FLOATING PHOTOVOLTAIC HYDROPOWER GENERATION MODELING

Mentors: Dr. Martine Ceberio & Dr. Alex Mayer

Student mentors: Arin, Leo, & Sojib

OUR TEAM

- Dr. Alex Mayer
- Dr. Martine Ceberio
- Betül Aslantas, PhD student in Civil Engineering
- Krissel Marin, PhD student in Civil Engineering
- Arin Rahman, PhD student in Computer Science
- Md. Nuruzzaman Sojib, PhD student in Computer Science
- Edwin Trejo, MS student in Computer Science
- Jose Vega, MS student in Computer Science (graduated in Spring 2025)

THE CONTEXT OF OUR WORK

Problems

- **Population increase** will cause a declining in the land area due to urbanization, therefore there won't be enough space for Photovoltaics cells.
- **Over-heating in the PVC** cause malfunctions which requires a cooling effect
- An anticipated increase in the **evaporation rate in the reservoirs** will decrease water availability for hydropower generation
- **These combined effects** are unknown for reservoirs and need to be observed for resilience

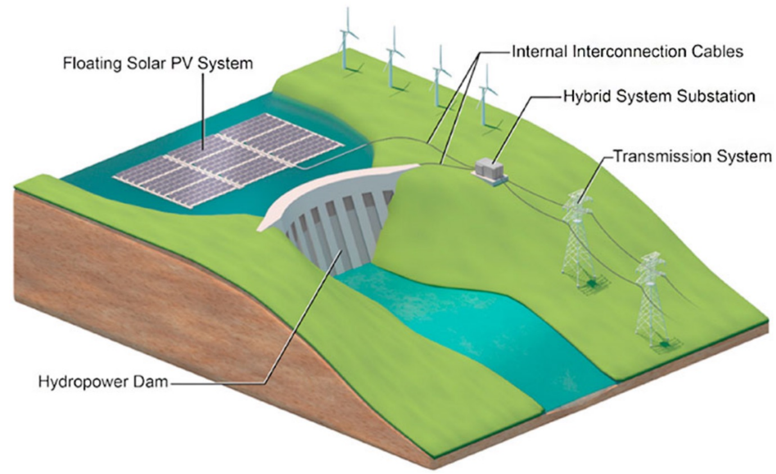
SOLUTIONS AND FURTHER CHALLENGES

Solution approach

- **Floating photovoltaics (FPV)** are solar panels placed on water, saving land and boosting energy efficiency with water's cooling effect & reduced evaporation

Next challenge

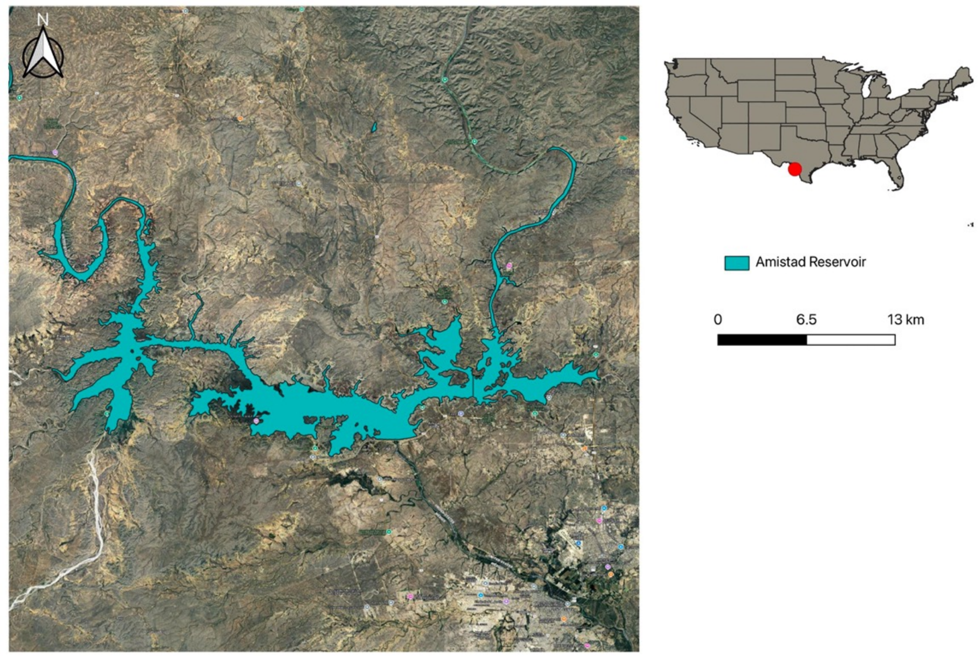
- **How many** FPVs?
- And since we are at it, how to manage water and **hydropower generation**?



