Science, technology and the state:

the quest for knowledge-based governance in synthetic biology

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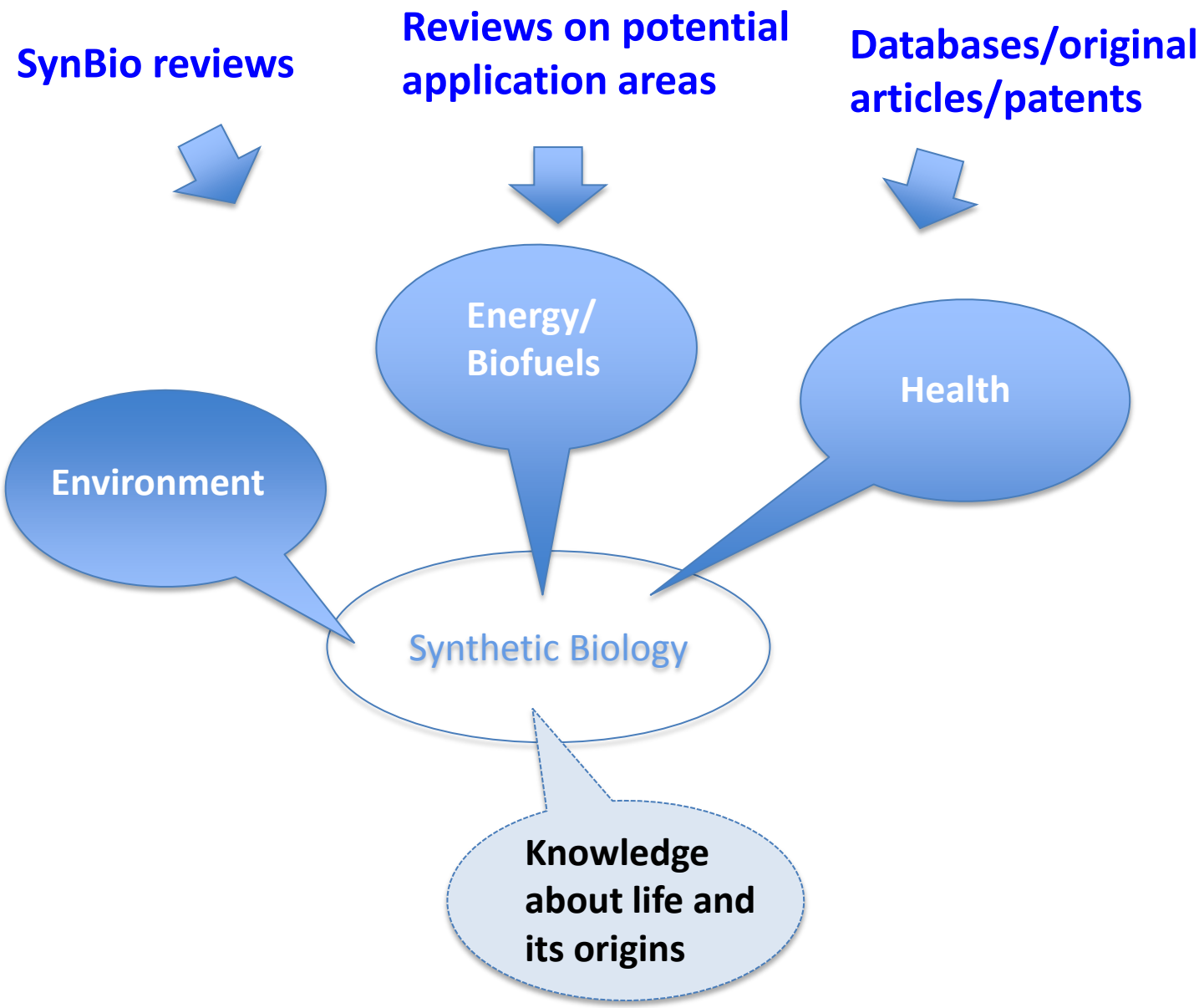
What are/may be SynBio approaches and applications?

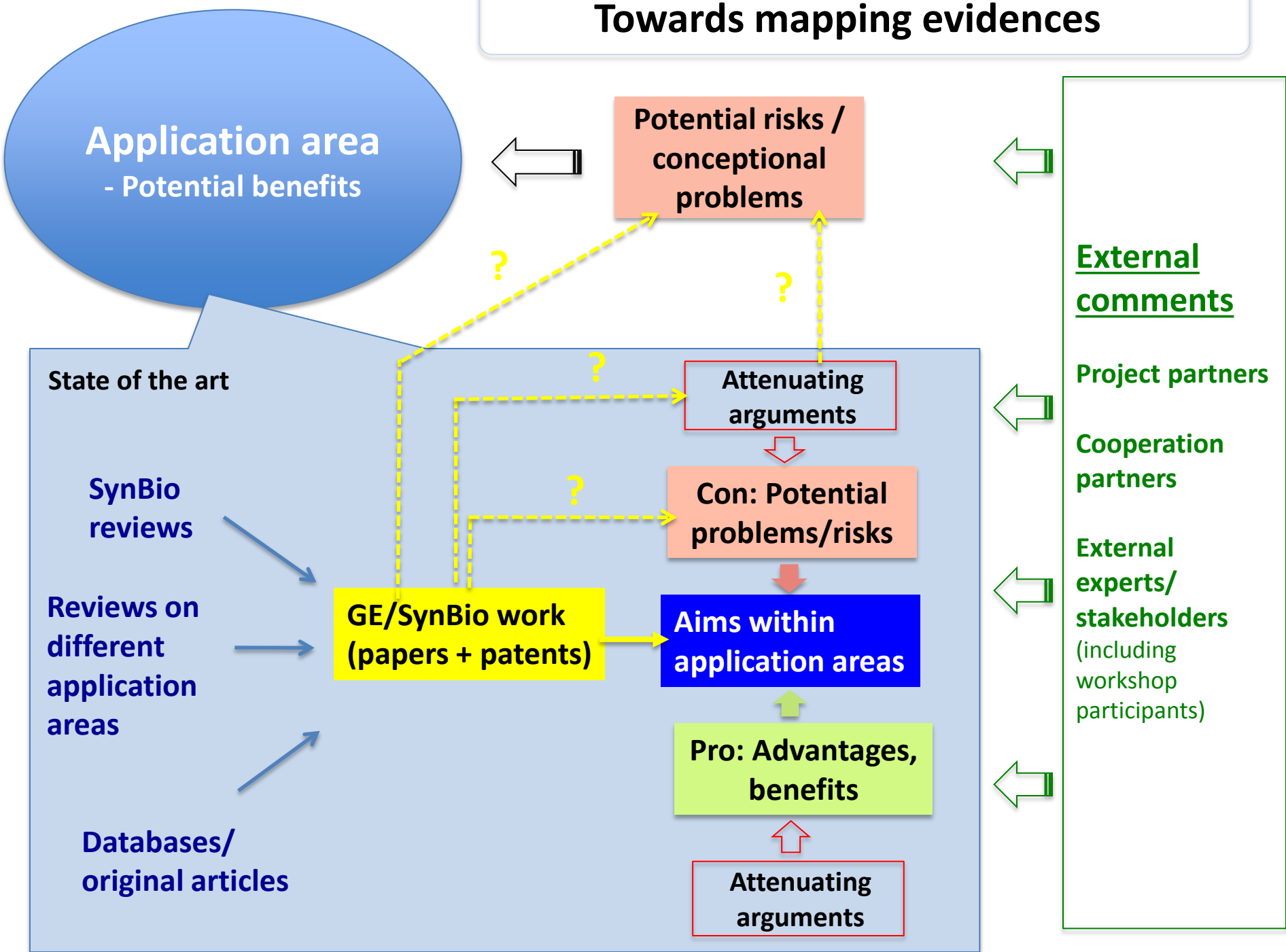
Dimensions of benefits and risks – implications for governance and knowledge-based policy-making

