Renewable phenol for DSM

A process for chemicals and fuels

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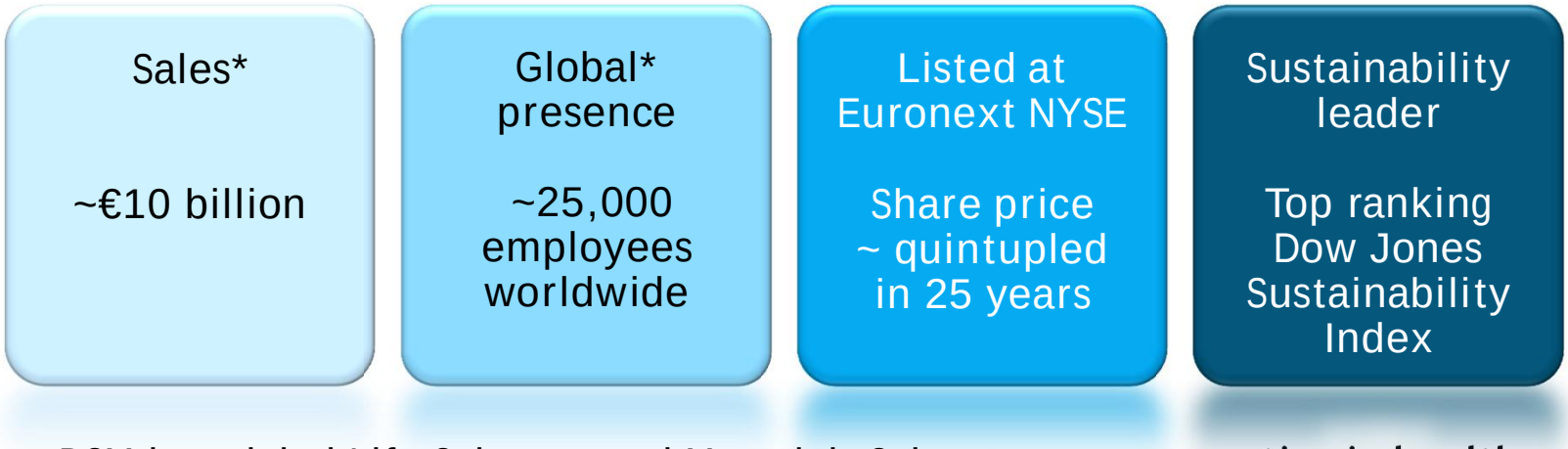
DSM at a glance (2014)



- DSM is a global Life Sciences and Materials Sciences company active in **health**, nutrition and materials
- DSM delivers innovative solutions that nourish, protect and improve performance in global markets such as food and dietary supplements, personal care, feed, medical devices, automotive, paints, electrical & electronics, life protection, alternative energy and bio-based materials
- DSM and its associated companies deliver annual net sales of about €10 billion with approximately 25,000 employees

* Including 2014 pro-forma and pro-rata (annualized) sales & number of employees (ultimo 2014) of non-consolidated Associates & Joint Ventures (for sales this is mainly DPx Holdings and DSM Sinochem Pharmaceuticals)

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Three attractive innovation platforms

DSM Biomedical

Innovative materials that deliver more advanced clinical procedures and improved patient outcomes

DSM Bio-based Products & Services

Advanced enzymes and yeast platforms: enabling advanced bio-energy and bio-based chemicals

DSM Advanced Surfaces

Smart coatings and surface technologies to boost performance in the solar industry

Bringing Life Sciences and Materials Sciences competences together

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Key markets*

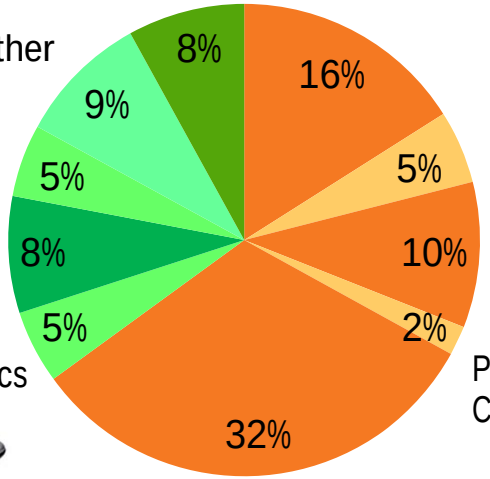
Dairy
RTE meals
Soups / Sauces / Spreads
Wine-Beer-Fruit drinks

Materials sciences

Life sciences

(Food) Packaging

Food & Beverages



Other

Building & Construction

Automotive

Electrical & Electronics

Infant nutrition

Dietary Supplements

Personal Care

Animal Feed

DSM offers products & solutions to a wide range of markets

* Excluding the activities for which we announced a partnership with CVC Capital Partners in March 2015, of which DSM remains a 35% shareholder and excluding our non-consolidated Associates & Joint Ventures

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DSM Products

And without fossil raw-materials?

EcoPaXX®

NATURAL BETACAROTENE CaroCare®

life's DHA™ HEALTHY BRAIN, EYES, HEART

fruitflow®

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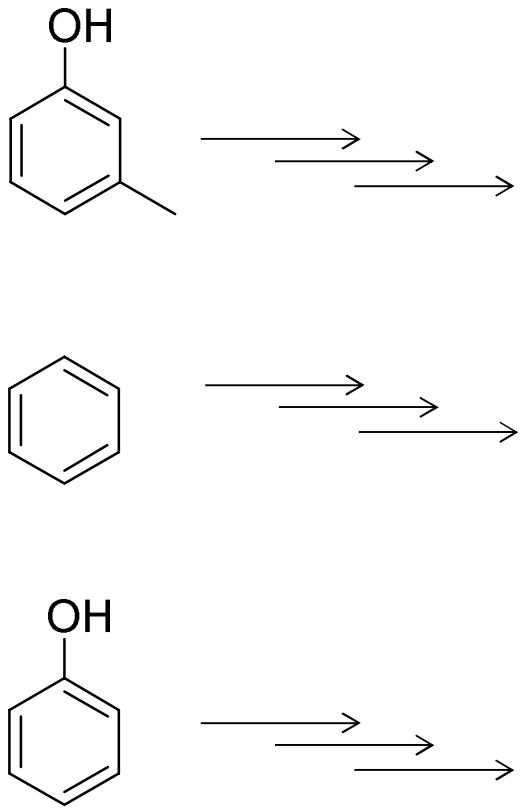
Aromatics and phenols for materials and vitamins



