

# Energy Technology Network (EnergyNET)

NorhedII project 2021-2026

## Project Report 2023 and Activity Plan 2024

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### Foreword

The following gives a report of activities and results of the NorhedII project "Energy Technology Network, EnergyNET". The report is updated every year for the project period 2021-2026. Activities are reported from the previous year and planned activities specified for the following year.

The Result Framework for EnergyNET consists of three files:

- EnergyNET-ResultsFrameworkTable.xls is the template format for the overall result framework.
- EnergyNET-WorkPlan.docx is the planning document, following the structure for Norhed projects.
- EnergyNET-TimePlan.xlsx is the time plan for the activities at each partner university

The structure of this report follows the structure of the Work Plan for ENET. Each section has a summary for 2023 and plans for 2024.

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## Summary 2023

The core of the ENET project is a group of PhDs working on the challenges of small scale energy technology, from development to implementation. A group of PhDs are established and progressing well on three types of renewable energy technologies:

- Heat storage for cooking, frying and baking
- Refrigeration systems
- Pumps as turbines

A PhD from UEM focus on the social side of energy transition technology. The PhD group is also extended with candidates who have partial ENET support but work under the ENET research objectives and contribute to the group. Master research topics are also defined in support of the ENET objectives.

The project has good synergies with two other projects.

- Students at NTNU and at UDSM who are defined within the ENET tasks have exchange periods between the universities in a NORPART project.
- ENET PhDs benefit from the PhD course developed in the Erasmus+ UNET project and the support for the training equipment can be optimized through both UNET and ENET. ENET PhD visits to partner training sites are planned for 2024 under UNET.

Some highlights on the technical side in 2023 are:

- Baking on a latent heat storage has been demonstrated.
- A solar water heating system to give 90 degrees hot water has been developed and tested.
- The heat storage or cooking system was demonstrated at an exhibition at MAK.
- An autonomous data logger was developed and presented to all partners.
- The first Photo Voltaic training event was conducted at UoJ, with support from MAK

It is important to at times meet physically, in addition to the on-line meeting events. OJ Nydal had the opportunity to meet with many during his partial sabbatical period in 2023. ENET researchers met at two conferences in 2023 and at 3 joint UNET/ENET events. Results from ENET is also being published at a higher rate than originally planned.

## Project participants

The NorhedII project "Energy Technology Network EnergyNET" builds on a long term collaboration with a group of universities on research and education in Renewable Energy Technology. A series of joint projects the last 15 years have resulted in master programs and research capacity in Renewable Energy, with particular focus on small scale systems with off-grid applications.

The participating universities, contact persons and supervisors in 2023 are:

*Table 1 Project members*

University		Name
NTNU	Norwegian University of Science and Technology, Trondheim, Norway	Ole Jorgen Nydal (Project Coordinator) Trygve Eikevik Govert Valkenburg Torbjørn Kristian Nielsen Johannes Jäschke
AAU	Addis Ababa University, Ethiopia	Abdulkadir Aman Hassen (Coordinator) Demiss Alemu Amibe Yilma Tadesse Birhane Kamil Dino Adem
MAK	Makerere University, Kampala, Uganda	Karidewa Nyeinga (Coordinator) Denis Okello
UEM	University of Eudardo Mondlane, Maputo, Mozambique	Boaventura Cuamba (Coordinator) Antonio Leao Rogério Uthui Alberto Tsamba
UDSM	University of Dar es Salaam, Tanzania	Joseph Kihedu (Coordinator) Cuthbert Z. M. Kimambo
MU	Mekelle University, Ethiopia	Mulu Bayray (Coordinator) Asfafaw Haileslassie Mulualem Gebregiorgis Akatew haile <akatew.haile@mu.edu.et>
MUBAS	Malawi University of Business and Applied Sciences, Malawi	Ishmael B.M. Kosamu (Coordinator) Suzgo Kaunda
UoJ	University of Juba, South Sudan	Konjo Francis (Coordinator) Tito Achire

Mekelle University, MU; has become active again in 2023. From 2024, Akatew Haile will be the coordinator from MU.

## Synergies with other projects

EnergyNET is linked with other projects, which gives the following synergies:

- **“UDSM-NTNU Mobility Program on Energy Technology, 2019-2023”**  
Exchange of master students. Students are initiated with research tasks in line with ENET PhD researchers and can travel to UDSM and to NTNU for a period of research during their master thesis work. <https://www.ntnu.edu/ept/udsm-ntnu>
- **“University Network on PhD Programmes in Energy Technology, UNET” 2021-2023**  
Erasmus+ Capacity Building program. Development of PhD Curriculum and improving Training Facilities. ENET PhD researchers can benefit from PhD courses, improvements in training facilities and some mobility opportunities from the UNET project to take part in courses and make use of training facilities. <https://www.ntnu.edu/uneterasmus/>
- **NORHEDII project: Capacity building for socially just and sustainable energy transitions**  
A master student will link the two projects with supervisors from both sides.
- ENET staff at UEM are involved in the **Energy Research Centre (CPE)**. The Energy Centre will interact more closely with the UEM **Center of Studies in Oil and Gas**, where PhD studies are not limited to the oil and gas area but can be initiated to also be relevant for the ENET work in Renewable Energy Technology.
- The group of master students at UEM is coordinated with another project with Chalmers University, Sweden. This gives a larger number of master students than it would otherwise be possible at UEM. The division of support is indicated in the Appendix in the table of master students.

The combined ENET/UNET group of universities is then:

University Dar es Salaam, Tanzania University of Dodoma, Tanzania	Makerere University, Uganda Busitema University, Uganda
Addis Ababa University, Ethiopia Mekelle University, Ethiopia	Eduardo Mondlane University, Mozambique SAVE university, Mozambique
Malawi University of Business and Applied Sciences, Malawi	JUBA University, South Sudan
Norwegian University of Science and Technology, Norway	

## 1 - Programmes and methods

### MSC programmes on Renewable Energy.

#### Background

Master programmes have been established during the sequence of earlier collaboration periods in the NOMA programme (UDSM and MAK), the EnPel programme (MU) and EnPell programme (UEM). UEM is implementing two Master Programmes: one on renewable energy science and technology, established under EnPell, and another one on management of renewable energy systems, established under ENET. The master programmes are operational but should now be updated and improved regarding digital teaching methods, research-based content update and better relevance to the private sector. The MUBAS and UoJ will benefit from knowledge transfer on MSc curriculum and research programmes at the other partner universities.

The review of the master programs has been on the agenda of two Workshops in 2021. A Working Group for the review has been established for the further work:

Table 2 Working group for the review of the master programmes.

University	Name
UDSM	Cuthbert Kimambo (Lead)
UEM	Boaventura Cuamba
AAU	Abdulkadir Aman Hassen
MAK	Denis Okello
MUBAS	Chiyembekezo Suzgo Kaunda
UoJ	Achire Tito
MU	

#### MSc. in Renewable Energy at UDSM

##### Curriculum review

An analysis from UDSM in 2021 indicated some points for considerations, notably on the point of training facilities:

- Fieldwork and internship not integrated in programme values
- Lack of equipment, outdated equipment and outdated instrumentation
- Low motivation for students and lecturers towards lab experiments
- Lack of applications on course contents, too much basics/fundamentals
- Limited number of students due to lack of online/evening delivery modes, scholarships/mobility schemes



Workshop November 2022. MSc programme review	Curriculum Review Validation Workshop 2023
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There is also a need to review the programmes with respect to the mismatch between the number of courses (28 at UDSM) and specialization offered (5 at UDSM) and the yearly number of students (about 5). UDSM has provided a template for a Course Mapping and a Tracer Study, which is shared with the group.

Mapping of courses at UDSM for MSc Renewable Energy was completed in 2022. Courses a set on compulsory and elective basis, with a total of 18 courses (10 compulsory and 8 elective courses). There are no specializations as opposed to current curriculum. Currently, there are 21 courses (5 specializations, each 4 courses). The UDSM course mapping has been shared with the other partner universities.

### Activities in 2023

Teams of experts related to the courses being offered under the programme embarked on the painstaking task of reviewing the programme curriculum, including all the courses that would be offered under the programme. Through a series of working many sessions involving experts from other related fields, the team came up with a draft curriculum document that is in line with the TCU Curriculum Development Framework of November 2021. The draft curriculum was submitted to Stakeholders Validation Workshop for Curriculum Review. This Validation Workshop on Curriculum Review for CoET was held on Saturday, 2<sup>nd</sup> December 2023. It was organized in the same manner as the one for the tracer study.

Currently, the curriculum has been approved at the department and College level and has been submitted to university level for further processing and approval by the Senate, before submitting it to TCU for accreditation. It is expected that the revised curriculum would be ready for implementation by the beginning of the 2024/25 academic year.

Details of the curriculum review is attached as appendix B to this report.

### Plans for 2024

#### *Approval by UDSM machinery and accreditation*

UDSM will conclude the process of approval and accreditation of the review of the master program, by the University Senate and the Tanzania Commission for Universities (TCU). The revised curriculum is expected to be offered starting from the beginning of 2024/25 academic year (November 2024).

#### *Preparation of teaching materials for the new and revised courses*

To facilitate smooth transition into the new curriculum, relevant course lecturers will be engaged to update/prepare teaching materials for the new curriculum.

#### *Mapping of master courses among partners*

Mapping of courses from related master programmes among partners will be mapped covering;

- MSc Renewable Energy Engineering at UDSM
- MSc Renewable Energy at MAK
- MSc Renewable Energy at UEM
- MSc Energy Technology at AAU
- MS Energy Technology MU

### Tracer Study at UDSM

The project created synergy with the ongoing University-wide tracer study in 2022. One survey tool for all UDSM programmes was developed, with a common section for social data. General information is requested from all UDSM graduates. There are customized sections for each degree programme and MSc

Renewable Energy has been set as per ENET objective. Programme review is requested from 2007 to 2022 graduates, which is thought to be useful for justification of curriculum review. Development of tracer study tools (January to October 2022) built on with support from an e-government survey tools. Pilot data collection conducted followed by hybrid data collection. The target is 60% online data collection, which is set as a threshold to be attained before field can be conducted. Field visits will focus on employers plus the remaining 40% of graduates.

Online data collection took place in November and December 2022. The threshold of 60% online data collection has been achieved for all the three targeted postgraduate programmes, namely MSc in Renewable Energy (70%), MSc in Energy Engineering (60%) and MSc in Oil and Gas Technology (107%).

Programme	Number of Completed Responses	Target Sample	Completion Status (%)
MSc in Renewable Energy	14	20	70%
MSc in Energy Engineering	6	10	60%
MSc in Oil and Gas Technology	16	15	107%

Tracer study at UDSM was concluded in June 2023 and the results obtained provided very important to curriculum review exercise.

### *MSc. in Renewable Energy at AAU*

#### Curriculum review at AAU

##### **Activities in 2023**

A curriculum review activity was not executed in 2023 as planned due to the restructuring of the university as Chartered University. A program review committee was established at university level and they are performing auditing of the existing programs. Accordingly, we are advised not to modify or launch new programs until the audit findings from the existing programs is completed which may include merging of some programs in the university. However, the activities we have in the project including the availability of funding for PhD students, improvement of infrastructure and research activity with partners demonstrated the positive side of the project and is in line with some of the requirements that we should fulfil in the auditing of the program. The contributions of the project were reported in the response for program auditing.

##### **Plans for 2024**

There is no specific plan related to curriculum review as we are expecting the decision on the auditing of the program.

#### Tracer Study at AAU

A tracer study was conducted at AAU in 2022 by customizing the template shared by UDSM. The collected responses were not sufficient to draw conclusions and the activity will continue by expanding the group of respondents and population size. The responses will be analyzed and documented.

### *MSc. in Renewable Energy at MAK*

#### Curriculum review at MAK

The MSc curriculum in Renewable energy at MAK has just been revised and approved outside this project network. Teaching based on the new curriculum started in October 2022. Similarly, MSc in Physics with renewable energy specialization has also been revised and teaching on the revised version started in 2022. Therefore, it was agreed that it is not appropriate to revise the program again at this stage under EnergyNET. However, the team at MAK will participate in revision of selected courses to enrich the programmes.

#### Tracer Study at MAK

##### **Activities in 2023**

At MAK, the tracer studies which was planned for November-December 2023 could not be conducted due administrative issues related to financial management at MAK.

##### **Plans for 2024**

Given the challenges in documenting air time, data, it is not possible to carryout tracer studies even in 2024. It is also not possible to estimate the time/hrs required to carry out tracer studies, usually they are expensive. Hence such an activity cannot be supported by the MAK budget. Therefore, MAK drops this particular activity. However, MAK will document the current status of former students supported by the EnPe project.

### *MSc. in Renewable Energy at UEM*

UEM is implementing two Master Programmes: one on renewable energy science and technology (MCTER), established under EnPe II, and another one, on management of renewable energy systems (MGSER), established under a project supported by the Dutch Government (NICHE – Netherlands Initiative of Cooperation in Higher Education). ENET project supported both master programmes.

#### Curriculum review at UEM

The master programmes are operational. Curriculum review is underway, which considers the introduction of new digital teaching methods, research-based content update and better relevance to the private sector.

##### **Activities in 2023 and plans for 2024**

The curriculum review process has started and is expected to be finished only in 2025, since the cohorts of enrolled students are delayed in the process of presenting their dissertations.

At UEM the curriculum review is perceived as an evaluation of a full study cycle, meaning that it should span until the end of 2024.

#### Tracer Study at UEM

Both the master's programmes were long awaited and well received by people working in government departments, public electricity utility, private sector companies and technical schools, so these are *a priori* employed and evaluate the courses positively.

A second group of students are young graduates from universities, who are expected to start their professional life and tracer studies shall be conducted hereof.

In both cases we expect to conduct the tracer studies during the curriculum evaluation and revision in 2025.

### *MSc. in Renewable Energy at MU*

#### **Status of the program**

The Masters program has been launched with sponsor of EnPE II project since 2010 with name of MSc in Energy Technology (Mechanical Engineering) with 2-year span. Since that year the program has been accepting students from university, industry and energy sectors until November 2020. But after the breakout of the war in Tigray (November 2020), the master's program has been suspended until November 2022. The program has resume work starting from 2023 and now the chair is working to support students to complete their study who have been interrupted due to the war. Actually, the Thermal and Energy Systems has additional one MSc Program in Thermo-Fluid Engineering with sponsor of Ministry of Education and One PhD program in Energy sponsored by NORAD and Center of renewable Energy in Solar and Wind (RE-WISE) project supported by KFW.

#### **Activities in 2023**

Starting from the year 2023 all programmes has restored and start normal work with a limited financial fund from the government but hoping we will back to the normal accelerated works in the coming 2024. The chair has many partners supporting the Master's program particularly the MSc in SEE has supported by many partners example UKAiD has sponsored with fund from Carbon Trust through the coordination of University of Cape Tawon through the project of Transforming Energy Access -Learning Partnership (TEA-LP) focusing curriculum review and course updating. The partners has now engaging with Program and support the establishment of dedicated website for the program found ([www.tes.mu.edu.et](http://www.tes.mu.edu.et))

#### **Plans for 2024**

The Plan from 2024 is to Two Masters students to be attached with the project for the MSc in Sustainable Energy Engineering (SEE) according to the updated budget plan of 2024.

#### **Tracer Study at UEM**

Regarding this, it would be possible to do a limited study like a list of EnPe graduates and current knowledge of their status, skills and knowledge they have obtained, recommendation for the MSc of the program for upcoming future and practical benefit they obtained from program in the perspective the real world.

## Multidisciplinary PhD program (UEM)

### Background

A research-based PhD programme in Energy Science and Technology is running at UEM since 2011. It is interdisciplinary in its nature, meaning that students can come from whatever the field of competence, i. e. engineering, natural sciences, social sciences, and economics, among others. The PhD study duration is scheduled to four academic years, meaning 240 credit points. This programme has graduated 6 (six) PhD in technological areas, 1 (one) is waiting for the defense of his thesis and 14 (fourteen) are at different stages of their research work leading to their thesis. For the first time a social sciences student has been enrolled in this PhD programme.

This type of PhD program is very convenient in situations where there are candidates from different fields of competence. Nevertheless, where situations justify the other type of PhD studies, combining taught courses and research activities, can be implemented. Such a taught based programme will be established as part of EnergyNET activities.

The activities in 2021 towards a new PhD program were preparational, including work during two EnergyNET workshops. The program will benefit from courses being developed in the Erasmus+ project "University Network on PhD program in Energy Technology, UNET". The UEM PhD programme will be designed making partly use of the course matrix from UNET.

A course catalogue for the technological PhD programme has been developed by the partner universities, as part of the UNET project, and approved in 2022. One student from social/economic/environmental sciences has been enrolled.

### Activities in 2023

The PhD program activities at UEM have in 2023 mainly concerned operation of the existing research based program. A local cooperation with the Center of Studies in Oil and Gas at the University, provided scholarship to seven students working on energy related issues.

Curriculum revision of this PhD programme to become a taught based program has been initiated.

### Plans for 2024:

A curriculum for the taught technological PhD programme will be developed at UEM, based on the course catalogue from UNET during the first semester of 2024. Approval from the university authorities will then follow, at the end, accredited by the National High Education Regulator by the end of the year.

The revision of the existing research based multi-disciplinary PhD programme will be ended and submitted to the university authorities and then accredited by the National High Education Regulator at the same period.



Photo: Amos Veremaci was the first graduate from the PhD programme at UEM (EnPe Capacity5 project). Opponent at the PhD defense was Bjørn Karlson (2019)

## Short training courses

### Background

The partner universities experience needs for specialized short training courses on a range of thematic areas and target groups. Research students (PhD/MSc) starting on laboratory work need introduction to experimental methods and procedures. Introduction to programming systems can be useful for both theoretical and experimental students. Knowledge of specialized simulation software is typically required in different branches of science and technology. New academic staff needs training for supervision of MSc/PhD students.

Such short-term courses are not part of the regular curriculum, and the intention is that such short courses can be developed and shared in such a way that they are sustained also in the future.

MUBAS and UoJ will benefit from knowledge transfer on short courses for postgraduate students.

### *Administration systems for PhD programs*

PhD studies at universities require administrative systems for the PhD programs, including the regulation frameworks for recruitment, financing, laboratory management, IP rights, supervision, thesis evaluation and defence.

During a Workshop at NTNU in May 2022, the following short courses were given:

- **PhD administration systems and regulations** (Runa Nilssen, 10 May 2022)  
The PhD management systems and regulations at the Faculty of Engineering was introduced to ENET partners. The introduction covered all aspects from initiation to thesis defence, both on the academic and the administrative side. A “PhD Handbook – Quality in PhD Education” includes the relevant information and is available for all partners.
- **Laboratory administration systems** (Morten Grønli, 10 May 2022)  
PhDs often make use of laboratories in experimentally oriented research tasks. The Department of Energy and Process Engineering maintains extensive and advanced laboratory facilities, which are used for both PhD research tasks as well as for external contract research (e.g. SINTEF and others). The laboratory has about 100 projects every year. This requires efficient management systems, including resource management (staff and material), procurement systems and financial management systems. The management systems were presented for the partners. Microsoft TEAMS has recently been introduced as an efficient communication tool between laboratory staff and the users.
- **Purchase Systems** (Marianne Trælnes 10 May 2022)  
Operation of efficient procurement systems is a challenge for many universities. An introduction on how this is made at NTNU was given by the procurement officer at Department of Energy and Process Engineering. Tender procedures are invoked for purchases above NOK 100.000. NTNU has framework agreements with suppliers for a range of products. Purchases are handled centrally at the department, based on forms submitted by the user, where each purchase needs a project number.
- **PhD supervision training courses** (Kristin Skjeldestad, 10 May 2022)  
An introduction to how training for PhD supervisors is made at NTNU was given during a Workshop with all partners in May 2022. NTNU has three levels of support for supervisors: 1) the Uniped pedagogical program has one module on professional guidance, 2) a Central NTNU PhD supervision seminar is given two times each year and 3) seminars/courses are also provided at Faculty levels.  
The NTNU central PhD supervision seminar was presented. It is a 2-3 day event which covers a range of aspects of PhD supervision and includes group work among the participants.

PhD supervision training schemes (Kristin Skjeldestad, 2022)	Laboratory management systems (Morten Grønli, 2022)

### *Photo Voltaics (MAK)*

Makerere has established a training program for PV systems, where attendants physically put together a small system to demonstrate PV charging of a battery which provides power for lights and mobile phone chargers.

### **Activities in 2023**

The participants have been complaining the attendance was primarily for females, so some openings have been made for males as well.

MAK has developed a PV training manual in 2023. The manual has been uploaded on TEAMS. Other partner institutions can use the manual as a basis for their own training programmes.

A positive side-effect of the training scheme at MAK in 2023 is that MAK supported a similar event at UoJ (see report in Attachment). This was very successful and due to the initiatives and dedication from the ENET staff at UoJ (Konjo Francis and Tito Achire). The ENET project at UoJ has strong attention from the institution in Juba.



PV training event at UoJ, with support from MAK in 2023

### **Plans for 2024**

Makerere has been offering PV training programme to female students and the industry on annual basis for more than 8 years. The programme is successful and will continue.

### *Experimental Methods (MAK/UDSM)*

Preparational work was made in 2022 with NTNU and MAK developing a stand-alone data logger based on Arduino. The Arduino can be powered by a small PV panel charging a small battery in the Arduino system. Data is logged to a memory card. The autonomous system can be useful for logging the performance of pilot systems in off-grid field locations.

**Activities in 2023**

A session at the UNET/ENET Workshop organized by AUU in September 2023 introduced the autonomous Arduino based data loggers, as prototyped at NTNU and MAK. Jimmy Chaciga (MAK) presented the temperature data logger which is powered by PV and stores data on a memory card. The system components were described together with the building procedures and the data logging program.

**Plans for 2024**

In 2024, this activity will be extended during the UNET/ENET workshop at NTNU in May 2024. 6 PhDs will be present at NTNU during the Workshop, as it coincides with their ENET mobility period. Training on the Arduino based data logger will be practical, with construction of some sample units starting from the basic components.

A session during the UNET PhD Mobility period at UDSM will also be used for this activity in 2024. Practical application of the training will be achieved through laboratory sessions of the Pumps and Hydroturbines course. Participants will include UDSM postgraduate students and staff members in addition to the ENET and other PhD students attending the course testing and mobility at UDSM.

*ANSYS short CFD course (AAU) and Computational Methods (MAK/UDSM)*

MAK acquired COMSOL licence under UNET Project in 2022 and AAU acquired ANSYS license. ENET PhD and MSc students are already learning and using the software.

The two simulation programs have similarities and overlapping areas of application. The two training activities are therefore merged and largely based on demonstration cases where ENET PhDs are making use of the simulators. The knowledge and experiences with the software will be shared on a detailed basis, including examples of case preparations based on the PhDs work.

**Activities in 2023**

In 2023, ANSYS Fluent and COMSOL were presented at AAU as part of a UNET Workshop. The presentations were based on demonstration cases by considering on-going research activities on single tank storage system and energy storage for Injera Frying. The case of a single tank oil/rock bed flow system was presented by Karidewa Nyeinga (MAK) on behalf of Tito Achire (PhD from UoJ at MAK) who is using Comsol as a tool for the flow analysis of the heat storage.

**Plans for 2024**

In 2024, extensions of this simulation activity will continue during the UNET/ENET workshop at NTNU in May 2024. 6 PhDs will be present at NTNU during the Workshop, as it coincides with their ENET mobility period. The introduction to the simulation systems will be practical, with detailed step-through on the procedures for building cases in COMSOL and ANSYS.

Two students at MAK (one PhD and one MSc) have been using Comsol Multiphysics for simulating heat storage systems. The PhD student has documented steps on how to use Comsol. This draft document will be improved in 2024. The document is expected to be used by students from partner universities who will participate in a UNET mobility programme in 2024.



