AØO fordypningen høsten 2024

Anvendt økonomi og optimering - fordypning

Fordypningstilbudet til studentene er en spesialisering innenfor økonomisk analyse og optimering som hovedsakelig er rettet mot industrielle og teknologiske anvendelser. De som velger denne fordypningen må velge både emnene og prosjektet som hører til fordypningen. Studentene spesialiserer seg ofte innenfor følgende temaer: bedriftsøkonomisk analyse, modeller og verktøy for å styre og koordinere industrielle verdikjeder, selskapsmodeller for analyse og styring av industrikonsern, økonomisk optimalisering av industrielle prosesser, transportoptimering, logistikk, analyse og beslutningstøtte rettet mot energimarkedene, etc.

Fagområde:

De aktuelle veilederne underviser og forsker innenfor

- Bedriftsøkonomi,
- Industriell økonomi,
- Optimering/operasjonsanalyse.

Vi fokuserer spesielt på tverrfaglig forskning som involverer flere av disiplinene over. Vi fokuserer på forskning og undervisning rettet mot industrielle og teknologiske anvendelser.

Mulige veiledere:

- *Professor Henrik Andersson, tlf. 90 07 49 68, e-mail: henrik.andersson@ntnu.no*
  I work with developing models and solution methods for different industrial applications. I have worked on applications within transportation and logistics, healthcare and emergency response among others. My main research focus is on exact methods and matheuristics, but I also like to mix this with machine learning and artificial intelligence. I have been at IØT since 2007 and have supervised more than 50 student groups.
- *Adjunct Associate Professor Stian Backe, tlf 48 18 38 19, e-mail: stian.backe@ntnu.no*
  I work with operations research methods applied to the energy sector, including stochastic programming, scenario generation, and model linking. I also work as a research scientist at SINTEF Energy, where we collaborate with industrial partners and other research institutes to study interesting challenges in the green energy transition. I have a PhD from NTNU-IØT, and a MSc in Energy and Optimization from University of Bergen. I have previously supervised several master students, and I am currently teaching Experts in Teamwork.
- *Forsker Steffen Bakker, tlf. 92 14 54 29, e-mail: steffen.bakker@ntnu.no*
  Jeg jobber med å anvende ulike kvantitative metoder (heltalls-/dynamisk-/stokastisk programmering, realopsjoner, økonometri) på problemstillingene som er relevant for industrien/samfunnet. Anvendelsesområdene ligger som regel i grensesnittet mellom transport- og energisystemer. Jeg har en doktorgrad i industriell økonomi / operasjonsanalyse, samt en mastergrad i økonometri, og har både veiledet og undervist på INDØK-studiet.
- *Forsker Mostafa Barani; tlf. 73558997, e-mail: mostafa.barani@ntnu.no*
  My current research mainly focuses on the long-term planning of energy systems, including scenario development, and modeling practices, as well as analyzing the results and policy making. My interests include optimization, energy and power systems planning, stochastic programming, statistics, and quantum computers."
- *Førsteamanuensis Peter Berling, e-mail: lars.p.berling@ntnu.no*
  In my research I work on developing models and methods to support operational and tactical decision making under uncertainty and risk. A special focus has been devoted to inventory control and the interface between operations and finance, but it also includes research on related fields such as transportation and contracts. I have been at IØT since the summer 2021 and have previous experience from Lund and Linnaeus University as well as MIT/ZLC.

- *Førsteamanuensis Pedro Crespo del Granado, tlf. 458 49 710, e-mail: pedro@ntnu.no*
  Han jobber i skjæringspunktet mellom energiøkonomi, energiomstilling, kraftsystemer, operasjonsforskning, AI (Model Predictive Control) og dataanalyse. Han jobber med virkelige anvendelser av optimaliseringsmodeller ved å koble akademisk forskning med norsk industri og europeiske forskningsprosjekter.
- *Professor Ruud Egging-Bratseth, e-mail: ruude@ntnu.no*
  Ruud arbeider i grenseflate av kvantitativ bedriftsøkonomi og operasjonsanalyse; og driver med beslutninger under usikkerhet; metodeutvikling og casestudier. Anvendelser handler ofte om omstillingen til lavutslippssamfunnet, med fokus på innpasning av fornybare energikilder i energisektoren.
- *Professor Kjetil Fagerholt, tlf. 97 56 84 97, e-mail: kjetil.fagerholt@ntnu.no*
  Han arbeider innen generell operasjonsanalyse/optimering. Anvendelser er ofte innenfor (maritim) logistikk og transport. Typiske oppgaver vil gjerne ha fokus både på modellering av det aktuelle problemet (som gjerne også kan kreve noe ingeniørkunnskap), samt utvikling av løsningsmetoder for dette. På metodesiden er både med eksakte og heuristiske løsningsmetoder aktuelle, samt ulike metoder for håndtering av usikkerhet om det er viktig i det aktuelle problemet.
- *Førsteamanuensis Anders N. Gullhav, e-post: anders.gullhav@ntnu.no*
  Jeg jobber med operasjonsanalyse og anvender og utvikler modeller og metoder for å løse reelle planleggingsproblemer. Jeg har jobbet med anvendelser innen flere industrielle sektorer, men har et spesielt fokus på helsesektoren. Oppgavene jeg veileder kan innebære å utvikle deterministiske optimeringsmodeller og avanserte løsningsmetoder (inkl. heuristikker), men kan også innebære å håndtere usikkerhet, for eksempel gjennom å kombinere optimering med simulering. De siste par årene har jeg også interessert meg for problemstillinger knyttet til kombinasjon av optimering og maskinlæring. Jeg har også en bistilling ved St. Olavs hospital hvor jeg jobber som prosjektleder og benytter operasjonsanalyse i praksis.
- *Researcher Kais Msakni, Phone. 73 55 97 83, e-mail: kais.msakni@ntnu.no*
  I work on optimization and operations research problems with deterministic and (to a lesser extent) stochastic aspects. The applications are mainly related to transportation, typically solved using mathematical modeling and solution methods. I have recently become interested in machine learning used for predictions and its potential to help to solve combinatorial optimization problems. I joined the IØT department in 2018 and supervised several master's students.
- *Prof. Dr. Anne Neumann* is full professor at the Department of Industrial Economics and Technology at NTNU and Director of Research for NTNU's Energy Transition Initiative (NETI). Previously she worked as Senior Researcher in the Department Energy, Transport, Environment at DIW Berlin, was Professor for Economic Policy at the University of Potsdam and Assistant Professor at NHH Bergen. Her research experience of 15+ years draws on industrial organization, competition economics and econometrics and has provided academic as well as policy relevant publications and advice. From 2014 until 2018 she served as Vice-President for Publications in the International Association for Energy Economics (IAEE; *The Energy Journal)*, is currently on the International Advisory Board of *Energy Policy* and on the Editorial Board of *Economics of Energy and Environmental Policy*. She has participated in several interdisciplinary EU projects, projects funded by the German Ministry for Education and Research and commissioned studies. Anne has international teaching experience, (co-) supervised PhD students from several universities and developed research agendas across disciplines. She studied economics at the European University Viadrina in Frankfurt/Oder and holds a PhD in economics from TU Dresden.
- *Forsker Paolo Pisciella; paolo.pisciella@ntnu.no*
  Jeg jobber med økonomiske analyser for avkarboniseringstiltak. Jeg har erfaring med likevektsmodeller, bi-level modeller og stokastiske modeller med applikasjoner innen

makroøkonomi, kraftnetts problemer, og fleksibilitet. Typiske analyser som jeg utfører er relaterte på påvirkninger for avkarboniseringstiltak innen Norske og Europeiske økonomi, BNP, utvikling på merverdi i de ulike næringer, pris og etterspørsel etter ulike goder og tjenester. Jeg er også interessert i algoritmer for å lenke økonomiske- og energi-modeller og metoder for å beregne erstattingselastisiteter mellom inngangsfaktorer i næringer.

- *Associate Professor Peter Schütz, phone: 73 59 35 85, email: peter.schuetz@ntnu.no*
  My research focuses on developing and applying methods from Operations Research to deal with uncertainty in real-world decision problems. Students I supervise often use stochastic programming, but other approaches for providing decision support are common too, e.g. combining deterministic optimization with simulation, deterministic optimization in a rolling horizon setting, or machine learning. Applications are usually within the rather wide field of quantitative logistics, covering both production and transportation planning.
- *Sarka Stadlerova; e-mail: sarka.stadlerova@ntnu.no*
  I am a Postdoc at the Department of Industrial Economy and Technology Management. I hold a master's degree in Mathematics and finance studies from the University of West Bohemia and a PhD in Industrial Economics and Technology Management from NTNU. My research focuses on the application of operations research methods to Location science. Specifically, my PhD was related to deterministic as well as stochastic facility location problems with capacity expansion. Now, during my postdoc, I focus on location-routing problems for aquaculture zero-emission vessels.
- *Professor Magnus Stålhane, tlf. 73 59 08 11, e-mail: Magnus.Staalhane@ntnu.no*
  Han arbeider innen fagfeltet operasjonsanalyse med fokus på anvendelser innenfor transport og logistikk, med særlig interesse for operasjonelle problemer som ruteplanlegging. Interesseområdene metodisk inkluderer eksakte og heuristiske løsningsmetoder for blandede lineære heltallsmodeller. Har siden 2013 veiledet 36 masteroppgaver, med over 70 masterstudenter.
- *Professor Asgeir Tomasgard* forsker på tekno-økonomiske modeller basert på stokastisk optimering. Mange av anvendelsene er innenfor energisystem, energimarkeder, klimapolitikk og energipolitikk. Asgeir er interessert både i modellering, analyser og algoritmeutvikling. Han leder instituttets High Performance Computing lab og har spesiell interesse for dekomponeringsalgoritmer basert på distribuert beregning. Når det gjelder modellering er han spesielt interessert i hvordan usikkerhet påvirker valg både på kort og lang sikt, samt virkemiddelutforming og markedsdesign for industrielle verdikjeder.
- *Dr Hongyu Zhang* is a Researcher (permanent position) at Norwegian University of Science and Technology (NTNU). He received a PhD degree in Operational Research under the supervision of Professor Asgeir Tomasgard (NTNU), Professor Ignacio E. Grossmann (Carnegie Mellon University) and Dr Brage Rugstad Knudsen. He held an MSc degree in Operational Research with Data Science from The University of Edinburgh in 2020, and a BSc degree in Mathematics and Applied Mathematics from Huaqiao University in 2019. His research interests include: (1) stochastic programming in the investment planning of energy systems, (2) decomposition algorithms for large-scale optimisation problems, and (3) large-scale system analysis regarding power, natural gas, hydrogen, and carbon capture and storage among others. More information can be found at www.hongyuzhang.com. Contact information: Tel: +47 46894583, email: hongyu.zhang@ntnu.no

I tillegg vil andre ph.d. stipendiater, post doktorer og evt. bedriftskontakter kunne inngå som medveiledere.

Forutsetninger for å velge AØO fordypning:

De studentene som høsten 2024 skal ha fordypningen "Anvendt økonomi og optimering" må ha tatt:

- TIØ4130 Optimeringsmetoder med teknisk-økonomiske anvendelser
- TIØ4150 Industriell optimering og beslutningsstøtte
- TIØ4285 Produksjons- og nettverksøkonomi

I tillegg til prosjektet må også fordypningsemnet *TIØ4505 Anvendt økonomi og optimering, fordypningsemne* velges.

Prosjektoppgaver høsten 2024 innen Anvendt økonomi og optimering:

Beskrivelsene av problemene er ment som en hjelp for å velge oppgave. De er ikke ment som komplette oppgavetekster. Det vil heller ikke bli laget noen oppgavetekst. Oppgaven vil bli til underveis i diskusjon mellom studenter, veileder(e) og eventuell bedriftskontakt. Oppgaven som velges skal i utgangspunktet videreføres i masterprosjektet. Erfaring har vist at studenter som gjør prosjekt- og masteroppgave i tilknytning til samme problemstilling blir mest tilfreds. Derfor ønsker vi ikke å gi prosjektoppgaver som vi ikke tror at det finnes en masteroppgave-oppfølging til.

Webskjemaet innebærer et valg av fem ulike oppgaver i prioritert rekkefølge. Studentene må velge oppgaver med minst tre ulike hovedveiledere (nevnt først blant veilederne i beskrivelsene nedenfor). Studentene må forvente å få tildelt hvilket som helst av disse, inkludert 5. valget.

Eventuelle studenter som har funnet oppgave selv og deretter funnet en eller flere veiledere blant de tidligere nevnte aktuelle veilederne som sier seg villig, skal velge AØO01 i webskjemaet. Det understrekes imidlertid at en skal først ha en avtale med minst en veileder før dette kan velges. Det må i så fall også oppgis potensielle veiledere i webskjemaet. Velg kun dette som en av prioritetene, og ikke på flere prioriteter. Det er ikke sikkert at en student blir tildelt en egendefinert oppgave. Dette avhenger av den totale ressurssituasjonen blant veilederne.

Der hvor det står to eller flere mulige veiledere skal dere i søkefasen primært snakke med den som står først, dette er hovedveilederen. Det er ikke mulig å ønske seg eksplisitt en av veilederne blant de som er listet. Der det er angitt kontaktpersoner i samarbeidsinstitusjoner skal disse ikke kontaktes før det eventuelt er gitt klarsignal fra oppgitt veileder (med mindre annet er angitt i oppgaveteksten).

I prosessen med tildeling av oppgaver vil det tas hensyn til fordelingen mellom de ulike veilederne og studentenes prioritering. Der en person står som veileder på mange oppgaver, kan det tenkes at personen ikke vil ha kapasitet til å ha studenter på alle oppgavene. Dersom dette blir tilfelle kan en annen veileder bli tildelt av de som står listet i oppgaveteksten. Vi vil enda en gang understreke at dersom det er mange studenter som har valgt de samme oppgavene, må en være forberedt på at en får tildelt oppgave som står lenger ned på prioriteringslisten.

Det er sterkt anbefalt at studentene utfører arbeidet i grupper på to studenter, selv om det er mulig å være 1 eller 3 studenter i en gruppe. Vi anbefaler at dere selv finner en student å samarbeide med i prosjektet.

Det kan også være mulighet for å fortsette på doktorgradsstipend i etterkant av mastergraden. Dersom noen ønsker å forhøre seg om muligheten for dette, anbefaler vi at de tar kontakt med de aktuelle veiledere, helst så snart som mulig.

Contents

AØO01: Egendefinert studentprosjekt

Studenter som finner et prosjekt selv og deretter finner en faglærer som vil veilede det egendefinerte prosjektet, bruker tittelen over for å angi et slikt valg i det webbaserte valgskjemaet. Avtale med veileder må være gjort før valget gjøres på web. **Veileders navn må stå i kommentarfeltet i webskjemaet.**

AØO02: A sea-based bunkering system for supplying Norwegian deep-sea fishing vessels with green fuels.

The Norwegian deep-sea fishing fleet comprises approximately 260 vessels. Although these vessels represent only 5% of the total fleet, they count for about 84% of the total fish catch [1]. They are also responsible for 75% of the fleet's total CO_2 emissions. A recent study shows that to meet greenhouse gas emission reduction targets of 2030 and 2050, it is crucial to start renewing the deep-sea vessels with low- and zero-emission propulsion systems [2].

Transitioning deep-sea vessels to zero-emission alternatives presents significant challenges, particularly due to the limited range of fuels like hydrogen and ammonia. These alternatives have a lower energy density compared to conventional fossil fuels, making current long-range sailing patterns impractical. The reliance on fossil fuel for towing operations, which are necessary for bringing vessels that have stayed out at sea back to port, further complicates the transition. Moreover, the fuel consumption pattern of deep-sea vessels is irregular, as they continue sailing until a fish catch is secured, and operations of fishing gear consume significant energy. For these reasons, innovative bunkering solutions are required to efficiently supply deep-sea vessels with zero-emission fuels.

Given that deep sea vessels sail far from coastal bunkering facilities, one novel approach consists of using large bunkering vessels. These vessels would refuel at coastline points and then sail to the open sea to supply fishing vessels at sea. This master project aims to design a reliable refueling system based on the bunkering vessel concept. Key research questions include: What routes should these vessels take? How many vessels are required to ensure a continuous supply of green fuels to all deep-sea fishing vessels? Where to locate the refueling points at sea for optimal access for both bunkering and fishing vessels?

The project involves the following tasks:

- Collect tracking AIS data for Norwegian deep-sea fishing vessels to analyze their sailing patterns
- Collect additional necessary data, including potential bunkering locations in the deep sea
- Develop a mathematical model to create a reliable sea-based bunkering system
- Conduct a computational study and assess the obtained results to test hypothesis related to the research questions.

This project is part of the research project ZeroKyst https://zerokyst.no/. Knowledge of optimization and programming skills (like Python) is expected.

Collaboration: ZeroKyst-project (ZeroKyst - SINTEF), SINTEF Ocean

Main supervisor: Kais Msakni

Co-supervisor: Peter Schütz

Strategic research initiative: Leading transitions: Co-create a sustainable future / Green Value Creation - Circular Economy

For more information, please contact Kais Msakni, kais.msakni@ntnu.no, to schedule a meeting.

References

[1] Directorate of Fisheries (2022), 'Utvikling i redskapsbruk', https://www.fiskeridir.no/Yrkesfiske/Tall-og-analyse/Fangst-og-kvoter/Fangst/Fangst-fordelt-paa-redskap. [Accessed 07-Feb-2023].

[2] Helle Hagli Sønnervik (2023), 'Strategic Fleet Renewal of Norwegian Fisheries with Environmental Considerations', Master thesis in Industrial Economics and Technology Management, NTNU.

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AØO03: Agent-Based Model for Families choosing Low Emission Cars

The transport sector is a major source of CO2 emissions and other pollutants. In recent years, electric vehicles have become increasingly popular in Norway, largely due to subsidies but also because of increasing environmental awareness of the population. However, for historical reasons, a large part of the passenger car fleet is fossil-fuel driven still. Furthermore, a significant share of newly bought cars is of the plug-in hybrid type, rather than fully electric, which means that for longer distances they still use fossil fuels.

