THE BIOECONOMY, THE CHALLENGE OF THE CENTURY FOR POLICY MAKERS

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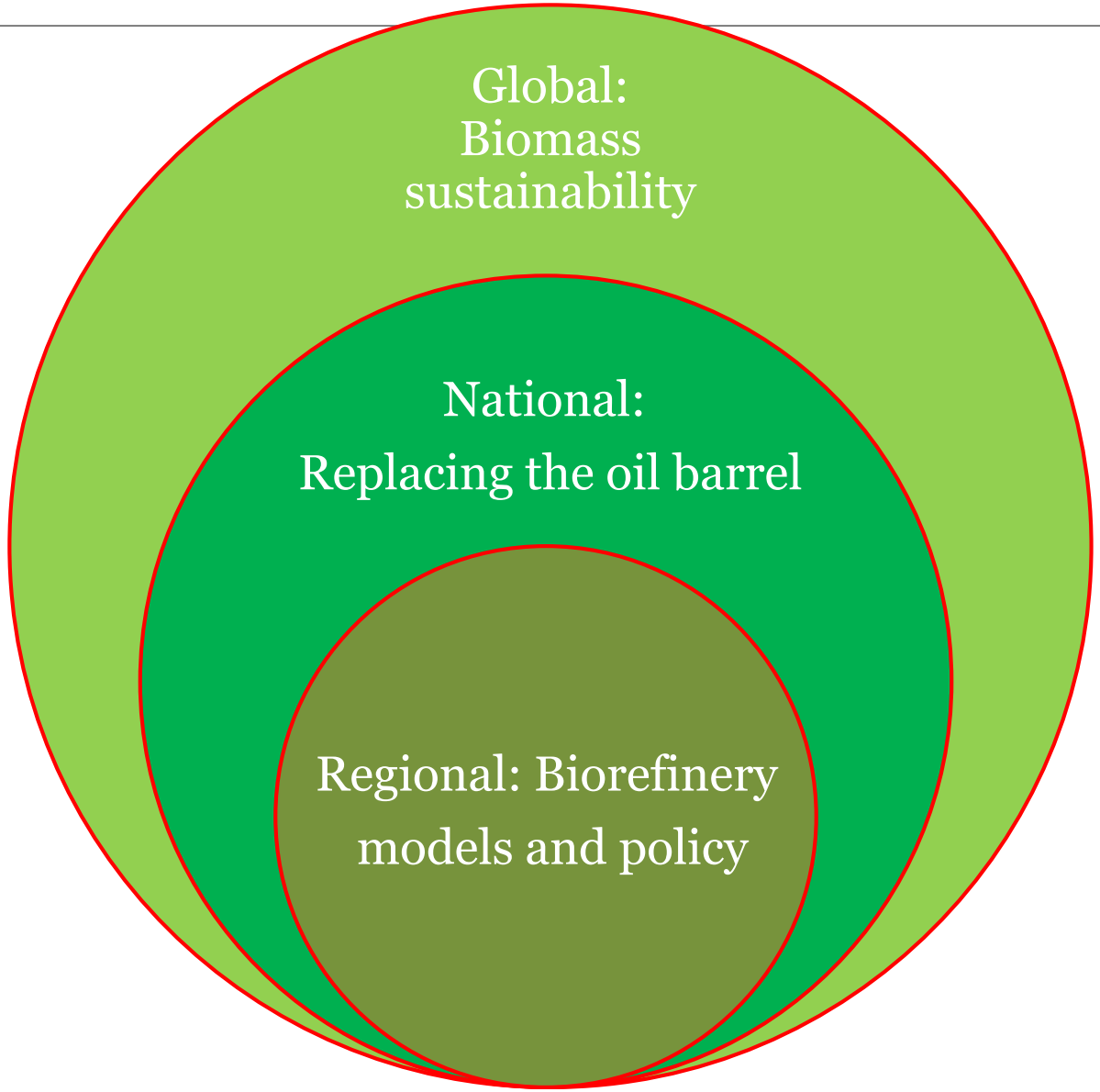
BETTER POLICIES FOR BETTER LIVES