Training on PhD mentorship at AAU in 2023, during UNET Workshop: Best practices and sharing of experiences among the partners.

Prof. Tesfaye from AAU offering training on PhD Mentorship



Training on Experimental methods at AAU in 2023, during UNET Workshop: Introduction to Arduino based data logging.

Jimmy Chaciga presented a case for building a temperature data logger with Arduino.

### *Scientific writing (AAU/UDSM)*

There is a need for some training in scientific writing in our type of project, where the core of the project is a group of PhD candidates. A PhD degree includes publications and preparation of PhD dissertations, and basic guidelines and introductions to good practices can then be useful.

### **Plans for 2024**

A UNET/ENET Workshop will be conducted at NTNU in May 2024. 6 PhDs will be present at NTNU during the Workshop, as it coincides with their ENET mobility periods. A session on introduction to scientific writing will be organized as part of the Workshop.

### *PV systems and energy efficiencies (UEM)*

In 2022 a preparation of several training courses was made. The plan was that UEM should offer short courses with the following content:

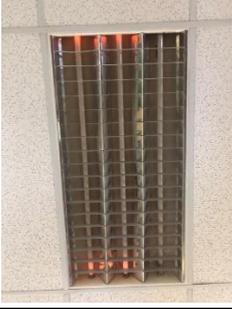
- Photovoltaic systems for productive uses of energy in rural areas (water provision, irrigation, cereal milling, among others).
- Photovoltaic systems for social uses of energy (rural institutions electrification and homes electrification).
- Energy efficiency for lighting and domestic appliances.

### **Activities in 2023**

The following short training courses have been designed and implemented in 2023:

- Energy Efficiency in Laboratories and Lecture rooms; and,
- Energy Efficiency in Buildings,

All of them in the perspective of energy auditing.

		
<p>Short Course on Energy Efficiency in Buildings. Training a group of students at UEM</p>	<p>Energy Audit Implementation at UEM campus</p>	

**Plans for 2024**

The activities mentioned above will continue in 2024, but will be implemented in the perspective of development of mitigation measures.

## 2 - Systems

### Outreach and Technology Transfer

#### *Background*

The aim of ENET is to contribute to exploitation of the results from the development work on small scale energy technology. PhD researchers and MSC students have in particular worked towards concepts and solutions for heat storage for cooking and for off-grid refrigeration systems.

The partner universities have offices and structures in place to assist in deployment of research results, to promote innovation and entrepreneurship. However, implementation is a rather challenging task, which is also limited by lack of funding mechanisms. EnergyNET will share experiences in this area, starting with introduction to the experiences from the Technology Transfer Office at NTNU.

This section concerns the system options and support structures at the universities for outreach and technology transfer. The actual cases for implementation are presented in the section on Outreach.

	
<p>MAK researchers visit a kitchen in a refugee camp (2021)</p>	<p>AAiT team visiting Bahirdar University Kitchen (2022)</p>

A TTO seminar with knowledge sharing by relevant officers from the partner institutions was planned for 2021 but deferred to 2022 as the pandemics prohibited group gatherings and travels to NTNU in 2021.

The TTO office at NTNU was presented to the partners, when they met for a Workshop at NTNU in May 2022. Results from the work of academic staff at NTNU needs to be assessed by the TTO office, before external exploitation can be considered. The TTO office can support possible commercialization of results or sign off any commercial interest from NTNU giving the inventor freedom for further use of the results.

A team of AAU researchers visited BahirDar university kitchen where about 5000 injera is baked per day. The visit was part of data collection for institutional baking and selection of potential implementation sites for project results.



TTO Seminar at NTNU, May 2022

Joseph Kihedu presenting a case for implementation from UDSM - adoption based refrigeration system.

### *Taking the results from the laboratory to the user*

The general question on how to bring the laboratory results to the user has been up for discussion in ENET.

Several external presenters were invited to give their opinions on the case, during a Workshop in 2022 at NTNU. The following options were considered:

*Table 3 Presenters on the topic on technology development and implementation. Workshop 2022.*

Topic	Institution	Name
Introduction	NTNU, EPT	Ole Jorgen Nydal
Design driven	NTNU, Design	Manisha Rayaprolu
Research driven: Social Science	NTNU, Multicultural	Govert Valkenburg
Research driven: Natural Science (on-line)	NWU, South Africa	Ashmore Mawire
Individual driven (on-line)	Simply-Solar, Germany (Scheffler)	Heike Hoedt
University driven: NTNU	NTNU, Innovation	Per Arne Wilson
Industry driven (Monday 8 May)	NABA and NTNU	Karl Klingsheim, Kjersti Blauenfeldt, Mathilde Emilie Thue
Public funding driven (on-line)	Innovation Norway	Therese Marie Uppstrom Pankratov
Development collaboration driven (on-line)	NORAD	Anette Løken
Public funding driven (on-line)	NTNU, EU	Patrick Reurink
Humanitarian Engineering driven	EWB	Heidi Hovland Bergfald
Civil Society driven (on-line)	CARE	Morten F. Thomsen
Environment and conservation driven	NTNU, Conservation	Eivin Røskoft

The participants in the Workshop could also give their opinion through a mini-survey during the Workshop, see the Workshop report for 2022 in the Appendix.

### **Activities in 2023**

Some mid-term reflections on the topic on technology implementation were shared during the ENET annual meeting for 2023, hosted by UEM in early 2024. The general view was that implementation will depend on the commercial viability of the products. The question is then on whether commercially based implementation is to be pursued within the universities or outside, or in a combination. Some views could be noted:

- **UDSM**  
UDSM has had successful experiences with a line of action form the university side. Collaboration with Technology Development and Transfer Centre (TDTC) on development and implementation and securing IPR with the UDSM Intellectual Property Management Office (IPMO). A similar scheme can be applied for ENET results.
- **AAU**  
There is a strong governmental push for universities on implementation of results, on engagement with the society and on income generating activities for the universities. AAU also has a demonstration site outside Addis Ababa (Butajira).

Banks in Ethiopia are forced to engage in Corporate Social Responsibility schemes which also includes results-based financing of commercialization initiatives. For the ENET case, tested pilots are first needed and these can be tested in dedicated pilot sites.

The AAU team discussed the options of technology transfer and outreach activities with the chair members and a preliminary plan is agreed to involve the technology transfer office in the deployment of research outputs from the chair members within the thematic areas of renewable energy technology.

- UEM

A possible scheme suggested by UEM is to engage with the Industrial institute of Maputo on the production of pilot units. The implementation could be made with the assistance of an NGO to lead the project, and a company to do the work. NGOs can attract funding and the actual work can be made by professionals on a commercial basis. The universities are not well designed to engage in such activities.

- MAK

Makerere university is prioritizing research and innovation, and the heat storage technology at the Phycis Department has also caught the attention of the TTO office. As the concept and systems have already been available in the public domain, patenting is not viable, and the current question is rather how the system can be forwarded out of from the university. Teaming up with NGOs and companies (existing or startups) can be considered. Ideally, after the field implementation; MAK share results with key stakeholders and this is expected to lead to the development concrete plans for either commercialization of securing funds for mass production and deployment of the system.

- NTNU

Results which may have commercial potentials from academic staff at NTNU is required to be screened by the TTO office at NTNU. TTO can then choose to take the case further or decline any commercial rights to the results. The prerequisite is often that the results have not been published in any form. Results which have been published can not be patented. Most of the heat storage concepts from the NTNU laboratory have been cleared and further use is not limited by TTO at NTNU.

The cases for implementation of ENET results are further considered in the section on Outreach.

### **Further plans**

The further involvement of the TTO offices (or corresponding offices) at the partner universities will be for each partner to initiate, depending on the status of technology implementation at each site.

- AAU

The AAU team will identify a possible technology demonstration site in consultation with TTO of AAU. The aim is to focus on one target group (society/village) to study and investigate the impact of renewable technologies which are the outputs of the research activity in the chair, and to closely monitor the results with objective of obtaining measurable KPI's

- UDSM

The UDSM Team continues to work hand in hand with the TDTC and IPMO on various aspects of the EnergyNET research works.

- MAK

As the prototypes have been published, patent based further engagement with TTO at MAK will not be pursued.

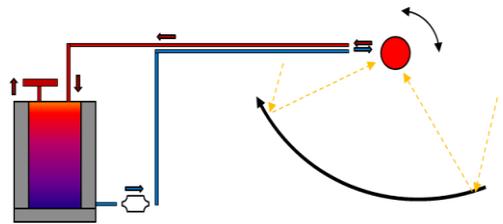
## Shared Network Resources

### Background

EnergyNET and UNET (University Network on PhD program in Energy Technology, Erasmus+ project) is based on a core group of universities which have collaborated through a series of joint projects for very many years. The group of universities has been extended, and the intention during ENET period is to prepare an MoU as a framework for further collaboration and sharing of results after the project period is completed.

An MoU between the partners, as a framework for a more open university network, may be formulated such as to cover both the interests of partners in UNET and in EnergyNET.

A framework for a new web site for a more open network has been established, to draw the attention of researchers in African universities who are active on development and testing of small scale renewable energy technology. The intention is that the site is managed on a yearly basis in turn among the participants. The site shall also serve as a repository for research results which can be useful for a broader community.



### Activities 2023

UDSM Team continued to cooperate with members of partner Universities of various areas outside the EnergyNET project, under the auspices of the existing MOUs between the institutions. There have been three visits to UDSM by researchers and leaders from UEM in 2023, all hosted by EnergyNET Team.

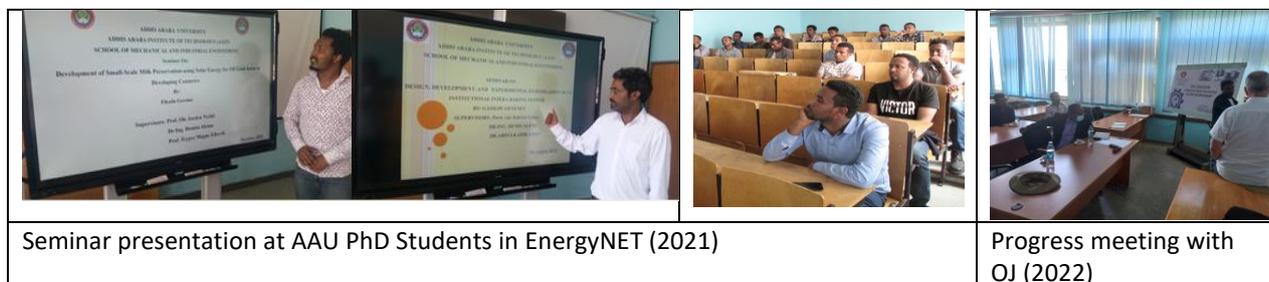
### Further activities

The experience from the UNET and ENET based discussions on an MoU for the further life of the university network is that we can wait until further approaching the end of the project period.

### 3 - People

#### Background

The core work force in EnergyNET is a group of PhD candidates and associated master students. The intention is also that EnergyNET shall provide opportunities for mobility and exchange of the participants.



#### PhD researchers

Table 4 Overview of PhD/PostDoc researchers

Partner	Title	Name	Supervisors	Start date	ENET Funding
UDSM	<i>Optimisation of Adsorption Refrigeration System Utilizing Various Heat Sources</i>	Joseph Ibrahim	Cuthbert Kimambo, and Joseph Kihedu (UDSM), Trygve Eikevik and Ole Jorgen Nydal (NTNU)	February 2022	Scholarship Laboratory support (Tuition fee waived by UDSM)
UDSM	<i>Performance Optimisation of Oil-Based Sensible Thermal Storage System for Cooking Application</i>	Anna Kisioki Sharishoy	Cuthbert Kimambo, Joseph Kihedu (UDSM) and Ole Jorgen Nydal (NTNU)	November 2022	Laboratory support Mobility (NORPART and UNET)
MAK	<i>Development and field testing of a solar cooker with a heat storage system</i>	Jimmy Chaciga	Karidewa Nyeinga and Denis Okello (MAK) and Ole Jorgen Nydal (NTNU)	April 2021	Scholarship Tuition fee Laboratory support
MU	<i>Heat storage for baking (post doc)</i>	Mulu Bayray	Ole Jorgen Nydal (NTNU)	2023	Scholarship  Laboratory support
MU	<i>Heating systems for solar heat storages</i>	Tsige Gebregergs Tesfay	Mulu Bayray (NTNU), Ole J. Nydal (NTNU)		Scholarship Tuition fee Laboratory support
AAU	<i>Design, Manufacture and Performance Test of Small Scale Milk Refrigeration and Pasteurization Unit</i>	Fikadu Geremu Bodena	Demiss Alemu (AAiT,AAU), Trygve Eikevik and Ole Jorgen Nydal (NTNU)	September 2021	Scholarship Tuition fee Laboratory support
AAU	<i>Design, Development and Experimental Investigation of an Institutional Solar Fryer</i>	Gashaw Getnet Birhanu	Abdulkadir Aman (AAiT,AAU), Demis Alemu and Ole Jorgen Nydal (NTNU)	September 2021	Scholarship Tuition fee Laboratory support
UEM	<i>Reconstructing life and energy after disaster</i>	Cândida Bila	Govert Valkenburg (NTNU), Inês Raimundo (UEM)	November 2022	Scholarship Tuition fee Laboratory support
UEM	<i>Experimental investigation of an oil based solar collector for cooking applications</i>	Tomas Nhabetse	Boaventura Cuamba, António Leão and Amós Veremachi (UEM), OJ Nydal	From EnPe	Scholarship Tuition fee Laboratory support

			(NTNU)		
UoJ / MAK	<i>Modeling and simulation of heat storage systems for cooking with multiple cookers</i>	Tito Achire	Denis Okello and Karidewa Nyeinga, (MAK), Ole Jorgen Nydal (NTNU)	October 2022	Scholarship Tuition fee Laboratory support
MUBAS / UDSM	<i>Performance Optimization of PAT-SEIG Operating in an Off-grid Energy Generation Setup</i>	Emmanuel Jack Nyirenda	Cuthbert Kimambo and Joseph Kihedu (UDSM), Torbjorn Nielsen (NTNU)	Dec 2021	Scholarship Tuition fee Laboratory support
NTNU	<i>CPC for solar cooking</i>	Casiana Lwiwa	Ole Jorgen Nydal (NTNU), Cuthbert Kimambo (UDSM)	2019	Laboratory support
MU/NTNU	<i>Direct and indirect solar fryers</i>	Mesele Hayelum	Ole Jorgen Nydal (NTNU) Mulu Bayray (NTNU)	From EnPe	Support for completion
MU/NTNU	<i>Medium scale wind turbines</i>	Hailay Kiros	Torbjørn Nielsen (NTNU) Mulu Bayray (NTNU)	From EnPe	Support for completion
NTNU	<i>PCM and heat pipe for frying on heat storage</i>	Abraham Parra	Ole Jorgen Nydal (NTNU)	From NTNU	Laboratory support

Recruitment of PhD candidates commenced at project startup, the status of the group is given in Table 2 and summaries of activities are given in the Appendix. The degree of ENET funding is also noted. The PhDs work typically in the domains of heat generation and heat storage (MAK, UEM, AAU, MU, UoJ), refrigeration technology (AAU, UDSM), Hydro power (UDSM, MUBAS) and the Social Side (UEM). There is therefore common ground among several PhDs and on-line progress meetings with in-depth presentations are then useful for the group as a whole.

The PhD group includes PhDs at NTNU who have other financing (Abraham Parra is self-financed and Casiana Lwiwa is supported through NTNU Energy) but are managed as part of the ENET group. Two candidates from MU have been transferred from the EnPe “Capacity 5” project, for completion during the ENET period.

### Activities 2023

UDSM initiated a new PhD on solar thermal in 2023 (Anna Kisioki). The tuition fees are self-financed and ENET supports the research costs. NORPART supported three months mobility to NTNU between February and April 2023.

The PhD group progresses well, and several have participated with presentations at conferences in 2023. On-line technical meetings on TEAMS are useful and we have had synergies with the UNET and NORPART project, where we could meet more frequent than in ENET alone. Ole Nydal also met with the PhDs during visits as part of his sabbatical period from NTNU the last part of 2023.

The initial list of PhDs included two candidates at MU. As MU became isolated during the period of armed conflict in Ethiopia, this was modified to become one PostDoc (partial) and one PhD. The PhD had already registered early on in the Norhed II period. Mulu Bayray had the opportunity to stay at NTNU under ENET support, and could perform work tasks with relevance for MU while at NTNU. MU started to become operational again in 2023. Hailay came to NTNU mid 2023, for his planned completion of the PhD dissertation at NTNU.

### Further plans

At UEM, Daniel Filipe, will be enrolled in March 2024 as the selected follow up student of Tomas Nhabetse's project.

The recruitment is then completed, and emphasis will be on supporting the PhDs such that completion is made within the NORHED program period.

### Master students

Master students are initiated to support the research areas of the PhDs, and they are reported here as part of the group when their research costs and/or their tuition /scholarship costs are supported by EnergyNET. The **Feil! Fant ikke referansekinden.** indicates the type of support from EnergyNET, the Appendix gives more details on the master students.

In 2022, Makerere recruited and offered scholarships to 6 students including one from Juba; 3 females and 3 males. One of the female students, Rebecca Nambuya pursuing MSc in Renewable Energy had dropped out of her studies due lack of tuition. Through the scholarship, she was able to resume her studies again. Research topics are yet to be provided since all the students started course work in 2022.

### Activities in 2023

- NTNU  
6 master students were involved in ENET research activities at NTNU in 2023. They also visited UDSM under the NORPART mobility project in early 2023.
- UDSM  
initiated the second master student (male) on oil-based cooker in 2023. The master student will work with PhD student to develop the cooker. The tuition fees and stipend are covered by UDSM Merit Scholarship programme while ENET supports research costs.
- AAU  
The Approach at AAU is to try to accommodate many applicants mainly female, by covering only the tuition fee for those who fulfil the requirements. Thus, we shift part of the scholarship fee for master students into tuition fee and enroll about 10 students to the program. It also gives us opportunity to work on about 10 research topics as part of their M.Sc. thesis work. AAU recruited 3 M.Sc students to join the M.Sc. program in mid of 2023. The plan was to recruit 10 competitive students through notice publicized on different platforms including university notice board, social media and emails. A poster for call of application was prepared and shared on different platforms. Accordingly, 37 applications were received in the first round of applications. The list was reduced to 15 for further screening through interview and entrance examination. However, the university requirement to sit for Graduate Admission Test was the main limiting factor as many of the applicants were not able to come and attend the test. The instabilities in different parts of the country were restricting many applicants to come and attend the test and only six of them managed to sit.
- UEM  
The implementation of both MSc programmes at UEM has continued. The taught component of the studies was successfully finished by all the cohort of students. About 40 students are in the process of finalizing their dissertations to be defended in the first semester of 2024. Twenty of them are sponsored by ENET program and their situation is illustrated in the Appendix.



**EXTENDED**

Addis Ababa Institute of Technology  
Addis Ababa University



**Norad**

### Call for Application (Tuition and Full Sponsored M.Sc. Study)

The Chair of thermal and energy systems engineering at the School of Mechanical and Industrial Engineering, Addis Ababa Institute of Technology, Addis Ababa University, calls applicants to award a scholarship to highly qualified candidates, who are looking to study their MSc in Thermal Engineering/Mechanical Engineering.

Addis Ababa University represented via the Chair of Thermal and energy systems engineering is a recipient of an attractive grant from NORAD. The University is one of the groups of African universities to collaborate with NTNU under the NORHED II Norad programme, on developing small scale renewable energy solutions for off-grid applications.

**About the Program**  
EnergyNET is a project under the NORHED II NORAD programme – the Norwegian Programme for Capacity Development in Higher Education and Research for Development. EnergyNET aims at bringing technical solutions from the laboratories into field testing. The EnergyNET project is based on many years of collaboration among African universities and NTNU, on the development of master's programmes and research capacities within Renewable Energy Technology.

**Advertising Unit**  
Thermal and Energy Systems Engineering unit at School of Mechanical and Industrial Engineering

**Area of Study**  
Renewable energy, Thermal engineering, energy systems, Thermal storage, Small scale off-grid energy systems for heating and cooling, hybrid systems with heat storage solutions for cooking, within the sub-specialties of Solar Thermal, Solar PV, Refrigeration and Hybrid Systems.

**Eligibility Criteria**

- Applicants who graduate from universities with BSc degree in Mechanical Engineering
- Applicants should obtain a minimum of CGPA of 3 or equivalent at the Undergraduate Degree level.
- Must have good English proficiency both written and speaking
- Must be able to demonstrate their work in seminars presentations and conference proceedings when requested
- Must have good knowledge and skill in computation, geometry modeling software and Analysis software such as ANSYS package
- Must fulfill the entrance requirements of the program applied for and the University's requirement such as passing the graduate admission test (GAT) exam
- Age must be not more than 35 years old at the time of application.

**Benefits of the Scholarship**

- 10 Applicants who won the scholarship award will be free from tuition fees
- Three female candidates additionally will get a monthly allowance of 8,000.00 birr
- Competent students will be recommended for PhD study programs in universities local abroad.
- Competition based conference proceeding presentations at international call for conferences

tuition covered **10** for awardees

**8,000.00** monthly allowance for 3 female candidates

and many more...

**Selection Criteria**  
Applications will be considered according to the following selection criteria:

- High-level academic and extra-curricular achievement.
- Excellent communication, writing and reading skills in the English Language.
- Female applicants will get eligible for additional fellowship payment.

**Terms and Conditions**

- Scholars must be a fulltime Masters students to give full attention and must not be parttime students
- Scholars must not change their programme during the tenure of the scholarship except with written permission from the university and the School graduate committee of SMIE.
- Scholars must fulfill the requirements of the study programme and abide by University laws and rules, regulations, and codes of conduct.
- Any suspension from the university will result in immediate suspension of the award. Monthly allowances are not payable during the suspension.
- Scholars must maintain good academic progress and good standing throughout the study duration as stipulated by the university. Failure to do so will result in the scholarship being withdrawn.

**Key days**

- University application calendar
- Advertising unit announcement dates
- Applications must be submitted to the contact person through email before **FRIDAY, AUGUST 15/2023 @ 23:00**.

**Contact**

**Dr. Abdulkadir Aman**  
Head, Thermal and Energy systems chair  
School of Mechanical and Industrial Engineering | AAIT | AAU  
Email: [abdulkadiraman@aait.edu.et](mailto:abdulkadiraman@aait.edu.et)  
Phone Number: Office: +25111232414  
Mobile: +251911811528

## Plans for 2024

- **NTNU**  
6 new master students at NTNU will be involved in the ENET work on heat storage, wind controllers and testing of refrigeration concepts. The students will also visit UDSM under the NORPART mobility project in early 2024.
- **AAU**  
AAU will continue recruiting more master students to achieve the goal of 10 Master students. The EnergyNET project will cover the tuition fee for male applicants and a tuition fee and scholarship for female applicants. 2 male and 1 female are already sponsored in 2023 and 7 master students will be sponsored in 2024.
- **MAK** will support two self-financed students in research and lab work in 2024.
- From UEM a total of 20 students from both MSc programmes (MCTER and MGSER) are being supported by EnergyNET. They started their studies in 2022, finished the taught component and submitted their research projects for their dissertations in 2023. In 2024 they are expected to finish their research work and pass the final examination.

Table 5 Master students with EnergyNET support

Year Start	University	Male	Female	Tuition	Scholarship	Lab costs	Completion by 2023
2021	NTNU	3	1			4	4
2022	NTNU	1	2			3	3
	AAU	2	3		5	5	4
	UDSM		1	1			
	MAK	5	3	5	4	5	
	MAK/UoJ	4	3	6	5	7	1
	UEM	8	12	20	12		
2023	NTNU	5	1			6	6
	UDSM	1				1	
	AAU	3		3		3	
All	<b>58</b>	32	26	35	26	34	18

### Graduation

#### Graduation of MSc students

A list of MSc students is given in the Appendix, and includes the thesis title, a short description of the work and the graduation status.

