FUTURE CITY COMPETITION

# Designing Resilient Power Grids

PRESENTED BY: TASO MALAPETSAS
STEM PROFESSOR AT RCBC
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# What is the grid?

How we deliver electricity everywhere!

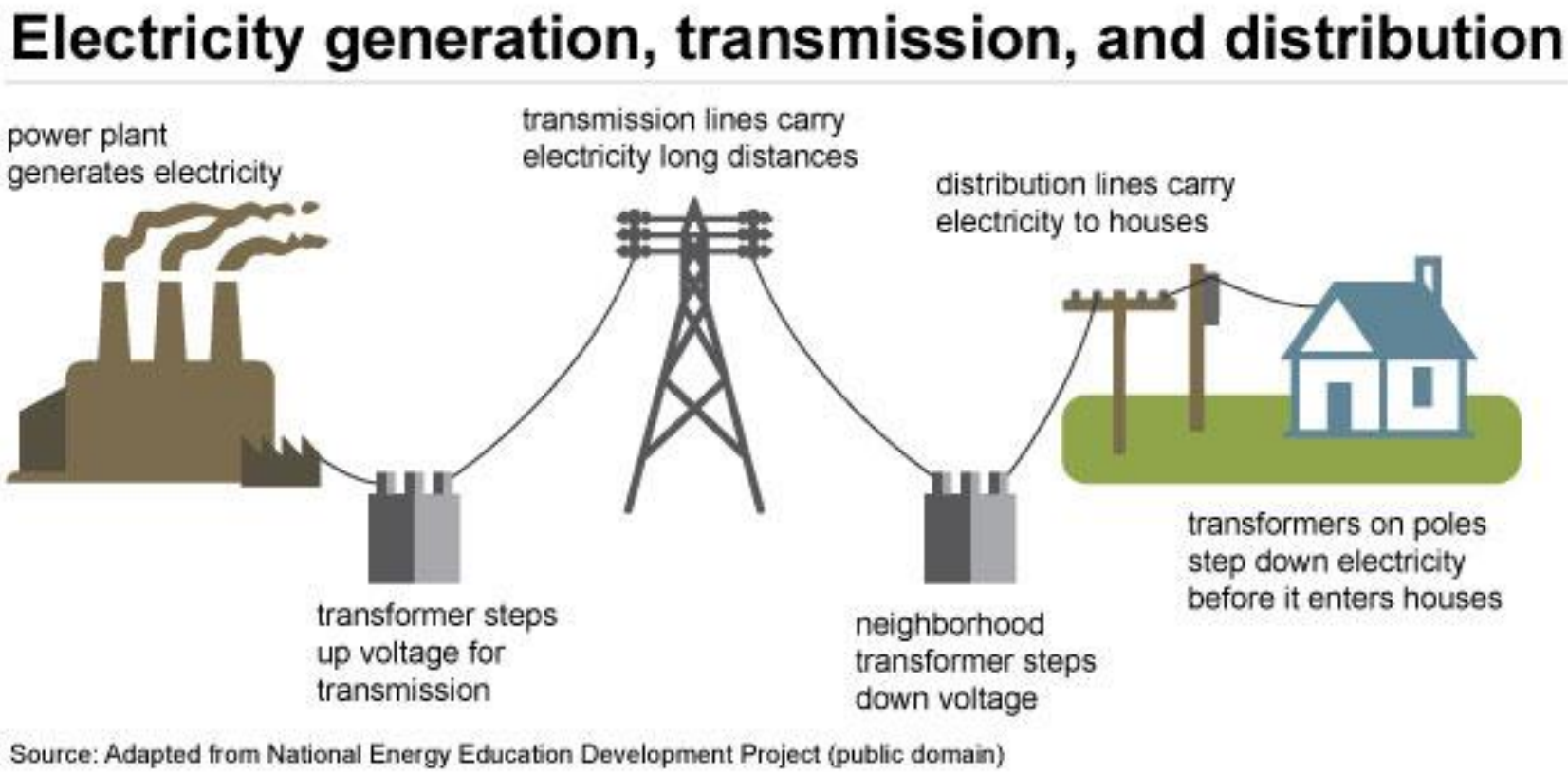
# Is Electricity Important?

