FACULTY OF ECONOMICS
AND MANAGEMENT

2018

International Conference on Computational Management Science

Local Chairs
Stein-Erik Fleten
Florentina Paraschiv

NORS THE NORWEGIAN OPERATIONS RESEARCH SOCIETY

CenSES Centre for Sustainable Energy Studies

EWG STOCHASTIC OPTIMIZATION

NTNU Norwegian University of Science and Technology

XV CONFERENCE ON COMPUTATIONAL MANAGEMENT SCIENCE (CMS 2018)

A warm welcome to CMS 2018!

We are delighted that you are joining us at the Norwegian University of Science and Technology (NTNU) for the 15th Conference on Computational Management Science (CMS 2018).

The CMS conference is an annual meeting associated with the journal Computational Management Science published by Springer.

The conference focuses on computational management science with emphasis on valuation problems, risk management and measurement applications, including optimal risk control problems, typically employing stochastic optimization, robust and distributionally robust optimization methods as in the tradition of CMS conferences. Increasingly over the years the conference attracted scholars from different scientific communities and Euro working groups, ranging from the optimization to the statistical, econometrical and applied maths communities and touching several application domains, including energy, finance, supply chain management and logistic problems.

This edition of the conference is co-organised by the Norwegian University of Science and Technology (NTNU), Faculty of Economics and Management, CMS Journal and the EURO Working Groups on Stochastic Optimization and Commodity and Financial Modelling.

We have a full conference programme over the next three days, so please take a few minutes to read through the important information provided in this book.

We hope you enjoy your stay in Trondheim and have a fruitful time at CMS!

Stein-Erik Fleten, Florentina Paraschiv, and Daniel Kuhn
On behalf of the CMS 2018 Committee

EWG STOCHASTIC OPTIMIZATION

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CenSES Centre for Sustainable Energy Studies

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Trondheim

Photo Pavel Szubert

Trondheim is the third largest city in Norway with its 187 000 inhabitants. Other major cities in Norways are Bergen and the capital Oslo. Trondheim is said to be founded in 997 by Olav Tryggvason, a retired Viking and later crowned king of Norway.

A statue of Olav Tryggvason is found in the city center.

The construction of Nidaros Cathedral started around 1070 and it is the northernmost medieval cathedral in the world.

The cathedral was built over the burial site of Saint Olav. Saint Olav was canonized in 1164 by Pope Alexander III and thereafter universally recognized as a saint of the Roman Catholic Church. The sculptures on the west side of the church are famous biblical figures, catholic saints and some former Norwegian kings. During maintenance on the sculpture of Archangel Michael, the artist gave him the face of Bob Dylan.

Photo Finn Bjørklid

Photo Michael Schuerle

The river Nidelva runs through the city center. Along Nidelva old tree houses, dating back to the 19th century, is a popular view for tourists. The camera is aimed at *Bakklandet,* an idyllic district known for its many old tree houses.

NTNU also has a central role in Trondheim. In 1996 the university was established, but with roots back to 1910, when the Norwegian Institute of Technology was established. Today the university has about 40 000 students where 34 000 of the students are located in Trondheim. The remaining are located at the campuses in Gjøvik and Aalesund.

On behalf of the conference crew, we hope you will enjoy the CMS conference and your stay in Trondheim.

International Conference on Computational Management Science
29 - 31 May 2018, Trondheim

Venue Information

Local transport train station – hotel: If you are arriving or departing by train, the hotels are within walking distance through the city from the train station (Sentralstasjonen), alternatively you can catch a bus from the train station or a taxi.

Local transport airport – hotel: If you are arriving or departing by plane, Trondheim airport Værnes is located 30 km outside the city. The airport bus (Flybuss or Værnesekspressen) runs every 10 minutes, cost 130 NOK (approx. 45 min) and will stop near almost all hotels in Trondheim. A taxi will cost about 650-770 NOK (approx. 30 min).

Local transport hotel – campus: From downtown, the main bus to Gløshaugen campus is AtB bus 5 (direction Lohove, bus stop: Gløshaugen Nord). Tickets can be bought at kiosks, at ticket machines in Trondheim center, or at AtB service centers, via the Mobilett app, or via SMS. Buying a ticket on the bus requires cash (50 NOK).

Flights through Trondheim Airport
The Oslo-Trondheim connection is Europe's 5th busiest, with 32 daily connections. SAS and Norwegian compete, and they both offer reasonable one-way tickets. Direct flights to London, Amsterdam, Copenhagen, Stockholm, Bergen etc.

Useful links
NTNU: www.ntnu.edu
Gløshaugen campus map: www.ntnu.edu/map
Trondheim city information: www.trondheim.no/engelsk
Bus in Trondheim: www.atb.no/?lang=en_GB
Taxi in Trondheim: +47 930 07373
Airport bus: www.flybussen.no/en/Trondheim
Train in Norway: www.nsb.no/en

NTNU Wireless network for visitors
Visitors can use either of the university's wireless networks, **Eduroam** or **ntnuguest**. The network ntnuguest allows web traffic, but nothing else. Eduroam assumes that your organization is in some way associated with the eduroam system, and that you have set up your computer according to the instructions from your local IT support.

How to connect to NTNU guest (ntnuguest)?:

1. Click on the wireless network options on on your machine or device.
2. Select **ntnuguest** in the window that appear and click Connect
3. Open your web browser.
4. Fill in your email adress and click on submit.

CMS 2018 Committee

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Florentina Paraschiv	Norwegian University of Science and Technology (NTNU)
Daniel Kuhn	Ecole polytechnique fédérale de Lausanne (EPFL)

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Sveinung Tyssedal	Norwegian University of Science and Technology (NTNU)

CMS Program

Tuesday May 29				
08:00-	**Registration**			
08:30-09:00	**Opening and welcome** **Room R5**			
09:00-10:30	**Computational Stochastic Optimization** **Chair: Alexei A. Gaivoronski** **Room: R3**	**Empirical modelling of energy markets** **Chair: Sjur Westgaard** **Room: R4**	**Optimization under uncertainty in logistics and transportation** **Chair: Francesca Maggioni** **Room: R5**	**Techno-Economic impact of CO2 reduction policies** **Chair: Paolo Pisciella** **Room: R90**
	Scenario Analysis for Energy Saving and Management Optimization in Complex Water Supply Systems **Jacopo Napolitano**	Business models for power-to-gas: A real options approach **Michael Schuerle**	Dealing with Demand Uncertainty in Service Network and Load Plan Design **Natashia Boland**	Optimization models for the participation of active power distribution networks to the ancillary services **Maria Teresa Vespucci**
	Engineer-to-order project planning with uncertainty in design and task duration **Michal Kaut**	Can Commodities Dominate Stock and Bond Portfolios? **Stein Frydenberg**	A Priori Routing for Time Slot Management in Online Grocery Retailing **Martin Savelsbergh**	Green Investment under Policy Uncertainty and Bayesian Learning **Verena Hagspiel**
	Scenario tree construction driven by heuristic solutions of the optimization problem. **Vit Prochazka**	Estimation of risk neutral moments from WTI crude oil options. **Valeriy Kunst**	Integer Stochastic Path Detection **Stephan Meisel**	Micro-grid expansion a cooperative game theory approach **Sambeet Mishra**
	Inexact cutting plane techniques for stochastic mixed-integer programs **Ward Romeijnders**	Forecasting Price Distributions in the German Electricity Market **Sjur Westgaard**	Optimizing workflow in cell-based slaughtering and cutting of pigs **Johan Oppen**	A Bilevel Programming Approach to Estimating Elasticities of Substitution for Computable General Equilibrium Models **Paolo Pisciella**
15 min break				
10:45-11:45	**Plenary speaker: Andy Philpott** **Professor at University of Auckland** **Competitive Equilibrium with Risk Averse Agents** **Room: R5**			
75 min Lunch break				
13:00-14:30	**Decision modelling in power markets** **Chair: Paolo Falbo** **Room: R3**	**Bounds and approximation methods in stochastic programming** **Chair: Francesca Maggioni** **Room: R4**	**Computational Methods for Markov Decision Processes** **Chair: David Wozabal** **Room: R5**	**Computational Finance** **Chair: Michael Schuerle** **Room: R90**
	Assessment of battery energy storage systems profitability in the Italian electricity wholesale market **Federica Davo'**	Sampling Scenario Set Partition Dual Bounds for Multistage Stochastic Programs **Ilke Bakir**	A Stability Result for Linear Markov Decision Processes **Adriana Kiszka**	Electricity Spot and Derivatives Pricing under Market Coupling **Roland Fuess**
	Interplay of Wind Energy Expansion and Regional Market Premia – A Fundamental Market Model Analysis with Application to Germany **Hannes Hobbie**	Using tropical optimization techniques in multi-criteria decision problems **Nikolai Krivulin**	Extracting 'Greeks' from Multistage Linear Stochastic Optimization: Computing parameter sensitivities in Stochastic Dual Dynamic Programming **Goncalo Terca**	The distortion premium principle: properties, identification and robustness under ambiguity **Daniela Escobar**

	Scheduling energy and reserves under contingencies in isolated power systems with high presence of electric vehicles **Ruth Dominguez Martin**	Incorporating statistical model error into the calculation of acceptability prices of contingent claims **Martin Glanzer**	Exact converging bounds for Stochastic Dual Dynamic Programming **Vincent Leclère**	Computing Credit Valuation Adjustment using hybrid approaches in the Bates model. **Ludovic Goudenège**
	Spot market, Futures and Risk management in the Generation of Electricity **Paolo Falbo**	Bounds for Probabilistic Constrained Problems **Francesca Maggioni**	Stochastic-dynamic Optimization of a Joint Strategy for Day-ahead Bidding and Intraday Trading **David Wozabal**	Call auctions, money, and equilibrium **Sjur Didrik Flåm**
15 min break				
14:45-15:30	**Semi-plenary speaker: Selvaprabu Nadarajah** **Assistant Professor at University of Illinois at Chicago** **Approximate convex programs for solving intractable operations management problems** **Room: R3**		**Semi-plenary speaker: Jens Arne Steinsbø** **Head of Digitalization and Strategic Analysis at Lyse AS** **Business value from hydropower innovations** **Room: R5**	
15 min break				
15:45-17:15	**Best Student Paper Prize Presentations** **Jury:** Miloš Kopa **(Chair of the EWGSO), Francesca Maggioni (UniBG), Daniel Kuhn (EPFL), Afzal Siddiqui (UCL)** **Room: R3**	**Model Uncertainty in Finance and Economics** **Chair: Daniel Kuhn** **Room: R4**	**Power System Planning and Operation under Uncertainty** **Chair: Arild Helseth** **Room: R5**	
	Stochastic optimization with importance sampling: using an analytical approximation of the zero-variance distribution **Jonas Ekblom**	Long-term asset allocation under time-varying investment opportunities: Optimal portfolios with parameter and model uncertainty **Alex Weissensteiner**	Forecast-based scenario-tree generation for prices in the Nordic power markets **Ellen Krohn Aasgård**	
	Long-term seasonal component in day-ahead electricity price forecasting with NARX neural networks. Part II - Probabilistic forecasting **Grzegorz Marcjasz**	Robust Multidimensional Pricing: Separation without Regrets **Cagil Kocyigit**	Offshore Grid connection optimisation with uncertain parameters **Harald G Svendsen**	
	A strategic investment model for multinational transmission expansion planning: Comparing competitive and cooperative solutions for a North Sea Offshore Grid **Simon Risanger**	Robust optimization by constructing near-optimal portfolios **Martin Van Der Schans**	Nonconvex Medium-Term Hydropower Scheduling by Stochastic Dual Dynamic Integer Programming **Martin Hjelmeland**	
	Efficient forecasting of electricity spot prices with expert and Lasso models **Bartosz Uniejewski**	Chebyshev Inequalities for Products of Random Variables **Napat Rujeerapaiboon**	Optimal Hydropower Maintenance Scheduling Under Uncertainty **Arild Helseth**	
17:30-18:30	**EWGSO meeting** **Chair: Milos Kopa** **Room: R5**			
19:00-19:30	**Jazz concert in the NTNU Business School**			

Wednesday May 30

08:30-09:15

Semi-plenary speaker: Nils Löhndorf Assistant Professor at University of Luxembourg	Semi-plenary speaker: Ruth Misener Assistant Professor at Imperial College London
An experimental comparison of tree-based stochastic programming and dual dynamic programming	**Online generation via offline selection of strong linear cuts from QP SDP relaxation**
Room: R3	Room: R5

15 min break

09:30-11:00

Managing uncertainty in energy systems and markets Chair: Ruud Egging Room: R3	Financial Optimization Chair: Giorgio Consigli Room: R4	Advances In Stochastic Optimization in Theory and Applications Chair: Alois Pichler Room: R5	Quantitative Methods for Financial Applications Chair: Khine Kyaw Room: R90
Reservation of transmission capacity on interconnectors **Endre Bjorndal**	Portfolio Choice Under Cumulative Prospect Theory: sensitivity analysis and an empirical study **Asmerilda Hitaj**	Stochastic optimization with importance sampling: using an analytical approximation of the zero-variance distribution **Jonas Ekblom**	Joint Estimation of Parameters of Mortgage Portfolio and the Factor Process **Jaroslav Dufek**
Value of information of snow measurements in hydropower scheduling **Jo Eidsvik**	Portfolio selection impact of multivariate dominance rules among financial sectors **Sergio Ortobelli Lozza**	Demand Side Management and the Participation in Consecutive Energy Markets – A Multistage Stochastic Optimization Approach **Markus Fleschutz**	Quantitative Studies in Stationary Gas Nets **Rüdiger Schultz**
Evaluating Security of Supply in the European Natural Gas Market – A Stochastic Programming Approach **Philipp Hauser**	Stochastic optimization with partial stochastic dominance constraints and its application **Zhiping Chen**	Stochastic capacity expansion considering renewables and electric vehicles **Miguel Carrión**	Is market surprised by the surprised? **Khine Kyaw**
Risk aversion in energy markets **Ruud Egging**	Goal-based investing under SSD constraints **Giorgio Consigli**	Multistage multivariate nested distance: an empirical analysis **Sebastiano Vitali**	

15 min break

11:15-12:15

NORS Plenary: Stein Wallace
Professor at Norwegian School of Economics

High-dimensional dependent stochastic speeds in vehicle routing

Room: R5

75 min Lunch break

13:30-15:00

Efficient Algorithms for Decision-Making under Uncertainty Chair: Wolfram Wiesemann Room: R3	Energy forecasting Chair: Rafal Weron Room: R4	Advances In Stochastic Optimization in Theory and Applications 2 Chair: Alois Pichler Room: R5	Financial Market Models and Multi-Criteria Portfolio Optimization Chair: Sebastian Utz Room: R90
Fast Bellman Updates for Robust MDPs **Ho Clint Chin Pang**	Comparing the Forecasting Performances of Linear Models for Electricity Prices with High RES Penetration **Angelica Gianfreda**	Two-stage Stochastic Programming under Multivariate Risk Constraints **Nilay Noyan**	Socially Responsible Index Tracking **Maximilian Wimmer**
Epsilon-Net Technique for a Class of Robust Optimization and its Applications in Wireless Communication **Yue Man-Chung**	Efficient forecasting of electricity spot prices with expert and Lasso models. **Bartosz Uniejewski**	Generation of scenarios for multiscale stochastic optimization problems **Georg Pflug**	Risk-Based Inclusion of ESG Ratings into Portfolio Optimization **Annette Krauss**
Valuing Portfolios of Interdependent Real Options under Exogenous and Endogenous Uncertainties **Sebastian Maier**	Conformal Prediction Interval Estimations in Day-Ahead and Intraday Power Markets **Florian Ziel**	Advances on time consistency of risk measures **Ruben Schlotter**	Not Necessary to Overfocus on Financial Performance in Strong Sustainability Investing: Evidence from a GABV Bank Case Study **Sebastian Utz**

	Distributionally Robust Risk-Averse Optimization over Structured Wasserstein Ambiguity Sets **Viet Anh Nguyen**	Forecasting the spread between the spot and the intraday market prices. **Katarzyna Maciejowska**	Approximation of Stochastic Processes **Alois Pichler**	
15 min break				
15:15-16:45	**Solution methods for mixed-integer SP** **Chair: Trine Krogh Boomsma** **Room: R3**	**Energy Forecasting 2** **Chair: Rafał Weron** **Room: R4**	**Robust and Distributionally Robust Optimization** **Chair: Wolfram Wiesemann** **Room: R5**	**Real options and Energy Markets** **Chair: Verena Hagspiel** **Room: R90**
	Bilevel Programming Investment Problems with Lower-Level Primal and Dual Variables **Henrik Bylling**	Modeling electricity price series with vector hidden Markov model **Carlo Lucheroni**	Distributionally Robust Inverse Covariance Estimation: The Wasserstein Shrinkage Estimator **Daniel Kuhn**	Pricing Perpetual Options with Stochastic Stopping Opportunities **Kristian Støre**
	Multi–Period Probabilistic Set Covering Problem **Konstantin Pavlikov**	Long-term seasonal component in day-ahead electricity price forecasting with NARX neural networks. Part II - Probabilistic forecasting **Grzegorz Marcjasz**	Robust Reformulations of Ambiguous Chance Constraints with Discrete Probability Distributions **İhsan Yanıkoğlu**	Technology driven capacity expansion of aluminum smelters **Maria Lavrutich**
	Utilizing strengthened lift-and-project cuts in decomposition methods to solve two-stage stochastic programming problems with binary first-stage variables **Pavlo Glushko**	Bayesian Electricity Price Forecasting. Models with Jumps or Stochastic Volatility **Maciej Kostrzewski**	Decision rules for adjustable integer robust optimization problems via branch-and-bound **Krzysztof Postek**	The effects of possible policy withdrawal on investment timing and investment size **Roel Nagy**
	A Scalable Solution Framework for Strategic Investment Problems via Progressive Hedging **Vladimir Dvorkin**	Modelig a non-linear impact of renewable energy forecasts on intra-day electricity prices **Sergei Kulakov**	Data size modulation and risk requirement in scenario optimization **Simone Garatti**	Photovoltaic Smart Grids in the prosumers investment decisions: a real option model. **Sergio Vergalli**
17:30-18:30	**Guided tour and organ concert in Nidaros Cathedral**			
19:00	**Conference Dinner**			