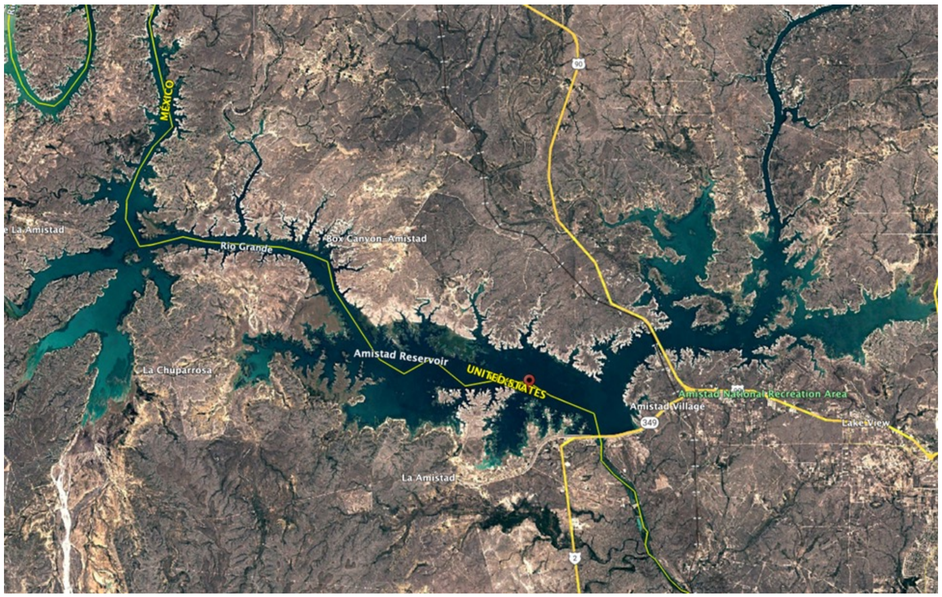
Schematic illustration of hybrid FPV-hydropower system (Gadzanku et al., 2022)

STUDY AREA


Elephant Butte Reservoir
Amistad Reservoir
NEW MEXICO
TEXAS
CHIHUAHUA
COAHUILA
Rio Grande
Conchos
Dallas
San Antonio
Las Cruces
El Paso
Ciudad Juárez
Carlsbad
Pecos
Amistad Res.
Del Rio
Ciudad Acuña
Eagle Pass
Piedras Negras
Laredo
Nuevo Laredo
Corpus Christi
Falcon Res.
McAllen
Brownsville
Matamoros
Reynosa
Monterrey
Monclova
Torreón
Chihuahua
Delicias
Hidalgo del Parral

