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**Key results KIT-IPT cooperation and green H2**

**Vittor Rodrigues Santos Alves**

*Lecture apresentado no: Workshop  
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slides.*

A série “Comunicação Técnica” compreende trabalhos elaborados por técnicos do IPT, apresentados em eventos, publicados em revistas especializadas ou quando seu conteúdo apresentar relevância pública.

**PROIBIDO REPRODUÇÃO**



Karlsruher Institut für Technologie



INSTITUTO DE  
PESQUISAS  
TECNOLÓGICAS

# KEY RESULTS KIT-IPT COOPERATION AND GREEN H2

Energy Business Unit

Bioenergy and Energy Efficiency Laboratory

28.10.2024

Vittor Rodrigues Santos Alves

**I WORKSHOP KIT-UFPR**  
OCTOBER 28-29, 2024

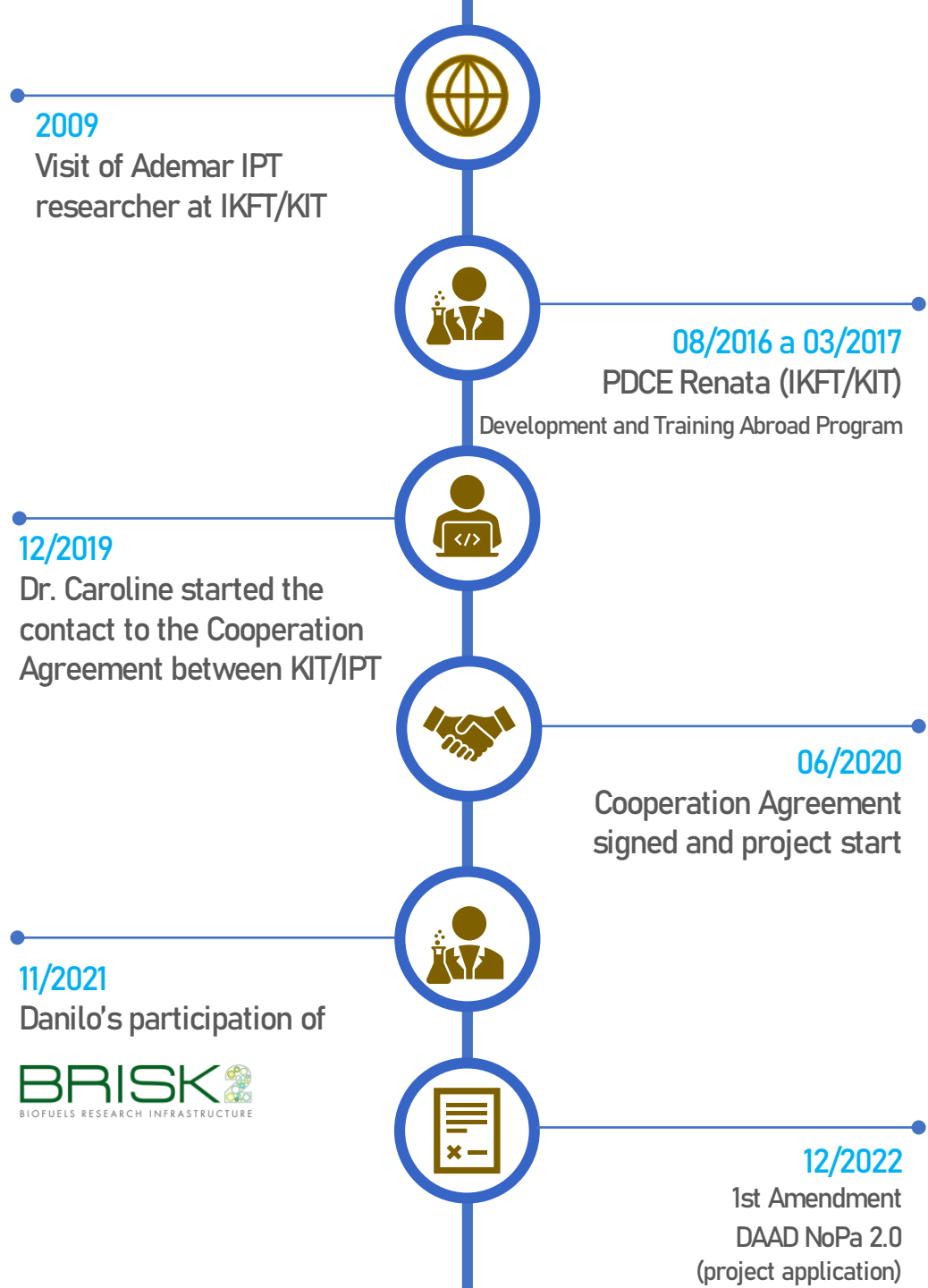


# OUTLINES

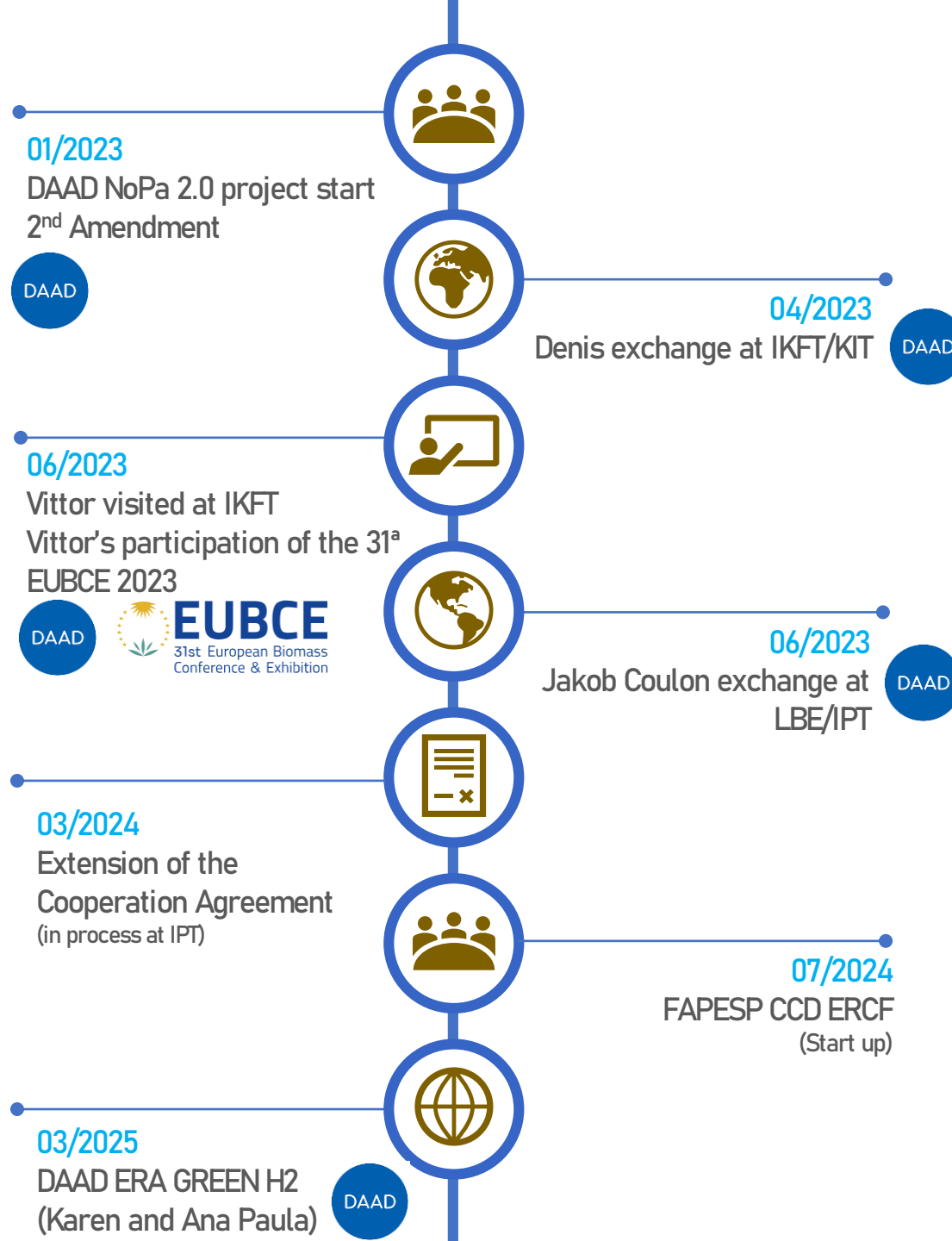
- **Timeline of the Cooperation IPT and KIT**
- **Cooperation agreement projects**
  - Valorization of sugarcane bagasse and straw by thermochemical conversion for energy integration into sugarcane refineries
  - DAAD NoPa 2.0
    - Master project – Sugarcane bagasse syngas reforming
    - Professional experience – Syngas reforming as precursor for chemicals
- **Scientific production**
- **DAAD ERA Green H2**
  - Master project – Sugarcane bagasse and straw syngas reforming
  - Postdoc project – Syngas reforming as precursor for chemicals
- **CCD ERCF**



# IPT AND KIT TIMELINE



# IPT AND KIT TIMELINE



# COOPERATION AGREEMENT PROJECTS

## ■ Cooperation Agreement between IPT and KIT

- 29/06/2020 to 29/06/2024
- Original project: *Valorization of sugarcane bagasse and straw by thermochemical conversion for energy integration into sugarcane refineries*

Green H<sub>2</sub> projects

- **1<sup>st</sup> and 2<sup>nd</sup> Amendment of the Cooperation Agreement**
  - **DAAD NoPa 2.0 program** (January/2023 to January/2024)
  - Project: *Hydrogen generation from sugarcane bagasse by dry syngas reforming and downstream storage in fuel precursors*
    - Responsible coordinator: Dr. Klaus Raffelt
    - Master thesis: *Biogenic synthesis gas for the hydrogenation of pyrolysis oil*
