ETH zürich

Energy Science Center

Annual Report 2018

Energy Science Center

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 and Partners,

2018 was another successful year for the Energy Science Center (ESC), and we are delighted to report on our activities. We start by extending a warm welcome to our new member, Prof. Christopher Onder from the D-MAVT. We are happy that, as of the end of 2018, the ESC had sixty active members from ten different departments.

In the area of research, we are very pleased that we successfully won funding from the Swiss Federal Office of Energy for the multidisciplinary "Renewables Management and Real-time Control Platform (ReMaP)" large scale project. This is a joint activity together with PSI, Empa and industrial partners that will enable testing of the setup and interplay amongst new energy technologies and carriers, as well as the interactions of energy suppliers with the distribution system.

In the area of education, we further enhanced the MSc Energy Science and Technology (MEST) programme by offering a wider choice of courses, and by extending it from 90 to 120 credits. A new highlight is a team-work course, where groups of students analyse real-world challenges proposed by industry experts, covering technical, economic and regulatory aspects, and elaborate potential solutions. We also celebrated ten successful years from the time when the first students graduated from the MEST programme.

To increase our outreach, we (co-)organised several public events with well over 400 participants, including the "eDays-Symposium", the second edition of the "Energy Day @ ETH", and the ETH Week "Energy Matters". Creating an inspiring as well as educational programme for the students participating in the ETH Week was especially rewarding. We were proud to watch the great team-work of the interdisciplinary students and the forward thinking ideas the teams came up with during the ETH Week.

Now we look forward to 2019!

Dimos Poulikakos
Chair

Christian Schaffner
Executive Director

The Energy Science Center

A sustainable energy system is one of the most complex challenges that humankind is facing. Such an energy system must be viable given the limited available resources; it must also relieve the strain on the natural environment and not compete with the basic needs of the world' s population. A plausible sustainability vision should be responsive to the central challenges facing the energy system. These are: climate change, access to energy services, local pollutants, risks and benefits to society.

To build such a sustainable energy system additional knowledge and new technologies are needed, relying on the expertise and cross-cutting research of engineering, economic and social scientists.

The ESC of ETH Zurich was founded in 2005 as an interdepartmental competence center to facilitate energy research and teaching activities across research fields and departments.

www.esc.ethz.ch →

The Research Center for Energy Networks (Forschungsstelle Energienetze – FEN) is affiliated with the Energy Science Center.

www.fen.ethz.ch →

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.

Organisational Structure

The General Assembly, containing the ESC members, is the ESC governing body. Currently 66 professors from eleven different departments are members of the ESC.

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

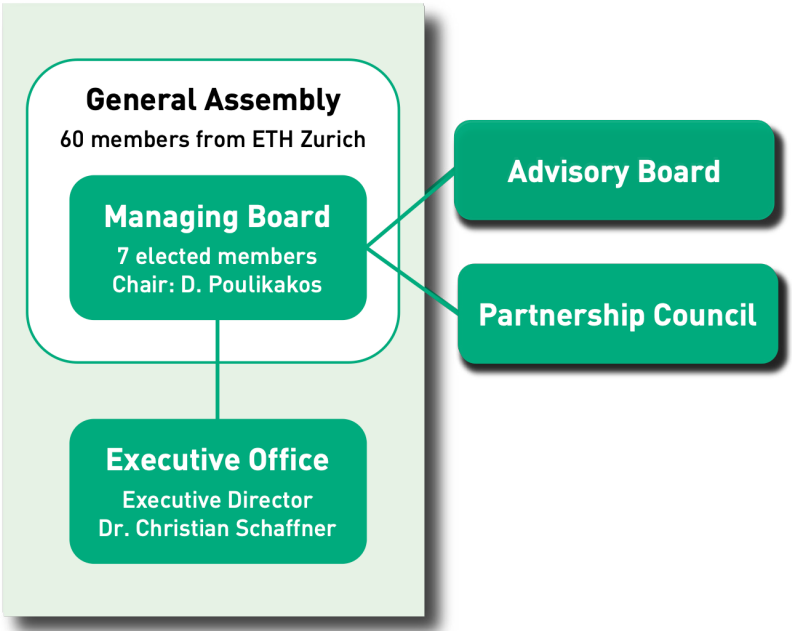
The **Executive Office** is run by the Executive Director, who reports to the chair of the managing board.

