IIJ and the Evolution of Data Centers —Commemorating 30 Years

3.1 1990s—It Started with the Effective Use of Space

Even before the privatization of the Nippon Telegraph and Telephone Public Corporation in 1985 (an event referred to as Japan's telecommunications deregulation), system integrators were engaged in the business of housing other companies' computers in their computing centers in space freed up by computer downsizing. International telecommunications companies were also in the business of housing dealer phone systems and private telephone exchanges for foreign financial institutions in space freed up in their telecommunications spaces by the downsizing of exchange and transmission equipment. Both types of buildings were sturdier than ordinary buildings, and people recall them as the predecessor to today's data center facilities.

Before Japan's telecommunications deregulation, international communications were handled exclusively by Kokusai Denshin Denwa Corporation (KDD, now KDDI), but post deregulation, several new communications carriers (NCCs) entered the market, and computer communications also started to spread, driven by Type 2 Communications Carriers (General, Special), which do not have their own transmission equipment.

IIJ was founded in 1992 and, after much effort, was licensed as a Special Type 2 Communications Carrier and thus permitted to provide Internet services. IIJ's first installation of communications equipment was in the KDD Otemachi Building (now the KDDI Otemachi Building) in Otemachi, within Tokyo's Chiyoda Ward. That was followed by the installation of NSPIXP-1 in the basement of Iwanami Shoten, Publishers' premises in Kanda Jimbocho, Chiyoda Ward, and when Internet exchange (IX) interconnectivity tests began, IIJ set up routers on dedicated lines. Once NSPIXP-2 was subsequently installed at the KDD Otemachi Building, Internet service providers (ISPs) began to congregate at that location.

ISPs use a huge number of dedicated lines and telephone lines, so it makes sense to install network equipment within communication stations and connect them to transmission equipment and exchanges on-site, but NTT's station facilities were not yet made broadly available, and because ISPs needed to connect both domestically and internationally, they naturally decided to make use of the communication stations of KDD and the NCCs. NSPIXP-3 was opened in Osaka, and 1997 saw Japan Internet Exchange Co., Ltd. and Internet Multifeed Co., Ltd. established, marking the beginning of commercial IX services. This was the era in which Japan's underlying Internet framework was formed.

The term data center was still not in use at this point. The services were called "co-location," because equipment was located alongside transmission equipment, and "housing," because they involved housing customer equipment. The rooms were heavily cooled and seemed cold and inorganic, and at the time, a supply of 1–2KVA per rack was quite sufficient.

3.2 2000s—Internet Data Centers

With the explosive growth of Internet connectivity services in the late 1990s, all at once many ISPs began leasing communications station buildings and providing services. Late in the era, in October 1998, IIJ established a joint venture with Sony and Toyota Motor Corporation called Crosswave Communications Inc. (CWC), which set up a nationwide network as an NCC. The following year, it opened access points across Japan.

At the same time, we selected buildings with a fairly large floor load capacity in major Japanese cities (Sapporo, Sendai, Tokyo, Nagoya, Osaka, and Fukuoka) and set up data centers equipped with uninterruptible power supplies and emergency generators. Later, we built our own data centers—encompassing land and structure—in Kawaguchi

Table 1: Differing Features of Computing Centers and Communications Stations

Feature	Computing center	Communications station (telephone & telegraph offices)
Air conditioning	Water cooled (large, general-purpose coolers)	Air cooled (transmission equipment, telephone exchanges)
Power supply	Main supply: AC (3-phase 200V)Generator backup	Main supply: DC (48V DC) CVCF also allows AC supply
Building structure	Designed on par with office buildings Free-access flooring	Designed as a telegraph and telephone office Slab floor
Provisioning	Mainly space leasing	Mainly rack leasing

City, Saitama Prefecture, and Yokohama City, Kanagawa Prefecture. Our guiding concept at the time was to create human-friendly data centers, with integrated people flow lines, cafeterias for break times, conference spaces, kitting rooms, and more. This marked a shift away from inorganic computing centers and communications stations to intelligent buildings for the Internet era.

While it was opening data centers, CWC was also providing wide area LAN services to which customers could connect via Ethernet, which was the standard LAN interface. This communications service (called a “virtual building”) allowed users to connect as if on a LAN even when physically distant and use the network as if they were all in the one building. Combined with a fee structure that was independent of physical distance, this service took the world by storm at the time, and it is fair to say that this setup has now become the de facto standard for L2 data services.

