# From the Sugar Platform to biofuels and biochemicals

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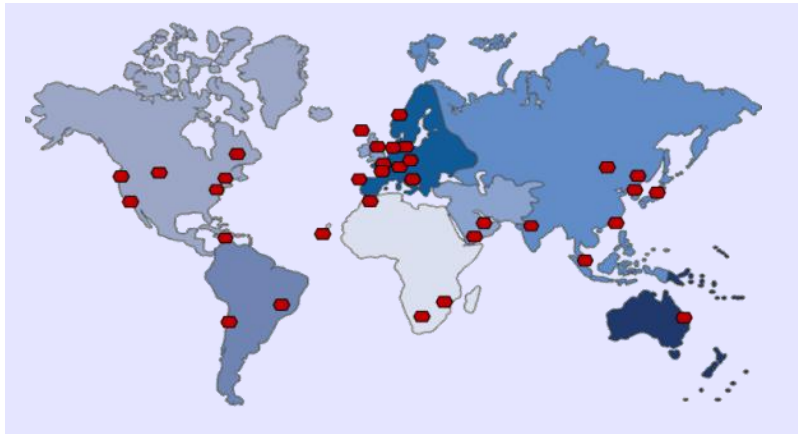
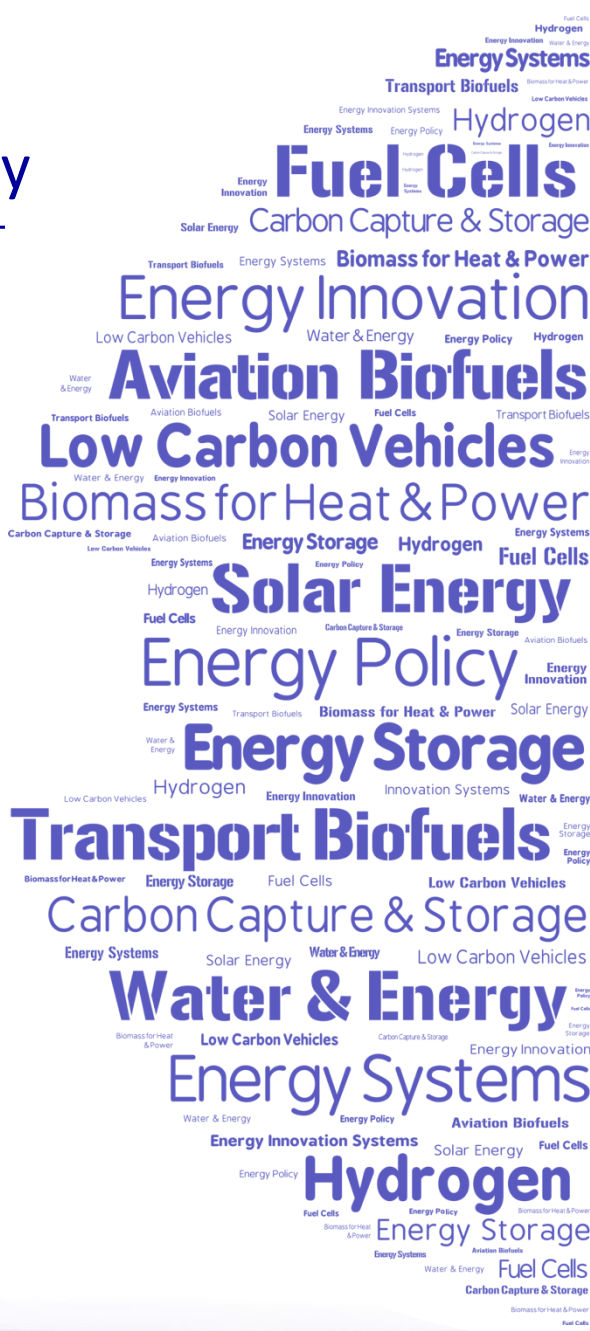
NRP66 Resource Wood – Novel ways in bio-refining of wood

BFH-HAFL, Zollikofen, 5 February 2016

# E4tech: Strategic thinking in sustainable energy

- International consulting firm, offices in UK and Switzerland
- Focus on sustainable energy
- Established 1997, always independent
- Deep expertise in technology, business and strategy, market assessment, techno-economic modelling, policy support…
- A spectrum of clients from start-ups to global corporations





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# An evidence base was needed for the sugar platform

- Numerous promising pathways exist to making biofuels and biochemicals via sugars using different feedstocks and downstream processes
- **DG ENER** commissioned E4tech, RE-CORD and Wageningen UR to assess:
  - technology options, development status, market potential, sustainability, economics and barriers to deployment
- Industry input was gathered via **case studies**, and **workshops**
- Final report is to act as an **evidence base** for policymakers and stakeholders to identify opportunities, their key benefits and development needs

