The Solar Energy-Water-Environment Nexus in Nevada

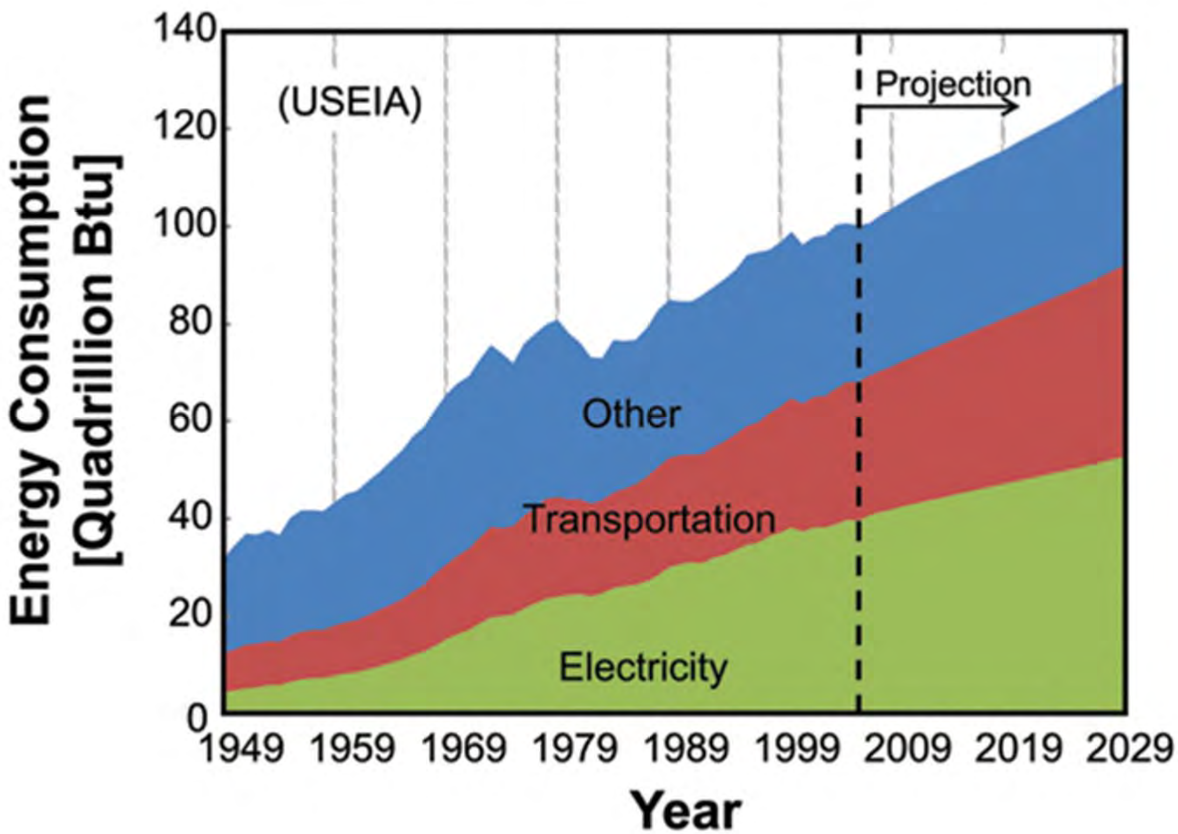
Tau Beta Pi Annual Banquet

UNLV Chapter

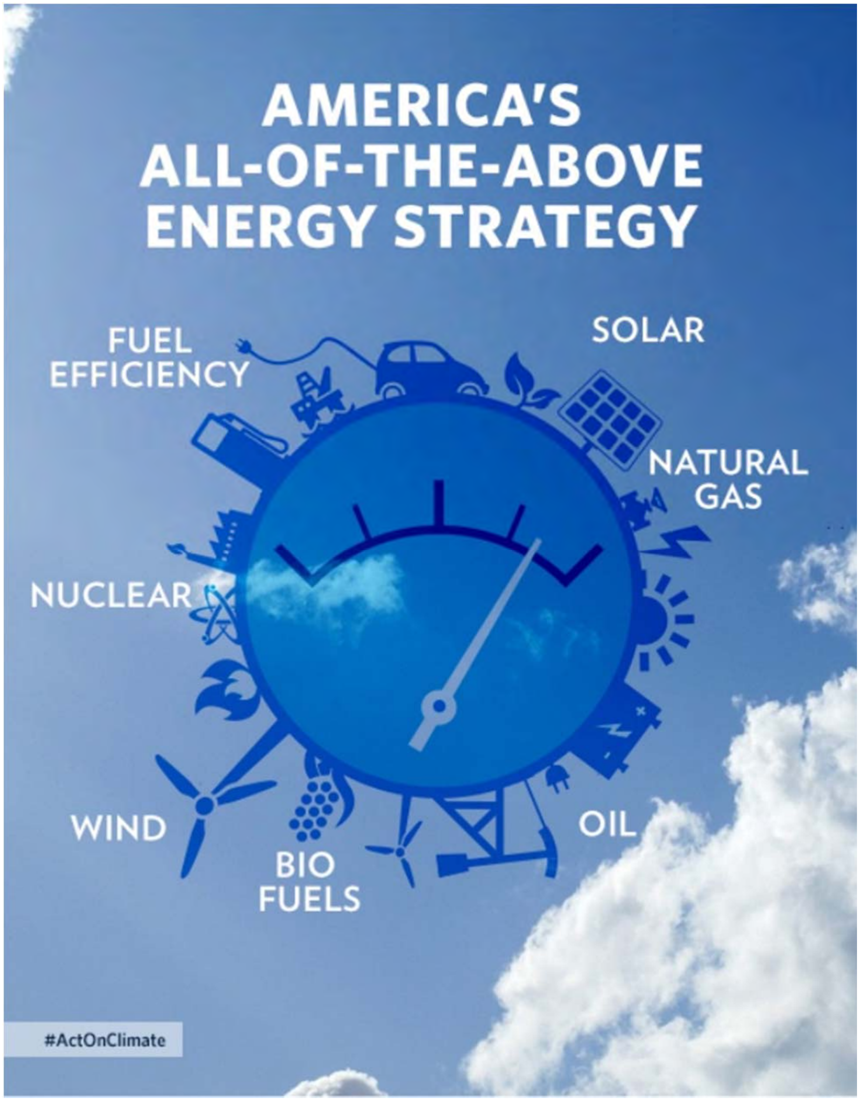
May 2, 2015

Energy -
We all use it

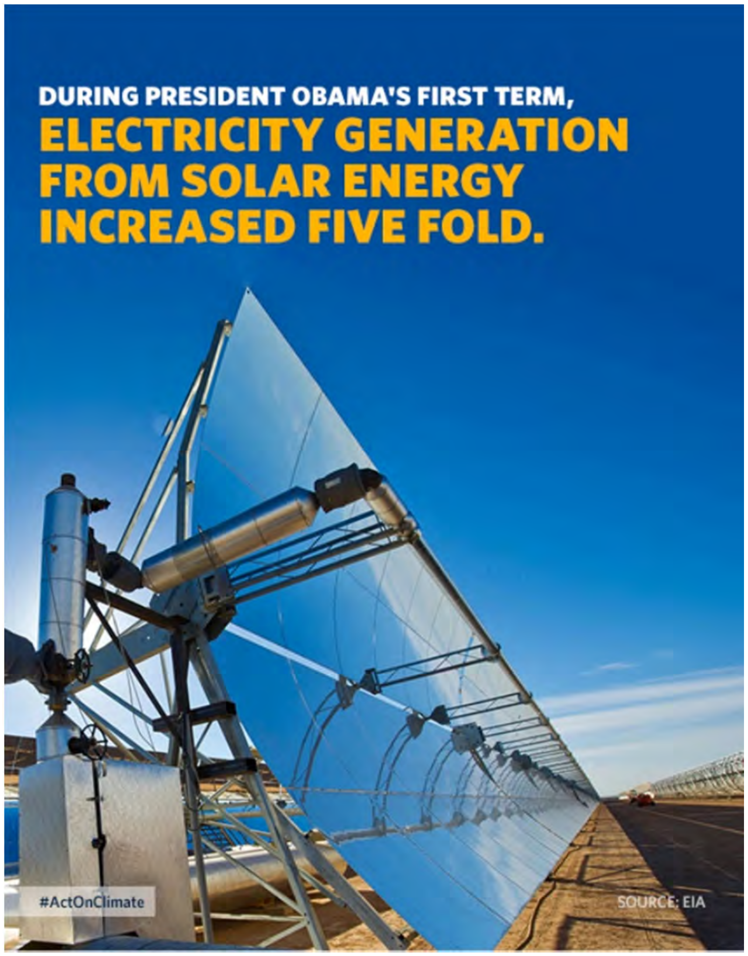
US Energy consumption will continue to rise



Clean Energy: A National Priority



2014 Presidential commitment to advance solar Energy



May 9, 2014: President Announced Commitments and Executive Actions to Advance Solar Deployment and Energy Efficiency

What is Nexus ?

