Transition to circular chemicals and materials; What it takes to make it happen.

ECRN regions' bioeconomy projects

Marijn Rijkers

21 January 2021

Chemelot InSciTe

Biobased materials

Chemelot Institute for Science and Technology (InSciTe)

Technical validation institute in a public-private partnership.
Founded in 2015 by DSM, UM & MUMC+, TU/e and Provincie Limburg

https://www.chemelot-inscite.com

Chemelot InSciTe Circular Economy

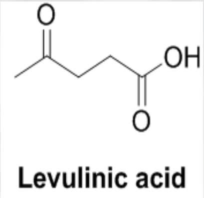
Shared infrastructure at the Brightlands Chemelot Campus with highly trained staff and top-notch equipment

Video tour: https://youtu.be/lUsUHyrZO2s

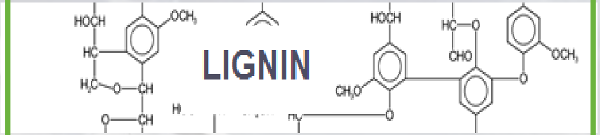
Chemelot InSciTe Circular Economy

Projects offer a window to circular drop-ins, new materials and sustainable energy.
https://www.chemelot-inscite.com/en/biobased

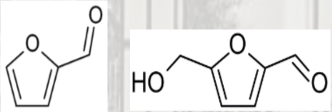
Levulinic acid products



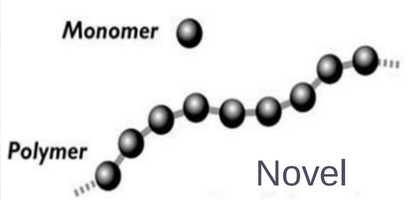
Lignin-based fuels



Furfural & HMF tree



Furfural & HMF



Novel materials

Chemelot InSciTe Circular Economy

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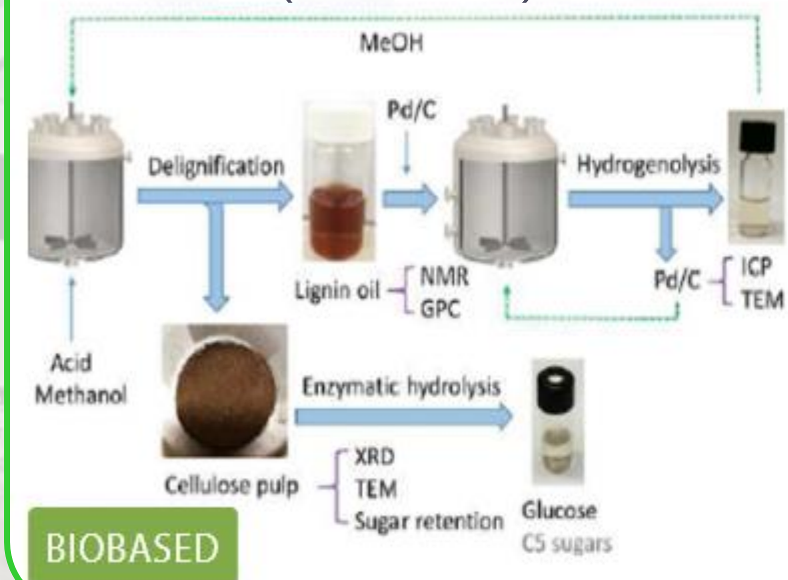
High Performance Biobased Polycondensates (HiPERBioPol)

A lignin-first approach (LIBERATE)