In the last twenty years, the policy focus has shifted from promoting diesel cars (which have lower CO2 emissions per km than petrol cars, but are far worse considering other polluting emissions) to promoting partial and fully electric cars. Alternative low carbon options, such as hydrogen-fueled cars, have hardly gained market share. Policies concern mostly direct subsidies on purchasing, ownership, and usage, including no or reduced toll and parking fees, and non-monetary benefits such as access to public transport lanes.

For many people, costs are not the only, or not even the main motive to choose a specific car type. People have transportation needs related to work and leisure activities, which concern traveling distances and frequencies, the number of persons, and the amount of baggage that must be transported. Access to public transport varies regionally, and for some trips going on foot, bike, or e-scooter may be viable. Some people have strong preferences for specific car brands. A car may be the main car, the second car, or even the third or higher.

We have several longitudinal data sets from Statistics Norway (SSB) and other sources, covering car ownership, car purchase transactions, detailed car types, and various socio-economic and policy data. We use these data sets to estimate behavioral, economic drivers, and other preferences to explain the car purchase choices made by individuals and households. PhD candidate Davood is currently working on a large-scale statistical analysis of these data (where students may contribute if they are interested). Using the estimated relations determining car purchase decisions, the students working on this project will develop an Agent-Based Model to analyze the development of car purchases and car ownership until 2050, with a particular focus on policies that can facilitate a cost-effective transition to a low carbon transport sector. In the model, representative households will be represented with their socio-economic characteristics, transportation needs, and car choice preferences. The aim is to analyze how different policies and other exogenous factors (including car and fuel availability and prices) affect these choices and the resulting car fleet composition.

Activities: Develop an agent-based model for families choosing low emission cars

Software: Dependent on student preferences, this can be developed from scratch in Python, or using open source software packages such as Mesa in Python 3+ (https://github.com/projectmesa/mesa) or NetLogo (https://ccl.northwestern.edu/netlogo).

Main supervisor: Ruud Egging-Bratseth

Co-Supervisor: PhD candidate Davood Qorbani

This project is connected to: the Research Center for Norwegian Energy Transition Strategies (FME NTRANS www.ntrans.no)

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AØO04: Algoritmer for storskala stokastisk optimering

Gjennom vårt industrisamarbeid har vi ulike modeller fra havbruksnæringen og energisektoren med et stort behov for utvikling av raskere algoritmer. Modellenes størrelse eksploderer ofte som en konsekvens av modellering av usikkerhet i noen av inputparametrene, for eksempel pris eller etterspørsel. Usikkerheten representeres inn i modellene ved hjelp av scenarier i multi-stegs stokastiske formuleringer. Anvendelsene leder ofte til formuleringer med heltallsvariable, så dette kan også sees på som storskala mixed integer modeller. I denne oppgaven kan man se på håndtering av usikkerhet gjennom stokastisk programmering. Studentene vil benytte IØT sitt beregningscluster for distribuert prosessering med 2700 prosessorer tilgjengelig. Algoritmene vil i hovedsak være rettet inn mot dekomponering for å utnytte underliggende struktur i problemene blant annet basert på scenarioformuleringene. Det er meningen å knytte arbeidet opp mot et prosjekt vi er i ferd md å starte sammen med Massachusetts Institute of Technology på Multiscale stochastic optimization.

Oppgaven krever interesse for optimering, algoritmeutvikling, programmering og vil skreddersyes for de studentene som velger oppgaven med tanke på fokus og underliggende anvendelse.

Veileder: Asgeir Tomasgard

Co-Supervisor: Forsker Hongyu Zhang

Collaborator: MIT ved Audun Botterud/Andy Sun

Strategic research initiative: NTNU Energy Transition Initiative

AØO05: Analyzing the requirements for profitable hydrogen production

Hydrogen is expected to play a major role in the transition to a low-emission or even zero-emission society, due to its versatility and potential for clean energy production. However, for hydrogen to make a substantial impact, it needs to be produced in a clean manner, as traditional hydrogen production is associated with considerable CO2 emissions. The main challenge lies in scaling up clean hydrogen production and bringing down costs to make it an attractive alternative to fossil energy carriers.

The purpose of this project is to carry out a techno-economic analysis to identify minimum requirements for profitable hydrogen production. One main assumption for the analysis is fossil parity for the price of hydrogen, i.e. hydrogen is sold at a price equal to relevant alternative fossil energy carriers. Important questions to be answered by the analysis can be

- What is the minimum production volume for a hydrogen production facility to break even?
- How different will minimum production volumes be for green and blue hydrogen?
- What is the impact of volatile electricity prices on break even and minimum production volumes?
- How does the type of produced hydrogen (e.g., compressed hydrogen 350 or 700 bar, liquid) impact profitability?

Tasks within the project usually include:

- Understand the problem and define its scope
- Review the literature and study existing methodological approaches
- Select/develop and implement a suitable methodological approach for the problem
- Collect data and set up relevant case(s)
- Solve the case(s) and analyze the results

Industry partner:	NTE Energi (www.nte.no)
Main supervisor:	Peter Schütz
Strategic research initiative:	Leading transitions: Co-create a sustainable future
	Sustainability

For more information, please contact peter.schutz@ntnu.no to schedule a meeting

AØO06: Bemanningsplanlegging på St. Olavs hospital

Helsepersonell er bærebjelkene i helsevesenet vårt. I likhet med mange andre land har Norge en aldrende befolkning som bidrar til å øke presset på helsetjenestene. Samtidig som at befolkningen blir eldre, minker andelen i yrkesaktiv alder og konsekvensene av demografiske forandringer er at det blir flere pasienter på relativt færre hender.

St. Olavs hospital er et av landets største sykehus og er avhengig av å utnytte sine ansatte godt og samtidig være en attraktiv arbeidsgiver som tiltrekker seg og holder på helsepersonell. I et historisk perspektiv har sykehuset manglet kompetanse på ressursplanlegging, men planlegging av personell er nå satt høyt på agendaen i sykehusets ledelse. Studentene som velger denne oppgaven vil få anledning til å tilegne seg kompetanse og innsikt i en sektor som vil være avhengig av bedre ressursplanlegging i årene som kommer.

Forskningsområder: Det overordnede temaet er bemanningsplanlegging i helsesektoren fra et optimeringsståsted. På strategisk nivå kan det dreie seg om å finne metoder for å estimere pleietyngde på en sengepost, og lage bemanningsplaner basert på den forventede pleietyngden. Det kan også innebære å dimensjonere bemanningspooler for å håndtere svingninger i personellbehov som konsekvens av høyt fravær eller økt aktivitet. På operasjonelt nivå er turnusplanlegging sentralt. Her skal sykepleiere planlegges til dager og skift gjennom uka, slik at bemanningsplanen innfris samtidig som at arbeidsbelastningen på den enkelte sykepleier ikke blir for høy. Det fins flere akademiske modeller for turnusplanlegging, men det er utfordrende å lage modeller som kan implementeres på et sykehus. En god modell skal være fleksibel nok til at flere avdelinger med noe ulike konfigurasjoner skal kunne bruke den.

Prosjektet vil tilknyttes en eller flere klinikker hvor det finnes tilgjengelige data. Endelig problemstilling og klinikktilknytning avklares i samråd med veiledere og St. Olavs hospital.

Oppgaver i arbeidet kan innebære:

- Opprette kontakt med en relevant avdeling på St. Olavs hospital og få innsikt i dagens planleggingsrutiner og utfordringer
- Identifisere et konkret problem å jobbe videre med
- Foreta en litteraturgjennomgang for å kartlegge hvorvidt problemet er studert tidligere
- Avgrense og beskrive planleggingsproblemet
- Utvikle simulerings- og optimeringsmodeller for problemet
- Implementere av modellen(e) ved hjelp av egnet programvare, analyse og testing av instanser basert på data fra St. Olavs hospital.

Collaborator:	*Tjenesteinnovasjonssenteret på St. Olav* (TIPS) er en enhet på St. Olavs hospital som støtter avdelinger I prosjekter relater til tjenesteinnovasjon og ressursplanlegging. Det er 14 personer ansatt på TIPS, og fire av disse har bakgrunn fra IØT og har doktorgrad i operasjonsanalyse.
Main supervisor:	Anders N. Gullhav
Co-supervisor:	Thomas Reiten Bovim
Strategic research initiative:	Health and the Public Sector

For more information, please contact Anders Gullhav, anders.gullhav@ntnu.no, to schedule a meeting.

AØO07: Beyond GDP: Reassessing Europe's Decarbonization Pathways through the Lens of Well-being

Transitioning towards a sustainable energy system is crucial for mitigating climate change. Traditional macroeconomic indicators, however, such as GDP growth and consumption price indices, do not fully capture the societal impacts of such policies. This project proposes to refine the REMES-EU Computable General Equilibrium (CGE) model to include well-being indicators, providing a more comprehensive analysis of decarbonization scenarios in Europe. By incorporating multiple household types and focusing on distributional issues, this research aims to evaluate the equity of decarbonization efforts beyond mere economic growth. This project aims to extend the REMES-EU CGE model to a multihousehold structure and to connect its outputs to well-being indicators, reflecting a broader range of societal impacts including health, income disparity, energy affordability, leisure time, and social justice. Subsequently, the aim will be to analyse the well-being impacts of various well established decarbonization scenarios to identify policies that ensure environmental sustainability while promoting societal well-being.

Activities:

Adapt the REMES-EU CGE model to include multiple households and labour segments, categorized by income, skill, age, and gender, to assess distributional impacts. Connect the output of the models to indicators that can be mapped to relevant UN Sustainable Development Goals (SDGs). Evaluate established decarbonization scenarios using the enhanced model, reassessing their impacts considering well-being indicators. Assess the effectiveness of policy instruments in promoting both environmental objectives and equitable well-being outcomes.

Pre-requisites:

A strong foundation in economic modelling and welfare economics. Proficiency in programming (GAMS) and data analysis tools. Interest in the intersection of environmental policy, sustainable development, and societal well-being.

Collaboration: The thesis is linked to the EU Project MultiFutures.

Supervisor: Paolo Pisciella

Questions and clarifications: paolo.pisciella@ntnu.no

References:

[1] Wilts, Rienne, and Wolfgang Britz. "Quantifying SDG indicators for multiple SSPs up to 2050 with a focus on selected low and low-middle income countries and the bio-economy based on CGE analysis." (2022).

[2] https://knowsdgs.jrc.ec.europa.eu/intro-models

AØO08: Blood preparedness for armed conflict

The Russian invasion of Ukraine fundamentally altered the security dynamics in Europe, prompting NATO nations to revisit the defence strategies of the Cold War. Civil and military preparedness and resilience are areas of rapid development.

The Norwegian blood banks are updating their emergency preparedness plans with the prospect of major joint military operations on Norwegian soil as the dimensioning scenario.

Blood is a necessity in the treatment of trauma victims, but due to limited shelf life it is not practical to store it in large quantities in the preparation for war. Limiting factors in the collection of large quantities of blood could be qualified labour, available blood donors, available equipment or consumables, refrigerated storage space or other unknown factors. The limitations may change depending on method of production.

The student(s) in cooperation with NTNU will define the problem in greater detail.

Research questions may include:

- Development of a simulation model for optimization of blood production in crisis.
- Identification of bottlenecks in the mass production of blood products.
- Identification of limiting factors for the sustained production of blood products.
- Comparison of production of blood components vs. whole blood.

Method/tasks:

- Define and scope the problem
- Review current literature for similar problems
- Develop optimization and simulation models for capacity optimization
- Run simulation and optimization models on real-life and/or mockup data and present recommendations.

Industry partner:	Norwegian Centre for Blood Preparedness
Main supervisor:	Henrik Andersson
Co-supervisor:	Anders Gullhav
Industry Co-supervisor:	Christian Medby (Norwegian Armed Forces/St Olavs), Oddvar Uleberg (St Olavs)
Strategic research initiative:	Health and the Public Sector

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no, to schedule a meeting.

AØO09: Collaborative Supply Vessel Planning in Offshore Oil and Gas Logistics

More than a quarter of today's global oil and gas (O&G) supply is produced offshore, and Norway is the world's third largest exporter of natural gas. With the oil and gas demands likely to remain high in the coming decades, the level of offshore activities on the Norwegian continental shelf is expected to remain high – way into the future. Greenhouse gas (GHG) emissions from the Norwegian petroleum industry are among the lowest in the world (though still the largest single source to the domestic emissions), and the industry has put forward ambitious goals for reducing emissions further.

The production of oil and gas on the Norwegian continental shelf takes place at offshore installations owned and controlled by different operators. Specialized platform supply vessels are used for servicing the installations with commodities needed for stable and continuous production. In current practice, each operator controls its own fleet of PSVs, and each installation is serviced from a dedicated supply base (among several) along the Norwegian coast, and each installation requires a specified number of visits/services per week from the fleet of PSVs.

In this project, we will explore how costs and GHG emissions from offshore logistics can be reduced by collaboration among operators through sharing of their vessels and supply bases. According to industry partners and researchers on the field, the trends of sharing information and resources (vessels and supply bases) can be a potential "game changer" in offshore logistics: Today, an O&G operator may for example have to charter 3 vessels if the actual need is 2.4 vessels. Another operator might arrange its logistics the same way, resulting in lower utilization of vessels and thus, higher emissions and costs. Chartering rates for supply vessels are very high (up to 25 000 USD/day), and some preliminary analyses indicate that such resource sharing represents a cost saving potential of 4 billion NOK – yearly.

To address the above questions, we aim in this project at developing optimization models and solution algorithms (e.g., exact based on decomposition and/or heuristic) for the Collaborative Supply Vessel Planning Problem (CSVPP). The CSVPP extends from the well-studied Supply Vessel Planning Problem (SVPP), which is in itself a complex planning problem involving decisions about 1) fleet size and mix of PSVs to charter in and 2) weekly routes and schedules of the PSVs. In the CVSPP, we extend the SVPP by also considering the mentioned collaborative aspects.

The master project will be a part of the ZEROLOG project, which is in collaboration with SINTEF Ocean, Equinor, and several other industry actors. These companies will also contribute with relevant input data. Potential topics that may be included in the project and master thesis are:

- Study existing approaches for the SVPP and in collaborative transportation planning
- Propose a mathematical model for the CSVPP
- Develop and implement an efficient (exact or heuristic) solution algorithm for the CSVPP
- Based on real data from large-scale case studies in the North Sea, investigate the effects of collaborative planning, both on the costs and the emissions from the operations
- Study the implications of using alternative non-fossil fuel technologies for PSVs

Collaborators: SINTEF Ocean and industry partners (e.g., Equinor)
Main supervisor: Kjetil Fagerholt
Co-supervisor: Andreas B. Ormevik (SINTEF Ocean and post. doc. in the ZEROLOG project)

Strategic research initiative: Leading transitions: Co-create a sustainable future

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et møte.

AØO10: Decision support for low-carbon ship refueling in ports

Maritime transport plays a crucial role in global trade, handling around 80% of total volume. This sector is also responsible for approximately 3% of global Greenhouse Gas emissions [1]. In light of the international commitments to achieve Climate neutrality by 2050 as set by the Paris Agreement, also ships will have to transition from using carbon-intensive to low-carbon fuels. The transition towards a decarbonized sector does not only entail equipping ships with low and net-zero carbon technologies but also significantly impacts the fuel market landscape. With the anticipated expansion of low- and net-zero carbon fuels, ports are strategically positioned to lead in decarbonization efforts.

Ports will have to transition to offer low- and zero-carbon fueling options for ships. The integration of new fuels into ports can be done by cables or pipelines or supplier ships for fuel delivery. Additionally, ports have some potential to engage in production of alternative fuels, taking advantage of the proximity to renewable energy resources (e.g., offshore wind), water access, and connections to significant industry clusters.

The project thesis aims to develop a decision support tool for the creation of strategic roadmaps for a port or several ports in a region to meet emission reduction targets of 2030 and 2050. Backdrop for the analyses are supply and demand scenarios for renewable energy and hydrogen-based fuels, such as ammonia, in North-West Europe. The strategic roadmap will inform the timing and sizing of port fueling infrastructure in the context of the local energy system(s). The research questions can be: What type of fuel technology should a port offer for bunkering? Which supply method should a port invest in based on costs and effectiveness? Should ports invest in fuel production, or should their role remain in providing bunkering services? What are the financial implications for shipping decarbonization for ports?

The project can include the following tasks:

- Review relevant literature on fleet decarbonization.
- Collect data and possibly discuss with stakeholders.
- Develop a decision support tool that suggests a decarbonization plan for ports.
- Perform computational experiments to test the tool with various port needs and settings.
- Analyze the results and assess the broader implications of implementing the suggested transition plan, including potential benefits and drawbacks for port operators.

This project is part of the research project NordH2ub https://csei.eu/nord_h2ub/. Knowledge of mixed integer optimization and programming skills (like Python) is expected.

Main supervisor: Ruud Egging-Bratseth

Co-supervisor: Kais Msakni

Strategic research initiative: Leading transitions: Co-create a sustainable future / Green Value Creation - Circular Economy

For more information, please contact Ruud Egging-Bratseth, rudolf.egging@ntnu.no, to schedule a meeting

AØO11: Dynamic and Just-in-Time Electricity Price Formation: Exploring Innovations for Future Power Systems

The current electricity prices (aka spot prices) are fixed in a day-ahead fashion, hence planning the operation of the electrical system despite the large uncertainties that will eventually affect it. Uncertainties are therefore dealt with using additional and costly markets dedicated to tackle the mismatches between production and demand as they arise. Moreover, the prices are fixed in a *static* fashion, i.e. (fairly) independently from each other across time. The development of flexible demand and short-term storage capacity (battery) may challenge this static approach.
In this project, we aim at exploring novel ideas to form electricity prices, better suited for the future power system where consumers become prosumers, provide flexible demand, energy storage capacity, and possibly participate in forming the prices. Two innovations will be explored, 1) the formation of prices in a *dynamic* fashion, accounting for and optimizing with the interdependence in time of the prices arising from flexible demand and short-term storage, and 2) a “just-in-time” (JIT) price formation whereby the prices are updated up to the very last moment, typically in a rolling-horizon optimization fashion, accounting for the latest information on the status of the system. The goal of the JIT approach is to avoid the issues associated with long-term planning, and therefore reduce the costs associated to uncertainties.

The activities of the project will consist in:

1. Understanding the concepts underlying the dynamic and “JIT” spot prices, including the associated optimization algorithms
2. Implement these concepts in simulation on a model of energy producers and prosumers with energy trading, e.g., of the scale of a virtual energy community
3. Compare the dynamic / JIT approach with a more conventional price formation mechanism, and asses the performance gains."

