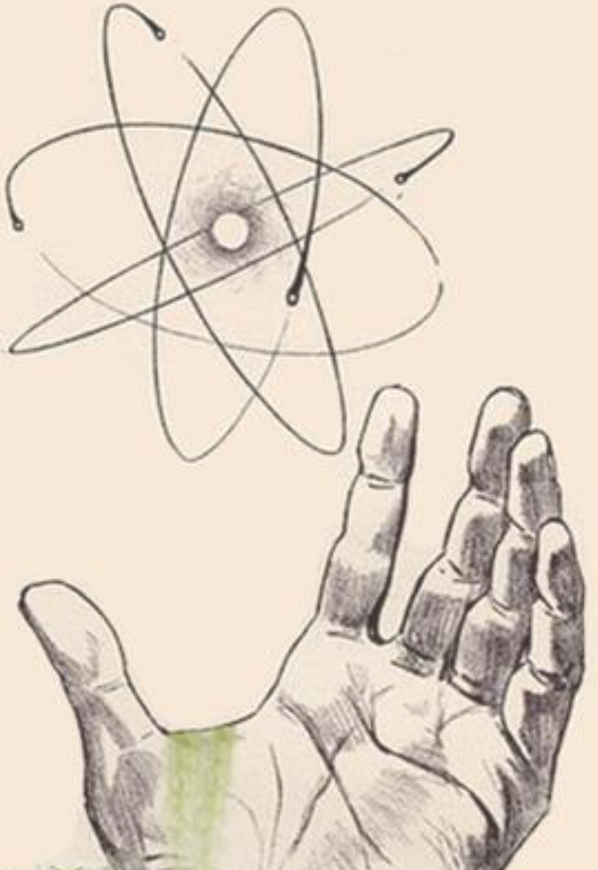
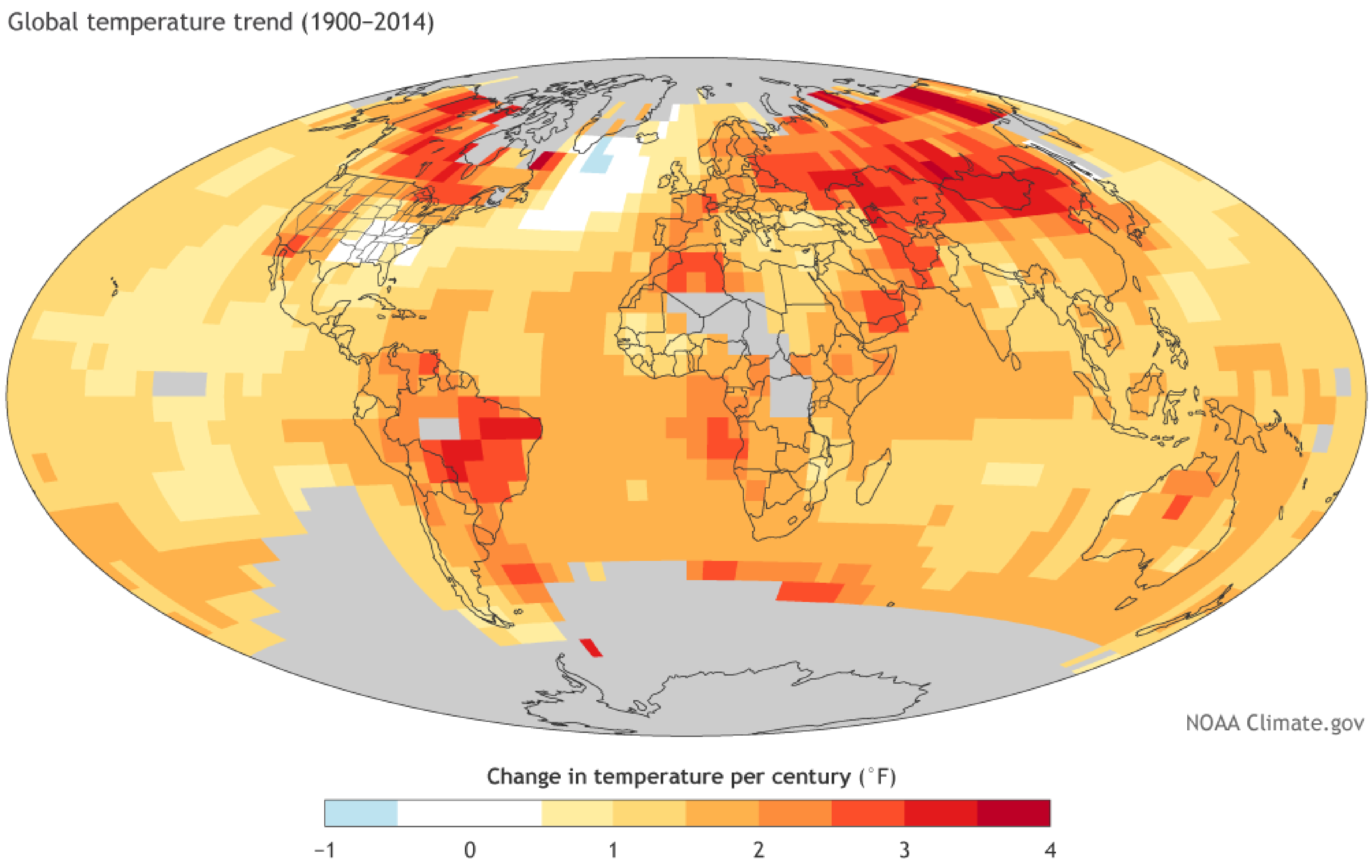
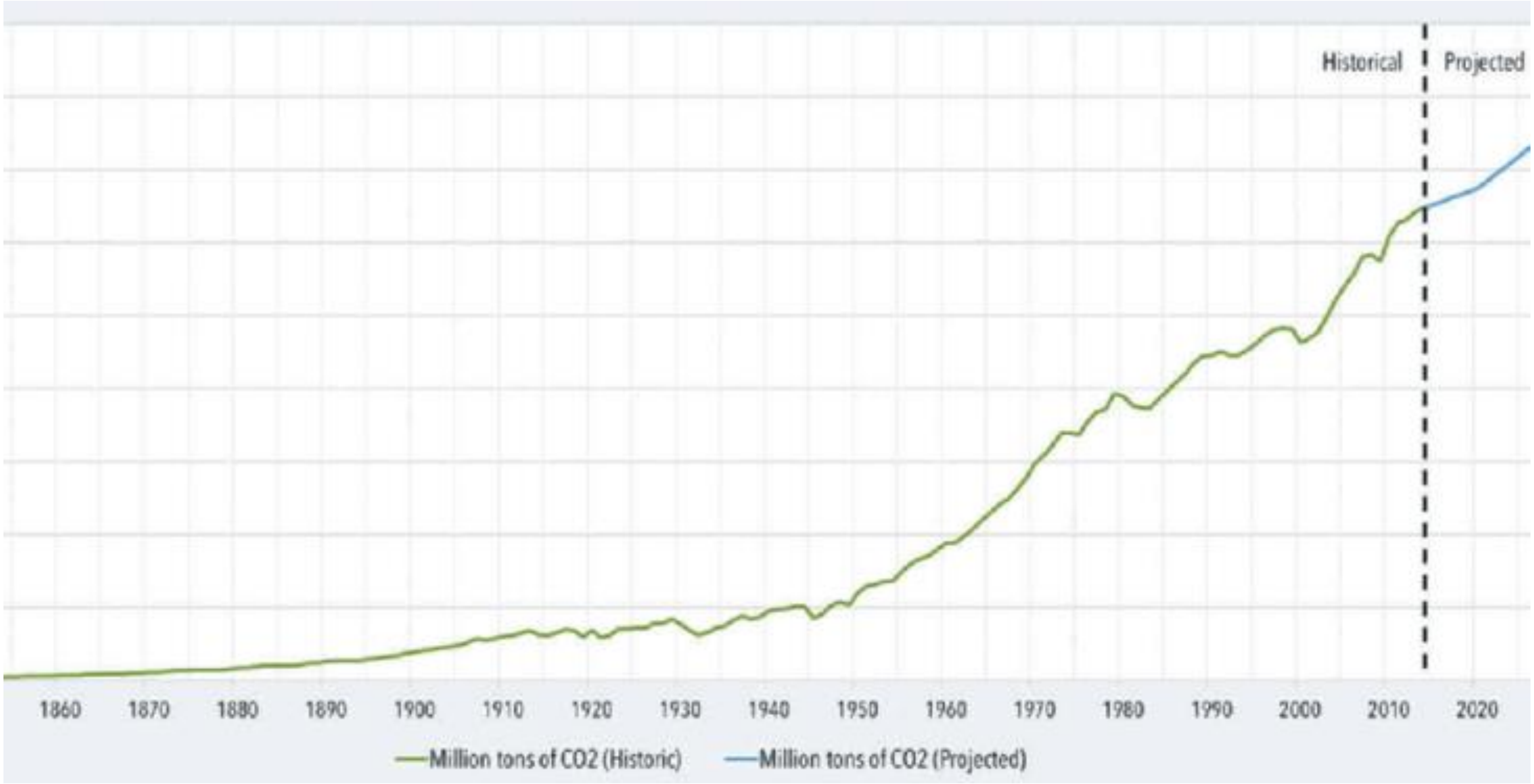
RE-IMAGINING THE NUCLEAR POWER INDUSTRY THROUGH INNOVATION, ARCHITECTURE, AND EDUCATION FOR A MORE SUSTAINABLE DYNAMIC BETWEEN THE BUILT AND NATURAL ENVIRONMENT

