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Singapore, the hub of South-East Asia

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OPTIMISATION DES SYSTÈMES ÉNERGÉTIQUES

Centre de Mathématiques Appliquées
MINES ParisTech

Chaire Modélisation prospective
au service du développement durable

Coordinator - Catherine Auguet Chadaj
Model maker - Samuel Petitjean
Photos - MS OSE Students

OVERVIEW

EDITORIAL

It goes without saying that Asia represents a significant share of global energy consumption, due to its sustained economic and demographic growth. We still often hear today that China is a major player in this growth, but Southeast Asia, through its strategic geographic positioning and atypical island structure, also plays a major role in developing the new energy infrastructures of tomorrow. That is why, in early March, the 18th class of the OSE Specialized Master's went on a study trip to Singapore, as part of its thematic promotion voyage. During the 8 days spent on site, the students were able to visit numerous installations, centered on a number of subjects, such as microgrids, and in particular on this year's theme: Hydrogen.

In this issue, we invite you to discover the places we had the privilege of visiting, along with the two themes focused on hydrogen, presented at conferences at Singapore's two major universities, National University of Singapore (NUS) and Nanyang Technological University (NTU). In this article, you will find a summary of the ideas presented at the conference and discussed in depth in a book entitled "Hydrogen, the energy carrier of the future ?" written by all of the engineering students on the OSE Master's program, due for publication in late 2018.

First of all, we would like to thank all of the people without whom this trip would not have been possible. We want to thank the partners and industrialists who welcomed us and took the time to present their activities, show us their installations, and exchange with us on various subjects, both technical and economic. Our thanks also go to the two Singapore Universities for their warm welcome and the quality of the audience at the conferences. Thank you to Professor CHAN from NTU for his very detailed presentation on hydrogen, which supported the writing of our book. Thanks to EDF Lab Singapore, Schneider Electric, BeeBryte PTE. LTD, Total, Air Liquide and notably the French Embassy in Singapore without which this trip would not have been as rich and captivating. Thanks also to REIDS Energy Research Institute and Engie who allowed us to visit their smart-grid demonstrator on Semakau Island.

Finally, a big thank you to Gilles Guerassimoff, in charge of the MS OSE, and to the CMA team for the exceptional organization and preparation of all of these visits, which made this study trip a real success.

Now let yourself be guided through the diversity of Singapore's energy world and enjoy reading!

Axel FELIZOT

STATE OF THE ART OF SINGAPORE'S ENERGY

Samuel PETITJEAN

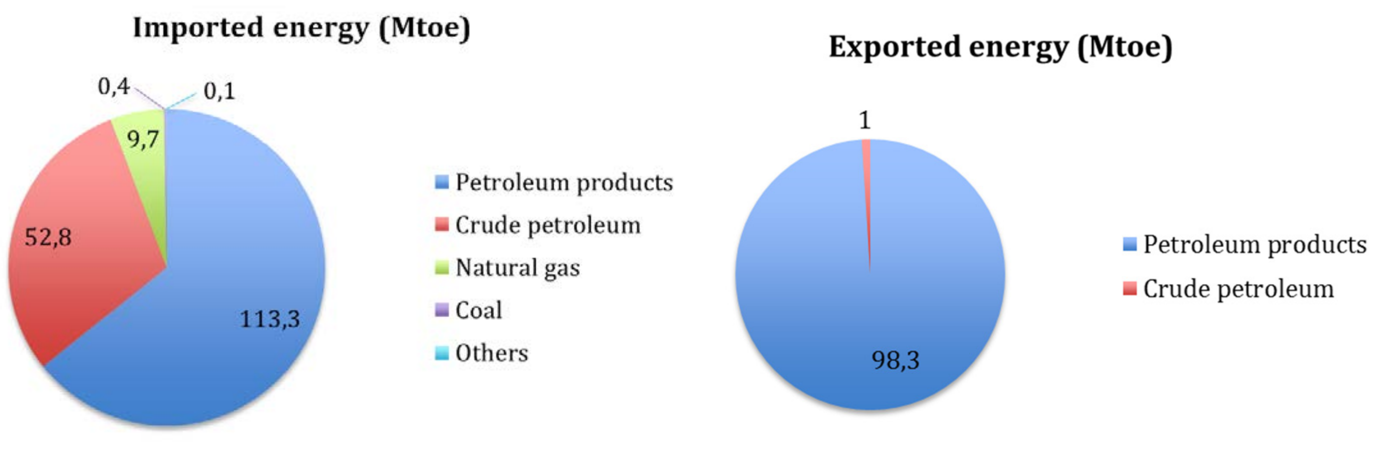
Singapore's location and energy strategy are strongly correlated with its geographical position and the small size of its territory (720 km^2).

LEADING COUNTRY IN PETROLEUM PRODUCT TRADE, REFINING AND STORAGE

Located south of Malaysia, the city-state is at the meeting point between the Indian and Pacific Oceans. This strategic location has enabled the island to develop its port activities on a world scale, mainly involving oil and its derived products. The latter constitute most of the country's energy flows. In 2016, they represented 29.9% and 64.2% of imported energy and all exported energy respectively. Gas and coal are also imported [1].

The country is thus the leading Asian logistics hub and the third largest in the world for bulk liquids [2]. Malaysia, Indonesia and China alone import more than half of Singapore's petroleum products.

Taking advantage of these exchanges, the country has historically developed processing and refining activities. For this reason, only a very small proportion of imported crude oil is exported. According to the EIA, in 2015, approximately 1.4 million barrels were produced per day at the country's 3 refineries [3]. To meet this demand and energy production, Singapore has significantly developed its storage solutions. Jurong Island reserves feature an additional 1.47 million cubic meters of underground storage and two LNG storage terminals [2].

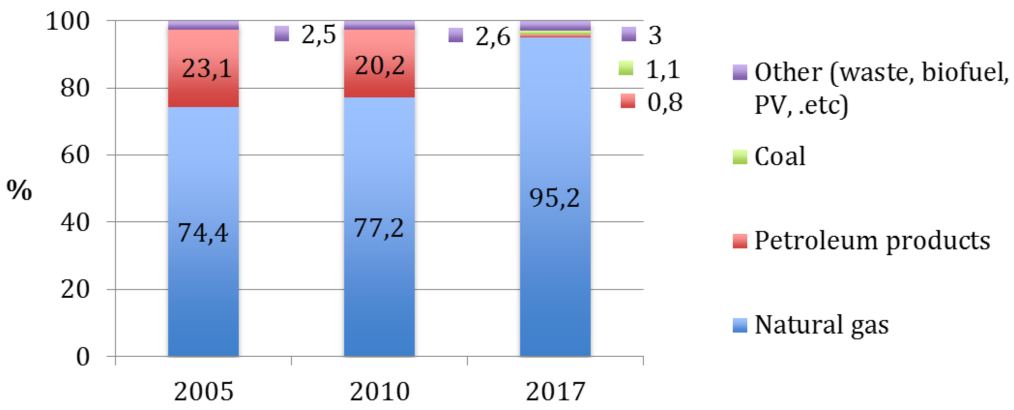


Imported & exported energy in Singapore © Energy Market Authority

OBJECTIVE: DEVELOP GAS AND PV SECTORS

The country's small size and high population density (8,188 inhabitants/km2, [4]) make it particularly difficult to develop renewable energies, such as biomass, hydroelectric energy, geothermal energy and wind power. Only solar energy has strong potential. For this reason, the Singapore government has planned to invest heavily in solar photovoltaics. The objective is to increase installed capacity from 71MW in 2016 to 350MW by 2020[3]. Despite this, photovoltaic production remains marginal for the moment since the total installed electrical power in 2016 amounted to 13,348MW [1]. Most electricity is produced from natural gas. Waste recovery comes second with 2.5% of the energy produced in 2015[5].

The development of the natural gas sector is at the heart of Singapore's strategy because it makes it possible to reduce dependence on oil products while decarbonizing the energy mix. Gas and photovoltaic technologies are the subject of much research, notably at the Solar Energy Research Institute of Singapore (SERIS). In 2013, the country began producing some of its LNG. Prior to that date, all natural gas was imported from Malaysia and Indonesia via pipelines.



Electricity production © Energy Market Authority

INNOVATION MOMENTUM

In addition to deploying its gas and photovoltaic sectors, the country is focusing on energy efficiency, intelligent energy management and new storage technologies. One of the results is its partnership with ENGIE, which has led to the creation of the ENGIE Lab, responsible for many projects such as the REIDS (Renewables Energy Integration Demonstrator) initiative. This demonstrator is used to test compound energy systems for renewable production and storage by battery and hydrogen [6].

