A ROUNDUP OF BIOECONOMY WORK AT DSTI

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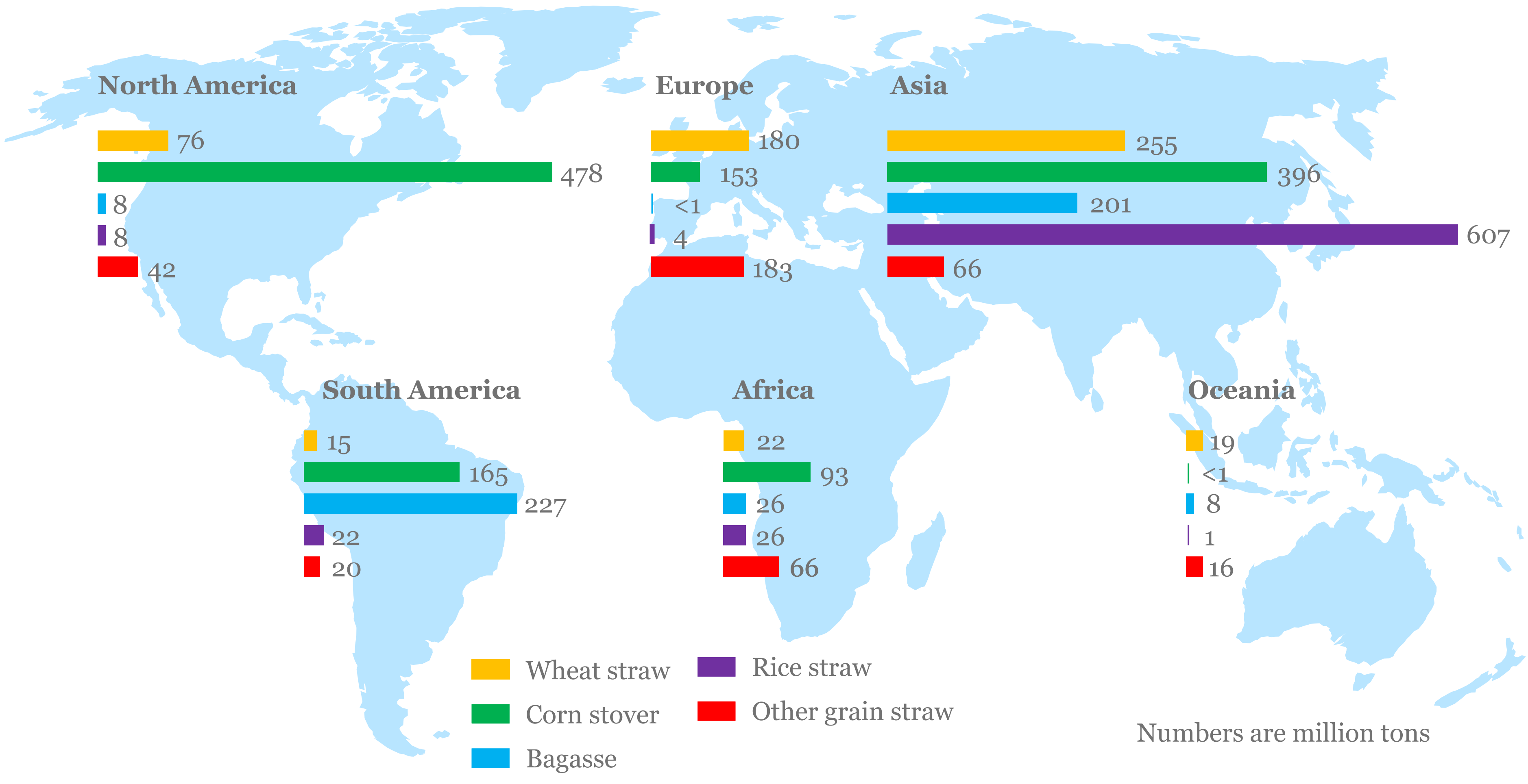
BETTER POLICIES FOR BETTER LIVES