Thursday May 31

09:15-10:45	**Computational Methods for Applications** **Chair: Pavlo Glushko** **Room: R3**	**Chance constrained optimization** **Chair: Abdel Lisser** **Room: R4**	**Stochastic and decentralized optimization for the management of smart grids** **Chair: Michel De Lara** **Room: R5**	**Modern tools for portfolio optimization** **Chair: Milos Kopa** **Room: R90**
	A randomized method for probabilistic problems **Csaba Fabian**	Strong Convexity for Mean-Risk Models with Complete Linear Recourse **Matthias Claus**	A strategic investment model for multinational transmission expansion planning: Comparing competitive and cooperative solutions for a North Sea Offshore Grid **Simon Indrøy Risanger**	Regularization Methods for Cardinality-Constrained Optimization Problems with an Application in Sparse Robust Portfolio Optimization **Martin Branda**
	Solving Stochastic Equilibrium Problems with Stochastic Gradient Methods: Analysis of Collaborative Service Provision in the Telecommunication Sector **Denis Becker**	Stochastic program with decision dependent randomness for determining the optimal interest rate of a loan **Tomáš Rusý**	Congestion management in an integrated cross-border intraday market : XBID **Somayeh Rahimi Alangi**	Robust Reward-Risk Ratio Portfolio Optimization **Ruchika Sehgal**
	Is it possible to increase the stability under parallelepiped uncertainty in robust portfolio optimization? **Güray Kara**	A Second-order cone programming formulation for two player zero-sum games with chance constraints **Vikas Vikram Singh**	Hierarchical control of microgrids using multi-time-scales stochastic dynamic optimization **Tristan Rigaut**	A BFC based matheuristic algorithm for solving stochastic mixed convex problems using SQP methods **Eugenio Mijangos**
	A Stochastic Dynamic Programming Approach for Near Real-Time, Residential Demand Response: Application to the Texas Power Market **Steven Gabriel**	An Adaptive Model with Joint Chance Constraints for a Hybrid Wind-Conventional Generator System **Bismark Singh**	Bounds on stochastic Bellman functions by decomposition into nodal value functions on a graph. Application to the decentralized optimization of urban micro-grids. **Michel De Lara**	Decreasing absolute risk aversion stochastic dominance in portfolio optimization **Milos Kopa**

15 min break

11:00-12:00	**Plenary Speaker: Jörgen Blomvall** **Professor at** Linköping University **What can optimization tell us about finance?** **Room: R5**

75 min Lunch break

13:15-14:45	**NORS session** **Chair: Peter Schütz** **Room: R3**	**Equilibrium modelling in energy markets** **Chair: Pierre Pinson** **Room: R4**	**Energy and Logistics — Theory and Applications** **Chair: Daniel Kuhn** **Room: R5**	
	Improving customs operations at Norwegian land border checkpoints **Maria Fauske**	To build or not to build. A game theory based model for generation & transmission capacity planning **David Pozo**	Robust Dual Dynamic Programming **Wolfram Wiesemann**	
	Quantifying the utility of war to increase deterrence capability of small states **Mona Sagsveen Guttelvik**	On risk averse competitive equilibrium **Henri Gerard**	A Multi-Scale Decision Rule Approach for Multi-Market Multi-Reservoir Management **Kilian Schindler**	
	Disjunctive conic cuts: the good, the bad, and implementation **Julio C Goez**	Meeting Corporate Renewable Power Targets **Alessio Trivella**	Distributionally Robust Capacitated Vehicle Routing **Shubhechyya Ghosal**	
	Are we too optimistic? Emission reduction from fleet operation after introducing Maritime Emissions Trading Scheme **Yewen Gu**	High-dimensional modelling and forecasting for renewable energy generation **Pierre Pinson**	Reducing lifecycle cost of electric vehicles by optimizing vehicle to grid strategies **Dirk Lauinger**	

15 min break				
15:00-16:30	**NORS session 2** **Chair: Peter Schütz** **Room: R3**	**Multistage stochastic optimization - theory and applications** **Chair: Milos Kopa** **Room: R4**	**Managing uncertainty in smart houses and smart grids** **Chair: Ruud Egging** **Room: R5**	
	Recruitment from the basic military service to the Norwegian Armed Forces **Petter Kristian Køber**	Optimal timing for sending pigs to the abattoir: a stochasting programming approach **Adela Pagès Bernaus**	A Battery per House or a Big One for All? The Value of Cooperation between Prosumers in Microgrid Communities **Jan Martin Zepter**	
	Solving reallife decision problems with multi criteria decision analysis **Alf Christian Hennum**	Multi-stage emissions management of a steel Company **Martin Šmíd**	Impact of redesigning electricity markets time-frames on distributed batteries facing wind uncertainty **Pedro Crespo del Granado**	
	Optimal hedging for Salmon Producers **Peter Schütz**	Stochastic Programs for Engineering Problems: Challenges and Recommendations **Pavel Popela**	Computational Challenges in Prosumer Flexibility Operation and Scheduling **Sigurd Bjarghov**	
		Modelling Long-term And Short-term Uncertainty In Power Market Investments **Asgeir Tomasgard**	Towards Zero Emission Neighborhoods: Implications for the Electricity Infrastructure **Stian Backe**	

Social events details

Monday 28.05. Welcome reception

Location: NTNU Business School

On Monday at 19.30 there will be a welcome reception at NTNU Business School. It will be possible to mingle and refreshments will be served. The registration desk will be available and your conference bags will be handed out.

If you can not make it to the welcome reception, a registration desk outside Room R5 will be manned Tuesday and Wednesday from 08.00-11.00.

Tuesday 29.05. Jazz concert and introduction of NTNU

Location: NTNU Business School

Thomas Brandt, associate professor at Department of Historical Studies at NTNU, has kindly agreed to hold a short introduction about NTNU. After the presentation there will be a jazz concert with the trio Grundt, Petersen and Svabø, who are all students at the Department of Music NTNU. Titles of Jazz pieces: 1. Kind Folk (Kenny Wheeler) 2. Subconscious-Lee (Lee Konitz)

The concert starts at 19.00 and will be held in room number A1. You can find A1 by entering in the main entrance and walk straightforward. We kindly encourage you to find seats in the middle rows of the room.

Wednesday 30.05. Tour to Nidaros Cathedral and dinner at Clarion Hotel & Congress

On Wednesday, there will be a guided tour inside of Nidaros Cathedral from 17.30 to 18.30. We will walk together from the conference location to Nidaros Cathedral, a walk that takes about 20 minutes. At the Cathedral there will be a guide informing about the history of the Cathedral.

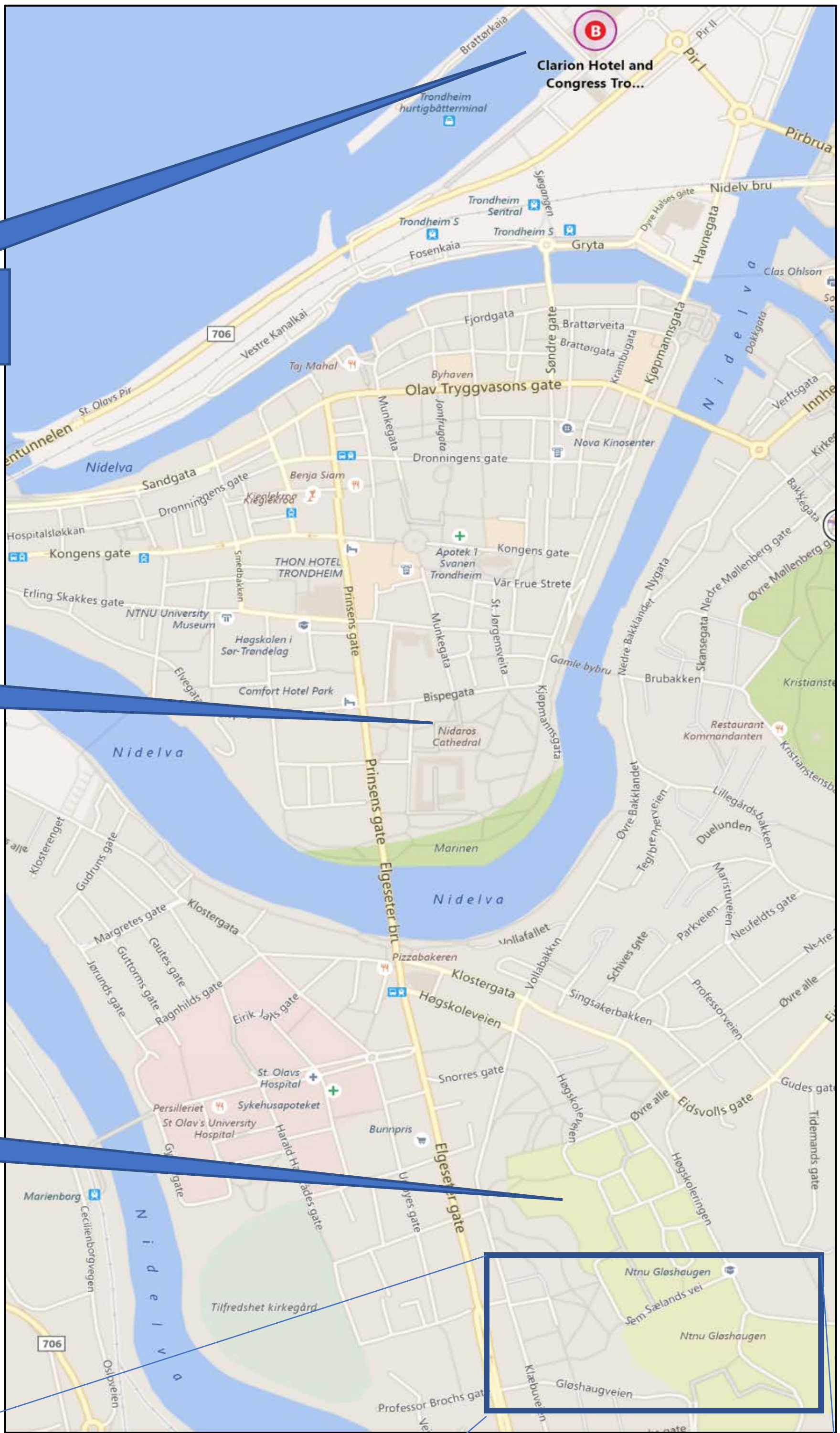
After the guided tour to Nidaros we will move on to the conference dinner at Clarion Hotel & Congress. The dinner will start around 19.00. We will walk together from Nidaros Cathedral to Clarion. The walk will take about 20 minutes.

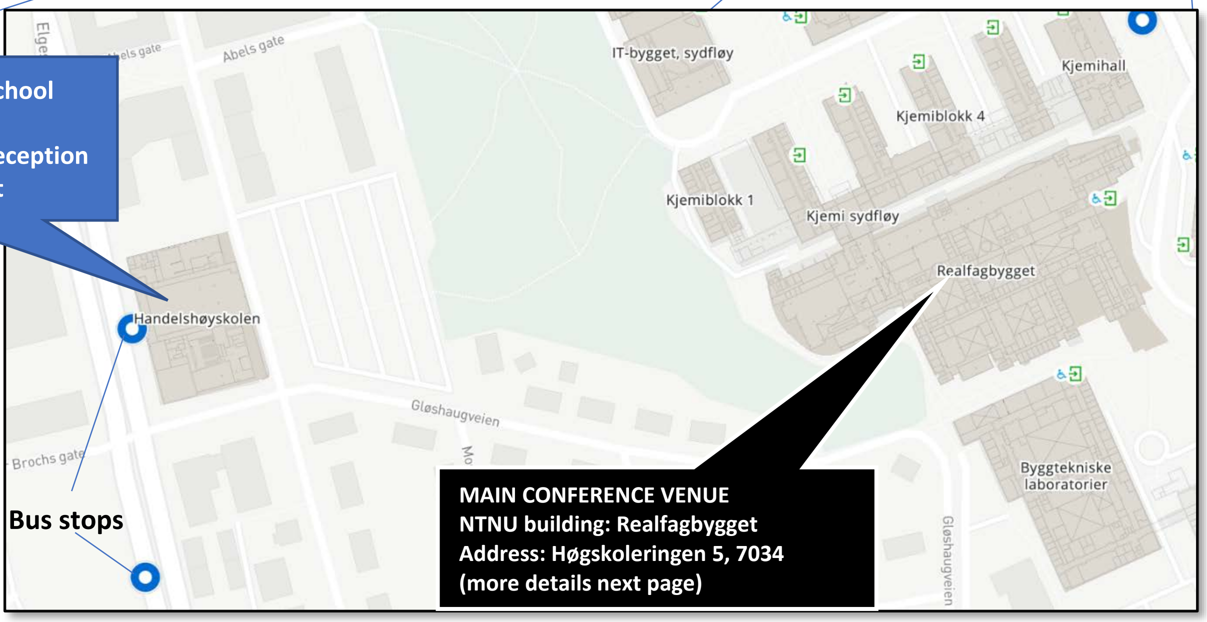
Maps

Wednesday 30.05. Dinner at Clarion Hotel & Congress

Wednesday 30.05. Tour to Nidaros Cathedral

NTNU main campus





Location: NTNU Business School
Activities:
Monday 28.05. Welcome reception
Tuesday 29.05. Jazz concert

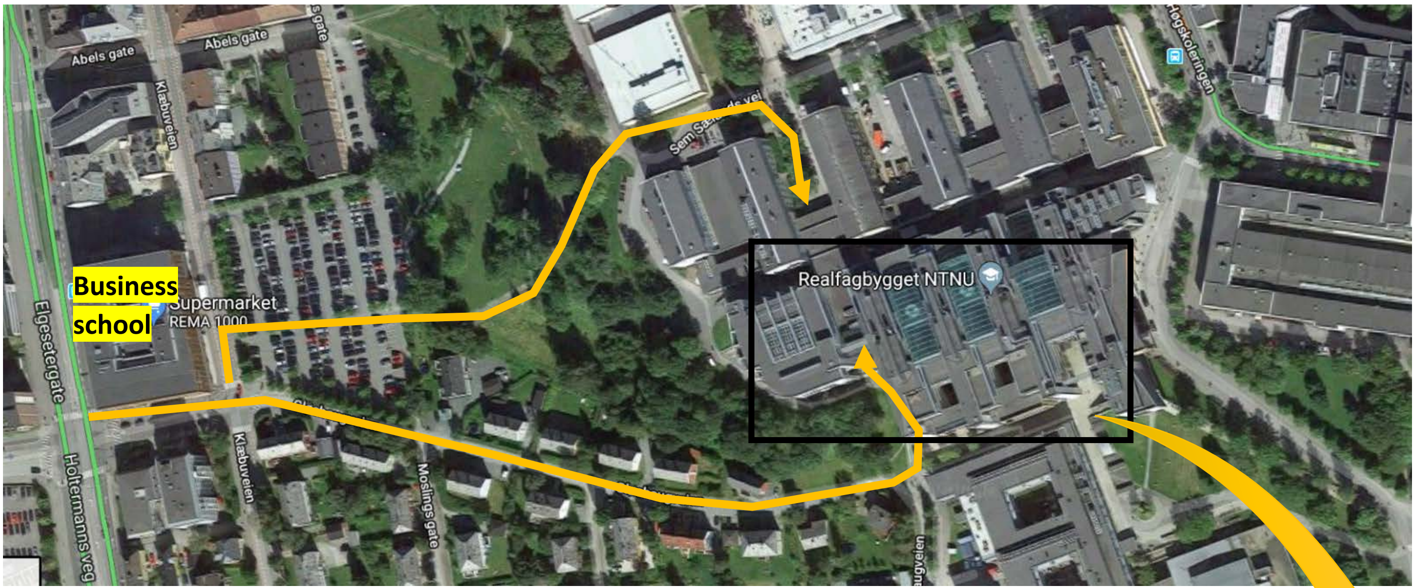
Bus stops

MAIN CONFERENCE VENUE
NTNU building: Realfagbygget
Address: Høgskoleringen 5, 7034
(more details next page)

Main conference venue location

NTNU building: Realfagbygget
Address: Høgskoleringen 5, 7034

Wallking paths from the Bussiness school to the Realfagbygget building



Realfagbygget building layout, room locations and entrance points

CMS Plenaries

Tuesday 29th, ***10:45-11:45, Room R5***

Competitive Equilibrium with Risk Averse Agents

Andy Philpott, Electric Power Optimization Centre, University of Auckland
(Joint work with Michael Ferris)

Motivated by the study of electricity systems, the talk will present a summary of our recent work on models for computing partial equilibrium in perfectly competitive settings where agents make decisions using coherent risk measures. We give two simple examples that illustrate some counterintuitive effects that can occur when agents have insufficient market instruments to trade risk. We define risked equilibrium in a multistage setting and outline circumstances in which a multistage risked equilibrium corresponds to a socially optimal risk-averse plan. Theoretical results will be illustrated with examples drawn from the New Zealand electricity market.

Wednesday 30th, ***11:15-12:15, Room R5,***
Norwegian Operations Research Society (NORS) plenary

High-dimensional dependent stochastic speeds in vehicle routing

Stein W. Wallace, NHH Norwegian School of Economics;
(Joint work with Zhaoxia Guo, Business School of Sichuan University, Chengdu, China; Michal Kaut, SINTEF, Trondheim, Norway.)

Speeds in cities are obviously both stochastic and dependent in time and space. This has not been much studied in the vehicle routing literature, simply because it has not been clear how to handle the high-dimensional random vector of speeds. In this work we make a first attempt to handle correlations in time and space. We analyze problems with up to 25,000 correlated random variables, by heuristically generating scenario sets with controllable qualities. We obtain accuracies around 1% when evaluation the objective function for feasible solution to a VRP.

Thursday 31th, ***11:00-12:00, Room R5***

What can optimization tell us about finance?

Jörgen Blomvall, Linköpings University

Optimization plays an important role to infer information about financial markets. We will give an overview of how optimization is used and also how the optimization models can be improved to obtain more accurate information. One fundamental problem is to make accurate measurements of financial quantities such as discount factors and risk-neutral probability distributions from market prices, through inverse problems. More accurate measurements of the risk-neutral probability distributions for instance allows us to recover the physical probability distribution of the S&P 500 index. More accurate measurements also lead to improved understanding of risk, performance attribution and eventually towards optimal decisions through stochastic optimization models.

Tuesday, May 29, 14:45 – 15:30

CMS Semi-Plenaries

Approximate convex programs for solving intractable operations management problems

Selvaprabu Nadarajah, Assistant Professor at University of Illinois at Chicago

Managing limited resources in the presence of stochastic prices and/or demand forecasts gives rise to challenging Markov decision problems (MDPs) in operations management. Examples include the merchant operations of energy storage and production assets and the partially backlogged inventory control of a perishable product. The intractability of MDP models in these applications may be due to a high-dimensional state space, the structure of the reward function and/or transition dynamics, and possible side constraints on the policy. Approximate linear programming (ALP) and least squares Monte Carlo (LSM) are popular techniques for the approximate solution of infinite- and finite-horizon MDPs, respectively. I will present recent advances in ALP and LSM that extend their applicability by leveraging convex optimization reformulations and solution methods, and also discuss a connection between these seemingly disparate approximate dynamic programming techniques.

