Clean Energy in Vietnam after COP21

Potential for production and application of bio-carbon in Vietnam

Khanh-Quang Tran
Energy and Process Engineering
Norwegian University of Science and Technology
Email: khanh-quang.tran@ntnu.no

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Outline

- Introduction to NTNU
- Technologies for production of bio-carbon
- Main applications of bio-carbon
- Potential in Vietnam
- Concluding remarks

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Trondheim- 3rd largest city in Norway

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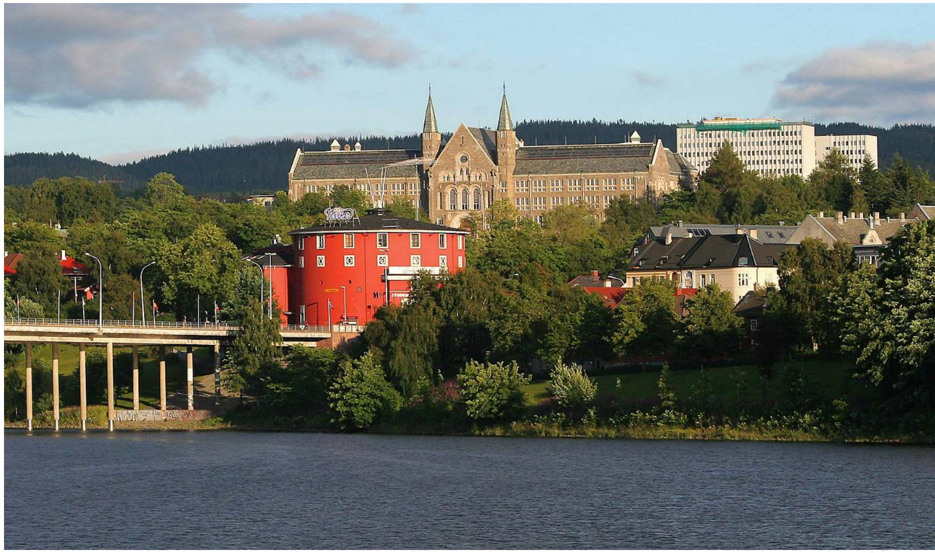
NTNU 2010

- **52** departments in **7** faculties
- **18 432** registered students, **6 726** admitted in 2010
- **2 785** degrees awarded
- **260** doctoral degrees awarded (32 % women)



- **4 935** employments
- **3 075** employed in education and research; **596** full professors
- Budget: **EUR 640 mill.**
- **590 000 m^2** of owned and rented premises

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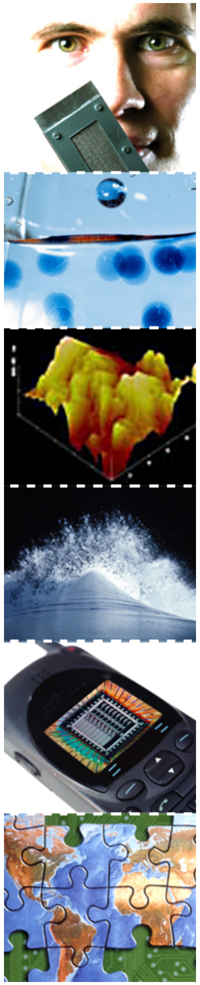
NTNU's six strategic areas

- Energy and Petroleum – Resources and Environment
- Medical Technology
- Materials Technology
- Marine and Maritime Technology
- Information and Communication Technology
- Globalization



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2014 Nobel Prize in Medicine

NTNU neuroscientists May-Britt and Edvard Moser won the 2014 Nobel Prize in Physiology or Medicine for their pioneering work in the field of brain research.

Energy and Process Engineering

- 148 employees within 4 divisions
- 91 Ph.D. students (15 Ph.D. graduate/year)
- 80 – 90 M.Sc. graduating annually
- Several hundred undergraduate students
- Study Programmes: Energy & Environment, Product development and production, Industrial Ecology, ICT in industrial processes
- In co-operation with SINTEF, the Department execute several hundred projects each year. External project activities: 114 MNOK per year:
  - NTNU 45 MNOK
  - SINTEF 79 MNOK

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Four divisions

- THERMAL ENERGY
- INDUSTRIAL PROCESS TECHNOLOGY
- ENERGY AND INDOOR ENVIRONMENT
- FLUIDS ENGENEERING

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Thermal energy

- Combustion
  - Combustion, including processes and equipment
  - Bio-energy
  - Waste combustion
  - Air pollution and gas cleaning
- Turbo machinery and power generation
  - Thermal turbo machinery, including gas turbines, multiphase- and NG compressors
  - Thermal power cycles including. CO_2 capture
  - High-temperature fuel cells
- LCA and industrial ecology
  - LCA – Life Cycle Analysis
  - Value Chain Analysis
  - Energy and Environment in developing countries
  - Systems engineering

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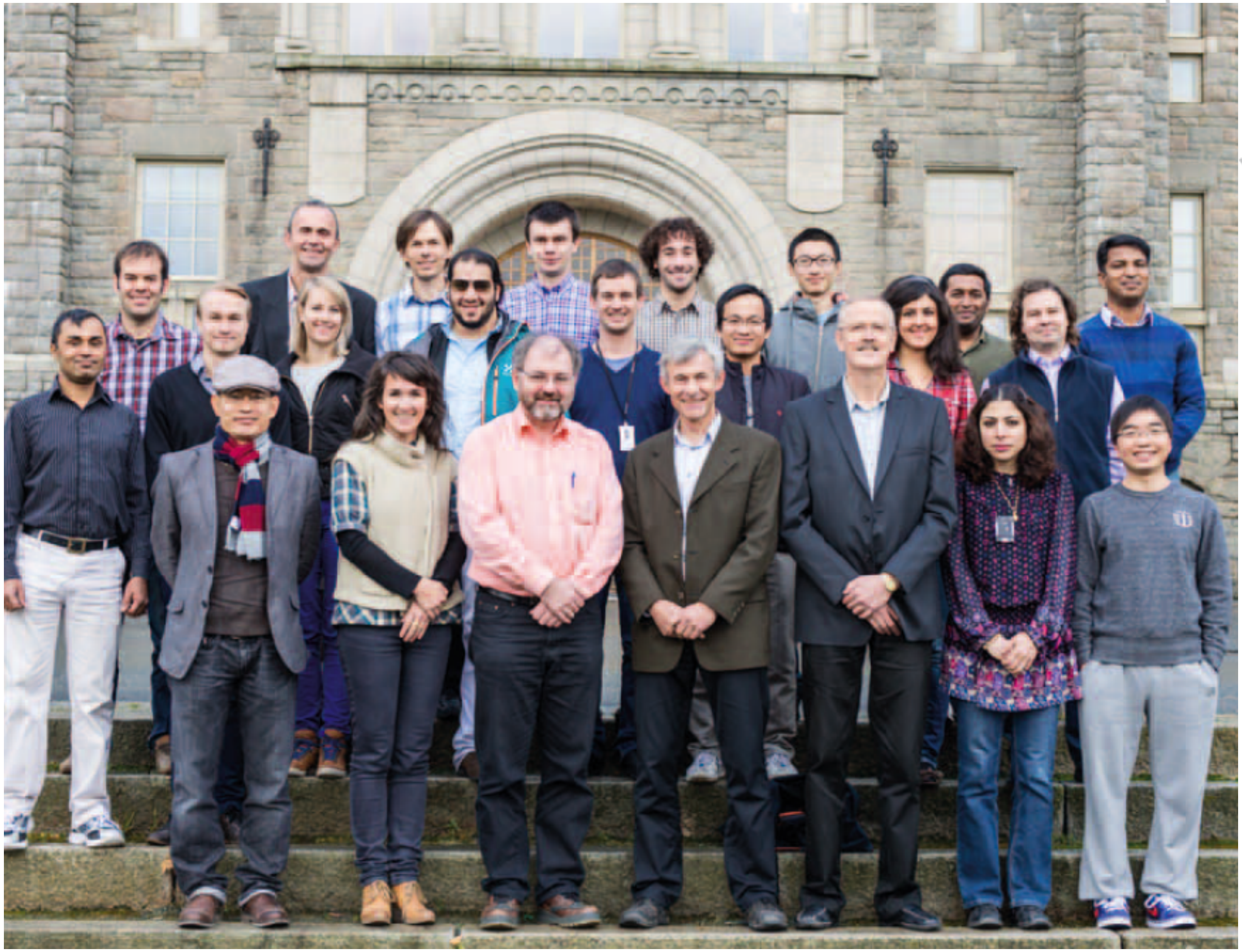
Thermal energy 2012



