INSTITUTO DE PESQUISAS TECNOLÓGICAS

COMUNICAÇÃO TÉCNICA

Nº 179396

Institutional presentation: Bioenergy and Energy Efficiecy Laboratory (LBE).

Vittor Rodrigues Santos Alves

Lecture apresentado no: Workshop Kit , UFPR, 1., 2024, Curitiba. 22 slides.

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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

SÃO PAULO GOVERNO DO ESTADO

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

2009
Visit of Ademar IPT researcher at IKFT/KIT

08/2016 a 03/2017
PDCE Renata (IKFT/KIT)
Development and Training Abroad Program

12/2019
Dr. Caroline started the contact to the Cooperation Agreement between KIT/IPT

06/2020
Cooperation Agreement signed and project start

11/2021
Danilo's participation of
BRISK2
BIOFUELS RESEARCH INFRASTRUCTURE

12/2022
1st Amendment
DAAD NoPa 2.0
(project application)

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IPT AND KIT TIMELINE

01/2023
DAAD NoPa 2.0 project start
2nd Amendment
DAAD

04/2023
Denis exchange at IKFT/KIT
DAAD

06/2023
Vittor visited at IKFT
Vittor's participation of the 31ª EUBCE 2023
DAAD
EUBCE 31st European Biomass Conference & Exhibition

06/2023
Jakob Coulon exchange at LBE/IPT
DAAD

03/2024
Extension of the Cooperation Agreement
(in process at IPT)

07/2024
FAPESP CCD ERCF
(Start up)

03/2025
DAAD ERA GREEN H2
(Karen and Ana Paula)
DAAD

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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_2 projects

- **1st and 2nd 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 de 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_2O_5 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

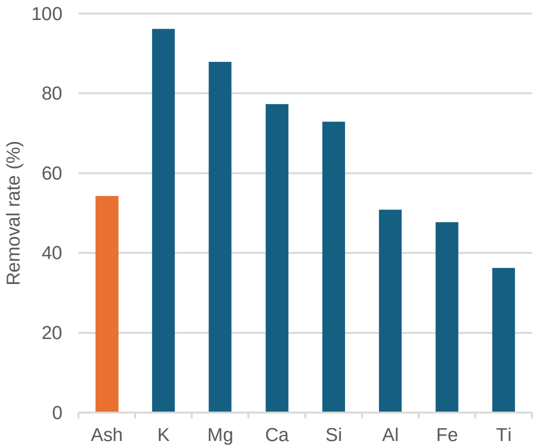


Figure 4. Removed ash and major inorganic elements fraction in the pretreated

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

	SCB/S-Mix	SCB/S Mix-PT
Proximate analysis (wt.%)		
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
Elemental analysis (wt.%)		
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
Major elements ($g\ kg^{-1}$)		
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