- **Electricity is the backbone of our living and has made our world what it is today:**
  - **Heat and cool our home,**
  - **Clean water and sanitation**
  - **Lighting,**
  - **Communication,**
  - **Entertainment,**
  - **Health support, etc. etc. etc.**
  - **Soon, we may use it to run our car.**
  - **Can you imagine living without electricity?**

# How does Electricity get to us?

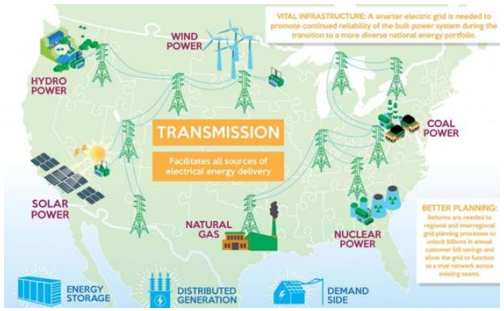
## The Electricity or “Power” Grid

# Basics of an Electricity Power Grid



# Grid Basics

- **Electricity grid** is a network of high voltage power lines and overhead transmission lines that link power generation facilities to the homes and businesses that use electricity.
  - On a national scale, this network is **huge**: there are over 450,000 miles of high-voltage power lines and over 160,000 miles of overhead transmission lines throughout the United States.
- Network consists of:
  - Generation (Supply)
  - Transmission
  - Distribution
  - Consumption (Demand)




- Inadequate means to store electricity means it has to be produced and delivered in **real time.** Power grid operators must respond **immediately** to any shifts in power demand or supply so that electricity is generated and delivered to where it's needed.
- **65%** of energy used to generate, convert, transmit electricity gets lost in the process. Generally speaking **we need 3W of raw energy for each 1W of demand**.

# Electricity Generation (Supply)

- Since the industrial revolution**, the process of generating electricity has been to**: generate steam and use to rotate large turbines with electromagnetic coils causing electrons to move and generate an electric current. The steam is created by burning:
    - Coal,
    - Natural gas,
    - Oil
    - Nuclear energy

- Other ways to move turbines without burning fossil fuels:
    - **Hydroelectric** dams
    - **Wind**
    - **Waves**

# New Forms of Electricity Generation

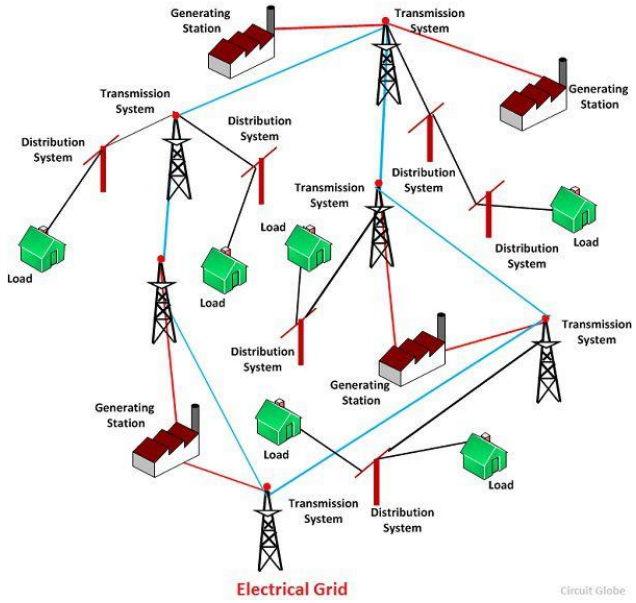
- Electricity can also be generated by:

- **Solar - photovoltaic** panels, which convert light from the sun directly into electricity.