Linkages – among solar power, water, and the environment.

- In Nevada, solar flux is abundant and exploration of this energy source has the potential to significantly diversify the economy of the state.
- Nevada lies within the Great Basin and Mojave Desert, both are fragile ecosystems easily altered by anthropogenic activities.
- The generation of all forms of energy, except wind, requires water. Yet, Nevada is an arid region with limited water resources.

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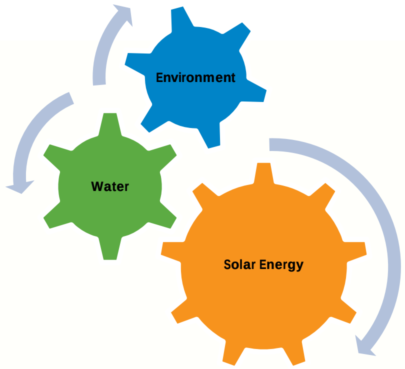


Nevada can help meet the nation’s energy needs

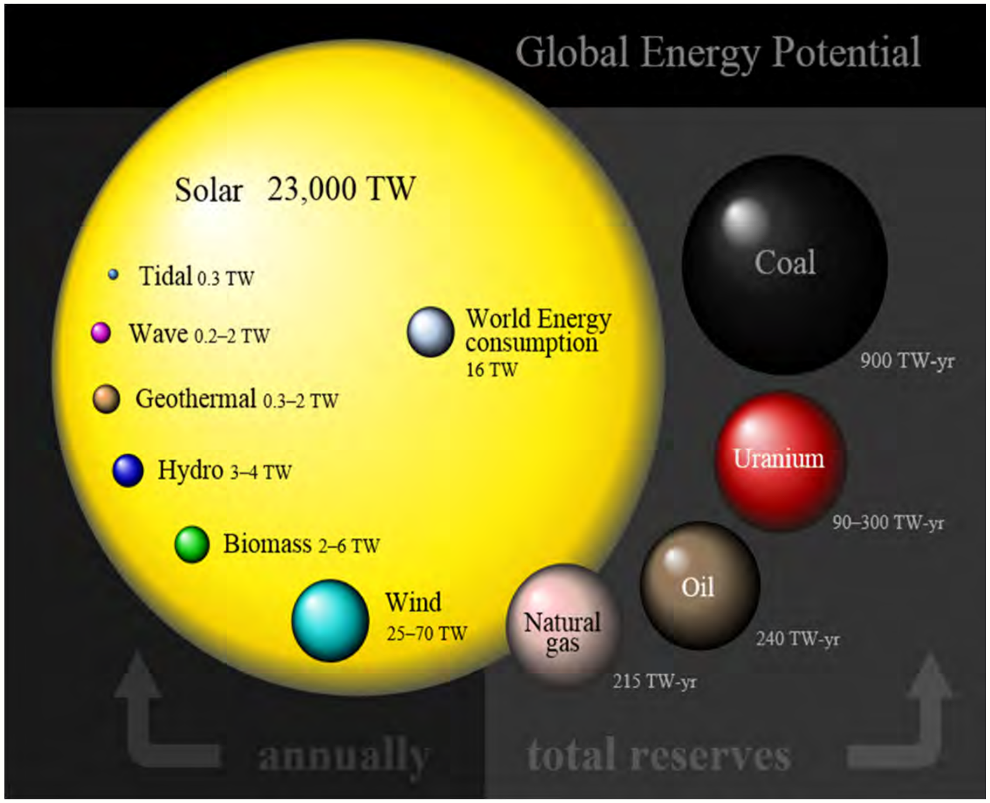
Sempra Copper Mountain Solar 1 Plant near Boulder City, NV

Abundant:

- ✓Sunlight
- ✓Cloud-free days
- ✓Undeveloped Land

GLOBAL SOLAR ENERGY POTENTIAL IS LARGE AND SUSTAINABLE

Nevada is in a unique position - here the solar flux is abundant and utilizing this energy source has the potential to significantly diversify the economy of the state.



Source: Perez et al., 2009, "A Fundamental Look At Energy Reserves For The Planet", p.3, PDF (archived). Licensed under Public Domain via Wikimedia Commons

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Who are the PI and Co-PIs?

Dr. Gayle Dana

Principal Investigator, Project Director
Desert Research Institute

Dr. Jaci Batista

Co-Principal Investigator
University of Nevada, Las Vegas

Dr. Robert Boehm

Co-Principal Investigator
University of Nevada, Las Vegas

Dr. Markus Berli

Co-Principal Investigator
Desert Research Institute

Dr. Sergiu Dascalu

Co-Principal Investigator
University of Nevada, Reno

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The Solar Energy-Water-Environment Nexus in Nevada

Research and Infrastructure Building Grant from the National Science Foundation (NSF) awarded to Nevada System of Higher Education

Duration: 5 years (2013-2018)
Amount: $20M from National Science Foundation (NSF) plus $4M cost share from the Nevada System of Higher Education (NSHE)

This material is based upon work supported by the National Science Foundation under grant number IIA-1301726

Who are the other people involved?

- 37 Nexus research faculty
- 5 Education faculty
- 1 Post-doc
- 21 Technicians and research associates
- 29 Graduate students
- 28 Undergraduate students
- 5 New faculty members
  - High temperature materials (UNLV)
  - Restoration ecology (UNLV)
  - Renewable energy economics (UNR)
  - Advanced water technology (DRI)
  - Intelligent data mining (UNR)

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New UNLV Women Faculty Hired

Dr. Moon

Dr. Bansal

Why is this research needed?

- To promote economic diversification in Nevada by supporting solar energy development.
- It is critical to understand and minimize the impacts of solar energy development on Nevada's limited water resources and the environment while achieving environmental benefits from renewable energy.
- Nevada needs cyberinfrastructure and an educated and diverse workforce to sustain the renewable energy industry.

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THE FIVE OBJECTIVES OF THE NEXUS RESEARCH

- **Objective 1: Explore new technologies that could minimize water use at solar facilities;**
- **Objective 2: Understand environmental impacts of solar energy projects;**
- **Objective 3: Develop sustainable and advanced water/wastewater approaches to support water needs for solar energy development;**

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THE FIVE OBJECTIVES OF THE NEXUS RESEARCH

- **Objective 4: Improve reliability, economic modeling, and sunlight forecasting for renewable solar energy supply;**

- **Objective 5: Develop new and use existing cyberinfrastructure capabilities to accelerate the Nexus research.**

TWO WAYS SOLAR IRRADIATION IS USED TO CREATE ELECTRICITY

- **Photovoltaics** —Electronic devices ("solar cells" or "PV") convert the sun's electromagnetic radiation directly into electricity.

- **Solar Thermal** —The sun's energy in concentrated (Concentrated Solar Power - CSP) form heats a fluid that is then used in an engine to produce power.

Photovoltaic systems located on the roof of the UNLV Engineering Building

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PV AND CONCENTRATING SOLAR PLANTS IN NEVADA


Photovoltaic (PV)


Concentrating Solar Thermal Power (CSP)

SOLAR POWER METHODS

Solar Thermal


Uses mirrors or lenses to concentrate thermal solar energy onto fluid-filled pipes

Photovoltaics


Uses materials like silicon and silver to capture solar energy and convert it into electricity. Systems can be planar or concentrators.

