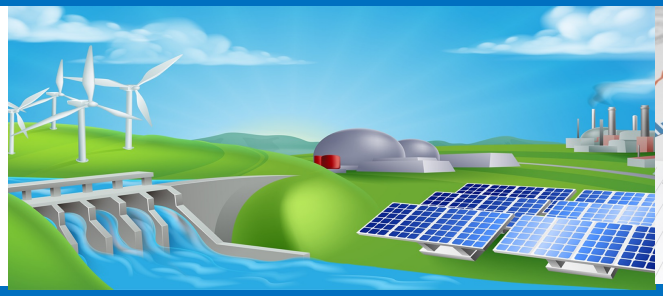



ECONOMICS OF MODERN POWER SYSTEMS

M1-Introduction to Smart Grid

Prof. Luana Medeiros Marangon Lima, Ph.D.

What you will learn?

- Review of Electric Power Systems
  - Generator, Transmission, Distribution, Load
- "Old" Grids and Its Problems
- The Solution: Smart Grid
- Introduction to Smart Grids or Modern Power Grids
  - Definition
  - Benefits
  - Opportunities and Challenges

Review of Electric Power System

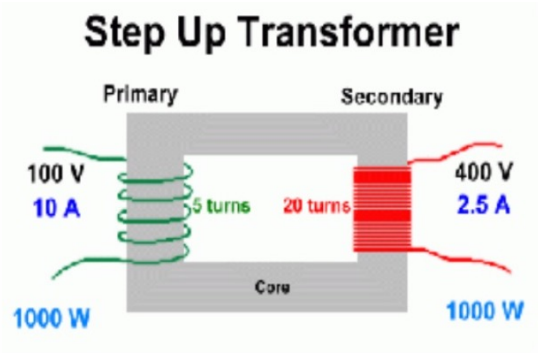
Electric Power Systems a.k.a. Electric grid

- Every power system has 4 major components
  - Generation: source of power
  - Load or demand: consumes power
  - Transmission system: transmits power (ex. lines and transformers)
  - Distribution system: transmits and deliver power

