Earth Talks: 21 Sept 2015

Solar Ecology:

Transformation of What "Doing Solar" Will Mean for the Next 100 Years (and Everyone is Invited to the Party)

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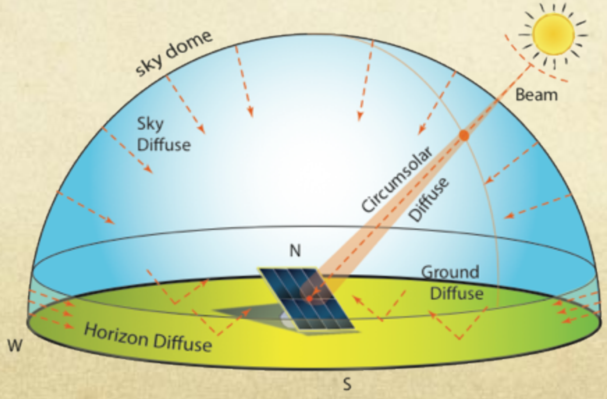

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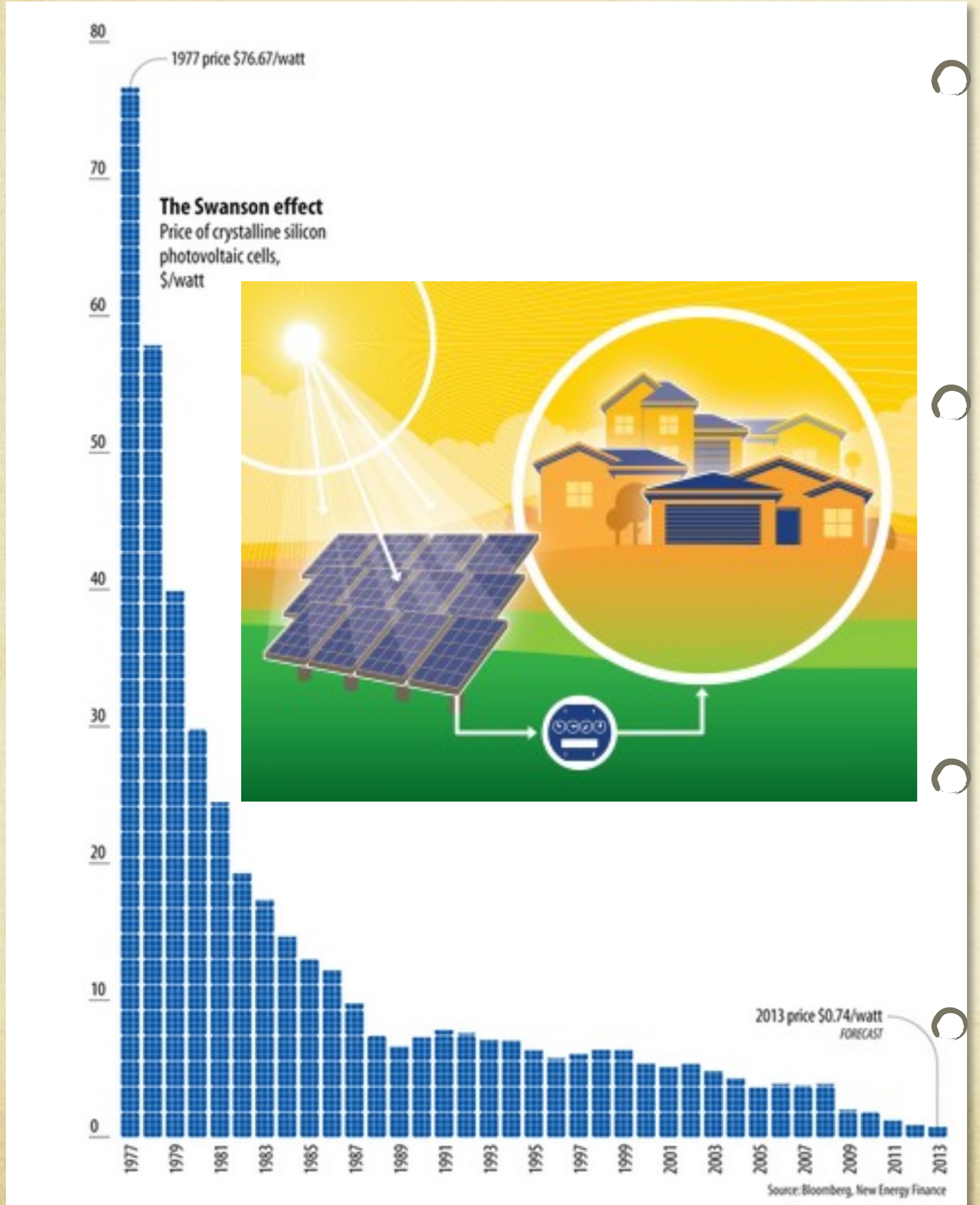
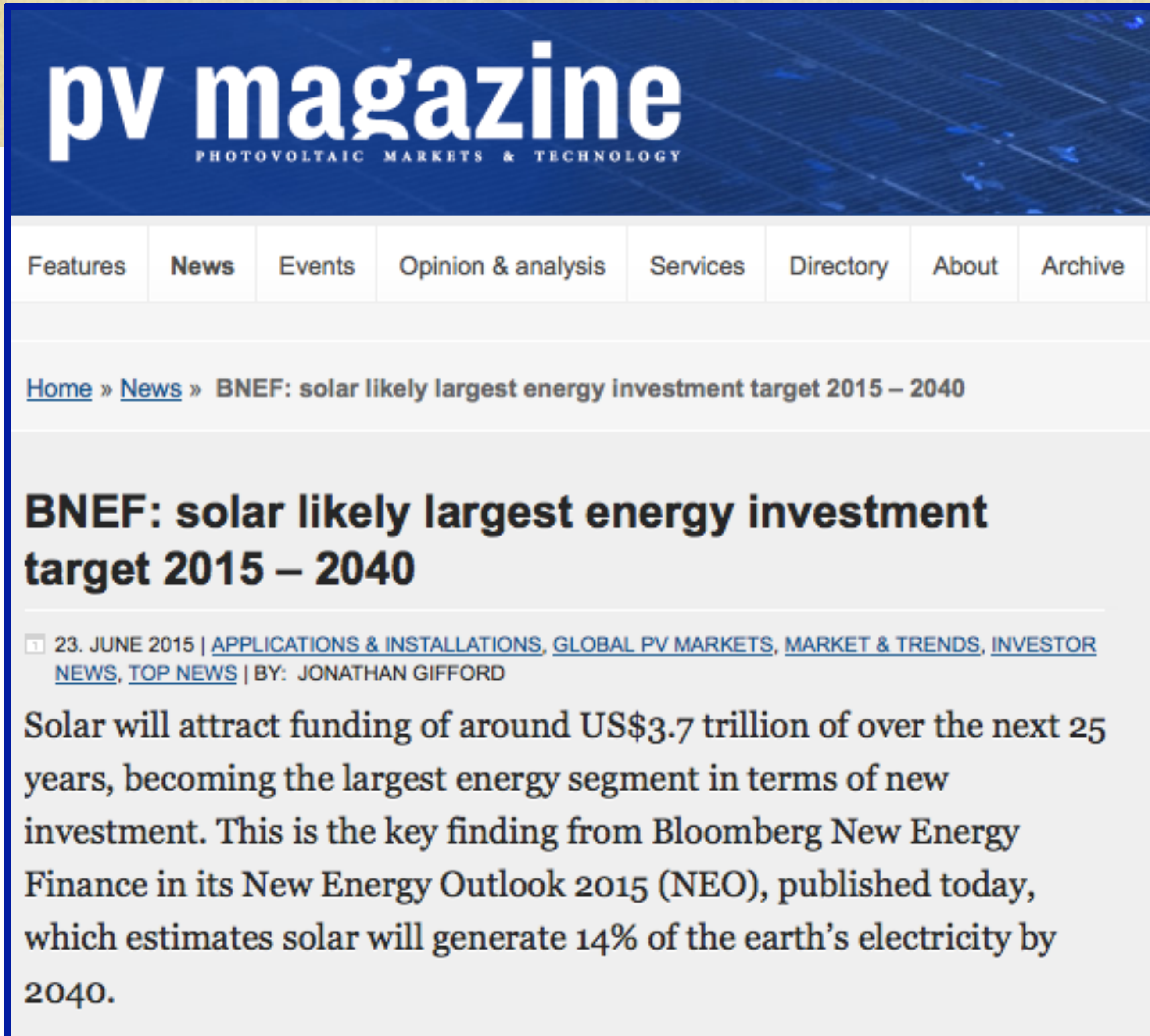
Photovoltaics: Doubling and Learning



