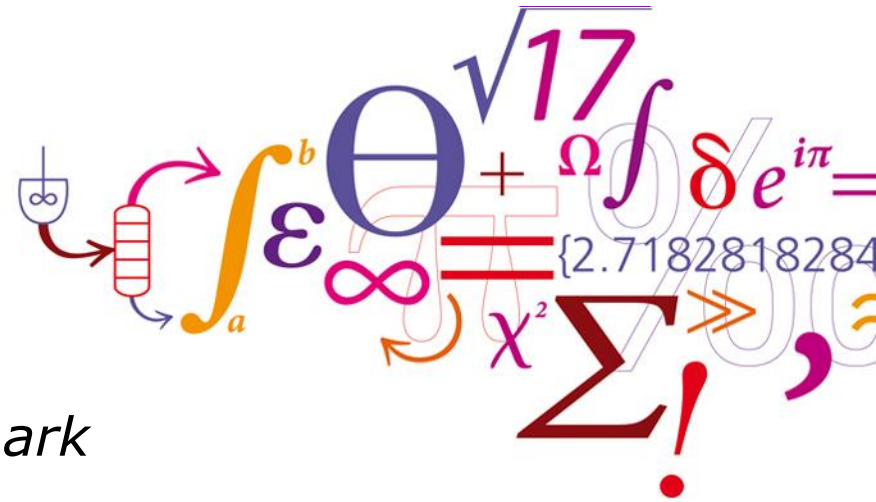
How to unlock the *circular potentials* of the Nordic BioEconomy

Lene Lange

Professor, PhD et Dr.Scient.

Center for Bioprocess Engineering

DTU, Technical University of Denmark



DTU Chemical Engineering

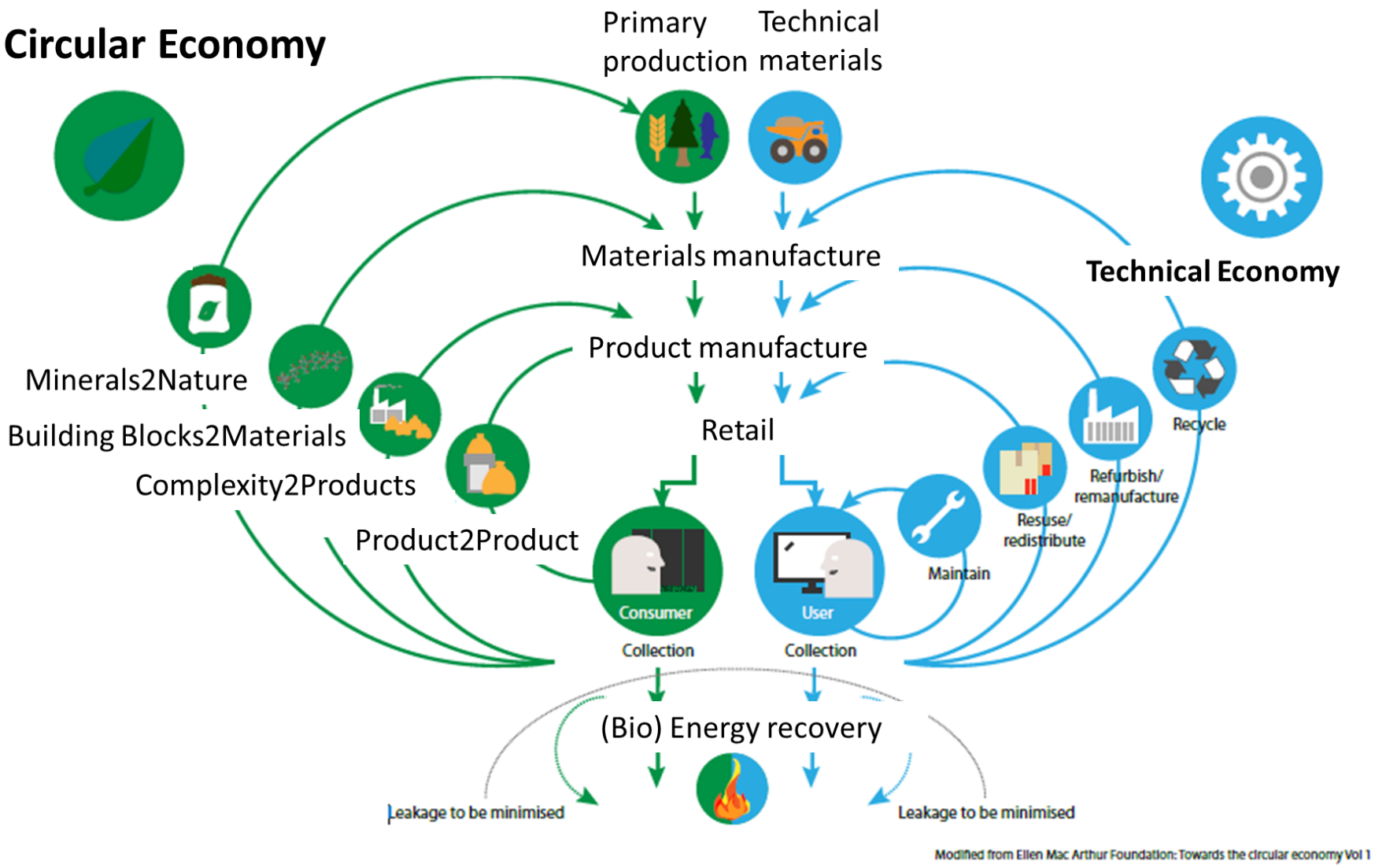
Department of Chemical and Biochemical Engineering