Luke Hoberg | NDSU 2023

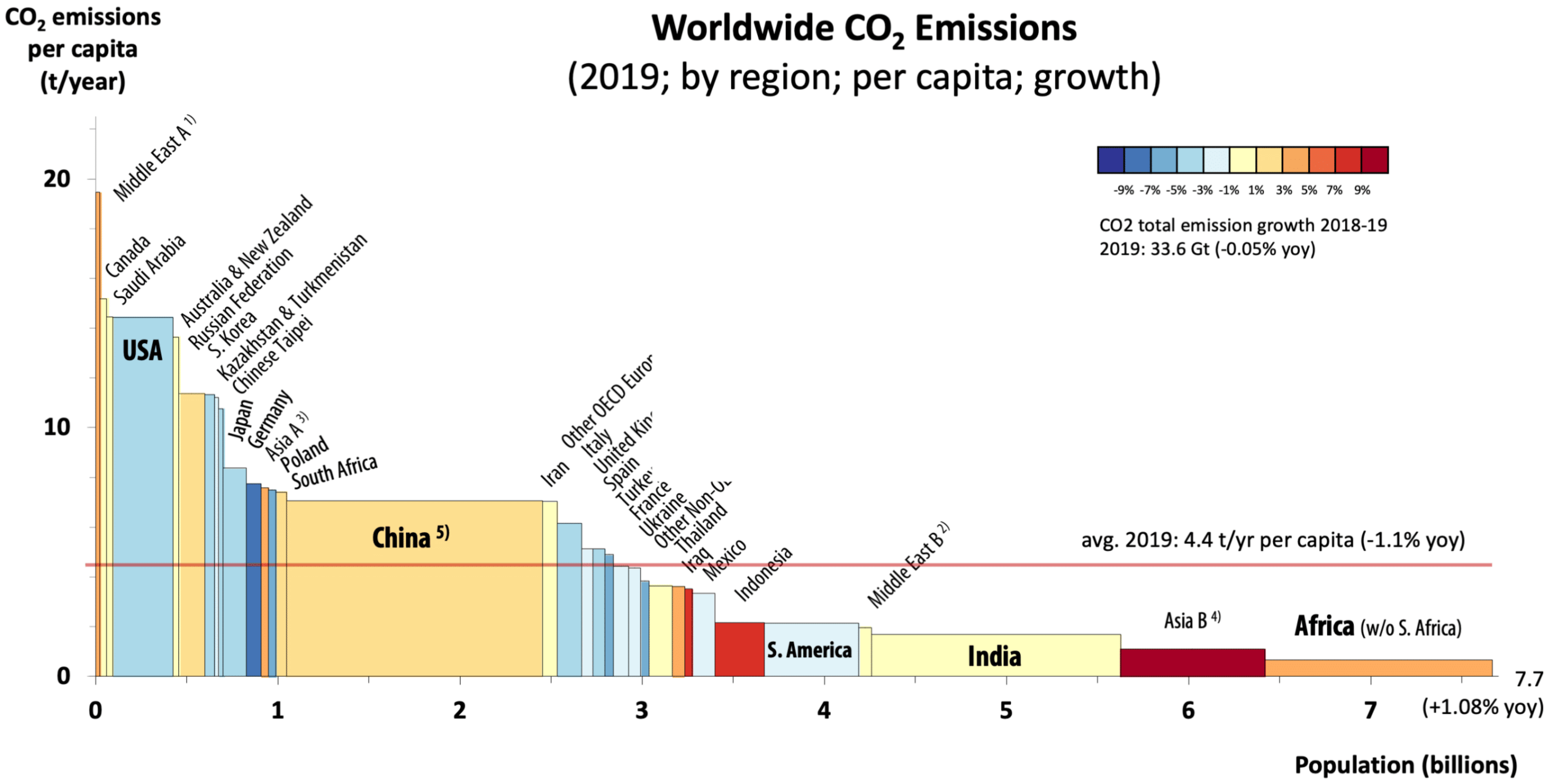



Global temperature trend (1900–2014)
NOAA Climate.gov
Change in temperature per century (°F)
−1
0
1
2
3
4

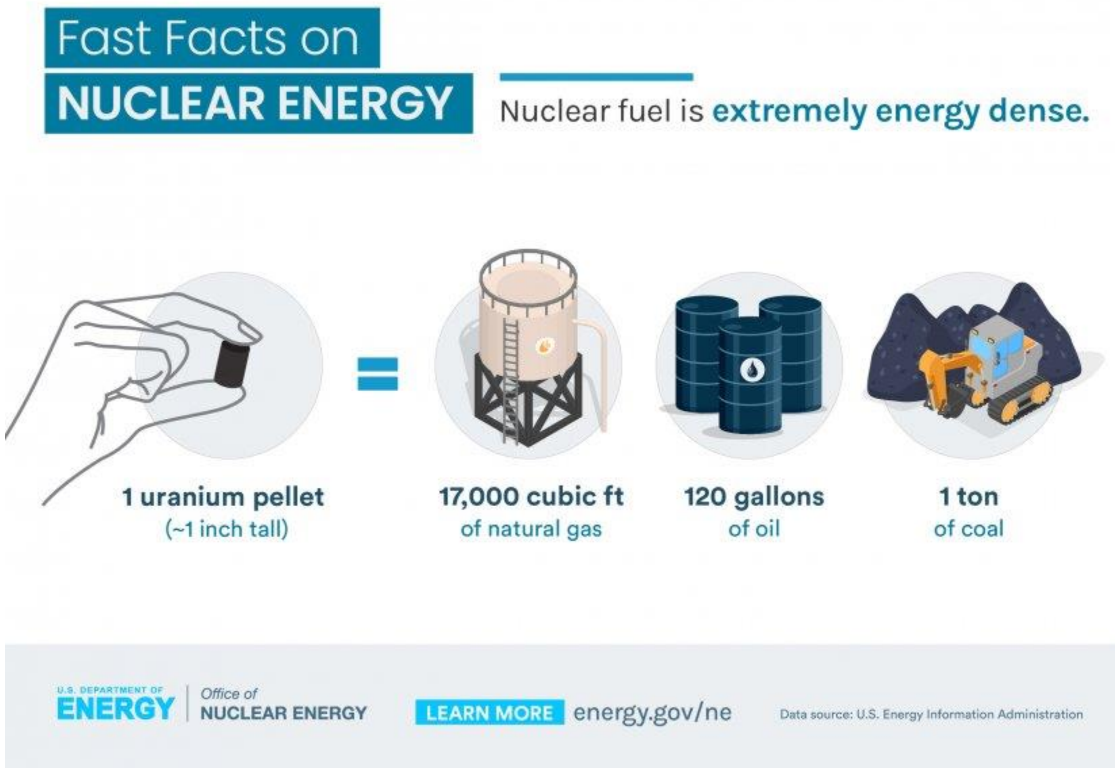

Historical
Projected
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Million tons of CO2 (Historic)
Million tons of CO2 (Projected)

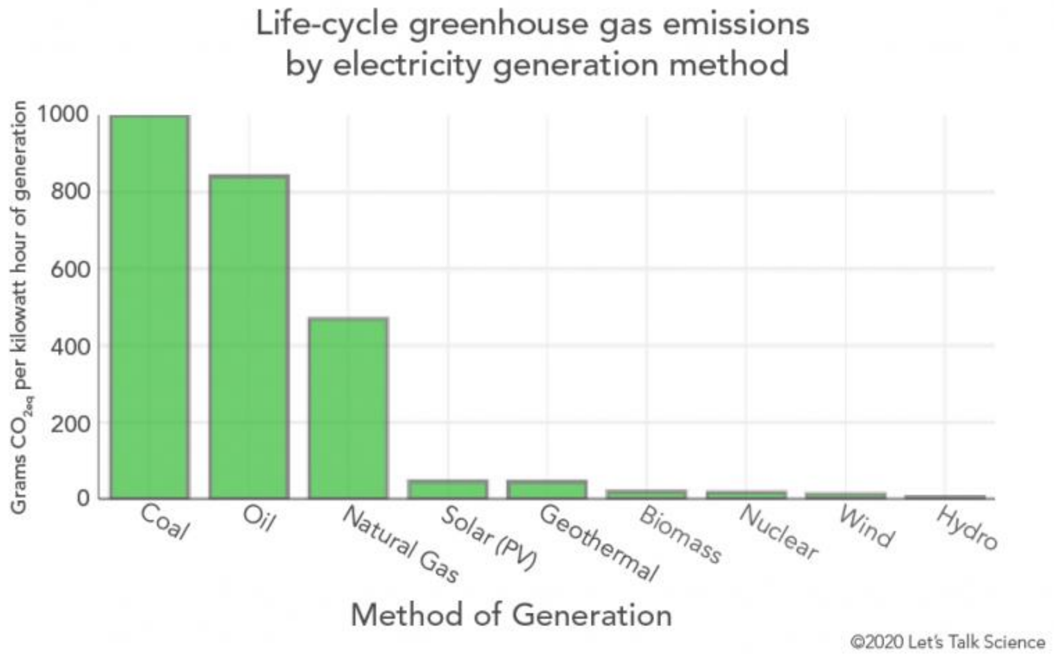
Worldwide CO_2 Emissions

(2019; by region; per capita; growth)



How can we implement more environmentally sustainable energy production methods to replace fossil fuel dependency that have lower emission rates and overall pollution?


Fast Facts on
NUCLEAR ENERGY
Nuclear fuel is extremely energy dense.
1 uranium pellet
(~1 inch tall)
17,000 cubic ft
of natural gas
120 gallons
of oil
1 ton
of coal
U.S. DEPARTMENT OF ENERGY
Office of NUCLEAR ENERGY
LEARN MORE energy.gov/ne
Data source: U.S. Energy Information Administration


Life-cycle greenhouse gas emissions
by electricity generation method
Grams CO_{2eq} per kilowatt hour of generation
1000
800
600
400
200
0
Coal
Oil
Natural Gas
Solar (PV)
Geothermal
Biomass
Nuclear
Wind
Hydro
Method of Generation
©2020 Let's Talk Science