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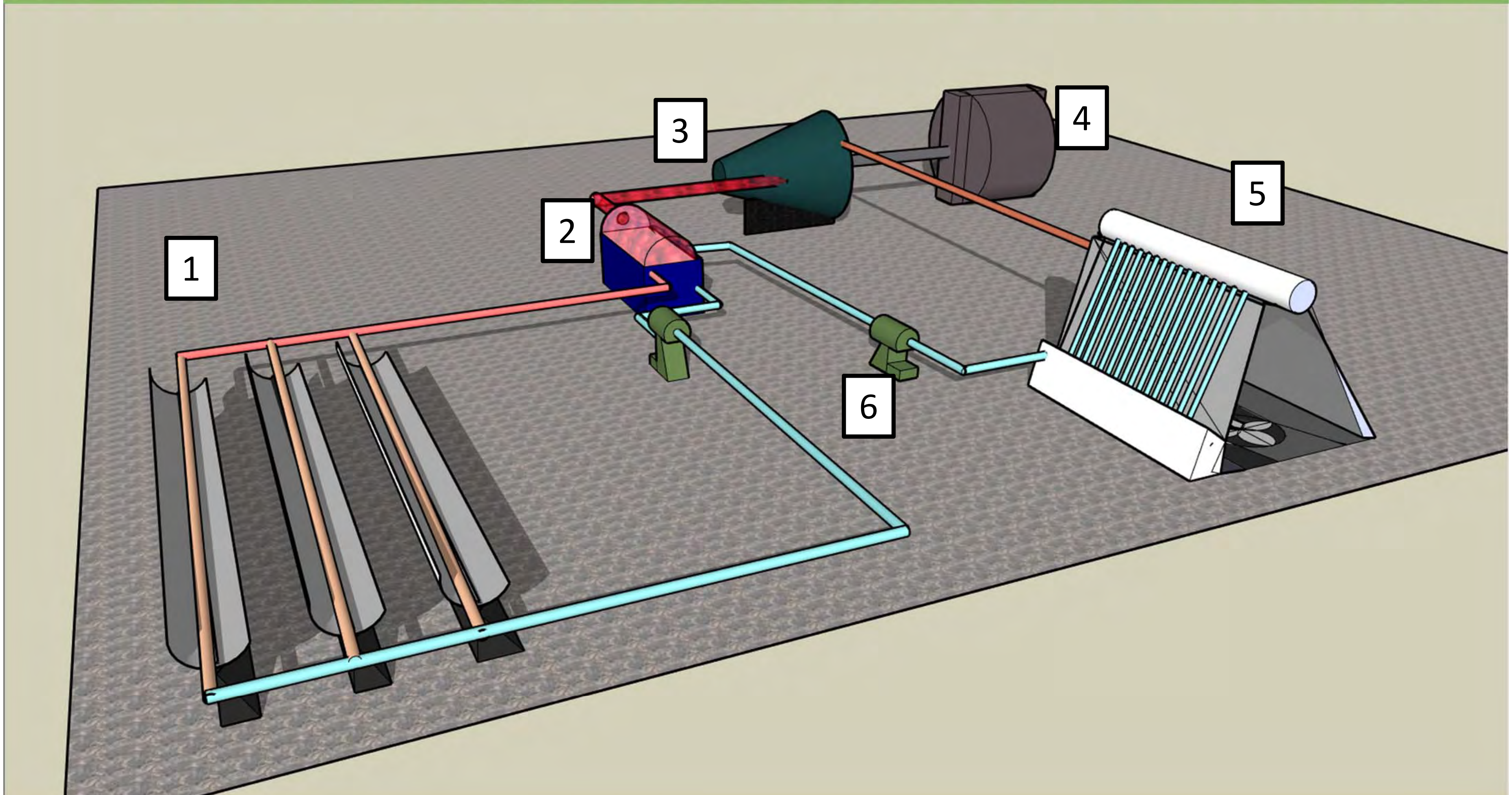
CONCENTRATING SOLAR POWER (CSP)



1	Solar Collectors		3	Turbine		5	Air cooled condenser
2	Steam generator		4	Electric Generator		6	Pumps

EXAMPLE OF SOLAR THERMAL
CRESCENT DUNES (TONOPAH)

Retrieved from http://solar-reserve.com/

Example PV Plants

Copper mountain PV plant,
Boulder City

Nellis AFB PV plant,
North las vegas

UNLV Mobile PV Unit

Mandalay Bay Convention Center
Solar Project – Las Vegas
"not constructed yet"

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OBJECTIVE 1-Benchmarks* 1 and 2

Benchmark 1: minimize cooling and cleaning water use through improvements to the power plant (e.g dry cooling and increasing plant efficiency.

Benchmark 1B: Hire new UNLV faculty member in high temperature materials (Dr. Moon)

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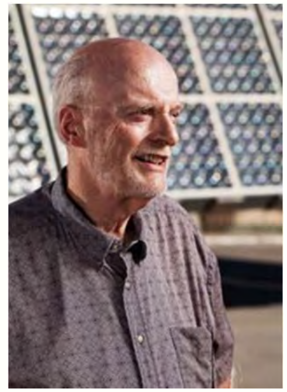