    - Professional exchange: *Catalytic hydrotreatment of fast pyrolysis bio-oil using syngas reforming from sugarcane bagasse gasification composition*



# VALORIZATION OF SUGARCANE BAGASSE AND STRAW BY THERMOCHEMICAL CONVERSION FOR ENERGY INTEGRATION INTO SUGARCANE REFINERIES

## ■ **Technical-scientific goals:**

- Acid pretreatment assessment for a mixture of sugarcane bagasse and straw (SCB/S-Mix) for the fast pyrolysis.
- Evaluate the organic composition of the fast pyrolysis organic rich condensate (ORC) when the **use of ethanol as a quenching medium** in the bypass of the Process Development Unit (PDU) from IKFT/KIT.
  - The **improvement** of fast pyrolysis bio-oil (FPBO) obtained from the fast pyrolysis of SCB and SCB/S-Mix from hydrodeoxygenation (**HDO**) using different catalyst compositions, including **Nb<sub>2</sub>O<sub>5</sub> catalysts**, which are attractive due to their high solid acidity, greater resistance to water and adjustable morphology → **Mariana's PhD thesis (results under publication)**
- **Technical-economic assessment** of SCB and SCS pyrolysis in the industrial context of sugarcane biorefineries → **Bachelor Thesis of Marcel Marín Janssen (IPP/KIT)**
  - Henri Steinweg (IKFT)
  - Dr. Axel Funke
  - Dr. Nicolaus Dahmen (IKFT)
  - Prof. Dr. Frank Schultmann (IIP)
  - Dr. Andreas Rudi (IIP)





# KEY RESULTS

Project: Valorization of sugarcane bagasse and straw by thermochemical conversion for energy integration into sugarcane refineries

## ■ Pretreatment of SCB/S-Mix



Figure 1. Sugarcane bagasse (SCB)

Figure 2. Sugarcane straw (SCS)

**54,7 %wt. ash content**  
 High content of major elements  
 $Si > Fe > Ca > K$

**70% SCB and 30% SCS**



(a) IKFT reactor under stirring.

(b) Collection of the mixture after washing steps in the reactor.

(c) SCB/S-Mix-PT

Figure 3. Steps of the SCB/S-Mix pretreatment process

Fast pyrolysis aqueous condensate as acid leaching

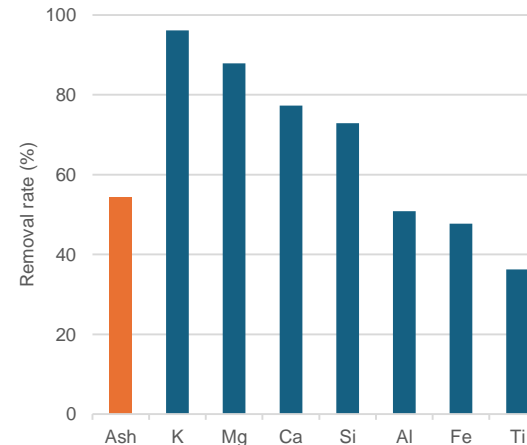


Figure 4. Removed ash and major inorganic elements fraction in the pretreated

Table 1. Physico chemical characterization of SCB/S-Mix before and after the pretreatment