Chemelot InSciTe Circular Economy

Business domain

Value creation

Primary raw materials

End-Of-Life products

Poly- / oligomers

Materials

Plastic waste

Naphtha

Engineering plastics

Municipal Solid Waste

RDF

Hydrogen

Chemicals

Woody biomass

Char

Fertilizers

Specialties

Agro waste

Natural oils

Liquid fuels

Construction

Plants

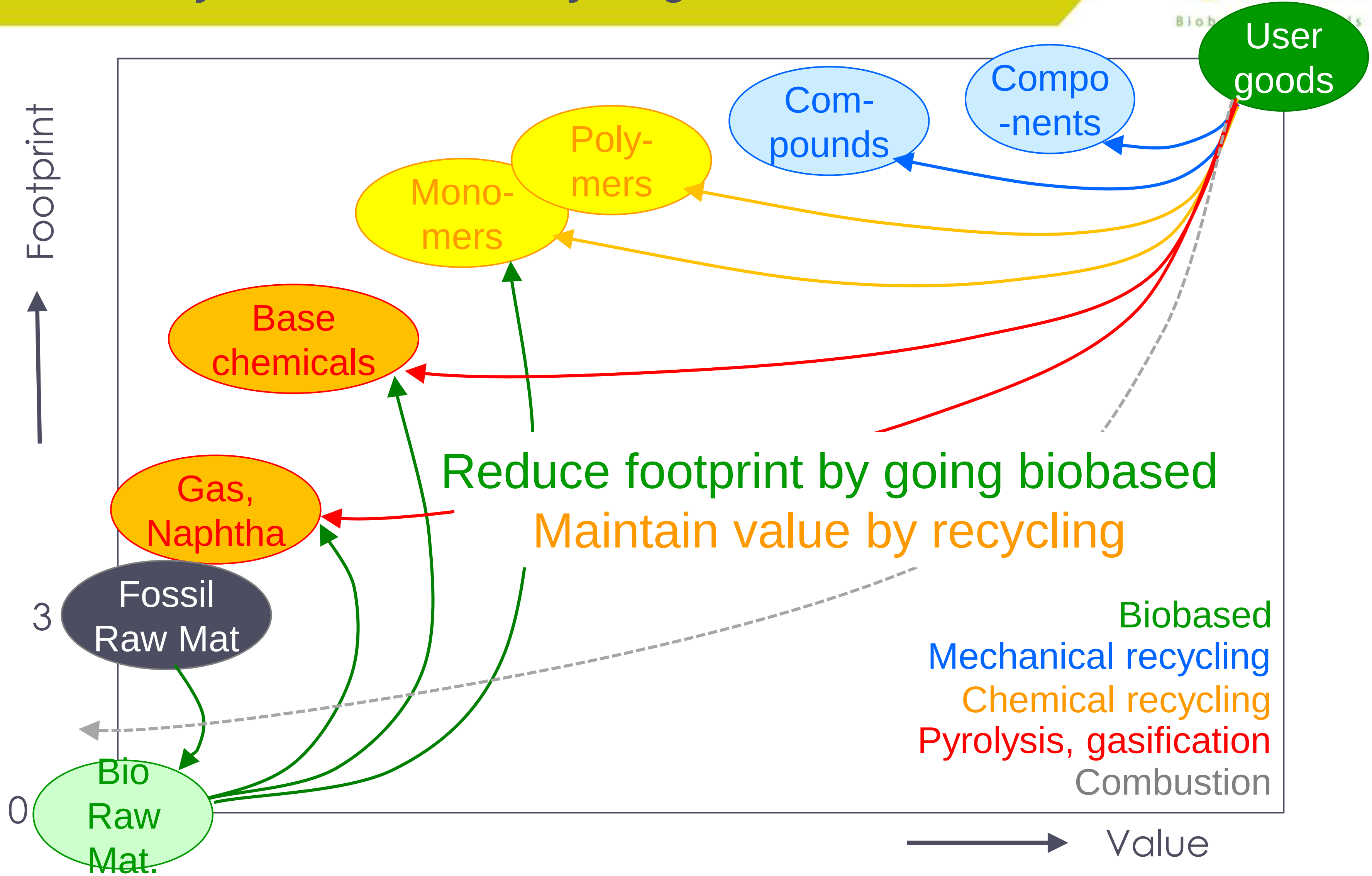
Fibers

Packaging

Natural products

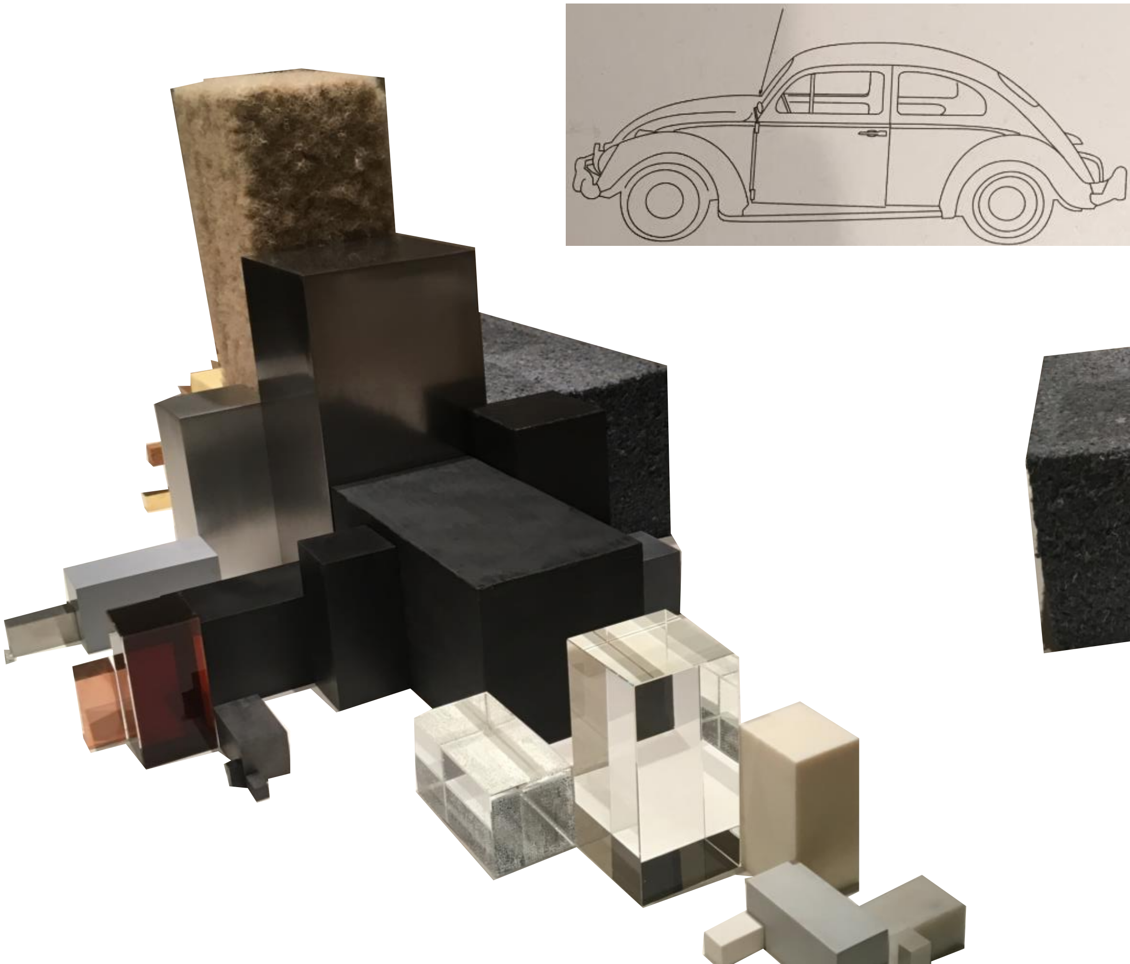
Circular materials

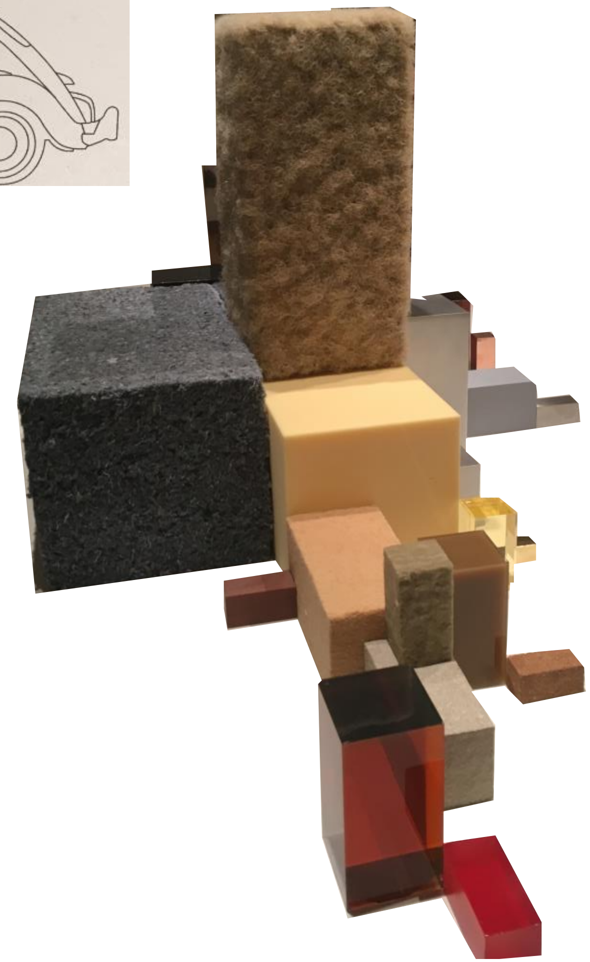
United by biobased and recycling



Inspired by the presentation of Gerard WerumeusBuning on circularity on 11 April 2019 at InSciTe

Raw materials for a Volkswagen Beetle





Studio DRIFT (2007)
Stedelijk Museum Amsterdam (2018)
https://www.studiodrift.com/work#/materialism/

