An "update" on The Conn Center

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Board, Center for Renewable Energy and Environmental Stewardship
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OUTLINE

- Motivation for renewable energy research
- Facility infrastructure & renovation
- Center organization & goals
- Research progress
- Going forward

Materials manufacturing Solar Smart buildings

Energy storage Biofuels Education

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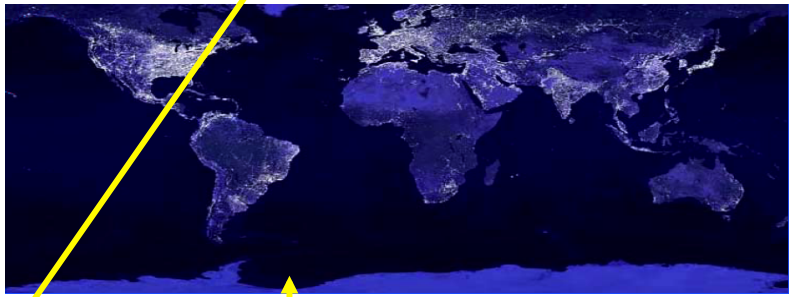
Motivation – Why renewable energy research?
Power Units: The Terawatt Challenge

Slide courtesy of Dr. Nate Lewis, CalTech



	1	10^3	10^6	10^9	10^{12}
Power	1 W	1 kW	1 MW	1 GW	1 TW

Energy
1 J =
1 W for 1 s

Global energy demand is about ~20 TW and is expected to double by 2050 and triple by end of century.

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MOTIVATION - GREEN CHALLENGE

To keep same CO_2 levels, need to produce 10 TW power by 2050 using carbon neutral sources ***(Nature, 395, 881 (1998))***

The solution – solar?

- **Earth receives about 120,000 TW/yr of energy from Sun**

- **Need less than 0.16% of globe area to produce 20 TW power using 10% efficiency Solar cells –** ***N. Lewis, CalTech (2005)***

CO_2-reduction in the energy sector

- Energy efficiency - in production, traffic, building sector
- Nuclear energy - non-renewable feedstock, final storage not clear, dangers during operation: no good solution for the global energy problem
- Clean coal technologies - requires carbon sequestration, unproven technology, energy inefficient, may pose danger of accidental release
- Wind - fluctuating production, limited number of suitable sites
- Hydro - can be switched on instantaneously, suitable for storage, good sites limited, production should be maximized
- Biofuels - interesting as liquid fuel for traffic, production energy intensive
- Solar energy (Photovoltaics, Solarthermal) - unlimited energy source
  PV: continuous price reduction through savings of scale

Courtesy of Dr. Eicke Weber of Fraunhofer Institute for Solar Energy Systems ISE

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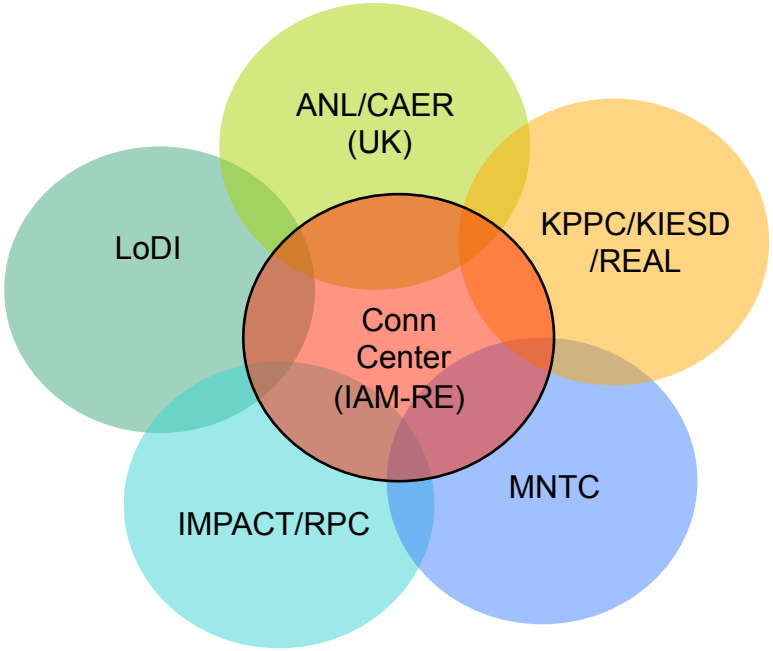


Goals for Conn Center
(Tentative)

- **Transportation Fuels/Sector**
  Electric & Hybrid Electric Vehicles
  Alternate Fuels (ANL/CAER/ Industry/
  UofL Vehicle Research effort/RPC)

- **Economic Impact**
  Translational R&D center to attract
  manufacturing sector to KY in the
  area of renewables.
  (ANL/CAER, RPC, MNTC)

