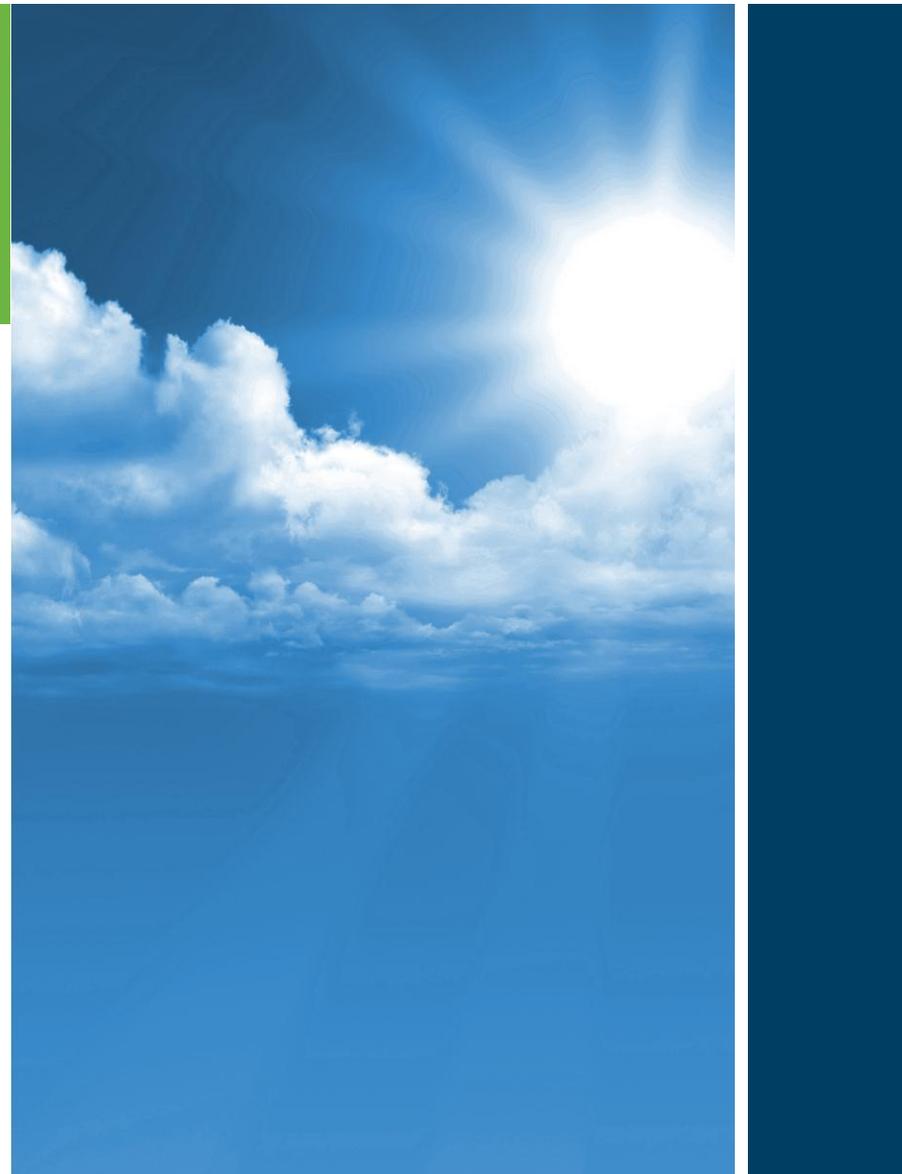


Solar Energy in a Sustainable and Equitable Electric Power System

International Off-Grid Renewable Energy Conference

November 2, 2012
Accra - Ghana

Dr. Andy Walker , Principal Engineer
Clean Energy Solutions Center
National Renewable Energy
Laboratory



Clean Energy Solutions Center

<http://www.CleanEnergySolutions.org>

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Background

- Clean Energy Ministerial (CEM) launched the Clean Energy Solutions Center in April, 2011
- Partnership with UN-Energy is extending scope to support all developing countries

Target Audiences

- Energy policy makers and advisors
- Analysts
- Private sector companies,
- Energy entrepreneurs and investors
- Non Governmental Organizations
- Civil society
- Others engaged in clean energy



