An Optimized LEED's Green FAB at TSMC

(1) Arthur Chuang, Mr. (2) Tony Chen, Mr.

(1) tschuang@tsmc.com

(2) cccheno@tsmc.com

Taiwan Semiconductor Manufacturing Company, Ltd.

No 8, Li-Hsin Rd. 6, Hsinchu Science Park, Hsinchu City, Taiwan 300-77

Abstract

TSMC Fab14 Phase-3 (F14P3) Fab building earned 40 points for gold rating from LEED-NC 2.2 (Leadership in Energy & Environmental Design for New Construction Version 2.2) in July 2008. F14P3 was designed to manufacturing capability of 32nm (nano-meter) technology. The architectural complex consists of a wafer fabrication building (Fab), a hazardous process material building (HPM), a central utility plant (CUP), and an on-site bulk gas plant. The space of production cleanroom is 31,000 m^2 and the total Fab / HPM floor space is 114,000 m^2. The process cleanroom is designed to ISO-5 specification for people and tools environment, and the mini-environment is designed to ISO-2 for wafer processing.

In addition to F14P3 project, the newly Fab12 Phase-4 (F12P4) project is progressing the final examination for LEED now. F12P4 was designed to LEED gold rating and will be certified in September 2009. The improvements that included in F12P4 project are reducing light pollution, increasing green space, and using more certified material.

Since 2004, when Texas Instruments (TI) reported the first LEED Fab study in the ISMI annual symposium, two LEED gold rating Fabs and one LEED gold rating TFT plant have been built worldwide. TSMC has completed two LEED Fab designs and learned from other LEED projects as well. Based on the practical point of view, we think that it is about time to conclude the optimized model of LEED's green Fab for the high-tech manufacturing facilities. The purpose of proposing this model is to help the strategic planning for your next LEED gold rating manufacturing facilities.

Keywords

LEED FAB, green building, sustainable site, water efficiency, energy conservation

1. Introduction

F14P3 (Figure 1) design was launched in late 2005. The original goal of green building design was targeting on the LEED's silver rating for Fab building and gold rating for office building. The Fab construction started in June 2006, the commissioning of facilities finished in May 2008. The major achievements of F14P3 green building design include:

Fig. 1 TSMC F14P3 Fab building information

Innovation and design process: The major innovations in F14P3 project are: (1) reclaim air from general exhaust and reuse it in HPM building, (2) use 5°C/12°C chilled water instead of 5°C/9°C, and (3) reclaim wasted heat from chillers instead of boilers for hot water system. Besides, F14P3 LEED project includes LEED certified architectures and commissioning engineers in working group.

Sustainable site: In order to reduce the loading of traffics, the facilities of community service are built in the campus; including cafeteria, convenience store, bookstore, coffee shop, juice bar, bake house, automated teller machine, laundry, mail, and parcel service. Moreover, on the subject of transportation service, TSMC has built completed bus routes to provide the commute service for operators. Besides that, the site is also connected with shuttle bus service to the high-speed rail station for the long distance traveling as well. It is estimated 9,600 tons of CO^2 emission reduction per year from these public transportation services. In addition to public transportation, considering minimizing heat island effect, F14P3 provides underground parking for employees only.

Energy conservation: The simulation software, DOE2/eQuest, was used to simulate and analyze the energy efficiency in design stage. F14P3 has achieved 20% energy performance improvement that compared with ASHARE 90.1 standard. The major power saving comes from using frequency inverters for rotation machines.

Water efficiency: F14P3 is operating an ultra-pure water system with 85% of process water reclaim rate. F14P3 also equipped a rain collection system with 700 tons capacity to increase water resource. No city water will be used for landscaping.

F12P4 is under final review process for LEED certification now and expected to be the 2nd gold rating's green Fab in TSMC. Based on the experiences and learning from the F14P3 project, F12P4 will receive 45 points toward LEED gold rating grade. F12P4 (Figure 2) consists of a wafer fabrication building (Fab), a hazardous process material building (HPM), a central utility plant (CUP) and an office building. The space of wafer production cleanroom is 23,000 m^2 and the total Fab / HPM floor space is 105,000 m^2. The improvements in F12P4 project include: (1) reducing light pollution, (2) using more low chemical emitting materials, (3) increasing green space, and (4) improving energy performance.