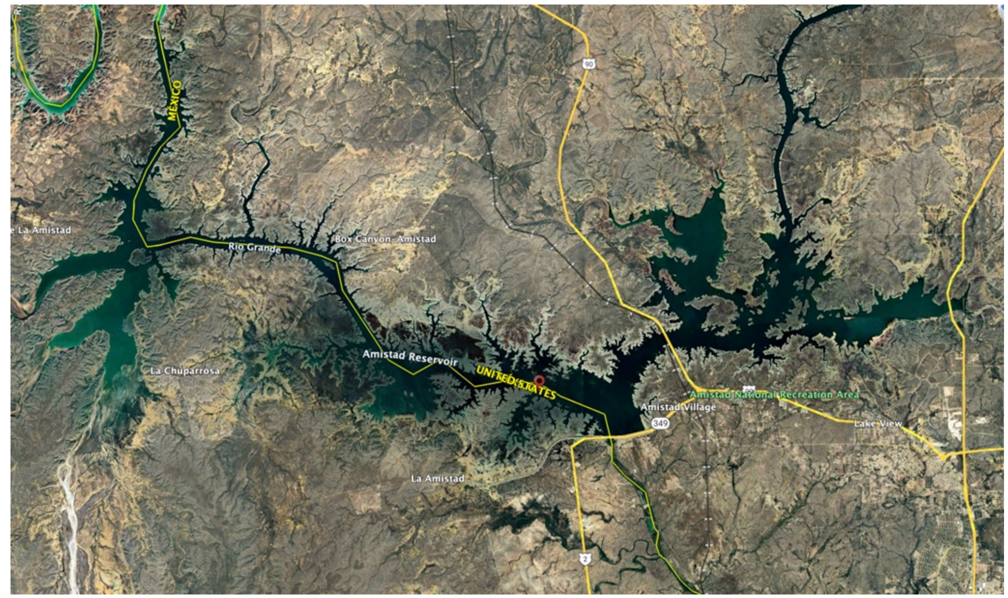

N
Amistad Reservoir
0
6.5
13 km

AMISTAD RESERVOIR



December 2020

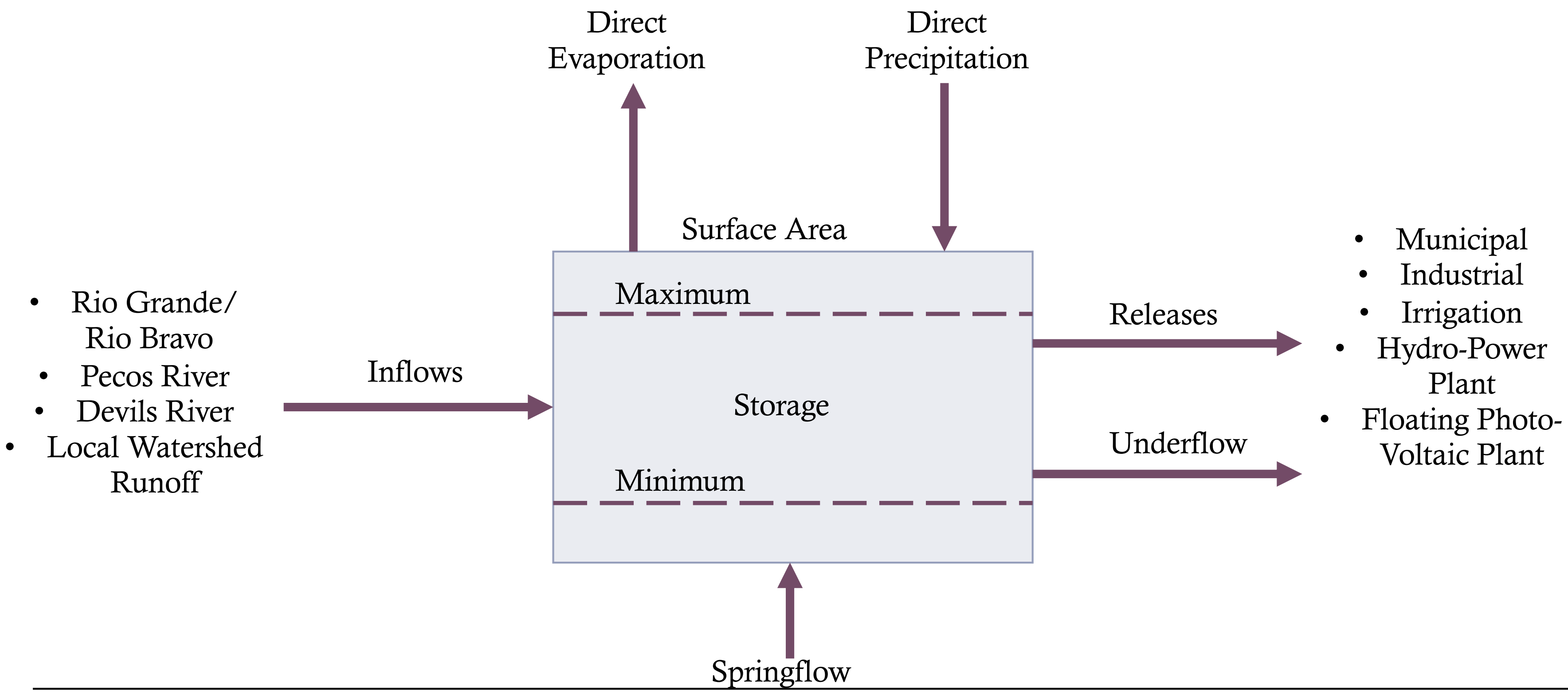
Surface area = 127 km^2



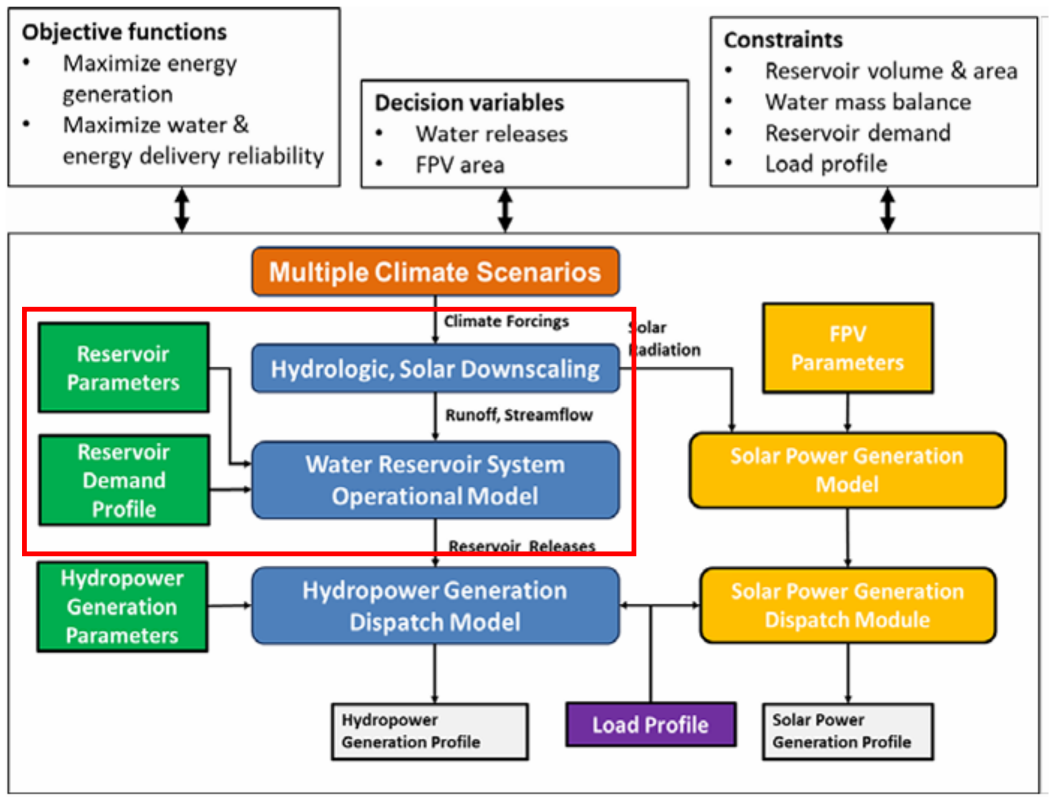
April 2024

Surface area = 73 km^2

WATER BALANCE FOR AMISTAD RESERVOIR



SIMULATION-OPTIMIZATION SCHEME



WATER BALANCE AND ENERGY PRODUCTION

Hydropower Production

