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Taiwan, heart of Asia

Special edition: study trip

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OPTIMISATION DES SYSTÈMES ÉNERGÉTIQUES

Centre de Mathématiques Appliquées

Chaire ParisTech Modélisation prospective au service du développement durable

Coordinator - Catherine Auguet-Chadaj
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Photos - MS OSE Students

OVERVIEW

Front page: Taipei 101 tower

As is customary, post-graduate master "OSE" students at the CMA had the opportunity to go on a one-week study trip at the beginning of March. This year, Taiwan was chosen in order to study its energy system. The energy situation in Taiwan is particularly interesting for several reasons: the country is an island, its geopolitical relationship with its closest neighbor, China, is complex, and it has strong geographical constraints. During the eight days they spent there, the students visited many installations involved in energy and attended some very interesting presentations.

In this special issue of our Inf'OSE gazette, we give an overview of the visits we had the chance to make during this enriching week. You will also find in this issue a synthesis of the ideas we shared during conferences on the theme of low-carbon mobility held at two top universities in Taiwan: National Central University (NCU) and National Cheng Kung University (NCKU).

First of all, we would like to thank all of those who made this trip possible. Our thanks go to the universities and industrials who warmly welcomed us, took the time to present us their activities, showed us round their installations, and talked with us about technical and economic topics. Thanks to NCU and NCKU for the quality of the audience at the conferences. We would like to thank Taipower, the Industrial Technology Research Institute (ITRI), Ciel et Terre, Wusanta Reservoir, Taiwan Cement Corporation and Ho-Ping Power Company for the fascinating visits they prepared for us. We also wish to thank Taiwan Tech Arena for receiving us, as well as EDF, Ubiik and UnaBiz for their very interesting presentations. Many thanks to the Bureau Français de Taipei and UBIK, who ensured that this trip was both rich and varied.

Finally, we would like to thank Gilles Guerassimoff, who heads the post-graduate OSE master's, and all the team at the Center for Applied Mathematics for organizing this exceptional study trip.

We now invite you to discover the richness of the Taiwanese energy system throughout the different steps of our exciting trip. Enjoy your read!

Dorine JUBERTIE

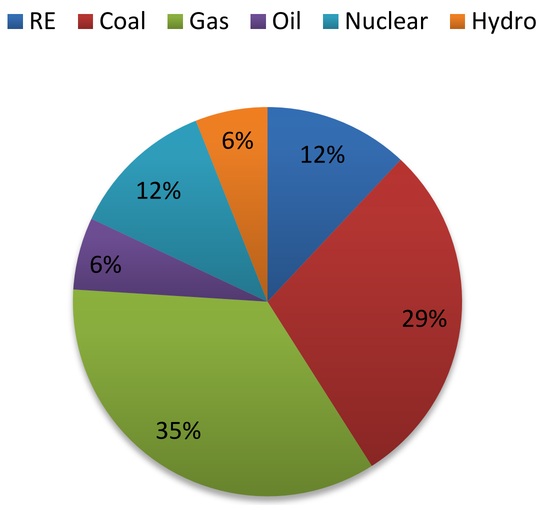
STATE OF THE ART OF ENERGY IN TAIWAN

Known as the "Heart of Asia" thanks to its attraction as a tourist destination and strong development of high technologies, Taiwan's energy situation nevertheless remains delicate. The island is subject to geographical constraints combined with the challenges of energetic transition and air pollution. For these reasons, the government has opted to make some ambitious political choices, such as a strong development of renewable energies and a radical withdrawal from nuclear energy.development of renewable energies and a radical stop of withdrawal from nuclear energy.

GEOGRAPHICAL FACTORS AT THE CORE OF ITS ENERGY STRATEGY

Above all, Taiwan is a small island (36,000 km^2), with only 30% of constructible land surface and the remainder covered by mountains. Because of this specific topography, the country possesses few natural resources, resulting in energy import requirements of more than 98%. These imports mainly comprise coal (from Australia, Russia, Indonesia) and gas in the form of liquid natural gas (from Indonesia, Saudi Arabia, USA). Lastly, although some thought has been given to the subject, interconnections with China remain impossible because of complex diplomatic relationships.

CURRENT ENERGY LANDSCAPE

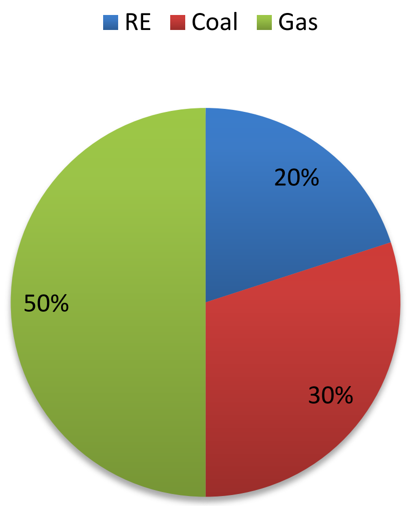


Current energy mix

The Taiwanese tropical climate is an important factor in its energy landscape. It is characterized by a hot, humid summer, with a rainy season beginning in April, and a mild, drier winter. The consequences are low gas consumption, and a heat demand satisfied by heat pumps. The need for electricity is thus high. Demand has continued to rise over the years, for example from 2017 to 2018, when the island's total consumption went from 231 TWh to 233 TWh, an increase of +2 TWh. The mean consumption per inhabitant equals nearly 10 MWh, with higher demand in the north. Indeed, both the concentration of inhabitants and industrial activity are greater in the north than in the south. Electricity is mainly produced from coal and gas (66% of the energy mix), and the rest is produced from nuclear energy and renewable energy, whose shares are slowly growing.

TARGET FOR 2025

The Taiwanese government has set a simple and ambitious objective for 2025, in a context of energy transition. They hope to put a radical stop to nuclear production (0% of the mix), and replace it by gas-fired and renewable energies. Coal-fired energy is also expected to be reduced. The expected mix in 2025 is shown below. This goal brings new challenges that the Taiwanese will have to tackle. On the one hand, the presence of coal in the mix remains significant (30%), which is inconsistent with the environmental challenges that need to be solved. On the other hand, an increase in gas-fired electricity production requires the construction of costly harbor infrastructures to receive imports. Moreover, renewable energies are expected to increase from 5% to 20% of the mix! This target will be difficult to reach, but high feed-in tariffs (incentives for renewables) and considerable offshore-wind potential (5.5 GW on the west coast, 5th worldwide deposit) may help the country reach its objective. Nevertheless, it will need to handle grid stability issues, as we know that the massive integration of renewable energy sources increases the risk of blackouts.



Target for 2025

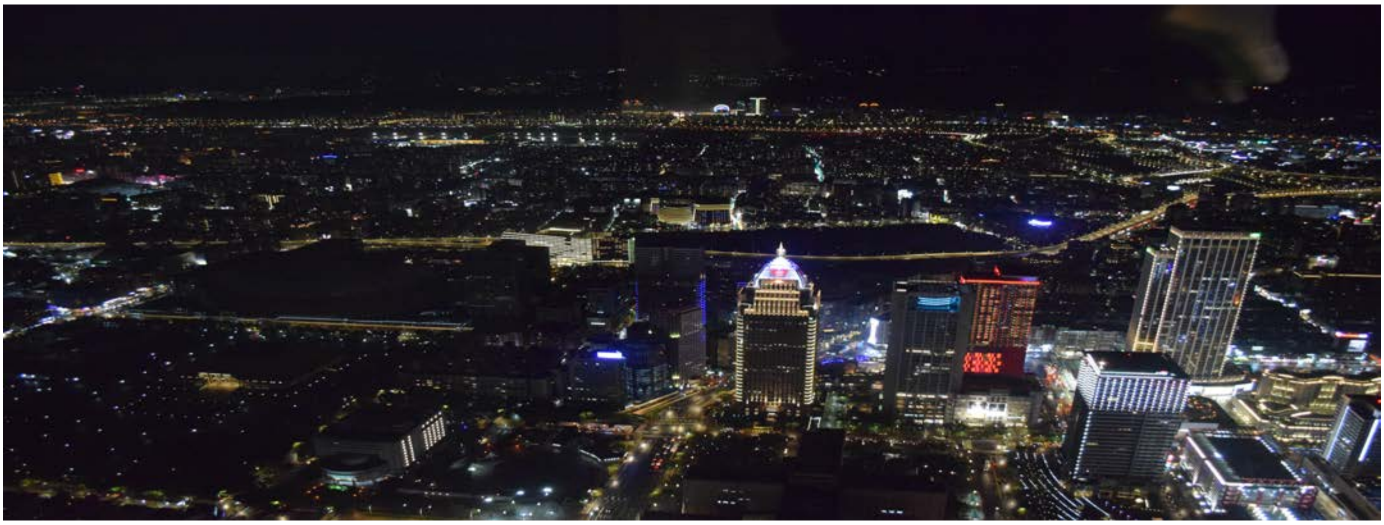
ZOOM ON PLACE OF NUCLEAR ENERGY

Nuclear energy occupies an important place in energy production thanks to its stability. Nuclear production is perfectly controllable, although time is needed to start or stop the reactors. This stability is vital for such an isolated country. In August 2017, Taiwan faced the greatest blackout in its history when one reactor came to a stop, which illustrates why this energy is important to satisfy increasing demand. However, the small size of the island does not allow a large zone for waste storage. Nuclear waste is stored in situ, which raises security questions. This is the main reason why the government asked for the complete stop of nuclear production before 2025. But the opposing points of view of the two main political camps may lead to a different option, leaving the question open.

CONCLUSION

To conclude, the island of Taiwan faces energy challenges due to geographical and geopolitical reasons combined with the constraint of the energy transition. Nevertheless, its 2025 objectives can be achieved provided it establishes sufficient incentives for renewables and acts to solve grid stability issues.

Antoine JOURDAIN DE MUIZON



Sources: *Martin TZOU, EDF – Taïwan Market Director, and Prof. Tsung-Kuang YEH, NTHU University, Hsinchu*

Visit of the Taiwan TechArena

On Monday March 4th, the Master's students were visited the Taiwan TechArena where they met two start-ups and the French Representative Office in Taipei.

WARM WELCOME AT THE FRENCH REPRESENTATIVE OFFICE IN TAIPEI

As part of their study trip to Taiwan, the Energy Systems Optimization Master's students had the opportunity to meet up with Mr. Benoît Guidée, Director of the French Representative Office in Taipei, on Monday March 4th 2019 at the Taiwan Tech Arena.

Mr. Guidée gave us a substantiated introduction to the island's history.

Taiwan is one of the most developed economies in Asia. The island is in fact the 21st global economy, with GDP of around 600 billion USD, making it the 6th economy in Asia ahead of Singapore and Thailand. Despite per capita GDP of 25,000 USD, Taiwanese purchasing power is in fact greater than the French equivalent. This is a mark of a very developed economy that features high-tech brands like HTC, Asus and Acer. The core of Taiwan's economy, though, is electronic giants such as Foxconn, Quanta and Pegatron, which are central to Asian value chains but little known by the general public because they mostly produce white-label goods.

Politically speaking, Taiwan is one of the most dynamic democracies in Asia, despite the fact that it was under martial law up until 1987. The first presidential election by universal suffrage took place in 1996, and the first change in political leadership dates from 2000.

