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KEY TOPIC

CLEAN AND SECURE ENERGY FOR THE FUTURE

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BACKGROUND

Many paths lead to the energy future

Energy production should be clean, inexpensive and safe. This undertaking already sounds challenging, but is even more complex in reality. To determine which paths could lead to this goal, PSI researchers use a computer model that is unique in its scope.

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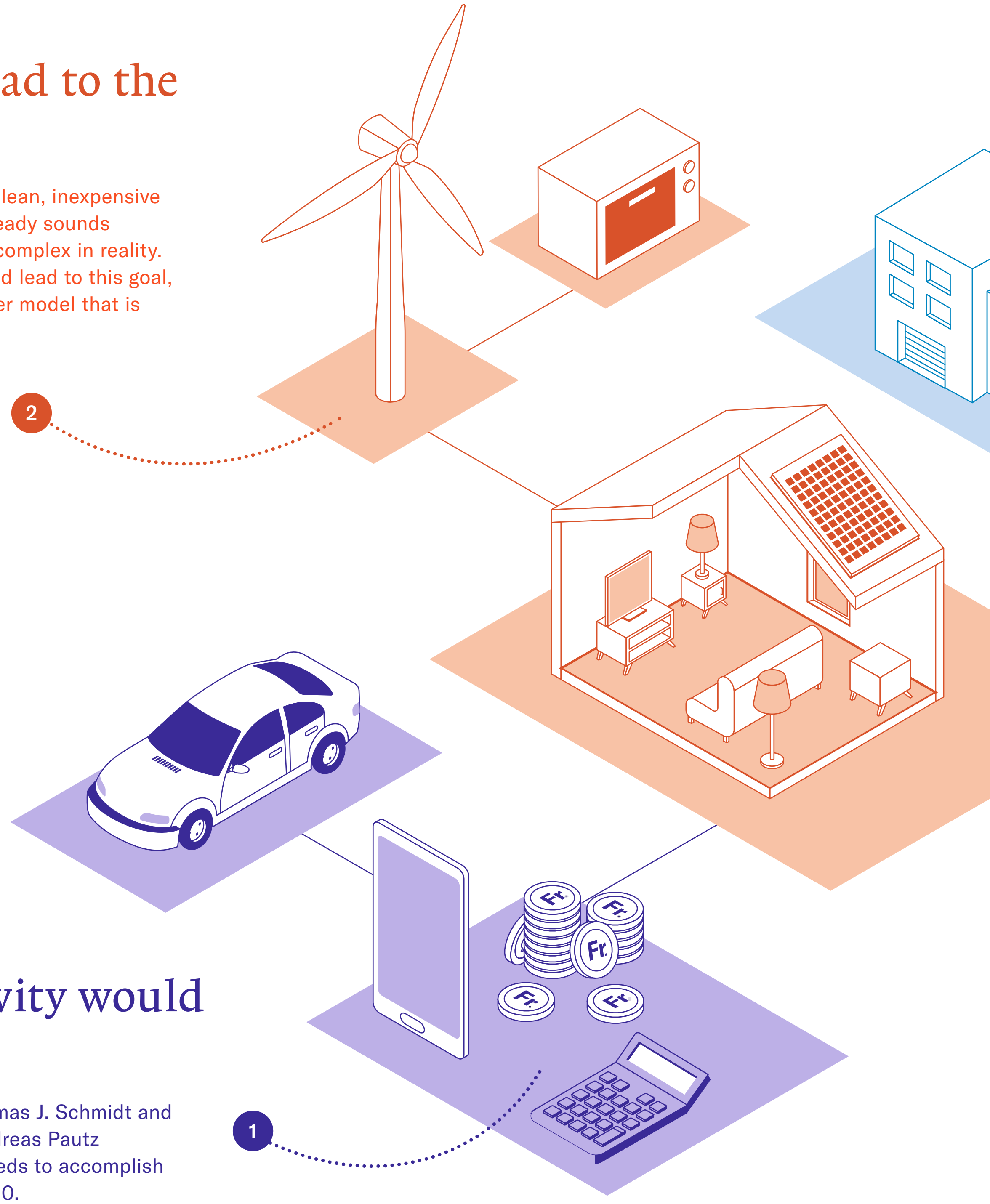

INTERVIEW

“More objectivity would be helpful”

Renewable energy expert Thomas J. Schmidt and nuclear energy researcher Andreas Pautz explain what tasks science needs to accomplish as part of Energy Strategy 2050.

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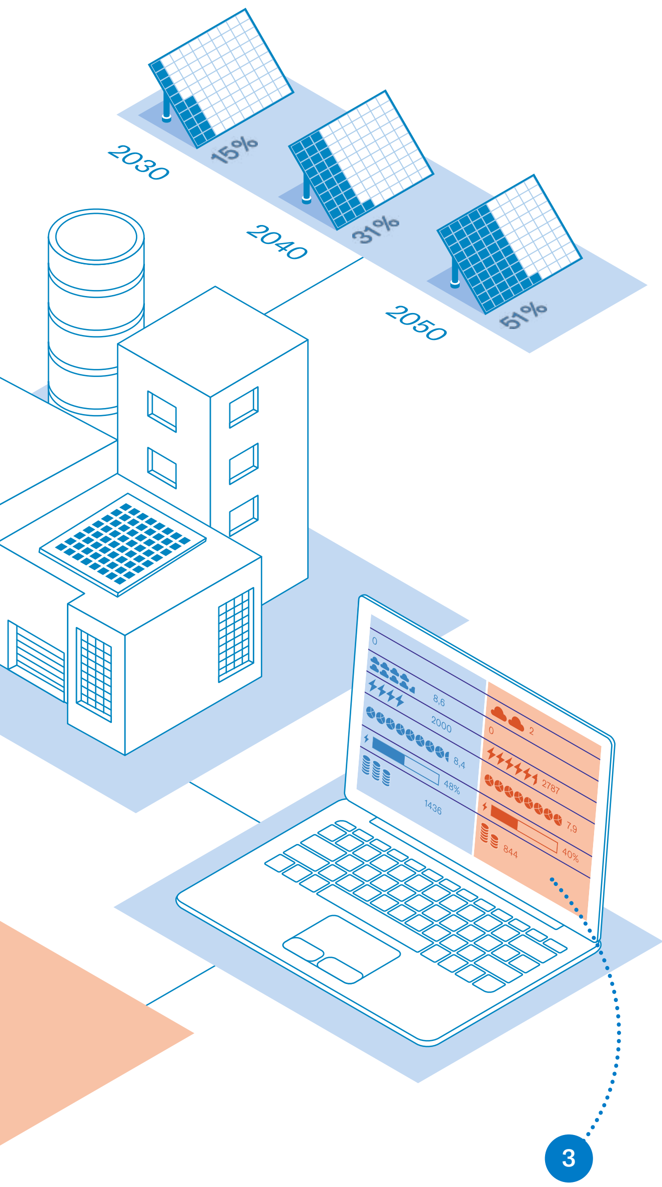

INFOGRAPHIC

Energy scenarios

The scenarios produced by PSI researchers can broaden the horizon for possible developments in energy systems.

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Everyone must play their part

We are facing major challenges. With the Energy Strategy 2050, Switzerland has set itself the ambitious goal of running the economy and adapting our lifestyles to minimise the emission of gases that contribute to climate change. The current crisis in Ukraine has made this goal more pressing and challenging than ever, as we need to rapidly reduce our dependence on fossil fuels and their suppliers, while at the same time ensuring a secure local energy supply.

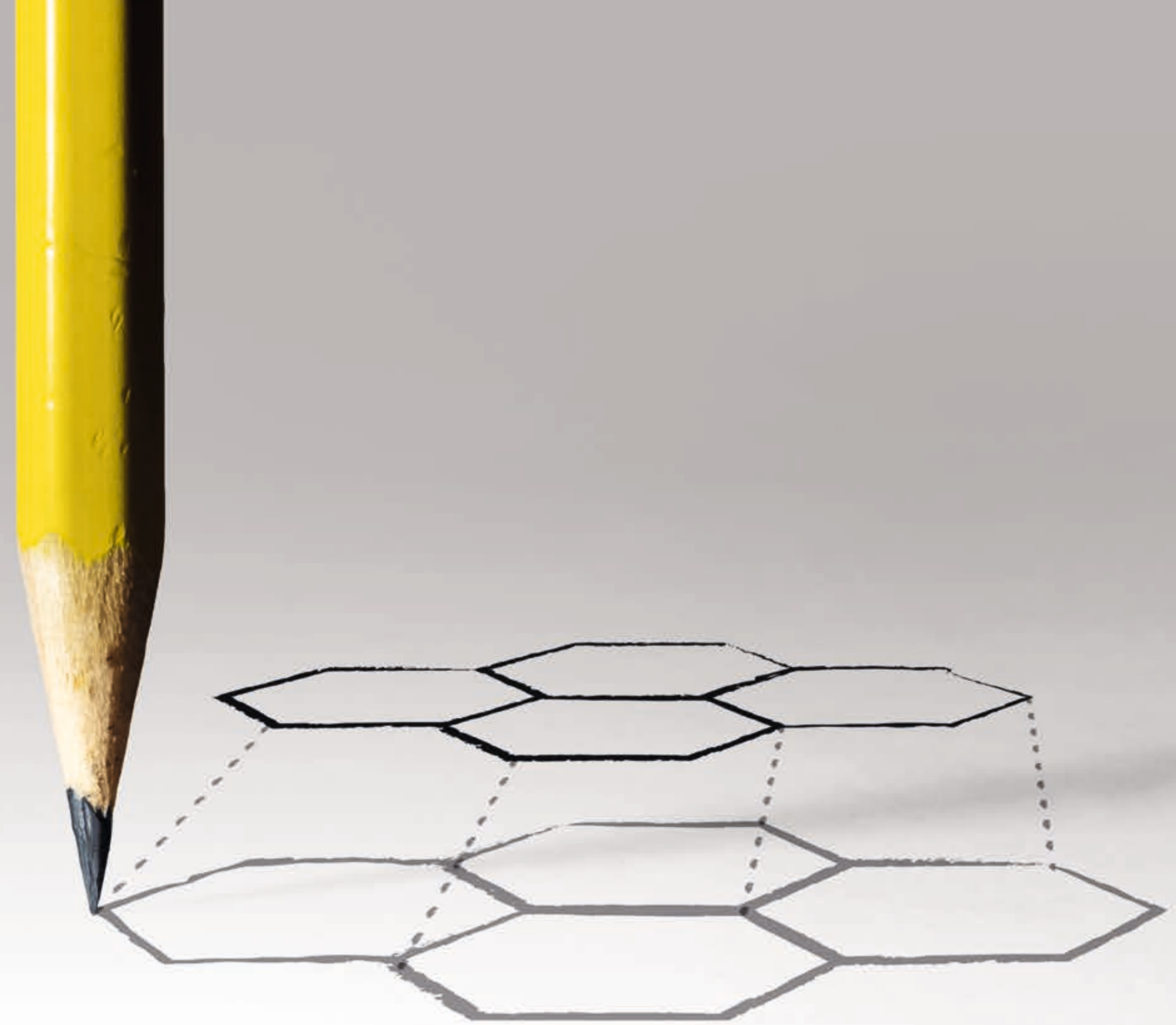
And one thing is clear: without new processes, technologies and materials we will not be able to accomplish this energy transition. That's why PSI researchers are helping pave the way through advances in their respective fields. For example, we are investigating and creating new materials and processes to optimise energy storage or conversion – such as the GanyMeth reactor behind me at our Energy System Integration Platform ESI. We are using it to study how to combine hydrogen and carbon dioxide most effectively to produce methane, a synthetic form of natural gas. The ESI platform is just one example of how we develop technical prototypes destined for large-scale application in industry and business. We are involved in many commercial partnerships to develop our basic research into solutions to complex problems. Using sophisticated and state-of-the-art computer models, we explore how energy systems will develop in the future, and gauge the associated costs.