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

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.



News

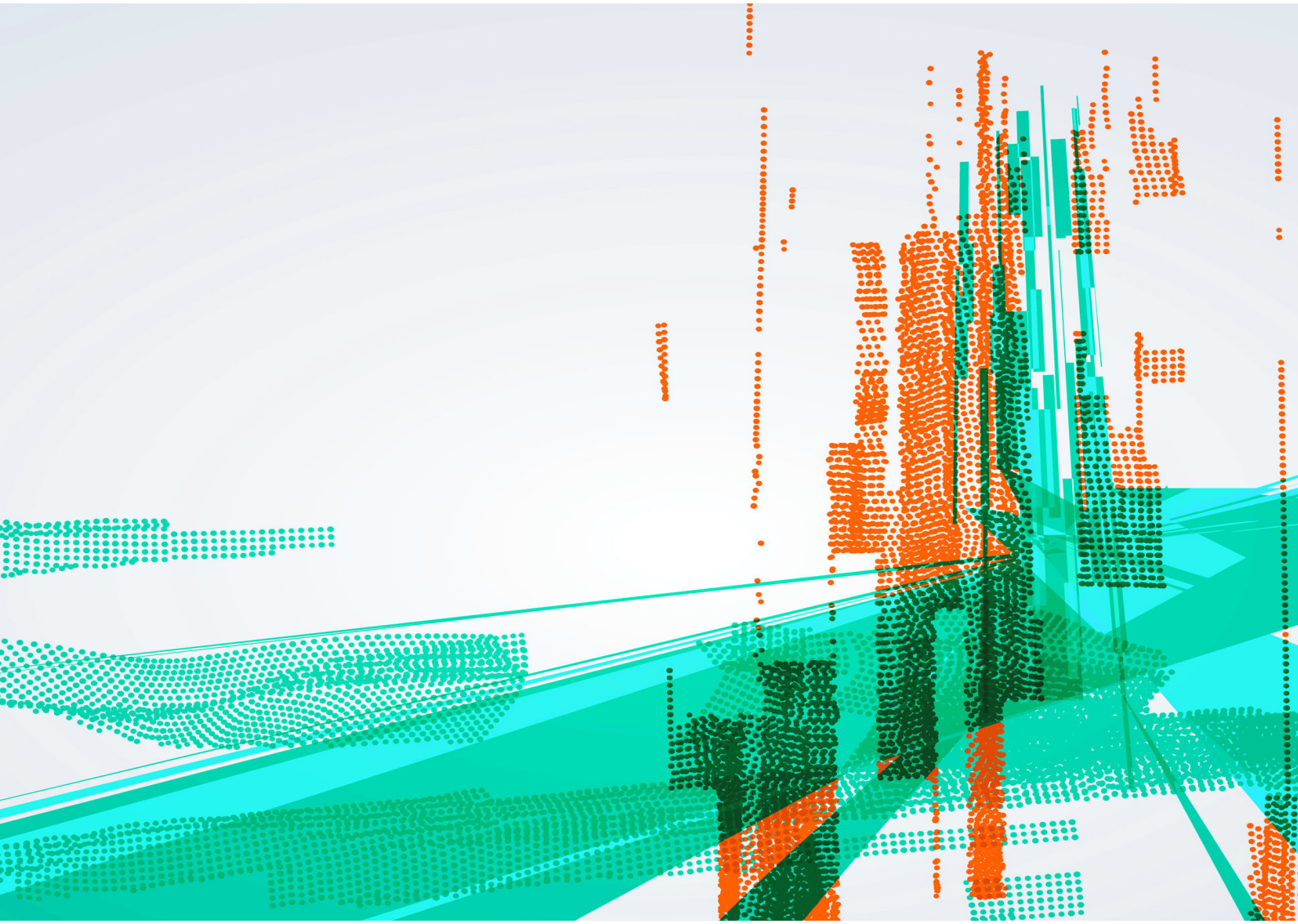
We warmly welcome Christopher Onder as a new member

Prof. Dr. Christopher H. Onder

Christopher H. Onder is professor at the Institute for Dynamic Systems and Control in the Department of Mechanical Engineering and Process Control of ETH Zurich. He heads the Engine Systems Laboratory and holds a diploma and a doctoral degree in Mechanical Engineering from ETH Zurich.

