Algemene gegevens	
PPS-nummer	BBE 1610 - BTG
Titel	Lignin2Fuels
Roadmap	Chemische conversie
Uitvoerende kennisinstelling(en)	BTG Biomass Technology Group BV RijksUniversiteit Groningen
Projectleider onderzoek (naam + emailadres)	dr ir RH Venderbosch venderbosch@btgworld.com
Penvoerder (namens private partijen)	BTG Biomass Technology Group BV
Contactpersoon overheid	
Startdatum	1-9-2017
Einddatum	31-7-2020
Korte omschrijving inhoud (max. 4 regels)	Lignin2Fuel is het omzetten van lignine-rijke stromen naar transportbrandstoffen, additieven en chemicaliën. Het is een tweetraps katalytisch proces, waarin de lignine eerst wordt gedepolymeriseerd en dan gedeoxygeneerd naar brandstof.

Goedkeuring penvoerder / consortium De jaarrapportage dient te worden besproken met de penvoerder/het consortium. De TKI's nemen graag kennis van evt. opmerkingen over de jaarrapportage.	
De penvoerder heeft namens het consortium de jaarrapportage	X goedgekeurd ☐ niet goedgekeurd
Evt. opmerkingen over de jaarrapportage:	

Planning en voortgang (indien er wijzigingen zijn t.o.v. het projectplan svp toelichten)	
Loopt de PPS volgens planning?	Diverse activiteiten binnen de PPS gaan volgens planning, echter was in de PPS voorzien in een PhD student die gedurende de looptijd van het project zijn thesis zou voltooien. Door persoonlijke omstandigheden is de PhD gestopt met de promotie, en is een andere invulling noodzakelijk geworden. Dit is gelukt door een PostDoc aan te nemen, die – zoals voorzien voor de PhD student – deels van zijn tijd bij BTG zal werken om de activiteiten af te gaan ronden. Dit heeft vertraging opgeleverd, orde grootte van zo'n 6 maanden
Zijn er wijzigingen in het consortium/de projectpartners?	Nee
Is er sprake van vertraging en/of uitgestelde opleverdatum?	Zie hierboven. Tgv het afhaken van een PhD student en aannemen/instrueren van een PostDoc is een vertraging van ca. 6 maanden realistisch.
Is er sprake van inhoudelijke knelpunten, geef een korte beschrijving	Nee
Is er sprake van afwijkingen van het ingezette budget/de begroting?	Nee
Verwacht u een octrooi-aanvraag vanuit deze PPS	(Nog) niet

Highlights: geef een korte beschrijving van de belangrijkste resultaten
Lignin is the second most abundant biological material present on Earth after cellulose. It is ~ 40% of the energetic value of the biomass and has unique chemical functionalities. Unfortunately, lignin is complex and diverse on a molecular level, contains residual cellulose and hemicellulose, enzymes, inorganic components, and not suitable to be directly used in the production of various

green chemicals and green fuels.
The project encompasses conversion of lignin from biomass into green materials (BTX as precursor for other products), chemicals (such as phenolics) and energy carriers (for example fuel precursors and additives). Relevant functionalities and molecular structures will be retained (viz. 'the original aromatic structure), while separation can be done efficiently. Sectors generating lignin-rich streams as main or by-product from their operations and benefitting are the pulp and paper industry, composting, anaerobic digestion and 2G bioethanol production.
The Scandinavian countries are the largest producers of pulp and paper lignin. It becomes available as 'black liquor', now mainly incinerated to produce the process energy required. Other types of lignin, lignosulfonates are used as concrete additive in the construction industry, while organosolv lignin is not yet available. The lignin market shows five players accounting for more than 85% share of the global market in 2014. Compost is produced in the aerobic conversion of bio-waste. Digestion is an anaerobic process in which biogas is produced. In Europe annually an estimated 14 Mton of compost is produced of which 1.600 kton/y is produced in The Netherlands, the fourth largest compost producing country in Europe.

The project is divided into 4 main research and development tasks, one task for the technical economic evaluation and one task for coordination:
WP1. Production of lignin feedstocks and pretreatment. Several qualities of lignin will be produced; a lignin with high ash and sodium content, a lignin with low ash content, and a lignin washed to reduce the ash content. Lignin will also be produced from a selection of other lignin-rich resources such as fermentation, anaerobic digestion, composting and sludge from wastewater treatment. A lignin precipitation and separation process will be developed and lignin produced.
Main results:
a) lignin from pyrolysis liquids are produced in larger amounts and further treated in reactors to be depolymerised and deoxygenated.
b) Lignins are pretreated by ozone, and then further depolymerised and deoxygenated.
c) Treated lignins from Sweden – Lignoboost – are shipped and being used in the various tests.

WP2) Screening catalysts and product identification – Initial benchmarking tests will be carried out on purified lignin. An experimental catalyst screening program will be performed in batch autoclaves to identify best catalyst, both commercial as in house made, for the depolymerisation step (step 1). Around 10 catalysts will be tested. Process conditions will be optimized using a multi-parameter study. Key performance parameter is the degree of depolymerisation of products (f.i. by GPC). Oils produced will be used as the starting feed for further LPR treatment in subsequent treatment processes to obtain the required specification as end-products.
Main results
a) Catalyst are screened in the activity in the depolymerisation of lignin; sofar homogenous (basic and acid catalysts) and heterogeneous catalyst (Picula, NiMo) are applied. For the Picula catalyst different types and compositions are applied (and compared to effect on sugars as well). A draft publication is ready for submission paper in the journal 'Energies' regarding a Special Issue entitled "Biomass Fast Pyrolysis" (Wang Yin, 2019).

