

Value chain structures that define second generation bio-refineries in Europe

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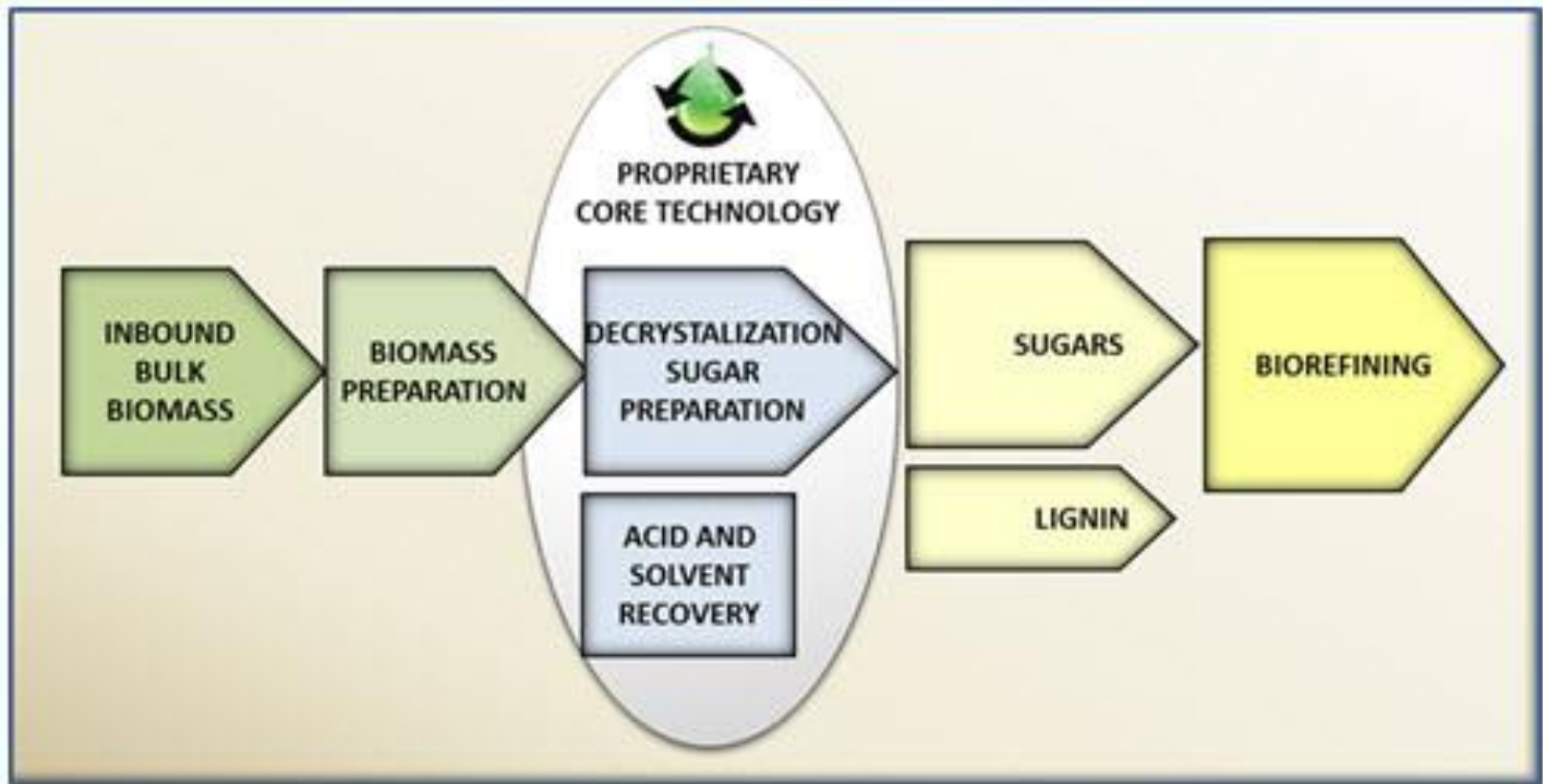


NIFU Nordic Institute for Studies in Innovation, Research and Education, Oslo, Norway



2nd Generation Ethanol; Cellulosic Ethanol (CE)

- Ethanol from cellulosic bio-materials (wood, crop residue, municipal waste, etc.)





