A five-week Bioenergy Master class

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Background and general philosophy

The present report describes an academic distance-learning master-level course intended for five weeks full-time studies. The course is offered free of charge.

The background and the explanation for this generous offer is the following.

During fall 2017 was an initiative taken to set up a flexible, international master-level education in energy engineering. The idea was to collect a group of senior academics to produce a huge number of course elements, "nuggets".

The reason we wanted to do this was that in today's world there are lots of young and bright people that, for one reason or another, do not have access to or cannot afford an academic education. And there is a global need for smart and educated people to tackle the challenges that humanity is facing.

What we wanted to do was to offer an advanced energy engineering master programme free of charge and available worldwide. The main final outcome was intended to be lots of small educational units called nuggets, and blocks of nuggets that would each cover a limited scope with very concrete and well-defined learning outcomes for each.

And these learning units would then be free for the student to combine. In case a student wanted to set up a cross-disciplinary course that might be up to the student but for a progression within a specific subject we, the seniors, would set up pre-defined and recommended nugget combinations, courses.

Nuggets – the central element

The central element in the concept is the short, self-sustained, teaching unit, the "nugget". Nuggets were intended to demand anything from 1-2 hours up to one full day for a student to complete. The nuggets could be traditional lectures or a call for the student to do a study visit or maybe do some practical exercise or something else. Common to all, though, was the demand that the material in the nugget should be completely self-sustained. A strict demand was that the student should not need to contact the teacher. Another demand was that there might be no cost for the student. So external material that was referred to had to be freely available on the web and copyright issues had to be resolved already from the beginning.

Nuggets in this course

The nuggets in the present course follow these guidelines so that each nugget has a limited scope. Each nugget is intended to take approximately one full day, some 4-8 hours of intensive studies.

Each nugget consists of three parts: A short presentation of the underlying theory, self-test questions and homework. The homework may contain literature reading and some type of exercise to be solved.

There is no further examination of the nugget but it is up to the student to do the homework according to the academic standard required at the master level.

Thematic blocks of nuggets

The nuggets would be the fundamental building block in the full educational structure. The vision was that nuggets could be combined into single-subject progressive advancement units or into cross-disciplinary blocks. To guarantee a professional and scientific progression within a specific subject we, the seniors, would set up smaller or bigger pre-defined nugget sequences.

The lessons in this course

I chose to call these units "lessons", staying in the academic tradition. Other terms such as "zepto's" and "femto's" were also used to distinguish different levels and units. But for me, I felt that putting nuggets together into something like one-week blocks was a natural thing to do. So my nuggets come together in lessons, each lesson planned for about one week of full-time studies.

For the student to check that she or he has grasped the content and reached the intended learning outcomes for each lesson there is not only a set of self-test questions but also a bigger task to be solved for each lesson. The task is such that it can only be successfully completed if the student is comfortable with all the material presented in the lesson nuggets. The final task in each lesson can, if the student is well prepared, be completed in about one day full-time work.

The course

So that is what I am presenting here. A master-class consisting of all in all five lessons. Each lesson will require approximately one week full-time studies.

The first lesson is about the fundamentals of biomass. The second lesson is about conversion processes. The third lesson introduces the one and only process to extract the energy from the biomass and the fourth lesson takes a system perspective and introduces circular economy thinking.

Following these is the fifth lesson introducing what might be called a mini-project. In this is the student challenged to do a thorough analysis in her or his own region and thus to uncover the local resources and potentials.

The final mini-project is intended for about one week full-time work for a well prepared student.

Examinations

One problem with an initiative like this is that if such a programme shall be formally recognised by high-rank universities there will be a demand that the examinations are recognised. But having regular examinations would violate our fundamental ambition. Because if "we" – those who originally developed the material – were to manually do the examinations, then we could not offer the education free of charge.

Hence, there are no regular examinations included in the material. There are self-tests and there are reports to be written – but there is no feedback included. So once you, the student, are asked to write a report it is all up to you to make a high-standard academic report. No-one will check it.

Live links to the Bioenergy course material

Course introduction 1: https://youtu.be/e9-ebDTMyFI
Course introduction 2: https://youtu.be/jW0oOeljsGs
Slides used in the introductions.

