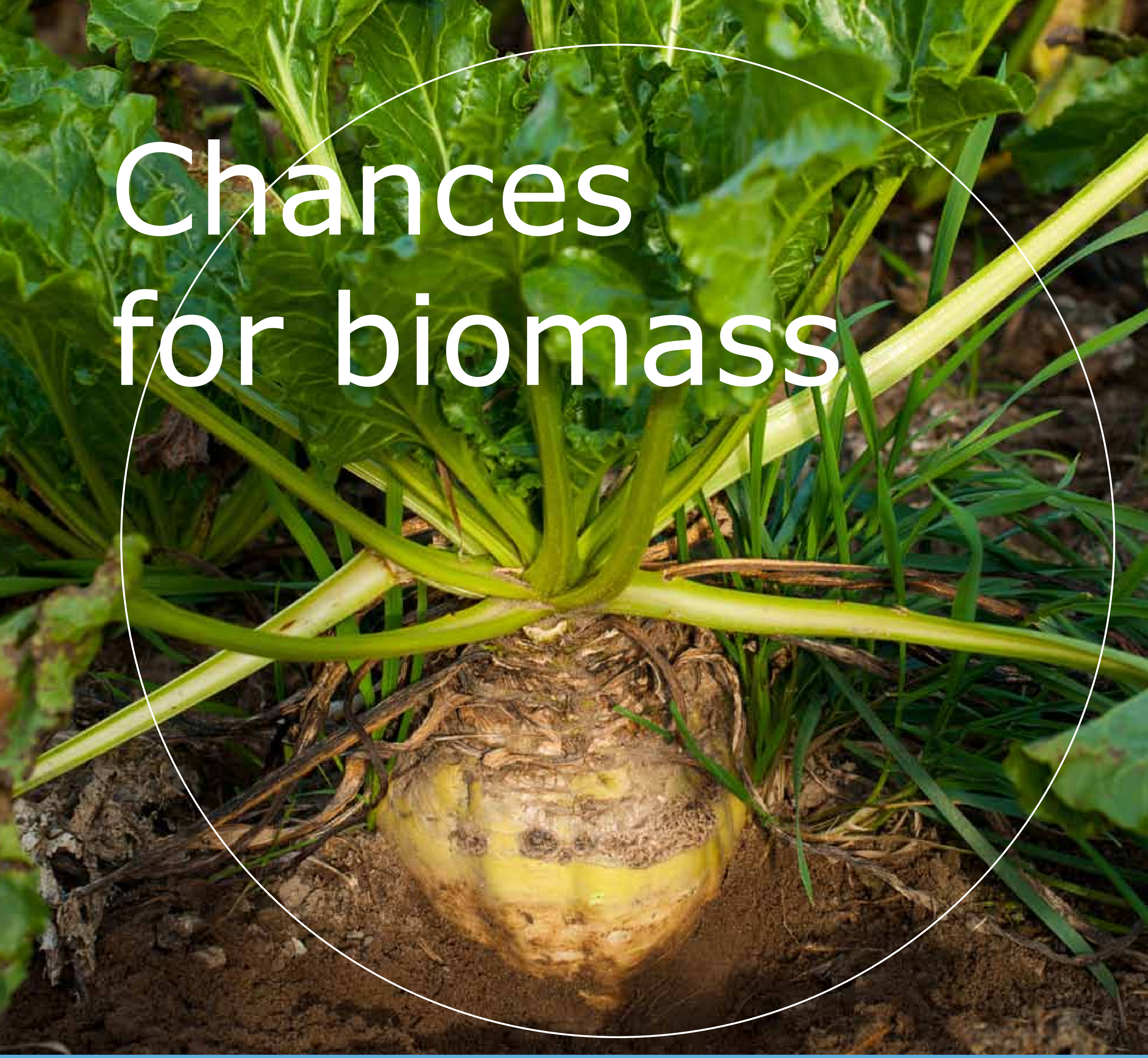
Chances for biomass



Integrated valorisation of biomass resources

Hilke Bos-Brouwers (FBR), Ben Langelaan (FBR), Johan Sanders (BCH),
Michiel van Dijk (LEI) en Ad van Vuuren (ASG)

Final version
December 2012

WAGENINGEN UR
For quality of life

Ministerie van Economische Zaken

Project code: BO-08-016-001

Table of contents

1 Kansen voor biomassa – integrale verwaarding (Samenvatting)

Biomassa wordt de komende decennia naar verwachting steeds belangrijker om in maatschappelijke behoeften aan materialen, brandstoffen, voedsel en diervoeder te voorzien. Oorzaken zijn de groeiende wereldbevolking, veranderende consumptiepatronen, toenemende welvaart en een niet-duurzaam gebruik van fossiele brandstoffen. Deze studie bevat een routekaart om te komen tot een productiever en efficiënter gebruik van grondstoffen, waarbij de negatieve gevolgen voor het milieu tegelijkertijd worden beperkt. Hierbij wordt uitgegaan van het bereiken van '2x meer met 2x minder', als basis voor de onderliggende visie van de routekaart. Cruciaal in deze visie is integrale verwaarding: biomassa is dan in alle toepassingsdomeinen van waarde: voedsel, diervoeder, functionele materialen en brandstoffen.[1]

De visie in '2x meer met 2x minder' is ambitieus. Om de verschuiving naar een *biobased economy* mogelijk te maken, moeten we de verbondenheid tussen de verschillende toepassingen van biomassa beter begrijpen en op basis daarvan een integrale aanpak ontwikkelen. De uitdaging voor de betrokken partijen (overheden, bedrijven en onderzoeksinstellingen) is groot, want zij moeten door nieuwe vormen van samenwerking en betrokkenheid de weg effenen voor deze integrale aanpak.

De routekaart in deze studie biedt een stimulans om biomassagrondstoffen stap-voor-stap integraal te valoriseren. De kaart beschrijft tussenstadia met aanknopingspunten die betrokken partijen kunnen benutten en barrières die zij moeten overwinnen voor de overgang naar een nieuw stadium. Deze barrières geven ook ontwikkelpunten voor de betrokken partijen weer. Denk aan het stimuleren van domein overstijgende samenwerkingsverbanden, het ontwikkelen van nieuwe kennis en het toepassen en uitbouwen van technologieën. De routekaart is gebaseerd op inzichten uit:

- literatuuronderzoek (wetenschappelijk onderzoek en bestaande *routekaarten)*;
- interactie met bedrijfsleven;
- inspirerende voorbeelden van innovatieve integrale benaderingen in de praktijk om biomassa te benutten, met speciale aandacht voor bijproducten en reststromen.

Waardenpiramide: een handvat om de meest hoogwaardige toepassing te benutten.
Het eerste uitgangspunt op weg naar integrale valorisatie vormt de hiërarchie van waarden voor biomassatoepassingen. Deze waardenpiramide wordt gebruikt als beslismodel op basis van cascadering: hoogwaardige toepassingen krijgen prioriteit, waarna de stap naar laagwaardiger toepassingen volgt. De volgorde van biomassatoepassingen is als volgt:

1. *food*: toepassingen voor menselijke consumptie;
2. *feed*: toepassingen voor diervoeder;
3. *functional materials*: toepassingen voor materialen en producten (bijvoorbeeld papier, biologisch afbreekbare verpakkingen, bouwmaterialen en basischemicaliën);
4. *fuels*: toepassingen voor brandstoffen.

Binnen de vier genoemde toepassingsdomeinen bestaan al vaste routines. Zo is gras bestemd voor de koe, paprika voor de mens en koolzaad voor biodiesel. Veel bulkgoederen kennen op dit moment al een relatief efficiënte structuur om biomassa om te zetten in toepassing. Het doel van deze studie is, voor vernieuwing te zorgen door de keten 'van akker tot toepassing' her in te richten. De focus richt zich daarbij ook op componentniveau (de bouwstenen van een gewas of dier), zoals koolhydraten, vetten, oliën, eiwitten, aminozuren en vezels. Deze vernieuwing is mogelijk door het beslismodel van cascadering te hanteren. Want daardoor kunnen (delen van) gewassen en dieren die nu nog niet of nauwelijks voor consumptie worden aangewend (denk bijvoorbeeld aan gras, insecten, micro-algen en loof van bieten), worden ingezet boven in de waardenpiramide. Deze componenten kunnen daardoor efficiënt worden gebruikt. Hierbij is het wel van belang dat er geen transport en concentratie meer nodig is van componenten die niet verder laagwaardig kunnen worden toegepast. Dit is mogelijk door er bijvoorbeeld voor te zorgen dat diervoeder geen componenten bevat die het dier niet kan omzetten in energie of massa of die niet bijdragen aan zijn gezondheid. Voorwaarde is wel dat een focus op

---

[1]Toepassingen zoals farmaceutische producten, chemicaliën, meststoffen en energie zijn in deze studie als subcategorieën geschaard onder de vier hoofddomeinen: voedsel, diervoeder, functionele materialen en brandstoffen.

laagwaardige toepassingen binnen technologische en beleidsprocessen geen belemmering vormt voor hoogwaardige toepassingen. Een voorbeeld is biet- of rietsuiker dat wordt toegepast als grondstof voor bio-ethanol in plaats van consumptiesuiker. Technologieën en beleid moeten worden ingezet om de beschikbaarheid te kunnen garanderen van hoogwaardige toepassingen die economisch efficiënt én grondstofefficiënt zijn.

Het tweede uitgangspunt op weg naar integrale valorisatie is dat er parallelle aandacht moet zijn voor korte- en lange termijnontwikkelingen. Op korte termijn zorgen efficiëntere processen voor een betere valorisatie van biomassa. Denk aan een lager energie- en watergebruik en teruggewonnen materialen. Op lange termijn is de verwachting dat nieuwe technologieën en heringerichte productieketens tot grote verbeteringen leiden. Deze innovaties zijn radicaler van aard en vergen daarom een langere aanloopperiode. Ze moeten nu al worden ingezet om de fundamentele basis van kennis en technologie te kunnen leggen die nodig is voor vervolgstappen op weg naar het eindstadium van integrale valorisatie. De verwachting is dat vooral de kennisgebieden rondom het scheiden en converteren van biomassa naar waardevolle ingrediënten een belangrijke rol gaan spelen. Expliciet gaat het hier om innovaties op het gebied van fractioneren, katalyseprocessen, fermentatie, en (her-)structureringsprocessen, waaronder vernieuwende milde conserveringstechnieken die energiezuiniger en waterbesparend zijn. Het gaat daarbij om toepassing op een brede schaal van producten.

Niet alleen technologische aspecten zijn cruciaal om duurzame ontwikkelingen te kunnen implementeren. Nieuwe verbanden in de waardeketen, waaronder die tussen de verschillende toepassingsdomeinen, zijn minstens even belangrijk. Maar de grootste barrière voor transitie is misschien wel de conservatieve houding van veel mensen. Ook een ontbrekend gevoel van noodzaak drukt een stevige rem op elke innovatieve vooruitgang. Het is niet makkelijk om mensen daarvan te overtuigen en hun vaste patronen te doorbreken. Maatschappelijke behoeften en benodigde verschuivingen in de toepassing van biomassa gaan bovendien geleidelijk en zijn niet altijd zichtbaar. Daarom gaat het creëren van urgentie en het stimuleren van dadendrang bij betrokkenen altijd vooraf aan elke transitiestap. Indien aangesproken, is de innovatiekracht van Nederland groot. De routekaart kan helpen om structuur aan te brengen in creativiteit en om expliciet díe activiteiten te benoemen die discussie en implementatie in de praktijk bevorderen.

Diverse barrières kunnen de noodzakelijke innovatieprocessen nu en in de toekomst belemmeren. Zoals:

- Technologische barrières: veranderingen in bedrijfsprocessen of nieuwe technologieën voor het bedrijf of de markt brengen vaak opstartproblemen of opschalingsproblemen met zich mee. Deze kunnen de effectiviteit en efficiëntie negatief beïnvloeden. Ondernemers zijn hier vaak huiverig voor, omdat deze problemen de winstgevendheid van de onderneming drukken. Ook zijn zij vaak bang dat veranderingen in productieprocessen een negatieve invloed hebben op de kwaliteit van het primaire proces. Tot slot weten bedrijven vaak niet wat technisch al mogelijk is. Dit geldt vooral voor kleinere bedrijven.
- Financiële (overheids)instrumenten die op enkelvoudige toepassingen gericht zijn, hebben de neiging om innovaties gericht op hoogwaardiger toepassingen te verhinderen. Dit geldt bijvoorbeeld voor biobrandstoffen.
- Technologieën en procedures die door regelgeving worden voorgeschreven, belemmeren creatieve oplossingen die bedrijven zelf ontwikkelen en verkleinen de experimenteerruimte voor innovatieve toepassingen.
- Concurrentie met conventionele producten op kostprijs is vaak niet realistisch: een hogere kostprijsstrategie voor nieuwe producten en componenten kan alleen succesvol zijn als deze gesteund wordt door aantoonbare verbeteringen in kwaliteit en functionaliteit, bij voorkeur in combinatie met een lagere milieu-impact. Gebeurt dit niet, dan zal de belangstelling van de klant, business-to-business en business-to-consumer, achterblijven.
- Het innovatieve karakter van voorziene ontwikkelingen is op het lijf geschreven van de startende en kleine tot middelgrote ondernemer. Maar deze heeft moeilijker toegang tot kennis en zijn budget is beperkt.

Deze overwegingen hebben bijgedragen aan de ontwikkeling van een routekaart die in deze studie wordt gepresenteerd. Deze routekaart bestaat uit vier fasen die doorlopen moeten worden om biomassagrondstoffen integraal te kunnen valoriseren op de vier genoemde toepassingsdomeinen. Elke fase combineert een fundamentele onderzoekslijn met praktische implementatie van toegepaste kennis.

Daardoor is de noodzakelijke ontwikkeling van kennis en technologieën in latere fasen van de transitie verzekerd. De vier fasen zijn:

- Fase 1: De efficiëntie van bestaande landbouw-, fossiele en minerale grondstoffen vergroten in alle toepassingsdomeinen, waaronder een efficiënte(re) valorisatie van rest- of bijproducten (vooral in het diervoederdomein). De focus ligt op verbeteringen binnen één domein. Het komt nu nog regelmatig voor dat biomassa waarde krijgt op een lager niveau dan op basis van de grondstofsamenstelling mogelijk is, bijvoorbeeld een voedselproduct dat wordt gebruikt voor de productie van energie.

- Fase 2: Producten op basis van niet-duurzame, conventionele (fossiele) grondstoffen vervangen door producten uit biomassa (bijvoorbeeld biobutaan en bio-ethanol). De focus ligt op verbeteringen binnen toepassingsdomeinen en valorisatie op hogere niveaus. Dit is het startpunt voor een integrale aanpak.

- Fase 3: Nieuwe procesroutes en ingrediënten formuleren die tegemoetkomen aan de basisbehoeften die in de waardenpiramide staan geformuleerd. Vernieuwen door producten en ingrediënten beter beschikbaar te maken voor hoogwaardiger toepassingen. Plantaardige eiwitbronnen die geschikt zijn voor menselijke consumptie, in diervoeder vervangen door eiwitbronnen uit non-foodbronnen. Dierlijke eiwitbronnen in het voedseldomein vervangen door plantaardige eiwitbronnen. Nieuwe, milde processen voor functionele halffabricaten en producten ontwikkelen, gebruikmakend van de complexiteit van biomassa. Nieuwe (fundamentele) kennis ontwikkelen over katalyse, enzymen, fermentatie en scheidingstechnologieën om nieuwe procesroutes mogelijk te maken voor halffabricaten en eindproducten.

- Fase 4: Het geïntegreerde en geoptimaliseerde systeem voor valorisatie van biomassagrondstoffen implementeren, gebaseerd op de complexiteit van biomassa en op de waardenpiramide. Zorgen voor een gespecificeerde en gecombineerde agrarische productie van biomassa voor alle domeinen. Innovaties verspreiden in de waardeketens en toepassingsdomeinen.

De routekaart bestaat uit twee delen:

1. Een inhoudelijke pilaar, waarin trends, principes, korte- en langetermijndoelen en de visie voor 2050 (2x meer met 2x minder) zichtbaar zijn (zie figuur 1).
2. Een procesgerichte pilaar, waarin de vier fasen van transitie naar integrale valorisatie zijn opgenomen (zie figuur 2).

2012 | **2020** | **2050**

Trends

Groeiende vraag naar dierlijke eiwitten; 1 miljard mensen ondervoed; voedselverspilling > 1.3 miljard ton/jaar; 35kJ nodig voor elke kJ voedselinname.

Niet-duurzame productiemethoden voor dierlijke eiwitten; opstapeling van mineralen uit mest in bodem en water; hoge ammoniak- en broeikasgas emissies; grote (milieu-)druk op ecosystemen.

Teruglopen van fossiele grondstoffen; ontwikkeling activiteiten verstoord door focus op biobrandstoffen.

Teruglopen van fossiele grondstoffen; eerste generatie biobrandstoffen concurreert met voedsel.

Algemene principes Stimuleren van innovatie

Ophogen van toepassingsniveau van biomassa grondstoffen o.b.v. de waardepiramide

Integrale verwerking van biomassa volgens een cascade van vermarktbare producten o.b.v. de waardepiramide

Bioraffinage concepten die bijdragen aan flexibiliteit van ruwe grondstoffen en onderlinge uitwisselbaarheid van componenten

Geen transport of concentratie van componenten zonder verdere laagwaardiger toepassingen

Richten van wettelijke en financiële regelingen op verdere optimalisatie; voorkomen van lock-ins

Opzetten van nieuwe partnerschappen binnen de Gouden Driehoek (bedrijfsleven – overheid – onderzoek); stimuleren van kleinschalige initiatieven om ondernemerschap te bevorderen

Korte termijn doelen

Verhogen van verwaarding van reststromen, ook binnen het voedseldomein

(NL) 1 MEuro omzet uit reststromen
(NL) 20% efficiëntieverbetering in het gebruik van ruwe grondstoffen
NL) 30% minder CO_2eq.

Converteren voedselindustrie reststromen en huishoudelijk organisch afval in diervoeder, functionele materialen en biobrandstoffen

(NL) verhoogde scheidings-efficiëntie van 3 – 25% in meststoffen en digestaat richting waardenvolle componenten

(NL) Reductie CO_2 emissies van 11.6 Mton
(NL) Reductie energiegebruik van 171 PJ
(EU) 30% van alle chemische producten is biobased

(EU) 10% hernieuwbare energie (biobrandstoffen)

VISIE 2x meer met 2x minder

Integrale verwaarding van biomassa grondstoffen voor alle toepassingsdomeinen

Productie met een veilige milieubeslag

Voedsel gebaseerd op duurzame, hernieuwbare en alternatieve grondstoffen (waaronder insecten, algen e.d.)

Gesloten kringlopen voor water en mineralen (N-P-K)

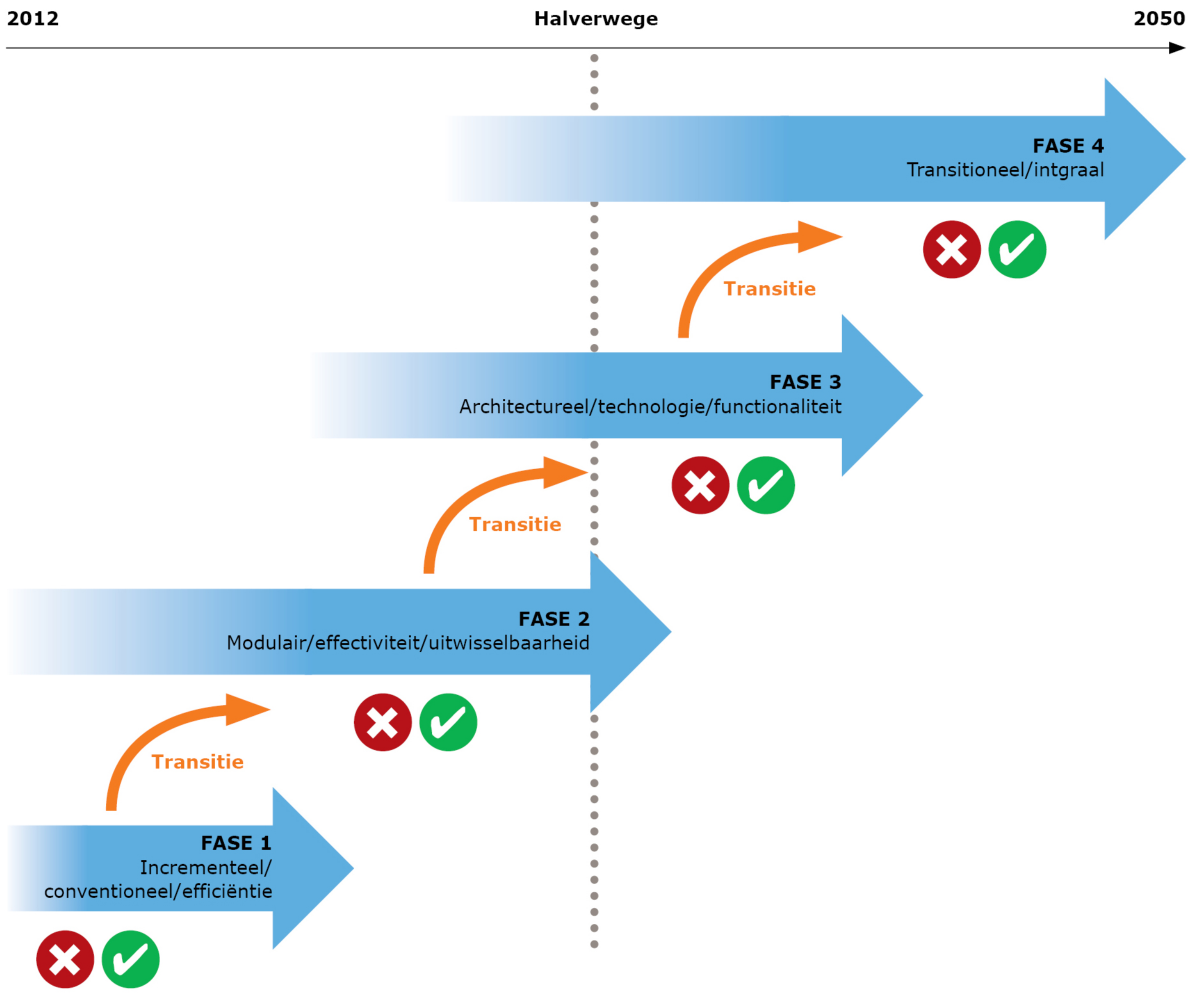
Landbouwproductie van (gespecificeerde) biomassa grondstoffen voor alle toepassingsdomeinen

Voldoende voor iedereen

(NL) 30% van fossiele energiedragers vervagen door biobrandstoffen

Legenda: Voedsel (groen) | Diervoeder (lichtblauw) | Functionele materialen (oranje) | Brandstoffen (donkerblauw)

Figuur 1: Trends, doelen en visie voor integratede valorisatie van biomassagrondstoffen.



Figuur 2: Fasen in transitie naar integrale valorisatie van biomassagrondstoffen.

Dankzij technologische ontwikkelingen (waaronder milde conservering en bioraffinage) is het makkelijker de complexiteit van biomassagrondstoffen te gebruiken. Om deze op industriële schaal toe te kunnen passen, is het nodig ze verder te ontwikkelen. Dankzij de nieuwe technieken moet het mogelijk zijn de hoge kwaliteit en functionaliteit van de individuele producten te behouden of verbeteren. Huidige technieken dragen weliswaar bij aan een hogere toegevoegde waarde van biomassagrondstoffen, maar leveren nog voornamelijk producten en componenten van lagere kwaliteit of met lagere zuiverheidsgraad op. Daarnaast kunnen agrochemicaliën efficiënter worden geproduceerd als de (raffinage)processen specifiek op één type biomassa zijn afgesteld. Toch is het vaak wenselijk om met gemengde input te werken, hiervoor zullen specifiek geoptimaliseerde systemen moeten worden ontwikkeld. De procesefficiëntie kan ook worden verbeterd door met plant- en dierveredeling (al dan niet bereikt met gentechnologie) te zorgen voor een andere, meer geschikte samenstelling van componenten voor hoogwaardige toepassing.

Deze ontwikkelingen worden gestimuleerd door intensievere samenwerkingsverbanden in waardeketens en tussen toepassingsdomeinen. Om de biomassatoepassingsdomeinen in de toekomst te verbinden, moet de samenwerking tussen stakeholders in de agro-food sector breed worden gestimuleerd.

De grootste kansen liggen op het snijvlak van de verschillende domeinen
De visie en routekaart leiden tot de volgende algemene aanbevelingen:

- Bewerkstellig nieuwe sector- en domein overstijgende samenwerkingsverbanden in open innovatieprogramma's. Deze verbanden vergroten de kennis over biomassavalorisatie op componentniveau door bioraffinage en procesefficiëntie.

- Leg prioriteit bij het ontwikkelen van criteria door integrale valorisatie en stimuleer initiatieven vanuit het bedrijfsleven die aan deze criteria voldoen. De overheid kan deze criteria samen met het bedrijfsleven en kennisinstellingen opstellen, waarna deze partijen de integrale valorisatie samen kunnen uitvoeren.

- Monitor het stimuleringsbeleid en de innovatieprocessen die daaruit volgen en pas de gewenste uitkomsten na elke periode (bij voorkeur na minimaal vijf jaar) aan op basis van de kennis die dan beschikbaar is.

- Buit de sterke kennispositie van Nederland uit:
    - Er is veel biomassa aanwezig: identificeer mogelijke bronnen voor hoogwaardige toepassingen.
    - Kies de te importeren en exporteren biomassagrondstoffen en hou daarbij niet alleen rekening met economische factoren, maar juist ook met milieudruk en sociale acceptatie.
    - Ondersteun de ontwikkeling van 'Euregio-gewassen' en streef ernaar om zelf in (toekomstige) biomassabehoeften te kunnen voorzien.
    - Gebruik de sterke logistieke positie van Nederland, lokaal en regionaal: gesloten systemen leiden tot efficiënte logistiek en voldoende schaalgrootte om nieuwe processen in te kunnen richten.

Aanbevelingen specifiek voor het bedrijfsleven: samenwerking over de ketengrenzen heen levert de meeste kansen op.

- Kijk verder dan de eigen keten en participeer in open innovatieprogramma's om ook kennis te ontwikkelen op nieuwe terreinen. Dit leidt wellicht tot nieuwe kansen en inspirerende ideeën. Zoek hiervoor actief sector overstijgende samenwerking op.

- Ontwikkel producten die ook binnen bestaande infrastructuren en traditionele ketens passen. Deze zijn daardoor ook interessant voor bestaande markten. Dit voorkomt een ongewenste afhankelijkheid van één afzetkanaal.

- Pluk het 'laaghangende fruit': in alle bestaande processtappen en ketens zijn nog mogelijkheden te vinden om grondstoffen en energie te besparen. Zijn deze stappen niet zelf te beïnvloeden, zoek dan samenwerking met andere partijen in de keten om kosten te spreiden en risico's eerlijk te verdelen.

Aanbevelingen specifiek voor kennisinstellingen/onderzoeksagenda's:

- Draag bij aan beslissingen op basis van feiten door het inzichtelijk maken van:
    - de duurzaamheidsimpact van de voorziene transitiestappen, inclusief onbedoelde effecten en mitigatiestrategieën;
    - criteria om kwaliteit, kwantiteit, functionaliteit en duurzaamheid vast te stellen van processen om fossiele grondstoffen te vervangen door hernieuwbare grondstoffen;
    - signaalindicatoren en monitoringsinstrumenten om de voortgang te kunnen meten vanuit een integraal perspectief, dat uitstijgt boven de belangen van individuele stakeholders.
- Ontwikkel nieuwe kennis over gewassen en veredeling om nieuwe plantensoorten te ontwikkelen waarmee de integrale valorisatie op alle domeinen efficiënter kan plaatsvinden.
- Maak de positieve en onbedoelde negatieve effecten van product- en procesinnovaties inzichtelijk vanuit een integraal perspectief.
- Verschaf inzicht in de voorwaarden en consequenties van succesvolle innovatieprocessen.

- Verbeter de samenwerking in en tussen ketens door kennis te delen en door nieuwe kennis te genereren over hoe je samenwerkingsprocessen kunt verbeteren.
- Verlaag de drempel van kennisvalorisatie: combineer toepassingen van biomassa en beschikbare of benodigde technologieën in een matrixmodel.
- Verminder het hokjesdenken: kruisbestuiving tussen de verschillende domeinen leveren de interessantste bijdragen voor de transitie naar integrale valorisatie.
- Ontwikkel milde procestechnologieën om biomassa te fractioneren en integreer deze kennis om duurzame bioraffinage routes mogelijk te maken.

Aanbevelingen specifiek voor overheden:

- Gebruik deze routekaart om beleid en instrumentarium te verbinden en geef zo een consistente boodschap af aan betrokken partijen. Doe zo tegelijkertijd een appèl op bedrijfsleven en kennisinstellingen om de noodzakelijke stappen te maken.

- Stimuleer discussie over verschillen en tegenstrijdigheden. Alleen dan kunnen de betrokkenen een stap vooruit zetten. Laat het bedrijfsleven meepraten: ondernemers inspireren elkaar het best. Faciliteer nieuwe uitprobeersels en maak het mogelijk dat bewezen nieuwe technologieën op grotere schaal worden gebruikt. Door werksessies met betrokken partijen te organiseren, ontstaan ontmoetingen tussen verschillende sectoren en ketens.

- Ontwikkel en evalueer het overheidsinstrumentarium op basis van de waardenpiramide om te voorkomen dat hoogwaardige toepassingen van biomassa hinder ondervinden van de steun die laagwaardige toepassingen krijgen. Biomassa voor energie moet het laagste waardeniveau hebben.

- Richt regelgeving meer op gewenste doelen en ambities en minder op de manier waarop deze bereikt moeten worden.

- Overleg met bedrijven en andere geïnteresseerde stakeholders tijdens de ontwikkelfase van overheidsinstrumenten om je ervan te verzekeren dat de instrumenten aansluiten bij de behoeften en mogelijkheden van de doelgroep.

- Versterk het gevoel van urgentie bij het bedrijfsleven en consumenten om biomassa integraal te valoriseren en te streven naar groene groei. Zij moeten beseffen dat hun individuele bijdrage meetelt en dat integrale valorisatie goede economische én milieukansen biedt.

- Ontwikkel doelstellingen voor hergebruik van niet-hernieuwbare grondstoffen en scherp deze doelstellingen regelmatig aan. Hou bij de ontwikkeling van de doelstellingen altijd rekening met onbedoelde negatieve effecten. Bijvoorbeeld door milieu- en sociale effecten mee te in de kostprijs van fossiele brandstoffen. Dit stimuleert de ontwikkeling van bio gebaseerde materialen, omdat grote prijsverschillen met fossiele brandstoffen verdwijnen.

- Stimuleer en ondersteun onderzoeksagenda's en innovatieprogramma's voor integrale valorisatie en creëer mogelijkheden om deze activiteiten op verschillende niveaus te coördineren (binnenlands-regionaal, nationaal, internationaal).

- Neem deel in publiek-private partnerschappen om technologische ontwikkelingen en het managen daarvan te stimuleren.

- Verbeter beslis- en evaluatieprocessen door de kwaliteit, het detailniveau en de scope van beschikbare data over materiaalstromen van biomassa te verbeteren.

Grensoverschrijdend en domein overstijgend: dat zijn de sleutelwoorden voor integrale valorisatie van biomassagrondstoffen. Verder kijken dan wat we al weten, buiten je eigen *comfort zone* gaan. Door zich actief op te stellen en zich open te stellen voor verandering, kunnen alle betrokkenen een bijdrage leveren aan dit proces.

2 Integrated valorisation of biomass Management summary

Integrated valorisation of biomass

Biomass is expected to become an increasingly important factor in meeting our need for functional materials, fuel, food and animal feed over the coming decades. These demands will rise due to a growing world population, changing consumption patterns, increasing prosperity and the unsustainable use of fossil fuels. This study contains a roadmap for achieving a more productive and efficient use of resources, while simultaneously limiting the negative consequences for the environment. The concept of attaining '2 times more with 2 times less' serves as the underlying vision for the roadmap. And a crucial component of this vision is integrated valorisation: Biomass used across all relevant domains, whether food, feed, functional materials or fuels. [2]

'2 times more with 2 times less' is an ambitious concept. In order to make the shift to a biobased economy possible, we need to better understand the connection between different uses of biomass and develop an integrated approach on this basis. This poses a major challenge for stakeholders – governments, companies and research institutions – as they need to pave the way for this integrated approach via new forms of cooperation and commitment.

The roadmap in this study provides an incentive for the step-by-step integrated valorisation of biomass feedstock. It describes intermediate stages with starting points for stakeholders and the barriers which they must overcome in order to make the transition to a new stage. These roadblocks also highlight issues on which the stakeholders need to work, including the stimulation of cross-domain partnerships, expanding and applying knowledge, and developing technologies. The roadmap is based on insights from:

- literature (scientific research and existing roadmaps);
- interaction with industry;
- inspiring examples of innovative integrated approaches for biomass use in practice, with special attention to by-products and waste streams.

Value pyramid: A rule of thumb to achieve the best possible application.
The first reference point on the road to integrated valorisation is the hierarchy of values for biomass applications. This is used as a decision model in the shape of a cascade: High-value applications are given priority, followed by a move to lower value applications. The order is as follows:

1. *food* for human consumption;
2. *feed* for animals;
3. *functional materials* and products (e.g. paper, biodegradable packaging, building materials and basic chemicals);
4. *fuels* and their applications.

There are already fixed routines within the four application domains. For instance, grass is intended for cows, peppers for humans and rapeseed for biodiesel. Many bulk goods are already organised in a way that is relatively efficient for biomass application. The purpose of this study is to ensure innovation by reorganising the chain from field to application. The focus is also on the component level (the building blocks of a plant or animal), such as carbohydrates, fats, oils, proteins, amino acids and fibre. This reorganisation is made possible by introducing a decision model based on the cascade principle. This allows (parts of) plants and animals that are currently rarely if ever used for consumption (such as grass, insects, micro-algae and beet leaves) to be deployed higher up the value pyramid, and thereby used more efficiently. An important consideration is that there be no need for transport or further concentration of components which can no longer be applied in a low-value way. This is made possible by, for example, ensuring that feed does not contain components that animals cannot convert into energy or mass, or which do not contribute to their health. A major condition is that a focus on low-value applications within technological and policy processes does not form a barrier for high-value applications,

[2]Applications such as pharmaceutical products, chemicals, fertilisers and energy are distributed across the four main domains food, feed, functional materials and fuels for the purposes of this study.

e.g. beet or cane sugar used as a raw material for bio-ethanol instead of sugar production. Technologies and policies should be deployed to ensure the availability of high-value applications that are both economically and resource efficient.

The second key reference point on the way to integrated valorisation is a parallel focus on short and long-term developments. In the short term, efficient processes ensure improved valorisation of biomass. Examples include lower energy and water consumption and recycled materials. In the long term, it is expected that new technologies and reorganised production chains will lead to major improvements. These innovations are more radical and therefore require a longer lead time. They need to be deployed now so as to lay the knowledge and technology foundations required for the following steps on the road to the final stage of integrated valorisation.

It is expected that the most important role will be played by fields of knowledge surrounding the separation and conversion of biomass into valuable ingredients. This specifically concerns innovations in the field of fractionation, fermentation, catalytic processes and restructuring processes, including mild preservation techniques which are more energy and water efficient. This will involve deployment across a broad scale of products.

It is not just technological aspects that are crucial for the implementation of sustainable development. New links in the value chain, including those between different application domains, are equally important. But the biggest barrier to transition is perhaps the conservative attitude of many people. A lack of a sense of urgency is another major brake on innovative progress. It is not easy to convince people to change their ways. Social needs and required shifts in the use of biomass are also gradual and not always visible. This is why creating a sense of urgency and stimulating a desire for action among stakeholders always precedes every transition step. When mobilised, the innovative energy in the Netherlands can be very impressive. The roadmap can help bring structure to this creativity and explicitly define those activities which promote discussion and practical implementation.

There are many barriers which can hamper the necessary innovation processes now and in the future. They include:

- Technological barriers: Changes in business processes or new technologies affecting the company or the market often lead to start-up issues or problems of scale. This can have a negative impact on effectiveness and efficiency. Businesses are often reluctant to go through with such changes, as the resulting problems can reduce profitability. They are also often worried that changes in production processes will have a negative influence on the quality of the primary process. Finally, companies are often not aware of what is technically possible at a given moment. This is especially true for smaller businesses.
- Financial instruments (often from the government) targeting single applications can have the tendency to prevent innovation aimed at higher value applications. This applies to biofuels, for instance.
- Technologies and procedures prescribed by regulations can impede creative solutions developed by businesses themselves, and reduce the space available for experimenting on innovative applications.
- Competition with conventional products on cost is often unrealistic: A higher price strategy for new products and components can only be successful if it is supported by demonstrable improvements in quality and functionality, preferably in combination with a lower environmental impact. If this is not the case, the interests of the customer, business-to-business and business-to-consumer, will not be served.
- While the innovative nature of the expected developments is ideal for start-ups and SMEs, they tend to have restricted access to knowledge and a limited budget.

These considerations have contributed to the development of the roadmap presented in this study. It consists of four stages that need to be covered in order to valorise biomass resources for the four application domains in an integrated way. Each stage combines a fundamental line of research with practical implementation of applied knowledge. This ensures the necessary development of knowledge and technologies in later stages of the transition. The four phases are:

- Phase 1: The efficiency of existing agricultural, fossil and mineral resources increases across all application domains, including a more efficient valorisation of residues or by-products (especially in the area of feed). The focus is on improvements within a given domain. It is common today for biomass to become valuable at a lower level than that which is possible based on raw material composition – e.g. a food product used for energy production.

- Phase 2: Replacing products based on non-renewable, conventional (fossil) raw materials with products from biomass (e.g. bio-butane and bio-ethanol). The focus is on improvements within application domains and valorisation at higher levels. This is the starting point for an integrated approach.

- Phase 3: Formulating new processing routes and ingredients to meet the basic needs formulated in the value pyramid. Regenerating the offer by making products and ingredients more easily available for higher value applications. Replacing vegetable protein sources suitable for human consumption in animal feed with protein sources from non-foods. Replacing animal sources of protein in the food domain by vegetable protein sources. Developing new, mild processes for functional intermediates and products, drawing on the complexity of biomass. Developing new fundamental knowledge about catalysis, enzymes, fermentation and separation technologies to make new process routes possible for semi-finished and finished products.

- Phase 4: Implementing an integrated and optimised system for the valorisation of biomass resources drawing on the complexity of biomass and on the value pyramid. Ensuring there is a specified and combined agricultural production of biomass for all domains. Spreading innovations in the value chains and application domains.

The roadmap consists of two parts:

3. A substantive pillar which comprises trends, principles short & long-term goals, and the vision for 2050 ('2 times more with 2 times less') (see Figure 1).
4. A process-oriented pillar, which comprises the four phases of transition to integrated valorisation (see Figure 2).

2012		2020	2050
Trends	**General principles to stimulate innovations**	**Short term objectives**	**VISION 2 times more with 2 times less**
Growing demand for animal protein 1 billion people malnourished Food waste >1.3 billion tons/yr 35jK required for each kJ food intake.	Upgrade applications of biomass on the value pyramid. Integral processing of biomass into a cascade of marketable products according to value pyramid. Biorefinery concepts to increase raw material flexibility and interchangeabililty. No transportation and concentration of components without further downstream application. Aim legal and financial regulations at further optimization; prevent lock-ins. Establish new partnerships within the Golden Triangle. Stimulate small-scale initiatives to enhance entrepreneurship.	Increase valorisation of byproducts also for food domain. (NL) 1 bn turnover from byproducts (NL) 20% more efficient use of raw materials (NL) 30% less GHG. Convert food industry by-products and household organic residues into Feed, Functional materials and Fuels.	Integral valorisation of biomass for all domains. Production with safe environmental operating space. Food based on sustainable, renewable and alternative sources (insects, algae, etc.). Closed loop cycles for water and minerals (NPK). Agricultural production of (dedicated) biomass for feed, food, fuels and entire spectre of functional materials. Ample supply for everyone. (NL) 30% of fossil energy carriers replaced by biofuels.
Unstustainable production methods for animals protein Accumulation of minerals from manure in soil and water High emission of ammonia and GHG Ecological pressure on ecosystems.		(NL) increasing separation efficiency from 3 to 25% for manure and digestate into valuable components.	
Declining fossil resources Development activities impeded by competition with biofuels.		(NL) reduction of CO_2 emission of 11.6 Mton (NL) reduction energy use 171 PJ (EU) 30% of overall chemical production is biobased.	
Declining fossil resources First generation biofuels in competition with food.		(EU) 10% renewable energy (biofuels).	

Legend: Food (green) — Feed (light blue) — Functional Materials (orange) — Fuels (dark blue)

Figure 1: Trends, objectives and vision for integrated valorisation of biomass resources.

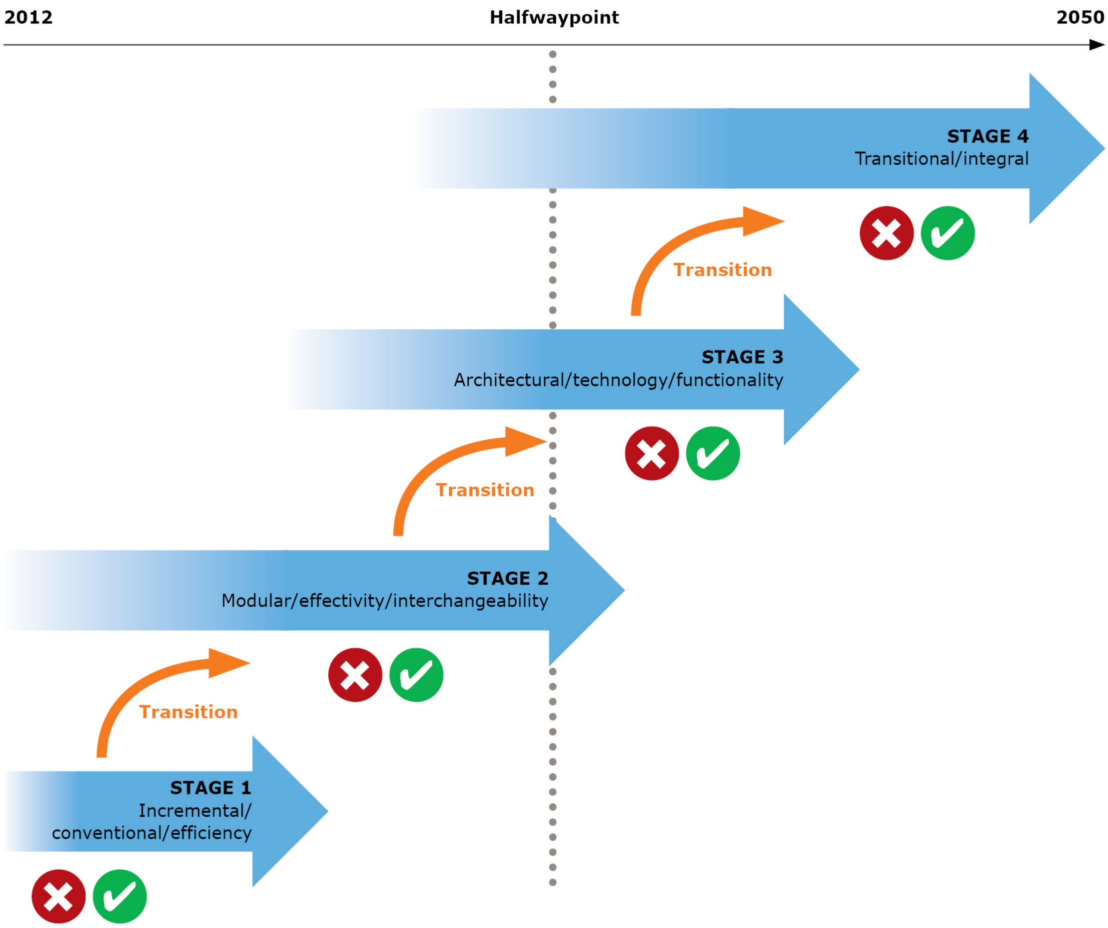


Figure 2: Stages of transition to integrated valorisation of biomass resources.

