The Path to Sustainability: Energy-Saving Achievements and Future Plans of the NSRRC

The concentration of carbon dioxide in the atmosphere rose from 280 ppm before the Industrial Revolution to 420 ppm. Fortunately, humanity has recognized the climate change problem caused by this issue and has been actively transitioning energy systems. This includes using low-carbon natural-gas power generation as a transitional step and introducing zero-carbon renewable energy sources.

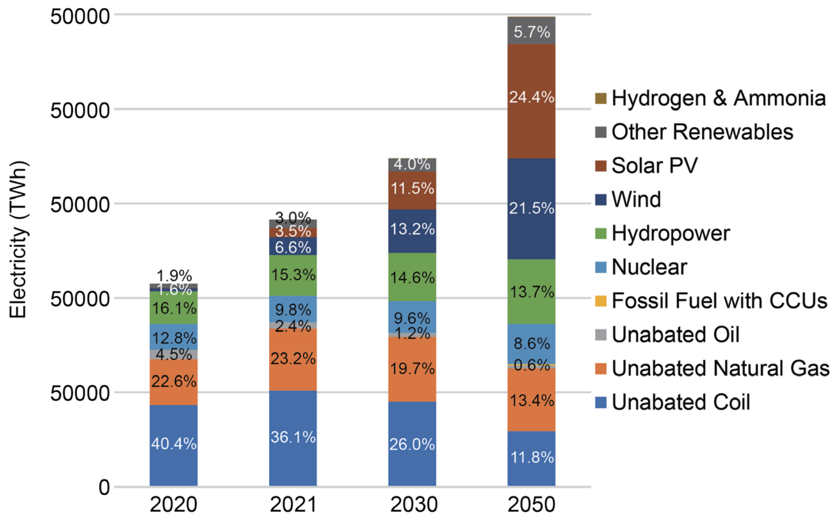

Fig. 1: Global power generation by energy type and percentage.[1]

The International Energy Agency compiled data on global power generation for 2020 and 2021 and predicted the energy mix for 2030 and 2050. As shown in **Fig. 1**, while energy demand continues to rise, the share of fossil fuels is expected to drop from 67.5% in 2020 to 25.8% in 2050. Meanwhile, renewable energy is projected to increase from 19.7% to 65.2%,[1] meaning that in 30 years, the roles of renewable and fossil energy will reverse.

Figure 2 illustrates the power usage and share of major facilities and buildings of the NSRRC in summer. The two accelerators, TLS and TPS, are the largest power consumers, with a combined usage of 4,341 kW. This accounts for 45.3% of the NSRRC total power consumption. The top three subsystems of the accelerators in terms of energy usage are the magnet power supply, radio-frequency (RF) systems, and cryogenic systems. Other major power consumers include the utility systems (3,241 kW, 33.8%), building electricity usage (1,378 kW, 14.4%), and beamlines and laboratories (629 kW, 6.6%).

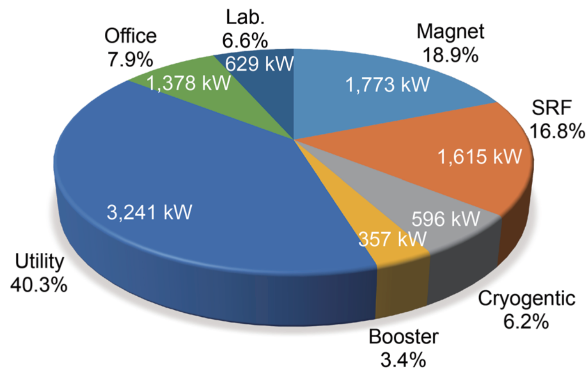

Fig. 2: Power usage and share by major facilities and buildings in summer 2021 at the NSRRC. [Reproduced from Ref. 2]

Using the ISO 14064-1 standard, we record the direct carbon emissions and indirect emissions from purchased electricity of the NSRRC, excluding indirect emissions from employee commuting, business trips, supplier transportation, or service provisions. The annual carbon emissions are about 35,265 tons of CO_2 equivalent, with 95.5% stemming from purchased electricity. The remaining 4.5% comes from kitchen liquid petroleum gas burning, emergency generator operation, official vehicle emissions, refrigerant leaks from air conditioning systems, and experimental processes. Therefore, reducing electricity use is key to decreasing carbon emissions.

From previous energy-flow statistics, it is clear that the accelerators are the most significant power consumers. However, before implementing energy-saving measures, we must consider whether the chosen technologies can affect reliability, safety, investment costs, and economic returns from lower electricity bills. Despite these challenges, recent breakthroughs have been made, such as the energy-efficient operation of booster ring dipole magnets and the implementation of solid-state RF systems in the TPS. Other advancements, such as using permanent magnets, have improved accelerator performance while saving energy, promising further progress.