Are there new aspects introduced by SynBio?

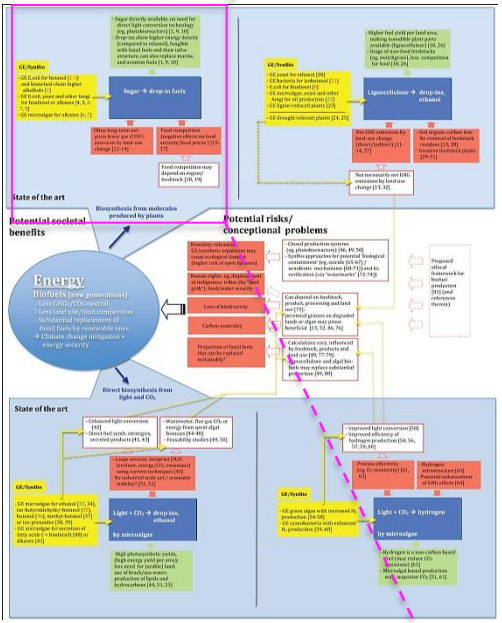
Politically and economically relevant fields with expected societal benefits from SynBio



Towards mapping evidences



Sugar → drop-in fuels



- Sugar directly available, no need for direct light conversion technology (eg, photobioreactors) [1, 9, 10]
- Drop-ins show higher energy density (compared to ethanol), fungible with fossil fuels and their infra-structure, can also replace marine and aviation fuels [1, 9, 10]

GE/SynBio

- GE E.coli for butanol [1-3] and branched-chain higher alkolhols [1]
- GE E.coli, yeast and other fungi for biodiesel or alkanes [4, 5, 6, 7, 8]
- GE microalgae for alkanes [6, 7]

Sugar → drop-in fuels

Often long-term net green house gas (GHG) emissions by land-use change [11-14]

Food competition (negative effects on food security/food prices) [15-17]

Food competition may depend on region/ feedstock [18, 19]

State of the art

Biosynthesis from molecules produced by plants

P

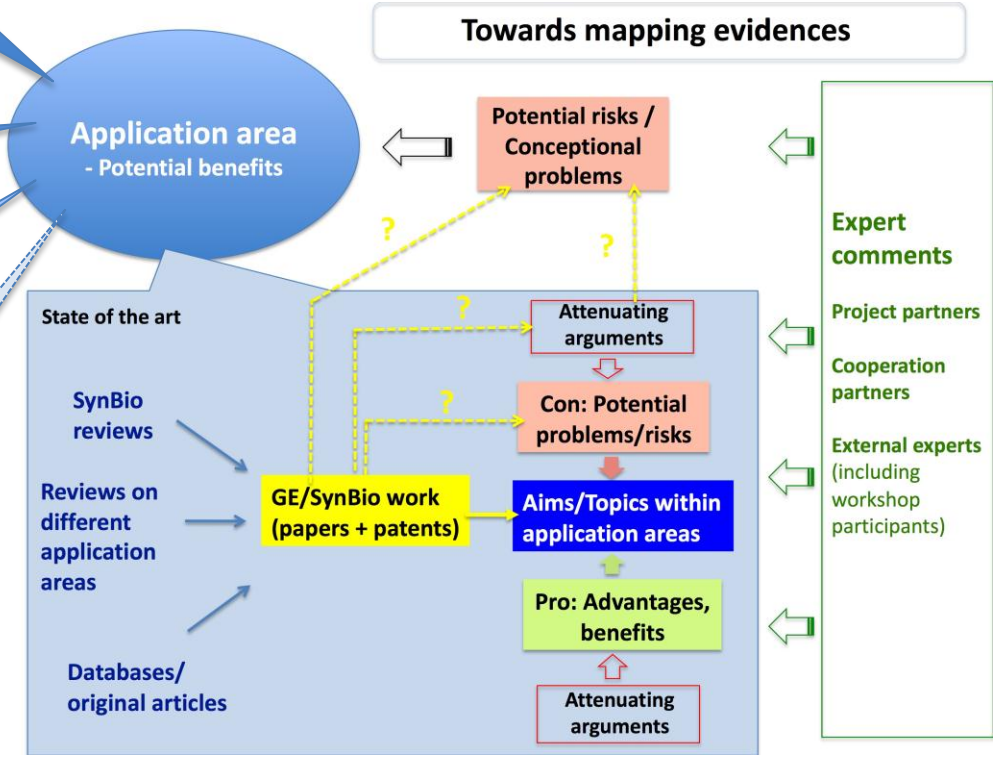
Potential benefits

Energy/biofuels
New generations of biofuels

Environment/ chemicals
Biosensors, bio-remediation, bio-based chemicals

Health
Drug production, 'living therapeutics', novel vaccines, vector control, therapeutic devices

