

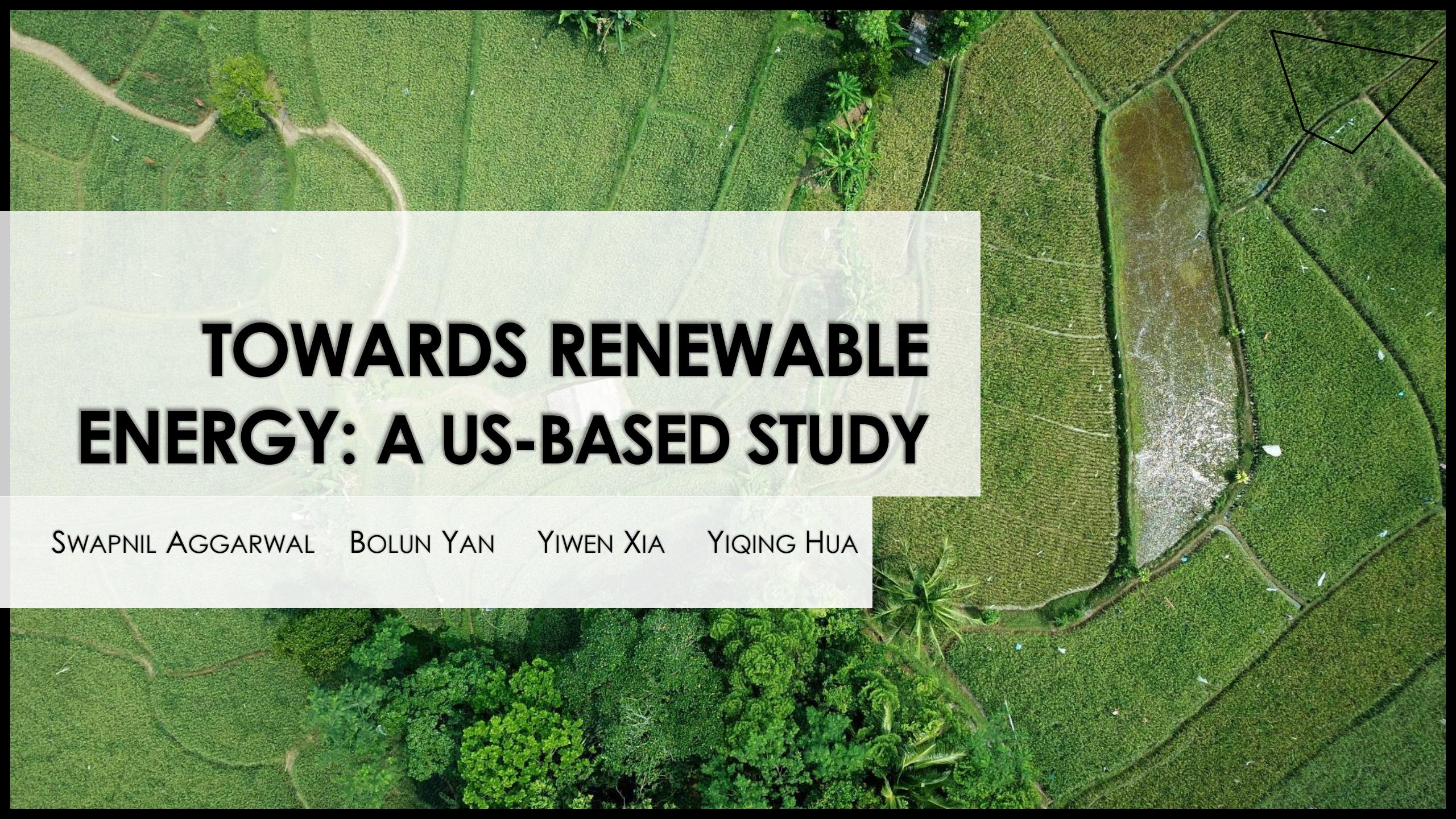
TOWARDS RENEWABLE ENERGY: A US-BASED STUDY

SWAPNIL AGGARWAL

BOLUN YAN

YIWEN XIA

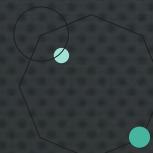
YIQUING HUA



INTRODUCTION

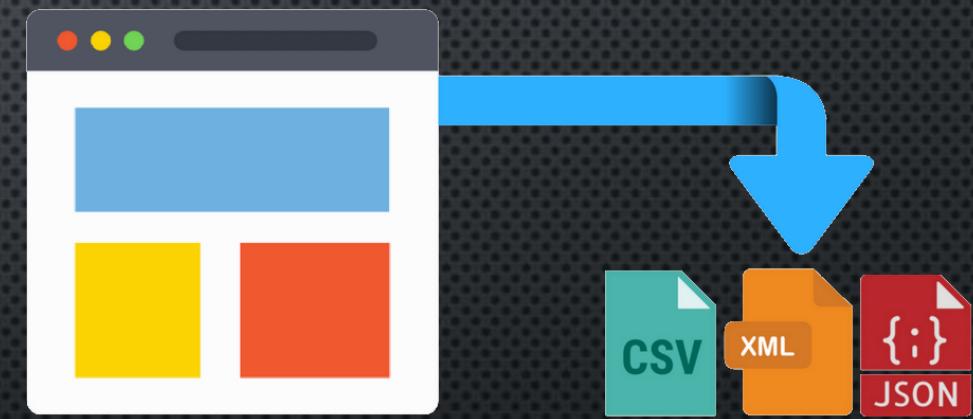
APPLY PYTHON SKILLS LEARNED IN THIS CLASS TO:

- DRAW POLARITIES IN PRODUCTION & CONSUMPTION.
- OUTLINE TRENDS FOR IMPORTANT ENERGY SOURCES.
- DRAW ANALYSIS WITH TIME, CONSUMER, ETC.
- HIGHLIGHT IMPORTANCE OF TECHNICAL POTENTIAL
- CALCULATE POTENTIAL & ANALYZE FINDINGS.



DATA OVERVIEW

- **WIKIPEDIA.ORG:** PRODUCTION & CONSUMPTION, NATIONAL + STATE, AUXILLARY STATE DATA
- **EIA.GOV:** YEAR-WISE STATISTICS OF CONSUMPTION SECTOR AND MONTH-WISE
- **NSRDB:** SOLAR RADIATION DATASET
- **WINDEXCHANGE:** COMPLETE WIND ENERGY AND WINDFARM DATASET
- **ARCGIS:** AUXILLARY DATA (STATE GEOMETRIES)