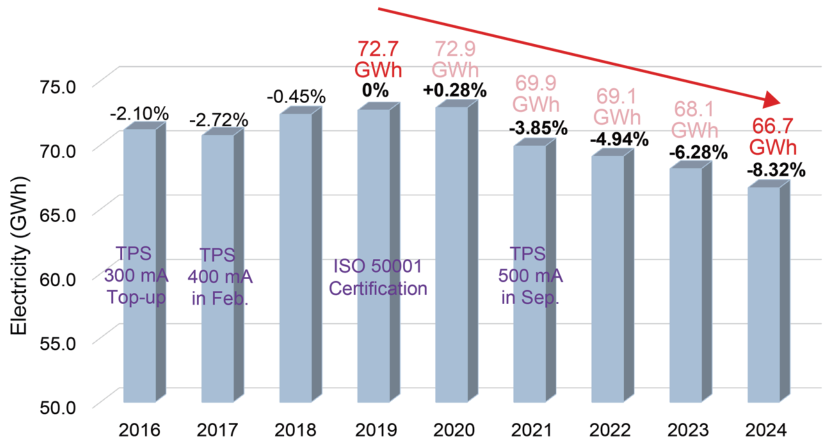

Fig. 3: Yearly electricity usage statistics for the NSRRC. [Reproduced from Ref. 2]

The second-largest power consumer is the utility system. During the construction of the TPS, energy-saving features like variable-frequency drives for pumps, air-conditioning fans, and air compressors were planned. The NSRRC recently implemented an energy management system, earning ISO 50001 certification. This recognition highlights the energy-saving efforts of the NSRRC and supports the development of new techniques, including:

A. Optimizing Chiller Operations: Chillers are the core of air conditioning and accelerator cooling systems and the most energy-intensive machines. Connecting the cooling systems with chilled water pipelines across the TLS and TPS allows chillers to be centrally managed for optimal operation and energy efficiency.

B. Heat Pump Energy Recovery: Waste heat from various equipment and air-conditioning systems can be recovered using heat pumps. This recovered heat can reheat dehumidified cool air to provide the dry, room-temperature air, reducing energy consumption from electric heaters by 70%.

C. Upgrading to light-emitting diode (LED) in the TPS Experimental Hall: Previously, this area used 384 metal halide lamps, each rated at 400 W. These have been replaced with 153 W LED lights, leveraging improvements in LED lighting technology.

Despite the addition of new equipment and record-high accelerator operation hours, our net electricity usage has decreased yearly thanks to collective efforts. As shown in **Fig. 3**, starting from the TPS's official launch in 2016, and using 2019 as the baseline, the annual electricity consumption of the NSRRC dropped from 72.7 GWh (about 7% of Hsinchu City's household electricity usage) to 66.7 GWh in 2024. This reduction saves at least 6.0 GWh annually, equivalent to TWD 26.5 million in electricity costs. Additionally, the NSRRC has installed solar panels with a total capacity of 1,187 kWp on building roofs, generating about 1.5 GWh of renewable energy yearly—2.1% of our annual electricity usage. Although the electricity generated is sold to the Taiwan Power Company and cannot be counted toward energy savings or carbon reductions, it provides considerable revenue for the NSRRC.

Saving energy protects the environment and addresses practical concerns such as rising electricity costs and potential carbon fees. From July 2022 to present, electricity rates have increased by 74.8%, and this year's summer rates were extended for an additional month. Energy costs have also been driven up by the war in Ukraine, and carbon fees may be introduced in the future. Under this stress, the NSRRC will continue to implement energy-saving measures such as:

A. Detecting pipeline leaks
B. Optimizing operational parameters of mechanical equipment
C. Recovering heat energy
D. Replacing outdated equipment
E. Improving building energy efficiency[3]
F. Maintaining heat exchangers
G. Generating renewable energy
H. Utilizing electrical energy or ice storage systems

By taking these actions, we aim to fulfill our corporate social responsibility and accelerate the transition to green energy. (Reported by Wen-Shuo Chan and Chin-Kang Yang)

References

1. The International Energy Agency, World Energy Outlook 2024, October (2024). https://www.iea.org/reports/world-energy-outlook-2024
2. W. S. Chan, "Towards a green accelerator: implementing energy-saving practices at NSRRC" in Proc. IPAC'**24**, May (2024). https://accelconf.web.cern.ch/ipac2024/pdf/WEZN1_talk.pdf
3. J. C. Chang, W. S. Chan, Proc. IPAC'**23**, 209 (2023).