Knowledge about life and its origin
Protocells, semi-synthetic cells, minimal genomes



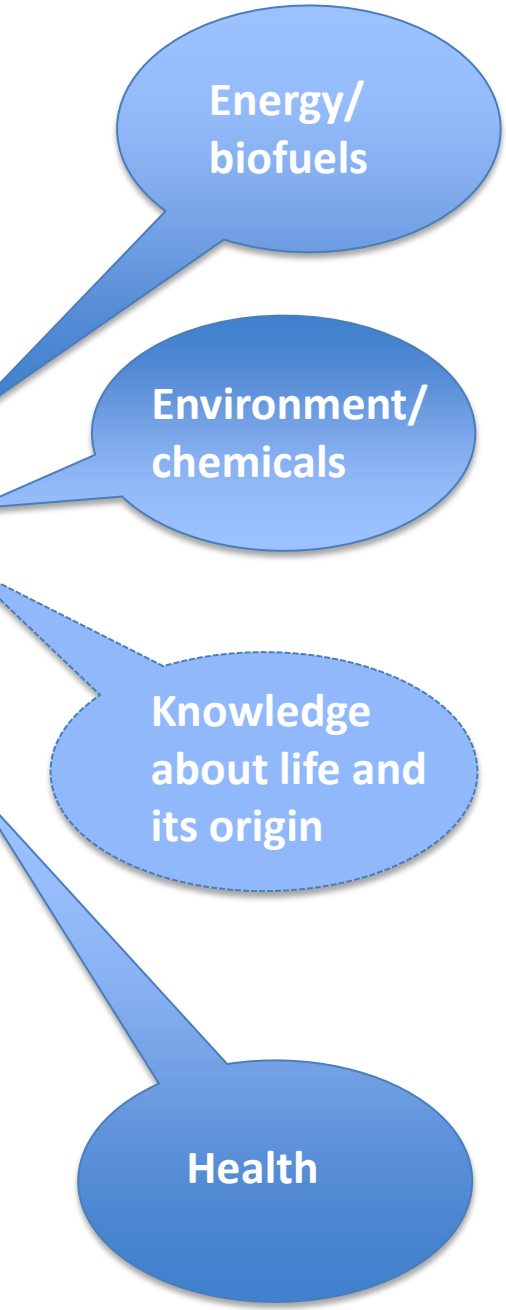
Evidence maps available at: egm**engineeringlife**.wordpress.com

Bundesministerium für Bildung und Forschung

Engineering Life
An Interdisciplinary Approach to the Ethics of Synthetic Biology

König et al., *Current Genomics* **14**, 11-24, March 2013

… and risks



Biosafety

Release of GE/'synthetic' organisms may have negative impacts on indigenous flora/fauna; loss of biodiversity
(e.g. algae, bioremediation organisms, 'synthetic life')

- **'Living therapeutics'**
  (Effects on patients, medical personnel)
- **Release of GE mosquitoes**

(Potential ecological damage/health issues)

Biosecurity

Easier acess to known pathogens by genome synthesis

Generation of pathogens with new functions or of 'new' pathogens
(by genome synthesis/ assembly, genome evolution techniques, metabolic engineering)

Socio-economics

Human rights: e.g. displacement of people, food/water security

Microbial synthesis of plant compounds may affect livelihoods of plant farmers

Broad patents/patent thickets may restrict access to technology/ products

Distribution of benefits from genetic resources

Microbial synthesis of plant-derived drugs may affect livelihoods of plant farmers

Benefits and risks may depend on issues linked to different layers

- Qualitatively not really new

- SynBio may make these issues more pressing

‘General‘ issues associated with application schemes

- Effects on biodiversity, water/food security/ land holder rights by biomass production
- Access to products and/or technologies due to broad patents/patent thickets
- Distribution of benefits from genetic resources

Depend on the way biomass is produced (SynBio may offer solutions)

