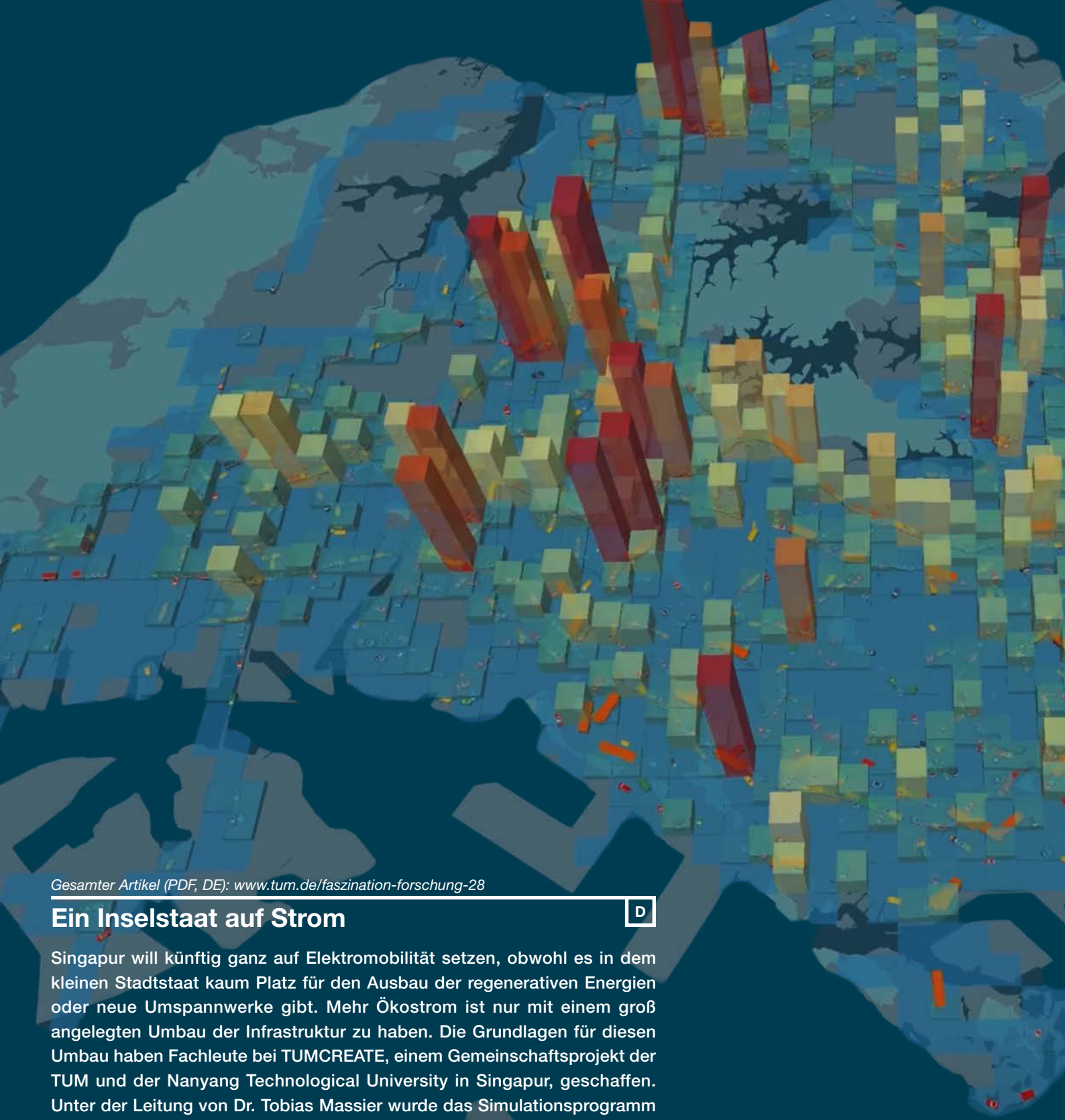


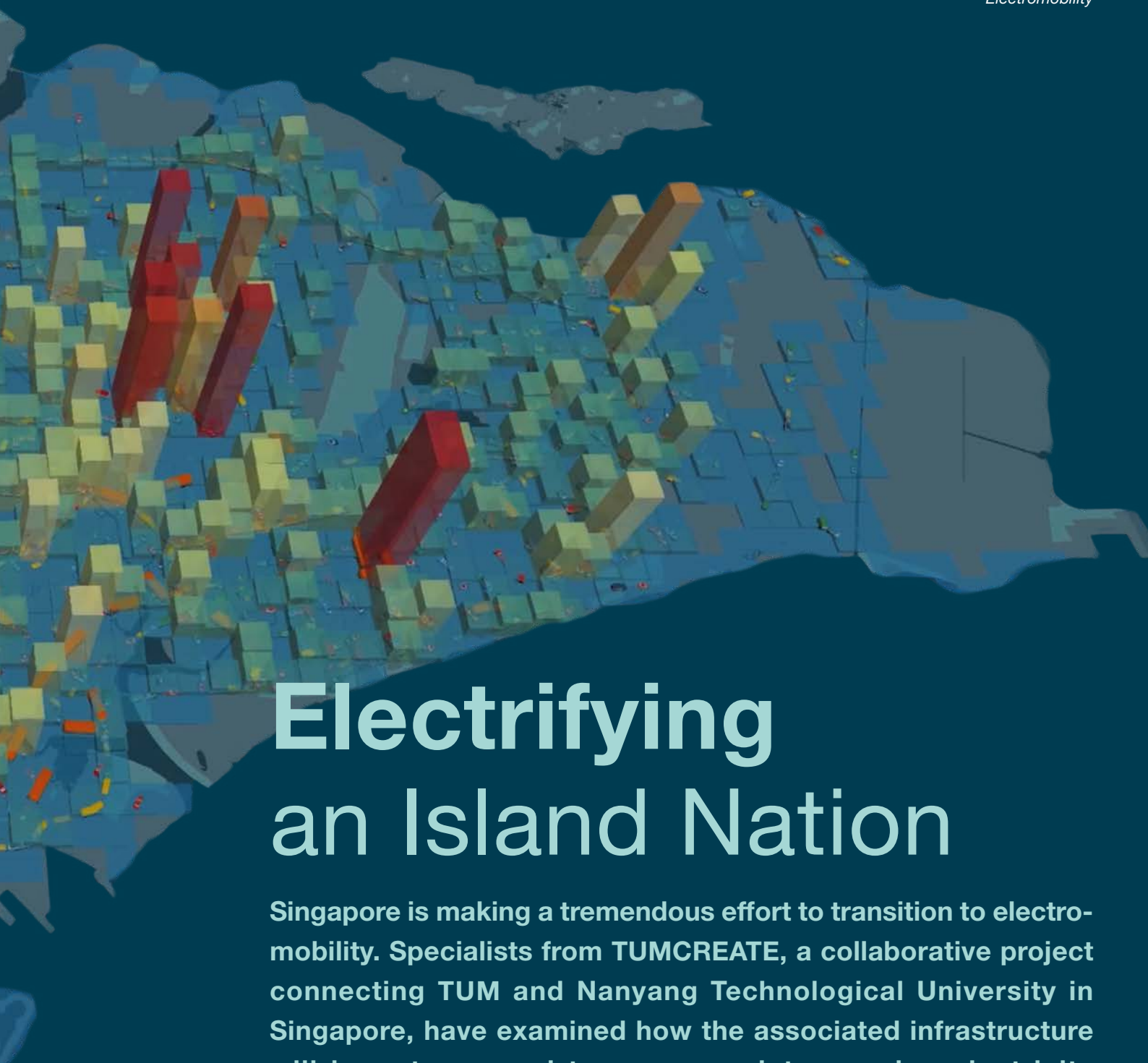
Gesamter Artikel (PDF, DE): www.tum.de/faszination-forschung-28