- Affected by the water demand downstream
- Optimal releases to meet water demand (irrigation, municipal, industrial) and Hydro-Electric Power Plant
- + Energy generation revenue

Photo-Voltaic Production

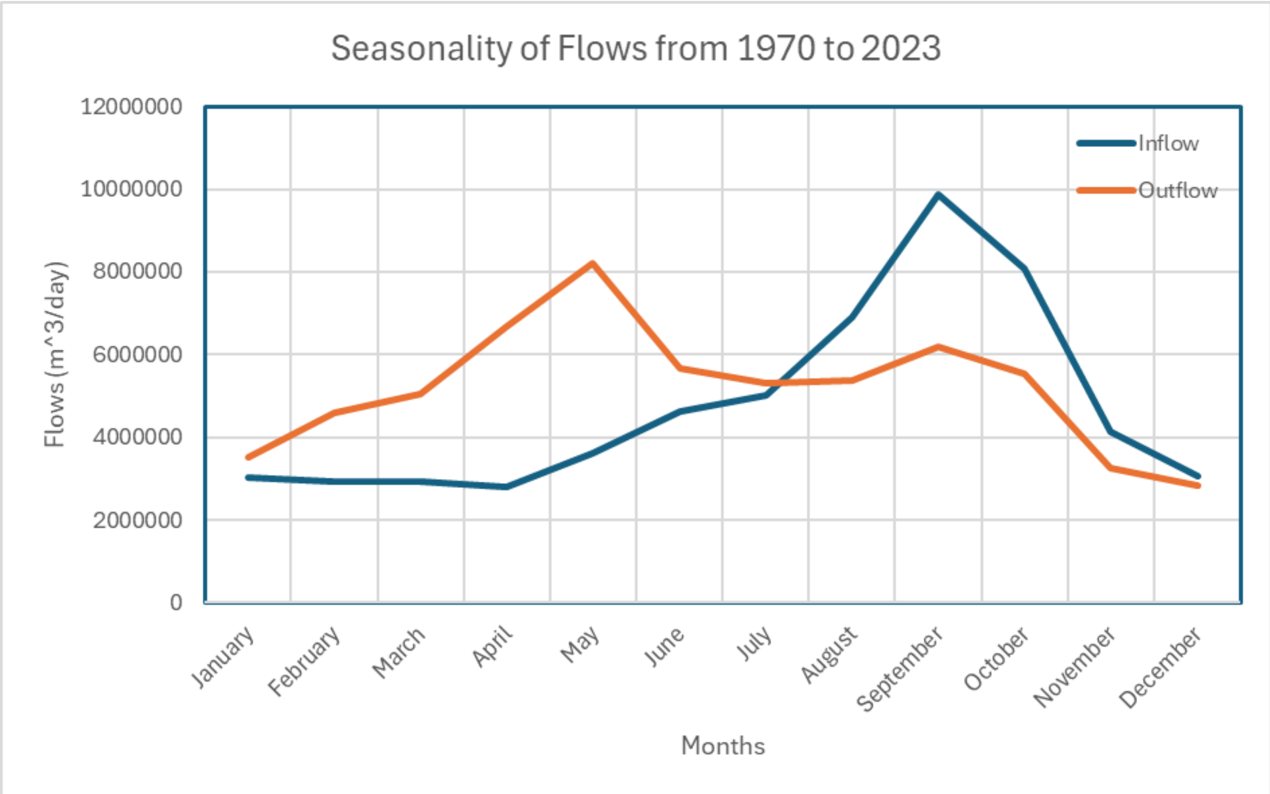
- Storage directly affects Surface Area
- Change in Surface Area helps determine the best number of solar panels for the model (simpler model)

