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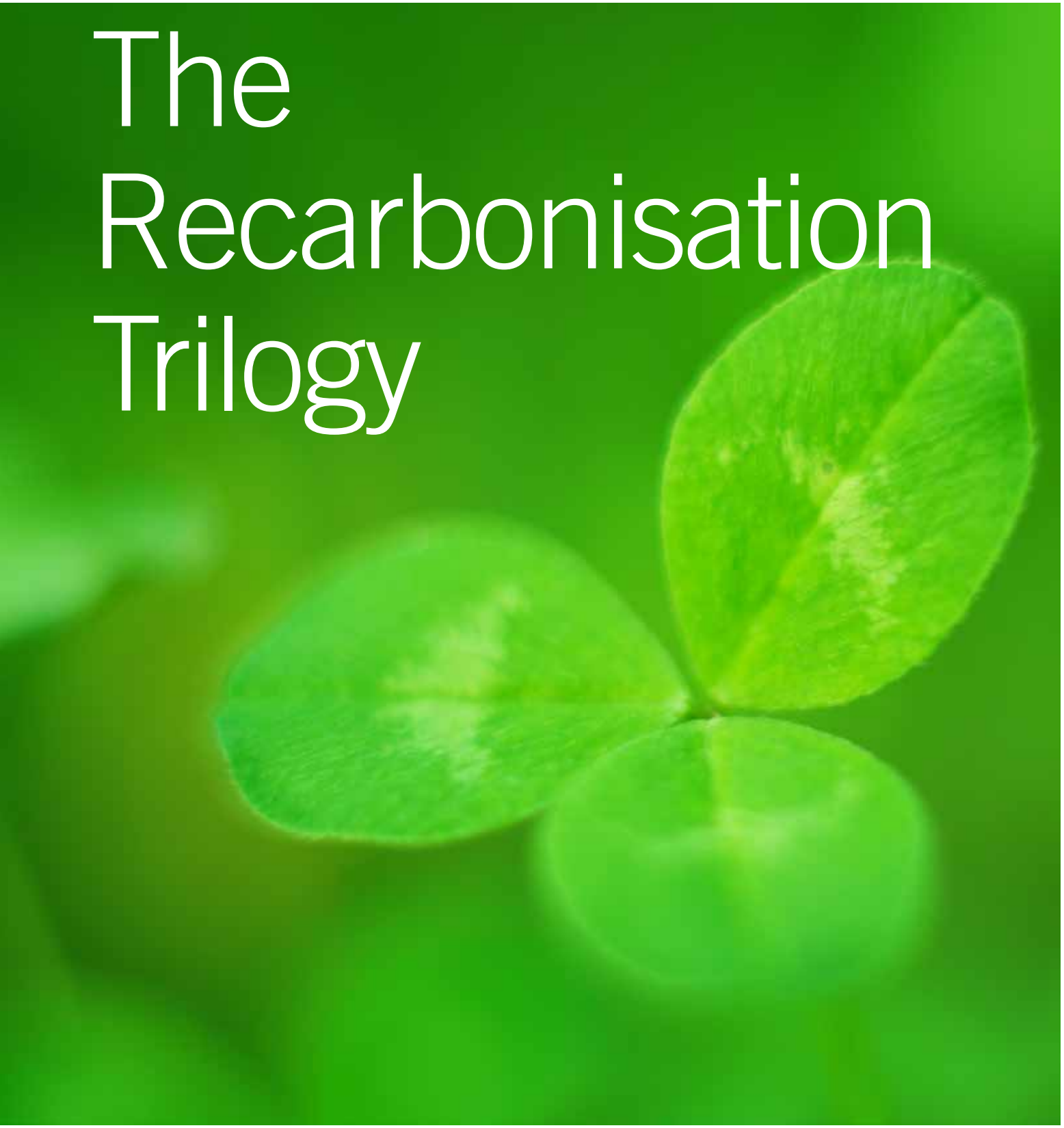
PÖYRY POINT OF VIEW - JANUARY 2016

The Recarbonisation Trilogy



The Recarbonisation Revolution

We need a 'recarbonisation revolution' of global material flows. We have to increase biomass and decrease non-renewable materials such as metals and minerals in the movement of global trade. Recarbonisation also means going from fossil carbon to biocarbon. The recarbonisation revolution gives us a simple way to define the bioeconomy: recarbonise materials, decarbonise energy.