Requisites: Programming skills (Python). Critical thinking and analytical skills. Curiosity on energy transition and energy system modelling

Supervisors: Pedro Crespo del Granado

Co-Supervisors: Sebastien Gros

Questions and clarifications: pedro@ntnu.no

AØO12: Dynamic management of energy storages in a large scale energy system model

The EMPIRE model is a stochastic European power market model developed at NTNU. It manages both capacity expansion, in terms of investments in cables and generation and operations of the power system in Europe. It can be categorized as a large scale multihorizon stochastic linear programming model. In this project we would like to improve the management of assets that has a seasonal perspective, like storages anf hydro power reservoirs. The work is motivated by the substantial role of hydropower in an evolving power system. With increasing volumes of renewables in Europe and Norway and the links between the power sector an hydrogen production, the seasonal dimension in security of supply is increasingly important. We introduce dynamic modelling of energy storages and hydro reservoirs as well as pumped hydro generation into a separate module in EMPIRE.

Needed background: strong interest in large scale optimization, modelling and stochasticity

Main supervisor: Professor Asgeir Tomasgard

Co-Supervisor: Forsker Hongyu Zhang

External Partner: Statkraft

Strategic research initiative: FME NTRANS, NTNU Energy Transition Initiative

AØO13: Dynamic pricing for charging battery-electric passenger vehicles

Battery-electric vehicles (BEVs) are becoming more and more popular in Norway, where they account for more 75% of new vehicles sold. Some of these vehicles will be charged at the owner's home, whereas others will rely on traditional filling stations. Charging of BEVs will change the business model of filling stations as these vehicles typically take longer to charge than gas-powered vehicles to refuel. This implies that BEVs occupy space at the filling station for longer periods of time, potentially reducing the overall revenues. In addition, the price for electricity is more volatile, impacting the costs of the filling station.

Dynamic pricing can be used both to respond to changes in the electricity prices and to provide incentives to owners of BEVs to shift their charging behavior, i.e. charge during off-peak periods. This may reduce overall waiting times and cost of charging while at the same time improve the overall utilization of charging infrastructure.

Uno-X operates more than 200 filling and charging stations throughout Norway. The importance of charging possibilities will increase in the future and Uno-X has the ambition to provide charging services at competitive prices. The use of dynamic pricing, possibly in combination with a booking system for charging slots, is considered as a possibly important component in the future business model.

The aim of this project is to develop and analyze dynamic pricing schemes for charging of BEVs. Some of the research questions that can be addressed during the work include:

- How to model and estimate the behavior of a BEV owner in response to a dynamic pricing scheme?
- How to design dynamic pricing schemes for both drop-in charging and booked time slots?
- How does volatility in the electricity price impact prices offered to the customers?
- What are the major impact factors on the dynamic pricing scheme and how should it differ between charging stations?

Tasks within the project usually include:

- Understand the problem and define its scope
- Review the literature and study existing models as well as solution methods
- Formulate and implement a model for the problem
- Collect data and set up relevant problem instances
- Solve the instances and analyze the results

Industry partner:	Uno-X Mobility (www.unoxmobility.com)
Main supervisor:	Peter Schütz
Co-supervisor:	Steffen Bakker
Strategic research initiative:	Leading transitions: Co-create a sustainable future
	Sustainability

For more information, please contact peter.schutz@ntnu.no to schedule a meeting

AØO14: Dynamic scenario generation for energy system investment planning

Long-term energy system planning faces uncertainty in short-term and long-term time horizons. For example, short-term uncertainty in renewable energy availability and long-term uncertainty in emissions targets.

Managing long-term and short-term uncertainty is important in optimising investment decisions for energy systems planning. Failing to model a relevant uncertain parameter may lead to nonoptimal or even infeasible solutions. Nearly all parameters are uncertain in the long term. However, adding too many long-term uncertainty parameters may lead to an explosion in the scenario tree and an intractable model. Therefore, it is important to design scenario trees carefully.

The process of making a scenario tree is called scenario generation. Traditionally, the scenario generation and reduction process is done before solving the problem, meaning a fixed scenario tree is used. However, it may be beneficial to adjust the scenario tree while solving the problem dynamically. In this project, students are expected to work on a novel dynamic scenario generation and reduction approach that can be applied when solving the problem. The method is potentially based on Benders decomposition. The students are expected to propose and implement the dynamic adjustment scheme and demonstrate the method on a long-term energy system planning problem.

The students can choose to work further on existing Julia code or develop their own code.

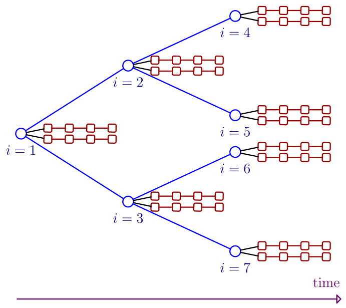


Fig: An example of a scenario tree

Prerequisites: knowledge of multi-stage stochastic programming, Benders decomposition, and Julia programming (possible to use another language).

Collaborator: Professor Ken McKinnon (The University of Edinburgh)

Main Supervisor: Dr Hongyu Zhang

Co-supervisor: Professor Asgeir Tomasgard

Strategic research initiative: Leading transitions: Co-create a sustainable future

For more information, please contact Dr Hongyu Zhang, hongyu.zhang@ntnu.no, to schedule a meeting.

References:

Michael S. Casey, Suvrajeet Sen, (2005). The Scenario Generation Algorithm for Multistage Stochastic Linear Programming. Mathematics of Operations Research, 30(3), 615-631.

Hongyu Zhang, Nicolò Mazzi, Ken McKinnon, Rodrigo Garcia Nava, Asgeir Tomasgard. (2022). A stabilised Benders decomposition with adaptive oracles applied to investment planning of multi-region power systems with short-term and long-term uncertainty. Available at arXiv:2209.03471

AØO15: Dynamisk replanlegging av prosjekter i bygg- og anleggsbransjen

I bygg- og anleggsbransjen er det viktig å planlegge byggeprosjekter, bestemme hvor og når ansatte skal utføre arbeidsoppgaver ut fra sin kompetanse og hvor og når maskiner skal brukes og transporteres så kostnadseffektivt som mulig. En utbygger jobber gjerne med flere prosjekter om gangen, som gjør at dette planleggingsproblemet blir komplekst og krevende å løse. Med tanke på at bygg- og anleggsbransjen utgjør rundt 13 % av verdens bruttonasjonalprodukt (BNP) kan en mer kostnadseffektiv planlegging av prosjekter føre til vesentlige besparelser.

Etter at en prosjekt- og arbeidsplan er utarbeidet kan det etter en viss tid oppstå uforutsette endringer som utbyggeren må ta hensyn til. Slike endringer kan for eksempel være at flere arbeidsoppgaver er nødvendige for å få fullført de pågående prosjektene og at enkelte arbeidsoppgaver vil behøve mer tid for å bli ferdigstilt. I tillegg kan det hende at utbyggeren vil avtale nye prosjekter som må gjennomføres en gang i fremtiden. Problemet blir da hvordan utbyggeren best kan utnytte de tilgjengelige ansatte og maskinene sine for at de allerede planlagte arbeidene ikke blir for forandret på når endringer oppstår. En måte å løse dette på er med dynamisk replanlegging av arbeidsoppgavene og allokeringen av de ansatte og maskinene.

En heltallsmodell som planlegger prosjekter og arbeidskraft samtidig, er allerede formulert for det deterministiske tilfellet av problemet. Denne oppgaven bygger videre på dette arbeidet ved å ta hensyn til de stokastiske hendelsene som kan forekomme i løpet av planleggingsperioden. Dette innebærer enten å utvide den eksisterende modellen eller å utvikle en ny løsningsmetode – eksakt eller heuristisk – til å løse den stokastiske utvidelsen.

Denne oppgaven kan blant annet inkludere:

- studere litteraturen for liknende problemer,
- avgrense og beskrive planleggingsproblemet,
- utvikle optimeringsmodell(er) for problemet,
- utvikle simuleringsmodell for hvordan usikkerhet påvirker planene,
- utvikle en heuristikk som utnytter strukturen i problemet,
- implementering av modellene ved hjelp av egnet programvare, analyse og testing av instanser

Anbefalte forhåndskunnskaper: Programmeringskunnskaper i språk som f.eks. Python og/eller C++ er fordelaktig.

Hovedveileder: Anders N. Gullhav

Medveileder: Brede Sørøy

Strategisk forskningsinitiativ: Leading transitions: Co-create a sustainable future

Hvis du ønsker mer informasjon om denne oppgaven, kan du ta kontakt med Anders N. Gullhav, anders.gullhav@ntnu.no, for å avtale et møte

AØO16: Economic and Well-Being Impacts of Sustainable Mobility Policies in Lofoten

In the face of climate change and environmental degradation, Norway is exploring sustainable solutions to reduce energy demand, and part of this effort can be linked to reducing the reliance on the usage of private vehicles. The role of mobility is particularly remarkable in areas like Lofoten, where the limited public transportation options and the reliance on personal vehicles can indeed contribute to environmental problems. This project aims to assess the economic and well-being impacts of policy measures targeting the shift from private mobility to more sustainable transportation options in Lofoten also in the view of a reduced future air transportation capacity, due to possible switch towards electric based transport. Such measures include promoting shared transportation services, enhancing public transport infrastructure, and encouraging remote work practices. By examining the effects on local sectors, employment levels, commodity prices, and emissions, this study seeks to provide a holistic understanding of the transition towards sustainable mobility and its implications for the local community and environment.

Activities:

Adapt the dataset used by the REMES-Norway Computable General Equilibrium (CGE) model to consider local accounting data for Lofoten. Examine the sectoral impacts of increased shared transportation and public transport use, focusing on tourism, fishing, and service sectors predominant in Lofoten. Analyse the implications of remote work policies on local businesses and employment patterns. Conduct scenario analyses to explore the effectiveness of various policy instruments, such as subsidies for public transportation, incentives for shared mobility services, and regulations promoting telework.

Pre-requisites:
Understanding of economic modelling. Proficiency in programming (GAMS) and data analysis tools (e.g., Excel Pivot Tables). Strong analytical skills and interest in energy economics, environmental policy, and sustainable development.

Collaboration:	The partners for this thesis will be Lofotrådet and SINTEF Ocean
Supervisor:	Paolo Pisciella
Industry co-supervisors:	Maren Lundhaug (Lofotrådet) and Sarah Schmidt (SINTEF Ocean)

Questions and clarifications: paolo.pisciella@ntnu.no

References:

[1] Steininger, Karl W., Birgit Friedl, and Brigitte Gebetsroither. "Sustainability impacts of car road pricing: A computable general equilibrium analysis for Austria." *Ecological Economics* 63.1 (2007): 59-69.

AØO17: Enhancing Efficiency of Container Handling in Norwegian Container Terminals through Automation Technologies

In the rapidly evolving landscape of maritime trade, optimizing port efficiency and enhancing terminal productivity through automation have become paramount objectives. The maritime sector has already experienced a noteworthy paradigm shift, with 4% of all container terminals have invested an estimated 10 billion USD in automation and adapted their processes accordingly. Over the next five years, an additional 10 to 15 billion USD will be expended. This trend indicates a broader industry movement toward adopting state-of-the-art technologies to meet the evolving demands.

Automation initiatives suggest improvements in the cargo handling, which is regarded as the most suitable process for automation. The cargo handling process includes the activities taking place in ports to transfer containers from a ship into the port area onto its next mode of transport and vice versa. Automated guided vehicles (AGVs) perform transportation activities in automated ports. They are almost exclusively electric vehicles with a charge of 6 to 8 hours and a power-down mode when not in use. Most AGVs travel on a fixed path guided by markers. A new generation of "intelligent" AGVs do not follow a fixed route allowing more freedom of movement. This flexibility, while beneficial, introduces complexities in traffic management since AGVs, before transitioning between zones, must seek permission to avoid potential collisions, congestion, and deadlocks. These conflicts are managed by two strategies: conflict prevention and conflict resolution.

This project aims to assess the potential benefits of implementing automation technology in Norwegian container terminals. While it is assumed that automation reduces operational costs and carbon emissions and improves efficiency, automation should always be linked to the general port context. Port organization and layout, as well as geographical location and port size, are factors that impact port performance more than technology alone. The project's objective will be achieved through the development of optimization and simulation techniques for the routing and scheduling of container handling activities in an automated setting. This extends to the development of efficient strategies for conflict prevention and recovery in automated container terminals.

The master project holds a central role within AutoPort, a collaborative research initiative involving a substantial consortium. Key participants include SINTEF (Digital, Ocean, and Community departments), Port Authorities in Moss, Larvik, and Narvik, and industry leaders like Grieg Connect and Maasterly. Potential topics that may be included in the project and master thesis are:

- Propose a mathematical model for the scheduling and routing problem of AGVs.
- Develop and implement solution algorithms for managing conflicts among AGVs.
- Simulate handling process activities employing AGVs within automated ports.
- Study the economic, environmental, and operational implications of AGV utilization in Norwegian ports.
- Investigate, based on data from Norwegian ports, the impact of port activity, size, and organization on the successful implementation of AGVs within these ports.

Collaborators: SINTEF and industry partners
Main supervisor: Kjetil Fagerholt
Co-supervisor: Mohamed Ben Ahmed, Steffen S. Bakker

Strategic research initiative: Technology-based organization design

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et digitalt møte.

AØO18: European wide integrated investment, retrofit and abandonment planning with hydrogen and carbon capture and storage

Energy system infrastructure planning is pivotal in achieving the climate target in a cost-effective way and ensuring the security of supply. Such planning problems are usually investigated using optimisation models to minimise the total costs. Traditionally, investment planning models only consider building new technologies and deciding their sizes, locations, and system topology. However, retrofitting existing infrastructures such as natural gas pipelines and oil and gas platforms for alternative use and decarbonised purposes may, under certain conditions, be more cost-efficient than building an entirely new infrastructure for, e.g., hydrogen export. Besides offshore hydrogen production, Carbon Capture and Storage (CCS) can be crucial to the energy transition. Depleted fields have a huge capacity for storing CO2, which makes retrofitting existing pipelines for CO2 transport and platforms for CO2 injection an option that should be explored. In addition, retrofitting means possible loss of massive future revenue streams from existing fossil products depending on demand, CO2 costs, prices and more. Therefore, the economic trade-off between building new infrastructure, retrofitting existing and abandoning existing infrastructure needs to be carefully investigated to facilitate knowledge-based decision support.

This project aims to develop further the REORIENT (REnewable resOuRce Investment for the Energy Transition) model developed as a part of Petrosenter LowEmission, which is a multi-horizon stochastic program targeted for above mentioned techno-economic analysis needs. The model has been further developed for considering CCS and hence reuse of North Sea infrastructure and fields for CO2 transportation and storage, as well as capture from gas turbines on the platforms. The current model only considers the retrofit of energy infrastructure in the North Sea. However, there is a mature European onshore energy infrastructure that can be potentially retrofitted.

To overcome this limitation and develop holistic oil and gas repurposing analysis, including CCS, the students are expected to extend and use the REORIENT model to (1) extend the modelling of the retrofit of the European onshore energy system, (2) increate the spatial resolution of the REORIENT model, and (3) conduct analysis of the entire European energy system transition using the REORIENT model.

Prerequisites: knowledge of energy system planning, experience in Julia programming

Main Supervisor:	Dr Hongyu Zhang
Co-supervisor:	Associate Professor Pedro Crespo del Granado
Research project:	Nordic Hydrogen Hubs (https://nordich2ubs.com)
Industry partners:	SINTEF Energy Research
Strategic research initiative:	Leading transitions: Co-create a sustainable future

For more information, please contact Dr Hongyu Zhang, hongyu.zhang@ntnu.no, to schedule a meeting.

References:

[1] Hongyu Zhang, Ignacio E. Grossmann, Brage Rugstad Knudsen, Ken McKinnon, Rodrigo Garcia Nava, Asgeir Tomasgard. (2023). Integrated investment, retrofit and abandonment planning of energy systems with short-term and long-term uncertainty using enhanced Benders decomposition. DOI: 10.48550/arXiv.2303.09927

AØO19: Fleet renewal in Norwegian aquaculture following new requirements for zero emissions

Producing enough healthy food for a growing world population is a global challenge. Fish farming will play a major part in this, and the World Bank projects that by 2030 62% of all seafood consumed will be farm raised. Norway's salmon farming industry is a key success story in global aquaculture production. From humble beginnings in the 1970s, the Atlantic salmon industry has expanded throughout fjord and coastal Norway to produce 1.7 million metric tons of fish in 2022 with a sales value of 108 BNOK. Fish farming is now a significant employer and a socio-economic pillar supporting regional communities throughout Norway. Further expansion is possible; Norway could farm 5 million tons of fish per year by 2050, if key production and environmental challenges are met.

The fish farming industry is in the beginning of an energy transition with proposed requirements for zero-emission solutions for vessels. A proposal from the Norwegian Maritime Authority says that all new vessels under 15m should be zero-emission from 2025, and all new vessels under 24m from 2030. Existing vessels must be retrofit to zero-emission by 2035 and 2040, respectively for vessels under 15m and 24m. This proposal is based on a perception of technology readiness and practicability of zero-emission solutions that is contested by the industry, which claim that batteries are heavy and expensive, infrastructure for charging is lacking, and alternative fuels are costly and are not widely available. In addition, in most cases, zero-emission solutions will give reduced energy capacity. However, the industry acknowledges the need for an energy transition and sees both the need and realism in new, strong requirements from authorities, clients, and the public. The result is a balancing exercise of transition to zero-emission solutions without losing the industry's competitiveness.

In this project, we want to study the Aquaculture Fleet Renewal Problem (AFRP) in order to investigate how the fish farming industry (and its shipowners) best can adapt to and contribute to achieving the zero-emission goals. The AFRP covers uncertainty in future costs, licenses to operate and availability of energy infrastructure and fuels, in addition to the problem of how the optimal fleet size and mix will be with respect to mission capabilities after the energy transition.