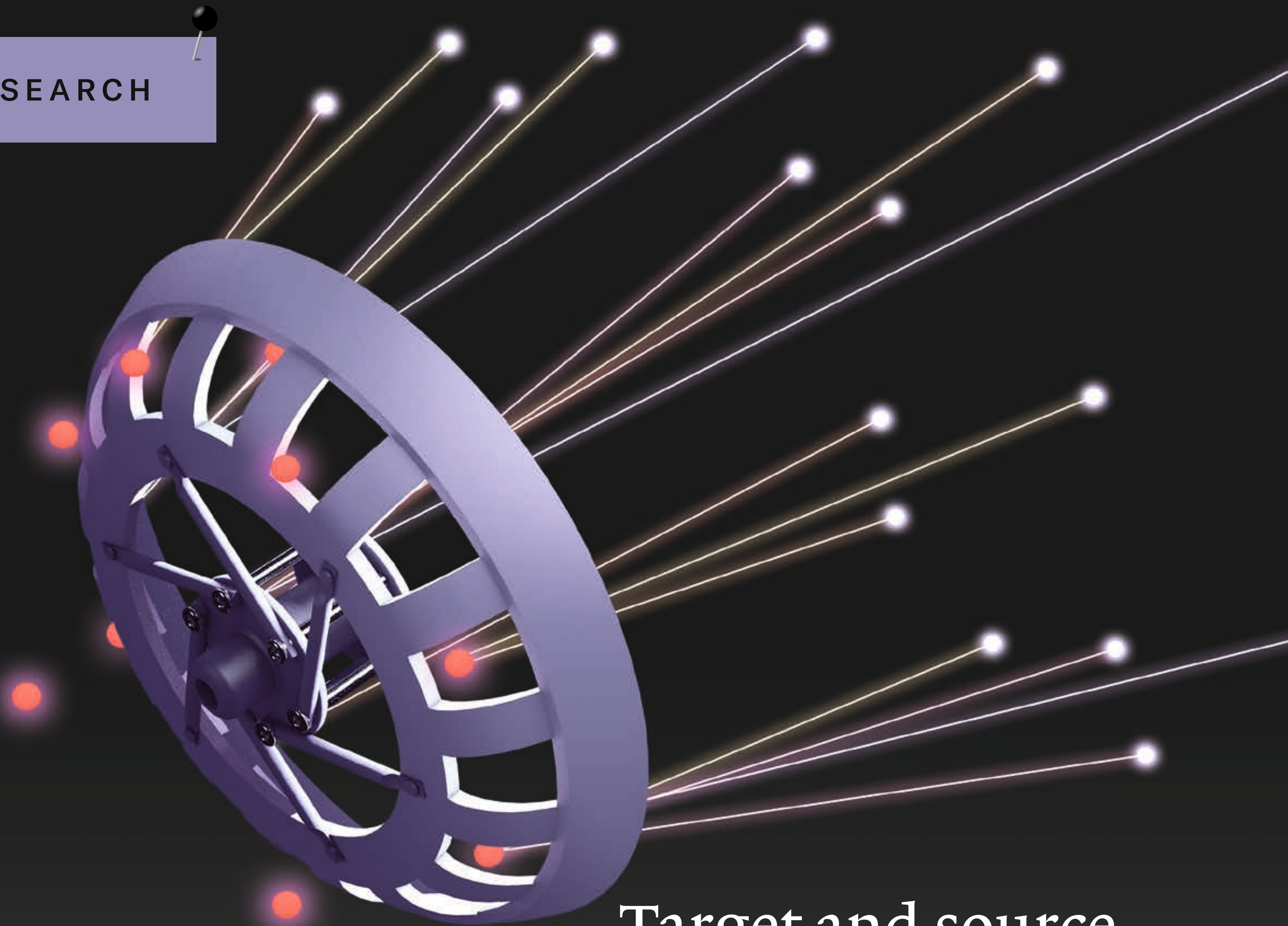
As usual, predictions about future developments are subject to uncertainties, and different development paths emerge depending on the various scenarios that we present in our key topic for this issue of 5232. Nevertheless, they do sketch out the possible steps forward within given parameters. Many of our findings also serve as a basis and orientation for political decisions, although the overall geopolitical conditions regarding energy imports, for example, are highly volatile. With these and many other initiatives, we want to contribute to achieving the goals of the Energy Strategy 2050 and ensure a more resilient and secure energy supply. Despite all the successes in research, one thing is also clear: to accomplish the necessary changes, all sections of society – politics, business and the general public – must play their part.

PSI-Director Christian Rüegg

Writing and more

Who has never held a pencil? In spite of digitalisation, it has still not disappeared from our everyday lives. This may be due, among other things, to its extraordinary properties, since we not only can write and draw with it, but also can easily remove the lines it draws with an eraser. The pencil owes this distinctive feature to its lead, which these days is made of graphite, a very special material. Graphite is pure carbon, the element that also forms diamonds and serves as the central framework for the carbohydrates, proteins and fats that essentially make up our bodies. This list alone illustrates the versatility of carbon. In graphite, carbon atoms arrange themselves in layers that are not firmly attached to each other. They can, for example, be easily rubbed off and then stick to paper. The graphite on the paper can be removed again because it sticks more strongly to the rubber of the eraser than to the paper. Lead was actually used for pencil cores until the 19th century, and this is reflected in the “leads” used in mechanical pencils designed for technical drawings.





Target and source

At PSI, graphite has a very special use. One is to make “targets”: rotating rings shaped a bit like hubcaps. Protons moving at roughly 79 percent of the speed of light are fired at them from the accelerator facility HIPA, so they become sources of elementary particles. The first target is designated M for mince, the French word for thin, because it is only five millimetres thick. In collisions with carbon nuclei of the graphite, the fast protons produce pions, which decay into muons in an extremely short time. After that, the proton beam hits a second target. This one is designated E for the French épais, or thick, because it has a thickness of 40 millimetres. Here significantly more pions – and thus more muons – are produced. Researchers use pions and muons to carry out experiments and investigations in particle physics or explore the properties of materials. For example, they allow the radii of the proton and a helium atom to be measured more precisely than ever before. This in turn makes it possible to test new theoretical models of the nuclear structure and gain a better understanding of atomic nuclei. Muons are also being used to study new materials for batteries and decipher the composition of archaeological artefacts.

Tom Kober, head of the
Energy Economics Group

Russell McKenna, head of the
Laboratory for Energy Systems Analysis

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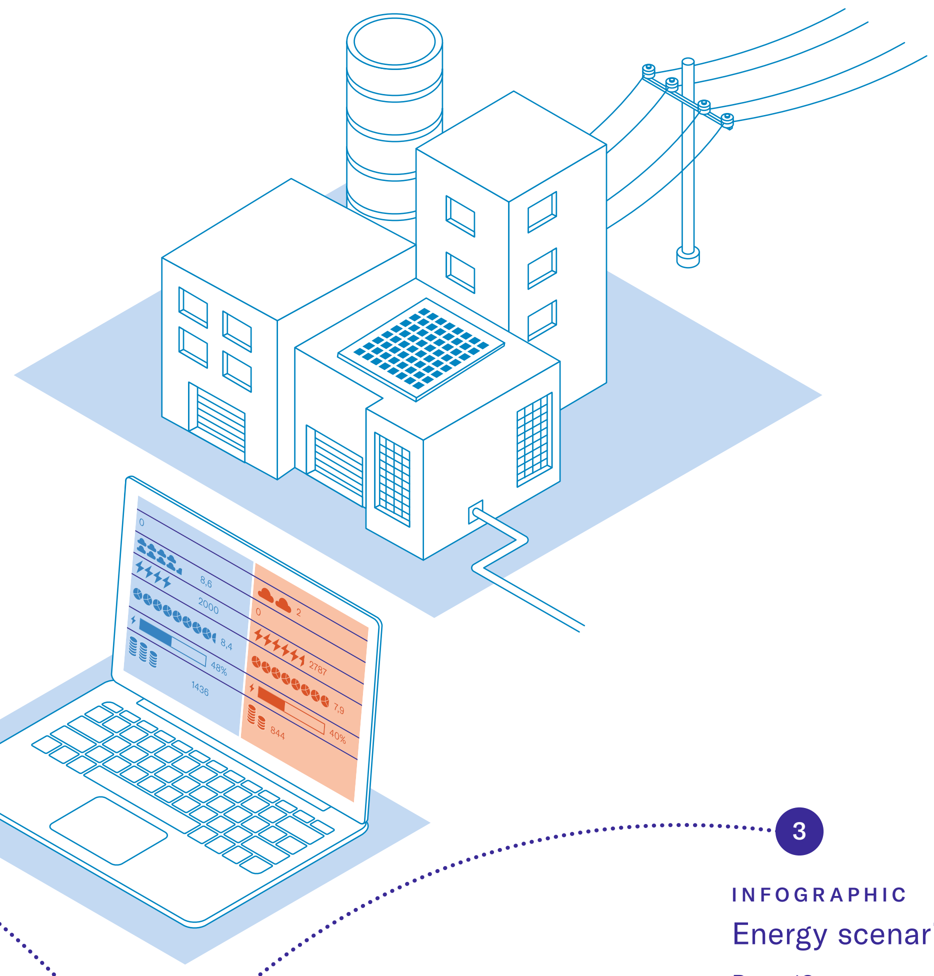
KEY TOPIC

Clean and secure energy for the future

Switzerland is facing major challenges. In light of current geopolitical developments and other crises, such as the global pandemic caused by the Sars-CoV-2 virus, the prerequisites for achieving the goals of the Energy Strategy 2050 appear to be in question. Researchers at PSI are trying to broaden the view of possible development paths through the use of complex calculations.



Evangelos Panos, a researcher in the Energy Economics Group

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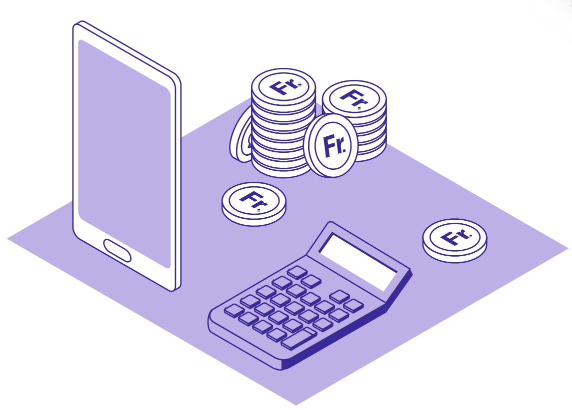
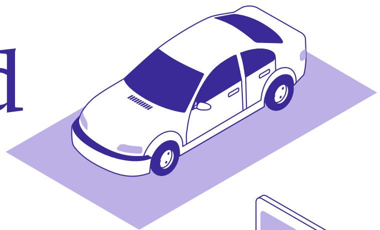


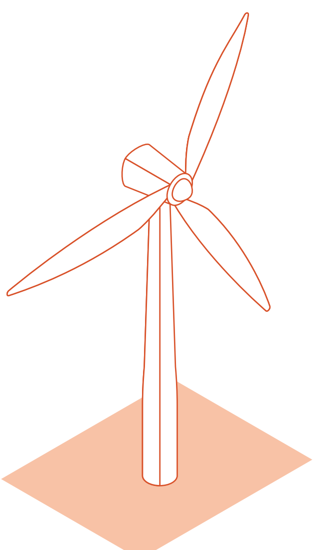
Thomas Justus Schmidt, head of the PSI Research Division Energy and Environment (left) and nuclear energy researcher Andreas Pautz, head of the Nuclear Energy and Safety Research Division.

“More objectivity would be helpful”



The current energy debate could do with more facts and less gut feeling – argue Thomas J. Schmidt, renewables expert and head of the PSI Energy and Environment Research Division, and Andreas Pautz, nuclear energy specialist and head of the PSI Nuclear Energy and Safety Research Division. In this joint interview, they set out the challenges that science needs to address in connection with the Swiss government’s Energy Strategy 2050 and why nuclear energy and renewables experts must work closely together.

Interview: Brigitte Osterath



Professor Schmidt, you head up the PSI Energy and Environment Research Division, and Professor Pautz, you oversee the Nuclear Energy and Safety Research Division. What are the differences between your two fields of research, and what do they have in common?

Thomas J. Schmidt: The Energy and Environment Division does research on the production, conversion, and storage of energy from renewable sources, as well as addressing the consequences our energy use has for the environment and atmosphere. Our research does not cover nuclear energy, however.

Andreas Pautz: That is our expertise. But we do have some common ground: We always work within the context of Switzerland’s Energy Strategy 2050. During this transition phase, we both have important tasks to perform: The Energy and Environment Division needs to push forward with renewables, while we have to solve the problem of how to ensure that nuclear power stations continue to operate safely up into the 2040s – possibly even well beyond – and lastly, how to safely dispose of radioactive waste. We play our part in maintaining high safety standards throughout and minimising the nuclear legacies for future generations to deal with.

So, you don’t see each other as rivals, championing different energy sources?

Schmidt: Not at all. We work closely together and in doing so have to keep an eye on time scales when it’s time to replace one technology with a different one.

Pautz: Exactly, our aim is to ensure optimal interplay with a view to avoiding potential environmental impacts as much as possible and minimising costs. We look at this purely from a scientific angle; we are not engaging in political discussions. The decision not to limit the lifetime of existing nuclear power stations effectively makes them an integral part of the country’s energy strategy. By the way, there is no other scientific institute in Switzerland where so much energy research is conducted as at PSI, in other words, where so many researchers are concentrated in such a small space.

Do you also work on joint projects?

Pautz: Certainly. For example, we work together on the SURE project, whose aim is to determine how we can build a secure and resilient energy supply for the country over the coming years. This involves much more than just minimising CO_2 emissions, but includes other aspects such as reliability of supply, network stability, and defence against external and internal threats. In addition, we are working together on net-zero, that is, on technology development and modelling for a society whose bottom line in terms of greenhouse gas emissions is zero. In this connection, we will be leading and coordinating a competence centre of the ETH Domain, beginning in autumn 2022.

Schmidt: We carry out this research in a joint PSI lab, the Laboratory for Energy Systems Analysis. This specialises in holistic analyses of the entire energy system. Transport, industry, private households, electricity generation – everything comes together here. Aside from that, though, there is a whole series of other subject areas in which synergies arise. These include materials aspects, the formation and spread of aerosols, flow processes in porous media, disposal and recycling processes, and much more.

Is more scientific objectivity necessary in the discussions about the energy transition and the various ways of achieving it?

Pautz: More objectivity in the energy debate would be extremely helpful. We simply need to carefully weigh the new facts that we have today – for example with regard to the increasingly visible consequences of climate change or the unfortunate lack of speed in the expansion of renewable energy and storage technologies. Due to the military conflict in Ukraine, which has made us aware of our dependency on fossil fuels, the issue of security of supply has come into focus in a massive way. In view of these new realities, I am pleading for an open debate on technology that does not exclude any form of energy, not even nuclear power. There needs to be an evaluative thought process.

