PERSPECTIVES OF INDUSTRIAL BIOREFINERIES IN THE GLOBAL BIOECONOMY – ROLE OF THE POLICY FRAMEWORK TO SUPPORT IMPLEMENTATION

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Biorefining policy needs to come of age

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After significant delays, the first commercial cellulosic biorefinery is open in Europe and three more are due this year in the USA, with others soon to follow. Although biofuels might be the mainstay, there has been a significant shift in emphasis towards bio-based chemicals. A major bio-based public–private partnership has launched in Europe, but obstacles to biorefining remain, and public policy is not yet directed at enabling the integrated biorefineries of the future.

Bioeconomy work in three projects

- Biomass sustainability
- *Biorefinery models and policy*
- Replacing the oil barrel

Additionally

- Building a sustainable bioeconomy: towards a framework for policy

Final output

- A single book, first draft complete
Bioeconomy strategies: long on talk, short on policy
A Bioeconomy policy framework

Based on presentation by M. Carus (2014)

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</table>
Example: Public Procurement

• An explanation of what PP is
• Why it’s important: OECD governments spend around 13% of GDP on PP

Example:
- Biopreferred Program of USDA
- Some 15,000 products in the catalogue
- Unique label
BIOREFINERY MODELS AND POLICY

Chapters
- WHAT IS A BIOREFINERY: DEFINITIONS, CLASSIFICATION AND GENERAL MODELS
- FINANCING BIOREFINERIES
- BIOWASTE BIOREFINING
- BIOREFINERY CASE STUDIES: DIFFERENT PERSPECTIVES FROM DIFFERENT COUNTRIES
- POLICY QUESTIONS REGARDING: R&D, FINANCING AND REGULATORY NEEDS AND OPPORTUNITIES FOR BOOSTING BIO-WASTE BIOREFINERY PRACTICES
- POLICY CONSIDERATIONS
General policy considerations

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Integrated biorefinery logistics

Coastal
Integrated Biorefinery
- Imported biomass
- Agriculture
- Forestry
- MSW
- Waste gas
- Algae?

Urban
Biomass conversion and/or ethanol / biodiesel plant

Rural
Logging/forest residues
Farm cooperative

Neighbouring farms
Rural biorefining: “soft” issues

- Water requirements and river regulations
- Do rural biorefineries conflict with green-field policy?
- Small *versus* large: economies of scale and petrochemicals competition
- Do city people want to move to the country?
  - Towns and villages across England are losing basic services at “their fastest rate ever” 1
- Do people already there want incomers?
- Biomass imports – sea *then* overland to biorefineries
- Other infrastructure – pipelines, electricity, rail, road – is expensive and can be unpopular

1 *Daily Telegraph*, 14 Apr 2008
What about rural *and* coastal?

- Build biomass pre-treatment and concentration plants rurally
  - Less environmental impact and infrastructure needs
  - Less impact on greenfield policies
  - Less public resistance?
- Build integrated biorefineries near waste CO$_2$ sources
- Re-develop brown-field sites $^1$
- Close to developed power and rail infrastructure
- Lesser water regulations?
- Fewer transport issues?
- Integrate with offshore wind energy?
- *Choice of feedstocks* – including gas
  - Switch between available and cheaper feedstocks
  - Cut idle times
- Easier political sell than rural location?

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1 Example: Porto Torres, Sardinia
Ludwigshafen integrated chemicals complex, Germany

- Employees: 39,000
- Buildings: 2000
- Production plants: 200

Lessons from cellulosic flagships: unusual and complex projects, many stakeholders

- High CapEx
  - Simultaneous commitment by many actors:
    - Technology providers, R&D partners
    - Customers (e.g. equity investors)
    - Banks/financial institutions
    - Funding bodies (EU/Regions)
    - Local authorities
- Sustained investment
  - Investors (many ongoing negotiations)
  - Grants (PPP, DG RTD, Regional funds)
  - Debt (main difficulty)
- Flagships are not easily bankable

Cellulosic biorefinery, Crescentino, Italy.
• Replaced the Biorefinery Assistance Program (9003) in the Farm Bill (2014)
• USDA approved to use loan guarantees to **maximum of 15% of mandatory funds for bio-based manufacturing**
• Thus the **same policy mechanism** is now being used to **support both biofuels and bio-based products and materials**
  – This brings automatic political visibility to bio-based products
  – Streamlines administration of bio-based products and biofuels (no need for replication of effort and personnel)

**Eligible projects**
• Development, construction, or retrofitting of a commercial-scale biorefinery using eligible technology
• Loan guarantees **up to USD 250 million (and up to 80%)**
• Bio-based product manufacturing facilities
• New technologies to manufacture bio-based outputs
Financing through Climate Change and Emissions Management Corporation (CCEMC)

