UCR | College of Engineering- Center for Environmental Research & Technology

2013 UC Solar Research Symposium

Solar Energy at UCR Riverside: From Materials and Devices to the Grid of the Future

May 2, 2013

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University of California, Riverside

Southern California Research Initiative for Solar Energy (SC-RISE)

www.scrise.ucr.edu

College of Engineering Center for Environmental Research and Technology (CE-CERT)

www.cert.ucr.edu

UC Riverside CE-CERT:

College of Engineering-
Center for Environmental Research and Technology

- **collaborative research center focused on *air quality*, *transportation*, and *energy***
- **brings together *academia*, *industry*, and *government* to develop and assess new technologies**
- **interdisciplinary center of approximately 45 full-time faculty and staff plus 60 graduate and undergraduate students**
- **contracts and grant activity at approximately $10M per year**

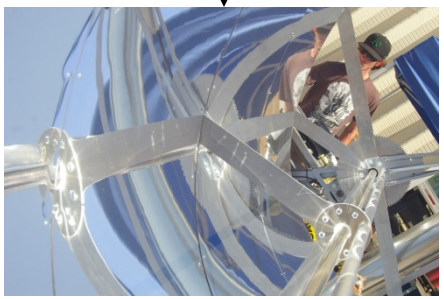
CE-CERT Laboratories

Atmospheric Processes

Emissions and Fuels

Sustainable Energy Systems

Intelligent Transportation Systems



Solar Energy

Energy and Power Systems

Cutting-Edge Fundamental Research

• Solar Thermal Material Research

Improving thermal storage and heat transfer by using the latent heat of eutectic materials used in CSP systems

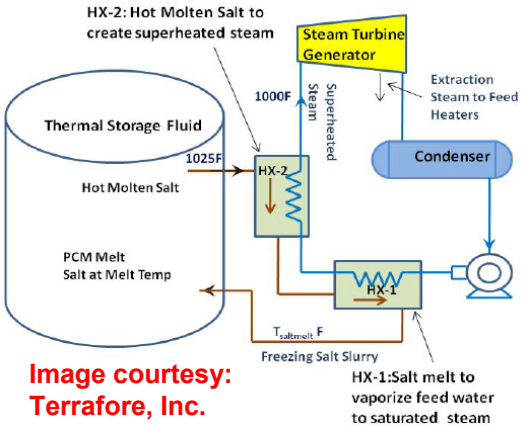
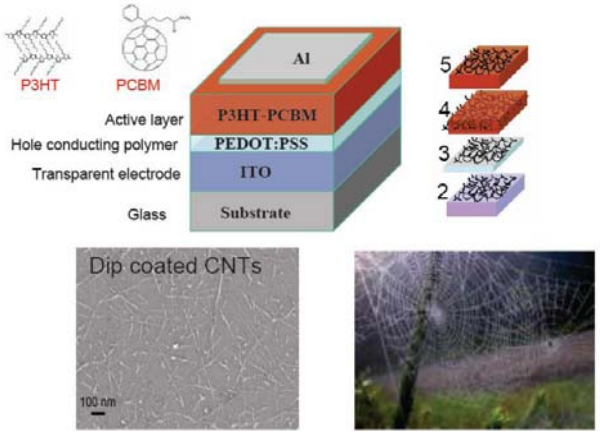


Image courtesy: Terrafore, Inc.

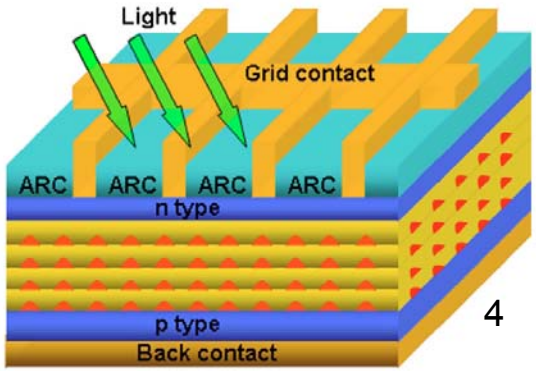


• Organic PV Materials and Devices

Enhancing efficiency and stability of polymer-based solar cells by the incorporation of novel nanostructures

• High Performance Multilayer PVs

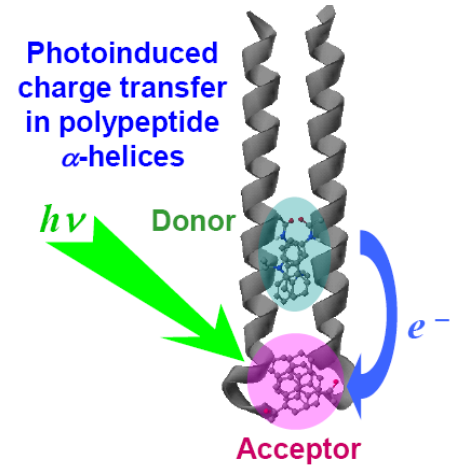
Increasing overall efficiency by tuning the effective band-gap in the cell structure and using tandem designs

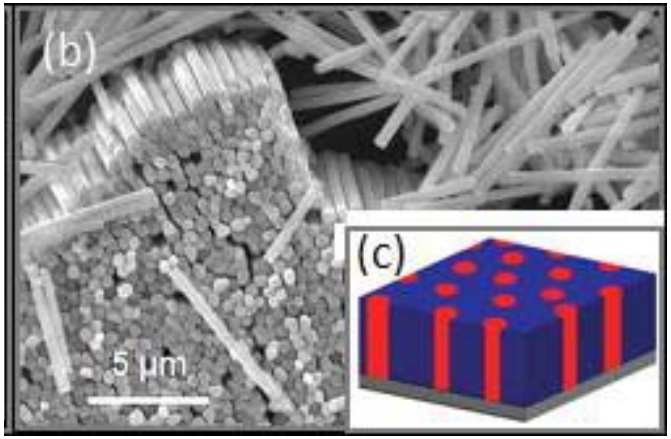


Cutting-Edge Fundamental Research

- **Biomimetic and Bioinspired Systems**

Developing photoredox materials for solar-energy conversion applications by studying charge separation and recombination



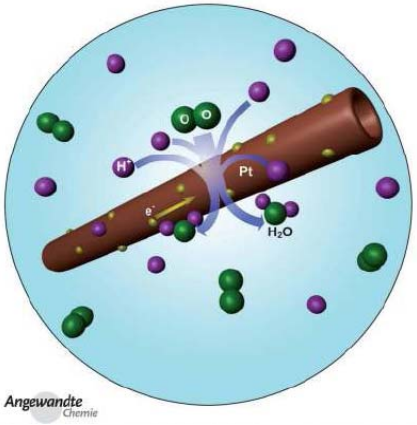


- **Nanowires for Multi-Junction PVs**

Enhancing solar energy conversion by large-area solar cells based on NW arrays embedded in a polymer matrix

- **Hydrogen as a Solar Fuel**

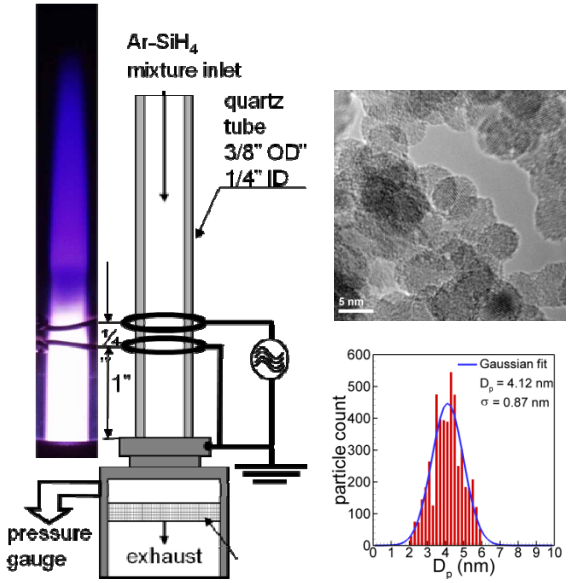
Production by electrolysis, used as energy storage and converted back to electricity by low-cost fuel cells