METHODOLOGY

Sources



ArcGIS



WIKIPEDIA



NREL



Data

BeautifulSoup



NumPy

pandas



SciPy



jupyter



SELENIUM
with
Python

ANACONDA

Analysis

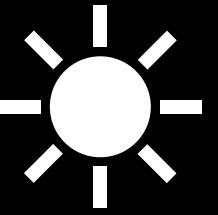


plotly

matplotlib

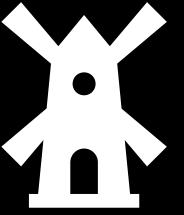


SOURCES



SOLAR ENERGY

RADIANT HEAT
ENERGY FROM SUN



WIND ENERGY

KINETIC ENERGY
FROM THE WIND



HYDRO-ELECTRIC

KINETIC ENERGY OF
FLOWING WATER

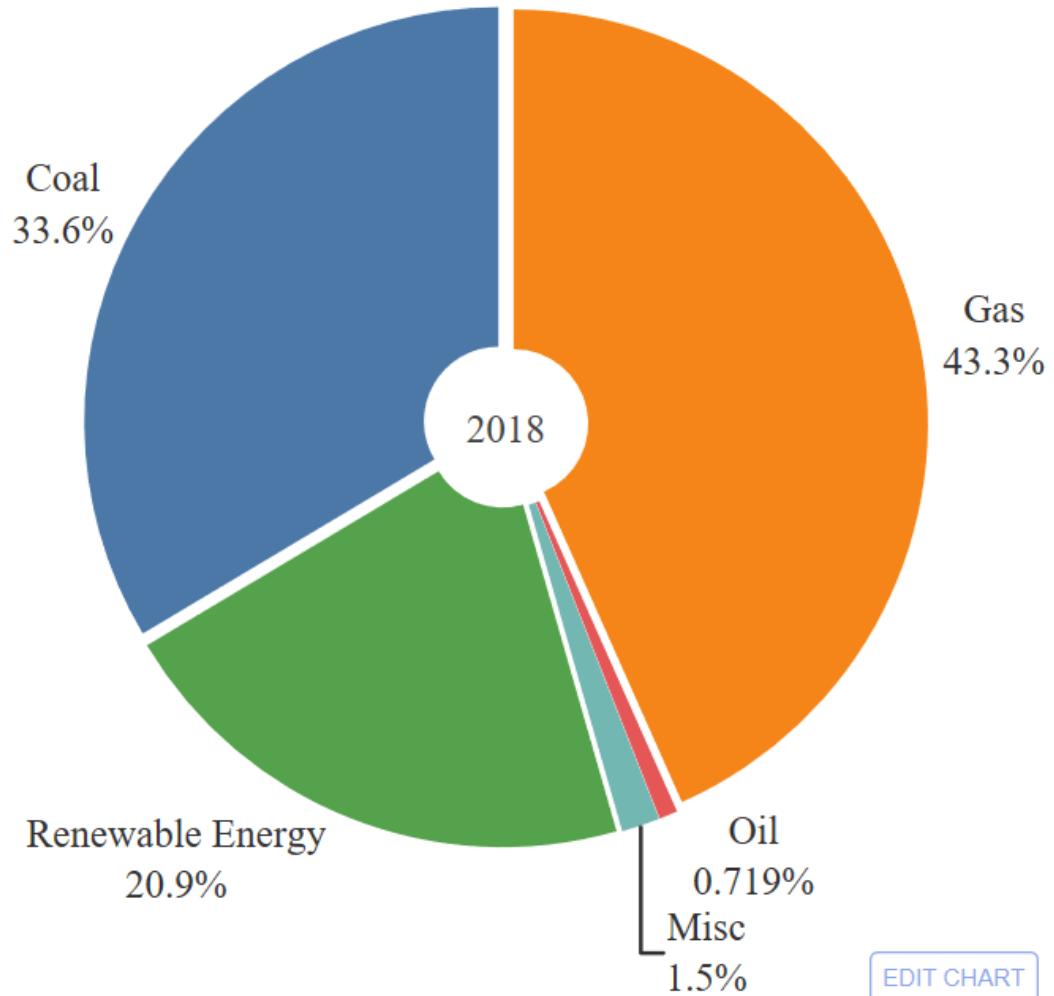
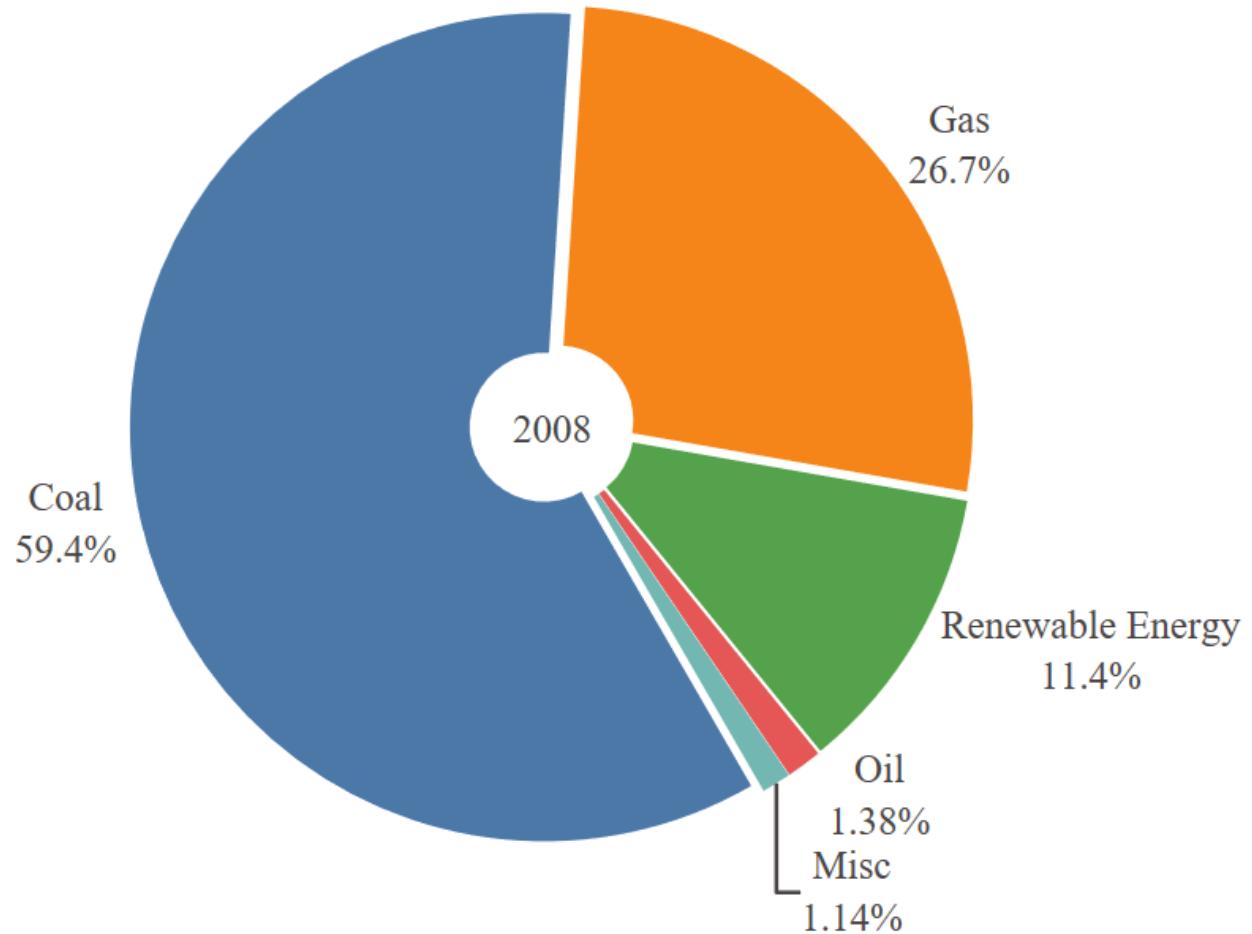


GEOTHERMAL

HEAT ENERGY FROM
THE EARTH



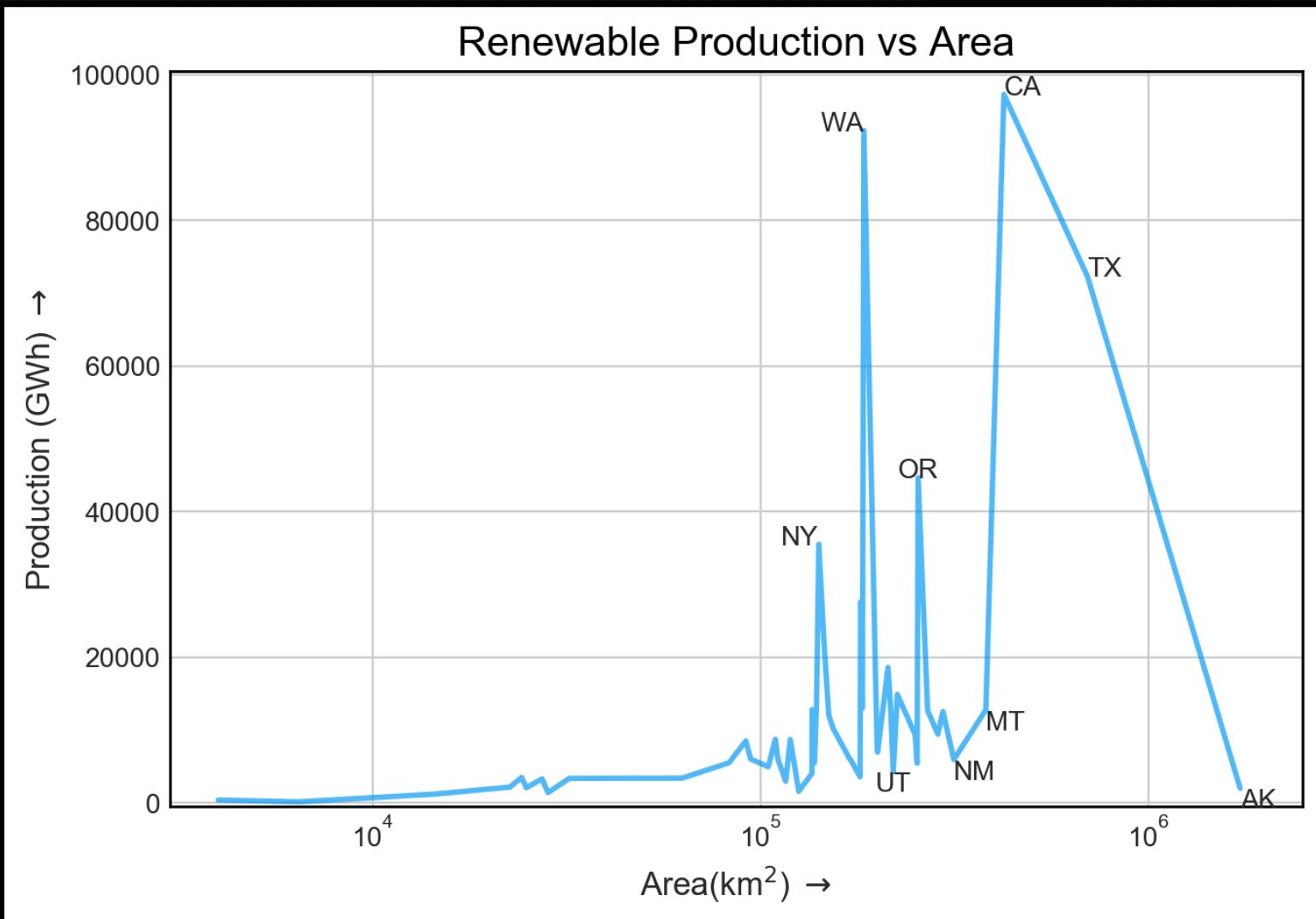
Energy Production in the US (TWh)



