REVIEWING THE WASTE-TO-ENERGY POTENTIAL IN SAUDI ARABIA

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The KSA population has increased from 7 million in 1975 to about 27 million in 2010 with an annual rate of 3.4%.

The population is expecting to continue growing in the same rate.

Urban area is expected to have higher population growth resulted from:
- Migration from rural to urban areas
- Expatriate workers
The electricity demand has grown on average rate of 5.8% between the years 2006 to 2010.

The current electricity peak demand is about 55 GW

KACARE forecasted a peak demand of about 120 GW in 2032

KACARE aims to maximize utilization of science, research, and industries related to atomic and renewable energy towards meeting future electricity demand.

Figure 2. Gap between (a) peak demand and (b) existing and planned capacity [1].
KSA Municipal Solid Waste Management

- Municipalities are governing MSW management in the KSA.
- The current MSW practices in the KSA are simple: collect and dump in landfill sites.
- The low cost of landfills limit the potential for large MSW recycling program.
- The only large scale recycling system currently exists is the trash sorters collection of metals and cardboards from garbage containers.
- A few initiatives for MSW recycling are in place in the Eastern Province of Saudi Arabia.
- These initiatives are in small scale and their contributions are not well documented.
The KSA currently generates about 14 million tons of MSW per year.

The average daily per capita generation is estimated to about 1.2 to 1.4 kg.

The landfill requirement is about 2.8 million m²/year.

KSA MSW wastes consists of 37% organic materials, 28.5% paper, 5.2% plastics, 8.3% mineral, 4.6% glass, 8% wood, 6.4% textile, and 2% others.
Research Objectives

Our research team's main objective is to scientifically support the development of Waste to Energy Industry in the Kingdom.

To achieve the stated objective, the research team develop a consecutive research phases including:

- Assess the Potential Contribution of Waste-to-Energy to Total Saudi Peak Power Demand (Accomplished)
- Develop a Roadmap for Construction of WTE Facility in KSA (Accomplished)
- Assess the Environmental and Socio-economic values of WTE to the Kingdom (Just started)
- Develop a State-of-Art Small to Medium Size WTE Facility as a Research and Lead by Example Facility
Potential Contribution of Waste-to-Energy

This research phase assess the potential contribution of waste-to-energy facilities to total Saudi peak power demand up to the year 2032.

- Two Scenarios were developed: Mass Burn and Mass Burn with Recycling.
- The Mass Burn scenario implies full utilization of MSW for WTE production.
- Mass Burn with Recycling assumes removal of all potentially recycled materials from the waste stream and utilizing the remaining MSW for WTE production.
- Total Saudi municipal solid waste (MSW) generation quantity and per city for the major six cities up to year 2032 will be forecasted as shown in the next figure.
Potential Contribution of Waste-to-Energy

Figure 4. MSW Generation Forecast Results.
Potential Contribution of Waste-to-Energy

![Chart showing the potential contribution of waste-to-energy over different years and materials.](chart.png)

**Figure 5. MSW Recycled Materials Forecast Results.**
Potential Contribution of Waste-to-Energy

- Total energy Content for MSW were calculated for the two scenarios as shown below.
- The energy content was calculated based on the material caloric contents.
- A combustion efficiency of 25% was implemented in WTE calculation.

### Table 2. Saudi MSW Energy Contents.

<table>
<thead>
<tr>
<th>Material</th>
<th>Waste Composition %</th>
<th>Energy Content (Btu/lb)</th>
<th>kWh/Kg in Material</th>
<th>kWh/Kg in Waste HHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>28.5</td>
<td>6800</td>
<td>4.39</td>
<td>1.18</td>
</tr>
<tr>
<td>Plastic</td>
<td>5.2</td>
<td>14000</td>
<td>9.05</td>
<td>0.46</td>
</tr>
<tr>
<td>Glass</td>
<td>4.6</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Wood</td>
<td>8</td>
<td>7300</td>
<td>4.73</td>
<td>0.33</td>
</tr>
<tr>
<td>Textiles</td>
<td>6.4</td>
<td>8100</td>
<td>5.20</td>
<td>0.28</td>
</tr>
<tr>
<td>Organic</td>
<td>37.0</td>
<td>2400</td>
<td>1.55</td>
<td>0.17</td>
</tr>
<tr>
<td>Others</td>
<td>10.3</td>
<td>5200</td>
<td>3.36</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Total Energy for Mass Burn with Recycling scenario (kWh/kg) 0.48
Total Energy contents of Mass Burn scenario (kWh/kg) 2.70
Figure 6. Mass Burn with Recycling Scenario Result.
## Potential Contribution of Waste-to-Energy

![Graph showing potential contribution of waste-to-energy (WTE) in different years with specific data for different cities and years.)