Today, the island is a fully fledged democracy with regular political changeovers, a very strong civil society, and more freedom of the press than the likes of Japan and South Korea according to RSF rankings. For this reason, the NGO Reporters Without Borders even chose to open its Asia office in Taipei.

Benoît Guidée, Director of the French Representative Office in Taipei © Y. LAHMA

The two main political parties govern alternately, with on the one side the more conservative Kuomintang, which dates from the former dictatorial regime and is now a democratic party, and on the other side the Democratic Progressive Party (DPP), viewed as liberal.

The main difference between the two parties is their attitude to relations with China: while Kuomintang affirms that Taiwan is an integral part of China, the DPP, currently in power, maintains the opposite point of view.

Historically, until the 17th century, Taiwan was inhabited by indigenous peoples fairly similar to those found in the Pacific Ocean, like the Melanesians in New Caledonia. The island was not affected by major Asian demographic movements. The key powers of the time initially saw Taiwan as a possible international trading post, and the first settlers were Dutch and Spanish, although they quickly made way for the Chinese. Chinese domination lasted for two centuries, with immigrants mainly coming from Fujian Province. Nevertheless, the island continued to remain relatively unaffected by China, which considered it as a fairly isolated settlement.

In 1895, the situation changed dramatically when Japan won the war against China and took possession of Taiwan. The Japanese remained for 50 years, during which time Taiwan became one of its colonies and was cut off from China. This colonization was accompanied by a wave of modernization that turned Taiwan into a fairly advanced country in terms of industry and economy. In 1945, when Japan lost World War II, Taiwan was returned to China. A few years later, at the end of the Chinese civil war, the nationalist government was beaten by the Communists and took refuge in Taiwan. Its leader Chiang Kai-shek saw himself as China's true leader in the face of the "Communist rebels". Countries in the West initially recognized him as China's official representative (Taiwan sat on the United Nations security council until 1971). However, France, headed by General De Gaulle, recognized the People's Republic of China in 1964, leading to a break in relations with Taipei, which only maintained 18 diplomatic allies including Honduras and the Dominican Republic.

Ultimately, it was the democratization of Taiwan that pushed some of its people to develop a notion of nationalism. The DPP's arrival in power in 2000 embodied this movement. Kuomintang did however return to power in 2008 with a policy to move closer to China, before once more handing over the government to DPP in 2016.

The result was strained relations with China. Currently, a status quo is in place. China refuses dialogue with Taiwan and maintains political and sometimes economic pressure. One of the consequences of this pressure is that Taiwan finds it difficult to sign free trade agreements with other partners and at times describes itself as an "orphan of the international community".

France, like all European states, does not maintain diplomatic relations with Taiwan, although this does not prevent it from developing concrete relations in four main areas:

- A community of democratic values and human rights Taiwan shows that Chinese culture is totally compatible with democratic values. The island is at the forefront on human rights issues and is the first territory in Asia to have adopted gay marriage (scheduled for May 2019). It also gives women an important place in society, illustrated by the fact that it is currently run by a female president, namely Tsai Ing-wen.

- Innovation because Taiwan is founded on a very powerful industry that has at the same time had difficulties moving on to a new phase. The island missed the internet boat and continues to mostly focus on the hardware and semiconductor industries. Taiwan struggles to innovate, opening up obvious possibilities for "win-win" innovation partnerships with Europe, and especially France. The latter appreciates Taiwan as a reliable economic partner because of its respect for intellectual property and the fact that it is a state of law with trustworthy commercial practices.

• Environment and climate: Taiwan faces several environmental challenges, including for its energy mix. The current government is implementing an ambitious energy policy with an accent on renewable energy and a rapid (but contested) withdrawal from nuclear power. This therefore opens perspectives for cooperation with France.

• Culture: France has a strong image that can be subject to cliché. The French Representative Office in Taipei is therefore attempting to rejuvenate this image with a policy of cultural innovation.

In conclusion, Taiwan is important for France because it represents a "regional hub" and a "laboratory" for technological, political, democratic and energy-based innovation. As an example, Taiwan is the offshore wind power leader in Asia. The game played out here will be crucial, in particular for standards, and the winners of the Taiwanese race will be well placed in the rest of Asia. Unfortunately, French industrial companies are not currently present in offshore wind projects in Taiwan (but our banks are closely involved in these programs).

Eli RAKOTOMISA

The Mastere's students at the Taiwan TechArena © Y. LAHMA

VISITS TO EDF AND TWO YOUNG START-UPS

On Monday March 4th 2019, the OSE master's students were hosted by Pascal Viaud, steering committee member of a business incubator called French Tech in Taiwan. Located in the center of the Tech Arena in Taipei, the main purpose of French Tech (which was set up in June 2018) is to help French and Taiwanese start-uppers build projects in Taiwan and Asia. In this capacity, the incubator promotes economic collaboration between France and Taiwan.

During our visit, EDF's Taiwan Market Director, Martin Tzou, presented the company's activities in Taiwan. Mr Tzou, who joined EDF five years ago, told us of EDF's ambition to develop sustainable city projects. At present, the Taiwanese electricity mix relies heavily on carbon, and public opinion supports reducing and closing thermal and nuclear power plants and promoting renewable energy development policies. As illustrated by the vertical disintegration of TaiPower (the country's historical electrical system operator), energy efficiency seems to be a lever to decarbonize the electrical system.

With its long-standing experience and expertise, EDF is well placed to advise Taiwan on numerous subjects such as smart meter development, pollution zone modelling, and the consequences of opening up the electricity system to competition. All of these are areas that EDF is keen to develop in Taiwan.

We would like to thank Martin Tzou for his presentation and the time he spent with the students, and sincerely hope that EDF's work in Taiwan will benefit the Taiwanese population.

While visiting the Taiwan Tech Arena, the OSE students had the opportunity to discover several new technologies devised by Ubiik and Unabiz, two start-ups that presented their work on IoT.

These companies decided to work on an innovative domain: IoT (Internet of Things), which refers to connected devices that can communicate via emitting or receiving data. These devices, sensors, traffic lights, GPS, cellular and electronic devices communicate between each other and with computers, creating a fast and inexpensive link between the physical and the virtual worlds. The networks on which the devices communicate are cheap and consume little energy. These are the main characteristics of the two companies we met, since they both work on long-range applications (LPWAN), rather than 4G or 5G.

Presentation of ubiik © Y. LAHMA

Meeting with Ubiik

Ubiik is a company specializing in IoT, notably in energy monitoring. The start-up was founded in 2016 and is already a market leader in LPWAN technologies (Low Power Wide Area Network). Clément Dieudonné, a French citizen living in Taiwan and strategy director of Ubiik, presented the company's activities and the technologies that he has developed with three others. The company was founded based on the observation that IoT is underexploited for industrial applications. Rather than using a network, which is able to handle a lot of data, Ubiik chose an innovative technology that allows long-range communication and long life for the infrastructures.

The start-up took off thanks to a TaiPower tender for developing smart meters throughout Taiwan. The start-up Ubiik has been selected for the first step of the biggest IoT project in Taiwan, which consists of connecting around 3 million wireless smart meters from 2030 onwards. One of the main strengths of the technology is that Ubiik chose not to patent it, but rather to make it "open standard", which means that it has free access. Thus, despite the product's newness and market instability, customers are reassured about the technology's sustainability. In comparison to competing products specializing in power line technology, Ubiik's long-range technology requires fewer infrastructures and so less investment. With regard to technology, the difference with other solutions on the market is that Ubiik's technology is bidirectional. Devices can be controlled, which is an interesting characteristic for security and updates.

Ubiik also works with industries that are interested in energy monitoring and machine tracking allowed by efficient sensors. Ubiik has developed an electronic paper used for industrial applications where its efficiency and swiftness makes it particularly interesting. Another application is photovoltaic energy with connected sensors, which monitors energy for remote maintenance. Ubiik's technology can be used for smart lighting and charging stations for electric vehicles.

We thank Mr Dieudonné for his presentation and wish him luck and success in connecting the remainder of the 70,000 smart meters.

Meeting with UnaBiz

Still on the subject of IoT, the start-up UnaBiz specializes in LPWAN technologies. A spin-off of the Sigfox company, Unabiz was set up in July 2016. It is the first Sigfox operator to work in Asia with two offices, in Singapore and Taipei, giving the company the opportunity to work in a safe space where the best technologies can be developed. UnaBiz operates, manufactures and develops Sigfox sensors, with more than 500 solutions available throughout the world. Over the last few months, Unabiz has provided consulting services to customers such as Safran, Engie and Airbus. The Sigfox network covers more than 95% of Taiwan and 99% of Singapore. Offering low prices, UnaBiz emerged on the market and has signed contracts with several well-known customers. Last year, UnaBiz had a turnover? of 10.4 million dollars via KDDI, SORACOM and Engie. Regarding its IoT technologies, Philippe Tzou, Business Development Manager, told us about several markets for UnaBiz in Asia, such as parking space connection. To monitor smart parking, sensors identify empty parking spaces, pay for them directly, inform parking

DAY 1

operators on which parking spaces are the most used and then adjust the parking space price depending on the attendance. In partnership with Airbus, UnaBiz is working on the connectivity of an engine that locates parking spaces and determines their frequency usage. To manage its cold chain logistics, Carrefour uses UnaBiz sensors to follow transportation and the temperature setpoint. UnaBiz is also working on a new smart city project. UnaBiz provides a free Sigfox network to Taipei. Other projects include monitoring photovoltaic power plants and public bike transport.

Lastly, these IoT solutions may be divided into four categories: sensor measurement, geo-tracking, event reporting and device management. Because they use the LPWAN network, these technologies are simple, cheap and efficient and do not need much maintenance. UnaBiz has found a new market niche.

We would like to thank Philippe Tzou for the time he spent with the OSE master's students and for his presentation.

Ana DAVID & Lionel FABIANI

Presentation of UnaBiz © Y. LAHMA

Visit of TaiPower

On Monday afternoon, the OSE students were warmly welcomed by Mr. Hsu Tun Kuei, deputy director of the Taiwan Power Company's distribution department (TPC afterwards). Mr. Tun Kuei introduced us to the Taiwanese power system, the challenges of the energy transition, and the role of smart grids in this transition. We invite you, curious reader, to discover the solutions implemented or planned by TPC.

TPC, also known as TaiPower, is a Taiwanese state-owned company, operating throughout the electricity sector value chain, from production to customer supply. A vertically integrated public monopoly, TPC was established on May 1st, 1946 to ensure electricity supply security for the Taiwanese island. It holds the exclusive rights to sell electricity to individuals at a rate regulated by the Ministry of Economic Affairs. Therefore, independent power producers (IPPs) have to sign a power purchase agreement (PPA) to sell their electricity to TPC, including IPPs using renewable energy.
In July 2015, the government of the Republic of China in Taiwan approved a bill put forward by the Minister of Economic Affairs. The project involves dividing TPC into two distinct groups of activities over the next five to nine years: a production company and a network company. In response to a question from the students about the legitimacy of this measure, Mr Tun Kuei stipulated that opening up to competition high up in the electricity chain would allow better integration of renewable energies, because it is more compatible with the public tender.

