UDSM-NTNU MOBILITY PROGRAM IN ENERGY TECHNOLOGY

NORPART project 2018/10001

Coordinators:
Ole Jørgen Nydal, NTNU
Joseph Kihedu, UDSM

UDSM-NTNU Mobility Program in Energy Technology is a project in the NORPART program for exchange of staff and students between University of Dar es Salaam in Tanzania (UDSM) and Norwegian University of Science and Technology in Norway (NTNU). MSc programs in both the areas of Renewable Energy and Oil and Gas Technology have been established at UDSM as part of a long term collaboration in NORAD funded programs. The NORPART mobility project supports this collaboration, with emphasis on MSc student exchange.

The following is a report which accumulates the activities and results of the project as it proceeds during the 5 year project period.

The NORPART program (Norwegian Partnership Programme for Global Academic Cooperation) is funded by the Ministry of Education and Research and the Ministry of Foreign Affairs in Norway. The program is managed by HKD (Norwegian Directorate for Higher Education and Skills, previous DIKU Norwegian Agency for International Cooperation and Quality Enhancement in Higher Education).

Contents

1 Summary

Background
A long term collaboration between the University of Dar es Salaam (UDSM) and the Norwegian University of Science and Technology (NTNU) has resulted in two master programs at UDSM within Energy Technology. One is within Renewable Energy (from the NOMA program) and the other within Oil and Gas Technology (from the EnPe program). The NORPART mobility project has supported these new master programs with mutual exchange of both students and staff.

Objectives
The objectives of the collaboration are to strengthen the quality and sustainability of master programs at UDSM and at NTNU within the field of Energy Technology. Focus has been on the research part of the master programs and the core element has been a mutual mobility scheme for students and supervisors.

Results
NTNU professors from 4 departments and UDSM professors from 2 departments have participated in the program by joint supervision of MSc/PhD research projects. These are dedicated staff members who have also been supportive during the startup of the master programs at UDSM.
27 UDSM MSc students and 3 PhDs have had visiting periods at NTNU, and 23 NTNU students have visited UDSM.

Industry partners have contributed primarily on the oil and gas side, with direct supervision support, hosting short term visits, excursions to industrial sites and laboratories and provisions of software licenses.

The capacity for research training has been supported at UDSM by shipment of laboratory training equipment, notably for multiphase pipe flows and solar thermal systems. The NORPART project has had good synergies through coordination with a parallel Erasmus+ capacity building project and a parallel and NORHEDII project, both including a group of African universities

2 Participants and contacts

UDSM and NTNU participants

The project participants come from 4 departments at NTNU and 2 departments at UDSM.

Table 1 Project participants

Name	E-mail	Department
Nydal, Ole Jorgen Project coordinator	Ole.J.Nydal@ntnu.no	NTNU Energy and Process Engineering
Kihedu, Joseph Project coordinator, UDSM	kihedu@udsm.ac.tz	UDSM Mech and Industrial Engineering
Kimambo, Cuthbert	kimambo@udsm.ac.tz	UDSM Mech and Industrial Engineering
Nielsen, Torbjorn	Torbjorn.K.Nielsen@ntnu.no	NTNU Energy and Process Engineering
Solbraa, Solbraa	Even.Solbraa@ntnu.no	NTNU and Equinor Energy and Process Engineering
Jasche, Johannes	johannes.jaschke@ntnu.no	NTNU Chemical Engineering
Johnsen, Roy	roy.johnsen@ntnu.no	NTNU Mech and Industrial Engineering
Stanko, Milan	milan.stanko@ntnu.no	NTNU Geoscience and Petroleum
Abraham Temu	atemu8@yahoo.co.uk	UDSM Chemical and Mining Engineering
Trygve Eikevik	trygve.m.eikevik@ntnu.no	NTNU Energy and Process Engineering

Industry links

The industry links serve as advisory support for the project as well as links for the exchange students. The list of companies has grown since the initiation of the project. Contact persons are:

Table 2 Stakeholders

Name	Company
Naomi Norah Makota	Equinor Tanzania
Furu, Mari Sofie Brelin	Multiconsult Tanzania
Michael Steinfeld	NVE Norway
Norbert Hoyer	Schlumberger Oslo
Dr. James Mataragio	Tanzania Petroleum Development Corporation (TPDC)
Dr.Tito E. Mwinuka	Tanzania Electrical Supply Company Limited (TANESCO)
Eng. Matthew J. Matimbwi	Tanzania Renewable Energy Association (TAREA)
Ms. Getrude Mpangile	TotalEnergies Tanzania

3 -Mobility and joint research projects

The following gives a list of the exchange students, short reports are provided as Attachments.

3.1 Students from NTNU to UDSM

Some travels from NTNU to UDSM were cancelled (2021-2022), following the governmental travel advice during the pandemics. The 2020 student group returned to Norway just before the travel restrictions came into effect. The student exchange from NTNU took up again in 2023 and continued with the two last students in early 2025.

Table 3 Students from NTNU to UDSM

Year	Name		Title	Supervisors
2019	Kolderup	Marie	Prototype heat storage for cooking	O J Nydal
2019	Gustavson	Kaja	Prototype heat storage for cooking	O J Nydal
2019	Thaule	Sigurd	Prototype heat storage for cooking	O J Nydal
2020	Anwar	Rinaldi	Multiphase Flow Modeling: Severe Slugging	O J Nydal
2020	Skjærpe	Mari	Multiphase flow and fluid models for a wet gas subsea pipeline	O J Nydal / Even Solbraa / Henning Holm (Equinor)
2020	Brude	Henrik	Multiphase flow and fluid models for a wet gas subsea pipeline	O J Nydal / Even Solbraa / Henning Holm (Equinor)
2020	Fjeldsæter	Oda Kristine	Heat storage for cooking	O J Nydal
2020	Stordal	Vilde Svanevik	Heat storage for cooking	O J Nydal
2020	Lyimo	Susan	Multiphase Flow Experiments on Surge Waves	O J Nydal / Milan Stanko
2020	Mikal	Rekdal	Optimization of renewable Energy Storage	Johannes Jasche
2020	Guro	Samnøy	Predicitions of gas compositions offshore, Neqsim.	Even Solbraa
2021	Gunn Helen	Nylund	Sensible Heat Storage for Cooking Single Tank System	Travel cancelled-Covid
2021	Andreas Bjørshol	Andreas Bjørshol	Sensible Heat Storage for Cooking Single Tank System	Travel cancelled-Covid
2021	Martin Systad	Geiran	Experiments with a latent heat storage for frying	Travel cancelled-Covid
2022	Berg	Kristina	Small scale PV to cooking heat	Travel cancelled-Covid
2022	Austjord Vik	Andrea	Small scale PV to cooking heat	Travel cancelled-Covid
2022	Peter Olsen	Alexander	Cooking on a heat storage	Travel cancelled-Covid
2022	Ginste	Joakim	Frying on a heat storage	Travel cancelled-Covid
2023	Egerdahl	Martin August	Testing of controllers for PV2Heat	O J Nydal
2023	Mjåtveit	Torbjørn	Small scale wind power to heat storage	O J Nydal /Mulu Bayray
2023	Finsås	Henrik Lund	Small scale wind power to heat storage	O J Nydal /Mulu Bayray
2023	Tømterud	Marte Maria	Heat storage for off-grid hytte	O J Nydal /Mulu Bayray
2023	Jørs	Andreas Grodås	Cold storage for an adsorption-based refrigeration cycle in Africa	Trygve Eikevik
2024	Torsvik	Olav	Small scale wind power to heat Optimizing power output by implementing load switching	O J Nydal
2024	Skogen	Une	Performance evaluation of Photo Voltaic clean cooker with oil based	O J Nydal

			heat storage	
2024	Enes	Eli	Performance evaluation of Photo Voltaic clean cooker with oil based heat storage	O J Nydal
2024	Riskild	Elias Kolle	Solar-based adsorption refrigeration systems for subzero cold storage	Trygve Eikevik / O J Nydal
2024	Ongstad	Ingvild Høilo	Solar-based adsorption refrigeration systems for subzero cold storage	Trygve Eikevik / O J Nydal
2025	Torvanger	Mina Andrea	Optimization of Adsorption Refrigeration Systems for Sustainable Cooling in Sunny Areas	Trygve Eikevik / O J Nydal
2025	Ida Fredrikke	Harsem	Optimization of Adsorption Refrigeration Systems for Sustainable Cooling in Sunny Areas	Trygve Eikevik / O J Nydal

The total number of NTNU students signing up to the mobility program was 30, of which, of which 7 cancelled the travels due to the pandemic.

3.2 Students from UDSM to NTNU

The visiting students to NTNU follow the NTNU standards for exchange students with two registrations each year (1 April and 1 August) and the student come and leave as a group. The mobility period is normally during the spring semester, which is normally the semester for the master thesis work at NTNU. A cohort of UDSM students planned for the autumn of 2020 were shifted to the spring 2021, and then again further delayed until the autumn 2021, due to the Covid19 travel limitation. The spring cohort of 2020 had to stay longer in Norway than planned, due to the outbreak of the pandemic and the following travel restrictions.

The project was awarded a full time MSc scholarship at NTNU for a UDSM student (Diku call for proposals). The recruitment process was made at UDSM, and a student was enrolled and completed in the International Master Program on Sustainable Energy at NTNU.

Student exchange group and supervisors in the EPT laboratories, spring 2020.

Weekly meetings. 2023.

Table 4 Students from UDSM to NTNU

2019	Gonzaga	G Wilfred	Experimental Investigation on Performance of Oil Based Solar Thermal System	C. Kimambo, J. Kihedu OJ Nydal
2019	Kusaja,	Doctor Jeremiah	Improvement of Laboratory Scale Multiphase Flow Demonstration Loop	C. Kimambo, J. Kihedu OJ Nydal
2019	Kyambile	Joshua Winfred	Assessment of Oil and Gas Training and Research Capacity of High Learning Institutions for Eastern and Southern Africa	C. Kimambo, J. Kihedu
2019	Malavanu	Libalata Sihama	Investigation of Fluid Dynamics in Natural Gas Pipeline Network during Line-break	C. Kimambo, J. Kihedu OJ Nydal
2020	Enock	Wilfred	Evaluation of Finger type Slug Cathcer Modelling Technique for Subsea to Shore Tieback	Michel Golan/Milan Stanko
2020	Mbuva	M.A Nchula	Wax Control for Oil and Gas Production with Integrated Production of Wax Inhibitor	Even Solbraa
2020	Dorothy	Ferdinand Komba	Corrosion properties of different Al-alloys exposed to seawater	Roy Johnsen
2020	Kaindi	Mandilindi	Prediction of the Remaining Useful Life of Oil and Gas Subsea Components (Choke valve in gas lift system)	Johannes Jaschke
2020	Geofrey	Mnkeni	Experimental investigaton on performance of oil heating system using micro hydroelectric dump load	T. Nielsen / O J Nydal
2020	Godwin	Nsema	Surge waves in gas-condensate pipelines	OJ Nydal
2020	Theresia	Herman Cyril	Development of energy pricing structure for deregulated solar PV mini grid projects in Tanzania	-- maternity limited--
2020 (PhD)	Joel	Mbewiga	Optimization of wind turbines at low wind speeds	T Nielsen
2021	Emmanuel John	Wangwe	Process technology enhanced glycol regeneration methods in TEG natural gas dehydration units	Even Solbraa, Abraham Temu
2021	Lucian,	Chrisostom	Separation / multiphase flow evolution of the oil droplet distribution	Milan Stanko Joseph Kihedu
2021	Athumani Yasini	Sizya	Optimization of gas lift	Johannes Jasche, Joseph Kihedu
2021	Emmanuel	Mposolo	Full time NTNU master scholarship	
2022	Mkacha	Rashid	Numerical and experimental work on parallel pipe bulk oil-water separator	Milan Stanko Joseph Kihedu
2022	Mkufu	Shaban Tindi	Wind Power for Charging Solar Salt Heat Battery	Torbjorn Nielsen / Ole Jorgen Nydal Joseph Kihedu
2022	Msolo	Piniel	Simulation of gas transport pipelines with liquid glycol phase	Even Solbraa Abraham Temu
2022	Michael	Sangiwa	Dynamic simulation of small scale laboratory experiments on gas lift optimization	Johannes Jäschke Joseph Kihedu
2022	Tshimuanga	Kabongo Leon	Testing of a controller for Photo Voltaic panels connected to a heating element	Ole Jorgen Nydal Joseph Kihedu
2022	Privatus	Pius	Challenges on the transition to electric vehicles in Tanzania	Ole Jorgen Nydal Joseph Kihedu
2023	Lema	Brayson Ezra	Multiphase Pump	Milan Stanko
2023	Mayanjo	Seleman Ally	Wind to Heat	OJ Nydal / Mulu Bayray