Due to its economic and scientific importance in South Asia, Singapore is the centre of several programs to address energy transition issues.

ENERGY IN SINGAPORE

SUMMARY

Petroleum products are historically at the heart of Singapore's economy, both in terms of trade and the refining industry. Nevertheless, the city-state is seeking to change its energy landscape and increase its independence. To this end, the country has targeted the gas and solar photovoltaic sectors. By partnering with neighboring countries and leading research groups, Singapore is proving to be an innovative and specialized energy-efficiency platform.

Sources :

[1] *Energy Market Authority, Energy Snapshot of Singapore 2016, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/ses/2017/snapshot/index.html*

[2] *French Chamber Singapore, Les secteurs énergie et énergies vertes à Singapour, 2017, http://www.fccsingapore.com/fr/business-services/pourquoi-implanter-singapour/fiche-pays/secteur-energies-energies-vertes*

[3] *U.S. Energy Information Administration, 07/2016, https://www.eia.gov/beta/international/analysis.cfm?iso=SGP*

[4] *CIA World Factbook – 23/02/2018*

[5] *International Energy Agency, Singapour Statistics 2015, https://www.iea.org/statistics/statisticssearch/report/?year=2015&country=SINGAPORE&product=ElectricityandHeat*

[6] *ENGIE ouvre à Singapour un nouveau Lab dans le domaine de l'énergie verte, 11/07/2016, https://www.engie.com/journalistes/communiques-de-presse/engie-singapour-nouveau-lab-lenergie-verte/*

Marina Bay Sands

NUS conference : does hydrogen belong in tomorrow's electricity grid ?

To begin the week, OSE students were warmly welcomed by Armin Aberle, director of the Solar Energy Research Institute of Singapore (SERIS), part of the National University of Singapore (NUL). They gave a talk on the subject they have been working on for the last few months, i.e. hydrogen as an energy carrier and its integration into electrical networks. We invite you to consult the following article summing up this conference and the discussions that made it such an enriching experience! The morning ended with a visit to the lab. The promotion was guided through the centre by Eddy Blokken, business manager of solar activity.

NUS in short: founded in 1905 and covering an area of 150 hectares, NUS is the most prestigious university in Singapore, including 16 faculties and schools spread on three campuses, Kent Ridge, Bukit Timag and Outram. These faculties dedicate their research to medicine, engineering, biotechnologies, nanotechnologies and international business. Among its research centers, SERIS is the national solar energy research center. Created in 2008 and funded by the National Research Fund and University, this autonomous laboratory combines R&D with industrial demonstrator conception and consulting activities in Singapore, and more widely in South-East Asia for solar technology-building integration purposes. These activities are related to development, system service optimization and material characterization of modules.

The visit began with a trip to the control center. Here, numerous screens display real-time data collected each second by a large fleet of photovoltaic cell sensors placed on the roof and about thirty weather stations uniformly spread around the territory. These captors provide various systems with production and demand data, while stations provide accurate data about solar irradiation and other meteorological factors useful to understand PV technology. The data are exploited by researchers to develop performance monitoring and prevision tools in order to more efficiently manage the solar energy available on the island, and also abroad through their consultant position in South-East Asia. Today, the models' error rate is comprised between 10% and 12% (Min Square Root). Two forecast models are being developed from cloud displacement

DAY 1

modeling. The first one uses fish-eye camera data, while the second analyzes radar meteorological maps.

Next came a presentation of PV cell production laboratories, with a specific focus on two cell technologies currently under study at SERIS. The first uses a copper layer technique for cell junctions. Very high precision is required (hundredth of a millimeter accuracy) to prevent copper migration phenomena in silicon. This results in a significant increase in capital investments. This technology, which is new at laboratory scale, nonetheless offers high throughput of up to 24 %.

The other technique is one of the most used in industry. It employs silver instead of copper to efficiently tackle migration phenomena. Thus, this simplified process requires less investment, but has to deal with high operation costs due to silver's relatively high price.

Our visit ended with a talk about ion implantation. This process, employed at laboratory scale in SERIS for photovoltaic application, is broadly used in many other industries. Researchers use it to create an extremely accurate doping profile in the silicon layer, to reach high yields capable of competing with today's PV cell leader, SunPower. One mid-term challenge is to reproduce ideal cells produced by an ion implantation process using a much cheaper standard diffusion process.

There is no doubt that these researchers are ambitious: in order to penetrate the Singaporean energy system while tackling prohibitive land prices that can lead PV projects to financial disaster, they are targeting water reservoir surfaces to set up floating PVs. A first 2 MW peak demonstrator on Tengeh reservoir should accelerate this technology deployment as part of the SolarNova program, which has fixed the objective of 350 MW in Singapore by 2020.

Furthermore, the work done at SERIS is not limited to PV technology. Chemical production cells and electrolyzors for methanol and hydrogen generation from extra intermittent electricity are also in an experimentation phase. In the near future, Eddy Blokken sees the wide scale spread of compact PV and chemical micro units producing decentralized hydrogen and methanol gathered in a collector.

We would like to warmly thank Armin Aberle and Eddy Blokken for their welcome and for sharing their thoughts with us on hydrogen and current research at SERIS. We are also grateful to the SERIS researchers that attended our presentation and made it so interactive.

Raphaël CLUET
& Adnane HATIM

STUDENT PRESENTATION SUMMARY

At the conference presented by the OSE Post-Graduate students at the SERIS laboratory (Solar Energy Research Institute of Singapore) in NUS, the integration of hydrogen into the electrical network was addressed. As an energy carrier, hydrogen has several advantages to tackle the intermittency of renewable energies. These renewables, although constantly growing in the energy mix, are part of a global energy production still composed of 80% fossil resources.

The hydrogen molecule does not exist in a natural state and needs to be produced before its energy can be applied for other purposes. Today, 95% of the molecule's production is carried out using fossil energies (Gas - 68%; Oil - 16% and Coal - 11%) and 5% from the electrolysis of renewable and nuclear energies, the most widespread method being the steam reforming of natural gas.

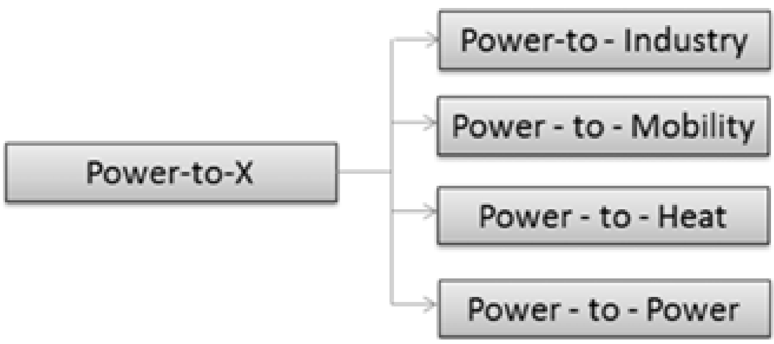
Nevertheless, the development of hydrogen as an energy carrier must be addressed throughout the whole value chain, including storage and transport.

Concerning storage, physical techniques exist, which are storage by compressed gas, and storage in liquid or cryogenic forms. Solid storage techniques are also being developed, by absorption or adsorption. The first of these consists in capturing hydrogen like a sponge, the second captures it on the surface of a material.

The matter of transport then arises. What are the most suitable means for different applications? Today, there is a network of around 5,000 km of gaseous hydrogen pipelines, 43% of which are operated by Air Liquide and 25% by the American company Air Products. However, numerous constraints should be considered. The cost of materials and labor required to build such structures does not make them economically competitive compared to natural gas.

For short-distances, some companies, like Shell, opt to transport hydrogen gas by truck, while liquefied hydrogen transport is preferable for longer distances (over 200 km). Both of these techniques have their advantages but require an expensive infrastructure depending on the state of the molecule (compression or liquefaction stations). Some more marginal long-term projects, aiming to cover longer distances, consider transportation by boat. This is the case of the project being developed by Kawasaki, which aims to connect Australia and Japan.

As for hydrogen consumption, several applications are concerned. Power-to-X represents the transformation of electricity into hydrogen for industrial, mobility, heat and electricity purposes, as shown in the following diagram:



Uses of hydrogen

DAY 1

It therefore offers flexibility advantages that can guarantee the stability of the electricity or gas network. Hydrogen gas on its own, or coupled with CO_2 to produce CH_4 (Power-to-Gas), can thus be injected into the gas network.