The Taiwanese electrical system is insular by nature; small and isolated, it has no interconnection with neighboring China. Despite the economic and technical interest of such an interconnection for Taiwan in general and for TPC in particular, for the moment this option remains unthinkable from a political standpoint. Furthermore, electricity consumed on the Taiwanese territory must be produced in situ, and the instantaneous supply / demand balance must imperatively be satisfied by the local production park.

In addition to this island characteristic, Taiwan is highly energy dependent. In fact, 98% of the country's energy needs are imported, 90% of them in the form of oil. In addition to environmental concerns, this causes high supply risks compounded by the political decision to phase out nuclear power by 2025.

To maintain security of supply, the Taiwanese government is banking on increasing the local renewable supply. However, large-scale integration of renewable energy is restrained by natural and geographical constraints. Indeed, of the 36,000 km^2 covered by the Taiwanese island, 60% is mountainous. Hence the encouragement of PV on roofs and the emergence of floating solar projects and offshore wind, with a two-fold strategy to support the energy transition.

As a result, the Taiwanese electricity grid will be gradually transformed to allow a higher share of dispersed and intermittent generation. TPC will support this transformation with both storage to

DAY 1

smooth the intermittency of renewable energy, and smart grid solutions to coordinate the dispersed means of production. We review below the solutions presented by Mr. Tun Kuei:

- The Home Energy Management System (HEMS): this solution allows better control of consumption. It consists of a smart meter, a data collection unit for household devices equipped with WIFI adapters and fitted with an HEMS. The consumption information of each device is centralized by the collection unit and sent by the smart meter to a remote data server. Thus, consumers can visualize their consumption profile at any time on their smartphones via a mobile application; better still, they can remotely control the connected devices to improve their energy consumption.

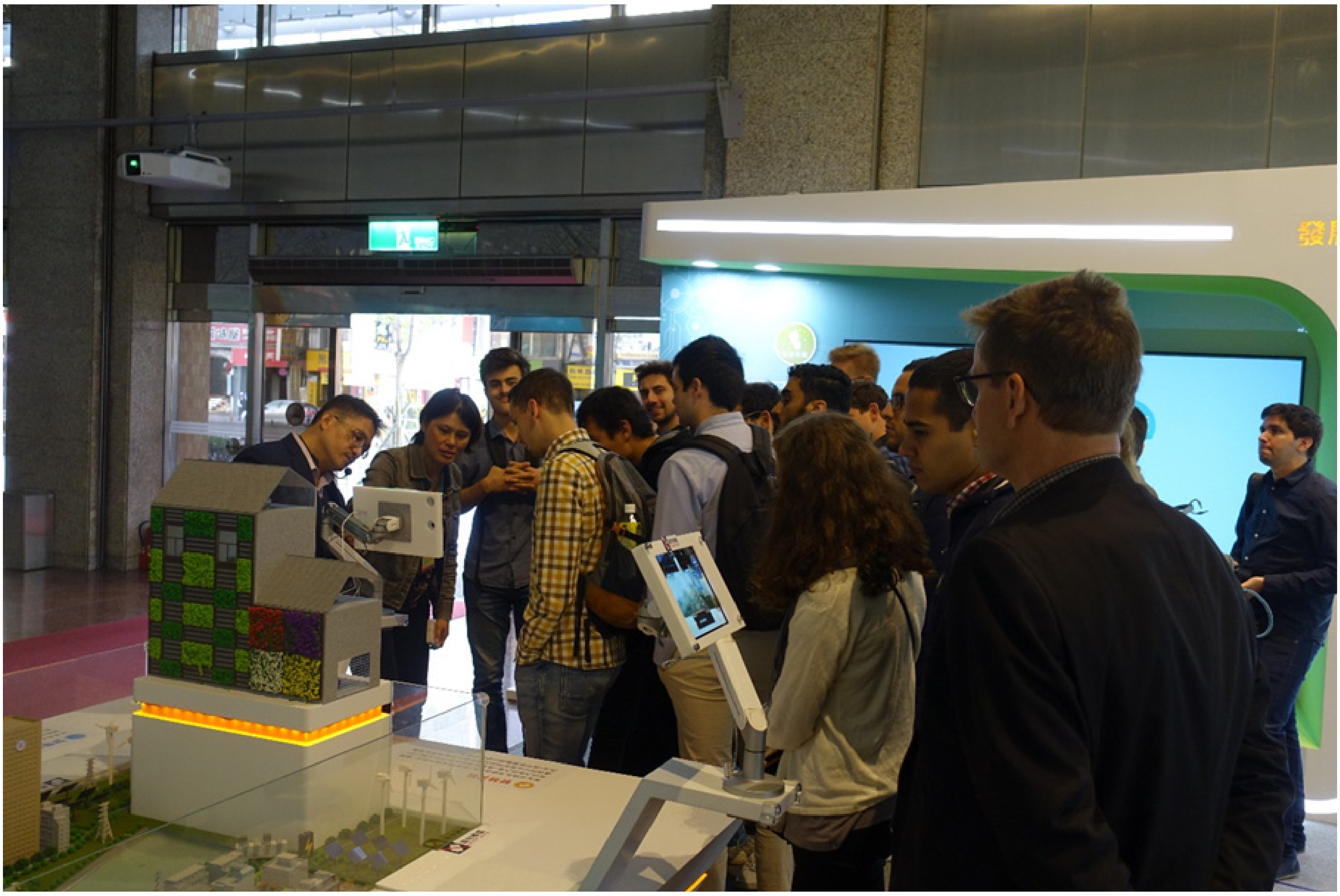
- The smart inverter for photovoltaic energy: this system allows the intelligent, optimized use of solar panels in a local mesh (a neighborhood for example). Unlike an ordinary invertor, a smart inverter is connected to other inverters in the same local mesh. This allows easier dispatch of solar energy from overproducing nodes to those in need within the same mesh; and thus optimal, local use of the electricity generated. The transactions made are tracked using Blockchain technology.

TaiPower's logo

- The Advanced Distribution Management System (ADMS): this distribution system manages the entire set of power plants supplying the network. At present, this set includes controllable production means (e.g. thermal power plants), storage facilities (STEP, batteries), and large wind and solar farms, and soon virtual power plants formed by the aggregation of small self-consumers. The ADMS is designed to be better suited to a new world, where production is decentralized and highly intermittent.

All in all, this visit allowed us to grasp the constraints of managing the electrical system of an island and gauge the effort made by TPC to support the Taiwanese energy transition. On behalf of the energy system optimization master students, we thank Mr. Hsu Tun Kuei for the quality of his introduction and for his warm welcome.

Ayoub EL BOUHALI &
Mahmouh MOBIR



Presentation of TaiPower's models © A. EL BOUHALI

National Central University

It was 9.30 am on Tuesday 5th March when we arrived at the National Central University (NCU) in Taoyuan, near Taipei. Assistant Professor Bor Kae Chang welcomed us and gave us a university campus tour among baseball players, cherry blossom, pine trees and squirrels. Prof. Bor Kae Chang said that he was particularly pleased to welcome us since French has been chosen as the official partnership language of the NCU. The university also works in a network with other universities in central Asia and especially South Korea and Japan.

After the campus tour, we went to the conference room, where the Professor and Vice Chairman of the Department of Mechanical Engineering, Chih-Ang Chung, introduced us to the university and to his department. We learned that NCU was founded in 1915 in Nanjing on mainland China, and that after Chiang Kai-shek's defeat against Mao Zedong, the university went into exile in Taiwan in 1962. Nowadays the university teaches at least 12,000 students divided amongst 8 departments and 25 specialties, and all working together on many objectives including tackling environmental issues.

The Department of Mechanical Engineering was founded in 1977 and is the biggest in the NCU with 1,200 students of which 68 are international students and 185 are PhD students. Its various courses focus on innovation in response to contemporary global issues. The department specializes in a number of fields, such as solid mechanics, materials, thermics and fluids, automation, mechatronics and energy. This reputed seat of learning spends more than 18 million dollars a year on research funded by the Ministry of Science and Technology, industrials and others.

After this presentation, it was time for our Professor Gilles Guerassimoff to introduce our school and our specialized Master program.

Then the students of the OSE advanced Masters went on stage to present their work on how electric vehicles influence every link of the electrical chain. The thirty-minute talk addressed many subjects from electricity production to the electrical grid, and including the opportunity that the expansion of electric vehicles represents for storage.

Warm welcome at NCU by Assistant Prof. Bor Kae Chang © Y. LAHMA

The introduction included a reminder that the transport sector depends mainly on fossil fuels (95% of final energy consumption in France). Hence, it is the second biggest greenhouse gas emitter in the world. Electrifying transport is a solution for France as electricity production has reduced CO_2 emissions. The market share of electric vehicles (EVs) in France in 2017 was presented before comparing this to the countries registering the highest sales of EVs for the same year. We observed that the market share of EVs in Europe is still very marginal due to the many associated constraints.

The primary constraint is electricity production. The global car fleet will face a drastic change with the development of electric cars. While its marginal impacts on annual mean electricity consumption are relatively easy to quantify, peak demand will be more difficult to apprehend. Therefore, effective measures must be taken to insure daily electricity demand. Potential solutions like demand management and the creation of a capacity market were mentioned during the presentation.

Once the electricity has been produced, it needs to be delivered to the vehicles. But energy transmission to electric vehicles is subject to constraints. Due to the specific features of the French electrical system, some impacts may concern the Transmission System Operator (TSO) and others the Distribution System Operator (DSO). Also, the charging modes of electric vehicles can ensure part of the electrical system's efficiency. So, while electric vehicles are a challenge for grid management, they can also provide some solutions to help the grid.