Dr. Bob Boehm
UNLV

Dr. Yitung Chen
UNLV

Dr. Jaeyun Moon
UNLV

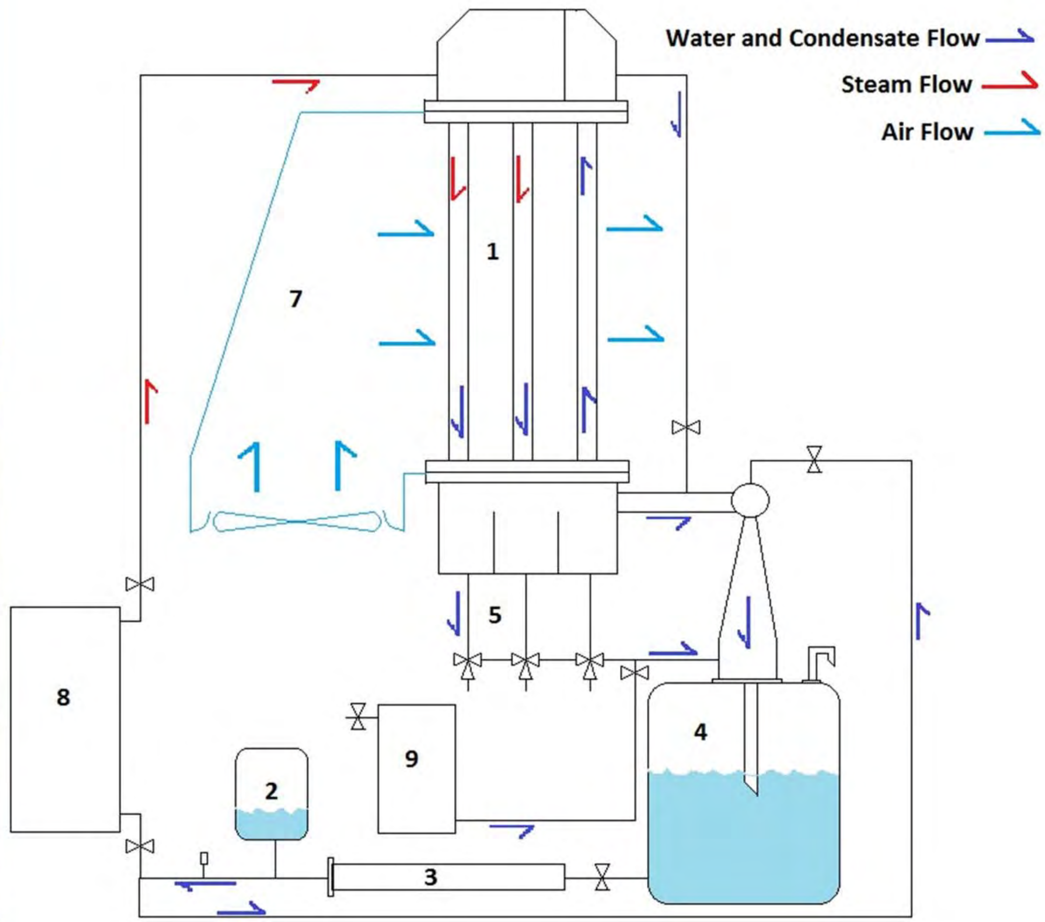
Rick Hurt
UNLV

Danielle Nobles
Dr. Boehm's Grad Student
UNLV

Kaipo Kekaula
Dr. Chen's Grad Student
UNLV

*Nexus Research Tasks

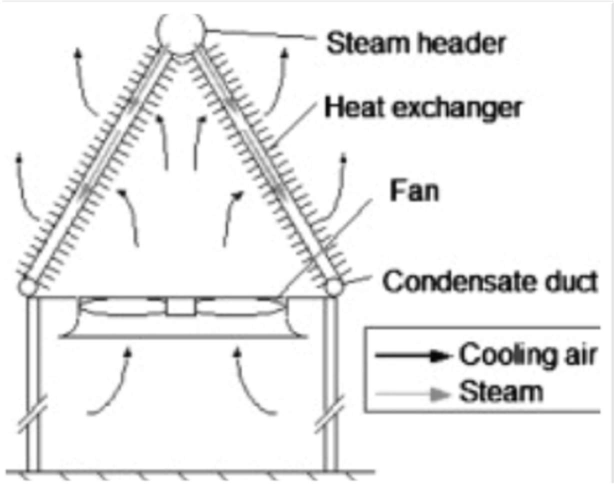
Dry Cooling Experiment, Year 1



Dry Cooling Study

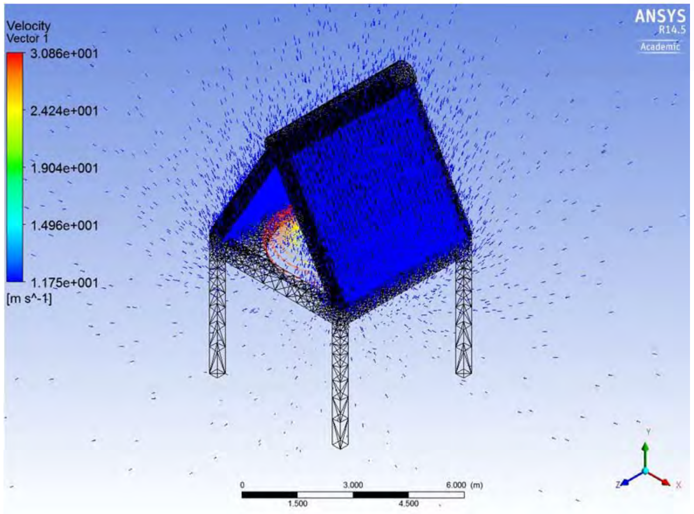
Drs. Boehm and Chen (UNLV)

Purpose: improve understanding of air-cooled condenser units in energy generation systems such as solar thermal power plants to improve energy efficiency and reduce water consumption



A-Frame system model geometry

Developing a numerical model to simulate condensation phenomena coupled with A-frame cooling towers



Experiments will verify and validate numerical results to assist and modify solar air-cooled system designs

3D Numerical model with swirl inlet conditions velocity vectors (isometric view)

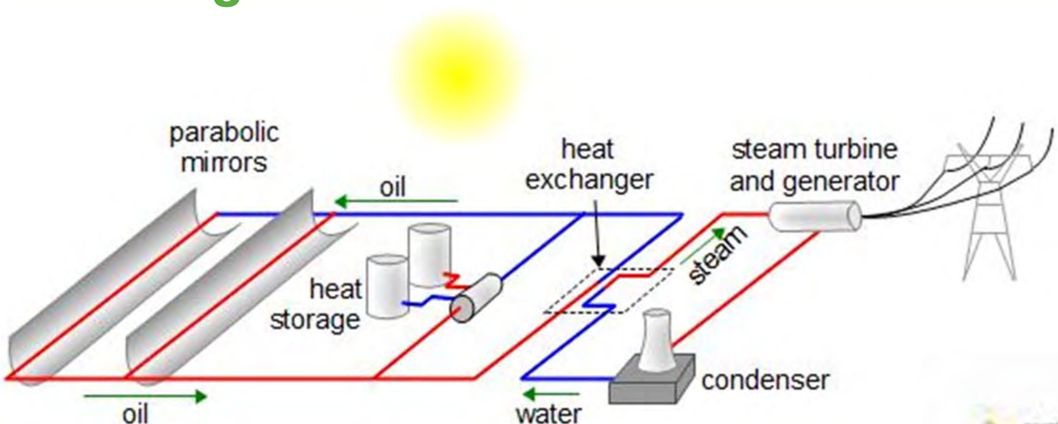
Year 2

Improving solar power cycle efficiency by raising high temperature

- High temperature receiver development using UNLV dish system. (Boehm, Chen)
- Incorporating high temperature coatings (new faculty member Moon).

WATER NEEDED IN SOLAR ENERGY GENERATION

CSP has a cooling tower to condense steam. Wet cooling evaporates water into the environment, while dry cooling does not. PV and CSP have solar surfaces that may need washing.



Water needed for CSP:

- **800-1000 gal/MWhr – wet cooling and washing mirrors**
- **105 gal/MWhr – dry cooling for washing mirrors**

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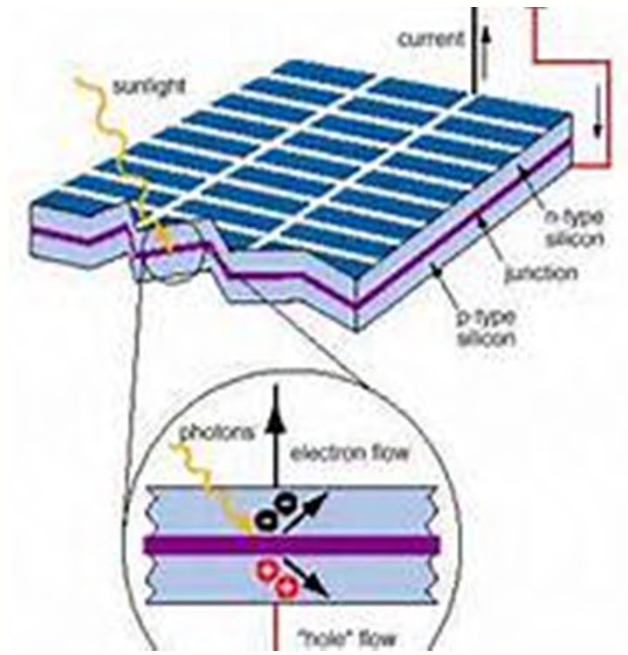
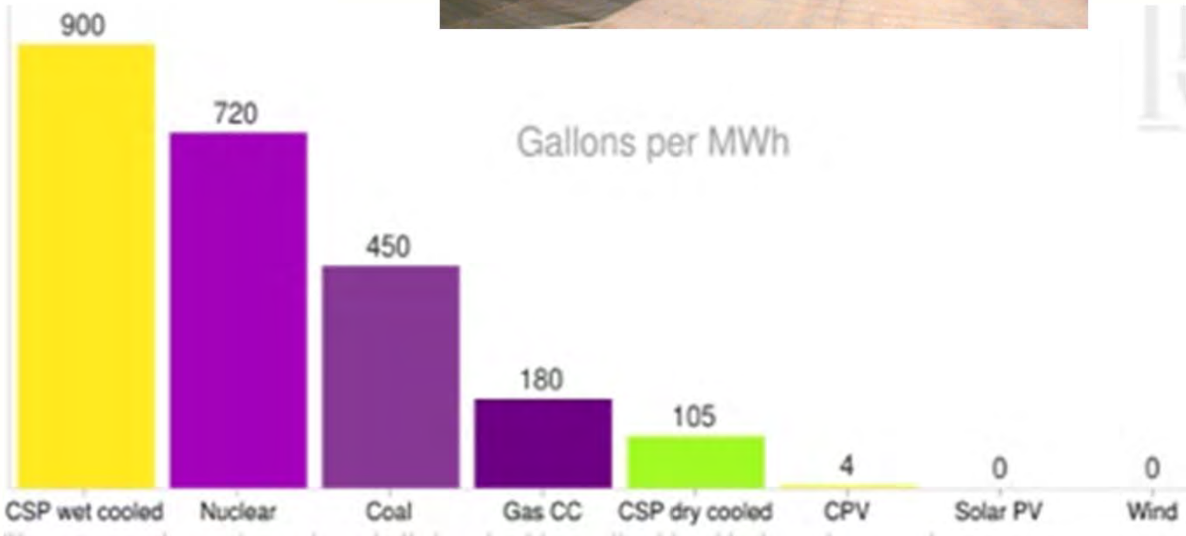
Water to wash PV panels
< 1 gal/MWhr is



WATER USE AND ENERGY GENERATION

Much less water is used in solar and wind energy generation, than in other types of power generation, but for water poor regions, such as Nevada, water use minimization in cleaning mirrors and panels and for cooling is critical.



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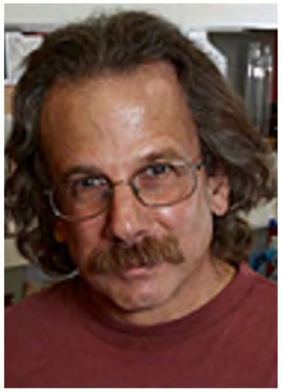
OBJECTIVE 1-Benchmark 3

Benchmark 3: understand dust deposition and removal from panels and mirrors.

