Introduction to EPGC

Experimental Power Grid Centre
(previously SINERGY Centre)

San Diego Microgrid Symposium
17th September 2009

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Energy R&D Initiatives in Singapore

Energy for Growth: National Energy Policy Report (Nov 2007): *Six Key Strategies*

1. **Promote Competitive Energy Markets**
2. **Diversify Energy Supplies**
3. **Improve Energy Efficiency**
4. **Develop Energy Industry and Invest in Energy R&D**
5. **Step up International Cooperation**
6. **Develop Whole-of-Government Approach**

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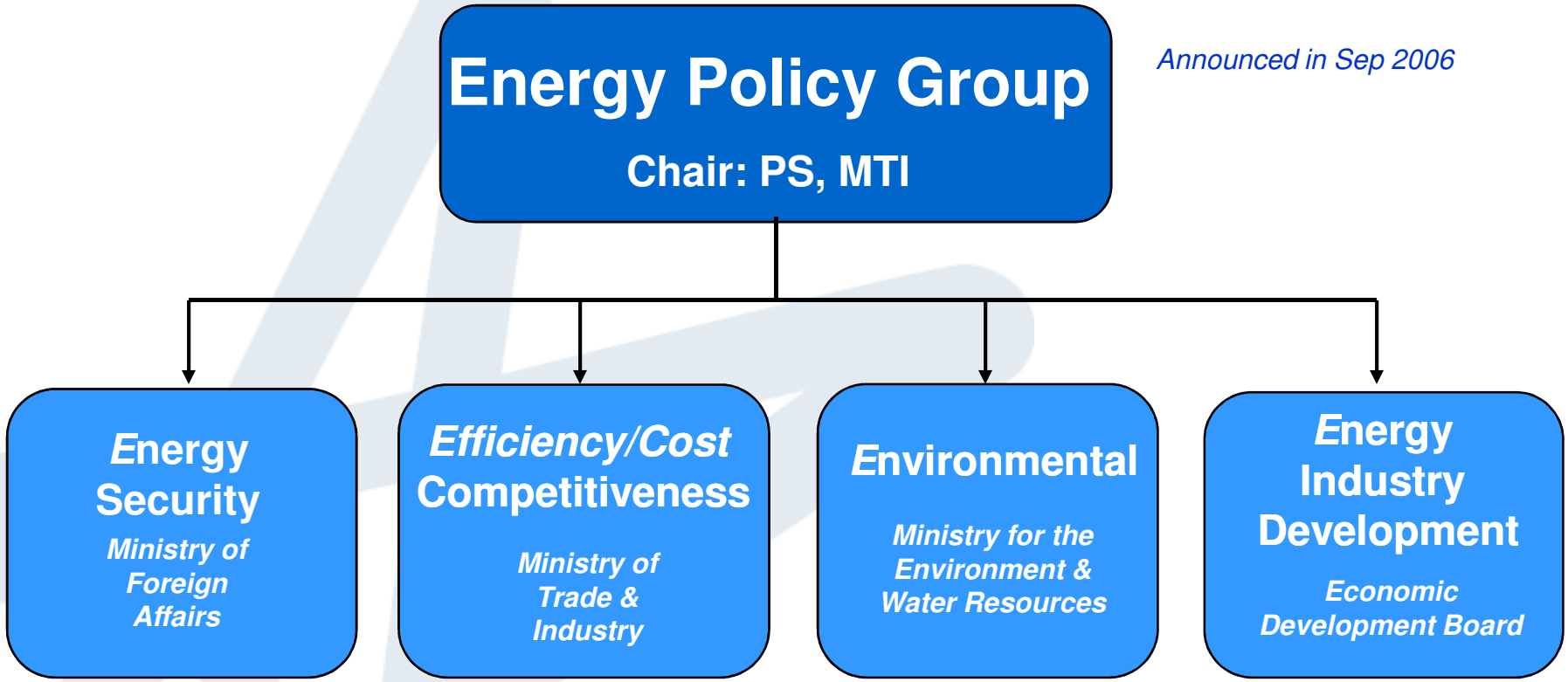
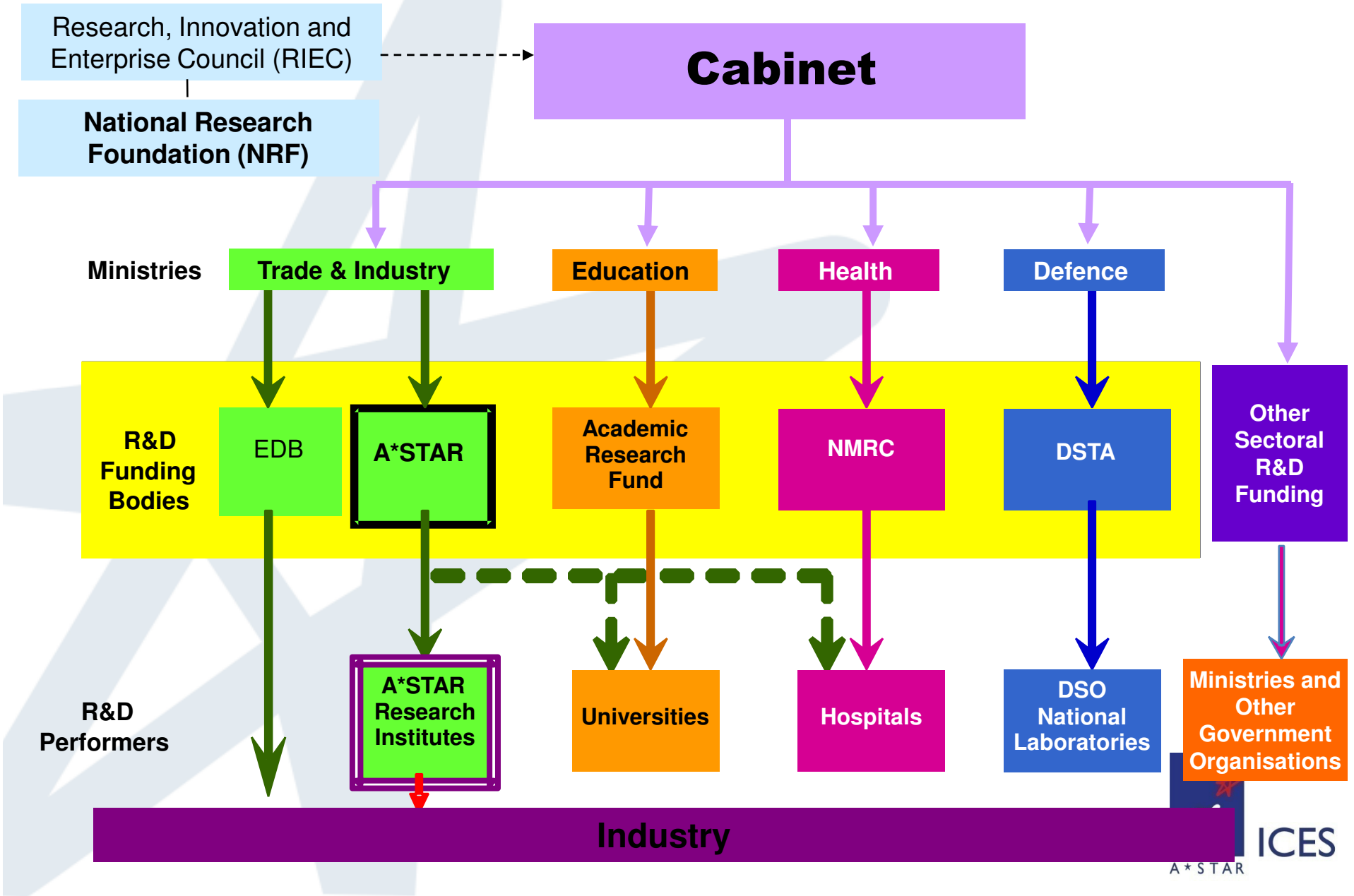
Inter-Ministry Energy Policy Group