Recarbonise materials, decarbonise energy

With the profound concern over climate change, the terms 'decarbonisation' and 'low carbon economy' have become so popular that a key truth has been forgotten - carbon is the basis of life. It is only in energy that we need to get away from fossil-based carbon as a fuel. In materials, we need carbon in the form of biomass to create a truly renewable and sustainable loop. This recarbonisation revolution gives us a simple way to define the bioeconomy: recarbonise materials, decarbonise energy .

New developments in technology and materials sciences have made this revolution both possible and desirable. Four material platforms stand out as examples of the possibilities we can achieve with recarbonisation: lignin, sugar, nanocellulose and graphene. The first three are carbon-based and graphene is actually pure carbon. Together they have the potential to radically change the materials world.

THE BIOECONOMY QUARTET OF MATERIALS

Lignin is nothing new, on the contrary it is a basic component of wood (approximately 20-30%); globally the forest industry produces about 50 million tons a year. It is a problem for pulping and has ended up in the lowest value end use as energy. Modern pulp mills are biobased power plants, producing a considerable surplus of energy. Taking out lignin increases pulp production and opens up side streams from energy to resins. In the surprisingly near future, high-value applications such as chemicals and carbon fibre are also possible.

Sugars are more than the white processed variant that is unhealthy and used in fizzy drinks. Sugar is the collective name for a large group of soluble carbohydrates, which can serve as the building blocks for the most varied chemicals and materials. Hemicellulose, another basic component of wood (20-30%), is an example of a platform from which to derive sugars.

Studies on carbon footprints show that there is no single figure that encapsulates the benefits of biobased solutions and recarbonisation but the rule of thumb is that a renewable biobased solution beats a fossil-fuel-based one. The carbon in recarbonised flows is basically CO_2-neutral, it is part of a closed loop as long as we let the loop function well. To get a feel for the savings, eliminating plastic bags globally, a process already underway, would reduce the equivalent of the UK's total CO_2 emissions by 5%.

Nanocellulose is actually as familiar as the first two – but previously scientists never saw it. It is cellulose (a third component of wood, compromising 40-45%) processed down to small fibres (or fibrils) and crystals of very small size. The definition for nanomaterials is materials between 1 and 100 nanometres in length, i.e. below 1/10,000 of a millimetre. Nanoscale cellulose can react, bind, and create many new applications, in areas as diverse as pulp and electronics.

Graphene is something we can all produce and use. We write with lead (i.e. graphite) pencils on paper. If you put some sticky tape on the paper and take it away, on the tape you will have graphene - carbon as a 2D matrix, one atom thick. On an industrial scale, this is not the best method, but the number and frequency of reported new graphene uses and discoveries is astonishing. Graphene is being tested to make things stronger, flexible, more conductive to heat and power, and almost everything else you can imagine. It is about 200 times stronger than steel, proportional to its weight, and more conductive than copper.

Interesting things happen when the four substances above are mixed with each other and/or other materials into biocomposites.

As an indication of the growing market for value added composites, where the old Airbus A340 consisted of about 10% composites, the new A350 is made of more than 50%.

THE ENVIRONMENTAL AND ECONOMIC BENEFITS OF RECARBONISATION

Imagine a solution where we recarbonise just 1% of the market of some key global material flows. The packaging market in 2013 was worth 590 billion Euros. Plastics and fibre are about even, with 220 and 215 billion Euros in turnover respectively. Moving 1% of the packaging market from fossil plastics to biopackaging equates to 6 billion Euros in turnover. With plastics we deal with about 300 million tons. Moving 1% from fossil plastics to bioplastics would mean about 3.5 billion Euros of new biobusiness. Finally, imagine that we can take 1% of the global volume of fossil fuels and substitute it with biomass, and process that biomass further in the forest industry – this means a green recarbonisation of a part of the world's materials flows. That would give roughly 30 billion Euros of annual new biobusiness. In all, these three 1% substitutions would give about 40 billion Euros per annum of new sustainable bioeconomy. The calculations above can be debated of course, but they are indicative of the potential size of the opportunity.

