Economical feasibility of the sugarbeet-to-ethylene value chain in Zuid-West Nederland

Biorenewable Business Platform
May 2012
Importance of Ethylene

- Ethylene is the largest basic building block for chemical industry and largest volume organic chemical produced (~120 million tons/yr)

- Products being produced from ethylene:
Current Olefins Technology

- Worldwide ethylene capacity in excess of 120 million MT pa
- Key products include ethylene, propylene, butadiene, and benzene
Current Feedstock Utilization

Key Olefin Starting Materials = Ethylene & Propylene
Green Route to Ethylene Derivatives

• 95% of all chemicals and plastics are produced from non-renewable energy sources, like natural gas, crude oil and coal

• Recently growing interest in alternative routes to ‘green’ chemicals

• Key factors hindering introduction of chemicals and plastics from agricultural feedstock:
  – Cost
  – Product functionality limitation
  – Size
Green Route to Ethylene Derivatives

The BBP\(^1\) has brought together potential partners Dow, Cargill and Suikerunie to assess and drive various business cases.
About Bio Renewable Business Platform
The goal of the platform is to advise the Biobased Economy Program direction how to replace approximately 30 percent of the fossil fuel and feedstock needs by biobased materials in the Netherlands. The BBP develops activities within the Biobased Economy by identifying opportunities and approaching parties that can convert this opportunities into business cases. The platform provides advice and facilitates cooperation. It also passes on bottlenecks, which emerge from projects, to the government. Its members come from industry and knowledge institutions. The platform is financed by the Ministry of Economic Affairs, Agriculture and Innovation.

About Roland Berger Strategy Consultants
Roland Berger Strategy Consultants, founded in 1967, is one of the world's leading strategy consultancies. With 2,500 employees working in 47 offices in 35 countries worldwide, we have successful operations in all major international markets. The strategy consultancy is an independent partnership exclusively owned by about 220 Partners.

About Cargill
Cargill is an international producer and marketer of food, agricultural, financial and industrial products and services. Founded in 1865, the privately held company employs 139,000 people in 65 countries. Cargill helps customers succeed through collaboration and innovation, and is committed to applying its global knowledge and experience to help meet economic, environmental and social challenges wherever it does business. In fiscal year 2011, Cargill had $119.5 billion in sales and other revenues.

About SuikerUnie
Suiker Unie develops, produces and markets sugar and sugar specialties. Her factories for the production of sugar in Dinteloord, Vierverlaten and Anklam (Northeast Germany) are among the most modern in the world. This is also true for the factories in Puttershoek and Roosendaal, which produce dry and liquid sugar specialties. The head office is located in Dinteloord.
Suiker Unie forms part of Royal Cosun. This international group develops, produces and markets natural foodstuffs and food ingredients. Royal Cosun is a cooperative of approximately 10,000 sugar beet growers. The group has an annual turnover of approximately EUR 1.8 billion and has more than 4,000 employees.

About Dow
Dow's diversified industry-leading portfolio of specialty chemical, advanced materials, agrosciences and plastics businesses delivers a broad range of technology-based products and solutions to customers in approximately 160 countries and in high growth sectors such as electronics, water, energy, coatings and agriculture. In 2011, Dow had annual sales of $60 billion and employed approximately 52,000 people worldwide. The Company's more than 5,000 products are manufactured at 197 sites in 36 countries across the globe.
Business Case: Sugar Beet-to-Ethylene
Photosynthesis

6 CO2 + 6 H2O → **Sugar**: C6-H12-O6 + 6 O2

6 CO2 + 5 H2O → **Starch**: (C6-H10-O5)n + 6 O2

6 CO2 + 5 H2O → **Cellulose**: (C6-H10-O5)n + 6 O2

Only +/- 1% of solar energy is converted to Bio Mass energy
Fermentation to Ethanol

\[ \text{C6-H12-O6} \quad \text{Sugar fermentation to Ethanol} \quad \text{2C2-H6-O + 2CO2} \]

\[ (\text{C6-H10-O5})n + n\text{H2O} \quad \text{Starch opening to Sugar then to Ethanol} \]

\[ (\text{C6-H10-O5})n + n\text{H2O} \quad \text{Cellulose opening Sugar then to Ethanol} \]

Opening of Starch is easier than Opening of Cellulose

Opening of Cellulose with Enzymes or Acid
Transition from fossil to renewable feed stocks for the production to ethylene will be a tremendous challenge

- Feedstock availability and cost
- Capital requirements
- ‘Food vs Fuel’ issues?
- Green premiums?
- Co-mingling
Global Ethylene Cash Cost
For the european situation the import duty of 192 Euro per 1000 became is serious bottleneck. Import duty converted to $ per MT Ethylene equals 480 $ / MT.