Building Footprint (m^2)	:	20,000
Building Total Floor Area (m^2)	:	105,000
Wafer Clean Room Area (m^2)	:	23,000
Manufacturing Technology	:	45nm ~ 28nm
Planned Capacity (12" wafer out)	:	30K / Month
Key Milestones:		
Construction Start	:	January 2008
Facility Readiness	:	May 2009
Production Start	:	August 2009

Fig. 2 TSMC F12P4 Fab building information

This paper will discuss an optimized green factory model through our experiences from two major projects. This model could be used as a remarkable benchmark when planning new high-tech facilities.

2. LEED Fab Practices in TSMC

Although a great difference exists between green semiconductor manufacturing plants and conventional green buildings, TSMC has so far already established the specific experience with two certified LEED gold rating green factories. Furthermore, in addition with the understanding from both of TI RFAB (Figure 3) and AU Optronics, a TFT panel maker, G8.5 project, the previous experience and methods are to hopefully establish a green building model for high-tech factories as a reference basis for the development of green buildings in the industry.

Fig. 3 TI RFAB, the 1st LEED Gold Rating FAB (Semiconductor International, 12/2007)

Starting from 2005, TSMC has started the implementation of green buildings, and the localization characteristics for green buildings were considered. However as semiconductor field is also an international industry, therefore double certification EEWH (Ecology, Energy saving, Waste reduction and Health, which is the green building certification system in Taiwan) and LEED were used in hope to maximize the values of the two green building assessment systems. In this article, the practical introduction of green buildings was mainly based on LEED experience and served as a background description for green building models. In addition, we especially added a supplementary description in regarding the ecological environment, which is based on the focus by EEWH, as to enable green buildings to become the main theme of an ecological city.

2.1 Sustainable sites

The main indicators with the assessment of sustainable sites include the following: first to encourage develop polluted lands, and secondary, maximize the green space and to protect the original ecology. In addition, substitutive traffic plans and functional living facilities to reduce carbon emission are to be established, and at the same time handle the issues regarding storm water control, light pollution, heat island effect etc.

The measures TSMC adopted for sustainable site development (Figure 4) includes: provide living facilities to all the employees such as convenience stores, bookstores, cafeterias, bakeries, and coffee bars. Furthermore services provided include automated teller machine, express delivery, laundry, and traveling agencies within the manufacturing plant area. In addition, traffic-commuting facilities for the manufacturing plant include: reserved parking spaces to encourage carpooling and for environmental friendly vehicles, transportation vehicles and commuter buses to and from the manufacturing plant area.

Mini-Mart / Book store / ATM **Cafeteria / Cafe** **Commuter Bus / Car Pool Web**

Fig. 4 Facilities and activities to reduce traffics in TSMC

Other issues and solutions to the sustainable site are: (1) built underground employee parking and used high SRI (Solar Reflectance Index) roofing material to omit heat-island effect, (2) minimized outdoor illumination to prevent light pollution, (3) cooperate with Park Administration and maintain effective capacity of storm ponds to enhance erosion control.

2.2 Water efficiency

The key point in water resource efficiency assessment is the innovation in water saving technology. For example, in Taiwan, Science Park Administration requested that all new manufacturing plants in the Science Park are requested to meet 85% recovery rate from process water. In order to meet with this regulation, the process drainages are separated into

25 streams for treatment in F14P3. The city water reduction rate (Figure 5) is 55% in this facility.

