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Science and Strategies to Drive Energy Access for Sustainable Development Goals

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The Many Dimensions of Energy Service Isolation

Off-grid:
Geographically remote

Off-grid:
Economically remote

Off-grid:
Politically and/or geographically remote

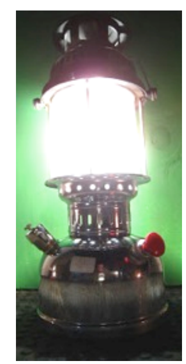
Fuel Based Lighting is a Incumbent Technology

<u>Fuel Based Lighting</u>: Expensive, Unhealthy, and Inefficient


Photo by Peter Alstone

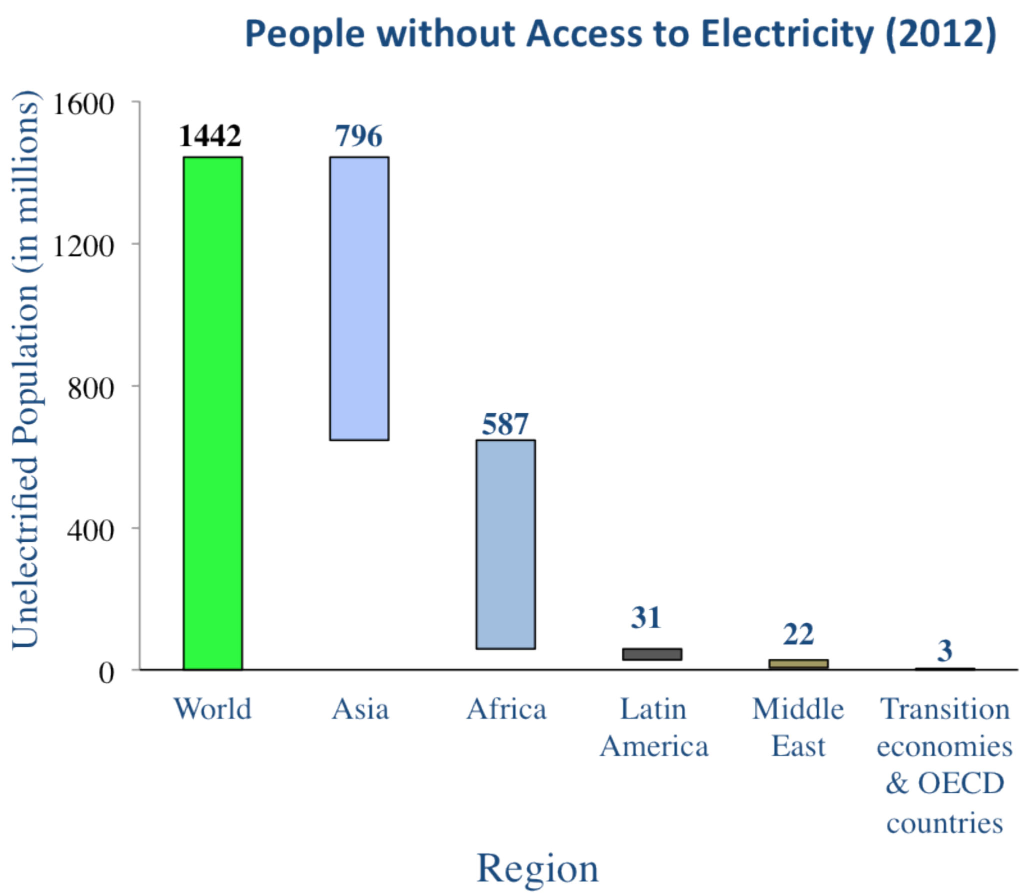
Photo by Daniel Kammen


Photo by Evan Mills



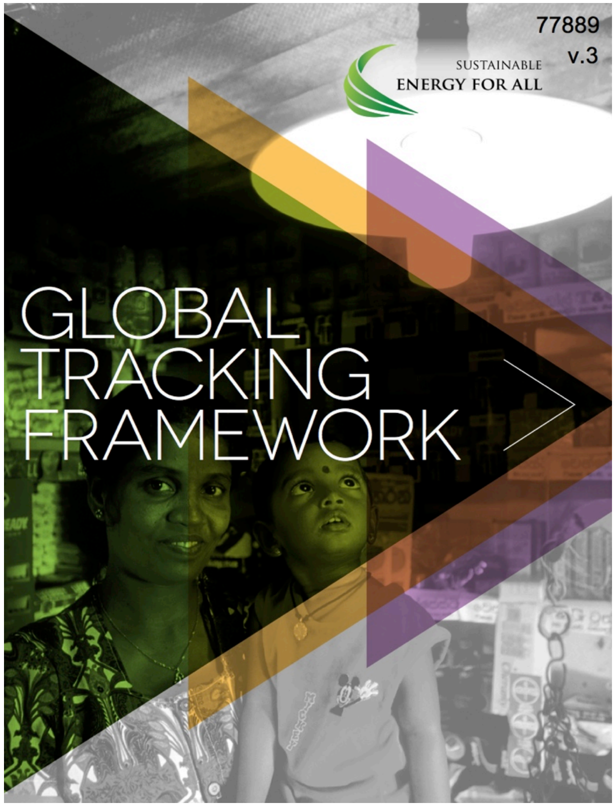
Kerosene for lighting is a $25 billion per year industry globally (source: UNEP, 2013)

