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出國報告（出國類別：開會）

參加第 31 屆歐洲生質能研討暨商業展示會議出國報告

服務機關：　　核能研究所
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派赴國家/地區：義大利波隆納
出國期間：　　112 年 6 月 3 日~112 年 6 月 10 日
報告日期：　　112 年 8 月 8 日

摘　要

「本次參與的第 31 屆歐洲生質能研討暨商業展示會議(31th European Biomass Conference and Exhibition；EUBCE 2023)的主題是「生質能在未來脫碳技術組合中的角色」。生質能界對歐盟是否能夠在 2050 年前將全球溫度上升控制在 1.5°C 以下感到擔憂。因此，強烈建議透過逐步限制化石燃料的使用來改變遊戲規則，以實現 2050 年淨零碳排的目標，並增加可再生能源的比例。屆時將有更多機會進行創新、競爭並引領可再生能源市場。

本屆歐洲生質能研討暨商業展示會議提出宣言，希望為化石燃料開採設定一個明確的結束日期，並使相關產業可以發揮轉型潛力，成為碳中和與永續生質經濟的一部分，減少對化石能源的高度依賴。

會議中展示了將廢棄物轉化為可再生能源和化學產品，以及在農村地區推動生質經濟實踐的研究。這些展示顯示了生質能源的巨大潛力和永續發展的方向，本所的研發技術發展也正朝向國際目標前進。期望未來能持續透過計畫與部門間相互合作，共同發展適合我國的循環經濟示範計畫，並擴大應用，增進減碳效益及環境永續發展。」

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一、目　的

配合「海洋可分解塑膠 PHAs 綠色生產技術開發與應用研究(3/4)」與「聚乳酸(PLA)化學解聚回收及再利用技術開發」計畫之研發進展，因此參加第 31 屆歐洲生質能研討暨商業展示會議(31st European Biomass Conference and Exhibition，EUBCE)，發表「Multiple Applications of Agricultural Residues Biorefineries for biochemical production」海報論文，以與國際同儕交流，掌握最新研發進展。

歐洲生質能研討會暨展示會是目前世界最大的生質能會議與展覽，而該領域的科學計畫受歐盟委員會、聯合國教科文組織自然科學部、歐洲生質能產業協會、世界可再生能源委員會等國際組織大力支持。每年 EUBCE 都會匯集生質能領域的專家學者分享創新想法與最新進展，加速全球的研究和產業化。會議期間，來自學術界和工業界的 2,000 多位專家分享和討論了生質物採購、生產和利用方面的創新想法、技術、應用和解決方案。本次會議主題探討生質能產業發展前景、促進環境永續發展、緩和氣候變遷之貢獻，以及碳捕捉、碳封存與碳移除技術，期望於 2050 年達到淨零碳排或負碳排。藉由導入生質化學品、生質燃料及相關生質產品，促進經濟發展，達成綠色循環經濟。本計畫研發主題，包含生質廢棄物轉化生質可分解生質塑膠 PHA 或 PLA 等應用，研究範疇與會議目標契合，因此透過國際研討會，蒐集最新生質能發展資料及經驗，並汲取國外生質能產業發展策略、生質精煉、工業生技等相關技術與整合情況，這些資訊對本所計畫執行與推廣具參考價值。

本次參與會議之效益簡述如下：

(1)掌握國際生質能源發展動態：藉由會議互動，取得生質能源研發的最新進程和市場發展趨勢，並參酌歐盟或國際上現行政策法規的推動情形，提供所內訂定生質能相關計畫目標參考。

(2)了解國外生質能源產業發展規劃：本次商展會有需多參展廠商為歐盟知名生質能源產業與相關工業組織，有助於了解國際上生質能源市場動態、技術需求，及討論其相關生質能源產業鏈之營運模式，所得資訊有助於生質能源產業本土化之發展規劃，接軌國際市場之產業布局。

(3)新興技術與淨零碳排的願景與目標：本次會議著重於瞭解國際廠商針對降低碳排量的

研究與試運轉情況，可做為所內計畫布局及國內廠商推動相關技術開發及土地管理、利用與相關生質物資源蒐集的參考，增加投入相關產業發展之信心，提升計畫研發人力及資源的運用更有效率，後續可依我國的環境現況設定技術研發目標，並與國際接軌。

二、過　程

(一)行程說明

本次行程於 6/3(六)自桃園國際機場啟程，於義大利當地時間 6/4(日)抵達米蘭國際機場，隨即前往會議地點波隆那會議中心(Bologna Congress Center)報到並依規定張貼海報論文。6/5(一)至 6/8(四)則依會議既定議程參與會議與壁報論文演示，會議結束後即於 6/9(五)於羅馬達文西國際機場搭機回程，並於 6/10(六)返抵桃園國際機場，本次行程如表 1 所示。會議地點(Bologna Congress Center)及相關會議室、展示會場及海報論文展示區域如圖 1 及 2 所示。

表 1 本次出國公差行程

日期	地點	行程
6/3(六)-6/4(日)	台灣桃園→ 義大利波隆那	去程、研討會報到及海報論文張貼
6/5(一)	義大利波隆那	參加第 31 屆歐洲生質能研討暨商業展示會議(31th European Biomass Conference and Exhibition，EUBCE)以及發表海報論文
6/6(二)		
6/7(三)		
6/8(四)		
6/9(五)-6/10(六)	義大利波隆那→台灣桃園	回程

圖 1 會議地點(Bologna Congress Center)

圖 2 Bologna Congress Center 國際會議廳

(二)會議主題及其相關簡介

研討會議程分為 7 個主軸議題，包括：

(1) 經濟脫碳的永續資源(SUSTAINABLE RESOURCES FOR DECARBONISING THE ECONOMY)；

(2) 永續性、影響和政策(SUSTAINABILITY, IMPACTS AND POLICIES)；

(3) 生質能、生質基產品和生質能源整合(BIOMASS, BIO-BASED PRODUCTS AND BIOENERGY INTEGRATION)；

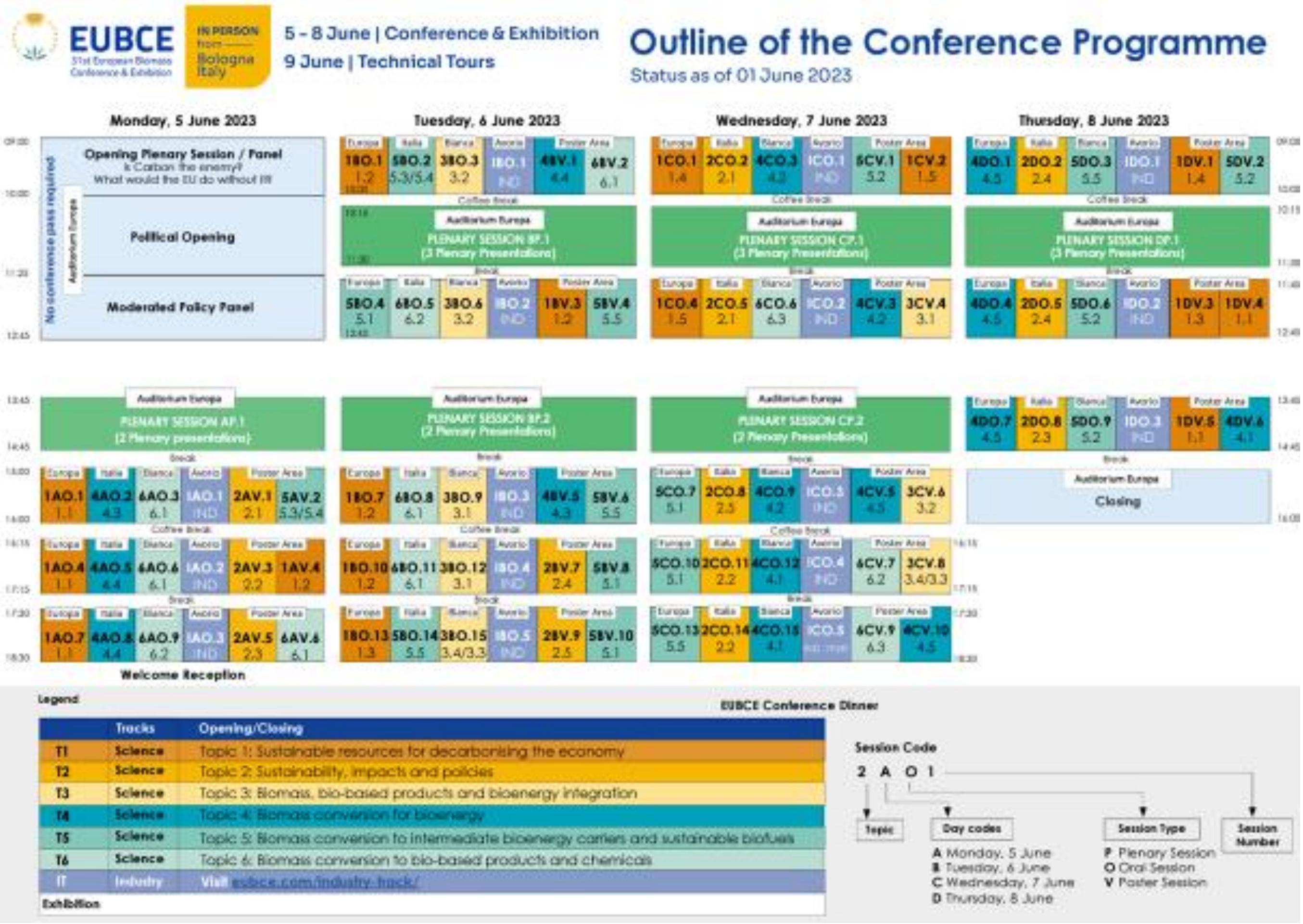
(4) 生質能源的生質能轉化(BIOMASS CONVERSION FOR BIOENERGY)；

(5) 生質能轉化為中間生質能源載體和永續生質燃料(BIOMASS CONVERSION TO INTERMEDIATE BIOENERGY CARRIERS AND SUSTAINABLE BIOFUELS)；

(6) 生質能轉化為生質基產品和化學品(BIOMASS CONVERSION TO BIO-BASED PRODUCTS AND CHEMICALS)；

(7) 產業發展(INDUSTRY TRACK)。

本次會議為期 4 天，議程如圖 3 所示，除開幕式、閉幕式及每天上午、下午各一場的大會會議(plenary session)外，每天有多個時段，同時進行 4 個不同主題之研討會議與海報演示(每個時段歷時 1 小時，包含口頭及海報展示會議)。同時，展示廠商(如圖 4 所示)並於會議的過程中，持續進行燃料、沼氣、氣化等相關生質能設備之展示以及歐盟整合計畫之簡介等活動。本次會議統計了從 1980 年以來與會者的資訊(如圖 5 所示)，該會議有來自超過 90 個國家、34,000 個參與者參與，顯見此會議越發受到重視。由於此次會議涵蓋的主題豐富，林員與朱員於行前已進行各主題相關會議參規劃及分工。



EUBCE
31st European Biomass Conference & Exhibition

IN PERSON from Bologna Italy

5 - 8 June | Conference & Exhibition
9 June | Technical Tours

Outline of the Conference Programme
Status as of 01 June 2023

Monday, 5 June 2023

No conference pass required — Auditorium Europa

Time	Session
09:00	**Opening Plenary Session / Panel** Is Carbon the enemy? What would the EU do without it?
10:00	**Political Opening**
11:20	**Moderated Policy Panel**
12:45	

Time	Europa	Italia	Bianca	Avorio	Poster Area	Poster Area
13:45–14:45	Auditorium Europa PLENARY SESSION AP.1 (2 Plenary presentations)					
	Break					
15:00–16:00	1AO.1 1.1	4AO.2 4.3	6AO.3 6.1	IAO.1 IND	2AV.1 2.1	5AV.2 5.3/5.4
	Coffee Break					
16:15–17:15	1AO.4 1.1	4AO.5 4.4	6AO.6 6.1	IAO.2 IND	2AV.3 2.2	1AV.4 1.2
	Break					
17:30–18:30	1AO.7 1.1	4AO.8 4.4	6AO.9 6.2	IAO.3 IND	2AV.5 2.3	6AV.6 6.1

Welcome Reception

Tuesday, 6 June 2023

Time	Europa	Italia	Bianca	Avorio	Poster Area	Poster Area
09:00–10:00	1BO.1 1.2	5BO.2 5.3/5.4	3BO.3 3.2	IBO.1 IND	4BV.1 4.4	6BV.2 6.1
	Coffee Break					
10:15–11:30	Auditorium Europa PLENARY SESSION BP.1 (3 Plenary Presentations)					
	Break					
11:40–12:40	5BO.4 5.1	6BO.5 6.2	3BO.6 3.2	IBO.2 IND	1BV.3 1.2	5BV.4 5.5
13:45–14:45	Auditorium Europa PLENARY SESSION BP.2 (2 Plenary Presentations)					
	Break					
15:00–16:00	1BO.7 1.2	6BO.8 6.1	3BO.9 3.1	IBO.3 IND	4BV.5 4.3	5BV.6 5.5
	Coffee Break					
16:15–17:15	1BO.10 1.2	6BO.11 6.1	3BO.12 3.1	IBO.4 IND	2BV.7 2.4	5BV.8 5.1
	Break					
17:30–18:30	1BO.13 1.3	5BO.14 5.5	3BO.15 3.4/3.3	IBO.5 IND	2BV.9 2.5	5BV.10 5.1

Wednesday, 7 June 2023

Time	Europa	Italia	Bianca	Avorio	Poster Area	Poster Area
09:00–10:00	1CO.1 1.4	2CO.2 2.1	4CO.3 4.2	ICO.1 IND	5CV.1 5.2	1CV.2 1.5
	Coffee Break					
10:15–11:30	Auditorium Europa PLENARY SESSION CP.1 (3 Plenary Presentations)					
	Break					
11:40–12:40	1CO.4 1.5	2CO.5 2.1	6CO.6 6.3	ICO.2 IND	4CV.3 4.2	3CV.4 3.1
13:45–14:45	Auditorium Europa PLENARY SESSION CP.2 (2 Plenary Presentations)					
	Break					
15:00–16:00	5CO.7 5.1	2CO.8 2.5	4CO.9 4.2	ICO.3 IND	4CV.5 4.5	3CV.6 3.2
	Coffee Break					
16:15–17:15	5CO.10 5.1	2CO.11 2.2	4CO.12 4.1	ICO.4 IND	6CV.7 6.2	3CV.8 3.4/3.3
	Break					
17:30–18:30	5CO.13 5.5	2CO.14 2.2	4CO.15 4.1	ICO.5 [illegible]	6CV.9 6.3	4CV.10 4.5

EUBCE Conference Dinner

Thursday, 8 June 2023

Time	Europa	Italia	Bianca	Avorio	Poster Area	Poster Area
09:00–10:00	4DO.1 4.5	2DO.2 2.4	5DO.3 5.5	IDO.1 IND	1DV.1 1.4	5DV.2 5.2
	Coffee Break					
10:15–11:30	Auditorium Europa PLENARY SESSION DP.1 (3 Plenary Presentations)					
	Break					
11:40–12:40	4DO.4 4.5	2DO.5 2.4	5DO.6 5.2	IDO.2 IND	1DV.3 1.3	1DV.4 1.1
13:45–14:45	4DO.7 4.5	2DO.8 2.3	5DO.9 5.2	IDO.3 IND	1DV.5 1.1	4DV.6 4.1
	Break					
–16:00	Auditorium Europa **Closing**					

Legend

	Tracks	Opening/Closing
T1	Science	Topic 1: Sustainable resources for decarbonising the economy
T2	Science	Topic 2: Sustainability, impacts and policies
T3	Science	Topic 3: Biomass, bio-based products and bioenergy integration
T4	Science	Topic 4: Biomass conversion for bioenergy
T5	Science	Topic 5: Biomass conversion to intermediate bioenergy carriers and sustainable biofuels
T6	Science	Topic 6: Biomass conversion to bio-based products and chemicals
IT	Industry	Visit eubce.com/industry-track/
Exhibition		

Session Code

2 A O 1

Topic	Day codes	Session Type	Session Number
2	A Monday, 5 June B Tuesday, 6 June C Wednesday, 7 June D Thursday, 8 June	P Plenary Session O Oral Session V Poster Session	1

圖 3 會議議程表

圖 4 第 31 屆歐洲生質能研討暨商業展示會議之參與廠商

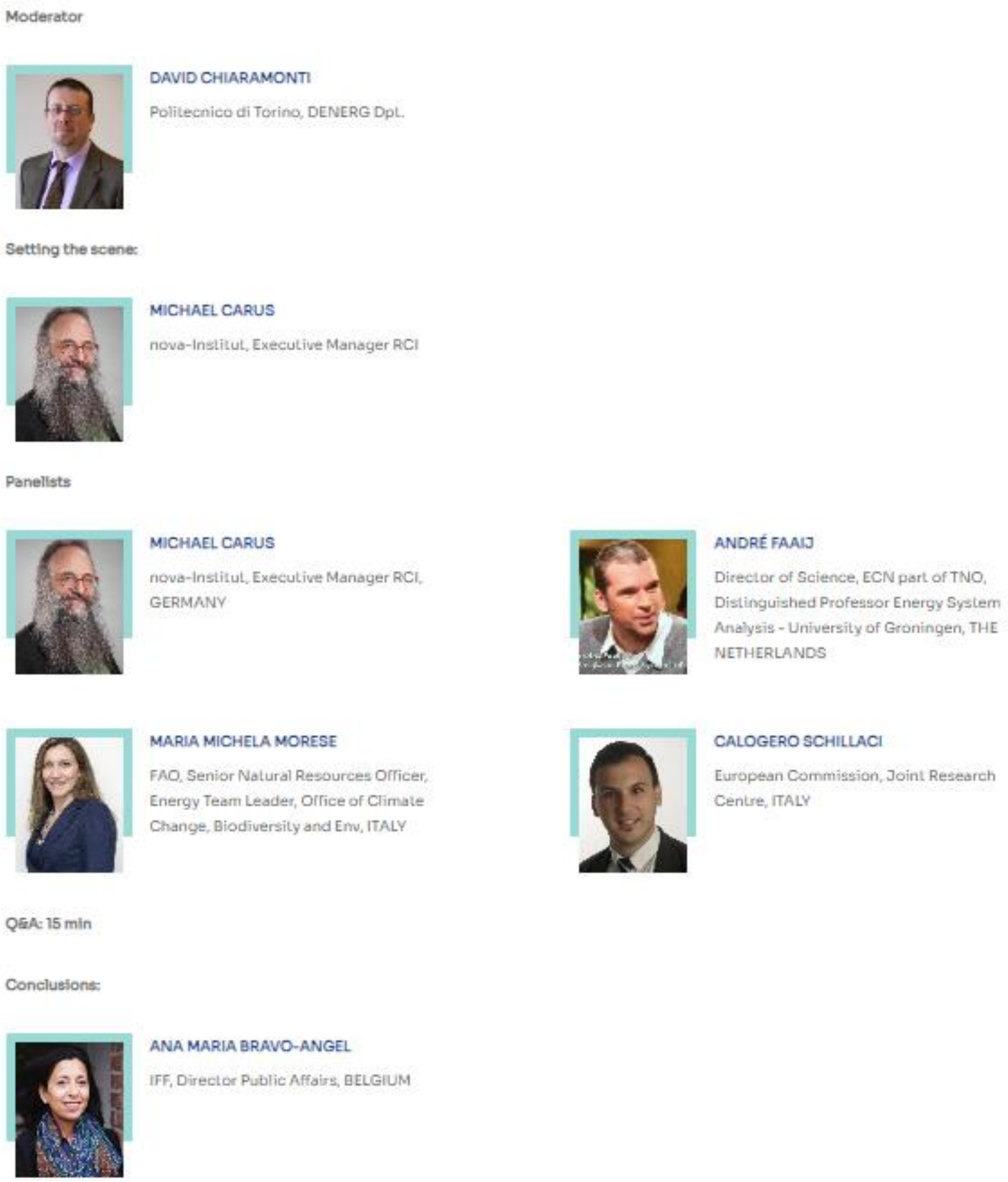
圖 5 EUBCE 與會者統計

(三)會議參與情形

本次會議議程較為緊湊，同一時段同時具有 4 場個人報告與 2 場海報演示，故會議參與以計畫相關主題為主，選取的會議場次如下：

1. 主論壇 Is Carbon the enemy? What would the EU do without it?

主論壇包含開幕致詞(Opening Addresses)、科學開幕式(Scientific Opening/Plenary Session Applications of Science in Industry)以及主題小組討論(Moderated Panel Discussion)。



Moderator

DAVID CHIARAMONTI
Politecnico di Torino, DENERG Dpt.

Setting the scene:

MICHAEL CARUS
nova-Institut, Executive Manager RCI

Panelists

MICHAEL CARUS
nova-Institut, Executive Manager RCI, GERMANY

ANDRÉ FAAIJ
Director of Science, ECN part of TNO, Distinguished Professor Energy System Analysis - University of Groningen, THE NETHERLANDS

MARIA MICHELA MORESE
FAO, Senior Natural Resources Officer, Energy Team Leader, Office of Climate Change, Biodiversity and Env, ITALY

CALOGERO SCHILLACI
European Commission, Joint Research Centre, ITALY

Q&A: 15 min

Conclusions:

ANA MARIA BRAVO-ANGEL
IFF, Director Public Affairs, BELGIUM

圖 6 開幕式與會講者

2.口頭發表組 6AO.3 : Biomass pre-treatment processes

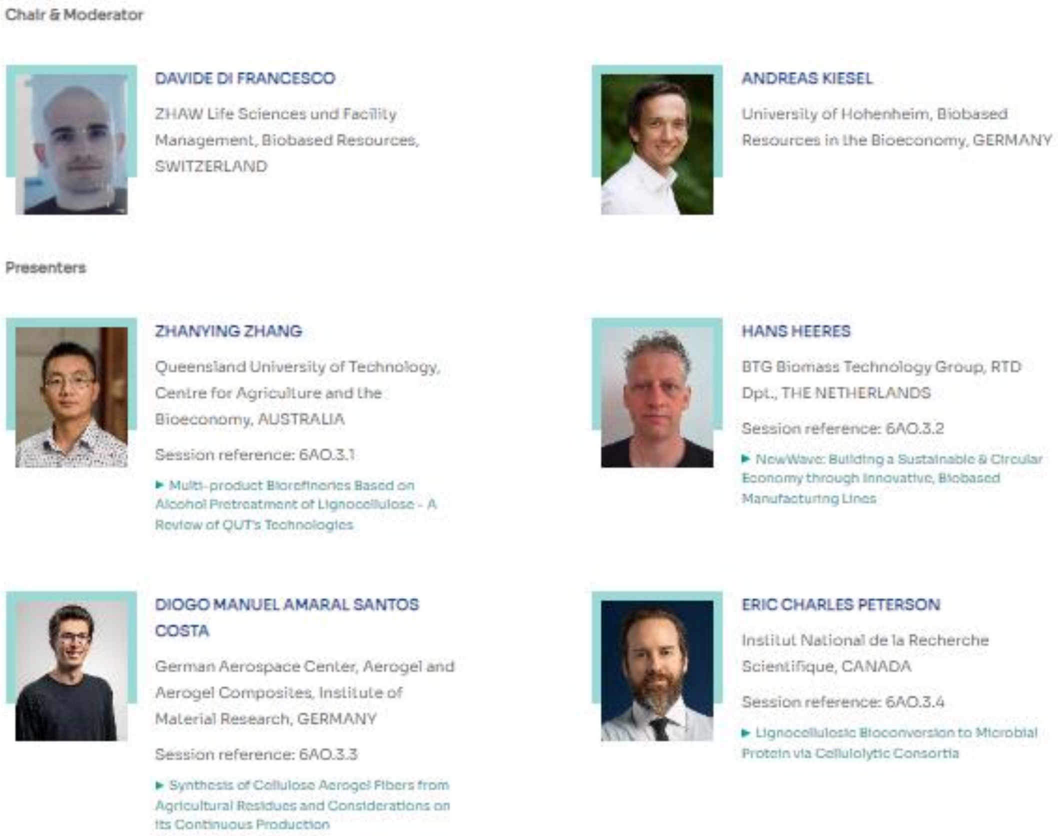
會議主要關注木質纖維素生質能原料在世界各地的生質精煉過程中轉化之前的預處理方法。

(1) ZHANYING ZHANG, Multi-product Biorefineries Based on Alcohol Pretreatment of Lignocellulose - A Review of QUT’s Technologies.

(2) HANS HEERES, NewWave: Building a Sustainable & Circular Economy through Innovative, Biobased Manufacturing Lines.

(3) DIOGO MANUEL AMARAL SANTOS COSTA, Synthesis of Cellulose Aerogel Fibers from Agricultural Residues and Considerations on its Continuous Production.

(4) ERIC CHARLES PETERSON, Lignocellulosic Bioconversion to Microbial Protein via Cellulolytic Consortia.



Chair & Moderator

DAVIDE DI FRANCESCO
ZHAW Life Sciences und Facility Management, Biobased Resources, SWITZERLAND

ANDREAS KIESEL
University of Hohenheim, Biobased Resources in the Bioeconomy, GERMANY

Presenters

ZHANYING ZHANG
Queensland University of Technology, Centre for Agriculture and the Bioeconomy, AUSTRALIA
Session reference: 6AO.3.1
▸ Multi-product Biorefineries Based on Alcohol Pretreatment of Lignocellulose - A Review of QUT's Technologies

HANS HEERES
BTG Biomass Technology Group, RTD Dpt., THE NETHERLANDS
Session reference: 6AO.3.2
▸ NewWave: Building a Sustainable & Circular Economy through Innovative, Biobased Manufacturing Lines

DIOGO MANUEL AMARAL SANTOS COSTA
German Aerospace Center, Aerogel and Aerogel Composites, Institute of Material Research, GERMANY
Session reference: 6AO.3.3
▸ Synthesis of Cellulose Aerogel Fibers from Agricultural Residues and Considerations on its Continuous Production

ERIC CHARLES PETERSON
Institut National de la Recherche Scientifique, CANADA
Session reference: 6AO.3.4
▸ Lignocellulosic Bioconversion to Microbial Protein via Cellulolytic Consortia

圖 7 口頭發表組 6AO.3 與會講者

3.口頭發表組 Biomass-based Technologies and Practices for Carbon Dioxide Removal

會議概述基於生質物技術的 NETPS 在歐盟和全球範圍內的評估情景中的作用，以及 NEGEM 項目內開發的不同建模工作和其他活動的初步結果，以評估潛力和基於生質能的 NETP 在技術參數、地球邊界內的部署、碳去除效率、與糧食系統的相互依賴性以及社會經濟方面的可能影響。

4.口頭發表組 1BO.1 : Innovative strategies to produce dedicated biomass for bioenergy, biofuels and bio-based products

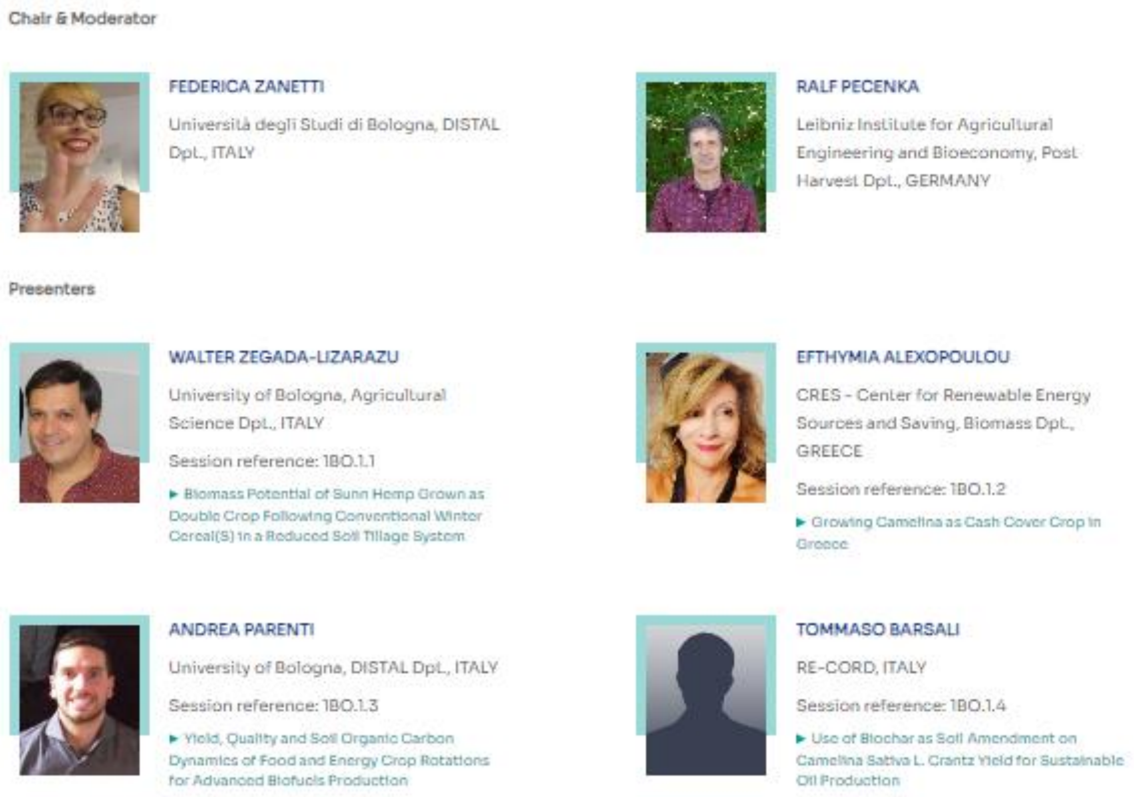
會議主要講述通過改變現有的農業實踐，生產專門用於生質能源、生質燃料和生質基產品的生質能。

(1) WALTER ZEGADA-LIZARAZU, Biomass Potential of Sunn Hemp Grown as Double Crop Following Conventional Winter Cereal(S) in a Reduced Soil Tillage System.

(2) EFTHYMIA ALEXOPOULOU, Growing Camelina as Cash Cover Crop in Greece.

(3) ANDREA PARENTI, Yield, Quality and Soil Organic Carbon Dynamics of Food and Energy Crop Rotations for Advanced Biofuels Production.

(4) TOMMASO BARSALI, Use of Biochar as Soil Amendment on Camelina Sativa L. Crantz Yield for Sustainable Oil Production.



Chair & Moderator

FEDERICA ZANETTI

Università degli Studi di Bologna, DISTAL Dpt., ITALY

RALF PECENKA

Leibniz Institute for Agricultural Engineering and Bioeconomy, Post Harvest Dpt., GERMANY

Presenters

WALTER ZEGADA-LIZARAZU

University of Bologna, Agricultural Science Dpt., ITALY

Session reference: 1BO.1.1

▸ Biomass Potential of Sunn Hemp Grown as Double Crop Following Conventional Winter Cereal(S) in a Reduced Soil Tillage System

EFTHYMIA ALEXOPOULOU

CRES - Center for Renewable Energy Sources and Saving, Biomass Dpt., GREECE

Session reference: 1BO.1.2

▸ Growing Camelina as Cash Cover Crop in Greece

ANDREA PARENTI

University of Bologna, DISTAL Dpt., ITALY

Session reference: 1BO.1.3

▸ Yield, Quality and Soil Organic Carbon Dynamics of Food and Energy Crop Rotations for Advanced Biofuels Production

TOMMASO BARSALI

RE-CORD, ITALY

Session reference: 1BO.1.4

▸ Use of Biochar as Soil Amendment on Camelina Sativa L. Crantz Yield for Sustainable Oil Production

圖 8 口頭發表組 1BO.1 與會講者

5.口頭發表組 3BO.3 : Integrated Biorefineries

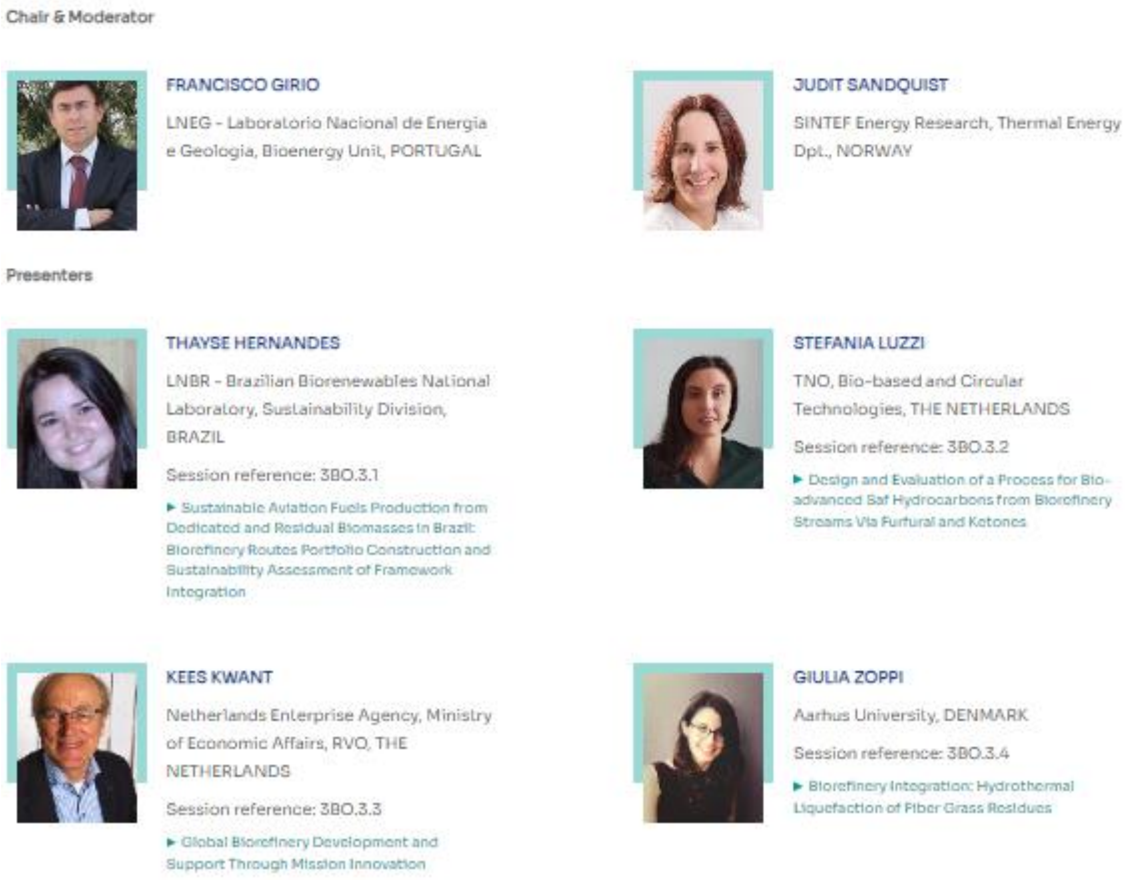
會議討論了生質精煉廠採用一系列技術實現產品最佳輸出的綜合概念，並包括對全球生質精煉廠發展的評估。

(1) WALTER ZEGADA-LIZARAZU, Biomass Potential of Sunn Hemp Grown as Double Crop Following Conventional Winter Cereal(S) in a Reduced Soil Tillage System.

(2) EFTHYMIA ALEXOPOULOU, Growing Camelina as Cash Cover Crop in Greece.

(3) ANDREA PARENTI, Yield, Quality and Soil Organic Carbon Dynamics of Food and Energy Crop Rotations for Advanced Biofuels Production.

(4) TOMMASO BARSALI, Use of Biochar as Soil Amendment on Camelina Sativa L. Crantz Yield for Sustainable Oil Production.



Chair & Moderator

FRANCISCO GIRIO
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Presenters

THAYSE HERNANDES
LNBR - Brazilian Biorenewables National Laboratory, Sustainability Division, BRAZIL
Session reference: 3BO.3.1
▸ Sustainable Aviation Fuels Production from Dedicated and Residual Biomasses in Brazil: Biorefinery Routes Portfolio Construction and Sustainability Assessment of Framework Integration

STEFANIA LUZZI
TNO, Bio-based and Circular Technologies, THE NETHERLANDS
Session reference: 3BO.3.2
▸ Design and Evaluation of a Process for Bio-advanced Saf Hydrocarbons from Biorefinery Streams Via Furfural and Ketones

KEES KWANT
Netherlands Enterprise Agency, Ministry of Economic Affairs, RVO, THE NETHERLANDS
Session reference: 3BO.3.3
▸ Global Biorefinery Development and Support Through Mission Innovation

GIULIA ZOPPI
Aarhus University, DENMARK
Session reference: 3BO.3.4
▸ Biorefinery Integration: Hydrothermal Liquefaction of Fiber Grass Residues

圖 9 口頭發表組 3BO.3 與會講者

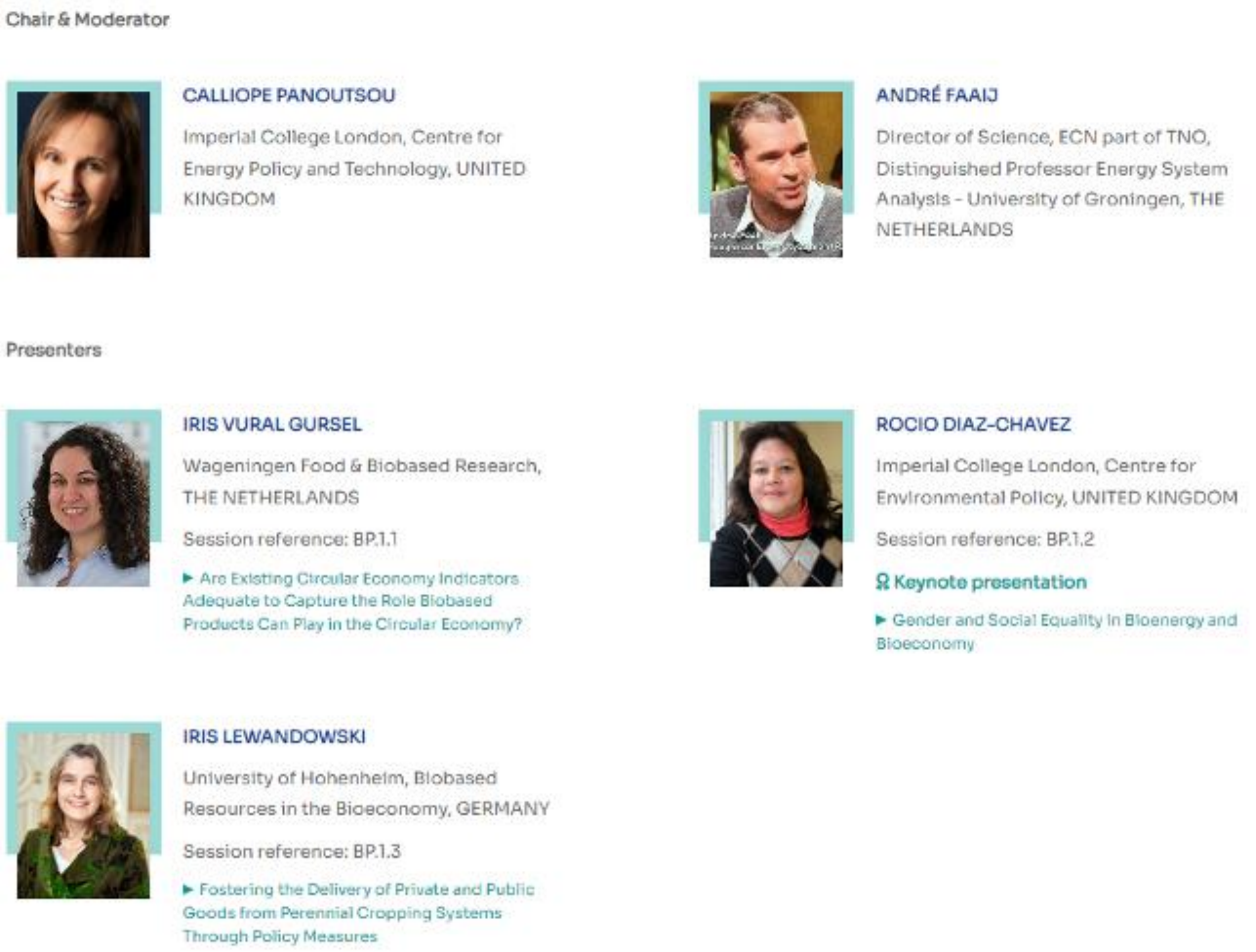
6.口頭發表組 BP.1 : Socio-economic aspects in circular economy

會議討論了循環生質經濟相關的一些更廣泛的永續性問題。

(1) IRIS VURAL GURSEL, Are Existing Circular Economy Indicators Adequate to Capture the Role Biobased Products Can Play in the Circular Economy?