Carbon footprint of a Volkswagen Beetle

Raw materials, personal estimate of carbon footprint

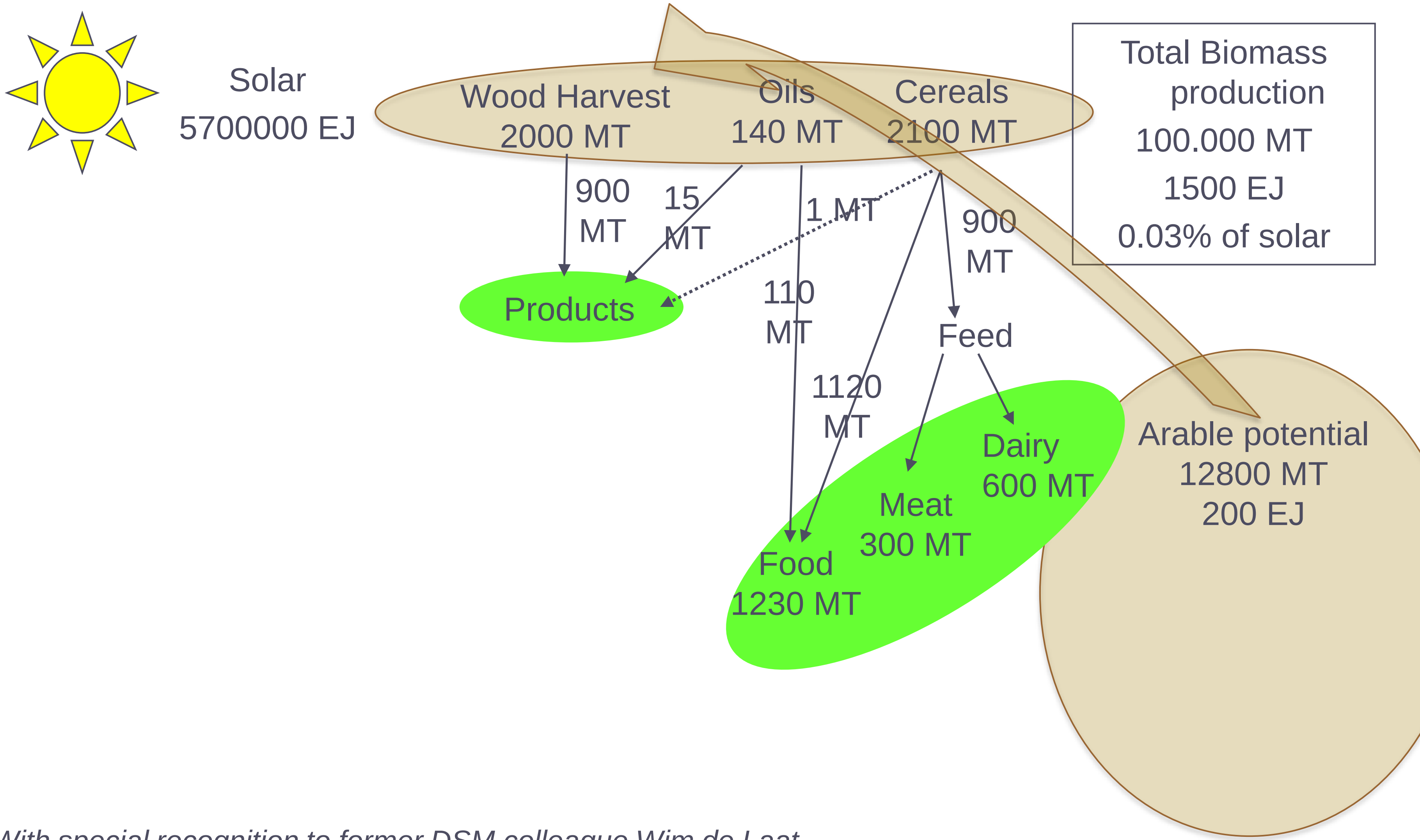
DRIFT completely dissected a Volkswagen Beetle, to the level of the smallest component, then organized all of these by their material and measured each group's accumulated mass. These masses are represented in 42 pure material volumes that begin to tell a variety of stories. The automobile, from 1980, contained surprising amounts of horsehair, cotton, and cork, amongst other unexpected commodities. These relate a tale about availability, tradition, and the state of our technical and material knowledge almost four decades ago.

Material	kg	kg CO2
Steel	420.0	5040.0
Aluminium	60.0	1200.0
Polyurethane	90.0	360.0
Aluminium magnesium alloy	9.0	180.0
Lead	9.0	180.0
Tar	32.0	128.0
Stainless Steel	7.0	84.0
Brass	3.0	60.0
Glass	16.0	32.0
Rubber	30.0	30.0
Tectyl	4.5	22.5
Polyvinylchloride	3.6	18.0
Tungsten	0.4	17.5
Magnet	1.4	16.8
Copper	4.0	16.0
Polyoxymethylene	3.2	16.0
Polyamide	1.8	14.4
Acrylonitrile Butadiene Styrene	1.8	14.4
Grease	2.7	13.5
Motor oil	2.7	13.5
Lacquer	2.4	12.0
Paint	2.4	12.0
Chrome	0.5	10.0
Gear oil	1.8	9.0
Tin	0.4	8.0
Polymethyl methacrylate	0.9	7.2
Cotton	10.0	5.0
Brake Fluid	0.9	4.5
Horse hair	8.0	4.0
Acid	3.6	3.6
Wood powder	6.0	3.0
Bakelite	1.5	3.0
Glasswool	1.5	3.0
Porcelaine	1.5	3.0
Plexiglass	1.2	2.4
High Density Polyethylene	0.5	2.3
Paper	3.0	1.5
Polybutylene terephthalate	0.3	1.4
Kit	0.2	0.9
Graphite	0.2	0.8
Vitrite	0.1	0.4
Cork	0.1	0.0
Total	**748.8**	**7553.5**

