

BioSolarEnergy

Combination of biological processes and fuel cells to harvest solar energy

Dieter F. Ihrig^a, H. Michael Heise^b, Ulrich Brunert^{a,b}, Thorsten Koetter^a, Manuel Gemuend^a, Darius Wilczek^a, Rüdiger Kuckuk^b, Martin Poschmann^a, Klaus Stadtlander^a

^aUniversity of Applied Sciences Suedwestfalen, Iserlohn, Germany

^bISAS - Institute for Analytical Sciences at the University of Dortmund, Germany

Corresponding author:

Prof. Dr. Dieter F. Ihrig, Interdisciplinary Center for Life Sciences, FH Suedwestfalen, Iserlohn, Germany, Ihrig@fh-swf.de

Introduction

Solar Energy

Solar Input: $1368 \pm 5 \text{ W/m}^2$

Mean Solar Input: $1368/4 \text{ W/m}^2 = 342 \text{ W/m}^2$
(Cross-section of a Sphere = $\frac{1}{4}$ of the surface)

Mean Solar Input at the Surface: 170 W/m^2
(reduced by the Albedo of the Atmosphere and the Surface)

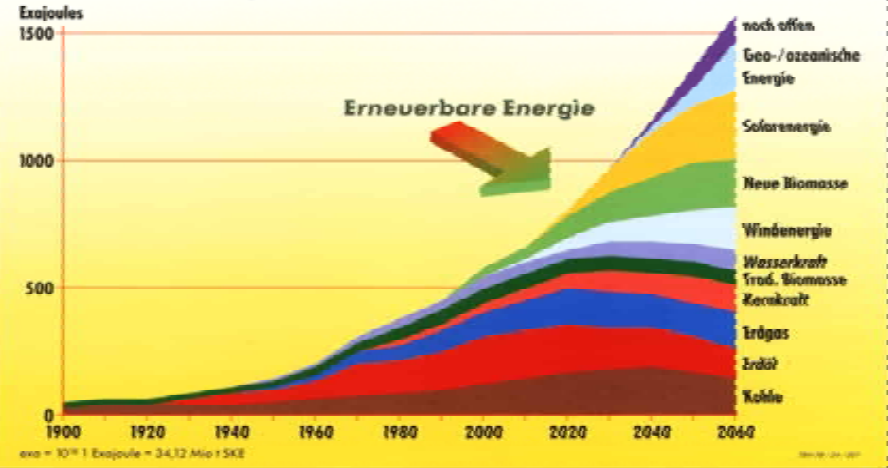
Total Yearly Solar Energy Input: $2,76 \cdot 10^{24} \text{ Ws/a} = 2,76 \cdot 10^9 \text{ PJ/a}$
(Surface of the Earth: $5,15 \cdot 10^{14} \text{ m}^2$)

Anthropogenic Energy Consumption 1997: 398.400 PJ/a

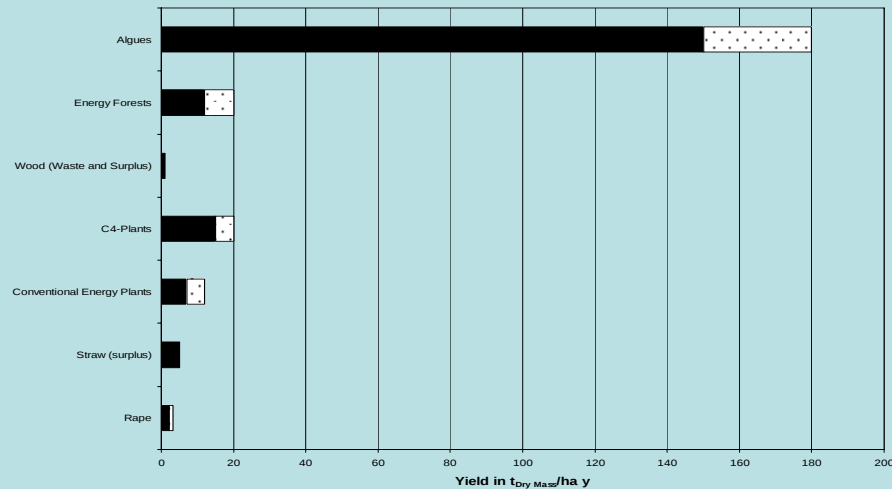
⇒ The Sun needs only 76 minutes to deliver the total yearly energy requirement of men!

Weltenergieverbrauch bis 2060

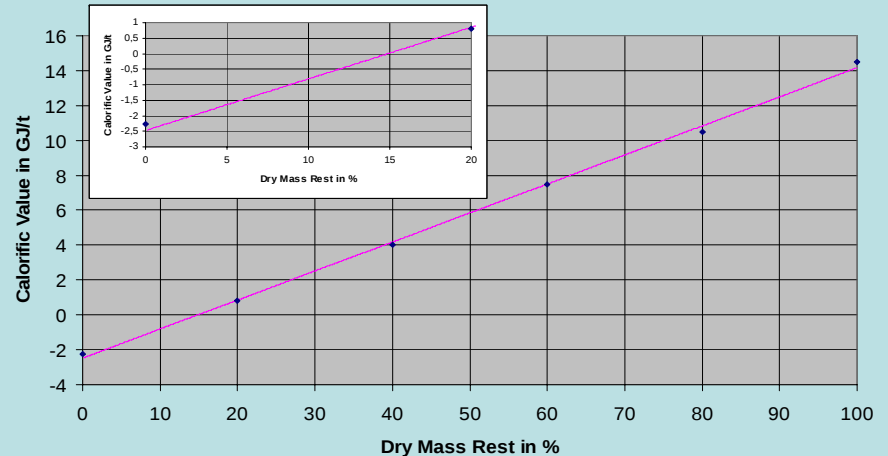
Szenario: nachhaltiges Wachstum



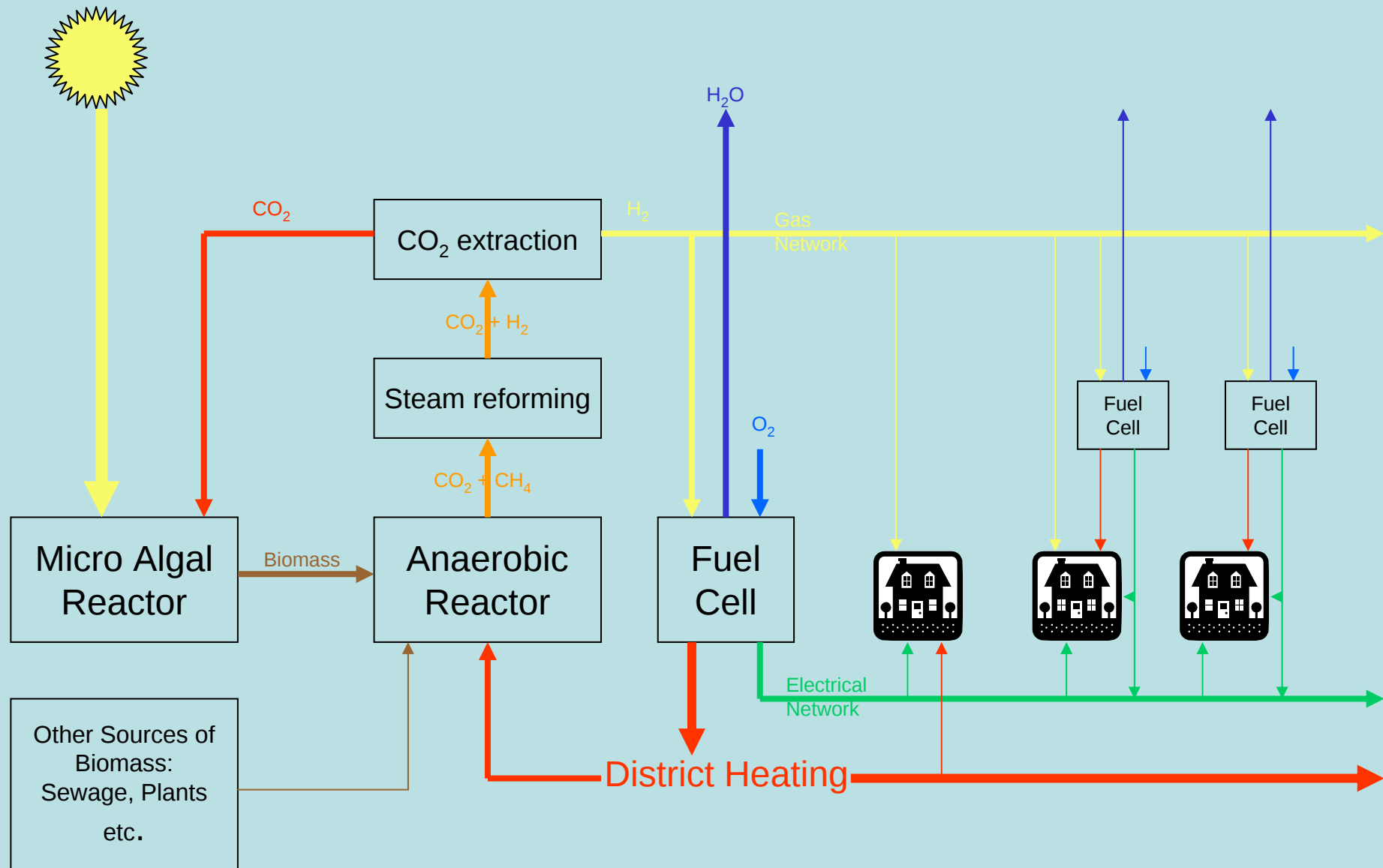
Yield of Biomass (Span of published values)



