RECLAMATION

Managing Water in the West

Renewable Energy Powered Desalination Systems for Potable Water Production in Rural Communities

KATIE GUERRA, PhD, PE

Presented at AWWA Sustainable Water Management Conference, Denver CO, March 31, 2014

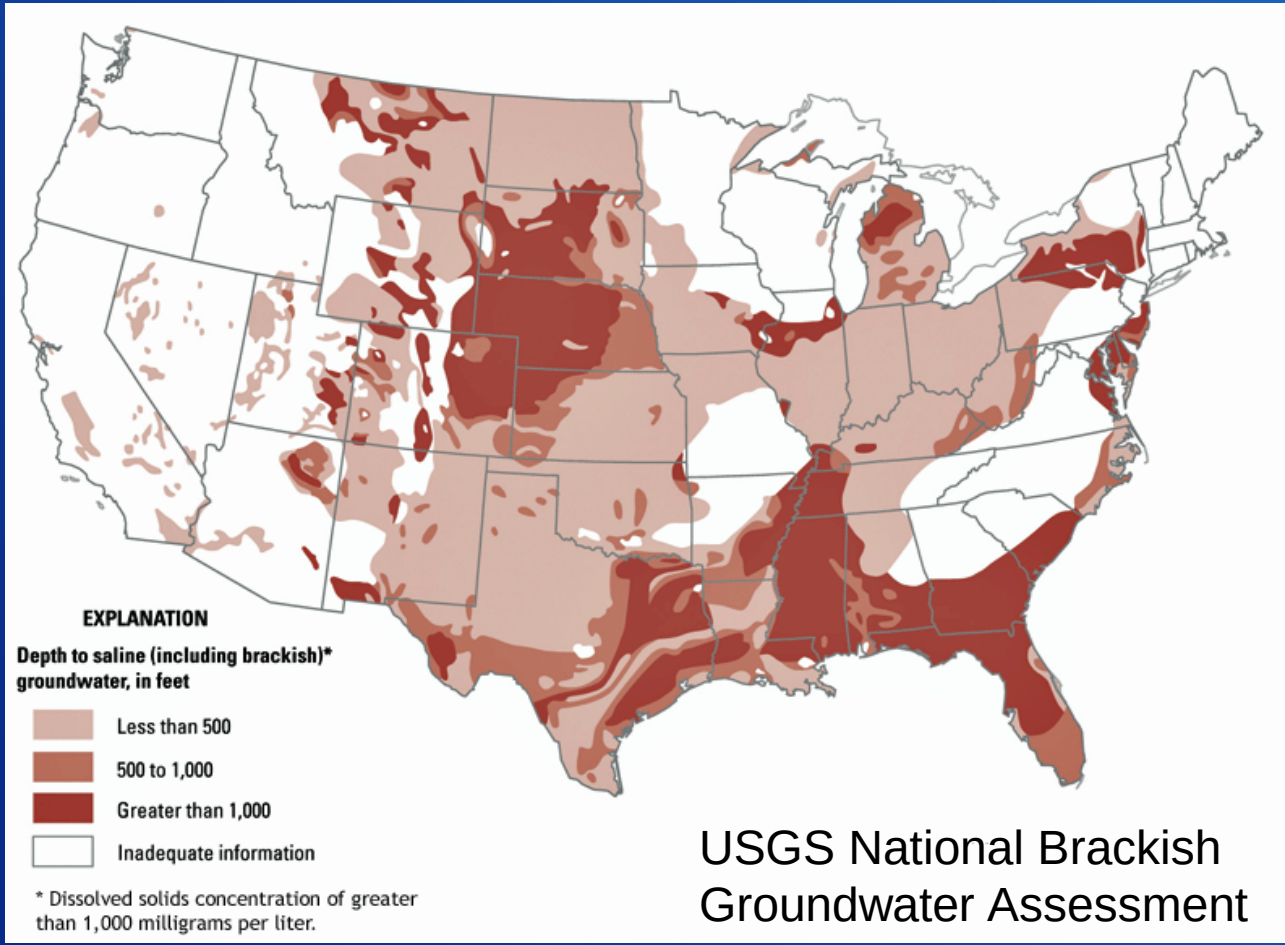
U.S. Department of the Interior
Bureau of Reclamation

In remote areas treatment must be low cost, reliable, and easy to operate.