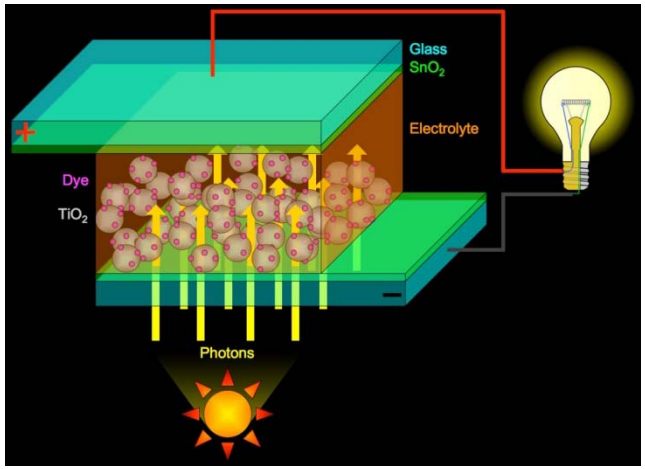


Cutting-Edge Fundamental Research

• Plasma Synthesis of Si Quantum Dots

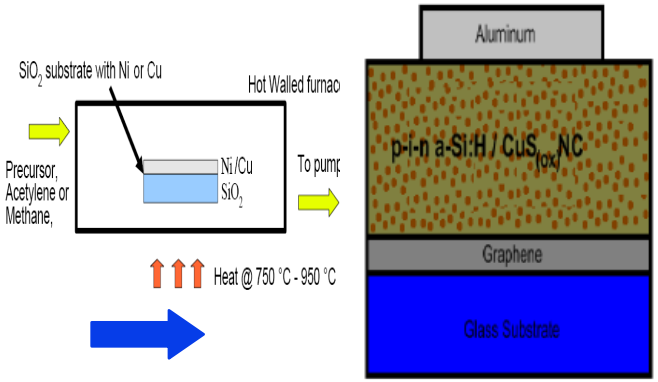
Multiple gas-phase (non-thermal) plasmas can are used in series to nucleate, grow and functionalize the surface of the NCs with the final goal of realizing a semiconductor 'ink'





• Structure-Directing Organic Scaffolds

Harnessing the Molecular Mechanisms of Biomineralization for the Synthesis of Nanostructured Materials for PV Applications



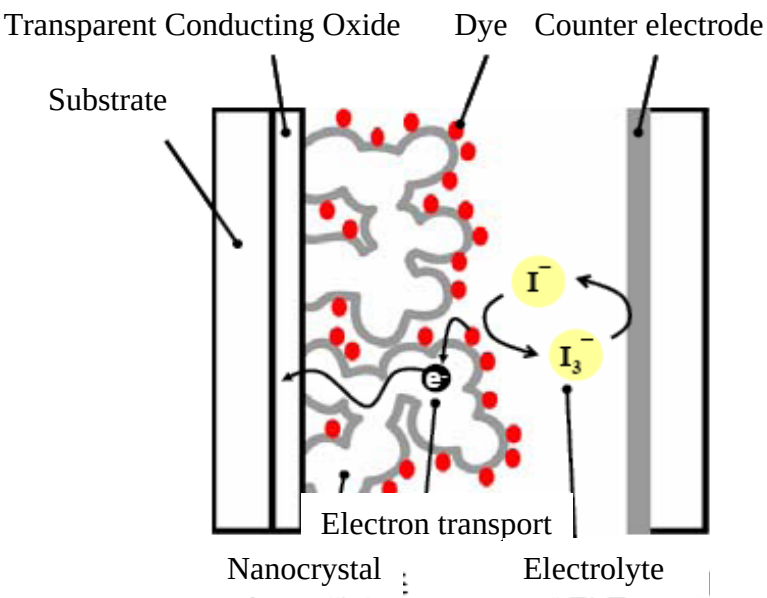
• Graphene as an Electrode

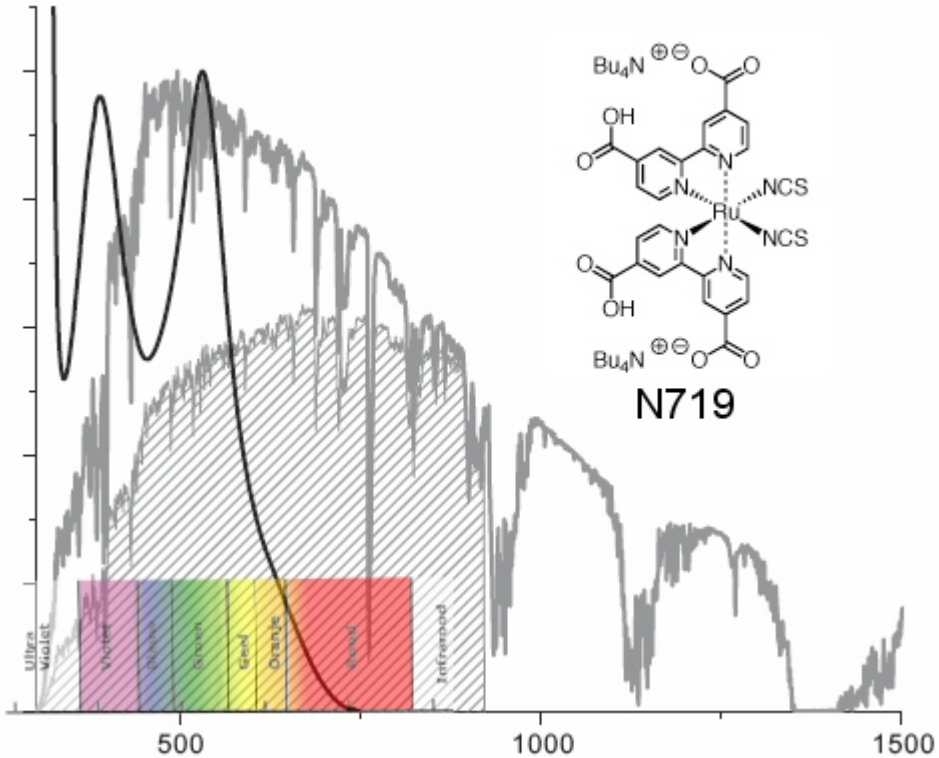
Large scale CVD growth of few layers of graphene for organic-based Photovoltaics