#### Graduation of PhDs

Some of the PhDs were initiated before the ENET project period. They complete their theses and are to graduate in the NORHED period.

The following is a list of the graduated PhDs:

- Pamella Kajumba (F) at MAK, 2022. PhD title: *Development and assessment of a cooking unit integrated with a solar thermal energy storage system*.  
Pamella was funded by the EnPe Project, she continued in ENET with graduation. She is a lecturer at Kabala University.
- Michael John (M) at UDSM, May 2022. PhD title: *Development of Adsorption Refrigeration System for Off Grid Application*.  
Michael works as a lecture at UDSM, Department of Mechanical and Industrial Engineering.

### Mobility

Mobility between partner universities gives efficient resource sharing, enhances the collaboration by personal contacts, increases the awareness of the differences and the similarities between the cultures and the socioeconomic conditions in the partner countries, and promotes further joint initiatives. These are benefits for both staff and students.

Travels to partner universities or workshops/meetings is also optimized together with the following projects:

- Erasmus+ project: University Network on PhD Program in Energy Technology.
- NORPART project: UDSM-NTNU Mobility Program in Energy Technology 2019-2023

#### Activities in 2021

Travels and exchanges were very limited in 2021 due to the pandemic regulations. Workshops were rescheduled and moved. Two workshops were nevertheless organized and hosted by UDSM in Tanzania. Even if not all project members can join, the physical meetings are very useful.

### Activities in 2022

In 2022, Mulu Bayera from MU happened to be in Europe during the challenging political situation in Ethiopia. It was therefore possible for him to come for a stay at NTNU with partial support from the MU part of the ENET budget (Post Doc). Mulu engaged in activities at NTNU which were planned for MU.

Jimmy Chaciga from MAK spent one and half month at NTNU in 2022, working in the laboratory together with NTNU master students on the solar storage technology. Going back to MAK, Jimmy could copy the system from the NTNU laboratory and proceed with it at MAK. MAK also hosted 2 master students from Upsala university, Sweden; they carried research within the project thematic areas. Thesis was supervised by Makerere and Uppsala.

OJ Nydal visited UDSM, MAK, AAU and UEM during his sabbatical period the last part of 2022.

### Activities in 2023

UDSM Team continued to cooperate with members of partner Universities of various areas outside the EnergyNET project, under the auspices of the existing MOUs between the institutions. There have been three visits to UDSM by researchers and leaders from UEM in 2023, all hosted by EnergyNET Team.

The NORPART mobility project facilitated exchange of MSc students between UDSM and NTNU also in 2023. This is very inspirational for the students. In 2023. Two ENET PhDs from UDSM (Ibrahim Joseph and Anna Kisioki) also joined the NORPART project group from UDSM. Ibrahim returned in late 2023 and continued with experimental work on adsorption refrigeration, under the ENET mobility funding.

Hailay Kiros (MU) is registered as a NTNU PhD candidate (from EnPe project) and came to NTNU for a half year period to work on the finalization of his dissertation. Mulu Bayray could also continue at NTNU, and later transferred to a Post Doc position at Electrical Department at NTNU.

The second part of the sabbatical period of OJ Nydal took place during the last part of 2023, where he again could visit the partners in Ethiopia, Tanzania, Uganda and Mozambique.

### Plans for 2024

A group of PhDs were planned for a period of stay at NTNU in 2023, but this was shifted to 2024, when OJ is to be more present at NTNU. The following mobility is planned for visitors to NTNU, many during the period April-May 2024.

- UDSM: Emmanuel Nyirenda (Hydropower).
- MAK/UoJ: Jimmy Chaciga (Solar thermal) and Tito Achire (Computational).
- AAU: Fikadu Geremu (Solar heating and cooling) and Gashaw Getenet (Solar frying).
- UEM: Candida Bila (Social science).

The new PhD candidate Daniel Filipe student will visit NTNU or MAK for a period of two months for introduction to the solar heating storage systems.

- MU: Tsige Gebregergs Tesfay (Solar thermal).

The group of PhDs will be involved in a mobility scheme under the UNET project in 2024, to take part in PhD courses and to visit laboratory facilities at partner universities. The hosting universities are: UDSM, MAK, AAU and UEM and students come for a period of 1-2 months each.

Table 6 Overview of mobilities

	Mobility	Months	Persons	Comments
2022	MAK-to-NTNU	1	1	

	MU-to-NTNU		1	Partial ENET support
	NTNU-to-all	Shorter visits	1	Facilitated by sabbatical period for OJ Nydal
2023	UDSM-to-NTNU	3	2	NORPART support
	UDSM-to-NTNU	3	1	Fully supported by ENET
	MU-to-NTNU	5-8	2	
	NTNU-to-all	Shorter visits	1	Facilitated by sabbatical period for OJ Nydal
2024				

## 4 - Gender and Equity

### Background

Inclusion of women will in particular be valuable for the research tasks in EnergyNET, as the implementation of the energy technology solution for reducing the use of fire wood will foremost benefit women. Female researchers taking part in the development and dissemination are therefore also expected to increase the impact of the results, in terms of awareness and acceptability among the users.

It is a challenge to recruit females to PhD positions among staff members, simply because the recruitment base is often very small. The female recruitment base for MSc studies is larger, as the applications are nationwide.

11 types of awareness and recruitment actions are planned, targeting females in particular. Some of these will be recurring events.

### Activities 2021

As the general academic activities have been reduced across most universities in 2021, the actions targeting females have also been limited in 2021.

At Makerere, Solar PV training sessions were conducted for female students at the bachelor level. Due to Covid restrictions, trainings were carried out in a staggered manner: separate trainings held for each class, i.e. year 1, year 2, and year 3 students. The training covered: design and installation of solar PV system mainly for standalone system; and system maintenance. After the theory and demonstration in the class; the students were moved into practical sessions outside where the small groups were guided by technical staffs.



PV training event at MAK 2023 (participants and Karidewa Nyienga) 2022)



Makerere: Students attending PV practical sessions; and students during classroom sessions on PV system.

**Activities 2022**

- **PV training for female students (MAK)**

Makerere carried out a five day PV training programme on 16-20 May 2022. The training programmes are designed to equip participants with competence and skills needed in the sizing, installation and maintenance of solar Photovoltaic systems and biogas plants. Technicians from the Industry participated as well. EnergyNET sponsored female students at both MSc and bachelor level to participate in the training. The training was reported on the College of Natural Sciences, Makerere, website on: <https://cns.mak.ac.ug/blog/8th-workshop-solar-photovoltaic-installation-biogas-production-underway-conas>. The training was also reported on social media platforms of the college: <https://twitter.com/MakCoNAS>.

- **Recruiting female students for EnergyNET supported studies (All)**

The current fraction of female master students in EnergyNET is 57%. The fraction for female PhD students in EnergyNET is less, 25%, due to smaller recruitment base among the university staff.

- **Awareness seminars in selected rural schools (MAK)**

The education sector in Uganda is still constrained by many challenges despite the increase of the number of children enrolled in schools. It is still a major challenge to transfer teachers to disadvantaged areas commonly referred to as “hard to reach areas”. Northern Uganda is a region which has been involved in war for more than twenty years; forcing the majority people into internal displaced people’s (IDP) camp. The number of girls attending secondary school education in most rural parts of northern Uganda is still low. During the period 11-15 July 2022, a team of staff from the Department of Physics, Makerere University visited 8 schools in Northern Uganda to promote/motivate girls to pursue science education beyond the secondary school level. The students were also given access to equipment; these are equipment taught in class but have never used them practically. The mobile lab has excited both students and teachers in the rural schools.

- **NORHED Gender Workshop (Entebbe)**

Jimmy, Karidewa, and Ole Jorgen participated in Gender Workshop at Entebbe, Uganda, 30 August – 1st September 2022, organized by NTNU (Charlotte). Karidewa made a presentation on gender related activities in the EnergyNET project.

- **Motivation to girls' secondary school (UDSM)**

Students from girls' secondary school in Morogoro region were invited to attend the Annual University Research Week event at UDSM, where renewable energy teaching and research activities were exhibited. The activity targeted to motivate girls to choose energy subjects, when they join university. It should be noted that the said secondary school in Morogoro admits girls who are school drop-outs due to failure to pay tuition fee or childhood pregnancy. The UDSM EnergyNET project Team organized a visit of staff and students to the same school in 2021 to provide inspirational talks. The activity was finance by the project.

← **Tweet**  
 @MakCoNAS  
 8th Workshop on Solar Photovoltaic Installation & Biogas Production Underway @MakCoNAS . Other areas of training: Photovoltaic system planning and sizing; storage batteries, introduction to biogas, classification of biogas, field trip to biogas plant.  
 @Makerere @norad\_g @Sida



2:13 PM · May 18, 2022 · Twitter Web App

Twitter on PV training at MAK



Mobile lab demonstration and career guidance in rural schools (MAK)



NORHED Gender Workshop at Entebbe, Uganda, 30 August – 1st September 2022



Secondary School Girls from Morogoro Region visited UDSM in April 2022



**Activities 2023**

- **PV training for female students (MAK).**

The history of the PV training for female students continued also in 2023.

- **Awareness creation for refugee communities (AAU)**

The training planned for refugee communities have been on hold, due to the security conditions in the country hindering safe implementation of project activities. An indirect awareness creation has been initiated for injera bakeries and cookstove users with a local company which has experience in offering similar trainings on cook stove users (DANAS Electrical Engineering). The Ethiopian Energy Authority proposed to engage stakeholders from regions, but this is on hold due to the ongoing conflicts in different region. We plan to offer the trainings in 2024.

- **Awareness creation for female students (AAU)**  
The awareness creation for female students on PV technologies has been initiated in 2023. A call for registration brochure is prepared and disseminated to reach out to as many female students as possible from the undergraduate program from remote areas. A local company named 'Green Scene Energy' with ample experience in the area expressed willingness to support in the offering of the training. The training content and venue for theoretical and practical trainings were identified and preparation are underway.
- **Support to Association of Women (UEM) in matters of solar irrigation.** This took place in a rural community of the district of Chókwè, Province of Gaza.

#### Plans for 2024

- **MAK**  
The successful annual PV training scheme continues at MAK also in 2024  
MAK will also continue visiting rural schools to motivate students to pursue further education. Mobile laboratory demonstrations will also be carried out in the rural schools.
- **AAU**  
Training events will be organized for female students on PV technologies and for mass bakeries in Addis Ababa.
- **UEM**  
Continued support to the Association of Women from Chókwè district in entrepreneurship, cooperativism and marketing.  
Training of peri-urban women in sustainable cooking (reuse of diversified domestic biomass wastes)
- **UDSM**  
Continue with motivation of girls at secondary level to science fields. Such activity will target schools in Morogoro and Southern regions.
- **MU**  
We are planning to conduct Gender mainstreaming initiatives training in collaboration with University gender office. The chair has conducted PV capacity training for women in February with the sponsor from other projects. Therefore, this training will add more values to the gender issues and sensitivity and motivates the university gender office to restore back to work on these issues and creates more awareness in the region.

## 5 - Infrastructure

### Background

One aim of the university collaboration is to share access to research resources. As scientific equipment can be rather expensive, this shared approach will be cost-effective, and promote future interactions. It will also give higher quality of the facilities, as the investments can be specialized.

The pandemic has also revealed the importance of efficient internet communication systems, as on-line events tends to become more common.

EnergyNET plans on improving three types of facilities.

- Upgrades of technical laboratories (dedicated rooms, equipment, tools and instrumentation)
- Computer laboratory (high capacity computers and software licenses)
- ICT rooms to also support EnergyNET collaboration on research and education

Most of the EnergyNET partners also participate in the Erasmus+ UNET project, which has some budget allocations for training facilities as well.

### Activities 2021

The planning of the equipment and infrastructure activities in ENET is made alongside the UNET planning. The UNET project time span is shorter than the EnergyNET time span. The time scheduling for the acquisition of research equipment in EnergyNET has therefore been proposed to come after the UNET UNET equipment has been processed first. This gives time for optimizing the further acquisition of EnergyNET equipment.

The facilities for upgrading are:

- UDSM: Upgrading Renewable Energy Laboratory and Computer laboratory for digital training
- MAK: Improved institutional small scale infrastructure and equipment for education and research
- MU: Hybrid solar/wind /hydro laboratory and Computer laboratory
- AAU: Thermal energy laboratory and ICT-room for e-learning
- UEM: PV/Thermal laboratory upgrade, with focus on thermal storage
- MUBAS: Hydropower
- UoJ: Solar energy

### Activities 2022

- **MAK: Improved Solar Seminar Room**

The solar seminar room which is being used by visitors (both students and professors from abroad) and for meeting graduate students was improved; the floor was tiled; curtains and basic furniture acquired; windows and outside repaired. The roof top was also worked upon to avoid water leakages. The front was improved to stop rain water from flowing in. Electrical work and internet network done.

- **MAK: Equipment for solar thermal research**

Solar PV modules and accessories were purchased for research in solar thermal heating. Insulating materials, charge controllers, heating elements and components for Arduino based data logger were received from NTNU. K-type thermocouples were purchased for temperature measurement.

### Activities 2023

- **UDSM: Upgrading of MSc Renewable Energy lecture room**

Upgrading of dedicated room in form of replacement of room air conditioners for MSc in Renewable Energy was initiated in August 2023. Due to major changes in financial and procurement systems, the tender for procurement of the air conditioners was delayed until March 2024. Supply and installation of the air conditioners conclude, payment is pending on UDSM internal procedures.

- **AAU: Seminar room upgrading**

Equipments to upgrade the seminar room were identified but the purchase was put on hold mainly due to the possibility of acquiring the resources from other sources of funding. In 2023 the plan was to purchase furniture and some electronic equipment for the room. However, as the furniture could be obtained from other funding sources the plan is to use the ENET budget in the procurement of other ICT facilities for the room.

#### **Plans for 2024**

- UDSM: Seminar room upgrading to be completed, focus on laboratory room.
- AAU: Seminar room upgrading with ICT equipment to be completed.
- MAK: Equipment and components will be needed for the planned field deployment of the heat storage cooker at a refugee camp in northern Uganda.
- UEM: Rehabilitation and refurbishment of the Doctorands working room will be undertaken at CPE-UEM. We have delayed the use of ENET money since we prioritized UNETs.

## 6 - Outreach

### Implementation of results

#### **Background**

An important objective of EnergyNET is to proceed towards implementation of research results. This involves more complex and multidisciplinary types of challenges than the pure technical ones. The aim is that university researchers shall be involved in these challenges through PhD studies and that master students can be trained in this area through relevant course work and through participation in research and field work.

The energy solutions for implementation have been selected based on the experiences and results from the previous collaboration and targets essentially off-grid solutions for food preparation (cooking and frying) and conservation (refrigeration).

The systems will be first established and kept operational as test systems at the universities, before ported to field tests.

#### **Activities on implementation**

The PhDs will be instrumental in the implementation activities. 2021 has been a year of startup for the PhDs, the status on each is given in the appendix. Implementation activities will follow, after a test and qualification period at the universities, which has proceeded in 2022.

The technology units for testing have the following plans:

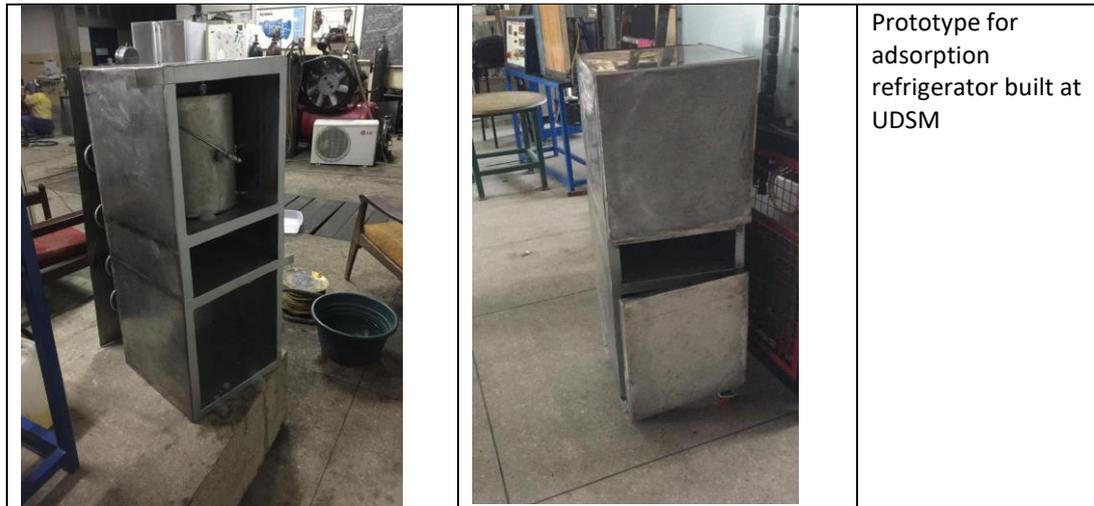
#### *UDSM: Solar refrigeration*

An adsorption refrigeration process has been explored in a PhD study at UDSM in an EnPell project (Capacity5). This is a static system, which have no moving parts and rely only on a heat source which can be direct or indirect solar energy or heat generated by burning biomass materials such as agricultural waste.

The main objective of the UDSM Energy Technology Transfer from University to Industry project is to fully develop and commercialize on prototype renewable energy technology. Specifically, the project aims finalize the development of the solar refrigeration prototype in collaboration with Technology Development and Transfer Centre (TDTC) conduct field tests of the systems and conclude arrangements for commercialization of the technology in collaboration with the UDSM Intellectual Property Management Office (IPMO).

#### **Activities 2022**

Prototype for adsorption refrigerator for household application has been manufactured at UDSM. The refrigerator has been made in standing box shape similar to common domestic vapour compression refrigerators. Performance testing has not been concluded; however, it is expected that temperature variation in the cold chamber (evaporator) is expected to prevail.



### Activities 2023

UDSM Team continued to work hand in hand with the TTO agencies, namely the Technology Development and Transfer Centre (TDTC) and Intellectual Property Management Office (IPMO) on various aspects of the EnergyNET research works.

### Plan for 2024

The further involvement of the TTO at UDSM will be made through the Intellectual Property Management Office (IPMO) and the Technology Development and Transfer Centre (TDTC). Activities to be performed are to explore and utilised any potential for intellectual property right and prototype manufacture and field testing respectively.

UDSM will continue to work towards transfer of solar refrigeration technology focusing on;

- Stabilize evaporator temperature oscillatory behaviours through cold storage
- Confirm suitability of solar energy as source of heat for adsorption refrigeration
- Testing of box type adsorption refrigeration
- Secure IPR for developed solar refrigeration technology with assistance of TTO and IPMO
- Commercialize solar refrigeration technology with partner company/agency/NGO

### *MAK: Solar cooker for a school*

The main goal of the outreach programme at Makerere is to deploy and test a solar cooker with thermal energy storage system at school in a refugee camp. This is line with the strategic plan of the university requiring researchers to conduct community outreach programmes. The proposed outreach is expected to establish and strengthen collaboration between academia, government, industry and humanitarian organizations.

Solar cooker –concepts/ system components have been developed and tested at NTNU and Makerere over the past years. No field tests of the solar cooker technology have been carried out in the previous projects. A solar cooker with heat storage will be deployed at a school in a refugee camp, in Adjumani district. The district hosts about 200,000 refugees from South Sudan.

### Activities 2022

- **Pilot systems**

The work at Makerere on thermal energy storage system integrated with cooking units has been in the laboratory in 2022. Several pilot units have been established at MAK

- 1) single tank heat storage system – small size;

- 2) single tank heat storage system –larger size;
- 3) dual tank – based on mild steel;
- 4) dual tank based on Aluminium.

Cooking units were fabricated out of Aluminium; and cooking units purchased from the local market.

- **Data logger**

An Arduino based autonomous data logger has been designed and produced, and will be installed on the test sites for the prototypes.

- **Field visit to refugee camps**

The Makerere team visited two refugee camps in northern Uganda, namely 1)Pagirinya in Adjumani district, and 2) Bidibidi in Yumbe district. The team held meetings with officials from UNHCR, Office of the Prime Minister – Refugee desk; school managers; local Community Based Organizations; and district local government officials. The research on solar cookers with heat storage thoroughly discussed; and the plan to pilot the system in a selected school in a refugee camp attracted a lot of interest from the stakeholders.

- **Field visit to solar measurement stations**

The department of Physics has established four solar measurement stations in the country. Our technical staffs visited the stations in Mbarara, and Tororo to download the data; and carryout maintenance work.

### Activities 2023

More laboratory tests were made at MAK on the system to be implemented. This concerned in particular the performance of the PV controllers and on the circulation system for the power regulation. The system seems to perform convincingly. The final needs before implementation will be a temperature safety control method, to avoid overheating of the oil.

The same principles with self-circulation in an oil based heat storage was also tested for a mini-version of the system. The aim is down-scaling to household levels.

### Plans for 2024

New heating elements will be tested in 2024. MAK then plans to carryout field deployment of solar cooker in a school within a refugee camp in northern Uganda. This will involve fabrication of new systems and purchase of components to be installed in the field.



The MAK team at Bidibidi refugee camp (2022)



Pagirinya refugee camp – March 2022.

**AAU: Milk cooling and pasteurization**

A theoretical study of a refrigeration system for off grid food preservation and pasteurization has been made. The developed computer model can size milk chiller or a refrigeration system with PV power supply and pasteurization system with solar water heater based.

The target system is for cooling and pasteurization of 50 liter milk per day at Semera, Afar Region, Ethiopia. The objective of the project is to manufacture and performance test a prototype small scale refrigeration and pasteurization system that uses solar energy (solar water heater and PV) with ice thermal storage for night cooling. First the system will be tested in the university compound followed by deployment of a mirror system in the village of the dairy farmers. The implementation of the technology is expected to pave the way for better cooperation with farmer cooperatives and improve the livelihood of the people.

**Activities 2022**

The PhDs have completed their course work. Detailed discussion on the proposal of the PhDs were conducted on dedicated sessions for PhDs both online and physical meetings. The PhD work was refined, and modeling and simulations of the proposed system was conducted to identify the best operating conditions and size of components. Based on the simulation results and sizing, the refrigeration system equipment procurement was started.

**Activites in 2023**

The implementation of results is the main issue nowadays in AAU. Our PhD researchers are at experimental phase of their PhD work. However, until the prototypes are tested and ready for deployment, the chair members are proposing to try the implementation of other research outputs in the chair by deploying in selected pilot demonstration site. Accordingly three technology types were identified for implementation purposes.

- Forced draft gasifier stove and dissemination with PV for cooking, lighting and charging to rural community
- Refrigeration PV technologies including Drying (solar bubble dryer)
- Institutional cook stoves( solar thermal storage)

It is also proposed to implement technologies which were already tested by EnergyNET partners in the project.



AAU EnergyNET PhD students while installing PV in AAiT compound (2023)



AAU building a latent heat fryer (2023)

### *AAU: Injera fryer*

AAU has been working on injera baking technologies for household use and encouraging results were obtained in terms of improving the thickness of the baking pan and the possibility of baking using heat transfer oils.

The objective is to manufacture and deploy a solar thermal based institutional baking system to be used in the university compound. Part of the existing biomass based injera baking system will be replaced by the proposed solar based system.

#### **Activities 2022**

Gashaw also conducted a series of experiments to check the possibility of baking on metal surfaces and encouraging results were obtained which will pave the way to consider baking on metal surfaces as an option to use in the system which is going to be developed in this project.