SINGAPORE
Land Transport Authority
Building and Construction Authority
EDB SINGAPORE
ENERGY MARKET AUTHORITY
ie Singapore
INTERNATIONAL ENTERPRISE SINGAPORE
jtc Corporation
MAS
National Environment Agency
SPRING singapore
MINISTRY OF FOREIGN AFFAIRS SINGAPORE
Ministry of the Environment and Water Resources
MINISTRY OF FINANCE SINGAPORE
Ministry of Trade and Industry
MOT MINISTRY OF TRANSPORT

National R&D Framework



Existing public sector Energy RD&D programs/ initiatives

- **National Research Foundation / EDB**
  - Clean Energy Program ($170m)
  - Clean Energy Research & Testbedding (CERT)
- **A*STAR**
  - Sustainable Development R&D Programme
- **IHLs**
  - NUS –Solar Energy Research Institute of Singapore (SERIS), Energy Sustainability Unit (ESU), etc
  - NTU – Energy Research Institute@ NTU (ERI@N), Smart Energy Centre, and various other Energy-related initatives/centre
  - Polytechnics – various smaller centres and initiatives in clean energy
- **EMA**
  - Proposed P Ubin energy/microgrid testbedding
  - Electric Vehicle and Intelligent Energy System Task Forces
- **MND/BCA**
  - Research Fund for the Built Environment ($50 m), including Zero Energy Building, eco-city interests etc.
- **MEWR/NEA**
  - Innovation for Environmental Sustainability Fund
- **MPA**
  - Maritime Innovation & Technology Fund (MINT) ($100m) – includes new Maritime Energy and Environment Programme

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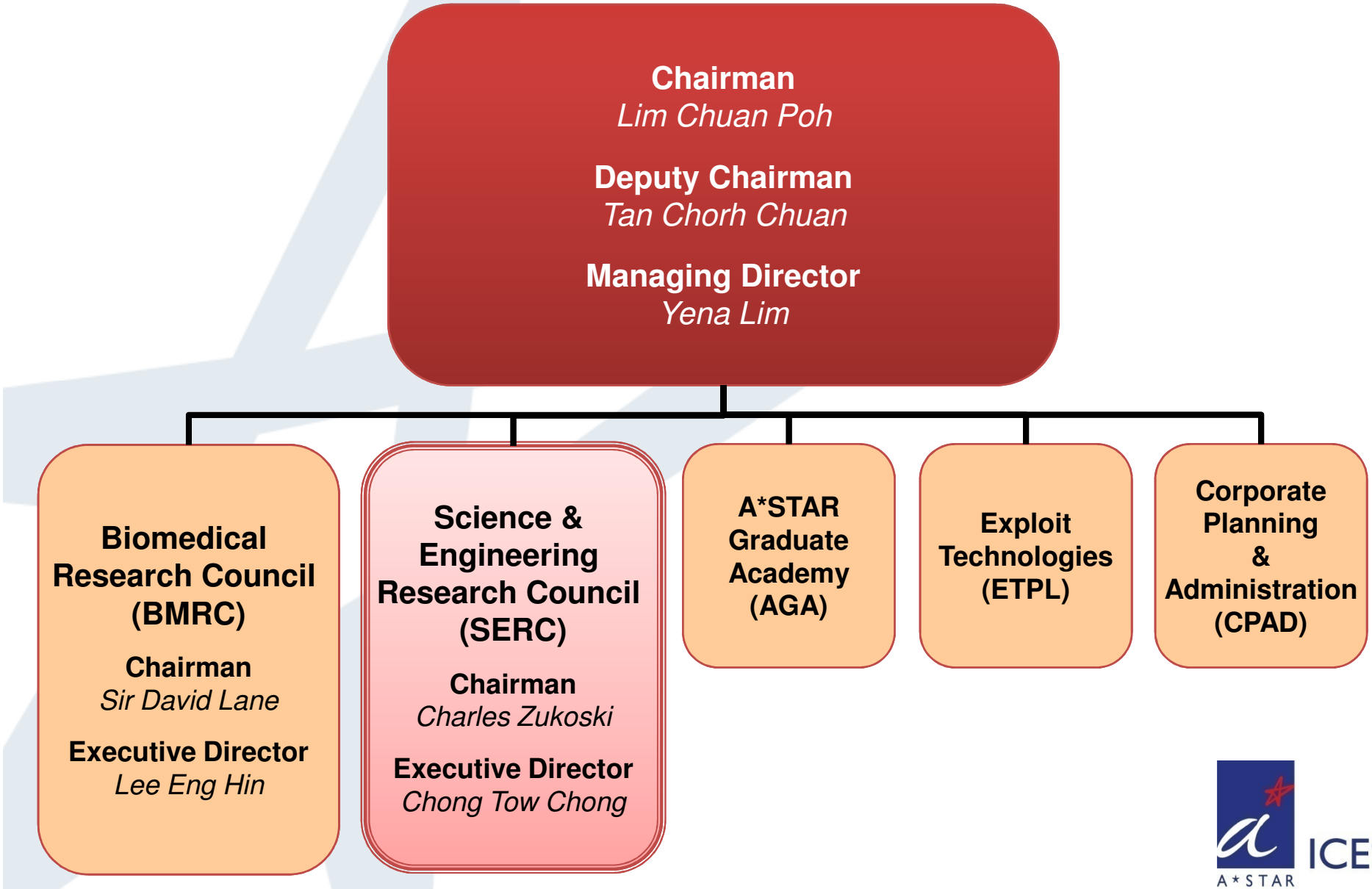
Clean energy RD&D initiatives under Clean Energy Program Office (CEPO)