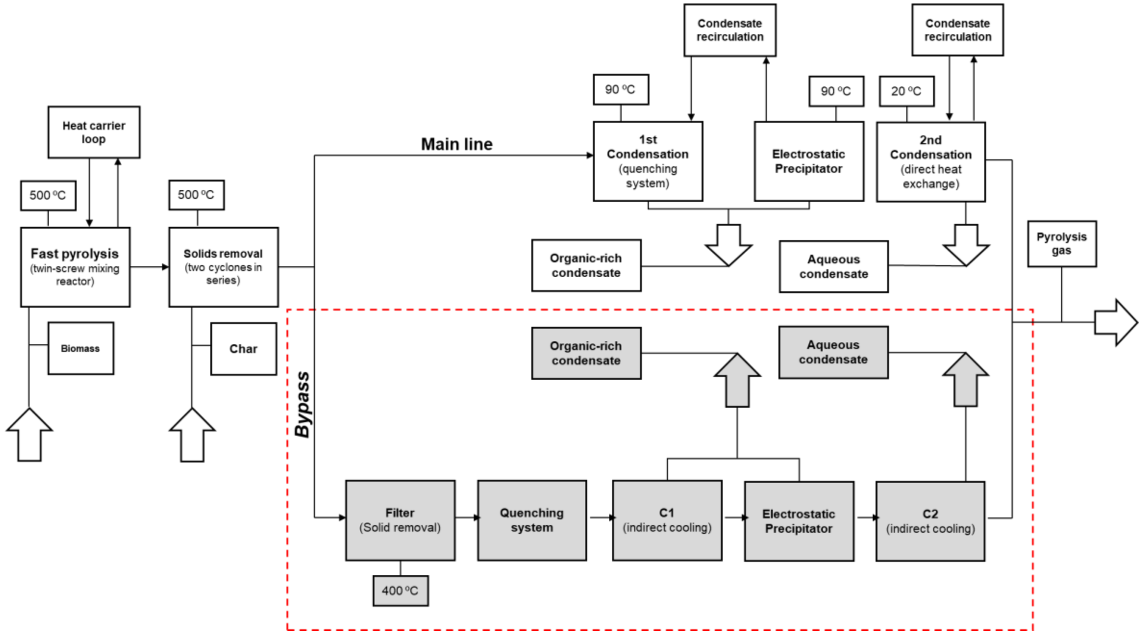


Figure 5 - Block flowchart of each step of the fast pyrolysis process at Process Development Unit (PDU/IKFT). Source: Adapted from Schmitt C. *et al.* (2020).

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

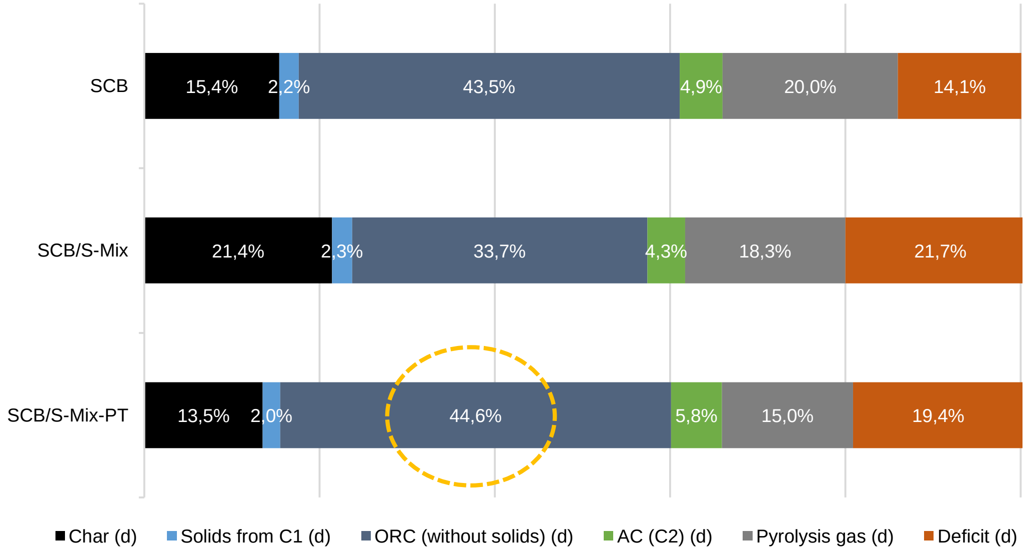


Figure 6. Mass balance, on a dry basis, of the PDU/IKFT main line for the fast pyrolysis experiments of SCB and untreated and pre-treated mixtures of SCB and SCS.

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

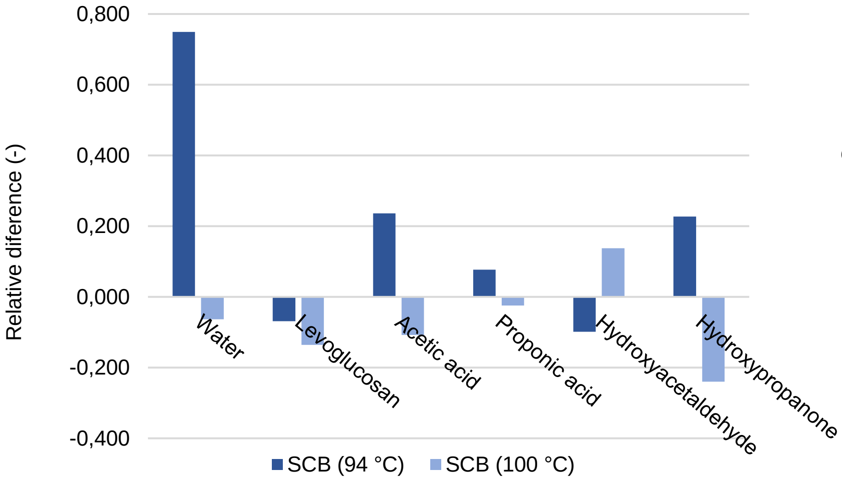


Figure 8. Relative difference of the ORC(s) composition obtained in the fast pyrolysis experiments of SCB when using EtOH-Quench related to the ORC obtained in the reference experiment.