Biennium 2015-2016

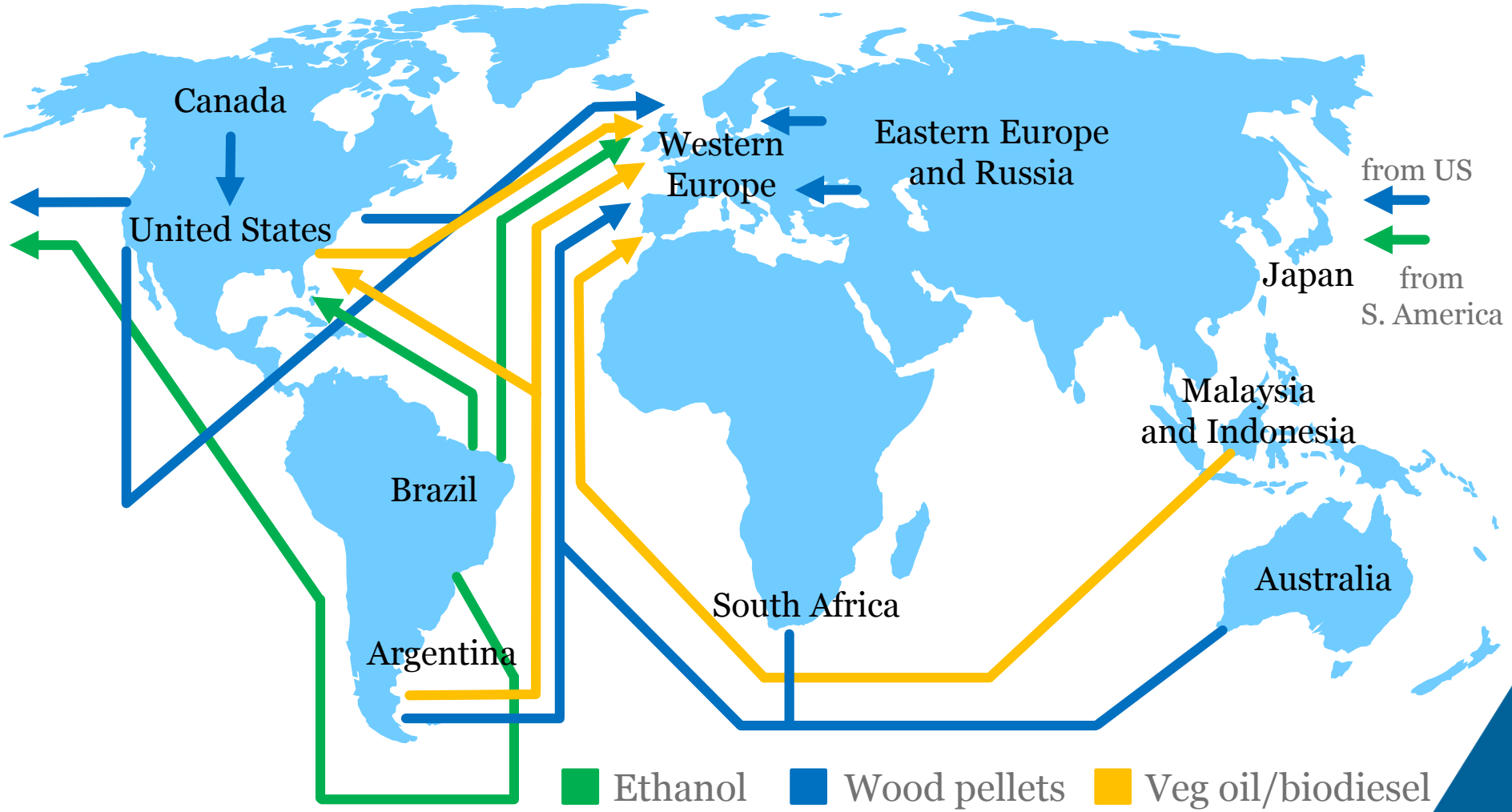


BIOMASS SUSTAINABILITY

Bioeconomy and the SDGs

El-Chichakli et al. (2016). *Nature* 535, 221-223

Biomass trade 2011: All routes lead to OECD countries



Redrawn from BP-EBI (2014). Biomass in the energy industry. An introduction. Pub. BP plc, London, UK