In France, projects such as GRHYD (Dunkerque) and Jupiter 1000 (Fos-sur-mer) are studying the feasibility and economic relevance of Power-to-X projects. Project yields are around 66% for a Power-to-Gas project without energy storage and 26% for a Power-to-Power project.

At the heart of the conference, the place of hydrogen in the electricity grid was brought to light, particularly in microgrids. The flexibility of the molecule makes it possible to compensate for the intermittency of the network, guaranteeing its stability. It provides medium-/long-term storage by replacing diesel generators. As with Power-to-X, some projects around the world aim to test the impact of this technology on the electricity grid, including:

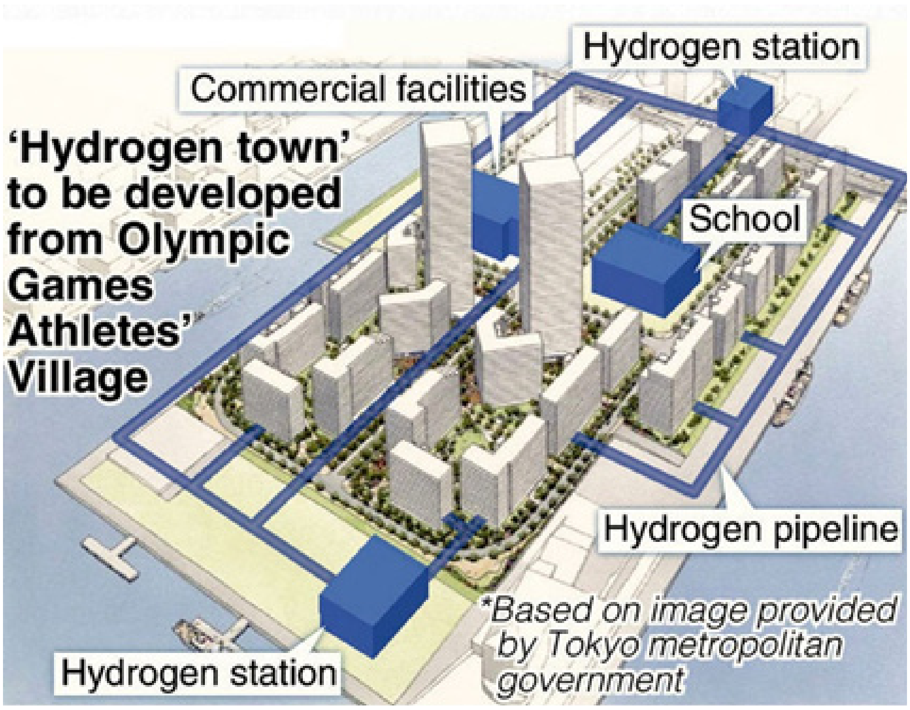
- SPORE in Singapore
- Mafate on Reunion Island
- Myrtle in Corsica

Similarly, Hydrogen can be considered for residential applications. It allows network congestion to be managed during peak periods and helps avoid infrastructure overload. This is the case, for example, for the Dunsfold project in the United Kingdom, which supplies 1.5MW to 2,500 houses on a Power-to-Power system.

Other applications can also be interesting on a large scale. After the Fukushima accident in 2011, Japan decided to put an end to its nuclear industry. This has directly impacted the country's mix, lowering its energy independence rate from 20% to 5%. As a result, the Japanese government has implemented a hydrogen deployment plan, the "Hydrogen Society". This plan is being implemented in three phases, the last being the production and use of 100% carbon-free Hydrogen :

- present - 2020 : expansion of residential and transportation uses
- 2020 - 2040 : energy production from hydrogen
- from 2040 : production and consumption of carbon-free hydrogen

The country is also aiming at becoming the world reference for the sector, for which the Tokyo 2020 Olympic Games will be the showcase.



Hydrogen at Tokyo's Olympics in 2020
© Tokyo metropolitan government

The question then emerges: is hydrogen really a sustainable energy carrier?

To date, 90% of global hydrogen production comes from fossil resources, which strongly goes against the green image of the sector linked to its association with renewable energies.

A European initiative, Certifhy (developed in Table 2), was carried out to control the origin of hydrogen, describing it as either grey, low-emitting, or green.

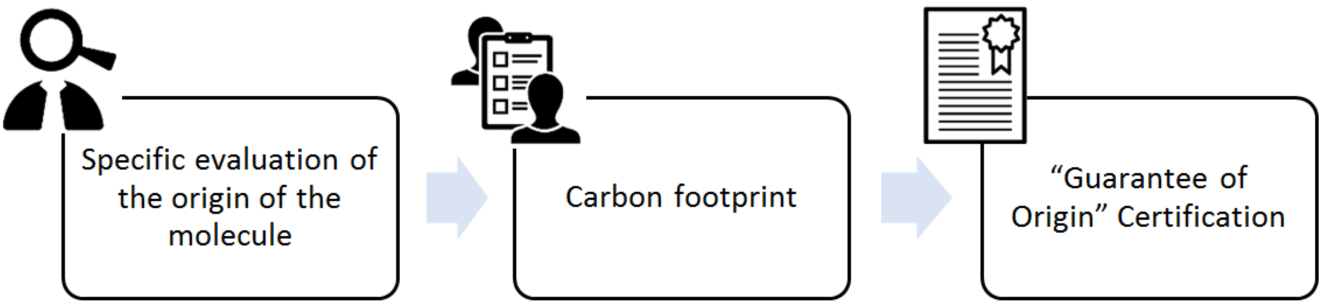
Beyond regulatory issues, there are economic requirements for the sector to be competitive by 2050:

- CAPEX reduction by 2;
- Low electricity prices for hydrogen production from renewable energies.

Today, the price of Power-to-Gas is ten times higher than natural gas, making incentive policies necessary to support the emergence of the sector.
To understand the factors that would allow this emergence, prospective studies have been analyzed modeling different scenarios. These studies focus on three different scales: Europe, Belgium and Mauritius. By varying parameters such as demand, number and types of interconnections, and renewable energy deployment (PV, biomass, wind), hydrogen only proves itself interesting after strong constraints on CO_2 emissions. In addition, the sectors in which the molecule's deployment is preferred are industry and transport.

Thus, although hydrogen technology can be used for a good number of applications, this sector still requires significant investments to become competitive and an integral part of the energy mix. Similar to renewable energies, hydrogen could find its place in the electricity grid of tomorrow.

Daniel ERBESFELD
& Lise ADEGNON



Schematic view of the certification process of hydrogen

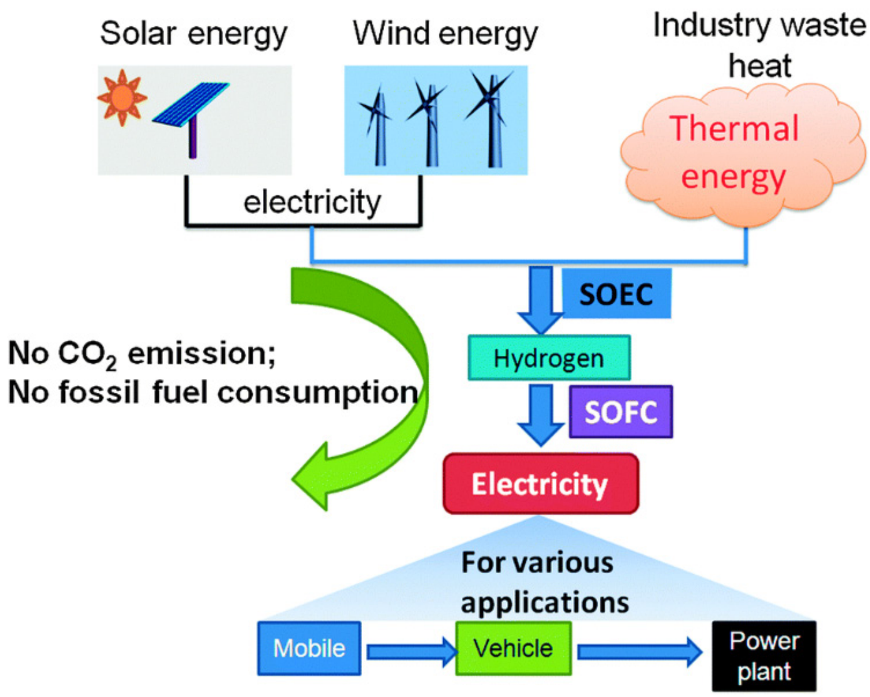
Presentation by OSE Master students at the SERIS laboratory in NUS

NTU Conference : Is hydrogen the solution for a sustainable mobility ?