Need for fresh water supplies for drinking and agriculture

RECLAMATION

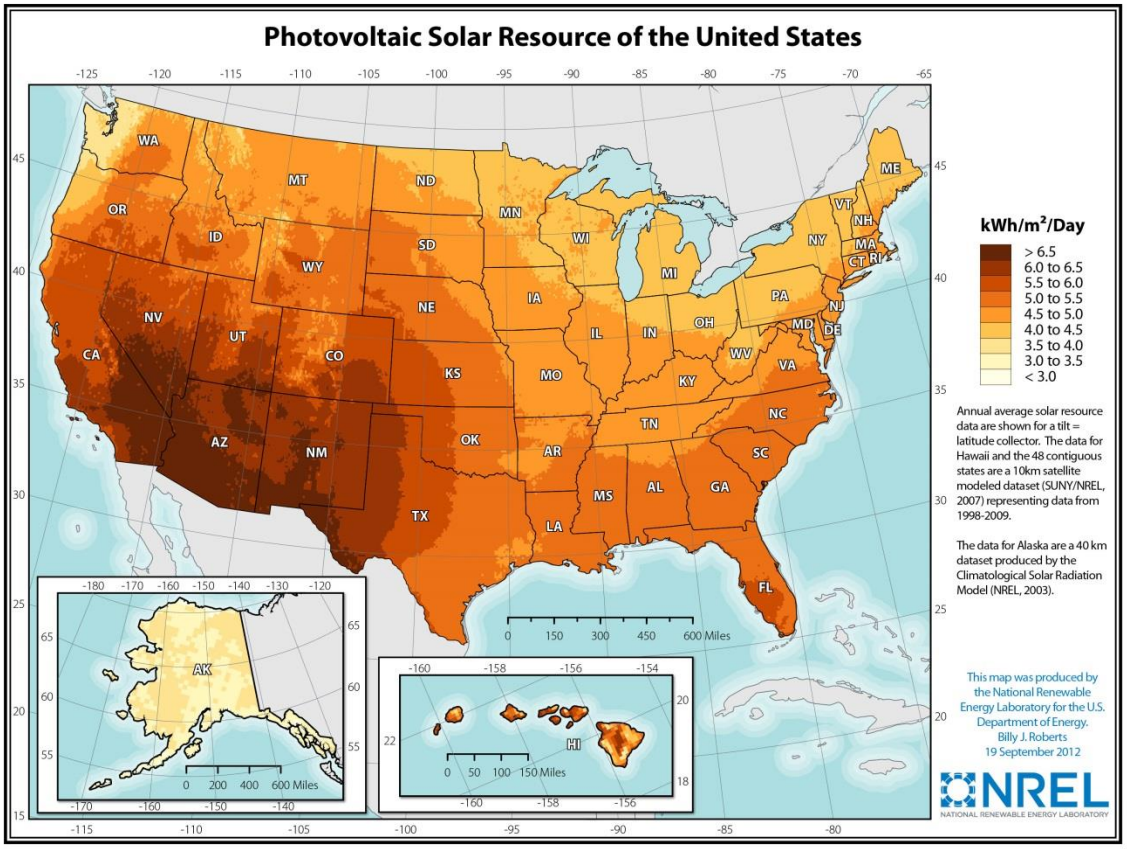
Location of Brackish Groundwater Supplies



USGS National Brackish Groundwater Assessment

RECLAMATION

Availability of solar resource PV



RECLAMATION

Hypothesis

Solar resource: PV and/or solar concentrating

+

Desalination: reverse osmosis/nanofiltration or membrane distillation

---

Increased water supply for remote areas

RECLAMATION

Goals of this Phase of Research

1. Establish benchmark for off-grid desalination using readily available components
2. Develop methodology for comparing different types of renewable-energy powered desalination technologies

Photovoltaic-Powered Reverse Osmosis (PVRO)

