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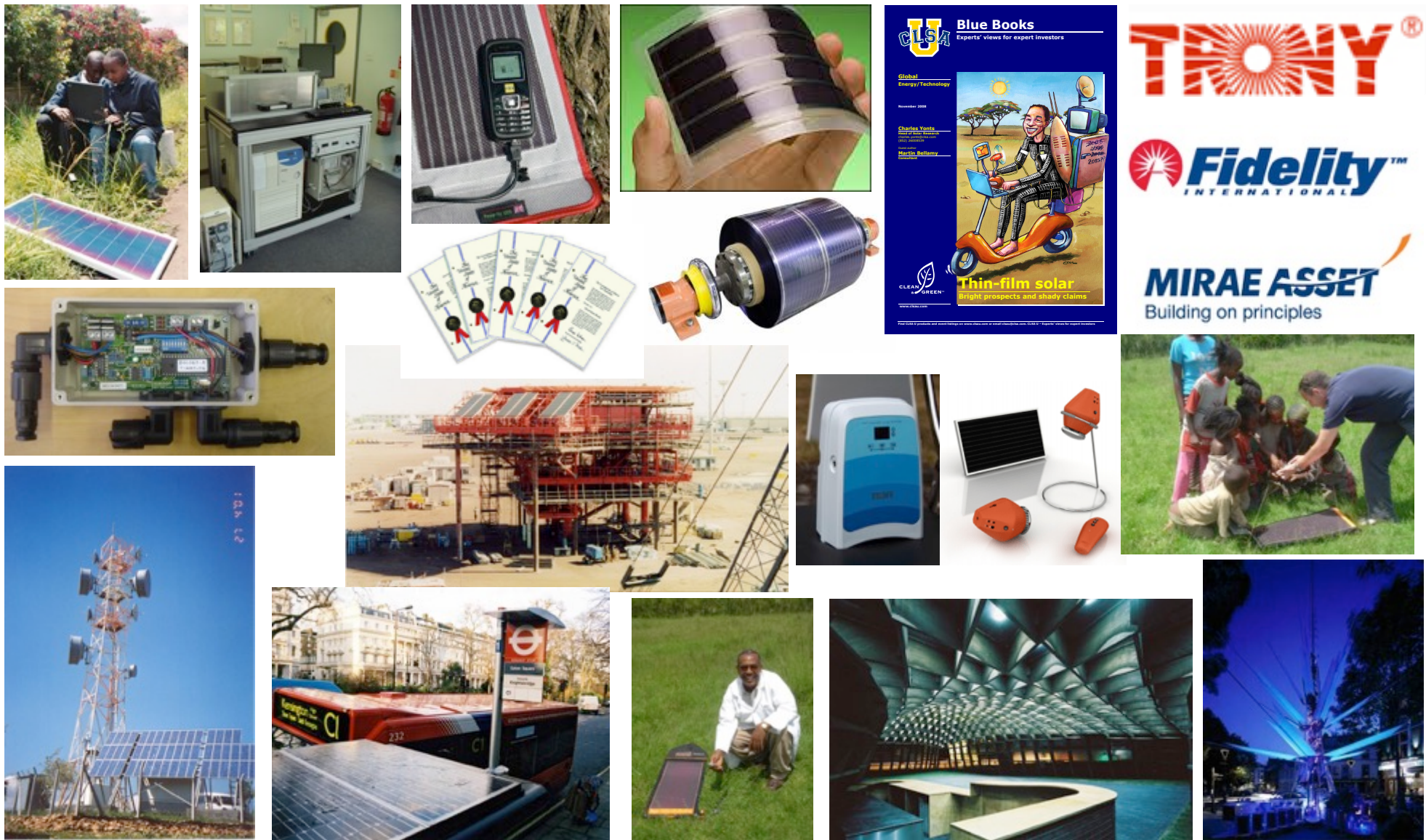
# **Solar Electricity Services in the Developing World**

**Engineers Without Borders**

*University of Exeter and Falmouth University,  
Penryn Campus*

28<sup>th</sup> November 2016

# Martin Bellamy



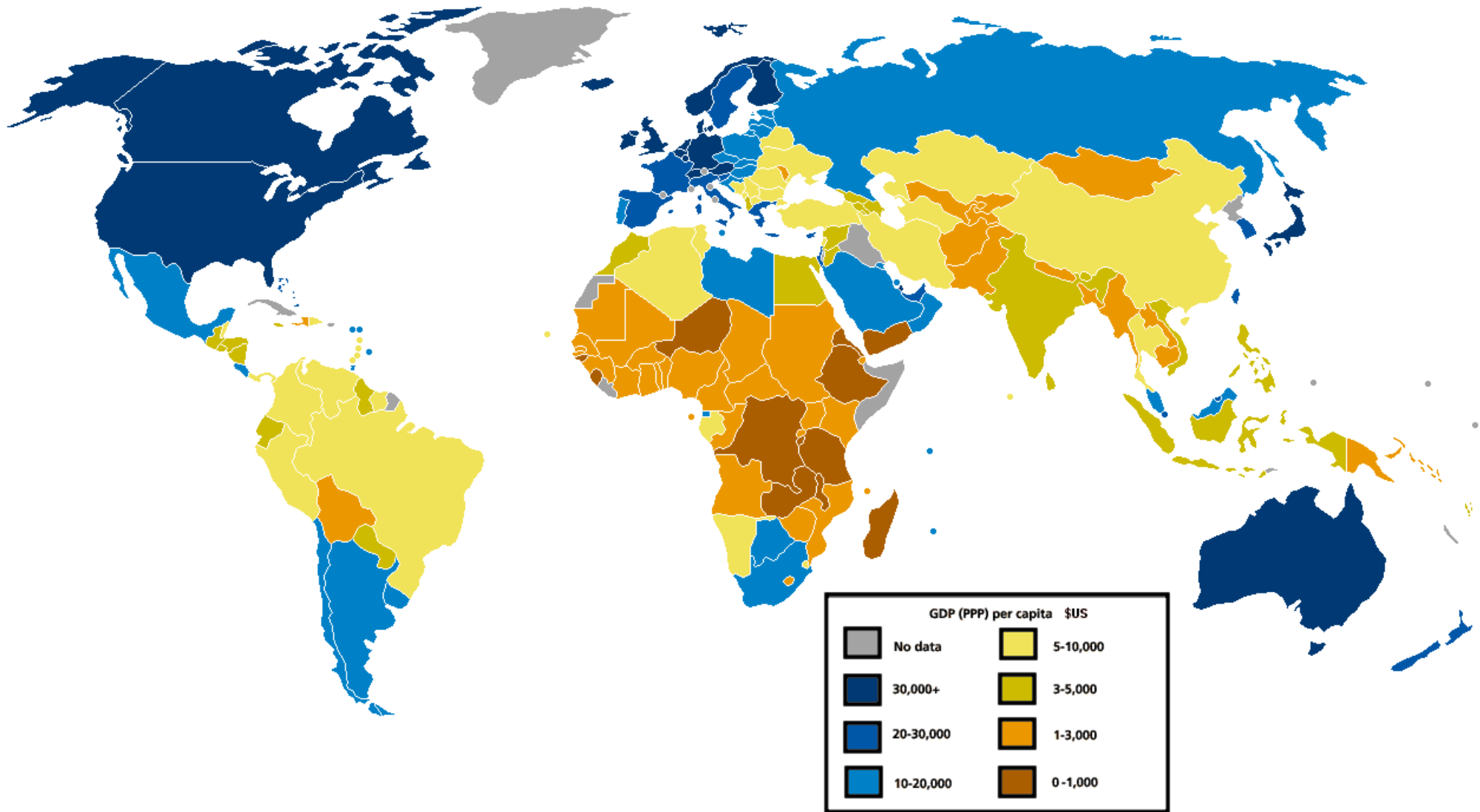
# Overview

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- The grids don't work
- Solar Photovoltaics – PV
- The PV Market
- Energy Services for the Developing World
- Designing Energy Services Solutions
- Language and expectations
- One day, everyone will use solar

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# The 'developing world'



# Why energy access matters

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Modern energy services are crucial to human well-being and to a country's economic development.

Access to modern energy is essential for the provision of clean water, sanitation and healthcare and for the provision of reliable and efficient lighting, heating, cooking, mechanical power, transport and telecommunications services.