	SCB/S-Mix	SCB/S Mix-PT
<b>Proximate analysis (wt.%)</b>		
Ash	14,5 ± 2,3	7,8 ± 2,7
Volatile matter	69,1 ± 0,9	77,0 ± 0,5
Fixed Carbon	16,4 ± 0,7	15,2 ± 2,8
<b>Elemental analysis (wt.%)</b>		
C	41,2 ± 0,5	47,5 ± 0,6
H	5,1 ± 0,1	5,4 ± 0,1
N	0,4	0,5 ± 0,1
O	38,8 ± 0,9	38,8 ± 3,0
S	n/a	n/a
Cl	n/a	n/a
<b>Major elements (g kg<sup>-1</sup>)</b>		
Al	6,4	3,7
Ca	1,5	0,4
Fe	7,8	4,8
K	2,2	0,1
Mg	0,7	0,1
Si	96,4	30,7
Ti	0,8	0,6





# KEY RESULTS

Project: Valorization of sugarcane bagasse and straw by thermochemical conversion for energy integration into sugarcane refineries

## Fast pyrolysis of sugarcane biomass

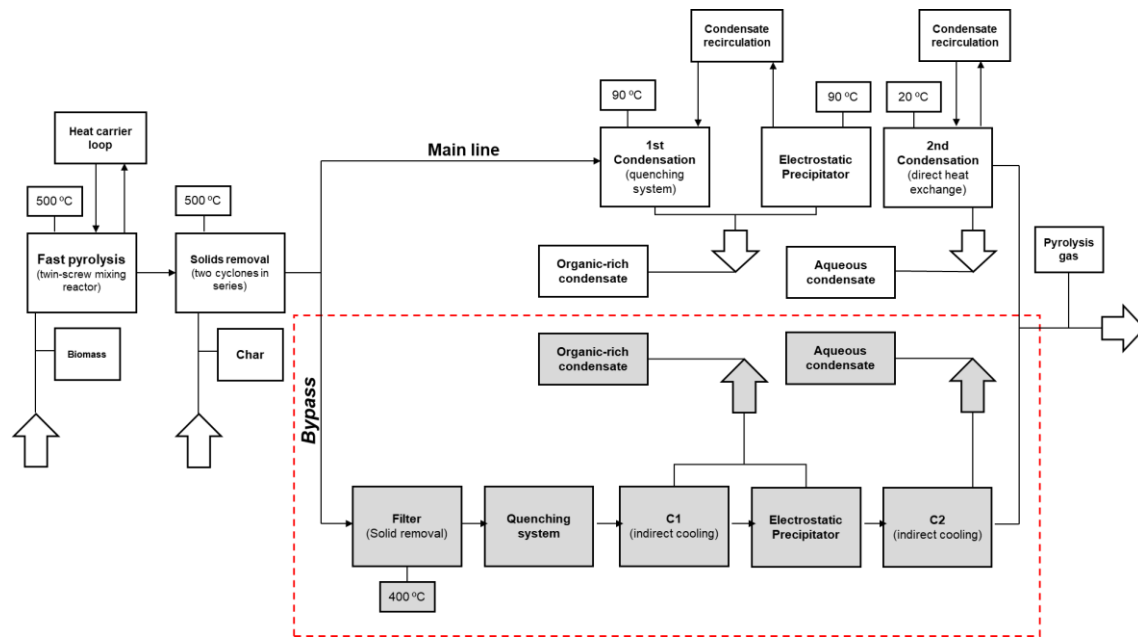


Figure 5 - Block flowchart of each step of the fast pyrolysis process at Process Development Unit (PDU/IKFT). Source: Adapted from Schmitt C. *et al.* (2020).

First scenario → Influence of pretreatment on SCB/S-Mix in terms of yield of products obtained from the PDU/IKFT main line

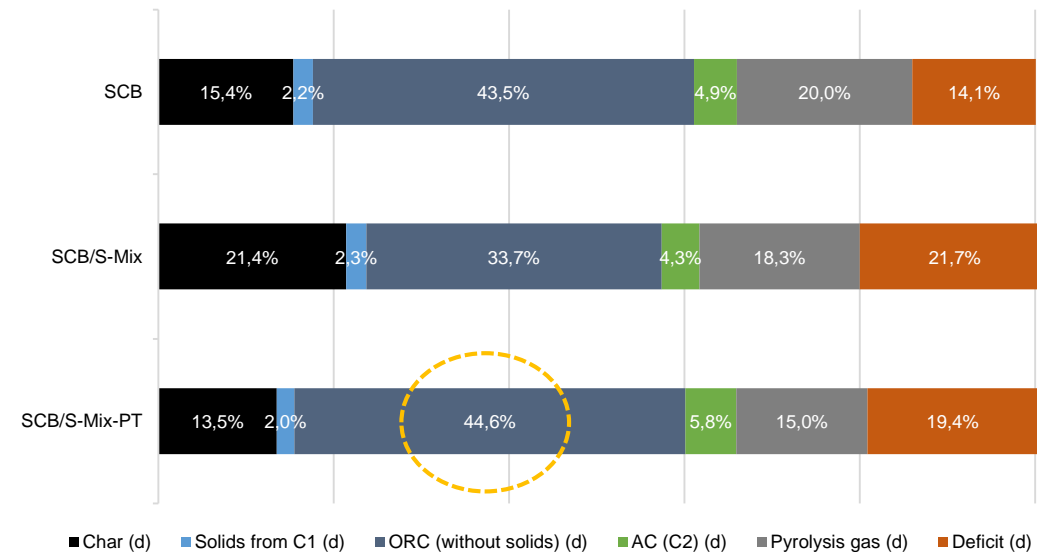


Figure 6. Mass balance, on a dry basis, of the PDU/IKFT main line for the fast pyrolysis experiments of SCB and untreated and pre-treated mixtures of SCB and SCS.



# KEY RESULTS

Project: Valorization of sugarcane bagasse and straw by thermochemical conversion for energy integration into sugarcane refineries

**Second scenario** – Ethanol as quenching medium in the PDU/IKFT bypass.  
Assessment of the chemical composition of the ORC(s) obtained.