BIOMASS SUSTAINABILITY

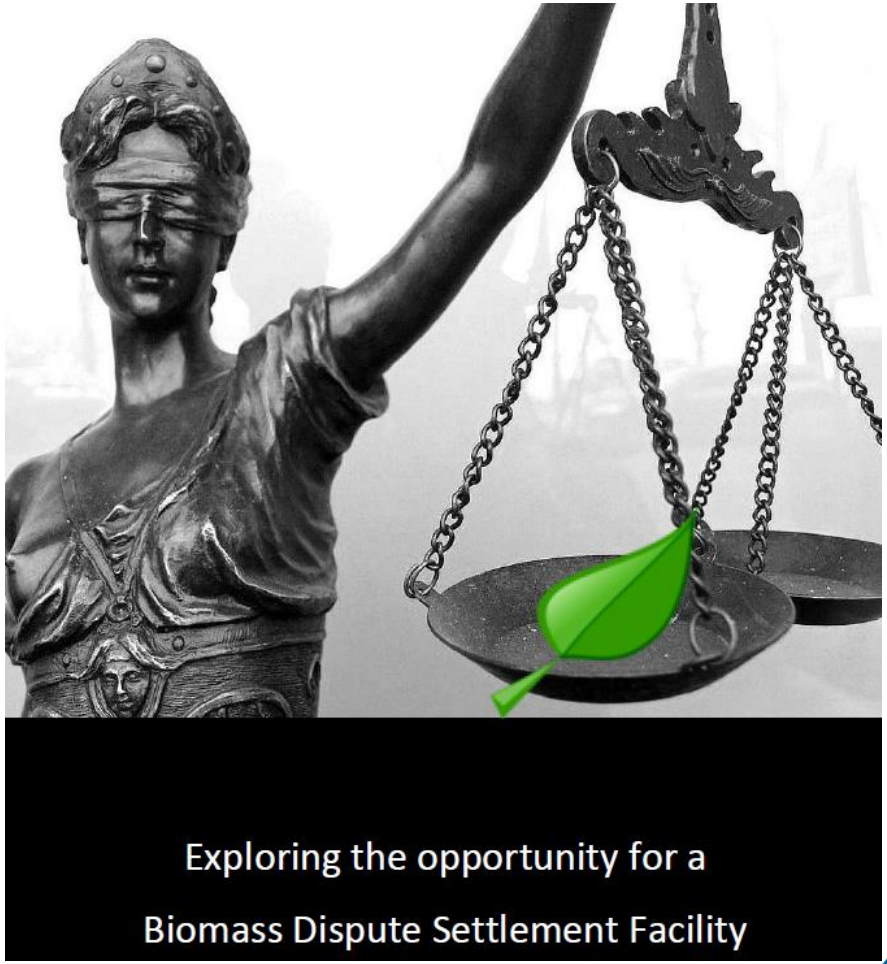
Main sources of lignocellulosic material around the world



Redrawn from KTN (2016). From Shale Gas to Biomass: the Future of Chemical Feedstocks. KTN, 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)