•**Fuel Cells** use an electrochemical process to produce electricity,

# Electricity Transmission

- Most power generation happens **far** from its end users, electricity must travel large distances to get to where it is eventually used. For this travel it is transformed to a **high voltage**, typically in the range of 110 to 765 kV (kilovolts), as less energy is lost due to resistance at high voltages.
- Transmission lines are either overhead power lines or underground power cables. Overhead power lines are more common, as they are cheaper and less intrusive to construct, but can be affected by poor weather (such as high winds or low temperatures).




•Transmission lines throughout the US are highly **interconnected**. This helps make the grid more **reliable**, as it offers grid operators more **flexibility** if there is an interruption in supply or a dramatic change in demand for electricity at any given point in time.

# Electricity Distribution

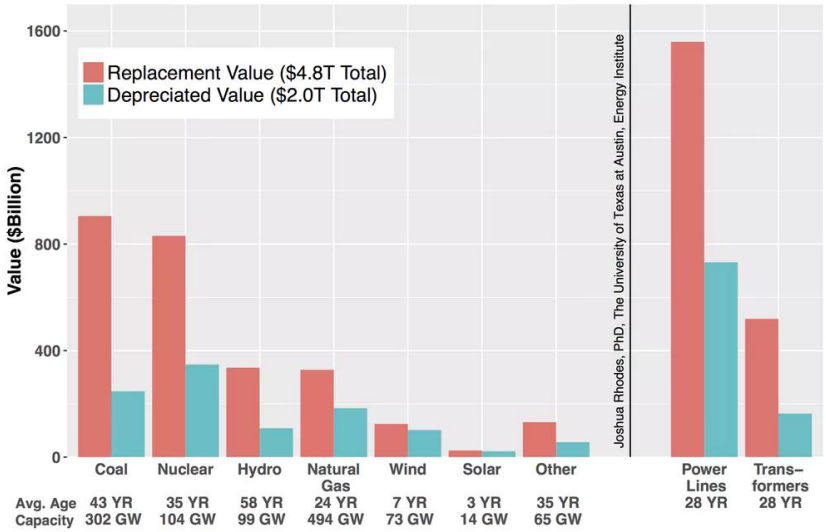
- **Distribution** of electricity covers the **local delivery of electricity along the wires in your community** to your home.
- Electricity is "**stepped down**", usually to about 50kV or lower at the **power substation** to a lower voltage that is suitable to travel along the distribution grid.
- The distribution network is made up of the wires and poles that bring electricity to your home. Before electricity reaches your home, it is further stepped down (transformed) to 240 V, which is the normal voltage for household electrical service.
- The electricity distribution network is **owned** and **operated** by your **local electric utility company**, which is responsible for ensuring the **reliable** and **safe** delivery of electricity to your home.
- Part of their services include
  - meter reading
  - maintenance
  - responding to outages.

# Consumer Use (Demand)

- Finally, electricity reaches your home and you use it.
- Electricity enters your home through a **meter**, which measures your consumption.
  - In the past this meter was an analog meter, and a representative from your utility company came to your home about once a month to take a meter reading.
  - Today, with the nation upgrading to smart grid technology, millions of residential meters have been replaced with **smart meters**. These meters are able to communicate your usage information directly to the utility, making for more accurate recordings of your usage and helping make the grid more efficient.

# Challenges to the Electricity Grid Today

- The **biggest challenge** facing the electric power grid today is;
  - **how to adapt an aging infrastructure to a rapidly changing demand**; while electricity use increased by 58% between 1980 and 1999, investment in transmission infrastructure declined by nearly half during the same time period. Today, around 70 percent of the power grid's transmission lines and transformers are over 25 years old, **yet our needs for electricity is as important as it has ever been**, placing even **higher stress** on the grid.



