Super Batteries
Final Presentation
Presentation Outline

- Project Goal
- The basics of batteries
- How a battery works
- Why use super batteries
- Market Analysis
- Battery synthesis

- Plant Location
- Transportation
- Environmental Impact
- Life Cycle Analysis
- Economic Analysis
- Conclusions
Project Goal

- Design a plant to make ingredients for super iron batteries
The Basics of Batteries
Definition:

Batteries are devices that translate chemical energy into electrical energy.
Standard AAA Dimensions

Dimensions:
- 3.3 ± 0.1
- 10.35 ± 0.1
- 1.2 ± 0.1
- 44.25 ± 0.2
- 0.5
Battery Basics

- The 7 basic parts
  - A) Container
  - B) Collector
  - C) Electrodes
  - D) Cathode
  - E) Anode
  - F) Electrolyte
  - G) Separator
Constructing the Battery

- Start with an empty steel can – the battery container.
Constructing the Battery

- A cathode mix of Super-Iron carrying a naturally occurring positive electrical charge is molded to the inside wall of the empty container.
Constructing the Battery

- A separator paper is inserted to keep the cathode from touching the anode.
Constructing the Battery

- The anode, which carries a negative electrical charge, and potassium hydroxide electrolyte are then pumped into each container.
Constructing the Battery

- The brass pin, which forms the negative current collector, is inserted into the battery, which is then sealed and capped.
How a battery works
Zn $\rightarrow$ Zn$^{2+}$ + 2 e$^-$

Fe (VI) + 3 e$^-$ $\rightarrow$ Fe (III)
Advantages of Iron (VI)
Advantages: Energy Storage

- Including a iron (VI) cathode in a standard battery increases the energy storage capacity by 50%.
Our Choice of Cathode

- Our choice of cathode material is based on cost and performance.
- 65 wt % Na$_2$FeO$_4$
- 5 wt % KMnO$_4$
- 30 wt % CF$_x$
Advantages:

Environmental

- **Standard Alkaline Battery**:

  \[
  2\text{MnO}_2 + \text{Zn} \rightarrow \text{ZnO} + \text{Mn}_2\text{O}_3
  \]

  \[
  2\text{Mn}^+ + 2e^- \rightarrow 2\text{Mn}^{2+}
  \]

  \[
  \text{Zn} \rightarrow \text{Zn}^{2+} + 2e^-
  \]

- **Super Battery Discharge Reaction**:

  \[
  \text{Na}_2\text{Fe(VI)}\text{O}_4 + \text{Zn} \rightarrow \text{Fe(III)}_2\text{O}_3 + \text{ZnO} + \text{Na}_2\text{ZnO}_2
  \]

  \[
  \text{Fe(VI)}^{6+} + 3e^- \rightarrow \text{Fe(III)}^{3+}
  \]

  \[
  \text{Zn} \rightarrow \text{Zn}^{2+} + 2e^-
  \]
Market analysis
Market Analysis

The most important objective of a company: To make profit

The most important person in a company: The consumer

A strategic plan defines a company’s overall mission and objectives. The goal is to build strong and profitable connections with consumers.
Points of Sale

- Provides enough power to last 50% longer than traditional AAA batteries and 200% longer in high drain applications (Licht)

- Contains fewer toxic metals than traditional batteries and its super iron cathode degenerates into environmentally friendly rust

- Will sell for a competitive price to the AAA batteries already on the market
Competitors?

SuperBattery’s total capital investment: $472,000
Energizer’s total capital investment: $3 billion

Conclusion:
SuperBattery’s market is 0.01% the size of Energizer’s market
Market Analysis

Segmentation of Market

The process of niching offers smaller companies the opportunity to compete by focusing their limited resources on serving niches overlooked by larger competitors.
Market Analysis

Consumers are grouped and served in various ways based on the following factors:

- Geographic
- Demographic
- Psychographic
- Behavioral
- Social-Cultural
  - Special Interest Groups
Market Analysis

- **Geographic Segmentation**
  A profitable company must pay attention to geographical differences in needs and wants.