Market for Modern Off-Grid Lighting and Other Services



- 1.4 billion people lack access to grid electricity
  - 96% in Africa and Asia
  - Many cannot afford higher cost alternatives to grid electricity
- Solar and LED off-grid lighting products can provide affordable and good quality lighting to un-electrified populations

Energy Access: SE4ALL



Multi-tier definitions for energy access. Designed for including in census.

Two metrics intertwine:

1. Electricity supply
2. Service levels.

Currently shaping thought in several institutions around electricity access.

Service tiers

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Actual use of indicative electricity services	—	Task lighting AND phone charging OR electric radio	General lighting AND television AND air circulation	Tier 2 package AND light and discontinuous application (thermal or mechanical)	Tier 3 package AND medium and/or continuous appli-cation (thermal or me-chanical)	Tier 4 package AND heavy and/or continuous appli-cation (thermal or me-chanical)

SOURCE: AUTHORS' COMPILATION.
NOTE: — = NOT APPLICABLE

A strategy for energy in the face of service 'isolation barriers'

- **Energy poverty** is pervasive and projected to be persistent. It is linked with human development.
- **Multidimensional isolation**—economic, geographic, and political—leads to a lack of access to centralized energy service systems.
- This "isolation barriers" characteristic is linked to the hierarchical, **centralized architecture** of electricity grids.
- A **continuum** of decentralized power technology can upend the paradigm by reducing isolation barriers and close the 'access gap'.
- **History** shows that disruptive electricity technology—electric grids in the 1900's or decentralized tech in the 2000's—results from innovation in generation sources, new loads "killer aps", and the soft infrastructure to deliver them, particularly including ICT.
- The **emerging architecture** of solar-LED-mobile phone technology systems is one system that can expand access for the last billion.

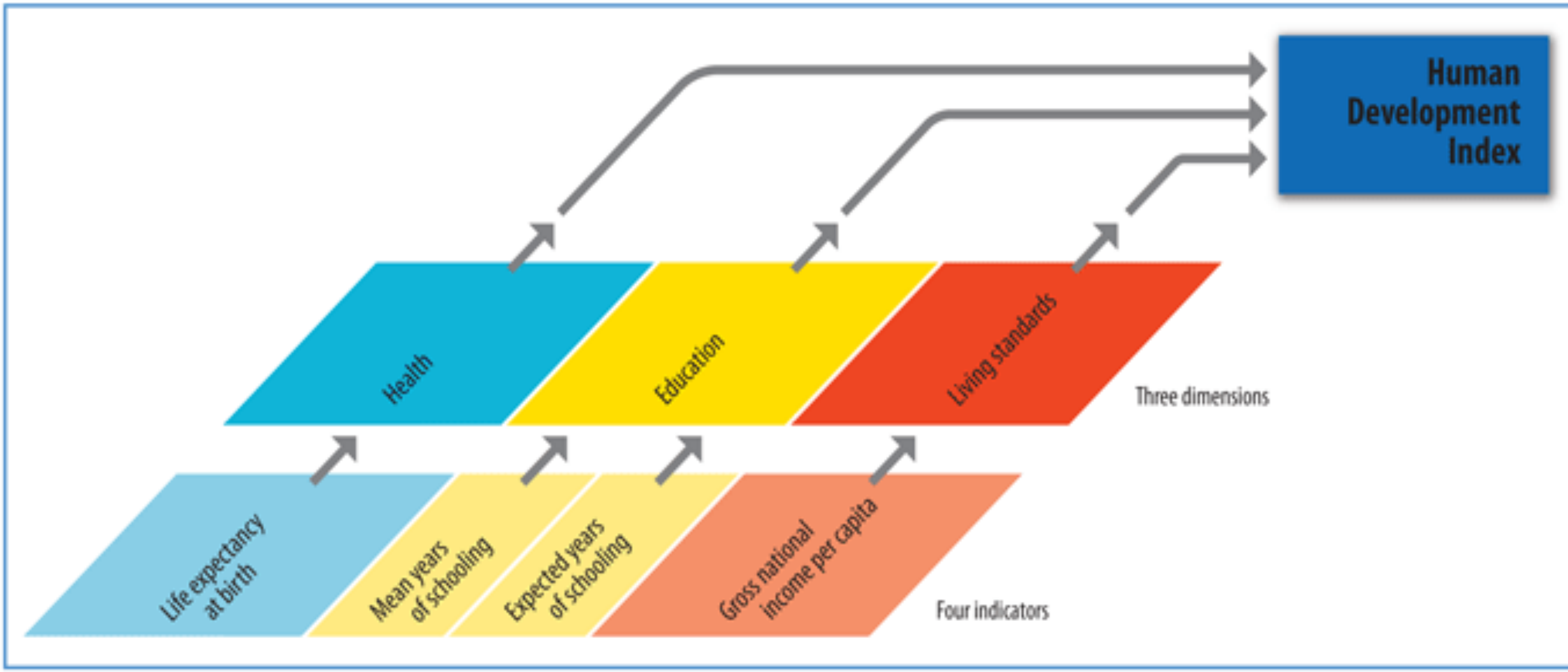
Disruptive Energy Technology
Technology advance + supporting systems