In the afternoon of Monday 13th March, we were welcomed by professor CHAN at Nanyang Technology University (NTU Singapore). Mr. CHAN Siew Hwa is Co-director of the Energy Research Institute at NTU (ERI@N) and Deputy Director of the Maritime Institute (MI@NTU). He started his academic research in the field of combustion in military engines. Since 1997, he has been working in the fuel cell field with a focus on solid oxide fuel cell (SOFC) technology and fuel reforming. He is chairman of the first World Hydrogen Technologies Convention (WHTC) and one of the defenders of hydrogen applications. His laboratory specializes in fuel cells with a focus on mobility (hydrogen vehicles, electric vehicles, etc.). During the presentation, Mr. Chan spoke about the collaboration with CEA to develop solid oxide fuel cells (SOFCs). This type of fuel cell is used for stationary applications and functions at high temperatures (450-1,000°C).

M. Chan also works on electrolyzers which he considers remain too expensive and require research into improving their yield. To this end, he is developing a new kind of technology named SOEC (solid oxide electrolyzer cell) which is able to make use of fatal heat and increase yields by up to 85%-119% versus 55%-83% for both conventional alkaline and PEM technologies. Combining SOEC and SOFC technologies, it is possible to obtain a new efficient energy system called "Power + Heat to Power".

Mr. Chan mentioned the French nuclear power park, which he considers has great potential for producing hydrogen from fatal heat. He also outlined the potential use of floating solar PVs installed at Singaporean



The « Power+heat to Power » operating principle © NTU reservoirs in order to produce green hydrogen. Currently, the Singaporean government is not in favor of developing such projects for hydrogen production within the "very dense" city state for security reasons.

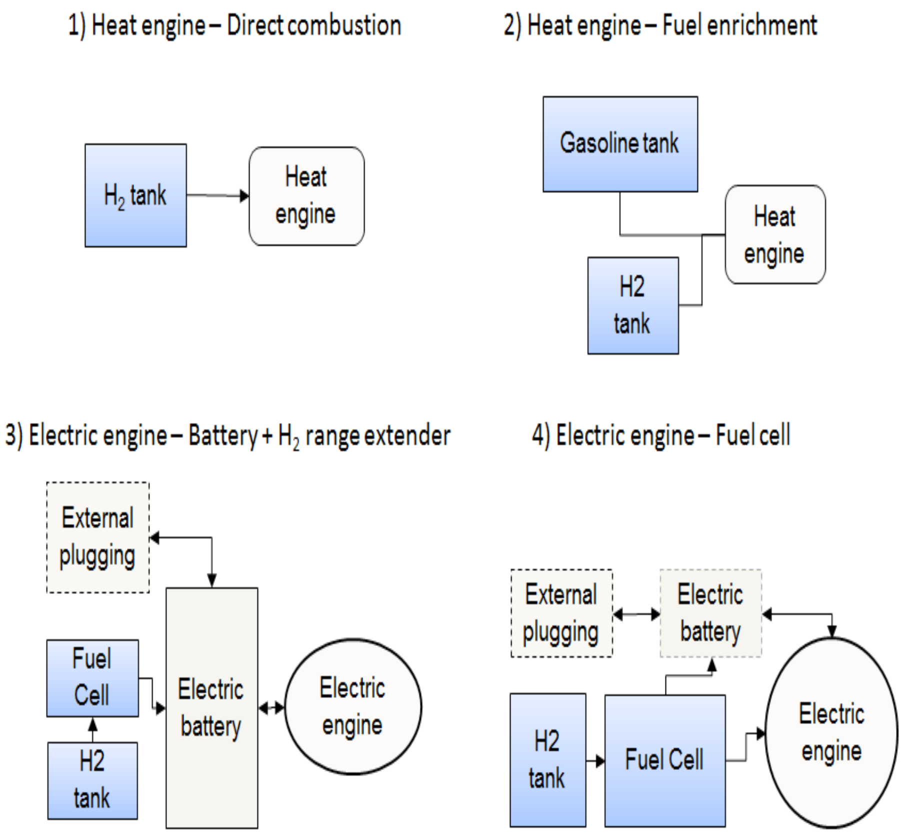
However, hydrogen is already produced and consumed on a large scale (3,000 kgH2/h) near Singapore at a refining plant operated by Shell, ExxonMobil and Chevron.

On a global scale, M. Chan organizes the annual Hydrogen Power Theoretical & Engineering Solutions International Symposium (HYPOTHESIS) whose purpose is to provide a forum where representatives from industry, public laboratories and government agencies can meet, discuss and present recent advances in hydrogen technology. This year it will take place in Singapore from 24 to 27 July.

Chaimaa ELMKADMI
& Florian ROUOT

SUMMARY OF THE STUDENTS' PRESENTATION

Following Professor Chan's presentation, the OSE Master students gave a 45-minute presentation summing up their work on hydrogen and its application to mobility. After highlighting the significant share of CO_2 emissions due to mobility, the different sources of hydrogen production were presented. This molecule is produced 95% from fossil energy and 5% from electricity, with production costs ranging from \$2.5/Kg to \$12/kg. The two available storage options were also discussed, with physical storage compressing hydrogen up to 700bar in a tank, and storage in materials using absorption and adsorption processes. Pipeline, truck and ship technologies were then described. The students ended the first part with a presentation of Power-to-X systems. Power-to-gas injects hydrogen produced from an electrolyzer or methane into the grid. Power-to-Power completes this process by converting hydrogen back into electricity using a fuel cell.



The different engine structures involving hydrogen

DAY 1

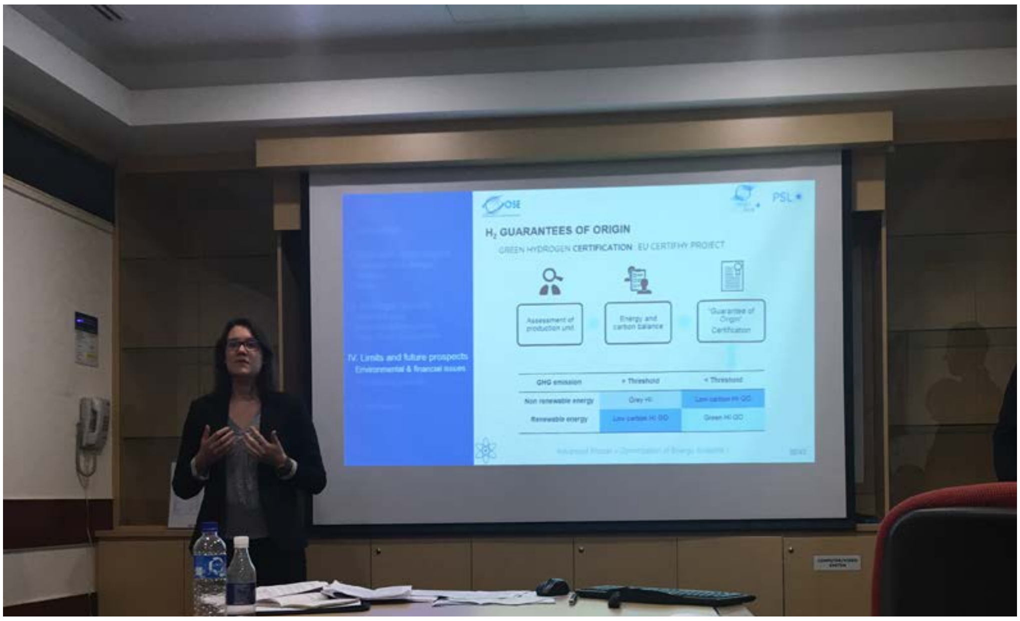
During the second part of the presentation, the place of hydrogen in the mobility sector was studied in more detail. The various engine structures involving hydrogen include those with internal combustion engines, which are not very widespread, and those with electric motors. In the latter, the fuel cell is either connected to a battery or directly to the engine. The different options for refueling stations were then explained. Hydrogen can be produced off-site or on-site and stored in existing or dedicated stations. After defining the notion of an ecosystem, the students then developed the examples of the Olympic village planned for the Tokyo Games in 2020 and the Tokyo and Osaka airports.