This is in the interest of Europe to become an attractive investment place and not of a company interest therefore it is evaluated against all other policy initiatives such as common agriculture policies and Mercusor free trade agreement and it will take a long period before this barrier will be removed.

This study therefore focuses on utilizing feedstock from within Europe.
2011 Global Ethylene Cash Cost

with European import duty
Global Commodity Production
Chemistry meets Agro....
From Sugar Beets to Ethylene...
Maximum logistic and energy integration
Economic feasibility of alternative ethanol-to-ethylene routes relative to fossil alternative
Economic feasibility of alternative ethanol-to-ethylene routes relative to fossil alternative

Seven business case alternatives

5. ETHANOL ETHYLENE INTEGRATED
   - Thick juice production
   - Transport
   - Ethanol production
   - Ethylene production
   - Assumes domestic ethanol fermentation from local sugar beets
   - Bio-ethylene production facility in existing on-site infrastructure
   - Integrated ethanol-ethylene production

6. ETHANOL ETHYLENE INTEGRATED GREENFIELD
   - Thick juice production
   - Transport
   - Ethanol production
   - Ethylene production
   - Same as domestic integrated route, but not built within existing refinery infrastructure
   - Entire back-end is assumed greenfield

7. FULLY INTEGRATED
   - Sugar beet transport
   - Thick juice production
   - Ethanol production
   - Ethylene production
   - Sugar production, ethanol production and ethylene production fully integrated at Temneuzen site
   - Bio-ethylene production facility in existing on-site infrastructure
Fossil reference business case (case 1)

- 200 kt/a cracker furnace to replace existing furnace and utilize existing capacity along process chain (i.e. cryogenic separation)
- Energy for operations from fuelgas, 35 bar HP steam and electrical power
- Majority of fuelgas produced in cracker process is used for fired duty in ethylene cracker
- TLA process (rapid cooling products) produces significant amount HP steam to be resold to on-site steam grid
- Significant by-products (i.e. propylene, crude C4, pygas, fueloil, fuelgas and hydrogen)
The fossil reference case delivers a relatively high NPV leveraging the existing cryogenic back-end separation infrastructure.

<table>
<thead>
<tr>
<th>Business case NPV breakdown [m EUR]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CASE</strong></td>
</tr>
<tr>
<td>CAPEX -96</td>
</tr>
<tr>
<td>FEEDSTOCK 3.648</td>
</tr>
<tr>
<td>ENERGY 151</td>
</tr>
<tr>
<td>OTHER 31</td>
</tr>
<tr>
<td>ETHYLENE 1.835</td>
</tr>
<tr>
<td>GREEN PREMIUM 0</td>
</tr>
<tr>
<td>BY-PRODUCTS 2.721</td>
</tr>
<tr>
<td>TOTAL 629</td>
</tr>
</tbody>
</table>
Integrated ethanol-ethylene (case 5)

This case assumes ethylene-ethanol integration at Terneuzen, transporting thick juice from Dinteloord.

Case operational description

- Ethanol production Terneuzen
  - IP Steam 12 bar 1,600 kta
  - Power 137 GWh
  - Process water 2,400 kta
  - Thick juice 1,141 kta
  - 50% Ethanol 720 kta

- Ethylene production Terneuzen
  - LP/IP Steam 227 kta
  - Fuel gas/power ~1.4 PJ
  - Ethylene 200 kta
  - Effluent water 160 kta

- Catalytic E2E converter

- Identical to case 3/4, apart from
  - Utilities are already covered by on-site installations, no additional investments required and natural gas consumption replaced by IP steam
  - Optional re-use of effluent water at Value park

- Identical to case 3/4
**Ethanol ethylene integration offers substantial business case improvement due to avoided investments and lower energy cost**