Optimizes

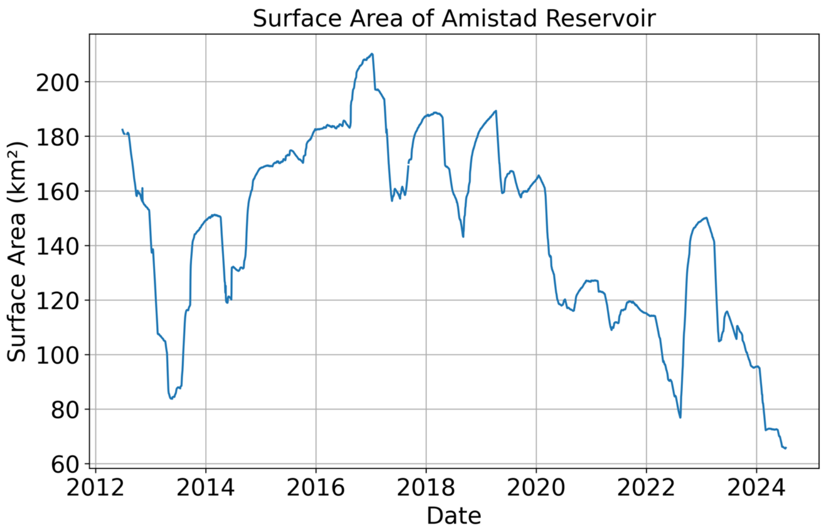
- Maximizes Cost/Benefits of energy production
- Photo-voltaic production offsets Hydropower production losses due to climate
- Minimizes the discrepancy from water commitment

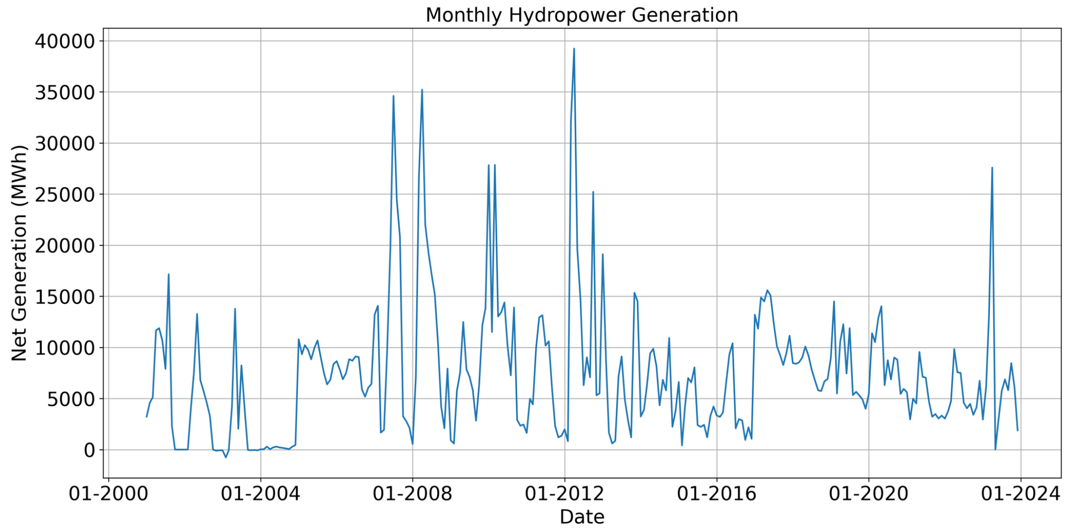
1. Based on historical data and records
2. Expected climate and demand predictions/ projections, using Machine Learning