International Energy Agency, World Energy Outlook, 2016

# Energy access in numbers



# One type of energy people



# Four types of energy people

**'Reliable' networked grids**



**Unreliable networked grids**



**Limited mains access**



**'Off-grid'**







# The Grids Don't Work

# Grid electricity cannot work



United States



China



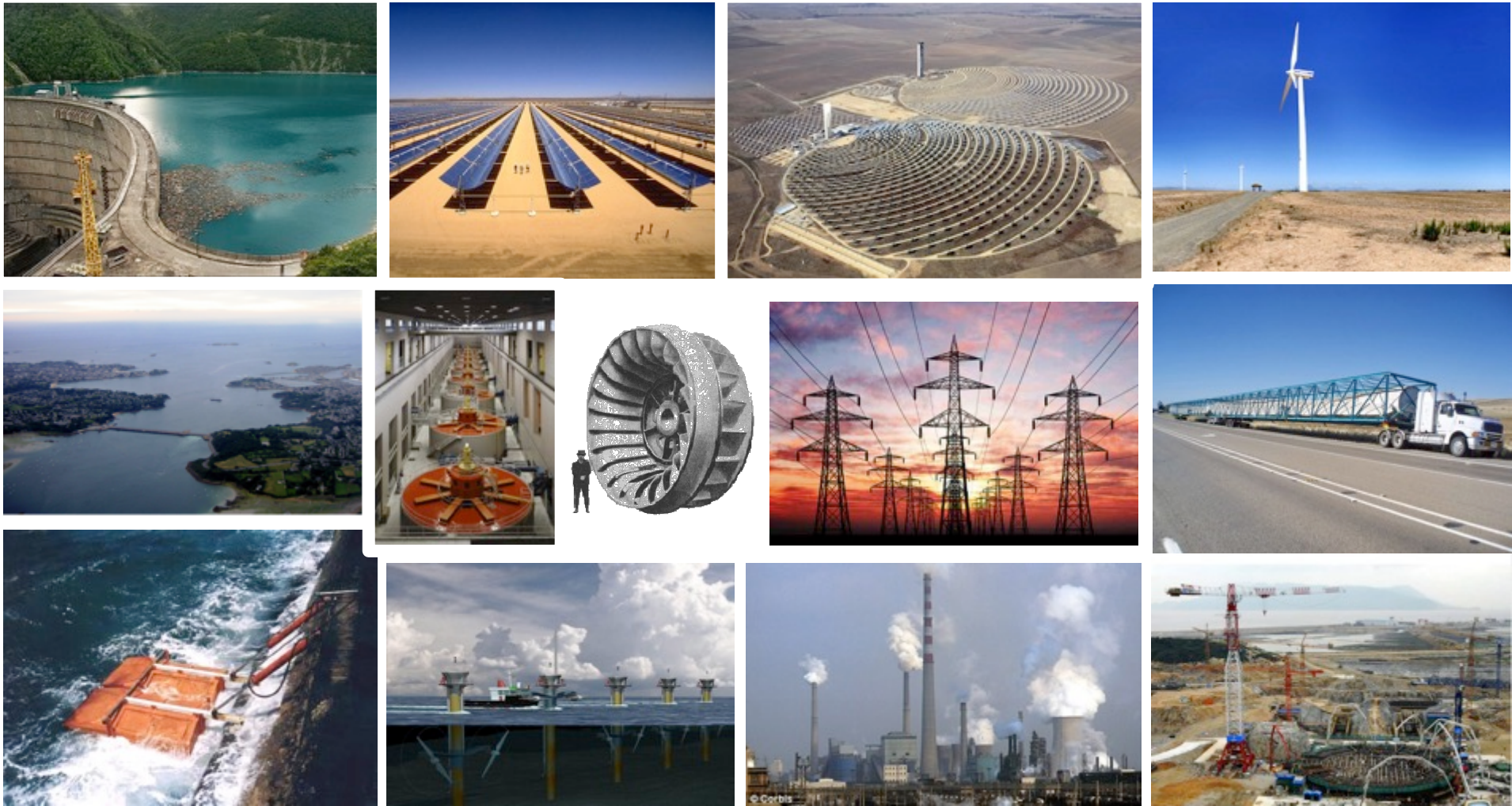
Europe



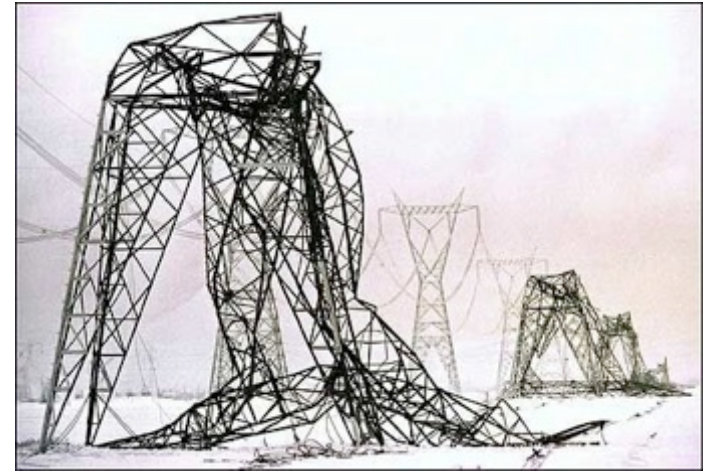
India

# Delivering electricity

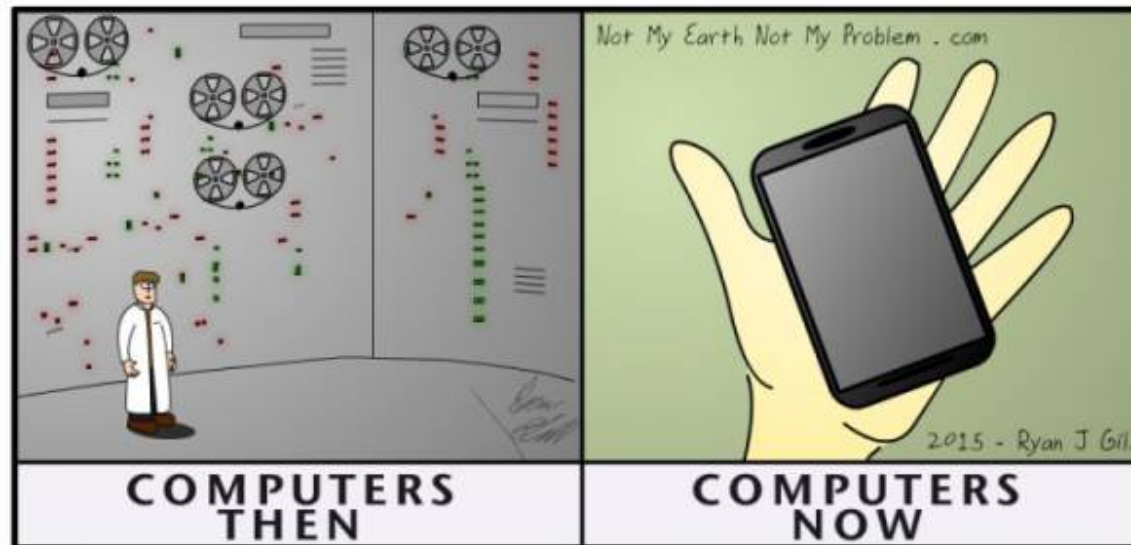
*It cannot be solved using central generation...*