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2007 Nobel Peace Prize

Olav Bolland

From Wikipedia, the free encyclopedia

Olav Bolland (born 17 January 1962) is a Norwegian researcher and Professor in Energy and Process Engineering. His specialization is in thermal power generation, carbon capture and storage, particle technology and drying. He has been Head of the Department of Energy and Process Engineering [1] at the Norwegian University of Science and Technology – NTNU since 2009.

Olav Bolland	
	
Born	January 17, 1962 (age 53) Norway Ler
Nationality	Norwegian
Occupation	Head of Department of Energy and Process Engineering at the Norwegian University of Science and Technology Professor in Energy and Process Engineering
Children	3

Career [edit]

Professor Bolland completed his MSc and PhD degrees in Mechanical Engineering at the Norwegian Institute of Technology (NTH), one of the precursors of the Norwegian University of Science and Technology - NTNU. From 1990 he was Associate Professor at NTNU until he was appointed Professor in 2002 at the Department of Energy and Process Engineering.

In 2003–2005 he contributed to the IPCC reports, the institution which was awarded the 2007 Nobel Peace Prize.[2] Professor Bolland was a lead author for the IPCC Special report on Carbon Dioxide Capture and Storage.[3]

He was director of the Gas Technology Centre NTNU-SINTEF[4] from 2008 to 2009. He was Associate Editor of the *International Journal of Greenhouse Gas Control* in the period 2006 to 2013.

Olav Bolland is a fellow of the Norwegian Academy of Technological Sciences.[5]

Awards [edit]

In 2011, Olav Bolland was awarded the Statoil Annual Award for Outstanding Research for his work on enhancing carbon capture understanding and processes for reducing emissions.[6]

References [edit]

1. ^ Website of the Department of Energy and Process Engineering
2. ^ NTNUs fredsprisvinner (Universitetsavisa 16.10.2007) (In Norwegian)
3. ^ The IPCC Special report
4. ^ [1] the Gas Technology Centre NTNU-SINTEF
5. ^ List of Norwegian Academy of Technological Sciences' members living in Norway (in Norwegian)
6. ^ Anti-pollution efforts rewarded with research prize (Statoil.com 11.05.2011)

In 2007 Prof. Olav Bolland was among the IPCC scientists researching climate change issues to receive the Nobel Peace Prize

Centres for Environment-Friendly Energy Research

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Top-level R&D groups cooperating with innovative industr
Established by the Research Council of Norway (2009)

FME Centre hosted by NTNU:

- **Research Centre on Zero Emission Buildings – ZEB**

FME Centres with NTNU as active partner:

- **BIGCCS – International CCS Research Centre**
- **Centre for Environmental Design of Renewable Energy (CEDREN)**
- **Bioenergy Innovation Centre (CenBio)**
- **Research Centre for Offshore Wind Technology**
- **The Norwegian Research Centre for Solar Cell Technology**

Duration: 2009–2017, based on evaluations

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CenBio overview

CenBio host institution: UMB
CenBio lead: SINTEF

Management and coordination SP0/SINTEF

Biomass supply and residue utilization SP1/UMB

- Feedstock supply WP1.1
- Logistics WP1.2
- Biomass and residue characteristics and quality WP1.3
- Residues upgrading and use WP1.4

Conversion mechanisms SP2/SINTEF

- Combustion WP2.1
- Gasification WP2.2
- Pyrolysis WP2.3
- Anaerobic digestion WP2.4
- KMB STOP: Torrefaction WP2.5

Conversion technologies and emissions SP3/SINTEF

- Small-scale WP3.1
- District heat WP3.2
- Heat and power WP3.3
- Emissions WP3.4

Knowledge transfer and innovation SP5/NTNU

- Bioenergy graduate school WP5.1
- Knowledge transfer and dissemination WP5.2
- Innovation management WP5.3

Sustainability assessments SP4/UMB

- Life cycle assessment (LCA) WP4.1
- Ecosystem management WP4.2
- Cost assessment and market analysis WP4.3

Bio-energy graduate school

CenBio

Bioenergy Innovation Centre

You are here: CENBIO_UK / **Graduate School**

- News
- Partners
- Project Overview
- Graduate School
- Publications
- Links
- Contact info
- Internal pages

Graduate School

Education is a corner stone of CenBio. This key aspect has been structured into the Bioenergy Graduate School (WP5.1) under the supervision of NTNU and UMB.

Post-Doc., PhD students and Master students will graduate and therewith contribute to the writing of scientific publications and the development of innovations all along the life of the Centre. Research areas will cover all fields relevant to CenBio (thermal conversion, biomass supply, emissions, etc).

The Bioenergy Graduate School will, at any time during the duration of CenBio, consist of 10-12 PhD students, 8-10 Master students (per year) and their supervisors with coordinated research and training activities. The activities of the Graduate School will, whenever possible, be open to students from other institutions.

The activities of the Graduate School will include: study and research visits, intensive courses, seminars and information sharing.

Contact Ottar Michelsen for more information.