Business value from hydropower innovations

Jens Ane Sensbø, Head of Digitalization and Strategic Analysis at Lyse AS

This presentation aims to answer how to best leverage research and academic results in hydropower scheduling and energy management to generate business value for the producer. We will share selected results from a recent study where Lyse identified a significant value potential from enhancing commercial operations and applying digital innovation to our hydropower portfolio. The presentation will also highlight areas particularly suited for machine learning and general takeaways from our digitalization journey.

Wednesday May 30, 08:30-09:15

An experimental comparison of tree-based stochastic programming and dual dynamic programming

Nils Löhndorf, Assistant Professor at University of Luxembourg (joint work with Vadim Gorski and David Wozabal)

There are two popular approaches for solving multistage stochastic programming problems: one is to reduce a continuous stochastic process to a scenario tree and solve a single optimization problem, the other is to use dual dynamic programming techniques. We discuss the advantages and disadvantages of either method and present the results of an extensive computational experiment that covers three problems of practical relevance: asset liability management, longterm hydropower planning, and production planning. Using case study data taken from the extant literature, we find that dual dynamic programming leads to superior policies, especially in settings with many time periods.

Online generation via offline selection of strong linear cuts from QP SDP relaxation

Ruth Misener, Assistant Professor at Imperial College London; Joint work with with Radu Baltean-Lugojan (Imperial), Pierre Bonami (IBM CPLEX) & Andrea Tramontani (IBM CPLEX).

Convex and in particular semidefinite relaxations (SDP) for non-convex continuous quadratic optimization can provide tighter bounds than traditional linear relaxations. However, using SDP relaxations directly in Branch-&-Cut is impeded by lack of warm starting and inefficiency when combined with other cut classes, i.e. the reformulation-linearization technique. We present a general framework based on machine learning for a strong linear outer-approximation that can retain most tightness of such SDP relaxations, in the form of few strong low dimensional linear cuts selected offline. The cut selection complexity is taken offline by using a neural network estimator (trained before installing solver software) as a selection device for the strongest cuts. Lastly, we present results of our method on several non-convex application problems.

Abstracts

Presenters (in alphabetical order)

Forecast-based scenario-tree generation for prices in the Nordic power markets

Ellen Krohn Aasgård[1]
[1]*NTNU, Trondheim, Norway*

The Nordic wholesale electricity market consists of a series of markets where power and related products are traded. Market agents may benefit from coordinating their trades across markets. Since future prices are unknown, stochastic programming may be used to determine coordinated trading strategies. Stochastic programming models need information of future data in the form of scenario trees. However, sometimes the best available information about an uncertain future is a single forecast. A single forecast does not provide enough information to construct a scenario tree, but may be combined with historical data on forecast errors to produce a scenario tree using the method in [Kaut, 2017]. In the current work, statistical models for the prices in the Nordic day-ahead market, the intraday market and the balancing markets are used to generate historical forecasts that are used together with the forecast-based scenario generation method to construct scenario trees that may be used as input to stochastic programming models for the multi-market trading of power.

Kaut 2017: Michal Kaut, "Forecast-based scenario-tree generation method", Optimization Online 2017

Towards Zero Emission Neighbourhoods: Implications for the Electricity Infrastructure

Stian Backe[1], Pedro Crespo del Granado[1], Dimitri Pinel[1]
[1]*NTNU, Trondheim, Norway*

As the world debates actions to combat climate change, the success of reducing greenhouse gas emissions might rely on two main developments: the transition to a low-carbon energy system and improvements in energy efficiency. To some extent, both options have put the end-user at the centre of the energy transition. This has translated into the adoption of distributed generation technologies and into policies directed to promote sustainable solutions for neighbourhoods.

However, it is unclear which solutions and technologies will be cost optimal in the energy transition, whether demand is best met locally or centrally and how the main power system is affected by developments on a neighbourhood level. In this regard, this paper analyses the development of neighbourhoods with ambitious emission targets, Zero Emission Neighbourhoods (ZEN), in the Nordic countries and their value for the power system. We analyse these questions by using two mathematical programming models: a neighbourhood model, ZENIT, and a power system model, EMPIRE. We look at how investments in distributed generation in ZENs affect the demand faced by stakeholders of the greater power system, and how investments at the neighbourhood scale affect cost-efficiency, emissions and long-term development of the interconnected power system.

The neighborhood model minimizes the operation and investment cost of neighborhood heat and electricity supply while compensating for emissions through local production. The aggregated power system model, EMPIRE, invests in bulk electricity generation per country with the investment option of ZEN. We link these two models to examine the effects of distributed investments from the greater power grid's perspective. Results indicate that neighbourhoods with co-generation of electricity and heat are most attractive for the power system in the Nordics, while neighbourhoods with solar PV provide most emission reduction.

Sampling Scenario Set Partition Dual Bounds for Multistage Stochastic Programs

Ilke Bakir[1], Natashia Boland[2], Brian Dandurand[3], Alan Erera[2]
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We consider multistage stochastic programming problems in which the random parameters have finite support, leading to optimization over a finite scenario set. There has been recent interest in dual bounds for such problems, of two types. One, known as expected group subproblem objective (EGSO) bounds, require solution of a group subproblem, which optimizes over a subset of the scenarios, for all subsets of the scenario set that have a given cardinality. Increasing the subset cardinality in the group subproblem improves bound quality (EGSO bounds form a hierarchy), but the number of group subproblems required to compute the bound increases very rapidly. Another is based on partitions of the scenario set into subsets. Combining the values of the group subproblems for all subsets in a partition yields a partition bound. In this study we consider partitions into subsets of (nearly) equal cardinality. We show that the expected value of the partition bound over all such partitions also forms a hierarchy. To make use of these bounds in practice, we propose random sampling of partitions and suggest two enhancements to the approach: sampling partitions that align with the multistage scenario tree structure, and use of an auxiliary optimization problem to discover new best bounds based on the values of group subproblems already computed. We establish the effectiveness of these ideas with computational experiments on benchmark problems. Finally, we give a heuristic to save computational effort by ceasing computation of a partition part-way through, if it appears unpromising.

Solving Stochastic Equilibrium Problems with Stochastic Gradient Methods: Analysis of Collaborative Service Provision in the Telecommunication Sector

Denis Becker[1], Alexei Gaivoronski[2]
[1]*NTNU Business School, TRONDHEIM, Norway,* [2]*NTNU Department of Industrial Economics, TRONDHEIM, Norway*

This paper is devoted to the analysis of patterns of competition and collaboration which often emerge in the telecommunications industry and, more generally, in the ICT industry. The reference example illustrates the relationship between incumbent fixed network providers and mobile operators (including virtual ones) who do not possess the network capacity. Such situations can be described by multilevel stochastic equilibrium optimization models. Usually such models defy analytical analysis and require specialized numerical methods. In this paper we develop a a method which belongs to the stochastic gradient class. Numerical experiments confirm its efficiency in solving the problems arising in the telecom environment. We apply this methodology to the analysis of markets for ICT products and services in the process of transformation from young markets with few actors to mature markets with a large numbers of participants.

Computational Challenges in Prosumer Flexibility Operation and Scheduling

Sigurd Bjarghov[1], Pedro Crespo Del Granado[1], Venkatachalam Lakshmanan[1]
[1]*NTNU, Trondheim, Norway*

The deployment of batteries in the distribution grid can provide an array of flexibility services to integrate renewable energy sources (RES) and improve grid operation in general. Capturing and quantifying the value of storage for different flexibility services require models that can represent the technological detail of battery-RES-load interactions. For this purpose, this presentation focuses on models and algorithms for: 1) battery capacity and location planning and 2) hourly operations. We propose a model designed for siting, capacity planning and investment analysis of batteries in low and medium voltage grids. That is, we represent detailed battery charging and discharging operations to find its optimal location and size in the distribution system. Since battery sizing has different applications (flexibility services) for distribution system operators (DSO) and prosumers, we discuss the value of batteries in providing flexibility services for: 1) kW-max control and self-balancing for prosumers, and congestion management for DSO. Moreover, we present illustrative examples on battery-PV sizing analyses for prosumers. These models and sizing methods are applied for a large prosumer (a Hotel in Bulgaria) and small houses in the Netherlands. We also discuss other battery modelling experiences and real-life implementation activities as part of the Horizon 2020 project: INVADE.

Reservation of transmission capacity on interconnectors

Endre Bjorndal[1], Mette Bjorndal[1]
[1]*Norwegian School of Economics, , Norway*

So far, transmission capacities between European countries have been allocated mostly to the day-ahead electricity market, where it has been used in the implicit auction for transmission capacity and energy. Recently, some of the new interconnectors have been built with a reservation of part of the transmission capacity for shorter term balancing markets. In this paper, we consider optimal reservation of transmission capacity for real time markets, in a setting where flexibility costs differ between regions. We consider an integrated stochastic dispatch model, taking into account the day-ahead bids and real time uncertainty, as well as a sequential myopic market design, that fits with the present European electricity market design.

Dealing with Demand Uncertainty in Service Network and Load Plan Design

Ahmad Baubaid[1], Natashia Boland[1], Martin Savelsbergh[1]
[1]*Georgia Institute of Technology, Atlanta, United States*

Less-than-Truckload (LTL) transportation carriers plan for their next operating season by deciding: (1) a load plan, which specifies how shipments are routed through the terminal network from origins to destinations, and (2) how many trailers to operate between each pair of terminals in the network. Most carriers also require that the load plan is such that shipments at an intermediate terminal and having the same ultimate destination are loaded onto trailers headed to a unique next terminal regardless of their origins. In practice, daily variations in demand are handled by relaxing this requirement and loading some shipments to an alternative next terminal. We introduce the stochastic p-alt model: a two-stage stochastic mixed integer programming model, with integer variables in both stages. The model integrates routing and capacity decisions, and allows p choices for the next terminal for shipments with a particular ultimate destination. We design and computationally test three, approximate, solution methods for the model, all based on sample average approximation (SAA). Two of them relax the second stage integrality; we consider two alternative approaches to tightening this relaxation within the SAA framework. Our results show that the second-stage relaxation allows good solutions to be found for larger instances and that much can be gained from using the p-alt model and explicitly considering uncertainty

Regularization Methods for Cardinality-Constrained Optimization Problems with an Application in Sparse Robust Portfolio Optimization

Martin Branda[1], Michal Červinka[2], Max Bucher[3], Alexandra Schwartz[3]
[1]*Charles University, Prague, Czech Republic,* [2]*Institute of Information Theory and Automation, Prague, Czech Republic,* [3]*Technische Universität Darmstadt, Darmstadt, Germany*

We consider general nonlinear programming problems with cardinality constraints.
By relaxing the binary variables which appear in the natural mixed-integer programming formulation, we obtain a related nonlinear programming problem, which is thus still difficult to solve. Therefore, we apply a Scholtes-type regularization method to obtain a sequence of easier to solve problems and investigate the convergence of the obtained KKT points. Additionally, we consider portfolio optimization problems where we minimize a risk measure under a cardinality constraint on the portfolio.
Various risk measures are considered, in particular Value-at-Risk and Conditional Value-at-Risk under normal distribution of returns and their robust counterparts under moment conditions. For these investment problems formulated as nonlinear programming problems with cardinality constraints we perform a numerical study on a large number of simulated instances taken from the literature and illuminate the computational performance of the Scholtes-type regularization method in comparison to other considered solution approaches: a mixed-integer solver, a direct continuous reformulation and the Kanzow-Schwartz regularization method.

Bilevel Programming Investment Problems with Lower-Level Primal and Dual Variables

Henrik Bylling[1], Steven A. Gabriel[2,3], s. Trine K. Boomsma[1]
[1]University of Copenhagen, Copenhagen, Denmark, [2]University Of Maryland, College Park, USA, [3] Norwegian University of Science and Technology, Trondheim, Norway

This paper examines bilevel programming investment problems in which the upper-level objective function depends on the lower-level primal and dual variables. These problems occur in for example power markets where a lower-level, market-clearing problem provides production (a primal variable) and prices (a dual variable) to the estimation of potential revenue in the objective function of the upper-level investment problem. As a contribution of this paper, we show that the upper-level objective function is piece-wise linear and discontinuous with regard to the upper-level variable. We use this to design a global solution method based on parametric programming and with the advantage that it allows for decomposition of separable lower-level problems. If the upper-level objective function is a bilinear function of the lower-level primal and dual variables, we also provide an exact linearization method under certain reasonable assumptions. This leads to an MIP formulation of the bilevel programming problem. We show numerically that the proposed decomposed method has significant computational advantages for bilevel investment problems with a high number of lower-level market clearing problems. Furthermore, since the proposed method is based on parametric programming, post-optimal sensitivity analysis is provided automatically which can be of high value for the non-convex bilevel programming problem.

Stochastic capacity expansion considering renewables and electric vehicles

Miguel Carrión[1], Ruth Domínguez[1]
[1]Universidad de Castilla-La Mancha, Toledo, Spain

This paper proposes a coordinated generation and storage expansion formulation considering the presence of electric vehicles. We consider that the power system operator is able to control the charging and discharging processes of those electric vehicles that are willing to get involved in the power system operation in exchange for a financial reimbursement. The day-ahead energy and reserve capacity markets are explicitly considered in this capacity expansion problem in order to properly account the impact of the production of intermittent power units in the capacity decisions. The resulting model is formulated as a three-stage stochastic mixed-integer linear problem that is solved in practical instances using Benders decomposition. The proposed formulation is tested on a realistic case study based on an actual isolated power system in Spain.

Risk aversion in energy markets

Ruud Egging[1]
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We consider risk aversion by natural gas supply companies considering investment in conventional and shale gas resources in a stochastic multi-period mixed complementarity problem. Uncertainty considered includes political risk and resource sizes. We consider shale gas investment in Poland and Ukraine in a realistic market setting in Europe. We discuss investment decisions and profits for varying levels of risk aversion. We show and explain how risk aversion may sometimes lead to higher expected profits.

Stochastic optimization with partial stochastic dominance constraints and its application

Zhiping Chen[1], Giorgio Consigli[2], Jia Liu[1], Rui Xie[1]
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We introduce a partial stochastic dominance (SD) constrained optimization model, which can put the first or second order SD control under different tolerance levels. We derive an equivalent formulation of the partial SD constraint, which is associated with a new risk measure, the partial-CVaR. Then we show how to transform the partial SD constrained optimization problem into deterministic convex programs and thus solve it efficiently. As an application, we consider an active index tracking problem with partial SD constraints, numerical results demonstrate the practicality and superiority of the partial SD constraints in real financial management.

Strong Convexity for Mean-Risk Models with Complete Linear Recourse

Matthias Claus[1], Kai Spürkel[1], Rüdiger Schultz[1]
[1]University Duisburg-Essen, , Germany

Optimal solutions to strongly convex stochastic programs enjoy privileged stability properties under perturbations, for instance, of the underlying probability measure. This justifies approximation of a given probability distribution by possibly simpler ones. Amongst others, this fact motivates the search for verifiable conditions for strong convexity in terms of model data.

In this talk we shall present such conditions for two-stage mean-risk models with complete linear recourse, extending results for risk-neutral models. Our analysis features well-known deviation measures such as expected excess and semi deviation.

Goal-based investing under SSD constraints

Giorgio Consigli[1], Vittorio Moriggia, Sebastiano Vitali
[1]University of Bergamo, , Italy, [2]University of Bergamo, , Italy, [3]University of Bergamo and Charles University, , Italy

We consider a family's dynamic asset-liability management (ALM) problem over a long-term planning horizon formulated as a stochastic program (DSP) with an individual objective to minimise the shortfall with respect to a terminal retirement goal, after investing in the real estate market. Both the intermediate and terminal goals are stochastic and the decision problem is formulated relying on estimates of average salaries, living costs and of a liquidity buffer for precautionary reasons. The attainability of each goal is subject to an uncertainty generated by asset returns and liability costs and we formulate the optimization problem with second order stochastic dominance (SSD) constraints. The asset universe includes mutual funds, pension funds, unit-linked contracts and annuities plus cash, while liabilities are limited to living costs and fixed or floating rate mortgages for the real estate investment. First and second order stochastic dominance conditions are evaluated by benchmarking the optimal DSP strategy against three policies, based on an equally

weighted portfolio, a money market portfolio and an inflation-adjusted portfolio. A rich set of computational evidences is presented related to the effectiveness of SSD constraints to determine the problem's optimal policy.

Distributed batteries facing wind uncertainty and time-frame decisions in electricity markets

Pedro Crespo del Granado[1]
[1]NTNU, Trondheim, Norway

The economic viability of distributed electricity storage depends on various short-term uncertainties (renewable generation, demand and electricity prices). To determine the value of batteries, this presentation proposes smart grid oriented business models that take into consideration features of electricity markets and renewable variability. Distributed electricity storage participation in electricity markets is, however, an open question; could local electricity storage become economically viable if they are integrated into current market time-frames (e.g. day-ahead and intra-day markets)? By modelling a distributed generation system under uncertainty realizations of wind power in a multi-stage stochastic programming problem, we analyse the stochastic effects of market time-frame options. We highlight that such effects would not be visible by employing a solely deterministic formulation. This presentation also discusses a distributed grid model to determine the optimal allocation of batteries in a neighbourhood.

Assessment of battery energy storage systems profitability in the Italian electricity wholesale market

Virginia Canazza[1], Federica Davo'[1], Alberto Rivorio[1]
[1]REF-E, Milano,

Battery energy storage systems (BESS) have a key role for enabling the effective integration of non-programmable renewable sources (RES-E) into the electricity system and their active participation to the electricity markets, as the ongoing reform of the European market organization will sustain the transition towards the European decarbonisation targets. BESS applications to power systems are increasing around the world proving their high quality technical potentialities even if technology's costs are still far from being competitive despite the expectation of a rapid decrease in the next years. For an investor the definition of the optimal business model must identify risks and opportunities emerging in the future market scenario and consistently explore the possible strategies to be adopted in order to enhance the profitability of BESS applications. BEST (BESs Tool) is a model implemented to this purpose, whose first version applied to the Italian electricity market is presented.
Given the hourly electricity price forecast on each Italian market phase (day ahead, intraday, programming and balancing phase of the ancillary services market, according to the rules currently in force) elaborated through a complementary suite of consolidated models, and assuming a "price taker" behaviour, BEST optimizes the hourly bidding strategy to be adopted by a BESS power plant to maximize the expected overall profit, taking into account the BESS's technical constraints and the hourly level of charge resulting from the BESS physical scheduling.
BEST simulation has been applied to a range of selected cases studies concerning stand-alone BESS, assuming a scenario evolution in line with the target indicated by the National Energy Strategy. Economic results strictly depends on expected zonal prices and BESS costs: a positive return of investment can be expected in the continental zones with costs lower than 350 €/kWh-150€/kW thanks to the active participation to Ancillary Services Market.