carophyll® yellow

Quali-Blends®

EcoPaXX®

Stanyl® ForTii™

Stanyl®

Novamid®

Akulon®

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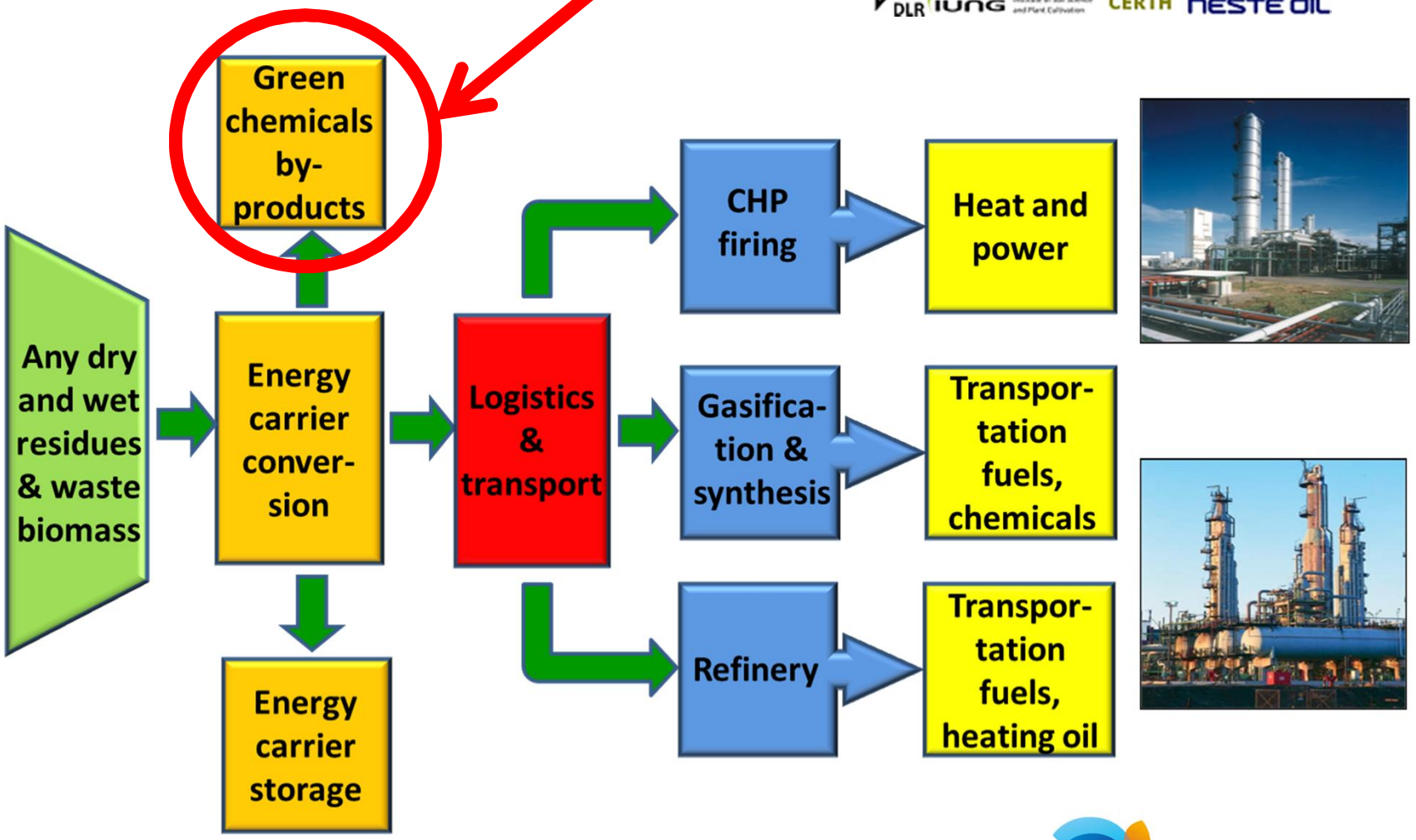
DSM in BioBoost

BioBoost



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Challenge

Pyrolysis oil

> 400 components
High viscosity
23 wt% oxygen

Hydrocarbon mix
Low viscosity
Low in oxygen

fuel

phenol

Single component
17 wt% oxygen
White crystals

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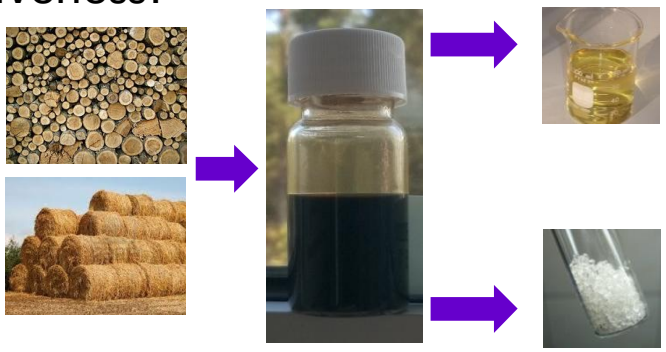
Challenge: develop a sustainable process

One of the biggest hurdles of true implementation of "sustainable processes" is their lack of cost-competitiveness.

Goal: develop cost-competitive bulk processes using renewable raw materials



What makes a bulk chemical process feasible?

