E *H* zürich

Energy Science Center

Annual Report 2020

Bridging research, education and outreach across departments and research fields to answer the energy challenges of today and tomorrow.





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DEAR COLLEAGUES, PARTNERS, AND FRIENDS OF THE ENERGY SCIENCE CENTER,

For all members of the academic community, including the ESC, 2020 was a special year. The necessity of remote working whilst still trying to push the frontiers of energy research forward brought challenges: most were managed effectively with back-to-back Zoom meetings, although we certainly all missed the informal face-to-face exchanges at the offices of the Energy Science Center.

Nevertheless, a very successful year was had, with one notable success being at the very core of the ESC: bringing together a large consortium of interdisciplinary faculty and industry to prepare a proposal for the new research programme from the Swiss Federal Office of Energy (SFOE) entitled "Swiss Energy Research for the Energy Transition" (SWEET).

Also, our teams involved in our two flagship projects "Renewable Management and Real-time Control Platform" (ReMaP) and Nexus-e, our integrated energy system modelling platform, have been busy expanding these platforms and preparing them for widespread use in academia, government/federal offices, and industry.

Now we look forward to 2021, together for a sustainable energy system!

Doulikako

Ch. Cluffre

Dimos Poulikakos Chair

Christian Schaffner Executive Director

The Energy Science Center (ESC)

To tackle the central challenges facing the energy specialists and disciplines even further by facilitatsystem (i.e. climate change, access to energy ser- ing inter-disciplinary and inter-departmental energy vices, local pollutants and risks and benefits to so- research, teaching and outreach activities. Thereciety), additional knowledge and new technologies fore, the ESC has strengthened its role as national are needed, relying on the expertise and cross-cut- and increasingly international player in the energy ting research of engineering, economic and social sector. scientists.

partments. In 2020, the ESC continued to integrate

The Energy Science Center (ESC) of ETH Zurich was The Research Center for Energy Networks founded in 2005 as an interdepartmental competence center to facilitate energy research and teaching activities across research fields and de-

www.esc.ethz.ch \rightarrow

(Forschungsstelle Energienetze - FEN) is affiliated with the ESC.

www.fen.ethz.ch \rightarrow

Organisational Structure

The General Assembly, containing the ESC members, is the ESC governing body. Currently 62 professors from ten different departments are members of the ESC.

The Managing Board is the executive body of the ESC and is composed of seven members elected by the General Assembly. The managing board elects one of its members as chair.

The Executive Office is run by the Executive Director, who reports to the chair of the managing board.

The Advisory Board comprises representatives from industry and commerce and advises the ESC on its activities.

News The FSC welcomed two new members in 2020:



Prof. Dr. André Bardow

Energy and Process Systems Engineering Department of Mechanical and Process Engineering (D-MAVT)

André Bardow has been full professor for Energy and Process Systems Engineering at ETH Zurich since 2020. He is also the director of the Institute for Energy and Climate Research (IEK-10) at Forschungszentrum Jülich, Germany. His research areas include energy systems optimization, conceptual process design, life cycle assessment, computeraided molecular design, thermodynamics, microfluidics and CO₂ capture & utilization.



Prof. Dr. Bjarne Steffen

Climate Finance and Policy Department of Humanities, Social and Political Sciences (D-GESS)

Bjarne Steffen is Assistant Professor of Climate Finance and Policy and the head of CFP. In his research, which is published in high impact journals, he analyzes policies related to the low-carbon transition in the energy and financial sectors. To this end, he works at the intersection of energy economics, financial economics, and innovation studies. His research covers both developed and developing countries.

Mission

The Energy Science Center (ESC) aims to facilitate the deployment of an environmentally friendly. reliable, low risk, economically viable and socially compatible sustainable energy system.

The ESC enhances cooperation between ETH Zurich, industry, government, and society on energy related issues, offering a platform for nourishing the exchange of information between the engineering sciences and the social sciences as well as for directing joint projects.

The ESC synergistically combines key expertise in various energy disciplines to address large-scale problems successfully and to form flagship projects.

Partnership Council

The Partnership Council is formed of foundations and industry partners who make substantial donations to the programme of the Center through the ETH Foundation, and who are interested in playing an active role in building joint initiatives.