Goals

- Serve as a first-stop clearinghouse of clean energy policy resources.
- Share policy best practices, data, and analysis tools across countries.
- Deliver dynamic services that will enable expert assistance, learning, and peer to peer sharing of experiences
- Foster dialogue on emerging policy issues and innovation ac

Solar Technology

- Photovoltaics
- Solar Thermal
 - Solar Water Heating
 - Solar Thermal Power
 - Solar Industrial Process Heat
 - Solar Drying, Heating Ventilation Air
 - Solar Cooking
- Passive Solar Architecture
- Energy Storage (Batteries, Thermal)

Direct Photovoltaic Devices

Cost of AA battery: \$0.50/1.5V/2.8AH = \$120/kWh!

Lanterns



Phones



Exhaust Fans



Sign Lighting



Consumer Electronics



Navigation Lighting



Important Off-Grid PV Applications

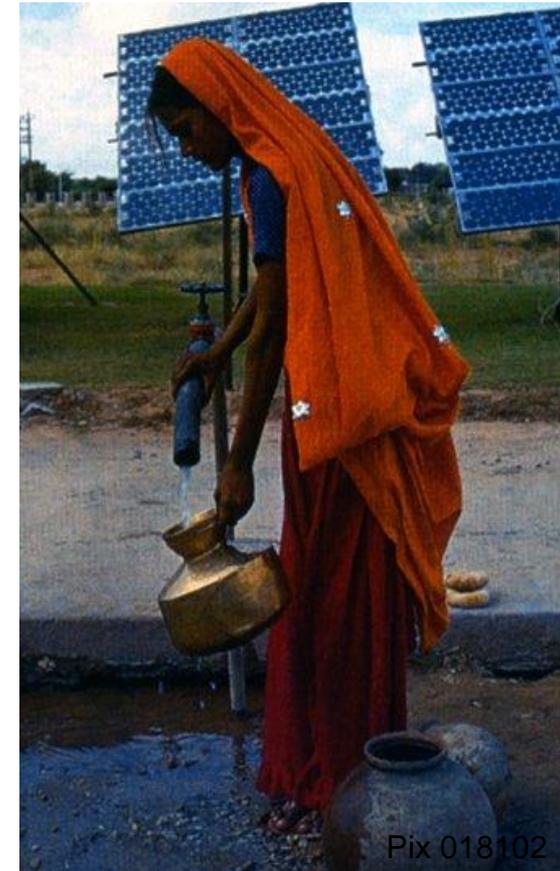
Lighting



Refrigeration



Water Pumping



Water Purification



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Communications



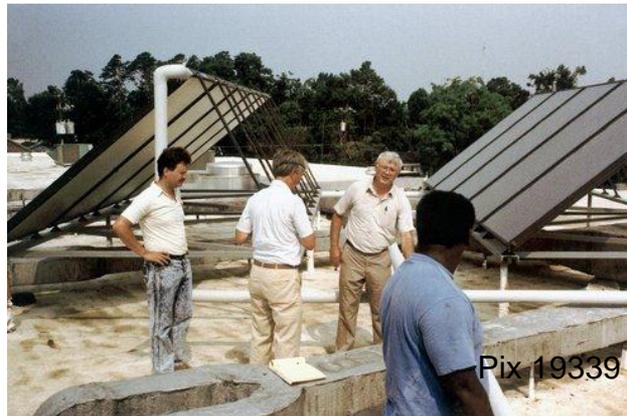
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Solar Water Heating

