TOYOTA MOTOR MANUFACTURING, KENTUCKY
LANDFILL GAS TO ENERGY PROJECT

Chris Adkins
TOYOTA MOTOR MANUFACTURING KY

1. Camry & Camry Hybrid, Avalon & Avalon Hybrid, Venza, Lexus ES 350
2. Powertrain: 4 cylinder & V-6 engines
3. Annual production 500,000 vehicles & 600,000 engines
4. Employ 8000 team members, 2 production shifts & 4 maintenance shifts
TOYOTA MOTORS MANUFACTURING KY

1,350 acre site
830 acres developed = 160 football fields
TOYOTA ENVIRONMENTAL CHALLENGE 2050

Challenge 1: New Vehicle Zero CO₂ Emissions Challenge

Challenge 2: Life Cycle Zero CO₂ Emissions Challenge

Challenge 3: Plant Zero CO₂ Emissions Challenge

Challenge 4: Challenge of Minimizing and Optimizing Water Usage

Challenge 5: Challenge of Establishing a Recycling-based Society and Systems

Challenge 6: Challenge of Establishing a Future Society in Harmony with Nature

Net Positive Impact Challenge

Challenge of Achieving Zero

Zero Environmental Impact Challenge

Contributing to a Better Society through Net Positive Impact
Electricity usage will increase over 20%
### IDEAS TO MINIMIZE CO2?

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CO2 GENERATION</th>
<th>COST</th>
<th>FEASIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Array</td>
<td>Zero</td>
<td>Cost / KW high</td>
<td>Only 30% effective in KY</td>
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<tr>
<td>Wind Turbine</td>
<td>Zero</td>
<td>Cost / KW high</td>
<td>Only 35% effective in KY</td>
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<tr>
<td>Combined</td>
<td>Low CO2</td>
<td>Higher energy usage to</td>
<td>Location remote from hot water process</td>
</tr>
<tr>
<td>Heat Process</td>
<td></td>
<td>generate</td>
<td></td>
</tr>
<tr>
<td>Electricity from Landfill Gas</td>
<td>Low CO2 &amp; reduces CO2 release from landfill</td>
<td>Fixed cost long term contract</td>
<td>Landfill has enough gas for 1MW of electricity generation that will grow over time</td>
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- **Solar Array**: Zero CO2 generation, high cost per KW. Only 30% effective in KY.
- **Wind Turbine**: Zero CO2 generation, high cost per KW. Only 35% effective in KY.
- **Combined Heat Process**: Low CO2, higher energy usage to generate. Location remote from hot water process.
- **Electricity from Landfill Gas**: Low CO2 & reduces CO2 release from landfill. Fixed cost long term contract. Landfill has enough gas for 1MW of electricity generation that will grow over time.
PROJECT SIGNIFICANCE

1. First non-utility business to business LFG project in Kentucky
2. First LFG to electricity project globally for Toyota
1. Municipal Solid Waste breaks down naturally in landfills, creating landfill gas (50% methane)
2. A network of wells collects and prepares the landfill gas
3. Landfill gas is used to fuel generators, producing renewable electricity
4. Electricity is transmitted through underground lines to TMMK
5. Renewable electricity created from the landfill will be used to power the production of 10,000 vehicles per year

Landfill greenhouse gas emissions will be cut by an estimated 95%, which adds up to better air quality for the local community
PARTNERING WITH THE LOCAL LANDFILL

1. Owner receptive to project.
2. Landfill had 1.2M tons of waste in place.
3. 400 tons per day of new waste inflow. Potential for that to increase.
4. Landfill Gas Emissions Model (Land-GEM) study revealed sufficient gas flow for 1Mw of electricity production.
5. Agreement for joint LFG venture.
ESTIMATED CO2 REDUCTIONS

1. Grid electricity for KY averages 9,000 Tons of CO2 per year per mW.
2. Methane equivalent escaping from landfill averages 42,000 Tons of CO2 per year per mW.
3. Combustion of the landfill methane creates an average of 5,000 tons of CO2 per year per mW.
4. Net reduction of 46,000 Tons of CO2 per year per mW.
   a. \((9,000 + 42,000) - 5,000 = \text{Net reduction of 46,000 T}\)
INITIAL CHALLENGES

- Local Utility Provider Rules
- Limited LFG Experience
- Business to Business
- Private Land Easements
- Gov’t & Public Support
- NO Three Phase Power Available
- Legal Agreements
- High Construction Costs
- Env Impact
- 6.5 miles Away from Plant
Toyota had no experience with generating electricity from landfill gas

Let’s “go and see” how others do this!