Bounds on stochastic Bellman functions by decomposition into nodal value functions on a graph. Application to the decentralized optimization of urban micro-grids.

Michel De Lara[1], François Pacaud[2], Jean-Philippe Chancelier[1], Pierre Carpentier[3]
[1]Ecole des Ponts parisTech, France, [2]Efficacity, France, [3]ENSTA ParisTech, , France

We consider a stochastic optimization problem where different units are connected together via a network. Each unit is a (small) control system, located at a node. Each unit state evolution is affected by uncertainties and by controls from the neighbor units transmitted through edges. Static constraints couple all units at each time. We formulate a global stochastic optimization problem. We propose two decomposition methods, whether we decouple the constraints by prices or by quantities. We show that the global Bellman function can be bounded above by a sum of quantity-decomposed nodal value functions, and below by a sum of price-decomposed nodal value functions. We provide conditions under which these nodal value functions can be computed by dynamic programming. We illustrate these results with numerical studies that tackle the decentralized optimization of urban micro-grids.

Scheduling energy and reserves under contingencies in isolated power systems with high presence of electric vehicles

Ruth Dominguez Martin[1], Miguel Carrion Ruiz Peinado[1]
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The use of electric vehicles in isolated power systems represents a beneficial option because of two reasons: first, their participation in the power system operation may allow a less use of fossil-fuel power plants and a better integration of renewable energies; and second, the comparatively shorter distances in small-isolated systems are in accordance with the battery autonomy. Thus, in this work we present a stochastic unit commitment problem to schedule energy and reserve capacity in the day-ahead market considering: i) the uncertainty related to the intermittent renewable production and the demand, ii) the provision of the primary frequency response under a N-1 reliability criterion, iii) different usage patterns of electric vehicles and their participation to provide reserve services to the power system. The model is formulated as a two-stage stochastic programming problem with binary variables. A solution procedure is proposed to solve instances of the problem with a large set of scenarios. Finally, the scheduling model is tested in a real isolated power system comprising 8 nodes and 38 generating units.

Joint Estimation of Parameters of Mortgage Portfolio and the Factor Process

Jaroslav Dufek[1,2], Martin Šmíd[1]
[1]MFF UK, KPMS, Prague, Czech Republic, [2]ÚTIA AV ČR vii., Prague, Czech Republic

In [1] a factor model for LGD (loss given default) and PD (probability of default) of mortgage portfolio based on KVM approach is proposed. The authors further fit an evolution of factors by a VECM model; however, they take the parameters of a portfolio as fixed instead of estimation. The present paper proposes a technique of a joint estimation of VECM and portfolio parameters in particular MLE function is defined; asymptotic properties are discussed. Our technic is demonstrated on US market data.

[1] Gapko, P. and Šmíd, M.: Dynamic Multi-Factor Credit Risk Model with Fat-Tailed Factors. Czech Journal of Economics and Finance, 62(2): 125–140, 2012.

A Scalable Solution Framework for Strategic Investment Problems via Progressive Hedging

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[1]Technical University of Denmark, Lyngby, Denmark, [2]Universidad de Castilla La Mancha, Ciudad Real, Spain

We consider a problem of a power system agent who strategically decides on future investments in generation units under uncertainty. Strategic behavior is exercised through optimal supply functions given by price-quantity pairs submitted to a day-ahead market throughout the entire investment horizon. We model such behavior using hierarchical optimization problem consisting of two levels: (i) the upper level is represented by expected profit maximization problem of the strategic agent, and (ii) the lower level is given by a set of market clearing problems for each scenario of uncertainty realization, time stage, and operating condition. This structure resembles Stackelberg game where the agent acts as a leader and market clearing problems constitute a set of followers. In this game, the agent aims at finding the optimal investment policies and supply functions of existing and candidate generation units that result in the best response from market clearing problems throughout the investment horizon. To derive computationally implementable version, we replaced a set of lower-level problems with their Karush–Kuhn–Tucker conditions, such that the model recast as a single-level mathematical programming with equilibrium constraints problem. Then, the mixed-integer linear programming (MILP) equivalent is derived by linearizing complementarity constraints using SOS1 variables.

The tractability of such problems reduces in size of uncertainty sets, and we propose a modified version of progressive hedging algorithm (PHA) to decompose the problem per scenarios of uncertainty realization. Unlike conventional PHA, we relax non-anticipativity constraints of both long-term (investment) and short-term (day-ahead offering) decision trees, significantly reducing the computational load of each sub-problem. To control the solution quality over iterations, we introduce two upper bounds on the objective function of the original problem. Two case studies illustrate the ability of the algorithm to reach the global optimum keeping simulation time in an appropriate range.

Value of information of snow measurements in hydropower scheduling

Ms Heidi Ødegård[1], Jo Eidsvik[1], Stein-Erik Fleten[2]
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We consider the problem of hydropower scheduling under uncertain inflow. In particular, our interest lies in the possible uncertainty reduction and improved scheduling resulting from snow information. Such measurements are often gathered during spring time before the snow melts, and the data can be useful for learning more about the future inflow. Quite a lot of resources and money is spent on acquiring and processing these snow data, and a question is if this is money well spent? We suggest a method for conducting value of information analysis of snow measurements. The value of information states how much a test is worth. If the price of acquiring and processing snow measurements is less than the value of information, the test is worth doing.

For scheduling a least squares Monte Carlo method is used in this paper. This approach is re-used in the value of information computation. The inflow is the uncertain variable, and it is represented by ensembles. The time-varying spot price is assumed known. Realistic input parameters and data from a Norwegian power plant are used to fit the inflow distribution as well as prices, water levels, etc. The numerical tests show that the value of information results are sensitive to the ratio between the total inflow and the upper reservoir limit. The snow measurements have very limited value when the reservoir is big compared to the total inflow. When the reservoir is smaller, the probability for overflow is bigger and the snow measurements can be valuable.

Stochastic optimization with importance sampling: using an analytical approximation of the zero-variance distribution

Jonas Ekblom[1], Jörgen Blomvall[1]
[1]Linköping University, Linköping, Sweden

In this paper, we propose a new approach to apply importance sampling in stochastic optimization. The idea is to utilize an analytical approximation of the zero-variance importance sampling distribution to reduce sampling uncertainty. We apply this on the classic dynamic portfolio choice problem of an investor with constant relative risk aversion preferences in the presence of proportional transaction costs. Solution quality is assessed by comparing the method to standard variance reduction techniques in single-period optimization and multistage stochastic programming formulations of the problem. The numerical experiments show that the method produces significant improvements in solution quality. In the single-period setting, the number of scenarios can be reduced by a factor of 400 with maintained solution quality compared to the best standard method; Latin hypercube sampling. Using importance sampling in multi-stage formulations, the gaps between lower and upper bound estimates are reduced by a factor of 26-500 with maintained scenario tree size. On a higher level, we consider analytical approximations of the zero-variance importance sampling distribution to be a promising method to improve solution quality in stochastic optimization.

Risk-Based Inclusion of ESG Ratings into Portfolio Optimization

Robert Erbe[1], Maximilian Adelmann[2]
[1]University of Zurich , Zurich , Switzerland, [2]AAAccell Ltd, Zurich , Switzerland

We lack consensus about the economic relevance of environmental, social, governmental (ESG) ratings for financial returns. In this paper, we focus on the notion that firms with poor ESG scores are more likely to experience severe losses and hence exhibit more tail risk. To follow this idea, we present an adoption of the Bayesian framework to accommodate the idea of shrinkage. This revised model enables an investor to articulate views on the mean and the covariances—whereas the famous Black–Litterman model only allows for views on the mean. To scale the covariance matrix according to ESG ratings, we use ideas from distribution theory. We also present various ways to derive the mean prior that do not rely equilibrium considerations, as this becomes cumbersome for international portfolios. Our numerical analysis demonstrates that the derived portfolios are clearly influenced by our views and that the revised model is able to deliver portfolios with an excellent performance in terms of Sharpe ratios and ESG criteria.

The distortion premium principle: properties, identification and robustness under ambiguity

Daniela Escobar[1], Georg Pflug[1]
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The distortion premium is a well-known premium for insurance pricing. In this talk we will present sensitivity properties of this premium w.r.t. the model and the risk aversion position as well as robustness w.r.t. the ambiguity of the model. The Wasserstein distance will be used to construct the ambiguity set. Worst-case solutions will be presented for different ambiguity sets. Finally, we would study the inverse problem, meaning how to identify the distortion density, which represents the risk-aversion position, from given prices as input. Two different approaches will be used when estimating the distortion function, a step function and splines. The estimated distortion functions will be based on future energy contracts.

Spot market, Futures and Risk management in the Generation of Electricity

Paolo Falbo[1]
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For electricity generators the two major channels to sell their production are spot market and bilateral contracts. At a first sight, a producer can see fixed price bilateral contracts as a way to reduce and control the risk. However, in the literature it has been already observed that committing a large share of the production with bilateral contracts, turns out as a way to actually increase the risk, instead of reducing it. A the heart of such puzzling outcome there are several features of the electricity markets: high concentration, technical impossibility to store large amount of energy, the uniform auction mechanism on the spot market and, last but not least, the high inelasticity of the demand. Together these factors strengthen a solid positive correlation between direct production costs and spot price of electricity This outcome introduces a significant risk reduction opportunity for spot markets as a channel to direct electricity sales.
In this work we consider risk averse electricity producers competing in an oligopoly. At the high level of a bilevel problem a producer seeks to optimize a linear trade-off between expected profits and conditional value at risk. He can decide the spot market/futures contracts mix (to sell his generation) as well as the bid price on the spot market. However, his choice is conditioned, at the lower level, by cost minimizer competitors. The problem is reformulated into a MILP. The uncertainty in the problem is driven by several factors. Maximum capacity of renewable sources (solar and wind), direct generation costs (gas and coal), and demand are random. Demand and renewable generation are analysed at different possible levels of correlations. The model is applied to the cases of Spanish and German markets.

A randomized method for probabilistic problems

Csaba Fabian[1], Edit Csizmas[1], Rajmund Drenyovszki[1], Tibor Vajnai[1], Lorant Kovacs[1], Tamas Szantai[2]
[1]Loránd Eötvös University of Budapest, Kecskemet, Hungary, [2]Budapest University of Technology and Economics, Budapest, Hungary

We deal with probability maximization and probabilistic-constrained problems. Based on a simple approximation scheme, we propose a column generation method that results easy subproblems and tolerates noise in gradient computation. The randomized method bears a resemblance to the stochastic approximation family. Computational results confirm the usability of the approach.

Improving customs operations at Norwegian land border checkpoints

Maria Fauske[1], Petter Køber[1], Thor Engøy[1]
[1]Norwegian Defence Research Establishment, , Norway

Norwegian Customs is investigating how the upgrade of the numerous land border checkpoints can improve capabilities in stopping illegal flow of goods. Technological solutions for monitoring vehicles are being installed at all border crossings. Furthermore, several Norwegian land border customs stations need to be upgraded in the near future. In assessing the overall effect of such an upgrade, various parameters need to be considered: traffic flow and pattern through the different border crossings, desired service levels, opening hours, facilities and equipment, type of control function, etc. The Norwegian Defence Research Establishment is supporting Norwegian Customs through the use of OR methods, such as morphological analysis and decision trees, in order to assess the performance of different solutions for border control.

Demand Side Management and the Participation in Consecutive Energy Markets – A Multistage Stochastic Optimization Approach

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Flexibility in industrial production processes offer the potential to generate revenue and/or reduce energy procurement cost. To fully exploit the economic potential of the flexibility of a production process multiple markets need to be considered at the same time. Production planning and the participation in the reserve markets can be formulated as a multistage Stochastic Mixed-Integer Linear Programming (SMILP) problem that minimizes the expected total costs, which consist of cost for purchasing power subtracted by the revenues from offering reserve energy. The proposed approach incorporates a production process model which determines the optimal production plan under real-time pricing while ensuring satisfaction of demand. The production process model is enhanced by a market model for the participation in consecutive energy markets, which identifies the optimal bids in different energy markets. Uncertainties of spot and reserve market prices are considered in terms of a stochastic process, equipped with a filtration that represents the information, which is available at each stage of the problem.

The cement milling process is predestined for Demand Response (DR) and therefore the proposed model is applied to the cement milling process of a real cement plant. Multiple price scenarios are generated using a Seasonal Autoregressive Integrated Moving Average (SARIMA) model. The problem was formulated in AMPL and solved with Gurobi 7.0.0, without computational complications. Results show that the change from a time of use tariff to real-time pricing leads to significant cost reduction. Participation in the reserve market leads to both, additional revenues obtained by the offering of reserve capacity and to additional energy procurement costs, caused by the shift of production towards more expensive time periods. The proposed approach enables the planner to identify the optimal trade-off between these effects.

Call auctions, money, and equilibrium

Prof em Sjur Didrik Flåm[1], Professor Teemu Pennanen[2]
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Call auctions facilitate price discovery in many markets. Invoking a money good, this paper uses idiosyncratic exchange rates, denominated in money, to define price schedules that agents submit to the auctioneer. It explores how the latter, by convoluting the schedules, can "create value." Also explored is whether iterated call auctions could carry the economy to market equilibrium.

Can Commodities Dominate Stock and Bond Portfolios?

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In this article we discuss whether commodities should be included as an asset class when establishing portfolios.
By investigating second order stochastic dominance relations, we find that the stock and bond indices used tend to dominate the individual commodities.
We further study if we can find a combination of stocks, bonds and commodities that dominate others. Compared to a 60 percent stock and 40 percent bond portfolio mix, portfolios consisting of long positions in gold futures and two different actively managed indices are the only commodity investments to be included as long positions in a stock/bond portfolio.
The results should be of interest for fund managers and traders that seek to improve their risk-return trade off compared to the traditional 60/40 portfolio.

Electricity Spot and Derivatives Pricing under Market Coupling

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Increasing interconnectivity between electricity wholesale markets requires an efficient allocation scheme in order to provide access to cross-border transmission capacities. The explicit schemes have primarily induced economically inefficient interconnector use given that flows have to be nominated prior to spot market clearing. By contrast, the market coupling mechanisms avoid these inefficiencies by implicitly allocating cross-border transmission capacity upon spot market clearance. In this paper, we show that these institutional aspects of market design clearly manifest in the empirical dynamics of both electricity spot and derivatives prices, and hence, do have important implications for pricing and hedging in these markets. We employ a fundamental multi-market model for electricity pricing in order to analyze how the key stylized facts of electricity spot, futures, and options prices are impacted by the different allocation schemes.

A Stochastic Dynamic Programming Approach for Near Real-Time, Residential Demand Response: Application to the Texas Power Market

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We present a new stochastic dynamic programming (SDP) approach for optimal shifting of residential customers' load. The SDP model can be using in near real-time to call demand response events with as little as 15 minutes lead time and is an important tool to help retail electric power (REP) providers maximize their expected profit and minimize risk. We also present numerical results for the Texas power market.

Data size modulation and risk requirement in scenario optimization

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Scenario optimization is a broad methodology for data-driven optimization, where one makes a decision that is consistent with the observations. The "risk" is the probability that the scenario solution is not consistent with a new, out-of-sample, situation and recent studies have unveiled a profound link between the risk and the solution complexity, meant as the minimum amount of data from the data set which is needed to reconstruct the solution. In this talk, we leverage these results to introduce new learning schemes where the size of the dataset is tuned during the optimization procedure. These schemes entail a better exploitation of the available resources and typically result in a huge saving of data to obtain a given level of risk.

On risk averse competitive equilibrium

Henri Gerard[1], Vincent Leclère, Andy Philpott
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Motivated by the management of electricity markets, we discuss risked competitive partial equilibrium in a setting in which agents are endowed with coherent risk measures. In this case, Philpott, Ferris and Wets have shown that it is possible to define a complete market for risk. Then a perfectly competitive partial equilibrium will be efficient, i.e. will also maximize risk-adjusted social welfare. If the market for risk is not complete, then equilibrium can be inefficient.
We make the following contributions:
– we show a reverse statement between risk averse equilibrium problems in complete markets adapting a result from Ralph and Smeers,
– in contrast to social planning models, we show by example that risked equilibria are not unique, even when agents' objective functions are strictly concave,
– we also show that standard computational methods find only a subset of the equilibria, even with multiple starting points.

Distributionally Robust Capacitated Vehicle Routing

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We study a variant of the capacitated vehicle routing problem (CVRP), which asks for the cost optimal delivery of a single product to geographically dispersed customers through a fleet of capacity-constrained vehicles. Contrary to the classical CVRP, which assumes that the customer demands are deterministic, we model the demands as a random vector whose distribution is only known to belong to an ambiguity set. Moreover, we require the delivery schedule to be feasible with a probability of at least 1 - epsilon, where epsilon characterizes the risk aversion of the decision maker. We argue that the emerging distributionally robust CVRP can be solved efficiently with modern branch-and-cut schemes if and only if the ambiguity set satisfies a subadditivity condition. We then show that this subadditivity condition holds for a large class of moment ambiguity sets. We derive efficient cut generation schemes for first-order and second-order moment ambiguity sets. Our numerical results indicate that the distributionally robust CVRP can be solved in runtimes comparable to those of the deterministic CVRP.

Comparing the Forecasting Performances of Linear Models for Electricity Prices with High RES Penetration

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This paper compares alternative univariate versus multivariate models, probabilistic versus Bayesian autoregressive and vector autoregressive specifications for hourly day-ahead electricity prices, with and without renewable energy sources. The accuracy of point and density forecasts are inspected in four main European markets (Germany, Denmark, Italy and Spain) characterized by different levels of renewable energy power generation. Our results show that the Bayesian VAR specifications with exogenous variables dominate other multivariate and univariate specifications, in terms of both point and density forecasting.

Incorporating statistical model error into the calculation of acceptability prices of contingent claims

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The determination of acceptability prices of contingent claims requires the choice of a stochastic model for the underlying asset price dynamics. Given this model, optimal bid and ask prices can be found by stochastic optimization. However, the model for the underlying asset price process is typically based on data and found by a nonparametric statistical estimation procedure. We define a confidence set of possible estimated models by a nonparametric neighborhood of a baseline model. This neighborhood serves as ambiguity set for a stochastic optimization problem under model uncertainty. We derive the dual problem formulation and relate the bid and ask prices under model ambiguity to the quality of the observed data. Eventually, we obtain distributionally robust solutions for the acceptability pricing problem. We examine the problem from a computational perspective by discussing its algorithmic solution and showing some numerical experiments.