This master project will be related to the EnerSea project, which is a collaboration between SINTEF Ålesund, SINTEF Ocean, SINTEF Energi, RENERGY, NCE Aquatech Cluster, Menon Economics and several industry actors. Potential topics that may be included in the project and master thesis are:

- Study current models and solution methods for different variants of maritime fleet renewal problems
- Propose an optimization model for the AFRP (possibly a stochastic programming model)
- Develop and implement an efficient (exact or heuristic) solution algorithm for the MFRP (if the model cannot be solved by commercial MIP-solvers like Gurobi or Xpress)
- Based on real data and best available knowledge for future scenarios, investigate the implications of various realizations of new emission requirements, both on the costs and the emissions from the operations

Collaborators: SINTEF Ocean and industry partners (including shipowners)
Main supervisor: Kjetil Fagerholt
Co-supervisor: Hans Tobias Slette (SINTEF Ocean)

Strategic research initiative: Leading transitions: Co-create a sustainable future

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et møte.

AØO20: Flexibility market and balancing market modelling and analysis using REORIENT model

This project aims to develop further the REORIENT (REnewable resOuRce Investment for the Energy Transition) model developed as a part of Petrosenter LowEmission, which is a multi-horizon stochastic program targeted for above mentioned techno-economic analysis needs. The model has been further developed for considering CCS and hence reuse of North Sea infrastructure and fields for CO2 transportation and storage, as well as capture from gas turbines on the platforms. The current model considers the retrofit of energy infrastructure in the European offshore energy system.

The interaction between energy infrastructure planning especially hydrogen and CCS infrastructure and European flexibility and balancing power markets is crucial. Therefore, in this project, the students are expected to (1) model flexibility and balancing power markets in the REORIENT model framework, (2) modify the REORIENT model for profit maximisation, and (3) conduct techno-economical analysis of the impact on the interaction of energy system investment planning and European flexibility and balancing power markets.

Prerequisites: knowledge of power markets, stochastic programming, experience in Julia programming

Collaborators:

Main Supervisor: Dr Hongyu Zhang

Co-supervisor: Associate Professor Pedro Crespo del Granado, Professor Asgeir Tomasgard

Research project: Nordic Hydrogen Hubs (https://nordich2ubs.com), iDesignRES (https://iiasa.ac.at/projects/idesignres)
Industry partners: SINTEF Energy Research
Strategic research initiative: Leading transitions: Co-create a sustainable future

For more information, please contact Dr Hongyu Zhang, hongyu.zhang@ntnu.no, to schedule a meeting.

References:

[1] Hongyu Zhang, Ignacio E. Grossmann, Brage Rugstad Knudsen, Ken McKinnon, Rodrigo Garcia Nava, Asgeir Tomasgard. (2023). Integrated investment, retrofit and abandonment planning of energy systems with short-term and long-term uncertainty using enhanced Benders decomposition. DOI: 10.48550/arXiv.2303.09927

AØO21: Forretningsmodeller og kontraktsdesign i fremtidens energimarked

Innføring av avanserte målings- og styringssystemer og annen type teknologi i energimarkedet åpner for innovative konsepter som kan gi gevinster for miljøet, for samfunnet og for ulike aktører i verdikjeden. Et viktig område de neste årene blir fleksible tjenester for lading av elbiler, der prisen for lading avhenger av hvor hurtig det må skje og av ledig kapasitet i distribusjonsnettet, men annen fleksibilitet i både private og næringsbygg spiller og en rolle sammen med fleksibilitet i industri. Per i dag er insentivene, for eksempel i form av kortsiktige prisvariasjoner på kraftkontraktene og dynamikk i nett-tariffer, ikke sterke nok til å motivere til differensiert kvalitet på ladetjenester eller å utløse nok fleksibilitet i andre deler av systemet. Vår hypotese er at nye forretningsmodeller og nye tjenester, kanskje levert av nye typer aktører, kan være med på å utløse potensialet. Mye av fokuset i bransjen er i dag knyttet til de teknologiske løsningene, mens det foreløpig er lite fokus på hvordan tjenester, forretningsmodeller og kontrakter kan utformes.

Oppgaven vil bestå i å foreslå og analysere forretningsmodeller og samarbeidskontrakter i det framtidige energimarkedet med minst ett av følgende fokusområder: 1) Nettselskapene og modeller for hvordan de kan utnytte fleksibilitet på sluttbrukersiden til å oppnå gevinster som økt driftssikkerhet og utsatt behov for nettforsterking. 2) Nye tjenesteleverandører for lading av el-biler og deres forhold til sluttbrukerne på den ene siden og nettselskapet på den andre siden. 3) Fleksibilitetstjenester fra industri eller bygg

Oppgaven vil gjøres i samarbeid Smart Innovation Norway

Fordelaktig: Kjennskap til energimarkedet er en fordel. Faget TIØ 4285 Produksjons- og nettverksøkonomi er en forutsetning.

Main supervisor: Professor Asgeir Tomasgard

Co-Supervisor: Stig Ødegaard Ottesen, Smart Innovation Norway

External Partner: Smart Innovation Norway. Oppgaven vil kobles mot et av energiselskapene som er med i senteret FME NTRANS

Strategic research initiative: FME NTRANS, NTNU Energy Transition Initiative

AØO22: Green hydrogen network design with emission scopes and risk considerations: a German case study

Green hydrogen is a promising option to decarbonize the transport and energy sectors. Since many countries do not have the capabilities to meet their demand for green hydrogen on their own, there has recently been an increased interest in studying and optimizing the design of hydrogen import networks.

This project aims at extending a previous optimization model, proposed by the project's co-supervisors, in terms of a sustainability perspective. In particular, the network structure should be designed such that it allows for a diversified network that trades off corresponding cost and greenhouse gas emissions. In this context greenhouse gas emissions should be considered according to the three 'scopes' defined by https://ghgprotocol.org/. Scope 1 describes emissions from sources a company directly owns or controls (e.g., burning fuel with own fleet). Scope 2 are indirect emissions (e.g., for the production of purchased energy). Scope 3 refers to indirect emissions (not included in scope 2) that occur in the value chain of the company, including both upstream and downstream emissions (e.g., waste disposal). The optimization model developed in this project should include the three scopes-classification of emissions into the optimization of green hydrogen import networks. This contains identifying relevant factors, extending the previous cost-oriented optimization model, identifying appropriate data, and conducting computational experiments. Eventually, the impact of considering scopes 1, 2, and/or 3 on the resulting network designs should be analyzed.

Furthermore, the optimization model developed in this project should explicitly consider some risk measures, with a particular focus on diversification of the countries to source from. Relying on one exporting country alone can cause political, financial and moral complications that further hinder the achievement of an environmentally friendly energy economy in the future. A large-scale hydrogen import, therefore, requires some sort of supplier diversification to avoid too strong dependencies.

The project may include the following work packages:

- Review of the scientific literature
- Problem definition w.r.t. network diversification/risk consideration and emission scopes
- Development and implementation of an optimization model for optimizing the emissions of green hydrogen import networks
- Experimental analysis of the effect of considering the three scopes in the network design

The project is conducted in cooperation between NTNU and partners from Kiel University (Germany). A visit for the Norwegian partners to Kiel could be part of the project (funding will be provided) to support a fruitful collaboration.

Collaborator: Kiel University, Germany

Main supervisor: Kjetil Fagerholt

Co-supervisors: Frank Meisel and Vincent Sroka (Kiel University)

Strategic research initiative: Leading transitions: Co-create a sustainable future

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et møte.

AØO23: Helhetlig ressursplanlegging mellom Trondheim kommune og St. Olavs hospital

I årene som kommer vil behovene for helse- og omsorgstjenester øke, samtidig som kapasiteten til å møte dem vil være presset. Årsakene er mange, sammenfallende og selvforsterkende, hvorav de mest sentrale er økningen i andelen og antallet eldre i befolkningen, spesialisering og desentralisering av tjenestetilbudene, samt svak rekruttering av kvalifisert helsepersonell. For at kommuner og sykehus skal kunne tilby nødvendige og forsvarlige tjenester til innbyggerne uten at de overskrider samfunnets øvrige ressurser, må de fordele oppgaver, bruke personell, kompetanse og infrastruktur på mer bærekraftige måter. Liggetiden på sykehusene er kortet ned og den polikliniske virksomheten har økt. Den videre behandlingen og oppfølgingen av pasientene foregår i kommunen som etablerer spesialiserte tjenester i helsehus, sykehjem og hjemmetjenesten. Pasientene med størst hjelpebehov mottar hjelp fra flere tjenester samtidig og de beveger seg mellom flere tjenester for å få den hjelpen de trenger. Behovet for koordinering og planlegging av tjenestene øker tilsvarende og blir mer komplekst.

En spesiell utfordring er å skape helhetlige pasientforløp for eldre med skrøpelighet som sikrer god pasientflyt. Eksempelvis har Trondheim kommune og St. Olavs hospital i dag store utfordringer med at sykehuspasienter blir liggende på sykehus etter utskriving i påvente av tjenester i kommunen, det være seg rehabilitering eller sykehjemsplass. Dette fører til avlyste operasjoner på sykehuset pga. manglende sengekapasitet og funksjonstap hos pasientene.

Trondheim kommune og St. Olavs hospital har i dag dårlig oversikt over pasientstrømmene, både internt i kommunen og mellom kommunen og sykehuset. Man mangler også en helhetlig oversikt over kapasiteten og helsehjelpen som gis i de ulike tjenestene i kommunen eller på sykehuset, som gjør at man hindres i å utnytte ressursene best mulig i forhold til behovet for helsetjenester. Det eksisterer heller ikke verktøy for å planlegge ressurskapasiteten på et taktisk nivå i forhold til pasientstrømmene på tvers av tjenestene.

Et interessant tema for en prosjektoppgave og påfølgende masteroppgave er å utvikle matematiske modeller som beskriver pasientflyten på tvers av kommune og sykehus og som kan benyttes i planlegging av ressurskapasiteten. Dette prosjektet er en del innovasjonsprosjektet HARMONI mellom Trondheim kommune, St. Olavs hospital og Institutt for industriell økonomi og teknologiledelse, hvor målet er å utvikle og pilotere beslutningsstøtte verktøy for ressursplanlegging på tvers av kommune og sykehus.

Arbeidet kan innebære ulike oppgaver som:

- studere litteraturen for liknende problemer;
- beskrive utfordringene knyttet til samhandling mellom sykehus og kommune;
- avgrense og beskrive planleggingsproblemet;
- utvikle simulerings- og optimeringsmodeller for å beskrive og optimere pasientflyt;
- implementering av modellen(e) ved hjelp av egnet programvare, analyse og testing av instanser basert på data fra Trondheim kommune og St. Olavs hospital.

Collaborator: Trondheim kommune og St. Olavs hospital

Main supervisor: Anders N. Gullhav

Co-supervisor: Thomas Reiten Bovim

Strategic research initiative: Health and the Public Sector

For more information, please contact Anders N. Gullhav, anders.gullhav@ntnu.no, to schedule a meeting.

AØO24: Innovation for the Energy Transition

Sustainable Development Scenarios tend to map out a path to meeting key international energy and climate goals. In these close to 10 000 gigawatt-hours of batteries across the energy system and other forms of energy storage are required worldwide by 2040 – 50 times the size of the current market.

One way of mastering this ambitious goal is to spur innovations related to renewable electricity generation, distribution and storage, and the heating, industry and transport sectors. Understanding the innovation processes of technologies is thus an essential factor for research itself and an issue for public policies for a magnitude of reasons. First, there is enormous economic potential for improved and innovative technologies. Second, policy-makers seek for technology leadership by their countries for which they need information about their national performance with respect to technology innovation. Third, utilities and energy system researchers are interested in getting insights, which energy technologies could dominate their field of application in the future.

In this project students look at patent data to identify trends in inventions in the field of electricity storage. Patents are filed many months, sometimes even years, before products appear on the market. Information on patent serves as an early indicator of which technologies could be poised to play ground-breaking roles in the future.

Students will collect patent data and employ quantitative and qualitative concepts of patent analysis and indicators.

Supervisor: Anne Neumann

Please contact me for more information or to schedule an (online) appointment (anne.neumann@ntnu.no).

Literature:

Baumann M., Domnik, T., Haase, M., Wulf, C., Emmerich, P., Rösch, C., Zapp, P., Naegler, T. and Weil, M. (2021): Comparative patent analysis for the identification of global research trends for the case of battery storage, hydrogen and bioenergy, Technological Forecasting and Social Change, Volume 165, 120505, https://doi.org/10.1016/j.techfore.2020.120505

Metzger, P., Mendonça, S., Silva, J. and Damásio, B. (2023): Battery innovation and the Circular Economy: What are patents revealing?, Renewable Energy (209), 516-532, https://doi.org/10.1016/j.renene.2023.03.132.

EPO and IEA (202): Innovation in batteries and electricity storage: A global analysis based on patent data. ISBN 978-3-89605-256-8

AØO25: Integrated Decision-Making in Airline Planning: Enhancing Efficiency, Resilience, and Sustainability

The airline industry, renowned for its fierce competition and operational complexities, faces many challenges. Fuel costs, constituting a substantial portion of operational expenses (20-30%), render airlines vulnerable to price fluctuations, impacting profitability. Moreover, the COVID-19 pandemic inflicted a severe blow, causing a dramatic 60-70% decline in passenger demand and imposing significant financial strain. In navigating these challenges, airlines must deal with regulatory complexities, pursue sustainable practices, and adopt technological innovations to ensure resilience in an ever-evolving landscape.

Effective resource planning is pivotal for airlines to surmount these challenges. Leveraging advanced technologies such as data analytics, artificial intelligence, optimization, and mathematical modeling presents a promising avenue to optimize resource allocation, streamline operations, and enhance overall efficiency. However, there lies untapped potential in integrated airline scheduling, where traditionally sequential functions—flight scheduling, fare filing, aircraft allocation, and crew scheduling—are performed independently, overlooking opportunities for enhanced efficiency.

In this project, we aim to investigate how different decision-making levels in airline planning can be holistically addressed. This entails integrating and solving decisions such as fleet assignments, aircraft maintenance routing, and crew scheduling. Integration in decision-making promises significant advantages, with studies indicating potential fuel savings of 5-15% through optimized route planning and a 10-20% improvement in operational efficiency by aligning crew schedules with aircraft routes. Moreover, it contributes to better operational resilience and robustness in the face of disruptions and uncertainties.

Due to the complexity of this problem, students should aim to develop advanced mathematical models, possibly including heuristic components, to solve it. Therefore, proficient computer programming skills and an interest in mathematical modeling will be required for this project. The developed solution methods will be tested on test instances derived from real applications across multiple airline companies, including a Norwegian carrier. This will enable students to become acquainted with scheduling challenges within the airline industry and to refine their problem-solving skills.

Relevant activities in this can be:

- Study several airline optimization problems.
- Expand currently existing mathematical models for the airline scheduling problem (ASP).
- Develop a (math-) heuristic for the ASP.
- Test the proposed heuristic's performance on several real case instances from the airline industry.
- Analyse the economic, environmental, and operational effects of integrating several decision levels of airline planning (possibly within a simulation framework).

Collaborators: Potentially with an international Airline, To be announced.
Main supervisor: Magnus Stålhane
Co-supervisor: Mohamed Ben Ahmed, Lars Magnus Hvattum (Molde University College)

Strategic research initiative: Technology-based organization design

For mer informasjon, ta gjerne kontakt med magnus.staalhane@ntnu.no for å avtale et digitalt møte.

AØO26: Integration of natural gas, hydrogen and renewables in the European energy system

Europeisk energisektor står midt oppe i omfattende endringer der andelen fornybar og ikke-planleggbar kraftproduksjon øker (vind og sol). Volumet av gass levert fra norsk sokkel er rekordhøyt, men vil antagelig reduseres fra 2030 om ikke nye felt utvikles. Samtidig er store mengder russisk gass borte fra markedet. I denne situasjonen skal Europa dramatisk øke sin fornybar produksjon og har samtidig store ambisjoner om en hydrogenøkonomi.

For det norske gass-systemet vil det være mulig å tilby fleksibilitetstjenester til et europeisk energisystem med økende behov for balansering av ikke-planleggbar produksjon. En annen mulighet er å produsere hydrogen for varme, kraft og transport. Hydrogen kan også komme fra fornybar energi og spesielt storskala utbygging av havvind er interessant å se i sammenheng med grønn hydrogenproduksjon.

Usikkerhet både på kort og lang sikt virker inn på hvordan resterende gasseksport fra Norge bør disponeres, både for å bidra inn mot omlegging til et grønnere energisystem og for å maksimere verdien av den norske eksporten. Samtidig må norsk fornybarutbygging sees sammenheng med egen bruk til ny industri, eller eksport i form av kraft og hydrogen.

Vi vil benytte multi-horizon stochastic programming for å analysere disse problemstillingene. Vi kan basere oss på EMPIRE modellen som er utviklet ved IØT, og utvikle nye moduler i denne. En rekke aktuelle problemstillinger er mulig å velge:

- Utbygging av CO2 fangst, transport og lagring verdikjeder i Europa og Norge. Både design av verdikjeden og forretningsmodeller knyttet til disse.
- Produksjon av hydrogen fra naturgass med CCS og samspillet mellom industri, transport kraft og varme sektorene
- Bruk av gassrør som store energilager på 1-2 døgns horisont. Både koblingen til kraft og varmesystem samt utvikling av nye tjenester i markedet er interessant. Aktuelle problemstillinger vil både være å finne gode løsninger for kapasitetstjenester for norsk naturgasseksport
- Studier av utbygging av norsk havvind
- Studier av hydrogenprouksjon fra vindkraft og fra gass

Nødvendig bakgrunn og interesser: optimering, modellering, planlegging under usikkerhet

Main supervisor: Professor Asgeir Tomasgard

Co-Supervisor: Forsker Hongyu Zhang

External Partner: Gassco, Equinor

Strategic research initiative: FME NTRANS, NTNU Energy Transition Initiative

AØO27: Intraday trading for hydropower

Hydropower is traded in day-ahead and intraday power markets, and Aneo AS schedules and trades approximately 2.6 TWh of hydropower annually in the Nordic market. This topic will focus on intraday operations, where power can be traded continuously until 1 hour ahead of delivery. Orders are made towards an open order book where bids/asks are submitted by market participants based on available capacity or flexibility. Hydropower is generally quite flexible and well suited for intraday trading, but there are some complexities related to cascaded watercourses where the water released from upstream reservoirs influence the decisions taken further downstream. These complexities specifically relate to pricing of bids. Should the price of a bid for an upstream plant take into account consequences downstream, or is the current practice with bids for individual plants reasonable? In addition, how should bids traded in the intraday market be benchmarked? The value gained of using water for production now must always be compared to the value of saving water for production later, i.e., the water value. Is comparison to the water value a good enough benchmark for intraday trading for hydropower in connected watercourses? Could other KPIs or benchmarking methods be developed? Also, in current operations the water value is calculated based on spot sales only, but in a future where intraday trades for hydropower increase, methods for water value calculation should potentially also reflect the opportunities in these markets.