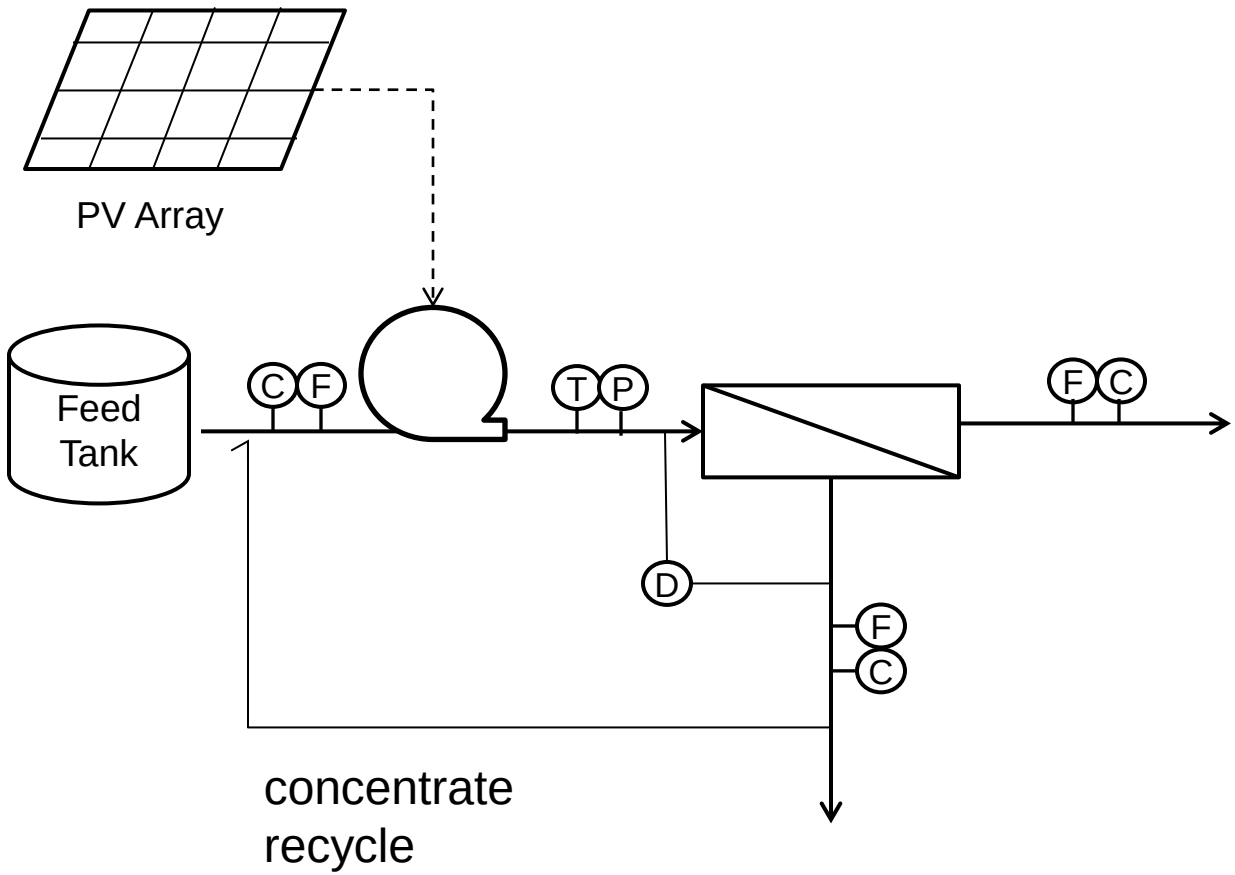
Benefits

- Combines 2 readily-available technologies
- Inexpensive capital investment
- Allows for automation and complexity in implementation
- Allows for operational improvements

Limitations

- Membrane scaling/fouling
- Need for membrane replacement
- Inherent losses in converting solar energy to DC power

Schematic Diagram of Simple PVRO



Legend

- P — Pressure transducer
- F — Flow sensor
- T — Temperature sensor
- C — Conductivity sensor
- D — Differential pressure transducer