Global challenges and needs:
Bioeconomy can deliver!

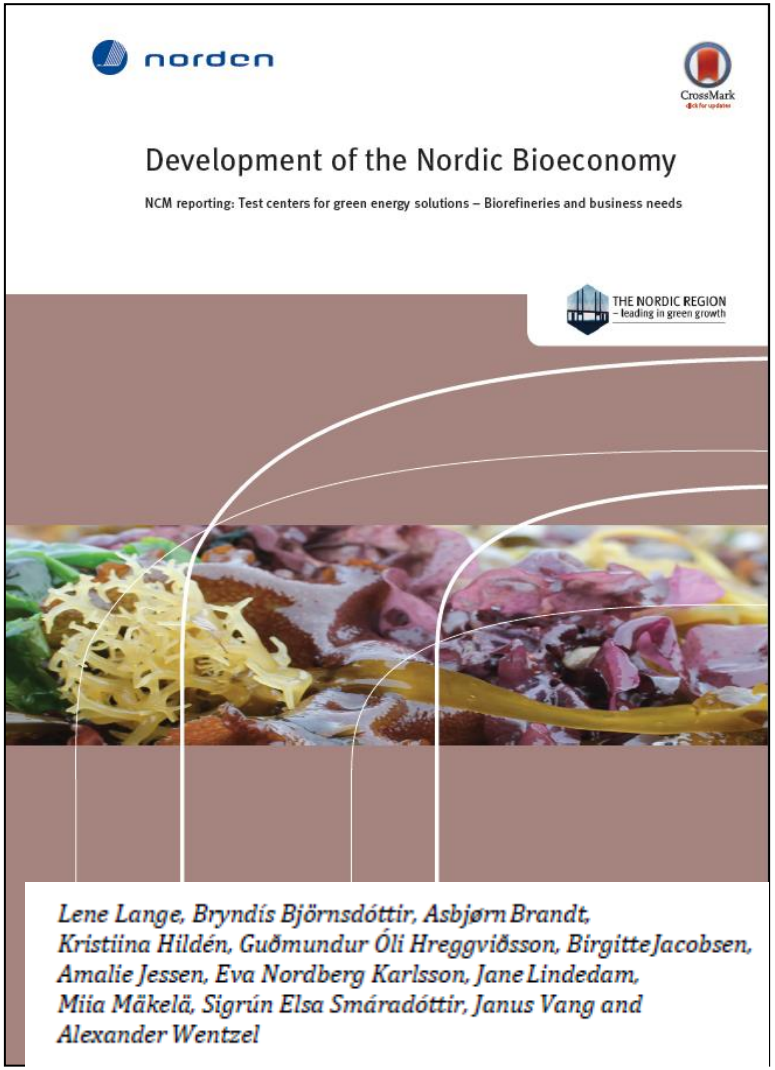
- Mitigating Climate Change by:
  - Improving resource efficiency = less CO2
  - Substituting for fossils = bio-based materials, chemicals & biofuels
- Feeding the world
  - Upgrading waste and residues (30-40% is wasted!)
  - Decrease land use for animal feed (now=70% globally)
  - Biorefinery =>Health promoting food/feed ingredients
- Stopping loss of biodiversity (we need the microbes)

