Soklynin Nou
IDST 104

# Maximizing The Californian Renewable Power Grid:

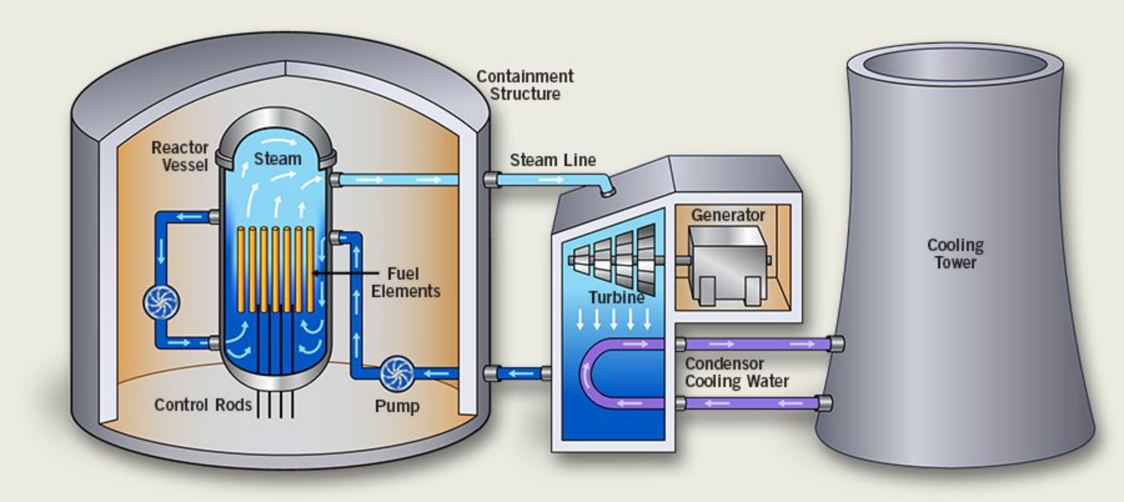
# An Application of Multivariable Optimization

Foundation Instructor: Alex Wong

# What is are the Factors?

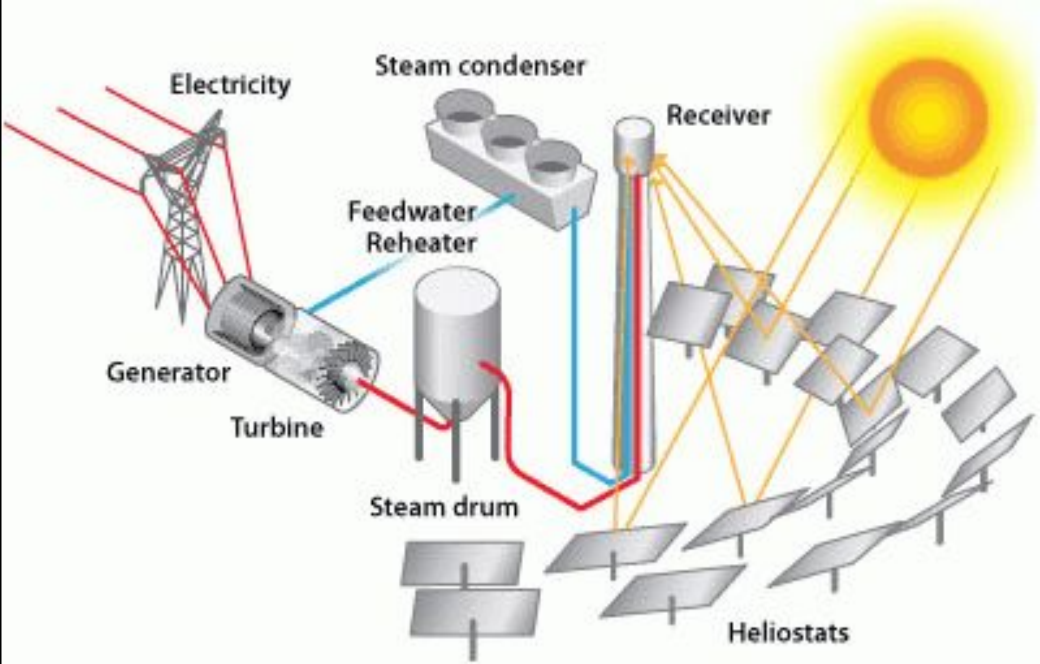
- Nuclear Power Plant
- Concentrated Solar-Thermal Power
- Wind Turbines / Photovoltaic Solar Panels
- Hydroelectric Dams
- Geothermal Power Plant