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Vinten

Inbicon makes lignocellulosic ethanol a commercial reality

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ABSTRACT

Based on the IBUS process, Inbicon has built an advanced biorefinery at the port of Kalundborg in Denmark. In this biorefinery Danish wheat straw is converted to second generation (2G) ethanol, lignin pellets and C5 molasses. It is a demonstration plant working 24 h 7 days a week. In this way it is working as a commercial plant, but the size of the plant is not large enough to carry out a feasible production. It is possible to run as a commercial plant as the Danish Energy Agency has granted the design and construction phase and the European Commission's 7th Framework Programme for Energy Research (FP7) has granted the commissioning and first three years of operation.

CELLULOSIC ETHANOL IS COMING

LARGE SCALE PRODUCTION PLANTS UNDER CONSTRUCTION (CAPACITY IN MILLION US GALLONS PER YEAR)



6

FIBERIGHT

BLAIRSTOWN, IOWA, US
FEEDSTOCK: MUNICIPAL SOLID WASTE
LAUNCH: 2013

20

MASCOMA

MICHIGAN, US
FEEDSTOCK: WOODY BIOMASS
LAUNCH: 2013

36

BP

FLORIDA, US
FEEDSTOCK: SUGARCANE BAGASSE
LAUNCH: 2013

1.4

INBICON

KALUNDBORG, DENMARK
FEEDSTOCK: WHEAT STRAW
LAUNCH: 2009

13

M&G - CHEMTEX

CRESCENTINO, ITALY
FEEDSTOCK: ENERGY CROPS
LAUNCH: 2012

15

COFCO/SINOPEC

HEI LONG JIANG PROVINCE, CHINA
FEEDSTOCK: CORN STOVER
LAUNCH: 2013

25

POET

EMMETSBURG, IOWA, US
FEEDSTOCK: CORN STOVER
LAUNCH: 2013

25

DCE

NEVADA, IOWA, US
FEEDSTOCK: CORN STOVER
LAUNCH: 2013

25

ABENGOA

HUGOTON, KANSAS, US
FEEDSTOCK: CORN STOVER
LAUNCH: 2013

72

BP

GULF COAST AREA, US
FEEDSTOCK: ENERGY CROPS
LAUNCH: N/A

4

PETROBRAS

BRAZIL
FEEDSTOCK: SUGARCANE BAGASSE
LAUNCH: 2013

13

ABENGOA

ARANCE, FRANCE
FEEDSTOCK: AGRICULTURAL RESIDUE
LAUNCH: 2013

AND WE ARE JUST GETTING STARTED

In 2014 the estimated production capacity of cellulosic ethanol is about 250 million US gallons. According to Bloomberg New Energy Finance there is enough biomass available to produce 93 billion US gallons of cellulosic ethanol in 2030.

Potential: 93 billion US gallons by 2030!
(350 billion liters)
(x 372)!

Source: "Moving towards a next generation ethanol economy" Bloomberg New Energy Finance, 2012 and public information on large scale production plants (biochemical conversion only) under planned construction