But how can we use electricity in vehicles? This part of

OSE advanced Masters students' presentation at NCU © Y. LAHMA

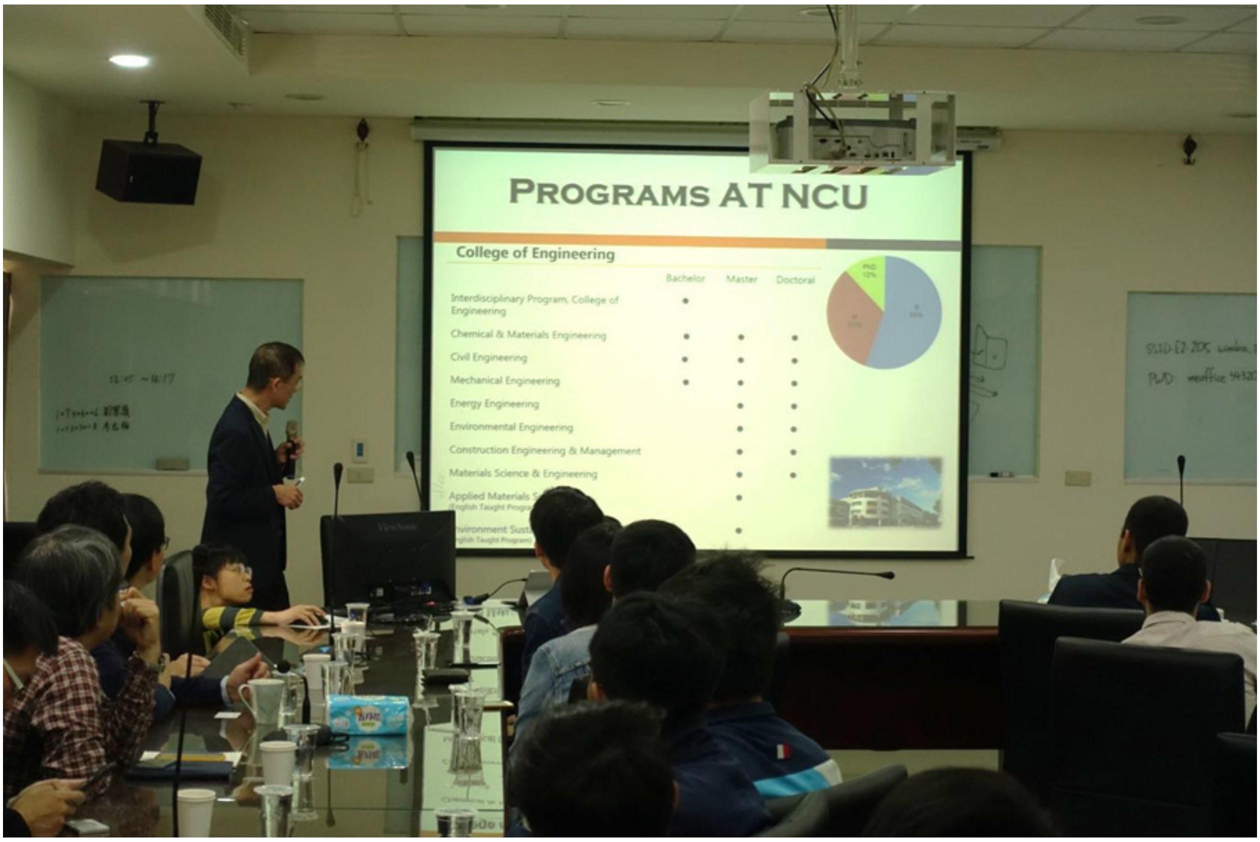
DAY 2

the presentation dealt with the interest of using electricity in a vehicle and how to implement it technically. The first option is to create a hybrid internal combustion engine and the second is a full electric vehicle, each of which has strengths and weaknesses. These different solutions are suitable for various uses and means of transport. Parallel hybrids are suited to diversified vehicle uses, whereas serial hybrids perform better for urban uses. Finally, fully electric vehicles have a simpler architecture and fewer emissions than hybrid vehicles, but are less autonomous.

The final part of the talk tackled the battery issue. Embedded storage systems have been the focus of considerable expectations since they are to date one of the last limiting factors to allow massive adoption of electric vehicles. The operation of lead acid, nickel-based and lithium-ion batteries was presented. They were then compared through key macroscopic criteria (energy, power, efficiency, cost, etc.) and related to the needs of individual vehicles.

The students' presentation raised a lot of questions from the very attentive audience composed of professors and students. During this questions and answers session, issues like battery recycling and policy incentives in France for the development of EVs were mentioned.

To conclude this visit to the NCU, distinguished Professor Chung-Jen Tseng from the Department of Mechanical Engineering gave us a presentation on "System Development and Operation Evaluation for Smart Green Buildings". To illustrate this subject, Professor Chung-Jen Tseng presented us with the prototype that they have on the university campus. This 60-square-meter building is



NCU presentation by Professor Chih-Ang Chung © Y. LAHMA

constructed with high performance materials such as aerogel and phase change materials paints. It is equipped with 8 kW of PV for energy production, 21.6 kWh of Li-ion batteries for energy storage, and 5 kW of proton exchange membrane fuel cell for backup power. It also has an Energy Management System to ensure such things as indoor comfort and air quality and to optimize the building's energy consumption.
Moreover, the implementation of smart lighting means that the building has very high energy performances. With such technologies, it is possible to attain energy savings of up to 35% on electricity consumption in the residential sector in summer.

Finally, we had the chance to visit the building with the professors and students who warmly welcomed us to their university.

We sincerely thank Professor Bor Kae Chang from the Department of Chemical and Materials Engineering for his warm welcome. We would also like to thank the Professor and Vice Chairman of the Department of Mechanical Engineering, Chih-Ang Chung, and distinguished Professor Chung-Jen Tseng from the Department of Mechanical Engineering for their very interesting presentations. Finally, our warm thanks to all of the professors and students who attended our presentation for their attention and very relevant questions.

Lyes AIT MEKOURTA
& Lucas DESPORT

Distinguished Professor Chung-Jen Tseng's presentation on Smart Green Buildings © Y. LAHMA

Focus on regulation, long-term prospective and new technology at ITRI

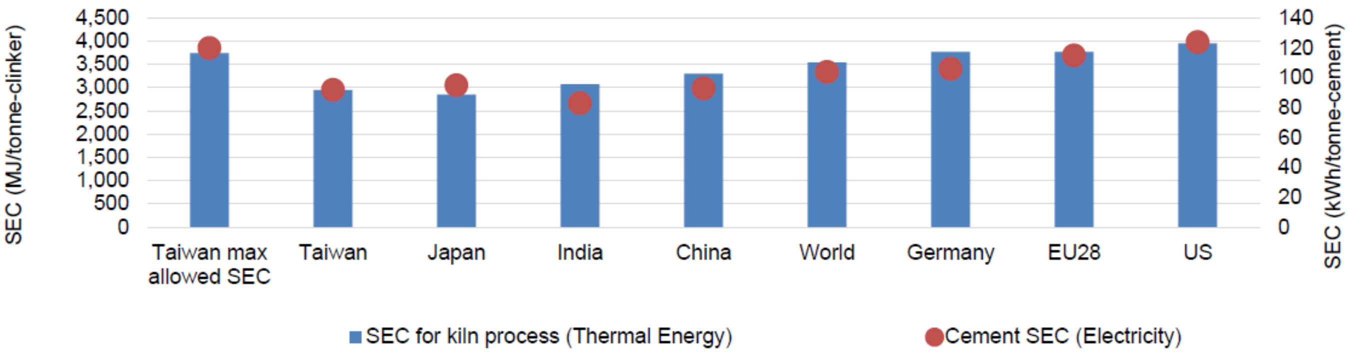
We visited the ITRI headquarters in Hsinchu on the afternoon of Tuesday, March 5th, 2019, where we were warmly welcomed by Mr. Jean-Baptiste Fichet, Account Manager at ITRI.

The Industrial Technology Research Institute (ITRI) is a Taiwanese technology R&D institution
founded in 1973. It has more than 6,000 employees around the world at various offices in the Silicon Valley (USA), Japan, Berlin, Moscow, and Eindhoven, and its head office in Hsinchu, Taiwan. ITRI currently owns more than 20,000 patents and has incubated more than 250 startups, including the Taiwanese semiconductor giants TMSC and UMC. Currently, research is focused on sustainable environment, smart living and quality health.

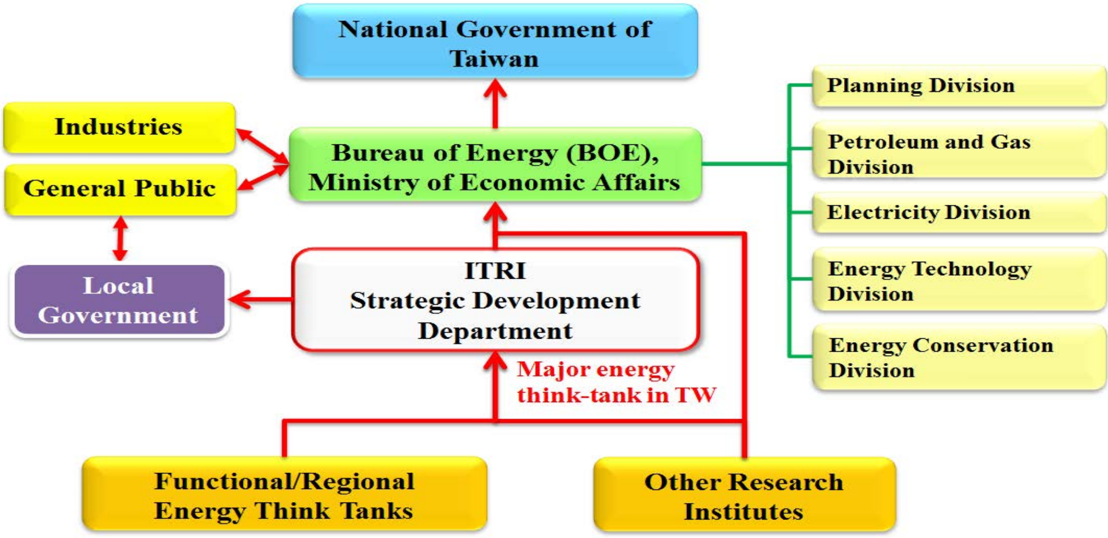
Regulation and prosepctive modeling

The first presentation was made by Dr. Tae-Chin Pan, the project's senior researcher and manager of decision support for industrial energy conservation, audits and consultations. 98% of Taiwan's energy consumption is imported and 90% comes from fossil energy. The industrial sector is the primary consumer of energy with 37% of the share of total consumption, followed by transport at 12% and the residential sector at 11%.
Taiwan's goal is to reduce the consumption share of industries by 50% between 2005 and 2025. Taiwan includes 3,200 factories with an annual power contract of more than 8,000 kW. They are subject to audits every 4 years and have to produce annual energy conservation plans. In addition, they must declare any new installation or expansion of facilities, which must be approved by the central competent authority.

The Bureau of Energy has mandated a target of 1% electricity savings per year for all large energy users with contract capacities higher than 800 kW. If this goal is not achieved, the users will have to pay a fine. In addition, the Taiwanese government has implemented



World mean SEC Values © ITRI



Role of ITRI for decision markers in energy © ITRI

a maximum specific energy consumption (SEC) threshold for different manufacturing systems that corresponds to the total energy consumption per unit of product. In 2012, the average SECs for the kiln process and cement plants in Taiwan was the lowest in the world.

In the future, this mechanism should only include energy consumption derived from fossil fuel in order to encourage the use of non-fossil fuels. The SEC data could be used to develop an SEC benchmark scheme through which factories or industries with the best SECs receive special awards, which would further enable factories to learn from each other.

Dr. Yi-Huang Wu, a researcher at ITRI, is developing the ITRI-CGE model to carry out policy simulation analysis of energy and economy. He is working on the Taiwan TIMES model. The 3E "Energy, Environment and Economy" models as well as "2050 calculator" are used to obtain more information in real time to identify problems related to energy. They are also decision support tools for the Taiwanese government. ITRI researchers are also integrating health impact assessment databases into Taiwan TIMES model optimization process. They are studying the impacts of power development plan on air-pollution, national health, environment and economy. ITRI has an important role in the decision-making of energy policies in Taiwan since it represents the major energy think tank. Researchers present their results to the Bureau of Energy, which will then make decisions to submit them to the national government of Taiwan as we can see in the figure below.