#### **Activities 2023**

2023 was a year of experimental work at AAU, building a prototype fryer.

#### **Plans for 2024**

Cases for implementation were identified in 2023 and will be the bases for the further actions in 2024. Pilot units can be validated at AAU before implementation.

### *UEM: PV/Thermal system test and socio-economic study*

UEM has been working on combined PV and thermal systems, where water heaters are converted to oil heaters and the PV power provides the additional rise in temperature which is needed for cooking. Extension of the concept is also the topic of a PhD study, which will include field testing. The socio-economic aspects of adaption to new energy technology is not well documented, and the awareness status is not well mapped.

The objective is to finalize and optimize the hybrid concept at the university first, and then introduce the concept in a field test. The developed cookers will be tested in a rural context. The field assessments will include a socio-economic study.

#### **Activities 2022**

The performance of water heaters converted to oil heaters, to provide heat for cooking, has been explored for flat plate collectors and for evacuated tube collectors, as part of the PhD work of Tomas Nhabetse. Work in 2022 has included documentation of the results in the form of conference presentations and the preparation of the dissertation has started.

#### **Activities 2023**

The work on water heaters converted to oil heaters, to provide heat for cooking, has been completed, and Tomas Nhabetse has mainly worked on the completion of his PhD dissertation.

#### **Plans for 2024**

The implementation potentials of the direct oil heaters for cooking will be analysed and concluded in 2024. A field implementation may be more costly than the budget allows for.

UEM is also working with an agrarian association in a rural area of the province of Gaza, southern Mozambique, on solar irrigation, training in marketing issues to the communities.

Regarding energy efficiency, UEM continued its collaboration with the National Railways Company. At the same time, UEM is implementing an energy efficiency study at the Main University campus.

UEM is implementing a study for the installation of photovoltaic systems in its buildings at the Main campus. This project is being implemented in collaboration with the Polytechnic of Milan, Italy (Polimi).

### *NTNU: Support partners on pilot implementation*

NTNU has participated with prototype development and testing in the NTNU laboratories in the past projects and in ENET. This has been in support of visiting researchers from partner universities and MSc students at NTNU have participated as well.

The objective is to provide support to EnergyNET partners on PhD supervision and on the technical and socio-economic aspects of development and implementation of specific small scale energy systems and components.

#### **Activities 2021**

The scope of work of the PhDs have been discussed in a number of dedicated meetings with the candidates and the supervisors. Such meetings are in particular important at the point of startup of the PhDs.

Master students at NTNU have participated with laboratory testing of solar cookers and fryers. One NTNU-supported PhD candidate at NTNU (Casiana Lwiwa) has worked on Compound Parabolic Concentrators for solar cookers. Some results were presented at the SASEC 2022 conference.

#### **Activities 2022**

NTNU continued to support the ENET objectives with activities defined as part of master theses (heat storage for cooking and frying, wind-to-heat, refrigeration).

OJ Nydal had half year sabbatical leave and visited the partners (MAK, UDSM, AAU, UEM) during the last part of 2022. The sabbatical period was used to support the construction of pilot units of a heat storage for cooking and to explore possible test sites. A unit was made at MAK and another was initiated at Arusha Technical College (ATC). An Arduino based data logger for temperatures was also made during a visit to MAK.

Visits to University of Namibia (UNAM), Namibia University of Science and Technology (NUST) and to Namibia Energy Institute (ENI) was also made, based on previous communication and interest from people at the Namibian institutions.

Particular test sites which have been identified and visited in 2022 are:

- Canteen at ATC and CoET canteen at UDSM
- Kikuletwa Renewable Energy Centre
- Haydom Lutheran Hospital, Mbulu, Tanzania

Off-grid tourist camp sites and lodges in the national parks are also relevant sites, and one tented camp with a PV system was visited.

PhD Casiana Lwiwa tested a box CPC funnel design with an iron cylinder as heat storage. The cylinder was also tested separately regarding the potential for being a dedicated bean cooker.

#### **Activities in 2023**

NTNU continued to support the ENET objectives with activities defined as part of master theses (heat storage for cooking and frying, wind-to-heat, refrigeration, instrumentation).

During the second part of the sabbatical period of OJ Nydal (last part of 2023) a small scale version of the oil based cooker was tested at MAK. Construction of two systems in Arusha were initiated. However, the experience is that progress is slow unless a contact person is present at the location.

#### **Plans for 2024**

The oil/rock bed system is ready for pilot implementations and NTNU will be supportive of such actions. MAK has plans for test introductions to a refugee camp and the piloting work started in Tanzania will be pursued further. The same system may very well be tested in Ethiopia and Mozambique as well, after some experiences in Uganda.

The work on the refrigeration concept will be supported with two master students at NTNU, in communication with UDSM.

Wind-to-heat still requires testing of load controllers.

## Dissemination and stakeholders involvement

Dissemination activities are planned at project level and partner level in the form of web pages, exhibitions, stakeholder workshops, field demonstrations and scientific publications. A list of publications is given in the Appendix.

### Dissemination activities and events

#### Activities 2021

- A project web page is hosted at NTNU, using the standard templates for projects at NTNU (<https://www.ntnu.edu/ept/energynet>)
- MAK prepared a project web site (<https://cns.mak.ac.ug/energynet/>) which includes a summary of results from previous projects supported by NORAD.
- AAU conducted an official kick-off meeting in July 2021, with participation of Institute management, TTO officer and private company working in the relevant area.
- At UEM, information about the project has been established at the official page of UEM, a facebook about dissemination activities of UEM has been established.



Official launch of UNET and EnergyNET projects in AAiT-AAU (2021)



Meeting VC and DVC at MAK during annual meeting 2022 (January 2023)

#### Activities 2022

- MAK is active in using social media on publishing ENET event, as also demonstrated during the annual meeting for 2022 (9-11 January 2023).
- ENET posters have been made at NTNU and at MAK.
- UNHCR is a stakeholder for the work at MAK on solar cooking. A representative from UNHCR travelled to Kampala and participated in the annual meeting with a presentation on the energy needs at refugee camps in Uganda.
- ENET Acknowledgements are noted in publications and conference presentations.
- Workshop 3 at NTNU in May 2022 included an Open Day, with 12 external presenters on the topic of drivers for technology development and implementation.
- ENET has been presented for the VC offices at universities during visits and events.
  - VC and DVC at MAK (during annual meeting for 2022).
  - DVC at UniSAVE during visit.
  - DVC at NTNU during Workshop 3.
  - Rector at ATC during visit.
- Presentation by MAK students at departmental seminars. A number of MSc students who have been doing research in the thematic areas within the project made presentations of their work at the weekly departmental seminars.

OJ gave a seminar at UNAM, Namibia (September 2022) on ENET and the research challenges on heat storage for cooking.

- NORHED II week  
EnergyNET participated in NORHED II week (25-29 April 2022) at Makerere; all Norhed II funded projects at Makerere attended this one-week event. Participants visited three selected laboratories; and the solar thermal lab was one of them.
- UDSM NORPART stakeholder meeting, ENET project summary presented
- Visit by Muni University. Muni staff visited Makerere and had a meeting with EnergyNET researchers on 30 May 2022. Muni being a young university, is interested in future collaboration and support for capacity building of their staffs in the field of energy.

### Activities 2023

- NORHED II week at UDSM. UDSM held NORHED II week at Dar es Salam between 9<sup>th</sup> and 13<sup>th</sup> October. ENET Project was represented by participants from UDSM and NTNU. Among other activities, presentation on ENET project was done covering project partner institutions, project set-up and planned objectives, PhD and research focus as well as synergy with other projects.
- UDSM-NTNU NORPART Stakeholders Meeting  
Annual stakeholders meeting was held on 27<sup>th</sup> February 2023 in Arusha and attended by stakeholders including ENET/NORPART project coordinators, ENET PhD student, NTNU Exchange students, representative from TotalEnergies and representatives from Tanzania renewable Energy Association (TAREA)
- The latent heat mini-cooker we tested some years back in Tanzania has now come on display at a new section on energy at the Technical Museum in Oslo!
- During the SWC2023 in India, we met by chance with the Minister of Energy in Uganda, and discussed the heat storage for cooking technology. He commented that a commercialization will be necessary for the technology to be disseminated.
- MAK hosted the project annual workshop for 2022 in early 2023.
- Project leaders had courtesy call at the office of the Vice Chancellor and his deputy at MAK. They expressed support for the project and were specifically interested in the project results on the cooking technology.
- EnergyNET participated in the MAK-Expo in October 2023 where the cooking technology was demonstrated for cooking. The Expo attracted several people from the country.
- 

### Plans for 2024

- MAK will engage a number of key stakeholders once the solar cooker has been deployed in the field. Officials from both government and NGOs will be met.
- MAK will update local project website and social media pages will be kept active
- MAK will print banners to be placed both in the field and in the lab at MAK.
- NTNU will coordinate input for EnergyNET web pages.
- UDSM will print banners for EnergyNET, NORPART and UNET project



The latent heat mini-cooker has come on display at Science Museum, Oslo



MAK-Expo in October 2023- The MAK team organized an exhibition stand with displays of the cooking technology, posters and videos.



### *Conferences and seminars*

The aim is that each PhD should present their work at one international conference every year. ENET researchers have contributed with presentation at the following conferences (see list of publications).

#### **Presentations at conferences in 2022**

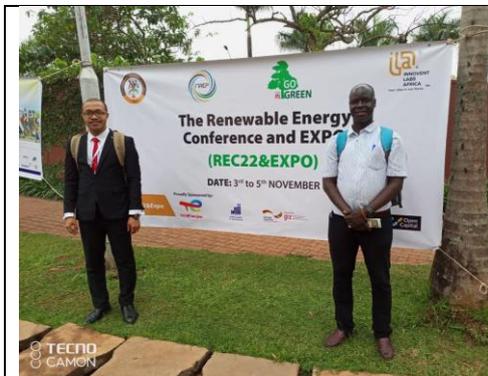
- 16th International conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT)
- 63rd International Conference of Scandinavian Simulation Society, SIMS 2022, Norway
- EuroSun2022- ISES and IEA SHC International Conference on Solar Energy for Buildings and Industry, Germany
- 7th International Conference In Mechanical and Industrial Engineering, MIE 2022, Tanzania: The conference is organized by UDSM

#### **Participation in other international conferences, workshops and seminars in 2022:**

- SANORD 2022  
The Southern African-Nordic Centre promotes academic collaboration and organizes yearly conferences. OJ Nydal participated at the SANORD 2022 event, which appeared to be a somewhat unstructured assembly of presentations in a very broad area.
- Renewable Energy Conference organized by Ministry of Energy & Mineral Development on 3-5 November 2022 in Kampala-Uganda (Jimmy Chaciga).
- Solar energy and materials workshop in Nairobi  
Karidewa and Denis participated in 2-day workshop in Nairobi on solar energy and material

science. Participants were from universities of Nairobi, Zambia, Dar es Saalam, Eldoret and Makerere. EnergyNET activities were presented. The workshop was to plan for online conference and supporting graduate studies in solar energy and material science.

- Online solar conference University of Eldoret, Kenya; 16-18 November 2022 (on-line). 6 students (PhD and MSc) who are doing research in solar energy at MAK attended an online conference on solar energy and materials
- Seminars  
 Presentation by MAK students at departmental seminars. A number of MSc students who have been doing research in the thematic areas within the project made presentations of their work at the weekly departmental seminars.  
 OJ gave a seminar at UNAM, Namibia (September 2022) on ENET and the research challenges on heat storage for cooking.  
 UEM (Tomás Nhabetse) presented a paper on “Experimental of an oil based solar thermal system for cooking applications” (25/5/2022), Online technical meeting.



Renewable Energy Conference, Kampala-Uganda. (November 2022)



Workshop in Nairobi held on 12-13 September 2022

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UNHCR representative at the ENET annual meeting for 2022 (MAK)



NORHEDII week at MAK: Participants from the various projects in the solar lab, 26 April 2022



Staff of Muni university were taken through the solar lab at Makerere. (MAK)

**Presentations at conferences in 2023**

- ICAE Conference 2023.  
Three PhD students and supervisors attended the 15<sup>th</sup> International Conference on Applied Energy (ICAE) hosted by Qatar University in Doha. During the conference, ENET project contributed three conference papers as indicated in the list of publications.
- SWC 2023  
Supervisors and PhDs from AAU, MAK and NTNU participated with presentations at the Solar World Conference in New Delhi, India in 2023.



Mr Joseph Ibrahim PhD Student from UDSM, presenting a paper at ICAE 2023



UDSM students and supervisors at ICAE 2023



Fekadu from AAU presenting at SWC2023

**Plans for 2024**

Some relevant conferences for presenting ENET results are:

- WREC / WREN World Renewable Energy Congress / Network 10-14 November 2024.
- EuroSun2024 ISES and IEA SHC International Conference on Sustainable and Solar Energy for Buildings and Industry. 26-30 August 2024, Cyprus.
- UDSM may host a conference in 2024 (Mechanical and Industrial Engineering).
- The UNET project will have a final and open event in November 2024, hosted by UEM. An ENET day will be included, for extended dissemination.

UNET partners will also take note of the successful use of social media at MAK regarding ENET events.

## 7 - Project coordination

### Background

The guiding documents for the project coordination is the Result Framework and supporting documents.

- EnergyNET-ResultsFrameworkTable.xlsx is the Result Framework for EnergyNET on the Norhed template format
- EnergyNET-ProjectPlan.docx Gives the detailed plan for the project, to be revised when needed
- EnergyNET-TimePlan.xlsx gives the timelines for the activities under each Outcome in the EnergyNET-ResultsFrameworkTable, to be revised when needed

The Partner Agreement is the legal document for EnergyNET, and follows the Norhed template.

EnergyNET is coordinated with two other projects

- A NORPART mobility project (2019-2023) "UDSM-NTNU Mobility Program in Energy Technology" <https://www.ntnu.edu/ept/udsm-ntnu>
- An Erasmus+ project on PhD programs "University Network on PhD Programs in Energy Technology" which includes most partners from EnergyNET. <https://www.ntnu.edu/uneterasmus/>

TEAMS is chosen for project communication and for repository of the results.

Photo: Screen capture of TEAMS meeting



A log of activities throughout the year is maintained and stored on Teams, see Attachment.

### Startup activities

- A kick off meeting was held on-line on 19.02.2021.
- Considerable time was spent on the budget reviews.
- The Partner Agreements were processed after the Norhed templates arrived.
- A Project Plan is prepared
- A Project Guide is prepared (reporting and administration, procedures, deadlines)
- The Result Framework was updated and detailed with a time plan for each activity
- TEAMS has been chosen as the framework for collaboration, all communication and documents are stored and available there.

### Meetings and Workshops

- Progress meetings have been conducted on TEAMS, agenda and MoM are posted on TEAMS
- Technical meetings specific for each PhD are held in between, when needed.
- Workshops have been conducted, in coordination with the UNET project, and if possible, with annual meetings. Some further details are given in the Appendices.

**Workshop 1**, 30 Aug. to 2 Sept. 2021: Organized by UDSM and hosted by ATC in Arusha , Tanzania.

**Workshop 2**, 29 Nov. to 1 Dec. 2021: Organized by UDSM and hosted by ATC in Arusha , Tanzania. The Workshop 2 was shifted from AAU to UDSM, due to the political uncertainties in Ethiopia.

**Workshop 3**, 6-9 May. 2022: Organized by NTNU, Trondheim, Norway. Workshop 3 included short training events, and an open day, with 13 contributions on drivers for technology development and implementation, see Appendix. AAU missed participation due to Visa Denial.

**Workshop 4** was a pure UNET event on teaching methods and online systems, hosted by USGM in Rome, Italy

**Workshop 5**, 4-7 September 2023: hosted by AAU, concerned mainly UNET issues on PhD course development, but included progress meeting on ENET.

**Workshop 6**, 27-30 November 2023, hosted by MAK, was mainly a UNET event on completion of the PhD Course Catalogue, but included status reporting on the ENET PhDs.

- **Annual Meeting 2022**, 9-11 January 2023: Annual Meeting hosted by MAK, Uganda.
- **Annual Meeting 2023**, 11-16 February 2024: Annual Meeting hosted by UEM, Mozambique.

		
Workshop 2021 Arusha, Tanzania	Workshop 2021 Arusha, Tanzania	Workshop 2022 Trondheim, Norway
		
Annual meeting 2022 Makerere, Uganda	Annual meeting 2023 Eduardo Mondlane University, Mozambique	Workshop at AAU in 2023

### Plans for 2024

The UNET project completes in 2024, and a final conference is planned towards the end of the year in November 2024, to be hosted by UEM. This is also a good opportunity for ENET PhD researchers to join and present results from the ENET work.

NTNU will also host a UNET Workshop in May 2024, which is at the same time as a group of ENET PhDs are at NTNU for 2-3 months period.



## Appendix MSc students

### NTNU

Year	University	Name	Supervisor	Support	Completion
2021	NTNU	Andreas Bjørshol (M)	OJ Nydal	Laboratory support	2021
<b>Sensible Heat Storage for Cooking. Single Tank System</b> A single tank oil/rock bed heat storage system has been constructed, analysed and tested. Heating power is provided from electrical heating elements and the heat transfer between the cooker and storage is by natural circulation. The system concept is explored in collaboration with MAK.					

Year	University	Name	Supervisor	Support	Completion
2021	NTNU	Gunn Helen Nylund (F)	OJ Nydal	Laboratory support	2021
<b>Sensible Heat Storage for Cooking. Single Tank System</b> Joint work with Andreas Bjørshol					

Year	University	Name	Supervisor	Support	Completion
2021	NTNU	Martin Systad (M)	OJ Nydal / Abraham Parra	Laboratory support	2021
<b>Experiments with a latent heat storage for frying</b> A heat storage solution for a fryer has been extended with a new fryer with 60 cm diameter. The heating is by heating elements and the heat transfer by heat pipe. The storage is PCM cylinders immersed in oil. The master student is supervised by the PhD student working on the concept (Abraham Parra). The concept is developed in communication with AAU, for injera baking purposes.					

Year	University	Name	Supervisor	Support	Completion
2021	NTNU	Joakim Ginste (M)	OJ Nydal	Laboratory support	2021
<b>Frying on a heat storage (project work 2021)</b> Frying of injera has been tested on two heat storage based fryers. One is the heat pipe concept with oil/PCM as storage. The other is a PCM storage with conducting fins to the frying plate. A silicon baking sheet was used between the injera and the metal surface. Tests by a project student showed that injera could be baked with acceptable quality. The concept is developed in communication with AAU.					

Year	University	Name	Supervisor	Support	Completion
2022	NTNU	Kristina Berg (F)	OJ Nydal	Laboratory support	2022
<b>Small scale PV to cooking heat (project work 2021)</b> Aspects of a three tank system has been tested, as part of a student project before the master thesis work. Heating of oil and water has been tested with and without an air volume above the surface. Evaporation reduces the rate of the temperature rise in the liquids. Long term oxidation tests have been made with several oils.					
<b>Demonstration of PV Power to High temperature Heat Storage for Solar Cookers (master thesis 2022)</b> Three charging methods for a heat storage are considered. The first using excess heat from PV panels, when the electrical batteries are full. The second applying power directly from PV panels to heating elements, using a dedicated mppt controller. The third combining wind and PV power for the charging of the heat storage.					

Year	University	Name	Supervisor	Support	Completion
2022	NTNU	Andrea Austjord Vik (F)	OJ Nydal	Laboratory support	2022

	Joint work with Kristina Berg
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Year	University	Name	Supervisor	Support	Completion
2022	NTNU	Alexander Peter Olsen (M)	OJ Nydal	Laboratory support	2022
<p><b>Heat storage for cooking (project work 2021)</b> The single tank storage system for a cooker has been improved and tested as part of a student project before the thesis work. A modified version has been designed, with the cooker now positioned outside of the heat storage. tank.</p> <p><b>Design and testing of a natural circulating heat storage for cooking (master thesis)</b> The system with separated storage unit and cooker unit has been constructed and tested. The system is based on natural circulation and seems to perform well. The cooker can be operated directly with power on the heating element or indirectly with heat extracted from the storage. A solution for a pumped system was demonstrated using a propeller in the lower pipe. The system is the basis for prototyping and was further tested with rock bed during a visit by PhD researcher Jimmy Chaciga from MAK. The system concept will be further explored in collaboration with MAK.</p>					

Year	University	Name	Supervisor	Support	Completion
2023	NTNU	Marte Maria Tømterud (F)	OJ Nydal / Mulu Bayray	Laboratory support	2023
<p><b>Technology from Africa to Norway: heat storage for off-grid cottages (project work 2022)</b> One of the concepts in the network project has been to direct excess power from PV systems to heat storage units (heat batteries). A student project work considers the applicability of this sort of technology to the case of Norwegian off-grid cottages. PV systems which provide light and power small appliances for cottages are available, but as the cottages are not used for long periods (often weeks) the PV power is not used after the electric batteries are fully charged.</p> <p><b>Solar Water Heater with Temperature Control for 90°C Water Requirements. Designed for the Rural African Environment (master thesis 2023)</b> A solar hot water system to deliver water at 90°C was developed, tested and verified to work. The system is according to a requirement from an African hospital. Solar evacuated tube collectors (ETC) heated a water tank which contained an automobile thermostat valve. During the day, the tank then collects water at 90 degrees C.</p>					

Year	University	Name	Supervisor	Support	Completion
2023	NTNU	Torbjørn Mjåtveit (M)	OJ Nydal / Mulu Bayray	Laboratory support	2023
<p><b>Small scale wind power to heat storage (project work 2022)</b> Small scale wind turbines are used for charging of electrical batteries. One aim of a student project work is to evaluate a commercial small scale wind turbine at EPT for diversion of excess power to a high temperature oil-based heat storage. The student work shall also give an overview of direct wind-to-heat solutions (both mechanical and electrical solutions).</p> <p><b>Wind power for cooking. Small scale wind power to heat storage (Master thesis 2023)</b> The continued work in a master thesis was based on tests of a wind generator in bench – where the torque and RPM could be set manually. The excess energy in a battery setup was dumped to a heating element in a small, insulated cylinder filled with Duratherm 630 oil, as a demonstration of the general case of using a high temperature heat storage as a dump load.</p>					

Year	University	Name	Supervisor	Support	Completion
2023	NTNU	Henrik Lund Finsås (M)	OJ Nydal / Mulu Bayray	Laboratory support	2023
Joint work with Torbjørn Mjåtveit					

Year	University	Name	Supervisor	Support	Completion
2023	NTNU	Andreas Grodås Jørs (M)	Trygve Eikevik	Laboratory support	2023
<p><b>Cold storage for an adsorption-based refrigeration cycle in Africa (project work 2022)</b> An adsorption-based refrigeration cycle can operate in batch mode, with ice generation during the night and regeneration during the day, using solar power. A prototype system has been built before and another one at</p>					

	<p>UDSM. There is, however, a need for a temperature-controlled storage on the cold side, such that the cold storage can provide constant temperature in a refrigeration chamber on a continuous basis. A student project concerns the cold part of the system, where the objective is to consider an ice bath for n the cold side.</p> <p><b>Cold storage for an adsorption-based refrigeration cycle in Africa (master thesis 2023)</b></p> <p>An adsorption refrigeration system was constructed and tested, in good communication with visiting NORPART students (Joseph Ibrahim, PhD from UDSM and Neema Wilfred Muhogolo, MSc from UDSM). The batch system is based on the carbon-methanol pair, and requires no electric power or control. The idea is use ice/water as cold storage. The system will be studied further with following students.</p>				
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Year	University	Name	Supervisor	Support	Completion
2023	NTNU	Adrian Danielsen (M)	Trygve Eikevik	Laboratory support	2023
Joint work with Andreas Grodås Jørs					

Year	University	Name	Supervisor	Support	Completion
2023	NTNU	Martin Egerdahl (M)	Ole Jorgen Nydal	Laboratory support	2023
<p><b>Testing of controllers for PV2Heat (project report 2923)</b></p> <p><b>PV-to-Heat: Control and monitoring methods (master thesis 2023)</b></p> <p>Power controllers for PV to heating elements were tested, one commercial and one in-house. An Arduino based data logger was assembled and options for remote data access were investigated. The data logger for temperatures and PV power was housed in a 3D printed container.</p>					

Year	University	Name	Supervisor	Support	Completion
2024	NTNU	Åsmund Nordskog and Olav Torsvik	Ole Jorgen Nydal	Laboratory support	2023
<p><b>Small scale wind power to heat. Optimizing power output by implementing a DC-DC converter (project 2023)</b></p> <p>A DC-DC converter was tested between a wind generator in bench and a resistive load. This gives improvements in the efficiency of the energy collection from a wind generator in the form of heat, but is limited to the accepted input band on the voltage</p>					

Year	University	Name	Supervisor	Support	Completion
2024	NTNU	Eli Enes (F) and Une Skogen (F)	Ole Jorgen Nydal	Laboratory support	2023
<p><b>Clean cooking in rural African areas (project 2023)</b></p> <p>The performance of a single tank oil/rock bed system with a new regulator is investigated. A funnel based system is controlled with a wire arrangement, such that the cooking power and temperature can be regulated.</p>					

Year	University	Name	Supervisor	Support	Completion
2024	NTNU	Eli Enes (F) and Une Skogen (F)	Trygve Eikevik	Laboratory support	2023
<b>XXX (project 2023)</b>					

## UDSM

Year	University	Name	Supervisor	Support	Completion
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2022	UDSM	Neema Muhogolo (F)	Cuthbert Kimambo	Tuition Fee Laboratory Support	End 2024
<b>Cold Storage for Adsorption refrigeration system</b> The main objective of this research work is experimental investigation of cold storage for reduction of variation of temperature in evaporator for the adsorption refrigeration system.					