- Besides quality of the product… its selling price.
- Cost effective process – fixed costs, variable costs, capital investments
  - Size of the production
    - A larger plant can operate at a lower unit production costs than a small plant
  - Complexity of the process
    - The simpler, the better
  - Operating mode
    - For bulk processes only continuous mode is of interest
    - E (ton of product/ton of waste) >>> 1 (otherwise too expensive)
  - Sufficient concentration of the desired product
    - > 2 wt.% (e.g. 10 kta plant requires 500 kta crude bio-oil)

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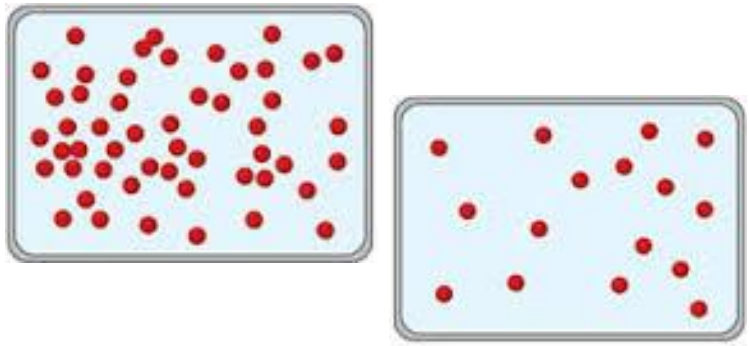
The best conversion technology

Concentration of phenols



Viscosity

Energy carrier conversion

~~Hydrothermal carbonization~~

~~Fast pyrolysis~~

Catalytic fast pyrolysis

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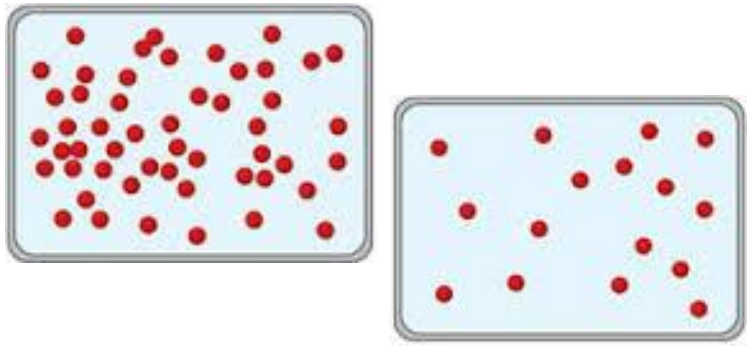
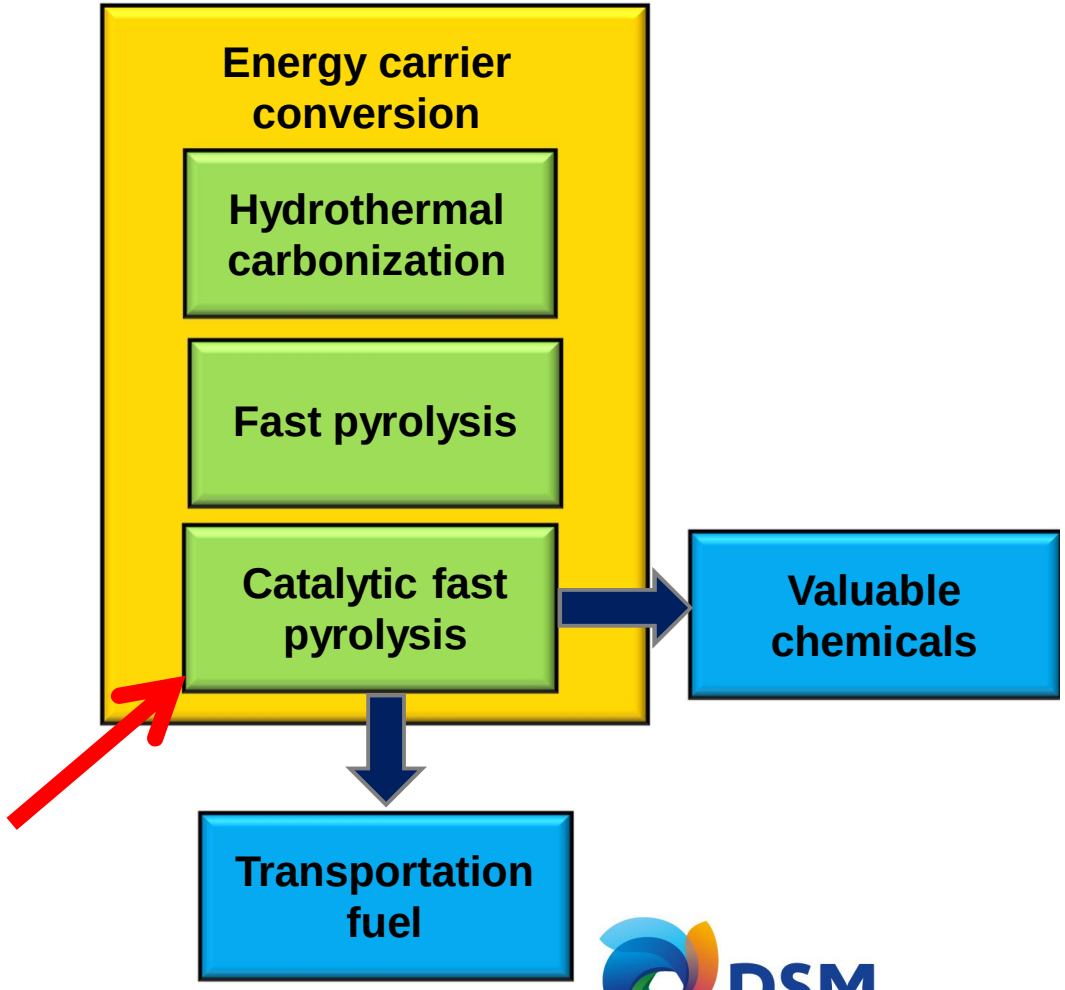
The best conversion technology