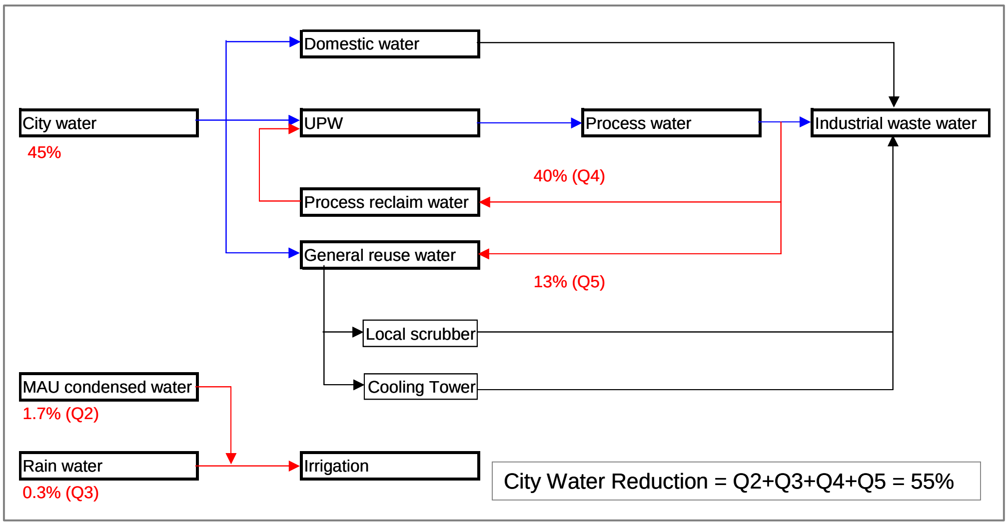

Fig. 5 TSMC F14P3 water reclaim diagram

Meanwhile, F14P3 also equipped a rain collection system (Figure 6) with 700 tons capacity to increase water resource. This rainwater collection system combined with an air conditioning condensation collection system provides a steady irrigation water supply for the irrigation. Therefore, no city water will be used for landscaping. The tap water saved is estimated to be about 16, 000 tons for each year.

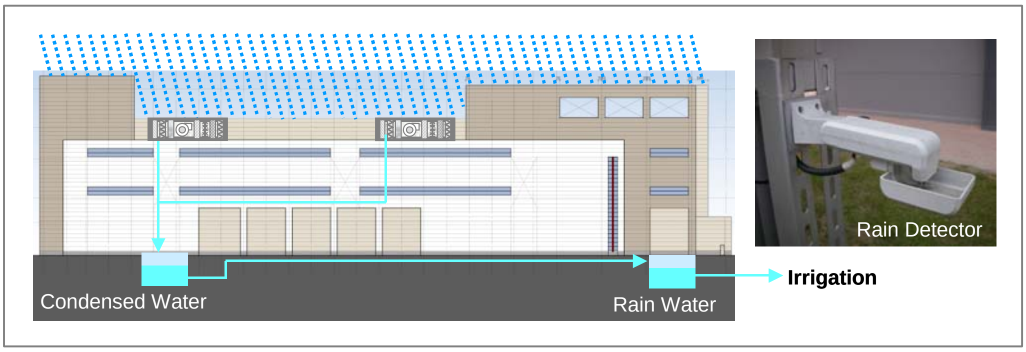

Fig. 6 TSMC F14P3 rain reuse system

2.3 Energy and atmosphere

According to LEED standards, the minimum energy performance for energy-related systems, at a minimum include heating, ventilating, air conditioning, and lighting system are to be first confirmed before the assessment of energy and atmosphere efficacy.

Meanwhile, the building is required with the demonstration of meeting with the minimum energy efficiency standard, ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) 90.1. The DOE2/eQuest was used to simulate and analyze the energy efficiency in design stage in F12P4 project (Figure 7).

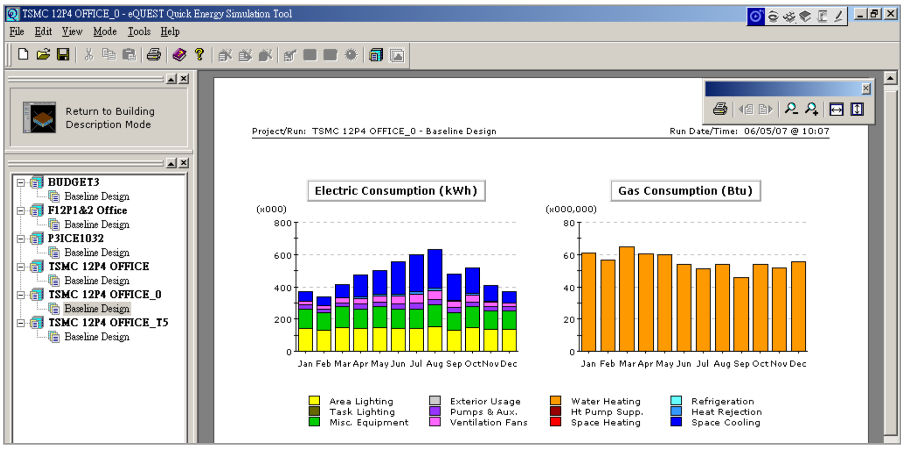

Fig. 7 TSMC F12P4 office building energy simulation model

F14P3 has achieved 20% energy performance improvement (Figure 8) that compared with ASHARE 90.1 standard. The major power saving comes from (1) using variable frequency inverters for fans and pumps, (2) applying heat recovery system to reclaim waste heat from chillers.