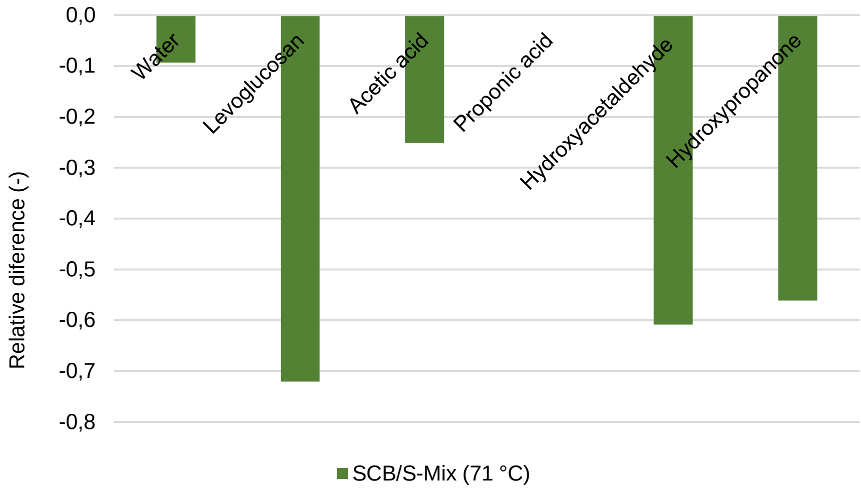


Figure 9. Relative difference of the ORC composition obtained in the PDU/IKFT bypass of the SCB/S-Mix using EtOH-Quench related to the ORC obtained reference experiment.

- ❑ GC-MS/FID
- ❑ Volumetric Karl Fischer

KEY RESULTS

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

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

COOPERATION AGREEMENT IPT AND KIT

Green H2 projects

ipt SÃO PAULO GOVERNO DO ESTADO

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

- **Technical-scientific goals**:

SCB conversion into H_2 and other products from integrated gasification process with thermal reforming and fast pyrolysis, followed by catalytic hydrotreatment of FPBO as a form of H_2 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_2 yield.