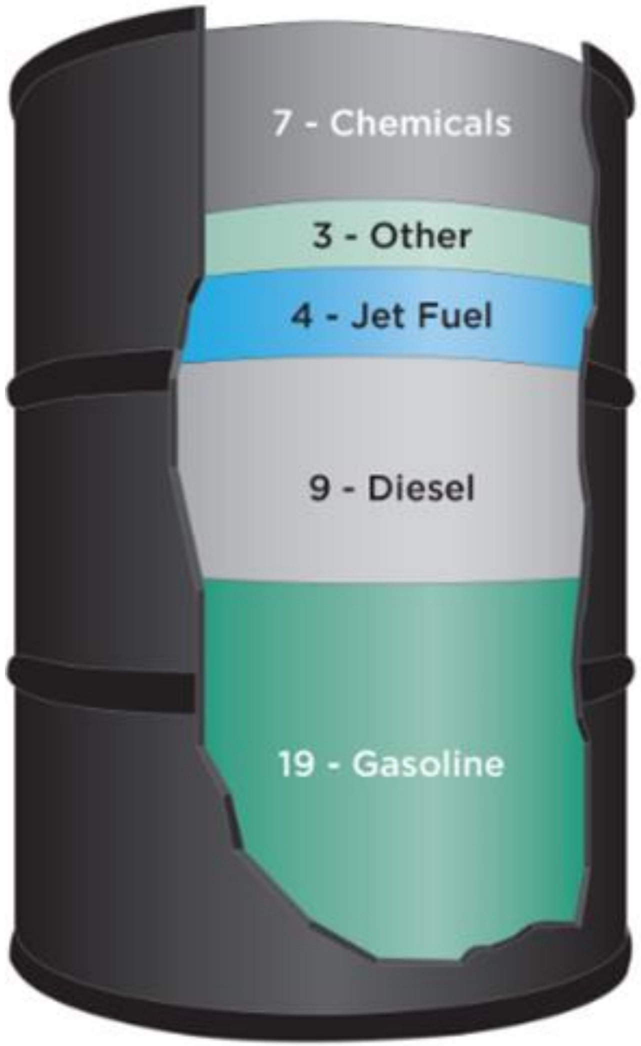
Top policy messages

- Food comes first
- But all feedstocks should be considered
- 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

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**



USDOE

Metabolic Engineering: Plenty of research success…

Class	Compound	Reference
Diols	1,3-Propanediol	Nakamura and Whited (2003); Maervoet et al. (2016)
	1,2-Propanediol	Clomburg and Gonzalez (2011); Lee et al. (2016)
	1,4-Butanediol	Yim et al. (2011); Burgard et al. (2016)
	2,3-Butanediol	Cho et al. (2015); Yang et al. (2016)
Bio-based plastics	Polyhydroxyalkanoates	Steinbüchel (2001); Escapa et al. (2011); Tokuyama et al. (2014); Chen et al. (2015); Chu et al. (2015); Kim et al. (2016)
	Polylactic acid	Jung and Lee (2011)
	PLGA	Choi et al. (2016)
Plastics intermediates	Muconic acid	Curran et al. (2013)
	Itaconic acid	Chin et al. (2015)
	1,5-Diaminopentane	Kind et al. (2014); Oh et al. (2015)
	1,3-Diaminopropane	Chae et al. (2015)
	5-Aminovalerate	Park et al. (2013); Rohles et al. (2016) ; Shin et al. (2016)
	3-Aminopropionic acid	Song et al. (2015)
	Gamma-aminobutyric acid	Dung et al. (2016)
Synthetic rubber	Isoprene	Lindberg et al. (2010); Ye et al. (2016)
Olefins (alkenes)		Chen et al. (2015); Kang and Nielsen (2016)
	1,3-Butadiene	EP2607340 (2013)
Spider silk		Xiaa et al. (2010); CEP (2015)
Biofuels	Butanol	Jang and Lee (2015); Gaida et al. (2016);
	Alkanes	Kageyama et al. (2015); Sheppard et al. (2016)
	Hydrocarbon fuels	Lee et al. (2015)
	Hydrogen	Srirangan et al. (2011); Tran et al. (2104); Rollin et al. (2015)

