grass and uses it as a basis for further recommendations. Table 1 provides the daily amount of water required for grass during irrigation season by climatic region, and Table 2 provides peak period demands of various crops relative to data shown in Table 1 for Grass.

Table 1: Daily Amount of Water Required for Grass during Irrigation Season [16]

Climatic zone	Mean daily temperature		
	low	medium	high
	(less than 15°C)	(15-25°C)	(more than 25°C)
Desert/arid	4-6	7-8	9-10
Semi arid	4-5	6-7	8-9
Sub-humid	3-4	5-6	7-8
Humid	1-2	3-4	5-6

Table 2: Crop Water Needs in Peak Period of Various Field Crops as Compared to Standard Grass [16]

Column 1	Column 2	Column 3	Column 4	Column 5
-30%	-10%	same as standard grass	+ 10%	+20%
citrus	cucumber	carrots	barley	paddy rice
olives	radishes	crucifers (cabbage, cauliflower, broccoli, etc.)	beans	sugarcane
grapes	squash	lettuce	maize	banana
		melons	flax	nuts & fruit trees with cover crop
		onions	small grains	
		peanuts	cotton	
		peppers	tomato	
		spinach	eggplant	
		tea	lentils	
		grass	millet	
		cacao	oats	
		coffee	peas	
		clean cultivated nuts & fruit trees e.g. apples	potatoes	
			safflower	
			sorghum	
			soybeans	
			sugarbeet	
			sunflower	
			tobacco	
			wheat	

Thus, maize (Table 2, Column 4) requires 11 inches of rain in the arid climate at the highest mean daily temperature. Table 3 below combines data presented in Tables 1 and 2 to generate required quantities of water for maize growth across the established sizes of maize farms in semi-arid climatic regions with high temperatures.

Table 3: Water Needed for Maize Growth for Three Crop Sizes

Peak Daily Water Needed per 10,000 m2	Farm Size (m2)	Daily Volume (m3)
9.90 Water Needed for Corn (mm)	10000	99
10000.00 Farm Size (m2)	100000	990
99.00 Water Needed for 10,000 m2 (m3)	1000000	9900

Thus, the design basis of 100 m^3 of water per 10,000 m^2 of maize is derived in accordance with recommendations provided by the UN FOA's Natural Resources Management and Environment Department. With appropriate bases established for the quantity of water for each of the farm sizes, the paper-briquette-manufacturing and agricultural-desalination processes are set to be presented and examined.

BRIQUETTE MANUFACTURING PROCESS: OVERVIEW AND DESIGN

The primary objective in manufacturing briquettes of any sort is to minimize the cost while maximizing the energy output. This objective, when achieved, enables the manufacturing process to attract more consumers who want to buy energy at a lower price than what they are currently paying. A secondary objective is to recognize the benefits of the product and leverage those benefits against government officials who can alter tax-rates - minimizing the cost even further. This secondary objective will not be pursued in this investigation; however, a discussion of the benefits associated with the product will be presented. This section will present the following aspects of the briquette manufacturing process in this order: an overview of the process; description of the product; equipment and operating costs; waste management; and finally, an operating procedure. This section will not provide the costs of collecting, separating or transporting the biomass used in the feed, nor the costs of pursuing new customers or delivering to existing ones. The biomass chosen as the feed for this investigation is newspaper.

Figure 2 presents a block-flow diagram of the briquette manufacturing process proposed.