Dr. Vic Etyemezian
DRI



Dr. Spencer Steinberg
UNLV

George Nikolich
DRI

Jason Sylva
Dr. Steinberg's Grad Student
UNLV

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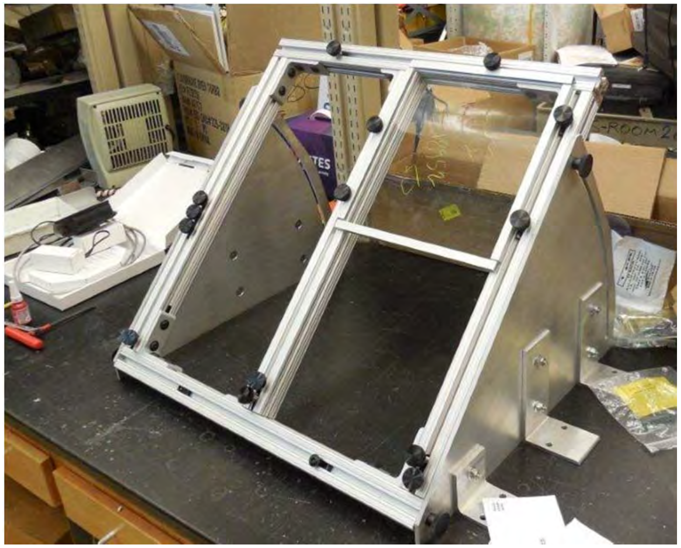
Test stand design

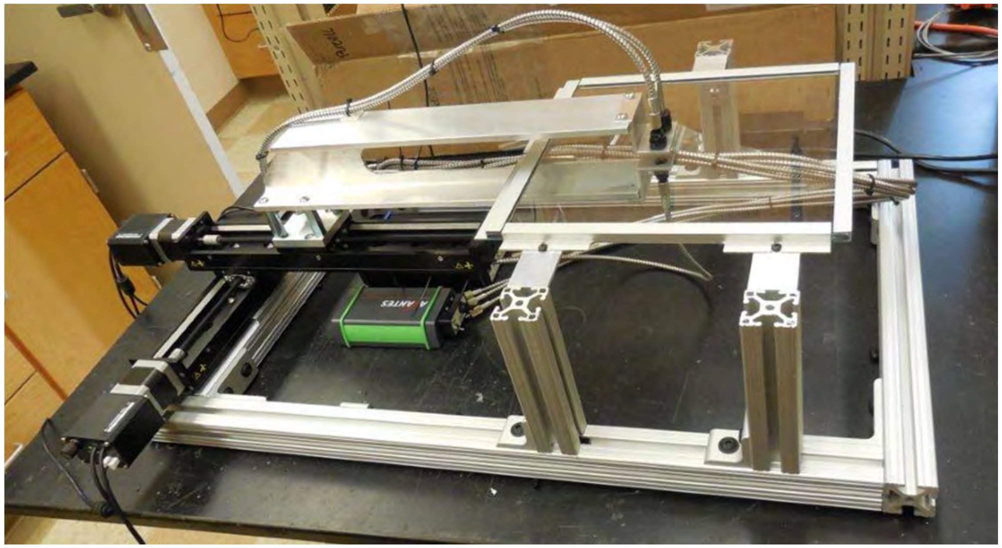
Two components

- Particle and wind characteristics
  - Anemometer – wind speed, turbulence
  - Particle profiler – optical particle counts
- Impact on PV by attenuation
  - Stand to expose several PV-like glass panels
  - Spectrometers scan panels to collect light attenuation information

Intent: Set "industry standard" for testing platform



Exposure Frame Components



Spectrometer traverse for testing exposed

OBJECTIVE 1-Benchmark 4

Benchmark 4: use nanotechnology to mitigate dust accumulation.

Dr. Kwang Kim
UNLV

Dr. BJ Das
UNLV

Jiyeon Park
Dr. Kim's Grad student
UNLV

Sanjana Das
Dr. Das' Grad Student
UNLV

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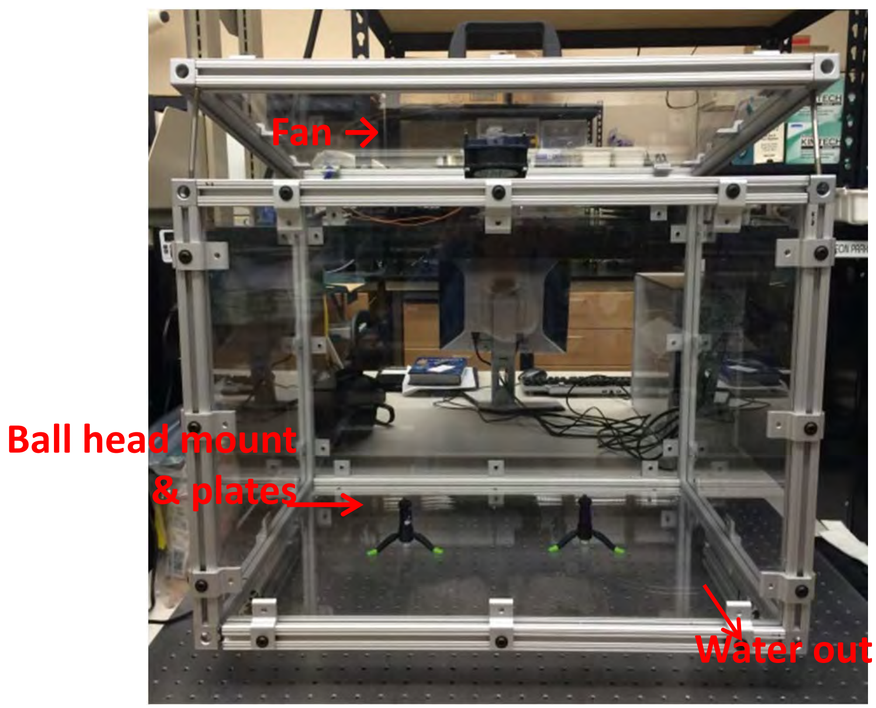
Dust accumulation process on solid surface and its affect on solar panel performance

Dr. Kim and Jiyeon Park (PhD student) (UNLV)

- Total number and mass of particles on surface and percentage covered area was estimated. Subsequently, total number of molecules and total intermolecular force between particles and surface was estimated solely based upon adhesion force.
- Currently developing Matlab-base imaging technique to find percentage area covered by particles.
- A laboratory-scale experiment facility was built to simulate dust accumulation on glass/acrylic surface.



OBJECTIVE 1-Benchmark 5

Benchmark 5: use remote sensing to detect particle deposition on panels and mirrors.

Dr. Evangelos Yfantis
UNLV

Konstantinos Moutafis
Dr. Yfantis' Grad Student
UNLV

OBJECTIVE 1-Benchmarks 6

Benchmark 6: expand CI connectivity and create NRDC*-UNLV

*NRDC = Nevada Research Data Center, with sites at both UNR and UNLV

Dr. Haroon Stephen
UNLV

Eric Fritzinger
Software Developer
UNR

Scotty Strachan
Field and Network Technician
UNR

Dr. Mei Yang
UNLV

Dr. Yingtao Jiang
UNLV

Xiangrong Ma
Dr. Jiang's student
UNLV

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OBJECTIVE 2

Understand Environmental Impacts of Solar Energy Projects

Retrieved from http://a-z-animals.com/

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Environmental Impacts of Solar Plants on Nevada's Environment

Solar energy projects, as being implemented on the arid lands of Nevada, must overcome numerous environmental challenges. Solar plants occupy large area of land and fauna and flora habitat destruction is likely to occur, if the impacts are not avoided or properly managed. More knowledge and strategies are needed for reducing and mitigating environmental degradation from solar energy development.

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OBJECTIVE 2-Benchmarks 1 and 2

Benchmark 1:
understand population dynamics of organisms influenced by solar energy facilities.

Dr. Brett Riddle
UNLV

Benchmark 2:
understand microclimate change on the desert plant communities due to solar installations.