2023	Kapwani	Mary Paul	Cathodic Protection	Roy Johnson
2023	Muhogolo	Neema Wilfred	Adsoption refrigeration system	Trygve Eikevik
2023 (PhD)	Mwasubila	Ibrahim Joseph	Adsoption refrigeration system	Trygve Eikevik
2023 (PhD)	Sharishoy	Annatumaini Kisioki	Solar thermal heat storage	OJ Nydal
2024	Nyandoro	Samwel Stephen	Experimental study on the variation of water-air volume fraction along a converging nozzle	Minal Stanko
2024	Mwakasege	Frank Raphael	Safe operation window for stainless steel in seawater	Roy Johnsen

The total number of mobilities have been 26 master students, one full time student and 3 PhDs.

3.3 Other

The intention is that supervisors from UDSM visit NTNU during the period of stay for UDSM students at NTNU. This has not always been possible due to travel limitations during the pandemic.

An inspiring event was also the visit to UDSM in 2019 by the DVC for Research at NTNU (Prof. Bjarne Foss) together with a senior advisor for external collaboration at NTNU.

Picture:
Visit of DVC Research NTNU Bjarne Foss, to UDSM, May 2019. Reception on at the Norwegian Embassy in Dar es Salaam.
(Photo Patrick Reurink)

The NORPART program is managed by DIKU (now HKD), on behalf of Norad. Diku ((Hilde Granås Kjøstvedt) visited UDSM during 2020.

Picture:
Diku (Hilde Granås Kjøstvedt) visit in 2020 to UDSM, Dar es Salaam.

Prof. Cuthbert Kimambo has been registered as a visiting professor at NTNU for the duration of the Norpart project period. The intention is that prof. Kimambo shall also serve to promote extended collaboration and communication between the universities.

	Picture: Social gathering with colleagues from NTNU (ANTHEI project) , UDSM and Equinor during a visit by Prof. Cuthbert Kimambo and Dr. Joseph Kihedu.

Our project was given presentation time at the NORPART seminar in Oslo, September 2022.

	Picture: Dr. Joseph Kihedu in panel discussion at the NORPART seminar in Oslo, September 2022..

4 Improved quality of educational programs

Improvements related to the educational programs are noted both on the course parts and the research parts.

4.1 Courses

A course on Multiphase Transport is similar between UDSM and NTNU, and was introduced at UDSM as part of the curriculum of a new master program at UDSM through the EnPe program (OGaT project in the Energy and Petroleum Norad program). Equinor have contributed with guest lectures for the Multiphase Transport course at NTNU, and 7 of these have been recorded and forwarded for presentations at UDSM as well.
Other courses from the OGaT project have also been recorded for further use in the NORPART framework.

- One NTNU master student completed programming of a demonstration simulator for large scale flow instabilities in oil-gas pipelines. The python implementation was presented at UDSM and will be of use in the multiphase transport courses.
- An NTNU student completed implementation of a dynamic model for a solar thermal system which is tested in the laboratory. The model has been presented at UDSM and can in the further be a useful tool for students in the area of thermal energy storage.
- A Ray Tracer has been developed at NTNU as part of the research on solar concentrating systems. The Ray Tracer was also used by a Tanzanian PhD researcher at NTNU, and has been forwarded to UDSM as a tool which can be used in solar energy courses.

4.2 Training facilities

Multiphase flow in pipes
A small scale flow loop for multiphase flow in pipes was installed at UDSM during the EnPe project, as part of a master student work at NTNU. A UDSM student developed the loop further with new instrumentation (pressure and flow measurements) and data logging, as part of his NORPART exchange stay at NTNU. The purpose of the loop is to demonstrate gas-liquid flow phenomena, which occurs in transport pipelines of oil-gas mixtures from subsea wells to shore.

Picture:
Small scale demonstration loop for two-phase flows at UDSM

Pump as Turbine
A setup for demonstration of Pumps as Turbine has been constructed at NTNU. A UDSM master student worked alongside a NTNU student on the experimental setup for in the hydropower laboratory at NTNU. The work had to be reduced as laboratory access became Covid19 limited. The system has been shipped to UDSM for further use there. The objective is to demonstrate that pumps can be used as generators in small scale hydropower systems.


Picture:
Small scale pump as turbine experimental setup at NNTU, which has been shipped to UDSM

Heat collection and storage

Development of heat storage solutions for cooking has been a research area at NTNU and partners for some time. Student exchange contributes to progress in this research area, one UDSM student also made a test for conversion of water heater to high temperature oil heater for cooking purposes.

Picture:
Water heater converted to oil heater for high temperature heat storage. UDSM (Gonzaga Wilfred)

Battery less refrigeration system

Development of refrigeration solutions without electric power or batteries has been a common research area at NTNU and UDSM. A concept which is being tested can be combined with the work on heat storage, and is suitable as a basis for exchange of NORPART students.

Picture:
Adsorption based refrigeration cycle test setup.
UDSM

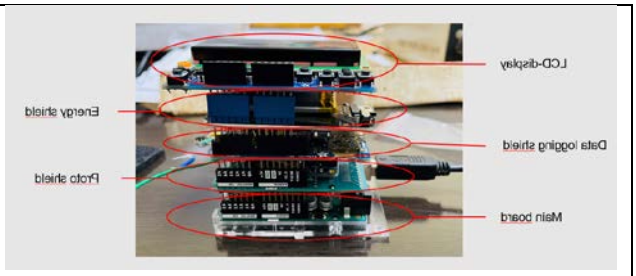
Wind power to heat

Wind power to heat was included as research area for master students in 2023. Small scale wind turbines can provide power for a heat storage directly, or indirectly as excess power in a battery system. The heat storage can be a high temperature storage for cooking. Challenges are related to the controllers for stand-alone wind-to-heat solutions. Similar facilities can be for future implementations at UDSM.

	Picture: Setup for testing of wind generator at NTNU.

Instrumentation for training facilities

Several students obtain experiences using different types of scientific instrumentation during periods at NTNU (PASCO systems, Arduinos, PV controllers). Some of these are implemented also at UDSM. Arduino based systems can in particular be useful for UDSM, as the systems are low cost and open for development by the students themselves.

	
PASCO instrumentation system at UDSM	Arduino temperature logger

Equipment for research training

Equipment was acquired at NTNU and shipped to UDSM. This included components, tools and instrumentation mainly for solar thermal research. This will be very useful for further master students at UDSM who will work on both solar heating and cooling. A test setup for solar refrigeration at NTNU was dismantled and added to the shipment as well.

	
Shipment of equipment for research training	Shipment also includes setup for solar refrigeration

5 Industry relations

The intention is that both NORPART exchange students and supervisors should be exposed to relevant industry partners in Tanzania and Norway.

Industry visits in Tanzania
During the time when NTNU students were at UDSM in 2020, excursions were organized (4 days) to visit gas processing and transport sites in the southern parts of Tanzania (Mtwara):

- Kinyerezi Receiving Terminal,
- Dangote Cement station,
- Mtwara Gas Plant,
- Tanesco Power Grid,
- TPDC Natural gas processing plant, Maurel & Prom receiving station
- SomangaFungu gas receiving facility.

The NTNU students have also appreciated meetings with Equinor in their offices in Dar es Salaam and with the Norwegian Embassy.

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<td>Pictures:
group of NTNU students visiting UDSM, spring 2020. Field visit to Mtwara Gas Plant.
Visit to Norwegian Embassy</td>
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Stakeholder meetings
Meetings with stakeholders have been arranged, where the student projects are presented and the program status reviewed.

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<td>Stakeholder meetings at UDSM in 2020</td>
<td>Visit to Kikuletwa Renewable Energy Centre in 2023</td>
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<td>Stakeholder meetings at UDSM in 2022</td>
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The stakeholder meetings have been hosted by UDSM. The 2022 meeting was chaired by the DVC for Research at UDSM and with contributions from Equinor, Gasco, Tarea, TPDC, Totalenergies and the group of UDSM and NTNU students and the involved supervisors. The meting in 2023 was in Arusha, at Arusha Technical College, and included a visit to Kikuletwa Renewable Energy Centre,

Industry support

Equinor experts have participated in defining master thesis topics and provided support during the thesis work of 2 NTNU students and 1 UDSM related to the gas-condensate pipelines planned from the gas field offhore Tanzania.

Equinor has consistently invited students for a briefings and laboratory tours at their Research Centre in Trondheim.

Schlumberger and Kongsberg provide academic licenses of commercial multiphase flow simulators to NTNU and UDSM students. Visits to their offices were made in 2019 when Schlumberger hosted students (2 NTNU and 2 UDSM) for training in computer simulators. The continued support on software issues was very useful for the students.

<table>
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<td rowspan="2">Pictures: UDSM students visiting Equinor and receiving training support at Schlumberger , Oslo.</td>
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<tr>
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<td>Visit to Equinor in Trondheim, 2023, with introduction to the development of the gas field offshore Tanzania.</td>
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Industry visits in Norway

One objective of the staff visit from UDSM to NTNU in 2019 was also to visit educational and industrial laboratories in Norway. One of the master students is preparing a base study as a background for a strategic evaluation of future laboratory facilities at UDSM. A visit to several laboratories in Norway was then very useful.

The visits to Norwegian laboratories have included:

- SINTEF Multiphase Flow Laboratory, Tiller
- Equinor Research Center, Rotvoll
- Institute for Energy Technology-IFE, Kjeller
- University of Oslo, Fluid mechanics laboratory
- Equinor Research Center, Porsgrunn and University of South East Norway
- Norwegian Research Centre Stavanger-NORCE
- NTNU Corrosion Laboratory (Mechanical and industrial Engineering)
- NTNU Petroleum Laboratory (Geophysics and Petroleum)
- NTNU Multiphase Flow Laboratory (Energy and Process Engineering)
- NTNU Hydropower Laboratory (Energy and Process Engineering)
- NTNU Process Control Laboratory (Chemical Engineering
- The NORPART students also joined a one day student excursion for NTNU students to Tjeldbergodden Methanol Plant, which is the largest of its kind in Europe.

