// Tailor-Made Fuels from Biomass
TMFB
// Tailor-Made Fuels from Biomass
Goal of the Research Work: Why “tailor-made”?

Funded by the DFG, located at RWTH Aachen University

Scientific Structure

CIF: Fuel Design

IRF-A: From Biomass to Biofuels

IRF-B: From Biofuels to Propulsion

Major Accomplishments of TMFB since 2007

Future Challenges

Cluster Management and Scientific and Industrial Support of TMFB

Additional Activities and Public Outreach

Research Groups of TMFB
Since 2007, the Cluster of Excellence “Tailor-Made Fuels from Biomass” (TMFB) has been working on a solution for one of the major challenges that our society is facing today: a rising energy demand and the limited availability of fossil energy resources.

For this purpose, researchers from the fields of chemistry, biology, process engineering and mechanical engineering have joined forces in this Cluster of Excellence to develop new alternative fuels from biomass which will not be competing with the food chain.

**Vision of the Cluster**

Establish innovative and sustainable processes for the conversion of whole plants into fuels which are tailor-made for novel low-temperature combustion engine processes with high efficiency and low pollutant emissions, paving the way to the 3rd generation of biofuels.
The common goal of all research activities carried out in TMFB is the definition of an optimized “tailor-made” fuel. Primarily, this means that researchers work towards the feasibility to match fuel properties with determining conditions. Due to the unique combination and direct interaction of fundamental natural sciences and applied engineering sciences though, the definition of a “tailor-made” fuel cannot only be attributed to the final fuel properties but is a characteristic of the system “fuel” over lifetime: A perfect, tailor-made fuel from biomass is characterized by a sustainable, clean and energetically optimized production and combustion. This definition at the same time displays the vision of the research group organization, namely the holistic and interdisciplinary solution of this extremely challenging scientific problem.

**Definition of “Tailor-Made Fuels”**

A well-defined blend of distinct molecular components with optimized physicochemical properties for future combustion systems, which can be produced by sustainable and economical production processes.
Funded by the DFG, located at RWTH Aachen University

The Cluster of Excellence was established at RWTH Aachen University in 2007 and enfolds the work of 28 research groups at RWTH as well as the Fraunhofer Institute for Molecular Biology and Applied Ecology (Aachen) and the Max-Planck-Institute for Coal Research (Mülheim an der Ruhr). It is part of the Excellence Initiative of the German Federal and State Governments and funded by the German Research Foundation DFG. In June 2012, the German Council of Science and Humanities and the DFG renewed their funding for TMFB for another five years.

The “Tailor-Made Fuels from Biomass” - Team

**Expertise**
- Heterogeneous Catalysis
- Homogeneous Catalysis
- Organic Synthesis
- Organometallic Chemistry

**Core team expertise**
- Chemistry
- Biotechn. / Microbiology
- Process Engineering
- Tribology
- Combustion Engineering
- Computational Engineering

**Expertise**
- Industrial Biotechnology
- Plant Biotechnology
- Integrated Production Platforms
- Systems Biotechnology

**Contribution**
- Economically and ecologically benchmarking
- Comparison to competing processes
The research activities of TMFB are organized in two major “Integrated Research Fields” (IRF): IRF-A “From Biomass to Biofuels” and IRF-B “From Biofuels to Propulsion”. These research fields are linked by the “Core Interaction Field” (CIF) “Fuel Design”. The major goal is to describe a “Fuel Design Process” with which a tailor-made fuel with any desired properties can be developed from biomass. Therefore, the direct link and interaction between the fuel production (addressed in IRF-A) and the fuel combustion (addressed in IRF-B) through the Core Interaction Field “Fuel Design” is crucial as well as unique worldwide.
CIF: Fuel Design

Who works in this field?
The Core Interaction Field „Fuel Design“ constitutes both an independent research unit with dedicated projects as well as a vital exchange platform for scientists from all groups of the Cluster of Excellence. Therefore, all research groups are involved in the CIF. The meetings of the CIF are open for all researchers from both Integrated Research Fields and the rest of TMFB and are especially important for those wanting to supply new fuel requirements or production methods.