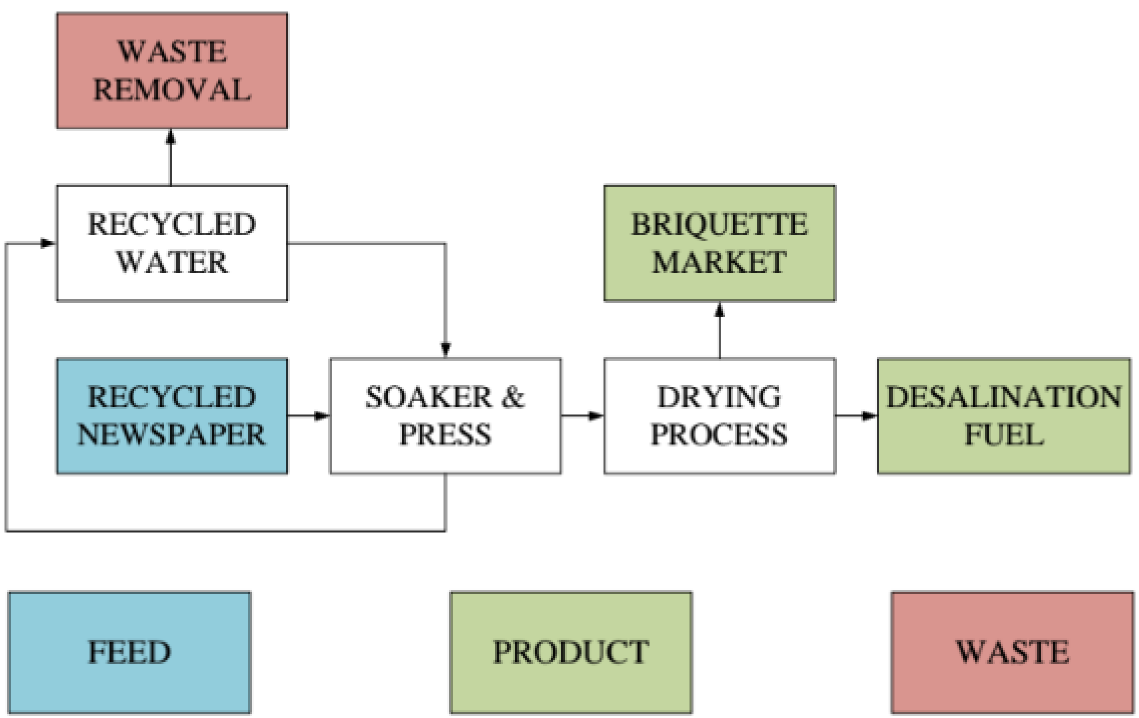

Figure 2: Block-Flow Diagram for the Briquette-Manufacturing Process

In designing the briquettes, maximizing potential combustion energy is the primary objective. To do this, the biomass is required to be compressed as tightly as possible while providing a maximum surface area for combustion to occur. With this objective defined, an optimal design can be reached; however, consideration must be given to the mechanical reliability of the product and the products of combustion. If the product is not structured well, it could fall apart at any stage of the supply chain. Two briquette designs (tubular and brick-shaped) are presented by Chaney in his thesis on the combustion characteristics of biomass briquettes in 2010 [17]. The analysis he performed is extremely useful in determining appropriate briquette designs and deriving the system proposed in this report. One of the designs examined is the product of The Legacy Foundation's low pressure briquetting technique. "The Legacy Foundation, an American NGO, have produced manuals describing the low pressure briquetting technique. They suggest that the best shape to make a briquette is a cylinder with a central hole, commonly known as a holey briquette." [17] Their biomass briquette generates a rapid and more complete combustion than its brick-shaped counterparts which burn slower and less completely. The Legacy Foundation's 'holy briquette' design is chosen for this investigation. "The calorific value (or heating value) is the standard measure of the energy content of a fuel. It is defined as the amount of heat evolved when a unit weight of fuel is completely burnt and the combustion products are cooled to 298K." [18] The calorific value of newspaper generated by Chaney was between 18-19 MJ/kg. [17] He also provides this table of experimental values:

Table 4: Experimentally Determined Heat Transfer Constants for Newspaper Briquettes [17]

Parameter	Value	Uncertainty
Flame temperature	$750\ K$	$\pm$ 50 K
Flame Emissivity, ϵ_f	0.54	$\pm$ 0.07
Heat convection coefficient, h	$102\ W/m^2K$	$\pm 26\ W/m^2K$
Thermal conductivity, virgin briquette	$\lambda = (0.000121\rho + 0.0526)\ W/mK$	$\pm$ 7%
Heat capacity, virgin briquette	$1612\ J/kgK$	$\pm 400\ J/kgK$
Density, virgin briquette	between 200 and 600 kg/m^3	see Section 5.2.6
Volatile fraction	mean from literature*: 85 %	$\pm$ 5%