Year	University	Name	Supervisor	Support	Completion
2023	UDSM	Juma Msuya (M)	Joseph Kihedu	Laboratory Support	End 2024
<b>Development of improved natural circulating thermal energy storage for a cooking application</b> The dissertation will support PhD work which requires to use developed cooker. The main objective is to develop oil-based cooker with thermal storage based on improved natural circulating.					

## AAU

Year	University	Name	Supervisor	Support	Completion
2022	AAU	Amir Nassir (M)	Dr.Ing Demiss Alemu and Fikadu Geremu	Scholarship and Laboratory Support	March 2023
<b>Effectiveness of heat exchange in two tank system with thermosiphon circulation</b> The main objective of this research is the evaluation of the heat exchange effectiveness between the two tanks with thermosiphon circulation by using two experimental cases.					

Year	University	Name	Supervisor	Support	Completion
2022	AAU	Tihun Birhanu (F)	Abdulakdir Aman and Kamil Dino	Scholarship and Laboratory Support	March 2023
<b>Design and Simulation of Institutional Clean Cookstove Using Thermal Storage System</b> The general objective of the research is to design, and simulate an institutional cookstove with thermal energy storage system. The performance of the developed institutional cook will be validated using existing institutional cookstove and national standard. The pot to be used has a diameter of around 600 mm for the preparation of sauce – 'wot'.					

Year	University	Name	Supervisor	Support	Completion
2022	AAU	Meseret Alemju (F)	Abduladadir Aman and Gashaw Getnet	Scholarship and Laboratory Support	June 2023
	<b>Numerical investigation on charging-discharging of a PCM using PV and thermal oil for injera baking application</b> The main objective of this research work is to numerically investigate the charging and discharging of a PCM using solar PV and thermal oil for injera baking applications. The EnergyNET project supported research and fellowship costs. She is currently working in Diredawa University in Ethiopia.				

Year	University	Name	Supervisor	Support	Completion
2022	AAU	Amir Nassir (M)	Dr.Ing Demiss Alemu and Fikadu Geremu	Scholarship and Laboratory Support	March 2024
<b>Effectiveness of heat exchange in two tank system with thermosiphon circulation</b> The main objective of this research is the evaluation of the heat exchange effectiveness between the two tanks with thermosiphon circulation by using two experimental cases.					

Year	University	Name	Supervisor	Support	Completion
2022	AAU	Tihun Birhanu Beyene (F)	Abdulakdir Aman and Kamil Dino	Scholarship and Laboratory Support	March 2023
	<b>Design and Simulation of Institutional Solar Powered Cookstove Using Thermal Storage System</b> The general objective of the research is to design, and simulate an institutional cookstove with thermal energy storage system. The performance of the developed institutional cook will be validated using existing institutional cookstove and national standard. The pot to be used has a diameter of around 600 mm for the				

	preparation of sauce – ‘wot’. The EnergyNET project supported research and fellowship costs. She is currently working in Haramaya University.
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Year	University	Name	Supervisor	Support	Completion
2023	AAU	Abdisa Biruk (M)		Tuition Fee Laboratory Support	
	To be defined				

Year	University	Name	Supervisor	Support	Completion
2023	AAU	Biruk Asrat (M)		Tuition Fee Laboratory Support	
	To be defined				

Year	University	Name	Supervisor	Support	Completion
2023	AAU	Dina Yacob (M)		Tuition Fee Laboratory Support	
	To be defined				

## MAK

Year	University	Name	Supervisor	Support	Completion
2022	MAK	Justine Mugala (F),	Karidewa Nyeinga Ndugu Nelson	Scholarship Laboratory Support Tuition Fee	
	<b>Single tank heat storage simulation using Comsol</b> <b>Developing proposal</b>				

Year	University	Name	Supervisor	Support	Completion
2022	MAK	Adons Agumenitwe (M)	Nicholas Kwarikunda Karidewa Nyeinga	Laboratory Support Tuition Fee	
	<b>Testing quality of Solar PV modules</b> <b>Thesis submitted for examination</b>				

Year	University	Name	Supervisor	Support	Completion
2022	MAK	Robinson Omony (M)	Denis Okello Karidewa Nyeinga	Laboratory Support	2022
	<b>Development of thermal energy storage system integrated with a cooking unit.</b> The EnPe project supported his research and he continued and graduated in ENET. Robinson is Assistant lecturer at Gulu University. Gulu and Kabale are public universities				

Year	University	Name	Supervisor	Support	Completion
2022	MAK	Francis Ochola (M)	Nicholas Kwarikunda Karidewa Nyeinga	Laboratory Support	2022
	<b>Automatic electronic photovoltaic heating system for charging thermal energy storage tank.</b> The EnPe project supported his research and he continued and graduated in ENET. Francis is Assistant lecturer at Gulu University. Gulu and Kabale are public universities				

Year	University	Name	Supervisor	Support	Completion
2022	MAK	Rebecca Nambuya (F)		Scholarship	

				Laboratory Support Tuition Fee	
working on proposa					

Year	University	Name	Supervisor	Support	Completion
2022	MAK	Pamella Sinia (F)		Scholarship Laboratory Support Tuition Fee	
working proposal					

Year	University	Name	Supervisor	Support	Completion
2022	MAK	Maseera Busiku Geofrey(M)	Dr. Erik Ochen Awic Dr. Firminus Mugumya Dr. Julius Omona	Scholarship Field work Tuition Fee	
Challenges and opportunities of access to clean and affordable cooking energy among refugee households in Bidibidi carryout field work in Bidibidi refugee camp, Yumbe					

**UoJ/MAK**

Year	University	Name	Supervisor	Support	Completion
2022	UoJ / MAK	Yak Mathok Kuc Baak(M)		Scholarship Laboratory Support Tuition Fee	
Still on course work Dropped out of study in 2023 due to family reasons. Not sure he will return in 2024					

**UEM**

	<b>Fully Financed</b>		<b>Tuition Fees Financed</b>
1	Neima Sibia (F)	1	Amélia Sique (F)
2	Ilídio Oliveira (M)	2	Marsílio De Andrade (M)
3	Celma Mahunguele (F)	3	Fernando Beira (M)
4	Edvânia D'Uamba (F)	4	Samuel Buvane (M)
5	Carlino Chey (M)	5	Reis Chirinze (M)
6	Cármén de Castro (F)	6	Édgar Bobotela (M)
7	Otília Hilário Jonasse (F)	7	Erika Machirica (F)
8	Arão Macuácuca (M)	8	Salima Salimo (F)
		9	Denise Vilanculo (F)
		10	Juliana Francisco (F)
		11	Taira Pene (F)
		12	Mário Chelengo (F)

Student Name / email	Specialization	Theme title	Supervisor
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<b>Ilídio Fernando Moisés Oliveira (M)</b> <a href="mailto:ilidiooliveira441@gmail.com">ilidiooliveira441@gmail.com</a>	Solar Energy	Environmental repercussions of solar energy - product chain and Projection PV Modules waste Management - case of Mozambique	<b>Alberto Tsamba</b> <a href="mailto:aj.tsamba@uem.mz">aj.tsamba@uem.mz</a>
<b>Amelia Antonio Sique (F)</b>	Biomass Energy	Renewable resources for energy within ecological sustainability restrictions in Mozambique.	
<b>Marsílio de Andrade</b> <a href="mailto:marsilioneves@gmail.com">marsilioneves@gmail.com</a> (M)	Solar Energy	Analysis of the relationship between access to electricity and entrepreneurship - A literature study.	
<b>Neima Lázaro Sibia (F)</b> <a href="mailto:sibianeimalazaro@gmail.com">sibianeimalazaro@gmail.com</a>	Biomass Energy	Technical viability studies for the installation of a biodigester in the future landfill of Matlemele	Rosa Chilundo <a href="mailto:rosychilundo@gmail.com">rosychilundo@gmail.com</a>
<b>Edvania Ana Paulino D'Uamba (F)</b> <a href="mailto:edvania.d'uamba@uem.ac.mz">edvania.d'uamba@uem.ac.mz</a>	Biomass Energy	Syn Gas production from coconut residues as a sustainable alternative of recycling	Miguel Uamusse <a href="mailto:miguelmegue@gmail.com">miguelmegue@gmail.com</a>
<b>Fernando Malanguisse Beira (M)</b> <a href="mailto:fernandobeira11@gmail.com">fernandobeira11@gmail.com</a>	Biomass Energy	Biogas production in humid zones	Alberto Tsamba <a href="mailto:aj.tsamba@uem.mz">aj.tsamba@uem.mz</a>
<b>Celma da Conceição Luís Mahunguele (F)</b> <a href="mailto:celmamahunguele@outlook.com">celmamahunguele@outlook.com</a>	Biomass Energy	Pre-carbonization of Jatropha seeds Shell for the production of bricks	Adolfo Condo <a href="mailto:condo.a1143@gmail.com">condo.a1143@gmail.com</a>
<b>Reis Bernardo Chirinze (M)</b> <a href="mailto:reisbirnardo@gmail.com">reisbirnardo@gmail.com</a>	Solar Energy	Simulation of a low-cost solar thermal system for buildings cooling in Maputo City	
<b>Édgar João Bobotela (M)</b> <a href="mailto:edgarbobotela@gmail.com">edgarbobotela@gmail.com</a>	Solar Energy	Projecto de um Sistema Híbrido Solar Térmico-Gás Natural para o Aquecimento da Piscina Josina Machel	Geraldo Nhumaio <a href="mailto:geraldo.nhumaio@gmail.com">geraldo.nhumaio@gmail.com</a>  Doutor Valter Manjate <a href="mailto:wvaltemanjate@gmail.com">wvaltemanjate@gmail.com</a>
<b>Mário Chelengo (M)</b>	Energy Systems Economic Management	Energy access challenges in the peri-urban areas of Mozambican town-the impact of georeferencing the electrical power losses	Alberto Júlio Tsamba <a href="mailto:aj.tsamba@uem.mz">aj.tsamba@uem.mz</a>
<b>Cármén Agapito de Castro (F)</b>	Energy Systems Economic Management	Technical and economic feasibility study for power generation using Hulene dumping site Urban Waste as feedstock	Carlos Lucas <a href="mailto:clucas33@yahoo.com">clucas33@yahoo.com</a> , Cardoso Muendane ( <a href="mailto:sics@sics.co.mz">sics@sics.co.mz</a> ) and Adolfo Condo ( <a href="mailto:condo.a1143@gmail.com">condo.a1143@gmail.com</a> )
<b>Otília Jonasse (F)</b>	Energy Systems Economic Management	Economic Feasibility Study of a Wind Power Park in Marracuene District	Rosa Chilundo <a href="mailto:rosa.chilundo@edm.co.mz">rosa.chilundo@edm.co.mz</a> , and Valter Manjate <a href="mailto:wvaltemanjate@gmail.com">wvaltemanjate@gmail.com</a>
<b>Érika Machirica (F)</b>	Energy Systems Technical Management	Study of the use of pico-hydro power for irrigation water pumping-the case of Boane District	Geraldo Nhumaio <a href="mailto:geraldo.nhumaio@gmail.com">geraldo.nhumaio@gmail.com</a>
<b>Arão Moniz Macuacua (M)</b>	Energy Systems Technical Management	Economic and Technical Feasibility study of the installation of small biodigesters in Zimpeto Wholesales Market	Carlos Lucas e Adolfo Condo
<b>Taira Otédia Pene (F)</b>	Energy Systems Technical Management	Economic and Technical feasibility and receptivity study of solar thermal powered desalination models-the case of Chicualacuala District (Gaza)	Genito Maure <a href="mailto:Genito.maure@uem.mz">Genito.maure@uem.mz</a>
<b>Denise Xavier Vilanculo (F)</b>	Energy Systems Technical Management	Cost-benefit analysis of small projects with energy storage systems for electricity-the case of the Solar PV Power plant in Mapulanguene	Manuel Sibia <a href="mailto:mansibia@hotmail.com">mansibia@hotmail.com</a>
<b>Juliana Jennifer Francisco (F)</b>	Solar Energy	Contribution of Solar Photovoltaic System for energy transition in project for supplying and desalination of drinking water.	Luís Chea

<b>Samuel Buvane (M)</b>	Solar Energy		To be submitted
<b>Salima Amade Salimo (F)</b>	Energy Systems Economic Management	Economic Feasibility Analysis for the installation of a biodigester to generate biogas for chicken litter	Cardoso Muendane and Carlos Lucas
<b>Carlino Tam Ming Chey (M)</b>	Biomass	National potential in marine biomass for biodiesel production	Alberto Júlio Tsamba <a href="mailto:aj.tsamba@uem.mz">aj.tsamba@uem.mz</a>

## Appendix Publications

### 2023

Ole Jorgen Nydal (2023) *Experiences on developing heat storage for cooking*. Fifth International Conference CONSOLFOOD2023 Advances in Solar Thermal Food Processing 12-13-14 July 2023, A Coruna, Spain. <https://www.youtube.com/watch?v=2pBCK3VCPbg&list=PLhg5QcqbudToUMKfiQFHKCsHC3Uwnj9&index=15&pp=iAQB>

Ole Jorgen Nydal (2023) *Heat Storage for Cooking: A Discussion on Requirements and Concepts*. Energies 2023, 16(18), 6623; <https://doi.org/10.3390/en16186623>

Abraham Parra and Ole Jorgen Nydal (2023) *Latent heat storage for solar frying* Solar World Conference SWC 2023, 30th Oct – 4th Nov 2023, New Delhi, India.

Nyirenda, EJ, Kihedu JH, Kimambo CZM (2024) *Transient Behaviour of Pump as Turbine Coupled to Self-Excited Induction Generator Under Variable Load Conditions*. Energy Proceedings, Volume 39, Energy Transitions towards Carbon Neutrality Part II, ISSN 2004-2965 (13<sup>th</sup> International Conference on Applied Energy, Doha, Qatar). <https://doi.org/10.46855/energy-proceedings-10927>

Mwasubila IJ, Kimambo CZM, Kihedu JH, Nydal OJ (2024) *Heating and Cooling Performance of Adsorber Bed Powered by Solar Lamps*. Energy Proceedings, Volume 42, Energy Transitions towards Carbon Neutrality Part V, ISSN 2004-2965 (13<sup>th</sup> International Conference on Applied Energy, Doha, Qatar). <https://doi.org/10.46855/energy-proceedings-10999>

Emanuel J. Nyirenda, Joseph H. Kihedu, Cuthbert Z.M. Kimambo (2023). *Performance Behaviors of PAT-SEIG when Operating Under Variable Load Conditions*. Renewable Energy and Environmental Sustainability (accepted for publication)

J. Chaciga, K. Nyeinga, D. Okello, and O. J. Nydal, *Design and experimental analysis on a 52 single tank energy storage system integrated with a cooking unit using funnel system* J Energy 53 Storage, vol. 79, Feb. 2024, doi: 10.1016/j.est.2023.110163.

Jimmy Chaciga, Karidewa Nyeinga, Denis Okello, Ole J. Nydal. *Experimental Analysis on a Single Tank Energy Storage System Integrated with a Cooking Unit*. ISES Solar World Congress, New Delhi India, 29 Oct – 5 Nov 2023.

Swaleh Tusiime, Karidewa Nyeinga, Denis Okello and Ole J. Nydal. 2023. *Thermal Performance of a Mechanical Thermostat for Charging an Energy Storage System*. Tanzania Journal of Science. Vol. 49(2), DOI: <https://dx.doi.org/10.4314/tjs.v49i2.1>

Fikadu G. Bodena , Ole J. Nydal, Trygve M. Eikevik, and Demiss A. Amibe (2023). *Long-Term Performance Analysis of Ice Thermal Cold Storage with Photovoltaic-Powered DC Refrigeration System for Milk Cooling Through Computational Model*. ISES Solar World Congress, New Delhi, India (to be published)

Gashaw G. Birhanu, Ole J. Nydal, Demiss A. Ambie, Abdulkadir A. Hassen (2023). *Development of a Thermal Storage System for Solar PV Based Injera Baking Application*. ISES Solar World Congress, New Delhi, India (to be published)

Abdulkadir A. Hassen, Mintesinot Yohannes Jorgaa (2023). *Design and Development of Double Exposure*

*Solar Cooker with Finned Cooking Vessel*. ISES Solar World Congress, New Delhi, India (to be published)

## 2022

Casiana Blasius Lwiwa, Ole Jørgen Nydal (2022) *3D Ray tracing for optimizing a mirror tiled Compound Parabolic Concentrator*. Proceeding of the 16th International conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT), 8-10 August, 2022, Online

Casiana Blasius Lwiwa, Ole Jørgen Nydal (2022) *A Ray tracer for optimizing solar concentrating systems: the case of discretized Compound Parabolic Concentrator* Proceedings of the 63rd International Conference of Scandinavian Simulation Society, SIMS 2022, Trondheim, Norway, 20-21 September 2022

Casiana Blasius Lwiwa, Ole Jørgen Nydal (2022) *Interception on Solar Absorbers: Ray Tracing for Comparison between a Parabolic Reflector and a Compound Parabolic Concentrator* Proceedings of the EuroSun2022- ISES and IEA SHC International Conference on Solar Energy for Buildings and Industry, Kassel, Germany, 25-29 September 2022

Tomás Nhabetse (2022) *Experimental study of an oil based heat pipe evacuated tube collector for cooking applications*, September 2022, Kassel, ISES and IEA SHC International Conference on Solar Energy for Buildings and Industry

Casiana Blasius Lwiwa, Ole Jørgen Nydal (2022) *Sensible heat bean cooker* Tanzania Journal of Engineering Technology (TJET), Volume XX, 2023, Pages xxx-xxx. (Presented in the 7th International Conference In Mechanical and Industrial Engineering (MIE 20-21 October 2022), New Library, UDSM-Tanzania

Denis Okello, Robinson Omony, Karidewa Nyeinga, and Jimmy Chaciga. (2022). *Performance Analysis of Thermal Energy Storage System Integrated with a Cooking Unit*. Energies 2022, 15, 9092. <https://doi.org/10.3390/en15239092> (results from EnPe project)

Pamella K. Kajumba, Denis Okello, Karidewa Nyeinga, and Ole J. Nydal. (2022). *Assessment of the energy needs for cooking local food in Uganda: A strategy for sizing thermal energy storage with cooker system*. Energy for Sustainable Development 67 (2022) 67–80. <https://doi.org/10.1016/j.esd.2022.01.005> (results from EnPe project)

Nyirenda, EJ, Kimambo CZ, Kihedu J (2022) *Performance Behaviors of PAT-SEIG when Operating Under Variable Load Conditions*. Proceedings of the 6<sup>th</sup> International Conference on Mechanical and Industrial Engineering, University of Dar es Salaam, Tanzania (presentation only)

Raymond J, Kihedu JH, Kimambo CZM. (2022) *A Model for Sustainable Adoption of Solar Photovoltaic Technology in Tanzania*. Tanzania Journal of Engineering and Technology, UDSM-CoET, ISSN: 2619-8789; Vol. 41 No 2, pp 16-33 (publication from previous EnPe program of the network).

## 2021

Casiana B. Lwiwa and Ole J. Nydal (2021). *3D ray tracing for optimizing the size of surface tiles on a compound parabolic concentrator* SASEC 2021 Southern African Sustainable Energy Conference 17-19 Nov. 2021, Stellenbosch, South Africa

Tomas M. Nhabetse, Boaventura C. Chongo, Claudio L. Tingote and Ole J. Nydal (2021) *Temperature*

*profile of an oil based evacuated tube solar collector for cooking application* SASEC 2021 Southern African Sustainable Energy Conference 17-19 Nov. 2021, Stellenbosch, South Africa (presentation only)

Tomás Nhabetse (2021) *Design solar PV for topping up energy of an oil based solar thermal collector for cooking applications*, 3<sup>rd</sup> International Conference on Solar Technologies and Hybrid Minigrids to improve energy access, September 2021, Mallorca, Palma, Spain;

John M, Kimambo CZ, Nydal OJ, Kihedu JH (2021) *Performance of Calcium Chloride-Ammonia Adsorption Refrigeration System*. Tanzania Journal of Engineering and Technology, UDSM-CoET, ISSN: 2619-8789; Vol. 40 No 1, pp 39-49 (publication from previous EnPe program of the network)

## Other dissemination

2023

MAK

Jimmy Chaciga summarized the Arduino based data logger as a tutorial for others

MAK staff participated in a Renewable Energy Conference and Expo 2023 in Uganda organized by Ministry of Energy and Mineral development, MEMED November 2023.

Jimmy Chaciga organized a stand presenting the MAK work on heat storage for cooking at the UNDP and Makerere University Expo 2023.