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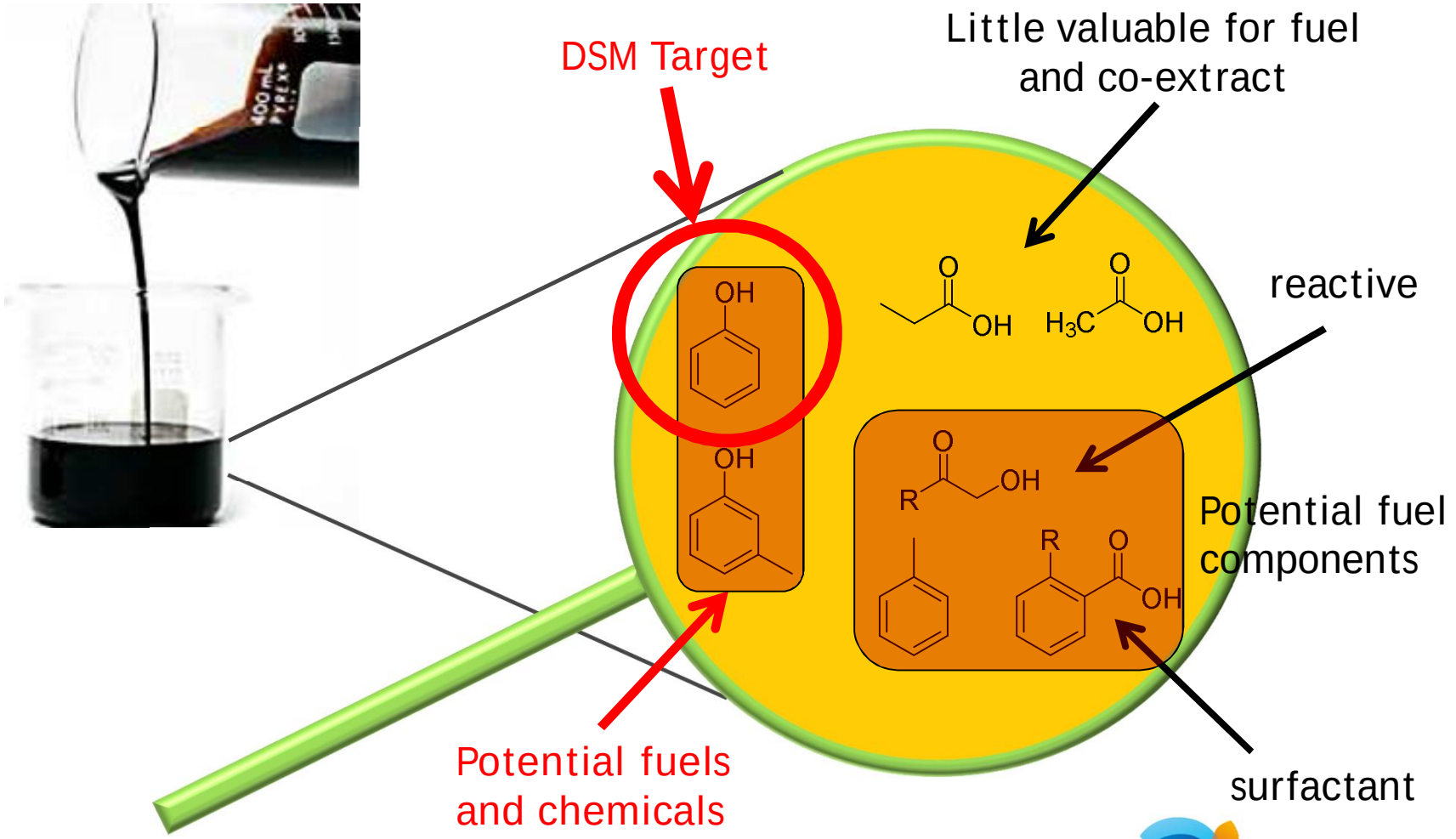
The playing field



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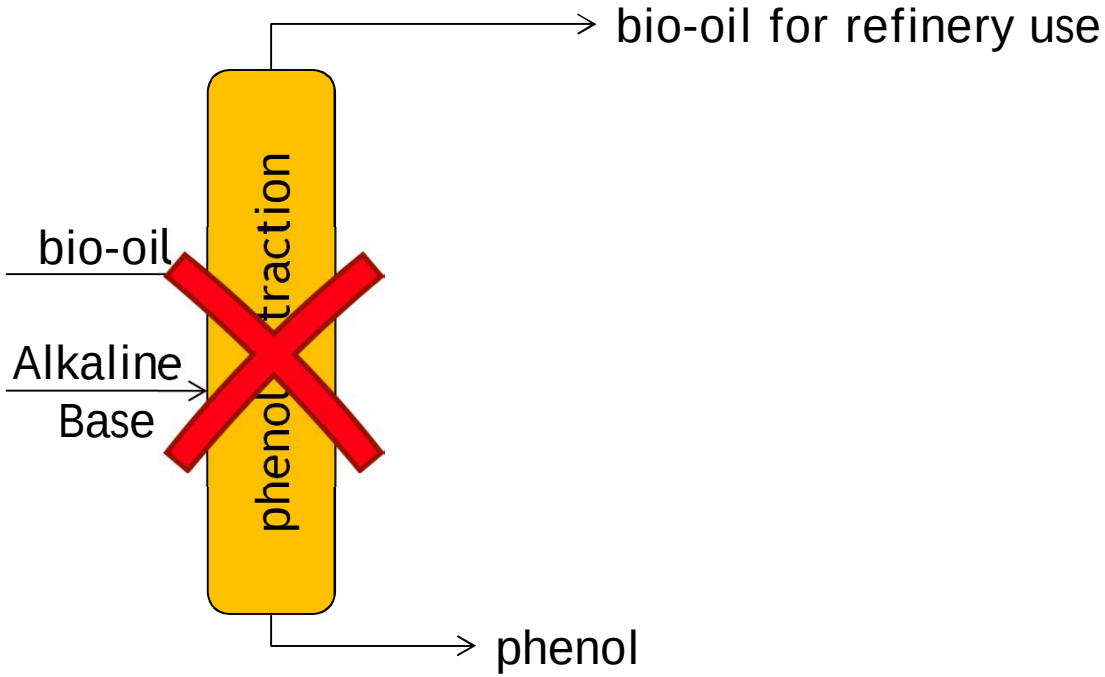
Extract phenol from Bio-Oil