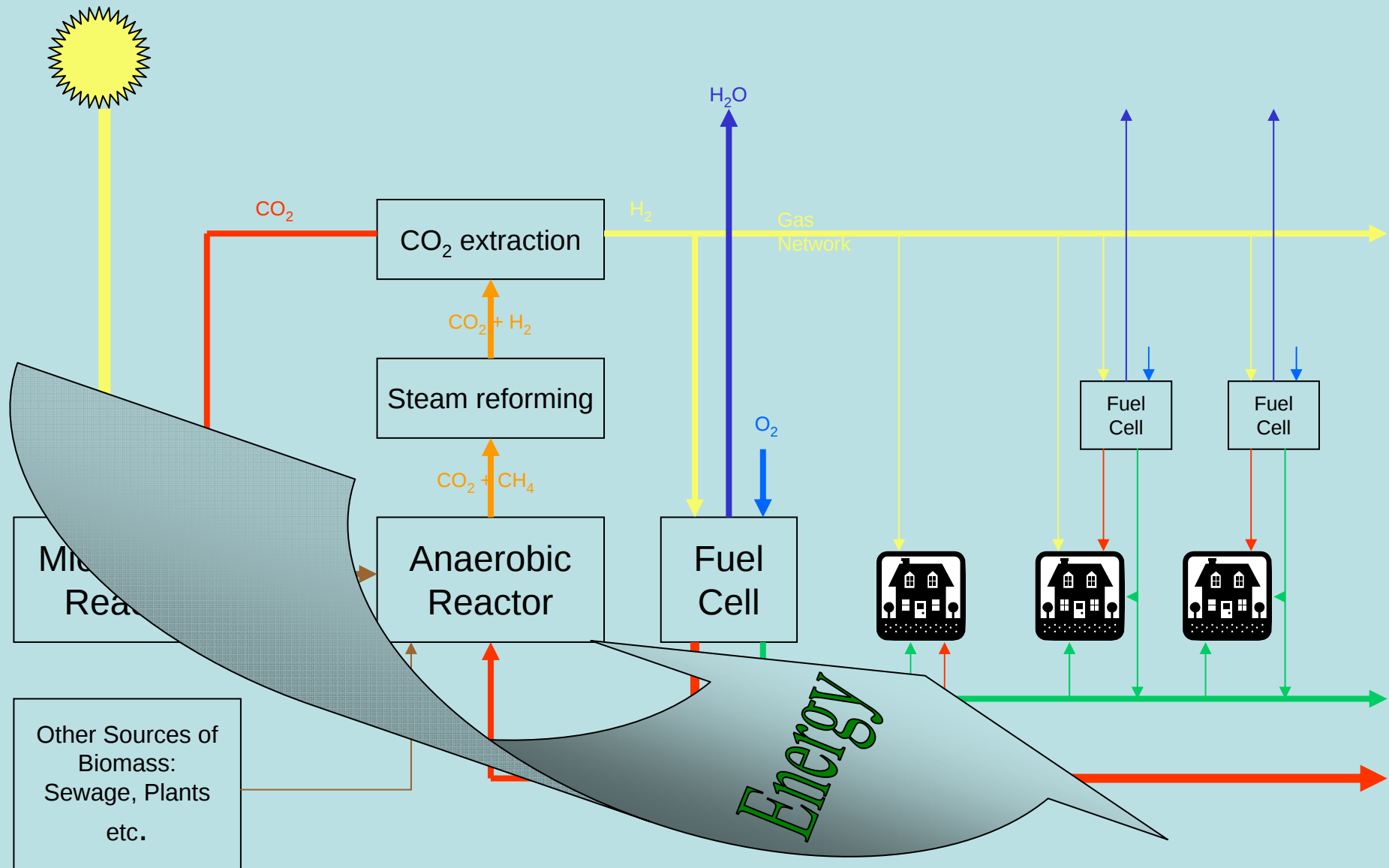
Calorific Value of Sludge



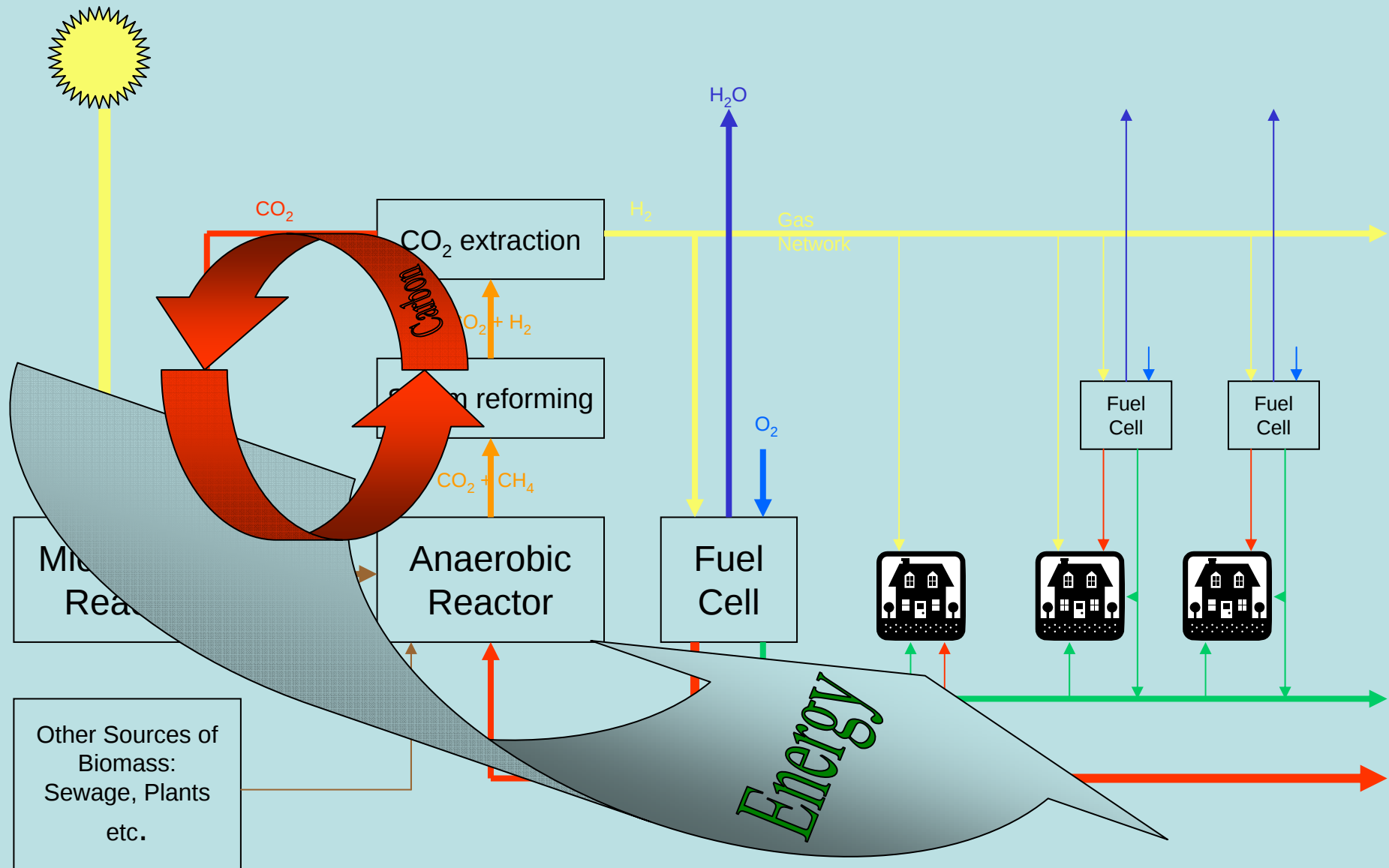
Biological Solar Energy Generator



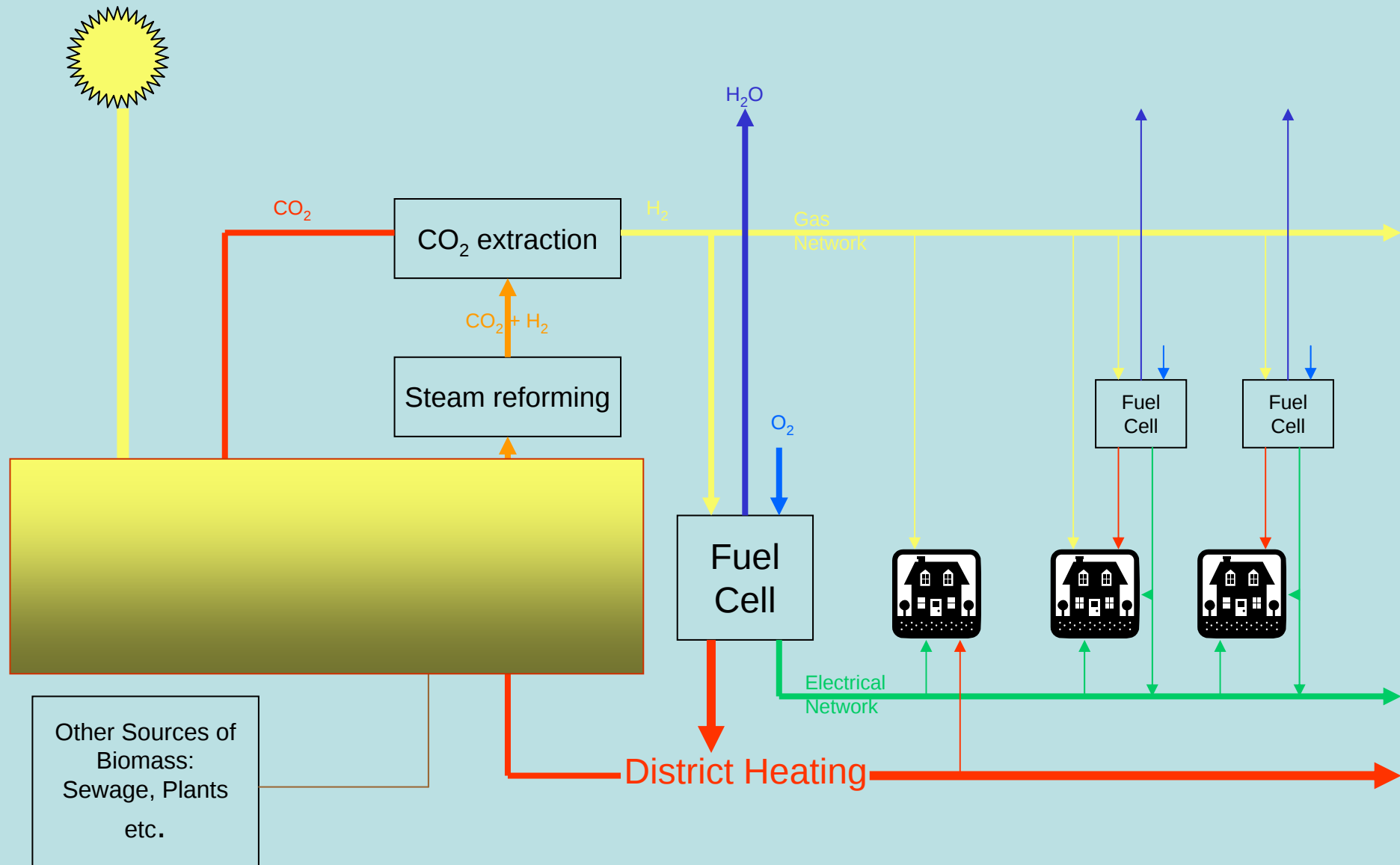
Biological Solar Energy Generator



Biological Solar Energy Generator

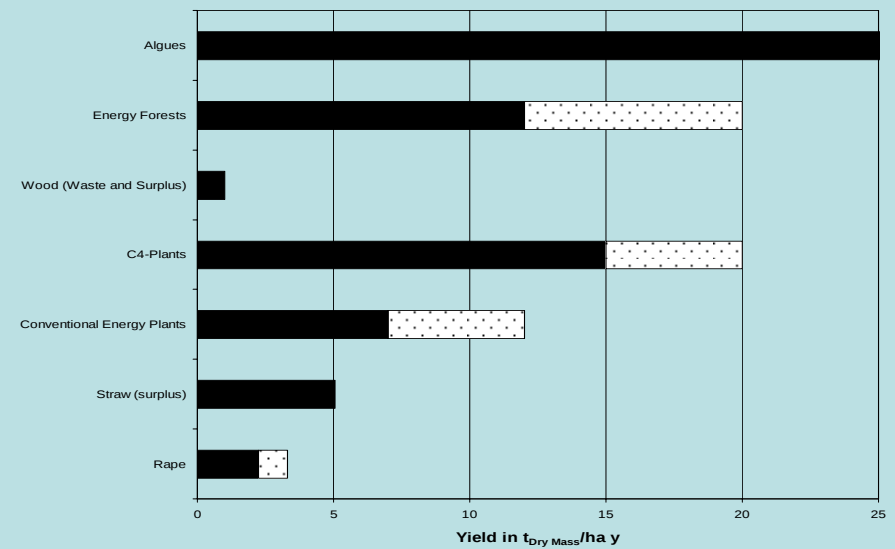
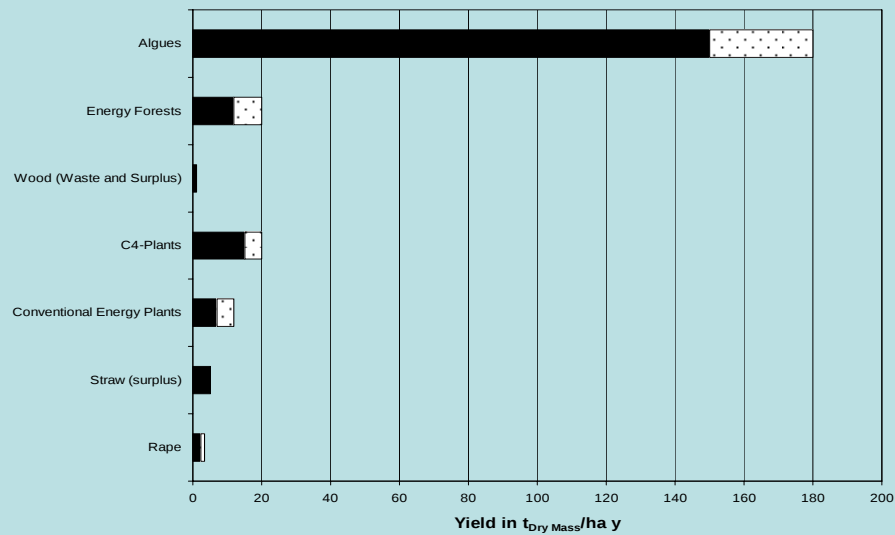