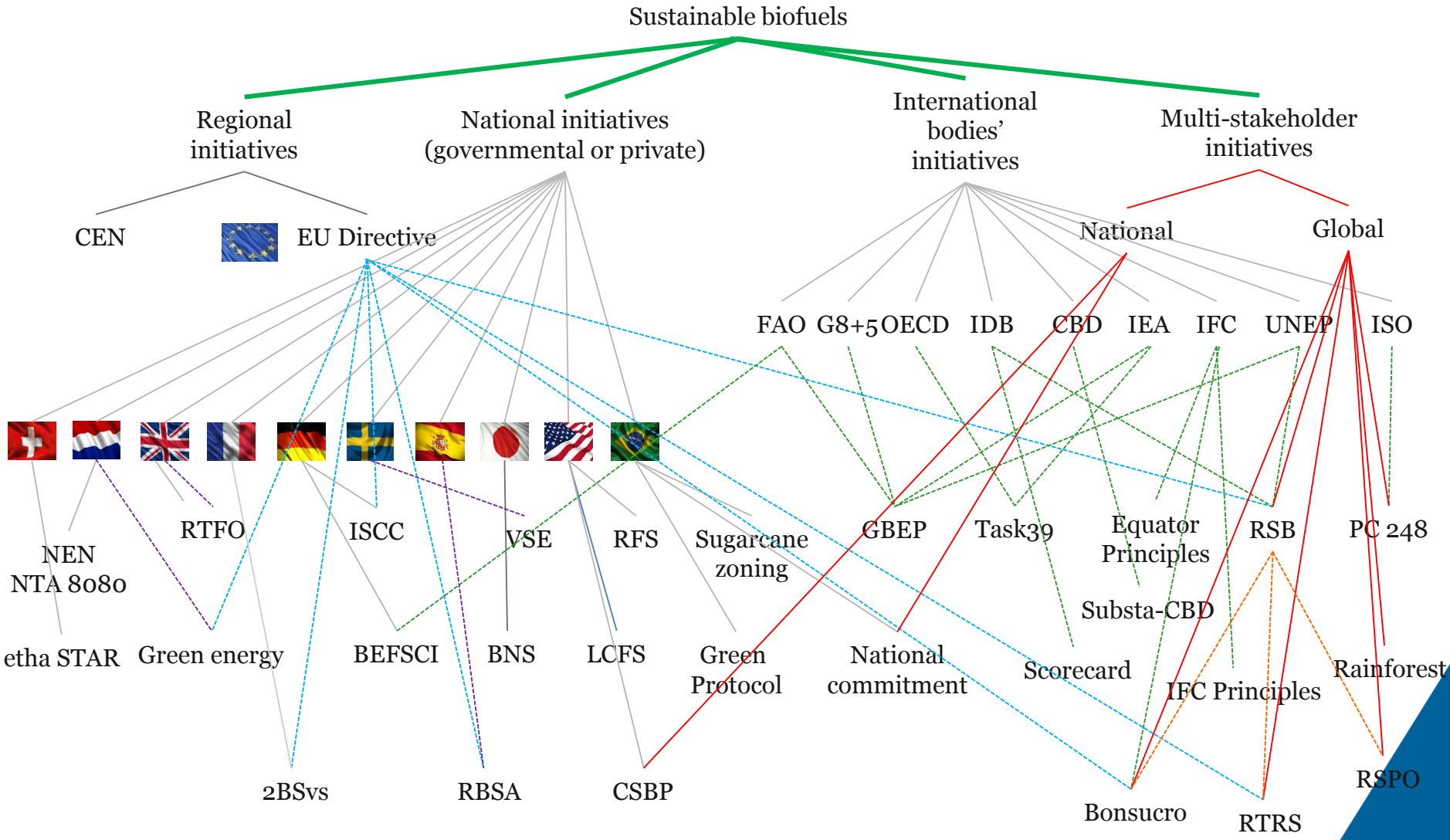
An international biomass dispute settlement facility ?

- Sustainable biomass conflicts will increase in future due to the increasing pressure on available fertile land
- Can't rule out violent conflicts and warlordism in future
- The issues relate to:
  - **Human rights** (land rights, worker's rights, local economies)
  - **Environment** (effects on soil, land, air, biodiversity and climate)
  - **Economics** (international trade, market distortions, property rights and business-to-business conflicts)

Biomass sustainability

- Food comes first
- Lacking internationally agreed criteria and tools for measuring solid biomass sustainability
- Soil degradation rates are much higher than restoration
- "*More with less*": land extensification prospects are lower than increased efficiencies
- Social aspects: land rights, workers' rights – needs strong governance