Depend on the way patents/distribution of benefits are organized and applied

‘SynBio-specific‘ issues

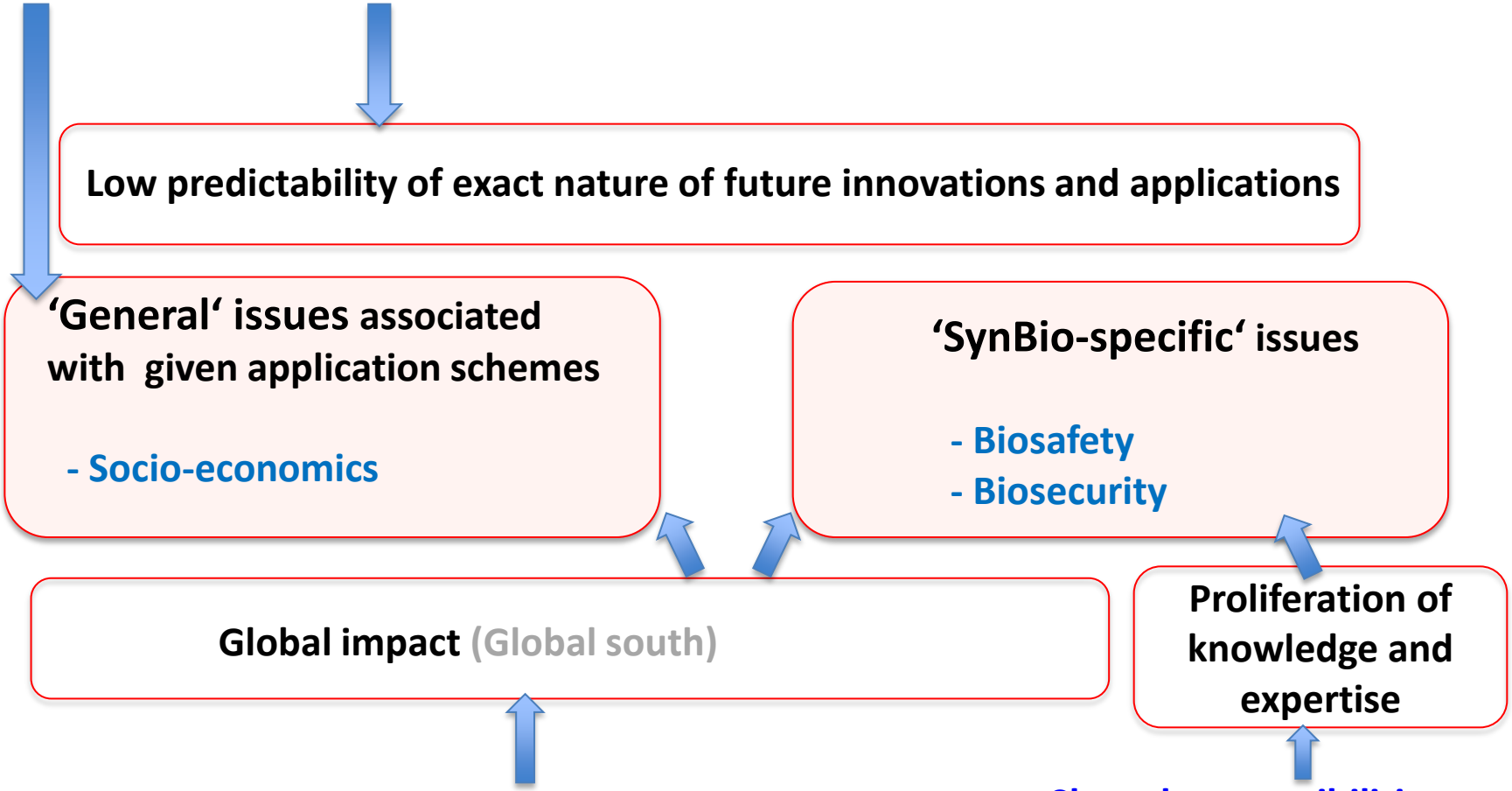
Qualitatively new

- Biosafety – risk assessment (in future)
- Biosecurity – synthetic/altered pathogens

Directly affected by SynBio technologies

Risk dimensions and implications for governance and responsibility

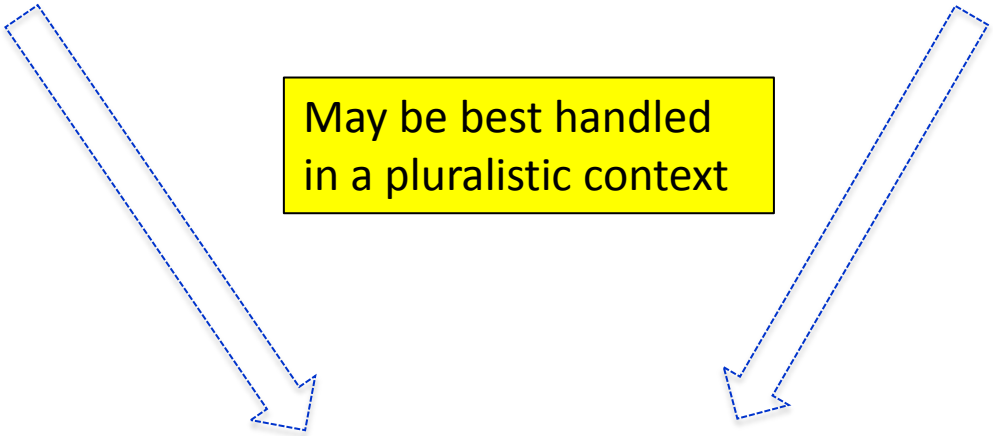
Broadly applicable and effective environmental, socio-economic and ethical standards (independent of the exact nature of the underlying technical approach)



Governance and responsibility: How to shape them?

Various layers of issues that underlie potential benefits and risks

Uncertainties from an emerging field



May be best handled in a pluralistic context

Governance should benefit from being informed by the **most pluralistic expertise and perspectives available**

Pluralistic input as part of knowledge-based policy making

Input:

*Most **pluralistic expertise/perspectives** possible*

Scientific expert knowledge ; TA **+**
perspectives/knowledge from potentially affected actors
[including stakeholders and the public(s)]

Participation; mutual learning

Conditions /(infra-)structures that can encourage and empower various actors

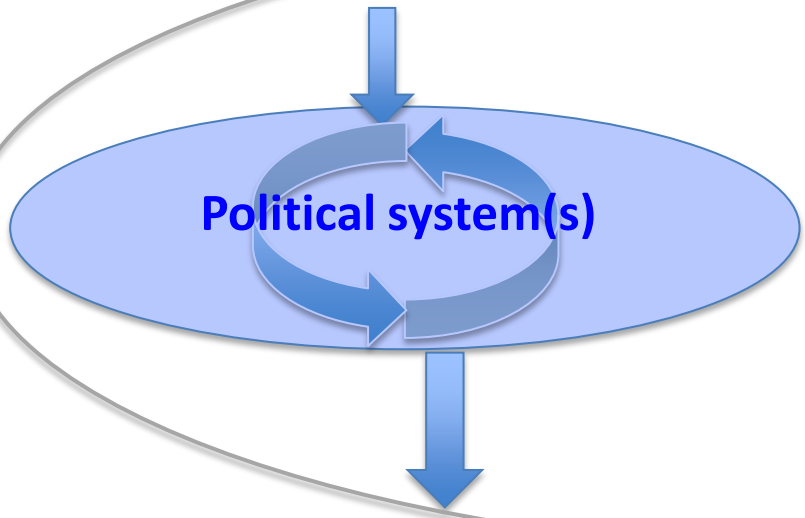
Output:

Efficacy (acceptance, accountability, control)
- justice (distributive/procedural)
- proportionality (benefits/risks)
- transparency

Getting the input right – and why this may not suffice

Input:

Most **pluralistic expertise** possible/
dialogue/participation



e.g.

Lack of independence of regulatory agencies

- regulatory capture/'revolving doors'
  [Regulation captured/manipulated by the players it is supposed to discipline]

State interests in 'own ventures'

- economic/financial interests
  [e.g. rise in state capitalism, "venturecrates", state-driven (applied) research/innovation programs]
- military/defense interests

Output: Inefficient policies/regulations

e.g. regulatory outcomes that are not in the public interest;
international treaties lacking compliance measures (BWTC)

TA
'Assessive capture' ?

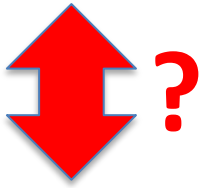
Is SynBio already shaped by vested ‘state‘ interests?