As networks and data centers evolved, companies began installing the equipment needed for email services, web services, firewalls for security, and remote access. The facilities attracted not only ISPs but also OTT (over-the-top) businesses such as content providers, and with the advent of rental server services and hosting services, the facilities became not just places to locate equipment but places for providing the functionality to connect such systems to the Internet.

And thus they came to be called Internet data centers. In this era, floor load capacities exceeded one ton per square meter, multiple power feeds were installed, and the power supply and air conditioning equipment was designed to facilitate 4–6KVA per rack. The Internet has long been likened to a cloud, and it was from around this time that Internet data centers would transform into cloud service and connectivity hubs.

3.3 2010s—Accommodating Cloud Services

With cloud services, which provide computing resources over a network, service providers and the like own and operate the servers and other IT equipment essentially on behalf of users. To achieve high equipment densities and efficiently run the huge amount of IT equipment involved, in the 2010s, operators began building hyperscale data centers capable of adequately cooling the equipment and supplying 10KVA or more per rack.

Power receiving capacities were now on the order of 50MW, equivalent to some 10,000 ordinary households (on 100V 50A contracts). The facilities were not only large in scale but also designed to be energy efficient. The rise of hyperscale data centers also saw improvements in an indicator of energy efficiency called PUE (power usage effectiveness; found by dividing the power consumption of the entire data center by the total power consumption of its IT equipment, with a score of 1 being optimal and the Japan average being 1.7). To build data centers that would accommodate cloud service platforms, IIJ developed the IZmo containerized modules capable of providing 10KVA per rack in a high-density environment with outside-air cooling for high energy efficiency, and this culminated in IIJ becoming the first in Japan to operate a commercial outside-air-cooled containerized data center facility in 2011. At the time, IIJ’s business model involved reselling data center capacity rented from other companies. We had no experience building our own data centers or developing electrical and air conditioning equipment, so we had to start from scratch. We visited the data centers of industry leaders (GAFA and the like) in North America and determined that outside-air cooling would be the most effective way to reduce power consumption, and we settled on the concept of combining this with containerized modules that would allow us to add capacity in stages. Working with our partners, we designed and built test facilities, and after a year

Table 2: Key Considerations when Constructing a Data Center

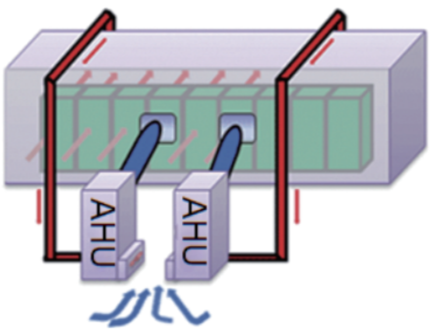
Consideration	Details
Building structure	Earthquake-resistant structure, seismic-isolation structure, seismic-isolation flooring
Power receiving system	3-spot network, receipt of power from substations
Power supply	UPS redundancy (standby redundancy, parallel redundancy, common standby method)
Communication circuits	Multi-carrier, carrier neutral, conduit redundancy
Disaster preparedness	Distance from active faults, avoidance of locations directly under air routes, hazard mapping
Ground	Ground strength (N value), liquefaction potential index
Indicators	PUE, WUE, PLM value, Tier level classification

of testing, we were able to build the Matsue Data Center Park (Matsue DCP).

We named IZmo after the Izumo region, where it was first implemented, and the kanji for "cloud" (which is part of the Japanese spelling of Izumo). IZmo's excellent energy-saving performance and ease of installation saw it not only used in Japan but also exported overseas for use at a hydroelectric power plant in Russia, a national data center in Laos, and elsewhere. And a project is currently underway to provide data centers to Uzbekistan's national telecommunications carrier. With edge computing becoming more widespread, we now offer the modules both in Japan and internationally under the DX edge moniker as a solution for easily and rapidly building edge computing environments and digital/IT infrastructure.