- We also need monitoring and control systems

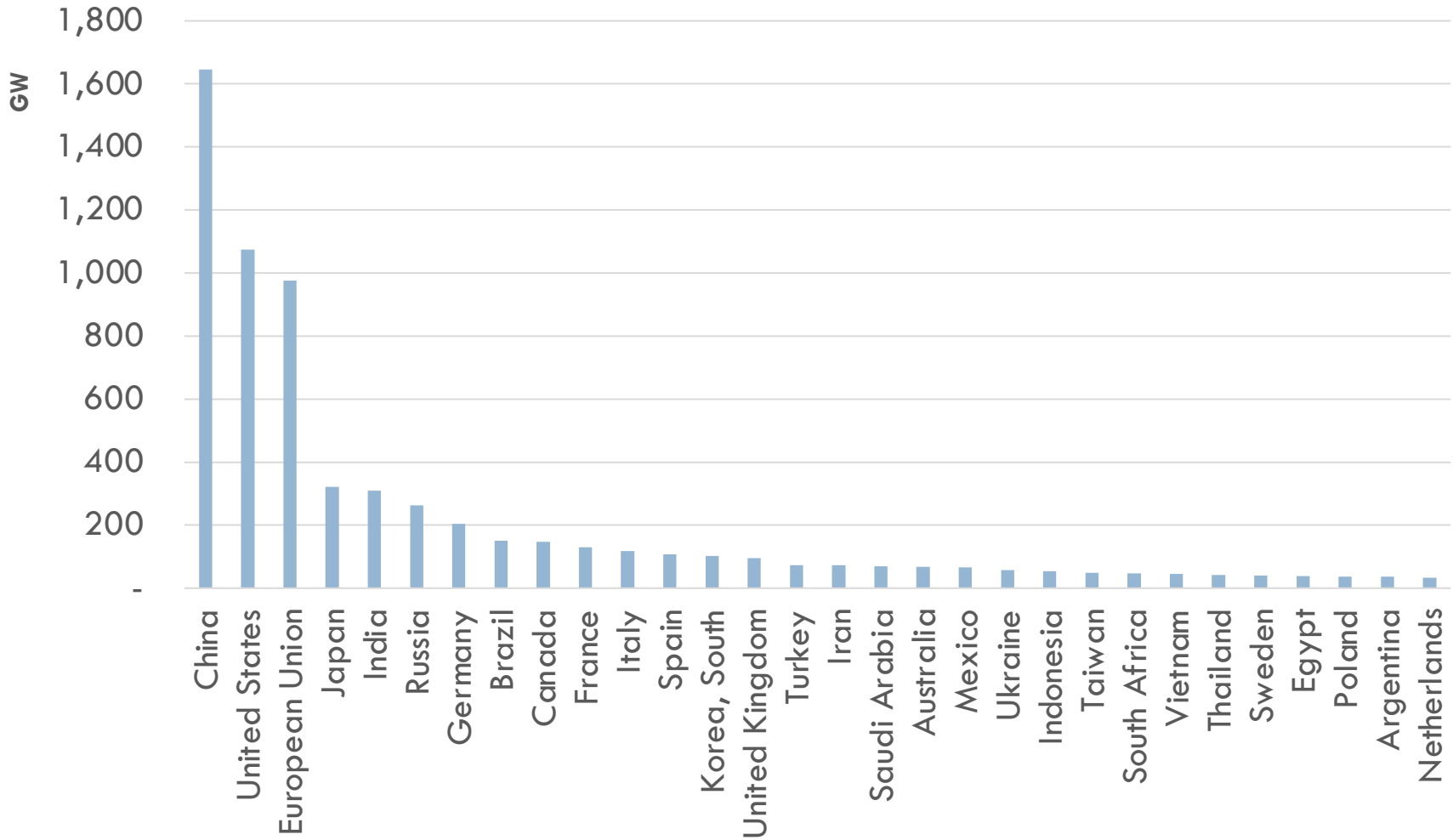
Power Generation

- Power production
  - Traditional
  - Renewable
  - Capacity
  - Carbon emission
  - Step-up transformers