His research focuses on engine systems modeling, control and optimization with an emphasis on experimental validation and industrial cooperation.

Research



Research Approach

The ESC research activities focus on large, cross-cutting themes run as inter-departmental and inter-disciplinary projects in the four strategic areas of: energy and information, integration of renewables, integrated modelling and energy-water-land nexus. 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).

The ESC research activities consist of:

Taking a proactive role in the energy research activities of ETH Zurich and supporting its strategic goals in all areas of action (efficiency, grids, storage, provision, economy, geothermal and more);

Supporting the professors and institutes active in these fields by leveraging its network inside ETH Zurich with other universities and industry;

Gathering opinions and open questions within the energy sector internally and externally, synthesising and disseminating them amongst researchers of ETH Zurich;

Hosting researchers for specific projects in order to facilitate inter-departmental research projects;

Promoting flagship programmes in the area of energy research.

www.esc.ethz.ch/research.html

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.

www.esc.ethz.ch/research-projects.html

Research Projects

Assessing Future Electricity Markets (AFEM)

The AFEM project investigates the wholesale market and reliability impacts of the Swiss electricity system in light of the planned nuclear phase-out and envisaged targets for intermittent renewable energy under alternative assumptions about future market and regulatory conditions. The possible future market designs will be assessed based on their performance and ability to achieve the targets set out in the Swiss Energy Strategy 2050 (ES2050). As a framework, AFEM utilizes a consistent coupling of the different model layers and cross-disciplinary approaches covering the technical, market and policy aspects to enhance the current decision making and provide consistent long- and short-term assessments on investments, operation and security aspects.

A clear innovation of this research has been to integrate technical and engineering-based models with economic and market models to create the coupled framework (AFEM) for wholistic assessments of future electricity markets scenarios. The developed

model framework provides a robust outlet for future scenario assessments of the Swiss and Central European electricity system. The linkage of long and short-term structures as well as the embedding of detailed renewable and system stability assessments can be seen as a blueprint for further detailed assessments.

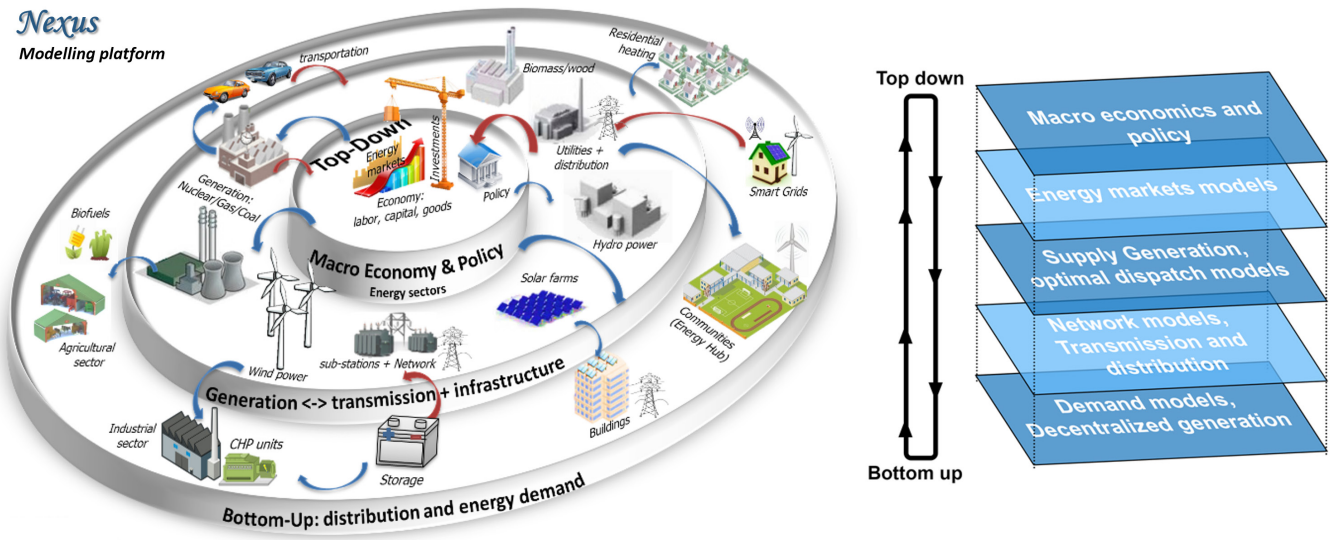
Integrated Energy Systems Modelling Platform (Nexus)

This research project is part of an initiative of the Energy Science Center to develop an integrated modelling platform for assessing energy systems that cuts across the boundaries of established fields of knowledge by combining existing and new tools from different disciplines.