SEASONALITY



Reservoir Properties

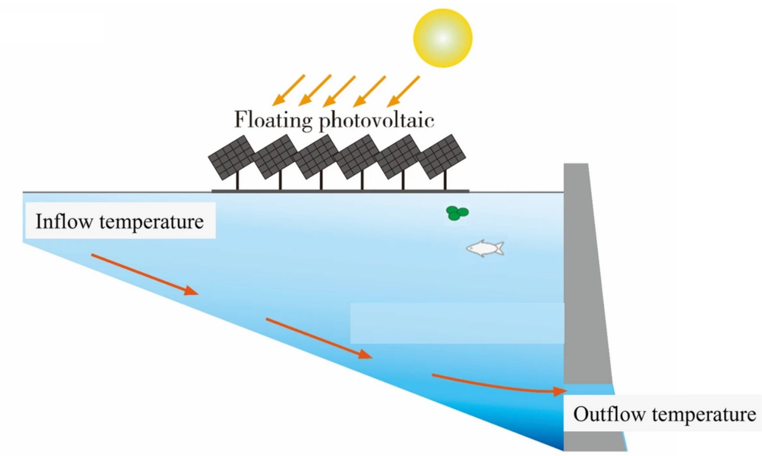


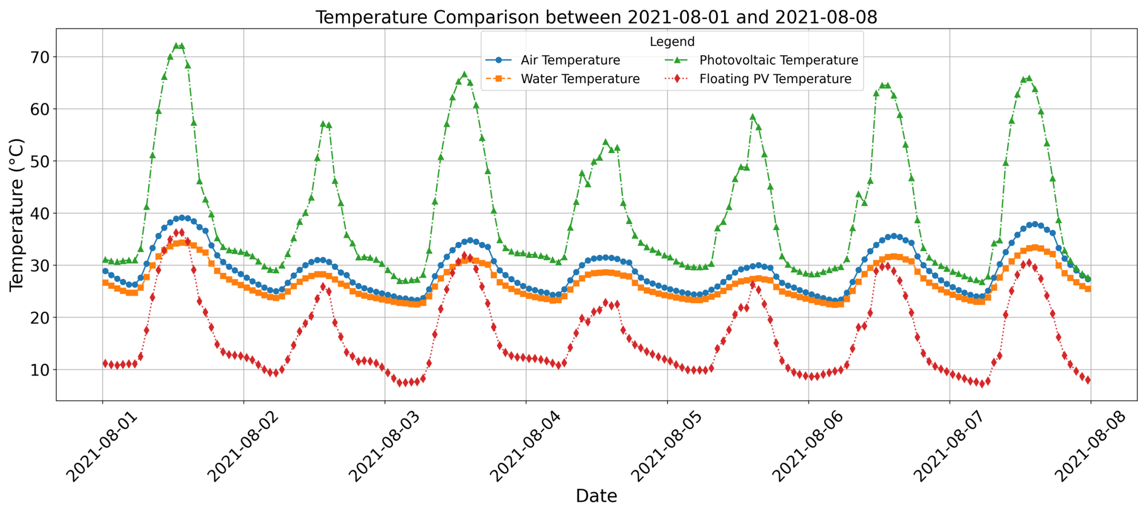


Challenge: these data are historical data. They may not be the ground truth for what we are trying to achieve

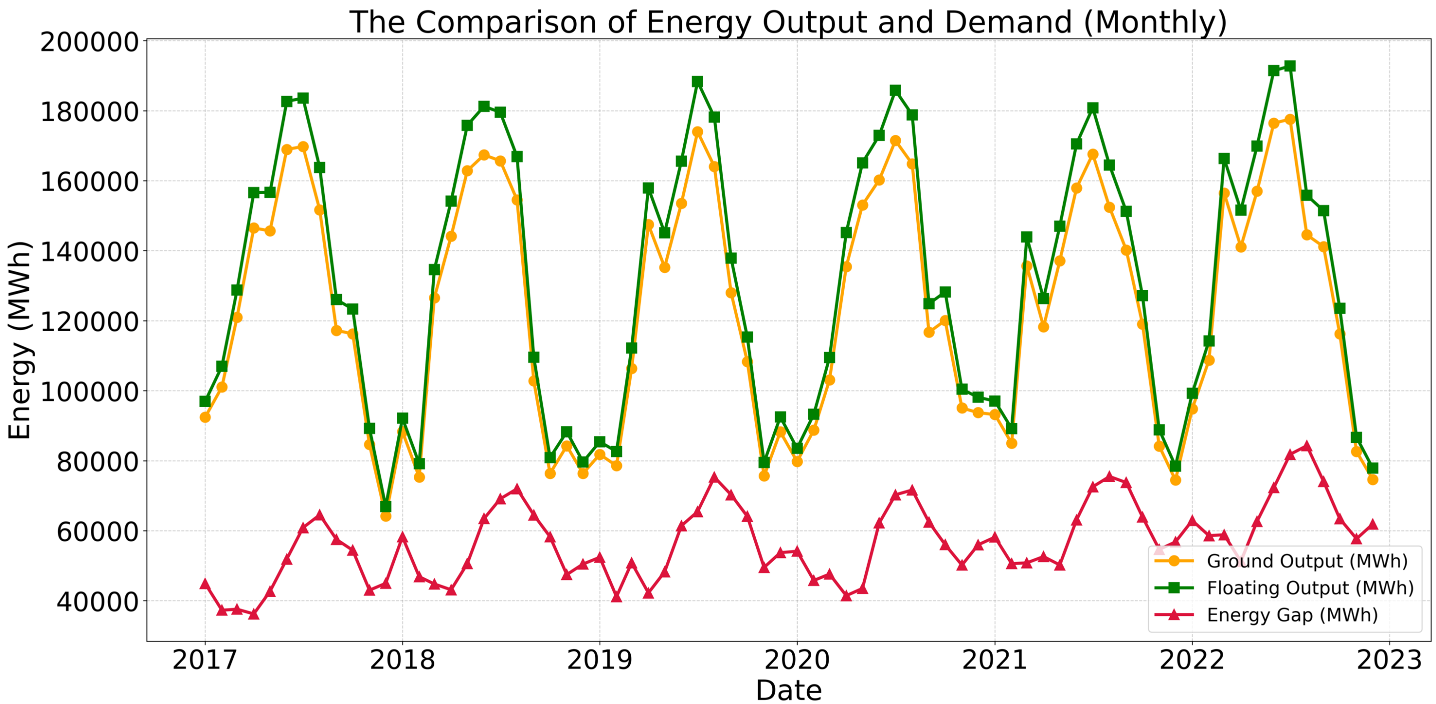
The Cooling Effect

- PV panel performance is very dependent on the operating temperature
- Overheated ground solar panels can cause malfunctioning of solar cells therefore they need to be cooled down
- Building solar panels on a waterbody overcomes the problem of overheating solar panel surface due to water temperature is cooler