- Cluster development – hugely successful with important new solar and other clean energy investments such as REC, Norsun etc.
- Solar Energy Research Institute of Singapore (SERIS) , headed by Prof J Luther (former Director of ISE, Fraunhofer), set up in Apr 08 (S$130 m) in NUS
- Centre for Sustainable Energy Research (CESR), part of Energy Research Institute@NTU
- Clean Energy Research Program (S$50m over 5 years)
  - Competitive call – 3rd call in progress
  - A "bottoms-up" approach
- CERT program (for public sector facilities) – initial sites at Singapore Polytechnic, BCA ZEB, Marina Barrage, Gardens by the Bay, HDB precinct, etc. (S$18m)
- Solar Capability Scheme for private sector adoption of solar technologies (S$20 m)
- Clean energy scholarships and new educational programs in polytechnics and universities (S$15 m)
- Incubation of new start-ups

EDB SINGAPORE · Building and Construction Authority · National Environment Agency · Energy Market Authority · Agency for Science, Technology and Research · ie Singapore International Enterprise Singapore · MTI Ministry of Trade and Industry Singapore · Ministry of the Environment and Water Resources · MND Singapore · A*STAR ICES

A*STAR Organization Structure



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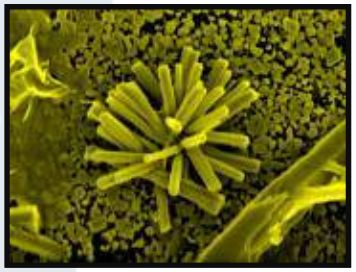
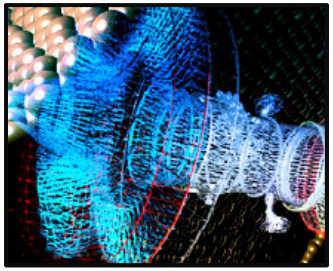
SERC Research Institutes and Centres

Institute of Microelectronics (IME)



Institute of Materials Research & Engineering (IMRE)



Institute of High Performance Computing (IHPC)

EPGC (under ICES)

National Metrology Centre (NMC)

1989 1991 1996 1997 2002 2008

Singapore Institute of Manufacturing Technology (SIMTech)

Data Storage Institute (DSI)

Institute for Chemical & Engineering Sciences (ICES)

Institute for Infocomm Research (I²R)

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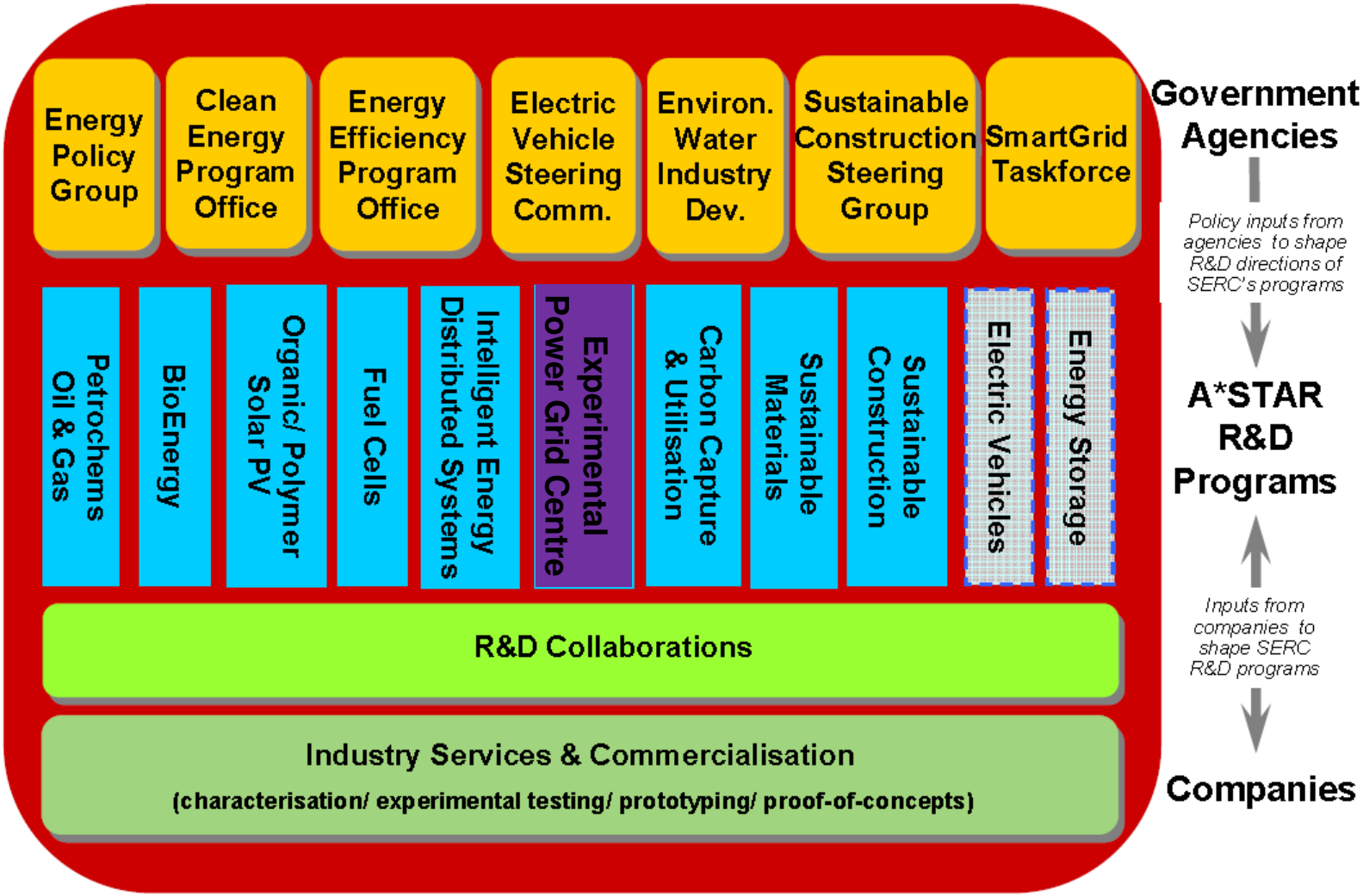
A*STAR Sustainable Development Thematic Research Program



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Overview of EPGC

Mission and objectives

- EPGC will support and conduct research, development, and demonstration (RD&D) of technologies for **intelligent grids, microgrids and distributed energy resources (DERs)**, by developing
  - a world-class research experimental and test infrastructure, and
  - core research competencies in Analysis and Modeling; Interconnection technologies; and Advanced system control and management.