[EDIT CHART](#)

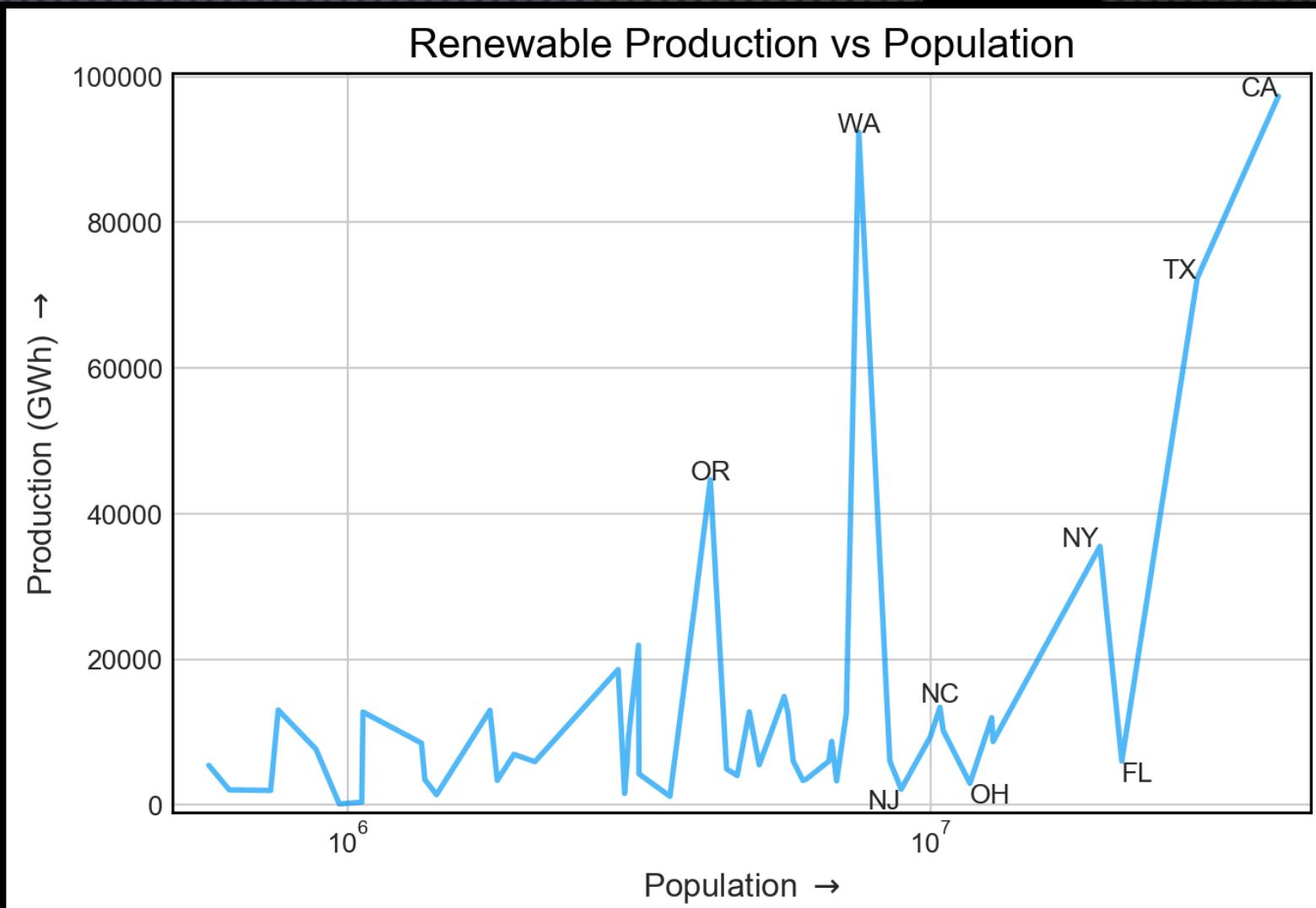
MORE AREA==MORE ENERGY?

- STATES WITH LARGER AREA GENERALLY MORE PRODUCTIVE
- SOME SMALLER STATES SHOW SIMILAR HIGHER PRODUCTION
- AREA NOT A RELIABLE METRIC ALONE TO QUANTIFY RENEWABLE ENERGY

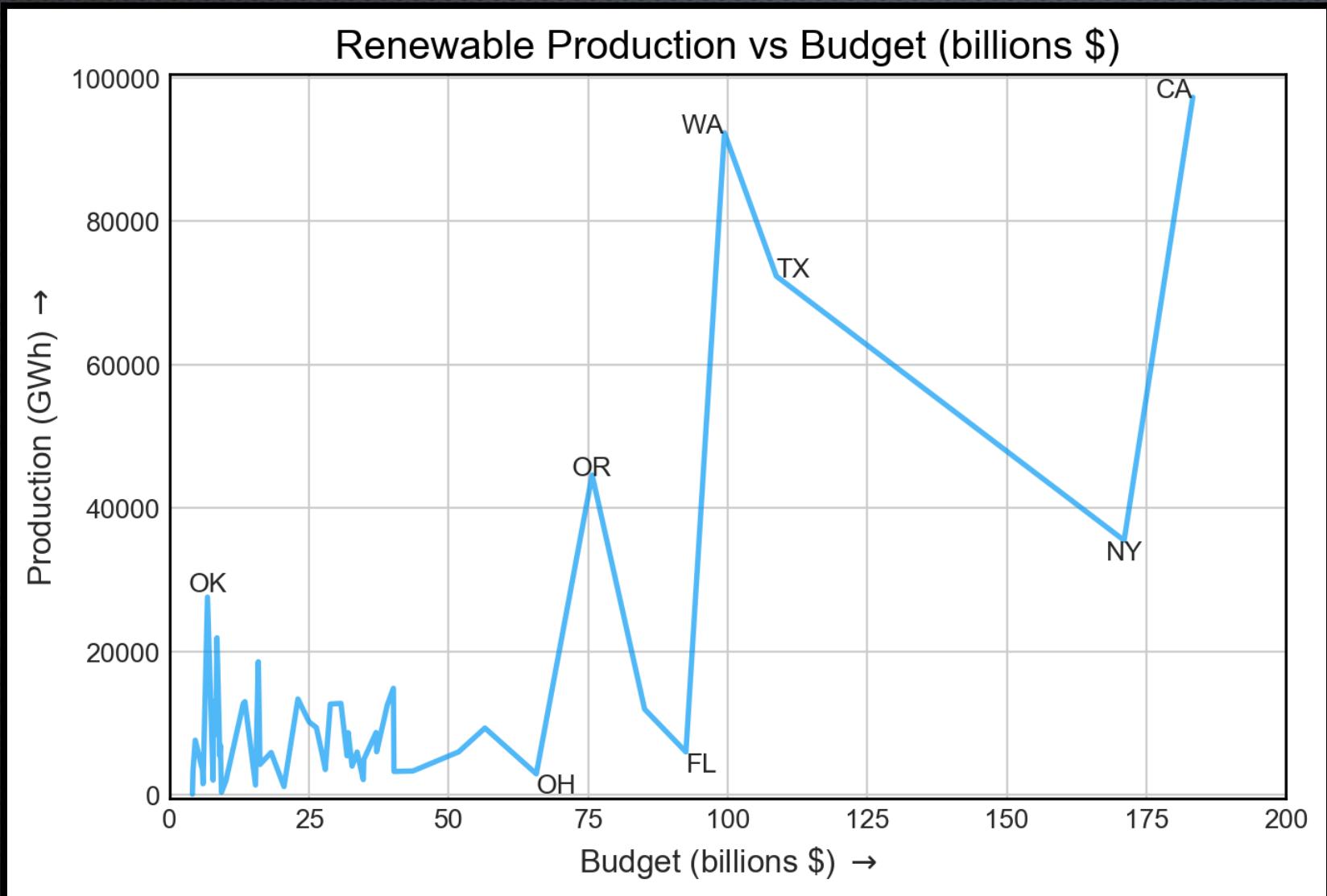


MORE PEOPLE==MORE ENERGY?