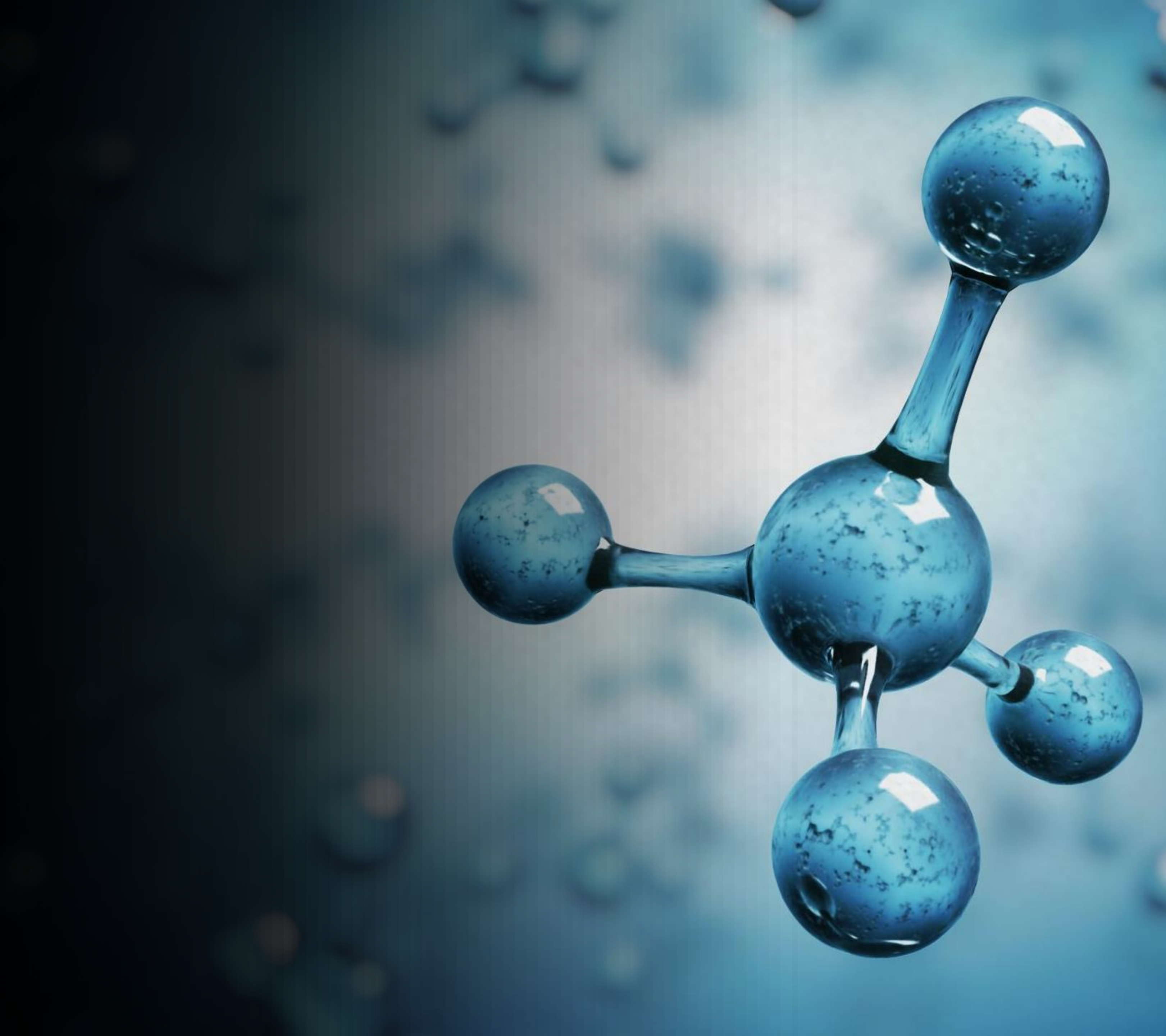
Problems with nuclear energy

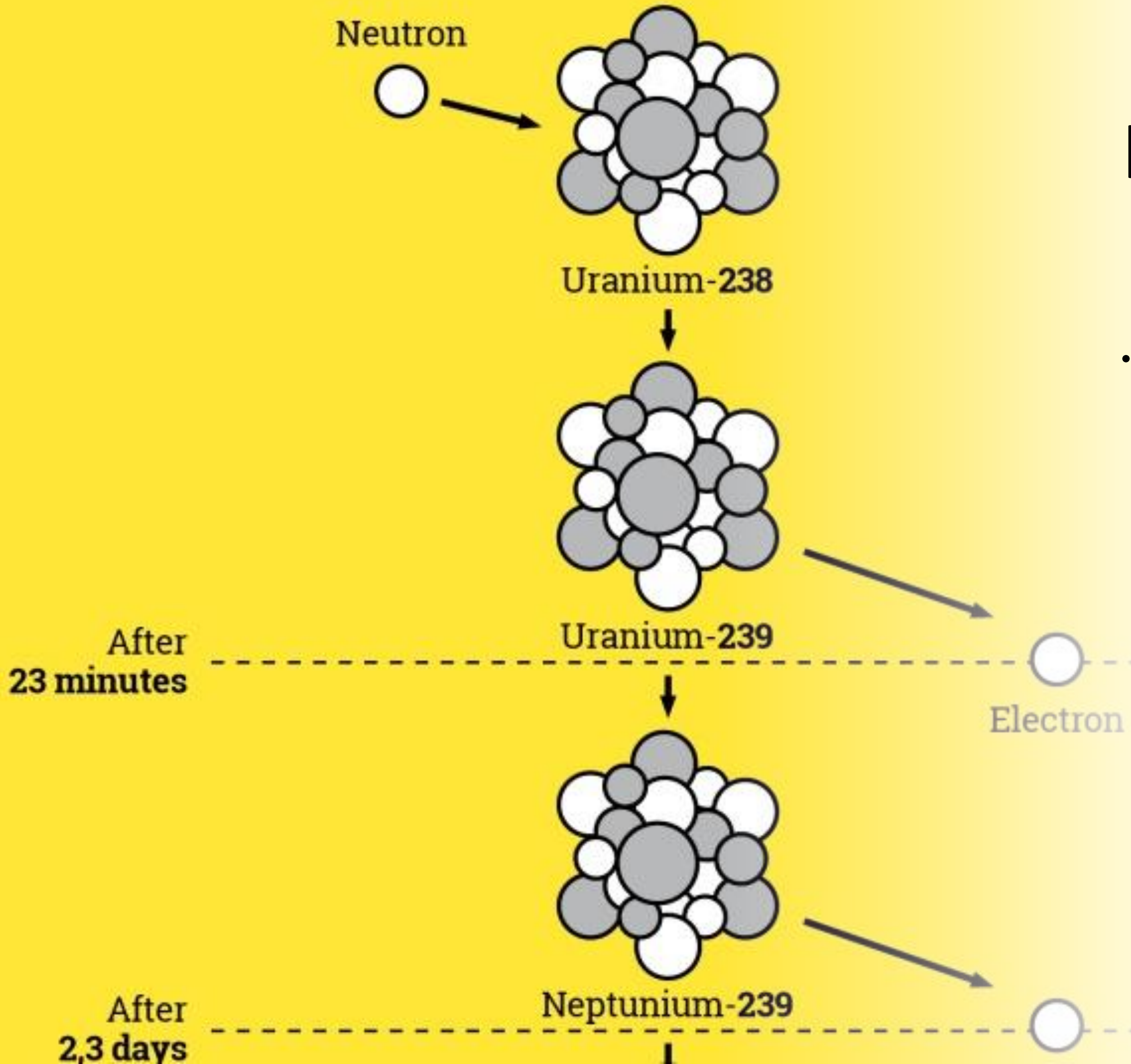
- Waste
- Safety
- Fear

Waste

Fast-neutron Reactors

- These reactors able to "unlock" more energy from the uranium fuel. These reactors differ than the current reactors in operation today which are only able to use approximately 10% of the stored energy in uranium fuel.





How they work

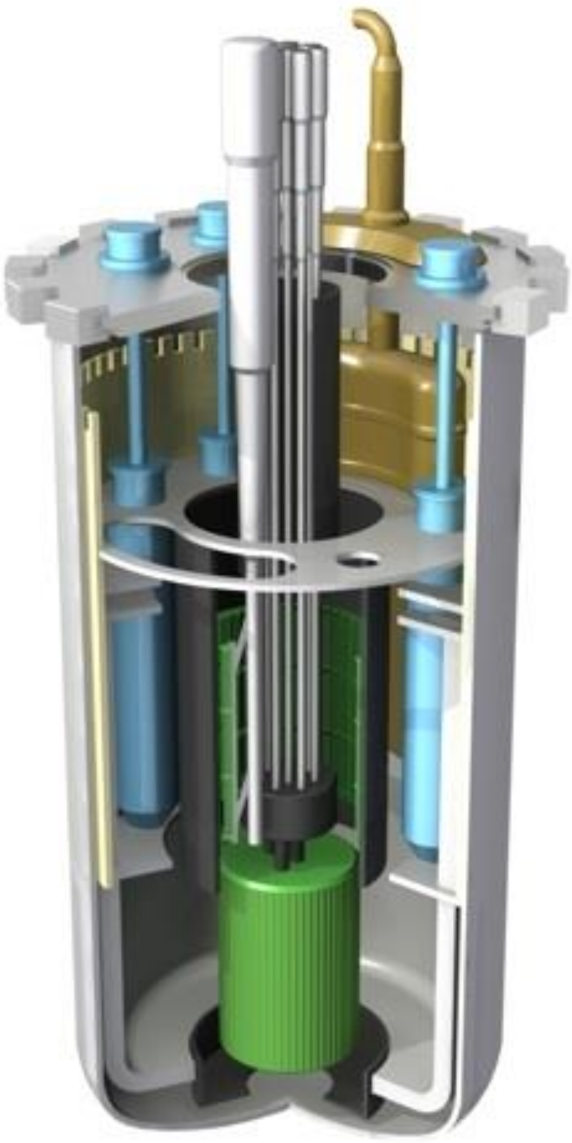
- Uranium fuel consists of approximately of 99.3% 238u and 0.7% 235U. U238 is only able to undergo fission by absorbing neutrons with high kinetic energy(fast neutron). 235U can undergo fission by fast and slow neutrons. A fast reactor utilizes fast neutrons by having U238 capture a fast neutron and through a decaying process convert into plutonium 239. This reaction becomes self-sustaining allowing the reactor to use the plutonium-239 as fuel and create more neutrons to sustain the chain reaction. Through this process fast reactors can use the uranium fuel much more effectively and use spent fuel from other reactors. Which also lowers the fuel radioactivity from thousands of years to hundreds.

Experimental Breeder Reactor(EBR)-1&2

- EBR 1 and 2 were research reactors that were made to test the theory of fast reactor technology. EBR 1 confirmed the hypothesis and EBR 2 was built to demonstrate reprocessing spent fuel from conventional reactors and utilizing it as fuel for itself. It ran from 1965 to 1994 until it was decommissioned.

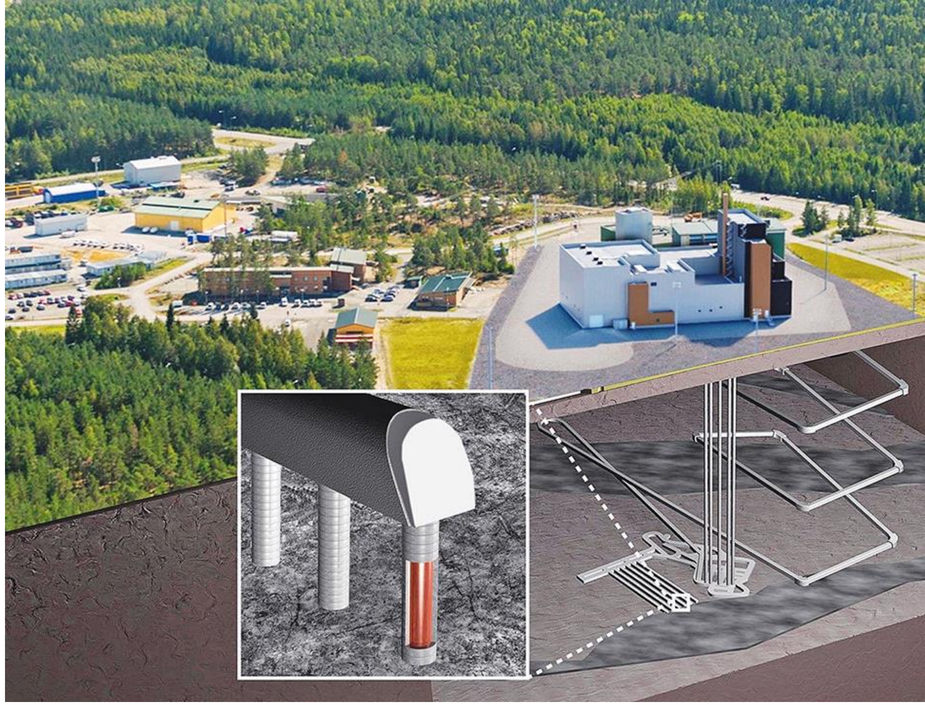
Gen IV Fast Reactor in Development

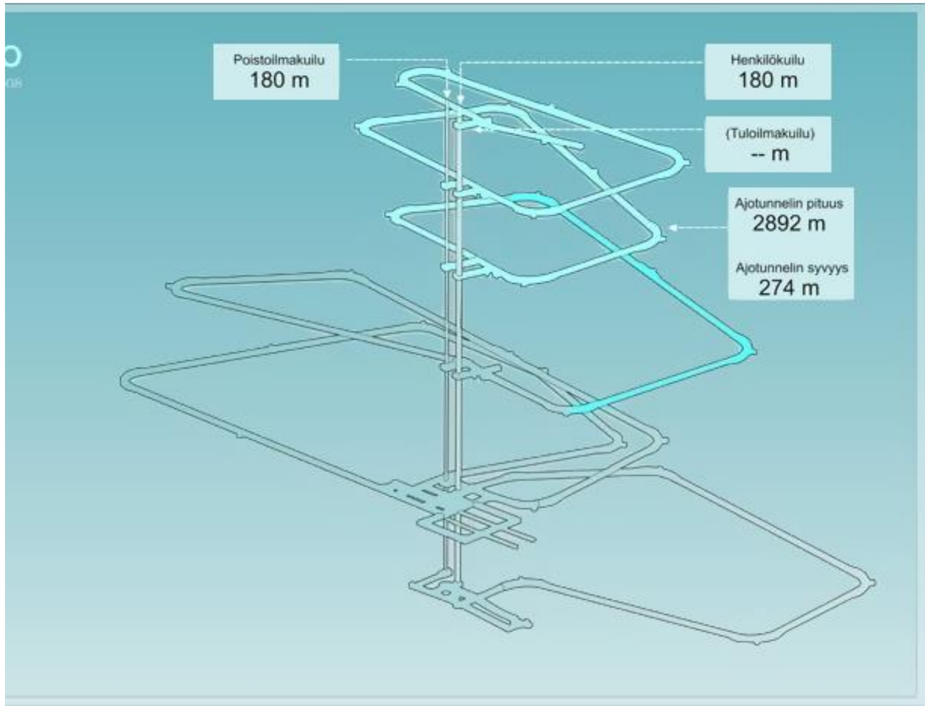
- GE's PRISM reactor is currently in development and has received funding from the DOE. It is one of the multiple Gen. IV prototype reactors that are receiving funding to be commercialized with the next decade. This is the reactor that I have implemented in my design. This reactor will allow to eat up current stockpiles of high level waste also known as spent fuel