### Table: Power Production in MW

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Power Production</th>
<th>Riyadh</th>
<th>Jeddah</th>
<th>Makkah</th>
<th>Al Taif</th>
<th>Madina</th>
<th>Dammam Area</th>
<th>Al-Hassa</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>1064</td>
<td>221</td>
<td>146</td>
<td>71</td>
<td>42</td>
<td>50</td>
<td>84</td>
<td>45</td>
</tr>
<tr>
<td>2017</td>
<td>1257</td>
<td>262</td>
<td>172</td>
<td>83</td>
<td>49</td>
<td>59</td>
<td>100</td>
<td>53</td>
</tr>
<tr>
<td>2022</td>
<td>1488</td>
<td>309</td>
<td>203</td>
<td>99</td>
<td>58</td>
<td>69</td>
<td>118</td>
<td>63</td>
</tr>
<tr>
<td>2027</td>
<td>1758</td>
<td>366</td>
<td>240</td>
<td>117</td>
<td>69</td>
<td>82</td>
<td>139</td>
<td>74</td>
</tr>
<tr>
<td>2032</td>
<td>2074</td>
<td>432</td>
<td>284</td>
<td>138</td>
<td>81</td>
<td>97</td>
<td>164</td>
<td>87</td>
</tr>
</tbody>
</table>
Potential Contribution of Waste-to-Energy

Conclusion

- The Mass Burn with Recycling scenario result shows a potential to produce about 166 (MW) of electricity by the year 2032.
- This value forms about 0.14% of the 120 GW peak electricity demand in 2032.
- The Mass Burn scenario results show a potential to produce about 2073 MW of WTE electricity.
- This is about 1.73% of the peak electricity demand in 2032.
- The forecast results of each city from the two scenarios can be used to design a future WTE facility in the main cities of Saudi Arabia.
- The Mass Burn scenario can produce 12 times WTE electricity more than the Mass Burn with Recycling scenario.
Potential Contribution of Waste-to-Energy

Recommendations

- Complete Life Cycle Assessment for Municipal Solid Waste in KSA is needed.
- Further investigations are recommended to compare among the two scenarios based on financial, social, technical and environmental criteria.
- The environmental studies should also include carbon credit analysis.
- The socio-economical studies shall consider WTE production cost, recycling value, land saving, job creation, and human capacity building opportunities.
- Technical studies shall be focused on determining the optimum Waste-to-Energy technology to be implemented in the KSA.
Roadmap for Waste-to-Energy

This research phase aims to develop a roadmap for construction of WTE Facility in Saudi Arabia and reviews the potential benefits to Saudi economy and environment.

- Construction of WTE facility requires significant investment from the community.

- Before embarking on a project of this magnitude, clear roadmap towards the final goal of constructing WTE facility is extremely needed.

- The developed roadmap consists of three distinctive phases as shown in the following figure:
  - Feasibility Study phase
  - Design and Construction phase
  - Operational phase
Roadmap for Waste-to-Energy

- Economic Assessment
- Technical Assessment
- Environmental Assessment
- Social Assessment
- Legal and Regulatory Assessment

**Feasibility Study Phase**

- Decision
  - Go!
  - Site Allocation
    - Permitting
    - Design
    - Financing
    - Human Capacity Building

**Designing and Construction Phase**

- Bidding and Construction
- Trial Operations

**Operational Phase**

- Trial Operation
  - Environmental and Social Impact Assessment
  - Technical Performance Evaluation
  - Human Resources Performance Evaluation
  - Financial Evaluation

- Modifications and Implementation

- Full Operation with Yearly Assessment
The purpose of the feasibility study (FS) is to evaluate the feasibility of developing a WTE facility project from economical, technical, environmental, social, and legal perspectives.

**Economical Feasibility:**
- The economical feasibility includes comprehensive cash flow analysis for the project design and construction cost, annual operation and maintenance cost, and annual revenue.
- The economical assessment shall provide a comprehensive review of all financial requirements of the projects and potential revenue.
- Data sources for cost and revenue include international financial institutions, NGO’s, countries with recent WTE experience, international renewable energy consultants and developers, and published literature.
- Financial analysis techniques such as payback period, present worth, and internal rate of return.
Roadmap for Waste-to-Energy Feasibility Study Phase

**Technical Assessment:**
- The technical assessment forecasts MSW quantities and compositions and reviews the WTE state-of-art technology.
- Alternative WTE technologies shall be compared with each other in the aspects of their advantages/disadvantages.
- Evaluation of the generation of heat/steam and the cogeneration potential (whether to generate both heat and electricity) to optimize the energy yield shall be studied.
- The technical feasibility identifies the:
  - Suitability of waste for thermal treatment,
  - Determination of the appropriate and efficient technology,
  - Local and regional availability of selected technology and,
  - Determination of expected plant life.
Environmental Assessment:

- The chief objective of this task is to ensure that the proposed facility will comply with environmental standards of Saudi Presidency of Meteorology and other local and international standards.

- The environmental assessment includes collection of environmental baseline data such as landscape, soil quality, groundwater and surface quality, air quality, ecosystem of the surrounding area.

- Potential for soil, air, groundwater, surface water, and noise pollution shall be identified. Set of mitigation measures shall be developed and evaluated.

- Cost of mitigation measures and mitigation measures implementation schedule shall be determined and incorporated in the project cost and schedule.
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Roadmap for Waste-to-Energy Feasibility Study Phase

Social Assessment:

- Public acceptance and support will facilitate collection and recycling of the MSW and construction of the facility.

