Smart Grid Technology

Prof. S. S. Kanojia

1. Motivation: Policies & Regulations

- **Electricity Act 2003** :
  - Compulsory Unbundling
  - Delicenses generation freely thus encourages distributed generation, Independent Power Producers (IPP) and local Microgrid controllers to play in the market makes distribution more reliable.
- **National Electricity Policy, 2005**
  - Promote competition for optimal pricing of power
- **National Action Plan on Climate Change, 2008**:
  - Promotes renewable energy trading through the power exchange.
- **Power Market Regulations, 2010**
  - Providing a regulatory framework for Competitive markets
- **Indigenous development of 1200 KV UHVAC System**

Motivation: RES Potential in India

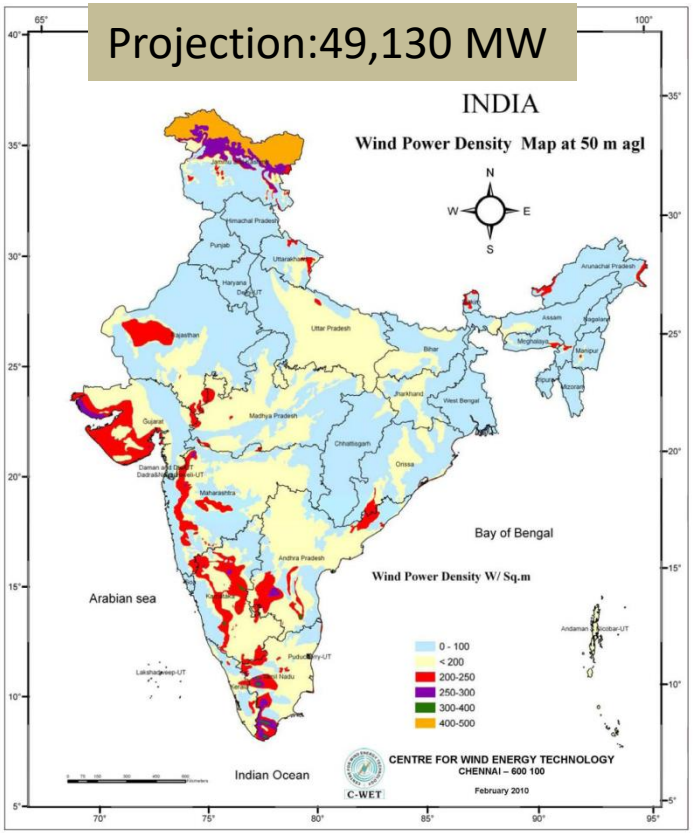


Figure1.1 Wind Energy potential in India[1]