- **Growth Rate:** 32-37% increase in PV installed globally
  - PV industry doubles every 2-2.2 years
  - Expanding Markets: Africa, Central/ South America, Asia
- **Swanson Effect:** 17-24% drop in manufacturing costs each doubling of cumulative production (learning curve)
  - $76.67/watt in 1977 to $0.72/watt for 2014
- **More to "Solar" than PV?** With every doubling, awareness of solar technologies and solar science is increasing
- What design fields share a solar history?

Credit: The Economist; "Sunny uplands" Nov. 21, 2012, G. Carr



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BNEF: solar likely largest energy investment target 2015 – 2040

23. JUNE 2015 | APPLICATIONS & INSTALLATIONS, GLOBAL PV MARKETS, MARKET & TRENDS, INVESTOR NEWS, TOP NEWS | BY: JONATHAN GIFFORD

Solar will attract funding of around US$3.7 trillion of over the next 25 years, becoming the largest energy segment in terms of new investment. This is the key finding from Bloomberg New Energy Finance in its New Energy Outlook 2015 (NEO), published today, which estimates solar will generate 14% of the earth's electricity by 2040.

Learning

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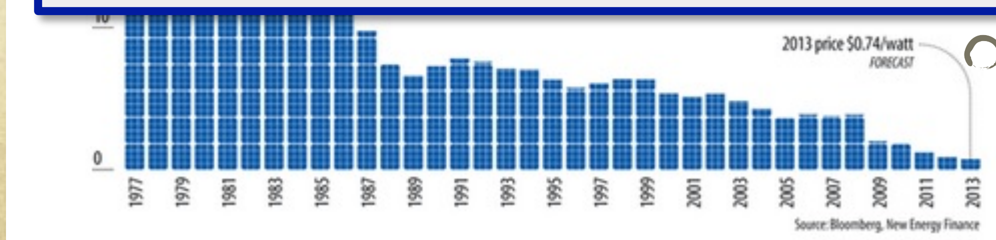

What design fields share a solar history?

Credit: The Economist; "Sunny uplands" Nov. 21, 2012, G. Carr

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Solar in Transition:
Connecting Opportunities with People

- “Solar” rides the wave of Photovoltaics
- PV is a global **commodity good**
- PV is a **bellwether for future opportunities** and value chains
- A future of solar as *goods and services*
- **A future of rich solar exploration**

Solar as Pattern,
Solar as Pattern with a Purpose

As science is the exploration of **patterns** in our universe,
then **design** can be specified as pattern with a purpose

Three Cultures of Design in Solar

- **Culture of Architecture** and the Built Environment
- **Agriculture (and Forestry)** for food, structural materials, and bioenergy
- **Culture of Solar Energy Conversion Systems** for heat, power, and processing

Each of these cultures are on a path to be aligned and integrated within the framework of solar ecology

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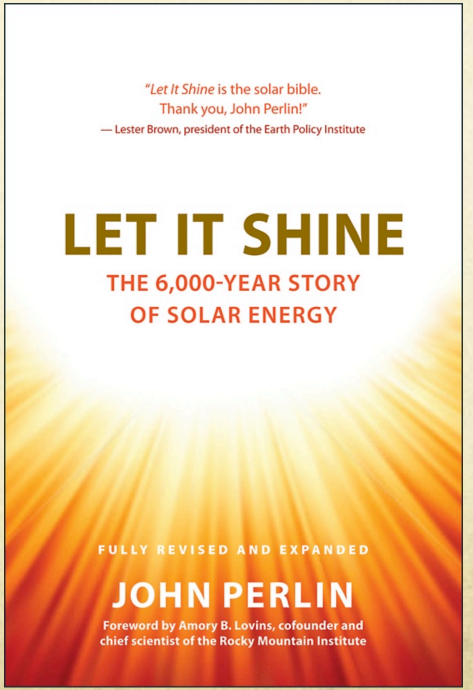
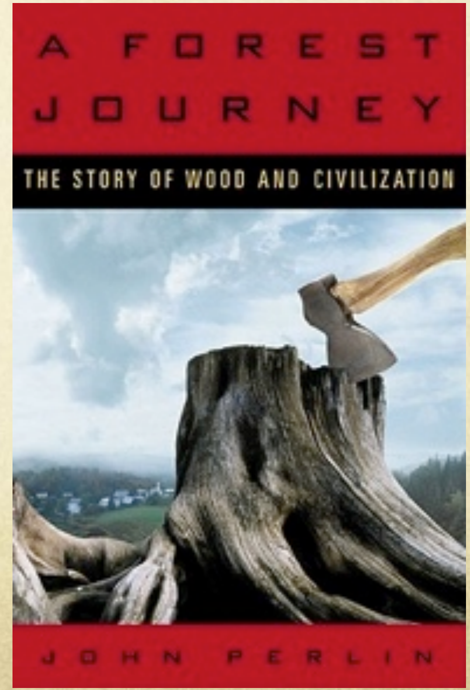
Story of Solar is Story of Society

- Solar encompasses the story of society through architecture, agriculture, and active technologies.
- Glass in Roman baths (*caldaria*) as a solar heat trap
- 1600/1700s: Fruit walls in France/England
- 1700/1800s: Solar Hot Boxes (Horace de Saussure)
- Neolithic Chinese villagers thatched roof homes faced South
- Continued through the layout of Beijing





Photovoltaics

But: When I say **solar,** you think...

