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

Jay Sterling Gregg*, Simon Bolwig*, Teis Hansen**, Ola Solér*, Sara Ben Amer*, Júlia Pladevall Viladecans*, Antje Klitkou#, and Arne Fevolden#

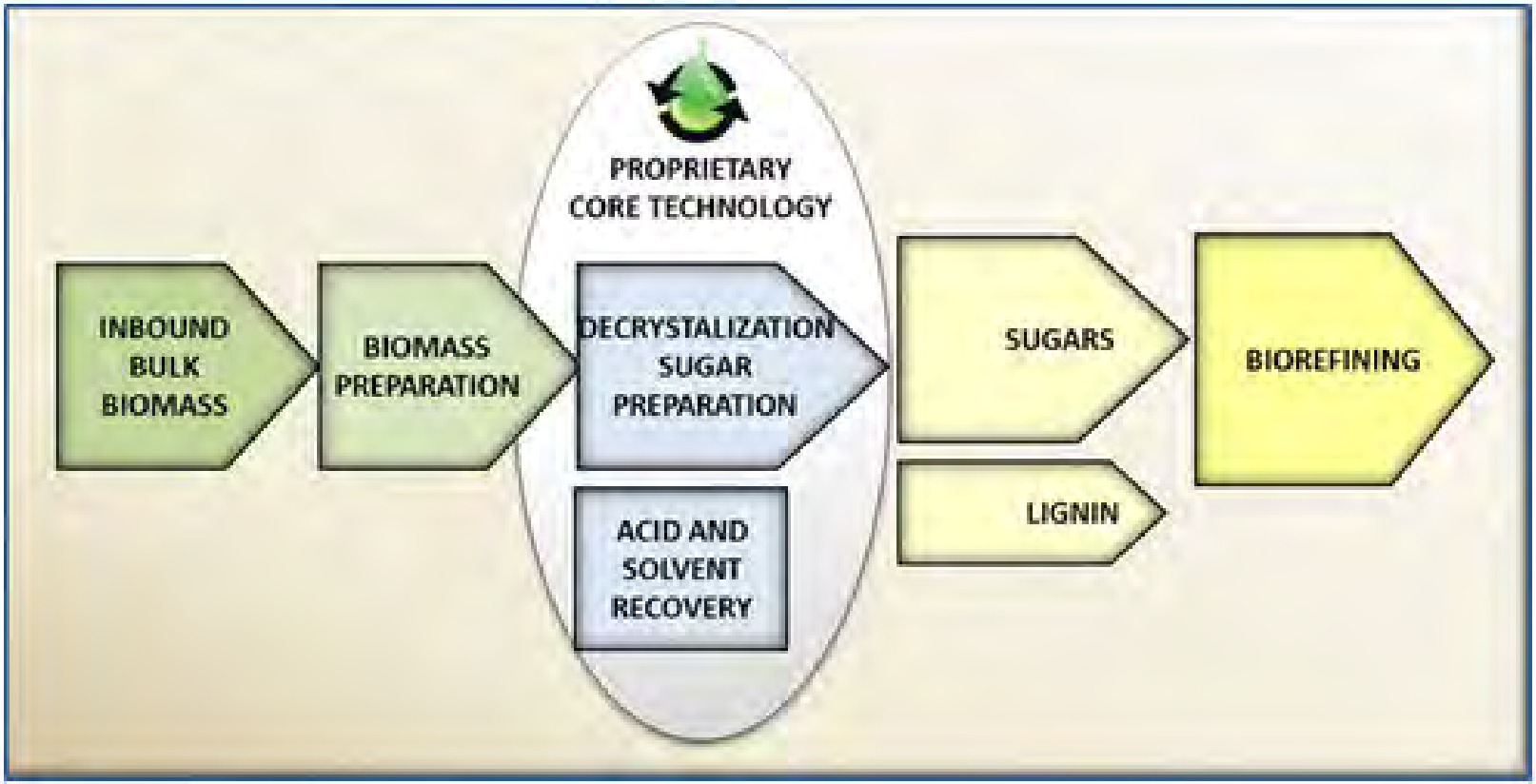
* Department of Management Engineering, Technical University of Denmark (DTU), Lyngby, Denmark