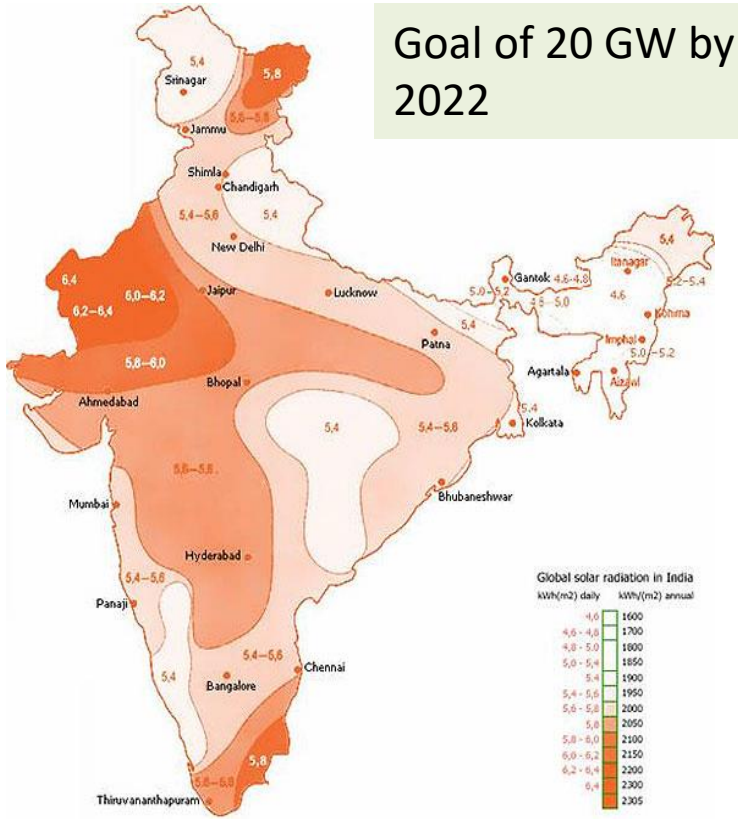
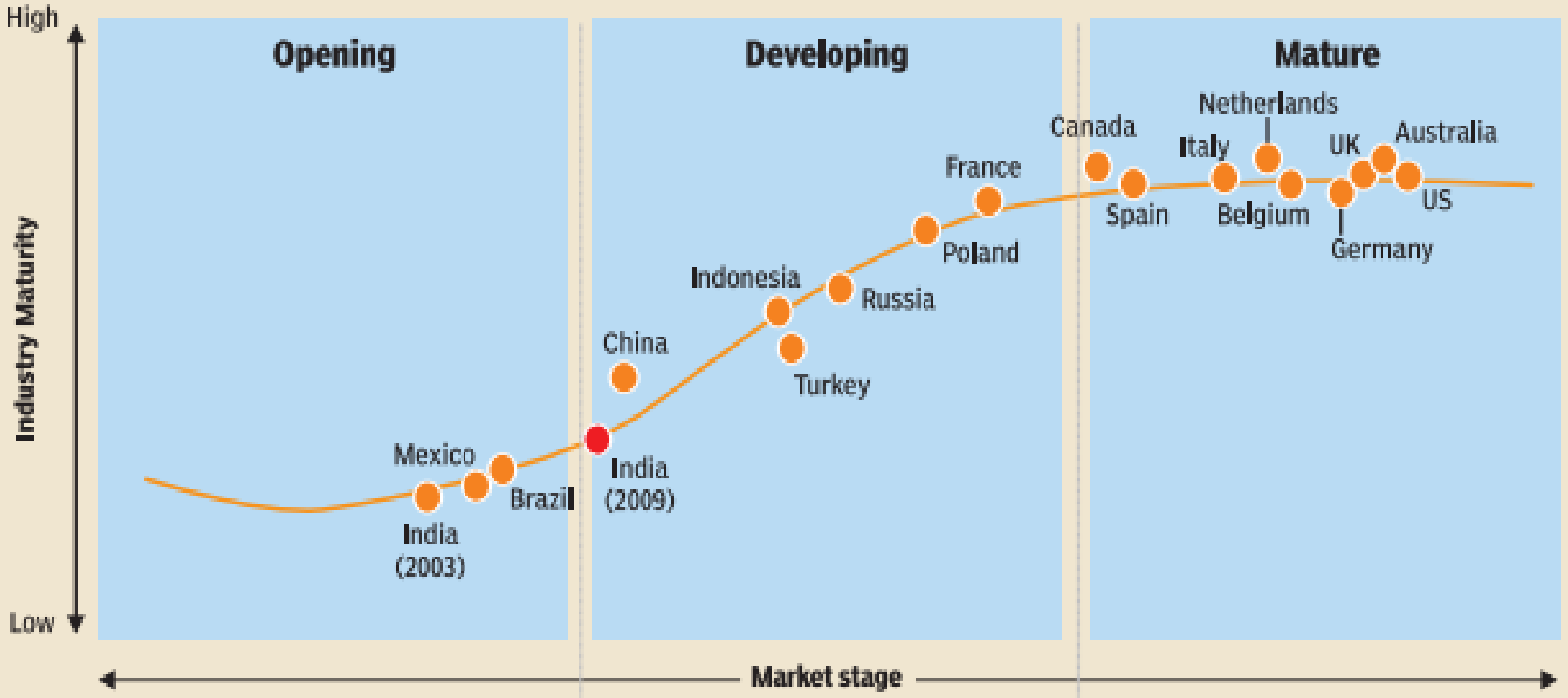


Figure 1.2 Solar Energy potential in India [2]