Courses

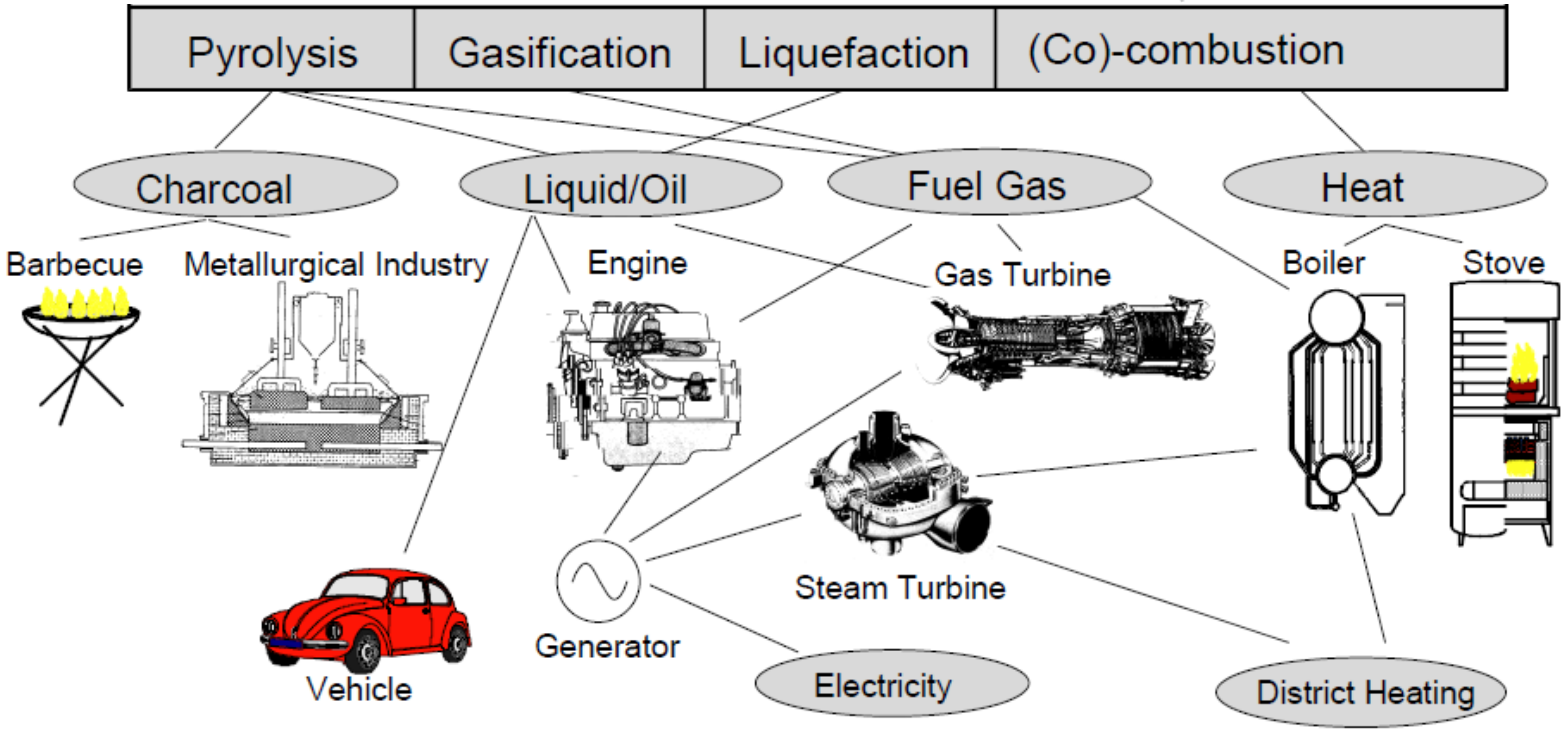
The Bioenergy Graduate School distributes information on relevant courses in bioenergy, both at NTNU and UMB, as well as relevant courses elsewhere.

Master level

- Bioenergy (NTNU)
- Bioenergy (UMB)
- Nordic Forestry and Forest Research (UMB)

http://www.sintef.no/Projectweb/CENBIO/Graduate-School/

Thermochemical conversion technologies



Source: IEA Bioenergy

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Bio-carbon and its main applications

- Fuels for heat and power generation
- Agricultural fertilizer for soil conditioning
- Carbon sequestration
- Activated carbon
- Reductant in the metallurgical industry

What is pyrolysis

- *Pyrolysis* is thermal decomposition in absence of oxygen, products: gas, liquid, and solid
- *Slow pyrolysis*: low heating rate, producing charcoal or biochar as the main products
- *Fast pyrolysis*: high heating rate, producing bio-oil as main

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Typical product yields* by pyrolysis

Mode	*Conditions*	*Liquid*	*Solid*	*Gas*
Fast	~500 °C, short hot vapor residence time ~1 s	75%	12% char	13%
Intermediate	~500 °C, hot vapor residence time ~10–30 s	50% in 2 phases	25% char	25%
Slow – Torrefaction	~290 °C, solids residence time ~30 min	0% if vapours are burned	80% solid	20%
Slow – Carbonization	~400 °C, long vapor residence hours → days	30%	35% char	35%
Gasification	~750–900 °C	5%	10% char	85%

* = Dry wood basis

Biomass torrefaction

- Is a thermal pre-treatment method to improve fuel properties of biomass
- Synonyms: mild pyrolysis, roasting, wood cooking, and even high temperature drying
- Typical conditions and process parameters
  - In the absence of O_2
  - Temperature window 200 – 300ºC
  - Heating rates < 50 ºC/min
  - Residence time 10 – 30 min