Matsue DCP is a medium-sized center with a power receiving capacity of 4MW, but from the late 2010s, the construction of multiple hyperscale data centers for foreign cloud providers began in earnest. These were initially clustered in the Inzai district around Chiba New Town Chuo Station. This area is so well known as a data center hotspot that the name Inzai is recognized internationally. This clustering can be attributed to a confluence of factors, including the area's solid ground, the fact that it is within 30km of Otemachi, easy access to a submarine cable landing station, and the fact that infrastructure is well developed by virtue of the area having long been a site for computing centers. Even overseas, though, data centers do tend to cluster in certain areas, so Japan is no exception here. Other cluster sites include Osaka's Saito region and the Keihanna area, and with multiple large-scale development plans underway in Japan, this trend can be expected to persist.

As the scale of IIJ's business expanded, in 2019, we also built and began operating a hyperscale data center, dubbed Shiroi Data Center Campus (Shiroi DCC), in the Inzai district (Shiroi City is next to Inzai City). Located on a 40,000sqm site, the facility can be expanded to a maximum power receiving capacity of 50MW. Matsue DCP can be expanded in container increments (nine racks), but to allow for the expansion of Shiroi DCC's service infrastructure in larger increments, we first constructed a system module building with a 1,000-rack capacity, and this is divided into four modules to allow for expansion in stages. The use of outside-air cooling systems on a large scale also means that the facility achieves excellent energy savings on par with Matsue DCP. In addition to outside-air cooling, Shiroi DCC also uses side-flow systems, which are often used in hyperscale data centers. The low-speed, high-capacity airflow of this system is more energy efficient than the conventional method of vigorously blowing cold air out from under the double floor and creates a comfortable working environment.



AHU : Air Handling Unit

Outside-air cooled container module concept at initial planning stage in 2009 (excerpt from internal documents)

Shiroi Data Center Campus, launched in 2019

Figure 1: Creating a New Form of Data Center, Something from Nothing

In the 2010s, as cloud services became widespread, the data center industry saw substantial change, including the ongoing build up of hyperscale data centers and the entry of foreign players into the market. In response, IIJ developed container modules from scratch (Figure 1) and was eventually able to build its own hyperscale data center. In 2023, the Shiroi DCC Phase 2 building went into operation, and IIJ is currently working on plans for the facility's Phase 3 building with a view to putting it into operation in 2026. We continue to explore new data center forms as we look further into the 2020s and the prospect of even more drastic change than we have seen so far.

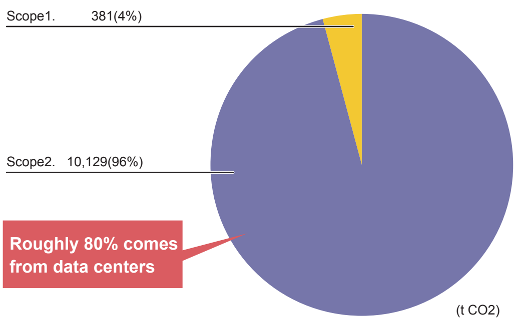
3.4 2020s—Next-generation Data Centers

After all the changes so far, what will we ask of data centers going forward? The data center equipment life cycle is over 10 years, longer than the 3–5 years for IT equipment, so societal and technological trends must be assessed from a medium- to long-term perspective. As calls for sustainability intensify and technological innovations like generative AI, large language models (LLMs), and post-5G move forward, IIJ will be focusing on the following three themes around next-generation data centers.

■ Carbon Neutrality

The use of data centers helps to save energy across society as a whole through the centralized, efficient operation of IT equipment, but even so, the energy consumption of the facilities themselves is a focus of attention. Japan's revised Energy Saving Act was enacted in 2023, introducing a benchmark system for the data center industry (PUE of 1.4 or less), and requiring operators to submit a plan for converting to non-fossil energy. Companies listed on the Tokyo Stock Exchange's Prime market are also now effectively required to disclose information on climate change risks based on the TCFD recommendations, and thus carbon neutrality is an issue of some urgency for data centers. At IIJ, data centers account for around 80% of greenhouse gas emissions (Scope 1 and 2)[*1], and we have set and are working toward goals concerning the use of renewable energy and improvements in energy-efficiency (Figure 2).

The use of renewable energy is a new initiative for IIJ, and takes into account not only the quantity of power but also types of power generation that do not produce CO2 emissions. When it comes to IIJ data centers, we evaluate power procurement methods based on delivery times, cost trends, and the



FY2022 unconsolidated data for IIJ

Calculation method: "Basic Guidelines for Calculating Greenhouse Gas Emissions Throughout the Supply Chain (Ver. 2.3)" (Ministry of the Environment, Ministry of Economy, Trade and Industry)

- **Usage of renewable energy*1**
  The target is to increase the renewable energy usage rate of data centers (Scope 1 and 2) to 85% in FY2030

- **Improvements in energy conservation**
  The target is to keep the PUE of data centers at or below the industry's highest level (1.4)*2 until FY2030 through continuous technological innovation.