**http://www.e4tech.com/project/from-the-sugar-platform-to-biofuels-and-biochemical**

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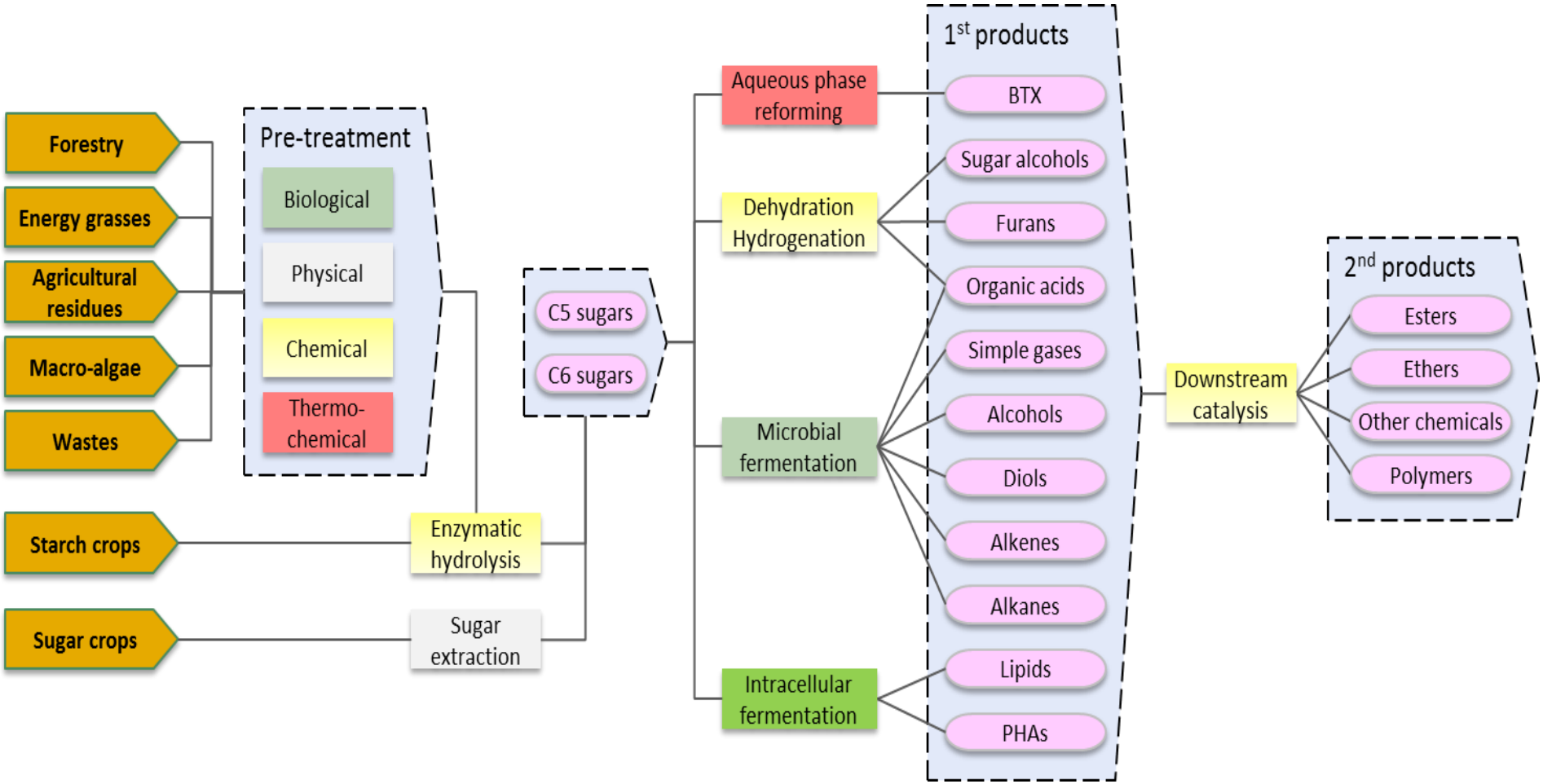
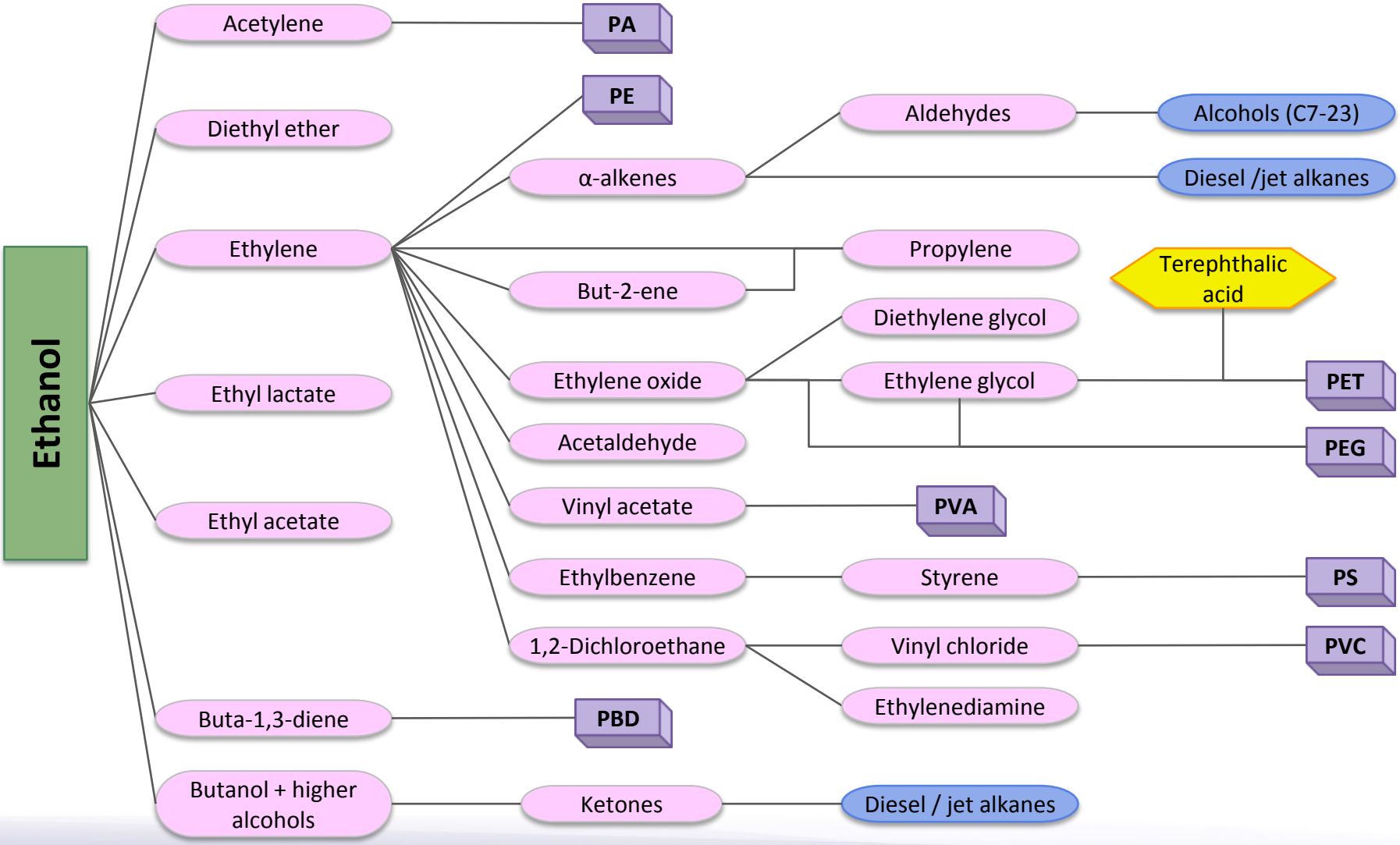
# High-level summary of the 94 pathways considered