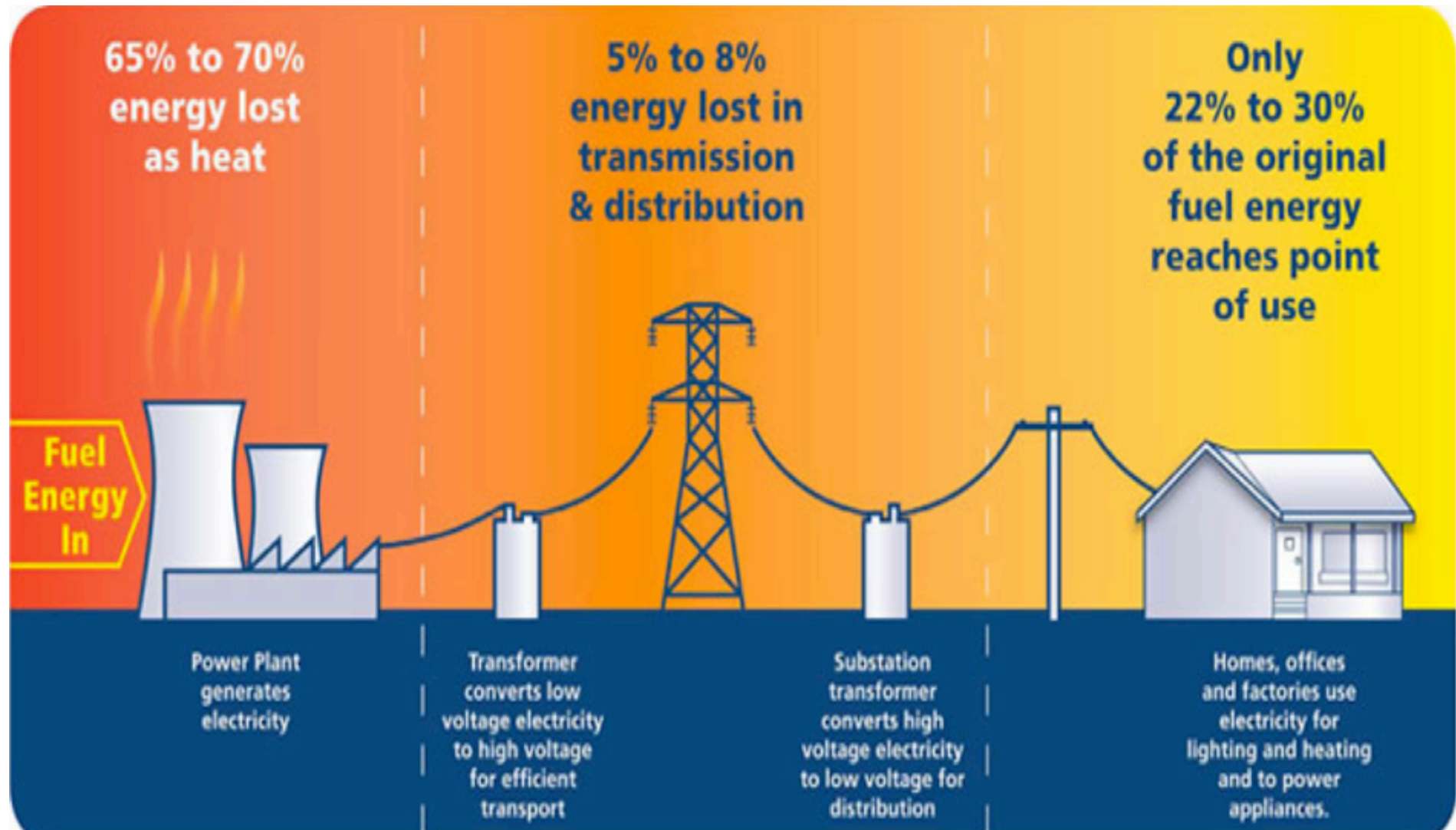
# Out of date option



# Holding back progress



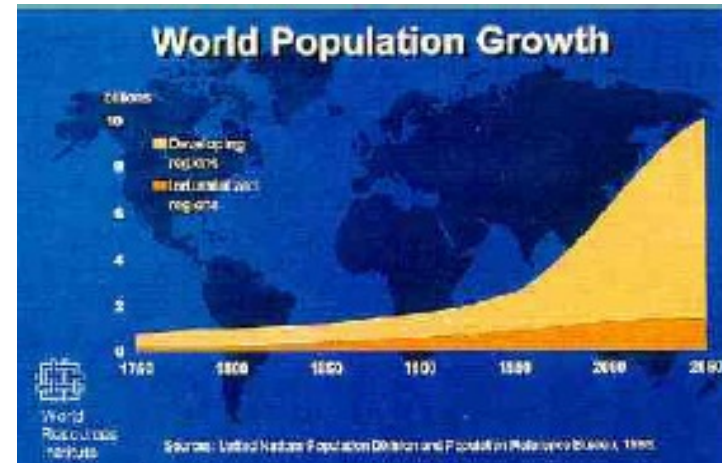
# Delivering electricity - badly



# Of course fuel is a problem



**Increasing demand**



**Limited availability of fossil fuels**



**Energy security**



**Ageing infrastructure**



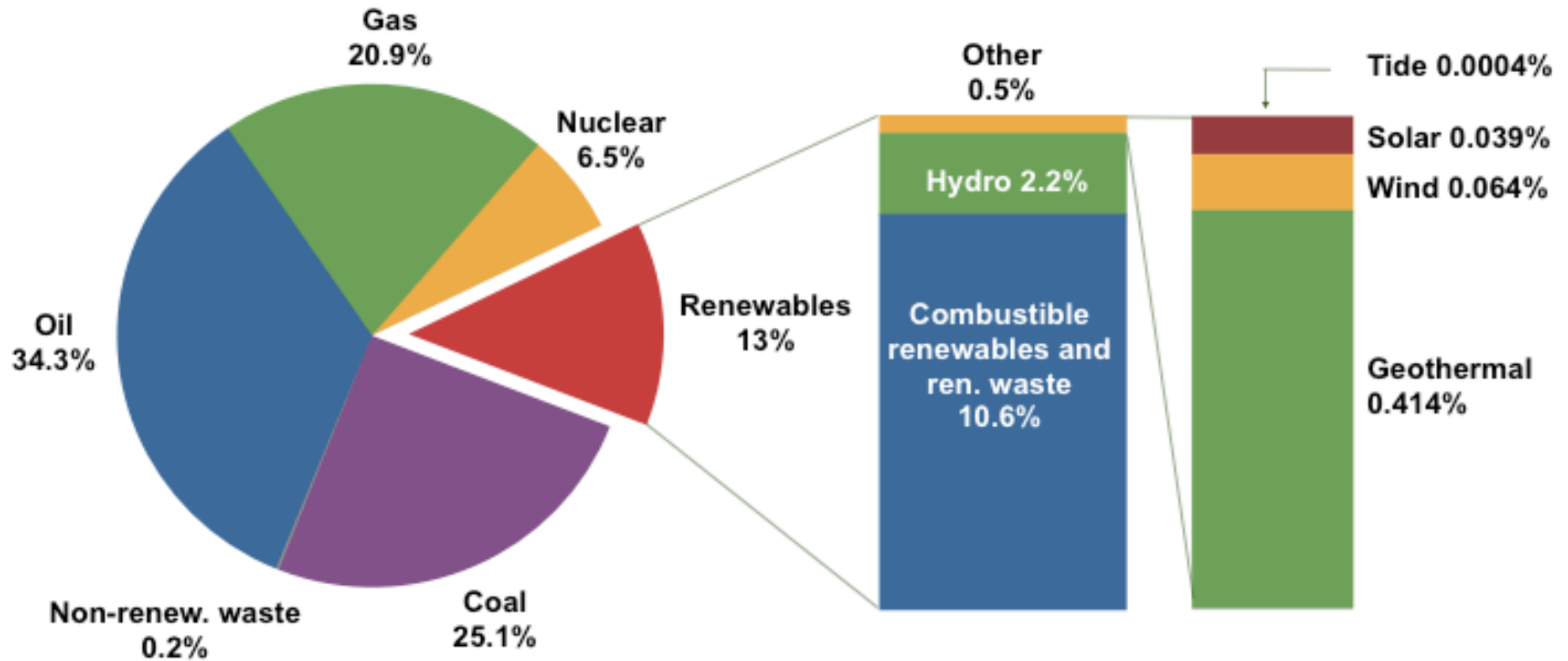
**Climate change**

# How fuel is used - off the grid





# Global fuel dependency



Source: IEA, 2007

# Climate is not a concern



**"HOW ON EARTH DO WE TURN IT OFF?"**

© MATSON  
STAYED HERE ON TRACK  
caglecartoons.com

# Ethical motivation doesn't work

Work with how the world is, not how it should be.



# Pushing LED Lighting

They're healthier and safer,  
with no dirty fuel dependency!