Simple PVRO Photos

RECLAMATION

System Component and Installation Costs

Component	Specification	Cost ($)
RO system (wateranywhere.com)	(2) 2.5” x 40” membranes	2,400
PV (local hardware store)	400 Watt	1,800
Pump	1/5 HP, DC motor	1,100
Labor	40 hrs @ $50/hr	2,000
Total		**7,300**

* Does not include the cost of well development or wellhead pumping

Operating Conditions

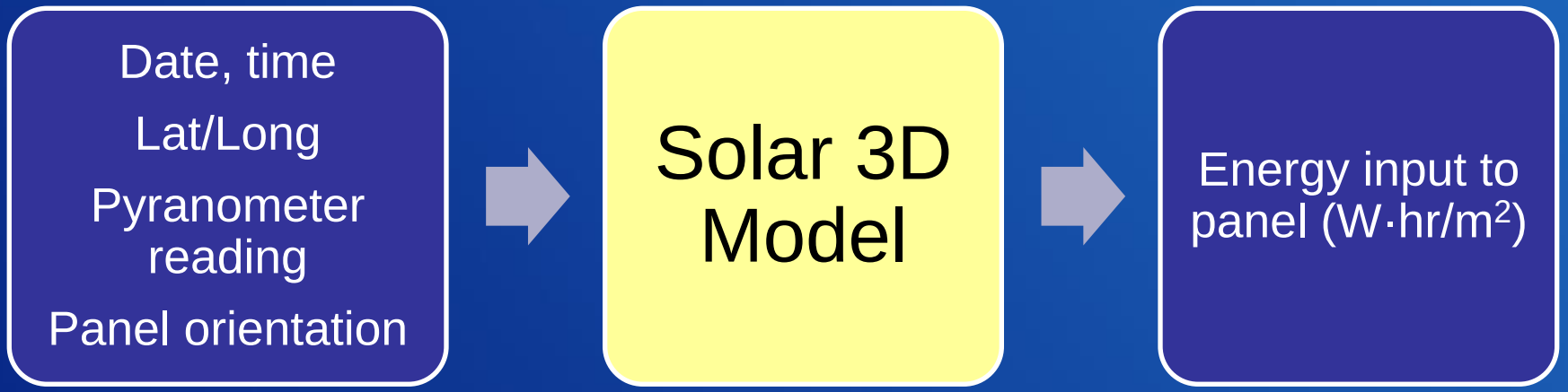
- Feed water: 2000 mg/L NaCl
- Membrane recovery: 30%
- Maximum feed pressure: 120 psi
- Feed pressure is a function of solar input

Data Collection

- Date, local time, latitude and longitude
- PV System
  - Panel angle (angle from the horizontal)
  - Panel bearing (from North)
  - Solar irradiance (typically horizontal indirect measurement)
- Membrane System
  - Feed: temperature, pressure, conductivity
  - Concentrate: pressure, flowrate, conductivity
  - Permeate: flowrate, conductivity