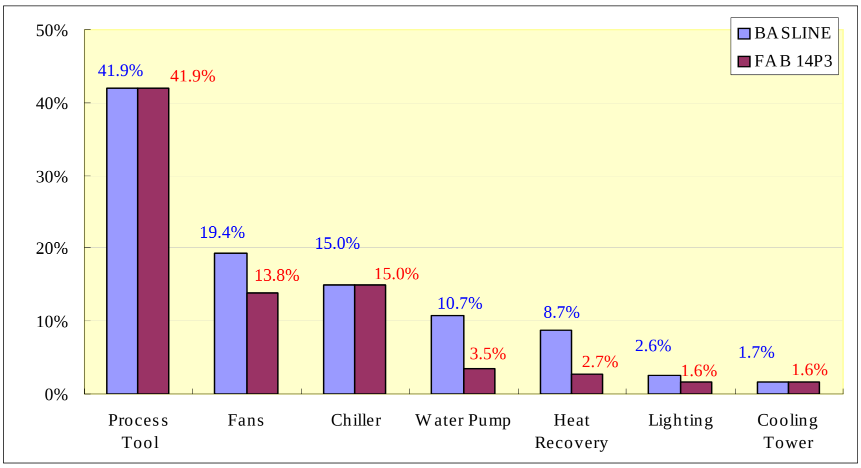

Fig. 8 TSMC F14P3 energy saving comparison diagram

2.4 Material and resources

As high-tech manufacturing buildings need to conform with the requirements of earthquake-resistance, anti-vibration, gas sealed insulation, high-standard manufacturing facilities etc., it is not easy to follow LEED requirements of reusing a large number of old buildings and construction materials. Therefore, the material and resources approach are as follow: (1) Strengthen the management of construction wastes, establish a waste collection center, and assign a specific group to intensify the reuse of construction wastes. (2) Use recycling construction materials such as blast furnace cement, slag, and steel moldboards. (3) Increase the usage of local construction materials, enabling the reduction of distance while transport.

2.5 Indoor environmental quality

The aspect of indoor air quality control for high-tech manufacturing buildings is a relatively easy task. Due to the manufacturing requirements, the clean room environment for high-tech manufacturing buildings are required to use low chemical emission materials, demand high air exchange rate and the monitoring of air cleanliness. However on the other hand, these cleanrooms have no windows for natural ventilation, nor are they able to draw in sunlight to reduce artificial illumination.

2.6 Innovation and design process

In the F14P3 green building project, the establishment of the air reclaim system (Figure 9) is a big step forward in innovation. The concept of air reclaim comes from the very successful water recovery experience in the Science Park. The common issues in air and water reclaiming are: Can the reclaimed water or air reach the standards in manufacturing requirements? Will it cause contamination issues in the production process?

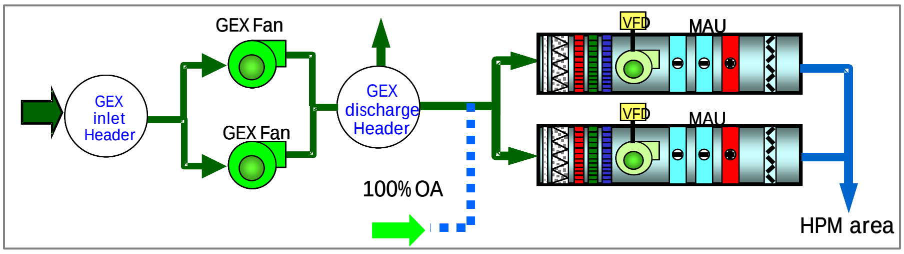

Fig. 9 TSMC F14P3 air reclaim system diagram

The purpose of the F14P3 air reclaiming system is to reclaim general exhaust air from the production cleanroom for the use of a chemical room with less demanding humidity and temperature requirements by slightly adjusting exhaust temperature and humidity if necessary. This system has been currently running for one whole year. According to the monitoring information, pollutant concentration of the reclaimed air is only 10% of outside polluted air in the past year. The toxic gas detectors also did not detect any abnormal situations. Thus the same design has been already used on the F12P4 project. In the future, we shall come up with more innovative methods to reduce the amount of air used in order to achieve the goal of saving energy and reducing carbon emission.