Such a platform enables the study of complex and interdisciplinary questions about the impact of technical, socio-economic and political decisions on the performance of the future energy system. While such decisions in the energy sector are of high national importance, currently there is no comprehensive and transparent platform that enables such broad studies and that provides a holistic view. With expertise in the energy domains of electrical engineering, building technologies, political sciences, economics and risk management, ETH Zürich is in the unique position to develop such a comprehensive platform.

The on-going effort to develop this integrated platform of models has progressed rapidly and is currently testing the combined modules in an iterative simulation process: a top-down economic computable general equilibrium module, a bottom-up centralized generation expansion and dispatch module, a decentralized (distribution grid scale) generation expansion module, a markets-based generator scheduling module, and a cascading-failure grid reliability module.

While the platform will enable studying a wide range of questions, the first case study will focus on the role of flexibility providers in the future electricity system, i.e. what level of flexibility will be needed and who can provide it in a scenario where nuclear energy is phased out and the penetration of variable renewable energy resources has increased significantly. These and other questions are directly linked to the needs and consequences of realizing the Energy Strategy 2050. Hence, this modelling framework (NEXUS platform) will help to answer current and upcoming energy policy questions.



Renewables Management and Real-time Control Platform (ReMaP)

The integration of high shares of fluctuating renewable energy sources and the transformation of the classical role of consumers to "prosumers" are significant challenges for the energy systems of the future, especially for distribution grids, where significant impacts like, e.g., overloading of grid components might occur.

The multidisciplinary research and demonstration project Renewable Management and Real-Time Control Platform (ReMaP) allows testing the best setup of and the interplay between energy technologies and carriers, the interaction between the distribution system and buildings and mobility, as well as educating students and experts in renewable technologies and decentralized energy systems in a close-to-reality environment. A number of institutes at ETH Zürich, Empa, and PSI have committed to carrying out research projects using the flexible, software- and hardware-based, modular platform through projects that feature inherent commonalities and that provide ideal conditions for fostering further collaboration.

ReMaP will allow for operation in different modes: standalone as a micro-grid system, as an island together with the existing platforms ESI, move, NEST and/or ehub, or fully connected to the distribution grid. The platform could thus be operated together with the NEST platform to investigate interactions between building technologies and the energy network, with ESI to assess the interaction of energy conversion & storage processes and the electricity grid, in conjunction with move to assess interactions with new mobility solutions, or it could be alternatively connected and disconnected to and from the grid to investigate transitions between coupled and micro-grid operation.

ReMaP is financed by the SFOE (Swiss Federal Office of Energy) and the ETH Foundation and became operative in late 2018.

Education

Photo: ETH Zürich/ Alessandro Della Bella

Master in Energy Science and Technology (MEST)

The ESC coordinates the interdisciplinary Master's degree programme Master in Energy Science and Technology (MEST) at ETH Zurich, a world-class master programme for energy engineers, aimed at students with an engineering or a technological science background. The compulsory courses are in the key areas of electrical power engineering, energy flows and processes, and energy economics and policy. For the electives, students can choose any energy-specific course from the whole of the ETH course catalogue (in accordance with their tutor).

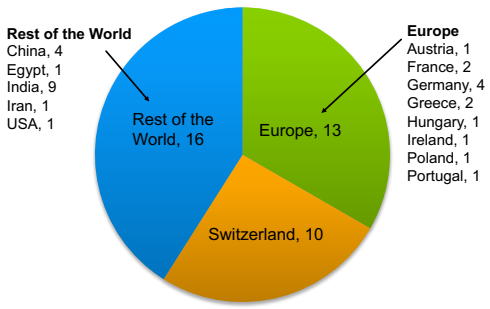
The MEST programme is jointly run by two Departments: the Department of Information Technology and Electrical Engineering (D-ITET), as the host department, along with the Department of Mechanical and Process Engineering (D-MAVT). Tutors from another seven departments actively contribute to the MEST, along with their energy-related core courses.