Schmidt: This also underlines the importance of the holistic approach we adopt at PSI in order to understand energy systems as a whole. Only a few other places in the world follow this approach.

Is it difficult for you to attract young scientists in your area of research?

Schmidt: No. Our international outlook helps: People from around 45 different countries work in the Energy and Environment Division.

Pautz: I can confirm that for my division as well. We have a very good reputation internationally and thus strong demand. Together with EPFL and ETH Zurich, we offer a master's course in nuclear engineering, for example. On average, 15 new students start every year, and the trend is upward. This year more than 25 are starting. It is also very gratifying that in the past three years more and more Swiss students have chosen nuclear engineering as their subject. This shows that nuclear energy is not an obsolete model internationally, and that the subject also motivates young people in Switzerland.

Is the criticism "Switzerland wants to discontinue nuclear energy, so why is PSI still doing research on it?" something that you hear often?

Pautz: Hardly ever. No one disputes that specialists are needed for the next 25 years at least, partly to solve the problem of radioactive waste disposal. The need for Switzerland to maintain its nuclear expertise is also widely recognised in political circles. When it comes to nuclear technology, Switzerland should also be able to defend its position as a global player and draw on a deep pool of know-how. This is only possible, however, if we continue to do research on important issues relating to nuclear safety, and on the sustainability aspects of this form of energy.

What has changed in your field of research over the past years, and what do you expect for the future?

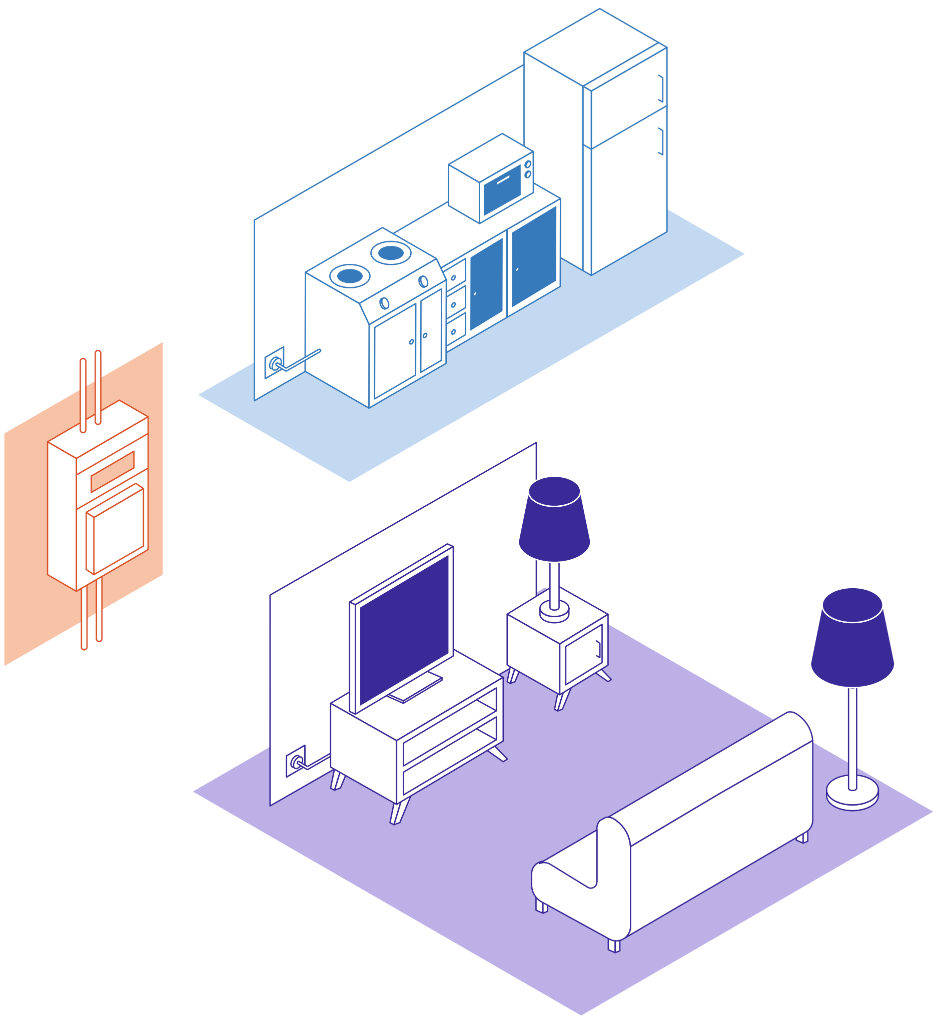
Schmidt: Amongst other activities, we have reduced our research into combustion technology. Although this used to be an important topic, it now has a limited future. On the other hand, we have taken on several new topics, such as hydrogen production. Another issue that has become more important is the impact of our energy use on the climate. For example, what effects do aerosols have on the atmosphere and on human health?

Pautz: The long-term operation of nuclear power stations tops our agenda, as well as the final disposal of nuclear waste and the dismantling of decommissioned plants. Since it became clear that Switzerland plans to phase out nuclear energy, we have suspended activities that are related to constructing new power stations, such as the development of new fuels. We are only marginally involved in investigating new safety systems. In the future, I'd really like to see collaborations between industry and research become much more international. We want to continue to capitalise on PSI's strong international reputation in nuclear energy research. ◆

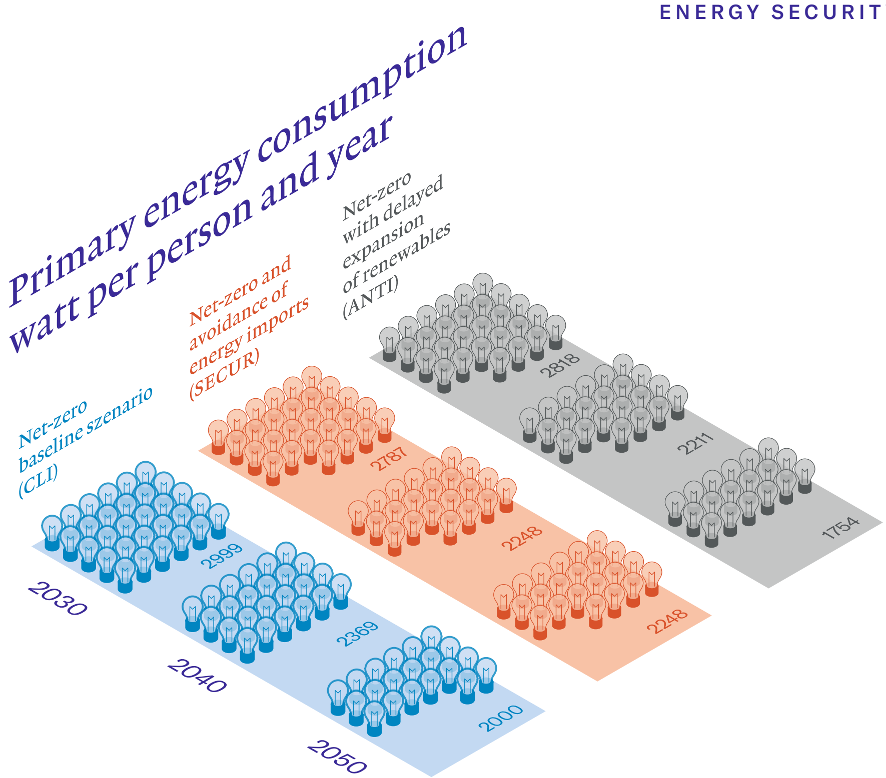
Many paths lead to the energy future

The goal is clear: zero greenhouse gas emissions by 2050. But how can Switzerland manage the energy transition at the lowest costs possible and ensure the security of the energy supply? PSI researchers are providing answers with a computer model that is unique in its scope.

Text: Bernd Müller



Evangelos Panos and his team develop complex computer models that simulate how the energy systems could change in the future. This allows different conclusions, for example: per capita energy consumption should decrease (see graphic, above right).



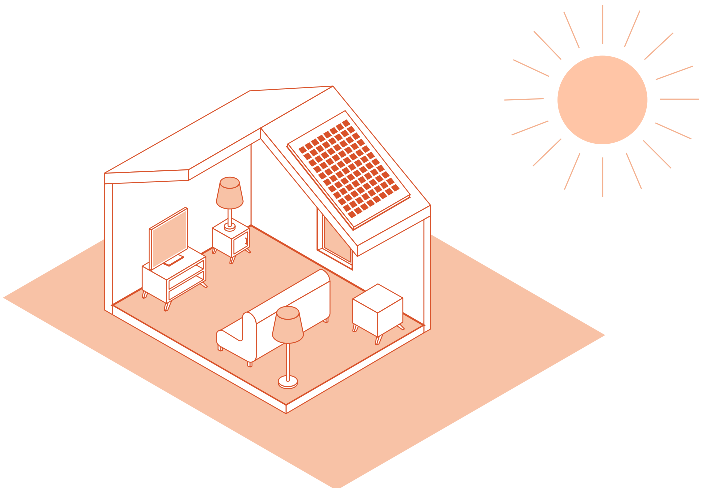
When Tom Kober talks about his work, he makes one thing clear right away: "We don't predict the future." This could be confusing at first, since "foresight" is Kober's special field. Even though Kober looks into the future, he does not make predictions. "We calculate scenarios on the what-if principle," Kober says, "but every computational model is still just an abstraction of reality, which means that certain aspects may well be disregarded." None of these scenarios will unfold in that exact way. Nevertheless, they should provide valuable support to decision-makers in politics and business. "The scenarios show possible options for action and the consequences they have, which is particularly interesting for the comparison of different scenarios."

For more than 15 years, Kober has been dealing with energy systems, CO_2 emissions and the pressing questions posed by advancing climate change. Since 2016 the 45-year-old has been the head of the Energy Economics Group, an important team in the Laboratory for Energy Systems Analysis (LEA) at PSI. "PSI is the ideal place for this interdisciplinary research," confirms Russell McKenna, the head of the LEA. The LEA represents the ideal complement to the main areas of work in PSI's two research divisions Nuclear Energy and Safety, and Energy and Environment. "We produce market analyses to support, among others, our colleagues who are developing electrolysers or fuel cells. We in turn benefit from the data and expertise of the colleagues who are developing new technologies," McKenna says.

This competence is also known to Innosuisse, the Swiss Innovation Agency. It determined that despite plenty of valuable foresight research on energy systems in Switzerland, this had not been well coordinated. In 2017, the agency launched a project – Joint Activity Scenarios and Modelling (JASM) – charged with calculating a development path for Switzerland towards a climate-neutral society. The aim was to provide orientation for politics and business. Participants included the eight Swiss Competence Centres for Energy Research (SCCERs). Besides PSI, this included other institutions in the ETH Domain such as Empa, EPFL, WSL, and ETH Zurich, the Lucerne University of Applied Sciences and Arts, and the universities in Basel and Geneva. Each of these research institutions has particular strengths and concentrates on specific research questions.

The modelling team in the PSI Laboratory for Energy Systems Analysis is recognised nationally and internationally for the STEM (Swiss Times Energy Systems Model) it developed. Kannan Ramachandran and Evangelos Panos were largely responsible for its development. "It is the only model that can map development paths for the entire Swiss energy system over long periods of time with very good temporal resolution and an extremely high level of technical detail," says Evangelos Panos, a researcher in the Energy Economics Group. Other researchers who use energy models only consider one specific year in the future, not a period covering several decades. In the JASM joint project supported by Innosuisse, PSI researchers investigated three net-zero scenarios in comparison with a baseline scenario in which, by 2050, CO_2 emissions would only be reduced 40 percent below 1990 levels (see infographic on page 18): a net-zero CO_2 emission reduction scenario (CLI), a variant that also calculates a reduction in energy imports to a minimum (SECUR), and a variant with fragmented expansion potential for new renewable energy sources (ANTI).

Last year Tom Kober's team presented the results of their models. Bad news first: to reach the net-zero goal by 2050, substantial efforts will be necessary. To achieve this goal in the most cost-effective way possible, the installed photovoltaic capacity needs to double every ten years, and three-quarters of all residential buildings will then have to be warmed by heat pumps. This would halve Switzerland's average per capita energy consumption compared to today. Thus Switzerland would transform itself into the much-cited 2,000-watt society, meaning that the annual primary energy consumption per capita would correspond to an average output of 2,000 watts. Today it is nearly 4,000 watts per person. With a delayed expansion



In order to achieve the goals of the lowest possible CO_2 emissions, a strong expansion of photovoltaics is necessary in all scenarios. In some cases, more than 90 percent of the possible fifty terawatt-hours, depending on the scenario (see chart below right).

"PSI is the ideal place for this interdisciplinary research."

Russell McKenna, head of the Laboratory for Energy Systems Analysis

of renewable energy sources, the average power requirement would have to be brought down even further, to 1,750 watts. In this case, the net-zero target could be achieved primarily through extra efforts to conserve energy – which would bring correspondingly higher costs, for example for more thermal insulation and better process integration.