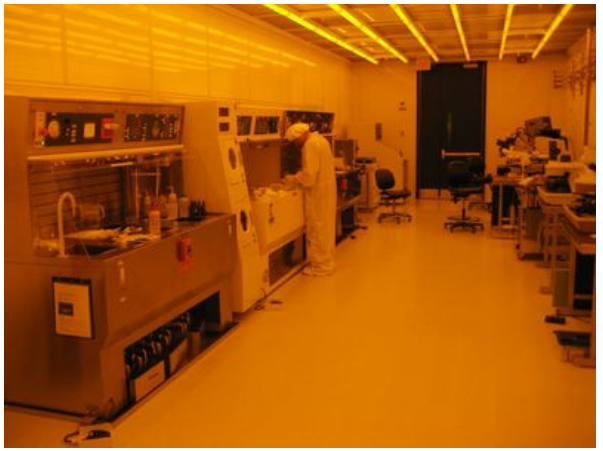
- **Smart Buildings for KY**
  Increase energy efficiency &
  use of renewable energy sources
  ((KPPC, KIESD, REAL, MNTC, LODI)

LEGEND

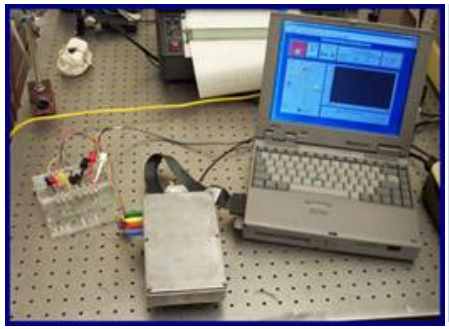
CCRERES – Conn Center for Renewable Energy Research and Env. Stewardship
IAM – Institute for Advanced Materials
KPPC – Kentucky Pollution Prevention Center
ANL – Argonne National Lab National Battery Research Center
LoDI – Logistics and Distribution Institute
RPC – Rapid Prototyping Center
MNTC – Micro/Nano Technology Center
IMPACT - Vehicle architecture research
REAL – Renewable Energy Applications Laboratory

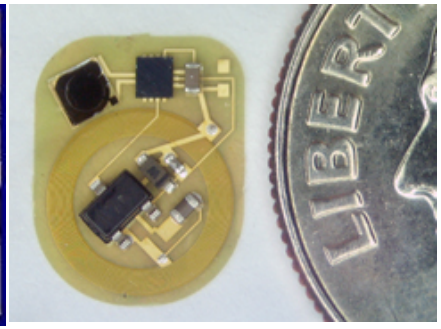
Micro/Nanotechnology Center (MNTC)

Houses 10,000 sq.ft cleanroom & associated labs for device packaging and testing.

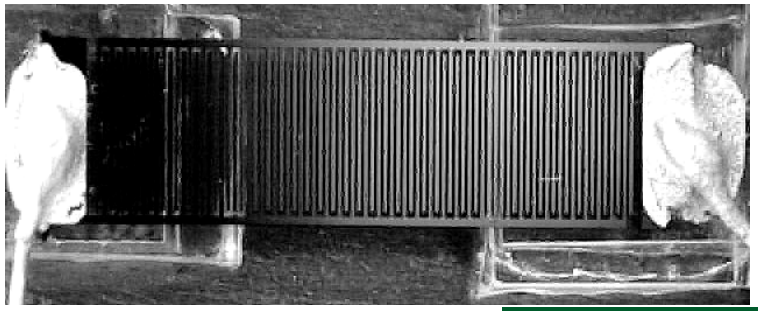


1. Energy efficiency: Novel sensors and low/no power systems for energy reduction.





2. Micro-energy and power sources



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Under renovation:
Front office space, conference room
Core staff office
Manufacturing R&D facilities (3000 sq. ft space)

ERNST
Total space approx. 5000 Sq.ft office + lab space

Test facilities for solar, battery, capacitor, fuel cell, thermionic.

Transient Spectroscopy

- Fempto-sec TAS
- Transient PL Spec.
- Photocurrent Trans. Spec.

FACILITY INFRASTRUCTURE 2005 - Present

Materials Characterization Facilities

- Electron Microscopy
- Surface Spectroscopy
- X-ray Diffraction
- Raman/PL/FTIR Spectroscopy
- Thermal Characterization
- PSD/Zeta

LUTZ
2500 Sq. ft
Three staff

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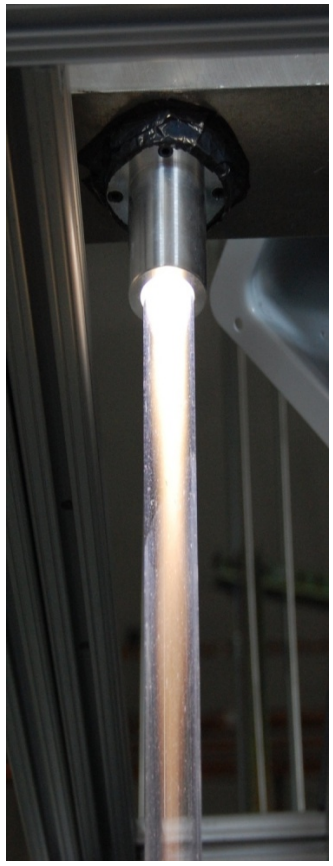
Research Progress