Disjunctive conic cuts: the good, the bad, and implementation

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In recent years, the generalization of Balas disjunctive cuts for mixed integer linear optimization problems to mixed integer non-linear optimization problems has received significant attention. Among these studies, mixed integer second order cone optimization (MISOCO) is a special case. For MISOCO one has the disjunctive conic cuts approach. That generalization introduced the concept of disjunctive conic cuts (DCCs) and disjunctive cylindrical cuts (DCyCs). Specifically, it showed that under some mild assumptions the intersection of those DCCs and DCyCs with a closed convex set, given as the intersection of a second order cone and an affine set, is the convex hull of the intersection of the same set with a parallel linear disjunction. The key element in that analysis was the use of pencils of quadrics to find close forms for deriving the DCCs and DCyCs. The first part of this talk will summarize the main results about DCCs and DCyCs including some results about valid conic inequalities for hyperboloids and non-convex quadratic cones when the disjunction is defined by parallel hyperplanes. In the second part, we will discussed some of the limitation of this approach to derive useful valid inequalities in the context of MISOCO. In the last part, we will briefly describe the software libraries that together constitute DisCO, a full-featured solver for MISOCP which we are currently used to explore the potential of DCCs and DCyCs.

Computing Credit Valuation Adjustment using hybrid approaches in the Bates model.

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Computing a Credit Valuation Adjustment (CVA), to account for a possible counterparty default, is an actual big challenge in risk management. Actually, if the studied financial product is a vanilla option, then the regulators -in the Basel III accords- have conclued that a single price of the option would not be sufficient. The financial institutions will also need to compute the creditworthiness of their counterparty, which is in fact done via the so-called CVA.

Even for vanilla options this becomes a high dimensional problem, especially if we want to take into account stochastic volatilities or jumps. For instance, the Heston and Bates models, which are the most popular stochastic models, are often used to simulate asset dynamics involved in the CVA computation.

In the literature it has already been demonstrated that hybrid approaches for the implementation of the Heston model are very efficient (see [1]). Moreover approaches using a coupling between a Monte-Carlo or Finite difference procedure and an hybrid tree have also been used for the pricing of complex products in [2].

We propose here to strongly use the hybrid tree method in order to developp a novel methodology for the computation of CVA. An alternative approach have been already presented with a coupling method using Finite-Difference-Monte-Carlo (FDMC) procedure in [3]. Given our numerical method we will compare it with the FDMC method in the framework of Bates model.

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Are we too optimistic? Emission reduction from fleet operation after introducing Maritime Emissions Trading Scheme

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Global warming has become one of the most popular topics on this planet in the past decades, since it is the challenge that needs the efforts from the whole mankind. Maritime transportation, which carries more than 90% of the global trade, plays a critical role in the contribution of GHGs emission. Unfortunately, the emission from the global fleet still falls outside the scheme of GHGs emission reduction established by the Kyoto Protocol. Alternative solutions are therefore strongly desired. Several market-based measures are proposed and submitted to IMO for discussion and evaluation. In this paper, we choose to focus on one of these measures, namely the Emissions Trading Scheme (ETS). An optimization model integrating the classical fleet composition and deployment problem with the application of ETS (global or regional) is proposed. The impacts of ETS on the fleet composition and deployment and the corresponding CO2 emission at operation stage are studied. The results of the computational study suggest that in general a global application of ETS has better performance in CO2 reduction than a regional ETS. Nevertheless, in some settings, neither a global nor a regional ETS will lead to a lower CO2 emission, comparing to the business-as-usual scenario. In some extreme but possible cases, a regional ETS may even bring higher emission due to operational reasons.

OR made in Norway transforms the scheduling of the 2018 FIFA World Cup Qualifiers

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Every four years, the 10 national teams members of the South American Football Confederation (CONMEBOL) compete for one of the South American slots in the final phase of the FIFA World Cup. The qualifying competition consists of a double round robin tournament. The matches are scheduled in 9 closely spaced pairs known as double rounds. Every team plays twice in each double round. The tournament is spread over 2 years, so the double rounds are months apart. After using the same mirrored schedule for about twenty years, and persistent complaints from its members, CONMEBOL decided to change the schedule for the 2018 World Cup. Supported by one of CONMEBOL's members, we used integer programming to construct schedules that overcome the main drawbacks of the previous approach. After exploring many design criteria, we proposed a candidate schedule whose main feature is that every team plays once at home and once away on each double round, a departure from traditional symmetric (mirrored) schemes. This proposal was unanimously approved by CONMEBOL members and was used in the qualifier tournament for the 2018 FIFA World Cup Russia.

Quantifying the utility of war to increase deterrence capability of small states

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Deterrence has been the main factor in Norwegian security policy since the Second World War. The deterrence has been based on the nuclear arsenal of the biggest NATO members and the large amount of conventional allied forces. The Norwegian deterrence has therefore been what is known as external deterrence. On the other hand we see that an adversary can use means “below” the threshold for NATO involvement, thus Norway has to be able to deter or counter this aggression on its own. We therefore need to explore the possibility of internal deterrence.
If we assume a rational adversary who calculates the utility of war before a possible conflict, we can use the utility function of war to explore how to best deter an opponent. In this paper we explore this function as it is seen for an adversary, and we explore different forms of deterrence and discuss what the Norwegians can do to minimize the enemy utility and make deterrence as effective as possible.

Green Investment under Policy Uncertainty and Bayesian Learning

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Many countries have introduced support schemes to accelerate investments in renewable energy (RE). Experience shows that, over time, retraction or revision of support schemes become more likely. Investors in RE are greatly affected by the risk of such subsidy changes. This paper examines how investment behavior is affected by updating a subjective belief on the timing of a subsidy revision, incorporating Bayesian learning into a real options modeling approach. We analyze a scenario where a retroactive downward adjustment of fixed feed-in tariffs (FIT) is expected through a regime switching model. We find that investors are less likely to invest when the arrival rate of a policy change increases. Further, investors prefer a lower FIT with a longer expected lifespan, while policy makers prefer a higher FIT with a shorter life span. We also consider an extension where, after retraction, electricity is sold in a free market. We find that if policy uncertainty is high, an increase in the FIT will be less effective at accelerating investment. However, if policy risk is low, FIT schemes can significantly accelerate investment, even in highly volatile markets.

Evaluating Security of Supply in the European Natural Gas Market – A Stochastic Programming Approach

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The European gas market faces uncertainties in different fields, driven e.g. by climate policy, geopolitics or declining natural gas reserves. On the supply side, a decreasing gas production in Western Europe enhances the dominance of non-European suppliers as Russia or Qatar. Additionally, uncertainties grow on the transmission side, where Russia strives to build new transmission routes to Europe e.g. Nord Stream II, Turkish Stream. These activities change the supply structure to Europe.
The presentation will focus on the supply and transmission side. As one major goal of energy policy is security of supply, diversification in both, gas suppliers and transmission ways, gains in importance. Therefore, the objective of this work is calculating the costs of diversified infrastructures using an extended version of the linear optimization Gas market model (GAMAMOD). In a deterministic model, differences in total system costs between high and low diversified scenarios can be interpreted as the value of supply diversification. Using a two-stage stochastic programming approach, the uncertainty of natural gas demand is considered. On the first stage, a central planer takes the decision of capacity extensions (e.g. pipelines). Thereby, the model takes uncertain future gas demand gas in the second stage into account.
First results indicate a fundamental change in gas flows in Europe. While Ukraine loses its position as an important transit country, Turkey becomes a new gas hub. Furthermore, the role of Germany is changing from a gas hub to an important gas transit country for the Western European gas market. The value of stochastic solution for a diversified supply structure is still under investigation. However, it might be that politicians promote diversification infrastructure projects not only for economical, but for geopolitical reasons. Hence, the danger of stranded assets is high. Stochastic programming can contribute to optimal investment decisions in this field of uncertainty.

Optimal Hydropower Maintenance Scheduling Under Uncertainty

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Maintenance scheduling is an important and complex task in hydropower systems. In a liberalized market, generation companies will schedule maintenance periods to maximize their expected profit. Traditionally, the maintenance and hydropower scheduling are treated as separate or loosely coupled tasks due to the computational complexity. We present a method for hydropower maintenance scheduling suitable for a profit maximizing, price-taking and risk neutral hydropower producer. Inflow to reservoirs and prices for energy and reserve capacity are treated as stochastic variables. The method coordinates maintenance scheduling and detailed hydropower scheduling by the use of Benders decomposition. First, the maintenance scheduling problem is solved as a mixed integer linear programming problem to provide a trial maintenance schedule to be considered in the hydropower scheduling. Subsequently, the hydropower scheduling problem is evaluated as a linear programming problem using multi-stage Benders decomposition, where an outer approximation of a convex expected future profit function is constructed for each time stage by adding Benders cuts. Two different sets of Benders cuts are built iteratively, one to decompose the multistage linear hydropower scheduling problem and one to coordinate the maintenance and hydropower scheduling problems.

The proposed method is suitable for maintenance scheduling in large and complex watercourses, allowing a rather detailed representation of the hydropower system and considering the relevant uncertainties in the scheduling problem. The proposed method was applied in a case study for a Norwegian watercourse, and results, in terms of maintenance schedules and computational performance, are presented and discussed. Although the convergence rate is significantly lower than for the hydropower scheduling problem separately, the results indicate that the proposed method is capable of efficiently exploring the search space of possible maintenance periods for multiple plants.

Solving real-life decision problems with multi criteria decision analysis

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FFI is supporting the armed forces with decision support. In this study FFI get tasked to support the Chief of Defence on how to utilize the NH90 helicopters given a gap between the operational needs and an estimated future operational capability. Additionally, FFI was tasked to identify mitigating measures to close the gap. Given the time constraints, we chose to use multi criteria decision analysis to model the decision problem. In this process we made the Defence staff quantify their preferences and using subject matter experts to assess different solutions performance.

Portfolio Choice Under Cumulative Prospect Theory: sensitivity analysis and an empirical study

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We perform a sensitivity analysis of the impact of Cumulative Prospect Theory (CPT) parameters on Mean/Risk efficient frontier, through a simulation procedure, assuming a Multivariate Variance Gamma distribution for log-returns. The optimal investment problem for an agent who behaves according to CPT is then investigated empirically, by considering different parameters combination for the CPT utility function. The CPT portfolios are compared with the mean-variance and the Global-Minimum-Variance ones. As out-of-sample performance measures the Omega ratio and Information ratio are used. For the optimization procedure a multistart Global Optimization algorithm is adapted.

Nonconvex Medium-Term Hydropower Scheduling by Stochastic Dual Dynamic Integer Programming

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The presented work shows how the newly developed Stochastic Dual Dynamic integer Programming (SDDiP) method performs for solving the medium-term hydropower scheduling problem of a Norwegian hydropower producer. The method is an extension of the renowned Stochastic Dual Dynamic Programming (SDDP) method that solves a stochastic multistage linear programming problem. With increasing profit opportunities for hydropower producers to sell capacity reserves, we have observed a need for more detailed modeling of the hydropower station. This is required in order to not overestimate the station's opportunity to provide capacity reserves. Nonconvexities, including, minimum generation limit, unit commitment, uncertain energy price and nonconvex generation function can, therefore, be more accurately described, without having to perform relaxations as in SDDP.

The presentation will show some of the challenges hydropower producers are faced with, an introduction to the SDDiP method and results from a recent publication.

Fast Bellman Updates for Robust MDPs

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We describe an algorithm for computing Bellman updates in robust Markov decision processes (MDPs). The proposed algorithm uses bisection to compute updates for robust MDPs with s-rectangular ambiguity sets. This algorithm, makes use of a homotopy continuation method, has a quasi-linear runtime for L1-constrained ambiguity sets. Unlike previous methods, our algorithm computes the primal solution in addition to the optimal objective value, which makes it useful in policy iteration methods. Our experimental results indicate that the proposed method is significantly faster than standard optimization solvers, and the performance gap grows considerably with problem size.

Interplay of wind energy expansion and regional market premia – A fundamental market model analysis with application to Germany

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Since the latest reforms of the renewable support regulation in Germany, renewable energy generators are obliged to sell their energy on wholesale markets. In addition to market revenues, they are granted a market premium, which can be interpreted as the difference between the discounted construction and operation cost and market revenues earned. As market revenues are directly based on wholesale electricity prices, the economic value of generation from a specific location is now determined by the temporal availability and magnitude of the physical energy supply, e.g. wind, and wholesale electricity prices, which themselves are negatively influenced by renewable energy feed-in (merit-order effect).
The objective of this work is thus to quantify the future development of local market premia for wind energy in Germany and to derive a general understanding of the interplay between different regional onshore wind expansion scenarios and support requirements endogenously considering electricity price formation.
To handle the high degree of complexity, Benders decomposition is applied to the large scale fundamental electricity market investment and dispatch model used. The master problem represents the capacity investment decision while the sub problem optimises the dispatch of the plants. The programme is solved using parallel computing. Investments in wind energy are highly granular as local technical potentials and time series are utilised. Conventional technologies are modelled plant-wise to reproduce valid electricity prices.
Two expansion strategies are examined: A rather centralised expansion utilising high wind coastal regions of Germany, which lowers electricity prices considerably due to a high correlation with offshore wind, and a rather decentralised expansion with a stronger focus on south Germany, whereby more low wind sites are considered buttressing electricity prices. Results will provide an indication of the total financial support required under the expansion pathways (and sensitivities), providing policy makers assistance in economically optimising onshore wind expansion planning.

Is it possible to increase the stability under parallelepiped uncertainty in robust portfolio optimization?

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In financial markets with high uncertainties, the trade-off between maximizing expected return and minimizing the risk is one of the main challenges in modeling and decision making. Since investors mostly shape their invested amounts towards certain assets and their risk aversion level according to their returns, scientists and practitioners have done studies on that subject since the beginning of the stock markets' establishment. In this study, we model a Robust

Optimization problem based on data. We found a robust optimal solution to our portfolio optimization problem. This approach includes the use of Robust Conditional Value-at-Risk under Parallelepiped Uncertainty, an evaluation and a numerical finding of the robust optimal portfolio allocation. Then, we trace back our robust linear programming model to the Standard Form of a Linear Programming model; consequently, we solve it by a well-chosen algorithm and software package. Uncertainty in parameters, based on uncertainty in the prices, and a risk-return analysis are crucial parts of this study. A numerical experiment and a comparison (back testing) application are presented, containing real-world data from stock markets as well as a simulation study. Our approach increases the stability of portfolio allocation and reduces the portfolio risk.

Engineer-to-order project planning with uncertainty in design and task duration

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We study engineer-to-order project planning problem, where the specified design is uncertain in the sense that it can change during the duration of the problem. In addition, we include uncertainty in duration of some selected tasks. The latter is resolved first after we have started the work on the task, so the problem falls into the realm of decision-dependent uncertainty.
We present a stochastic MIP model for the problem and results for a simple test case, illustrating different strategies for handling the double uncertainty.

A Stability Result for Linear Markov Decision Processes

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The approximation of stochastic processes is an important topic in multistage stochastic optimization. In this paper we focus on the approximation of Markov process by lattices.

We propose a semi-metric for Markov processes that allows to bound optimal values of linear Markov Decision Processes (MDPs). Similar to existing notions of distance for general stochastic processes our distance is based on transportation metrics. Apart from the specialization to MDPs, our contribution is to make the distance problem specific, i.e., explicitly dependent on the data of the problem whose objective value we want to bound. As a result, we are able to consider problems with randomness in the constraints as well as in the objective function and therefore relax an assumption in the extant literature. We derive several properties of the proposed semi-metrics and demonstrate its use in a stylized numerical example.

Utilizing strengthened lift-and-project cuts in decomposition methods to solve two-stage stochastic programming problems with binary first-stage variables

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Lift-and-project cuts are well-known general 0-1 programming cuts which are typically deployed in branch-and-bound-type methods to solve MILP problems. In this talk, we discuss ways to use these cuts in Benders' type decompositions algorithms for solving two-stage stochastic programming problems with binary first-stage variables. In particular, we show how L&P cuts derived for the mixed-binary first-stage master problem can be strengthened by utilizing second-stage information. We present an adapted L-shaped algorithm and some computational results.

Robust Multidimensional Pricing: Separation without Regrets

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We study a mechanism design problem where a seller offers a finite number of goods to a single buyer. The existing literature models the buyer's willingness to pay through a set of random values, one for each good, that follow a known joint probability distribution. The seller then selects an allocation and payment rule that maximize expected revenues. As expected revenue maximization is intractable and sensitive to the value distribution, we instead propose to minimize the seller's worst-case regret. We show that this problem admits an analytical solution and is generalizable along several directions.

Decreasing absolute risk aversion stochastic dominance in portfolio optimization

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An optimization method is developed for constructing investment portfolios which stochastically dominate a given benchmark for all decreasing absolute risk-averse investors, using Quadratic Programming. The method is applied to standard data sets of historical returns of equity price reversal and momentum portfolios. The proposed optimization method improves upon the performance of Mean-Variance optimization by tens to hundreds of basis points per annum, for low to medium risk levels. The improvements critically depend on imposing Decreasing Absolute Risk Aversion instead of Global Risk Aversion or Decreasing Risk Aversion.

Bayesian Electricity Price Forecasting. Models with Jumps or Stochastic Volatility

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Sharp movements are a hallmark of electricity price time series. Electricity supply and demand are subject to weather conditions as well as daily, weekly or yearly seasonality. These features have a significant impact on price behaviour. The research is focused on forecasting electricity prices by means of models with jumps and exogenous variables. We employ a Bayesian jump-diffusion model with time-varying intensity of jumps and a stochastic volatility model with jumps and exogenous variables in order to produce probabilistic forecasts. We employ predictive distributions which handle formally the uncertainty about the unknown parameters and model specification. The results obtained by means of the Bayesian and non-Bayesian methods are compared. Our empirical study is based on day-ahead electricity prices. We argue that the Bayesian models and Bayesian pooling approach can be useful for the modelling and probabilistic forecasting of electricity prices.

Using tropical optimization techniques in multi-criteria decision problems

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We consider problems of rating alternatives based on their pairwise comparisons according to several criteria. Given pairwise comparison matrices for each criterion, the problem is to find the overall priorities of each alternative. We offer a solution that involve the minimax approximation of the comparison matrices by a common (consistent) matrix of unit rank in terms of the Chebyshev metric in logarithmic scale. The approximation problem reduces to a multi-objective optimization problem to minimize simultaneously the approximation errors for all comparison matrices. We formulate the problem in terms of tropical (idempotent) mathematics, which focuses on the theory and applications of algebraic systems with idempotent addition. To solve the optimization problem obtained, we apply methods and results of tropical optimization to derive a Pareto optimal solution. As an illustration of the approach, we present a complete Pareto optimal solution for a general problem of rating alternatives in the case of two criteria used for comparisons.