Photovoltaics has a major role to play in the energy transition. Switzerland could harvest around 50 terawatt-hours of solar power annually if all available surfaces were used. Today, however, only four percent of them are in use. If the country wants to largely do without energy imports by 2050, more than 90 percent of these surfaces would have to be exploited. On the other hand, only around 50 percent of the possible solar energy surfaces would need to be used to achieve the goal in the baseline scenario. In the scenario with delayed expansion, it would be 40 percent.

In the meantime, other research institutions have also presented their JASM results and summarised them in a synthesis report. Besides that, there are also the federal government's scenarios – known as Energy Perspectives 2050+. The researchers agree on the main findings, but there are differences as well. The PSI models, for example, indicate higher costs than in other groups' results.

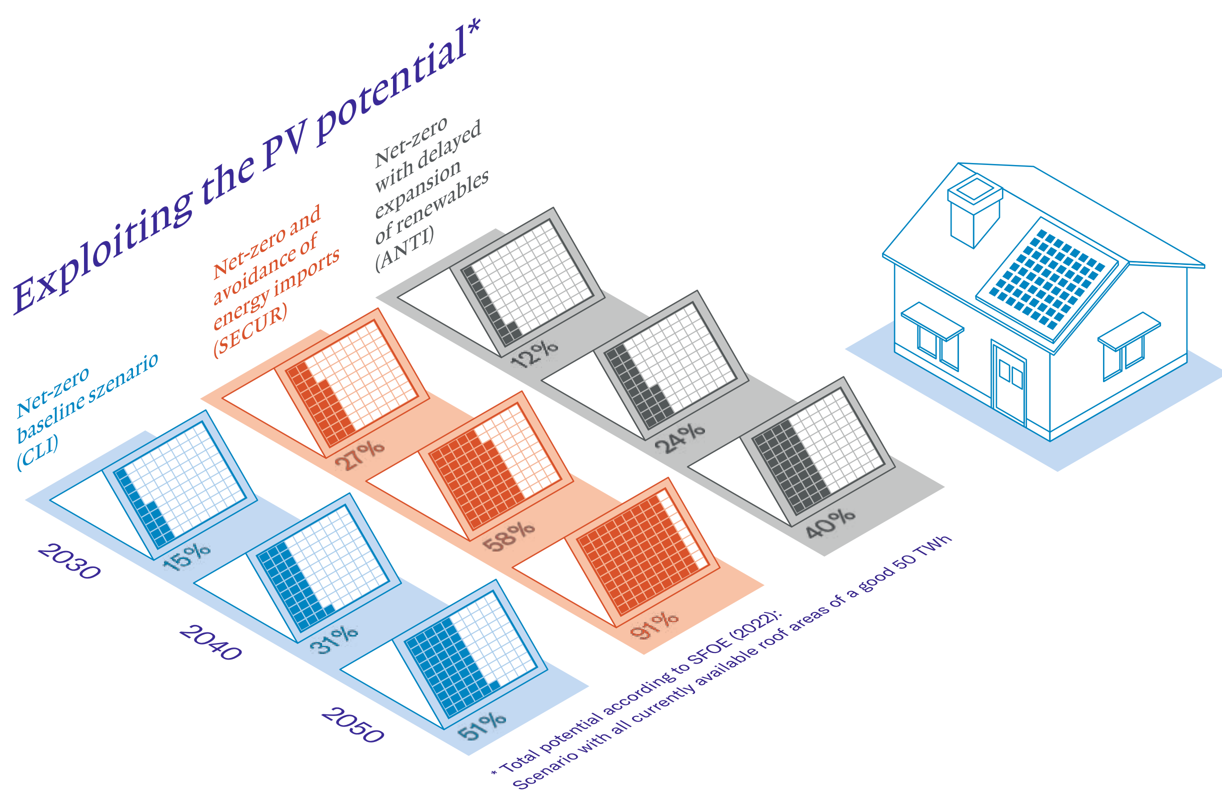
"Some events, however, cannot be predicted by even the best computational models, for example when a virus holds the world in suspense or a war threatens the reliable supply of fossil fuels," laboratory head McKenna points out. Such shock events are topics explored by SURE (Sustainable and Resilient Energy for Switzerland), a research project in the SWEET programme (Swiss Energy Research for the Energy Transition) of the Swiss Federal Office of Energy. In SWEET, ten research partners, led by Tom Kober, are investigating how the energy system behaves in the event of a shock and what countermeasures can be taken. With regard to the Covid-19 pandemic, experts are quite sure that the immediate effects on the energy system will only be short and medium term, and that long-term goals such as decarbonisation will not change.

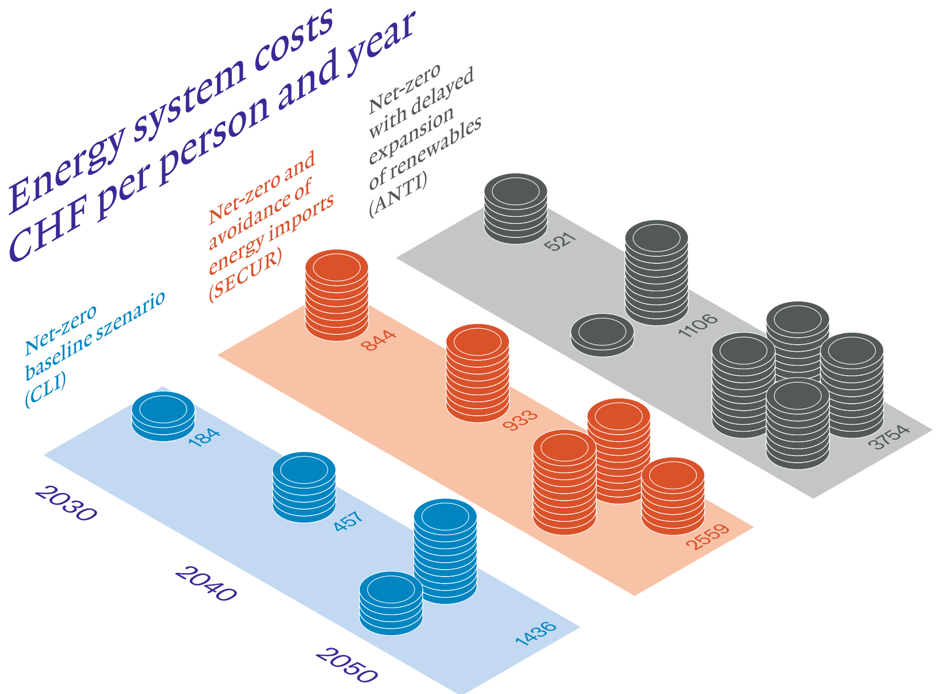
The war in Ukraine could be a different story. As a result, some scenarios in PSI's JASM report have suddenly been brought into sharp focus. Today around three-quarters of Switzerland's total annual energy consumption is imported. Besides decarbonisation, the SECUR scenario is designed to achieve independence from imports as rapidly as possible, for example by using domestic renewable energy to produce hydrogen. In such a scenario, it is not only necessary to increase electricity production, but also to conserve more energy and enhance the flexibility of the energy system to integrate large amounts of energy from renewable sources. This also makes climate protection efforts around two and a half times more expensive.

As an industrial engineer, Kober is particularly interested in such economic aspects of the transformation of energy systems, as well as in the technical interdependencies. The question is: What does it cost if we make this or that decision in a scenario, and what interactions result from this in a system as complex as the energy system? The answer is unambiguous: it's not going to be cheap. Society will have to bear substantial costs, depending on the scenario. No wonder: if Switzerland wants to get from its CO_2 output of 43.4 million tonnes per year (as of 2020) to net-zero by 2050, then in the future CO_2 emissions will have to decrease every year by one and a half million tonnes on average compared to the previous year. But there's also good news: this decarbonisation of the energy supply is technically possible and in principle affordable – if the measures are chosen wisely.

Looking at the costs of the baseline scenario in which CO_2 emissions fall by 40 percent by 2050 compared to 1990, one can see that the total costs of the energy system by 2050, compared to today, will more than double. There are additional costs associated with achieving the net-zero target. Depending on the scenario, these will be between around 180 and 840 Swiss francs per capita annually up to 2030. Up to 2050, the additional costs will be between 1,440 and 3,750 Swiss francs (see graphic page 16). Evangelos Panos explains the differences in costs between the scenarios: "The reasons for such a broad range are different developments in energy source prices, energy technologies, resource availability, market integration, acceptance of technologies and dependence on energy imports. If the framework conditions change, this results in a different technology mix, combined with rising costs for the energy system if the inexpensive climate protection options are only available to a limited extent."

So it's clear: the energy transition will be expensive – how expensive depends on political decisions. The hope of saving money by doing nothing is something Kober rejects outright: the ANTI scenario, in which more cost-effective measures for the energy transition such as the expansion of renewables make only slow progress, is the most expensive scenario of all. Instead of just 1,440 francs as in the net-zero baseline scenario (CLI), the Swiss would then have to pay an additional 3,750 francs per year in 2050. If expansion of renewable energy sources is delayed, hydrogen would become significantly less important, since the domestic resources for production would not be fully available. To compensate for this, measures to conserve energy would





Industrial engineer Tom Kober tries to use the scenarios, among other things, to investigate how the costs of the energy transition will develop. One thing is clear: it's going to get expensive (see graphic above).

have to be given preference, and energy from environmentally friendly sources would have to be imported from abroad at high prices. Even if Switzerland wants to be as independent as possible from energy imports, the additional costs of the energy transition would almost double in 2050 to 2,560 Swiss francs per year, mainly due to the accelerated installation of photovoltaics and better building insulation in combination with heat pumps.

One key to the success of all ambitious development paths, aside from the costs, is acceptance. In the ANTI scenario, the researchers assume the population takes a pessimistic and defensive stance, which would set the energy transition back by ten years. The referendum in June 2021, in which Swiss voters rejected important climate protection measures in the amended CO_2 Act, shows that this is not far-fetched.

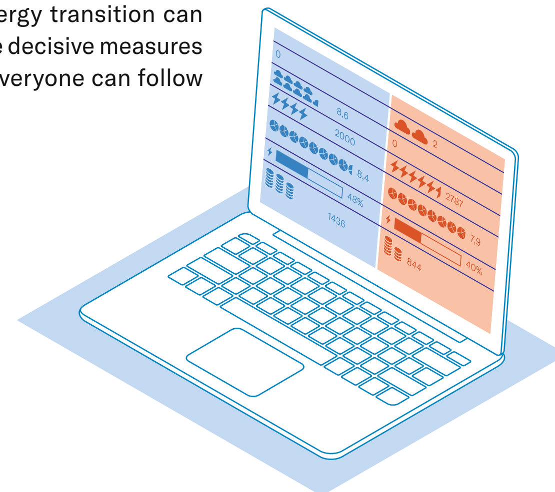
Kober also sees the world of finance as having an obligation. The energy system of the future is increasingly capital-intensive. Although people will save on fuel, larger sums must first be invested, for example in photovoltaic installations or hydrogen technology. Banks assess the risks of investments and distinguish between mature technologies like photovoltaics or thermal insulation, and other technologies that today are only on the way to market maturity. But the energy transition will only succeed if new technologies associated with hydrogen, or with separating CO_2 out of exhaust gases from power plants or incineration facilities, are introduced on a massive scale. Here new financing instruments and government guarantees are needed.

Which scenario is now the best or the most likely? As has been said: no scenario of the PSI JASM report predicts the future; none has only advantages, inasmuch as there is no good or bad. But there are a few basic principles common to all scenarios:

- A price must be put on greenhouse gas emissions – that means energy prices must reflect the costs for the environment and for people. In addition, the decarbonisation measures must be coordinated and implemented rapidly, otherwise it will get really expensive.

- Electricity from low-emission sources, especially renewables, is the raw material of the energy transition. Switzerland's power consumption could increase from around 60 terawatt-hours today to 80 in 2050. To meet this need and to compensate for the gradual phase-out of nuclear energy, the output from photovoltaics must at least double every decade.
- More weather-dependent electricity production, such as from photovoltaic and wind power plants, means that the energy system has to react much more flexibly. This requires additional energy buffers (short-term and seasonal) in the form of battery, thermal or chemical storage, as well as the willingness of consumers to adapt their energy consumption to the energy supply.
- Without the separation and underground storage of CO_2, the decarbonisation goals cannot be achieved. Switzerland must coordinate this with its neighbours.
- Openness to technology pays off. Competition combined with incentives can bring the best results at the lowest costs.

Research using the STEM model continues and will be extended to other aspects of the sustainability and resilience of the energy system, most notably the social impact of the energy transition. Tom Kober is optimistic that the energy transition can succeed: "What we need now are decisive measures and concrete regulations that everyone can follow to control carbon emissions." ◆



> "For the energy transition we also need new financing instruments and government guarantees."
>
> Tom Kober, head of the Energy Economics Group

6 million equations – one energy system

The trained software engineer and energy modeller Evangelos Panos has built up a complex computational model over the years with his colleague Kannan Ramachandran and a team of other researchers: STEM, the Swiss TIMES Energy System Model. It consists of six million equations with six million variables that describe various aspects of the Swiss energy system. The variables are linked in many dimensions via the equations. If you change one variable, such as the price of emitting a tonne of CO_2 or the expansion of photovoltaics, dozens of other variables change, sometimes in unforeseen ways.