Disclosures based on TCFD (Task Force on Climate-related Financial Disclosures) recommendations

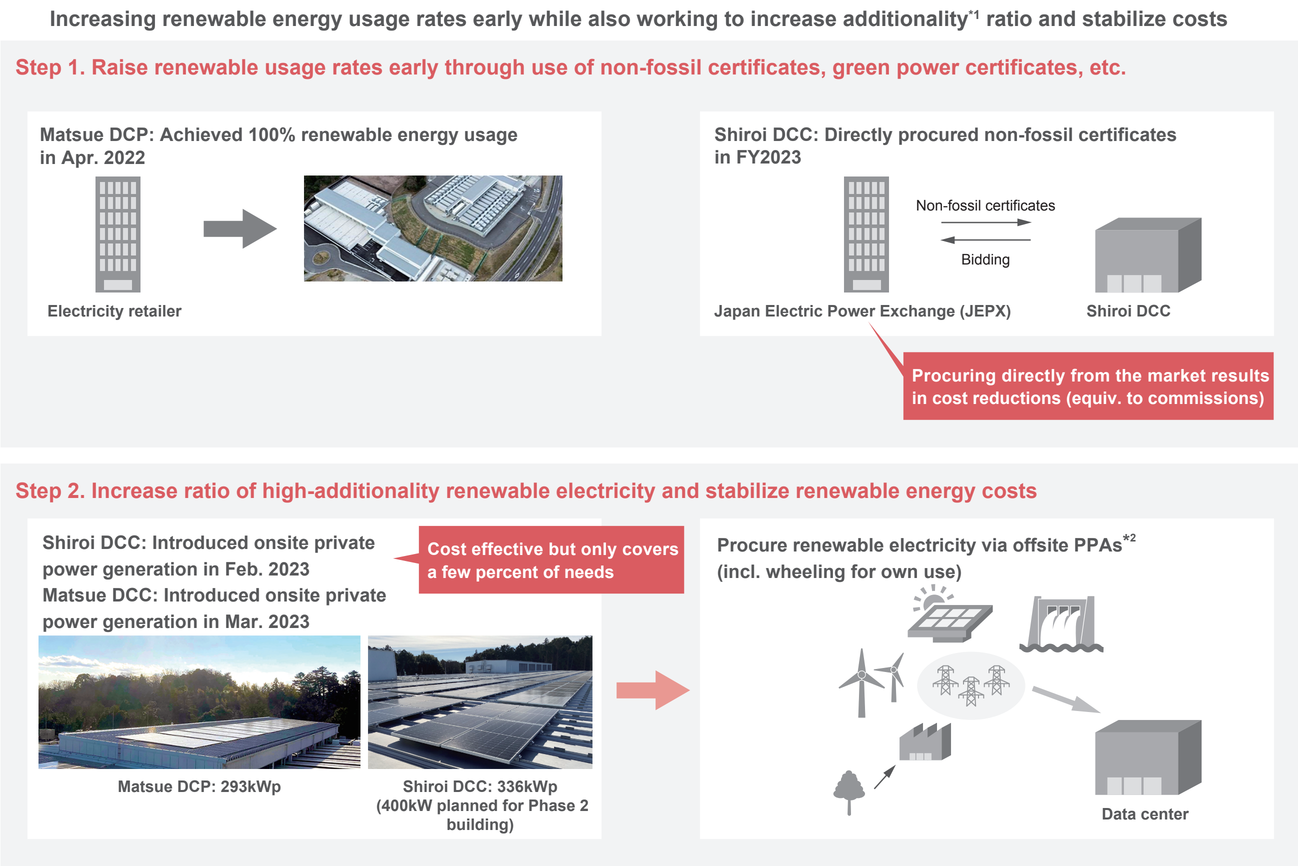
*1. Renewable energy usage includes substantial renewable energy through the use of non-fossil fuel certificates.
*2. As of April 2022, the Agency for Natural Resources and Energy set the benchmark index and target level for the data center industry to be a PUE of 1.4 or lower; businesses that achieve this are regarded as energy-saving leaders.