RECLAMATION

Solar Data Analysis Protocol

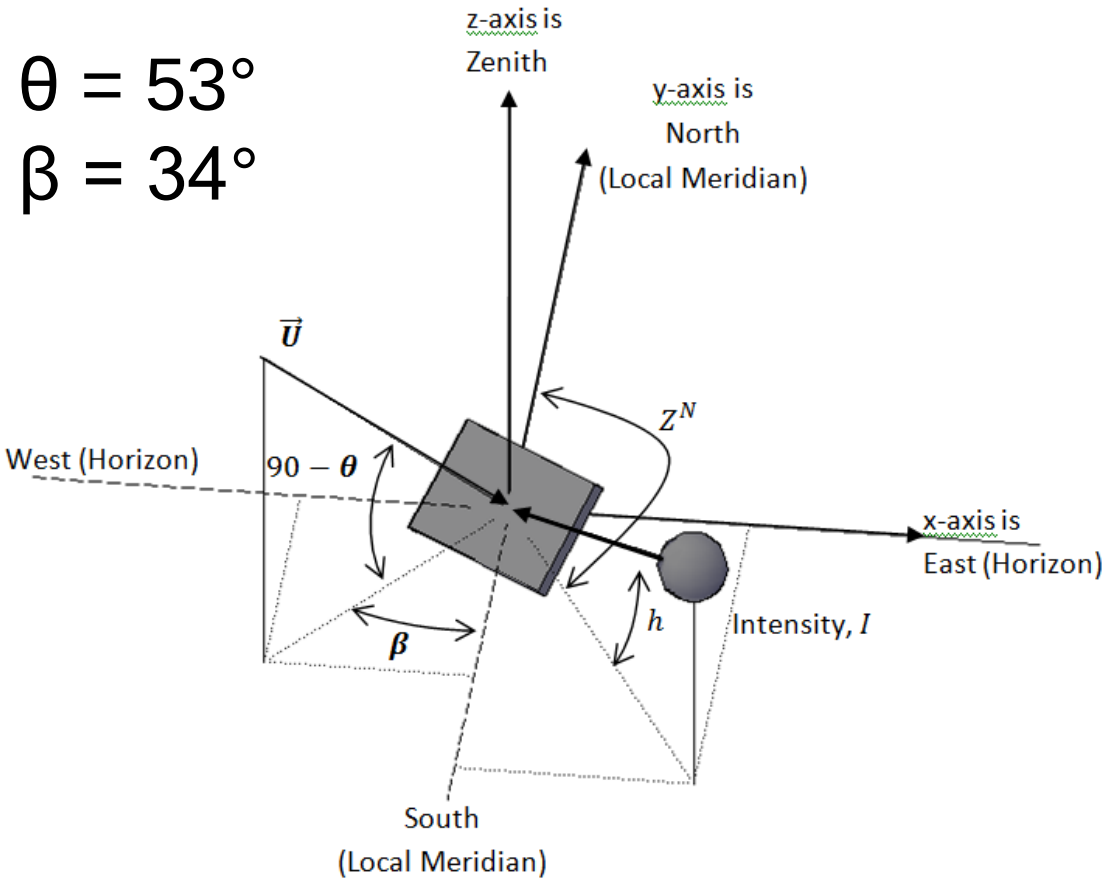


RECLAMATION

Solar 3D Model

θ = 53°

β = 34°