The Circular Bioeconomy

–we must be better to communicate its complexity & potentials



Development of the Nordic Bioeconomy



The new Nordic bioeconomy includes development of biobased products of higher value, such as healthy food and feed ingredients, specialty chemicals and functional materials from residues of both primary production (agriculture, forestry and fishery) and industrial processing.

The Nordic BioEconomy is developing!
-in all countries including higher value products!

- Sweden, Public strategies => market drivers = > bio-based value chains; anchored in strong Universities; and SME´s!
- Iceland: Strong RTD&I; the best Entrepreneurs: marine biomass upgrade => early upstart of new business
- Finland: Pulp & Paper = strong start for BioEconomy; VTT = a knowledge platform, international profile & position
- Norway: Large salmon industry => need for Feed; & Side stream potentials; ”Foods of Norway”, interesting concept
- Denmark: intl. biotech, enz.&ingredients; coop-industries, upgrading sidestreams; strong research in biol-solutions
- Faroe Islands: Seaweeds; Greenland: Shrimpmeal & Ferti?

Nordic Bioeconomy can contribute
-moving EU ahead in biobased economy

- Advanced Bio-industries
- International level research in bioprocesses, biobased products and biological solutions
- Competences and skills
- Preferred partners

But what about relations to ROW? (rest of the world)

No International EU strategy for Bioeconomy

=> Room for Nordic initiatives!

International: The Bioeconomy & UN
-is the UN SDG´s a Nordic and an EU opportunity?

- Partnering in developing the New Bioeconomy for Africa *40% of all children will be in Africa 2050*
- **Green Revolution 2G**: microbes for resilient, sustainable Agriculture under Climate Change challenged conditions:
  - Stronger plants by microbial inoculants
  - More food, feed and fertilizer from crop residues
  - Agroindustry: value, food, feed and fertilizer from side streams
  - Creating local jobs -also for young people

Norman Borlaug, Nobel Prize Winner, the Green Revolution, was a Norwegian. Celebrated all over the world. Next celebration in Oslo? In a meeting where we focus on the 2G Green Revolution!

The green biorefinery

- New, decentralized
  - Small scale
  - On farm or in local community
- Feedstock: fresh green leaves, grass, clover, beets
- Simple processing: screw press, pulp and juice
- Low investment
- Mobile, seasonal variations

DK ex: Change in agricultural practice -shifting from cereals to grass?

Cereal (barley/wheat) stop photosynthesis 3rd week of July
=>No photosynthesis in August, September & October!

2X BIOMASS per hectar; less use of fertilizer
Full use of sunlight if changing to perennial **grass** and clover
$\Rightarrow$ Twice us much biomass!

½POLLUTION
Grass has better root system than cereals
=> lower negative impact on the environment (as less run off to freshwater and sea)

Green biorefinery: New valorization

- Soluble feed protein recovered by precipitation
- Additional protein extracted by protease treatment of pulp (Rubisco protein; for Food!)
- Prebiotic feed ingredients from hemicellulose
- Nutritious fiber for cattle feed
- Minerals for fertilizer: back to the soil!

Green biorefinery
= a Nordic opportunity?

Bulk Chemicals
- *organic acids, e.g. lactic acid*
- *solvents*
- *plastics (monomers)*

Fuels
- *ethanol*
- *butanol*
- *acetone*
- *ester*

Food/Feed
- *amino acids*
- *protein products*
- *peptides*

Fibre Products
- *fibreboards*
- *biocomposites*
- *insulation material*

Is Bio-based solutions relevant for arctics?