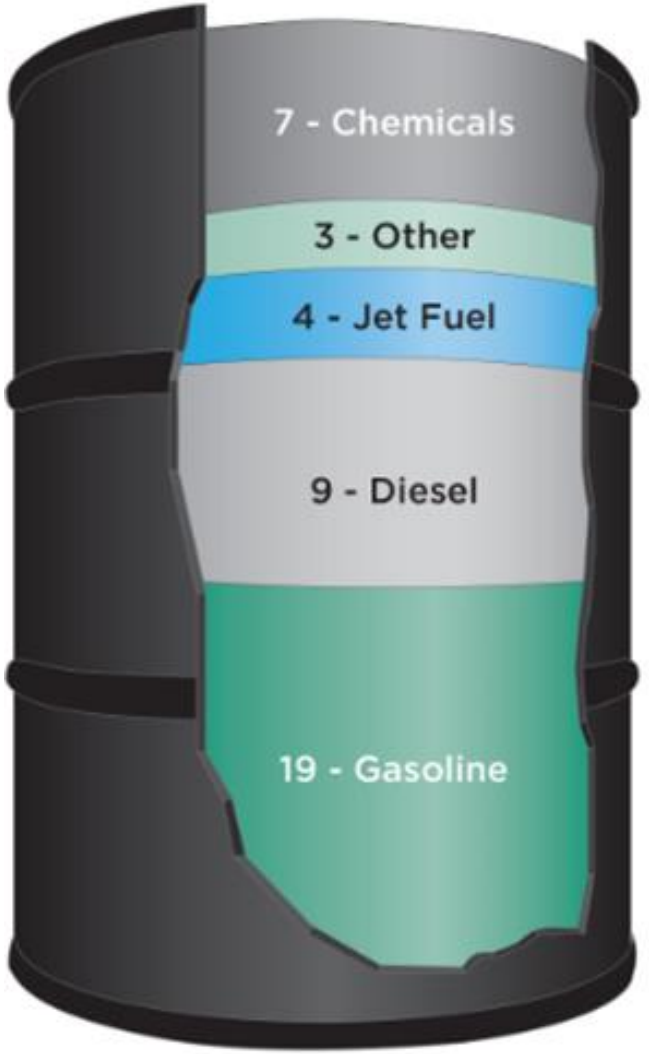
Star wars or biofuels sustainability



REPLACING THE OIL BARREL

The value-added message

- Only ~40% of a barrel of crude oil is used to produce petroleum gasoline
- **Fuel** makes up **76%** of the volume of US oil products and is worth **~USD 935 billion**
- **Chemicals** make up **17%** of the volume of US oil products and is worth **~USD 812 billion**



Biotechnology lagging way behind

- BioPreferred programme: over 15,000 bio-based products listed on-line
- Over 30 bio-based chemicals at TRL 8.5 - 9
- Metabolic engineering: a handful at commercialisation
  - Many research successes
  - Why not more commercialisation?
  - System failures

Bottlenecks everywhere

- Robustness of production strains
- Titre, yield, productivity
- Computational enzyme design
- Chassis cells and biocontainment
- Microfluidic fermentation systems
- Reproducibility challenge
- **Lack of systems integration**

10 integration strategies (Lee & Kim, 2015)

1. **Project design**: objective and strain metrics should be designed based on various technical, economical, legal and regulatory factors
2. **Host strain**: *E. coli*, *S. cerevisiae*, *C. glutamicum*, others
3. **Metabolic pathway reconstruction**: candidate enzymes, genes through mining genomes and metagenomes
4. **Increase tolerance to product**: robustness
5. **Remove negative regulatory circuits**: to allow overproduction
6. **Reroute fluxes**: optimise cofactor and/or precursor availability
7. **Diagnose and optimise metabolic fluxes**: to maximise flux towards the end product
8. **Diagnose and optimise microbial culture conditions**
9. **System-wide gene manipulation**: further increase production
10. **Scale-up fermentation of developed strain**: additional problems can be found during the scale-up

Lee & Kim (2015). *Nature Biotechnology* 33, 1061-1072.