Lesson 1 Biomass as such, 7 nuggets including intro, 30-35 h

	Theory	Self-test	Homework	Slides
Introduction	Link			Link
Photosynthesis	Link	Link	Link	Link
Cell walls.	Link	Link	Link	Link
Plant residues	Link	Link	Link	Link
Society residues	Link	Link	Link	Link
Evaluate/Classify	Link	Link	Link	Link
Lesson examin.	Link	Link		Link

Lesson 2 Conversion processes, 7 nuggets including intro, 35-40 h

	Theory	Self-test	Homework	Slides
Introduction	Link			Link
Heating value	Link	Link	Link	Link
Physical conv.	Link	Link	Link	Link
Chem.synthesis	Link	Link	Link	Link
Biochem. conv.	Link	Link	Link	Link
Thermochem	Link	Link	Link	Link
Lesson examin.	Link	Link	Link	Link

Lesson 3 Energy extraction, 8 nuggets including intro, 35-40 h

	Theory	Self-test	Homework	Slides
Introduction	Link			Link
Comb. stoichio.	Link	Link	Link	Link
Flame temp.	Link	Link	Link	Link
Flame furnaces.	Link	Link	Link	Link
Indirect heating	Link			Link
Turbines/Carnot	Link	Link	Link	Link
Small-scale CHP	Link	Link	Link	Link
Lesson examin.	Link	Link	Link	Link

Lesson 4 System perspectives, 9 nuggets including intro, 50-55 h

	Theory	Self-test	Homework	Slides
Introduction	Link			Link
Basics	Link	Link	Link	Link
Yield/Harv./Collect	Link	Link	Link	Link
Transport	Link	Link	Link	Link
Storage	Link 1 Link 2 Link 3	Link	Link	Link
User demands	Link	Link	Link	Link
Forest fuel CHPC	Link	Link	Link	Link
Ash recirculation	Link	Link	Link	Link
Lesson examin.	Link	Link		Link

Lesson 5 Mini-project and femto certificate, 1 nugget, 40-50 h

	Theory	Self-test	Homework	Slides
Introduction	Link			Link
Project instruction			Link	Link

Links to external material in single nuggets

General course material that can always be referred to in the nuggets:
Bisyplan handbook: The main course book
RES-Chains material: Complementary to the main course book
International standards
European federal standards

Course introductions:
WEC: Report on world energy resources
IEA: On the situation for bioenergy

Lesson 1: Biomass as such and its properties
Introduction (Z1 Introduction)
No external links
Photosynthesis (Z1a)
Introduction, Calvin cycle.
Khan Academy C4 photosynthesis:
Paper: *Temperature response of photosynthesis in C3, C4, and CAM plants: temperature acclimation and temperature adaptation*
Paper: *What is the maximum efficiency with which photosynthesis can convert solar energy into biomass*
Cell walls and membranes (Z1b)
Online biology textbook.
Carnegie-Mellon on-line course in biology.
Cell membranes.
Khan Academy, cell membranes, diffusion and osmosis:
Paper: *Engineering of plant cell walls for enhanced biofuel production*
Direct download book chapter about LignoCellulose.
Plant residues (Z1c)
FAO on agricultural and forest residues.
Direct download FAO user manual on crop and livestock residues.
Societal residues (Z1d)
FAO Database start page.
World Bank page for the report "What a waste".
Homework example: London 1 solid waste
Homework example: London 2 water
Homework example: New York 1 solid waste
Homework example: New York 2 water
Homework example: Tokyo 1 solid waste
Homework example: Tokyo 2 water
Classification and evaluation of biomass (Z1e)
FAO terminology and dictionary.
Review-article about biomass classification and properties.
Certificate task for the first lesson.
No external sources or references used.

Lesson 2: Conversion routes

Introduction (Z2 Intro)

No external sources or references used.

Heating value (Z2a)

No external sources or references used.

Changing the physical properties of the material (Z2b)

Pellets trade and markets, IEA task 40 reports.
Fundamental understanding of pelletization.
Factors affecting pellet durability.
Glycerin as a binder in densified RDF.
Report on Swedish pellet factories and the need of energy.
Forest Products Laboratory, search for wood handbook chapter 05.
Direct download: Frodeson: Towards understanding…
Screw extruder video on youtube.
Excenter press animation on youtube.

Chemical synthesis to change the properties (Z2c)

Distance learning at Penn State University.
Video link: FAME process demonstrated 1(3)
Video link: FAME process demonstrated 2(3)
Video link: FAME process demonstrated 3(3)
Direct download: Paper from Aachen University on HVO production.
Direct download: Paper on boiling and freezing points of hydrocarbons.