- EPGC will focus on a system-of-systems approach, and through its collaborative research projects and programs, help to accelerate the development, adoption, and implementation of innovative and sustainable energy technologies related to intelligent grids, microgrids and distributed energy resources.

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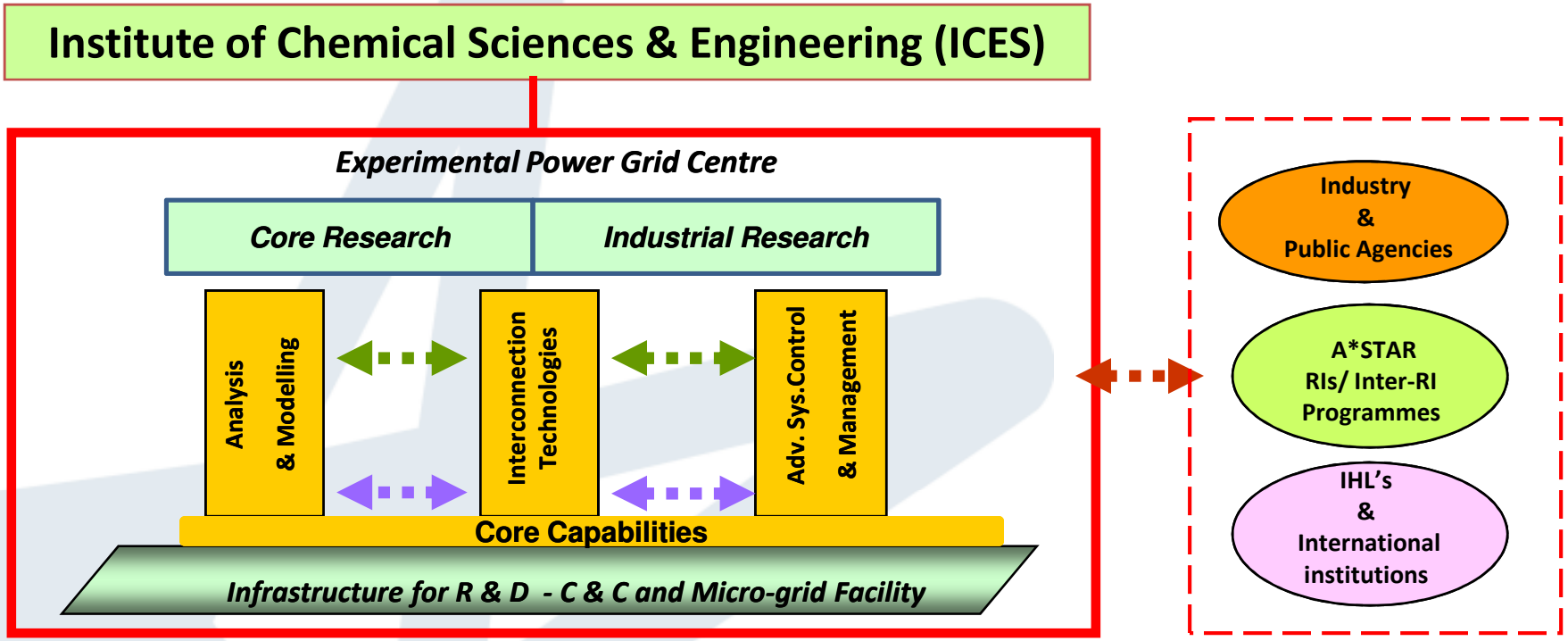
EPGC: Focus on Next-Gen Power Grid Technologies



Core Research Programmes

1. Planning & Design of Micro Grids
2. Micro Grid Stability for islanded and grid connected operation
3. Plug and play capability for intelligent/micro grids

Industrial Research Programmes

Application Areas:

1. Vehicle to Grid
2. Smart Grids
3. Rural/Remote micro Grid
4. Specialised Urban Application
5. Demand response
6. Marine Application

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Infrastructure development

Command & Control Facility (@ FP)

- Recently “completed” (Jan 09) (with basic infrastructure and software)
- Will serve as the control centre for EPGC’s microgrid facility on Jurong Island
- Will have access to other energy systems/facilities operated by collaborators in research community and industry
- The facility will enable
  - ✓ Advanced simulation and modeling of energy and power systems
  - ✓ Real time information exchange
  - ✓ Remote and intelligent monitoring
  - ✓ Prognosis/ Diagnosis / Analysis
  - ✓ Control and Management

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EPGC Jurong Island Infrastructure

- Microgrid and Distributed Energy Test Facility
  (Jurong Island – next to Institute of Chemical & Engineering Sciences)
  - Microgrid for grid-isolated (islanded) or grid-paralleled mode testing
  - Test facilities for distributed energy systems
  - R&D laboratory & incubation space

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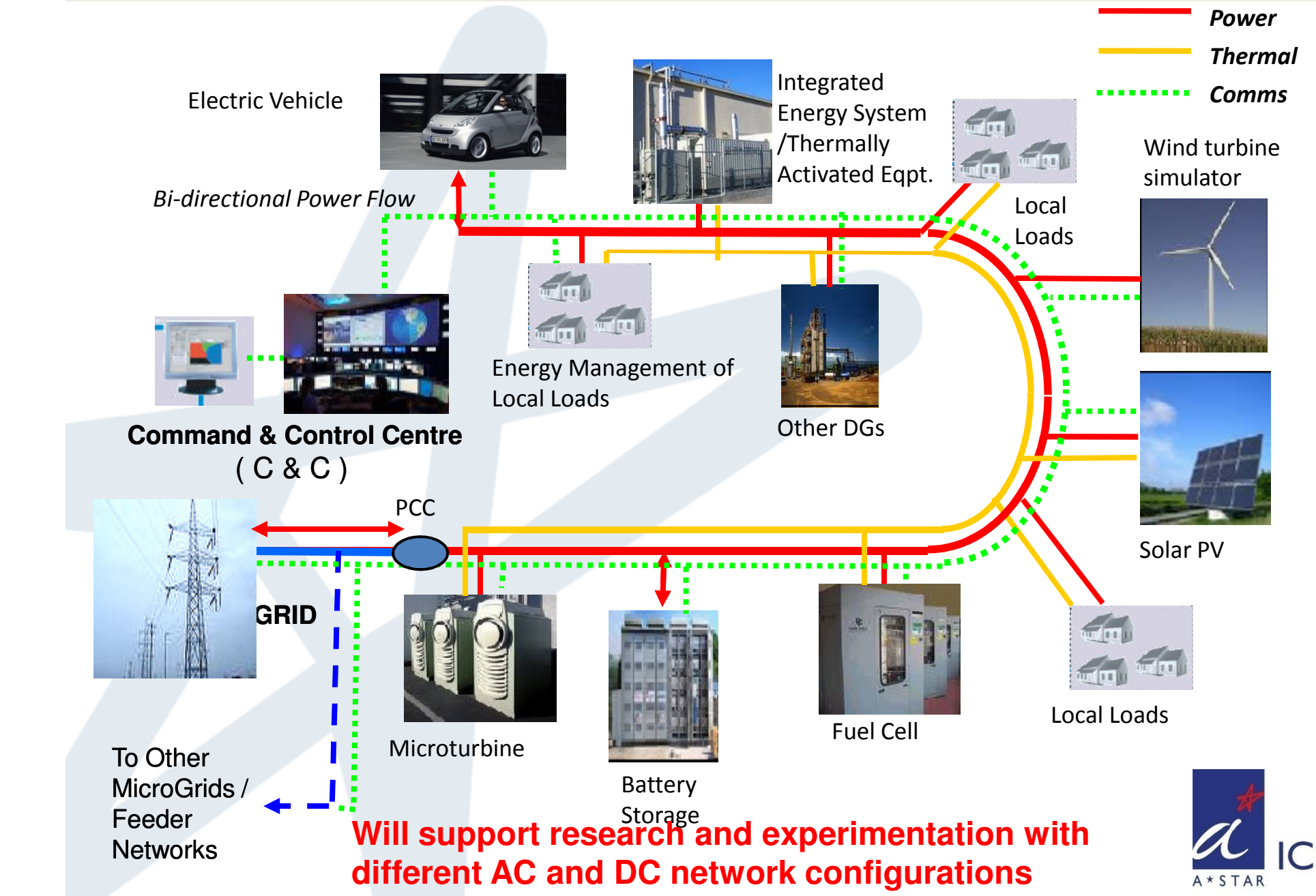
Concept of Microgrid Facility @ JI