Industry Maturity[1] Curve



Salient feature			
Regulatory stage	▪ Reforms initiated to emerge from regulated environment ▪ High control involvement of government	▪ Increasing influence of market forces; greater transparency	▪ Highly de-regulated; high degree of influence of market forces
Market characteristics	▪ Unmet/latent demand ▪ Dominance of few players (mainly government agencies)	▪ Increasing competitive intensity ▪ Strong demand & supply growth	▪ Highly competitive ▪ Focus on scale and consolidation Lower demand growth

(1) Industry maturity is based on per capita consumption, consumption growth rate, competitive intensity and stage of regulatory reforms in market. Select countries amongst the top twenty nations by GDP have been reprented in the chart

Source: Business Monitor International, EIA, A.T. Kearney Analysis

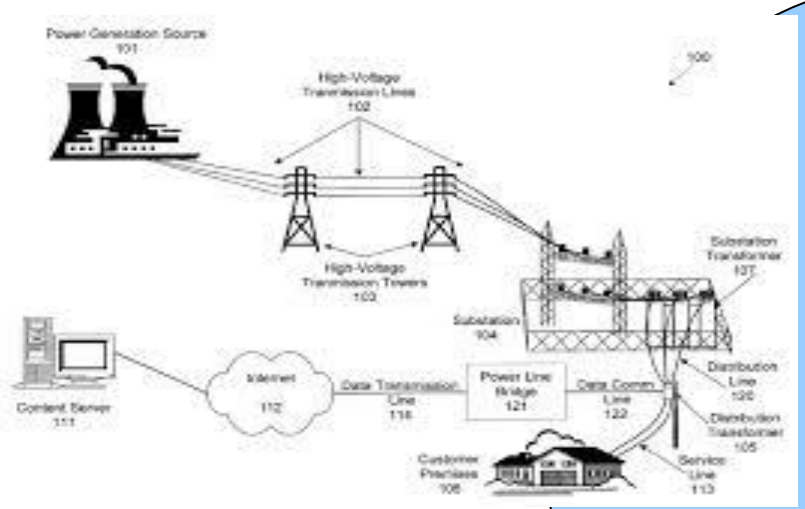
Motivation: Smart Grid in India

- India Smart Grid Forum (ISGF) came in to functioning on May 2010.[3]

- The India Smart Grid Task Force chaired by Mr. Sam Pitroda came into existence with five work groups sharing responsibilities of different tasks[4]

- One of the pilot projects under taken by Uttar Gujarat Vij Company Ltd. (UGVCL) in Gujarat.

Smart Electric Network or ELECTRINET:



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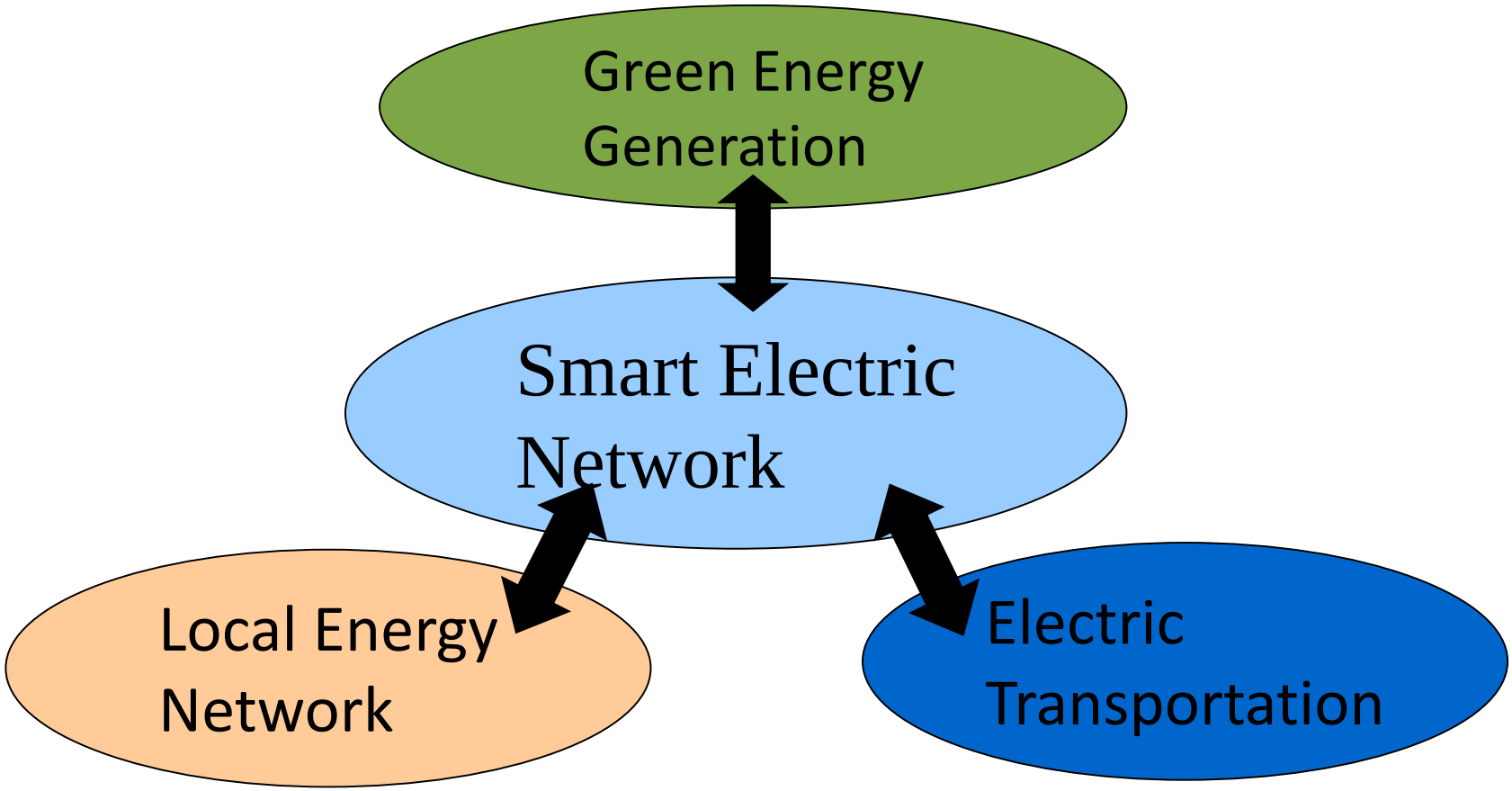
- The ElectriNetwork recognizes the evolution of the power system into a highly interconnected, complex, and interactive network of power systems, telecommunications, the Internet, and electronic commerce applications.
- At the same time, the move towards more competitive electricity markets requires a much more sophisticated infrastructure for supporting myriad informational, financial, and physical transactions between the several members of the electricity value chain that supplement or replaces the vertically integrated utility
- Realizing the ElectriNet depends on developing the IntelliGrid communications architecture to enable connectivity between each element of the ElectriNet with requirements for developing agent-based software systems, which can facilitate the informational, financial, and physical transactions necessary to assure adequate reliability, efficiency, security, and stability of power systems operating in competitive electricity markets.