Distributionally Robust Inverse Covariance Estimation: The Wasserstein Shrinkage Estimator

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We introduce a distributionally robust maximum likelihood estimation problem with Wasserstein ambiguity set to infer the inverse covariance matrix of a p-dimensional Gaussian random vector from n independent samples. We prove that this estimation problem is equivalent to a semidefinite program, which is tractable in theory but beyond the reach of general purpose solvers for practically relevant values of p. In the absence of conditional independence constraints we show that the estimation problem has an analytical solution that is naturally interpreted as a nonlinear shrinkage estimator with several desirable properties: besides being invertible and well-conditioned even for p>n, it is rotation-equivariant and preserves the order of the eigenvalues of the sample covariance matrix. Finally, we develop a sequential quadratic approximation algorithm for efficiently solving the generic estimation problem in the presence of conditional independence constraints.

Modelling a non-linear impact of renewable energy forecasts on intra-day electricity prices

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It seems undeniable that energy collected from renewable resources constitutes a substantial part in the overall supply of electricity in many contemporary energy markets. The German EPEX SPOT SE is not an exception in this case. One of the major features of this exchange is that it establishes prices for a MWh of electricity multiple times a day. This is primarily done on day-ahead auctions and during intra-day trading. The latter tends to be conducted on the grounds of a more precise renewable energy supply data. The day-ahead auctions are, in turn, based on the respective forecasts. Needless to say, those forecasts are prone to be erroneous. In this paper we demonstrate that the influence of forecasting errors on a difference between intra-day and day-ahead prices is non-linear. That is, a wrongly calibrated forecast may exert different impact on electricity prices depending on a sector of a merit-order curve. To show this explicitly, we model intra-day prices given day-ahead data and errors in the forecasts for wind and solar energy generation. In doing so, we exploit an empirical supply and demand curves approach as well as a non-linear optimization technique. We show that forecasting accuracy increases as long as we take non-linear effects into account.

Estimation of risk neutral moments from WTI crude oil options.

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It is possible to estimate statistical distributions' moments that are based not on a historical data but are incorporated in derivatives' prices and are forward looking. Thus risk neutral moments, that are backed out from options with wide range of strike prices, can be advantageous for forecasting, risk management and policy analysis. In this work, risk neutral moments are calculated for WTI crude oil options with maturities of one and six months. Taking into consideration that observable strike prices are discrete and have relatively big increments, there is a need for interpolation. It is applied not directly on options prices but on implied volatilities with two methods: cubic spline smoothing and kernel smoothing. Furthermore, options with extremely low and high strike prices are not traded. Therefore risk neutral distributions' tails are extended by Generalised Extreme Value distributions. Moreover, tails of distributions are extrapolated using another approach: constant volatilities are attached to the left and right side of implied volatility. Consequently, estimated with these approaches, risk neutral moments are compared across time and two maturities of one and six months. Some analysis of potential of risk neutral moments describing major events is analysed as well.

Is market surprised by the surprised?

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This paper investigates how investors respond to earnings surprises. We study over 9,000 annual earnings announcements made by US companies during the period 2002 through 2016. Each surprise is classified as either good, neutral or bad depending on whether firms meet analysts' expectations or not. Market reactions to the surprises are then explored using panel data models. We find that market reactions to the earnings surprises are asymmetric between positive and negative surprises. We also explore the effect corporate governance and market uncertainty have on the market reactions earnings surprises incite. We find that market reactions have changed during the global financial crisis.

Recruitment from the basic military service to the Norwegian Armed Forces

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The basic military service is a valuable source for recruitment of personnel to the Norwegian Armed Forces. We will present some preliminary results from a study on how the Norwegian Armed Forces can make the most of this opportunity. The study is based on data from the selection process for conscripts. By means of statistical methods such as logistic regression and survival analysis, we explore some characteristics of those conscripts who choose to pursue a military career.

Reducing lifecycle cost of electric vehicles by optimizing vehicle to grid strategies

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To combat urban air pollution, many cities around the world favor electric mobility. However, due to the high battery cost, electric vehicles continue to have a higher purchase price than their electric counterparts. Vehicle-to-grid, the idea of using electric vehicle batteries to balance electricity supply and demand in the power grid, has been proposed as a method to reduce the purchase price of electric vehicles. Using state-of-the art convex optimization methods, we investigate how vehicle-to-grid affects the lifetime costs of electric vehicles.

Technology driven capacity expansion of aluminum smelters

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With the recent strong growth in aluminum demand, upcoming supply deficit, and in general a positive outlook for the industry, many aluminum producers are considering investment in additional aluminum smelter capacity. This type of investment characterized by a high degree of irreversibility and several sources of uncertainty. Furthermore, many producers have a certain degree of flexibility with regards to investment timing. These features of the investment are not captured by traditional valuation techniques. Supplementary valuation methods are thus required to adequately capture the value of the flexibility and ensure investment profitability. In this paper, we develop a framework to value an aluminum producer that has the option to invest in a predetermined amount of additional capacity. We focus on assessing how the technological uncertainty with regards to aluminum smelter energy intensity affects the value of this option. We find that there is a significant value in being flexible with the investment timing. The value of the capacity expansion option increases both with higher arrival rate of new technology and higher magnitude of the efficiency improvements at each arrival. Furthermore, we perform a comparative statics analysis in order to see how the optimal investment threshold is affected by aluminum price, electricity price, arrival rate, magnitude of efficiency improvement, investment cost, and interest rate.

Exact converging bounds for Stochastic Dual Dynamic Programming

Vincent Leclère

The Stochastic Dual Dynamic Programming (SDDP) algorithm has become one of the main tools to address convex multistage stochastic optimal control problem. Recently a large amount of work has been devoted to improve the convergence speed of the algorithm through cut-selection and regularization, or to extend the field of applications to non-linear, integer or risk-averse problems. However one of the main downside of the algorithm remains the difficulty to give an upper bound of the optimal value, usually estimated through Monte Carlo methods and therefore difficult to use in the algorithm stopping criterion. In this paper we present a dual SDDP algorithm that yields a converging exact upper bound for the optimal value of the optimization problem. Incidently we show how to compute an alternative control policy based on an inner approximation of Bellman value functions instead of the outer approximation given by the standard SDDP algorithm. We illustrate the approach on an energy production problem involving zones of production and transportation links between the zones. The numerical experiments we carry out on this example show the effectiveness of the method.

Modeling electricity price series with vector hidden Markov models

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Electricity price series display peculiar features, from daily periodicities and price spikes to long autocorrelation. Most of the discrete time econometric models that can support these kinds of features have no internal representation of them and limit themselves to mimic the phenomenology.
In the seminar, a machine learning approach and its econometric equivalent will be presented, that allow for a nice reproduction of many important features of electricity series, but also help look at the data in a way that has a clear and direct interpretation in terms of classes of market days and high level representations of market features

Forecasting the spread between the spot and the intraday market prices.

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The rising share of Renewable Electricity Sources (RES) in the generation mix have led to development of intraday electricity markets, which offer the possibility of trade energy close to the delivery time. Small RES utilities may now sell on both spot and intraday markets, in order to increase their profits and reduce the risk. The efficient choice between these markets is a new challenge to utility owners. In this research, econometric models aiming at forecasting the spread between the spot and the intraday markets are proposed. Their performance is evaluated with two data sets describing a German and a Polish electricity market. The results indicates that the trading strategy based on proposed models results in a profit increase and hence could be recommend to energy sellers.

Bounds for Probabilistic Constrained Problems

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In this talk we develop bounds for different types of chance constrained optimization problems: single chance constraints, joint chance constraints with independent matrix vector rows and joint chance constraints with dependent matrix vector rows. The deterministic approximations of probability inequalities are based on the one-side Chebyshev inequality, the Berstein's inequality, Chernoff inequality and Hoeffding inequality and allow to reformulate the chance constrained problem considered in a convex and efficiently solvable way under specific conditions. Approximations based on piecewise linear and tangent approximations are also provided allowing to reduce further the complexity of the problem. Finally numerical results on randomly generated data are provided allowing to identify the tighter deterministic approximations for single and joint chance constrained problems.

Valuing Portfolios of Interdependent Real Options under Exogenous and Endogenous Uncertainties

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Although the value of portfolios of real options is often affected by both exogenous and endogenous sources of uncertainty, most existing valuation approaches consider only the former and neglect the latter. In this paper we present a new approach for modelling and approximating the value of portfolios of interdependent real options under both types of uncertainty. In particular, we study a large portfolio of options under conditions of four uncertainties. Two of the underlying uncertainties, decision-dependent cost to completion and state-dependent salvage value, are endogenous, the other two, operating revenues and their growth rate, are exogenous. The stochastic processes describing the dynamics of all four uncertainties and the set of constraints modelling the options' interdependencies are integrated in a multi-stage stochastic integer program. Combining a simulation-and-regression approach with a reachability analysis to approximate the value of this optimisation problem, we present an efficient valuation algorithm that exploits the problem structure to explicitly account for the (sub)sets of sample paths in which resource states can actually be reached. The applicability of the approach to complex investment projects is illustrated by valuing an infrastructure investment. We find that while the total number of reachable resource states, as expected, increases in both the number of paths simulated and the degree of the decision-dependent uncertainty, the percentage share of paths available per resource state in the valuation algorithm decreases not only in the latter, but, somewhat paradoxically, also in the former. This means that, in contrast to simulation-based approaches for standard problems, generating more sample paths will in general not improve the algorithm's approximation accuracy when addressing problems with endogenous, decision-dependent uncertainty. In addition, we investigate the way in which the value of the portfolio and its individual options are affected by the operating revenues, and by the degrees of exogenous and endogenous uncertainty.

Long-term seasonal component in day-ahead electricity price forecasting with NARX neural networks. Part II - Probabilistic forecasting

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Daily and weekly seasonalities are always taken into account in day-ahead electricity price forecasting, but the long-term seasonal component has long been believed to add unnecessary complexity, and hence, most studies have ignored it. The recent introduction of the Seasonal Component AutoRegressive (SCAR) modeling framework has changed this viewpoint. However, this framework is based on linear models estimated using ordinary least squares.

This paper considers non-linear autoregressive (NARX) neural network-type models with the same inputs as the corresponding SCAR-type models, more importantly, a novel extension of the SCAR concept to probabilistic forecasting and applies two methods of combining predictive distributions. Given that probabilistic forecasting is a concept closely related to risk management, our study has important implications for risk officers and portfolio managers in the power sector.

Integer Stochastic Path Detection

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Stochastic path detection problems occur in many domains where supply chains or traffic networks must be protected. In these problems a protector and an attacker operate in a network with a set of source-destination paths. The protector has beliefs about the attacker's movements, and a given budget of security resources. He aims at allocating his resources in the network such that the attacker is detected with high probability. In this work, we consider two-stage integer stochastic path detection problems. We propose cutting plane methods to derive policies for allocating security resources. The methods are compared with respect to computational properties and quality of the resulting allocation policies.

A BFC based metaheuristic algorithm for solving stochastic mixed convex problems using SQP methods

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We present a matheuristic algorithm to solve multistage mixed 0-1 stochastic problems with nonlinear convex objective function and convex constraints. These problems have continuous and binary variables in each stage and the number of contingencies of the nodes is not the same in at least one stage, i.e. the uncertainty is represented by a nonsymmetric scenario tree. The algorithm is based on the Branch-and-Fix Coordination method (BFC) modified to get a higher efficiency. Some heuristic criterions are proposed in order to reduce the number of Twin Node Families visited during the performance of the algorithm, which are numerically tested. In order to solve each nonlinear convex subproblem generated at each node of the trees of the BFC method we propose to use Sequential

Quadratic Programming (SQP) methods. The algorithm has been implemented in C++ with the help of Cplex to solve quadratic subproblems. Test problems have been randomly generated by a C++ code. Computational tests have been performed and its efficiency has been compared with that of MINLP codes.

Micro-grid expansion a cooperative game theory approach

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Existing power-grids are becoming obsolete, and the centralized power production paradigm is slowly deteriorating and giving way to a cleaner solution, where power generation is carried out by renewable sources located in proximity to the load. Nevertheless, introduction of new and renewable sources brought challenges in integration with the existing power infrastructure. The top-down framework of energy flow from producer to consumer is changing fast with prosumers and community energy hubs. A Micro-Grid (MG) is a supplementary and practical solution for both restructured and isolated power infrastructure. The substantial issue of continuous power supply from local MG with renewable resources is no longer a threat due to the technological advancements in the efficient energy storage systems as in hydrogen energy, advanced batteries poly-ionics, traction based rail energy storage. MGs are normally endowed with some degree of intelligence (smart-micro-grid - SMG), thanks to the significant advancements in responsive ICT ecosystem. For instance, a MG might be equipped with smart energy management in coordination with smart instruments like smart meters, lighting, heating, cooling.

The effects of possible policy withdrawal on investment timing and investment size

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This paper analyzes the effect of a possible withdrawal of a tax credit policy on investment timing and investment size, and the interaction between investment timing and investment size. If the policy maker can only withdraw a policy once and not enact it in the future, we find that increasing the probability of withdrawal of a tax credit policy, increases the incentive to invest now and decreases the optimal investment size. Huisman and Kort [2015] show that investing later means that the investor invests at a larger capacity, which is confirmed in this paper. It is found that a firm that invests at the timing threshold value invests at larger scale when the policy is not in effect than when it is in effect. This results from the fact that subsidy speeds up investment and earlier investment is done at a lower capacity.

Unlike the price premium in Chronopoulos, Hagspiel and Fleten [2016], these conclusions do not hold only for low withdrawal probabilities, but for all withdrawal probability values, as the tax credit policy is only relevant at the time of investment. Therefore, increasing the withdrawal probability to a large value speeds up investment more. When the investor is a social planner who aims to the maximize social welfare, it is found that the social planner has the same timing as the profit-maximizing monopolist, but invests at twice the investment size. The monopolist seems to keep the price up by producing less.

Scenario Analysis for Energy Saving and Management Optimization in Complex Water Supply Systems

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The pumping schedules optimization of complex water supply systems considering different hydrological scenarios occurrences is a significant issue when defining the activation of emergency and costly water transfers. As well known, this problem is characterized by a huge uncertainty level and it requires specific stochastic models in order to achieve optimized management rules. Particularly, treating the effectiveness of early warning and emergency transfers alleviating droughts, the operating costs required by pump stations activation stress the water systems' Authorities to define a robust approach identifying these optimized rules.
In this paper, this optimization procedure has been developed using the scenario analysis approach. The model allows identification of the optimal management rules by balancing the risk of water shortages under different hydrological scenarios and the energy costs due to the pumping stations operation. Scenario analysis optimization provides the water resource management Authority with information defining optimal activation thresholds for pumping stations in order to assure a water demand level fulfillment for users (irrigational, civil, industrial) and an energy saving policy.
This optimization model has been implemented using the software GAMS, specifically designed for modelling mixed integer optimization problems. A model application has been developed to a real water supply system located in South-Sardinia (Italy) area. The obtained results define a cost-risk trade-off considering water shortage probability minimizing energy and operative costs.

Distributionally Robust Risk-Averse Optimization over Structured Wasserstein Ambiguity Sets

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By injecting structural information about the unknown true distribution of the uncertain problem parameters into a Wasserstein ambiguity set, we obtain several new optimization problems where the decision maker is minimizing risk measures such as the Value-at-Risk, the Conditional Value-at-Risk or the entropic risk measure.

Two-stage Stochastic Programming under Multivariate Risk Constraints

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In this study, we consider two classes of multicriteria two-stage stochastic programs in finite probability spaces with multivariate risk constraints. The first stage problem features a multivariate stochastic benchmarking constraint based on a vector-valued random variable representing multiple and possibly conflicting stochastic performance measures associated with the second stage decisions. In particular, the aim is to ensure that the associated random outcome vector of interest is preferable to a specified benchmark with respect to the multivariate polyhedral conditional value-at-risk or a multivariate stochastic order relation. In this case, the classical decomposition methods cannot be used directly due to the complicating multivariate stochastic benchmarking constraints. We propose an exact unified decomposition framework for solving these two classes of optimization problems and show its finite convergence. We apply the proposed approach to a stochastic network design problem in a pre-disaster humanitarian logistics context, and conduct a computational study to demonstrate the value and effectiveness of the modeling and solution framework.

Optimizing workflow in cell-based slaughtering and cutting of pigs

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We introduce a scheduling-like problem taken from the slaughterhouse industry. In an on-going research project, a new concept for slaughtering and cutting of pigs is developed. The basic idea is to replace the traditional production line with a number of meat factory cells, where an operator slaughters and rough-cuts the pig. The operator is assisted by a robot or robot arm, which performs the heavy work of lifting parts over to a rack or trolley. The operator and the robot have a number of tasks to perform before the pig is processed and the parts are placed on the rack. The ordering of these tasks are partly given by precedence, but there is still some freedom in how the tasks are ordered, mainly because both operators and robots can work in more than one cell at the time and move between cells to avoid interrupting the other part. Some operations require that the operator and the robot is working together, for example when a heavy part is lifted by the robot while the operator cuts it free from the carcass. A problem description and a mathematical model for the problem is presented together with preliminary computational results.

Portfolio selection impact of multivariate dominance rules among financial sectors

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The paper evaluates the impact of a multivariate stochastic dominance comparison among different financial sectors. In particular, we consider Gaussian and non-Gaussian distributional hypotheses for the multivariate distribution of financial sectors, and we test whether there exists some dominance among them. In this context, we also discuss the asymptotic dominance between financial sectors. Finally, an ex-ante and an ex-post empirical analysis examine the impact of sector dominance on the optimal investors' choices in the US stock market.

Optimal timing for sending pigs to the abattoir: a stochastic programming approach

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Pig production is structured in three main stages: piglets are born in sow farms, transferred to rearing farms and finally send to fattening farms before going to the abattoir. In this last stage, pigs are fattened until they reach a desired marketable weight. Although fattening farms operate in batches (due to sanitary reasons) and host pigs of the same age, each individual grows at a different pace leading to a wide market window. At the abattoir, a carcass is paid according to a weekly base price which is bonused or penalized depending on the weight and lean percentage. From the operational point of view, the key question is to decide how many pigs have to be send each week to the abattoir so the batch profit is maximum. From the tactical point of view, the user can be interested on the optimal length of the market window, as closing a batch in shorter time can give advantage in the following batch to have higher prices.

In this work, a stochastic programming approach is presented. Given that the main uncertainty comes from the weekly pig price evolution, several strategies can be adopted. A multistage risk-neutral model was first developed to cover the operational decisions. This model was extended to include time-consistent risk-aversion measures. The tactical model is approached with a multi-horizon stochastic programming problem and multiple batches are considered. These models will be exemplified with a case from the Spanish market, and the solutions will be compared.