About 95% of weight comes from fossil sources, adding >99.5% to carbon footprint

Global yearly annual energy and material balance

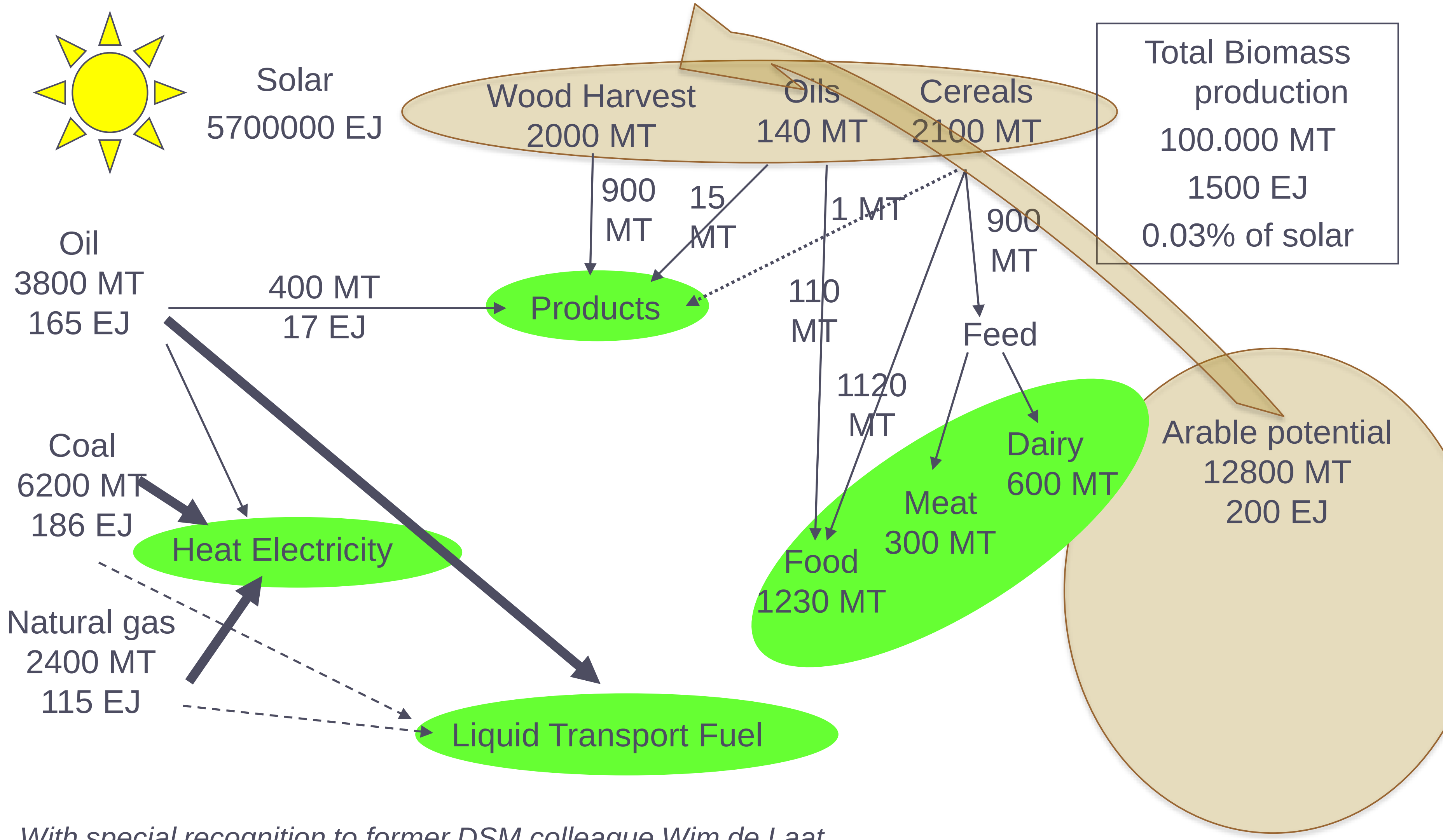
Up to the 19th century



With special recognition to former DSM colleague Wim de Laat

Global yearly annual energy and material balance

The fossil era



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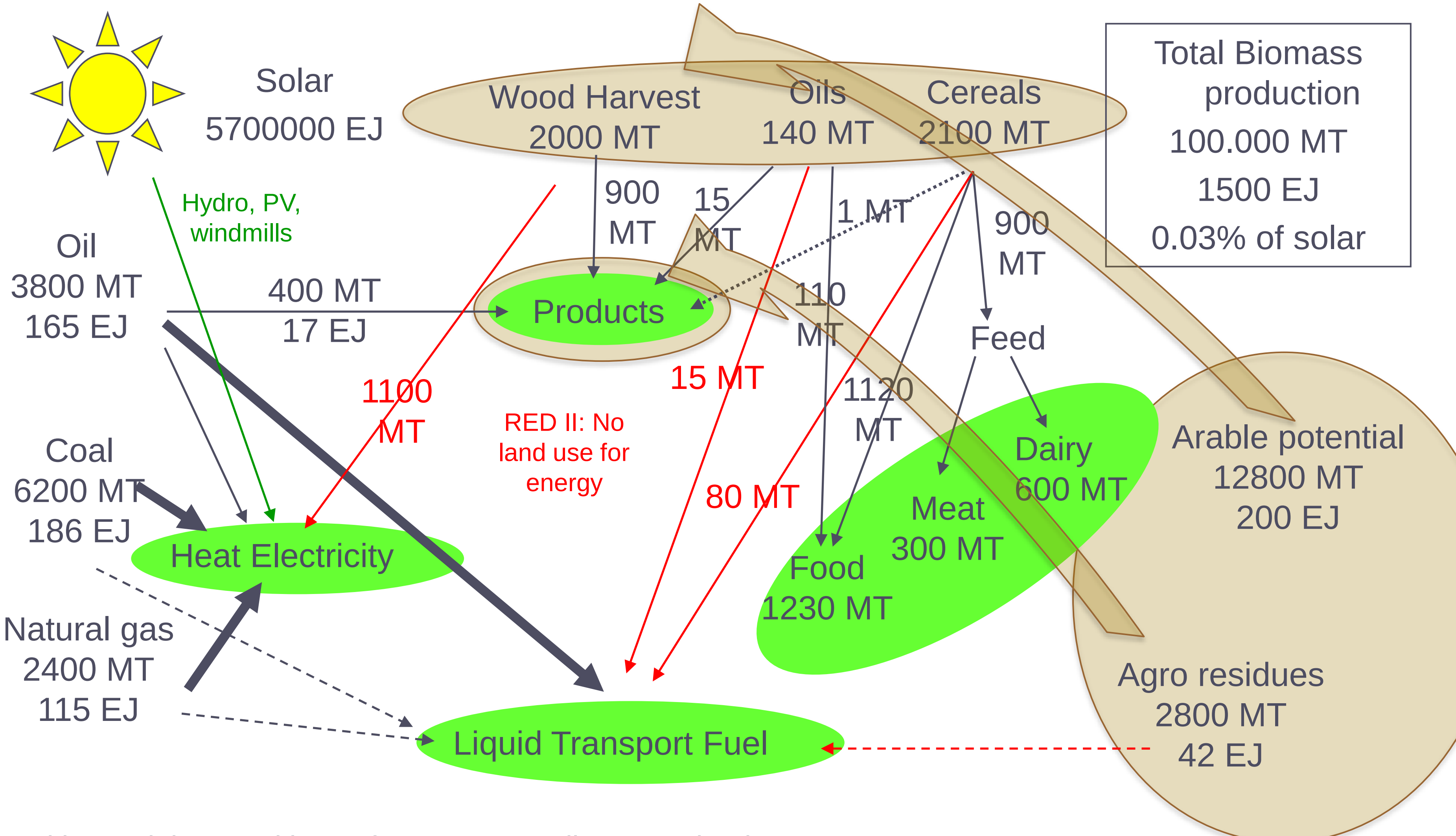
Global yearly annual energy and material balance