…but hardly any commercialisation

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

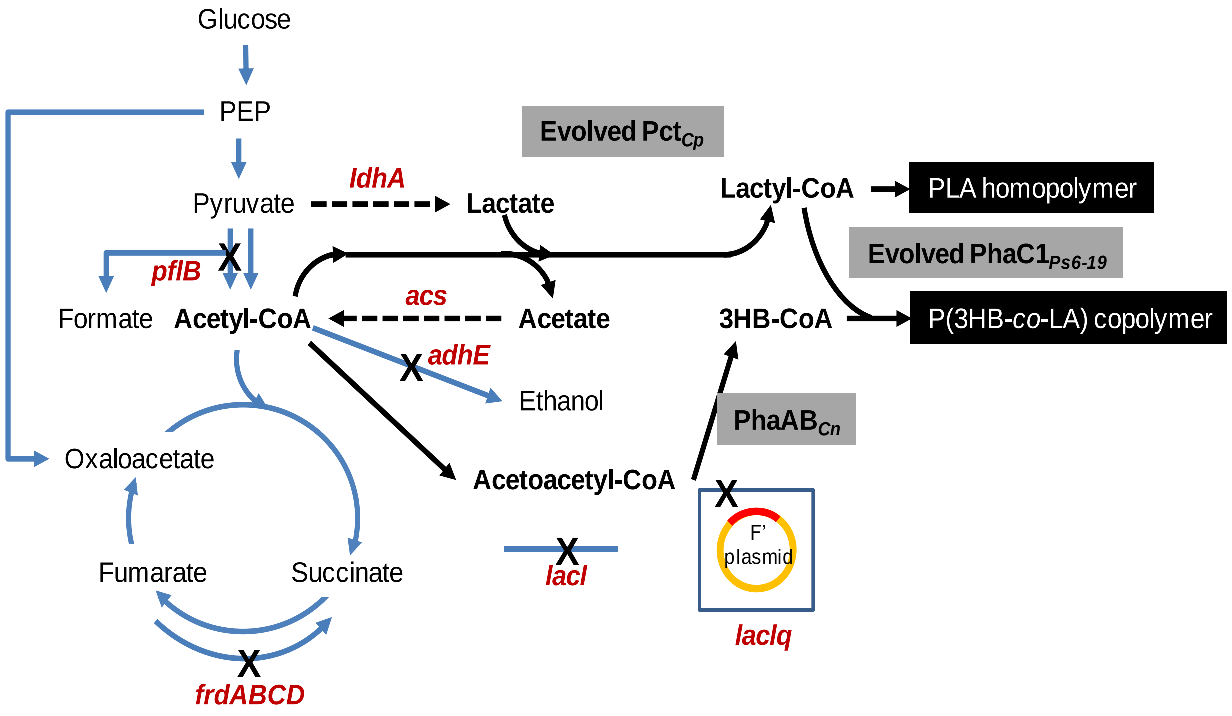
MATER BIOTECH

genomatica
sustainable chemicals

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

Top policy messages

- **Level playing field**: with fossil products and with biofuels and bioenergy
- **Capacity building**: most of the larger OECD economies are capacity building in industrial biotechnology:
  - Regional and technology clusters
  - Public-private partnerships
  - Forming and fostering spin-out companies
- **R&D subsidy**: towards automation, IT/computation convergence and systems integration
- **Measuring the impact of the bioeconomy**: mixed terminology, lack of definitions, which indicators to use



Jung and Lee (2011). *Biotechnology* 151, 94–101.

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
- Where are **loan guarantees** in Europe?

Cellulosic biorefinery, Crescentino, Italy.