# Nuclear Energy



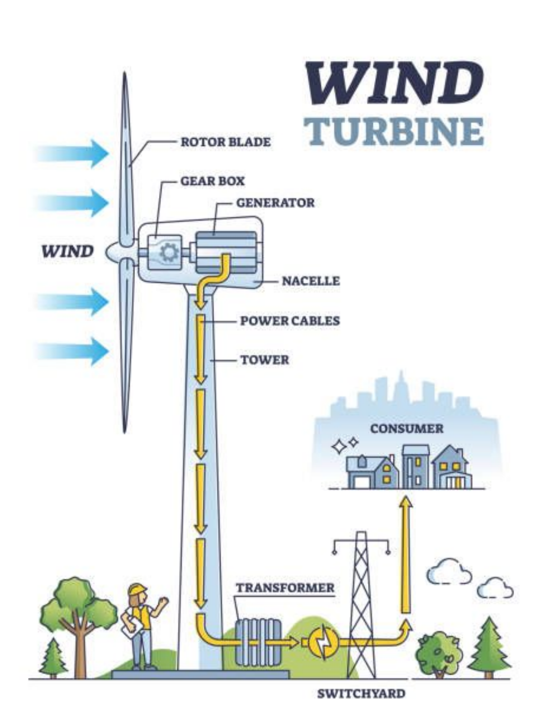

Atoms are split in nuclear fission, generating energy in the form of heat. This heat is then used to create steam, which spins a turbine to generate energy.

# Concentrated Solar-Thermal Power




Sunlight is concentrated into a central tower that is filled with water. This water then turns into steam which turns a turbine to generate energy.

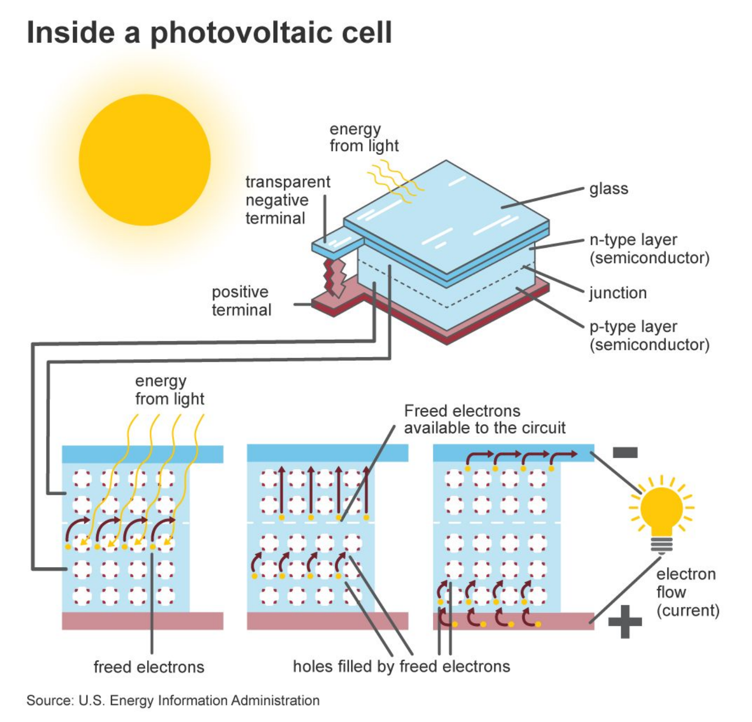
# Wind Turbines




Turbine is in the name.