Element	Central Grids (ca. 1900)	Off-grid Power (ca. 2010)
Innovative Generation Technology	Steam Turbines	Solar PV
New Loads	Arc Lighting Motors for factories and streetcars	LED lighting Mobile phones
Financing	Large capital finance supported by emerging global industry	Very small loans and microfinance; coordination with central grid efforts (?)
Facilitating ICT	Telegraphs – support global finance and coordination of network	Mobile phones – support financing and supply chain management

Human Development: UNDP (HDI)

Components of the Human Development Index

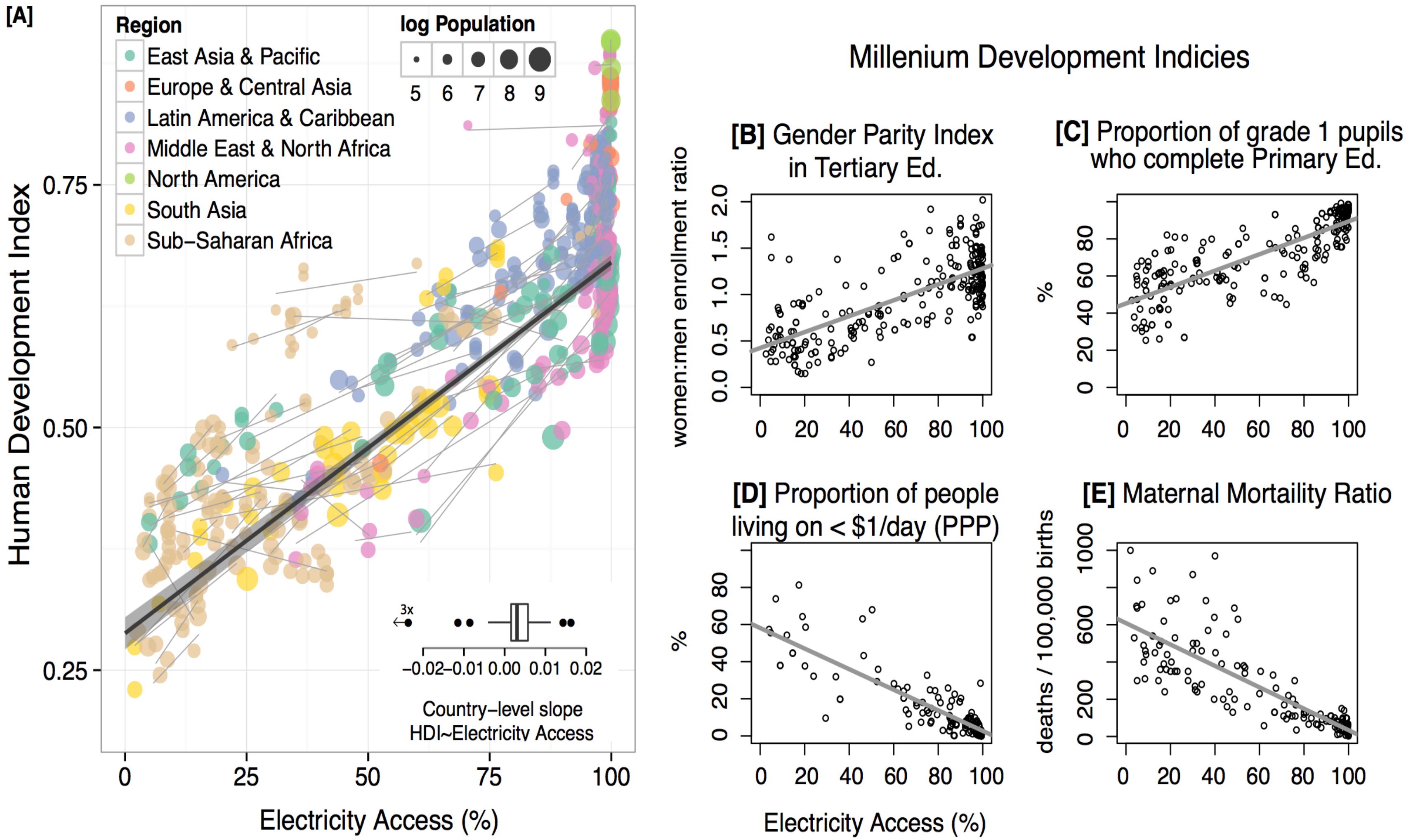
The HDI—three dimensions and four indicators



Note: The indicators presented in this figure follow the new methodology, as defined in box 1.2.