- STATES WITH LARGER POPULATION GENERALLY MORE PRODUCTIVE
- BUT NOT ALL, MANY OUTLIERS THAT FARE POORLY
- SOME LESS POPULATED STATES SHOW MUCH HIGHER PRODUCTIVITY



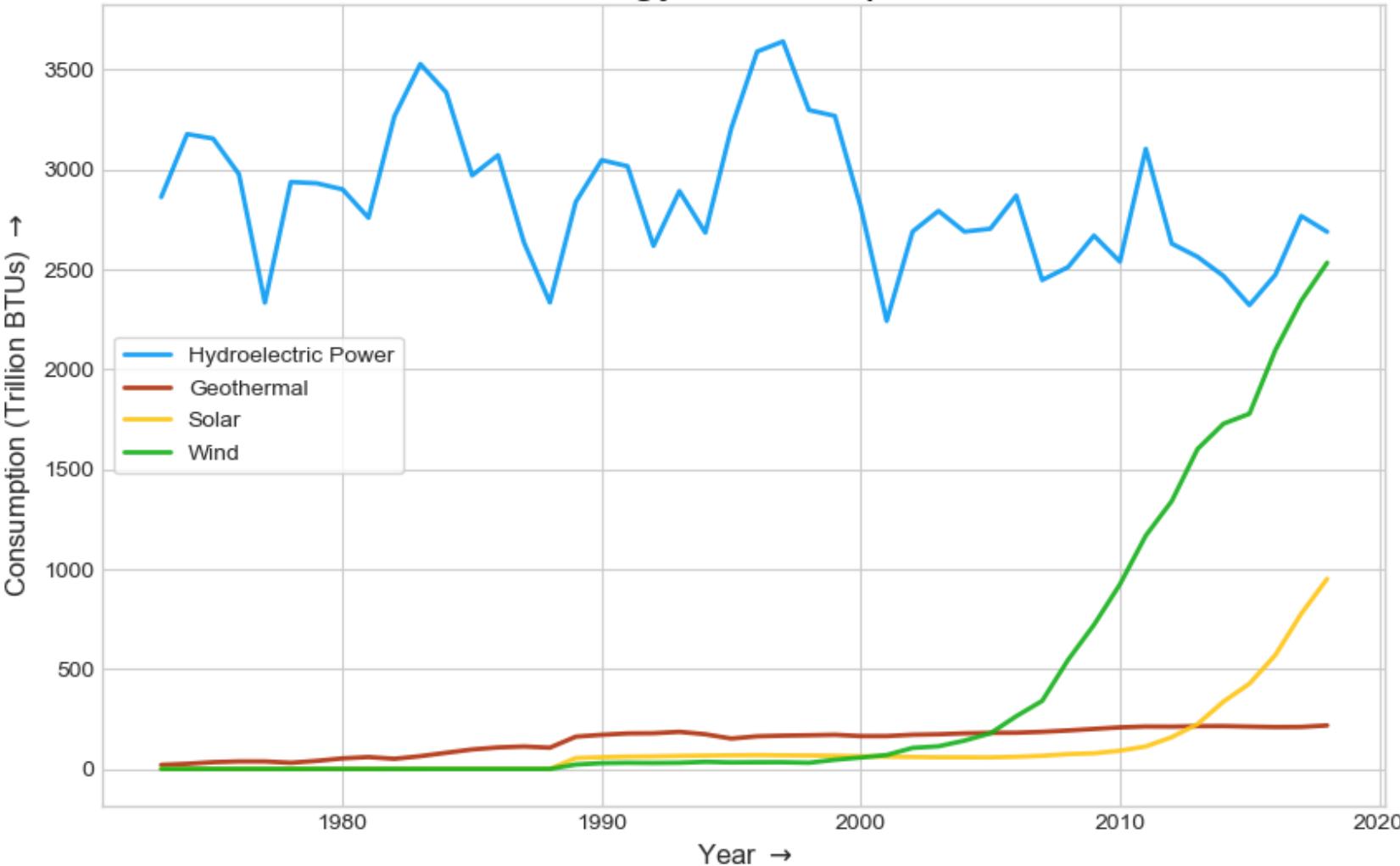
MORE BUDGET ==MORE ENERGY?



- CA ✓ WA ✓ TX ✓
- NY X OR X FL X
- **OK - DECENT EVEN WITH VERY LITTLE BUDGET**

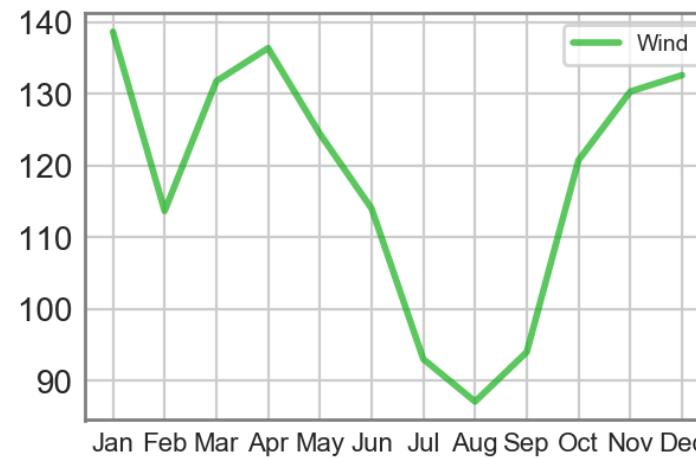
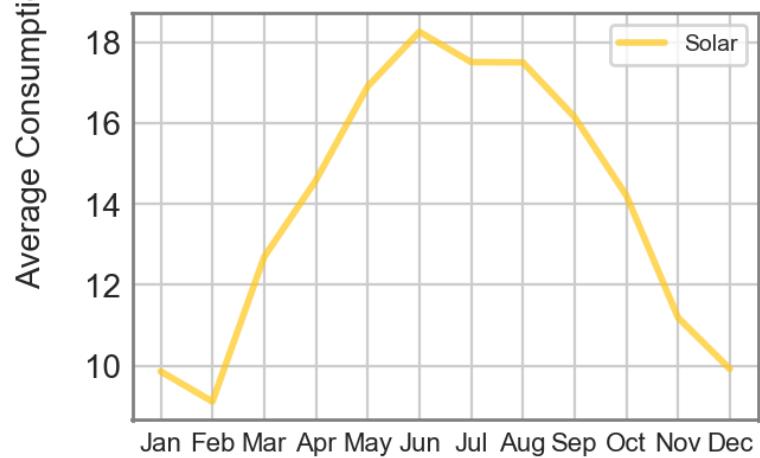
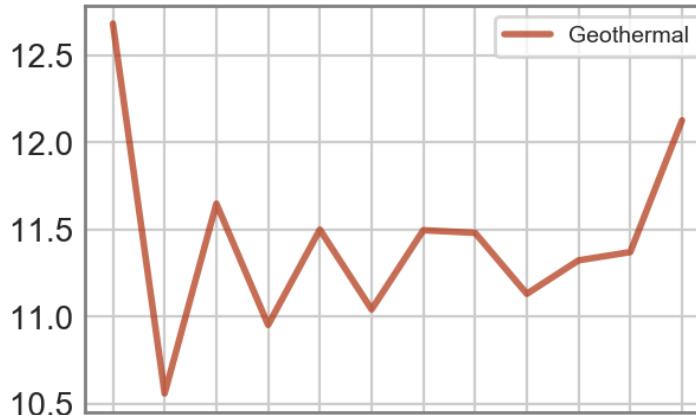
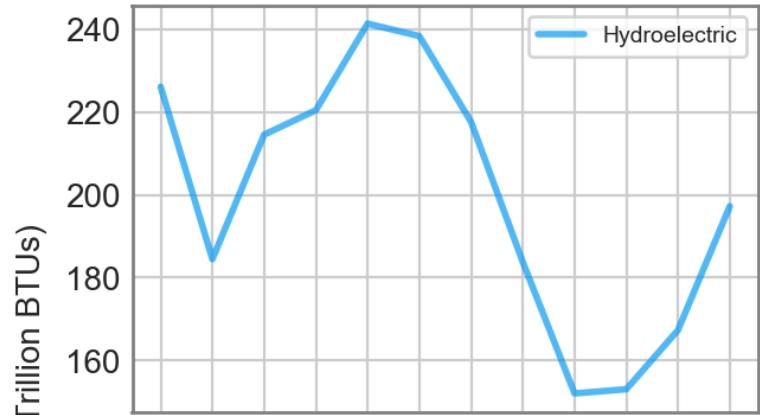
CONSUMPTION