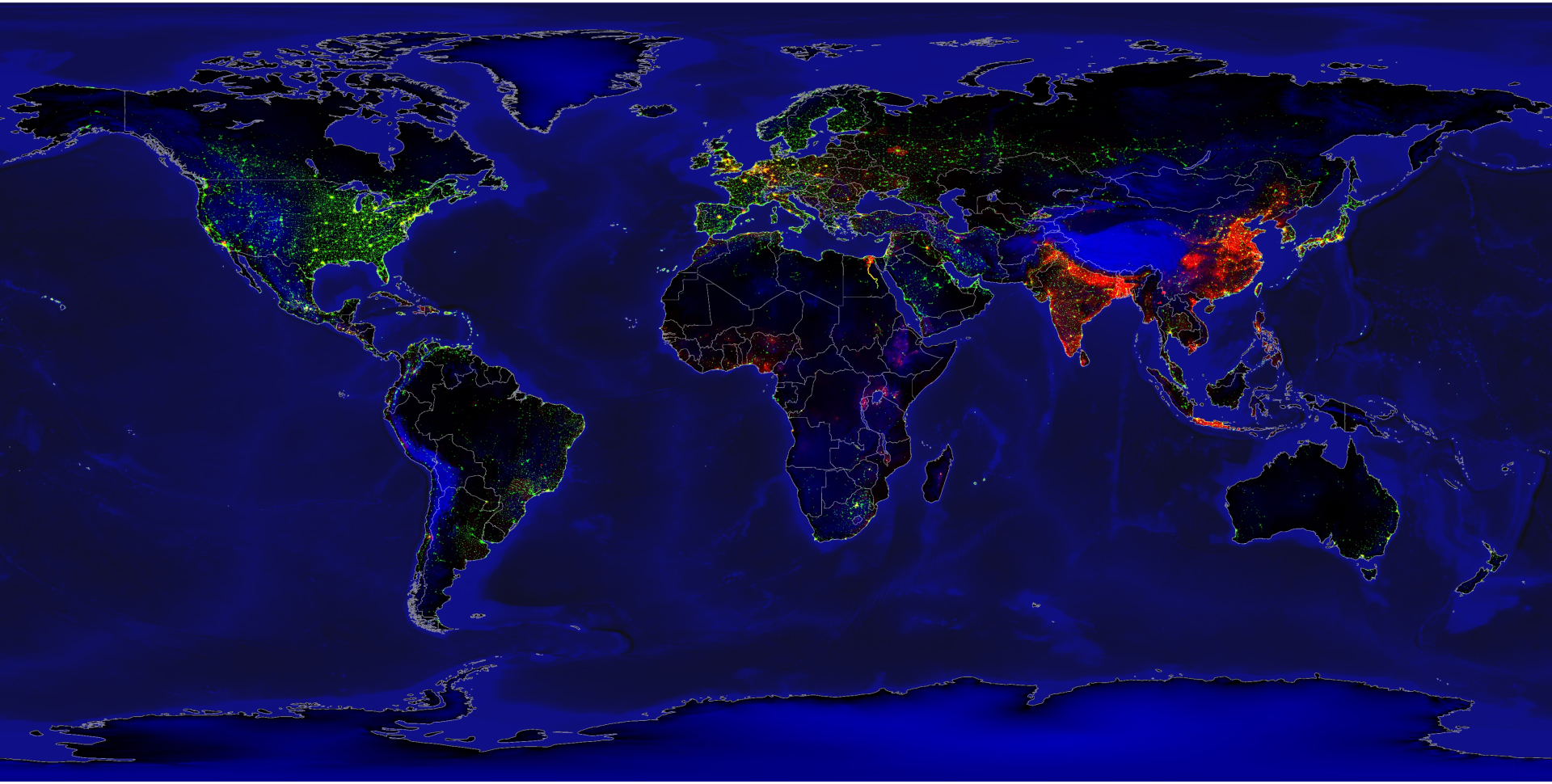


Why we increase voltage to transport energy?

Top 30 countries by installed capacity



Map of Earth lights vs population density

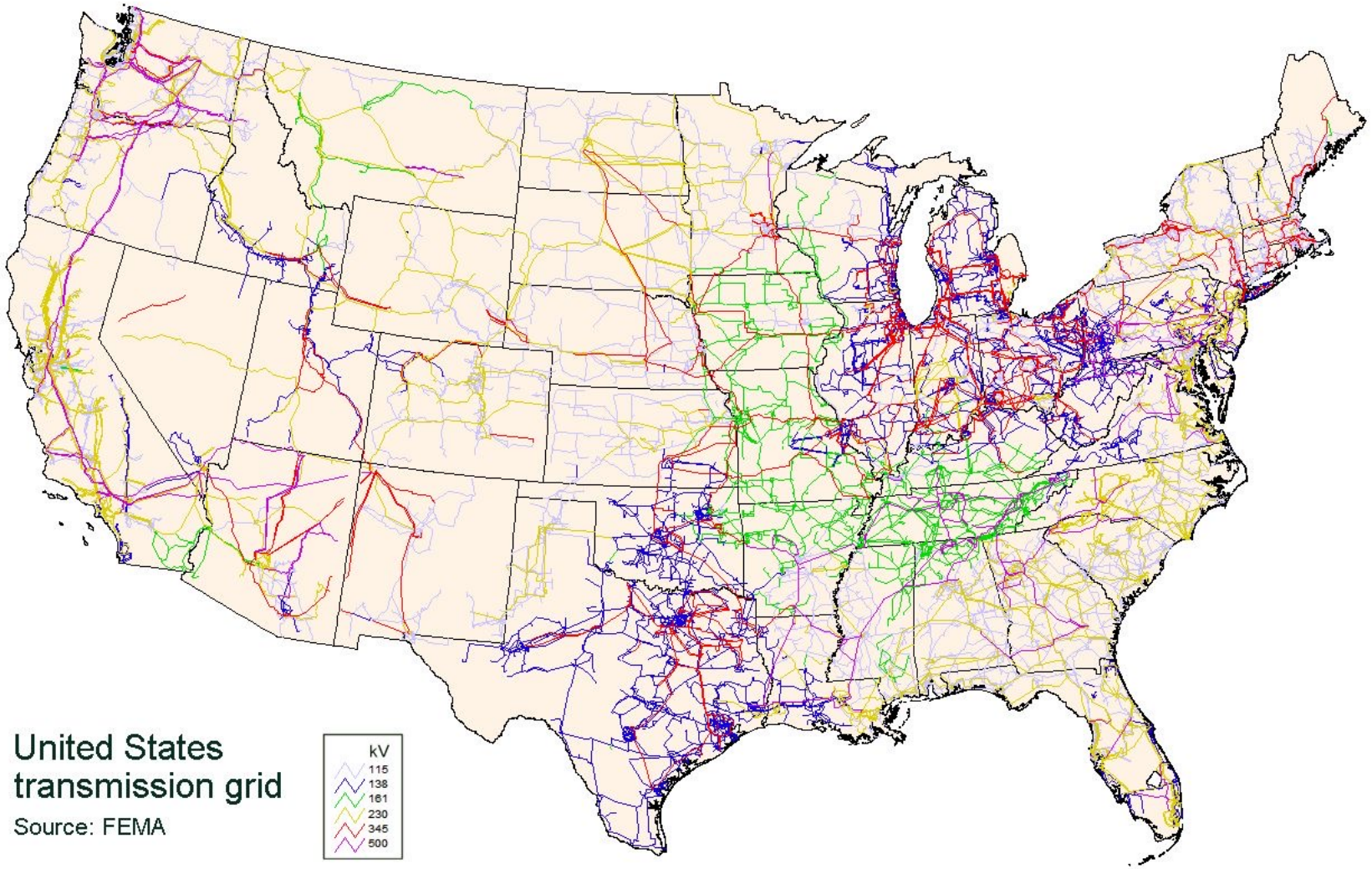


Source: NASA, cmglee, John Harvey, Citypeek, Kathovo -

Power Transmission

- High Voltage (HV) transmission lines
- US: several hundred miles
  - more than 600,000 miles of lines
  - 240,000 of which 230kV or greater
- Switching Stations
  - Transformer
  - Circuit Breakers