2.7 EEWH, beyond LEED

The main difference between the green building certification in Taiwan, EEWH, with LEED is the means of biodiversity indicating. Most factories within the industrial area have used land to the upper limit for building coverage, therefore there are relatively fewer green areas for ecological designs, such as eco ponds, forests mixed with grasslands, and artificial islands. Thus, if the required space for an ecological system is considered during the base planning stage, manufacturing buildings still have the opportunity to coexist and prosper with an ecological system.

The key design of the F12P4 Ecology system (Figure 10) is planting native plant species, raise the survival chance, and reduce the amount of irrigation water. In addition, combine an ecological green design in various levels: from the planting of trees, shrubs, flower and plants to emphasize the extension of green lands, to attract more species for habitation and create a green ecology net. A natural versatile habitat is created for plants and animals to inhabit, hunt for food, and reproduce in.

Besides the establishment of the ecological scenery in F12P4, the participation of ecological volunteers and associations are actively conducted. By good care from professional volunteers, the development of the ecological system will hopefully flourish. We hope that this may also raise concern for the employees toward the ecological system. A true green building will establish biodiversity and an everlasting ecological environment.

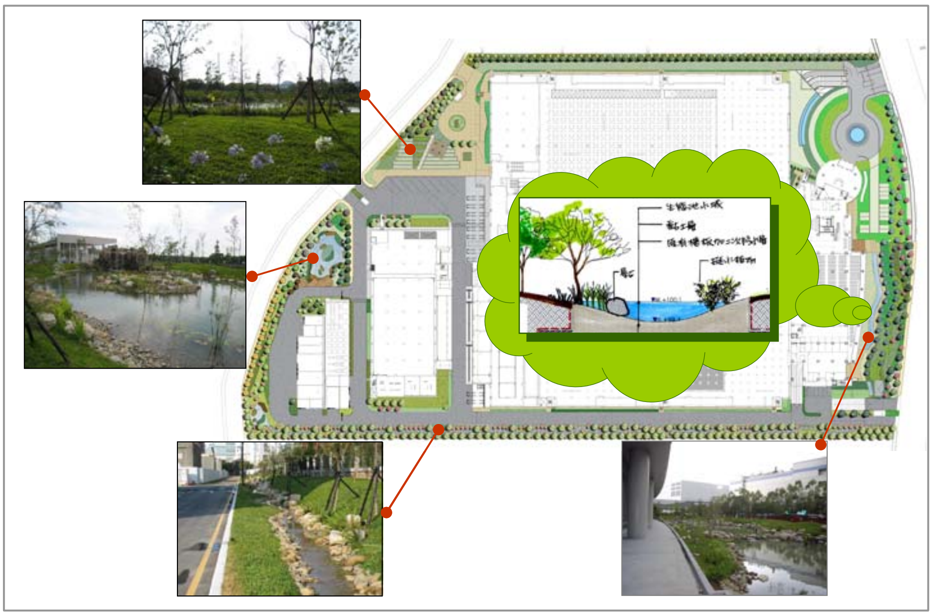

Fig. 10TSMC F12P4 Ecosystem

3. LEED Optimized Model

Since 2004, when Texas Instruments (TI) reported the first LEED Fab study in the ISMI annual symposium, two LEED gold-rating Fabs and AUO LEED gold-rating TFT plant have been built worldwide. TSMC has completed two LEED Fab designs and learned from other LEED projects as well. We would like to conclude the optimized model (Figure 11) of LEED’s green Fab for the high-tech manufacturing facilities.