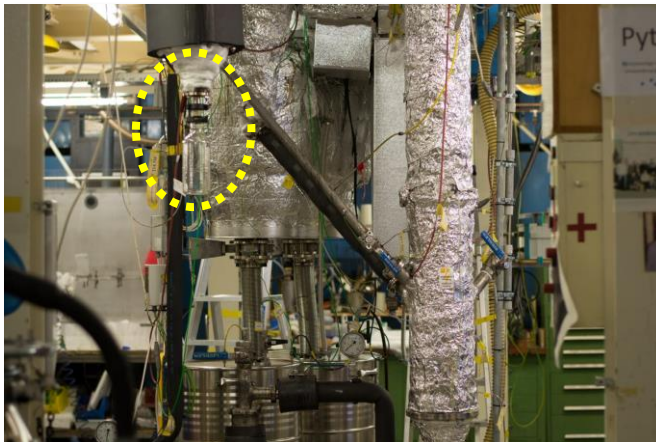


Figura 7. ORC recovery system in the bypass of PDU/IKFT

- GC-MS/FID
- Volumetric Karl Fischer

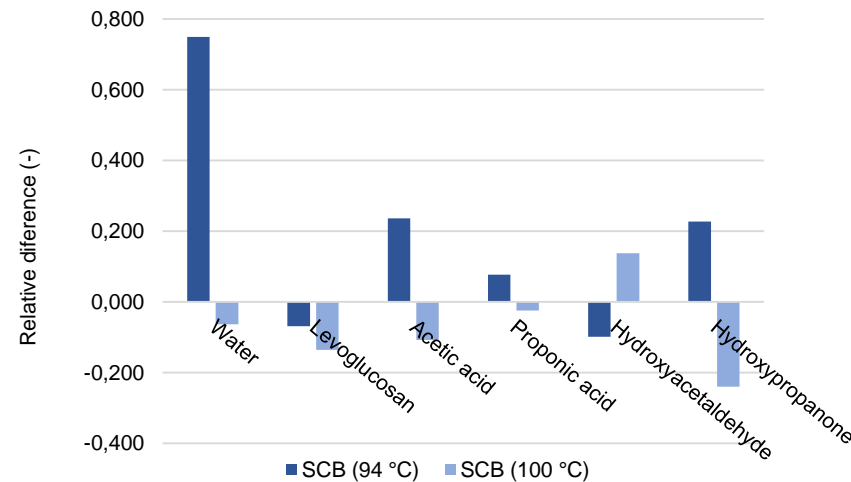


Figure 8. Relative difference of the ORC(s) composition obtained in the fast pyrolysis experiments of SCB when using EtOH-Quench related to the ORC obtained in the reference experiment.

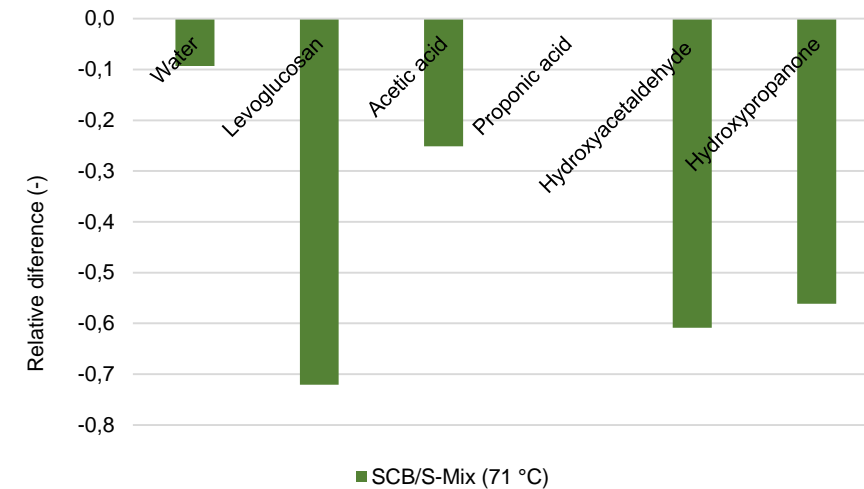


Figure 9. Relative difference of the ORC composition obtained in the PDU/IKFT bypass of the SCB/S-Mix using EtOH-Quench related to the ORC obtained reference experiment.

# KEY RESULTS

*Project: Valorization of sugarcane bagasse and straw by thermochemical conversion for energy integration into sugarcane refineries*

## **Results under process** → **Mariana Miryam Campos Fraga** (PhD thesis)

*Manuscript preparation*

Briefly observations:

QM directly affects phase separation during pyrolysis and hydrotreatment.

- Phase separation has a strong influence on the success of HDO and viscosity control.
- Ethanol as QM helped with viscosity problems.
- Ethanol was one of the main components in almost all cases. Regardless of the QM used.

The catalyst was successful in reducing the O/C ratio for all four bio-oils tested.



# SCIENTIFIC PRODUCTION

Cooperation Agreement IPT and KIT

<b>Conferences/Congress and others Scientific Events</b>	<b>18</b>	
<b>Manuscript</b>	<b>4</b>	
<b>Bachelor thesis</b>	<b>1</b>	
<b>Master thesis</b>	<b>1</b>	
<b>PhD thesis</b>	<b>1</b>	
<b>HDO Mini-Course</b>	<b>1</b>	Dra. Caroline Carriel Schmitt Prof. Dr. Alberto Wisniewski Jr
<b>Total Scientific Productions</b>	<b>24</b>	considering the production regarding the DAAD NoPa 2.0 program



COOPERATION  
AGREEMENT IPT  
AND KIT

# Green H2 projects



# HYDROGEN GENERATION FROM SUGARCANE BAGASSE BY DRY SYNGAS REFORMING AND DOWNSTREAM STORAGE IN FUEL PRECURSORS

DAAD NoPa 2.0 | 01/2023 to 01/2024

## ■ Technical-scientific goals:

*SCB conversion into H<sub>2</sub> and other products from integrated gasification process with thermal reforming and fast pyrolysis, followed by catalytic hydrotreatment of FPBO as a form of H<sub>2</sub> storage.*

IPT

- Optimize thermal reforming by evaluating the process at three different temperatures (930 °C, 1030 °C and 1100 °C), of the gases in their raw and clean form obtained from the gasification of SCB.
- The effect of temperature and process configuration was analyzed in order to obtain a gas with a higher H<sub>2</sub> yield.

KIT

- Simultaneously, pure H<sub>2</sub> was used as a precursor in the HDO process of FPBO obtained from the SCB.
  - Stabilization and HDO reactions:
    - 5% Ru/C and 5% Pd/C
  - HDO tests used synthetic gas with a composition similar to previous gasification test carried out in IPT.





# KEY RESULTS

Project: Hydrogen generation from sugarcane bagasse by dry syngas reforming and downstream storage in fuel precursors