Dye Sensitized Solar Cells

Basic concept

- Dye-sensitized solar cells



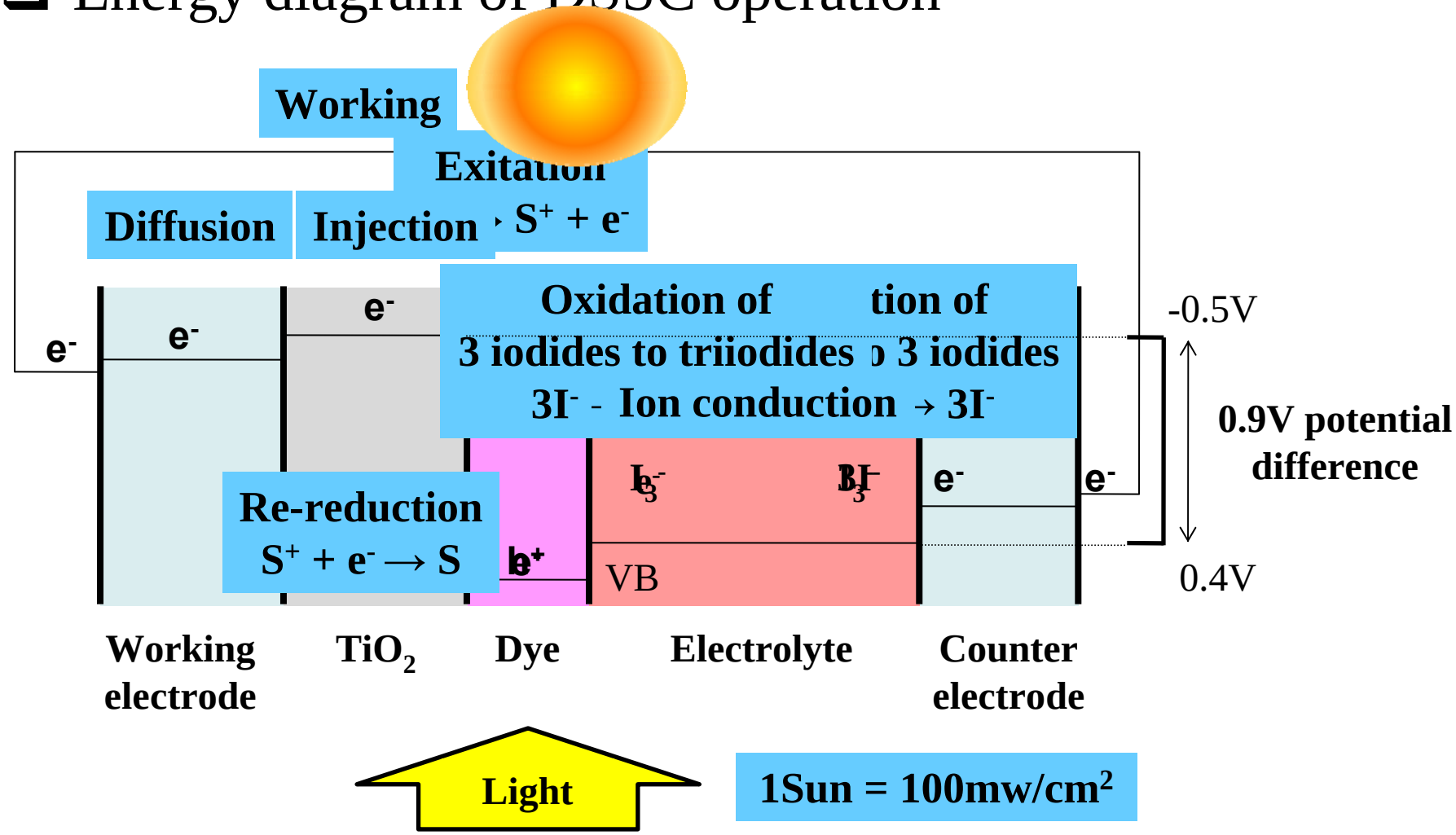


http://www.kennislink.nl/publicaties/nieuwe-kleurstof-biedt-perspectief-op-betere-gratzel-zonnecellen

- Photoelectrode
- Dye
- Electrolyte
- Counter electrode
- Transparent electrode

Principles

- Energy diagram of DSSC operation

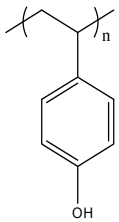


To improve DSSCs

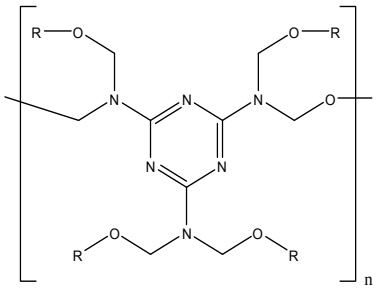
- Photoelectrode
  - Novel metal-oxide nanocrystal with suitable energy level
- Dye
  - Panchromatic dyes for high efficiency
  - Organic dyes for low cost
- Electrolyte
  - Liquid state electrolytes for high efficiency
  - Solid state electrolytes for long-term stability
- Platinum layer
  - Novel reduction catalyst(ex : CNT, carbon black) for low cost
- Module
  - Tandem structure for high efficiency
  - Arrays for large area device

Research objective

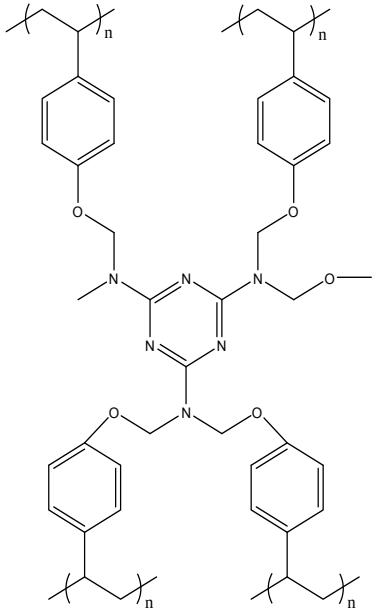
- To make chemically cross-linked polymer gel electrolyte
- To make long-term stable DSSC with high efficiency by using the gel electrolyte



Poly(4-vinylphenol) (PVP)



Poly(melamine-co-formaldehyde) methylated (CLA)



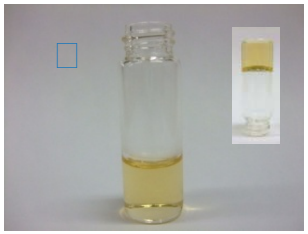
Crosslinked PVP (C-PVP)

Chemical structure of PVP, cross-linking agent(CLA) and cross-linked PVP(C-PVP)