(2) ROCIO DIAZ-CHAVEZ, Gender and Social Equality in Bioenergy and Bioeconomy.

(3) IRIS LEWANDOWSKI, Fostering the Delivery of Private and Public Goods from Perennial Cropping Systems Through Policy Measures.



Chair & Moderator

CALLIOPE PANOUTSOU

Imperial College London, Centre for Energy Policy and Technology, UNITED KINGDOM

ANDRÉ FAAIJ

Director of Science, ECN part of TNO, Distinguished Professor Energy System Analysis - University of Groningen, THE NETHERLANDS

Presenters

IRIS VURAL GURSEL

Wageningen Food & Biobased Research, THE NETHERLANDS

Session reference: BP.1.1

▶ Are Existing Circular Economy Indicators Adequate to Capture the Role Biobased Products Can Play in the Circular Economy?

ROCIO DIAZ-CHAVEZ

Imperial College London, Centre for Environmental Policy, UNITED KINGDOM

Session reference: BP.1.2

Keynote presentation

▶ Gender and Social Equality in Bioenergy and Bioeconomy

IRIS LEWANDOWSKI

University of Hohenheim, Biobased Resources in the Bioeconomy, GERMANY

Session reference: BP.1.3

▶ Fostering the Delivery of Private and Public Goods from Perennial Cropping Systems Through Policy Measures

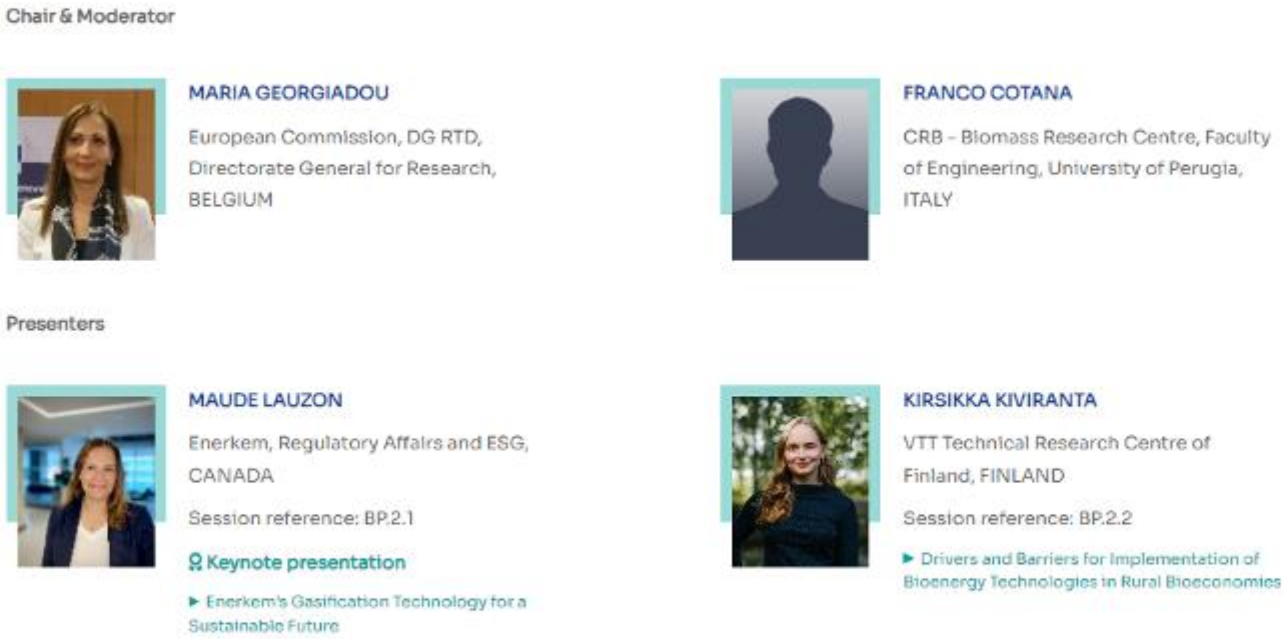
圖 10 BP.1 與會講者

7.口頭發表組 BP.2 : Bioenergy and biobased products

會議討論了綜合生質精煉概念的實施以及生質能源技術實施的驅動因素和障礙。

(1) MAUDE LAUZON, Enerkem’s Gasification Technology for a Sustainable Future.

(2) KIRSIKKA KIVIRANTA, Drivers and Barriers for Implementation of Bioenergy Technologies in Rural Bioeconomies.



Chair & Moderator

MARIA GEORGIADOU
European Commission, DG RTD, Directorate General for Research, BELGIUM

FRANCO COTANA
CRB - Biomass Research Centre, Faculty of Engineering, University of Perugia, ITALY

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Enerkem, Regulatory Affairs and ESG, CANADA
Session reference: BP.2.1
Keynote presentation
▶ Enerkem's Gasification Technology for a Sustainable Future

KIRSIKKA KIVIRANTA
VTT Technical Research Centre of Finland, FINLAND
Session reference: BP.2.2
▶ Drivers and Barriers for Implementation of Bioenergy Technologies in Rural Bioeconomies

圖 11 BP.2 與會講者

8. 口頭發表組 6BO.8 : New products from biomass

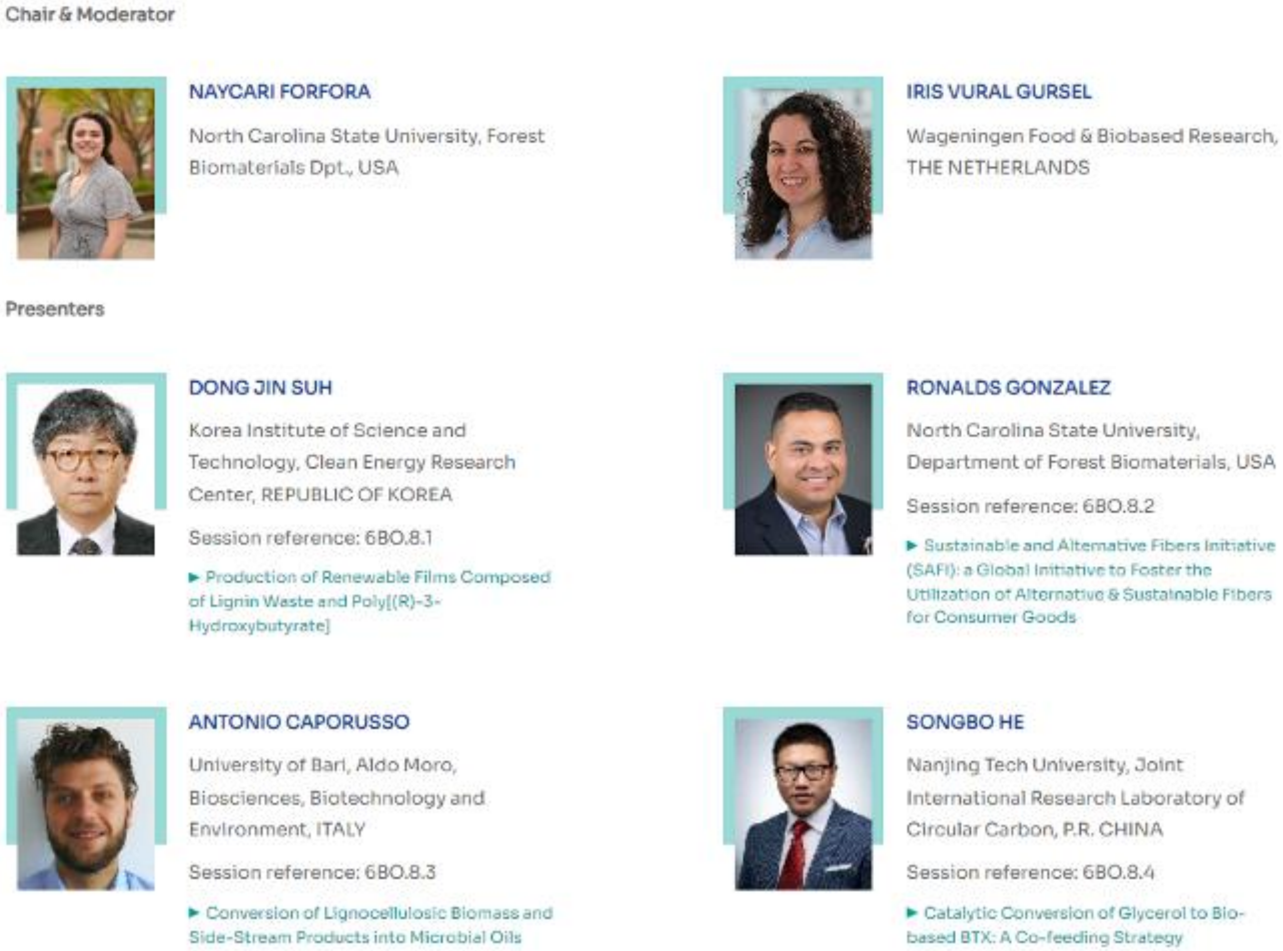
由於創新的生質精煉系統正在湧現出新產品，故本次會議著眼於新產品的示例，包括可再生薄膜、橄欖纖維增強聚合物、來自甘油的生質基 BTX，以及從中試規模的生質多元醇生產中吸取的一些經驗教訓。

(1) DONG JIN SUH, Production of Renewable Films Composed of Lignin Waste and Poly[(R)-3-Hydroxybutyrate].

(2) RONALDS GONZALEZ, Sustainable and Alternative Fibers Initiative (SAFI): a Global Initiative to Foster the Utilization of Alternative & Sustainable Fibers for Consumer Goods.

(3) ANTONIO CAPORUSSO, Conversion of Lignocellulosic Biomass and Side-Stream Products into Microbial Oils.

(4) SONGBO HE, Catalytic Conversion of Glycerol to Bio-based BTX: A Co-feeding Strategy.



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NAYCARI FORFORA

North Carolina State University, Forest Biomaterials Dpt., USA

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Presenters

DONG JIN SUH

Korea Institute of Science and Technology, Clean Energy Research Center, REPUBLIC OF KOREA

Session reference: 6BO.8.1

▸ Production of Renewable Films Composed of Lignin Waste and Poly[(R)-3-Hydroxybutyrate]

RONALDS GONZALEZ

North Carolina State University, Department of Forest Biomaterials, USA

Session reference: 6BO.8.2

▸ Sustainable and Alternative Fibers Initiative (SAFI): a Global Initiative to Foster the Utilization of Alternative & Sustainable Fibers for Consumer Goods

ANTONIO CAPORUSSO

University of Bari, Aldo Moro, Biosciences, Biotechnology and Environment, ITALY

Session reference: 6BO.8.3

▸ Conversion of Lignocellulosic Biomass and Side-Stream Products into Microbial Oils

SONGBO HE

Nanjing Tech University, Joint International Research Laboratory of Circular Carbon, P.R. CHINA

Session reference: 6BO.8.4

▸ Catalytic Conversion of Glycerol to Bio-based BTX: A Co-feeding Strategy

圖 12 口頭發表組 6BO.8 與會講者

9. 口頭發表組 3BO.9 : Biogas and Power to Gas

本次會議討論關於沼氣廠和電轉氣系統有很好的機會來支持能源系統，並且在會議中展示了該領域的一些具體示例和進展。

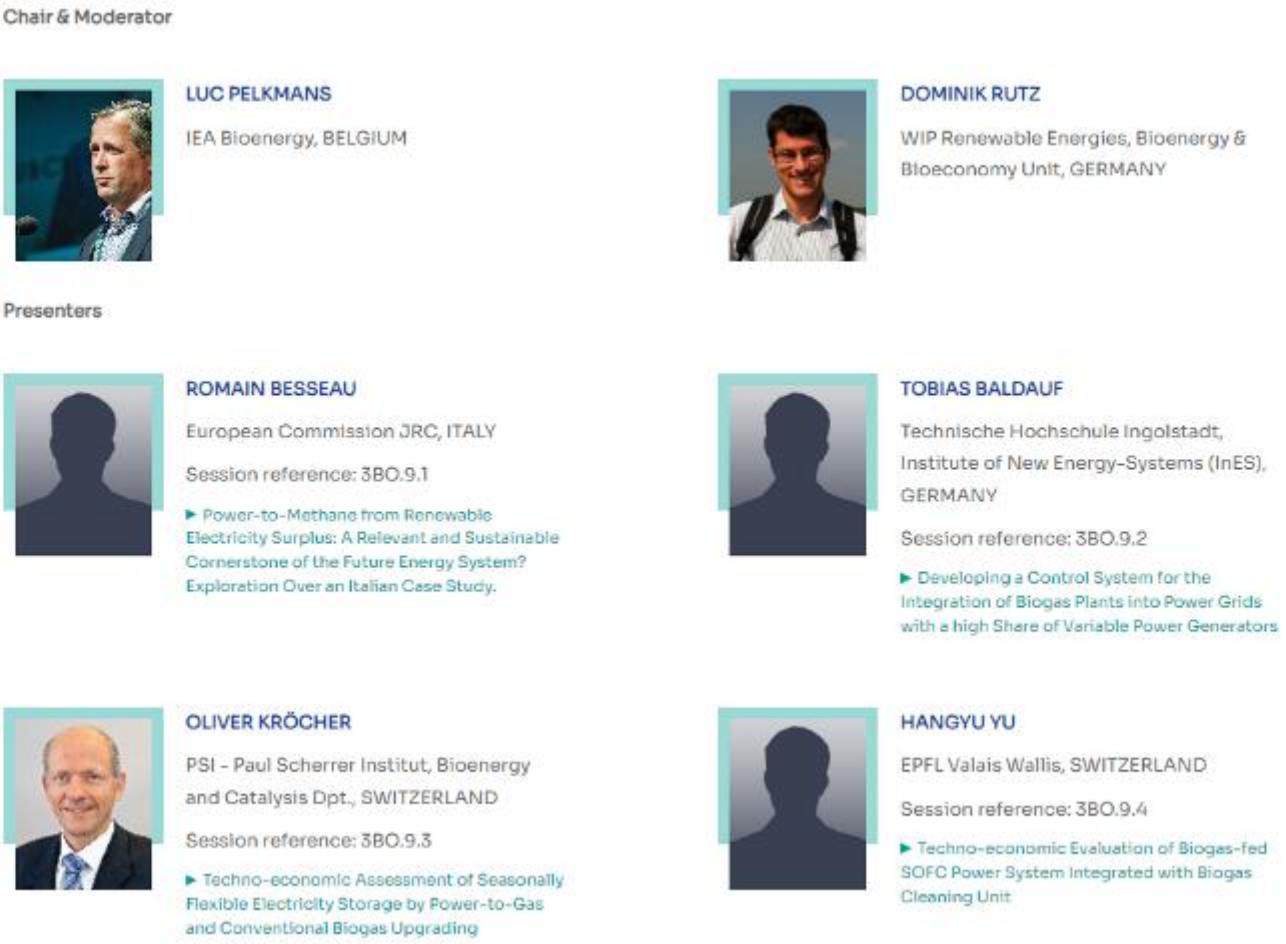
(1) ROMAIN BESSEAU, Power-to-Methane from Renewable Electricity Surplus: A Relevant and Sustainable Cornerstone of the Future Energy System? Exploration Over an Italian Case Study.

(2) TOBIAS BALDAUF, Developing a Control System for the Integration of Biogas Plants into Power Grids with a high Share of Variable Power Generators.

(3) OLIVER KRÖCHER, Techno-economic Assessment of Seasonally Flexible Electricity Storage by Power-to-Gas and Conventional Biogas Upgrading.

(4) HANGYU YU, Techno-economic Evaluation of Biogas-fed SOFC Power System

Integrated with Biogas Cleaning Unit.



Chair & Moderator

LUC PELKMANS

IEA Bioenergy, BELGIUM

DOMINIK RUTZ

WIP Renewable Energies, Bioenergy & Bioeconomy Unit, GERMANY

Presenters

ROMAIN BESSEAU

European Commission JRC, ITALY

Session reference: 3BO.9.1

▸ Power-to-Methane from Renewable Electricity Surplus: A Relevant and Sustainable Cornerstone of the Future Energy System? Exploration Over an Italian Case Study.

TOBIAS BALDAUF

Technische Hochschule Ingolstadt, Institute of New Energy-Systems (InES), GERMANY

Session reference: 3BO.9.2

▸ Developing a Control System for the Integration of Biogas Plants into Power Grids with a high Share of Variable Power Generators

OLIVER KRÖCHER

PSI - Paul Scherrer Institut, Bioenergy and Catalysis Dpt., SWITZERLAND

Session reference: 3BO.9.3

▸ Techno-economic Assessment of Seasonally Flexible Electricity Storage by Power-to-Gas and Conventional Biogas Upgrading

HANGYU YU

EPFL Valais Wallis, SWITZERLAND

Session reference: 3BO.9.4

▸ Techno-economic Evaluation of Biogas-fed SOFC Power System Integrated with Biogas Cleaning Unit

圖 13 口頭發表組 3BO.9 與會講者

10.海報發表組，挑選領域相關之發表內容，可參閱附件：

1.1DV.4.3 AGROCLIMATIC MODELING FOR EUCALYPTUS AVAILABILITY ESTIMATION TO PRODUCE ADVANCED BIOFUELS.

2.1DV.4.18 UPDATING OF WOOD FUEL TERMINAL MODELS TO ENSURE FUEL SUPPLY IN FINLAND.

3.3CV.4.2 INTEGRATED APPRAISAL OF SUGARCANE BIOREFINERIES FOR GREEN HYDROGEN PRODUCTION IN THE BRAZILIAN CASE.

4.3CV.4.4 TECHNO-ECONOMIC AND LIFE-CYCLE ASSESSMENT OF FOREST RESIDUE SUPPLY CHAIN AND COMBINED HEAT POWER GENERATION IN RURAL COMMUNITIES:A CASE STUDY IN CANADA.

5.3CV.4.15 BIOGAS-REFORMING CATALYSTS DEACTIVATION MECHANISMS OF NI-FE AND RU-EXSOLUTION DURING PROLONGED EXPOSURE TO H2S AND DMS CONTAMINANTS.

6.3CV.6.16 EVALUATION OF SUGAR AND FURFURAL PRODUCTION POTENTIAL USING DOMESTIC FOREST RESIDUE FROM SUSTAINABLE FOREST MANAGEMENT.

7.3CV.8.1 TOWARDS NEW APPROACHES FOR ASSESSING THE CLIMATE CHANGE MITIGATION POTENTIALS OF NOVEL BIOPOLYMERS FROM LIGNOCELLULOSIC BIOMASS.

8.3CV.8.5 EUBCE Student Awardee Presentation ROLE OF BIOMASS USAGE IN EU AT POINT OF CARBON NEUTRALITY.

9.4BV.5.8 UTILIZATION OF GASIFICATION BIOCHAR FOR THE REDUCTION OF GREENHOUSE GASES AND AMMONIA EMISSIONS IN SWINE SLURRY STORAGES.

10.4CV.10.5 BIOGAS DIAGNOSTICS: QUANTIFYING SILOXANES AND SULFUR COMPOUNDS FORIMPROVING ENERGY USE OF BIOMASS.

11.4CV.10.6 RECOVERY OF AGRIFOOD BY-PRODUCTS AND FOOD WASTE FOR BIOMETHANE PRODUCTION.

12.4CV.10.10 COMBINING DARK FERMENTATION WITH ANAEROBIC DIGESTION ENHANCE BIOGAS PRODUCTIONFROM PRE-TREATED GIANT REED (ARUNDO DONAX L.).

13.5AV.2.6 ACID CATALYSED ALCOHOLYSIS OF LIGNOCELLULOSIC BIOMASS TO ADVANCED BIOFUELS.

14.5AV.2.14 MICROBIAL HYDROCARBON PRODUCTION BY FATTY ACID PHOTODECARBOXYLASE PHOTOENZYME IN PHOTOBIOREACTORS.

15.5AV.2.17 USE OF NATIVE YEAST STRAIN (SACCHAROMYCES CEREVISAE) AS INOCULUM IN BIOETHANOL FERMENTATION.

16.5AV.2.18 EFFICIENT SUGARS RECOVERY FROM CYTISUS SCOPARIUS FOR BIOENERGY AND BIOPRODUCTS PRODUCTION: OPTIMIZATION OF STEAM EXPLOSION FRACTIONATION STEP.

17.5AV.2.19 OXALIS TUBEROSA CARBOHYDRATE FOR OBTAIN SECOND GENERATION BIOETHANOL.

18.5AV.2.23 VALORIZATION OF LIGNIN-FIRST CARBOHYDRATES THROUGH BIOCHEMICAL CONVERSION TOWARDS ETHANOL.

19.5DV.2.16 A MULTI-PARAMETRIC STUDY ON HYDROTHERMAL CARBONISATION OF MIXED AGRI-FOOD WASTE FOR THE PRODUCTION OF HIGH-QUALITY SOLID BIOFUEL.

20.6BV.2.14 ENHANCING THE VALUE OF LIGNOCELLULOSIC BIOMASSES THROUGH THE PRODUCTION OF BIONANOCOMPOSITES.

21.6BV.2.32 SYNTHESIS AND CHARACTERIZATION OF BIO-POLYOLS SYNTHESIZED FROM VARIOUS TREATED DEPOLYMERIZED SUBERIN FOR RIGID POLYURETHANE FOAMS.

22.6CV.7.5 EVALUATION OF FURFURAL AND 5-HMF SEPARATION EFFICIENCY FROM SUPERCRITICAL HYDROLYSATES USING ORGANIC SOLVENT EXTRACTION.

23.6CV.7.9 OPTIMISATION OF CATALYTIC PRODUCTION OF 5-HMF AND FURFURAL USING

PHOSPHOTUNGSTIC-DERIVED HETEROPOLY ACIDS.

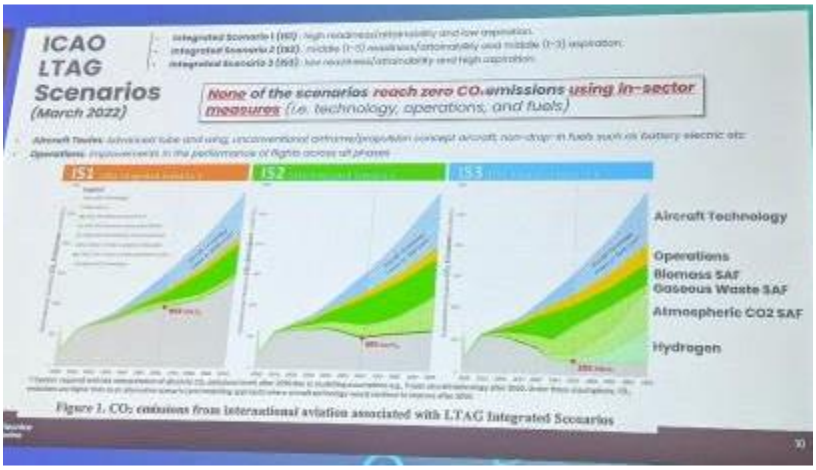
24.6CV.7.13 DAWN TECHNOLOGY TM - SECOND GENERATION BIOREFINERY AND ITS LIGNIN PROPERTIES.

25.6CV.7.14 BIRCH OUTER BARK CHARACTERISATION AFTER EXTRACTION AND ITS POTENTIAL FOR OBTAINING SUBERIN FATTY ACIDS.

(四)重要會議內容摘要

1. Plenary Session: Is Carbon the enemy? What would the EU do without it?

主論壇延續會議精神，始於減少碳排放，並深入分析不同產業在 2050 年脫離使用石化原料並進行減碳後的成果。根據目前的現況，預計到 2050 年，航空業每年碳排量將達到 945 百萬噸二氧化碳。然而，透過使用各式可再生航空燃油、氫能等方法，遵循國際民用航空組織(International Civil Aviation Organization, ICAO)所提出的長期全球理想方針(Long-Term Global Aspirational Goal)，有望將 2050 年的碳排量降低至 203 百萬噸，說明降低碳排量的潛力及效益相當巨大(見圖 14)。



ICAO LTAG Scenarios (March 2022)

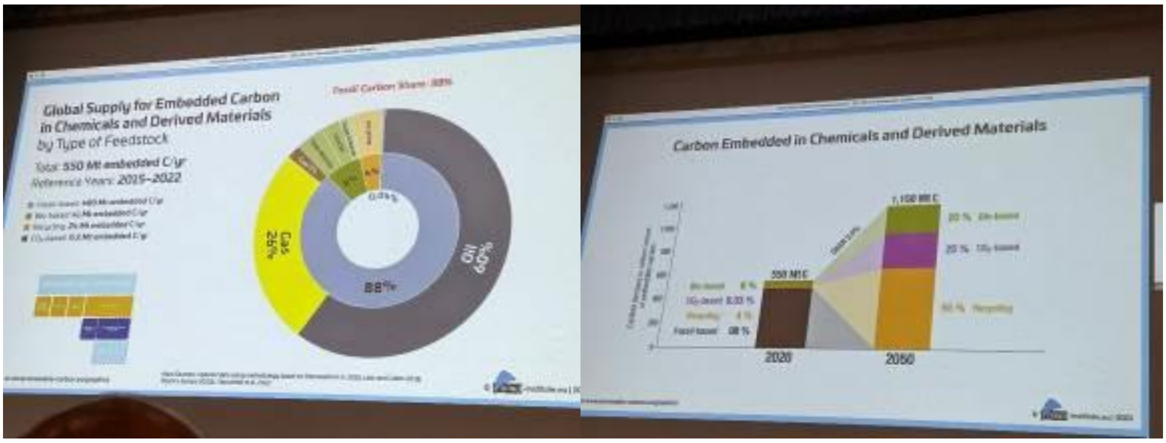
None of the scenarios reach zero CO₂ emissions using in-sector measures (i.e. technology, operations, and fuels)

Figure 1. CO₂ emissions from international aviation associated with LTAG Integrated Scenarios

圖 14 航空業依據措施不同於 2050 年的碳排降低情況

然而，本次會議提出了一個重要議題，即「碳是否為我們的敵人？」，若不將目前提出的各項方案再進行整合，將無法達到淨零碳排的目標。

目前化學品工業中，88%的化學品隱含碳(Embodied Carbon)來源於不可再生資源(例如石油、天然氣、煤礦等)，僅有 12%來自於生質物或回收資源等(2015 - 2022 年統計資料)。然而，若能整合各方技術，則可脫離對不可再生資源的依賴。其中，技術方案佔主要措施的 55%，其次依序為固碳(25%)和生質能來源(20%)。這顯示未來生質物與回收資源將在隱含碳中占比越來越高(圖 15)。


Global Supply for Embedded Carbon in Chemicals and Derived Materials by Type of Feedstock

Total: 550 Mt embedded C/yr

Reference Years: 2015–2022

Carbon Embedded in Chemicals and Derived Materials

圖 15 化學品製造業的隱含碳分布情況

不過，不論是航空業還是化學品業，要達成淨零或減碳目標或首先必須仔細盤整可利用之生質物資源，而其中最重要的，就是善用土地並改良耕作技術，只要土地的使用能得到更加先進的規劃，就能提升單位產量、降低耗水、增加單位面積固碳量並增進生質多樣性，最終目標是創造一個永續的生質經濟體系(圖 16)。


Sustainable biomass supplies can increase considerably in synergy with:

MANY, ALSO RECENT, STUDIES IGNORE PARTS OR A MULTITUDE OF THESE FACTORS!

The wider bioeconomy context – holistic approach

- We have to take into account the trade-offs and synergies between **different demands on biomass** to contribute to the overall sustainable bioeconomy
- Integrating biomass conversion for multiple purposes using **innovative approaches** can have synergistic effects

圖 16 歐洲生質物資源盤查與循環經濟體系示意圖

今年會議有兩個重點，第一是：「土壤」(Soil)，後續的會議中提到更多關於土壤、土地的利用與改良、規劃及再生等，以及歐盟對於不同經濟作物輪替種植的政策等，這與本所目前研究領域相差較遠，因此僅稍微了解其概念。第二個是：「碳移除」(Carbon Removal)，尤以生質碳方式為目前的尖端研究，並可結合前述的土壤政策，使永續農業、林業提供更有生質經濟價值的作法。

生質碳可用作一種土壤的物理改質劑，由於大部分的生質碳都偏鹼性，適合用於酸性土壤且休耕期短或原生森林被砍伐的土地，非洲與印度尼西亞的貧脊土壤就屬於此類型。一般農民會使用燃燒後的農業廢棄物，這種傳統的方式僅能維持至數十年，但生質碳除了改變酸鹼度之外，也能改善土壤的結構、孔隙度、增加滲透率與減少逕流，同時，生質碳能在土壤中存在長達百年以上，能大幅延長固碳效益。生質碳的缺點是不具肥力，需搭配肥料使用。

除此之外，肥料的選用也為土壤永續管理的一環，在西班牙推展的 Diverfarming 計畫則是利用多樣化種植產生綠肥提供給土壤，同時也創造不同於糧食作物的經濟來源。Diverfarming 計畫中的研究係在西班牙的橄欖田實施藏紅花、薇甘菊、燕麥與薰衣草的輪作，藏紅花只播種一次、薇甘菊與薰衣草則是每年輪種一次，如此即可不施用肥料與除草劑但能確保土壤肥力同時降低土壤侵蝕造成的土壤流失。

以上兩者如分別於適當的土地施用：生質碳於酸性貧脊土壤、永續管理實施於受侵蝕的土地，即可達到減少肥料浪費、減少土地流失、增加土地產值、並大幅增加固碳效益(或減少施肥所需的碳排)，減少土地流失可使土壤上層沉積物的流動減少、增加土壤中有機碳、磷、氮等養分含量，而有機碳含量增加，等同是減少向大氣碳排的碳量。惟此舉需總體考量區域內的土壤及耕作性質，才能對症下藥。

會議最後由 UMP 芬歐匯川公司的公共事務總監 Marko Janhunen 介紹該司在全球各地的生質精煉工廠(圖 17)。

UPMBIOREFINING

UPM

UPM Lappeenranta Biorefinery

- Advanced biofuels
- Since 2015
- Production volume: 130000 tonnes per year

UPM Leuna Biorefinery

- Renewable biochemicals
- 750 million € investment
- Start late 2023
- Production volume: 220000 tonnes per year

UPM Rotterdam Biorefinery

- Advanced biofuels and biomaterials including SAF
- Basic engineering phase ongoing
- Production volume: upto 500000 tonnes per year

UPMBIOFORE-BEYOND FOSSILS

圖 17 芬歐匯川 UPM 公司的生質精煉場現況

2. 口頭發表組 6AO.3 : Biomass pre-treatment processes

生質酒精是最早期被研究也相對應用多的生質燃料，因為電動車的崛起，導致2020 年以後全球的需求量逐年遞減，然而生產酒精使用的生質精煉製程，能夠應用在後續更多的生質能產品中，其中包含：貪銅菌胞內累積的中性脂肪、耶氏解脂酵母生產的檸檬酸等兩大項。在木質纖維素料源的利用，利用蔗渣生產奈米纖維素是可行的研究方向，這項產品也可用於個人的皮膚保健。另一個木質素的應用是電池陽極(圖 18)。

圖 18 木質素後續應用的案例

目前有一實驗室案例，係使用農業廢棄物生產纖維素氣凝膠纖維(cellulose aerogel fiber)(圖 19)，它是一種能用於醫材的多孔性材質，並經過材料機械強度測試、孔隙度測試與比表面積測試，由於其孔隙度相當高，比表面基則可達到 400 平方米/每克材料，但結構強度相對下降顯示這個材料仍然有相當改善空間，也完成了到 Pilot plant 等級的放大驗證。


Cellulose aerogel fibers: Synthesis

圖 19 纖維素氣凝膠纖維合成簡易步驟

農業廢棄物的纖維素不僅可以像上述一樣用來做多孔性纖維，經過前處理後的糖液以菌株發酵(如耶氏解脂酵母)，可用用來生產揮發性脂肪酸(volatile fatty acid, VFA)，再將 VFA 轉換為不同的生質產品(圖 20)，

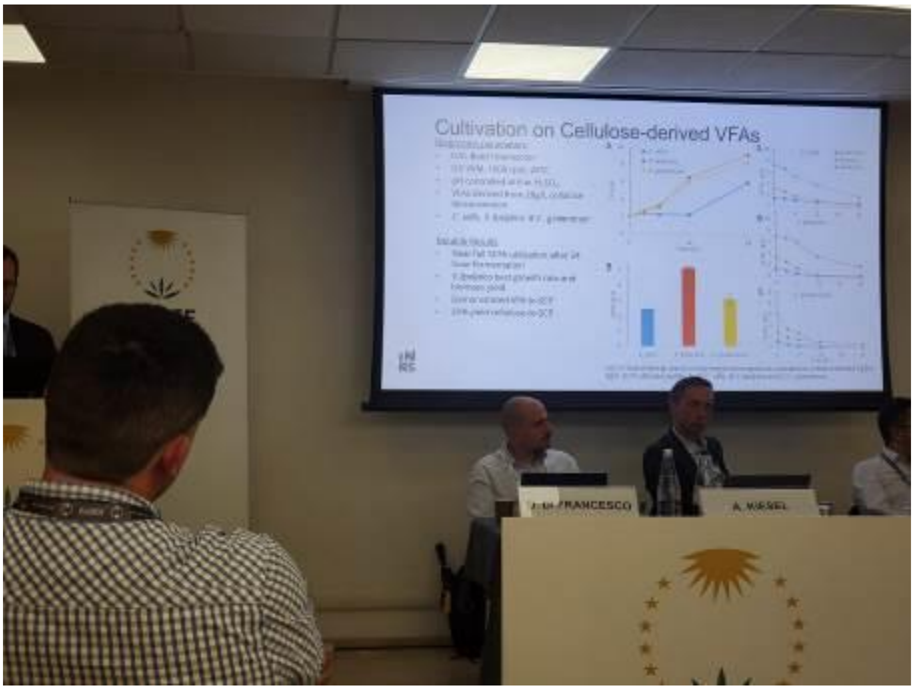
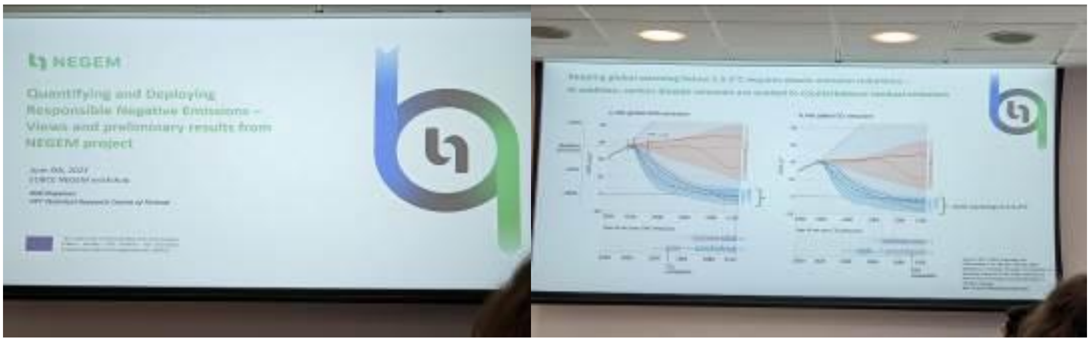

Cultivation on Cellulose-derived VFAs

圖 20 菌株透過水解液生產 VFA 數據圖

綜上所述，雖然初期的生質產物以酒精為大宗，但因應時代變化可能會需要生產更多不同類型的生質產品，前處理平台並不會因此而式微，反之更加成熟的製程能夠提供給更多不同的菌株或製程使用，創造更多價值。

3.口頭發表組 Biomass-based Technologies and Practices for Carbon Dioxide Removal

作為今年度本會的重點項目之一的二氧化碳移除，其最終目標是為了實現整體二氧化碳的「負碳排」， EU 的 Horizon 2020 針對負碳排與實踐(negative emission technologies and practices, NETPs)資助了一項稱為 NEGEM 的計畫(圖 21)，主要是為了符合巴黎氣候協議的延緩全球暖化而進行的戰略組織，從 2020 年 6 月起執行至 2024 年 5 月底為止，目前橫越了 11 個國家包含 6 所大學、3 個技術研究機構、2 個非政府組織及 5 家企業共 16 名伙伴，總預算達 20 億新台幣。



NEGEM

Quantifying and Deploying Responsible Negative Emissions – Views and preliminary results from NEGEM project

圖 21 NEGEM 計畫針對巴黎協議的貢獻

現階段最有創造負碳潛力的技術應屬於生質能源與碳捕獲和儲存(Bio-energy with carbon capture and storage, BECCS)，除此之外，生質碳(biochar)也是一個與 BECCS 相似的技術，但其施作規模相當彈性，不像森林復育或 BECCS 會需要大量土地且技術相對成熟。生質碳的優勢在於可用做農業土地的土壤改良，而且生質碳也可以農業廢棄物製作，歐洲每年具有至多 287 百萬噸農業廢棄物，做為負碳措施及廢棄物去化有雙重功效(圖 22)。

NTNU

Biochar potential to deliver negative emissions and improve soil quality in Europe