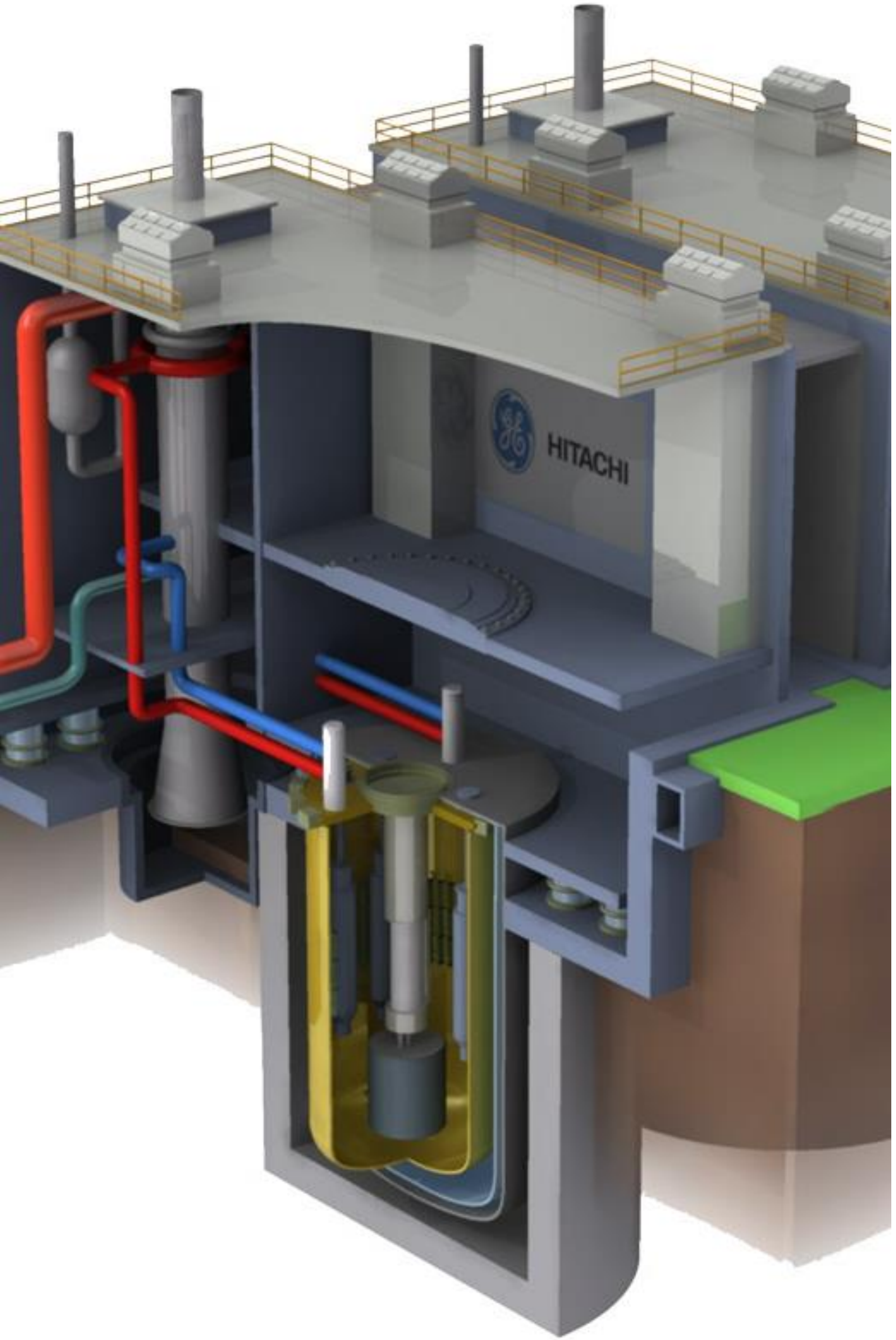
Geological Repository

- A nuclear repository is an underground storage area to stockpile spent fuel also known as high-level radioactive waste. Once spent fuel from current stockpiles has been reused in the fast reactor the waste will be stored in an underground repository to live out its remaining radioactive lifespan.





Safety



Sodium Cooled

The PRISM reactor uses molten sodium as a coolant. This allows for the reactor to operate at higher temperatures and at lower pressures. Negating the possibility of an explosion scenario like Fukushima. If temperatures rise too high the core will expand which decreases its density slowing the fission reaction. The molten sodium dissipates this heat very efficiently and stops the core from a meltdown. There have also been many technological advancements in digital automation that reduces the chance of human mishaps. With external threats in mind the reactor is designed to site below ground as well.

Fear and Stigmas of Nuclear Energy

1

Design a contemporary facility that is harmonious with its local environment. This approach will be much better received to the public than the previous utilitarian designs.

2

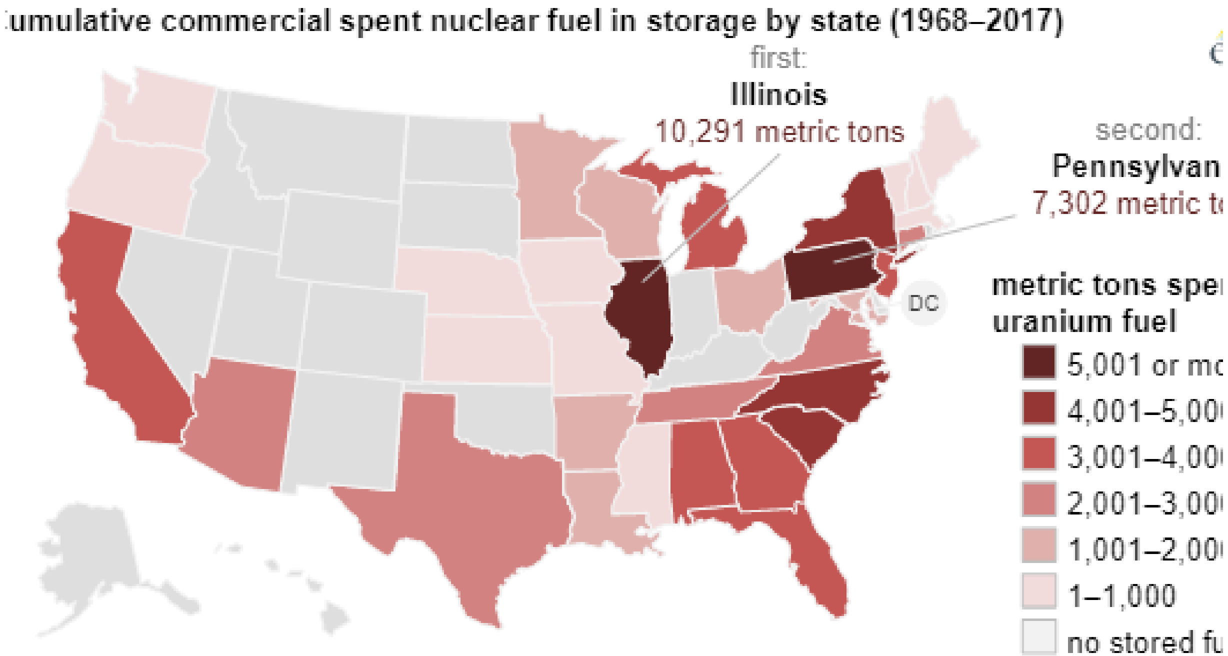
Incorporate a visitor center where people can learn about the process and safety features integrated within the facility.

3

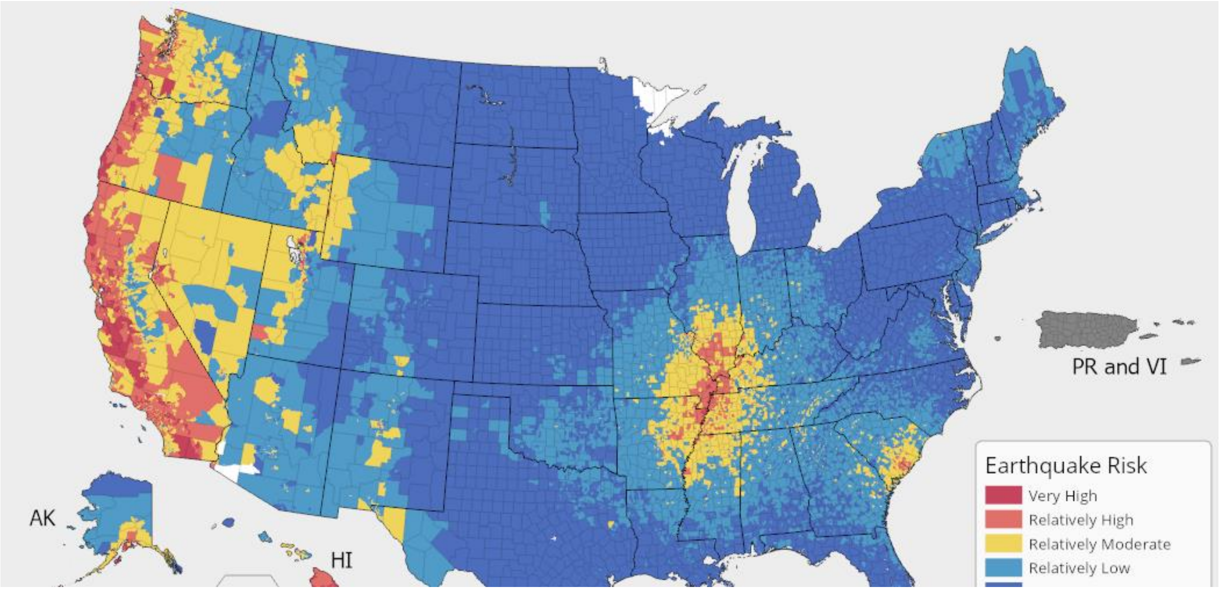
Be a part of the local community. Host events directed towards the neighboring communities to promote a healthy and mutually beneficial relationship.