- Public consultation sessions shall be conducted as early as possible in the feasibility study phase.

- During the session:
  - The project information should be clearly described.
  - The potential project, social, economical, and environmental benefits and impacts shall be outlined.
  - Public feedback and concerns shall be documented in the social assessment reports and incorporated in the project final design.
Legal Assessment:

- The project team reviews pertinent local regulatory and legal framework.

- The review shall reflect the latest developments in the Renewable Energy and MSW related laws of local permitting and licensing requirements.

- Local building codes, local right-of-way, and zoning ordinances should be taken into account and reviewed.

- All problematic or lengthy permitting and lengthy licensing requirements need to be identified at this stage.

- Project team should meet with local authority officials

- The meeting aims to introduce the project scope and objective, and gathers information about their legal and technical requirements and guidelines.
Roadmap for Waste-to-Energy Feasibility Study Phase

Findings and Site Allocation:

- The feasibility study paramount is the Go/No Go decision.
- The decision shall be based on multi-criteria analysis of feasibility study findings.
- If a Go decision is taken, the next step is to scout the project site.
- The project site scouting shall consider existing landfill locations, MSW collection routes, and electrical grid and feed in point, local building codes, local right-of-way, and zoning ordinances.
Roadmap for Waste-to-Energy Designing and Construction Phase

- Most of the capital investment will be spent during this phase.
- Design-Build-Operate-Transfer contracts could be the right option to develop the first few projects.
- Joint venture will enhance technology transfer and ability of local capacity building for WTE facility design, construction and operation.
- Applications for the lengthy permitting and licensing have to start as early as possible.
- Measures to meet environmental requirements and public concerns have to be incorporated in the detailed design.
The operational phase shall be started with at least 6 months trial operation.

During the trial operation, the environmental, social, technical, human resources and financial performance should be carefully monitored and evaluated.

Modifications and development plan shall be prepared and implemented to overcome any shortcomings in the project performance.
Roadmap for Waste-to-Energy
Benefits of WTE Projects

Literature and international project records extensively document the significant benefits of WTE projects on economy and environment worldwide.

Economical Benefits:

- In 2004, WTE industry in the US produced much more energy than all other renewable energy sources with the exception of hydropower and geothermal sources.
- A metric ton of MSW produced almost an equivalent to the electricity production of one barrel of oil.
- WTE plant will burn and reduce the volume of the MSW by 90%, which would otherwise be deposited in the landfills.
- Such volumetric reduction of MSW would significantly extend the remaining life of the landfills and reduce the amount of top soil required to cover the fresh MSW after each dumping.
Economical Benefits Continue:

- Implementation of WTE technology will result in increasing recycling activities.
- US communities with WTE facility had an average recycling rate of 21% versus the country rate of 17%.
- During the construction of the WTE facility, new jobs in construction, technical services/engineering and landscaping, are likely to be created for two-three years.
- When the facility is in operation, it will require about a number of full-time operations and maintenance personnel who will require special training.
Roadmap for Waste-to-Energy
Benefits of WTE Projects

Environmental Benefits:

- US EPA considers WTE technology as a renewable source of electricity with less environmental impacts than almost any other sources.

- Modern incineration plants are so clean that many times more dioxin is now released from home fireplaces and backyard barbecues than from incineration.

- WTE reduces the amount of MSW deposited at landfill sites; typically about 90% volume reduction and 80% mass reduction are achieved depending upon composition and degree of recovery of materials.

- Incineration also minimizes leachate and methane formation and door emissions.

- Methane is 21 times more detrimental than carbon dioxide from the global warming perspective.
Roadmap for Waste-to-Energy
Benefits of WTE Projects

Environmental Benefits Continue:

- Many of landfills in KSA are mature landfills in that substantial amount of volume has already been used by municipal waste deposits.

- With additional dumping, the amount of undesirable by-products such as leachate, municipal waste sludge, renegade methane and odor emissions and all health hazards associated with these will keep increasing.

- More specifically, by employing a WTE facility at these landfill sites, the following potential environmental problems will be mitigated;
  
  - The existing leachate treatment system has a fixed membrane capacity which will be overused with the continued dumping of MSW. This in turn would increase the likelihood of groundwater contamination and the associated health risks.
Environmental Benefits:

- If the MSW is not burnt as collected, it would keep creating waste sludge in the landfill basin which is very hard to get rid of once formed. Municipal waste sludge cannot be incinerated in self-sustaining mode. Costly mechanical or thermal pretreatment systems would be required to incinerate the sludge.

- With each load of MSW deposited into landfills, additional methane would automatically be generated in six months to a year time frame. Even though the existing landfill-gas-to-energy plants suck the landfill gas out of the deposited MSW piles, the gas collection efficiency is limited to about 80% and drops significantly as the landfill expands laterally. Therefore as the landfills expand renegade methane emissions will also increase.

- Landfills cannot be expanded indefinitely; since the surroundings of large lots of land which can be used for habitation, cultivation, commerce or recreation
Thank You

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