The Center's Partnership Council meets biannually with the ESC Managing Board and Executive Director.

ESC highlights in 2020



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Highlights

Research Approach

The ESC research activities focus on large, in all areas of action (efficiency, grids, storage, cross-cutting themes run as inter-departmental provision, economy, geothermal and more); and inter-disciplinary projects. In 2020, two flagship supporting the professors and institutes active in programmes that started as strategic initiatives, these fields by leveraging its network inside ETH have been further developed to build the basis for Zurich with other universities and industry; services to the ETH research community and beyond: "Renewable Management and Real-Time gathering opinions and open questions within the Control Platform (ReMaP)" and "Integrated Energy energy sector internally and externally, synthesising Systems Modelling Platform (Nexus-e)". and disseminating them amongst researchers of ETH Zurich;

Furthermore, the ESC identifies relevant topics in the area of energy research. This also includes participation in National Research Programs (NRP) and European Research projects (Horizon 2020).

Generally, the ESC research activities consist of:

Taking a proactive role in the energy research activities of ETH Zurich and supporting its strategic goals

Research Focus

Clean, affordable and reliably available energy is of paramount importance to the well-being of modern societies. Developing future environmentally friendly energy systems requires research in a large number of scientific disciplines. Most of these are cultivated at ETH Zurich, which has a bright tradition in energy-related research.

Research



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promoting flagship programmes in the area of energy research.

www.esc.ethz.ch/research.html

Research

Research Projects

Integrated Energy Systems Modelling Platform (Nexus-e)

With Nexus-e, an Energy Systems Modelling Platform, we develop and maintain a modeling infrastructure that cuts across the boundaries of established fields of knowledge by combining existing and new tools from various disciplines. With expertise in electrical engineering, political sciences, economics, risk engineering, and management, ETH Zurich is in the unique position to develop such a comprehensive platform. Leveraging this expertise, Nexus-e enables studying the impact of technical, socio-economic, and regulatory developments on the future electricity system.

In 2020, we completed both the development of the platform's five core modules and the pilot project "The role of flexibility providers in 2050". The core modules represent the overall Swiss economic structure and the electricity market, investment in decentralized and centralized energy sources, network security, and grid expansion. The modular approach makes it possible to map the energy system and the interaction of its components much more extensively than conventional, isolated simulations of sub-systems. For the pilot project, we ran three scenarios for the transition of the Swiss power system by 2050. Our simulations suggest that phasing out nuclear energy could be achieved with considerable investment in new photovoltaic systems



and that Switzerland is in a good position to balance out the daily and seasonal fluctuations in power with its available hydropower. On our homepage (www. nexus-e.org), we provide the final reports of the pilot project and an interactive webviewer for additional visualization and data.

For the coming years, we envision Nexus-e to serve as a modeling infrastructure that is used in education and simplifies interdisciplinary research within the university. Nexus-e is already being used as a basis for several ETH projects. One example is the CH2040 research project, in which the Nexus-e team and Anthony Patt's Climate Policy Group are investigating to what extent a decarbonization of Switzerland by 2040 is technically and financially feasible.









The main objective of the ReMaP project is to pro- elements at EMPA, PSI and ETH could be demonvide a platform that allows the interaction of diverse strated during a public event in December 2020. A energy conversion and storage technologies to be total number of nine experiments - using various tested and demonstrated in a realistic environment. shares of modelling tools and real hardware - are This platform builds on and extends the NEST/ being conducted by researchers at the three move/ehub demonstrators at Empa and the Energy institutions. System Integration (ESI) platform at PSI. Additional further demonstrators. A long-term goal of the ReMaP project - especially in a possible second project phase (July 2021+) - is therefore to convince demonstrators developed in other projects (e.g.,

objectives of the ReMaP project are the use of the The platform is designed to allow the integration of platform in (a) educating students in decentralized renewable energy systems and (b) informing decisionmakers and the public about the importance and the development of such systems. Quartierstrom) and making both the hardware at Using a cloud-based infrastructure, the platform the various locations as well as the simulation and allows researchers to carry out experiments with archiving capabilities accessible to a broad research hardware at NEST/move/ehub and ESI and as well community. ReMaP will also play a pivotal role in as simulations of the hardware. In addition, the the recently acquired SWEET project PATHFNDR platform permits the exchange of information be-(PATHways to an Efficient Future Energy System through Flexibility aND SectoR Coupling) that will tween the experiments and simulations and therealso be managed by the ESC. fore enables hardware-in-the-loop simulations. Data from the experiments and simulations are stored in a dedicated archive, permitting its later **Project partners** use in simulations as well as model formulation and • Empa PSI validation.