Energy Output and Consumption(2)

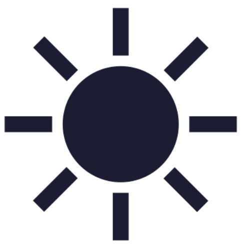


Energy Gap = Total demand – Hydropower energy generation

SO, WHAT'S THE PROJECT ABOUT?

- Identify the **best design**
- What do we have control over?
  - **FPV surface** → photovoltaic power
  - **Water release: when/how much** → hydropower + irrigation

HOW?



If we can predict solar radiation

→ we can understand the potential for solar power generation

→ we can assess (simulate & estimate) how much return panels can yield

→ are photovoltaic panels worth the cost?

If we can predict precipitation / evaporation & energy prices

→ we can determine how much water and when to release it

BUT SERIOUSLY, HOW?

- **Predictions**:
  - You will use **Machine Learning tools**: tools that learn from existing data (there is a lot of data)
    - Specifically, you will use an LSTM developed in Dr. Ceberio's lab
- **Simulations and Assessment of Decisions (release, surface of panels):**
  - You will use a **constraint solver**
    - Which means that constraints will need to be defined
    - You can design the system as you prefer it
- **And ultimately: Optimization:**
  - If you have time and are interested ☺

WHAT'S THE PLAN?

- **Week 1:** general presentation of the project
- **Week 2:** [teams are formed] **access** our LSTM + Realpaver + water data
  - Goal = run LSTM and draw prelim. conclusions
  - Needs = learn ML LSTM + how to handle data and report results
- **Week 3:** diving into **LSTM**
  - Slice the data, e.g., per season; figure out what good data looks like
  - Start looking for different data (not water)
  - + Intro to realpaver: start to learn about modeling constraints and design your own first programs
- **Week 4:** diving into **realpaver + integration**
  - Simulate the dynamics of a water reservoir + power
  - Integrate your model with data received from LSTM
- **Week 5:** several options:
  - Option 1: extension of the work of week 4 but for other types of data
  - Option 2: further extension of the model for water (more constraints or optimization)
  - Option 3: catch-up on what was not done in the previous weeks
- **Week 6:** finalization of the project and presentations

WHAT WILL YOU HAVE LEARNED?

- **Data handling**
  - Visualization
  - Slicing
  - Result reporting
- **Machine learning**
  - LSTM
  - Other as you like (we'll discuss that too)
- **System modeling**
  - Using constraints (a cute tool that you can use in other contexts)
- **Optimization**

+ the whole application context:
Energy generation – Water needs and diplomacy – Environment

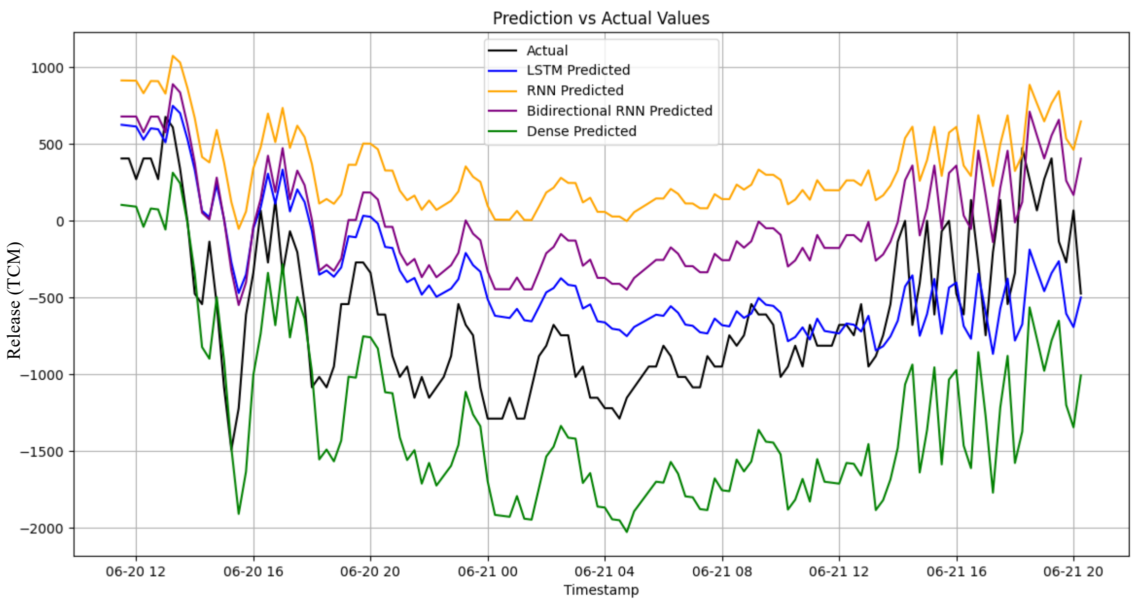
THANK YOU!