6 Synergies with other projects

The NORPART project is linked with two other parallel projects:

- "**Energy Technology Network, ENET" 2021-2026**
  Education and research on small scale renewable energy systems.
  NORHEDII Program (https://www.norad.no/en/front/funding/norhed/)

- **"University Network on PhD Programmes in Energy Technology, UNET" 2021-2023**
  Development of PhD Curriculum and improving Training Facilities
  https://www.ntnu.edu/uneterasmus/
  Erasmus+ Capacity Building program

The projects cover the following partner universities

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

The synergies for NORPART students are:

- Exposure to researchers from a large group of African universities, through participation in project events
  The UNET and ENET projects organize joint events, where students can take part.
- Relevant research tasks
  The research tasks defined for the master students in the NORPART project are in line with the research aims of the ENET group, with participation of about 10 PhD researchers.
- Awareness of global energy challenges
  "Energy Technology" is the framework for the NORPART project, and the NORPART students are exposed to the challenges in both the African and European context.

Pictures: NORPART students participate in UNET/ENET Workshop May 2022, NTNU

7 Impact of the pandemics

The Covid19 has affected the mobility project in the following ways:

NTNU students to UDSM

The NTNU students returned to Norway in 2020 just in time before close down. They had to spend 14 days in quarantine but were not stranded in Tanzania.
Students planned on visiting UDSM in both 2021 and 2022. Travel arrangements were made but the plans were aborted after evaluation of the situation close to the time of traveling. The final student exchange form UDSM was in the spring of 2023.

UDSM students to NTNU

UDSM students arrived to NTNU before close down in 2020. After close down they were not permitted to NTNU campus until late in the spring semester. For the laboratory based students, we then had to put more emphasis on simulation and theoretical work. Such changes in priorities were not easy to implement in all cases. Some students were eventually allowed back to the laboratories and could achieve some results before the term ended. The period of the students had to be extended, due to airlines not operating. The students could returne mid July 2020.
The exchange cohort for the autumn 2020 was shifted to the spring 2021, and then further on to the autumn 2021.

Staff mobility

Planned staff exchanges were cancelled in both 2020 and 2021.

Industrial interaction in Norway

Similar industrial visits as in 2019 was not possible in 2020 or in 2021. The yearly stakeholder meeting in Tanzania was canceled in 2021.

Joint teaching and supervision

The UDSM students coming to NTNU had their supervisors and work places at several different NTNU departments. All NTNU and UDSM students joined for weekly progress meetings. After shut down of NTNU, the communication and the meetings were made on-line, with establishment of a MS TEAMS for the group. Face-to-face is definitely preferable for exchange students coming to a new place, but the on-line option served as an alternative. The positive aspect of on-line meeting is that it is easier to involve persons at a distance in a regular way (e.g. supervisors at UDSM could participate in the NTNU progress meetings). This is an option which will also be explored in the future, with combined face-to-face and on-line meetings.

8 Attachments: Student reports

Project Report

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Name: **Kusaja, Doctor Jeremiah**

Home Department and supervisor: Department of Mechanical and Industrial Engineering
Prof. C.Z. Kimambo and Dr. J. Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. O.J. Nydal
Period: Autumn 2019

Title: Improvement of Laboratory Scale Multiphase Flow Demonstration Loop

Summary

A mini-loop for two phase flow in pipes has been installed at UDSM. The main purpose of the loop is to support lectures in two phase flows. However, with extended instrumentation, the loop can also be usde for small student projects.
The purpose of the exchange visit to NTNU is to 1) review instrumentation options for flow and pressure measurements and 2) acquire components and install at UDSM upon return.

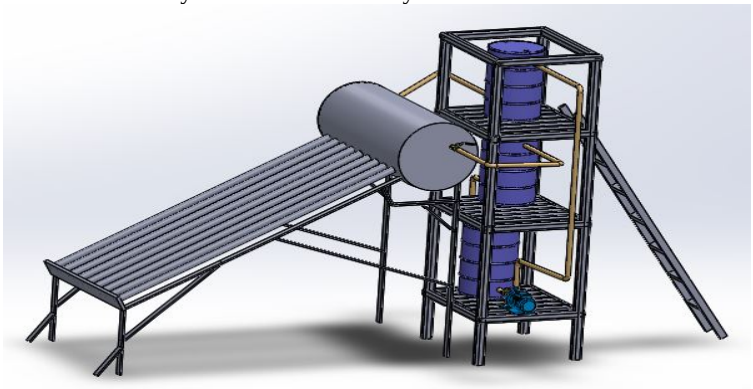
The PASCO system was selected. Flow and pressure sensors, with remote data logging, were acquired and successfully tested at UDSM on return after the NTNU period.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Gonzaga G Wilfred
Home Department and supervisor: Department of Mechanical and Industrial Engineering Prof. C.Z. Kimambo and Dr. J. Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. O.J. Nydal
Period: 4 months

Title: Experimental Investigation on Performance of Oil Based Solar Thermal System.

Summary: The visit to NTNU covered both school undertakings and study visits outside the campus. In school undertakings, some tasks were assigned individually and some were performed in groups. Individually I was assigned to have an engineering drawing using Solid Work software for the solar thermal system that I used for my dissertation at UDSM as shown in the Figure below.



I had the opportunity to have laboratory visits to familiarize with the ongoing projects that were carried out by our fellow students at NTNU. This includes; three tank oil heating system using solar energy with the aim of storing energy and cooking as application while oil being both a heat transfer and storing media. Another project involved the multiphase fluid flow experiments to determine types of waves.
I also participated in weekly meetings which were held at Gloshaugen Varmeteknisk 2 every Friday for almost 2 hours. During these meetings we were able to link with other NTNU students under NORPART who presented their projects such as solar energy storage using salt and oil (a PhD project), maximization of solar intensity received by a collector using compound parabolic collector (a PhD project).
And finally I was able to prepare a draft paper of my dissertation for publication which is yet to be sent to the intended journal.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2019/10001

Name: **JOSHUA WINFRED KYAMBILE**

Home Department and supervisor: Department of Mechanical and Industrial Engineering Prof. C.Z. Kimambo and Dr. J. Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. O.J. Nydal

Field trip Period: Two weeks(from 10th October 2019 to 17th october 2019)

Title: Assessment of Oil And Gas Training and Research Capacity of High Learning Institutions for Eastern and Southern Africa

The visit to Norway aimed towards studying oil and gas laboratories from both high learning institutions and research institutions. It involved studying how the lab operates, safety adherence, tests undertaken and how the labs are equipped. Below is the summary of the visits to accomplish this project.

Summary

NTNU Oil and Gas laboratories

During the whole period of stay in Norway,I got a chance of visiting and even spending sometimes in the university labs more than visiting other institutions listed below, that provides trainings and undertaking researches related to oil and gas like transportation,fuel testing,gas compression,process control and corrosion testing.NTNU Labs included the followings;

Process control lab
Corrosion in oil and gas system lab
Compressor lab
Multiphase transportation lab
Petroleum New Mining lab

10th October 2019 (SINTEF multiphase loop- Tillerbruvegen)

Visit to Sintef multiphase loop laboratory at Tiller involved one master student (Joshua) and two supervisors (Prof. Kimambo and Dr. Kihedu). At tiller we were taken through Large scale multiphase loop, medium scale multiphase loop and to the small scale loop that were used for hydrate studies previously.

Figure 1; visit at Sintef multiphase laboratory

11th October 2019 (Equinor Rotvoll)

Visit to Equinor Rotvoll at Ranheim Trondheim involved five master students (Susan, Joshua, Kusaja, liberate and Gonzaga), one PhD student (Casiana) and two supervisors (Prof. Kimambo and Dr. Kihedu). At Equinor we were taken through both Subsurface Laboratory, where they do all reseach activities related to subsurface and Processing Laboratory, whose researches are based on investigating challenges that occur in processing of oil and gas.

Figure 2; visit at Equinor subsurface and processing laboratory

14th October 2019 (Institute for Energy Technology - IFE)
Visit to Institute for Energy Technolgy (IFE) at Lillestrom Oslo involved one master student (Joshua) and two supervisors (Prof. Kimambo and Dr. Kihedu). At IFE we couldn't have access to the Lab due to security issues that mostly was due to the fact that they received lately information about our visit. But the visit was very informative since we had a conference meeting with Research Director, Mr. Martin Foss.

15th October 2019 (University of Oslo)
At University of Oslo, we got a chance to go through Hydrodynamic Laboratory and Rheology Laboratory. Hydrodynamic Lab is much based on modelling waves effects and some multiphase studies while in Hydrology Laboratory work most with drilling fluids analysing viscosity and how do particles settle**.**

16th October 2019 (Equinor Porsgrunn and University of Southern North Norway)
Visit at Equinor in Porsgrunn was through Multiphase Laboratory, which they use for all researches in the flowlines. The visit included indoor material laboratories like Rheology Lab, where they work with crude oil and Corrosion and Scaling Laboratory.

Also we got time to visit University of Southern North Norway Lab where they do multiphase loop, CO_2 capturing and storage and open channels experiments mainly for drilling activities.

Figure 3; visit at UiSN Multiphase

17th October 2019 (Norwegian Research Centre Stavanger-NORCE)
Lastly, the visit was at Norce Stavanger where we went through Enhanced Oil Recovery Lab (EOR) and in Special Core Analysis Lab (SCAL).

Figure 4; Visit at NORCE Laboratory

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: **LIBALATA DAVID S MALAVANU**

Home Department and supervisor: Department of Mechanical and Industrial Engineering Prof. C.Z. Kimambo and Dr. J. Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. O.J. Nydal

Period: 4 Months

Title: A report on activities conducted as an exchange student at the norwegian university of science and technology (ntnu

Summary: A brief account of the undertakings that were performed by the students as well as the experience we shared and gained both individually and collectively during our stay at the NTNU (Norwegian University of Science and Technology), Energy and Processing Department in Norway.

From Left to Right: Gonzaga Ngalinda, Dr Kihedu, Doctor Kusaja, Libalata Malavanu, Prof. Kimambo, Joshua Kyambile and Cassiana Lwiwa

ACTIVITIES CONDUCTED COLLECTIVELY:

At NTNU and outside the University, there are a number of activities that all of the exchange students participated in collectively;

a) Laboratory Tours:

Upon arrival we were given a tour around the various laboratories that the Energy and Process Department has and we had the opportunity to see the various experiments that were being done and tested and were currently ongoing.

b) Weekly Progress Meetings:

Professor Nydal held weekly progress meetings in which other members of the Energy and Processing were invited to take part in as well as all the Masters' student in which everyone presented their progress for the week and the challenges they faced. A discussion on ideas and the way to go forward was then given for the week that followed.

A weekly meeting in progress with Prof Ole Nydal

c) Educational Tours:

- A trip to a Methanol Production Plant in Tjeldbergodden

The visit was carried out on grounds of familiarization with production of Methanol.
31 students from NTNU went on this expedition including 4 exchange students from UDSM; Joshua Kyambile, Doctor Jeremiah Kusaja, Libalata Malavanu and Gonzaga Wilfred and one second year Masters' student from NTNU; Susan Lyimo. They are all under the NORPART project scheme.
The students were split into three groups to allow easy access around the plant and facilitate involvement of each. All were introduced to Tjeldbergodden plant that consists of three units which are; a methanol plant - which is the main unit of all the three, followed by a gas factory which produces gas to be used in methanol production. Such gases include oxygen, hydrogen and argon and the remained gas is transported to customers by trucks. The last unit is an LNG plant that produces LNG and supply to Norwegian customers.

