Pingtung County, Taiwan

Smarter Cities Challenge report

Contents

1. Executive summary

Introduction

Pingtung County, Taiwan, is one of 100 cities or other jurisdictions selected to receive a Smarter Cities Challenge® grant from IBM as part of its citizenship efforts to build a Smarter Planet®. During three weeks in November 2013, a team of five IBM experts worked to deliver recommendations on a key challenge identified by the County's Magistrate Tsao and his senior leadership team, as below:

Deliver a roadmap to lessen the county's dependence on traditional energy consumption, increase awareness and use of renewable energies, deliver an integrated plan for a microgrid demonstration site in Pingtung County and ultimately improve the quality of life for citizens.

The challenge

The challenge presented to the IBM Smarter Cities Challenge team required an awareness of key facts in order to define both the problem statement and a set of recommendations. The key facts are about the following:

- Environmental change, including Typhoon Morakot
- Ecofriendly challenges that face current County processes
- Regional conservation and waste management practices
- Regional and national regulation and compliance considerations

The recommendations address the following:

- Environmental changes underway produce violent weather events, threatening existing infrastructure
- To move forward with sustainable and renewable energy programs, Pingtung County requires a strategic vision
- Recommendations, placed on an implementation roadmap, are required to achieve the County's vision

Findings and recommendations

The findings are based on research by the Smarter Cities Challenge team and facts shared through government and private company briefings. This information yielded findings in 11 areas relating to energy and economic factors, as below:

- Geographic limitations
- Renewable energy progress
- Biogas leadership
- Renewable energy investment considerations
- Renewable energy goals
- Resource-heavy industries
- Stakeholder alignment
- Integrated energy monitoring
- Renewable energy limitations
- Microgrid governance
- Business case and rationale

The team recommends that Pingtung County create a vision statement focusing on its economic model of the future, use of the renewable energy resources it is developing and improvements in quality of life for citizens. An example is presented below:

> "Pingtung County's vision is to leverage its renewable energy successes to become more self sufficient, create a better quality of life for citizens, and develop leadership and innovation in the environment and waste management."

There are several success factors critical to the pursuit of this vision:

- Leverage existing experience in deploying renewable energy technologies to focus on select areas for achievement of scale and increase in competitiveness
- Establish a "smarter" microgrid strategy that integrates next-generation renewable energy technologies, dashboards and analytics as a showcase for the county
- Establish a working group of key vendors and partners that creates the strategic alignment required to deliver microgrid success and a broader forum for influence
- Leverage a mix of renewable energy know-how and experience — as well as energy and environmental impact data — with which to approach the Taiwan Bureau of Energy for support
- Develop a communications and education plan to ensure that the microgrid and demonstration site have strong local support

Long-term strategic goals are imperative. Leading up to 2020, the team recommends that Pingtung County establish goals that are communicated to citizens and become guiding principles toward achievement of the vision, as listed below:

- Continue photovoltaic projects
- Increase biogas initiatives
- Reduce CO2 emissions
- Establish a county focus on communicating and delivering positive environmental outcomes

Specific recommendations to achieve these goals and the County's vision are grouped under three focus areas:

1. Build a microgrid that integrates renewable energy technologies, incorporates an Integrated Operations Control Center and implements advanced analytics in order to achieve Pingtung County's vision of becoming more energy self-sufficient
2. Create an organized governance model in order to manage efficient decision making and drive implementation plans
3. Deploy a strategic communications and education model to drive knowledge to stakeholders and citizens

Conclusion

Pingtung County has a future with great potential. Citizens show great pride in their history, significant determination to move forward with diversification and passion for improving the quality of life for future generations. Creating a vision, setting goals, and implementing the key recommendations for energy and environmental management are critical. Success will require navigating a changing environmental and economic landscape. Pingtung County's leaders understand these key principles and, with good execution, will demonstrate great success.

Highlights

1. Build a microgrid that integrates renewable energy technologies, incorporates an Integrated Operations Control Center and implements advanced analytics
2. Create an organized governance model in order to manage efficient decision making and drive implementation plans
3. Deploy a strategic communications and education model to drive knowledge to stakeholders and citizens

2. Introduction

A. The Smarter Cities Challenge

By 2050, cities will be home to more than two-thirds of the world's population. They already wield more economic power and have access to more advanced technological capabilities than ever before. Simultaneously, cities are struggling with a wide range of challenges and threats to sustainability in their core support and governance systems, including transport, water, energy, communications, healthcare and social services.

Meanwhile, trillions of digital devices, connected through the Internet, are producing a vast ocean of data. All of this information — from the flow of markets to the pulse of societies — can be turned into knowledge because we now have the computational power and advanced analytics to make sense of it. With this knowledge, cities can reduce costs, cut waste and improve efficiency, productivity and quality of life for their citizens. In the face of the mammoth challenges of economic crisis and increased demand for services, ample opportunities still exist for the development of innovative solutions.

In November 2008, IBM initiated a discussion on how the planet is becoming "smarter." By this IBM means that intelligence is becoming infused into the systems and processes that make the world work — into things no one would recognize as computers: cars, appliances, roadways, power grids, clothes and even natural systems, such as agriculture and waterways. By creating more instrumented, interconnected and intelligent systems, citizens and policymakers can harvest new trends and insights from data, providing the basis for better-informed decisions.

A Smarter City uses technology to transform its core systems and optimize finite resources. Because cities grapple daily with the interaction of water, transportation, energy, public safety and many other systems, IBM is committed to a vision of Smarter Cities® as a vital component of building a Smarter Planet. At the highest levels of maturity, a Smarter City is a knowledge-based system that provides real-time insights to stakeholders and enables decision makers to manage the city's subsystems proactively. Effective information management is at the heart of this capability, and integration and analytics are the key enablers.

Intelligence is being infused into the way the world works.

As IBM aligns its citizenship efforts with the goal of building a Smarter Planet, it realizes that city leaders around the world face increasing economic and societal pressures. Given the increased demand for services, these leaders have to deliver new solutions ever more rapidly.

With this in mind, IBM Corporate Citizenship has launched the Smarter Cities Challenge to help 100 cities and other jurisdictions around the world become smarter through grants of IBM talent. Pingtung County, Taiwan, was selected through a competitive process as one of 31 cities to be awarded a Smarter Cities Challenge grant in 2013.

During a three-week period in November of 2013, a team of five IBM experts worked in Pingtung County to deliver recommendations for the County's leader, Magistrate Tsao.

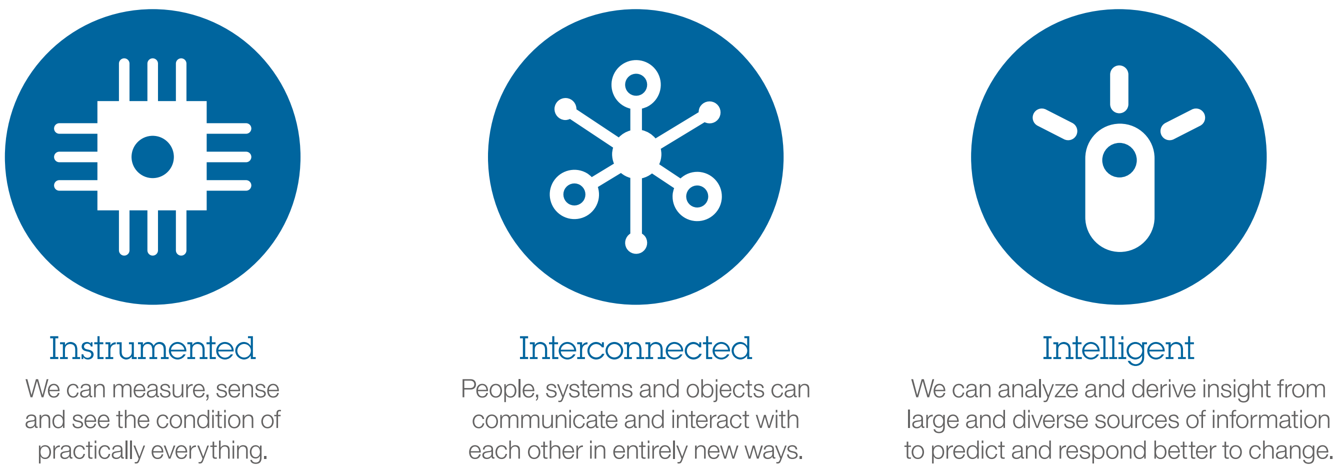


Figure 1: Instrumented, interconnected, intelligent

B. The challenge

The key challenge identified by Magistrate Tsao and his senior leadership team is presented below:

Deliver a roadmap to lessen the county's dependence on traditional energy consumption, increase awareness and use of renewable energies, deliver an integrated plan for a microgrid demonstration site in Pingtung County and ultimately improve the quality of life for citizens.

Pingtung County has faced a series of environmental and energy issues in recent history. These issues are indicative of larger forces at work and impact Pingtung County in a disproportionately heavy manner because of the nature of economic trade and geography in this part of Taiwan.

The challenge issued to the Smarter Cities Challenge team by Magistrate Tsao required an awareness of key facts that play an integral role in the development of a roadmap. Understanding these facts is imperative to understanding the environment and providing sound recommendations leading to an improved future for Pingtung County and its residents. The key facts are as follows:

- **Environmental change, including Typhoon Morakot:** Pingtung County experienced the devastating effects of Typhoon Morakot in 2009. Representative parts of the county such as Linbian Township sit below sea level yet are home to significant agriculture and other economic ventures. The typhoon destroyed much of these low-lying areas and hence much of Linbian Township. The intensity of typhoons here is great, and their future impact must be mitigated.
- **Ecofriendly challenges that face current County processes:** Today's heavy agricultural economy and practices involve farming procedures that apply pressure on the environment. Heavy underground water use has resulted in significant ground collapses, in which the ground level is sinking at more than a meter per decade. Large hog farm operations affect the environment because of the odors from the pig waste.
- **Regional conservation and waste management practices:** The significant water treatment requirements resulting from agricultural commerce apply a heavy burden on treatment facilities and increase the risk of ecological contamination.
- **Regional and national regulation and compliance considerations:** Aided by Taiwan's 2009 Renewable Energy Development Act (REDA), significant opportunities to invest in renewable energy technologies have spurred the deployment of photovoltaic (PV) farms, fuel cell technology development and biogas initiatives in Pingtung County. Policies governing the wise ecological use of land throughout Pingtung County also have been established, influencing future economic investments.

The team gathered information on these environmental influencers and synthesized this information to achieve a clearer description of the problem statement. This problem statement helps ensure the team understand the challenge and that the recommendations, approach and roadmap will yield the results desired by Pingtung County. The problem statement can be described as follows:

- **Future environmental catastrophes could occur.** Pingtung County experienced the devastating effects of Typhoon Morakot in 2009. The county is home to one of Taiwan's three nuclear reactors. Though not impacted by Typhoon Morakot, this poses a great potential risk to Taiwan in the event of future natural disasters, such as typhoons, earthquakes or tsunamis.
- **A strategic vision is imperative.** Typhoon Morakot led Pingtung County to dramatically rethink the way in which it moved forward — in terms of economics, environmental considerations, energy management, urban development and management and citizen wellbeing. The County is determined to avoid the vulnerabilities of future catastrophes by integrating renewable resources and technologies into a strategic vision. This vision's purpose is not only to avoid future vulnerabilities but also to drive improvements in citizens' quality of life.
- **The strategic vision and implementation roadmap must improve economic stability, reduce ecological vulnerabilities and improve quality of life.** Progress in these areas has been made in the years following Typhoon Morakot. Public and private initiatives have included significant deployments of PV farms, fuel cell technology development, biogas initiatives and policies to govern the ecological use of land. Assembling these important elements into the overall cohesive strategic vision is the challenge now facing County leaders. The team endeavors to lay out a strategic roadmap, provide for economic stability and ensure reductions in ecological vulnerabilities.

3. Findings, context and roadmap

A. Findings and context

The Smarter Cities Challenge team's research, coupled with valuable facts from government and partner briefings, resulted in the compilation of the following key findings. These findings form the basis for the final recommendations provided to Pingtung County.

Geographic limitations: One-third of Pingtung County sits below sea level and opens up either to the sea or to the Linbian river. The low-lying areas are flanked by high mountains to the east. During the rainy season, rainwater flows from the mountains into the low-lying areas and floods fields and fish farms. Water must be constantly pumped out of the low-lying areas and into the sea. In the city of Pingtung alone, there are several pumps that operate continuously and require uninterrupted energy sources. In addition, retention ponds are used to offset the need for continuous pumping during heavy rains and the typhoon season. Geological indications are that low-lying areas such as Linbian Township are continuing to sink at a very rapid pace (more than a meter per decade). In sinking areas, limits on housing and farming are then applied.

Renewable energy progress: Pingtung County has introduced renewable energy, with solar PV energy farms being by far the most popular. Pingtung County has approximately 90 MW of installed capacity. All energy generated is fed back to the grid, and revenue is collected by the investors. In general, the investments are made by PV manufacturers (such as LCY, Sunny Rich and Arima). Farmers lease the land used by the PV farms for 20 years in return for a 5% to 10% share of the revenue, which is paid by the investors.

1. Total power consumption in Pingtung County is ~4 billion kWh/year (renewables are four percent of nationwide demand)
2. Grid operator Taiwan Power has capped the distributed energy generation in certain areas, citing safety and infrastructure limitations
3. Emerging players and technologies include bioenergy generation and storage, wind turbines and aquaculture
4. Although currently deployed on a smaller scale, wind renewables play a role in Pingtung County, where one small wind farm exists and another is planned to be deployed in Wetlands Park

Biogas leadership: Pingtung County is home to the largest pig farming industry in Taiwan. There are more than 2,000 pig farms (~23% of the nationwide total) and almost 1.5 million pigs (~24% of the nationwide total). This combination of a stable supply of pig waste and the right weather conditions favors biogas energy generation. Pingtung County biogas generation is still in its infancy, and it has localized biogas generation for immediate consumption. Farms are able to install small digesters to generate a portion of their total energy needs. For example, Yougxingyu and Chenrongxing pig farms are each able to generate 150 kW of power while reducing the harmful effects on the environment. The farms are able to save more than NT$20,000 in electricity expenses every month. Meanwhile the County is working with the Liukuaitsu sewage treatment plant to install a centralized bioenergy generation plant in Pingtung. The program is still in the design stages, and the intention is to produce 720 kWh/day in the first phase and 3 MWh/day in the follow-up phase.

Renewable energy investment considerations: Pingtung County will need to rely on external investments to progress further. The national philosophy of setting "market rates at cost level" means that the revenue generation potential of investing in renewables may be too low to justify capital expenditure by vendors (for example NT$3.25/kWh for biogas and NT$7.20/kWh for solar, of which 90% to 95% goes to investors and 5% to 10% goes to farmers or landowners). National subsidies are provided on a case-by-case basis for unproven technologies and methods. Policies are reviewed annually and exacerbate concerns of long-term profitability for investors and vendors. Additionally, Bureau of Energy (BoE) policy is moving away from PV farms because of the limited availability of flat land (only about one-third of the land in Taiwan is flat), and the BoE is heavily promoting rooftop solar power generation.

Renewable energy goals: Pingtung County has a vision to be green, self-sufficient and independent of traditional energy generation by 2030. Though this is in line with national objectives, the County is focused on local solutions that allow for the use of land, income generation and positive environmental outcomes. The wetlands and devastated fish farms or wax apple farms were initially targeted for PV. Now the government of Linbian Township and wetlands are beginning short-term implementation. Each site incorporates the production of food (farming under PV panels), sources of income (for example rent and labor from security and PV maintenance) and renewable energy to improve the overall quality of life. PV projects from 2010 through 2012 have made significant inroads increasing renewable energy consumption, representing more than one percent of total energy consumption and contributing more than 23% of national energy production.

Resource-heavy industries: Pingtung County relies on industries, such as fish and pig farming, that require large amounts of natural resources to operate, process and perform waste disposal.

1. Fish farming requires large amounts of water and energy. The water is generally drawn from underground sources, which is causing the land to sink at a rate of more than a meter a decade in certain areas that are already below sea level. These areas become more prone to flooding and natural disasters.
2. Fish farming also requires power to run aerators in ponds. These aerators draw close to 800 W and must run around the clock. There are usually two aerators per pond, and dozens of ponds on a farm. Though not a significant cost factor, the efficacy of aerators impacts fish density and health.
3. Pingtung County is home to many pig farms. Waste management, waste disposal and stench—as well as government regulations—are major challenges to farmers and the county.

Stakeholder alignment: There are many stakeholders involved in Taiwan's national and local energy efforts. Specific to the Pingtung County plan, there are several constituencies working within the Magistrate's vision. These stakeholders impact the pace of renewable energy adoption. Each has unique goals and objectives. In such areas as the microgrid, agreement on outcome-based metrics can help focus investment. The key stakeholders are the following:

1. Local government (public departments, schools)
2. National government (for example the BoE)
3. Taiwan Power (the government-owned monopoly power provider)
4. Investors (generally PV, biogas and other manufacturers)
5. Farmers and landowners
6. Citizens of Pingtung County
7. Non-governmental organizations (NGOs)

Integrated energy monitoring: Progress in Pingtung County's renewable energy industry has been made possible through brokering collaboration between vendors and farmers, with a focus on implementation. For the next phase, everyone is interested in integrating power from different generation sources (traditional with renewable). But what is lacking are monitoring and control systems for renewable energy. Pingtung County wishes to integrate all power generation sources into a single dashboard view and collect key metrics to allow for optimization.

Renewable energy limitations: Renewable energy generation in Pingtung County is dependent on external factors. Examples include fluctuations in sunshine and wind and the limitations of what the Taiwan Power infrastructure will support. Some substations allow just 25 MW feeds of renewable energy. This can be because of policy, physical limitations or both. In addition, the costs of laying feeders less than 5 km from the grid are no longer subsidized, shifting the costs to the vendor. Some of the technology limitations may be overcome with modifications in design, but some of the infrastructure challenges require collaboration and investment. The challenges include the following:

1. Intermittent solar radiation during the day and in certain seasons.
2. Intermittent wind, based on the season and time of day, as well as accompanying noise levels
3. Inefficiencies in biogas generation equipment and transport of manure to a centralized processing area; in addition, the high equipment acquisition costs for anaerobic digesters, generators and methane gas storage
4. Low-voltage feeders are generally limited in capacity, and high-voltage feeders are more efficient but costly
5. Lack of energy storage capability and management
6. Limited grid infrastructure at the Linbian Township substation will require expanding certain portions of the city's power grid infrastructure into remote areas as biogas and microgrid capabilities come on line

Microgrid governance: County skills, processes and governance are currently lacking for a successful microgrid implementation, as below:

1. Lack of a strong and dedicated program manager with experience implementing microgrids
2. Lack of local skills and dedicated resources
3. Lack of clarity on the role of the integrators — who takes the lead, and in which capacity?
4. Absence of a steering committee to facilitate communications and decision making
5. Lack of understanding of a structured set of metrics and of the need for managing those metrics
6. Early phases of an education plan or curriculum to develop skills
7. Communication is needed to educate farmers and local residents

Business case and rationale: Investment funds are available at a municipal level for ongoing renewable energy expansion and are being selectively considered for use in education and microgrid enablement. Given the low cost of traditional electricity, there are volume limits in place for high-cost renewable energy sources. Additionally, many vendors in renewable energy are small in scale and still are not profitable.

B. Roadmap of recommendations

The team derived its recommendations by using the progress that Pingtung County already has gained, building upon that progress with proven technologies, gaining citizen and stakeholder buy-in and forming strategies focused on a successful future. The team's approach is based on the IBM Smart Grid Maturity Model (SGMM), described in detail in Appendix D. The roadmap to a successful outcome is depicted in Figure 2.

The goal for Pingtung County's renewable energy and microgrid projects is to reach Level 3 of the SGMM (see Figure 3) at the end of the above-illustrated "In production" phase.

Proposed roadmap for Pingtung County

Figure 2: Recommendation roadmap

Recommended areas of focus – IBM Smart Grid Maturity Model

Pioneering
5
Optimizing
4

Smart grid phases
- Integrated scheduling and coordination of distributed generation and storage
- More accurate energy forecasting
- Device-level energy usage forecasting
- Renewable asset management
- Customer experience
- Effective use of energy storage
- Advanced predictive analytics

Integrating
3
Enabling
2
Initiating
1
Default
0

Production phase
- Augment capacity with additional resources: solar, wind and biogas
- Integrate storage and energy management system capability
- Connect to Taiwan Power Company grid
- Add additional monitoring, control, KPI and reporting

Demonstration site phase
- Build solar and wind generation infrastructure
- Install integrated monitoring capability (dashboard)

Figure 3: Mapping of SGMM levels with proposed phases

4. Recommendations

The Smarter Cities Challenge team recommends that Pingtung County create a vision statement focusing on its economic model of the future, use of the renewable energy resources it is developing and improvements in quality of life for citizens. An example is presented below:

> "Pingtung County's vision is to leverage its renewable energy successes to become more self sufficient, create a better quality of life for citizens, and develop leadership and innovation in the environment and waste management."