KIT

- Simultaneously, pure H_2 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

GASIFIER
HOT SYNGAS CLEANING
COLD SYNGAS CLEANING

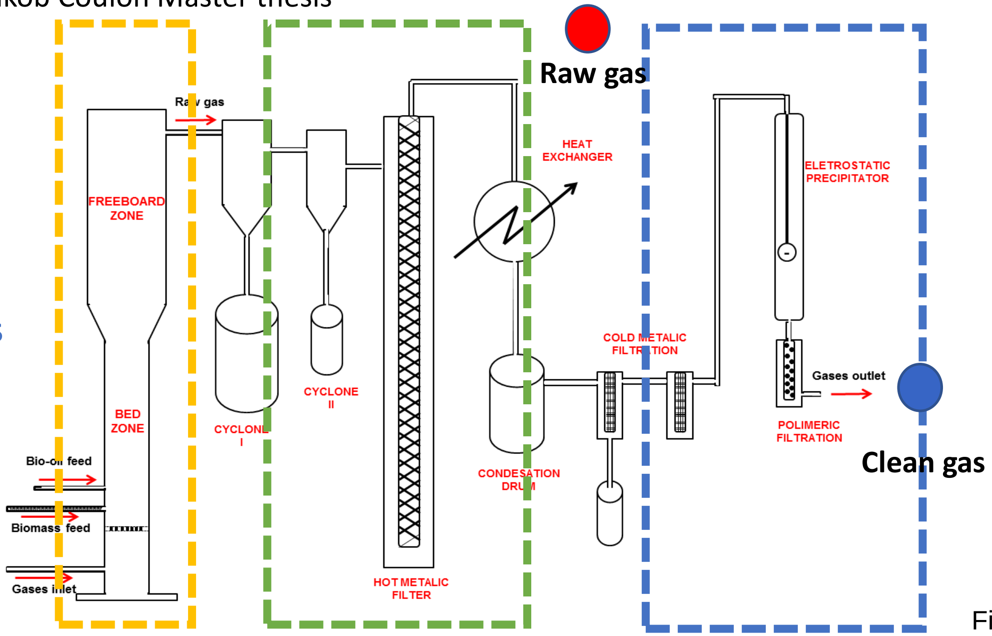


Figure 11. Diagram of LBE/IPT gasification unit

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

Gasification and reforming experiments

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

- 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

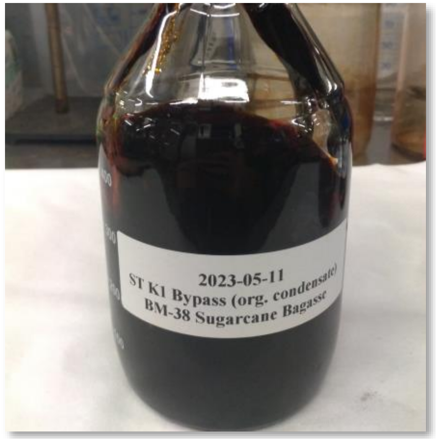


Figure 13. Fast pyrolysis ORC

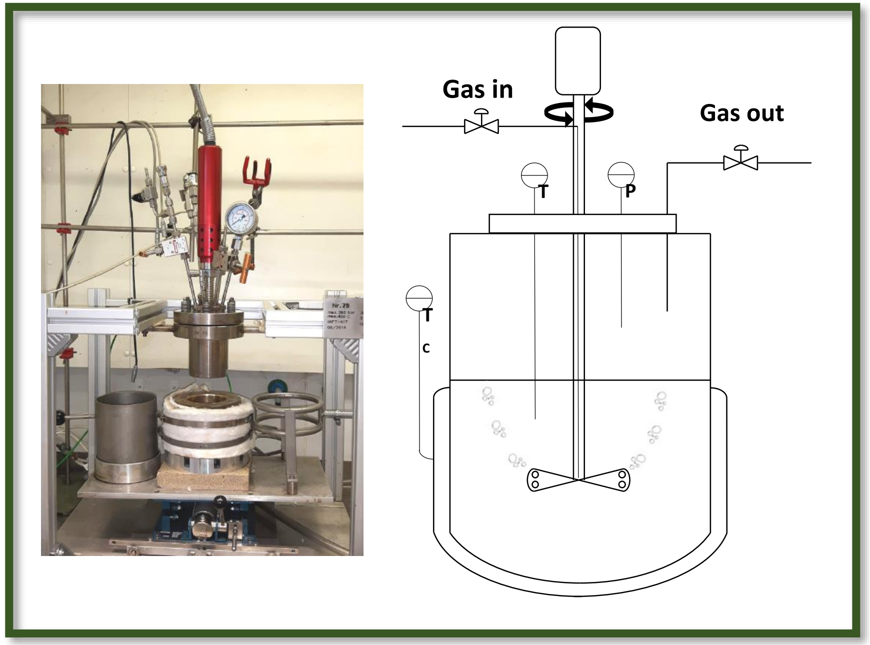


Figure 14. HDO reactor of IKFT/KIT.