Ein Inselstaat auf Strom

D

Singapur will künftig ganz auf Elektromobilität setzen, obwohl es in dem kleinen Stadtstaat kaum Platz für den Ausbau der regenerativen Energien oder neue Umspannwerke gibt. Mehr Ökostrom ist nur mit einem groß angelegten Umbau der Infrastruktur zu haben. Die Grundlagen für diesen Umbau haben Fachleute bei TUMCREATE, einem Gemeinschaftsprojekt der TUM und der Nanyang Technological University in Singapur, geschaffen. Unter der Leitung von Dr. Tobias Massier wurde das Simulationsprogramm MESMO entwickelt, mit dem sich durchspielen lässt, wie sich das Stromnetz verhält, wenn Elektroautos und vor allem Elektrobusse geladen werden. Ein anderes Team hat ergänzend das Simulationsprogramm CityMoS entwickelt, das den Straßenverkehr im Detail nachspielen kann. Damit lässt sich jedes Fahrzeug oder auch jede Ampelanlage in Singapur in Echtzeit simulieren. Im aktuellen Projekt SITEM werden MESMO und CityMoS verknüpft. Damit lässt sich fein aufgelöst analysieren, wie sich das Stromnetz im Konzert mit den Fahrzeugen verhält. □

Researchers at TUMCREATE developed the software CityMoS, which is able to perform agent-based large-scale microscopic simulation of road traffic.



Electrifying an Island Nation

Singapore is making a tremendous effort to transition to electromobility. Specialists from TUMCREATE, a collaborative project connecting TUM and Nanyang Technological University in Singapore, have examined how the associated infrastructure will have to expand to accommodate growing electricity demand. The simulation programs developed in the project demonstrate how electric cars, buses and taxis will interact and interoperate with the power grid in the future.

Link
www.tum-create.edu.sg/research/energy-and-power-systems-group www.tum-create.edu.sg/research/computational-modelling-research-department

Picture credit: TUMCREATE CityMoS

Singapore is renowned the world over. This Southeast Asian state is one of the largest trading hubs on the planet, boasts the world's second-largest container port, and is also a top tourist destination. Given these feats, it is an astonishingly small country. In fact, Singapore is only around two-thirds the size of the German state of Hamburg, yet it has over five million inhabitants. Space on the roads is at a premium on the main island, which stretches around 50 kilometers from east to west. In total, Singapore has around a million cars. In rush hour, around 6,000 public buses also roll around the island. On top of that are several thousand taxis. And, as almost all these vehicles run on gasoline or petrol, emissions of carbon dioxide and airborne pollutants are high. Thankfully, there is also an underground rail system, which the majority of Singaporeans use.

Target: 50% electric buses by 2030

The administration has therefore resolved to switch from vehicles with internal combustion engines to electric cars and buses in the coming years. By 2030, every other bus in the public transport system will be electric. This target presents a challenge for the small state at the southern tip of the Malay Peninsula, as there is limited space to expand regenerative energy systems or install new substations. The only way to increase the use of green energy is through large-scale infrastructural reorganization. Before embarking on this project, the city's administration wants to know exactly whether this transformation can succeed and, if so, how – without causing power cuts or impacting on quality of life. Specialists at TUMCREATE, a collaborative project connecting TUM and Nanyang Technological University in Singapore, have been working to put down the foundations for this immense retrofitting project in several projects over recent years. One of its research groups, the Energy and Power Systems Group, uses simulations to analyze in detail how the rise of electromobility will affect the power grid. "First, we took a close look at all road users," says Dr. Tobias Massier. "For example, we fitted taxis with GPS transmitters and collected all available data on car journeys to find out when cars are on the road, how they travel, and where they park." ▷