# Disposable batteries

No logic  
No consideration  
No conscience



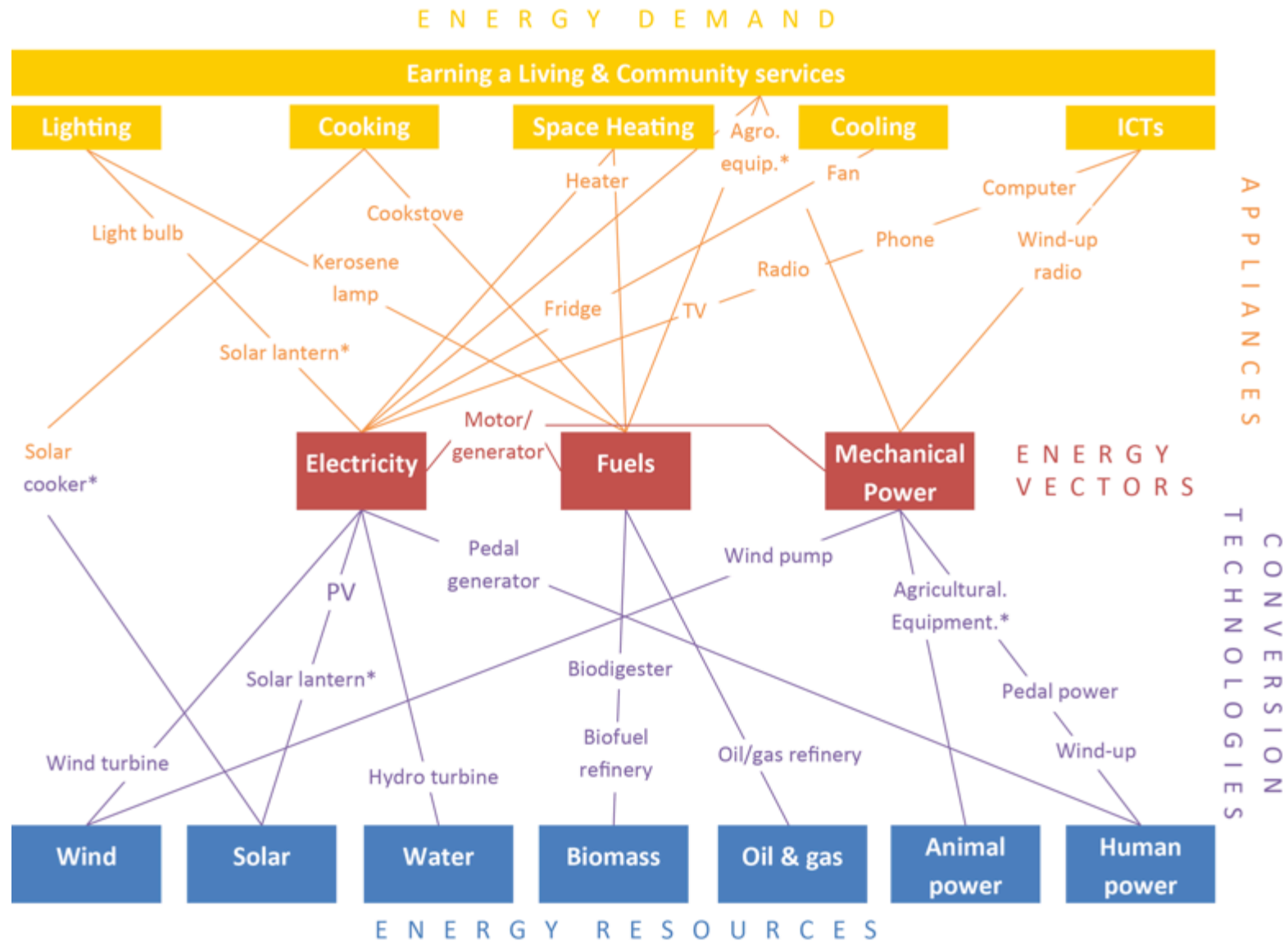
# Nobody wants electricity anyway



# People want services



# Know your options

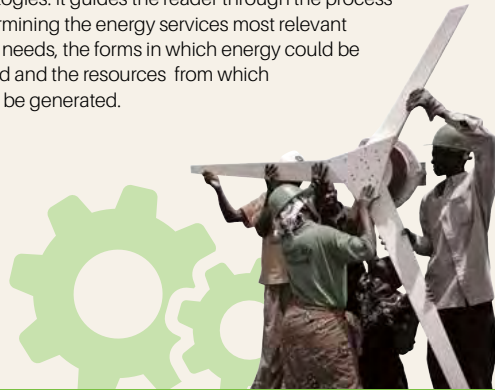




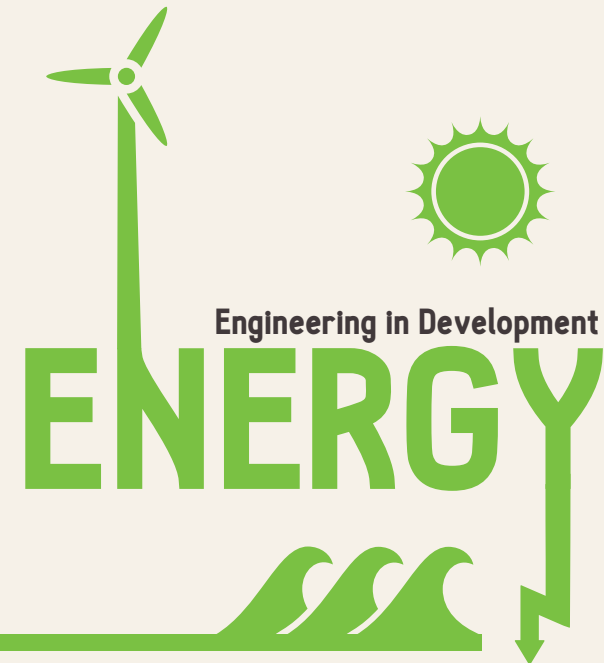
# Be cautious...

Energy enables technology that can improve quality of life for the world's poorest. Access to modern energy services allows women to cook without having to inhale toxic smoke, permits life-saving vaccines to be kept cool and empowers farmers by increasing agricultural yields with irrigation systems.

Engineering in Development: Energy draws on the technical expertise of our many contributors and presents case studies from around the world. It is a technical handbook that takes a systems-level approach to improving quality of life with energy technologies. It guides the reader through the process of determining the energy services most relevant to local needs, the forms in which energy could be supplied and the resources from which it could be generated.



Engineering in Development:  
**ENERGY**



Engineering in Development

**ENERGY**

Jon Sumanik-Leary, Milan Delor,  
Matt Little, Martin Bellamy,  
Arthur Williams & Sam Williamson



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# Solar Photovoltaics - PV

# Two main solar technologies

**Thermal** – using the sun for heating (usually of a fluid)



Cooking

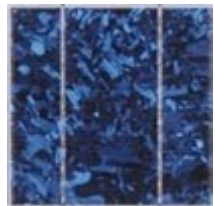


Domestic hot water



Industrial systems using mirrors

**Photovoltaics (PV)** – the direct generation of electricity from light  
Several technologies, which all function the same way



Crystalline silicon

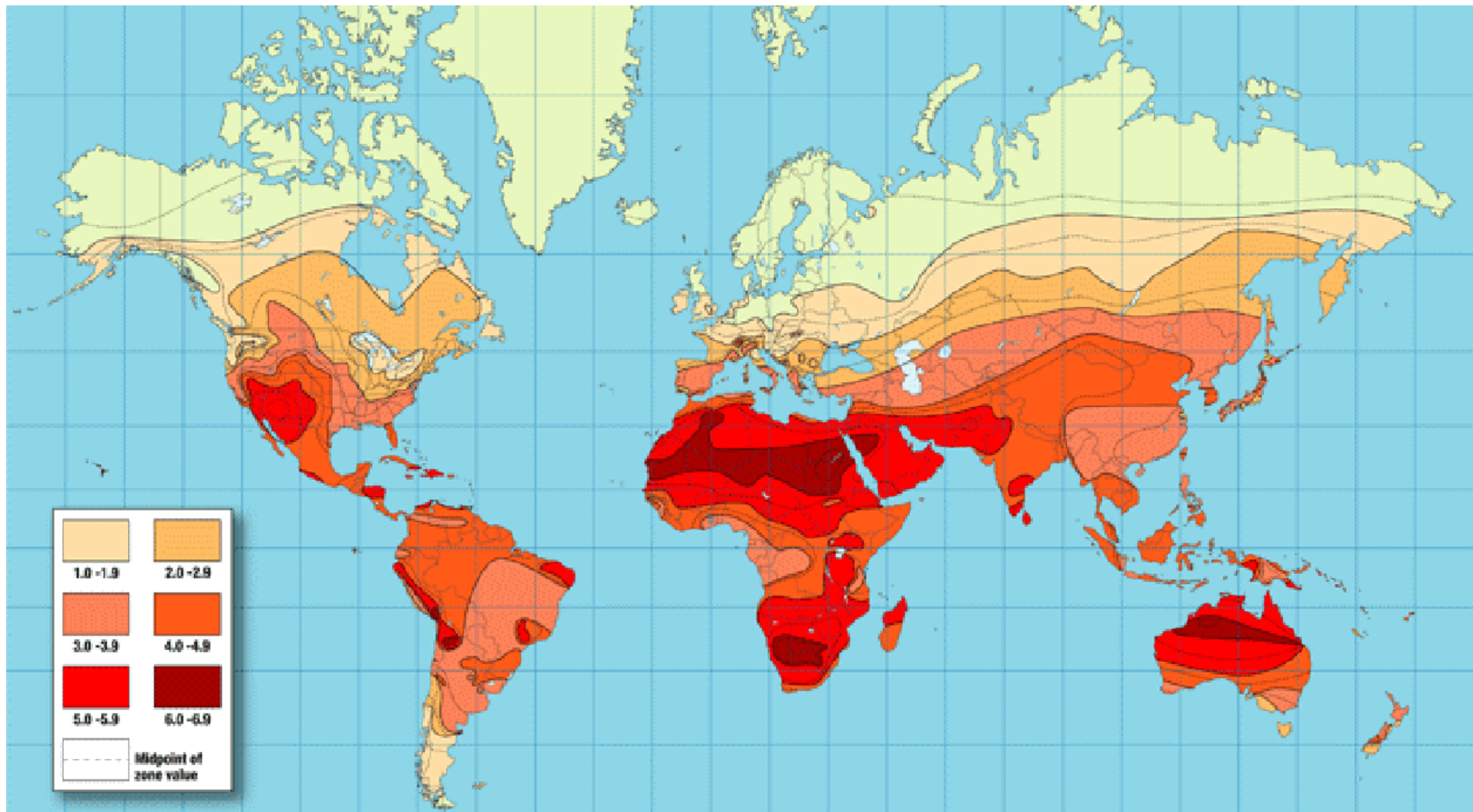


Thin-Film (glass)