The integrated biorefinery: the rural model can work

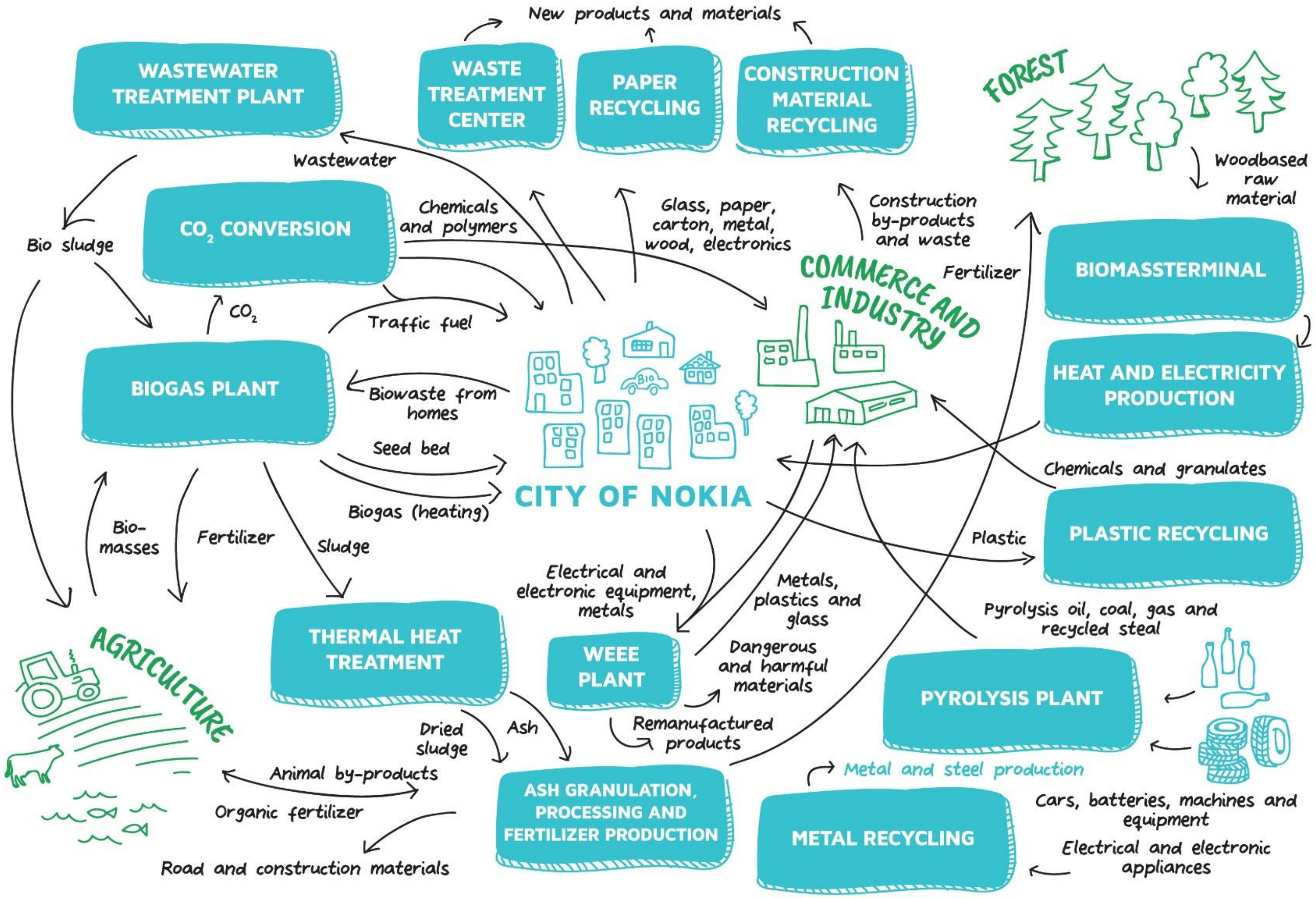
Top policy messages

- **Policy certainty, stability and consistency**: a **15-25 year competitive advantage** over fossil-based production?
- **Farmers and foresters cannot be ignored**: our work in Biennium 2017-2018
  - A sustainable bioeconomy needs sustainable forestry
- **R&D subsidy**: A need for balance between upstream R&D and downstream research closer to market
- **Biorefinery financing**: innovative hybrid PPP models
- **Flexible waste management regulation**: already there are challenges
- **Policy alignment**: how does biorefining fit with *Circular Economy*
  - Cascading use of biomass – much talk, little policy action

CURRENT BIENNIUM:
CIRCULAR BIOECONOMY ECOSYSTEMS

Preliminary observations on public policy

- **Clusters dominate** (but not in the US)
- Emphasis on R&D subsidy/ funding: **a warning** from Sweden
- Pilot and demonstration phase funding (Norway and Sweden examples especially noteworthy)
- Given the importance of climate obligations, little attention is paid to C price and taxation (Sweden notable exception)