www.master-energy.ethz.ch

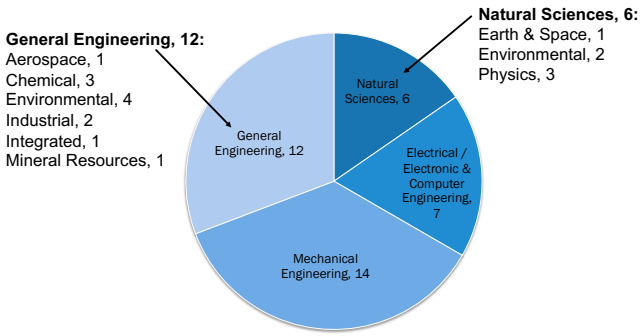
The MEST programme has been enhanced, offering a wider choice of courses and extended from 90 to 120 credits. A new highlight is a (compulsory) team-work course, uniquely designed for MEST students, to provide them with an interdisciplinary overview of the topic 'Energy' and the challenges associated with building a sustainable energy system for the future. Each team analyses a real-world challenge proposed by industry experts, covering technical, economic and/or regulatory aspects and elaborates a potential solution. For 2018-19, the challenges have been provided by Energie 360°, ewz, SBB, SBB Cargo and Swissgrid. For the students, working in teams encourages knowledge-sharing, as well as an opportunity to strengthen social bonds. Senior MEST students are engaged as coaches.

For entry in autumn 2018, the MEST admission committee received nearly 160 applications from all over the world, of which 66 high-calibre students were offered a place.

2018 MEST students: Home country



2018 MEST students: Previous study



Master in Integrated Building Systems (MBS)

The ESC supports the interdisciplinary Master's degree programme in Integrated Building Systems (MBS) at ETH Zurich.

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.

www.master-buildingsystems.ethz.ch

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. At the end of the semester, a 'Best Frontiers Presenter' award is given based on the audience feedback.

The Frontiers presentations are held annually throughout the spring semester, 14 each year, and have been running since 2012. In spring 2018, both the presenters and the attendees (just over 50 of them) came from 11 different ETH departments, plus PSI & EMPA.

www.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 an Alumni Network for career support and development. Regular social events bring together past and present students to help strengthen the MEST students' network. At the MEST 10-year event (see below) held in May 2018, two MEST alumni, now both working for ewz, gave short talks outlining their careers to date.

MEST 10th anniversary

The MEST programme was founded in 2007, so in May 2018 celebrated 10 successful years since its first students graduated. The celebration was held in Zurich in a fashionably industrial setting – a decommissioned substation. All MEST students, past and present, were invited. The welcome address was given by Prof. Sarah Springman, Rector of ETH Zurich, followed by the former (Prof. Göran Andersson) and current (Prof. Christian Franck) heads of the programme. The event provides the backdrop to a new video, created on the day, of impromptu impressions by students of how the MEST programme has benefitted them. Video: www.master-energy.ethz.ch/the-programme/news-and-events.html

Photo: ETH Zürich/ Tom Kawara

Outreach

Photo: ETH Zürich/ Alessandro Della Bella

ESC Events

Energy Day @ ETH 2018

December 11, 2018

What role will hydropower play in the future in Switzerland? How long will the Nuclear power plants remain on the grid? What new technologies can we expect? Will we have a battery storage in every house? How will the grids of the future look like? These and many more questions were discussed at the Energy Day @ ETH 2018. We were very happy to have welcomed more than 400 visitors that discussed together with ETH researchers, ETH Professors, ETH Spin-offs, as well as distinguished guest lecturers from the energy field. www.esc.ethz.ch/events/previous.html

Focus-Dialogues in the morning
Photo: ETH Zürich/ Tom Kawara

Symposium in the afternoon with Prof. Gabriela Hug
Photo: ETH Zürich/ Tom Kawara

ESC Collaborations

ETH Week "Energy Matters"

Sept 9 to 14, 2018

ETH Week is a key project of the Critical Thinking Initiative with the goal to foster independent thinking and responsible acting. It promotes interdisciplinary collaboration by building on disciplinary expertise and gives students the opportunity to analyse and reflect important societal problems. The ESC was delighted to be part of this transformative Week, working together very closely with ETH students and professors from all disciplines, as well as inspiring guest lecturers and experienced experts from the industry on the topic of "Energy Matters".