### Business case NPV breakdown [m EUR]

<table>
<thead>
<tr>
<th></th>
<th>CASE</th>
<th>Δ to CASE 3/4</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX</td>
<td>-408</td>
<td>82</td>
<td>• Due to co-siting investments in utilities can be avoided relative to case 3/4</td>
</tr>
<tr>
<td>FEEDSTOCK</td>
<td>3.868</td>
<td>0</td>
<td>• Feedstock (thick juice) procurement identical to case 3/4</td>
</tr>
<tr>
<td>ENERGY</td>
<td>467</td>
<td>19</td>
<td>• Lower energy cost due to lower on-site cost (i.e. IP steam instead of natural gas)</td>
</tr>
<tr>
<td>OTHER</td>
<td>228</td>
<td>7</td>
<td>• Thick juice transport added, ethanol transport cost subtracted</td>
</tr>
<tr>
<td>ETHYLENE</td>
<td>-1.835</td>
<td>0</td>
<td>• Sales from 200 kt/a ethylene, same as reference case</td>
</tr>
<tr>
<td>GREEN PREMIUM</td>
<td>367</td>
<td>0</td>
<td>• 20% green premium assumed on bio-ethylene</td>
</tr>
<tr>
<td>BY-PRODUCTS</td>
<td>39</td>
<td>0</td>
<td>• Only by-products is 160 kt/a effluent water, substantial difference with reference case</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>-2.730</strong></td>
<td><strong>74</strong></td>
<td>• Relative to case 3/4, NPV results improve by 74 m EUR</td>
</tr>
</tbody>
</table>
Green premiums over fossil in the study 20% at ethylene level ... basic view however

Seem to become higher when product application is inside the body
On the skin
Distance to the skin (packaging)

or

When Brand owner identifies the brand with low carbon footprint and pays for it

or

Legislation such as bio Fuels
The Green Premium (achieved for limited available volume)

Bio Polyethylene over fossil 30 to 50 %
Bio PLA over fossil PET 25 to 30 %
Bio Methanol over fossil Methanol > 100 %
Eco PET (Teijin) over virgin PET 60 %
Bio MEG 60 %

Hunt is on for bio p-xylene to bring Bio PET
Economic feasibility of alternative ethanol-to-ethylene routes relative to fossil alternative

NPV comparisons ethylene business cases [m EUR]

CAPEX

OPEX

REVENUES

TOTAL NPV

FOSSIL REFERENCE

IMPORTED ETHANOL

DOMESTIC ETHANOL

ETHANOL ETHYLENE INTEGRATED

E&E INTEGRATED GREENFIELD

FULLY INTEGRATED NET-BACK

FULLY INTEGRATED BOTTOM-UP

-96

-3.831

4.556

629

-130

-3.805

-2.730

-2.813

-2.655

-1.022
Is there the capacity in the first place…?

- Between 1990 and 2011, land for sugar beet shrank from 125 to 74 kHa
- Productivity rose to ~14 ton sugar per hectare
- Total productivity remained constant at around 1 million ton sugar per year

- Yield can increase from 14 to 20 ton/ha
- Room to reclaim "lost" area of 50,000 ha for sugar beet cultivation
- Additional 1.5 million ton sugar production by 2020
- Additional 1.5 million ton sugar is equivalent to 400 kt ethylene
Thought Provoking Questions……

• Is there a match between bulk chemicals and bio-based feed stocks? Because of mere size, replacement of fossil feed stocks by bio feed stocks poses enormous challenges

1ha sugar beets -> 12 MT sugar -> 6 MT bio-ethanol -> 3 MT bio-ethylene
1ha wheat -> 4-5 MT straw -> 1 MT bio-ethanol -> 0.5 MT bio-ethylene

Dow Benelux produces 2 MMT of ethylene.
To base this volume on renewable raw materials requires ~600,000 ha sugar beets or 4,000,000 ha of wheat! This is the area of The Netherlands!

• Is a breakthrough in technology possible to reduce ethanol feedstock costs to below cash cost of fossil ethylene?
• Is the customer willing to pay a premium for bio-renewable products?
• Will the brand-owner/customer accept co-mingling of fossil and ‘green’ feed stocks, or will segregation be the norm?
Conclusions…..

• Business case calculations indicate that bio-ethylene from sugar beet is only commercially viable with a substantial higher green premium than 20%

• Only if market conditions significantly improve or process from farmers field to ethylene achieve substantial cost reductions, ethylene from sugar beets can become commercially attractive even at a premium cost over naphtha
Acknowledgements

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Thank You

It is not easy bein’ GREEN