Notable answers to the questions posed by OSE students include environmental policy targets. In fact, in 2025, the government plans the final shutdown of nuclear power plants and this decision is influenced by the fact that storing nuclear waste is difficult in Taiwan, given the risky geological situation related to earthquakes. As the presidential elections approach, the policy adopted will depend mainly on the next president. For now, the people are encouraged to become more involved in energy issues.

Technology showroom

The technology showroom is an exhibition showcasing the best technology developed at the laboratory. Some of the researchers have won the most prestigious competitions including the well-known R & D 100 Awards.

Mrs. Jessica Ma took us on a tour of the most state-of-the-art innovations concerning energy and the environment: Entering the showroom, we discovered a curious and luminous tree, called the "eco tree". It is actually a demonstrator of different in-house technologies. Between the tree branches, the glass canopy contains transparent micro-optical films that are able to redirect the sunlight onto a solar cell, placed at its side. At the base of the tree, the eco pool is able to recycle water.

Around the tree, the innovation exhibition begins. First, a textile dyeing process uses supercritical CO_2 and totally respects the environment. Not only does it consume no water, it also releases no chemicals. Then, a water purification process using an LED chip developed in-house, which replaces conventional UV technology. The advantage of this process is that it does without the use of toxic mercury.

Next in the exhibition comes an innovative and complex liquid crystal recycling process, which is the result of ten years of laboratory research.

Now concerning batteries and energy, a polymer material which was created at the institute can triple the life of lithium-ion batteries. It is called Stoba and follows the growth of the SEI layer (Solid Electrolyte Interphase), which means better control and slower ageing.

In parallel, an Ultra-Fast Charging Aluminum-Ion battery has been developed in collaboration with the University of Sandford. This type of battery has a record charging time of less than one minute and improved safety, thanks to its innovative aluminum- graphite structure. Its low cost and fast charging capacity makes it suited to applications like sustainable mobility and renewable energy storage.

Finally, a fascinating 5G-connected drone can be controlled from Las Vegas but located in Taiwan, thanks to its ingenious software management system. On top of that, it can be recharged quickly and does not require human intervention thanks to an intelligent charging bar, which can be placed in contact with the structure. Interesting applications could be risky monitoring missions and remote areas.

We would like to warmly thank all of the team who welcomed us to the ITRI Institute and shared their exciting work with us: Jean-Baptist Fichet, Jessica Ma, Dr. Tze-Chin Pan, Dr. Yi-Hua Wu and their colleagues.

Laura SOBRA &
Rihab BEN MOKHTAR

Master Ose students accompagnied by Gilles Guerassimoff, Meiling Tsai (Ubik Consulting) and Jean-Baptiste Fichet (ITRI) à l'ITRI © Y. LAHMA

ITRI's buildings © ITRI

Conferences at National Cheng-Kung University

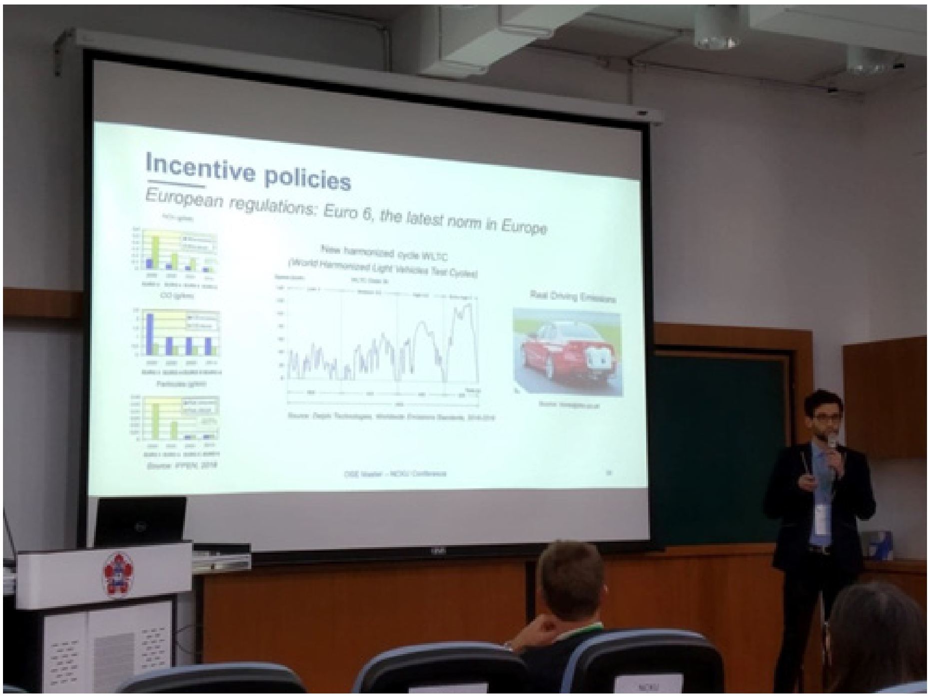
Despite the dim sunshine the heat was intense on Wednesday 9 March when the 21 OSE master's students attended National Cheng Kung University (NCKU) in Tainan, south of the island, for a day of discussions with various representatives from this prestigious university. Founded in 1931 and with 21,805 students in 2015, the university comprises nine faculties split over four campuses. The OSE group was hosted on the main campus, at the science and materials department of the engineering faculty. Following a warm welcome by Weili Teng and Chia-Yuan Chen, respectively coordinator and director of international relations, the morning of conferences kicked off with a word of introduction from professors Yen-Jong Chen and Jow-Lay Huang, respectively director of the Research Center for Energy Technology and Strategy and director of the Hierarchical Green-Energy Materials Research Center (Hi-GEM). Professor Chen spoke of the island's specific features and the constraints on its energy system, and concluded his introduction with the following summary of the situation: "You can't know Taiwan without coming to Taiwan". The OSE master's students then took the floor to begin the conferences.

Master OSE students arriving at the Material Engineering Sciences Department © M. TOULOT

Following a presentation of the master's program and school by Gilles Guerassimoff, two groups of students successively gave two talks on this year's them: "Potential future energy sources for sustainable mobility". The first presentation took up the theme of electric vehicles presented the previous day at NTU. The second focused on existing incentives and policies for decarbonized mobility. Following a review of the current greenhouse gas emissions situation relating to the transport and mobility sector, and the targets for decarbonizing the sector, the presentation moved on to look at the policies in place to meet these objectives. It began with a presentation of the European targets and then concentrated on the French policy. The students also described the various incentives for new mobility practices and the use of new alternative fuels like electricity, hydrogen and biofuel. In the last part, the students showed the importance and methodology of a prospective approach to support decision-making to meet mobility decarbonization targets.

The two presentations were positively received by the audience, mainly comprising lecturers, students and a few members from the French Office in Taipei. They were followed by a twenty-minute question and answer session involving interesting debates on several topics. The vehicle-to-grid system described in the first presentation was the subject of numerous questions, including the possibility of using stored energy in a vehicle's battery for personal domestic consumption, and on different current projects and experiments on the system. The discussion also focused on the importance of taking social factors into account when drawing up policies to encourage change. This discussion highlighted the major difficulty of considering individuals' behavior when establishing policies to change behavior patterns.

Questions then turned to the prospective model presented in the second talk, including whether it integrates behavior influence constraints and a social factor. A thesis is in fact currently under way at the Center for Applied Mathematics to introduce these aspects into prospective models. A third major exchange centered on hydrogen as a source of energy. This had been expected by the students because hydrogen is the subject of extensive research on the island. Questions focused on the development perspectives of this source in France. The discussion was an occasion to describe the problems of insufficient infrastructure and its cost, as well as the cost of the current development of embedded hydrogen storage. The observation was made that investment decisions on developing alternative fuels are almost automatically correlated to a country's energy policy: in fact, decarbonized electricity and a highly developed network favor the development of electric vehicles in France, whereas in Taiwan, this type of vehicle is not a priority because the country's electricity production mix is highly carbonated. Lastly, the remarks led to an exchange on the French electricity production mix and the issue of nuclear energy, a controversial energy source in both countries.



Presentation of the incentive policies © M. TOULOT

DAY 3

After highly instructive discussions for both parties and a well-deserved tea break, the OSE master's students attended a presentation of Hi-GEM by its director and professor, Jow Lay Huang. Hi-GEM is a research center that works on new materials for greener energy. The center's objective is to develop new materials technologies that respect the environment and are suitable for storage and energy conversion, along with smart energy systems. Hi-GEM comprises 29 lecturers and three PhD students. The center's main research subjects cover six major technologies, i.e. fuel cells, photovoltaic cells, super capacitors, a second life for batteries, solid-state batteries, and integrated energy systems. Hi-GEM is in a fast development stage and has concluded numerous international partnerships involving 36 projects over the last five years. In Taiwan, the research center works with NCKU, seven other universities and another research center. Hi-GEM is keen to promote innovation and greater, faster integration of these new materials into industry. It also has its own Lithium battery assembly line and its own photovoltaic panel production line. In the long term, the center would like to continue to expand and forge new international partnerships with an estimated budget of € 1.7 M from 2018 to 2023.

To conclude the highly informative morning, the students visited different laboratories at the engineering materials and science department, accompanied by Professor Changshu Kuo. They were able to observe the various highly advanced tools available to NCKU university students for

The students and their audience © Y. LAHMA

Professor Huang presenting Hi-GEM organisation

their research. This included the demonstration of two microscopes to analyze the impact of a magnetic field and temperature on the kinetics of chemical reactions and the composite elements of different materials.

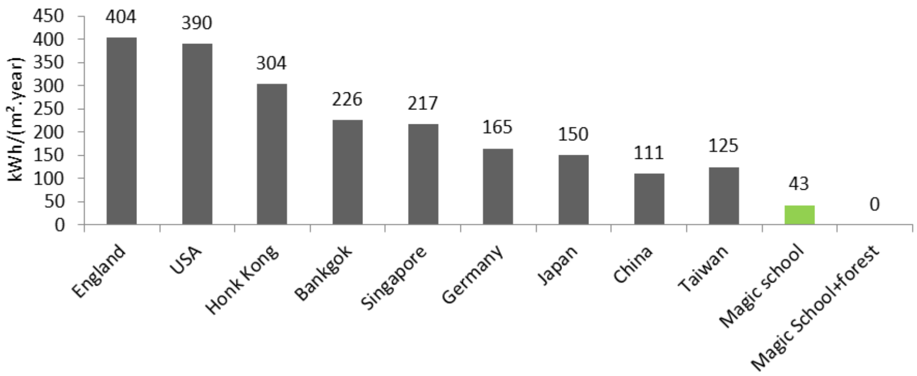
The event was an occasion for interesting, enthusiastic exchanges between the OSE master's students and various NCKU members. We would therefore like to warmly thank professors Hong-Tzer Yang, Yen-Jong Chen, Chia-Yuan Chen and Jow-Lay Huang for their warm welcome, and all of the NCKU members who honored us with their presence, as well as members of the French Office in Taipei, in particular Jonathan Drubay and Sasha Ting for organizing the conference.

Lastly, we would like to thank all of those who attended the event, without whom this exchange would not have been possible.