- **Demographic Segmentation**
  Demographic segmentation divides the markets into groups based on variables such as age, gender, family size, family life cycle, income, occupation, education, religion, race, and nationality.
Segmentation Variables

Geographic

World region or country: US
Country region: Pacific, East South Central, East North Central, New England, Middle Atlantic
City or Metro size: 500,000-1,000,000; 1,000,000-4,000,000; 4,000,000 or over
Density: Urban
Climate: Northern, Southern
Segmentation Variables

Demographic

Age: Under 6, 6-11, 20-34, 35-49
Gender: Male, Female
Family Size: 1-2, 3-4, 5+
Family Life Cycle: Young, single; young, married, no children; young, married, children; older, married, children; older, married, no children; older, single
Income: $50,000-over
Occupation: Professional and technical; managers; officials, and proprietors; clerical, and sales; supervisors, students, homemakers; volunteer workers
Education: High school graduate, some college, college graduate
Generation: Generations X, Y, Z, echo boomer
Race: N/A
Market Analysis

Demographics come into play here because different ideas appeal to different groups consisting of different characteristics.
Market Analysis

ADOPTER CHARACTERIZATION BREAKDOWN

- 34% Early Majority
- 34% Late Majority
- 16% Laggards
- 13.5% Early Adopters
- 2.5% Innovators

Time of adoption of innovation
Adopter Characterization

- **Innovators** – young, better educated, higher income; venturesome.
- **Early Adopters** – leaders in the community; adopt new ideas early but carefully; trendsetters.
- **Early Majority** – deliberate; adopt new ideas before the average person.
- **Late Majority** – skeptical; older in age and wait until the reviews are massively published.
- **Laggards** – tradition bound and brand loyal; won’t change until the new trend becomes tradition.
Market Analysis

- Large market appeals to the idea of MORE POWER FOR YOUR MONEY

- Segmentation for a small new company leads to THE ENVIRONMENTALLY FRIENDLY BATTERY
# Population Characteristics

<table>
<thead>
<tr>
<th>City</th>
<th>Population</th>
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<tbody>
<tr>
<td>National Average</td>
<td>52,000</td>
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<tr>
<td>Austin, TX</td>
<td>587,900</td>
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<tr>
<td>Seattle, WA</td>
<td>537,200</td>
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<tr>
<td>Portland, OR</td>
<td>503,600</td>
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<tr>
<td>San Francisco, CA</td>
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<tr>
<td>Charlotte, NC</td>
<td>520,800</td>
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<tr>
<td>NYC, NY</td>
<td>7,428,200</td>
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<tr>
<td>Washington, DC</td>
<td>519,000</td>
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## Economical Demographics

<table>
<thead>
<tr>
<th>City</th>
<th>Cost of Living Index</th>
<th>Median Income ($)</th>
<th>Per Capita Income($)</th>
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<tr>
<td>National Average</td>
<td>100</td>
<td>53,475</td>
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<td>102.9</td>
<td>50,179</td>
<td>20,118</td>
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<td>135.7</td>
<td>50,993</td>
<td>26,516</td>
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<td>Portland, OR</td>
<td>127</td>
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<td><strong>San Francisco, CA</strong></td>
<td><strong>209.5</strong></td>
<td><strong>74,773</strong></td>
<td><strong>27,727</strong></td>
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<td>Charlotte, NC</td>
<td>108.3</td>
<td>58,713</td>
<td>21,862</td>
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<td>NYC, NY</td>
<td>189.1</td>
<td>60,765</td>
<td>24,877</td>
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<tr>
<td>Washington, DC</td>
<td>120.9</td>
<td>65,083</td>
<td>26,855</td>
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</tbody>
</table>
SF Demographics