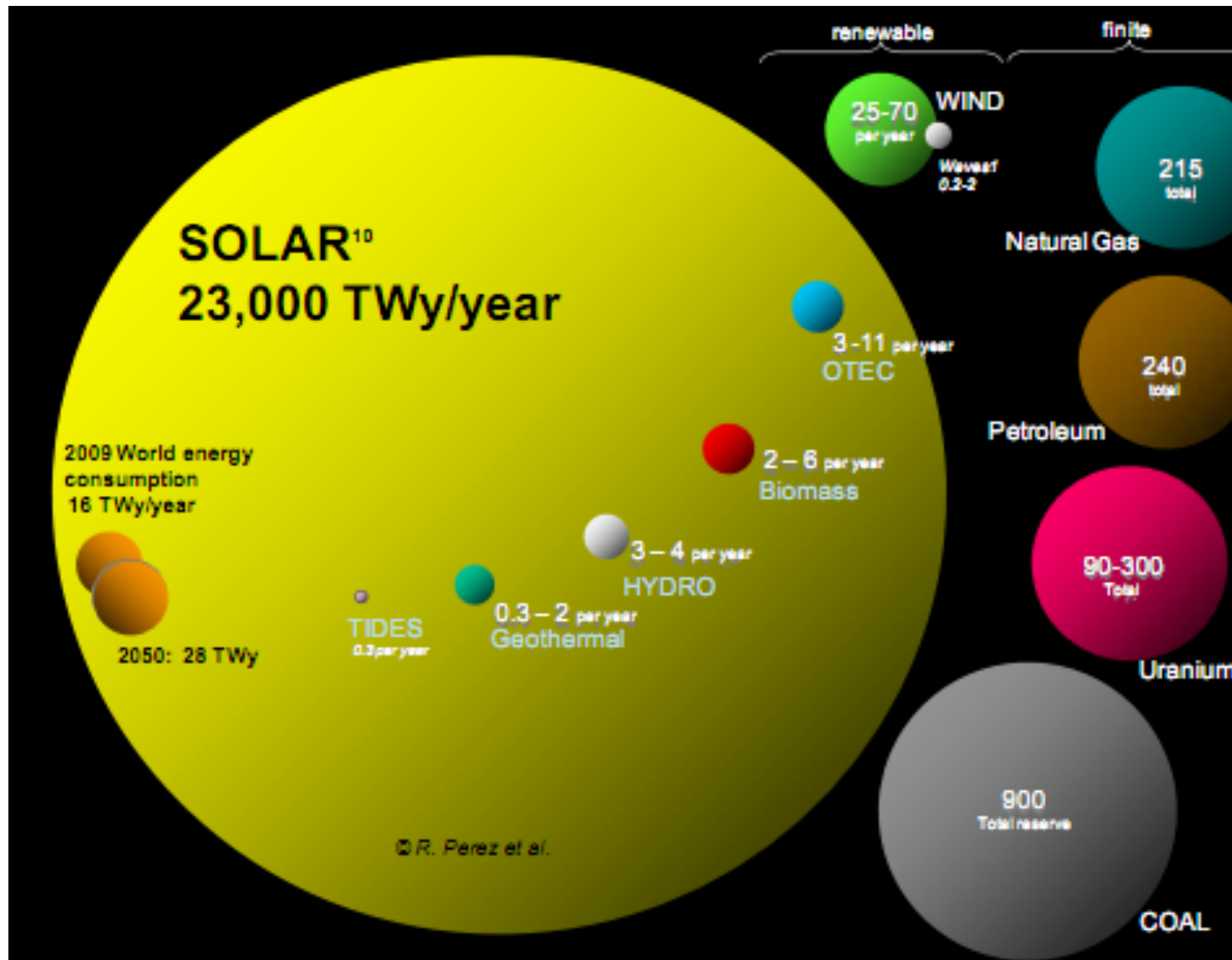
Thin-Film (flexible)

# Sunlight energy is the fuel

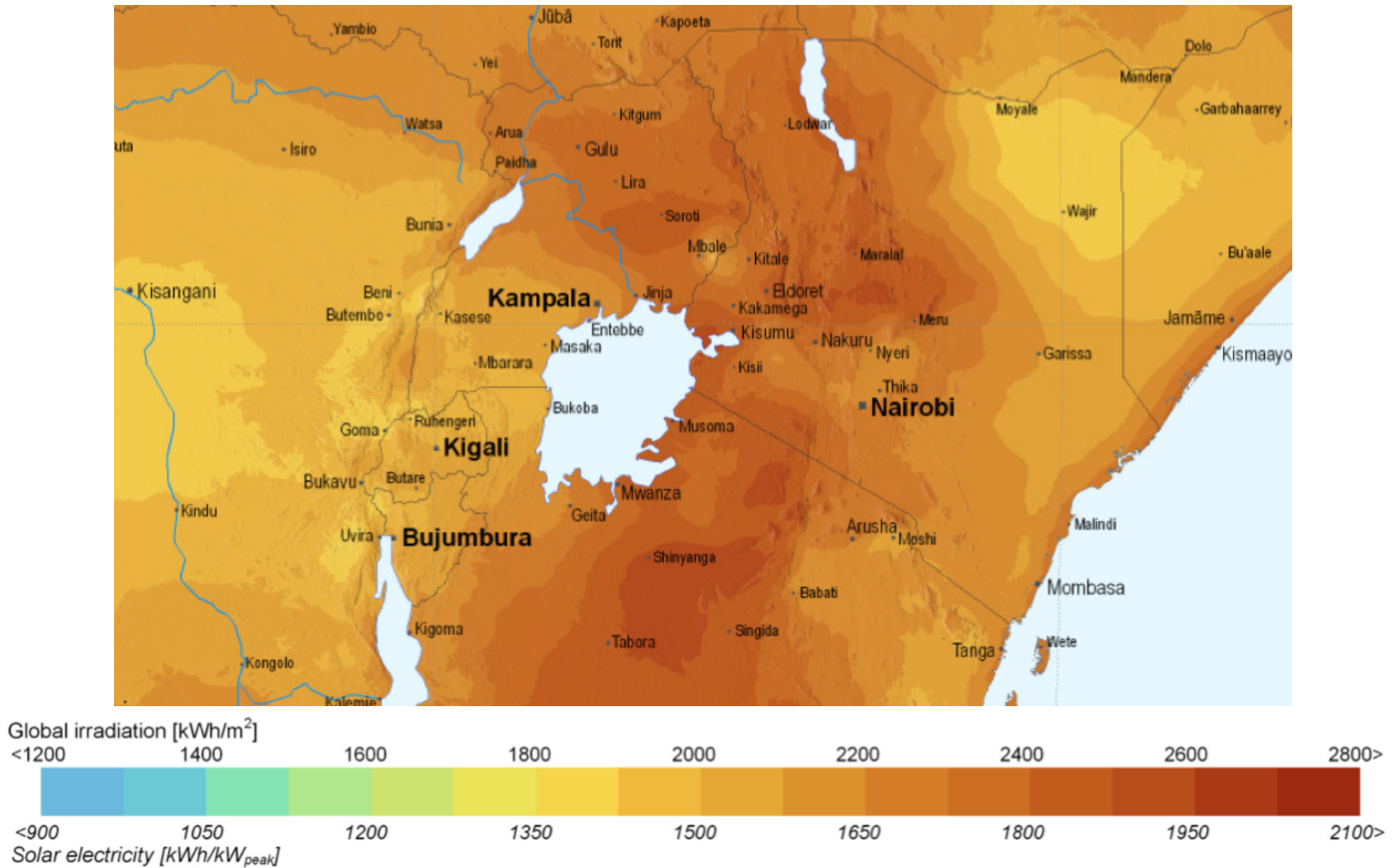


*Electrical generation is directly proportional to sunlight intensity*

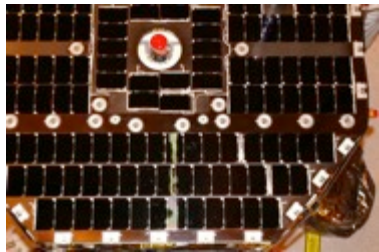
# There is no fuel shortage



# Predictable generation



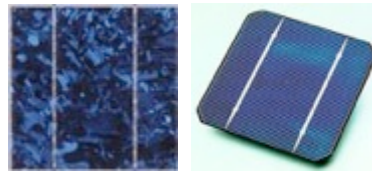
# The main PV technology groups



**Space**



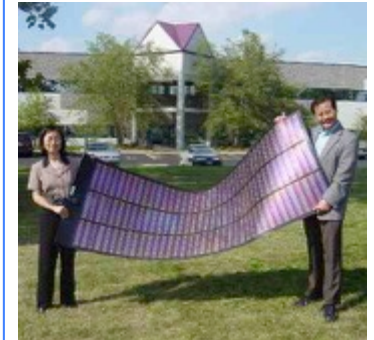
**Concentrated**



**Crystalline**



**Thin-Film  
Glass**



**Thin Film  
Flexible**

# Why PV is so important

- Works almost anywhere
- Very reliable
- Can be almost any size
- No fuel required
- Silent in operation
- Very low maintenance
- Environmentally friendly