Maxence TOULOT

NCKU An-Nan Campus

Magic School of Green Technology



Energy usage intensity of "green"office buildings (2011)

Our visit to the NCKU An-Nan Campus started with the renowned Magic School of Green Technology. We were welcomed by Eric Chen, a Project Executive at the Research Center for Energy Technology and Strategy.

This school is a positive energy building ranked as the best Taiwanese building for the environment. The goal of this project is to act as an innovative laboratory for future sustainable green architecture.

This innovative magic school was built in 2011 at a total cost of NT$ 180 million (€5 million), including NT$ 60 million from the University Research Development Fund, a donation of NT$20 million in equipment from 34 entrepreneurs and a donation of NT$100 million from Bruce Cheng, founder of Delta Electronics and the Magic School of Green Technology.

This unusual project is a home-grown solution specific to the sub-tropical weather in Taiwan. The building's green architecture halves its water and energy consumption and reduces its carbon footprint by 37%. In order to attain such efficiency, many techniques were used, such as energy-saving equipment, a roof garden, reduced air-conditioning, open design, etc.

These techniques help the building reach a low energy usage intensity of 43 kWh/m^2 per year. This energy usage intensity is way below any other "green" building in Taiwan. The column chart below illustrates a comparison between the magic school project's energy usage intensity and average values of other "green" office buildings around the world.

The Magic School of Green Technology © Y. LAHMA

Département of chemical engineering

We then visited the laboratory for the platform technology specialized in microalgae bioenergy production, which is part of the department of chemical engineering at NCKU. We were welcomed by Mr. Ri-Heng Chen, a PhD student at NCKU, who explained that the main mission of the laboratory is to experiment on ways of absorbing carbon dioxide using microalgae.

Different types of micro-algae can be used to simulate natural carbon dioxide reserves, such as oceans and trees and thus help reduce the amount of CO_2 in the atmosphere.

One specific feature of these organisms is that they multiply quickly. Microalgae are first cultivated in a one-ton open pond of water for one week. It is also possible to shorten this period by pumping acetate into the water instead of CO_2.

Every week, the pond produces 2 kg of microalgae. The mature microalgae are then transferred to another basin where they serve many purposes. The first is filtering the water from different particles that are harmful to tiger shrimps by decomposing NOx molecules. The second purpose is to serve as a food supply for the shrimps after being compressed. Another purpose is to absorb the carbon dioxide that is pumped to the open pond via an external pump. Every basin consumes 4kg CO_2/week. Another use for these algae is to produce substances that can protect the retina from ultra-violet rays.

Finally, at the end of the lifecycle of these microalgae, they can be fed to cattle or used as fertilizers in agriculture.

Les étudiants devant les cuves où sont cultuvées les algues © Y. LAHMA

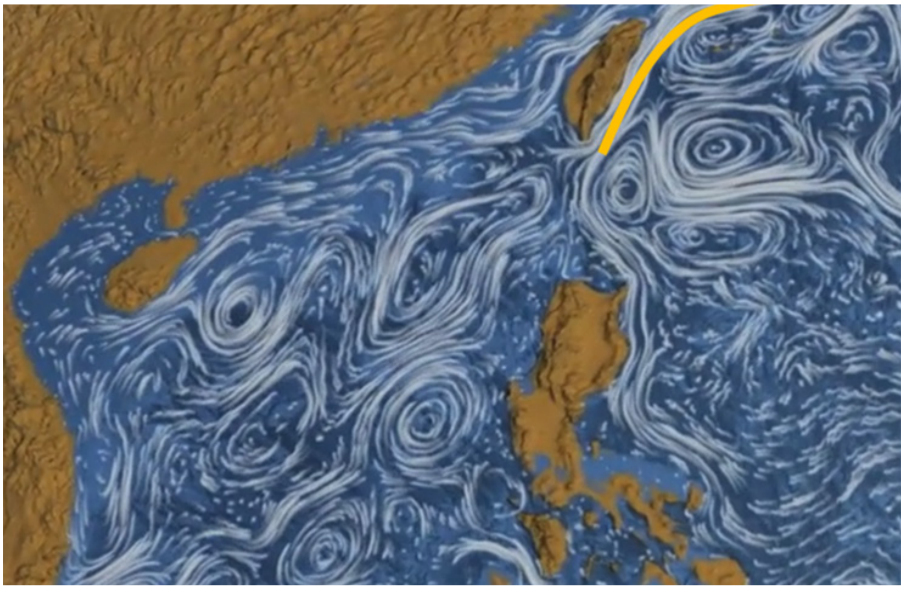
DAY 3

Ocean Energy Research Center

After our visit to the department of chemical engineering, we were welcomed by the deputy director of the Tainan Hydraulic Laboratory, Dr. Weng-Shang Chiang. Since Taiwan imports 98% of its energy needs, this department experiments on the energy potential of tidal waves.
Taiwan has great ocean energy potential. The Kuroshio Current is the strongest current in East Asia with a width of 200km and a depth ranging from 500 to 1000m (see NASA map below).
Tidal wave energy is renewable and predictable as it depends on the gravitational forces of the sun and moon. The laboratory studies different means to exploit this energy and develops different ways to simulate waves and currents similar to real environments.
According to Dr. Weng-Shang Chiang, a turbine with vertical blades is the most promising method to harness ocean energy. These turbines capture the power of tidal waves whatever the direction of the current. In addition, studies showed that the horizontal component of the energy is much higher than the vertical component of the energy.
However, this technology faces many challenges. First, corrosion and biofouling effects are a crucial issue for materials immersed in the ocean since they greatly decrease the yield of the turbines. Second, electricity storage and distribution problems can make projects economically non-viable because of the high costs of systems that need to withstand extreme conditions. Finally, the slow rotary speeds of turbines make it necessary to install more equipment in order to reach the standard alternative frequency of 60Hz in Taiwan.

We would like to thank all of the members of the An-Nan NCKU campus for their kind welcome. We also give our special thanks to Dr. Eric Chen, Phd student Ri-Heng Chen, and Dr. Weng-Shang Chiang for their very instructive presentations that expanded our knowledge of new sustainable and innovative technologies of the future.

Yacine LAHMA



The students and Dr. Weng-Shang Chiang © Y. LAHMA

Ocean Energy Research Center of NCKU © Y. LAHMA

Ciel et Terre: visit of a floating solar power plant

On Wednesday 6th March, Audrey Leblic and Jasmine Lin, from the company Ciel et Terre, introduced us to a floating solar power plant, located in the Tainan Science Park in the south of the island.

Ciel et Terre is a French company, whose headquarters are located in Lille. It was created in 2006 and today has about 100 employees all over the world. Originally, Ciel et Terre specialized in installing solar panels on roofs in France. In the early 2010s, after a drastic drop in the feed-in tariff for electricity from PVs in France, the company decided to enter the floating solar market.

The first floating solar power plant developed by Ciel et Terre was born in Japan in 2012. Today, 300 MW are installed all over the world. The main advantage of floating solar panels is that they can produce electricity via a renewable source without any land use. This is particularly relevant on island territories such as Taiwan or Japan, where land costs are very high, due to strong geographical constraints and very dense populations. A floating solar power plant can take advantage of unusable stretches of water, such as industrial lakes and dam storage, to produce electricity without modifying land use. In arid areas, installing floating PVs on water reservoirs can limit evaporation. Maintenance is easier than for a classic solar power plant, as it is easy to clean the solar panels using the water available close by.

Ciel et Terre's know-how involves designing and installing floating solar power plants. The solar panels lay on floats, which are anchored either to a bank or at the bottom of a lake. Originally, the firm sold power plants to customers. Now Ciel et Terre increasingly operates its own power plants. Its subsidiary company in Taiwan was created at the end of 2016 and has already installed 20 MW.
The plant we visited is able to withstand winds of up to 210 km/h and has an installed capacity of 4 MW. Its production is about 1,400 kWh/kWpeak compared to 1,000 kWh/kWpeak on average in France. This impressive result is explained by the significant sunshine irradiation in the south of the island. The plant was delivered in December 2018 at a cost of 21 million Taiwanese dollars. The project was mostly financed by Japanese investors and Ciel et Terre.

In Taiwan there is a specific feed-in tariff for electricity from solar floating, fixed annually by Taipower and amounting to 4.9 NT$/kWh. Moreover, a 6% bonus is granted if the panels are highly efficient and produced in Taiwan, which is the case at the plant we visited.

There are three possibilities to win a contract to install a floating solar plant in Taiwan. The company can either: call for tender, be requested directly by customers (tender is not compulsory), or contact the owners of lakes, which is what Ciel et Terre had done for the plant we visited.

Floating solar power plant in Tainan Science Park © J. THOMAS

This plant is operated directly by Ciel et Terre, which aims to achieve a return on investment within 10 years, bearing in mind that the contract with Taipower lasts 20 years.

There is no regulation for solar floating in Taiwan. The Taiwanese government only recommends not to exceed a 50% coverage of the lake. At this time, we do not know how this type of plant impacts the local ecosystem, but studies are ongoing.

To conclude, the solar floating sector is booming and is suitable for densely populated, urbanized territories such as Taiwan, which wants to increase the share of renewable energy in its energy mix. Ciel et Terre is a successful company that has been able to expand abroad. It has an ambition to position itself in the market for solar floating on the sea. Indeed, this market which is not mature, represents an interesting development perspective and is already being investigated by industrials.

We would like to thank Audrey Leblic and Jasmine Lin for this instructive visit and for taking the time to answer all of our questions about solar floating.

Tristan DELIZY &
Dorine JUBERTIE

Visit of Wushantou Dam

After an early departure from the hotel in Tainan and a one-hour drive, we arrived near Guantian in Wushantou, which has given its name to a dam and reservoir. We were welcomed by Mr. Zhen, the reservoir manager and control room engineer, who explained to us how the power plant works and told us the history of the reservoir.

Aerial view of the Wushantou reservoir © stock-clip.com

Reservoir construction started in 1930 and lasted 10 years, during which time 134 workers died, now marked by a memorial. It was designed during the Japanese occupation by the engineer Yoichi Hatta. The original aim of the reservoir was to regulate the irrigation of farmlands in nearby Chianan. It represents 90,000 hectares of arable lands and produces the highest quantities of rice in Taiwan.
With a height of 56 m, a width of 1,273 m and a water surface of 13 km^2, it was designed as the largest reservoir in Asia. When it was inaugurated, it had a total capacity of 150 million m3. However, sand and rocks have since stacked at the bottom of the reservoir reducing its capacity to 80 million m^3.
Moreover, significant quantities of garbage and waste water are discharged into the reservoir which has led to the installation of nets to filter them.

In order to make the most of the potential energy storage of the infrastructure, the construction of a hydroelectric power plant began at the end of 2000. The total cost of the project at the time was NT$ 360 million and the first electrons were injected into the Taiwanese grid in August 2002. The plant is owned 70% by the Chianan Irrigation Association and 30% by the Formosa Chemicals Fiber Corporation.

This plant has two turbines and a nominal power of 9 MW (2 x 4.5 MW). The head height is rather low (20 m), therefore it is fitted with Kaplan turbines with an average flow rate of about 15 t/s for 303 rpm. Over the year, this plant produces an average of 42,170 MWh for less than 100 days of operation. The most active months are from April to June with the monsoon and from June to September during the typhoon season. All electricity produced at the dam is bought by Taipower at a variable rate depending on the time of day. The plant employs four people to operate 24/7: three operators work on eight-hour shifts under the direction of a supervisor.