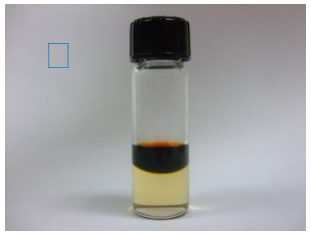
Procedure

- Fabrication process of c-PVP gel electrolyte

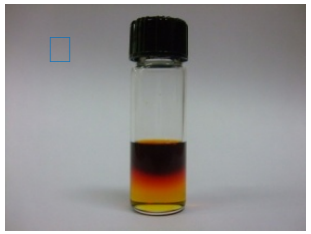
PVP + CL in PC solution



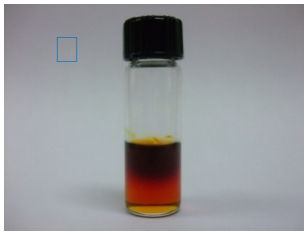
Thermally cross-linking



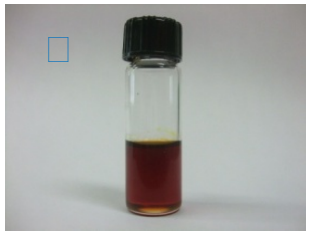
Ions added



1 day after



3 days after

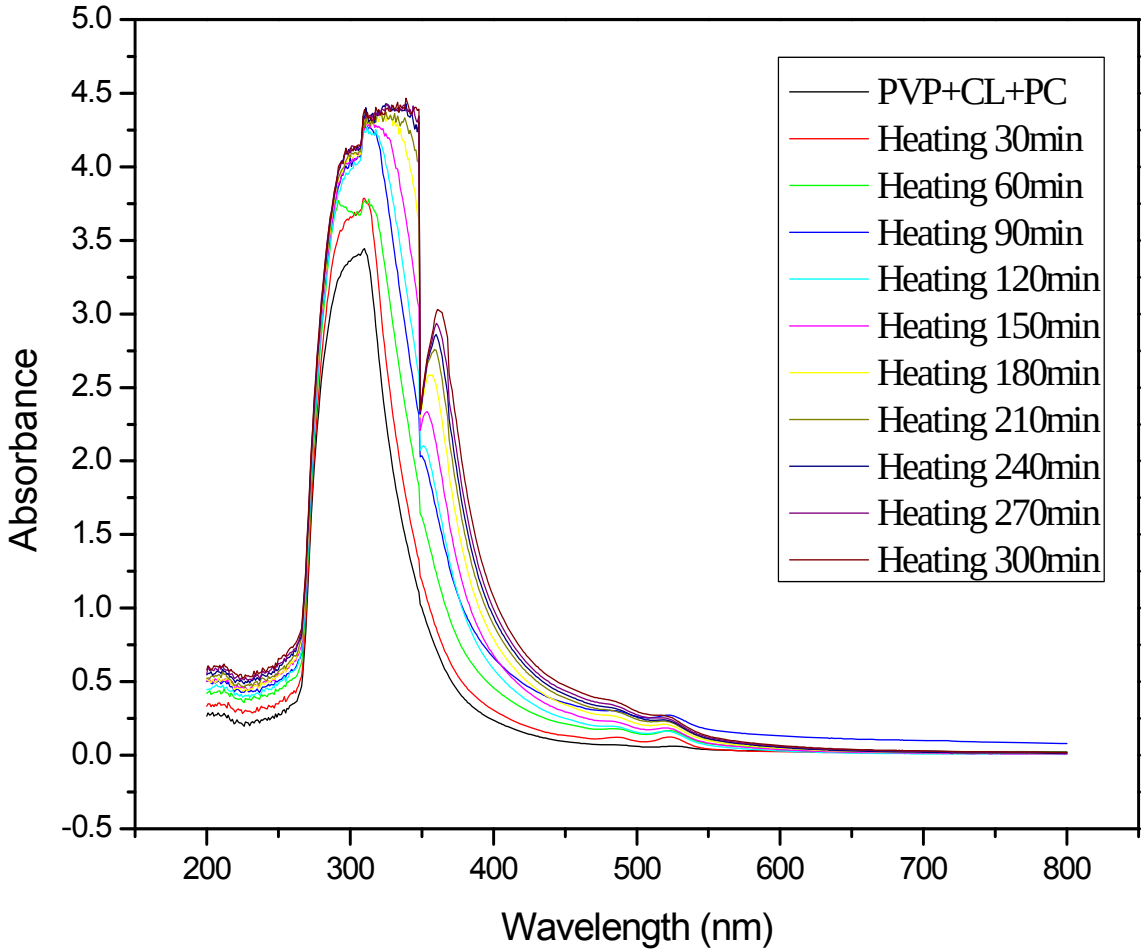


5 days after

Ion	LiI	I_2	t-BP	GuNCS	MPII
Molar concentration (M)	0.2067	0.1250	2.0831	0.4129	Used as solvent

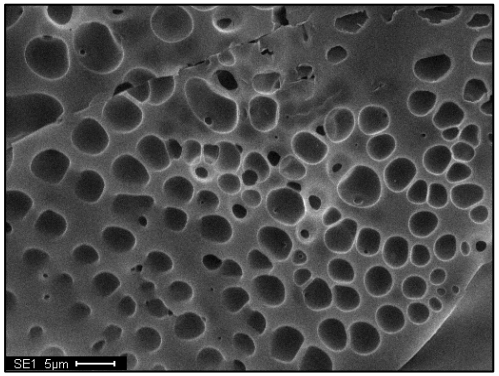
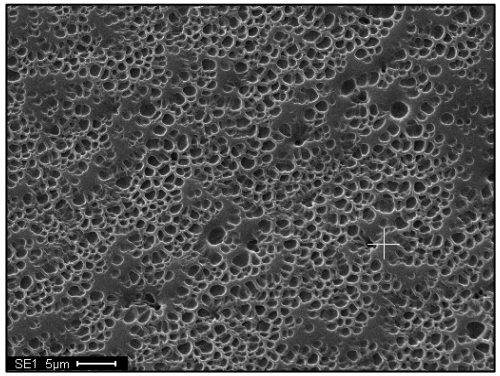
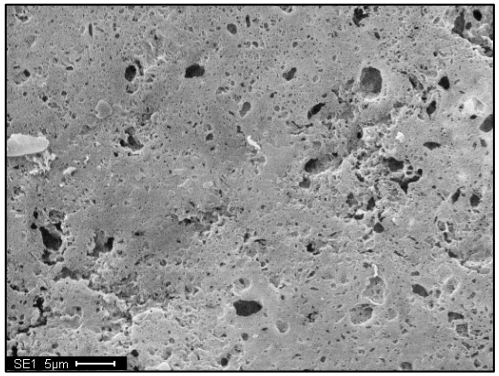
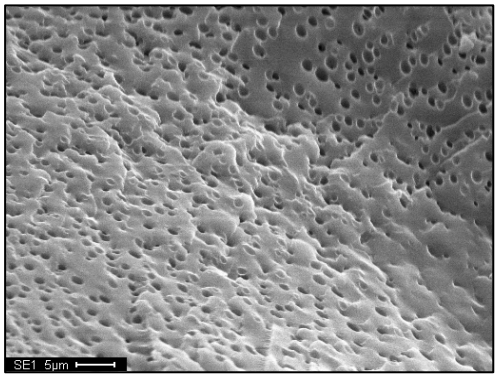
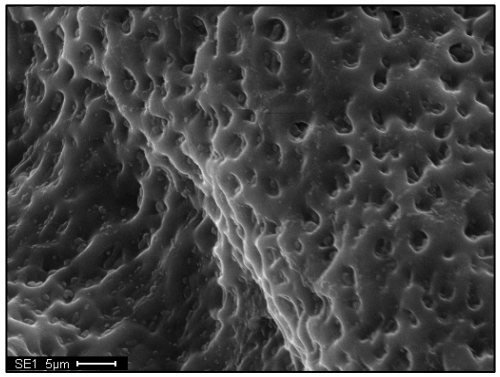
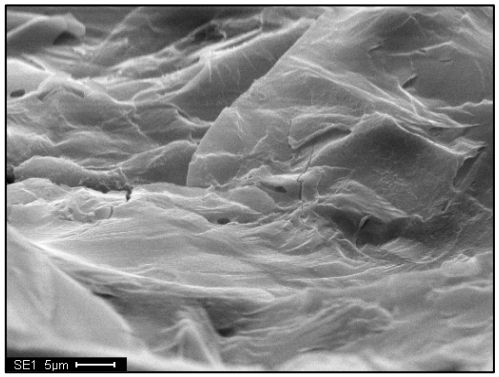
Results

- UV-vis spectra



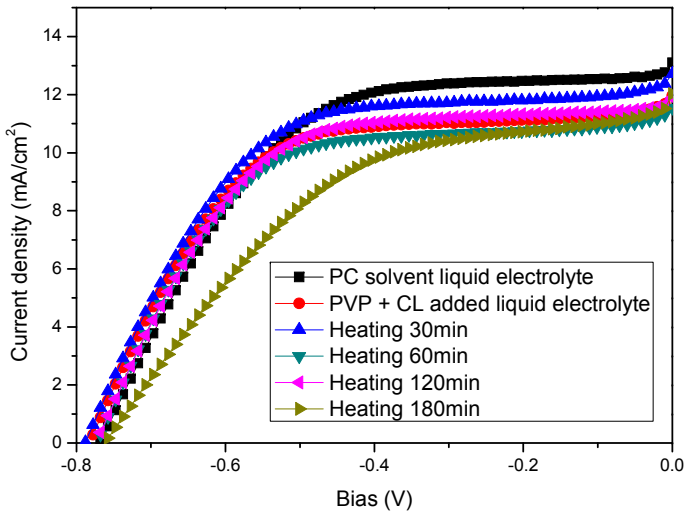
Results

- SEM image (x2000, heating for 2 hours)