Estimates of biomass residues potentials

圖 22 生質碳的潛力與歐洲農業廢棄物的資源調查

未來勢必得整合複數的碳去除技術，才能達到淨零或負碳排，而這些措施須符合QU.A.L.ITY(可量化/額外性/長期儲存/永續性)標準(圖 23)。並包括：土地管理(森林復育(包括造林、景觀恢復與生態復育等)、濕地管理、泥炭環境管理等)、碳捕捉、使用長週期性碳產品及石化來源碳的貯存與利用(capture of fossil carbon for storage (CCS) or utilization (CCU))等。

Criteria for a EU Certification System

Bioenergy EUROPE

The EU certification framework can only be used to certify carbon removals that meet the following QU.A.L.ITY criteria

QUantification: Carbon removal activities are measured accurately and deliver unambiguous benefits for the climate

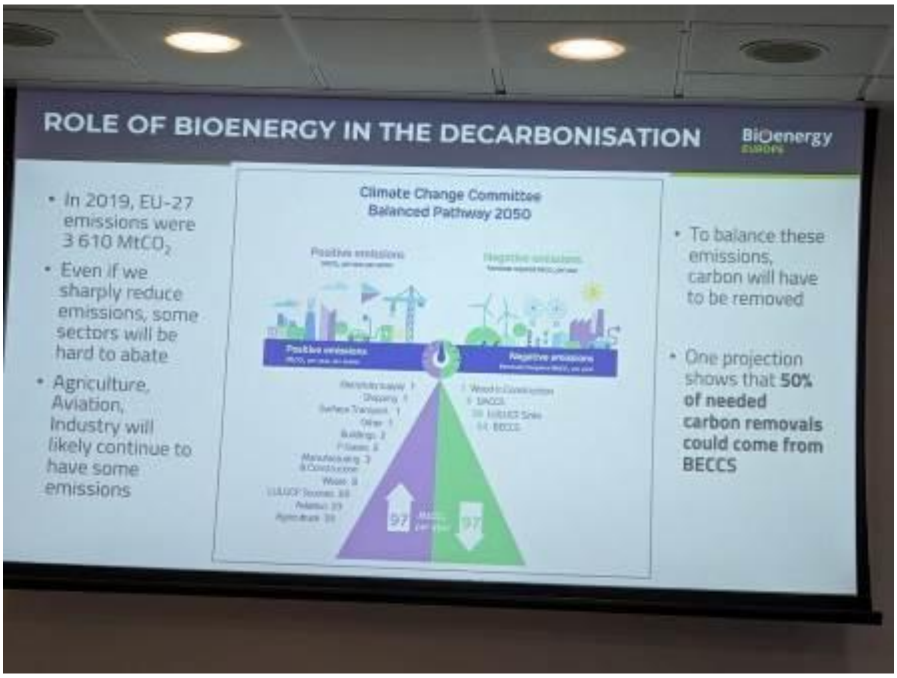
Additionality: Carbon removal activities go beyond standard practices and what is legally required

Long-term storage: Certificates clearly account for the duration of carbon storage and distinguish permanent storage from temporary storage

Sustainabil-ITY: Carbon removal activities must support sustainability objectives such as climate change mitigation and adaptation, biodiversity, circular economy, water and marine resources

圖 23 歐洲淨零與負碳之 QU.A.L.ITY(可量化/額外性/長期儲存/永續性)標準

在 2019 年，整體 EU27 國的碳排總量約為 36.1 億公噸，依據其中一個預測模型，如果利用 BECCS 可以蒐集並封存多達 50%的碳排量，此一模型中 BECCS 若能與生質碳技術結合，將能創造更長的固碳時間及更佳的固碳效益(圖 24)。



ROLE OF BIOENERGY IN THE DECARBONISATION

BiOenergy EUROPE

- In 2019, EU-27 emissions were 3 610 $MtCO_2$
- Even if we sharply reduce emissions, some sectors will be hard to abate
- Agriculture, Aviation, Industry will likely continue to have some emissions

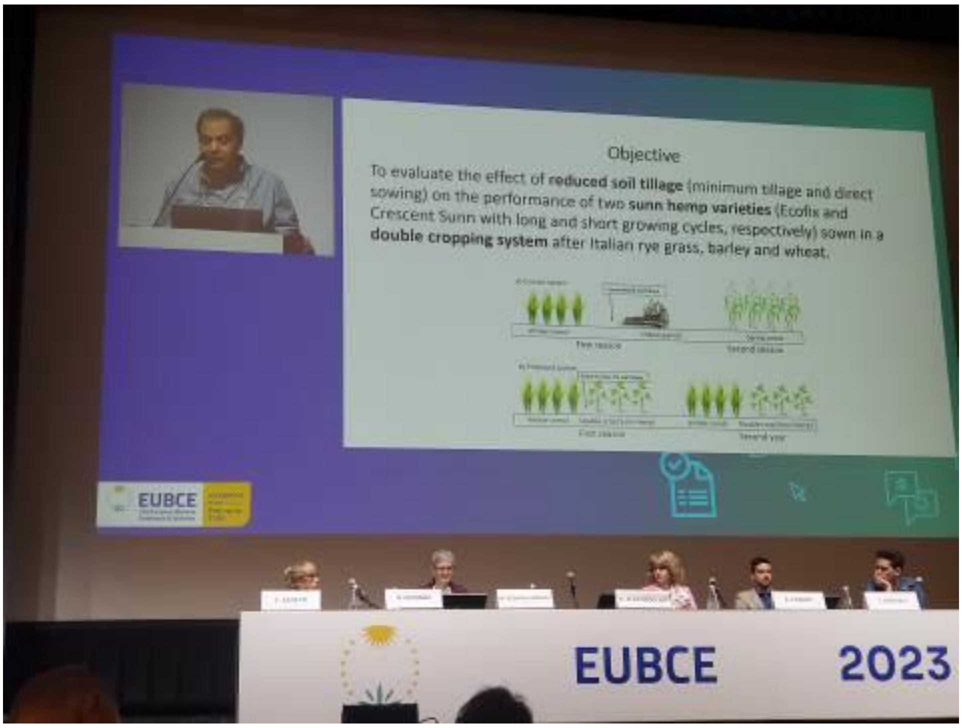
- To balance these emissions, carbon will have to be removed
- One projection shows that **50% of needed carbon removals could come from BECCS**

圖 24 歐洲 2050 碳排與碳封存示意圖

4. 口頭發表組 1BO.1：Innovative strategies to produce dedicated biomass for bioenergy, biofuels and bio-based products

本主題目的為通過改變現有的農業實踐，生產專門用於生質能源、生質燃料和生質基產品的生質能。

會議中探討了具有專用生質能源豆科作物的雙熟耕作系統，展示了有吸引力的生產潛力，以及增強的環境效益和優化的土壤覆蓋和土地利用資源，並且不會與食物/飼料作物爭奪土地。本研究的目標是評估減少土壤耕作(最小耕作和直播)對兩種向日葵大麻品種(Ecofix 和 Crescent Sunn，分別具有長生育週期和短生育週期)在義大利黑麥草、大麥和小麥後進行雙熟耕作系統的影響。在最小土壤耕作條件下，交替種植飼料大麥和向日葵大麻可獲得最高的生質量產量和可利用能源(圖 25)。



Objective

To evaluate the effect of **reduced soil tillage** (minimum tillage and direct sowing) on the performance of two **sunn hemp varieties** (Ecofix and Crescent Sunn with long and short growing cycles, respectively) sown in a **double cropping system** after Italian rye grass, barley and wheat.

圖 25 雙熟耕作系統

總結來說，該研究評估了減少土壤耕作對雙熟耕作系統中向日葵大麻的表現的影響。研究結果顯示，在最小耕作條件下，交替種植飼料大麥和向日葵大麻可實現最高的生質量產量和可利用能源。這種雙熟耕作系統具有生產潛力，同時具備增強的環境效益和優化的土壤覆蓋和土地利用資源，並且不會競爭食物/飼料作物的土地。

此外，會議中也探討了在多功能農業中，多用途作物集約化的可行性。種植一系列食物和能源作物有潛力增強作物輪作效應，同時不減少食物用地。本研究的目標是評估六年期間以下輪作的生質量和糧食產量，比較糧食品質並識別土壤有機碳(SOC)的變化：i) 玉米-休閒-小麥-玉米 (C)；ii) 玉米-向日葵大麻-小麥+向日葵大麻-玉米 (R1)；iii) 玉米-纖維高粱-小麥+向日葵大麻-玉米 (R2)；iv) 玉米-黃麻-小麥+向日葵大麻-玉米 (R3)；v) 玉米-工業大麻-小麥+向日葵大麻-玉米 (R4)。

總結來說，R2 相較於 C，能夠將先進生質燃料的生質量產量增加三倍(圖 26)，儘管從長遠來看，似乎對糧食的產量和品質產生負面影響。從這個角度來看，R1 和 R4 在糧食產量、品質和 SOC 的永續性方面具有興趣，因為它們的生質量產量是 C 的兩倍。

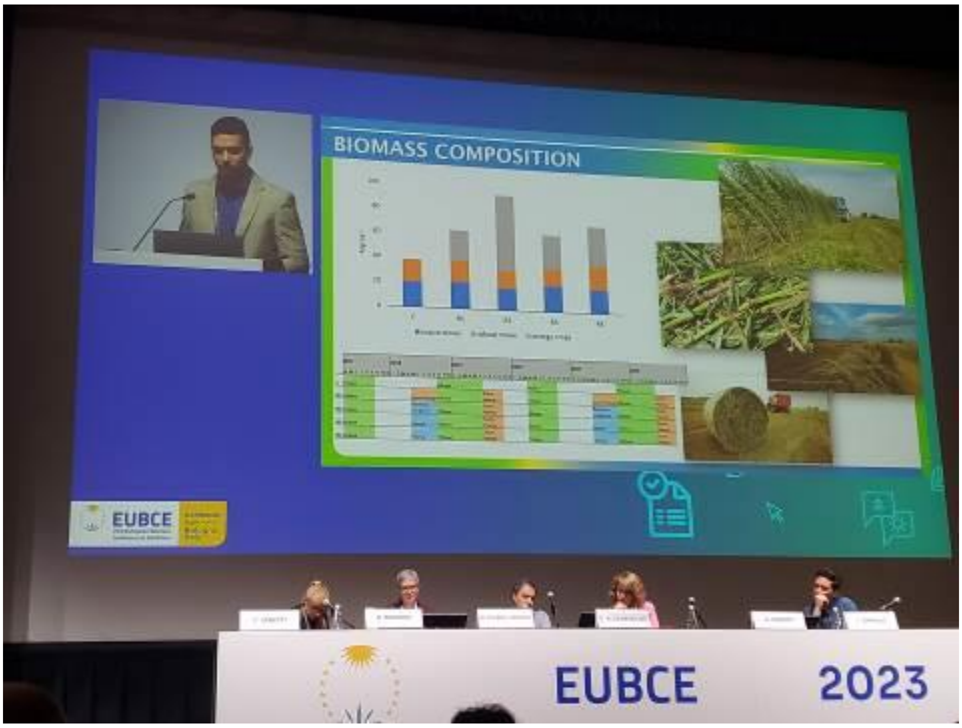


圖 26 不同輪作狀況下，產量比較

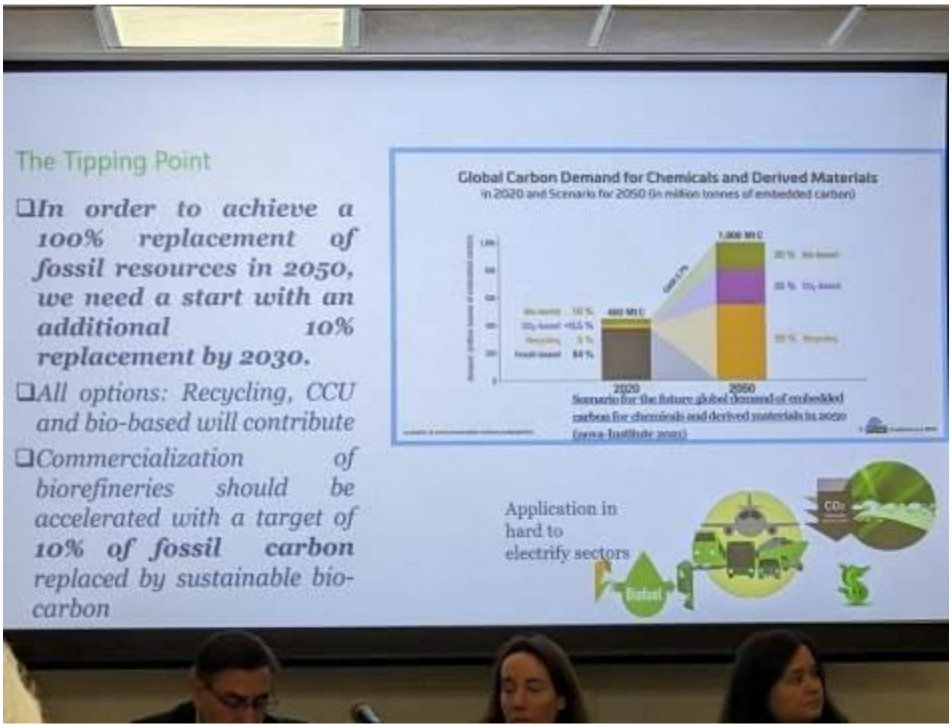
這項研究旨在評估不同作物輪作模式下的生質量、糧食產量和品質以及土壤有機碳變化。結果顯示，在某些作物輪作模式中，生質量的增加可能會對糧食產量和品質產生負面影響，但仍有一些模式能夠保持良好的糧食產量和品質，同時提高生質量產量和土壤有機碳的永續性。這些結果為農業生產中的多功能性提供了實質性的貢獻，並為永續的生質能源和食物生產提供了可能的解決方案。

5. 口頭發表組 3BO.3 : Integrated Biorefineries

生質航油一直是歐洲技術開發的重點項目，透過生質精煉技術將蔗渣轉換為燃料也是行之有年的項目，目前除了利用蔗渣之外，也將擴大使用木片或農林廢棄物做為原料。HIGFLY 為 EU 的 Horizon 2020 資助計畫所推廣的技術之一(圖 27)，目前包括來自 4 個不同家的 9 個合作夥伴組成，主要係利用麥稈及玉米稈等農業廢棄物為原料，經前處理後進行發酵，希望能取代至少 10%的石化燃料，此技術的最終目標是能減少 4900 萬噸的二氧化碳，並降低原油進口數量。

圖 27 HIGFLY 的製程示意圖及歐洲農業廢棄物資源盤點

如同上述，生質精煉技術的整合仍舊是相當有潛力，歐盟目標是在 2030 年能夠利用生質精煉取代 10%的石化燃料、化學品及材料，並在 2050 年完全取代石化產品(圖 28)。


The Tipping Point

- ☐ ***In order to achieve a 100% replacement of fossil resources in 2050, we need a start with an additional 10% replacement by 2030.***
- ☐ *All options: Recycling, CCU and bio-based will contribute*
- ☐ *Commercialization of biorefineries should be accelerated with a target of* ***10% of fossil carbon*** *replaced by sustainable bio-carbon*

圖 28 生質精煉技術的整合潛力與目標

現階段在印度，已經具有一個日產量 10 萬公升酒精的第二代生質料源廠，利用稻稈作為原料，可年去化 21 萬噸稻稈。另有一年產量 5000 噸之 2,5-呋喃二甲酸(Furan-2,5-dicarboxylic acid, FDCA)生產工廠預計於 2024 年興建完成，利用 YXY® 技術，以 FDCA 為原料做出 PET 的替代品 PEF。除了現有的研究及工廠之外，未來更將與 MI mission (Mission Innovation)、CEM biofuture (Clean Energy Ministerial Biofuture)、IEA bioenergy (International Energy Agency Bioenergy)進行合作，研究更多新的產品，並規劃更多的試運轉廠及市場評估(圖 29)。

Mission Integrated Biorefineries

MISSION INNOVATION

Roadmap with 3 pillars:

Research and Development
- New products
- Improved efficiency

Pilots and Demo
- Showcase results
- Learn and improve

Market and Policies
- Enabling environment
- LCA and carbon accounting

In collaboration with other initiatives like MI missions, CEM Biofuture, IEA Bioenergy etc.

圖 29 會議 roadmap

6.口頭發表組 BP.1 : Socio-economic aspects in circular economy

為了支持向循環生質基經濟的進展，能夠測量和監控循環性是至關重要的。這項主題中討論了與生質基產品和相關生質基系統(例如，可再生資源利用、生質能的級聯利用、自然系統的再生)相關的特定因素，以制定一套循環經濟要求(圖 30)。針對這些要求，對現有的循環性指標進行了批判性分析，包括生質基系統的特定特徵。這項分析用於揭示現有指標對每個要求的覆蓋程度，確定存在的差距並指出值得特別關注的方面，以進一步發展適合評估生質基系統循環性的度量指標。這將支持產業和政策制定者制定適當的循環生質經濟目標(即與循環經濟策略相關的可量化目標)。

總結來說，會議探討了測量和監控循環性對於推進循環生質基經濟的重要性。通過考慮生質基產品和相關系統的特定特點，該研究確定了一套循環經濟要求。該研究對現有的循環性指標進行了批判性分析，並提出了進一步發展適合生質基系統評估循環性的度量指標的建議。循環經濟的指標中，希望納入減少浪費、資源有效利用、資

源再生與生質物取代石化原料等。

而循環經濟的所產生的產品，則是利用「內在循環指標」來評估其生命週期，包括：回收的難易度、再利用的次數、再生的難易度、是否最大限度利用物料資源等。

以上兩種指標與內容主要希望能量化循環經濟的成效，並使產品的生命週期具有真正意義上的負碳效益。而且這些指標有助於產業再進行轉型的時候的評量標準，希望能最大限度的利用資源並最小限度的產生廢棄物。

會議中也提及，回收與再生、再製可能是循環經濟的重大挑戰，有許多指標也許在實際的執行中仍須更動或刪除以符合現階段經濟模式轉型時的缺口，但仍能提供一個明確的方針使政府協助企業轉型。考量生質基產品和相關生質基系統(例如，可再生資源利用、生質能的級聯利用、自然系統的再生)相關的特定因素將有助於產業和政策制定者設定適當的循環生質經濟目標，以促進永續發展。

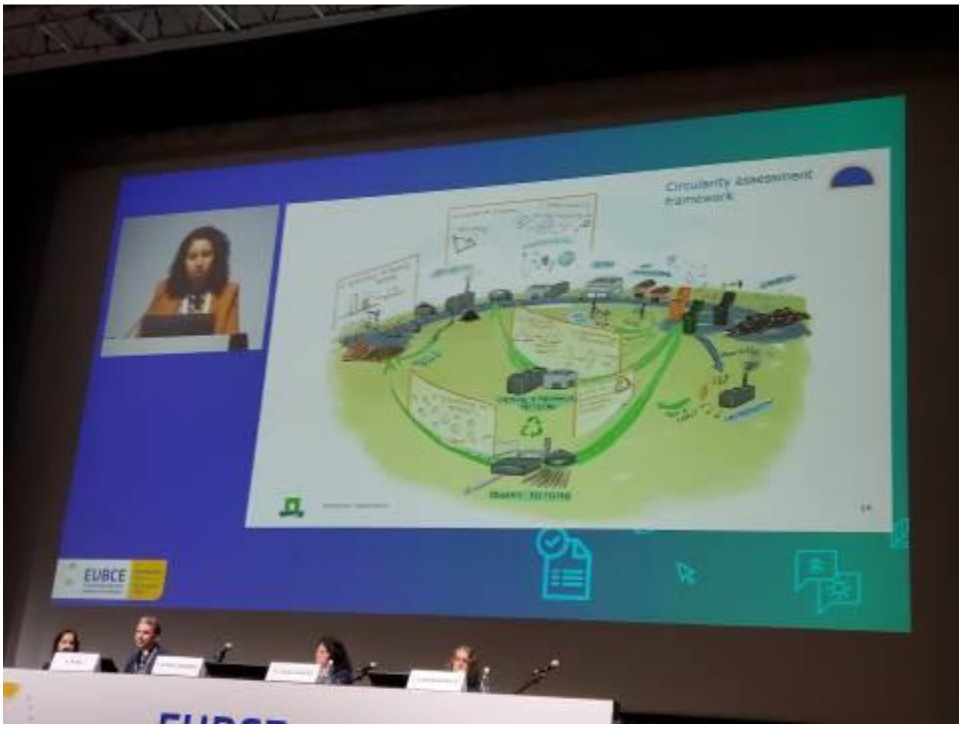


圖 30 循環經濟框架圖

7.口頭發表組 BP.2 : Bioenergy and biobased products

本次全體會議討論了綜合生質精煉概念的實施以及生質能源技術實施的驅動因素和障礙。Enerkem 是一家擁有熱化學技術的公司，他們能夠將各種不可回收的廢料(例如農業和林業廢物、市政、商業和工業混合廢物以及混合廢塑膠)轉化為可再生燃料和

化學產品。他們的技術是在鼓泡流化床中對固體廢料原料進行氣化，產生粗合成氣。然後，這些合成氣通過 Enerkem 獨有的合成氣調節裝置進行淨化和優化，以提高碳回收率並提供穩定且超潔淨的合成氣流，以進一步進行常見的催化合成處理。Enerkem 已經在位於埃德蒙頓的商業示範設施中使用他們的專有技術生產甲醇和乙醇(圖 31)。

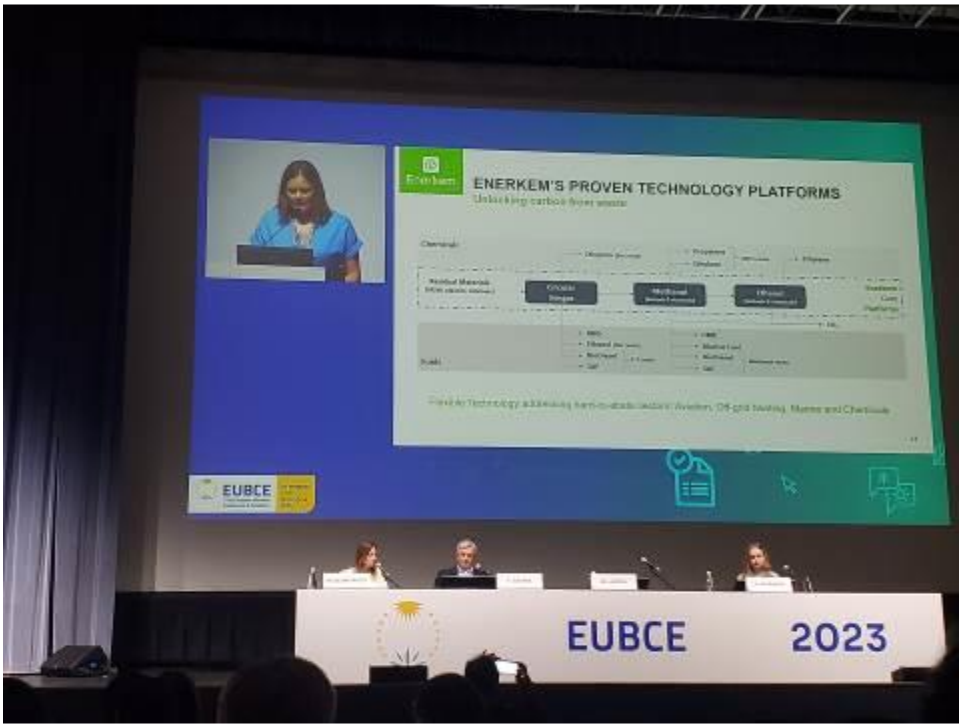


圖 31 廢棄物再製甲醇與乙醇流程圖

這項研究的目標是尋找永續的方法來處理廢棄物並生產有價值的產品，Enerkem 的熱化學技術提供了一種將廢料轉化為可再生能源和化學產品的解決方案，透過氣化和合成氣的優化處理，他們能夠最大限度地回收碳並生產高品質的產物，透過商業示範設施中的成功應用表明了技術潛力和可行性(圖 32)。

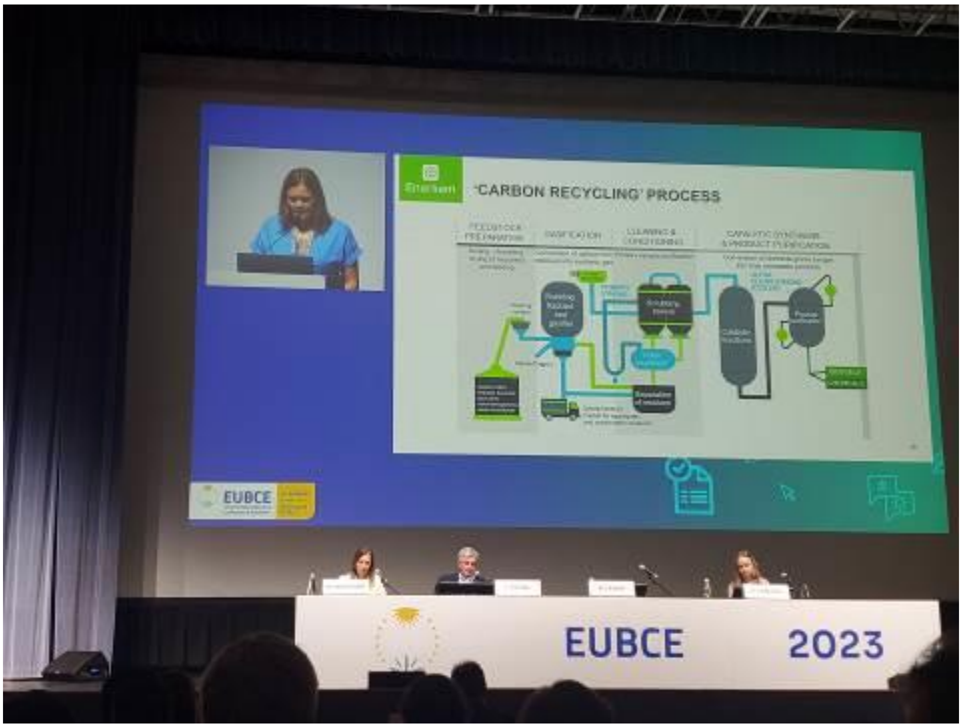


圖 32 碳回收再循環程序

會議同時也講述了 Horizon 2020 BRANCHES 計畫的一項研究(圖 33)，該計畫旨在推動農村生質經濟網絡的發展，並涉及沼氣生產、混合能源解決方案、生質能供暖和熱電聯產以及先進熱化學轉換等相關實踐。該研究旨在探討這些實踐在農村地區實施的推動因素和障礙。研究根據 DEPEST 方法評估了影響生質經濟解決方案實施的各種因素。

這項研究的目標是瞭解在農村地區實施生質經濟實踐的動因和阻礙。通過評估人口統計、經濟、政治、生態、社會文化和技術等因素，研究可以提供對這些實踐是否被實施和實踐的原因有所了解。

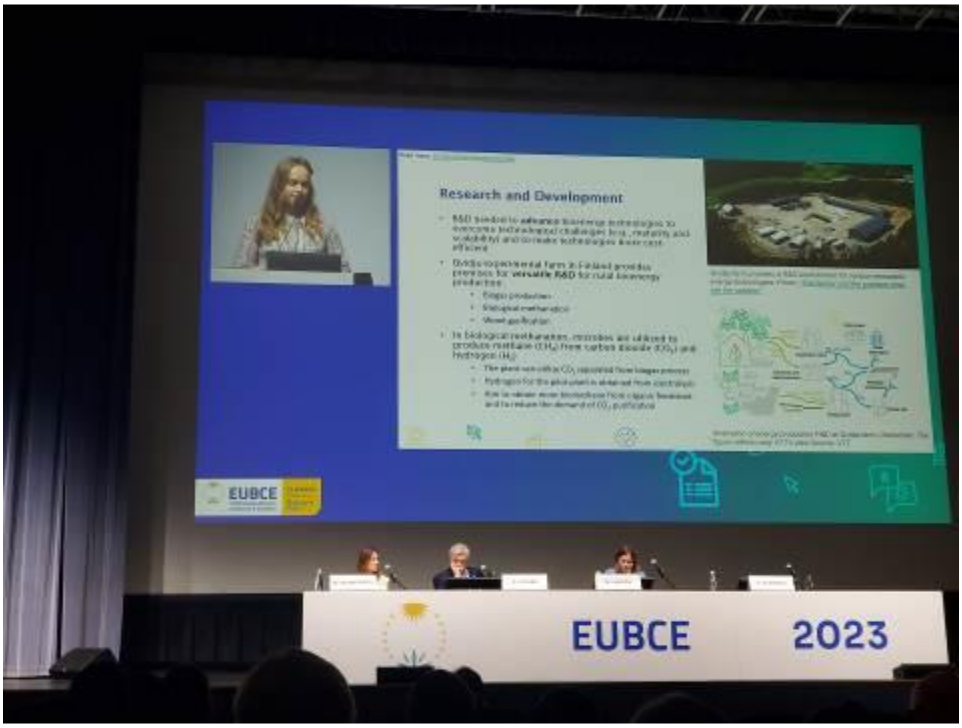
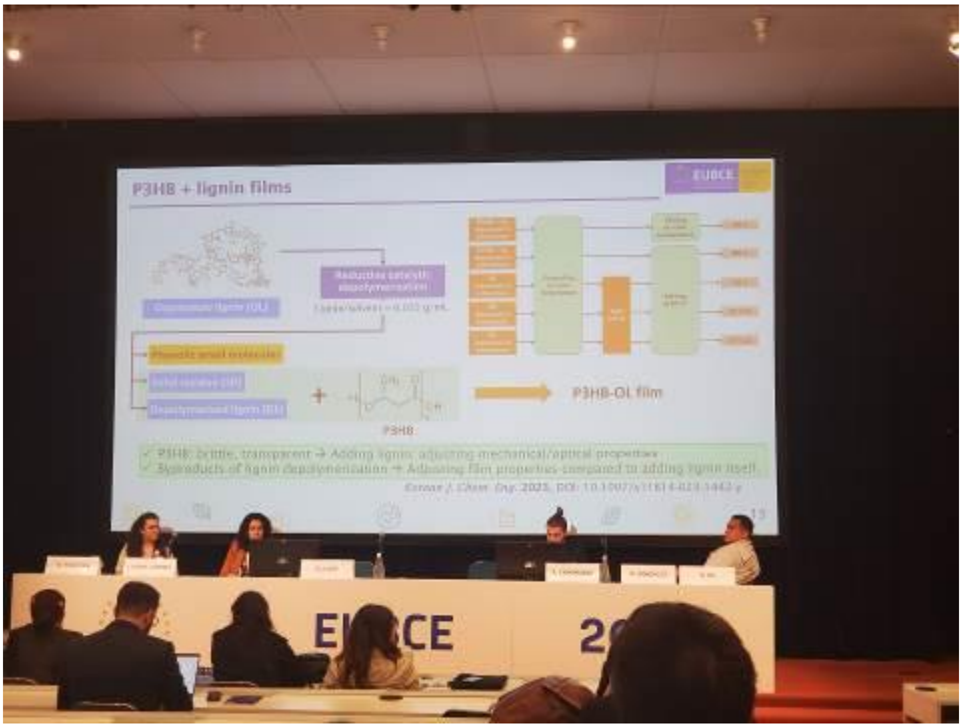


圖 33 Horizon 2020 BRANCHES 計畫

8. 口頭發表組 6BO.8 : New products from biomass

會議題到了聚羥基丁酸酯的研究，是一種常用的聚羥基脂肪酸酯 (PHA)，也是最常被推薦的可生質降解塑膠之一。然而，聚 3-氫丁酸酯 (P3HB)、聚 4-氫丁酸酯 (P4HB)、聚羥基戊酸酯 (PHV) 及其共聚物在製造薄膜時機械性能較差，因此應用受到限制。為了改善這些聚合物的性能並保持其生質降解性，研究人員提出了一種方法，即將木質素與 PHA 混合，並調整其機械和光學性能。這種含木質素的複合材料不僅可以改善熱性能和機械性能，還可用於製造透明的紫外線阻擋膜(圖 34)。



P3HB + lignin films

✓ P3HB: brittle, transparent → Adding lignin: adjusting mechanical/optical properties
✓ Byproducts of lignin depolymerization → Adjusting film properties compared to adding lignin itself

圖 34 該研究之實驗組織圖

以往已經有嘗試使用木質素來改善可生質降解 PHA 薄膜的性能，但本研究在這方面有所突破。研究人員開發了一種製備 PHA 和 P3HB 的技術，利用從木質素解聚過程中產生的木質素衍生廢物。在木質素解聚過程中，會形成固體殘留物和無法進一步降解為酚類單體的木質素降解產物，這些廢料可以添加到 P3HB 薄膜中，一方面能調整 P3HB 薄膜的性能，另一方面則提高木質素解聚技術的應用及經濟可行性。

總結而言，這項研究旨在改善聚羥基丁酸酯 (PHA) 薄膜的性能，特別是聚 3-氫丁酸酯 (P3HB)。通過將從木質素解聚過程中獲得的廢料添加到 P3HB 薄膜中，可以調節其性能並提高木質素解聚技術的經濟可行性，這將有助於擴大可生質降解塑膠的應用領域，同時減少對傳統塑膠的依賴(圖 35)。

Summary

- ✓ Reductive catalytic depolymerization of lignin successfully produced phenolic monomers, oligomers, and solid residue.
- ✓ Adding lignin-derived oligomers and solid residue to P3HB adjusted the mechanical properties of P3HB + lignin-derivative films.
- ✓ Visible light was less blocked for the lignin-derived depolymerized oligomer-added P3HB films compared to the lignin-added P3HB films.

Lignin → Reductive catalytic depolymerization

→ Phenolic compounds → Chemicals/Fuels

Bio-based alternatives to petroleum products

→ Solid residue Depolymerized lignin + P3HB → P3HB films

Biodegradable plastic films

圖 35 該研究之結論

會議同時也討論關於 Sustainable and Alternative Fibers Initiative(SAFI)的全球努力，該倡議旨在推動從替代來源生產纖維的負責任和永續做法(圖 36)。該倡議將從技術和社會經濟兩個方面進行評估，以展示替代纖維的潛力。在演講中，演講者將分享他們的研究方法、面臨的挑戰以及初步結果。此外，他們還將介紹評估生質能和轉化系統碳足跡的正確方法，以生產可應用於不同領域的纖維。

這項研究旨在促進永續和替代纖維的發展，並解決紡織和纖維產業面臨的環境和永續性問題。通過評估技術和社會經濟因素，研究人員希望揭示替代纖維的潛力，並提供相應的解決方案。這將有助於推動更加負責任和永續的紡織生產方式，減少對傳統紡織原料的依賴，同時降低碳足跡和環境影響。

圖 36 替代纖維的解決方案

此外，會議中也針對不同的生質原料進行分析，包括木質纖維素生質能和粗甘油，作為產油微生質生長所需的碳源。通過進行蒸汽預處理並在高乾物質濃度下進行酶水解的優化條件，可以獲得從木質纖維素中提取的糖分。研究中探索了菜豆殘渣、蘆葦和小麥秸稈等不同原料，因為不同的原料可以產生具有不同發酵特性的水解產物。除了典型的影響微生質生長的技術參數外，研究還發現接種物的年齡和大小在確定整體微生質效率方面起著關鍵作用。最終，對該技術進行了技術經濟評價(圖 37)。

總結來說，這篇演講主要探討了使用不同原料作為產油微生質生長所需的碳源。通過優化的蒸汽預處理和酶水解條件，研究人員成功提取了木質纖維素中的糖分。他們探索了多種原料，並研究了不同原料對水解產物發酵特性的影響。此外，他們還發現接種物的年齡和大小對整體微生質效率非常重要。最後，通過技術經濟評價，研究人員對這項技術進行了綜合評估。

Flow chart of our biorefinery process

圖 37 生質精煉之實驗設計

這項研究的目標是探索永續的碳源來支持產油微生質的生長，從而提供替代石化產品的解決方案。通過研究不同的原料和優化的生產條件，研究人員期望能夠找到更有效和永續的方法來生產微生質油。這將有助於減少對傳統石化資源的依賴，並為可再生能源和環境永續性做出貢獻(圖 38)。

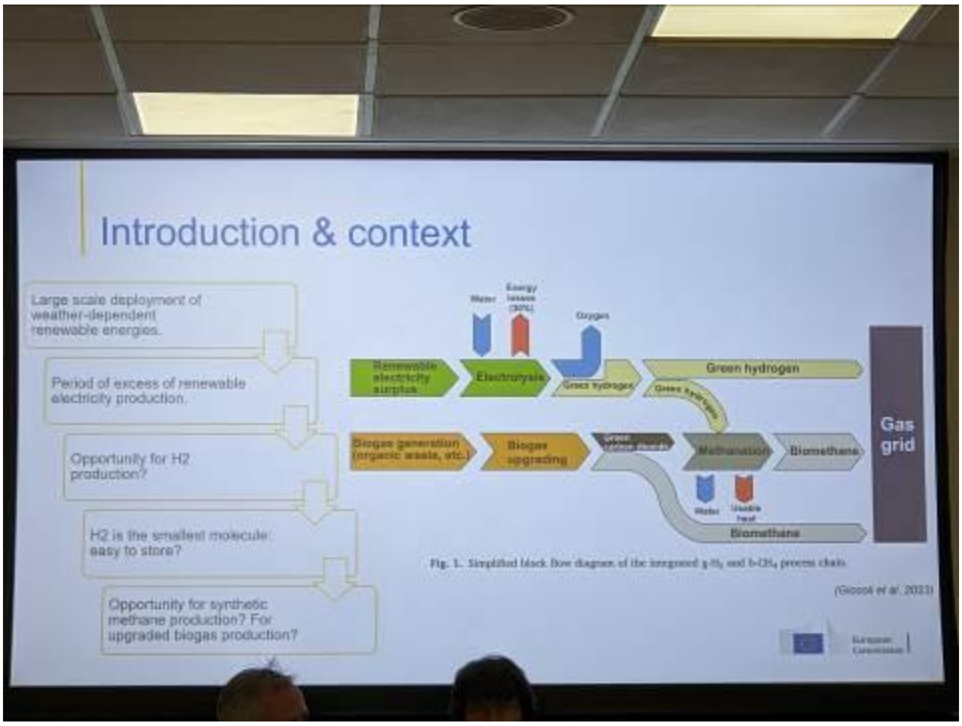
Conclusions

- Yeast inoculation in the stationary phase is a good process strategy to overcome microbial inhibition induced by degradation products, only for some yeast species;
- Fatty acid production and profile is influenced by the yeast species, the substrate and the process conditions;
- Biodiesel from microbial oils has similar chemical-physical properties to biodiesel from vegetable oils, so it is a suitable alternative to traditional vegetable oils;
- A microbial oil production cost in the range 2-4 €/kg was estimated. The most important parameter determining the final cost is the lipid yield.
- Further improvement can be achieved by reducing enzyme cost or increasing the enzyme activity

圖 38 生質精煉之結論

9. 口頭發表組 3BO.9 : Biogas and Power to Gas

這段演講主要討論了 Biogas 與天然氣發電等議題，會議探討了沼氣、天然氣發電和兩者結合的相關議題，提到義大利南部具有生產藥物和消費的潛力，但運輸能力有限，因此天然氣發電可以作為進一步部署可再生能源系統的解決方案。作者與一些同事一起完成了這項工作，旨在提供獨立的基於證據的知識和科學來支持歐盟政策(圖 39)。



Introduction & context

Large scale deployment of weather-dependent renewable energies.