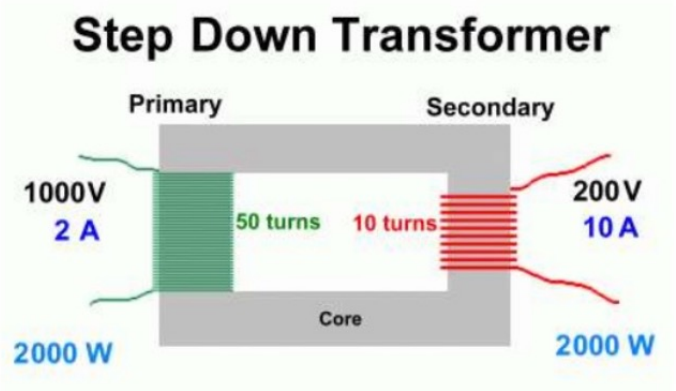
Power Transmission Grid in the US



Power Distribution

- Medium Voltage (MV) transmission lines (<50 kV)
- Power delivered to load locations
- Interface with consumers /metering
- Distribution sub-stations
  - Step-down transformers
  - Distribution transformers

The classification HV, MV or LV differs from one country to another

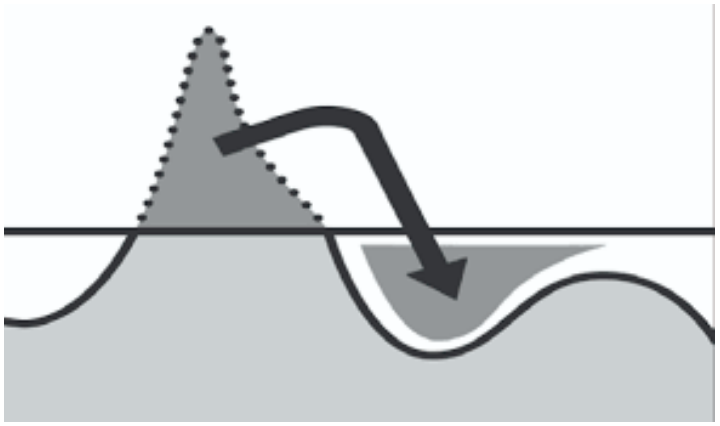


Power Consumption

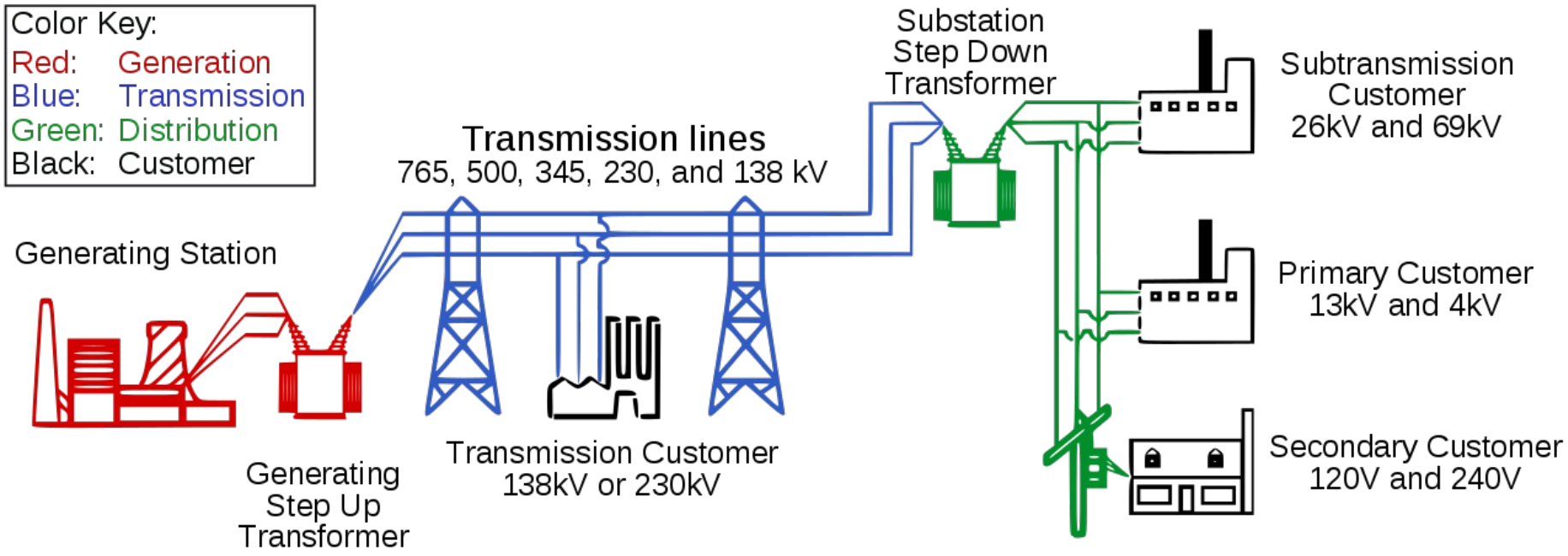
- Industrial
- Commercial