# Ethanol downstream products



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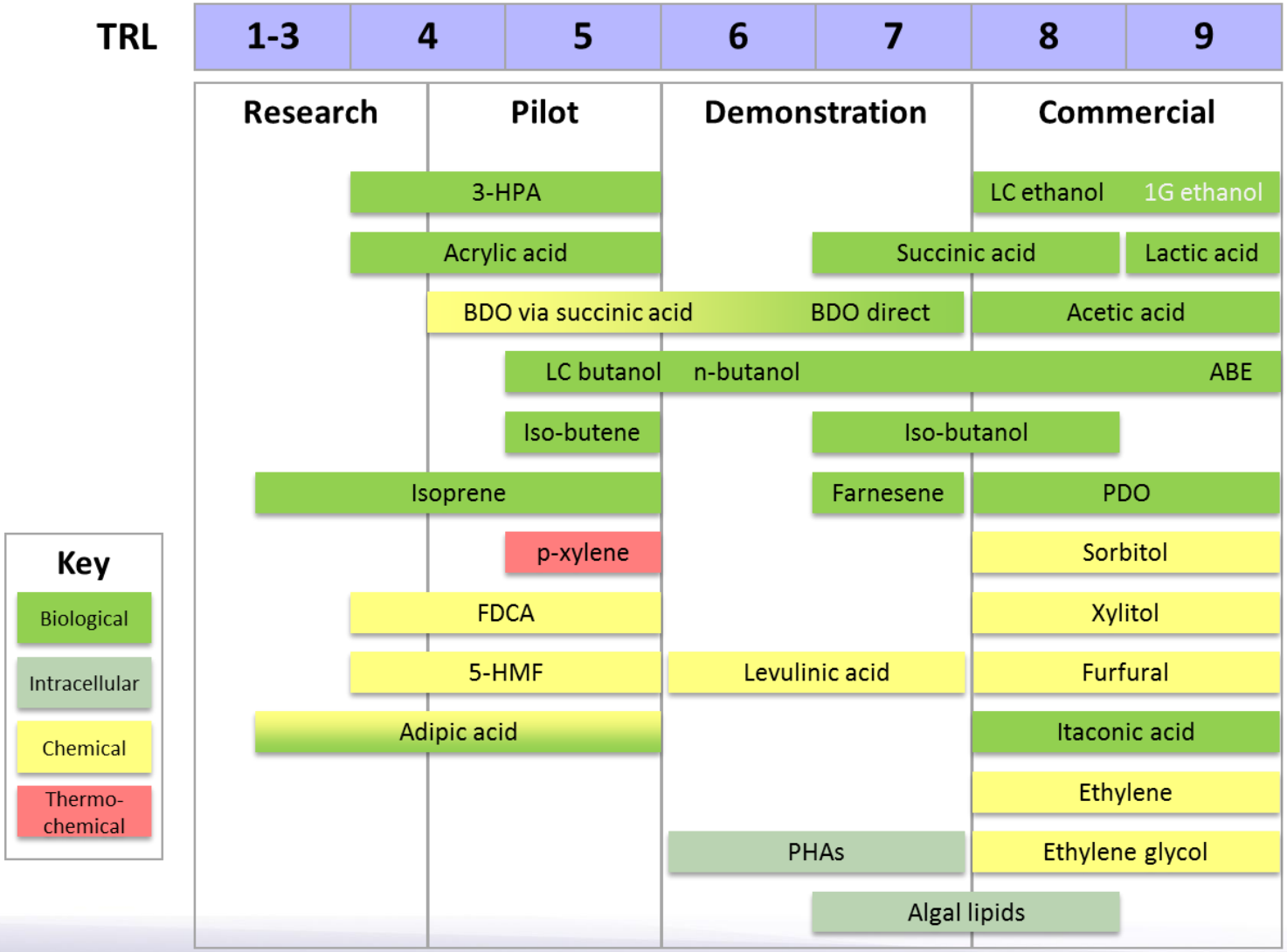
# Company database created with 250+ plants, using public data

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | ktpa | Activity | | | | | | | |
| 2 | Organisation | Address | Product | Technology | TRL | # TRL | Scal | EU | NA | SA | Asia | Oth | Latest updates | Ref | ence |
| 50 | Cargill/Novozymes | Denmark | 3-HPA | Fermentation | 5 | 5 | 0.01 | | R&D | | | | Cargill and Novozymes announced in 2008 a joint agreement to | Ref | Ref |
| 51 | Cathay Industrial Biotech | China | Acetone | ABE fermentation | Commercial | 8.5 | 22.5 | | | | M | | Production facility in Jilin Province has an annual production cap | Ref | |
| 52 | Cathay Industrial Biotech | China | n-butanol | ABE fermentation | Commercial | 8.5 | 67.5 | | | | M | | Cathay Industrial Bio produces corn-based n-butanol for chemi | Ref | Ref |
| 53 | Central Romana Corporation | Dominican Rep | Furfural | Dehydration | Commercial | 8.5 | 35 | | M | | | | In the 1950's the present-day world's largest furfural unit was sta | Ref | |
| 54 | Chongqing Bofei Biochemical Pro | China | Lactic acid | Fermentation | Commercial | 8.5 | 75 | | | | M | | Henan Jindan Lactic Acid Technology and Chongqing Bofei Bioc | Ref | |
| 55 | Cobalt Technologies | California, USA | Acetone | Fermentation | Pilot | 5 | | | R&D | | | | Make n-butanol, and a very small amount of acetone.2011 | Ref | |
| 56 | Cobalt Technologies | California, USA | n-butanol | Fermentation | Pilot | 5 | 0.08 | | R&D, P 1.4 | P | P 100 | | Cobalt Technologies announced its successful scale-up of its bi | Ref | Ref |
| 57 | Cobalt Technologies | California, USA | Jet fuel | Dehydration, oligomerisation | R&D | 3.5 | | | R&D | | | | 2010 Cobalt Technologiesannounced the signature of a Cooper | Ref | Ref |
| 58 | Corbion | Netherlands | FDCA | Fermentation | R&D | 4 | | R&D | | | | | Corbion is currently looking at FDCA and bought chemical engir | Ref | Ref |
| 59 | Corbion Purac | Netherlands | Lactic acid | Fermentation via HMF | Commercial | 8.5 | 230 | D | M | M | M | | Plants in the Netherlands, Spain, USA (180ktpa) and 100ktpa lac | Ref | Ref |
| 60 | Corbion Purac | Netherlands | Lactide | Fermentation | Commercial | 8.5 | 80 | D | | | M | | 5ktpa demo plant in Spain, plus 75ktpa (lactide) commercial plan | Ref | Ref |
| 61 | Corbion Purac | Netherlands | PLA | From lactide | Pre-commercial | 5.5 | | | | | P 75 | | Corbion Purac announced in October 2014 that they will make th | Ref | |
| 62 | Davy Process Technology | UK | THF | Hydrogenation, deoxidisation | Pilot | 5 | | R&D | | | | | Collaboration with Myriant. Successfully made BDO and THF at | Ref | Ref |
| 63 | Davy Process Technology | UK | 1,4 butanediol (BDO) | Hydrogenation | Pilot | 5 | | R&D | | | | | Collaboration with Myriant. Successfully made BDO and THF at | Ref | Ref |
| 64 | Deinove | France | n-propanol | Fermentation | 2 | 2 | | R&D | | | | | The DEINOCHEM programme aims to produce a new generation | Ref | Ref |
| 65 | Deinove | France | n-butanol | Fermentation | 2 | 2 | | R&D | | | | | Deinove (Alternext Paris:ALDEI has announced that the award of | Ref | Ref |