Parameters influencing product quality

- Torrefaction temperature
- Reaction time
- Fuel type
- Hemicelluloses content

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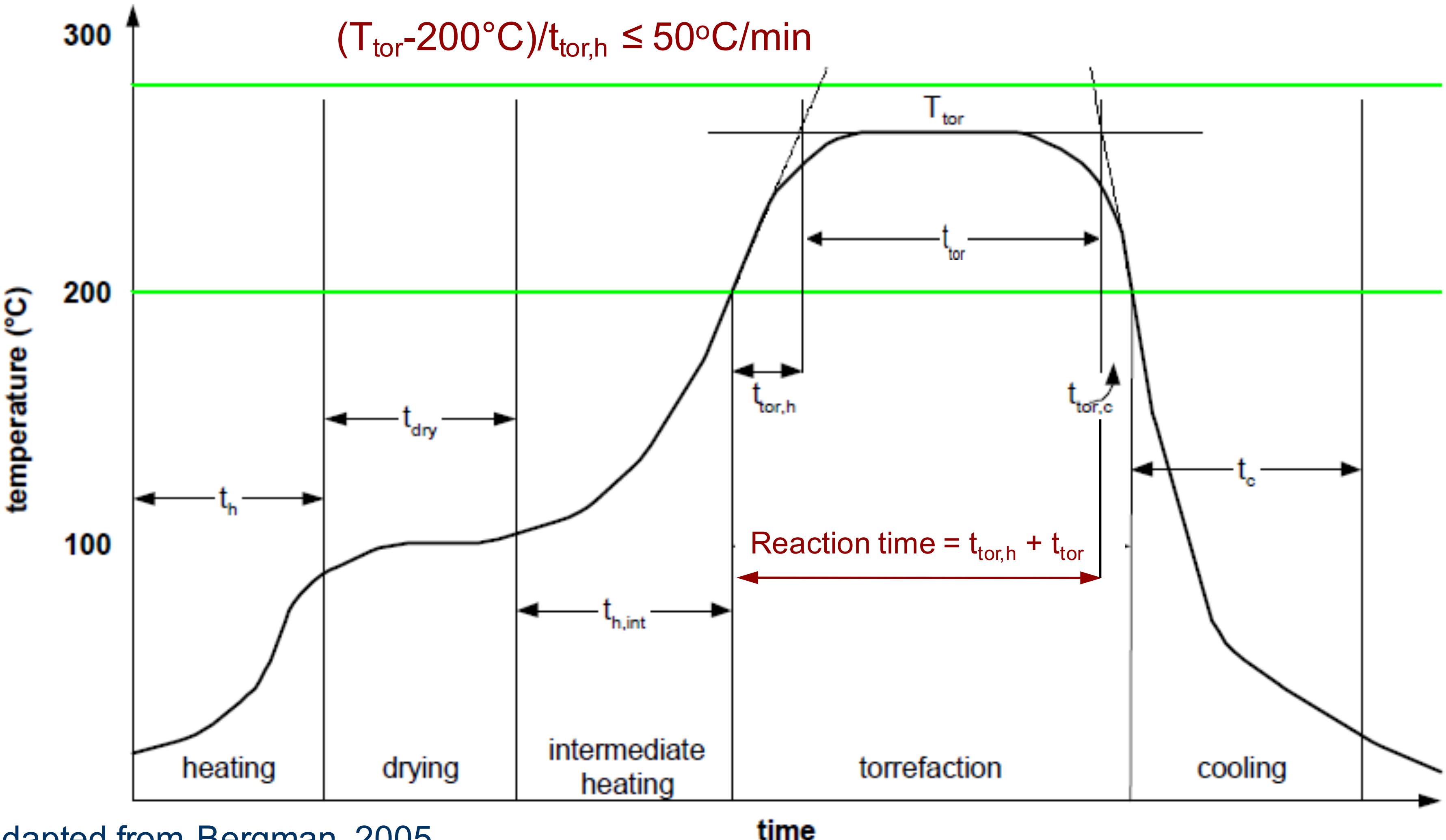
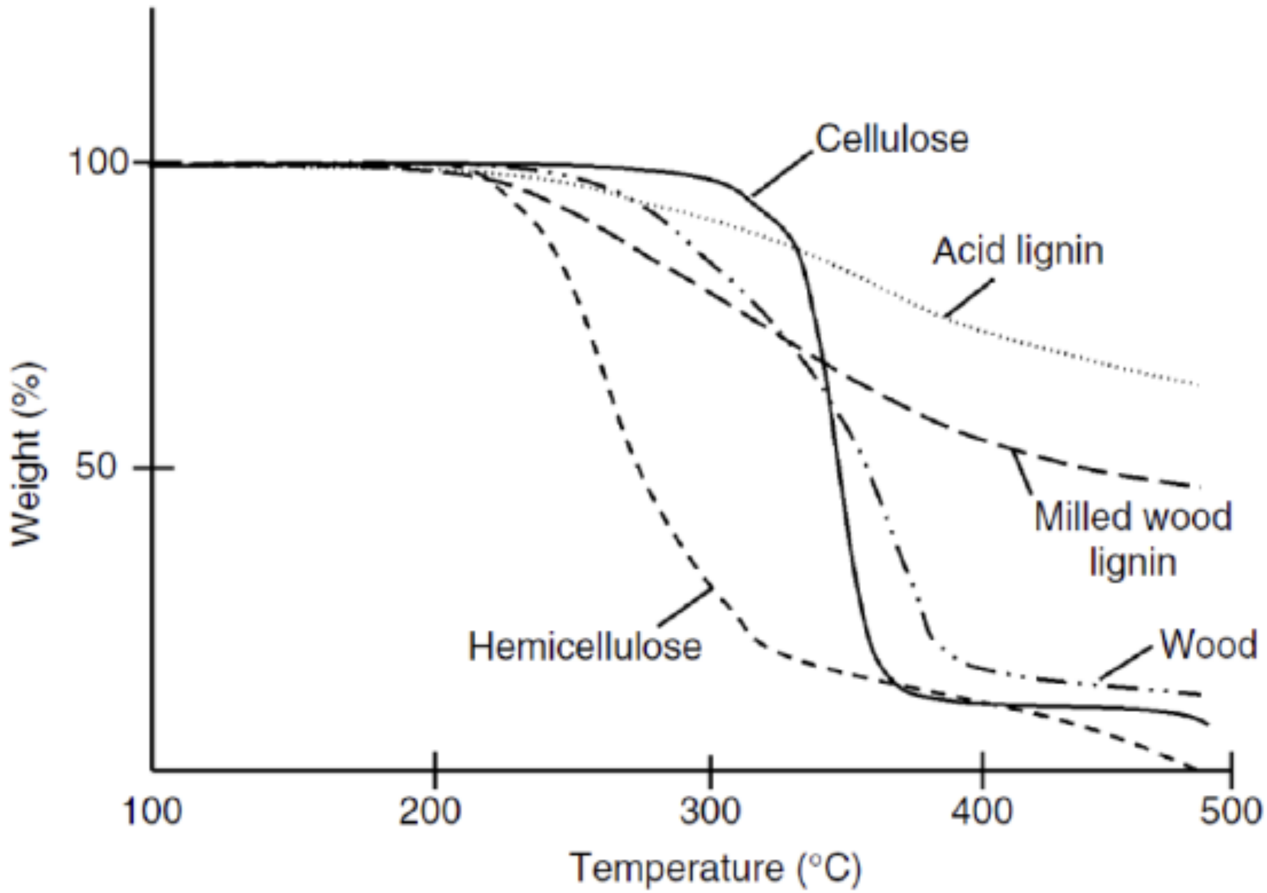
Temperature-time profile of torrefaction



Addapted from Bergman, 2005

TG of lignocellulosic biomass materials



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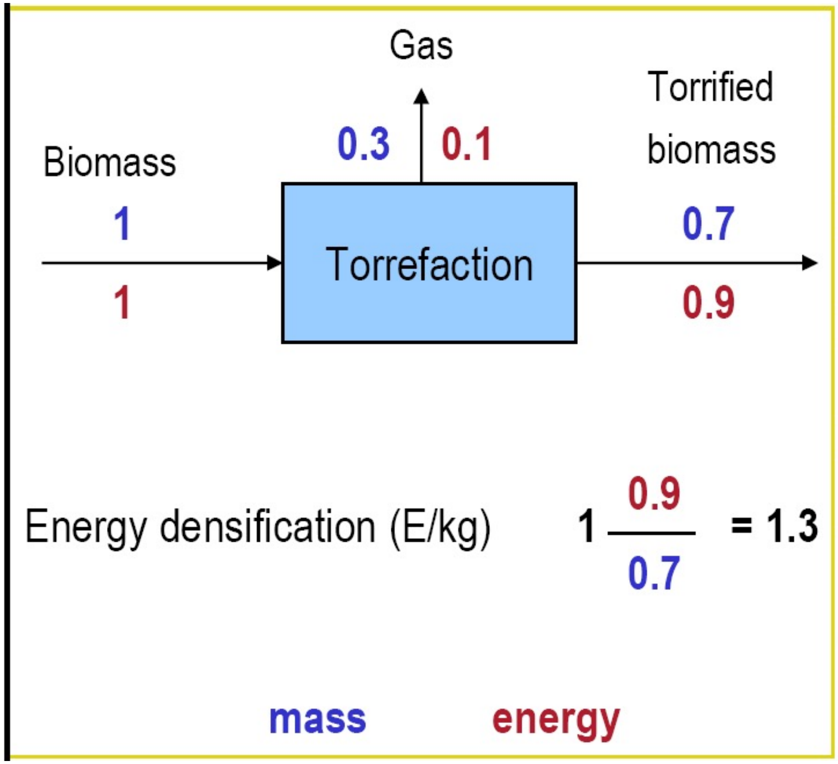
Mass and energy distribution for torrefaction of willow