	130□	140□	150□
Surface			
Cross-section			

Results

- I-V curve with different heating time

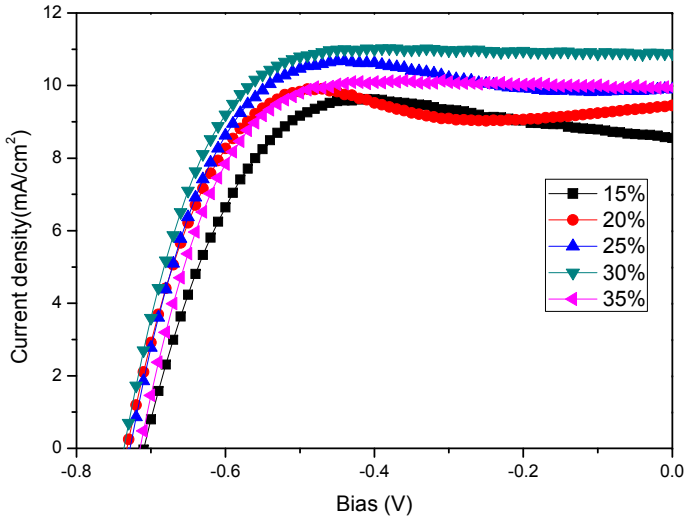


100mW/cm^2

Electrolyte	J_{sc}(mA)	V_{oc}(mV)	F.F.(%)	Efficiency(%)
PC solvent liquid electrolyte	13.1	767.7	54.4	5.5
PVP+CL added electrolyte	12.0	777.8	57.7	5.4
Heating 30 min	12.7	787.9	56.4	5.6
Heating 60 min	11.5	767.7	58.6	5.2
Heating 120 min	11.9	777.8	57.6	5.3
Heating 180 min	12.0	757.6	45.3	4.1

Results

- I-V curve with different ion concentration



Concentration	J_{sc}(mA)	V_{oc}(mV)	F.F.(%)	Efficiency(%)
15%	7.70	715	75.2	4.14
20%	9.24	715	72.7	4.80
25%	9.76	724	72.2	5.10
30%	10.25	730	71.2	5.33
35%	9.29	714	71.8	4.76

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Winston Chung Global Energy Center

PV, Wind, Battery and Electrical Distribution Issues

UC Solar Research Symposium

May 2, 2013

Dr. Sadrul Ula
University of California, Riverside
Bourns College of Engineering
Center for Environmental Research and Technology

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Winston Chung Global Energy Center

- $10 million gift established:
  - Winston Chung Global Energy Center
  - Winston Chung Endowed Professorship in Energy Innovation
  - Winston Chung Endowed Professorship in Sustainability

Dean of Engineering Reza Abbaschian (left) with Winston Chung at Winston Chung Hall at UC Riverside

- $3.3 million gift funded:
  - Six faculty research projects in energy storage
  - 1.1-megawatt battery storage project for Winston Chung Hall
    - 330 1,000-amp-hour rare-earth yttrium-iron-sulfate batteries
    - Can be charged during less costly off-peak hours
    - Delivers power to building during peak hours

Vision

The charter of Winston Chung Global Energy Center is to advance solutions for today's energy storage demands, while developing far-sighted energy storage, generation, and distribution research and energy-use strategies for tomorrow's applications. This center will take a holistic approach **to bridge the gap between industry and academia** to address ***energy generation, storage, and distribution*** needs and issues, broadly ranging from technical issues, economic development, and ecological wellness.

The Center will:

- Foster a premier academic environment of research and discovery in sustainable energy, with an initial focus on materials, storage and distribution issues
- Educate a diverse and distinguished engineering workforce that is dedicated to addressing global energy needs
- Offer tools and training that will increase the capacity of public and private planners, architects, engineers, utilities and developers to design and build energy-efficient community projects
- Reach out to global organizations and businesses as a partner in fostering clean energy storage solutions
- Inspire leadership and community action to address energy issues in California and the world.

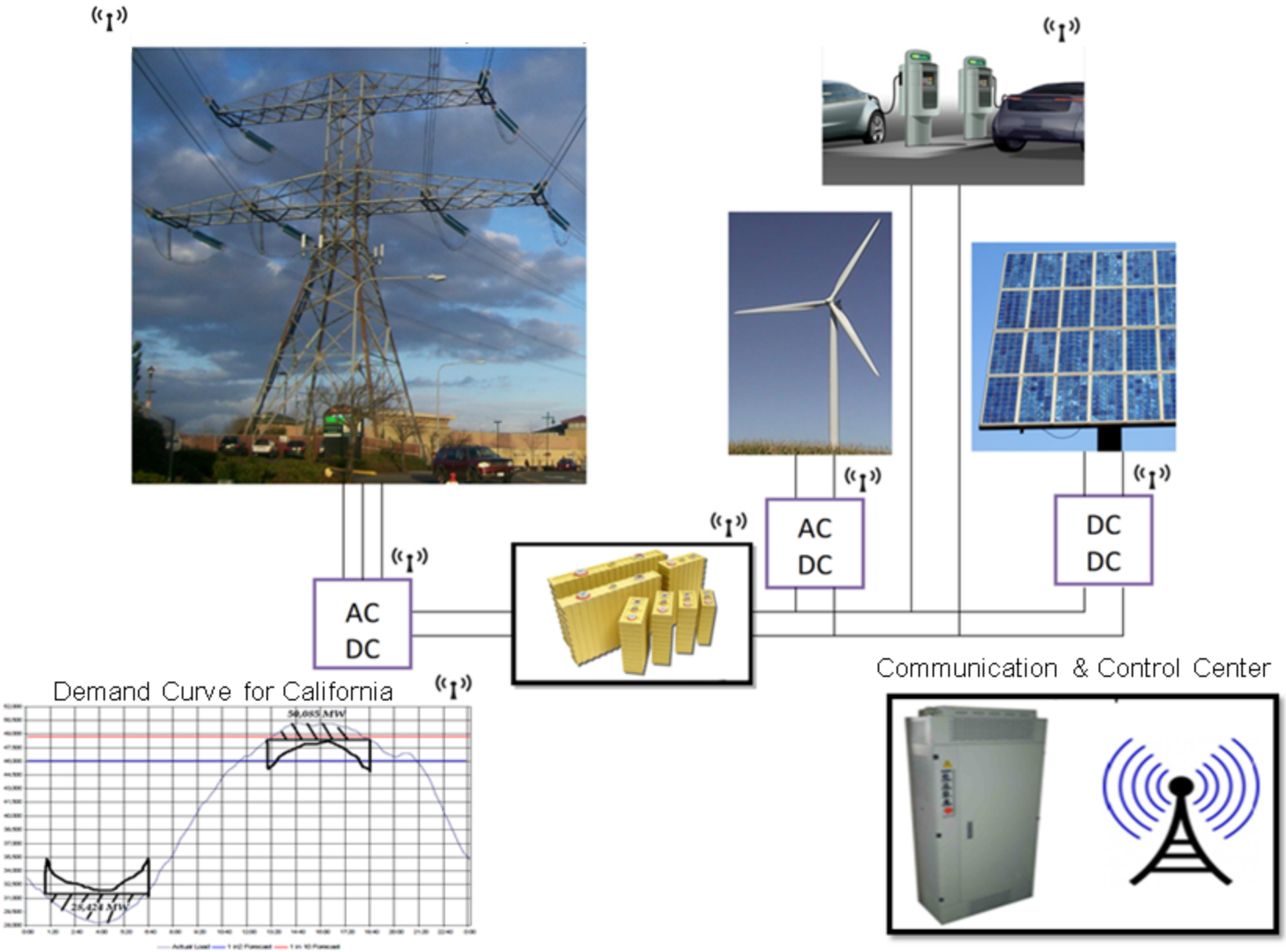
Future Trends/Important Drivers

1. More renewable energy integrated into the system, California requirement 33% by 2020 (20% by 2013, 25% by 2016)
   - But solar and wind energy intermittent
   - Electrical storage needed for dispatch
   - Lithium-ion batteries are promising with deep discharge, repeated cycling & long life
2. Zero emission vehicles – all electric car, bus, truck, etc. – million vehicle infrastructure in CA by 2020; state fleet 10% by 2015, 25% by 2020
   - Causing more demand on the power grid
3. Zero net energy – all new buildings – residential by 2020, commercial by 2030

Future Trends/Important Drivers …….