Biological Solar Energy Generator

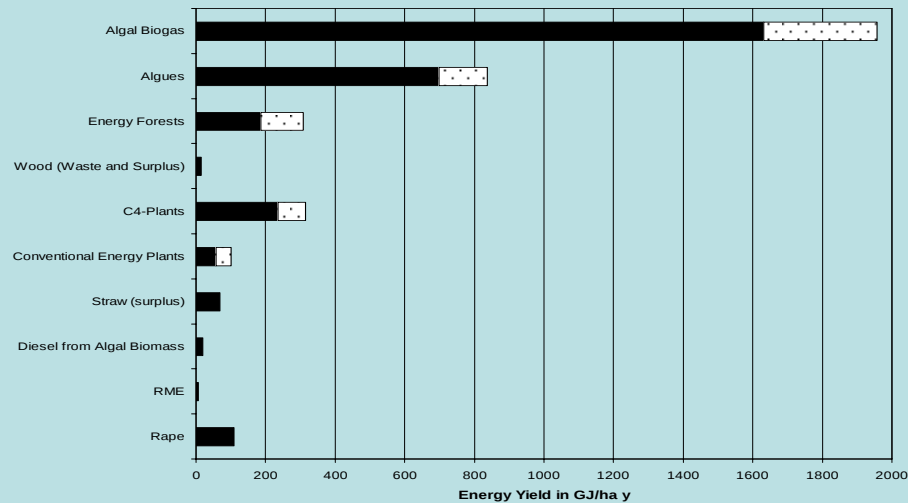


Efficiency of biomass production

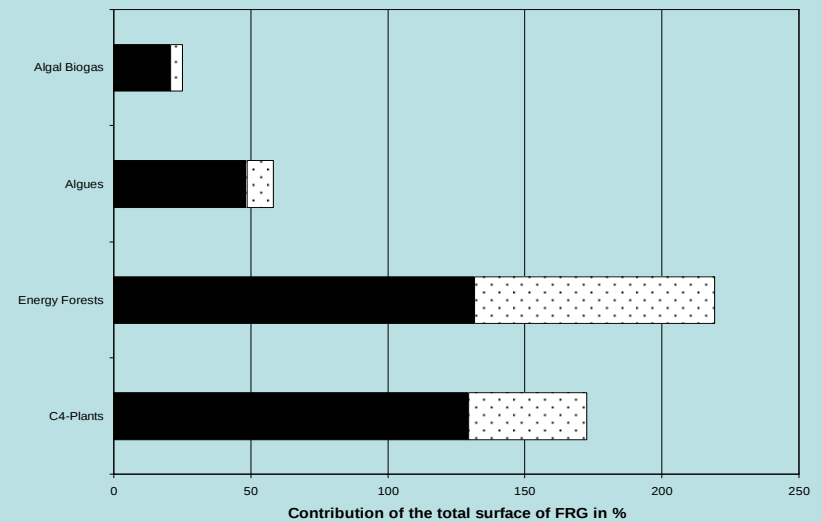
Yield of Biomass (Span of published values)



Energy Yield (Span of published or estimated values)



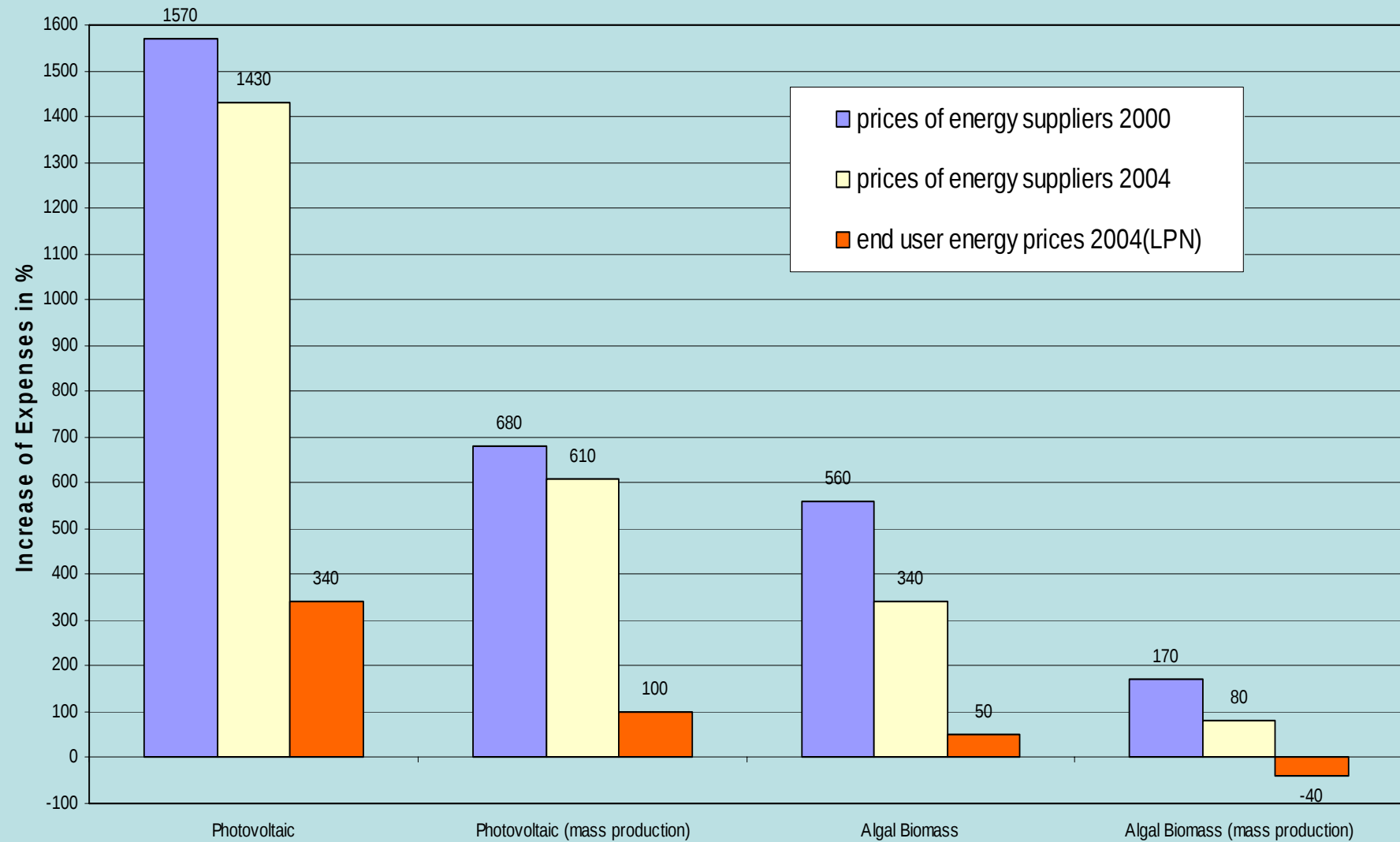
Requirement of Space to Deliver Primary Energy in FRG