In order to realize this vision, there are several critical success factors that the team recommends for the short term (prior to year-end 2014):

- Leverage existing experience in deploying renewable energy technologies to focus on select areas for achievement of scale and increase in competitiveness
- Establish a "smarter" microgrid strategy that integrates next-generation renewable energy technologies, dashboards and analytics as a showcase for the county
- Establish a working group of key vendors and partners that creates the strategic alignment required to deliver microgrid success and a broader forum for influence
- Leverage a mix of renewable know-how and experience — as well as energy and environmental impact data — with which to approach the Taiwan Bureau of Energy for support
- Develop a communications and education plan to ensure that the microgrid and demonstration site have strong local support

Long-term strategic goals are imperative. Up through 2020, the team recommends the following key goals for Pingtung County:

- Continue PV projects that have scale, have a proven technology and business model and make use of local geographical resources and space
- Expand the biogas industry, which will have a multiplier effect on small farms and a positive environmental impact by reducing smell, producing energy that is used locally and providing a fertilizer byproduct
- Target a 50% reduction in CO_2 emissions through the execution of a trifecta renewable energy strategy
- Establish a county focus on communicating and delivering positive environmental outcomes

The Smarter Cities Challenge team has made 11 specific recommendations to continue progress in the investment areas already being pursued by the County; to focus on additional future areas of importance; and, ultimately, to achieve the County vision statement. The above critical success factors, when used as guiding principles, will maximize the opportunities that are available for the County as it implements the recommendations.

The team’s recommendations are aimed at both the tactical (short term) and strategic (10+ years) needs of Pingtung County. The recommendations focus heavily on the establishment of a functional microgrid and associated demonstration center to educate stakeholders. The 11 recommendations are mapped to three focus areas and are summarized in Table 1:

Focus area	IBM recommendation
Microgrid implementation	1. Deploy a Pingtung County microgrid project
	2. Explore microgrid technologies
	3. Construct an Integrated Operations Control Center (IOCC)
	4. Implement analytics, resulting in a smart microgrid
	5. Leverage anaerobic biogas generation
Governance	6. Establish a microgrid program management office (PMO), including appointed project leaders
	7. Establish an executive steering committee
	8. Organize a Pingtung County integrator group
Strategy, communications, investment	9. Explore funding methodologies
	10. Develop a communications and education plan
	11. Establish a long-term strategic roadmap

Table 1: Recommendations

Recommendation 1: Deploy a Pingtung County microgrid project

Pingtung County should deploy a microgrid in Linbian Township. This microgrid may be expanded, and its deployment should be phased in as below:

1. Create a demonstration site (6 - 12 months)
2. Move the demonstration site into a production microgrid
3. Transition the microgrid into a “smarter” microgrid through the addition of advanced applications and data analytics

Scope and expected outcomes

Scope

A microgrid’s purpose includes the following:

- Studying the inclusion of a variety of renewable energies and demonstrating how they are used locally and managed intelligently
- In an emergency, such as a natural disaster, providing emergency power for a Linbian command center; in a normal situation, providing a power supply for local loads and reducing the power transmission losses
- Studying and demonstrating a self-sustaining community that manages local generation, storage, loads and grid connectivity
- Serving as a demonstration center for clean energy development and for public education and acceptance

Please refer to Appendix C for full technical implementation considerations. Key aspects and actions include the following:

- Collecting detailed technical and engineering requirements for the microgrid site
- Assessing the current energy consumption patterns of Linbian Township, including the township office, schools, the hospital, pumping stations and other places to be included in the microgrid
- Assessing the energy consumption patterns of the significant pig farms that will be included in the biogas generation aspect of the microgrid
- Comparing capabilities with consumption patterns to determine gaps that need to be filled
- Defining and closing on the budget requirements
- Engaging strategic partners, such as the systems integrators that are already working with Pingtung County
- Generating a complete project plan (tasks, resources, schedule, risks, expenditures and dependencies)
- Considering an execution plan with the following elements:
  - Building renewable power sources (PV, wind, bioenergy)
  - Building infrastructure (transmission and distribution systems, data communications systems, metering, grid-tie inverters)
  - Building an Integrated Operations Control Center (IOCC) – see Recommendation 3

Expected outcomes

A microgrid demonstration site that allows Pingtung County to do the following:

- Determine the feasibility of a smart microgrid in which renewable energy resources are consumed locally and managed intelligently
- Engage partners to test and study their technologies in a functional microgrid

Recommendation 1: Deploy a Pingtung County microgrid project (continued)	
Scope and expected outcomes (continued)	
• Showcase its ability to execute complex projects • Create an education platform • Raise additional funding and incentives from partners • Help build a long-term strategic roadmap **Cost of inaction** Inaction will hurt Pingtung County's ability to raise additional funding from private and government programs; it will not be able to justify additional growth in renewable energy generation outside PV generation.	
Proposed owner and stakeholders	**Suggested resources needed**
Owner: Executive secretary to Pingtung County Magistrate Tsao **Stakeholders:** • County • Selected integrators and manufacturers • Landowners and farmers	• Establish a program management office (PMO) • Engage outside consultants and vendors to complete the design of the microgrid • Hire experienced engineers to execute the project **Cost estimate:** High
Dependencies	**Key milestones, activities, and timeframe**
• Closing on the plan and funding • Securing sufficient land area during the project's expansion phases	**Short term (3 – 6 months):** • Finalize the project's scope • Establish the PMO and validate the project plan • Contract vendors and integrators • Update and revise the plan as needed **Long term (12 – 18 months):** • Execute the project • Collect and share initial data
Priority	
High	

Recommendation 2: Explore microgrid technologies

Pingtung County should explore different microgrid technologies in order to adopt the best renewable energy and microgrid technologies for efficient and economic operation.

Scope and expected outcomes

Scope

Renewable energy and power electronics technologies advance very quickly. Pingtung County should explore the following innovative and emerging microgrid technologies:

- Solar power
- Wind power
- Biogas energy
- Energy storage systems (ESS)
- Fuel cell systems
- Micro-CHP (combined heat and power)
- Microgrid energy management systems (EMS)
- Advanced control, such as smart power control for power stability and smart voltage control for power quality
- Smart meters and advanced metering infrastructure (AMI)
- Communication
- Substation automation
- Customer management and demand response

The experiment and evaluation should focus not only on performance characteristics but also on the cost of fuel, capital carrying, grid-based power and feed-in tariffs. Standards, such as the IEC 61850 protocol for distribution substation automation and especially the IEC 61750-4-420 for distributed energy resources (DER), also need to be taken into consideration.

Expected outcomes

A means of selecting the best microgrid technologies suitable for Pingtung County and Taiwan. The microgrid can then be used as a test bed for manufacturers and partners that are looking to try out the performance of their technologies.

Cost of inaction

The County will be unable to adopt renewable energy and microgrid technologies for efficient and economic operation.

<table>
<tr><th colspan="2">Recommendation 2: Explore microgrid technologies (continued)</th></tr>
<tr><th>Proposed owner and stakeholders</th><th>Suggested resources needed</th></tr>
<tr><td>Owner: Microgrid manager

Stakeholders:
• County
• Microgrid PMO
• Renewable resource vendors
• Taiwan Power
• Research institutes and universities</td><td>• Engage with Taiwan Power
• Engage microgrid technology vendors
• Engage research institutes and universities

Cost estimate: Medium</td></tr>
<tr><th>Dependencies</th><th>Key milestones, activities, and timeframe</th></tr>
<tr><td>• Involvement of microgrid technology vendors
• Research and development capability</td><td>Short term (3 – 12 months):
• Install renewable energy and microgrid technologies
• Test the technologies
• Evaluate the technologies

Long term (12 – 24 months):
• Certify the technologies
• Commercialize the technologies</td></tr>
<tr><th colspan="2">Priority</th></tr>
<tr><td colspan="2">Medium</td></tr>
</table>

Recommendation 3: Construct an Integrated Operations Control Center (IOCC)

Pingtung County should construct an IOCC to integrate, monitor and control the microgrid and other areas, such as water, waste and public safety management.

Scope and expected outcomes

Scope

Pingtung County has a vision to build a demonstration microgrid in Linbian Township. The County should integrate all the generation and distribution activities of the microgrid into a single platform. The IOCC will do the following:

- Integrate, visualize and analyze the real-time information that is gathered onto a single platform by the supervisory control and data acquisition (SCADA) systems of different renewable energy technologies
- Provide a holistic dashboard view of the events and activities within the microgrid
- Establish key performance indicators (KPIs) to continuously monitor grid's performance
- Enable analytics and predictive analysis to establish a future "smart" grid
- Establish the microgrid as a test bed for integrators and manufacturers

Please refer to Appendix C for implementation considerations and an execution plan.

Expected outcomes

The IOCC will do the following:

- Integrate several renewable energy technologies onto a single platform
- Efficiently add new technologies (such as smart water management) in a plug-and-play manner
- Drive collaboration across fragmented systems and multiple stakeholders
- Leverage information to make better decisions on how to optimize energy generation and consumption
- Integrate weather information, CO2 and pollution levels, water management capability and additional data sources as they become available
- Improve operations through systems-level decision making
- Reduce costs, provide new insights and make operations proactive — provide a "single pane of glass" for all data and key application output
- Improve efficiencies by tracking KPIs

Cost of inaction

Inability to integrate all technologies and a lack of data to control the microgrid.

<table>
<tr><th colspan="2">Recommendation 3: Construct an Integrated Operations Control Center (IOCC) (continued)</th></tr>
<tr><th>Proposed owner and stakeholders</th><th>Suggested resources needed</th></tr>
<tr><td>Owner: Executive secretary to Pingtung County Magistrate Tsao

Stakeholders:
• County
• Microgrid PMO
• IOCC vendor</td><td>• Engage an IOCC vendor to help develop a detailed plan
• IOCC software and hardware

Cost estimate: Medium</td></tr>
<tr><th>Dependencies</th><th>Key milestones, activities, and timeframe</th></tr>
<tr><td>• A demonstration site with heterogeneous sources
• Sensors and communications infrastructure
• SCADA and EMS</td><td>Short term (3 – 12 months):
• Complete the definition of the microgrid
• Engage an IOCC vendor as part of the definition phase
• Work with a communications vendor to develop wired and/or wireless data communications with the IOCC
• Work with SCADA and EMS vendors to integrate the real-time and historical database with the IOCC database

Long term (12 – 24 months):
• Extend the IOCC to other areas, such as water management, waste management and public safety management
• Implement analytics to enable a smart grid</td></tr>
<tr><th colspan="2">Priority</th></tr>
<tr><td colspan="2">High</td></tr>
</table>

Recommendation 4: Implement analytics, resulting in a smart microgrid

Pingtung County should build an analytics capabilities into its microgrid in order to adopt best practices and to progress to a smart microgrid.

Scope and expected outcomes

Scope

Pingtung County has a vision to expand renewable energy generation to 260 MW by 2020. In order to meet this challenge, it should build the following analytics capabilities to allow resources to operate effectively, make better decisions leveraging information and provide more safety and stability to the microgrid:

- Solar, storage, wind (SSW) generation scheduling, coordination and optimization
- More accurate wind and solar power generation forecasting
- Renewable energy generation asset management
- Condition-based maintenance (CBM) for solar and wind farms
- Optimal connection and disconnection with the utility grid
- Optimal pricing management on sales of excess power to the utility grid
- Smart meters and AMI
- Dynamic control of loads and demand response
- Decision-making tools, KPIs and dashboard integration

Please refer to Appendix C for implementation considerations and an execution plan.

Expected outcomes

- Analytics that allow resources to operate effectively
- The ability to make better decisions by leveraging information
- More safety and stability to the microgrid

Cost of inaction

Inability to break new ground and become an innovation leader.

<table>
<tr><th colspan="2">Recommendation 4: Implement analytics, resulting in a smart microgrid (continued)</th></tr>
<tr><th>Proposed owner and stakeholders</th><th>Suggested resources needed</th></tr>
<tr><td>Owner: Microgrid manager

Stakeholders:
• County
• Microgrid PMO
• Renewable resource vendors
• Taiwan Power</td><td>• Engage with Taiwan Power
• Engage a consulting and software company to develop an analytics capability and provide software

Cost estimate: High</td></tr>
<tr><th>Dependencies</th><th>Key milestones, activities, and timeframe</th></tr>
<tr><td>• Increased capabilities of built and integrated solar and wind farms
• Industrial-scale storage
• A grid capable of integrating the large renewable generation</td><td>Short term (3 – 12 months):
• Increase the capability of solar and wind farms
• Build the power transmission and distribution systems with the capability of connecting to the grid
• Build two-way data communications systems
• Enhance the IOCC with more advanced analytics functionalities

Long term (12 – 24 months):
Interconnect the microgrid with Taiwan Power’s grid, selling excess power to Taiwan Power</td></tr>
<tr><th colspan="2">Priority</th></tr>
<tr><td colspan="2">Medium</td></tr>
</table>

Recommendation 5: Leverage anaerobic biogas generation

Pingtung County should take advantage of existing pig farming capacity to achieve the REDA target of increasing biogas capacity by a factor of three to 31 MW by 2030. Pingtung County should consolidate initiatives into a biogas strategy, use the positive environmental impact to gain support and investment and unite key stakeholders to a target of 3–10 MW by 2020.

Scope and expected outcomes

Scope

For medium-term significant increase in biogas production, the County should do the following:

- Focus on the microgrid, which will help capture national attention
- Engage experts to help design an aggressive growth plan
- Start with large-scale farmers (2,400 pigs) to form a biogas work group
- Assess the latest technologies to improve efficient generation, management and biogas storage
- Feed indicators and KPIs into the IOCC and dashboard
- Have a charter of key challenges to be resolved — for example, biogas storage, distribution of slurry for reuse and consolidation of waste for biogas generation
- Contribute data on biogas generation, waste management and water impact for analytics and metrics to reduce pollution and improve air quality
- Develop a business case that achieves reasonable returns over 5 - 10 years by offsetting the up-front capital cost
- Consider sources for external investment and facilitate collaboration among experts
- Develop collaboration among haulers, pig farmers, biogas engineers and others to roll out a comprehensive plan

Expected outcomes

The County will establish the validity of biogas, which will become a competitive differentiator as below:

- Feed-in tariffs are not yet subject to aggressive declines
- That the risk is higher makes a strong case for national support for subsidies in capital investment
- Establish if biogas will reduce CO_2 emissions by 0.7kg/kWh

Cost of inaction

A lost opportunity to automate and modernize Pingtung County's pig farming industry and thereby to improve citizens' quality of life through such metrics as CO_2 reduction and better water affluence and recyclability.

Recommendation 5: Leverage anaerobic biogas generation (continued)

Proposed owners and stakeholders	Suggested resources needed
Owners: County officials and the pig farming association **Stakeholders:** • Large-scale anchor farms, plus 28 pig farms already participating (44,600 pigs) • Bioprocessing systems and ancillary equipment manufacturers (for example, construction, digestion, generators, desulfurization)	• Financial analysis • Expertise in biogas systems design, including the following: – Sanitation hauling (such as Hochen, Shuencheng, Xinli) – Water distribution and planning – Waste management • Investors with a scale and interest in greening the pig farming industry (for example Taisugar, Asian Development Bank, clean energy venture capital) **Cost estimate:** High

Dependencies	Key milestones, activities, and timeframe
• A read-out to the executive steering committee chaired by Magistrate Tsao • A partnership with technology and equipment manufacturers • Capital investment and long-term tariff agreement	**Short term:** • Convene a subcommittee of experts to assess and design an optimal biogas collection and waste treatment process and create a business case • Pitch green investors that have a proven track record in biogas • Submit a comprehensive application to the BoE by mid-2014 per current subsidy guidelines **Long term:** • Develop a consortium that establishes lead contributors and a sustainable funding model to increase production from 0.5 MW to 5 MW • Incorporate biogas electric, storage waste treatment, H2 storage technologies and water, and test compatibility with the microgrid project and with the dashboard's monitoring • Consider methods for treating solid waste

Priority
Medium to high

Recommendation 6: Establish a microgrid program management office (PMO), including appointed project leadership

Pingtung County should establish a PMO led by a project manager skilled in smart grid implementation to manage and provide oversight of the microgrid deployment, starting with creation of the demonstration site.

Scope and expected outcomes

Scope

1. Establish a PMO that will guide and govern the microgrid implementation project. The PMO will do the following:
   - Develop a project charter for the mission, a statement of purpose and expected outcomes
   - Define a practical project plan
   - Determine the budget required for the microgrid
   - Define an overall resources plan
   - Build a specific set of execution measurements to measure success
   - Identify risks and mitigation plans
   - Report progress and evaluate the program
2. Define the PMO structure. Typical structures include the following:
   - Design authority (technical)
   - Change management
   - Project communications
   - Project administration (budgets, status reports)
3. Identify a project manager who has the right skills to lead the microgrid program and guide the PMO. The project manager's role should include:
   - Securing funding for the microgrid program
   - Defining the microgrid project's structure and key roles and responsibilities:
     - Business, engineering, technical and integrating workstreams
     - The executive steering committee's structure
     - A working group
4. Define the critical skills and experience required to deliver the microgrid project, including the skills listed below:
   - Workstream leadership
   - Project administration, change management, project communications
   - Technical skills:
     - Architectural design, development, integration as needed
     - Control center, demand response, EMS, customer experience
     - Communications network
     - Analytics and optimization
   - Engineering skills
5. Define the detailed resources needed to deliver the microgrid program and hire or appoint those resources
6. As part of the working group's structure, engage a small set of systems integrators in Pingtung County to consider participating in the microgrid project

Recommendation 6: Establish a microgrid program management office (PMO), including appointed project leadership (continued)	
Scope and expected outcomes (continued)	
Expected outcomes A comprehensive plan with a detailed breakdown of work, schedule and established project leadership for implementing the microgrid. **Cost of inaction** An ineffective plan without the right leadership to execute a microgrid implementation project in Linbian Township.	
Proposed owners and stakeholders	**Suggested resources needed**
Owners: County officials **Stakeholders:** • County • Selected integrators and manufacturers • Landowners and farmers	The PMO may be established with minimal resources and funding. **Cost estimate:** Low
Dependencies	**Key milestones, activities, and timeframe**
• The right skills and talent to lead and deliver the microgrid in Pingtung County • County leadership to coordinate stakeholders • Integrators' willingness to participate in the microgrid program	**Short term:** • Finalize the PMO structure • Hire or assign a project manager with the right skills to deliver a microgrid • Define the project plan and key resource requirements • Define the budget requirements and secure funding • Establish an executive steering committee • Engage an initial working group • Identify and close any gaps with organizational or leadership skills • Update and revise the plan as needed **Long term:** • Define the microgrid project's structure • Define the skills needed to deliver the microgrid program and hire those skills
Priority	
High	

Recommendation 7: Establish an executive steering committee

Pingtung County should establish an executive steering committee to govern the microgrid implementation program and to drive strategic advice and decision making for the long-term strategic roadmap.

Scope and expected outcomes

Scope

1. Establish an executive steering committee structured to include the following:
   - A strategic subcommittee that meets quarterly in order to (a) pose or answer strategic questions for the microgrid implementation program, such as the inclusion of new technologies or a shift in strategic direction and (b) lead discussion and revisions of the long-term strategic roadmap. The strategic subcommittee interfaces with the integrated group (see Recommendation 8) in the long-term strategic discussion.
   - An operational subcommittee that meets monthly in order to address (a) the progress of the microgrid implementation, (b) key risks and issues associated with the project, (c) key escalation points, (d) key areas of help needed for the project and (e) any budget issues.
   - A weekly project-level status meeting to discuss the project's status and any issues related to delivery of the microgrid implementation plan. The meetings are tactical and are focused on plan delivery, operational metrics, resources and risk and issue management.
2. Identify the subcommittee's chairs and participants. The initial recommendation is that the chairs be from Pingtung County.
3. Define specific integration points for the strategic subcommittee and the integrator working group.
4. In conjunction with the long-term strategic recommendations, define specific strategic objectives for the executive steering committee and define what role the executive steering committee will play in taking strategic ideas to the national government.

Expected outcomes

An established executive steering committee consisting of strategic and operational subcommittees that meet regularly and guide both the microgrid implementation and the long-term strategic roadmap.

Cost of inaction

Lack of a strategic leadership body to provide decision making and guidance to deliver the microgrid program and coordinate long-term strategy and execution. The microgrid will not be delivered and that momentum will be lost.