## Appendix Project log

### Time log of EnergyNET events 2021

Date	Name	Event
27.01.2021	OJ	NTNU information meeting on Norhed projects and consolidated management
18.02.2021	OJ	UNETAfrica.net domain established and hosted by Wordpress.com
19.02.2021	Partners	Kick-off meeting on TEAMS
26.02.2021	NTNU students	Presentation of status on single tank system
05.03.21	NTNU Students	Presentation of PCN fryer system
08.03.21	OJ, Tonje, Camilla	EnergyNET adm systems and budget revision
09.03.21	OJ, Tonje, Norad	Meeting with Vibeke Sørum in Norad on budget revision
12.03.21	Partners	Progress meeting. Budget revision.
19.03.21	Demis, Abdulkadir	Technical discussions on AAU milk pasteurization/chilling system
23.03.21	MUBAS, UDSM ++	Discussion on PAT PhD plans. for MUBAS candidate (Emmanuel) at UDSM
24.03.21	MAK ++	Discussion on solar system for PhD at MAK (Jimmy)
26.03.21	Mulu, Thomas, OJ	Discussion on hybrid system: PV/thermal/wind
23.04.21	Partners	Progress meeting instead of workshop
07.05.21	Partners, MSc stud	MSc students at NTNU presents single tank cooker
10.05.21	Partners, MSC stud	MSc student at NTNU presents PCM fryer
12.05.21	NTNU Norhed	Information meeting on partner agreements
25.05.21	NTNU	Template Partner Agreement ready
15.06.21	NTNU, Camilla	First version of partnership contract ready, saved in the folder "partnership contract"
06.07.21	NTNU,UDSM	Telephone meeting Workshop1
08.09.21		Last signature on PA received (MU on hold). Fund transfers have been executed after each signature
30.08-03-09	Partners	Workshop organized by UDSM, hosted by ATC, Arusha, Tanzania
30.09.21	Partners	Technical meeting on MAK PhD Jimmy: single tank heat storage system
09.11.21	NTNU	NTNU seminar with all NTNU NorhedII projects
30.11.21	Partners	Workshop organized by UDSM, hosted by ATC, Arusha, Tanzania
14.01.22	Partners	Startup meeting 2022
24.01.22	NTNU	Norhed NTNU meeting on reporting. Templates posted
26.01.22	NTNU	Information on Audition - templates for requests on auditors
26.01.22	OJ	Templates for financial and narrative reports posted
11.02.22	Partners	Progress meeting on reporting, Teams
11.02.22	OJ	Framework for ENET report 2021 for updating by all
18.03.22	AAU/UDSM	Technical meeting on refrigeration systems at AAU and UDSM
25.03.22	UEM	Technical meeting on the results from the solar heat collection with evacuated tube collectors
18.03.22	AAU,partners	Technical meeting on Electric Injera Baking
01.04.22	AAU	Technical Meeting on refrigeration system at AAU
08-04-2022	AAU	Technical Meeting on Injera Fryer
08.04.22	Partners	Progress meeting, Workshop, Teams
25-28.04.22	MAK	MAK hosted an overall Norhed seminar week at Makerere, 21 MAK projects.

06.05.22	NTNU	Open day at Workshop3, 13 contributions on drivers for technology development and implementation
9-10.05.22	Partners	Workshop3 hosted by NTNU
10.05.22	MAK	Jimmy stays at NTNU for one month working on the single tank system
16-20.05.22	MAK	Workshop8 at MAK on PV and biogas
25.05.22	All	Audit Report Templates received and posted on Teams. Rechecked signature dates
31.05.22	All	Rechecked signature dates on Audit Report Templates and notified all on need for processing
24.06.22		Technical meeting
29.06.22	NTNU	Norhed NTNU meeting
01.09.22		Norhed seminar Oslo
10.09.22	NTNU	OJ research period Tanzania
20.09.22	NTNU, UDSM	MIE2022 conference UDSM
25.09.22	NTNU	OJ Research period Uganda
20.10.22	UDSM	MIE 2022 Conference organized by UDSM. OJ attended.
19.10.22	NTNU	OJ visit AAU
09.11.22	UEM, NTNU	Social-scientific PhD at UEM: Cândida Bila. Working meeting with Inês Raimundo and Govert Valkenburg, will continue weekly.
5-12.12.22	UEM	OJ attended SANORD conference and visited UEM and UniSAVE
9-11.1.23	MAK	MAK hosted annual meeting for 2022
27-28.2.23	UDSM	UDSM hosted the Third NORPART Stakeholders meeting in Arusha, Tanzania.
8.2-7.5.23	UDSM	Two PhD candidates visited NTNU under the NORPART Project
8.2-7.6.23	UDSM	Four master students visited NTNU under the NORPART Mobility Project support.
10-14.4.23	UDSM	Four UDSM supervisors visited NTNU under the NORPART Mobility Project support.
4.8.2023	All Partners	EnergyNET progress review online meeting on Teams platform.
10.8.23	UDSM	OJ Nydal visited UDSM and met with Project Coordinator, Team and students.
23.08.23	MAK	OJ spent some time at MAK, Jimmy and Tito and returned again in October and November.
30.8-28.11.23	UDSM	One PhD candidate visited NTNU under the ENET Project
4-7.9.23	All Partners	Fifth Workshop of EU Erasmus - UNET project at AAU.
28-9.23	UDSM/NTNU	NTNU, UDSM and SJTU online meeting on possible collaboration.
9-13.10.23	UDSM/NTNU	NORHED II Week in Dar es Salaam, Tanzania - hosted by UDSM.
15-18.11.23	UDSM	Hosting visitors from UEM.
30.11.23	MAK, AAU, NTNU	SWC2023 ISES conference, India.
27-30.11.23	MAK	Hosted UNET Workshop at Kampala Uganda.
9-6.12.23	UDSM	Supervisors and three PhD students attended ICAE Conference in Doha, Qatar.

## Appendix PhD researchers

	<p><b>Title:</b> <i>Optimization of Adsorption Refrigeration System using Different Heat Sources</i></p> <p><b>Name:</b> Joseph Ibrahim Mwasubila</p> <p><b>University:</b> University of Dar es Salaam (UDSM), Tanzania</p> <p><b>Supervisors:</b> Cuthbert Kimambo, and Joseph Kihedu (UDSM), Trygve Eikevik and Ole Jorgen Nydal (NTNU)</p>
<p><b>Baseline</b></p> <p>The needs of UDSM with regard to the proposed project are to create a proven and effective mechanism for dissemination of research results. Lack of cold storage facilities for ensuring year-round availability of food and an adequate supply of immunization vaccines is a serious challenge in many parts of the of developing countries that either have little or no access to electricity. Solar thermal refrigeration using the principle of adsorption is one of the viable ways of utilizing solar energy to power cooling systems.</p> <p>Research work on solar refrigeration using the adsorption principle started at UDSM in the mid - 1980s. Currently, UDSM in collaboration with NTNU are undertaking research and development work, involving a PhD thesis on development of solar adsorption refrigeration system for off - grid application. Two pairs, namely NH<sub>3</sub> - CaCl<sub>2</sub> and NH<sub>3</sub> - activated carbon have been studied. The tested laboratory adsorption prototypes attained temperatures that are sufficiently low for storage of vaccines and foods products, producing ice or in air conditioning systems by using low temperature heat source of 75 °C to 110 °C, which can be supplied by solar thermal collectors. Also, the use of waste heat in small renewable energy systems and heat generated by burning biomass materials such as agricultural waste is possible, in the remote parts of developing countries or islands where conventional cooling is difficult. The preliminary results that have been obtained so far, have prompted UDSM to seek support for the development of a full-scale adsorption refrigeration system, which can eventually be commercialized.</p> <p><b>Objectives</b></p> <p>The proposed PhD research will be multidisciplinary research covering technical issues related to the adsorption refrigeration systems, socio-economic, environmental and technology transfer aspects of the technology. It will involve upscaling of the system researched in the EnPe project, manufacturing and assembly at a field operation. A replicable technology transfer framework will be developed and applied to the system. A batch of the system will be manufactured for field testing and feedback obtained will be used to improve the systems and its dissemination frameworks.</p>	
<p><b>Status</b></p> <p>The candidate was recruited in late 2021. A project plan in form of a research proposal has been made, as a required PhD startup activity. This was accomplished in communication with co-supervisors at UDSM and at NTNU. The research proposal was built on the results from previous PhD candidate from the EnPe program. The candidate managed to defend PhD research proposal before Departmental Postgraduate Committee in October 2022 and again in December 2022. The candidate finalized defense of PhD research proposal before Special Postgraduate Panel in January 2023.</p> <p>The candidate has visited NTNU between February and April 2023 and then August to November. In his stay at NTNU, the candidate developed two experimental rig and conducted tests from which adequate data has been obtained.</p>	

So far, the candidate has managed to publish one conference paper and currently working on a journal paper.

**Further work**

After exchange visit to NTNU in 2023, the candidate will re-build adsorption refrigeration system and conduct laboratory experiments. Likewise, he will finalize with optimization of adsorption refrigeration system.

	<p><b>Title:</b> <i>Development of solar thermal energy technology for off-grid cooking application</i></p> <p><b>Name:</b> Jimmy Chaciga</p> <p><b>University:</b> Makerere University, Uganda</p> <p><b>Supervisors:</b> Karidewa Nyeinga and Denis Okello (MAK) and Ole Jorgen Nydal (NTNU)</p>
<p><b>Baseline</b></p> <p>The solar group at Makerere has long experience in development and testing of solar heat storage methods for cooking. A particular result from the EnPe project will be optimized and brought to field testing. The system use PV (or other power sources) to charge an oil based heat storage which delivers hot oil (about 250 degrees C) to a cooker. Emphasis has been made on simplicity, robustness, safety and the potentials for local production. The concept has been proven at MAK and NTNU.</p> <p><b>Objectives</b></p> <p>The main objective is to arrive at field testing of a system after constructing and testing a prototype solar cooker in the laboratory. The laboratory units will mirror the system to be deployed in the field. The system should be possible to be upscaled for application to a school in a refugee camp in Northern Uganda. Performance tests in the field will be made and the results from an autonomous data logging system will be analyzed.</p>	
<p><b>Status</b></p> <p>Jimmy Chaciga is a MSc graduate from the former EnPe project. Jimmy registered as a PhD candidate at MAK, defended his PhD proposal in 2021 and got full admission in 2022. He embarked on experimental work immediately after registration and has been very active in building and testing a prototype single tank cooker, powered by PV panels and including a heat storage unit. The first test is conceptual, with power from the grid. The concept is similar to the one developed jointly with NTNU students, and the collaboration is very efficient with TEAMS meetings and sharing of models and drawings.</p> <p>Jimmy visited NTNU lab for a period of about one and half month in 2022, where he performed experiments on single tank heat storage with rock pebbles; experiments on dual tank heat system with rock pebbles. Cooking tests were also done.</p> <p>At Makerere, Jimmy carried out tests on a single tank heat storage with rock pebbles and tested PV based electrical heating using MPPT controllers. A stand-alone data logger based on Arduino was developed, together with the team at NTNU. This can be used in remote places and does not require a computer.</p> <p>A second version of the heat storage system for cooking was constructed and tested at MAK. This has been demonstrated in particular for cooking beans, which require long cooking times. The system will be the basis for pilot units to be field tested.</p> <p>Dissemination activities in 2023 have been:</p> <ol style="list-style-type: none"> <li>1. Participated in one international conference, ISES, Solar World Congress 2023 in New Delhi, India with oral presentation of a research paper. 29<sup>th</sup> Oct-04<sup>th</sup> November 2023</li> </ol>	

2. Published on research paper in peer reviewed Journal: Title: J. Chaciga, K. Nyeinga, D. Okello, and O. J. Nydal, "Design and experimental analysis on a 52 single tank energy storage system integrated with a cooking unit using funnel system," J Energy Storage, vol. 79, Feb. 2024, doi: 10.1016/j.est.2023.110163.
3. Participated in a Renewable Energy Conference and Expo 2023 in Uganda organized by Ministry of Energy and Mineral development, MEMED November 2023.
4. Participated in the UNDP and Makerere University Expo 2023 and exhibited Mini cooker for household cooking.

**Further work**

The pilot systems will be completed and tested with new PTC heating elements. The aim is to initiate field tests of pilot units in a refugee camp in 2024. The aim is also to complete the PhD dissertation of Jimmy in 2024.

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	<p><b>Title:</b> <i>Design, Manufacture and Performance Test of Small Scale Milk Refrigeration and Pasteurization Unit</i></p> <p><b>Name:</b> Fikadu Geremu Bodena</p> <p><b>University:</b> Addis Ababa University (AAiT, AAU), Ethiopia</p> <p><b>Supervisors:</b> Dr. Ing Demiss Alemu (AAiT, AAU), Trygve Eikevik and Ole Jorgen Nydal (NTNU)</p>
<p><b>Baseline</b></p> <p>Like any other developing countries in Africa, small holder milk farmers are major contributors of milk production in Ethiopia. According to the statistical survey for the reference period of 2014/2015, there are 11.38 million milking cows in the rural sedentary areas of Ethiopia producing 3.07 billion liters per year.</p> <p>Milk being perishable and the requirement being high to urban consumption, collection and transportation of this bulk from widely scattered rural sources requires improved methods of preservation and distribution. Energy and methods for preservation is the main challenge in marketing milk surplus in rural areas. Due to the lack of proper storage and transport facilities, milk and other agricultural products in remote areas lose their value. This spoilage could be prevented at the local village level by providing pasteurization and cooling units. With low coverage of the electricity grid, such units require off-grid energy supply methods. Development of small scale distributed energy systems to power milk pasteurization and cooling units will enable the integration of rural small-scale farmers and pastorals in the milk supply chain.</p> <p><b>Objectives</b></p> <p>The research objective of the project is to manufacture and performance test a prototype small scale refrigeration and pasteurization system that uses solar energy (solar water heater and PV )with ice thermal storage for night cooling for application in off-grid rural areas.</p> <p>A computer model for design of the refrigeration and pasteurization system has been established. A prototype will be made at AAU as a baseline for implementation of test units at selected field locations and as a base unit for further student activities on optimization and improvements.</p>	
<p><b>Status</b></p> <p>Gashaw Geremu Birhanu registered as PhD candidate at AAU in mid 2021. His scope of work has been discussed with co-supervisors at Workshop1 and on dedicated TEAMS meetings. Startup activities include coursework and detailed design of the experimental setup.</p> <p>Fikadu Geremu Bodena finalized his course work in 2022 as originally planned. He also submitted conference abstract for participation in World Energy Conference which was held in Australia in December 2022. His submission was accepted but he is forced to withdraw due to the high travel costs. He is considering submission of the article to another conference and requested his travel funds to be transferred to 2023. He also co-supervised a M.Sc. student in the mainstream area of his PhD work. The Thesis is titled 'Effectiveness of heat exchange in a two tank system with thermosyphon circulation'. This work is part of his plan for 2022 to construct a stand-alone setup for pasteurization and refrigeration of milk. The lists of items required for the construction of the M.Sc. work were purchased and prototype making is started. A detailed specification of the PV panel, support structure, MPPT and battery were also prepared and submitted for procurement.</p>	

**Status in 2023**

The PV unit and its accessories required to power his system is installed and waiting for the entire system to be installed and tested. The work of the M.Sc student co-supervised by Fikadu on Two tank system was constructed and tested. The test results are completed and submitted as part of the M.Sc. Thesis of the student. Fikadu also participated in ISES 2023 conference held in India and presented a paper which is currently ready for publication after review. The mobility to NTNU in 2023 was not successful due to inconveniences related to hosting supervisor at NTNU. A detailed specification was prepared for the remaining materials to purchase and produce prototypes of as per the findings from the simulation results.

**Further work**

Fikadu will spend three months at NTNU to work on existing facilities for refrigeration system. He will also finalize the purchase of the remaining materials to manufacture milk pasteurization and milk chilling. The plan in 2024 mainly to finalize the prototype construction and start experimentation at university compound. Fikadu is also planning to participate in at least one international conference in 2024.

	<p><b>Title:</b> <i>Design, Development and Experimental Investigation of an Institutional Solar Fryer</i></p> <p><b>Name</b> Gashaw Getnet Birhanu</p> <p><b>University:</b> Addis Ababa University (AAiT, AAU), Ethiopia</p> <p><b>Supervisors:</b> Dr Abdulkadir Aman (AAiT,AAU), Ole Jorgen Nydal (NTNU) and Dr. Ing Demiss Alemu Amibe (AAiT-AAU)</p>
<p><b>Baseline</b></p> <p>AAU has been working on Injera baking under the NUFU period and promising results were obtained with use of high temperature thermal oil for baking on a new thin Ceramic baking pan. The ceramic baking pan is also tested for baking with electric power and promising efficiency improvement was recorded. The quality of the injera baked on the ceramic pan is good. A conclusion from the previous concept tests has been that an oil based heat storage system gives flexibility in terms of power sources and heat transfer, and PV systems provide simple heating solutions, although at lower energy collection efficiencies. A cost comparison (KWh cost of stored energy) between PV and thermal collectors has not been made for the high temperature case, but large scale PV power plants are less cost efficient than thermal power plants today.</p> <p><b>Objectives</b></p> <p>The target groups are institutions which are providing injera baking for many people on a daily basis. Several options can be considered for implementation for injera frying.</p> <ul style="list-style-type: none"> <li>• A combined heat collector and PV system is a research topic of UEM, where water heaters are converted to oil heaters and PV powered heating elements gives the additional power needed to reach 200-250 degrees C in the storage. This concept can also be explored for injera baking.</li> <li>• A combination of oil and latent heat, together with a heat pipe connection with a frying pan, has been tested at NTNU, and can be upscaled and implemented at AAU.</li> <li>• A sensible heat based storage option, promoting thermal stratification for efficient heat storage and recovery, is also a technically simple system which has been tested, and can be applied for injera testing.</li> <li>• A Scheffler type of concentrator can be considered, where the focal point of a solar concentrator can be positioned through a hole in a wall. The energy in the solar rays are then converted to heat at a receiver and stored in a heat storage (sensible or latent heat).</li> </ul> <p>The tasks of a PhD researcher can include:</p> <ul style="list-style-type: none"> <li>• Determining the energy requirement for institutional cooking in remote locations (clinics, schools, correction centers or group of households) preferably located in arid zones.</li> <li>• Selection of concept, designing and sizing main components of the relevant capacity.</li> <li>• Constructing and testing the system, including modeling and simulation of the system.</li> <li>• Implementation of the system using the AAU canteen as a test site.</li> </ul>	
<p><b>Status</b></p> <p>Gashaw Getnet registered as a PhD candidate at AAU in mid 2021. His scope of work has been discussed with co-supervisors at Workshop1 and on dedicated TEAMS meetings. Startup activities include coursework and detailed planning leading to the concept choice and the further construction of the prototype. The AAU team has particular experience in the challenge of new concepts for injera baking. Two particular concepts at NTNU also form a good basis for concepts to be taken to field testing.</p>	

Gashaw Getnet finalized his course work in 2022 as originally planned. He also submitted conference abstract for participation in World Energy Conference held in Australia in December 2022. His submission was accepted but he is forced to withdraw due to the high travel costs. He is considering submission of the article to another conference and requested his travel funds to be transferred to 2023. He also co-supervised a M.Sc. student in the mainstream area of his PhD work. The Thesis is titled 'Numerical Investigation on charging-discharging of a PCM using PV and thermal oil for Injera baking application'. He has finalized the concept selection for his system based on detailed simulation studies of three options. He has also performed experiments on metal baking surfaces which are Teflon coated. The result paves the way for future research on Teflon coated metal surfaces and Aluminum gives better quality of injera. He also collected data on institutional baking setup from Bahirdar and Debrebirhan Universities. A detailed specification of the PV panel, support structure, MPPT and battery were also prepared and submitted for procurement.

#### Status in 2023

Gashaw started constructing the physical system by installing the PV unit required to power his system. Casting of the thermal storage is completed and machining is underway. He is finalizing preparation to test the unit using PV power. Gashaw also participated in ISES 2023 conference held in India and presented a paper which is currently ready for publication after review. He also Co-supervised a Master student to completion. Currently a joint article is submitted for a journal and it is under review. The mobility to NTNU in 2023 was not successful due to inconveniences related to hosting supervisor at NTNU.

#### Further work

Gashaw will spend three months at NTNU to work on existing facilities for storage based systems for frying. He will also finalize the construction of the system at AAiT and conduct tests for injera baking. The plan in 2024 is mainly to finalize the prototype construction and start experimentation at university compound. Gashaw is also planning to participate in at least one international conference in 2024.

	<p><b>Title:</b> <i>Reconstructing life and energy after disaster</i></p> <p><b>Name:</b> Cândida Bila</p> <p><b>University:</b> Eduardo Mondlane University (UEM), Mozambique</p> <p><b>Supervisors:</b> Govert Valkenburg (NTNU), Inês Raimundo (UEM)</p>
<p><b>Baseline</b></p> <p>The work of Cândida Bila fills in a broader need to connect energy and technology research with social-scientific and cultural research. A case study is selected where tensions are studied between reconstructing social and economic life after two decades of disasters, the need to transition towards clean, renewable and accessible energy, and the establishment of governance practices (top-down versus bottom-up). Connection to the more technology-oriented research and education in the consortium is secured by a focus on cooking practices and the feasibility of solar cookers.</p> <p><b>Objectives</b></p> <p>A PhD will be trained in social science through the conducting of a case study in the Limpopo valley, Mozambique. The area is regularly struck by disasters, significantly displacing its population. At the same time, moving towards clean energy use is an urgency broadly felt. Through interviews, focus groups and the reporting of life histories (oral history), the candidate will investigate how meaning is given to climate change, disaster, and a deeply cultural practice such as cooking. In terms of its theoretical embedding, an explicit aim is to build on intellectuals from the Global South, rather than replicating the Western canon.</p>	
<p><b>Activities 2023</b></p> <p>The candidate started work only towards the end of 2022. She participated in two workshops:</p> <ol style="list-style-type: none"> <li>1. UNET - ENET Workshop 6 in MAK, Uganda, where she had the first interaction with the supervisor.</li> <li>2. Kigali Workshop, Rwanda (II LEAP – RE Stakeholder Forum) with the presentation of a communication.</li> </ol> <p>Work on the Research project and preparation for the internship at NTNU.</p>	
<p><b>Plan for 2024</b></p> <ul style="list-style-type: none"> <li>- Implementation of the theoretical framework developed in 2023;</li> <li>- Field work;</li> <li>- Two month internship at NTNU</li> <li>- Attendance of a Course on Social Sciences Methodology at NTNU;</li> <li>- Drafting of a first paper.</li> </ul>	

	<p><b>Title:</b> <i>Experimental Investigations of an Oil Based Solar Thermal Collectors for Cooking application</i></p> <p><b>Name:</b> Tomas Nhabetse</p> <p><b>University:</b> Eduardo Mondlane University (UEM), Mozambique</p> <p><b>Supervisors:</b> BoaventuraCuamba, António Leão and AmósVeremachi (UEM), OJ Nydal (NTNU)</p>
<p><b>Baseline</b></p> <p>UEM has been building research capacity on both the PV and the solar thermal side. Rock bed systems with solar concentrators have been explored in NUFU/EnPe projects. A concept for study at UEM is the use of a commercially available solar thermal collectors which can be converted to oil systems to provide high temperature energy for cooking. A question is whether top-up PV heating is required or not, to reach heat storage temperatures which are suitable for cooking.</p> <p><b>Objectives</b></p> <p>The objective is to experimentally study water heaters converted to oil heaters regarding capacity (oil temperatures) and energy efficiency (the fraction of solar energy converted to heat). The work will conclude on whether stand-alone converted water heaters can provide heat storage for cooking (hot oil) or whether hybrid systems are required (top-up energy from PV or wind). The heat storage should then be designed to accept several types of heat sources.</p>	
<p><b>Status</b></p> <p>The work of Tomas was initiated during the EnPe project. The experimental work is completed showing oil temperatures could reach up to 140-170 degrees C, depending on flow rates. Evacuated tubes perform better than flat plate collectors.</p> <p>A PV system for topping up the energy to higher temperatures has been designed. Higher temperatures in the oil-based heat storage gives more efficient cooking. Storage temperatures in the order of 150 degrees C, from a converted water heater, can be used for cooking but the time for water heating may be large depending on the amount to cook.</p> <p>Tomas Nbatetse's participation in the project has ended in June 2023 although the submission of the thesis will happen only at the beginning of 2024.</p>	
<p><b>Plan for 2024</b></p> <p>Submission of his thesis and examination.</p>	