WP3. The lignins produced will be depolymerized (applying selected solvents) in a continuous trickle bed reactor by applying process conditions based on earlier performed experiments and on input provided by the screening experiments. To understand the influence of the catalysts, the process conditions and lignin quality on the oil yield, the entire product distribution is tracked.
Main results
a) A large number of tests are done using lignins from pyrolysis liquids in continuous set-ups (Scholten 2017; Harbers 2017)
b) Test are done in an autoclave system (Bassa, 2018)

WP4. Longer term demonstration of LPR using lignin. The most promising catalyst/solvent system will be used in extended test runs in a continuous bench scale unit in a matrix of conditions varying the moisture content, catalyst to lignin ratio, temperature, pressure and gas feed rate. Data on conversion, yields (qualities and quantities), catalyst stability and coke formation, and results from reaction network analysis will deployed for process design and economics
Main results
a) A number of tests are done using lignins from pyrolysis liquids in continuous set-ups (Scholten 2017; Harbers 2017)
b) The existing autoclave system has been modified to operate on a continuous basis. Tests are ongoing.

WP5. Product analysis and Techno-Economic Evaluation (TEE) (M12-M36) (BTG, RUG). Lignin oils from WP2-4 will be analyzed to fit with requirements on advanced biofuels compatible with existing infrastructure. The data collected and information from WP3-4 are basis for a conceptual design of the crude lignin-oil stabilization, upgrading and refining processes. A simulation tool will be used for optimization and integration this new technology in an existing environment. The output will be used for a LCA-analysis and an economic assessment, with input on process layout and performance as well as estimated costs on lignin depolymerisation and upgrading. Detailed information about process design and performance will become available and yields from the different process steps as well as estimated investment costs of equipment and operating cost. Process models will be developed, and the heat and mass balance for the overall value chain concept established. Additional value generated from extraction of chemicals (incl. char) will be assessed. Costs will be estimated based on results from the comprehensive modelling software, while LCA analysis will be made. Case studies will be conducted to identify the most favourable production routes.
Main results

a) Activities on the TEE are started, but lack information on the appropriate mass and energy balances. A benchmark case study is to be selected in the coming 6 months.

WP6 Coordination (M1-M36) (BTG, RUG). BTG is coordinator, to monitor progress towards milestones and deliverables, to properly exchange documents, follow-up of time schedules, budgets and registration of deliverables. Routines for quality control of technical work and deliverables will be implemented. The project manager will manage the communication and reporting to TKI. BTG is also responsible for setting up routines for risk management including a project risk register to be discussed and updated at project board meetings, WP-meetings and in WP project progress reports. Coordination and management of the project will also include dissemination, exploitation management and IPR management.
Main results:

a) Continuous task

Aantal opgeleverde producten in 2018 (geef in een bijlage de titels en/of omschrijving van de producten of een link naar de producten op openbare websites)			
Wetenschappelijke artikelen	Rapporten	Artikelen in vakbladen	Inleidingen/ workshops
5); 7)	1); 2); 6)	n/a	n/a

Bijlage: Titels van de producten of een link naar de producten op een openbare website

1) J.M.T. Harbers, 2017, Aromatics production via lignin hydrotreatment, MSc thesis, University of Twente Chemical & Process Engineering
2) W.M. Scholten, 2017, Renewable Bio-Based Chemicals: Aromatics from Lignin, MSc thesis, University of Twente Chemical & Process Engineering
3) Figueirêdo, Monique & Jotic, Z & Deuss, Peter & H Venderbosch, R & Heeres, H.J. (2019). Hydrotreatment of pyrolytic lignins to aromatics and phenolics using heterogeneous catalysts. Fuel Processing Technology. 189. 28-38. 10.1016/j.fuproc.2019.02.020.
4) Figueirêdo, Monique & Deuss, Peter & Hendrikus Venderbosch, Robertus & Jan Heeres, Hero. (2019). Valorization of Pyrolysis Liquids: Ozonation of the Pyrolytic Lignin Fraction and Model Components. ACS Sustainable Chemistry & Engineering. 7. 10.1021/acssuschemeng.8b04856.
5) Wang Yin, Maria V. Bykova, Robertus Hendrikus Venderbosch, Sofia A. Khromova, Vadim A. Yakovlev, Hero Jan Heeres, Catalytic Hydrotreatment of Pyrolytic Sugars and Pyrolytic Lignin Fractions from Fast Pyrolysis Liquids using High Loading Nickel Based Catalysts, For publication in: Energies
6) R. Bassa, 2018, Valorization of Kraft lignin via solvolysis and hydrotreatment, MSc thesis, University of Twente Chemical & Process Engineering

7) M.B. Figueirêdo, P.J. Deuss, R.H. Venderbosch and H.J. Heeres, 2020, Catalytic hydrotreatment of pyrolytic lignins from different sources to biobased chemicals: Identification of feed-product relations, submitted to Biomass & Bioenergy