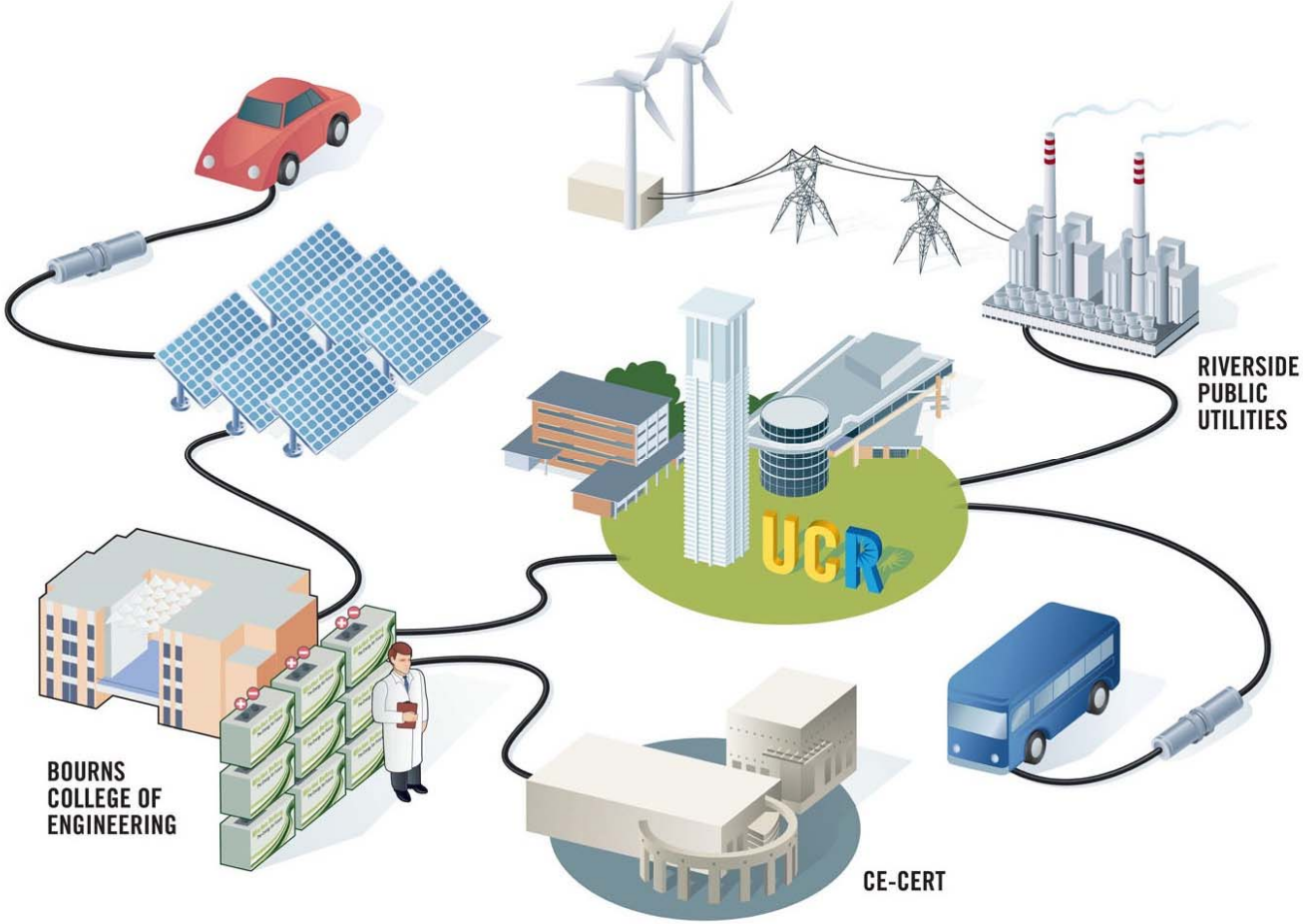
4. Adverse impact on power distribution lines
   - Uncontrolled intermittent power
   - Arbitrary EV charging
5. Lack of new transmission and distribution lines
   - Due to lack of right of way
   - Permitting hurdles