- Residential

- Behind the meter generation
- Demand Response
  - Controllable Load
  - Non-controllable

More on that later!



Simple Representation of the Grid

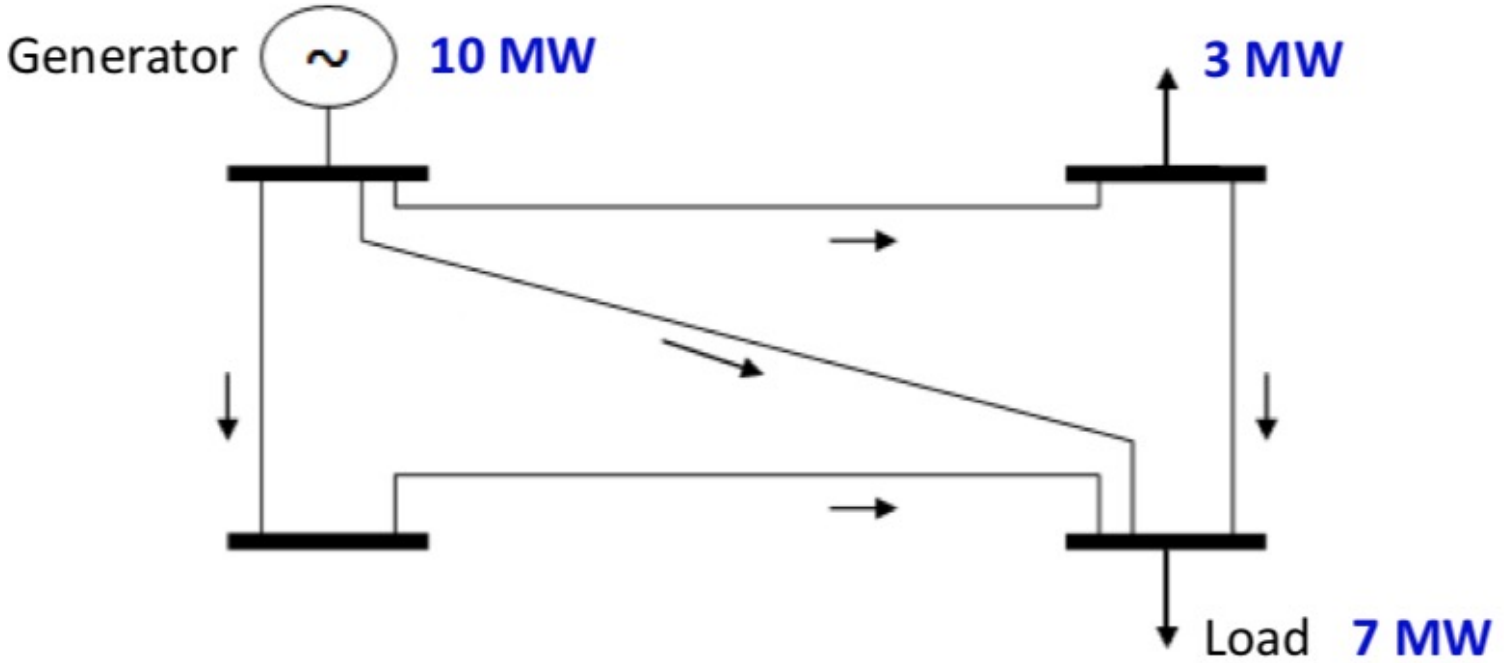


Power System Control

- Data collection
  - Sensors, Phasor Measurement Units (PMUs), etc …
- Decision making: controllers
- Actuators: circuit breakers

Power Grid Graph Representation

- Node: buses
- Links: transmission or distribution lines
- Arrow on a link: power flow direction
- Arrow on a bus: load