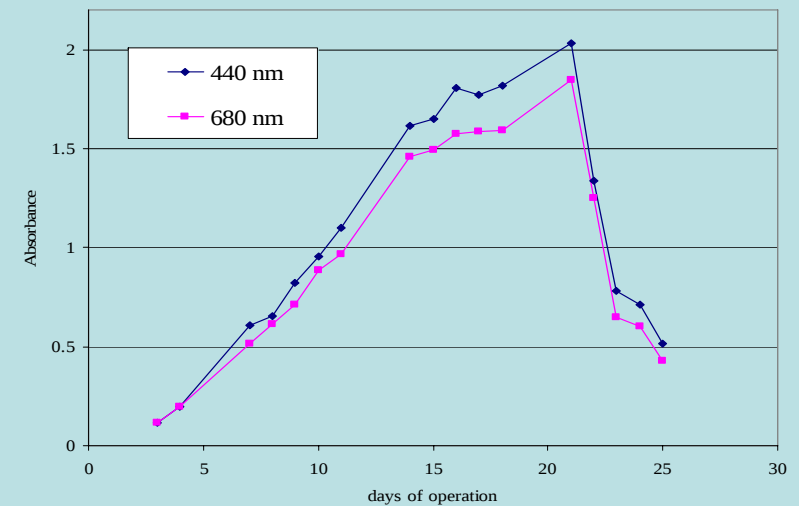
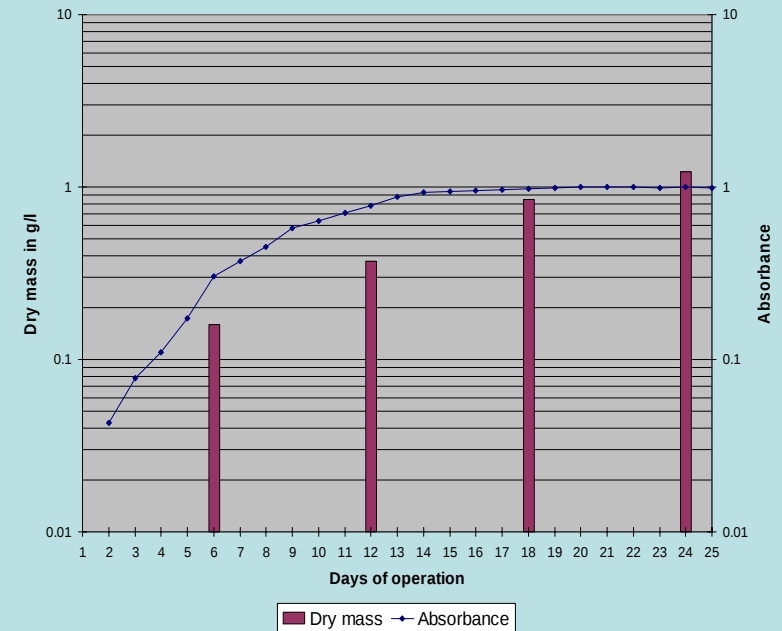
Process Simulation

Loss of Carbon					Compensation of carbon losses:		Slurry from cows
CO ₂ -loss via exhaust:	2,416,574 m3/a =	1,208.29 t/a			Content of Carbon:		33.6 %
CH ₄ -delivery:	3,844,750 m3/a =	1,922.38 t/a			Moisture:		70 %
Sum:		3,130.66 t/a			Mass:		31,058.2 t/a
					after adjusting process moisture:		39,931.9 t/a
					Calorific value:		6.99E+13 J/a
Process data							
Moisture:	90 %						
Mass flow at process moisture:	134,486.3 t/a						
Mass flow at 70 % moisture:	104,600.5 t/a						
Energy harvest							Power
Electrical:	5.60E+13 J/a	1.55E+04 MWh/a					1,775.0 kW
Thermal:	1.29E+13 J/a	3.58E+03 MWh/a					409.1 kW
Methane:	1.38E+14 J/a	3.83E+04 MWh/a					4,376.8 kW
Sum:	2.07E+14 J/a	5.75E+04 MWh/a					6,560.9 kW
Net yield:	1.37E+14 J/a	3.81E+04 MWh/a					4,345.0 kW
Requirement of floorspace					Investment		
Algal reactors (ponds):	590,965 m2				Algal reactors (ponds):		4,834,500 €
Anaerobic reactor:	20,000 m2				Anaerobic reactor:		40,903,400 €
Local power plant / Gas separation:	2,212 m2				Local power plant / Gas separation:		4,329,000 €
Sum:	613,177 m2				Sum:		50,066,900 €
Specific floorspace:	2.96 m2/(GJ/a)				End energy supply (1998)		
Specific energy harvest:	3,374.3 GJ/ha a				Base: consumption		only households total
Net specific energy harvest:	2,234.7 GJ/ha a				Citizens		6,041 1,790
					Households		2,762 818

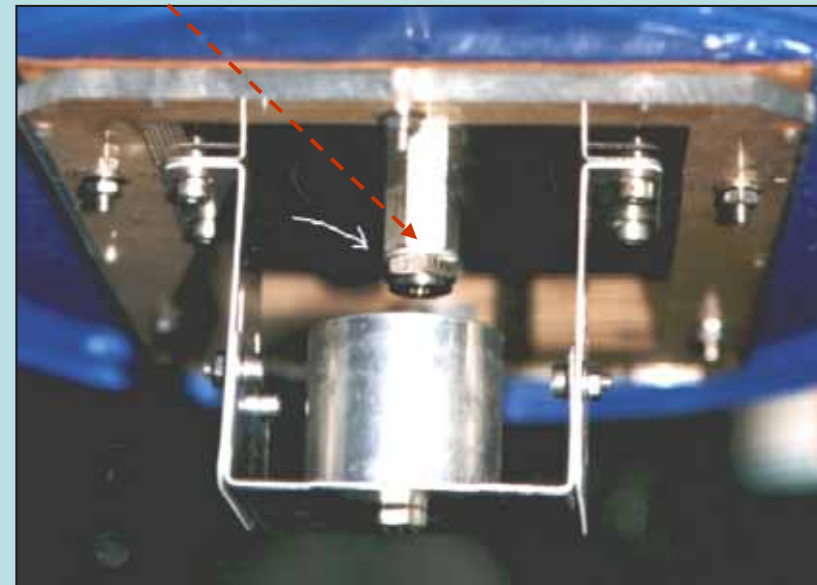
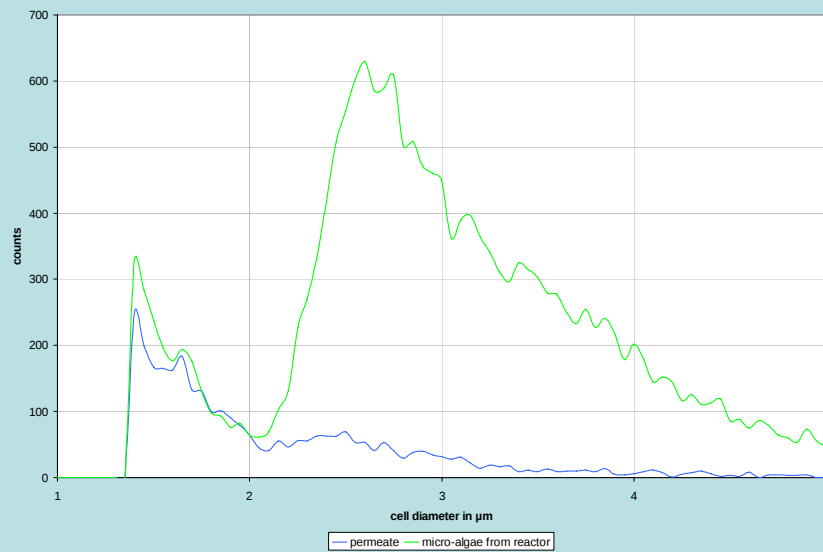
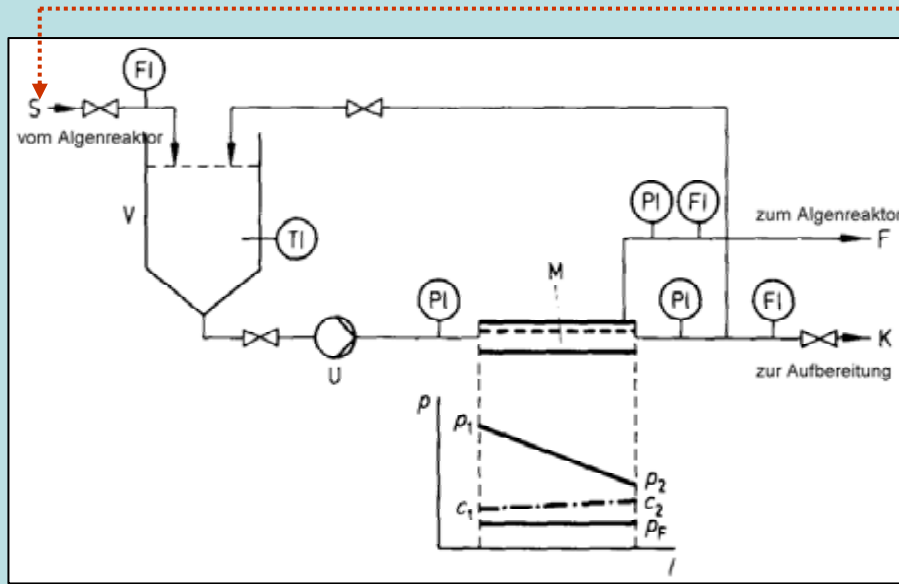
Economic Efficiency Calculation