Dr. Dale Devitt
UNLV

Brian Bird
Field Technician
UNLV

L. Apodaca
Dr. Devitt's Grad Student
UNLV

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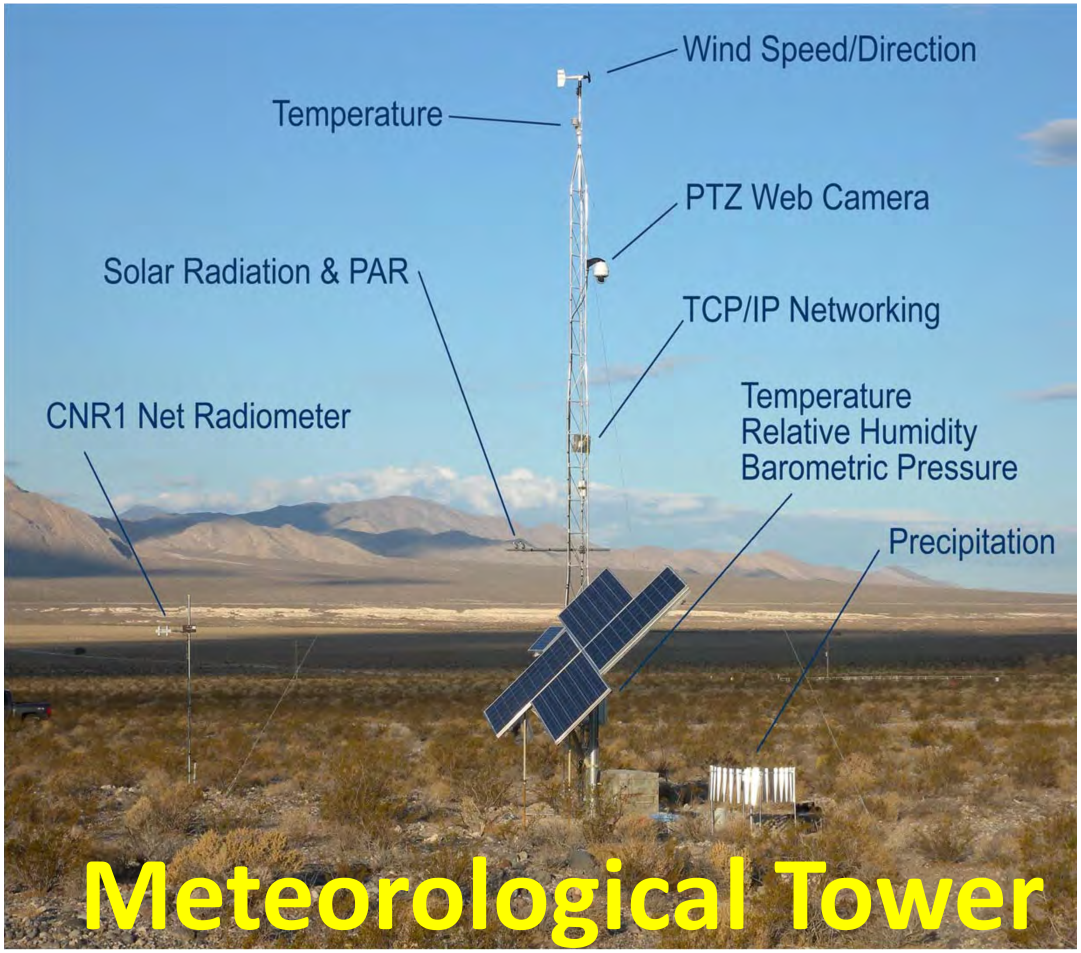

Heat pulse technique to measure transpiration velocity in stems

The 10 m towers are more than meteorological towers, as they also have soil and plant sensors

- Soil water content, matric potential, temperature, salinity and soil heat flux.
- Plant level NDVI, leaf canopy temperature and transpiration velocity.

OBJECTIVE 2-Benchmarks 4 and 5

Benchmark 4: **understand soil crust degradation and mitigation.**

Benchmark 5: **remote sensing of pre Syn and post installation of solar plant.**

Dr. Henry Sun
DRI

Dr. Haroon Stephen
UNLV

Dr. Mary Cablk
DRI

Masih Edalat
Dr. Stephen's Grad Student
UNLV

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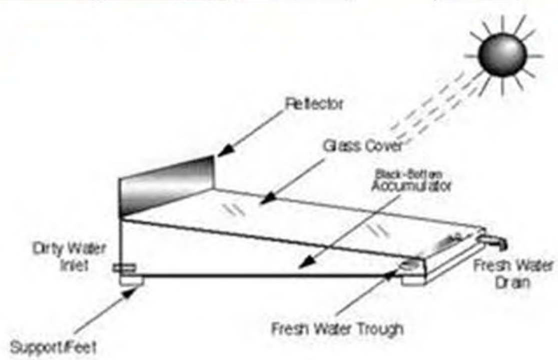
OBJECTIVE 3

Develop Sustainable and advanced water/wastewater approaches to support water needs of solar energy development



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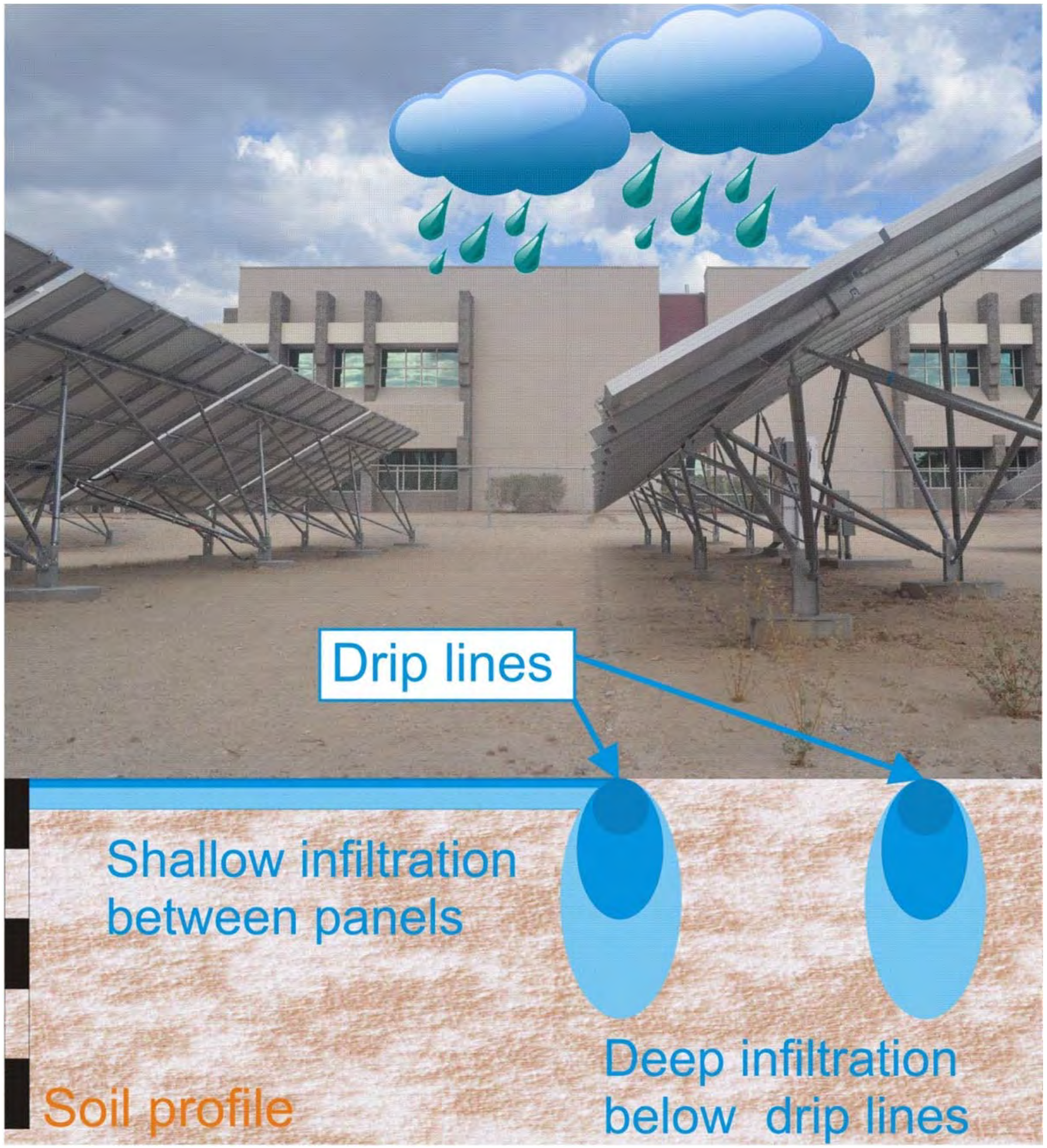
Solar Arrays and Rainwater Harvesting?