“Old” Grids and Its Problems

Old Power Grid

- Designed by pioneers like Nikola Tesla, Thomas Edison and George Westinghouse in **early 20th century**
- One of most complex man-made machines
- **"No" mechanism for storage:**

  Generation – Transmission – Distribution - Use

Characteristics of "Old" Grids

- **One way energy flow** to customers
- Mostly **centralized** electricity production
- **Few communication nodes**: utilities have to wait for customer report to realize component failure
- Few control nodes: **limited automation**
- Utilities usually only had monthly contact with customers

Problems of "Old" Grids

- Reliability
  - Overburdening of the system results in numerous **brownouts and blackouts**
  - Frequency of those has been increasing
- Efficiency
  - About 7% of power is **lost in transmission and distribution**
  - Gap between energy generated and energy delivered
- Economy
  - Electricity is the backbone of the **world's economy**
  - Blackout results in heavy losses
- Environmental impacts
  - Electricity still generated mostly from **fossil fuel**
  - High levels of **GHG emissions**

The Solution: Smart Grid

Introduction to Smart Grids or Modern Power Grids

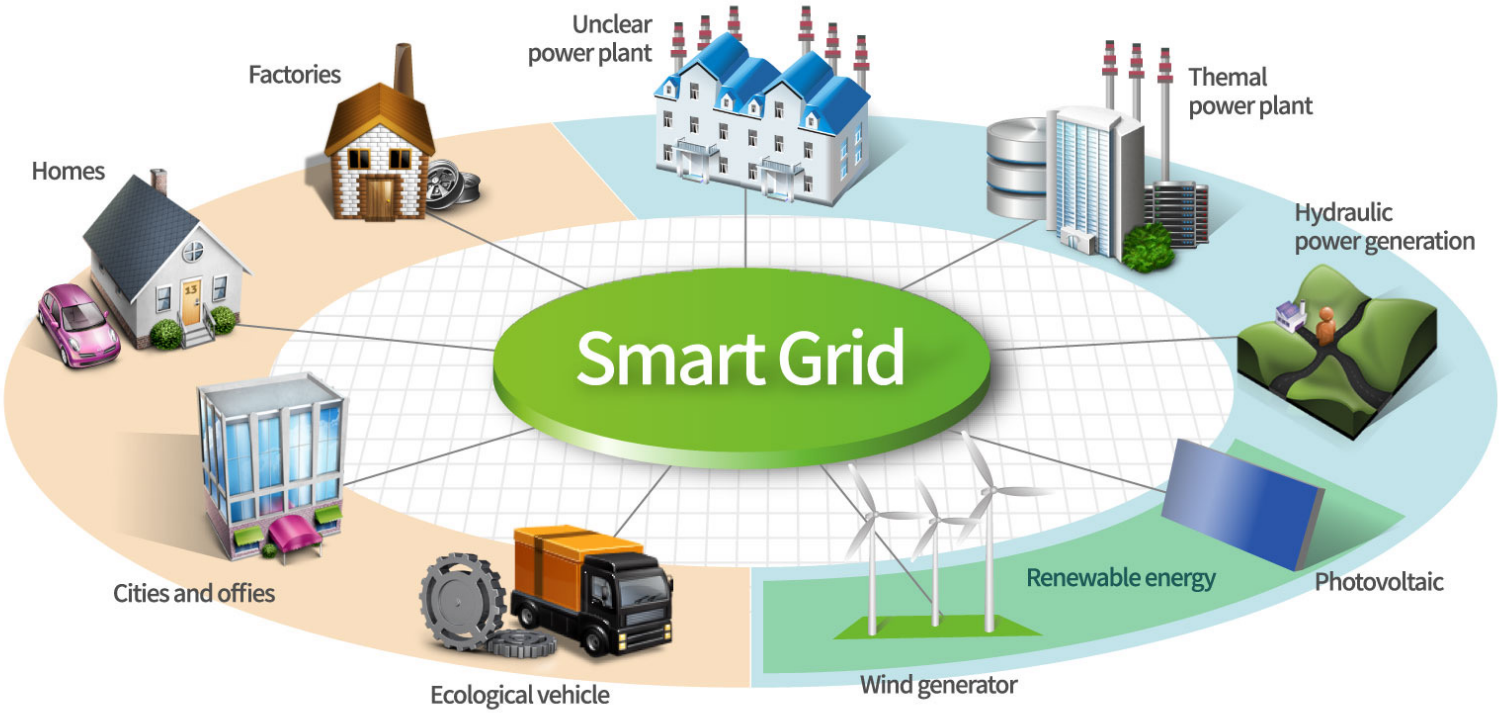
SMART Grid Definition

Does anyone know what SMART Grid stands for?