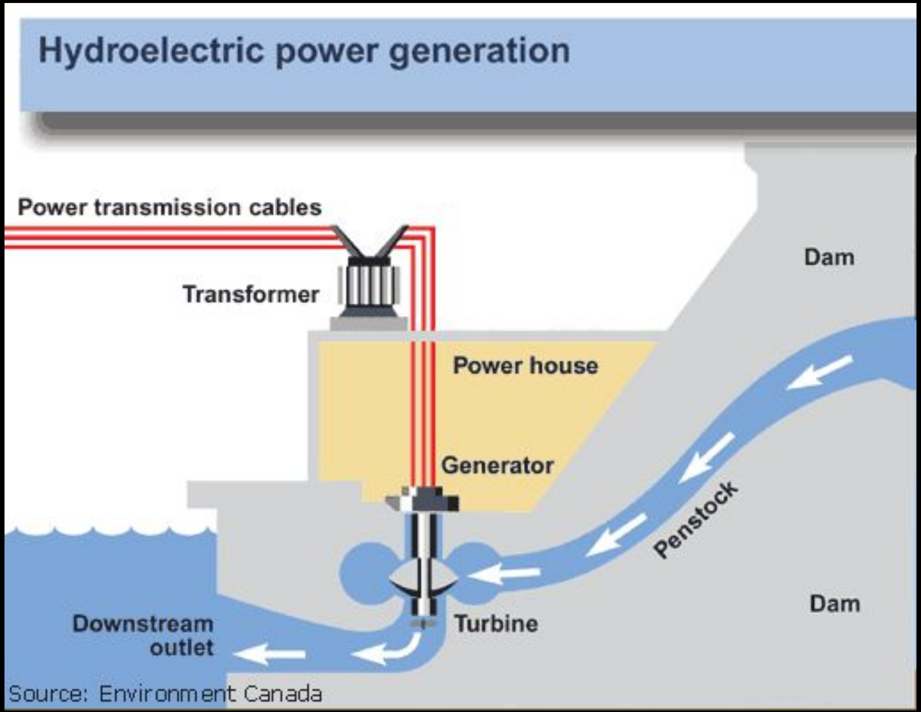
Transform the kinetic energy of the wind into electrical energy using turbines