Core Capabilities and Research Programmes

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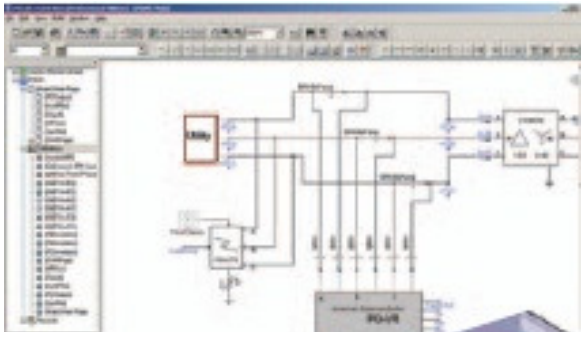
Analysis & Modelling (1)

- Enable the **planning, design and optimization** of systems and solutions that will have improved cost, durability, efficiency, and other performance characteristics such as power quality, stability and carbon emissions
- **Incorporate and integrate empirical knowledge with multi-physics models** (mechanical, thermal, chemical, electrical, electro-chemical) at various levels of granularity, abstraction, complexity and time-frames (ranging from micro-seconds to entire system life cycles), depending on the purpose and objective of the analysis (e.g. for planning, design, optimization, control, prognosis).
- Emphasis will be on analysis and modeling at the **system and system-of-systems-level**, involving primarily electrical power, thermal energy, and information flows



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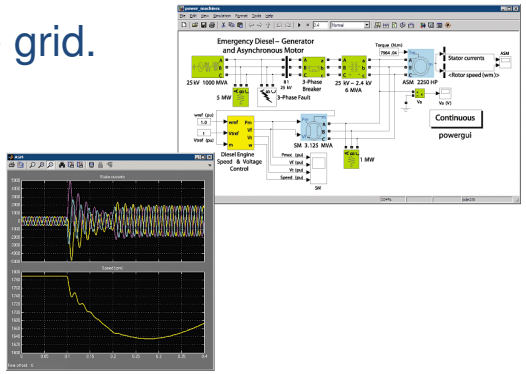
Analysis & Modelling (2)

- Examples of research in analysis and modeling include :
  - ✓ **"System of systems" level analysis and modeling of integrated and distributed electrical/thermal energy systems,** to improve and optimize their configuration, design and performance, and make such systems more "intelligent" and "smart grid ready – to be competitive participants in the energy marketplace.
  - ✓ **Simulating and analyzing the dynamic response of the microgrid** during islanding, resynchronisation, sudden voltage disturbances and unbalanced operating conditions to enable improvements in control and interconnection technologies.
  - ✓ **Modeling vehicle-grid bi-directional electrical power flow and interactions** that will facilitate the development of improved EV charging infrastructure and control systems, and enhancing the potential for EVs to improve the stability and efficiency of the power grid (rather than to de-stabilise it), even at high penetration of EVs or plug-in hybrid vehicles connected to the grid.



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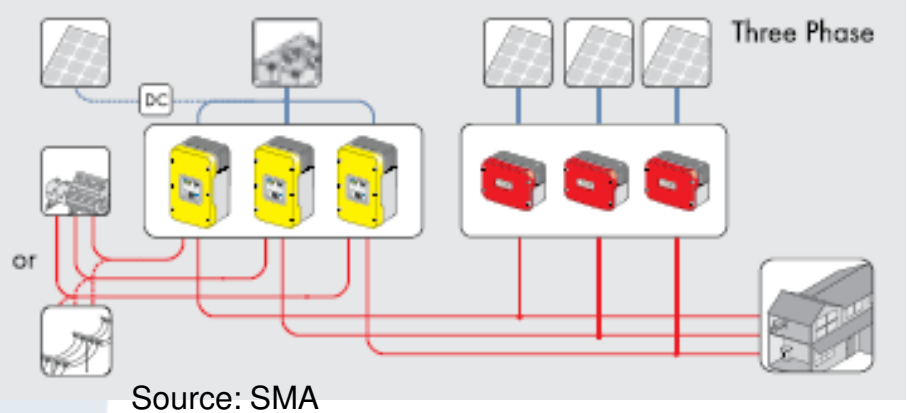
Interconnection Technologies (1)

- Interconnection technologies refer to the class of embedded system technologies (both software and hardware) at the component/device level that enables microgrids, DERs and end-use loads to be interfaced to (other) microgrids and utility grids.
- Include technologies for power conversion (e.g. DC-AC inverters and DC-DC converters), power quality, protection, metering, and switching.
- Interconnection technologies will enable the transfer of both power and control signals bi-directionally between individual DERs and loads, and to other networks, such as the microgrid and main grid.