Communities only connect "solar" with "PV"

We need to **grow human capacity**
and shift our thinking

Rooftop Incorporation

Field and Pasture Integration

Parking Parasol Integration

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Technological goods only part of the message.

The **processes of exchange and discovery** will have higher value.

Solar Energy Conversion Systems

Solar **science** is systemic, systematic, and integrative.

Every project for research has a **local nature.**

Integration of solar science and design is a **collective action** challenge for society.

SOLAR 2100

On the way to 2100, we will dramatically shift our thinking

Think about social connectivity to energy systems

Think about local food systems

Think about regional water systems

Think about land use affected by solar

Solar Utility

Conceptual Shifts

Framing: **What is “doing solar”?**

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Utility in Economics

- **Utility: client/stakeholder preference for goods and services**
- **Solar Utility:** preference for **solar goods and services**
- Co-creation of knowledge: *solar vernacular*

Creativity to understand the lives of communities leading to solar engagement, in the way they are actually lived

- Shaping Cultural Cognition of Risk

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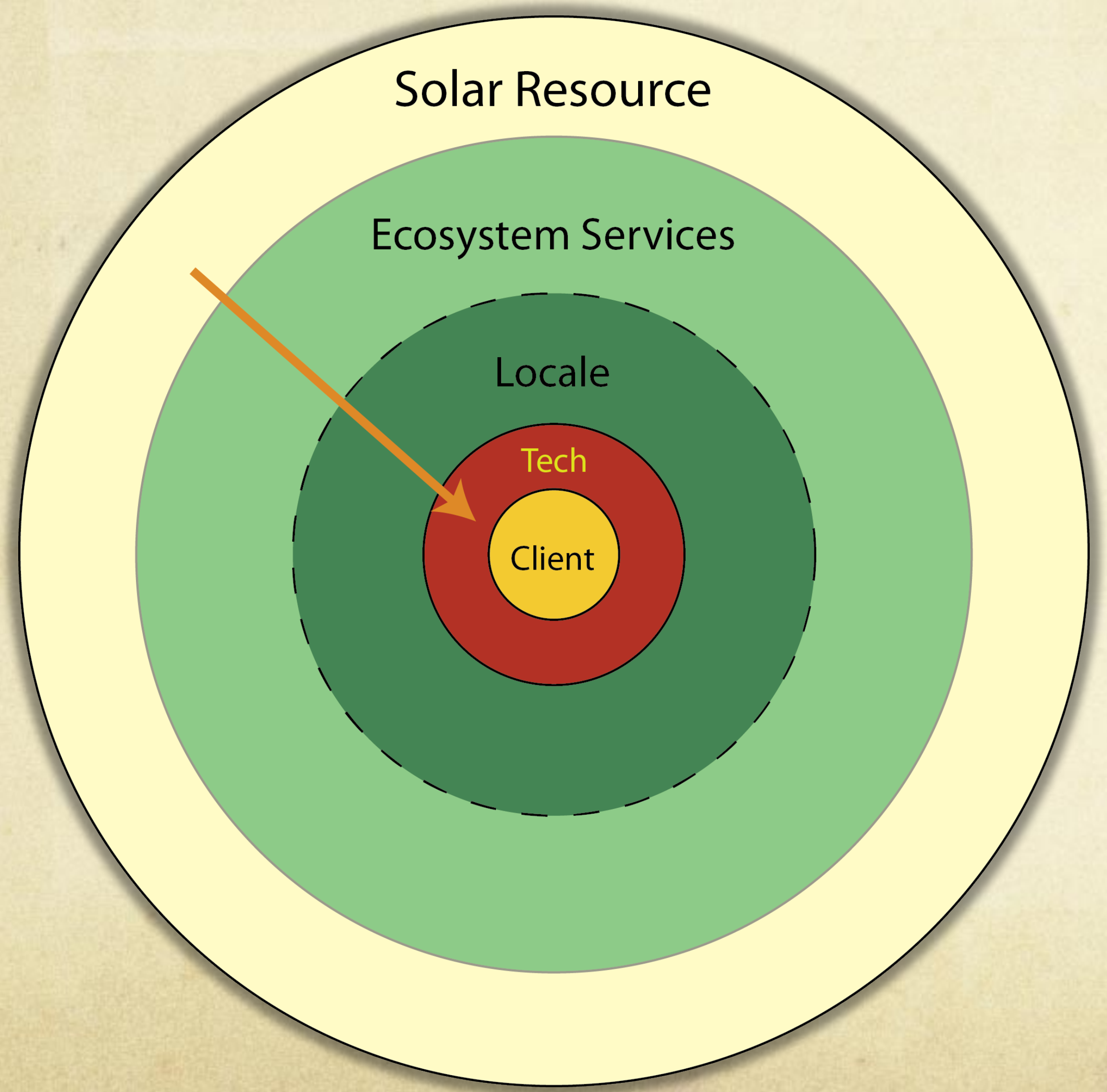
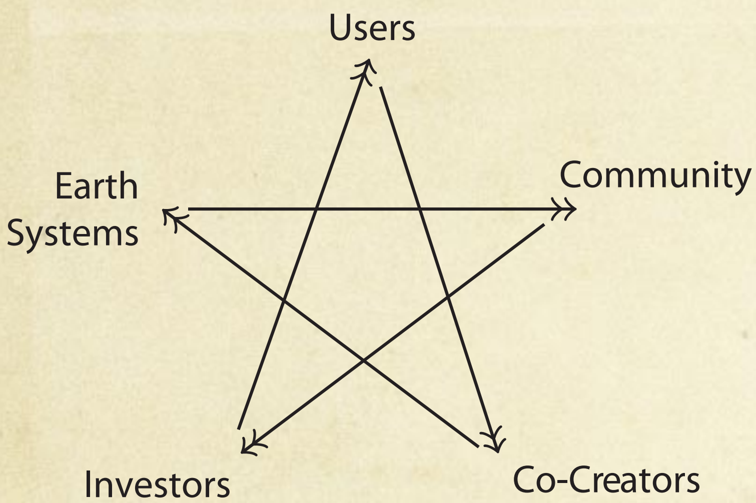
Solar: Social & Technology Ecosystem