Table I: *Mass and energy distribution for torrefaction of willow and 280 °C and 17.5 min reaction time [1]*

Reaction products	Mass yield (daf) (%)	Energy yield (LHV, daf) (%)
Solid	87.5	94.9
Lipids	1.40	3.40
Organics	1.70	1.60
Gases	1.40	0.10
Water	8.00	0.00

Mass and energy balance



- Temperature: 200-300 °C
- Pressure: near atmospheric
- Absence of oxygen
- Product: solid fuel
- Particle size < 4 cm thickness
- Residence time 10-30 min
- Heating rate: <50 °C/min

Source Kiel, 2007

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Van Krevelen diagram for torrefied biomass

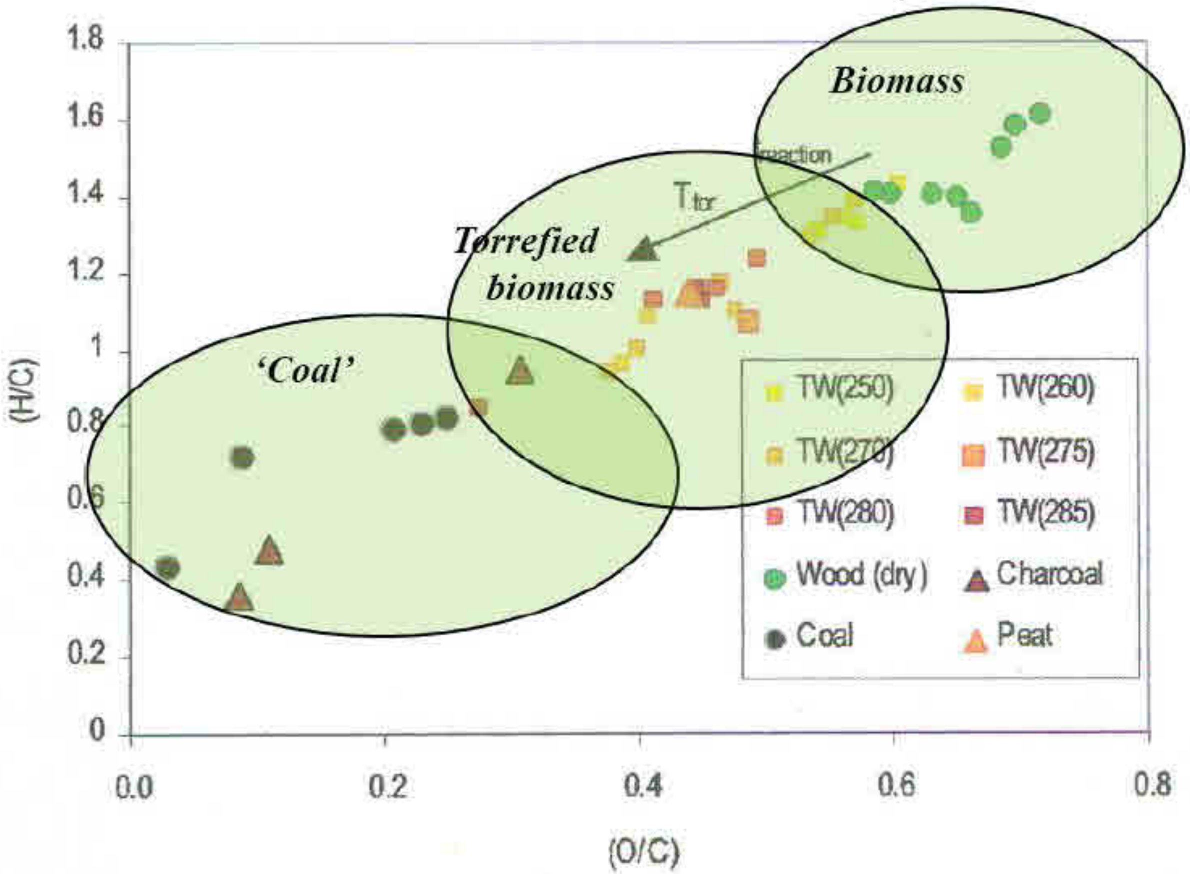

Figure 2.6 *Van Krevelen diagram for torrefied wood (TW) produced at different conditions, untreated wood, coal, charcoal and peat samples. Coal and peat data is taken from Ullmann (1999). Wood and torrefied wood from Bourgois and Doat (1984), Girard and Shah (1989) and Pentananunt et al. (1990)*

Source: Prins,2006

Evaluation of torrefied pellets (TOP)

Properties	unit	Wood	Torrefied biomass	Wood pellets		TOP pellets	
				low	high	low	high
Moisture content	% wt.	35%	3%	10%	7%	5%	1%
Calorific value (LHV)							
as received	MJ/kg	10,5	19,9	15,6	16,2	19,9	21,6
Mass density (bulk)	kg/m^3	550	230	500	650	750	850
Energy density (bulk)	GJ/m^3	5,8	4,6	7,8	10,5	14,9	18,4
Pellet strength		-	-		good		very good
Dust formation		moderate	high		limited		limited
Hygroscopic nature		water uptake	hydrofobic		swelling / water uptake		poor swelling / hydrofobic
Biological degradation		possible	impossible		possible		impossible
Seasonal influences (noticable for end-user)		high	poor		moderate		poor
Handling properties		normal	normal		good		good

Ref: Bergman (2005)