For this investigation, a hypothetical economic analysis and operating procedure are presented for the production of dry briquettes in Mumbai. First, the monthly cost of a warehouse can be found online - see Figure B1. This warehouse is 5,000 square feet (465 square meters), costs 60,000 rupees per month (~932 USD p.mo), and is assumed to be perfectly square (21.56 meters by 21.56 meters) for this analysis. Newspaper waste can be brought in the front of the warehouse and loaded into one of 1,000 200-L plastic containers which can also be found online for ~10 USD per container - see Figure B2. Newspaper waste is managed by the municipality of Mumbai. It is in the city's best interest to reduce the amount of material in their landfills; thus, the cost of acquiring used newspaper can be ignored. In the future as new users demand this same supply of waste, the price may go up; however, the core concept of this technology is to be used as a source for water purification. The social good of that mission may drive advantageous negotiations in the future with the municipality. Once the paper is loaded into the 200-L plastic containers, the container will be timestamped with one of six different-colored stickers (one for each of the five days required for soaking and one for the current day) and set on a space in one of the 120 4-level industrial racks in the warehouse. Industrial stainless steel racks cost ~100 USD each and increase the production volume of newspaper briquettes because you can soak 4 times the amount of newspaper by stacking the containers vertically on the racks - see Figure B3. Given the 465 square-meter floor space of the warehouse, roughly 120 of these 2 meter x 0.6 meter industrial racks will allow for optimal process flow. 80 will be used for soaking, and 40 will be used for forced convection drying (both are five day processes). There should be 1 meter between racks and the excess ~ 4 meters of space in the warehouse will be filled with compression stations. Once in the rack and timestamped, the 200-L plastic containers will be filled with water and left to soak for 5 days. Cheney has the following to say about the soaking process:

> "If the alkali metals are removed from the biomass, it is known to increase the fusion temperature of the ash, the temperature at which it conglomerates together. Experiments have shown that this can be done by washing or soaking the biomass in water to leach the alkali metals, and this gives significant reductions in the fusion temperature of ash. In fact this simple technique has been shown to remove more than 80% of the alkali and most of the chlorine, which has the added advantage of reducing corrosion and acid gas emissions." [17]

After soaking for 5 days, the mixture will be manually transferred from the soaking racks to one of 4 compression mold stations. These molds will be welded pipes and plates which allow for a 'holy briquette' design to be formed using one of the four 2-ton car jacks. These were found online for 30 USD each – see Figure B4. The water which was separated from the paper during the compression process will be captured and sent to a collection drum before being gravity fed to a direct-fire boiler. In the direct-fire boiler, the water will be boiled and naturally rise toward one of 4 tanks on top of the warehouse (dry briquettes produced from a previous run are the source of the fire). This water vapor will condense when it meets the cool liquid feed from the collection drum in a countercurrent double-pipe heat exchanger at an elevation higher than the nozzle to the water tanks on the top of the building. The feed-water to the direct-fire boiler will naturally travel to this high heat exchanger as the exit from the collection drum is higher than the entrance to the boiler at ground level. The direct-fire boiler found online will cost 22,000 USD – see Figure B5. The collection drum and water tank quality will be recorded daily at manually-installed sample valves. The collection drum and water tanks are the same tanks and were found online to cost 300 USD each – see Figure B6. The pure water sitting in the water tanks on the top of the building is gravity fed back to hoses on the ground level where workers can easily use them to fill new plastic containers and soak new newspaper. After compression molding, the briquettes (reduced in volume from their pulp state) will be set on the remaining 40 industrial racks, and 10 fans will be used to dry the briquettes over a 5 day period. Industrial fans found online will cost 30 USD and 20 will be ordered – see Figure B7. Since fans will operate continuously, and each one requires 1.1 Kw, 7200Kwh will be consumed powering fans. When combined with other normal electricity consumption, monthly electricity costs will be around 1,000 USD. [19] Utility rates will be around 250 USD per month. [20] The entire process requires 20 minutes of labor per plastic container, and only 20% will be handled on any given day. Therefore, 3,840 worker minutes are required each day. This is equivalent to 64 worker hours or 8 workers working 8 hours shifts each day of the week. Similar *unskilled* jobs in Maharashtra include the following: Cardboard Boxes, Cement Industry, Paper & Paperboard, Plastic, Saw Mill, Cotton Ginning & Pressing, and Factory Under Fy Act Residuary. If the highest and lowest paying of those jobs are excluded, the resultant average wage is $116.71 per month. [21]

ECONOMIC ANALYSIS: REQUIRED PRICING FOR TWO YEAR RETURN ON INVESTMENT

To offset the investment, operating costs presented in the previous section, and a standard opportunity cost of 10% (which you would receive on a 30 year investment in a broad based index fund), the maximum volume of products must be calculated and the price must be set so as to return value to the business in 2 years. It is important to note that in doing a *green* business, the tax rate is eliminated.