Domestic Use



Schools



Prisons



Hospitals



Hotels



Agriculture-Food Processing

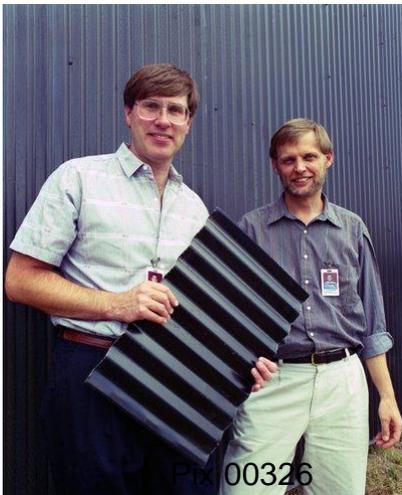


Transpired Solar Collector

Crop Drying



Industrial Ventilation



Solar Cookers



Pix 11359



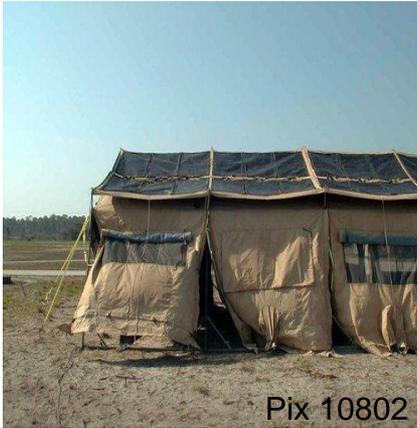
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Solar in the Built Environment