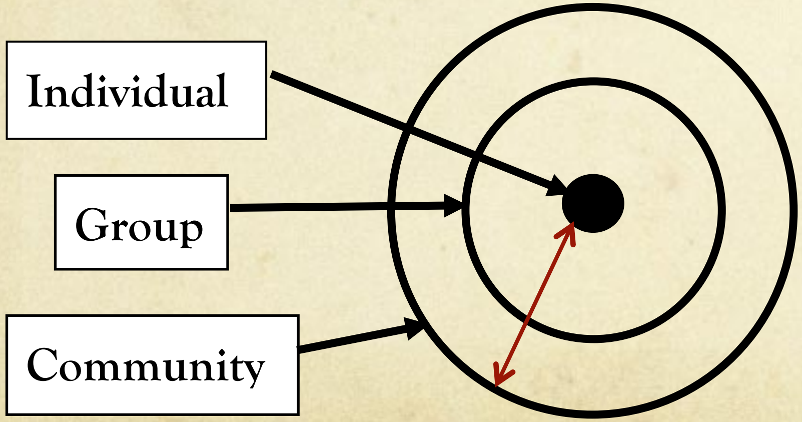


Goal of Solar Design:

- Maximize the *solar utility*
- for *stakeholders*
- in a given *locale.*

Stakeholders are Diverse





- Each provide **constraints** and **opportunities**
- Each seeks a **dynamic reciprocal relationship** with the rest
- **Individual Agency** is increasingly coupled to **Group Agency** and **Community**
- *Community Solar:* Alignment of the around a **sense of being** and **pride in place is essential**, and **takes the most time**

* C. Sanford, *The Responsible Business: Reimagining Sustainability and Success* (2011)

Locale in Solar

- **Solar resource is dynamic:**
  - Meteorology and diurnal/annual cycles
  - Emergent ecosystems services dynamic too
  - Time + Space

- **Culture is dynamic:**
  - Policy, Code, and Law
  - Elasticity of Demand and Finance
  - Cultural Cognition of Risk

Perspectives to 2100

- Goal of Solar Design: **to maximize the solar utility for stakeholders in a given locale**
- **Solar Services will predominate:** Unimagined new applications emerge from decentralized energy
- **Solar Goods will diversify beyond PV:** New strategies will emerge from the pull of new **services and science**
- **Solar Human Capacity will grow:** We succeed where and when we empower young agents in relationship with their communities
- **Land Use will be strongly affected**

Solar Ecology

Visual Shifts

How do we communicate the idea: **What *is* solar?**

Solar Energy Conversion Systems

Ryōan-ji: Kyoto, Japan (founded: 1450)

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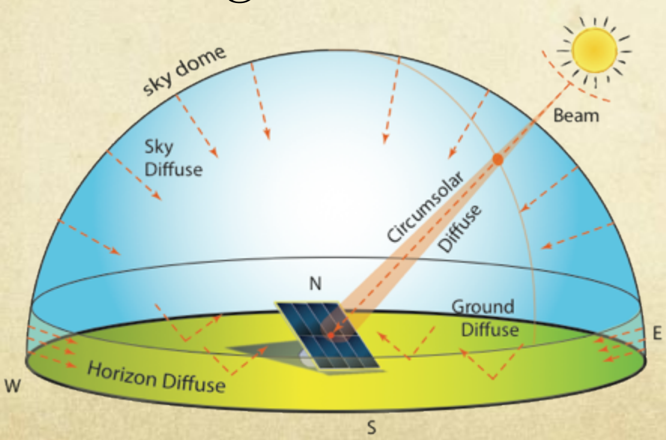
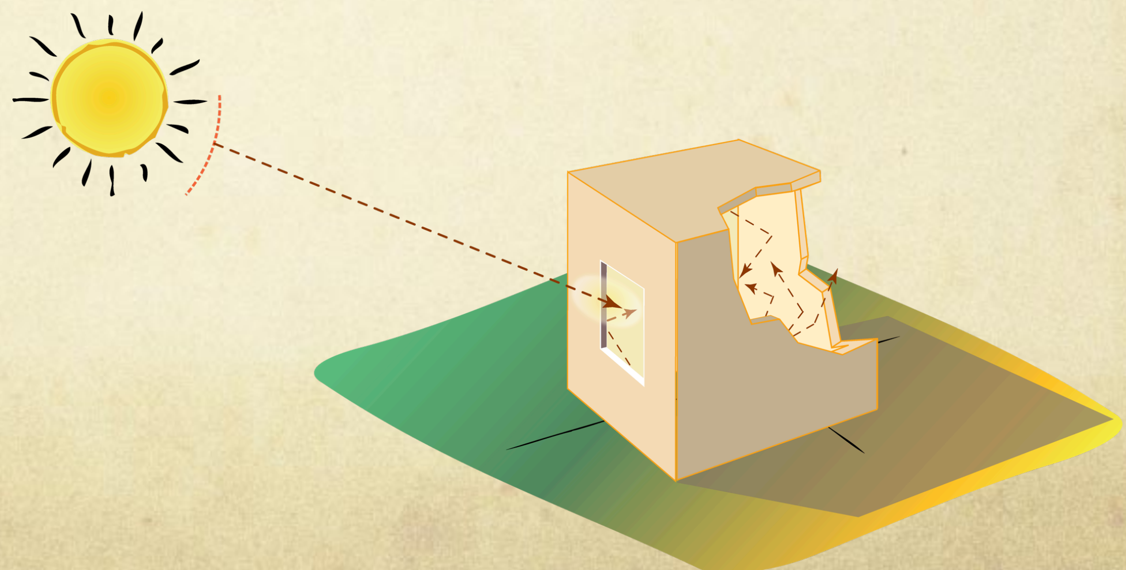
Solar Ecology

- Ecology: a study of the "home"
- **Emerging transdisciplinary systems field within the context of the environment, society and technology**
- Connecting Science and Design/Engineering with Business, Lifestyle, Health, and Well-Being
- **Transdisciplinary fields already in society:**
  - Geology with Petrochemicals/Geofuels
  - Wireless Communications Ecology