Thanks to technical developments (including mild preservation and bio-refining), it is now easier to build on the complexity of biomass resources. Further developments are required for application on an industrial scale. The latest technologies should make it possible to maintain or improve the quality and functionality of individual products. While current technologies do contribute to the higher added value of biomass resources, they still mainly result in products and components of lower value or purity. In addition, agro-chemicals can be produced more efficiently if the (refining) processes are adjusted specifically for a given type of biomass. Even so, it is often desirable to work with mixed inputs, and specially optimised systems will need to be developed for this. Process efficiency can also be improved by using plant and animal breeding (possibly by means of genetic engineering) to deliver a different, more suitable composition of components for high value application.

These developments are stimulated by enhanced cooperation in value chains and between application domains. To link the biomass application domains in the future, cooperation between stakeholders in the agri-food sector will need to be promoted across the board.

The greatest opportunities are at the intersection of several domains
The vision and roadmap lead to the following general recommendations:

- Establish new cross-sector and cross-domain cooperation in open innovation programmes. These links expand the knowledge of biomass valorisation at the component level through bio-refining and process efficiency.

- Prioritise the development of criteria through integrated valorisation and stimulate those industry initiatives which meet these criteria. The government can set these criteria up together with industry and research institutes, after which these parties can perform the integrated valorisation together.

- Monitor the stimulation policy and innovation processes which follow and adapt the desired outcomes after each period (preferably after at least five years) based on the knowledge available at that time.

- Leverage on the strong expertise position of the Netherlands:
    - There is a lot of biomass available: Identify potential sources for high value applications.
    - Choose the biomass resources to be imported and exported while keeping in mind not just economic factors, but also environmental pressures and social acceptance.
    - Support the development of 'Euregio plants' and strive to achieve self-sufficiency in current and future biomass needs.
    - Use the strong logistical position of the Netherlands, locally and regionally: closed systems lead to efficient logistics and a sufficient scale to develop new processes.

Recommendations specific to businesses: Cooperation across chain borders provides the most opportunities.

- Look beyond the chain and participate in open innovation programmes to develop knowledge in new areas. This may lead to new opportunities and inspiring ideas. Actively seek out cross-sector cooperation.

- Develop products which also fit within existing infrastructures and traditional chains. This makes them interesting to existing markets and avoids an undesirable dependence on a single sales channel.

- Pick the low hanging fruit: In all existing process steps and chains, there are still opportunities to save resources and energy. If these steps cannot be influenced directly, seek cooperation with other parties in the chain to spread costs and risks fairly.

Recommendations specific to knowledge institutes / research agendas:

- Contribute to decisions based on facts by providing insight into:
    - the sustainability impact of the planned transition steps, including unintended effects and mitigation strategies;
    - criteria for establishing the quality, quantity, function and durability of processes for replacing fossil fuels with renewable resources;
    - signal indicators and monitoring tools which measure progress from an integrated perspective that transcends the interests of individual stakeholders.

- Develop new knowledge about crops and breeding to develop new plant varieties with which the integrated valorisation can take place more efficiently in all areas.

- Make the positive and unintended negative impacts of product and process innovations transparent from an integrated perspective.

- Provide insight into the conditions and consequences of successful innovation processes.

- Improve cooperation within and between chains by sharing expertise and generating new knowledge on how to improve cooperation processes.

- Lower the threshold of knowledge valorisation: Combine biomass applications and available or required technologies in a matrix model.

- Reduce thinking within the box: Cross-fertilisation between various domains provides the most interesting contributions for the transition to integrated valorisation.

- Develop mild process technologies for biomass fractionation and integrate this knowledge in order to make sustainable bio-refinement routes possible.

Recommendations specific to governments:

- Use this roadmap to link policies and tools and thereby convey a consistent message to interested parties. Simultaneously appeal to businesses and knowledge institutes to take the necessary steps.

- Encourage discussion about differences and contradictions. Only then can the stakeholders move forward. Give business a say: Entrepreneurs are best placed to inspire each other. Facilitate new experiments and make it possible to use proven new technologies more widely. Organising working sessions with stakeholders allows for encounters between different sectors and chains.

- Develop and evaluate government instruments based on the value pyramid in order to prevent high-value biomass applications from being hampered by the support given to low-value applications. Biomass for energy must have the lowest value level.

- Align regulation more on desired goals and ambitions and less on the way in which they are to be achieved.

- Consult with industry and other interested stakeholders during the development phase of public instruments to ensure that the measures correspond to the needs and capabilities of the target group.

- Strengthen the sense of urgency among businesses and consumers to valorise biomass in an integrated way, and to strive for green growth. They must realise that their individual contribution counts and that integrated valorisation offers excellent economic and environmental opportunities.

- Develop targets for the reuse of non-renewable resources and re-focus these goals regularly. When developing the objectives, always keep in mind unintended negative effects, e.g., by including environmental and social costs in the price of fossil fuels. This encourages the development of bio-based materials by removing a significant price difference with fossil fuels.

- Encourage and support research agendas and innovation programmes for integrated valorisation and create opportunities for these activities to be coordinated at different levels (regional, national, international).

- Take part in public-private partnerships to stimulate technological developments and their management.

- Improve decision-making and evaluation processes by improving the quality, level of detail and scope of the available data on material flows of biomass.

Cross-border and cross-domain: These are the key words for the integrated valorisation of biomass resources. Look beyond what we already know, go outside your comfort zone. All stakeholders can contribute to this process by being active and open to change.

3 Preface

This report is the final document of the project "Integrated Valorisation of Biomass Resources". Commissioned by the Dutch Ministry of Economic Affairs, Agriculture and Innovation, a group of experts of Wageningen UR has investigated future developments to stimulate the integration of food and non-food value chains. There is much on-going research and (international) political attention for the various application domains of biomass (Food, Feed, Functional Materials and Fuel). Answers are needed to address current and foreseen crises that the world is facing, including a rapidly growing population, increasing consumer demands, climate change, water scarcity, availability of minerals and other fossil resources, and biodiversity loss. These issues can have significant impacts on the quality of our (future) lives. However, there are two major thresholds that need to be overcome to implement the necessary transition process to a more sustainable use of biomass resources:

1) A departmentalised approach to biomass application development blindfolds stakeholders for negative externalities
2) Short term focus on quick wins and return on investments instigate a lack of sense of urgency, impeding the necessary actions that enable the long term transition process.

The magnitude of the challenge could be paralysing, if it weren't for the innovativeness of people and the ability to change. This project calls upon the examples of possible solution pathways that clearly show a road to a sustainable, biobased economy, that is an answer to these facing threats. Renewable resources are available in sufficient quantities to serve as sustainable input for Food, Feed, Functional materials and Fuels. The project wants to investigate the barriers and opportunities to overcome the mentioned thresholds and to inspire the stakeholders involved in further action.

For this purpose a number of activities have been executed in the period of January 2011 – May 2012, involving stakeholders such as scientists, entrepreneurs and policy makers. Four main activities were undertaken, including vision building, expert Judgment, example Business cases and numerical analysis, converging into a Roadmap on the Integrated valorisation of Biomass By-products.

The authors wish to thank all people who have made a valuable contribution in the realisation of this document. In the first place the experts and entrepreneurs who have been willing to share their views during the interviews and the attendees to the workshop for their time, energy and enthusiasm. Next, we thank the colleagues from Wageningen UR, who made a (minor to large) contribution to the realisation of this document. And finally, we would like to thank the supervisors of the Ministry of Economic Affairs, Agriculture and Innovation for their valuable comments.

Wageningen,
September 2012

The IVBR Project Team:

Dr. Hilke Bos-Brouwers*, Wageningen UR - Food & Biobased Research*
Dr. ir. Ben Langelaan, *Wageningen UR - Food & Biobased Research*
Prof. dr. ir. Johan Sanders*, Wageningen University - Biobased Commodity Chemicals*
Dr. ir. Ad van Vuuren*, Wageningen UR – Animal Sciences Group*
Dr. Michiel van Dijk*, Wageningen UR – Landbouw Economisch Instituut*

Project details

Commissioned by: Ministry of Economic Affairs, Agriculture and Innovation
Supervised by: Freija van Duijne, Annelie Boogerd, Tonnie Greutink, Dirk de Jong
Project code: BO-08-016-001
Execution period: January 2011 – December 2012

4 Introduction

This report presents the results of the project "Integrated Valorisation of Biomass Resources".

The transition towards a sustainable biobased economy is expected to provide solutions to a number of interdependent challenges the world currently is facing, like population growth, climate change, availability of mineral and fossil resources and loss of biodiversity. This transition, however, will not occur automatically as it requires a radical change in the organisation of value chains compared to the current situation. This project seeks to define business opportunities and solution pathways via an integrated approach on the valorisation of biomass by-products. It searches for options to stimulate entrepreneurs, governmental institutions and knowledge institutes to join forces in reshaping the biomass value chains to open up opportunities to valorise biomass at the highest-end value possible by 2050.

A number of questions are at the root of the project:

1. What does a system of food production and –consumption look like, which provides sufficient food in 2050 and is also able to fulfil demands from other domains (feed, fuel, functional materials)?
2. What are promising new value chains in the domains of food, feed, fuel and functional materials that have the potential to contribute to a sustainable biobased economy in the Netherlands in the future?
3. Which decoupling and tipping points in the value chain can be discerned within the 4 domains (food, feed, fuel, functional Materials)?
4. Which technological developments play a role within and between the 4 domains, which have an impact on the exchange of side- and waste streams between the food and the biobased (non-food) economy?
5. Which opportunities and threats (in terms of people-planet-profit) play within and between these domains?
6. Which optimisations are possible in decoupling and tipping points in the value chain to improve the exchange of biomass over the 4 domains?
7. Which (evolutionary and revolutionary) adaptations to biomass value chains provide the largest effect, and is it possible to estimate the economic feasibility?
8. Which (policy) recommendations for stakeholders from government, research and business can be formulated in terms of a roadmap, based on the insights gained in this project?

These questions have inspired a number of activities converging into a Roadmap of activities to achieve an integrated approach on the valorisation of biomass resources for food, feed, functional materials and fuels. In the vision of the project team, this is an important main building block contributing to a sustainable use of resources.

The goals of the project are:

(1) To inspire innovative entrepreneurs within start-ups, SMEs as well as large companies, involved in the valorisation process of biomass in the value chain, to engage in an integrated approach towards a sustainable use of biomass resources. This report will suggest incentives that can motivate to take the next step towards clustering, cooperation and business development, responding to a common sense of urgency.

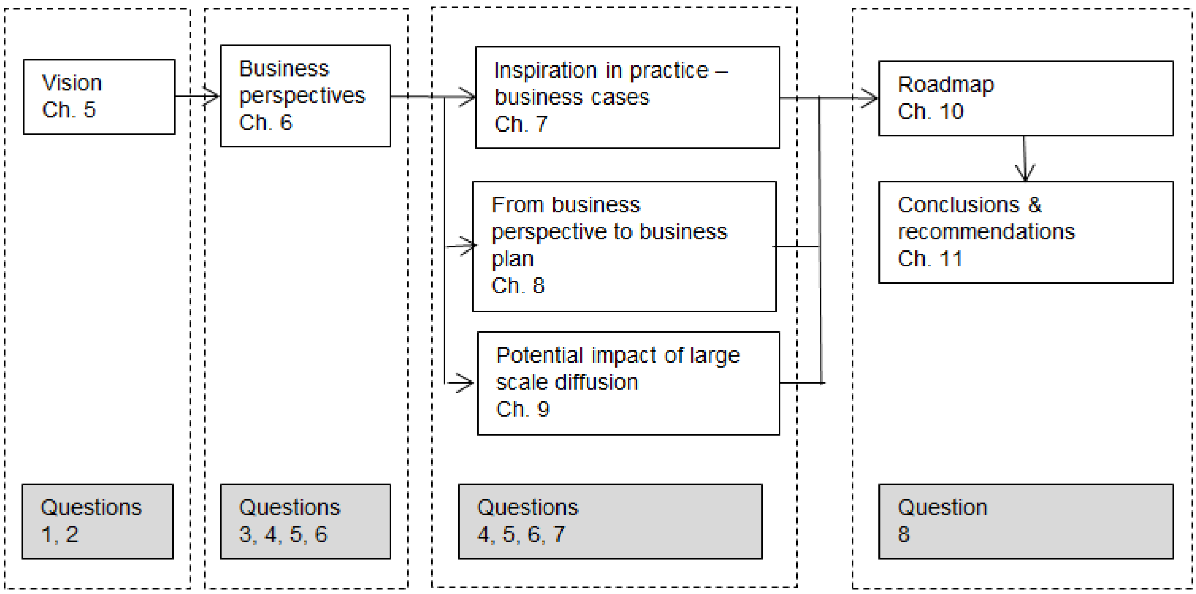
(2) To contribute to national and European research agendas on biomass resources, by offering a new approach on integrated aspects of the transition to a sustainable use of resources. For the Netherlands: including (but not limited to) Topsector approach in Public-Private Partnerships, Innovation Contracts and technology research programming via the "Golden Triangle" (*cooperation between businesses – research institutes – government*). For Europe: including (but not limited to) the Research Agenda of Horizon 2020 (including the upcoming 8th Framework Programme), the ERA-Net approach, and the Joint Programming Initiative.

(3) To provide new insights for governmental policies, laws and regulations, and governmental instruments (including grants and taxations), on national and European level, on options for stimulating entrepreneurs and researchers on long(er) term innovation strategies for the biobased economy and sustainable use of biomass resources, against a background of financial crises and focus on budget cuts combined with deregulation. Including, but not limited to: the Dutch Topsector policy approach (mainly on the sectors Agro & Food, Chemical industry and Energy), the EU Horizon 2020 (amongst others the Flagship Resource Efficient Europe) and the Common Agricultural Policy.

The activities contributing to the project outcomes are

1. The formulation of a vision on an integrated approach of the valorisation of biomass by-products.
2. Expert judgment on this vision and on potential business cases underlying the transition to a sustainable use of biomass resources.
3. Elaboration of example cases including business opportunities and tipping points
4. Workshop with business entrepreneurs to explore bottlenecks and solution pathways.
5. Modelling and numerical analysis, quantifying economic, environmental and social impacts, relevance and significance.
6. Formulation of a roadmap, framing these solution pathways into stimulating activities within a business-government-research context.

This report has the following outline:



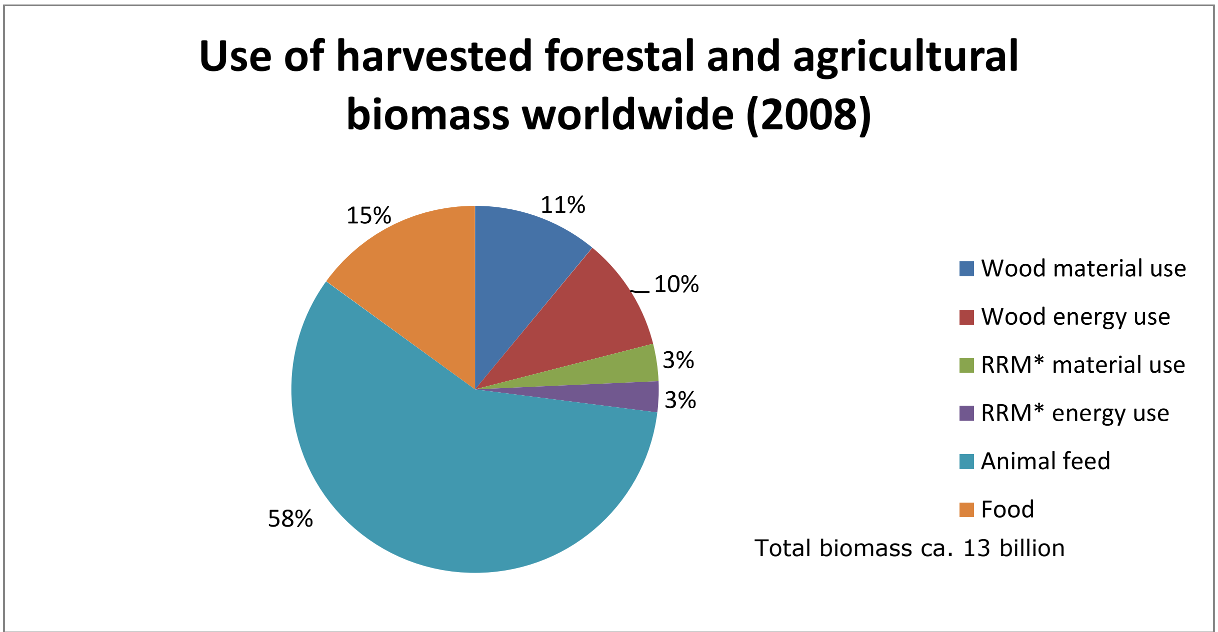
Chapter 5 presents the vision on integrated valorisation of biomass resources by presenting the four application domains food, feed, functional materials, fuels and their interconnectedness to invoke optimal and sustainable use of resources. Chapter 6 presents the insights on business perspectives by analysing expert judgments on the scope boundary issues of biomass resources, with special focus on main products and by-products or rest-flows, and addresses barriers and opportunities on the short and longer term to make the transition towards an integrated use of biomass, following the value pyramid principles presented in chapter 5. Chapter 7 shows example business cases on making new, high-value use of biomass resources, especially focusing on waste or rest flows from food and feed production processes to highlight the first steps towards an integrated valorisation of biomass resources and are intended to inspire the business and research communities to use applied knowledge in creating economically viable new business. Two of these examples cases are then further elaborated in chapter 8 to make the step from perspective, idea towards actual business planning, investigating the barriers, but foremost the opportunities to venture into new food products based on waste flows or feed/fuel ingredients. All example cases are then analysed on their potential economic and environmental impact if they would diffuse on a large (industrial) scale in the marketplace. This modelling and numerical analysis is based on the availability of biomass resources in the Netherlands to make the scale estimations. Having outlined a vision on integrated valorisation and providing examples and business context to these transitional innovations necessary to achieve the 2050 ambition of sustainable use of resources and a 2 times more with 2 times less efficiency level, chapter 10 presents the Roadmap on how to get there in 4 transition steps. The conclusions that can be drawn from the research work are presented in chapter 11, as well as the recommendations that could be formulated for governments, businesses and the research agenda, in a (inter)national context.

5 Integrated vision on valorisation of biomass resources

This chapter provides a vision on the development of a biobased economy[3] in which future demands (or claims on biomass) from the four biomass application domains of (human) Food, (animal) Feed, Functional materials and Fuels are in equilibrium. It addresses current and foreseen trends and challenges in the four application domains and gives an analysis on the cutting edge of these domains: the hotspots for the implementation of an integrated approach to the valorisation of biomass by-products. It sketches what a system of food production and consumption looks like, which provides sufficient food in 2050 and is also able to fulfil demands from other application domains (research question 1). In addition, promising new value chains that have the potential to contribute to a sustainable use of biomass resources in a biobased economy in the Netherlands are outlined (Q.2).

Other organisations and opinion leaders have formulated and published various vision documents[4], which often take a departmentalised view on biomass valorisation. This project aims to develop an integrated vision, starting from availability of biomass and biomass by-products towards the exchange of these material flows between the four application domains to achieve the highest- possible value in its final destination, following the principle of the biomass Value Pyramid.

The focus on these four domains within this project is based on a generalisation of the multiple functions that biomass can have within society, such as pharmaceuticals, cosmetics, food, feed, biobased chemicals and performance materials, and biofuels (e.g. bio-ethanol and biodiesel). An indicative distribution of current applications of biomass for the main domains is show in **figure 1** below.



* RRM: Renewable Raw Materials

Figure 1*: Current applications of biomass (Raschka & Carus, 2012).*

The further development of the biobased economy will comprise additional claims on biomass, especially for the production of a broad spectrum of non-food chemical products, ranging from pharmaceutical

---

[3] *An economy in which companies produce a portfolio of non-food products (chemicals, materials, fuels, power and heat) from biomass, next to the existing and future food and feed products. Biomass is virtually any organic material which originates mainly from agricultural produce (e.g. crops such as soy, maize, wheat and rape seed, but also [aquatic] animal livestock) and residues (e.g. straw, leafs), forestry, wood processing industries and waste (e.g. biological waste from households, animals and food production).*

[4] See also reference list in chapter 11.

ingredients (high value) to bulk chemicals (low value). In this project, we use the term "Functional Materials" to address this application domain.

The world is facing a number of interdependent challenges, which will affect the availability and application of biomass resources in the different domains. For example, the world population growth towards 9.3 billion people in 2050 (prospected by the United Nations in 2011), shall lead to an increase in food demand of around 65%. When taking into account that each kilo Joule (kJ) caloric content of a food product requires 20 to 25 kJ of energy(originating from biomass and fossil resources) earlier in the food chain, it becomes clear that the current agro-production will not be sufficient to meet this demand, let alone provide sufficient biomass to sustain or develop other applications. The demand for biomass will also increase because of the expected decreasing availability of fossil resources in the coming century, along with a transition to a biobased economy. Consequently, current agro-production chains cannot fulfil this need and alternatives need to be found. For this, three strategies seem likely:

1. Changing the mind set of consumers with respect to abundance and scarcity; motivate them to make their consumption patterns more sustainable (reduction of consumption, shift to sustainable goods) (consumer oriented)

2. Policies and regulations, e.g. production or purchase criteria, taxes or the internalization of external environmental and social impacts into the cost of goods (policy oriented)

3. Developing new functional and more efficient agro-production systems and value chains (business oriented).

During the scoping phase of this project, it has been decided to focus on the integration of the 2nd and 3rd strategy, to clarify the interrelations between government and business, but also research stakeholders in the Golden Triangle (businesses – research institutes – government) on solution pathways for integrated valorisation of biomass by-products. The consumer oriented strategy is also important in achieving a transition to a biobased economy, but in this report, the influence of the consumer is mainly used as bottleneck in the societal acceptance of new processes and products.

In this project the possibilities to optimize the integrated valorisation of biomass main and by-product flows within (near) future agro-production systems are explored. The focus will be on reducing the ecological footprint by:

- The optimization of the added value of the different components that can be isolated or fractionated from biomass, through the redesign of, and exchange between, different production chains
- The conservation of raw materials, i.e. closure of cycles, re-use of materials, avoidance of waste
- Efficient use of water, energy, minerals
- The right scale, the right time and the right location for the different processes (organisation)

5.1 Introducing the four biomass application domains

Today's world is facing a number of interdependent challenges: the exhaustion of mineral and fossil raw materials, the growing world population (and its increasing standard of living), increase in food prices, competing claims for land use, climate change, conflicting interests between economy and ecology and globalisation. Whereas for some of these challenges a critical threshold for the earth system has become infinitely close, for others there may still be time left to take appropriate measures (Rockström *et al.*, 2009). There is a growing consensus that the development of a sustainable society will only be realised through a transition towards a biobased economy. In this economy, the growth of consumption does not automatically lead to a growing impact on the environment (Rijk & Gulpers, 2011). The challenge will be to move away from existing, fossil and mineral resources based production chains and develop new innovative methods for effective and efficient use of energy and renewable resources (such as agro-materials and wood). The application of renewable resources based on biomass, the development of clean production processes and smart materials, and cradle-to-cradle concepts may provide the required solution pathways.

This transition, however, requires new approaches for food production, energy supply, use of materials and production processes (see e.g. Topsector Chemie, 2011). Existing value chains will have to be re-examined against the new criteria set by the integrated biobased economy. This will lead to a "re-valuation" of raw materials, intermediates, products and waste streams as well as water and energy consumption. As a starting point for this valuation stands the "Value Pyramid" (originating from WTC-BBE, 2011), a concept which defines the allocation of biomass to preferential value (and valorisation) levels (see **Figure 2**)[5].

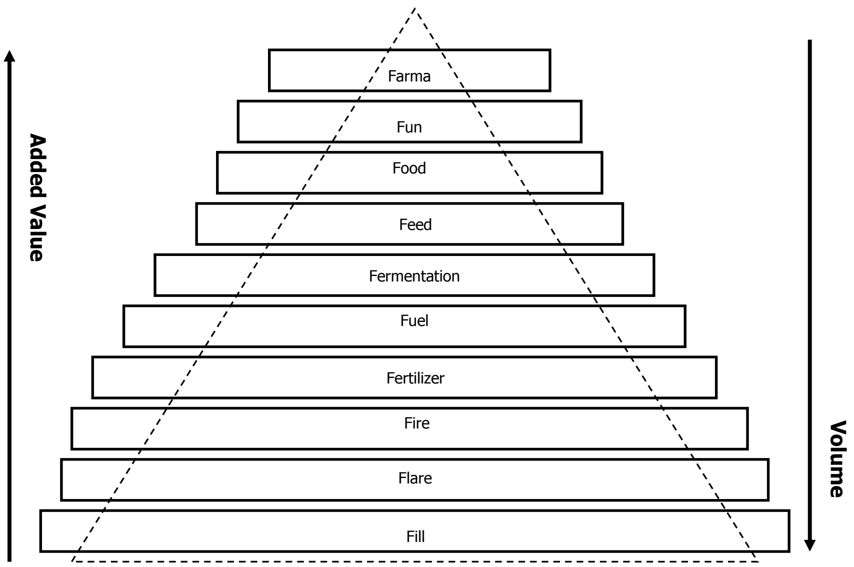


***Figure 2**: The value pyramid to classify biomass on the value of its application(s) (derived from WTC-BBE, 2011)*

[5] A similar concept is also used for the valorisation / upcycling of food waste (The "Ladder of Moerman", see, e.g. www.groenekennisnet.nl).

For the purpose of this project, we have modified the Value Pyramid through grouping the application in four domains Food, Feed, Functional Materials and Fuels (see **Figure 3**).

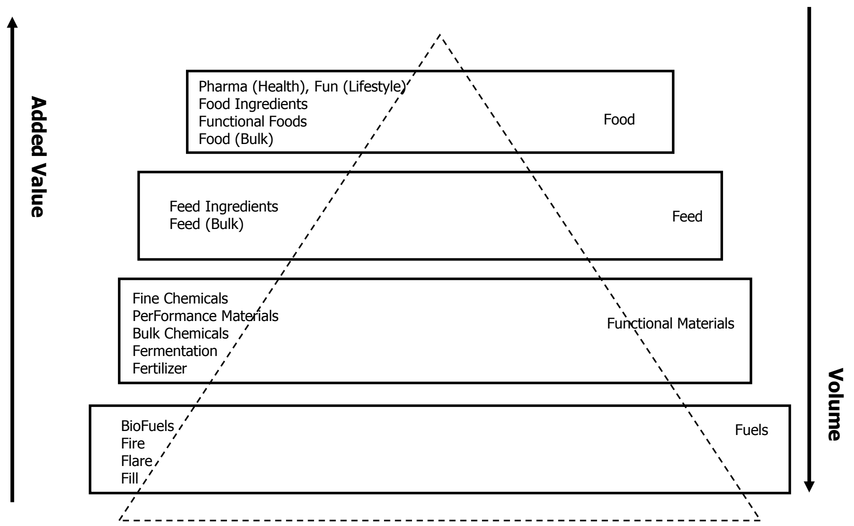


Figure 3*: The modified value pyramid. This version is used within this project to classify biomass on the value of its application(s) within the four domains of Food, Feed, Functional Materials and Fuels*

As becomes clear from **Figure 3**, biomass can represent a specific value depending on its application (e.g., food ingredients represent a higher value than feed ingredients). It is also clear that by reducing the number of domains to 4, some details have been lost compared to the initial model. As a consequence, some specific applications within a lower domain will represent a higher value than applications in a higher domain. For example, biomass converted into specific valuable fine chemicals will represent a higher value than feed applications. This simplification, however, will not affect the overall conclusions of this study.

According to the Wageningen UR philosophy "2 times more with 2 times less", agro-production systems have to be 4 times as efficient in 2050 as compared to their current performance. For the scope of this project, a sub-target can be derived from this philosophy for the year 2025, i.e., "1.4 times more with 1.4 times less", resulting in systems that are twice as efficient as they are now (or, to state it otherwise, reduction of the footprint with a factor 2).

In this vision, "More" stands for:

- Integrated valorisation of biomass, with maximization of the value of its constituents on the different domains Food, Feed, Functional Materials and Fuels (economics, including employment)
- The value generated on a specific domain is directly linked to the avoidance of bottlenecks on other domains

"Less" stands for:

- Minimal water and energy consumption during all stages of the product life cycle (as a measure for emission of greenhouse gases)
- (Direct and indirect) land use (as a measure for preservation of ecosystems)
- Reduction of N, P, K use by cycle closure

In this project, a number of case studies are presented, visualising how existing value chains can be re-organized, what impact this re-organization has on the footprint, and how these new value chains fulfil future demands on the domains Food, Feed, Fuels and Functional Materials.

5.2 Context for developments in the Biobased Economy

This section provides a brief overview of the national and international context in which the further development of the biobased economy will take place. This analysis provides drivers and boundary conditions for the cases that will be worked out in a later stage of this project.

National context
Within the "top sector policy" approach, the Dutch government has expressed the ambition to further strengthen the industrial sectors in which the Netherlands already have a prominent position. For the fulfilment of this ambition the *golden triangle (*industrial partners, the government and universities/knowledge institutes) will work together on knowledge generation and innovation. Agreements have been made in so called innovation contracts. In total 9 different top sectors have been identified.

The recommendations as recently presented by these 9 different Dutch Top Sectors (see Topsector Chemie (2011), Topsector Water (2011), Topsector Agro& Food (2011), Topsector Tuinbouw & Uitgangsmaterialen (2011) and Topsector Energie (2011), an overview is presented in **Annex 2**) express the ambition for the Netherlands to become frontrunners in the development of the biobased economy. Building a biobased economy will create new economic opportunities for all relevant sectors of the Dutch industry: agriculture, chemistry, materials, energy and logistics (SER, 2010). This development, however, also implies that these sectors will put an increasing claim on the (future) available biomass. An integrated approach is an absolute prerequisite for a successful transition from a fossil-based to a biobased economy. The Innovation Contract Biobased Economy (Werkgroep Businessplan BBE, 2011) presents a first action plan for this integrated, cross-sectorial approach, based on two principles: maximum valorisation of biomass and sustainability from the start. The strong agro- and chemical sectors, logistic position and the strong knowledge infrastructure, provides the Netherlands a very good starting position for the realisation of the biobased economy.

The vision as laid down in the Innovation Contract Biobased Economy builds further upon previous studies (like SER (2010), Ministerie LNV (2007) and Annevelink *et al.* (2009)). The successful transition towards a biobased economy should be accomplished by 2050, and will be achieved through a number of steps which are already more (stage 1 and 2) or less (stage 3 and 4) visible:

- Stage 1: increase efficiency of use of fossil and mineral resources
- Stage 2: Replacement of (molecular) building blocks in fossil resources by (molecular) building blocks from biomass (e.g. bio-butane and bio-ethane).
- Stage 3: Generation of new (fundamental) knowledge in the field of catalysis, enzymes and fermentation (enabling new processing routes for [intermediate] products).
- Stage 4: Agricultural production of biomass for food, feed, fuels and the entire spectrum of functional materials; fully developed biorefinery utilising available complexity in nature.

These stages have inspired the formulation of the vision outlined further in this chapter, but lack the integrated approach on the valorisation on all biomass application domains by its focus op non-food applications.

In line with stage 4, biorefinery is defined as the sustainable processing of biomass into a cascade of marketable products (from high added-value chemicals to low-added value energy), maximizing the potential value and impact of biomass use. The most promising directions for biorefinery in the Netherlands have been identified as follows (Annevelink *et al.*, 2009):

1. Biorefinery based on domestic Dutch crops, using synergy of existing agro- and chemical sectors, including the Dutch plant breeding sector.
2. Biorefinery of aquatic biomass, using Dutch microbiology, plant breeding and processing knowledge.
3. Biorefinery of bulk imported biomass and biomass-derived intermediates, using existing logistic and petrochemical infrastructure (like the port of Rotterdam).
4. Biorefinery of residues, based on co-operation in production chains and networks, relatively small transport distances and business competences of Dutch entrepreneurs.

Actual figures on the availability and (potential) applications of biomass in the Netherlands will be presented in the case-studies in **Chapter 7**.

International context
When searching for new interactions between the biomass domains, the international context should be taken into account as well. The Netherlands are a nexus (connecting chain) in importing and exporting biomass, and are thus (in-)directly affected by the growing world population, food security issues, volatile biomass prices, climate change and availability of raw resources. Many OECD countries have expressed their commitment towards the further development of a biobased economy, realising that the goals of Green Growth and the biobased economy significantly coincide (OECD, 2011). Within the European context, the following goals have been defined for the establishment of biobased application domains for functional materials and fuels (Star-Colibri, 2011):

- In 2030, Europe is a world leading and competitive biobased economy. At that time, the European biobased industry is innovative and competitive, with cooperation and support between research, industry, forestry, agriculture and civil society.
- All actors along the value chain are profiting from this flourishing biobased economy.
- The success of the European biobased industry comes from being a world-leader in efficient and flexible utilisation of biomass and having a strong focus on market opportunities for higher-added value products.
- By 2030 a significant part of the European demand for chemicals, energy, materials and fibres is produced using biomass as a feedstock for biorefinery technologies.

One of the underlying assumptions for the definition of these goals is that food production (primary production as well as food industry) within the EU will stabilise at a level of food self-sufficiency slightly above 100%. Here, a thorough analysis of import and export of biomass resources should contribute to sustainable sourcing. Due to the higher productivity the area required for food production will decrease compared to 2012 and, thus, more arable land will be available for the production of other biomass. Also, a shift towards more protein rich crops could influence the productivity and availability of arable land. Although a renewable resource, biomass is not available in unlimited supplies. Sufficient biomass availability is a key success factor for the development of the European biobased economy. To ensure biomass availability, the main challenges in Europe are:

- To increase the productivity of existing farmland without any negative environmental effects to supply sufficient high-quality food and feed for EU-27 (and to still be able to play a key-role in the world-wide trade).
- To increase the efficiency in the food/feed chains, to avoid unnecessary waste and to increase recycling measures.
- To supply the industry with secure and sustainable raw materials, by efficient land use as well as measures to cope with seasonal supply
- To enhance availability and use of forest biomass

Sufficient biomass availability also means: biomass on the right place and time (logistics), in the right amount (scale) and of the right type. From a logistics point of view, the biomass production areas in Europe will remain fragmented (with the exception of the Northern European forest). This has a significant impact on the value chain due to the importance of the logistical factors related to harvesting and transport. The sustainability and the competitiveness of the different value chains will always rely on a close collaboration within the concerned industrial sectors (from either upstream or downstream sectors) whilst also depending on a high level of integration between the different production processes.

The choice of an optimal biorefinery scale will depend on the type of biomass used, logistic constraints, production costs and processes. In the fossil-based economy, low transportation costs have led to the development of large-scale industrial processes that maximally benefit from the "economy of scale". Higher fuel prices may drive industry to develop smaller scale concepts with a more regional character. The selected scale will have a major impact on the emergence of industrial biorefineries and their distribution. To summarize:

- Very large-scale integrated biorefineries, mainly based on thermochemical process, are likely to emerge in Northern Europe (driven by Pulp & Paper industries) possibly associated with large industrial harbours (driven by Chemical or Oil industries).
- Small/medium scale integrated biorefineries, mainly based on biotech processes, are likely to emerge in rural areas, mainly in "Mid-Europe" (driven by Agro-industries).
- Decentralised biorefineries will also emerge throughout Europe, based on the development of a network of pre-treatment units (biomass fractioning and/or concentrating units) coupled with bigger biorefineries.

With respect to the type of biorefineries, it is expected that in 2030 many biorefineries will operate at a large-scale commercial level. Most of these biorefineries will be developed through the integration with existing industrial value chains. However, another interesting development path for biorefineries is envisaged based on emerging new industrial value chains. As a consequence, there will not be one but several biorefinery types in Europe, with a predominance of specific types according to geographical biomass sourcing locations:

- Biorefineries based on wood (locally produced biomass) are likely to be developed in Northern Europe or in densely forested rural area in "mid-Europe".
- Biorefineries based on classical agricultural crops (cereal, sugar beets, oilseed crops, dedicated biomass feed stocks) are likely to be developed in rural areas in "mid-Europe" (western, central and eastern Europe).
- Biorefineries based on imported biomass will be established mainly in or very near to large industrial harbours (like Rotterdam).
- The development of biorefineries in Southern Europe is more difficult to predict. It could be either connected to industrial harbours or to the development of regionally-related crops productions (dedicated crops) in rural areas.

5.3 Overview of trends and domain challenges

In this paragraph an overview is given of the trends and challenges on the specific domains. Similar to the previous paragraph, this analysis may provide drivers and boundary conditions for the cases that will be worked out later in this report. The overview draws on prior research and studies to provide a cross-cutting view on the biomass application domains. These provide the building blocks for the integrated valorisation of biomass resources.

5.3.1 Domain Food

The major challenge in the Food Domain is to guarantee the availability of safe and healthy food for a growing global population with increasing welfare standards, against the background of increasing consumer demands and sustainability concerns. Climate change, the intensified competition for fresh water and land, as well as the shift in dietary patterns (increasing consumption per capita, growing meat consumption) across the world will have a major impact on the food supply chains of current times.

Up to now, in the western society the food production system has managed to keep pace with the increasing demand for food, through increasing the yield per hectare by using crop selection and fertilizers, and improving the efficiency of animal production by breeding and management practices. However, it is predicted that the problem of food insecurity will escalate due to the global population growth (estimated to rise from 7 billion in 2011 to 8 billion in 2030 and 9.3 billion in 2050 (Parker, 2010), climate change combined with an decrease in energy and water availability and an increase in food consumption. The UN Food and Agriculture Organisation (FAO) has defined food security as "Food security exists when all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Currently, over one billion people in low-income countries are malnourished (FAO/OECD, 2011) with 60% of deaths in the under-five-year-olds resulting from a lack of protein, vitamins and minerals.

Projections show that the demand for food will further increase by up to 65% in 2050 (Topsector Agro & Food, 2011), in particular grains (cereals, wheat, rice, oats, maize), which makes up 70% of all the agricultural plant produce produced in the world (Rijk & Gulpers, 2011). As a major part of these grains is used for the animal production (in 2000: 40% of the grain harvest and 75% of the soy harvest), the increasing demand for animal-based proteins may have serious consequences for global food security (Boer & Aiking, 2011). On top of this, the production of (first generation) bio-fuels as well as the expected future demand from the domain of Functional Materials (see, e.g., Mulder (2012), IEA Bioenergy (2011)) also contribute to a rising demand for grain (or specific parts thereof, e.g., the protein or carbohydrate fraction).

Annual demand growth for grain is estimated at 1.7-3.2% whereas the rise in annual yield is estimated at 0.6-0.9%. The gap that remains could be filled by using more land (~ 20%), which is in principle available in areas like Latin America, Central/East Europe and Africa (Rijk & Gulpers, 2011). This approach however, will inevitably lead to a further loss of biodiversity (Vuuren *et al.*, 2011). The scale and intensity of current food production already led to crossing three planetary boundaries: loss of bio-diversity, climate change and the nitrogen cycle, while pressure is put on three other boundaries: land use, fresh water use and the phosphate cycle (Rockström (2009), Boer & Aiking (2011)). Food production now claims about 1/3 of the available land world-wide (including non-arable land such as desserts, mountains and frozen lands), as well as ¾ of the available fresh water. In addition, it is estimated that 1/3 of all transport is food related. Solutions will, therefore, have to be found in further increasing the efficiency and sustainability of current agro-production chains (*the food system* FAO/OECD, 2011). Two examples which demonstrate inefficiencies in the current production chains are given below:

- Production of more sustainable proteins for human consumption (Boer & Aiking, 2011)
- Reduction of food waste (FAO (2011a), Milieu Centraal (2007), Ministerie LNV (2010))

Additional examples will be provided by the case studies which are described in **Chapter 7** of this document.

Proteins for human consumption
The inefficient conversion of plant proteins into animal proteins is a major cause for many of the problems in the food domain as stated above. The growth of the human population to 9.3 billion people by 2050 (estimated by the UN) and increased welfare status are expected to lead to a doubling of the demand for animal protein. The meat demand will increase from 229 to 465 billion kg, the demand for dairy products from 580 to 1043 billion kg. This will lead to a larger demand for biomass for feed

applications: in the coming 10 years the global demand for soy in feed is expected to increase by 25%; for maize by 30%.

In a recent publication the sustainability impacts of healthy foods were evaluated (Gezondheidsraad, 2011). The overall conclusion is that healthy food is in general ecologically sustainable, and most profit in terms of health and sustainability can be realised by replacing meat proteins by plant proteins[6]. However, in an optimised system, animal proteins consumption to a certain level is still possible. From an ecological perspective, the maximum for animal protein consumption should be 500 gr meat and 1 litre milk per capita per week. Although changing consumer behaviour is not part of the scope of this project, incentives focused on the reduction of animal protein intake may reduce the pressure on current ecosystems significantly. In addition, the amount of fresh water necessary to produce these proteins could be reduced by a factor of 100 (FAO/OECD, 2011). Additional reductions of land use can be realised by using crops that have an even higher yield of high quality protein per hectare, such as grass, lupines, peas, rape seed or clover.

A less radical strategy may be found in reformulation of existing products. A good example has been provided by the dairy industry: currently produced desserts contain a higher amount of whey proteins compared to years ago. Whey used to be a waste stream and has now been converted into a valuable food ingredient.

Food Waste

About one-third of the food produced for human consumption is lost or wasted every year, amounting to about 1.3 billion tonnes annually (FAO/OECD, 2011). In mid-to-high income countries about 95-115 kg/capita/year is wasted at household level (FAO, 2011a) and around 25% within the entire food chain (10% at primary agriculture, 10% in processing and 20% in retail/consumption, (Milieu Centraal, 2007, Ministerie LNV, 2010). In low-income countries (often supplying bulk biomass commodities) most wastage occurs after harvest and during storage and transport. The highest volumes of food waste are found within the production chains of fresh fruit, vegetables and bakery products. Also within dairy and grain[7] production chains significant losses occur.