The first step in finding the maximum volume of products is to assume a density. Using Cheney's Thesis for reference, the dry briquette density is assumed to be 400 kg/m^3, and each briquette produced is 5 kg dry. [17] Therefor the product volume is 0.0125 m^3. If the wet to dry volume ratio is 4-1, then - at 200L - each plastic container generates 4 briquettes. Thus, for any given day, 768 briquettes will be produced. Over the course of 2 years (selling 50% of the maximum possible production), 280,000 briquettes will be sold. At this point, the NPV of all cash flows can be generated and divided by -280,000 briquettes to determine the price. Table 5 shows the final price at which each briquette should be sold for investors to receive their money back.

Table 5: Price Point Determination to Break Even after 2 Years

Category	Quantity	Annual Cost
Plastic Containers	1000	$ (10,000.00)
Industrial Racks	120	$ (12,000.00)
Car Jack	4	$ (120.00)
DF Boiler	1	$ (22,000.00)
Water Tanks	5	$ (1,500.00)
Fans	20	$ (600.00)
Initial Investment		**$ (46,220.00)**
Electricity	12	$ (12,000.00)
Utilities	12	$ (3,000.00)
Labor	12	$ (11,204.16)
Lease	12	$ (11,184.00)
Annual Operating Lease		**$ (37,388.16)**
Opportunity Cost		**10%**

2 Year NPV	**$ (111,108.54)**
# of Briquettes produced	$ (280,000.00)
Price per Briquette	**$ 0.40**

CONCLUSION: DISCUSSION OF RESULTS & OPPORTUNITIES IN AGRICULTURAL DESALINATION

The 0.40 USD price point of briquettes produced from this process – in combination with a purification process similar to that of Figure 3 - must produce enough energy to distill the flows presented in Table 3 a total cost less than 450.00 USD per 10,000 m^2 of maize crops during the Raji season. This price point has two biases that have the greatest potential to vary the value. First, the assumed fraction of potential sales actually sold was 50% for the first two years. Investors in this process would understand their market very well and have several customers ready to drive that fraction up when the operation opens its doors and starts producing the biomass. On the other hand, the supply of newspaper may not exist to the same extent described in the introduction and this may limit the number of newspapers the operation is able to produce. In conclusion, this process appears to be profitable; however, without an understanding of the costs associated with an innovative agricultural desalination process like Figure 3, it is impossible to predict.