Exploration: Solar Science

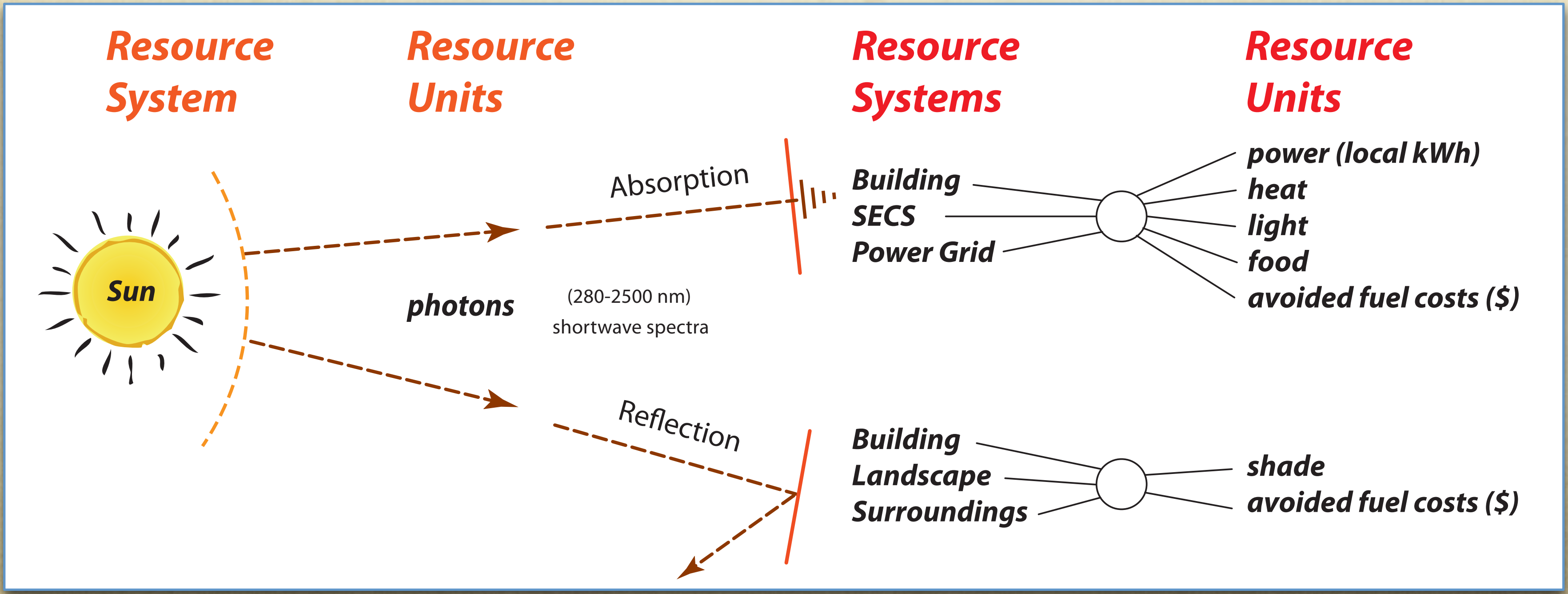
- Science of solar is still young, or old and forgotten
- Exploration of **pattern in the locale**
- Exploration of stakeholder vernacular knowledge
- Exploration of solar utility, communication, cultural cognition of risk





Flow-based Predominance

- We are all participants in an emerging era of renewable energy expansion
- Transition from *stock-* to *flow-based* energy supplies (solar, wind, hydro).



Convergence: Shift to Flows

- **Unifying approach:** shared primary awareness for flow of solar resource units *prior to conversion*
- Deeply influential role of solar on the **energy–water–food nexus** can be explored in transdisciplinary approach
- New frameworks can grow!

Transdisciplinary Vehicle

Framing the research platform: **What can solar be in 2100?**

Frameworks for Study

- Water-Energy
- Solar and Land Use
- Ecosystems Services
- Food Systems
- Social Systems

Welcome to the Party!

Water and Energy

- **Energy intermittency:** Atmospheric water (clouds) defines the major dynamics of risk from solar power
- **Water informing Solar Energy:** Energy Authority, Solar Access/ Rights
- **Water for energy,** combined constraints:
  - Energy Cost + GHG Emissions + *Water Demand* changes optimal power planning schemes
  - Suggests power supply rich in Photovoltaic and Wind electricity

*[M. Webster, P. Donohoo, and B. Palmintier. Water-CO2 trade-offs in electricity generation planning. *Nature Climate Change*, 3:1029–1032, December 2013]

Solar and Land Use

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Rapid Land Use Change

- Rule of thumb: 8 acres per MW_{ac} (or 3.2 hectares per MW_{ac})*
- **Chankara Solar Park (Gujarat, India):** 500 MW of PV consumes 4,900 acres (2000 hectares)
- **Rajasthan, India:** 4000 MW of solar power planned.

*Ong et al. (2013) "Land-Use Requirements for Solar Power Plants in the United States" NREL Technical Report: NREL/TP-6A20-56290

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Rapid Land Use Change

- **EME 810:** The Dust Bowl of the USA in the 1930s affected 100 million acres (400 thousand km^2), but was initiated by the release of land use changes of only about *1000 acres in marginal lands* by US government.
- *"Recognizing the challenge of cultivating marginal arid land, the United States government expanded on the 160 acres offered under the Homestead Act–granting 640 acres to homesteaders in western Nebraska under the Kinkaid Act (1904) and 320 elsewhere in the Great Plains under the Enlarged Homestead Act (1909)."*

  -Dust Bowl (Wikipedia entry, accessed Nov. 15, 2013)