Governmental SynBio support:
often framed according to roadmapping/planning schemes and dogmatic engineering notions

→ “national strategic missions“: application-oriented science funding

Early emergence of a dominant set of methodologies/technologies

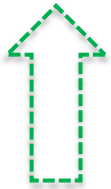
‘Strategic‘ interventions susceptible to capture



Cultures to manage uncertainty from emerging technologies

- **Science/innovation culture**
- **Safety culture**

- Science/innovation culture
- Safety culture



Political system(s)
- Political culture

Pluralistic/open, iterative and 'capture-insensitive' approaches

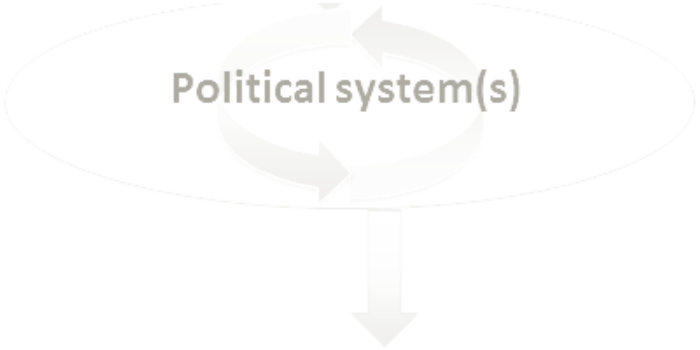
"Cultures of responsible experimentation (CORE)"

Getting the input right – and why this may not suffice

Input:

Most **pluralistic expertise** possible/

What may be pathways to alleviate capturing effects and vested interests in political systems?



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Output: Inefficient policies/regulations

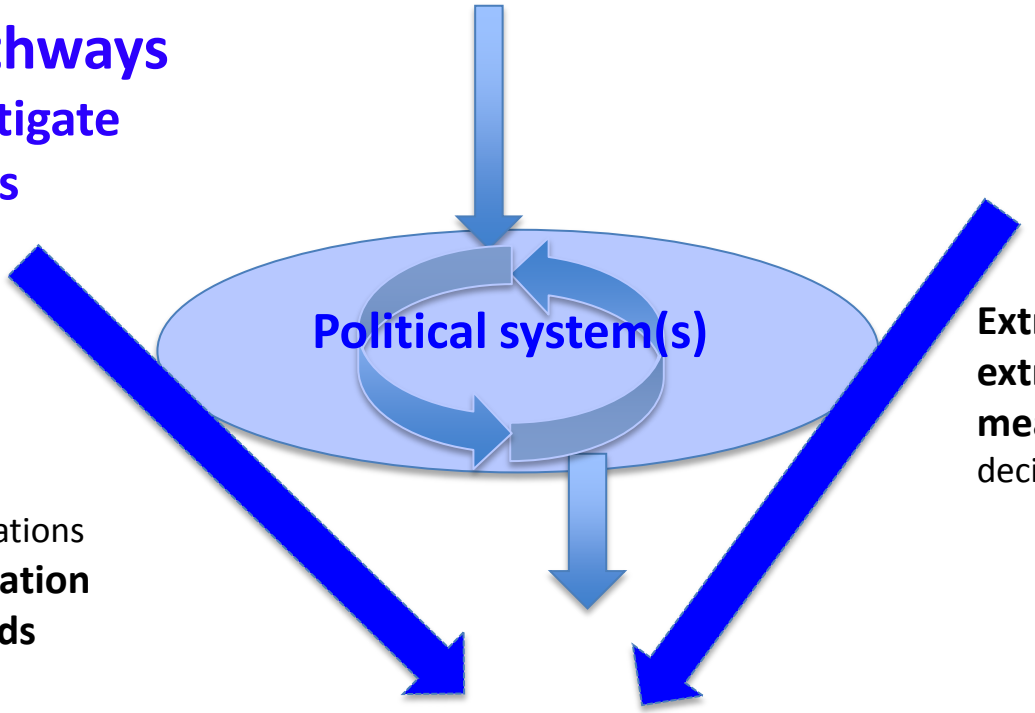
e.g. regulatory outcomes that are not in the public interest;
international treaties lacking compliance measures (BWTC)

Potential pathways to mitigate issues (likely) inherent to political systems

Input: Most **pluralistic expertise** possible/**dialogue/participation**

Complementing pathways
that can prevent or mitigate political system failures

- **More democratic say in nominating members of regulatory agencies**
- Conditions allowing corporate **competition** based on innovations advancing **resource conservation and respect social standards**
- and that may also **empower consumers** to make responsible/ directive choices

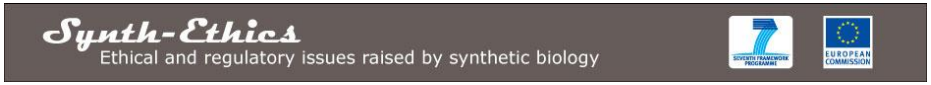


Extra-governmental/ extra-parliamentary means for political decision-making

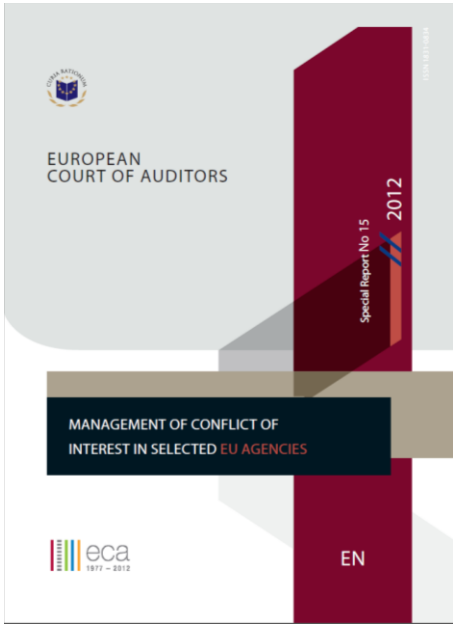
Improved output

Thanks to

egm**engineeringlife**.wordpress.com



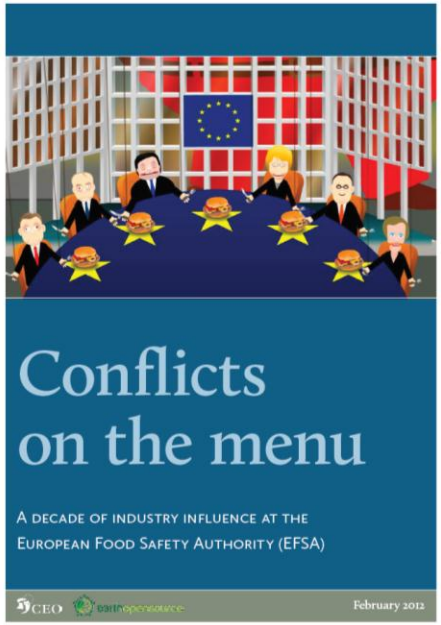
Conflicts of interest (mis)management in European regulatory agencies