acids extract, bad separation

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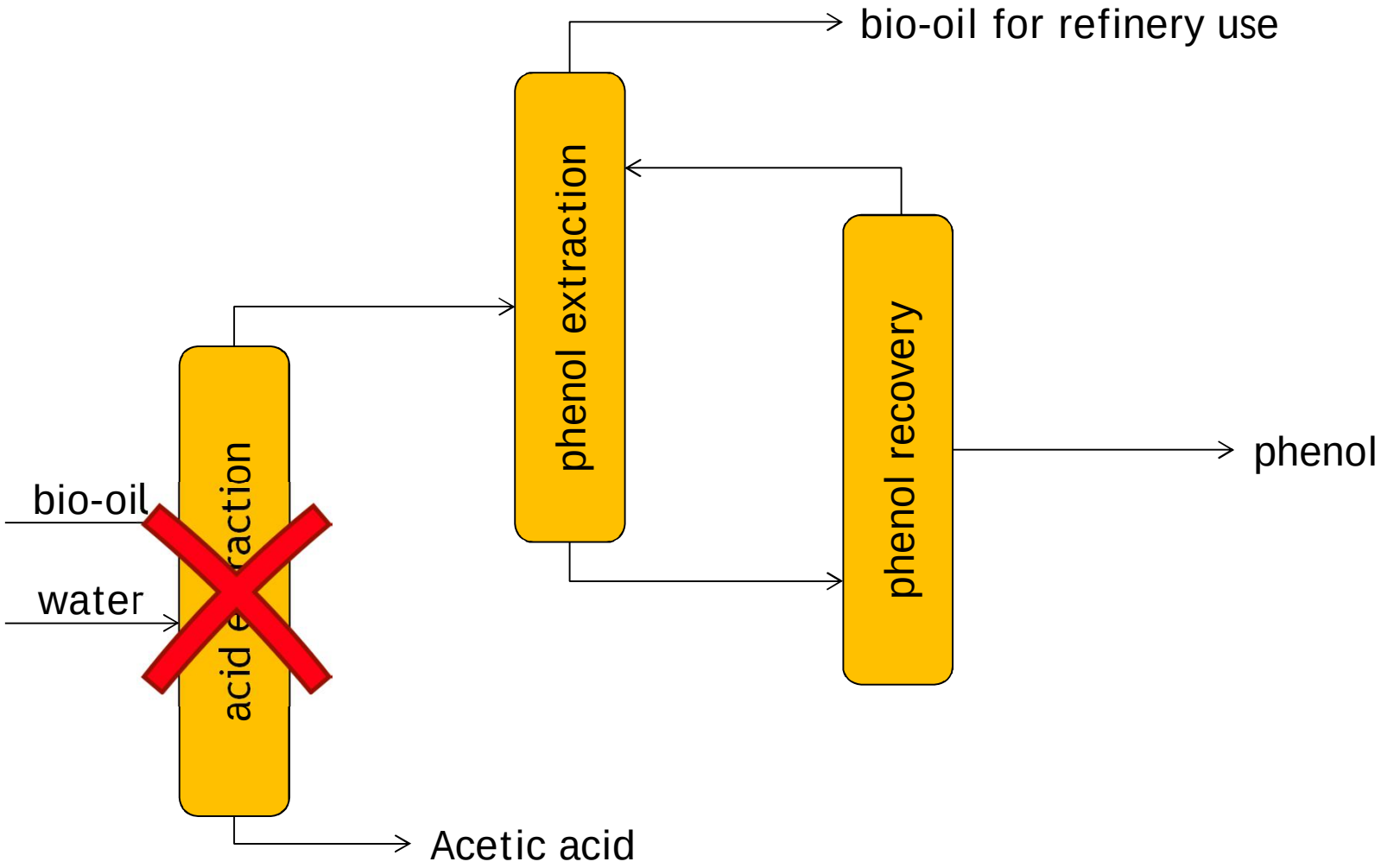
First extract acid – then phenol



Viscosity increase

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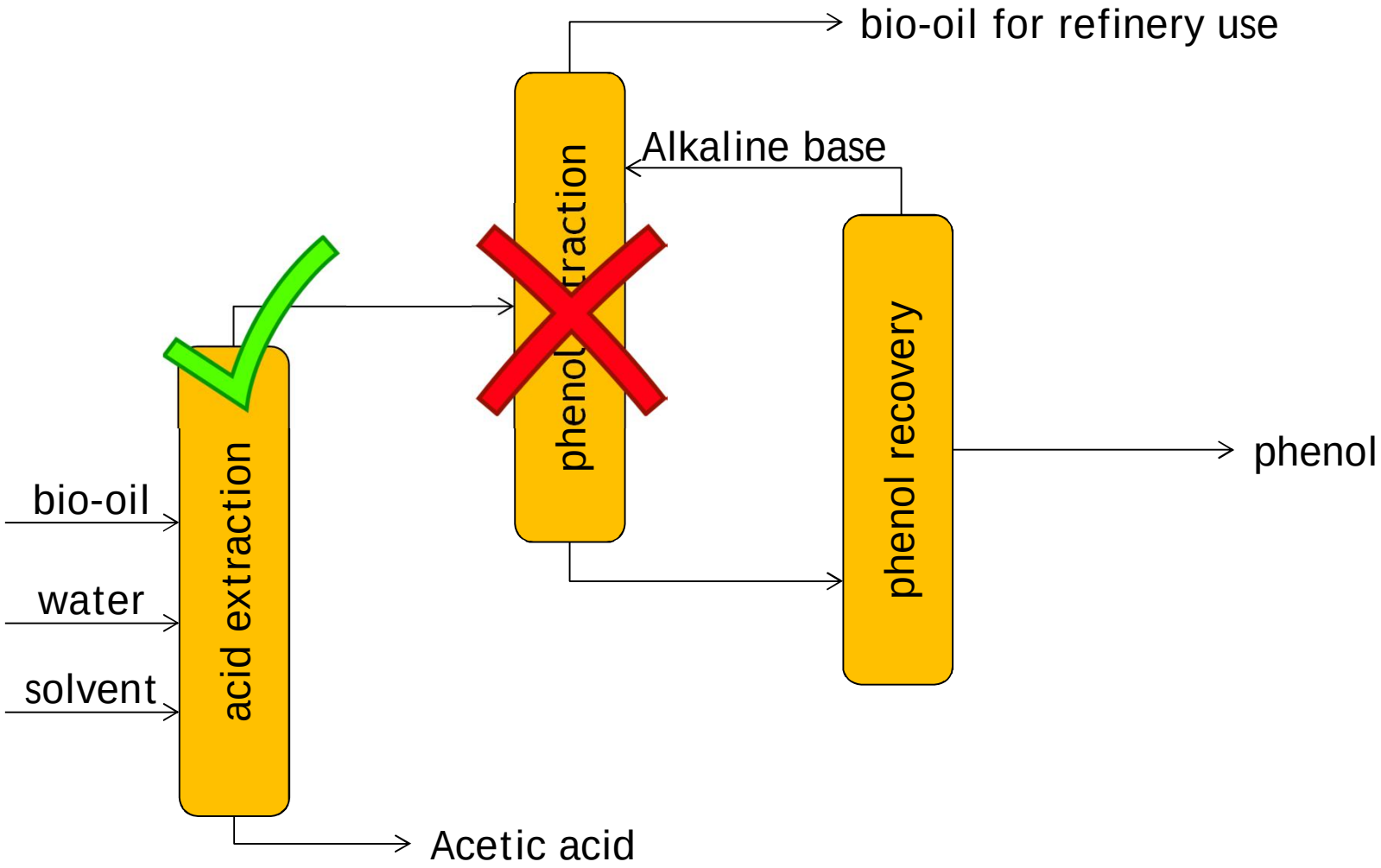
First extract acid – then phenol