Period of excess of renewable electricity production.

Opportunity for H2 production?

H2 is the smallest molecule: easy to store?

Opportunity for synthetic methane production? For upgraded biogas production?

Fig. 1. Simplified block flow diagram of the integrated g-H₂ and b-CH₄ process chain.

(Giocoli et al. 2023)

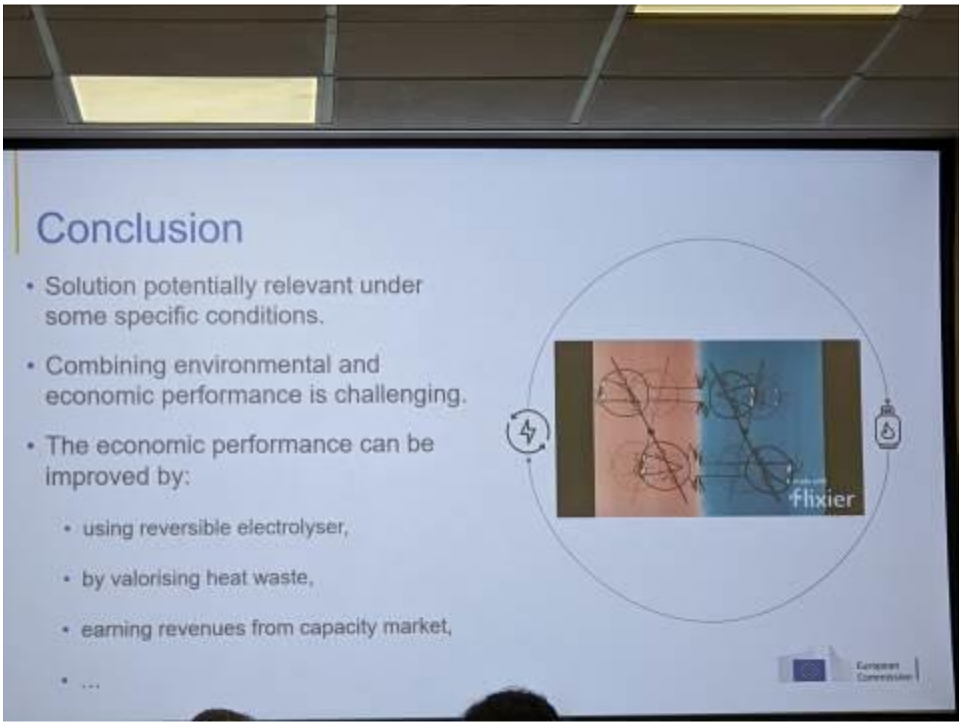
圖 39 沼氣、天然氣發電研究大綱

報告中提到了一些問題和挑戰。首先是能源效率的問題，將電能轉化為氫氣可能存在能量損失，因此需要考慮效率更高的解決方案。其次是整個系統生命週期的考慮，包括電力生產的生命週期影響以及電解和基礎設施的生命週期影響。最後，演講提到經濟層面的問題，如減少溫室氣體碳排是否可行且具有成本效益。

為了解決這些問題，作者提出了一種方法論，以瞭解在何種條件下電力轉化為天然氣是有意義的。該方法包括使用時間序列和前瞻性生命週期分析來確保假設的一致性。同時還需要考慮經濟維度。

總結來說，作者討論了可再生能源與天然氣發電的結合，以解決能源供應和溫室

氣體碳排等問題。作者提出了一種方法論，通過考慮能源效率、系統生命週期和經濟因素來評估這種解決方案的可行性。演講強調了基於科學和證據的知識對支持政策和產生積極社會影響的重要性(圖 40)。



Conclusion

- Solution potentially relevant under some specific conditions.
- Combining environmental and economic performance is challenging.
- The economic performance can be improved by:
  - using reversible electrolyser,
  - by valorising heat waste,
  - earning revenues from capacity market,
  - …

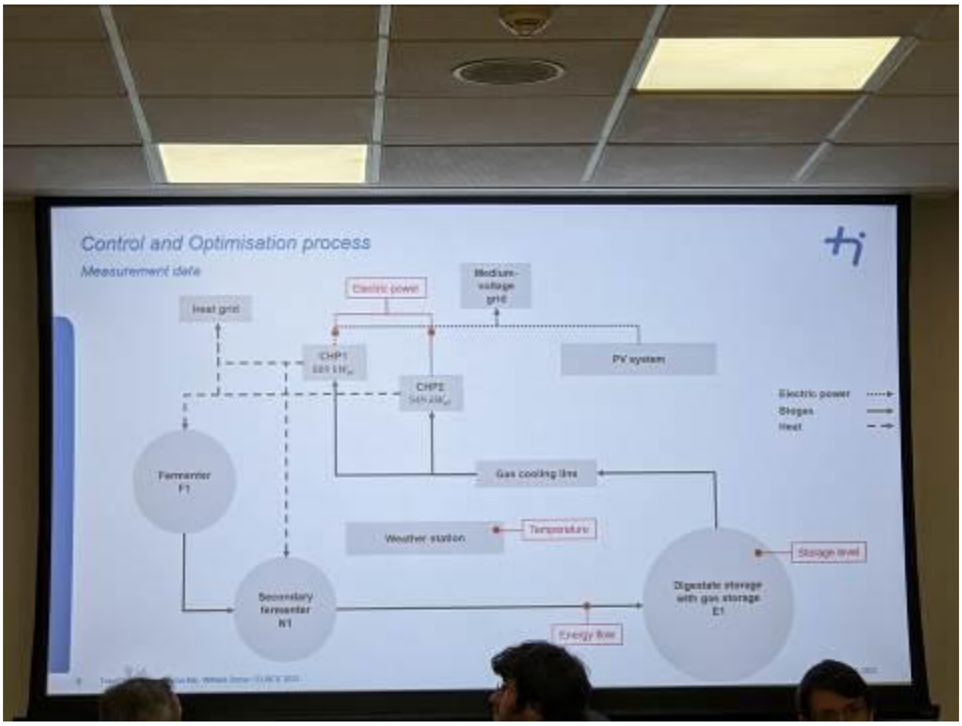
European Commission

圖 40 沼氣、天然氣發電可行性結論

會議也討論關於整合控制系統的主題，以解決未來可再生能源使用所面臨的挑戰。

演講中提到了幾個問題。首先，隨著可再生能源的增加，能源分配和供應將變得更加困難，可能導致區域過載的問題。其次，目前的電壓控制主要依賴傳統發電機，需要尋找替代機器的解決方案。第三，系統的連接點和技術限制可能導致系統過載。

演講提到一個名為 Netflex 項目的解決方案(圖 41)，該項目採用以需求為導向的運營來應對這些挑戰。該項目包括太陽能利用、控制算法開發和利用天氣預測等方面。通過優化和調整系統，以確保系統的平穩運行。



Control and Optimisation process

Measurement data

Heat grid

Electric power

Medium-voltage grid

CHP1

CHP2

PV system

Electric power

Biogas

Heat

Fermenter F1

Gas cooling line

Weather station

Temperature

Storage level

Secondary fermenter N1

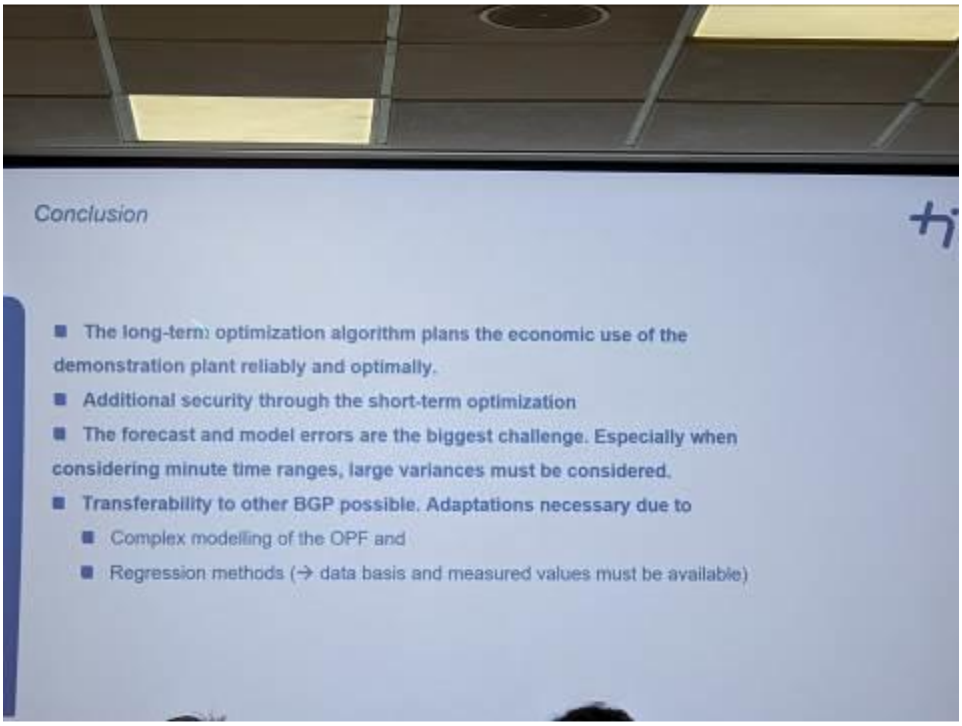
Digestate storage with gas storage E1

Energy flow

圖 41 整合控制系統概念圖

在會議的最後，提到了一些測試運行的結果。他們在模型和系統的運行中遇到了一些錯誤，並進行了詳細的分析和修正。他們強調了持續測試和改進的重要性。

總結來說，這篇演講介紹了開發整合控制系統以應對可再生能源使用中的挑戰。該系統包括太陽能利用、控制算法和天氣預測等方面，以優化和調整系統運行。然而，演講也指出了在測試運行中遇到的錯誤和問題，並強調了持續改進的重要性(圖 42)。



Conclusion

- The long-term optimization algorithm plans the economic use of the demonstration plant reliably and optimally.
- Additional security through the short-term optimization
- The forecast and model errors are the biggest challenge. Especially when considering minute time ranges, large variances must be considered.
- Transferability to other BGP possible. Adaptations necessary due to
  - Complex modelling of the OPF and
  - Regression methods (→ data basis and measured values must be available)

圖 42 整合控制系統研究總結

會議還介紹了季節性彈性儲能技術的經濟評估，作者的研究主要集中在化學和化學過程開發，並探討了季節性彈性在沼氣升級中的應用(圖 43)。

報告中提到的問題是在將沼氣注入電網之前，需要對沼氣進行清潔和升級。這包括去除雜質和分離二氧化碳。作者提出了一個問題，即是否可以在冬季使用相同的膜升級設備去除二氧化碳，在夏季去除多餘的氫氣，並循環到甲烷化設備中進行快速注入。

Seasonal Operation Mode of Biogas Upgrading

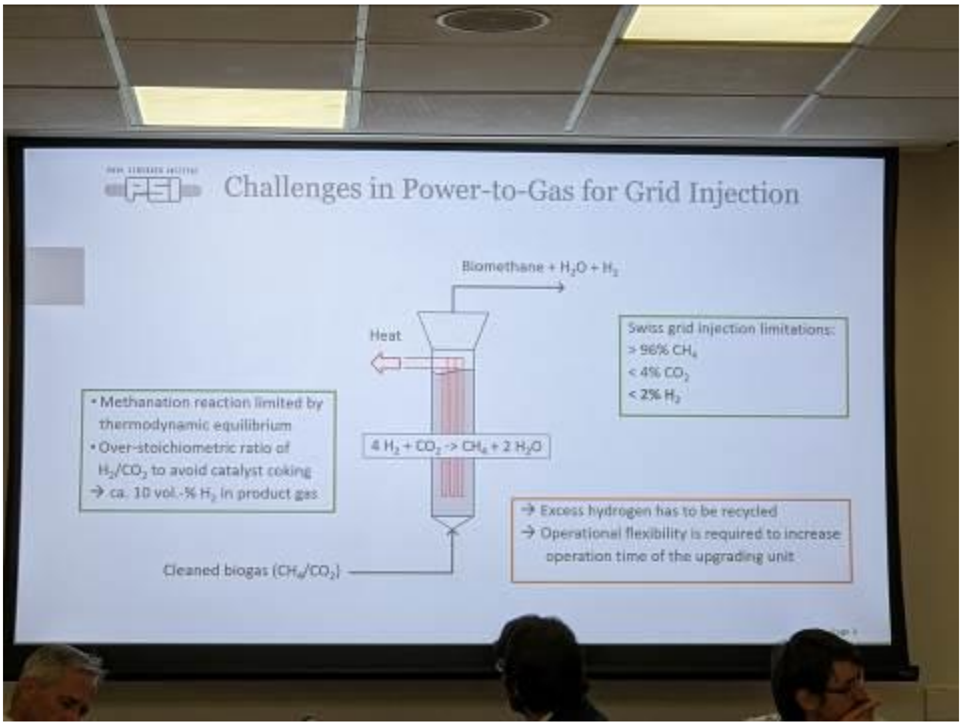
Biogas upgrading (e.g. winter)

Direct methanation (e.g. summer)

圖 43 季節性彈性儲能技術的經濟評估

作者介紹了他們研究和開發的甲烷化設備(圖 44)，該設備使用了一種流化床甲烷化技術。他們還考慮了固定甲烷化的應用。演講中提到了氣體質量的限制，例如二氧化碳含量必須低於 4%，氫氣必須低於 2%，並且必須注入 96%以上的甲烷。

作者進行了幾個實驗，包括使用膜裝置進行 CO2 和 H2 的去除。結果顯示，在適當的壓力下，可以將殘餘 CO2 降低到 4%以下，將殘餘 H2 降低到 1%以下。作者還考慮了電力價格波動對生產成本的影響，並進行了經濟建模。



Challenges in Power-to-Gas for Grid Injection

Biomethane + H_2O + H_2

Heat

Swiss grid injection limitations:
> 96% CH_4
< 4% CO_2
< 2% H_2

- Methanation reaction limited by thermodynamic equilibrium
- Over-stoichiometric ratio of H_2/CO_2 to avoid catalyst coking

→ ca. 10 vol.-% H_2 in product gas

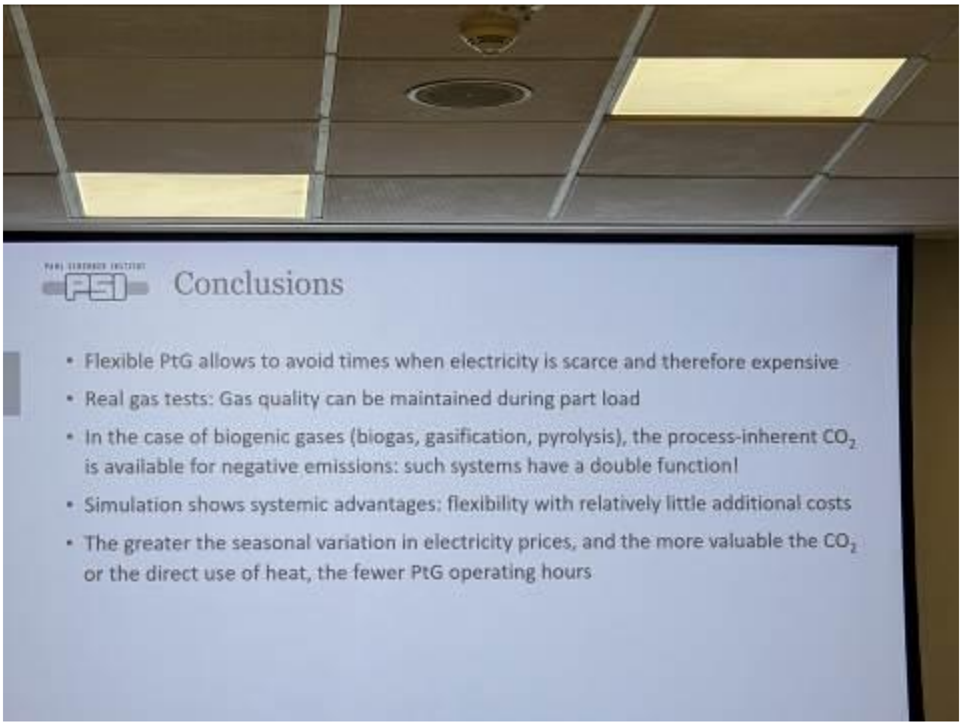
$4 H_2 + CO_2 \rightarrow CH_4 + 2 H_2O$

→ Excess hydrogen has to be recycled
→ Operational flexibility is required to increase operation time of the upgrading unit

Cleaned biogas (CH_4/CO_2)

圖 44 甲烷化設備運作圖

演講最後得出的結論是，季節性靈活性技術是可行的，並且可以根據電力需求的變化進行調整(圖 45)。該技術在某些情況下可能更具成本優勢。總的來說，這項研究提供了關於季節性靈活性和儲能技術經濟可行性的見解。



Conclusions

- Flexible PtG allows to avoid times when electricity is scarce and therefore expensive
- Real gas tests: Gas quality can be maintained during part load
- In the case of biogenic gases (biogas, gasification, pyrolysis), the process-inherent CO_2 is available for negative emissions: such systems have a double function!
- Simulation shows systemic advantages: flexibility with relatively little additional costs
- The greater the seasonal variation in electricity prices, and the more valuable the CO_2 or the direct use of heat, the fewer PtG operating hours

圖 45 季節性靈活性技術總結

三、心　得

(一) 生質精煉發展有其必要性

從廢棄物轉化為可再生能源和化學產品，到在農村地區推動生質經濟實踐的研究中，顯示了生質能源具備相當潛力以及永續發展的方向。透過有效地利用廢棄物資源並推動生質經濟，不僅能夠實現能源和環境的雙重效益，同時也有助於促進經濟的成長與社會的永續發展。

展望未來，所內可以更加積極地朝向這些領域進行研究和實踐，研擬更多創新的解決方案，以實現更廣泛的生質能源應用和生質經濟的發展。同時也需要關注和解決相關的挑戰和障礙，包括技術成熟度以及市場需求等方面，以確保生質能源和生質基產品的永續發展。僅有通過持續的努力和合作，才能夠實現綠色、永續和低碳的能源未來，為地球和人類創造更美好的明天。

(二) 生質材料逐步取代石化產品

生質材料的發展在整個環保議題中佔舉足輕重的地位，本次研討會展示的研究都在探索從生質能中開發新產品的方法和技術，本所相關計畫制定也努力朝此方向邁進，以實現永續性和環境保護。這些研究對於如何更好地利用生質資源、減少對有限資源的依賴以及降低環境影響提供了方向，對於生質塑膠的應用、推動永續紡織生產以及開發替代石化產品具有重要意義。隨著研究技術進一步發展，可為永續發展做出貢獻。

(三) 生質燃氣其他發電方式結合，解決能源供應問題

研討會展示有關沼氣和天然氣發電的結合、整合控制系統的開發以及季節性彈性儲能技術的經濟評估。研究展示了對於解決能源供應問題、減少溫室氣體碳排以及優化系統運行等方面具有重要意義。他們的研究方法和解決方案為未來的永續能源開發提供了有價值的參考。

(四) 從回收著手，達到淨零碳排的目標

研討會各項研究表達了對淨零排碳進行了努力，例如航空業透過使用可再生航空燃料和氫能等替代方案，在 2050 年的碳排量可以從每年 945 百萬噸二氧化碳降低到 203 百萬噸。化學品工業的統計數據顯示，88%的化學品的隱含碳來源於不可再生資源，僅有 12%來自生質能或回收資源。通過整合各種技術，有機會完全脫離對不可再生資源的依賴。其中，回收就佔了 55%的比例，其次是固碳(25%)和生質能來源(20%)。

無論是航空業還是化學品工業，要實現淨零或減碳的目標，需要充分利用可用的生質能資源，並改善土地利用和耕作技術。透過先進的土地規劃，可以提高單位產量、減少水耗、增加固碳量並促進生質多樣性，從而建立一個永續的生質經濟體系。

研討會焦點主要放在「土壤」和「碳移除」議題上。前者涵蓋了土地的利用、改良、規劃和再生，以及歐盟關於經濟作物輪替種植的政策，後者則是指透過生質碳方式將碳永久地從大氣中移除。這些議題與建立永續農業和林業，提供具有生質經濟，希望這樣的努力可以讓未來能走向更環保的大目標(圖 46)。

歐盟期望人類的生活可以逐漸降低對石化原料的依賴，並有效利用可再生資源，從根本上解決溫室氣體碳排日漸增加的問題。利用生質能發電或產熱、材料回收再利用以及使用生物方式(如厭氧發酵)將碳源分解為無害無毒的底渣等技術，達到廢棄物減量，對環境產生正面價值。

圖 46 歐盟理想的綠色經濟模式(IRIS VURAL GURSEL 之投影片擷取)

(五) 各領域整合，達到淨零碳排的目標

歐盟的整體作為，從最早的巴黎協議「延緩全球暖化 1.5 到 2℃度」，到現在「追求淨零碳排乃至於負碳排」，他們各項任務及計畫均進行各式的評估分析、計畫改善與未來規劃。截至目前為止，除了生質物原料及相關生質精煉技術的取代之外，近來還著重在現有石化廠與生質技術的整合。

如同生質燃氣的部分，將石化燃料電廠與 BECCS 技術整合是目前歐洲的最新共識，在此技術框架下，歐洲也試圖將生質物原料納入製程中，使石化與生質物製程相輔相成。台灣中小企業群聚興盛，大量轉型具有難度，若能採取項歐盟策略，以生化製程取代部分製程，能降低產品或程序的碳足跡。

為因應部分產業轉型不易、人類活動日趨繁盛以及碳排量日益增加之問題，會議中著重於前端的土地管理與後端的碳捕捉、碳封存，替許多企業找尋更多永續經營的可能性。以上要素均圍繞在「整合」的概念，當部門、計畫、產業和技術間相互整合，就能達到淨零碳排的目標。

(六) 發展適合台灣的碳捕捉與碳封存規劃

碳捕捉的目標通常涉及能源產業或石化工業所排放的二氧化碳，主要來源是這些產業的煙道廢氣，也可能包括工業廢棄物或其他城市、農業廢棄物。目前最常見的方式分為兩大類：工業捕捉和生質捕捉。

生質捕捉可以與生質能源結合，通常稱為生質能源與碳捕獲和利用(bioenergy with carbon capture and utilization, BECCU)。這種技術對於減碳效益有淨零或負碳的可能性。歐盟目前的做法是整合上述各項關鍵技術，例如之前提到的「生質碳與土壤管理並用」、「不同輪作模式提升生質能源產量與減少肥料施用」、「利用生質精煉平台生產固碳效益更長的產品」等。基於對整體生質物、環境、土壤和工業模式的調查，並在不同場域進行實驗，歐盟提出了相應的經濟評估。

由於國情不同，歐盟所採用的整合方式在國內可以進行部分調整。在整合方面，可以考慮整合農業廢棄物資源，同時協助農民建立良好觀念(例如：勿燃燒廢棄物、勿將土

石垃圾混入廢棄物中等)。待前端資源整合後，才能吸引更多企業以商業模式進駐或評估其後續的經濟價值。

歐盟對於捕捉大氣中二氧化碳的技術，以植樹造林為主要方式，但對於台灣而言，土地並不如此豐富，且部分學者認為森林固碳後進行造粒燃燒仍無法實現減碳。因此，考慮到實際情況，如果能以微藻取代植林，在用地面積及循環時間上可能更具優勢。

在此次會議中，歐盟主要聚焦於「封存」，除了生質碳和土地改質固碳的方式外，還開發了將二氧化碳固定後用作混凝土材料的方法。與歐盟的封存做法相比，我們更應該採用碳捕捉及利用的方式。

台灣許多的大型企業對減碳也越來越重視，例如台泥、長春化工等，這些企業已經開發出了自己的固碳技術，並以碳捕捉後的利用為主要目標。這些技術可供未來所內計畫發展參考，並且更積極地探索後續應用，創造價值，為中小企業提供更多的誘因。

總結來說，歐盟著重生質物資源的整合，可做為所內參考，發展固碳後產物的進行高值化應用。

四、建議事項

(一) 歐盟合作模式可供所內參考，透過計畫與部門間合作，達到淨零排碳願景。

研討會中展示了 EU task、MI mission、Horizon 2020 以及 IEA energy 的合作成果。其中，Horizon 2020 旗下就有相當多的合作計畫，如 FlexSNG 與加拿大合作，以雙重系統操作，依能源或固碳需求，調整驗證廠生產方式。產品為生質燃氣或生質碳，是目前少數以氣化方式生產生質碳，並建立生質燃氣示範廠。此類合作模式可供參考，透過計畫與部門間相互合作，掌握更多資源，達到淨零排碳之願景。

(二) 運用本所技術，開發次世代料源生質精煉技術，朝向淨零排碳目標邁進。

歐洲開始著重土地管理與相關生態保存是否能為淨零碳排增加更多價值。目前傾向於利用次世代料源(如：農業廢棄物或非糧食作物)為原料，結合現有的生質精煉技術開發新產品。本所目前對於生質能的發展目標也朝此方向邁進，利用生質精煉前處理平台進行各類料源測試，建立不同生質料源之精煉技術。

(三) 開發生質原料多元化應用，逐步取代石化產品，形成經濟循環體系。

參考歐洲現階段推廣循環經濟的精神，著重在「取代」。除了開發生質能產品之多元化運用，逐步取代傳統石化產品外，也重視這些產業間的連結是否夠創造工作機會、是否永續且是否更加在各個方面貼合人類的生活。

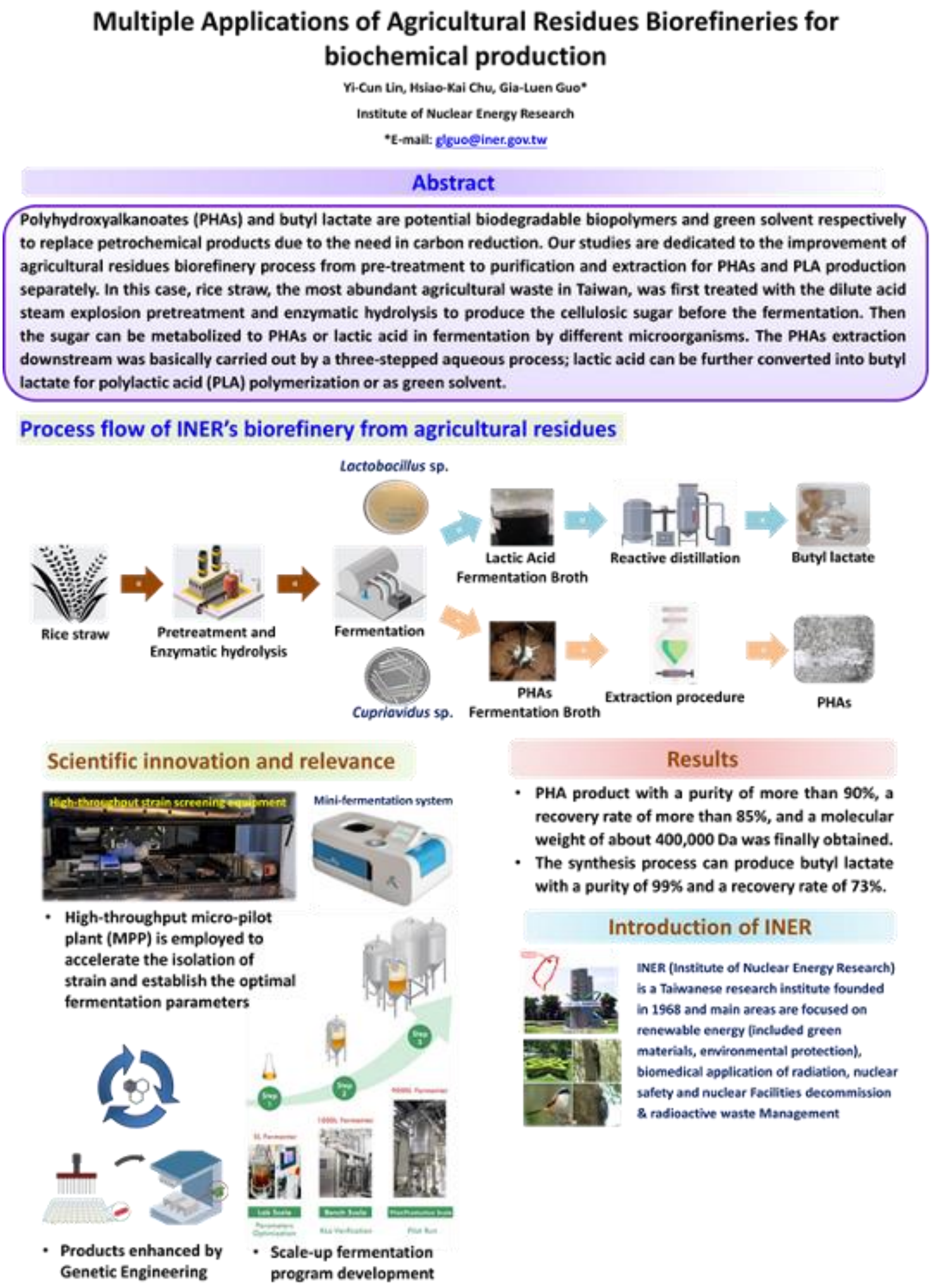
(四) 研討會聚焦生質能未來發展，並提供生質能近期技術發展與政策展望，可持續參與以獲得寶貴資訊，增進國際視野並作為計畫目標訂定參考。

每年研討會主論壇會彙整目前歐盟對於淨零碳排所做的努力，並進行政策面宣導，

可供所內做為未來計畫制定參考。同時，數以百計的口頭演講與壁報論文展示了各國對於生質能源與生質產品的技術發展，以及針對淨零碳排所做的研究。研究資訊寶貴，可協助本所生質精煉技術往高值化方向前進。

五、附　錄

(一)本次參展投稿之會議論文海報



Multiple Applications of Agricultural Residues Biorefineries for biochemical production

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Abstract

Polyhydroxyalkanoates (PHAs) and butyl lactate are potential biodegradable biopolymers and green solvent respectively to replace petrochemical products due to the need in carbon reduction. Our studies are dedicated to the improvement of agricultural residues biorefinery process from pre-treatment to purification and extraction for PHAs and PLA production separately. In this case, rice straw, the most abundant agricultural waste in Taiwan, was first treated with the dilute acid steam explosion pretreatment and enzymatic hydrolysis to produce the cellulosic sugar before the fermentation. Then the sugar can be metabolized to PHAs or lactic acid in fermentation by different microorganisms. The PHAs extraction downstream was basically carried out by a three-stepped aqueous process; lactic acid can be further converted into butyl lactate for polylactic acid (PLA) polymerization or as green solvent.

Process flow of INER's biorefinery from agricultural residues

Scientific innovation and relevance

- High-throughput micro-pilot plant (MPP) is employed to accelerate the isolation of strain and establish the optimal fermentation parameters
- Products enhanced by Genetic Engineering
- Scale-up fermentation program development

Results

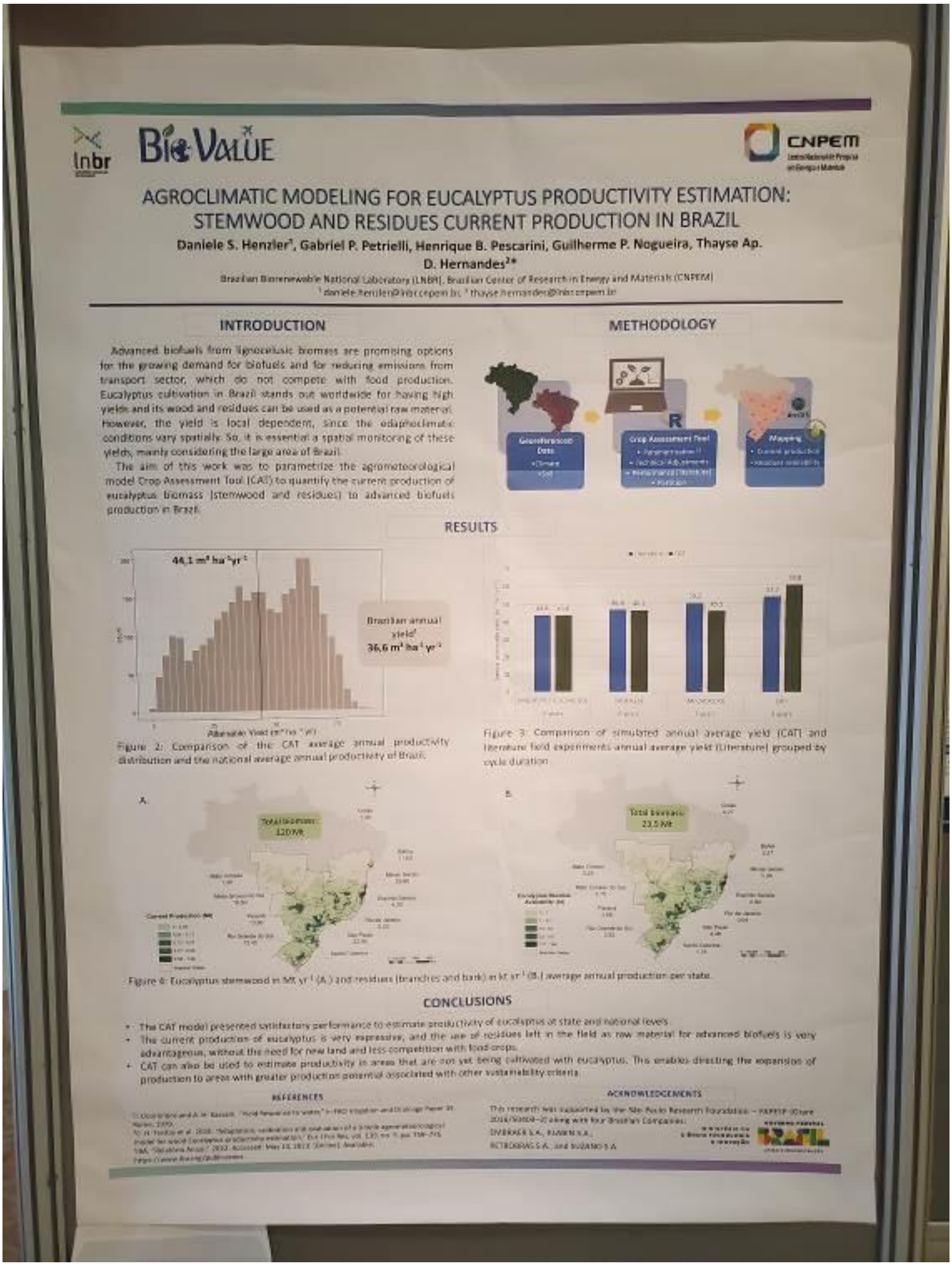
- PHA product with a purity of more than 90%, a recovery rate of more than 85%, and a molecular weight of about 400,000 Da was finally obtained.
- The synthesis process can produce butyl lactate with a purity of 99% and a recovery rate of 73%.

Introduction of INER

INER (Institute of Nuclear Energy Research) is a Taiwanese research institute founded in 1968 and main areas are focused on renewable energy (included green materials, environmental protection), biomedical application of radiation, nuclear safety and nuclear Facilities decommission & radioactive waste Management

(二)本次會議與本計畫主題相關之海報收錄：

1.1DV.4.3 AGROCLIMATIC MODELING FOR EUCALYPTUS AVAILABILITY ESTIMATION TO PRODUCE ADVANCED BIOFUELS.



AGROCLIMATIC MODELING FOR EUCALYPTUS PRODUCTIVITY ESTIMATION: STEMWOOD AND RESIDUES CURRENT PRODUCTION IN BRAZIL

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INTRODUCTION

Advanced biofuels from lignocelusic biomass are promising options for the growing demand for biofuels and for reducing emissions from transport sector, which do not compete with food production. Eucalyptus cultivation in Brazil stands out worldwide for having high yields and its wood and residues can be used as a potential raw material. However, the yield is local dependent, since the edaphoclimatic conditions vary spatially. So, it is essential a spatial monitoring of these yields, mainly considering the large area of Brazil.

The aim of this work was to parametrize the agrometeorological model Crop Assessment Tool (CAT) to quantify the current production of eucalyptus biomass (stemwood and residues) to advanced biofuels production in Brazil.

METHODOLOGY

RESULTS

Figure 2: Comparison of the CAT average annual productivity distribution and the national average annual productivity of Brazil.

Figure 3: Comparison of simulated annual average yield (CAT) and literature field experiments annual average yield (Literature) grouped by cycle duration.

Figure 4: Eucalyptus stemwood in Mt yr⁻¹ (A.) and residues (branches and bark) in kt yr⁻¹ (B.) average annual production per state.