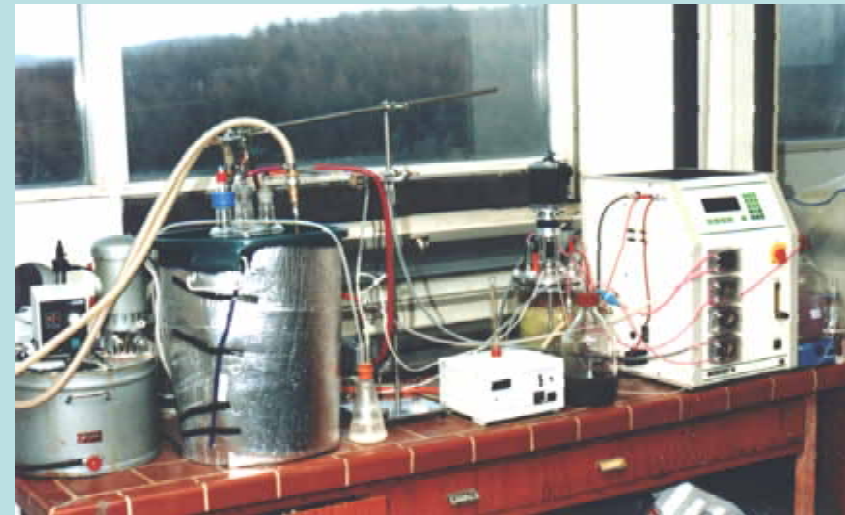
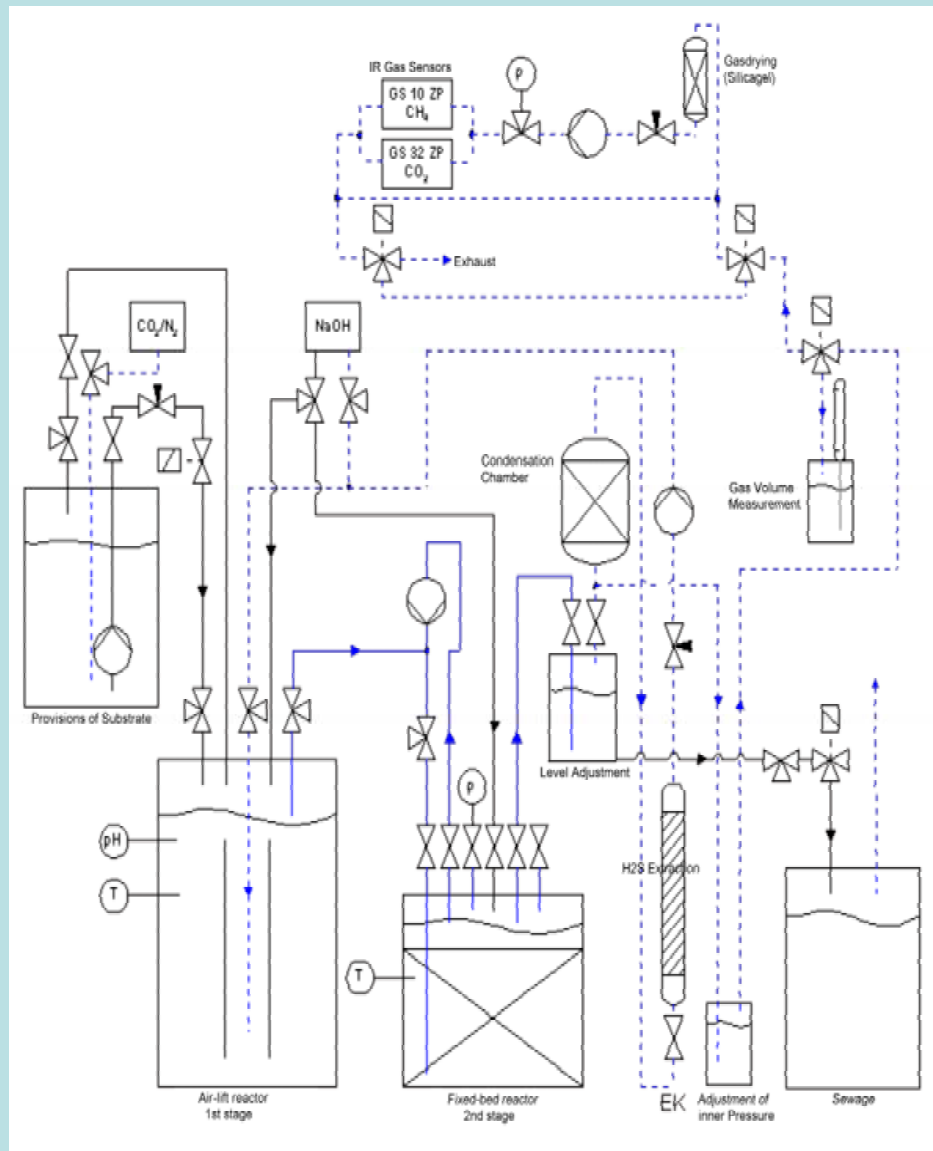
Micro-algal biomass production