- 8.2% children ages 5-14
- 48% ages 20-45
- 44.3% of all families having children
- 45.6% of all families young and single
- 1.7% unemployment rate
- 56.8% making $50,000 and over per household
<table>
<thead>
<tr>
<th>City</th>
<th>Sales Tax (%)</th>
<th>AAA Duracell 4pk ($)</th>
<th>AAA Duracell 8pk ($)</th>
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<tr>
<td>National Average</td>
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<td>3.17</td>
<td>5.89</td>
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<td>Seattle, WA</td>
<td>8.35</td>
<td>3.39</td>
<td>6.09</td>
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<td>Portland, OR</td>
<td>0.00</td>
<td>2.99</td>
<td>5.89</td>
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<tr>
<td>San Francisco, CA</td>
<td>8.25</td>
<td>4.99</td>
<td><strong>8.79</strong></td>
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<td>6.15</td>
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<td>8.25</td>
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<td>Washington, DC</td>
<td>5.75</td>
<td>3.79</td>
<td>6.49</td>
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BATTERY PRICES ACCORDING TO CVS PHARMACIES
Cost Comparison

- CVS Pharmacy has a standard markup for all batteries – about 25%
- According to the price list above, San Francisco has the highest cost of batteries
- Duracell sells their batteries to CVS Pharmacy for about $1.00/battery

CAN SUPER BATTERY COMPARE?
Cost Comparison

- For Super Battery to be cost competitive, a battery must be sold for $1.00/battery
- The cost per battery for production is $0.86
- $0.14 profit per battery is about 16%
- If a higher profit margin is needed, extra investment would have to be dumped into advertisements and promotions stressing the environmental aspect of the battery
- Economics will discuss this in further detail
Battery Synthesis
Cathode Synthesis
The cathode is the material between the casing and the separator.

The volume of the cathode is an estimated 49% of the battery interior.
Cathode Challenge

- To create a cathode based on Iron (VI).

- This process has never been completed on an industrial scale.

- Very little information exists concerning the chemical characteristics of Iron (VI) and its different compounds.
Chemists vs. Engineers

City water

T-2
2400 L

T-3
380 L

V-2

V-3
Chemists vs. Engineers

Chemists: Cathode synthesis scaled-up directly from laboratory work:
Weekly Cost: $4,889,000

Engineers: Modifications throughout cathode synthesis:
Weekly Cost: $39,600
Iron (VI) Super Battery Cathode

Mass Breakdown of Cathode Components:
- 2.38 g Na₂FeO₄
- 0.183 g KMnO₄
- 1.098 g CFₓ
- 3.66 mL KOH (13.5 M)
Fe(NO₃)₃•9H₂O + 3/2NaClO + 5NaOH → Na₂FeO₄ + 3/2NaCl + 3NaNO₃ + 23/2 H₂O
Anode Synthesis
Anode Synthesis: Why?

- Provide low cost negative electrodes at a high voltage
- Low weight addition to battery
- Lowest possible oxidation state for anode material
- High discharge capability
- Not susceptible to corrosion in saturated KOH to stabilize iron (VI)
- The alternative cadmium or mercury additives may be cheaper, but not environmentally friendly
Common Methods

- Using pure zinc metallic powder mixed with electrolyte
  Problem: hydrogen is generated by the zinc and causes a corrosion reaction – leads to increased pressure inside the battery and electrolyte leak

- Kneading zinc powder, gel forming materials and magnesium with a small amount of water
  Problem: Too much time for electrolyte to penetrate into the zinc electrode paste
Using a mixture of pure zinc and either indium, aluminum, or lead to prevent corrosion.

Problem: Inability of the zinc paste to hold its shape in the battery which lead to leakage and early loss of charge capability.
1982 Jones US Patent 4358517 explains the effectiveness of using carbon hydroxide mixed with potassium hydroxide as the electrolyte solution.

1990 JP 227729/89 discussed the role of a gelling agent such as carboxymethyl cellulose.

Problem: With time, the electrode falls out of gel state due to its large specific gravity or contact between zinc particles become unstable.

Ten years ago the method involved an addition of mercury in order to prevent corrosion.