What is it about?
The Core Interaction Field strives to develop a model-based description of the entire process chain from biofuel production to fuel conversion in the combustion engine, eventually leading to the envisioned model-based fuel design. “Model-based” in this context means that the results can be predicted a-priori with specifically designed tools. To develop this fuel description and design, the dedicated projects within the CIF mainly aim to bridge the gaps between the different disciplines. With model-based approaches (e.g. group-contribution methods or quantum mechanic calculations) the exchange on desired fuel properties and possible fuel production pathways between chemists, biologists, chemical engineers and combustion engineers is enabled and facilitated. Hence, in the CIF new fuel components are invented and their possible production routes and combustion properties can be predicted with the developed models.
IRF-A: From Biomass to Biofuels

Who works in this field?
The Integrated Research Field “From Biomass to Biofuels” focuses on the complete transformation from biomass via platform molecules to biofuels. Therefore, the research groups of the chemical, biological and process engineering sciences found the core of this column of TMFB.

What is it about?
The IRF-A addresses the conversion of lignocellulosic biomass to tailor-made fuels via selective chemical and bio-chemical transformation processes. This research domain develops fundamental scientific understanding and methodological innovations in the field of selective biomass conversion in a highly interdisciplinary approach. The described scientific pathway starts with the analysis of the biomass fractionation with specifically designed solvents (like e.g. Ionic Liquids) and continues with the (bio-)catalytical transformation of the cellulosic and hemicellulosic biomass components into platform molecules and finally into fuels. In parallel, the conversion of lignin into biofuel compounds is investigated in a dedicated subgroup. In order to make the findings of the specific subproject work accessible for larger scale processes, two further subgroups investigate the multi-phase integration of numerous processes and combine selected promising steps in a so called “Reference Process”.

[Diagram of biomass to biofuels conversion]
IRF-B:
From Biofuels to Propulsion

Who works in this field?
In the Integrated Research Field „From Biofuels to Propulsion“ all aspects associated with the combustion of tailor-made biofuels are investigated mainly by the research groups from the mechanical engineering faculty.

What is it about?
The main aim of the work within the IRF-B is to describe and understand all properties of the new biofuels in order to modify and define desired fuel properties for an efficient and clean combustion.

New biofuels differ notably from the well-known especially with regard to their interaction with the environment. This applies for the spray break up and evaporation when the fuel comes in contact with the air but also when it interacts with the combustion system’s material like the injection system. Finally, the physical and chemical phenomena describing the ignition, combustion and emission formation of the fuels alter significantly. All these characteristics are thoroughly investigated in the IRF-B.
Major Accomplishments
of TMFB since 2007

In the course of the research activities within the Cluster of Excellence “Tailor-Made Fuels from Biomass” numerous scientific challenges could be solved by the chosen interdisciplinary research approach.

• The Fuel Design Process was established as envisioned before the start of the research activities. Uniquely worldwide, chemists, chemical- and process engineers as well as combustion scientists exchange on a regular basis and develop and investigate new fuel components together instead of isolated from each other.

• Several tailor-made fuels, for which neither the production nor the engine application had been investigated before, were described and developed.

• New (bio-)catalytic processes and methods, which allow an ecologically reasonable and very efficient conversion from biomass to fuel, were developed.

• Promising results of experiments based on the fuels developed in the CoE were achieved: 1. The tailor-made fuel 2-MTHF (2-Methyltetrahydrofuran) enables a nearly soot-free combustion in the Diesel engine 2. The tailor-made fuel 2-MF (2-Methylfuran) is more knock-resistant than standard gasoline and therefore allows efficiency improvements of about 10%.

**Engine speed = 2000 l/min**

- Conventional gasoline, $r_C = 8.5$
- TMFB: 2-methylfurane, $r_C = 12$

**Smoke Number / FSN**

<table>
<thead>
<tr>
<th>Load / %</th>
<th>0</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind. Efficiency / %</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

**NO$_X$-Emissions / g/kWh**

<table>
<thead>
<tr>
<th>Load / %</th>
<th>0.0</th>
<th>0.4</th>
<th>0.8</th>
<th>1.2</th>
<th>1.6</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke Number / FSN</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
</tr>
</tbody>
</table>

- Diesel
- 2-MTHF

$n=2280$ rpm; IMEP=9.4 bar
Future Challenges

The results accomplished since 2007 are very promising and constitute a great motivation for the challenges that lie ahead of the people within TMFB: In the next years, the researchers will seek to strengthen and optimize the whole process chain from biomass to combustion of the biofuel. To achieve this, the cluster researchers will increasingly work systematically, i.e. with a broad data basis and enhanced models, to search for particularly suitable molecules. In the long run, the cluster activities aim at technologies that will work in an industrial scale and still be affordable. The scale-up of the so far achieved results therefore is a challenge for the research in the Cluster of Excellence.