Figure 2: IIJ's Carbon Neutrality Initiatives

*1 Scope 1, 2 (company's own greenhouse gas emissions): Direct emissions from fuel used or industrial processes, and indirect emissions from energy/heat purchased (GHG Protocol definition).

like, and we are combining multiple methods in an effort to increase our renewable energy usage rates, increase our proportional usage of power with high "additionality," and stabilize our procurement costs (Figure 3). We have joined the Japan Electric Power Exchange (JEPX)'s renewable energy value trading market, obtaining certificates directly from the market, and we have installed solar power generation systems on our data center premises, reducing our renewable energy procurement costs. We aim to achieve carbon neutrality by combining our traditional approach to energy savings with offsite power purchasing and the like. We have also launched a new service that utilizes these resources to provide environmental value to data center users (Figure 4).

We are also working on initiatives to develop the environmental value trading business, with plans to start providing digital assets (tokens) representing environmental value in July 2024 (Figure 5). And we are developing new roles for the data center to help solve societal issues, such as power grid stabilization and resilience bolstering. For instance, we are part of a VPP (virtual power plant) project to use storage batteries in data centers (launched in FY2023), and we are working with Matsue City, Shimane Prefecture as a co-proposer in the Ministry of the Environment's Decarbonization Leading Regions program, with plans to use storage batteries to supply power to local communities in the event of disasters.



*1. Has the effect of encouraging growth and investment in new renewable energy equipment.

*2. Power Purchase Agreement. Electricity sales agreement between an electricity user (consumer) and an electric power company (PPA operator) that sells electricity to the consumer.

Figure 3: IIJ's Efforts to Use Renewable Energy

AI-based Control and Automation

Reducing energy usage is crucial to achieving carbon neutrality in the data center. The air conditioning systems used to cool IT equipment account for the greatest share of energy consumed by equipment other than IT equipment like servers. To achieve data center PUEs close to the optimal value of 1.0, we are actively using outside air to cool IT equipment, and we select highly efficient equipment. At Shiroi DCC, we are also using AI technologies to further improve energy-saving performance. We aim to achieve more effective control of the overall air conditioning system by training AI on data from sensors and IT equipment. In addition to automating air conditioning systems, we are also taking steps to reduce operator workloads at data centers. We are, for instance, working to automate the various procedures and tasks that are crucial to providing data center services, a key example being the use of automated reception systems, which automate the procedure of admitting people into data center buildings. We are moving in this direction because, amid the decline in Japan's working population and the country's work-style reforms, we expect it to become more and more difficult to maintain the quality of our product offerings as the scale of our data centers expands if we continue to rely on solely on human resources through the hiring and training of operations personnel. We are looking to progressively expand automation to other areas. For example, with respect to our