Proposed owners and stakeholders	Suggested resources needed
Owners: County officials **Stakeholders:** • County • Selected integrators and manufacturers • Landowners and farmers	The executive steering committee may be established with minimal resources and funding. **Cost estimate:** Low

<table>
<tr><th colspan="2">Recommendation 7: Establish an executive steering committee (continued)</th></tr>
<tr><th>Dependencies</th><th>Key milestones, activities, and timeframe</th></tr>
<tr><td>All stakeholders’ clear understanding of the executive steering committee concept and of the linkages among the executive steering committee, the PMO, the project team and the integrator working group
County leadership to chair the executive steering committee
Integrators’ willingness to participate in the microgrid program</td><td>Short term:
Educate all involved stakeholders about the executive steering committee and how it will work
Finalize the executive steering committee, with project charters for the subcommittees
Finalize the criteria for selecting the subcommittee members
Appoint the subcommittee chairs
Define the integrator working group’s links with the executive steering committee
Review and understand the long-term strategy
Coordinate one version of the project’s governance chart to include the PMO, the executive steering committee and the integrator working group
Engage the initial strategic subcommittee and the PMO to plan initial governance meetings
Long term:
Define a more strategic role for the executive steering committee and the integrator working group, and define how the two will interact</td></tr>
<tr><th colspan="2">Priority</th></tr>
<tr><td colspan="2">High</td></tr>
</table>

Recommendation 8: Organize a Pingtung County integrator group

Pingtung County should immediately organize an integrator working group made up of officials, advisors and select members of the integrator community who are stakeholders in the development and deployment of renewable energy. The group should work to deliver and harvest the success of the microgrid program and help advance the work being done on biogas in Pingtung County.

Scope and expected outcomes

Scope

1. Develop criteria for selecting members of a new integrator working group. Sample criteria might include alignment with biogas vision, alignment with microgrid vision, fiscal viability, credibility of leadership, growth vision, commitment to Pingtung County for at least five years and a national network with Taiwan Power and the BoE.
2. Appoint a chair to lead the integrator working group. At the outset, the chair should be an official from Pingtung County, but there should be a rolling governance process similar to that of a traditional board.
3. Establish the integrator working group made up of Pingtung County officials, advisors and select members of the integrator community.
   - Members of the working group will have the following responsibilities:
     - Participating in the Pingtung County microgrid program to provide key delivery skills, advise the project on key utility topics and collaborate with the County to communicate with and educate citizens.
     - Agreeing on components of a strategic roadmap and long-term vision for renewable energy generation in Pingtung County.
     - Representing the interests of the County and members at a national level.
     - Developing three to five areas of focus — aligned to microgrid and biogas success — for which members will try to find national investment.
     - Approaching the BoE and Taiwan Power with ideas on how to improve collaboration and make progress on the three to five areas of focus; financial models, incentives and subsidies should be part of this.
     - Reporting progress and evaluating the program as part of the microgrid executive steering committee.
   - The evolution of the working group will include both short-term and long-term roles for its members:
     - **Short term** — members asked to participate in the working group will focus on building collaboration within the group and on what is needed for the success of the microgrid program. The timeframe for this is 3 - 6 months.
     - **Long term** — members will try to harvest the successes of the microgrid effort, including the new analytics capability, and will package and try to promote with Taiwan Power and the BoE some key messages about the microgrid and biogas. The timeframe for this is 6 - 24 months.

Expected outcomes

An integrator working group capable of influencing the successful outcome of the microgrid implementation project and building a long-term vision for influencing energy policy in Taiwan that is based on microgrid and biogas success. The working group will create a united front and shared set of expectations from all active stakeholders to articulate a comprehensive plan and formulate the assistance that will be required from the government and Taiwan Power. All this will make for a practical plan and will reduce the adoption timescale.

Cost of inaction

A set of independent activities will be delivered in an uncoordinated way, leading to a lack of buy-in and collaboration among the integrators and other stakeholders in Pingtung County and suboptimal influence with the national government.

Recommendation 8: Organize a Pingtung County integrator group (continued)	
Proposed owners and stakeholders	**Suggested resources needed**
Owners: County officials **Stakeholders:** • County • Integrators and manufacturers • Landowners and farmers • Taiwan Power • Education officials • Ecofriendly supporters	• The integrator working group may be established with minimal resources and funding. • The integrator working group should establish rules and regulations for each member and meet regularly to advance the agenda. **Cost estimate:** Low
Dependencies	**Key milestones, activities, and timeframe**
• County leadership to chair the integrator working group • Integrators' willingness to participate in the microgrid program	**Short term:** • Establish criteria for selecting members • Form the parameters for the integrator working group, including the charter • Appoint a chair for the integrator working group • Develop members' rules and regulations • Define members' roles • Build a short-term detailed plan for advising the microgrid program • Define a long-term strategy for broader influence, including key messages on microgrid development and biogas **Long term:** • Get involved with key national organizations, such as the Taiwan Smart Grid Association, Taiwan Power and the BoE • Meet with these organizations regularly to influence energy policy
Priority	
High	

Recommendation 9: Explore funding methodologies

Pingtung County should leverage the executive steering committee to explore funding vehicles and options to generate sufficient investment and financial support to implement the County's renewable energy vision.

Scope and expected outcomes

Scope

1. Define the costs of Smarter City implementation for each phase and identify potential sources of funding.
2. Ensure adequate returns and payback periods (15% internal rate of return, positive net present value) to cover capital expenditures and department and maintenance costs over five, 10 and 20 years for Smarter City implementation, as well as to ensure government protection. For the smart grid, guarantee that vendors have a positive return in five to seven years (typical of other renewable energy investment projects) as follows:
   - Selectively deploy the municipal budget to promote short-term smart grid implementation and secure local support (for example education, school PV rollout, small farm assistance)
   - Develop the business case and investment thesis for biogas and broader integrated renewables
   - Identify investors that have a track record of early stage biogas and renewable energy projects
   - Consider best-of-breed models for fundraising for renewable energy (for example single large donors, social venture models, consortiums)

Expected outcomes

- The integrated analysis of major cost elements and funding source options, which analysis will enable structured discussions with investors beyond the current partner set
- A logical plan that combines goals and needs to secure support from national funds
- A systematic approach to renewable energy growth

Cost of inaction

A missed opportunity to secure financial support from global or regional vendors who are looking to invest their money.

Proposed owner and stakeholders	Suggested resources needed
Owner: The County's director of development, with the executive steering committee	Marketing, finance, a PMO leader, insight from the executive steering committee **Cost estimate:** Medium

<table>
<tr><th colspan="2">Recommendation 9: Explore funding methodologies (continued)</th></tr>
<tr><th>Dependencies</th><th>Key milestones, activities, and timeframe</th></tr>
<tr><td>Recommendation of the executive steering committee</td><td>Short term:
• Put together a capital investment plan using assumptions and averages, focusing on a smart grid showcase
• Present the plan to the executive steering committee for comment
• Identify potential investors and choose a few that have a track record in renewable energy investment, preferably in Asia
• Build an educational presentation for key biogas and microgrid business partners in order to refine and update financial assumptions
• Establish break-even point and reasonable return levels over five- and 10-year horizons under two or three market scenarios

Long term:
• Establish funding as a key agenda topic for the executive steering committee
• Track results and revise a request for tariff changes, subsidies and other offsets accordingly
• Invite speakers from the venture capital industry, vendor CFOs, the BoE, NGOs and others in order to gain additional perspective</td></tr>
<tr><th colspan="2">Priority</th></tr>
<tr><td colspan="2">High</td></tr>
</table>

Recommendation 10: Develop a communications and education plan

Pingtung County should work with the local press and educators to develop materials and methods for the County's renewable energy vision, progress and outcomes.

Scope and expected outcomes

Scope

The County should provide education for schools and the opportunity for Pingtung County's citizens to advocate.

The public relations (PR) scope includes the following aspects:

- Attending regional or international conferences focused on smart grid sustainability, entering international renewable energy competitions and applying to be on advisory boards
- Using education centers to host a "Light Up Your Life" industry symposium with lectures, demonstrations and foods that showcase how renewable energy impacts daily life
- Conducting regular interviews or news segments featuring proof of how small-scale initiatives are making an impact locally, with tips on things people can do at home to help the environment (for example, solar cookers, LED lightbulbs)
- Publishing results and KPIs to facilitate knowledge sharing and promote international standardization (for example, on County and school billboards)
- Publishing results and progress on a dedicated municipal website, as well as leveraging social media
- Promoting Pingtung County as an ecofriendly travel destination under the theme of sustainability

The schools scope includes the following:

- Having elementary school children visit environment educational centers as field trips and encouraging high school or university students to create social responsibility clubs
- Building an education curriculum unit for Pingtung County schools on renewable energy and assigning each child a project to complete during the unit (for example, interview grandparents on how renewable energy may impact their lives and why renewable energy is important)
- Recruiting children as volunteers (for example, a two-month community service project for school credit)
- Conducting writing, drawing and music competitions with energy themes
- Selectively deploying the municipal budget to promote short-term smart grid implementation and secure local support (for example, education, school PV rollout, small farm assistance)
- Considering best-of-breed models for fundraising for renewable energy (for example, single large donors, social venture models, consortiums)
- Creating an investment pitch-book and presentation and delivering this to key business partners to attract interest

Recommendation 10: Develop a communications and education plan (continued)

Scope and expected outcomes (continued)

Expected outcomes
- An educated citizenry that is passionate about Pingtung County's contributions
- A supportive base for future initiatives and government spending
- Citizens' contributions of time, energy and money

Cost of inaction
Ad hoc execution can undermine the sustained focus that is needed to achieve the 2020 roadmap.

Proposed owner and stakeholders	Suggested resources needed
Owner: Pingtung County's communications director	Marketing, public relations, local press, board of education, principals **Cost estimate:** Low
Dependencies	**Key milestones, activities, and timeframe**
Recommendation of the executive steering committee	**Short term:** • Appoint a communications resource • Create a municipal website for posting renewable energy progress • Create an education subcommittee to make a local hands-on environmental curriculum and to share best practices • Pull together an education and PR plan to present to the executive steering committee **Long term:** • Create forums to showcase and celebrate progress in the community (for example, celebrate Earth Day, create conferences and symposiums on the theme of sustainability) • Roll out a plan to share an education curriculum among schools and to share best practices

Priority

High

Recommendation 11: Establish a long-term strategic roadmap

Pingtung County should establish a 2020 roadmap to achieve its strategic goal (see page 7):

Scope and expected outcomes

Scope

Pingtung County should establish a plan deliver the long-term vision by the year 2020. The key objectives are listed below:

- Improve energy self-sufficiency
- Reduce greenhouse gas emissions
- Stabilize energy costs and improve economic competitiveness
- Provide an emergency supply in case of grid power interruption
- Deliver leadership in biogas energy generation
- Reduce reliance on traditional energy generation

Expected outcomes

- Leadership in renewable energy across the county and Taiwan
- Improved energy self-sufficiency
- Reduced greenhouse emissions
- Reduced environmental and public health risks
- Improved environmental and public economic conditions

Cost of inaction

Inaction means an unsustainable renewable energy strategy and thus significant harm to the environment.

<table>
<tr><th colspan="2">Recommendation 11: Establish a long-term strategic roadmap (continued)</th></tr>
<tr><th>Proposed owners and stakeholders</th><th>Suggested resources needed</th></tr>
<tr><td>Owners: County officials

Stakeholders:
• County
• Public health officials
• Bureau of Energy
• Environmental protection administration
• Education officials
• Ecofriendly supporters</td><td>Proven success in renewable energy generation

Cost estimate: Low

Effort: High</td></tr>
<tr><th>Dependencies</th><th>Key milestones, activities, and timeframe</th></tr>
<tr><td>None</td><td>Short term:
• Declare a long-term strategic vision
• Establish a long-term strategic roadmap
• Establish an official department responsible for the communication and execution of the long-term vision
• Develop a long-term plan</td></tr>
<tr><th colspan="2">Priority</th></tr>
<tr><td colspan="2">High</td></tr>
</table>

5. Conclusion

Pingtung County has a future with great potential. But changing climate conditions and the evolution of energy economics pose threats. Acknowledging these threats, creating a renewable energy vision, understanding the critical success factors, creating specific goals and implementing key recommendations are imperative to overcoming the threats.

Global climate change is occurring, resulting in new weather patterns impacting geographical areas in new ways. Typhoon Morakot in 2009 is one example of how a long-standing economic culture in a jurisdiction such as Pingtung County can be changed significantly. Taking action to reduce this vulnerability is key to Pingtung County's future success.

Energy economics in Taiwan are changing. As evidenced by the REDA, Taiwan is committed to new energy generation paradigms. The economics of generating and selling this energy back to Taiwan Power's grid are changing quickly. As policies grow and mature, jurisdictions, such as Pingtung County that are aggressive and at the forefront of emerging renewable energy must consider how best to use technologies for their long-term energy needs and economic success.

Pingtung County's citizens show great pride in their history, determination and passion to move forward in diversifying their economic model and leadership in the creation of renewable energy. Strategic success requires navigating the changing environmental and economic factors.

Pingtung County's leaders understand all this. Defining and implementing renewable energy actions in the short term, as well as considering the long-term strategic vision, is imperative for success. Though funding may be an immediate challenge, meeting this challenge in bold and creative ways will ensure that citizens realize a long-term improvement in their quality of life.

6. Appendix

A. Acknowledgments

IBM Taiwan and Greater China Group:

- Anny Tseng, Professional, Corporate Citizenship and Corporate Affairs, IBM Taiwan
- Elisa Hsu, Attorney, IBM Taiwan
- Janet Hsueh, Executive of Marketing, Communications and Citizenship, IBM Taiwan
- Freda Chen, CFO, IBM Taiwan
- George Thomas, Partner/Director, Public Sector, IBM Greater China Group
- Jennifer Hwang, IBM Taiwan Country General Manager
- Li-Fen Li, Manager of Brand and Communications, Citizenship, University Relationship, IBM Taiwan
- Lisa Chen, Project Manager, Corporate Citizenship and Corporate Affairs, IBM Taiwan
- Mandy Tsai, Professional, Brand and Communications, Citizenship, University Relationship, IBM Taiwan
- Paige Shyu, Marcom and Travel Sourcing Buyer, Procurement, IBM Taiwan
- Simon Lee, Contract Professional, IBM Taiwan
- Teresa Lin, Manager, HR, IBM Taiwan
- Gill Zhou, VP, Marketing, Communications and Citizenship, IBM Greater China Group
- Ivan Lee, HR Partner, HR, IBM Taiwan
- Sophia Chiu, HR Partner, HR, IBM Taiwan
- Andersen Lin, Security Manager, IBM Taiwan
- Linda Huang, HR Professional
- Sophie Tao, Senior Consultant, IBM Global Business Services, IBM Taiwan
- Kelly Chang, Manager of Telecom and Utility Territory, General Business, IBM Taiwan

Pingtung County:

- Linbian Township Office
- Pingtung County Ken-Ding Elementary School
- Pingtung County Hengchun Primary School
- Pingtung County Taiwu Elementary School
- Pingtung County Yuguang Elementary School
- Pingtung County Linbian Junior High School
- Lihan Hong
- Remuch Energy Inc.
- Taiwan Power Company
- Bureau of Energy, Ministry of Economic Affairs
- National Museum of Marine Biology and Aquarium
- Metal Industries Research and Development Center
- King Energy Co., Ltd.
- LIJIA Green Energy Biotechnology Co., Ltd.
- Arima Photovoltaic & Optical Corporation
- LCY Chemical Corporation
- Sunny Rich Power Co., Ltd.
- Yung Hsine Livestock
- Central Farm
- Sharp Ray Bioentergy Co., Ltd.
- Asia Pacific Fuel Cell Technologies, Ltd.
- Pingtung County Government, Liukuaitsu Wastewater Treatment Plant
- AECOM Taiwan Corporation
- Tsinghua Foundation for Web Culture & Education
- Chi-Hung Tsao, Magistrate of Pingtung County government
- Urban and Rural Development department of Pingtung County government
- Research and Evaluation department of Pingtung County government
- Agriculture department of Pingtung County government
- Environment Protection Bureau of Pingtung County government

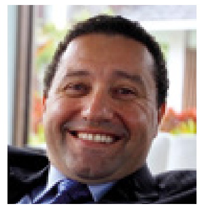
B. Team biographies

Moneshia zu Eltz
Managing Director of Mergers and Acquisitions, Corporate Development
United States

Zu Eltz is currently responsible for accelerating nonorganic growth via acquisitions, partnerships and alternative structures. She develops and implements strategic rationale, negotiations, diligence and integration for software and services transactions, focusing on cloud, analytics, mobile and security. Immediately prior to this role, zu Eltz was based in Prague, Czech Republic, leading business development for the Middle East, Africa and Eastern Europe, with a focus on the Gulf region and South Africa.

Over the last decade, zu Eltz's experience with business model transformation and integration has resulted in value creation and realization of human capital potential for more than 30 mergers and divestitures, including large strategic investments in Japan, India, Scandinavia and Brazil. Prior to IBM, zu Eltz worked as Strategic Management Consultant at Monitor Group. She has studied at INSEAD and the London School of Economics, and she holds an MBA from Wharton School at the University of Pennsylvania and a bachelor's degree in economics from Smith College.

Zu Eltz lives in New York with her husband Johannes and has two daughters whom she aspires to raise as citizens of the world. She enjoys Middle Eastern dance, yoga and meditation. With field experience leading pro bono economic development projects in South America, she is currently spearheading global grassroots initiatives that foster the spiritual development of humanity, particularly women and children, by promoting universal education and community building.



Dr. Hassan Zamat
Director, Financial Services Sector
Brazil

Zamat is the IBM executive responsible for improving operational efficiency, systems availability and business continuity in Brazilian banks. He also is tasked with simplifying and modernizing the enterprise architecture of the banking industry. Prior to this assignment, he was in strategic alliances and licensing with IBM HQ, a principal and site manager of the IBM Wireless Design Centers worldwide.

Before joining IBM in September 2000, Zamat held several senior positions: he was Senior Director of Engineering at Mobilian (Intel), Director of Engineering at Motorola, Senior Principal at Hughes Networks Systems and Director of Engineering at Uniden. He holds a PhD in electrical engineering and an MBA. He has more than 25 years of work experience, with 18 years of experience in product development.

During the past seven years, Zamat has been focusing on strategy and client-facing engagements.

Paul Yin

Senior Managing Consultant and Smart Grid Architect, IBM Global Center of Competence for Energy and Utilities

Yin is a Smart Grid Solutions Architect specializing in power systems engineering, grid operations, smart metering, work and asset management, distribution management systems, and renewable energy generation and integration, among others.

Yin has more than 18 years of experience in the design and delivery of complex information technology projects in electric power industries. He gained this expertise through work as a consultant with IBM and as a project engineer with Alstom Grid and Siemens T&D. His experience includes various electric utility companies in the United States, Europe and China. Within IBM he is responsible for several large-scale Smart Grid Programs, leading the design and integration of multimillion-dollar projects. Prior to joining IBM in 2010, he worked as a consultant for Luminant Energy in Texas, where he was the Solutions Architect for a real-time energy management systems project. His work includes leading a pilot project to integrate renewable energy generation into grid operations.

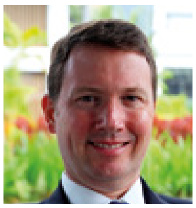
Yin started his career in 1994 as a Research Engineer with the Belgian Nuclear Research Center. He has a PhD in Electrical Engineering from the Université Catholique de Louvain, Belgium, and speaks English, Chinese and French.

Jim Rubish

Director, Enterprise Systems Technical Support United States

Rubish joined IBM in 1984 as a microprocessor development engineer in Rochester, Minnesota. He spent his early career in various development and management positions with hardware and software design for the IBM AS/400® and IBM i family of IT solutions, as well as in leadership positions with client satisfaction and critical situation management.

More recently, as Director of Enterprise Technical Support for IBM servers, Rubish has led hardware and software post-sales technical support delivery for IBM server clients around the world. Rubish also currently is a leader with IBM's initiatives to drive technical support improvements and consistencies across server platforms worldwide.



Steve Ferencie
Partner, Industrial Strategy and Transformation, IBM Global Business Services
United States

Ferencie is responsible for the development and growth of the strategic consulting business. This includes the sales and delivery of critical transformation programs to IBM's clients, development of a world class team of IBM consultants and extension of the IBM brand in the marketplace. Ferencie and his team are focused particularly on helping industrial clients (electronics, chemicals and petroleum, auto, aerospace, industrial products), as they transform their front offices and as they increasingly become globally integrated enterprises, to meet new customer demands.

Ferencie has more than 20 years of experience as a Partner and executive consultant, delivering value to clients in strategy development and execution, financial and operational improvement, merger integration, technology strategy and technology implementation. He has spent dedicated time working globally with senior executives in the industrial, energy and utilities, media, telecommunications and distribution (hospitality, real estate, life sciences, business services) industries, among others. Ferencie has been fortunate to work as IBM's nonprofit consulting leader for many years, blending his personal passion with his business interests to provide strategic leadership to nonprofits, such as United Way Worldwide, and to provide board leadership to a host of other nonprofits.

Ferencie recently returned to the United States after more than four years on IBM international assignments in Canada and Mexico, leading various IBM consulting businesses. He currently lives in Atlanta with his family. He has his bachelor's degree in industrial engineering from the Georgia Institute of Technology and an MBA from Emory University.

C. Pingtung County smart microgrid technical implementation considerations

1. Introduction

A microgrid[1] is a small energy system capable of balancing captive supply and demand resources to maintain stable service within a defined boundary. There is no universally accepted minimum or maximum size for a microgrid. Defining characteristics involve function, not size.