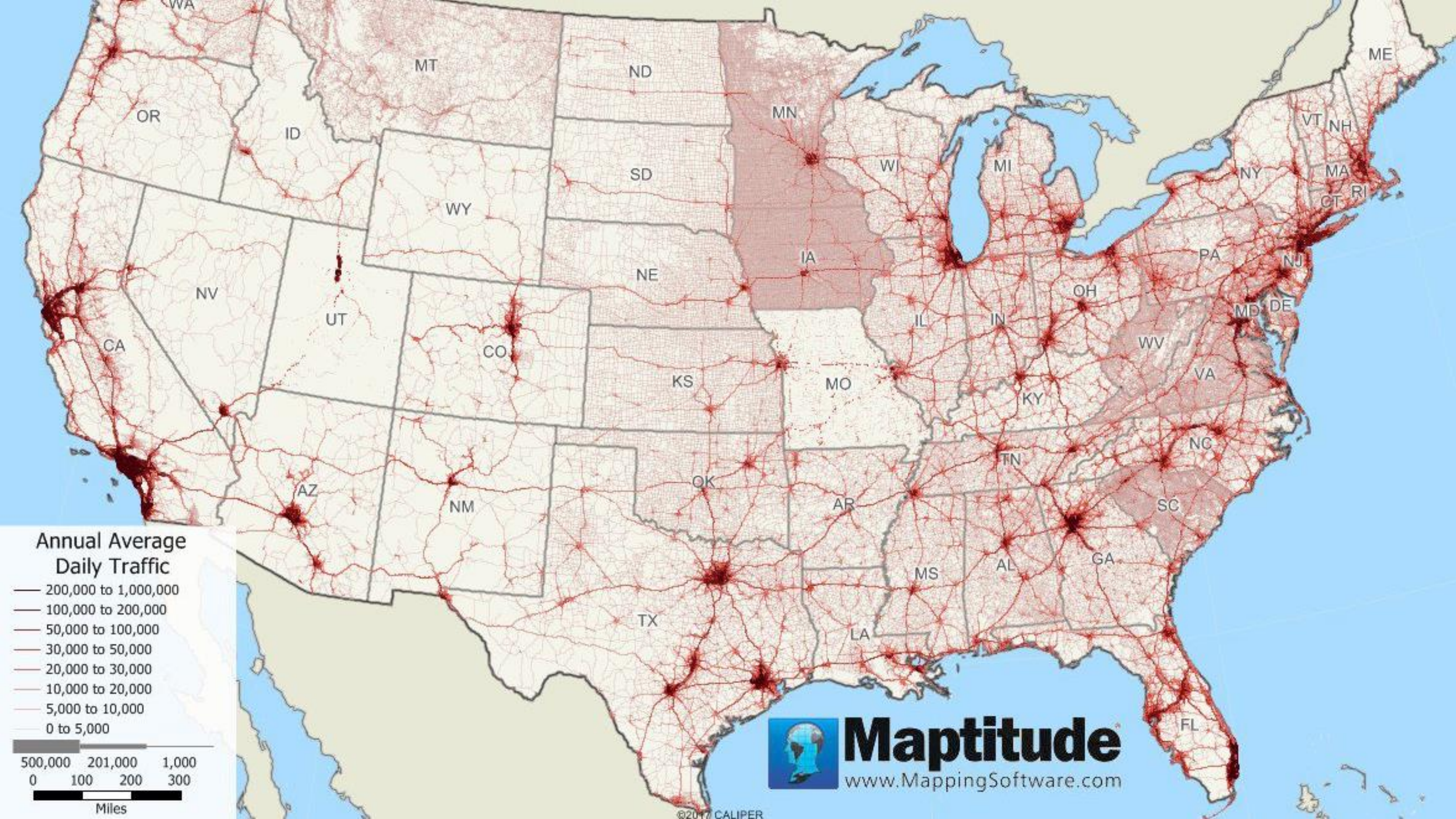

Site


Granite Outcrops in the United States


umulative commercial spent nuclear fuel in storage by state (1968–2017)
first:
Illinois
10,291 metric tons
second:
Pennsylvan
DC
metric tons spe
uranium fuel
1–1,000


Nuclear Power Plants in North America
Canada
United States of America


AK
HI
PR and VI
Earthquake Risk
Very High
Relatively High
Relatively Moderate
Relatively Low


WA
MT
ND
MN
OR
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SD
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VT
NH
NY
MA
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WY
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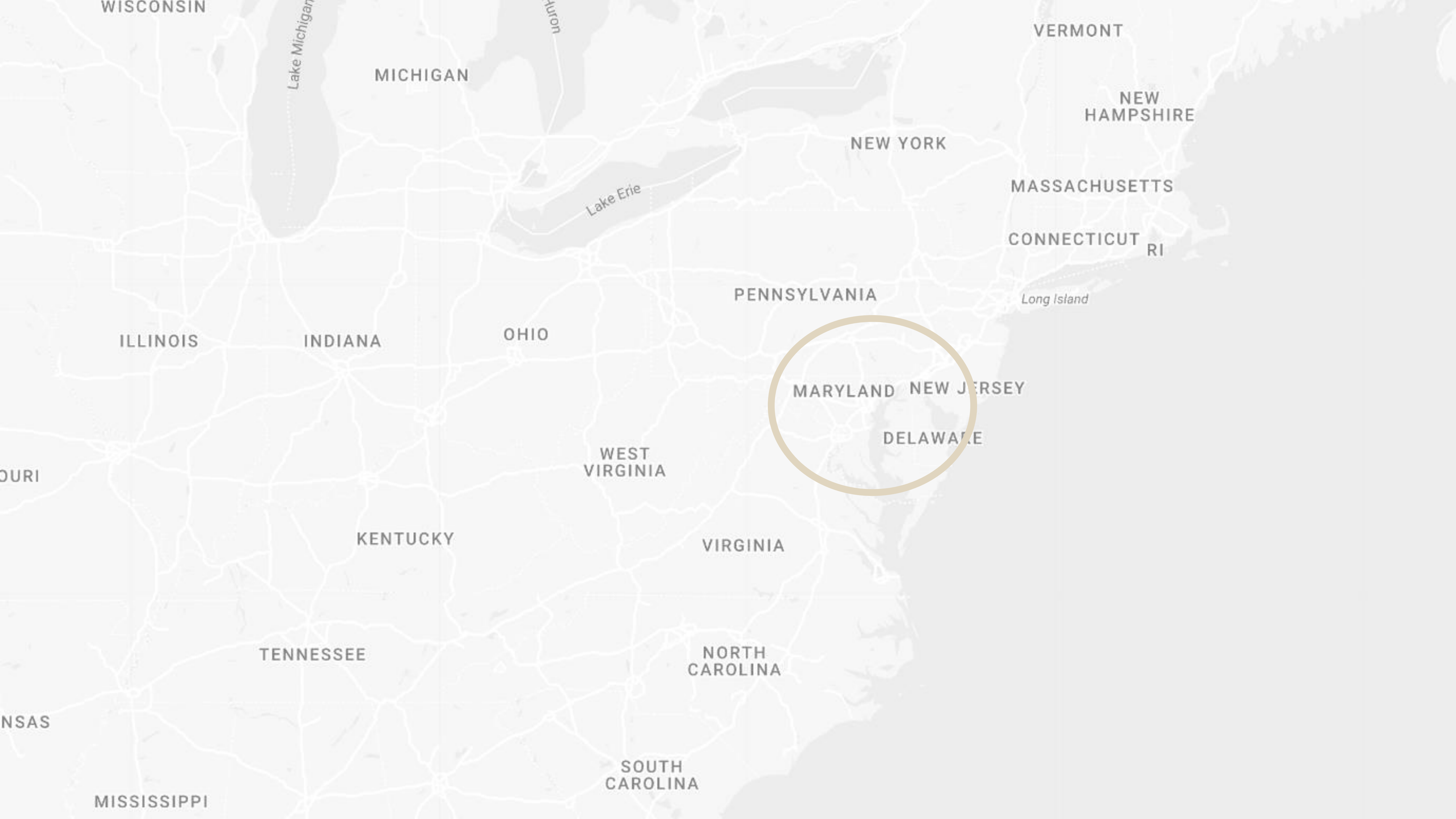
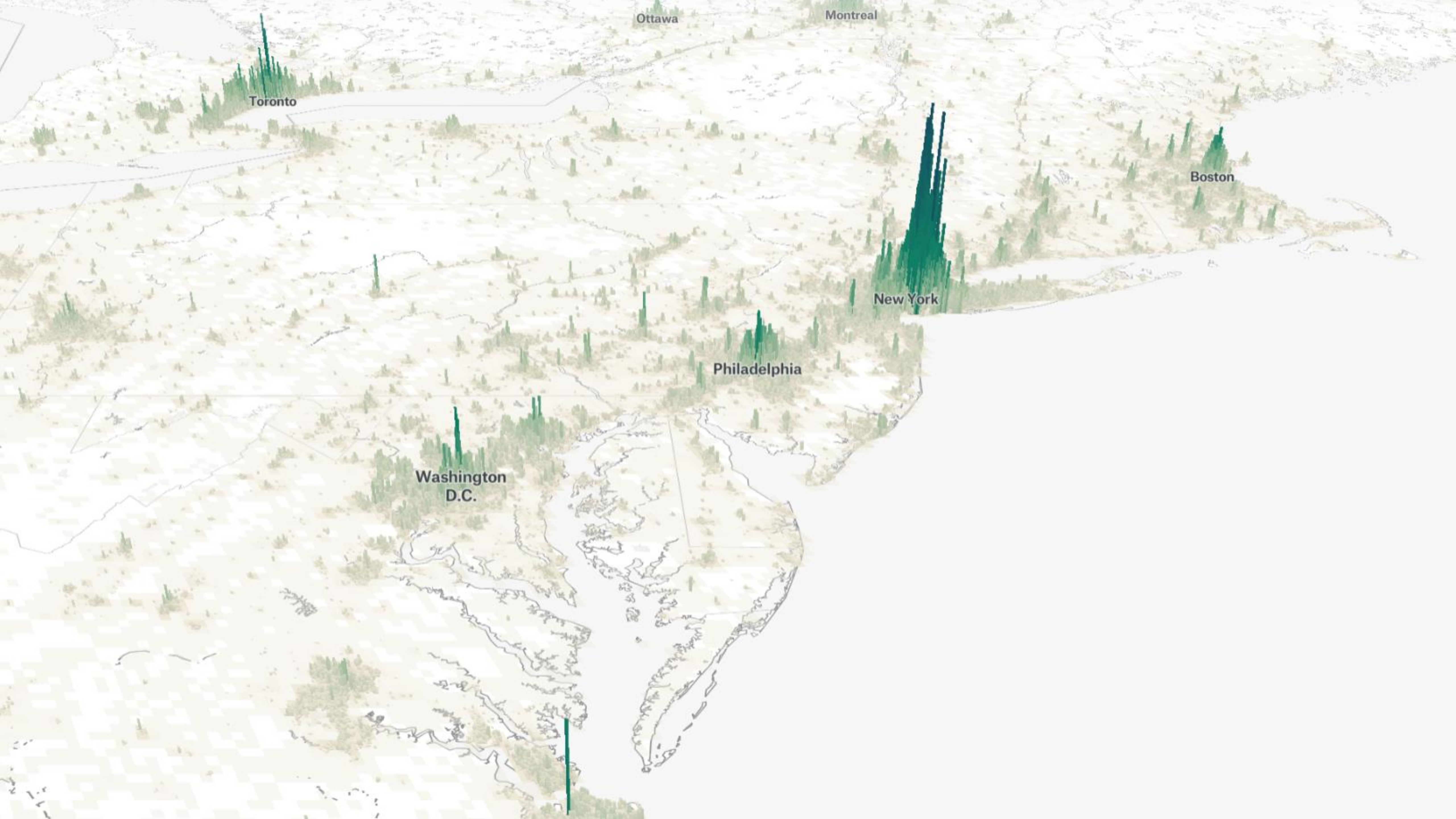
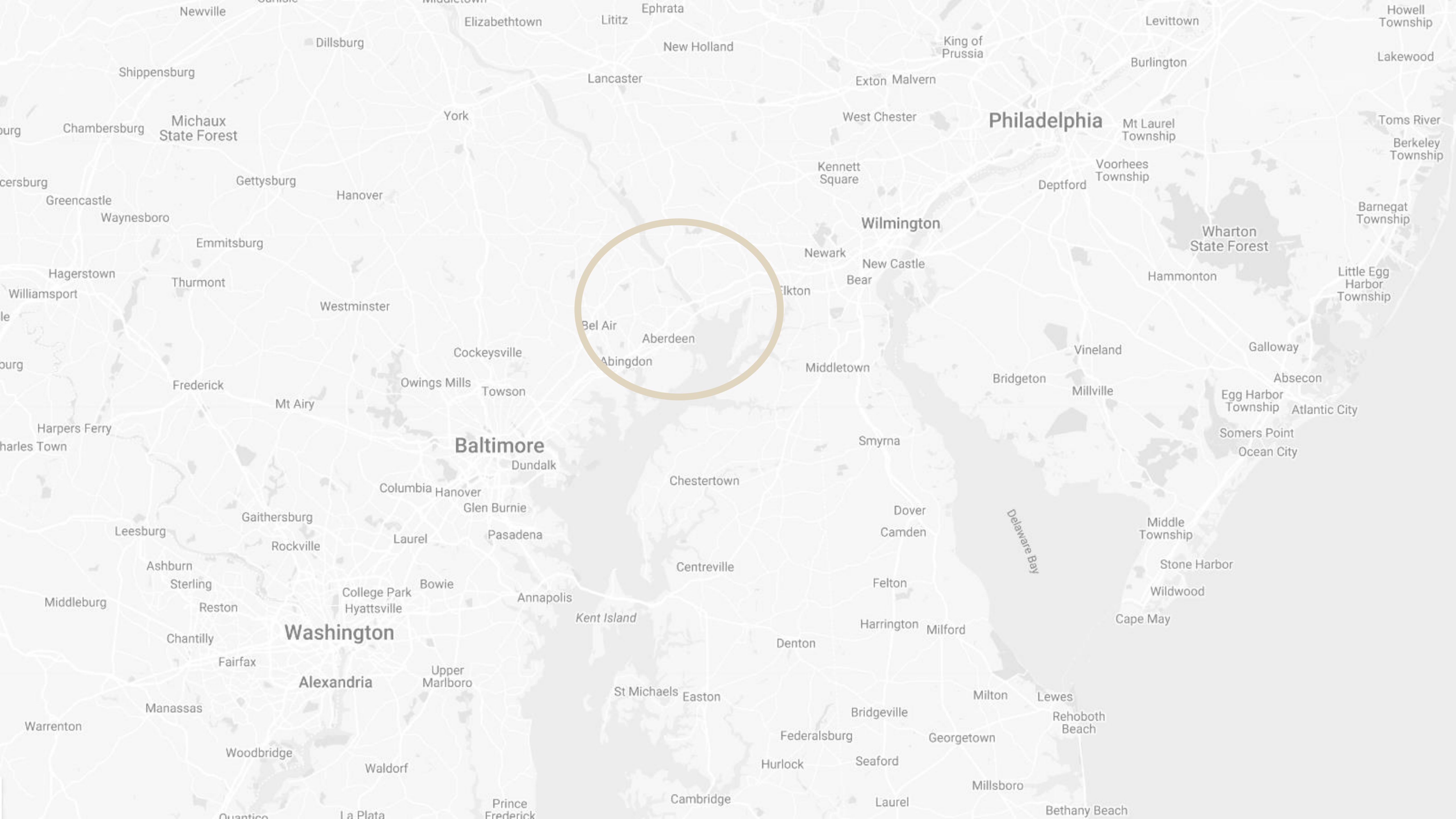
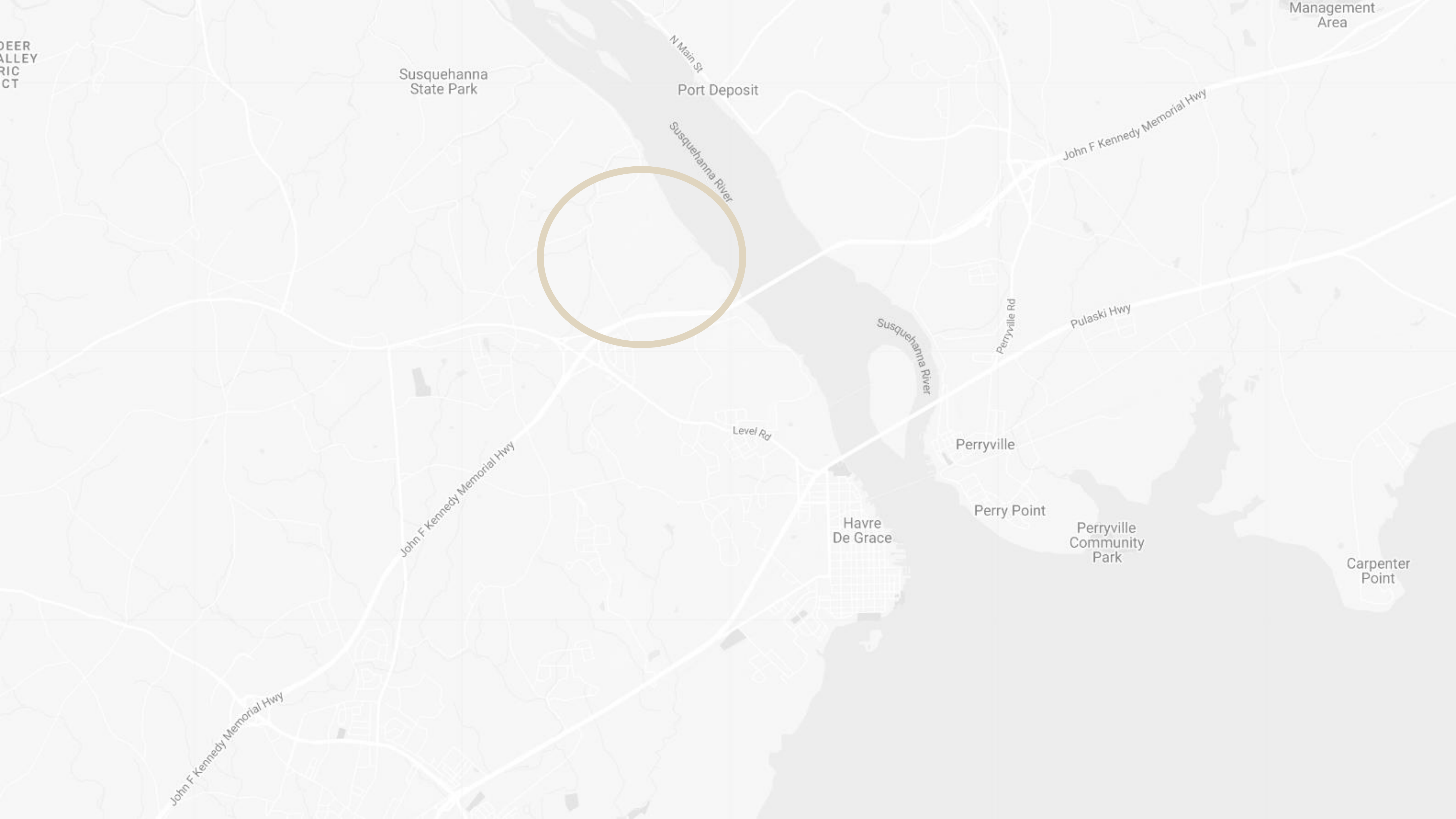
IA
PA
NJ
NV
UT
CO
OH
MD
DE
IL
IN
CA
WV
KS
MO
VA
KY
NC
TN
AZ
NM
OK
AR
SC
GA
AL
MS
TX
LA
FL
Annual Average Daily Traffic
200,000 to 1,000,000
100,000 to 200,000
50,000 to 100,000
30,000 to 50,000
20,000 to 30,000
10,000 to 20,000
5,000 to 10,000
0 to 5,000
500,000
201,000
1,000
0
100
200
300
Miles
Maptitude
www.MappingSoftware.com
©2017 CALIPER