DAAD NoPa 2.0 | 01/2023 to 01/2024

## Biogenic synthesis gas for the hydrogenation of pyrolysis oil

### Jakob Coulon Master thesis

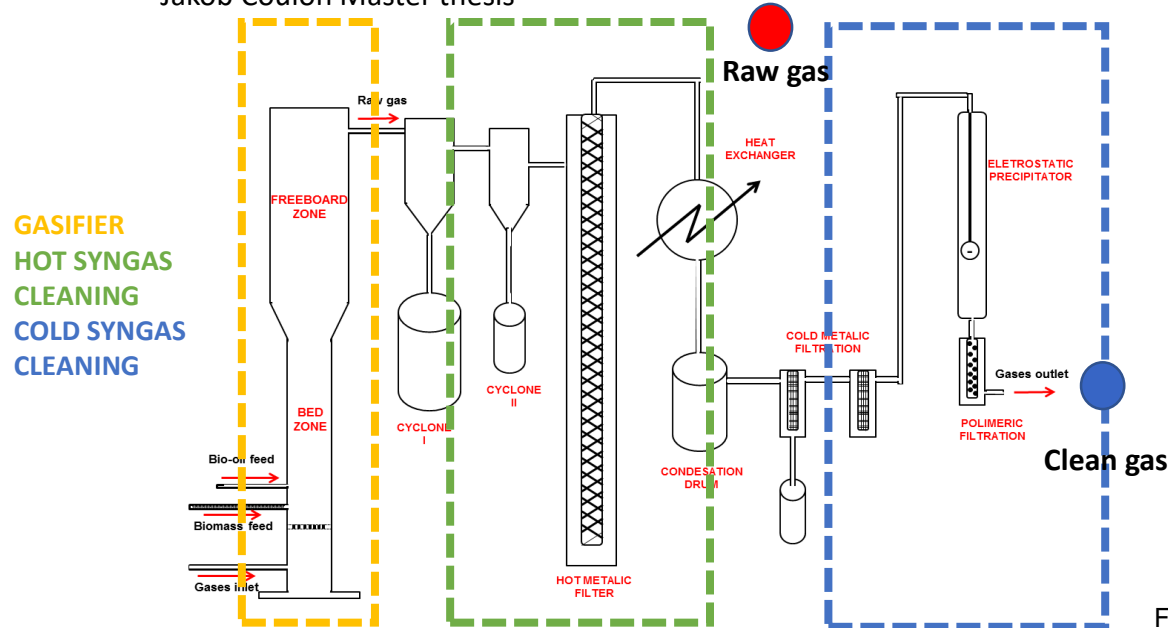


Figure 11. Diagram of LBE/IPT gasification unit

### Gasification and reforming experiments

- CLEAN gas
- RAW gas
- Reforming Temperatures: 900, 1000 and 1100 °C.



Figure 12. Connection of the reformer to the LBE/IPT gasification unit

- The highest difference between "Raw" and "Clean" reforming syngas is the presence of water vapor (Dry vs. Steam Reforming)
- Reforming "Raw Syngas" is possible and offers several advantages:
  - Syngas rich in  $H_2$  ( $H_2/CO > 2$ )
  - Fewer deposits
  - Robust process with fewer steps and better energy efficiency
- Reforming at 1100 °C offers the best results in the temperature range investigated



# KEY RESULTS

Project: Hydrogen generation from sugarcane bagasse by dry syngas reforming and downstream storage in fuel precursors

DAAD NoPa 2.0 | 01/2023 to 01/2024

## ■ Catalytic hydrotreatment of fast pyrolysis bio-oil using syngas reforming from sugarcane bagasse gasification composition

- Dênis Correa Meyer and Vittor Rodrigues Santos Alves – Professional exchange

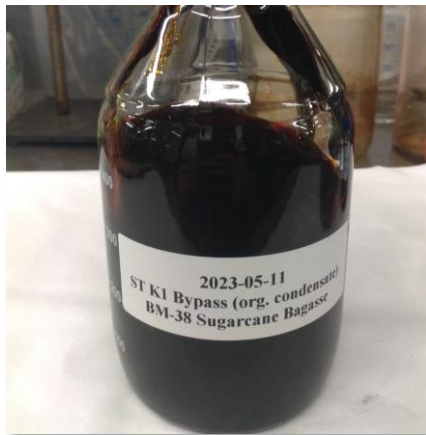


Figure 13. Fast pyrolysis ORC

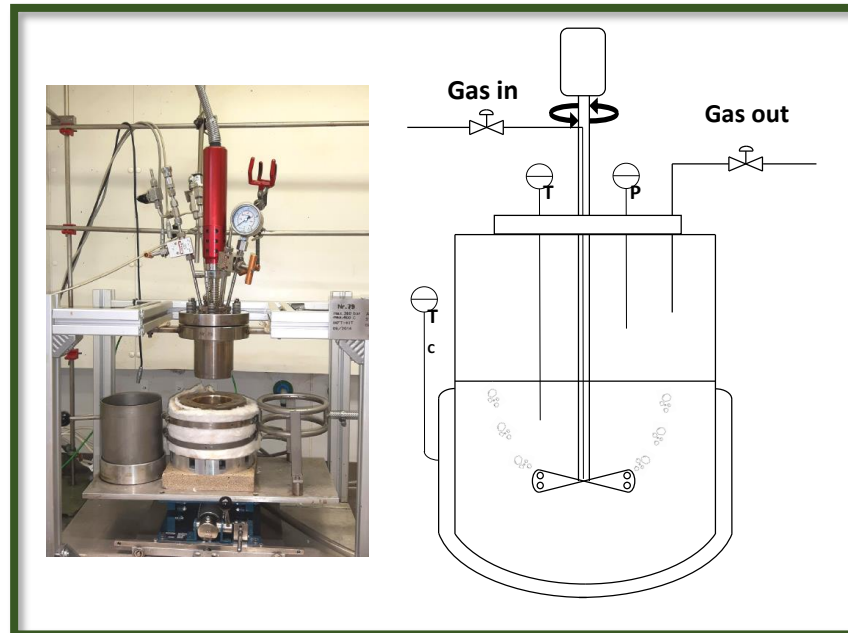


Figure 14. HDO reactor of IKFT/KIT.