Hamburg *Singapore*

Population

1,906,411 **5,936,160**

Surface area

755.22 km² **728.6 km²**

2,524 persons/km² **8,147 persons/km²**

Number of public buses***

2,322 **7,704**

Number of cars

804,196 **579,369**

Residents per car

2.4 **10.2**

Number of taxis

3,213 **18,542****

Taxis per 1,000 residents

1.68 **3.12**

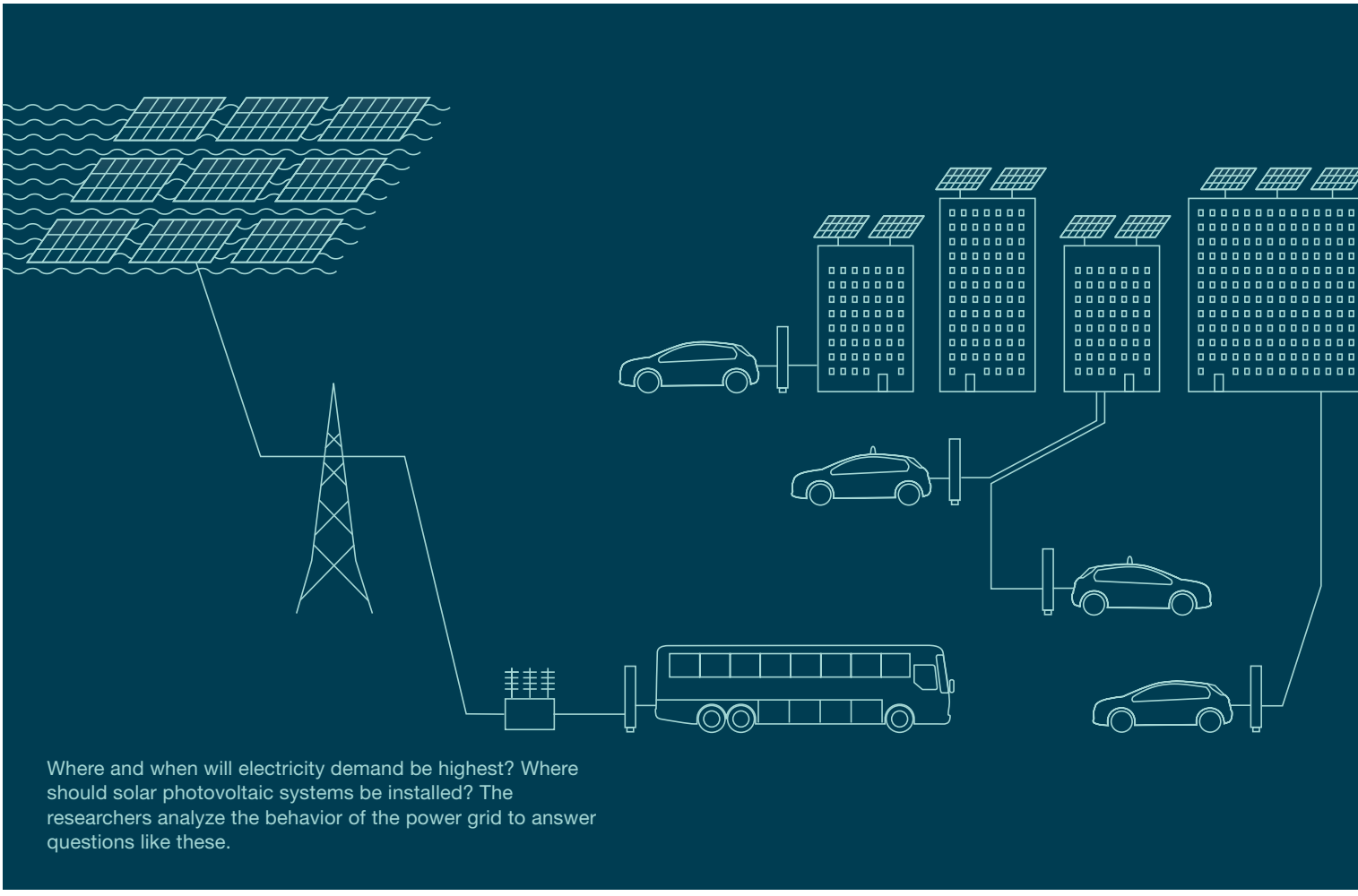
Public transport (bus & rail): passengers per day

2,156,000
(1.1 rides/resident/day)

7,691,000
(1.3 rides/resident/day)

Sources: Statistisches Amt für Hamburg und Schleswig-Holstein, HVV Zahlenspiegel 2018; Singapore Land Transport Authority; worldometer May 2022
*** incl. school buses
**** excluding private hire vehicles