The methanol plant at Tjeldbergodden is the largest in Europe and most energy efficient plant worldwide. The produced tons of methanol are shipped to various parts of the world, mainly Europe.

- **Visit to Equinor Rotvoll at Ranheim Trondheim:**

This visit involved five master students (Susan, Joshua, Kusaja, Libalata and Gonzaga), one PhD student (Casiana) and two staff members form the University of Dar es salaam (Prof Kimambo and Dr.Kihedu). At Equinor we were taken through both subsurface laboratory where they do all research activities related to subsurface and processing laboratory whose researches are based on investigating challenges that occur in processing of oil and gas.

Students and teachers in the NORPART Program along with their host from Equinor.

ACTIVITIES CONDUCTED INDIVIDUALLY:

My Masters' thesis is based on the study of natural gas flow characteristic during rupture. My main task was to familiarize myself with OLGA which is a standard tool for transient simulation of multiphase petroleum production. This was accomplished through a visit to Schlumberger SIS offices in Asker for OLGA Software familiarization.

The visit was carried out for the purpose of training and obtaining some much needed hands on experience with the OLGA software which the partaking students were using in their thesis. I was introduced to various components and options that could be used in the simulation of a rupture in a pipe network system as I am working on capturing the different behaviours of gas flow and pressure during pipeline rupture in a gas network. A total of three other students from different disciplines Susan Lymo, Mari Skjærpe, Henrik Brude and myself, took part in this two-day training session.

From the left to right: Libalata, Henrick, Susan, Espen and Mari

APPRECIATION:

I would like to take this opportunity to thank the University of Dar es salaam in co-ordination with the Norwegian University of Science and Technology through NORPART for presenting me with an opportunity to broaden my skills and knowledge through the exchange program. I have learned many things both on an education spectrum and a cultural one too. I have also been exposed to a lot more information, ideas and opportunities.

This really was a great experience and I'm humbled and grateful for your support. A big thank you to the NORPART coordinators Dr. Joseph Kihedu, Prof. Ole Nyal and Professor Cuthbert Kimambo for their astonishing work and valiant efforts in making this a memorable and wonderful experience for all of us who participated.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2019/10001

Name: Susan Lyimo

Home Department and supervisor: Department of Energy and Process Engineering
Prof. O.J. Nydal
Host Department and supervisor: Schlumberger – Software Intergrated Solutions.
Supervisor: Espen Egner

Period: Two days (from 14th October to 16th October)

Title: Visit to Schlumberger SIS offices in Asker for OLGA Software familiarization

Summary
The visit was carried out for the purpose of training and obtaining some hands-on experience with the OLGA software which the partaking students were using in their thesis.
The participants included; Susan Lyimo a M.Sc student in Natural Gas Technology, Libalata Malavanu a M.Sc student in Oil and Gas Technology, Mari Skjærpe a M.Sc student in Energy and Process Engineering and Henrik Brude who is pursuing a M.Sc in Mechanical engineering.
The training highlighted generic operations and cases in OLGA and also touched on specific topics based on what the students were intrested in.
For the case of Susan, who is dealing with surge waves, demonstrations on how to create, study and simulate the waves was provided.
Libalata was introduced to various components and options that could be used in the simulation of a rupture in a pipe network system as she is working on capturing the different behaviours of gas flow and pressure during pipeline rupture in a gas network.
Mari and Henrik were provided with material on transient modelling of multiphase flow in wells as they are looking into well clean up, and introduced to the near well reservoir tool called Rocx.

From the left fo right: Libalata, Henrik, Susan, Espen and Mari

UDSM-NTNU Mobility Program in Energy Technology NORPART-2019/10001

Name(s): Joshua Kyambile, Doctor Jeremiah Kusaja, Libalata Malavanu, Gonzaga Wilfred and Susan Lyimo

Host Department and supervisor: Equinor Rotvoll, Processing department

Period: One day (31st October 2019)

Title: Visit to Tjeldbergodden Methanol Plant

Summary
The visit was carried out on grounds of familiarization of methanol production at Tjeldbergodden.

The participants were 31 students from NTNU including 4 exchange students from UDSM;Joshua Kyambile, Doctor Jeremiah Kusaja,Libalata Malavanu and Gonzaga Wilfred and one second year masters student from NTNU; Susan Lyimo. They are all under the NORPART project scheme.

The students were divided into three groups to ease the tour around the plant and facilitate involvement of each. All were introduced to Tjeldbergodden plant, that consists of three units which are; a methanol plant - which is the main unit of all the three, followed by a gas factory which produces gas to be used in methanol production. Such gases include oxygen, hydrogen and argon and the remained gas is transported to customers by trucks. The last unit is an LNG plant that produces LNG and supply to Norwegian customers.
The methanol plant at Tjeldbergodden is the largest in Europe and most energy efficient plant worldwide. The produced tons of methanol are shipped to various parts of the world, mainly Europe.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: DOROTH FERDINAND KOMBA

Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. Bwire NDAZI
Host Department and supervisor: Department of mechanical and industrial engineering.
Prof. Roy Johnsen

Period: 4 months

Title: Corrosion properties of different aluminium alloys in seawater.

Summary
A study has been initiated to investigate corrosion properties of AA1050.25, AA5005.05, AA6005.40, AA6082.T6 and AA7046.92 aluminium alloys in seawater. The test specimens were exposed in natural seawater at a temperature of 10±2^{0}C at an open circuit potential (OCP) for the period of four months. Other test specimens were cathodically polarised by connecting to a sacrificial anode while other test specimens were anodically polarized by connecting to AISI 316 stainless steel. The protection potential (E_p) and the current density (i_p) were then measured on the cathodically polarized test specimens. Linear polarization resistance and cyclic polarization curves were recorded to determine the corrosion rate. An Optical Microscopy (OM) and Scanning Electron Microscopy (SEM) coupled with Energy Dispersive Spectrograph (EDS) to examine the surface conditions, surface chemistry and precipitation of calcareous deposits on the specified areas of the test specimens after exposure. The corrosion tests results show that there are differences in the corrosion behaviour, and this can be reflected in current density and OCP. Physical examinations and microscopical results revealed and confirmed severe pitting corrosion of the sample of AA7046.92 compared to the rest of alloys.

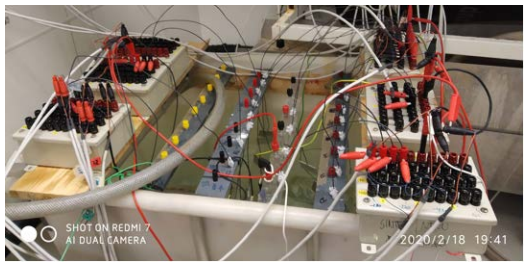


Figure 1: The experiment set-up in the SEALAB.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Joel Mbwiga

Home Department and supervisor: Department of Mechanical and Industrial Engineering Prof. Dr. J. Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Torbjon Nielsen

Period: 6 months

Title: Performance Optimization of Small Wind Turbines under Low Speed Conditions

Summary
Objectives: (i) To analyze the impact of low wind speed operating conditions on SWTs' design parameters (ii) To develop an optimal parametric model of SWTs for low wind speed conditions (iii) To perform an experimental validation of the model
Aim of participation in 6 months exchange program at NTNU: Availability of research facilities for accomplishment of third objective.
Methods and materials for third objective:
The objective is split into three activities each with the following methods, materials, and tools:
(a) **To design a small wind turbine rotor**: Analytical method was used to get size of rotor. Airfoils were selected by analyzing published airfoil data available at www.Airfoiltools.com for lift to drag ratio at various angles of attack given low Reynolds number of 30,000. Xfoil and MATLAB was used in analysis. Blade cord and twist distributions were determined analytically. The 3-D blades were drawn using Solidworks. The hub was designed and drawn in Solidworks and the entire 3-D rotor assembly.
(b) **To manufacture the rotor**: Using SprutCam the milling process was designed, and G-code post-processing for blades and hub prepared. Using composite wood called eboad, the blades and the hub were milled (Fig. 1). Fig.2 shows the assembled rotor.
(c) **To perform experiments**: Setup of rotor complete with generator and instrumentations was done for either of 3-blades conventional rotor and 6-blades novelty rotor in the wind tunnel. The torque, power and rotational speed were measure with respect to wind speeds. The data were analyzed and interpreted.


Fig. 1


Fig.2

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Mikal Rekdal

Home Department and supervisor: Department of Chemical Engineering
Prof. Johannes Jäschke
Host Department and supervisor: Department of Mechanical and Industrial Engineering.
Dr. Joseph Kihedu

Period: 20.02.2020 – 15.03.2020

Title: Optimal Operation of a Solar Powered Thermal Energy Storage System for Cooking

Summary
My work involved developing a model of the assembled solar powered thermal energy storage system in Arusha, Tanzania and investigating how the current and alternative designs can be optimally operated. The model was implemented in MATLAB, while using CasADi to solve the optimization problems. Main objectives of the project included establishing a realistic model of the physical system, define realistic operating conditions, investigate weather effects and model the performance of modifications to the current system.

One of the most challenging aspects of the work was to create a framework for the model that accurately represents how the system is to be used. Relevant questions included how often the system is to be used for cooking, should the system be manually or automatically controlled and what are practical challenges with the system. It was therefore very helpful to be able to go to Tanzania to test the system for myself. The trip also gave me the chance to talk to Per Bjerre, who has been working with the system for a while. During our time in Tanzania we also got to present our work to faculty and students at UDSM. Their questions and comments shone light on ways to improve the work further, possible extensions on the work and the opportunities to collaborate across projects.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Susan Lyimo

Home Department and supervisor: Energy and Process Engineering
Prof. Ole Jørgen Nydal
Host Department and supervisor: Department of Mechanical and Industrial Engineering.
Dr. Joseph Kihedu and Prof. Cuthbert Kimambo

Period: 26.02 – 11.03

Title: NTNU-UDSM Exchange

Summary: A group of students from NTNU travelled to Tanzania for an exchange of one month hosted by UDSM. On 27th February we visited the Norwegian Embassy for a lunch meeting with the ambassador and her associates. We discussed their efforts in the energy and entrepreneurship sectors and shared details of our works as well. A NORPART/UDSM meeting was held on 28th February at UDSM by our hosts, representatives from different energy cooperations in Tanzania (GASCO, TAREA and TPDC). There we had a discussion on exchange experiences, student projects and various opportunities for students and universities with the cooperations. After that we took a tour of the laboratory facilities at UDSM.
The excursion to Mtwara followed from 01.03 to 06.03. The agenda was as follows;
We visited the **Kinyerezi Receiving Terminal**, **Dangote Cement station**, **Mtwara Gas Plant** operated by Maurel & Prom (French Oil and gas service company), **Tanesco Power Grid**, **TPDC Natural gas processing plant**, **Maurel & Prom receiving station** and **SomangaFungu gas receiving facility**. The following week, from 9th to 11th March, we had student presentations at the university campus where we got to present our work to our fellows at UDSM and vice versa. Overall, the experience was very insightful and familiarized us with the oil and gas sector progress in Tanzania. We were able to exchange ideas and knowledge with the students at UDSM and experience a new working environment from what we are used to at NTNU.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Marie Kolderup, Kaja Gustavson, Sigurd Thaule