Cluster Management and Scientific and Industrial Support of TMFB

The central supervisory board of TMFB is the Steering Committee, which determines and monitors the scientific and supplementary cluster activities in its monthly meetings. It is directed by the Cluster Coordinator, Stefan Pischinger, who is in charge of the scientific, technical, financial, legal and administrative coordination.

The Cluster Office is the central point of contact for all internal and external inquiries. The Chief Operating Officer, Chief Financial Officer and Cooperation and Supplementary Activities Manager are responsible for matters of organization, research management and development of human resources as well as interdisciplinary cooperation.

The Cluster of Excellence TMFB receives feedback from a high profile international scientific and industrial advisory board. This way, the high quality of the research as well as the industrial applicability are ensured.
Scientific Advisors

Yale
Yale University
R. Anastas
Center of Green Chemistry and Engineering

The University of Nottingham
M. Poliaikoff
Chemistry

Universidad de Valencia
A. Corma
Chemistry

CatchBio
B. Weckhuysen
Inorganic Chemistry and Catalysis

DTU
Techn. -Univ. of Denmark
J. Förster
Biology Science

Techn. -Univ. of Denmark
R. Gani
Chemical Engineering

Massachusetts Inst. of Techn.
G. Stephanopoulos
Biotechnology and Chemical Engineering

Univ. Wisconsin-Madison
J. A. Dumesic
Chemical and Biological Engineering

University of California
C. K. Westbrook
Combustion Chemistry

Energy Biosc. Institute
A. Bell
Chemical Engineering

Princeton University
E. L. Dryer
Combustion Science

University of Notre Dame
J. E. Brennecke
Chemical Engineering

Industrial Advisors

Lurgi
L. Plass
Director Technology

A. Schamel
Chief Technical Officer
Ford Europe

O. Storz
Head of Injection Systems & Operating Fluids

J.W. Gosselink
Regional Manager
Biodomain

DEHEMA
K. Wagemann
Executive Director

VDA
A. Röj
Head of the Fuels and Lubricants Group

Evonik
T. Haas
Director Macromolecular Chemistry

DAIMLER
A. Schamel
Chief Technical Officer

VOLKSWAGEN
T. Lösche-ter Horst
Director Group Research Powertain

W. Warnecke
Head of Global Fuel Development

Bayer Technology Services
L. Mieczko
V.P., Key Expert

BRW
Volvo

BP
R. Sauermann
Director BP Global Fuels Technology

University of California
J. F. Brennecke
Chemical Engineering

Energy Biosc. Institute
A. Bell
Chemical Engineering

Princeton University
E. L. Dryer
Combustion Science

University of Notre Dame
J. E. Brennecke
Chemical Engineering

Massachusetts Inst. of Techn.
G. Stephanopoulos
Biotechnology and Chemical Engineering

Univ. Wisconsin-Madison
J. A. Dumesic
Chemical and Biological Engineering

University of California
C. K. Westbrook
Combustion Chemistry

Energy Biosc. Institute
A. Bell
Chemical Engineering

Princeton University
E. L. Dryer
Combustion Science

University of Notre Dame
J. E. Brennecke
Chemical Engineering

Scientific Advisors

Yale
Yale University
R. Anastas
Center of Green Chemistry and Engineering

The University of Nottingham
M. Poliaikoff
Chemistry

Universidad de Valencia
A. Corma
Chemistry

CatchBio
B. Weckhuysen
Inorganic Chemistry and Catalysis

DTU
Techn. -Univ. of Denmark
J. Förster
Biology Science

Techn. -Univ. of Denmark
R. Gani
Chemical Engineering

Massachusetts Inst. of Techn.
G. Stephanopoulos
Biotechnology and Chemical Engineering