Source: SMA

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Interconnection Technologies (2)

- Examples of research
  - ✓ **Power Electronics**
    - customizing power electronics modules for advanced power networks
    - developing new algorithms and specialized control modules for existing inverters/converters in DER/microgrid applications to enhance overall power quality
    - power electronics modules and protection systems for V2G applications
  - ✓ **Algorithms development in:**
    - Advanced sensing & communication protocols for intelligent, micro grids
    - Enabling communications between various DERs/Microgrids using novel communications media and protocols
    - New fault detection schemes for islanding/re-synchronization during Microgrid operations
  - ✓ **Fast switchgear technologies (semiconductor based), multi-function protection devices/relays** and **fault limiting technologies**

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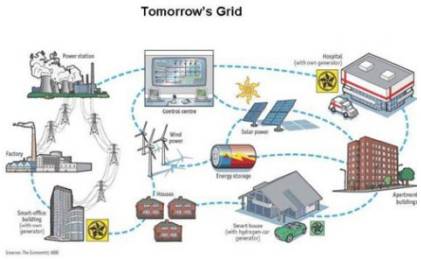
Advanced Control & Management

- Development of improved, flexible and optimized control strategies (both hierarchical and autonomous), for different application objectives while maintaining safe and reliable operation.
- Examples of research include :
  - ✓ **Advanced control and management strategies** for different microgrid network and DER configurations and applications, including for rural communities (islanded mode) and urban environments (grid-connected mode).
  - ✓ **Advanced alternate control strategies such as use of intelligent multi-agents** - embed local intelligence in each DER to enhance control for the transfer of power & energy, between various sources and loads.
  - ✓ **Specialized software algorithms for faults handling, and enhancing protection, network stability and system reliability.**



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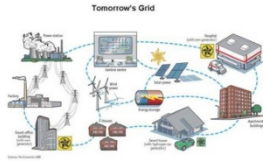
Examples of research projects and activities

- Ongoing research projects
  - Collaborating in several *Intelligent Energy* Distribution *Systems (IEDS) Program* projects with IHLs and I2R
  - Economic and technical analysis of SINERGY Centre's proposed microgrid facility using HOMER (Internal project using software from DOE's NREL)
  - Modeling of SOFC system for integration into power system model of microgrid (internal project)



- Research projects under discussion
  - Microgrid applications in urban centres (Singapore and region) – with international partner (DOE lab)
  - Enhancements to microgrid technologies for rural applications (with industry SME)
  - Monitoring, analysis, and modeling of advanced distributed energy system (with industry MNC)
  - Vehicle-grid integration technologies (with MNC)
- Participation in A*STAR and national level initiatives, such as A*CAR, **EV Task Force**, and **Intelligent Energy Systems Task Force**

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Collaboration in projects under A*STAR Intelligent Energy Distribution Systems (IEDS) $10m Program

Novel sensors / instrumentation

- Voltage collapse monitoring instrument (NTU)
- Open architecture for intelligent power quality monitoring and evaluation (NTU) (Uni. of Canterbury)

Smart and optimized operation and control of distributed energy resources and microgrids

- Power converter & Grid Architectural Design (NTU) (Coy, Aalborg University)
- Modular Distributed Energy Resource Network (NUS) (Coy)
- Microgrid Energy Management System (NTU) (Coy, Imperial College, National Taiwan University of Science & Technology)

Reliable and secure communications and data transmission

- Secure architecture & techniques (I2R) (Purdue, Malaga universities)
- Intelligent wireless sensor network (NUS) (Coy)

Energy trading and billing management systems

- Intelligent Trading, Metering and Billing System (NTU) (Power Coy, Coy)

Energy storage and integrated energy technologies

- A Temperature-cascaded Cogeneration plants (NUS)
- Electrical energy storage by supercapacitors (ICES) (Coy)

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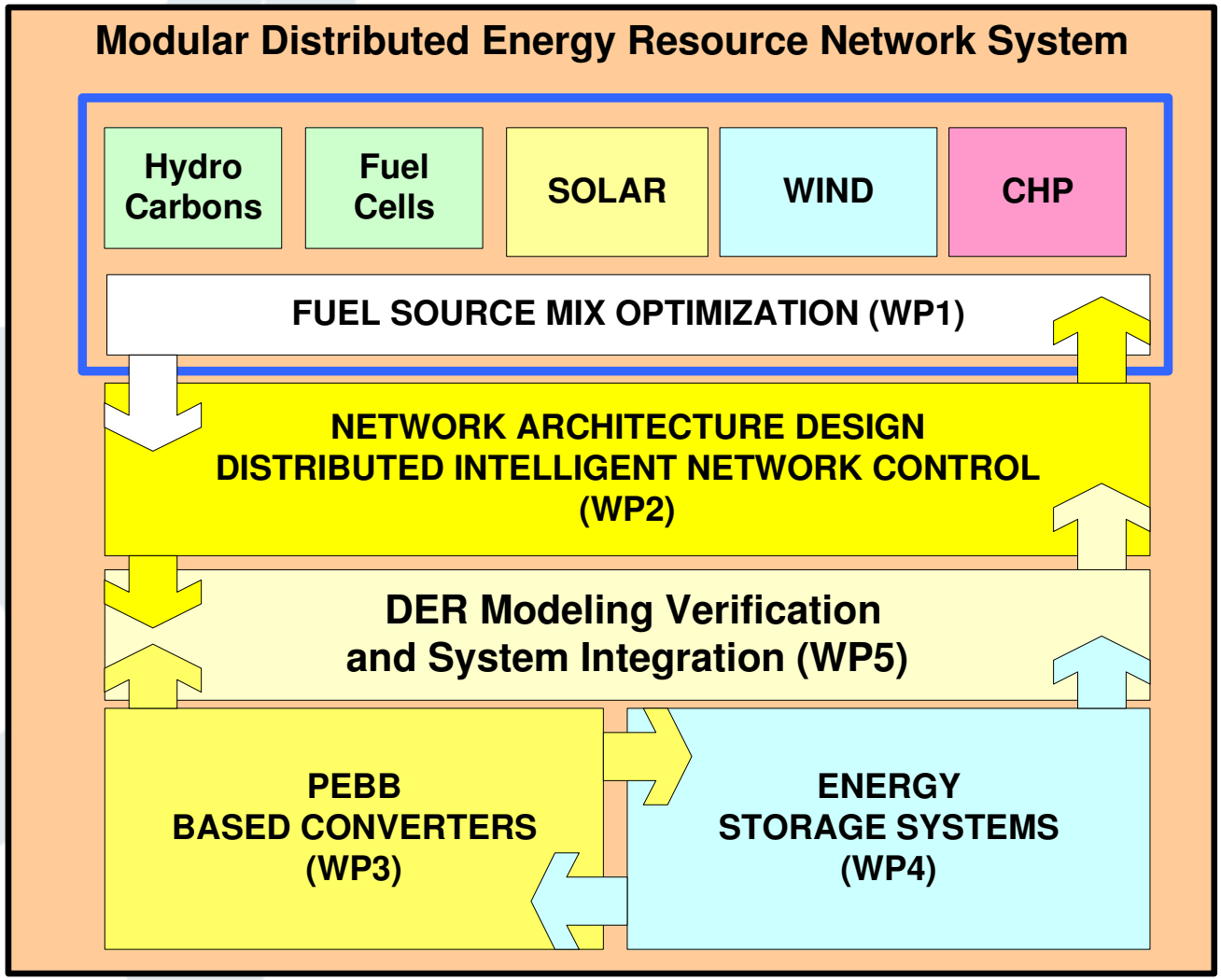
Modular Distributed Energy Resource Network (MODERN)
P/I : A/P Ashwin M Khambadkone (NUS)