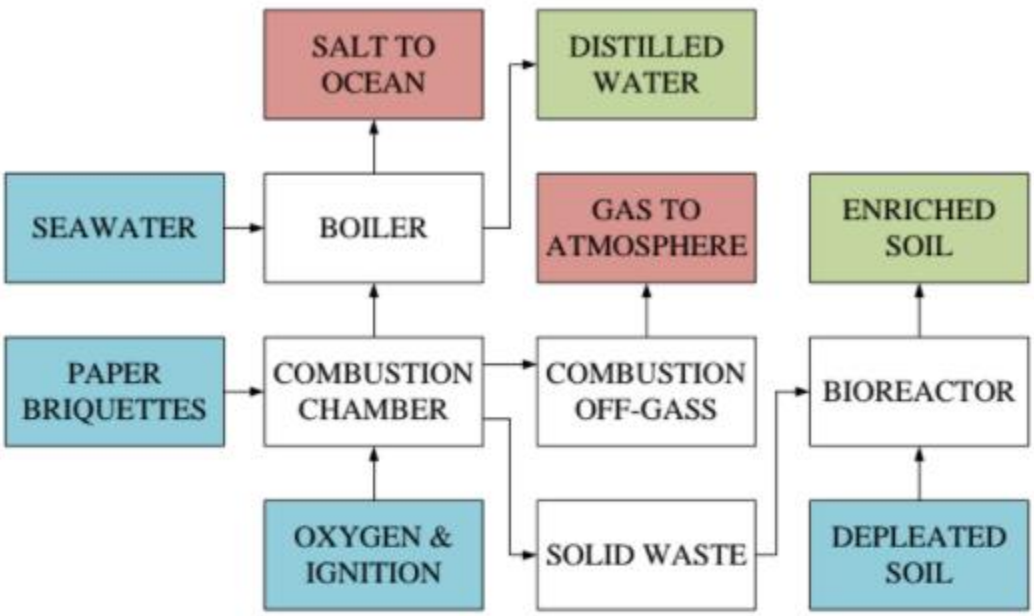

Figure 3: Overview of an Agricultural Desalination Process

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APPENDIX A: 2016-2017 SPOT PRICES FOR MAIZE ACROSS INDIA

Figure A1: Maize Kharif Spot Prices in Nizamabad 2016-2017

Figure A2: Maize Feed/Industrial Grade Spot Prices in Sangli 2016-2017

Figure A3: Maize Feed/Industrial Grade Spot Prices in Karimnagar 2016-2017

Figure A4: Maize Feed/Industrial Grade Spot Prices in Jalgaon 2016-2017

Figure A5: Maize Feed/Industrial Grade Spot Prices in Davengere 2016-2017

Figure A6: Maize Feed/Industrial Grade Spot Prices in Delhi 2016-2017

Figure A7: Maize Rabi Spot Prices in Gulabbagh 2016-2017

Figure B1: Warehouse Pricing in Mumbai for Newspaper Briquettes

Platinum

₹ 60,000 WareHouse for lease/rent in Vasai East

Map

2 Property Photos

Plot Area : **5000 Sq.Ft.**

Highlights: On Lease / 1 to 5 years old

Description : First floor industrial gala/premises/unit/wareshouse/godown in vasai. Waliv road touched building newly constructed...

Features:

Dealer : Vastu Entperprise   Posted : Apr 24, 2017

Contact Dealer FREE | View Phone Number | Shortlist | Report problem with listing

Figure B2: 200 L Plastic Boxes – Batch Process Containers for Newspaper Soak

200 L Large White Plastic Water Box

FOB Reference Price: Get Latest Price

US $9.5-12 / Piece | 200 Piece/Pieces (Min. Order)

Supply Ability: 3000 Piece/Pieces per Month

Port: Qingdao

Contact Supplier

Chat Now! Add to Favorites

Payment: VISA TT e-Checking More

Product specification

Model	DX200
Material	PE
Capacity	200L
Color	WHITE
Up dia.	785*580mm
End dia.	770*565mm
Height	555mm
Weight	4.05kg

Product advantages

<1> Main material: LLDPE food-grade raw plastic

<2> Common color: white

<3> Performance of Rotation:High density,strong toughness,stable quality, will never broken,10

Figure B3: Warehouse Racks for Newspaper Briquetting Process

Overview

Specifications

Place of Origin:	Jiangsu, China (Mainland)	Brand Name:	fangkun	Model Number:	Selective
Type:	Boltless / Rivet Shelving	Material:	Steel	Feature:	Corrosion Protection
Use:	Warehouse Rack	Certification:	ISO9001	Depth:	600mm
Weight Capacity:	300kgs	Width:	2000mm	Height:	2000mm
Product name:	China Warehouse Rack And S...	Scale:	Medium Duty	shelf type:	warehouse racking
surface treatm...	powder coated	color:	blue & white	raw materials:	hot rolled steel
Style:	D+DIY	Usage:	Warehouse Storage System	Packing:	Customers' Request
Structure:	Bolted				

China Warehouse Rack And Shelf System

FOB **Reference** Price: Get Latest Price

US $80-150 / Piece | 1 Piece/Pieces China Warehouse Rack And Shelf System (Min. Order)

Supply Ability: 100000 Piece/Pieces per Month China Warehouse Rack And Shelf System

Port: Shanghai nanjing guangzhou dalian lianyungang

Contact Supplier | Start Order

Chat Now! | Add to Favorites

Figure B4: Car Jack for Compression in Newspaper Briquetting Process

High Quality 1.5ton to 3 ton Hydraulic Jacks/Hydraulic Car Jacks/Hydraulic Floor Car Jack

FOB **Reference** Price: Get Latest Price

1 - 4	>=5
US $50.00	**US $30.00**

Supply Ability: 120 Set/Sets per Month

Port: Qingdao, Shanghai, Tianjin or the customer required port

Contact Supplier   Start Order

Overview

Specifications

Use:	Car Jack	Type:	Hydraulic Jack	Capacity (Load):	1-10T
Max Height:	475mm	Min Height:	140mm	Certification:	ISO9001
Place of Origin:	Henan, China (Mainland)	Brand Name:	Yigong	Model Number:	YG-FJ
Warranty:	12 Months	Color:	Option	Product name:	Hydraulic Floor Jack
product size:	600x335x180mm	function:	car lift		

Packaging & Delivery

Packaging Details: the hydraulic floor jack are packaged into our special maded box

Delivery Detail: Shipped in 7 days after payment

High Quality 1.5ton to 3 ton Hydraulic Jacks/Hydraulic Car Jacks/Hydraulic Floor Car Jack