No phase separation

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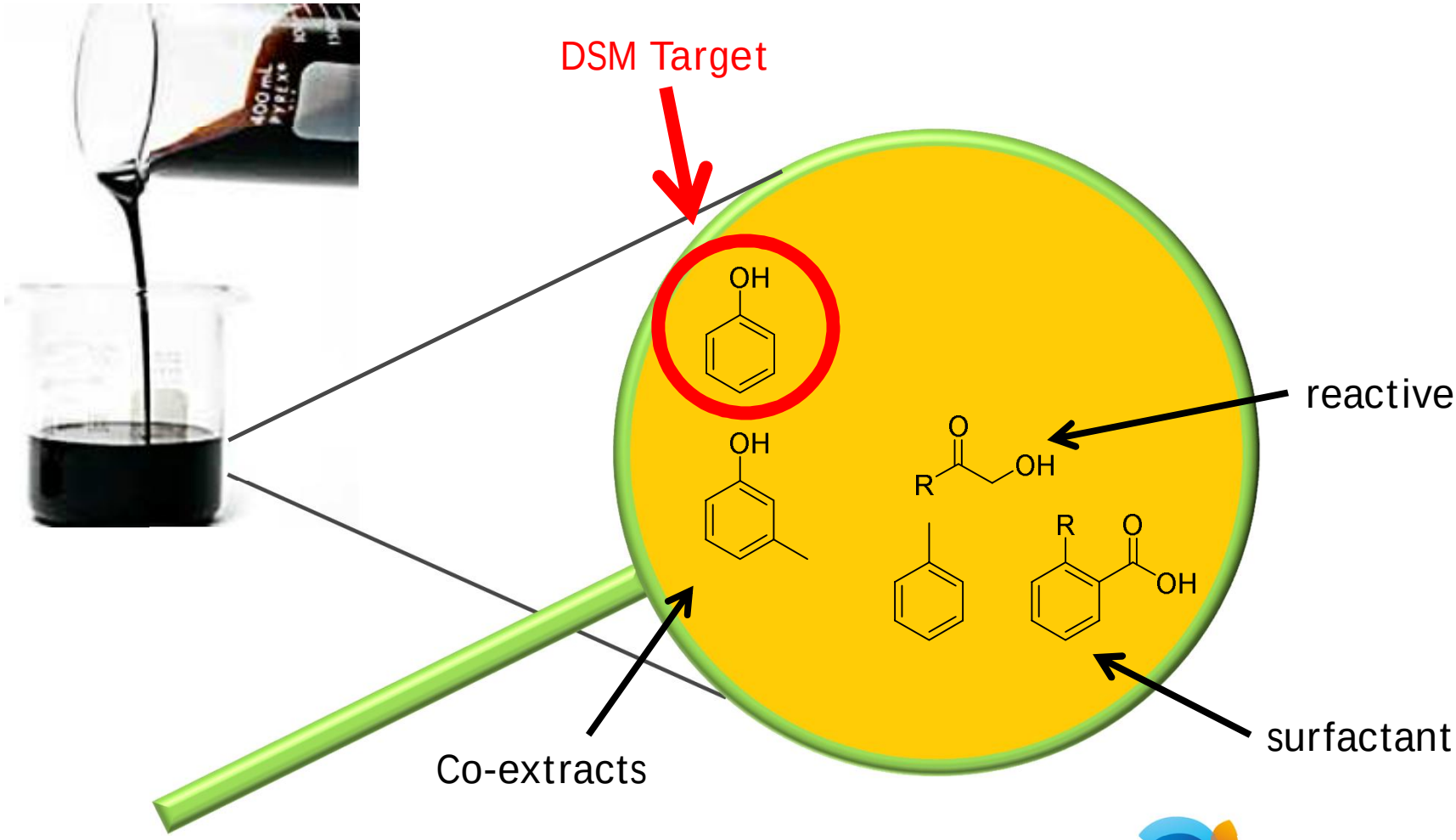
The new playing field



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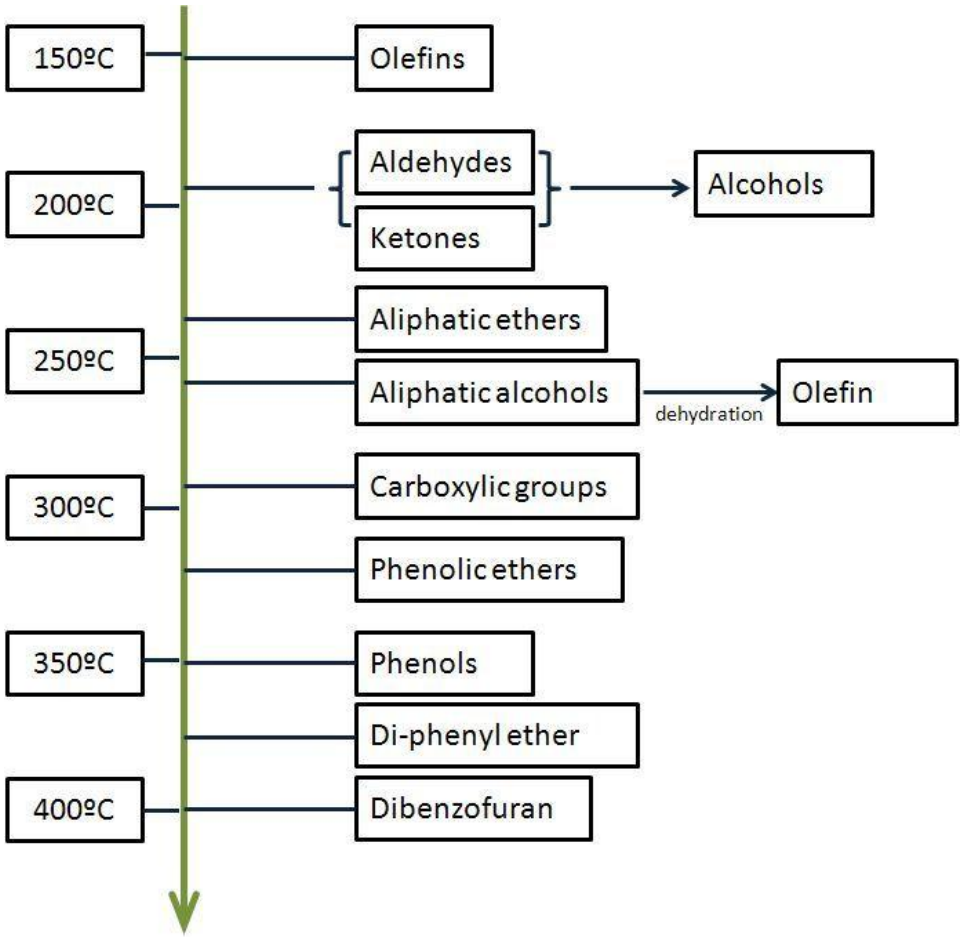
HDO chemistry