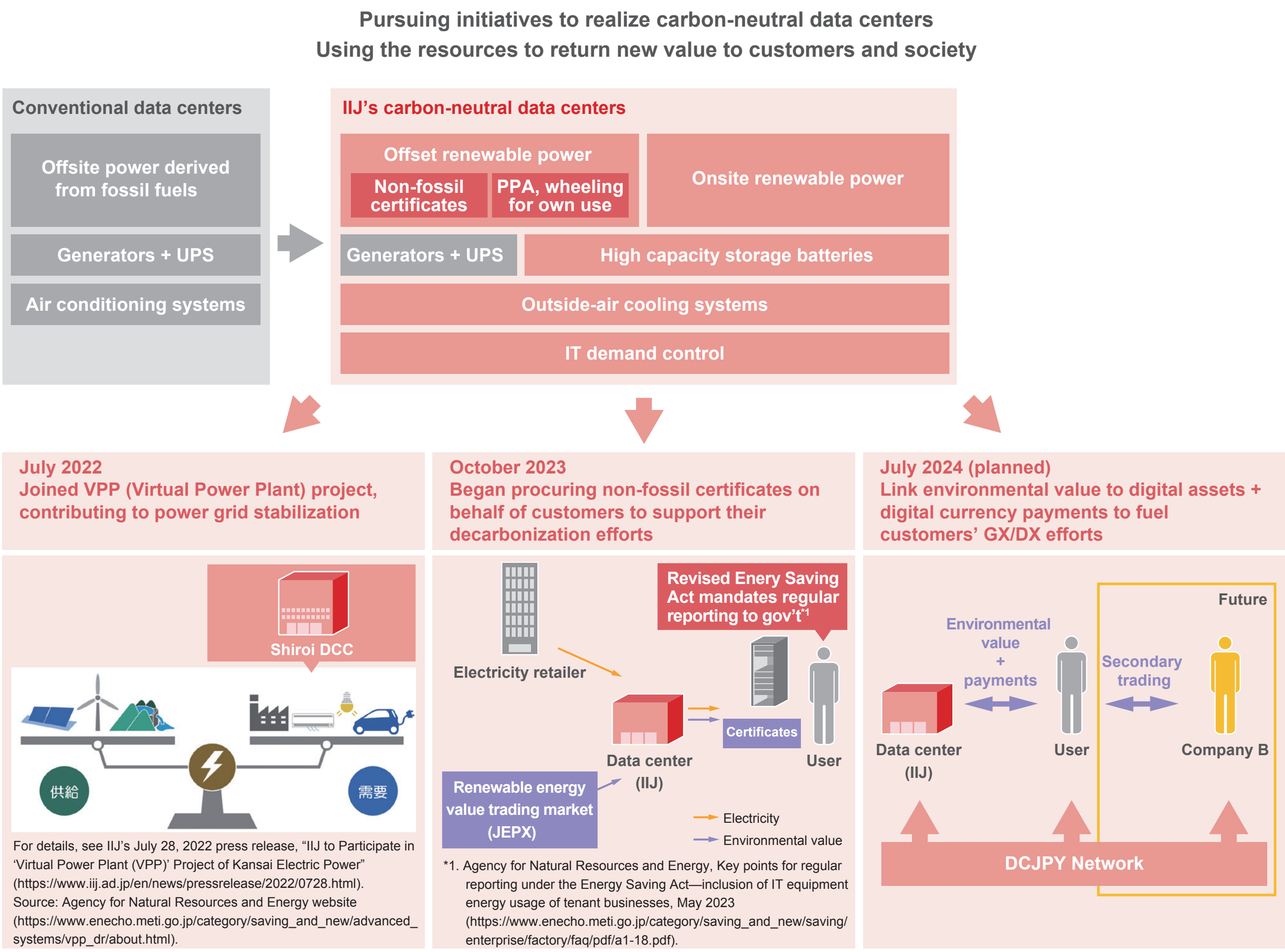


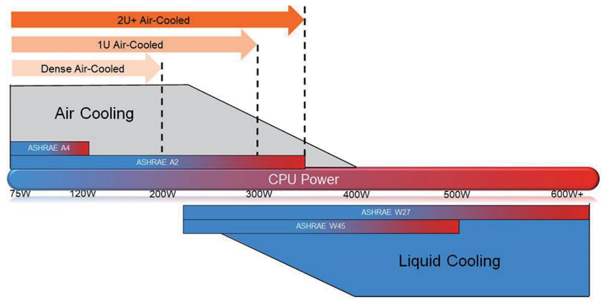
Figure 4: Beyond Carbon-Neutral Data Centers

plans to supply environmental value-linked power to data center users, as described in the previous section, we hope to go beyond simple automation to provide more sophisticated, higher-quality offerings by developing an electricity supply/demand matching platform, introducing digital currency payments, and the like.

Supporting Higher Server Densities and Water Cooling

As the use of technologies like generative AI and LLMs in a range of fields continues to advance and the processing power of CPUs and GPUs increases, next-generation data centers will need to be able to efficiently accommodate huge numbers of these CPUs and GPUs. Ahead, data center CPUs are set to come out with TDP (thermal design power) ratings in excess of 300W, and this is only expected to rise ahead in response to demand for AI. According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASRAE), once TDP exceeds 300W, facilities will need to adopt water-cooled systems instead of conventional air-cooled systems (Figure 6).

Because they will also house network devices and other such IT equipment that is air coolable, future data centers will need to adopt hybrid cooling systems that combine air and water cooling while also providing excellent energy-saving performance in order to achieve carbon neutrality. IT equipment



Source: Ashrae Emergence and Expansion of Liquid Cooling in Mainstream Data Centers (https://www.ashrae.org/file%20library/technical%20resources/bookstore/emergence-and-expansion-of-liquid-cooling-in-mainstream-data-centers_wp.pdf).