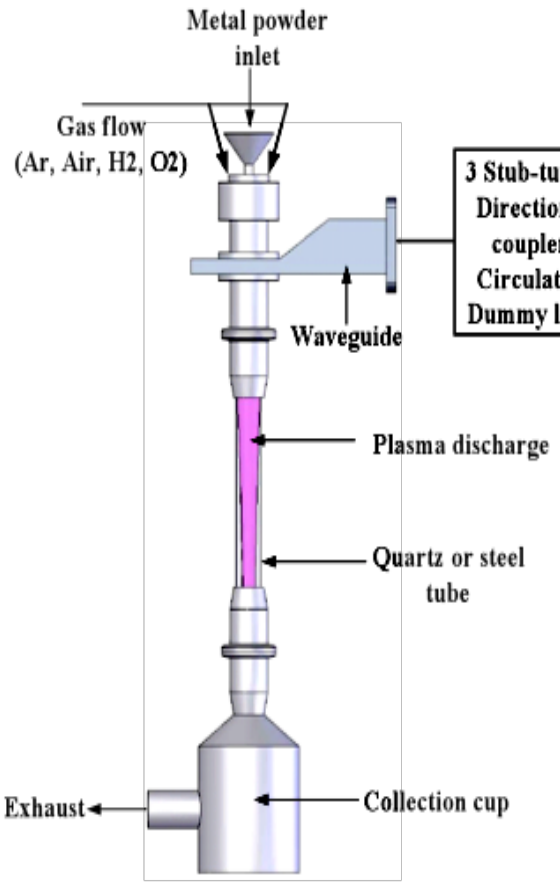
- **Infrastructure development (DOE, NSF, SMDC)**
  - Acquired materials characterization & solar test capabilities
  - Recruited Dr. Jacek Jasinksi as the characterization theme leader
  - Rodica McCoy, temporary postdocs and students support it.
  - Recruited distinguished scientist, Dr. P. Ratnasamy, to develop biofuels theme
- **Renewable energy research (DOE-EPSCoR, KREC)**
  - ***DOE-EPSCoR Cluster:*** $1M per yr, 10 faculty from UofL & UK

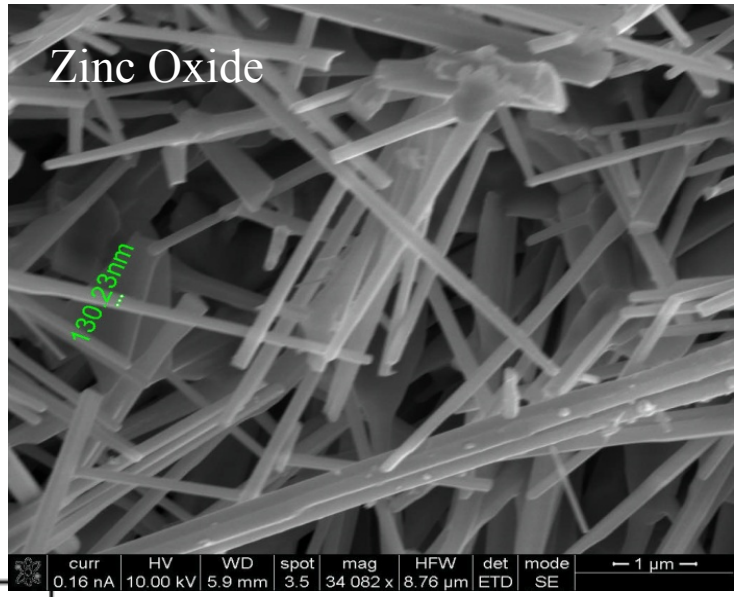
  (Solar-hydrogen; Solar-electricity; Thermionic) (2007-2010; 2010-2013)
  - ***KREC Grants***: $1.2M, 6 faculty from UofL (2007-2010)

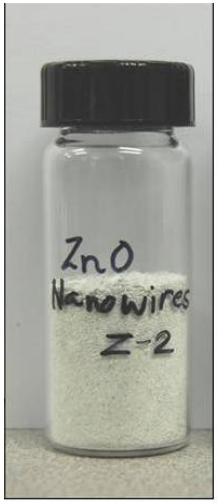
  (Solar-electricity; Passive solar; Li ion Battery; Biofuels)
  - Currently organizing group proposals to NSF' RESTOR and SEED initiatives
- **Industry-university service center**
  - Facilities were used by industry researchers -> $150K per yr
  - Sudchemie reported a successful catalyst due to the interaction.