Research topic: The research challenge is to develop new strategies and benchmarking methodologies for intraday trading of hydropower in cascaded watercourses. This will involve elements from optimization and finance, as well as insights into power markets and hydropower production scheduling.

Methods/tasks:

- Understand how intraday trading of hydropower is done today and the potentials for improvement.
- Understand the dynamics of pricing and cost calculations for hydropower in short and longer term applications.
- Review the current literature for similar problems (similar applications and also problems from other applications of a similar structure).
- Implement strategies for trading, benchmarking and performance evaluation.
- Carry out experiments to assess the performance of different trading strategies.
- Describe the problem, the methods, and the results in a way that can be published.

Expected Results and Learning Outcome:

- An understanding of the dynamics of pricing of hydropower in cascaded watercourses
- An understanding of the dynamics and applicability of different trading and pricing strategies
- A prototype trading strategy and benchmarking framework that has been tested for realistic problem instances
- A publishable description of the work.

Recommended prerequisites: Knowledge of Optimization and some Finance. Programming skills, preferably Python

Industry partner:	Aneo AS
Collaborator:	Ellen Krohn Aasgård, Aneo AS
Main supervisor:	Ruud Egging-Bratseth
Co-supervisor:	Stein-Erik Fleten
Industry Co-supervisor:	Ellen Krohn Aasgård, Aneo AS
Strategic research initiative:	Leading transitions: Co-create a sustainable future ; Sustainability

For more information, please contact Ellen Krohn Aasgård, ellen.krohn.aasgard@aneo.com , to schedule a meeting.

AØO28: Investigating the effects of guaranteed level of availability in service contracts between offshore wind turbine manufacturers and wind farm operators

The world stands in front of a major task of transitioning to renewable energy to solve the climate crisis. With the goal of turning Europe into the first climate neutral continent by 2050, EU launched the Green Deal in July 2021. Offshore wind is a young industry that is in rapid development and is expected to constitute an important part of the future energy system. Hence, among other initiatives within renewable energy, the ambitions are to meet the European Green Deal partly by reaching 300 GW of installed offshore wind capacity by 2050. For reference 1 GW of electricity is enough to support 750,000 homes. It is estimated that 16-24 % of the total costs related to offshore wind stem from operations and maintenance (O&M). O&M costs for offshore wind ranged between 70-129 USD/kW in 2018. For onshore it was 33-56 USD/kW. These higher O&M cost for offshore wind is related to the harsh conditions at sea which makes maintenance planning a complex task. To ensure that the ambitions of offshore wind are viable, it is crucial to decrease the maintenance costs.

Many new wind farms are currently being planned and will be installed in the coming years. Typically, the manufacturer delivering the wind turbines is responsible for maintaining the wind farm the first five years after installation. After that the wind farm operator takes over the maintenance for the remaining lifetime of the wind farm. One of the key elements in the service contract between the wind turbine manufacturer and the wind farm operator is that the manufacturer guarantees a certain level of availability of the wind farm, i.e. how large fraction of the time the wind turbines are available for power production. While the guaranteed availability gives the operator a lower bound on the availability of the wind farm, there might be little incentive for the manufacturer to carry out more maintenance than necessary to achieve the guaranteed availability. At the same time the goal of the wind farm operator is to maximize the power production.

This project is connected to work-package 2: "Marine operations and Logistics" within the FME NorthWind which focus on effective logistics planning for maintenance at offshore wind farms. The aim of this project is to investigate the effects of the guaranteed availability on the maintenance carried out and thereby the actual availability of the wind farm, and hence deliver decision support for future negotiations between wind turbine manufacturers and wind farm operators. This investigation could for instance entail the development of a mixed integer stochastic model and/or discrete event simulation framework of a maintenance planning problem for an offshore wind farm addressing the uncertain underlying parameters such as failure rates and weather conditions.

Some relevant topics that may be included in the project (and/or Master thesis) are:

- Investigate the problem, study existing models and solution methods for related problems
- Develop precise mathematical model formulation(s)
- Consider methods for handling the problems underlying uncertain parameters
- Implement solution method for the problem
- Test the implemented solution method on problem instances and analyse/discuss the results

Industry partner: Potential partners in FME NorthWind

Main supervisor: Magnus Stålhane

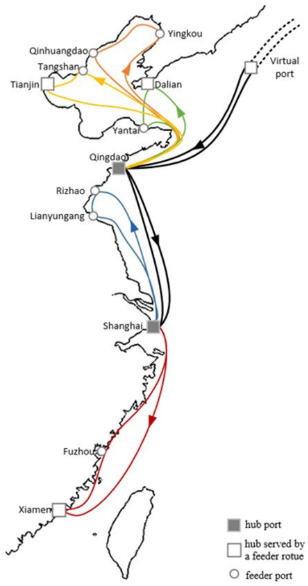
Co-supervisor: Vibeke Hvidegaard Petersen

If you are curious to know more about the project, please contact Magnus Stålhane, magnus.staalhane@ntnu.no, to schedule a meeting.

AØO29: Liner shipping network design for joint operations: case from China

The container trade between Asia and Europe has experienced significant growth and the vessels used on such "trunk lines" has steadily increased in size, and only a few major hub ports have the capabilities of accommodating these. Hence, containers are transshipped onto smaller feeder vessels at such hub ports to reach their final destinations. The major trunk lines (e.g., between Asia and Europe) and the feeder lines (e.g., within Chinese ports) are often operated by different shipping companies, partially because of cabotage regulations restricting foreign vessels to engage in feeder operations between domestic ports. Therefore, shipping alliances are often initiated between the (foreign) shipping companies operating the trunk lines and the (domestic) feeder service operators. Currently, alliance members primarily collaborate on shipping space utilization, while deeper cooperation, particularly at the fleet resource level, remains limited. Therefore, it will be highly relevant to consider a more extensive collaboration with the planning of joint operations within a liner alliance.

With the above in mind, we want in this project to study the Liner Feeder Service Network Design Problem (LFSNDP) for a joint operation between a trunk line and a feeder operator. The LFSNDP includes decisions about i) vessel routes, ii) hub ports where transshipment can take place, iii) vessel fleet deployment, and iv) flow of containers in the network. An illustration of a solution to the LFSNDP is shown to the right.



The master project will extend from previous relevant studies. New practical features to include may for example be vessel speed optimization (as sailing speeds significantly affect fuel consumption and costs) and the addition of transit time restrictions for the containers. The project will be done in collaboration with Dalian Maritime University (DMU), which will also contribute with data for a Chinese case study. Additionally, we also have data for a Norwegian case study, which can be used if found relevant. Potential topics that may be included in the project and master thesis are:

- Study relevant literature and the existing solution approaches for the LFSNDP
- Propose a mathematical (MIP) model for (different versions of) the LFSNDP
- Develop and implement an efficient (exact or heuristic) solution algorithm
- Analyze the effects or relaxing the above mentioned cabotage regulations (which is now a relevant scenario for China)
- Analyze the effects of planning joint operations

Since the LFSNDP is a very complex planning and optimization problem, we expect that specialized (heuristic) solution algorithms need to be developed, which will require a good background in computer programming. Furthermore, depending on funding possibilities, it might be relevant to organize a visit at DMU in China to exchange research ideas during the project/master.

Collaborators: DMU, China
Main supervisor: Kjetil Fagerholt
Co-supervisor: Mohamed Kais Msakni (NTNU) and professor Yuzhe Zhao (DMU)

Strategic research initiative: Leading transitions: Co-create a sustainable future

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et møte.

AØO30: Liner Shipping Network Design using the Arctic Ocean

The effects of global warming are particularly evident in the Arctic, where there has been a significant decrease in the amount of ice. As the Arctic ice melts due to rising temperatures, new maritime trade routes are opening up. These routes are shorter and offer both financial and environmental benefits due to reduced travel time, reduced fuel consumption and associated CO2 emissions. It is therefore widely expected that maritime transportation between Asia and Europe through the Arctic Ocean will increase.

Navigating the Arctic Ocean however, presents substantial challenges. These include encounters with icebergs and varying ice conditions, which may have a major impact on vessel speed. As liner shipping is characterized by scheduled services, operating on fixed routes with published timetables, encountering heavy ice conditions can severely impact travel times and disrupt the service. Liner shipping network design deals with determining the (weekly) schedules for all vessels, ensuring that the flow of goods through the network arrives at destination within given time constraints. Accounting for environmental conditions in the Arctic Ocean may considerably increase the complexity of this task.

The purpose of this project is to study the potential of including routes through the Arctic Ocean in intercontinental liner shipping. The work should include an analysis of both the economic and the environmental benefits (in terms of reduced CO2 emissions) of increased maritime transportation through the Arctic Ocean. In a first step, a deterministic analysis is expected, but uncertainty in ice conditions and navigability of the Arctic Ocean are considered to be an essential part of subsequent analyses.

Tasks within the project usually include:

- Understand both real-world problem and liner shipping network design problems in the research literature
- Review the literature and study existing models as well as solution methods
- Formulate and implement a mathematical model for the problem
- Collect data and set up relevant problem instances
- Solve the instances and analyze the results

Main supervisor:	Peter Schütz
Co-supervisor:	Gleb Sibul
Strategic research initiative:	Leading transitions: Co-create a sustainable future
	Sustainability

For more information, please contact peter.schutz@ntnu.no to schedule a meeting

AØO31: Locating fast charging infrastructure for heavy trucks

The transport sector causes approx. 33% of greenhouse gas emissions in Norway. A transition to low- and zero-emission technologies is necessary to reach the national goals for emission reduction. Battery-electric passenger vehicles have stood for the majority of new car sales for several years already, but the electrification of heavy trucks has not yet come as far. Still, several hundred battery-electric trucks do currently operate in Norway.

One of the challenges for the electrification of long-haul truck transportation is limited access to fast charging infrastructure. This is often referred to as chicken-and-egg problem: limited infrastructure slows down the increase in number of battery-electric trucks, whereas the slow growth in number of battery-electric tricks reduces the willingness to invest in fast charging infrastructure.

Uno-X operates more than 50 filling stations for trucks throughout Norway. As of today, the majority of these stations do not provide charging infrastructure for trucks. Over the next few years, this network will undergo major development: most filling stations will be upgraded with fast charging infrastructure, new charging stations will be opened in suitable locations, and some of the existing locations may have to relocate or close if they cannot accommodate truck charging at their current location.

The purpose of this project is to analyze how the network of filling stations should transition towards a network of charging stations. This includes determining when and where new stations may have to be opened. The analysis needs to consider (amongst others)

- the existing station network,
- suitable locations for new stations,
- traffic flows and volumes,
- driving patterns (incl. regulations), and
- access to power.

Tasks within the project usually include:

- Understand the problem and define its scope
- Review the literature and study existing models as well as solution methods
- Formulate and implement a model for the problem
- Collect data and set up relevant problem instances
- Solve the instances and analyze the results

Industry partner:	Uno-X Mobility (www.unoxmobility.no)
Main supervisor:	Peter Schütz
Co-supervisor:	Steffen Bakker
Strategic research initiative:	Leading transitions: Co-create a sustainable future
	Sustainability

For more information, please contact peter.schutz@ntnu.no to schedule a meeting

AØO32: Location-Routing for hydrogen service vessels

The aquaculture industry contributes considerably to CO_2 emissions in Norway, with approximately 40% of the emissions in aquaculture sector being caused by aquaculture vessels. The industry is expected to grow in the coming years. However, emissions must be reduced by 55% by 2030 to meet the goals set in the Paris Agreement. It is therefore critical to decarbonize the aquaculture operations. Transitioning the aquaculture vessels to zero-emission energy carriers such as hydrogen is a promising solution. However, the adoption of hydrogen solutions is hindered by non-existing hydrogen infrastructure.

The purpose of this project is to develop an optimization model that finds the optimal locations of ports that offer hydrogen refueling for aquaculture service vessels, considering the operations of the vessels. The demand for vessels consists of different tasks in a specific sequence, which may also require synchronization of the vessels. For example, when installing a new net at a fish farm, the following sequence is required: transporting a new net to a fish farm, installing the net, and returning the used net. Further, two vessels simultaneously are required to perform the net installation. Therefore, they need to be synchronized. The goal is to find fueling station locations that minimize the total costs of hydrogen supply and fleet operations and ensure that demand is satisfied.

The following main tasks are usually part of the project work:

- Understand the problem and study relevant literature
- Develop a mathematical formulation for the problem
- Collect data and set up test instances based on available data
- Implement and solve the model
- Analyze and discuss the results

This project is part of the ongoing research project *ZeroKyst KSP – Decarbonising the fisheries and aquaculture industry through hydrogen-electric propulsion.*

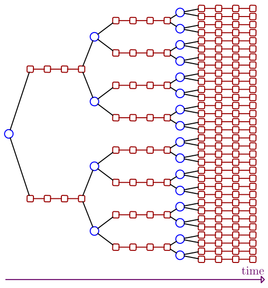
Collaboration: ZeroKyst-project (ZeroKyst - SINTEF), SINTEF Ocean
Main supervisor: Sarka Stadlerova
Co-supervisor: Peter Schütz

Strategic Research Initiative(s): Leading transitions: Co-create a sustainable future
UN SDG 7, 14

For more information, please contact Sarka Stadlerova, sarka.stadlerova@ntnu.no

AØO33: Long-term energy system planning with long-term storage under uncertainty: multi-stage stochastic programming model and Benders decomposition

Managing long-term storage, such as pumped hydro storage and hydrogen storage, in long-term energy system planning problems is very important. This requires saving information like reservoir level from one planning stage to the next, which links all the planning stages and make the problem hard to decompose.



In addition, long-term energy system planning problems often face uncertainty in short-term and long-term time horizons. For example, the wind availability uncertainty in the short term and CO2 tax uncertainty in the long term. Including uncertainty from both time horizons leads to a multi-stage stochastic problem, see figure above. Such a problem can be intractable to solve. Also, because long-term storage links all the stages, the problem is also hard to decompose. Traditionally, nested Benders decomposition is used to decompose the problem with such a structure. However, by introducing communication nodes in the scenario tree, a multi-stage stochastic programming problem can be decomposed using Benders decomposition.

In this project, the students are expected to work on developing a new model formulation for multi-stage stochastic programming with communication nodes and demonstrating the new formulation can be directly decomposed by Benders decomposition. Then students are expected to conducted system analysis in terms of long-term storage management in long-term energy system planning problems.

The students can choose to work further on existing Julia code or develop their own code.

Prerequisites: knowledge of Benders decomposition, multi-stage stochastic programming, and strong skills in programming, preferably Julia programming.

Collaborator: rofessor Ken McKinnon (The University of Edinburgh)

Main Supervisor: Dr Hongyu Zhang

Co-supervisor: Professor Asgeir Tomasgard

Strategic research initiative: Leading transitions: Co-create a sustainable future

For more information, please contact Dr Hongyu Zhang, hongyu.zhang@ntnu.no, to schedule a meeting.

References:

[1] Hongyu Zhang, Nicolò Mazzi, Ken McKinnon, Rodrigo Garcia Nava, Asgeir Tomasgard. (2022). A stabilised Benders decomposition with adaptive oracles applied to investment planning of multi-region power systems with short-term and long-term uncertainty. Available at arXiv:2209.03471

[2] Hongyu Zhang, Ignacio E. Grossmann, Brage Rugstad Knudsen, Ken McKinnon, Rodrigo Garcia Nava, Asgeir Tomasgard. (2023). Integrated investment, retrofit and abandonment planning of energy systems with short-term and long-term uncertainty using enhanced Benders decomposition. DOI: 10.48550/arXiv.2303.09927

[3] Hongyu Zhang, Ignacio E. Grossmann, Asgeir Tomasgard. (2023). Decomposition methods for multi-horizon stochastic programming. DOI: 10.21203/rs.3.rs-3258743/v1

AØO34: Machine learning model to integrate tacit knowledge in delivery route optimization

Routing problems for last-mile deliveries have been extensively studied by the operations research (OR) community. The routes generated by the developed OR methods have contributed to billions of euros in annual savings for companies worldwide, as well as reductions in driving time. However, these OR methods often rely on simplified representations of reality, overlooking the complexity and unpredictability of real-world environments.

Zendera, a software company specializing in last-mile delivery solutions, observes a significant discrepancy between actually driven routes and those suggested by optimization algorithms. This discrepancy arises because traditional optimization focuses on travel time, neglecting that 75% of the route duration comes from the last 100 meters of transport: finding a parking spot and making the delivery, possibly after waiting in line. The optimization algorithms fail to account for the varying experience levels of drivers, which can significantly impact the efficiency of route execution, especially in unfamiliar areas where drivers face challenges like locating the delivery address, dealing with closed roads and local traffic patterns, or finding the correct recipient at a given address.

This suggests a gap in understanding, corresponding to the tacit knowledge of drivers and dispatchers, that both academic research and optimization algorithms have yet to fully capture. This master project aims to bridge this gap by employing machine learning models to extract and formalize this tacit knowledge and then apply it within the optimization process. Key research problems include addressing 1) the capability of machine learning to predict the non-execution of a planned route by an optimization algorithm and 2) the possibility of machine learning to accurately estimate the true costs and durations of routes, considering factors such as parking, delivery time, and other logistical challenges.

The project can include the following tasks:

- Reviewing the relevant literature that applies machine learning to delivery and routing problems
- Collecting data from the industry partner
- Developing and implementing a machine learning model
- Evaluate and analyze the ability of the model to capture tacit knowledge

The project requires proficiency in optimization and programming skills.

Industry partner: Zendera

Main supervisor: Kais Msakni

Co-supervisor: Lars Magnus Hvattum, Professor at Molde University College

Industry Co-supervisor: Kim Iversen

Strategic research initiative: Leading transitions: Co-create a sustainable future / Green Value Creation - Circular Economy

For more information, please contact Kais Msakni, kais.msakni@ntnu.no, to schedule a meeting.