It is inconceivable to work out such a gigantic system of equations with paper, pencil and pocket calculator. Even the special computer that Panos uses takes several hours to solve the system of equations for a single scenario. But the modelling of energy systems using different scenarios is more than that, because it involves converting specialist knowledge about the energy system from different disciplines into efficient algorithms in order to be able to calculate them using computers at all. Thus it's no wonder that it took months of meticulous, detailed work to calculate all of the scenarios and their variants in the JASM project.

In comparison to models from other research teams, PSI's STEM has some outstanding distinctive features – but naturally, it can't do everything. It is a model focused on technological and economic optimisation. For example, it does not make any statements as to how the scenarios in Switzerland will affect the labour market or value creation. The researchers also excluded emissions from international air traffic and emissions that occur abroad in connection with the importing of goods into Switzerland. Therefore, the modelling of the Swiss energy system is not a solo task of PSI, but a contribution embedded in cooperative research involving other renowned research groups: working together to ultimately draw a comprehensive picture, with as many facets as possible, of the transformation of the energy system.

Energy scenarios

The scenarios produced by PSI researchers are not forecasts, but rather assumptions as to how Switzerland's energy systems could change. Nevertheless, they broaden the view of possible developments.

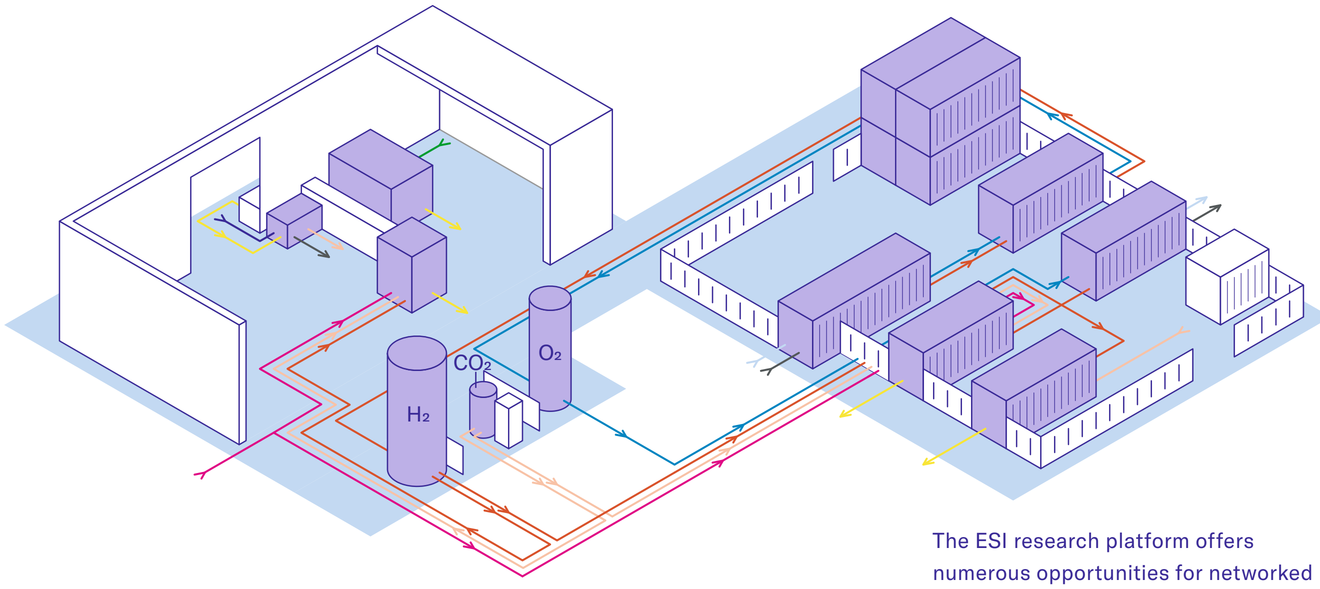
Net-zero baseline (CLI)

		2019	2030	2050
General indicators	CO_2 emissions per capita (tonne/year)	4,4	2,6	0
General indicators	CO_2 capture and storage/use (megatonne)	0	0	
General indicators	Primary energy consumption (watts) per person	3828	2999	
General indicators	Diversity of primary energy supply (Shannon-Wiener index: higher value = more diversity)	5,6	8	
General indicators	Share of electricity in final energy consumption	27 %	33 %	
General indicators	Annualised costs for the energy transition compared to baseline scenario (CHF/person)		184	
Supply side	Net imports (TWh) Petroleum products, natural gas, "climate-friendly molecules" (bioenergy, synthetic fuels, hydrogen), electricity	132	82	31
Supply side – Domestic Electricity production	Nuclear energy (TWh)	25	19	0
Supply side – Domestic Electricity production	Hydropower (TWh)	37	37	38
Supply side – Domestic Electricity production	Photovoltaics (TWh)	2	7	26
Supply side – Domestic Electricity production	Other (TWh)	4	7	14
Supply side	Additional electricity generation compared to 2019 (TWh)		3 %	
Supply side	Domestic production of bioenergy (TWh)	31	38	47
Supply side – Hydrogen production	Electrolysis (TWh)	0	1	6
Supply side – Hydrogen production	Other (methane steam reforming, biomass gasification) (TWh)	0	2	5
Supply side	Seasonal storage (TWh/year) mainly hydrogen	0	0	1.6
Demand side – Car fleet	Share of e-mobility (PHEV and BEV)	1 %	27 %	
Demand side – Car fleet	Share of fuel cell vehicles	0 %	0 %	
Demand side – Car fleet	Share of cars with internal combustion engines	99 %	73 %	
Demand side	Specific space heating demand (kWh/m³) averaged over all private residential buildings	86	75	
Demand side – Provision of space heating	Proportion of heat pumps	12 %	35 %	
Demand side – Provision of space heating	Proportion of district heating	4 %	6 %	
Demand side – Provision of space heating	Share of other renewable sources	10 %	10 %	

Basic assumptions for all scenarios:

	2030	2050
Population growth compared to 2019	9 %	21 %
Economic growth compared to 2019	16 %	24 %

	Net-zero and avoidance of energy imports (SECUR)		Net-zero with delayed expansion of renewables (ANTI)	
	2030	2050	2030	2050
	2	0	2,6	0
8,6	0	7,4	0	8,3
2000	2787	2248	2818	1754
8,4	7,9	6,9	7,3	7,5
48 %	40 %	49 %	36 %	49 %
1436	844	2559	521	3754
	57	1	81	33
	19	0	19	0
	37	39	37	38
	13	46	6	20
	7	18	7	12
14 %	13 %	51 %	2 %	3 %
	39	47	32	41
	3	26	0	0
	0	2	0	3
	0	2.2	0	0.1
83 %	29 %	61 %	25 %	81 %
17 %	1 %	39 %	0 %	7 %
0 %	70 %	0 %	75 %	12 %
45	55	39	60	37
77 %	45 %	72 %	36 %	74 %
9 %	8 %	11 %	8 %	14 %
14 %	19 %	17 %	17 %	10 %



The ESI research platform offers numerous opportunities for networked energy research.

Energy research at PSI

Cooperation for a secure energy supply
The Paul Scherrer Institute participates in many cooperative projects, either in a leadership role or as a partner. PSI led the **Swiss Competence Centre for Energy Research (SCCER) on Heat and Electricity Storage,** within the framework of the federally initiated Energy 2013-2020 funding programme of the Swiss Innovation Agency Innosuisse. Also, in a joint research project of five SCCERs, PSI prepared a **white paper on "Power-to-X"** for consideration by the Swiss Federal Energy Research Commission (CORE). The goal of the white paper is to gather together the most important findings currently available about Power-to-X technologies. Similarly, PSI led the energy research association **SCCER Biosweet,** in which up to 15 academic research groups and dozens of implementation partners took part, with a focus on biomass conversion processes. At present researchers from ten institutions, under PSI leadership, are investigating how best to make Switzerland's energy supply sustainable and resilient over the coming years. This is within the framework of a research project called **SURE** (SUstainable and Resilient Energy for Switzerland) funded through the Swiss Federal Office of Energy.

Networked platform
On the experiment platform **ESI** (Energy System Integration; see also graphic above), research and industry can test promising approaches for integrating new renewable energy sources such as sun, wind, and biomass into the energy system. Also, through the project **ReMaP,** the demonstrators of the ESI Platform are networked with the Empa research platforms ehub, NEST and move, as well as ETH Zurich and renowned partners from industry.

Efficient storage and conversion of energy
In the search for more efficient usage of energy, one area PSI is focusing on is the characterisation and development of materials for new energy storage media, including lithium-ion batteries. These will play an essential role in future hybrid, electric, and fuel-cell vehicles.

Safe use of nuclear energy
One key research focus is to gain an even better understanding of the processes in nuclear power plants, to contribute to their safe operation. These investigations are carried out by means of computer simulations, among other approaches. Another aspect is the safe disposal of radioactive waste. One goal of the work in this area is to determine how well suited different geological formations are for safely storing radioactive waste over long periods of time.

Holistic assessment of energy systems
Beyond investigations into individual energy technologies, PSI researchers also take a holistic view that includes comparisons of nuclear, fossil and renewable energy systems. Using this approach, they analyse the structures and effects of national and international energy systems to better understand the connections between energy, economy, environment and technology, or they explore different options for the energy supply. ◆

Destroying cancer cells

Susanne Geistlich, head of the Clinical Drug Supply Group at the Centre for Radiopharmaceutical Sciences at PSI and ETH Zurich, is on a mission to fight tumours. She and her PSI team produce radiopharmaceuticals to detect and destroy cancer cells in the body. To the right, in the before-and-after picture in the background, you see the successful result of one such treatment. Drug safety requires the highest levels of purity in the facilities and laboratory where production takes place. These were newly confirmed through the recent certification by Swissmedic, the Swiss Agency for Therapeutic Products.

Even everyday objects are subject to non-destructive examination at ANAXAM. CEO Christian Grünzweig and project manager Cynthia Chang philosophise about the distribution of sealant in a tin can.

IN SWITZERLAND

Of fusion reactors, fuel cells, and tin cans

Whether everyday objects or high-tech materials for renewable energy technologies: for more than three years now, the technology transfer centre ANAXAM has been facilitating access to the large research facilities at PSI and supporting small and medium-sized enterprises (SMEs), start-ups and large companies worldwide with a complete package of services to use these facilities for their own material analytics.

Text: Benjamin A. Senn

150 million degrees Celsius – that's how hot the plasma is supposed to be inside the fusion test reactor ITER in Cadarache in southern France, which researchers want to use to put a future energy production technology to the test. For comparison: we can bake the perfect, crispy pizza at around 350 degrees Celsius; lava flows, depending on the type of rock, at a temperature of more than 1,000 degrees Celsius; and there is a remarkable heat of around 15 million degrees Celsius in the interior of the sun. The unimaginable 150 million degrees Celsius researchers plan to achieve at ITER would be unique in our solar system. Even if the hot plasma in this so-called tokamak never comes directly into contact with the walls, one can vaguely imagine what enormous thermomechanical and radiation-intensive stresses these materials will have to withstand.

Before the start of test operations under such infernal conditions, the materials must be subjected to controlled stresses, and any structural changes inside them must be checked with high precision. This is exactly why the technology transfer centre ANAXAM offers many state-of-the-art analytic methods that can be carried out at the large research facilities of PSI.

Precise materials analysis

ANAXAM is a non-profit association founded in 2019 by the Paul Scherrer Institute, the University of Applied Sciences and Arts Northwestern Switzerland, the Swiss Nanoscience Institute and the Canton of Aargau. The association's goal is to facilitate access to the large research facilities for industrial projects. The acronym ANAXAM stands for **A**nalytics with **N**eutrons **A**nd **X**-ray **A**dvanced **M**anufacturing.

Neutron beams and synchrotron radiation – a special form of X-rays – can be used to examine objects non-destructively. This not only allows a three-dimensional view inside the object, but also lets us identify and localise the different chemical elements through spectroscopy, or characterise a material morphologically through diffraction and small-angle scattering. Depending on the object, neutron and synchrotron beams can be applied one after the other, and the results can be combined, for example, to achieve different contrasts in the imaging.

The sheer dimensions of PSI's large research facilities allow material analytics that is simply impossible in conventional industrial laboratories. "For example, the Swiss Light Source SLS at PSI, which is used to generate X-rays, delivers a brilliance that exceeds that of laboratory-scale X-ray sources by an impressive factor of ten billion," says Christian Grünzweig, ANAXAM's CEO. In Switzerland, analytics using neutron and synchrotron radiation is only possible at the large research facilities SLS and the Swiss Spallation Neutron Source SINQ at the PSI.

For companies to benefit from these complex facilities, ANAXAM's core team of six is on hand to provide advice and practical assistance. "We are a one-stop shop. Customers come to us with a problem, we advise them, we purchase measurement time from PSI, we set up a specific infrastructure if needed, and we carry out the measurements, including data analysis. The customers receive the data and their interpretation in a final report," explains ANAXAM project manager Cynthia Chang. Before joining ANAXAM, materials scientist Cynthia Chang and Christian Grünzweig were engaged in analytics research at PSI – Chang with synchrotron and Grünzweig with neutron analytics. Their expertise is perfectly complementary in their current positions. Together with their team, with a wide range of backgrounds in research and industry, they are reinforcing Switzerland's status as an industrial location using the most advanced analytical methods for the products and processes of tomorrow.