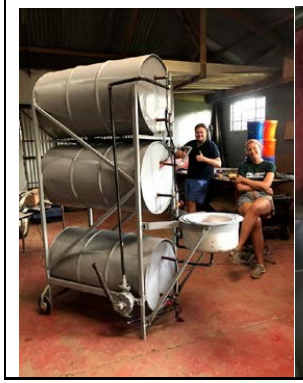
Home Department and supervisor: Department of Energy and Process Engineering
Prof. Ole Jørgen Nydal
Host Department and supervisor: Department of Mechanical and Industrial Engineering.
Dr. Joseph Kihedu and Prof. Cuthbert Kimambo.
TecnixTZ, Arusha, Per Bjerre

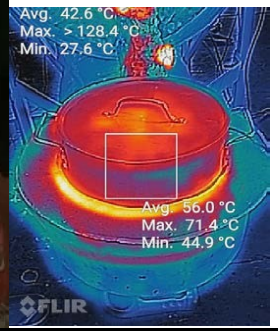
Period: 21 February – 25 March 2019

Title: Prototype heat storage for cooking

Summary

Three students spent one month in Tanzania, as part of their MSC thesis work on solar heat storage for cooking. Two of the students had spent one semester at UDSM in 2018 and they continued at NTNU with thesis work related to the ongoing NTNU-UDSM collaboration (EnPE and NORPART project). A prototype system has been established at NTNU and the students participated in making a version in Tanzania. Co-financing has been achieved through NTNU Discovery (prototype and solar panels costs) and Engineers Without Borders (travel costs).
NORPART contributions have been subsistence and some instrumentation costs.
The system was established at a company in Arusha (NTNU Discovery project partner, Tecnix) and the students spent some time at UDSM where the system will be copied.
The system is based on using excess electricity from Photovoltaic Panels to store heat for cooking. Tests were successful, 10 kg rice was cooked on the heat storage.





UDSM-NTNU Mobility Program in Energy Technology NORPART-2019/10001

Name: Godwin NSEMWA

Home Department and supervisor: Dr. Joseph Kihedu

Host Department and supervisor: Ole J Nydal

Period: 30th January - 15th July

Title: Numerical Simulation and Experimental Investigation on the surge waves in gas-condensate pipelines

Summary

Gas condensate pipelines transport unprocessed multiphase well stream fluids over long distances. During operation, however, the flow rate may be reduced allowing significant liquid accumulation, when the flow rate is increased, surge waves will be created. Surge waves causes serious operational problems due to large amounts of excess liquid being expelled from the pipeline into the receiving facilities during ramp-up of production. The problem with surge waves is the large unpredicted liquid volume which can flood the receiving facility if the liquid volume arriving in the surge waves exceeds its liquid handling capacity. Accurate prediction and ability to handle surge waves is crucial in the design of optimal size of the slug catcher, the plant liquid processing capacity and the pipeline.
Surge wave phenomenon is not accurately accounted for by available commercial multiphase simulators, leading to inaccurate prediction of the onset of liquid accumulation in large gas condensate pipelines. Reducing the prediction uncertainties can lead to more optimal dimensioning of the liquid receiving facilities, thus potentially reducing both costs and technical risks. This work aimed at investigating surge waves prediction in gas-condensate pipelines, the performance of Ledaflow transient multiphase simulator in predicting surge waves have been evaluated by comparing with experimental results.
Experiments on surge waves were conducted in the multiphase flow laboratory at NTNU to produce long surge waves in a stratified three phase flow utilizing air, oil and water as test fluids. The multiphase flow loop has a test section with 57.84m long test pipeline of 60mm internal diameter and a dip 1m from the inlet. Along with experimental tests, numerical simulations for the same test conditions have been performed using Ledaflow transient commercial simulator. Comparing the simulation results and liquid hold up measured experimentally, Ledaflow revealed a somewhat good agreement on only two of the five cases studied. Improvement of the current version of Ledaflow is needed for it to comprehend the surge waves phenomenon.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Susan Lyimo

Home Department and supervisor: Department of Chemical Engineering
Prof. Johannes Jäschke
Host Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. Joseph Kihedu

Period: 06.01 – 10.08 2020

Title: Experimental Investigation on Three-Phase Surge Waves

Summary
The scope of the thesis study was to perform experiments on three phase surge waves. Three phase surge waves were produced in the NTNU multiphase laboratory at the NTNU campus in Trondheim. The three phases used for these experiments were air, water and oil. The waves were initiated by introducing a dip at the start of a long pipeline (approx. 58m) with two 180 degree loops. Cameras were used to observe surge wave propagation at three observation points along the flowline. Experiments were performed with varying gas and liquid fractions. Some good cases which showed surge waves propagating throughout the pipeline were selected and investigated further. This was done by varying water cuts for those particular cases. Along with experimentation, simulations were carried out. Twophase cases from previous work were simulated with newer versions of OLGA dynamic simulator. Results of wave velocity and holdup were compared with previous work and was found to show some similarity with some older versions of OLGA. Differences were concluded to be due to numerical changes in calculation between versions. One among the good selections of three-phase flow cases was simulated with the latest version of OLGA (2019.1). The aim of this was to compare the trend of results with experimental findings as well as the wave velocities. It was found with lower water cut in the flow, the calculated wave velocity from the experiments was comparable to simulation results. It was suggested that further investigation on three phase surge wave flow is required. A major hindrance for this research was the delay brought about by the covid-19 pandemic.

DSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001 Report Summary

Name: Mbuva Muzamil Ally Nchula

Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. Joseph Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Even Solbraa

Period: Jan 2020 – July 2020

Title: Wax control for oil and gas production with integrated production of wax inhibitor.

Summary
Developing fields found in harsh environments such as offshore deep water and artic conditions of extremely low temperatures face challenges regarding flow assurance. Reservoir hydrocarbon fluids contain paraffin that may form solid phases and deposit as wax at low temperatures. The current typical wax control methods are; pipe in pipe, electrically heated pipes, continuous pigging and the most reliable efficient method adapted to minimize wax deposition in pipeline during production is the continuous addition of wax inhibitor. These methods however, require a lot of high investments and operational costs.
The goal of this work was to integrate the oil and gas process to produce a light condensate as a wax inhibitor. To evaluate the potential of this technology for offshore fields, for a given waxy fluid composition, a model using Aspen HYSYS as a process simulation tool and NeqSim for wax calculations is developed to test the effect on the wax appearance temperature reduction after reinjecting the light condensate into the well head. NeqSim is used to analyse the effect of adding the light condensate by measuring the reduction of wax appearance temperature of the reservoir fluid at separator conditions before and after the addition of the light condensate. Simulation and analysis results of the model show that, reinjecting the light condensate to reduce wax deposition has a significant reduction of wax appearance temperature by 6 oC for a gas condensate fluid composition and 16 oC for an oil fluid composition when recycling up to 10% of the total volume flow of the well stream. The energy consumption was optimized to reduce the effect on the total energy consumption of heating the inlet stream. Further study on evaluating the possibility of storing the light condensate into a storage tank to be used as a wax inhibitor after shutdown process is recommended.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Vilde Svanevik Stordal

Home Department and supervisor: Department of Energy and Process Engineering
Prof. Ole Jørgen Nydal
Host Department and supervisor: Department of Mechanical and Industrial Engineering.
Dr. Joseph Kihedu and Prof. Cuthbert Kimambo.

Period: 13. Feb - 15.march 2020

Title: Heat storage for cooking

Summary
From August 2019 to June 2020 I have been in this collaboration project between UDSM and NTNU. The main goal of my project and master thesis in this period is to develop a system that will use solar power to produce heat for cooking. This has been an ongoing project over several years.

During fall 2019 the system was tested and further developed at NTNU. In the start of 2020, we prepared us for a 4 weeks long field trip in Tanzania. The four weeks was divided into two weeks of further testing of a similar system as at NTNU, only at Arusha. It was very useful to get to try the system at intended conditions, and we learned a lot from this.

The following week, we traveled to Dar Es Salaam and joined a field trip together with students from UDSM down the coast to Mtwara. During this trip, we were able to visit several processing plants, gas power plants and block valve stations. We got to learn a lot about the gas processing in Tanzania, together with learning more about Tanzania as a country and the culture there. For the last week we got to present our master thesis to the professors and students connected to the program at UDSM, and they got to tell us about their thesis.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Oda Kristine Sneen Fjeldsæte

Home Department and supervisor: Department of Energy and Process Engineering
Prof. Ole Jørgen Nydal
Host Department and supervisor: Department of Mechanical and Industrial Engineering.
Dr. Joseph Kihedu and Prof. Cuthbert Kimambo.

Period: 13. Feb - 15.march 2020

Title: Heat storage for cooking

Summary
Vilde and I travelled to Tanzania before the rest of the group, because we were going to work on a system similar to the one that has been developed at NTNU. We write our master thesis together, and the master thesis include testing and furhter improvement of a system that has been developed during a master thesis in 2019 through the NORPART project. The system will generate heat from electricity provided by solar panels, and store the heat for cooking at a later time, when the sun is not necessarily available. and the PV panels cannot provide electricity.
The system in Tanzania was developed by Per Bjerre in his workshop in Arusha, where it is also located. Therefore, we were in Arusha for two weeks to test the system in the intended ambient conditions, using PV panels for power input unlike electricity from the grid as at NTNU.
The experiences gained by using the system in Arusha have been very important for imporvement of the system and understnading of its limitations. Moreover, we gained experiences beyond physical properties. Conversations with our hosts and a visit to a local Maasai village gave us further understanding and an impression of current cooking methods, daily routines and general habits, which also needs ot be taken into consideration.
The rest of the group joined us in Arusha after one week, and contributed with ideas and tested the system to give feedback.
After Arusha, we joined the group in Dar es Salaam. At UDSM we participated in several meetings and conference days, where we presented our thesis work with the students at UDSM, both master students and PhD candidates. This resulted in questions and feedback on our work that we will take into consideration.
Moreover, we joined a student excursion to several gas plantantions to see different parts of the gas processing in Tanzania.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Wilfred Enock Lyimo

Home Department and supervisor: Department of Mechanical and Industrial Engineering.
Dr. Joseph Kihedu
Host Department and supervisor: Department of Geophysics and Petroleum
Prof Michael Golan and Prof Milan Stanko

Period: 5 Months and 2 weeks 2020.

Title: Investigation of root causes on oversizing land based finger-type slug-catcher. A Case of Snøhvit LNG Project, Norway

Summary

A study was conducted to investigate root causes of finger-type slug-catcher oversizing. To achieve this task, a slug-catcher sizing template was developed based on recommended mathematical models. Snøhvit LNG project was selected as a case study where its slug-catcher was resized to determine its adherence to recommended mathematical models. Results revealed that all slug-catcher main dimensions deviated from recommended dimensions and some of them deviated by more than 50%. Also volumetric analysis showed that snøhvit slug-catcher was bigger than recommended by 8%. The study went further to establish margin of error due to prediction of slug-catcher design basis. It was found that errors due to prediction of slug-catcher design basis contributed significantly on slug-catcher oversizing problem. The margin of error was found to be 249%. In the end, it was recommended that slug-catcher manufacturer should stick to the recommended mathematical models and prediction techniques of slug-catcher design basis should be reviewed.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Mari Skjærpe and Henrik Brude

Home Department and supervisor: Department of Energy and Process Engineering
Prof. Ole Jørgen Nydal, Even Solbraa (NTNU/Equinor) , Henning Holm (Equinor)
Host Department and supervisor: Department of Mechanical and Industrial Engineering.
Dr. Joseph Kihedu and Prof. Cuthbert Kimambo.