The software and hardware architecture is now • fully operational, the interaction of the modelling • and control framework involving hardware •



- Adaptricity
- Smart Grid Solutions
- Supercomputing Systems
- National Instruments

Master Energy Science and Technology (MEST)

The ESC coordinates the interdisciplinary Master's can be selected from any energy-related course programme Master Energy Science and Technology within the ETH Course catalogue. (MEST) at ETH Zurich, a world-class Master's programme for energy engineers, aimed at students A unique aspect of the MEST programme is an inwith an engineering or a technological science novative course that provides the students with the background. MEST continues to offer a specialised experience of working on real-world problems programme of a unique type, enabling study across currently faced by companies within the energy a wide range of energy-related courses offered by sector, thereby linking industry and academia. ETH Zurich and providing students with the aca-These problems cover some of the technical, ecodemic skills required by the energy marketplace. nomic and regulatory aspects of the challenges of building a sustainable energy system for the future. The joint programme between D-ITET and D-MAVT The students work together in teams, and present has been running since 2007 and is a well sought-aftheir final work to the whole class and industry ter interdisciplinary Master's programme at ETH partners.

The joint programme between D-ITET and D-MAVT has been running since 2007 and is a well sought-after interdisciplinary Master's programme at ETH Zurich. A further nine departments actively contribute to the MEST through tutors and their offer of nearly 50 energy-related core courses.

The fundamental aspects of Energy Science and Technology are covered by a range of compulsory courses in the three academic areas of electrical power engineering, energy flows and processes, and energy economics and policy; elective courses



2020 MEST students by home country

Master Integrated Building Systems (MBS)

The ESC supports the interdisciplinary Master's degree programme in Integrated Building Systems (MBS) at ETH Zurich. The chair of the board and the executive director of the ESC are members of the admission committee and were on the advisory committee during the initial planning phase of the Master programme.

This programme provides a science-based education in building systems and technologies with a strong emphasis on the energy performance and the environmental impact of buildings. The emphasis is on the integration of sustainable energy technologies at both the building and the urban level.

Education



Frontiers seminar held online due to Covid-19 restrictions (Photo: ESC / ETH Zurich)

Due to Covid-19 restrictions, all lectures and events were speedily and successfully transferred online in Spring 2020. The number of new entrants in Autumn 2020 accepting their offered place on the MEST programme was lower than in previous years, although a handful opted to defer entry until Autumn 2021.



www.master-energy.ethz.ch

Number of MEST students

Education

CAS Applied Technology in Energy (CAS ATE)

ETH Zurich's continuing education programme CAS Applied Technology in Energy (CAS ATE) is part of the Master of Advanced Studies in Applied Technology (MAS AT), together with other CAS courses. The CAS ATE is designed to provide managers with a deeper education in the rapidly evolving world of energy and electrification. It's a so-called "Reverse MBA". It will help participants to better understand the ongoing "Energy Revolution" and enable them to shape the energy future of their company and industry. The start of the first class has been postponed to 2021 due to the Covid-19 pandemic.

The MAS AT is a continuing education programme offered by D-ITET in cooperation with multiple departments and research centres at ETH Zurich. Within the MAS AT, ESC executive director Dr. Christian Schaffner is programme co-director of the CAS ATE. Furthermore, the ESC and its staff contribute directly to two modules within the CAS ATE, one of which is an online module to transfer the basics of energy engineering and systems.