European Aviation Safety Agency (EASA)
European Chemicals Agency (ECHA)
European Food Safety Authority (EFSA)
European Medicines Agency (EMA)

*"[] The Court concluded that **none of the selected Agencies adequately managed the conflict of interest situations.** The shortcomings identified were, however, of varying degrees."*

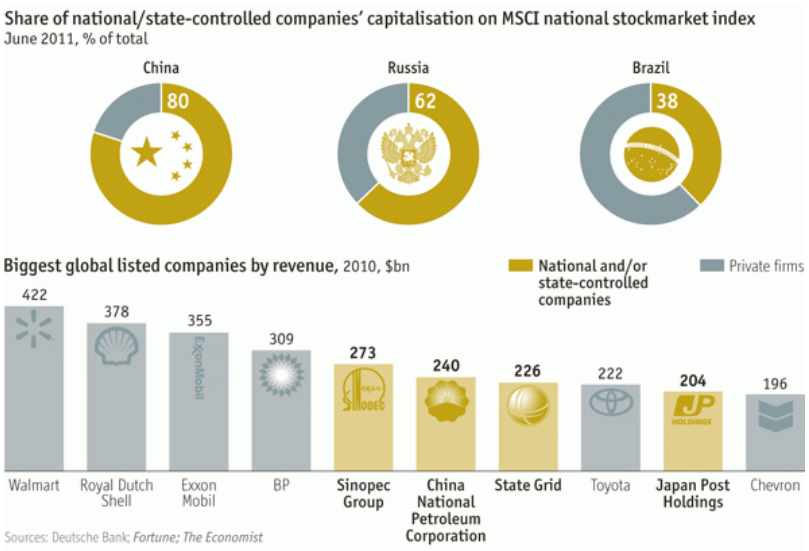
*"In general, the selected Agencies failed to perform a thorough assessment of post-employment cases, in order to anticipate and prevent **'revolving doors'** type of conflict of interest situations []".*

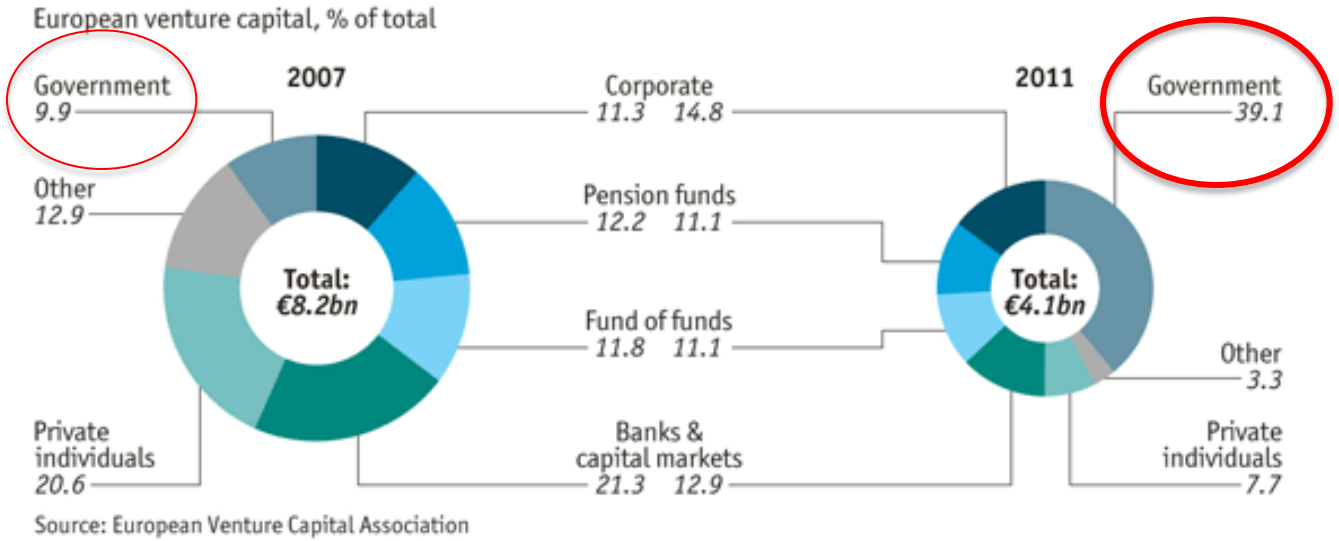


*"[] EFSA has often been **found to ignore independent research** for unscientific reasons. The agency has issued controversial guidelines for the assessment of pesticides and GMOs thatbenefit industry, not the public interest."*

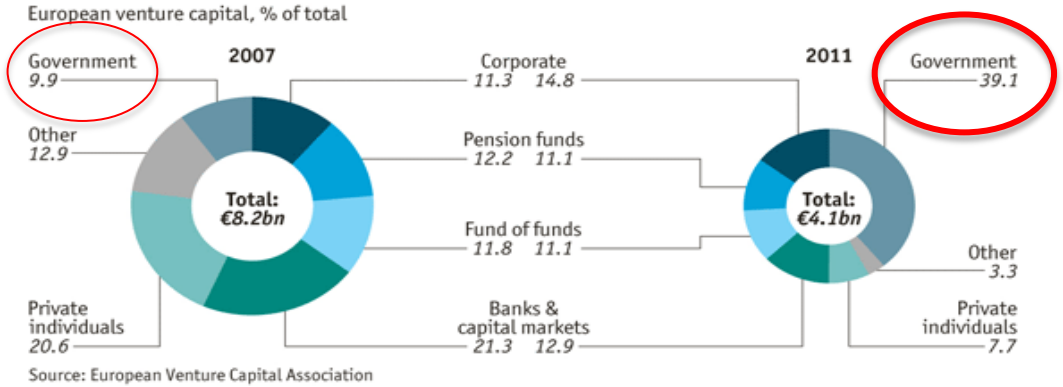
*"[] Panel members and management **have strong, systematic ties to the industry lobby group**, the International Life Sciences Institute (ILSI), which is funded by major food, chemical, and biotech corporations. The **'revolving door'** (where public officials move to industry jobs or vice versa) is also at work in EFSA."*