- More food, feed and fertilizer from crop residues and green grass; silage
- Agroindustry side streams upgraded to food and feed
- Household waste: converted to grow microorganisms on (= new biomass)
- Microbes for making more resilient, sustainable agriculture
  - Stronger plants by microbial inoculants
- Creating local jobs -also for young people
- Driver for rural and coastal development

Arctic symbiosis in Nature

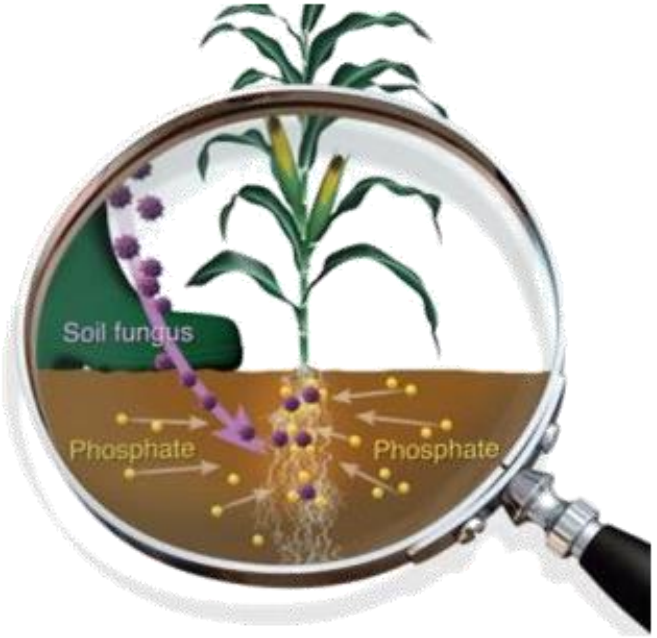
- The fungi are bigger than the trees!

The new BioAg products (ex)

- A new product: Jump start, commercialized in North America and South America
  - (by a Novozymes & Monsanto joint venture)
- Fungi like *Penicillium* can make plants more resilient to drought and low level of accessible nutrients
- Also bacteria like Yield Improving Bacteria (YIB) can stimulate expression of genes in the plant:
  - Nutrient efficiency, water efficiency and higher tolerance for diseases

Microbial value proposition, Inoculant example: Jumpstart

- Microorganism applied to the seed before planting
- The active ingredient, a soil fungus, grows on the roots and solubilizes the residual soil phosphate, unavailable for plant use
- Yield increases due to superior nutrient uptake in plant's early life stage
- Research: what happens between the fungus and the plant?



Value for both plant and fungus is reflected in their ”interaction secretome”

- Genomics focused on organisms, each studied in isolation
- Now we take next step: studying interaction
- Genomics focused on the genes; not on the biology: which are expressed; and that is the function of the proteins produced by the active genes
- The next step is to study function of proteins not interpreting biology only based on genes

What makes fermented and air dried meat and fish so delicious?

- Micro-organisms!
- Interacting with the meat and the fish; make meat and fish last long; but also adding flavor
- If we knew what was going on we might be able to diversify the products
- Modern molecular biology and bioinformatics can be used to understand the process

The Blue biorefinery for local development = a Nordic opportunity!

Sidestream valorization:

- Fish cut offs & by-catch => health promoting products

Biomass upgrade:

- Mussels, Seaweeds, Invertebrates & invasive species
- Year-round operations, several feedstocks
- Local, small scale opportunity ; attractive for investors

Aquaculture, new sustainable systems export:

Combining fish with mussels and algae; utilizing CO2 and nutrient run-off from agricultural fields

Macroalgae/seaweeds Value chains

Products:

- Food and Feed ingredients
- Health promoting compounds
- Cosmetics
- Wound healing

Components:

- Proteins, Alginate, Laminarin, Fucoidans, minerals, antioxidants

Technology & export, optimizing aa/feed, combining blue and green biorefinery

Health promoting feed ingredients:

- For Fish, Chicken, Pigs
- Protein substituting for soy
- Prebiotics to stimulate gut flora

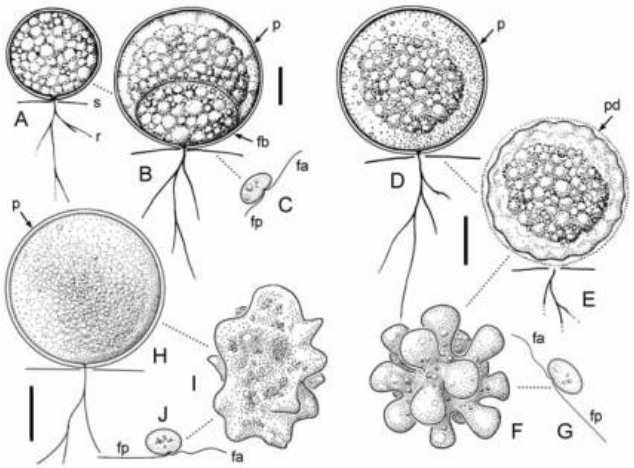
  => less antibiotics
- Export potentials in healthy food
  - Strong Nordic technology *(combining the green and blue)*
  - Good Nordic branding