National infrastructure to support SMEs developing a bioprocess

- Carry out **market analysis** with businesses or partners with technology or defined market need

- Set up a team of technology, market and commercial professionals to **design assets** to develop a range of technologies which meet the market need

- **Combination of private and public investments**

- Private companies use the assets and expertise to prove, develop and scale-up for commercialisation

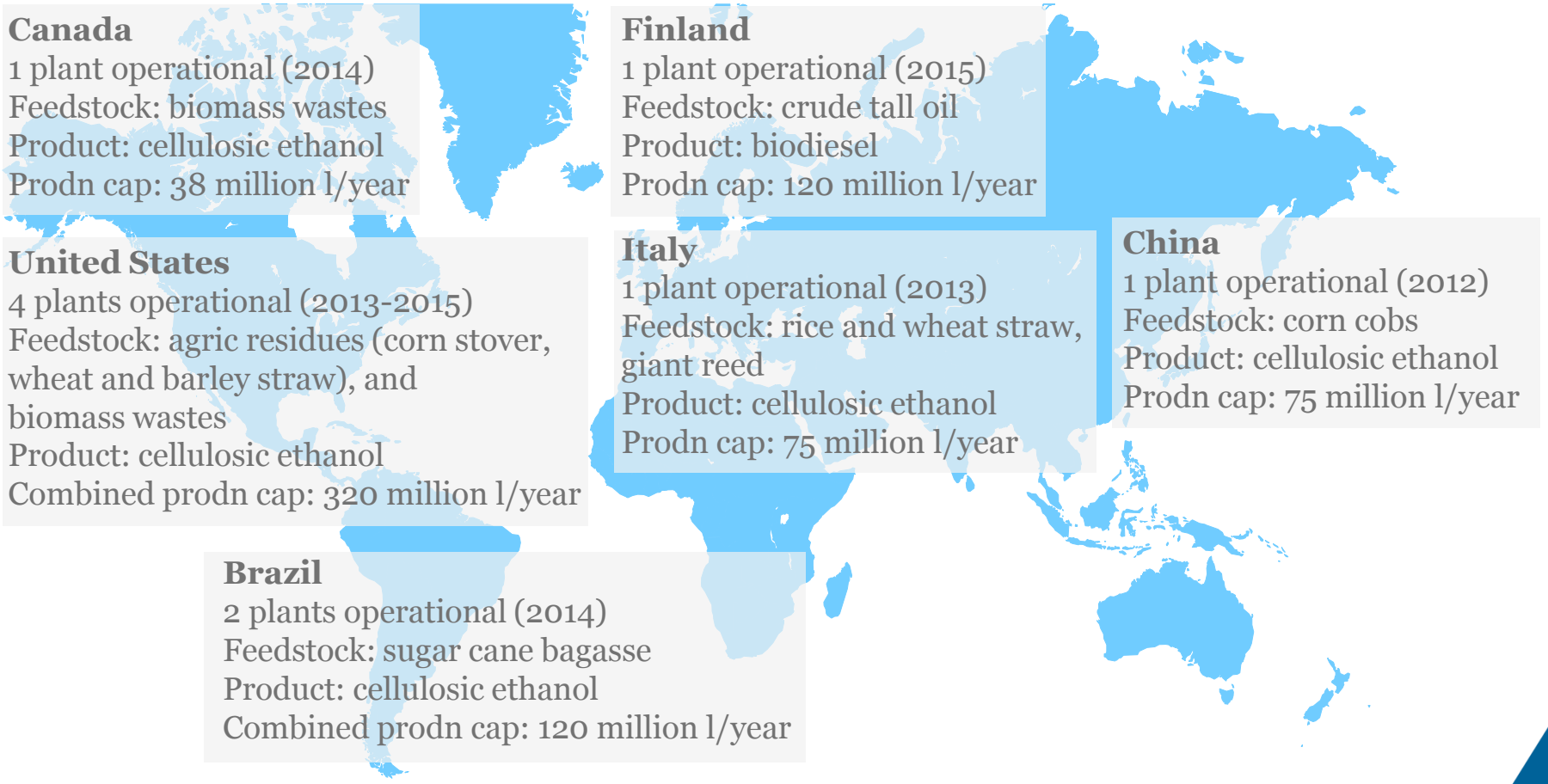
- Companies then **invest their own funds** to take the technology to market

- Assets are retained and developed by CPI for use by other companies and projects to **build a national capability** in the sector

Courtesy of CPI, Redcar, UK
www.uk-cpi.com

BIOREFINERY MODELS AND POLICY

Cellulosic ethanol a mere trickle



Canada
1 plant operational (2014)
Feedstock: biomass wastes
Product: cellulosic ethanol
Prodn cap: 38 million l/year