Progress Example 1: Materials Manufacturing (Sunkara)









These materials have been demonstrated to considerably improve Li ion batteries and low-cost solar cells

(UofL Patent Pending; Kumar et al., J. Phys. Chem C., 112, 17750 (2008))

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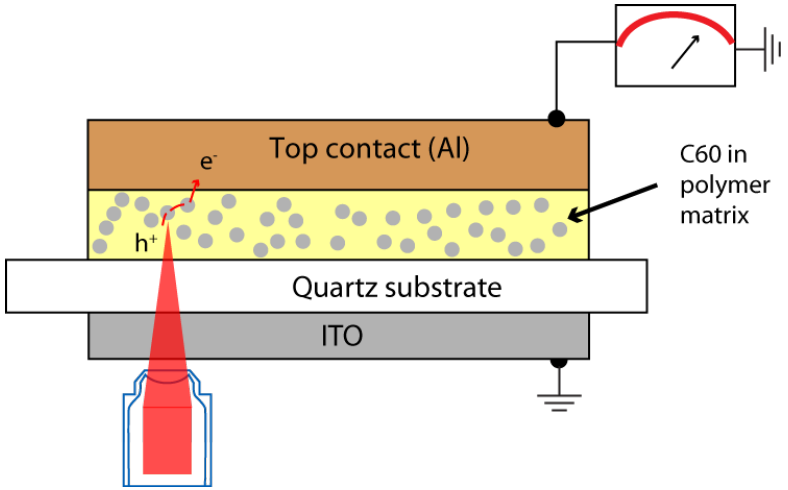
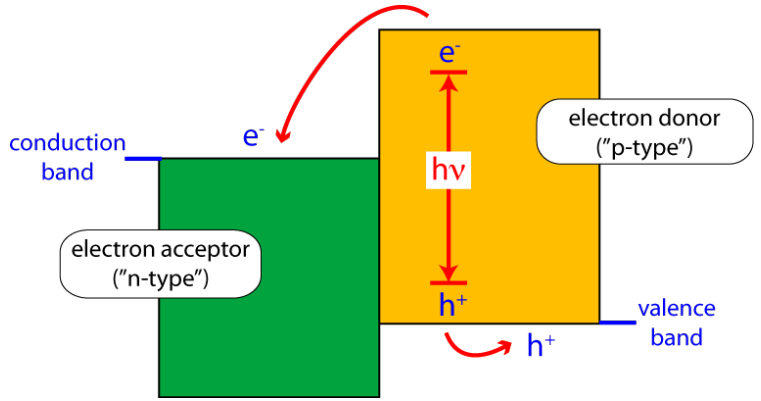
Progress Example 2: What limits efficiency of low cost solar cells? (B. Alphenaar)

In a recent article in *Nature Nanotechnology (2009)*, Alphenaar made a fundamental discovery that can be explored further for improving efficiency of low-cost solar cells such dye solar cells and organic photovoltaics





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Progress Example 3: Batch Biodiesel pilot plant (E. Berson)

- Sodexo is providing spent cooking oil from campus restaurants.
- Batch system (50 gal), fuel meets ASTM standards.
- The fuel will be used in the campus shuttle bus in ~10% blend.
- Future research is to convert glycerol in to other products

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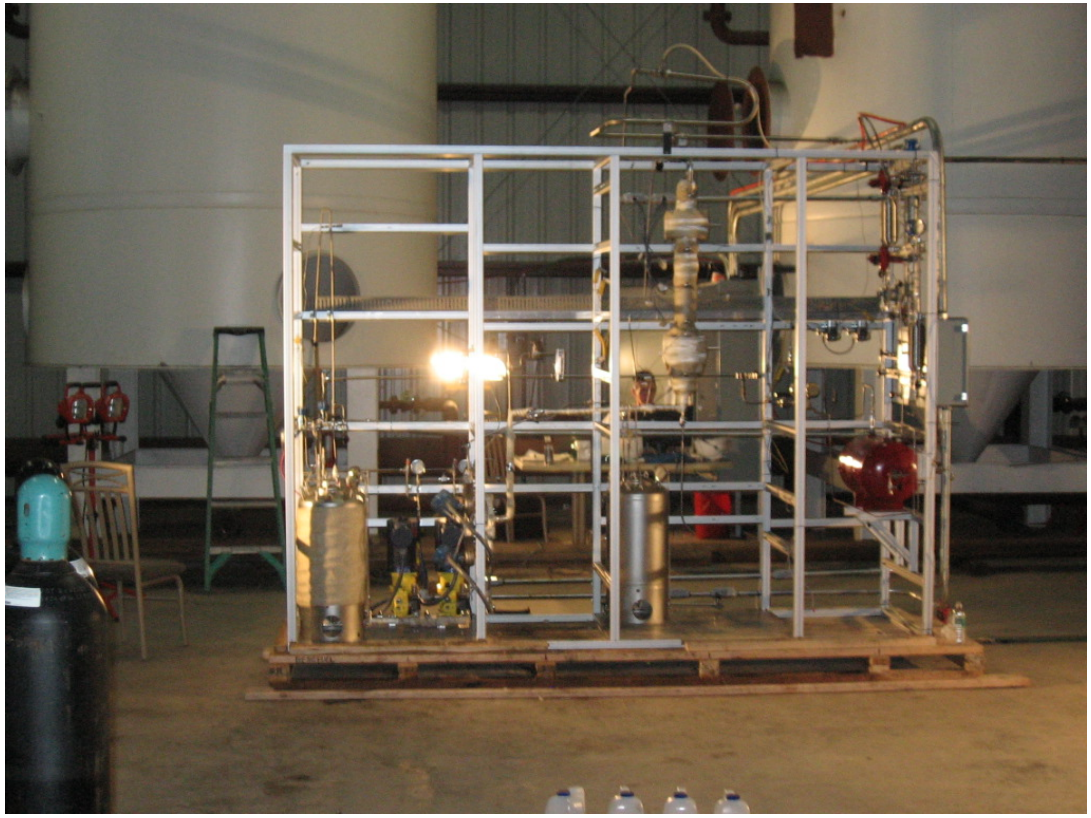
Progress Example 4: Small automated plants for distributed Biofuel production *(P. Ratnasamy)*