Nordic Opportunities: Upgrade of household waste

- Decentral sorting and separation:
  - REnescience -steaming & liquefaction by enzyme treatment
- Processing
  - Cascading use of all organic components
- Products
  - Organic acids, Materials, Fertilizer, (Animal feed?)

- Challenges –steaming of organic waste => chemical residues from plastic bags!

New Nordic Opportunity? Microbial Omega3



Opportunity:

- Omega3 produced not by modified bacteria or plants but by a new type of organism:
  - **Thraustochytrium spp** (Sparrow: Aquatic Phycomycetes)
    - (Saprolegniales, fungal-like Oomycetes)

Challenge:

- Several patents but not commercialized;
- Too short Shelf Life / smelly and off taste

A new, sustainable and job creating opportunity for Greenland?

Glacial Rock Dust is a natural mineral product, produced over thousands of years by glacial action.

Greenland: Recovered before washed to the sea

It contains the full range of natural minerals and trace elements (active geology!)

Fertilizer use:

Agricultural and horticultural remineralization

Recommendations from the Danish Bioeconomy panel (all public! See links)

- **Yellow Biorefinery**: blend-in directive (is being implemented)
- **Green Biorefinery**: change agricultural practice; build 10 decentral Green biorefineries; develop feed!
- **Blue Biorefinery**: high potentials from mussels and algae
- **Household waste**: waste for electricity and heat to be phased out; use for biogas is current best practice; start introducing new technologies to use more of the organic waste fractions (Renescience/DONG)

Drivers & Obstacles for the bioeconomy

Drivers:

- Status 2016: Bio-Blend-in directives introduced in EU, incl penalty in some countries
- Proposal: bio-blend-in should count double when higher value cascading, making fuel for the residue only
- Introduce stronger requirements for %recycling. Proposal: Higher price for waste if too low &recycling

Obstacles:

- Regulatory Obstacles for commercialization of waste-derived products –also if safe. Proposal: Nordic countries to take initiative to inventory and change!

Bioeconomy can lead to

significant steps towards climate change mitigation!

- More sustainable Biomass available in DK:

  ”The +10mill tonnes Plan”, 2015, AU and KU

- Fall 2016 impact calculated of using such biomass for upgrading to biofuel, substituting for fossils =>
- Surprising effect on total CO2 emission from DK:
  - **Total DK CO2 emissions down with 14-21%!**
  - However, Low incentive for change

UNEP: “Feeding the planet’s ever-expanding population, while dealing with climate change, will require a new way of thinking about agriculture”

Nordic Opportunities

- **Together, Building markets** for biobased products faster
- **Funding: BBI call,** Nordic Universities & Nordic Companies
- **Contribution to** developing the New Bioeconomy for **Africa**
- **Collaboration** in ÈU between New Member States, the Baltics and Nordic countries

  -sharing pilot facilities at new Biorefineries (5 more!)

  -priority to high value products *(unlocking the full potentials)*

Nordic impact in EU:

- Skills and competence building
- Market-driving incentives coordinated and installed
- Regulatory EU impacted, to remove obstacles

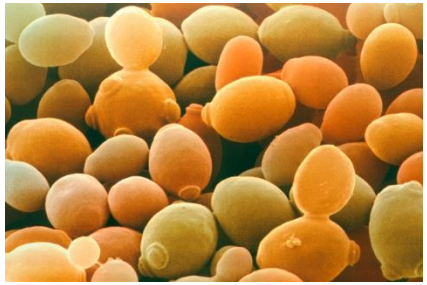
Nordic countries to be leading in Bioeconomy!

For a more Sustainable world

and

For Social and Economic benefits:

- Jobs!
- Technology & Export
- New biological solutions
- & Rural and Coastal development



Strategic thinking & Sense of urgency needed!