CONCLUSIONS

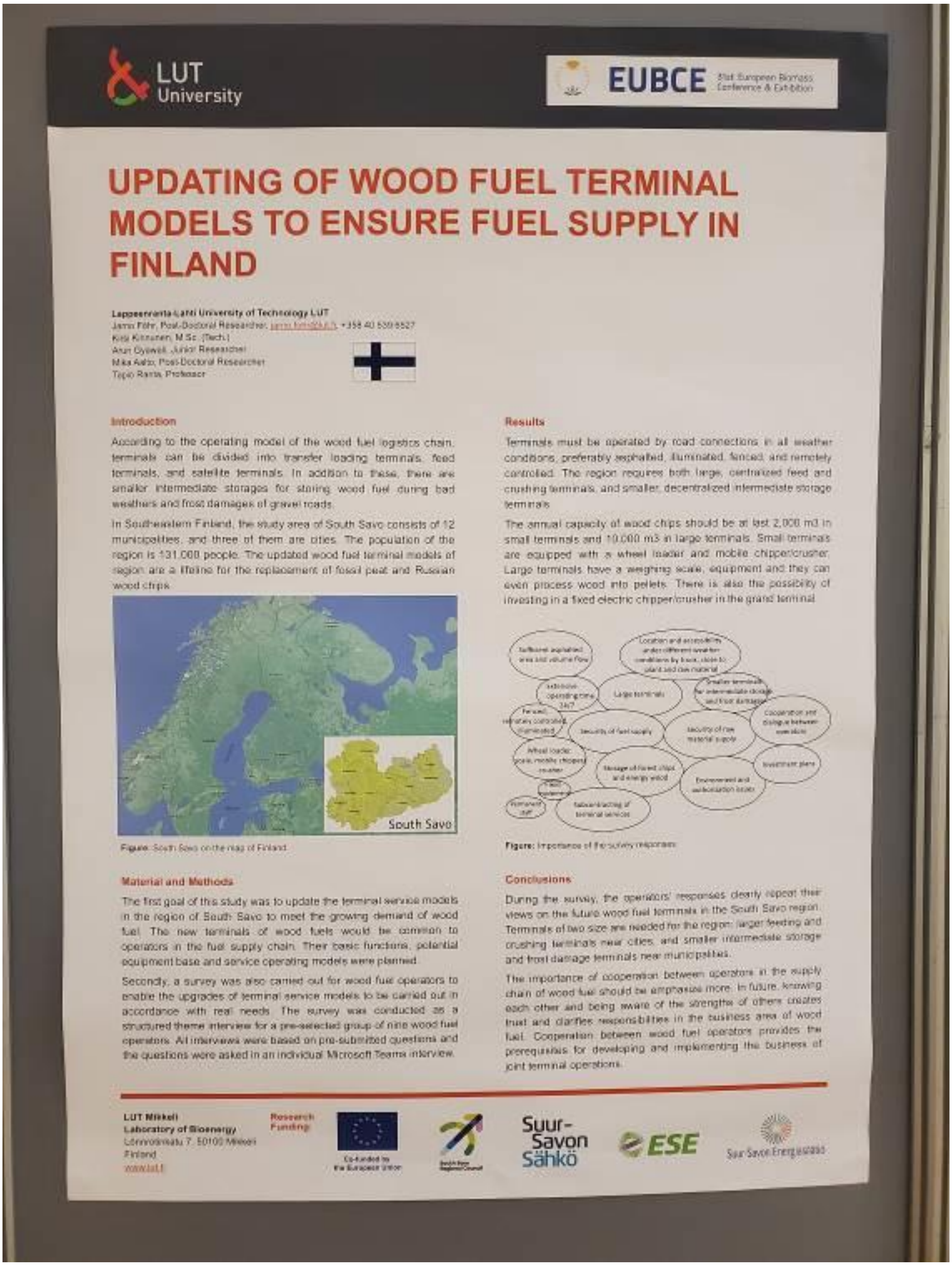
- The CAT model presented satisfactory performance to estimate productivity of eucalyptus at state and national levels.
- The current production of eucalyptus is very expressive, and the use of residues left in the field as raw material for advanced biofuels is very advantageous, without the need for new land and less competition with food crops.
- CAT can also be used to estimate productivity in areas that are not yet being cultivated with eucalyptus. This enables directing the expansion of production to areas with greater production potential associated with other sustainability criteria.

REFERENCES

ACKNOWLEDGEMENTS

This research was supported by the São Paulo Research Foundation – FAPESP (Grant 2016/[illegible]) along with four Brazilian Companies: EMBRAER S.A., KLABIN S.A., PETROBRAS S.A. and SUZANO S.A.

2.1DV.4.18 UPDATING OF WOOD FUEL TERMINAL MODELS TO ENSURE FUEL SUPPLY IN FINLAND.



UPDATING OF WOOD FUEL TERMINAL MODELS TO ENSURE FUEL SUPPLY IN FINLAND

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Introduction

According to the operating model of the wood fuel logistics chain, terminals can be divided into transfer loading terminals, feed terminals, and satellite terminals. In addition to these, there are smaller intermediate storages for storing wood fuel during bad weathers and frost damages of gravel roads.

In Southeastern Finland, the study area of South Savo consists of 12 municipalities, and three of them are cities. The population of the region is 131,000 people. The updated wood fuel terminal models of region are a lifeline for the replacement of fossil peat and Russian wood chips.

Figure: South Savo on the map of Finland

Material and Methods

The first goal of this study was to update the terminal service models in the region of South Savo to meet the growing demand of wood fuel. The new terminals of wood fuels would be common to operators in the fuel supply chain. Their basic functions, potential equipment base and service operating models were planned.

Secondly, a survey was also carried out for wood fuel operators to enable the upgrades of terminal service models to be carried out in accordance with real needs. The survey was conducted as a structured theme interview for a pre-selected group of nine wood fuel operators. All interviews were based on pre-submitted questions and the questions were asked in an individual Microsoft Teams interview.

Results

Terminals must be operated by road connections in all weather conditions, preferably asphalted, illuminated, fenced, and remotely controlled. The region requires both large, centralized feed and crushing terminals, and smaller, decentralized intermediate storage terminals.

The annual capacity of wood chips should be at last 2,000 m3 in small terminals and 10,000 m3 in large terminals. Small terminals are equipped with a wheel loader and mobile chipper/crusher. Large terminals have a weighing scale, equipment and they can even process wood into pellets. There is also the possibility of investing in a fixed electric chipper/crusher in the grand terminal.

Figure: Importance of the survey responses

Conclusions

During the survey, the operators' responses clearly repeat their views on the future wood fuel terminals in the South Savo region. Terminals of two size are needed for the region: larger feeding and crushing terminals near cities, and smaller intermediate storage and frost damage terminals near municipalities.

The importance of cooperation between operators in the supply chain of wood fuel should be emphasized more. In future, knowing each other and being aware of the strengths of others creates trust and clarifies responsibilities in the business area of wood fuel. Cooperation between wood fuel operators provides the prerequisites for developing and implementing the business of joint terminal operations.

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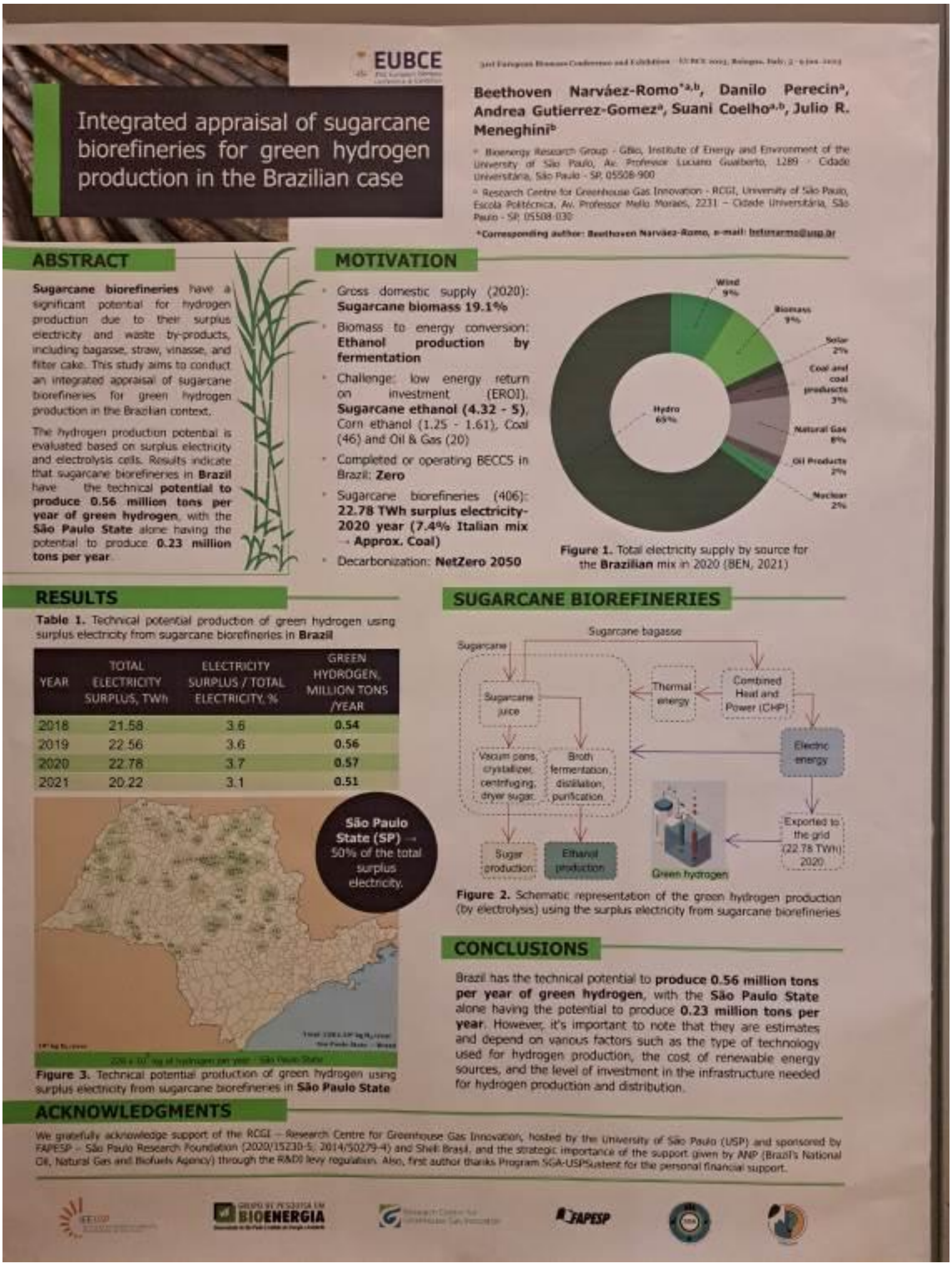
Research Funding
Co-funded by the European Union
South Savo Regional Council

3.3CV.4.2 INTEGRATED APPRAISAL OF SUGARCANE BIOREFINERIES FOR GREEN HYDROGEN PRODUCTION IN THE BRAZILIAN CASE.



Integrated appraisal of sugarcane biorefineries for green hydrogen production in the Brazilian case

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ABSTRACT

Sugarcane biorefineries have a significant potential for hydrogen production due to their surplus electricity and waste by-products, including bagasse, straw, vinasse, and filter cake. This study aims to conduct an integrated appraisal of sugarcane biorefineries for green hydrogen production in the Brazilian context.

The hydrogen production potential is evaluated based on surplus electricity and electrolysis cells. Results indicate that sugarcane biorefineries in **Brazil** have the technical **potential to produce 0.56 million tons per year of green hydrogen**, with the **São Paulo State** alone having the potential to produce **0.23 million tons per year**.

MOTIVATION

- Gross domestic supply (2020): **Sugarcane biomass 19.1%**
- Biomass to energy conversion: **Ethanol production by fermentation**
- Challenge: low energy return on investment (EROI). **Sugarcane ethanol (4.32 - 5)**, Corn ethanol (1.25 - 1.61), Coal (46) and Oil & Gas (20)
- Completed or operating BECCS in Brazil: **Zero**
- Sugarcane biorefineries (406): **22.78 TWh surplus electricity- 2020 year (7.4% Italian mix → Approx. Coal)**
- Decarbonization: **NetZero 2050**

Figure 1. Total electricity supply by source for the **Brazilian** mix in 2020 (BEN, 2021)

RESULTS

Table 1. Technical potential production of green hydrogen using surplus electricity from sugarcane biorefineries in **Brazil**

YEAR	TOTAL ELECTRICITY SURPLUS, TWh	ELECTRICITY SURPLUS / TOTAL ELECTRICITY, %	GREEN HYDROGEN, MILLION TONS /YEAR
2018	21.58	3.6	**0.54**
2019	22.56	3.6	**0.56**
2020	22.78	3.7	**0.57**
2021	20.22	3.1	**0.51**

São Paulo State (SP) → 50% of the total surplus electricity.

Figure 3. Technical potential production of green hydrogen using surplus electricity from sugarcane biorefineries in **São Paulo State**

SUGARCANE BIOREFINERIES

Figure 2. Schematic representation of the green hydrogen production (by electrolysis) using the surplus electricity from sugarcane biorefineries

CONCLUSIONS

Brazil has the technical potential to **produce 0.56 million tons per year of green hydrogen**, with the **São Paulo State** alone having the potential to produce **0.23 million tons per year**. However, it's important to note that they are estimates and depend on various factors such as the type of technology used for hydrogen production, the cost of renewable energy sources, and the level of investment in the infrastructure needed for hydrogen production and distribution.

ACKNOWLEDGMENTS

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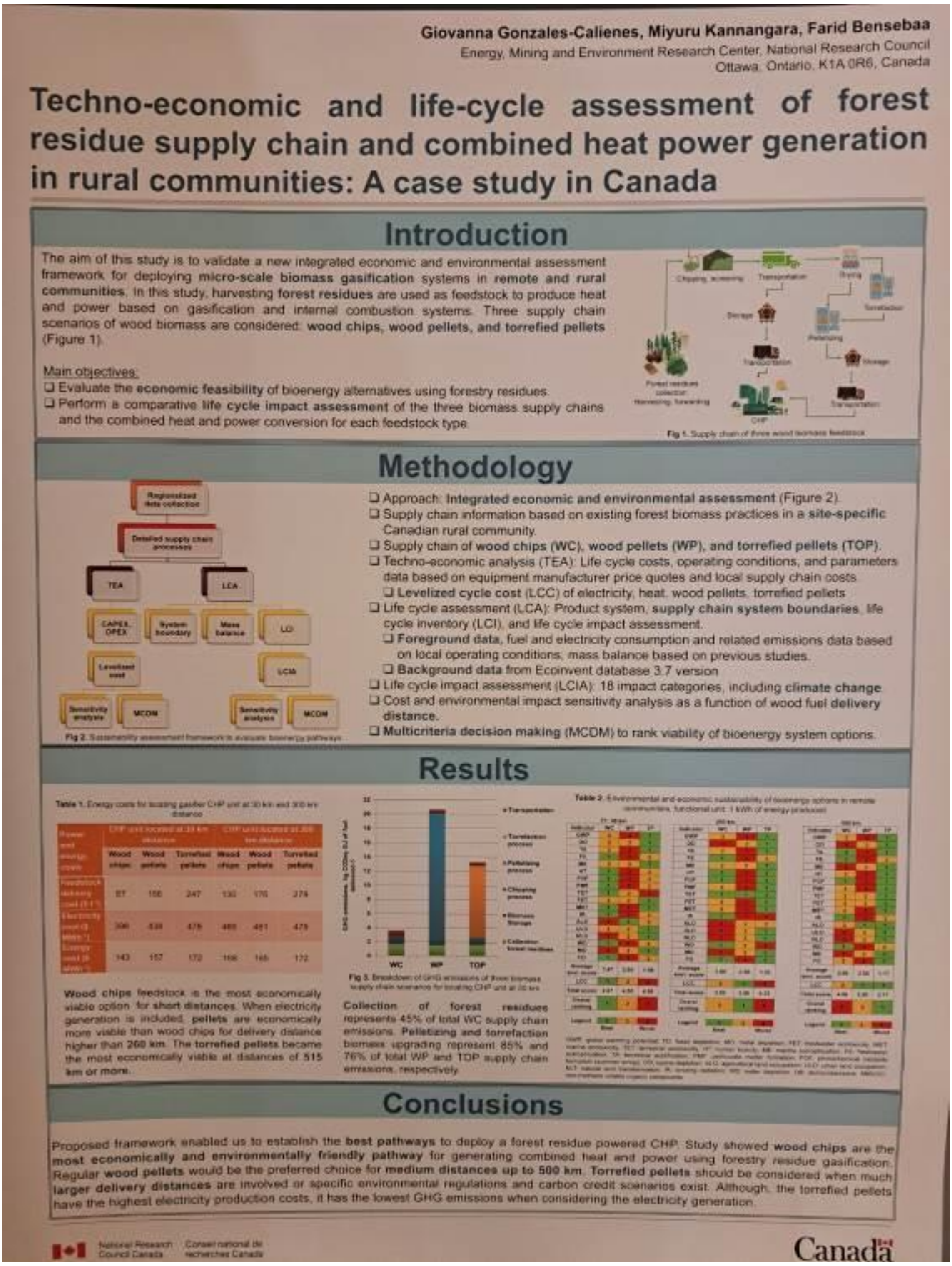
4.3CV.4.4 TECHNO-ECONOMIC AND LIFE-CYCLE ASSESSMENT OF FOREST RESIDUE SUPPLY CHAIN AND COMBINED HEAT POWER GENERATION IN RURAL COMMUNITIES:A CASE STUDY IN CANADA.



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Techno-economic and life-cycle assessment of forest residue supply chain and combined heat power generation in rural communities: A case study in Canada

Introduction

The aim of this study is to validate a new integrated economic and environmental assessment framework for deploying **micro-scale biomass gasification** systems in **remote and rural communities**. In this study, harvesting **forest residues** are used as feedstock to produce heat and power based on gasification and internal combustion systems. Three supply chain scenarios of wood biomass are considered: **wood chips, wood pellets, and torrefied pellets** (Figure 1).

Main objectives:

- ❑ Evaluate the **economic feasibility** of bioenergy alternatives using forestry residues.
- ❑ Perform a comparative **life cycle impact assessment** of the three biomass supply chains and the combined heat and power conversion for each feedstock type.

Fig 1. Supply chain of three wood biomass feedstock

Methodology

Fig 2. Sustainability assessment framework to evaluate bioenergy pathways

- ❑ Approach: **Integrated economic and environmental assessment** (Figure 2).
- ❑ Supply chain information based on existing forest biomass practices in a **site-specific** Canadian rural community.
- ❑ Supply chain of **wood chips (WC), wood pellets (WP), and torrefied pellets (TOP).**
- ❑ Techno-economic analysis (TEA): Life cycle costs, operating conditions, and parameters data based on equipment manufacturer price quotes and local supply chain costs.
  - ❑ **Levelized cycle cost** (LCC) of electricity, heat, wood pellets, torrefied pellets
- ❑ Life cycle assessment (LCA): Product system, **supply chain system boundaries**, life cycle inventory (LCI), and life cycle impact assessment.
  - ❑ **Foreground data**, fuel and electricity consumption and related emissions data based on local operating conditions; mass balance based on previous studies.
  - ❑ **Background data** from Ecoinvent database 3.7 version
- ❑ Life cycle impact assessment (LCIA): 18 impact categories, including **climate change**
- ❑ Cost and environmental impact sensitivity analysis as a function of **wood fuel delivery distance.**
- ❑ **Multicriteria decision making** (MCDM) to rank viability of bioenergy system options.

Results

Wood chips feedstock is the most economically viable option for **short distances**. When electricity generation is included, **pellets** are economically more viable than wood chips for delivery distance higher than **260 km**. The **torrefied pellets** became the most economically viable at distances of 515 km or more.

Fig 3. Breakdown of GHG emissions of three biomass supply chain scenarios for locating CHP unit at 30 km

Collection of forest residues represents 45% of total WC supply chain emissions. **Pelletizing and torrefaction** biomass upgrading represent 85% and 76% of total WP and TOP supply chain emissions, respectively.

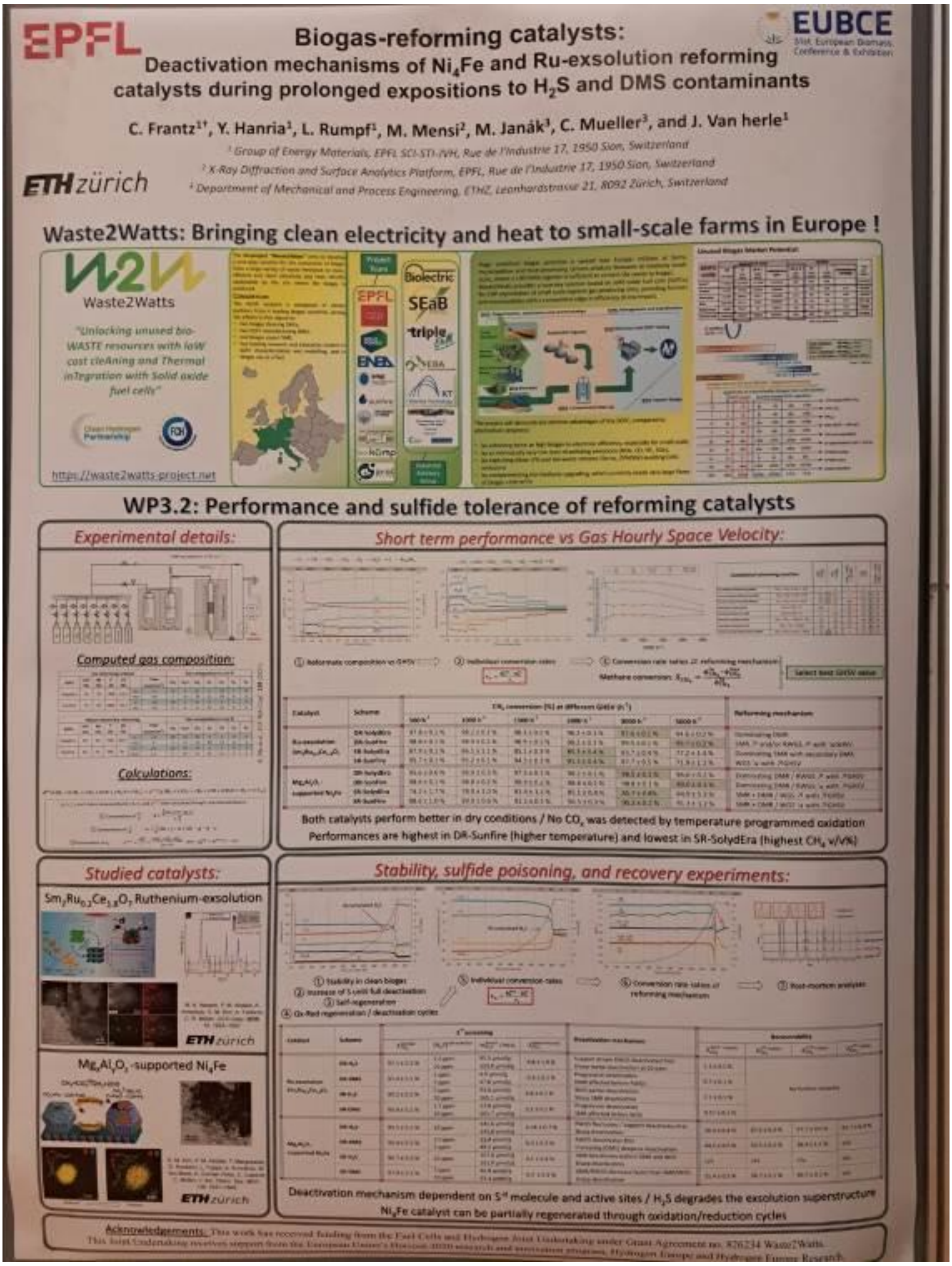
Conclusions

Proposed framework enabled us to establish the **best pathways** to deploy a forest residue powered CHP. Study showed **wood chips** are the **most economically and environmentally friendly pathway** for generating combined heat and power using forestry residue gasification. Regular **wood pellets** would be the preferred choice for **medium distances up to 500 km**. **Torrefied pellets** should be considered when much **larger delivery distances** are involved or specific environmental regulations and carbon credit scenarios exist. Although, the torrefied pellets have the highest electricity production costs, it has the lowest GHG emissions when considering the electricity generation.

National Research Council Canada | Conseil national de recherches Canada

Canada

5.3CV.4.15 BIOGAS-REFORMING CATALYSTS DEACTIVATION MECHANISMS OF NI-FE AND RU-EXSOLUTION DURING PROLONGED EXPOSURE TO H2S AND DMS CONTAMINANTS.



EPFL

EUBCE 31st European Biomass Conference & Exhibition

Biogas-reforming catalysts:
Deactivation mechanisms of Ni_4Fe and Ru-exsolution reforming catalysts during prolonged expositions to H_2S and DMS contaminants

C. Frantz[1†], Y. Hanria[1], L. Rumpf[1], M. Mensi[2], M. Janák[3], C. Mueller[3], and J. Van herle[1]

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ETH zürich

Waste2Watts: Bringing clean electricity and heat to small-scale farms in Europe !

Waste2Watts

"Unlocking unused bio-WASTE resources with loW cost cleAning and Thermal inTegration with Solid oxide fuel cells"

https://waste2watts-project.net

WP3.2: Performance and sulfide tolerance of reforming catalysts

Experimental details:

Computed gas composition:

Calculations:

Short term performance vs Gas Hourly Space Velocity:

Both catalysts perform better in dry conditions / No CO_x was detected by temperature programmed oxidation
Performances are highest in DR-Sunfire (higher temperature) and lowest in SR-SolydEra (highest CH_4 v/V%)

Studied catalysts:

$Sm_2Ru_{0.2}Ce_{1.8}O_7$ Ruthenium-exsolution

ETH zürich

$Mg_xAl_yO_z$-supported Ni_4Fe

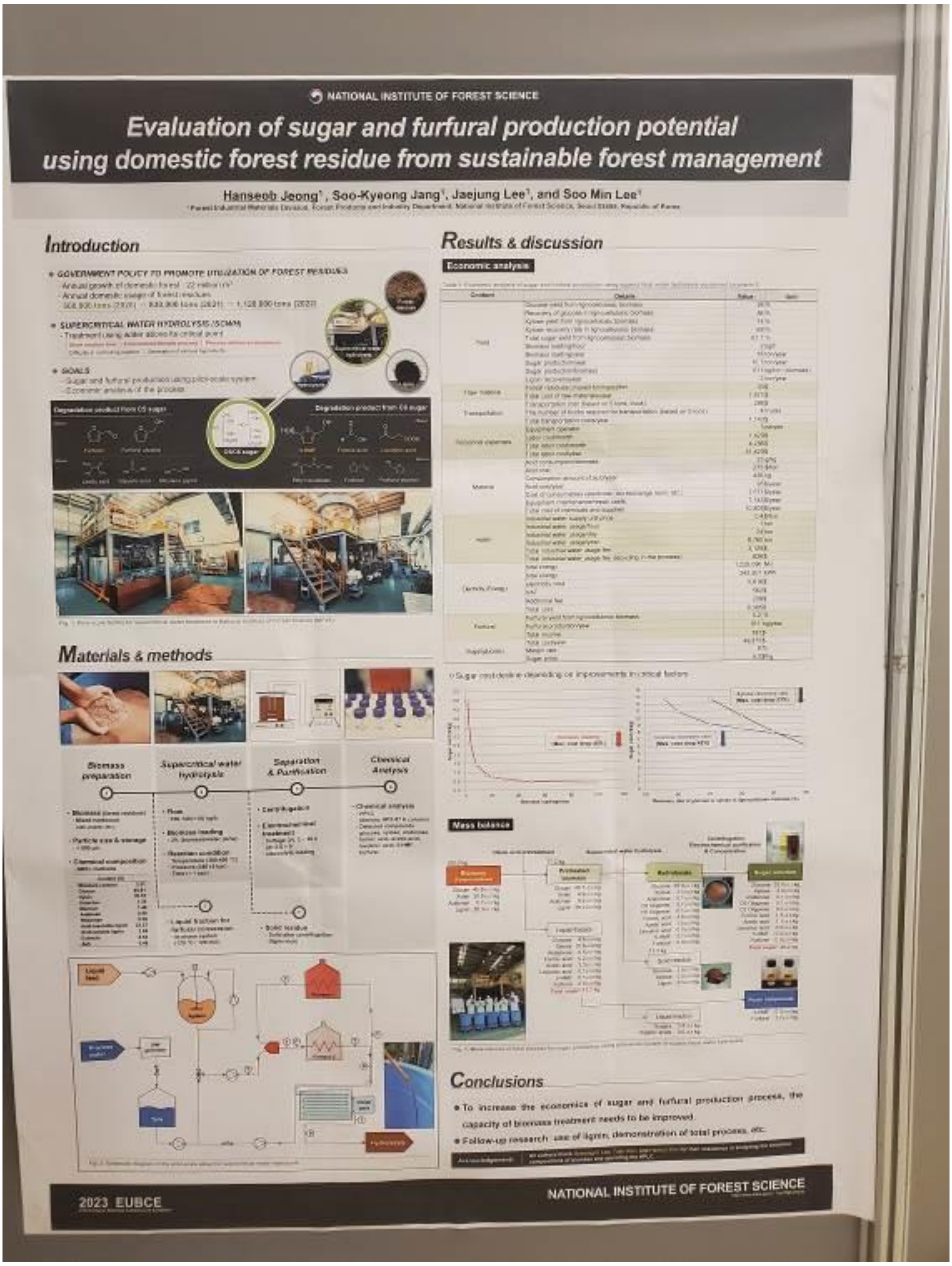
ETH zürich

Stability, sulfide poisoning, and recovery experiments:

Deactivation mechanism dependent on S^{-II} molecule and active sites / H_2S degrades the exsolution superstructure
Ni_4Fe catalyst can be partially regenerated through oxidation/reduction cycles

Acknowledgements: This work has received funding from the Fuel Cells and Hydrogen Joint Undertaking under Grant Agreement no. 826234 Waste2Watts. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe Research.

6.3CV.6.16 EVALUATION OF SUGAR AND FURFURAL PRODUCTION POTENTIAL USING DOMESTIC FOREST RESIDUE FROM SUSTAINABLE FOREST MANAGEMENT.



NATIONAL INSTITUTE OF FOREST SCIENCE

Evaluation of sugar and furfural production potential using domestic forest residue from sustainable forest management

Hanseob Jeong[1], Soo-Kyeong Jang[1], Jaejung Lee[1], and Soo Min Lee[1]

Introduction

- GOVERNMENT POLICY TO PROMOTE UTILIZATION OF FOREST RESIDUES
- SUPERCRITICAL WATER HYDROLYSIS (SCWH)
- GOALS

Materials & methods

Biomass preparation

Supercritical water hydrolysis

Separation & Purification

Chemical Analysis

Results & discussion

Economic analysis

Mass balance

Conclusions

- To increase the economics of sugar and furfural production process, the capacity of biomass treatment needs to be improved.
- Follow-up research: use of lignin, demonstration of total process, etc.

Acknowledgement

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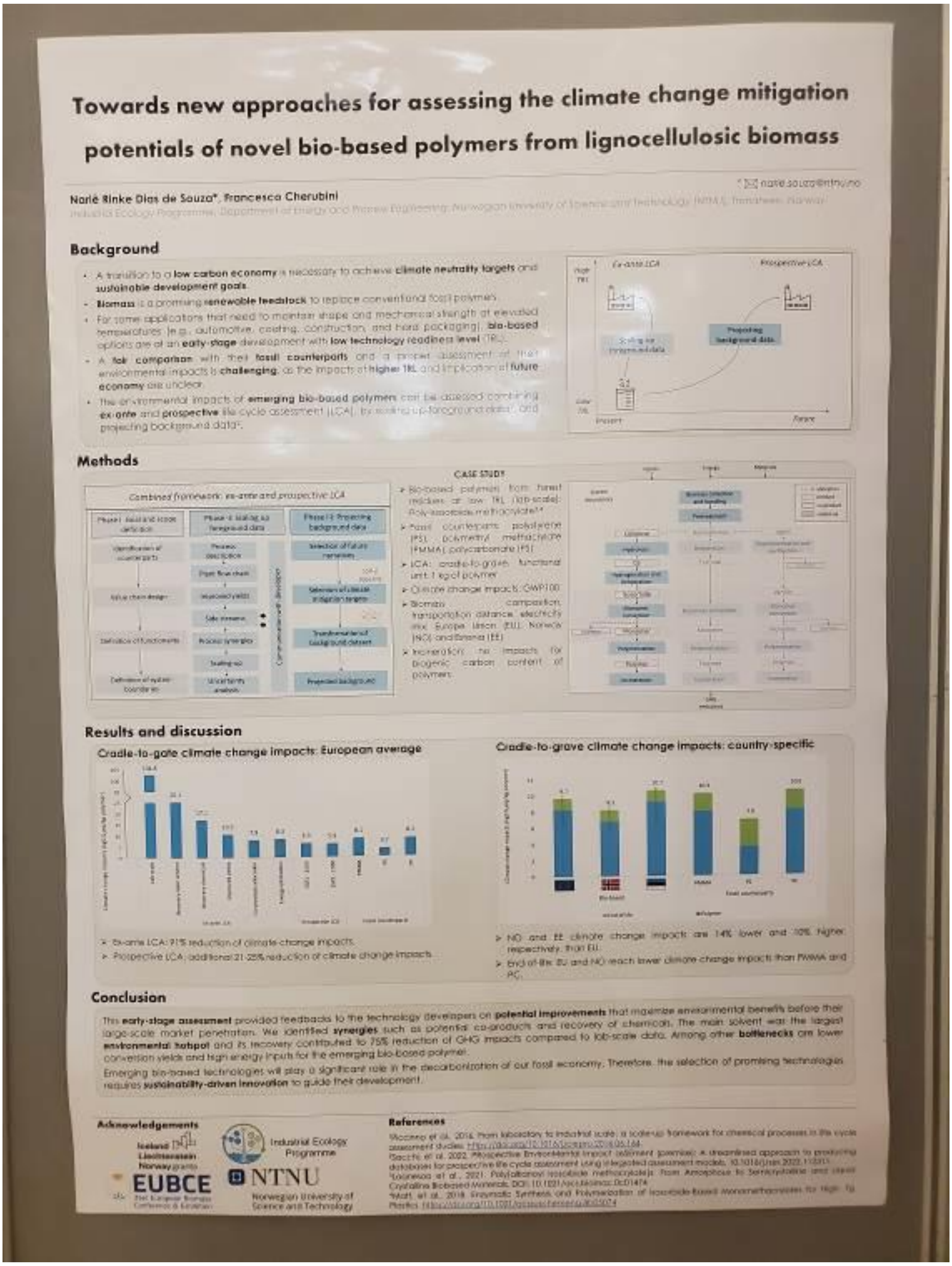
7.3CV.8.1 TOWARDS NEW APPROACHES FOR ASSESSING THE CLIMATE CHANGE MITIGATION POTENTIALS OF NOVEL BIOPOLYMERS FROM LIGNOCELLULOSIC BIOMASS.



Towards new approaches for assessing the climate change mitigation potentials of novel bio-based polymers from lignocellulosic biomass

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Background

- A transition to a **low carbon economy** is necessary to achieve **climate neutrality targets** and **sustainable development goals**.
- **Biomass** is a promising **renewable feedstock** to replace conventional fossil polymers.
- For some applications that need to maintain shape and mechanical strength at elevated temperatures (e.g., automotive, coating, construction, and hard packaging), **bio-based** options are at an **early-stage** development with **low technology readiness level** (TRL).
- A **fair comparison** with their **fossil counterparts** and a proper assessment of their environmental impacts is **challenging**, as the impacts at **higher TRL** and implication of **future economy** are unclear.
- The environmental impacts of **emerging bio-based polymers** can be assessed combining **ex-ante** and **prospective** life cycle assessment (LCA), by scaling-up foreground data[1], and projecting background data[2].

Methods

CASE STUDY

- Bio-based polymers from forest residues at low TRL (lab-scale): Poly-isosorbide methacrylate[3,4]
- Fossil counterparts: polystyrene (PS), polymethyl methacrylate (PMMA), polycarbonate (PC)
- LCA: cradle-to-grave, functional unit 1 kg of polymer
- Climate change impacts: GWP100
- Biomass composition, transportation distance, electricity mix: Europe Union (EU), Norway (NO) and Estonia (EE)
- Incineration: no impacts for biogenic carbon content of polymers.

Results and discussion

Cradle-to-gate climate change impacts: European average

- Ex-ante LCA: 91% reduction of climate change impacts.
- Prospective LCA: additional 21-25% reduction of climate change impacts.

Cradle-to-grave climate change impacts: country-specific

- NO and EE climate change impacts are 14% lower and 10% higher, respectively, than EU.
- End-of-life: EU and NO reach lower climate change impacts than PMMA and PC.

Conclusion

This **early-stage assessment** provided feedbacks to the technology developers on **potential improvements** that maximise environmental benefits before their large-scale market penetration. We identified **synergies** such as potential co-products and recovery of chemicals. The main solvent was the largest **environmental hotspot** and its recovery contributed to 75% reduction of GHG impacts compared to lab-scale data. Among other **bottlenecks** are lower conversion yields and high energy inputs for the emerging bio-based polymer.

Emerging bio-based technologies will play a significant role in the decarbonization of our fossil economy. Therefore, the selection of promising technologies requires **sustainability-driven innovation** to guide their development.

Acknowledgements
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Industrial Ecology Programme
NTNU Norwegian University of Science and Technology
EUBCE

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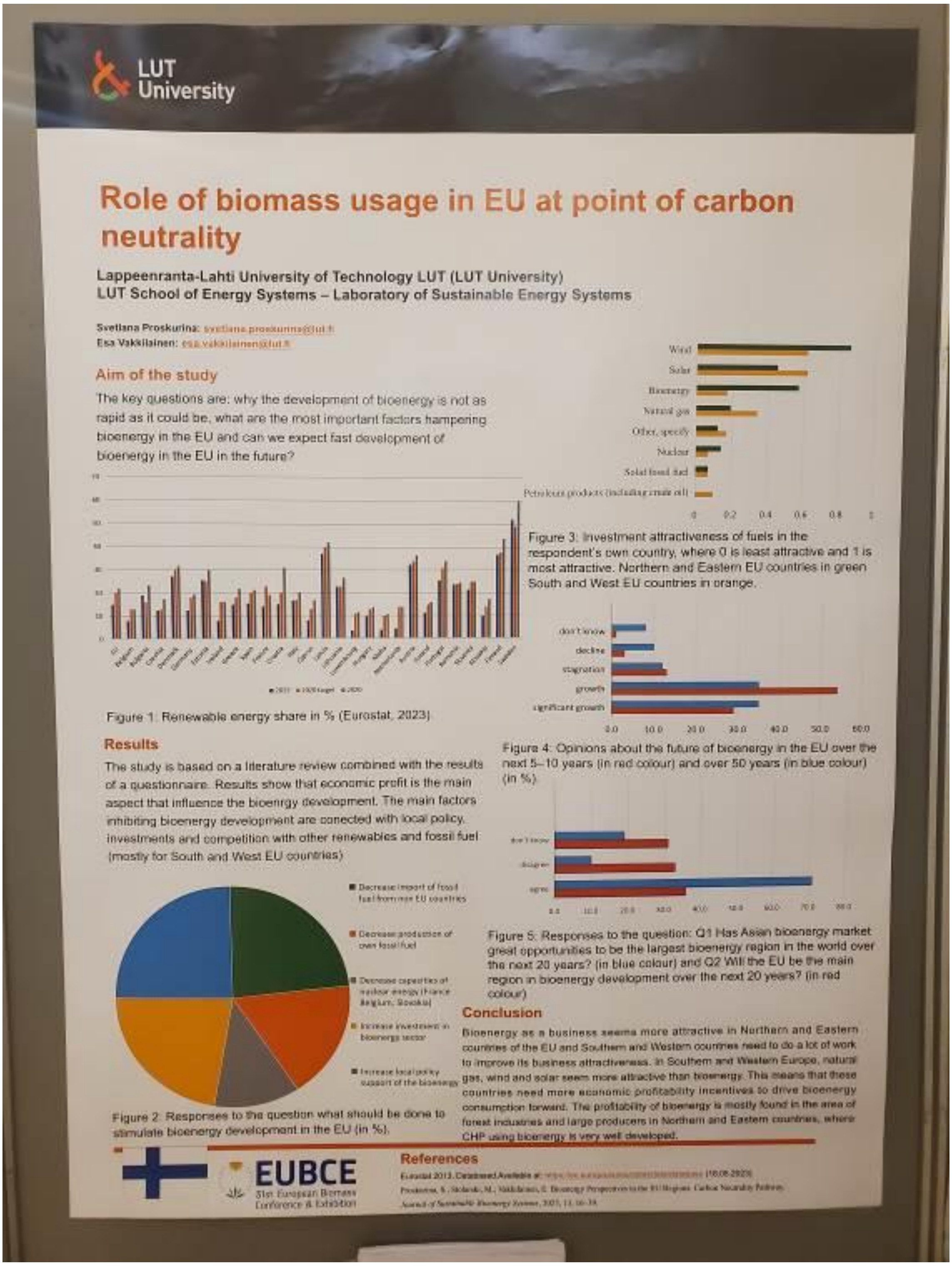
[3] [illegible] et al., 2021. Poly(alkanoyl isosorbide methacrylate)s: From Amorphous to Semicrystalline and Liquid Crystalline Biobased Materials. DOI: 10.1021/acs.biomac.0c01474
[4] Matt, et al. 2018. Enzymatic Synthesis and Polymerization of Isosorbide-Based Monomethacrylates for High-Tg Plastics. https://doi.org/10.1021/acssuschemeng.8c02074

8.3CV.8.5 EUBCE Student Awardee Presentation ROLE OF BIOMASS USAGE IN EU AT POINT OF CARBON NEUTRALITY.