Problem: Environmentally Unacceptable.
1996 Charkey US Patent 4084047 discusses beneficial oxide additives that enhance electrode conductivity, particularly $\text{Bi}_2\text{O}_3$
Goals

– Minimize the shape change
– Provide a stable construction to achieve prolonged cycle life
– Improved capacity under heavy current discharge loads and low temperature
– Improved stability during storage
– Maximum energy density
– Avoid toxicity to the environment
– To provide the highest utilization of the iron (VI) electrode as possible in order to be cost effective
**Anode Synthesis**

**Mass Breakdown per Battery:**

- 0.554 g of calcium oxide
- 1.4674 g of zinc oxide (volume fraction 0.51 ZnO:0.32 CaO)
- 0.1523 g of bismuth oxide
- 0.2547 g of hydroxy-eth cellulose (10%wt)
- 0.1247 g PTFE (known as the binder, 5%wt)
- 2.5472 mL KOH
Components

- **Zinc Oxide**
  - important material for obtaining good dispersion in a short time
  - Ability to absorb large quantities of electrolyte solution between particles
  - Has high capability to combine the particles of the zinc electrode material with electrolyte

- **Calcium Oxide**
  - Shown to significantly improve performance by maintaining stability (preventing migration) in order to hold the capacity of the battery longer
  - Reduce the solubility of active material through formation of CaZn$_2$(OH)$_6$
Components

- **Bismuth Oxide**
  - Provides a conductive matrix which is more electropositive than zinc
  - Easily reduced to metal
  - Considered an inorganic inhibitor

- **PTFE**
  - Binder aids in connecting all the elements
  - Enhances oxygen recombination with the formation of calcium zincates at the zinc electrode
  - Affinity for reacting with oxygen
  - Aids in rapid oxygen recombination during discharge
Anode Synthesis

- ZnO
- CaO
- H₂O

Mixer

Dryer

ZnO

Bi₂O₃

Et-OH cellulose

PTFE

Stirrer

Zinc Paste
Reasoning

1. Metallic oxide (calcium oxide) adds stability without altering other components of the battery
2. Capable of keeping the low oxidation level necessary
3. High life cycle
4. Good rate capability
5. Excellent mechanical characteristics
6. Capable of mass production
Components
Casing Material

- **304 Cold Rolled Stainless Steel**
  - Manufactured in a variety of shapes and sizes cheaply
  - Durable with high corrosion resistance

Circular cylindrical fabricated as a deep drawn can
- Reduces the number of fabrication processes
- Enhances the case integrity
- Allows for less variation in the diameter
- Produces better quality welds increasing shelf-life
Casing Material

Battery Dimensions (AAA)

- Wall thickness: .635 mm
- Length: 44.5 mm
- Diameter: 10.5 mm
Glass-to-metal sealed electric terminal

Fit is important to obtain high quality welding

Thickness – 3.175 mm
Ultrasonic Metal Welding

- Cold-phase friction welding technique
- Surfaces subjected to high frequency oscillations while being rubbed together under pressure
- Molecules on the surfaces mix with one another, creating a firm bond
- Weld cycles typically under one-half seconds allowing high productivity rates
Separator

- Microporous membrane
- Prevents contact between the positive and negative electrode
- Allows ions to move freely between the anode and the cathode without internal shorts
- Insulator
- Permeability, strength, ability to maximize ionic conductivity
Collector

- Electrical connection between the porous cathode and the positive terminal of the battery

- Brass pin
  - 20 mm long, 1.5 mm diameter
  - Brass is a high purity homogeneous alloy
  - Good corrosion resistance
  - High surface quality that minimizes the formation of hydrogen inside the battery
Construction Process
Packaging

- Ensure product quality
- Important role in the marketing strategy
- Sleek plastic cylinders made from ecologically friendly recyclable and reusable materials
- Self-contained shipper that doubles as a floor display
- Uses 40 percent less shelf space than that of other battery suppliers
Plant Location
Plant Location