** Department of Human Geography and Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE), Lund University, Sweden

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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Inbicon makes lignocellulosic ethanol a commercial reality

Jan Larsen [a,*], *Mai Østergaard Haven* [a,b], *Laila Thirup* [a]

[a] *Inbicon A/S, Kraftværksvej 53, 7000 Fredericia, Denmark*

[b] *University of Copenhagen, Faculty of Life Sciences, Rolighedsvej 23, 1958 Frederiksberg C, Denmark*

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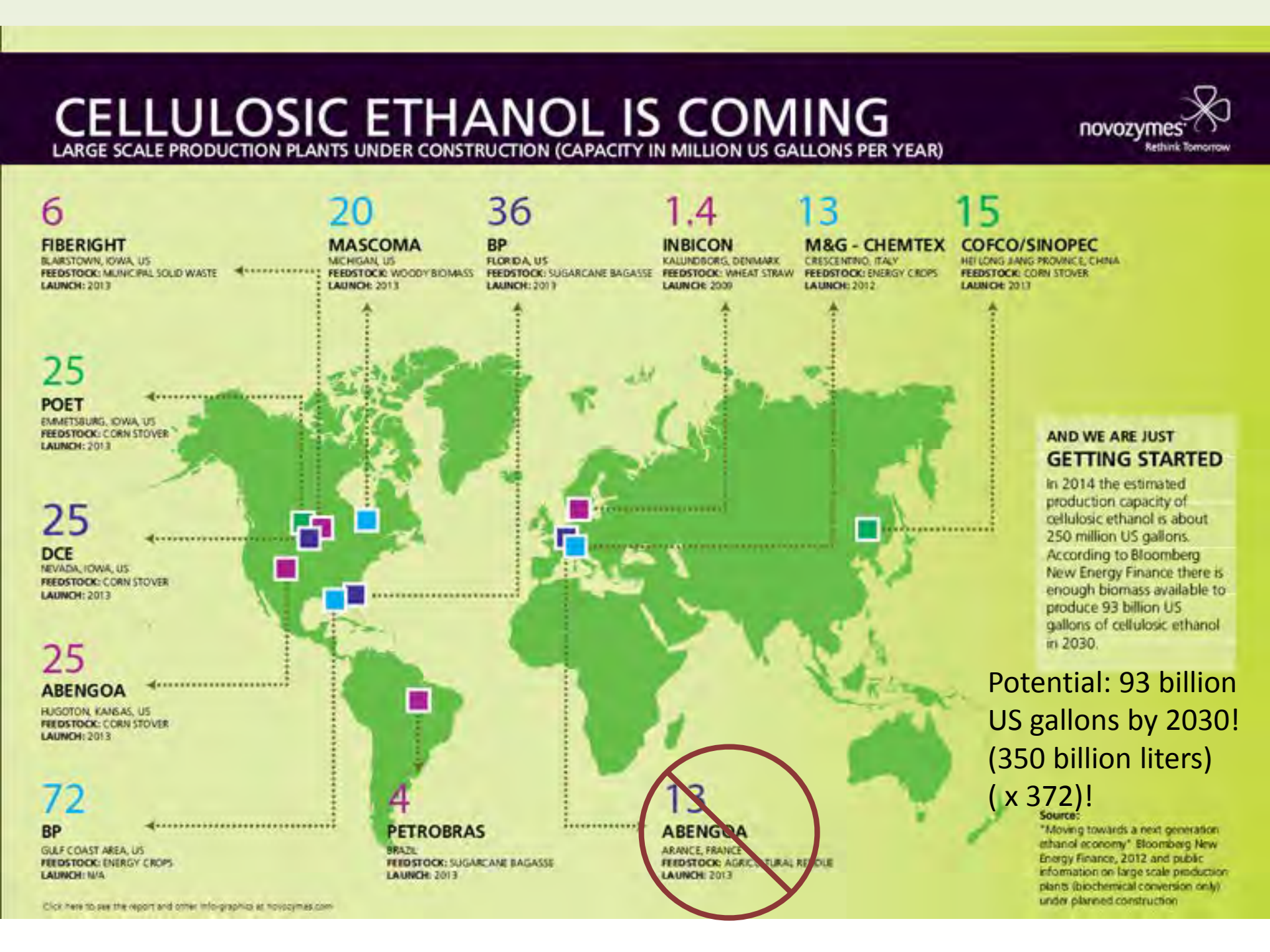
ABSTRACT