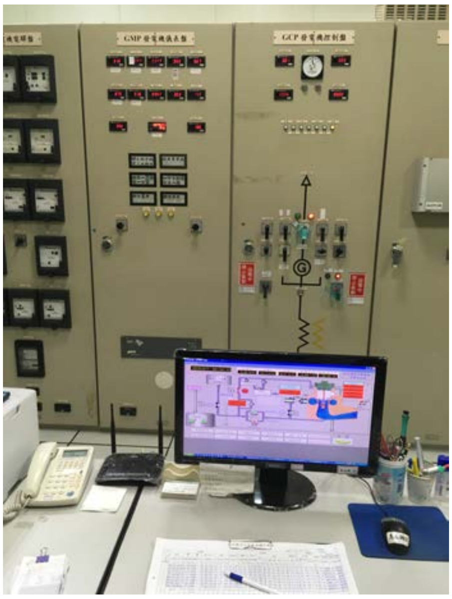
Two other hydroelectric plants have been built to take advantage of the Wushantou Reservoir's energy storage potential. These two other facilities add a nominal power of approximately 12 MW to the Wushantou site.

Since the 1970s, the reservoir has been a popular tourist spot in Taiwan. It now includes an aquatic park, a memorial dedicated to Yoichi Hatta, and a museum recounting the history of the construction of the reservoir and the life of its designer.

We are very grateful to the Chianan Irrigation Association for making our visit possible.

Florian MARCHAT & Valentin MATHIEU

Output of one of the turbines © F. MARCHAT



Command center © F. MARCHAT

Inauguration of the plant in 2002 © F. MARCHAT

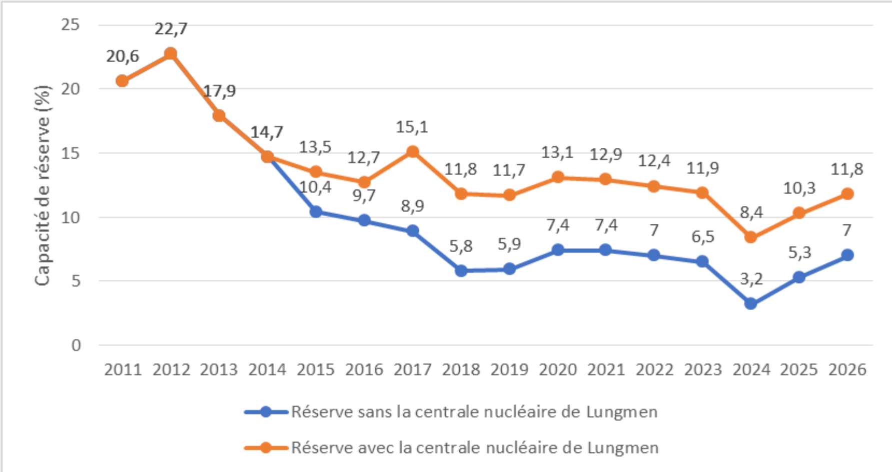
Tsing Hua University

After taking the popular High Speed Rail (HSR) train from Tainan to Hsinchu to go up the West Coast, we arrived at National Tsing Hua University on the afternoon of Thursday, 7th March to visit the third and final university of the trip. NTHU is one of the most prestigious universities in East Asia. It was established in 1911 in Beijing before being exiled to Hsinchu in 1956 as a result of the Chinese civil war with the flight of the government of the Republic of China to Taiwan. The university is divided into 7 colleges, 17 departments and 22 research institutes. Approximately 16,000 students including 1,736 PhD students are enrolled at the university, which also boasts three Nobel Prize alumni.

We were welcomed in the rain by Dr. Rong-Jiun Sheu and then settled in a room at the NTHU College of Nuclear Science. This college has more than 1,000 students divided mainly between two departments but also three institutes. Its research activities focus on peaceful applications of nuclear energy. Although it did not include a conference by OSE students on mobility, the visit did feature presentations by local teacher-researchers followed by a visit of the university's THOR nuclear facilities. The audience was mainly composed of the Master's students, two scientific attachés from the Representative Office of France in Taipei, international relations representatives from NTHU, and several members and professors from the College of Nuclear Science. Following the ritual greetings made by Dr. Rong-Jiun Sheu, the floor was given to Dr. Gilles Guerassimoff, head of MS OSE, to present MNES ParisTech, PSL University, the Center for Applied Mathematics (CMA) at Sophia-Antipolis and the Master on Energy Systems Optimization (MS OSE). Next came the turn of the director of the Nuclear Engineering & Science Institute (NES), Dr. Tsung-Kuang Yeh. His presentation focused on the Taiwanese energy context and its future challenges.

Taiwan's energy plan consists in stopping electricity generation from nuclear by 2025 and increasing renewable energy in the production mix from 4.9% to 20%. The Taiwanese mix in 2025 would then be 50% gas, 30% coal and 20% renewable. Dr. Tsung-Kuang Yeh expressed his concerns about the feasibility of such a renewal of production in only six years. Indeed, the island has already experienced one "blackout", in August 2017, while one of the four nuclear power plants was undergoing maintenance. The electricity reserve capacity could decrease very significantly according to the NES estimation, as shown in the graph below. The non-opening of the yet-to-be-built Lungmen nuclear power plant continues to weaken electricity production in Taiwan.

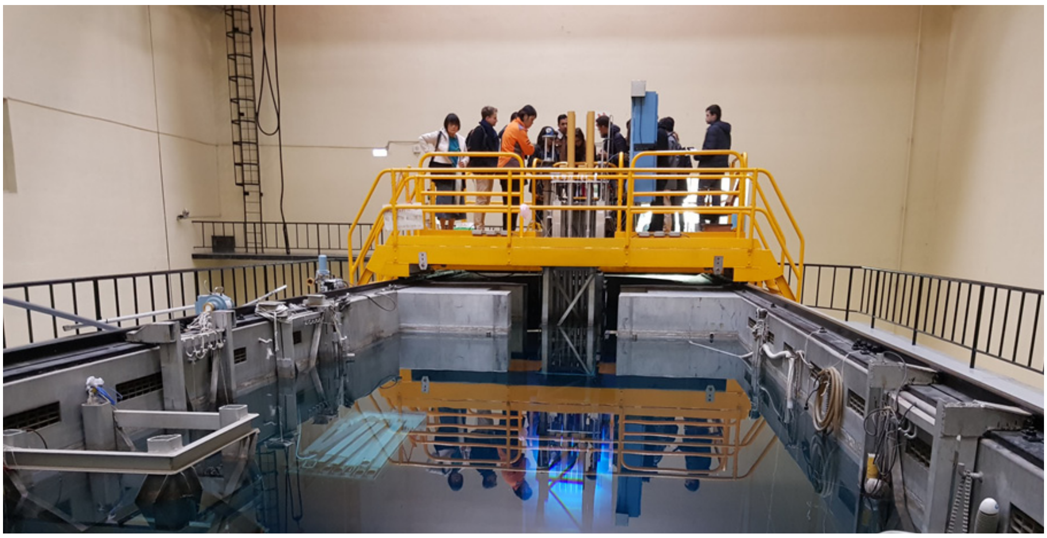
In a second part, a technical presentation was given by Dr. Tsan-Yao Chen on the next generation of heterogeneous catalysts for the development of high efficiency fuel cells. He pointed out that a university study has found that atomic cluster decoration makes the highly disordered Co@Pd nanocatalyst stable with promising performances in catalysis reactions. Thanks to this control of the atomic structure, the energy density can be multiplied by 2.3.



Reservoir capacity in Taiwan

Following this presentation, the University Dean, Dr. Min Lee, came to greet the scientific attachés, Gilles Guerassimoff and the Master's students. The visit ended with a (radio-) active discovery of the campus's scientific facilities, including the Tsing-Hua Open-pool Reactor (THOR) nuclear infrastructure, which began operation in 1958. Dr. Jin-Der Lee We led the visit of the control center, the pool around the fuel. In the last five years, research on boron neutron capture therapy (BNCT) at NTHU has contributed to the treatment of recurrent head and neck cancer. The neutron beam part of the BNCT research was carried out using Tsing Hua's Open-pool Reactor (THOR). This is a 2 MW reactor, moderated and cooled with light water (visible on the picture, under the yellow nacelle). Clinical trials are currently underway on head and neck cancer. Dr. Jin-Der Lee used patient pictures to explain that the goal of this treatment is to eliminate as many cancer cells as possible while minimizing collateral damage to healthy cells. The use of THOR in the conduct of BNCT research has considerable potential to advance the clinical treatment of cancer.

Ahmed CHAABANE &
Martin PIERSON



Nuclear installation in NTHU © L. SOBRA

HoPing cement factory and coal power plant

On the last day of industrial and academic visits, the OSE master's students left the deserted district of Ximending in Taipei (the Taiwanese Times Square) at 6.30 AM. After a journey through the North East of the island, they were greeted at the industrial park of HoPing.
This park is the result of a joint venture between the Taiwan Cement Company and the Ho-Ping Power Station. An overview of the park can be seen in the photograph below, taken by a master's student from the entrance of the limestone quarry. Built at the end of the 1990s, it includes a cement plant (bottom left), a coal-fired plant, and an artificial port capable of accommodating ships carrying coal, cement and other materials (up to 80,000 tons).

HoPing Industrial park © Y. LAHMA

The cement factory

The Taiwan Cement Corporation (TCC) was founded in 1946 and its headquartered in Taipei. It has three plants: the first is in Hoping, the second in Suao, and the last one is in Hualien. TCC was officially transformed from a state-owned enterprise into a public company in 1954. In 1962, it was the first Taiwanese company to go public. The company's sales are split between sales to Taiwan, sales to China and exports. In 2017, turnover from sales amounted to 98,312 million Taiwan dollars (about 2.8 billion euros). [1]
Initially, TCC's plants were located on the west coast of the island. In 1991, in an

attempt to decarbonize the western part of the island, which houses the majority of the population, the state imposed the relocation of all cement factories to the east coast. The company followed this decision by choosing Hoping to build its plant. The Hoping plant started operations in 2000. The production capacity of this plant is around 4,000 kt/year according to Mr. Cheng-Tse Wu (assistant manager of the processing control department), who welcomed us to the company and introduced us to its activity.