Environmentally, the rule of thumb is that a renewable biobased solution beats a fossil-fuel-based one. Studies on carbon footprints show that there is no single figure that encapsulates the benefits of biobased solutions and recarbonisation; it all depends on the end use, the chain to the end use, the location and other parameters. The carbon in recarbonised flows is basically CO_2-neutral, it is part of a closed loop as long as we let the loop function well. To get a feel for the savings: the amount of CO_2 per kilograms of plastic for plastic bags is around 5-6 kilograms. The estimate for the amount of plastic bags per year is from 0.5 to 1 trillion (10^12). One bag weighs about 5 grams, so we generate about 25 million tons of CO_2 per year from plastic bags. The 2013 EU/Dutch Emissions Database for Global Atmospheric Research estimates the emissions of the UK at 480 million tons of CO_2. Eliminating plastic bags globally, a process already underway, would reduce the equivalent of the UK's total CO_2 emissions by 5%.

The Recarbonisation Business

The bioeconomy is often painted as a distant vision despite being an existing global business. Taking advanced biomaterials as an example, we calculated that five years ago there was already a global business equating to 22 billion Euros, a figure which does not even include the conventional forest industry.

RECARBONISATION IS AN EXISTING BUSINESS, NOT JUST A VISION

Cosmetics, electronics, automotive and aerospace, construction, hygiene and packaging are all sectors where new biomaterials and recarbonisation are growing. It is an interesting business area as many companies do not even realise they are members of this 'open club'.

THE RECARBONISATION PLAYERS ARE GLOBAL AND LOCAL, LARGE AND SMALL

Since we are dealing with so many end use sectors, innovative start-ups and medium-sized specialised producers connect with major producers and brands such as Unilever, Nestlé, Samsung, Coca-Cola, Akzo Nobel, Cargill, Dow, Braskem, BASF, IKEA, Lego, Toyota, Ford, Neste, DSM and Walmart. The food, chemical, petrochemical, automotive, electronics and retail sectors are of course accompanied by the major players in the forest industry.

A FRAGMENTED BUSINESS EXPLODING OUTWARDS

As the end uses are so numerous and the companies involved so diverse, with different structures, strategies and goals, we do not have single-minded growth. Instead, separate branches of recarbonisation technologies bring separate types of products to the market. It is easier to concentrate on two examples: lignin and biocomposites.

THE LIGNIN BUSINESS

Lignin is a strange material: it is natural and complex, not fully understood, is found in abundance, has traditionally been a nuisance rather than an asset, and it has been researched extensively. Yet, many concrete signs point to a long-awaited rise

Why all the talk about graphene? This very basic form of carbon was first produced in a lab in 2003, after years of speculation. Imagine a matrix of hexagons, like the tiling of a bathroom floor. There is one carbon atom in each corner of the hexagon and the whole structure is one atom thick. From this simple structure come all the amazing properties now being demonstrated. Simple is beautiful - and versatile.

of the lignin business. Lignin has its lowest value as energy, but businesses built on lignin can proceed towards fuels, resins, platform chemicals, bioplastics and other lignin-based products. Among existing business applications, phenolic resins (part of glues for wood products, for example) are increasingly available. Carbon fibre and activated carbon are high value end uses for a sophisticated material market, ranging from consumer products to aerospace. A recent demonstration showed a composite laminate carbon fibre: a 'sandwich' where balsa wood is laminated with carbon fibre, for use in lightweight cars. Foams and films are other examples.

THE BIOCOMPOSITE BUSINESS

The composite business is even more an explosion of different combinations to be tested. We can start with the biocomponents pulp, nanocellulose, biobased chemicals from sugars, lignin and graphene. These can be the major component of a biocomposite, or a key ingredient giving a new functionality. Among materials to combine with these components are cement, metals, glass, minerals, plastic - and of course paper. A biocomposite need not be fully biobased, as long as the biobased part is large enough or brings a significant contribution. Recarbonisation is pragmatic: if we can bring in new advantages with a bio/metal-composite, it is worth it. Biocomposites are already being used or tested in e.g.:

- Pulp with plastics as a new bioplastic composite
- Nanocellulose into minerals as a new filler/coater
- Nanocellulose with cement giving new properties
- Graphene in paper as conductive paper
- Bioplastic and paper for waterproof biocomposite bags
- Aluminium and graphene for new batteries

BUSINESSES NEED EXISTING AND NEW MARKETS

It is certain that the different branches of recarbonisation will recombine sooner or later. This is happening spontaneously, but it can also be promoted by alliances and through cooperation.