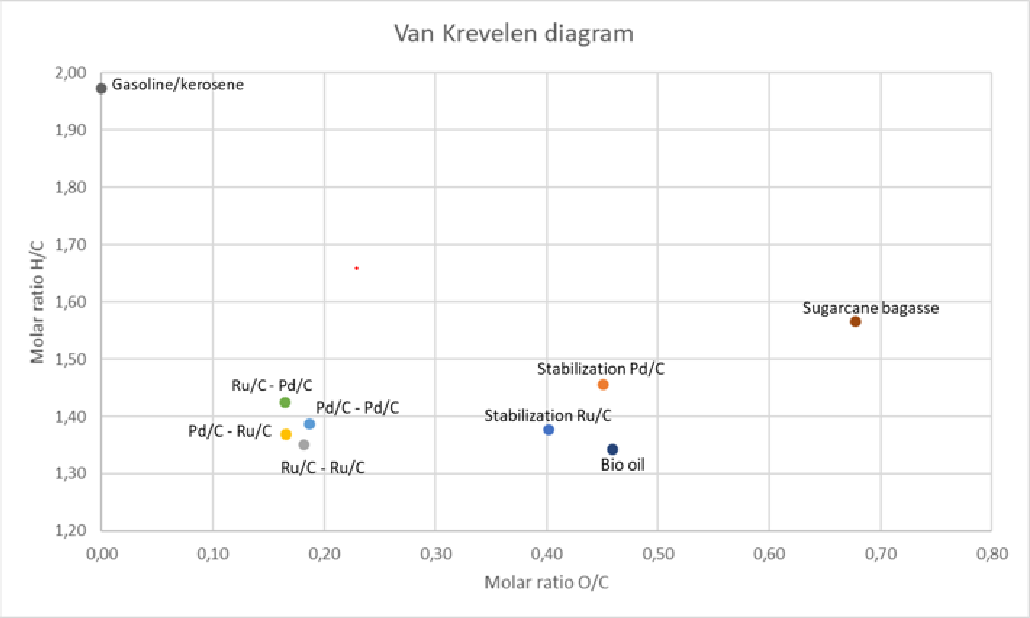


Figure 15. Van Krevelen diagram with data from each stage of hydrotreatment

- 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_2 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

Media disclosure (2023)

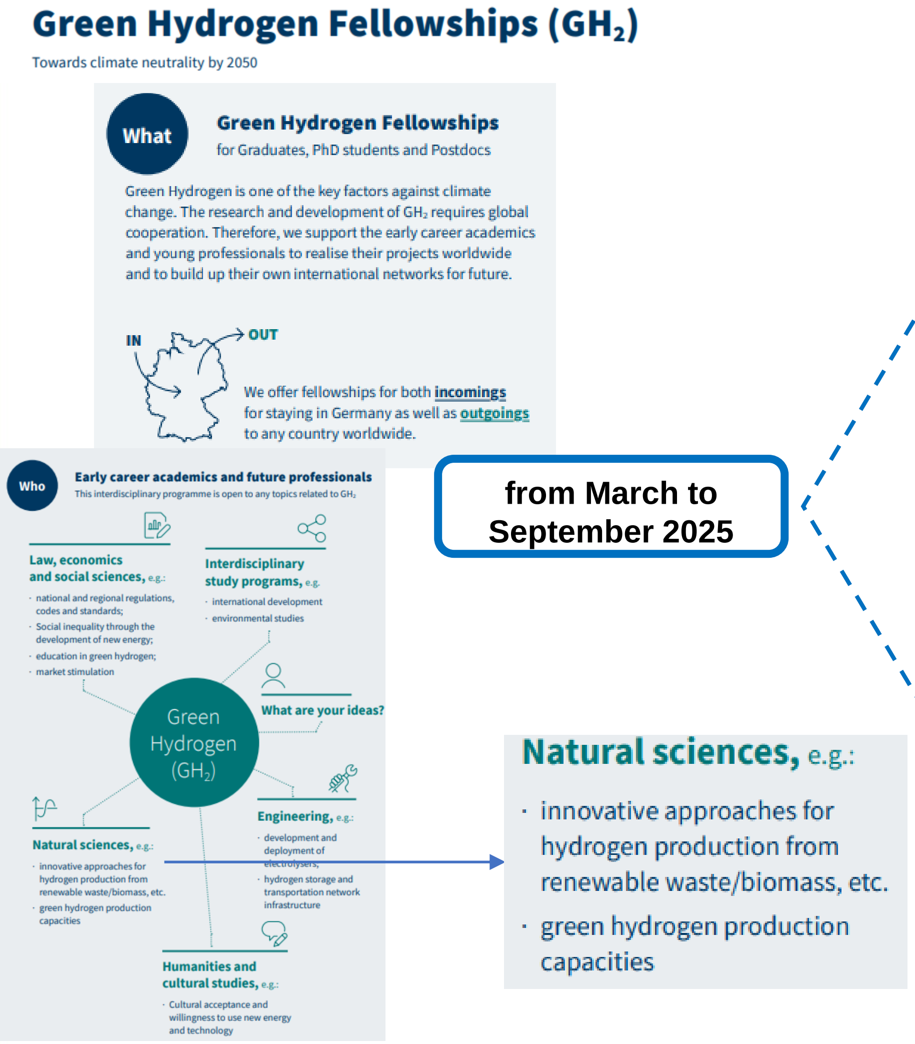

GasNet
O site do gás natural
ENERGIA RENOVÁVEL Flavio Freitas 10 julho 2023
Projeto de hidrogênio verde a partir de biomassa é parceria do IPT com os alemães do KIT