(Partners: Benefuel; Unitel; and Sudchemie)

- Pilot plant with 30-50 Gals/day fuel output (continuous)
- Liquid/gas feed
- Product can be gas or Liquid
- Co-op student training



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Going forward

- Materials manufacturing
- Solar
- Biofuels
- Renewable energy storage
- Smart buildings
- Education

Key strategy in each theme:

- Build/foster partnerships among all KY institutions
- Establish corporate partnerships

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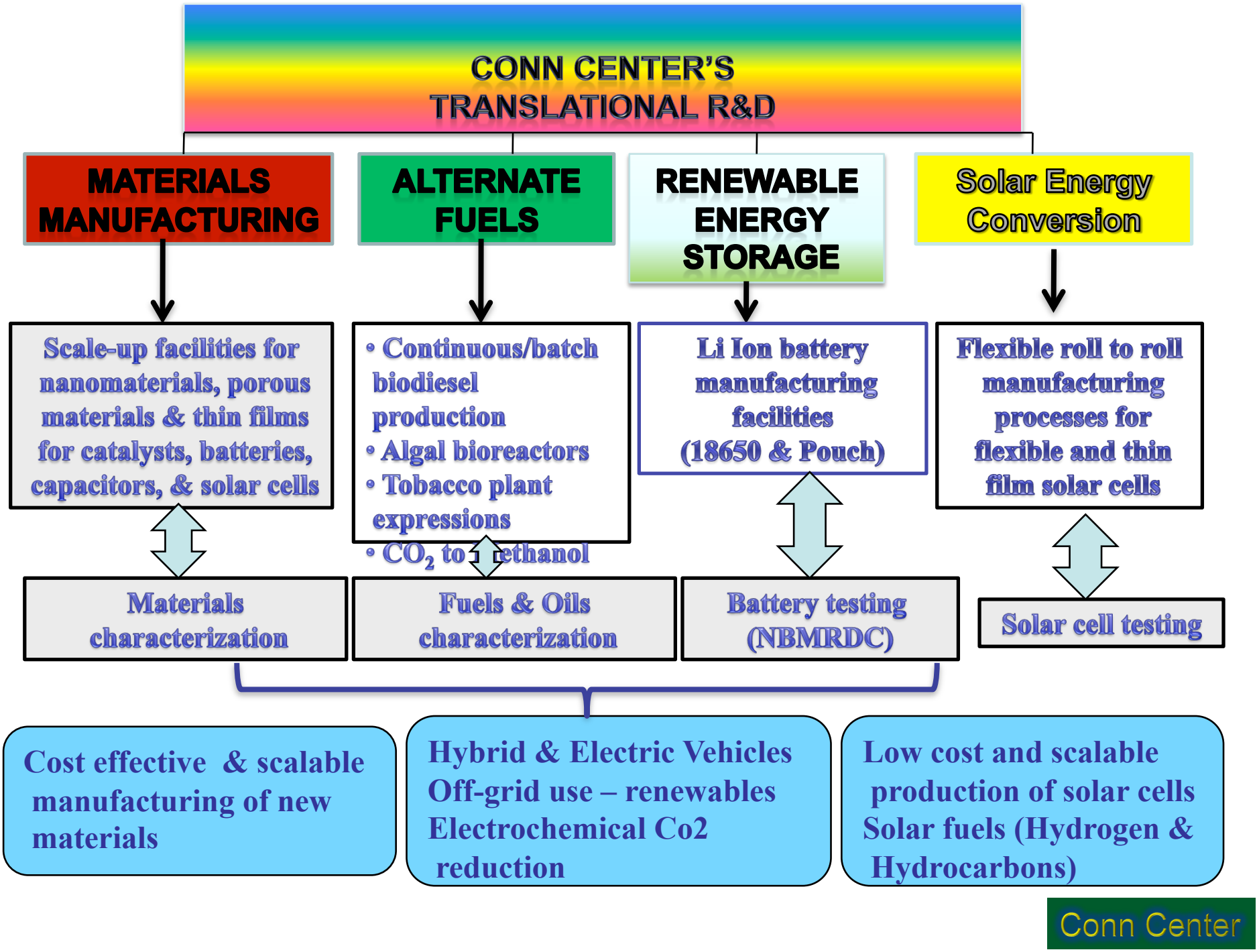
CONN CENTER'S
TRANSLATIONAL R&D
MATERIALS MANUFACTURING
ALTERNATE FUELS
RENEWABLE ENERGY STORAGE
Solar Energy Conversion
Scale-up facilities for nanomaterials, porous materials & thin films for catalysts, batteries, capacitors, & solar cells
• Continuous/batch biodiesel production
• Algal bioreactors
• Tobacco plant expressions
• CO_2 to ethanol
Li Ion battery manufacturing facilities (18650 & Pouch)
Flexible roll to roll manufacturing processes for flexible and thin film solar cells
Materials characterization
Fuels & Oils characterization
Battery testing (NBMRDC)
Solar cell testing
Cost effective & scalable manufacturing of new materials
Hybrid & Electric Vehicles
Off-grid use – renewables
Electrochemical Co2 reduction
Low cost and scalable production of solar cells
Solar fuels (Hydrogen & Hydrocarbons)
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Materials Manufacturing