# Photovoltaic Solar Panels



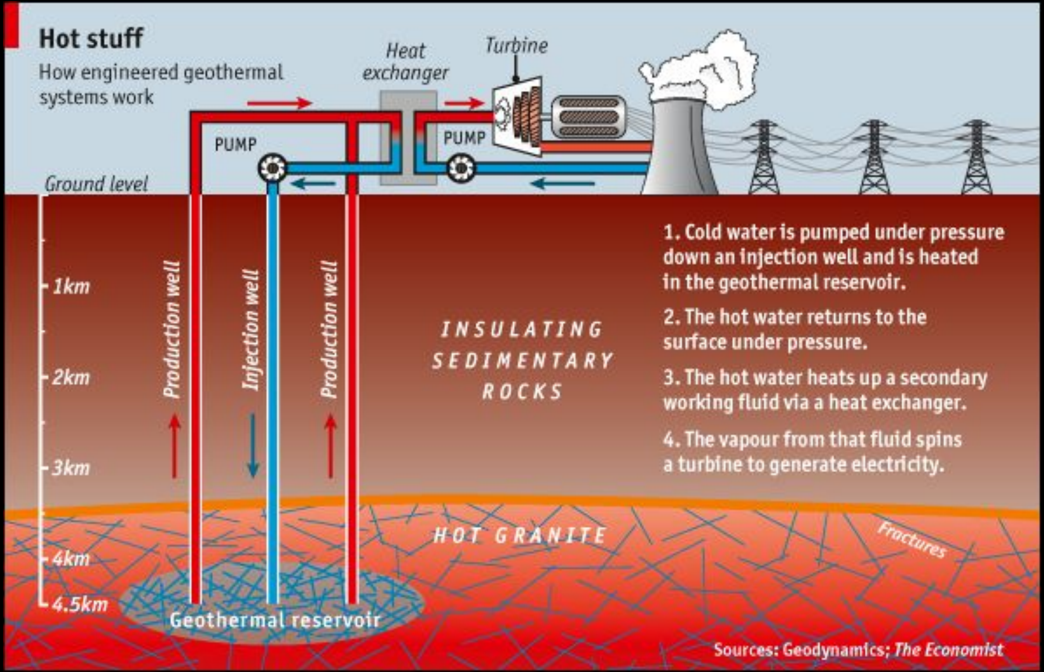

Photovoltaic solar panels convert sunlight directly into electricity using semiconductors. When sunlight hits the solar panels, it creates an electric current by causing electrons in the material to move.

# Hydroelectric Dams

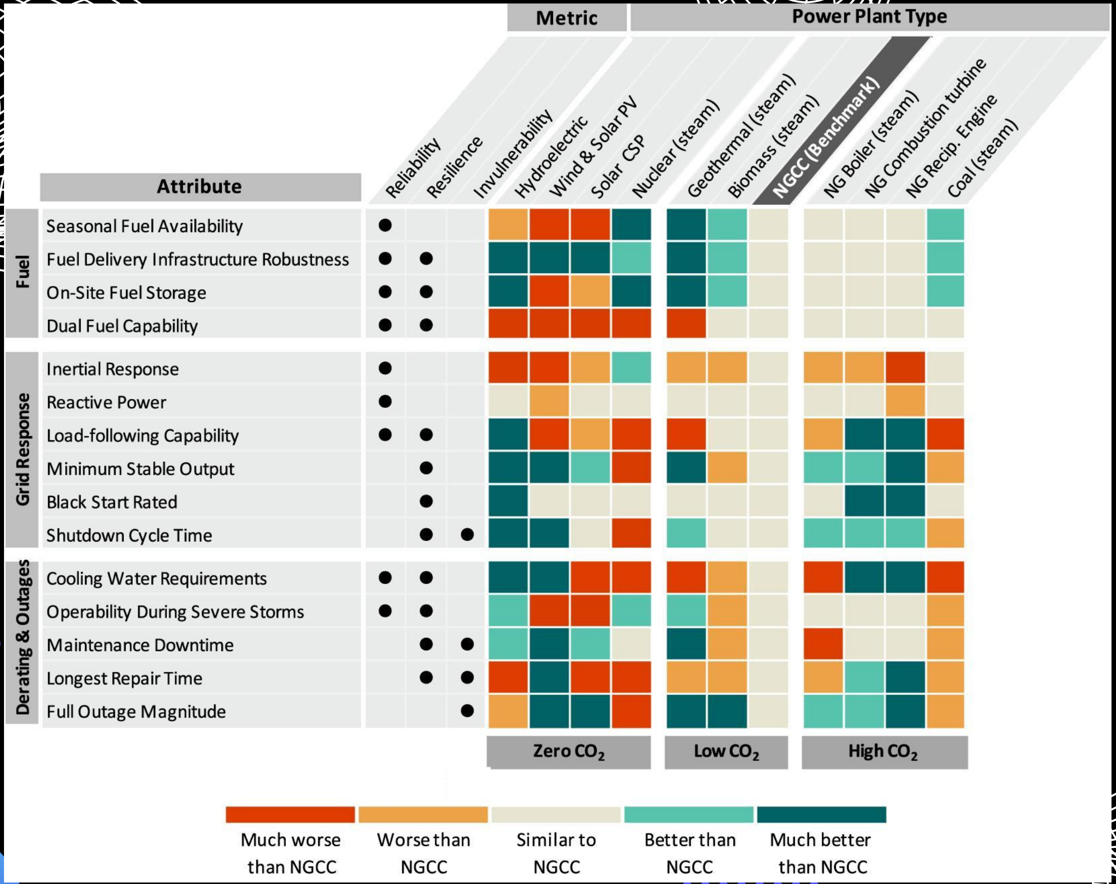



Hydroelectric power uses the potential energy of flowing water to make turbines spin, generating electricity.