Univ. Wisconsin-Madison
J. A. Dumesic
Chemical and Biological Engineering

University of California
C. K. Westbrook
Combustion Chemistry

Energy Biosc. Institute
A. Bell
Chemical Engineering

Princeton University
E. L. Dryer
Combustion Science

University of Notre Dame
J. E. Brennecke
Chemical Engineering

Industrial Advisors

Lurgi
L. Plass
Director Technology

A. Schamel
Chief Technical Officer
Ford Europe

O. Storz
Head of Injection Systems & Operating Fluids

J.W. Gosselink
Regional Manager
Biodomain

DEHEMA
K. Wagemann
Executive Director

VDA
A. Röj
Head of the Fuels and Lubricants Group

Evonik
T. Haas
Director Macromolecular Chemistry

DAIMLER
A. Schamel
Chief Technical Officer

VOLKSWAGEN
T. Lösche-ter Horst
Director Group Research Powertain

W. Warnecke
Head of Global Fuel Development

Bayer Technology Services
L. Mieczko
V.P., Key Expert

BRW
Volvo

BP
R. Sauermann
Director BP Global Fuels Technology

University of California
J. F. Brennecke
Chemical Engineering

Energy Biosc. Institute
A. Bell
Chemical Engineering

Princeton University
E. L. Dryer
Combustion Science

University of Notre Dame
J. E. Brennecke
Chemical Engineering

Scientific Advisors

Yale
Yale University
R. Anastas
Center of Green Chemistry and Engineering

The University of Nottingham
M. Poliaikoff
Chemistry

Universidad de Valencia
A. Corma
Chemistry

CatchBio
B. Weckhuysen
Inorganic Chemistry and Catalysis

DTU
Techn. -Univ. of Denmark
J. Förster
Biology Science

Techn. -Univ. of Denmark
R. Gani
Chemical Engineering

Massachusetts Inst. of Techn.
G. Stephanopoulos
Biotechnology and Chemical Engineering

Univ. Wisconsin-Madison
J. A. Dumesic
Chemical and Biological Engineering

University of California
C. K. Westbrook
Combustion Chemistry

Energy Biosc. Institute
A. Bell
Chemical Engineering

Princeton University
E. L. Dryer
Combustion Science

University of Notre Dame
J. E. Brennecke
Chemical Engineering

Industrial Advisors

Lurgi
L. Plass
Director Technology

A. Schamel
Chief Technical Officer
Ford Europe

O. Storz
Head of Injection Systems & Operating Fluids

J.W. Gosselink
Regional Manager
Biodomain

DEHEMA
K. Wagemann
Executive Director

VDA
A. Röj
Head of the Fuels and Lubricants Group

Evonik
T. Haas
Director Macromolecular Chemistry

DAIMLER
A. Schamel
Chief Technical Officer

VOLKSWAGEN
T. Lösche-ter Horst
Director Group Research Powertain

W. Warnecke
Head of Global Fuel Development

Bayer Technology Services
L. Mieczko
V.P., Key Expert

BRW
Volvo

BP
R. Sauermann
Director BP Global Fuels Technology

University of California
J. F. Brennecke
Chemical Engineering

Energy Biosc. Institute
A. Bell
Chemical Engineering

Princeton University
E. L. Dryer
Combustion Science

University of Notre Dame
J. E. Brennecke
Chemical Engineering
Additional Activities and Public Outreach

01

TMFB Seminar
Each semester, the Cluster Office organizes a seminar series to which speakers from industry and relevant fields of science are invited. This way, direct scientific exchange is enabled and students and PhD students get to know different fields of application for TMFB research.

02

TMFB Internal Colloquia
In order to enhance the interdisciplinary exchange and support the education of the PhD students within TMFB, an internal TMFB colloquium series was created which covers all disciplines involved in the Cluster of Excellence. The lectures explain the fundamentals of each scientific field especially to those members who are not familiar with one specific discipline.
**03**

**Website**

The TMFB website provides comprehensive information on all matters concerning contact persons, events, publications, vacancies and links to research partners.

[www.fuelcenter.rwth-aachen.de](http://www.fuelcenter.rwth-aachen.de)

---

**04**

**Facebook Page**

On the TMFB Facebook Page, up-to-date information as well as interesting links and photos that give insight in the work and social activities of the Cluster of Excellence are published.

[www.facebook.com/tailormadefuelsfrombiomass](http://www.facebook.com/tailormadefuelsfrombiomass)

---

**05**

**TMFB International Conference**

Since 2008, the Cluster of Excellence used its “International Workshop” as a platform for the exchange of TMFB Members with external researchers. In 2013, the conference’s stage was opened and for the first time more than half of the 40 speakers visited from external institutions. The program of the annual International Conference includes lectures from invited speakers and researchers from inside and outside the Cluster of Excellence, a poster session, where young researchers from different scientific disciplines are able to present and discuss their work, and a supporting program for the purpose of networking.
Research Groups
of TMFB

Jr.-Prof. Dr. rer.nat. M. Agler-Rosenbaum
Junior Professorship for Microbial Electrocatalysis
www.iamb.rwth-aachen.de

Prof. Dr.-Ing. A. Bardow
Technical Thermodynamics (LTT)
www.ltt.rwth-aachen.de

Prof. Dr.-Ing. L. Blank
Institute of Applied Microbiology (iAMB)
www.iamb.rwth-aachen.de

Prof. Dr.rer.nat. C. Bolm
Institute for Organic Chemistry (IOC)
www.oc.rwth-aachen.de