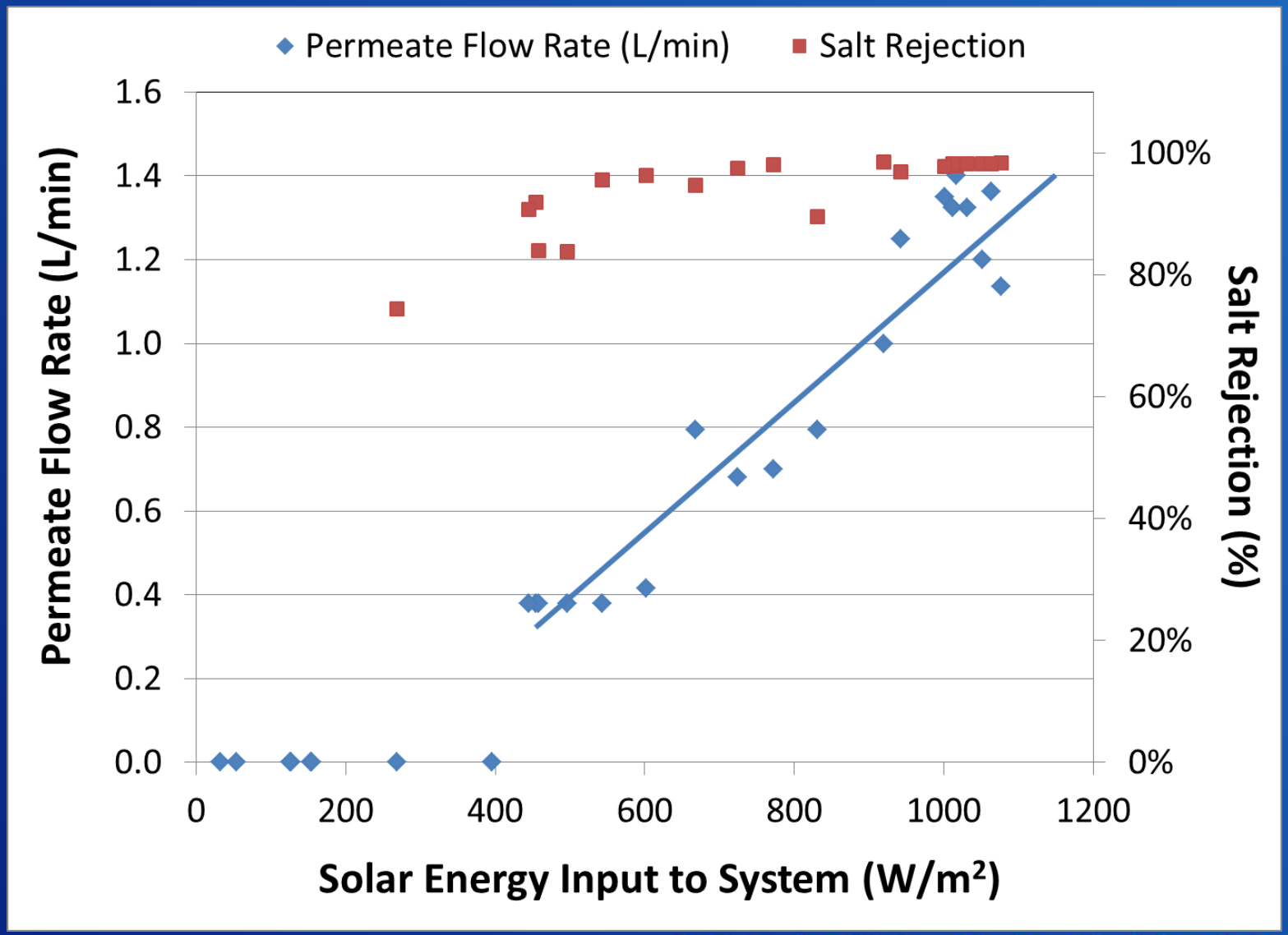


$$\vec{U}^{sol} = \pm \sin(Z^N) \cdot \cos(h))\boldsymbol{i} + -\cos(Z^N) \cdot \cos(h)\boldsymbol{j} + -\sin(h)\boldsymbol{k}$$