The "Ladder of Moerman" is an accepted model for the valorisation of food losses within the value pyramid (www.groenkennisnet.nl). This model reads as follows (from high-value to lower-value solutions):

1. Prevention (prevent food losses to occur)
2. Direct application for human food (e.g., via charity institutions)
3. Conversion into human food (via reprocessing)
4. Conversion into animal feed (as alternative to imported proteins)
5. Feed stuff for industrial applications (biobased economy)
6. Fertilizer production through fermentation (including energy production)
7. Fertilizer production through composting
8. Application as sustainable energy source (primary purpose is energy production)
9. Incineration as waste (primary purpose: destruction; secondary purpose: energy production)
10. Composting of organic degradable waste
11. Landfill

[6] It has to be noted, however, that policies on sustainable agriculture in Europe aim towards reduced import of soy and other protein-rich crops from abroad. Local, environmental-friendly produced food, may not always have a good score on land use and greenhouse gases emissions due to the lower yield per hectare.

[7] Non-bakery products, such as pastas, rice.

Current valorisation of waste and side streams in food production is often limited to conversion into products with a significantly lower value, i.e., substrate for biogas fermentation or animal feed. Major obstacles for many high-value valorisation routes are legislation and food safety considerations. Food safety is a prerequisite for all food production chains and limits application of many side streams in the Food domain. It is expected that increased consumer concern as stimulated by the 2011 EHEC outbreak will be a driver for increased legislation within the EU, especially towards trace ability of food components. Additional limitations towards the use of biomass streams from other domains are set by the Novel Food Regulation (Regulation 258/97/EC, (EC, 1997)), which states the rules for the marketing of novel foods and novel food ingredients. Specific measures will thus be necessary when upgrading side streams to food applications.

5.3.2 Domain Feed

The feed industry in the Netherlands produces 14.3×10^9 kg compound feed per year for the Dutch market and approximately 5×10^9 kg of other animal feed. In addition to this volume, about 10×10^9 kg of raw materials for the compound feed industries in Germany and other hinterland countries are shipped through Rotterdam. Within the Netherlands, compound feed is mainly used for pigs (44%), poultry (27%) and cattle (25%). The remaining part (4%) is used for calves, horses, goats, sheep and pet animals (www.nevedi.nl). Cattle, sheep and goats also consume farm-grown forages, being the major portion of their biomass intake. Within the Netherlands, annually 9.0×10^9 kg of forage dry matter is harvested as grass and maize silage (60% and 40% of produced forage biomass dry matter, respectively). Approximately 2.8×10^9 kg of farm grown forage dry matter is being grazed, a portion that is gradually declining. Thus, it can be concluded that total biomass used as feed within the Netherlands amounts to approximately 26.5×10^9 kg of dry matter per year, of which 63% is consumed by cattle, 22% by pigs, 13% by poultry and 2% by other animals, including pet animals. Including the transit feed materials, more than 35×10^9 kg of biomass is available to increase economic value and at the same time reduce the food footprint.

To reduce the ecological footprint and to increase economic profit of livestock production systems, a high efficiency of livestock production is needed. This can be realised through feeding high quality grains and protein ingredients to livestock. These types of components, however, are also potential food ingredients for humans. Although animal proteins have a higher economic value than plant proteins and its consumption is usually related to wealth status, this extra link in the food production chain may be questioned with respect to the ecological use of plant proteins. Thus, animal production chains using inedible feed materials that do not compete with human consumption are to be favoured.

Imported feed materials are produced overseas usually in monocultures on large areas which are partly obtained through deforestation, thereby heavily contributing to the ecological footprint of food production. Part of the imported feed material is not retained into animal products, but excreted as manure. For economic reasons, these excreted nutrients and minerals are not returned to the original area of crop production, but applied to the area of animal production, where these nutrients are used as fertilizer for local biomass production or bioenergy purposes. Often the amount of minerals applied to the soil is in excess of the productive capacity of the soil, resulting in environmental burdens, such as eutrophication by phosphorus and nitrogen, ground and surface water pollution and gaseous emissions of ammonia and nitrous oxide, the latter adding to greenhouse gas emission.

Major concerns on livestock production systems are arising in regions with a high density of livestock animals. The housing of livestock animals within a relatively small region has not only increased the risk of outbreaks of contagious diseases, but also endorsed farmers to high investments in housing and hardware to produce within the EU environmental protection legislations at a profitable margin. Because large numbers of animals are kept within a relatively small region, the crop production within that region required to feed these number of animals is usually inadequate. This results in the import of vast amounts of feed material. The high investments also necessitate an economic and efficient production, thereby increasing the demand for high-quality feed materials and for animals with a high production potential.

Because of specific characteristics of the digestive tract of ruminants that enable a longer residence time of feed within the digestive tract and the fermentative degradation of feed material by micro-organisms, ruminants can extract energy and nutrients from plant cell walls (fibre) from grasses and other leafy plant biomass. However, the microbial degradation of fibre coincides with the production of methane. Methane is one of the greenhouse gases (besides CO_2 and nitrous oxide), which is regarded as a factor influencing global climate. This enteric methane production can be reduced by improving the quality of ruminants' diets. This is achieved by feeding other carbohydrates, in particular starch from grains, or by increasing fibre digestibility. Including grains and other high-quality feed materials again leads to the competition for plant materials between humans and animals. Increasing fibre digestibility can achieved by feeding grasses in a young vegetative state, generally requiring high levels of fertilizer. The latter results in excessive mineral deposition.

The symbiotic micro-organisms can convert non-protein nitrogen into microbial protein, which is a valuable source of amino acids for the animal. Thus, cattle can produce valuable animal protein in milk and meat when fed on non-protein nitrogen. The capacity for microbial protein synthesis in the rumen is limited and not sufficient to meet the requirements of high-producing (more than 30 kg of milk) dairy cattle and therefore, rations for high-producing dairy cattle are often supplemented with high-quality protein sources, which could also be consumed by humans.

To reduce the risk of disease outbreaks, the preventive application of antibiotics became common practice and implied severe restrictions for using certain waste products as feed material, such as the recycling of high-quality animal protein. The EU ban on the preventive use of antibiotics in livestock production, has accentuated the impact of feed materials on animal health, in particular gut health, demanding high quality standards for animal feed. Stocking animals at high density in isolated, high-tech production systems increased the distance between crop and animal producers (farmers) and the gap between farmers and consumers (Broeze *et al.*, 2012). This reduced the transparency of food production and lead to a feeling of being "out-of-control" among consumers. This added to stricter hazard control systems, thereby reducing the possibility to use wastes from households or feed industry as animal feed material and implementing strict legislation within the EU for manufacturing and marketing feed materials.

High-quality feed ingredients, derived from alternative raw materials which are split into different fractions, may improve the availability of nutrients for livestock animals. To market such novel feed materials an accurate assessment of its safety and feeding value is required to predict its usability in animal diet formulation. An additional advantage of fractioning feed materials is to extract components with little or even negative nutritional value for animals (anti-nutritional factors; bulk) to become available for other applications and/or domains within the biobased economy. With a current amount of biomass dry matter for feed applications (> 35 Mt), the Netherlands has a huge potential for the further development of the biobased economy.

5.3.3 Domain Functional Materials

Functional materials like paper, construction wood, cotton for clothes and modified starches for various applications are well known biomass derived non-food applications. In the future biobased economy we foresee that also other functional materials will be used on large scale. Examples are biopolymers like poly-lactic acid, polyesters and polyamides, for which replacing fossil sources by biobased sources is 5 to 20 times more efficient than for transportation fuels or electricity. Similar advantages are foreseen for the production of individual chemical building-blocks. These chemical building-blocks, which represent a value of about 9-10% of the Dutch GNP, are currently produced from fossil oil components at the cost of a lot of additional energy and a lot of capital costs. Interesting enough, the molecular structure of the bulk chemical building blocks is essentially present in many plant (residual) materials. Maintaining this molecular structure during the refinement process will provide significant savings in terms of energy use (*low entropy transition*), compared to breaking them down into smaller building blocks. Thus, biorefinery can lead to a higher added value since the energy as well as the capital costs of the petrochemical industries can be reduced significantly.

Three recent documents (Mulder (2012), IEA Bioenergy (2011), Sanders *et al.* (2012)) provide a comprehensive overview of the possibilities for substitution of oil-based chemicals / building blocks by biobased alternatives. The examples presented clearly highlight the large number of opportunities for chemical applications derived from biomass. They also show that for many biomass-derived chemical applications, biofuels can be produced as a co-product (instead of being the main product).While (EU) governments have stimulated very much on heat, electricity and fuels, the development of chemicals from biomass is only starting right now, with examples like poly-lactic acid, 1,3 propane diol and epichlorohydrine. On the EU level heat, electricity and fuels were favoured because on the average these three caloric applications are much larger than the chemical sector, which is about only 3 % of EU BNP. In Belgium, NordRhein Westphalia, Rheinland-Pfaltz and the Netherlands this is about 10% and consuming about as much fossil resources as is used for all road transportation. In Europe, USA, China we now see a lot of developments on chemical building blocks from biomass, either from the natural precursors or from sugars by fermentation processes.

The potential of applying biomass for chemical applications is indicated by the following figures. Currently, the overall turnover of the Dutch chemical industry on the end product level is 45-50 G€. On the building block level this turnover is 15 G€, for which the raw material input is valued at about 6G€. The transportation fuels consumed in the Netherlands (diesel and gasoline) represent a value of 6G€, for which the raw material cost represent 5G€ (for the total production of fuels in the Netherlands a 2,5 times higher value should be taken in to account). The electricity value is around 6 G€, for which raw materials cost 2G€ annually and finally heat has an overall value of 2,5G€ of which the raw materials costs equal 2G€.

5.3.4 Domain Fuels

The Fuel Domain does not only cover biofuels in the narrow sense, e.g. transport fuels such as bio diesel, but refers to wider application of biomass for the generation of energy, also including the conversion of wood, wood waste, straw, palm oil residue and other (by)products from agricultural production. Several inventory studies have been performed to study the impact and availably of using biomass in the Netherlands for energy purposes (see, e.g., Ministerie LNV (2007), Platform Groene Grondstoffen (2009), Rabou *et al.* (2006), Elbersen *et al.* (2011), Koppejan *et al.* (2009)). In (Rabou *et al.* 2006) the potential of primary, secondary and tertiary bio-based by-products[8] for energy purposes has been analysed. The authors calculated the gross Dutch biomass consumption to be 42.3 Mt (dry matter; DM), or about 740 PJ, in the year 2000. This equals to 24% of the Dutch primary energy consumption in 2000. The main part of this biomass has been used in the food- and animal feed industries. Only a small fraction of it was available for the energy and functional materials domain. According to the author's projections, in 2030 the total biomass availability for these domains amounts to 18-27 Mt (DM) (300-450 PJ), being:

- Up to 6 Mt DM primary by-products (100 PJ);
- Near 12 Mt DM secondary by-products (200 PJ);
- Between 0-9 Mt DM energy crops (0-150 PJ).

[8] The Platform Biobased Raw Materials (Platform Groene Grondstoffen) has expressed the ambition to substitute 30% of the fossil energy-carriers by biomass in the Netherlands by 2030, based on a total consumption of primary energy-carriers of 3000 PJ. The contributions of biomass for different applications have been set at 60% in transportation, 25% in electricity production, 25% in raw materials for chemicals, materials and products and 17% in heat production. Primary by-products are products directly from the field, such as sugar beet tops, straw, verge grass, pruning, greenhouse residues, etc. Secondary by-products are processing residues later, like potato peels, sugar beet pulp, sawdust, etc. Tertiary by-products are wastes, like used frying oil, slaughterhouse waste, manure, household organic wastes, used paper, demolition wood.

As a consequence, to meet the ambition to substitute 30% of the fossil energy-carriers by biomass in the Netherlands by 2030, between 60-80% of the biomass required will have to be imported from outside the Netherlands. When aquatic biomass crops grown within The Netherlands could be used, the import demand could be reduced significantly. This will be further worked out in one of the example cases (micro-algae).

In (Elbersen *et al.* 2011), the focus is on the biomass that is released from the agro-industry / first processing phase of agricultural production. In order to be able to estimate the biomass production by 2020, 4 scenarios are used, which are built on the following two characteristics: (1) the degree of regulation; and (2) the degree of globalization. The results of the analysis show that the available biomass from agro-industry residues for energy production are in the range of 0,5-1,9 Mt DM in 2020 (14-53 PJ (HHV) primary energy). This is equal to 11,7-47,3 PJ final energy and to about 13-49 PJ avoided fossil fuel energy, which is equal to 0,4-1,4% of the primary energy use in the Netherlands in 2008. The largest contribution comes from biodiesel production, mainly from cooking oils, animal fats and various vegetables oils. When upstream (agricultural) and downstream (retail) sectors are included in the analysis, the results are as follows: 2,3-6,0 Mt DM biomass in 2020 equal to 44-122 PJ (HHV) primary energy, 20-73 PJ final energy from biomass and 28-88 PJ avoided fossil fuel energy. This is about 0,9-2,2% of the primary energy use in the Netherlands in 2008.

As a consequence of rising oil prices, the need for increased energy security, concerns about greenhouse gas emissions and climate change the production of biofuels has attracted the most public attention. This has led to EU biofuels directive which establishes a goal of reaching a 10% share of renewable energy in the transport sector by 2020. While all Member States have to fulfil the mandatory use of biofuels, they follow different strategies. Some Member States stimulate the new technology development with temporary tax reductions. Others, such as the Netherlands, have turned the initiative towards incumbent multinational oil companies, potentially inhibiting fresh initiatives from start-up entrepreneurs. This can lead to the situation that, e.g., bulk biofuel prices on the producer level are kept high by import duties to be paid on, e.g., Brazilian bioethanol. The temporary tax reductions in 7 Member States compensate on the consumer level for these high prices. Furthermore, subsidies on the lowest value applications, such as biogas/ bio-electricity, will take away the drive to use raw materials for higher value applications and may, therefore, work contra-productive. The EU biofuels directive and other policies to increase the use of biofuels have led to much controversy. In particular, the use of first-generation biofuels – which are produced predominantly from food crops such as maize, sugar cane and palm oil – has been criticised because of its links with increasing food prices, controversial land acquisition in developing countries and negative effects on the environment. These issues have raised attention to the potential of second-generation biofuels that are produced from non-edible biomass and waste products. At present the production of this new class of biofuels is in the pilot phase with the first commercial plants expected to start production in a number of years.

5.4 Outline for integrated valorisation of biomass resources

The previous paragraphs have shown an overview on the trends and challenges on the four application domains for biomass resources, including by-products and residues. They clearly indicate that there is much potential for the development of future agro-production systems and value chains that are more sustainable and far more efficient than their current performance. The developments within the domains will significantly contribute to address the global challenges such as growing population, food security, climate change and availability of materials and energy. In order to realise this, the following outlines are formulated:

1. The **value pyramid** (Food – Feed – Functional Materials – Fuel) provides a strong and simple model to determine the potential value and impact of biomass resource use.

2. **Application prioritization follows the value pyramid**: New value chains rely on the integrated processing of biomass into a cascade of marketable products (from high added-value food ingredients via feed materials to low-added value energy, according to the value pyramid). Within this concept, it is not possible to speak about main and side streams anymore.

3. **Biorefinery is the priority technology to increase the applicability of biomass resources**: The optimal use of biomass can only be realised through unravelling the raw material into a number of separate components (biorefinery). Technology development is required to guarantee that biorefinery processes are running in a sustainable, economic and efficient way.

4. **Avoid unnecessary transport:** Transportation and concentration of components without any further downstream application should be avoided. Examples are: leaving plant residues, water and minerals on the field after harvesting; avoiding the presence of components in animal feed that do not contribute to an effective feed conversion.

5. **Avoid negative externalities and lock-ins from legal and financial instruments:** the governmental "support system" must support/stimulate the optimal and integrated use of biomass instead of creating lock-in situations for non-optimal applications.

6. **Establish new cross-sector partnerships within the golden triangle:** Bringing together organisations within the golden triangle (industry, government, universities/knowledge institutes) which will create new forms of complementarity.

7. **Stimulate entrepreneurship via small-scale initiatives:** The stimulation of small-scale initiatives is an effective method to enhance entrepreneurship in the transition to the biobased economy. New industrial activities will be started through newcomers (i.e., challenging the incumbent entities) around new opportunities following from "what-if" scenarios based on inspiring example cases. Instruments like SBIR can be used to build sound business cases and facilitate sharing of risks.

The transition from a fossil-resources based economy towards a fully developed biobased economy and the sustainable use of biomass resources, provides economic opportunities for all relevant sectors of the Dutch industry: agriculture, chemistry, materials, energy and logistics. The strong agro- and chemical sectors, the logistic position (import streams) and the strong knowledge infrastructure provides the Netherlands a very good starting position. Linked to the biomass availability in the Netherlands, four different routes have been discerned (Annevelink *et al.* 2009):

1. Biorefinery based on domestic Dutch crops, using synergy of existing agro- and chemical sectors, including the Dutch plant breeding sector. The cases "sugar beets and beet foliage", "cultivated grass", "potato protamylasse" and "maize protein" will elaborate on this route.

2. Biorefinery of aquatic biomass, using Dutch microbiology, plant breeding and processing knowledge. The case "micro-algae" will provide more insight on the potential of this route.

3. Biorefinery of bulk imported biomass and biomass-derived intermediates, using existing logistic and petrochemical infrastructure (like the port of Rotterdam). For this route, the case "rape seed meal" will be further worked out.

4. Biorefinery of residues, based on co-operation in production chains and networks, relatively small transport distances and business competences of Dutch entrepreneurs. The cases "damaged carrots", "grass from natural land and road verges", "low protein content residues", "wheat middlings" and "brewers' and distillers' grain" will further elaborate on this.

The next chapters will give an outlook on the steps that need to be taken to exploit this potential, converging in the Roadmap and recommendations in **Chapter 10** and **11**.

6 Business perspectives on biomass valorisation

In the previous chapter, the outlines for a vision on the integrated valorisation of biomass resources, with a focus on by-product flows have been presented. This vision is based on an academic approach, based on literature. However, this project also aims to provide the business perspective on this speck on the horizon (2050). Their actions, processes and products will ultimately shape the economy and are vital parties in the transition towards an integrated valorisation of biomass resources. Therefore, we explored the opinion of several experts[9] from industry (re. biomass value chains) on bottlenecks and solution pathways along the road to a biobased economy.

Contributing to the objectives of this project, the results of the interviews also have provided input for the successive chapters on example cases (**chapter 7**) and workshop on valorisation of biomass by-products (**chapter 8**), which results converge in the Roadmap and recommendations (**chapter 10 and 11**). The methodology of expert judgment and the outcomes are presented below.

6.1 Methodology

Expert judgment is an interview technique, in which the opinion is asked from a number of respondents on a fixed number of topics. Expert judgment differs from conventional interview techniques with respect to the applications for expert judgment:

- Determining the probability that a key event will take place
- Predicting the performance of a product or a process
- Determining the validity of assumptions used to select a model for analysis
- Selecting input and response variables for a chosen model.

Expert judgment builds on data and information given by qualified individuals that in turn can be used to solve problems or make decisions in a number of areas, including engineering, science and manufacturing. Amongst other purposes, the expert judgment can be used to determine what is currently known, what is not known and what is worth learning in a field of knowledge. In general, expert judgment can be viewed as a representation, a snapshot, of the expert's knowledge at the time of response to the question. The expert's judgment legitimately can and should change as the expert receives new information. In addition, because the judgment reflects the expert's knowledge and practical experience, the experts can validly differ in their judgments (Meyer & Booker, 2001). The interview topics were sent to the participating experts before the interview took place, in order for him/her to prepare. The topics are formulated as semi-structured interview questions, including follow-up items. The analysis of results is made anonymous and answers/opinions are not retraceable to individual experts.

6.2 Bottlenecks & solution pathways in practice

The analysis of the expert judgment outputs is based on the following (interview) topics:

1. Definition and origin of by-product flows (side and rest streams)
2. Future developments (short term, evolutionary perspective): barriers & opportunities
3. Future developments (longer term, radical/transitional perspective)
4. Wider developments in the Biobased Economy (BBE) and consequences for own resources (supply security, quality)
5. Changes in main product to enhance by-product/rest stream applications (kind, quality, composition) and optimisation processes within organisations: options, how to organise, barriers, solution pathways (internal / external)

The outcomes are discussed in the following subsections.

[9] The experts are listed in **Annex 3**

6.2.1 Scope boundaries and origin of biomass resources

A major issue in the valorisation of biomass and the exchange between domains is based on the definition of by-products or rest streams. Hardly an academic exercise, since various applications and legal directives are coupled with its description and scope. The experts all refer to this interpretation issue: it is not exactly clear what the definition of a by-product is, and it seems to vary between different steps in the biomass chain. It also interferes with the definition of waste, and the definition for food waste specifically. The priority ordered in the value pyramid with Food on top is perceived as arbitrary. The suggestion that human food application of biomass delivers the highest value is not always true. The applications within the Food, Feed and Functional materials domains are preferred over the Fuel application, since the latter implies the loss of material to a closed loop life cycle of biomass.

The priority of the Food domain over others also implies that land use allocation should follow the same value pyramid order. This raises the question whether dedicated feed (e.g. roughage, Dutch Wheat, forage maize) functional material (e.g. rape seed, flowers, sunflower, tobacco, Jatropha, medicinal plants), or other non-food crops really compete with food crops. From the Dutch perspective, the experts agree that this is not (yet) the case. The outlook on a more global level lies outside the scope of this project, but raises concerns in developing agricultural areas.

The experts perceive it to be wasteful not to use by-product flows for 'second life' applications, especially with regards to landfill or incineration. To their opinion, most of the by-product flows are already destined for other applications, including food, feed, function and (bio)fuel. Also, many of the by-products that end up in animal feed already have the major portion of the starch component removed. If food products are discarded as waste for incineration/landfill, it is mainly because of regulations on animal by-products. Category 1 animal by-products are to be sent to incineration (with best case applied energy recovery). Other categories end up in oleo-chemistry, pharmaceuticals or feed applications. Typical food by-products that end up in the Feed domain are maize gluten, soybean meal, liquid wheat starch, wheat yeast concentrates, potato peels/cuts, beet pulp, whey/milk products, vegetable juices, rinsing water containing carbohydrates and brewers and distillers' grains (BDG). Up to 70% of animal feed consists of food by-products, in cow feed more than in chicken feed. The percentage of by-products (as opposed to dedicated feed crops and roughage) depends on the type of resource and the target animal category. It varies between 20 and 50%. It is noted that within the Netherlands, it is more common to valorise 'wet by-products' as animal feed input than in other (European) countries. Other well-known by-product applications are fertilizer (agro), technological applications (functional), energy via biofuels or digesting (fuel).

The application of non-edible parts of food-crops is regarded as new economic opportunities, including foliage of beet and carrots and (pea) straw. A better utilization of the ingredients or components from these biomass resources are at the heart of this development.

6.2.2 Future developments – Short term

Short term, evolutionary perspective: barriers & opportunities

The most common distinction on innovation is between (short term) incremental / evolutionary and (long term) radical innovations (Henderson & Clark, 1990). Some scientists may argue that there is a third, transitional perspective, which is in fact an elaboration of the radical perspective within a system innovation context (e.g. transition towards sustainable mobility as elaboration of the radical innovation of distance-controlled car travel on motor highways). The radical and transitional perspectives are both applied within this project. Where a system context is applicable, this is indicated in the text. However, the newness of the innovation is less relevant than the fact that the ideas, practices or objects are new to the operational unit which is adopting them (Bhasrakan, 2006). Below, the barriers (part A) and opportunities (part B) are presented.

A: Barriers

The experts were asked to judge the barriers for higher value valorisation of existing by-product flows and/or new applications for inter-domain biomass exchanges. In general, barriers such as time-to-market, price volatility in energy and material resources, the availability and competitiveness of fossil based resources and high entry levels into the market, combined with high demands and criteria for new products were mentioned. These do not significantly differ from other types of innovations within other application domains. Their significance to the research topic is explained below.

The barriers can be categorised as follows:

1. Economic barriers
2. Market barriers
3. Governmental barriers, specifically deriving from financial instruments and regulatory issues
4. Logistics barriers
5. Technology barriers
6. Societal barriers
7. Environmental barriers

Ad 1 – Economic barriers

Economic barriers refer to the financial capacity of organisations and imply that (perceived) profitability does not exceed costs.

Experts claim that SMEs or start-up companies usually do not have the financial resources to develop medium to large scale production facilities. These facilities are mainly achievable by larger companies, or have to be (pre-)financed by investors (formal, venture or angel). The perceived risks to carry such a large investment with uncertain outcomes can be a great burden for an SME with limited liquidity or cash flow. Investments must fit within the financial capacity of SMEs. Banks need to be willing to accommodate that, but are often not inclined to grant risk loans to SMEs. Revolving funds or guarantees are not easily accessed. Also, when the pay-back time of installations (return-on-investment, not specific for SMEs) is too long, it is not attractive for a company to change its production process.

Economic barriers:

- *Lack of financial capacity for initial investment(s) on production scale*
- *High investment risk vis-à-vis financial capacity*
- *Uncertainty of success of innovation*
- *Lack of access to investment capital (formal, venture, angel)*
- *Unprofitable term for return-on-investment*

Ad 2 – Market barriers

Market barriers refer to the competition with existing products/applications/processes and supply/demand issues.

Markets are a web of co-lateral agreements on the value of products: nobody is a neutral player, not even the government. VAT, other taxes and (environmental) permissions play a key role in markets and their development. There are different types of markets, with various degrees of competition (e.g. monopolistic / oligopolistic). Some markets allow easy entrance, others may have lock-ins, preventing or inhibiting change. The market for innovations on biomass valorisation and the exchange of by-product flows between application domains is by definition an imperfect one, since it is a renewal or improvement of existing market (infrastructures). The experts indicate that from an evolutionary perspective, developments should fit into existing infrastructure (e.g. biofuel added to conventional combustion products, including petrol and natural gas). Many markets in the application domains of Food, Feed, Functional materials and Fuel are characterised by consolidation, with mainly large players. These compete on costs and volumes, hampering product innovation. In a competitive environment, it is difficult to achieve the necessary levels of trust and goodwill to participate in innovation and development projects. This is also hampered by confidentiality issues. Trust is a key word and needs to be developed and maintained on each occasion. Another market mechanism focuses on prices, quality and product criteria: new entries need to be better, cheaper and more functional than their incumbent counterparts. This is often disadvantageous for SMEs, since their potential for large investments is lower than for large companies. Lock-ins create inertia on markets: if there is a lack of concrete activities on new applications for by-product flows, it will put off entrepreneurial companies to invest time and money in new developments. E.g. algae are a new biomass resource, but currently not economically attractive and not available on large scale. Therefore, competition with conventional products is difficult. Furthermore, many companies are satisfied with a low price for their by-products or waste streams. As long as it pays more than costs for waste management, they do not strive for the highest possible profit.

Market barriers:

- *Imperfect market mechanisms: unbalance in supply & demand, non-neutral players*
- *Existing lock-ins for new entrants: high accession costs, competition with conventional products*
- *Consolidation processes leading to high volume – low margin business strategies*
- *Lack of trust to engage in cooperation and/or networking processes for innovation and market introduction*
- *Low priority for value creation through innovation on by-products flows*

Ad 3 – Governmental barriers

Financial instruments: Since the government is not a neutral player, the experts indicate the different instruments the government can put to use to influence markets. Their execution is not univocally perceived as desirable, creating negative externalities, un-level playing fields as well issues with availability, accessibility and administrative requirements.

Typical stimulating instruments are placed within the category of financial instruments, including grants, launching customer and co-finance. Although they have positive effects, the experts point out common pitfalls for this type of market interference: it is seen as typical for the Dutch government not to transfer responsibilities to the market. Instead, government chooses limited grant instruments to stimulate desired development. Also, many grants and other financial instruments (including beneficial or restrictive taxation regimes) are not accessible to SMEs.

This is not formalised, but the majority of administrative requirements are difficult to meet by SMEs.[10] Although attractive financial instruments exist (e.g. SBIR, SDE), the availability of such instruments is often not very sufficient. One expert actually stated that 'companies have higher chances to win the State Lottery than be granted participation in the SDE-regulation'. The chance to be included in this grant scheme is perceived to be very low. It seems from the companies' perspective that the government has underestimated the popularity of such grant schemes. Also, targeted financial instruments can be market disruptive: e.g. German prices for feed maize have risen considerably after financial promotion of the production of biofuel (bio-gas, bio-electricity) based on maize. These instruments influence the application of biomass flows (and of by-products), but can lead to competition with their original destination. Depending on the functioning of the market, also consumers will notice this influence. Nevertheless, food prices are perceived to be relatively low in the Netherlands.

Regulatory instruments: Main barriers are inconsistent policies and ambitions[11], leading to abiding attitudes from companies.

Legislation is unavoidable, companies have to adapt to it. Experts state that many barriers with regards to technical or ingredient innovations and developments are to be found within legislation. In their opinion, legislative standards and regulations lag several years behind developments within industry. E.g. are the Feed Ban influencing new applications in food, feed and functional materials domains, specifically

---

[10]*For transportation fuels from biomass, there are major differences in Governmental interventions: some biofuels have the same or even higher taxation as petrol, while others have a lower taxation of even no taxation combined with SDE subsidies. The differences caused by government interventions can be as large as € 1.30 per litre petrol equivalent, although the CO_2 emission reduction is quite similar. This absence of Level Playing Field, reduces the possibilities for newcomers to this market.*

[11] See also an overview in: AgentschapNL, 2011. Stand van zaken biobased economy vanuit perspectief van Agentschap NL. 20 juni 2011.

with regards to ruminants, cannibalism, 134 degrees / 10 minute treatment, and the enforced incineration of category 1 animal by-products. Although most innovation-inhibiting legislation is derived from European Directives (including Animal by-products and Novel Foods), the interpretation of these differ between the EU Member States. This creation of un-level playing field intensifies when compared with international markets (e.g. on bone meal). Grasping the intention of legislation and regulatory instruments is also a key factor. E.g. the specific legislation for animal feed applications is often unknown by newcomers to the market, especially those entrants who have no prior experience within the Feed domain. These newcomers are usually from the Food domain, where a different set of restrictions applies. Possibly influenced by the woolly and complicated legislative texts, or wrong assumptions/interpretations of the regulations/standards[12], the fact remains that legal barriers are perceived and are therefore real to the organisation encountering them.

A more exhaustive study on (perceived) legal barriers with regards to the re-application of by-product flows from the Food Domain has been conducted by Wageningen UR in 2011 by Waarts et al., 2011. They conclude that the provision of food information legislation (specifically regarding expiration date and product liabilities) and Hygiene code (specifically regarding the two-hour guarantee display in the catering industry) are inhibiting the prevention of waste and a higher value added application in a 'second life' of biomass. Laws and regulation correlating with this topic are:

- *European marketing standards*
- *Contamination in food*
- *Import control*
- *Phytosanitary policies*
- *Novel food*
- *Cooling and freezing meat products*
- *Hygiene rules and product liability*
- *The provision of food information*
- *Norms and quotas in fisheries*
- *The use of animal by-products*

Also, when upgrading the by-product flows into the Food domain, organisations will hit the barrier of those flows not being compliant with food regulations. This will lead to legislative problems with regards to food safety and Novel food, but can as well lead to issues with customer acceptance.
The Ministry should realise that from the viewpoint of companies, 'the' government does not exist. Before decisions are being made, at least 5 governmental bodies need to have their say on it, leading to long waiting times for entrepreneurs to implement new technologies. It would be favourable when governmental institutions could act as a reliable partner, and not only work from an enforcing viewpoint. The tendency to dictate means-oriented legislation instead of goal-oriented legislation is an eyesore to companies.

[12] Including Novel Food legislation and its authorisation process for EU-permission.

Governmental barriers:

- *Financial instruments*
    - *Creating negative externalities and/or market disruption, unlevel playing fields*
    - *Difficulties with availability, accessibility and administrative requirements*
- *Regulatory instruments*
    - *Focus on means-oriented regulation inhibits creative solutions by companies*
    - *Lagging behind technical/industrial developments*
    - *Disparities in interpretation of regulations*
    - *Compliance with food regulations (safety, hygiene, Novel Foods).*
- *Government role*
    - *Inconsistent policies*
    - *Not trusted by entrepreneurs*

Ad 4 – Logistics barriers

Logistics refer to supply and demand mechanisms as well as transport issues. They play a major role in the (practical) organisation of integrating biomass domains.

Most entry barriers for new ingredients / products (e.g. in Feed domain) lay within logistical aspects: volumes, guarantees on delivery, continuity of supply[13]. The supply side within new applications is usually the bottleneck: there is usually not enough of the product in stock to match customer demand (also dependent on the scale of the new application process). If supply is limited, this complicates the logistical aspects of introducing new components or products. E.g. farmers have only limited storage capacity on their farm. Furthermore, transport is relatively cheap, but the question is if it will remain that way? Experts tend to think not. There is more uncertainty on how future transport costs will balance out on scale, costs and geographical location. Increased costs of transportation will drive towards more local, small scale processing (instead of central, large scale installations).

Logistics barriers

- *Too low production volumes to meet demands*
- *Difficulties to provide guarantees on delivery; continuous supply*

Ad 5 – Technology barriers

Technology barriers associated with inter-domain exchange of biomass and by-product flows mainly concentrate on the extraction of components before, during or after the main product process. The main barrier originates from the physiological fact that the extraction of a certain ingredient / component will influence the functionality (and therefore the application or end-product) of the other ingredients.

Most experts focus on proteins, as being considered the highest value ingredient of biomass. In downstream processes, however, proteins are often last in line of all components to be isolated. Many of the process technologies used damage the protein quality (heat, chemicals, pressure). It is technologically and investment-wise a challenge to change or redesign main product(ion) processes to isolate proteins in a more efficient way. There are also differences between plant and animal proteins, the first having several disadvantages: lower availability and more difficult to release as well as transform into a successful new product (e.g. meat alternatives in food). Plant proteins also differ in functionality, typically relating to storage characteristics and solubility, leading to lower-value added applications. However, this is not necessarily true for long term technology developments within plant proteins.

[13] *Farmers are themselves not always willing to commit to long term agreements with fixed prices, due to volatility of prices on the feed market. Banks on the other hand prefer the security of long term agreements to avoid fluctuations in capital need.*

Technology barriers

- *Process difficulties in extraction process*
- *Functionality issues between plant and animal proteins*

Ad 6 – Societal barriers

Societal barriers originate in public opinion and social perspectives on new (technology) developments and applications.

Experts expect that acceptance of e.g. alternative proteins (meat alternatives), new biomass resources (e.g. grass, algae, insects, 'waste' from feed, functional material or fuel domains) can encounter high resistance. Also encountered within GMO matters, public perception and insecurity on health and safety aspects can seriously inhibit developments in the reprocessing and application of by-products and new sources of biomass. E.g. the application of food grade animal fat through use of animal by-products is limited. Furthermore, vegetable fats are considered to be healthier than animal fats ("bread spread vs. cream butter"). Not all assumptions are supported by sound scientific evidence, and the use of companies of e.g. health claims on certain ingredients or food products is guided heavily by the marketing departments[14]. Important gatekeepers to the demand of household customers are the supermarkets. Experts indicate that retail has the strongest voice in decision making processes. However, they usually do not commit themselves to agreements longer than 6 months.

Societal barriers

- *Low perceived acceptance of new (technology) developments and applications of alternative proteins or reprocessed biomass by-products from other application domains.*
- *Short term strategy of decision makers in retail business*

Ad 7 – Environmental barriers

Attention for the availability of (fossil) resources and energy, the damaging impact of emissions (both greenhouse gases as health-impairing dangerous substances), in combination with water, waste, and soil issues and environmental disasters (nuclear, toxins, spillage, etc.) has led to an increasing attention for environmental impacts of current ways of production of consumption.

When adopting a starting point that exchange of biomass and by-product flows within integrated application domains is beneficial to the environment, experts stress that striving for two times more with two times less also should include environmental impact. They are not highly in favour of all existing mitigating technologies, including carbon capture, biofuels from first or second generation, since they are entropically inefficient, requesting a comparable amount or more energy than they save and the loss of material flows to a closed loop of resources. Renewables derive from natural resources, but are not necessarily limitless. True sustainability should strive to zero environmental impact.

Environmental barriers

- *Environmental impact often not considered in efficiency developments*
- *Mitigation technologies divert the focus from prevention and transitional innovation strategies for the sustainable use of biomass resources.*

B: Opportunities

[14] See also Stijnen et al., 2011. Consumentenperceptie van nanotechnologie in voedsel en landbouw: een eerste verkenning. Wageningen UR. *In this report it was concluded that nanotechnology is acceptable for consumers, when producers focus mainly on its advantages (health/functionality claims). Consumers expect from government to secure and safeguard consumer safety aspects.*

When questioned on the opportunities associated with higher value valorisation of existing by-product flows and/or new applications for inter-domain biomass exchanges, the experts indicated the following categories:

1. Market opportunities
2. Energy efficiency
3. Governmental instruments (best practice, financial instruments, research funding, legislation)
4. Technology

Ad 1 – Market opportunities

The opportunities from a market perspective derive from reduction of costs, increase in profits, cooperation, increasing ingredient / component demand, and an entrepreneurial attitude.

The experts perceive that the producers of by-product flows will calculate the highest profit from different markets. The one with the most beneficial outcome will get the order. If no other incentive exists, the economic one will be leading. People are willing to think about alternatives and improved applications to reduce waste flows from biomass, but it must have a financial benefit. This also includes a willingness to allow for longer than normal terms for return on investment, but it should happen within a scope of 10-15 years. Evaluation of cost-benefit is mainly economical, but also quality aspects and, e.g., nutritional values are to be considered: the new / alternative ingredient, component or product needs to compare to or outperform conventional ones.

> *Experts present the example of animal feed and the trend towards self-mixing of ingredients by farmers: the demand for complete formulations of animal feed decreases: farmers increasingly formulate their own feed for their livestock based on ingredients from multiple suppliers. They primarily want to decide on the nutritional value. The feed industry and knowledge institutions on livestock (as are Wageningen UR – Livestock Research) accommodate this with ingredient information and studies into the effect of nutrition on animal health and conversion rates. This is a dynamic process, with a continuous need to develop new knowledge. Within the feed industry, conventional resources for animal feed production have been changing recently. Companies see the composition of by product flows from intake vary, due to ingredient removal for human food applications (e.g. whey). That does not pose a problem to animal feed production, as long as the remaining composition and its nutritive value of the input is known.*

As became clear from the barriers section, market entry and competition with conventional biomass applications is difficult. However, presenting yourself as 'sustainable' to draw attention to alternative (protein) resources can work to your advantage. Also, producing in the EU is expensive, when compared with costs prices from non-EU countries. However, for some ingredients, distance[15] is a decisive factor for quality criteria *(spoilage, shrinkage, decomposition)* and transport costs.

Following up on the innovation dilemma between large, multinational companies and SMEs, which are disadvantageous for SMEs with regards to financial capacity and access to grant schemes, there are also opportunities from SME perspective: they will invest in their company, while large, multinationals will pay dividend.

---

[15] *Distance counts when there is a large proportion of not useful components in the product, such as water and low value ingredients. Transport itself is relatively cheap, especially when transported by ship. Trade barriers due to hygiene regulation or measures close off markets from import of low-cost countries such as Thailand and Brazil.*

SMEs are more flexible and less bureaucratic[16]. SMEs need to cooperate to accumulate strength and decision power. Cooperation is a key word for integrated exchange between biomass application domains. Long term agreements leave room for quality based considerations with suppliers. Connecting with different organisations from the biomass value chain has surplus value: getting future possible competitors or adversaries around the table in an early stage of development can create a cooperative atmosphere head on. For participation in cooperative developments, it is essential that (a portion of) the added value returns to the organisation which implements changes or improvements. The partners need to be willing to trust each other and to share knowledge. Furthermore, most companies enjoy (positive) publicity, but in a partnership, it is necessary to make agreements on external communication matters.

In general, experts indicate that effort must be placed where the most effect is to be expected. E.g. it is claimed that there are sectors in which more results can be achieved than within agriculture. The processing industry and further downstream activities also need to be aligned to reach optimal use of resources. A solitary focus on agriculture or another sector approach will mask opportunities or even create negative externalities by shunting issues towards another sector or application domain.

Ad 2 – Energy efficiency (deduced from markets)
Energy efficiency is considered as the most important short term approach that is achievable (with considerable results!) within current processes and products.

It is a low hanging fruit approach, but a very effective one in that. When companies concentrate their initial efforts on efficiency measures, they can create profit through reduction of costs quite easily.

Ad 3 - Governmental instruments (best practices, financial instruments, research funding, legislation)
Sharing and endorsing best practices (e.g. based on pilot projects), financial instruments (including taxes, revolving funds and goal oriented grants), stimulating research funding on knowledge development, and legislation (including knowing when flexibility is called for) are considered to facilitate opportunities within companies best.

Entrepreneurs prefer to receive inspiration and motivation by other entrepreneurs or experts with a profound knowledge on the business perspective on innovation processes. This can be done by means of networking, but more specifically through sharing best practices. On individual level, entrepreneurs are interested in new opportunities, but do not prefer large scale approaches. Rather, they enthuse on 'round-the-kitchen-table' sessions with other entrepreneurs, looking for concrete actions. Within the pilot projects, there needs to be room for experiments (e.g. different standards for natural and synthetic fertilisers; manure derivates are considered as natural fertilisers to which more strict application standards apply, when they are not chemically different from synthetic ones). There are existing success

---

[16] See also Bos-Brouwers, 2010. *Sustainable innovation processes within small and medium-sized enterprises.* VU Amsterdam. *Page 29 reflects on the innovative advantages of SMEs including: flexibility of organisation, less bureaucracy, responsiveness to changing circumstances (technology and market), faster and more efficient internal communication processes, entrepreneurial attitude: dynamic owner-manager, horizontal leadership style and a direct role in innovation as ideas generator. Commonly cited disadvantages are: (owner-manager) poor managerial skills (planning, inadequate delegation, lack of functional expertise or support), dependency on [specific] persons for survival, lack of formalised planning; (financial) difficulties attracting venture capital and bank investments, failure of innovation projects may be financially disastrous, high fixed costs for technological investments and start-up; (labour) difficulties attracting skilled personnel, harder to update technological knowledge. Advantages within large companies are: (financial) less difficulties attracting venture capital and bank investments, innovation risks diverted by diversity in production, sales and innovation projects; (labour) less difficulties in attracting skilled labour; (knowledge) participation in networks and conference visits to update (technological) knowledge, information management systems; (management) decentralised management style with decision power on low levels in the organisation, long term strategic management capabilities. Disadvantages for large companies are: (management) top management isolated from customers and work floor, emphasis on short term cost-cutting instead of long term infrastructural enhancements; (labour) no entrepreneurial fanatics tolerated; (flexibility) bureaucratic, highly formalised organisation structure.*

stories that have spurred sector wide developments. E.g. milk: up until 20 years ago, whey was regarded as a waste product. Today, it has proven its value in multiple high-end applications.