Conversion of wet plant biomass

- Anaerobic digestion
- Bioethanol production
- **Hydrothermal processing**

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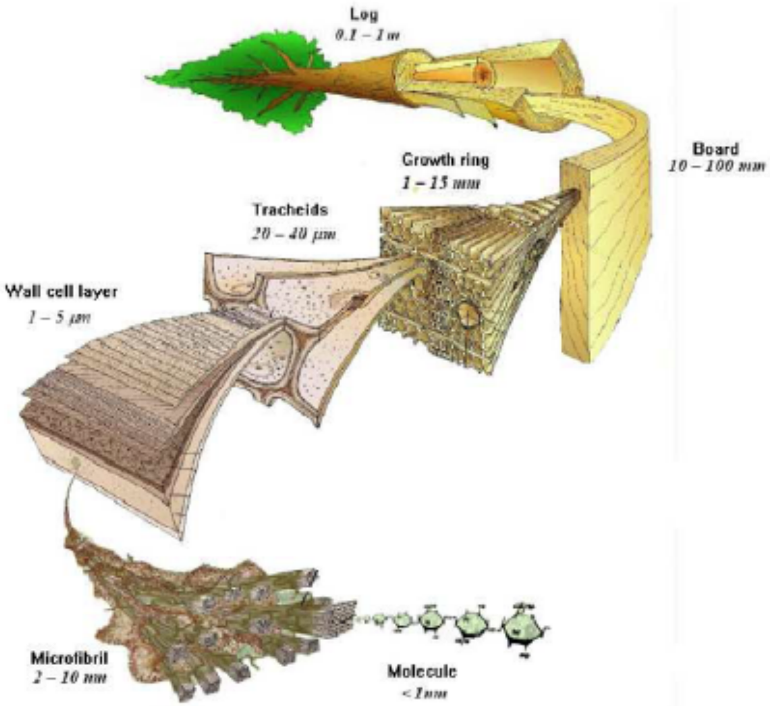
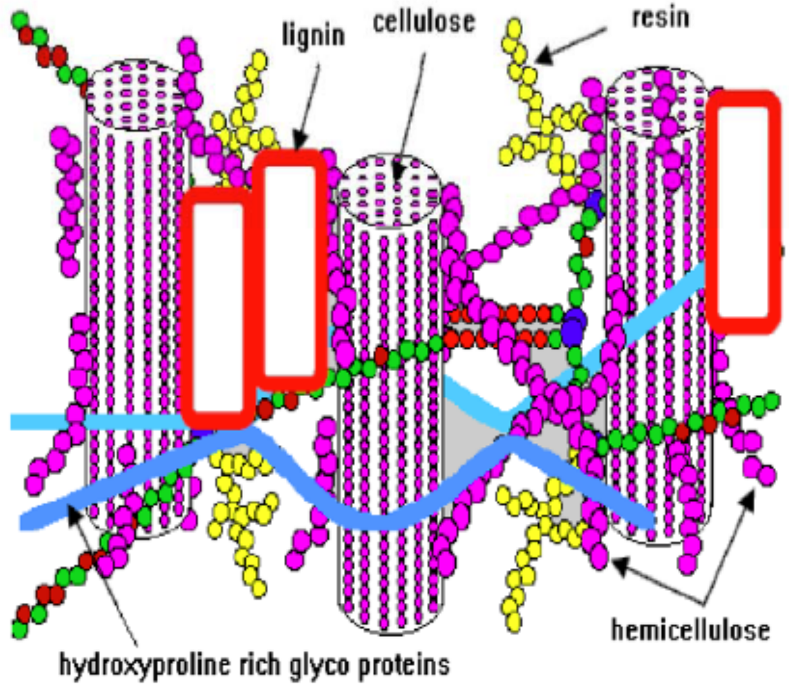
Plant biomass



Wood Physical Structure



Wood Microscopic Structure

Chemical composition of Scandinavian birch, spruce and pine.

	Birch	Spruce	Pine	Pineroot
Cellulose (wt%)	40	44	43	-
Hemicellulose (wt%)	39	27	27	-
Lignin (wt%)	21	29	30	-
Extractives (wt%)	3	2	5	20

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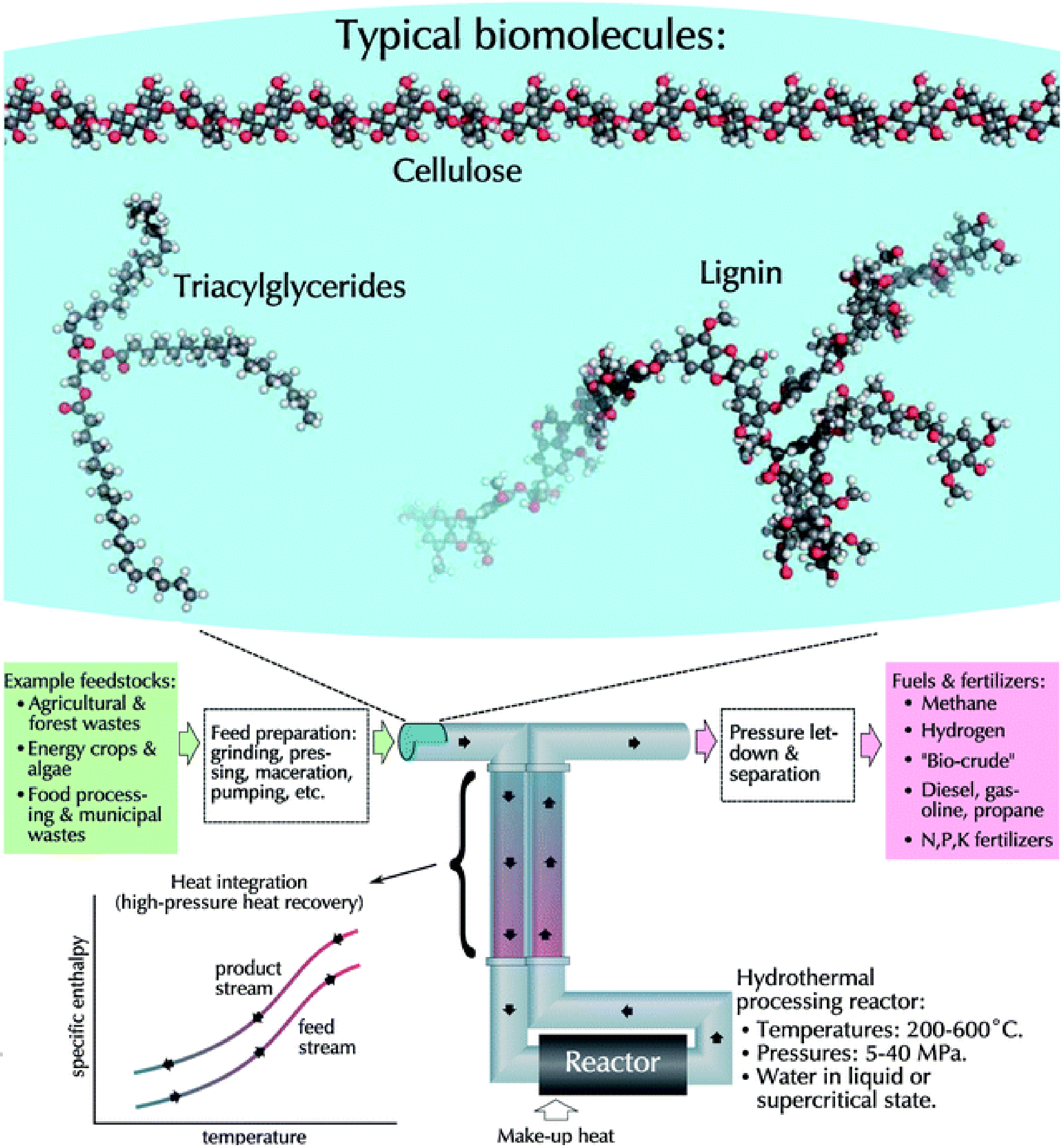
Hydrothermal processing of biomass - Overview