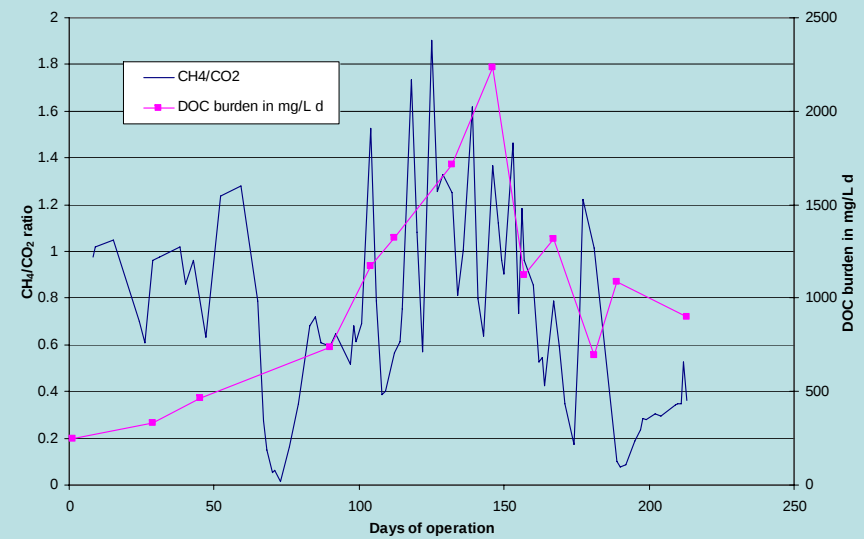
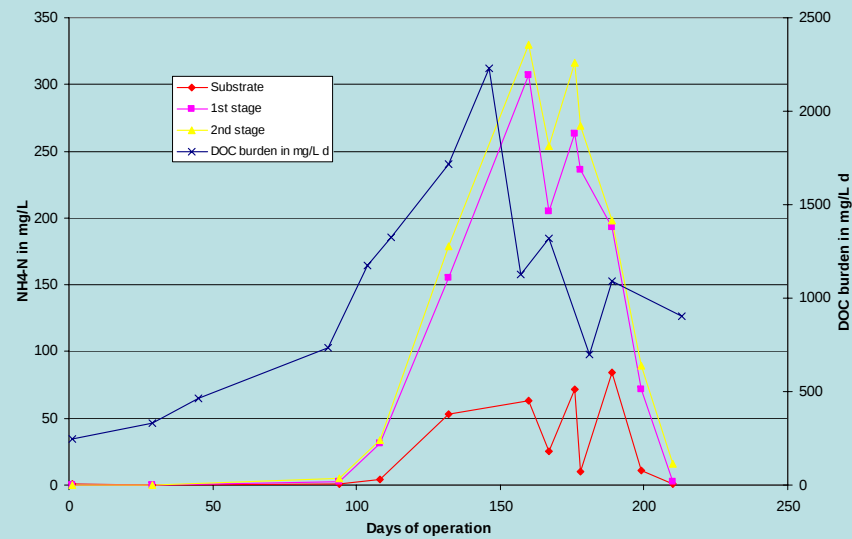
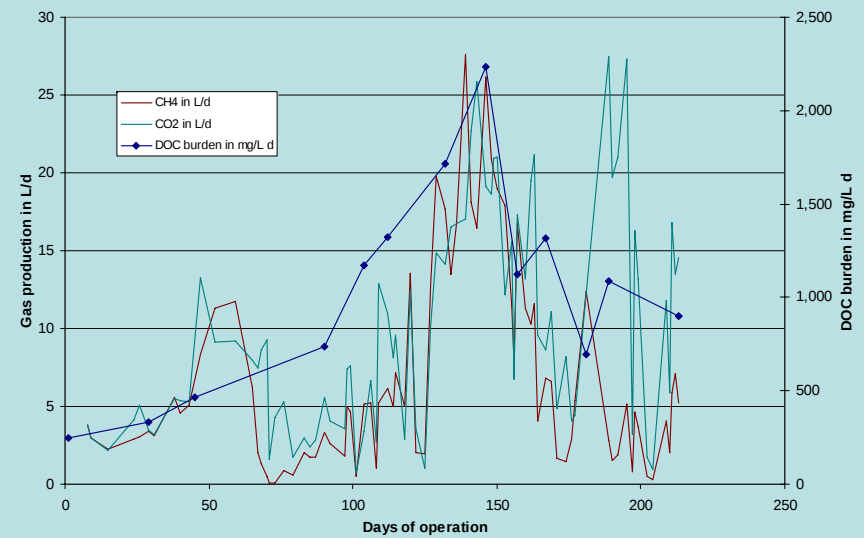
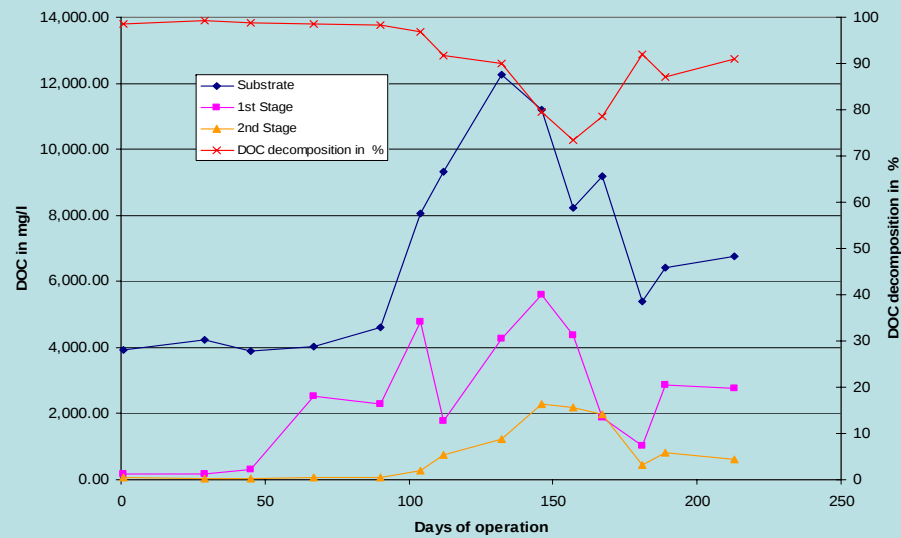
Harvest and treatment



Anaerobic Reactor

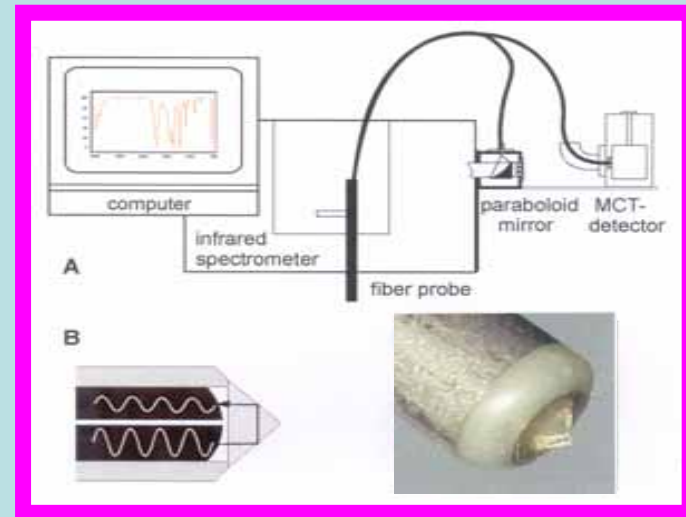
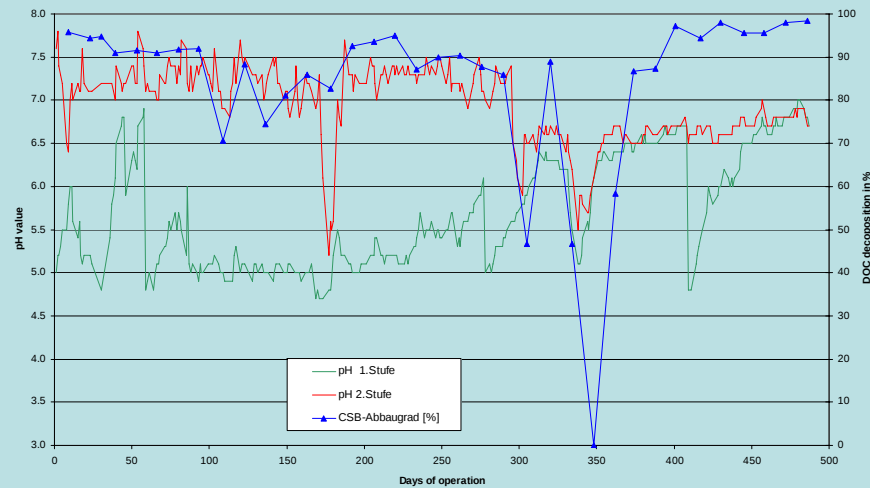
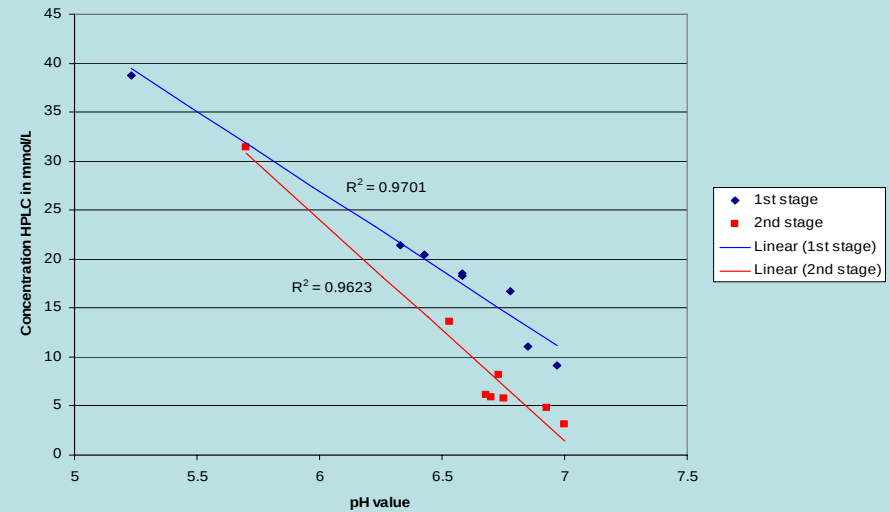
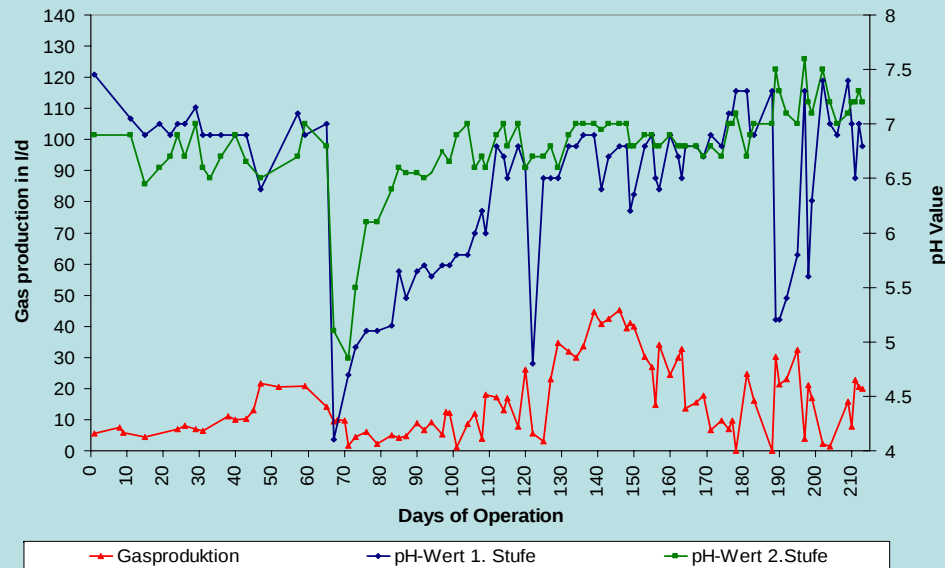