The history of cement in Taiwan began in 1915, when the Japanese company Asano Cement began building cement factories. The annual production of its plants was 30 kt/year. In 1942, the Suao plant was built. In 1954, the Taiwanese state decided to develop the cement industry and open up the market. Several private companies invested in these state enterprises. The period between 1975 and 1980 saw considerable expansion, with the building of 10 plants with a production capacity of 1,403 kt/year. In 1988, the government blocked imports of cement.[2]

Cement production takes place according to the following process:

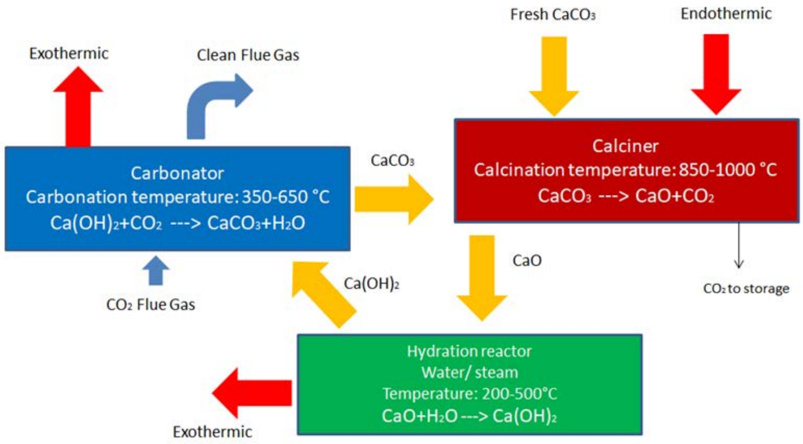
The first phase is consists in extraction and crushing. Bulldozers break up the quarry face and crush the large extracted rocks. The TTC quarry has the advantage of being situated at a height of 1,200 m above the factory, which avoids wasting energy to move the rocks because they are transported by gravity (a large pipe through which the rocks fall towards the factory). The following phase is pre-homogenization. This operation is carried out in vast sheds where the slabs are sampled, mixed then screened (mainly limestone $CaCO_3$ and schist). The resulting aggregate is then crushed and transformed to meal, which is stored in homogenizing silos. Air from blowers in the silos regulates the chemical composition and density of the meal components. The meal is then put in an kiln reaching temperatures of up to 1,400°C. During the routing, a first preheating stage reduces energy consumption by recovering heat from the furnaces to dry and heat the meal, which dehydrates and partially decarbonates. The result is clinker. The clinker is cooled to stabilize its composition, and then ground. Other components such as gypsum are added to the clinker in different amounts depending on the use of the cement (masonry, dams, etc.). This final cement is now ready to ship.

Raw materials, such as fuel, iron residuals, and gypsum, are imported from Hoping Harbor, and co-products are exported to the west coast port.

The joint venture was created to adopt a circular economy in favor of the environment. The cement plant's waste heat has a production capacity of 31.5 MWh. When both furnaces at the cement works are in operation, up to 21.3 MW of electricity is generated.

In addition, TCC has developed CO_2 capture techniques. It uses limestone as an absorbent due to its high absorption capacity and reduced energy consumption (additional energy expenditure <20% at a cost of <US$30/t). Absorbent limestone can be used as a raw material in the cement manufacturing process to achieve zero waste. The following figure, from a photo taken during our visit to the cement factory, illustrates the principle of this technique.

DAY 5



Operation of carbon capture © A. MACHRAFI

The process efficiency is greater than 80% (Ca/C 5 ratio) and the CO_2 capture capacity is 0.16 t/h. To increase its efficiency, TCC uses cascading cyclones because the vertical structure of the cyclones promotes thermal exchange and limits the occupied surface. In 2025, TCC hopes to reduce its costs to US$10-15/t.

The CO_2 captured is then used to produce energy by biomass through the cultivation of micro-algae.

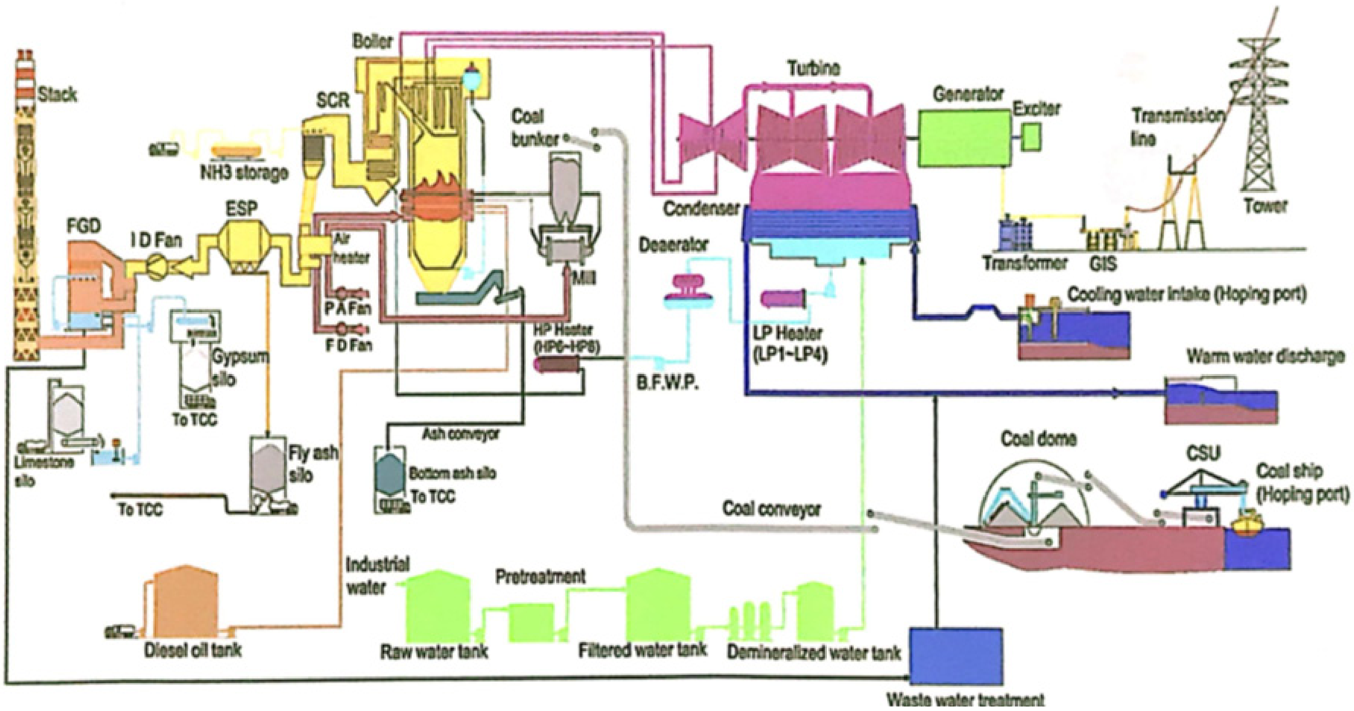
The coal plant

After lunch at the plant's canteen, students were welcomed at the offices of the coal-fired plant by Mr. Mu Chuan Tseng, the site's Vice President, and Mr. Gary J. G. Wei, manager of the Engineering Services Department, who explained how the plant operates and its place in the Taiwanese energy mix. The plant site covers 27 hectares and includes two generating units, each generating 660 MW maximum power. It fulfills 3.7% of the island's electricity demand, making it the fourth coal plant. In Taiwan, coal accounts for 22% of installed power (9.2 GW) and 30% of net electricity generation (nearly 70,000 GWh).

Construction of the plant began at the same time as the cement plant. Their production units produced their first flames in July and November 2001 and commercial operations began in June and September 2002.

The owner of the plant is Ho-Ping Power Company, which owns the site, equipment and machinery. Investment to build the plant amounted to NT$ 38,500 million (1.1 billion euros). The plant's shares are split between three entities: CLP (20%), the Mitsubishi Corporation (20%) and the Taiwan Cement Corporation (60%). The manager of operations and maintenance of the site is the HPC Power Services Corp (HPSC), which handles human resources.

Coal, which arrives at the port, comes mainly from Indonesia, Australia and Russia. It is transported to the storage dome via treadmills. Two of these domes have a diameter of 146 m for 105 kT of coal storage capacity. The last dome has a diameter of 126 m for a capacity of 155 kT. On average, a boat containing about 70,000 tons of coal supplies the power plant every week. We were able to visit one of the coal storage domes. As we can see on the following figure representing the general operation of the plant, the coal comes from the top of the dome and is stored



Operation of the plant and its relationship with its environment © A. MACHRAFI

Inside one of the coal-storing domes © J. THOMAS in a heap. A shearer then picks up the coal to transport it via an underground conduit to the boilers. The flow of coal for one boiler is 213.7 tons/hour, which corresponds to approximately 70,000 tons of coal per week for the two boilers.

The general characteristics of the boilers, turbines and generators are represented in the following table:

	Boilers (yellow part)	Turbines & Generators (pink part)
Mean steam pressure (bar)	182	177,5
Mean steam temperature (°C)	542	540
Mean flow rate (t/h)	1990	1930

Boiler and turbine characteristics © J. THOMAS

Although it has a 40% yield, this plant is characterized as a subcritical plant. It is important to note that here boilers are preheated using diesel (orange at the bottom left of the figure). The water used to generate steam (green part at the bottom) is industrial water; it is filtered and purified prior to being routed to the turbines. Seawater from the port is used to cool the turbine. Before entering the plant cooling system, it is filtered by titanium cathodic protection. The sea water enters at a temperature of 25°C and is discharged at around 33°C (the legal limit is 42 °C).

After the combustion phase, the fumes are then processed through three different systems. First, a selective catalytic reduction (SCR) transforms the nitrogen oxides NOx into nitrogen N_2 and water. Fine particles are then filtered through an electrostatic precipitator (ESP). Finally, a desulfurization unit (FGD) uses limestone to capture sulfur dioxide. This reduction reaction uses the limestone extracted from the cement quarry and produces the gypsum used by the cement plant.

Thanks to these filtering systems, the plant limits greenhouse gas emissions, which are below or equal to national standards, as shown in the following table.

The rest of the smoke is released through a 250 m-high chimney whose diameter is 25.1 m at its base and 17.1 m at the top.

Master's student in front of the two boilers © J. THOMAS

	The plant emission limits	National standards
SOx	≤ 50 ppm	≤ 60 ppm
NOx	≤ 50 ppm	≤ 50 ppm
Fine particles	≤ 20 mg/Nm³	≤ 20 mg/Nm³

Limits and national standards © J. THOMAS

Finally, the plant is connected to the high-voltage network (345kV) for a capacity of 2180 MVA via the Sub Tong Shan station. This connection between the plant and the substation is 53 km long and requires 123 pylons. The plant was certified ISO 9001 in May 2003, and 14001 in October 2004. In 2011, it was awarded five stars by the National Standards Authority of Africa (NOSA), an agency that certifies the quality and safety of production of goods and services. The authority audits the plant annually in order to check compliance with greenhouse gas emissions standards.

As part of the electricity contract signed with Taipower for a period of 25 years, the plant is obliged to guarantee production hours. In summer (June to September), it must operate at maximum capacity every day from 7:30 to 22:30. During the other months, it must operate from 8:30 to 21:30. During the rest of the time, the plant meets the needs of Taipower. As a result, high-risk activities that require landfills and stoppages are planned during unguaranteed production periods. The plant is stopped to carry out minor revisions for 25 to 35 days a year. Every six years, a period of major revision is carried out lasting 50 days.

In terms of performance, over the past 15 years, the plant has been available on average 90% of the year during periods of production guarantees and around 83% over the whole year. Production therefore equals approximately 9 500 GWh annually.

All of the students would like to thank the cement and coal plant staff for their warm welcome and the valuable information provided on the operations of their factories.

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Juliette THOMAS &
Hamza MRAIHI

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