Shipping Cost

- Import Raw Materials
- Export Complete Super Battery
Raw Materials

- Catoosa, OK
- Bethlehem, PA
- Fort Harrison, NJ
Locations Considered

- Oakland, CA
- Wichita, KS
- Indianapolis, IN
- Charlotte, NC
- Philadelphia, PA
- Portland, OR
Shipping Costs

Transportation Costs

- **Oakland, CA**: $1,061
- **Portland, OR**: $1,166
- **Wichita, KS**: $974
- **Indiana, Indianapolis**: $922
- **Philadelphia, PA**: $903
- **Charlotte, NC**: $1,046
## Factors Considered

<table>
<thead>
<tr>
<th>Location</th>
<th>Utilities</th>
<th>Property Tax</th>
<th>Sales Tax</th>
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</thead>
<tbody>
<tr>
<td>Wichita, KS</td>
<td>105.4</td>
<td>11.5%</td>
<td>5.30%</td>
</tr>
<tr>
<td>Indianapolis, IN</td>
<td>98.9</td>
<td>13.8%</td>
<td>6%</td>
</tr>
<tr>
<td>Philadelphia, PA</td>
<td>144.5</td>
<td>25.4%</td>
<td>6%</td>
</tr>
<tr>
<td>Charlotte, NC</td>
<td>97.2</td>
<td>12.4%</td>
<td>4.50%</td>
</tr>
</tbody>
</table>

The plant will be located in Charlotte, NC.
Transportation
Different Modes of Transportation

- **Rail**
  - 20, 50, or even 100 carload movements
  - lacks flexibility to service all markets
  - deliveries can vary by a number of days
  - ability to move large quantities
  - long distances
  - relatively low cost
Different Modes of Transportation

- **Trucking**
  - High-speed intercity movement
  - Smaller shipments
  - More-frequent deliveries
Trucking makes up 15% of all vehicles on US roadways.

Trucking involved in only 3% of accidents.
Environment
Method to Protect Environment

- The most effective measure in preserving our environment is not to react to environmental accidents, but to prevent accidents and spills.
Sources of Environmental Harm

- **Point Source Pollution (PS)**
  - Spills or disposal into local sewer.

- **Non-Point Source Pollution (NPS)**
  - Uncontrolled spills or disposal into surrounding environment.
Preventing Environmental Harm

- Prevention during:
  - Receiving hazardous materials.
  - Fabrication
  - Plant transportation
  - Storage
  - Disposal
Non-Point Source Spill (NPS) Prevention

- Preventing truck incidents with Camel Fiberglass Drive-Thru Systems
  - Contain a 500 gallon spill
Non-Point Spill (NPS) Prevention

- Preventing rail incidents with the “Star Track” system
- Contain a 500 gallon spill.
Non-Point Spill (NPS) Prevention

Chemically resistant polyurethane box curds are installed around the parameter
Non-Point Source Spill (NPS) Prevention

- Transportation within the plant
Point source (PS) pollution prevention

Conical plug drain seal and drain protector safety seal
Storage Color Code

- Blue: Poison
- Red: Flammable liquid
- Yellow: Store away from flammable or combustible materials (oxidizers)
- White: Store in a corrosion-proof area
- Orange: General chemical storage
- Striped: Store individually. Material is incompatible with other materials in the same color class.
Dangers Inside Plant

- Potassium Hydroxide, KOH
  - POISON! DANGER! CORROSIVE!
  - Special spill and leak measures inside and outside of plant

- Occupational Exposure Limits and Health Hazards
Battery Plant Waste

- **Sodium Chloride**
  - Stable salt that dissolves in water.
  - No special clean up standards.

- **Sodium Nitrate**
  - Strong oxidizer
  - Minor health hazards

- Disposed of by EcoMat system.
Plant Waste Disposal

- **EcoMat Inc.**
- Based in San Francisco Bay Area
- Environmentally friendly
- Recycles nitrates to nitrogen gas and CO$_2$
EcoMat Inc.