Government can steer developments and applications of biomass through specified and dedicated instruments, especially financial ones. Experts name revolving funds, fiscal instruments (taxes) and grants as preferred financial instruments. Subtle steering is preferable, to avoid negative externalities on markets. E.g. Germany: maize production for biofuels (bio-electricity) is regarded as 'over-stimulated' whereas forage maize for cattle feed has become increasingly expensive. This hampers the competitiveness of farmers, not originally intended by the biofuel initiative.

Knowledge includes detailed information on successful best practice and pilot outcomes. Government has the tendency to invest in the development of fundamental knowledge, which is the primary task of science, but the application of knowledge is equally important, creating spin-off and valorisation of knowledge. Research institutes should show that it is possible to optimise the use of biomass for food and other application domains without negative externalities. Knowledge from universities and other knowledge institutes must be disclosed and be applicable for companies. As many companies will not easily read extensive research reports or peer reviewed scientific articles, this can take place through workshops and 'master classes' to create a 'can-do' atmosphere.

Legal directives and standards can inhibit as well as stimulate innovation: since its application is enforced, companies are pressured in developing new ways around it. E.g. the Feed Ban (EU) has had its advantages. It has led to innovative approaches to markets and spurred the development of application of by-products. The limitations posed on feed and fuel applications are strict, but the number of limitations is small, especially within the Fuel domain. In practice, there are only some 9-10 products/ingredients which are banned from feed applications. For all others, the application depends on the decision and responsibilities of the farmers. The responsibility for food safety lies within the organisation that markets the food / feed products. The (n)VWA (Dutch Food & Products Authority) is very clear on that respect. The experts indicate that legislative incentives have priority over financial ones.

On how governments can stimulate exchange between domains and development of new/alternative applications of biomass, experts indicate the following: Vision – Cooperation – Facilitation. In their opinion, The Netherlands need an integrated vision on valorising biomass on the four domains, including stimulating policy and ambitions. There is enthusiasm and knowledge on the market, but the time is now to take action. There are movements worldwide, technological developments are highlighted in media, to upgrade feed to food. There is an increase in scientific publications on this matter as well: we cannot afford to miss the boat. Government should facilitate developments instead of enforcing them. They influence the playing field: a participatory approach fits innovative developments best: consistency, long term commitment, reliability and following up on agreements to build trust. The Netherlands are perceived as a country of limitations, a more forward approach is essential. To take entrepreneurs seriously requires a partner attitude, and focus on SMEs and start-up as well as incubators for entrepreneurial, innovative activity. SMEs want to be involved in innovation agendas as well. Companies are where the 'real' innovations happen. Interactive involvement between government and companies more often lead to successful outcomes, but only with a flexible and cooperative attitude and room for experiments in new technologies. "You are not in the same seat, but you drive in the same direction". Expert committees can contribute to developments, but independency is necessary, there should be no conflict of interest or bias. Not only policy makers should be in decision roles, but entrepreneurs and scientists as well. The experts do not elaborate on how this decision process must be structured.

Ad 4 - Technology opportunities
Technology can be a driver as well as a requirement for innovation. From an evolutionary perspective, technology developments target on efficiency: doing the same thing with less inputs, or with gradual changes in biomass systems. As breakthrough / radical technology development is not intended here, developments should bring more application knowledge on composition, digestibility, availability, quality,

safety and interaction of biomass resources. E.g. feed: animal feed must meet the nutritional demand of the target animal, matching its use and its life cycle phase (piglet, sow, meat production, milk production, etc.). Once the requirements of the target animal are known, the required resources can be assessed and a mix of ingredients to meet that demand can be formulated. Therefore, new by-product flows to be incorporated into animal feed production need constant assessment. The past 20 years have shown dramatic improvements in feed conversion and meat quality by improving the nutritional value and application profile of animal feed products.

6.2.3 Future developments – Long term

Longer term, radical perspective

The experts were questioned on their future outlook on longer term developments and more radical/transitional innovations necessary to make the transition to an integrated application of biomass on the domains.

The main categories according to the experts were as follows:

1. Future outlook
2. Market
3. Logistics
4. Environment
5. Government
6. Technology

1 – Future outlook

Future outlooks cannot be based on facts; instead, they are based on extrapolations.

Firstly, the experts offer their future insights with enthusiasm: inspired by images as circular economy driven by climate change (influence on harvest/losses) and population growth (up to 9 billion in 2050) resulting in scarcity. It is expected that, when no measures are taken, the available agricultural land area will not suffice to meet the demand for protein. We all need to keep our eyes on new developments in order to be able to make a (future) shift. Wheat offers opportunities, as well as other biomass resources, such as potato peels, beet pulp, grass, rapeseed and palm oil. However, experts rationalise their ability to predict the future: in the 1970s, the world looked very different from today, in a way they could not have foreseen back then. What is the truth regarding future prediction? No one can really tell, because there are too many stakeholders involved. There are too many variables, and too many yet unknown variables. A technological background helps to see the necessity to achieve new developments faster. One thing remains clear: innovation is a discontinuous process, speeding up and down and with disruptive force. It can be a matter of joining the flow or become obsolete (e.g. Kodak / microfilm).

To further the transition to sustainable production and consumption systems and the reduction of by-products, companies should lead the way forward, supported by knowledge from universities and knowledge institutes and resources from government in terms of Public Private Partnerships, pilot demonstration projects, facilitating the development of consortia, adapting legislation to include permissions for experimental technologies to anticipate on new (technological) developments. Factors that influence the transition process: money, knowledge, experimentation, security for customers.

Ad 2 – Market

Markets are the place where supply and demand meet. From a radical perspective, it is about new products for existing needs and new products for new needs.

When business is tough, the first thing companies put to a halt are the radically innovative development projects. These do not (yet) generate a cash flow. But can therefore be temporarily stalled and restarted later. New developments have a long time-to-market: new (energy) infrastructures take at least 10 years to mature. Transition is the organisation of a long term perspective: multiple year development strategies (3-5 years minimum), keeping promising opportunities on the agenda, allow for maturation, and a shared vision to go the long road together. Existing examples of improved utilization and valorisation of biomass show long term trajectories. It can be speeded up considerably when scarcities exist. This increases the sense of urgency. Combined with facilitating policy and technology developments it will rapidly open up market opportunities. Alternatives for conventional products often meet financial, technical and acceptance barriers. These will need several years to tackle. Also, the achievements of frontrunners need to be adopted by followers.

Experts indicate that preliminary meetings to sketch outlooks on future applications on biobased material applications are taking place. These cooperative efforts include finding enthusiastic entrepreneurs to participate and ensure that they can find each other. Communication and visibility are important to create networks. Also informal meetings can result in unexpected acquaintances. Assemble enthusiastic cooperation partners and avoid that they get bored, undersupplied or under resourced. E.g. Dutch farmers are innovative and open for new products and approaches. As long as the nutritional values are proven (health, feed conversion value), the choice depends on a cost/benefit analysis. If it balances out, they will use the new ingredient/ product. There is a high acceptance level for new ingredients / products. Also, fatty acids from animal products could be applied within biobased products. This will be stimulated when prices and markets for biobased materials develop. Pharmaceutical materials are also an interesting application area for new by-product flows. More specifically, experts indicate the developments within new proteins on the market: new sources such as algae, duck weed or insects are not yet developed significantly to replace conventional animal feed input. The experts foresee that this will happen in the future. It is about improving cost price and values, finding entry points, and valorising all its components in different domains, allowing for raw material flexibility and interchange-ability. The focus on biofuels from algae might not be the right approach. If they must compete with one application only, they will lose the battle. Other promising developments are within hybrid meats (plant and animal proteins combined), synthetic meats and imitation of meat consumption. The discussion on plant over animal proteins continues without definitive answers, and with very outspoken promoters on both sides. The fact remains that breeding new varieties of conventional animals/plants still leaves room for improvements (efficiency), as well as the introduction of new biomass resources. From the perspective of the feed industry each biomass resource or by-product is suitable as feed material: as long as it contains proteins and/or carbohydrates of sufficient quality, an application in feed is possible.

An important success factor will be consumer perception, to which Dutch companies are sensitive, especially when regarding certain feed or food ingredients. Consumer awareness, new consumption patterns and lifestyles, responsible behaviour: all influenced by circumstances, following Maslow's pyramid of needs. When all basic needs are satisfied (including a secure job), people can target more idealistic principles. However, application of biomass on multiple domains, especially within functional materials, should not be equalled to idealism: it has an economic imperative. The long term it takes to mature is a significant bottleneck. Markets want short term profits, and therefore do not necessarily reflect the real value of developments. The value or new developments usually expresses in the long run. Developments targeted on the long run should not be left to market mechanisms alone: we shouldn't wait for the last drop of fossil resources to change to renewables. The market mechanism is one of risks and can lead to a race to the bottom. Society focuses on discussions on the welfare and keeping of farm animals (including 'megastables'), and the prevention of mass outbreaks of infectious diseases. Consumers decide on emotion, they need to feel comfortable with new products and new applications for acceptance. This is tricky to see through: e.g. Consumer perception might limit applications on food grade level. Research into the effect of animal fatty acids could contribute to a better understanding and application of animal fats in a healthy diet.

As costs-benefit analysis drives investment and purchasing decisions, innovation can be driven by sustainable sourcing: including economic, environmental and social criteria in input. Following the sustainability debate on the origin of renewable resources closely (e.g. soy, palm oil, fish feed), it will stimulate companies to take their actions on this topic more seriously. Profits from existing production (e.g. energy) should be used to invest in new / alternative technologies, ensuring continuity. Resource dependency also plays a role here. Sustainability criteria will dictate a 'license to produce' and influence economic sustainability. If non-sustainable costs will be included in costs calculations, sustainable alternatives will more rapidly become cheaper than conventional products. More research is needed to make the sustainability claim viable. E.g. to provide guarantees that animals are not presented with the wrong type of animal by-product in their feed and will extend the possibilities to valorise animal by-products on a higher level.

When population increases, and food demand rises on a global scale, a number of mechanisms will get into gear: less withdrawal of fruit and vegetables from the market (harvested produce) since overproduction decreases: other quality norms, including divergent shapes and sizes, optimisations of crops through breeding and modifications. Addressing food waste is a serious issue, and influences the complete biomass value chain, including harvest, transport, processing, trading and consumption.

Ad 3 – Logistics
Central issue for future developments on logistics is the economy of scale.

Will it be small scale / decentralised processing of biomass for various applications / domains, or high volume / centralised processing units. Both have their advantages, and both will be applied based on the specific type of biomass. Feeding into this discussion is the public debate on the desirability of long distance transport of biomass (including livestock). Should Europe be self-sufficient? An underexposed element in this discussion is the closing of mineral loops: feed is imported, but no organic fertiliser is transported back: the countries of feed stock origin should be assisted in closing the mineral loop.

Ad 4 – Environment
Materials and energy have high environmental impact correlations, on all biomass domains. Meat consumption and energy are indicated as important environmental topics for future developments.

Experts indicate that it is difficult to predict whether the consumption of meat and milk/dairy products will decrease or how much they will increase. It was mentioned that current consumption levels overshoot the daily need for calories and proteins. The Dutch "Health Council (Gezondheidsraad)" states that 1 litre of milk and 500 grams of meat per week is sufficient for a healthy diet within the current ecological boundaries. The consumption of animal products has a higher environmental impact than fruits and vegetables. With regards to carbon footprint, chicken and fish have the best track records.

The availability of energy is not the top priority sustainability issue: there is enough potential in solar power, wind energy and fossils to organise transport and production. The main issue addresses the circular economy of mineral supplies including nitrogen, phosphates and carbons. Energy production through combustion usurps the material availability of these resources and should therefore be avoided. Caching energy is a promising development, especially considering wind energy technology, as was stated by the experts.

Ad 5 – Government
Experts challenge government to step out reflective behaviour and sticking to lessons long learned. Circumstances change and future developments require vision and flexibility.

They advise to step free from conventional, monopolistic, large company based ambitions, and leave room for entrepreneurs and private utilities. However, experts do not agree on this approach: some indicate that legislation and enforcement leads to better integration, whereas others want to leave it up to the marketplace. They do agree about not putting a "Dutch top" on European directives, but instead create a European level playing field.

Ad 6 – Technology
The main technological challenges will be in the fractionation of biomass.

*G*etting to its components and how we use them will be changed significantly. The use of agricultural products will change towards integrated use of all components, not just one or two main ingredients. Animal products will always be intrinsically different from plant products: enzymes might make up for differences in applicability and functionality.

6.2.4 Redesign of main production processes

To enhance by-product/rest stream applications (kind, quality, composition) and optimisation processes within organisations: options, how to organise, barriers, solution pathways (internal / external)

One of the solution pathways towards a more integrated application of biomass is looking into options to make changes in the main product production processes to ensure a better application of its by-products and rest flows. Main questions are: what are options, how to organise their implementation, which barriers do you encounter and what are solution pathways (based on internal and external factors). This also leads to technology and logistics issues: fractionation, preventing damage and optimising physical supply and demand aspects.

As was stated at the beginning of section 6.2.2 (on incremental and radical innovation barriers), many operations managers are not very enthusiastic about changing main processes. However, the experts state that the earlier in the process chain of improving the application of by-products, by removing unwanted / unnecessary components from main product flows, the cheaper it will be. Existing refinery processes are able to isolate components as long as it is done efficiently and the process does not damage the components for further application (e.g. heat treatment of proteins). The earlier you 'cross-over' in the process, the more energetic, caloric, and/or economic value will remain in the ingredients. The changes in the main product need not necessarily take place within the boundaries of one step of the chain, it can also happen on several chain levels, e.g. flexible / mobile biorefinery units on the farm. Many companies only use 1 key ingredient from a biomass resource. The rest is left untouched and leaves via the easiest route the main process: often feed or waste. An utilisation level of 95% would be more desirable, with applications running over multiple domains at high-level valorisation. The main question to investigate an integrated approach is how to insert technology in the production process? On which scale will investments be needed? Which markets exist for the products? When picking up an integrated approach, we should anticipate on failure as well. There are technological barriers to optimise the utilization of by-product flows. Components need to be freed from the original biomass or by-product. Here, generic technologies can be applied, but each biomass resource has its specific conditions and possibilities. The current process technology is able to improve the availability of ingredients (mix, grind, squeeze, extrude, enzymes, heating). The combination of mechanical, chemical and biological processes will help to increase this availability. Breeding and modifications to the original biomass resource also can play a role here, which is nowadays a much faster process than before. The developments here should not lead to a loss of viability for the plant or animal.

Technological developments will increase the application options on the four Domains. The necessary technologies will have a generic criterion: How to decompose the product without damaging its ingredients? Nature has a build-in resistance to decomposition: difficult degradability, toxicity, etc. there are also other anti-nutritional components, including high levels of sulphates (damaging animal health) and phosphates (jeopardising the farmland's mineral balance). The other way around, when additives are used to improve the availability of biomass components, these need to be regenerated for further applications (e.g. hexane in oil extraction). The experts regard this however as a minor issue.

There is also the option of changing the main product input as well: a very promising alternative for conventional protein feed input are legumes (beans, lupine). These have been underexposed within existing breeding developments for the past 20 years. Each replacement crop of Wheat ("the golden standard") should match its profits (about € 800 / hectare) and nutritional characteristics to convince farmers to grow 'new' crops. At this point, the profits from legumes are about € 400 / hectare, with room for improvement. Other good examples are changes in feed for livestock to reduce phosphate excretion, or research into removing less beneficial components of cultural distillers' grain targets the improved application of the protein fraction.

Next to technology developments, logistics matter in changing existing main product processing: logistics play a crucial role to optimise availability of by-product flows to their new application. Improvement processes will need to be aligned with existing logistical processes, to reduce costs. To avoid lock-ins from waste management regulation, proximity based technologies are preferable. The experts indicate that excessive transport over long distances is not a preferable development strategy.

6.2.5 Wider developments in the Biobased Economy
Consequences for available and availability of resources (including supply security, quality)

While the previous two sub-paragraphs present the analysis of incremental and more radical/transitional innovation paths towards integrated sustainable production and consumption, the wider developments in the Biobased Economy and consequences for resources on the four application domains (including supply security and quality) were judged by the experts as well. They indicated the following significant developments:

1. Scarcity issues
2. Market mechanisms
3. Land use
4. Valorisation

Ad 1 – Scarcity issues
Will there be enough for everybody? Main concern rising from the development of Feed, Functional materials and Fuel expansion is the availability of biomass for Food.

A central question if demands for biomass resources increase with growing populations, wealth levels and meat consumption worldwide, combined with question marks on the availability of conventional, mainly fossil, resources. An expert stated that 'any vision on interrelations between the four Domains should include the phrase "there is enough for everybody". Not launching into discussions on the possible end of fossil resources, the experts agree that while future claims on biomass will not threat food security worldwide, there will be scarcity for certain resources (e.g. phosphor). However, scarcity, real or not, threat or opportunity, it does create movement on political and societal playing fields. The growing population and increasing scarcity of resources may occur on a global scale, but in the Dutch context it is not always visible. Here we have a surplus of food, materials and minerals, which hampers the profitability of alternative technologies, e.g. mineral retrieving from manure or slaughterhouse by-products.

As an expert stated, the rise of biobased in functional materials or fuels will not hamper the developments within the feed domain. The creativity and innovative capacity of the animal feed sector (worldwide) will be able to tackle sourcing issues: by-product flows that contain carbohydrates and / proteins of sufficient quality will always draw the attention of this sector. The law of economic profitability will decide the destination of each flow. The development of biobased materials (Functional materials Domain) is connected with the generation of carbohydrates. And it appears that there is no real shortage of those in the world. Utilising the non-used parts of crops (such as foliage or peels) does not affect the availably of food. The provision of Food is connected with the availability of proteins.

Ad 2 – Market mechanisms

New applications, new ingredients, integrated approaches: they appear to be marginal, and their impact on incumbent markets is difficult to foresee. It depends on market forces (players, interests, flexibility, openness) whether innovations will diffuse throughout markets and with what speed this process will happen.

There appears to be little competition between the four application domains nowadays, except for very targeted crops in specific situation (e.g. German market for maize has been heavily influenced by the feed-in tariff for renewable energy and has led to increasing prices , also in the animal feed application domain). Market mechanisms of supply-and-demand will influence the allocation of biomass resources to applications, including process and costs. The main driving force will be the improvement of valorisation of resources. This is changing from using whole products towards use of components / ingredients and put them to multiple uses / applications (raw materials flexibility and interchange-ability). This also enables the availability of cheap ingredients for food applications. The experts are not very much in favour of biofuels, but mainly because they do not yet have a proven business case and because of the materials loss when incinerating. It is predicted that if legislation, grants and tax schemes for these types of applications is withdrawn, the market for biofuels will collapse.
Another prophesized market mechanism, the one of the reduction of meat consumption, does not show in consumption statistics and show relatively stable figures throughout the EU. This leads to a stable market, which is very difficult to influence. Meat consumption in the EU is not likely to increase, according to the experts, but it will in the rest of the world.

Ad 3 – Land use

Connected with scarcity is the allocation of land use and the provision of biomass. The general opinion within the expert group is to grow food where it grows best.

Rotation of food and non-food crops will also increase fertility and improve the soil, aeration, etc. It is not perceived as feasible to compel that all arable land should bare only food crops. Flowers (tulips, roses), rubber and cotton are also non-food crops, but contribute to society considerably. The discussion is between local production and import, especially from tropical regions or underdeveloped areas. Decisions should be based on a complete set of sustainability criteria, without bias for local or biological. It also includes environmental impact, fair treatment of employees and not endangering local food security. Carbon footprint, energy and material use and transport all are part of this decision. The health and fertility of the soil should prevail.

Ad 4 – Valorisation

Market mechanisms will influence the application. The mechanisms itself needs to acquire knowledge on valorisation issues as well, to make informed decisions.

A number of starting points were formulated by the experts:

- Functional material applications should be preferred over biofuels
- Oil reserves should be used as material resources, not energy
- Valorisation should happen on the highest level, with Health products at the top
- Specialty products are able to compete with products from other countries / continents

Valorisation can be better understood from the value pyramid or cascading principles. Food at the top, feed, materials and fuels will follow. This also explains the resistance to first or second generation biofuels, based on food products. The experts indicate that governments should not stimulate developments herein. They should stimulate those by-product flows / kinds of biomass that achieve their highest possible level of utilization within fuels. However, they feel that the ultimate goal should be unlimited renewable resources, such as sun, wind and water.

6.2.6 Concluding remarks

The expert judgment insights provide valuable and detailed information on barriers and solution pathways on the road towards integrated valorisation of biomass in the four application Domains. Cutting through the analysis, the following insights can be formulated:

1. The economic efficiency and quality of production systems needs to be increased, initiated from multiple parties within the value chain. These improvements are both incremental and radical by nature, whereas the timing of the implementation differs: incremental on current systems (short term, quick wins), radical re-design for new systems (long term, structural changes/reform).

2. The environmental footprint of biomass resources needs to be reduced, including the agricultural stage (distance from origin, monocultures, biodiversity issues, 'importing' phosphates and other minerals).

3. The availability of 'green hectares' needs to be safeguarded to secure biomass resources supply.

4. Technologies (on molecular structure, characteristics and costs) need to be developed, that help mature biobased applications in the transition towards an integrated production and consumption system.

5. A choice needs to be made between the stimulation of 1^{st} / 2^{nd} / 3^{rd} generation of biomass applications (specifically on biofuels).

6. More action is required for stimulation of development and application of biobased functional chemicals.

7. Stakeholders need to be aware of negative externalities of market-driven governmental instruments, which may lead to lower valorisation levels.

8. In all developments within the (animal) value chain, animal health and welfare need to be safeguarded.

The experts indicated that not all policies and governmental instruments always achieve their intended results, regularly because of unforeseen negative externalities, often presenting themselves from a non-integrated approach. Next to this, there seems to be a lack of sense-of-urgency within the established value chains for conventional biomass resources. The experts indicated that the majority of companies involved, earn sufficient amounts from their primary/main products, which reduces the attention for by-products and waste stream valorisation. On the other hand, this provides new business opportunities for entrepreneurs from outside the traditional companies. There is also a strong feeling that new types of cooperation should be established to get to the next stage of transition to a sustainable use of biomass resources by 2050 and that this will require a cooperation and partnership attitude from all stakeholders involved, also focusing on the interrelations between business, government and research. It was also indicated that an economic business case inspires innovation and implementation.

These insights were used to develop a shortlist of cases and select them on basis of significance, relevance and impact on the exchange of biomass by-product flows between the four application domains. These cases are described in the following chapter. In the roadmap, these insights are translated in actions along the transition pathway to 2050.

7 Inspiration in practice – example cases

In the previous chapter a number of bottlenecks and solution pathways have been described for the establishment of new business activities around the high-end valorisation of biomass. These outcomes inspired the project team to make a selection of 11 exemplifying cases, to demonstrate the business case of innovative approaches towards a more integrated valorisation of biomass resources and by-products. They each envision a high-end valorisation of biomass, with the following scope:

- Biomass resource available in the Netherlands
- By-products from existing production chains
- Focus on protein, carbohydrates, oil/fat, fibre content

Also one case from a new biomass resource (microalgae) is presented in this chapter, to include a case based on a more fundamental change in the value chain.

Although very different in subject, the common thread in the 11 cases is that the utilization options of biomass are largely increased by the isolation of more or less pure components out of this biomass (the biorefinery concept, using fractioning technology). Using this approach, a higher added value can be created (up to 1.8 billion Euro/year for the cases presented below) in combination with a reduction of the ecological footprint (reduced CO_2 emissions). These 11 practical examples for the "more with less" horizon 2050 are linked to the 4 different classes of biomass availability in the Netherlands:

- Biorefinery of residues (by-products/waste streams), based on co-operation in production chains and networks, relatively small transport distances and business competences of Dutch entrepreneurs. Five cases are presented:

  1. Damaged carrots
  2. Grass from natural land and road verges
  3. Low protein content residues
  4. Wheat middling
  5. Brewers' and distillers' grain

- Biorefinery based on domestic Dutch crops, using synergy of existing agro- and chemical sectors, including the Dutch plant breeding sector. Four cases are presented:

  6. Sugar beets & beets foliage
  7. Cultivated grass
  8. Potato protamylasse[17]
  9. Maize protein

- Biorefinery of bulk imported biomass and biomass-derived intermediates, using existing logistic and petrochemical infrastructure (like the port of Rotterdam). One case is presented:

  10. Rapeseed meal

- Biorefinery of aquatic biomass, using Dutch microbiology, plant breeding and processing knowledge. One case is presented:

  11. Micro-algae

The next paragraphs gives a summary of each case, explaining the content of the case and its context, describing the current bottlenecks in the development of the case and sketching the tipping points to initiate future perspective of the case from a government and business perspective. As each case has very specific technology and organization needs, the tipping points are very limitedly addressed. Except for two cases which have been elaborated in the project workshop, which has been included in **chapter 8**. The lessons learned here are translated in the roadmap and recommendations (**chapter 10** and **11**).

[17] Protamylasse is a residual compound occurring during the industrial production of starch from potatoes.

The inspiration and tipping point of the other 9 cases lie in the attractive economic potentials described below. It is a role for research and business cooperation in networks and/or clusters to organize demonstration pilot projects, supported by government to co-finance initial investments.

For all cases, the inserted quantitative data are based on available data and information sources in the public domain. If not, best 'guestimates' are used, based on the experience of the project team and its network.

7.1 Damaged carrots

Aim: higher added value through a better distinction between Food and Feed applications

Background: Currently a certain percentage of carrots is rejected for further processing into food applications because of (mostly visual) imperfections ("beauty" criteria). Even in the case of a small defect the entire carrot will be rejected and become available for application in animal feed. Within the French fries industry, a cutting and sorting technology has been developed that rejects only the bad parts of the potato. When this technology is applied in the carrot industry, the total weight of rejected carrots can be brought back to about 20%.

Added value: Shifting the application from feed to food will generate an extra yield of 450€/ha/year. With an average annual cultivation area of 10.000 ha, the total extra added-value generated is 4.5 M€. The additional investment costs are limited.

Reduction ecological footprint: the main effect is a more effective land use (total reduction estimated at 669 ha). Substitution of the carrots which are no longer available for animal feed by corn will generate an extra amount of protein. Thus, the import of soy can be reduced. No large effect foreseen on water, energy and mineral use.

Potential spin-offs: the technology is available and can be applied for processing of all available fresh crops

Limitations: no limitations are foreseen. However, the positive business case is currently not sufficient for market parties to take the initiative. Reasons may be: the fact that there is an outlet for the rejected carrots and the perceived barrier for investments in new technologies.

Tipping point (from perspective of government and business): A successful demonstration outside the French fries industry can help to create a sense of urgency in the sector. Via the organization of workshop(s) other potential crops (also outside the Netherlands) can be identified where the technology could be applied to increase the added value through a shift from feed to food. Investment subsidies, SBIR or other (financial) risk reduction measures could stimulate the first movers.

7.2 Grass from natural land and road verges

Aim: Increase added value of grass from natural land and road verges through application as ingredient for animal feed.

Background: Currently about 600 kton (on dry matter basis) grass from natural land and road verges becomes available on a yearly basis in the Netherlands. Instead of applying this grass for fuel purposes, (enzymatic) treatment of the protein and fibre fraction can make a part of this grass available as feed for bovine animals. Enhancement of the digestibility of the fibre fraction from 20 to 40% increases the availability of NDF as energy source with about 84 kton. This corresponds to a saving of 3,743 ha of maize field. A concomitant increase of the availability of amino acids (from 25 to 50%) will make an extra 15 kton of protein available as feed ingredient. This corresponds to 15,000 ha of soy.

Added value: the separated fibre and protein fraction represent an extra value of about € 200/ ton. With 600 kton the potential extra added value is about 120 M€. The investment costs for the biorefinery equipment is estimated at 100 M€, provided it is run on a small scale. The additional employment is estimated to be 300-500 fte.

Reduction ecological footprint: Mainly savings in land use (3,743 ha corn, 15,000 ha soy). The extra energy costs related to the grass biorefinery are estimated to be of the same order as the avoided energy related to the processing of soy. No large effect foreseen on water and mineral use.

Potential spin-offs: In 2031 about 50% of the total available grass can be processed in the above mentioned way. Small-scale versatile biorefinery equipment can be applied for all types of "fresh biomass".

Limitations: the basic biorefinery technology is available, but process development requires further research. Further research is also required for the enhanced of the digestibility of the fibre fraction (e.g., via enzymatic treatment). Logistics constraints (grass transports include a lot of water and other unnecessary 'weight') and animal feed regulations (risk on toxic components, e.g. from Equisetium palustre, Hypericumperforatum and Jacophae vulgaris[18] hamper fast implementation. The risks associated with these toxic components has not yet been conclusively investigated, but will require a broad based scientific study, including composition variance analysis as well

Tipping points: as this resource is not on the radar of high-end processing companies, the economic advantages should be demonstrated via a small scale demonstration phase, providing prototype ingredients for high-end applications in functional materials applications. Purified fractions should be tested on animal health and nutritional aspects. The government could allow experiments to apply grass from nature land into the Feed chain. Research project(s) should focus on the biorefinery of the different components free of toxic components and to reach an economic process. Use these experiments to quantify the risks associated with the presence of undesired toxic components from poisonous plants.

7.3 Low protein content residues

Aim: using co-firing[19] residues as input for functional materials (protein, fibre and ethanol).

Background: many residues from agricultural activities (3 Mton/yr) contain protein in a too low content (3 to 15%) to make isolation of this fraction economically feasible. As the value of the other components (e.g., lignocellulose) is low too, in many cases these residues remain on the field. Recently, subsidies to convert this lignocellulose into electricity (via supplementary heating or biogas fermentation) have mobilized a certain volume of these residues. In principle, these residues may provide the following components: fibers for paper/cardboard and electricity generation, ethanol, potassium, phosphate, soil improver and proteins. However, ingenious biorefinery processes are required to isolate these components in the required purity.

Added value: 3 Mton residues can be converted into 160 kton proteins / amino acids (value: € 500/ton), 900 kton lactic acid (value € 300/ton), 1,5 Mton lignocellulose (value € 50/ton) and 4,5 PJt electricity. This total added value is 450 M€. Total investment costs are estimated to be 600 M€ (60 units à 10 M€). Additional employment is estimated to be 3,600 fte.

Reduction ecological footprint: Potential savings on land use are estimated to be 0.2 ha per ha. The electricity generated is sufficient for the pre-treatment step of the biomass. Additional electricity is

---

[18] In Dutch resp. Moeraspaardenstaart, St Janskruid and St Jacobskruiskruid.

[19] Co-firing is defined here as simultaneous combustion of different fuels in the same boiler, usually referred to as biogas installations.

required for the further isolation steps. No effect on water use, as well as potassium and phosphate (remain on the land). An additional amount of nitrogen (15 kg/ha) is required to compensate for the residues which not remain on the field.

Potential spin-offs: When the first demo unit is realized in 2015, the further implementation scheme is foreseen: 2020: 5%, 2025: 25%, 2031: 50% (based on isolation of the protein fraction). Valorisation of the technological knowledge is possible in other countries. Additional value can be created through the use of the protein fraction and/or hydrolysates in food applications. This requires, however, safety guarantees as well as consumer acceptance tests, e.g. on taste.

Limitations: Technology should be developed by a consortium of different stakeholders with quite different interests. The organization of the logistics requires special attention due to the large variance in type and quality of biomass. Biobased chemical applications need to be developed. The government could allow experiments to use this type of biomass for feed applications. So far, the compound feed industry sticks to existing raw materials.

Tipping points: companies are waiting for the technological demonstration of the feasibility of the prolonged value chain for co-firing residues. Their awareness to this option should be increased by establishing a small scale demonstration unit and determining the economically viable fractions and markets hereof. Frontrunners on biofuels could be interested to support this demonstration, since they have an increased awareness for sustainable innovations. Government could support research into biobased application routes and co-finance first demonstration or pilot units, to overcome the 'valley of death' for this case. Allowance to use these residues in the feed chain. Wait for the more stringent phosphate directives from the EU.

7.4 Wheat middling

Aim: Towards high value animal feed applications

Background: The Netherlands produces yearly 600,000 ton wheat middlings as side stream of the flour production for bread. Wheat middlings contain about 17% protein, 20% starch, 18% C5 sugars and 5% fat. Irrespective of the presence of these valuable components, wheat middlings are only limited applied as animal feed. On the one hand this is caused by the relatively high phosphate content (3% which leaves the farmer with manure problems), on the other hand by the unfavourable protein composition and the limited digestibility. Subsidies (SDE+) make application in biomass power plants attractive. Removal of the phosphate and increasing the digestibility of the protein fraction and the C5 sugars (from 40 to 80%) opens the option for high added-value applications, but attractiveness for the feed applications is reduced by the SDE+ subsidies.

Added value: The earnings based on a volume of 300,000 tons are estimated to be 19.2 M€ (= € 64/ha). The additional investment costs are estimated to be 12.6 M€. The additional employment is estimated to be 75 fte, based on the installation of 30 unit in the Netherlands.

Reduction ecological footprint: The potential is to save 10% of current land use. Compared to a complete application as fuel, 60,000 tons proteins can be saved from incineration. Compared to improved application as animal feed (increase of digestibility), the savings are 12,000 tons. No water savings are foreseen; savings on minerals depend on the reference situation: compared to incineration 10,000 tons of nitrogen and 9,000 tons phosphate is saved. For application in animal feed these savings are lower. The same holds for the energy savings.

Potential spin-offs: Within the first year, the first prototype needs to be installed (project currently in preparation). In 2020 100,000 tons can be processed, in 2031 the entire volume. Processing of another 300 – 400,000 ton wheat middlings which are on the Dutch market. Future improvement may be to split the protein fraction into amino acids, which allows for higher added value applications (feed ingredient, food ingredient, chemical building block).

Limitations: Currently the SDE+ regulation (subsidies for biomass power generation) forms a limitation for application as animal feed. It is economically more attractive to use it as feedstock for electricity generation than a more high-end application in the other domains. Also, the wheat milling industry is happy with the prices of the middlings for energy applications.

Tipping points: frontrunners within the animal feed industry investigate the potential central processing of the middlings by feasibility logistics and support applied research into the composition and nutritional value of the middling as high-end high protein animal feed resource. Research institutes can help to develop biorefinery technologies to fractionate middlings into valuable components. Encourage the companies from the wheat milling industry to take initiatives for further valorisation of these and similar raw materials. Stop SDE+ subsidies.

7.5 Brewer and distiller grains

Aim: Increase added value of co-products of beer and ethanol production

Background: Within the Netherlands, about 130 kton dry matter of brewers' grains and 225 kton dry matter of distillers' grain are produced per year as co-products of beer and biofuel production, respectively. Both products are used as low-dry matter feed ingredients mainly for ruminants (brewers' grain) and pigs (distillers' grain). Both products are relatively high in protein, fibre and fat. Extracting valuable components – amino acids, fat, phosphate – and hydrolysing fibre will increase the economic value of these co-products. Essential amino acids can be used as food ingredient for humans and monogastric animals; non-essential amino acids (glutamate) as flavour enhancer. The remaining fibre can be used as feed for ruminants or as substrate for biogas production; hydrolysing fibre may increase the nutritive value of brewers' and distillers' grain for monogastric animals (and humans). Fat can be used as alternative to sunflower oil.

Withdrawal of brewers' and distillers' grain as animal feed has to be compensated by extra energy and protein from other sources. Compensating for extracting 50% of the amino acids requires 2,636 ha of extra maize land and 50,640 ha of extra soy land for feed supply. Compensating for extracting 75% of fibre for biogas production requires 3,889 ha of extra maize land for feed supply; the extra protein production from maize land will save 5,315 ha of soy land for ruminant feed.

Added value: At present, no reliable estimates of investments costs can be made. For brewers' grain it is estimated that the value will increase from € 140/ha to € 660/ha if separated in feed protein for monogastric animals, digestible fibre and fat. The estimated value for separated components of distillers' grain is € 440/ha, which is close to the production costs of ethanol (€ 500/ha). Additional employment will depend on scale of production; estimated range 10 to 100 extra fte.

Reduction ecological footprint: Savings in land use are estimated at 0.31 ha/ha of barley. With *ca*. 60,000 ha of barley, 18,000 ha of land would be saved (less soy for pigs and poultry feed and less sunflowers; extra soy and maize for ruminant feed). For distillers' grain, land use savings are estimated at 0.60 ha/ha of maize and 0.44 ha/ha of wheat. No large effect on water use is expected. Improved utilisation of protein reduces demand for protein and consequently P and K import

Potential spin-offs: In 2031100% of brewers' and distillers' grain will be processed. To stimulate development, more emphasis on protein extraction than on fibre processing will be essential during initial phase.

Limitations: Technology and process development require further research. In recent history, beer companies have put a lot of effort in the valorisation of spent grain but have lost their belief in a solution. The biobased economy, however, might give them new chances. Due to high margin on their main product, beer and ethanol producers have no drive to increase the added value of co-products. Brewers are very negatively positioned against any change in their main process that might affect taste or smell.

Tipping points: in a research-business consortium targeted at small scale initiative located on a front running brewer to be close to the soured of spent grain, the innovative research on the development of improved refinery technology on these by-products. The economic potential should be clarified and communicated to attract this frontrunner. This will encourage other beer and ethanol producers to increase added value of their co-products. Identify the users of flavour enhancers, fat and proteins and develop new health products with enhanced fibres.

7.6 Sugar beet & beet foliage

Aim: increase the field yield through small-scale processing of beet and beet foliage to sugar, ethanol, biogas and protein, using less energy and transport.

Background: The growth of sugar beets is currently aimed at the highest yield of crystal sugar. It is well-known that amino acids accumulate in the beet as a consequence of a higher nitrogen gift during the growth of the beet, which has a negative effect on the crystallization yield. In the future biobased economy there will be an outlet for both the remaining sugar as well as for the amino acids, so the yield per hectare can be further increased.

Small-scale processing of beets to crystal sugar, ethanol and biogas is advantageous in terms of energy use: no energy is required for the carbonation (use of calcium hydroxide for the removal of impurities) and for the concentration of minerals that remain after conversion of the rest sugars to biogas and ethanol. As the fiber fraction is also converted to biogas, no additional drying is required. The overall investment costs are therefore not higher than large scale processing (per ton sugar beets). In this example case, also the leafs of the beets are processed, according to the process as applied in the grass biorefinery.

Added value: the increase of the field yield of this case is set on 20%, i.e. per hectare in total 100 tons beet and 6 tons dry matter from the leafs. From this are produced: 9 tons crystal sugar, 3 tons ethanol and 60 GJ electricity. The leafs provide 1.2 tons protein, 0.5 ton fibre, 0.3 ton amino acids and 60 GJ electricity. The residual heat which is released during the electricity production is applied for the process, including the distillation of ethanol. The required investments are similar as described in the grass case (not further worked out here). Additional employment will be realised compared to large scale sugar production, estimated to be 10 fte /1,000 ha. Extra products are ethanol and electricity.

Reduction ecological footprint: land savings through processing of the leafs are estimated to be 0.35 ha / ha (0.1 ha forest based on processing of lignocellulose and 0.25 ha maize through starch and proteins). Energy use will increase due to processing of the leafs (7.5 GJ/ha), but savings on fossil energy are estimated to be 25-30 GJ/ha. Phosphate and potassium loops can be closed by feeding it back to the field. Additional nitrogen (75 kg /ha) is required because processing of the leafs leads to ammonia release to the atmosphere. No impact on water use.

Potential spin-offs: It is expected that in 2031 about 25% of the 100.000 ha sugar beets can be processed in this way. This is not the full potential, as the large scale sugar beet processing plants will remain operational. In 2020 about half of the implementation can be realized.
Increase of the added value can be realized through application of the protein fraction for human food purposes. In a later stage also the amino acids can be isolated from the beets. With GMO high-added value chemical building blocks can be accumulated in the beet, without significant additional costs.

Limitations: The technology for this case has been developed and is available. The question is who will take the lead for the required investments. Given the small-scale character this should either be a small cooperation of farmers and/ or a large sugar refining company. This investment means a breakthrough in the large-scale processing of sugar, and might also have an impact on the relation between the farmers and the current sugar processors. Furthermore, the production of ethanol in the Netherlands should no longer be hampered by high Dutch taxations and at the same time by EU import levies that have a price increasing effect (level playing field for transportation fuels).

Tipping points:
Implement a level playing field for the use of biomass for fuel applications, e.g. by reducing taxations or even stop taxations as is the case for electricity and natural gas as transportation fuels and/ or even subsidize by SDE+ or by reducing car taxation (BPM and/ or 'bijtelling"). Allow experiments with beet protein for human food applications. Allow minerals to be fed back to farmers in the area of the beet processing unit, so the installations can be run at a larger capacity.

7.7 Cultivated grass

Aim: Increase added value of grass from cultivated grassland through application as ingredient for monogastric animal feed, cellulose, phosphate and potassium

Background: Within the Netherlands, about 10.5 Mton dry matter per year is being produced from 1 Mha of cultivated grassland. This is exclusively used as fresh or preserved feed for cattle, sheep, goats and horses. However use efficiency of grass protein in these ruminating animals is low: 20 to 25%. Improved protein use can be achieved by increasing grassland productivity from 10.5 to 16.0Mton, with a concomitant increase in protein content, and separating grass components by bio refinery into high-valued protein and minerals (P, K) as feed ingredient for monogastric animals (pigs, poultry) and low-valued plant fibre as feed ingredient for ruminants or for industrial applications. It is anticipated that annually 2.5 to 3 Mton of protein can be extracted. This corresponds to 3 Mha of soy. The reduction of soybean oil (1.5 Mton) can be compensated by increased rapeseed production within Europe. The increase in grass production will also yield an extra of about 3 Mton of cellulose for industrial applications (paper), corresponding to 300,000 ha of forest.

Added value: The separated fibre and protein fractions represent an extra value of about € 1,000 to 2,000/ha. Due to better protein and phosphate use efficiency, costs for manure disposal will be reduced by 500 M€/yr. The investment costs for the bio refinery equipment are estimated at 1,500 to 2,000 M€. Consequently, payback time will be 1 to 2 years. The additional employment is estimated to be ca. 5,000 fte (loss of employment for manure transport not included).

Reduction ecological footprint: Mainly savings in land use, estimated at 3.3 Mha of land for soy, corn and forestry, which is a reduction of the Dutch footprint of approximately 30%. The extra energy costs related to the grass bio refinery are estimated to be of the same order as the avoided energy related to the extraction of protein from of soy. Within the Netherlands, water is not limiting for grassland production. Increasing grassland productivity will require extra nitrogen fertilizer, partly originating from manure and digestate. On the other hand protein imports (as soy) will be reduced.

Potential spin-offs: In 2031 about 60% of the total available cultivated grass can be processed as mentioned above. Part of cultivated grassland will be required for grazing of animals during summer.

Limitations: The basic bio refinery technology is being developed. The process development requires further research. Logistics are currently under development. Protein producers will be critical, possibly mobilising public opinion on intensive grassland production and summer grazing. To increase grassland productivity the level of fertilizer application will be above EU allowed standards. This will require room for experimentation for differentiation of regulatory standards in relation to biomass application.