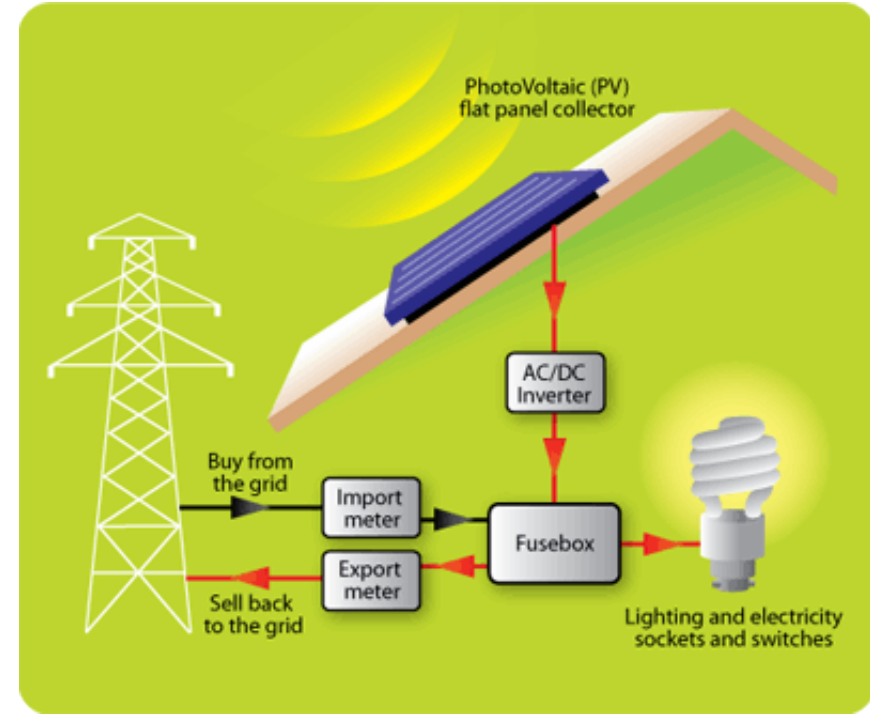
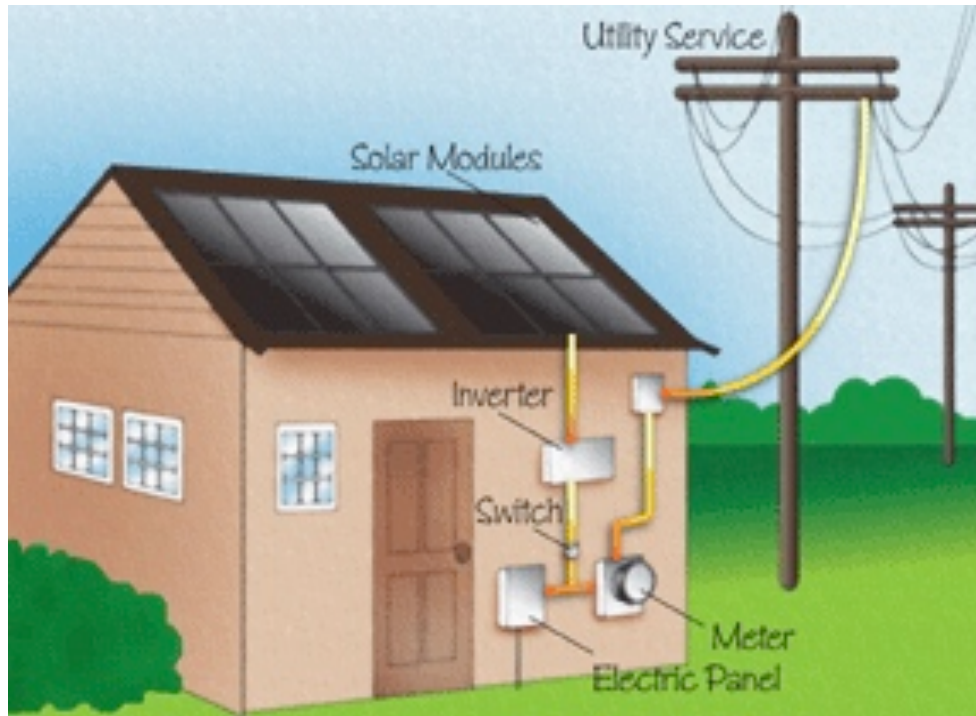






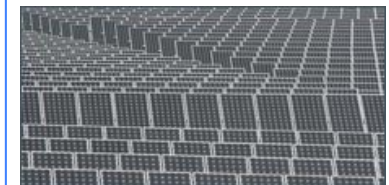
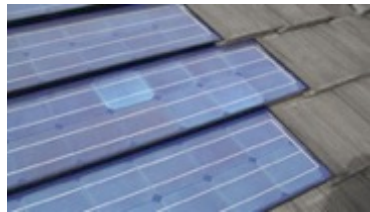
# The PV Market

# Grid-Connected PV Systems



- These systems feed electricity into the mains grid
- They do not operate if there is no mains electricity
- Electricity is only produced during the day, there is no energy storage
- Systems are designed for maximum annual energy generation

# Grid-connect sectors



**BIPV**

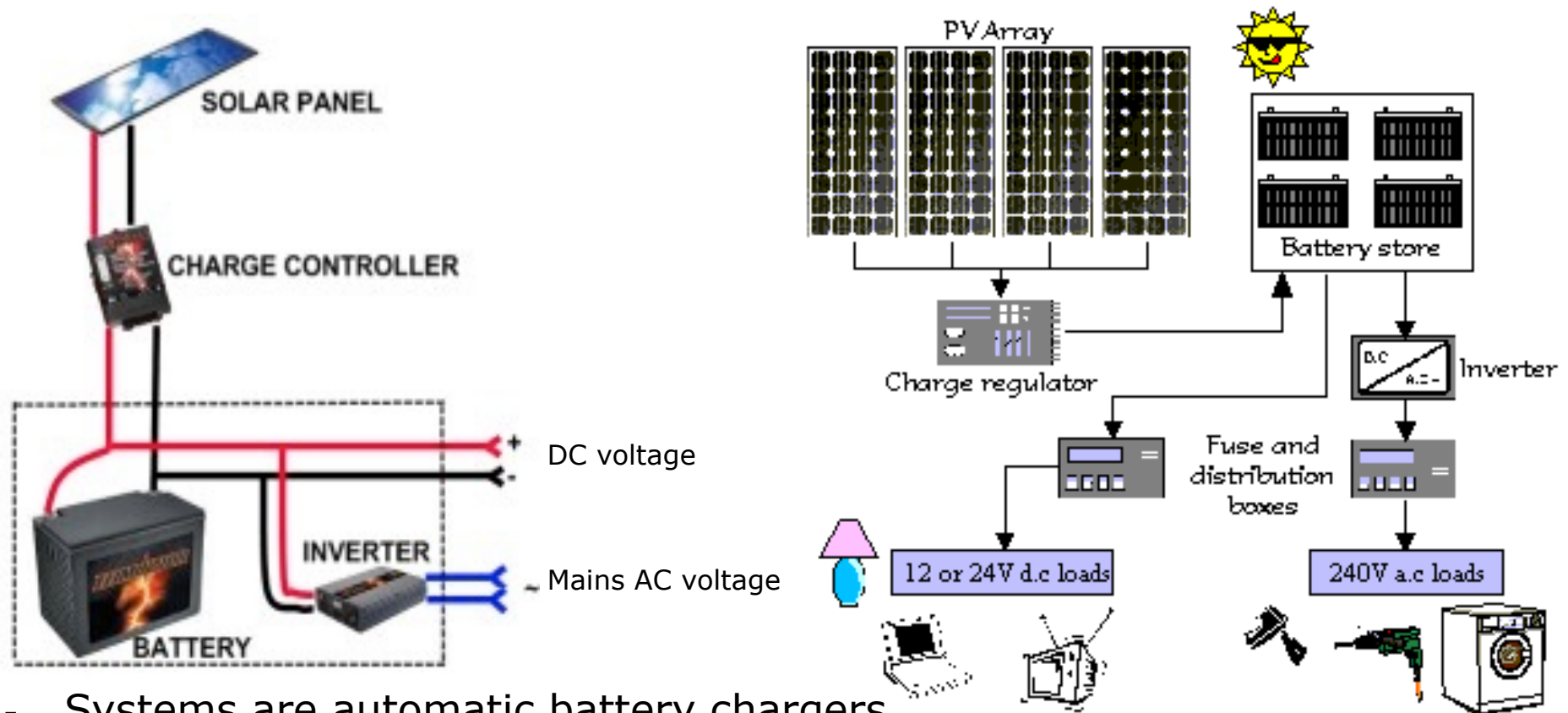
**Residential**

**Small Commercial**

**Large Commercial**

**Utility Scale**

# 'Off-Grid' PV Systems



- Systems are automatic battery chargers
- They provide electricity 24 hours a day
- Systems designed to supply reliable power all year round
- The most reliable form of energy available – when designed correctly

# Example stand-alone applications



# Stand-alone PV sectors



**Bespoke design**

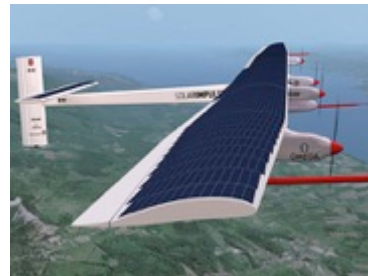


**Regional solutions**



**Portable & consumer products**

# Bespoke designs



# Regional solutions





# Portable & consumer products





# **Energy Services for the Developing World**

# Hundreds of applications

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**There are more applications of stand-alone PV than there are apps for smart phones**

Just a few examples:

- **Medical / health** - *Refrigeration (vaccines, blood, organs), lighting, monitors, water purification*
- **Communications** - *mobile phones & networks, computers & wireless networks, Satellite & international phones*
- **Rural electrification** - *Electric fences, security, irrigation, lighting (domestic & community)*
- **Media & IT** - *Schools & colleges computers, TV, Radio, internet access, educational films, etc.*
- **Transport** (road & rail) - *Lighting, signaling, warning signs, monitoring*

# Common generic services

- Phone charging
- **Lighting**
- ICT
- Monitoring
- Media and entertainment
- Refrigeration
- Device charging
- Battery charging
- ICT peripherals

## Lighting:

- portable navigation (torches)
- Street and **amenity lighting**
- kerosene lamp replacement
- personal reading/craftwork/food preparation
- domestic rooms of all sizes
- public and commercial buildings of all sizes
- public services (toilets, emergency phones)
- Medical lights
- Security and safety

## Amenity lighting:

- Walkways
- Car parks
- Gathering and trading areas
- Healthcare waiting areas
- Building security
- Perimeter area
- Hazardous areas (holes, cliff edges, water, wildlife, etc.)