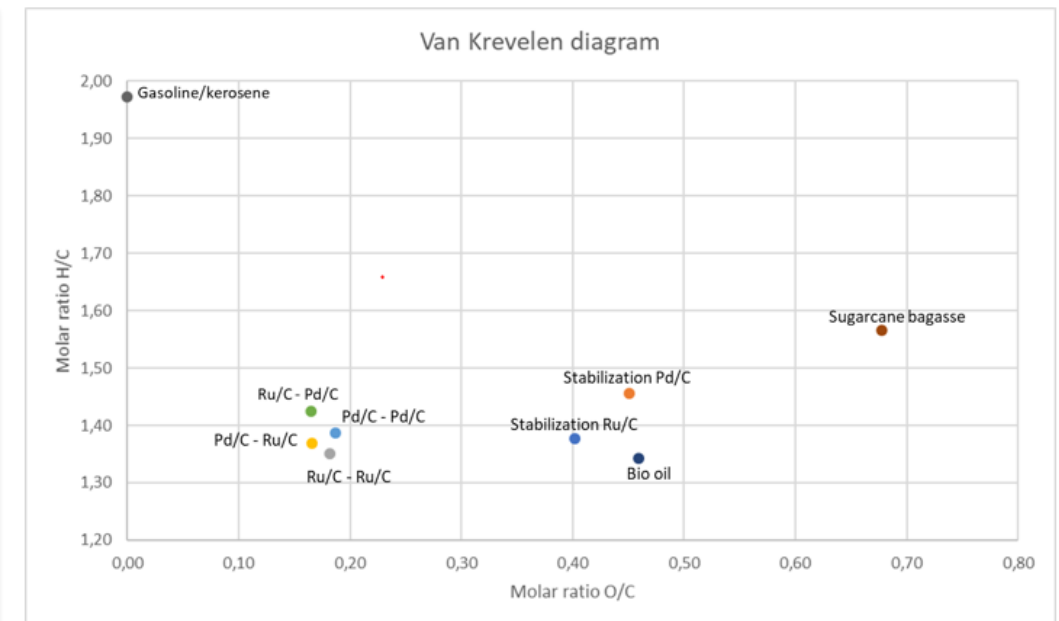


Figure 15. Van Krevelen diagram with data from each stage of hydrotreatment

- The best combination of catalysts was observed for: **Pd/C** for FPBO **stabilization** and **Ru/C** for **HDO** of the stabilized oil.
- Pd/C Stabilized oil followed by HDO with Ru/C presented a significant **reduction of 53.4 wt.% in oxygen** and **H<sub>2</sub> consumption of 78.4 vol.%**.
- FPBO stabilization proved to be efficient for the conversion of ketones, aldehydes and furans.



# SCIENTIFIC PRODUCTION AND MEDIA DISCLOSURE

Project: Hydrogen generation from sugarcane bagasse by dry syngas reforming and downstream storage in fuel precursors

DAAD NoPa 2.0 | 01/2023 to 01/2024

Scientific events



Stabilization Step within Hydrotreatment of Fast Pyrolysis Bio-Oil

Naiara Telis  
Denis C. Meyer  
Klaus Raffelt  
Ricardo R. Soares  
Nicolaus Dahmen



KIT – Die Forschungsuniversität in der Helmholtz-Gemeinschaft

www.kit.edu

PRODUCTION OF HYDROGEN-RICH SYNTHESIS GAS THROUGH THE OPTIMIZATION OF THERMAL REFORMING

Denis Correa Meyer (a), Vittor Rodrigues Santos Alves (a), Renata Moreira (a), Bruno Alexandre de Lemos (a), Samuel Dias Duarte (a), Ademir Hakuo Ushima (b), Jakob Coulon (b), Klaus Raffelt (b)

(a)Laboratory of Bioenergy and Energy Efficiency (LBE) – Institute for Technological Research (IPT), São Paulo, Brazil.  
(b)Institute of Catalysis Research and Technology (IKT) – Karlsruhe Institute of Technology (KIT), Germany



Optimization of the bio-oil stabilization process to minimize hydrogen consumption.  
Denis Correa Meyer (a); Renata Moreira (a); Caroline Carriel Schmitt (b); Naiara da Costa Telis (b); Klaus Raffelt (b)  
(a)Bioenergy and Energy Efficiency Laboratory (LBE) – Institute for Technological Research (IPT), São Paulo, Brazil.  
(b)Institute of Catalysis Research and Technology (IKT) – Karlsruhe Institute of Technology (KIT), Germany

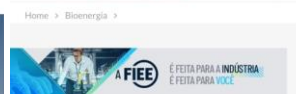


## Media disclosure (2023)



ENERGIA RENOVÁVEL | Flavio Freitas | 10 julho 2023

Projeto de hidrogênio verde a partir de biomassa é parceria do IPT com os alemães do KIT



**Bioenergia**  
IPT desenvolve H2V pela gaseificação do bagaço da cana  
Projeto em parceria com pesquisadores alemães utilizará ainda a reforma térmica do gás de síntese para gerar o hidrogênio verde  
Por Marcelo Furtado — Publicado em 4/07/2023



Etapa de preparação do bagaço de cana-de-açúcar no IPT

O Instituto de Pesquisas Tecnológicas (IPT), do governo paulista, está desenvolvendo um processo de produção de hidrogênio verde por meio da gaseificação de biomassa e da reforma térmica de gases. A pesquisa, em execução desde janeiro, é feita em conjunto com o Instituto Tecnológico de Karlsruhe (KIT), da Alemanha. O projeto coordenado pelo laboratório de



Notícia  
**Laboratório do IPT desenvolve projeto de gaseificação de biomassa com o Instituto Tecnológico de Karlsruhe, da Alemanha**  
Um dos principais desafios técnicos do projeto é a deposição excessiva de carbono no reator de reforma térmica



Divulgação, IPT

Fonte  
IPT | Instituto de Pesquisas Tecnológicas do Estado de São Paulo

Data  
quarta-feira, 31 maio 2023 06:15

Áreas  
Biomassa. Biotecnologia. Economia. Energia. Engenharia Ambiental. Gestão de Resíduos. Inovação. Negócios. Química Verde. Tecnologias.



Entrevisas | Óleo & Gás | Energia | Nuclear | Renováveis | Hidrogênio | Biocombustíveis | Tecnologias

Ligue 2102-5555 ou procure o seu corretor. ASSIM SAÚDE

PESSOAS BRASILEIRAS E ALEMÃES SE UNEM PARA DESENVOLVER UM NOVO PROCESSO DE PRODUÇÃO DE HIDROGÊNIO VERDE

O Instituto de Pesquisas Tecnológicas (IPT) em parceria com os alemães do Instituto Tecnológico de Karlsruhe (KIT) desenvolvem um processo de produção de hidrogênio verde por meio da gaseificação de biomassa e da reforma térmica dos gases. O projeto de P&D coordenado pelo Laboratório de Bioenergia e Eficiência Energética do IPT tem a duração prevista de 12 meses e desenvolverá dentro do seu escopo dois tópicos: o primeiro é a geração de hidrogênio via gaseificação de bagaço de cana-de-açúcar e reforma térmica do gás; o segundo é o armazenamento de hidrogênio via hidrogenação catalítica de bio-óleo (hidrodesoxigenação) gerado a partir da pirólise rápida de bagaço de cana. O pesquisador do IPT, Ademir Hakuo Ushima, explica que "a parceria entre o IPT e o KIT está focada em uma pesquisa colaborativa dentro do eixo do H2V, bem como promover o intercâmbio e a capacitação de pesquisadores de ambas as instituições".

As atividades experimentais do projeto estão sendo executadas simultaneamente nas duas instituições: a etapa de gaseificação do bagaço de cana-de-açúcar em um reator de leito fluidizado, seguida da reforma térmica do gás de síntese gerado, por exemplo, é realizada pelo IPT. A segunda fase, executada no IKT/KIT, consiste em realizar a pirólise rápida do bagaço de cana-de-açúcar para a obtenção do bio-óleo, que será então melhorado para precursores de combustível com maior teor de energia do que o óleo de pirólise original via hidrogenação catalítica. Os produtos serão 100% renováveis e adequados para refino adicional em plantas comerciais. A execução do projeto envolve um total de 14 colaboradores, sendo sete pesquisadores de cada instituição. Dois deles vinculados ao IPT e dois do KIT são realizar um intercâmbio.