SMART Grid Definition

Does anyone know what SMART Grid stands for?

Self-Managing And Reliable Transmission Grid



Source: http://www.editiontruth.com/smart-grid-security-market-technological-progress-energy-power-industry-trends-2025/

SMART Grid Definition

- First definition (Khoi et. al. 1997)

  *"The Self-Managing and Reliable Transmission Grid is seen as the future of protection and control systems, It is an **automated system of monitoring, control, and protection devices that improves the reliability of the transmission grid** by preventing wide spread break-ups."*

- In other words…

  *Smart grid is a electric power grid that **employs information and digital communication technologies to constantly optimize power generation, delivery and consumption***

Visions of the Smart Grid

- Smart Grid will:
  - Enable **active participation** by consumers
  - Accommodate all **generation and storage options**
  - Enable new products, services and markets
  - Provide **power quality**
  - **Optimize asset utilization and operate efficiently**
  - Anticipate & respond to system disturbance (**self-heal**)
  - **Operate resiliently** against attack and natural disaster

Source: DOE SmartGrid Implementation Workshop

Nice video from DOE: "What is the Smart Grid?"
https://www.youtube.com/watch?v=JwRTpWZReJk

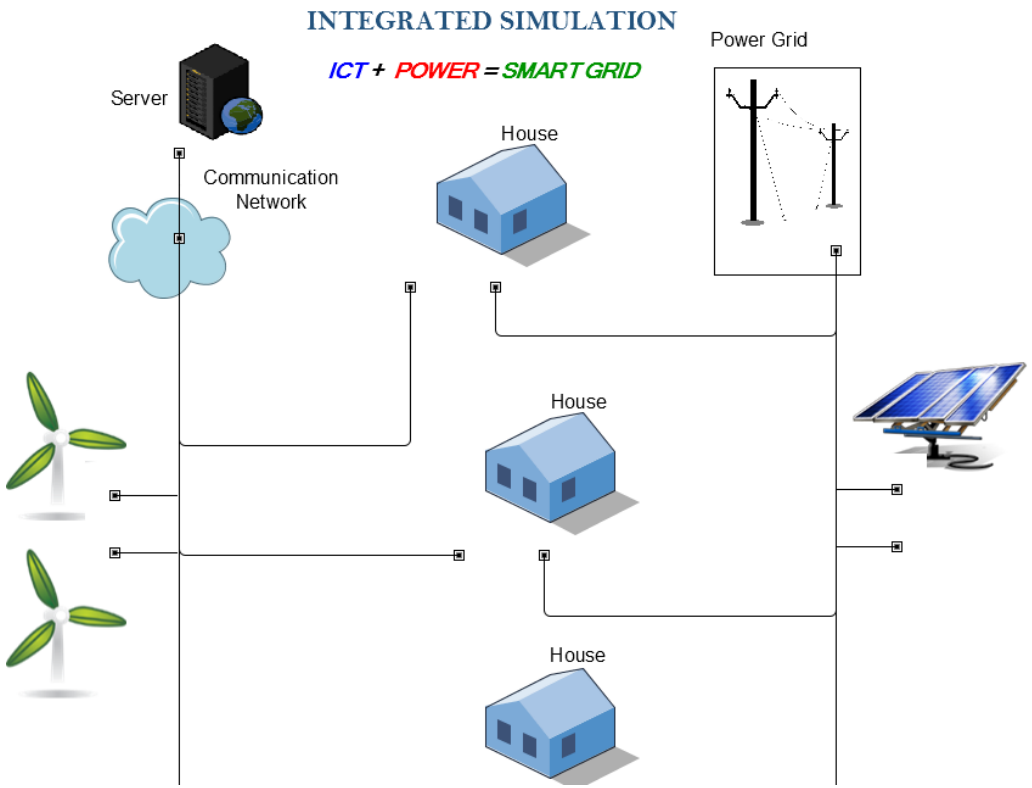
Main debates...

1. How to incorporate and balance the often fluctuating production of renewable electricity into the grid?

2. How to manage infrastructure with the increasing electricity demand of society in particular peak demand?

Answer...

Information & Communication Technologies - ICT



Source: https://www7content.cs.fau.de/~akarim/projects/smartgrid/

Merging software of ICT and hardware of energy infrastructures

Adding a layer of digital information to the operations of the grid and to the management of supply and demand

Smart Grid Benefits

- Fuel saving and reduced electricity price
- Reduced transmission cost
- Reduced emission from power generation and transportation tools
- Improved management of outage & reliability
- Enhanced customer service and improved satisfaction
- Stimulate economy

Technologies Involved & Paradigm Shift

- The smart grid is **not a single technology**
- It includes telecommunication, smart energy devices, information technology, sensing, signal processing, advanced control
- But it's **not just about technology**
- Implementation requires a complete rethinking of public policy, utility business model, customer behavior, social issues

It's a paradigm shift!