Radar » Eletrobras é autorizada a atuar no âmbito da CCEE
ENERGIA HOJE
Uma publicação da Editora Brasil Energia
Home › Bioenergia ›
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...


ambiental t4h
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.


petronotícias
Entrevistas Óleo & Gás Energia Nuclear Renováveis Hidrogênio Biocombustíveis Tecnologias
Ligue 2102-5555 ou procure o seu corretor. ASSIM SAÚDE
PESQUISADORES BRASILEIROS E ALEMÃES SE UNEM PARA DESENVOLVER UM NOVO PROCESSO DE PRODUÇÃO DE HIDROGÊNIO VERDE
21. JUN, 2023 0 COMENTÁRIOS
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 combinam-se 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, **Ademar Hakuo Ushima,** explica que "**a parceria entre o IPT e o KIT está focada em uma pesquisa colaborativa dentro da cadeia 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 IKFT/KIT, consiste em realizar a pirolise 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 irão realizar um intercâmbio.
Mercado
DIRETOR DO ONS DIZ QUE O PAÍS JÁ GERA E CONSOME 80 % DE ENERGIAS RENOVÁVEIS E PEDE AO SETOR ELÉTRICO APOIO NA TRANSIÇÃO ENERGÉTICA
Redes Sociais
Publicidade
ROLETE GIRO LIVRE
O ASSIM SAÚDE tem amplo portfólio para atender empresas dos setores de óleo e gás e energia.
ambipar response
Tenenge
EBCO systems

DAAD ERA GREEN H_2


Green Hydrogen Fellowships (GH_2)

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_2 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.

IN → OUT

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_2

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

Green Hydrogen (GH_2)

What are your ideas?

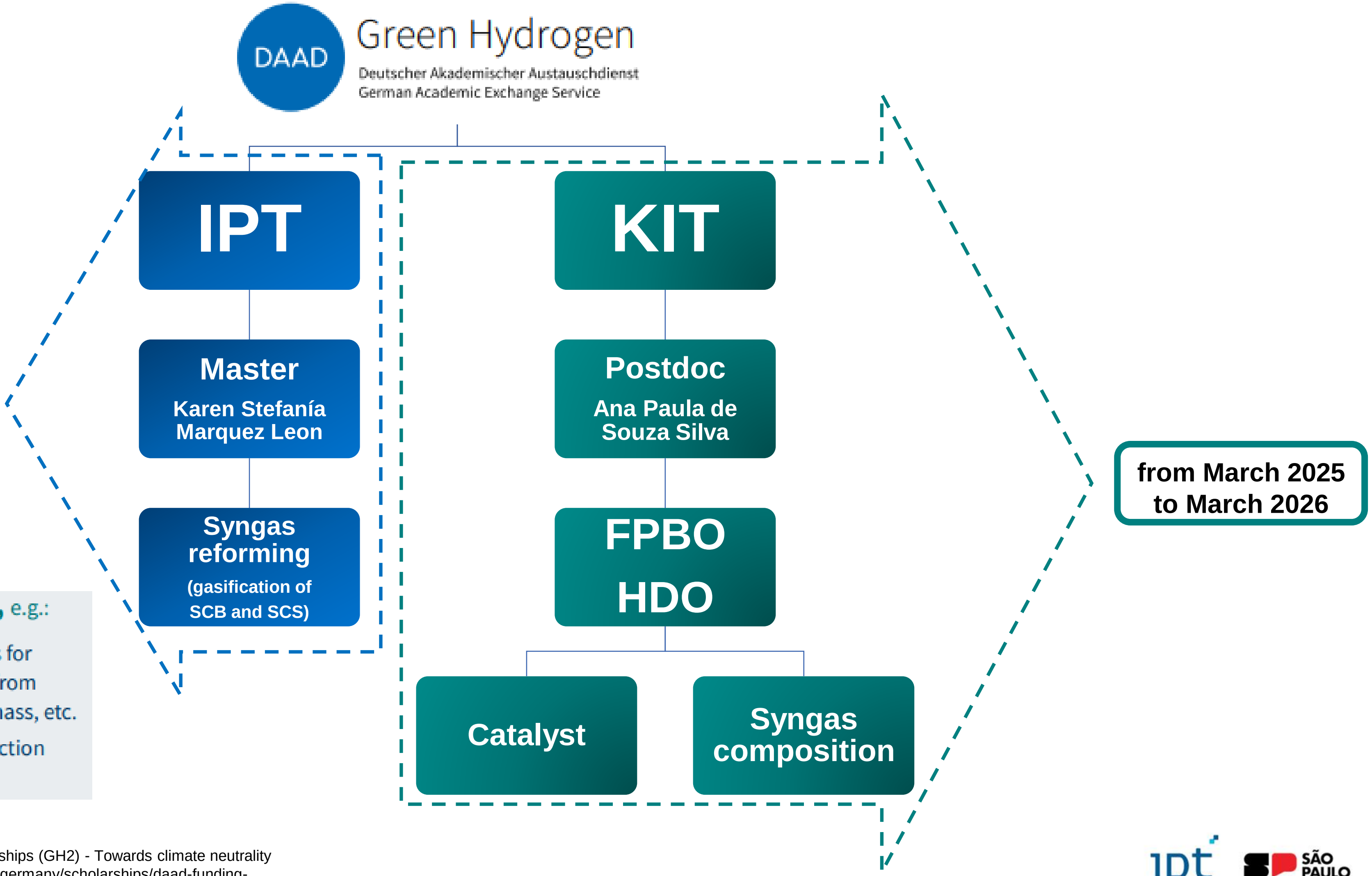
Engineering, e.g.:
- development and deployment of electrolysers,
- hydrogen storage and transportation network infrastructure