- Company names, countries
- Products made, process technology used, Technology Readiness Level (TRL)
- Production capacity, locations and type of facilities
- Not fully comprehensive for all products, but covers all the major players
- Most routes still based on 1G sugar and starch crops

# TRL progression and the “valley of death” for 25 products



# LC pre-treatment is vital to unlocking sugar platform potential, but matching to downstream is key reason for lower TRLs

- **Pre-treatment** technical obstacles include insufficient separation of cellulose and lignin, formation of inhibitors, high use of chemicals and/or energy, enzyme costs (although falling rapidly), capital costs, and the need to deal with feedstock variability
- **Alcohol** production needs to lower **energy** cost of product separation, and overcome micro-organism **toxicity** to improve product concentrations in the fermentation broth
- **Organic acid** production is focused on reducing unwanted by-products and improving process **selectivity** (particularly for chemical catalytic routes)
- **Biopolymer production** needs high **purity** monomers to ensure on-spec
- **Process integration** along new technology chains needs optimisation

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# Bio-ethanol is by far the largest sugar platform product

- We collected indicative prices and global production volumes for the selected 25 bio-products (along with their fossil counterparts where applicable):
  - Dominant (~$58bn/yr): **bio-ethanol**
  - Big (~$1bn/yr): n-butanol, acetic acid and lactic acid
  - No fossil alternatives, >$100m/yr for routes to xylitol, sorbitol and furfural
  - Many small markets for earliest TRL products (<$1m/yr)

- If economically competitive, many bio-chemicals could grow to exceed the current fossil-based product demand and expand into new markets, replacing other products
- **Crude oil prices** since mid-2014 leave many sugar platform products extremely challenged

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# 10 case studies selected to highlight EU actors active in attractive markets

- Acrylic, adipic & succinic acids, FDCA, BDO, farnesene, isobutene, PLA, PHAs and PE case studies are standalone ~4 page documents:
  - **Description** of the bio-based product
  - **Actors** involved in its production (EU and ROW)
  - **Value proposition** - production economics, GHG savings and physical properties. Chemicals market offers major differences to biofuels sector
  - **Market** outlook and expected growth

- All claimed “viable economic production costs” once at scale (pre-oil crash)
- All have modest GHG savings on 1G sugars, high GHG savings on 2G sugars
- All have either equal quality (drop-in) or enhanced properties (non drop-in)

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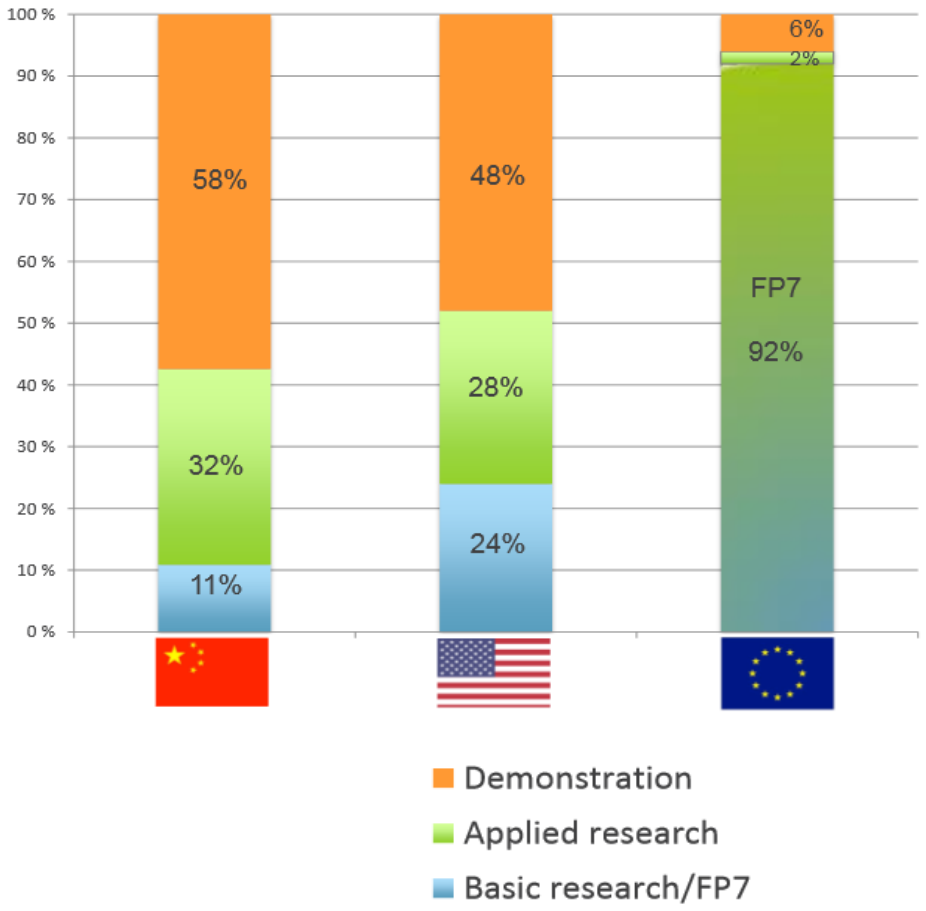
# EU competitiveness assessed based on 7 criteria vs. US, Brazil and China