Smart Grid Investments

- Research and Development
  - Communication and system integration
  - Energy storage solutions
  - Distribution automation and advanced control
  - **Cyber security (More on that later!)**
- Renewable sources
- Infrastructure Upgrade
  - Intelligent and programmable monitoring devices
  - Sensing and metering devices
  - Communication and control systems
- Power engineer education
  - IEEE Power and Energy magazine: http://www.nxtbook.com/nxtbooks/pes/powerenergy_091018/index.php#/0)

Opportunities and Challenges

- Government is in favor of investing money
- Renewable sources attractive and eco-friendly
- Innovation is needed

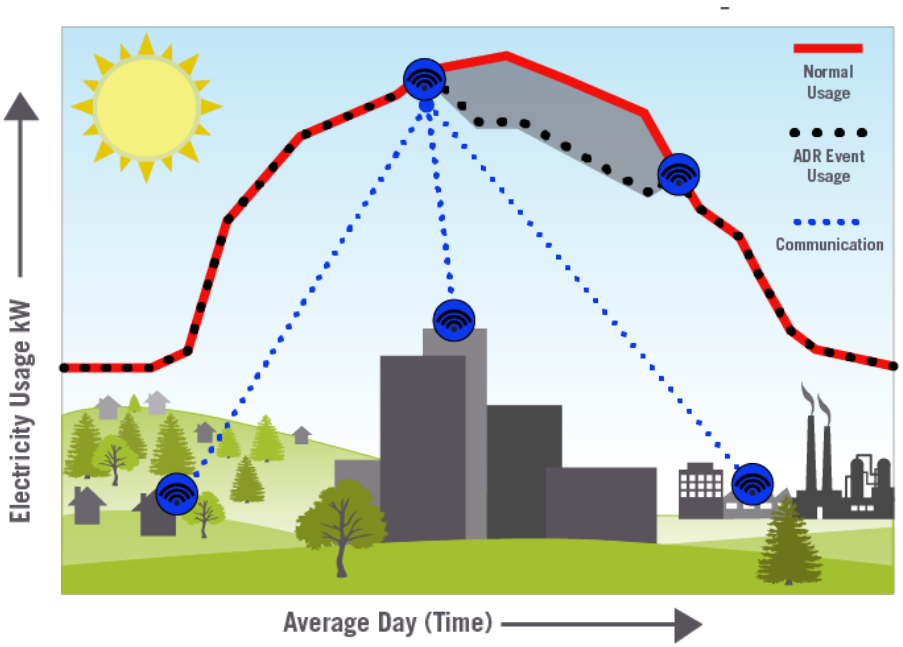
- Payback cycles are long
- Old industries change slowly (inertia)
- Complex combination of technology and policy
- Cyber security

SG Technologies will enable/facilitate

- Demand response
  - Real-time pricing (dynamic pricing)

    Smart meter will record power usage and report it back to utilities to enable a variable price structure
  - Load control
  - Intelligent appliance

    Programmed in a way such that they can communicate with utilities and can work during off-peak time



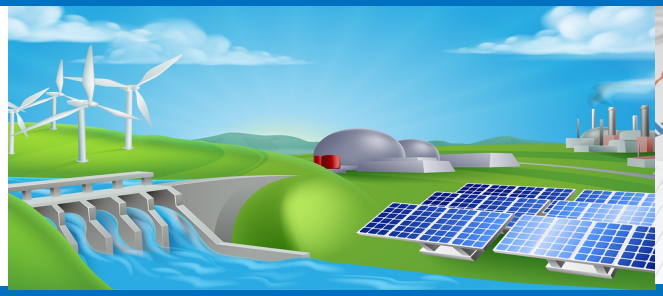
SG Technologies will enable/facilitate

- Distribution Automation
  - Improves reliability with real-time monitoring and intelligent control
  - Smart Meters will report outages to facilitate fault detections
  - Helps localize fault
  - Open switches around the fault and restore unfaulted sources
  - Allows faster adjustments to abnormal conditions
  - Helps preventing blackouts and allows for faster recovery

- Watch the video about outage in old and smart grid: https://www.youtube.com/watch?v=2VGs7FdrSIE

SG Technologies will enable/facilitate

- Green energy
  - Solar/wind power forecasting
  - Power storage
- EV charging system
  - Home charging equipment
  - Public charging infrastructure




THANK YOU !

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