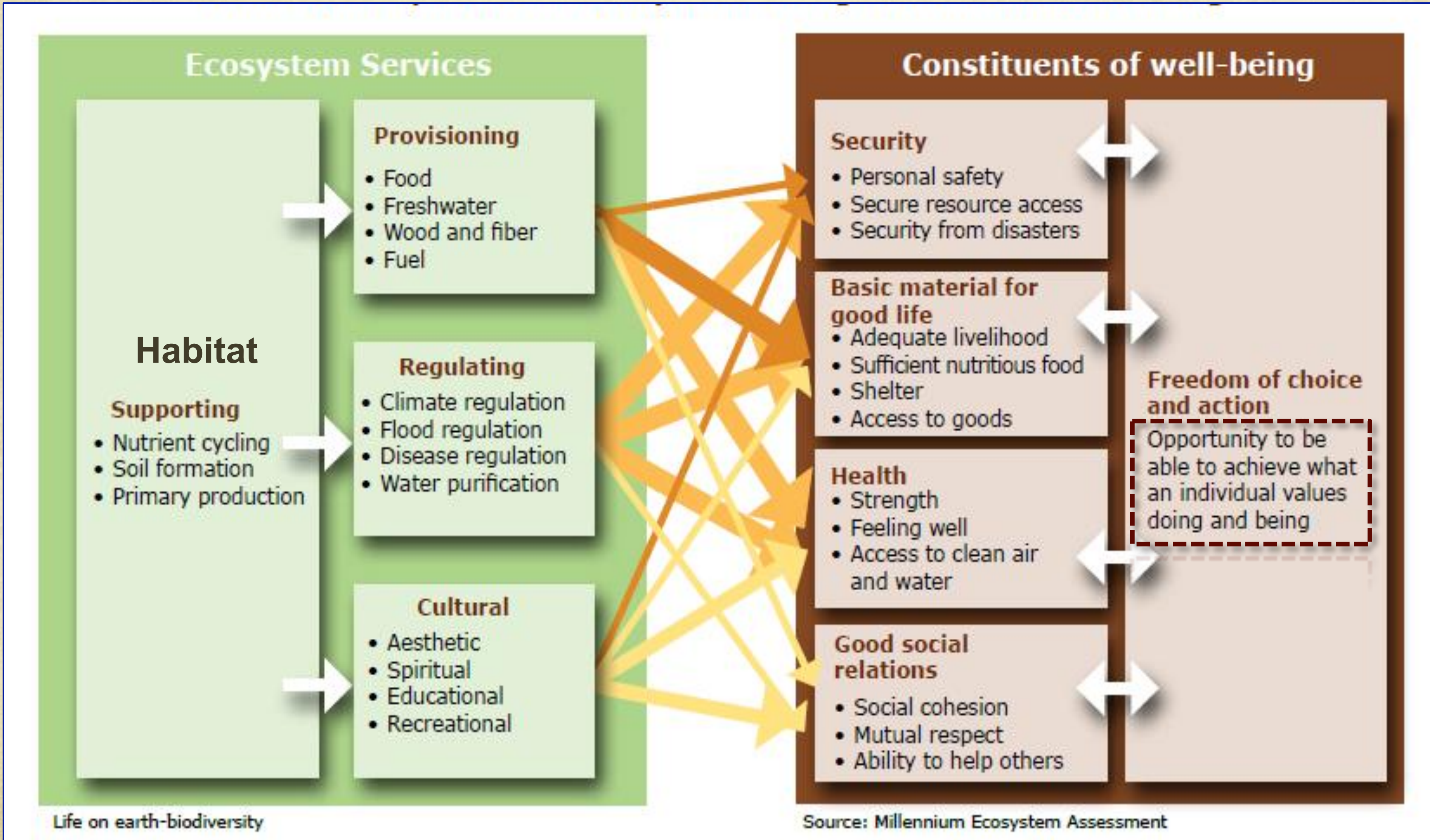
Envision energy like top *food systems*

- Localized strategies enabling **capacity building and co-creation of knowledge**
- **Community Gardens,** *common pool resources*
  - Laureate Eleanor Ostrom: *Governing the Commons*
- Providing **cultural services** beyond marketable goods
- Providing **ecosystems services** that enable our **constituents of well being***

* [UN Millennium Ecosystems Assessment (2005) General Synthesis Report http://www.unep.org/maweb/en/index.aspx Accessed June 2013]

Ecosystems Services

couple to our Constituents of *Well-Being*



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Food and Energy

- **Food Systems informing Solar Energy:** Energy Extension, Solar Co-operatives, Solar Gardens/Farms, Community Solar
- **Agriculture is Solar:** Modern solar resource assessment may add value as another aspect of weather risk contributions
- **Solar for Food Processing:** Dryers, cookers, steam, heat (and *beer*)
- Solar cooking: **societal change for women and avoided fuel use and health benefits** in in Central America, Asia, Africa*

  *[Brown and Lankford. *Sustainability: Clean cooking empowers women. Nature*, 521(7552): 284–285 (2015)]

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Solar and Social Systems

- Law and Policy
- Communication and Solar
- Ethics of Solar
- Cultural Barriers for Change and Adaptation

Goal: human capacity in solar

We wish to grow communities of enthusiastic and informed solar agents

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Solar Ecology Impacts?

- "Young" space to explore an entire ecosystem of science and design (pattern and pattern with a purpose)
- **Numerous access points** with enormous potential for exploration and learning
- **A future of rich solar exploration** and career development for emerging solar professionals
- Fields already being engaged: **Geospatial Information Science, Economics, Meteorology, Communication**
- **Where would *you* like the party to go next?**