Finland
1 plant operational (2015)
Feedstock: crude tall oil
Product: biodiesel
Prodn cap: 120 million l/year

United States
4 plants operational (2013-2015)
Feedstock: agric residues (corn stover, wheat and barley straw), and biomass wastes
Product: cellulosic ethanol
Combined prodn cap: 320 million l/year

Italy
1 plant operational (2013)
Feedstock: rice and wheat straw, giant reed
Product: cellulosic ethanol
Prodn cap: 75 million l/year

China
1 plant operational (2012)
Feedstock: corn cobs
Product: cellulosic ethanol
Prodn cap: 75 million l/year

Brazil
2 plants operational (2014)
Feedstock: sugar cane bagasse
Product: cellulosic ethanol
Combined prodn cap: 120 million l/year

Peplow (2014). Cellulosic ethanol fights for life. *Nature* 507, 152–153.

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.

BETARENEWABLES

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

WHAT ABOUT JOBS?

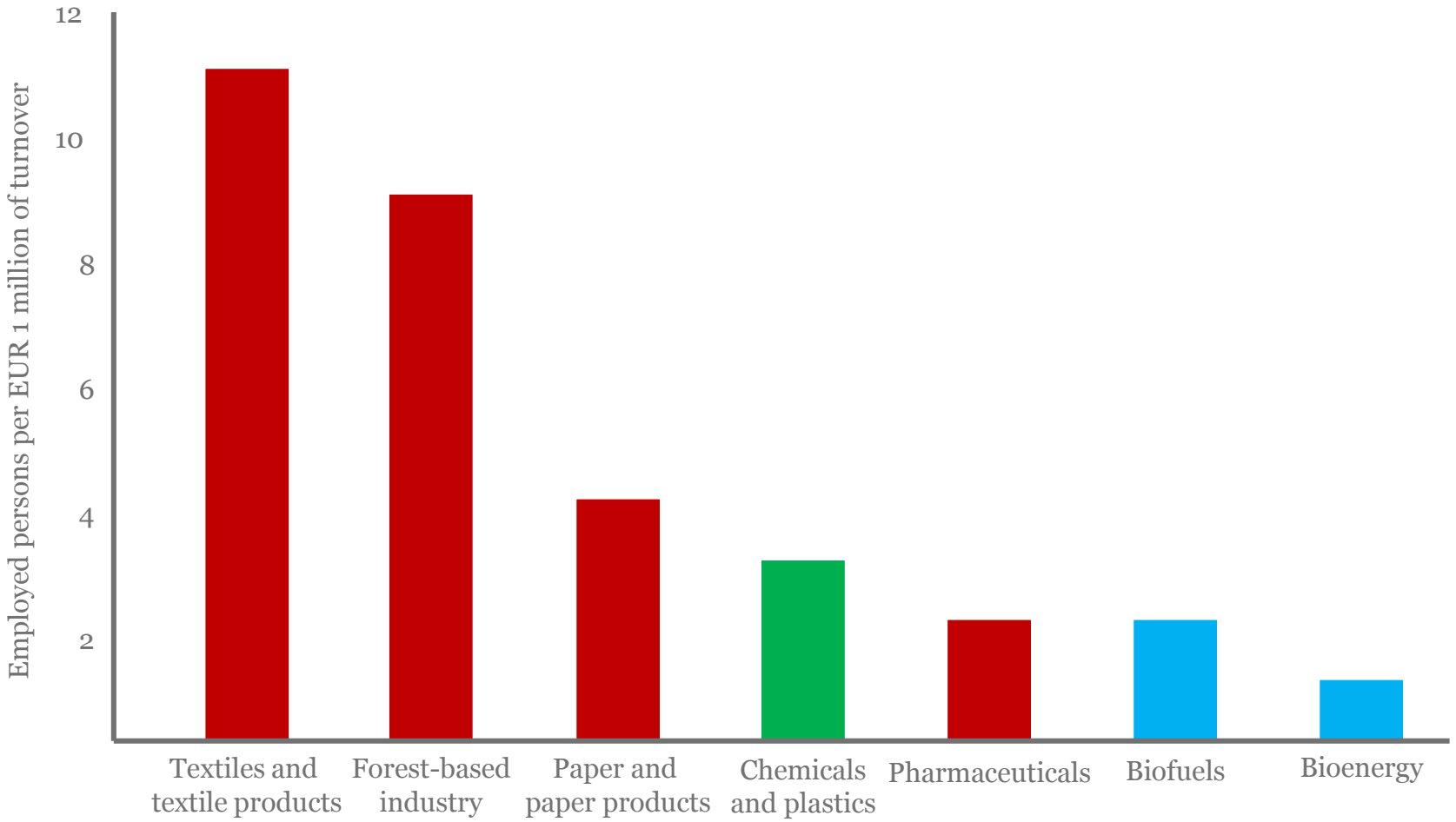
US jobs and sales (2014) of the bio-based industry