Scale-up of manufacturing new materials to quantities suitable for full scale testing of renewable energy conversion and storage devices

Example:

Develop new cost-effective, scalable processes for certain new materials (eg. metallic SWNTs)

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"Preferential growth of single-walled carbon nanotubes with metallic conductivity", **G. U. Sumanasekera et al**, **SCIENCE, 326**, p116-120 **(**2009)

- Fundamentally a transformative discovery on synthesis method for single walled, metallic carbon nanotubes.
- Need to scale up manufacturing to kilogram scale
- Need to demonstrate its use as low cost, transparent & conducting substrates for solar cells.

SOLAR ENERGY

Low cost & scalable solar cell technology:

- Low cost, transparent conducting substrates
- Low cost, efficient & stable thin film absorbers

Flexible, roll to roll manufacturing R&D:

- Thin composite films for conducting substrates
- Thick film technology for solar absorbers
- Rapid testing of potentially transformative material and device concepts in a manufacturing environment

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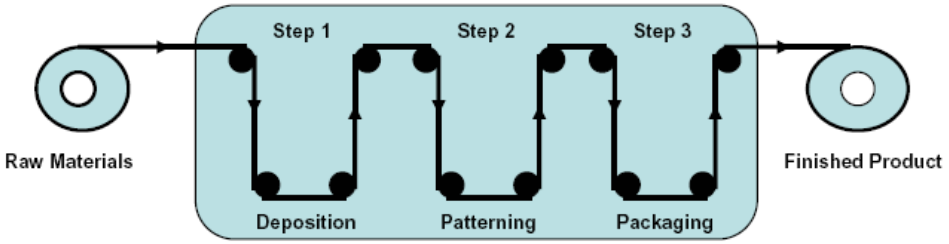
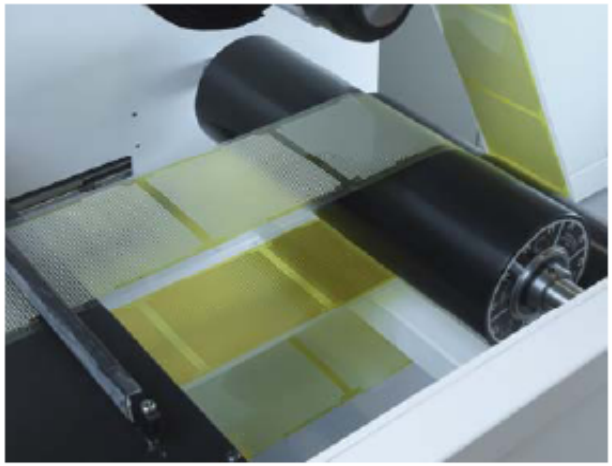
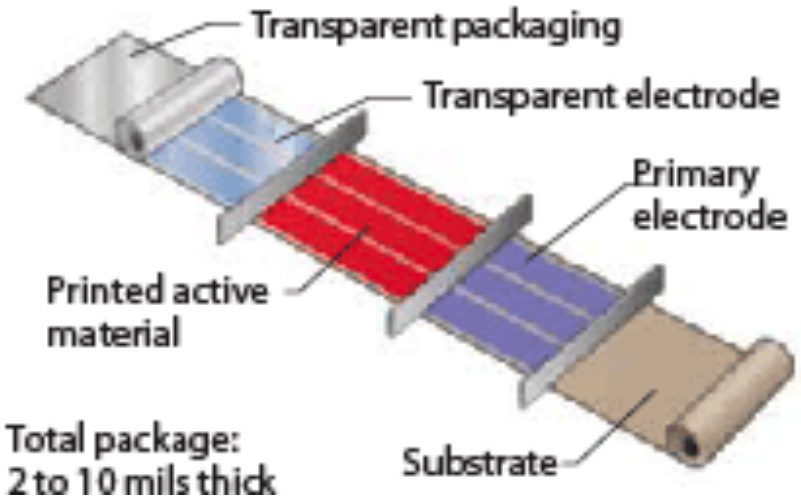
Roll to Roll Manufacturing: Low-cost solar cells