State capitalism and ‘venturecrats‘





European governments as venture capitalists



- Governments invest in privately managed funds; e.g. via the European Investment Fund (EIF)
- Direct investment in nascent businesses through state-backed organisations; e.g. Germany's High-Tech Gründerfonds

Governmentally funded SynBio institutions/networks

	USA		UK		CH	D
	SynBERC	**JBEI**	**CSynBI**	**IKC**	**ETH/ D-BSSE**	**HI Syn**
Biol. parts library	✓ Reg. of Standard Biol Parts		✓ BioFAB			✓ HeRBi
National strategic 'mission'	✓	✓	✓	✓		✓
Industry partnership	✓	✓	✓	✓	✓	✓
ELSA	✓		✓	✓		✓

Government investment in biorefineries in the US

Table 3.3. US Department of Energy grants for biorefineries announced at end of 2009

Grantee	DoE grant (USD millions)	Non-federal (USD millions)	Location (state)	Description
Pilot scale				
Algenol Biofuels	25	33.915	TX	Ethanol from CO_2 and seawater, 100 000 gallons fuel-grade ethanol per year.
American Process	17.944	10.148	MI	890 000 gallons ethanol and 690 000 gallons potassium acetate per year.
Amrys Biotechnologies	25	10.489	CA	Diesel substitute from sorghum fermentation, co-products lubricants, polymers and other petrochem substitutes.
Archer Daniel Midland	24.834	10.946	IL	Acid treatment of biomass to make liquid fuels. Will also make ethyl acrylate.
Clearfuels Tech	23	13.433	CO	Diesel and jet fuel from woody biomass.
Elevance Renewable Sciences	2.5	0.625	IA	Preliminary engineering design for a future facility producing jet fuel, renewable diesel and high value chemicals

Table 3.3 shows the support given to the construction of major biofuels facilities by the US Department of Energy (DoE), as published at the end of 2009. The USDA has also been instrumental in funding many necessary aspects of biofuels and other bio-based materials development in the United States *e.g.* basic and applied research, incentives to promote the production of biomass, loan guarantees and grants to support development of processing facilities for bioproducts, importantly including biofuels.

Grantee	DoE grant (USD millions)	Non-federal (USD millions)	Location (state)	Description
Gas Technology Institute	2.5	0.625	Il	Preliminary engineering design for green gasoline and diesel from woody biomass, agricultural residues and algae.
Haldor Topsoe	25	9.701	Il	Convert wood to green gasoline through gasification, 21 tons feedstock per day.
ICM	25	6.268	MO	Modify ethanol plant to produce cellulosic ethanol from switchgrass and sorghum.
Logos Technologies	20.445	5.113	CA	Convert switchgrass and woody biomass to ethanol by biochemical process.
Renewable Energy Institute	19.980	5.116	OH	Green diesel from agricultural and forest residues, 25 tons of feedstock per day.
Solazyme	21.765	3.857	PA	Validate economics of commercial-scale production of advanced biofuels, algal oil that can be converted to oil-based fuels.
UOP LLC	25	6.685	HI	Green gasoline, diesel, jet fuel from agricultural residue, woody biomass, algae.
ZeaChem	25	48.4	OR	Hybrid poplar trees for fuel-grade ethanol.
Demonstration scale				
BioEnergy International LLC	50	89.589	LA	Succinic acid from sorghum.
Enerkem Corp	50	90.470	MS	Woody biomass and municipal solid waste (MSW) biomass for ethanol and green chemicals
INES New Planet Energy LLC	50	50	FL	Ethanol and electricity from wood and vegetable residues, 8 million gallons ethanol and 2 megawatts electricity per year.
Sapphire Energy	50	85.064	NM	Algae in ponds to convert to green fuels.
Increased funding to existing biorefinery projects				
Bluefire LLC	81.134	223.227	MS	Ethanol from woody biomass, mill residues and sorted MSW.

Source: Adapted from Industrial Biotechnology (2009). December 2009, 5(4): 193-205, *http://dx.doi.org/10.1089/ind.2009.5.193*

Ethical framework for biofuels

Renewable fuels must account for **10% of transport fuel by 2020 in the European Union** (EU) and for **36 billion gallons by 2022 in the United States** (among those shall be 13 billion gallons **(7%) transport fuel**)

Science. 2011 Apr 29;332(6029):540-1. Epub 2011 Apr 12.

Ethics. Ethical framework for biofuels.

Buyx A, Tait J.

Nuffield Council on Bioethics, London WC1B 3JS, UK. abuyx@nuffieldbioethics.org

5 proposed principles

(1) Biofuels development should not be at the expense of people's essential rights.

(eg, health, food prices they can pay)

(2) Biofuels should be environmentally sustainable.

(Biodiversity, water over-use, pollution by pesticide and fertilizer use)

(3) Biofuels should contribute to net reduction of total GHG emissions and not exacerbate global climate change.

(Single international standard with methodological framework for calculating GHG emissions over whole life cycle; measures against land-use change protecting high-carbon stock)