Source: HDRO.

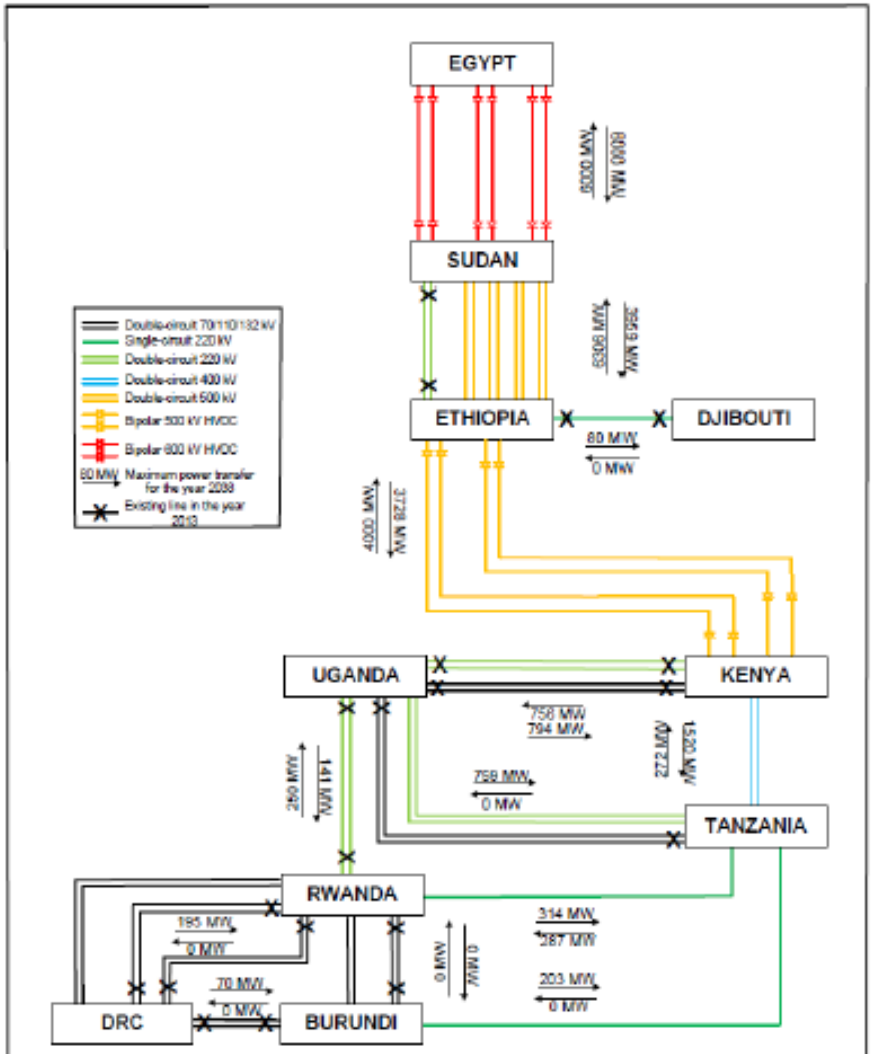
Energy Access and Development Indices: the HDI and MDGs



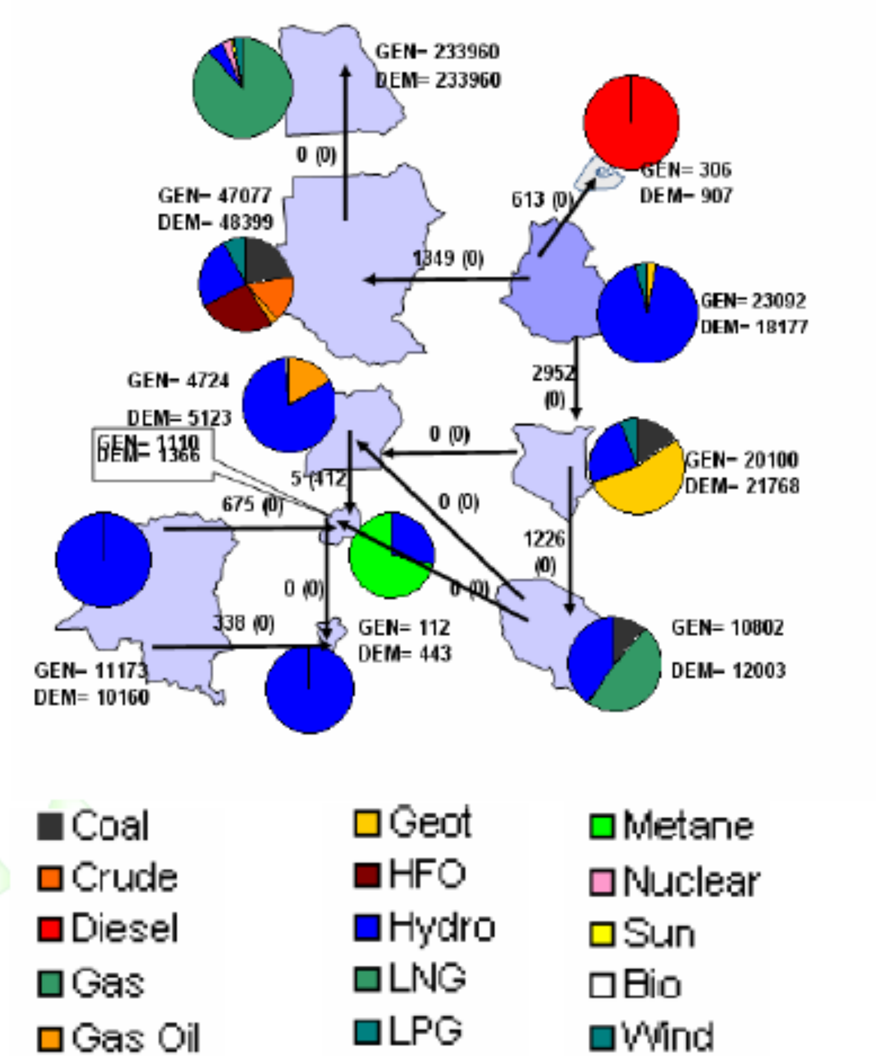
Alstone, Gershenson, and Kammen, in review