A Comprehensive Approach: Work packages synergize to achieve Objectives



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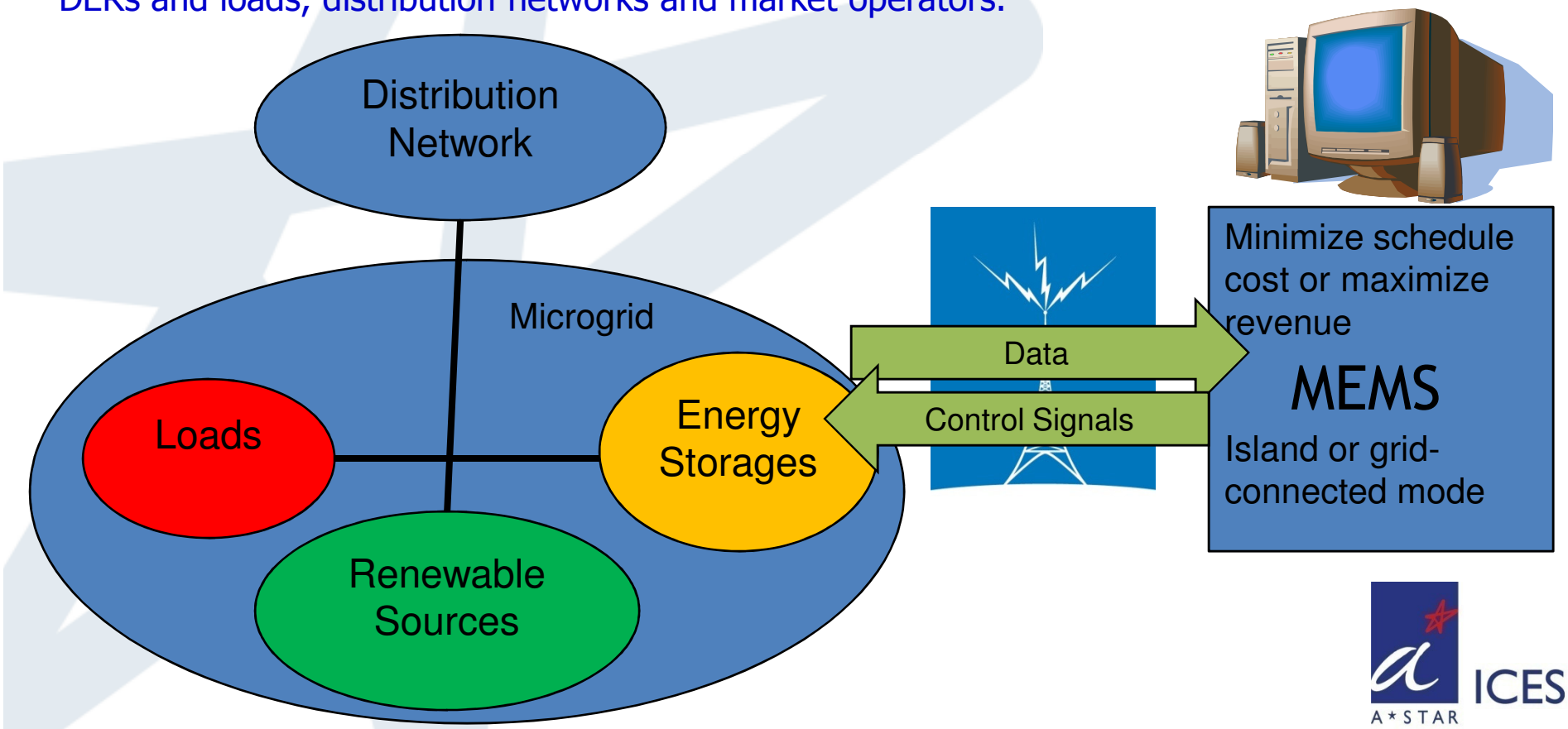
Microgrid Energy Management Systems (MEMS)

PI: A/P Gooi Hoay Beng (EEE/NTU)

The objectives of the project are (i) to design software algorithms and control schemes for minimizing schedule cost or maximizing revenue of MEMS while ensuring its secure operations, (ii) to design hardware controllers and demonstrate how proposed prototype can coordinate and schedule one or more DERs and price-sensitive loads and (iii) to develop a web-based GUI and incorporate sensing and communication devices for interfacing with local DERs and loads, distribution networks and market operators.