AØO35: Macroeconomic Analysis of the Economic Impacts of Coal Phase-Out in Europe

The transition towards a sustainable energy system is a critical component in combating climate change, with coal phase-out being a central strategy for reducing greenhouse gas emissions in Europe. The challenge lies not only in achieving environmental targets but also in understanding and mitigating the economic impacts of such transitions on various sectors and regions. This project aims to employ the REMES-EU Computable General Equilibrium (CGE) model to analyse the broader economic implications of coal phase-out in Europe, considering both the direct and indirect effects across sectors and regions. The model will be used to evaluate the potential economic impacts under different scenarios of coal phase-out, including immediate and gradual transitions, and assess policy interventions that can facilitate a just and efficient transition. The project aims to provide comprehensive insights into the economic ramifications of coal phase-out in Europe, identifying sectors and regions most at risk and the potential for economic transformation. It will offer evidence-based recommendations for policymakers and stakeholders on designing policies that ensure economic stability and growth while achieving environmental objectives.

Activities:

Adapt the REMES-EU CGE model to analyse different policies to phase out coal, both on the supply and on the demand side. Analyse the impact of coal phase-out on energy prices, sectoral outputs, employment, and regional economic activities. Evaluate the effectiveness of various policy instruments (e.g., carbon pricing, subsidies for renewable energy, and retraining programs for the workforce) in mitigating negative economic impacts. Conduct scenario analysis to explore the economic outcomes of different speeds and strategies of coal phase-out, considering the international commitments under the Paris Agreement and the European Green Deal. Assess the role of technological advancements (e.g., renewable energy sources, energy efficiency improvements) in supporting the transition.

Pre-requisites:
Understanding of economic modelling. Proficiency in programming (GAMS) and data analysis tools (e.g., Excel Pivot Tables). Strong analytical skills and interest in energy economics, environmental policy, and sustainable development.

Collaboration:
JUSTCOAL Project: Modelling the regional welfare impacts of just coal transitions

Supervisor: Paolo Pisciella

Co-supervisors: Omkar Patange and Michael Kuhn (IIASA)

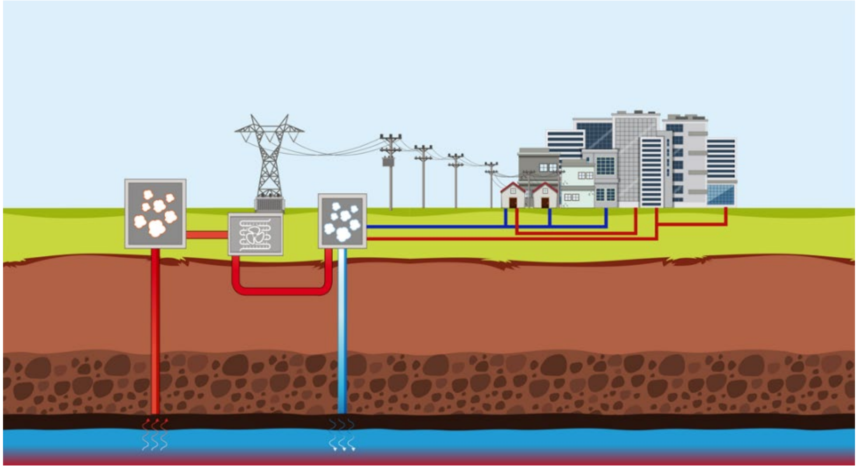
Questions and clarifications: paolo.pisciella@ntnu.no

References:

[1] Böhringer, Christoph, and Knut Einar Rosendahl. "Europe beyond coal–An economic and climate impact assessment." *Journal of Environmental Economics and Management* 113 (2022): 102658.

[2] Oei, Pao-Yu, et al. "Coal phase-out in Germany–Implications and policies for affected regions." *Energy* 196 (2020): 117004.

AØO36: Modellering av fremtidens energisystem med fleksibel bruk av termiske laster



Beskrivelse: Oppvarming og kjøling står for halvparten av det totale endelige energibehovet i Europa. I motsetning til strømbehovet dekkes størstedelen av oppvarmingsbehovet fortsatt med fossile brensler i Europa: naturgass står for 66 % av produksjonen av rom- og tappevannsoppvarming i Europa. Samtidig, med økende andel av variable fornybare energikilder i kraftnettet, vil det kreves en betydelig mengde sluttbrukerfleksibilitet i fremtiden. For dette formål har fleksibel drift av varme- og kjølelaster et høyt potensial. Nøkkelteknologier i dette samspillet er varmepumper og termisk lagring: varmepumper muliggjør utslippsfri og energieffektiv produksjon av varme og kulde, og med termisk lagring kan produksjon skje i perioder når det er mye fornybar kraft tilgjengelig i kraftnettet.

Oppgave: Prosjektet FLXenabler har som mål å utvikle et modelleringsrammeverk for å analysere samspillet mellom økt fornybar energiproduksjon, avkarbonisering av termiske laster, og bruk av fleksible termiske laster. Hypotesen er at med smart kobling av varmepumper og termisk lagring, vil overgangen til et fullstendig avkarbonisert energisystem kunne skje raskere og med lavere totalkostnad. Utfordringen er at det ikke finnes et dekkende modelleringsrammeverk som kan vise effekten av termisk fleksibilitet i kraftsystemet i sin helhet, både på sentralisert og desentralisert nivå.

Oppgaven består i å:

- Sette seg inn i bruk av eksisterende lineære optimeringsmodell GENeSYS-MOD
- Kartlegge dagens representasjon av termisk fleksibilitet i GENeSYS-MOD og lignende modeller
- Foreslå forbedret representasjon av fjernvarme, termisk fleksibilitet, og termisk energilagring i GENeSYS-MOD
- Implementere forbedret representasjon av fjernvarme, termisk fleksibilitet, og termisk energilagring i GENeSYS-MOD
- Løse noen case med GENeSYS-MOD for å sammenligne og validere påvirkning av modelltilpasninger tilknyttet termisk fleksibilitet.

Forutsetninger: Det er en fordel at studenten har kjennskap til (eller evne til å sette seg inn i):

- Programmering (fortrinnsvis Julia, Python og GAMS er også relevant)
- Operasjonsanalyse, Lineær Programmering
- Energisystemanalyse
- Kraftmarkeder

Collaboration: SINTEF Energi og Equinor via prosjektet: [FLXenabler - Flexible heating and cooling and geothermal energy storage as an enabler for decarbonized integrated energy systems - SINTEF]

Supervisor: Stian Backe (Førsteamanuensis II @ NTNU)

Co-Supervisors: Dimitri Pinel (Forsker @ SINTEF Energi), Sturla Sæther (Overingeniør @ Equinor), Konstantin Löffler (Research Associate @ TU Berlin)

AØO37: Multimodal rebalancing of micromobility solutions

Micromobility solutions are becoming an increasing popular means of transport in cities. This includes light shared vehicles such as e-scooters, mechanical bikes, cargo-bikes and e-bikes. Micromobility fleet operations face some of their most challenging times as interest from investors often comes with a requirement of proven profitability. Each operator in a city has their own crew to

ensure availability, order, and uptime for their shared vehicles. They typically operate out of trucks, continuously trying to figure out the most efficient route to fulfill their tasks:

- *Rebalancing* - predicting demand, moving vehicles to where they generate the most trips, and moving vehicles away from full stations.
- *Maintenance* - ensuring that vehicles are safe and functional. Often possible to solve on the spot.
- *Battery swap/charging* - infrastructure availability and/or battery swap management becomes increasingly important with the electrification trend. Often solved on the spot.

To improve profitability, operators can collaborate across these operations. The typical use case will be to investigate the simultaneous rebalancing and swapping of batteries of e-scooters and city bikes.

The envisioned research project focuses on developing optimization models that allow for the multimodal rebalancing, while potentially integrating other tasks such as maintenance or battery swaps. Nevertheless, different research questions can be investigated. The students can build on existing work that has been performed in the last couple of years. Through our collaboration with Urban Sharing, Ryde Technology and Oslo Bysykkel, we are able to work with real life data from a range of cities (including Oslo, Bergen and Trondheim). The developed models can be tested and implemented in these cities and lead to actual improvements.

Regardless of the chosen problem, the following elements will be part of the thesis:

- Identifying the scope and problem description
- Formulation and implementation of an optimization model. Most likely a variant of the stochastic-dynamic bicycle rebalancing problem
- Development of an appropriate solution method. Heuristics tend to be needed.
- Testing of the solution method on problem instances based on real life data

Urban Sharing is a Norwegian startup developing technology for better resource utilization I cities. Their software is being used in the bike-sharing systems Oslo, Trondheim, Bergen, Milano og Verona. Urban Sharing has their main office in Parkveien in Oslo.

Industry partners: Urban Sharing, Ryde Technology, Oslo Bysykkel

Supervisor: Henrik Andersson

Co-supervisor: Steffen Bakker

Strategic research initiative: Leading transitions: Co-create a sustainable future

Sustainability

For more information, please contact henrik.andersson@ntnu.no to schedule a meeting.

AØO38: Myopic Improvement of Current Operational Policies for Dual Sourcing

It is well known that demand uncertainty sparks the need for safety stock and that the longer the lead-time is the more safety stock is needed. Dual sourcing is a commonly used method to reduce the need for safety stock by using an alternative supplier with a shorter lead-time and a higher cost unit cost as an "emergency" source when the stock is running low.

Determining when and how much to order from the "normal" and "emergency" source is a complicated problem as the optimal decision depends on the exact location of all the units currently in the pipeline. For example, it makes less sense to order from the "emergency" source if there is some units order from the "normal" source that will be available just a short time after any unit ordered from the "emergency" source. The most used policies, e.g., the dual-index policy and standing order policy, are easy and intuitive to implement but make little or no use of the exact information about the current pipe-line inventory.

Simple methods to myopically improve on these policies thus have a great potential of reducing the total cost. Moreover, they serve as a good benchmark and starting point for more advanced methods for optimizing the system such as for example machine-learning approaches.

Tasks within the project can include:

- Study of existing models and solution methods for dual sourcing.
- Developing a method for myopic improvement of some selected policies.
- Evaluation of a heuristic based on this myopic improvement.

Main supervisor: Peter Berling

Strategic research initiative: Leading transitions: Co-create a sustainable future / Sustainability.

For more information, please contact Peter Berling, lars.p.berling@ntnu.no, to schedule a meeting.

AØO39: Nordic Hydrogen Hubs - Roadmaps towards 2030 and 2040

Description: Hydrogen and its derivatives are considered as key pillars in the green transition. Globally, there are significant ambitions and a high number of initiatives to increased usage of hydrogen in the energy sector and as replacement for fossil sources in industrial processes. Hydrogen can also play a critical role as a supplement to direct electrification in hard-to-abate sectors, such as high temperature heat applications in industry, maritime and heavy-duty transport.

In 2019, all the Nordic countries committed to work towards carbon neutrality in the Nordic region by signing the "Declaration on Nordic Carbon Neutrality", which highlights the importance of a Nordic collaboration for decarbonizing the transport sector and removing obstacles to low-emission development. All the Nordic countries have Hydrogen plans, roadmaps and/or strategies as well as ongoing hydrogen related research and demonstration programs. There is a need to understand the implications of different Nordic hydrogen roadmaps in terms of costs, production, transport infrastructure, and storage of hydrogen.

Task: As part of a Nordic research project, the student will use and develop the existing stochastic linear programming model EMPIRE to study the cost optimal investment pathway of the blue and green hydrogen production in the Nordics, as a part of the wider European power system.

The project tasks can include:

- Learning to run and adjust EMPIRE to analyse investments in the Nordic energy system with a European perspective towards 2030 and 2040.
- Collect sector-specific data for the potential hydrogen value chains in Norway, Sweden, Denmark, and Finland based on national roadmaps/strategies.
- Solve EMPIRE in several cases to study how the development of different Nordic hydrogen roadmaps impact investment decisions regarding power supply for electrolysis, gas reformation with carbon capture and storage, and hydrogen infrastructure.

Prerequisites: The student should be familiar with (or have capacity and interest to learn):

- Programming/coding (Python)
- Stochastic programming (decision making under uncertainty)
- Energy system analysis
- Power markets and sector coupling

Collaboration: SINTEF Energi via Nordic project **"NordicH$_2$ubs"**

Supervisors: Stian Backe (Assoc. Professor II)

Co-Supervisor: Pedro Crespo del Granado (Assoc. Professor)

AØO40: Optimal replacement of a fishing vessel with a zero-emission alternative

The Norwegian fishing fleet consists of approximately 6000 fishing and utility vessels that predominantly use marine diesel for propulsion and auxiliary power. Their annual fuel consumption constitutes emissions amounting to about 1.1 Mt CO2-equivalents or 23.4% of the total CO2 emissions from domestic shipping. Reaching Norway's ambitious emissions reduction goals of 50% by 2030 will therefore require a significant number of vessels to be replaced by or converted to zero-emission fuels in the years to come.

Unfortunately, the adoption of zero-emission technologies in the maritime sector is slower than for road-based transportation. This might be due to a lack of infrastructure insufficient incentive schemes, immature technology, and/or uncertainty regarding costs and regulatory framework, among others. In addition, (as of today) zero-emission alternatives cannot compete economically with existing solutions based on fossil fuel. However, technology is expected to mature and zero-emission fuels will become available at lower costs (while fossil fuel will become more expensive). Replacing an existing fossil-fuel powered fishing vessel with a zero-emission powered vessel may therefore not only make sense from an environmental point of view, but also become an economically viable alternative.

The purpose of this project is to develop a model for providing decision support to a fisherman for determining the optimal point in time to replace the existing fishing vessel with a zero-emission alternative. The analysis can also include how different incentive schemes, e.g. CO2 taxes or subsidies for investing in zero-emission technology, will impact the fisherman's decision. As a first step, a deterministic analysis may be carried out, but extensions to account for uncertainty should be considered in subsequent analyses.

The following main tasks are usually part of the project work:

- Understand the problem and study relevant literature
- Develop a mathematical formulation for the problem
- Examine applicable solution methods
- Collect data and set up test instances based on available data
- Implement and solve the model
- Analyze and discuss the results

This project is part of the ongoing research project *ZeroKyst KSP – Decarbonising the fisheries and aquaculture industry through hydrogen-electric propulsion.*

Collaboratiom: ZeroKyst-project (ZeroKyst - SINTEF), SINTEF Ocean

Main supervisor: Peter Schütz

Strategic research initiative: Leading transitions: Co-create a sustainable future

Sustainability

For more information, please contact Peter Schütz, peter.schuetz@ntnu.no.

AØO41: Optimalisering innhenting av melk med optimal frekvens

TINE SA ved Norsk Melkeråvare er landets markedsregulator av melk, på vegne av den Norske stat, og skal sikre at melkeproduksjonen gis anledning til å bli utøvd på like vilkår over hele landet. Hos omkring 6500 hentelokasjoner ble det i 2023 hentet omring 1.386 mill. liter ku melk og omkring 18 mill liter geitmelk. All melk som hentes inn skal til anvendelse, og tankbilene leverer melken for videre bearbeidelse hos TINEs 28 anlegg, eller til eksterne meieriselskaper som Synnøve Finden, Q Meieriene, Rørosmeieriet eller Normilk iht behov og bestilling. Det hentes regelmessig melk hos produsentene iht dagens frekvenser som ligger på 2 eller 3 dagers frekvens, gjennom hele året, fra Finnmark i Nord og til Lindesnes i Sør.

Melk hentes med ca 250 tankbiler og 220 hengere. Årlig samlet kjøredistanse ligger omkring på 22 mill km. Melken skal anvendes/tildeles iht prioritet av anvendelsen:

1. Drikkemelk/Konsum
2. Ost dagligvare
3. Regulering ost / Skummetmelk pulver

Det er en sentral utfordring å kunne samle inn melk i distriktene, og levere denne til optimal anvendelse, siden melk med sine naturlige betingelser, bør ha ubrutt kjølekjede og kort lagringstid før videre bearbeidelse og anvendelse på mottakende anlegg. Melk som levert til drikkemelk/konsum skal bearbeides innen 36 timer etter levering, og ost dagligvare / regulering ost/skummetmelk pulver, skal bearbeides innen 48 timer.

Utfordringen er å hente melk til fast frekvens som dekker mottakende anleggs behov, uten at det genereres unødig kjøring innenfor de betingelser som er gitt for henting og anvendelse. Vi har i dag ulik hentefrekvens basert på anleggenes mottak og anvendelse av melk, men ønsker en vurdering av optimal drift. Denne oppgaven handler om å ruteplanlegge med optimal innhentingsfrekvens sett opp mot lavest mulig totalkostnad målt opp mot kjørte km og antall tankbiler i de ulike geografiske områdene.

Følgende hovedelementer vil inngå i prosjektoppgaven:

- Sette seg inn i problemet og studere relevant litteratur
- Formulere en matematisk modell for problemet
- Utvikle og teste aktuelle løsningsmetoder på reell data fra TINE
- Analysere og diskutere resultatene

Det er naturlig at prosjektoppgaven forlenges inn i en masteroppgave med dypere analyse av problemet og utforskning av metoder for å håndtere økt problemstørrelse og kompleksitet. Et eksempel på utvidelse av problemet er å vurdere hvilke frekvenser som vil være optimal og konsekvenser de eventuelt måtte ha for foredlingsleddet av melken. Oppgaven vil gjennomføres med veiledning fra instituttet. I tillegg stiller TINE med med-veiledere med bakgrunn fra optimering i TINE, samt god tilgang på reell data fra deres operasjon.

Veileder: Magnus Stålhane

Samarbeidsbedrift: Norsk Melkeråvare / TINE SA

Ta gjerne kontakt med Magnus Stålhane (magnus.staalhane@ntnu.no) for et kort møte dersom dere har spørsmål vedrørende oppgaven.

AØO42: Optimization and Learning for Warehouse Logistics

In wholesale warehouses items arrive from manufacturers on standard-sized pallets in single-item stacks, which are stowed away in the warehouse. Items are then retrieved and stacked in mixed-item stacks according to customer orders before they are transported to the stores. The retrieval and restacking related activities are co-dependent, and jointly considering up- and down-streams operations is key to aid and/or replace hard human labor with robots. The SINTEF project Optimization and Learning for Warehouse Logistics (OWL) addresses the lack of algorithms for solving these complex problems that prevent further development and implementation of digital solutions and feasible and affordable autonomous systems in warehouse operation.