# Geothermal Energy




Geothermal power harnesses the heat from the Earth's core. This heat is used to produce electricity, making it a renewable energy source.




***K Ramirez-Meyers et al 2021 Prog. Energy***

# What is being optimized

## 01

### Reliability

- Seasonal Fuel availability
- Load-following Capability
- Operationality during Severe Storms

## 02

### Resilience

- Load-following Capability
- Minimum Stable output
- Operationality during Severe Storms
- Maintenance Downtime
- Shutdown Cycle Time

## 03

### Invulnerability

- Shutdown Cycle Time
- Maintenance Downtime
- Full Outage Magnitude

# 01

# Reliability

How few disruptions a grid experience

# Optimization of Reliability

$$SFA = H_0 n_{H0} + W_0 n_{W0} + S_0 n_{S0} + N_0 n_{N0} + G_0 n_{G0}$$

$$LFC = H_1 n_{H1} + W_1 n_{W1} + S_1 n_{S1} + N_1 n_{N1} + G_1 n_{G1}$$

$$ODSS = H_2 n_{H2} + W_2 n_{W2} + S_2 n_{S2} + N_2 n_{N2} + G_2 n_{G2}$$

$$Reliability = SFA + LFC + ODSS$$

# Optimization of Reliability

$$SFA = 0.52n_{H0} + 0.62n_{W0} + 0.35n_{S0} + 1n_{N0} + 1n_{G0}$$

$$LFC = 1n_{H1} + 0.1n_{W1} + 0.25n_{S1} + 0.1n_{N1} + 0.1n_{G1}$$

$$ODSS = 0.75n_{H2} + 0.1n_{W2} + 0.1n_{S2} + 0.75n_{N2} + 0.75n_{G2}$$

02

# Resilience

How quickly a grid can recover after disruptions

# Optimization of Resilience

$$SFA = H_0 n_{H0} + W_0 n_{W0} + S_0 n_{S0} + N_0 n_{N0} + G_0 n_{G0}$$

$$ODSS = H_2 n_{H2} + W_2 n_{W2} + S_2 n_{S2} + N_2 n_{N2} + G_2 n_{G2}$$

$$MSO = H_3 n_{H3} + W_3 n_{W3} + S_3 n_{S3} + N_3 n_{N3} + G_3 n_{G3}$$

$$MD = H_4 n_{H4} + W_4 n_{W4} + S_4 n_{S4} + N_4 n_{N4} + G_4 n_{G4}$$

$$SCT = H_6 n_{H6} + W_6 n_{W6} + S_6 n_{S6} + N_6 n_{N6} + G_6 n_{G6}$$

$$Resilience = SFA + ODSS + MSO + MD + SCT$$

# Optimization of Resilience

$$LFC = 1n_{H1} + 0.1n_{W1} + 0.25n_{S1} + 0.1n_{N1} + 0.1n_{G1}$$

$$ODSS = 0.75n_{H2} + 0.1n_{W2} + 0.1n_{S2} + 0.75n_{N2} + 0.75n_{G2}$$

$$MSO = 0.9n_{H3} + 0.9n_{W3} + 0.8n_{S3} + 0.1n_{N3} + 0.9n_{G3}$$

$$MD = 0.75n_{H4} + 0.1n_{W4} + 0.1n_{S4} + 0.75n_{N4} + 0.75n_{G4}$$

$$SCT = 1n_{H6} + 1n_{W6} + 0.5n_{S6} + 0.25n_{N6} + 0.75n_{G6}$$

# 03

# Invulnerability

How minimal are the disruptions

# Optimization of Invulnerability

$$MD = H_4 n_{H4} + W_4 n_{W4} + S_4 n_{S4} + N_4 n_{N4} + G_4 n_{G4}$$