Limits and prospects were the subject of the last part. The development of the sector depends on the one hand on CO2 emissions during production and on the other hand on the evolution of technology costs. In order to ensure a low environmental impact, certificates of origin, as proposed by the European Certifhy project, can be set up. Finally, an analysis of prospective studies at national level, featuring Belgium, and international level, with Europe, showed that the sector's development relies in particular on freight transportation and greater investments.

The conference wound up with questions between the audience and the students. The auditors, already specialists in hydrogen, discussed the issue of safety and the various European projects under way.

We would like to thank Professor Chan for his welcome and for sharing his experience in the field of hydrogen, as well as all of the conference participants for the dynamism they brought to the exchanges with the students.

Samuel PETITJEAN
& Thomas BAZIRE



OSE Master student presenting at NTU

EDF LAB tackles smart cities and microgrids in Southeast Asia

On the second day, the OSE Master students visited the Center of Building Research, which houses the EDF Lab Singapore headquarters. As we entered the building, we passed through a gallery with a panorama of Singaporean urban history illustrating the city-state's meandering housing development from 1963 to 2014 and the transformation of its green spaces, environment, waste and water management, technology and energy. On the 1st floor of the building we were welcomed by an OSE alumnus from the class of 2016: Geoffrey ORLANDO who has just joined the EDF Lab team, and the director of the laboratory Maxime CASSAT who presented us the main research areas of the laboratory.

He told us that the Singapore Research and Development division had been created by EDF Group to strengthen its presence in South Asia. The city-state commissioned EDF R&D to develop a decision support tool for urban management and planning. The steadily growing demographics of Singapore (+ 1.45% last year) in a limited space require action plans to ensure sustainable development.

EDF has developed a groundbreaking urban modeling tool in collaboration with the Housing and Development Board of Singapore [HDB], the country's biggest housing provider (in charge of 83% of housing). Mr. CASSAT told us about this 3D platform that allows decision-makers to compare the impact of planning policy scenarios on different urban components and identify the most appropriate one for achieving its goals. These components include building design, water and waste management (in collaboration with Veolia), green space and transport management. The twofold aim is to design resilient and sustainable smart neighborhoods and to facilitate discussions between Singaporean authorities and industrial partners. The systemic modeling approach consists in designing building typologies in order to construct a three-dimensional plan of the studied space. The next step involves building load curves and scenarios of population evolution and technologies such as air conditioning and LED bulbs. This decision support tool can be adapted to different cases, in particular for large-scale planning programs (Master Plans), for diagnoses aimed at improving deficient plans, and for buildings.

Mr. CASSAT described the concrete study case of Yuhua district, Jurong East, in western Singapore. Following implementation of the IT tool, EDF recommended three development scenarios:

- Sustainable: a 10% increase in PV electricity production, and a 12% reduction in consumption through energy-saving actions.
- Smart: Energy management in housing.
- Resilient: Use of other energy sources.

Other research fields and learning programs with innovative projects are carried out in partnership with several universities

DAY 2

(NTU, SUTD, NUS and the ESSEC Business School). One example is the New Urban Kampung project, which was developed with Singapore University of Technology and Design to add functionalities such as standard of living, including noise and ecosystem services. The aim is to formulate indicators based on surveys of the Singaporean population. In addition, progresses in Big Data make it possible to extract the information for decision-making.

Mr. CASSAT concluded his presentation with a microgrid demonstrator project in the context of the REIDS (Renewable Energy Integration Demonstrator) program. Its objective is to develop a reliable energy management system by maximizing production (from several energy sources and storage) and minimizing losses via an optimized and centralized energy system.

The exchanges between the students and the director of the laboratory on various themes at the heart of energy issues in Southeast Asia were both fruitful and enriching. These included the design, architecture and benefits of microgrids in island areas of the region (Indonesia, Philippines, Malaysia) and their ability to compete with the future development of an electricity grid mainly based on coal.

We would like to thank all of the members of the EDF Lab Singapore team and in particular Maxime Cassat and Geoffrey Orlando for the time they devoted to us during the visit.

Yacine ALIMOU

Presentation of the EDF Lab Singapore by Mr. CASSAT

Schneider Electric : What future for microgrids in South-East Asia ?

Schneider Electric, a global specialist in energy management and automation present in more than 100 countries, develops microgrid energy solutions for remote sites in South-East Asia, a region where electricity is often unreliable. In 2016, this region accounted for approximately 27% of Schneider Electric's worldwide revenues. The growing electricity market in Indonesia is Schneider Electric's largest partner in Asia. Thomas Polliand, Microgrid Business Developer, and Tushar Menon, Microgrid Application Design Engineer, welcomed us at Schneider Electric's headquarters in Singapore to present us the activities of the French company in this region.

Schneider Electric's maxim, "more electricity, more digitalized, more decarbonized and more decentralized" is perfectly applicable to their microgrid activities in South-East Asia. Indeed, the microgrid presents many interesting features: it is a small, decentralized electrical network that provides reliable, cheap electricity from renewable energy sources. Three types of microgrid exist, each with specific features :

- So-called "off-grid" microgrids; these microgrids never connect to the macrogrid and operate completely independently from the main network, mainly for economic reasons or due to their geographic position. Typically, this type of microgrid is built in areas far away from any transportation and/or distribution infrastructures, and consequently, with no link to the main network. This type of microgrid is mainly developed in Indonesia.

- So-called "grid-tied" microgrids; this type of microgrid is fully connected to the main network. They are generally installed in areas where the electrical network is reliable, such as Singapore.

- So-called "islandable" microgrids; this type of microgrid is highly similar to the previous one, the only difference lying in the fact that in case of accident on the main network due to the weather for instance, the microgrid can disconnect and switch to island mode. These microgrids recently entered the market, mainly in Thailand.

The business model of a microgrid project for Schneider Electric is simple: Schneider does not finance a microgrid entirely but rather acts as a technology provider (products and solutions). Thus, Schneider Electric offers its customers two microgrid control solutions based on the same IoT technology developed in-house: the open and interoperable platform EcoStruxure™. The first solution is an EMS (Energy Management System) that enables optimization, based on cloud prediction, of periods of consumption, production, storage and energy sales (up to one minute accuracy). This first solution is particularly well adapted to the "grid-tied" and "islandable" microgrids, with a capacity of between 100 kW and 20 MW. The other microgrid control solution is a PMS (Power

DAY 2

Management System). This solution, which is more suitable for "off-grid" microgrids presenting several distributed energy sources, ensures microgrid stability in real time by balancing production, consumption and storage thanks to a supervisory control and data acquisition system (accuracy to the order of a second to a millisecond).

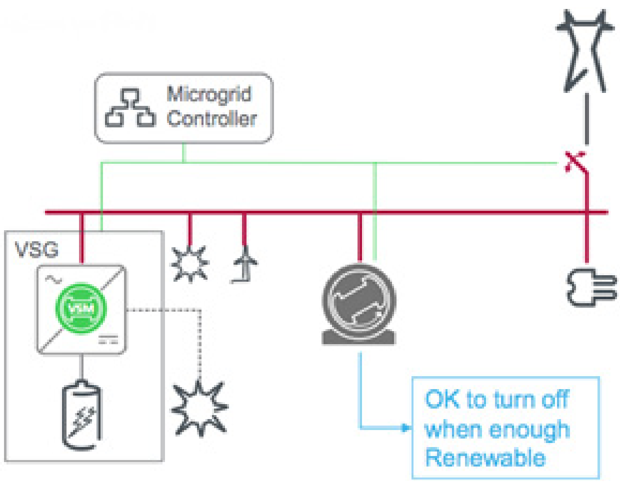
In collaboration with ENGIE, Schneider Electric is developing a PMS for the project SPORE (Sustainable Powering of Off-Grid Regions) in southern Singapore, precisely on Semakau Island. This initiative is part of the project REIDS (Renewable Energy Integration Demonstrator in Singapore) conducted by Nanyang Technology University (NTU) with a consortium of partners. REIDS represents the largest multi-fluidal microgrid based on renewable energy, integrating the biggest wind turbine in Singapore, PV panels and battery storage. REIDS is also designed to be flexible and adaptable to local people's needs.