The evaluation data in Table 1 is based on the 58 review items of LEED-NC towards the implementation of TSMC’s LEED experience, where each results was done by the inspection on every item. As aspects of environmental manufacturing requirements, environmental protection, energy saving, regulations such as construction law were taken into consideration, we have discovered that the high-tech manufacturing plants scored between 26~49 points, which in other words meet with current regulations or general standards; high-tech manufacturing plants are able to at least obtain the LEED Certified rating. Furthermore, we had predicted that 85% of high-tech manufacturing buildings should be able to lie within the 39~49 point region. Among them, 5% are predicted to lie within 47~49, 30% within 43~46, and 50% within the 39~42 region.

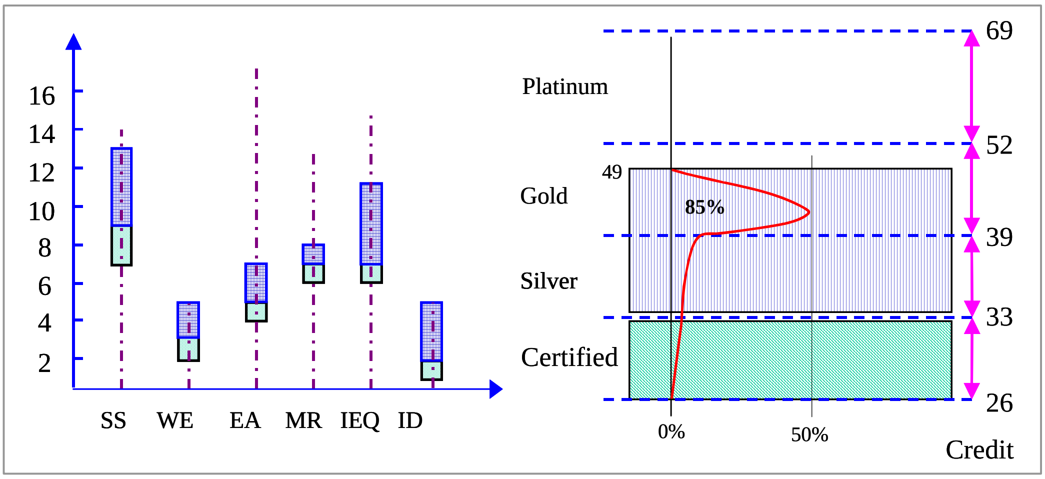

Fig. 11 Proposed LEED FAB Targeting Model

For newly constructed manufacturing plants, a score above 47 points is an extremely difficult challenge. Although difficult, there are still some directions to be found, such as: achieve 24.5% energy reduction, use 2.5% on-site renewable energy, or pursue brownfield redevelopment.

	SS	WE	EA	MR	IEQ	ID	Sum
Regulation Given	7	2	4	6	6	1	26
Acceptable Target	9	3	5	7	7	2	33
Moderate Target	10	4	6	7	9	3	39
Aggressive Target	13	5	7	8	11	5	49

Table. 1 LEED FAB Credit Range

4. Conclusion

When there is determination, creating a high quality green building is not a difficult goal. Every high-tech manufacturing plant is able to achieve this goal. Based on TSMC's practical experience, we believe that 85% of the high-tech manufacturing plant projects are able to reach the LEED-NC Gold certification. Our conclusions to develop a high quality green building are as follow:

(1) The importance of high-tech industrial green buildings is to significantly reduce the use of resources. Single industrial green buildings are the starting point in developing green

industrial parks, and green industrial parks are the driving force in developing an ecological city.

(2) The three major increments in costs are establishing underground parking lots, using variable frequency inverters and creating water reclaim systems.

(3) The development of renewable energy and the use of green power is a topic which urgently requires combined efforts from the industry.

(4) The focus on air reclamation topics and actively developing reclamation technologies for cleanroom air in the industry is recommended.

Let us work together to make the high-tech industry a good example in the green industry.

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Presentation of Author

- Received B.S. from Mechanical Engineering, National Taiwan Institute of Technology in 1987.
- Work Experience:
  1987 - 1988: TI Taiwan, IC Packaging Process Engineer.
  1989 - 1992: TSMC, Equipment Engineer.
  1993 - Now : TSMC, Facility planning, design and construction for Fab3, WaferTech, Fab6, SSMC, Fab12, TSMC Shanghai, Fab14.
  Had built around 2.4 million ft2 of production cleanroom since 1993.
- Currently,
  Director of New Fab Planning & Engineering Division (TSMC).
  Ph.D. Candidate in Graduate School of Civil Engineering, National Taiwan University (NTU).