LUT University

Role of biomass usage in EU at point of carbon neutrality

Lappeenranta-Lahti University of Technology LUT (LUT University)
LUT School of Energy Systems – Laboratory of Sustainable Energy Systems

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Aim of the study

The key questions are: why the development of bioenergy is not as rapid as it could be, what are the most important factors hampering bioenergy in the EU and can we expect fast development of bioenergy in the EU in the future?

Figure 1: Renewable energy share in % (Eurostat, 2023)

Figure 3: Investment attractiveness of fuels in the respondent's own country, where 0 is least attractive and 1 is most attractive. Northern and Eastern EU countries in green South and West EU countries in orange.

Figure 4: Opinions about the future of bioenergy in the EU over the next 5–10 years (in red colour) and over 50 years (in blue colour) (in %)

Results

The study is based on a literature review combined with the results of a questionnaire. Results show that economic profit is the main aspect that influence the bioenrgy development. The main factors inhibiting bioenergy development are conected with local policy, investments and competition with other renewables and fossil fuel (mostly for South and West EU countries)

Figure 2: Responses to the question what should be done to stimulate bioenergy development in the EU (in %).

Figure 5: Responses to the question: Q1 Has Asian bioenergy market great opportunities to be the largest bioenergy region in the world over the next 20 years? (in blue colour) and Q2 Will the EU be the main region in bioenergy development over the next 20 years? (in red colour)

Conclusion

Bioenergy as a business seems more attractive in Northern and Eastern countries of the EU and Southern and Western countries need to do a lot of work to improve its business attractiveness. In Southern and Western Europe, natural gas, wind and solar seem more attractive than bioenergy. This means that these countries need more economic profitability incentives to drive bioenergy consumption forward. The profitability of bioenergy is mostly found in the area of forest industries and large producers in Northern and Eastern countries, where CHP using bioenergy is very well developed.

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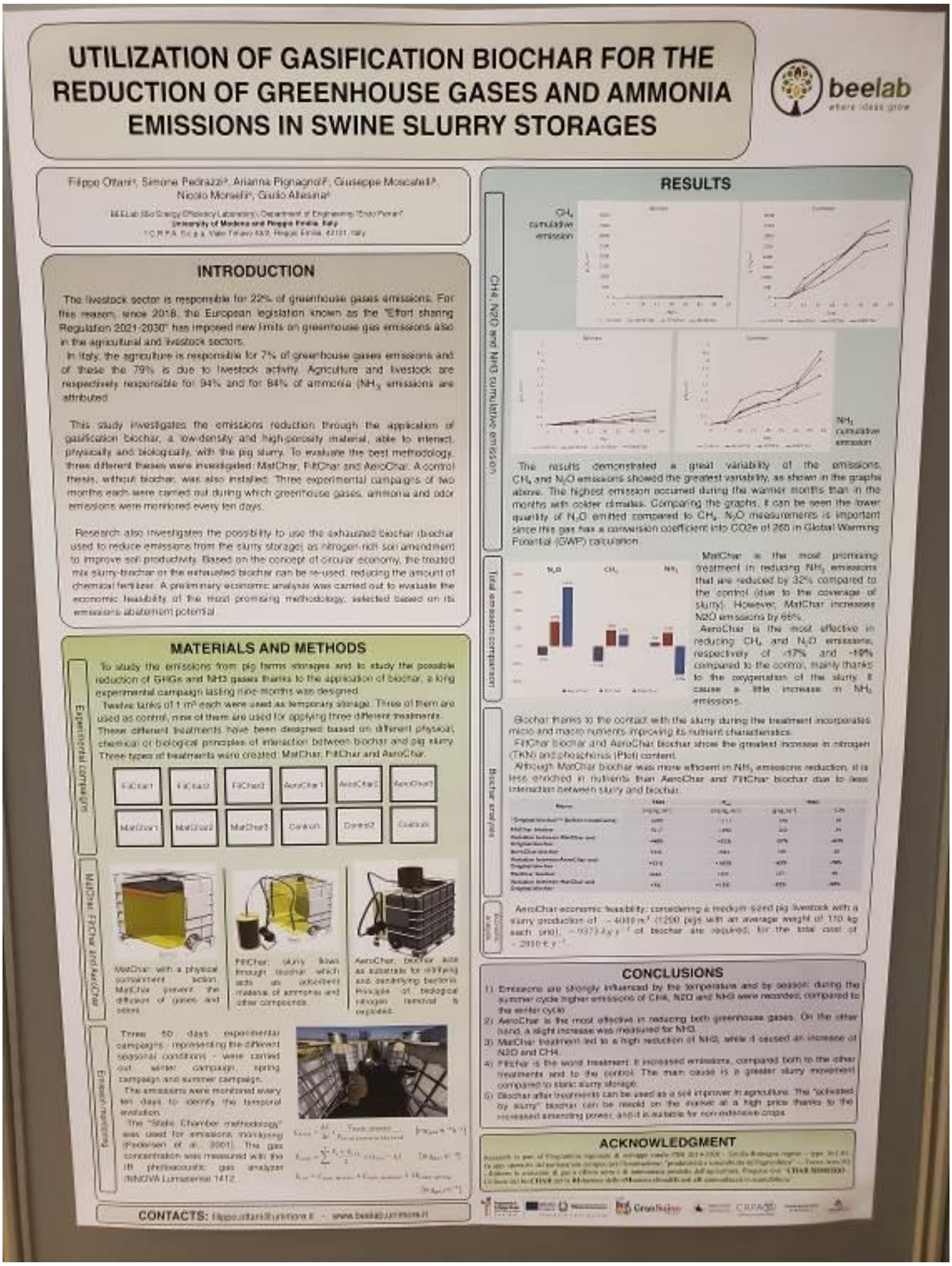
References

9.4BV.5.8 UTILIZATION OF GASIFICATION BIOCHAR FOR THE REDUCTION OF GREENHOUSE GASES AND AMMONIA EMISSIONS IN SWINE SLURRY STORAGES.



UTILIZATION OF GASIFICATION BIOCHAR FOR THE REDUCTION OF GREENHOUSE GASES AND AMMONIA EMISSIONS IN SWINE SLURRY STORAGES

Filippo Ottani, Simone Pedrazzi, Arianna Pignagnoli, Giuseppe Moscatelli, Nicolò Morselli, Giulio Allesina
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INTRODUCTION

The livestock sector is responsible for 22% of greenhouse gases emissions. For this reason, since 2018, the European legislation known as the "Effort sharing Regulation 2021-2030" has imposed new limits on greenhouse gas emissions also in the agricultural and livestock sectors.

In Italy, the agriculture is responsible for 7% of greenhouse gases emissions and of these the 79% is due to livestock activity. Agriculture and livestock are respectively responsible for 94% and for 84% of ammonia (NH_3) emissions are attributed.

This study investigates the emissions reduction through the application of gasification biochar, a low-density and high-porosity material, able to interact, physically and biologically, with the pig slurry. To evaluate the best methodology, three different theses were investigated: MatChar, FiltChar and AeroChar. A control thesis, without biochar, was also installed. Three experimental campaigns of two months each were carried out during which greenhouse gases, ammonia and odor emissions were monitored every ten days.

Research also investigates the possibility to use the exhausted biochar (biochar used to reduce emissions from the slurry storage) as nitrogen-rich soil amendment to improve soil productivity. Based on the concept of circular economy, the treated mix slurry-biochar or the exhausted biochar can be re-used, reducing the amount of chemical fertilizer. A preliminary economic analysis was carried out to evaluate the economic feasibility of the most promising methodology, selected based on its emissions abatement potential.

MATERIALS AND METHODS

To study the emissions from pig farms storages and to study the possible reduction of GHGs and NH3 gases thanks to the application of biochar, a long experimental campaign lasting nine months was designed.

Twelve tanks of 1 m^3 each were used as temporary storage. Three of them are used as control, nine of them are used for applying three different treatments. These different treatments have been designed based on different physical, chemical or biological principles of interaction between biochar and pig slurry. Three types of treatments were created: MatChar, FiltChar and AeroChar.

MatChar: with a physical containment action. MatChar prevent the diffusion of gases and odors.

FiltChar: slurry flows through biochar which acts as adsorbent materials of ammonia and other components.

AeroChar: biochar acts as substrate for nitrifying and denitrifying bacteria. Principle of biological nitrogen removal is exploited.

Three 60 days experimental campaigns - representing the different seasonal conditions - were carried out: winter campaign, spring campaign and summer campaign.

The emissions were monitored every ten days to identify the temporal evolution.

The "Static Chamber methodology" was used for emissions monitoring (Pedersen et al., 2001). The gas concentration was measured with the IR photoacoustic gas analyzer INNOVA Lumasense 1412.

RESULTS

The results demonstrated a great variability of the emissions. CH_4 and N_2O emissions showed the greatest variability, as shown in the graphs above. The highest emission occurred during the warmer months than in the months with colder climates. Comparing the graphs, it can be seen the lower quantity of N_2O emitted compared to CH_4. N_2O measurements is important since this gas has a conversion coefficient into CO2e of 265 in Global Warming Potential (GWP) calculation.

MatChar is the most promising treatment in reducing NH_3 emissions that are reduced by 32% compared to the control (due to the coverage of slurry). However, MatChar increases N2O emissions by 66%.

AeroChar is the most effective in reducing CH_4 and N_2O emissions, respectively of -17% and -19% compared to the control, mainly thanks to the oxygenation of the slurry. It cause a little increase in NH_3 emissions.

Biochar thanks to the contact with the slurry during the treatment incorporates micro and macro nutrients improving its nutrient characteristics.

FiltChar biochar and AeroChar biochar show the greatest increase in nitrogen (TKN) and phosphorus (Ptot) content.

Although MatChar biochar was more efficient in NH_3 emissions reduction, it is less enriched in nutrients than AeroChar and FiltChar biochar due to less interaction between slurry and biochar.

AeroChar economic feasibility: considering a medium sized pig livestock with a slurry production of ~ 4000 m^3 (1200 pigs with an average weight of 110 kg each one), ~ 9373 kg y^{-1} of biochar are required, for the total cost of ~ 2800 € y^{-1}.

CONCLUSIONS

1) Emissions are strongly influenced by the temperature and by season: during the summer cycle higher emissions of CH4, N2O and NH3 were recorded, compared to the winter cycle.
2) AeroChar is the most effective in reducing both greenhouse gases. On the other hand, a slight increase was measured for NH3.
3) MatChar treatment led to a high reduction of NH3, while it caused an increase of N2O and CH4.
4) FiltChar is the worst treatment: it increased emissions, compared both to the other treatments and to the control. The main cause is a greater slurry movement compared to static slurry storage.
5) Biochar after treatments can be used as a soil improver in agriculture. The "activated by slurry" biochar can be resold on the market at a high price thanks to the increased amending power, and it is suitable for non-extensive crops.

ACKNOWLEDGMENT

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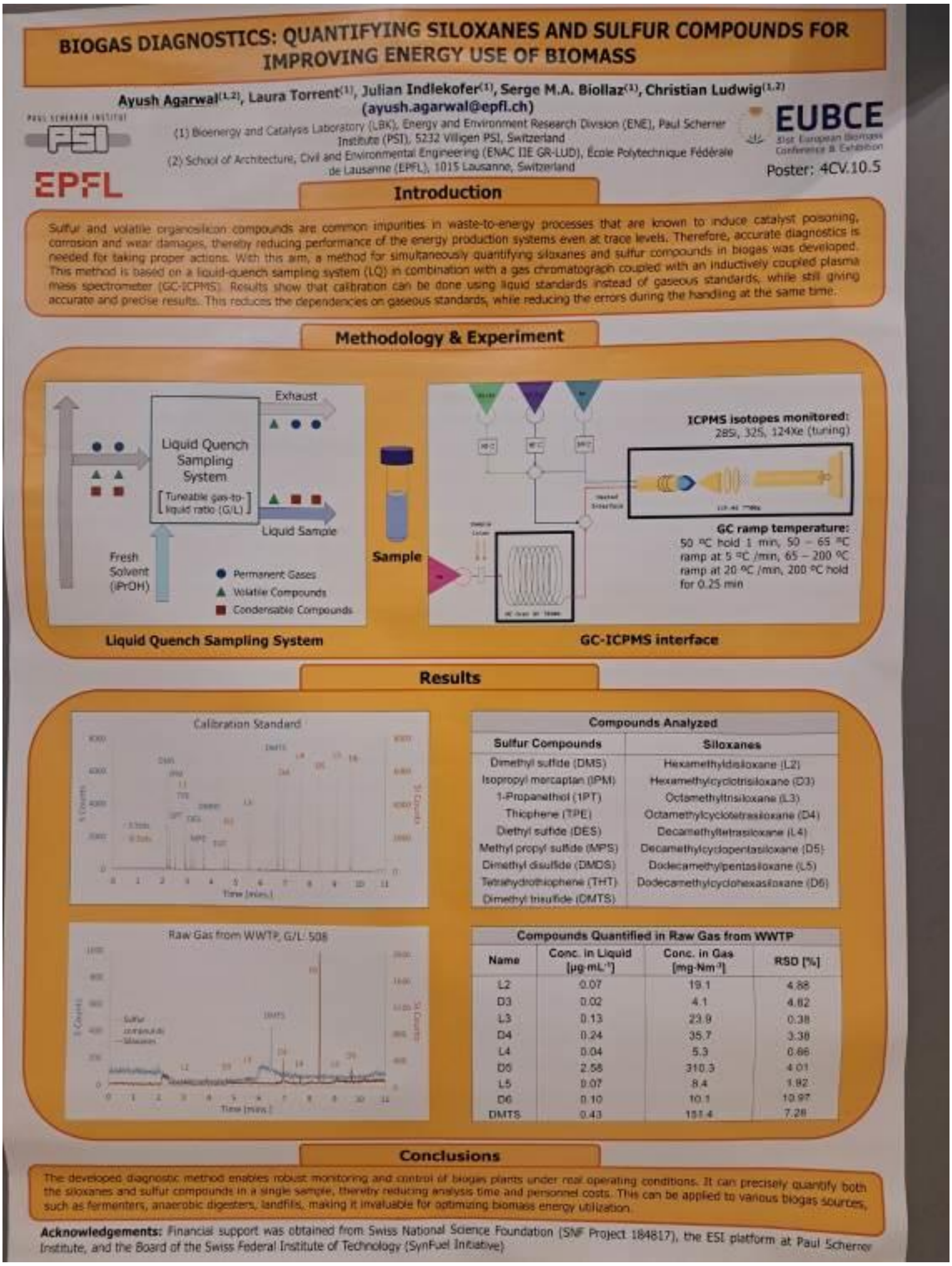
10.4CV.10.5 BIOGAS DIAGNOSTICS: QUANTIFYING SILOXANES AND SULFUR COMPOUNDS FORIMPROVING ENERGY USE OF BIOMASS.



BIOGAS DIAGNOSTICS: QUANTIFYING SILOXANES AND SULFUR COMPOUNDS FOR IMPROVING ENERGY USE OF BIOMASS

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Poster: 4CV.10.5

Introduction

Sulfur and volatile organosilicon compounds are common impurities in waste-to-energy processes that are known to induce catalyst poisoning, corrosion and wear damages, thereby reducing performance of the energy production systems even at trace levels. Therefore, accurate diagnostics is needed for taking proper actions. With this aim, a method for simultaneously quantifying siloxanes and sulfur compounds in biogas was developed. This method is based on a liquid-quench sampling system (LQ) in combination with a gas chromatograph coupled with an inductively coupled plasma mass spectrometer (GC-ICPMS). Results show that calibration can be done using liquid standards instead of gaseous standards, while still giving accurate and precise results. This reduces the dependencies on gaseous standards, while reducing the errors during the handing at the same time.

Methodology & Experiment

Liquid Quench Sampling System

ICPMS isotopes monitored:
28Si, 32S, 124Xe (tuning)

GC ramp temperature:
50 °C hold 1 min, 50 – 65 °C ramp at 5 °C /min, 65 – 200 °C ramp at 20 °C /min, 200 °C hold for 0.25 min

GC-ICPMS interface

Results

Calibration Standard

Raw Gas from WWTP, G/L: 508

Compounds Analyzed	
Sulfur Compounds	**Siloxanes**
Dimethyl sulfide (DMS)	Hexamethyldisiloxane (L2)
Isopropyl mercaptan (IPM)	Hexamethylcyclotrisiloxane (D3)
1-Propanethiol (1PT)	Octamethyltrisiloxane (L3)
Thiophene (TPE)	Octamethylcyclotetrasiloxane (D4)
Diethyl sulfide (DES)	Decamethyltetrasiloxane (L4)
Methyl propyl sulfide (MPS)	Decamethylcyclopentasiloxane (D5)
Dimethyl disulfide (DMDS)	Dodecamethylpentasiloxane (L5)
Tetrahydrothiophene (THT)	Dodecamethylcyclohexasiloxane (D6)
Dimethyl trisulfide (DMTS)	

Compounds Quantified in Raw Gas from WWTP

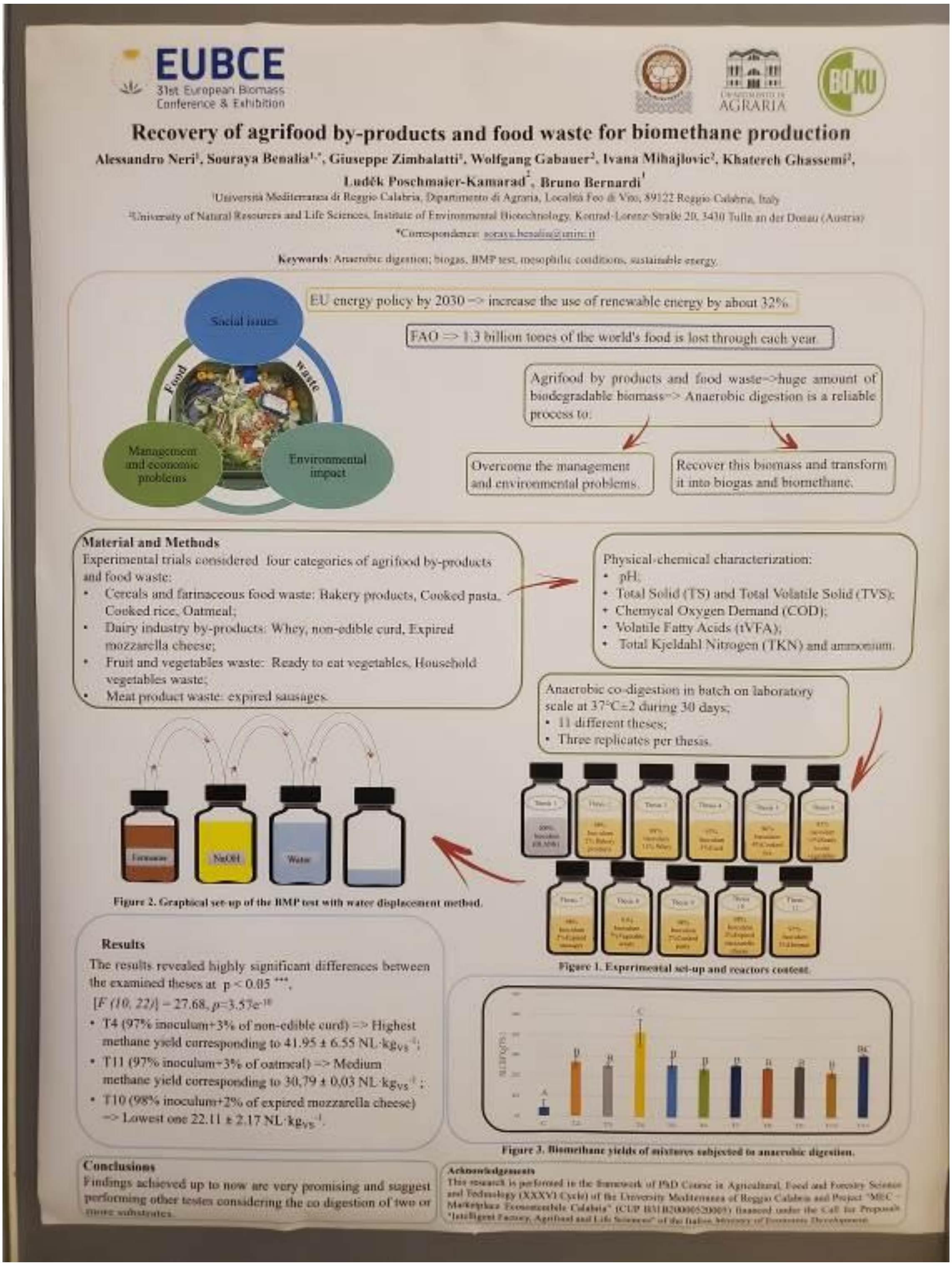
Name	Conc. in Liquid [μg·mL^{-1}]	Conc. in Gas [mg·Nm^{-3}]	RSD [%]
L2	0.07	19.1	4.88
D3	0.02	4.1	4.82
L3	0.13	23.9	0.38
D4	0.24	35.7	3.38
L4	0.04	5.3	0.66
D5	2.58	310.3	4.01
L5	0.07	8.4	1.92
D6	0.10	10.1	10.97
DMTS	0.43	151.4	7.28

Conclusions

The developed diagnostic method enables robust monitoring and control of biogas plants under real operating conditions. It can precisely quantify both the siloxanes and sulfur compounds in a single sample, thereby reducing analysis time and personnel costs. This can be applied to various biogas sources, such as fermenters, anaerobic digesters, landfills, making it invaluable for optimizing biomass energy utilization.

Acknowledgements: Financial support was obtained from Swiss National Science Foundation (SNF Project 184817), the ESI platform at Paul Scherrer Institute, and the Board of the Swiss Federal Institute of Technology (SynFuel Initiative)

11.4CV.10.6 RECOVERY OF AGRIFOOD BY-PRODUCTS AND FOOD WASTE FOR BIOMETHANE PRODUCTION.



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AGRARIA

BOKU

Recovery of agrifood by-products and food waste for biomethane production

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Keywords: Anaerobic digestion; biogas, BMP test, mesophilic conditions, sustainable energy.

EU energy policy by 2030 -> increase the use of renewable energy by about 32%.

FAO => 1.3 billion tones of the world's food is lost through each year.

Agrifood by products and food waste->huge amount of biodegradable biomass-> Anaerobic digestion is a reliable process to:

Overcome the management and environmental problems.

Recover this biomass and transform it into biogas and biomethane.

Material and Methods

Experimental trials considered four categories of agrifood by-products and food waste:

- Cereals and farinaceous food waste: Bakery products, Cooked pasta, Cooked rice, Oatmeal;
- Dairy industry by-products: Whey, non-edible curd, Expired mozzarella cheese;
- Fruit and vegetables waste: Ready to eat vegetables, Household vegetables waste;
- Meat product waste: expired sausages.

Physical-chemical characterization:

- pH;
- Total Solid (TS) and Total Volatile Solid (TVS);
- Chemycal Oxygen Demand (COD);
- Volatile Fatty Acids (tVFA);
- Total Kjeldahl Nitrogen (TKN) and ammonium.

Anaerobic co-digestion in batch on laboratory scale at 37°C±2 during 30 days;

- 11 different theses;
- Three replicates per thesis.

Figure 2. Graphical set-up of the BMP test with water displacement method.

Figure 1. Experimental set-up and reactors content.

Results

The results revealed highly significant differences between the examined theses at $p < 0.05$ ***,
[$F(10, 22)$] = 27.68, p=3.57e-10

- T4 (97% inoculum+3% of non-edible curd) => Highest methane yield corresponding to 41.95 ± 6.55 $NL \cdot kg_{VS}^{-1}$;
- T11 (97% inoculum+3% of oatmeal) => Medium methane yield corresponding to 30,79 ± 0,03 $NL \cdot kg_{VS}^{-1}$;
- T10 (98% inoculum+2% of expired mozzarella cheese) => Lowest one 22.11 ± 2.17 $NL \cdot kg_{VS}^{-1}$.

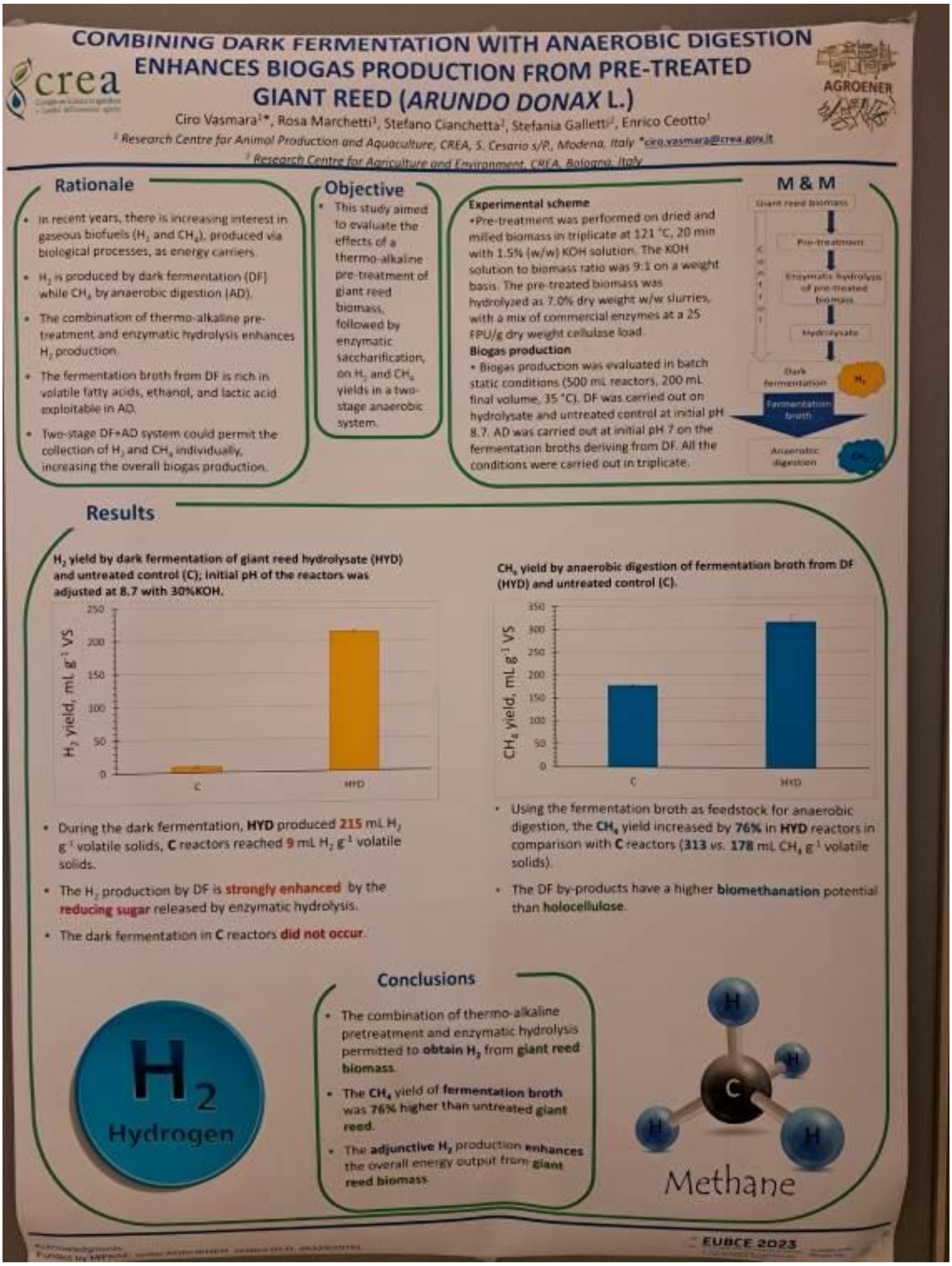
Figure 3. Biomethane yields of mixtures subjected to anaerobic digestion.

Conclusions

Findings achieved up to now are very promising and suggest performing other testes considering the co digestion of two or more substrates.

Acknowledgements
This research is performed in the framework of PhD Course in Agricultural, Food and Forestry Science and Technology (XXXVI Cycle) of the University Mediterranea of Reggio Calabria and Project "MEC – Marketplace Ecosostenibile Calabria" (CUP B31B20000520005) financed under the Call for Proposals "Intelligent Factory, Agrifood and Life Sciences" of the Italian Ministry of Economic Development.

12.4CV.10.10 COMBINING DARK FERMENTATION WITH ANAEROBIC DIGESTION ENHANCE BIOGAS PRODUCTIONFROM PRE-TREATED GIANT REED (ARUNDO DONAX L.).



COMBINING DARK FERMENTATION WITH ANAEROBIC DIGESTION ENHANCES BIOGAS PRODUCTION FROM PRE-TREATED GIANT REED (*ARUNDO DONAX* L.)

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Rationale

- In recent years, there is increasing interest in gaseous biofuels (H_2 and CH_4), produced via biological processes, as energy carriers.
- H_2 is produced by dark fermentation (DF) while CH_4 by anaerobic digestion (AD).
- The combination of thermo-alkaline pre-treatment and enzymatic hydrolysis enhances H_2 production.
- The fermentation broth from DF is rich in volatile fatty acids, ethanol, and lactic acid exploitable in AD.
- Two-stage DF+AD system could permit the collection of H_2 and CH_4 individually, increasing the overall biogas production.

Objective

- This study aimed to evaluate the effects of a thermo-alkaline pre-treatment of giant reed biomass, followed by enzymatic saccharification, on H_2 and CH_4 yields in a two-stage anaerobic system.

M & M

Experimental scheme

•Pre-treatment was performed on dried and milled biomass in triplicate at 121 °C, 20 min with 1.5% (w/w) KOH solution. The KOH solution to biomass ratio was 9:1 on a weight basis. The pre-treated biomass was hydrolyzed as 7.0% dry weight w/w slurries, with a mix of commercial enzymes at a 25 FPU/g dry weight cellulase load.

Biogas production

• Biogas production was evaluated in batch static conditions (500 mL reactors, 200 mL final volume, 35 °C). DF was carried out on hydrolysate and untreated control at initial pH 8.7. AD was carried out at initial pH 7 on the fermentation broths deriving from DF. All the conditions were carried out in triplicate.

Results

H_2 yield by dark fermentation of giant reed hydrolysate (HYD) and untreated control (C); initial pH of the reactors was adjusted at 8.7 with 30%KOH.

- During the dark fermentation, **HYD** produced **215** mL H_2 g^{-1} volatile solids, **C** reactors reached **9** mL H_2 g^{-1} volatile solids.
- The H_2 production by DF is **strongly enhanced** by the **reducing sugar** released by enzymatic hydrolysis.
- The dark fermentation in **C** reactors **did not occur**.

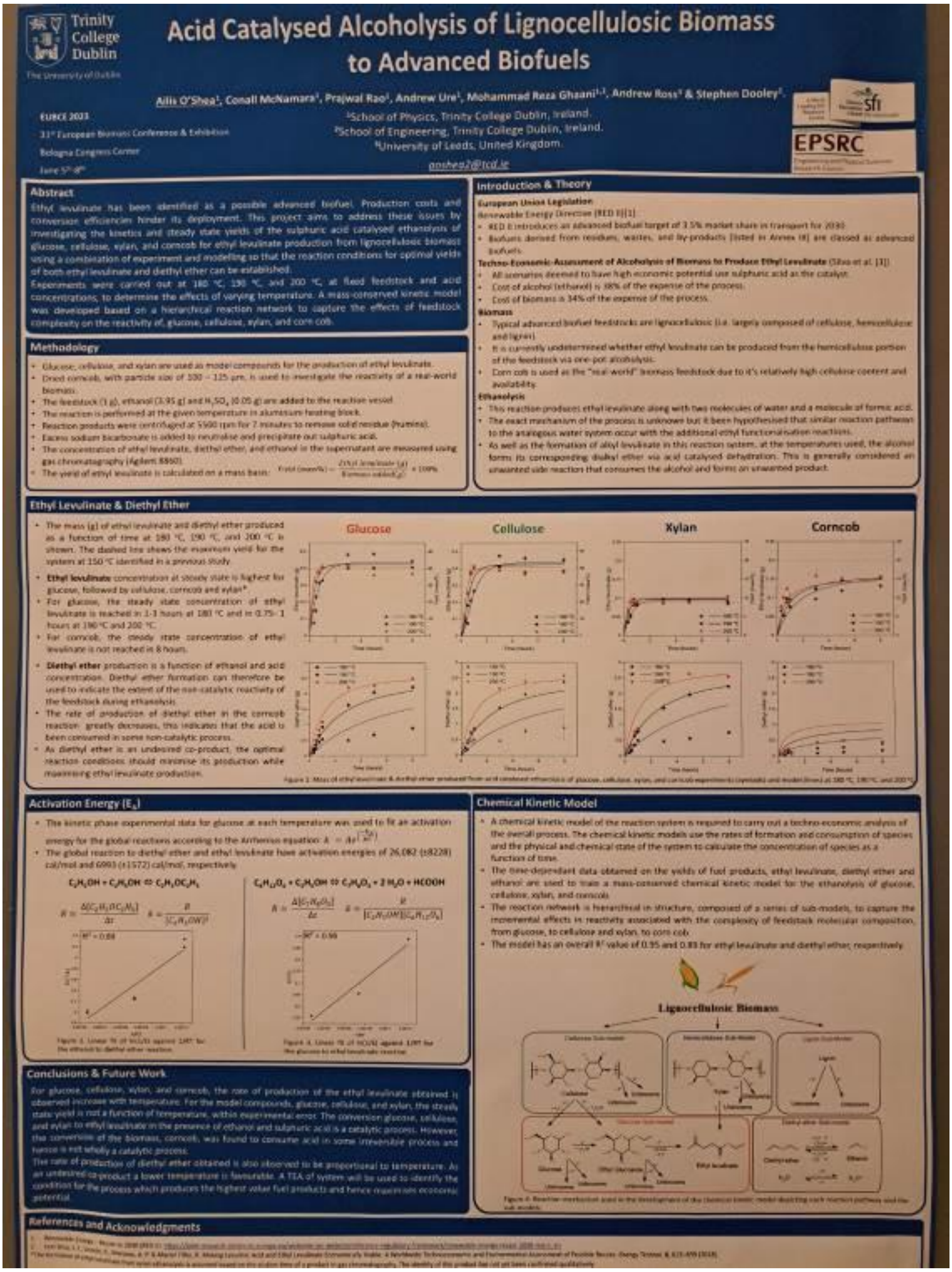
CH_4 yield by anaerobic digestion of fermentation broth from DF (HYD) and untreated control (C).

- Using the fermentation broth as feedstock for anaerobic digestion, the **CH_4** yield increased by **76%** in **HYD** reactors in comparison with **C** reactors (**313** vs. **178** mL CH_4 g^{-1} volatile solids).
- The DF by-products have a higher **biomethanation** potential than **holocellulose**.

Conclusions

- The combination of thermo-alkaline pretreatment and enzymatic hydrolysis permitted to **obtain H_2** from **giant reed biomass**.
- The **CH_4** yield of **fermentation broth** was **76%** higher than untreated giant reed.
- The **adjunctive H_2** production **enhances** the overall energy output from **giant reed biomass**.

13.5AV.2.6 ACID CATALYSED ALCOHOLYSIS OF LIGNOCELLULOSIC BIOMASS TO ADVANCED BIOFUELS.



Acid Catalysed Alcoholysis of Lignocellulosic Biomass to Advanced Biofuels

Ailis O'Shea[1], Conall McNamara[1], Prajwal Rao[1], Andrew Ure[1], Mohammad Reza Ghaani[1,2], Andrew Ross[3] & Stephen Dooley[1].
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EUBCE 2023
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Bologna Congress Center
June 5th-8th

Abstract

Ethyl levulinate has been identified as a possible advanced biofuel. Production costs and conversion efficiencies hinder its deployment. This project aims to address these issues by investigating the kinetics and steady state yields of the sulphuric acid catalysed ethanolysis of glucose, cellulose, xylan, and corncob for ethyl levulinate production from lignocellulosic biomass using a combination of experiment and modelling so that the reaction conditions for optimal yields of both ethyl levulinate and diethyl ether can be established.

Experiments were carried out at 180 °C, 190 °C, and 200 °C, at fixed feedstock and acid concentrations, to determine the effects of varying temperature. A mass-conserved kinetic model was developed based on a hierarchical reaction network to capture the effects of feedstock complexity on the reactivity of, glucose, cellulose, xylan, and corn cob.

Methodology

- Glucose, cellulose, and xylan are used as model compounds for the production of ethyl levulinate.
- Dried corncob, with particle size of 100 – 125 µm, is used to investigate the reactivity of a real-world biomass.
- The feedstock (1 g), ethanol (3.95 g) and H_2SO_4 (0.05 g) are added to the reaction vessel.
- The reaction is performed at the given temperature in aluminium heating block.
- Reaction products were centrifuged at 5500 rpm for 7 minutes to remove solid residue (humins).
- Excess sodium bicarbonate is added to neutralise and precipitate out sulphuric acid.
- The concentration of ethyl levulinate, diethyl ether, and ethanol in the supernatant are measured using gas chromatography (Agilent 8860).
- The yield of ethyl levulinate is calculated on a mass basis: $\text{Yield (mass\%)} = \frac{\text{Ethyl levulinate (g)}}{\text{Biomass added (g)}} \times 100\%$

Introduction & Theory

European Union Legislation

Renewable Energy Directive (RED II)[1]

- RED II introduces an advanced biofuel target of 3.5% market share in transport for 2030.
- Biofuels derived from residues, wastes, and by-products (listed in Annex IX) are classed as advanced biofuels.