Renewable Energy Consumption in the USA



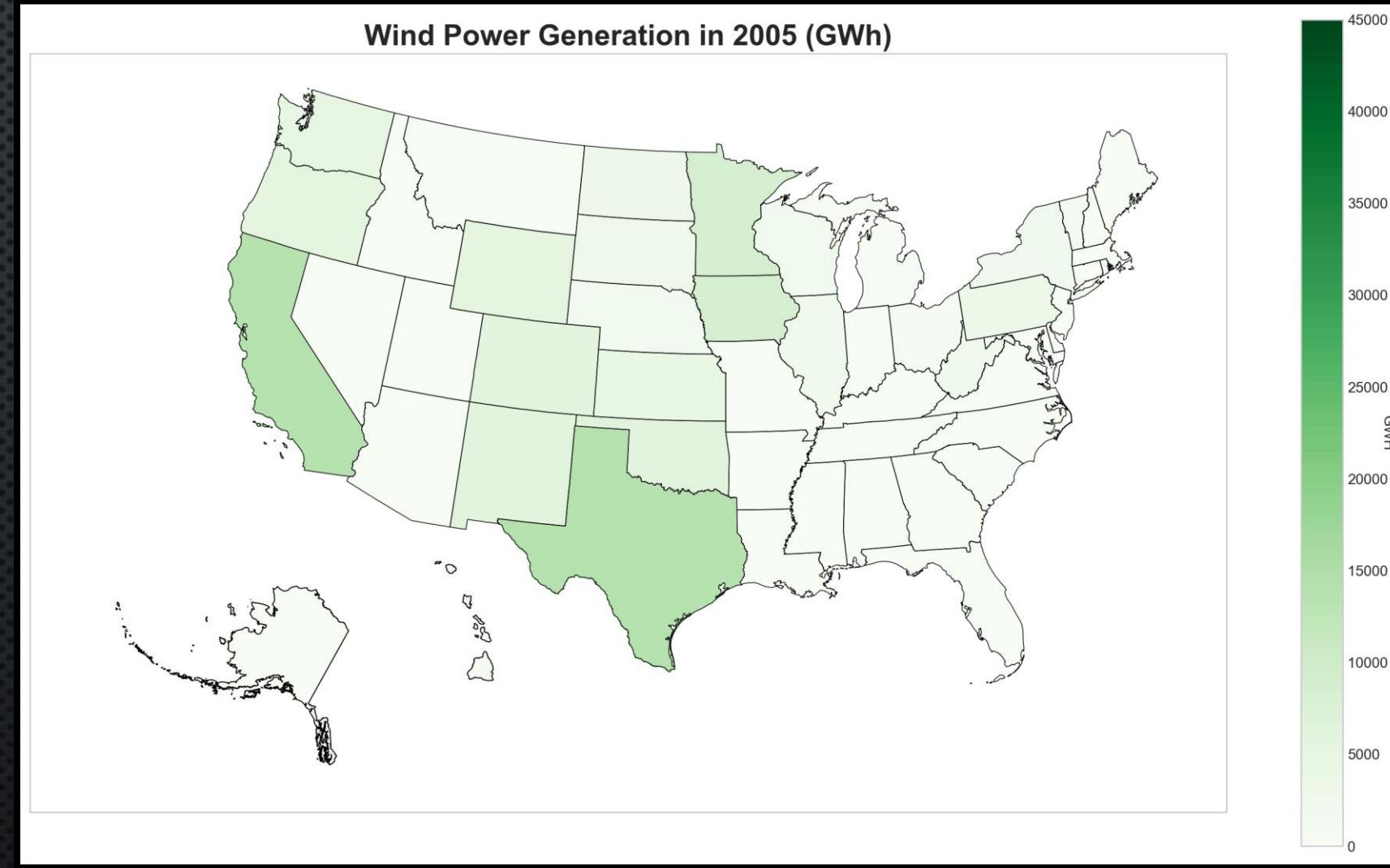
- **SHARE OF WIND INCREASED RAPIDLY.**
- **SHARE OF SOLAR INCREASED LATE BUT RISING STRONG.**
- **HYDRO REMAINS CONSTANT, STARTED REDUCING RECENTLY.**
- **GEOTHERMAL STILL INSIGNIFICANT TO TOTAL CONSUMPTION**

MONTH-WISE



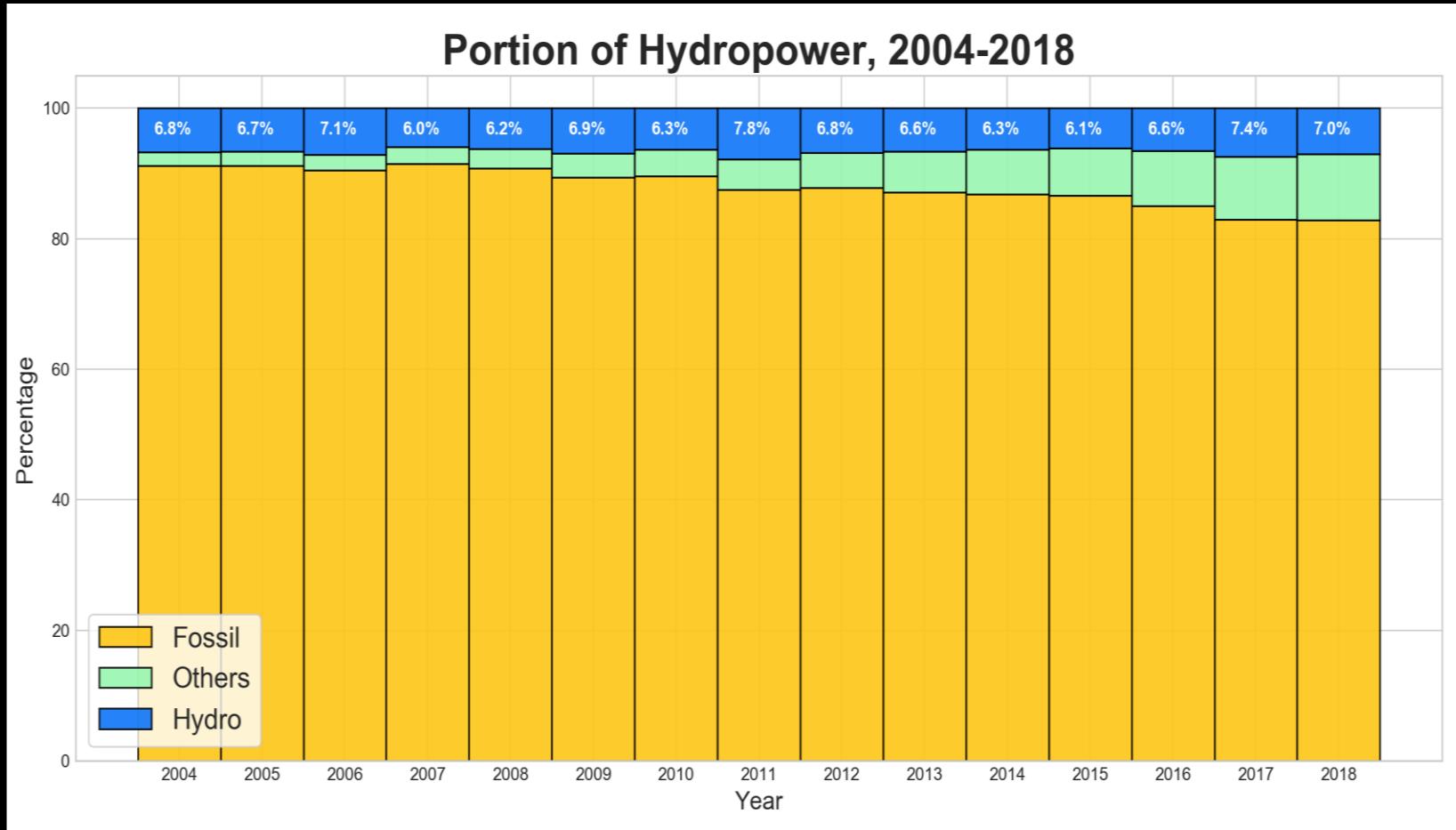
- HYDRO: APR-SEP
- SOLAR: APR-OCT
- WIND: SEP-MAY

WIND ENERGY



- PRIMARILY TX, THE WEST AND MIDWEST.
- EXPANDED RAPIDLY IN TX, MASSIVE GROWTH.