Are there any questions?

MODELLING & COMPUTATIONAL CHALLENGES

- **Defining Problem Constraints** - Identifying and modelling all relevant constraints accurately.
- **Predictive Modelling** - Forecasting future trends using historical data.
- **Ensuring Data Robustness** - Validating and improving the reliability of real-time data.
- **Optimizing Forecasting Strategies** - Evaluating whether predicted data leads to the best operational decisions.
- **Adaptive Learning** - Implementing a feedback loop to continuously refine models based on real-world performance.

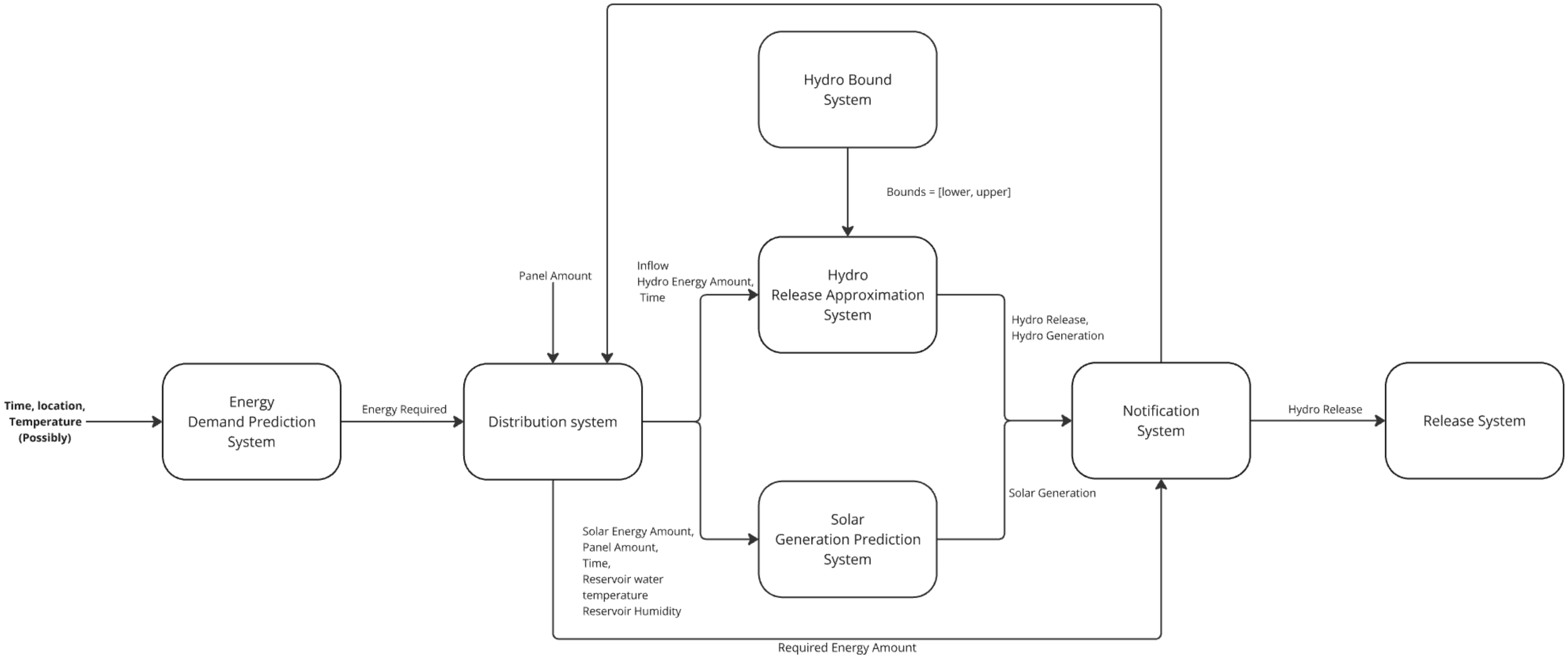
OUR APPROACH: LEVERAGING LSTM & OTHER ML TECHNIQUES



- **Time Series Forecasting Techniques**
- **Constraints solving techniques**
- **Optimization algorithms**

OUR APPROACH: LEVERAGING LSTM & OTHER ML TECHNIQUES

- Constraints solving techniques
- **Optimization algorithms**



QUESTIONS?