Solar Tents



Shade Structures



Window Overhangs



Roofs



Covered Parking

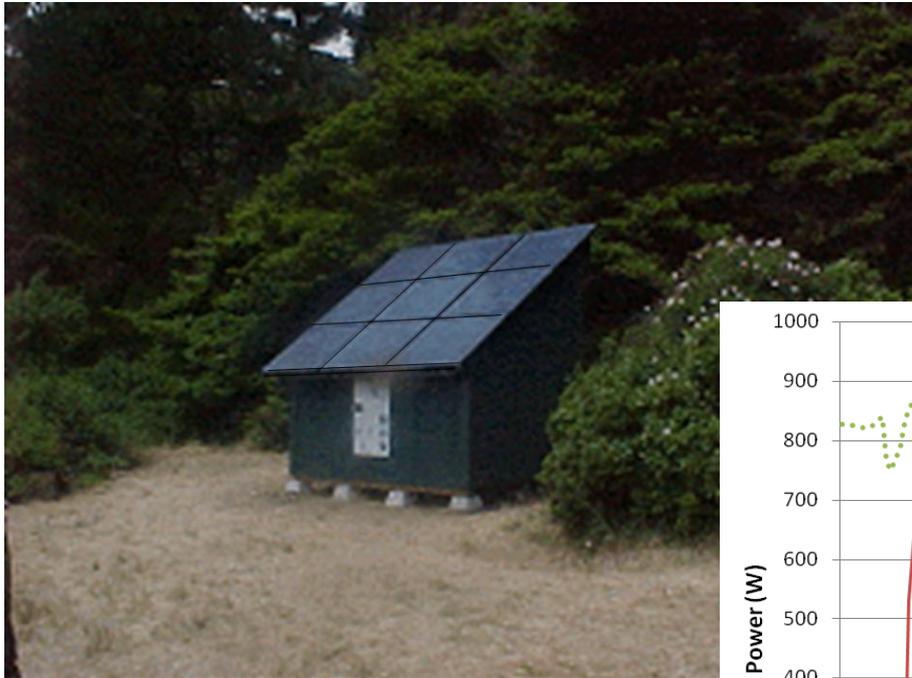


Windows

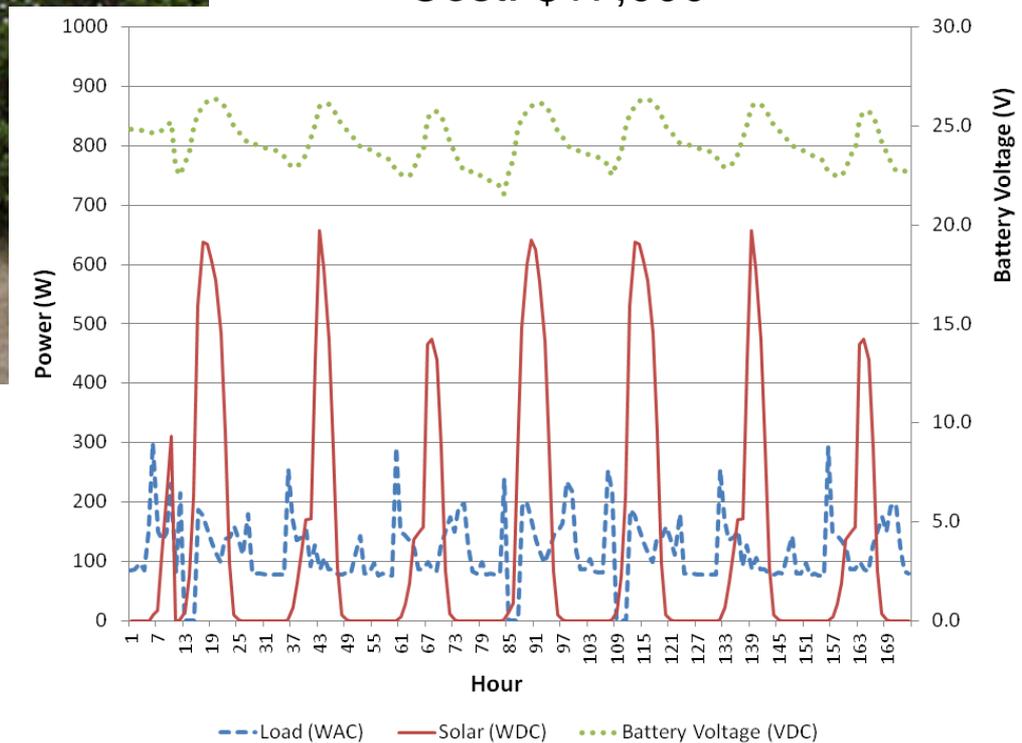


Example of Small Off-Grid System: Kirby Cove, CA

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- 960 W_{DC} PV Array
- 9 kWh Battery Bank
- 4 kW_{AC} maximum peak power inverter.
- Cost: \$17,000



Example of Mid-sized Off-Grid System: Joshua Tree National Park

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- 20.5 kW PV Array
- 613 kWh battery bank
- 35 kW propane generator
- \$273,000 cost financed by Southern California Edison under 15 year tariff



Example of Large Off-Grid System: Alcatraz Island Microgrid

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- 305 kW PV Array
- 1,900 kWh battery bank
- 200 kW diesel generator
- Cost: \$3.6 million



Advantages of Solar

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- Fast and Easy to Implement
- Small Investment
- Close to demand
 - less loss in transmission
- Clean- no emissions on-site
- Local Jobs
 - manufacturing
 - installation
 - maintenance
- Energy Security
 - fuel supply interruption
 - fuel price volatility



Pix 10706

Focus Areas

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Financing; incentives

Resource Assessment

Integrated Planning

- Solar

- Wind, hydro, and other renewables

- Fossil, nuclear

Technical Assistance

- Design, Maintenance

Environmental Awareness

Perception of Risk

Resource Assessment (maps and data)

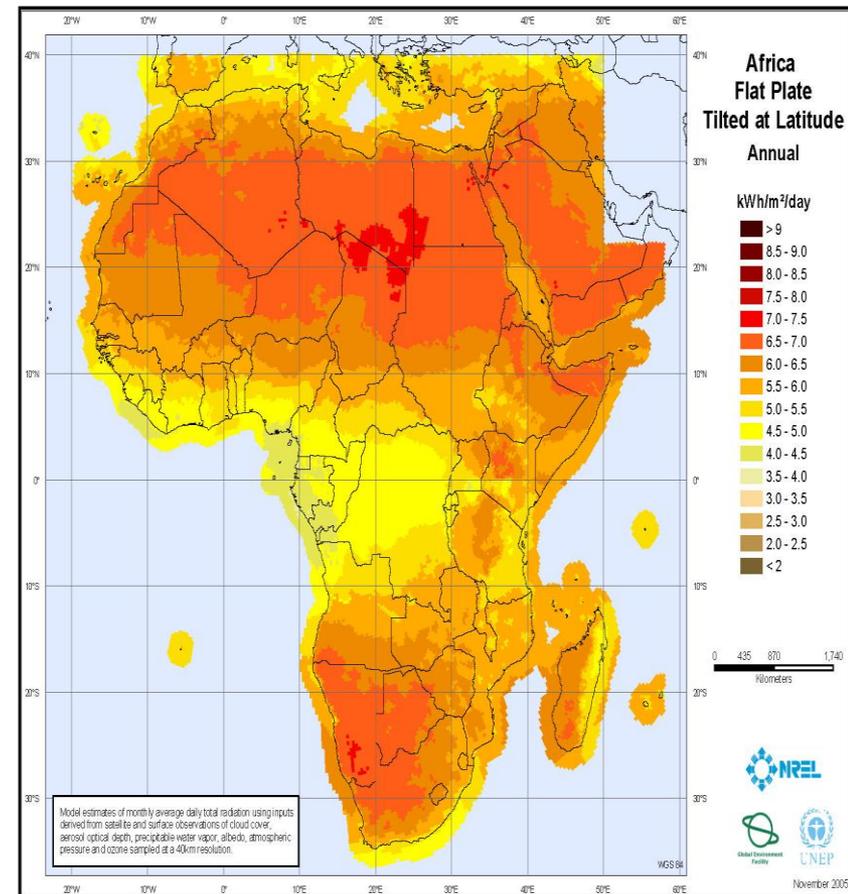
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United Nations Environment Programme (UNEP)
Solar and Wind Energy Resource Assessment
(SWERA) (<http://swera.unep.net>)