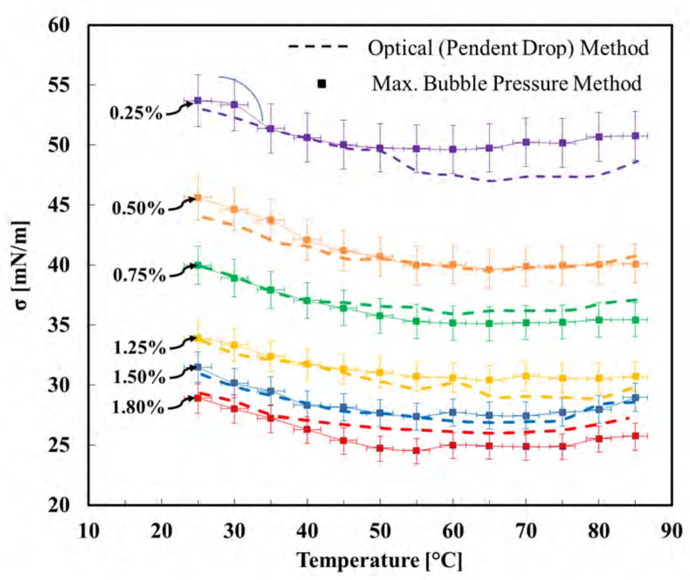


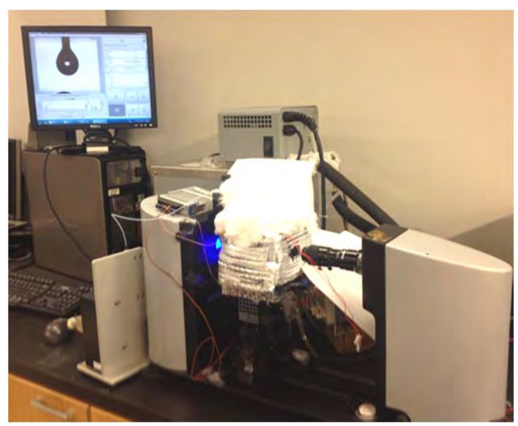
- Solar arrays change the way rain reaches the soil
- Rainwater concentrates along drip lines -> “concentrated infiltration”
- “Concentrated infiltration” leads to deeper infiltration -> more water is stored, less water evaporates
- Solar arrays: The long sought structures for rainwater harvesting?

Membrane Distillation, cont.

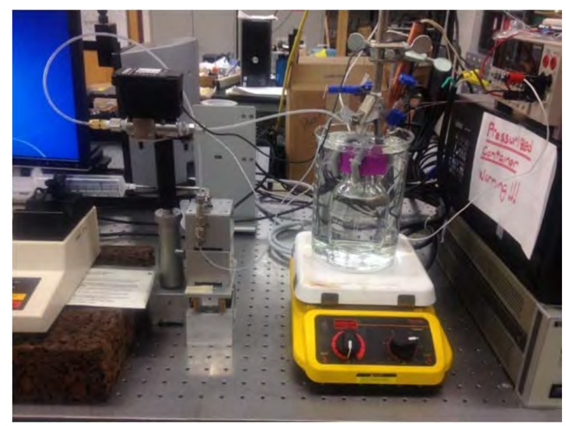
Surface Tension Property Measurement

- Comparison of Measurement Methods
  - Optical Method using tensiometer (pendant drop method)
  - Maximum Bubble Pressure Method
  - Working Fluid (Pentanol/Water mixture, Pentanol: 0.25 ~ 1.8 wt%)





Optical (Pendent Drop) Method



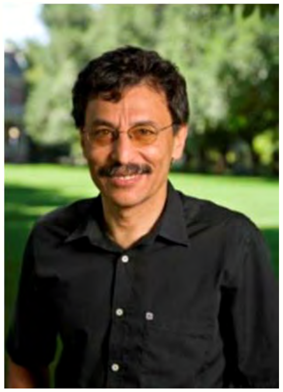
Bubble Pressure Method

OBJECTIVE 3-Benchmark 1

Benchmark 1: understand energy intensity for transport and treatment of water and wastewater.

Dr. Jaci Batista
UNLV

Dr. Yahia Baghzouz
UNLV



Dr. Sami Fadali
UNR

Dr. Sajjad Ahmad
UNLV

Dr. Mehdi Etezadi-Amoli
UNR

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Christopher Hicks, Dr. Baghzouz's Grad Student, UNLV
Hamid Khodabandehlou, Dr. Fadali's Grad Student, UNR
Mehrdad Majidi, Dr. Etezadi-Amoli's Grad Student, UNR

OBJECTIVE 3-Benchmark 2

Benchmark 2: membrane distillation of solar facility waters.

Dr. Jaci Batista
UNLV

Dr. Sage Hibel
UNR

Dr. Chanwoo Park
UNR

Saroj Napit
Dr. Hibel's Grad Student
UNR

Kevin Salls
Dr. Hibel's Grad Student
UNR

Bhaumik Parekh
Dr. Parks's Grad Student
UNR

Vahid Vandadi
Dr. Parks's Grad Student
UNR

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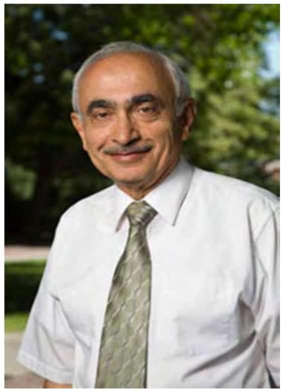
OBJECTIVE 4-Benchmark 1

Benchmark 1: understand energy generation in landholdings.

Dr. Yahia Baghzouz
UNLV

Dr. Sami Fadali
UNR



Dr. Mehdi Etezadi-Amoli
UNR

Christopher Hicks
Dr. Baghzouz's Grad Student
UNLV

Hamid Khodabandehlou
Dr. Fadali's Grad Student
UNR

Mehrdad Majidi
Dr. Etezadi-Amoli's Grad Student
UNR

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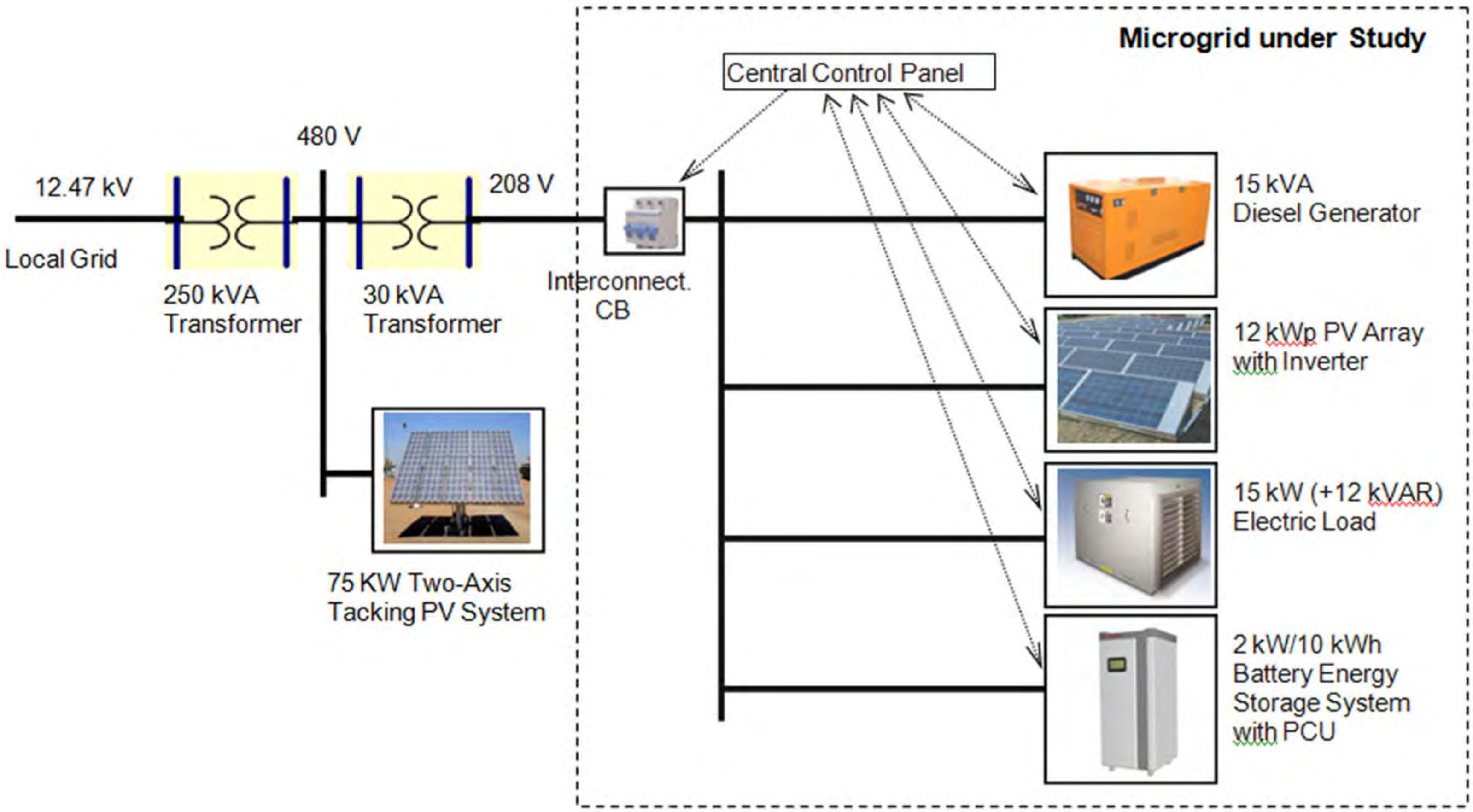
Schematic Diagram of UNLV Microgrid



The microgrid is being designed and built at the UNLV Solar Site. Initially, two distributed resources (a 12 kW flat-plate PV system and a 15 kVA diesel-powered generator) will be installed. Future expansion will include a battery energy storage system.