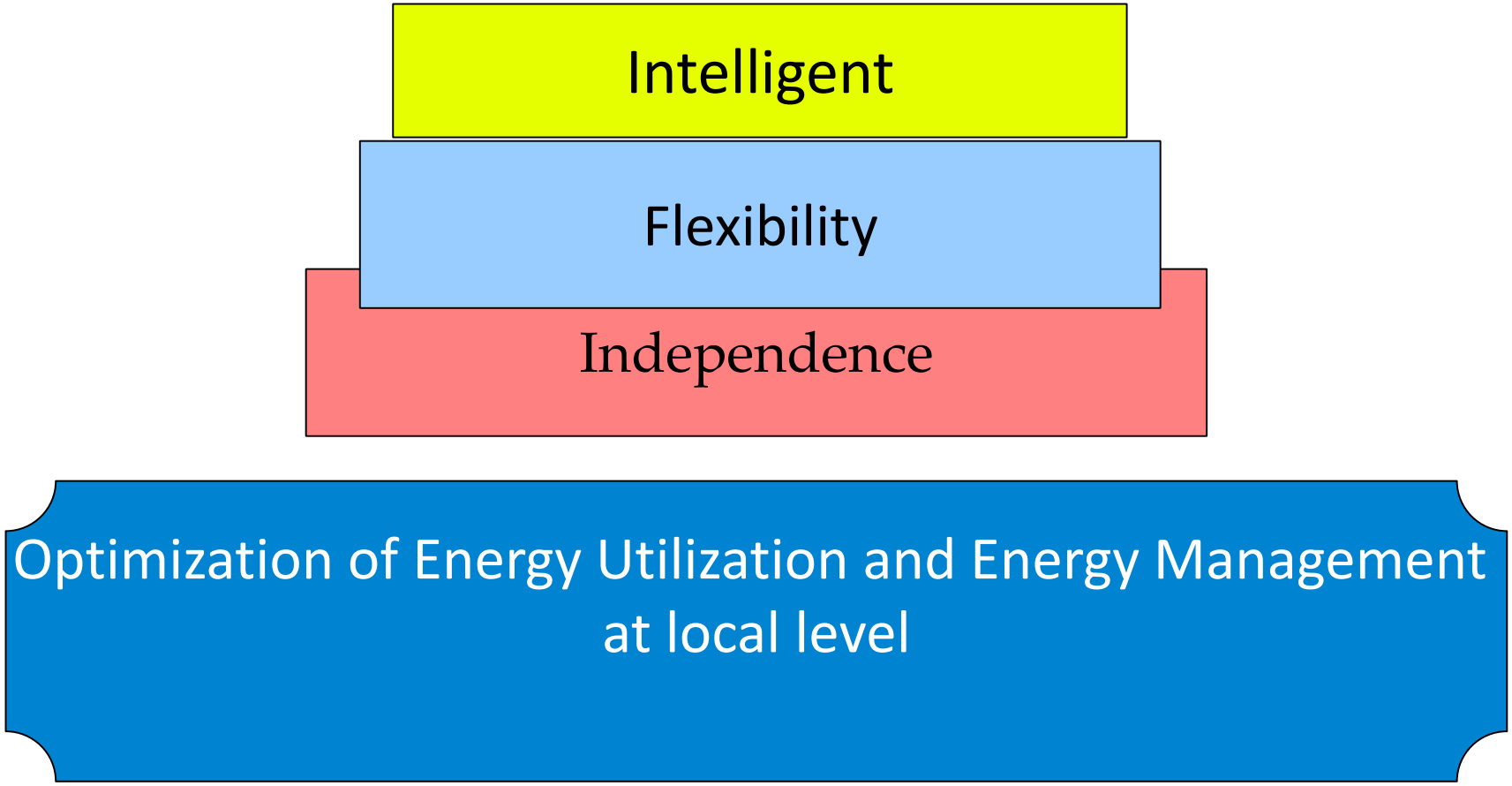
Smart Energy Network

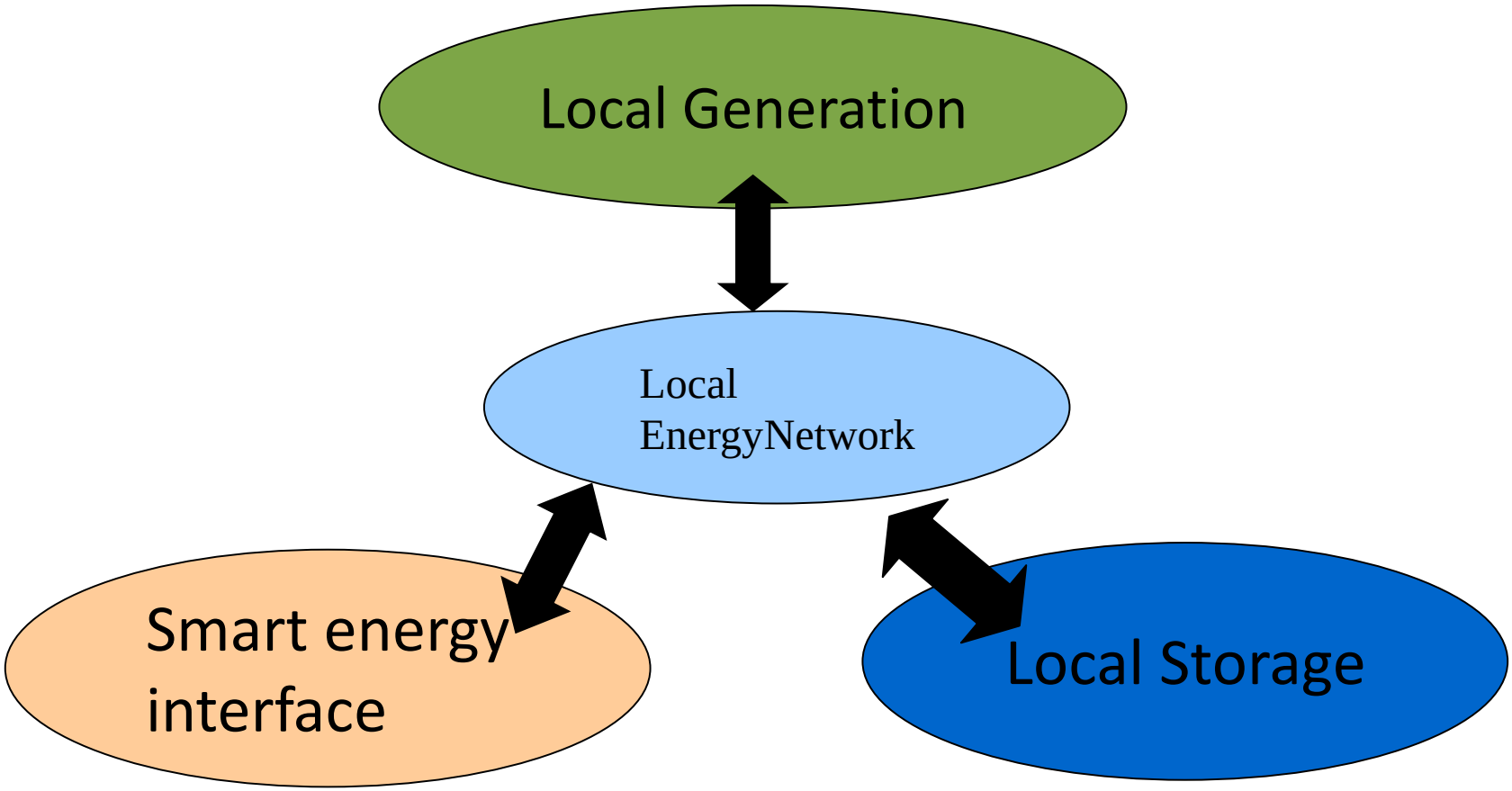


Local Energy network

- The local energy network facilitates the functionality of the ElectriNet. Overall, the combination allows for the operation of a powersystem that is self-sensing, secure, self-correcting and self-healing and is able to sustain failure of individual components without interrupting service.
- It is able to meet consumer needs at a reasonable cost with minimal resource utilization and minimal environmental impact and, therefore, enhance the quality of life and improve economic productivity.

Local Energy Network




Local Generation
Local
EnergyNetwork
Smart energy
interface
Local Storage

Electric Transportation

- Introduction of the significant use of electricity as transportation fuel.
- The availability of both a controllable load and controllable on-site electrical storage.

Green Generation

- **Flexibility to transmit power over long distances**
- **to optimize generation resources**
- **ability to deliver the power to load centers in the most efficient manner**
- **deployment several advanced technologies as a basis for estimating CO2 emissions reduction potential.**
- **Use of renewable energy+**
- **deployment of advanced light water nuclear reactors, advanced coal power plants operating at substantially higher temperatures and pressures, and wide-scale use of CO2 capture and storage**

Definition of Smart Grid

Grid 2030 is a fully automated power delivery network that monitors and controls every customer and node, ensuring a two-way flow of electricity and information between the power plant and the appliance, and all in between. Its distributed intelligence, coupled with broadband communications and automated control systems, enables real-time market transactions and seamless interfaces among people, buildings, industrial plants, generation facilities, and the electric networks.