- Environmentally friendly
- Economical
- Very light maintenance
- Lower chance of Non point source pollution
Battery Disposal Waste

- **Potassium Hydroxide KOH**
  - *Same precautions*

- **Zinc**
  - One of the most common elements in the earth's crust.
  - Most does not dissolve in water.
  - Minor health hazards
Battery Disposal Waste

- Iron Oxide Fe$_2$O$_3$

- Minor health hazards

- Environmental Effects
  - Can make drinking water taste bad, and can stain plumbing fixtures and laundry.
  - U.S. Environmental Protection Agency (EPA) has established secondary drinking-water standards.
Battery Disposal Waste

- Stainless Steel & Brass
  - No threat to soil or ground water.
  - Life Cycle well over 100 years.
Life Cycle Analysis
Cathode Raw Materials

- NaOH
- NaClO
- Fe(NO$_3)_3$·9H$_2$O
- KMnO$_4$
- CF$_x$
- KOH

\[
\text{Fe(NO}_3\text{)}_3\cdot9\text{H}_2\text{O} + \text{NaClO} + 5\text{NaOH} \\
\rightarrow \text{Na}_2\text{FeO}_4 + \text{NaCl} + \text{H}_2\text{O}
\]
Anode Raw Materials

- ZnO
- CaO
- Bi$_2$O$_3$
- Et-hydroxy cellulose
- PTFE
- KOH
Additional Raw Materials

- 304 stainless steel header equipped with a glass-to-metal sealed electric terminal
- Brass Current Collector
- NFWA Membrane Battery Separator
The cathode, anode, separator, shell, and brass pin are used in the construction of the final battery.
Battery Production

- Water Usage: 10.8 mL/battery
- Energy: 0.105 kWhr/battery
Transportation

- All raw materials and product batteries are transported using:

LTL Trucking and Cargo Company
Battery Usage

- Standard sized AAA batteries are purchased by consumer.
- The iron (VI) super-batteries are used in electronic devices, where the following reaction occurs during cell discharge:

\[
\text{Na}_2\text{Fe(VI)O}_4 + \text{Zn} \rightarrow \text{Fe(III)}_2\text{O}_3 + \text{ZnO} + \text{Na}_2\text{ZnO}_2
\]
Disposal

- The consumer discards the battery in the trash.

- Eventually, the discarded super-batteries will be placed into landfills.
Economic Analysis
Economic Analysis

Outline

- Economic Background
- Chemists vs. Engineers
- Equipment, FCI, TCI
- Profitability
- Effect of Capacity on Economics
- FCI vs. Capacity
- Risk Analysis
Economic Background

- Economic life of 10 years
- Operating rate of 40 hrs / week
- Inflation rate of 4%
Chemists vs. Engineers

- FCI: $978,000
- TCI: $1,125,000
- Weekly Cost: $4,889,000
- NPW: $-147,000,000
- ROI: -227%

- FCI: $411,000
- TCI: $472,000
- Weekly Cost: $43,200
- NPW: $2,750,000
- ROI: 79%
Purchased equipment, FCI, TCI

- Capacity ~ 50,000 batteries / week
- Total Purchased Equipment ~ $82,000
- Fixed Capital Investment (FCI) ~ $411,000
- Total Capital Investment (TCI) ~ $472,000
## Equipment Cost

<table>
<thead>
<tr>
<th>Cathode Equipment</th>
<th>Volume (gal)</th>
<th>Cost ($)</th>
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<tbody>
<tr>
<td>Deionizer</td>
<td></td>
<td>$2,526</td>
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<tr>
<td>Tank-1 Carbon Steel (Distilled H₂O)</td>
<td>5.28</td>
<td>$20</td>
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<tr>
<td>Tank-2 Carbon Steel (NaClO)</td>
<td>16.09</td>
<td>$25</td>
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<tr>
<td>Tank-3 Carbon Steel (Fe(NO₃)₃ 9H₂O)</td>
<td>36.60</td>
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<tr>
<td>Tank-4 Carbon Steel (NaOH pellets)</td>
<td>16.58</td>
<td>$25</td>
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<td>Tank-5 Carbon Steel (Na₂FeO₄)</td>
<td>11.64</td>
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<tr>
<td>Tank-6 Carbon Steel (KMnO₄)</td>
<td>0.90</td>
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<td>Tank-7 Carbon Steel (CFx)</td>
<td>5.58</td>
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<td>Tank-8 Carbon Steel (KOH pellets)</td>
<td>17.95</td>
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<td>Tank-9 Carbon Steel (Waste Storage)</td>
<td>74.21</td>
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<tr>
<td>Reactor-1</td>
<td>69.27</td>
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<td>Filter-1  Cast iron</td>
<td>69.27</td>
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<td>Mixer-1 Steel bhp=2.7 (NaOH)</td>
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<td>Mixer-2 Steel bhp=2.7 (KOH)</td>
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<td>Mixer-3 Steel bhp=2.7 (Cathode)</td>
<td>4.82</td>
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<tr>
<td>Vacuum Dryer-1</td>
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## Equipment Cost