Techno-Economic-Assessment of Alcoholysis of Biomass to Produce Ethyl Levulinate (Silva et al. [3])

- All scenarios deemed to have high economic potential use sulphuric acid as the catalyst.
- Cost of alcohol (ethanol) is 38% of the expense of the process.
- Cost of biomass is 34% of the expense of the process.

Biomass

- Typical advanced biofuel feedstocks are lignocellulosic (i.e. largely composed of cellulose, hemicellulose and lignin).
- It is currently undetermined whether ethyl levulinate can be produced from the hemicellulose portion of the feedstock via one-pot alcoholysis.
- Corn cob is used as the "real-world" biomass feedstock due to it's relatively high cellulose content and availability.

Ethanolysis

- This reaction produces ethyl levulinate along with two molecules of water and a molecule of formic acid.
- The exact mechanism of the process is unknown but it been hypothesised that similar reaction pathways to the analogous water system occur with the additional ethyl functionalisation reactions.
- As well as the formation of alkyl levulinate in this reaction system, at the temperatures used, the alcohol forms its corresponding dialkyl ether via acid catalysed dehydration. This is generally considered an unwanted side reaction that consumes the alcohol and forms an unwanted product.

Ethyl Levulinate & Diethyl Ether

- The mass (g) of ethyl levulinate and diethyl ether produced as a function of time at 180 °C, 190 °C, and 200 °C is shown. The dashed line shows the maximum yield for the system at 150 °C identified in a previous study.
- **Ethyl levulinate** concentration at steady state is highest for glucose, followed by cellulose, corncob and xylan*.
- For glucose, the steady state concentration of ethyl levulinate is reached in 1-3 hours at 180 °C and in 0.75-1 hours at 190 °C and 200 °C.
- For corncob, the steady state concentration of ethyl levulinate is not reached in 8 hours.
- **Diethyl ether** production is a function of ethanol and acid concentration. Diethyl ether formation can therefore be used to indicate the extent of the non-catalytic reactivity of the feedstock during ethanolysis.
- The rate of production of diethyl ether in the corncob reaction greatly decreases, this indicates that the acid is been consumed in some non-catalytic process.
- As diethyl ether is an undesired co-product, the optimal reaction conditions should minimise its production while maximising ethyl levulinate production.

Figure 1: Mass of ethyl levulinate & diethyl ether produced from acid catalysed ethanolysis of glucose, cellulose, xylan, and corncob experiments (symbols) and model (lines) at 180 °C, 190 °C, and 200 °C

Activation Energy (E_a)

- The kinetic phase experimental data for glucose at each temperature was used to fit an activation energy for the global reactions according to the Arrhenius equation: $k = Ae^{\left(\frac{-E_a}{RT}\right)}$
- The global reaction to diethyl ether and ethyl levulinate have activation energies of 26,082 (±8228) cal/mol and 6993 (±1572) cal/mol, respectively.

$$C_2H_5OH + C_2H_5OH \Leftrightarrow C_2H_5OC_2H_5$$

$$R = \frac{\Delta[C_2H_5OC_2H_5]}{\Delta t} \quad k = \frac{R}{[C_2H_5OH]^2}$$

Figure 3. Linear fit of ln(k/A) against 1/RT for the ethanol to diethyl ether reaction.

$$C_6H_{12}O_6 + C_2H_5OH \Leftrightarrow C_7H_{12}O_3 + 2\,H_2O + HCOOH$$

$$R = \frac{\Delta[C_7H_{12}O_3]}{\Delta t} \quad k = \frac{R}{[C_2H_5OH][C_6H_{12}O_6]}$$

Figure 4. Linear fit of ln(k/A) against 1/RT for the glucose to ethyl levulinate reaction.

Chemical Kinetic Model

- A chemical kinetic model of the reaction system is required to carry out a techno-economic analysis of the overall process. The chemical kinetic models use the rates of formation and consumption of species and the physical and chemical state of the system to calculate the concentration of species as a function of time.
- The time-dependant data obtained on the yields of fuel products, ethyl levulinate, diethyl ether and ethanol are used to train a mass-conserved chemical kinetic model for the ethanolysis of glucose, cellulose, xylan, and corncob.
- The reaction network is hierarchical in structure, composed of a series of sub-models, to capture the incremental effects in reactivity associated with the complexity of feedstock molecular composition, from glucose, to cellulose and xylan, to corn cob.
- The model has an overall R² value of 0.95 and 0.83 for ethyl levulinate and diethyl ether, respectively.

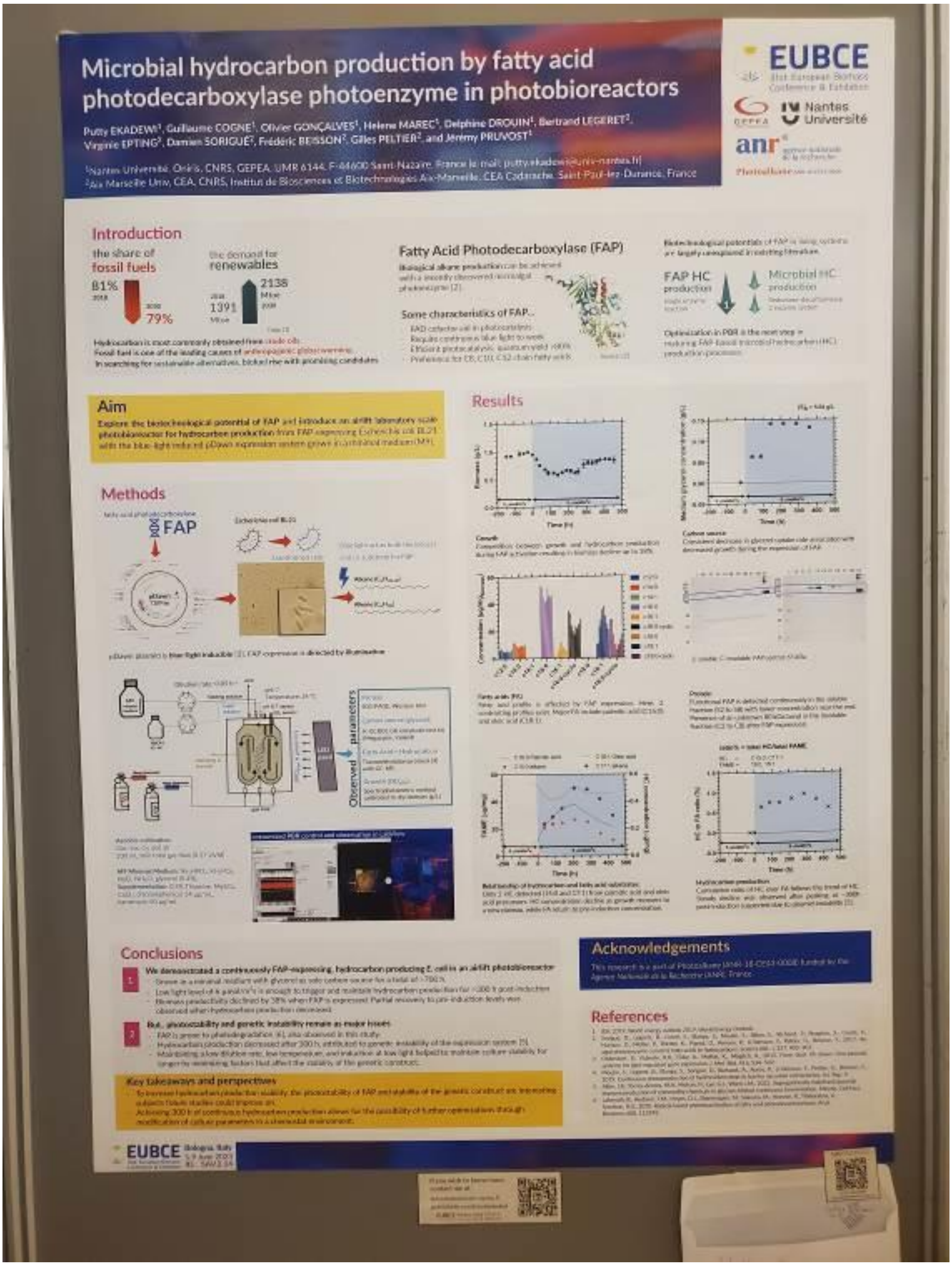
Conclusions & Future Work

For glucose, cellulose, xylan, and corncob, the rate of production of the ethyl levulinate obtained is observed increase with temperature. For the model compounds, glucose, cellulose, and xylan, the steady state yield is not a function of temperature, within experimental error. The conversion glucose, cellulose, and xylan to ethyl levulinate in the presence of ethanol and sulphuric acid is a catalytic process. However, the conversion of the biomass, corncob, was found to consume acid in some irreversible process and hence is not wholly a catalytic process.

The rate of production of diethyl ether obtained is also observed to be proportional to temperature. As an undesired co-product a lower temperature is favourable. A TEA of system will be used to identify the condition for the process which produces the highest value fuel products and hence maximises economic potential.

References and Acknowledgments

14.5AV.2.14 MICROBIAL HYDROCARBON PRODUCTION BY FATTY ACID PHOTODECARBOXYLASE PHOTOENZYME IN PHOTOBIOREACTORS.



Microbial hydrocarbon production by fatty acid photodecarboxylase photoenzyme in photobioreactors

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anr

Introduction

the share of fossil fuels

81%

79%

the demand for renewables

1391

2138

Fatty Acid Photodecarboxylase (FAP)

Some characteristics of FAP...

FAP HC production

Microbial HC production

Aim

Methods

FAP

Results

Conclusions

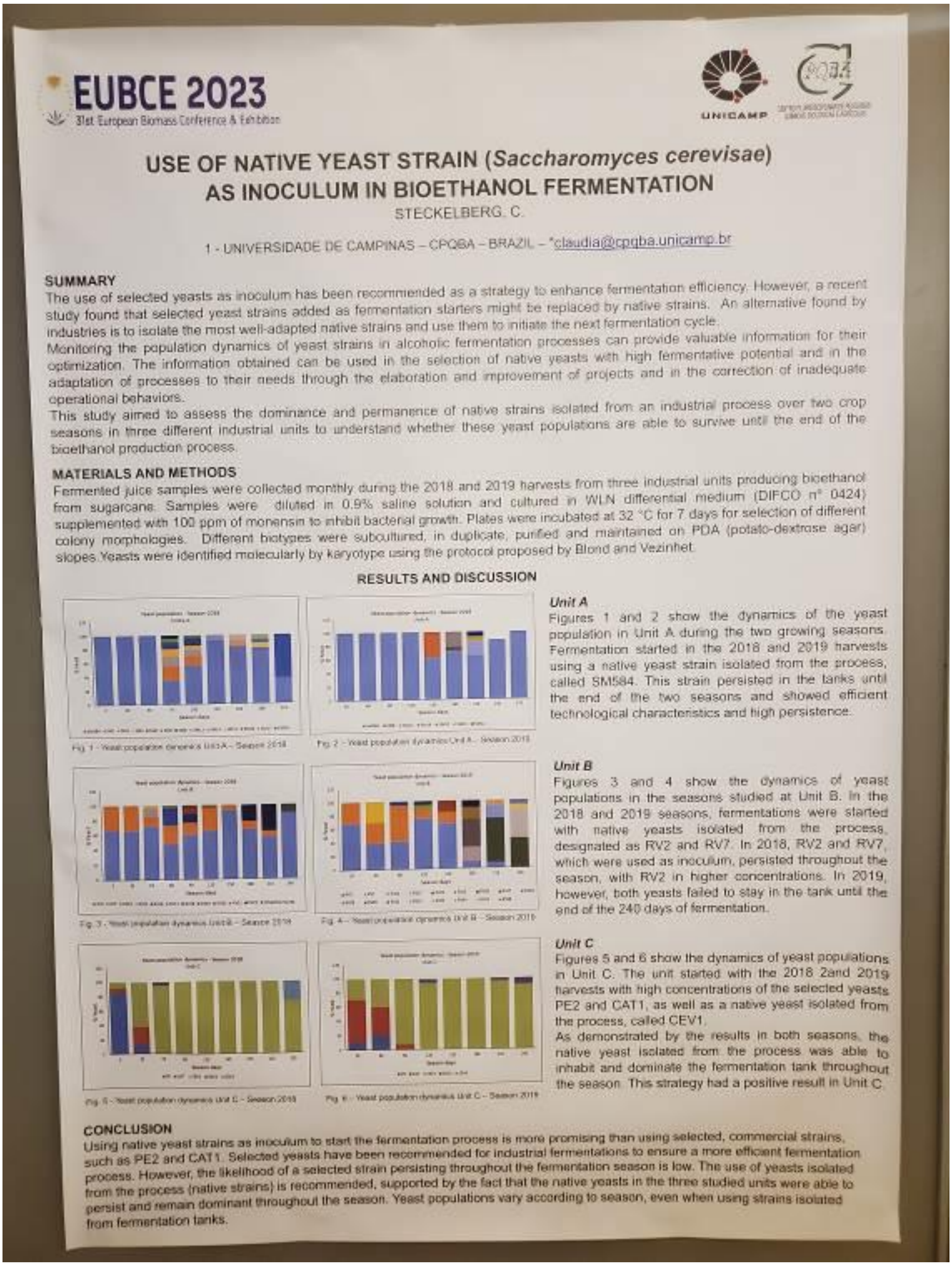
Key takeaways and perspectives

Acknowledgements

References

EUBCE Bologna, Italy

15.5AV.2.17 USE OF NATIVE YEAST STRAIN (SACCHAROMYCES CEREVISAE) AS INOCULUM IN BIOETHANOL FERMENTATION.



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UNICAMP

USE OF NATIVE YEAST STRAIN (*Saccharomyces cerevisae*) AS INOCULUM IN BIOETHANOL FERMENTATION

STECKELBERG, C.

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SUMMARY

The use of selected yeasts as inoculum has been recommended as a strategy to enhance fermentation efficiency. However, a recent study found that selected yeast strains added as fermentation starters might be replaced by native strains. An alternative found by industries is to isolate the most well-adapted native strains and use them to initiate the next fermentation cycle.
Monitoring the population dynamics of yeast strains in alcoholic fermentation processes can provide valuable information for their optimization. The information obtained can be used in the selection of native yeasts with high fermentative potential and in the adaptation of processes to their needs through the elaboration and improvement of projects and in the correction of inadequate operational behaviors.
This study aimed to assess the dominance and permanence of native strains isolated from an industrial process over two crop seasons in three different industrial units to understand whether these yeast populations are able to survive until the end of the bioethanol production process.

MATERIALS AND METHODS

Fermented juice samples were collected monthly during the 2018 and 2019 harvests from three industrial units producing bioethanol from sugarcane. Samples were diluted in 0.9% saline solution and cultured in WLN differential medium (DIFCO n° 0424) supplemented with 100 ppm of monensin to inhibit bacterial growth. Plates were incubated at 32 °C for 7 days for selection of different colony morphologies. Different biotypes were subcultured, in duplicate, purified and maintained on PDA (potato-dextrose agar) slopes. Yeasts were identified molecularly by karyotype using the protocol proposed by Blond and Vezinhet.

RESULTS AND DISCUSSION

Fig. 1 - Yeast population dynamics Unit A – Season 2018

Fig. 2 - Yeast population dynamics Unit A – Season 2019

Unit A

Figures 1 and 2 show the dynamics of the yeast population in Unit A during the two growing seasons. Fermentation started in the 2018 and 2019 harvests using a native yeast strain isolated from the process, called SM584. This strain persisted in the tanks until the end of the two seasons and showed efficient technological characteristics and high persistence.

Fig. 3 - Yeast population dynamics Unit B – Season 2018

Fig. 4 – Yeast population dynamics Unit B – Season 2019

Unit B

Figures 3 and 4 show the dynamics of yeast populations in the seasons studied at Unit B. In the 2018 and 2019 seasons, fermentations were started with native yeasts isolated from the process, designated as RV2 and RV7. In 2018, RV2 and RV7, which were used as inoculum, persisted throughout the season, with RV2 in higher concentrations. In 2019, however, both yeasts failed to stay in the tank until the end of the 240 days of fermentation.

Fig. 5 - Yeast population dynamics Unit C – Season 2018

Fig. 6 - Yeast population dynamics Unit C – Season 2019

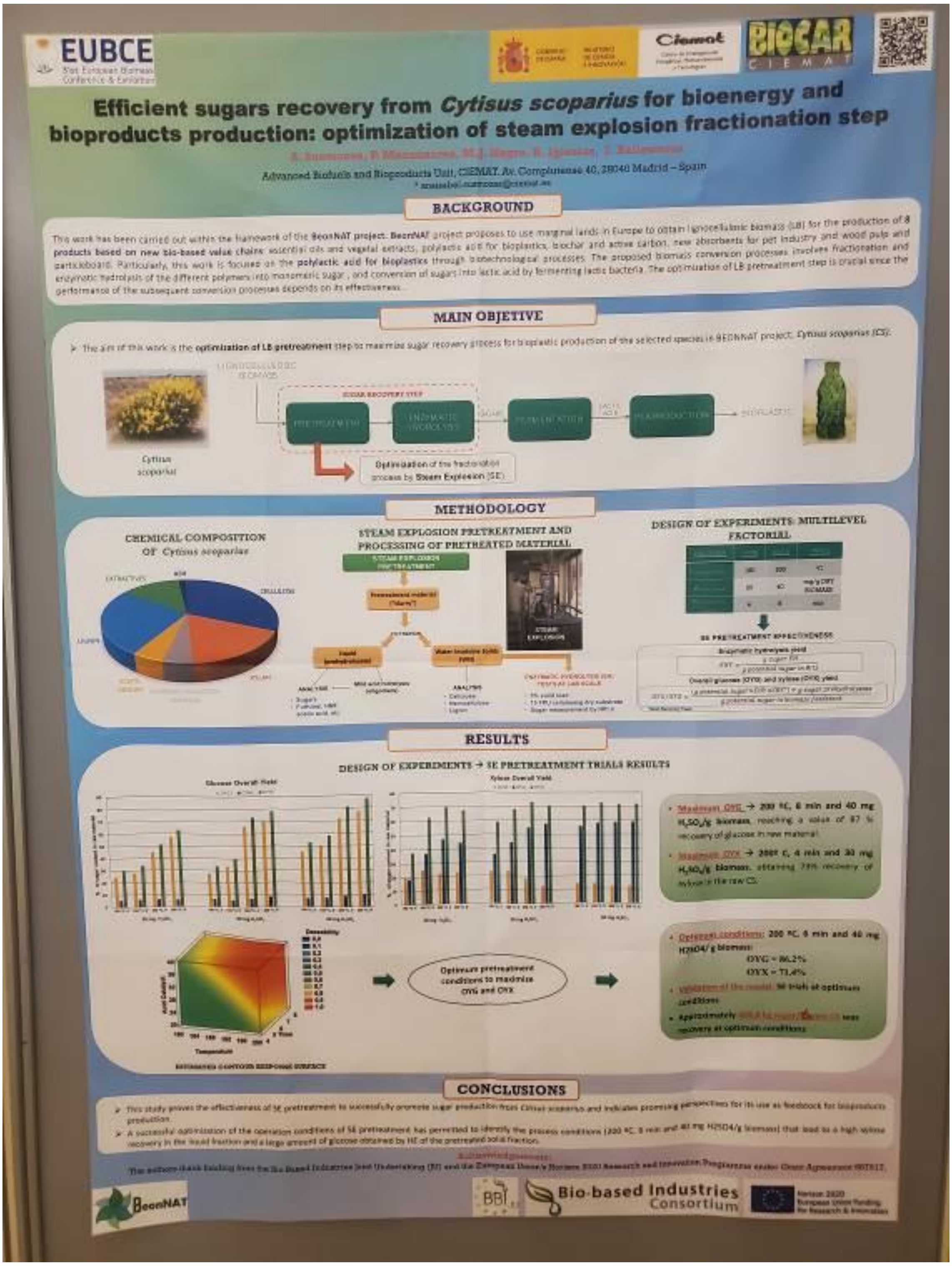
Unit C

Figures 5 and 6 show the dynamics of yeast populations in Unit C. The unit started with the 2018 2and 2019 harvests with high concentrations of the selected yeasts PE2 and CAT1, as well as a native yeast isolated from the process, called CEV1.
As demonstrated by the results in both seasons, the native yeast isolated from the process was able to inhabit and dominate the fermentation tank throughout the season. This strategy had a positive result in Unit C.

CONCLUSION

Using native yeast strains as inoculum to start the fermentation process is more promising than using selected, commercial strains, such as PE2 and CAT1. Selected yeasts have been recommended for industrial fermentations to ensure a more efficient fermentation process. However, the likelihood of a selected strain persisting throughout the fermentation season is low. The use of yeasts isolated from the process (native strains) is recommended, supported by the fact that the native yeasts in the three studied units were able to persist and remain dominant throughout the season. Yeast populations vary according to season, even when using strains isolated from fermentation tanks.

16.5AV.2.18 EFFICIENT SUGARS RECOVERY FROM CYTISUS SCOPARIUS FOR BIOENERGY AND BIOPRODUCTS PRODUCTION: OPTIMIZATION OF STEAM EXPLOSION FRACTIONATION STEP.



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Efficient sugars recovery from *Cytisus scoparius* for bioenergy and bioproducts production: optimization of steam explosion fractionation step

Advanced Biofuels and Bioproducts Unit, CIEMAT. Av. Complutense 40, 28040 Madrid – Spain

BACKGROUND

This work has been carried out within the framework of the **BeonNAT project**. **BeonNAT** project proposes to use marginal lands in Europe to obtain lignocellulosic biomass (LB) for the production of 8 **products based on new bio-based value chains**: essential oils and vegetal extracts, polylactic acid for bioplastics, biochar and active carbon, new absorbents for pet industry and wood pulp and particleboard. Particularly, this work is focused on the **polylactic acid for bioplastics** through biotechnological processes. The proposed biomass conversion processes involves fractionation and enzymatic hydrolysis of the different polymers into monomeric sugar, and conversion of sugars into lactic acid by fermenting lactic bacteria. The optimization of LB pretreatment step is crucial since the performance of the subsequent conversion processes depends on its effectiveness.

MAIN OBJETIVE

- The aim of this work is the **optimization of LB pretreatment** step to maximize sugar recovery process for bioplastic production of the selected species in BEONNAT project: *Cytisus scoparius* (CS).

Cytisus scoparius

Optimization of the fractionation process by **Steam Explosion** (SE)

METHODOLOGY

CHEMICAL COMPOSITION OF *Cytisus scoparius*

STEAM EXPLOSION PRETREATMENT AND PROCESSING OF PRETREATED MATERIAL

DESIGN OF EXPERIMENTS: MULTILEVEL FACTORIAL

RESULTS

DESIGN OF EXPERIMENTS → SE PRETREATMENT TRIALS RESULTS

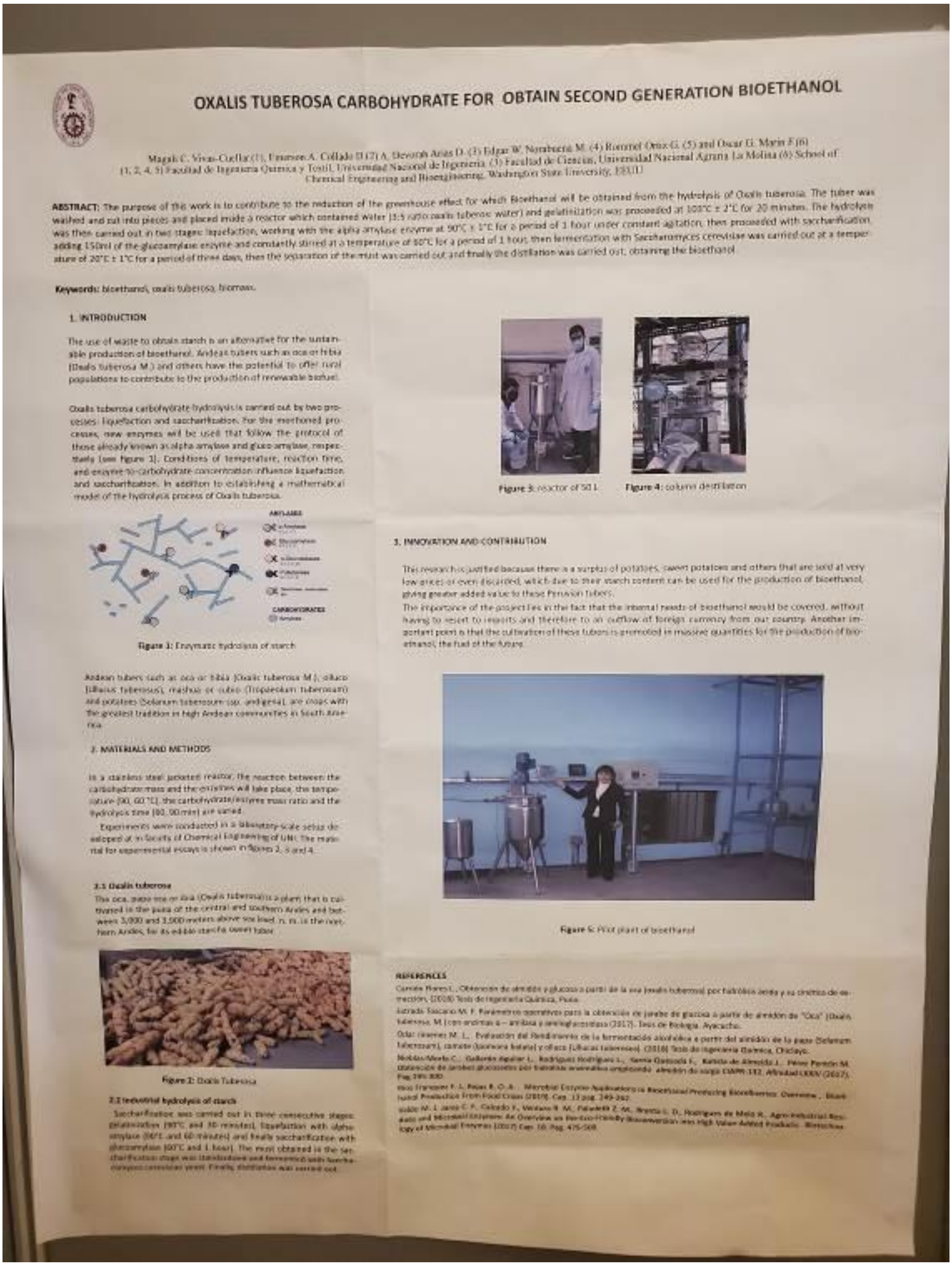
Optimum pretreatment conditions to maximize OYG and OYX

OYG = 86.2%

OYX = 71.4%

CONCLUSIONS

17.5AV.2.19 OXALIS TUBEROSA CARBOHYDRATE FOR OBTAIN SECOND GENERATION BIOETHANOL.



OXALIS TUBEROSA CARBOHYDRATE FOR OBTAIN SECOND GENERATION BIOETHANOL

Magali C. Vivas-Cuellar (1), Emerson A. Collado D. (2) A. Devorah Arias D. (3) Edgar W. Norabuena M. (4) Rommel Ortiz G. (5) and Oscar G. Marin F.(6)
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ABSTRACT: The purpose of this work is to contribute to the reduction of the greenhouse effect for which Bioethanol will be obtained from the hydrolysis of Oxalis tuberosa. The tuber was washed and cut into pieces and placed inside a reactor which contained water (1:5 ratio oxalis tuberosa: water) and gelatinization was proceeded at 100°C ± 2°C for 20 minutes. The hydrolysis was then carried out in two stages: liquefaction, working with the alpha amylase enzyme at 90°C ± 1°C for a period of 1 hour under constant agitation, then proceeded with saccharification adding 150ml of the glucoamylase enzyme and constantly stirred at a temperature of 60°C for a period of 1 hour, then fermentation with Saccharomyces cerevisiae was carried out at a temperature of 20°C ± 1°C for a period of three days, then the separation of the must was carried out and finally the distillation was carried out, obtaining the bioethanol.

Keywords: bioethanol, oxalis tuberosa, biomass.

1. INTRODUCTION

The use of waste to obtain starch is an alternative for the sustainable production of bioethanol. Andean tubers such as oca or hibia (Oxalis tuberosa M.) and others have the potential to offer rural populations to contribute to the production of renewable biofuel.

Oxalis tuberosa carbohydrate hydrolysis is carried out by two processes: liquefaction and saccharification. For the mentioned processes, new enzymes will be used that follow the protocol of those already known as alpha amylase and gluco-amylase, respectively (see figure 1). Conditions of temperature, reaction time, and enzyme-to-carbohydrate concentration influence liquefaction and saccharification. In addition to establishing a mathematical model of the hydrolysis process of Oxalis tuberosa.

Figure 1: Enzymatic hydrolysis of starch

Andean tubers such as oca or hibia (Oxalis tuberosa M.), olluco (Ullucus tuberosus), mashua or isaño (Tropaeolum tuberosum) and potatoes (Solanum tuberosum ssp. andigena), are crops with the greatest tradition in high Andean communities in South America.

2. MATERIALS AND METHODS

In a stainless steel jacketed reactor, the reaction between the carbohydrate mass and the enzymes will take place, the temperature (90, 60 °C), the carbohydrate/enzyme mass ratio and the hydrolysis time (60, 90 min) are varied.

Experiments were conducted in a laboratory-scale setup developed at in faculty of Chemical Engineering of UNI. The material for experimental essays is shown in figures 2, 3 and 4.

2.1 Oxalis tuberosa

The oca, papa oca or ibia (Oxalis tuberosa) is a plant that is cultivated in the puna of the central and southern Andes and between 3,000 and 3,900 meters above sea level. n. m. in the northern Andes, for its edible starchy sweet tuber.

Figure 2: Oxalis Tuberosa

2.2 Industrial hydrolysis of starch

Saccharification was carried out in three consecutive stages: gelatinization (90°C and 30 minutes), liquefaction with alpha-amylase (90°C and 60 minutes) and finally saccharification with glucoamylase (60°C and 1 hour). The must obtained in the saccharification stage was [illegible] and fermented with Saccharomyces cerevisiae yeast. Finally, distillation was carried out.

Figure 3: reactor of 50 L **Figure 4:** column destillation

3. INNOVATION AND CONTRIBUTION

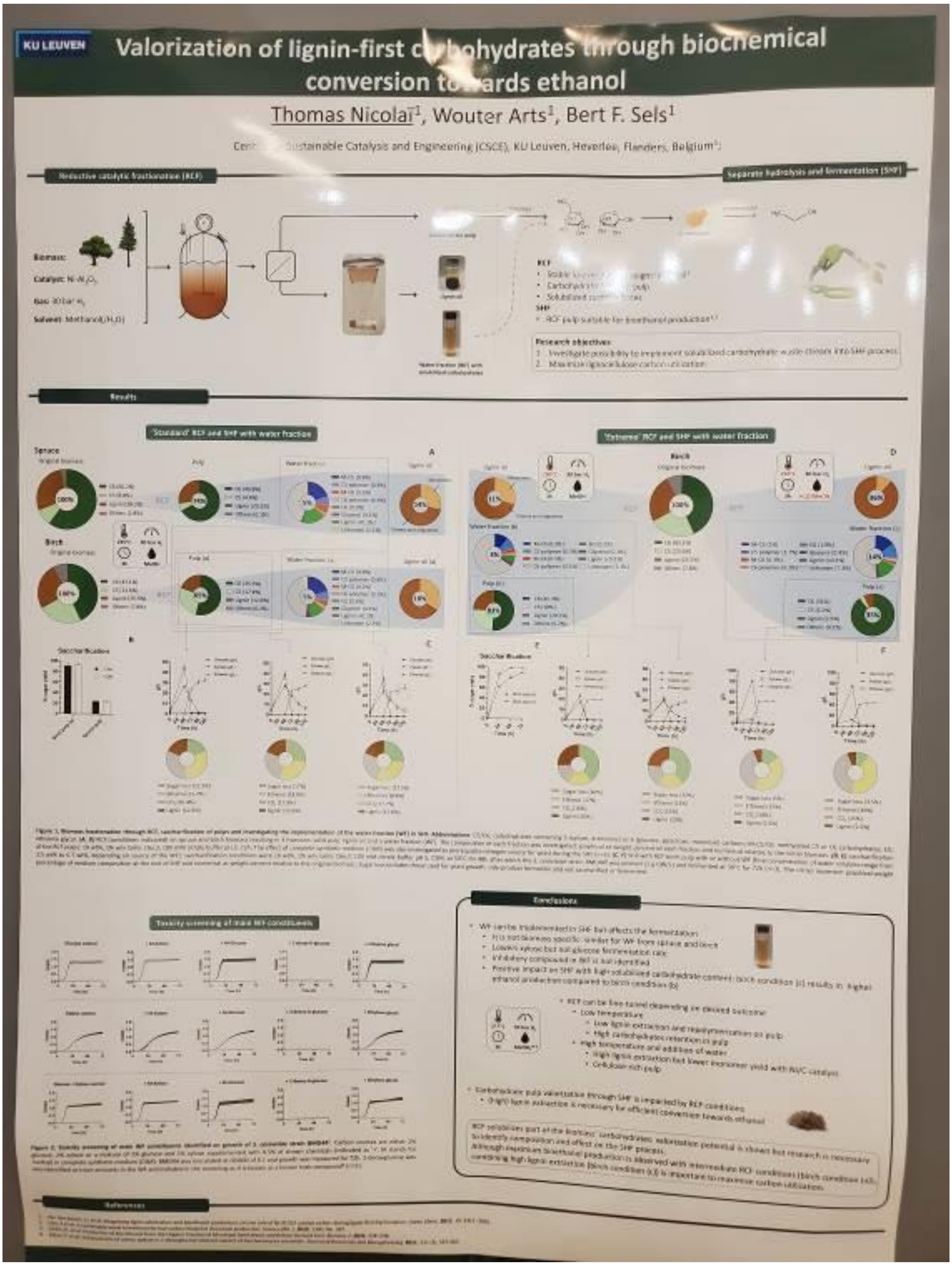
This research is justified because there is a surplus of potatoes, sweet potatoes and others that are sold at very low prices or even discarded, which due to their starch content can be used for the production of bioethanol, giving greater added value to these Peruvian tubers.

The importance of the project lies in the fact that the internal needs of bioethanol would be covered, without having to resort to imports and therefore to an outflow of foreign currency from our country. Another important point is that the cultivation of these tubers is promoted in massive quantities for the production of bioethanol, the fuel of the future.

Figure 5: Pilot plant of bioethanol

REFERENCES

18.5AV.2.23 VALORIZATION OF LIGNIN-FIRST CARBOHYDRATES THROUGH BIOCHEMICAL CONVERSION TOWARDS ETHANOL.



KU LEUVEN

Valorization of lignin-first carbohydrates through biochemical conversion towards ethanol

Thomas Nicolaï[1], Wouter Arts[1], Bert F. Sels[1]

Cent[illegible] Sustainable Catalysis and Engineering (CSCE), KU Leuven, Heverlee, Flanders, Belgium[1]

Reductive catalytic fractionation (RCF)

Separate hydrolysis and fermentation (SHF)

Research objectives

1. Investigate possibility to implement solubilized carbohydrate waste stream into SHF process
2. Maximize lignocellulose carbon utilization

Results

'Standard' RCF and SHF with water fraction

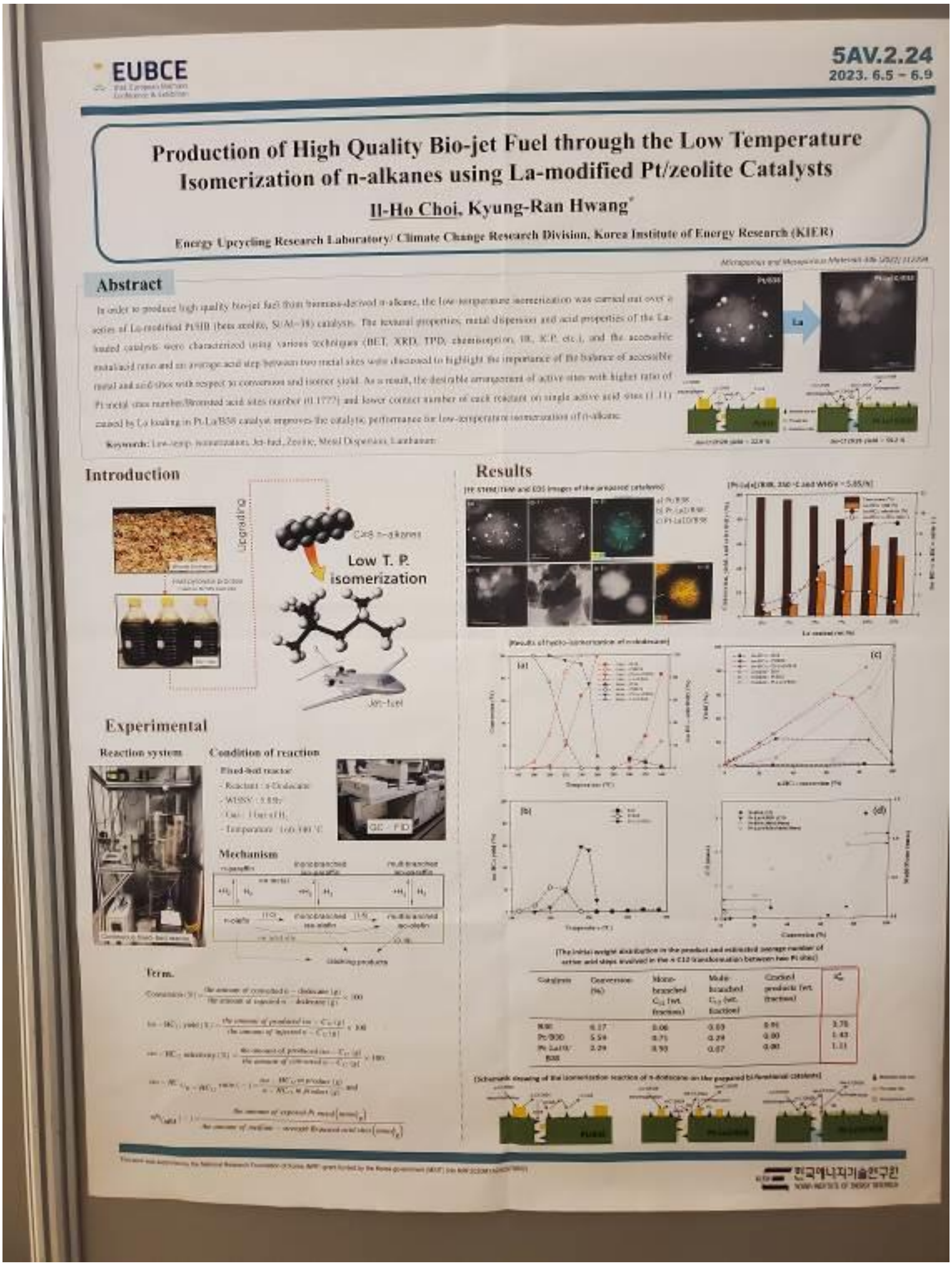
'Extreme' RCF and SHF with water fraction

Conclusions

Toxicity screening of main WF constituents

References

19.5DV.2.16 A MULTI-PARAMETRIC STUDY ON HYDROTHERMAL CARBONISATION OF MIXED AGRI-FOOD WASTE FOR THE PRODUCTION OF HIGH-QUALITY SOLID BIOFUEL.