Most microgrids are in one of three categories:

- **Isolated microgrids, islands and other remote sites** that are not connected to a local utility grid
- **Islandable microgrids** that are fully interconnected and capable of both consuming and supplying grid power but that also can maintain some level of service during a utility outage
- **Nonsynchronous microgrids** that are connected to utility power supplies but are not interconnected or synchronized with the grid — they are capable of consuming power from the grid but are not capable of supplying power to it

Microgrids are defined by their function, not their size. The appropriate size of a microgrid varies depending on its deployment. Most microgrids are typically 10 MW or less.[2] A larger system, such as a campus, may be as much as 40 MW, which is believed to be the upper capacity for a microgrid.

A microgrid is a self-sustaining community managing local generation, storage, loads and grid connectivity. It can operate as part of a larger grid or independently of the larger grid. A smart microgrid can help maximize the value of Distributed Energy Resources (DERs) by integrating them with emerging microgrid technologies.

Innovative and emerging microgrid technologies include the following:

- Solar power
- Wind power
- Biogas energy
- Energy Storage System (ESS)
- Fuel cell system
- Micro-CHP (combined heat and power)
- Microgrid energy management system (EMS)
- Advanced controls, such as smart power control for power stability and smart voltage control for power quality
- Smart meters and Advanced Metering Infrastructure (AMI)
- Communication
- Substation automation
- Customer management, demand response

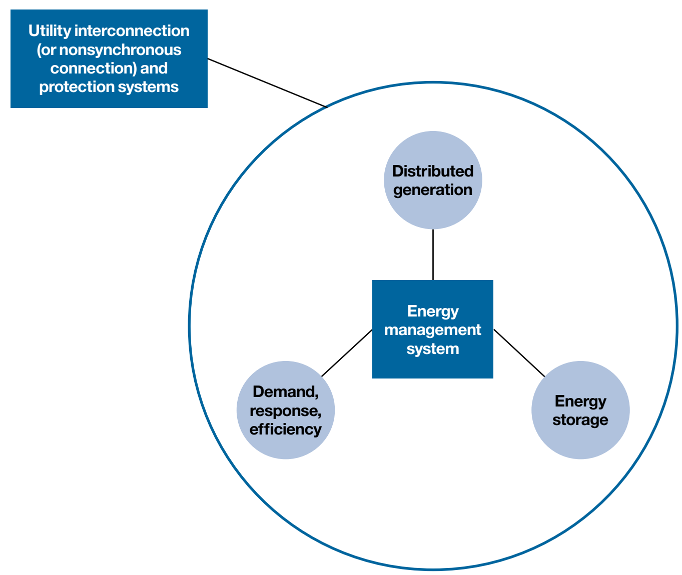


Figure C1: Components of a typical islandable microgrid

Microgrid components include the following five layers:

- **Field layer**
  - Distributed generation (DG): photovoltaic (PV), wind turbine, CHP and so on
  - Energy storage: battery, ultra capacitor, flywheel, electric vehicle
  - Grid components: protection, switchgear, distribution line, transformer

- **System layer**
  - Power electronics: smart inverter, smart connection
  - Smart controller: DG, storage, loads

- **Communication layer**
  - IT communication
  - Smart meters, sensors

- **Control and supervisory layer**
  - Supervisory control and data acquisition (SCADA) system
  - EMS
  - Unified user interface for visualization, reporting and so on

- **Analytics layer**
  - Solar, storage, wind (SSW) generation scheduling, coordination and optimization
  - Wind and solar power forecasting
  - Renewable generation asset management
  - Condition-based maintenance for wind and solar farms
  - Optimal connection and disconnection with the utility grid
  - Smart meters and advanced metering infrastructure
  - Dynamic control of load and advanced metering infrastructure
  - Decision-making tools, key performance indicators (KPIs), dashboard integration

Some key drivers of microgrid projects include the following:

- Customer need for more reliable, resilient and sustainable service
- Grid security and survivability concerns
- Utility needs for grid optimization, investment deferral, congestion relief and ancillary services
- Lack of access to utility service (mostly in remote locations and developing countries)
- Demand for low-cost energy supplies — supplies that are of a cost lower than what is locally available (especially at remote sites, such as islands, military or mineral/resource installations and isolated communities relying on expensive, high-pollution fuels)
- Environmental efficiency and renewable energy benefits

In many areas, however, microgrids face challenges and uncertainties across a range of issues, including utility tariffs and contracting, financing and risk management, interconnection and interoperability, resource planning and system operations and technology fuel supply.

Because the price of distributed generation has been rapidly declining in recent years, and with progresses in technology, there may be economies of scale, innovation, competition and more flexible financing that could make a microgrid part of a more diversified future.

The salient characteristic of distributed and renewable energy sources is volatility and intermittency of supply. The “smartness” of a smart microgrid comes from exploiting its special characteristics to achieve higher efficiency and management. Smart microgrid management technology, specifically an Integrated Operations Control Center (IOCC), consists of real-time monitoring and control of the distributed energy resources, more accurate generation forecasting for wind power and solar power, asset management for field generation assets, dynamic control for loads, KPIs, dashboard, analytics and so on. The advancement and application of the IOCC technology makes microgrids smart.

This report validates the purpose of building a smart microgrid demonstration site in Pingtung County, assesses the current plan, provides IBM best practices for the smart microgrid and proposes high-level architecture for a smart microgrid. It includes a technical implementation plan and IBM recommendations and roadmaps.

2. Motivation of Pingtung County microgrid

Pingtung County had no electricity for almost two months during Typhoon Morakot because of damage to the power distribution line that runs from the grid utility. Very-large-scale events (VLSEs) such as this not only destroy the electrical infrastructure but also bring down the entire economy of an area, which remains depressed until the electric infrastructure is restored. Often a VLSE's effects span an entire region of the country. Pingtung County wants to have a reliable alternative power source to the power fed by the grid utility.

Pingtung County has abundant renewable resources, for example, solar or photovoltaic (PV) energy. It has gained successful experience in such projects as the PV Farming Project. But the electricity generated by PV farms was sold to Taiwan Power. Pingtung County wants to explore the microgrid option by using its own natural renewable resources.

The motivations for a Pingtung County microgrid are the following:
- Security (no single point of failure)
- Reliability (fewer wires)
- Environmental sustainability (using renewable energy resources)
- Local economic development and jobs

This kind of microgrid is referred to as a dynamic microgrid[3] and is characterized by the following:
- Accommodating different sources of energy
- Being self sufficient at least for short periods
- Having advanced self-healing capabilities
- Automatically optimizing supply and demand resources

The purpose of building a Pingtung County microgrid includes the following:
- To study and demonstrate the feasibility of implementing a smart microgrid, consisting of a variety of renewable energy resources, and of its intelligent use and management
- To provide energy assurance in an emergency, such as a natural disaster, to provide an emergency power supply for a command center and, in a normal situation, provide power supply for local loads and reduce power transmission losses
- To study and demonstrate the ultimate goal of a self-sustaining community that manages local generation, storage, loads and grid connectivity
- To serve as a demonstration center for clean energy development and for public education
- To serve as a future Smart Grid test bed as more renewable energies plug in and microgrids evolve

3. Current plan (as-is architecture)

The current plan is to use the area (2 × 2 km) near Linbian train station (about 200 users), the new Linbian Township building, the public health building, Linbian High School and so on. The solar power generation system will be built on the rooftops of public facilities. The areas available for PV panel installation are 928.64 m^2 and 2,403.00 m^2, a total of 3,331.64 m^2:

- The power needed for the new Linbian Township building will be about 400 kW
- One possible location is the Linbian Township building – another is the Energy Center of Wetland Park
- One wind generator of 10 kW is planned to be installed in Wetland Park
- A farm-based biogas power generation of perhaps 3 MW is included in the plan

Figure C2: Current Plan for Pingtung County microgrid demonstration site

4. Assessment of current plan

The Smarter Cities Challenge team assessed the current Pingtung County plan with respect to renewable energy resources, vendors and partners and to-do checklist.

4.1 Renewable energy resources (field layer)

Currently, the main source of renewable energy is PV. Other types of resources need to be added to the microgrid demonstration site to show the diversity of renewable resources. The resources to be considered are wind farm, biomass and storage (hydrogeneration and battery storage). The capability of each source needs to be evaluated and determined to meet the load demand in the area of the demonstration site.

4.1.1 Rooftop PV power

A rooftop PV power station is a system that uses one or more PV panels, installed on rooftops of residential or commercial buildings, to convert sunlight into electricity. The various components in a rooftop PV power station include PV modules, mounting systems, cables, solar inverters and other electrical accessories.

The energy density of a solar panel is the efficiency described in terms of peak power output per unit of surface area, commonly expressed in units of Watts per square foot (W/ft^2). The most efficient mass-produced solar panels have energy density values greater than 13 W/ft2 (140 W/m^2). The most efficient mass-produced solar modules have energy density values up to 16.22 W/ft2 (175 W/m^2).

Taking an average of 150 W/m^2 and taking a usable area for PV panel installation of 3,000 m^2, the expected PV generation is 150 x 3,000 = 450 kW.

Taking the typical efficiency of a grid tie inverter to be 90%, the generation output will be 450 x 0.9, which is about 400kW.

The rooftop PV generation is about equal to the power needed in the new Linbian Township building. This means that the generation and load can be balanced locally.

Given the average PV generation capability of 1,200 hours per year, the PV system on the new Linbian Township building can generate 400 x 1,200 = 480,000 kWh per year, where kWh stands for kilowatt/hour. The building will be switched to the larger grid when PV generation is not enough.

The PV generation capability is about 1,200 hours/year (which is only 13% of the power needed by Linbian Township). Thus if the Linbian Township building is to be self-sufficient in power for about three months, it is recommended to double the PV generation to about 900 kW in the production phase.

4.1.2 Wind generation

A 10 kW wind generator can produce about 20,000 kWh per year of electricity with an average wind speed of 5 m/s and can produce about 37,000 kWh per year electricity with an average wind speed of 7 m/s. The small size of a 10 kW turbine means a better economic return and less noise. Because the current plan is to build this wind generator inside Wetland Park, the generation and load can be balanced locally.

4.1.3 Bioenergy generation

Currently, local farmers consume biogas-generated electricity onsite. Because biogas is a cost-effective resource for electricity generation, it is recommended that this type of resource be included at the demonstration site.

4.2 Vendors and partners

- Vendors can be suppliers of electric power conditioners and system integrators
- Strategies and financial incentive models are needed to attract vendors and partners into the project
- Pingtung County gained a lot experience in partnership with different solar power vendors in the PV Farming Project
- Pingtung County initiated talks with potential wind power vendors
- A bioenergy vendor has already installed a bioenergy-powered generator in pig farms in the county
- A used electric vehicle and recycled laptop battery vendor has contacted the Pingtung County government

4.3 To-do checklist for Pingtung County microgrid

4.3.1 Build renewable power station (field layer)
- Generation and load requirement assessment
- Microgrid ownership and service models setup
- Microgrid financial model setup
- Site location assessment
- Power station design
- Power station procurement
- Power station construction
- Power station testing with Taiwan Power
- Power station connection to the Taiwan Power grid
- Power station commissioning
- Power station handover
- Power station operation
- Power station maintenance

4.3.2 Infrastructure build (system, communication layers)
- Transmission and distribution system: feeder lines, switches, transformers and so on
- Design and build the transmission and distribution system for connecting to the Taiwan Power grid
- Communication system: sensors, feeder remote terminal units (RTUs) for getting the real-time data of generators and the real-time network status, communication standards and protocols
- Metering system buildup: smart metering
- Connect device/system to the Taiwan Power grid

4.3.3 Control system build (control and supervisory layer)
- SCADA system that gets the real-time data for the supervision and control of the renewable power
- Distribution management system (DMS) that manages the real-time balance of the generation and load

4.3.4 IOCC
- IOCC that provides a unified dashboard that shows the visualization, alarm, report, KPIs and so on in a single user interface
- Analysis of generation and consumption patterns

5. IBM best practice on smart microgrids

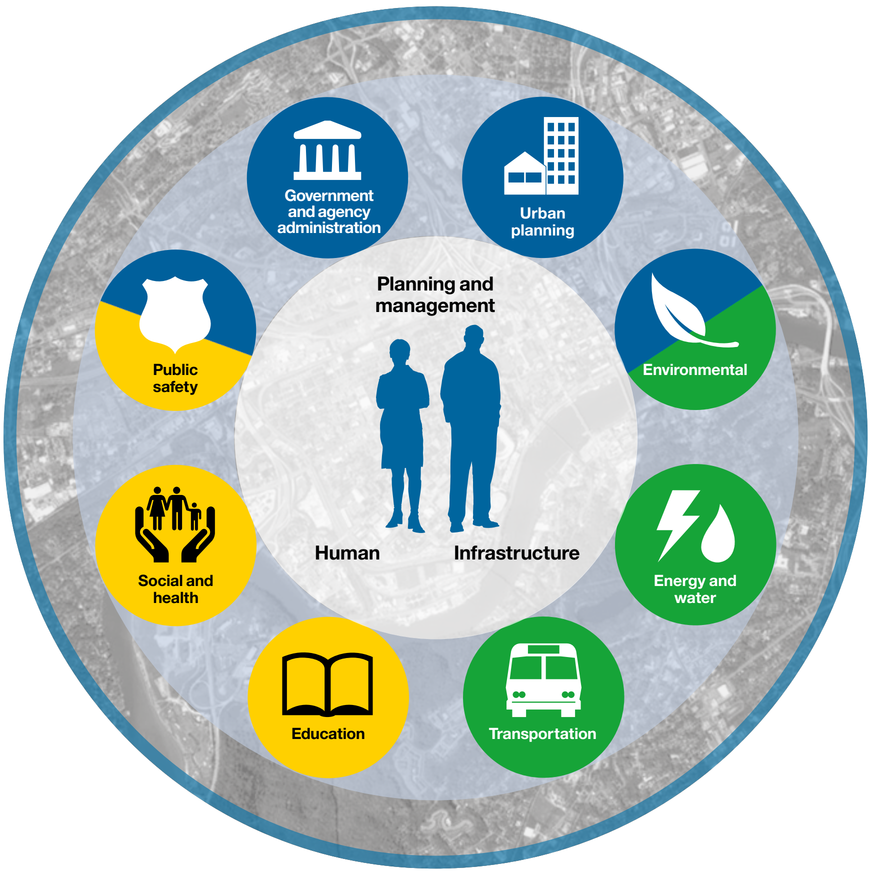
5.1 IBM has engaged more than 150 smart grid projects around the world

A smart grid is an energy system characterized by two-way communication and distributed sensors, automation and a supervisory control system. Through its Modern Grid Initiative, the US Department of Energy has defined a smart grid as the application of advanced sensing, communication and control technologies to produce and distribute electricity more effectively, economically and securely.

Microgrids play an important role in the effort to make the electric grid smarter, greener, and more resilient. A microgrid can be part of an optimized smart grid, and a microgrid itself can be considered to be a tiny smart grid.

5.2 Smart energy is an important building block of the IBM Smarter Cities Challenge

Smart energy for smart cities uses new energy resources and information and communication technology (ICT) technologies, innovates commercial models, constructs the city ecosystem with consumers' participation and interaction, improves the city's energy supply safety and efficiency and prompts the city's sustainable development.



Planning and management

Design and implement a city plan to realize full potential for citizens and businesses while efficiently running daily operations

Infrastructure

Deliver efficient funadmental services that make a city desirable for citizens

Human

Provide effective services that support the economic, social and health needs of citizens

Figure C3: Existing IBM Smarter Cities Challenge segments

5.3 The market of smart energy and the ecosystem

	Distributed energy and microgrid (including user distribution network)	Energy management and energy services (industrial/public and commercial buildings)
Market status	• A policy and technology-driven emerging sector, which is in pilot and field testing phase • Presents huge potential, with possible disruptive impact on the energy and utility market	• Relatively mature market in which energy services companies (ESCOs), regulated and incentivized by governments, provide services under energy management contracts • Numerous players in a market undergoing consolidation, in which firms with client resources and technological advantages will see rapid growth
Market segments	• Distributed PV • Distributed natural gas combined heat and power (CHP) system • Other distributed energy sources (wind, bioenergy, waste heat recovery and so on) • Microgrid (including renewable energy, conventional energy, energy storage, microgrid control)	• Industry/regional energy regulation – government-led investment initiatives • Industrial energy management and energy services – self-funded projects or ESCO-funded projects • Energy management and energy services for public and commercial buildings: public transportation hubs, schools, hospitals, hotels, malls, office buildings, datacenters – self-funded projects or ESCO-funded projects
Investors and operators	• Local governments /industrial parks (government-invested pilot and demonstration projects) • Traditional large energy and utility firms (R&D pilot projects or BOT-commercial operations) • Local energy and utility companies and new entrants	• Local governments, energy-intensive industrial and public facilities • Traditional large energy and utility companies, local ESCOs • Green building/datacenter owners/developers/operators
Engineering procurement and construction (EPC) contractors and system integrators	• Microgrids: For example, in China, there are Beijing Microgrid and Beijing Sifang Automation.	• Energy regulatory and supervisory bodies • Smart building/building automation system integrators

Table C1: The market of smart energy and the ecosystem

5.4 IBM strategic target for smart energy

Target customers	Strategic objectives	Key measures
Local governments/ industrial parks	**Innovation and development** • Develop new energy and energy services industries. Leverage innovation and application demonstration to drive domestic demand, propel industry transformation and boost the city/industrial park's brand image and core competency.	• Top-level design: Smart cities and smart energy system planning and design for the city/industrial park • Innovation and application demo: Utilize innovative technological and business models to build user experience centers and application demo sites • Public service platform establishments: Deploy public service platforms for supporting information, logistics, commerce and marketing activities
Traditional large energy and utility companies	**Innovation and transformation** • Enhance the capability and contribution of innovation for sustainable business development • Manifest corporate image and social responsibilities, so as to maintain/strengthen industry position and influence • Foster and develop new business, optimize product mix	• Innovation and application demonstration: Leverage innovative technologies and business models to build demonstration/user experience centers and application demonstration sites of distributed energy/microgrids and energy services projects • Business transformation: Set up a specialized entity to explore opportunities for new business development and existing business transformation • Platform construction: Build energy service system platforms
Emerging energy and utility companies and partners	**Innovation and growth** • Fast market entry and expansion; brand image, awareness and core competitiveness	• Take advantage of local resources, integrate with supply chain partners, innovate business models, enable fast market entry • Work with leading firms, implement signature projects, gradually enhance core competitiveness

Table C2: IBM strategic target for smart energy

5.5 IBM smart energy solutions for smart cities: user experience center

Solution	Target clients/partners	Assets and use cases
Smart energy planning • Industry • Applications • Business models • IT systems	• Local governments/industrial parks • Traditional large energy and utility enterprises	• Pudong New Area – new energy industry planning • HengQin Island – smart distribution grid demonstration project design
Smart energy user experience centers • Distributed energy and microgrids • Energy management services	• Local governments/industrial parks • Traditional large energy and utility enterprises	• Shanghai World Expo state grid pavilion

Table C3: IBM smart energy solutions for smart cities: user experience center

5.6 IBM smart energy solutions for smarter cities: distributed energy and IOCC

Solution	Target clients/partners	Assets and use cases
Distributed energy and microgrid control center • PV/CHP/microgrid, user distribution network • Supporting a specific single project or multiple projects	• Local governments/industrial parks • Traditional large energy and utility enterprises • Emerging energy and utility companies and partners	• IBM Renewable Energy Forecasting and Regional Energy Management (asset) • HengQin smart power distribution grid operation cente
Building energy management and Building Operation Center (BOC) • Public and commercial buildings, datacenters • Supporting a large single building or complex of buildings	• Local governments/industrial parks • Traditional large energy and utility enterprises • Emerging energy and utility companies and partners: developers, ESCOs, smart building system integrators	• Japan: Building Energy Management System assets and use cases • BOC assets, jointly developed with LG Electronics

Table C4: IBM smart energy solutions for smarter cities: distributed energy and IOCC

5.7 Smart microgrid case study 1

Smart renewable energy and microgrid energy management system on Jeju Island, Korea

Solution:

- IBM partnered with POSCO ICT to develop a renewable energy management system for a microgrid consisting of wind, solar and diesel power generation, as well as energy storage solutions to enable optimization of economic dispatch and demand management.
- Consulting, algorithm designs and testing support, and developed models for load forecasting, as well as wind and solar power generation forecasting.
- A day-ahead forecast and forecasting at five-minute intervals
- Dashboard capability enabled to provide users with key operational information for informed dispatch and control decisions.

Benefits:

- Optimization tools such as demand management make it possible for the microgrid owner to maximize revenues.
- POSCO-ICT is set to begin the next phase of the project, building on the current results.