Tipping points: Stimulate initiatives on bio refinery of cultivated grass and utilization of novel products in livestock farming: high protein diets for milking cows and calves, against less protein rich feed for dry cows, or grass protein in compound feed for pigs and poultry. It can also include new products for the cellulose and paper industries so that economic profitable processes can be developed that do not need subsidies. In order to increase yield per ha high nitrogen applications are required even if nitrogen use efficiency is above 75%. If possible toxic components in verge grass can be degraded, and quality of the protein obtained by similar methods as from cultured grass can be controlled, also verge grass can be a good source for feed protein.

7.8 Potato protamylasse

Aim: Higher added value application: from fertilizer to food ingredient and bulk chemicals

Background: the potato starch industry produces a watery side stream of about 120,000 tons with 60% dry matter content, next to the 600,000 tons of potato starch. This side stream contains all soluble components from the potato, like amino acids, organic acids, potassium, phosphate and sulphate. Because of the high potassium content and the presence of toxic components like chaconin and solanin, the value of this stream for animal feed purposes is limited. Isolation of value components from this side stream will increase the total added value.

Added value: The current main application is fertilizer, with a value of €40 / ton. Isolation (via ion exchange or other selective isolation methods) of the pure amino acids would create an additional added value of 14 M€ (7,000 ton à €2,000). For the isolation of the citric acid this would be 5 M€ (5,000 ton à €1,000). It may be possible to isolate the phosphate and sulphate as well, leaving a potassium-rich residue. Addition employment is estimated to be 6 fte (on 50,000 ha).

Reduction ecological footprint: This case may provide an extra 7,000 ton proteins on 50,000 ha potato field. Potential land saving is 0.09 ha/ha potato field. The effect on water use and the mineral balance of this case are neutral. Energy use is neutral as well, in case heat-power coupling is applied.

Potential spin-offs: To demonstrate the applied technology, a pilot unit needs to be build which is sufficient to handle the volume of 5,000 ha. In a later stage this can be scaled up to 50,000 ha, provided the market for the end products is sufficiently developed. The technology can be applied to other wet side streams, including the press fiber fraction which is released in the potato processing industry.

Limitations: The technology to be applied (ion exchange) is currently under study. It will not be easy to identify markets for more than 10 products at the same time. So the initiative should be content with fewer added values initially.

Tipping points: Development of (alternative) economic technologies and development of market channels for the high value amino acids, the organic acids such as citric acid and the remaining components as animal feed. Coupling large agro-food processing industries with SME companies may catalyse this innovation.

7.9 Maize protein

Aim: Increase added value of maize from methane and ammonia production to food ingredient and industrial coating

Background: Traditionally, maize is used for feed (bovine animals and pigs) as well as biogas production. As industrial crop in the Netherlands, maize is attractive as it contains a substantial amount of starch (8 ton/ha), proteins (1 ton/ha), oil (0.7 ton/ha) and lignocellulose (10 ton/ha). Furthermore, maize is resistant towards high manure concentrations. Because of the SDE subsidies, it is attractive to use maize for co-fermentations. In this process, the protein fraction is converted to biogas and ammonia and the oil fraction to biogas. The conversion of the lignocellulose fraction into biogas is only limited, because most gas is formed by the starch fraction. Following the value pyramid for the highest value application, many improvements are foreseen on the short and the long term. A simple examples is the separation of kernel and stalk, of which the latter fraction can be treated to increase applicability for animal feed as well as biogas and fermentation. The kernel can be applied for food (starch, protein, oil fraction). A technical application of maize protein is as adhesive coating. For biofuels application the kernel could be applied; during the fermentation the protein and oil fractions can be separated.

Added value: stalks and leafs are about 50% of the total maize. The stalk consists of about 800 g NDF/kg dry matter. The available energy is made available for about 50% in the gut of the ruminants. If this is increased to 75%, this provides an additional 415 million kg digestible fiber for bovine animal feed. Theoretical savings for feed concentrate is about 410 million kg. High end use of maize protein and oil in food applications may provide earnings in the order of 0.50 – 1 € /kg.

Investment costs are estimated on 2 M€ / unit. For each 100.000 ha, in total 60 units are required for the production of 320.000 tons of ethanol (à 500€) and 80.000 tons of protein (à 600 €). This leaves 400.000 ton feedstock for electricity (24 M€). Total turnover is 230 M€, with a profit marge of about 10%. Running the installations requires an additional employment of 180 FTEs.

Reduction ecological footprint: The impact on land use is significant: the additional amount of sugars corresponds to 1/6 of the area, the additional amount of proteins and oil corresponds to a similar area (if related to lupine). No extra energy use is foreseen in case heat power coupling is applied. Savings on nitrogen binding energy is estimated to be 0.5 PJ. No impact on water and potassium. Savings are foreseen on nitrogen (no ammonia release to the atmosphere) and phosphate (4.000 ton due to reduced protein import).

Potential spin-offs: the process can already be competitive on a small scale, because some of the process steps have limitations when run on a large scale. This has already been demonstrated in practice. Additional benefits can be gained through: increase crop yield from 18 to 25 tons/ha/year, by the prolongation of the growing season and intermediate harvesting of the leafs. The latter will also improve the quality of the proteins, with the provision that leafs are processed in a grass biorefinery unit. GMO crop improved may further increase the crop yield.

Limitations: The required technology is available. Development of high added-value products is hampered by SDE+ subsidy for biogas production which takes away the raw materials. Furthermore, the cost price of ethanol is kept high due to governmental regulations like import duties on Brazilian ethanol and high Dutch taxation on ethanol.

Tipping points: create a level playing field in transport fuels, e.g. via a tax on CO_2 production.

7.10 Rapeseed meal

Aim: Increase added value through separation into components

Background: Rapeseed is a relatively small crop in the Netherlands (10.000 ha); additional rapeseed is imported, mainly for the production of biodiesel. Per hectare the yield of rapeseed is 4 ton, which can be separated into 1.6 ton oil and 2.4 ton rapeseed meal. Current application of rapeseed meal is mostly for animal feed (both pigs and cows), at a relatively low cost of 180 €/ton. Higher added value applications are limited because of the presence of undesired components like potassium and phosphate. A better separation of all components present in the rapeseed meal (proteins, oil, cell wall material, sugars and other carbohydrates (pectins, hemicellulose), phosphate, potassium, calcium and magnesium) would open the option for higher added value applications on other domains. A process consisting of alkaline extraction of proteins followed by fermentation of sugars into lactic acid could transform rapeseed meal into 3 fractions. Fraction 1 (about 60%) consisting of proteins and calcium lactate; Fraction 2 (about

20%) consisting of lactic acid, peptides and potassium; Fraction 3 (about 20%) consisting of lignocellulose, phosphate and other insoluble components. Fraction 1 can be applied for pig feed, fraction 2 for bovine animals and fraction 3 as fertilizer.

Added value: Current application of rapeseed meal: 180€/ton. The fractions mentioned above have a value of about 500€/ton (fraction 1) and 150€/ton (fraction 2 and 3). These figures result in a doubling of the total added value. Investment costs for a processing plant for an annual amount of 10,000 ton rapeseed meal are estimated to be 25 M€. About 20 FTE are required to run this plant.

Reduction ecological footprint: A large effect is expected on the land use, through reduction of the import of soy (about 31, 000 ha). The additional processing requires additional energy (estimated to be 60,000 GJ) and water (1 Mm^3). More effective use of nitrogen and phosphate.

Potential spin-offs: The approach of separating the biomass into useful fractions for animal feed and components which can used applied for other purposes, can be applied to all (processed) oil seeds. These are currently imported in large quantities (e.g., soy). In terms of applications: in a later stage proteins from rapeseed meal could be used for human food applications. This market needs to developed, but could be about 5,000 ton in 2020 and 15,000 ton in 2030. Because of the specific emulsifying properties, the estimated price of this protein is € 2000 – 3000 / ton. A drawback is that for the isolation of this protein fraction more water and energy is required.

Limitations: Technology should be optimized in order to become economic. Market outlets should be developed although they are commodity products.

Tipping points: Formation of a strong consortium of different stake holders that wants to invest in technology development and the first demo plant.

7.11 Microalgae

Cultivating and downstream processing of microalgae
Aim: a new sustainable source for a spectre of raw materials

Background: micro algae are considered as one of the most promising raw materials for bulk products like biofuels, chemicals, food and feed ingredients. The yield per hectare of micro-algae is with 40-80 tons considerable higher than for traditional agricultural crops. Algae can be used for a number of applications, e.g., the fats for biofuels or chemistry, the proteins for food (soluble proteins) or feed purposes (see **Figure 4**). The amino acid composition of micro-algae is comparable with the composition of soy or egg.

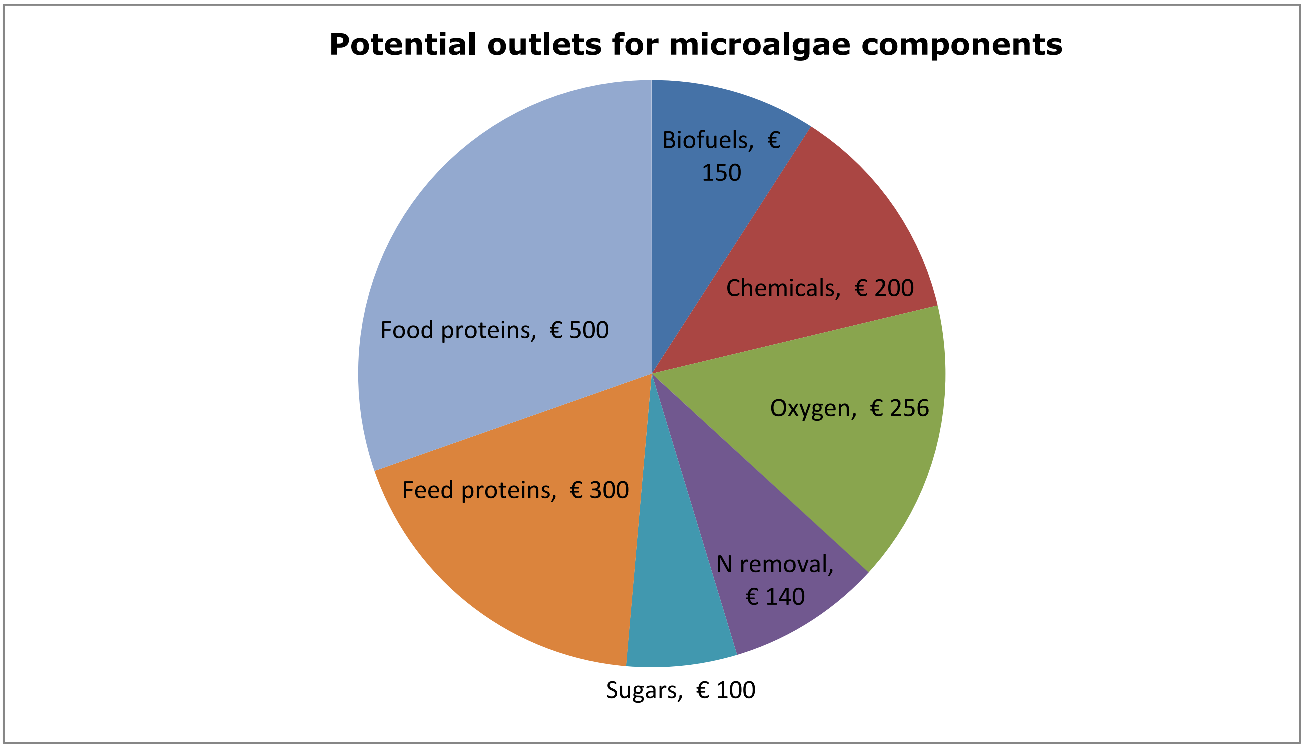


Figure 4: *Potential outlets for microalgae components (Wijffels et al., 2010).*

Added value: currently mostly high-end applications, market volume 5,000 tons dry algae biomass, with average market prices of € 250/kg.

Reduction ecological footprint: algae do not compete on land use with traditional crops. Algae can be grown on waste streams. If the production of algae is scaled up so that amount of fats is sufficient to replace all current transportation fuels (0.4 trillion m^3 biodiesel), then the concomitantly produced amount of proteins would be 0.3 trillion m^3, which is about 40 times the imported amount of soy. For this 25 Mton nitrate and 4 Mton phosphates are required, which corresponds to twice the amount of artificial fertilizer currently produced in Europe. Recirculation of nutrients is, therefore, a prerequisite. Figures on water, energy use and employment are not available yet. These should follow from the current pilot projects that run within Algae Parc in Wageningen.

Potential spin-offs: Increase of market volume and reduction of production costs need to be realised through up scaling. It is that within 15 years the production costs can be decreased from €10/kg to €4/kg. Further optimization can even lead to a decrease of the production costs to € 0.50/kg.

Limitations: For food and feed applications waste streams cannot be used. Differentiation between growing conditions and applications may thus be required. For one individual application (e.g. feed) algae are not competitive (thus multiple applications should be developed through biorefinery approaches). No ideal biorefinery processes have yet been established for the downstream processing and integrated valorisation of algae (e.g., current lipid extraction process compromises the quality of protein fraction). Novel food regulation and consumer acceptance (colour deviation of proteins) impede application in Food domain.

Tipping points: Stimulate research on production and downstream processing of algae in order to reduce costs and identify high value applications. Allow experiments with higher end applications in Feed and Food domain.

7.12 Concluding remarks

As they are inspired by developments in practice, we learned that many of these cases have not yet been fully developed. The main reason behind this are a lack of sense of urgency (background of ample supply of many agricultural products within/to Europe), low economic imperative (by-products are valorized on a low-end level application, but usually not a cost within the production value chain; focus is on the main/primary products). However, within the contours of a biobased transition, these cases include promising business perspectives. As each case has very specific technology and organization needs, the tipping points are only very limitedly addressed in this chapter. Two cases (Brewers and distillers' grains, and Cultivated Grass) which have been elaborated in the project workshop, which has been included in **chapter 8**. The lessons learned here are translated in the roadmap and recommendations (**chapter 10** and **11**).

8 From business perspective towards business plan

In the previous chapters, bottlenecks and inspirational business were presented. We concluded that cases may seem promising on paper, but experience limitations in practical application. Since each case has very specific characteristics and the bottlenecks, tipping points and incentives to implement, it is difficult to establish a one-size-fits-all approach to stimulate their implementation. In other words: it matters when, with whom and how a business case is developed and implemented. To gain more insights in the mechanisms behind the barriers and opportunities of promising cases for integrated valorisation, we used a business oriented interactive workshop as methodology. This setting creates a constructive group process in addressing and iterating on barriers perceived and to think through solution pathways, indicating incentives for business, research and government. It also provide opportunities to get behind the 'why' of certain perceived barriers, and achieves greater details in the incentives provided.

To support this methodology, a number of questions were addressed during the workshop, held on 25th of August 2011[20]:

- Which technological innovations are necessary to optimize the utilization and valorisation of biomass applications?
- Which barriers exist?
- Which opportunities and solution pathways exist??
- How about economic viability of innovative approaches.

To make the connection with barriers and opportunities in practice, the workshop focused on two cases (also included in **Chapter 7**): Cultivated grass and Brewer and distiller Grains (BDG). The moderating mechanisms of the workshop focused on two parts: (1) recognition (are example material flows and barriers recognizable?) and iteration (snowballing on further barriers) and (2) thinking in opportunities using a business case approach. The following analysis of the workshop outputs has been made anonymous and the answers are not traceable to individual representatives.

8.1 Biomass value chains and innovation opportunities

An important step in creating awareness to new opportunities for products and applications of biomass by-product flows is to iterate on the conventional processing route of the target biomass resource. This iteration process starts with existing resources/material flows and builds in new routes, processes, products and applications, either by adding, moving or deleting them. In this way, the group is encouraged to discuss the graphic representation of existing routes of biomass main and by-products throughout the value chain, and propose new/alternative exchanges within the value chain. The final result depicts an integrated system for biomass valorisation. The pre-composed and newly created flow charts which were presented and developed in the workshop are included in **Annex 5** and **Annex 6**. Viewing these charts, it becomes clear that there are many inter linkages with new application and process steps throughout the material value chain. The graphic representation helped to create a new mind-set, leading to the workshop participants to critically create and evaluate new process steps and product application domains. Getting off the beaten track and using a multiple application approach provided eye-openers for innovative solution pathways. The groups then discussed the perceived barriers for innovation processes, based on the newly created flow-chart. These insights on barriers (specific for the two cases addressed) are listed below.

[20] The participants to the workshop are listed in **Annex 4**

8.1.1 Case: Brewers' & distillers' grains

Introduction case (see also § 7.5): Brewer and distiller grains originate in the beer/alcohol producing process. They are most commonly used as low-dry matter feed ingredients mainly for ruminants (brewers' grain) and pigs (distillers' grain). Both products are relatively high in protein, fibre and fat. These ingredients could be valorised on a higher quality and application level by fractioning and extraction, and put to use as food ingredients and flavour enhancers. The fat can be used as an alternative for sunflower oil.

The following comments were not associated with a specific step or process in the value chain.

1. *General barriers regarding the value chain*

1a. Market mechanisms

- A successful business model needs to extend throughout the value chain: where the investments/costs are made, there also needs to be (increased) profits. Too often, it focuses on one application / one product ingredient, this limits the integrated approach.
- The highest price is not the same as the highest value. A valorisation process on a higher level of the value pyramid does not necessarily mean a higher profit.
- Vested interests of incumbent players in sectors will inhibit change.
- Vested interests of incumbent customers will inhibit changes.
- New products and existing applications in new domains have to compete with the conventional application of biomass.
- By-products are not sexy: they are regarded as non-priority materials, not high-potential money makers.
- Focus on this case leaves blindfolds for competitive ingredients for DDGS / brewer & distiller grains, such as soy.

1b. Cooperation issues

- Difficult to organize and maintain cooperation in the value chain.

1c. Governmental instruments:

- There are too many innovation themes in policy: The "BV Nederland" does not know how to choose.
- Strict legislation and contradictory explanations of EU regulations and directives
- Positive list of allowed feed ingredients will shift production to regions with minimum legal requirements (un-level playing field).
- Grants in one application domain will limit developments in another.
- Who is willing to make the first step? Front runners need to guide the way to new developments. "If one sheep crosses over…".

The following are barriers specifically associated by the workshop participants to a certain step or process within the material flow chart. Their ranking is deducted from their position on the flowchart (see **Annex 4**).

2. *On the farm (process)*
    - Grants in one domain limit developments in another.
    - High risks are associated with the introduction of new legislation when introducing new, competitive technologies.
    - Limited visionary power on various levels.
    - Life cycle analysis results are unclear. What is the carbon footprint?
    - Time is a bottleneck: competitors can overhaul us.

3. *Manure (product)*
    - Legislation on nitrogen and phosphate

4. *In the Brewery (process)*
    - Little room for experiment on the development of non-brewery activities on-site.
    - The producer of the main product is not really interested in marginal by-products

- Beer has a certain experience and expectancy within industry and customers. They are not prepared to make changes to the production process that might negatively influence taste or image.
- The production manager is not fond of changes in the main process technologies. Also, he will be apprehensive for quality changes in the main product or the revision of permissions.
- There is not enough sense of urgency. When the Chinese take over, it will be too late.

5. *Yeast for brewing (product)*
    - Existing hardware, infrastructure, knowledge and investments limit system changes or renewals.
    - From global to regional focus.
    - Not a core business practice.
    - Transport costs of liquid product are high: proximity is necessary.

6. *Grains (dregs; product)*
    - Organizing logistics (demand / supply and transport)
    - Guaranteed supply of dregs for refinery due to minimum scale of process.

7. *Brewers & Distillers' Grains (product)*
    - Wrong drying processes influence the protein content considerably. This leads to high analysis costs and uncertainty of the application level.
    - Within BDG, contaminants will concentrate (e.g. mycotoxins)

8. *At Energy production (process)*
    - Doubts at the economic feasibility of combined combustion technologies

9. *At Ethanol production (process)*
    - Uncertainties on continuity in bio-ethanol production
    - By-product originates from production, which makes it a supply-driven resource: how to get it to be market-driven?

10. *At Biogas (process)*
    - Three step approach: innovation - surpassing barriers –return on invested capital

11. *At Refinery (process)*
    - Extraction vs. Purity: which refinery technology provides a good quality output, based on a mixture of input products?
    - Conversion and refinery require energy: are there closed loops possible?
    - What are the consequences of large scale refinery?
    - Unclear cost-profit analysis results
    - Investment costs are high
    - Not easy to access risk venture capital
    - Feed price volatility due to grants within biofuels
    - Environmental permit issues
    - Lacking entrepreneurship
    - Little attention for by-products

12. *Proteins (product – component)*
    - GMP and hygiene regulations (EU) lead to high analysis costs and limit the applications
    - Competition from other biomass chains: is there a surplus of protein supply?
    - Proteins from brewery dregs are low quality
    - Market demand is unpredictable
    - Legislation on the entry of new food ingredients
    - Economic profitability? Costs associated with refinery versus the profit on food proteins.

13. *Fibre (product – component)*
    - Innovation on extraction processes necessary.
    - Quality of fibres to match application requirements.
    - Variable quality and quantity hinders application.

- Unfair competition from energy sector (infrastructure, market power).
- Venture capital over 10 Million Euro is very hard to come by (financial capacity).
- Economic profitability: is there a sense of urgency? Fossil resources are still cheap.

14. Human Consumption (application domain)

- Consumer acceptance of dreg proteins?
- Essential for high value application
- Unsecure market demand
- Chemistry building blocks
- Market mechanisms on supply and demand

15. Feed (application domain)

- More stringent legislation on production biogas from by-products to limit use of biomass for fuels that can be valorised at a higher level.

8.1.2 Case: Cultivated /natural Grass

Introduction case (see also § 7.7): Cultivated grass (some 950.000 ha in the Netherlands in 2010[21] is harvested 2-4 times a year, and exclusively used as fresh or preserved feed for cattle, sheep, goats (ruminants) and a small part for domestic animals (horses, rodents). Higher end valorisations include the fractioning and extraction of proteins as food ingredient and as feed ingredient for monogastric animals (pigs, poultry) and fibres for industrial applications and feed ingredients for ruminants.

The following comments were not associated with a specific step or process in the value chain.

1. General barriers regarding the value chain

- What is the definition of waste?
- Low sense of urgency
- Entrepreneurship: who goes first?
- Need for 'running in packs'
- Too positive representation of the potential of cultivated grass into Food domain applications might turn out to be too idealistic to attract entrepreneurs.
- Large companies often do not have the same interests as small company (start-ups). The case might be too ‘green’ for a large company and too complex for a little one.

1a. Knowledge

- There is no decision system for application selection in place
- Is there enough knowledge on the application of cultivated grass in new application domains? Sharing of knowledge and development of applied knowledge is not yet sufficient.
- Sharing and applying knowledge: what are real possibilities and good examples thereof?
- There is no overview of application options
- Many ideas fail: how to select them?
- Too radical innovation.

1b. Cooperation

- Lack of cooperation between food and non-food application domains
- Afraid that others will steal your idea.
- Every company reinvents the wheel
- Matchmaking in the value chain (finding cooperation partners)

[21] CBS Statline: *grass silage: 5139 mln kg dry matter; hay: 183 mln kg dry matter*

1c. Governmental instruments

- Cultivated grass quickly falls under waste transport legislation when leaving the farm.
- Water quality legislation.
- Legislation lags behind technological developments.
- Although cultivated grass is a common biomass resource in the Netherlands, it is not applied within biofuel applications (via fermentation, gasification or similar); subsidies on biofuel research and demonstration focus more on by-product or waste material flows (e.g. organic waste from industry, manure, sewage sludge).

1d. Market mechanisms

- Company's survival comes first
- Entry to incumbent markets is difficult
- Unclear business model: no target applications, focus mainly on technology for fractionation
- Competition with low cost conventional products.
- The establishment can negatively influence newcomers' development
- Not favoured by NGOs
- Much technology push, little market pull
- Grass fibre already is applied within paper products
- Producers tend towards more extensive processes and applications
- Volatile market prices and short term contracts

1e. Logistics:

- Discontinuous supply, influencing profitability

1f. Financial capacity factors

- Who pays for R&D costs?
- Unclear profit from sustainability perspective: what are the people – planet – profit advantages?
- Looking for start-up funding.
- Large bank players are not interested.

The following are barriers specifically associated by the workshop participants to a certain step or process within the material flow chart:

1. *Natural grass (input biomass product)*
   - Landscape effect of harvesting, intensive vs. extensive use and its influence on nature values
   - *Starting point: leave at the land what the land needs (fertility, soil structure)*

2. *Contaminants (also relevant for refinery process) (product)*
   - Verge of the road: litter, downpour of emissions from traffic or nearby industry
   - Spatial development plan and non-agricultural activities
   - Spread of animal diseases through deliveries from contaminated companies.
   - Are there any toxic additives in the processing stage?

3. *At Logistics (process)*
   - Surplus of grass is inaccessible for other applications
   - Discontinuities in grass supply due to growing season and weather conditions
   - Grass needs a quick processing timeframe. Grass needs to be processed quickly or it will deteriorate.
   - Little market demand for grass as a whole product
   - It is not desirable to transport grass over long distances.

4. *At Refinery (process)*
    - Use of enzymes to assist fractionation is still in its infancy with regards to grass
    - Retrieving soluble amino acids is challenging
    - Grass refinery demands highly complex processes, and will require high investments
    - Is it desirable to allow for additional industrial activity in the countryside?
    - NIMBY effect with regards to spatial planning.
    - Legal costs for addressing permits and regulation enforcement
    - Limited space for installation available in on-farm applications

5. *At Biogas (process)*
    - Safety issues on small scale, proximity based, mobile installations
    - Grants stimulate uneconomic application of other by-product flows / biomass sources.

6. *Proteins (product)*
    - Economy of scale vs. costs of extraction
    - Complexity decreases with scale increase. Question is feasible it is to reach the desired scale?
    - Will it replace imported soy? And by which percentage?

7. *Carbohydrates (products)*
    - Unstable carbohydrate levels inhibit application (process insecurities).

8. *Fibres (products)*
    - Technology for refinery and extraction
    - water is not an economic product
    - transport of water is expensive
    - efficiently de-water biomass
    - Research needed into hydrophilic characteristics of grass (fibre) structures.

9. *Markets (application domain)*
    - What is the added value of the new application? What are its unique selling points (USPs)?
    - There is competition with worldwide biomass markets (soy, wheat, etc.)
    - There are many entry barriers for newcomers, related to technology, logistics and economic aspects. The demands are voluminous, which are difficult to match for SMEs.
    - Interesting research question is to look in the willingness of consumers to buy alternative proteins (meat replacements) when these are cheaper than their animal counterparts. Research question to study at which point in innovation process the social/societal/consumer acceptance becomes a determining factor.

10. *Food (application domain)*
    - Is grass suited for food products?
    - Will consumer accept grass (derivate) as food product: grass is perceived as food for cattle.
    - Does processed food match with current or future Pure food trends?
    - Will farmers use biotechnology on grass?
    - How will legislation concerning novel food grass proteins affect market introduction in food application domain
    - What food safety issues are there with regards to grass (derivate)?
    - Legislation: no non-food crop may access the food chain.

11. *Feed (application domain)*
    - Influence on farm animal health when reducing roughage supply and/or replacing it with processed component ingredients.

12. *Functional materials (application domain)*
    - Functionality of ingredients need to match those of conventional products, surpass them, or need to comply with requirements for new products and applications (equal or better).
    - Applications in the functional materials domain often require redesign or reformulation of the (main) end product. This has to be accepted within industry and consumers.
    - Are pharmaceutical ingredients from grass feasible? Will require more research.

13. *Energy (application domain)*
    - Energy is as application for biomass less important than Food.
    - Entering existing energy infrastructure is difficult.

Iterating on innovation barriers have provided ample factors influencing the transition process towards an integrated valorisation of biomass by-products negatively. The most important barriers concentrate on:

- Entry barriers → a combination of lack of urgency and the incumbent conventional applications of biomass resources and by-products inhibit the economic profitability and entrepreneurship towards innovative alternatives. Incumbent companies are often satisfied with the existing traditional markets and value chains.
- Negative externalities of financial government instruments, targeted at the stimulation of specific, means oriented technological processes mask the interrelations between resource flows and application domains.
- Technological developments to ensure and make use of the quality, functionalities and characteristics of biomass ingredients and products in new and alternative applications.

It should be noted that although there are common factors (see above), the combination and details of barriers is very case specific. This provides an explanation why seemingly attractive business opportunities (including those in chapter 7) are not automatically successful in their development. Open doors for a lack of success, such as too little money, knowledge or skilled personnel are true on a high aggregation level, but are more nuanced in practice. The following paragraph addresses the opportunities and incentives to create successful business cases.

8.2 Business plan approach: insights on opportunities

In a development process it is important to create a ‘can-do’ atmosphere, where barriers are turned into opportunities and solutions are created to overcome barriers and to make inventory of incentives for different stakeholders involved. By introducing a game of innovation project team into the workshop, participants were invited to think out a business plan for their case and present an approach to get a new product accepted on the market. The participants were asked to provide actions from the company (start-up) itself and what would be needed from a governmental perspective. The two examples are presented below.

Business case of “Future Burger” (based on the grass case).

- Company actions:
    - Build a consortium with interested business partners, across a number of steps in the value chain (farmers, producers, wholesale). Cooperation will facilitate technology development: fractionation, transforming grass protein into a ‘burger’, refining fibres into composites for food application.
    - Present the concept of developing and marketing a ‘burger’ (meat-like product based on protein and fibre from refinery of grass) to the consumer. Important aspects to address:
        - Product itself (design, characteristics, taste, feel)
        - Food safety: notify existing regulations, and apply for permits
        - Patent(s) on ingredients or production process
        - Good manufacturing management system (GMP, HACCP)
    - Take care of capital investment by private or venture capital during the start-up phase. Important to have a balanced liquidity aimed at process investments and product development.
    - Marketing should focus on: “Tasty”, “Healthy” and “Dutch”. A sustainable image can be enhanced by ‘endorsement’ by NGOs as attractive addition to the Dutch menu. The burger is the main product, but also market for other applications: feed (protein) and functional materials such as paper (fibre).

- Governmental actions:
    - Subordinated loan.
    - Pilot within Ministry's canteen on the Future Burger.
    - Speed up access to novel food permits (room for technological experiments).
    - Increase import taxes on competitive conventional animal feed, such as soy.
    - Facilitate permissions and permits via a one-door counter ("loketfunctie") .

Business case of "Brewer grains in the future"

- Company actions:
    - Locate the new activity near (but independent from) an animal feed company, preferably near (inland) harbours.
    - Start with the product input: focus on protein rich fractions (including glutamate) and fibre fraction from wet biomass flows in the region. Proximity is necessary for certain wet flows with regards to food hygiene.
    - Start small, prove the principle. Use a combination of the conventional biomass input with the by-products from the brewery (brewery grains).
    - Develop cooperation agreements with suppliers on the quality specifications you need for your applications.
    - Use the utilities of the parent beer company.

- Governmental actions:
    - Decrease the nitrate norms for manure (cattle, pigs) to stimulate innovations in animal feed.
    - Guarantee start-up financial credit loans.
    - Ease and facilitate the permits' process (guide through all the necessary offices).
    - Show best practices to inspire entrepreneurs.

The workshop participants focused mainly on a consortium or cooperative approach, matching the different requirements of developing a new product (knowledge, technology, finance) and the integrated application of multiple components from the grass refinery process (marketing, legal facilitation) to develop a successful business case. Typical for governmental facilitation are the generic instruments (loans, permits facilitation), resembling the goal-oriented preference from the business perspective. The launching customer idea, based on demonstration sales within a canteen setting provides a very specific experimental setting, but can prove difficult to realize in light of government endorsement legislation and competition rules for (partial) outsourcing of the catering organization.

8.3 Analysis of major issues

Major issues in defining barriers and opportunities for the development, implementation and marketing of a new product or application are as follows:

- SMEs vs. Large companies

Are multinational companies more suited to successfully engage in chain innovation? A company or cooperation of companies needs to have the knowledge, market outlets and resources to implement the innovation processes. There are many differences between large companies and SMEs, but no blueprint for which of these two categories are better in creating and implementing innovations. It depends on many more factors than the size of the company.

- Centralized vs. de-centralized processing

The trend is that small-medium scale and decentralised processing has more opportunities for success than large scale and centralised processing. This trend can be nurtured by regulatory standards (including mineral balance of agricultural areas).

- Frontrunners vs. free riders

There is a big problem of free-riders and companies that wait to see which way the cat jumps. Profits can only be shared when the money is made: the first step needs to be taken to create value. If a new technology and applications need to be developed, it is necessary to include players from multiple steps in the chain: they all need to 'move' to accommodate the innovation process.

- One-size-fits-all vs. customization

With refinery technology, a choice needs to be made between a one-size-fits-all approach and customization. One size fits all includes a technology that can process various biomass (by-product) resources, but with lower quality output levels. Customization is a refinery technology that is optimized for a specific input, but also becomes dependent on that resource, leaving little room for diversification and combined inputs. The intensification of processes (using more of the biomass in marketable products) and how waste is managed at the processing unit influence the choice of scale. Refinery processes require a consistent input with a predefined / predictable / consistent composition. It is more difficult to design a refinery process that fits multiple types of biomass as it is opposed to single types of biomass. The first is however more attractive due to logistical reasons. How choices are made, is usually based on the origin of available resources to the innovation partners, and where are they familiar with.

- Integrated use vs. single component

When new resources are derived from refinery processes, they should be targeted at multiple applications: application-dependency is a risky business strategy, because if certain application markets fail, it means the end of economic profitability. Can other application products take over? Within refinery it is necessary for the business case to find markets for almost all components that result from the process. Biofuel is representing the lowest value, but can serve as starting point to make other fractions/components available from the biomass (e.g. digesting).Biomass for functional materials will always compete with their synthetic counterparts.

- Innovation vs. conventional

New applications or new biomass resources for existing applications always need unique selling points to compete with existing markets. These must be researched.

- Main product vs. by-product

When you interfere in the main product processing, the quality of the main product must not be affected. Therefore, not all components that can be valorised can be subtracted in an earlier processing stage (e.g. proteins in the brewery process can only be removed after the right alcohol levels are achieved). Companies are not necessarily ready to make changes in existing, successful or downright traditional production lines. For many companies, by-products are insignificant from the profitability of the main products. The incentive to change is very low: only when considerable profits above the conventional applications of by-products can be made, there will be business interests. Research indicating the higher value of the alternative application can induce behavioural change.

- Invention vs. implementation

Companies with established commodity products in high volume markets are more fearful of competition than new applications/biomass resources that are in earlier stages of development (pre-competitive research & development stage). The influence of stimulating policy instruments is also perceived differently in this innovation life cycle.

- Fresh vs. stored biomass

Are biomass resources, that are stored, preserved or out-of-season the same as 'fresh' biomass? This requires more research and new applications of existing storage technologies.

8.4 Concluding remarks

Focusing on the business perspective, this type of workshop can contribute to a better understanding of entrepreneurial attitudes towards more radical innovation processes and insights in how to overcome valorisation barriers from fundamental and applied science into business cases. It provides a networking opportunity (getting to know and trust each other) as well as creating a cooperative atmosphere for exploring what is necessary to create a successful business case and market introduction. Extracting the knowledge and insights from the workshop results, there are five main lessons to be learned to the integrated valorisation of biomass resources and by-product flows on the four application domains:

1. The redesign of existing, already fairly optimized production chains from one main product to optimal utilization of biomass with new resources and new applications is very complex and not an easy solution for biomass availability issues. The lack of sense of urgency is revealing. The Netherlands face the danger to seriously lag behind other countries which seize the opportunities. The participants do not expect incumbent industry to initiate such a radical transition. Vested interests and current economies of scales are important barriers.

2. There is an impressive body of (fundamental) knowledge on new resources and applications, however, there is a lot of technology push and little market pull. The time is not ripe, when existing markets function against low costs. The challenge is to get organizations in the value chain to cooperate for optimization of utilization and valorisation.

3. The technology and the processes are too complex for stand-alone SMEs or start-ups.

4. Governmental instruments are both stimulating and inhibiting. Dedicated instruments and restrictive instruments are less preferred than generic financial instruments and room to experiment with new alternatives. It is very easy to let innovation smother in barriers and reservations. It is much harder to engage in innovation processes. Innovation researchers find that the first motivational predictor of a firm's innovative behaviour includes a certain eagerness, illustrated as an innovation orientation or willingness to change[22]. There should be funds that attract a more entrepreneurial attitude. SBIRs are perceived as good governmental financial instruments, which leave little room for misuse. Grants should serve research and development projects: however, the facilitation of pilot projects can serve to stimulate the business case as well. These are more successful as consortia are behind them. Example is better than precept: Best practices are useful as inspiration sources, but also the translation into new context should receive attention. How to prevent to kill the goose that lays the golden eggs? They need to hatch. How to achieve this should be thought out by companies themselves as well. In the transition from feasibility towards market introduction, the funding should not only come from government, but from other parties as well (investors, companies, business networks/associations). Subsidies like SDE+ for low value application of biomass inhibit/ slow down the developments for higher value applications of biomass. The high tax barriers for transportation fuels that could benefit from existing infrastructure are inhibiting the learning curves from low value into high value applications. Subsidies and absence of taxation for transportation fuels that do not have good infrastructure yet, does not give compensation since volumes are still small and entrepreneurs do not have enough confidence in the Government that these attractive conditions will continue when volumes become larger.

[22] See for example *Porter, M.E., 1985. Competitive advantage: creating and sustaining superior performance. Free Press, New York NY; Montalvo, C., 2003. Sustainable production and consumption systems: cooperation for change. Journal of Cleaner Production, 11, pp. 411-426; Tushman, N., Nadler, D., 1986. Organizing for innovation. California Management Review, 28 (3), pp. 74-92; Van Hal, A., 2000. Beyond the demonstration project: the diffusion of environmental innovation in housing. Aeneas, Best (NL).*

5. For new partnerships to be established, companies which have not been natural partners so far, need to find each other. By-product flows within a region could be auctioned off for new applications. Criteria: round table approach, companies only, confidentiality. Companies need to find each other. The auction (or similar process) will not be self-organising: there needs to be a trigger / initiating party. This could be facilitated by government. There are many opportunities for companies to connect and network: when and if there is money involved, the companies will come to talk business.

The insights from this workshop serve as inspiration to go from generally formulated tipping points (such as presented in **chapter 7**) for innovation processes towards a more nuanced and detailed approach. A world of new knowledge opens up, and lessons can be learned. However, it is difficult to generalise or provide a receipt for success. The cases discussed in the workshop have a high level of detail on barriers and opportunities. However, all cases are unique, internal and contextual factors matter. Innovation processes are dependent on:

- Entrepreneurial attitude and orientation
- Business strategy
- Business competences (including knowledge, labour, financial capacity)
- Cooperation strategy
- External pressures (market, societal)
- Economic relations
- Governmental role
- Stakeholder engagement
- Network cooperation

The variations in constellations on these factors are multiple, which indicates that there is also not a one-size-fits all solution. Stimulation of innovation processes requires customisation for different types of companies and consortia. Their stimulation depends on the context and the participants. The business case approach is important to gain more insight to transit from technological development to a marketable product. The creativity of entrepreneurs, to accommodate to circumstances, and to optimize the internal performance should therefore not reigned by prescription regulation or annexed financial instruments.

If one thing can be learned, it is that involving entrepreneurs in working sessions to go into practical details of business cases with inspiring examples of potential successful innovations, it helps to improve chances of the actual implementation of the business case. Such a working session should therefore include a follow-up strategy, leading to consortia development and joint investments in the development of the case into new products and processes. One example for such a follow-up strategy includes the "Kansendag kleinschalige bioraffinage", organised by Accres and Wageningen UR at June 5th 2012. Here, the results of the first workshop were presented during a parallel session and opportunities to valorize urban by-product flows were formulated. Other parallel sessions included wet by-product flows, green leafs, fermentation, value chain redesign and discontinuous organic flows. and were also directed to stimulate the building of consortia between research institutes and business. A number of these efforts will be included in the Public-Private Partnership proposals within the Topsector framework for 2013 onwards. A report of the workshop is included in **Annex 7** (in Dutch).

Important findings on developing a follow up strategy were the following:

- Important questions to investigate the potential of high level and integrated valorisation:
    1. Defining material flows: what is the composition (quality, homogeneity) and what are its characteristics?
    2. Locating material flows: where do they originate, and how can return logistics be organised against acceptable cost (€ and CO_2 emissions)?
    3. Critical volume: is there enough volume available to start up a processing step?
    4. Technique: which processing steps are possible and opportune? Which pre-processing steps and material flows are necessary?
    5. Market: does the product meet the needs and demands of the market (quantitatively and qualitatively)?
    6.
- Steps towards collaborative partnerships
    1. Established opportunities for collaboration defined
    2. Insight on quality/characteristics of input flows, technological knowledge (gap), including risk analysis (technical, financial, management)
    3. Front runner orientation and identification of partners with aligned interests
    4. Budgetary and organisational preparation
    5. Organisation of research (feasibility and technology) and demonstration phase

The methodology of working sessions was perceived as successful and motivation. Some important factors for success are:

- Number of participants (3 – 15 is considered appropriate)
- Participants from various stakeholders in the value chain
- Available time (1 hour is too short, at least half day sessions)
- Clear ambition what to expect from the workshop
- Take time to develop relationship and trust between participants

9 Potential impact of large scale diffusion of new valorisation processes

In the preceding two chapters, 11 high-potential cases for the development of the bio-based economy in the Netherlands have been illustrated. Per case, information was provided on potential environmental footprint as well as economic effects (e.g. employment). This chapter places the cases in a broader perspective, to indicate the potential of a full, national out roll of the presented cases and its impact on economic, environmental and social parameters. Firstly, a brief overview is presented of previous studies on biomass impact and availability in the Netherlands. Next, the biomass needs of the case studies are compared with total biomass availability in the Netherlands. This comparison gives an indication of the relative size and potential of the cases. Finally, the total footprint of the case studies is summarized. These two indicators together with the qualitative assessment of the opportunities and constraints give an indication about which case studies should be given priority and which are relatively less important. These findings will be further elaborated in the following chapters Roadmap and Recommendations.

9.1 Biomass availability and impact in the Netherlands

Biomass is of diverse type, composition and availability, and is becoming increasingly used for various purposes. The question whether sufficient biomass is available in the Netherlands has played a major role in several inventory studies (Rabou *et al.*, 2006; Platform Groene Grondstoffen, 2009; Koppejan *et al*., 2009; Elbersen *et al.,* 2011).