Multi–Period Probabilistic Set Covering Problem

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This study extends the classical probabilistic set coverage problem to a multi-period setting. The problem focuses on finding a least cost facility locations to cover random demand over one period of time with a specified probability. If facility engagement lasts more than one period of time, then little is known about how well the remaining operational facilities can satisfy demand in period two. Hence, the two-period model maximizes the probability of satisfying demand in period two by facilities not engaged in satisfying demand from period one. We demonstrate how solving multi-period version of the problem can be reduced to solution of a sequence of one-period probabilistic set coverage problems.

Generation of scenarios for multiscale stochastic optimization problems

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We consider a stochastic decision problem in energy management where the decisions are to be made on a weekly basis, but the resulting costs are calculated on an hourly basis.
We generate first a lattice for the weekly process using optimal quantification techniques. This gives the decision tree/lattice. Then we generate the process between the weekly already generated

values by sampling from the conditional distribution of the scenario process, which is conditioned on the staring and the ending values in a given interval. We derive the correct interpolating processes for autonomous stochastic differential equations (Ito-processes) and a way how to sample from them.

Approximation of Stochastic Processes

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We consider approximations of stochastic processes. Continuous stochastic processes require discretizations in time and space. We discuss optimal schemes, which balance the time-versus-space aspects.

High-dimensional modelling and forecasting for renewable energy generation

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The large-scale deployment of renewable energy generation capacities brings challenges and opportunities for its management. While forecasts are now a muct-have as inpuyt to decision-making, forecast quality has not improved as much as we would have hoped over the last few decades. However, the increasing amount of data being collected (meteorological observations, power production measurements, etc.) allows us thinking that once could profit of this additional information to improve forecasts at various temporal and spatial scales.
Increasing number of variables and quantity of data to be considered translates to high-dimensional modelling of power production dynamics. Since we expect a non-negligible decorellation in time and in space, those models should eventually be sparse, though with model structure evolving through time and as a function of weather regimes. Consequently, we will propose and discuss alternative approaches to sparse and adaptive high-dimensional modelling of relevance for renewable energy forecasting. The main application considered is wind power forecasting with case-studies consisting of 100s of wind farms in Denmark and in France. Finally, the possibility to generalize to distributed learning will be discussed.

A Bilevel Programming Approach to Estimating Elasticities of Substitution for Computable General Equilibrium Models

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The analysis of economical impacts for climate and energy policies often requires the employment of general equilibrium models. These constitute a valid tool to provide simulations to test the effects of different possible policies. Nevertheless, the accuracy of a simulation heavily relies on the quality of the calibrated parameters. This is especially true for what concerns the elasticities of substitution, where the lack of reliable methodologies forces the analysts to specify these parameters borrowing their values from previous work. In this paper we introduce a novel methodology to estimate the elasticity of substitution for CES functions to be used in Computable General Equilibrium models. The methodology allows the estimation of the elasticities of substitution for each production sector and is based on solving a bilevel programming problem.

Stochastic Programs for Engineering Problems: Challenges and Recommendations

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The aim of the paper is to discuss the role and importance of stochastic programming approach applied to engineering problems. The author has participated in model building and solution techniques development for various application areas like waste management, energy production, reliable engineering design, steel production technologies, stone blending, marble tiles production, water systems organization, etc.
Although the studied problems are of different origins, they still have many common features, and so, related general challenges can be identified. Problems are often represented by complex systems of hierarchical structure, they also involve elements with network-like structure, linear and nonlinear terms and both continuous and integer variables. From decision maker's point of view they combine local decisions, regional allocating policies, and overall strategic designs. Additionally, there are dynamically changing uncertain parameters of various nature and heterogeneous sources of data.
It is shown that classical scenario-based programs and separable approximations can also support engineering specific combinations of wait-and-see and here-and-now decision stages including some decision dependent randomness cases. Thus the sequences and even networks of stochastic programs can be utilized to tackle the problems complexities. To achieve solvability for real-world data, problems are frequently modeled separately or weakly linked by implementation of suitable decomposition ideas at the modeling level and satisfying suboptimal solutions can be obtained in a straightforward way. Afterwards, their improvement is achievable by modification of scenario-based and node-related decomposition techniques combined with heuristics into hybrid algorithms. The collected recommendations are presented and some of them are selected and illustrated for a specific application area. Implementation in GAMS modelling system is shortly mentioned and for chosen real-world data results are commented, conclusions are derived, and possibilities for further research are mentioned.

Decision rules for adjustable integer robust optimization problems via branch-and-bound

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Postek and den Hertog (2016) and Bertsimas and Dunning (2016) have proposed to construct piecewise constant decision rules for mixed-integer robust optimization problems by partitioning the uncertainty set. The partitions are executed so as to separate the so-called critical scenarios of the uncertain parameter and the authors present theory on how such scenarios can be identified. This theory, however, is most suitable for problems with continuous decisions and many uncertain constraints. In particular, it cannot provide informative sets of scenarios for integer problems with only objective function uncertainty. In this work we propose a more general framework of identifying such critical scenarios based on the branch-and-bound solution scheme of the static robust problem.

To build or not to build. A game theory based model for generation & transmission capacity planning.

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A fundamental challenge in power system planning is how to handle the interactions of participants' behaviors in deregulated markets. This is important due to the high cost involved in their decisions. Proactive or anticipative transmission expansion planning models have been proposed to jointly model the interactions among deregulated electricity market participants making market-driven investment decisions. It has shown that a Transmission Network Planner can increase social welfare by anticipating line expansion planning to generation expansion equilibrium and market outcomes. However, proactive transmission expansion decisions may lead to suboptimal solutions when the generation expansion equilibrium problem has multiple solutions (i.e., leading to higher total costs and lower social welfare). We propose a methodology to study the potential impacts of proactive expansion planning on generation expansion decisions. The resulting formulation is stated as a mathematical program subject to an equilibrium problem with equilibrium constraints (EPEC). To deal with this problem, we also propose an approach to derive tractable EPEC solutions with global optimality guaranteed based on a column-and-row generation algorithm. Our numerical results show that a proactive investment plan can lead to higher total cost than not investing at all because of the existence of multiple market-driven generation expansion equilibria.

Scenario tree construction driven by heuristic solutions of the optimization problem.

Vit Prochazka[1], Stein W. Wallace[1]
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Many methods for generating scenarios for stochastic programs aim to ensure a good fit (in a sense of some statistical measure) between the scenario tree and the underlying probability distribution. We offer an alternative approach where the scenario generation process is driven purely by the out-of-sample performance of a pool of non-optimal solutions, obtained by some heuristic procedure. In order to do that, we formulate a fit function that measures discrepancy between out-of-sample and in-sample (in-tree) performance of the solutions. Both the value of the objective function and feasibility of the solution are taken into account. By minimizing such a (non-linear, non-convex) fit function for a given number of scenarios, we receive an approximation of the underlying probability distribution with respect to the optimization program. This approach is especially convenient in cases where the optimization problem is solvable only for a very limited number of scenarios, but an out-of-sample evaluation of the solution is reasonably fast.

Congestion management in an integrated cross-border intraday market : XBID

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Intraday markets play an important role to allow renewable generators to adjust their schedules closer to the real-time, according to the updated forecasts. The Cross-border intraday (XBID) project is a joint initiative by the Power Exchanges and Transmission system Operators to create a joint integrated intraday cross-border market for trading across the entire Europe. This integrated market will promote effective competition and pricing, increase liquidity and enable a more efficient utilization of the generation resources across Europe. The current debate in Europe tends more towards a continuous trading approach; an extension of ELBAS intraday market which is run by NORDPOOL.
We think that the current approach for managing congestion in this new integrated market (which is based on allocating available transfer capacities (ATC) to the interfaces or the latest approach of flow-based market coupling) is not very efficient. Because, when the transmission network is simplified as zonal configuration, then the flows over interfaces are approximated and it can be very problematic in continuous trading approach because of the accumulation of approximations after each trade.
Therefore, we suggest the coordinated multilateral trades approach which fits very well to the continuous trading scheme. In this approach ,first mentioned by Wu and Varaiya (1999), all market participants are allowed to arrange bilateral trades by disregarding network constraints, then system operator will check the feasibility of trades. If they are not feasible they have to be curtailed into feasible solutions and if some lines are congested, the Power Transfer Distribution Factors (PTDF) of related lines have to be announced by system operator as a common information to all market participants. Then they can use these factors to find profitable trades.
By implementing XBID through the suggested approach, the congestion can be managed accurately before the real-time and therefore the imbalances costs will reduce dramatically.

Chebyshev Inequalities for Products of Random Variables

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We derive sharp probability bounds on both left and right tails of a product of nonnegative random variables using only information about their first two moments. We first prove that these bounds can be computed efficiently using semidefinite programming. Then, we show that all left probability bounds, in fact, reduce to the trivial bound 1 if the number of random variables in the product exceeds an explicit threshold. Thus, in the worst case, the weak-sense geometric random walk defined through the running product of the random variables is absorbed at 0 with certainty as soon as time becomes sufficiently large. Finally, our techniques for computing Chebyshev bounds for products can also be used to derive Chebyshev bounds for sums, maxima, and minima of nonnegative random variables.

Hierarchical control of microgrids using multi-time-scales stochastic dynamic optimization

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Microgrids control architecture is often decomposed into multiple levels to handle multiple time scales. Voltage and power stability have to be ensured every seconds while energy tariff arbitrage is made between different hours of the day. We focus on microgrids with energy storage that is used to mitigate renewable production and demand uncertainty. These storage devices are very expensive and their long term rentability as well as real time performances have to be optimized. Such dynamical systems in an uncertain environment can be managed using Stochastic Optimal Control (SOC) techniques.

However the interaction between multi-time scales decisions and uncertain phenomenon requires to model the optimization problem with a massive amount of time steps. It is therefore not straightforward to apply classical methods such as Stochastic Dynamic Programming (SDP) or Model Predictive Control (MPC).

We propose hereby a methodology to model optimization problems with multiple time scales as well as stochasticity and information revelation throughout time. That kind of problem and methods have been already studied in a deterministic setting. Our contribution is to highlight the difficulties that arise in a stochastic setting and some methods to tackle them. Then we present a method mixing average cost dynamic programming, SDP by blocks and MPC to solve a microgrid control problem involving long term management, intraday energy arbitrage and voltage stability.

A strategic investment model for multinational transmission expansion planning: Comparing competitive and cooperative solutions for a North Sea Offshore Grid

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A strategic investment model is developed for multinational transmission expansion planning. The countries will act in a strategic manner, which renders more realistic behaviour than system optimising models. A tri-level complementarity model is developed to represent the relationship between different power market agents. The lower level consists of a market clearing optimising short term social welfare dependent on the actions of the countries. Strategic countries are present in the intermittent level where they perform generation planning with expectations from the actions of other countries, the market clearing and corridor investments. Their goal is to maximise their own individual profit. Transmission expansion is performed at the top level by a system benevolent authority anticipating the behaviour of the countries. Such a model better represent market operation when countries have control over their own national decisions. Because the strategic behaviour prevent perfect competition, market efficiency decreases. Hence it is of interest to compare the value of full cooperation compared to strategic behaviour. The models and their results are examined on a case study of the North Sea Offshore Grid. A project being of relevance to European power market integration and implementation of renewable energy sources.

Inexact cutting plane techniques for stochastic mixed-integer programs

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We derive error bounds for a class of inexact cutting plane techniques for stochastic mixed-integer programs. These error bounds converge to zero if the total variations of the probability density functions of the random variables in the model converge to zero. Moreover, we show several numerical experiments, illustrating the actual error of using these inexact methods.

Stochastic program with decision dependent randomness for determining the optimal interest rate of a loan

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We deal with a financial application of stochastic programming, where we formulate a model describing a life-cycle of a loan. Such a program is non-linear in decision variables, which moreover affect the distribution of random elements. More precisely, offered interest rate for a loan is modelled to be the main driver of unknown client's decision to take the loan. If the deal is finalised, the company issuing the loan can decide on how to finance it. First, we present the formulation of the model and explain how different types of a loan can be taken into account in the program. Thereafter, we discuss approaches which can be adopted in solving such a non-linear, decision dependent randomness programs. Finally, we show results we have reached.

A Multi-Scale Decision Rule Approach for Multi-Market Multi-Reservoir Management

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Peak/off-peak spreads on European electricity spot markets are eroding due to the nuclear phaseout and the recent growth in photovoltaic capacity. The reduced profitability of peak/off-peak arbitrage thus forces hydropower producers to participate in the reserve markets. We propose a two-layer stochastic programming framework for the optimal operation of a multi-reservoir hydropower plant, which sells energy on both the spot and the reserve markets. The backbone of this approach is a combination of decomposition and decision rules techniques. Numerical experiments demonstrate the effectiveness of the suggested framework.

A Priori Routing for Time Slot Management in Online Grocery Retailing

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We consider an emerging strategy for offering and managing time slots for home grocery delivery: a set of routes is generated a priori and customers are assigned a time slot based on their home location and these routes. In such an environment, customers may only be offered a few time slot choices per week, but it greatly simplifies operations for the retailer (time slot management and routing). We develop a two-stage stochastic programming approach for designing a set of a priori routes and time slot assignments to be used in such an environment.

Advances on time consistency of risk measures

Ruben Schlotter

In the past years the measuring of risk in a dynamic setting became a topic of increasing importance. A fundamental aspect of dynamic risk measurement is the notion of time consistency. We look at different approaches towards constructing time consistent risk measures in a Markov setting. Recently Dentcheva and Ruszczyński obtained a HJB equation for a class of risk measures called Markov risk measures. We relate their results with the theory of g- and G-expectation initiated by Peng and with the notion of an infinitesimal risk generator.

Business models for power-to-gas: A real options approach

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Power-to-gas (P2G) is a technology that converts electrical power to gas fuels like methane, which can be stored and distributed via the natural gas grid. However, at present time the technology suffers from high specific investment costs, low efficiency and grid fees that must be paid if electricity is obtained from the power grid. We use a real options approach to assess the profitability of different operational concepts. As P2G facilities are flexible consumers, they can benefit from short-term price fluctuations on the electricity spot market. In order to estimate the value of this flexibility, we use a regress-later Monte Carlo approach to determine the optimal dispatch taking into account various operational constraints. This allows evaluating the future revenues for simulated scenarios of power and gas prices. Then the real options approach determines the project value and the optimal timing of the project start, given the uncertainties in future energy prices, exchange rates and investment costs.

Quantitative Studies in Stationary Gas Nets

Ruediger Schultz

The talk addresses mathematical models derived from Kirchhoff's Laws for gas transportation in stationary networks. Feasibility of nominations is related to parametric optimization as well as to Grobner bases methods and accompanying structures of affine varieties. The polynomial nature of Kirchhoff's Laws is the key to algorithmic options going beyond classical optimization techniques. Using a combination of re-parametrization of multivariate Gaussian integrals and feasibility testing by symbolic computation, substantial speed-ups in the calculation of feasibility probabilities by Quasi-Monte Carlo techniques can be obtained. The role of mutually non-edge-disjoint cycles in the gas net is highlighted.

Optimal hedging for Salmon Producers

Peter Schütz[1]
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We present a multistage stochastic programming model for studying the optimal hedging decisions for a risk-averse salmon producer. The objective is to maximize the weighted sum of expected revenues from selling salmon either in the spot market or in futures contracts and Conditional Value-at-Risk (CVaR) of the revenues over the planning horizon. CVaR is implemented as nested CVaR to ensure time-consistency of the optimal decisions. We present results and analyse the salmon producers' decisions for various degrees of risk aversion.

Robust Reward-Risk Ratio Portfolio Optimization

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The classical portfolio optimization models typically assume the input data to be known
with certainty and completely ignore the uncertainty in any parameter involved in the model. Uncertainty in portfolio selection can be encountered in returns as well as in the underlying probability distribution of returns. The robust optimization (RO) techniques attempt to construct optimal portfolios immune to the parametric uncertainty.

In this paper, we propose the robust portfolio optimization models for reward-risk ratios utilizing omega, semi-mean absolute deviation, and weighted STARR ratios. The primary reason for selecting these ratios in this study is that their conventional optimization models are computationally tractable linear programs. In this paper, we address the uncertainty in returns of assets by taking them varying in symmetric uncertain intervals. The introduced robust reward-risk ratios preserve linearity in the resulting models. However, the robust models involve sizably voluminous number of constraints especially when the number of constituent assets and scenarios are immensely large. We employ the cutting plane algorithm to efficiently solve the proposed models in a much reduced time.

The performance of the robust reward-risk ratio models are evaluated on the listed stocks of some global markets. The robust portfolio optimization models are found to outperform their counterpart conventional models in terms of risk measured by the standard deviation worst return, value at risk (VaR), and conditional value at risk (CVaR) of the portfolios.

Economic and Environmental Consequences of Market Power in the South-East Europe Regional Electricity Market

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We are interested in the economic and environmental effects of market power on electricity and permit markets in regional electricity markets where participants are not all subject to the same carbon-reduction policies. An example is the South-East Europe Regional Electricity Market (SEE-REM), which comprises both EU members subject to the emissions cap of the EU Emissions Trading System (ETS) and non-EU members exempt from such a cap. In a perfectly competitive setting, Višković et al. (2017) demonstrate that between 6% and 40% of the carbon emission reduction in the ETS portion of SEE-REM may be leaked into the non-ETS portion as non-ETS producers with a relatively dirty generation portfolio receive the price signal to increase their exports. In this paper, we examine how a dominant firm, i.e., Enel with ca. 20% of the SEE-REM market share, can (i) gain an economic advantage and (ii) affect carbon leakage by manipulating both the electricity and permit prices. We have (i) a baseline perfect competition equilibrium model and (ii) a bi-level model in which the dominant firm manipulates both the electricity and permit prices. The former is a mixed-complementarity problem (MCP-PC), which we solve as a quadratic program. By contrast, the latter cannot generally be solved directly and requires reformulation first as a mathematical program with equilibrium constraints (MPEC-PC) in which the lower-level equilibrium problems are replaced by the followers' first-order Karush-Kuhn-Tucker conditions. Next, the MPEC-PC is rendered as a mixed-integer quadratic programming problem using strong duality and disjunctive constraints to remove the MPEC-PC's non-convexities. A 10% emissions reduction in the ETS portion of SEE-REM reduces consumer surplus, increases producer surplus, and leads to carbon leakage. However, the extent of the carbon leakage is actually lower than in MCP-PC due to the absence of lignite from the dominant firm's generation portfolio.