Natural sciences, e.g.:
- innovative approaches for hydrogen production from renewable waste/biomass, etc.
- green hydrogen production capacities

Humanities and cultural studies, e.g.:
- Cultural acceptance and willingness to use new energy and technology

Natural sciences, e.g.:

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



Source: Factsheet - Green Hydrogen Fellowships (GH2) - 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

FAPESP

CCD
Centros de Ciência para o Desenvolvimento

39

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

3º 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)

Source:

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

→ **37% for research fellowship**

Project period: 60 months

Start up: 01 July 2024

FAPESP

CCD
Centros de Ciência para o Desenvolvimento

CCD Renewable Energies and Fuels of the Future

1. Production
IPT

- 1.1 Electrolysis
  Marcos A. C. Berton
  ISI Electrochemistry
- 1.2 Catalytic Reforming
  Helton José Alves
  UFPR
- 1.3 Biotechnology
  Alfredo Maiorano
  LBI - IPT

2. Storage and Transportation
UFABC

- 2.1 “Solid State” Storage
  Guilherme Zepon
  UFSCAR
- 2.2 High Pressure Composites
  Danilo J. Carastan
  UFABC
- 2.3 Logistics and Distribution
  Carlos D. Padovezi
  LInE - IPT

3. Uses and Applications
Poli - USP

- 3.1 Component Durability
  Roberto M. de Souza
  Poli - USP
- 3.2 Route Optimization and Monitoring
  Gabriel M. Martins
  TD - IPT
- 3.3 Fuel Cell and Batteries
  Marcos A. C. Berton
  ISI Electrochemistry

4. Regulation
IPT

- 4.1 Certification and Sustainability
  André Themoteo
  ABBEólica
- 4.2 Public Policies
  Jacqeline F.T. Oliveira
  SEMIL

5. Center Management
IPT

- 5.1 Technical Management
  Pâmela Coelho Tambani
  LBE - IPT
- 5.2 Administrative and Financial Management
  Sérgio F. D. Antônio
  LInE - IPT
- 5.3 Partnerships and New Projects
  Newton K. Fukumasu
  LinE - IPT
- 5.4 Knowledge Dissemination
  Ana Paula de S. Silva
  LBE - IPT

UFPR
UNIVERSIDADE FEDERAL DO PARANÁ

KIT
Karlsruher Institut für Technologie

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

ipt

SÃO PAULO
GOVERNO DO ESTADO

Thank you!