Overall objective of OWL:

The overall project aims to improve human working conditions and reduce environmental and economic cost across the wholesale warehouse value chain by developing analytic and learning based algorithms for internal warehouse optimization problems.

Potential research questions:

Within this context there are various research challenges that are suitable as master projects:

- (ML) Reinforcement learning for stacking pallets. Train an algorithm that can decide where boxes should be placed on the pallet given an item order. Alternatively, train a model that decides which order is likely to yield high quality pallets.
- (ML/OPT) Bayesian-Hyper-parameter tuning for stacking algorithms. Algorithms for solving this problem are typically parametrized. Given an instance of the problem, finding a good performing set of parameters is an open challenge.
- (OPT/ML) Characterising and balancing objectives. Acceptable solutions (stacks) are typically balancing multiple desirable facets while stacking. Eg. compactness, and stack stability. Finding out how much an objective can be traded off for another one is an open question.
- (OPT) Bounded re-stacking. By allowing a bounded number of items to be restacked as the stack is being built, we expect finding solutions with higher compactness. Finding out how much can be gained is an open question.

The project will be defined jointly by the students and the supervisors.

Recommended prerequisites: Knowledge of Discrete Optimization and machine learning, elements of statistics, good command of Python/Julia/Rust.

Industrial partner: SINTEF Digital, OWL - Optimization and Learning for Warehouse Logistics

Main Supervisor: Henrik Andersson,

Industry Supervisors: Atle Riise/Milan De Cauwer (SINTEF) depending on topic.

If you are curious to know more about the project, please contact Henrik Andersson, henrik.andersson@ntnu.no, to schedule a meeting.

AØO43: Optimizing Power Market Dynamics: A Study on Intraday Markets, Congestion Management, and Distributed Flexibility Integration

The evolution of power markets and the increasing integration of renewable energy sources present new challenges for energy systems worldwide. This proposed master thesis aims to investigate the intricate relationship between power market modeling, intraday markets, congestion management, and the integration of distributed flexible sources within novel TSO-DSO schemes. Research Objectives:

1. Develop Optimization Models for Power Markets: Utilize optimization techniques to model the dynamics of power markets, considering various factors such as supply, demand, pricing mechanisms, and market participants' behaviors.

2. Analyze the Role of Intraday Markets in Congestion Management: Investigate how intraday markets impact congestion management strategies, including redispatching of generation resources and alleviation of grid constraints.

3. Study New Market Designs for Distributed Flexible Sources: Explore innovative market designs that facilitate the integration of distributed flexible sources, such as demand response, energy storage, and distributed generation, into existing power market frameworks.

Expected Outcomes: i) Insights into the complex interactions between power market dynamics, intraday trading, congestion management, and the integration of distributed flexibility and ii) Identification of opportunities and challenges in implementing new market designs and TSO-DSO schemes

Potential Impact: This research has the potential to inform policymakers, energy regulators, and industry stakeholders about the design and implementation of effective market mechanisms for accommodating renewable energy integration, enhancing grid flexibility, and ensuring reliable and sustainable electricity supply. The project will be in collaboration with iDesignRES and PowerDig research projects with industry partners. There might travelling opportunities for hands-on discussions.

Requisites: Programming skills (Python). Critical thinking and analytical skills. Curiosity on energy transition and energy system modelling

Supervisor: Pedro Crespo del Granado

Co-Supervisors: Stefan Jaehert (SINTEF energi), Ehsan Chokani, and Wouter Koks

Questions and clarifications: pedro@ntnu.no

AØO44: Optimizing the maintenance level to extend the life of offshore wind farms

The world stands in front of a major task of transitioning to renewable energy to solve the climate crisis. With the goal of turning Europe into the first climate neutral continent by 2050, EU launched the Green Deal in July 2021. Offshore wind is a young industry that is in rapid development and is expected to constitute an important part of the future energy system. Hence, among other initiatives within renewable energy, the ambitions are to meet the European Green Deal partly by reaching 300 GW of installed offshore wind capacity by 2050. For reference 1 GW of electricity is enough to support 750,000 homes. As a consequence many new wind farms are currently being planed and will be installed the coming years.

Compared to other energy sources offshore wind energy has a relatively high levelized cost of energy (LCOE), that is the average production cost over the wind farms lifetime. To ensure that the ambitions of offshore wind are viable, it is crucial to decrease the LCOE. One potential way of doing this is to extend the lifetime of wind farms. Offshore wind farms have an expected operational lifetime of 20 to 25 years, however, the actual operational life of a wind farm is closely related to how operations and maintenance (O&M) is handled. The harsh conditions at sea makes the logistic planning a complex task and therefore maintaining offshore wind turbines is costly.

This project is connected to work-package 2: "Marine operations and Logistics" within the FME NorthWind which focus on effective logistics planning for maintenance at offshore wind farms. In particular, the focus is on the connection between the maintenance level during the operational lifetime of the wind farm and the possibility of extending the lifetime of the wind farm beyond the expected operational lifetime. The investigation could entail (but is not limited to) the formulation of a mixed integer stochastic programming model and/or simulation framework that captures this connection and address the uncertain underlying parameters such as component degradation rates and weather conditions. Wind farm owners are obligated to have a plan for the end of life of the wind farm already in the planning phase before the wind farm is installed. Therefore this project can deliver decision support in the planning phase of the wind farm as well as later life stages of the wind farm.

Some relevant topics that may be included in the project (and/or Master thesis) are:

- Investigate the problem, study existing models and solution methods for related problems
- Develop precise mathematical model formulation(s)
- Consider methods for handling the problems underlying uncertain parameters
- Implement exact and/or heuristic solution method for the problem
- Test the implemented solution method on problem instances and analyse/discuss the results

Industry partner: Potential partners in FME NorthWind

Main supervisor: Magnus Stålhane

Co-supervisor: Vibeke Hvidegaard Petersen

If you are curious to know more about the project, please contact Magnus Stålhane, magnus.staalhane@ntnu.no, to schedule a meeting.

AØO45: Planning policies for surgery planning under uncertainty

The Control Tower project is an innovation project between Oslo University Hospital and KPMG with ServiceNow to develop a unique digital tool for surgery planning (video link). The partnership has produced a KPMG-owned product, with optimization algorithms as core functionalities.

We wish to analyze the effects of uncertainty on surgery schedules, and to identify strategies on how planners should handle this uncertainty. To do this, students should develop an optimization model to solve a complicated stochastic surgery planning problem. Furthermore, testing should be done in a way that provides managerial insights.

A practical understanding of this problem is that surgical managers, based on the specific mix of patients they must treat under existing resource limitations, need to consider their approach to handling disruptions. Such disruptions include emergency cases, uncertain duration of surgeries, absence among staff etc. How should managers handle this? In real-life, some have a designated operating room for emergency cases. In what cases are designated ORs advised? Some designate a room for a specific time period during the day. Is this a smart approach to planning? And are there any recourse actions that can improve effectiveness of schedules when disruptions occur?

Insights from this project should be of practical use for implementation of the KPMG-product, when discussing planning policies with surgical managers. Ideally, the project delivers clear managerial insights, and in specific cases we are open to discussing implementation as part of the project, so long as it does not reduce the academic qualities of the work.

Research topic: Develop algorithms and optimization models of a stochastic surgical planning problem. Ideally the problem solved closely resembles real-life surgery planning problems. Find managerial insights for stochastic surgical planning, that are relevant in practice. Students should in cooperation with industry supervisors identify the best approach to making insights and deliverables from the project relevant for real-life problems.

Methods/tasks:

- Understand the nature of real-life surgery planning
- Review the current literature for similar problems (similar applications, and also problems from other applications of a similar structure).
- Understand the current KPMG models for surgery planning
- Develop a stochastic surgery planning model
- Design tests and perform analyses to provide managerial insights

Recommended prerequisites: Knowledge of Optimization. Programming skills. Interest in health care industry. Interest in ServiceNow technologies and/or javascript is an advantage.

Industry partner:	KPMG
Main supervisor:	Anders Gullhav
Industry Co-supervisor:	Kjartan Kastet Klyve/ Jørgen Schreiner/ Colleagues (KPMG)
Strategic research initiative:	Health and the Public Sector

For more information, please contact Anders Gullhav, Henrik Andersson, henrik.andersson@ntnu.no, to schedule a meeting.

AØO46: Quantum computing - Quantum optimisation for operational research and energy systems

The field of Quantum Computing (QC) has seen great improvements over the last decade with companies like IBM and Google investing heavily in order to develop resources capable of solving challenging computational problems. By using phenomena such as superposition, entanglement and tunnelling QC has the potential to offer unparalleled computational power to solve certain complex optimisation problems and more. Although these machines are still subject to errors and their applicability is limited by their scalability, D-Wave's quantum annealers are slowly pushing into the realm of industrial use. Especially so-called hybrid workflows, where both the power of classical and quantum computers is leveraged with respect to their individual strengths, have shown very promising results in recent years. Decomposing suited problems and embedding these properly on the quantum hardware can possibly lead to both a performance increase in solution quality and computational time.

Activities:

Understanding some of the fundamental laws of quantum mechanics and how they can be used for computation. The focus will lie on D-Wave's quantum annealers [1]. Decomposing a suited problem in the field of operational research or energy and create a custom hybrid workflow using both classical and quantum computing instances to solve the problem. Therefore, a possible embedding of the optimisation problem onto D-Wave's quantum annealing hardware has to be found.

Pre-requisites:

Programming skills (Python), experience with optimisation, mathematical models and possibly decomposing. Interest in learning some quantum physics. Critical thinking and analytical skills.

Supervisor: Mostafa Barani

Co-supervisor: Finley Quinton, Tatiana Grandon Gonzales, Pedro Crespo del Granado

Questions and clarifications: quinton.f.alexander@ntnu.no, mostafa.barani@ntnu.no

[1] https://www.dwavesys.com/

[2] McGeoch, Catherine C., and Pau Farré. "Milestones on the Quantum Utility Highway: Quantum Annealing Case Study." *ACM Transactions on Quantum Computing* 5.1 (2023): 1-30.

AØO47: Scenario Generation procedure for treating renewable generation uncertainties in stochastic long-term expansion planning tools

EMPIRE, a linear multi-horizon stochastic programming model, is utilized for studying long-term investment planning within electricity systems, encompassing Europe. The electricity system, represented as a network of nodes and arcs, comprises countries or regions (nodes) and cross-border transmissions (arcs). Decision-making occurs on two temporal scales: investment, spanning 5-year intervals, and operational, with hourly steps. Input parameters encompass technology costs, capacities, constraints, resource potential, carbon emissions, and demand, while output parameters include investments, production, and emissions. Developed at NTNU, EMPIRE has been instrumental in analyzing European power system decarbonization in multiple studies.

Investment decisions within EMPIRE address endogenous operational uncertainty through stochastic operational scenarios, focusing on short-term uncertainties rather than long-term ones. Currently, three methodologies generate operational scenarios, capturing short-term uncertainties related to renewable energy production (wind, solar, and hydro) and system load variability.

This thesis aims to improve the process of scenario generation by introducing a novel methodology and conducting a comparative analysis with existing ones. The resulting algorithm will be openly accessible alongside EMPIRE, possibly through an online repository. While the developed methodologies are tested on EMPIRE, they will be designed as a unified tool capable of being used with other expansion planning tools.

For further details on EMPIRE's mathematical formulation, refer to the software documentation in the open-source repository [1].

Key Activities:

1. Understanding stochastic programming and the EMPIRE model.
2. Exploring existing scenario-generation procedures within EMPIRE and other tools, as well as reviewing methodologies in the literature.
3. Developing and comparing a new scenario-generation method for EMPIRE through various stability tests.

Prerequisites:

Candidates should possess programming skills, particularly in Python, along with experience in optimization and a strong background in mathematics and possibly statistics. An interest in managing uncertainties linked to renewable generation resources in long-term electricity system investment planning, alongside critical thinking and analytical abilities, is crucial.

Reference:

[1] Backe, S., Skar, C., Crespo del Granado, P., Turgut, O., & Tomasgard, A. EMPIRE: An open-source model based on multi-horizon programming for energy transition analyses. SoftwareX, 17, 100877. doi: https://doi.org/10.1016/j.softx.2021.100877.

Main Supervisor: Mostafa Barani, NTNU

Co-Supervisor: Pedro Crespo Del Granado, NTNU

For questions and clarifications, contact mostafa.barani@ntnu.no.

AØO48: Solving the Feeder Network Design with inventory as a buffer mechanism

Liner shipping is the world's most important mode of freight transport, accounting for about 60% of the total volume of international trade. Typically, large container vessels sail regular routes to connect major hub ports on different continents. Containers are then transported from a hub port to regional (feeder) ports using medium and small vessels. The process of establishing liner routes from/to feeder ports and assigning vessels (in terms of number and size) to deploy these routes on a regular basis is called *Feeder Network Design*. This process is at a tactical level, and the routes are planned to be used for several months.

The Feeder Network Design has been solved using optimization methods, considering various problem characteristics, from integrating a homogeneous fleet of vessels to adopting a more complex routing structure. Although more realistic characteristics are considered when solving the problem, the demand for containers between the hub and feeder ports is considered to be known and weekly fixed for the whole planning period. However, the demand is usually uncertain in practice, making the problem even more complex. In fact, if weekly demand is lower than expected, vessels operate at a lower capacity. Conversely, higher demand leads to a need to charter excess capacity, delayed deliveries, or lost sales. In all cases, additional (unplanned) costs are incurred by the logistics company. To cope with the demand uncertainty, safety measures must be determined, e.g., safety-stock or excess transport capacity.

This project aims to study the Feeder Network Design with demand control. Two aspects of the problem can be considered:

- Optimal/efficient inventory policy given limitations of transport capacity.
- Creating feeder routes that are more robust to the demand variations.

The case studies will be based on realistic data for a feeder network between the port of Rotterdam and Norwegian ports.

The following main tasks are expected to be part of the project work:

- Understand the problem.
- Write a literature review of related works.
- Formulate the problem mathematically and possibly propose a specialized solution method.
- Conduct a computational study.
- Discuss and analyze the results.

Main supervisor: Peter Berling (NTNU)

Co-supervisor: Kais Msakni (NTNU)

Strategic research initiative: Leading transitions: Co-create a sustainable future, Sustainability.

AØO49: Stochastic and dynamic production optimization

When operating a production process, good estimates of Key Performance Indicators (KPIs) are imperative to make good operational decisions over time. Measuring KPIs is typically complex, and the quality of the data from the measurements is often mediocre. Either the measurements are of high quality but scarce, or they are noisy but frequent, depending on the process and measurement techniques. In addition, the system that is measured is dynamic and changes over time. Making reliable decisions under these circumstances, therefore, means facing three major challenges: a small data regime, poor measurement quality, and non-stationary underlying processes.

Optimizing production under such circumstances is extremely complex and developing methods for decision support is challenging. Insight into how stochastic and dynamic production systems behave, how the uncertainty can be modeled and the interaction between uncertainty models and production optimization is lacking. Solution Seeker is developing system simulators that allow for a realistic description of production systems, but where the underlying uncertainties can be controlled. This enables the development of methods that can be rigorously tested and that can give new insight into stochastic and dynamic production systems and how uncertainty can be handled.

Solution Seeker (https://www.solutionseeker.no) develops and delivers AI-as-a-service to among others, the petroleum industry, including technology for optimizing the production of oil and gas assets. They have been the industrial partner for more than 10 MSc theses at IØT. This project is linked to RICO - Robust Intelligent Control, an ongoing Collaborative and Knowledge-building Project funded by the Research Council of Norway. Partners in the project are NTNU, SINTEF, Solution Seeker, TrønderEnergi among others, see https://www.ntnu.edu/ailab/rico for more information.

Using machine learning to model uncertainty and combine these models with production optimization models is a key challenge in this project. More specifically, neural networks will be used in modeling the production process as these models are highly flexible. Despite their enormous potential, neural networks are facing major challenges when modeling physical processes. While the main focus of the master project will be on optimization using neural network models, researchers in the RICO project and in Solution Seeker are constantly working on the challenges of modeling physical processes with neural networks, and the master student will get the possibility to gain insight in how these challenges are addressed.

The case study of this master project is likely to be conducted on simulation models of petroleum wells. However, the general nature of the AI and optimization methods that will be used in the project means that the outcome of the research is likely to be transferrable to other domains and production processes.

The following main tasks are usually part of the project work:

- Understand, define, and describe the problem and its setting
- Investigate what mathematical optimization and machine learning methods can be used
- Design and implement a solution method
- Set up a computational study where the solution method is tested using the simulator
- Analyze the results from the computational study to gain insight

Recommended prerequisites: A strong background in artificial intelligence/machine learning

Industry partner: Solution Seeker

Supervisor: Henrik Andersson

Co-supervisor: Erlend Torje Berg Lundby

Industry co-supervisors: Bjarne Grimstad (Solution Seeker)

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no , to schedule a digital meeting.

AØO50: Strategiske og taktiske beslutninger for Oda's distribusjonsnettverk

Oda er den ledende dagligvarebutikken på nett i Norge, og er kjent for sin effektive logistikkoperasjon. Selskapet har utviklet operasjonen med teknologi i sentrum gjennom mange år, og har en unik og innovativ lager-operasjon og en effektiv distribusjon. Oda er et selskap i kraftig vekst og slo seg nylig sammen med det svenske selskapet Mathem som tilrettelegger for videre ekspansjon og fører til nye utfordringer innen optimalisering av verdikjeden.

I distribusjonsleddet til Oda er det en rekke taktiske og strategiske beslutninger som må løses. Eksempler på dette er hvor man skal ha distribusjonspunkter, hvilke områder man skal levere til og hvilke tidspunkter for levering man skal tilby kundene i hvert område. Problemstillingene er tett knyttet til et operasjonelt routing-problem som daglig løses av Oda sin egenutviklede ruteplanlegger, men på strategisk og taktisk nivå er man nødt til å forenkle selve routing-problemet for å søke et større løsningsrom.