HYDRO-ENERGY

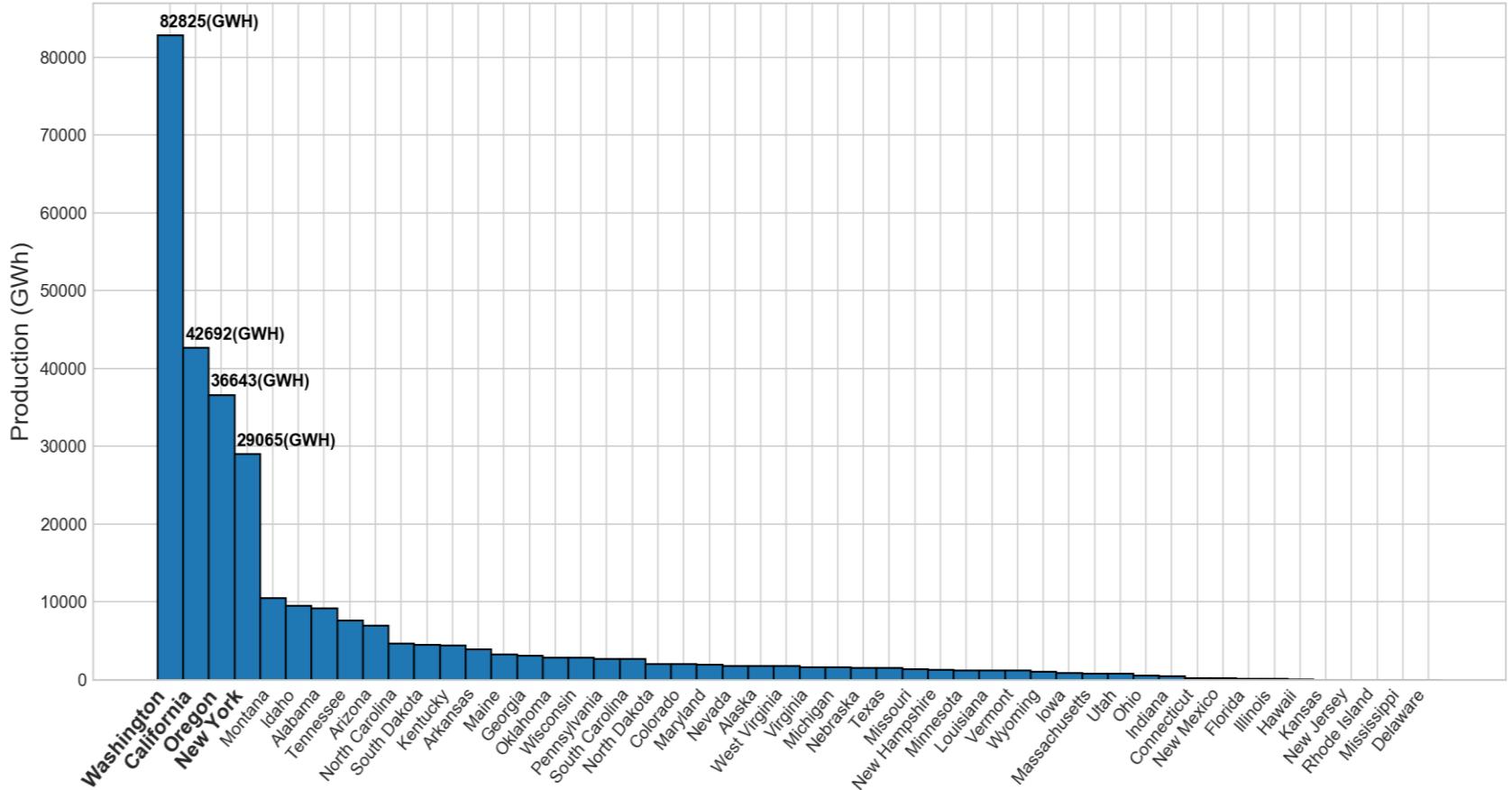


HYDRO-POWER HAS
REMAINED STAGNANT

EVEN THOUGH FOSSIL
HAS REDUCED, OTHER
RENEWABLES HAVE
TAKEN OVER

HYDRO-ENERGY

Hydroelectricity Production by States, 2017



- ✓ WASHINGTON
- ✓ CALIFORNIA
- ✓ OREGON
- ✓ NEW YORK

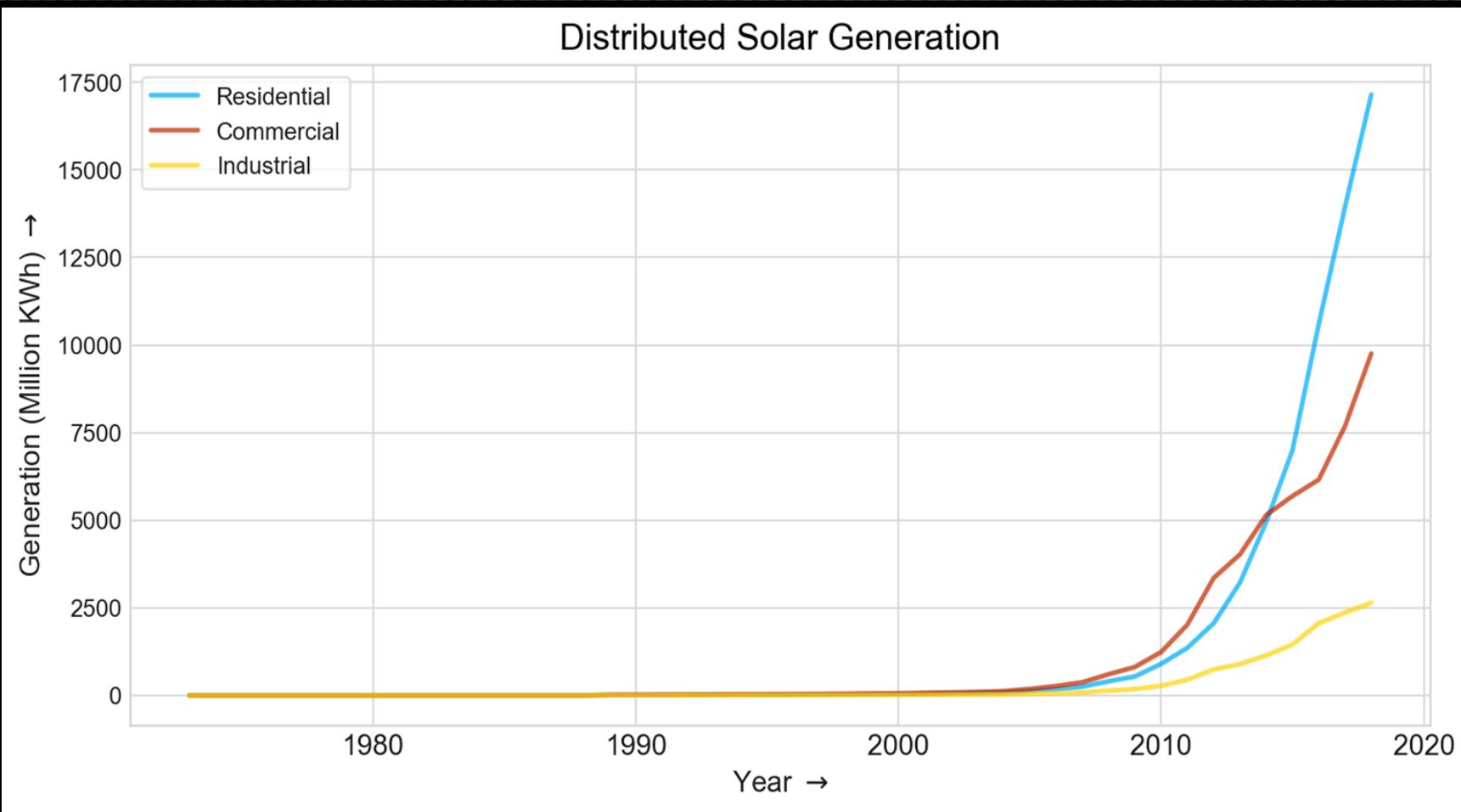
LARGE INFRASTRUCTURE
REQUIREMENT

TECHNOLOGY UPDATION
EXPENSIVE

EXISTING SYSTEM
ADEQUACY



SOLAR ENERGY



MAINLY FOR
RESIDENTIAL

COMMERCIAL
AND INDUSTRIAL
RELY LESSER

ENERGY POTENTIAL

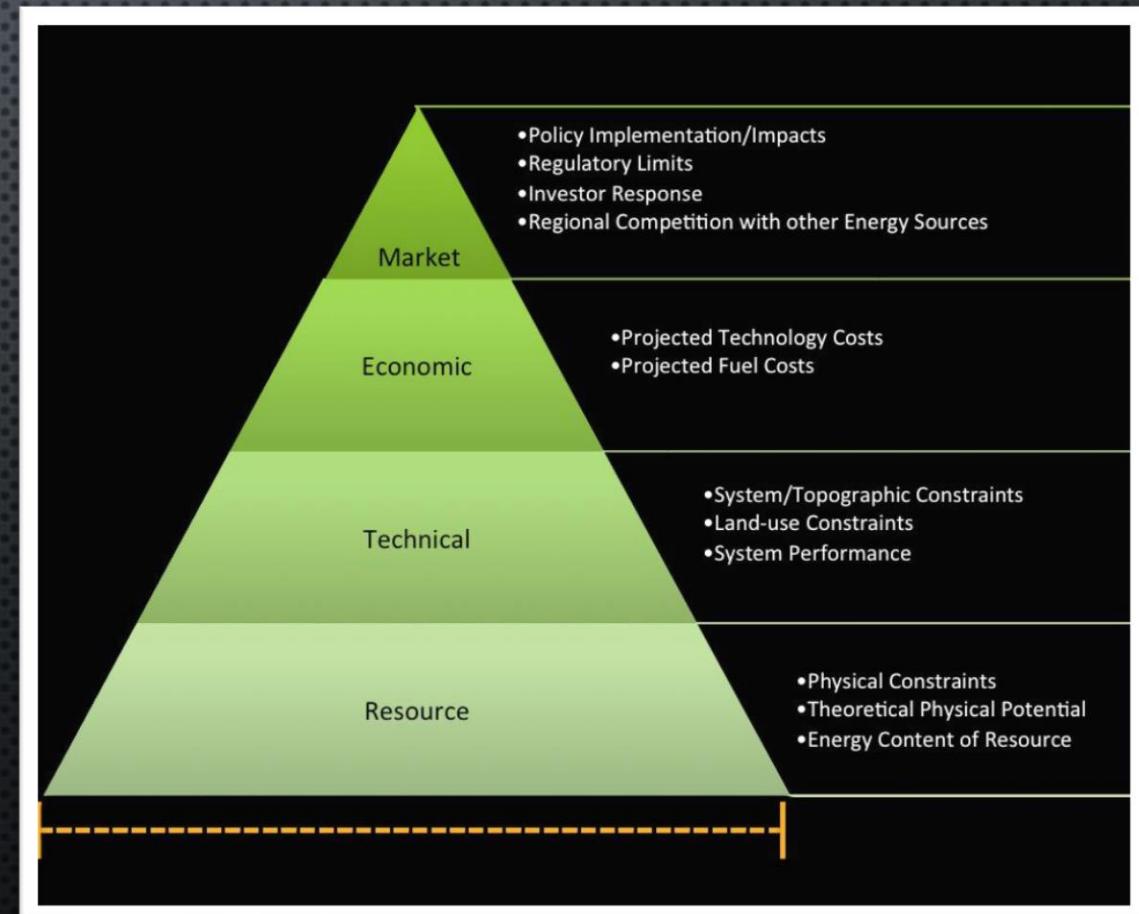
- DOES RENEWABLE MEAN INFINITE?
- HOW DO WE KNOW WHAT IS ENOUGH?
- CAN IT BE MORE? WHAT ARE THE HINDRANCES?