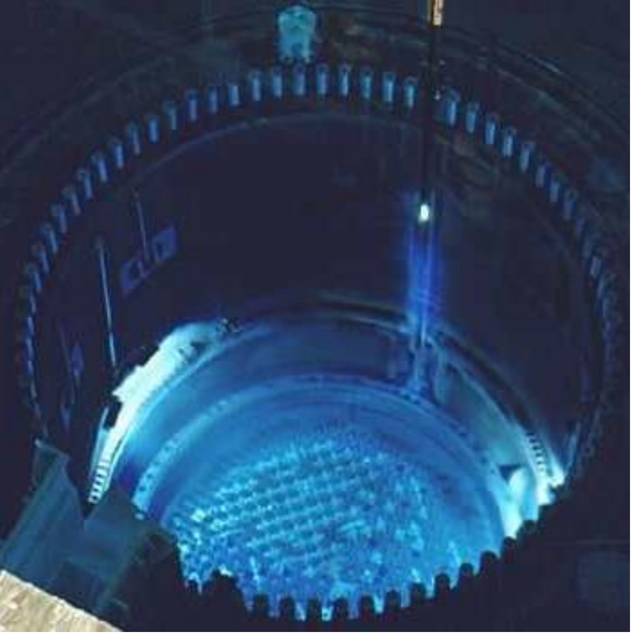

WISCONSIN
Lake Michigan
MICHIGAN
VERMONT
NEW HAMPSHIRE
NEW YORK
MASSACHUSETTS
Lake Erie
CONNECTICUT
RI
PENNSYLVANIA
Long Island
ILLINOIS
INDIANA
OHIO
MARYLAND
DELAWARE
WEST VIRGINIA
KENTUCKY
VIRGINIA
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
MISSISSIPPI


Ottawa
Montreal
Toronto
Boston
New York
Philadelphia
Washington
D.C.


Newville
Elizabethtown
Lititz
Ephrata
Levittown
Howell Township
Dillsburg
New Holland
King of Prussia
Shippensburg
Lancaster
Exton
Malvern
Burlington
Lakewood
York
West Chester
Philadelphia
Mt Laurel Township
Toms River
Chambersburg
Michaux State Forest
Berkeley Township
Gettysburg
Kennett Square
Voorhees Township
Greencastle
Hanover
Deptford
Waynesboro
Wilmington
Barnegat Township
Emmitsburg
Wharton State Forest
Newark
Hagerstown
New Castle
Thurmont
Bear
Hammonton
Little Egg Harbor Township
Williamsport
Westminster
Bel Air
Aberdeen
Abingdon
Cockeysville
Vineland
Galloway
Middletown
Bridgeton
Absecon
Frederick
Owings Mills
Towson
Millville
Egg Harbor Township
Mt Airy
Atlantic City
Harpers Ferry
Baltimore
Smyrna
Somers Point
Dundalk
Ocean City
Chestertown
Columbia
Hanover
Glen Burnie
Dover
Gaithersburg
Middle Township
Leesburg
Laurel
Pasadena
Camden
Rockville
Delaware Bay
Ashburn
Centreville
Stone Harbor
Sterling
Bowie
Felton
College Park
Wildwood
Middleburg
Annapolis
Reston
Hyattsville
Kent Island
Harrington
Milford
Cape May
Washington
Chantilly
Denton
Fairfax
Upper Marlboro
Alexandria
St Michaels
Easton
Milton
Lewes
Manassas
Bridgeville
Rehoboth Beach
Warrenton
Federalsburg
Georgetown
Woodbridge
Waldorf
Hurlock
Seaford
Millsboro
Cambridge
Laurel
Bethany Beach


Management
Area
Susquehanna
State Park
N Main St
Port Deposit
Susquehanna River
John F Kennedy Memorial Hwy
Pulaski Hwy
Perryville Rd
Susquehanna River
Level Rd
Perryville
Perry Point
Havre
De Grace
Perryville
Community
Park
Carpenter
Point
John F Kennedy Memorial Hwy
John F Kennedy Memorial Hwy