| Criteria | EU | US | Brazil | China | Notes |
|---|---|---|---|---|---|
| **Policy** | C | A | B | B | US RFS and BioPreferred. Brazil and China have biofuel mandates, but EU lacks long-term policy |
| **Financing** | B | A | B | A | Interest rates lowest in China, highest in Brazil DOE and BNDES provide loan guarantees |
| **Public perception & demand** | B | B | B | B | Biochemicals yet to suffer ILUC backlash, no sustainability requirements exist yet |
| **R&D activity** | A | A | B | B | EU & US have best researchers, hence top locations for labs & pilots |
| **Commercial activity** | C | B | C | A | Strongest in China. US leader on demos and LC ethanol. EU focused downstream, Brazil limited |
| **Feedstock availability & cost** | B | A | A | B | All regions have significant 1G crops.<br>US and Brazil cheapest LC residues and forestry, China yet to mechanise |
| **Other production costs** | C | B | B | A | US highest wages, Brazil highest energy costs, but EU second on both counts. US lowest energy and China lowest wages |

# EU technology is being deployed abroad

- **Easier/safer to invest** in plants, and products cheaper to make, in the US, Brazil and China:
  - US guaranteeing $1.4bn in loans, $2.5bn more to come
  - Brazil $0.4bn low interest loans + $0.6bn more by 2018
- EU still focusing on R&D
- **NER300** funds (€127m) awarded to 4 advanced ethanol plants, only 1 built to date (Crescentino)
- **BBI** set up with €3.7bn for demo and flagships – yet to kick in



# In summary

- Wide range of potential chemicals can be made from LC sugars or LC ethanol
- TRL of LC routes generally at least 1-2 steps behind 1G sugars
- Partnerships starting to form with pilots and toll demos of LC sugars from the likes of Biochemtex
- Main difficulty is matching LC sugar purities with downstream needs
- Value proposition is vital in biochemicals space:
  - Drop-ins compete on price, and only sometimes green credentials
  - Non drop-ins often have superior properties or market niches
- EU faces particular challenges over production cost competitiveness compared to ROW, and lack of clear long-term policy for the bioeconomy

# Thank you for your attention!

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# E4tech – strategic thinking in sustainable energy