AMBIÇÃO DO BRASIL QUE O PAÍS A GERA E CONSUME 9% DE ENERGIAS RENOVÁVEIS E PERDE AO MENOS 1,5 TRILHÕES ANUAL NA TRANSIÇÃO ENERGÉTICA  
CENTRO DE INOVAÇÃO EM GASES DE EFEITO ESTUFA DA USP E SUAS ENERGIAS ASSIM CONVENDO PARA PROJETO DE PESQUISA E DESENVOLVIMENTO



# DAAD ERA GREEN H<sub>2</sub>

## Green Hydrogen Fellowships (GH<sub>2</sub>)

Towards climate neutrality by 2050

### What

### Green Hydrogen Fellowships for Graduates, PhD students and Postdocs

Green Hydrogen is one of the key factors against climate change. The research and development of GH<sub>2</sub> requires global cooperation. Therefore, we support the early career academics and young professionals to realise their projects worldwide and to build up their own international networks for future.



We offer fellowships for both **incomings** for staying in Germany as well as **outgoings** to any country worldwide.

### Who

### Early career academics and future professionals

This interdisciplinary programme is open to any topics related to GH<sub>2</sub>.

**Law, economics and social sciences, e.g.:**

- national and regional regulations, codes and standards;
- Social inequality through the development of new energy;
- education in green hydrogen;
- market stimulation

**Interdisciplinary study programs, e.g.:**

- international development
- environmental studies

What are your ideas?

**Natural sciences, e.g.:**

- innovative approaches for hydrogen production from renewable waste/biomass, etc.
- green hydrogen production capacities

**Engineering, e.g.:**

- development and deployment of electrolyzers;
- hydrogen storage and transportation network infrastructure

**Humanities and cultural studies, e.g.:**

- Cultural acceptance and willingness to use new energy and technology

from March to September 2025

**Natural sciences, e.g.:**

- innovative approaches for hydrogen production from renewable waste/biomass, etc.
- green hydrogen production capacities



Green Hydrogen  
Deutscher Akademischer Austauschdienst  
German Academic Exchange Service

IPT

Master

Karen Stefanía Marquez Leon

Syngas reforming  
(gasification of SCB and SCS)

KIT

Postdoc

Ana Paula de Souza Silva

FPBO  
HDO

Catalyst

Syngas composition

from March 2025 to March 2026

Source: Factsheet - Green Hydrogen Fellowships (GH<sub>2</sub>) - Towards climate neutrality by 2050 <https://www.daad.de/en/studying-in-germany/scholarships/daad-funding-programmes/green-hydrogen/>



# FAPESP CCD - RENEWABLE ENERGIES AND FUELS OF THE FUTURE



CCD  
Centros de Ciência para o Desenvolvimento

39

## CENTRO DE CIÊNCIAS PARA O DESENVOLVIMENTO EM ENERGIAS RENOVÁVEIS E COMBUSTÍVEIS DO FUTURO (CCD-ERCF)

3ª EDITAL

PESQUISADOR RESPONSÁVEL  
Adriano Marim de Oliveira

INSTITUIÇÃO-SEDE  
Instituto de Pesquisas  
Tecnológicas do Estado  
de São Paulo

Processo FAPESP 2024/01059-3

O Centro de Ciências para o Desenvolvimento em Energias Renováveis e Combustíveis do Futuro foi criado para enfrentar os desafios relacionados à descarbonização da indústria e do setor de transporte paulista de forma economicamente viável e ambientalmente adequada.

O CCD buscará soluções para implementação do hidrogênio de baixa intensidade de carbono com as seguintes verticais de pesquisa: Produção, Armazenamento e Transporte, Usos e Aplicações e Regulamentação, de modo a buscar o protagonismo do Estado de São Paulo no desenvolvimento de tecnologias avançadas e na promoção da indústria nacional.

O Centro articulará uma rede de parcerias formada pelo IPT, a Escola Politécnica da USP, UFSCar, UFPR, UFABC, o ISI de Eletroquímica e a Associação Brasileira de Energia Eólica (ABEEólica), para garantir o alinhamento estratégico dos temas abordados com as necessidades da indústria. Esse alinhamento permitirá o desenvolvimento da cadeia de fornecedores nacional para componentes relacionados ao uso de H2 como fonte de energia. As instituições participaram ativamente da estruturação dos temas a serem desenvolvidos no CCD-ERCF, incluindo a definição das metas e a contrapartida econômica.

### Instituições parceiras

- Secretaria de Meio Ambiente, Infraestrutura e Logística de SP
- Instituto de Pesquisas Tecnológicas (IPT)

Total Financial Resources: R\$ 8.237.557,35 (1,34 million €)