For some parts of the recarbonisation businesses, the markets are well established. Examples include drop-in chemicals, i.e. chemicals that fully substitute a fossil-based alternative without any change in production processes. For others, markets are as yet unformed. Lignin from kraft pulping does not really have a market price, nanocellulose is developed on an attempt-by-attempt basis, and graphene is even more wildly heading in all directions without clear production routes. So the promotion and creation of new markets is essential in the recarbonisation business and the recarbonisation revolution. Which makes sense, as this is a business, not just a vision.

The Recarbonisation Value Chain

While recarbonisation is already a global business with a turnover in the tens of billions of Euros and major players across the globe, companies are only now organising the complex value chains. The roles of players remains unclear and the rules are still being determined.

THE RECARBONISATION VALUE CHAIN GOES FROM BIOMASS TO BRANDS

The recarbonisation value chains are many and complex, but it is possible to make a simplified value chain for the recarbonisation business.

It starts with biomass (wood, agro, waste, algae or other interesting biomass fractions), used by dedicated plantation owners or waste management companies interested in deriving value from their biomass or waste. It ends with the consumer interacting with brands. In fact recarbonisation in materials is very much driven by brands, as the pull of a brand promise is a powerful incentive for the whole value chain. In between, actors in forestry, chemicals and petrochemicals process the biomass until it ends up at converters. The converters transform chemicals and biopolymers, such as pulp and lignin into bioplastics, biofilms, biocomposites and many other bulk and niche uses.

THE FEEDSTOCKS MEET THE BRANDS

It used to be that brands stood at a great distance from the raw materials they used. A food brand had nothing to do with the land that produced its grains and crops. This has changed. Regardless of who owns the land, does the procurement or processing, or sells the final product to consumers, brands are now held responsible for what happens in their raw material chain. That means that brands have to take action regarding sugarcane, forests and waste.