Figure 6: TDP (CPU Power) and Cooling Methods

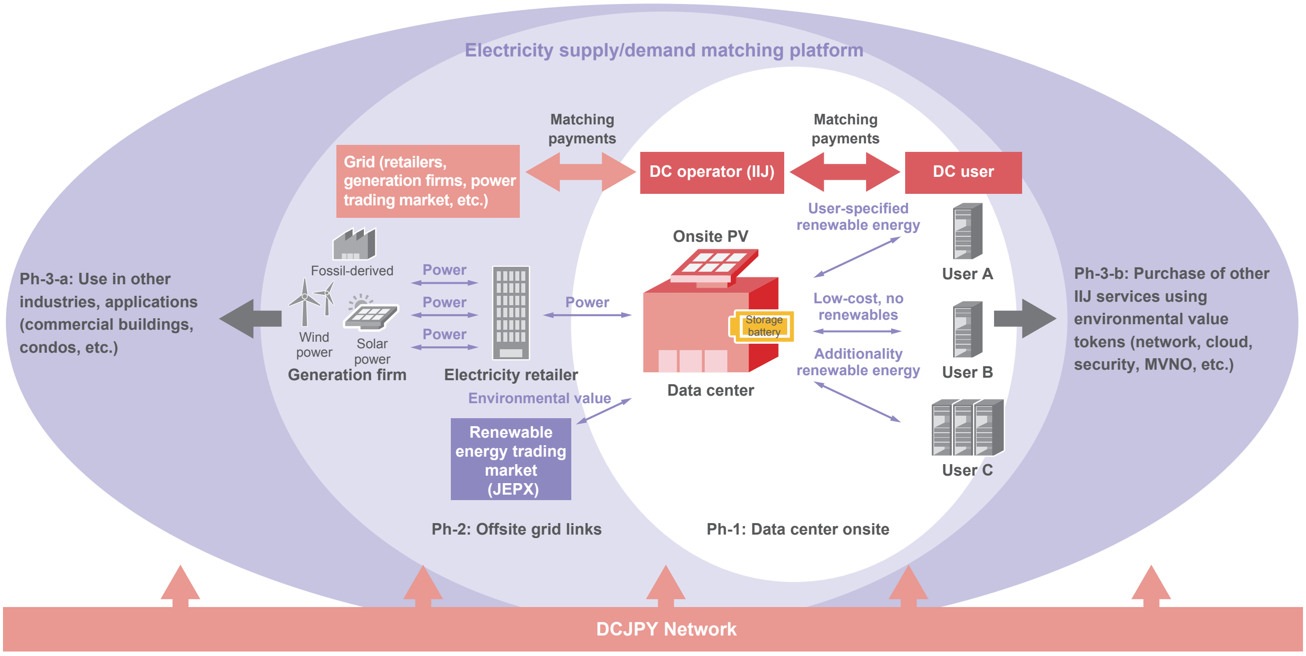


Figure 5: Addressing the Rising Need for Decarbonization

and facilities will become more closely intertwined, and we believe this will be an area in which IIJ will be able to leverage its strengths, given the company's experience building and operating large-scale data centers and cloud services. IIJ, Preferred Networks Inc., and the Japan Advanced Institute of Science and Technology (JAIST) jointly put forward a project, which was subsequently accepted, for research and development into ultra-high-efficiency AI computation infrastructure for inclusion in the Ministry of Economy, Trade and Industry and the New Energy and Industrial Technology Development Organization (NEDO)'s program of research and development of enhanced infrastructure for post-5G information and communication systems, specifically addressing the "Development of post-5G information and communication systems (commissioned project)" category. IIJ is responsible for research and development of basic technology for high-density data centers. We will be working on the development of a high-density data center reference model, establishing hybrid cooling methods that combine air-cooling and water-cooling technologies, and formulating and developing evaluation methods for energy-saving indicators geared to AI computing platforms.

3.5 Conclusion

While the users of IT systems may not often give much thought to data centers, there is growing recognition that data centers are a key component of the infrastructure underpinning a digitalized society. Drawing on our data center journey so far, from computing centers and communications stations, through to colocation services, the cloud, and hyperscaling, we will continue to pursue new forms of data centers and as we go about operating the infrastructure that supports our society.

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