Graphics: ediundsepp



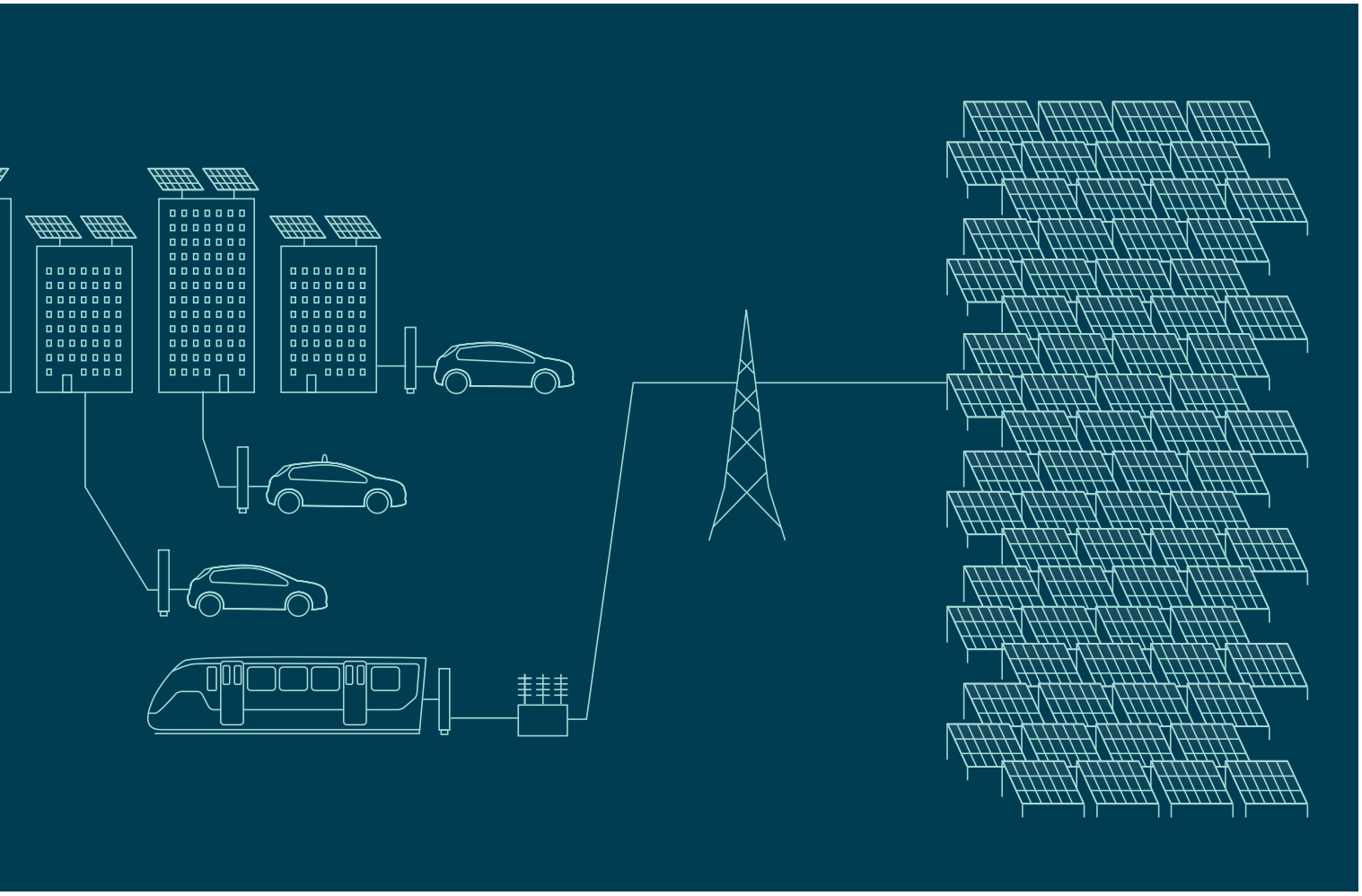
Where and when will electricity demand be highest? Where should solar photovoltaic systems be installed? The researchers analyze the behavior of the power grid to answer questions like these.

On average, private cars do not travel more than 50 kilometers per day, so electric versions would consume relatively little electricity. In the future, electric cars could be charged adequately in garages and parking structures beside office buildings and apartment blocks. Buses, however, pose a challenge: they operate for hours at a time, with little time for charging between journeys. In addition, there is very little space to install fast-charging stations beside bus stops in the heavily built-up urban area, as the huge batteries and high charging currents would require safety clearances to nearby buildings and thoroughfares. So, the electric buses of the future will have to be charged primarily at their final stops or at depots.

Understanding how the grid reacts

Over the last few years, Tobias Massier and his team have been developing MESMO, a simulation program that makes it possible to mimic exactly how the power grid will behave if high numbers of electric cars and buses need to be charged. Due to the high load requirements, it is likely that new transformers will be required in the vicinity of bus depots if the public bus network is to be fully electrified. Such insights are vital for the city administration and facilitate accurate, detailed planning. Colleagues of Tobias Massier have also developed a program called CityMoS, which can perform detailed simulations of road traffic. It can simulate every car, bus, taxi and traffic light in Singapore in real time, taking into account the current battery level and range of each and every vehicle.