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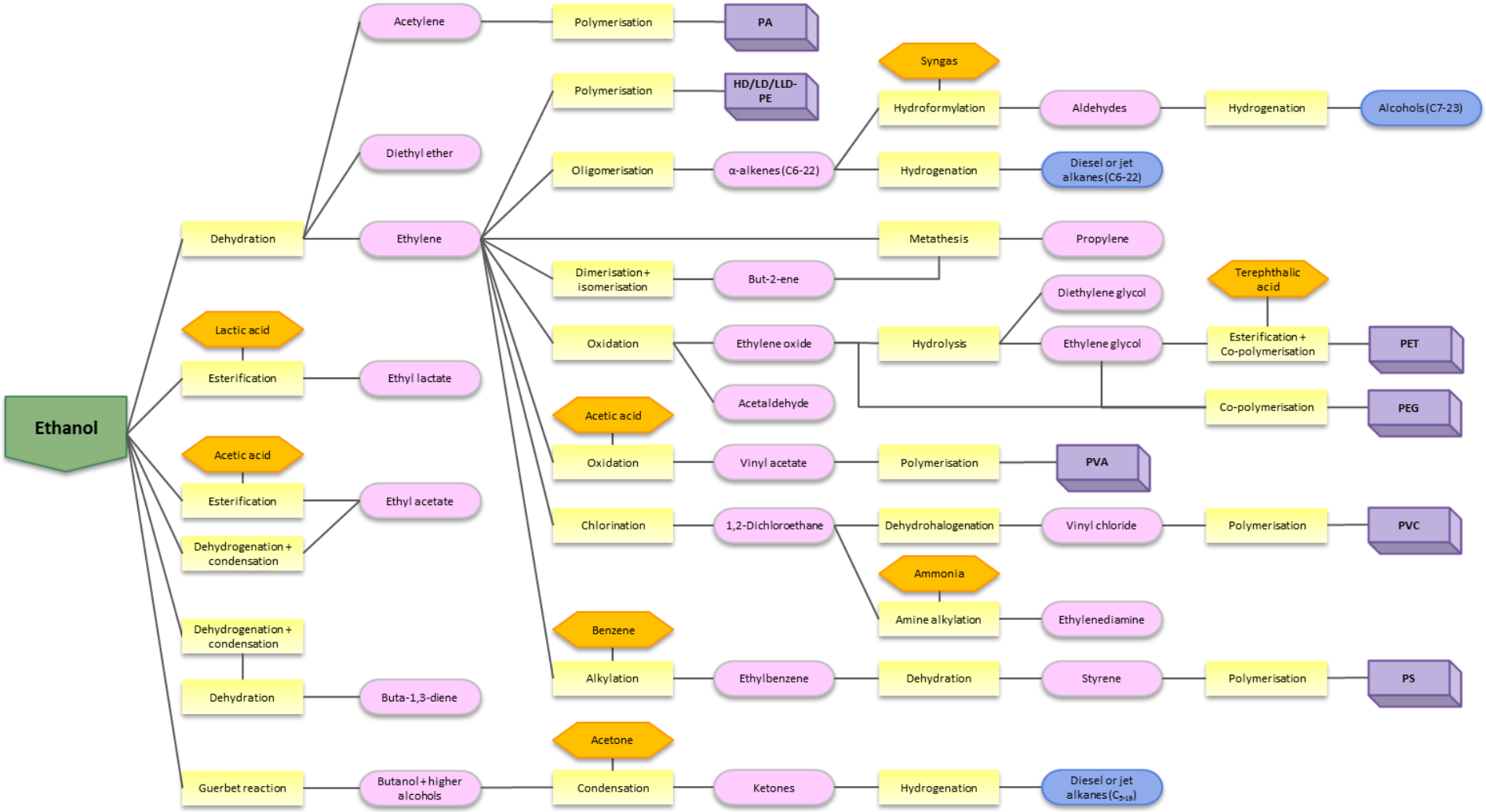
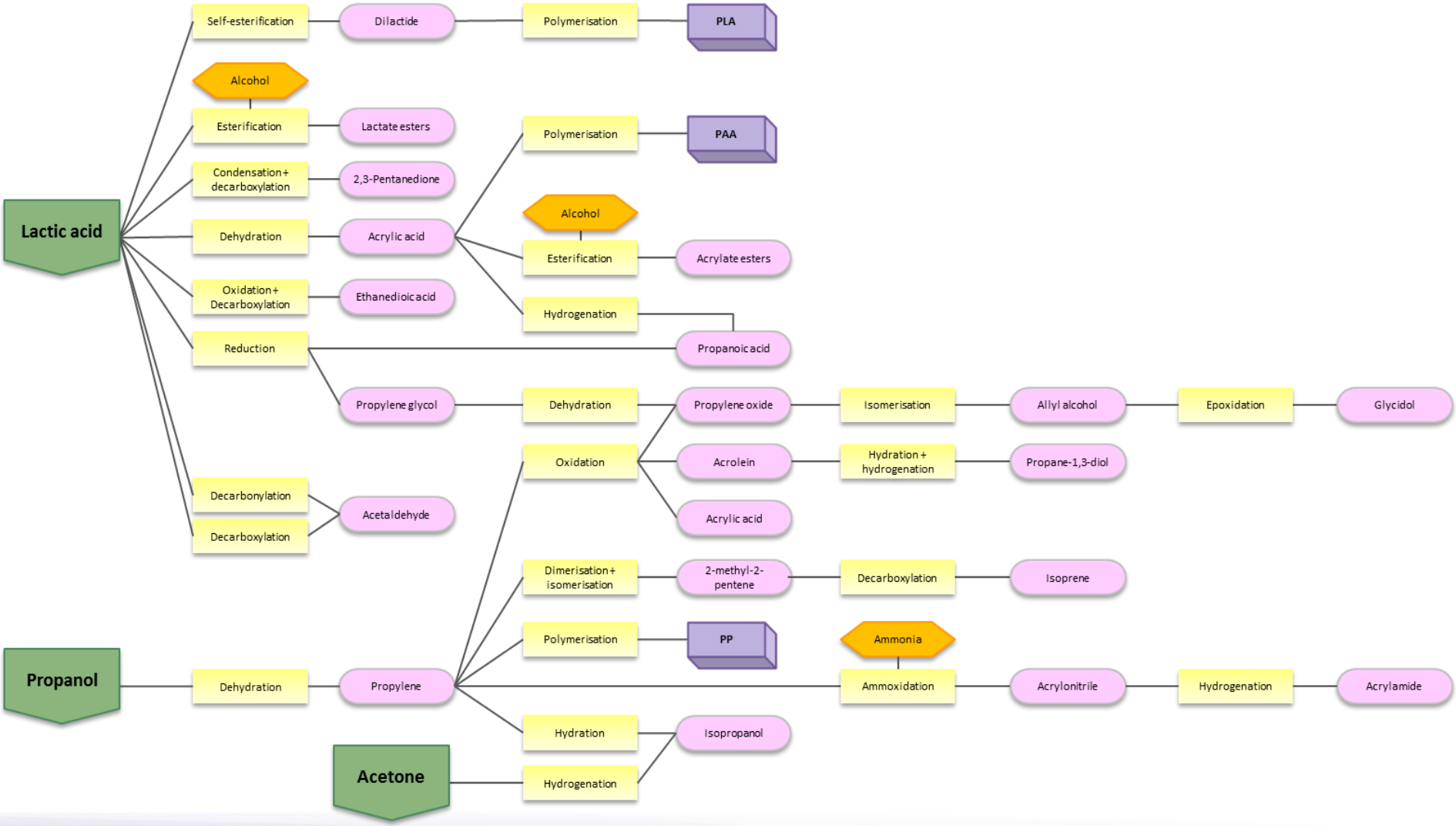
# Backup slides for Q&A