In 2005, the Electric Power Research Institute (EPRI) has developed an initiative for the Smart Grid called **IntelliGrid** which states,

EPRI's IntelliGridSM initiative is creating the technical foundation for a smart power grid that links electricity with communications and computer control to achieve tremendous gains in reliability, capacity, and customer services.

A definition of the Smart Grid proposed by Cisco states :

A Smart grid is the term generally used to describe the integration of all elements connected to the electrical grid with an information infrastructure, offering numerous benefits for both the providers and consumers of electricity.

Defination of smart grid

In a digital age when consumers demand higher quality, more reliable power and long-distance power trades place unprecedented demands on the system, adequate investment in the nation's electric infrastructure is critical. The development and deployment of a more robust, functional and resilient power delivery system is needed. The overall system is being called a smart grid.

Under this definition, the smart grid is an advanced system that will increase the productivity resulting from the use of electricity, and at the same time, create the backbone application of new technologies far into the future.

To achieve each of the following, which together characterize a Smart Grid:

1. Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.
2. Dynamic optimization of grid operations and resources, with full cyber-security.
3. Deployment and integration of distributed resources and generation, including renewable resources.
4. Development and incorporation of demand response, demand-sidere sources, and energy-efficiency resources.
5. Deployment of ‘‘smart’’ technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.
6. Integration of ‘‘smart’’ appliances and consumer devices.

7. Deployment and integration of advanced electricity storage and peak shaving

   technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning.

8. Provision to consumers of timely information and control options.

9. Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.

10. Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

Characteristics of the Smart Grid

Smart Grid characteristics based on functionality approach include seven principal characteristics as listed below:

1. ***Optimize*** asset utilization and operating efficiency.
2. ***Accommodate*** all generation and storage options.
3. ***Provide*** power quality for the range of needs in a digital economy.
4. ***Anticipate and respond*** to system disturbances in a self-healing manner.
5. ***Operate resiliently*** against physical and cyber-attacks and natural disasters.
6. ***Enable*** active participation by consumers.
7. ***Enable*** new products, services, and markets.

Why Smart Grid?

- Power delivery system is to be stressed in new ways for which it was not designed!!!
- Under deregulation of wholesale power transactions, electricity generators:
  - both traditional utilities and independent power producers, were encouraged to transfer electricity outside of the original service areas to respond to market needs and opportunities.
  - This can stress the transmission system far beyond the limits for which it was designed and built.

Facts:

- bottlenecks in the flow of wholesale power—which increases the level of stress on the system.
- While increasingly embracing the use of renewable power generation:
- transmission and distribution largly developed in era 1940-1950
    - large wind and solar resources are located far from population centers. Substantial new transmission must be built to add these resources to the nation's generation portfolio.

Distributed Energy Resources

- distributed energy resources include technologies for distributed generation (non-renewable and renewable), combined heat and power, energy storage, power quality, and even demand-side management and demand response.
- demand-side management and demand response have been treated separately herein, the current scope of distributed energy resources will include energy generation and storage technologies, including the generation of heat and power, and the storage of electricity.
- Distributed energy resources can be applied at the utility-scale where they feed into the distribution system, or they can be applied at the building level

The principal purposes of distributed energy resources are:

1. To supply stand-alone power and/or heat (e.g., for remote locations).
2. To augment power from the grid (e.g., to minimize power purchases).
3. To reduce transmission and distribution losses by placing power and energy sources closer to loads.
4. To provide peak shaving or load leveling (e.g., to reduce peak demand costs and/or to enable participation in demand reduction programs).
5. To guarantee power quality, reliability and security (e.g., for critical operations and processes).
6. To reduce capital cost of transmission facility construction.

Some distributed energy resource technologies include:

- Solar photovoltaics
- Reciprocating engines
- Stirling engines
- Combustion turbines
- Microturbines
- Wind turbines
- Fuel cells (e.g., phosphoric acid, molten carbonate, polymer electrolyte membrane)
- Batteries (e.g., lead acid, nickel-cadmium, nickel-metal hydride, lithium ion, vanadium redox, zinc-bromine, sodium-sulfur, solid oxide)
- Superconducting magnetic energy storage
- Flywheel energy storage
- Ultracapacitors for storage