	<p><b>Title:</b> Modelling and simulation of hybrid heat sources for charging thermal energy storage system integrated with multiple cookers.</p> <p><b>Name:</b> Akire Tito</p> <p><b>University:</b> University of Juba, South Sudan</p> <p><b>Supervisors:</b> Denis Okello and Karidewa Nyeinga (MAK), Ole Jorgen Nydal (NTNU)</p>
<p><b>Baseline</b></p> <p>University of Juba is the main university in South Sudan. The impact of the long war in the country affected training programmes at the university. The majority of the staffs do not have PhD training; in many departments, the staffs have only bachelor degrees. In addition, the departments lack laboratory facilities and technicians. This has greatly affected the quality of training at the university. In most cases, staffs have to seek for training opportunities abroad. There is urgent need for capacity building (at both MSc &amp; PhD levels) and equipping the laboratories to improve the quality of training.</p> <p><b>Objectives</b></p> <p>University of Juba will recruit one PhD candidate. The student will undertake PhD studies at Makerere at the Department of Physics, in the research group on solar thermal systems. Tito will complement the work on solar heat storage for cooking with contributions on the computational side. COMSOL Multiphysics will tentatively be used for heat transfer analysis of the storage systems based on natural circulation of hot oil. Multiple energy sources (wind and solar) and multiple cookers with a single heat storage concept is open for analyzing as well.</p>	
<p><b>Status</b></p> <p>Tito was admitted for his PhD in October 2022; and he started work in November 2022. He performed the following tasks:</p> <ul style="list-style-type: none"> <li>• Training on the use of Comsol and Solid Works; and building components in solid works</li> <li>• Basic modelling of wind power generated</li> <li>• Writing proposal</li> </ul>	
<p><b>Further work</b></p> <p>Tito will make use of Comsol multiphysics to evaluate the heat storage-cooker system with natural circulation. A particular aspect is the conditions when circulation can stop prematurely and the effect of increasing the length between the storage and the cooker. Thereafter, a concept with several cookers connected to a single storage can be computationally analyzed. The mini-cooker configuration is also suitable for flow analysis with COMSOL. Tito will join a visiting group of PhDs to NTNU in 2023.</p>	

	<p><b>Title:</b> <i>Performance Optimization of PAT-SEIG Operating in an Off-Grid Energy Generation Setup</i></p> <p><b>Name:</b> Emmanuel Jack Nyirenda</p> <p><b>University:</b> University of Malawi (MUBAS), Malawi</p> <p><b>Supervisors:</b> Cuthbert Kimambo and Joseph Kihedu (UDSM), Torbjorn Nielsen (NTNU)</p>
<p><b>Baseline</b></p> <p>The University of Malawi has a postgraduate programme in Renewable Energy whose goal is to meet the national demand for appropriately trained people in the field of renewable energy technologies and applications. It is envisaged that the programme will achieve effective training in renewable energy technologies, acquisition of advanced knowledge and understanding in the selected specialist areas of renewable energy and broadening the knowledge of engineers and scientists in areas of renewable energy specializations. The area of developing Renewable Energy technologies is a top priority, and hydro power is an relevant area where post graduate training is important.</p> <p><b>Objectives</b></p> <p>A PhD will be trained in the hydro power technology by developing and testing small scale systems where commercial pumps can be converted to turbines. A setup for this will be available at UDSM, as a result of the EnPe Capacity5 and the NORPART project. A practical result could be the development of design guidelines for converting mass produced asynchronous motors to turbines, testing with Electronic Load Controller together with a dump loading arrangement where the waste power is accumulated in the form of heat storage for cooking.</p>	
<p><b>Status</b></p> <p>The PhD researcher was recruited at MUBAS and registered as PhD candidate at UDSM in 2021. The scope of work was discussed during Workshop in Arusha, with participation of MUBAS staff. Emmanuel produced a project plan in form of a research proposal, as PhD startup activity. This was accomplished in communication with co-supervisors at UDSM and at NTNU. The candidate managed to defend PhD research proposal before Departmental Postgraduate Committee in September 2022 and again in November 2022. The candidate finalized defense of PhD research proposal before Special Postgraduate Panel in January 2023.</p> <p>A Pump as Turbine test setup (PAT) to be used by the candidate, was shipped from NTNU under the NORPART project, and was received at UDSM in January 2022. An Electric Load Controller is also part of the received PAT system. The new PAT system has been installed at UDSM and currently the candidate is conducting some tests on the rig.</p> <p>So far, the candidate has managed to publish one conference paper, one journal paper accepted for publication and currently working on a journal paper.</p>	
<p><b>Further work</b></p> <p>As from March 2024, the candidate is expected to model PAT system for power quality issues. Also, variation of capacitor bank size, resistive and inductive loads will also be investigated. Meanwhile, the candidate expects to visit NTNU between April and June 2024.</p>	

	<p><b>Title:</b> <i>Optimization of Oil-Based Sensible Thermal Storage System for Cooking Application</i></p> <p><b>Name:</b> Anna Kisioki Sharishoy</p> <p><b>University:</b> University of Dar es Salaam (UDSM), Tanzania</p> <p><b>Supervisors:</b> Cuthbert Kimambo, and Joseph Kihedu (UDSM) and Ole Jorgen Nydal (NTNU)</p>
<p><b>Baseline</b></p> <p>Solar resource has been proven to be well adopted technologically to collect energy for cooking but its widespread application has been limited by the intermittent nature of sunshine; this results in poor cooking performance. Researchers reviewed and developed solar cookers but not considered as best option for all seasons and all societies due to their limitation o to indoor cooking.</p> <p>The research aims to optimise the STS system for cooking applications by conducting laboratory experiments of the existing setup and optimising the selected parameters. The optimised prototype will be developed and tested at the workshops and laboratories of College of Engineering Technology (CoET) at the University of Dar es Salaam. The exergy analysis will be conducted and based on the existing (un optimized system) and the optimised STS system. The stakeholders and other beneficiaries will be involved to ensure the practicality, scalability and sustainability of the STS system.</p> <p><b>Objectives</b></p> <p>The main objective of this research is to optimize the performance of the oil-based sensible thermal storage system for cooking applications. In details, this work will involve investigation of the performance of the STS system available at NTNU laboratory for cooking applications. Then optimization of the operating parameters followed up by development a prototype at UDSM. Finally, comparison of performance of the optimized STS system with performance of existing system will be done.</p>	
<p><b>Status</b></p> <p>The candidate was recruited in late 2022. A project plan in form of a research proposal has been made, as a required PhD startup activity. The research proposal was built on the results from previous PhD candidate from the EnPe program. The candidate has spent three months at NTNU Norway, between February and April 2023 where she worked on laboratory scale oil based cooker.</p> <p>The candidate managed to defend PhD research proposal before Departmental Postgraduate Committee in January 2023 and again in August 2023. Also, the candidate defended PhD research proposal before Special Postgraduate Panel in February 2024.</p> <p>So far, the candidate has managed to publish one conference paper and currently working on a journal paper.</p>	
<p><b>Further work</b></p> <p>The candidate will optimize and or improve design of oil-based cooker. Thereafter, she will build oil-based cooker at UDSM and conduct/field tests.</p>	

	<p><b>Title:</b> <i>CPC for solar cooking</i></p> <p><b>Name:</b> Casiana Lwiwa</p> <p><b>University:</b> Norwegian University of Science and Technology (NTNU)</p> <p><b>Supervisors:</b> Ole Jorgen Nydal (NTNU), Cuthbert Kimambo (UDSM)</p>
<p><b>Baseline</b></p> <p>A drawback with using solar concentrators for high temperature heat collection is that they need solar tracking. This is technically fully feasible but does reduce the robustness of such heat collection systems. A Compound Parabolic Concentrator (CPC) is a device that is designed to be stationary and still concentrate sun rays for a range of acceptance angles. A simple system could be that an insulated CPC reflector is placed on top of a heat storage and left in the sun. After charging the heat storage, the reflector can be removed and replaced by an insulator for the heat storage. Cooking can then be on the top surface when needed.</p> <p>A PhD was initiated from NTNU Energy, with the purpose of exploring the use of CPC for charging a heat storage for cooking.</p> <p><b>Objectives</b></p> <p>The objectives of the work is to analyze different CPC concepts for cooking, select a concept and build a small scale prototype for testing. A challenge is to simplify the design by using flat mirror tiles to represent the reflecting CPC surface.</p>	
<p><b>Status</b></p> <p>Casiana made use of an in-house Ray Tracer for analysis of CPC options. The Ray Tracer has been extended to include 2D CPC and 3D CPC reflector geometries.</p> <p>A simplified CPC, with only 8 mirrors in a square shaped form was tested, using an iron cylinder as heat absorber. The mirror positions were optimized using the Ray Tracer, which have been extended to include 2D and 3D CPC geometries. Some tests in the sun at NTNU were made, giving temperatures of the storage to about 120 degrees C. Some insulation was attached on the CPC, but could be improved, as seen by the temperature decline of the cylinder after the tests.</p> <p>The iron cylinder as a heat storage was tested separately. An insulated cylinder (20 cm diameter and 30 cm height) was heated with electrical heating elements (potentially from PV) and cooking tests were made with beans. The amount of beans can be calibrated to the initial storage temperature, such that the beans are left to cook and then keep warm without further attention (a sensible heat bean cooker).</p> <p>Parts of the work of Casiana has been presented at 5 conferences.</p> <p><b>Further work</b></p> <p>The PhD period of Casiana at NTNU is completed, and Casiana has moved back to Tanzania and has taken up her position with Mkwawa University College of Education (MUCE) again. She is working on completing the write-up of her thesis there.</p>	
<p><b>Publications/Conferences</b></p> <p>Paper 1</p> <p>3D Ray tracing for optimizing the size of surface tiles on a Compound Parabolic Concentrator.</p> <p>Authors: Casiana Blasius Lwiwa, Ole Jørgen Nydal</p>	

Published in: Proceeding of the Southern African Sustainable Energy Conference (SASEC), Cape town, South Africa, 17 – 19 November 2021.

Year: 2021

Paper 2

3D Ray tracing for optimizing a mirror tiled Compound Parabolic Concentrator.

Authors: Casiana Blasius Lwiwa, Ole Jørgen Nydal

Published in: Proceeding of the 16th International conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT), 8-10 August, 2022, Online

Year: 2022

Paper 3

A Ray tracer for optimizing solar concentrating systems: the case of discretized Compound Parabolic Concentrator

Authors: Casiana Blasius Lwiwa, Ole Jørgen Nydal

Published in: Proceedings of the 63rd International Conference of Scandinavian Simulation Society, SIMS 2022, Trondheim, Norway, 20-21 September 2022

Year: 2022

Paper 4

Interception on Solar Absorbers: Ray Tracing for Comparison between a Parabolic Reflector and a Compound Parabolic Concentrator

Authors: Casiana Blasius Lwiwa, Ole Jørgen Nydal

Published in: Proceedings of the EuroSun2022- ISES and IEA SHC International Conference on Solar Energy for Buildings and Industry, 25-29 September 2022

Year: 2023

Paper 5

Sensible heat bean cooker

Authors: Casiana Blasius Lwiwa, Ole Jørgen Nydal

Published in: Tanzania Journal of Engineering Technology (TJET), Volume XX, 2023, Pages xxx-xxx.

(Presented in the 7th International Conference In Mechanical and Industrial Engineering (MIE 20-21 October 2022), New Library, UDSM-Tanzania)

Year: 2023

A paper on the testing of CPC heated aluminum cylinder will be the last contribution to the thesis.

	<p><b>Title:</b> <i>Direct and indirect solar fryer</i></p> <p><b>Name:</b> Mesele Hayelum</p> <p><b>University:</b> Norwegian University of Science and Technology (NTNU)</p> <p><b>Supervisors:</b> Ole Jorgen Nydal (NTNU), Mulu Bayray (MU)</p>
<p><b>Baseline</b> Mesele Hayelum is a PhD candidate from the EnPe Capacity5 project, who was hindered to return to NTNU after a period at MU, due to the political unrest and warfare in Ethiopia. Parts of his rest budget was approved for use in the NorhedII project period, for him to return to NTNU and complete the PhD thesis.</p> <p><b>Objectives</b> Investigate direct and indirect solar methods for frying injera</p>	
<p><b>Status</b> Mekelle University started to come back in normal operations in 2023 and Mesele has taken up his PhD work again. Experiments with direct frying of injera with a parabolic concentrator was first made in Trondheim and then taken further in Mekelle. This has given valuable experimental results on direct frying. The data is being analysed with the help of a numerical model, which Mesele has implemented in the Matlab framework. The intention is to use the model for optimization of frying systems. Direct PV frying of injera has also been tested in Mekelle with PV panels powering heating elements directly. Solar radiation has also been recorded for a period of nearly two years at Mekelle, and the data analysed and a prediction model has been tuned to the data.</p>	
<p><b>Plan for 2024</b> The aim is for Mesele to complete his PhD thesis in 2024. Work on publications is ongoing. The fund transfer from the previous EnPe program gives Mesele the opportunity to come to NTNU for finalizing the dissertation and the defence.</p>	

	<p><b>Title:</b> <i>Flow-structure analysis of medium scale wind turbines</i></p> <p><b>Name:</b> Hailay Kiros</p> <p><b>University:</b> Norwegian University of Science and Technology (NTNU)</p> <p><b>Supervisors:</b> Torbjørn Nielsen (NTNU), Mulu Bayray (MU)</p>
<p><b>Baseline</b> Hailay Kiros is a PhD candidate from the EnPe Capacity5 project, who was hindered to return to NTNU after a period at MU, due to the political unrest and warfare in Ethiopia. Parts of his rest budget was approved for use in the NorhedII project period, for him to return to NTNU and complete the PhD thesis.</p> <p><b>Objectives</b> The objectives of the work is to support implementation of medium scale wind turbines by structural analysis of the blades under different wind conditions.</p>	

**Status**

The situation in Mekelle was such that experimental work could not be made, and the analysis of the problem is therefore made using the ANSYS software.

The work of Hailay has made him an expert on ANSYS. Hailay came back to NTNU in mid 2023 and has managed to prepare publications on the subject, which gives the base for completing his thesis.

**Plan for 2024**

The plan is to finalize the last publication and then proceed with the PhD defence.

	<p><b>Title:</b> <i>Latent heat storage with a heat pipe frying pan</i></p> <p>Name: Abraham Parra</p> <p><b>University:</b> Norwegian University of Science and Technology (NTNU)</p> <p><b>Supervisors:</b> Ole Jorgen Nydal (NTNU)</p>
<p><b>Baseline</b></p> <p>The case for study is the heat transfer from a heat storage to a frying pan. One particular method is by phase change, where a working fluid evaporates in the heat storage and condenses at the frying pan. This is a very efficient mode of heat transfer and it is a method which can support several frying pans on a single heat storage. The concept for testing is a thermosyphon, where the return of the condensate to the evaporator is by gravitational flow.</p> <p><b>Objectives</b></p> <p>To arrive at a suitable system for a large diameter fryer powered with energy from a latent heat storage.</p>	
<p><b>Status</b></p> <p>The work started with an assessment of using a computational method developed for the flow dynamics in oil/gas pipelines for the particular case of a pulsating heat pipe for the heat transfer. Some trial experiments indicated this was difficult to achieve in large diameter tubes (5-10 mm). The further work was experimental. Cylinders with a Phase Change Material (PCM) were immersed in a container with a thermal oil, where heating elements were placed. The evaporator was in the oil and connected to a hollow frying pan. The system was constructed and successfully tested. Some additional experimental work has also been made with flow analysis of natural circulation with air in a rock bed heated directly with heating elements.</p>	
<p><b>Plan for 2024</b></p> <p>Abraham has been largely self financed and his work has therefore been extended in time. The work has been presented at a conference, and needs to be published in a journal paper, as part of his thesis. The aim is that the thesis will be completed in 2024.</p>	

## Appendix Workshops

### Workshop August 2021, Tanzania

*Time:* 30 August to 2 September 2021  
*Place:* Arusha, Tanzania  
*Organizer:* University of Dar es Salaam (UDSM)  
*Host:* Arusha Technical College (ATC)  
*Report:* Joseph Kihedu (UDSM), Ole Jorgen Nydal (NTNU)  
See TEAMS for more details of the Workshop

#### Workshop

The EnergyNET workshop is held in conjunction with a Erasmus+ project status meeting: " University Network on PhD Programs in Energy Technology, UNET". UNET concerns PhD curriculum and training facilities, ENET concerns research. UNET and ENET includes many of the same partner universities.

The aim of the Workshop is to present and discuss the project status and plans, in particular related to

- 1) MSc programs on Renewable Energy and needs for reviews
- 2) Status on PhDs: Scope of work, recruitment and needs for equipment

#### Reviews of Renewable Energy MSc programs

- **UDSM** gave an overview of the MSc program status, as it has evolved from the original NOMA program (2008). The program was reviews in 2011. It is a challenge to maintain 6 specializations for a limited number of students.
- The MSc program on renewable Energy has recently been reviewed at **MAK** (Department of Mechanical Engineering). The master program in physics has a solar part, which attracts very good interest among the students.
- The master program in Thermal Engineering at **AAU** (AAiT) has been revised 4 times, with surveys on relevance and usefulness of courses. Updating of the research and demonstration facilities are needed.
- **UEM** has established a master program as part of the previous EnPe program. The program now attracts a good number of students during the startup of the program.

#### Conclusion on review of master programs

Harmonizing programs between the ENET partners may be challenging, whereas collaboration on course level can be directly between the course responsible persons. An ENET Working Group for the master programs was established.

#### PhD programs and equipment

The PhD programs at the ENET partners were presented, with general comments on plans and needs. The PhD proposal for about 10 ENET candidates were reviewed together with the status on the recruitment. The detailed specification of the equipment is deferred to after the UNET process, in order to optimize the synergies between the projects.



## Workshop November 2021, Tanzania

*Time:* Monday 29 November to 1 December 2021  
*Place:* Arusha, Tanzania  
*Organizer:* University of Dar es Salaam (UDSM)  
*Host:* Arusha Technical College (ATC)  
*Report:* Joseph Kihedu (UDSM), Ole Jorgen Nydal (NTNU)  
 See TEAMS for more details of the Workshop

### Workshop

The venue for the Workshop was shifted first from the original plans at NTNU (entry limitations), then from Addis Ababa (escalating political tensions in Ethiopia). Given the short notice for change, the ongoing pandemic travel limitations (Mozambique closed), visa time requirements, the most convenient place to meet was in Arusha, Tanzania.

The aim of the Workshop is to present and discuss the project progress. The Workshop was organized together with the Erasmus+ UNET project.

### Project progress

The scope of work for the PhDs were discussed in detail at Workshop1. The review at Workshop2 was mainly on the recruitment status, many of the PhDs have been initiated already.

The MSc program at UDSM was presented in detail, together with an evaluation given by Prof. Kimambo. There is a need to review the program form the mismatch between the number of courses (28) and specialization offered (5) and the yearly number of students (about 5).

UDSM presented draft tools for Tracer Studies among students and employers. The questioners can be reviewed and made use of by all the universities.

A Working Group for the ENET web pages was established. The framework for the web pages are prepared, more content is needed.

**Pictures**

Thanks to Arusha Technical College (Dr. Peter Mashingo) who hosted our meeting venue!



Workshop 2 pictures Tanzania

## Workshop May 2022, Norway

*Time:* Friday 6 May - Tuesday 9 May 2022  
*Place:* Trondheim, Norway  
*Organizer:* Norwegian University of Science and Technology (NTNU)  
*Host:* Department of Energy and Process Engineering, Strategic Area NTNU Energy  
*Report:* Ole Jorgen Nydal (NTNU)

### Workshop

The EnergyNET workshop is held in conjunction with the Erasmus+ project status meeting: " University Network on PhD Programs in Energy Technology, UNET". UNET concerns PhD curriculum and training facilities, ENET concerns research. UNET and ENET includes many of the same partner universities.

The aim of the ENET part of the Workshop is

1. Progress Reviews and Short training sessions and an
2. Open Day with external presentations on the topic present and discuss the partner contributions related to the questions:
  - 1) How can small scale energy systems be developed?**
  - 2) How can new technology be implemented?**



The group in front of the Hydro Power Laboratory, NTNU

## 1 Progress Reviews and Training Sessions

The progress of 12 ENET PhDs, master students and other ENET activities were reviewed. The following training events on Systems and Programs were given:

- PhD administration systems and regulations (Runa Nilssen)  
The PhD management systems and regulations at the Faculty of Engineering was introduced to ENET partners. The introduction covered all aspects from initiation to thesis defence, both on the academic and the administrative side. A “PhD Handbook – Quality in PhD Education” includes the relevant information, and is available for all partners.
- Laboratory administration systems (Morten Grønli)  
PhDs often make use of laboratories in experimentally oriented research tasks. The Department of Energy and Process Engineering maintains extensive and advanced laboratory facilities, which are used for both PhD research tasks as well as for external contract research (e.g. SINTEF and others). The laboratory has about 100 projects every year. This requires efficient management systems, including resource management (staff and material), procurement systems and financial management systems. The management systems were presented for the partners. Microsoft TEAMS has recently been introduced as an efficient communication tool between laboratory staff and the users.
- Purchase Systems (Marianne Trælnes)  
Operation of efficient procurement systems is a challenge for many universities. An introduction on how this is made at NTNU was given by the procurement officer at Department of Energy and Process Engineering. Tender procedures are invoked for purchases above NOK 100.000. NTNU has framework agreements with suppliers for a range of products. Purchases are handled centrally at the department, based on forms submitted by the user, where each purchase needs a project number.
- PhD supervision training courses (Kristin Skjeldestad)  
An introduction to how training for PhD supervisors is made at NTNU was given during a Workshop with all partners in May 2022. NTNU has three levels of support for supervisors: 1) the Uniped pedagogical program has one module on professional guidance, 2) a Central NTNU PhD supervision seminar is given two times each year and 3) seminars/courses are also provided at Faculty levels.  
The NTNU central PhD supervision seminar was presented. It is a 2-3 day event which covers a range of aspects of PhD supervision and includes group work among the participants.



TTO at NTNU



Laboratory management

## 2 Open Day, Friday 6 May 2022

### Presentations

The ambition of ENET is to jointly develop small scale energy technology concepts for implementation in rural Africa. Towards that end, we have invited experts and stakeholders to give their views on drivers for change: **1) How can small scale energy systems be developed?** and **2) How can new technology be implemented?**

Introduction	NTNU, EPT	Ole Jorgen Nydal
Design driven	NTNU, Design	Manisha Rayaprolu
Research driven: Social Science	NTNU, Multicultural	Govert Valkenburg
Research driven: Natural Science (on-line)	NWU, South Africa	Ashmore Mawire
Individual driven (on-line)	Simply-Solar, Germany (Scheffler)	Heike Hoedt
University driven: NTNU	NTNU, Innovation	Per Arne Wilson
Industry driven (Monday 8 May)	NABA and NTNU	Karl Klingsheim, Kjersti Blauenfeldt, Mathilde Emilie Thue
Public funding driven (on-line)	Innovation Norway	Therese Marie Uppstrom Pankratov
Development collaboration driven (on-line)	NORAD	Anette Løken
Public funding driven (on-line)	NTNU, EU	Patrick Reurink
Humanitarian Engineering driven	EWB	Heidi Hovland Bergfald
Civil Society driven (on-line)	CARE	Morten F. Thomsen
Environment and conservation driven	NTNU, Conservation	Eivin Røskaft



- **Design driven.** Early involvement of end users can be important for a successful implementation of new technology. A research group at NTNU advocates design driven technology development. **Manisha Rayaprolu (NTNU)** presented the aims and examples of design driven development in Asia based projects, which may be equally applicable in Africa
- **Industry driven.** For cases where there is a commercial market, new technology can be developed and implemented based on private investments. NABA (Norwegian African Business Association) promotes investments in Africa. **Karl Klingsheim (NTNU), Kjersti Blauenfeldt (NABA) and Mathilde Emilie Thue (NABA)** presented some views on the question: Can small scale technology be a case of interest for NABA members?
- **Research driven.** University staff have some opportunities to define their own research directions. Some project members will comment on the question of researchers as driving forces for the small scale technology development. Are researchers also interested in being drivers for the implementation?. The drivers can come both from the technical and the social side. **Govert Valkenburg (NTNU)** participates in the collaboration project and gave views from the social side. **Ashmore Mawire (North West University, South Africa, on-line)** presented his long research experience on solar solutions for cooking.
- **University driven.** Innovation and entrepreneurship are frequent words also on the agenda of universities. Can our Small Scale Technology Development be driven by innovation programs at universities? **Per Arne Wilson (NTNU Strategic Area Innovation)** presented examples of programs promoting innovation at NTNU.
- **Public funding driven.** Grant programs are sometimes directed towards innovation and the energy transition challenge, at EU and at national levels (Research Councils). Are such funding schemes relevant for our Small Scale Technology Development for the African context? **Patrick Reurink (NTNU) on-line** is a contact point for the collaboration with universities in Low Middle Income Countries (LMIC). Patrick gave some views on opportunities in EU programs. **Therese Marie Uppstrom Pankratov (Innovation Norway) on-line** presented the Humanitarian Innovation Programme at Innovation Norway.
- **Humanitarian Engineering driven.** Engineers are challenged by the need for technical solutions which can improve efficiencies, reduce costs and therefore presumably lead to better living conditions. Engineers Without Borders (EWB) target the cases where the purchasing power is low and technical support is needed. Can EWB also be drivers for development of new technology? **Heidi Hovland Bergfald (EWB)** and Ida Fuchs from NTNU presented the organization together with examples of projects and activities.
- **Development collaboration driven.** NORAD programs include collaboration on education and research. Can NORAD take on a role as a driver, or facilitator, for implementation of research results in Small Scale Renewable Energy Technology as well?. **Anette Løken (Norad) on-line** presented the Norad Strategy with particular comments on the relevance for universities.
- **Civil Society driven.** Can the various organizations on development collaboration also be partners in development and implementation of small scale energy systems? **Morten Fauerby Thomsen**

**(CARE Norge) - on-line** presented experiences from the CAMP+ project, which includes energy systems designed for refugee camps in Uganda.