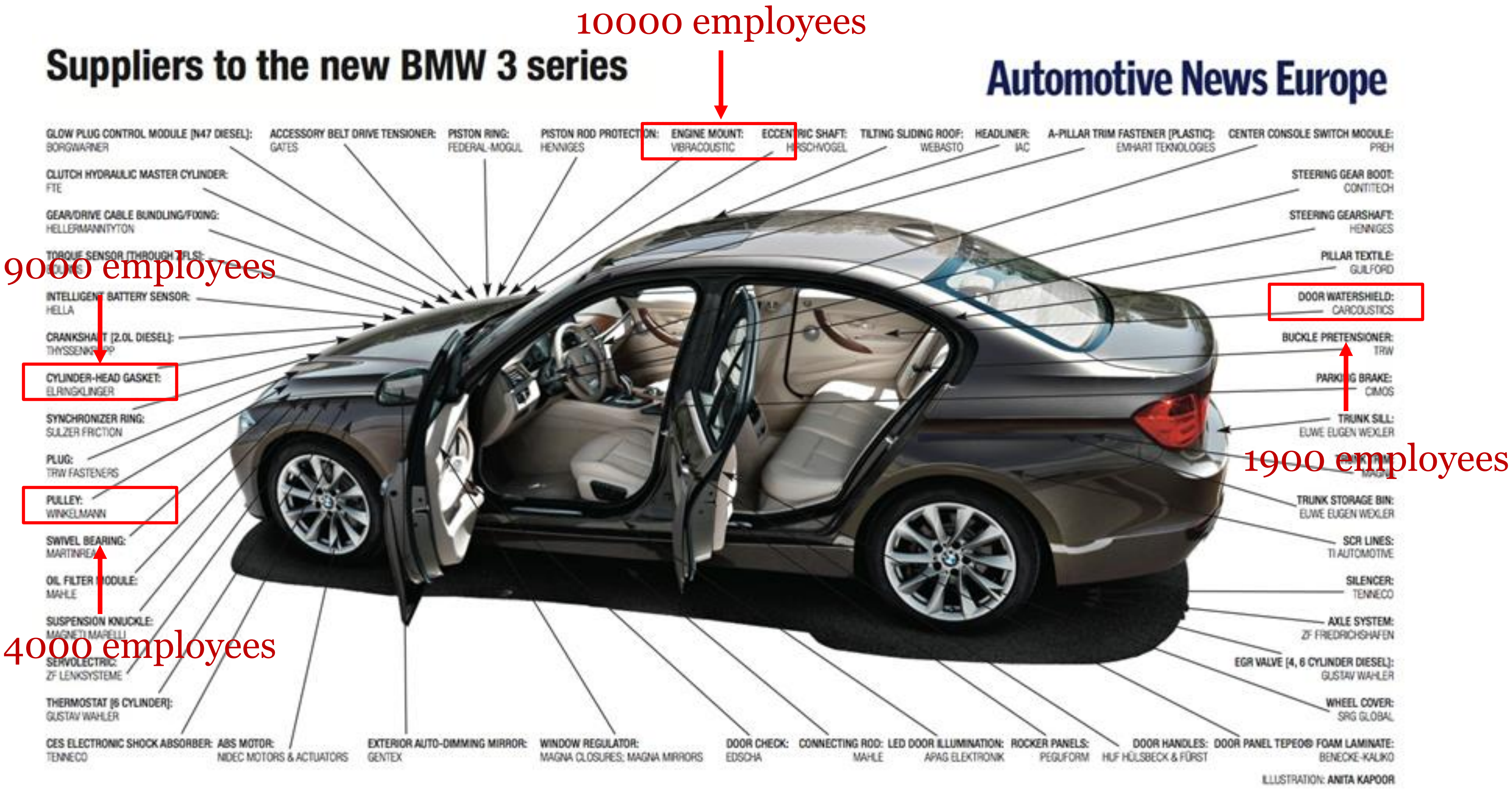


City of Nokia: ECO3's potential for innovative circular economy concepts

A significant emphasis on supply side measures

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	Governance and regulation
Tax incentives for industrial R&D	Removing fossil fuel subsidies	
Technology clusters		
SME and start-up support		

Where are the medium-sized companies?