- TECHNICAL AND SOCIO-ECONOMIC IMPLICATIONS?



TECHNICAL POTENTIAL

**ACHIEVABLE ENERGY
GENERATION GIVEN:**

- **SYSTEM PERFORMANCE**
- **TOPOGRAPHY**
- **ENVIRONMENTAL**
- **LAND-USE CONSTRAINTS**



AN EXAMPLE: HYDRO



GRID CONNECTIVITY



SITE ACCESSIBILITY

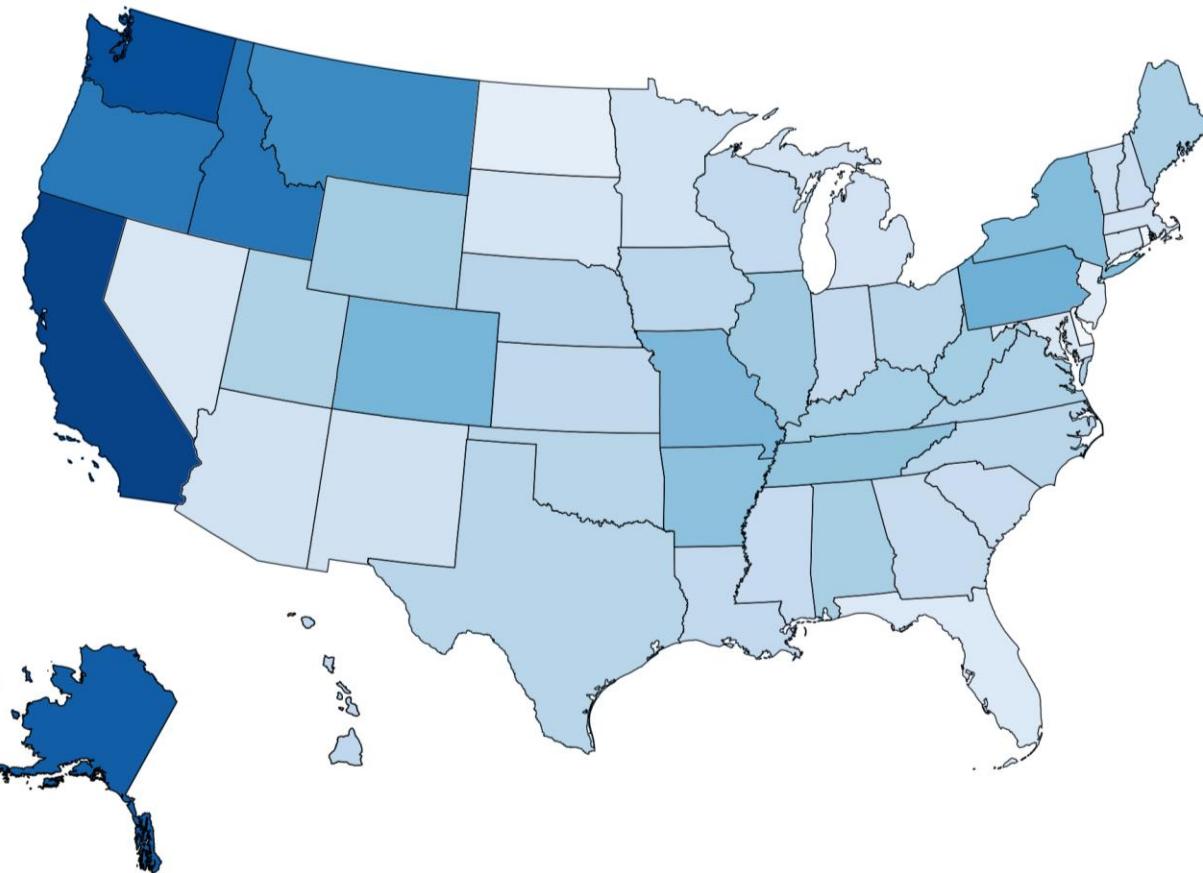


POWER MODEL IN PLACE



HYDRO POTENTIAL MAP

Technical Potential for Hydropower in the US, 2012



HIGHLY CONCENTRATED
AROUND CA, OR,
WA, AK.

MODERATE POTENTIAL
AROUND CO, MI, AK,
WV, BUT NOT BEING
REALIZED.

OUR ANALYSIS

CALCULATE THE POTENTIAL FOR:

- CONCENTRATED SOLAR POWER
- WIND POWER (ONSHORE + OFFSHORE)