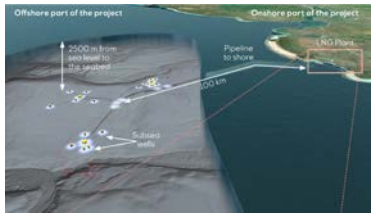
Period: Spring 2020

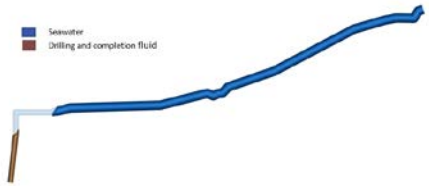
Title: Simulations of multiphase pipeline Tanzania Block 2

Summary

The aim of the thesis is to investigate the contingencies of well cleanup to shore, combined with dewatering of the trunkline for a gas-condensate field on Block 2 offshore Tanzania. Initial well conditions inhibit an efficient startup and well unloading. Thus, gravity driven mud drainage to the near-wellbore zone during well suspension is investigated as a possible solution. Furthermore, emphasis is made on the flushing of filtrate in the near-wellbore zone during early production, along with predictions of the period of time the drilling- and completion fluids will affect the production.

The work was defined in collaboration with Equinor. The simulation work was made using the OLGA program.





Offshore gas development Tanzania. OLGA simulation case.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

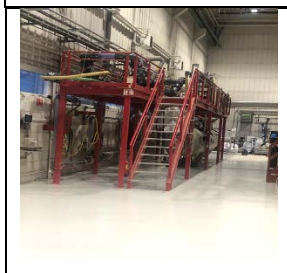
Name: Chrisostom Lucian Kibongolo

Home Department and supervisor: Dep. of Mechanical and Industrial Engineering .
Dr. J. Kihedu
Host Department and supervisor: Department of Geoscience and Petroleum.
Prof. Milan Stanko

Period: 4 months 2021

Title: Evolution of the Oil Droplets Distribution in a bulk Oil - Water pipe Separator.

Summary: The visit to NTNU covered experimental study on the evolution of the Oil Droplets Distribution in a bulk Oil - Water pipe Separator. Individually I was assigned to determine properties of liquid; in the reservoir laboratory, properties of liquids with different concentrations (Exxsol D60 red crude oil and salt water) to be used in the experiments were determined, these properties were; concentration, densities and viscosities. Thereafter experiments were carried out to the oil – water pipe separator, data were captured using Labview software. Data obtained were analysed using ImageJ software to get oil droplets diameters and distribution at different water cuts and flow rates



Picure: Water pipe separator in laboratory

During the experiment, I was linked to PhD candidate who is doing research work on the Pipe separator. I also participated in different meetings held at NTNU; first meeting was NORPART meetings which were held at Gløshaugen Varmeteknisk 2 on Friday of every two week, during these meetings we were able to meet with other NTNU students under NORPART program and their supervisors. The second meetings was status meeting, which was held on Thursday of every two week at the Department of Geoscience and petroleum, meetings involved master and PhD candidates supervised by Prof. Milan Stanko, where I had opportunity to give brief summary on the work progress, familiarize to what others are doing, find possible synergies, solve/inform about challenges and make an action list; in additional to that we had separate meetings with Prof. Stanko on challenges associated with the research work on oil – water pipe separator.
And finally I was able to analyse data using ImageJ software for preparation of a draft paper of my dissertation for publication which is yet to be sent to the intended journal.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Emmanuel J Wangwe

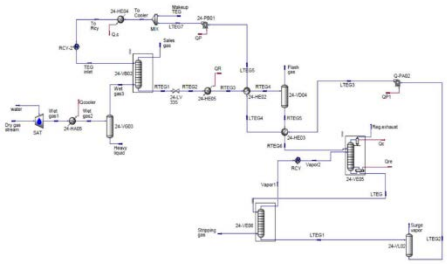
Home Department and supervisor: Department of Mechanical and Industrial Engineering
Prof. Abraham Temu and Dr. Joseph Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Even Solbraa

Period: 4 months 2021

Title: Modelling of Enhanced Glycol Regeneration Methods in TEG Natural Gas Dehydration Units

Summary: The visit to NTNU covered both school undertakings and study visits outside the campus. In school undertakings, I was assigned specific tasks concerning my project and required to present the results every week to my supervisor Prof. Even Solbraa. Some of the tasks which were assigned to me was; to prepare a mathematical Code of Equinor gas dehydration unit by using NeqSim software (utilizing python language) and also to model both a real Process flow diagram of Equinor gas dehydration unit and modified Equinor gas dehydration unit (integrated with enhanced TEG regeneration technologies) by using Aspen Hysys software. The process flow diagram of Stahl column TEG regeneration technology of Equinor gas dehydration unit which I created in Aspen Hysys software is as shown in the Figure below.

I had the opportunity to have laboratory visits to familiarize with the ongoing projects that were carried out by our fellow students at NTNU. This includes; three tank oil heating system using electricity with the aim of increasing the efficiency of cooking stoves while oil being both a heat transfer and storing media.
I also participated in weekly meetings which were held at Gloshaugen Varmeteknisk 2 every Friday for almost 2 hours. During these meetings we were able to link with other NTNU students under NORPART who presented their projects such as, maximization of solar intensity received by a collector using compound parabolic collector (a PhD project).



And finally I was able to prepare my dissertation work and submit it to my home University (University of Dar es Salaam) for the Master degree award and in the future I am planning to publish a paper from the same work.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Piniel Mashauri Msolo

Home Department and supervisor: Department of Chemical and Mining Engineering
Prof. Abraham Temu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Even Solbraa and Prof Ole Jorgen Nydal

Period: Spring 2022

Title: Prediction of Pressure Drop of a Gas Pipeline with Low Liquid Loading.

Summary: The visit to NTNU covered simulation study on the Prediction of Pressure Drop of a Gas Pipeline with Low Liquid Loading. My assignment was first, to use OLGA in simulating NTNU-experimentally collected data set so as to study pressure drops and friction factor. Secondly, I was tasked to compare Aasgard data set to simulated experimental data and finally, I was given a task on finding an error in approximating pressure drop while assuming only gas phase.

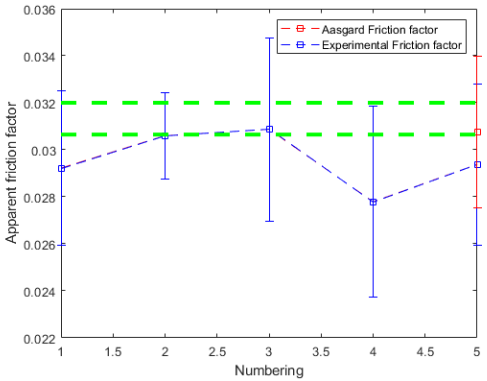


Figure: Comparison between Experimental Friction factor and Aasgard Friction Factor

During simulation period, I worked close with Prof Even Solbraa and Prof Ole Jorgen Nydal. We had status meeting every Wednesday from 16 February 2022 to 1 June 2022 which was conducted in Varmeteknisk 3, office number 511 and 399. I had opportunity to give brief summary on the work progress and challenges and there after we had discussion and they helped on challenging issues. Besides simulation we discussed on report writing whereas I was able to analyse and discuss my findings.
Finally, would like to give words of gratitude for this great opportunity that I received. In deed this has been great opportunity to me in learning and social perspective.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

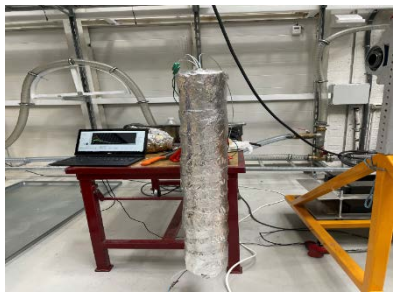
Name: Tshimuanga Kabongo Leon

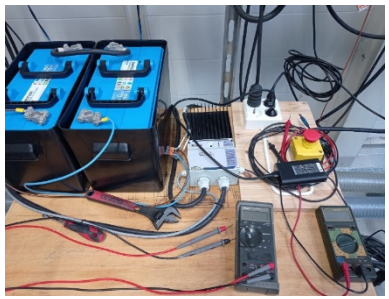
Home Department and supervisor: Department of Mechanical and Industrial Engineering.
Prof Cuthbert Kimambo
Host Department and supervisor: Department of Energy and Process Engineering
Prof Ole Nydal

Period: 4 months Spring 2022

Title: Performance Evaluation of an Improved PV Cooking System

Summary: My work at NTNU consisted mainly on carrying out experiment on a solar PV cooking system connected directly to a controller. Different configurations were tested and compared to each other in order to determine which one gives better results. The first experiments were curried on the controller and heating elements, this was done to determine the performance and compare with the manufactures ratings then other experiments were done on the 3 tank system. Results were variable mainly due to climate conditions.





Pictures: Tools used to carryout experiment.

Pico Loggers connected to multiple type-K thermocouples were used to measure temperatures within the system. Some thermocouples were placed directly in contact with the heating elements while others were placed at the wall of the cylinders to measure the oil temperatures.
The collected data was then analyzed using MatLab and Microsoft Excel

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Rashid Omari Mkacha

Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu
Host Department and supervisor: Department of Geoscience and Petroleum
Prof. Milan Stanko
Period: 4 months 2022

Title: Experimental Investigation and Numerical Modelling of Droplets Formation in Parallel Pipe Bulk Oil - Water Separator.

Summary: The visit to NTNU covered experimental investigation and numerical modelling of droplet formation in parallel pipe bulk oil-water separator. Individually I was assigned to quantify the separation performance of an isolated tapping point for parallel pipe bulk oil-water separator by interpolating the experimental data for the flowrate range of 300 L/min to 700 L/min and water cut range of 30% to 90% obtained from the reservoir laboratory at NTNU, properties of liquids with different concentrations (Exxsol D60 red crude oil and salt water) used in the experiments were; concentration, densities and viscosities. Thereafter I was assigned to determine the best strategy (number of tapping points in series and how much to drain from each) and to separate as much water as possible and as little oil as possible from a stream.

During my research, I was linked to PhD candidate who is doing research work on the Pipe separator. I also participated in different meetings held at NTNU; first meeting was NORPART meeting which was held at Gløshaugen Varmeteknisk 2, during the meeting we were able to meet with other NTNU students under NORPART program and their supervisors. The second meeting was status meeting, which was held on every two week at the Department of Geoscience and petroleum, meetings involved master and PhD candidates supervised by Prof. Milan Stanko, where I had opportunity to give brief summary on the work progress, familiarize to what others are doing, find possible synergies, solve/inform about challenges and make an action list; in additional to that we had separate meetings with Prof. Milan Stanko on challenges associated with the research work on oil – water pipe separator.