Rabou *et al.* (2006) present one of the first studies to estimate the potential of primary, secondary and tertiary bio-based by-products, mainly for fuel applications as the study is linked to the ambition of the Platform Groene Grondstoffen to have substituted 30% of the fossil energy carriers by biomass in 2030 (see **chapter 5**). The authors calculated the year 2000 gross Dutch biomass consumption[23] to be 42.3 Mt (DS), or about 740 PJ. This equals to 24% of the Dutch primary energy consumption in 2000. The main part of this biomass has been used in the food- and animal feed industries. Only a small fraction of it was available for non-food applications. According to the author's projections, in 2030 the total biomass availability for non-food applications amounts to 18-27 Mt (DS) (300-450 PJ), or respectively: (i) up to 6 Mt (DS) primary by-products (100 PJ); (ii) near 12 Mt (DS) secondary by-products (200 PJ); and (iii) between 0-9 Mt (DS) energy crops (0-150 PJ). Rabou *et al.* (2006) conclude that between 60-80% of the biomass required to meet the Platform's 2030 vision will have to be imported from outside the Netherlands. When aquatic biomass crops grown within The Netherlands could be used, the import demand could be reduced significantly.

Platform Groene Grondstoffen (2009) quantifies the macro-economic impact of large-scale deployment of biomass based resources and related infrastructure and production capacity for the supply of energy and materials in the Netherlands. The study makes projections to 2030 using four different scenarios and focuses primary on bio-based production of electricity, liquid fuels for road transport and chemicals. In order to quantify the macro-economic impact of biomass in the Netherlands, a novel and successful combination of macro-economic top-down model was used supported by inputs of bottom-up information. The bottom-up model consists of detailed physical as well as economic data[24], which were used in an advanced multi-sector multi-region macroeconomic computable general equilibrium model (CGE) to evaluate the macro-economic impacts of a shift in fuel and/or technology mix.

Similar to Rabou *et al.* (2006) the study finds that a significant amount of biomass needs to be imported in the future to develop the biobased economy of the Netherlands. All biobased scenarios are expected to

---

[23] Import [32,8Mt] – Export [21,5Mt]) + Domestic Primary Production [31Mt]. Expressed in energy terms this amounts to (620 – 405) + 527 = 742 PJ.

[24] *Baseline situation includes a detailed assessment of current biomass use for bioenergy; Projections of final energy demand for electricity, transport fuels and chemicals; Technology characterisation and aggregation per sector and commodity; and Cost and supply of biomass.*

have a positive effect on the Dutch trade balance but, with a shift towards the biobased economy, agricultural employment will continue to decline. Depending on the scenario, a greenhouse gas reduction of between 5% and 30% can be realized in 2030. The analysis concludes that the high technology scenarios offer significantly better economic, energy security and environmental revenues, but are relatively risky in terms of technology development and implementation. That is why it is important that future policies focus on developing of advanced biofuels, strengthening of biochemical sector and efficient electricity production.

Koppejan *et al*. (2009) have conducted a detailed study to estimate the availability of local biomass for production of electricity and heat in the Netherlands by 2020. The aim of their study is to get a better understanding of the possible role of energy from biomass, taking into account: (i) the availability of all primary and relevant secondary and tertiary biomass, both domestic produced and imported; and (ii) measures to improve the availability of biomass, taking into account competing uses and various impacts, like on the environment. The study also contributed as an input for Netherlands National Renewable Energy Action Plan (NREAP)[25]. For their future (2020) predictions Koppejan *et al*. (2009) use 4 scenarios for each of the identified biomass types. These scenarios are characterized by open or closed markets and by different drivers for bioenergy demand and supply (e.g. security of supply versus ecological and social sustainability requirements).

The quantitative approach of the analysis can be summarized as follows:

- To determine the amount of biomass present;
- To determine how much is available for energy production;
- What is the energy content in terms of higher heating value (HHV) and lower heating value (LHV);
- Which conversion technologies are applied in the scenario assumed;
- The yield of energy produced;
- The amount of fossil energy use avoided.

The results of the analysis show that biomass for electricity and heat in The Netherlands amounts to 13-16 Mt (DS) in 2020. This corresponds to about 226-268 PJ (HHV) and 167-179 PJ (LHV) primary energy under scenario's driven by security of supply and scenario's driven by sustainability demands respectively. This comprises between 30 and 40% of all biomass present in the Netherlands annually. The final energy from biomass is between 44-95 PJ by 2020, which is equal to 102-158 PJ avoided fossil fuel energy (or it is about 3.4-5.4% of the expected primary energy use in the Netherlands in 2020). The study indicates that the availability of biomass and energy production from biomass can further increase after 2020 and the largest potential lies in better use of the biomass.

Elbersen *et al*. (2011) estimate the availability of biomass from the Dutch agricultural industry for energy production by 2020. The main purpose of this study is to identify the quality and quantity of residues from the Dutch agricultural industry that are currently present and used for bioenergy and their availability by 2020. In this study the authors mainly focus on the biomass that is released during the first processing phase, the food industry itself. In order to be able to estimate the biomass production by 2020, Elbersen *et al*. (2011) use 4 scenarios, which are built on the following two characteristics: (i) the degree of regulation; and (ii) the degree of globalization. The results of the analysis show that biomass for energy production from the food industry amounts to 0.5-1.9 Mt (DS) in 2020 (14-53 PJ (HHV) primary energy). This is equal to 11.7-47.3 PJ final energy and to about 13-49 PJ avoided fossil fuel energy, which is equal to 0.4-1.4% of the primary energy use in the Netherlands in 2008. The largest contribution comes from biodiesel production, which mainly uses cooking oils, animal fats and various vegetables oils as input sources. When upstream (agricultural) and downstream (retail) sectors are included in the analysis, the results turned out quite a bit better, resulting to 2.3-6.0 Mt (DS) in 2020; 44-122 PJ (HHV) primary energy; 20-73 PJ final energy from biomass and 28-88 PJ avoided fossil fuel

[25] The EU Renewable Energy Directive (EC, 2009) requires Member States to submit NREAP's. In these plans each Member State has to provide detailed roadmaps of how it expects to meet its legally binding 2020 targets for the share of renewable energy (i.e. wind-, solar-, hydro- and biomass).

energy. This is about 0.9-2.2% of the primary energy use in the Netherlands in 2008. **Table 1** gives a brief comparison of the results for biomass availability according to Koppejan *et al*. (2009) and Elbersen *et al*. (2011).

Biomass balance for the Netherlands by 2020	Koppejan *et al.*, 2009 (Total economy)	Elbersen *et.al.*, 2011 (Agro-industry)
Mt (DS)	13 – 16	2.3 – 6.0
PJ HHV	226 – 268	44 - 122
PJ Final	44 – 95	20 - 73
PJ av. Fossil	102 – 158	22 – 88
		Source: Koppejan et al. (2009); Elbersen et al.(2011)

Table 1*: Comparison of the results for biomass availability according to Koppejan et al. (2009) and Elbersen et al. (2011)*

9.2 Quantification of the case studies

The previous section reviewed various studies that analysed the macro-economic impact of the BBE with a link to the estimated availability of biomass in the Netherlands. This section is a first attempt to quantify the case studies of this chapter in a similar manner.

The first part of this section puts the case-studies in a macro context. On the basis of estimations by Koppejan *et al.* (2009) and Elbersen *et al*. (2011), the potential supply for the case-studies is compared with the total biomass supply from the agro-sector. This gives an impression of the relative size of the case-studies and the potential future demand for certain biomass sources in comparison to other biomass flows in the Netherlands.

The second part provides a first estimation of the potential 'footprint' of the case studies. A 'back of the envelope' calculation is presented which examines the economic and environmental effects *in case the examples would have been implemented* on a commercial scale. The most appropriate approach to analyse macro-economic impact would be to follow the approach of Platform Groene Grondstoffen (2009) and apply a CGE model, which takes into account the interaction between different markets and countries, combined with a scenario analysis to deal with uncertainties. However, given the available time and the lack of detailed data on (inter)national biomass flows, this is out of the scope of this study. Instead, an alternative approach is used that compares the effect of the case-studies, where relevant, on agro-raw materials that it tends to replace, mainly maize, soy and forestry. In addition, the case studies describe innovative technologies and bio-refinery processes that are currently under development and often have only been used in pilot projects or in laboratory settings. The conversion factors that are used in the calculations are, therefore, only a first approximation. The outcomes of the analysis below are purely meant to reveal trends and highlight opportunities. They should not be considered as final figures and must, therefore, be treated with caution.

9.2.1 Biomass availability

Table 2 gives an indication of the biomass supply, expressed in kton of wet and dry matter, that is potentially available as resource for 10 of the 11 cases studies. Given the fact that micro-algae are a completely new source of biomass, no information is available yet to conduct the analysis for the 11th case. The table indicates the sources of biomass. For instance, the total supply of biomass for the *low protein content residue* case (2,000 kton of wet matter) is the sum of residue from wheat and colza straw, and the supply for grass from nature is composed of grass from both nature and road verges. The estimates are based on figures from Elbersen *et al*. (2011) and insights from the project team (when no other sources are available). In addition, the table presents the total supply of biomass from the agro-sector in the Netherlands and the shares for the case-studies in this total. Please note that the figures from Elbersen *et al.* (2011) reflect present biomass availability while the demand as described in the case studies might only emerge in the future. As the supply of biomass is expected to grow (see **Table 1** above), relative biomass demand of the case-studies will be lower in the future.

The table shows that the biomass which potentially can be used by the case studies makes up 47% of the total wet matter biomass sourced from the agro-sector. Due to the low dry mass content in some of the organic materials, the percentage for dry matter (48%) is slightly higher. By far the largest flow of biomass – 16,000 kton ds or 37% of the total in the Netherlands – originates from the cultivated grass case. The main reason for this finding is that it is assumed that the grass yield will increase from 8 to 16 ton ds per hectare (see case study description). Other case studies for which a relative large supply of biomass is potentially available are grass from natural land and road verges*,* low protein content residues and sugar beets and beets foliage*.* Rape seed meal and damaged carrots are relative small case studies measured by the size of potential biomass that is available as supply.

Case study	Supply		Share of total agro biomass in NL	
	Kton wet	Kton ds	Kton wet (%)	Kton ds (%)
Biorefinery of residues				
Damaged carrots*	27	3	0.0%	0.0%
Grass from natural land and road verges*	4,300	1,720	2.2%	4.0%
Low protein content residues*	2,000	1,200	1.0%	2.8%
Wheat middlings	690	600	0.3%	1.4%
Brewers' and distillers' grain	540	124	0.3%	0.3%
Biorefinery based on domestic crops				
Sugar beets & beets foliage*	4,800	480	2.4%	1.1%
Cultivated grass*	80,000	16,000	40.2%	37.2%
Potatoprotamylasse*	419	251	0.2%	0.6%
Maize protein	NA	NA	0.0%	0.0%
Biorefinery of bulk imported biomass				
Rape seed meal*	113	100	0.1%	0.2%
Total Biomass: case studies	92,889	20,478	47%	48%
Total Agro Biomass in NL	198,870	43,065	100%	100%

Table 2*: Biomass supply for each case-study*[26]

Table 3 breaks the biomass flow down in a number of key components, including fibres (cellulose, hemicelluloseand lignin), starch, carbohydrates, fats, proteins, ash and other. This approach is in line with the previously indicated driver for higher added value applications, namely biorefinery of biomass into separate components.

One of the most important components for (future) food supply are proteins. Not surprisingly the two grass cases are associated with the highest supply of protein, followed by wheat middlings, low-protein content residuesand sugar beets and beets foliage.

The figures in **Table 3** reflect the supply of biomass for the case studies that is theoretically available in the Netherlands. The actual availability is, however, not guaranteed. For several cases the availability of

[26] Source: own calculations and Koppejan et al. (2009); Elbersen et al. (2011). Note: Total agro biomass is taken from Elbersen et al. (2011) but additional supply of biomass is added for case studies with * that were not covered by that study. To avoid unnecessary complications it is assumed that grass from natural land and road verges is part of the agro-sector. See Koppejan et al. (2009) for another classification.

residues depends on the development of specific processing or collecting technologies, as well as logistical concepts, that are not yet available for (commercial) operation. These include sugar beets and beets foliage, damaged carrots(technology to screen carrots), low-protein content residues(collection of wheat and colza straw), and grass from natural land and road verges (harvesting of grass). The case study summaries provide more information. For other case studies the biomass is already available but used for other purposes, mainly feedstock for animals. This applies to the cases potato protamylasse and brewers' and distillers' grain. As indicated in the previous chapter, whether the biomass will eventually be collected and/or used for the case studies depends on a number of factors.

Case study	Cellulose	Hemi-cellulose	Lignin	Starch	Carbo-hydrates	Fats	Proteins	Ash	Others	Total Kton ds
Biorefinery of residues										
Damaged carrots	0.08	0.14	0.03	1.99	0.06	0.01	0.27	0.15	0.00	3
Grass from natural land and road verges	466.09	404.08	62.00	0.00	173.73	58.55	118.00	149.73	287.81	1,720
Low protein content residues	120.00	240.00	240.00	0.00	0.00	60.00	96.00	120.00	324.00	1,200
Wheat middlings	90.00	90.00	30.00	136.20	45.60	24.00	102.00	34.80	47.40	600
Brewers' and distillers' grain	18.63	18.63	12.42	6.21	2.48	6.21	24.84	6.21	28.57	124
Biorefinery based on domestic crops										
Sugar beets & beets foliage	72.00	72.00	19.20	0.00	120.00	9.60	96.00	48.00	43.20	480
Cultivated grass	3200.00	2400.00	576.79	0.00	1616.00	800.00	2676.79	1392.86	3337.57	16,000
Potato protamylasse	5.03	5.03	5.03	12.57	37.72	10.06	50.29	50.29	75.43	251
Maize protein	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Biorefinery of bulk imported biomass										
Rape seed meal	15.00	10.00	10.00	0.00	10.00	5.00	35.00	9.00	6.00	100
Total Kton ds	**3986.82**	**3239.88**	**955.47**	**156.97**	**2005.59**	**973.43**	**3199.18**	**1811.04**	**4149.98**	**43,065**

Table 3: *Biomass supply broken down by component for each case-study (k ton)[27].*

9.2.2 Potential economic and environmental impact

As was mentioned above, for the data presented in this study it was not possible to run a CGE model that takes into account all interactions in a (global) economy. Therefore, an alternative approach was used. The essence of most case studies is that separating organic materials into sub-components (e.g. fibre, protein, starch and sugar) leads to a more efficient use (material flexibility and interchange ability). In most cases this means that maize and soy which is presently used as feedstock for animals can be replaced by protein from other sources, or one of the other components. In some of the case studies also wood sources are substituted because fibres can be extracted from other available biomass sources as well. To capture these substitution processes we consistently compare the case studies (where relevant) by three reference sectors: maize (in the Netherlands), soy (from Brazil) and forestry (in the Netherlands). For each of the sectors key figures on land use, energy, phosphate use and nitrogen use are collected. This information is subsequently used to estimate the footprint of the case studies. **Annex 8** presents more information on the methodology.

Table 4 shows the potential impact of the cases on the ecological footprint in case they would materialize in the future. The footprint analysis includes both environmental indicators (land use, energy, phosphate use and nitrogen use) as well as an economic indicator (employment). The estimations for land use are net figures, which mean that both the extra land that is needed for the case studies and the

[27] Source: own calculations. Composition shares by type of biomass and total biomass from Elbersen et al. (2011).

land that is saved in Brazil and/or the Netherlands because of substitution is accounted for. All the other figures are in gross terms as no information on energy, phosphate, nitrogen and employment in the reference chains is available. The net footprint would have been lower if such figures would have been included because substitution of soy, maize and forestry production by the case studies would be accompanied by energy, phosphate and nitrogen savings in the reference chains. Equally, however, the net demand for labour would also decrease as a result of substitution effects. It is not possible to estimate the footprint for all cases due to a lack of detailed information.

The table shows that the case studies have the potential to save almost 4 million ha of land in Brazil and the Netherlands, which otherwise would have been needed to grow maize and soy for the production of feedstock and the plantation of trees for the production of wood. The largest reduction in land use is caused by the cultivated grass case*,* which has the potential to generate a large amount of protein. Other cases that have the potential to decrease the pressure on land use are the maize protein, wheat middling and low protein content residues*.*

Apart from savings in land, it is estimated that the cases will also lead to savings in energy and phosphate. However, to increase the production of natural and cultivated grass, it is expected that there will be an increase in the demand for nitrogen. Finally, all the case studies together can generate about 9000 jobs in the Netherlands.

Case study	Area (ha)	Energy (TJ)	Phosphate (ton)	Nitrogen (ton)	Labour (FTE)
Biorefinery of residues					
Damaged carrots	- 649	3	-	-	-
Grass from natural land and road verges	- 18,743				
Low protein content residues	- 80,000	1,600	-	8,000	2,400
Wheat middling	- 91,454	- 117	- 4,695	- 516	150
Brewers' and distillers' grain	- 12,351	-	-	-	-
Biorefinery based on domestic crops					
Sugar beets & beets foliage	12,000	- 4,800	-	- 6,000	800
Cultivated grass	- 3,335,711	-	- 40,000	250,000	5,000
Potato protamylasse	- 4,500	- 250	-	-	10
Maize protein	- 360,000	- 1,500	-15,000	-45,000	600
Biorefinery of bulk imported biomass					
Rape seed meal	- 14,037	-150	-900	-750	15
Total	**- 3,905,446**	**- 5,215**	**- 60,595**	**205,734**	**8,975**

Table 4: *Potential impact of case studies on ecological footprint and employment*[28]*.*

9.3 Concluding remarks

This chapter analysed 11 cases that can contribute significantly to the development of the biobased economy and a sustainable use of biomass resources in the Netherlands. These cases were selected because of the potential to create high added value through the biorefinery of biomass resources. For each of the cases a qualitative assessment was undertaken to identify opportunities and constraints for

[28] Note: positive numbers mean an increase (additional use), negative numbers imply a decrease (saving). Because no information on energy, phosphate, nitrogen and employment in the reference chain is available, the possible saving in the reference production chains are not included in the results.

implementation combined with a quantitative assessment of the ecological footprint and economic impact.

On the basis of the analysis, the case “cultivated grass” clearly provides the most positive contribution in terms of relative importance and expected positive environmental impact and employment. Potentially, cultivated grass makes up more than 37% of total biomass available in the Netherlands. When processed in a biorefinery unit, it can reduce land use with more than 3 million, create around 5000 jobs and reduce the supply of phosphate that otherwise would have been imported as part of soy imports from Brazil. On the other hand, the cultivated grass case will require a large amount of additional nitrogen to increase the productivity of the land[29].

Another case that has the potential to reduce the ecological footprint and contribute to employment is the maize protein case, which leads to a considerable reduction in land use, energy, phosphate and nitrogen and has the capacity to create 600 jobs. Also the low protein content residues case can lead to substantial reduction in the pressure on land and many jobs but will demand the use of more nitrogen.

As all of these cases are still in the development pilot phase or even conception phase and data availability is limited, this analysis in this chapter is preliminary. The outcomes should not be regarded as actual predictions or exact. Instead, they present a broad picture of the relative importance of the case studies and directions of impact. It is a first step in a trajectory to facilitate the transition from a fossil-based to a bio-based economy, and can act as a source of inspiration for new entrepreneurs.

The authors of this report recognize the fact that the long-list of potential cases can easily be extended with opportunities that follow from other waste streams or (dedicated) crops. A next step may therefore be to bring together interested stakeholders on a regular basis and let them freely formulate new ideas around this topic. Thus, enthusiasm and new ideas will be created to further work out the cases into real business opportunities. This initiative may be combined with a full macro-economic impact assessment of the case-studies (and other potential new bio-refinery technologies) on economic growth, international trade and environmental footprint in the Netherlands (e.g. Platform Groene Grondstoffen, 2009), which was out of the scope of this study. Such an analysis requires the formulation of scenarios that reflect future uncertainties combined with economic models that capture the interaction between new bio-refinery sectors and the rest of the (bio-based) economy, and the influence of international markets.

[29] The cultivated grass case has been embraced by the Dutch Biorefinery Cluster as pilot for higher end valorisation. Its pilot project Grassa will try to develop high level protein ingredients for the feed industry. See www.grassanederland.nl

10 Roadmap towards integrated valorisation of biomass resources

"As for the future, your task is not to foresee it, but to enable it"
(Antoine de Saint-Exupery)

"When it comes to the future, there are three kinds of people: those who let it happen, those who make it happen, and those who wonder what happened." (John M. Richardson)

"'Ask him for some wood,' she said. 'Food leftovers. And grass or straw. Old bones. Everything that once lived. I have a plan, but that means that we need to feed the dumbwaiter.' They were using the dumbwaiter as wood factory. When the first arrow-straight yards of board were appearing from under the machine's lid, the whole colony set to work. Large tresses of seaweed were thrown in the feeder belt of the dumbwaiter […]." (Terry Pratchett, Digging)

Ambitions including the transition towards an integrated valorisation of biomass resources and by-products are high. To achieve these ambitions, we need to understand the interrelations between the application domains food, feed, functional materials and fuels, and develop an integrated approach based on the interconnectedness of these domains. A roadmap can assist in providing descriptions and guidance for each step on the way to the ambitions. The roadmap presented in this report intends to contribute to this understanding and inspire companies, research institutes and governmental organisations to develop strategies and actions to follow this road to transition. It indicates the actions that need to be undertaken now to enable 2 x more with 2 x less in 2050.

One of the main barriers for transition is the way people, organisations and society tend stick to what they already know and are convinced of. A lacking sense of urgency slows down innovative processes. Convincing people that things are otherwise than they have always believed, may prove difficult. Imagination and inventiveness are human competences that ensure continuous development. A roadmap can help structure creativity and make activities explicit to enable discussion and implementation.

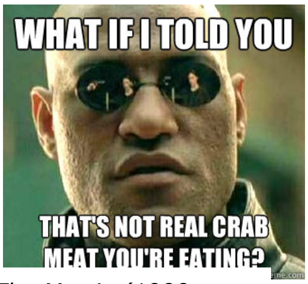
There are a number of conditions to create a sense of urgency, apart from the apparent, visible and immediate effect of disasters. These are:

- Problem awareness by a significant and relevant group of people
- Ownership feeling
- Perceived ability to contribute to solution
- Inspiration, knowledge and means to take actions

Inspiration comes from many places:

Star Trek food synthesiser (Original series 1966-1969, courtesy Paramount Television)

Soylent Green (1973, courtesy MGM Motion Pictures)



The Matrix (1999, courtesy of Warner Bros. and Village Roadshow Pictures)

Inspiration is not something to be planned orderly, since few inventions originate behind a desk, but the chance of inspiration increases when you go into new surroundings, meet new people, or acquaint yourself with new (artistic) content. This report intends to inspire business as well as research and government, to take a step back from day-to-day activities and consider new options to enable a more sustainable future within the use of biomass resources. The roadmap towards sustainable use of resources, emphasising the integrated valorisation, contributes to solving resource scarcity, competing biomass application demands and sustainability issues including climate change and population growth. The roadmap is introduced below. Firstly by charting road mapping as methodology, next the context of the roadmap presented in this report, as well as the outline of the roadmap including the description of the different stages, transitions, barriers and opportunities.

> Successful businesses adapt to changing market realities and regulatory environments. They have learned when to lead and when to follow. And they have reached out to new resources, both natural and human, in order to transform themselves and their products to serve a new world.
>
> Experimentation and creativity have been the most renewable and sustainable resources for this transformation. Creativity has been sought and found in product development, as always. It has also been sought from customers, governments, suppliers, neighbours, critics and other stakeholders.
>
> Where companies have succeeded in tapping new sources of creativity, success has come from these new directions, and it has happened because the business culture has been open to new ideas.
>
> WBCSD, 2012. Vision 2050.

10.1 Roadmap as methodology

To draw a metaphor, a roadmap is basically a detailed description of the way to the destination of a journey and an explanation of relevant waypoints. As with travelling, you can bring along a travellers' companion handbook, indicating the do's and don'ts and some outlines of the climate, culture and historic/economic background. As with a real journey, the start is from familiar surroundings, of which many details are known, and whose changes are seen on a day-to-day basis. Further along the road, indicated points of interest can be visited (or missed/skipped). Milestones which sounded promising from the planning table, only become clear when approaching them. In scientific literature, road mapping is used to explain the prioritization of future research (funding) (Weinberger *et al.*, 2012). It is put to use as a tool to promote continuous investment and cooperation in (clean energy) research, development, demonstration and deployment (McDowall, 2012). It is used for policy, strategy and business development, including visions, ambitions and key milestones and activities towards the goal destination. These road mapping efforts are also described and analysed by science. Important recommendations to improve the use and implementation of road maps, especially considering those for technology development, do not focus on the content of milestones or ambitions, but indicate that road mapping for transitions need to place greater emphasis on ensuring good quality and transparent analytic and participatory procedures (McDowall, 2012).

Limitations of roadmaps

Roadmaps are built upon contemporary knowledge and as such are subject to advancing insights and developments. This means that this roadmap should not be considered as a blueprint where concrete steps exactly lead to defined goals.
External (partly unpredictable) developments will change the context for the developments; these will affect practical development of the production system and markets for food, feed, fuels and materials. For example, the continuing financial crisis in Europe, threatening economic recession, widespread social unrest and regime changes throughout Europe, and the toll that many natural and man-made disasters continue to take largely affect the appreciation of sustainable innovations. Also varying appreciation of sustainability (and prioritisation of various criteria) will affect preferences for specific developments in the markets and society (Broeze et al., 2012).
Furthermore, also complexity of the agro-food system prevents the exact prediction of the developments. For instance, upcoming of alternative market demands for specific biomass streams will

affect prices and hence potentially stimulate or frustrate specific developments (think of the recent increase of biomass prices simultaneous to upcoming biofuel systems; this price increase was possibly partly due to that development, but anyway has somewhat frustrated bioenergy initiatives).

10.2 Connections to other Roadmaps

In recent years various roadmaps for the development of the biobased economy and sustainable use of resources have been formulated. They come from different sources (research, business, policy), are more general ("sustainability"; "biobased economy") or more specific by nature. There are practice oriented roadmaps and more reflective roadmaps in scientific body of literature (also reviewing conditions, criteria and effectiveness of road mapping). They include comprehensive overviews of needs and necessary activities to achieve them. We specifically want to highlight 7 of them, which have been an inspiration for our own work:

Research/technology oriented roadmaps

1. European Biorefinery Joint Strategic Research Roadmap (Star-COLIBRI)
2. Opportunities for Dutch Biorefineries (Annevelink *et al.*, Wageningen UR)
3. " Toekomstverkenning transities tot 2040 voor de topsectoren Agrofood en Tuinbouw vanuit logistiek perspectief" (Van der Vorst, 2011).

Business oriented

4. "Naar Groene Chemie en Groene Materialen", report of the Scientific and Technological Committee for the Biobased Economy (WTC Biobased Economy, 2012).
5. Een punt op de horizon – Aanzet voor een intersectoraal Businessplan Biobased Economy (2011).
6. "Vision 205", and "Changing Pace"; reports from the World Business Council for Sustainable Development (2012).

Policy oriented

7. Roadmap to a resource efficient Europe / Horizon 2020, from the European Commission (2010-2012).

Most documents aim specifically at biobased developments (roughly the domains functional materials and fuels). These roadmaps provide a comprehensive and complementary overview of the needs and necessary actions to achieve the full potential of the biobased economy. Although these apparently seem similar to the message of this report, the scope, context and ambition of the roadmaps differ: the roadmap presented in this report takes the combination with the domains food and feed in account. Some further explanations of the listed roadmaps:

- The first four documents primarily focus on the further deployment of the biobased economy in terms of required technology and product development aimed at non-food applications (functional materials and fuels in our terminology). The integration with the domains food and feed, and the potential benefits this may give, has attracted less attention (although the transition to a safe food production system has been separately mentioned in "Een punt op de horizon").

- More specifically: The EU Star-COLIBRI document provides very valuable recommendations for Innovation and Support Actions (*"what needs to be done"*). The answer to the question "*how this should be realized"* has been left open.

- The WTC Biobased Economy document gives an answer to this question within the context of the Netherlands. The focus, however, is on the establishment of large programs like Programma Katalyse, Programma Bioraffinage and Programma Agro & Logistiek.

- "Een punt op de Horizon" mentions the importance of business cases to establish a system of market-driven innovations. The report even defines three concrete ones, however, without providing information how these business cases can be brought into reality.

- The Roadmap to a resource efficient Europe does not specifically address the potential of biomass by-products valorisation; with respect to food production, arguments are limited to reducing environmental impact of food production.

Roadmaps for the feed and food domains are rare. Most relevant examples are:

- The EU *High Level Group on the Competitiveness of the Agro-Food Industry* has formulated a 'Road map of key initiatives'[30]. This "roadmap" addresses various subjects related to the food production chain (from sourcing concerns and measures to consumer preferences). It does, however, not address developments or relationships with other domains than Food.

- The project "Agro & Food Systems Roadmap Zuidoost-Nederland"[31] initiative focuses on innovations within the regional agro & food industries, aimed at practical implementation of scientific knowledge in food industries.

10.3 The roadmap

Roadmap format

The format of the roadmap has been derived from the generalized technology roadmap architecture, as developed by the Centre for Technology Management of the University of Cambridge (Phaal *et al.*, 2001). The information used to fill the roadmap has been gathered from the sources mentioned in the previous chapters.

In the creation of the roadmap for this project a three-step back-casting approach has been used (similar to the approach that was used in the Delft Skyline Debates (Phaal *et al.,* 2001), containing the following elements:

- Definition of the beacon(s)
- Milestones
- Activities (short & long term)

Important examples on ambitions and strategies were presented in **Chapter 5** (vision). These form the basic outline for the milestones of the roadmap. **Chapters 6 to 9** provided the specific additional input on objectives and activities.

1. *Definition of the beacon(s) in 2050: Global ambitions*

For this project, the beacon is defined as "2 times more with 2 times less" in 2050, i.e., by then all agro-production systems have to be 4 times as efficient as compared to their current performance. Into more detail this means:

- Increase the valorisation of biomass with 100% through integrated utilisation and maximization of the value of its constituents on the different application domains Food, Feed, Functional Materials and Fuels.
- Reduce the required inputs by 50% through minimization of water and energy consumption, land use and cycle closure for the NPK-minerals

2. *Key Milestones:*

   Definition of (technological) achievements that have to be accomplished by or around the year 2030 in order to reach the beacon in 2050. For this purpose, different milestones that are mentioned in **chapter 5** are summarized as halfway achievements.

---

[30] Accessed through http://ec.europa.eu/enterprise/sectors/food/competitiveness/high-level-group/documentation/index_en.htm

[31] Accessed through www.agrofoodsystems.nl

3. *Short and longer term activities:*
   Definition of the objectives that should be achieved in order to realize the key milestones. For the short term the formulation of these activities is more specific than the description for the longer term activities.

The roadmap as developed within this project is founded on 2 major pillars, based on the elements described above. The first pillar describes the basic trends and objectives of the intended transition towards integrated valorisation of biomass resources and by-products. These ambitions are based on the outcomes of **chapter 5** and are summarized in **figure 5**. The activities towards these ambitions are also summarised in this figure. It gives an overview of the current challenges in the application domains as well as an outline of the objectives for 2050. This pillar depicts the contents of the roadmap.

2012 | **2020** | **2050**

Trends

Growing demand for animal protein
1 billion people malnourished
Food waste >1.3 billion tons/yr
35jK required for each kJ food intake.

Unstustainable production methods for animals protein
Accumulation of minerals from manure in soil and water
High emission of ammonia and GHG
Ecological pressure on ecosystems.

Declining fossil resources
Development activities impeded by competition with biofuels.

Declining fossil resources
First generation biofuels in competition with food.

General principles to stimulate innovations

Upgrade applications of biomass on the value pyramid.

Integral processing of biomass into a cascade of marketable products according to value pyramid.

Biorefinery concepts to increase raw material flexibility and interchangeabililty.

No transportation and concentration of components without further downstream application.

Aim legal and financial regulations at further optimization; prevent lock-ins.

Establish new partnerships within the Golden Triangle.

Stimulate small-scale initiatives to enhance entrepreneurship.

Short term objectives

Increase valorisation of byproducts also for food domain.

(NL) 1 bn turnover from byproducts (NL) 20% more efficient use of raw materials (NL) 30% less GHG.

Convert food industry by-products and household organic residues into Feed, Functional materials and Fuels.

(NL) increasing separation efficiency from 3 to 25% for manure and digestate into valuable components.

(NL) reduction of CO_2 emission of 11.6 Mton
(NL) reduction energy use 171 PJ (EU) 30% of overall chemical production is biobased.

(EU) 10% renewable energy (biofuels).

VISION
2 times more with 2 times less

Integral valorisation of biomass for all domains.

Production with safe environmental operating space.

Food based on sustainable, renewable and alternative sources (insects, algae, etc.).

Closed loop cycles for water and minerals (NPK).

Agricultural production of (dedicated) biomass for feed, food, fuels and entire spectre of functional materials.

Ample supply for everyone.

(NL) 30% of fossil energy carriers replaced by biofuels.

Legend: Food (green) | Feed (light blue) | Functional Materials (orange) | Fuels (dark blue)

***Figure 5**: Overview of the current agenda on the domains Food, Feed, Functional Materials en Fuels, coupled to the short and long term objectives (as formulated in previous chapters) and the vision on 2050 of the project team.*

As described in **Chapter 5**, the transition from the as-is situation to a fully developed biobased economy is most likely to be accomplished through a number of steps which are already more (stage 1 and 2) or less (stage 3 and 4) under development. Since the described stages were focusing mainly on a non-food perspective and also not from the integrated valorisation of biomass resources based on the hierarchy of the value pyramid, we broadened the stages to include these aspects as follows:

- Stage 1: Increase efficiency of use of conventional agricultural, fossil and mineral resources in all application domains, including efficient valorisation of by-products (primarily for feed). Focus on improvements within application domains and valorisation on lower application levels.
- Stage 2: Replacement of products based on unsustainable conventional (fossil)resources by sustainable biomass derived products (e.g., bio-ethanol and bio-ethane). Focus on renewal/innovation within application domains and initiating valorisation on higher application levels (starting point for exchange and integrated approach).
- Stage 3: New processing routes and ingredients matching functional needs along the value pyramid. Innovations for increasing the availability of high-value products/ingredients for multiple high level applications targeted at food en feed levels. Replacing feeding animals with protein resources which are fit for human consumption with protein content from non-food resources. Replacement of animal proteins by plant proteins for human consumption. Development of new, mild processing routes for functional intermediates and products, utilising complexity of biomass (molecular complexity for functional fractions in the food/feed/functional materials domains). Generation of new (fundamental) knowledge in the field of catalysis, enzymes, fermentation as well as separation technology to enable new processing routes for intermediates and final products.
- Stage 4: Implementation of the integrated optimised system for valorisation of biomass, based on the complexity of biomass and the value pyramid. Dedicated and combined agricultural production of biomass for food, feed, fuel and the entire spectre of functional materials; implementation of the integrated systems for valorisation, diffusion of innovations throughout value chains and application domains.

These stages describe the content-wise activities and are linked with the halfway goals and objectives along the road to 2050 (**figure 5**).

The second pillar describes the development process how the objectives can be reached, indicating the steps of the roadmap. This particular type of roadmap is inspired by classic transition and innovation theory[32], and draws on the lessons learned in the previous chapters. This pillar contains the pathways (structure) of the roadmap and is visualised in the **figure 6**.

[32] The scientific body of literature sees different periods or schools of thought about the definition and description of innovation processes. The view and roadmap outlined in figure 6 are adapted from Rogers (1988) and Kemp & Rotmans (2004).

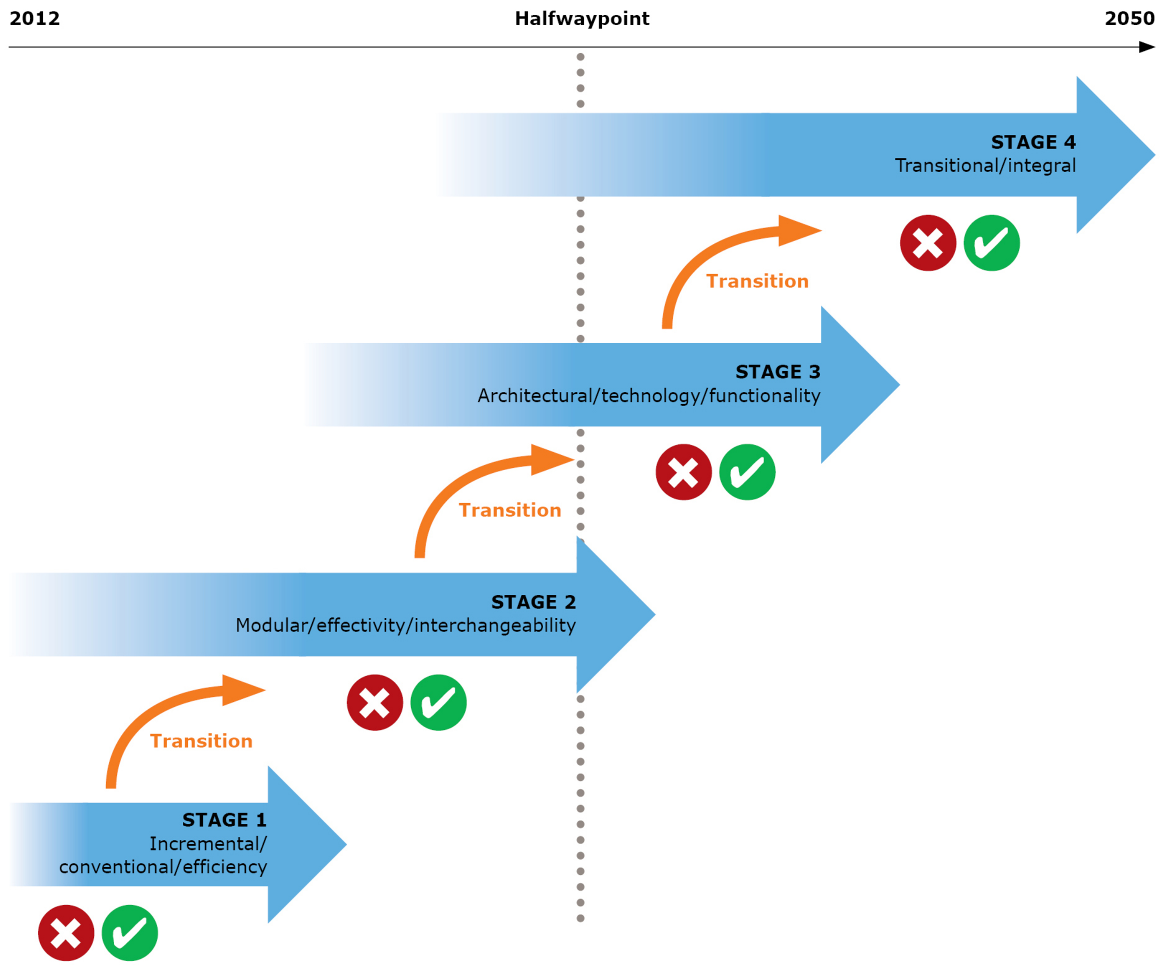


Figure 6: *Roadmap integrated valorisation of biomass resources*

Below an explanation of the stages in the transitional development process is given, including practical bottlenecks and opportunities for development of the stage, and institutional barriers for transition between stages.

Stage 1: Increase efficiency of use of traditional agricultural, fossil and mineral resources and valorisation of by-products

At stage 1, optimizations are developed within the boundaries of the existing system and within the application domains. Typically, this involves incremental changes, aimed at increased efficiency of conventional value chains. There are exchanges between the domains, but they are targeted at lower levels of valorisation. It includes the valorisation of residue streams from the agro-food sector into existing and relatively low added-value applications (e.g., feed or biogas). Most existing relations between parties in the value chain are economic, contract based relations, not targeting cooperation for innovation as key driving factor.

Bottlenecks:

- A lack of sense-of-urgency exists within the established value chains: many companies earn enough money with their primary product(s), and waste and side streams have low priority.
- Worries about sustainability of solutions such as loss in biodiversity, indirect land use change, social conditions of workers abroad, decay of tropical rain forest, and the food vs. fuel debate.
- With an eye on the economic relevancy of the primary product, there is a general fear that changes in the process may affect the primary product quality.
- Current stimulation framework favours low added-value applications (bio-energy), neglecting potential sustainable development opportunities through other valorisation routes. Because of

subsidies on bio-energy, the bio-energy has become primary product of biomass plants, whereas bio-energy could still be a valuable by-product after extracting other (more valuable) materials.

- Mono-disciplinary approaches: focus on efficiency with respect to the primary product has distracted attention from by-products. Common business development is often focussing on adding value to primary products, and reducing costs for side and waste streams. Searching for added value to the by-products is mostly delegated to 'by-product traders': they have no (or minimal) influence on their suppliers' process. This hinders practical developments on by-product valorisation.

Opportunities:

- Economically sound business cases exist (although practical development is hindered by bottlenecks mentioned above).
- Current knowledge base is adequate (although part of this knowledge is academic, where practical implementation is limited: innovation paradox).
- Increasing awareness of sustainability issues affects entrepreneurs' vision on market developments and technological challenges. On one hand entrepreneurs have a growing interest in sustainable marketable products (and product image), on the other hand entrepreneurs anticipate to expected scarcity of resources, higher energy prices and increasing costs for waste.
- Growth of scale sizes has reduced traditional by-product valorisation routes (e.g. traditional mixed farm) but forms a suitable context for innovative by-product valorisations.

Transitional barriers towards stage 2

The transition towards stage 2 is aimed at initiating higher level applications of biomass resources (specifically by-products and organic residue flows) as new protein/carbohydrates/oils sources or ingredients. This includes moving away from the application of biomass resources or by-products used within biofuels productions towards feed and food applications. A known example is the switch from first to second generation biofuels. The discussion 'food – or – fuel' is typical for this transitional phase.

Main barriers identified:

- Sense of urgency to go to higher application levels (e.g. fuel to functional materials) is missing amongst business actors, mainly driven by short term profit orientation and uncertainty of front running strategy.
- Regulatory boundaries are adapted to common practices (e.g. minimising food safety risks and ecological problems): many rules dictate methods and means, thereby reducing potential alternative valorisation routes.
- Economic viability of new opportunities: subsidies for traditional applications (including biogas) hinder alternative uses of biomasses.
- At the same time production processes and markets need to be developed.

Stage 2: Replacement of products based on unsustainable conventional resources by biomass based products.

Stage 2 includes the introduction of biobased products replacing fossil sources, and it is an intermediate step towards integrated valorisation of biomass for food, feed, fuels and materials. It depicts the learning stage for transition towards biobased production of fuel and functional material application domains. It also signifies the start for replacing traditional and conventional animal protein based food products and ingredients, discovering the potential for alternative sources (including insects, algae, etc.) for Food applications, but also for fuel and functional materials, replacing food ingredients by lower value input flows.

Typical developments in stage 2:

- Modular changes, in which parts of the existing system (including raw materials) are replaced by alternative options. Existing by-products in new applications. The overall architecture of the system, however, remains the same.

- Applied research: improved knowledge on components, composition and functionalities, searching for alternatives which offer similar functionalities (e.g. interchangeability: biobased and fossil based resources, plant and animal derived proteins)

- Cooperative relations between value chain stakeholders
- New markets open up
- Increasing flexibility of materials & people
- Looking for added value to compensate for higher cost prices than for fossil-based materials (e.g. through lower end-of-life costs and through eco-image advantages).

The cases described in this report (**chapter 8**) are linked to this stage.