mas-at.ethz.ch/cas-programs/cas3a.html

Frontiers in Energy Research

Frontiers in Energy Research is a series of lectures which disseminates knowledge of ETH Zurich energy-related research activities throughout the research community. Each lecture is given by a different PhD student who is at an advanced stage of their research, and attended by any PhD student interested in this area. The seminars have been held annually since 2012, 14 lectures each Spring semester. At the end of the semester, a 'Best Frontiers Presenter' award is given based on the audience feedback. In Spring 2020, the 35 attendees and presenters came from 7 different ETH departments, plus PSI & EMPA: the lectures were successfully transferred from lecture hall to online, with no loss of impact on the presentations or attendees.

esc.ethz.ch/events/frontiers-in-energy-research.html

Alumni Support and Career Development

Alongside the MEST academic studies, the ESC plays a role in developing networks amongst MEST students, past and present, for career support and development with regular social events. Of particular note this year was a Zoom event in May 2020 with two Alumni describing how their experience of the MEST programme led to their successful careers in the energy industry. With the support of the ESC, an official MEST Alumni organisation commenced in June 2020, set up and run by Alumni.

Outreach

ETHZU

Energy Day @ ETH

Fokus Dialoge

Symposium

Photo: ETH Zürich/ Alessandro Della Bella

ESC Events

Energy Week @ ETH 2020

November 24-26, 2020

During the three-day online conference, faculty from ETH and other academic institutions, representatives from Swiss and international industry, and members of the Swiss Federal Office of Energy (SFOE) as well as the participants discussed past and future evolutions and revolutions of the energy systems.

On the first two days, the participants of the Energy Week had the opportunity to hear from experts and discuss current research and trends with them. The so-called "Focus Dialogues" took place six times, every dialogue covering a different key area of the wider energy topic: "Storage Revolution", "Szenarien vs. Prognosen vs. Realitäten", "Revolution dank Dezentralisierung und Digitalisierung", "Wirtschaft, Politik, Gesellschaft und Energie-Revolutionen", "Solar Revolution" and "Mobility Revolution".

On the third day, a symposium took place and it covered three key topics: "Energy and Politics in Switzerland", "Heavy Mobility" and "Technologies for the energy (r)evolution". The speakers ranged from a very diverse field, coming from different ETH Zurich research groups, Swiss administration (SFOE) and international industry. The participants got to know the scientific perspective and they also had the opportunity esc.ethz.ch/events.html to engage in an online discussion with the experts.



Photo: ESC / ETH Zurich



ReMaP Update and Outlook

December 17, 2020

The Renewable Management and Real-Time Control Platform (ReMaP) project was launched at the end of 2018 and presented to the public in June 2019 in order to gain a better understanding of the interaction between distribution network, buildings and mobility on the one hand and various technologies for the production, conversion and storage of energy on the other. The platform connects and expands the existing demonstrators ehub, NEST and move at Empa and the Energy System Integration Platform at the Paul Scherrer Institute and will make them accessible to universities, colleges and industry. With this event, an overview of the current status of the project, first results and next steps were presented to a selected audience with representatives from academia and industry. https://remap.ch/news/

Photo: ESC / ETH Zurich

ESC Collaborations

Energy Data Hackdays August 28-29, 2020

The ESC supported the C2SM (Center for Climate During the Energy Data Hackdays in Brugg, the ESC Systems Modeling) in the organization and successchallenged an interdisciplinary team into rethinking ful realization of Klimarunde 2020, which took place ways of visualising existing energy data. In a rapid digitally for the first time. In light of the Covid19 and creative process and under the guidance of ESC pandemic, climate and energy researchers disteam members, a team of four successfully tackled cussed possible lessons learned and ways forward the posed challenge and presented a well-functionfor the climate crisis. One leading question throughing prototype after only 30 hours. out the event was: How does the Covid19 crisis affect our approach to climate change?



Photo: ESC / ETH Zürich



Photo: ESC / ETH Zürich

Fachtagung Elektromobilität October 27, 2020

The conference on E-Mobility was organised in CO2 capture and permanent storage collaboration with the Verband Schweizerischer January 23, 2020 Elektrizitätsunternehmen (VSE). Experts from aca-Kjetil Wilhelmsen, Northern Lights CCS demia and industry and the participants discussed opportunities and challenges regarding the integra-Co-organised by sus.lab and the Chair for Sustaintion of e-mobility in existing and future electricity ability and Technology, the Separation Processes grids. Laboratory and the Energy Science Center.