CCEMC

- CO₂ Solutions secured CAD 5.2 million from:
  - Government of Canada’s ecoENERGY Innovation Initiative and
  - CCEMC
- Towards a CAD 7.5 million project for **biological CO₂ capture from oil sands production**
- 70% from public funding

Postscript: Government of Alberta outlined a plan in November 2015 for cutting the province’s GHG emissions. The proposals include:
- End to coal-fired power generation
- Carbon price of CAD 30 per tonne to 2018 and rising in real terms
Bio-based chemicals policy

Bio-based X → X “ethanol equivalent”

% GHG savings cf. petro-equivalent

20%  50%  60%

Production volume factor

Production efficiency factor (yield, titre productivity)

Support (mandate, subsidy, tax incentive)

1 EISA biofuels reference
Renewable fuel  20%
Advanced biofuel  50%
Biomass-based diesel  50%
Cellulosic biofuel  60%

2 Small volumes will not have significant total GHG emissions savings ⇒ inefficient

3 Encourages innovation to improve efficiency

Philp (2015). Energy & Environmental Science 8, 3063-3068
Fossil fuel subsidies: a level playing field is impossible

- IMF calculation: USD 5.3 trillion, or 6.5% of global GDP, in post-tax subsidies in 2015
Waste = any substance or material that the holder discards, intends to discard or is required to discard

Where does bio-based production come in the hierarchy?
REPLACING THE OIL BARREL
<table>
<thead>
<tr>
<th>Class</th>
<th>Compound</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Diols</td>
<td>1,3-Propanediol</td>
<td>Nakamura and Whited (2003); Maervoet et al. (2016)</td>
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<tr>
<td></td>
<td>1,2-Propanediol</td>
<td>Clomburg and Gonzalez (2011); Lee et al. (2016)</td>
</tr>
<tr>
<td></td>
<td>1,4-Butanediol</td>
<td>Yim et al. (2011); Burgard et al. (2016)</td>
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<tr>
<td></td>
<td>2,3-Butanediol</td>
<td>Cho et al. (2015); Yang et al. (2016)</td>
</tr>
<tr>
<td>Bio-based plastics</td>
<td>Polyhydroxyalkanoates</td>
<td>Steinbüchel (2001); Escapa et al. (2011); Tokuyama et al. (2014); Chen et al. (2015); Chu et al. (2015); Kim et al. (2016)</td>
</tr>
<tr>
<td></td>
<td>Polylactic acid</td>
<td>Jung and Lee (2011)</td>
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<tr>
<td></td>
<td>PLGA</td>
<td>Choi et al. (2016)</td>
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<tr>
<td>Plastics intermediates</td>
<td>Muconic acid</td>
<td>Curran et al. (2013)</td>
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<td></td>
<td>Itaconic acid</td>
<td>Chin et al. (2015)</td>
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<td></td>
<td>1,5-Diaminopentane</td>
<td>Kind et al. (2014); Oh et al. (2015)</td>
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<tr>
<td></td>
<td>1,3-Diaminopropane</td>
<td>Chae et al. (2015)</td>
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<td></td>
<td>5-Aminovalerate</td>
<td>Park et al. (2013); Rohles et al. (2016); Shin et al. (2016)</td>
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<tr>
<td></td>
<td>3-Aminopropionic acid</td>
<td>Song et al. (2015)</td>
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<tr>
<td></td>
<td>Gamma-aminobutyric acid</td>
<td>Dung et al. (2016)</td>
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<tr>
<td>Synthetic rubber</td>
<td>Isoprene</td>
<td>Lindberg et al. (2010); Ye et al. (2016)</td>
</tr>
<tr>
<td>Olefins (alkenes)</td>
<td>1,3-Butadiene</td>
<td>Chen et al. (2015); Kang and Nielsen (2016)</td>
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<td></td>
<td></td>
<td>EP2607340 (2013)</td>
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<tr>
<td>Spider silk</td>
<td></td>
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<tr>
<td>Biofuels</td>
<td>Butanol</td>
<td>Jang and Lee (2015); Gaida et al. (2016);</td>
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<td></td>
<td>Alkanes</td>
<td>Kageyama et al. (2015); Sheppard et al. (2016)</td>
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<tr>
<td></td>
<td>Hydrocarbon fuels</td>
<td>Lee et al. (2015)</td>
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<tr>
<td></td>
<td>Hydrogen</td>
<td>Srirangan et al. (2011); Tran et al. (2014); Rollin et al. (2015)</td>
</tr>
</tbody>
</table>
...but hardly any commercialisation

- 1,3-PDO, 1,4-BDO, 5-amino valerate (??), artemisinin

**Sep 30, 2016:** Inauguration of Mater-Biotech’s plant in Bottrighe di Adria
30,000 tonnes per year of 1,4-BDO
Biotechnology

Cell-free biotech will make for better products

A new type of biological engineering should speed up innovation
Thank you for your time

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