# Sectors of society

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- Healthcare
- Education
- Communications
- Business and commerce
- Personal devices
- Rural electrification
- Community energy
- Infrastructure
- Domestic services
- Shelter and enclosures
- Water and agriculture
- Transport
- Marine
- Security
- Recreation
- Outdoor pursuits
- Consumer and lifestyle
- Gadgets, gifts and toys
- Military
- Indoor

# Distributed Solutions – off-grid



**Resource limited, skills dependent**



**Limited use**

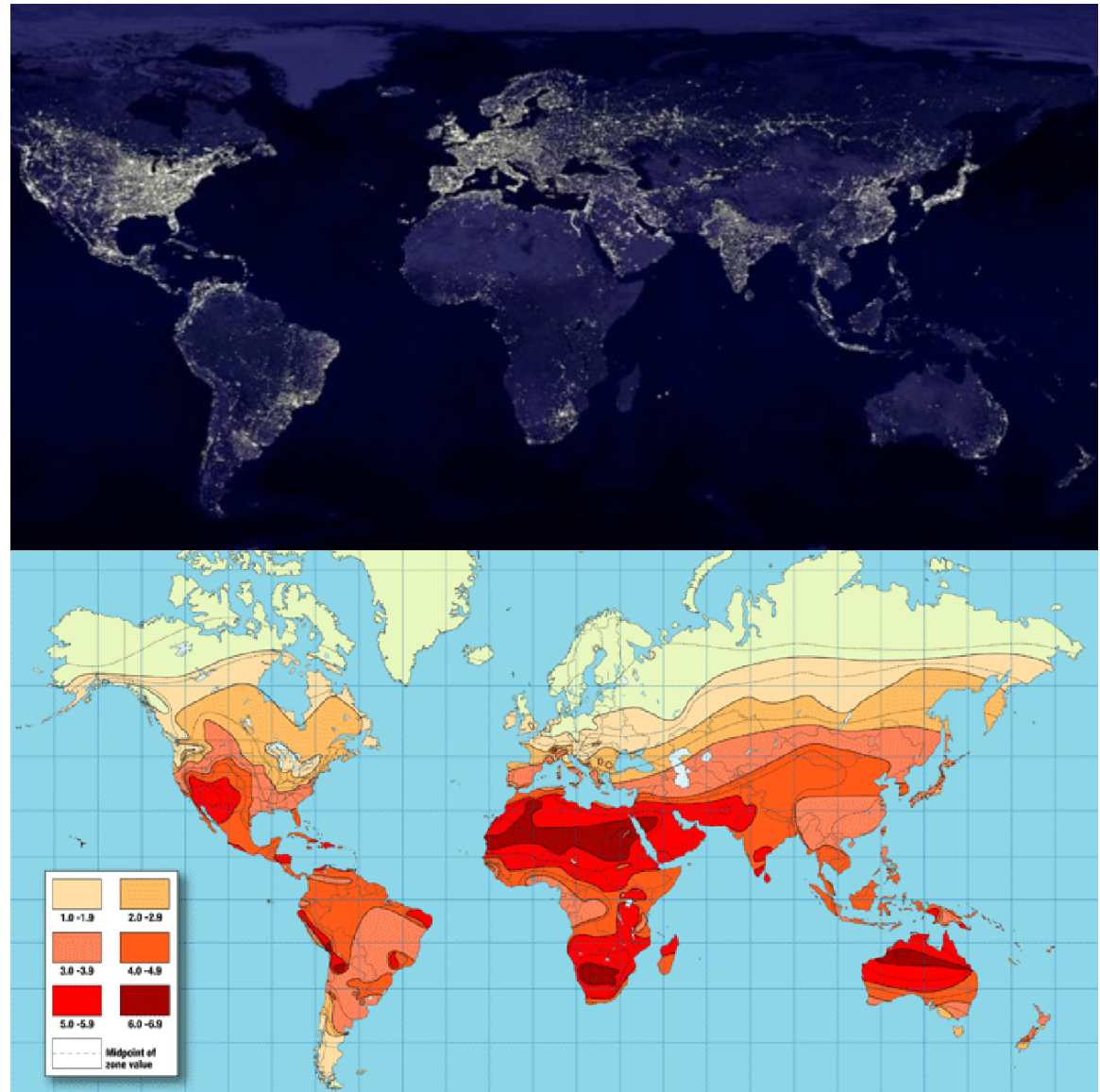


**Fuel dependency**

# Ideal for the developing world

- ❑ No or unreliable mains grid
- ❑ High levels of sunlight energy
- ❑ Largest customer base
- ❑ Strong demand
- ❑ Strongest value for PV
- ❑ Weakest competition
- ❑ Highest commercial potential

The method of implementation is critical



# Bigger is not always better





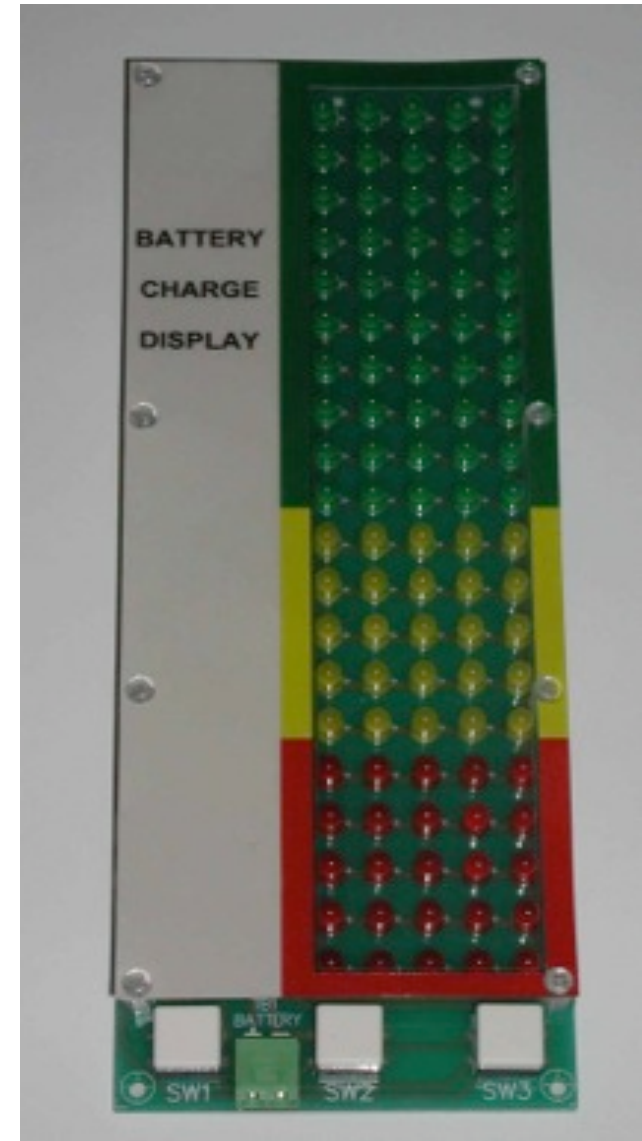
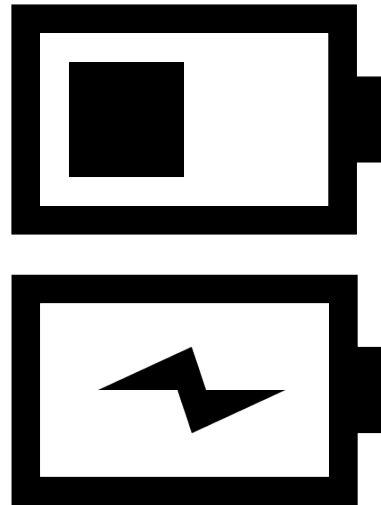
# Local ownership



# Correct PV use is essential



# User Displays



# Maintenance



# User engagement is critical

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**A product's lifespan, versatility, performance and value for money are all inextricably linked with its user's involvement and appreciation**