Biogas production using micro-algal biomass

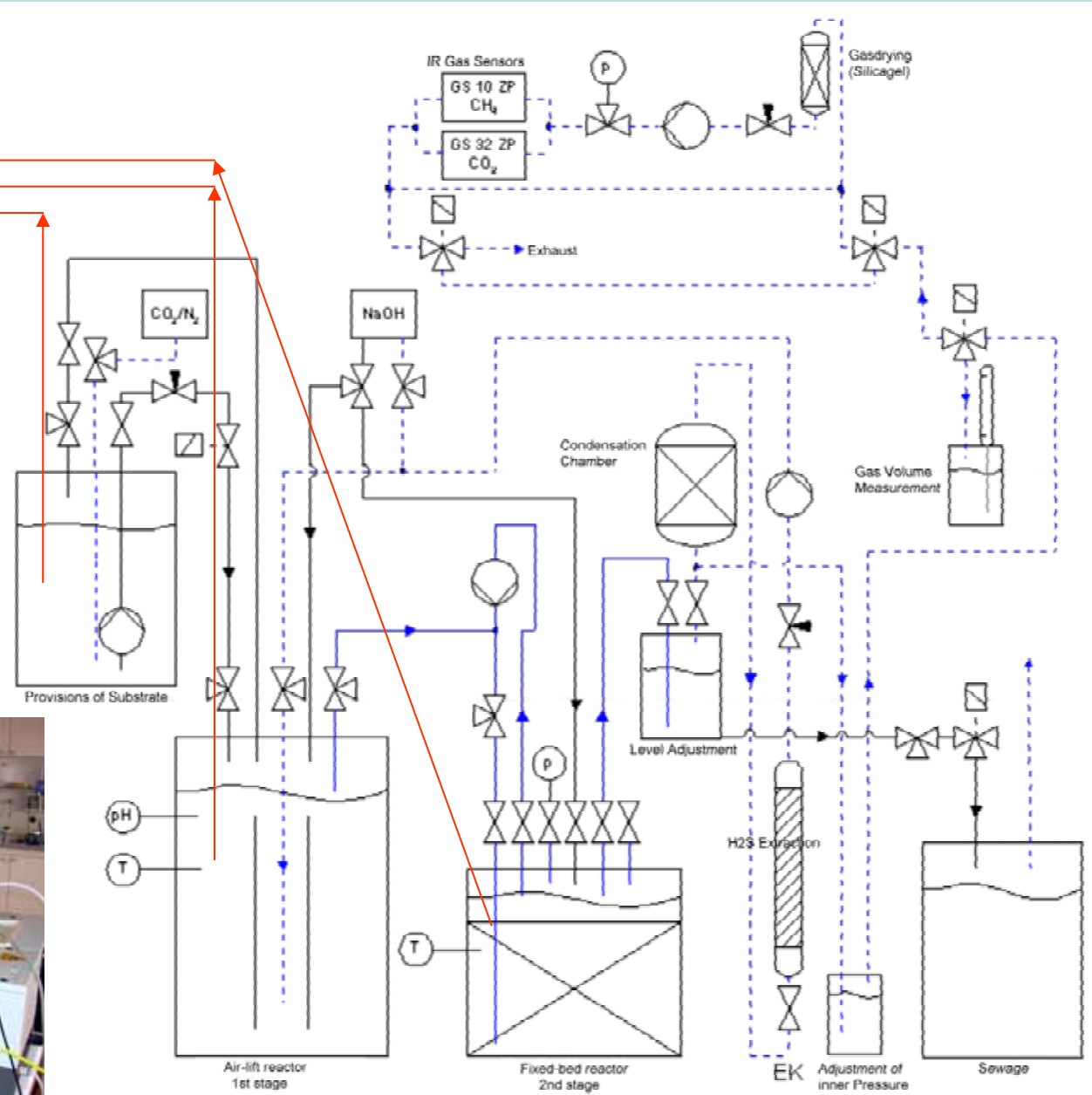
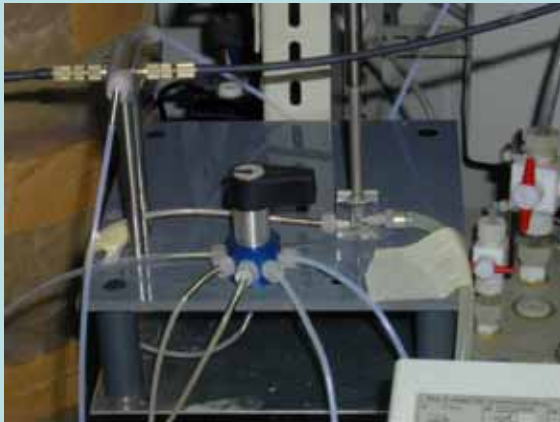


Process control

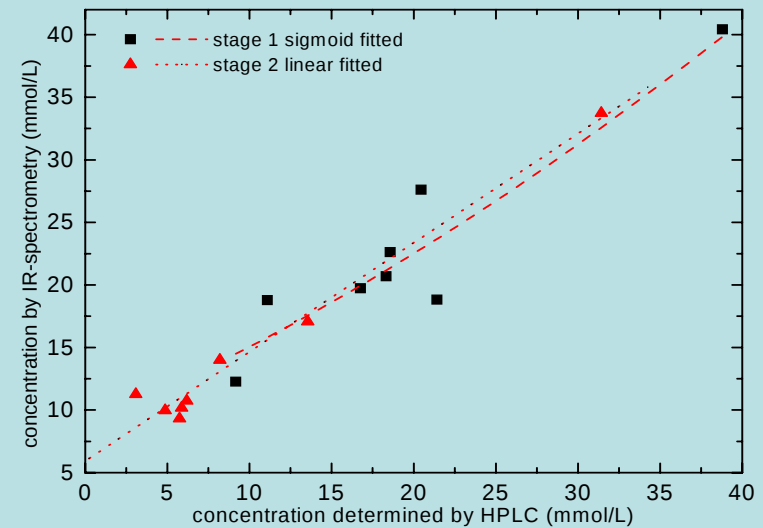
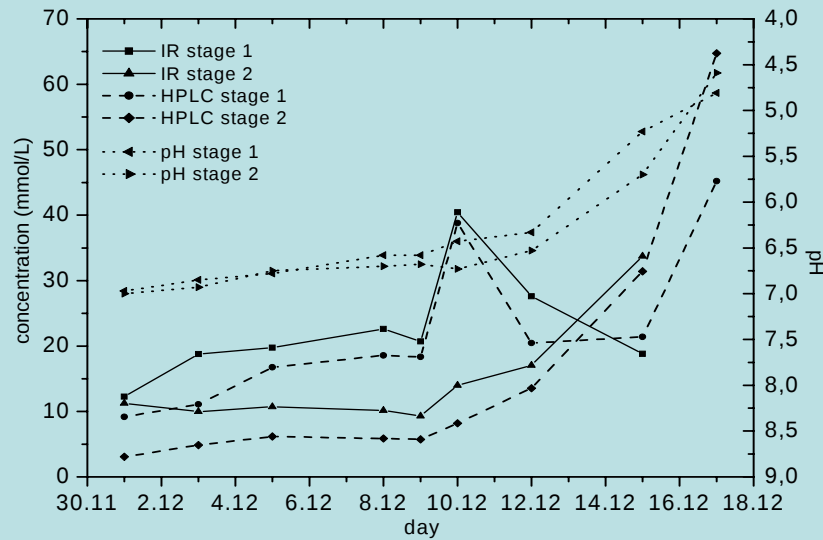
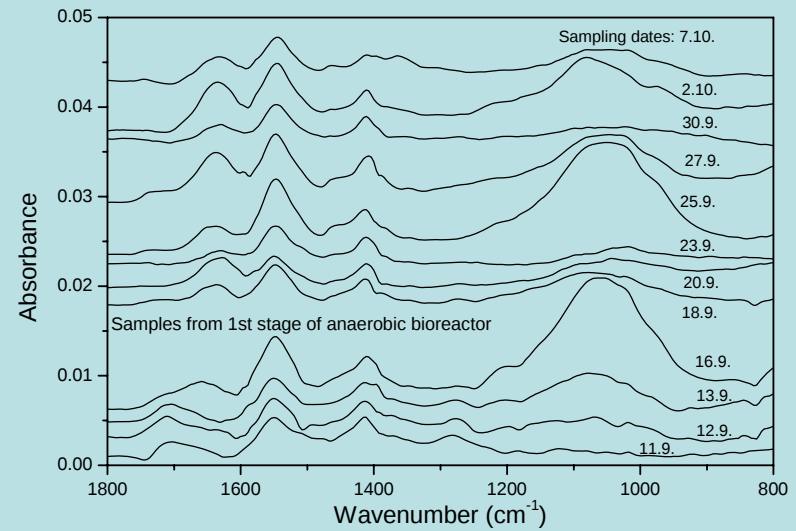
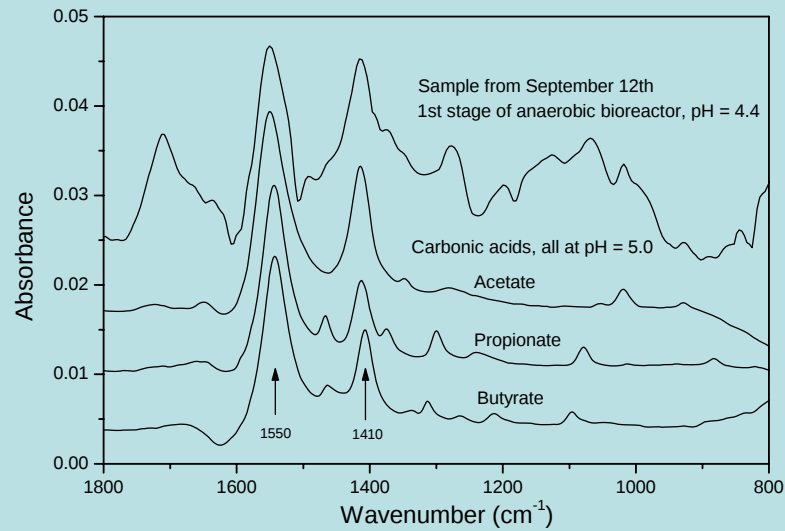
Gas production and pH Value



ATR-Measurement



Carboxylic acids



FH Suedwestfalen
Interdisciplinary Center for Life Sciences
(Prof. Dr. D. Ihrig, Prof. Dr. K. Stadtlander)

- Micro algal biomass production
 - Harvesting of algal cells
 - Treatment of algal cells
 - Anaerobic biogas production
 - Analytics: Photometry, UV/Vis Spectrometry, HPLC
- (Since 1996)