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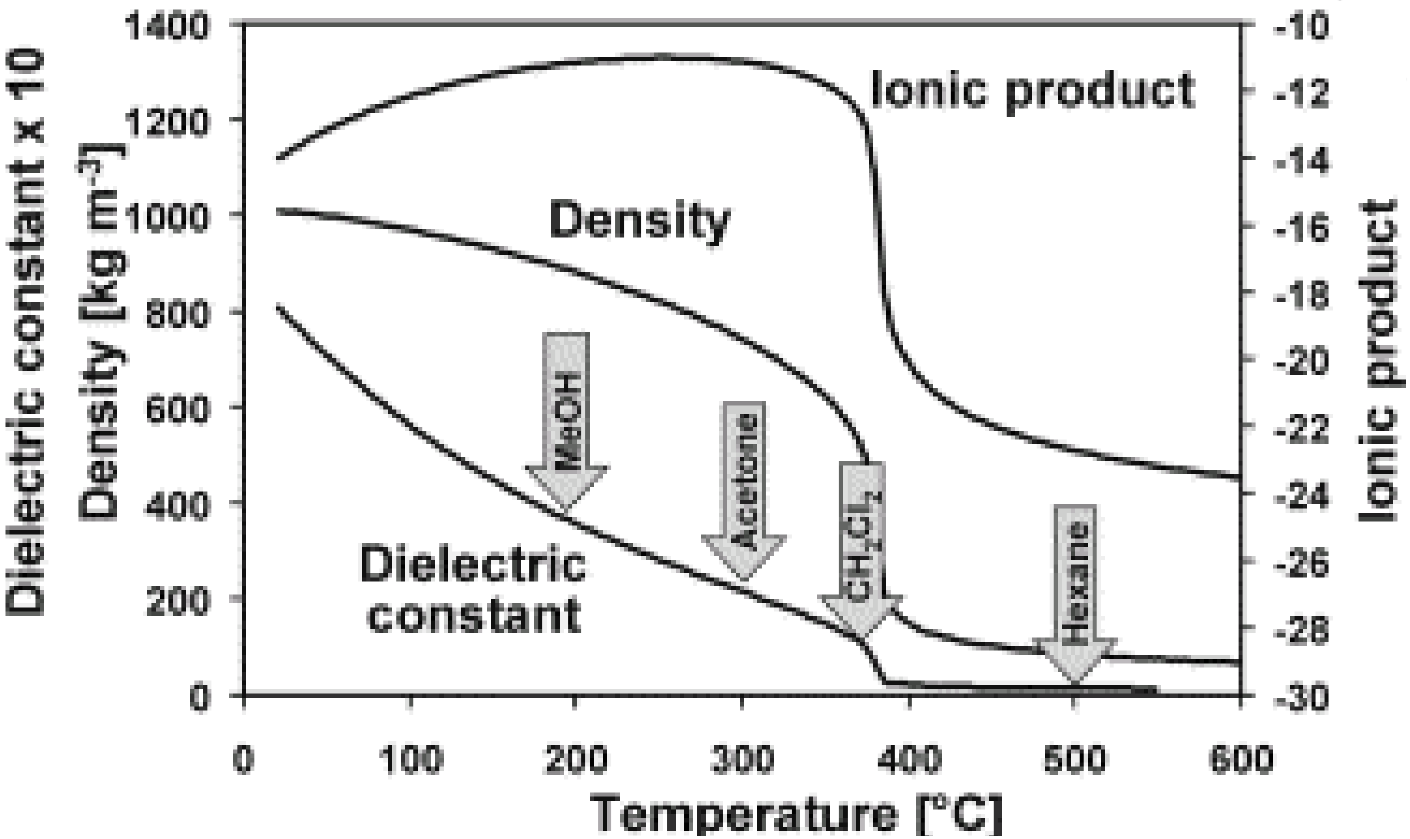
Properties of hot compressed water



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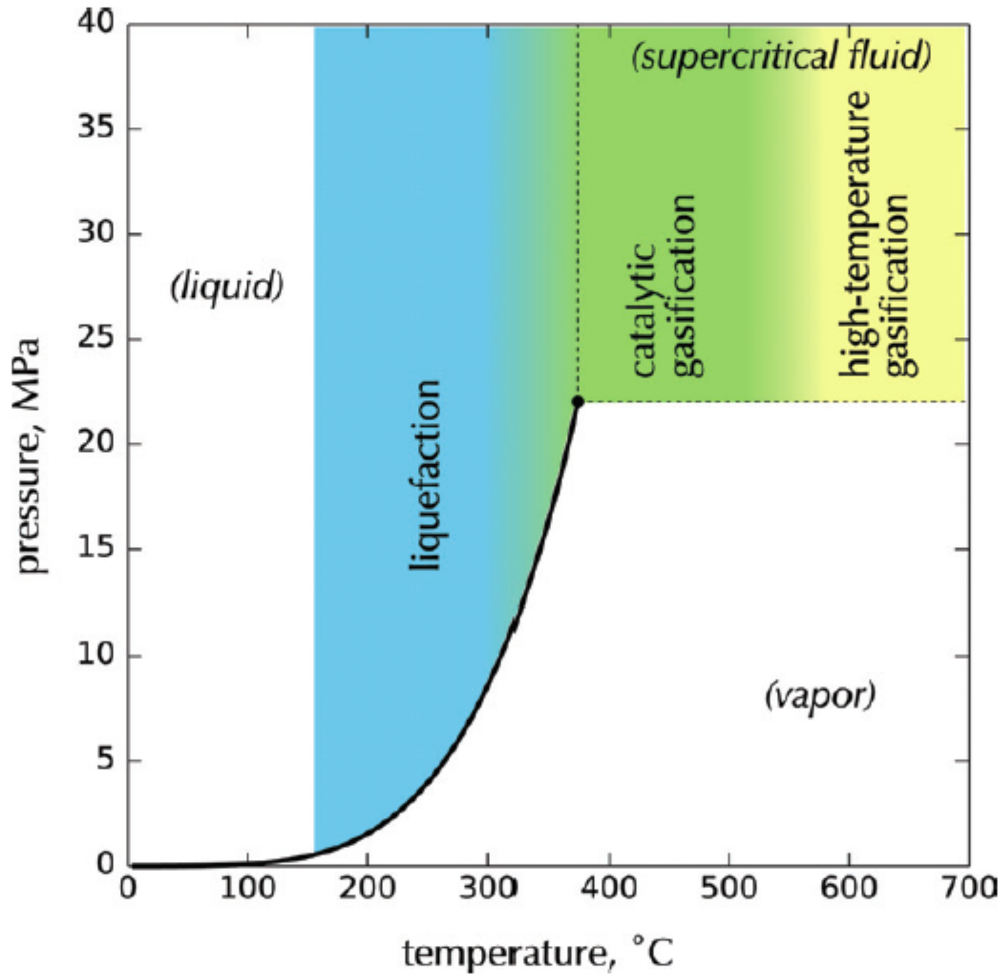
Hydrothermal processing regions