Motivation

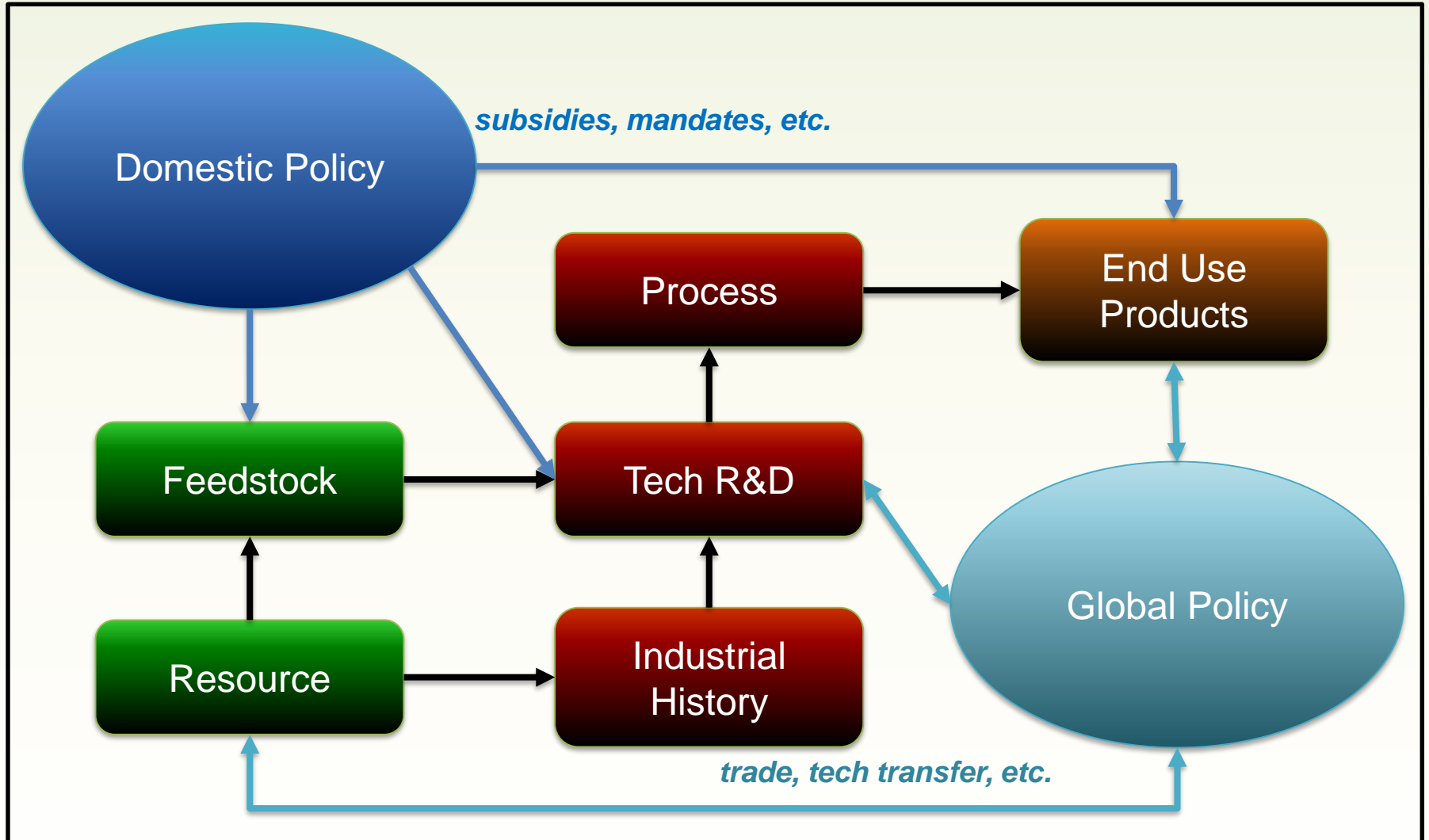
CE (cellulosic ethanol) is calculated to have large technical and economic potential.

Why are economies of scale for CE slow to develop in Europe?

What are the barriers between pilot/demonstration scale to production scale?

What is the political landscape?

Framework: Global Value Chain Structure








EU Policy

- The Renewable Energy Directive (2009/28/EC)
By 2020, 10% of transport fuel must come from renewable energy.
 - Biofuels produced from lignocellulosic, waste, non-food cellulosic and residue materials will count double.
 - Biofuels yielded from municipal and industrial waste, straw, algae, palm oil, leaves, sawdust and branches will count four times.

National Policies

 **SE:** Ethanol exempt from energy and carbon fuel taxes (5.63 SEK/liter in 2014), initiatives to involve public R&D, searching for support to forestry sector

 **NO:** Complicated. CE not competitive with fossil (low carbon tax), unpredictable and inconsistent policy, emphasis on electricity and hydro. Search for support of forestry sector, but highest wood prices in the world. 3.5% blending target, plans to expand to 10% by 2020.

 **DK:** 100% fossil free by 2050. Wheat straw subsidy for power plants, but not yet for ethanol.

 **ES:** Tax incentives to ethanol consumption and investment in ethanol production plants. Bioethanol counts towards national sustainability objectives.