$$Energy\ input = U \cdot I$$

RECLAMATION

PVRO Operational Data



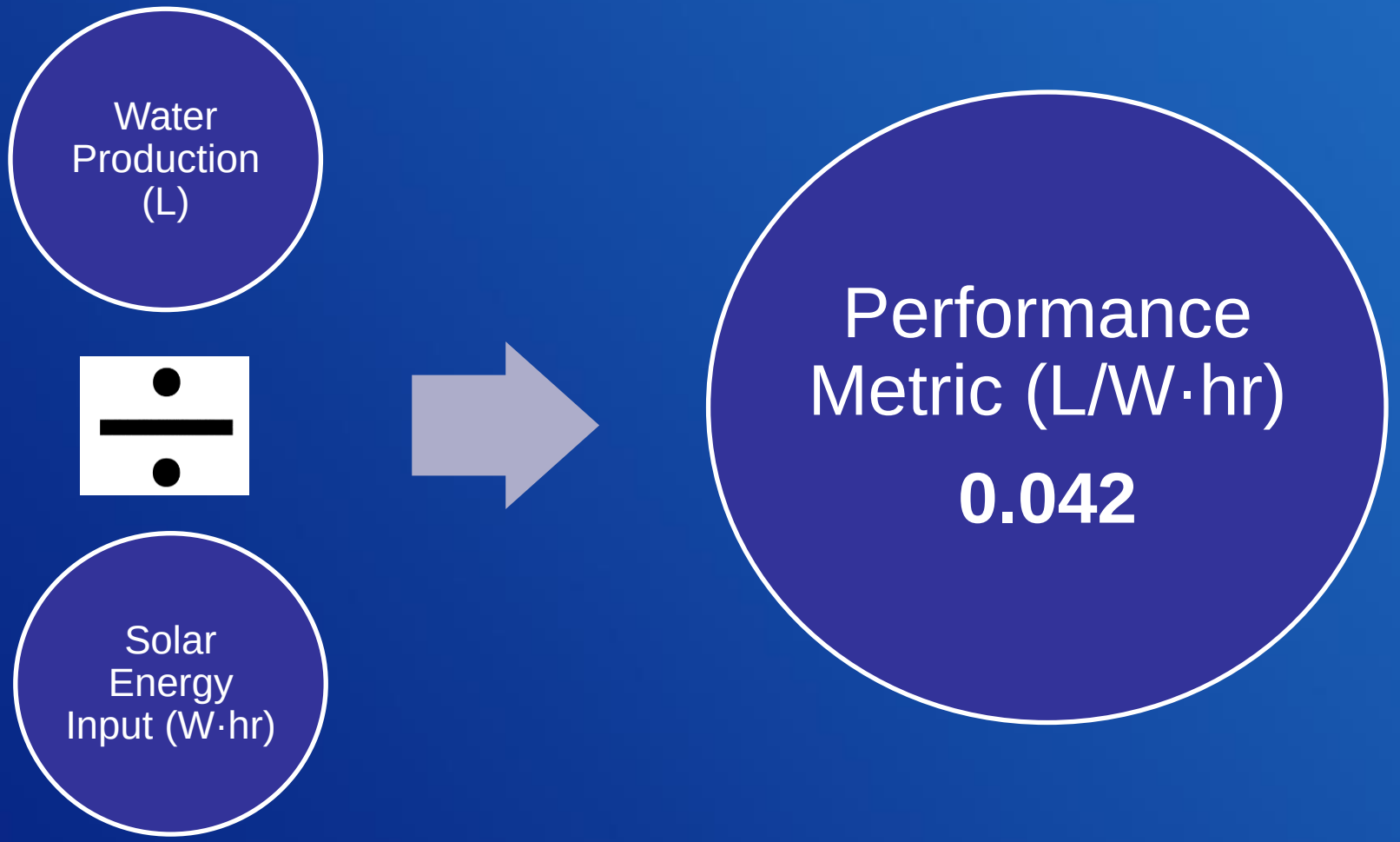
RECLAMATION

Summary of PVRO Results

- Cumulative water production: 144 L
- Solar input: 2195 W·hr/m^2
- Solar panel area: 1.57 m^2
- Average salt rejection: 94%