Prof. Dr.-Ing. J. Büchs
Aachen Chemical Engineering – Biochemical Engineering (AVT.BioVT)
www.avt.rwth-aachen.de

Prof. Dr.rer.nat R. Fischer
Fraunhofer Institute for Molecular Biology and Applied Ecology (FhG)
www.ime.fraunhofer.de

Prof. Dr.rer.nat. G. Grünefeld
Institute for Laser-Diagnostics in Thermo-Dynamics (LTFD)
www.ltfd.rwth-aachen.de

Jr.-Prof. Dr.-Ing. A. Heufer
Physico Chemical Fundamentals of Combustion (PCFC)
www.pcfc.rwth-aachen.de

Prof. Dr.rer.nat. H. Hollert
Department of Ecosystem Analysis (ESA)
www.bio5.rwth-aachen.de

apl. Prof. Dr. phil. I. Isenhardt
Centre for Learning and Knowledge Management / Institute of Computer Science in Mechanical Engineering (IMA/ZLW & IfU)
www.ima-zlw-ifu.rwth-aachen.de

Prof. Dr.-Ing. A. Jupke
Aachen Chemical Engineering – Fluid Separation Processes (AVTFVT)
www.avt.rwth-aachen.de

Prof. Dr.rer.nat. J. Klankermayer
Junior Professorship for Mechanisms in Catalysis (MiC)
www.tc.rwth-aachen.de

Prof. Dr.-Ing. R. Kneer
Institute of Heat and Mass Transfer (WSA)
www.wsa.rwth-aachen.de

Prof. Dr.rer.nat. W. Leitner
Institute of Technical Chemistry and Macromolecular Chemistry (ITMC)
Chair of Technical Chemistry and Petrochemistry
www.itmc.rwth-aachen.de

Jr.-Prof. Dr.rer.nat. K. Leonhard
Junior Professorship for Model-Based Fuel Design (MBFD)
www.ltt.rwth-aachen.de/forschung/model_based_fuel_design

Prof. Dr.rer.nat. M. Liauw
Institute of Technical Chemistry and Macromolecular Chemistry (ITMC)
Chair of Industrial Chemistry
www.itmc.rwth-aachen.de

Prof. A. Mitsos, Ph.D.
Aachen Chemical Engineering – Process Systems Engineering (AVT.PT)
Center for Computational Engineering Science (CCES)
www.avt.rwth-aachen.de
www.cces.rwth-aachen.de

Prof. Dr.-Ing. H. Murrenhoff
Max-Planck-Institute für Kohlenforschung, Mülheim (MPI)
www.mpi-muelheim.mpg.de/kofo/

Prof. Dr.rer.nat. E Schüth
Institute of Biotechnology (Biotec)
www.biotec.rwth-aachen.de

Prof. Dr.-Ing. M. Wessling
Aachen Chemical Engineering – Chemical Process Engineering (AVT.CVT)
www.avt.rwth-aachen.de

Prof. Dr. rer. nat. J. Okuda
Institute of Inorganic Chemistry (IAC)
www.ac.rwth-aachen.de

Prof. Dr.rer.nat. R. Palkovits
Institute of Technical Chemistry and Macromolecular Chemistry (ITMC)
Chair of Nanostructured Catalysts
www.itmc.rwth-aachen.de

Prof. Dr.-Ing. S. Pischinger
Institute for Combustion Engines (VKA)
www.vka.rwth-aachen.de

Prof. Dr.-Ing. H. Pitsch
Institute for Combustion Technology (ITV)
www.itv.rwth-aachen.de

Prof. Dr.-Ing. W. Schröder
Institute of Aerodynamics (AIA)
www.aia.rwth-aachen.de

Prof. Dr.rer.nat. U. Schwaneberg
Institute of Biotechnology (Biotec)
www.biotec.rwth-aachen.de

Prof. Dr.-Ing. M. Wessling
Aachen Chemical Engineering – Chemical Process Engineering (AVT.CVT)
www.avt.rwth-aachen.de
Tailor-Made Fuels from Biomass

**Contact Details:**
Fuel Design Center
RWTH Aachen University
Schinkelstr. 8
52062 Aachen, Germany
exc@vka.rwth-aachen.de
www.fuelcenter.rwth-aachen.de
Tel.: +49 241 80-95352
Fax: +49 241 80-92630

The Cluster of Excellence TMFB is also on Facebook. "Like" our page to get the latest updates, photos and additional information on our research and the cluster in general.

facebook.com/tailormadefuelsfrombiomass