- Vittor Rodrigues Santos Alves
- vittoralves@ipt.br

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INSTITUTO DE PESQUISAS TECNOLÓGICAS

SÃO PAULO GOVERNO DO ESTADO

IKFT/KIT PYROLYSIS DEVELOPMENT UNIT (PDU)

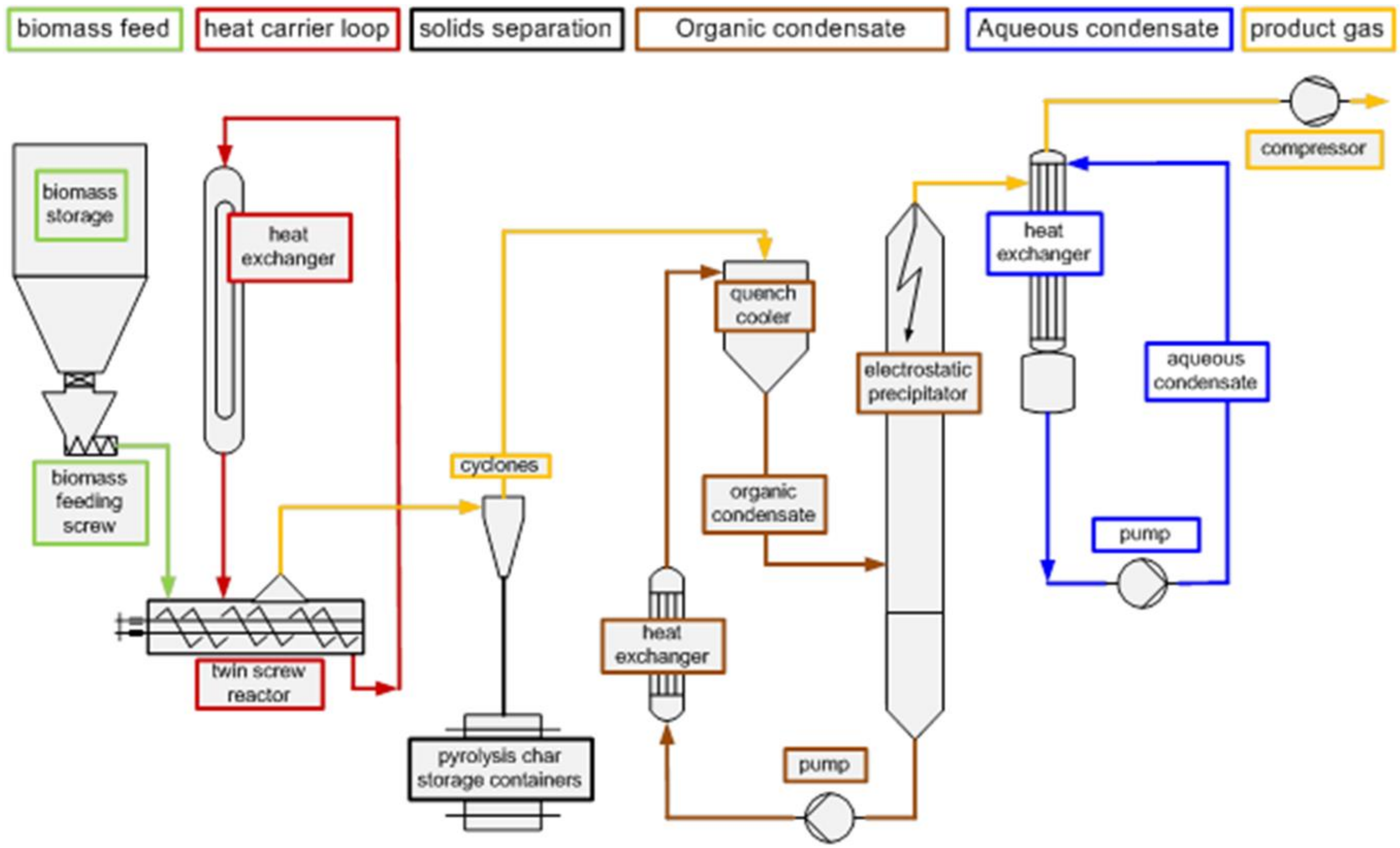

Figure 16. Flowchart of the Process Development Unit of IKFT/KIT (Copyright 2021 by KIT)

Biomass feed rate: 5 kg h^{-1}

Reactor temperature: 500 °C

Residence time: 2 s

ORC temperature: 90 °C

AC temperature: 20 °C

ORC – Organic rich condensate; AC – aqueous condensate