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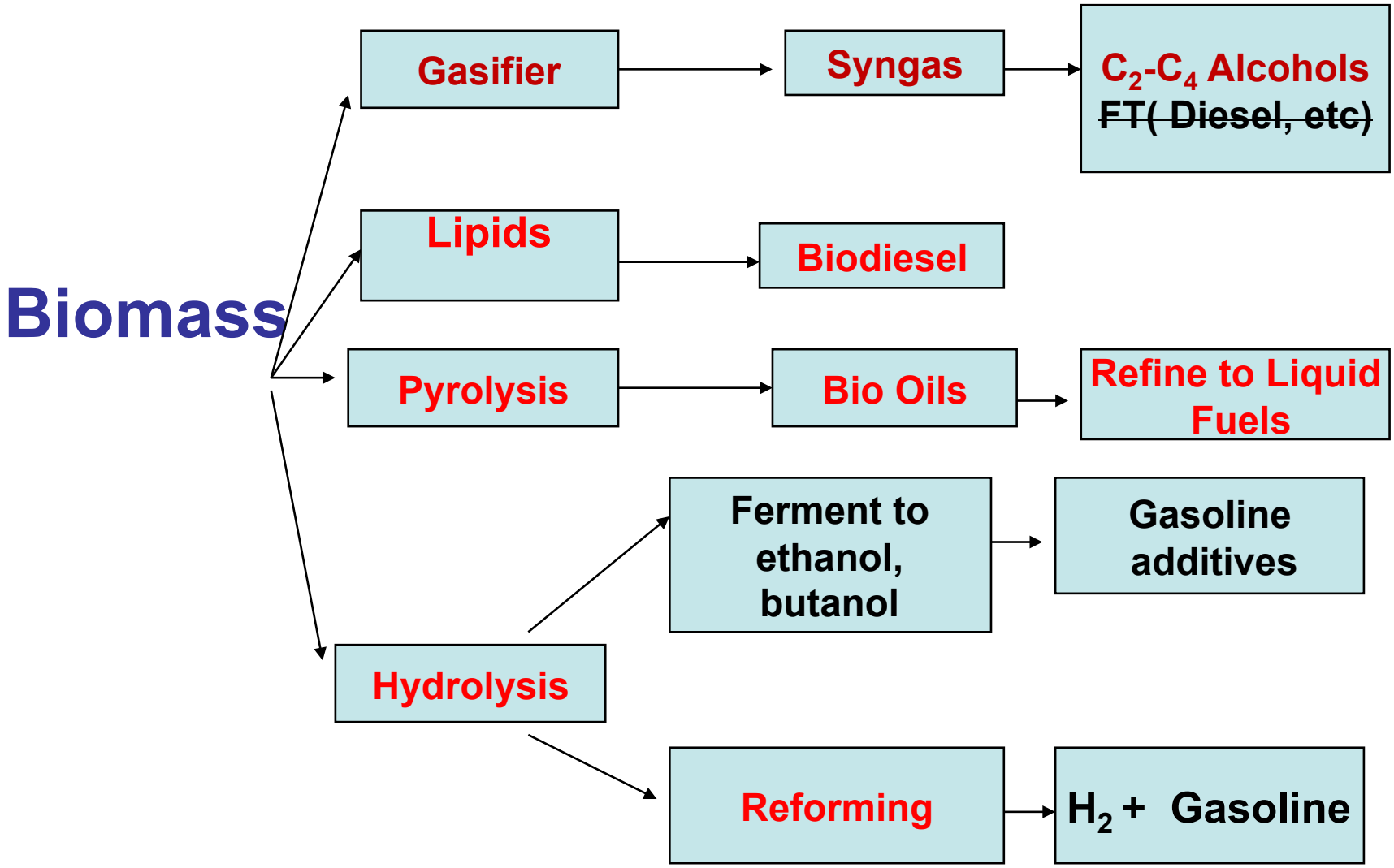
Biofuels