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)

novozymes
Rethink Tomorrow



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

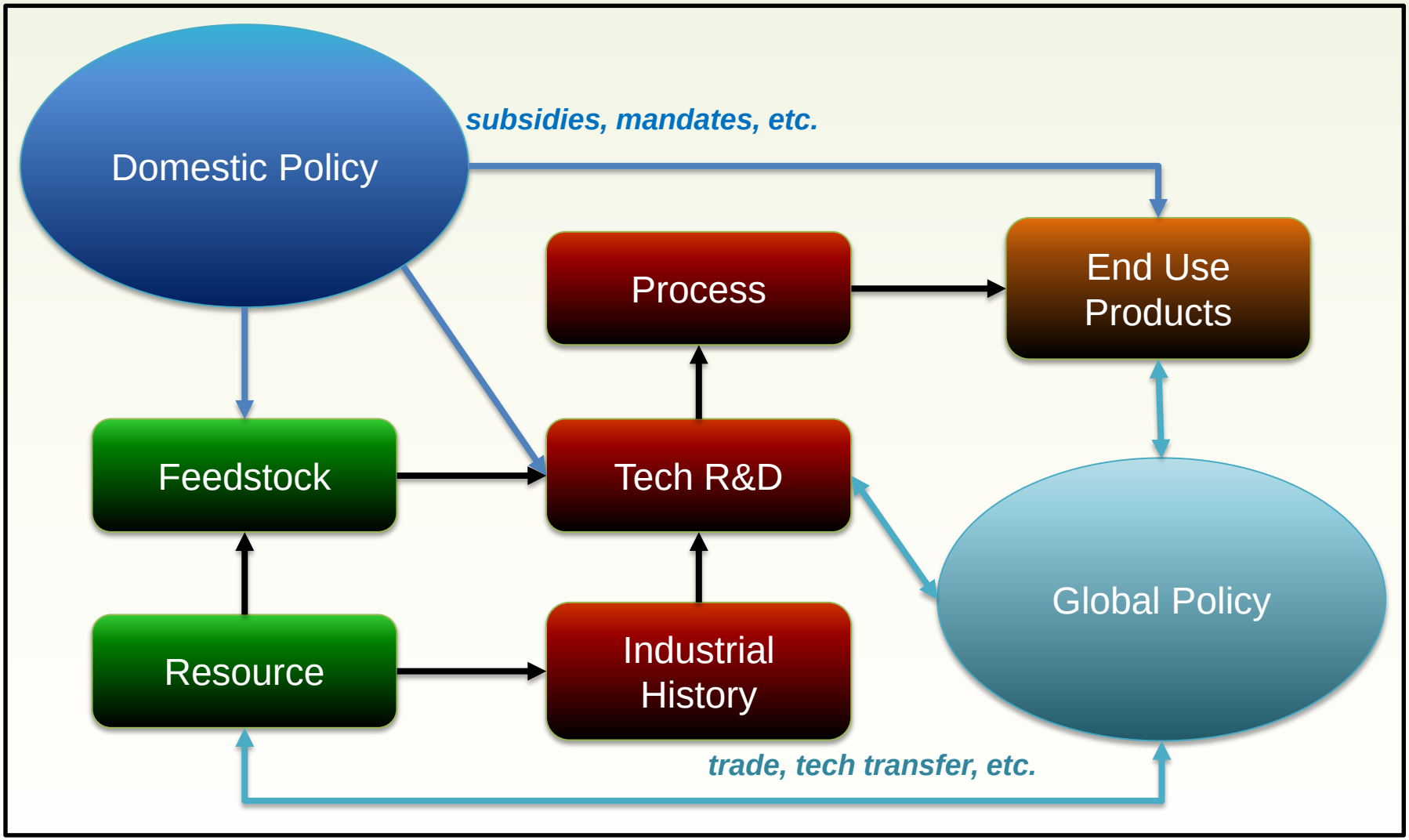
Motivation

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.