EV Charging Station with Battery Energy Storage: PV, Wind, and Smart Grid

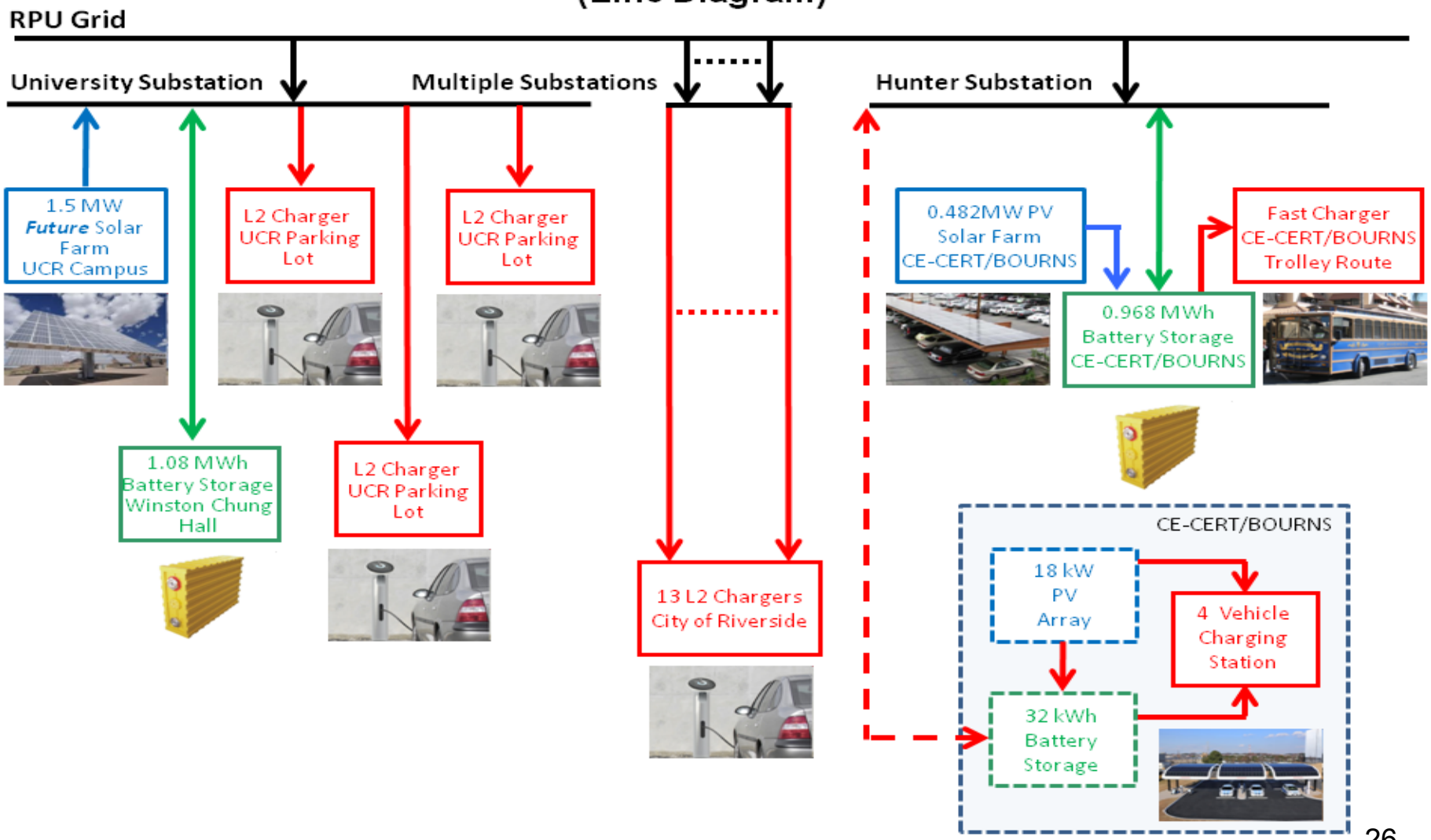


UCR New Grid

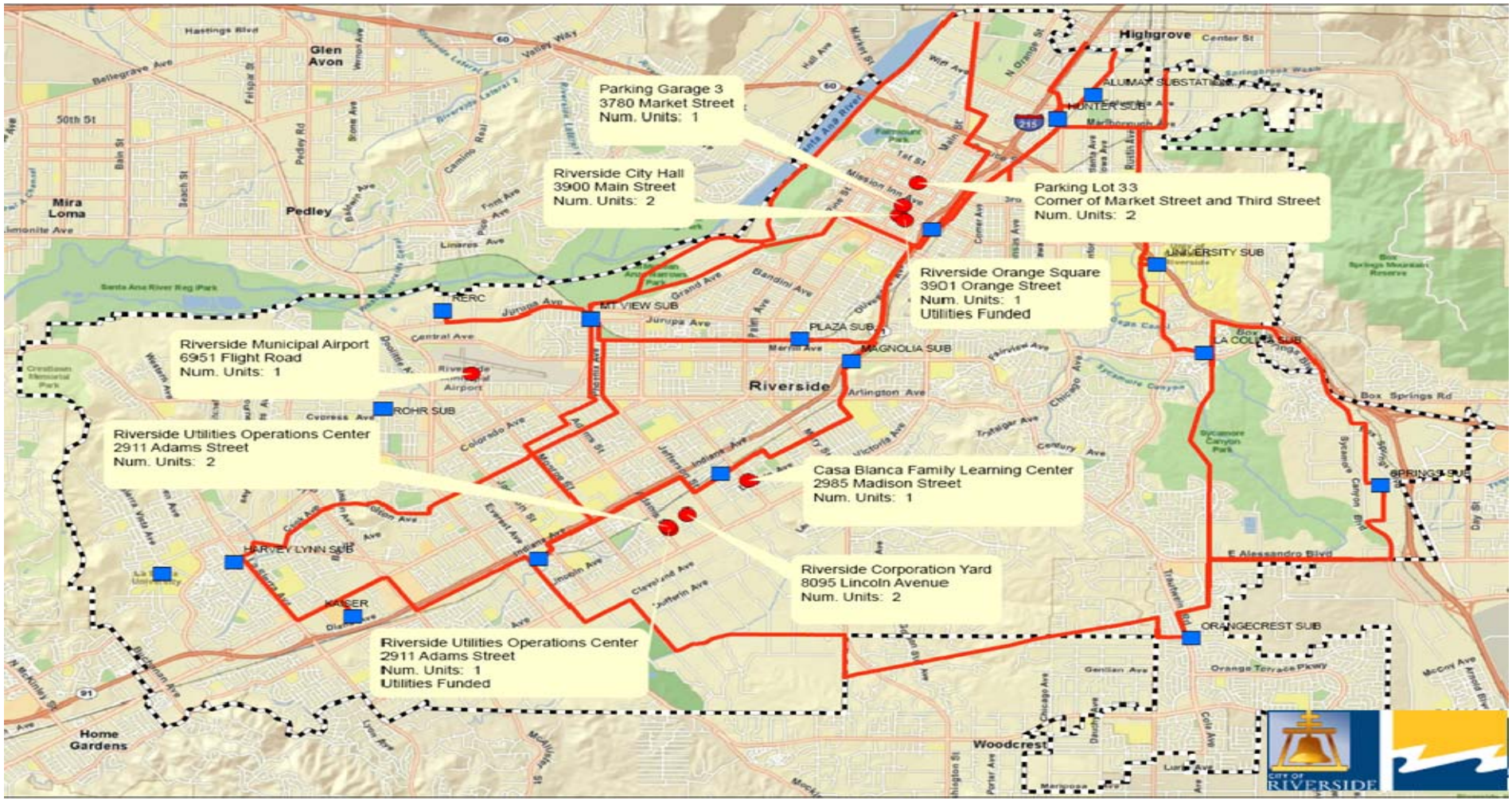
- **Integration of Renewable Energy Generation, Energy Storage, and EV Charging funded by SCAQMD**
- **Smart Grid Testbed**



Citywide Grid Connected Smartgrid Testbed System (Line Diagram)



City and Utility Level 2 EV Chargers



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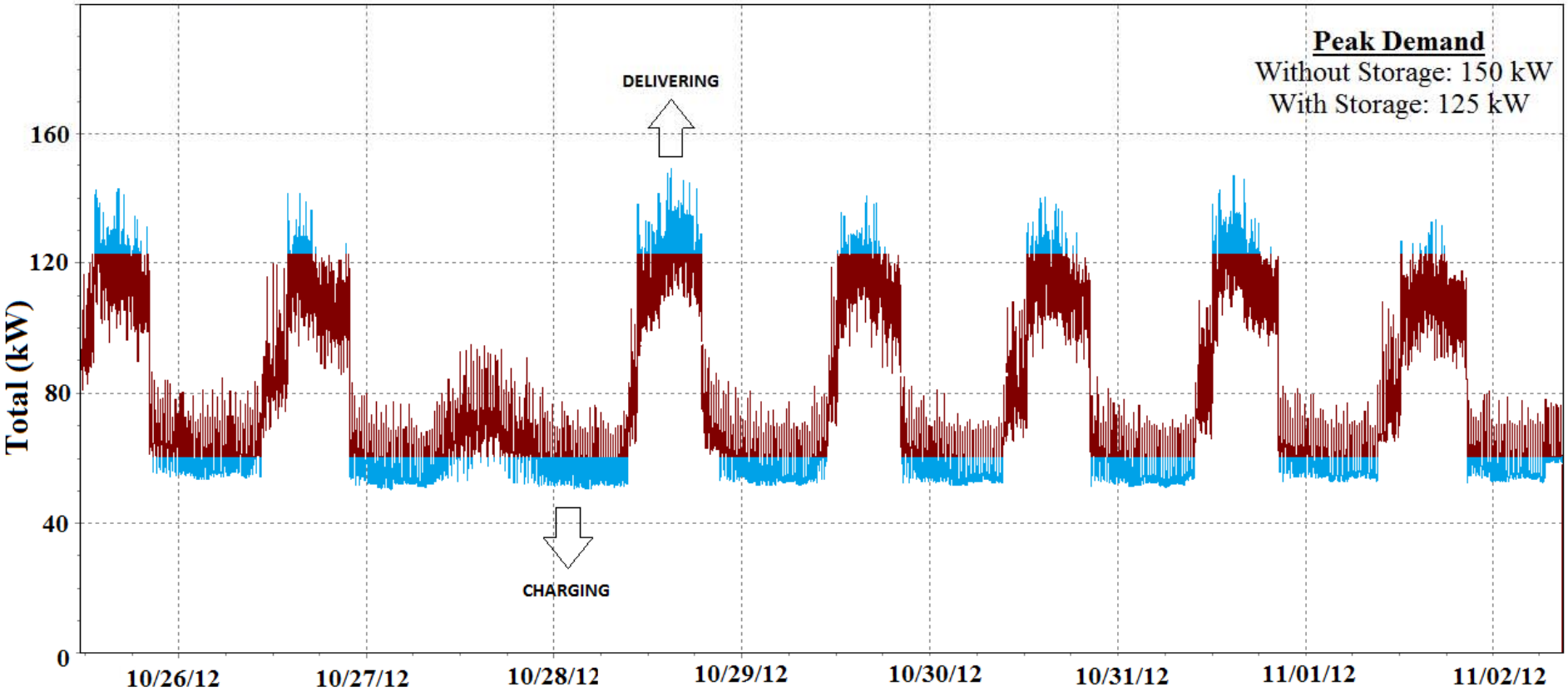
Smart Building With Battery Energy Storage