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<th>Anode Equipment</th>
<th>Volume (gal)</th>
<th>Cost ($)</th>
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<td>Mixer-4 stainless steel – 6 hp</td>
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<td>Stirrer-1 stainless steel – 2 hp</td>
<td>10.82</td>
<td>$2,259</td>
</tr>
<tr>
<td>Tank-10 Carbon Steel (ZnO)</td>
<td>3.59</td>
<td>$20</td>
</tr>
<tr>
<td>Tank-11 Carbon Steel (CaO)</td>
<td>2.15</td>
<td>$20</td>
</tr>
<tr>
<td>Tank-12 Carbon Steel (Et-hydroxy)</td>
<td>3.74</td>
<td>$20</td>
</tr>
<tr>
<td>Tank-13 Carbon Steel (Bi₂O₃)</td>
<td>0.23</td>
<td>$20</td>
</tr>
<tr>
<td>Tank-14 Carbon Steel (PTFE)</td>
<td>1.12</td>
<td>$20</td>
</tr>
<tr>
<td>Tank-15 Carbon Steel</td>
<td>10.83</td>
<td>$20</td>
</tr>
<tr>
<td>Vacuum Dryer-4 carbon steel</td>
<td></td>
<td>$12,000</td>
</tr>
</tbody>
</table>
Profitability

- Total Weekly Cost ~ $43,200
- Total Weekly Sales ~ $50,000
- Yearly Cash Flow ~ $373,000
- Net Present Worth (NPW) ~ $2,750,000
- Return of Investment (ROI) ~ 79%
- Pay Out Time ~ 1 yr and 3 months
Economic Analysis

Cash flow vs. years

Cash flow ($)

$0  $100,000  $200,000  $300,000  $400,000  $500,000  $600,000

years

0  2  4  6  8  10
Capacity Effects

EXCEL
Fixed Costs = $375,000

FCI vs. Capacity

\[ y = 0.6144x + 375307 \]

\[ R^2 = 0.9884 \]

FCI vs. Capacity

Fixed Costs = $375,000

\[ y = 0.6144x + 375307 \]

\[ R^2 = 0.9884 \]
Risk Analysis
Risk Analysis

- Based on NPW
- Sensitivity Strauss Plots
- Product cost, product sales, FCI
- NPW Histogram
Sensitivity

Strauss Plot
Net Present Worth Vs Product Cost Standard Deviation

\[ y = -18.6x + 4.54 \]
Sensitivity

Strauss Plot
Net Present Worth vs. Sales Standard Deviation

\[ y = 23.4x + 4.54 \]
Sensitivity

Strauss Plot
Net Present Worth vs. Fixed Capital Investment
Standard Deviation

\[ y = -4.6x + 4.54 \]
NPW Histogram
Conclusions
Conclusions

- Lots of potential!
- Batteries last longer and are more environmentally friendly
- Process is profitable
Challenges & Improvements

- Chemists vs. Engineers
- Make process profitable
- Very little information about Iron (VI) compounds

- Use mathematical model to optimize capacity, plant location, and market
- Research more on Iron (VI) compounds to optimize process
Any Questions???