Now: *Where biobased opportunities come in*



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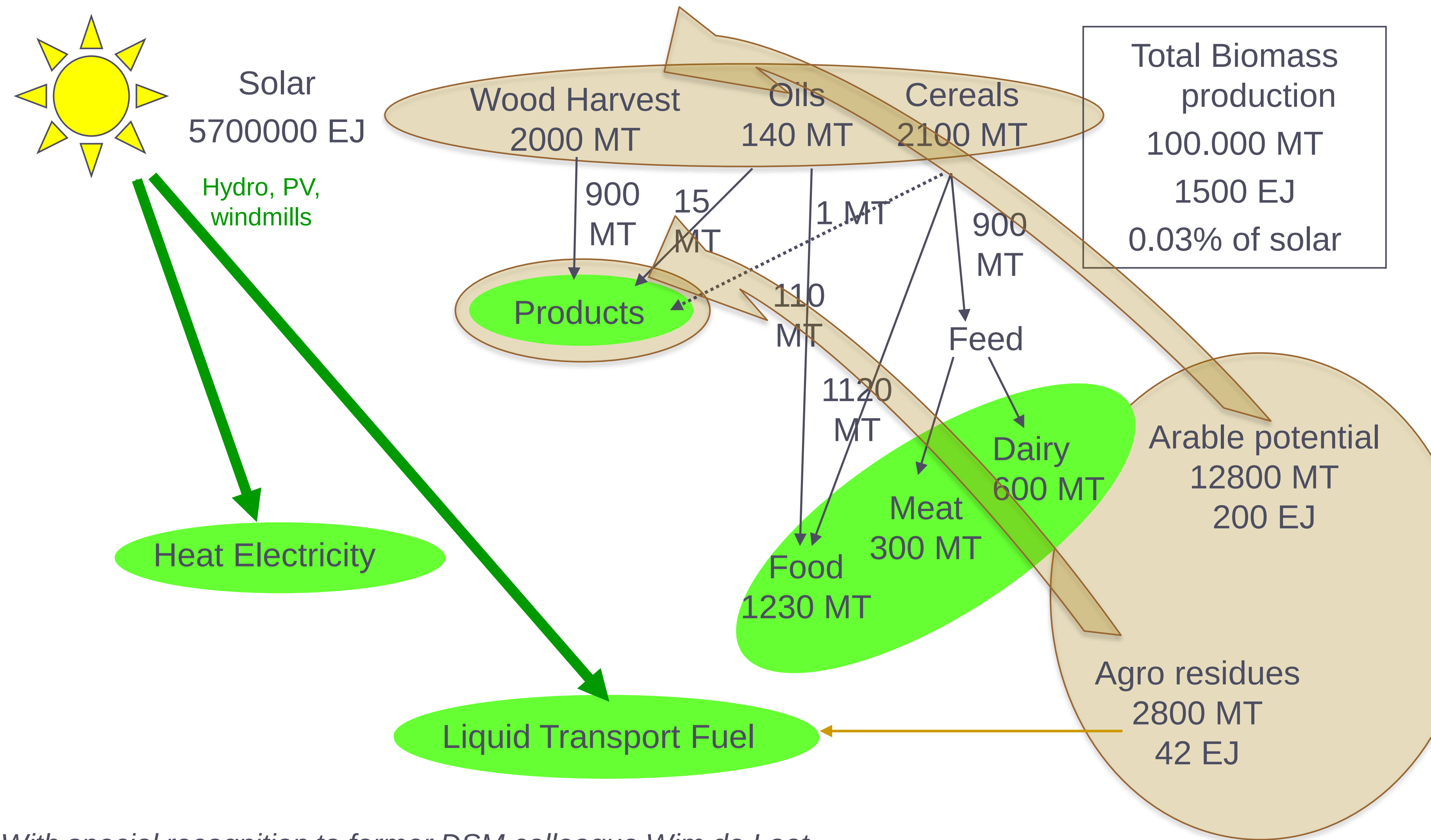
Global yearly annual energy and material balance

2050 or earlier (our choice)



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Chemical circularity connects

Harvests from the land or sea and end-of-use products

Alternative feedstocks and functionalities examples:

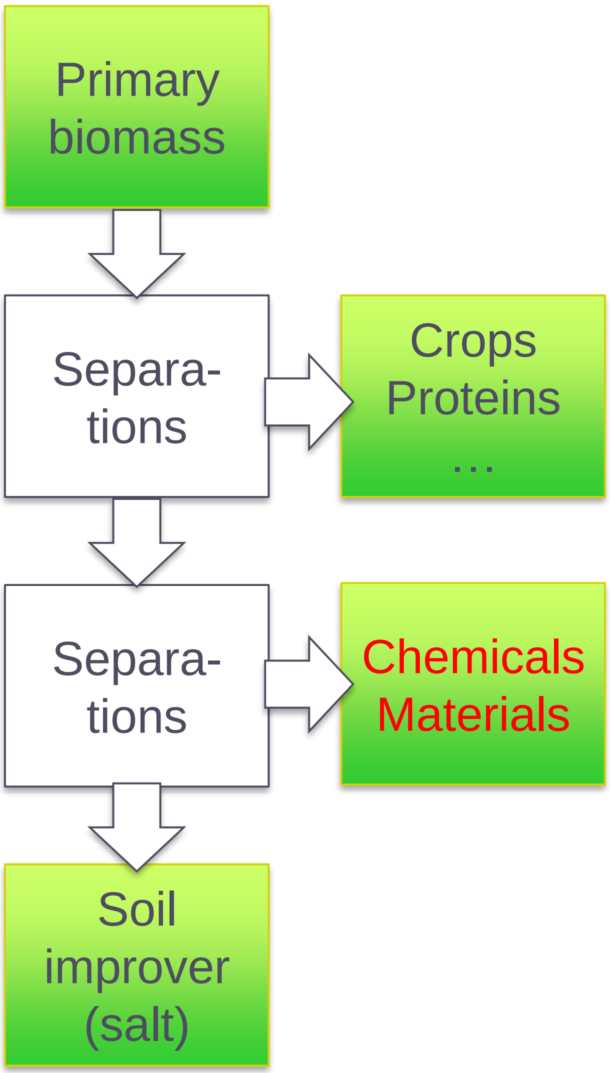
- Woody biomass, lignocellulose, including agro waste
- Natural oils, carbon chains with functionality
- Aquatic biomass, diversity of specialties
- Organic waste, lignocellulose, natural oils
- Plastic waste, long carbon chains
- Municipal solid waste, mix of the above
- Side stream of processing industry, defined quality
- Last but not least: “Engineered waste” (assemble-to-disassemble)

Typical agricultural value chains

Elements:

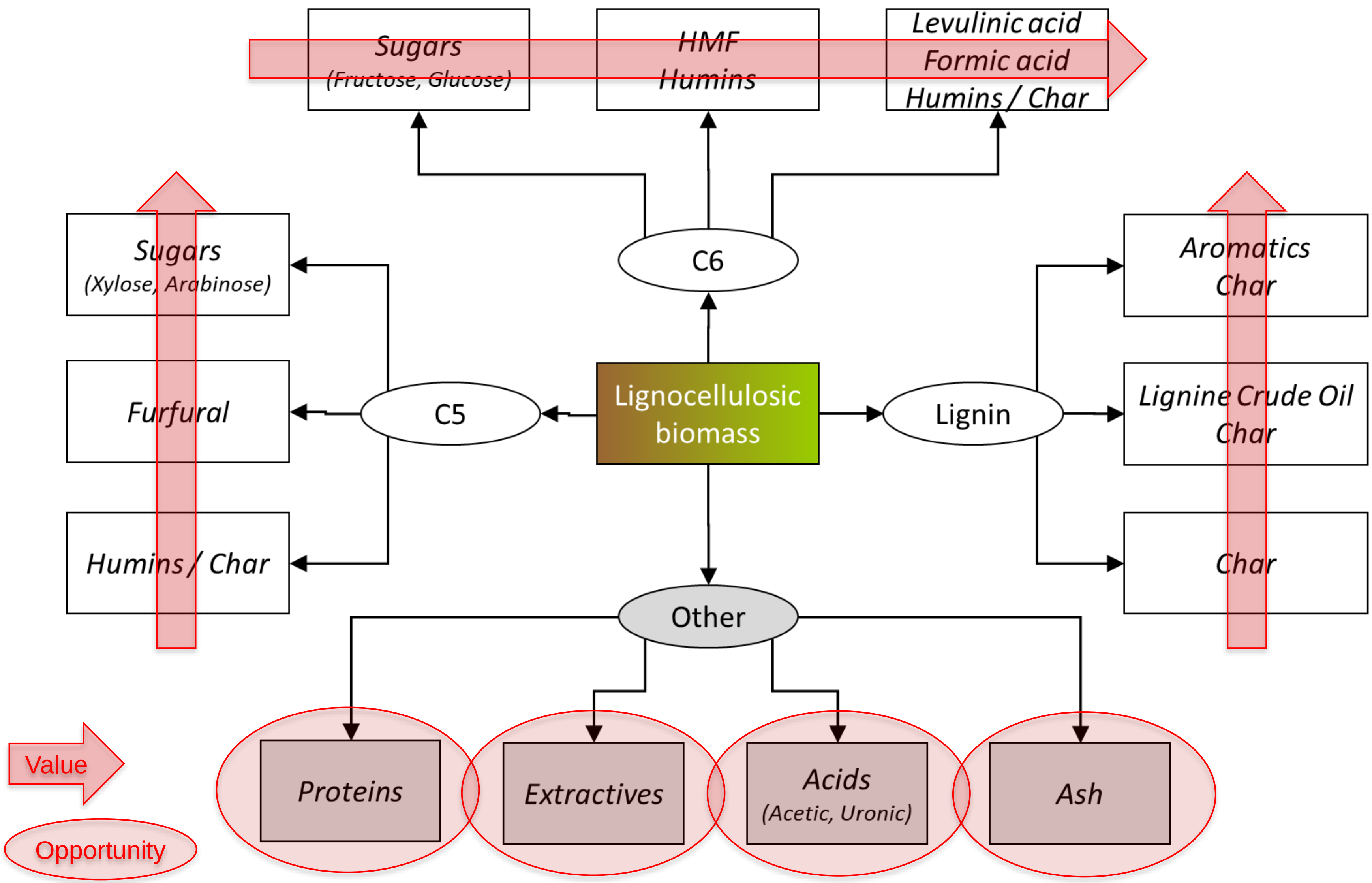
- Primarily lignocellulosic basis (natural oil opportunity ?)
- Maximize value creation: Food > Fibers > chemicals > soil improver
- Mild treatment (ambient temperature, aqueous)
- Small scale, cooperative
- Commoditize (stability)
- Logistic cost (collection radius)

Chemistry offers new dimension to state-of-the-art refinery concepts.