Developing a smart renewable energy and microgrid energy management system

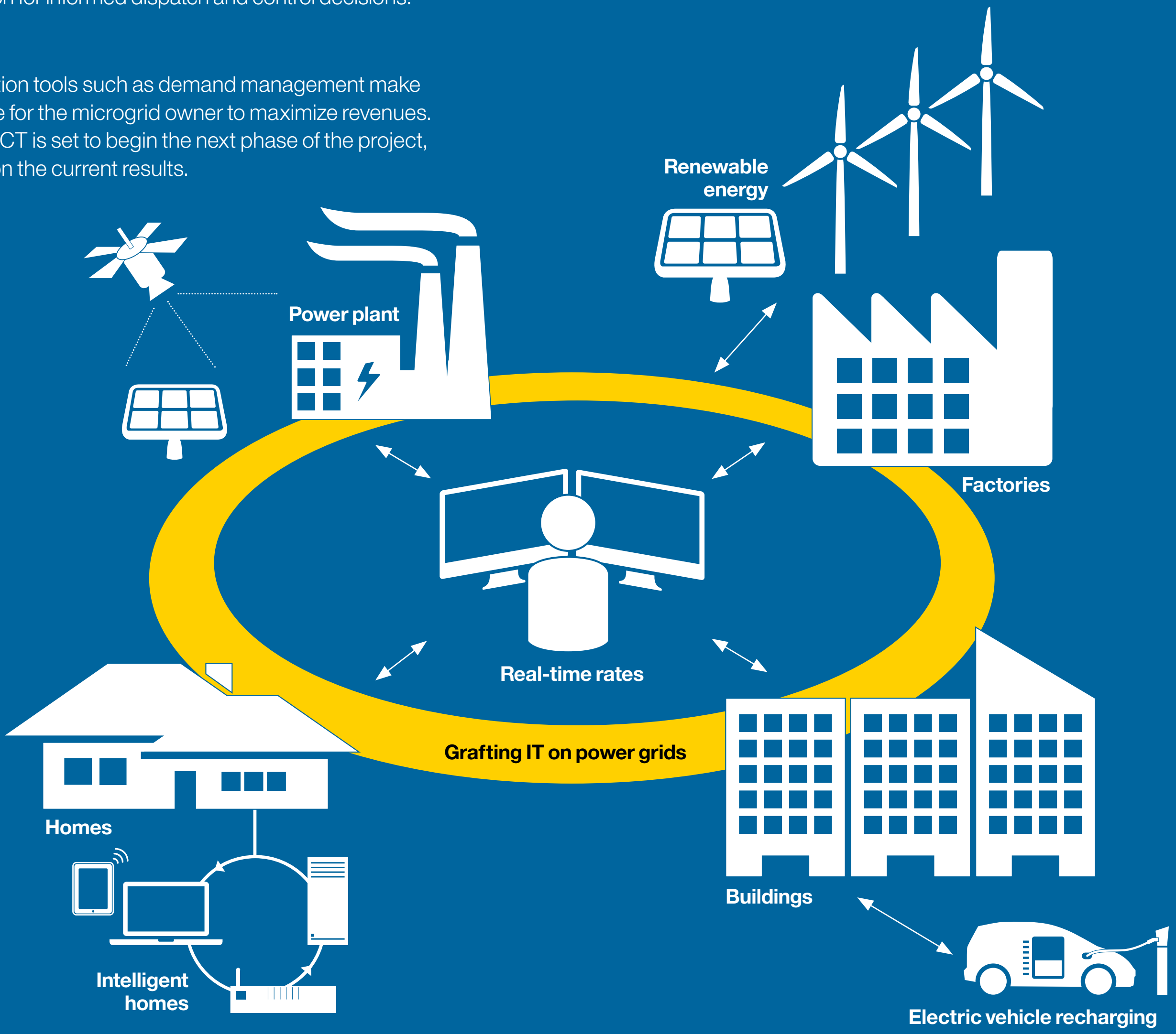


Figure C4: Smart renewable energy and microgrid energy management system on Jeju Island, Korea

5.8 Smart microgrid case study 2: Smart regional island utility in China southern power grid

This island utility in China southern power grid is a proof-of-concept smart grid site.

- **Smart regional grid:**
  - New form of grid emerging – islands, industry parks, city districts
  - Different from traditional grid in topology and operations

- **Challenges to manage smart regional grid:**
  - Hard to coordinate wind, solar, energy storage and consumption in an integrated fashion
  - Uncertainty in both supply/demand side
  - Real-time requirement for energy scheduling (every 5 - 10 minutes)

- **Intelligent Regional Energy Manager (iREM):**
  - Global optimization of smart regional grid:
    - Integrated scheduling of DG/storage/customer
    - More accurate distributed energy forecasting
    - Device-level energy usage forecasting
    - Effective usage of energy storage
  - Leveraging IBM IOCC integration and optimization abilities
  - Advanced features to traditional DMS/EMS packages

- Area: 106km2
- Population: 120,000 by 2015

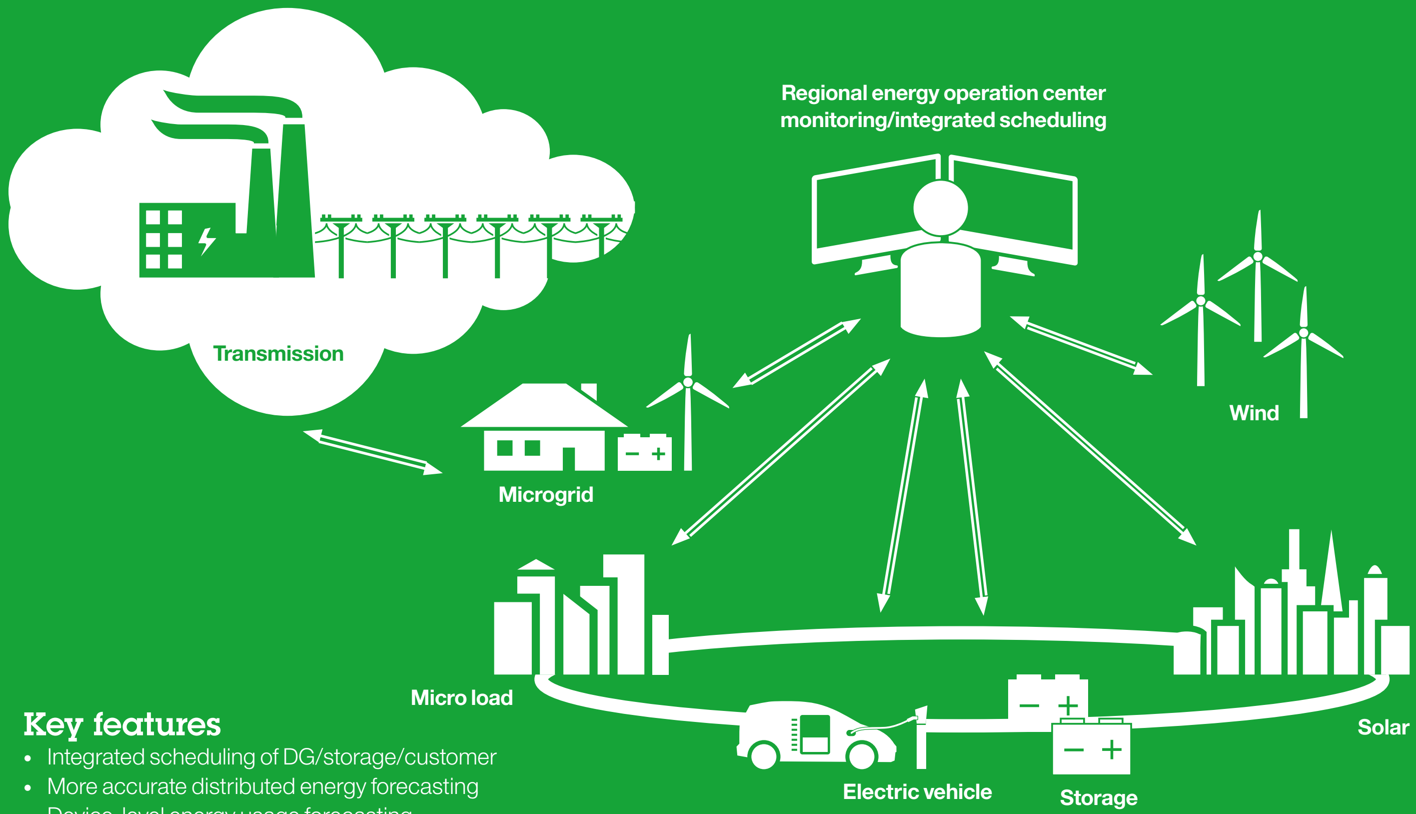
- CHP: 390MW
- Roof PV: 20MW
- Onshore wind: 15MW
- Offshore wind: 50MW
- Battery: 16MW, 4Hours
- Flywheel: 3MW, 2Hours

- Residential load: 70MW (18MW controllable)
- Commercial load: 140 MW (28MW controllable)
- Industrial load: 40MW (4MW controllable)

Figure C5: Ongoing smart regional grid project in China southern power grid

iREM execututve summary

iREM is an IOCC-based analytics and optimization solution for regional grid energy coordination and management.



Key features

- Integrated scheduling of DG/storage/customer
- More accurate distributed energy forecasting
- Device-level energy usage forecasting
- Effective usage of energy storage

Business value

- Optimizes energy usage
- Reduces operations cost
- Improves smart regional grid reliability
- Increases renewable energy utilization

Figure C6: iREM executive summary

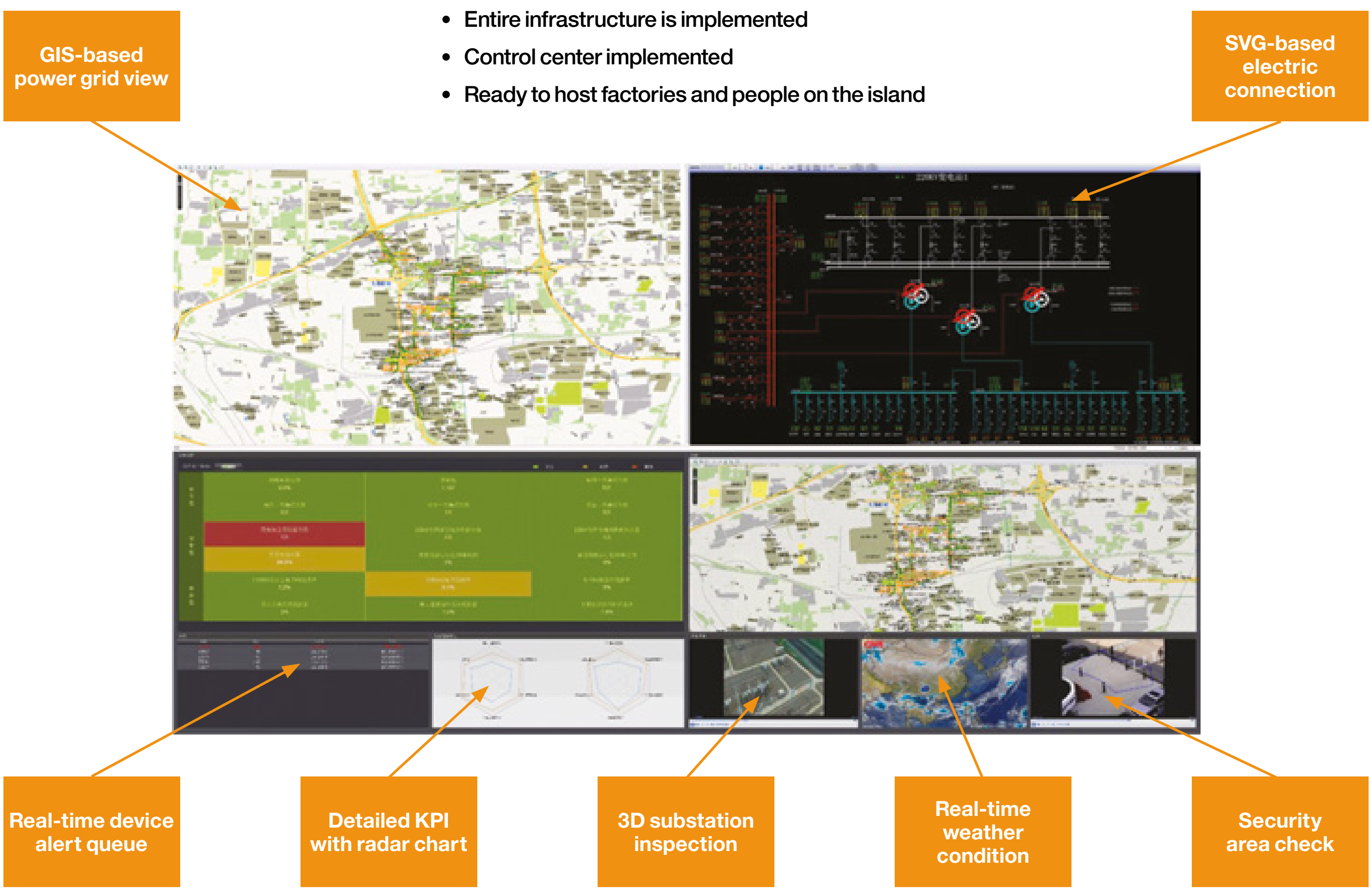


Figure C7: Typical scenario – comprehensive monitoring

Figure C8: Smart power distribution grid operation center layout for a utility in China southern power grid

5.9 Smart microgrid case study 3: Smart microgrid in the Brunei rainforest area

The IBM Smarter Energy Group has a team in IBM Research – India with expertise in environmentally focused microgrids. The 18 experts in this pool have deep backgrounds in embedded system optimization, microgrid deployment, renewable energy technologies, metering and data mining.

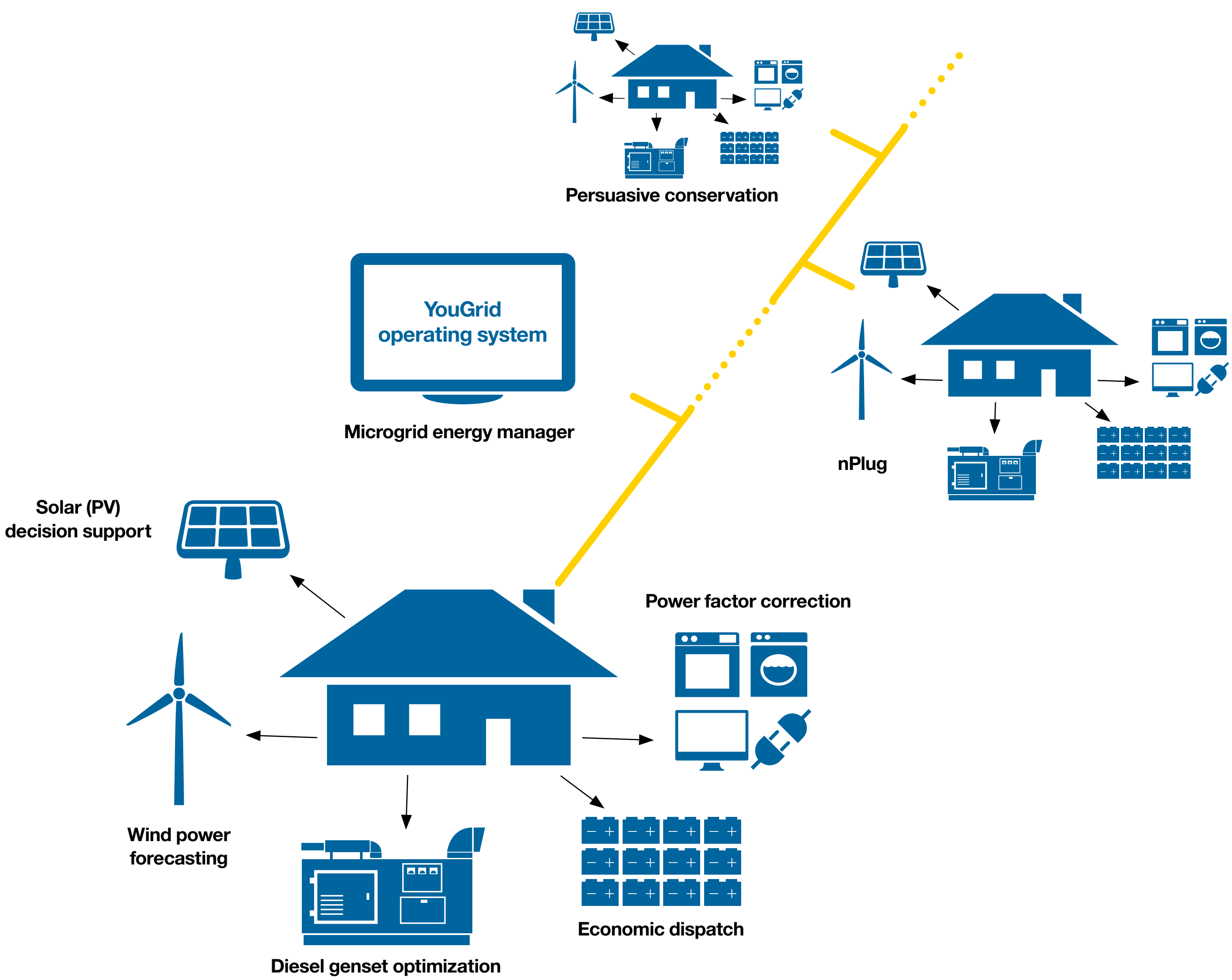


Figure C9: Smart microgrid in the Brunei rainforest area

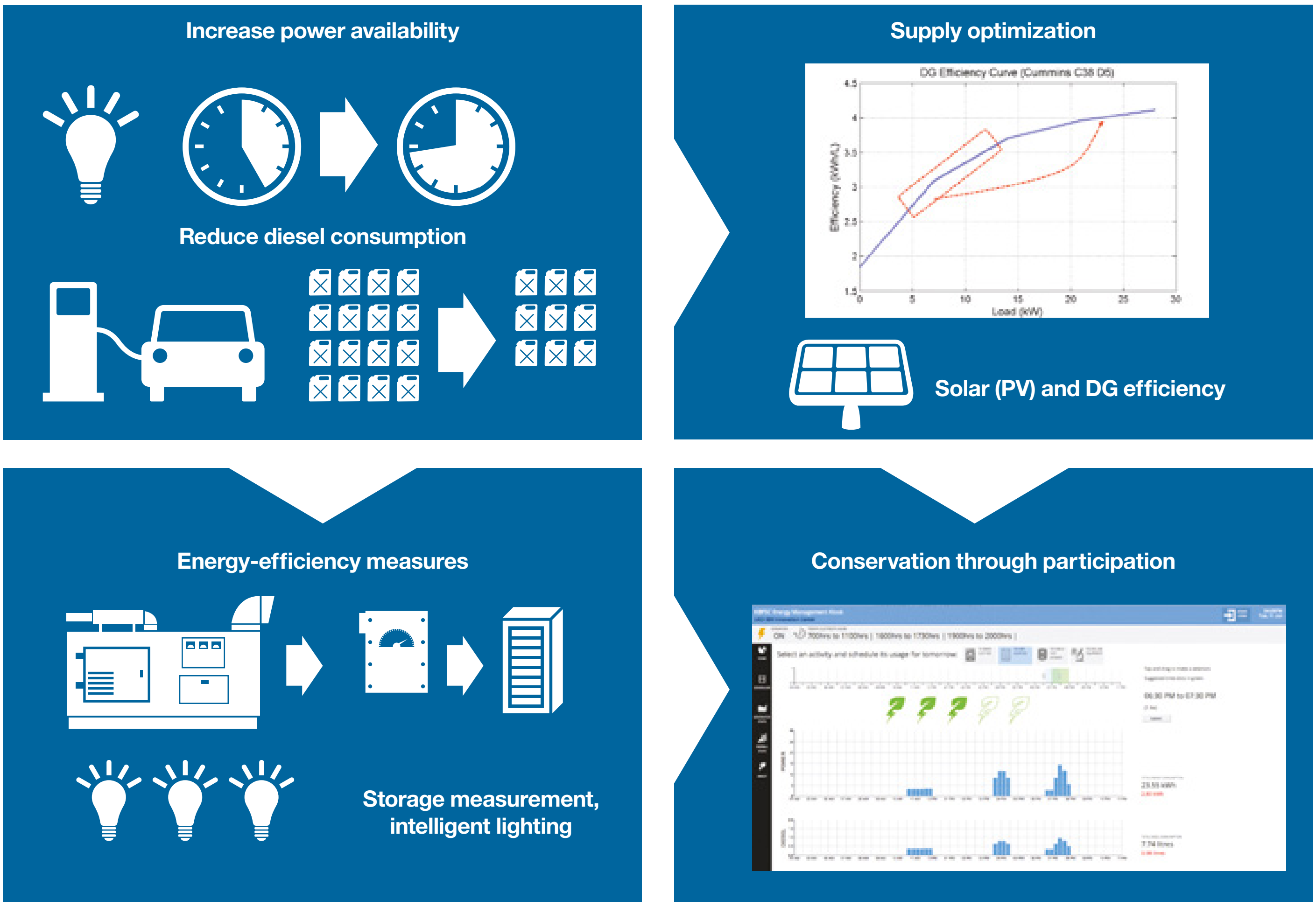


Figure C10: Overview

Kuala Belalong Field Studies Center

Kuala Belalong Field Studies Center (KBFSC) is a biological research facility. Researchers from all around the world visit to study the plant and animal life in the forest around the center. It has encountered the following problems:

- **No direct grid connection**
- **Three diesel generators for five building blocks**
- **Diesel generator hours: 6 - 9am and 4 - 11pm (~10 hrs)**
- **Diesel generator consumption: ~30 L/day**
- **Transporting diesel is difficult: 30- to 150-minute long boat ride**