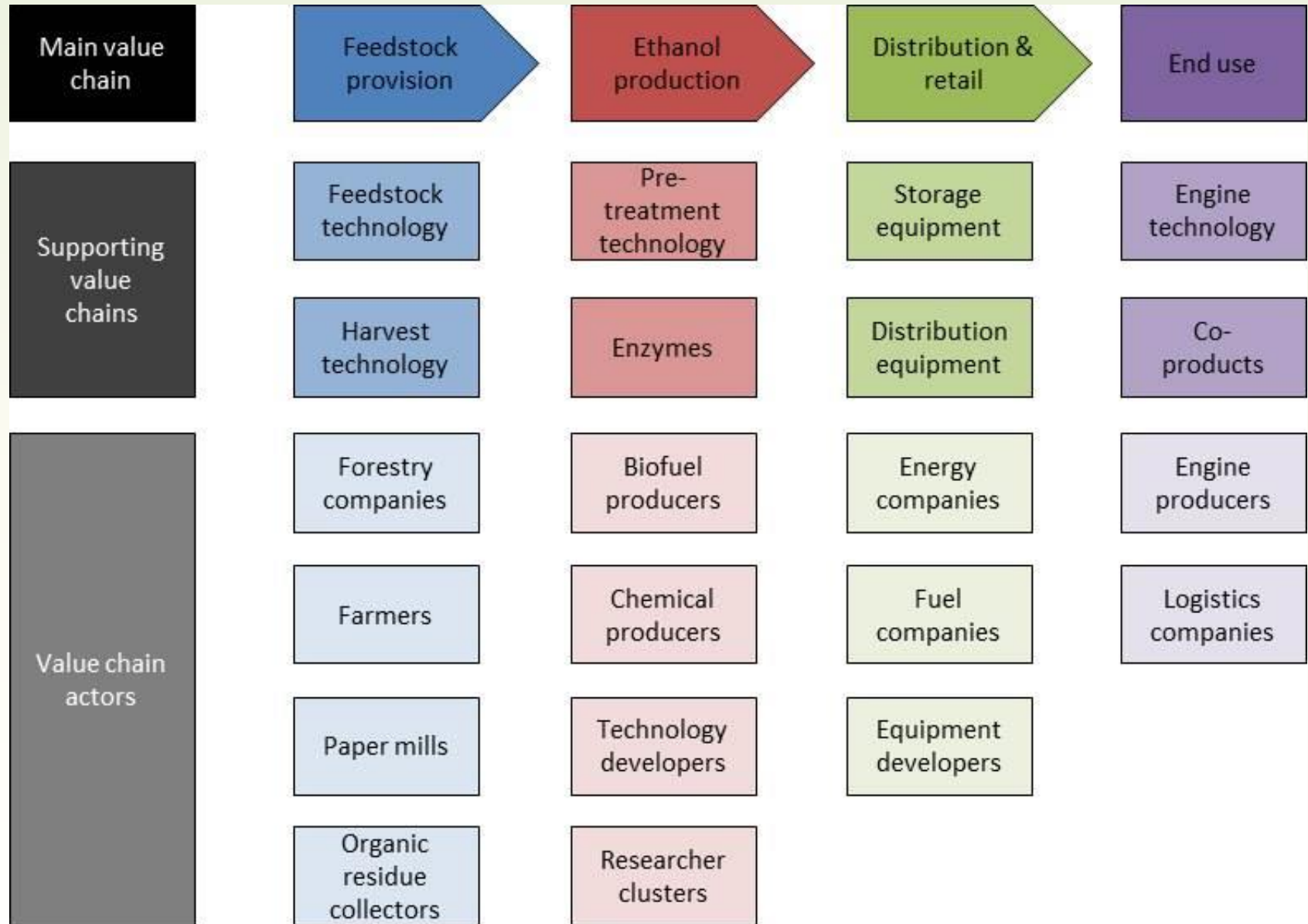
 **IT:** 10% RE target in transport by 2020. Target for 2% advanced biofuels by 2022.