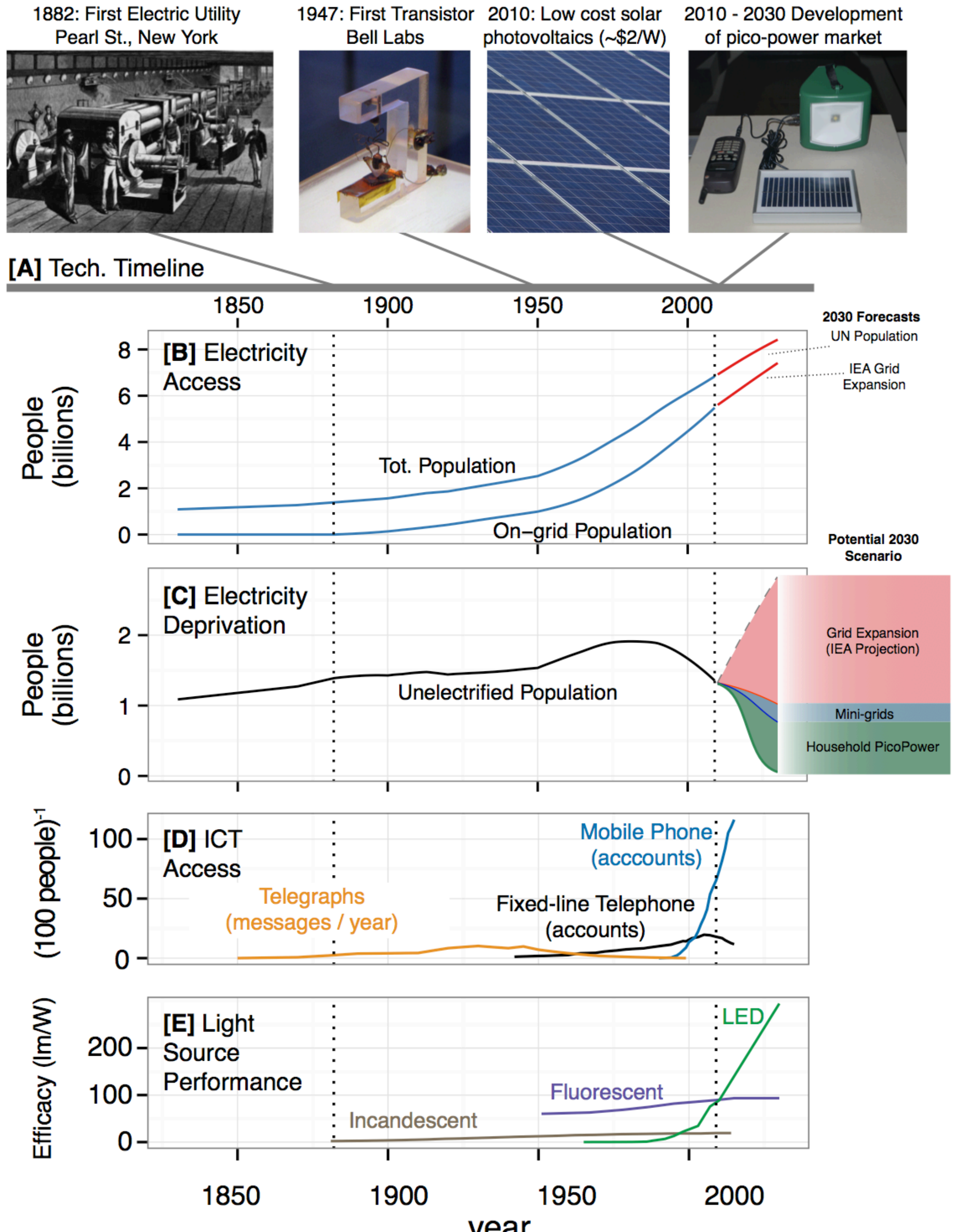
East Africa Power Pool: Regional Trade and Inter-connections