Figure C11: Photographs from the KBFSC

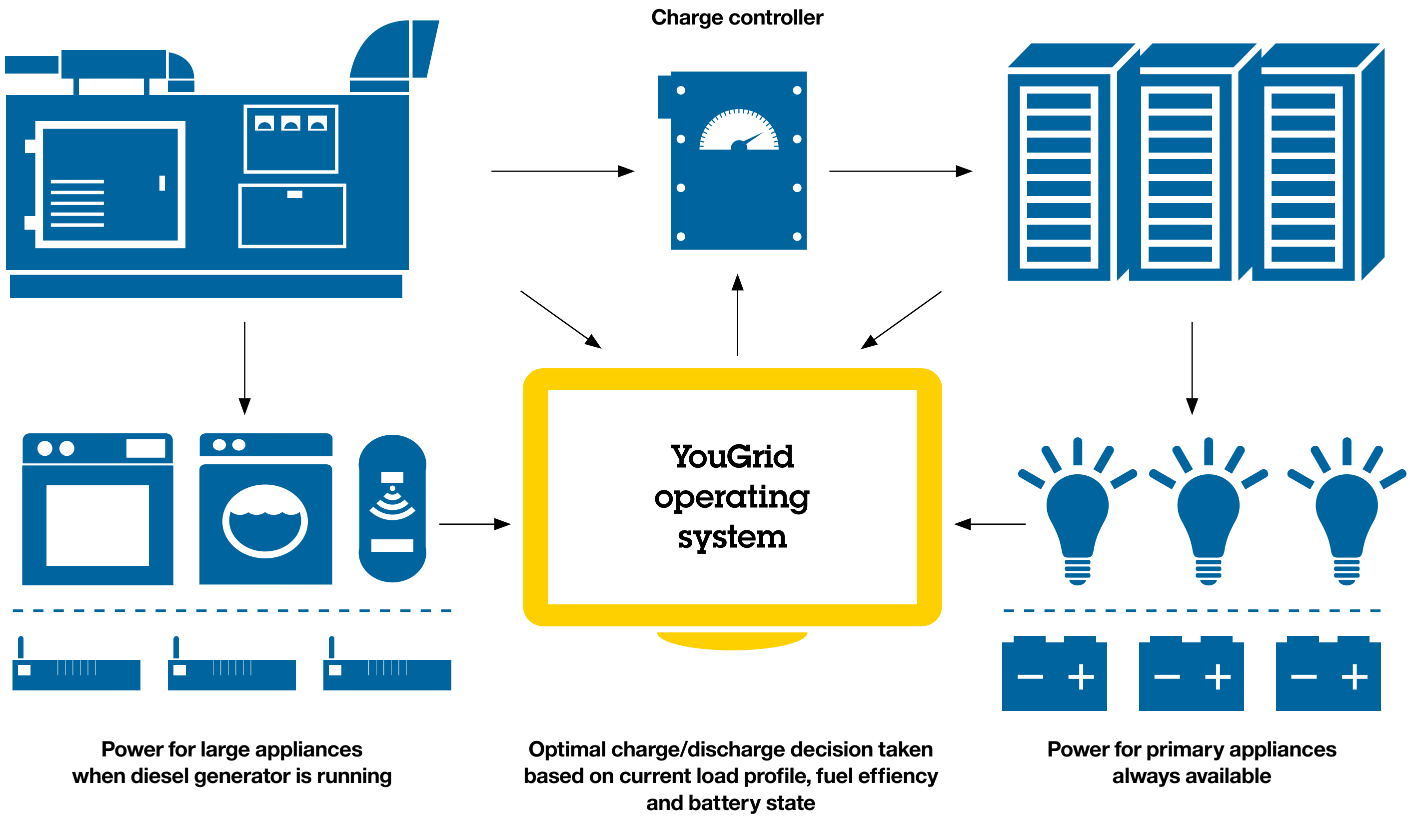


Figure C12: Battery optimized diesel generator

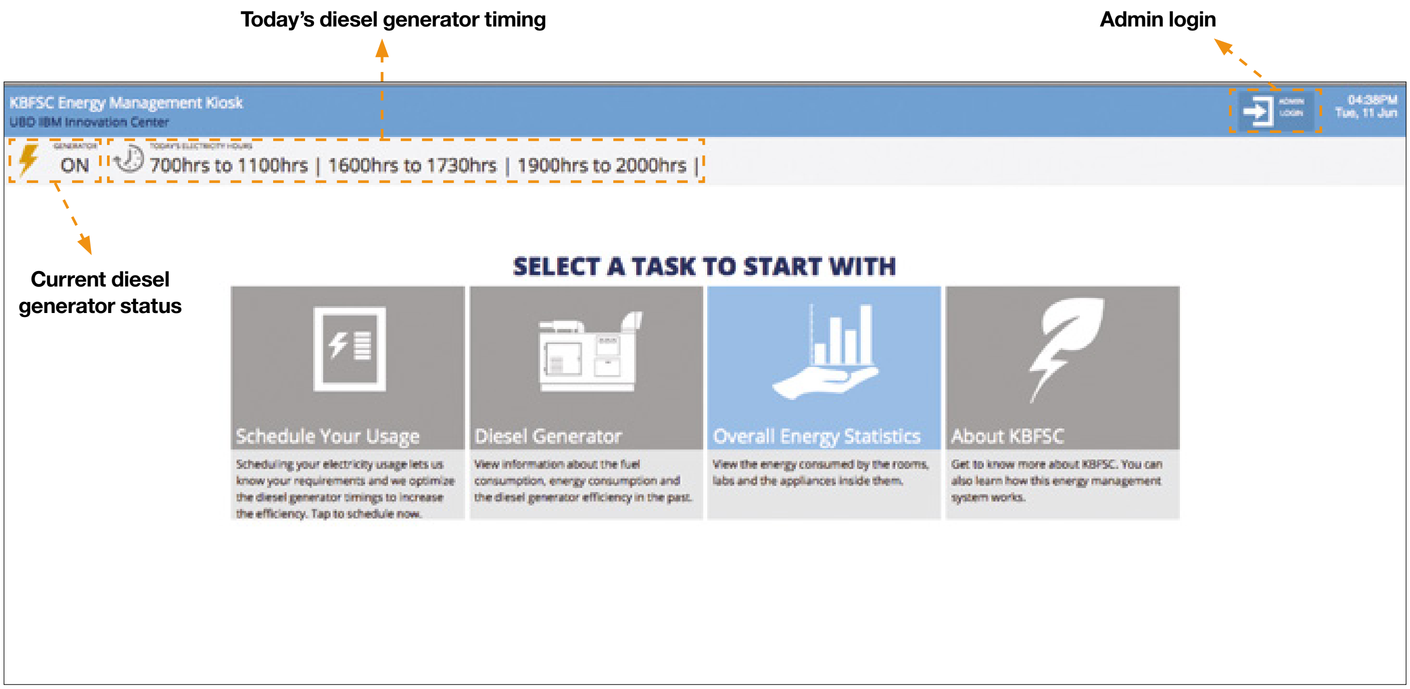


Figure C13: Home screen

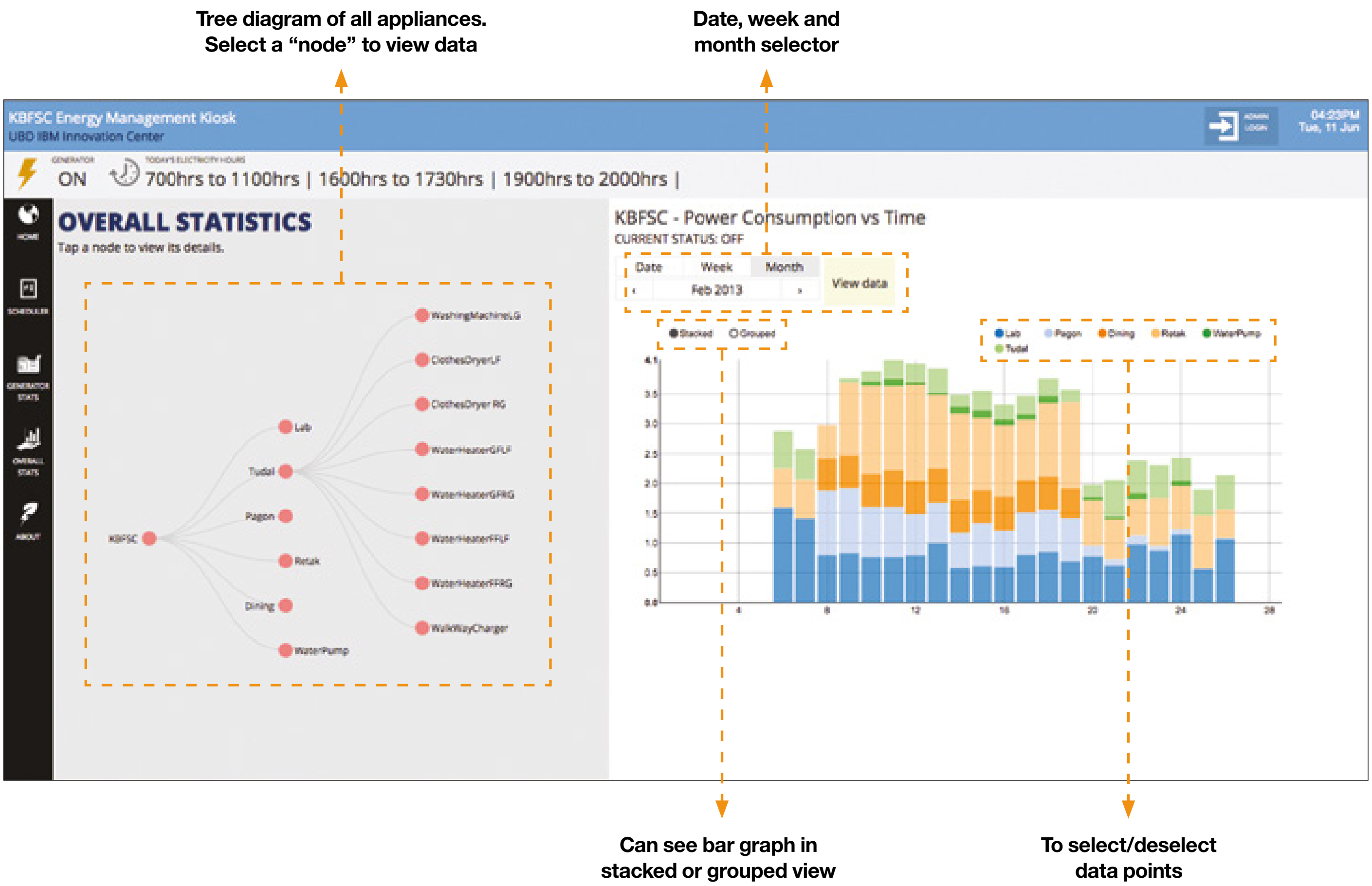


Figure C14: Power flow/usage visualization

5.10 Lessons learned from IBM smart microgrid projects engagement

- The development of a smart microgrid should be aligned with the long-term strategic roadmaps (multiyear programs)
- Customer/regulatory/vendor involvement programs
- Big data:
  - Collection processes
  - Data storage and processing
  - Analytics (historical/real-time/predictive)
- The role of research in “proof of concepts” and “first of a kinds”
- A commercialization model — who invests, who owns the intellectual property (IP), what are the standards in use?
- Use of many delivery models:
  - Cloud technology/application hosting/outsourcing/insourcing
  - Integration of many systems (master integration services)
- Demonstration center services — design, layout, examples, use cases
- Certification of technology — interoperability of various vendors (AMI, geographical information systems (GIS), SCADA/DMS)

5.11 Functions of an IOCC

- Integrate, visualize and analyze the real-time information that is gathered onto a single platform by the SCADA system, sensors and other outputs of the different renewable technologies
- Provide a holistic dashboard view of the events and activities within the microgrid
- Establish KPIs to monitor continuously the performance of the grid
- Enable analytics and predictive analysis to establish a smart grid in the future
- Enable the microgrid as a test bed for integrators and manufacturers

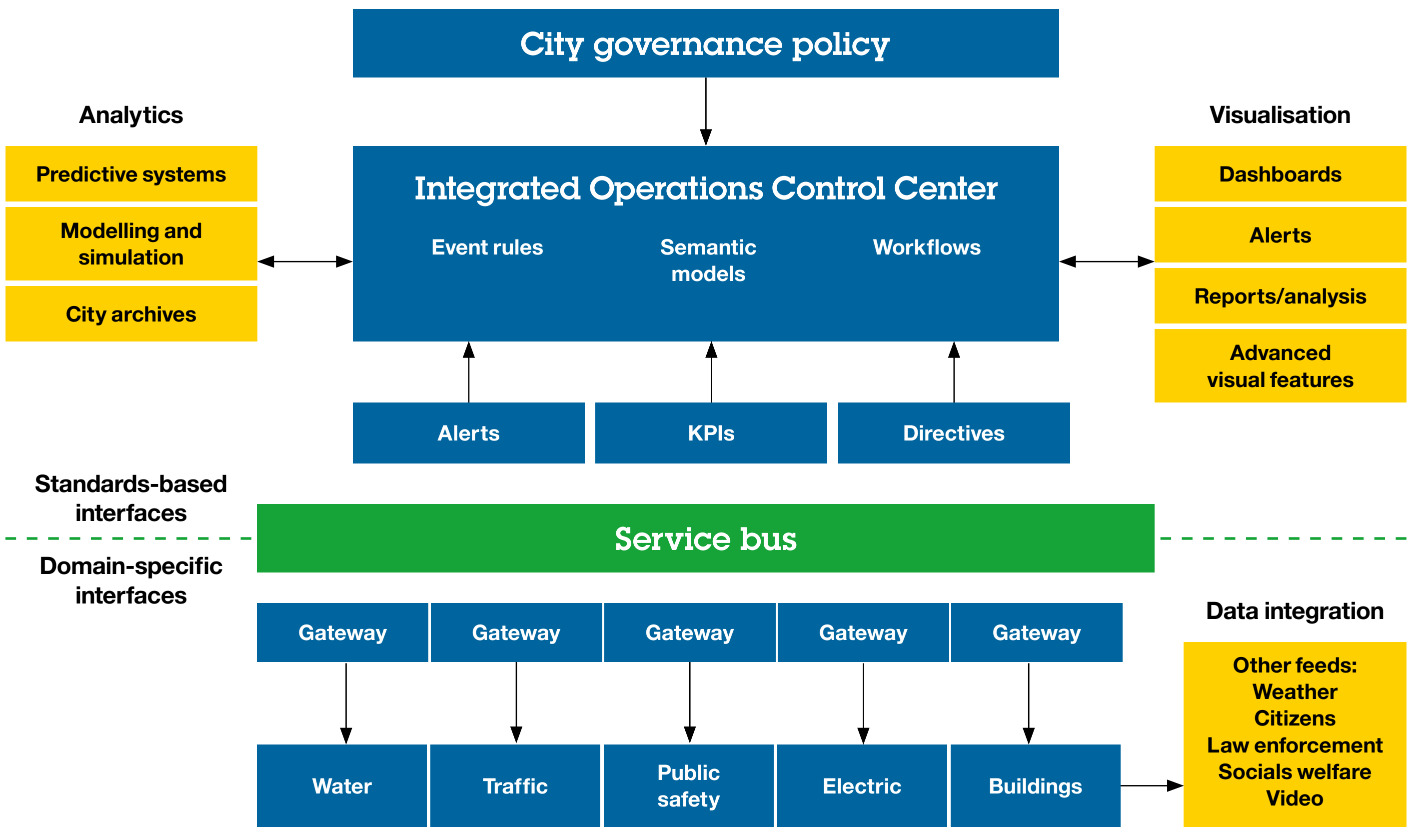


Figure C15: IOCC architecture

Advanced applications within the IOCC

- Power monitor and dispatching (control)
- EMS
- Remote centralized supervision and control
- Asset management
- Connection to grid and demand response
- Operation optimization
- Wind and solar power generation forecasting
- Metering and settlement
- Real-time dashboard

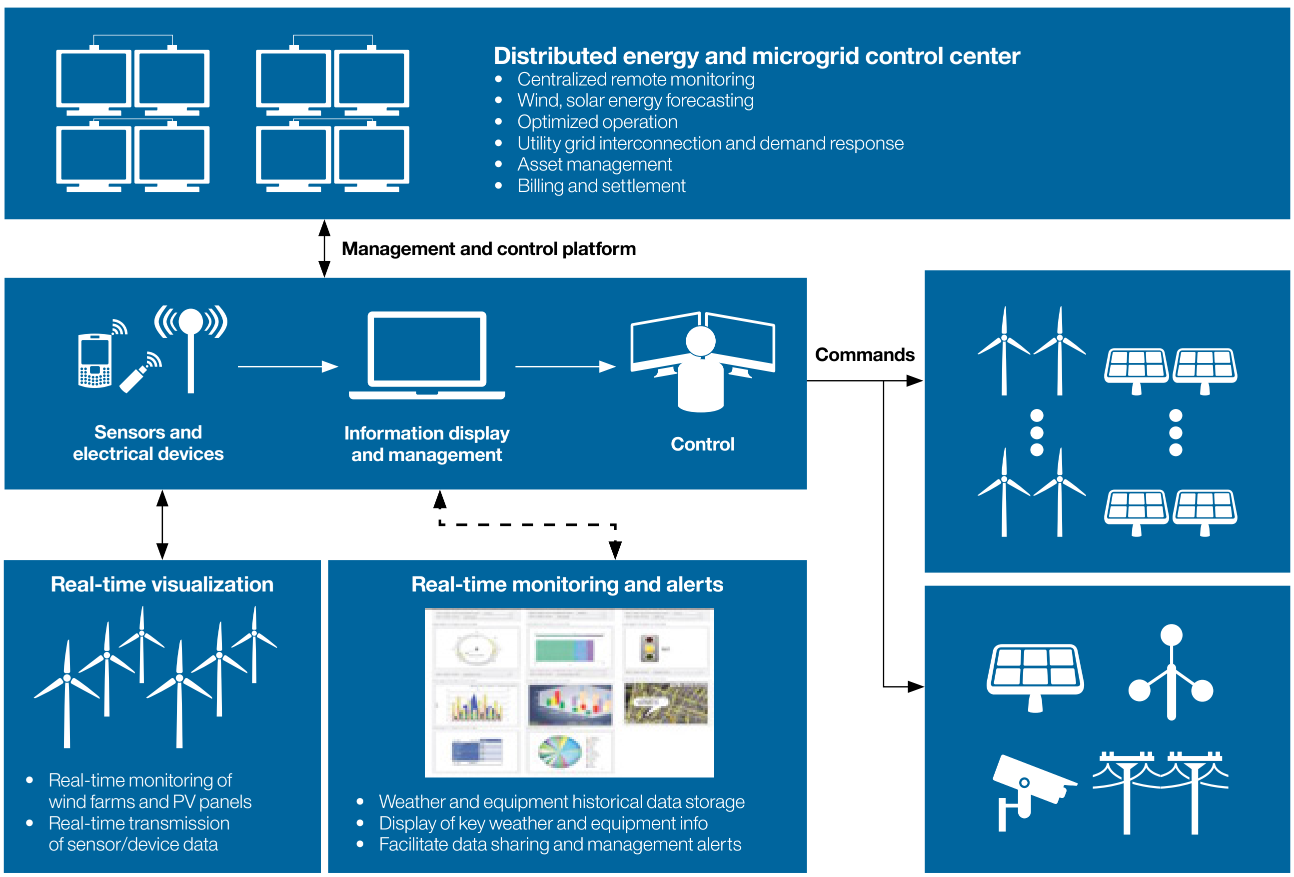


Figure C16: Architecture of the distributed energy and microgrid control center

6. Smart microgrid to-be architecture

The Pingtung County smart microgrid demonstration site is architected as shown in Figure 18.