Oppgaven vil kunne bygge videre på tidligere masteroppgaver med Oda som blant annet har sett nærmere på clustering, funksjonsapproksimering og bruk av maskinlæring for øke hastigheten på det underliggende routing-problemet. Sentrale utfordringer som vil bli adressert inkluderer:
- Optimalisering av leveringstilbud for ulike områder med ulik kundetetthet, med fokus på tidsvinduer for levering, pris og kapasitet.
- Modellering av kundeoppførsel som funksjon av leveringstilbud.
- Plassering og dimensjonering av distribusjonspunkter basert på stokastisk etterspørsel.
- Flåteallokering på tvers av distribusjonspunkter.

Oda møter i tillegg en rekke optimeringsproblemer i sin lageroperasjon. I dette domenet finnes det mulige problemstillinger innen ting som routing av paller, produktplassering og samlebåndskontroll. En del av detaljene er konfidensielle, men dersom dette skulle være av særlig interesse kan studenten(e) diskutere dette med selskapet.

Studenten(e) oppfordres til å anvende kreative og innovative tilnærminger til å takle disse utfordringene i tett samarbeid med veiledere fra Oda. Oda vil gi tilgang til rike datasett og innsikt i industrien, og det vil være mulig å teste løsningene med reell operasjonell data. Det er naturlig at prosjektoppgaven forlenges inn i en masteroppgave med dypere analyse av problemet og utforskning av metoder for å håndtere økt problemstørrelse og kompleksitet.

Følgende hovedelementer vil inngå i prosjektoppgaven:
- Sette seg inn i konteksten og formulere relevant problemstilling
- Formulere en matematisk modell for problemet og studere relevant litteratur
- Utvikle og teste aktuelle løsningsmetoder på reell data fra Oda
- Analysere og diskutere resultatene

Oppgaven vil gjennomføres med veiledning fra instituttet og med-veiledere fra Oda med bakgrunn fra optimering på NTNU.

Veileder: Magnus Stålhane
Industripartner: Oda
Industriveileder: Vegard Pedersen
For mer informasjon, ta kontakt med Vegard Pedersen (vegard.pedersen@oda.com).

Ta gjerne kontakt med Magnus Stålhane (magnus.staalhane@ntnu.no) for et kort møte dersom dere har spørsmål vedrørende oppgaven.

AØO51: Surgery planning with up- and down-stream activities

The Control Tower project is an innovation project between Oslo University Hospital and KPMG with ServiceNow to develop a unique digital tool for surgery planning (video link). The partnership has produced a KPMG-owned product, with optimization algorithms as core functionalities.

We wish to analyze how the scope of the algorithm could be increased to explicitly include planning of up- and down-stream activities. For many types of surgery, a patient will have multiple necessary steps prior to their surgery and after their surgery. These steps may include activities that should occur in some predefined sequence or within some time window relative to the surgery. For example, a patient could need a scan a minimum of 1 week prior to a surgery, or the hospital should reserve a bed at a suitable ward for 3 days after the patient has gone through a specific surgery. This project should provide insights on how this can be modelled and produce algorithms and heuristics that solve the problem.

The approach will likely involve a focus on developing algorithms and/or heuristics rather than MIP-models, although exact methods can become relevant for evaluating solution quality and optimality. Insights from this project should be of practical use for further development of the KPMG-product, and in specific cases we are open to discussing implementation as part of the project, so long as it does not reduce the academic qualities of the work.

Research topic: Develop algorithms and optimization models of a surgery planning and perform technical tests with them. Focus on modelling and analyzing the inclusion of up- and down-stream activities in planning. Ideally the problem solved should resemble real-life surgery planning problems closely. Students should in cooperation with industry supervisors identify the best approach to making insights and deliverables from the project relevant for real-life problems.

Methods/tasks:

- Understand the nature of real-life surgery planning
- Review the current literature for similar problems (similar applications, and also problems from other applications of a similar structure).
- Understand the current KPMG models for surgery planning
- Develop an algorithm/heuristic
- Use an optimization/computer science method for solving realistic surgery planning problems
- Possibly incorporate uncertainty modelling
- Design tests and perform analyses to provide insights for academic and industry use

Recommended prerequisites: Knowledge of Optimization. Programming skills. Interest in health care industry. Interest in ServiceNow technologies and/or javascript is an advantage.

Industry partner:	KPMG
Main supervisor:	Henrik Andersson
Industry Co-supervisor:	Kjartan Kastet Klyve/ Jørgen Schreiner/ Colleagues (KPMG)
Strategic research initiative:	Health and the Public Sector

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no, to schedule a meeting.

AØO52: The economics of gas storage: lessons from natural gas for hydrogen

Three types of geological underground formation are used for storing natural gas today: depleted oil / gas fields, aquifers, and caverns. Cavern storage typically is done in salt formations which are also apt to host hydrogen storage, unlike the two other natural gas storage types (e.g., Ozarslan, 2012, Amirthan & Perera, 2022). Salt caverns for natural gas storage are man-made structures. In other words, there can be investment in more of these caverns if a future hydrogen economy requires more storage capacity.

In Europe, in particular in Germany, there has been a vast expansion of salt cavern gas storage capacity in the past two decades (see GIE). Stronzik et al. (2008) and Neumann and Zachmann (2009) provided an analysis of this investment "wave" in its early phases. Yet, more updated research on the European case is scarce. The task of this project is to identify the economic factors that have driven the construction of salt caverns for natural gas storage in the past decades in order to deduct whether the same drivers can help the expansion of hydrogen storage.

Generally, gas storage operators can be thought of as actors that optimize the gas supply between periods of low demand / prices (when there is injection in storage) and periods of high demand / prices (when there is extraction from storage) (e.g., Chaton et al., 2008). The arbitrage (storage cycle) can be between summer and winter, but can also be on a much shorter time scale to benefit from price variations (e.g., de Jong, 2015).

The aim of the project is for students to develop an empirical model of storage operations and investments that examines the factors of high profit expectations of storage operators. Activities include:

- Familiarization with the topic, relevant literature and methods, including software tools;
- Familiarization with the European natural gas storage data;
- Application of relevant econometric model to the case of European or German natural gas storage since the 2000s;
- Analysis and discussion of results.

There will be an opportunity to spend time in Berlin and work as guest researcher at the German Institute for Economic Research (DIW Berlin) in downtown Berlin .

Main supervisor: Anne Neumann

External partner: Franziska Holz (adjunct professor at NTNU and deputy head of department at DIW Berlin (German Institute for Economic Research), supervision mainly online

References:

T. Amirthan, M.S.A. Perera (2022): The role of storage systems in hydrogen economy: A review. Journal of Natural Gas Science and Engineering, Volume 108, 104843, https://doi.org/10.1016/j.jngse.2022.104843.

C. Chaton, A. Creti, B. Villeneuve (2008): Some economics of seasonal gas storage. Energy Policy, Volume 36, Issue 11, pages 4235-4246. https://doi.org/10.1016/j.enpol.2008.07.034

Cyriel de Jong (2015): Gas storage valuation and optimization, Journal of Natural Gas Science and Engineering, Volume 24, pages 365-378, https://doi.org/10.1016/j.jngse.2015.03.029.

GIE (undated): Storage Database. Gas Infrastructure Europe. Available online at : https://www.gie.eu/transparency/databases/storage-database/

Neumann, A., Zachmann, G. (2009). Expected Vs. Observed Storage Usage: Limits to Intertemporal Arbitrage. In: Cretì, A. (eds) The Economics of Natural Gas Storage. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-79407-3_2.

Ahmet Ozarslan (2012): Large-scale hydrogen energy storage in salt caverns, International Journal of Hydrogen Energy, Volume 37, Issue 19, pages 14265-14277, https://doi.org/10.1016/j.ijhydene.2012.07.111.

Stronzik, Marcus; Rammerstorfer, Margarethe; Neumann, Anne (2008) :Theory of storage: an empirical assessment of the European natural gas market, DIW Discussion Papers, No. 821, Deutsches Institut für Wirtschaftsforschung (DIW), Berlin. Available online: https://www.econstor.eu/bitstream/10419/27344/1/586179844.PDF.

Franziska Holz is an International Adjunct Professor in the NTNU's Energy Transition Programme (NETI). Franziska is an economist by training with a Master degree from Paris 1 University Panthéon-Sorbonne (2003) and a PhD in energy economics from TU Berlin (2009). Franziska's main affiliation is with the German Institute for Economic Research (DIW Berlin) where she is Deputy Head of the Department Energy, Transportation, and Environment and coordinates the research area resource and environmental markets in the department. Her research deals with international natural gas, coal, and oil markets. She focuses on the interaction of these markets with climate policies, mostly by applying OR methods such as numerical equilibrium models (also see www.diw.de/cv/en/fholz).

AØO53: Towards Net-Zero: Decision Support for Decarbonizing Port Operations

Decarbonizing the maritime industry is often associated with transitioning ships to low and zero-emission fuels, mainly driven by the urgency to meet emission reduction targets for 2030 and 2050. However, also port operations are energy-intensive, with large equipment traditionally fueled by diesel fuels. Policy and planning strategies are essential for setting guidelines and roadmaps towards decarbonization goals. Ports, in particular, hold a central role in decarbonizing the maritime sector, as they provide the infrastructure to enable refueling of ships, and will be the hubs where different energy carriers are supplied, stored, used, and possibly transformed (fuel production).

Some ports are making great progress in sustainability development. The case of Port of Roenne exemplifies this proactive approach as it aims to become the most sustainable commercial port in the Baltic Sea [1]. The port operator has set an ambitious target to achieve CO2 neutrality across its entire value chain by 2030. This goal includes not only the direct emissions from the combustion of fossil fuels (e.g., cranes, ships, and vehicles), but also the indirect emissions from energy purchased for building heating and lighting, as well as activities at both the upstream and downstream levels, including business trips, waste management and product disposal.

This project thesis aims to provide tools to help a port operator moving its value chain towards net-zero emissions. Through analysis and modeling, the project will calculate outline plans for the timing and sizing of investment in equipment to decarbonize port operations, including cost assessments and CO_2 emissions.

The project includes the following tasks:

- Reviewing relevant literature
- Identifying port operations and priorities in decarbonization
- Collecting data on CO_2 emissions from operations and potential alternatives.
- Developing a model to assist port operators in progressively decarbonizing their operations
- Performing computational experiments on a real-world case
- Evaluating the results from both economic and environmental perspectives

This project is part of the research project NordH2ub https://csei.eu/nord_h2ub/. Knowledge in mixed integer optimization and programming skills (e.g., Python) are expected.

Industry partner: Port of Roenne A/S

Main supervisor: Ruud Egging-Bratseth

Co-supervisor: Kais Msakni

Strategic research initiative: Leading transitions: Co-create a sustainable future / Green Value Creation - Circular Economy

For more information, please contact Ruud Egging-Bratseth, rudolf.egging@ntnu.no, to schedule a meeting

References

[1] Port of Roenne, “Sustainability report,” 2022, https://portofroenne.com/media/4lvnqhlp/sustainability-report-en-final-6-0.pdf [Accessed on 05-03-2024].

AØO54: Transport problems in circular mass management

Feiring is an industrial group with expertise in sustainable solutions and products within crushed stone, asphalt and geosynthetics. As part of an ongoing research project, Feiring together with SINTEF and NGU, is working on new and efficient solutions for circular mass management. Good rock sources for crushing are a limited resource, leading to a focus on developing new services to streamline the use, reuse, and recycling as well as the storage and transport of mass flows between players in the building and construction industry.

As part of this project there is an activity to investigate the role of optimization models and tools to efficiently manage the value chain of Feiring, both on a tactical and operational level.

Research topic: Develop models and algorithms to optimize the transport of various stone products between Feiring's departments and the projects they serve. The optimization should be on an operational level and consider the detailed routing of trucks taking into account the specifics of the industry. Environmental effects are an important aspect and should be included in the models, possibly with a multi-objective approach.

Methods/tasks:

- Understand the value chain of Feiring and the role of transport.
- Review the current literature on related transport and planning problems.
- Create models and associated solution algorithms for the transport needs of Feiring.
- Implement solutions based on the developed models and algorithms.
- Carry out experiments to assess the performance of the above solutions, both in terms of solution quality and running time.
- Describe the problem, the methods, and the results in a way that can be published.

Expected Results and Learning Outcome:

- An understanding of the most suitable models and algorithms for circular mass transport.
- A prototype software that has been tested for realistic problem instances.
- A publishable description of the work.

Recommended prerequisites: Good competence in optimization modelling and algorithms. Programming experience.

Industry partner:	Feiring / SINTEF
Main supervisor:	Henrik Andersson
Industry Co-supervisor:	Truls Flatberg (SINTEF)
Collaborator:	Fredrik Hausmann (Feiring)
Strategic research initiative:	Leading transitions: Co-create a sustainable future
	Green Value Creation - Circular Economy

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no, to schedule a meeting.

AØO55: Transportstyringssystem for veibasert godstransport

Haste AS er et programvareselskap som jobber med å utvikle et transportstyringssystem for godstransport på vei. På sikt vil et slikt system måtte håndtere et bredt spekter av problemer innenfor ruteplanlegging, lagerstyring, multimodal transport, timeplanlegging for sjåfører, osv. I dette prosjektet vil det derfor være flere aktuelle problemstillinger og de(n) som blir tildelt prosjektet vil være med å utforme disse i samarbeid med Haste AS og veiledere.

Tidligere masteroppgaver og case fra Haste AS vil være et naturlig utgangspunkt der man jobber med algoritmeutvikling for å løse eksisterende problemer, utvider tidligere problemstillinger, eller jobber med en kombinasjon av disse. Typiske problemstillinger ligger under kategorien Vehicle Routing Problems (VRPs), med nærliggende rikere varianter slik som pick-up and delivery problemer, multi-periode problemer, ruteplanleggingsproblemer med lagerstyring, osv. Aktuelle utvidelser kan blant annet være håndtering av usikkerhet, inkludere mer detaljerte pakke- og lagerstyringsbeslutninger, komplekse tidsvinduer, osv.

Caset fra Haste AS omhandler en lokal transportør som videredistribuerer ulike vareflyter i sin region. Her er målet å maksimere profitt, samtidig som servicekvalitet og klimagassutslipp overholder en gitt standard. Den mest nærliggende problemstillingen er å se på en variant av et multi-periode VRP med lagerstyring og tidsvinduer. Uansett valg av problemstilling vil følgende hovedelementer inngå i prosjektoppgaven:

- Sette seg inn i problemstillingen.
- Studere relevant litteratur.
- Matematisk formulering av planleggingsproblemet.
- Studere løsningsmetoder for planleggingsproblemet, både eksakte og heuristiske optimeringsmetoder kan være av interesse.
- Implementere aktuell løsningsmetode.
- Teste løsningsmetode på probleminstanser basert på virkelig data fra en norsk logistikkaktør. Analysere og diskutere resultater.

Haste AS har virksomheten sin i Trondheim. Om du har spørsmål knyttet til oppgaven må du gjerne ta kontakt med Martin Naterstad Digernes (martin.digernes@hastelogistics.no) eller Jørgen Skålnes (jorgen.skalnes@hastelogistics.no) hos Haste AS i tillegg til veiledere angitt under.

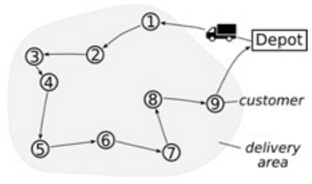
Samarbeidsbedrift: Haste AS (Martin Naterstad Digernes, Jørgen Skålnes)

Veileder: Magnus Stålhane

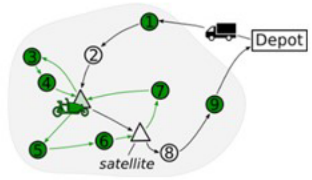
Ta gjerne kontakt med Magnus Stålhane (magnus.staalhane@ntnu.no) for et kort møte dersom dere har spørsmål vedrørende oppgaven.

AØO56: Vehicle Routing in Hybrid Systems for Urban Parcel Delivery

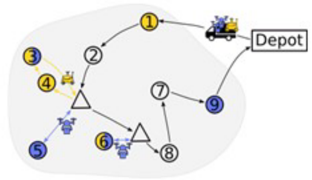
Currently, urban parcel delivery is in many countries dominated by diesel-powered vans or trucks. However, with society's growing awareness of sustainability, delivery companies are now encouraged to adopt more innovative and environmentally friendly systems. As a result, cargo bikes, robots, and drones are being investigated as potential alternatives. However, it is not always feasible to rely on only one delivery system, as the customers' locations may not be suitable for these vehicles or the parcels may be too large for particular delivery options. A possible solution is to combine multiple delivery systems (i.e., hybrid systems) in order to ensure efficient and cost-effective parcel delivery in urban areas. Findings from a previous study (by the co-supervisors of this project) indicate that cargo bikes are a cost-effective option for delivery depending on the urban infrastructure. Similarly, if robots and drones are available, they can take over a large share of deliveries.



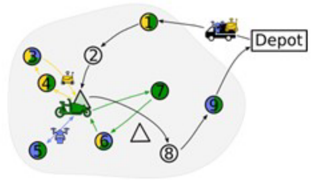
Traditional delivery



Bike delivery



Autonomous delivery



Combined delivery

The goal of this student project is to extend the previous study (mentioned above) towards delivery scheduling, which synchronizes the delivery operations of robots and drones with the time windows of customers. Furthermore, locker boxes or other delivery concepts could be included into the model to provide a more diverse set of delivery options. The resulting planning problem becomes a rich and complex vehicle routing problem. To solve problem instances of real size, we expect that advanced (meta- and/or math-) heuristics need to be developed. Hence, a good background in computer programming will be beneficial.

The following tasks are part of the project:

- Review of the scientific literature
- Expanding the previous model to incorporate delivery schedules, locker boxes, and/or further innovative delivery concepts
- Development of heuristics to solve the new problem variant(s)
- Computational experiments to assess the effectiveness and viability of different delivery strategies

The project is conducted in cooperation between NTNU and partners from Kiel University (Germany). A visit for the Norwegian partners to Kiel could be part of the project (funding will be provided) to support a fruitful collaboration.

Collaborator: Kiel University, Germany
Main supervisor: Kjetil Fagerholt
Co-supervisors: Frank Meisel and Barbara Himstedt (Kiel University)

Strategic research initiative: Leading transitions: Co-create a sustainable future

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