In a current project called SITEM, which is supported by the Singapore city administration and led by the research enterprise A*Star, the TUMCREATE experts are working to connect MESMO and CityMoS. In the future, with the help of CityMoS, MESMO will be able to conduct high-resolution analyses of how the power grid behaves in concert with electric vehicles. Where should solar photovoltaic

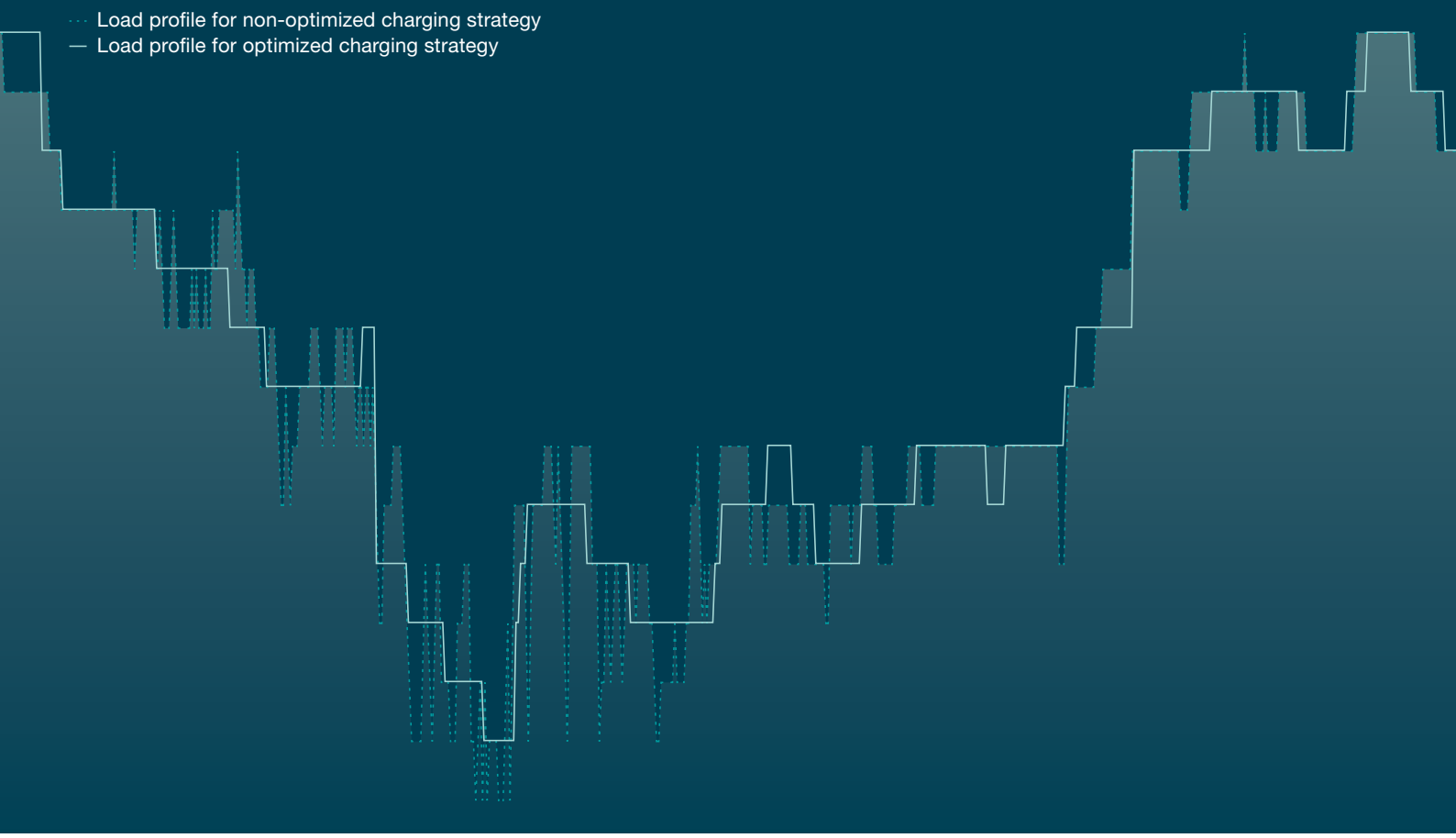


systems be installed on building façades and roofs? Where and when will demand for electricity be highest? These are the sorts of questions that SITEM will be able to answer for researchers and the local authorities. A particularly critical issue for power grids is load peaks – times when there is particularly high demand for electricity, such as first thing in the morning, when people switch on lights, turn on the radio and boil the kettle. To avoid exacerbating these peaks, it would be better to charge electric vehicles at times when demand for power is lower. Another concern in Singapore's hot, sultry climate is the thousands of air-conditioning systems in the city. Tobias Massier and his team have therefore examined the extent to which demand for electricity can be calibrated. One conceivable example, for instance, would be to reduce the output of air conditioning units during load peaks without allowing air conditioned rooms to become uncomfortably warm. That could also reduce the burden on the grid. ▷

"Over the years, the question of how to integrate electromobility into power grids became increasingly important."

Tobias Massier

Graphics: ediundsepp (source: TUM)



With a proper charging strategy, electric vehicles can help stabilize the power grid. The curves show the load profile during a typical day with fluctuating power supply from solar PV. Without optimization, the load profile reflects the high intermittency of solar PV supply. An optimized charging strategy for electric vehicles smoothes the load profile.

Electromobility entails high power demands

Singapore has long been striving to reduce the impact of road traffic. In 2018, for example, the administration placed a cap on the number of private cars allowed on the roads. Since then, citizens can only register a new private car when they take another off the road. However, such measures do not have a significant impact on emissions. Singapore will also have to do far more to combat the effects of climate change in the future. Tobias Massier explains that this is the reason behind the accelerated desire to move to electromobility. The city's plans also include expanding its photovoltaic systems. In addition to roof-based systems, Singapore started to install floating solar photovoltaic systems. However, the report 'Solar PV Roadmap' by