$$SCT = H_6 n_{H6} + W_6 n_{W6} + S_6 n_{S6} + N_6 n_{N6} + G_6 n_{G6}$$

$$FOM = H_5 n_{H5} + W_5 n_{W5} + S_5 n_{S5} + N_5 n_{N5} + G_5 n_{G5}$$

$$Invulnerability = SCT + MD + FOM$$

# Optimization of Invulnerability

$$MD = 0.75n_{H4} + 0.1n_{W4} + 0.1n_{S4} + 0.75n_{N4} + 0.75n_{G4}$$

$$SCT = 1n_{H6} + 1n_{W6} + 0.5n_{S6} + 0.25n_{N6} + 0.75n_{G6}$$

$$FOM = 0.27n_{H5} + 0.99n_{W5} + 0.99n_{S5} + 0.1n_{N5} + 0.99n_{G5}$$

# 04

# Optimization

# Constraints

$$SFA = H_0 n_H + W_0 n_W + S_0 n_S + N_0 n_N + G_0 n_G > 0.67684$$

$$LFC = H_1 n_H + W_1 n_W + S_1 n_S + N_1 n_N + G_1 n_G > 0.394$$

$$ODSS = H_2 n_H + W_2 n_W + S_2 n_S + N_2 n_N + G_2 n_G > 0.4431$$

$$MSO = H_3 n_H + W_3 n_W + S_3 n_S + N_3 n_N + G_3 n_G > 0.6162$$

$$MD = H_4 n_H + W_4 n_W + S_4 n_S + N_4 n_N + G_4 n_G > 0.64767$$

$$FOM = H_5 n_H + W_5 n_W + S_5 n_S + N_5 n_N + G_5 n_G > 0.64767$$

$$SCT = H_6 n_H + W_6 n_W + S_6 n_S + N_6 n_N + G_6 n_G > 0.59725$$

# Objective Function

$$OPG = Reliability \cdot Resilience \cdot Invulnerability$$

$$Reliability = SFA + LFC + ODSS$$

$$Resilience = SFA + ODSS + MSO + MD + SCT$$

$$Invulnerability = SCT + MD + FOM$$

# Results

- Hydro < 15% (y = 16.786)
  - n_1 = 0.15 = 15%
  - n_2 = 0 = 0%
  - n_3 = 0.8222 = 82.22%
  - n_4 = 0.0001 = 0.01%
  - n_5 = 0.3139 = 31.39%
- Hydro < 15% (y = 17.2276)
  - n_1 = 0.15
  - n_2 = 0.114
  - n_3 = 0.7722
  - n_4 = 0.0951
  - n_5 = 0.2040
- No upper bounds (y = 15.7144)
  - n_1 = 0.4005 = 40.05%
  - n_2 = 0.3445 = 34.45%
  - n_3 = 0 = 0%
  - n_4 = 0 = 0%
  - n_5 = 0.255 = 25.5%
- No upper bounds (y = 11.3356)
  - n_1 = 0.2824
  - n_2 = 0.114
  - n_3 = 0.2654
  - n_4 = 0.093
  - n_5 = 0.2451

# Possible Errors

- Reflects a theoretical power grid
  - Doesn't consider political, social, or economical factors
- Doesn't consider logistical challenges
- Assumes that the relationship between the factors are linear
- A simplification of the grid rather than slower fluctuations
- There are likely other factors

# Works Cited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# Thank you

## Special Thanks

## Foundation Instructor: Alex Wong

## Honors Instructor: Joshua Rhodes