Solution

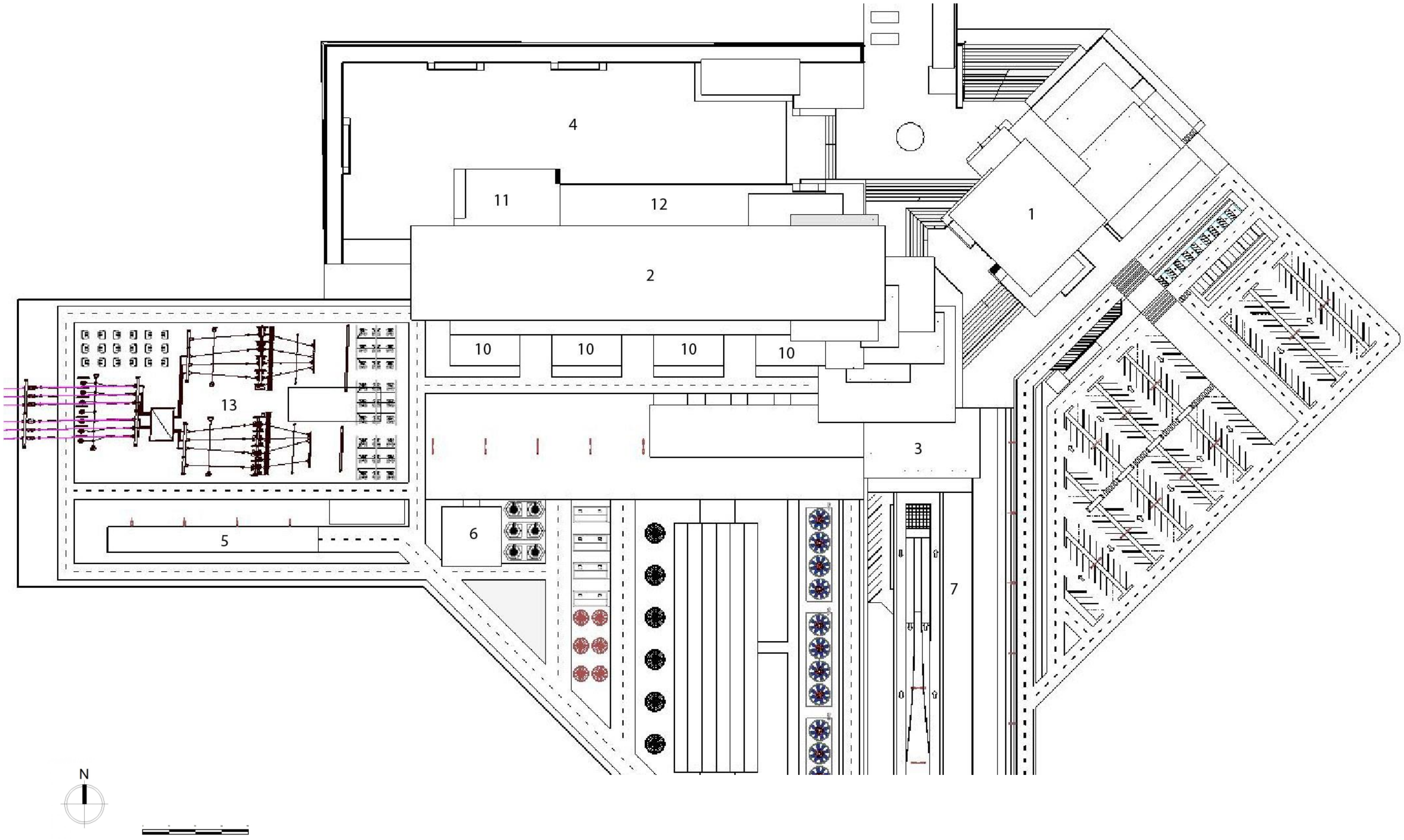


Design Inspiration

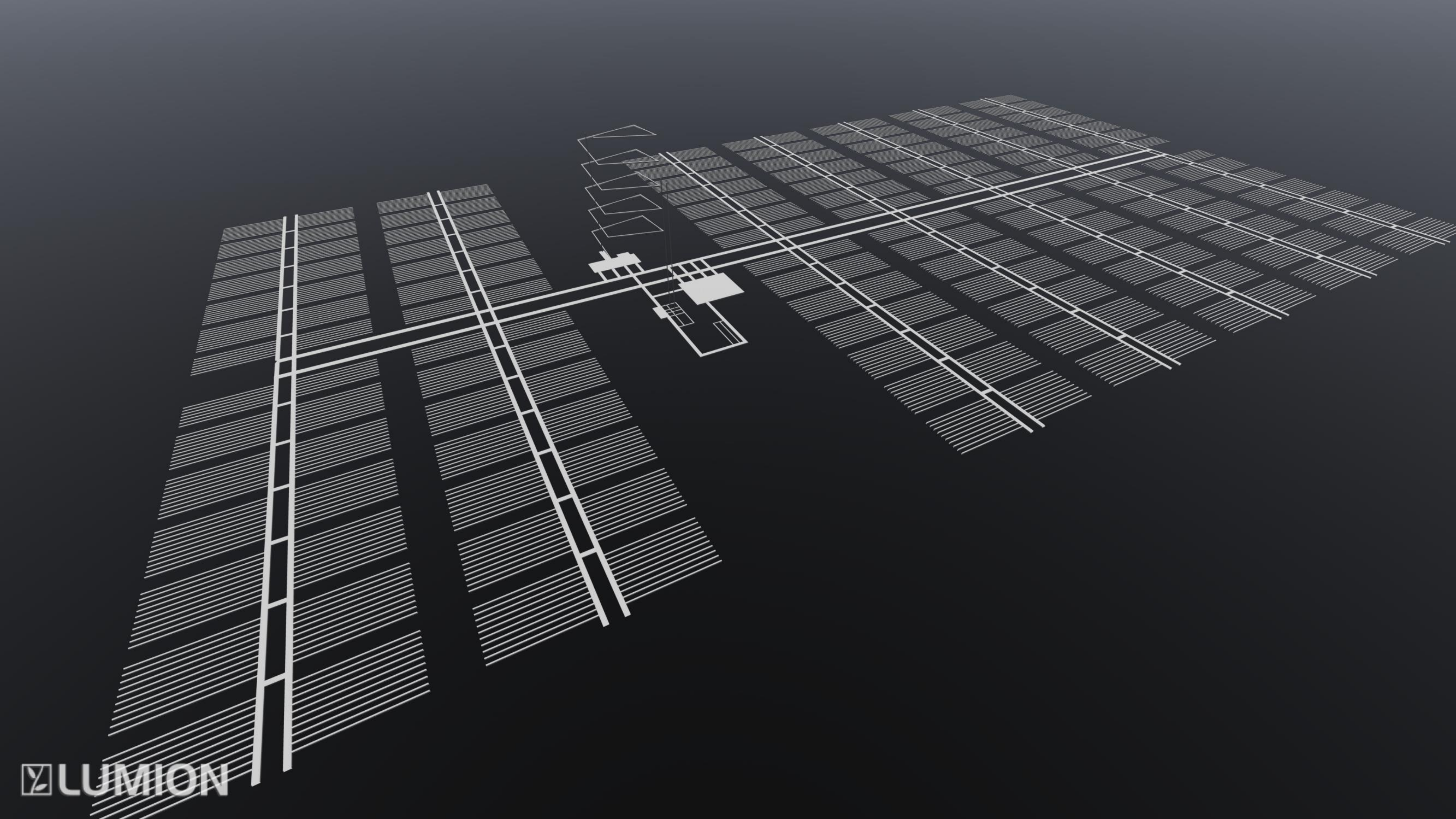
- Large over hangs and "zig zags" facing south to combat sun.
- Separation of visitor center and power plant but still allowing self-guiding tours.
- Pass through to sights of the river and rock structure.
- Large garden and stage for hosting events.
- "Billboard" to attract visitors.
- Pattern from nuclear reactor core for curtain system.


Walter H. Zinn
Nuclear Generating Station

Site Plan

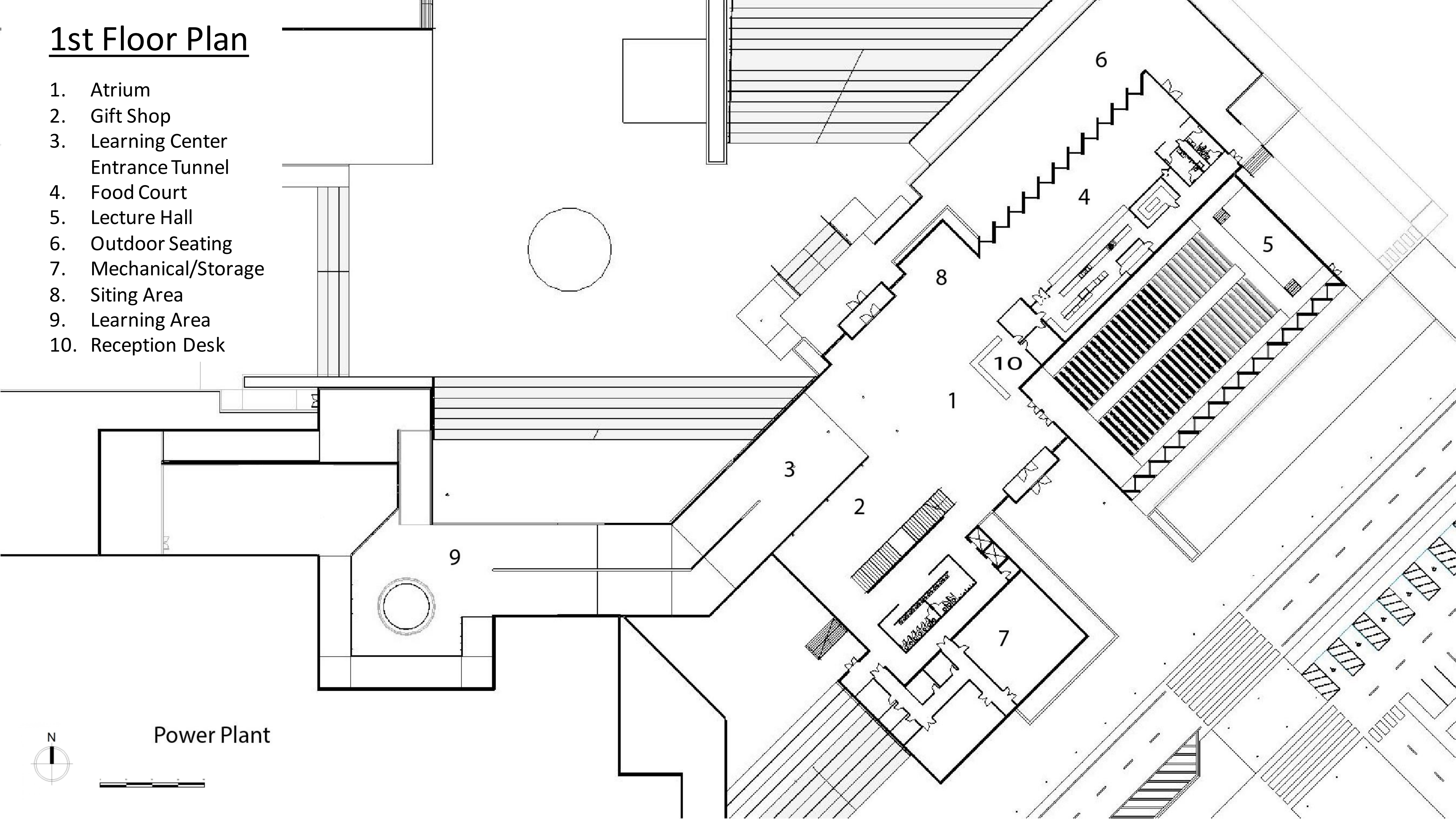


1. Visitor Center
2. Turbine Housing
3. Power Plant Operations
4. Lawn
5. Repository Entrance
6. Deisel Generator
7. Underground Parking
8. Boardwalk
9. Auxiliary Bldg.
10. Reactor
11. Outdoor Stage
12. Reflecting Pool
13. Electrical Substation