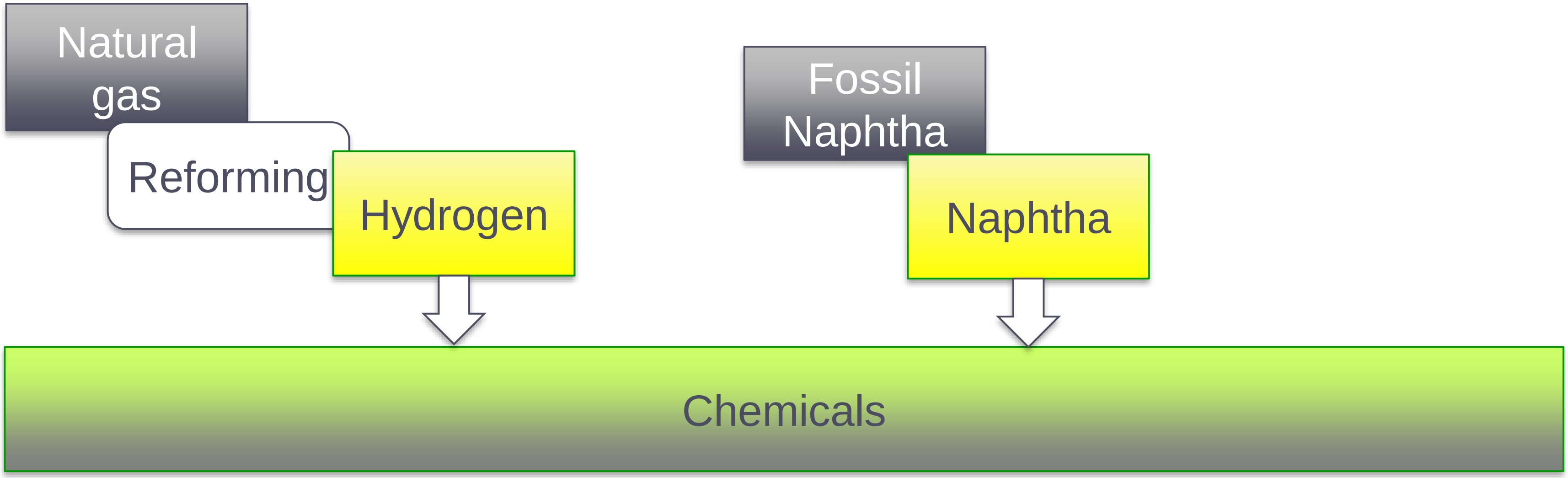
Lignocellulosic biomass uses

Plenty of value creation possible



Connecting chemical sites to circular feedstocks

Opportunity for commoditized biomass



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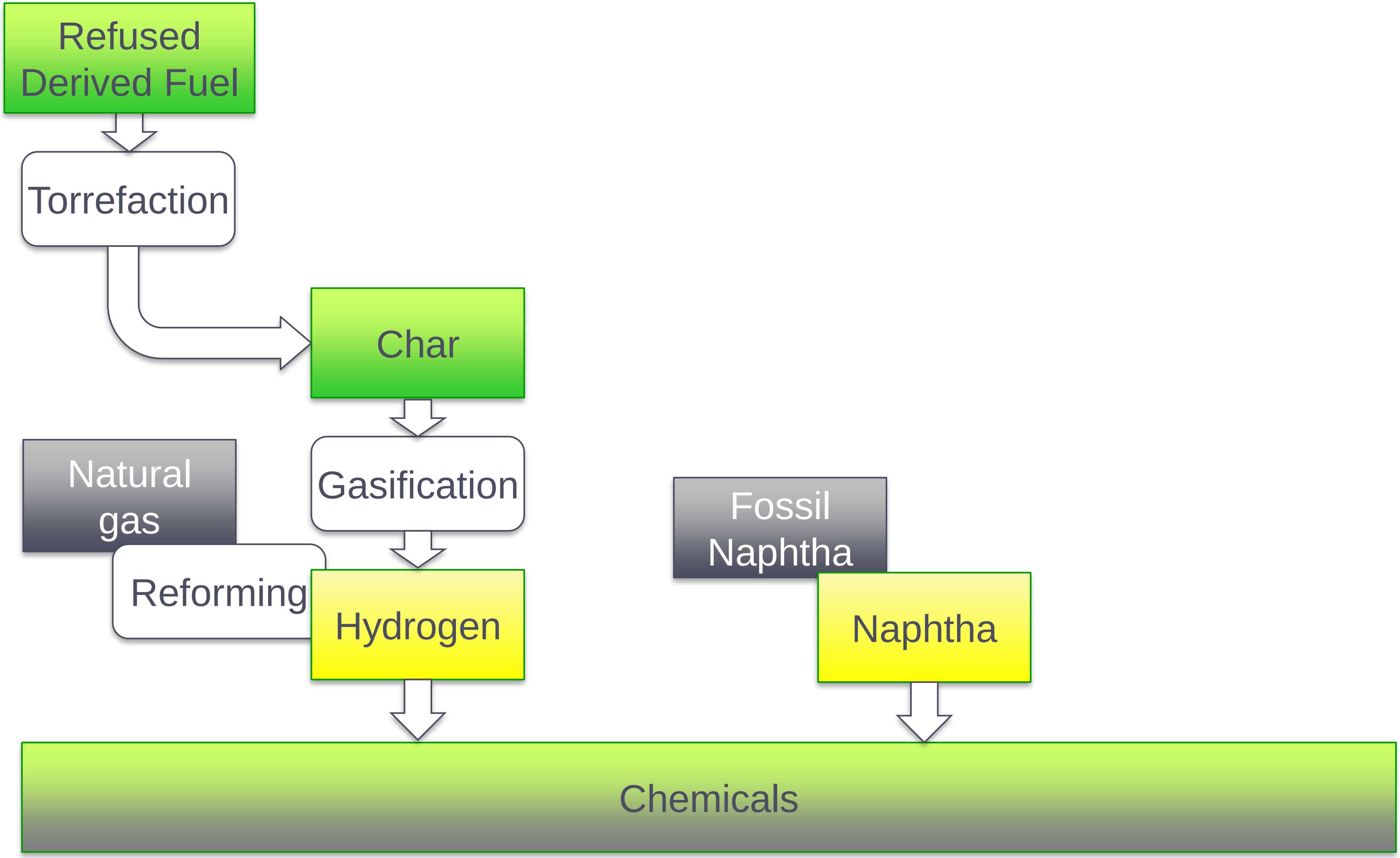

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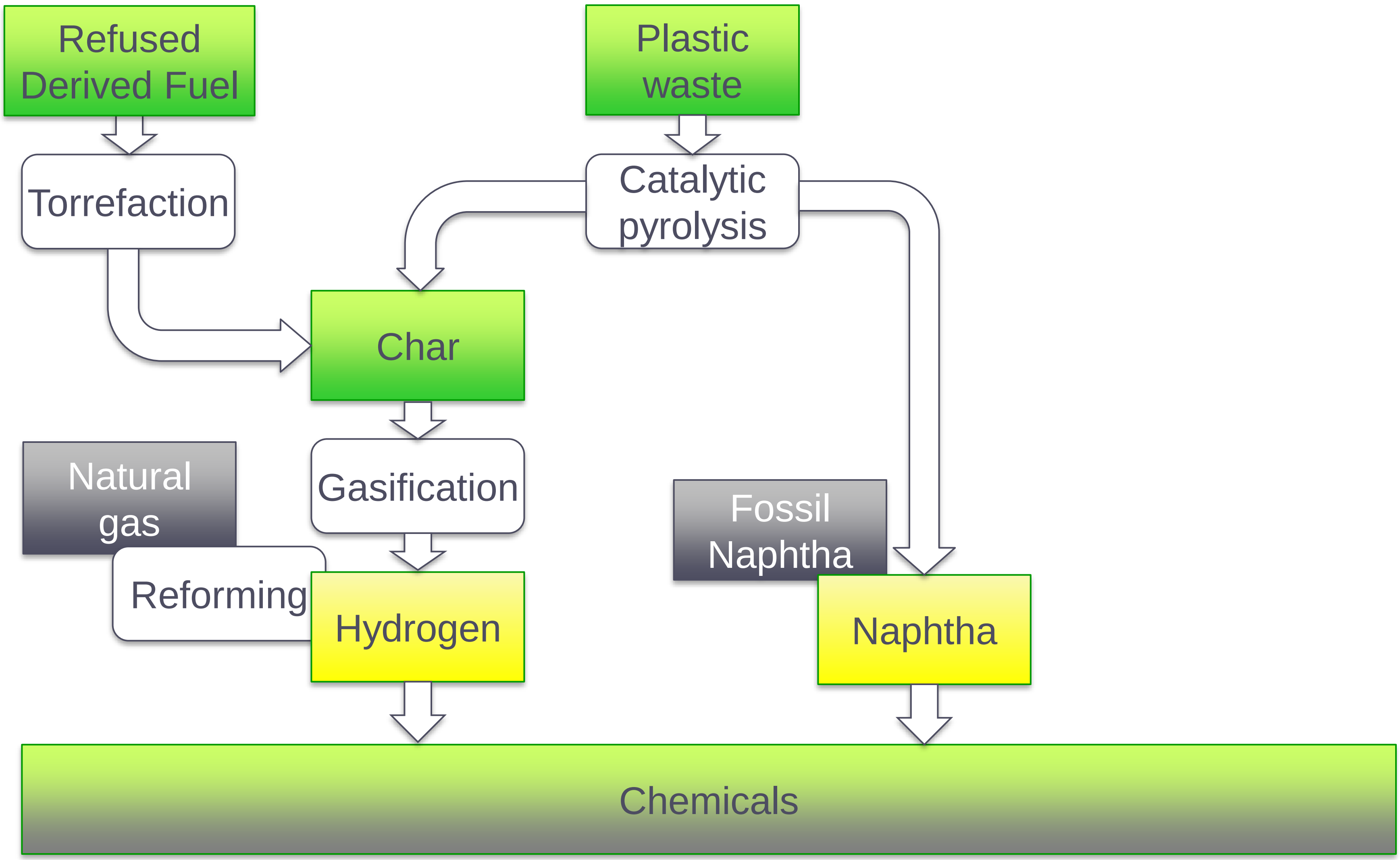