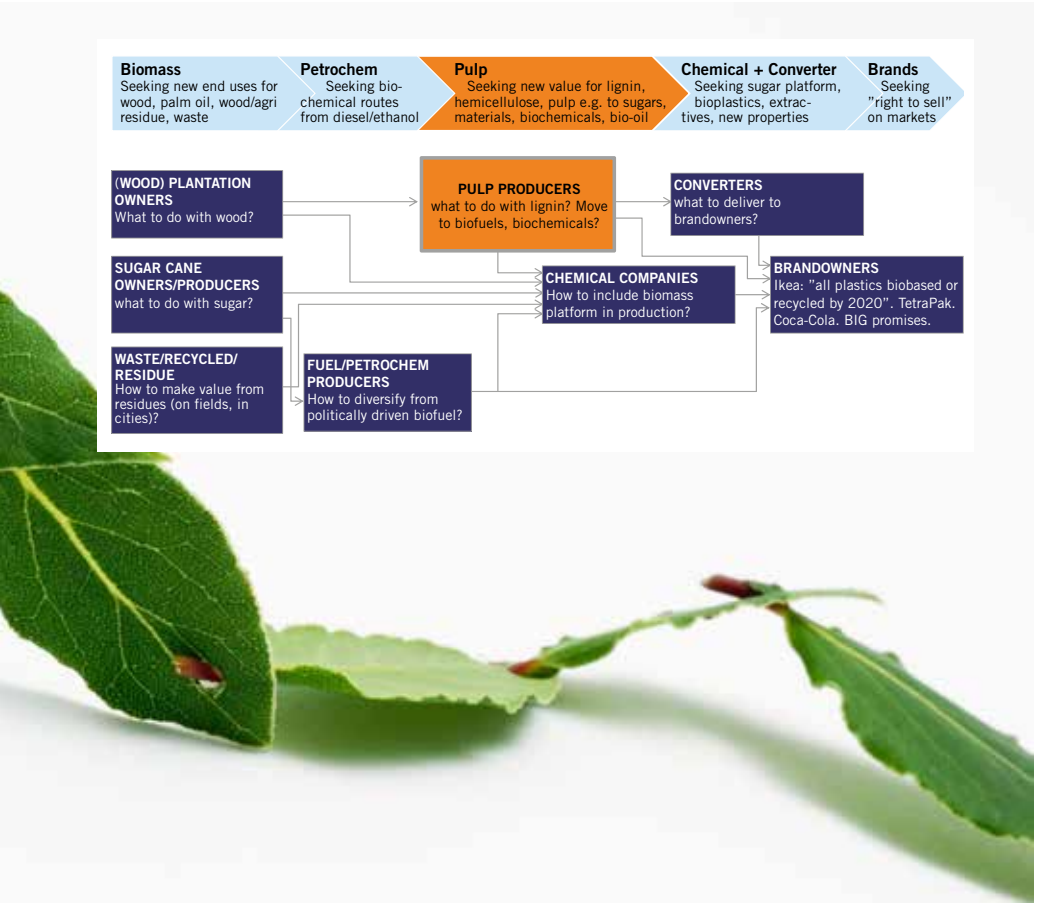
THE DYNAMICS IN THE VALUE CHAIN

Global brands such as IKEA, Lego, Toyota, Procter & Gamble, Coca-Cola, Heinz, and Ford have their own reasons for pushing biomaterials. Sometimes it is a functional or cost-related decision - biocomponents in cars weigh and cost less than metal, for example. Sometimes it is a question of brand image.

Brands promising to drive the recarbonisation value chain are many. IKEA has promised to have 100% renewable or recycled plastic in its products by 2020. Tetrapak is committed to developing 100% renewable packaging. Toyota aims to increase the share of bioplastics in its cars.

Converters often work together with brands to develop biomaterials to the right specifications. Behind the converters, the forestry industry is developing pulp into composites, biobased chemicals from side streams, and resins and more value-added products from lignin. For the forest industry, biomass is familiar but some of the related chemical processing procedures less so. For the petrochemical and chemical industry, processing is a standard activity, but biomass is a mystery. For them it is far less standardised and uniform than the oil or other raw materials they are used to.

Since nobody is quite in their comfort zone, and alliances across sectors are not yet the norm, a transformation of the value chain must and is taking place.



INNOVATION AT THE BORDER CROSSINGS

With major industry sectors and global players trying to settle into new forms of cooperation with unfamiliar partners, feedstock or products, several strategic questions are being discussed:

- Should the forest industry just supply lignin or also process it closer to the end product?
- Should a biomass-based sugar platform for chemicals be run by chemical or forest industry companies?
- Can suppliers 'bypass' the intermediate steps and talk directly to brands and get an offtake agreement?
- Should companies go it alone or join forces with others?

AN ONGOING GAME OF 'MUSICAL CHAIRS'

It seems that very few want to go it alone; most want to find partners and build knowhow through alliances. The challenges of shaping a new value chain with many complex materials, competing technologies and consumer demands are considerable.

However companies know that these challenges can be and have to be surmounted. Meanwhile, different combinations of alliances are being tried, feedstock tested and technologies developed.

No revolution is easy, and the 'recarbonisation revolution' is no exception. However, we are all now fortunate to be part of the process, able to at least partly influence what is going to happen. There is room for many winners in the recarbonisation revolution.

Recarbonisation: too good to be true?

There is always hype. Surprisingly many miracle cures turn out to be worse than the disease. This means we must also be careful with recarbonisation. The figures provided here are just indications of potential outcomes. Likewise, biobased solutions are in many cases still far from competitive with fossil-based solutions. However, there are very strong foundations for recarbonisation. As we have shown the business is already underway in some sectors and is being further encouraged by brands.

Recarbonisation is natural, based on either existing creations of nature, such as lignin, sugars, graphene and nanocellulose, or the processing of such materials. We know that the loop works or can be made to work. We understand a great deal of the environmental benefits. All things considered, the case for recarbonisation is certainly compelling.

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