Biomass -> Biofuel by biochemical processes (Z2d)

Biogas handbook, 3 chapters and 4 appendices.
Homepage for the World bioenergy association.
Ethanol fermentation, biology textbook, cell respiration chap 12.
Ethanol upgrading: Paper by Zentou & al.
Biogas upgrading: Paper by Awe & al.
Side-reading: Paper by Rosales-Calderon and Arantes.

Biomass -> Biofuel by thermochemical processes (Z2e)

Distance learning at Penn State University.
Paper: Larina - Comparison of methods for gaseous fuel.
Paper: Zhang – Liquefaction and bio-oil upgrading.
Paper: Sikarwar – Advances in biomass gasification.
Paper: Christiansen – Fuel yield in gasification and pyrolysis.
Direct download: IEA-Task 33 report on gasification.
Direct download: Calculation techniques for efficiency evaluation.

Certificate task for the second lesson.

No external sources or references used.

Lesson 3: Extraction of bioenergy from the biofuels

Introduction (Z3 Intro)

No external sources or references used.

Combustion stoichiometry (Z3a)

No external sources or references used.

Adiabatic reaction temperature and fuel usability (Z3b)

Isidoro Martinez' material.

Open-flame furnaces (Z3c)

World Bank Health and Safety Guidelines.

About cement kilns and cement production.

Indirect heating furnaces (Z3d)

No external sources or references used.

Turbines and the Carnot efficiency (Z3e)

Paper: Energy, entropy and exergy concepts …

Khan Academy, thermodynamics.

InfoCoBuild free online courses.

Small-scale CHP (Z3f)

IEA/33 Bioenergy country reports.

IEA/37 Bioenergy country reports.

Univ. of Florida page about Biogas.

Small-scale wood gasifier for power production.

Farm-scale anaerobic digestion for power production.

Paper: Biogas development in Germany.

Paper: State-of-art for small scale gasification for power production.

Certificate task for the third lesson.

Examination excel-sheet.

Lesson 4: The supply system as a part of a sustainable society

Introduction (Z4 Intro)

Recorded master-class on circular economy, first lecture.
Recorded master-class on circular economy, second lecture.
Recorded master-class on circular economy, third lecture.
Paper: More complete quantification of the carbon cycle.
Paper: Policy for material efficiency.
Link page: Climate change in a religious and ethical perspective.

System fundamentals and basics (Z4a)

Direct download: Decision Support tool (report) from UN/FAO.
Direct download: The How2Guide (report) from UN/FAO.

The first steps in the supply, harvesting and collection (Z4b)

Solar irradiation data from NASA.
Company "Fondriest" page on solar irradiation.
International Energy Agency, IEA homepage.
International Renewable Energy Agency, IRENA homepage.

The next steps: Loading onto a truck and road transport (Z4c)

European Federation department of transport.
European Federation workshop on longer and heavier vehicles 2009.
Weights and measures allowed for trucks in Ireland.
Example of truck fleet with a transport company from Russia.
Example of a truck: Video with a side-tipping truck and trailer.
Example of a truck: Video with a rear-emptying trailer.
Data for a small chipper, used in a worked example.

Storing of biomass, risks and problems (Z4d)

Montgomery County, Maryland, on spontaneous ignition.
Book chapter: Equilibrium moisture quotient, Glass and Zelinka
Video: About composting and wood degradation
Direct download: Fire Hazards from self-heating…, R3Environmental
Direct download: Seasonal and long-term storage…, Researchgate.
Direct download: Linear programming model for supply chains.

End-user demands and expectations on the supply system (Z4e)

International Energy Agency: World Energy Outlook.
Direct download: Biofuels for aviation, from IRENA.
Direct download: Paper on co-firing wood and coal.
Direct download: Paper on coal milling.
Direct download: Paper on milling energy for torrefied wood.

Forest-fuel-based CHPC-production, example from Sweden (Z4f)

Direct download: Excel worksheet.

Circular economy and ash recirculation (Z4g)

Libretext homepage: https://libretexts.org/
Bioenergy Professor homepage: https://bioenergyprof.eu/
OECD homepage: http://www.oecd.org/
IVL-report: Nutrient budgets in forest soil …
Cornell University: Agricultural factsheets …
Paper: Biomass ashes and their phosphorous …
Direct download: Oecd/Eurostat Nitrogen Balance Handbook …
Direct download: Power-point lecture slides from Åbo Akademi …

Certificate task for the fourth lesson.

No external sources or references used.

Lesson 5: Final mini-project for a femto certificate on the course

Introduction (Z5 Intro)

No external sources or references used.

Project instructions (Z5 Mini-project)

No external sources or references used.