THE NEXT TWO YEARS:
MEASURING THAILAND’S BIOECONOMY
ADVANCED BIOECONOMY INFRASTRUCTURES

Towards a bio-production policy framework

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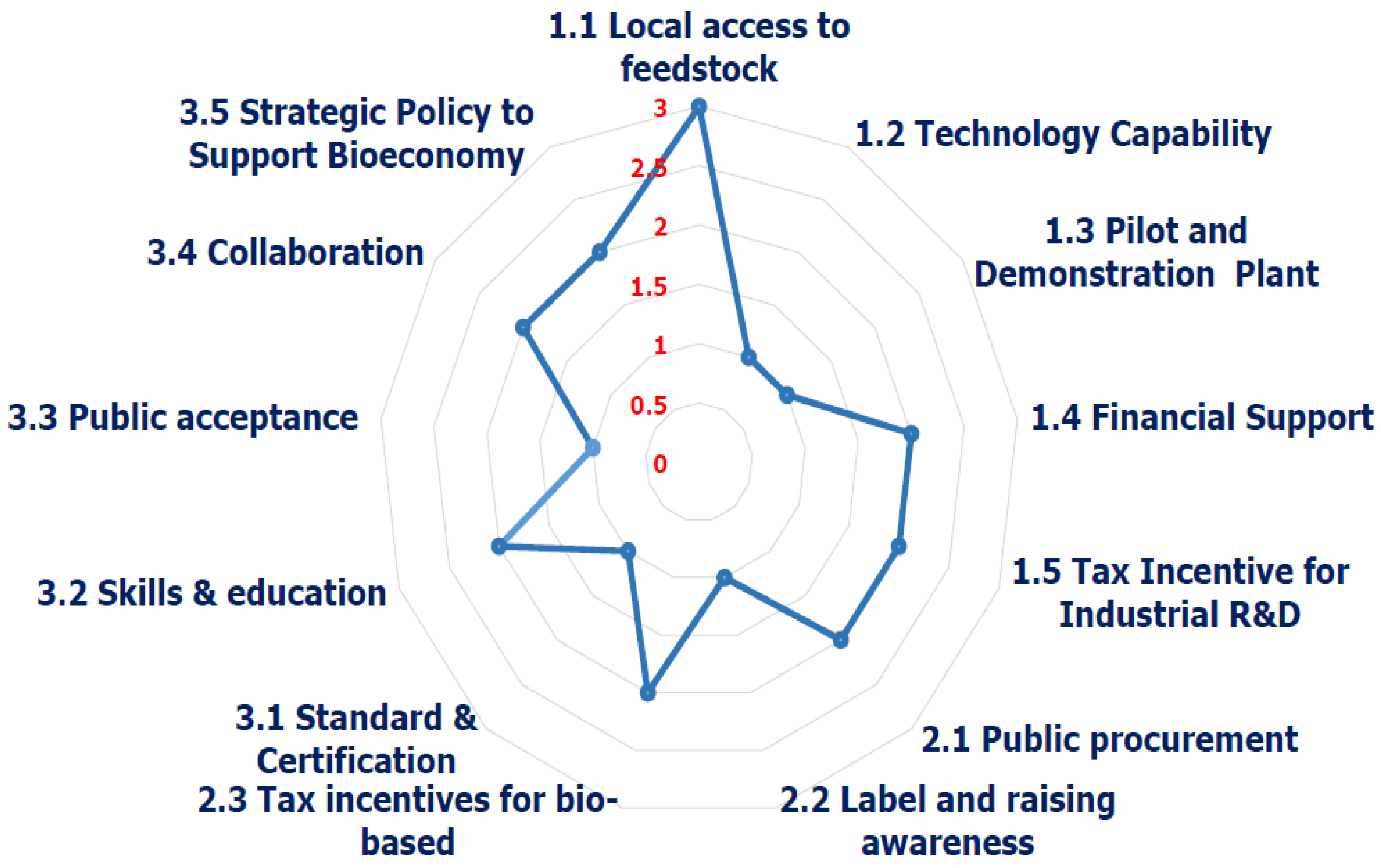
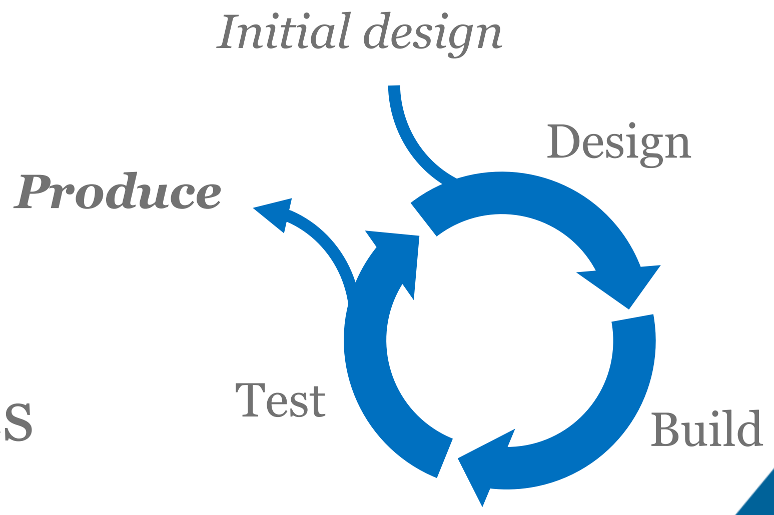
OECD (2018). Meeting policy challenges for a sustainable bioeconomy. OECD Publishing, Paris.