A Second-order cone programming formulation for two player zero-sum games with chance constraints

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We consider a two player finite strategic zero-sum game where each player has stochastic linear constraints. We formulate the stochastic constraints of each player as chance constraints. We show the existence of a saddle point equilibrium in mixed strategies if the row vectors of the random matrices defining the stochastic constraints are elliptically symmetric distributed random vectors. We further show that a saddle point equilibrium can be obtained from the optimal solutions of a primal-dual pair of second-order cone programs.

Multi-stage emissions management of a steel company

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We present a multi-stage stochastic model for determining the optimal production and emission covering of a real-life steel company participating in the European emissions trading system. The mean-multiperiod CVaR criterion is used to deal with risk caused by two stochastic parameters – market demand and emission allowance prices. The company can reduce the risk by using futures on emission allowances and/or by transfering the allowances between time periods (banking).
The model is solved for a continuum of risk-aversion coefficients and several levels of allowance prices. Subsequently, a stress testing of demand is performed using a contamination technique.
It is found that the production is little influenced either by the current level of emission price or by the risk-aversion degree. Futures and banking are always used to reduce risk.

Pricing Perpetual Options with Stochastic Stopping Opportunities

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We present a new numerical method for pricing perpetual options (options with no specified maturity date) where the opportunities to exercise the options are stochastic. In particular, we assume the decision maker is permitted to exercise the option only at the arrival times of an exogenous Poisson process. The proposed method can be used either to determine option values in settings where decision times are indeed uncertain, or it may be used as an approximation for American style options, which may be exercised at any time and which are recovered in the limiting case where the intensity of the Poisson process goes to infinity. For real (as opposed to financial) options, the former may be of particular relevance. In the setting of stochastic exercise dates, we show the option value can be obtained by an increasing sequence of lower bounds. To investigate the quality of our proposed numerical procedure, we compare our numerical solution for the two-dimensional exchange option under random exercise opportunities against a new analytic solution. Having demonstrated the viability of the proposed method, we illustrate some of the general applicability by applying the method to a more complex real options case with compound options. The methodology is straightforward to extend to other cases with multiple sources of uncertainty and complex compound options settings.

Offshore Grid connection optimisation with uncertain parameters

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A lot of wind farms and clusters of wind farms in will be built in the North Sea. As distances from shore are becoming very large, the relative cost of the transmission system becomes more important. To obtain the lowest possible cost of energy, it is key to design the offshore transmission grid in an economic way, that takes into account the variable nature of production and demand, cost of other generators, and the possibility of sharing infrastructure.

This presentation will contain recent work with methods and results related to the problem of offshore grid planning, more specifically the optimal grid connection of offshore wind farm clusters. The optimisation is a mixed-integer linear problem with uncertain parameters related to e.g. the realised capacities of future wind farm capacity extensions.

Variability in power demand/prices and wind power availability is represented by time-series, and the optimisation is done for a sample of operating conditions. The objective is to minimise the socio-economic cost, i.e. the sum of generation cost and investment costs. Results will demonstrate the benefit of including uncertain parameters in the optimsation of the offshore grid for wind farm clusters. Detailed results from a realistic case study will be provided, both the underlying assumptions and the optimal solution. Sensitivity of the results to key parameters, such as infrastructure cost will be assessed and presented.

Extracting 'Greeks' from Multistage Linear Stochastic Optimization: Computing parameter sensitivities in Stochastic Dual Dynamic Programming

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We propose a method to calculate the sensitivities of the optimal value of a multistage stochastic optimization problem with respect to changes in the model parameters using Stochastic Dual Dynamic Programming.
As a first step, we set up a discrete-time replication problem for a standard European option and study the sensitivity of the minimal initial amount of required capital with respect to the value of the underlying. Since this problem approximates the classical continuous time setting for option pricing, we use it as a testbed, comparing our results with the analytical solutions that are available for this problem.
We proceed by showing that parameter sensitivities may be calculated by the algorithm, for more complicated contracts for which there exist no closed form solutions.

Modelling Long-term And Short-term Uncertainty In Power Market Investments

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The EMPIRE model is a European multiscale power market model with investments towards 2050 as well as representative hours. It is well suited to capture operational uncertainty in generation from intermittent energy sources like wind and sun.
In this paper we add long-term uncertainty to the formulation. This makes it possible to also study uncertain learning curves, policy uncertainty, long-term commodity process and demand trends. The resulting models are large scale stochastic multi-stage recourse models with hundred of millions of variables. We present both solution methods and analysis of the most important factors.

Meeting Corporate Renewable Power Targets

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Large companies have recently started to incorporate renewable energy standards in their corporate sustainability goals. In particular, several companies have announced commitments to procure a specific percentage of their electricity demand from renewable sources, that is, reach a renewable power target by a future date. Dominant procurement strategies used by corporations include (i) buying power from the spot market and supplementing it with renewable energy certificates (RECs) and (ii) entering bilateral contracts known as power purchase agreements (PPAs) to buy power directly from a renewable generator for a predefined number of years. Constructing a multi-period procurement portfolio containing these buying options is complex due to stochastic power demand as well as volatile power and RECs prices. In this work, we investigate how to set up a power sourcing policy to reach a renewable target and sustain this target at minimum expected cost. We provide analytical insights on stylized models containing a few periods. We also formulate a multi-period Markov decision process (MDP) that incorporates a PPA pricing model consistent with practice. This MDP has high-dimensional endogenous and exogenous components in its state and is thus intractable. We overcome this intractability by developing a heuristic policy based on a new dual reoptimization scheme that relies on information relaxations. We find that our dual reoptimization approach outperforms commonly used primal reoptimization methods and simple heuristics on realistic instances.

Efficient forecasting of electricity spot prices with expert and Lasso models.

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Recent electricity price forecasting studies indicate that using the LASSO operator may lead to better performing forecasting models. Conducting an empirical study involving three expert models, two baseline models and four variance stabilizing transformations, this paper presents the optimal way of implementing the LASSO operator and shows that using a more complex baseline model and well chosen transformations (asinh or NPIT) indeed leads to a significant improvement in accuracy of the price forecasts.

Not Necessary to Over focus on Financial Performance in Strong Sustainability Investing: Evidence from a GABV Bank Case Study

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A GABV bank is one from the Global Alliance for Banking on Values, an international network of 46 banks unique in their total commitment to sustainability in investing. In contrast to the usual model in which financial performance is objective one and sustainability is objective two, in a GABV bank, sustainable impact is objective one with only sufficient financial performance being objective two. By sustainable impact we mean focusing on companies that create positive change rather than only being satisfied with those that merely create no harm. Through a thorough analysis of a member of this alliance for which we have unique firm-level data, it is found that by focusing on portfolios of high sustainable impact, sufficient financial performance will tend to take care of itself on its own.

Robust optimization by constructing near-optimal portfolios

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Many investors use optimization to determine their optimal investment portfolio. Unfortunately, optimal portfolios are sensitive to changing input parameters, i.e., they are not robust. Traditional robust optimization approaches aim for an optimal and robust portfolio which, ideally, is the final investment decision. In practice, however, portfolio optimization supports but seldomly replaces the investment decision process. In this paper, we present an approach that both solves the robustness problem and aims to support rather than replace the investment decision process. The method determines a region with near-optimal portfolios which, especially in light of the robustness problem, are all good allocation decisions. Then, as is already common practice, an investor can bring in expert opinion or additional information to select a preferred near-optimal portfolio. We will show that the region of near-optimal portfolios is significantly more robust than the optimal portfolio itself.

Photovoltaic Smart Grids in the prosumers investment decisions: a real option model.

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The last decades have been characterized by the development of the renewable energy sources. The search for a sustainable development of production has in fact led to the search for an alternative energy to the conventional one. In this context there has been an increase in the number of distributed generation power plants both in Italy and in many EU countries. The new alternative sources have the considerable advantage of having a lower environmental impact but are often characterized by a discontinuous production. This has involved some problems related to the management of the electricity grid (for example inefficiency, congestion rents, power outages, etc.) which can often be solved by the implementation of a "smarter" electricity grid. Smart grids have the significant advantage of increasing the flexibility of production and consumption. Smart grids give producers and consumers the opportunity to be active in the market and to strategically decide their optimal production / consumption scheme. Our paper provides a theoretical framework for modeling the decision of two agents to invest in two photovoltaic plants, assuming they are integrated into an intelligent network. To capture the value of managerial flexibility, a real option approach is implemented. Each agent can at the same time produce, consume and exchange both with the public grid and with the other agent (for this reason they are called "prosumers"). The purpose of the paper is to verify if the energy exchange between agents is convenient. Secondly, we will try to calculate the optimal size of the plant in order to maximize the benefit of each agent. Finally, the model will be calibrated and tested using energy market data.

Optimization models for the participation of active power distribution networks to the ancillary services

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The share of renewable generation produced by distributed renewable energy sources (DRES) connected to distribution networks is going to increase in a near future. Power system stability will be affected by the non-programmable nature of many renewable resources, as well as by the decrease of the share of conventional generation. Ancillary services to the power transmission network are currently provided by conventional generators. DRES and loads will also be allowed to participate to power system operation (see Regolamento per l'approvvigionamento del servizio di regolazione di tensione, TERNA, 21/11/2017). However, voltage and current congestions could limit the power exchange of distributed resources, as MV networks are designed neither for high penetration of distributed generators nor for participation to the management of the transmission network. The complex behaviour of distribution networks makes it difficult to determine the capabilities of the resources (i.e. the active and reactive limits of the power exchange). Distribution System Operators (DSOs) need advanced control schemes in order to foster the participation of distributed resources to the transmission network management. Ancillary services are usually purchased in real time by the Transmission System Operator on different markets, where each resource offers a power variation, with respect to its scheduled commitment, at a certain marginal cost. With an increasing share of small decentralized generations the structures of these markets are expected to change, in order to facilitate the integration of more resources. The role of DSOs within these architectures has to be carefully designed: in this work we show how DSOs can foster the participation of DRES to the ancillary services market by a technical aggregation of the available resources in the distribution network, which is made possible by the use of innovative methodology and by an efficient OPF algorithm.

Multistage multivariate nested distance: an empirical analysis

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Multistage stochastic optimization requires the definition and the generation of a discrete stochastic tree that represents the evolution of the uncertain parameters through the time and the space. The dimension of the tree is the results of a trade-off between adaptability to the original probability distribution and computational tractability. Moreover, the discrete approximation of a continuous random variable is not unique. The concept of best discrete approximation has been widely explored and many enhancements have been proposed to adjust and fix a stochastic tree in order to represent as well as possible the real distribution. Still, an optimal definition is practically not achievable. Therefore, the recent literature investigates the concept of distance between trees which are candidate to be adopted as stochastic framework for the multistage model optimization. The contribution of this paper is to compute the nested distance between a large set of multistage and multivariate trees and, for a sample of basics financial problem, to empirically show the positive relation between the tree distance and the distance between the corresponding optimal solutions and the optimal objective values. Moreover, we prove that the Lipschitz constant that bounds the optimal value distance is relatively weak.

Long-term asset allocation under time-varying investment opportunities: Optimal portfolios with parameter and model uncertainty

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We study the implications of predictability on the optimal asset allocation of ambiguity averse long-term investors. We analyze the term structure of the multivariate risk-return trade-off in a VAR model under full consideration of parameter uncertainty, and we decompose the predictive covariance along different sources of risk/uncertainty. We calibrate the model to real returns of US stocks, US long-term government bonds, cash, real-estate and gold using the term spread and the dividend-price ratio as additional predictive variables. While over short periods the model-implied conditional covariance structure of asset-class returns determines the optimal allocation, we find that over longer horizons the optimal asset allocation is significantly influenced by the covariance structure induced by estimation errors. As a consequence, the ambiguity averse long-term investor tilts her portfolio not simply toward the global minimum-variance portfolio but shrinks portfolio weights toward a seemingly inefficient portfolio which shows maximum robustness against estimation errors. Most interestingly, we find that even though time diversification of stock returns vanishes after consideration of estimation errors, real long-term bond returns are even more affected, making stocks an important asset class for the ambiguity averse long-term investor.

Forecasting Price Distributions in the German Electricity Market

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Electricity price distributional forecasts are important input to energy risk management. In this chapter we compare a set of models w.r.t. predicting the price distribution in the German electricity spot market (the EPEX market) using various supply and demand variables. We apply static and dynamic quantile regression models and benchmark the forecasts with different GARCH and CAViAR type models. Since the aim is predicting, we select the subset of possible variables for each quantile and trading period such that the performance is maximized. Our findings highlight the importance of variable selection, and show that it in many cases it is just as important as the choice of the model itself. The empirical study indicates that exponential weigthed quantile regression is the best model overall. It give consistently good forecasts across trading periods and quantiles, and performs particularly well in the outer tail quantiles. Hence, we this model capture the changing input mix of electricity production in Germany market. The CAViaR models are the best performing benchmarks, but their performance is not consistent over all quantiles and trading periods. The GARCH model captures clustering of exceedances the best, but it's performance is rather poor generally speaking. Based on these results we recommend exponential weighted quantile regression as a solid model for energy risk management in the German el-market. In addition, it is a model that is transparent, easy to implement and to communicate.

Robust Dual Dynamic Programming

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Multi-stage robust optimization problems, where the decision maker can dynamically react to consecutively observed realizations of the uncertain problem parameters, pose formidable theoretical and computational challenges. As a result, the existing solution approaches for this problem class typically determine suboptimal solutions under restrictive assumptions. In this talk, we propose a robust dual dynamic programming (RDDP) scheme for multi-stage robust optimization problems. The RDDP scheme takes advantage of the decomposable nature of these problems by bounding the costs arising in the future stages through lower and upper cost to-go functions. For problems with uncertain technology matrices and/or constraint right-hand sides, our RDDP scheme determines an optimal solution in finite time. If also the objective function and/or the recourse matrices are uncertain, our method converges asymptotically (but deterministically) to an optimal solution. Our RDDP scheme does not require a relatively complete recourse, and it offers deterministic upper and lower bounds throughout the execution of the algorithm. We demonstrate the promising performance of our algorithm in stylized instances of inventory management and energy planning problems.

Socially Responsible Index Tracking

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We introduce a new methodology for modeling optimal institutional portfolios, and using this methodology, we report on results that combine the benefits of passive investing with the needs of socially responsible (SR) investors. Our methodology is based on the hypothesis that in SR investing, social responsibility is a third criterion, and this causes the classical bi-criterion efficient frontier to become a tri-criterion efficient surface. Using this surface, in an empirical study, we estimate the costs resulting from adding a social responsibility threshold to a passive index investment. Our preliminary findings are that by our implementation, the costs are marginal. One of the features of this paper is that we are able to show graphically exactly the theory that we are following and the empirics that we are carrying out.

Stochastic-dynamic optimization of a joint Strategy for day-ahead bidding and Intraday Trading

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Power market participants with flexible capacity, such as pumped-hydro storages, face a complex decision problem when trading on spot markets for electricity. As electricity for the same delivery periods, say a specific hour of a day, trades in multiple markets, bidding decisions must be made jointly, while at the same time open positions can be rebalanced as time moves on. Moreover, as the number of delivery periods is high, participants make multiple decisions simultaneously under uncertainty about electricity prices and future opportunities. We consider the case of a hydro storage operating on the German spot market for electricity and propose a model for the day-ahead intraday trading problem as a Markov decision process, where all open market positions, storage content, as well as the dynamic factors that drive day-ahead and intraday prices are represented as state variables. The state space of the proposed MDP is continuous and high dimensional, so that the resulting optimization problem is computationally intractable and an optimal solution can only be found by approximation. To obtain a quality approximation of the optimal solution, we resort to approximate dual dynamic programming (ADDP). Based on a case study of a fast pumped-hydro storage unit, we demonstrate that ADDP can provide near-optimal solutions for model instances with hourly time resolution and a time horizon of one week. Our results indicate that a joint strategy of day-ahead bidding and intraday trading leads to allocation of flexible capacity to the intraday market and that bidding decisions are non-trivial.

Robust Reformulations of Ambiguous Chance Constraints with Discrete Probability Distributions

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This paper proposes robust reformulations of ambiguous chance constraints when the underlying family of distributions is discrete and supported in a box or an ellipsoidal uncertainty set. Using the robust optimization paradigm, the deterministic counterparts of the (ambiguous) chance constraints are reformulated as mixed-integer programming problems which can be tackled by commercial solvers for moderately sized instances. The associated approach can be easily extended to joint chance constraints and dependent data without introducing additional mathematical optimization complexity.

Epsilon-Net Technique for a Class of Robust Optimization and its Applications in Wireless Communication

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We consider optimization problems subject to multiple robust quadratic constraints, where matrices defining the constraints are rank-one outer products of some unknown vectors. Problems of this form are NP-hard and often arise in the field of wireless communication. A standard approach is to apply the semidefinite relaxation and S-lemma. A feasible solution is then obtained by the Gaussian rounding. We establish theoretical guarantees for this approach by proving a novel probabilistic bound on the approximation accuracy of the rounded solution. Our proof is based on the epsilon-net argument, a technique from geometric functional analysis. We demonstrate the usefulness of our result by applying it to a robust beamforming problem.

A Battery per House or a Big One for All? The Value of Cooperation between Prosumers in Microgrids

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The integration of end-users also as producers of electricity – prosumers – poses an alternative to the classical electricity market structure. It remains unclear in the existing literature what the value of cooperation among prosumers is. Designing local market places will discuss the question: What if prosumers can trade with their neighbour first, before they procure electricity from the grid? This paper assesses the value of cooperation between prosumers to determine: Should batteries be deployed at either house or community level? And, how could prosumers interact in a microgrid setting to achieve high levels of self-sufficiency?

To answer these questions, we apply a linear programming model to test the value of centralised or decentralised storage subject to trade between prosumers to minimise overall costs. The community aims at achieving high levels of independence from the electricity grid. We use a data set of real houses in the United Kingdom. Results give insights into the value of cooperation and the associated optimal placement of storage entities. Enabling trading activities in a community has in either case positive influence on the overall costs. In a set-up with decentralised storage, the cooperation gains importance due to higher trading volumes. Especially the interplay of prosumers with renewable generation technologies and those with sole storage possibilities makes interconnection worthwhile. For a set-up with centralized storage, the beneficial influence on costs of direct trade in a community is, however, insignificant. The centralised battery is used as a trading platform, making the additional value of cooperation in the community almost negligible. Nonetheless, a set-up with a centralised storage entails highest savings, due to higher arbitrage possibilities and better utilization of renewables.

Conformal Prediction Interval Estimations in Day-Ahead and Intraday Power Markets

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We introduce the merely unknown concept of conformal prediction to the world of energy price forecasting and compare its performance to other state-of-the-art models. The versatility and additive application next to existing forecast models render this model to be a decent extension to the numerous approaches already available. We demonstrate its convincing performance in the Nordpool day-ahead as well as the German intraday market. Our findings suggest that conformal prediction reveals better performance than quantile regression averaging.