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OBJECTIVE 4

Improve reliability, economic modeling, and sunlight forecasting for renewable and solar energy supply

Clouds over the Black Rock Desert by Standley White

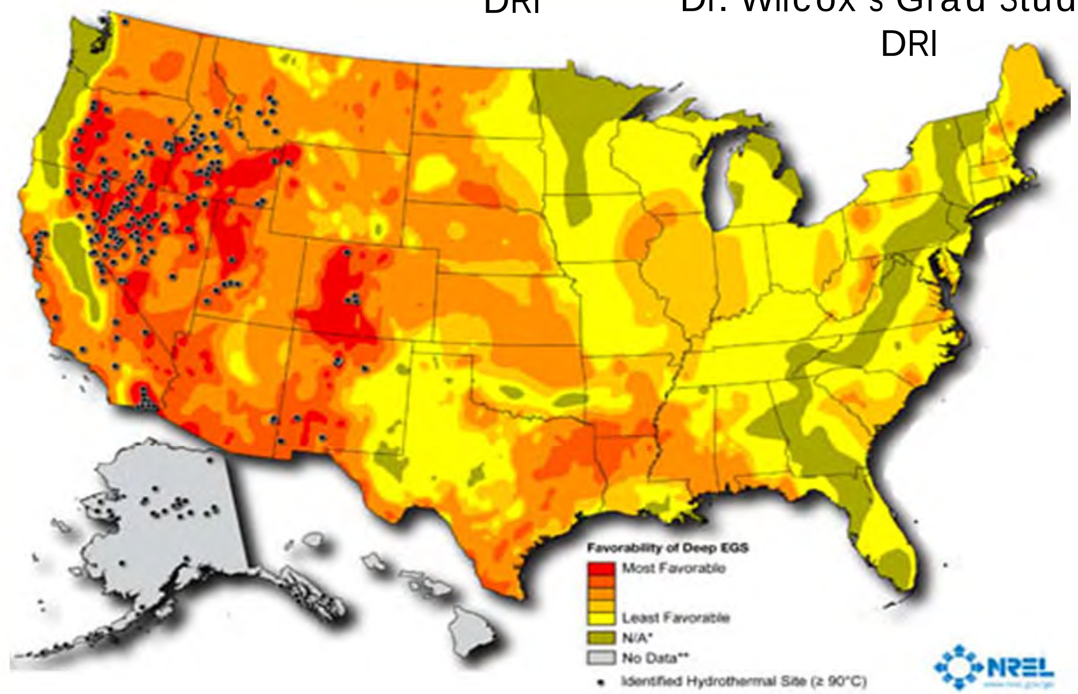
OBJECTIVE 4-Benchmark 2

Benchmark 2: forecast solar irradiance.

Dr. Eric Wilcox
DRI

No image available

Yupeng Shan
Dr. Wilcox's Grad Student
DRI



http://www.nrel.gov/gis/solar.html

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Solar Energy Reliability and Modeling

The State of Nevada's Renewable Portfolio Standard calls for 25% energy generation from renewable sources by 2030. There is a need to investigate the renewable resources that are accessible to Nevada utilities, identify areas where the expansion of these renewables can be achieved economically, and operate these utilities independently from the power grid during power outages.

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OBJECTIVE 4-Benchmarks 3 and 4

Benchmarks 3 and 4: economic analysis of solar/renewable energy projects and hire new faculty in renewable energy economics at UNR.

Dr. Thomas Harris
UNR

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HOW MUCH SOLAR POWER IS INSTALLED IN NEVADA?

- In large plants of many types there are over 500 MW installed, including
  - 75 MW solar thermal trough plant "Nevada Solar One" near Boulder City
  - 110 MW solar thermal tower plant "Crescent Dunes" near Tonopah
  - Over 200 MW of PV plants "Copper Mountain 1 and 2" near Boulder City
  - Several other smaller plants
  - There are also many small PV systems on buildings
- For comparison, Hoover Dam is 2000MW

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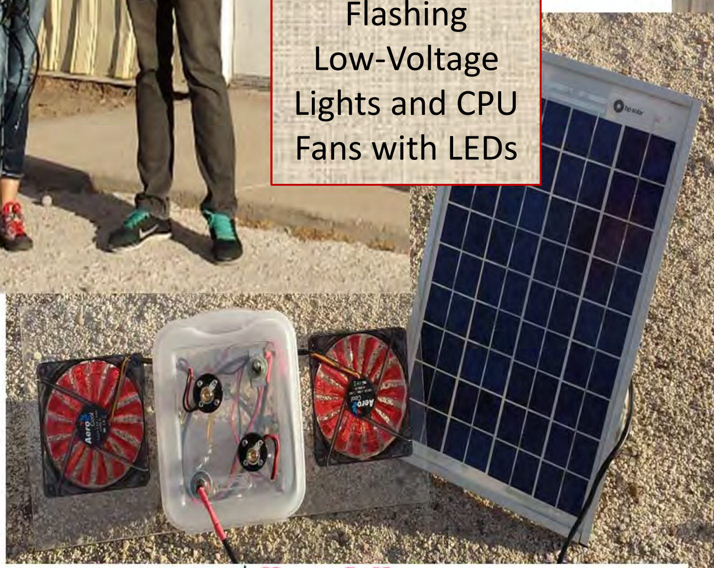
NEXUS Solar Kits in Action

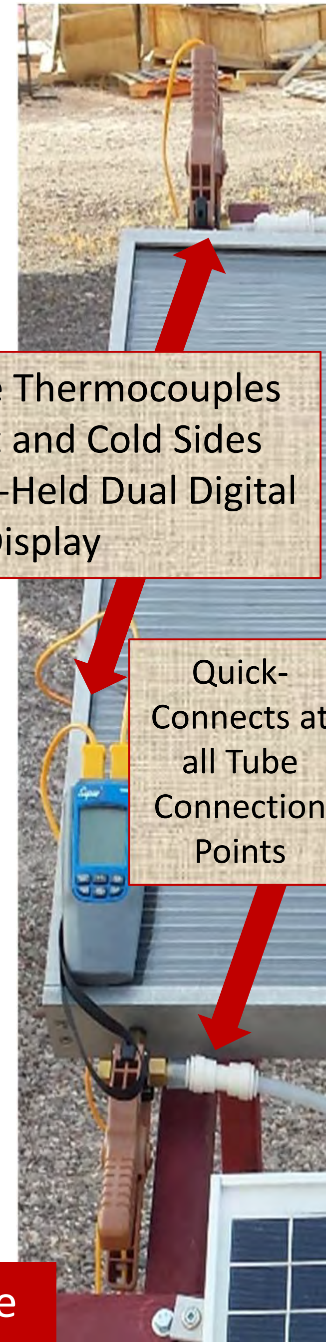


Hand-Held DC Displays

Provides Visual Changes with Varying Degrees of Panel Shading

Flashing Low-Voltage Lights and CPU Fans with LEDs

Solar Hot Water Heater Display:
Standing, Flat-Folding Stand, with Table-Top Stands Coming Soon



Clamp-Style Thermocouples on the Hot and Cold Sides With a Hand-Held Dual Digital Display

Quick-Connects at all Tube Connection Points

Howard R. Hughes College of Engineering

UNLV

Additional Kits, Including DC/AC Kits, are on the Way!