Measuring the Thailand bioeconomy



Automation in the engineering biology design cycle

- 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**
- **Skills and education** gap in the life sciences

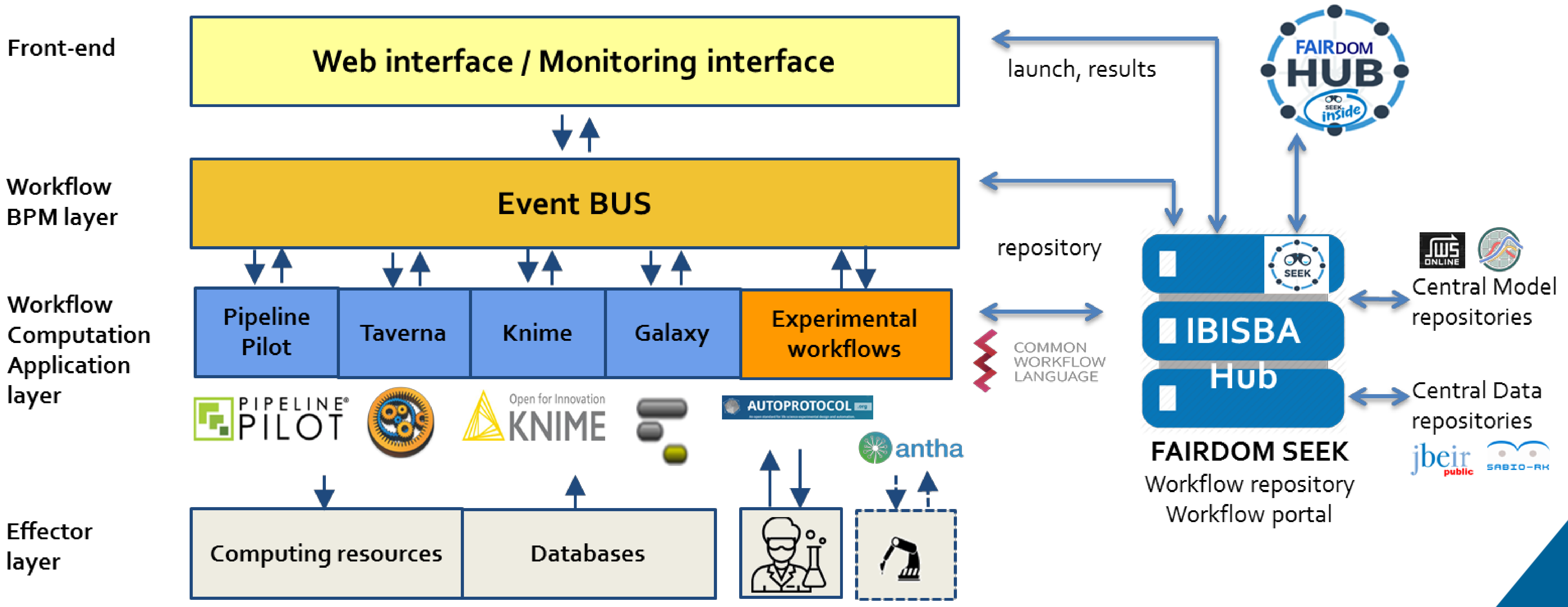


Centralised biofoundries or…

“That will make it easier for the process of designing new synthetic lifeforms to be scaled up from the bespoke boutique business it is now to **something more like a global industry**. That day is not yet here. But if there is demand, then biofoundries will surely play their part in the next phase of the Industrial Revolution”.

The Economist, March 01/2018.

…IBISBA distributed biomanufacturing architecture



Thank you for your time

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