<table>
<thead>
<tr>
<th>VISITS</th>
<th>SYSTEM</th>
<th>LEARNING</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Landfill gas is piped to the site – installed by NG gas co. Direct burn and generate electricity</td>
<td>1. Gas company owns/installed/maintains line, obtained easements. 2. Siloxanes issues - Installed gas conditioning system</td>
</tr>
<tr>
<td>#2</td>
<td>Electricity generation by power company and put on grid</td>
<td>1. Power company adjacent to landfill. 2. Siloxane issues - PM program set up.</td>
</tr>
<tr>
<td>#3</td>
<td>Electricity generation by third party operator and sold to power company</td>
<td>1. De-regulated state. 2. Siloxanes initially removed by gas conditioning system as preventive measure</td>
</tr>
</tbody>
</table>
## TOYOTA LFG OPTIONS

<table>
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<tr>
<th>Options</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill to collect gas, generate electricity and sell to Toyota</td>
<td>Only change electricity supplier</td>
<td>Electricity regulated in KY, provider must be KU or TMMK Owned generator</td>
</tr>
<tr>
<td>Pipe landfill gas to TMMK and generate electric on site</td>
<td>Electricity generation at TMMK</td>
<td>Pipe maintenance &amp; cleaning. Landowners would not allow gas pipe on their land</td>
</tr>
<tr>
<td>TMMK to Generate electricity at landfill and transmit to our site</td>
<td>Meets KY electricity generation rules</td>
<td>Equipment at remote location</td>
</tr>
</tbody>
</table>

Contracted with Landfill to operate and maintain our equipment
Landscape between TMMK and Landfill:
a. Privately owned – 33 easements obtained  
b. Owners desired underground installation  
c. Very hilly and rocky  
d. Includes public roads, railroads and streams
## Initial Project Estimates Were Higher than Anticipated

### Opportunity to “Value Engineer”

<table>
<thead>
<tr>
<th>VE ITEM</th>
<th>DESCRIPTION</th>
<th>BENEFIT</th>
<th>SAVINGS</th>
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<td>Cable / conduit</td>
<td>Put cable in conduit at the factory</td>
<td>Separate pulls for conduit &amp; cable becomes one pull for both</td>
<td>50% installation labor reduction</td>
</tr>
<tr>
<td>Cable rating</td>
<td>Use 35kV rated cable</td>
<td>3 cables instead of 6. Smaller bore hole (7” vs 12”), Can expand to 10mW</td>
<td>60% cable cost savings</td>
</tr>
<tr>
<td>Boring operation</td>
<td>Use air hammer vs. traditional drill bit</td>
<td>600’/day vs. 200’/day (300% improvement in output), 75% reduction in water</td>
<td>56% boring cost reduction</td>
</tr>
<tr>
<td>General contractor</td>
<td>TMMK serve as general contractor for project</td>
<td>Reduce sub-contractor markup through direct negotiation</td>
<td>10% project cost savings</td>
</tr>
</tbody>
</table>

Initial Project Estimates Were Higher than Anticipated
ORIGINAL IDEA:

a. 12” bore hole
b. 6 conduits pulled
c. 15kV wire rating
d. Pull 3 wires, getting 5mW capacity
e. Future activity pull 3 more wires for additional 5 mW capacity
NEW TRANSMISSION CIRCUIT DESIGN

VALUE ENGINEERING:
- a. 7” bore hole
- b. 3 conduits & wire pulled
- c. 35kV wire rating
- d. Initially transmit at 15kV
- e. Wire in conduit from factory
- f. After 5mW. Add transformers for 35kV (10 mW capacity)

Savings = 60% from original
DIRECTIONAL BORING INSTALLATION CHOSEN

Let’s bore the path for the conduit & wire

- Very little disturbance to the owners land
- Simplified overall construction of installing the wire
CONSTRUCTION PICTURES

- AIR HAMMER DRILL BORING
- TRENCHING
- WIRE MANHOLE
- CABLE & WIRE
CONSTRUCTION PICTURES CONTINUED

LANDFILL GAS WELLS

OFFICE

GENERATOR

GAS VACUUM EQUIP
COMPLETED LFG SITE

1 mW GENERATOR
480 V, 3PH

SUPPORT SHOP/ OFFICE

3 mW TRANSFORMER
480 V, 3PH TO 13,800 V, 3PH

LANDFILL GAS VACUUM / PRESSURIZATION SKID
THE FUTURE OF LANDFILL GAS AT TMMK

- Based on US Landfill Gas Model - landfill gas output lags waste input by ~ 3 yrs
- Landfill waste is expected to support up to 5 mW by 2025
LEARNING POINTS

1. Project took longer to complete than anticipated
2. Gaining approval from private/public sector is very relationship driven which takes time to develop
3. Understand local government ordinances
4. Understand local environmental issues for construction
5. Working with a partner vs. a supplier was a different situation for TMMK as well.
6. Ensure all expectation and goals are understood from all parties
7. Flexibility is key
8. Plan for the unexpected
THANK YOU

Q & A