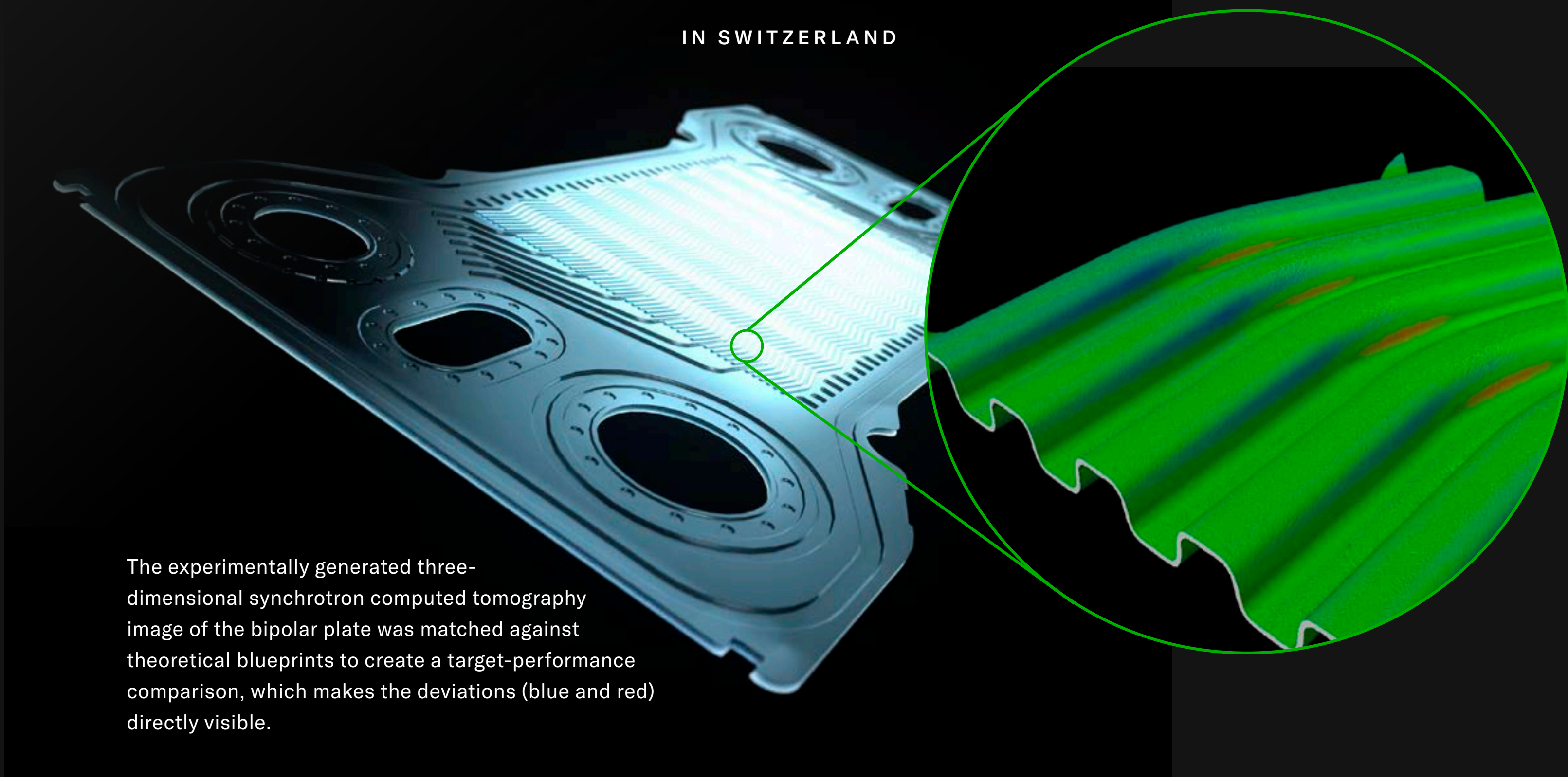
Fuel cell components made in Switzerland

Fuel cells are considered an important technology for electromobility in the future. Inside such a cell, hydrogen and oxygen react to produce water, releasing energy in the form of electricity and heat.

The central component in a fuel cell is the so-called bipolar plate (see figure, top of page 25), where the electrochemical reaction takes place. With respect to its channel geometry (the fine grooves seen in the figure), this plate must be designed in such a way that oxygen and hydrogen can be distributed evenly, the heat of the reaction can be dissipated efficiently and the water resulting from the reaction can be reliably transported away. The plate must also be made with a precise fit to ensure the cells are gas-tight.

To achieve this precision, bipolar plates are conventionally cast from the material graphite. This process is very complex and expensive, however – graphite bipolar plates account for up to 40 percent of the production cost of a fuel cell. In addition, they are very heavy, which in turn has a negative effect on performance.

To address these problems, the company Feintool developed a process enabling bipolar plates to be manufactured from extremely thin stainless steel sheets in a single production step. Besides offering a faster and cheaper production method, the use of stainless steel also results in lower overall weight and reduced volume compared to fuel



The experimentally generated three-dimensional synchrotron computed tomography image of the bipolar plate was matched against theoretical blueprints to create a target-performance comparison, which makes the deviations (blue and red) directly visible.

cells with conventional graphite plates. However, forming and cutting out such a plate demands maximum precision, since the metal used is extremely thin (0.075 millimetre) – the sheet metal press has to work with a very delicate touch.

Instead of time-consuming iterative testing to ensure the perfect interaction of press and tools, Feintool turned to ANAXAM. Cynthia Chang explains the team's successful collaboration with Feintool: "We were able to examine the manufactured bipolar plates using high-resolution synchrotron computed tomography and thus characterise their three-dimensional structure. This enabled us to determine exactly where the channel geometry shows deviations and where the production process needs to be further optimised."

Everyone is welcome at ANAXAM

But it's not only high-tech materials like bipolar plates that find their way to PSI by way of ANAXAM. Everyday objects are also subject to non-destructive examination, so it can happen that the CEO and the project manager sometimes may philosophise about the structure of a tin can.

Its most important property is that it is airtight. The German company Henkel Adhesive Technologies uses a special sealant that is applied between the rim of the can and the lid before these two components are folded together. "We used high-resolution neutron computed tomography for this project. This enabled us to analyse the distribution of the sealant in the seam of the can non-destructively and three-dimensionally. This helps the company understand potential faults in application, which in turn can help to extend the shelf life of the packaging," Grünzweig explains.

"It doesn't matter whether a customer comes to us with an everyday object or a high-tech product," the ANAXAM boss continues. "Because what can be measured can also be improved. That's why a large multinational or the smallest SME can benefit from our methods and, thanks to state-of-the-art material analytics, further optimise its products or processes."

ENEA, Italy's national agency for new technologies, energy and sustainable development – which is co-developing the wall materials for the ITER tokamak in Cadarache – was also able to benefit from this expertise. ENEA managed to characterise microstructural changes in their materials that were caused by the harsh conditions in the plasma. For this project, ANAXAM employed a number of unique neutron analysis methods. It was also possible to mimic the plasma-generated radiation exposure of the wall materials by means of neutron beams at PSI. In this way ANAXAM made an important contribution to one of the many puzzle pieces that have to come together to pave the way towards a functioning fusion reactor, and thus a possible energy source of the future. ◆

Latest PSI research news

1 Aerosol pollution map of Europe

An international team led by PSI has analysed measurement data on air pollution collected at 22 sites in both urban and rural areas throughout Europe. They concentrated on pollution due to so-called aerosols. Also known as fine dust or particulate matter, these pollutants can be harmful to human health, in part because these airborne particles penetrate deep inside the lungs. While the composition of the fine dust varied across the sites, the researchers consistently identified one main source of aerosol pollution: heating residential buildings with solid fuels such as wood and coal. The data obtained in this way should help to improve models of air quality.

Further information:
http://psi.ch/en/node/51953

14 European countries were sources of data for a new study of aerosol pollution.

<1 micrometre: the size of the particles of the organic aerosols studied.

2 Visiting the researchers

PSI is searching for sustainable solutions to central issues for society, business and science. The newly redesigned and recently reopened exhibition in the PSI Visitor Centre provides insight into current research. How do we ensure our future energy supply in a way that conserves natural resources? What does medicine have in store for us in the future? Which new technologies will bring further progress to our society? Thirteen interactive thematic islands invite visitors to discover PSI and its wide-ranging research. Questions about storing energy from renewable sources are central here, as are the further development of medical diagnostics and therapies, the search for new materials for the development of novel electronics and the realisation of future technologies such as quantum computers.

Further information:
http://psi.ch/en/node/51489

3 Finding anti-cancer agents

Agents that act on the cytoskeleton are among the most effective drugs against cancer. Researchers at PSI and the Italian Institute of Technology IIT have developed an especially potent substance that disables a protein in the cell skeleton, leading to cell death. For their work, they used computers to combine the structures of three molecular fragments that preferentially dock at a specific point, or binding, on the cytoskeleton. After using computational design in the development stage, the researchers subsequently synthesised the chemical compound in the laboratory. They hoped the compound produced in this way would be more effective than previously known active ingredients. Using measurements at the Swiss Light Source SLS, the researchers checked how the molecule actually docks to the binding site. In two further cycles, they improved the substance. They were then satisfied with the compound, which they dubbed 'Todalam'. They have already been able to demonstrate its deadly effect in cell cultures.

Further information:
http://psi.ch/en/node/51112

4 A look into the magnetic future

Researchers at PSI have observed for the first time how tiny magnets in a special arrangement reorient themselves solely as a result of temperature changes. This insight into processes that take place within so-called artificial spin ice could play an important role in the development of novel high-performance computers. When water freezes to form ice, its molecules, with their hydrogen and oxygen atoms, arrange themselves in a complex structure. In the laboratory, it is possible to produce crystals in which the elementary magnetic moments, the so-called spins, form structures comparable to ice. That's why researchers also refer to these structures as spin ice. Now the scientists have managed to produce artificial spin ice that essentially consists of nanomagnets that are so small that their orientation can only change as a result of temperature. The control of these different magnetic phases could be interesting for new kinds of data processing. At PSI investigations are under way to determine how the complexity of artificial spin ice could be used for novel high-performance computers with low power consumption.

Further information:
http://psi.ch/en/node/50890

Music at PSI

Sounds coming from technical devices and scientific research processes are the order of the day at PSI. We already presented a tiny excerpt of the PSI soundscape in the 1/2022 issue. Now and then, though, completely different sounds ring out on both sides of the Aare campus, because many of our researchers are also musicians. Let us introduce you to some of them.

Text: Christian Heid

The band

When Robert Sobota (drums), Ludmila Leroy (bass and vocals), and Peter Alpert (guitar) cut loose, a powerful, groovy sound reverberates from the PSI research building. They came together with their own respective preferences: the guitarist, founder of the PSIchedelics, goes for grunge; the singer especially loves the songs of Freddie Mercury, the long-deceased lead singer of the group Queen; the drummer has a soft spot for progressive and art-rock. Their research interests, too, are different. Ludmila Leroy works in solid-state physics at the X-ray free-electron laser SwissFEL and at the Swiss Light Source SLS. Peter Alpert works with airborne particles at the SLS. And for Robert Sobota the focus is on next-generation superconductors. Yet anyone who has heard them immediately knows: on the musical level, they're in perfect harmony!


Ibanez
PEAVEY
VOX
VOX

Bouzouki

At the age of five, Ioannis Samaropoulos had already begun studying a musical instrument. First violin, then guitar as well, before he decided on the bouzouki, a Greek stringed instrument, at the age of 11. The starting point was rembetiko, a musical style born in the early 20th century with a confluence of Greek folk music and Ottoman musical traditions. In these songs, homesickness and longing are common themes. Ionnis Samaropoulos partly financed his university studies by playing bouzouki and singing. He now works at PSI as an incident analysis specialist in the area of radiation protection and safety.

Viola

Originally, Lily Bossin studied classical guitar at the music conservatory in her spare time, but then – in search of a “more social” instrument – she opted for the viola and its full, soft and somewhat melancholy sound. She especially loves baroque pieces such as those by 18th century German composer Georg Philipp Telemann. At PSI Lily Bossin works in the area of radiation protection and conducts research into new solutions and new materials for measuring the radiation dose from ionising radiation.

Oboe

The oboe has an expressive tone that extends from nasal and light to dark and velvety and is associated with the sound of ducks, as can be heard in the symphonic fairy tale *Peter and the Wolf.* Margaux Schmeltz, like anyone who wants to bring forth melodious tones from an oboe, spends a lot of time shaping the double-reed mouthpiece, which resembles a crushed drinking straw. Among her favourite pieces are baroque compositions by Tomaso Albinoni and modern sonatas by Francis Poulenc. At PSI she is engaged with the dynamic mapping of systems in motion, particularly in connection with human hearing, to gain new insights into their biomechanical properties.

Alphorn

The tones that Micha Dehler elicits from the alphorn using articulation techniques known as growl, bend and shake, can drown out the seemingly endless technical background noise inside the Swiss Light Source SLS for a few moments. Actually at home in jazz, where he plays trumpet and flute, he is also a big fan of the piece *Sura Kees*, a funky piece for alphorn and big band by the Aargau composer Urs Erdin. At PSI he is working on the SLS update to be implemented by 2025, concentrating in particular on calculations to prevent beam instabilities.

IN PERSON

The best of both worlds

Annalisa Manera's career has taken her through half of Europe and to the USA. Now she is a nuclear researcher at PSI and a professor at ETH Zurich. She exudes enthusiasm for her subject and never loses sight of the big picture.