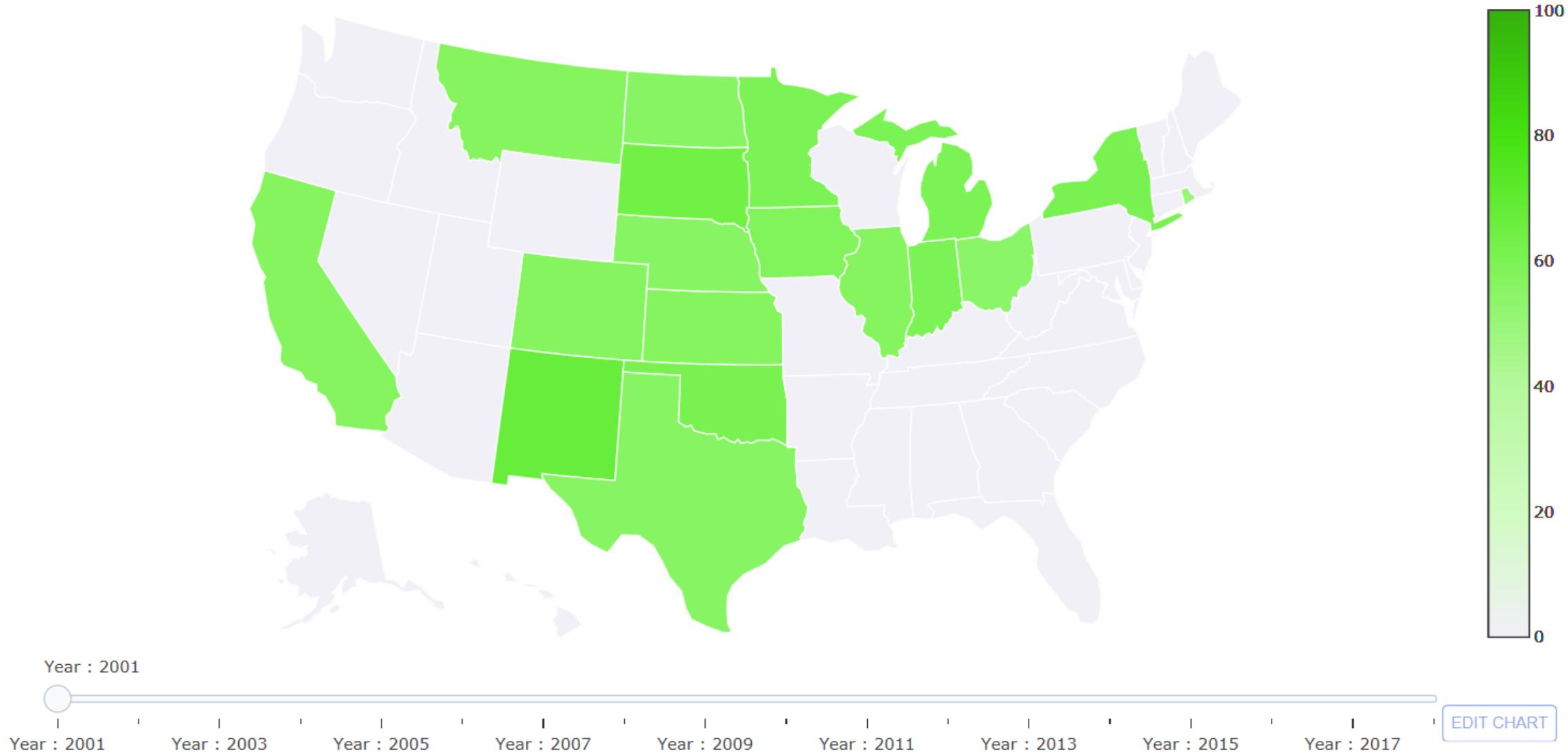
WIND ENERGY POTENTIAL

FACTORS:

- CURRENT AREA UNDER AUTHORIZED WIND FARMS
- WIND FARMS WITH HEIGHT > 80M
- POWER DENSITY (5 MW/M²)
- ANNUAL AVERAGE CAPACITY FACTOR OF 25.5%



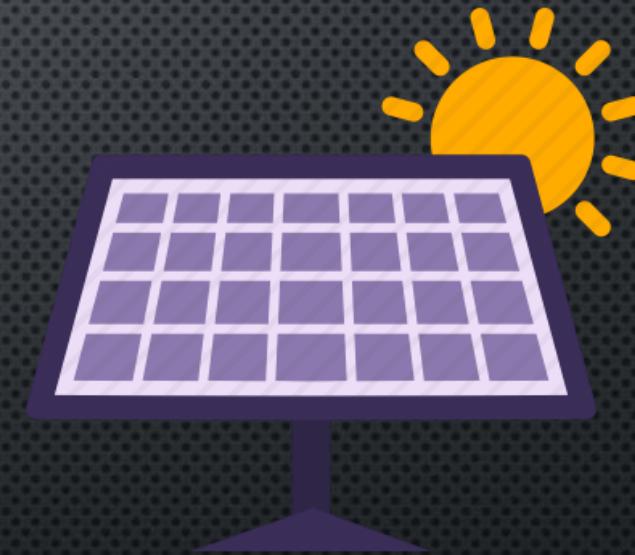
Wind Energy Potential Achieved (%)



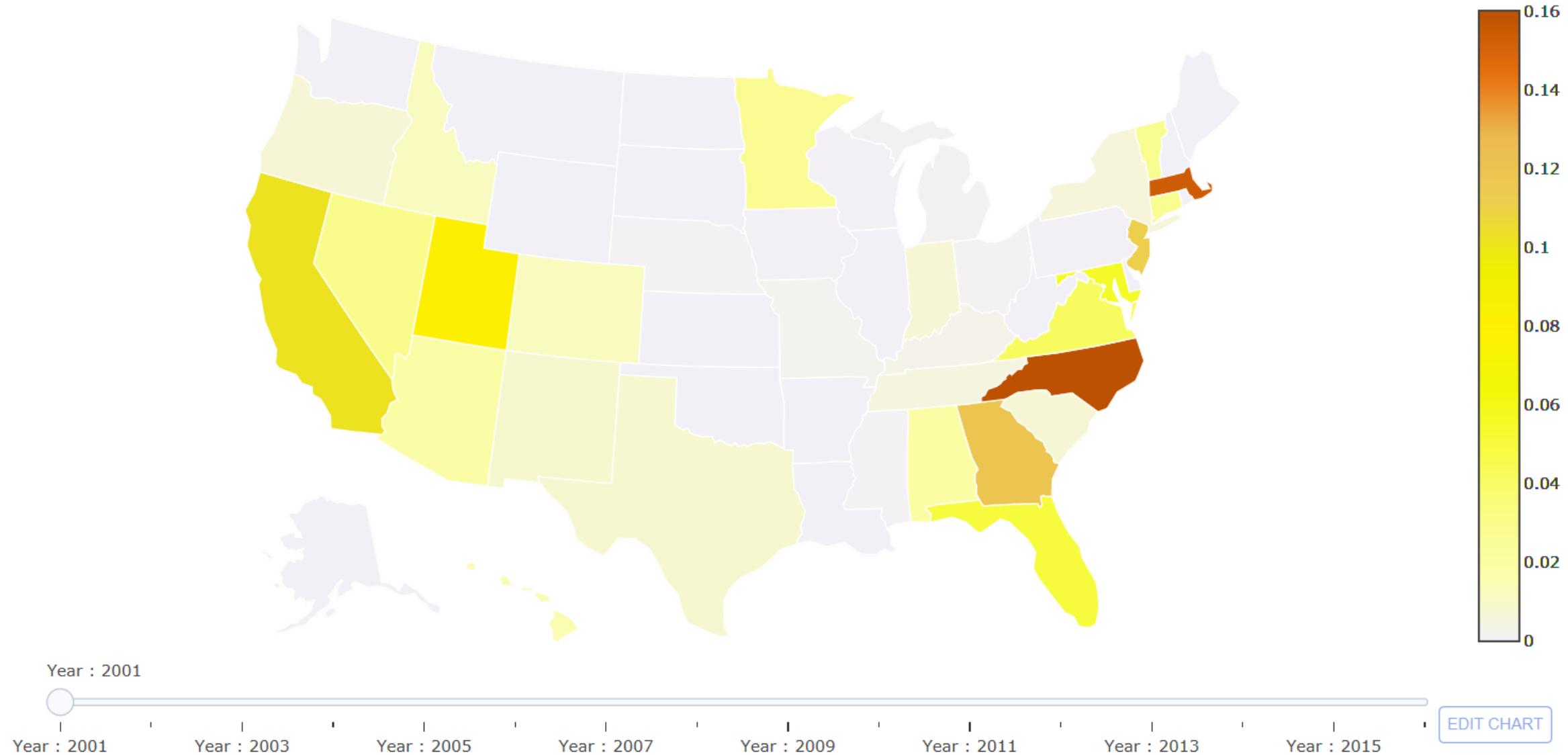
SOLAR ENERGY POTENTIAL

FACTORS:

- CURRENT NON-URBAN AREA
- STATE CAPACITY FACTORS
- DNI > 5 kWh/m²/DAY
(DIRECT NORMAL IRRADIANCE)
- AVERAGE POWER DENSITY
(~32.895 MW/km²)



Solar Energy Potential Achieved (%)





SUMMARY

- RENEWABLE SHARE INCREASED 2X IN THE PAST 10 YRS.
- AREA, POPULATION OR BUDGET NOT A DISTINCT RELATIVE FACTOR
- WIND ENERGY: TX, WEST, MIDWEST, STEEP GROWTH IN OUTPUT
- HYDRO ENERGY: WA, OR CA, NY, OUTPUT REMAINED STAGNANT
- SOLAR ENERGY: CA, STEEP GROWTH SINCE 2010+
- TECHNICAL POTENTIAL A GOOD MEASURE OF PROGRESS
- WIND POTENTIAL: >50% POTENTIAL REALIZED IN MOST PRODUCTIVE STATES
- SOLAR POTENTIAL: < 0.1% REALIZED FOR MOST STATES, BUT MAXIMUM IN CA AND SOME SMALLER STATES
- GETTING REALIZATION TO MERELY ~5% WILL MAKE SOLAR THE MOST PRODUCTIVE SECTOR

THANK YOU | TEAM 12

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