Nevertheless, the introduction of too much renewable energy into the microgrid raises some issues because of their intermittency, particularly with regard to frequency and voltage on the microgrid. Tuskar Menon presented us an innovative solution developped by Schneider to overcome this 30% limit of renewable energy penetration on the grid while ensuring the microgrid's stability: the VSG inverter (Virtual Synchronous Generators). The principle, shown in the graph below, is simple. The VSG inverter, by imitating the behavior of a genset, starts the microgrid. Equipped with a battery for power smoothing, the VSG inverter provides synthetic inertia to the microgrid. Generators running in parallel can be switched off when a sufficient rate of renewable energy has been reached on the grid.

We would like to thank Thomas Polliand and Tushar Menon for welcoming us and for this very interesting presentation.

Haris DJOUBRI

Thomas Polliand presenting us with Schneider Electric's microgrid activity in South-East Asia



Principle of the VSG inverter in the microgrid © Schneider Electric

Singapore City Gallery : the history of a city in perpetual evolution

Singapore is one of the three sovereign states of the world, with Monaco and the Vatican. The island's land area is 17 times greater than Paris and hosts over 5.6 million people.

Singapore City Gallery gives us an interesting understanding of Singapore's construction and unique development featuring rapid transformation since its independence on 9 August 1965.

The first floor of the building houses a model of the Central Area of Singapore that highlights the high population density of this country (one of the greatest in the world) with multiple towers, but also numerous green spaces, which is remarkable for such a small, dense country. Today, the city continues to grow and new towers are still being constructed.

Vertical urbanization: conservation or reconstruction ?

To face the issue of its limited area coupled with significant demographic growth, the government of Singapore had to decide whether to conserve its old buildings or demolish them to construct new, more practical ones. Some of the oldest districts of Singapore which date

Singapore Central Area Model (accounting for only 2.3% of the country) back to the late 1800s and 1900s, like Chinatown, Little India and Kampong Glam, have been conserved. However, several other areas have been demolished and reconstructed to make full use of the prime land. In addition to the buildings, many trees have been conserved, creating pleasant shaded areas in the city. The young state-city is today a world-class example of architecture, able to conciliate massive urbanization and green spaces.

Singapore has the highest housing owner rate in the world, with 89% of citizens owning their home. 85% of accommodation is managed by the Housing Development Board.

Singapore's economic drivers

Singapore is one of the three biggest oil exporters in the world, with 68 million tons of oil exported in 2007 (BP Statistical Review of World Energy, June 2008).

This state-city is a world trading hub and a key player in Asia featuring the world's second-largest container port in the world. In 2008, its marine and offshore industries' profits increased by 18.8 billion dollars and employed 70,000 workers (Economic Development Board 2010). Changi Airport is the fifth biggest cargo airport in the world. Singapore has also developed solid expertise in aerospace, and is the number one in Asia today. Research and development is also of a high level in the continent with two of the greatest universities in Asia: the National University of Singapore (NUS) and Nanyang Technological University (NTU).

The country's industrial activity is mainly located on Jurong Island, an artificial island created in the 2000s in the South West of the country. Today, this island ranks as one of the top 10 petrochemical hubs in the world with the presence of Shell, ExxonMobil, Chevron, DupontTM, BASF, Sumitomo Chemicals, Mitsui Chemicals, etc.

Interactive board at the Singapore City Gallery

Waste and water managment

A few kilometers away from Jurong Island, another island called Semakau recovers Singapore's waste. 57% of the country's waste is recycled, and 41% is incinerated in 4 different incinerators that produce 3% of Singapore's total electricity demand. The government aims to recycle 70% of its waste by 2030. Incinerator ashes are taken to Semakau landfill.

Water supply is a real issue in Singapore as the country imports most of its needs from Malaysia. However, the country is developing desalinization plants to treat seawater and other processes to recycle sewage water into drinking water. Three plants of this type are currently running in Singapore, providing 30% of the country's water demand.

Underground: a perfect solution

Singapore's underground is exploited down to 150 meters. Each level has a specific use:

- Between 1 and 3m, the gas and sewage networks are located, and also pedestrian tunnels.
- Between 5 and 10m, the Common Services Tunnel at Marina Bay area can be found with telecom cables, power lines and other utilities
- Between 15 and 20m, the subway system operates used by more than 2 million people.
- Between 20 and 60m, deep waste and sewage networks cover 48km.
- At 150m, lie the Jurong Rock Carverns featuring nine 340m-long storage caverns with 9 levels storing military munitions .

What about Singapore's political model?

This description gives the impression that Singapore is a perfect city and a unique development model in many aspects. However, this is the vision delivered by the Singapore City Gallery, and we should not forget that the same People's Action Party (PAP) government has been in place in the country ever since its independence...

Nalini GASCON

One of the several rooms at the Singapore City Gallery with interative maps

BeeBryte: Energy Intelligence to optimize electricity uses and create value from flexibilities

On the third morning of our trip, we visited the French-Singaporean start-up company BeeBryte, represented by Elodie Hecq, sales engineer.

Ms Hecq presented the products and services sold by BeeBryte in the "Energy Intelligence" sector, centered on tertiary buildings and industry.

What is BeeBryte ?

BeeBryte is a French start-up company incubated in Singapore: it is the fourth project created by a duo of engineers from one of the top French engineering schools, Polytechnique. It is also their first technical project, since the first three were sustainable investments funds. What is more, the company is multinational: in addition to its Singaporean headquarters, which employs 1 to 2 full-time-equivalent engineers (about ten are expected to be hired within the next few weeks!), BeeBryte has created a research centre in Lyon (France), comprising a dozen staff. The company makes its income from a percentage of the savings it generates for its customers.

How does BeeBryte create value ?

This start-up company uses machine-learning and data analytics technologies to provide customers with an accurate understanding and analysis of their electricity consumption. These algorithms are fed with data from a set of sensors that measure energy systems in real-time. They allow BeeBryte and customers to identify and visualize electricity consumption levels, and even anticipate them thanks to predictive analysis. If necessary, depending on the commercial option chosen by the customer, BeeBryte can even remotely stop or curtail some appliances in order to create value from flexibilities.

The highest level of service that BeeBryte offers customers is its Hive Supply option, by which BeeBryte operates as an electricity supplier. In this configuration, BeeBryte guarantees a flat electricity price to its customer, below the market price. To do so, BeeBryte optimizes its curtailment capacities from an aggregated group of customers to avoid buying electricity at

Hive Vision	Hive Optimal	Hive Supply
• Supervision • Energy efficiency consulting • Anomaly and deviation detection • Consumption prediction	• Hive Vision • Control of appliances • Creation of value from flexibilities (curtailment)	• Hive Optimal • Electricity supply at a lower price than the market

Commercial offers of BeeBright

peak hours, when it is expensive. BeeBryte even sells these "curtailment blocks" during the peaks to gain money, which serves to bring down the mean price in general. As a result, BeeBryte can offer its customers a lower price. In financial terms, the company buys its electricity on the futures market, which is cheaper than the spot market, and covers its risk by using its curtailment or stimulation capacities (known as "load-shifting"), a system that BeeBryte masters well (thanks to the Hive Optimal option).

Questions and answers with Elodie Hecq

Can the IT in the business tertiary sector contribute to flexibilities ?

Unfortunately, that is still very difficult: the software interfacing is extremely hard to set up to control these systems. In the real world, software architecture can be very different from one computer to another, even in the same IT pool. As it is impossible to standardize the procedure, costs increase dramatically and so the project is never profitable.

Do you think it would be possible to adapt the cost optimization solutions to carbon emissions criteria ?

In fact, when prices are high in the market, it's because some power plants have to start up and operate to cover the demand peak. These are mainly carbon-intensive plants, so in a way the cost optimization already tackles the carbon emissions issue.

What do you think about the potential competition between you and giants like Schneider Electrics which already provide energy services ?

Although competition seems obvious, in fact these types of company, i.e. more focused on hardware than software, are less efficient and less profitable when it comes to energy services, which require a layer of software intelligence.

All of the OSE master's students are very grateful to Elodie Hecq and BeeBryte for welcoming us, presenting their activities in such detail, and answering our questions.

Romain SAINT-LÉGER

OSE students with Élodie Hecq

Total lubricants Singapour : the wold's largest lubricant plant

In 2015, Total built the biggest lubricant factory in the world, which employs 425 people. With a production of more than 310,000 tons a day, the plant consolidates TOTAL's foothold in Asia ,where the group already holds 25% of the market shares. After a brief introduction of the security rules, M. Kok Choy NG, head of the marine logistics department, took us on a tour of the facilities to see the entire production line.