Interconnections & Forecast Trade: 2038



Generation Mix After Interconnections: 2019





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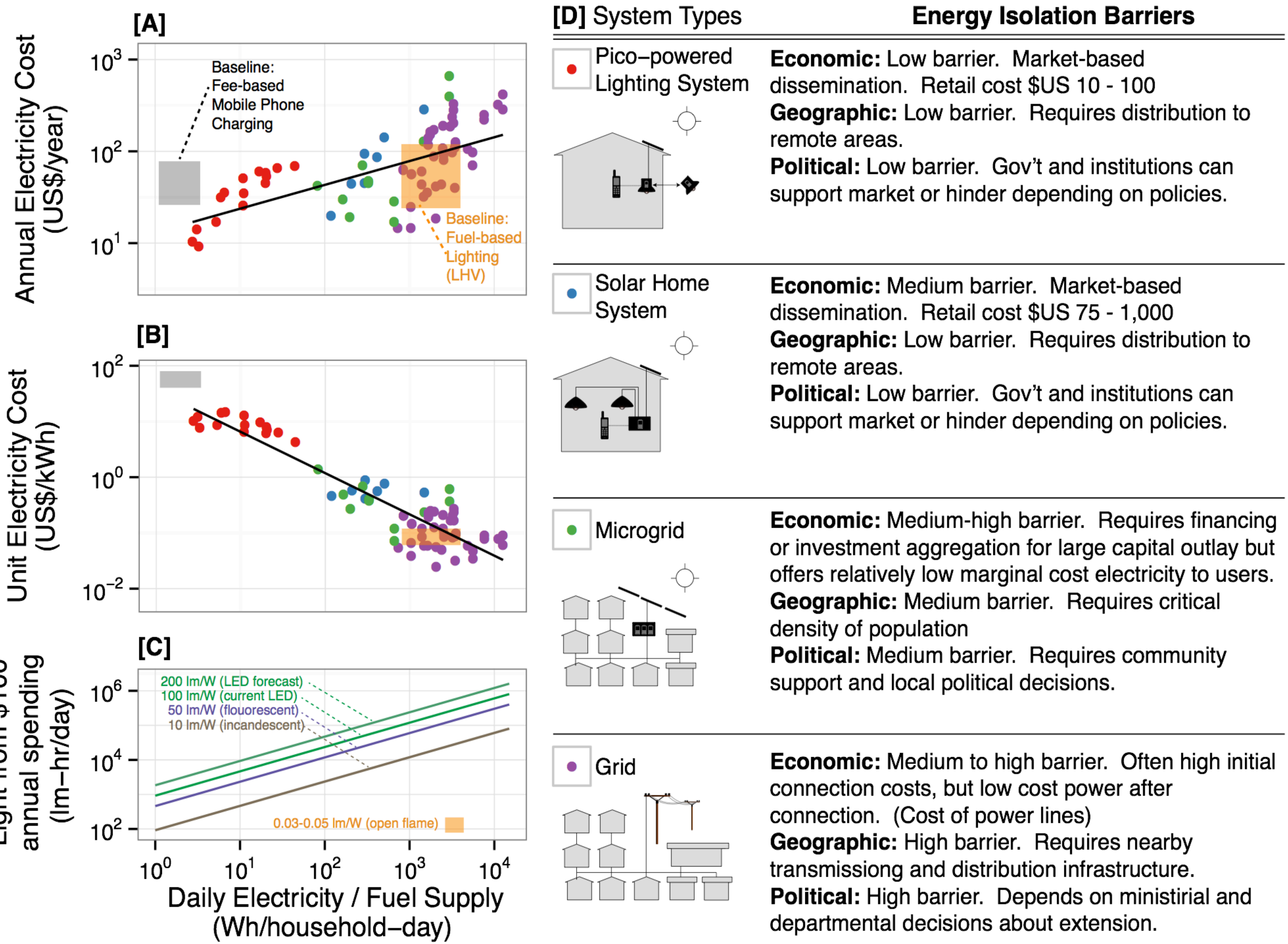
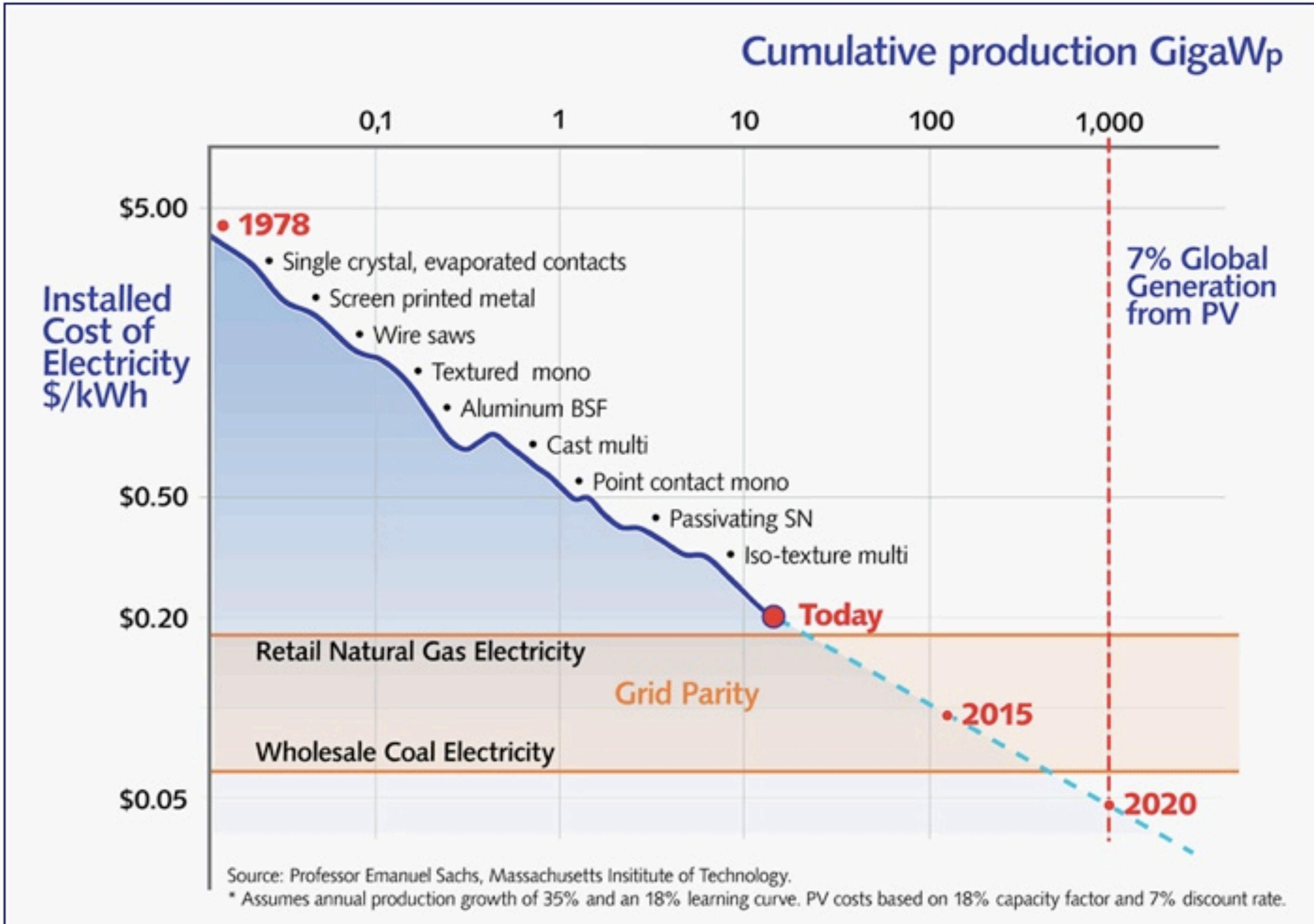