→ 37% for research fellowship

Project period: 60 months

Start up: 01 July 2024



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TECNOLÓGICAS



Associação Brasileira de Energia Eólica



UNIVERSIDADE FEDERAL DO PARANÁ



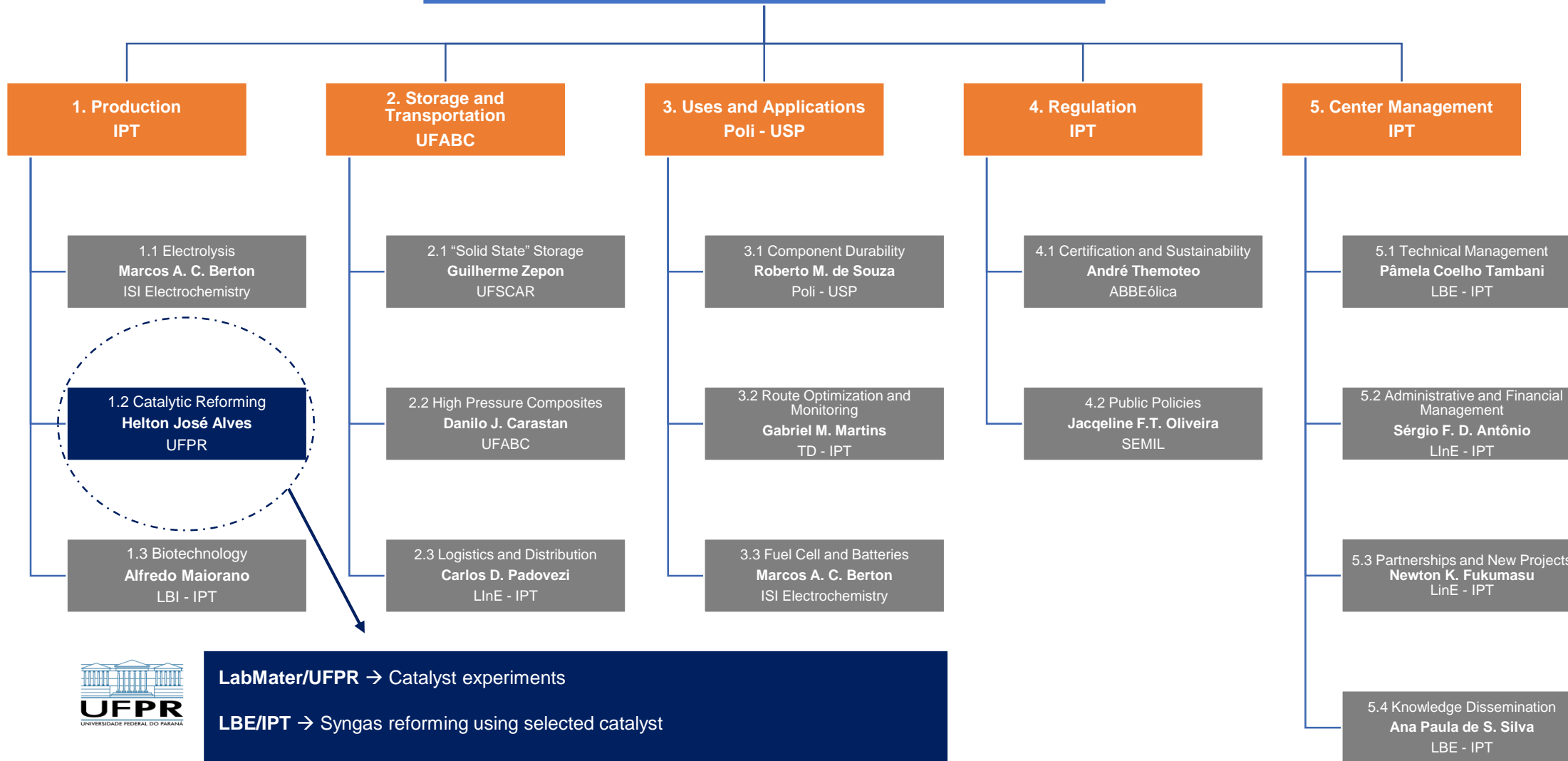
Karlsruher Institut für Technologie



Source:



# CCD Renewable Energies and Fuels of the Future



LabMater/UFPR → Catalyst experiments

LBE/IPT → Syngas reforming using selected catalyst

LPP/IPT → Mathematical modeling of the process parameters

IKFT/KIT → Monitoring the project through meetings, workshops and one week exchanges





# Thank you!

- Vittor Rodrigues Santos Alves
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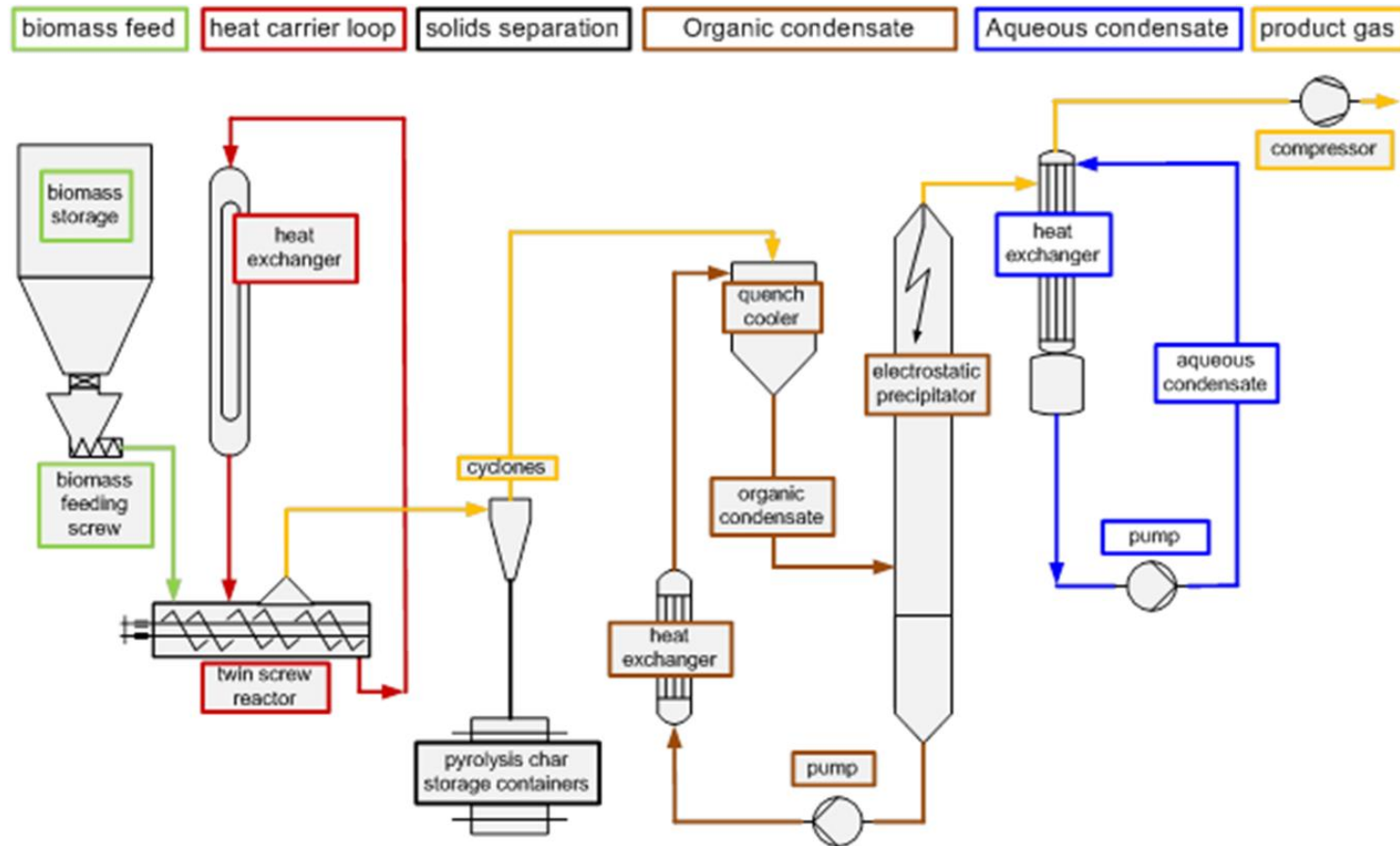
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 **SÃO  
PAULO**  
GOVERNO  
DO ESTADO

# IKFT/KIT PYROLYSIS DEVELOPMENT UNIT (PDU)



**Biomass feed rate: 5 kg h<sup>-1</sup>**  
**Reactor temperature: 500 °C**  
**Residence time: 2 s**  
**ORC temperature: 90 °C**  
**AC temperature: 20 °C**

ORC – Organic rich condensate; AC – aqueous condensate

Figure 16. Flowchart of the Process Development Unit of IKFT/KIT (Copyright 2021 by KIT)