Thank you

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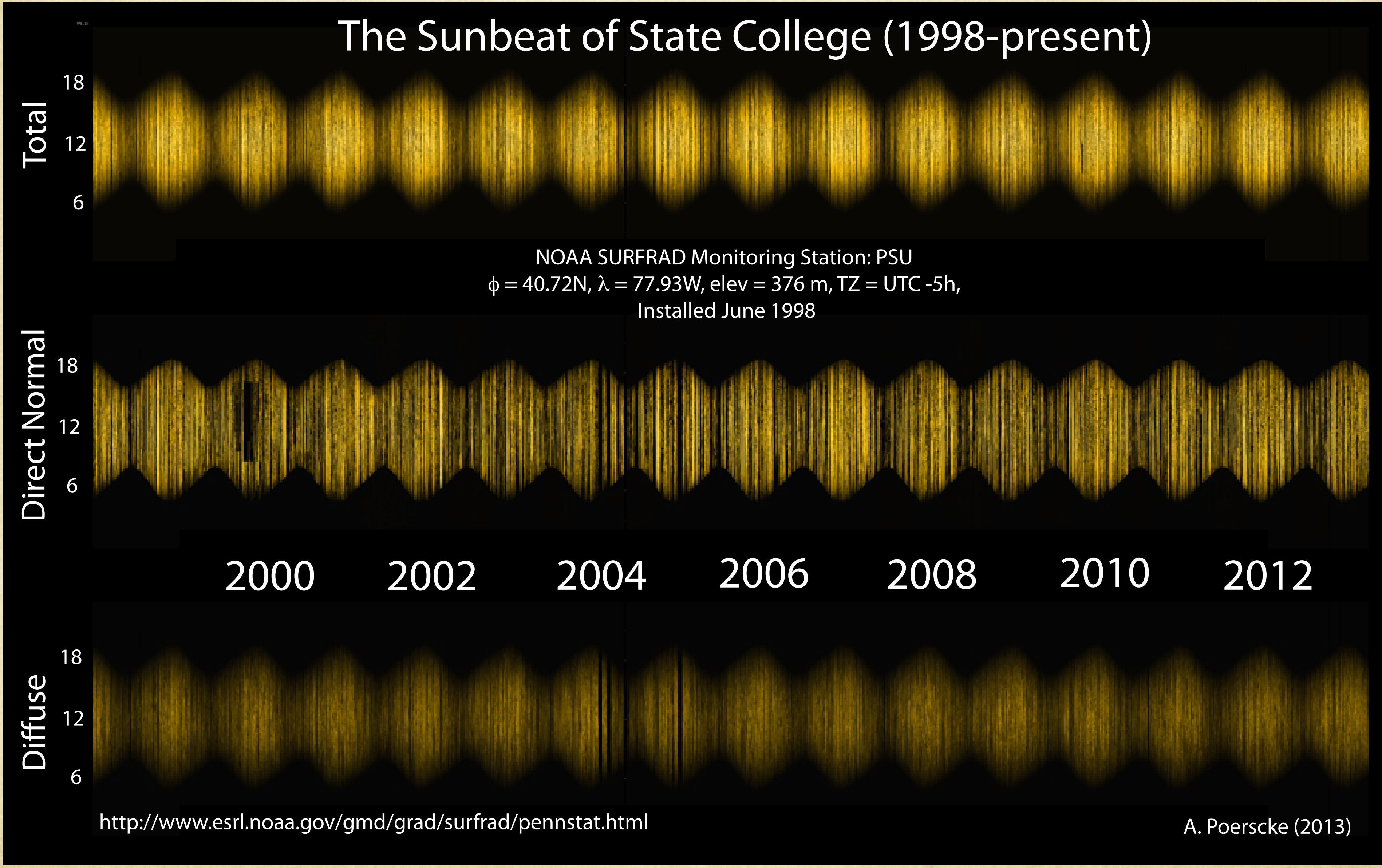
The Sunbeat of State College (1998-present)
Total
18
12
6
NOAA SURFRAD Monitoring Station: PSU
ϕ = 40.72N, λ = 77.93W, elev = 376 m, TZ = UTC -5h,
Installed June 1998
Direct Normal
18
12
6
2000
2002
2004
2006
2008
2010
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Diffuse
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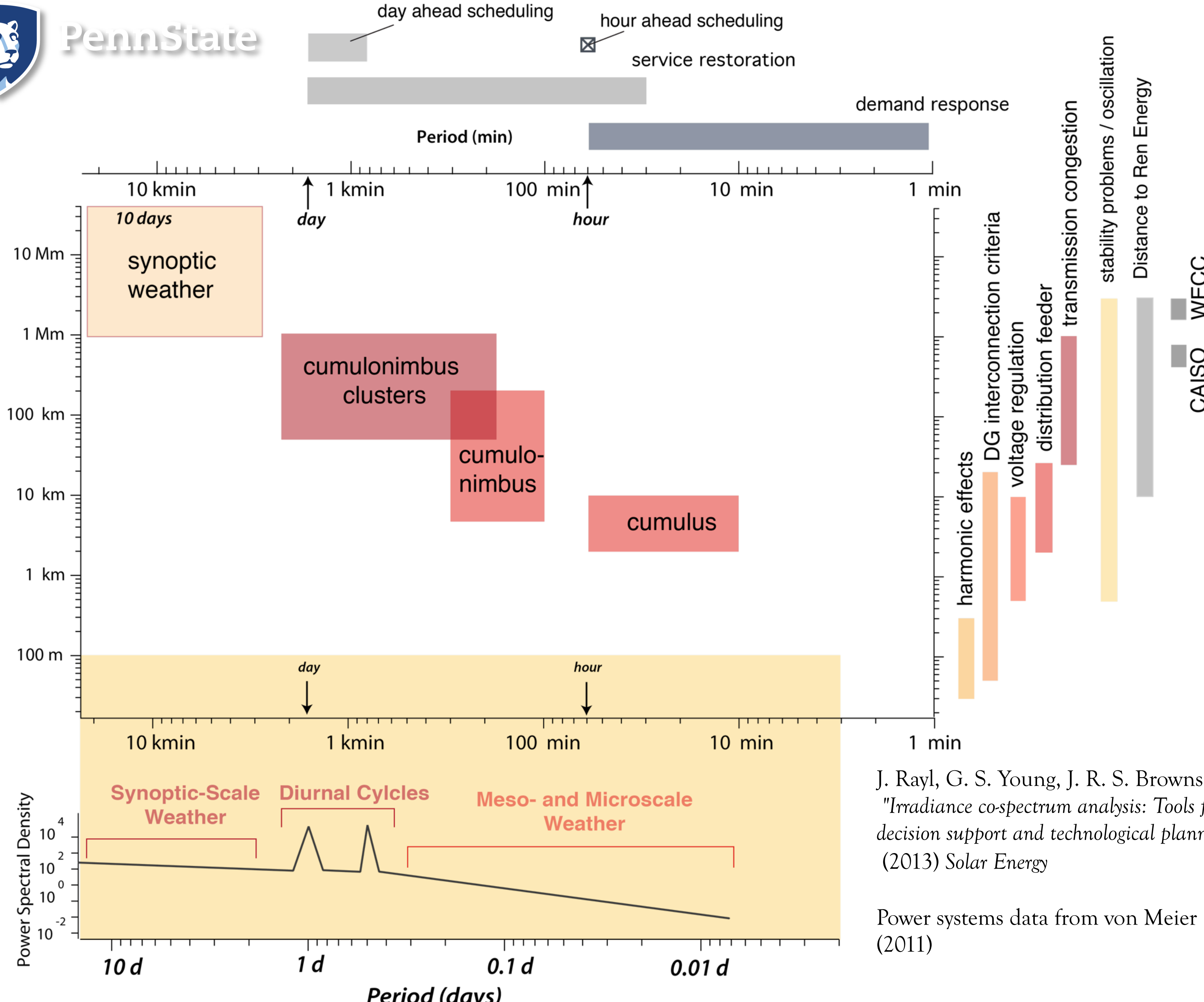
http://www.esrl.noaa.gov/gmd/grad/surfrad/pennstat.html
A. Poerscke (2013)