Elliot, Energy & Fuels 2007.

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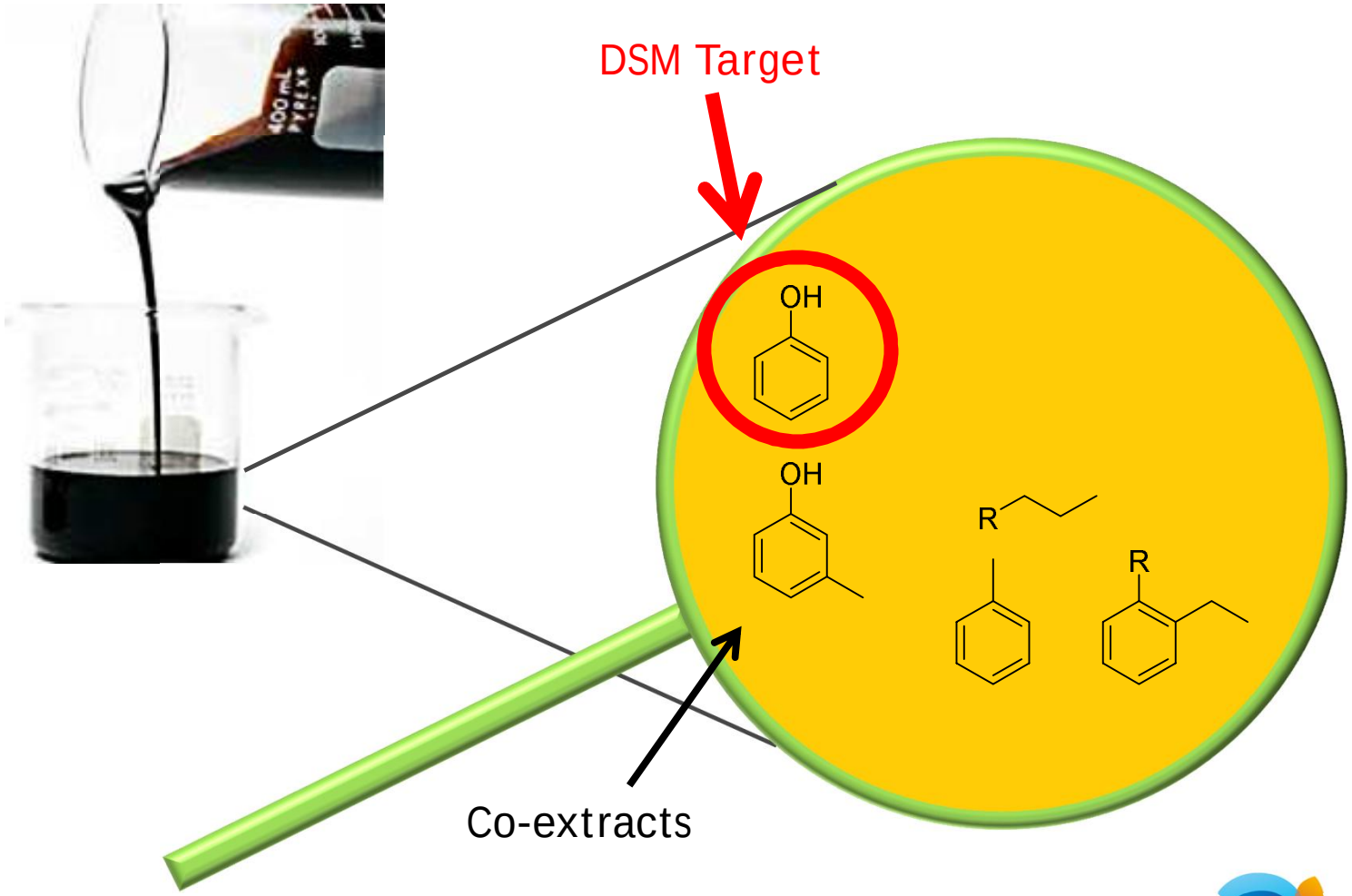
The really new playing field