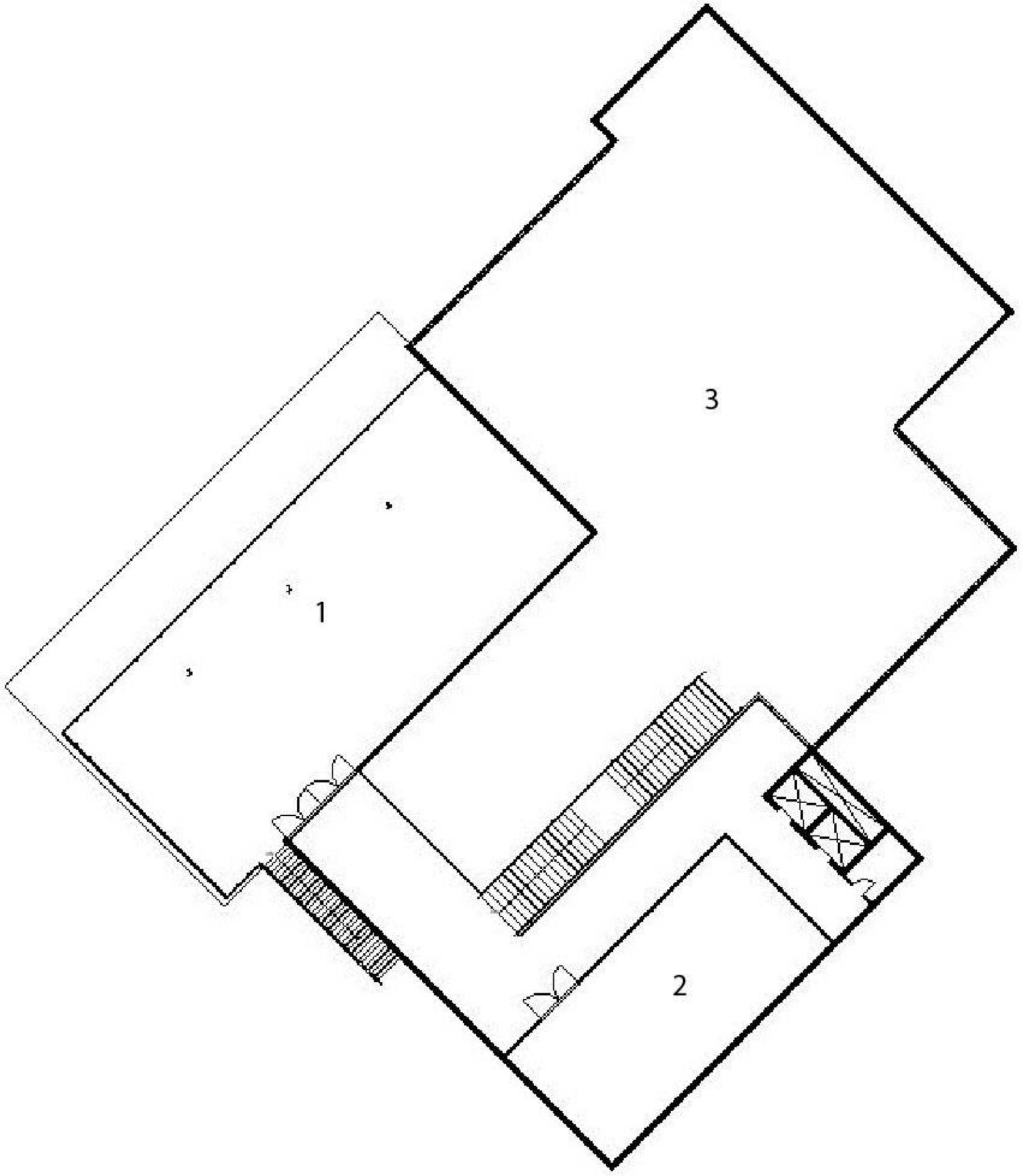
1st Floor Plan

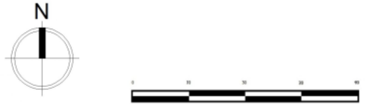
1. Atrium
2. Gift Shop
3. Learning Center Entrance Tunnel
4. Food Court
5. Lecture Hall
6. Outdoor Seating
7. Mechanical/Storage
8. Siting Area
9. Learning Area
10. Reception Desk

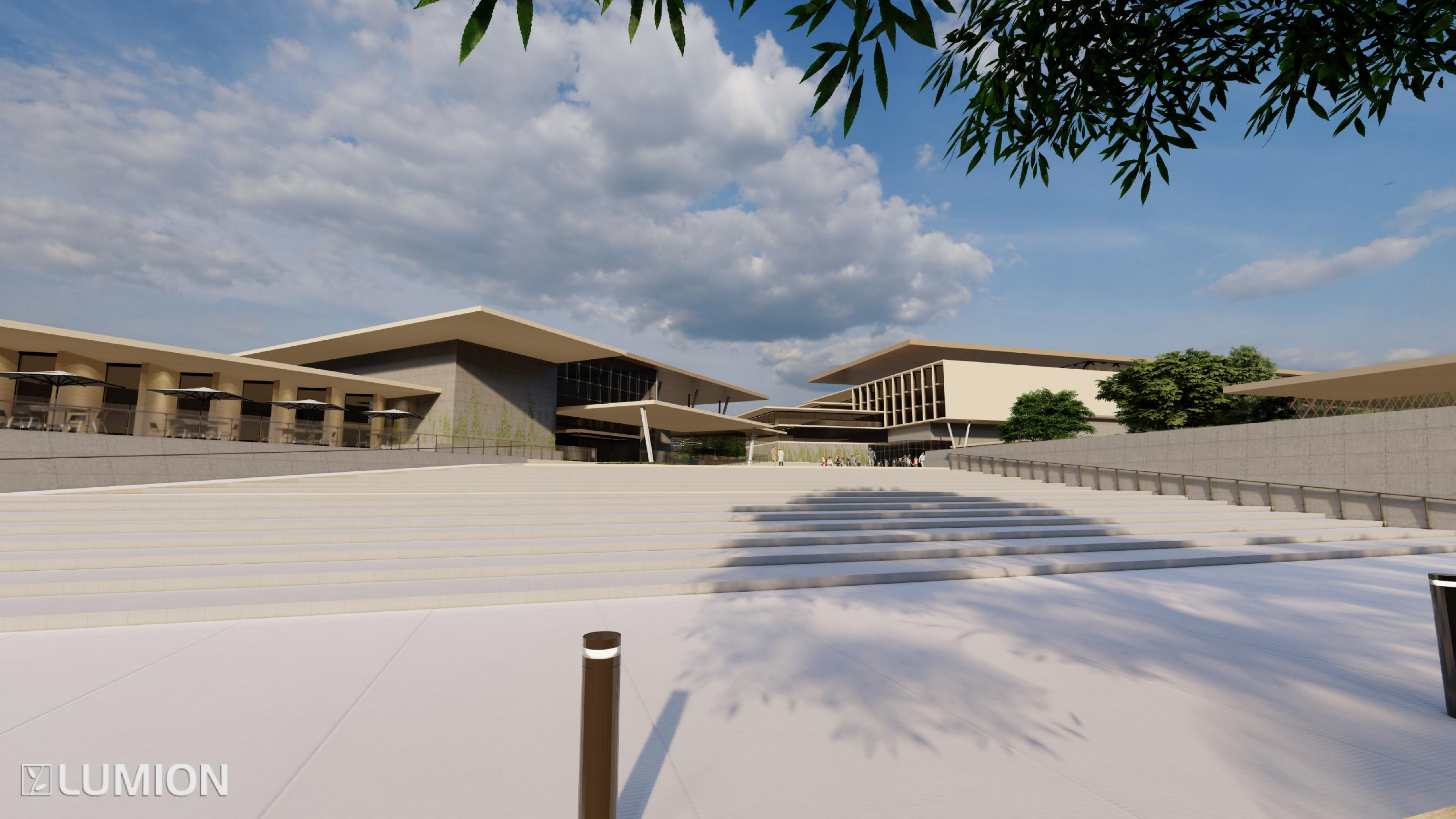


2nd Floor Plan

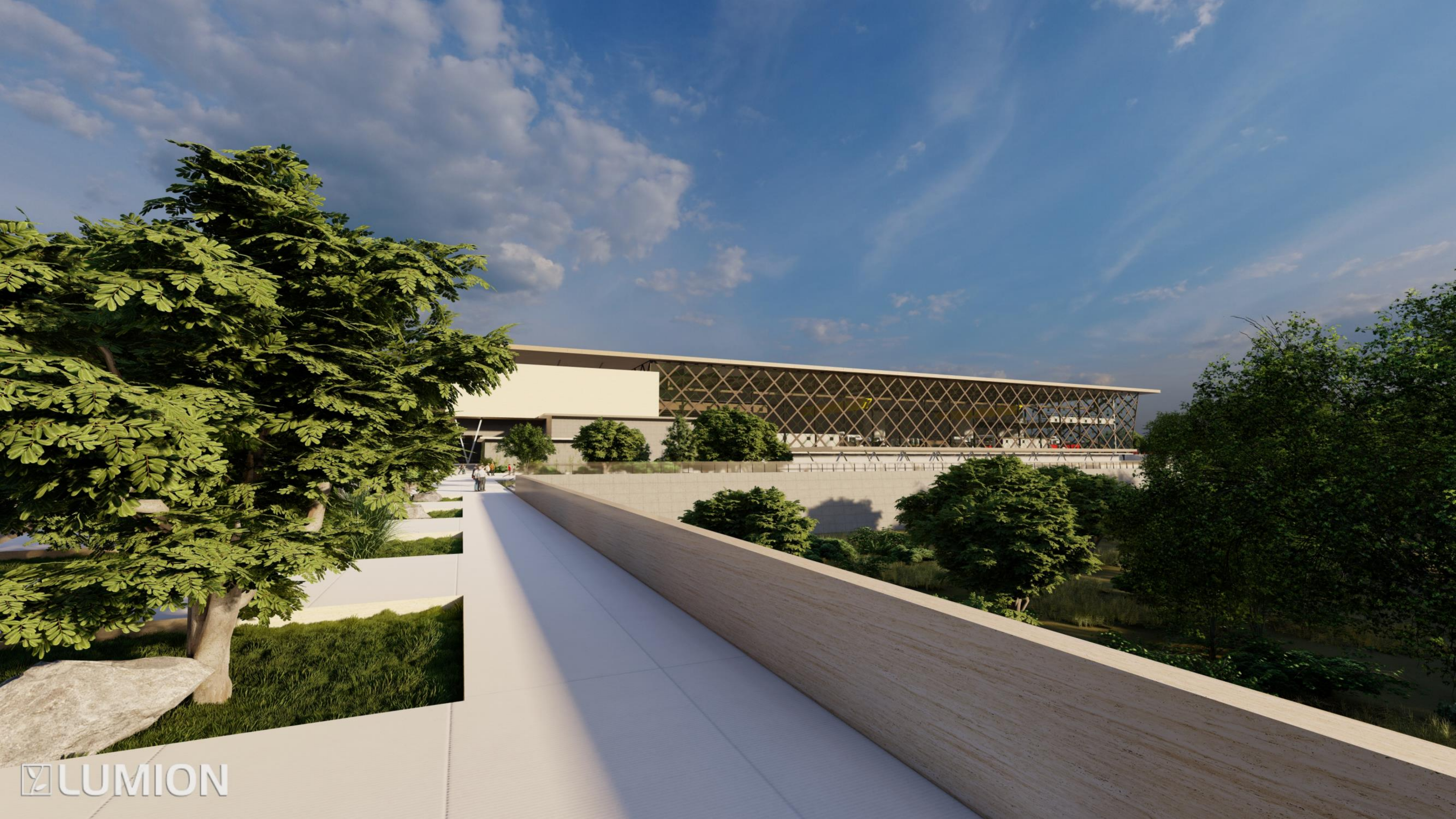
1. Outdoor Balcony
2. Private Room
3. Open to 1st Floor Below








LUMION



Questions

Thank You