the Solar Research Institute of Singapore has shown that, even if it were to expand its photovoltaic systems as far as possible, Singapore could only cover around 10% of its electricity demand using solar power. Consequently, it will have to source renewable energy generated by its neighbors, Indonesia and Malaysia. Plans for the first cable runs are currently being drawn up. For the project's cooperation partners in Singapore, such as A*Star and the city administration, the simulations conducted by TUMCREATE experts are an essential tool for estimating future electricity demand and imports. TUMCREATE is already planning a new project focusing on achieving a sustainable energy supply for Singapore.

TUM has been active in Singapore since 2010. Back then, its primary focus was perfecting automotive technology for electric cars, including for TUM's electric city car, the MUTE, under the leadership of Prof. Markus Lienkamp. "Over the years, the question of how to integrate electromobility into power grids became increasingly important," says Tobias Massier. "We are now reaping the rewards of these years of research. Singapore has everything it needs to embrace electromobility."

■ *Tim Schröder*

Dr.-Ing. Tobias Massier

received his doctoral degree in electrical and computer engineering from TUM in 2010. His research focused on the structural analysis of analog integrated circuits. In 2009, he took over the position of program manager in order to establish a new Master's program in Power Engineering (MSPE) at TUM. In 2013, he joined TUMCREATE as Principal Scientist and department head. His research focuses on integration of electric vehicles and renewable energies into the grid, as well as alternative energy supply options.

"Singapore has everything it needs to embrace electromobility."

Tobias Massier

TUM CREATE – TUM's innovation platform in Singapore

TUMCREATE was founded in 2010 to foster research collaborations between Singapore and TUM and is made up of over 100 scientists, researchers and engineers. As part of the NRF-funded Campus for Research Excellence And Technological Enterprise (CREATE), TUM has the opportunity to tap into Singaporean research funding and to partner with local institutions as well as leading global universities that are part of the CREATE campus. Researchers appreciate this unique opportunity for academic exchange and research ideas in Asia.

TUMCREATE has successfully managed various multidisciplinary projects within its mobility programs, in collaboration with academic and industry partners in Singapore. With its latest large-scale program Proteins4Singapore, TUMCREATE adds a complex, cutting-edge life science project to its portfolio.

Picture credit: TUMCREATE; Graphics: ediundsepp (source: TUM)