Klimarunde 2020 October 27, 2020



Energy Startup Day 2020 December 1, 2020

The Energy Startup Day is a yearly event connecting Swiss start-ups to incumbent companies, public institutions and new actors to foster relationships and collaborations in the sectors of energy, cleantech, mobility and smart buildings. The ESC is institutional partner, the event is organised by ZHAW School of Management and Law, Institute of Innovation and Entrepreneurship.

ESC Seminar

Northern Lights project for full-scale

Annex

62 active Members (as of December 31, 2020)

D-ARCH

Prof. Dr. Andrea Deplazes Prof. Dr. Arno Schlüter

D-BAUG

Prof. Dr. Robert Boes Prof. Dr. Paolo Burlando Prof. Dr. Eleni Chatzi Prof. Dr. Daniel Farinotti Prof. Dr. Olga Fink Prof. Dr. Guillaume Habert Prof. Dr. Stefanie Hellweg Prof. Dr. Martin Raubal

D-CHAB

Prof. Dr. Gonzalo Guillén Gosálbez Prof. Dr. Maksym Kovalenko Prof. Dr. Javier Pérez-Ramirez Prof. Dr. Thomas Schmidt Prof. Dr. Jeroen A. van Bokhoven

D-ERDW

Prof. Dr. Domenico Giardini Prof. Dr. Johan Robertsson Prof. Dr. Martin Saar Prof. Dr. Stefan Wiemer

D-GESS

Prof. Dr. Tobias Schmidt Prof. Dr. Renate Schubert Prof. Dr. Bjarne Steffen Prof. Dr. Andreas Wenger

D-INFK Prof. Dr. Friedemann Mattern

D-ITET

Prof. Dr. Jürgen Biela Prof. Dr. Florian Dörfler Prof. Dr. Christian Franck Prof. Dr. Ulrike Grossner Prof. Dr. Gabriela Hug Prof. Dr. Maryam Kamgarpour Prof. Dr. Johann Walter Kolar Prof. Dr. John Lygeros Prof. Dr. Roy Smith Prof. Dr. Ayodhya Nath Tiwari Prof. Dr. Vanessa Wood

D-MAVT

Prof. Dr. André Bardow Prof. Dr. Konstantinos Boulouchos Prof. Dr. Jan Carmeliet Prof. Dr. Paolo Ermanni Prof. Dr. Lino Guzzella Prof. Dr. Patrick Jenny Prof. Dr. Maria Lukatskaya Prof. Dr. Edoardo Mazza Prof. Dr. Marco Mazzotti Prof. Dr. Christoph Müller Prof. Dr. Nicolas Noiray Prof. Dr. David Norris Prof. Dr. Christopher Onder Prof. Dr. Dimos Poulikakos Prof. Dr. Horst-Michael Prasser Prof. Dr. Giovanni Sansavini Prof. Dr. Aldo Steinfeld Prof. Dr. Melanie Zeilinger

D-MTEC

Prof. Dr. Lucas Bretschger Prof. Dr. Massimo Filippini Prof. Dr. Elgar Fleisch Prof. Dr. Volker Hoffmann

D-USYS

Prof. Dr. Reto Knutti Prof. Dr. Anthony Patt Prof. Dr. Sonia I. Seneviratne Prof. Dr. Michael Stauffacher Prof. Dr. Bernard Wehrli

Managing Board (as of December 31, 2020)

Prof. Dr. Dimos Poulikakos (Chair) Prof. Dr. Robert Boes Prof. Dr. Volker Hoffmann Prof. Dr. Gabriela Hug Prof. Dr. Marco Mazzotti Prof. Dr. Anthony Patt Prof. Dr. Arno Schlüter

Executive Office (as of December 31, 2020)

Dr. Christian Schaffner – Executive Director Annina Gantenbein - PR, Communication and Events Dr. Andreas Haselbacher - Senior Scientist, Project Manager ReMaP Deborah Hufton – Education Elena Raycheva – Research and Teaching Assistant Dr. Marius Schwarz - Project Manager Nexus-e Xuqian Yan - Scientist Nexus-e

Partnership Council (as of December 31, 2020)

ABB Schweiz Alpiq Axpo BKW CKW EKZ ewz



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