# **Other challenges** to the grid

- **Vulnerability** due to exposed infrastructure to the elements heat/cold
- Determining **fair cost-recovery agreements** when new transmission construction happens in one state but benefits other states
- Finding **ways to integrate greater renewable energy generation** (such as wind farms and solar panels) into the power generation mix when it is often located far away from demand

# **Other challenges** to the grid

- Increasing the **resiliency** of the power grid against storms and severe weather, and keeping it **protected** from physical and cybersecurity attacks

# Designing a resilient Electricity Grid

1. **Smartening the grid**

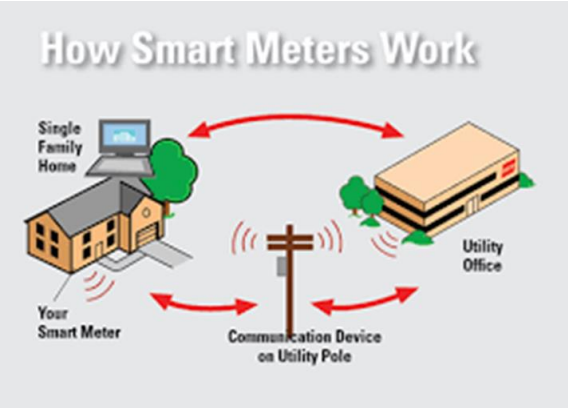
2. **Hardening the grid**

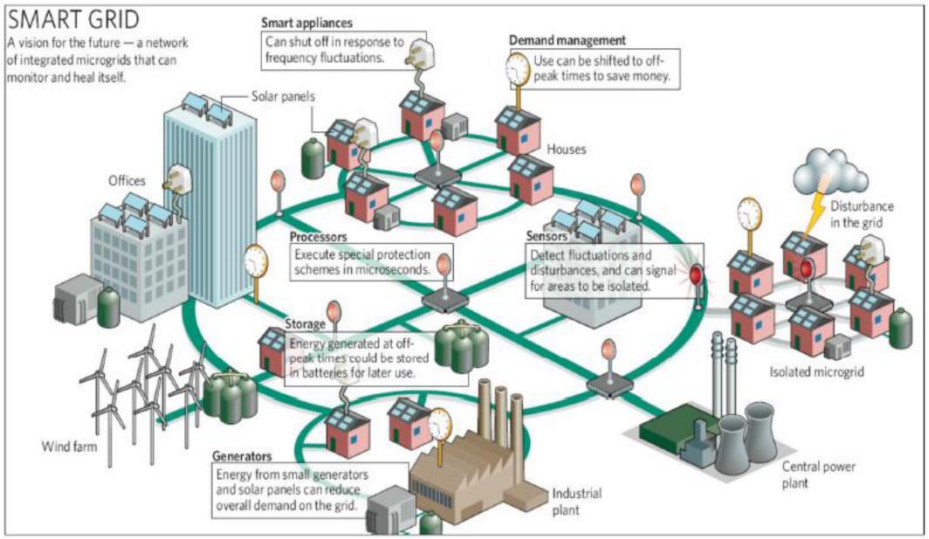
3. **Distributing generation**

4. **Building resilience on demand**

# Smartening the Grid

- Solutions include advanced metering and distribution automation deployment.
- Fortunately, the electricity grid is **evolving** thanks to **new technologies** that can prevent/shorten outages, improve energy-efficiency, and encourage the integration of clean power onto the grid. Here are just a few innovations that are helping the electricity grid adapt to a changing world.