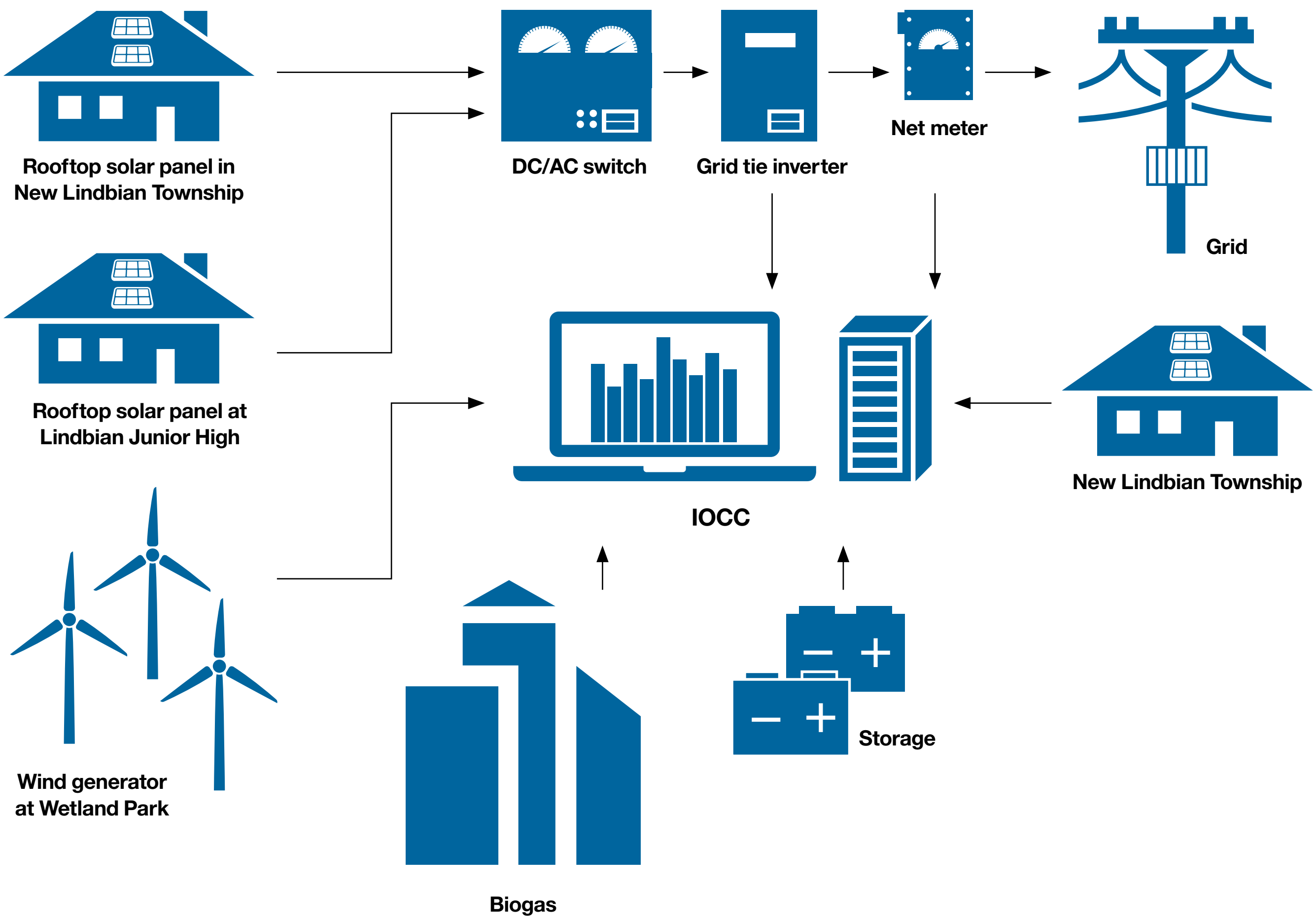


Figure C17: Architecture of Pingtung County smart microgrid demonstration site

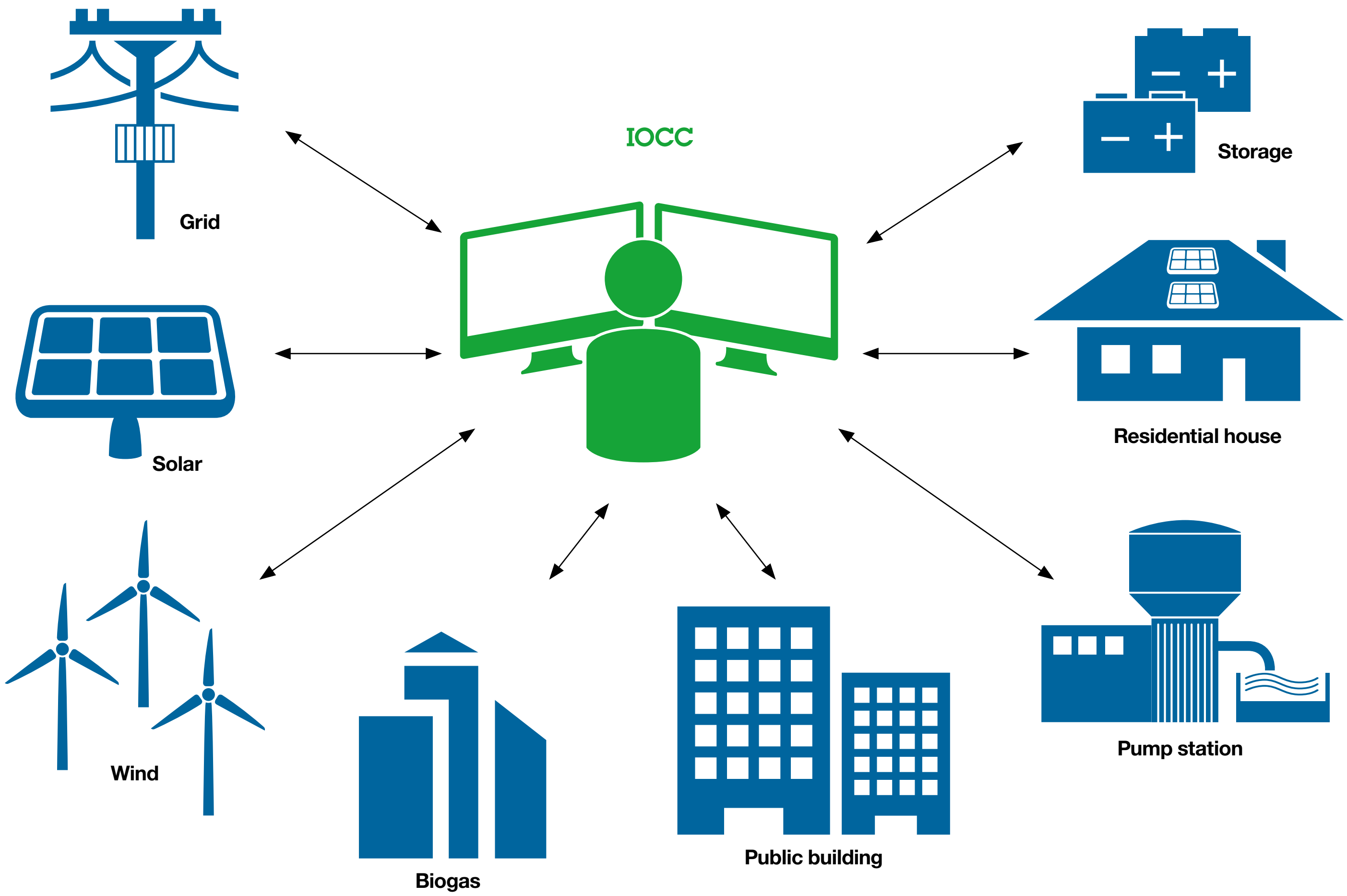


Figure C18: Components of the Pingtung County smart microgrid

The Pingtung County smart microgrid has the following main components:

- Solar power
- Wind power
- Biogas generation
- Grid-tie switch
- Storage (optional)
- Loads, such as public buildings, residential houses and pump stations
- IOCC

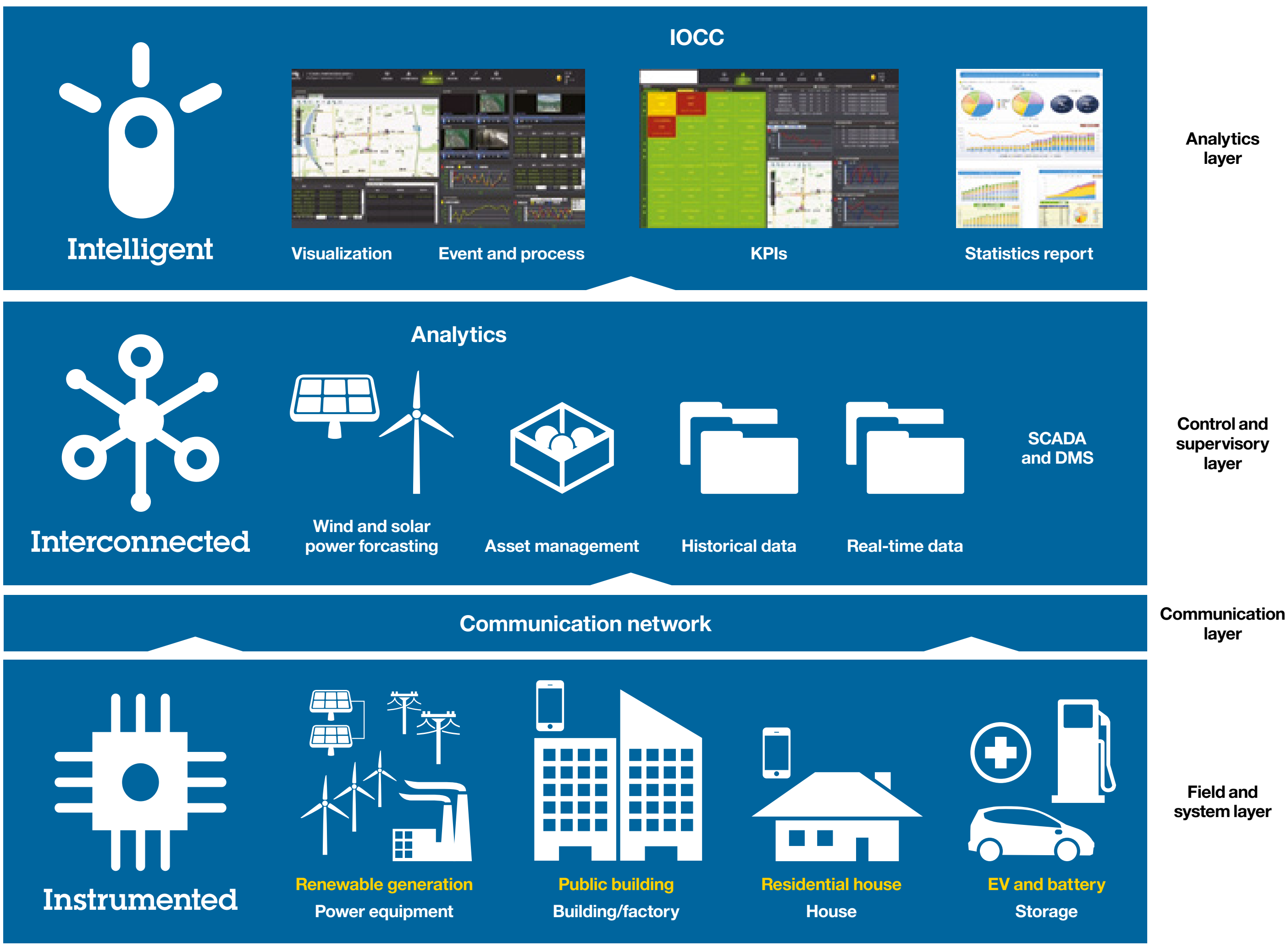


Figure C19: IT architecture of the Pingtung County smart microgrid

- Pioneering 5
- Optimizing 4
- Integrating 3
- Enabling 2
- Initiating 1
- Default 0

Smart grid phases
- Integrated scheduling and coordination of distributed generation and storage
- More accurate energy forecasting
- Device-level energy use forecasting
- Renewable asset management
- Customer experience
- Effective use of energy storage
- Advanced predictive analytics

Production phase
- Augment capacity with additional resources: solar, wind and biogas
- Integrate storage and energy management system capability
- Connect to Taiwan Power Company grid
- Add additional monitoring, control, KPI and reporting

Demonstration site phase
- Build solar and wind generation infrastructure
- Install integrated monitoring capability (dashboard)

Figure C20: Recommended areas of focus – IBM Smart Grid Maturity Model phases

The IT architecture of the Pingtung County smart microgrid is developed from the field and system layer, to the communication layer, to the control and supervisory layer and then to the analytics layer, in order to instrumented, interconnected and intelligent.

In order to fulfill the microgrid's functionality and have all the components connected to the microgrid, the team recommends that the smart microgrid be implemented in different phases: demonstration site phase, production phase and smart grid phase.

6.1 Phase 1: Demonstration site

Assumptions

- The capital expenditure to build the smart microgrid demonstration site is low
- Because of the small scale of solar and bioenergy, microgrids are easy and fast to build with minimum financial risk
- The local Pingtung government builds, operates and owns the assets of renewable generation
- The primary purpose of power generation is to feed the local loads; there is no plan to sell the excess power to the Taiwan Power grid

Goal

- Realize the smart microgrid for demonstration purposes
- A "quick win" strategy: get the project up and running quickly and accelerate time to value
- Get started with less need to staff up, and acquire technology and skills quickly

Capability

Generation:

- New PV power systems installed at the new Linbian Township building and at Linbian Junior High School (400 kW)
- One windmill at Wetland Park (10 kW)
- One biogas power station at a pig farm (3 MW)
- Total capability: about 3.5 MW

Loads:

- New Linbian Township building

Functionality
- Visualization and monitoring of different types of renewable resources
- Power supply for Linbian Township in case of an emergency
- IOCC visualization, event notification, KPI dashboard

Implementation steps
1. Define/validate the microgrid requirements with existing or new vendors
2. Apply for permission for renewable generation construction
3. Design/build a renewable energy generation station
4. Design/build a power transmission and distribution system
5. Design/build a grid connection
6. Design/build a communication system
7. Design/build a SCADA and DMS system
8. Design/build a smart microgrid management center (the IOCC)

6.2 Phase 2: Production
Assumptions
- More renewable resources integrated into the microgrid with larger PV and wind farms
- Industrial-scale storage

Goal
- Coordinate resources to operate effectively
- Manage storage effectively
- Increase flexibility/agility: plug and play of renewable resources and different loads

Capability
- Increasing the capability of renewable resources up to the 10 MW scale

Functionality
- Connection to the Taiwan Power grid
- Integrated storage
- EMS function to balance generation and load locally
- Additional monitoring control, KPIs and reporting

Implementation steps
1. Design/build larger PV and wind farms
2. Connect the generated power and loads to the smart microgrid
3. Design/build a power transmission and distribution system with the capability of connecting to the grid
4. Design/build a two-way data communication system
5. Design/build a SCADA and DMS system
6. Design/build an IOCC with advanced analytics functionality
7. Interconnect the microgrid with the Taiwan Power grid

6.3 Phase 3: Smart grid
Assumptions
- The impact that the high penetration of renewable resources into the grid has on the grid's safety and stability is studied and analyzed.
- An existing electric utility, such as Taiwan Power, may own and maintain the electric distribution facilities serving the microgrid, while the generation or storage assets are owned by Pingtung County or third parties; this is an Unbundled Utility Model[2] in which the utility is an active partner with customers and generators to facilitate and manage the aggregation of loads and the deployment of generation on the microgrid.

Goal
- Coordinate resources to operate effectively
- Leverage information to make better decisions
- Business transformation
- Provide timely and efficient services to Pingtung County's citizens

Capability
- Increasing the capability of renewable resources up to the 200 MW scale

Functionality

- SSW generation scheduling, coordination and optimization
- More accurate wind and solar power generation forecasting
- Renewable generation asset management
- Condition-based maintenance for optimal wind farm and solar farm connection and disconnection with the utility grid
- Optimal pricing management on sales of excess power to the utility grid
- Smart meters and AMI
- Dynamic control of loads and demand response
- Decision making tools, KPIs, dashboard integration

Implementation steps

1. Design/build large-scale PV and wind farms
2. Design/build a power transmission and distribution system with a capability of connecting to the grid
3. Design/build a two-way data communication system
4. Design/build a SCADA and DMS system
5. Design/build an Integrated Operations Control Center with more advanced analytics functionality
6. Interconnect the microgrid with the Taiwan Power grid
7. Consider microgrids in utility system planning and resource planning processes, including in periodic Integrated Resource Plans (IRPs) and regional transmission plans

7. Recommendations

Initialization:

- Resource determination (location, capability, connectivity and so on)
- Infrastructure building
- IOCC system building

Architecture design:

- Application architecture
- Communication architecture
- Infrastructure architecture
- Data integration architecture

Implementation timeline, priorities:

- Implement the project in phased approaches, with the first phase focused on the quick show — that is, the dashboard — of different resources.
- Build up the infrastructure and management center first, then have the resources and load ready to be plugged in.
- Priorities on the resources to plug into the demonstration center are PV first, storage next, then wind, followed by bioenergy.
- Priorities on the load to plug into the demonstration center are public facilities, such as township building, schools, streetlights and so on, then pump stations, then fish pond electricity, then 207 residential households.

Long-term roadmap:

- Connect to the larger solar park, wind farm and so on, then leverage the full capabilities of the microgrid and the IOCC
- Include a waste management system, a fishing pond monitoring system and an emergency management system in the IOCC

8. References

1 Microgrid Institute. www.microgridinstitute.org

2 "Microgrids: An Assessment of the Value, Opportunities and Barriers to Deployment in New York State." Final Report 10-35, New York State Energy Research and Development Authority (NYSERDA), September 2010.

3 Vadari, M. and Stokes, G. "Utility 2.0 and the Dynamic Microgrid," Fortnightly Magazine, November 2013. www.fortnightly.com/fortnightly/2013/11/utility-20-and-dynamic-microgrid

D. Assessment of the Pingtung County smart microgrid using the IBM Smart Grid Maturity Model (SGMM)

The SGMM was developed by IBM and a group of global utilities and is hosted by the Carnegie Mellon University Software Engineering Institute. IBM has licensing rights to this process.

What is it?

The SGMM is a management tool to guide, appraise and improve toward a smart grid transformation through distinct levels of capabilities and associated results.

How does it help?

The SGMM creates a clearly articulated journey for smart grid transformation, with defined stages and options. It creates a common framework and language. It defines all the elements of a smart grid transformation and helps to bridge gaps between strategy and execution that might exist.

How is it used?

The SGMM can be used in a variety of ways, the most powerful of which is to create a common vision and prioritization of initiatives, providing the greatest opportunity for improvement, innovation and transformation and helping utilities develop a programmatic approach to track progress.

Eight domains – logical groupings of functional components of a smart grid transformation implementation

SGMM	Strategy, management and regulatory	Organization and structure	Technology	Societal and environmental	Grid operations	Work and asset management	Customer management and experience	Value chain integration
5. Innovating next wave improvements	• Overall strategy expanded due to SG capabilities • Optimized rate design/regulatory policy (most beneficial regulatory treatment for investments made) • New business model opportunities present themselves and are implemented.	• Collaboratively engage all stakeholders in all aspects of transformed business • Organizational changes support new ventures and services that emerge • Entrepreneruial mind set, culture of innovation	• Autonomic computing, machine learning • Pervasive use and leadership on standards • Leader and influence in conferences and industry group • Leading edge grid stability systems	• Actualize the "triple bottom line" – (financial, environmental and societal) • Customers enabled to manage their own usage (e.g. tools and self-adaptive networks) • Tailored analytics and advice to customers • Managing distributed generation	• Grid employs self-healing capabilities • Automated grid decisions system wide (applying proven analytic based controls) • Optimized rate design/regulatory policy • Ubiquitous system wide dynamic control	• Optimizing the use of assets between and across supply chain participants • Just in time retirement of assets • Enterprise-wide abstract representation of assets for investment decisions	• Customer management of end-to-end energy supply and usage level • Outage detection at residence/device • Plug-n-play customer based generation • Near real-time data on customer usage • Consumption level by device available • Mobility and CO2 programs	• Coordinated energy management and generation throughout supply chain • Coordinated control of entire energy assets • Dispatchable recourses are available for increasingly granular market options (Locational Marginal Pricing)
4. Optimizing enterprise wide	• SG drives strategy and influences corporate direction • SG is a core competency • External stakeholders share in strategy • Willing to invest and divest, or engage in JV and IP sharing to execute strategy • Now enabled for enhanced market driven or innovative regulatory funding schemes	• Integrated systems and control drive organizational transformation • End-to-end grid observability allows organizational leverage by stakeholders • Organization flattens • Significant restructuring likely occurs now (tuning to leverage new SG capabilities and processes)	• Data flows end-to-end (customer to generation) • Enterprise business processes optimized with strategic IT architecture • Real world aware systems – complex event processing, monitoring and control • Predictive modeling and near real-time simulation, analytics drives optimization • Enterprise-wide security implemented	• Collaboration with external stakeholders • Environmentally driven investments (aligned with SG strategy) • Environmental scorecard/ reporting • Programs to shave peak demand • Ability to scale DG units • Available active management of end user energy uses and devices	• Integration into enterprise processes • Dynamic grid management • Tactical forecasts based on real data • Information available across enterprise through end-to-end observability • Automated decision making within protection schemes (leveraging increased analytics capabilities and context)	• Enterprise view of assets: location, status, interrelationships, connectivity and proximity • Assets models reality based (real data) • Optimization across fleet of assets • CBM and predictive management on key components	• Usage analysis within pricing programs • Circuit level outage detection/notification • Net billing programs in the home • Automated response to pricing signals • Common customer experience integrated across all channels • Recent customers usage data (daily) • Behaviour modeling augments customer segmentation	• Energy resources dispatchable/ tradable, utility realizes gain from ancillary services (power on demand) • Portfolio optimization modeling expanded for new resources and real time markets • Ability to communicate with Home Ability Network, incl. visibility and control of customer large demand appliances