The choice of Singapore is further proof of Total's commitment to operational effectiveness and optimization. According to M. Kok Choy NG, the strength of this plant lies in its fully automated logistics and processes, which we were able to see, from the loading facility to the blending and conditioning line. The recipe is in fact fairly simple: it consists in blending base oil with a specific proportion of additives depending on the intended use (marine oil, automobiles, construction trucks etc.). Robots, automated forklift trucks and control systems can be found all over the factory. As the line operates on its own, the workers and technicians just seem to carefully watch out for incidents from the control room. The plant's very strict standards have earned it top certifications (ISO 9001, 14001 and 18001) and seen it quadruple its production ratio compared to facilities of the same type.

Productivity is not the staff's only concern. To ensure a reliable business and win 27 F1

Total's production site in Singapore © Total Media

Class photo with M. Kok Choy NG

championships, TOTAL had no choice but to guarantee the highest quality of its lubricants. In Singapore, the oil is directly controlled when it comes out the blender. Every single liter of final product is stored in buffer tanks from which samples are taken to the laboratory. The chemists showed us typical tests, such as the composition, viscosity or the ability of the oil to separate from air or water. If any anomaly is noticed, the whole buffer tank is sent back to the start of the line to be diluted and re-blended. Lastly, we visited the storage facility, where the samples are kept for one year for customer-services purposes.

Although the challenge of running such an efficient factory mainly involves the management and logistics, energy still plays an important role in its performance. The ambient temperature allowed the designer to save on an expensive heating system to maintain the oil's viscosity. Prices of crude oil also influence the production, as customers prefer to anticipate high prices and overbuy as soon as the price rises slightly. Finally, despite fully electrified plants which make the plant highly vulnerable to power cuts, the extreme stability of the Singaporean grid allows the factory to run without a back-up generator.

The plant currently runs at its optimal levels in terms of workforce, M. Kok Choy NG told us. However, the staff still works in 2 shifts a day, which allows the management to increase activity in the case of a dramatic increase in demand.

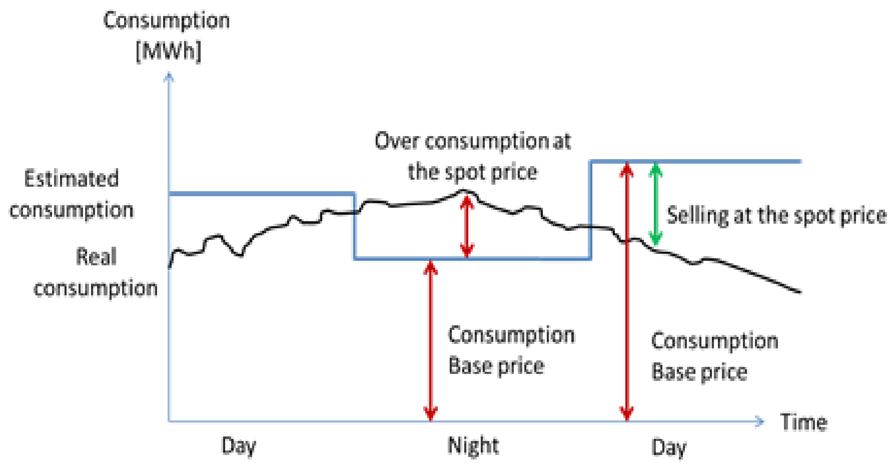
All of the OSE Master's students are very grateful to M. Kok Choy NG, See-Beng TANG, Ivan LOH and Ana COSCOLLUELA for their warm welcome at the Total Lubricant factory.

Louis POLLEUX

Air Liquide, an optimization model turned towards the financial world ?

We were welcomed at Air Liquide Singapore (ALS) by Mr. Ferreol De La Tullaye, who has been Air Liquide's energy manager in Asia for over 10 years. ALS is an Asian cluster of the group comprising 8 countries, and the leading industrial gas company in Southeast Asia. It employs nearly 800 people, recognized for their high level of expertise in supplying gases such as oxygen (O_2), nitrogen (N_2), hydrogen (H_2) and carbon monoxide (CO). ALS offers solutions for small and large industries such as Jurong Island where the group has invested more than 280 million euro in recent years. The company's presentation began with a futuristic marketing video of the Smart Innovation program in Kuala Lumpur. It highlighted technological advances in the service of industrial optimization from a technical point of view, with the use of "Google Glass" or even touch tablets in order to better monitor maintenance operations and improve the organization of predictive maintenance. However, we quickly moved on to the second part, financial optimization, and in particular sourcing and risks related to energy markets. Indeed, energy represents nearly 85% of Air Liquide's costs, including 27 TWh of electricity and 92 TWh of natural gas. By way of comparison, staff costs represent only 2% to 3% of total costs. This energy is mainly employed in the manufacturing processes of the various gases produced. Electricity, for example is used in the compressors of the cooling units to lower the temperature of the gases in order to liquefy them, and in the steam cracking processes to extract hydrogen from methane and nitrogen from the air. Since the cessation of oil imports (35%) in favor of 100% natural gas as a raw material, a strong dependence on energy prices has emerged. The price of energy depends on many parameters such as subscriptions, the molecule, transport taxes, balancing, risks and flexibility. For example, a 50% increase in energy prices would cost more than 3 billion euro for a margin of 1.6 billion euro. It is clear that we should not therefore reason in terms of purchase cost but in terms of margin generated. However, part of Air Liquide's business model is based on transferring variable costs to consumers in order to better stabilize its margin.

To stabilize Air Liquide's margin, Mr. De La Tullaye presented us with 5 methods based on financial energy optimization. The first employs "load shifting" and "peak shaving" mechanisms to benefit from advantageous spot prices by shifting production to the night or by optimizing subscribed capacity. A feedstock option can be a way of choosing the best primary energy source, such as between naphtha and natural gas, based on both their costs and their efficiency in the process concerned. The next method involves a tradeoff between self-production and subcontracting, in which case the production load must be reduced, which also leads to a drop in yield, in order to integrate hydrogen from an external supplier, which considers this resource as an externality and sells it at a reduced price. A threshold is thus established below which the system is no longer profitable because the yield is too unfavorable. Another method consists in choosing a primary gas delivery method, between pipeline and LNG (Liquid Natural Gas), respectively indexed to HSFO and Brent prices. This kind of choice can also be made for electricity, choosing between the spot market and the power rate. If you consume more than expected, you pay the difference at the spot price, if you consume less, you sell the unconsumed energy at the spot price. An optimization of the mechanism thus consists in estimating higher consumption during the day in order to resell the excess production at a high price during the day and vice versa (see figure 1 below).



Contractual arbitration curves on electricity © Air Liquide

Finally, the last lever, called "demand response", uses the market's capacity or spot price reduction mechanisms by playing on the production switch's limit zones, as shown in the diagram below (figure 2), given as an example by Mr. De La Tullaye. The gains are then split 50-50 between the customers and the actor at the origin of the curtailment.

Following the presentation of these different levers for action, a question came to mind: How are the gains split between technical process energy improvement actions and those resulting from the financial optimization of primary energy resource purchases? The answer is clear, according to Mr. De La Tullaye: over the last year, energy savings from financial optimization were 3 times greater than the technical gains on processes. He explained that production systems are now well established and that it is difficult to make even 1% savings with returns on investments that span several years, unlike financial optimization. This raises the question of whether technical improvement still has real value. It is clear that for companies as big as Air Liquide and with similar business models, only the price of carbon tax will have a real impact on the desire to reduce gross consumption, which is directly linked to CO_2 emissions.

We thank Mr. Ferreol De La Tullaye, for his welcome and presentation, which allowed us to approach an optimization model from a different angle than we had seen up until then during our Singapore travels.

Axel FELIZOT

Engie Lab: visit of the SPORE microgrid site on the island of Semakau

The last morning of visits was devoted to the SPORE (Sustainable Powering of Off-grid Regions) microgrid. This project is part of the Renewable Energy Integration Demonstrator in Singapore (REIDS) initiative developed at the Semakau landfill by NTU (Nanyang Technological University) in collaboration with two international French companies, Engie and Schneider-Electric. On our journey to Semakau, we were accompanied by the Engie Lab team: Zen Tan, Natacha Bunel, Paul Dupont De Dinechin and Victor Chapotard, as well as Tan Choon Hock representing NTU. We visited a pilot project featuring an R & D demonstrator for hydrogen storage in microgrids, the first of its kind in Southeast Asia, and which particularly sparks our interest since our promotion's topic is hydrogen.