In 2014, the industry:

- Supported a total of **4.2 million** American jobs through direct, indirect and induced contributions
- Contributed a total of **USD 393 billion** value added to the US economy
- Generated 1.76 jobs in other sectors of the economy for every bio-based job
- Generated **USD 127 billion in direct sales**, and
- **USD 266 billion in spillover sales**

USDA (2016). Fact Sheet: An economic impact analysis of the U.S. biobased products industry: 2016 Update

Employment per turnover in the EU



Piotrowski et al. (2016). European bioeconomy in figures. Report of the Nova-Institute, Cologne.

SKILLS AND EDUCATION

Not just about research: build skills and courses with industry

IBioIC, Scotland

- Modern Apprenticeships
- Higher National Diploma (HND)
- UK's first collaborative MSc in Industrial Biotechnology
- PhD studentships with universities across Scotland and industrial partners across the UK
- SynbiCITE and IBioIC are bringing a **4–day MBA** to Glasgow in November 2016

https://www.ibioic.com/skills.htm

A BIOECONOMY POLICY FRAMEWORK

Bioeconomy Strategies: long on talk, short on policy

Feedstock/Technology push	Market pull	Push and pull
Local access to feedstocks	Mandates and targets	Metrics, definitions, terminology
International access to feedstocks	Public procurement	Skills and education
R&D subsidy	Standards	Regional clusters
Pilot and demonstrator support	Labels, certification	Public acceptance, raising awareness
Flagship financial support	Fossil carbon taxes and incentives	Knowledge-based capital
Tax incentives for industrial R&D	Removing fossil fuel subsidies	Governance and regulation
Technology clusters		
SME and start-up support		

LOOKING FORWARD TO 2017-2018

Industrial and innovation ecosystems
Bio-production and the Circular Economy

Integrated biorefinery logistics

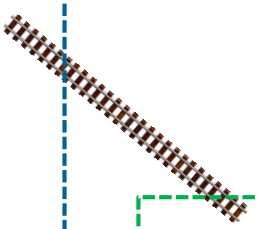
MSW

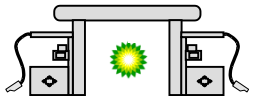
Urban

Coastal

Integrated Biorefinery

- *Imported biomass*
- *Agriculture*
- *Forestry*
- *MSW*
- *Waste gas*
- *Algae ?*

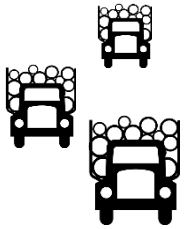




Rural

Biomass conversion and/or ethanol / biodiesel plant

Logging/forest residues

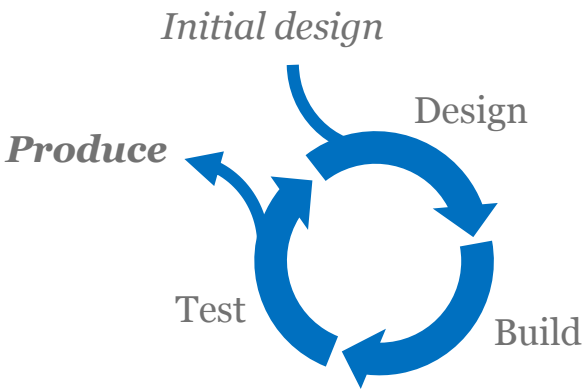


Farm cooperative

Neighbouring farms

Automation in the engineering cycle: **an international workshop?**

- DNA synthesis costs have plummeted
- Engineering cycle is blocked at the **test phase**
- A **fully multiplexed** design-build-test cycle that links phenotype to DNA sequence
- Algorithms are needed that incorporate **machine learning**
- Dedicated high-level **programming languages**



Thank you for your time

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