www.ethz.ch/en/the-eth-zurich/sustainability/education/ETHweek

Photo: ETH Zürich/ Alessandro Della Bella

eDays-Symposium: Intelligente Wege zur Mobilität der Zukunft

June 8, 2018

On June 10th, 2018, for the first time, a Formula E race took place in Zurich. Within the framework of this event, the ESC supported the ETH Zurich in organizing a full-day symposium with over 400 participants. The newest concepts and ideas in the field of e mobility were discussed and presented, along with an exhibition of mobility Startups.

www.ethz.ch/de/news-und-veranstaltungen/veranstaltungen/edays.html

eDays Symposium

Photo: ETH Zürich/ Alessandro Della Bella

SINN Power at the eDays startup exhibition

Photo: ETH Zürich/ Alessandro Della Bella

Energy Startup Day

November 29, 2018

Photo: Energy Startup Day 2019, ZHAW

Also this year, the Energy Science Center came together at the SwissECS (Swiss Energy and Climate Summit). with over 800 decision makers of the energy sector. This year, the ETH Spin-off Gilytics represented the ETH Zurich at the expo zone.

www.energy-startup-day.ch

SwissECS

September 19, 2018

Photo: ETH Zürich/ Alessandro Della Bella

Also this year, the Energy Science Center came together at the SwissECS (Swiss Energy and Climate Summit). with over 800 decision makers of the energy sector. This year, the ETH Spin-off Gilytics represented the ETH Zurich at the expo zone.

www.swissecs.ch/

Individualisierung statt Segmentierung

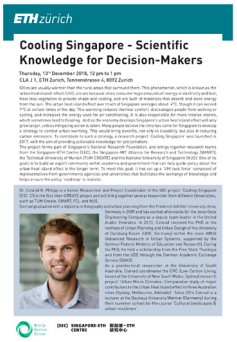
June 1, 2018

www.esc.ethz.ch/events/previous.html

Cooling Singapore: Scientific Knowledge for Decision-Makers

December 13, 2018

www.esc.ethz.ch/events/previous.html



Annex

60 active Members (as of December 31, 2018)

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. Guillaume Habert
Prof. Dr. Stefanie Hellweg
Prof. Dr. Martin Raubal

D-CHAB
Prof. Dr. Maksym Kovalenko
Prof. Dr. Javier Pérez-Ramirez
Prof. Dr. Thomas Schmidt

D-ERDW
Prof. Dr. Domenico Giardini
Prof. Dr. Christoph A. Heinrich
Prof. Dr. Johan Robertsson
Prof. Dr. Martin Saar
Prof. Dr. Stefan Wiemer

D-GESS
Prof. Dr. Tobias Schmidt
Prof. Dr. Renate Schubert
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. Reza S. Abhari
Prof. Dr. Konstantinos Boulou-chos
Prof. Dr. Jan Carmeliet
Prof. Dr. Paolo Ermanni
Prof. Dr. Lino Guzzella
Prof. Dr. Patrick Jenny
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. Hyung Gyu Park
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
Prof. Dr. Sebastian Rausch

D-USYS
Prof. Dr. Reto Knutti
Prof. Dr. Johan Lilliestam
Prof. Dr. Anthony Patt
Prof. Dr. Michael Stauffacher
Prof. Dr. Bernard Wehrli

Total: 60 members

Former ESC members
Prof. Dr. Göran Andersson (Em.)
Prof. Dr. Kees Christiaanse (Em.)
Prof. Dr. Christophe Copéret
Dr. Keith Frederick Evans
Prof. Dr. Konrad Hungerbühler (Em.)
Prof. Dr. Wolfgang Kröger (Em.)
Prof. Dr. Hansjürg Leibundgut (Em.)
Prof. Dr. Reinhard Nesper (Em.)
Prof. Dr. Jennifer Rupp
Dr. Evelina Trutnevyte
Prof. Dr. Alexander Wokaun (Em.)

Managing Board (as of December 31, 2018)

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, 2018)

Dr. Christian Schaffner – Executive Director
Deborah Hufton – Education
Tanja Meier – PR and Communications
Elena Raycheva – Research and Teaching Assistant

Members Partnership Council

ABB Schweiz
Alpiq
GE Power
Axpo
BKW
CKW
EKZ
ewz
Repower
Shell
swisselectric

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Layout Tanja Meier