- Store energy at off-peak - plentiful and cost effective electricity
- Deliver energy at peak demand - higher priced electricity and help solve power line capacity limit

APL Building



http://www.wcgec.ucr.edu/

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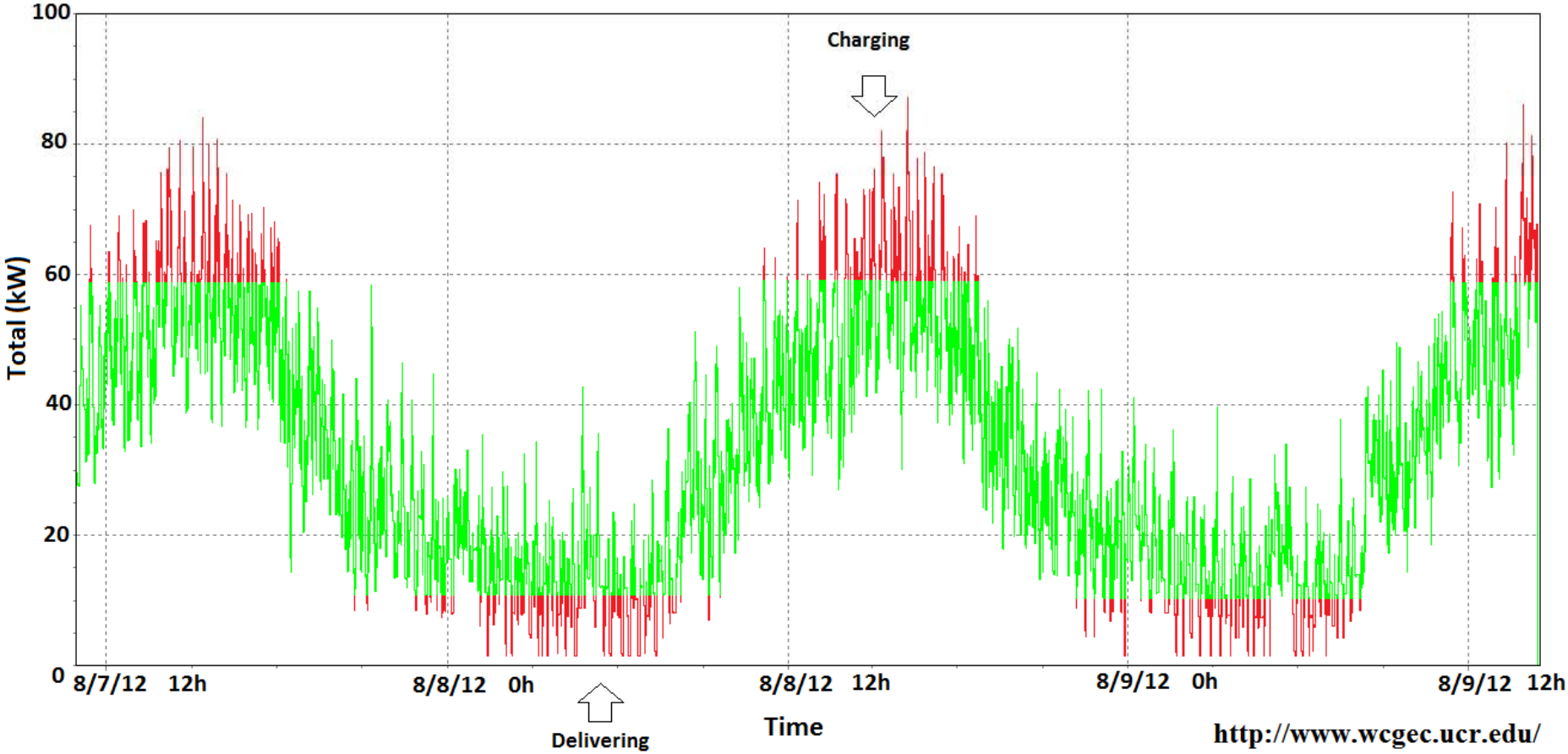
Wind Power Generation with Battery Energy Storage

- Store energy at peak production
- Deliver Energy at lowest production



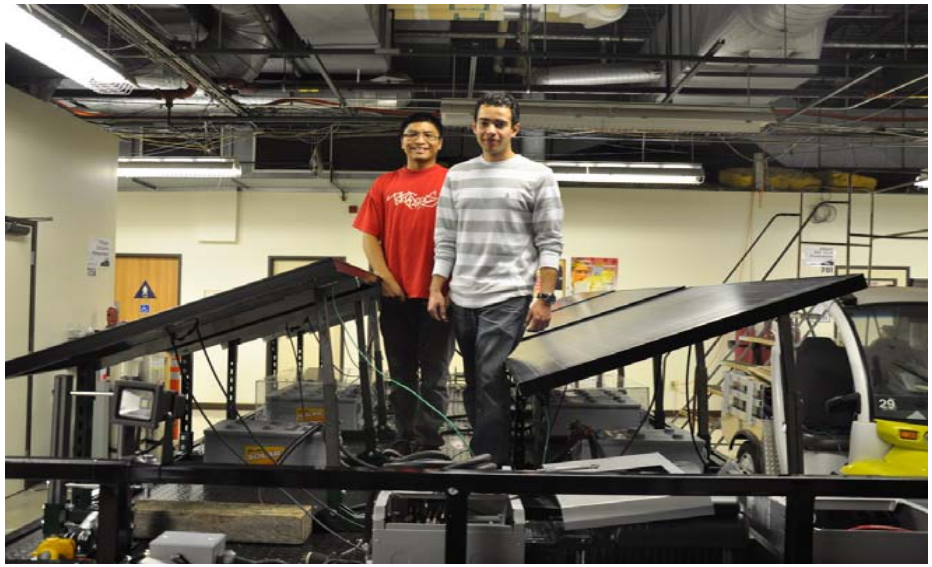
http://www.wcgec.ucr.edu/

Research Areas - current

Identified Target Research Areas	Specific Area & Tools needed
Battery materials research	Material science – coin cell development • WCGEC lab in MSE building • Six Winston funded projects
Large battery demonstration	1.1 MWh in WCH - Durability, cycling & reliability testing; sensors and instruments suitable for high V & I
500 kW Solar PV intermittent power converted to valuable dispatch able power	Coupled to 1.1 MWh battery system at CE-CERT; monitoring and control instruments and power electronics components, battery management system
Electric vehicle charging from clean energy source	Level 2 and level 3 fast chargers at CE-CERT; Appropriate software and sensors for communication and control
Supervisory control and smart grid	Adapt commercial software and use student developed protocols
Power distribution system study	Solar PV power production characterization and quantification; battery charging and delivery for system peak load reduction; performance and energy quantification for the test bed with PV, battery and EV

Students Build Mobile Solar Power System

- UCR student funded as the 1st project of Green Campus Action Plan (GCAP)
- Designed and built by engineering students: 6 kW capacity initially
- For use in campus events, e.g., concerts which use mobile diesel generators
- Eliminates emissions from small engines
- Future development of a version to reduce emissions by using smaller engines and batteries to supply varying mobile load instead of a large part loaded mobile engine running continuously




Battery
Monitoring
System Lab
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