Finally, I was able to quantify the separation performance of an isolated tapping point for parallel pipe bulk oil-water separator and three tapping point in series was the best strategy to separate as much water as possible and as little oil as possible from a stream. The obtained solution was useful for preparation of a draft paper of my dissertation for publication.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

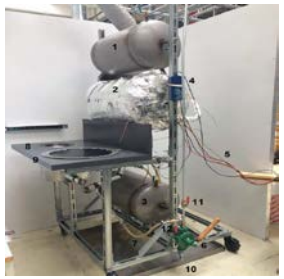
Name: Mkufu Shabani Tindi

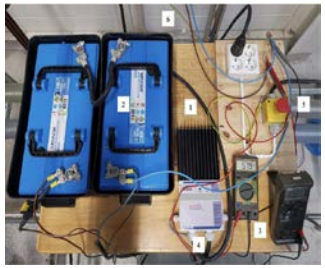
Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Ole Jorgen Nydal

Period: 4 months

Title: Performance Analysis of High Temperature Heat storage system using excess energy from isolated small-scale renewable energy systems (Wind and Solar)

Summary: The 4 months visit to NTNU purpose was to investigate performance of the available 3 tank storage system when powered by excess energy (dump load) from the installed wind turbine. During the period of my study, I was able to participate into several experimental study by using different energy sources such as solar, AC from the grid. For the purpose of my individual work the experimental study aim was to investigate the three tank storage system by using wind turbine excess energy. Due to some technical issues and the weather conditions the experiment results were unsatisfactory. After agreement and discussion with supervisors the experimental study using excess energy from the solar PV. Data such as temperature of the oil, current and voltage from the power source were collected manually and using Labview software. Data were analysed using different tools to assess the performance of the three-tank storage system.





The experimental work was done in a group of four students, two from the NTNU and two from UDSM. Together we worked with the storage system doing several experiments aim at analysing the system different parameters. Six experimental work with different set up were performed giving chances to perform individual analysis and write a report.

Apart from the experimental work, I have attended project progress meeting to discuss the way forward and challenges encountered during the experiments. Also, we been able to take part into different workshops under NORPART and NORHEAD programs held during our stay at NTNU. The NORPART programme was very successful and managed to assist my desertion work through Experiments and data for analysing performance of the three-tank storage system. The desertion work is finalised for submission.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

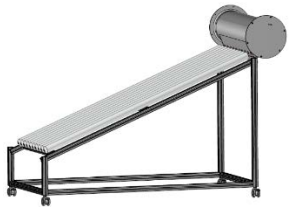
Name: Marte Maria Tømterud

Home Department and supervisor: Department of Energy and Process Engineering
Prof Ole Jorgen Nydal, Prof. Mulu Bayray
Host Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu

Period: Spring 2023

Title: Solar Water Heater with Temperature Control for 90˚C Water Requirement

Summary:
The Haydom Lutheran Hospital (HLH), located in Tanzania, requires water at 90˚C for laundry. Today, the water is heated by a diesel fueled steam boiler, but they desire to replace it with a solar based system. To meet the hospital's requirements, a cheap, simple, sustainable, and efficient solution, suitable for the rural African environment is designed and tested in the laboratory. The system includes heat pipe evacuated tubes directly inserted into a water storage tank. To the best of the authors' knowledge, this is the first study addressing such a system. This design prevents the need of circulation equipment, which lower the expenses and decreases the need of maintenance. To enable temperature control, a simple thermostatic valve, originally designed for use in car engines, is included as well as an external cold-water tank.
The test-design was a small-scaled version of what the hospital needs, and it must be scaled up. Depending on available area, the system may have to be split into several subsystems. Excess hot water can be stored in insulated tanks and be further heated when needed or used directly.
During the working period of the thesis, a field trip to Tanzania and UDSM was executed. The trip gave a good insight into African life, and it provided depth and meaning to the study. Multiple activities were arranged, such as school tours, trip to Arusha, excursion to a decommissioned hydroelectric plant, and visits to museums. Students from UDSM have also visited NTNU, which was very enjoyable.



UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Martin August Egerdahl

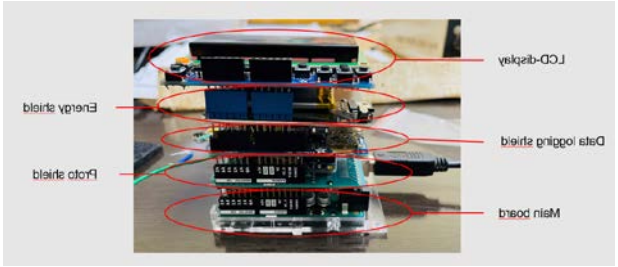
Home Department and supervisor: Department of Energy and Process Engineering
Prof Ole Jorgen Nydal, Prof. Mulu Bayray
Host Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu

Period: Spring 2023

Title: Arduino and Controllers for PV to Heat

Summary:
Connecting a Photo Voltaic (PV) panel directly to a load (heating element) will lead to poor performance as soon as the sun intensity falls (clouds or panel orientation). Controllers are available for the case of battery chargers (including Maximum Power Point Trackers) or for the case of grid connection (with inverters). For stand-alone PV to heat systems, a purpose made controller is needed.
MPPT controllers for PV to heat has been tested, and an Arduino based data logger for temperature and power has been constructed. The data logger is autonomous, where a small PV panels powers a mobile phone type of battery in the Arduino stack. The data logger is useful and can be copied at UDSM.

PV controllers for testing



Arduino data logger

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Lema, Brayson Ezra

Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr Joseph Kihedu
Host Department and supervisor: Department of Geophysics and Petroleum IGP-NTNU
Prof Milan Stanko

Period: Autumn 2023

Title: Experimental investigation of performance and modelling of a Helico-axial multiphase pump

Summary
A helico-axial multiphase pump designed and manufactured at NTNU has been installed at IGP PTS laboratory. This pump share rig with bulk water/oil separator existing in the lab hence its operational performance must be investigated and documented to lay a foundation for its use and further studies in the laboratory.

1. Labview Code is created, the pump is up and running, and multiphase flow tests have been done up to 40% gas void fraction at 1500rpm,2000rpm,2500rpm pump speed.
2. Performance predictions models have been studied and tested, selected are used to predict the performance of the pump
3. Model validation is ongoing, for the completed part of model validation; Empirical model prediction tally well enough with the experimental data. As it is from test results, the pump is suitable for up to 40% gas void fraction application.

Recommendations
1. Replacing the current separation tank with a bigger tank to be able to run the pump with higher GVF 60% and 75%. Separation tank at the discharge line after choke valve does not work hence both liquid and accumulated air is forced back into the water tank, this causes excessive vibration of associated pipelines at higher GVF.
2. Review on Choke valve model and maybe replace it if needed as it is unstable at low openings, this causes excessive instability of the whole LabVIEW control system and eventually it shut down the operation. For this reason, low limit for flowrate range was limited and even more limited at higher GVF hence few test points.

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Name: Mary Paul Kapwani

Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. Bwire Ndazi
Host Department and supervisor: Department of Mechanical Engineering
Prof Roy Johnsen

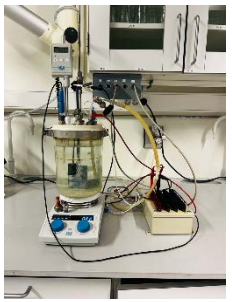
Period: Autumn 2023

Title: Cathodic Protection Investigation of Components in Closed Compartments Exposed on Seabed

Summary
In connection with subsea production of oil and gas, the subsea components need to last for long time, therefore there is a need for a scheduled inspection and maintenance. During this action, water may be trapped inside closed compartments. Since seawater is corrosive to most metal, so these areas need to be protected against corrosion

Therefore, the purpose of of the exchange visit to NTNU is to utilize the laboratory equipments to conduct cathodic protection of components in closed compartments by simulating the seabed environments and closed compartments conditions.

The study was done to find the relevant protection current density depending on temperature and oxygen availability. The data were successfully acquired through data logger, Thereafter, the size and number of anodes which will be suitable to protect the required area and materials were calculated



Simutalated seabed and closed compartments. Carbon steel

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Names: Neema Wilfred Muhogolo (UDSM)
Adrian Peder Malum Danielsen (NTNU)
Andreas Jørs (NTNU)

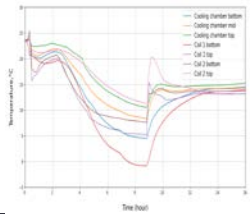
Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu and Prof. C. Kimambo
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Trygve Eikevik and Ole Jorgen Nydal

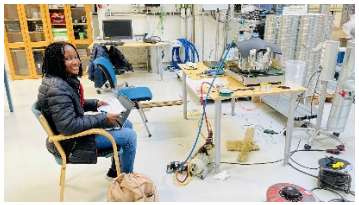
Period: Spring 2023

Title: Cold storage for an adsorption-based refrigeration cycle in Africa

Summary
Adsorption refrigeration system has been developed in UDSM and shows the potential of providing cooling for off-grid cooling applications. However, the system is characterized with non-continuous cooling process hence affecting the cold chamber temperature. Therefore, the purpose of this project is to develop an adsorption refrigeration system with an ice bath as a cold storage to maintain cold chamber temperature.

The system was designed, developed, and tested at NTNU. The adsorption pair used was Activated carbon/methanol due to its suitability with working temperature range. The lowest temperature achieved was -0.8 ℃ hence offering the potential for off-grid applications.





UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Names: Henrik Finsås, Torbjørn Mjåtveit (NTNU)
Seleman Mayanjo (UDSM)

Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Ole Jorgen Nydal and Mulu Bayray

Period: Spring 2023

Title: Thermal heat storage of small scale wind power

Summary
A Tristar controller has been successfully used with the existing thermal storage to demonstrate diversion, obtaining an optimal dump load resistance to maximize power output. Several tests on direct wind to heat have also been conducted, yielding similar results for dimensioning of the dump load. Nearly all tests with the small scale wind turbine were done in a lab, driven by an asynchronous machine, due to poor wind conditions in original location.

Part of the project offered an exchange visit, in which the students spent four weeks in Tanzania, visiting a hydro power plant, a few universities, and met with both local students and professors. The project has also made possible a great collaboration with students from Tanzania visiting NTNU, who have been working alongside exchanging knowledge and experiences.

Laboratory setup with wind generator

Varying load on the generator

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Names: Ibrahim Joseph Mwasubila

Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu and Prof. C. Kimambo
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Trygve Eikevik and Ole Jorgen Nydal

Period: Spring 2023

Title: Adsorption refrigeration technology (PhD)

Summary

The goal of the three months spent at NTNU (from February to May 2023) was to obtain some practical experience in the design and development of an adsorption refrigeration system. A test system using methanol and activated carbon was designed, constructed and tested. The testing concerns both the heating and the cooling side. An arrangement with glass shutters was tested to provide insulation during heating (desorption) and to open for cooling during the adsorption process. A similar system will be constructed in UDSM.

Laboratory setup with solar lamps

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Names: Anna Kisioki

Home Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu and Prof. C. Kimambo
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Ole Jorgen Nydal

Period: Spring 2023

Title: Optimization of Oil-Based Sensible Thermal Storage System for Cooking Application (PhD)

Summary

Anna Kisioki is embarking on a PhD study on heat storage for cooking. The concept at NTNU with natural circulation in a rock bed was tested. A similar system is evaluated in Uganda at Makerere University. The experience will be the background for an evaluation and analysis of Anna, who will optimize the concept and test it at UDSM.