Text: Laura Hennemann

Anyone who thinks it's just the same arguments that are always trotted out in the energy debate has never talked with Annalisa Manera. "There is no energy source that doesn't generate waste. And none whose risk is absolutely zero," the researcher says.

Manera, in her late 40s with curly brown hair, works as a scientist at PSI, where she has been leading a group for over a year now in the Nuclear Energy and Safety Division that focuses on fluid dynamics and heat transport. She is also Professor of Nuclear Systems and Multiphase Flows at ETH Zurich. In short: she knows all about nuclear energy.

But anyone who expects that nuclear power takes precedence over everything else for her is wrong again. "We should put as many solar panels as possible on the roofs of our houses! Photovoltaics are perfect for covering most of our personal needs," she says. She speaks briskly and clearly, in perfect American English with a trace of an Italian accent – Manera was born in southern Italy.

What quickly becomes clear: if you move away from accepted viewpoints, things can get complex. And it's then that Manera's eyes sparkle happily – here she's in her element. She approaches complexity with a sharp mind and pragmatic attitude.

This is already evident in her choice of a major: "I fell in love with physics and mathematics. I just wanted to be able to understand and explain everything. But the career prospects in physics at that time, in the 1990s in Italy, were not so good." So she enrolled at the University of Pisa to study engineering. "Here nuclear engineering had the most to offer me in terms of physics and mathematics, and I was still able to get a master's degree in engineering."

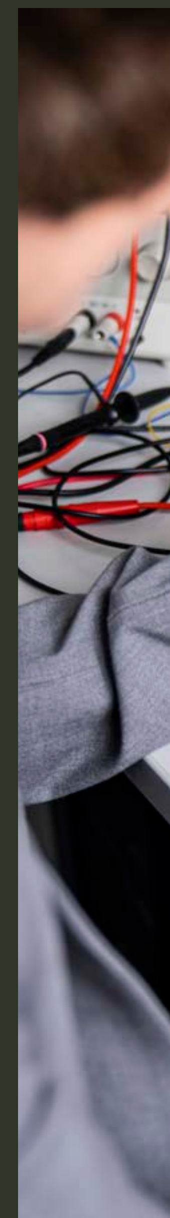
Changing countries

In 1998 she went abroad for her master's thesis, to the Technical University of Delft in the Netherlands. And evidently she did well in academia: she was immediately offered a PhD position, which she accepted, and then an assistant professorship, which she declined. "I wanted to experience a different scientific environment and broaden my horizons." She went to Germany for two years and worked as a scientist at the Helmholtz-Zentrum Dresden-Rossendorf.

The next stage in her career brought her to Switzerland for the first time, in 2006. She was curious to see if a job in industry was something for her, and started at a consulting company in Dättwil, Aargau. One of her projects was to evaluate the different types of nuclear reactors on the market, in order to develop recommendations for interested countries. "But in the first three months I realised that this work didn't challenge me enough," she says matter-of-factly, as if that suggested nothing about her ambitions.

She stayed in Aargau but went back to research: at PSI. Here Manera's career again took a steep turn upwards, and after just six months she was head of the group conducting research into the behaviour of nuclear systems. She remained in this position for five years.

Her next position was a professorship, but again abroad, at the University of Michigan in the USA. "In the USA, Michigan is number one for nuclear engineering research," Manera says. "And I liked the atmosphere there."



She stayed ten years in Michigan, where her child was born. Today Manera is a single mother with a ten-year-old son.

Manera has been back in Switzerland since the summer of 2021, with dual status at ETH Zurich and PSI. And she feels she has really arrived in Switzerland. “I now live with my son in a small town near Baden.” For her, it is ideally located between ETH Zurich and PSI. It’s also a good starting point for excursions. “We often do something on weekends, go hiking with other families or visit a museum.”

It also seems as if one aspect of Manera’s work has become something of a hobby: the researcher is in demand in the media, as an expert on energy security in times of climate change. “I get a lot of interview requests. And I try, as much as possible, not to turn them down.”

What motivates her above all is the chance to challenge popular but unfounded claims: “I often see misleading statements in the media.” Naturally she is keen to correct them. For example, she explains that neither an accident like the one in Chernobyl nor the one in Fukushima can be repeated in Switzerland: “Chernobyl was a totally different reactor. This kind of accident can be completely ruled out in Switzerland on the basis of physical laws.” A catastrophe like Fukushima will also be prevented by the continuous improvements which local reactors underwent. Something else is important to Manera: “In my interviews, I try to translate technical concepts into language that is easier for the general public to understand.” And she adds: “I just don’t want decisions to be made on the basis of misinformation.”

A table full of electronics

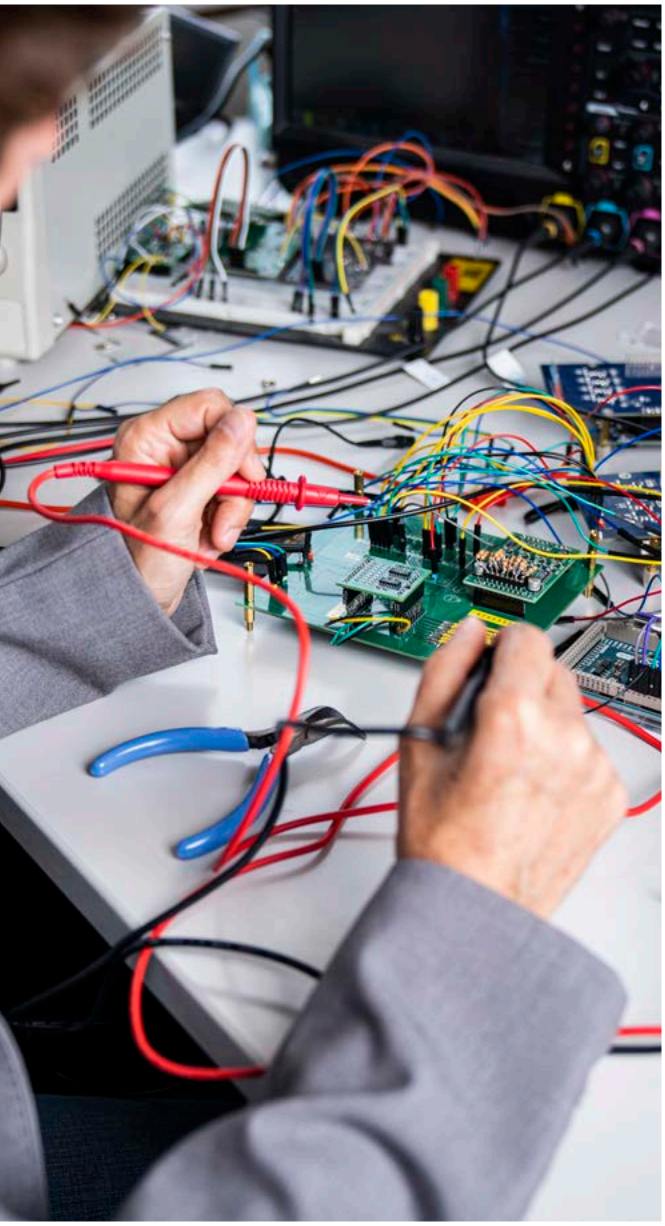
Even in a period when nuclear energy is being phased out, Manera is convinced that research in this area must be continued. “In Switzerland, we will need specialist knowledge on nuclear issues for decades to come, especially when it comes to dismantling the plants. And as long as other countries continue to have nuclear energy, we should not leave future advances in knowledge to them alone.”

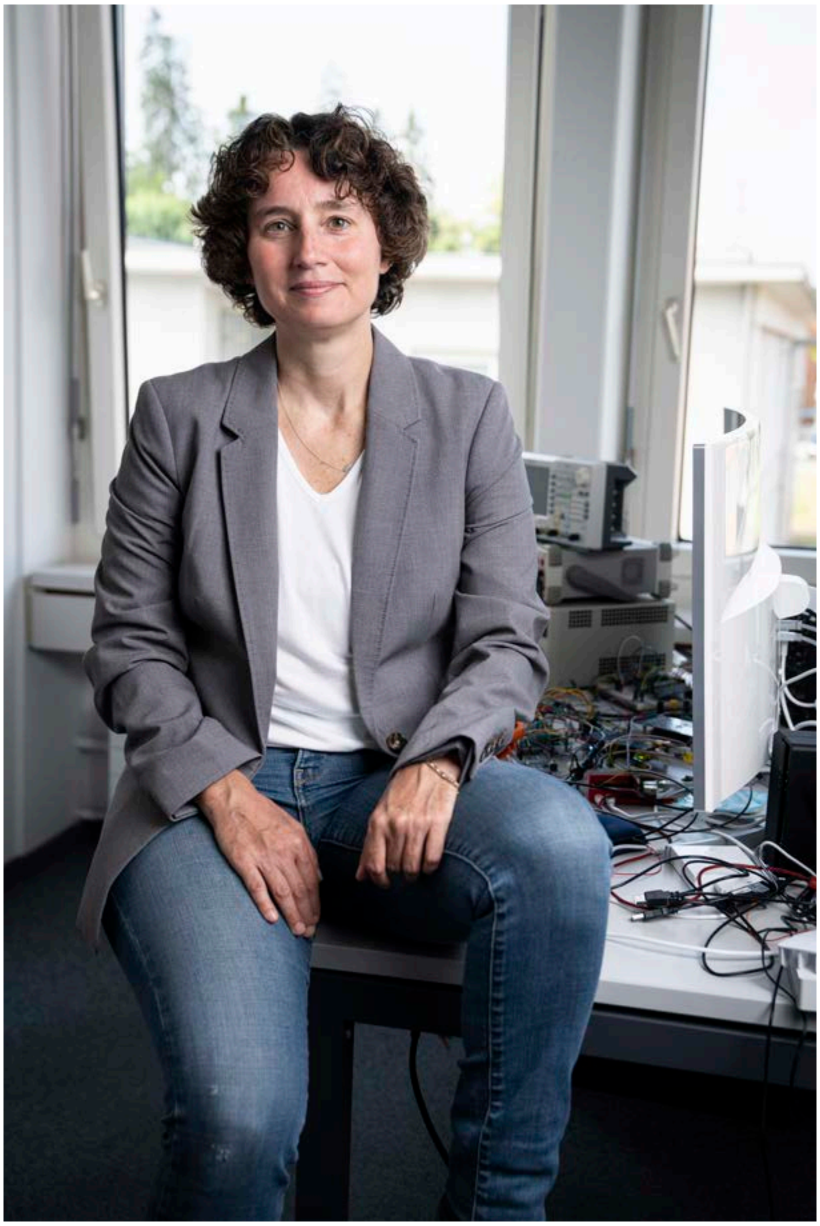
She also feels at home because the Swiss research landscape appeals to her. In the USA there is no basic funding for science, Manera says; everything has to be raised through third-party funding. This in turn can be achieved primarily through collaborations with other researchers. So Manera has built up a network of her own. “And now I have the best of both worlds,” she says. “I benefit from my many contacts. And because I can now rely on stable funding for my laboratory here in Switzerland, I have more time for actual research.” She finds the atmosphere at PSI to be a good mix of aspiration and constructive freedom: “Here, if necessary, I can pause and take time for in-depth reflection.”

One of the topics she and her group are currently working on is passive cooling – that is, how it might be possible to operate a reactor whose cooling liquid would circulate solely on the basis of physical principles. “When you have a pump, the behaviour of the liquid is quite predictable. Simulating and understanding passive flow behaviour, on the other hand, requires much more complex computer models.” In parallel with these theoretical calculations, her research group at ETH Zurich is conducting experiments that reproduce flow behaviour on a smaller scale. The work at the two institutions appears to go hand in hand: at PSI, Manera points to an office table that is covered with colourful electronic components. “We design and build our own ultrahigh-resolution measuring devices for the experiments.”

Manera has to run. She’s about to have a meeting two buildings further down the PSI campus with representatives of the European Space Agency ESA. “A Mars mission will not be feasible without nuclear energy,” she says on her way out.

It would be great to listen to her some more and be infected by her enthusiasm for applied physics. Manera has so many numbers and correlations at her fingertips, yet she never talks down from a superior position. But both of her calendars – for PSI and ETH Zurich – are full. She waves goodbye and disappears in the direction of her next meeting. ◆

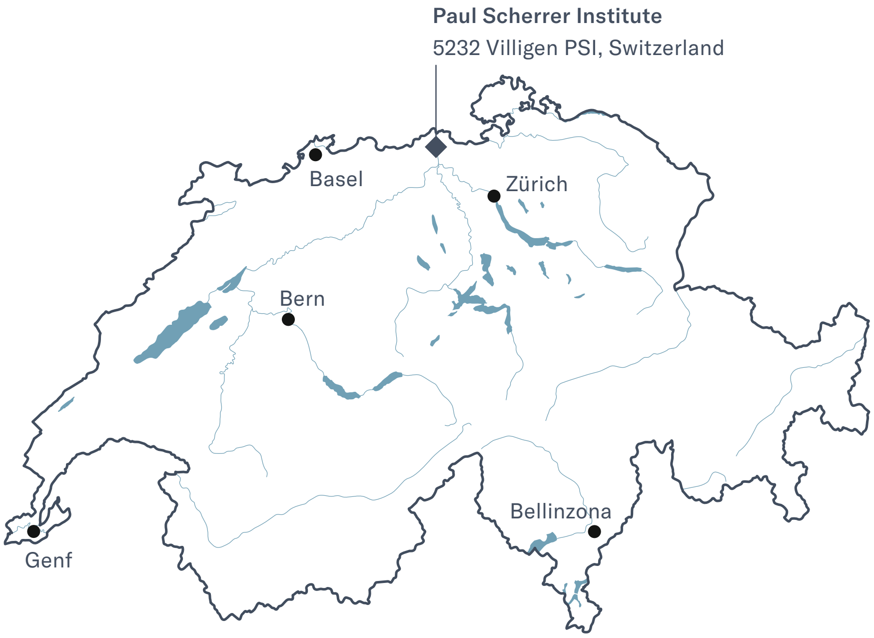




“I wanted to experience a different scientific environment and broaden my horizons.”