Figure B5: Direct Fired Boiler for Water Recycle in Newspaper Briquetting Process

Professional manufacturer suppky directly wood fired steam boiler

FOB **Reference** Price: Get Latest Price

US $13,500-25,000 / Unit | 1 Unit/Units Professional manufacturer suppky directly wood fired steam boile (Min. Order)

Supply Ability: 100 Unit/Units per Month

Port: SHANGHAI

Contact Supplier   Start Order

Leave Messages   Add to Favorites

Seller Support: Trade Assurance – To protect your orders from payment to delivery

Overview

Specifications

Condition:	New	Type:	Natural Circulation	Usage:	Industrial
Structure:	Water Tube	Pressure:	High Pressure	Style:	Horizontal
Fuel:	deponds on customer	Place of Origin:	Jiangsu, China (Mainland)	Brand Name:	YONGLI
Model Number:	YLB2	Output:	Steam	Dimension(L*W...	5488*2000*2832MM
Weight:	15T	Certification:	CE Certificate	After-sales Ser...	Engineers available to service...
Item:	Professional manufacturer su...	Initial moisture...	45	Final moisture(...	10~13
Evaporation(kg...	1164	The volume of ...	8312	The temperatu...	500
The temperatu...	80	Heat consump...	88	Utilization rate...	0.8
The consumpti...	333				

Packaging & Delivery

Packaging Details: Iron case or iron pallet etc for Professional manufacturer suppky directly wood fired steam boiler

Delivery Detail: 30 Days for Professional manufacturer suppky directly wood fired

Figure B6: Collection Drums for Water Recycle in Newspaper Briquetting Process

2000litres plastic water collection tank for sale

FOB **Reference** Price: Get Latest Price

US $250-300 / Piece | 5 Piece/Pieces (Min. Order)

Supply Ability: 100 Piece/Pieces per Day

Port: Shanghai/Ningbo

Contact Supplier   Start Order

Leave Messages   Add to Favorites

Overview

Specifications

Place of Origin:	Jiangsu, China (Mainland)	Brand Name:	linhui	Model Number:	LT2000L
Capacity:	2000L	Material:	LLDPE, food grade	Length:	1700mm
Width:	1400mm	Height:	1200mm	Weight:	95kg
Thickness:	8mm				

Packaging & Delivery

Packaging Details: plastic wrap and customized

Delivery Detail: 7~15 days

Product Description

1. Material: imported LLDPE, food grade
2. Color: white, black and customized
3. Performance: one-piece molding, no welds or joints to fail, smooth internal surfaces, excellent hygienic features, UV stabilized for outdoor application, collision resistant, intensive vibration resistant, aging resistant, perfect algae control, easy cleaning, rodent prevention and termite prevention
4. Application: secondary water supply of high-rise building, roof water tank in town and country and wide application to food, pharmacy, hotel, restaurtant, electronics and chemical industry, medicine, construction, etc.
5. It is convenient in erection and movement and it can drain off thoroughly
6. Thickness and weight can be varied for extra strength requirements
7. Uniform wall thickness with no thinning at the extremities

Figure B7: Industrial fans for Forced Convection Drying in Newspaper Briquetting Process

waterproof wall mounted industrial floor stand fan

FOB **Reference** Price: Get Latest Price

US $1-50 / Piece | 1 Piece/Pieces could discuss for floor stand fan (Min. Order)

Supply Ability: 100000 Piece/Pieces per Month we have big storage

Port: Ningbo or Shanghai

Contact Supplier Start Order

Leave Messages Add to Favorites

Overview

Specifications

Type:	Axial Flow Fan	Electric Curren...	DC	Mounting:	Wall Fan
Blade Material:	Stainless Steel	Place of Origin:	Zhejiang, China (Mainland)	Brand Name:	TNDACN
Model Number:	BT35	Voltage:	220V	Power:	1.1KW
Air Volume:	938~64825m3/h	Speed:	1400-3300 R/min	Certification:	CCC, CE, ROHS, UL
After-sales Ser...	No overseas service provided	Power voltage:	220v	rated power:	11/15/40/48/55/65/85/100/1...
lamp socket:	E27/E40	Ex-mark:	Exd IIBT4	Protection clas...	IP65
Erosion-proof-c...	WF1	inlet thread scr...	3/4	cable's outer di...	10~14
Warranty:	1 Year	Installation:	pendant/wall type/ceiling		