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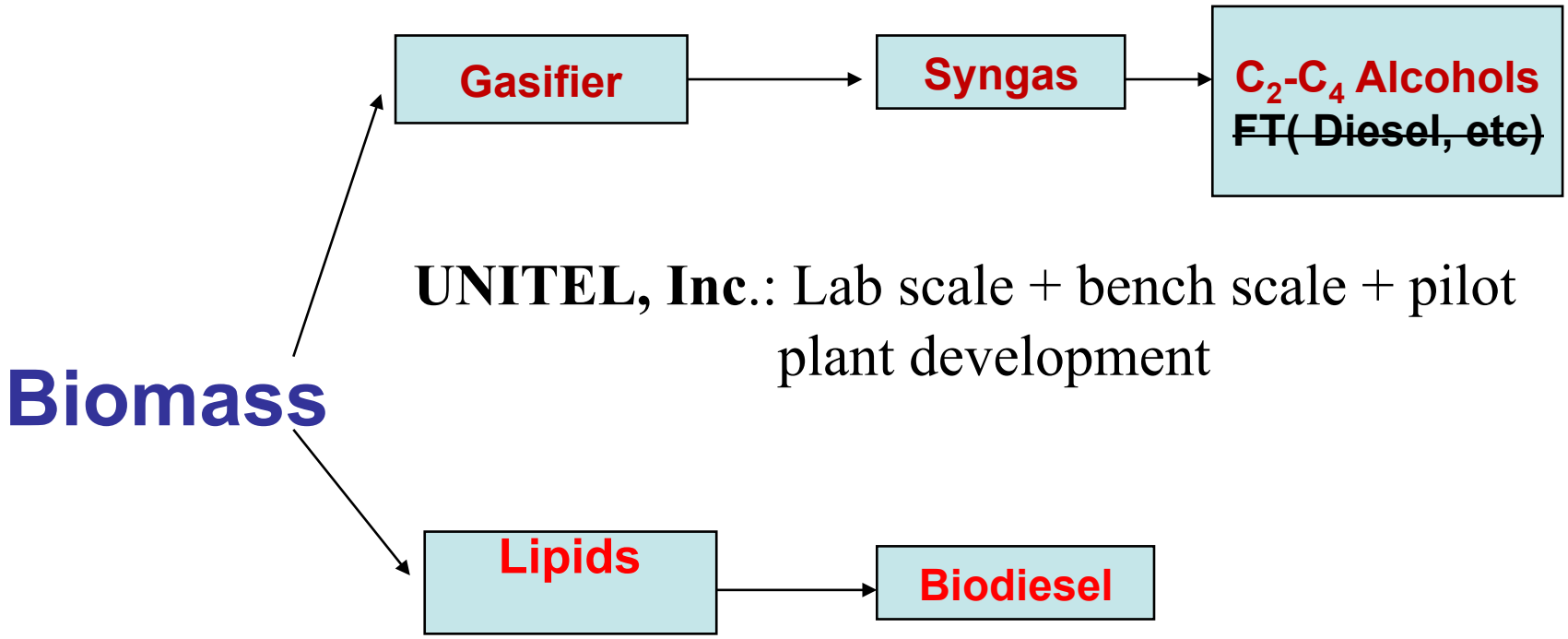
Technology Roadmap for Biofuels (P. Ratnasamy)



UNITEL, Inc.: Lab scale + bench scale + pilot plant development

Benefuel, LLC: Trans-esterification pilot plant (50 gals/day)

UNITEL, Inc. : Esterification of fatty acids
(bench scale + pilot plant development)

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Renewable Energy Storage

- Cost-effective, scalable manufacturing of Li ion batteries for 10 MW or higher capacity (for solar or wind farms)
  Partner - Planar Energy Devices, Inc.

- Super-capacitors

- Electrochemical production of chemicals and fuels

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Smart Buildings

- Solar water heating/cooling/storage *(Sharp)*
- HVAC analysis *(Lian)*
- Building information/flow system modeling & control *(McGinley & Graham)*

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EDUCATION

- Wide spread interest from young students in renewable energy research due to sustainability aspects.

- Opportunity for new multi-disciplinary curriculum development!

- Conn center's manufacturing R&D facilities offer unique student and co-op training opportunities.

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EARLY EXPOSURE TO A LARGE STUDENT BODY

Solar cell experiment

- Students were provided with "solar paint" (titania NPs + cranberry juice), two FTO slides and electrolyte.
- 400 freshmen made solar cells and tested them in a 45 min. class (resulted > 350 mV)

Conn Center's Impact on Kentucky's Energy Plan and Economy

- Improve the energy efficiency of Kentucky's homes, buildings, industries and transportation fleet.
- Increase Kentucky's use of renewable energy.
- Sustainably grow Kentucky's production of biofuels.
- Economic impact through high tech manufacturing jobs in renewables.

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Final Slide
Holy Grail in Renewable Energy Research

e-

H_2O → Electrolyzer → H_2, O_2

e-

CO_2, H_2O → Electrolyzer → **Methanol**

Search for black magic dust!

H_2O → Photo Electrolyzer → H_2, O_2

CO_2, H_2O → Photo Electrolyzer → **Methanol**

Fuel, Air → Fuel Cell → H_2O, **e-**

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