- **Environment and sustainability driven.** Sustainability, conservation, natural environment and climate are rising on the political agendas. Can these be major drivers for the development and implementation of small scale energy systems?. **Eivin Røskoft (NTNU)** Eivin Røskoft gave his views based on his more than 30 years of experience in Conservation projects in Tanzania.
- **Individuals driven.** Individual persons who have the dedication and resilience to pursue ideas and goals, often outside an institutional base and funding, and often on an idealistic basis. The internet access to knowledge and communication, as well as backyard workshops, makes this "Boot-strap" driver today a worldwide option. **Heike Hoedt (Simply Solar) on-line** have almost a life time of experiences on development and application of the Scheffler Reflector system for various energy needs at various scales. They will give a brief overview of their experiences on development and implementation of the systems.
- **Round-The-Table Discussions**  
The presentations were followed by a round-the-table discussion including the presenters. A survey was then conducted on how the audience would rate the relative importance of the various aspects presented.

**Mini survey**

A survey among the participants was made after the presentations, as described below.

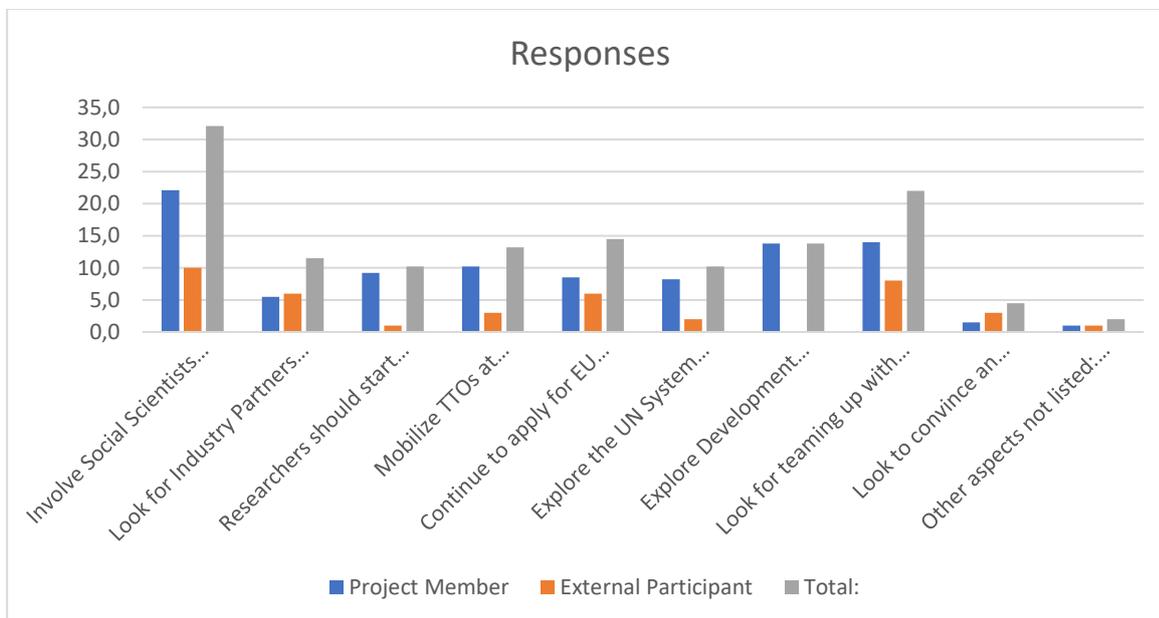
Please give 5 points on the aspects you believe should get special attention at the stage we are now.

- If you are project member: What should we at best do now? **I AM A PROJECT MEMBER**
- If you are not project member: What is your advice? **I AM NOT A PROJECT MEMBER**

You can spread the 5 points as you wish on several or only on a few of the aspects. The total sum of points should not exceed 5. You can also add other aspects.

Aspect	Points
Involve social scientists and designers now	
Look for industry partners now	
Researchers should start companies for implementation now	
Mobilize the TTOs at the universities to contribute to the case now	
Continue applying for EU Grant funding	
Explore UN system (UNDP etc.) for implementation support now	
Explore Development Agencies for implementation support now	
Look for teaming up with Civil Society partners now	
Look to convince an individual with dedication and willingness to take the case!	
Other	

The response of the mini survey is given below.



The tendencies from the external participants is to look for involvement of social scientist and teaming up with industry and civil society partners. The participants are more evenly spread out, but do also point to collaboration and also to exploration of funding options.

## Appendix Curriculum of MSc. in Renewable Energy at UDSM

The MSc. REN has been offered as an 18-month full - time (regular mode) programme. However, after 16 years of running the programme, several drawbacks were observed, which necessitated a major review of the programme curriculum. Among the major deficiencies observed in the curriculum is the fact that it did not provide sufficient advance/specialized knowledge and skills in all the potential renewable energy sources and technologies available in Tanzania and elsewhere in the world. The design of the curriculum also did not provide efficient use of resources, especially considering the relatively low number of students enrolled in the programme and the many specialisations that were offered. Another weakness of the programme is that it lacked engineering rigour as it was designed to include applicants with non-engineering backgrounds.

The curriculum review process, which was implemented between November 2022 and January 2024, started with a consultation process and involved a tracer study, SWOT analysis and stakeholders' validation workshops. The target of the tracer study was gathering of stakeholders' evaluation on adequacy and appropriateness of imparted knowledge, developed skills and attitudes enhancement. It was conducted utilizing online and field data collection methods and involving graduates and employers. The data collection was followed by data analysis, preparation of a report and stakeholders validation Workshop. The College of Engineering and Technology (CoET) organized a validation workshop for the tracer study finding, for external and internal stakeholders, which was held on Saturday, 24<sup>th</sup> June 2023. The Workshop was organized in two sessions; a plenary session for all CoET internal and external stakeholders, and departmental breakaway sessions for each department to discuss their report with their specific internal and external stakeholders. Both sessions discussed the report in details, and recommended it with specific recommendations.

The Self-Assessment / SWOT Analysis involved self-reflection of programme by internal stakeholders (academic staff, technical staff and students). The objective of the analysis was to compliment information provided by tracer study report towards informed curriculum review. It was carried out through desk analysis at the campus. The SWOT matrix was designed based on Inter-University Council of East Africa (IUCEA) Handbook for QA in Higher Education - Guidelines for Internal and External Programme Assessment, Section 4: Programme Assessment Tool. The exercise was conducted in July 2023.

Teams of experts related to the courses being offered under the programme embark on the painstaking task of reviewing the programme curriculum, including all the courses that would be offered under the programme. Through a series of working many sessions involving experts from other related fields, the team came up with a draft curriculum document that is in line with the TCU Curriculum Development Framework of November 2021. The draft curriculum was submitted to Stakeholders Validation Workshop for Curriculum Review. This Validation Workshop on Curriculum Review for CoET was held on Saturday, 2<sup>nd</sup> December 2023. It was organized in the same manner as the one for the tracer study.

The employment status of graduates in the period of 0-6 months to 6 years and above after graduation show that graduate of MSc. REN perform best as shown in **Feil! Fant ikke referansekinden.** shows the details.

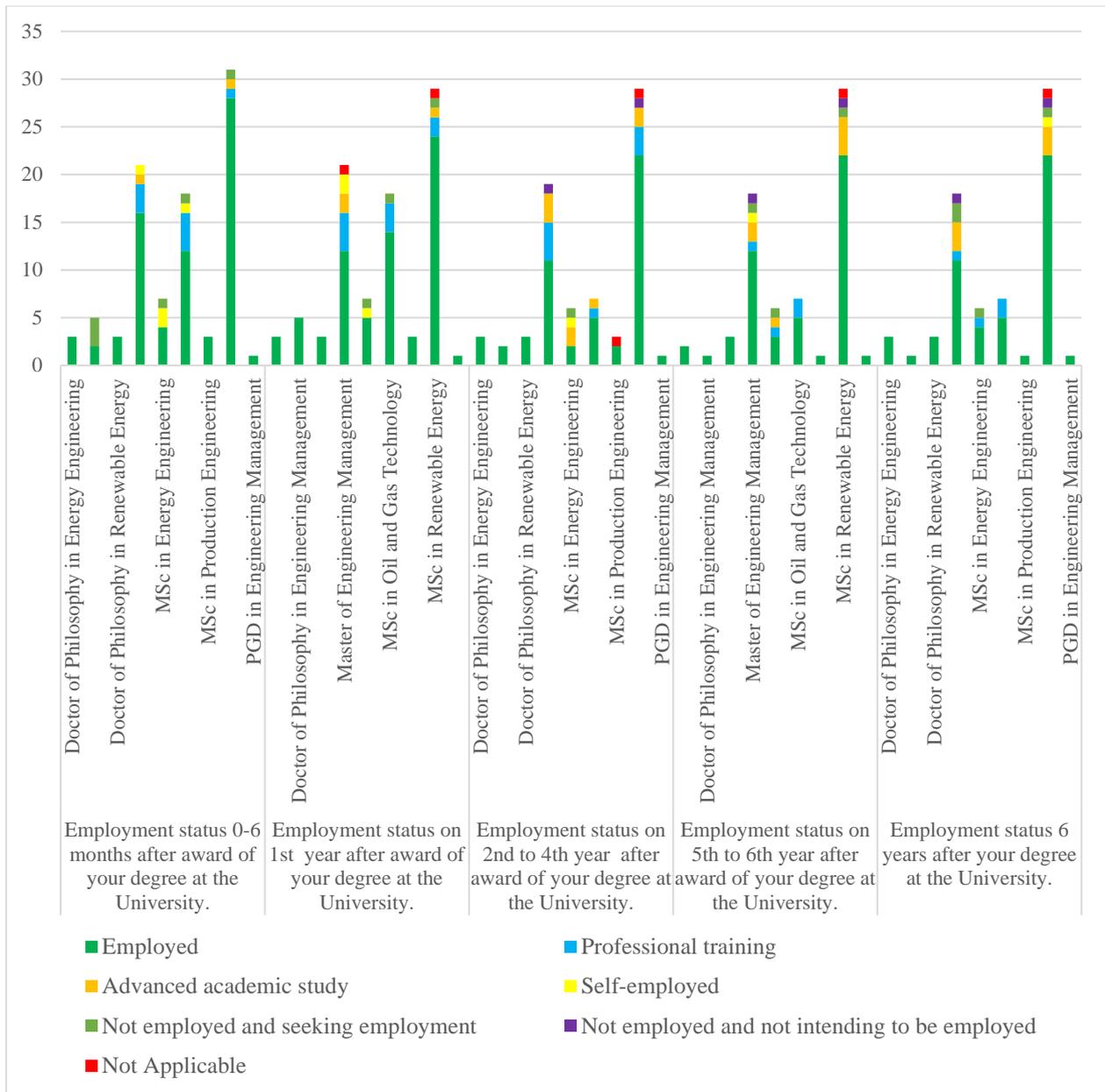


Figure 1: Employment Status after Graduation for Postgraduate Respondents

Figure 2 shows the Relevancy of Education to the Occupation for Postgraduate, whereby the MSc. REN programme also performs well.

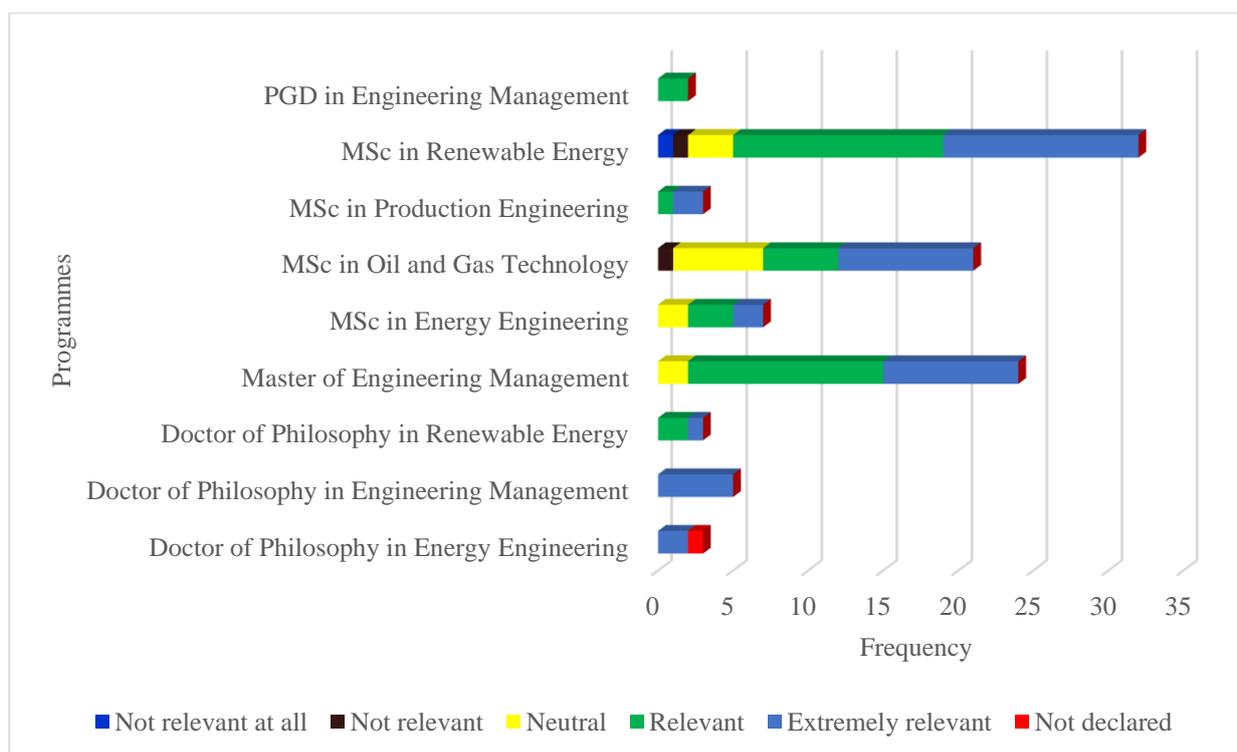


Figure 2: Relevance of Education to the Occupation for Postgraduate Programmes

Table: Comparison Matrix for Old and Reviewed Curriculum

<i>Existing/Old Courses</i>		<i>Revised/New Courses</i>	
<i>Course Title</i>	<i>Core/ Elective</i>	<i>Course Title</i>	<i>Core/ Elective</i>
Statistics and Research Methods	Core	Research Proposal Formulation	Elective
Bioenergy	Core	Bioenergy	Core
Solar Energy	Core	Solar Thermal Energy	Core
Hydropower	Core	Hydropower	Core
Mathematical Methods	Core	Applied Mathematics in Energy Engineering	Elective
Energy Policy and Planning	Elective	Energy Policy and Economics	Elective
Computational Fluid Dynamics	Elective	Experimental and Computational Methods for Engineers	Core
Project Management	Elective	Engineering Project Management	Elective
Entrepreneurship Development	Elective		
Electrical Energy Systems	Core		
		Thermal Turbo - Machinery and Internal Combustion Engines	Core
		<u>Environmental Management and Climate Change</u>	Elective
Other Forms of Renewable Energy	Elective	Wind Energy	Core
		Geothermal Energy	Core
		Ocean Energy	Core
Thermo-Chemical Conversion Processes	Core	Bioenergy	Core
Biochemical Conversion Processes	Core		
Design and Modelling of Thermal Power Systems	Core	Design and Modelling of Energy Systems	Elective

<i>Existing/Old Courses</i>		<i>Revised/New Courses</i>	
<i>Course Tittle</i>	<i>Core/ Elective</i>	<i>Course Tittle</i>	<i>Core/ Elective</i>
Hydropower Mechanical Equipment	Elective	Thermal Turbo - Machinery and Internal Combustion Engines	Core
Solar Thermal Technology	Elective	Solar Thermal Energy	Core
Hydropower Electrical Machines	Elective	Hydropower	Core
Hydraulic Structures in Hydropower	Core		
Development of Small Hydropower	Elective		
Solar Cell Technology	Elective	Solar Photovoltaics	Core
Electrical Energy Conversion in PV Systems	Elective		
Sustainable Building	Elective	Energy Efficiency and Management in Buildings	Elective
Thermal Comfort in Buildings	Elective		
Lighting in Buildings	Elective		
Smart Grid Technologies	Elective	Mini and Smart Grid Technologies	Elective
Renewable Energy Hybrid Systems	Elective		
Energy Storage Systems	Elective		
Renewable Energy Pricing and Financing	Elective		
		Occupational Health and Safety Engineering	Elective
Dissertation	Core	Dissertation	Core
		Selected Topics in Energy Engineering	Core

Currently, the curriculum has been approved at the department and College level and has been submitted to University level for further processing and approval by the Senate, before submitting it to TCU for accreditation. It is expected that the revised curriculum would be ready for implementation by the beginning of the 2024/25 academic year.

## Appendix First Photovoltaic training at University of Juba



**University of Juba**  
**School of Applied & Industrial Sciences**  
**Department of Physics**

**First Photovoltaic training conducted in the University of Juba with the support from NORHED II - ENET**

**Executive summary Report on Photovoltaic training conducted in the University of Juba-South Sudan**

Name of the Project	Photovoltaic Training
Duration of the Training	Jan. 29 <sup>th</sup> - 31 <sup>st</sup> , 2024
Funding agency	NORHEDII-Energy Technology Network
Objective for the training	<ul style="list-style-type: none"> <li>i. To introduce solar energy basics and photovoltaic system components.</li> <li>ii. To equip the participants with design and installation practices of photovoltaics. System</li> <li>iii. To impart safety skills in the management of the solar panels</li> </ul>
Training Location	STEM Center, University of Juba South Sudan.
Target Group	Staff & Students from the Department of Physics, University of Juba South Sudan. 45 Males 5 Females
Institution	University of Juba (Host) Mr. Konjo Francis Pote (ENET Project Coordinator) Tel: +211926591456/ +211918666400 Email: konjofrancis81@gmail.com
Partners	Makerere University (Partner) 1-Mr. Micheal Musoke Mob: +256706921069 Email: <a href="mailto:musokem@yahoo.com">musokem@yahoo.com</a> 2-Aguminetwe Adons Mob: +256700780484 Email: agumenitweadons@gmail.com

This report was made to detail the results of the Photovoltaic technical training conducted by E-NET in the department of Physics, School of Applied and Industrial Sciences. It was a 3-day session that started on January 29<sup>th</sup> - 31<sup>st</sup>, 2024. Photovoltaic training included education on solar energy and photovoltaic systems. This training typically includes understanding solar energy basics, learning about PV system components, design and installation practices. The purpose of training was to give the students and the staff in the department of Physics and School of Applied and Industrial Sciences a foundation for careers in design, installation, maintenance, and management of Photovoltaic Systems which will give them a chance to contribute to the global transition toward cleaner and more sustainable energy solutions.

### Scope:

The training basically concentrated on solar energy basics, Photovoltaics System Components, Design and Installation of Photovoltaic System

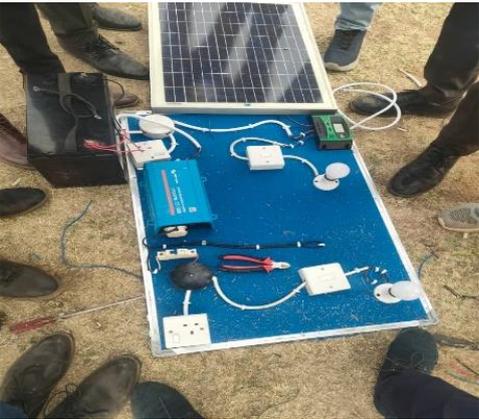
### Methodology:

- a) The training was delivered in two ways that is, through oral presentations detailing the theoretical background of solar energy and PV system components.
- b) The presentations were accompanied with hands-on activities by the participants with the support of Facilitators.

**Training programs and skills acquired:**

The training started with opening remarks from Dean school of applied and industrial sciences who officiated the commencement of the training.

Day one	Responsible	Activities	Skills acquired and comments
	University of Juba	Welcoming remarks	 <p>Official Opening by the Dean School of Applied Industrial Sciences-University of Juba</p>
	Makerere University	Introduction to Basic Electronics  Use of digital multimeters and other tools <ul style="list-style-type: none"> <li>• Continuity measurements</li> <li>• Electrical parameters such as voltage, current, power etc.</li> <li>• Connection of the switch in an electrical system</li> <li>• Measurement of the semiconductor diode being a key component in PV module</li> </ul>	
<b>Day 2</b>	Makerere University	<ul style="list-style-type: none"> <li>• PV system planning and sizing</li> <li>• Installation of DC and AC PV systems</li> </ul>	

<p>Day Three</p>	<p>Participants</p>	<ul style="list-style-type: none"><li>• demonstrating and explaining the skills they acquired throughout the course of the training.</li></ul>	 <p>Participants Connected Solar PV System</p>   <p>Participants reporting on what they learn</p>
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<p>Use of electrical equipment and connection of PV system</p>		<p>Equipment were bought using Enet Fund. Some of the equipment were taken from Makerere University. Provided in the tool box are equipment such as,</p> <ul style="list-style-type: none"> <li>• PV modules (commonly known as solar panels)</li> <li>• Charge controllers</li> <li>• Batteries</li> <li>• Inverters</li> </ul>	 <p>Trainers from Makerere demonstrating how to connect PV components</p>
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We thank the NORHEDII who provided the fund under the ENET project. It is the first training on Photovoltaic ever done in the University of Juba-South Sudan. It provided the basic skills students wanted in this modern time. One of the students in the Department of Physics said;

*This is a great opportunity for me. It is the first time in my life I ever had hand-on training. Will you please coordinator do this training again?*

In his closing remarks the Dean stressed the need for continuity of the training to the secondary schools. It was noted that the gender participation was very low. There is n need to include more gender in the PV training.

**Group photos:**



**Participants taking notes of basics electrical theory :**



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