Connecting chemical sites to circular feedstocks

Opportunity for commoditized biomass

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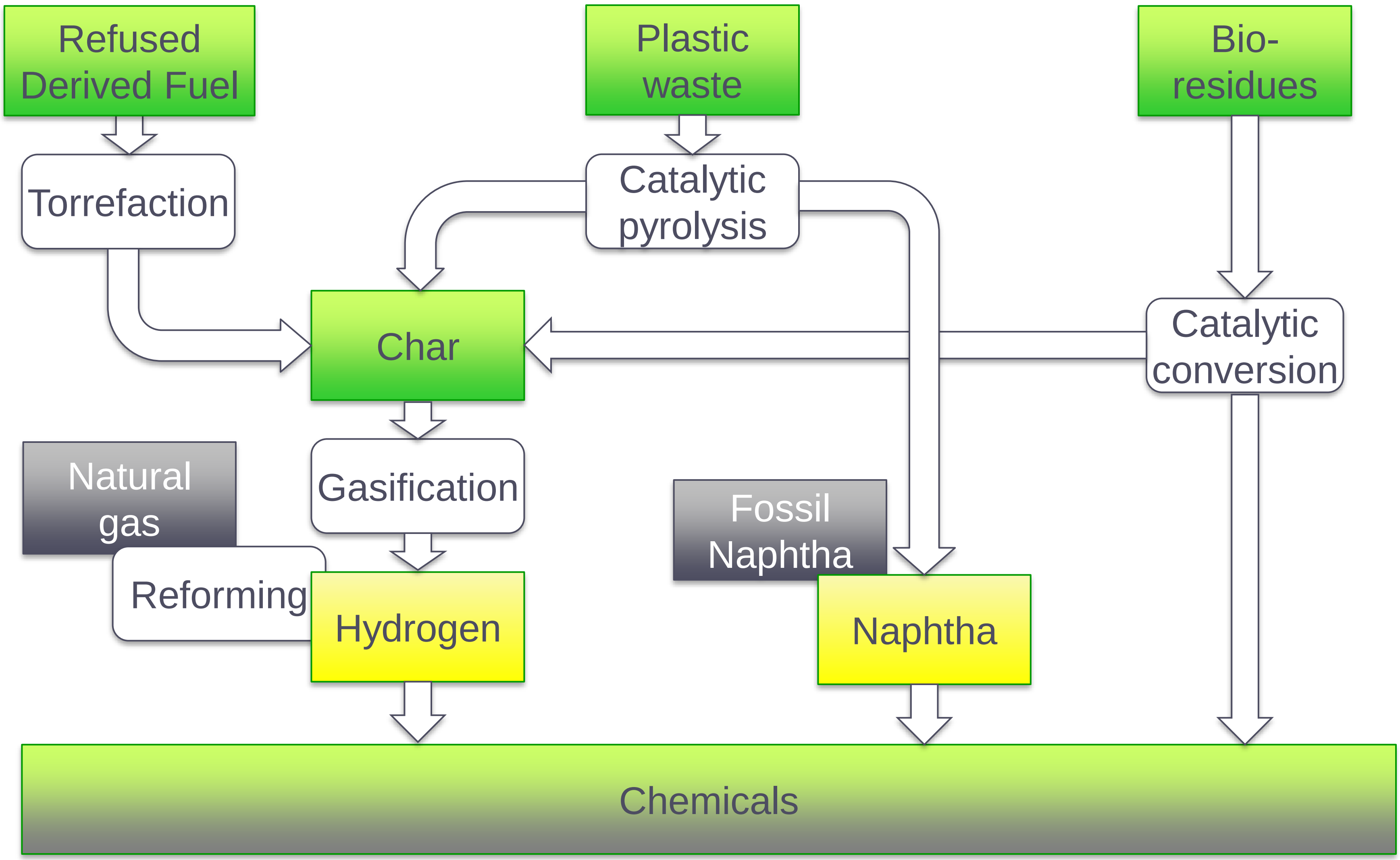
Biobased materials



Circular chemical value chains

Chemelot on headlines, 2019

Natural gas

Naphtha

Hydrogen

Capro-lactam

Ethylene Propylene Pygas

Ammonia

Acrylo nitrile

Urea, fertilizers, melamine

Carbon dioxide

Poly-amines

Poly-olefines, aromatics

Circular chemical value chains

Opportunities 2021 ?

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Biobased materials

Bio-residues

Natural gas

RDF

Naphtha

Mixed plastic waste

Hydrogen

Capro-lactam

Ethylene
Propylene
Pygas

Ammonia

ACN

Urea, fertilizers, melamine

Carbon dioxide

Poly-amines

Poly-olefines, aromatics

Circular chemical value chains

New value chains 2030 ?

Bio-residues

Natural gas

RDF

Naphtha

Mixed plastic waste

Bio-naphtha

Formic
Levulinic
GVL

Hydrogen

Bio-char

Capro-lactam

Ethylene
Propylene
Pygas

Ammonia

ACN

Urea, fertilizers, melamine

Carbon dioxide

Poly-amines

Poly-olefines, aromatics

Circular chemical value chains

Transition completed 2050 ?

Chemelot InSciTe
Biobased materials

Bio-residues

RDF

Mixed plastic waste

Bio-naphtha

Formic
Levulinic
GVL

Hydrogen

Bio-char

Capro-lactam

Ethylene
Propylene
Pygas

Ammonia

ACN

Urea, fertilizers, melamine

Carbon dioxide

Poly-amines

Poly-olefines, aromatics

What will happen ?
Innovation – Innovation – Innovation !

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Biobased materials

- New circular sources emerge (most are already there, “collecting themselves” !), e.g.:
  - Agro feedstocks (ditch clippings, field grass, roadside grass, champost, wood thinnings …)
  - Municipal solid waste
  - Mixed recycle plastics
- Develop new processes and assets to connect the new sources to (fossile) intermediates or products. E.g.:
  - Torrefaction and gasification
  - Pyrolysis and hydrodeoxygenation (HDO)
  - Thermo-catalytic conversion (e.g. Levulinic tree)
- Embark on business opportunities for new (circular, often biobased) products
- Start replacing of fossil intermediates by circular intermediates and monitor effect on product quality and (*level playing field*) process cost
- Gradually increase the circular contribution, satisfying *level playing field* economics

Q: What is a sustainable CO2 price ?
A: *(Biobased fuel – Fossil fuel) / 3.*

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Mineral oil → refining → jet fuel
40 $/brl 400 €/ton

$-CH_2-$
Mw=14

CO_2
Mw=44

44/14 ≈ 3

Biomass residues → Gasification → Syngas → Fischer-Tropsch → jet fuel
120 €/ton 400 €/ton 1000 €/ton

Level playing field CO2 price: (1000 – 400) / 3 = **200 €/ton**

50 kg fuel /1000 km = 0.15 ton CO2 / 1000 km = 0.15*200 = 30 €/1000 km

What can *we* do ?

Join forces and collaborate !

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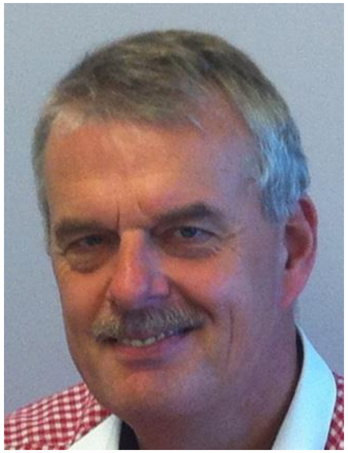
- Find owners driving this transition, provide supporting and stimulating means for this
- Make *level playing field* happen (preferably globally, next best locally)
- Develop competitive regional biorefinery concepts (with maximum value creation)
- With commoditized outlets towards chemistry applications (quality, availability, price)
- Develop competitive processes towards circular intermediates
- Minimize energy consumption (and therefore cost, at *level playing field*)
- Involve society (NGO) in all steps

Join forces !

- Teaming up in collecting sufficient circular feedstocks
- Finding best refinery concepts
- Contribute to establish circular value chain, connect with down-stream partners
- Help in preparing circular business plans, “project incubator”
- Obtain together sufficient support from governments (and EU)
- Set-up and execute projects for boosting circularity

For technology valorization, Chemelot-InSciTe could take a supportive role by providing knowledge and (piloting) infrastructure.

Thank you !



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