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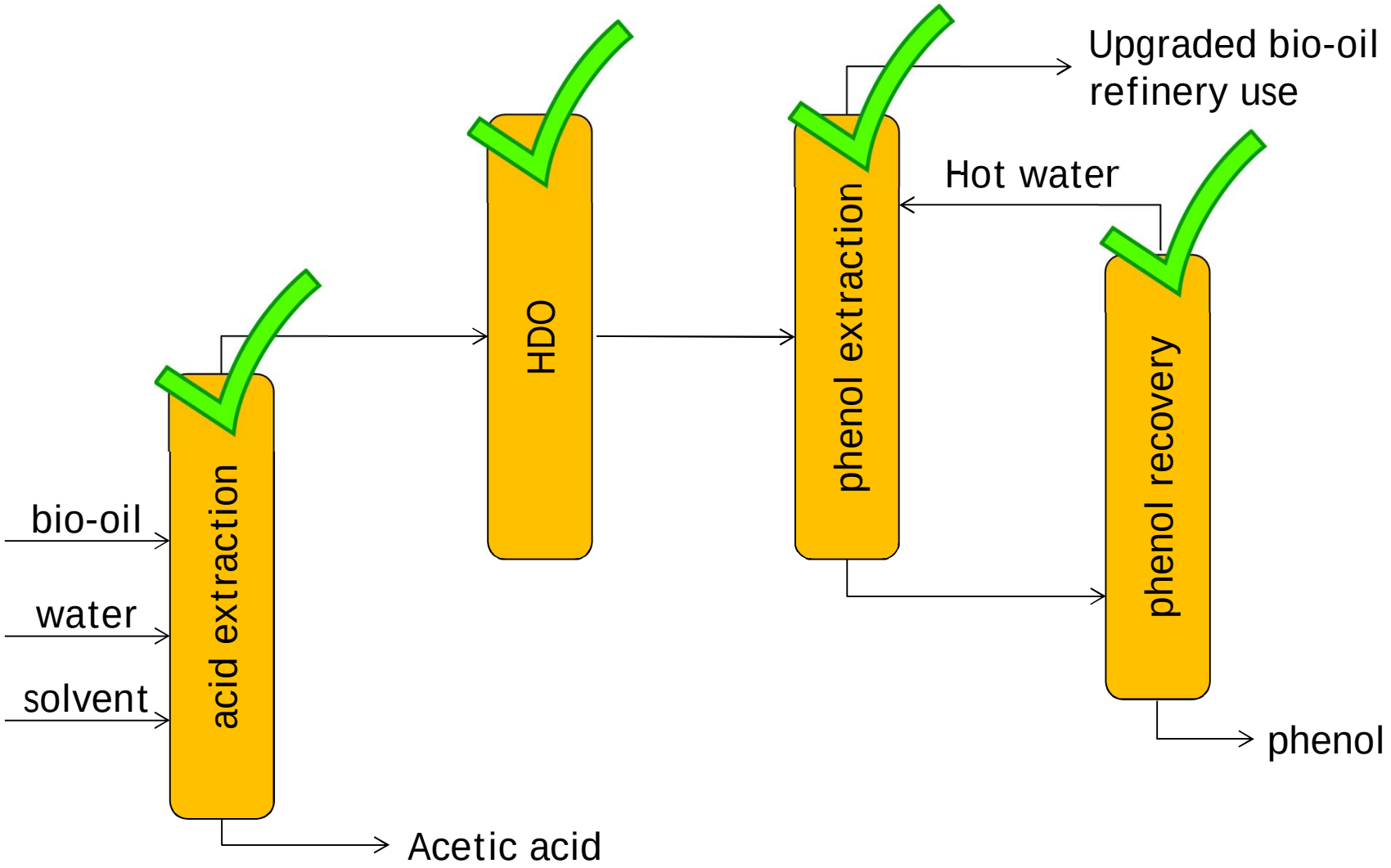
First extract acid – then phenol



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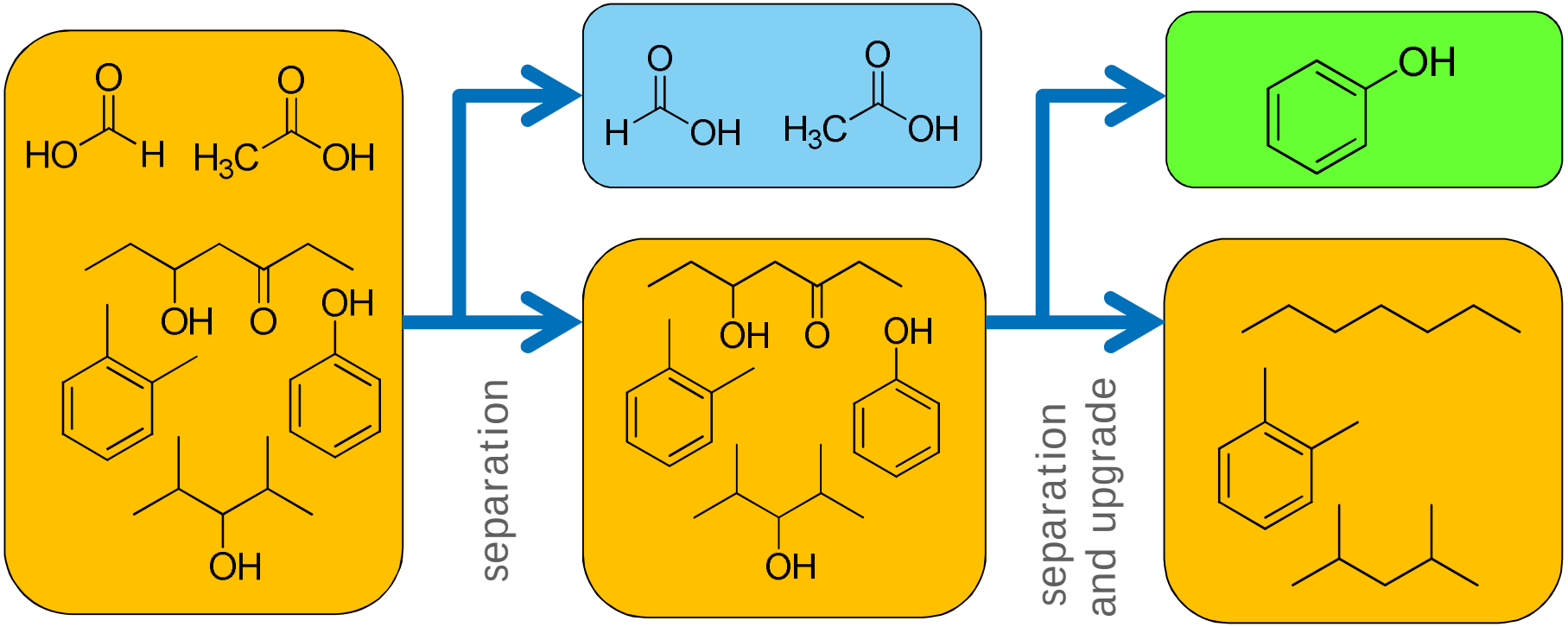
Summary



Fuel
Phenol
Organic acids

Fuel
Phenol

Fuel

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