What are the main targets of this microgrid project ?

Natacha explained that the idea beyond this project was mainly motivated by the high number of people in the world living in remote areas or on isolated islands who do not have access to a reliable electricity grid. The diesel solution is by no means a sustainable response in these non-interconnected zones. The aim of this project is to provide a solution integrating renewable energies into a microgrid that could be tested on Semakau for later deployment in other islands, sites, remote villages, resorts, etc. in Southeast Asia. Alongside NTU, Engie and Schneider-Electric, which are working closely on the SPORE microgrid, several other stakeholders are involved in the project, such as the NEA (National Environment Agency), Economic Development Board (EDB), Energy Market Authority (EMA) and the National Research Fund (NRF) of Singapore.

One of the main goals of this demonstrator is to prove the effectiveness of the technical solutions elaborated by Engie and Schneider-Electric by testing them on a practical case that fits into the context of Southeast Asia's tropical climate. Natacha pointed out that the humidity level in Singapore (84%) could be a challenge for wind turbines and various electrical components.

The project's first installation phase was achieved in October 2017. Zen Tan, a member of Engie Lab, mentioned the regulatory considerations to be met prior to the installation and commissioning on site. These involve submitting plans and technical files to the relevant competent Singaporean authorities, namely the NEA (National Environment Agency) and the BCA (Building and Construction Authority). Ms. Tan also told us that at this stage the objective is to ensure that the microgrid conforms to the standards in force in Singapore and to obtain the necessary authorizations for its commissioning by the third quarter of 2018.

What are the principal components of the SPORE microgrid?

The SPORE microgrid is powered by a multifluid system: along with electricity, its operation involves a hydrogen storage system. A

Photographie of a part of the microgrid SPORE

Power-To-Power system stores the renewable energy surplus produced in the microgrid for later use, or for refueling a fuel cell electric vehicle, the first in Singapore. This system is composed of an electrolyzer and an HRS (Hydrogen Refueling Station) designed to refill one car in just 5 minutes, and up to 20 vehicles per day.

Engie has also installed photovoltaic panels along with the first and tallest wind turbine in Singapore. The 32-meter high wind turbine has a capacity of 100kW, and the photovoltaic panels are of two types: a standard version with a capacity of 70 kW, and a PIPV system with a capacity of 7 kW.

Thanks to these installed features and to the innovative energy management solutions developed by Engie and Schneider-Electric, the SPORE microgrid will enable high renewable energy integration that could reach 100%.

What are he key technological innovations in the SPORE microgrid ?

The SPORE microgrid features three major technological innovations. The main one is Engie's hydrogen solution, which will contribute to improving the microgrid's flexibility. Along with its easy storage, hydrogen can also be used in various applications, such as mobility, and electricity and gas generation.

A key innovation is also the "smart grid forming inverters" solution developed by Schneider-Electric. In order to tackle the microgrids's permanent technical challenge of grid stability, Schneider Electric has designed and implemented an innovative solution by combining "smart grid forming inverters" with energy or power storage systems. The solution is devised to allow the system to boot "from scratch" or to "black start" in case of absence of rotating equipment, such as gensets or diesel generators. This innovation will enable a significant penetration of renewables without compromising the stability of the system.

In addition, the SPORE microgrid management system includes a PMS (Power Management System) for short-term storage and an EMS (Energy Management System) for medium-term storage.

The PMS is responsible for ensuring network stability in real time by balancing production, storage and demand. The main advantages of the system are the optimal control of the microgrid in islanded mode as well as

DAY 5

high renewables integration.

The EMS operates on a monthly or medium-term basis in order to forecast energy demand and production to provide reliable and affordable access to energy. The system also manages intermittent renewable energy generation due to changing weather patterns and the multi-fluid configuration of the microgrid.

We would like to thank all Engie Lab Singapore team members for their warm welcome, their support that made this visit possible and enriching, and their readiness to answer all our questions. We especially thank Zen Tan who guided us throughout the visit, Natacha Bunel who explained to us the targets of the project and depicted the various components installed on the site, and Paul Dupont De Dihechin and Victor Chapotard who illustrated the main activities and projects implemented by Engie-Lab Singapore. Our warm thanks also go to Tan Choon Hock, project manager at NTU, who introduced us to the REIDS project from NTU's point of view.

Emna BERKAOUI
& Dhekra BOUSNINA

Group photo with the Engie Team

Immersion into Singapore's maritime history at the Singapore Maritime Gallery

For our last visit, we went to Singapore Maritime Gallery, where our guide Anthony told us enthusiastically about the story of the state, from its emergence as a small trading port in the 14th century to later developments that saw Singapore become the leading global maritime hub it is today. Anthony guided us through the 3 sections of the museum, respectively narrating the past, the current situation and the future prospects of Singapore's maritime activities. Indeed, the explosive growth experienced by Singapore in recent decades is closely linked to its maritime development. Today, this sector accounts for 7% of the nation's GDP and employs 170,000 people both onshore and offshore.

However, Singapore's maritime history began much earlier. Archaeological studies have shown that during the fourteenth century, the island already included a port through which ships transited carrying silk, ivory and cotton. Events then accelerated from 1819 with the arrival of the British statesman Sir Thomas Stamford Raffles, who set up a trading post for the British East India Company. This port aimed a centralizing trade transiting through Asia, thus competing with the Dutch-controlled port of Batavia in Indonesia. The opening of the Suez Canal connecting the Mediterranean Sea and the Red Sea in 1869, and tax exemptions for goods in transit, resulted in significant growth for Singapore during the colonial era, growth that continued after the country's independence. Today, because of its strategic geographical position at the crossroads between Asia and the rest of the world, Singapore is the busiest transshipment port on the globe. This

OSE Master's students listening to the guide's explanations

DAY 5

is of particular importance considering that 90% of world trade is carried by sea, including vital commodities such as food and oil.

The main port is Jurong Harbor, located on an island reclaimed from the sea. This harbor attracted more than 12,000 boats in 2016. Jurong is a petrochemical hub that receives imports of oil (from neighboring Indonesia in particular) and natural gas (via pipelines from Malaysia), and features refineries.

One of the key issues for Singapore's maritime activities is the refueling of ships. About 1,000 boats are permanently stationed along the coast. Fuel is delivered to the harbor by pipelines or tankers. While most ships still operate using oil, a transition to LNG seems to be underway to reduce the carbon footprint of the transportation sector. Singapore is encouraging this transition and aims to be ready for LNG refuelling by 2020. Pipelines linking Malaysia to Singapore already import LNG to Jurong Island, and ongoing discussions should help determine the appropriate regulatory framework, as LNG raises new safety issues, including for instance its high inflammability .

The self-lifting oil platform West Elara

In order to ensure the accuracy and precision of fuel refills, mass flow meters are used. This is of particular importance as huge quantities of fuel are at stake, so that even minor inaccuracies in fuel measurements can add up to millions of dollars. Mass flow meters allow the immediate measurement of the bunker fuel quantity introduced into a ship, and are more accurate than manual methods. Since January 2017, all Singapore tankers have been equipped with this technology.

What is more, Singapore is the world's leading producer of oil platforms, in particular jack-up drilling rigs, thanks to companies like Sembcorp Marine and Keppel. For instance, the photo below shows a model of the West Elara jack-up rig built in Singapore by Sembcorp Marine in 2011. This rig can endure harsh climatic conditions specific to the North Sea, and drill down 10,000 m under the seabed, at water depths reaching 150m. The platform is now operated by the American company ConocoPhillips in the North Sea.

To wrap things up, OSE students would like to thank Anthony, our guide for this visit, who enlightened us on Singapore's history, and gave us a sense of how the country transitioned from a developing country to a rich one in only fifty years.

Chloé POTIER

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Last but not least, we would like to thank all of the Ecole des Mines de Paris alumni who honored us with their presence on the Friday evening to meet the OSE Advanced Masters students.

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EDF Lab.: M. Maxime Cassat, Mr. Geoffrey Orlando

SCHNEIDER ELECTRIC: Mr. Thomas Polliand, Mr. Tushar Menon, Mr. Alfredo Samperio

BeeBryte: Mme Elodie Hecq

TOTAL: Mr. Olivier Chalvon-Demersay, Mr. Christian Cabrol, Ms. Ana Coscolluela

Air Liquide: Mr. Bernard Dhainaut, Mr. Ferreol De La Tullaye

Engie Lab.: Ms. Caroline Guyot

PARTNERS

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