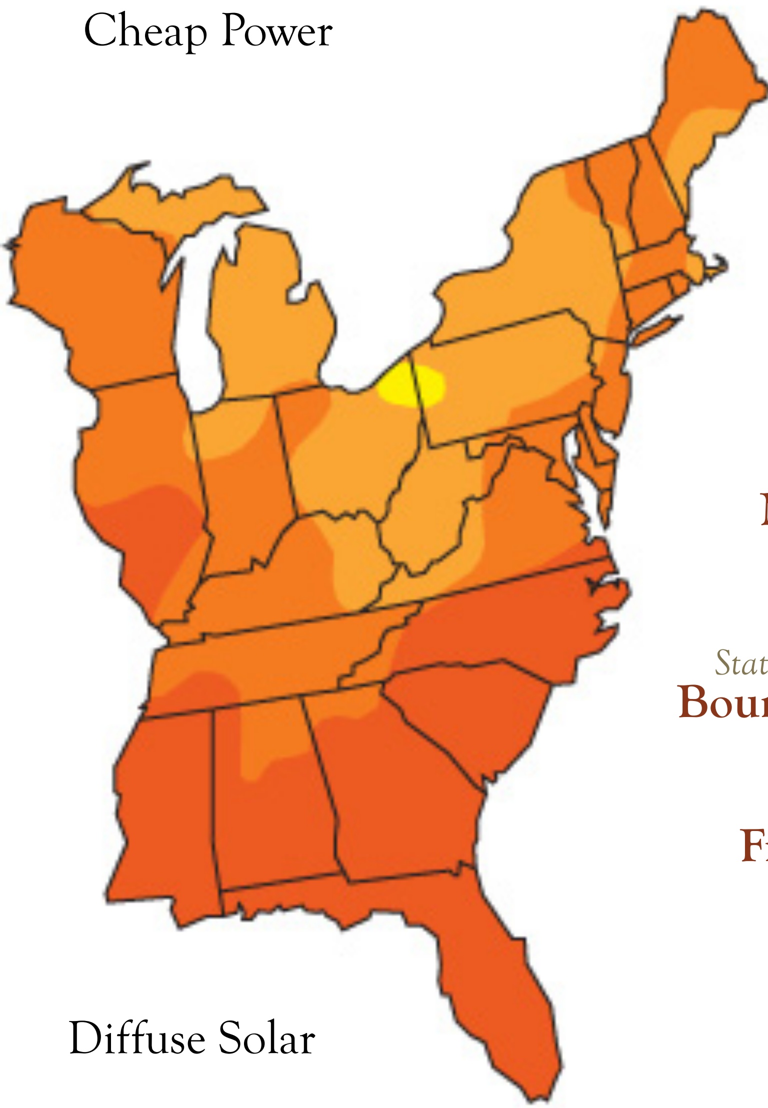


J. Rayl, G. S. Young, J. R. S. Brownson: *"Irradiance co-spectrum analysis: Tools for decision support and technological planning"*. (2013) *Solar Energy*

Power systems data from von Meier (2011)

But not here, right?

Cheap Power



Diffuse Solar

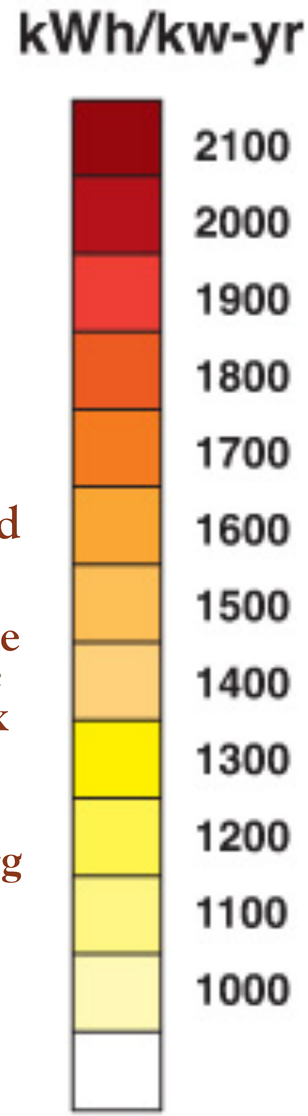
Madrid

Rome

State College

Bourdeaux

Freiburg

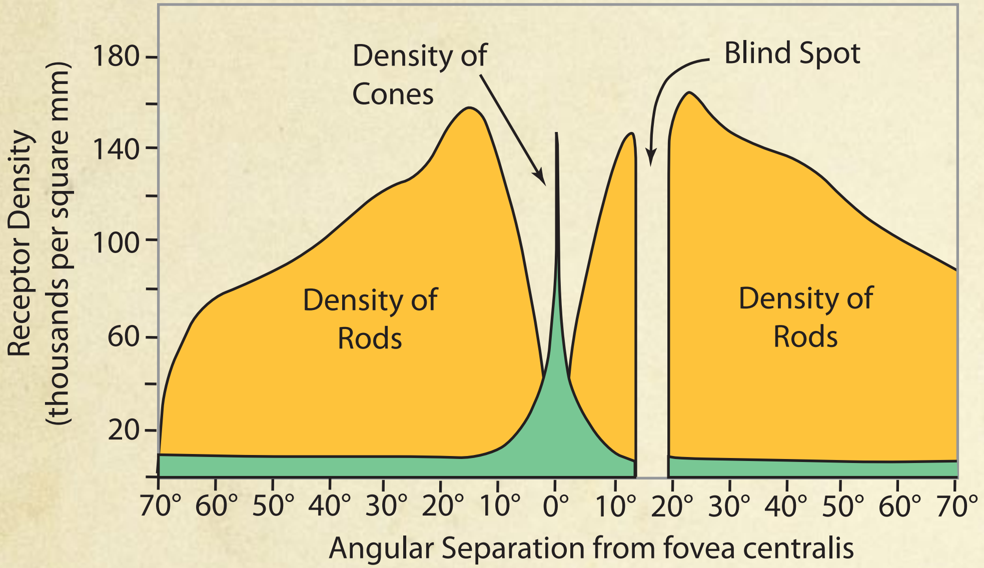


Costly Power

Vast Solar Resource

Image Source: [Hudson Valley PV Alliance]

The Human Eye & the Candela



- Color: **Cones**
- Lens works with cones
- Dim light: **Rods**
- Big range of operation
- Not like a PV panel

- Great for information: **highs and lows**
- Poor on incremental change
- Biased cognition of risk

- No base unit for **radiometry**, only a unit for **photometry.**
- SI unit of luminous intensity: **Candela (cd)**
- Embedded Ethics: **Light emitted as a source, based on the human eye**

http://hyperphysics.phy-astr.gsu.edu/hbase/vision/rodcone.html

Energy Constraint Response

Fuel Constraints:

1. Physically inaccessible
2. Limited access from policy/law
3. Economically inaccessible (high cost fuel)
4. High risk for access

- For periods when fuels were constrained locally, societal innovation led to solar systems solutions
- Constrained Fuels
  - Solar => Ubiquitous
- Unconstrained Fuels
  - Solar communicated as diffuse/ intermittent/ weak / insufficient