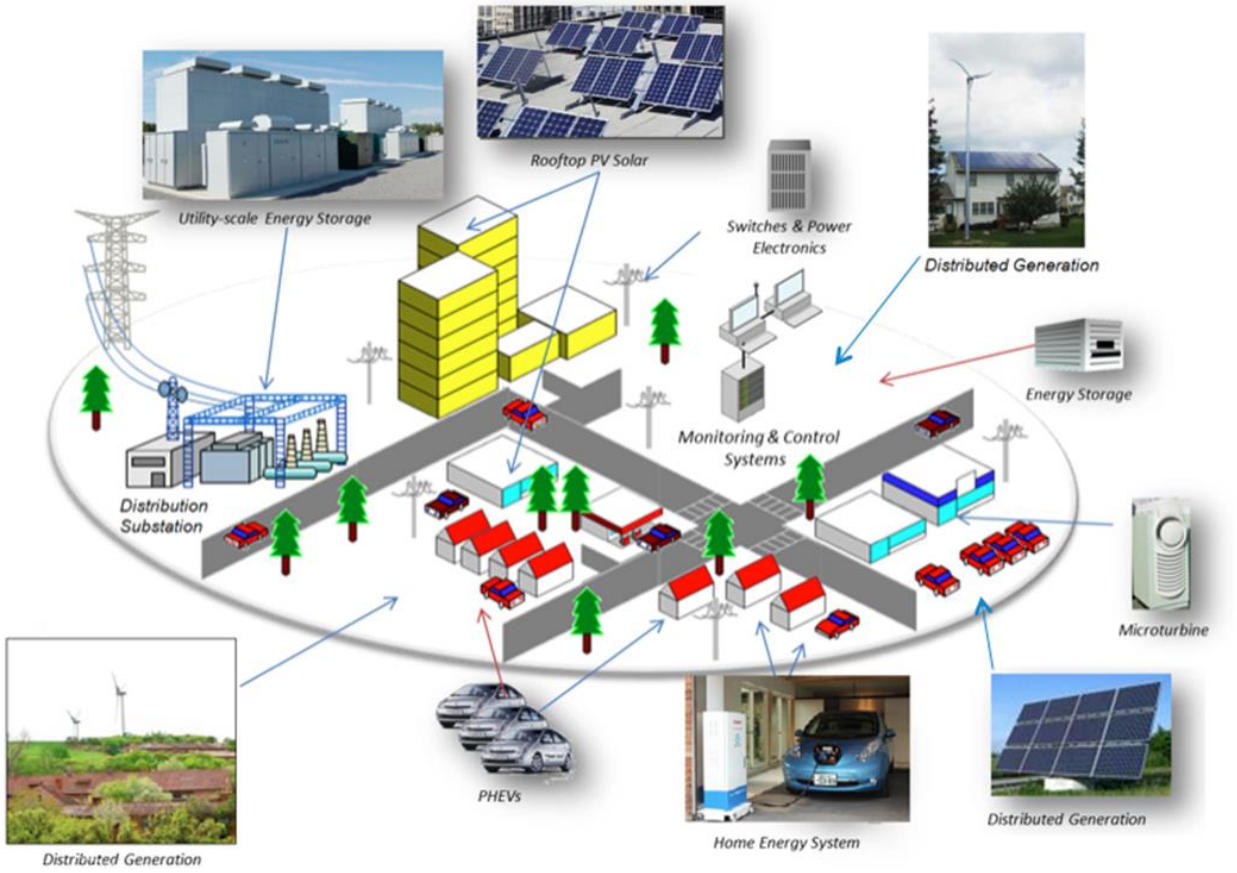



# Hardening the Grid

- Solutions include:
  - raising seawalls around key assets,
  - restoring natural coastal protections,
  - relocating key assets,
  - undergrounding powerlines,
  - expanding tree-trimming programs and
  - improved transmission line materials such as high-temperature, low-sag conductors.


# Distributing Generation on Supply

Solutions include utility-owned combustion turbines for peak power, customer-owned diesel generation, customer-owned/grid-connected CHP systems, and microgrids that may include CHP, renewable power, and other elements.



# Building resilience on demand

- Solutions include battery storage, internet-addressable thermostats and appliances, and a range of energy-efficient building thermal design features such as thermal insulation, efficient windows, passive solar, thermal mass and natural ventilation.
- Advances in **energy storage technologies** (batteries) could allow electricity to be stored for use when electricity demand increases rapidly, which would increase energy efficiency, reliability, and the development of a “clean grid”.

# Critical Thinking

- Can you think of ways to build resilience in the Grid?
- Do we even need the Grid?
- What does the future look like?

# Future looks bright!

Artificial Intelligence allows for smart systems coupled with
Lower cost modular technologies make it possible to be independent

- Solar
- Small size CHPs, generators
- Fuel Cells
- Storage
- Controls

# Questions???

- Thank you!

- Enjoy the Competition