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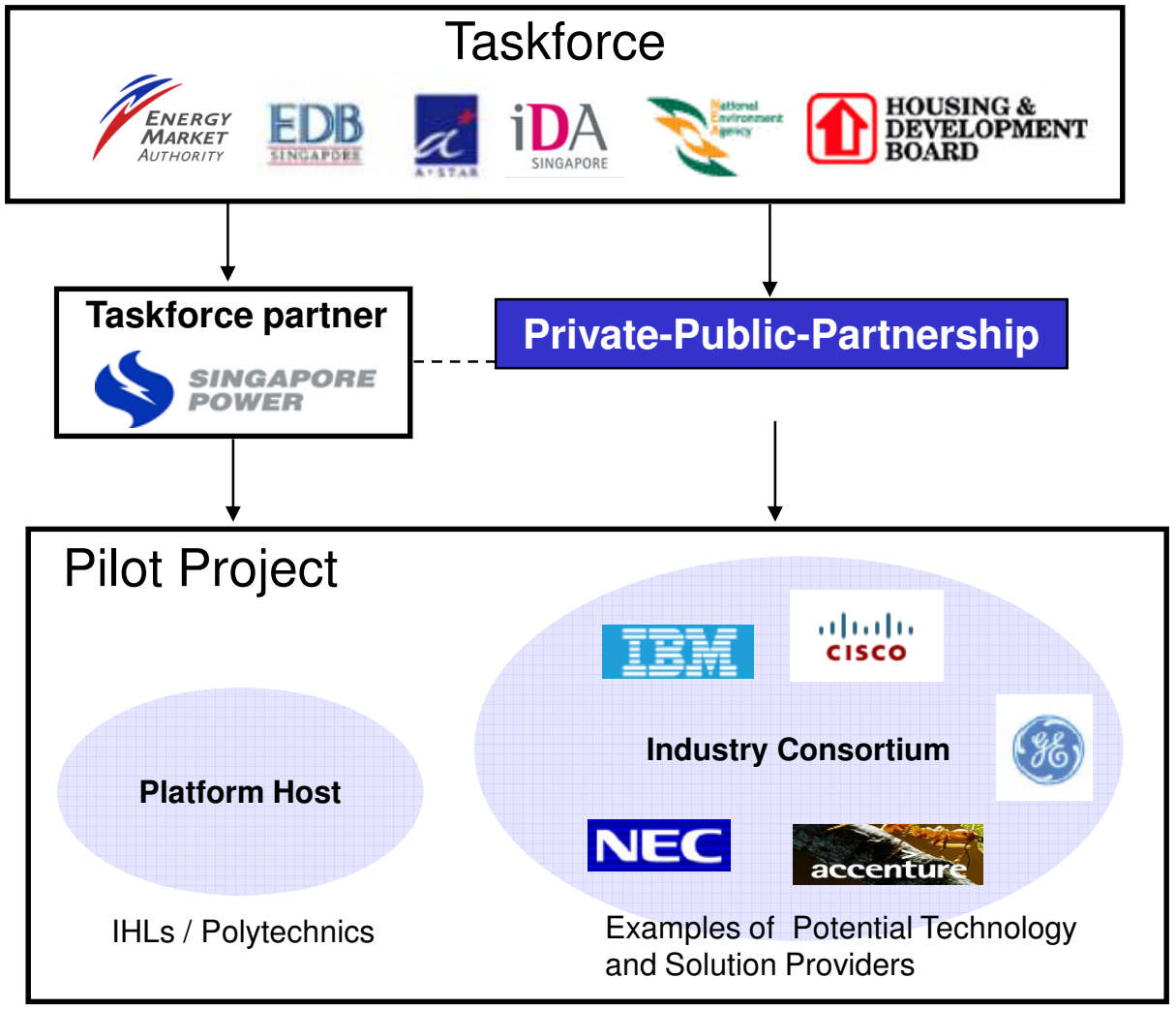
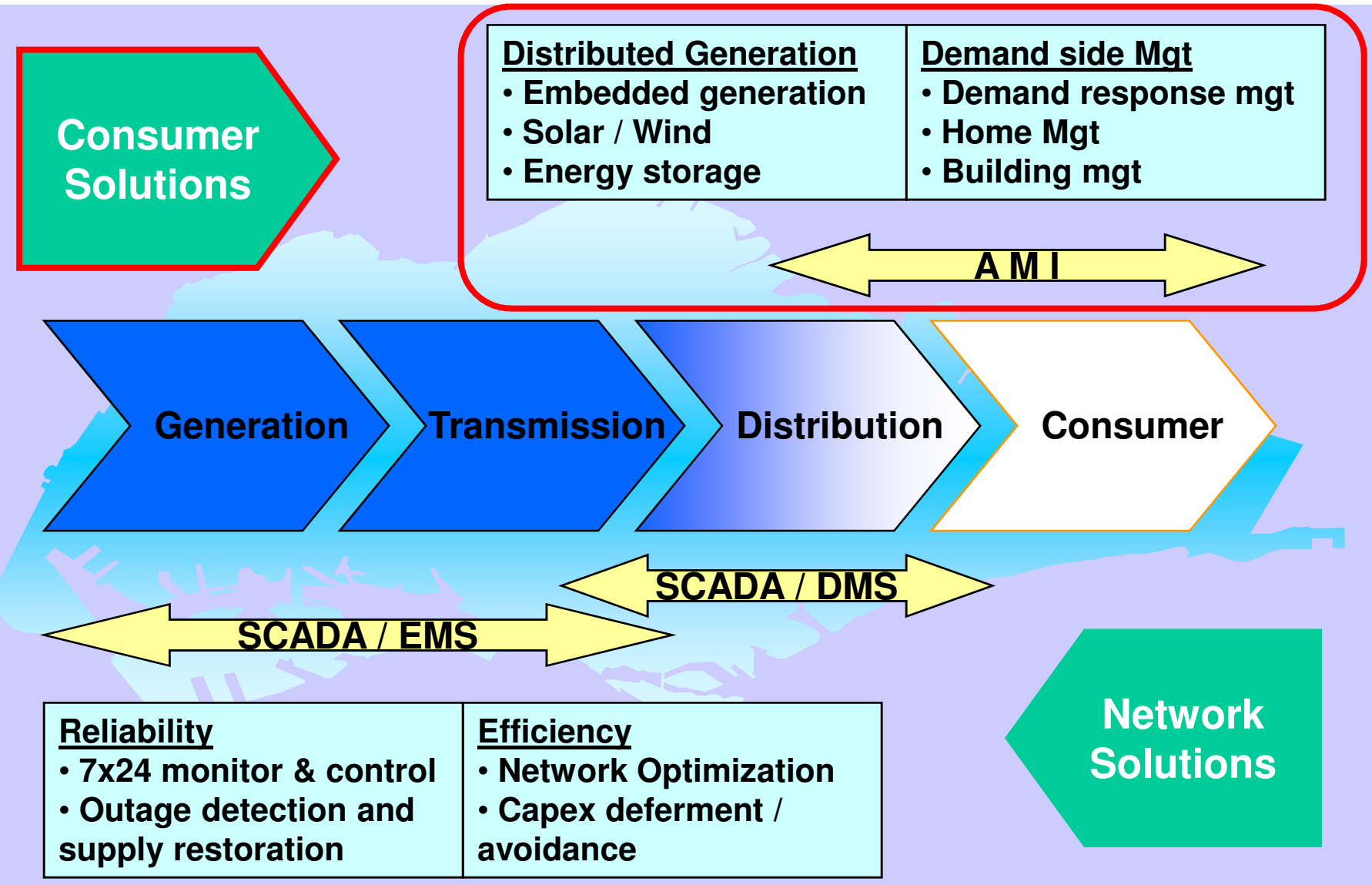
Intelligent Energy System Task Force



Background: Need to Smarten the "Last Mile"



Scope of test-bed (under discussion)

1. **Distribution Automation System**
   monitors and controls two-way electricity flows at selected 22kV and 6.6 kV substations.

2. **Advanced Metering Infrastructure**
   two-way communication flow of accurate real-time information on electricity consumption at the consumer's premises.

3. **Home and Building Management System**
   optimizes the use of electricity in the home and building by monitoring and managing various equipment and appliances.

4. **Distributed Generation and Energy Storage**
   connects seamlessly to the distribution network, including V2G interactions.

5. **Demand Response Management System**
   facilitates the control and reduction of electricity demand of buildings and consumer's premises during periods of high electricity prices.

Thank you