Bottlenecks:

- Introduction of biobased products requires multiple innovations: production, trading and application, where all stakeholders are facing new issues (e.g. bio-variability, seasonality, quality management, etc.).
- Matching the small scale of farmers with the large scale of industry is a challenge. Linked to this are logistic questions.
- Lack of knowledge on the chemical, structural and/or functional comparability with existing / conventional products (or improved performance)
- Competition with incumbents, based on market entry, product comparison (cheaper, volume, availability, performance/quality. Availability and access to external (formal) funding: especially banks are risk adverse, and context of financial crisis.
- Lacks of trust within value chain, stakeholders are unsure that win-win situations across the value chain can be reached (uneven distribution of risks and profits).
- Knowledge fields on biobased materials and fuels are relatively new. Many technologies are still in R&D phase. Positive results at the R&D stage may lead to over-enthusiasm, which may result in practical deceptions.
- Because of the high speed of knowledge development early adopter may quickly lose competitive power.
- International competition (especially from countries with lower prices/costs of agro-products).
- Consumer acceptance of alternative sources for food and feed products/ingredients
- Legislation on novel foods, hygiene regulation and environmental emission standards.

Opportunities:

- Existence of developed organic chemical industries: ability to change from fossil to biobased input. Using the complexity of available molecules
- Existence of cross-sector consultative platforms which create networking opportunities; organising 'network meetings', improving stakeholder relationships
- Increasing awareness that an individual company cannot solve the sustainability issues by itself, but needs partners (consortium) to develop new sustainable solutions.

Transitional barriers towards stage 3

In this transition added value for biobased products (as developed in stage 2) is obtained through high-tech processing, so higher-value applications can be attained based on the biomass. Typically the type of developments in stage 2 can be associated with 'primary biorefinery' (possibly small-scale); the developments in stage 3 fit more to the high-tech specialised character of a large-scale knowledge-intensive industry.

The transition from stage 2 towards stage 3 can be considered as the halfway point. Here, concrete and foreseeable detailed actions become more abstract and unpredictable. Critical issues to be addressed during the transition towards stage 3 are the following:

- Local vs. global logistics: fresh biomass needs to be processed quickly; competition with cheap international bulk imports

- Small scale vs. large scale: proximity as quality or legislative argument, cost-volume and/or environmental impacts based technology and logistics decisions, or does it remain/become a mix?
- Increase biomass availability through the inclusion of new biomass resources of alternative origin (e.g. algae, insects, bacteria/fungi, etc. for food and feed).

Main barriers identified:

- Need for sufficiently developed supplying value chain.
- Dependency on R&D in multiple domains: breeding (e.g. varieties of crops/animals with increased yield of the functional ingredients), processing (extraction, purification, modification, etc.).
- Intermediate products are less visible for the consumer: a price-competitive market.
- Alternative ingredients/formulations of food may hinder broad consumer acceptance.

Stage 3: New processing routes and ingredients matching functional needs along the value pyramid

Except for some specific processes by biotechnology companies, stage 3 type activities lie in the further future. These developments will build on developments in stage 2: typically adding value to products from the 'primary refinery steps' (stage 2). In stage 3 higher value applications of ingredients and products can be reached through advanced, mild processes routes and technology, typically for:

- functional materials, utilizing complexity of bio-molecules,
- functional fractions for food applications. Mild separation processes will bring less purified/refined fractions than the traditional highly refined food intermediates; adequate tuning of the separation process to the application will be sufficient to meet the end products' quality standards. Result is large saving on water and energy, and possibly higher product quality because of the milder processing conditions.

These developments will increase complexity of the food system: adding value steps will lead to the development of new/additional and specific requirements to the biomass resources as input for the system: these will possibly include specific preferences or requirements with respect to the biomass properties and primary refinery processes.

Typical properties:

- Architectural innovation: In stage 3 the architecture of the system is changed, leading to a new overall process design. This type of changes typically requires the development of new technologies.
- Activity: screening existing knowledge development roadmaps to assess their potential to make a balanced, integrated decision what to stimulate and facilitate from a multiple stakeholder perspective, integrating needs and interests from business, research institutes and government.
- Clustered relationships within and between value chains. Economic relations have more influence than other external stakeholders relations, although negative public pressure (via consumers decisions or opinions from civilian non-governmental organisations) can influence the decision process heavily: end-user acceptance is influenced by these public debates and therefore influences the commercial viability of new/alternative products.
- Effective production of functional materials and fuels, utilising molecular functionality of the biomass materials (using functionally-optimised crops).
- Producing high-quality proteins based on alternative sources (for food and feed).
- Applying mild separation processes: next to intensive processing routes[33] milder routes are introduced: less intensive fractionation processes will result in non-pure streams; attention should be paid to an appropriate fractionation efficiency, to make the components adequate for the intended application(s). This development involves closer relationships between ingredient supplier and food producer.

[33] Isolation of pure components like starch and proteins from crops, including energy-intensive drying processing, followed by mixing again later in the chain

Bottlenecks:
- The innovation paradox: difficulties in translating fundamental knowledge into applied knowledge and practical implementation
- Short term strategies from stakeholders where a visionary, long term orientation is required combined with entrepreneurial competences (including willingness to change, business competences and networking capabilities). Developing crop varieties with specific properties for these new markets takes long completion times.
- Need of more intensive relationships along the production and processing chain.
- A focus on specialty components or products could hamper the introduction into commodity market, but could also be targeted at more niche markets, with low-volume / high margin products.

Opportunities:
- High-tech industries generally have long-term vision and market strength.
- Joint research or open innovation research programs can map potencies of innovative processes for high-value product development from various biomass sources; combining potential suppliers, processors and potential end-users in such programs will stimulate this development in practice.
- Specialized products or components are more favourable in regional (here: Netherlands or regions within the Netherlands) production chains, since competition on commodity markets need high-volume and intensive production investments.

Transitional barriers towards stage 4

In the transition towards stage 4, the integrated valorisation of the crops is further optimised. Typically for this transition is the transition from production chains to production networks (where all by-products are appreciated as primary products).

Main barriers indicated:
- Lack of sense of urgency to go from one primary application towards an integrated biomass valorisation.
- Spatial distances between specialised production chains (focussing on one group of primary products).
- Economic viability of business case.
- Societal resistance / acceptance.
- The innovations require active involvement of parties in multiple stages of the chain (farmer, ingredient producer and food producer, and possibly up to the consumer with modified foods). Organising such joint developments is a challenge.
- Development of fundamental knowledge needs support from non-commercial sources to allow room for experimentation and learning processes. Targeted funding to develop both technological, logistics and network management knowledge at the base of integrated valorisation of biomass resources needs to be extended. It requires a multi-dimensional approach, combining the insights of various scientific disciplines.

Stage 4

In stage 4 the transition is completed: an integrated valorisation system for sustainable use of biomass resources for food, feed, functional materials and fuels, based on redesign of the value chain. Various components from the biomass are valorised, aiming for adequate purity & functionality. Characterisation[34]:

- From fundamental research towards proofs of principle: valorising the knowledge base will deliver more radical inventions needed to make the shift towards integrated valorisation of biomass resources. Connecting the science and business stakeholders with a focus on practical implantation. Within these more radical innovation processes, it has become clear that different

[34] These characterisations are based on chapter 5, and partly modified from WBCSD, 2012. Changing pace. Geneva.

stakeholders need to work in networks targeted at the value chain and combination of the four application domains to deliver successful new products and processes to the market.

- A combination of general and dedicated crops as biomass resources: where possible, varieties can be cultivated that increase the high-value application of components at the top of the valorisation ladder. Within general crops, the whole resource is used.
- Biomass resources, and specifically by-products or waste streams should be diverted from landfill or incineration applications. To accommodate these diversions, these biomass products should be marked as 'waste' as this implies barriers for higher-level applications. Reusing the biomass within the materials, feed and food domains, biomass resources will reach an "end of waste" status, making waste obsolete. Biomass resources will be included in a circular economy or closed-loop system.
- Integrated valorisation: upgraded valorisation in perspective of the value pyramid. Demands for low-value application at the bottom of the pyramid (e.g. soil fertiliser) are fulfilled through upgrading streams that are currently considered waste.
- ▪ Used products and materials, can be reengineered to function again for multiple and distinct purposes, or reduced to raw materials for manufacturing other products.
- ▪ The eco-efficiency of materials has, on average, improved by a factor of 4.
- ▪ Advanced materials enable resources hyper-efficiency in key sectors; for instance, in lightweight transport and renewable energy.
- ▪ Greenhouse gas emissions, energy and water use, are no longer constraints on the materials industry.

Bottlenecks:

- Integrated valorisation complicates business management, e.g. process modification for the benefit of one of the products will affect the other products as well (e.g. the servicing of very different application fields).
- Upgrading applications of by-products will introduce insufficiencies for low-level functions.
- Economic viability of business cases
- Difficulties with integration of multiple application domains perspectives and the organisation of cooperation along and between value chains.
- Redesign and restructuring will invoke resistance to change, especially without a non-clarified and specific sense of urgency and cooperation between stakeholders.

Opportunities:

- Increasing (social) interest in specialty applications of valuable, high quality regional/national biomass resources;
- Similar interests of food and feed producers (e.g. food/feed functionality) will facilitate developments.
- System boundaries will fade, making integrated valorisation possible in practice. Markets or resources will no longer be associated with sectors, but with applications and functionality. This leads to a focus on fulfilling needs of customers, instead of selling products to clients.
- The need for food security, scarcity of resources (both biomass as fossil) and a societal demand for sustainable development drive this transition towards integrated valorisation of biomass resources.

Overall remarks

The description and characterisation of the different steps in the roadmap towards an integrated valorisation of biomass resources reveals different barriers, bottlenecks and opportunities. A roadmap becomes less specific in describing activities and ambitions further away in time, so adequate use will require regular updates and monitoring mechanisms to evaluate and adjust the strategies of stakeholders towards 2050. A number of lessons learned in developing this roadmap can be summarised as follows:

- The redesign of existing, already fairly optimized production chains from one main product to optimal utilization of biomass with new resources and new applications is very complex and not an easy task for biomass availability issues. Vested interests and current economies of scales are critical barriers in each transition stage.

- Knowledge and technology development are important supporting factors for the transition towards an integrated valorisation of biomass resources. The translation from scientific knowledge to practical application should be based on market pull as well as on societal needs. Businesses need to be able to handle the new knowledge, and the translation towards application is a two-way communication process, targeted at involved cooperation.

- Next to translation, timing is important. Architectural, modular and transitional innovation activities are difficult to implement when existing markets function have created lock-ins based on low costs and high volumes within an oligopolistic or monopolistic market. The challenge is to get organizations in the value chain to cooperate for optimization of utilization and valorisation.

- Typically traders of by-products and new entrants have most direct interest in creating new added-value uses for their products. To break through lock-in situations, entrepreneurs from outside the vested interests are required. However, the technology and the processes are relatively complex for stand-alone SMEs or start-ups.

- Subsidies that aim to develop low value application of biomass inhibit/ hamper investments and knowledge developments for higher value applications of biomass resources. More result is to be expected from market driven experiment support, both legal as financial, combined with criteria setting for the granting of subsidies based on: involvement of value chain stakeholders, and cooperation between technological, financial, knowledge and network actors.

- For partnerships to be established, companies which have not been 'natural' partners so far, need to find each other. By-product flows within a region could be matched between suppliers and producers. This could take the form of round-table markets (where supply and demand of biomass resources are open on the table) or auctions. Criteria: round table approach, companies only, confidentiality ensured. The auction (or similar process) will not be self-organising: there needs to be a trigger / initiating party. This could be facilitated by government. There are many opportunities for companies to connect and network: when and if there is profit involved, the companies will come to talk business.

11 General conclusions and recommendations

This research project aimed to provide insights to stimulate the integration of food and non-food value chains. By presenting a new Roadmap towards integrated valorisation of biomass resources, new answers are formulated to some of society's urgent sustainability issues regarding the efficient use of resources. An overview of current trends and issues within the four biomass application domains (food, feed, functional materials, fuels) shows that this efficiency could be improved by applying a more integrated approach to the valorisation process, covering these domains. Following a stepwise roadmap, based on different innovation levels (from incremental to radical) and a hierarchy of applications (from high-end/high-value valorisation towards low-end/low-value valorisation), this transition comes within reach.

Each step towards the integrated valorisation of biomass resources encounters specific bottlenecks and barriers. These are technical, economic, environmental, but also social/organisational by nature. Already technologies are available or under development to facilitate the separation and conversion of biomass resources and by-products into valuable ingredients or components for a wide range of products. However, the application of these technologies needs to be transferred from single, demonstration or experimental units towards market-accepted and large scale applications. Also, much technology is based on improving existing products and processes, whereas we need new products and new processes to fulfil (near) future demands from resources. Starting today, we need to lay the fundamentals of future technologies that enable a further efficient and targeted use of biomass. Also, current processes still can harvest low-hanging fruits in effectiveness and efficiency, within energy or water use as well as using the opportunities from the whole of the biomass resource. These waves of technology development happen simultaneously, but not spontaneously. The 10 demonstration cases provide a good overview of existing developments, as well as potential for future developments. The 11th demonstration case (micro-algae) adds to the insight of the future potential of an entire new source of biomass.

For the short term, quick wins can be gained with the valorisation of existing by-product flows or waste-streams, using small-scale demonstration and pilot units. Small scale processing has the advantage that investments are relatively moderate, which makes these installations within reach for SME's. This approach fits into the vision that the time span of implementation can be reduced through new public-private partnerships: new energy can be created by bringing together sectors that have never worked together before.

Expert judgment as well as example cases point out that the government can serve as an important driving force in the realisation of the biobased economy, through:

- Formulating a vision on integrated sustainable development, with clear underlying targets
- Creation of new networks of stakeholders, and connecting existing networks in a multi-sectoral and disciplinary innovation process.
- Measures to stimulate continuous improvement and avoid lock-ins for low-value application
- Creation of room for experiments within existing regulations

We are not the first to present a new vision towards resource efficiency and the biobased economy. We add to this discussion by focussing on the interconnectedness of the biomass domains. Instead of singling out an application or technology, what happens in too many macro level explorations and future trends studies, we pay tribute to the interdependency of the application domains of biomass resources and by-products. In practice, many markets/applications operate in isolated worlds. In reality, the domains of food, feed, functional materials and fuels are interdependent. With the transition to a biobased economy, this interdependency will become even stronger. As a consequence, all claims on biomass for new applications must be evaluated on their impact on food security and environmental footprint.

Within this project, a more integrated approach is used to create synergies between the different application domains. The necessity for this transition is clear: targeting technology and economic efforts towards low-level applications of biomass is the wrong way round: first, high-level applications should be addressed, followed by creating closed loop supply chains through the lower level-applications. However, getting there is the difficult part: with each improvement, each innovative step, we should consider the consequences for developments on other domains and other innovation processes. Each market entry should be evaluated by criteria, including technology, economy, environmental and societal requirements and needs. These criteria need to be established between enablers and implementers, by stakeholders from business, government, knowledge institutions and the public. On the practical, individual level, networks need to be developed (either new ones or connecting existing ones) to understand mutual needs and to profit from each other's input and output flow. This happens from cradle to cradle, integrating the value chain.

Broad groups of stakeholders have been involved in the process developing the Roadmap presented in this report, resulting in:

- A vision on the integrated valorisation of biomass resources, with a special focus on by-product formulated from an academic perspective.
- A contribution from business perspective by several industrial experts to the formulation of bottlenecks and solution pathways in general and based on specific cases through elaborate discussion in expert judgment and workshops.
- 11 example cases have been presented for inspiration and demonstration, based on practical experiences and literature.
- These example cases were numerically analysed on economic and environmental impact to show the potential in a national context, clearly displaying the advantages of integrated valorisation based on economic and environmental factors.

This process has resulted in a roadmap that distinguishes 4 transition stages:

- Stage 1: Increase efficiency of use of conventional agricultural, fossil and mineral resources in all application domains, including efficient valorisation of by-products (primarily for feed). Focus on improvements within application domains and valorisation on lower application levels.

- Stage 2: Replacement of products based on unsustainable conventional (fossil)resources by sustainable biomass derived products (e.g., bio-ethanol and bio-ethane). Focus on renewal/innovation within application domains and initiating valorisation on higher application levels (starting point for exchange and integrated approach).

- Stage 3: New processing routes and ingredients matching functional needs along the value pyramid. Innovations for increasing the availability of high-value products/ingredients for multiple high level applications targeted at Food en Feed levels. Development of new, mild processing routes for functional intermediates and products, utilising complexity of biomass (molecular complexity for functional fractions in the food/feed/functional materials domains). Generation of new (fundamental) knowledge in the field of catalysis, enzymes, fermentation as well as separation technology to enable new processing routes for intermediates and final products

- Stage 4: Implementation of the integrated optimised system for valorisation of biomass, based on the complexity of biomass and the value pyramid. Dedicated and specified agricultural production of biomass for food, feed, fuel and the entire spectre of functional materials; implementation of the integrated systems for valorisation, diffusion of innovations throughout value chains and application domains.

Radical solutions are foreseen for the long-term future. Stage 4 will involve new combinations of parties with valorisation of different products (mostly combinations of food, feed, functional materials and/or fuels) out of one agro-product chain (including the whole-plant-concept). This development will be boosted by economic (e.g. increased prices), societal (e.g. climate change) and political drivers (e.g. anticipations to legislation). Awareness of technical as well as sustainability potentials (including externalities) will stimulate developments.

In that development process collaboration is a key word. Sector-crossing collaborations may lead to unexpected new opportunities. Large and small scale businesses need each other in innovation processes (with for example combinations of small-scale biorefinery supplying intermediate products to large-scale centralised plants). Although a lack of means (money, time, knowledge, personnel) are often mentioned (in literature and practice) as main barriers innovation and transition processes in small and medium sized companies or start-ups, it appears that many companies are able to overcome these shortcomings by enhancing the competences (including motivation) of their personnel and cooperation with stakeholders in the value chain. In general, the level of success of new ventures and innovations of a company are greatly determined by the motivation, skills and qualities of its employees. These can be influenced by the entrepreneur, through elements such as personal vision, communication and leadership style, work atmosphere, human resources development and employment conditions. Companies differ in their innovative approach, some more prone to introducing new, radical products or processes than others. You need them both, as the frontrunners tackle initial difficulties, the followers can contribute to the demonstration effect of adopting the innovations at a large scale, enabling the shift towards integrated valorisation. Translating and adopting new knowledge and technologies will be one of the most important topics of the years to come.

The Netherlands forms an adequate context for the foreseen developments, with an eye on its agro- and chemical industries, logistics position and strong knowledge infrastructures. Such developments have large environmental and labour potential as shown by the numerical analysis of the example cases including the cultivated grass refinery and separate valorisation of maize kernels for food and technical applications. This analysis provides a rough overview of the potential. This potential still needs to be proven in practice. The workshops with entrepreneurs show that the interest is there, which can lead to promising experimental follow-up trajectories.

11.1 General recommendations

This report focuses on an integrated approach to achieve an optimal use of biomass resources. Optimal is defined as high level, high value application of biomass resources, based on the value pyramid of the application domains food, feed, functional materials and fuel. As sustainability is defined as the integration of people, planet and profit, stakeholders should realise that the whole is more than the sum of its parts. On comparison of theoretical vision and practical view/experiences, typically the theoretical ideal valorisation (according to the value pyramid) and sustainability (e.g. environmental impact) preferences are hampered by practical context:

- Various technology barriers (or unawareness of technological opportunities) exist.
- With an eye on the economic relevancy of the primary product, there is a general fear that changes in the process may affect the primary product quality.
- Financial instruments stimulating bio-energy as contribution to prevention of climate change go at the risks of innovative efforts on higher-end applications of biomass.
- Focus on means-oriented regulation inhibits creative solutions by companies.
- Because of limited knowledge and appreciation of eco-sustainable solutions in society together with short term strategies by retailers, business planning based on premium pricing for sustainable products is not realistic on the short term. These should be addressed in the mid- to long term to prevent new lock-ins in the near future.
- The innovative character of the foreseen developments fits well to SMEs and start-ups; however their access to knowledge and financing is limited.

Based on these findings and the other results presented in this report, recommendations for various stakeholders are presented below. As these are summarised, the level of detail found within the previous chapters should be taken into account. First, general recommendations are given, followed by specific recommendations for business, research agendas and governmental institutions.

- Establish new sector-crossing collaborations in open innovation programs to increase fundamental knowledge on biorefinery. In the next step (applied research, valorisation) developing cross-sector collaborations are needed along particular production chains. The formation of such new partnerships can be facilitated on a national level (e.g., via new public-private-partnerships (PPS) in one of the "Topsectoren" or via competence centers where business meets science (e.g. TKI ISPT[35], Top Institute for Food & Nutrition, Protin, Green Genomics, Protein Competence Center, etc.) or on an international level (e.g., in the Horizon 2020 program or the sustainable, people-planet-profit based economy, which is currently under development).

[35] Top centre for Knowledge and Innovation: Institute for Sustainable Process technology

- Prioritize the development of criteria for integrated valorisation and stimulate initiatives from start-ups, spin-off, SME and large companies, which comply with those front running criteria. This type of stimulation will require a tiered approach, since companies differ in their strategy, competences and resources. Government can sketch the outlines; businesses must fit it with their possibilities and opportunities. These should include amongst others the integration of sustainability criteria (economics, environment, society) as well as including (network) stakeholders from the biomass value chain they target. The inclusive nature of these criteria as foundation for governmental facilitation and support is required to prevent unforeseen negative externalities or barriers arising in adjacent application domains and/or knowledge development. Departmentalization or single-technology/aspect stimuli often blindfold the outlook for aggregated effects. Sustainability also includes the issue of national and international equity, not hampering the development of natural and fossil resources abroad. The target of '2 times more with 2 times less' is not intended to be a national topic only, since all resources and markets are interrelated. Inviting companies into integrated valorisation innovation processes will require a lead from government, together with knowledge institutes, to advocate larger scales transition processes which exceed the individual business level. On the other hand, this should not lead to a laissez-faire approach to innovation ('let 1000 blossoms bloom'): the criteria should focus and channel innovation for integrated valorisation.

- Monitor the stimulation (government) and innovation (business/network) process, (re)define desired outcomes after each (5 year) period and adapt to (technological and social) developments and progressing knowledge (time or action-dependent developments). Sustainability is a dynamic concept, developing over the years to include new insights and opportunities. Such process will need clear decision criteria and sustainability/impact assessments of foreseen developments. To monitor progress, appropriate indicators should be developed as well as scenarios to predict time or action-dependent developments in a joint process of government, industries and knowledge organisations.

- Exploit strong assets within the Netherlands:
    - Available sources of biomass: identify suitable sources for higher valorisation processes (including biorefinery)
    - Establish choices within export and import of biomass resources and the sustainability issues associated with them, not only on economic parameters, including amongst others environmental impact and social acceptance (amongst others).
    - Support the development of EU-regional crops towards self-sufficiency in future biomass supply

- Exploit logistics as key factor for local/regional successes within a closed loop system. Many biomass streams, including product streams that will originate from innovative fractionation processes, are highly perishable. Effective logistics and adequate scale size per processing step are crucial for practically feasible new processes.

11.2 Recommendations for business

The business perspective on an integrated valorisation of biomass resources will prove vital on the road towards 2050. Cooperation, inspiration, willingness to change, shared learning (by doing), entrepreneurship are all elements to achieve the necessary transitions. Specifically for business, the following recommendations are formulated:

- Foreseen developments offer chances of business developments beyond the traditional focus domain. Therefore, it is recommended to develop sector-crossing collaborations. Participate to open innovation programs to increase knowledge beyond the traditional areas. These may lead to surprising ideas. In the next step (applied research, valorisation) setting-up sector-crossing collaborations are needed along production chains.

- Develop products that fit in traditional (commodity) chains, so that risks of 1-to-1 supplier-customer dependency are reduced (most relevant in stages 2 and 3).

- In all relations within the value chain, check for opportunities in reducing use of energy or material resources at the chain level: establish innovation partnerships to disseminate investments (costs) and benefits fairly in the relation between suppliers and customers.

11.3 Recommendations for research agendas

Research institutes have the primary aim to develop new fundamental knowledge, and have an important role in making this knowledge accessible, transferable and translatable in practice through applied sciences, in cooperation with businesses and societal stakeholders. Fundamental knowledge is the underlying basis for continuous and long term targeted transitional innovation within a multitude of scientific disciplines. Combined, transferred and valorised as applied science brings forth the more incremental and radical innovation processes as well as the diffusion from pilot demonstration scale, towards large scale implementation. The roadmap towards integrated valorisation should inspire research agendas to (re)evaluate starting points and ambitions and to specifically include the valorisation of knowledge by putting effort in the transfer and cooperation with value chain stakeholders. To further the transition processes, the following issues should be addressed within the research agenda for integrated valorisation of biomass resources:

- Elaborate sustainability impacts of the envisaged transitions, including and indicating negative externalities and their mitigation strategies.
- Include criteria and specifications for substitution processes (targeting quality, quantity, functionality as well as sustainability criteria) of conventional (fossil based) resources.
- Introduce Develop and introduce signal indicators and sound monitoring practices to evaluate cross sectoral progress through the transitional stages, from an integrated perspective, exceeding the interest level of individual stakeholders.
- Develop new knowledge on dedicated crops and animal breeds to improve integrated application in the value chain and across application domains of food, feed, functional materials and fuels.
- Study generation, impact and mitigation of negative externalities of product/process and market innovations and/or introductions from a value chain and integrated valorisation perspective. Provide insights on consequences and requirements for successful innovations with regards to context and application. These consequences should be address at multiple levels, including individual stakeholders to global/cross-border aspects.
- Include the improvement of cooperation in and between value chains, by sharing knowledge and analysing/evaluating cooperation processes on success factors.
- Lower the threshold for knowledge valorisation: set up a 'state-of-the-art biorefinery matrix' for combinations of biomasses and processing technologies to assess which products can be produced, at what yields, at what qualities/functionalities, etc.
- Reduce compartmentalisation (envisaged developments require involvement from perspective of food, feed, functional materials and fuels).
- Develop mild processing technologies for biomass fractionation and downstream processing for each of the "valuable" biomass components, and develop knowledge bad knowhow to integrate these in order to obtain sustainable biorefinery routes.

11.4 Recommendations for government

The role of government in the stimulation of innovation has been researched extensively in the past decades, building upon knowledge and hindsight of earlier efforts. In practice, it becomes clear that stimulating policies and instruments have both common aspects as well as a large demand for specification and customisation. With regards to common aspects, this report presents the business perspective on governmental measures indicating that a facilitating role has the highest preference. Not too much meddling or smothering, but assisting business to create the necessary conditions (awareness, means and cooperation) for the transition processes. However, all developments left to market mechanisms or depending on enlightened self- interest of companies is not a recipe for success from a sustainability perspective. Governments are a typical stakeholder to protect and further common interests and goods, which are not always to be defined in terms of economic costs. On the other hand, companies are not all similar in their (sustainability or innovation) orientation, competences and networking capabilities. There are frontrunners, followers and laggards (and multiple variations in between) which all have a role to play. Here, specific, customized approaches, using a mix of instruments (regulatory, policy, advocacy, and financial) for different groups of companies is called for. These groups are not to be formulated along the lines of sectors or biomass resources, but at their innovation strategies and capabilities. We found that differences between sectors are smaller than between companies (within sectors).

Therefore, we recommend for the Dutch national government and in specific the Ministry of Economic Affairs, Agriculture and Innovation, to:

- formulate policies and instruments to match these groups to achieve higher levels of efficiency and effectiveness;
- define specific target groups for policy and instruments;
- use a mix of policy and financial instruments (including procurement and launching customer, grants and taxation) and to remove clear obstacles from advocacy or regulatory instruments, based on a balanced consultation process with businesses and other interest groups.

The topic of biomass resources and sustainable valorisation are not bound by geographic borders. Developments in the Netherlands are heavily influenced by European and non-EU international developments and also subject to European policies and directives as well as non-EU's, such as WTO, Climate Conventions and the World Bank. The front running ambitions of the Netherlands to belong to the innovative top of Europe are appreciated by business and research institutes, but require at the same time a hands-on translation to inspire action. Awareness starts with signalling problems and problem ownership, two issues to which government can contribute significantly. Using an integrated translation of different governmental ambitions from agricultural, economic, environmental and social policies on national and European levels (including the EU Common Agricultural Policy), the Roadmap developed in this project may contribute to a clearer understanding of the necessary actions with regards to biomass resources and by-products.

General recommendations to inspire and foster innovation for integrated valorisation of biomass resources are to:

- use the integrated approach presented in the roadmap to align policy and instrumental measures, to enable a consistent message and appeal to industry and research on the necessary developments;

- stimulate stakeholder discussion on differences and contradictory preferences between various applications of biomass resources. Only then negative externalities are identified, enabling remedies or mitigation strategies. Government can take a frontrunner and motivational role here, but it is more efficient to let inspirational voices from business and research be heard on and between their own podia. Stimulate the creation of new ideas, facilitate the development of demonstration / proof of principle, and accommodate the diffusion of proven technologies and concepts. Using methods as described in this report, including the working session approach will significantly contribute to the development of new cooperation within and between value chains;

- evaluate and design instruments (including policy, advocacy, financial and regulatory) against the value pyramid to avoid low level applications that hinder the development of higher level applications. Using biomass for fuel applications should become the lowest valorisation application. Instead, fuel should be an additional application level to enable an economically viable higher level application.

- aim legislation more on intended (sustainability) effects and ambitions, with fewer restrictions on means;

- use consultation with business and other interest groups in the development phase of supporting/facilitating instruments.

More specific recommendations are formulated as follows:

- Create sense of urgency for integrated valorisation of biomass resources green growth amongst business and consumer stakeholders, and the awareness of individual contribution and beneficial opportunities from economic and environmental perspectives.

- Set and tighten recycling levels and content standards for all non-renewable resources. Develop instruments to include negative externalities in the cost price of unsustainable, fossil based resources to speed up the introduction and diffusion of biomass based ingredients and products.

- Stimulate and support research agendas and programs that support innovation for integrated valorisation and set-up possibilities for coordination of these activities on multiple levels (regional / national / international).

- Participate in public-private partnerships for developments in technology and management of integrated valorisation of biomass resources.

- Improve depth, coverage and reliability of material flows data to improve decision and evaluation process.

11.5 Concluding remarks

The roadmap presented in this report sketches a development within the next forty years:

- From short-term developments: optimising efficiency of existing chains, including optimal valorisation of by-products within the technical limitations of current focus on the main product.
- Through developments in intermediate phases: upcoming alternative biobased sources and alternative uses of biomass. First steps could be aimed at straightforward applications (e.g. biofuels). Next steps can target utilising (molecular and compositional) complexity of biomass, so that intensity of biological, chemical and physical processes can be reduced.
- And on the long term: integrated valorisation of biomass, applying mild processes so that the intrinsic high quality of each component is available (no longer sacrificing quality of by-products in favour of the primary product), enabling efficient and effective use of biomass resources for food, feed, functional materials and fuels applications.

Crucial for this development process is crossing borders, looking for links beyond the well understood, current comfort zone of the food and feed domains. All stakeholders can contribute to this process through active participation and reducing obstacles. As Einstein once said*: "problems cannot be solved within the same framework they originate from...".*

12 References

- Annevelink, E., Broeze, J., Van Ree, R., Reith, J.H., Den Uil, H., 2009. Opportunities for Dutch biorefineries: Dutch roadmap biorefinery. Wageningen UR, ECN.
- Banse, M., Van Meijl, H., Tabeau, A., Woltjer, G., Hellmann, F., Verburg, P., 2011. Impact of EU biofuel policies on world agricultural production and land use. Biomass and Bioenergy, vol. 35, pp. 2385-2390.
- Becker, E.W., 2007. Micro-algae as a source of protein. Biotechnology Advances, 25, pp. 207-210.
- Berenschot, 2010. RKI-Koolstof ketencirkels: voorstudie MJA3, rubber-, lijm- en kunststofindustrie. Utrecht.
- Bergsma, G.C., Kampman, B.E., Croezen, H.J., 2010. Goed gebruik van biomassa. CE Delft, Delft.
- Berkhout, P., Bruchem, van, C., 2011. Agricultural Economic Report 2011 of the Netherland. Report No. 2011-017. Wageningen UR – LEI, Den Haag.
- Bhasrakan, S., 2006. Incremental innovation and business performance: small and medium-size food enterprises in a concentrated industry environment. Journal of Small Business Management, 44, 1, pp. 64-80.
- Blaauw, R., Van Haveren, J., Scott, E.L., Bos, H.L., 2008. Biomass for the Dutch chemical industry: opportunities for agriculture. Wageningen UR – FBR.
- Boer, de, J., Aiking, H., 2011. On the merits of plant-based proteins for global food security: Marrying macro and micro perspectives. Ecological Economics, 70, pp. 1259-1265.
- Bondt, N., Meeusen, M., 2008. Bijproducten voor biobrandstoffen. Wageningen UR – LEI, Den Haag.
- Bondt, N., Meeusen, M.J.G., 2008. Bijproducten voor biogrondstoffen. Wageningen UR – LEI.
- Bont, N., et al., 2010. Afval uit de landbouw. Report no. 10-061, Wageningen UR – LEI, Den Haag.
- Bos, H., Conijn, S., Corré, W., Meesters, K., Patel, M., 2011. Duurzaamheid van biobased producten: energiegebruik en broeikasgasemissie van producten met suikers als grondstof. Publicatiereeks Groene Grondstoffen, Wageningen UR.
- Bouwmeester, H., Bokma-Bakker, M.H., Bondt, N., Van der Roest, J., 2006. Alternatieve aanwending van (incidentele) reststromen buiten de diervoedersector. Wageningen UR – RIKILT.
- Broeze, J., et al., 2012. Herontwerp duurzame voedselsystemen, Wageningen UR - Food & Biobased Research report 1323.
- BTG Biomass Technology Group, 2002. Beschikbaarheid van reststromen uit de voedings- en genotmiddelenindustrie voor energieproductie.
- Commissie Duurzaamheidsvraagstukken Biomassa, 2010. Duurzaamheid en daadkracht: advies over een duurzame bio-economie.
- Commissie Duurzaamheidsvraagstukken Biomassa, 2010. Maak landbouw deel van de oplossing! Advies over Indirect Land Use Change.
- Commissie Van Doorn, 2011. Al het vlees duurzaam: de doorbraak naar een gezonde, veilige en gewaardeerde veehouderij in 2020. Den Bosch.
- Creatieve Energie, 2007. Toetsingskader voor duurzame biomassa: eindrapport van de projectgroep "Duurzame productie van biomassa".
- Criekemans, D., 2011. The geopolitics of renewable energy: different or similar to the geopolitics of conventional energy? Paper presented at the ISA Annual Convention 2011, Montréal, Québec, 16-19 March.
- De Buisonjé, F., Aarnink, A., 2011. Algenkweek op stallucht: cultivation of alge on ventilation air from animal houses. Wageningen UR – Livestock Research, Lelystad.
- De Gruiter, J., 2011. Focus op groene en innovatieve economie in 2050: interview met Jan Lommerts. Chemie Magazine, juni, pp. 24-27.
- De Jong, E., Van Ree, R., Van Tuil, R., Elbersen, W., 2009. White paper: Biorefineries for the chemical industry – a Dutch point of view. Wageningen UR.

- Dumont, M., 2010. Towards a mature green gas market: state of affairs and point of action, A report commissioned by the New Gas Platform, Energy Transition, Utrecht.
- EC, 1997. Novel Food Regulation: Regulation 258/97/EC of the European Parliament and of the Council concerning novel foods and novel food ingredients. European Council, Brussels.
- EC, 2009. Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, Document L 140/16, Official Journal of the European Union, Publications Office of the European Union, Luxembourg.
- Eickhout, B., Van Meijl, H., Tabeau, A., Van Rheenen, T., 2007. Economic and ecological consequences of four European land use scenarios. Land Use Policy, vol. 24, issue 3, pp. 562-575.
- Elbersen, W., Janssens, B., Koppejan, J., 2011. De Beschikbaarheid van biomassa voor energie in de agro-industrie. Wageningen UR – FBR. Report No. 1200, Wageningen
- EnergieTransitie, 2008. Innovatieagenda Energie. EnergieTransitie, Utrecht.
- EU DG AGRI. Economic impacts of genetically modified crops on the agri-food sector.
- EU DG Agriculture, 2001. Economic impacts of genetically modified crops on the agri-food sector: a synthesis. Brussels.
- EU DG Environment, 2011. Economic analysis of resource efficiency policies. Brussels.
- Euralcodelijst betreffende (Gevaarlijke) Afvalstoffen Europese Richtlijn 75/442/EEG en 91/689/EEG.
- FAO, 2011a. Global food losses and food waste.
- FAO, 2011b. FAO at Rio +20: Food availability and natural resource use in a green economy context. Rome.
- FAO / OECD, 2011. Improving Food Systems for Sustainable Diets in a Green Economy. Working document FAO/OECD Expert Meeting on Greening the Economy with Agriculture, Paris, September 2011 (www.fao.org).
- Federatie Nederlandse Levensmiddelenindustrie, 2010. De stille kracht: route voor de Nederlandse levensmiddelenindustrie. FNLI, Den Haag.
- Gezondheidsraad, 2011. Richtlijnen goede voeding ecologisch belicht. Publicatienr. 2011/08, Den Haag.
- Górak, A., Stankiewicz, A., 2011. Research Agenda for Process Intensification, Towards a Sustainable World of 2050.
- Hamelinck, C., Koper, M., Marsidi, M., 2009. Brede inzet van biomassa: vergelijkingsmethodiek voor verschillende toepassingen. CreatieveEnergie, Platform GroeneGrondstoffen, Ecofys.
- Henderson, R.M., Clark, K.B., 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly*, 35, 1, pp. 9-30.
- Hoop, de, W., et al., 2010. Alternatieve vormen van regulering co-vergistingsproducten. Report no. 2010-047, Wageningen UR - LEI, Den Haag.
- Huang, H-J., Ramaswamy, S., Tschirner, U.W., Ramarao, B.V., 2008. A review of separation technologies in current and future biorefineries. Spearation and Purification Technology, vol. 62, pp. 1-21.
- ING Equity Markets, 2010. Food, beverages and HPC: a thematic insight.
- IEA Bioenergy, 2011. Biobased Chemicals: Value Added Products from Biorefineries.
- Kemp, R. and Rotmans, J. (2004), 'Managing the Transition to Sustainable Mobility', in: Elzen, B., Geels, F. and Green, K. (eds.) (2004), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy, Edward Elgar Publishers, Camberley, UK.
- Kerste, M., Rosenboom, N., Sikken, B.J., Weda, J., 2011. Sustainability: insights for investors, corporate executives, and policymakers. VU University of Amsterdam.
- Koppejan, J., et al., 2009. Beschikbaarheid van Nederlandse biomassa voor elektriciteit en warmte in 2020. Procede Biomass B.V. & Wageningen UR, in opdracht van SenterNovem.
- Kuiper, L., De Lint, S., 2008. Binnenlands biomassapotentieel: biomassa uit natuur, bos, landschap, stedelijk groen en houtketen. Ecofys, Utrecht.

- Landeweerd, L., Surette, M., Van Driel, C., 2011. From petrochemistry to biotech: a European perspective on the bio-based economy. Focus, online publication 2 February.
- Laybourn, P., 2011. Recent developments in industrial symbiosis: policy and practice. Presentation at the 11th Annual Netherlands Process Technology Symposium, 26 October, TU Twente, Enschede.
- LEAD & FAO, 2006. Livestock's long shadow: environmental issues and options.
- LeCoq, E., 2011. Towards a European strategy on bioeconomy. Presentation at the 4th Dutch Bioplastics Value Chain Meeting, The Hague, 14 December 2011.
- McDowall, W., 2012. Technology roadmaps for transition management: the case of hydrogen energy. Technological Forecasting & Social Change, 79, pp. 530-542.
- Meeusen, M., et al., 2008. Verwaarding reststroom uienbewerking. Report no. 886, Wageningen UR.
- Meyer, M.A., Booker, J.M. 2001*. Eliciting and analysing expert judgment*. SIAM, Philadelphia, PA.
- MilieuCentraal, 2007. Verspilling en indirecte energie van voeding.
- Milz, M., 2011. Green Deal. Presentation at the 4th Dutch Bioplastics Value Chain Meeting, The Hague, 14 December 2011.
- Ministerie EL&I, Directie VDC, 2010. Duurzaam voedselbeleid en doelstellingen. Brief aan de Tweede Kamer, 10 december 2010.
- Ministerie IenM, 2011. Agenda duurzaamheid: een groene groei-strategie voor Nederland, In: Kamerbrief Duurzaamheidsagenda No: Dp2011054467, 3 oktober 2011, Ministerie van Infrastructuur en Milieu (IenM), The Hague
- Ministerie LNV, 2007. The Dutch governmental Vision on a Bio-based Economy in the Energy Transition. Ministerie LNV, Den Haag.
- Ministerie LNV, 2010. Factsheet voedselverspilling. Den Haag.
- Ministerie van de Vlaamsche Gemeenschap – Beleidsdomein Landbouw en Visserij, 2005. Koolzaad van zaad tot olie.
- Ministry of Agriculture – Dpt. Trade & Industry, 2008. Biobased economy: combining agro and chemical. The Hague.
- Mulder, W., et al., 2012. Biobased Economy: de potentie van eiwitten voor technische toepassingen. Wageningen UR *(in preparation)*
- Novem, 2003. Biofuels in the Dutch market: a fact-finding study. Novem, Utrecht.
- Nowicki, P., et al., 2007. Scenar 2020 - Scenario study on agriculture and the rural world. Contract No. 30 - CE - 0040087/00-08. European Commission, Directorate-General Agriculture and Rural Development, Brussels.
- nVWA, 2011. Advies van dir BuRO/VWA: over alternatief gebruik van voormalige voedingsmiddelen. Den Haag.
- OECD, 2011. OECD recommendation on assessing the sustainability of bio-based products – draft.
- OPNV 2011. Data 2010.
- Overleggroep Producenten Natte Veevoeders, 2009. Afzet van vochtrijke voedermiddelen in 2009. OPNV.
- Parker, J., 2010. Another year, another billion, John Parker. The Economist, 22nd November.
- Paulussen, K., Temminghoff, M., 2010. Voeding in 2020: gezond en duurzaam eten. PresentatieConsumentenonderzoekGezond en DuurzaamEten, Voedingscentrum, 16 november 2010.
- Phaal, R., et al., 2001. Characterisation of technology roadmaps: purpose and format. Proceedings of the Portland International Conference on Management of Engineering and Technology, pp. 367-374, Aug 2001.
- Planbureau voor de Leefomgeving, 2011. The Protein Puzzle.
- Platform Groene Grondstoffen, 2009. Biobased Economy in Nederland: Macro-economische verkenning van grootschalige introductie van groene grondstoffen in de Nederlandse energievoorziening.