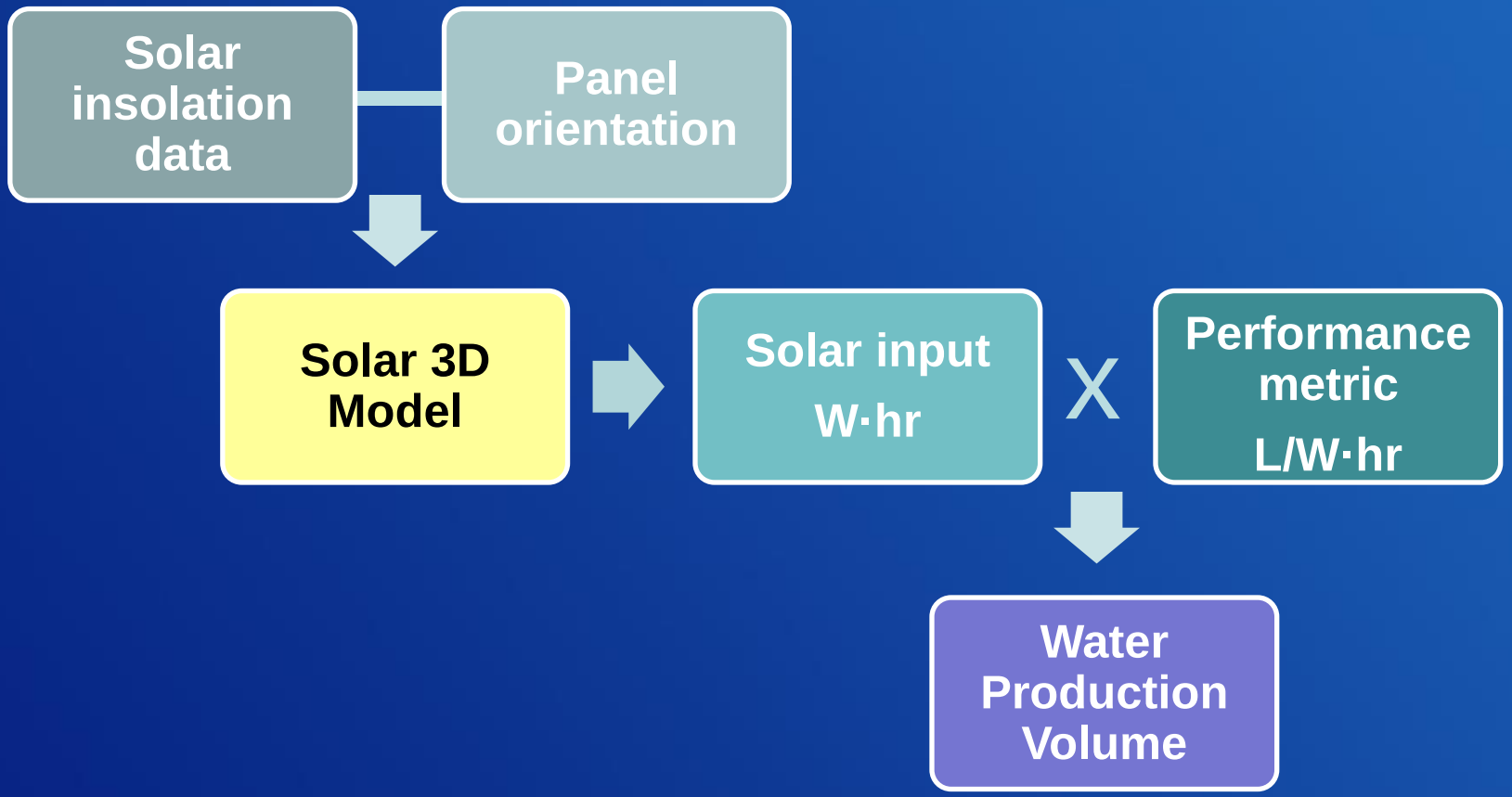
RECLAMATION

Performance Metric Allows For Comparison Between Projects



RECLAMATION

Extrapolation to Other Location/Conditions



RECLAMATION

Establishing a Benchmark

Performance metric for PVRO = 0.042 L/W·hr

Metric allows for comparison of

- Systems run in different geographic locations and with different solar resource (i.e. seasonal, weather events)
- Different types of solar-desalination hybrid systems
  - Solar distillation
  - Solar-membrane distillation
  - PV-ED/EDR
- Performance metric of system improvements
  - Adding batteries
  - Energy recovery

Things to be Considered…

- Develop metric to incorporate system cost
- Incorporate energy requirement for source water pumping
- Concentrate disposal
- Develop testing/data analysis methodology for brackish groundwater source

Test Facility for Renewable Energy-Desalination Research

- Supply 4 different brackish water sources
- Abundant solar resource
- Outdoor test pads
- Laboratory facility
- 3+ years of meteorological data

RECLAMATION

Partnerships and Programs

- Reclamation programs
  - Science and Technology Program
  - Desalination and Water Purification Program (grants.gov)
  - Cooperative agreement with NMSU
- Securing Water for Food Grand Challenge – USAID
  - www.thedesalprize.net

Funding and Contributors

Funding provided by Reclamation's Science and Technology Program

PVRO system and testing: Dan Gonzales, Andrew Katers, Nathan Myers, Mike Simonovice (Reclamation)

Solar 3D Model: Dr. Andrés Guerra (Colorado School of Mines)

RECLAMATION

RECLAMATION

Managing Water in the West

Contact Information

PVRO, desalination technology information

Katie Guerra, kguerra@usbr.gov, 303.445.2013

Brackish Groundwater National Desalination Research Facility

Randy Shaw, rshaw@usbr.gov, 575.443.6540

Solar Calculations

Andrés Guerra, aguerra@mines.edu, 303-910-9320

U.S. Department of the Interior
Bureau of Reclamation