The NASA Solar Data Analysis Center
(<http://umbra.nascom.nasa.gov/>)
The NASA Surface Meteorology and Solar Energy
(SSE) site (<http://eosweb.larc.nasa.gov/sse/>)

SOLEMI - Solar Energy Mining
(<http://www.solemi.de/home.html>) service from the
German Aerospace Center (DLR)

NREL's Renewable Resource Data Center
(<http://rredc.nrel.gov>); Solar resource GIS map
data and GIS map software tools are available at
<http://www.nrel.gov/GIS>.



Analytic Tools for Off-Grid Systems

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HOMER Hybrid Optimization Multiple Energy Resources.

Hourly simulation PV, Wind, generator systems

Homerenergy.com

On-line version for off-grid health clinics at <http://www.poweringhealth.org>

RETScreen Natural Resources Canada

PV, Wind, Solar Hot Water, Solar Ventilation Air/Drying

<http://www.etscreen.net/>

SAM System Advisor Model (SAM)

PV, Wind, Solar Thermal Electric, Solar Water Heating

<http://www.nrel.gov/analysis/sam;>

Example:

<http://www.poweringhealth.org>

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1) Location and Time Zone

Click on the map below to mark your location



2) Power Assumptions

Electric Grid (if available)

Start hour: 17:00

Duration (hours): 0

Electric Grid Price (\$/kWh): 0.15

On-site Generation

Type of Fuel: []

Cost of Diesel (\$/litre): []

Cost of PV System (\$/kW): []

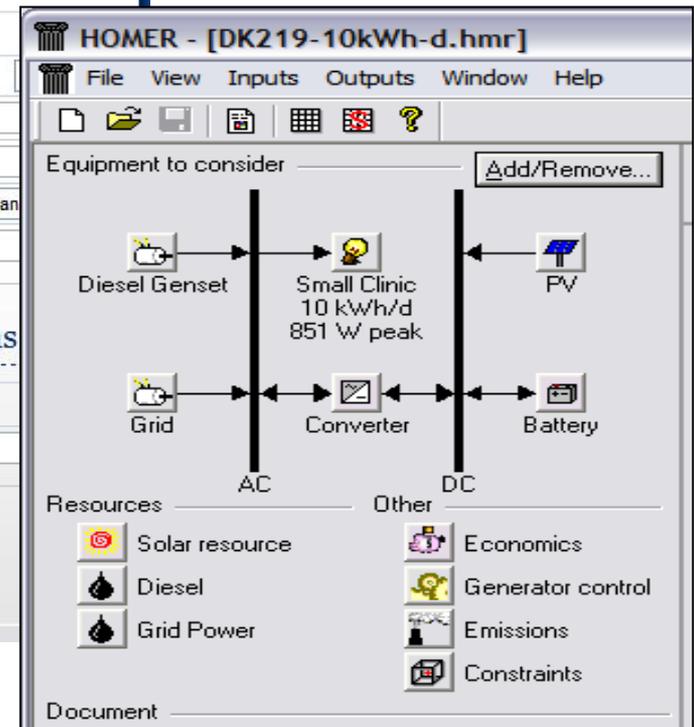
Type of Battery: Trojan

Cost of Batteries (\$/battery): []

3) Financial Assumptions

Interest Rate

Interest Rate (percent per year): []



Example:

<http://www.poweringhealth.org>

Device	Quantity	Power (Watts)	Total (Watts)	Day (07:00-17:59) On-Time hours	Evening (18:00-21:59) On-Time hours	Night (22:00-06:59) On-Time hours	Power (kWh/day)
Refrigerator-Vaccine	1	60	60				0.60
Refrigerator-Non-med	0	300	0				0.00
Centrifuge	1	400	400	1	0	0	0.40
Hematology-Mixer	1	29	29	1	0	0	0.03
Microscope	1	20	20				0.20
Incubator	1	100	100				1.00
Water-Bath	1	100	100				1.00
Water Purification	1	100	100				1.00
Hematology Analyzer	1	100	100				1.00
CD4 Machine	0	100	0				0.00
Sterilization oven	0	100	0				0.00
Portable X-ray	0	100	0				0.00
Radio	1	100	100				1.00
Lighting-CFL	8	100	800				8.00

List of Suggested Configurations

PV (kW)	Generator (kW)	Grid (kW)	Batteries	Converter (kW)	Initial Capital (\$)	Total Net Present Cost (\$)	COE (\$/kWh)	Renewable Fraction (%)	Diesel (L)	Gen (hrs)	Grid (hrs)
Configuration: PV/Grid/Batt											
2	0	100	40	3	30,400	53,742	0.62	0.36			1,460
Configuration: PV/Gen/Grid/Batt											
2	6	100	40	3	37,200	59,497	0.68	0.36	41	29	1,460
Configuration: Gen/Grid/Batt											
0	6	100	64	6	24,400	61,016	0.70	0.00	70	36	1,460
Configuration: Gen/Grid											
0	6	100	0	0	6,800	214,046	2.46	0.00	6,791	7,300	1,460
Configuration: PV/Gen/Grid											
0.25	6	100	0	3	11,700	219,266	2.52	0.02	6,790	7,300	1,460

Sustainable & Equitable Power System

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- Accommodates a two-way flow of electricity and information.
“upward compatible”
- Configured Circuits.
get power from where available to where needed
- Demand Response.
control demand when resource not available
- Spatial Diversity
not all in one place, distributed generation
- Diversity of Resources
solar, wind, hydro...
- Forecasting solar and wind resources
hours, days, weeks in advance
- Tracking Solar Collector Mounts.
uniform delivery
- Isolate Critical Circuits.
- Energy Storage.
Electric power
End use such as pumped water, ice, hot water
- Microgrid controls.

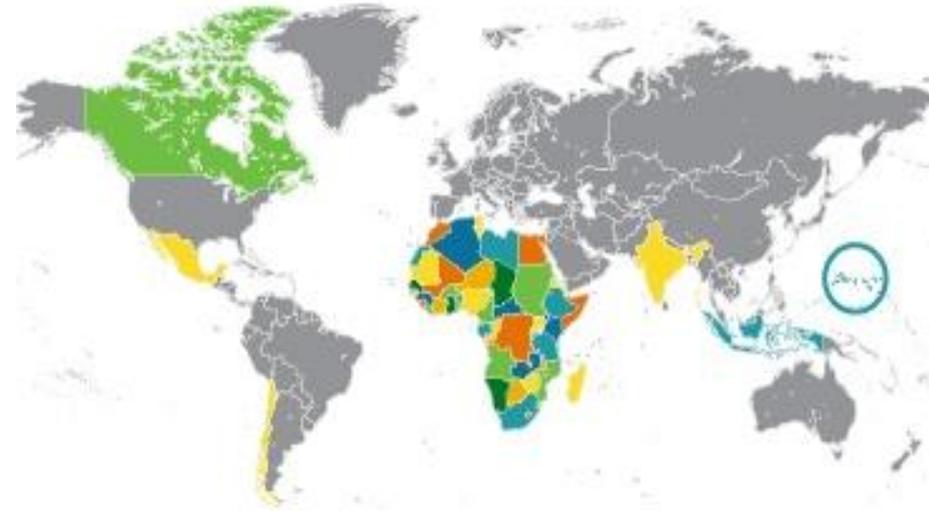
Ask an Expert: Our Experts in Action

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We connect you to a global network of energy experts for personalized attention and quick response technical assistance on **strategies, regulations, standards, financial incentives, and deployment programs** for a broad range of clean energy sectors and technologies including:

- Energy Access
- Energy Efficiency
- Renewable Energy
- Smart Grid
- Micro-Grid
- Transportation
- Utilities
- Regulations



Requesting Assistance:

Register on <http://cleanenergysolutions.org/expert>

Time for Q&A

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Thank you!
...any questions