Alstone, Gershenson, and Kammen, in review

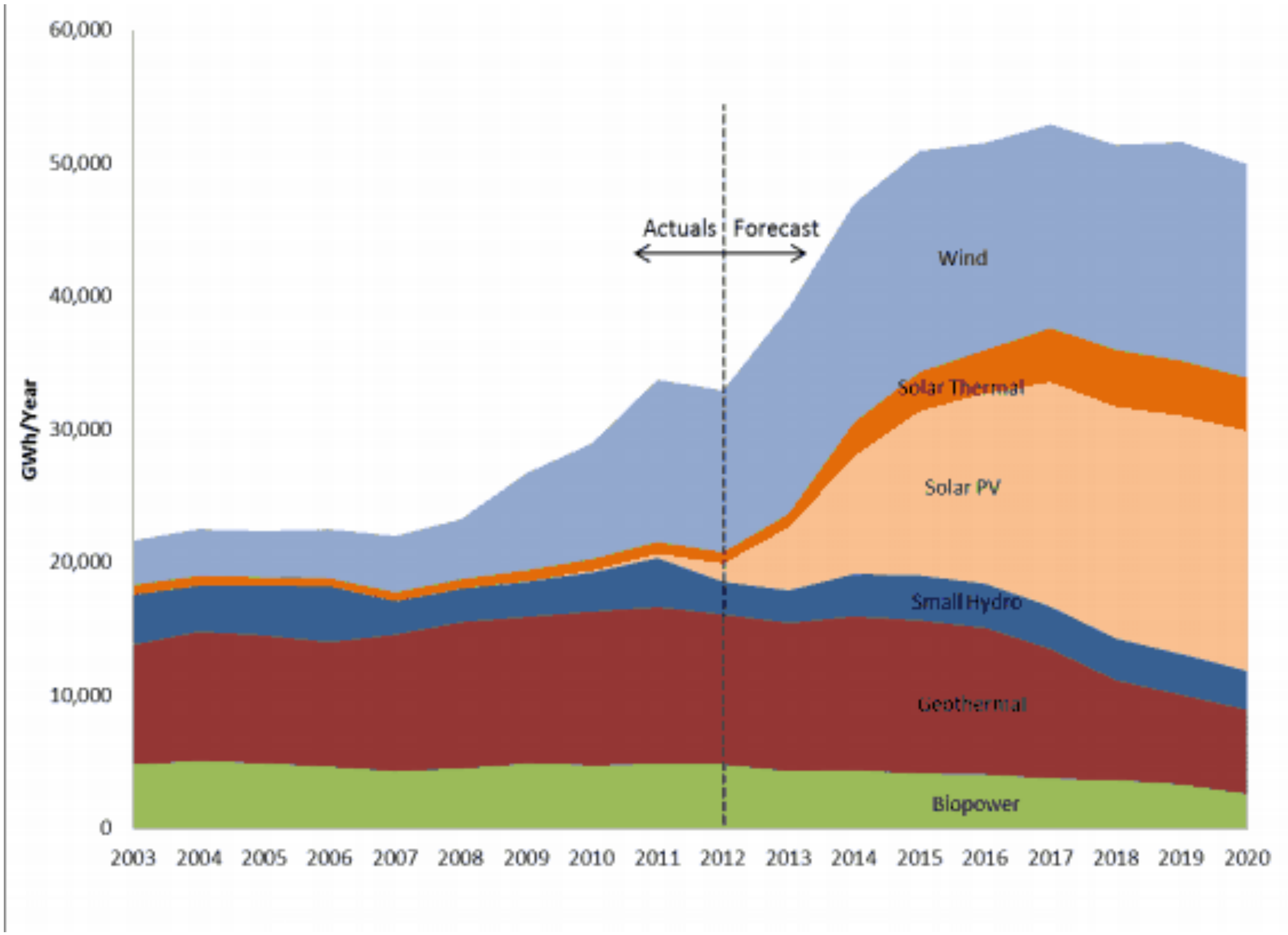
Solar cost decreases 10% per year



Source: Professor Emanuel Sachs, Massachusetts Insititute of Technology.

*Assumes annual production growth of 35% and an 18% learning curve. PV costs based on 18% capacity factor and 7% discount rate.

Almost 80% of the California's 2020 33% RPS (~25 GW) is forecast to be met by solar & wind



Source: California Public Utilities Commission RPS Report

Energy Services Testimonial

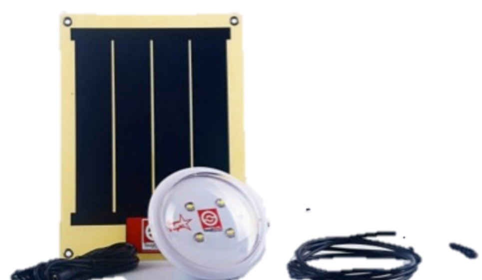
"I stay open longer now than before. I've noticed more customers are attracted to my business in the evening compared to before, and they can see my goods more clearly. **More customers means more sales and more money for me.** Some people come from far [out of their way] to see the lamp, [due to its novelty and services]" [1/2009]

LUMINA PROJECT:
http://light.lbl.gov

Low cost solar powered home energy products are transforming rural energy access in developing nations








CA Leads the US in New Solar Home Construction

<u>Reinforcing state mandates</u>:

By 2020 CA forecast to have:

- 1 million solar rooftops
and
- 1 million electric vehicles

Largest Manufacturing Operation in CA is now Electric Vehicles

Automation is allowing "on-shoring" of manufacturing processes back from Asia

Tesla Factory, Fremont, CA

Over 3000 workers now working at the Tesla Factory

Community Energy Mini-grid Systems:

Efficiency, solar, and wind on the Atlantic coast of Nicaragua

Community energy education

Energy options: wind and biodiesel

Market vehdors, "must freeze fish"

Households with mini-grid and satellite

Casillas and Kammen (2010) "The energy-poverty-climate nexus," *Science*, 330, 1182 - 1184

Energy systems and peace-building: Integrating On-and off-grid energy services in South Sudan


Charcoal vendor: Nimule airstrip


Fula Rapids Mini-hydropower site, Nimule, South Sudan


New housing developments in Juba, South Sudan


Photos by Daniel Kammen

Conclusions and Directions

- Many dimensions of energy isolation
- Fuel-based lighting illustrative of the financial impacts of broader social costs
- Distributed, lighting + information applications open new avenues to service
- Additional 'killer applications are needed'
- Hybrid strategies of on- and off-grid coordination are vital