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HTC or wet torrefaction

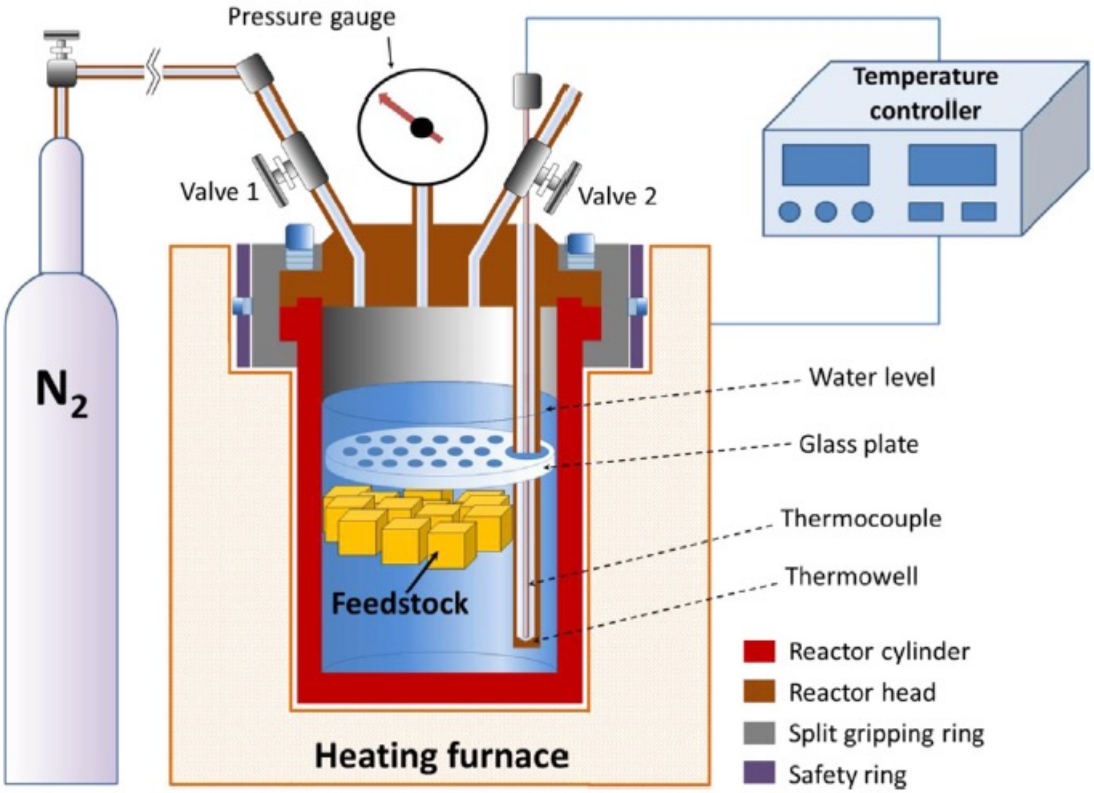

Fig. 1. A batch reactor setup for WT at laboratory scale (adopted from [20]).

T window: 180-300°C

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Agricultural residues in Vietnam

	Rice straw	**Rice husk**	**Bagasse**	**Corncob**	**Cassava pulp**	**Molasses**
Capacity	**15 million tons/year**	**6.7 million tons/year**	3.1 million tons/year	3.1 million tons/year	*0.59 million tons/year*	*0.54 million tons/year*
Stability	**Long-term stability, (3 crops/year)**	**Long-term stability (whole year) based on the milling plant.**	Seasonal stability (from Sep. to March of next year)	Seasonal stability (from August to April of next year)	*Seasonal stability (from August to April of next year)*	Seasonal stability (from Sep. to March of next year)
Concent-ration	**Concentrated on national granaries, like Mekong river delta (53%), Hong river delta (18%)**	**Concentrated on milling plants in areas, like Mekong river delta (53%), Hong river delta (18%)**	Concentrated on sugar plants in the areas, like Central Coast (37%), Mekong river delta (32%), South East (12%).	*Concentrated on households of the areas, like North of Midland (33%), Highland (24%) and Central Coast (19%)*	Concentrated on cassava-starch plants in the areas, like Central Coast (30%), South East (29%), Highland (25%)	Concentrated on sugar plants. Scattered in the Central Coast (37%), Mekong river delta (32%), South East (12%)
Ability of collection & transpor-tation	**Available collection system in Mekong river delta by waterway**	**Available collection system in Mekong river delta by waterway**	Sugar plants scattered → disadvantage of large quantity collection and high cost.	*Hard to collect due to concentration on households and the sources scattered in many areas.*	Cassava-starch plants scattered → drawback of large quantity collection and high cost	Sugar plants scattered → disadvantage of large quantity collection and high cost
Ability to purchase	**A large amount of rice straw is burned**	A large amount is unused but expect to be used for gasification projects, mainly in Mekong river delta	*Competition with boiler fuel in sugar plants to utilize heat*	**Mostly burned away**	Competition with animal food	*Competition with the current ethanol plants*
Composition & cellulose structure	Medium cellulose, low lignin, amorphous & crystalline structure.	*Low cellulose, low lignin, high silicon content. Major crystalline structure.*	**High cellulose, high lignin, combination between amorphous & crystalline structure**	**High cellulose, high lignin, major crystalline structure**	*Low lignin, major crystalline structure.*	**Major sugar (62%), non-sugar (20%)**
Estimated conversion	284 liters/ton[1], [2]	*165 liters/ton [3]*	**358 liters/ton [1]**	**300 - 340 liters/ton [1]**	*67 liters/ton [4]*	> 250 liters/ton [5], [6]
Required feedstock quantity*	0,36 million tons/year	*0,6 million tons/year*	**0,28 million tons/year**	**0,30 - 0,33 million tons/year**	*1,49 million tons wet pulp/year*	0,35 million tons/year
Current feedstock price	200 - 500 VND/kg	200 - 500 VND/kg	**50 VND/kg**	**	<400 VND/kg	*1.600 VND/kg*
Enviro-nmental impact	**Decreasing environmental impact in comparison with current burning.**	**Decreasing environmental impact in comparison with current burning**	**Decreasing environmental impact in comparison with current burning**	**Mainly burned □ utilize to decrease environmental impact**	**Decreasing environmental impact due to mainly throw away**	**No environmental impact**

Note: The level of assessment: **bold: advantage**; regular: normal; *italic: disadvantage*
** Ethanol plant capacity: 100 million liters/year ** Currently, in burning, no price*

- 62 million ton/year

Concluding remarks

- High potential for production and application of bio-carbon in Vietnam
- Various feedstock including 62 million tons of agricultural residue annually
- Long costal line with large sea water areas: high potential for aquatic biomass cultivation
- Carbon sequenstration for climate change combat
- High demand of organic fertilizer

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Thank you for listening!

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