Figure D1: Three key concepts for the SGMM

3. Integrating cross functional	• Completed SG strategy and business case incorporated into corp. strategy • SG governance model deployed • SG leader(s) (with authority) ensure cross LOB application of SG • Mandate/ consensus with regulators to make and fund SG investments • Corp. strategy expanded to leverage new SG enabled service or offerings	• SG is driver for org. change (addressing aging workforce, culture issues) • SG measures on balanced scorecard • Performance and compensation linked to SG success • Consistent SG leadership cross LOBs • Org. is adopting a matrix or overlay structure • Culture of collaboration and integration	• SG impacted business processes aligned with IT architecture across LOBs • Common architectural framework – standards, common data models • Use of advanced intelligence/ analytics • Advanced sensor plan (PMUs) • Implementing SG technology to improve cross LOB performance • Data comms. detailed strategy/ tactics	• Active programs to address issue • Segmented and tailored information for customers – including environmental and social benefits • Programs to encourage off-peak usage • Integrated reporting of sustainability and impact • Synthesize triple bottom line view across LOBs	• Sharing data across functions/ systems • Implementing control analytics to support decisions and system calculations • Move from estimation to fact-based planning • The customer meter becomes an essential grid management "sensor" • New process being defined due to increased automation and observability	• Efficient inventory management utilizing real asset status and modelling • Component performance and trend analysis • Developing CBM on key components • Integrating RAM to asset management mobile work force and work order creation • Tracking inventory, source to utilization • Modelling asset investments for key components based on SG data	• High degree customer segmentation • Two-way meter, remote disconnect and connect, and remote load control • Outage detection at substation • Common customer experience • Customer participation in DR enabled • New interactive products/services • Predictive customer experience	• Integrated resource plan includes new targeted resources and technologies (DR, DG, volt/VAR) • Enabling market and consumption information for use by customer energy management systems • New resources available as substitute for market products to meet reliability objectives
2. Functional investing	• Integrated vision and acknowledgement • Initial strategy/ business plan approved • Initial alignment of investments to vision • Distinct SG set-aside funding/ budget • Collaboration with regulators and stakeholders • Commitment to proof of concepts • Identify initial SG leader	• New vision influences change • Organizing more around operational end-to-end processes (breaking silos) • Matrix teams for planning and design of SG initiatives across LOBs • Evaluating performance and compensation for smart grid	• Tactical IT investments aligned to strategic IT architecture across LOB • Common selection process applied • Common architectural vision and commitment to standards across LOBs • Conceptual data comms. strategy • IED connectivity and business pilots • Implementing information security	• Established energy effiency programs for customers • "Triple bottom line" – (financial, environmental and societal) • Environmental proof of concepts underway • Consumption information provided to customers	• Initial distribution to substation automation projects • Implementing advanced outage restoration schemes • Piloting remote monitoring on key assets (RAM) for manual decision making • Expanding and investing in extended communications networks	• Developing mobile workforce strategy • Approach for tracking, inventory and event history of assets under development • Developing an integrated view of GIS and RAM with location, status and nodal interconnectivity	• Piloting AMI/AMR • Modeling of reliability issues to drive investments for improvements • Piloted remote disconnect/connect • More frequent customer usage data • Assessing impact of new services and delivery processes (HAN) • Research on how to reshape the customer experience through SG • Broad customer segmentation (geography, income) • Load management in place for C&I • Reactive customer experience	• Introducing support for home energy management systems • Redefine value change to include entire eco-system (RTOs, customers, suppliers) • Pilot investments to support utilization of a diverse resource portfolio • Programs to promote customer DG
1. Exploring and initiating	• Developing first SG vision • Support for experimentation • Informal discussion with regulators • Funding likely out of existing budget	• Articulated need to change • Executive commitment to change • Culture of individual initiatives and discoveries • Knowledge growing; possibly compartmentalized	• Exploring strategic IT arch. for SG • Change control process for IT for SG • Identifying uses of technology to improve functional performance • Developing processes to evaluate technologies for SG	• Awareness of issues and utility's role in addressing the issues • Environmental compliance • Initiating conservation, efficiency, "green" • Renewables program		• Conducting value analysis for new systems • Exploring RAM (Remote Asset Monitoring), beyond SCADA • Exploring proactive/ predictive asset maintenance • Exploring using spatial view of assets	• Research on how to reshape the customer experience through SG • Broad customer segmentation (geography, income) • Load management in place for C&I • Reactive customer experience	• Identified assets and programs within value chain to facilitate load management programs • Identified distributed generation sources and existing capabilities to support • Develop strategy for diverse resource portfolio

Five maturity levels – defined sets of characteristics and outcomes

200 characteristics – capabilities you would expect to see at each stage of the smart grid journey

Pioneering	5	Breaking new ground; industry-leading innovation
Optimizing	4	Optimizing smart grid to benefit entire organization; may reach beyond organization; increased automation
Integrating	3	Integrating smart grid deployments across the organization, realizing measurably improved performance
Enabling	2	Investing based on clear strategy, implementing first projects to enable smart grid (may be compartmentalized)
Initiating	1	Taking the first steps; exploring options, conducting experiments, developing smart grid vision
Default	0	Default level (status quo)

Figure D2: IBM SGMM – five maturity levels

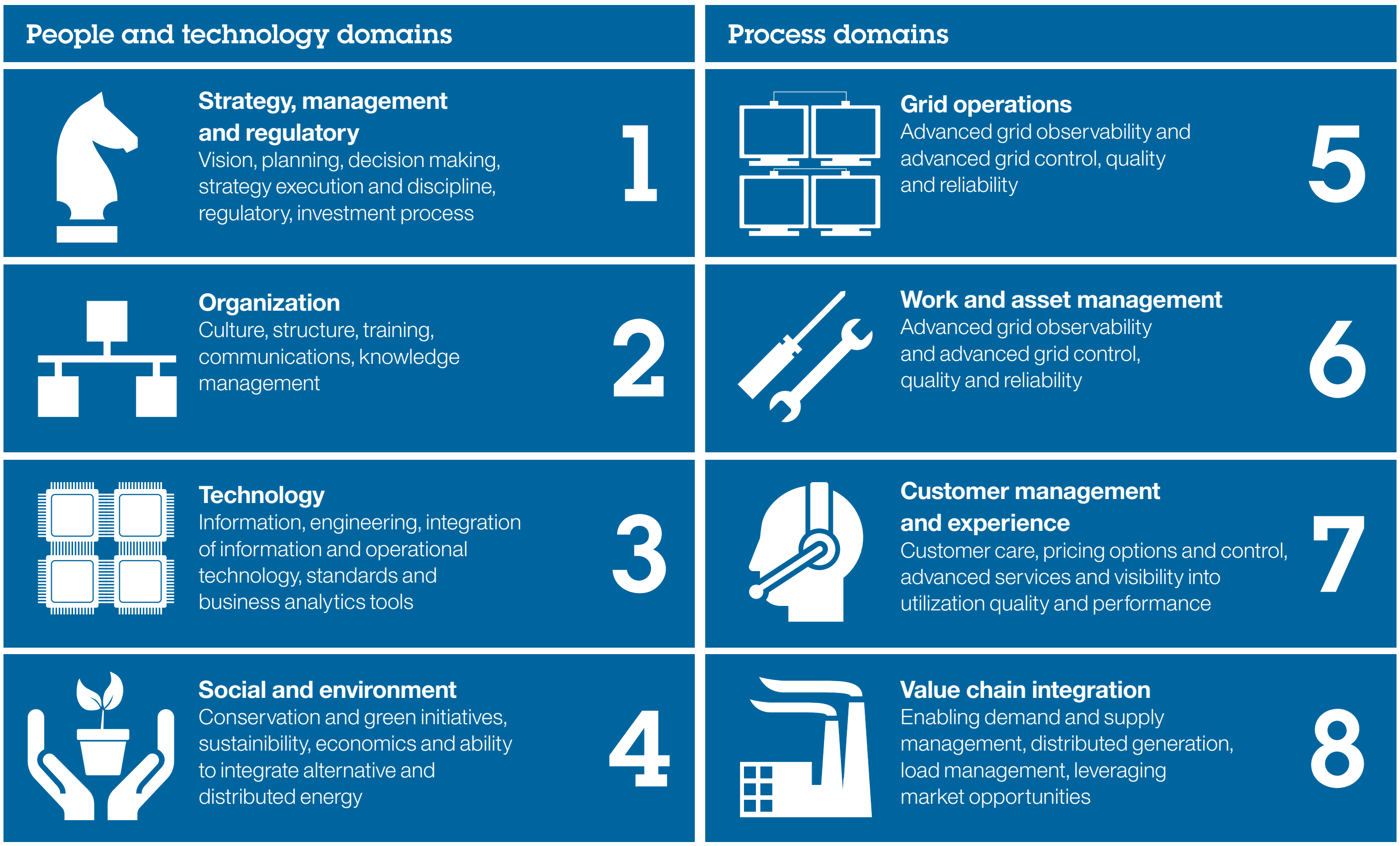


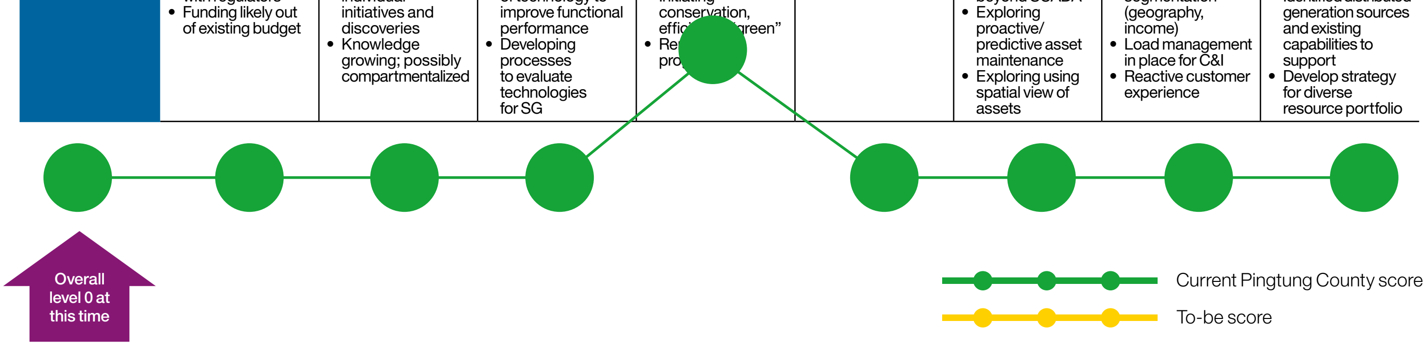
Figure D3: IBM SMGG – eight domains

There is a goal for Pingtung County's renewable energy and microgrid to reach Level 3 at the end of Phase 2 (Production)

SGMM	Strategy, management and regulatory	Organization and structure	Technology	Societal and environmental	Grid operations	Work and asset management	Customer management and experience	Value chain integration
5. Innovating next wave improvements	• Overall strategy expanded due to SG capabilities • Optimized rate design/regulatory policy (most beneficial regulatory treatment for investments made) • New business model opportunities present themselves and are implemented.	• Collaboratively engage all stakeholders in all aspects of transformed business • Organizational changes support new ventures and services that emerge • Entrepreneruial mind set, culture of innovation	• Autonomic computing, machine learning • Pervasive use and leadership on standards • Leader and influence in conferences and industry group • Leading edge grid stability systems	• Actualize the "triple bottom line" – (financial, environmental and societal) • Customers enabled to manage their own usage (tools and self-adaptive networks) • Tailored analytics and advice to customers • Managing distributed generation	• Grid employs self-healing capabilities • Automated grid decisions system wide (applying proven analytic based controls) • Optimized rate design/regulatory policy • Ubiquitous system wide dynamic control	• Optimizing the use of assets between and across supply chain participants • Just in time retirement of assets • Enterprise-wide abstract representation of assets for investment decisions	• Customer management of end-to-end energy supply and usage level • Outage detection at residence/device • Plug-n-play customer based generation • Near real-time data on customer usage • Consumption level by device available • Mobility and CO2 programs	• Coordinated energy management and generation throughout supply chain • Coordinated control of entire energy assets • Dispatchable recourses are available for increasingly granular market options (Locational Marginal Pricing)
4. Optimizing enterprise wide	• SG drives strategy and influences corporate direction • SG is a core competency • External stakeholders share in strategy • Willing to invest and divest, or engage in JV and IP sharing to execute strategy • Now enabled for enhanced market driven or innovative regulatory funding schemes	• Integrated systems and control drive organizational transformation • End to end grid observability allows organizational lever… stak… • Orga… …attens • Signifi… restructuring likely occurs now (tuning to leverage new SG capabilities and processes)	• Data flows end-to-end (customer to generation) • Enterprise business processes optimized with strategic IT architecture • Real world aware systems – complex event processing, monitoring and control • Predictive modeling and near real-time simulation, analytics drives optimization • Enterprise-wide security implemented	• Collaboration with external stakeholders • Environmentally driven investments (aligned with SG strategy) • Enviro… …l score… repor… • Progra… …shave peak demand • Ability to scale DG units • Available active management of end user energy uses and devices	• Integration into enterprise processes • Dynamic grid management • Tactical forecasts based on real data • Information available across enterprise through end-to-end observability • Automated decision making within protection schemes (leveraging increased analytics capabilities and context)	• Enterprise view of assets: location, status, interrelationships, connectivity and proximity • Assets models reality based (real data) • Optimization across fleet of assets • CBM and predictive management on key components	• Usage analysis within pricing programs • Circuit level outage detection/notification • Net billing programs in the home • Automated response to pricing signals • Common customer experience integrated across all channels • Recent customers usage data (daily) • Behaviour modeling augments customer segmentation	• Energy resources dispatchable/ tradable, utility realizes gain from ancillary services (power on demand) • Portfolio optimization modeling expanded for new resources and real time markets • Ability to communicate with Home Ability Network, incl. visibility and control of customer large demand appliances
3. Integrating cross functional	• Completed SG strategy and business case incorporated into corp. strategy • SG governance model deployed • SG leader(s) (with authority) ensure cross LOB appl… …f SG • Ma… con… …ith regula… to make and fund SG investments • Corp. strategy expanded to leverage new SG enabled service or offerings	• SG is driver for org. change (addressing aging workforce, culture issues) • SG measures on balanced scorecard • Performance and compensation linked to SG success • Consistent SG leadership cross LOBs • Org. is adopting a matrix or overlay structure • Culture of collaboration and integration	• SG impacted business processes aligned with IT architecture across LOBs • Common architectural framework – standards, common data mod… • Use… …ed intell… analytic… • Advanced sensor plan (PMUs) • Implementing SG technology to improve cross LOB performance • Data comms. detailed strategy/ tactics	• Active programs to address issue • Segmented and tailored information for customers – including environmental and social benefits • Programs to encourage off-peak usage • Integrated reporting of sustainability and impact • Synthesize triple bottom line view across LOBs	• Sharing data across functions/ systems • Implementing control analytics to support decisions and system calculations • Move from estimation to fact-based… …g • The c… meter… …s an essential grid management "sensor" • New process being defined due to increased automation and observability	• Efficient inventory management utilizing real asset status and modelling • Component performance and trend analysis • Developing CBM on key comp… • Integ… …M to ass… …, mobile work force and work order creation • Tracking inventory, source to utilization • Modelling asset investments for key components based on SG data	• High degree customer segmentation • Two-way meter, remote disconnect and connect, and remote load control • Outage detection at substation • Common customer experie… • Custo… particip… in DR enabled • New interactive products/services • Predictive customer experience	• Integrated resource plan includes new targeted resources and technologies (DR, DG, volt/VAR) • Enabling market and consumption information for use by customer energy mgmt systems • New re… availab… substit… market products to meet reliability objectives

Figure D4: The assessment of current and future Pingtung County smart microgrid maturity level

2. Functional investing	• Integrated vision and acknowledgement • Initial strategy/ business plan approved • Initial alignment of investments to vision • Distinct SG set-aside funding/ budget • Collaboration with regulators and stakeholders • Commitment to proof of concepts • Identify initial SG leader	• New vision influences change • Organizing more around operational end-to-end processes (breaking silos) • Matrix teams for planning and design of SG initiatives across LOBs • Evaluating performance and compensation for smart grid	• Tactical IT investments aligned to strategic IT architecture across LOB • Common selection process applied • Common architectural vision and commitment to standards across LOBs • Conceptual data comms. strategy • IED connectivity and business pilots • Implementing information security	• Established energy effiency programs for customers • "Triple bottom line" – (financial, environmental and societal) • Environmental proof of concepts underway • Consumption information provided to customers	• Initial distribution to substation automation projects • Implementing advanced outage restoration schemes • Piloting remote monitoring on key assets (RAM) for manual decision making • Expanding and investing in extended communications networks	• Developing mobile workforce strategy • Approach for tracking, inventory and event history of assets under development • Developing an integrated view of GIS and RAM with location, status and nodal interconnectivity	• Piloting AMI/AMR • Modeling of reliability issues to drive investments for improvements • Piloted remote disconnect/connect • More frequent customer usage data • Assessing impact of new services and delivery processes (HAN) • Research on how to reshape the customer experience through SG • Broad customer segmentation (e.g. geography, income) • Load management in place for C&I • Reactive customer experience	• Introducing support for home energy management systems • Redefine value change to include entire eco-system (RTOs, customers, suppliers) • Pilot investments to support utilization of a diverse resource portfolio • Programs to promote customer DG
1. Exploring and initiating	• Developing first SG vision • Support for experimentation • Informal discussion with regulators • Funding likely out of existing budget	• Articulated need to change • Executive commitment to change • Culture of individual initiatives and discoveries • Knowledge growing; possibly compartmentalized	• Exploring strategic IT arch. for SG • Change control process for IT for SG • Identifying uses of technology to improve functional performance • Developing processes to evaluate technologies for SG	• Awareness of issues and utility's role in addressing the issues • Environmental compliance • Initiating conservation, effic[illegible]green" • Re[illegible] pro[illegible]		• Conducting value analysis for new systems • Exploring RAM (Remote Asset Monitoring), beyond SCADA • Exploring proactive/ predictive asset maintenance • Exploring using spatial view of assets	• Research on how to reshape the customer experience through SG • Broad customer segmentation (geography, income) • Load management in place for C&I • Reactive customer experience	• Identified assets and programs within value chain to facilitate load management programs • Identified distributed generation sources and existing capabilities to support • Develop strategy for diverse resource portfolio



Pioneering 5 Optimizing 4	**Smart grid phases** • Integrated scheduling and coordination of distributed generation and storage • More accurate energy forecasting • Device-level energy use forecasting • Renewable asset management • Customer experience • Effective use of energy storage • Advanced predictive analytics
Integrating 3 Enabling 2 Initiating 1 Default 0	**Production phase** • Augment capacity with additional resources: solar, wind and biogas • Integrate storage and energy management system capability • Connect to Taiwan Power Company grid • Add additional monitoring, control, KPI and reporting **Demonstration site phase** • Build solar and wind generation infrastructure • Install integrated monitoring capability (dashboard)

Figure D5: Association of the level of maturity with the different phases of Pingtung smart microgrid

E. Glossary

Combined heat and power (CHP) (also known as "cogeneration" or "trigeneration"): Energy systems that supply both electricity and thermal energy.

Demand response (DR): Energy loads capable of being reduced or curtailed under certain conditions.

Distributed energy resource (DER): Any form of decentralized generation, storage or demand management capability.

Distributed generation (DG): A small power plant located near an end-use customer, often interconnected with the low-voltage utility distribution grid (versus the high-voltage transmission system).

Dynamic microgrid: A portion of a distribution grid that has the ability to independently separate itself from the main grid when in duress, be able to sustain itself in a stable manner for extended periods of time by creating a balance between supply and demand within its boundaries then reattach itself to the main grid once normal operation has been achieved.

Energy management system (EMS): Software and hardware for balancing energy supply (including storage) and demand to maintain stable operations.

Integrated Operations Control Center (IOCC): Offers integrated data visualization, real-time collaboration and deep analytics that can help city agencies prepare for problems before they arise and coordinate and manage problems as they occur, enhancing the ongoing efficiency of city operations. Executive dashboard capabilities give decision makers a real-time, unified view of operations so they can see who and what resources are needed and available. Cities can share information instantly across agency lines to accelerate problem response and improve project coordination.

Microgrid: A small energy system capable of balancing captive supply and demand resources to maintain stable service within a defined boundary.

Supervisory Control and Data Acquisition (SCADA): Consists of data acquisition (that is, sensing and communication), data processing, remote control of mechanical devices (that is, switches), event processing and other data analysis functions required to support the automated operation of a system. On a microgrid, SCADA may be deployed to monitor and control electric and/or heat generation, storage devices, distribution equipment and other ancillary services, such as capacitors and other Volt-Ampere Reactive (VAR)-control devices.

Remote terminal unit (RTU): A microprocessor-controlled electronic device that interfaces objects in the physical world to a distributed control system or SCADA system by transmitting telemetry data to a master system.

ICT: Information and Communication Technology

IBM Corporate Citizenship & Corporate Affairs
1 New Orchard Road
Armonk
NY 10504

Produced in the United States of America
March 2014