Annalisa Manera, head of the Thermofluid Experiments and Modelling Group, PSI, and Professor of Nuclear Systems and Multiphase Flows, ETH Zurich

From our base in Aargau
we conduct research for Switzerland
as part of a global collaboration.



5

large research facilities that are unique in Switzerland

800

scientific articles a year based on the experiments performed at PSI's large research facilities

5,000

visits every year from scientists from across the globe who perform experiments at our large research facilities

5232 is Switzerland's prime address for experiments on large research facilities. The Paul Scherrer Institute PSI even has its own postcode, a distinction that seems justified for an institute that extends over 342,000 square metres, has its own bridge across the River Aare, and has around 2,200 employees – more people than in most of the surrounding villages.

PSI is situated on both banks of the River Aare in the canton of Aargau, in the municipal areas of Villigen and Würenlingen. Its main areas of research are in the natural sciences and engineering. Funded by the federal government, it belongs to the domain of the Swiss Federal Institute of Technology (ETH Domain), which also includes ETH Zurich, EPFL Lausanne, and the research institutes Eawag (Swiss Federal Institute of Aquatic Science and Technology), Empa (Swiss Federal Laboratories for Materials Science and Technology) and WSL (Swiss Federal Institute for Forest, Snow, and Landscape Research). We conduct basic and applied research and thus work on sustainable solutions for central questions from society, science and business.

Complex large research facilities

Switzerland's federal government has given PSI the mandate to develop, build, and operate large, complex research facilities. These are the only such facilities within Switzerland, and some are the only ones in the world.

Running experiments at our large research facilities enables many scientists from the most diverse disciplines to gain fundamental insights for their work. The construction and operation of these kinds of facilities involve so much time, effort, and cost that comparable measurement equipment is not available to academic and industrial research groups at their own institutions. That is why we keep our facilities open to all researchers worldwide.

To obtain a time slot to use the experimental stations, however, both Swiss and foreign scientists first have to apply to PSI. Selection committees comprising experts from all over the world assess the scientific quality of these applications and recommend to PSI which candidates should be given measurement time. Even though there are around 40 measuring stations where experiments can be carried out at the same time, there is never enough capacity for all of the proposals submitted – around one-half to two thirds have to be rejected.

Around 1,900 experiments are performed every year at PSI's large research facilities. Time slots are free of charge for all researchers working in academia. In a special process, users from private industry can buy time to carry out proprietary research and use the PSI facilities for their own applied research. For this, PSI offers special research and development services.

PSI operates five large research facilities in total where the internal processes of materials, biomolecules, and technical devices to explore the processes taking place inside them. Here scientists use different beams to "illuminate" the samples they want to investigate in their experiments. The beams available for this range from particles (neutrons or muons) to intense X-ray light from a synchrotron or X-ray laser source. The different types of beams allow a wide variety of material properties to be studied at PSI. The high complexity and cost of the facilities is due to the massive size of the accelerators needed to generate the different beams.

Three main areas of research

However, PSI not only acts as a service provider for researchers, but also carries out an ambitious research programme of its own. The findings produced by PSI scientists help us to understand the world better, and also lay the foundation for developing new types of equipment and medical treatments.

At the same time, our own research is an important prerequisite for the success of our user service programme for the large research facilities. Only researchers personally involved in current scientific developments in the fields external researchers are working in can support them in their investigations and further refine the facilities to ensure they continue to meet the needs of cutting-edge research in the future.

PSI has three main areas of research. In the area of Matter and Materials, scientists study the internal structure of different materials. These results contribute towards a better understanding of processes occurring in nature and provide starting points in the development of new materials for technical and medical applications.

In the Energy and Environment area, activities focus on the development of new technologies to facilitate the creation of a sustainable and secure supply of energy, as well as an uncontaminated environment.

In the Human Health area, researchers search for the causes of illnesses and explore potential treatment methods. Their fundamental research activities also include the elucidation of generic processes in living organisms. In addition to research activities, PSI operates Switzerland's sole facility for the treatment of specific malignant tumours using protons. This particularly sensitive procedure allows tumours to be destroyed in a targeted manner, leaving the surrounding tissue largely undamaged.

The brains behind the machines

The work at PSI's large research facilities is challenging. Our researchers, engineers, and professionals are highly specialised experts. It is important for us to foster this expertise. So we want our employees to pass on their knowledge to the next generation, who will then put it to use in a variety of professional positions, not just at PSI. Around a quarter of our staff are therefore apprentices, doctoral students, or postdocs.

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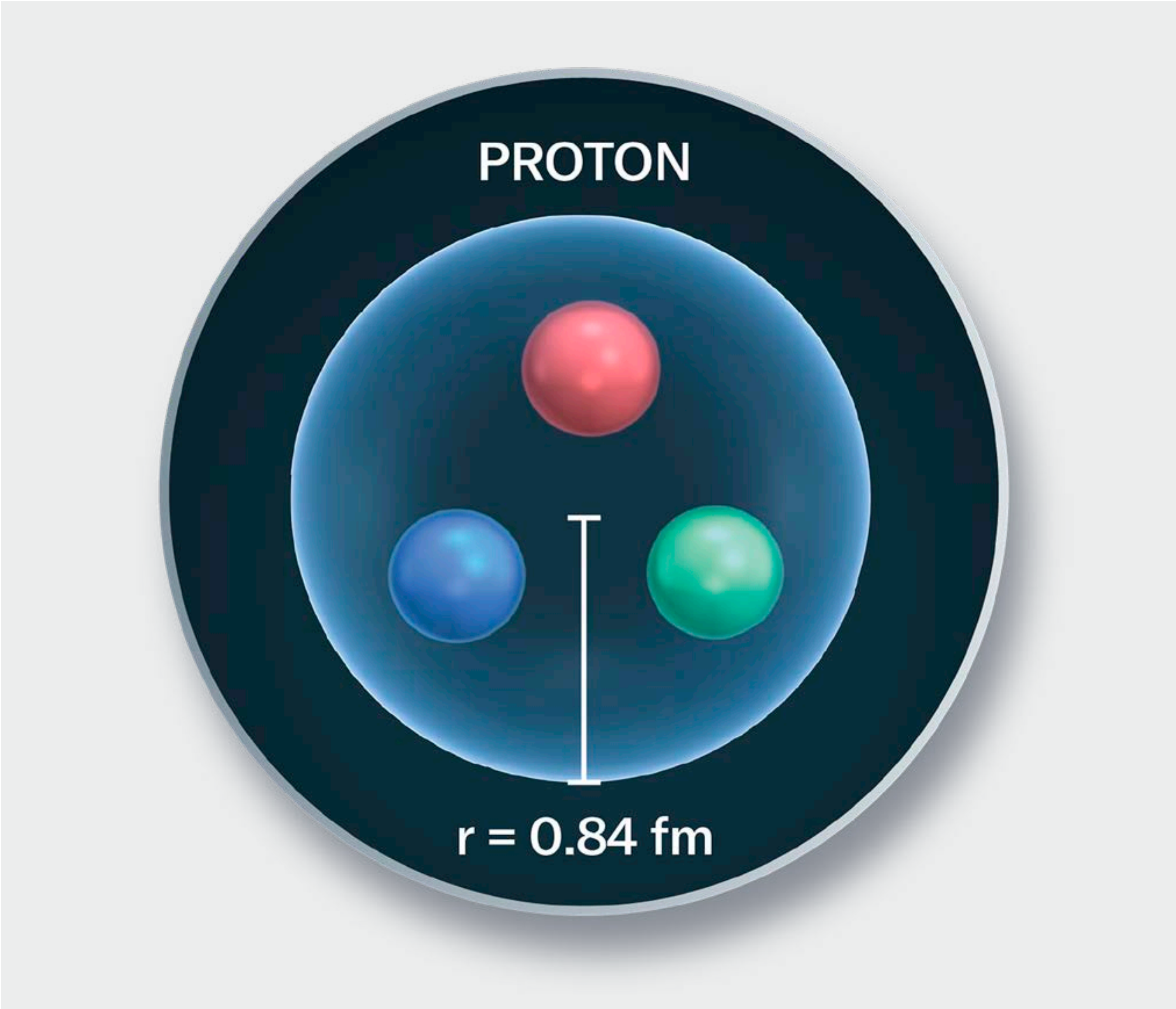
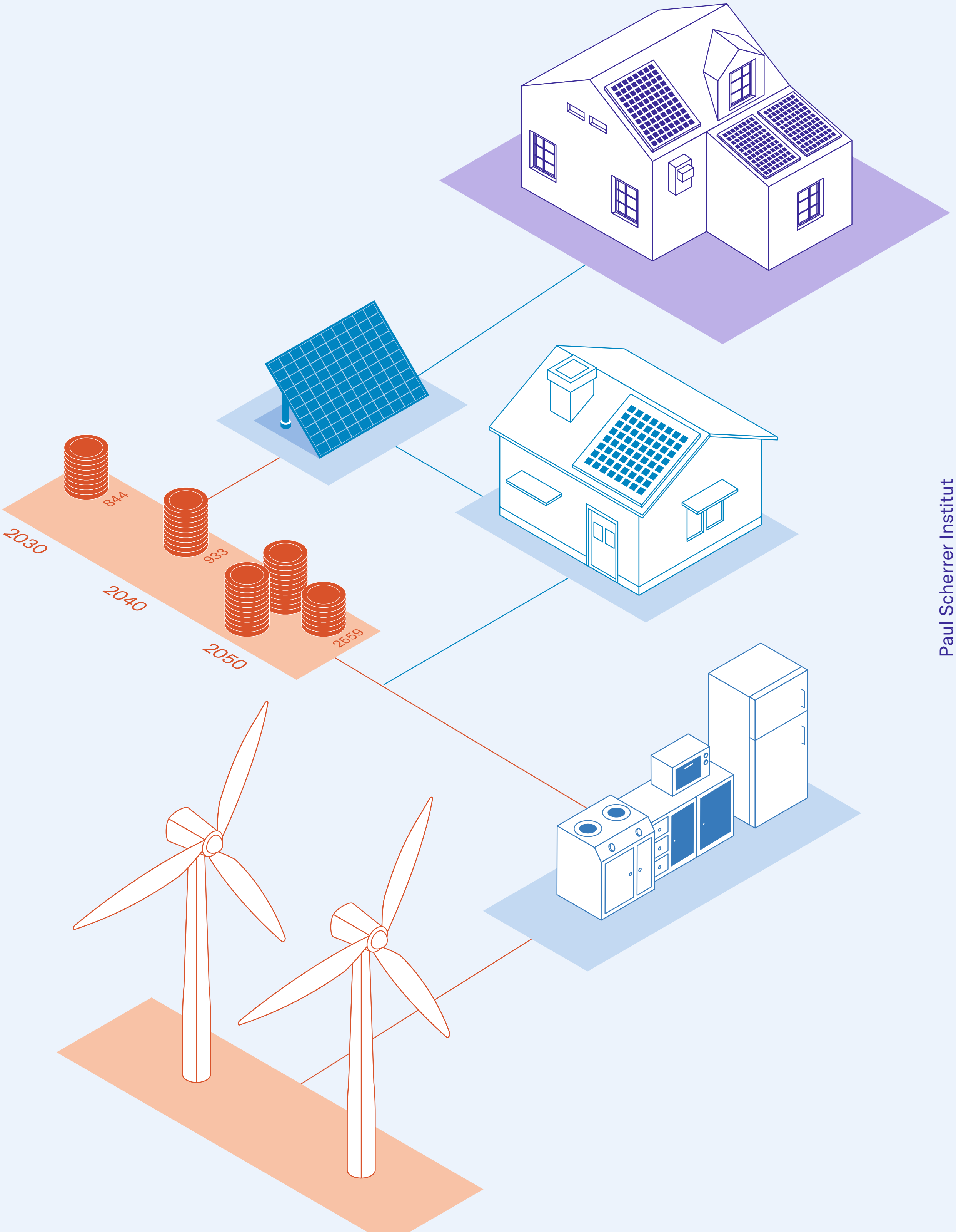


Coming up in the next issue

Researchers at the Paul Scherrer Institute are seeking answers to central questions concerning the basic structures of matter and fundamental functional principles of nature. They investigate the structure and properties of atoms and elementary particles. In doing so, they push the limits of knowledge and set out in search of nature's last mysteries. With the large research facilities of PSI they can, for example, measure the diameter of particles such as the proton or the helium nucleus more precisely than ever before, or pursue phenomena that have never yet been measured – such as the electric dipole moment of the neutron or a particular decay of a muon. The results of this research even have the potential to change the fundamentals of physics as we know them today.



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