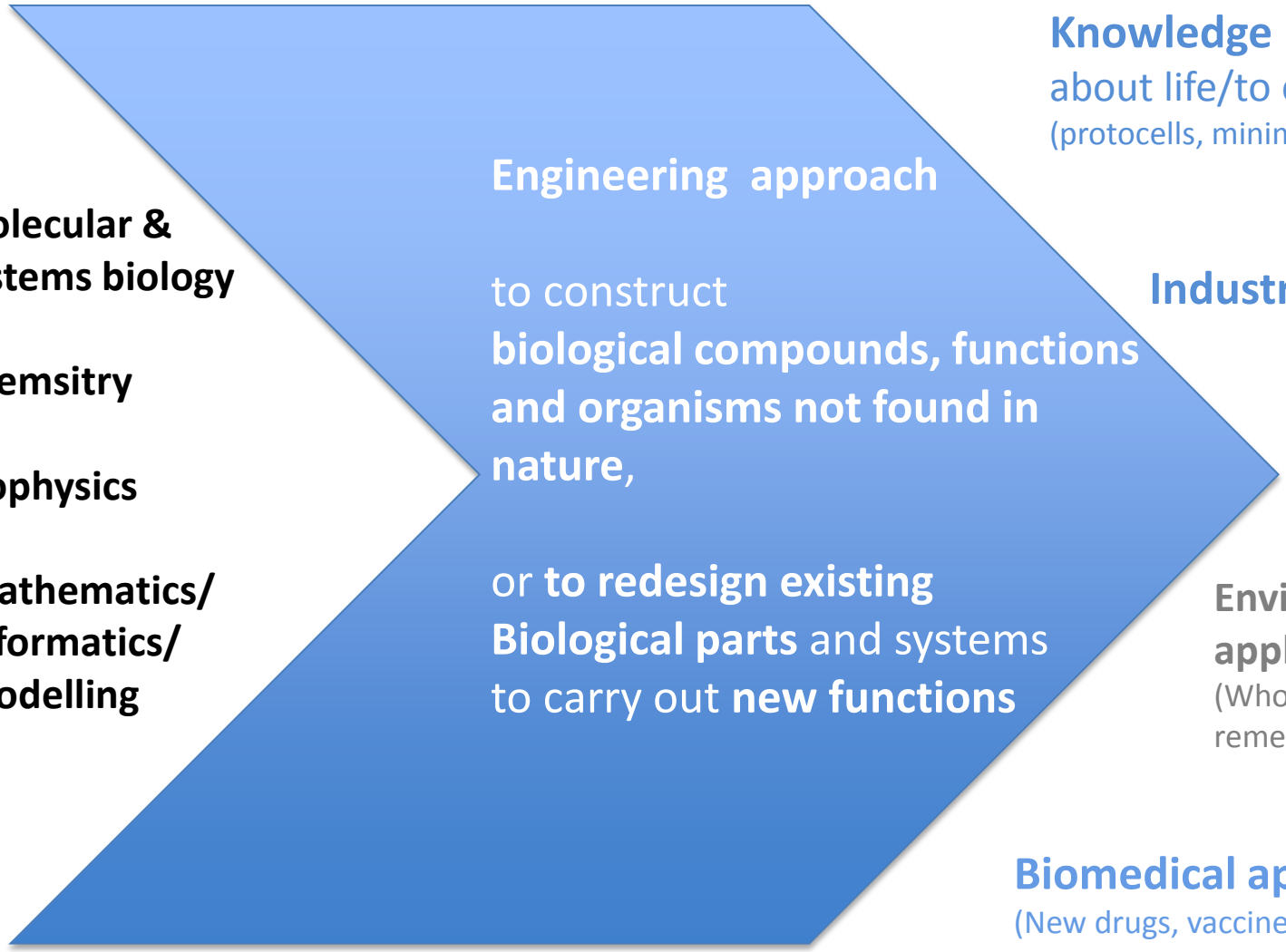
(4) Biofuels should recognize the rights of people to just reward.

(Adequate payment for labour, working conditions; intellectual property protection, fexible use of license agreements)

(5) Costs and benefits of biofuels should be distributed in an equitable way.

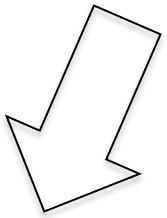
(eg, should not threaten food security in poor countries or local markets while delivering benefits for climate change and energy security in developed world)

What is synthetic biology?



Summary

Informed by the most **pluralistic expertise** possible – participation of all stakeholders and public



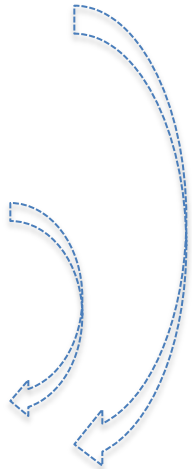
- **Regulations, standards**

  Broadly applicable and effective environmental, socioeconomic and ethical standards

In addition, especially regarding biosecurity:

- **Shared responsibilitiy, culture of awareness**
  (policy makers, industry, scientists, CSOs)

- **Influencing/participating in all stages of technology development ("Responsible research and innovation, RRI")?**



- **Create 'pathways' to alleviate/correct issues likely inherent to political/ scientific systems** (e.g. direct democracy, 'empowering' consumers)

Getting the input right

What should (public) participation mean?

Lobbying/interest representation by certain stakeholders
vs 'broad public' participation (incl. citizens as individuals)?

Where should/could participation take place?

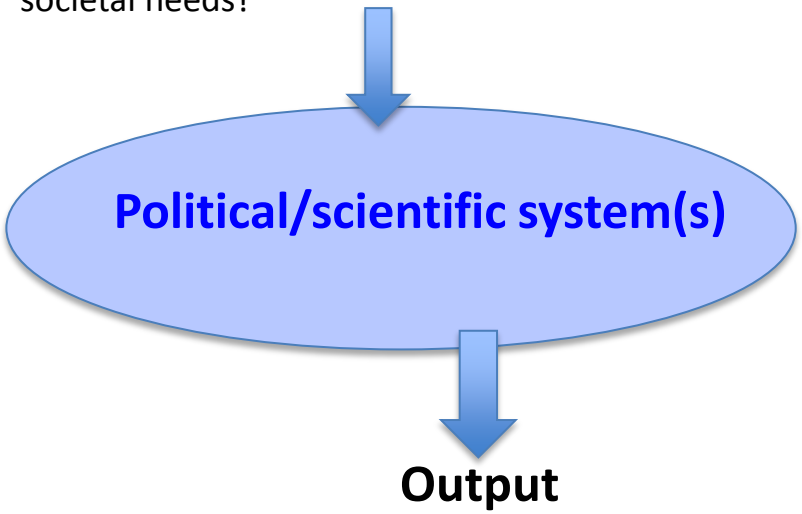
Political/regulatory bodies, intergovernmental organizations, scientific councils, research/technical design processes?

Who decides on who shall participate or on the framing of participation?

top-down framing: no challenge of entrenched assumptions or power structures?

- Collaborative shaping of regulatory frameworks (incl. laws, code of conducts)?
- Co-shaping all stages of research/innovation to include societal needs? – Responsible research and innovation (RRI)

Who defines such needs? What are means inside and outside science to implement societal needs?



Evidence map Energy/Biofuels