Laboratory life

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

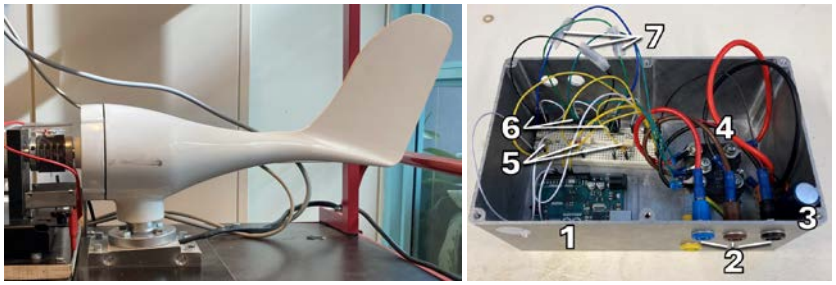
Names: Olav Torsvik

Home Department and supervisor: Department of Energy and Process Engineering
Prof. Ole Jorgen Nydal
Host Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu and Prof. C. Kimambo

Period: Spring 2024

Title: Small scale wind power to heat. Optimizing power output by implementing load switching.

Summary
The challenge is the case with wind power converted directly to heat. Heating elements can be positioned in a heat storage to accumulate energy for cooking. Commercial small scale wind turbines together with charge controllers are available for charging electrical batteries. For the case of direct wind to heat, alternative controllers are investigated to optimize the power form the wind turbines at varying wind conditions.
A load switching method was designed, constructed and successfully bench tested for a small scale wind generator. Three loads can be combined in different ways to provide many power steps. The tests were made using Arduino microprocessor and triac AC switches.



Laboratory setup with wind generator and Arduino based load switching

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

Names: Une Skogen and Eli Enes

Home Department and supervisor: Department of Energy and Process Engineering
Prof. Ole Jorgen Nydal
Host Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu

Period: Spring 2024

Title: **Performance evaluation of Photo Voltaic clean cooker with oil based heat storage**

Summary
A rock bed heat storage solution for cooking has been tested before, with oil providing heat transfer between the cooker and the storage by natural circulation. The system is heated with grid power and an AC heating element. The goal now is to test with a PTC heating element and DC power from the grid and form solar panels. A PTC (Positive Temperature Coefficient) element is inherently self-regulating as the power decreases with increasing temperatures. This eliminates the risk of overheating the oil.
The results showed that it was difficult to reach target temperatures of 220 degrees in reasonable times, as the decrease in power form the PTC element started at too low temperatures. This also proved to be challenging for the case of power from PV panels. The conclusion is that alternative PTC elements could be tested.

Laboratory setup for testing of PTC heating element in dual tank solar cooker

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

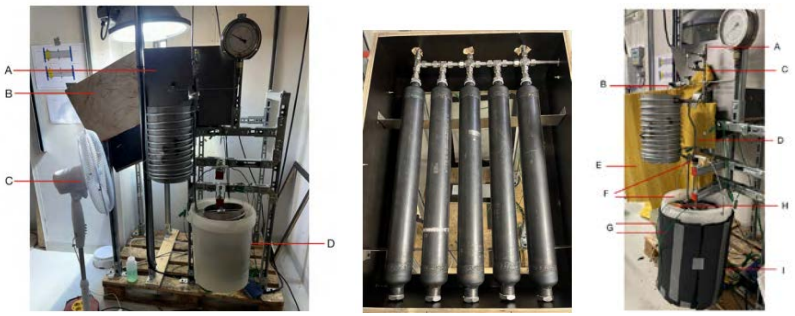
Names: Mina Andrea Torvanger and Ida Fredrikke Harsem

Home Department and supervisor: Department of Energy and Process Engineering
Prof. Trygve Eikevik and Ole Jorgen Nydal
Host Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu and Prof. C. Kimambo

Period: Spring 2025

Title: Optimization of Adsorption Refrigeration Systems for Sustainable Cooling in Sunny Areas

Summary
A test setup for an adsorption refrigeration cycle using ammonia and carbon as working pair has been tested optimized and tested using solar lamps as heat source.
The optimum ammonia charge was found to be 450 g and the importance of high quality insulation was highlighted. Simulations under realistic solar radiation profiles confirmed the system's potential to operate effectively in sunny environments, achieving a solar coefficient of performance (COP) of 0.06. Recommendations for further work include improvements to evaporator geometry, condenser slope, and integration of thermal shielding strategies.
The system was later shipped to UDSM for further work in Tanzania.



Laboratory setup for testing of adsorption refrigeration cycle with carbon/ ammonia

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

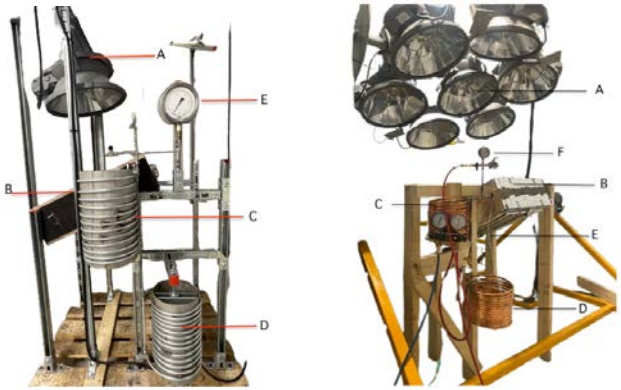
Names: **Elias Kolle Riskild and Ingvild Høilo Ongstad (NTNU)**

Home Department and supervisor: Department of Energy and Process Engineering
Prof. Trygve Eikevik and Ole Jorgen Nydal
Host Department and supervisor: Department of Mechanical and Industrial Engineering
Dr. J. Kihedu and Prof. C. Kimambo

Period: Spring 2024

Title: Solar-based adsorption refrigeration systems for subzero cold storage

Summary
A test setup for an adsorption refrigeration cycle was established with a visiting PhD from UDSM earlier. The performance of the system has been further evaluated experimentally and computationally in a master thesis work. The system is operated with carbon and methanol as working pairs. Methanol vapor is generated from solar heating during the day and stored as liquid methanol after condensing. The liquid methanol is evaporating during the night, to form ice as a cold storage.
The conclusion from the tests is that methanol may be a challenging medium in this process, as it is vulnerable for high temperatures and the vapor pressure is very low. A new setup was therefore designed and constructed, using ammonia as working fluid.



Laboratory setup for testing of adsorption refrigeration cycle with carbon/ ammonia and with carbon/methanol

UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

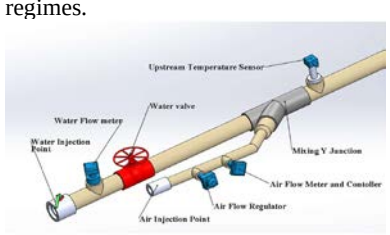
Name: SAMWEL STEPHEN NYANDORO

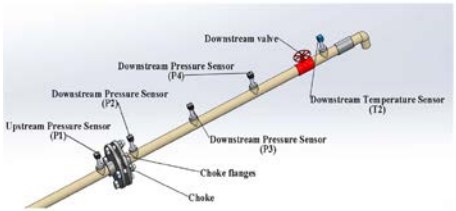
Home Department and supervisor: Mechanical and Industrial Engineering (MIE)
Dr. Joseph Kihedu
Host Department and supervisor: Petroleum Teknisk Senter (PTS)
Prof. Milan Stanko

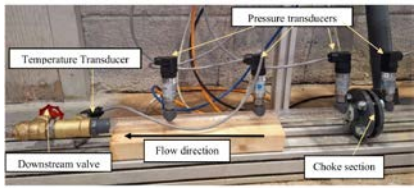
Period: January 2024 – May 2024 (4 months)

Research Title: Experimental Investigation of Multiphase Flow Mechanistic Models for Oil and Gas Production Choke

Summary
Oil and gas fields are subjected to multiphase flow and extensively utilize mechanistic choke models for flow prediction and measurement. Current models are often based on limited datasets that may not capture the full range of operational conditions and flow behaviors encountered in the field. Hence, demanding evaluate o predictability and benchmarking these models using different fluid flow conditions. A two-phase flow loop designed and developed as part of this study was used to generate 192 experimental datasets for evaluating the effectiveness of mechanistic choke models. Applying a specific plotting technique, a clear trend was observed in the prediction of mass flow rates across data points within the study's parameters.
Comparison of predicted mass flow from two mechanistic models and experimental two-phase flow datasets by statistical parameters. From the two mechanistic choke models evaluated in this study, Mwalyepelo and Stanko (2016) model predicts mass flow rate under critical and subcritical flow with less absolute errors than other published models, and with best performance for the critical flow regimes.







UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001

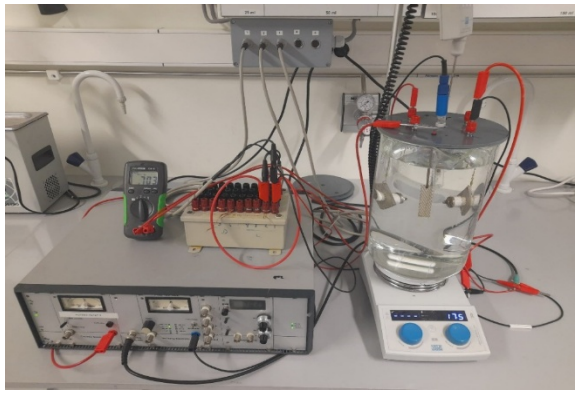
Name: Frank Raphael Mwakasege

Home Department and supervisor: Department of Mechanical and Industrial Engineering,
Dr Bwire Ndazi.
Host Department and supervisor: Department of Mechanical and Industrial Engineering (MTP), Professor Roy Johnsen,

Period: January 2024 – May 2024 (4 months)

Research Title: Safe Operating Window Investigation of 25 Cr SDSS in Seawater under Shock Chlorine Dosage.

Summary
In this study, corrosion resistance of 25Cr SDSS was investigated in seawater through a series of tests. The plate, forged and welded samples of 25Cr SDSS were immersed in seawater that was treated with constant shock dosage of chlorine of 200 ppm from 25° C to 40° C. Further, the plate, forged and welded samples were anodic polarized while being exposed in seawater from 25° C to 40° C. Susceptibility of 25 Cr SDSS to localized corrosion was also investigated by cyclic polarization of the plate, forged and welded samples in the seawater at 30° C and 40° C. This was done to achieve their corrosion initiation and re-passivation potentials.



UDSM-NTNU Mobility Program in Energy Technology NORPART-2018/10001Report

Name: **Mposola, Emmanuel Hosea**
Home Department and supervisor: Department of Mechanical and Industrial Engineering,
DrJoseph Kihedu
Host Department and supervisor: Department of Energy and Process Engineering
Prof. Armin Hafner

Period: 2021-2023 (full time master)

Title: MSc in Sustainable Energy use in buildings

Summary

All semesters were attended at NTNU, from autumn 2021 to autumn of 2022 the following courses were completed; Energy management in buildings, Energy performance in buildings simulation, Indoor environment, Life cycle analysis, Impact indicators for decision making, Heat pumps, Sustainable food processing, Refrigeration technology, Project management and HVACS.

A master's thesis was written during spring of 2023 in which the title of the Thesis was **Designing and Implemetation of a plate freezer test facility applying R744 at -50°C**.
The test facility was designed with simulation provided using Modelica, 3D Solidworks diagram was developed, BOQ , P&ID for installation and operation purposes was developed and a draft of a scientific paper was included as well.