Method: Case Study Interviews

CE production facilities in Europe

- History
- Feedstock
- Output
- Firm characteristics
 - Innovations and R&D funding
 - Sources of finance
 - Market characteristics
 - Value added in different value chain segments

Ethanol value chain



(adapted from Klitkou, 2013)

Örnsköldsvik (Sweden)

- History: Retrofitted pulp and paper plant from 1903
- Feedstock: wood
- Output: Specialty cellulose and lignin products, CE (17.7 Mil. l/yr)
- Notes: Lack of attention to industry actors in policies
 - Indian owners (Domsjö) invested for access to pulp- main focus on cellulose and textiles.
 - SEKAB bought ethanol for further refining and blending, but now switching focus to high value chemicals.
 - Lignin for concrete; specialty cellulose for pharmaceuticals
 - Widespread imported conventional ethanol in Sweden; EU obligation already fulfilled this way

Borregaard (Norway)

- History: Established in 1889, pulp and paper. 1930s-chemicals. Taken over by Orkla group in 1986, focus on chemicals
- Feedstock: wood
- Output: Specialty cellulose, specialty lignin, vanillin, electricity, biogas, and CE (20 Mil. l/yr)
- Notes:
 - Supported by Norway innovation grants
 - Unfavorable and uncertain policy landscape in Norway for 2GE and biofuels.
 - More focus on high value chemicals.



Weyland (Norway)

- History: 2001, goal to commercialize 2GE, R&D from Bergen University; 2010 pilot plant built
- Feedstock: versatile (forestry, paper waste, demolition wood waste, crop residue)
- Output: Chemicals, CE (0.2 Mil. l/yr)
- Notes:
 - “Our business model is to provide core technology for the cellulose to sugar conversion process”
 - Supported by Innovation Norway, and Norwegian research council
 - Technology licenses, process engineering, and key process components



Inbicon (DK)

- History: Fully owned subsidiary of DONG Energy; pilot plant in 2003, biorefinery opened in 2010
- Input: wheat straw
- Output: C5 molasses, fibers, solid biofuel, CE (5.4 Mil. l/yr)
- Notes:
 - Ethanol blend for Statoil in DK
 - Competition for straw (co-firing is subsidized by DK gov't)
 - Technology licensing with Novozymes



Abengoa (Spain)

- History: Abengoa largest ethanol producer in Europe; Largest producer of bioethanol in Spain. CE plant in Salamanca, Spain 2012
- Feedstock: wheat and barley straw, MSW
- Output: Lignin, C5 Molasses, Dried Distillers Grains (DDG), CE (5 Mil. l/yr)
- Notes:
 - goal is to generate knowledge and data for production scale CE plant
 - FP7 Lignocellulosic Ethanol Demonstration Project (LED) Demonstration of production scale 2GE from crop residue (?)
 - Took cheap loans for expansion during boom years; Spain withdrew RE subsidies in 2013.
 - Anticipated industry growth never happened.
 - ~15 billion € debt; started bankruptcy proceedings in 2015, potentially to become Spain's largest bankruptcy in history.

Crescentino (Italy)

- History: Became operational in 2012; largest plant in Europe.
- Feedstock: Rice straw, wheat straw, cane
- Output: CE (50 Mil. l/yr)
- Notes:
 - FP7 Support
 - Main purpose of plant is to sell the technology licenses, and construction of new plants in Asia, North and South America
 - Long term strategy is for niche chemicals and bioplastics (Chemtex and M&G group)
 - Feedstock problems, problems reaching full capacity
 - Novozymes 650 million kr investment written down to 0



Summary of Case Studies

- Forestry Based
 - Örnsköldsvik (SE), Borregaard (NO)
 - Goal: re-conceptualize forestry product market and retool pulp and paper mills
- Tech-licensing based
 - Weyland (NO), Inbicon (DK)
 - Goal: proof of conversion technology, licensing and IP
- Large scale
 - Abengoa (ES), Crescentino (IT)
 - Goal: proof of production scale, contract to build new plants
 - **Faltering...**

What we've learned

Why are economies of scale for CE slow to develop in Europe?

What are the barriers between pilot/demonstration scale to production scale?

What is the political landscape?

Our thinking was too narrow: it is a question of economies of scope and the larger bio-economy.

Without a competitive and cohesive policy landscape, the technology licensing becomes the main output (lower risk).

Conclusions & Policy Recommendations

- Longer-term policy to phase out support for conventional biofuels and biodiesel
- Policies and guarantees to reduce investor risk
- Larger-scale policy to support bio-economy rather than just fuels. Economy of scope.
- Include ILUC in accounting
- Recognize the need for flexibility in both feedstock, outputs, and links to industrial history
- Promote linkages across potential value chain actors
- Harmonization of goals and infrastructure across the EU