Institute for Analytical Sciences, Dortmund
(Dr. H. M. Heise)

Infrared fiber sensors, Aachen
(Dr. L. Kuepper)

- On site IR analytics
- Development of IR sensors

BMBF Project (2001-2004)

RWTH Aachen
Institute for Hygiene and
Environmental Medicine
(Prof. Dr. W. Dott)

- Bioanalytics
- Micro algal biomass production

IGV Institut fuer
Getreideverarbeitung, Nuthetal
(Prof. Dr. Dr. O. Pulz)

- Micro algal biomass production
- Bioanalytics

FH Suedwestfalen
Laboratory for Computational Intelligence
and Control
(Prof. U. Lehmann)

- Modeling of biomass power plants
- Virtual power plants

- Fuel Cell Technologies
- Catalytic Steam Reforming
- Membrane based Gas Separation

Envisaged further cooperation

Summary and Conclusion

- An algal biomass based solar energy generator is possible
- Fuel cells combined with biomass and biogas production gives high sophisticated sustainable system
- There is a high efficient anaerobic process
- Higher organisms are problematic in the algal reactor
- Nitric species are problematic in the anaerobic process
- Currently the process is not economic (but in 1 or 2 decades)

Acknowledgements

- German Federal Ministry for Education and Research (BMBF) for funding this project (FKZ 170 02 01)

Summary and Conclusion

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- Fuel cells combined with biomass and biogas production gives high sophisticated sustainable system
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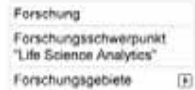
I thank you for your attention!



Forschungsschwerpunkt "Life Science Analytics"

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Forschungsschwerpunkt "Life Science Analytics"

Der Forschungsschwerpunkt Life Science Analytics wird gemeinsam betrieben durch

- das Interdisziplinäre Zentrum für Lebenswissenschaften der Fachhochschule Südwestfalen und
- das [ISAS - Institute for Analytical Sciences in Dortmund](#).

Die Leiter sind

- [Prof. Dr. Dieter F. Ihrig](#), FH SWF
- [Dr. H. Michael Heise](#), ISAS

Ziel des Forschungsschwerpunktes ist, in den Lebenswissenschaften neue analytische Methoden zu entwickeln oder etablierte analytische Methoden in neuen Gebieten anzuwenden.

Forschungsgebiete

Bearbeitet werden die Gebiete

- Arbeitsschutz
- Spektrometrie an der Haut als diagnostische Verfahren
- Einsatz von frequenzanalytischen Systemen für diagnostische Probleme
- Verbesserung medizinischer Routineanalytik – Beispiel Blutanalysen
- IR-Analytik wässriger biologischer Systeme
- Biophotonik - Fluoreszenzspektroskopischer Nachweis von Keimen



ISAS

Institute
for
Analytical Sciences
Dortmund and Berlin

Wissenschaftliche Veröffentlichungen, Vorträge und Poster

International Conference on Advanced Vibrational Spectroscopy (ICAVS-2) Nottingham, England, 24. – 29.8.2003

Lecture: Recent advances in robust silver halide fiber-optic probe development and applications for infrared spectrometric analysis
H.M. Heise, R. Kurte, A. Moor, E. Diessel, D. Ihrig, L. Küpper

Statusseminar Innovationswettbewerb Medizintechnik, Bonn 29. 9.2003

Fortschrittsbericht: Entwicklung einer nicht-invasiven Diagnosemethode zur Diabetes-Früherkennung mittels NIR-Spektrometrie,
Heise, H.M.; Ihrig, D.; Stücker, M.; Haiber, S.; Licht, M.; Moll, C.;

Biotechnica, Hannover, 7.10.2003

Poster: Bioreactor monitoring using a fiber-optic probe based on silver halide fibers and basic infrared spectrometric analysis
Heise, H.M.; Moor, A.; Küpper, L.; Ihrig, D.

3rd Annual Diabetes Technology Meeting, San Francisco, USA, 6.11.2003 - 8.11.2003

Poster: Non-invasive diabetes screening by near infrared spectroscopy
H.M. Heise, S. Haiber, D. Ihrig, M. Licht, M. Stücker, and C. Moll

DPG-Frühjahrstagung, Biological Physics, Regensburg, 8.3. – 12.3.2004

Poster: A biological solar energy generator
D.F. Ihrig, H.M. Heise, A. Moor, M. Gemünd, D. Wilczek, R. Kuckuk, M. Poschmann

European Geosciences Union, 1st General Assembly, Nice 25. – 30. 04. 2004

Lecture: A biological solar energy generator
Dieter F. Ihrig, H. Michael Heise, Alexander Moor, Manuel Gemuen, Darius Wilczek, Ruediger Kuckuk, Martin Poschmann

XXVII European Congress on Molecular Spectroscopy, Kraków (Poland), September 5-10, 2004

Lecture: Process monitoring for bioreactors using infrared-spectrometry
H.M. Heise, D.F. Ihrig, A. Moor, U. Brunert, R. Kuckuk, M. Gemuend, D. Wilczek, and M. Poschmann

Poster: In-vivo characterization of human skin by mid- and near-infrared spectroscopy
H.M. Heise, S. Haiber, M. Licht, D. Ihrig, C. Moll, and M. Stücker

VDI-Kompetenzfeld Optische Technologien: 4. Konferenz über Optische Analysentechnik, Anwendungen und Trends in der Optischen Analysentechnik, 7. - 8.10.2004, Düsseldorf

Lecture: Process monitoring for bioreactors using infrared-spectrometry
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Workshop „FT-IR Spectroscopy in Microbiological and Medical Diagnostic“, 21. - 22.10.2004, Robert Koch-Institut, Berlin

Poster: Cumulative microbial biomass characterization of a 2-stage anaerobic bio-digester using ATR-infrared spectroscopy
H.M. Heise, A. Moor, R. Kuckuk and D.F. Ihrig

Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Arbeitskreis Energie, Berlin 4. 3.2005 - 9. 3.2005

Vortrag: Ein biologischer Solarenergie-Generator
Ihrig, D.F.; Koetter, T.; Gemuend, M.; Wilczek, D.; Poschmann, M.; Stadlander, K.; Heise, H.M.

Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Arbeitskreis Biologische Physik, Berlin, 4. 3.2005 - 9. 3.2005

Poster: Use of carboxylic acids for the monitoring of anaerobic fermentation processes
D.F. Ihrig, H.M. Heise, U. Brunert, A. Moor, R. Kuckuk, and M. Poschmann

ANAKON, Regensburg 15. 3.2005 - 18. 3.2005

Poster: Process monitoring for a biofermenter using Raman difference spectroscopy
Heise, H.M.; Brunert, U.; Kuckuk, R.; Ihrig, D.F.

InCom 2005, Heinrich Heine-Universität Düsseldorf, 29.3.2005-03-31

Pleanarvortrag: Monitoring of anaerobic fermentation processes Part I: Classical Methods
Dieter F. Ihrig, H. Michael Heise, Vera Schimetzek, Markus Kochbeck, Stefan Groll, Thorsten Koetter, Manuel Gemuend, Darius Wilczek, Alexander Moor, Ulrich Brunert & Martin Poschmann
H.M. Heise, U. Brunert, R. Kuckuk, D.F. Ihrig

Pleanarvortrag: Monitoring of anaerobic fermentation processes Part II: IR and Raman spectroscopy
H.M. Heise, U. Brunert, R. Kuckuk, D.F. Ihrig

3rd International Conference on Advanced Vibrational Spectroscopy (ICAVS-3)

Delavan, Wisconsin (USA) August 14th - 19th, 2005
Poster: Dermatological studies by attenuated total reflection iR-spectroscopy using probes based on square cross-section silver halide fibers
H.M. Heise, S. Haiber, C. Moll, M. Stücker, M. Licht, D. Ihrig

Poster: In-vivo characterization of human skin and study of glycation effects from hyperglycemia by near-infrared spectroscopy
Heise, H.M.; Haiber, S.; Moll, C.; Stücker, M.; Licht, M.; Ihrig, D.

Poster: Monitoring of an anaerobic fermenter for biogas production using infrared spectrometry
Heise, H.M.; Ihrig, D.F.; Brunert, U.; Kuckuk, R.

Poster: Difference Raman spectroscopy for monitoring anaerobic biomass fermentation
Heise, H.M.; Brunert, U.; Kuckuk, R.; Ihrig, D.F.

5th Diabetes Technology Meeting (DTM), 10. – 12. November 2005, San Francisco, USA

Poster: Recent progress in non-invasive diabetes screening by dermal near-infrared spectroscopy
Heise, H.M.; Haiber, S.; Licht, M.; Ihrig, D.; Moll, C.; Stücker, M.

Humboldt-Symposium Nov. 28-30, 2005 in Varanasi, India

Lecture: Mid-Infrared Spectrometry using Fibre-optic Probes for Process Monitoring in Industrial Applications and Biotechnology
H.M. Heise, R. Kuckuk, L. Küpper, U. Brunert, and D. Ihrig

First European Fuel Cell Technology and Applications Conference, Rome 14. – 16. 12. 2005

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Eingereichte Beiträge:

H.M. Heise, U. Damm, S. Haiber, R. Kurte, M. Stücker, C. Moll, D. Ihrig, M. Licht, Mid- and near-infrared spectroscopy in medical diagnostics – recent advances in instrumentation and applications Journal of Pure and Applied Spectrophysics

Dieter F. Ihrig, H. Michael Heise, Ulrich Brunert, Thorsten Koetter, Manuel Gemuend, Darius Wilczek, Rüdiger Kuckuk, Martin Poschmann, Klaus Stadlander: Combination of biological processes and fuel cells to harvest solar energy; Fuel Cell Sciences and Technologies (ASME)