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2023. 6.5 – 6.9

Production of High Quality Bio-jet Fuel through the Low Temperature Isomerization of n-alkanes using La-modified Pt/zeolite Catalysts

Il-Ho Choi, Kyung-Ran Hwang*

Energy Upcycling Research Laboratory/ Climate Change Research Division, Korea Institute of Energy Research (KIER)

Abstract

Introduction

Results

Experimental

Reaction system

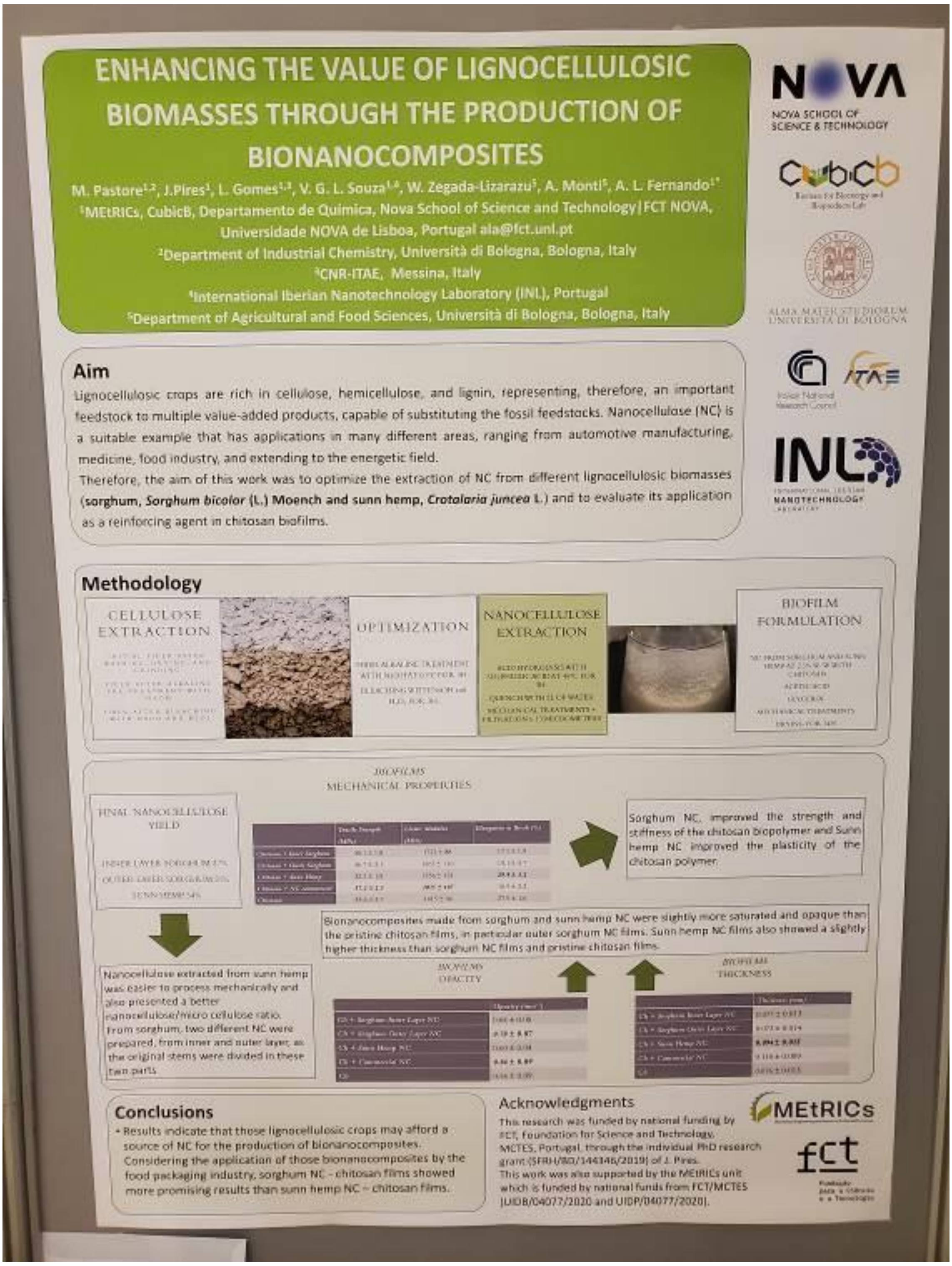
Condition of reaction

Fixed-bed reactor

Mechanism

Term.

20.6BV.2.14 ENHANCING THE VALUE OF LIGNOCELLULOSIC BIOMASSES THROUGH THE PRODUCTION OF BIONANOCOMPOSITES.



ENHANCING THE VALUE OF LIGNOCELLULOSIC BIOMASSES THROUGH THE PRODUCTION OF BIONANOCOMPOSITES

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Aim

Lignocellulosic crops are rich in cellulose, hemicellulose, and lignin, representing, therefore, an important feedstock to multiple value-added products, capable of substituting the fossil feedstocks. Nanocellulose (NC) is a suitable example that has applications in many different areas, ranging from automotive manufacturing, medicine, food industry, and extending to the energetic field.

Therefore, the aim of this work was to optimize the extraction of NC from different lignocellulosic biomasses (**sorghum, *Sorghum bicolor* (L.) Moench and sunn hemp, *Crotalaria juncea* L.**) and to evaluate its application as a reinforcing agent in chitosan biofilms.

Methodology

CELLULOSE EXTRACTION

OPTIMIZATION

NANOCELLULOSE EXTRACTION

BIOFILM FORMULATION

BIOFILMS MECHANICAL PROPERTIES

FINAL NANOCELLULOSE YIELD

Sorghum NC improved the strength and stiffness of the chitosan biopolymer and Sunn hemp NC improved the plasticity of the chitosan polymer.

Bionanocomposites made from sorghum and sunn hemp NC were slightly more saturated and opaque than the pristine chitosan films, in particular outer sorghum NC films. Sunn hemp NC films also showed a slightly higher thickness than sorghum NC films and pristine chitosan films.

Nanocellulose extracted from sunn hemp was easier to process mechanically and also presented a better nanocellulose/micro cellulose ratio. From sorghum, two different NC were prepared, from inner and outer layer, as the original stems were divided in these two parts

BIOFILMS OPACITY

BIOFILMS THICKNESS

Conclusions

- Results indicate that those lignocellulosic crops may afford a source of NC for the production of bionanocomposites. Considering the application of those bionanocomposites by the food packaging industry, sorghum NC - chitosan films showed more promising results than sunn hemp NC – chitosan films.

Acknowledgments

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21.6BV.2.32 SYNTHESIS AND CHARACTERIZATION OF BIO-POLYOLS SYNTHESIZED FROM VARIOUS TREATED DEPOLYMERIZED SUBERIN FOR RIGID POLYURETHANE FOAMS.

LATVIAN STATE INSTITUTE OF WOOD CHEMISTRY

POLYLABS

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SYNTHESIS AND CHARACTERIZATION OF BIO-POLYOLS SYNTHESIZED FROM VARIOUS TREATED DEPOLYMERIZED SUBERIN FOR RIGID POLYURETHANE FOAMS

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Introduction

Effective usage of waste products is critical to promote a circular bio-economy. Despite the possibility of producing valuable products from birch bark (e.g. betulin, lupeol, suberinic acids), many businesses, burn a significant amount of leftover birch bark for energy.
Suberin is a lipophilic complex polyester biopolymer, composed of long-chain fatty acids and glycerol.

Climate changes
High Energy prices
Risk of supply shortages

Circular bio-economy

Effective usage of waste products

Outer birch bark

Objective

The aim of this work was to synthesize and characterize polyols from various fractions of suberinic acids (SA).

Experimental design

Outer birch bark

Suberin 53.6%

Extractives (betulin) 30.0%

Lignin-carbohydrate complex 16.4%

Untreated SA SAF-1

Purified SA SAF-2

SA salts SAF-3

Polyols

?

Rigid PU foams

Materials and methods

Suberinic acids fractions

SA fraction	Acid value, mg KOH/g	Hydroxyl value, mg KOH/g	Saponification value, mg KOH/g	Apparent viscosity, mPa·s
SAF-1	37	318	139	$6.1 \cdot 10^6$
SAF-2	112	267	10	$5.0 \cdot 10^5$
SAF-3	53	205	18	NA

Polyol synthesis

SAF-1 + alcohol, molar ratios 1:1, saponification value to alcohol

SAF-2 + alcohol, molar ratios 1:1, acid value to alcohol
SAF-3 + alcohol, molar ratios 1:1, acid value to alcohol

Multifunctional alcohols:
Diethylene glycol (DEG)
Diethanolamine (DEOA)
Triethanolamine (TEOA)
Trimethylpropane (TMP)

195 °C
145 °C
175 °C
205 °C

6 h

Zink acetate 1% of SAF

Results

Polyol characterization

SAF-1	DEG	TMP	DEOA	TEOA
Acid value, mg KOH/g	[illegible]	21±4	[illegible]	22±4
Hydroxyl value, mg KOH/g	520±8	385±10	397±10	486±10
Viscosity, mPa·s	[illegible]	[illegible]	[illegible]	[illegible]

SAF-2	DEG	TMP	DEOA	TEOA
Acid value, mg KOH/g	6±2	18±3	NA	9±3
Hydroxyl value, mg KOH/g	443±15	570±12	NA	585±20
Viscosity, mPa·s	[illegible]	[illegible]	Too high	[illegible]

Better reaction progress than SAF-1

SAF-3	DEG	TMP	DEOA	TEOA
Acid value, mg KOH/g	7±2	NA	NA	9±3
Hydroxyl value, mg KOH/g	507±10	NA	NA	620±20
Viscosity, mPa·s	Too high to detect			

Conclusions

Acknowledgements

NATIONAL DEVELOPMENT PLAN 2020

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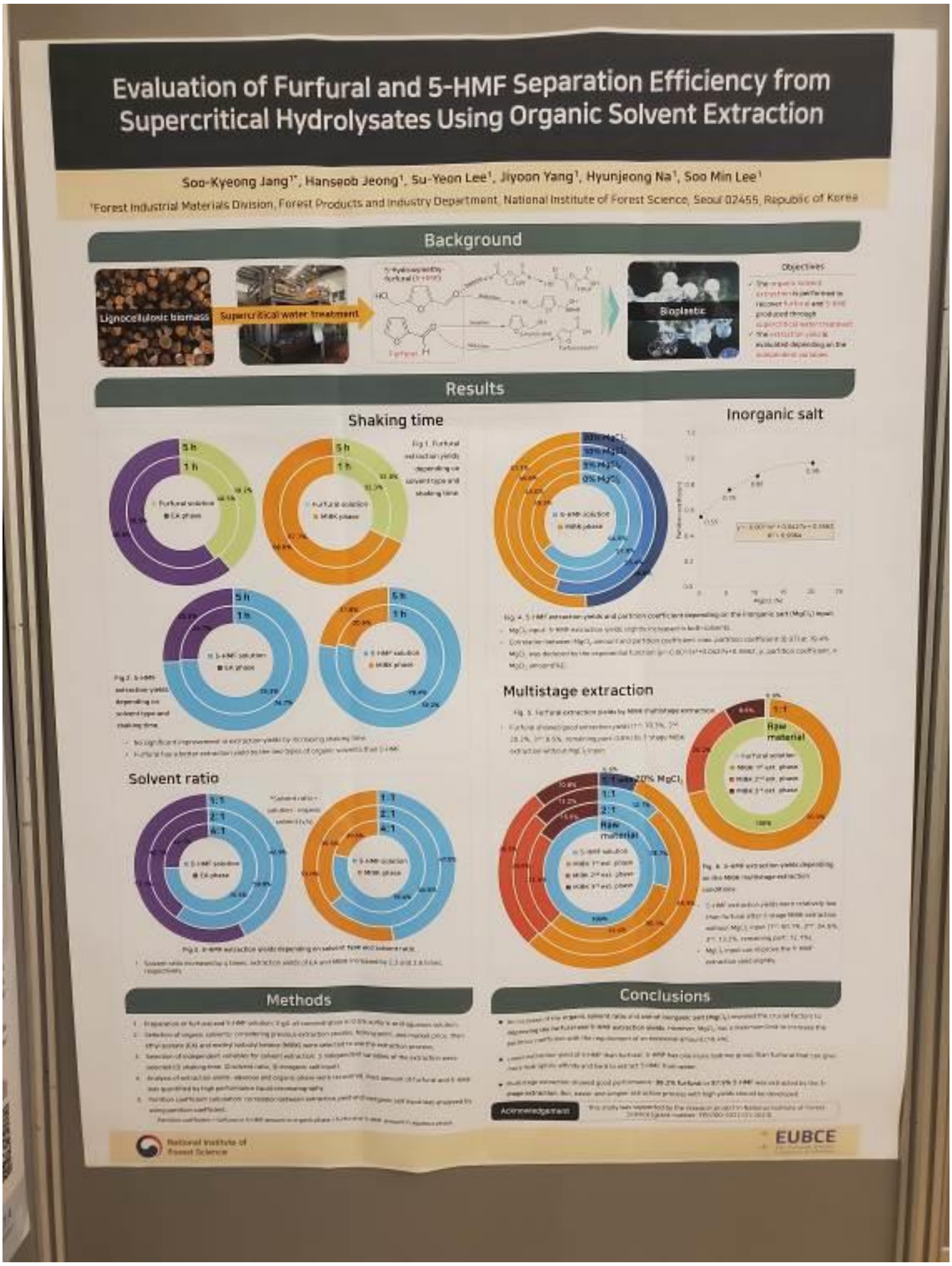
22.6CV.7.5 EVALUATION OF FURFURAL AND 5-HMF SEPARATION EFFICIENCY FROM SUPERCRITICAL HYDROLYSATES USING ORGANIC SOLVENT EXTRACTION.



Evaluation of Furfural and 5-HMF Separation Efficiency from Supercritical Hydrolysates Using Organic Solvent Extraction

Soo-Kyeong Jang[1*], Hanseob Jeong[1], Su-Yeon Lee[1], Jiyoon Yang[1], Hyunjeong Na[1], Soo Min Lee[1]

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Background

Results

Shaking time

Inorganic salt

Solvent ratio

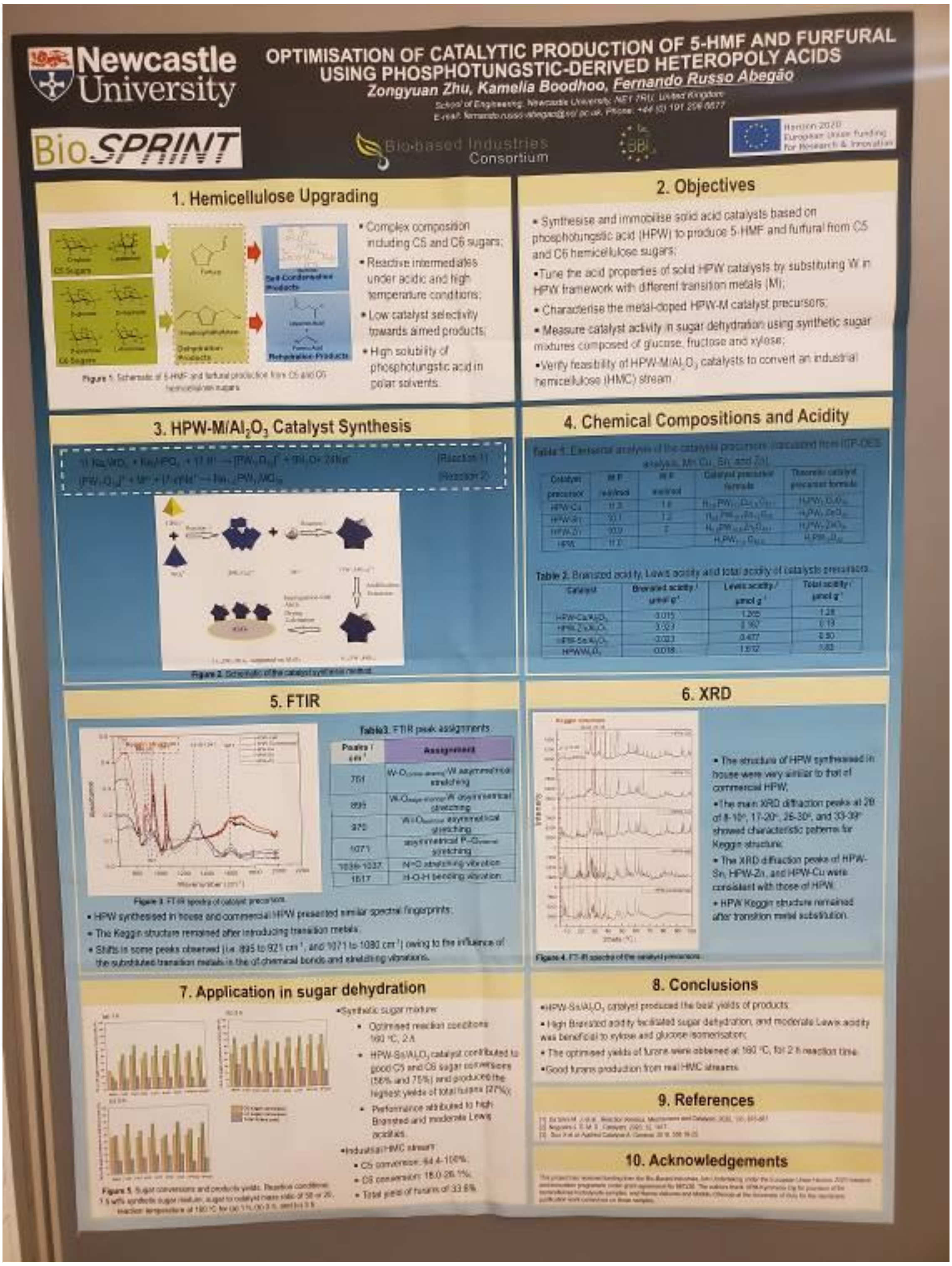
Multistage extraction

Methods

Conclusions

Acknowledgement

23.6CV.7.9 OPTIMISATION OF CATALYTIC PRODUCTION OF 5-HMF AND FURFURAL USING PHOSPHOTUNGSTIC-DERIVED HETEROPOLY ACIDS.



Newcastle University

OPTIMISATION OF CATALYTIC PRODUCTION OF 5-HMF AND FURFURAL USING PHOSPHOTUNGSTIC-DERIVED HETEROPOLY ACIDS

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Bio-based Industries Consortium

BBI

Horizon 2020 European Union funding for Research & Innovation

1. Hemicellulose Upgrading

Figure 1. Schematic of 5-HMF and furfural production from C5 and C6 hemicellulose sugars

- Complex composition including C5 and C6 sugars;
- Reactive intermediates under acidic and high temperature conditions;
- Low catalyst selectivity towards aimed products;
- High solubility of phosphotungstic acid in polar solvents.

2. Objectives

- Synthesise and immobilise solid acid catalysts based on phosphotungstic acid (HPW) to produce 5-HMF and furfural from C5 and C6 hemicellulose sugars;
- Tune the acid properties of solid HPW catalysts by substituting W in HPW framework with different transition metals (M);
- Characterise the metal-doped HPW-M catalyst precursors;
- Measure catalyst activity in sugar dehydration using synthetic sugar mixtures composed of glucose, fructose and xylose;
- Verify feasibility of HPW-M/Al_2O_3 catalysts to convert an industrial hemicellulose (HMC) stream.

3. HPW-M/Al_2O_3 Catalyst Synthesis

(Reaction 1)

(Reaction 2)

Figure 2. Schematic of the catalyst synthesis method

4. Chemical Compositions and Acidity

Table 1. Elemental analysis of the catalysts precursors calculated from ICP-OES analysis, M= Cu, Sn, and Zn).

Table 2. Brønsted acidity, Lewis acidity and total acidity of catalysts precursors

5. FTIR

Table3. FTIR peak assignments

Peaks / cm^{-1}	Assignment
751	W-$O_{corner-sharing}$-W asymmetrical stretching
895	W-$O_{edge-sharing}$-W asymmetrical stretching
975	W=$O_{terminal}$ asymmetrical stretching
1071	asymmetrical P-$O_{internal}$ stretching
1036-1037	N=O stretching vibration
1617	H-O-H bending vibration

Figure 3. FT-IR spectra of catalyst precursors

- HPW synthesised in house and commercial HPW presented similar spectral fingerprints;
- The Keggin structure remained after introducing transition metals;
- Shifts in some peaks observed (i.e. 895 to 921 cm^{-1}, and 1071 to 1080 cm^{-1}) owing to the influence of the substituted transition metals in the of chemical bonds and stretching vibrations.

6. XRD

- The structure of HPW synthesised in house were very similar to that of commercial HPW;
- The main XRD diffraction peaks at 2θ of 8-10°, 17-20°, 26-30°, and 33-39° showed characteristic patterns for Keggin structure;
- The XRD diffraction peaks of HPW-Sn, HPW-Zn, and HPW-Cu were consistent with those of HPW.
- HPW Keggin structure remained after transition metal substitution.

Figure 4. FT-IR spectra of the catalyst precursors

7. Application in sugar dehydration

- Synthetic sugar mixture:
  - Optimised reaction conditions 160 °C, 2 h
  - HPW-Sn/Al_2O_3 catalyst contributed to good C5 and C6 sugar conversions (56% and 75%) and produced the highest yields of total furans (27%);
  - Performance attributed to high Brønsted and moderate Lewis acidities.
- Industrial HMC stream:
  - C5 conversion: 64.4-100%
  - C6 conversion: 18.0-26.1%
  - Total yield of furans of 33.6%

Figure 5. Sugar conversions and products yields. Reaction conditions: 1.5 wt% synthetic sugar mixture, sugar to catalyst mass ratio of 50 or 20, reaction temperature of 160 °C for (a) 1 h, (b) 2 h, and (c) 3 h.

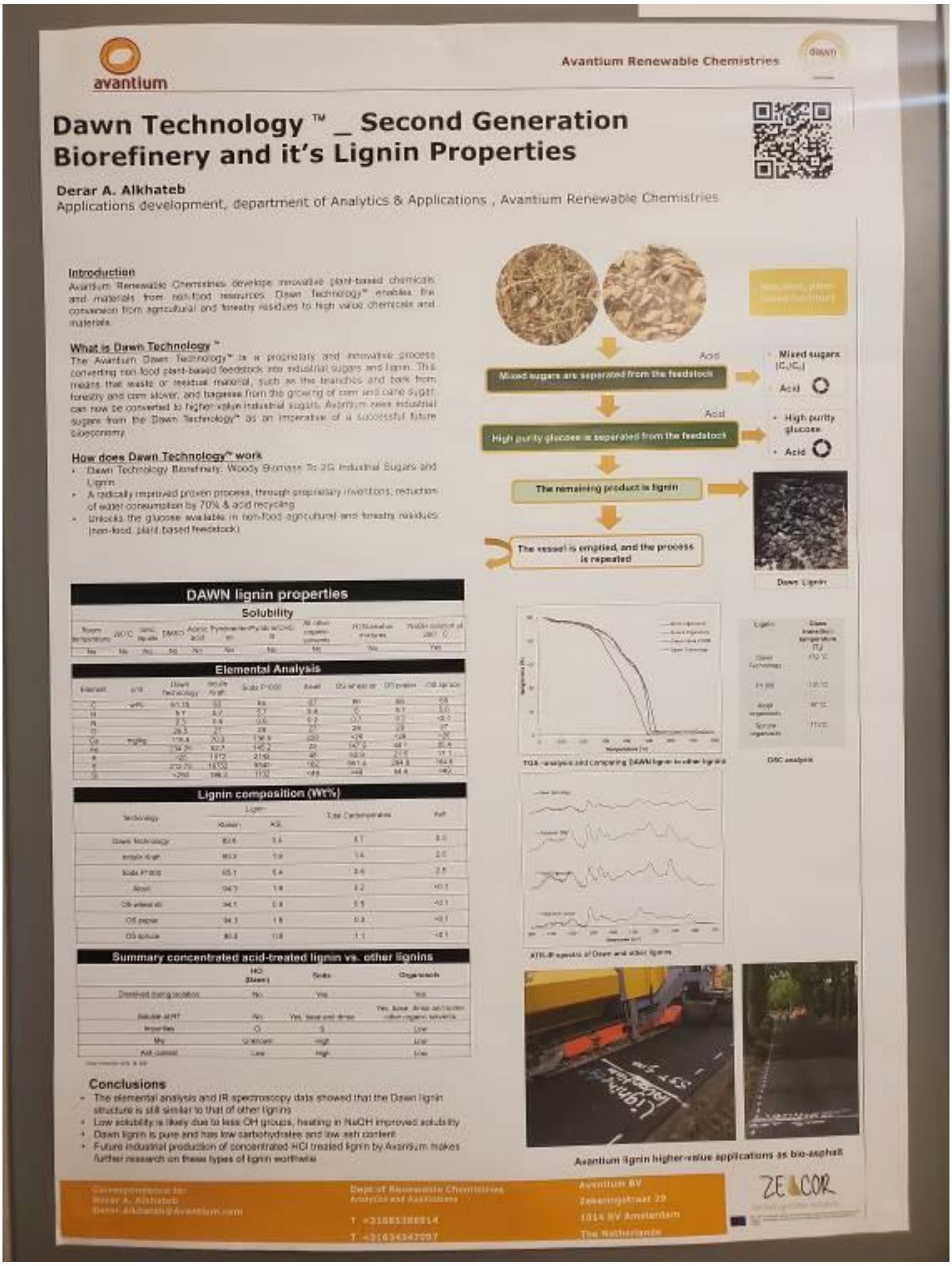
8. Conclusions

- HPW-Sn/Al_2O_3 catalyst produced the best yields of products;
- High Brønsted acidity facilitated sugar dehydration, and moderate Lewis acidity was beneficial to xylose and glucose isomerisation;
- The optimised yields of furans were obtained at 160 °C, for 2 h reaction time.
- Good furans production from real HMC streams.

9. References

10. Acknowledgements

24.6CV.7.13 DAWN TECHNOLOGY TM - SECOND GENERATION BIOREFINERY AND ITS LIGNIN PROPERTIES.



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Avantium Renewable Chemistries

Dawn Technology ™ _ Second Generation Biorefinery and it's Lignin Properties

Derar A. Alkhateb
Applications development, department of Analytics & Applications , Avantium Renewable Chemistries

Introduction

Avantium Renewable Chemistries develops innovative plant-based chemicals and materials from non-food resources. Dawn Technology™ enables the conversion from agricultural and forestry residues to high value chemicals and materials.

What is Dawn Technology ™

The Avantium Dawn Technology™ is a proprietary and innovative process converting non-food plant-based feedstock into industrial sugars and lignin. This means that waste or residual material, such as the branches and bark from forestry and corn stover, and bagasse from the growing of corn and cane sugar, can now be converted to higher-value industrial sugars. Avantium sees industrial sugars from the Dawn Technology™ as an imperative of a successful future bioeconomy.

How does Dawn Technology™ work

- Dawn Technology Biorefinery: Woody Biomass To 2G Industrial Sugars and Lignin
- A radically improved proven process, through proprietary inventions; reduction of water consumption by 70% & acid recycling
- Unlocks the glucose available in non-food agricultural and forestry residues (non-food, plant based feedstock)

Acid

Mixed sugars are seperated from the feedstock

- Mixed sugars
- Acid

Acid

High purity glucose is seperated from the feedstock

- High purity glucose
- Acid

The remaining product is lignin

The vessel is emptied, and the process is repeated

Dawn Lignin

DAWN lignin properties

Solubility

Elemental Analysis

Lignin composition (Wt%)

Summary concentrated acid-treated lignin vs. other lignins

	HCl (Dawn)	Soda	Organosolv
Dissolved during isolation	No	Yes	Yes
Soluble at RT	No	Yes, base and dmso	[illegible]
Impurities	[illegible]	S	Low
Mw	Unknown	High	Low
Ash content	Low	High	Low

TGA-analysis and comparing DAWN lignin to other lignins

DSC analysis

ATR-IR spectra of Dawn and other lignins

Conclusions

- The elemental analysis and IR spectroscopy data showed that the Dawn lignin structure is still similar to that of other lignins
- Low solubility is likely due to less OH groups, heating in NaOH improved solubility
- Dawn lignin is pure and has low carbohydrates and low ash content
- Future industrial production of concentrated HCl treated lignin by Avantium makes further research on these types of lignin worthwile

Avantium lignin higher-value applications as bio-asphalt

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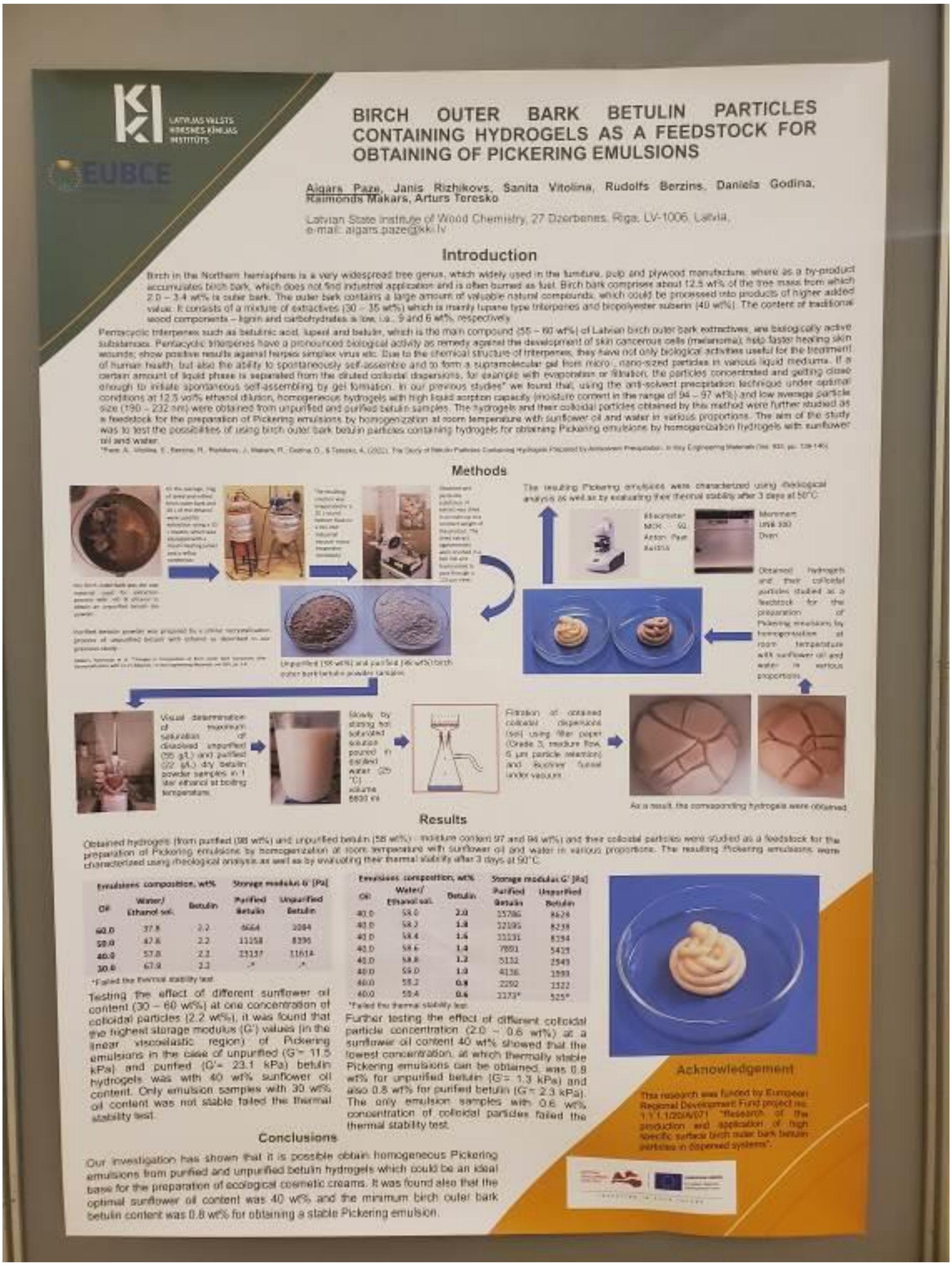
ZEACOR

25.6CV.7.14 BIRCH OUTER BARK CHARACTERISATION AFTER EXTRACTION AND ITS POTENTIAL FOR OBTAINING SUBERIN FATTY ACIDS.



BIRCH OUTER BARK BETULIN PARTICLES CONTAINING HYDROGELS AS A FEEDSTOCK FOR OBTAINING OF PICKERING EMULSIONS

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Introduction

Birch in the Northern hemisphere is a very widespread tree genus, which widely used in the furniture, pulp and plywood manufacture, where as a by-product accumulates birch bark, which does not find industrial application and is often burned as fuel. Birch bark comprises about 12.5 wt% of the tree mass from which 2.0 – 3.4 wt% is outer bark. The outer bark contains a large amount of valuable natural compounds, which could be processed into products of higher added value. It consists of a mixture of extractives (30 – 35 wt%) which is mainly lupane type triterpenes and biopolyester suberin (40 wt%). The content of traditional wood components – lignin and carbohydrates is low, i.e., 9 and 6 wt%, respectively.

Pentacyclic triterpenes such as betulinic acid, lupeol and betulin, which is the main compound (55 – 60 wt%) of Latvian birch outer bark extractives, are biologically active substances. Pentacyclic triterpenes have a pronounced biological activity as remedy against the development of skin cancerous cells (melanoma), help faster healing skin wounds; show positive results against herpes simplex virus etc. Due to the chemical structure of triterpenes, they have not only biological activities useful for the treatment of human health, but also the ability to spontaneously self-assemble and to form a supramolecular gel from micro-, nano-sized particles in various liquid mediums. If a certain amount of liquid phase is separated from the diluted colloidal dispersions, for example with evaporation or filtration, the particles concentrated and getting close enough to initiate spontaneous self-assembling by gel formation. In our previous studies* we found that, using the anti-solvent precipitation technique under optimal conditions at 12.5 vol% ethanol dilution, homogeneous hydrogels with high liquid sorption capacity (moisture content in the range of 94 – 97 wt%) and low average particle size (190 – 232 nm) were obtained from unpurified and purified betulin samples. The hydrogels and their colloidal particles obtained by this method were further studied as a feedstock for the preparation of Pickering emulsions by homogenization at room temperature with sunflower oil and water in various proportions. The aim of the study was to test the possibilities of using birch outer bark betulin particles containing hydrogels for obtaining Pickering emulsions by homogenization hydrogels with sunflower oil and water.

Methods

The resulting Pickering emulsions were characterized using rheological analysis as well as by evaluating their thermal stability after 3 days at 50°C.

Rheometer MCR 92 Anton Paar

Memmert UN 300 Oven

Unpurified (58 wt%) and purified (98 wt%) birch outer bark betulin powder samples

Obtained hydrogels and their colloidal particles studied as a feedstock for the preparation of Pickering emulsions by homogenization at room temperature with sunflower oil and water in various proportions.

Visual determination of maximum saturation of dissolved unpurified (55 g/L) and purified (22 g/L) dry betulin powder samples in 1 liter ethanol at boiling temperature.

Slowly by stirring hot saturated solution poured in distilled water (25 °C) volume 5800 ml

Filtration of obtained colloidal dispersions (sol) using filter paper (Grade 3, medium flow, 5 µm particle retention) and Buchner funnel under vacuum.

As a result, the corresponding hydrogels were obtained.

Results

Obtained hydrogels (from purified (98 wt%) and unpurified betulin (58 wt%) - moisture content 97 and 94 wt%) and their colloidal particles were studied as a feedstock for the preparation of Pickering emulsions by homogenization at room temperature with sunflower oil and water in various proportions. The resulting Pickering emulsions were characterized using rheological analysis as well as by evaluating their thermal stability after 3 days at 50°C.

Emulsions composition, wt%			Storage modulus G' [Pa]	
Oil	Water/ Ethanol sol.	Betulin	Purified Betulin	Unpurified Betulin
60.0	37.8	2.2	6664	3084
50.0	47.8	2.2	11258	8396
40.0	57.8	2.2	23137	11614
30.0	67.8	2.2	-*	-*

*Failed the thermal stability test

Testing the effect of different sunflower oil content (30 – 60 wt%) at one concentration of colloidal particles (2.2 wt%), it was found that the highest storage modulus (G') values (in the linear viscoelastic region) of Pickering emulsions in the case of unpurified (G'= 11.5 kPa) and purified (G'= 23.1 kPa) betulin hydrogels was with 40 wt% sunflower oil content. Only emulsion samples with 30 wt% oil content was not stable failed the thermal stability test.

Emulsions composition, wt%			Storage modulus G' [Pa]	
Oil	Water/ Ethanol sol.	Betulin	Purified Betulin	Unpurified Betulin
40.0	58.0	2.0	15786	8628
40.0	58.2	1.8	12195	8238
40.0	58.4	1.6	11131	8194
40.0	58.6	1.4	7891	5415
40.0	58.8	1.2	5132	2549
40.0	59.0	1.0	4136	1999
40.0	59.2	0.8	2292	1322
40.0	59.4	0.6	1173*	525*

*Failed the thermal stability test

Further testing the effect of different colloidal particle concentration (2.0 – 0.6 wt%) at a sunflower oil content 40 wt% showed that the lowest concentration, at which thermally stable Pickering emulsions can be obtained, was 0.8 wt% for unpurified betulin (G'= 1.3 kPa) and also 0.8 wt% for purified betulin (G'= 2.3 kPa). The only emulsion samples with 0.6 wt% concentration of colloidal particles failed the thermal stability test.

Conclusions

Our investigation has shown that it is possible obtain homogeneous Pickering emulsions from purified and unpurified betulin hydrogels which could be an ideal base for the preparation of ecological cosmetic creams. It was found also that the optimal sunflower oil content was 40 wt% and the minimum birch outer bark betulin content was 0.8 wt% for obtaining a stable Pickering emulsion.

Acknowledgement

This research was funded by European Regional Development Fund project no. 1.1.1.1/20/A/071 "Research of the production and application of high specific surface birch outer bark betulin particles in dispersed systems".