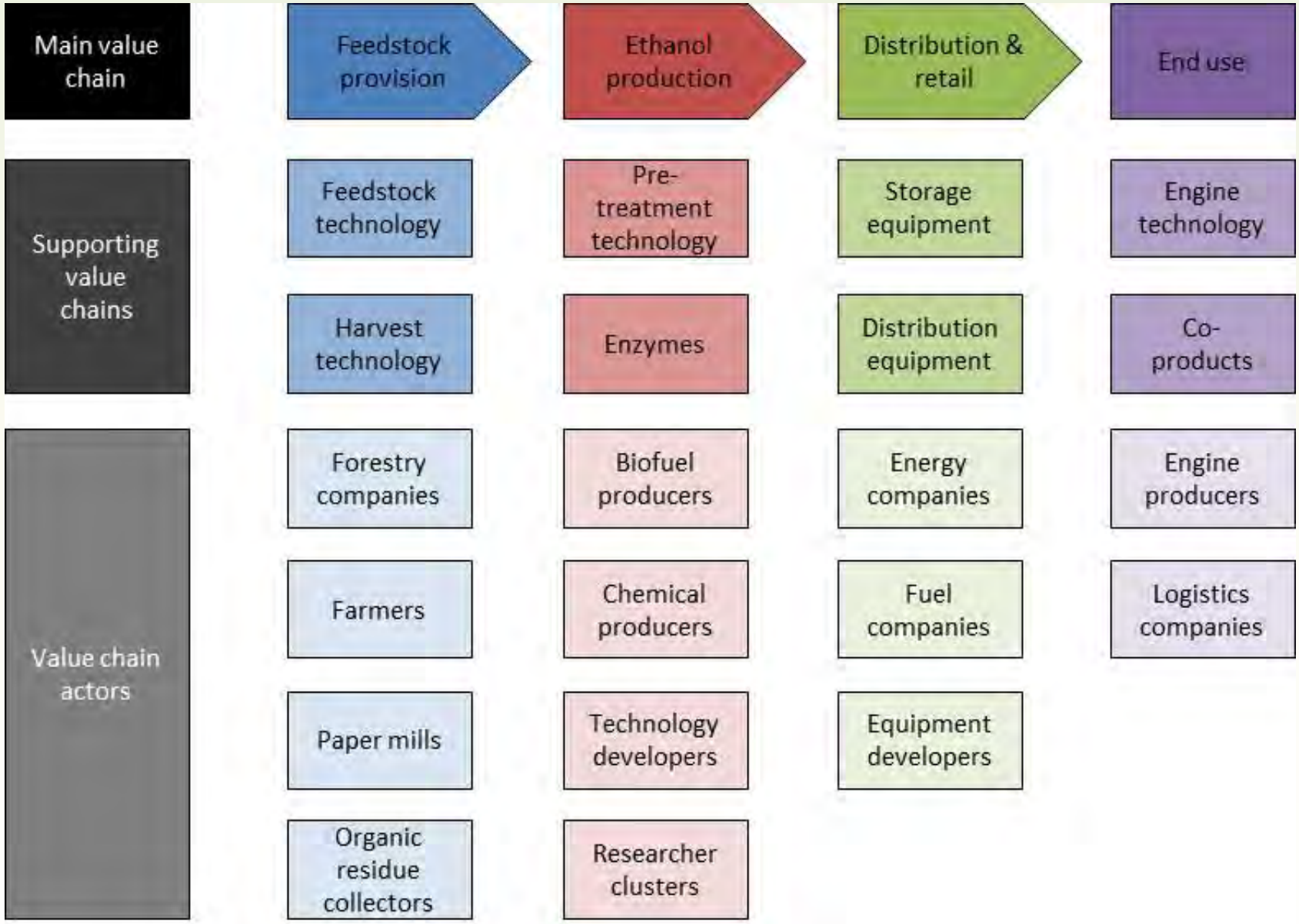
IT: 10% RE target in transport by 2020. Target for 2% advanced biofuels by 2022.

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