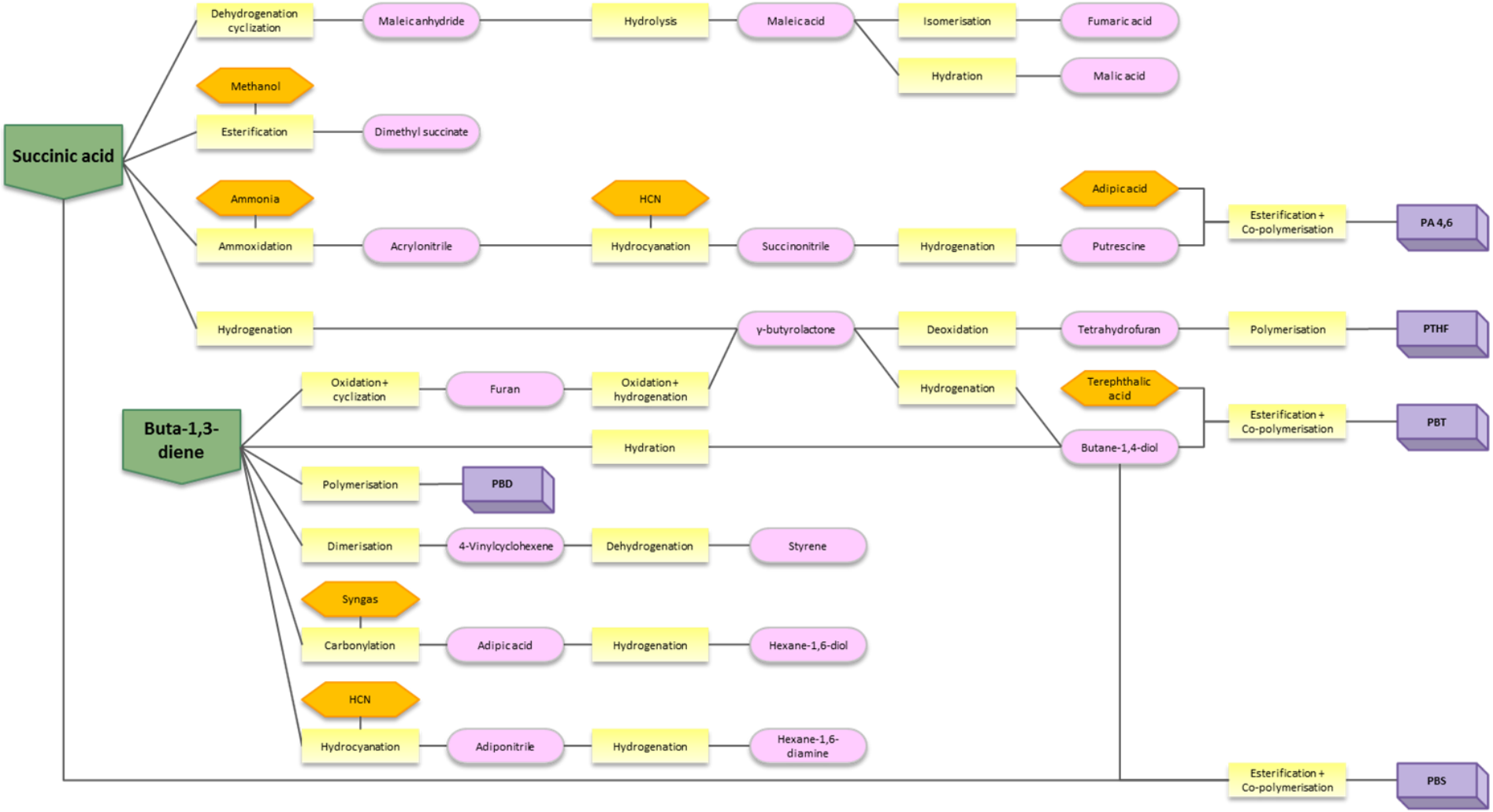
# Ethanol pathways – detailed example



# C3 pathways – detailed example



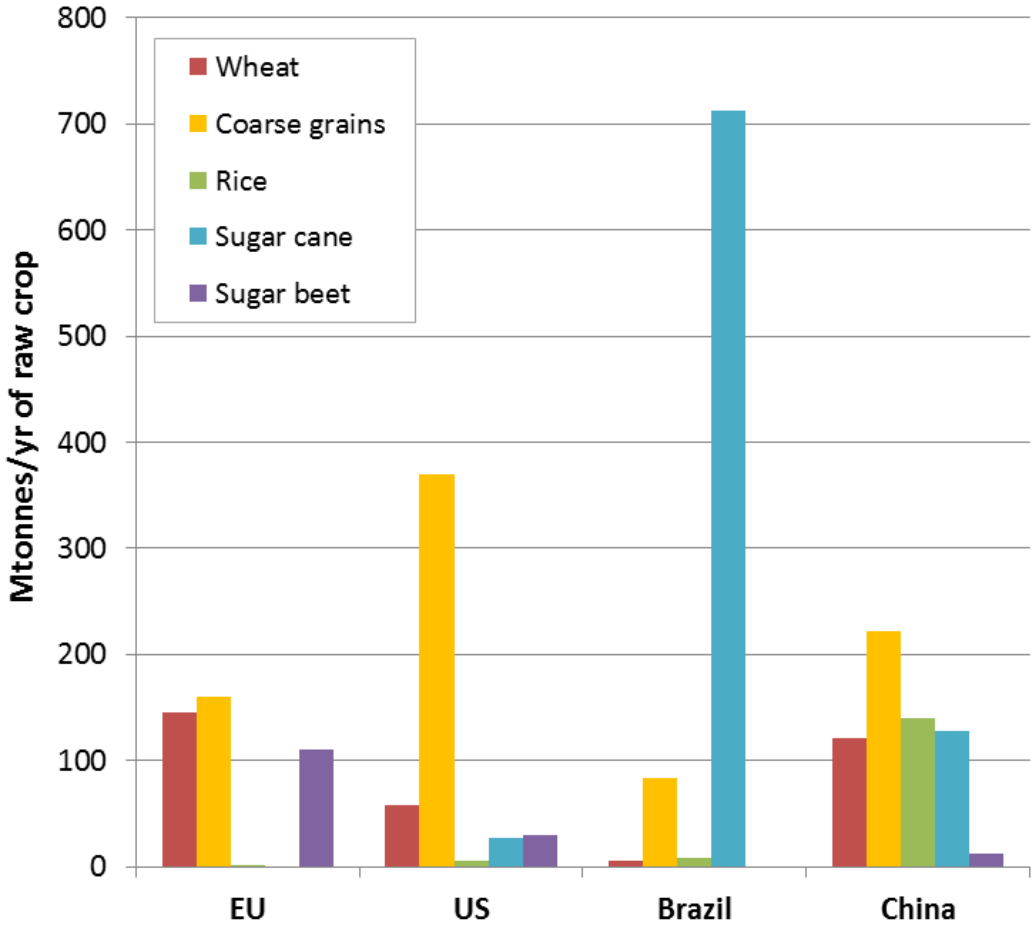
# C4 pathways – detailed example

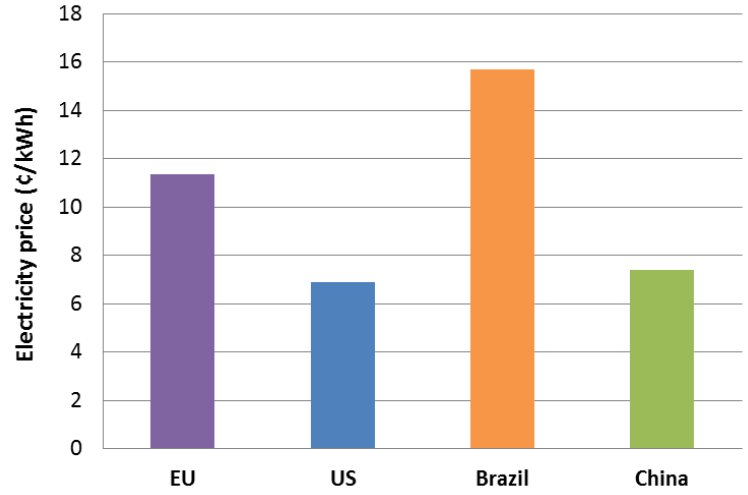


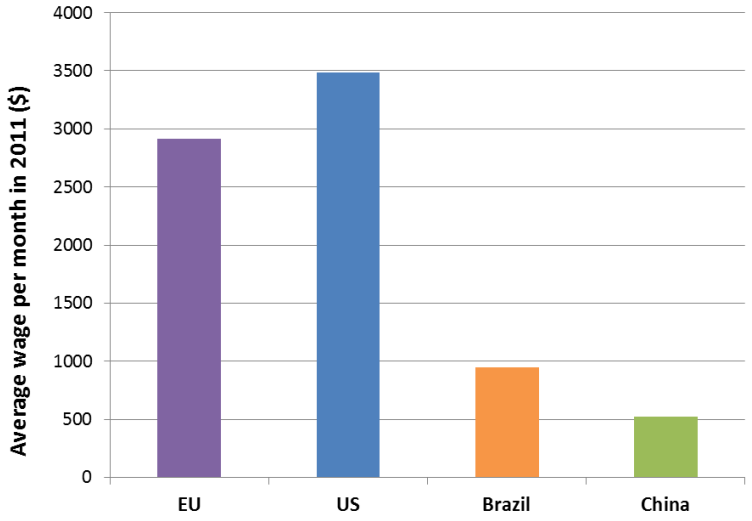
# Technology Readiness Level (TRL) definitions

| TRL | Plant stage | Definition |
|---|---|---|
| **1** | Basic research | Principles postulated & observed but no experimental proof available |
| **2** | Technology formulation | Concept and application have been formulated |
| **3** | Applied research | First laboratory tests completed; proof of concept |
| **4** | Small scale prototype | Built in a laboratory environment ("ugly" prototype) |
| **5** | Large scale prototype | Tested in intended environment |
| **6** | Prototype system | Tested in intended environment close to expected performance |
| **7** | Demonstration system | Operating in operational environment at pre-commercial scale |
| **8** | First of a kind commercial system | Manufacturing issues solved |
| **9** | Full commercial application | Technology available for consumers |

# Feedstock availability & cost, plus labour and energy costs vary widely between regions

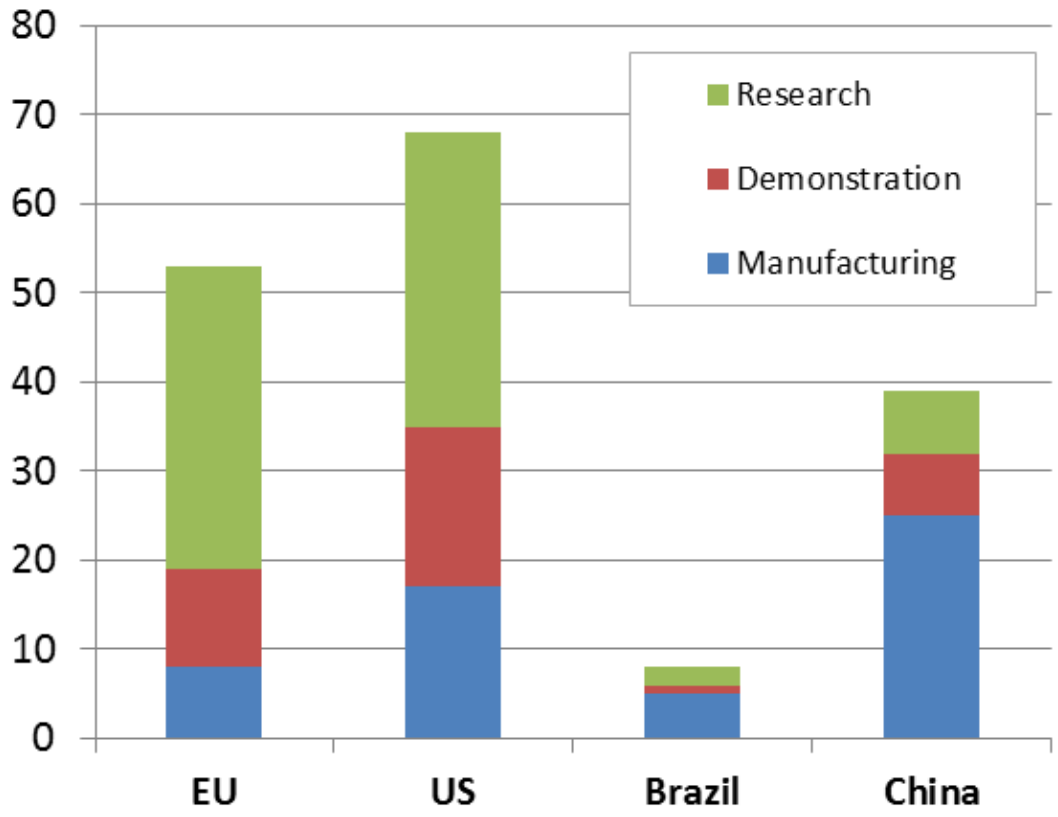


# EU focus on R&D backed up by evidence from the company database

- Most R&D labs and pilot plants are located in Europe and US (+Canada)
- US has significantly more demonstration facilities than EU
- Asia (mainly China) has a good manufacturing base of high TRL products
- South America has a few early commercial projects



# Non-technical barriers examined by Bio-TIC project

- Bio-TIC project has done considerable work in understanding this area and preparing recommendations for improvement
- Categories of non-technical barriers have been **prioritised** into their importance to the sugar platform as follows:
  1. Demand side policy (most important)
  2. Public perception & communication
  3. Investment & financing
  4. Feedstock
  5. Other barriers (least important)

# Stakeholder suggestions for potential policy improvements

- Longer-term **stability** of mandates
- Setting biomass use between fuels and chemicals on a **level playing field**
- Incentivising **biomass** production
- Creating a clear Europe-wide **communication** campaign
- Dis-incentivising **fossil**-derived products
- **Improving access** to capital and loan guarantees
- **Simplifying** available funding mechanisms