- Platform GroeneGrondstoffen, 2010. Potential of coproduction of energy, fuels and chemicals from biobased renewable resources. WISEBIOMAS.
- Prins, A., Eickhout, B., Banse, M., Van Meijl, H., Rienks, W., Woltjer, G., 2011. Global impacts of European agricultural and biofuel policies. Ecology and Society, vol. 15, pp. 49-68.
- Prins, A.G., Eickhout, B., Banse, M., VanMeijl, H., Rienks, W., Woltjer, G., 2011. Global impacts of European agricultural and biofuel policies. Ecology and Society, vol. 16, issue 1., online publication.
- Rabou, M., et al., 2006. Biomassa in de Nederlandse energiehuishouding in 2030. Platform Groene Grondstoffen & Wageningen UR.
- Rebel Group Advisory, 2010. Vergisting van reststromen VGI: business Case.
- RIVM-RIKILT Frontoffice Voedselveiligheid, 2010. Risicobeoordeling inzake alternatief gebruik van voormalige voedingsmiddelen inclusief groente en fruit. Wageningen UR – RIKILT.
- Rockström, J., et al., 2009. A safe operating space for humanity. Nature, 461, pp 472-475.
- Rogers, E.M., 1988. Diffusion of innovation, 4^{th} edition. Free Press, New York, NY.
- Rijk, G., Gulpers, M., 2011. The third industrial revolution. ING.
- Sanders, J., 2012. personal communications.
- Sanders, J.P.M., et al., 2012. Process intensification in the future production of base chemicals from biomass. Chemical Engineering and Processing, 51 (1), pp. 117 – 136.
- Schösler, H., De Boer, J., Boersema J.J., 2011. Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution. Appetite, online publication 1 October.
- Schutsyser, M.A.I., Van der Goot, A.J., 2011. The potential of dry fractionation processes for sustainable plant protein production. Trends in Food Science in Technology, vol. 22, pp. 154-164.
- Schwenzfeier, A., et al., 2011. Isolation and characterization of soluble protein from the green microalgae Tetraselmis sp. Bioresource Technology, 102 (19), pp. 9121-9127.
- Šebek, L.B.J., Temme, E.H.M., 2009. De humane eiwitbehoefte en eiwitconsumptie en de omzetting van plantaardig eiwit naar dierlijk eiwit. Wageningen UR – ASG.
- SER, 2010. Meer chemie tussen groen en groei, De kansen en dilemma's van een biobasedeconomy. Adviesnr. 10/05, SER, Den Haag.
- SER NN, 2010. De Bio-BasedEconomy in Noord-Nederland, Sociaal Economische Raad Noord Nederland (SER NN), Groningen.
- Slot, van der, A., et al., 2010. Stimulering van de economische potentie van duurzame energie voor Nederland, A Report of Roland Berger Strategy Consultants, Amsterdam.
- Star-COLIBRI, 2011. European Biorefinery 2030 Vision Document, Deliverable 3.5. Star-COLIBRI Project, 241535 – FP7.
- Stegeman, D., Janssen, A.M., Helsper, J.P.F.G., Van der Meer, I.M., Van Kernebeek, H.R.J., 2011. Technologie en grondstoffen voor vleesvervangers en hoogwaardige eiwitten. Wageningen UR.
- Tabeau, A., Banse, M., Woltjer, G., Van Meijl, H., 2011. Impact of EU Biofuels Directive on the EU food supply chain. Journal of Food Products Marketing, vol. 17, pp. 2-3.
- Tabeau, A., Banse, M., Woltjer, G., Van Meijl, H.. 2011. Impacts of the EU biofuels directive on the EU food supply chain. Journal of Food Products Marketing, vol. 17, pp. 373-385.
- Ten Pierick, E., 2011. Whitepaper: the Dutch policy regarding the transition towards a bio-based economy: ex-ante evaluation from a transition science perspective. Wageningen UR – LEI.
- Topsector Agro & Food, 2011. Agro & Food: de Nederlandse groeidiamant. Den Haag.
- Topsector Chemie, 2011. New earth, new chemistry: actie agenda top sector chemie. Den Haag.
- Topsector Energie, 2011. Energie in beweging: advies topsector energie. Den Haag.
- Topsector Tuinbouw en Uitgangsmaterialen, 2011. Bron voor groene economie: wereldoplossingen voor werelduitdagingen. Den Haag.
- Topsector Water, 2011. Water Verdient Het, Advies Topsector Water.
- Topteams Topsectoren, 2011. Samenvatting adviezen topsectoren.

- Topteams Topsectorenbeleid, 2011. Topsectorenaanpak. Brief aan Minister EL&I, 17 juni 2011.
- Tweede Kamer der Staten Generaal, 2011. Parlementair onderzoek economische dimensie verduurzaming voedselproductie. Brief van het presidium, 23 maart.
- Van Baarle, D., 2011. Bioraffinage bidet kansen voor groene reststromen. Biochem, vol. 2, issue 6, pp. 10-13.
- Van der Vorst, J.G.A.J., 2011. Toekomstverkenning transities tot 204 voro de topsectoren AgroFood en Tuinbouw vanuit logistiek perspectief. Raden voor de Leefomgeving en Infrastructuur.
- Van Kasteren, J., 2011. Benut complexiteit biomoleculen. Chemie Magazine, juni, pp. 20-23.
- Van Oosterhout, T., Van Laarhoven, W., 2004. Het gebruik van reststoffen van de voedings- en genotmiddelenindustrie in de veevoeding: een verkennend onderzoek naar risicobeleving, risico's en risicobeheersing. SIRNED b.v.
- Verburg, P.H., Eickhout, B., Van Meijl, H., 2008. A multi-scale, multi-model approach for analyzing the future dynamics of European land use. Annals of Regional Science, vol. 42, issue 1, pp. 57-77.
- Visiewerkgroep Biomassa Transitie, 2003. Visie op biomassa: de rol van biomassa in de Nederlandse energievoorziening 2040.
- Vuuren, van, A.M., Chilibroste, P., 2011. Challenges in the nutrition and management of herbivores in the temperate zone. Animal, 2011 (published online: September 2011)
- Waarts et al., 2011. Reducing food waste: obstacles experienced in legislation and regulations. Wageningen UR – LEI and FBR, Wageningen.
- Waldron, K., Moates, G., Faulds, C. (eds.), 2009. Total food: sustainability of the agri-food chain. RSC publishing, UK.
- Webber, D., 2011. The Dutch bioplastics value chain: a 'value adding' initiative. Presentation at the 4th Dutch Bioplastics Value Chain Meeting, The Hague, 14 December 2011.
- Wempe, J., Dumont, M., 2007. Let's give full gas! The role of green gas in the Dutch energy management system, A report commissioned by the New Gas Platform, Energy Transition, Utrecht.
- Werkgroep Businessplan BBE 2.0, 2011. Groene Groei, van biomassa naar business, Innovatiecontract 2012-2016.
- Westhoek, H., Rood, T., Van den Berg, M., Janse, J., Nijdam, D., Reudink, M., Stehfest, E., 2011. The protein puzzle. PBL Netherlands Environmental Assessment Agency, The Hague.
- Wetenschappelijke en Technologische Commissie voor de BiobasedEconomy, 2011. Naar groene chemie en groene materialen: kennis- en innovatieagenda voor de biobasedeconomy.
- Weinberger, N., Jörissen, J., Schippl, J., 2012. Foresight on environmental technologies: options for the prioritisation of future research funding – lessons learned from the project "Roadmap Enbvironmental Technologies 2020+". Journal of Cleaner Production, 27, pp. 32-41.
- Wijffels, R.H., et al., 2010. Microalgae for the production of bulk chemicals and biofuels. Biofuels, Bioproducts & Biorefining (Biofpr), 4, 3, pp. 287-295.
- Willemse, H., 2011. Standards for bio-based products. Presentation at the 4th Dutch Bioplastics Value Chain Meeting, The Hague, 14 December 2011.
- Williams, P.J., Laurens. L.M.L., 2010, Microalgae as biodiesel and biomass feedstocks: review and analysis of the biochemistry, energetics and economics. Energy & Environmental Science, 3, pp. 554-590.
- WTC-BBE, 2011. Naar Groene Chemie en Groene Materialen: report of the Scientific and Technological Committee for the Biobased Economy (WTC Biobased Economy). Den Haag.
- www.groenkennisnet.nl
- www.nevedi.nl

Annex 1 – Abbreviations list

ANF	Anti-nutritional factor
BBE	Biobased Economy
CGE	Computational General Equilibrium
DDGS	Dried Distillers Grains with Solubles
DM	Dry matter
DSP	Downstream Processing
FTE	Full time equivalent
GLP	Good agricultural practice
GMO	Genetically Modified Organism
H	Higher Heating Value
ha	hectare
K	Potassium
(k) J	(kilo) Joule
LC	Lignocellulose
LHV	Lower Heating Value
LPF	Level Playing Field
N	Nitrogen
NDF	Neutral Detergent Fibre
P	Phosphor
SDE	Stimulering Duurzame Energieproductie
WDG	Wet Distillers' Grain
WKK	Co-firing

Annex 2 – Ambitions and objectives BBE

With respect to the Biobased economy from Top Sectors Chemistry, Agro-Food, Water and Energy

Top Sector Chemistry:

- Efficiency improvement, development of sustainable products and the production of sustainable energy should lead to a reduction in CO_2-emission with 11.6 Mton, and energy savings of 171 PJ in 2030

Top Sector Energy:

- A transition towards a more sustainable and CO_2-neutral sector, e.g. 20% less CO_2-emission as well as 14% sustainable energy. Gas will be given a prominent role, as compared to existing fossil sources the CO_2-emission is less, and the application of gas may form the linking pin towards the biobased economy via green gas from bio-waste streams.

In a previous document the Platform Groene Grondstoffen has formulated the following goals for the energy transition:

- *In 2030 30% of the Dutch energy will be provided by green raw materials. For this a limited amount of Dutch raw materials will be used (mainly: specifically grown, and waste and rest-streams). The remainder will be provided by imported biomass. The energy use in 2030 will be on the same level as in 2000 (3000 PJ); to be realized via energy savings.*

Topsector Water:

- No specific targets have been formulated with respect to the biobased economy. One of the business cases described is "more crop per drop": high added value solutions for fresh water supply for food production: innovative technologies for closing of water loops, as well as innovative concepts like "Leven met Zout" for food production in areas with brackish water.

Topsector Agro-Food has formulated the following goals for the year <u>2020</u>:

- Contribution of waste-streams to the added value of the sector: $1x10^9$ € (current level: 0)
- 20% More efficient use of raw materials
- 30% reduction in greenhouse gases (as compared to level of 1990)
- Increasing separation percentage from 3% to 25% for animal manure and digestate into valuable components
- 90% of the large import streams is made sustainable
- Only curative use of antibiotics in the animal sector

Annex 3 – Overview of Experts

From the network of the Project team, experts were asked to participate to the interviews. They received a description of the project and the interview topics. The following experts participated in the project (random alphabetical order):

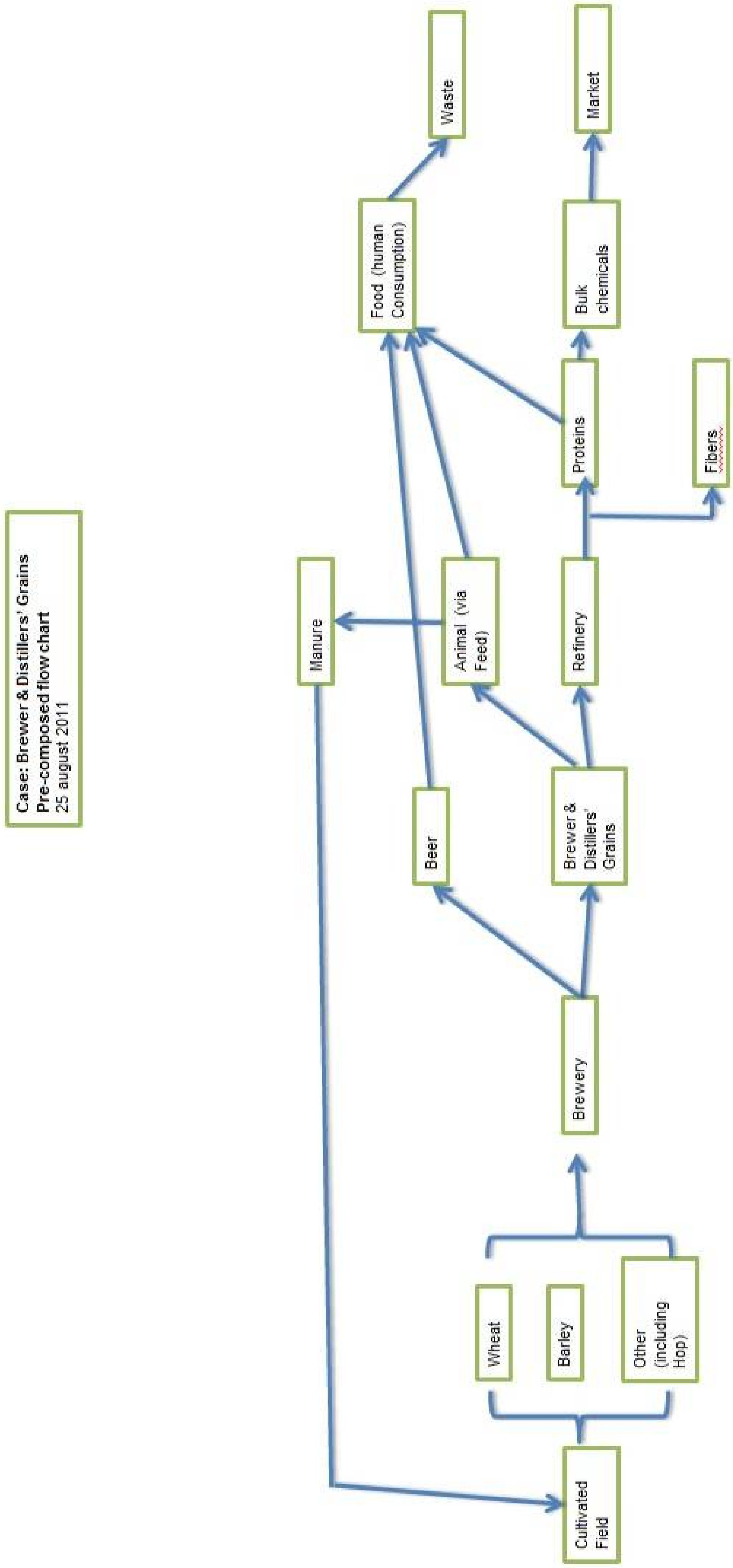
- Fred Beekmans – VION Ingredients
- Frank Gort – Productschap Diervoeder
- Leo den Hartog – Nutreco
- Tjeerd Jongsma - ISPT
- Gert Jan Smolders - DSM Climate Change Innovation Centre
- Herman Vermeer – Plus Ultra
- Carel de Vries – Stichting Courage 2025

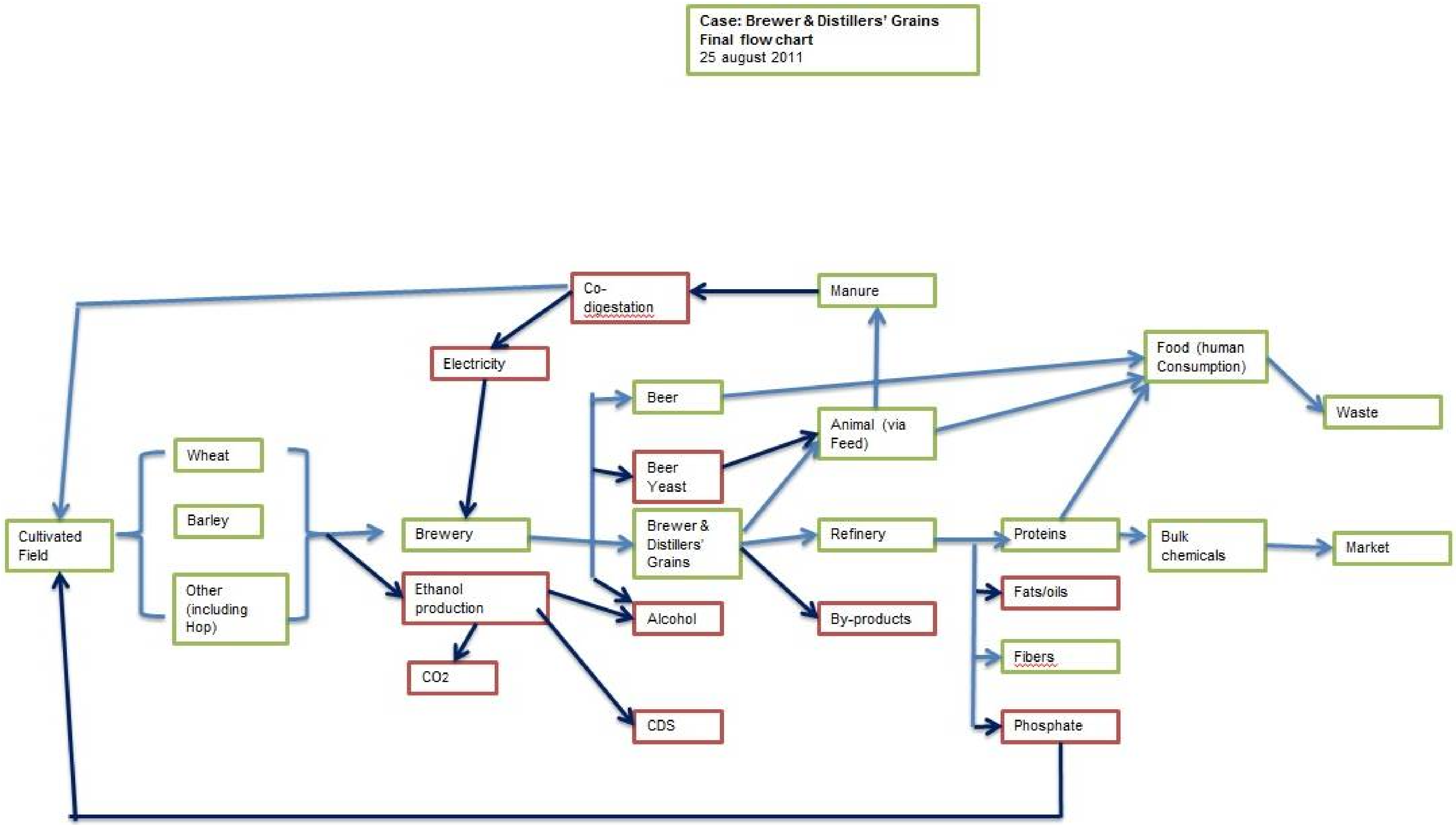
The Project team appreciates their insightful comments and time devoted to this Project and thanks them for their participation. The results of the interviews have been anonymised, and answers are not retraceable to the respondents or organisations.

Annex 4 - List of workshop participants

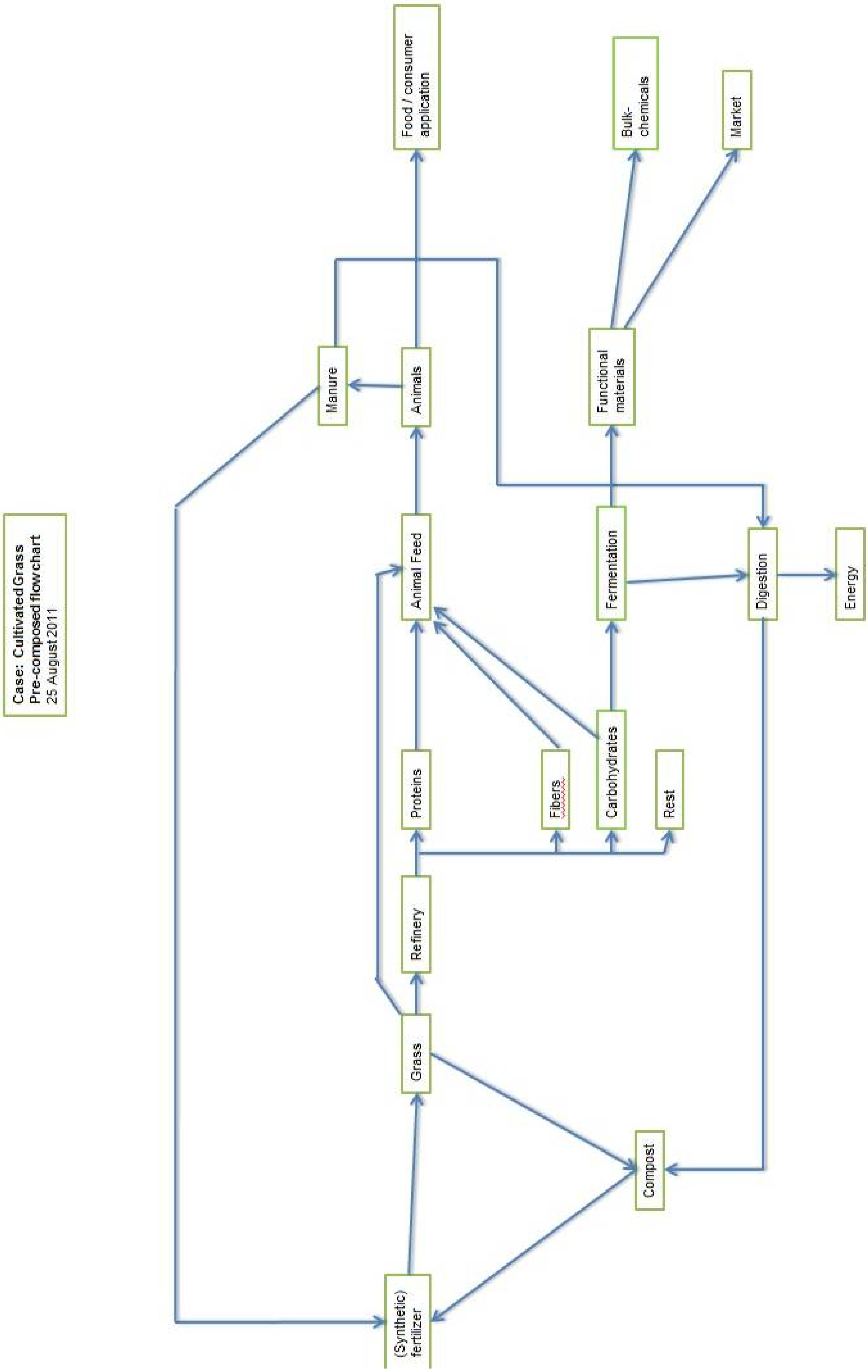
Organisation	Representative
Avebe	Piet Buwalda
Bio-based Business Professionals	Hans Derksen
DSM	Gert Jan Smolders
Duynie	Mike Litjes
Essent	Peter Paul Schouwenberg
FeyeCon Carbon Dioxide Technologies	Frank Wubbolts
Havenbedrijf Rotterdam	Frans Jan Hellenthal
Nutreco	Leo den Hartog
PPO / Acrres	Chris de Visser
ProductschapDiervoeder	Frank Gort
VION Food	Fred Beekmans
Wageningen UR - FBR	Jan Broeze (moderator)
Wageningen UR - ASG	Onno van Eijk (moderator)
Wageningen UR - FBR	Hilke Bos-Brouwers
Wageningen Universiteit – BCH	Johan Sanders
Wageningen UR - ASG	Ad van Vuuren
Wageningen UR - LEI	Michiel van Dijk
Wageningen UR - LEI	Douwe-Frits Broens
Wageningen UR - FBR	Brenda Israels
Wageningen Universiteit - BCH	Marieke Bruins

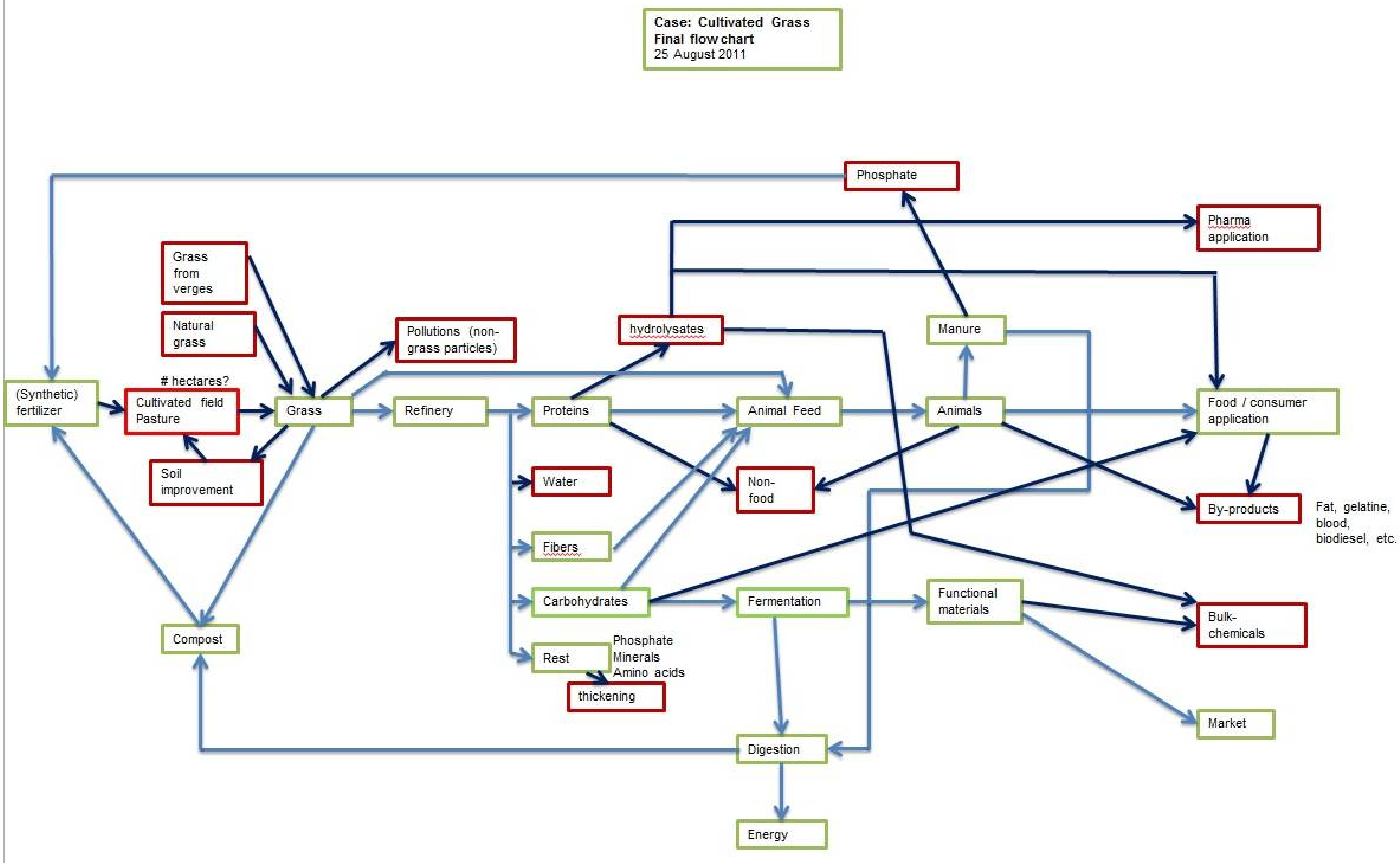
Annex 5 - Flow charts of brewer & distiller grains case




Case: Brewer & Distillers' Grains
Final flow chart
25 august 2011
Co-digestation
Manure
Electricity
Food (human Consumption)
Beer
Waste
Animal (via Feed)
Beer Yeast
Wheat
Cultivated Field
Barley
Brewery
Brewer & Distillers' Grains
Refinery
Proteins
Bulk chemicals
Market
Other (including Hop)
Ethanol production
Alcohol
By-products
Fats/oils
Fibers
CO2
CDS
Phosphate

Annex 6 - Flow charts of cultivated grass case





Case: Cultivated Grass
Final flow chart
25 August 2011
Phosphate
Pharma application
Grass from verges
Natural grass
Pollutions (non-grass particles)
hydrolysates
Manure
hectares?
(Synthetic) fertilizer
Cultivated field Pasture
Grass
Refinery
Proteins
Animal Feed
Animals
Food / consumer application
Soil improvement
Water
Non-food
By-products
Fat, gelatine, blood, biodiesel, etc.
Fibers
Carbohydrates
Fermentation
Functional materials
Bulk-chemicals
Compost
Rest
Phosphate
Minerals
Amino acids
thickening
Market
Digestion
Energy

Annex 7 – Minutes of Workshop Urban Organic Waste Flows

Verslag parallelsessie Stedelijke Groene Reststromen
Kansendag Kleinschalige Bioraffinage
Dinsdag 5 juni 2012
Lelystad
www.accres.nl

Beschrijving - doel/ambitie
Afbakening van de stedelijke groene reststromen binnen de sessie:

- GFT-afval van huishoudens
- Groen afval uit het Beheer Openbare Ruimte (BOR)
- Afval Klein Kantoor Winkel en Diensten (KWD)
- Voor een deel GFT-afval uit restaurants en andere horecagelegenheden

Een groot deel van de GFT en BOR stromen wordt nu door de afvalverwerkers gecomposteerd. Het waterige deel dat bij compostering vrijkomt zou kunnen worden gebruikt bij de recycling van nutriënten.

Volgens een deelnemer is vergisting de norm geworden in de duurzame verwerking van GFT en BOR stromen. Op dit moment draaien veel afvalverwerkers met biogasinstallaties en worden er nog steeds vergistingsinstallaties gebouwd. Bedrijf 1 heeft als doel om het volume aan reststromen (GFT en BOR) te doen groeien en is op zoek naar mogelijkheden om deze reststromen op een andere/betere manier te verwerken en te verwaarden dan via vergisting. De deelnemer is op zoek naar mogelijkheden en technieken,die kunnen worden toegepast op hun reststromen.

Momenteel wordt ca. 50% van het GFT-afval gescheiden opgehaald en aangeboden aan de verwerkende bedrijven. De andere helft verdwijnt in het grijze afvalcircuit. Daarbij laat de inzameling van GFT over de afgelopen jaren een dalend verloop zien. Minder mensen doen om uiteenlopende redenen aan afvalscheiding, maar er zijn ook gemeenten waar ophalen van gescheiden GFT afvalstromen niet plaatsvindt.

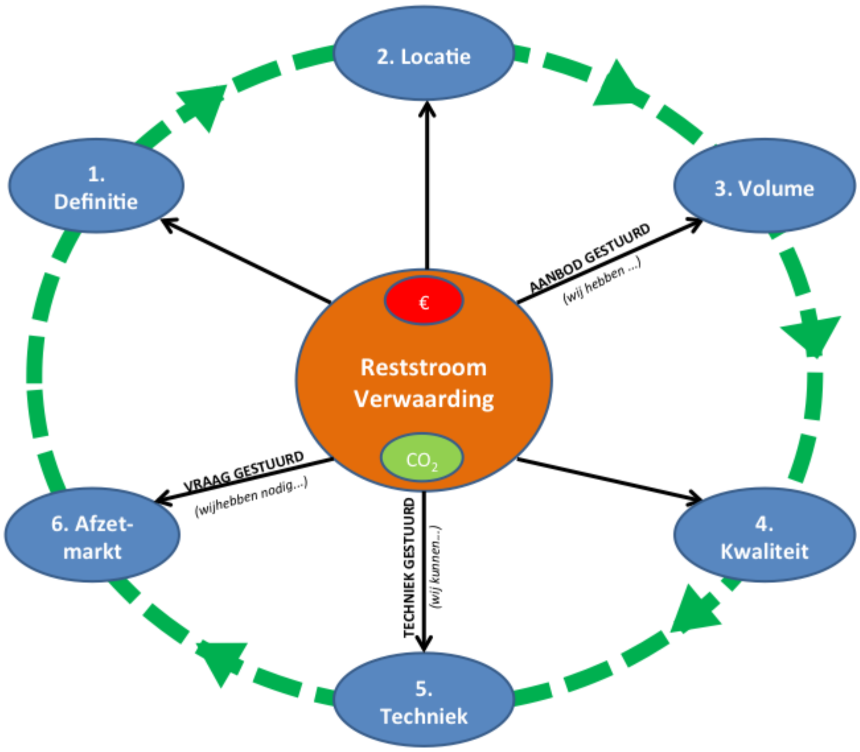
Bedrijf 1 heeft als doelstelling om de GFT en BOR stromen naar zich toe te trekken, enerzijds door contracten met meer opdrachtgevers in de regio, anderzijds om huishoudens in hun regio's te stimuleren om meer en betere GFT scheiding toe te passen. Eén van de middelen die ROVA wil toepassen is de aanpassing van de tarifering voor verwerking van GFT afval door deze los te laten en te vervangen door een kosteloze verwerking van GFT-stromen en een verhoogd tarief voor afval in de grijze container. Doel is om daarmee een stimulans te creëren bij de huishoudens om GFT-afval meer te gaan scheiden.

Ambitie (bedrijf 1): duurzame rendabele verwerking van GFT en BOR reststromen
Doel: hogere verwaarding van de beschikbare stedelijke groene reststromen door toepassing van alternatieve verwerkingsmethode zoals (kleinschalige) bioraffinage

Vragen:
- *Op welke manier kunnen huidige GFT-/BOR stromen worden verwerkt op een manier, die meer waarde toevoegt vanuit de intrinsieke waarde van de specifieke reststroom (GFT/BOR)?*
- *Welke technieken zijn nu beschikbaar en hebben zich in praktijk bewezen?*
- *Welke technieken bevinden zich in welke fase van ontwikkeling: commercieel /demo / pilot / prototype / lab?*
- *Op welke termijn zouden deze technieken in praktijk kunnen worden toegepast?*

Ontwikkeling van de business case: stappenplan:

1. Definitie reststromen = keten specifiek: wat is de samenstelling van de reststromen en welke waarde hebben deze?
2. Locatie specifiek: waar zijn de reststromen en kan ik deze tegen acceptabele kosten (€ en CO2) verplaatsen?
3. Kritische volumes: zijn er voldoende volumes van de reststroom beschikbaar om een be-/verwerkingsstap op te starten (make or buy)?
4. Kwaliteit: homo-/heterogeniteit van de reststromen?
5. Techniek: welke verwerkingsstappen zijn mogelijk? Welke voorbewerking van de reststromen daarbij nodig?
6. Afzetmarkt: sluiten de verwerkte volumes als grondstof aan op de specifieke afzetmarkt (kwantitatief, kwalitatief)?



Kansen

De markt groeit:

- Duurzaamheid scoort in aanbestedingen Toenemende interesse bij eindverwerkers in duurzame verwerking van reststromen
    - Toepassen van voorbewerkingstechnieken van reststromen:
- Hogere maatschappelijke / toegevoegde waarde voor GFT / BOR stromen door productie biobased grondstoffen i.p.v. biogas
- Voorbewerking van stedelijke rest- stromen
- Nabewerking van reststroom digestaat
- Techniek ontwikkeling maakt kleinschalige verwerking (financieel) interessant
    - Toevoegen / benutten organische KWD-stromen uit het stedelijk gebied (B1A)
    - Hogere waarde biogrondstoffen
    - Inzicht in en optimaliseren van de kwaliteit van de reststromen:
- Welke bioraffinage technieken zijn beschikbaar gegeven de samenstelling en kwaliteit van de specifieke reststroom?
- Welke eisen stelt een specifieke bioraffinage techniek aan de kwaliteit van de specifieke reststroom?
- En op welke wijze kan de kwaliteit van de reststroom worden verbeterd, gegeven deze eisen?
- Verleggen van systeemgrenzen door samenwerking tussen de afvalsector en de agro-/biobased sector

Obstakels

- Vastgeroeste infrastructuur binnen de afvalverwerkingssector:
- Binding tussen aandeelhouders en eindverwerkers creëert ook restricties
- Sector is beperkt innovatief en sterk conservatief (combi afval- sector, overheid, beheer openbare ruimte en stedelijk beheer
    - Complex stakeholdersveld van verwerkende bedrijven met lagere overheden als aandeelhouder / opdrachtgever:
- Het verkrijgen en behouden van voldoende bestuurlijk draagvlak voor innovaties en vernieuwingen
- Huiver bij lagere overheden voor financiële risico's die gekoppeld zijn aan nieuwe initiatieven (risico's die door de verwerkers worden afgewenteld op de aandeel- houders)
    - Fragmentatie in het vinden en implementeren van oplossingen: het is moeilijk:
- Gemeentelijk clientelisme: gemeentes stellen zich als individuele klant op en zoeken (te) weinig de samenwerking onderling op om tot duurzame oplossingen te komen
- Kwaliteit & continuïteit van de reststromen:
- Probleem van het ondervangen van fluctuaties in volumes, de kwaliteit ervan in de tijd
    - Het vinden / ontsluiten van de juiste kennis is moeilijk:
- Welke route moet worden gekozen in de verwaarding van stedelijke reststromen: bioraffinage vs. energie
    - Financiering van innovatie (=risico) trajecten is moeilijker in de huidige economische situatie.
    - Eventuele garantstellingen door aandeelhouders (=gemeentes) t.b.v. de financiering van innovatie- projecten maakt het noodzakelijk alle stakeholders op juiste moment te betrekken en goed voor te lichten.

Toevoegingen uit kansenronde:

- Aparte recycling van bioplastics
- Andere inzamelstructuren t.b.v. het concentreren van gespecificeerde reststromen (eierschalen?)
- Idem m.b.t. taxus snoeiafval: een voorbeeld uit België waarbij een aantal gemeenten en een verwerker van taxus inzamelingspunten hebben opgezet waar bewoners hun taxus snoeiafval naar toebrengen (Uit sommige taxus-soorten wordt de grondstof voor het kankermedicijn Paclitaxel gewonnen
- Zichtbaar maken naar de consument / maatschappij van er gebeurt met GFT / BOR reststromen. → Motiveert de mensen om specifieke reststromen goed te scheiden en aan te leveren (vgl. moeders-voor-moeders)

Uitkomst: (kansen) van de werksessie Stedelijke Groene Reststromen

1. Kansen op cross-sector samenwerking binnen het thema kleinschalige bioraffinage van GFT en BOR reststromen tussen biobased technology WUR en de afval- verwerkende industrie
2. Er is bij bedrijf 1 behoefte aan kennis over / inzicht in de bioraffinage technieken die (kunnen) aansluiten op de specifieke reststromen van bedrijven (GFT, BOR)
3. Technische kennis vraag
4. Behoefte aan kennis over / inzicht in de kwaliteit van de specifieke reststromen gegeven specifieke keuzes in bioraffinage technieken, en de wijze waarop deze kwaliteit zou kunnen/moeten worden verbeterd.
5. Ten opzichte van branchegenoten is bedrijf 1 koploper als bedrijf dat duurzame innovaties opzoekt en implementeert. Zij zijn de eerste partij in NL die groen gas invoert in het gasnet en bekend met innovatietrajecten. Bedrijf 1 zoekt partijen die kennis en expertise kunnen leveren op het onderwerp bioraffinage GFT/BOR reststromen met het doel inzicht te krijgen in de mogelijkheden in de toekomst (middellange termijn).
6. Investeren in klantrelatie
7. Inventariseren / identificeren van andere afvalverwerkende partijen die een gemeenschappelijk belang kunnen hebben in de verduurzaming van stedelijke reststromen via de bioraffinage route.

Conclusie m.b.t. het thema stedelijke groene reststromen

- Mogelijkheden om onderzoekstraject te ontwikkelen lijkt aanwezig, en zal mogelijk kunnen starten bij een inventarisatie / technische haalbaarheid onderzoek op hoofdstromen, evt. op specifieke (GFT/BOR) stromen.
- Bedrijf 2 zit in adviestrajecten bij gemeenten in Flevoland. Nog niet duidelijk wat de rol kan zijn in de ontwikkeling van mogelijke onderzoeksprojecten.
- Advies zou een rol kunnen hebben in de complexe stakeholderstructuur met ge- meenten die opdrachtgever zijn aan bedrijven die hun GFT/BOR stromen verwerken, en soms ook aandeelhouder zijn van afvalverwerkende bedrijven. Daarin kunnen op verschillende niveaus maatschappelijke en financiële belangen elkaar doorkruisen: duurzaamheidsdoelstelling gemeenten vs. beperkte financiële middelen bij de afvalverwerkers zelf. Daardoor moeten aandeelhouders zich financieel garant stellen bij afdekking financieringsrisico’s een lang proces
- Gedegen risico analyse van geselecteerde bioraffinage route(s) noodzakelijk:
- technisch (FMEA), financieel, organisatorisch.
- Kwaliteitsanalyse van de beschikbare groene reststromen, gegeven de geselecteerde bioraffinage route(s)

Voor indiening van een pre-proposal Kleinschalige Bioraffinage Stedelijke Groene Reststromen in deze ronde is het te vroeg. Investeren in de klantrelatie is nodig en daarbij mogelijkheden te onderzoeken voor het O&O traject. Complexe beslisstructuur (afhankelijk van de omvang van het benodigde budget) kan een rol spelen in de benodigde aanlooptijd naar een project. Mogelijke samenwerking met andere commerciële partijen uit de sector zal daarin ook moeten worden meegenomen, zeker met oog op eventuele indiening van een pre-proposal in 2013.

Conclusie m.b.t. de opzet en structuur van de middag:

- Opzet met werksessie rondom een thema werkt goed en motiverend
- Minpunt was het klein aantal deelnemers; uiteindelijk waren de deelnemers tevreden over de sessie en de uitkomst
- Gegeven de doelstelling vond ik één uur met de groep om het thema concreet uit
- te werken te kort. De interactie met andere deelnemers tijdens de ‘carrousel’
- ronde was leuk maar de opbrengst vond ik uiteindelijk laag.
- Volgende keer proberen meer bedrijven uit de sectoren te werven die verbonden zijn aan verwerking van stedelijke groene reststromen

Annex 8 - Additional information on quantification of the cases

Reference chains

Three reference chains are used to estimate the food print reduction: forest, maize and soy. The following conversion factors are assumed:

Forest

- The yield of forests is 10 ton (DM) of fibre per ha.

Maize

- Maize yield is 18 ton (DM) per ha. It can be decomposed into: 8 ton of starch, 1 ton of protein, 0.7 ton of fat and 4 ton of carbohydrate.

Soy

- Soy yield is 2.9 ton (DM) per ha, 70 per cent remains as waste (2.03 ton (DM) soy waste per ha) and 40 per cent of this waste is composed of protein.

In order to estimate the footprint the following assumptions are made:

- The substitution of feedstock from maize, soy and wood by biomass residue is purely based on the *technical conversion* of protein (and sometimes other materials) from both sources. 1 ton of protein that is extracted from biomass residue substitutes for 1 ton of protein that is contained in feedstock from soy or maize. This implies that the production of protein by means of a bio-refinery and the subsequent conversion into a consumable feedstock product is perfectly substitutable and, hence, competitive with the production of feedstock from maize and soy. If this is not the case, substitution might not take place or in a different proportions due to price and cost differences. The case study description provides more background information on the bio-refinery process and the production of protein and other materials to replace feedstock.
- There are no energy and labour gains and losses associated with transport in the Netherlands (i.e. from and to the bio refinery, to and from the land in case of maize and from the soy crushers to the field in case of soy).

To explore the potential of nature to improve the quality of life

CAT-Agrofood, Wageningen UR
P.O. Box 17
6700 AA Wageningen
The Netherlands
E info.cat-agrofood@wur.nl

www.wageningenUR.nl/cat-agrofood