# How to engage users?



# It doesn't have to be a burden



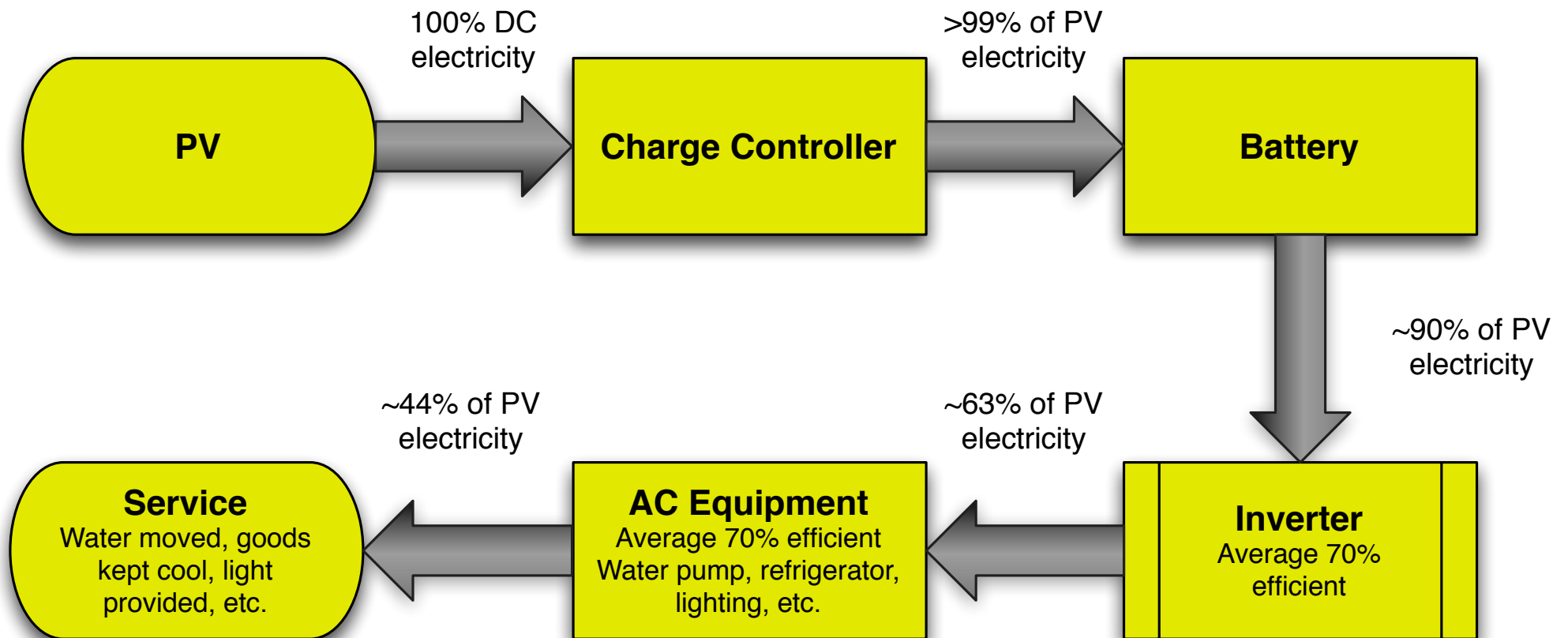


# **Designing Energy Services Solutions**



# Holistic solutions

## Typical AC solution with inverter and inefficient user equipment



# Efficient equipment



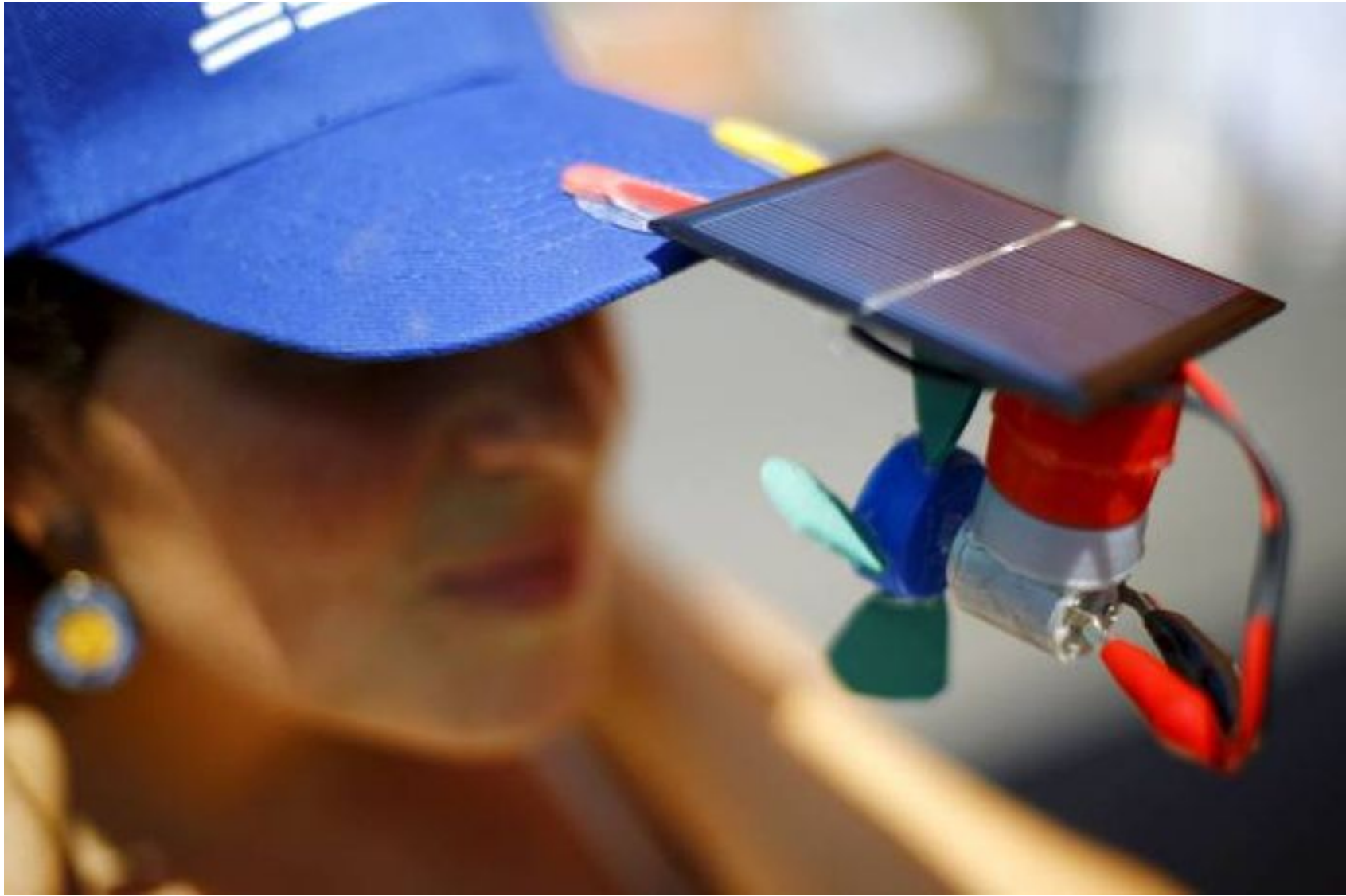
# Inefficient people

A person can make an inefficient appliance work efficiently.

A person can also do the opposite.



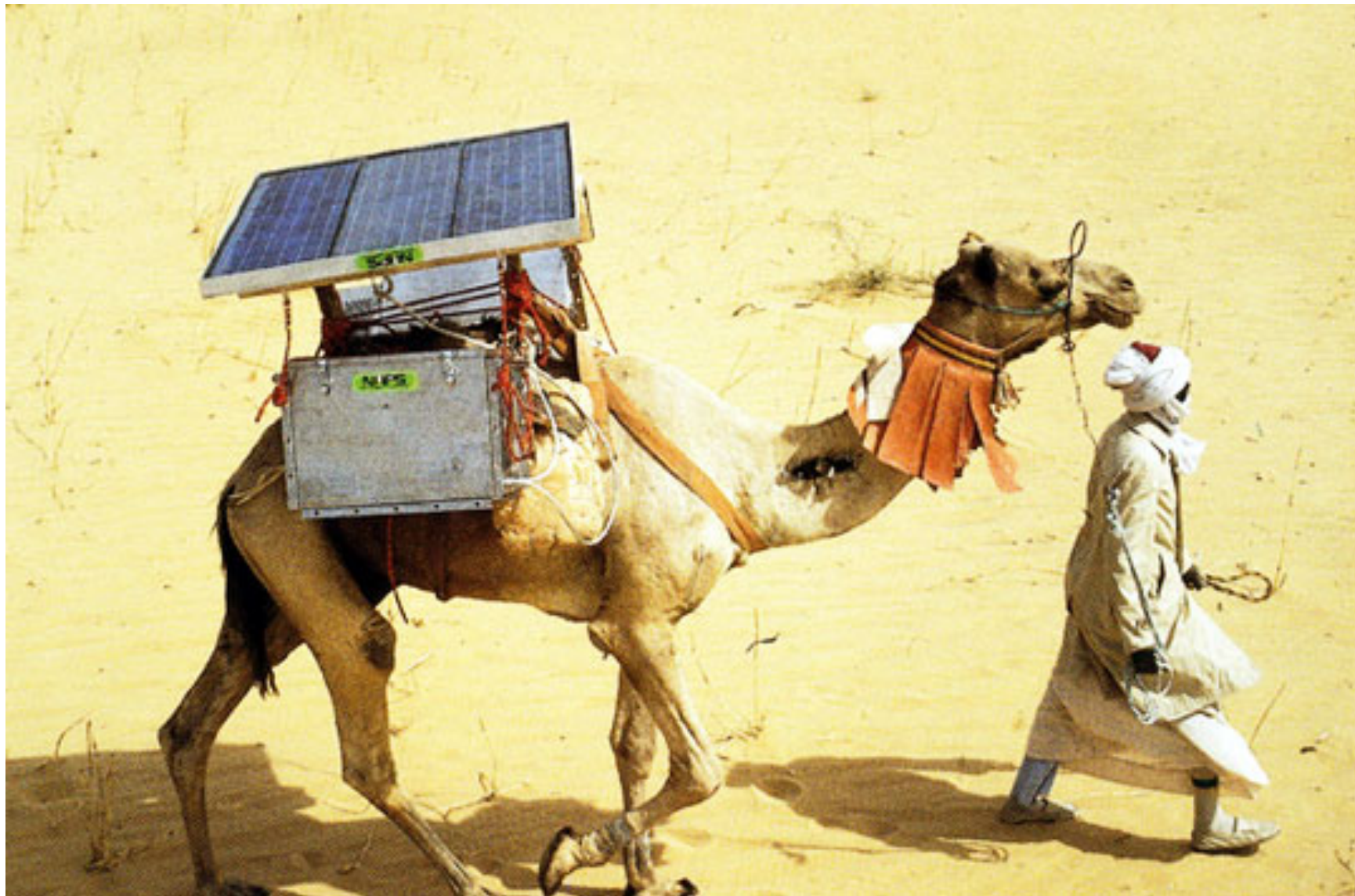
# It is not just about functionality



# Fitness for purpose?



# It can't always be elegant



# Understand product use

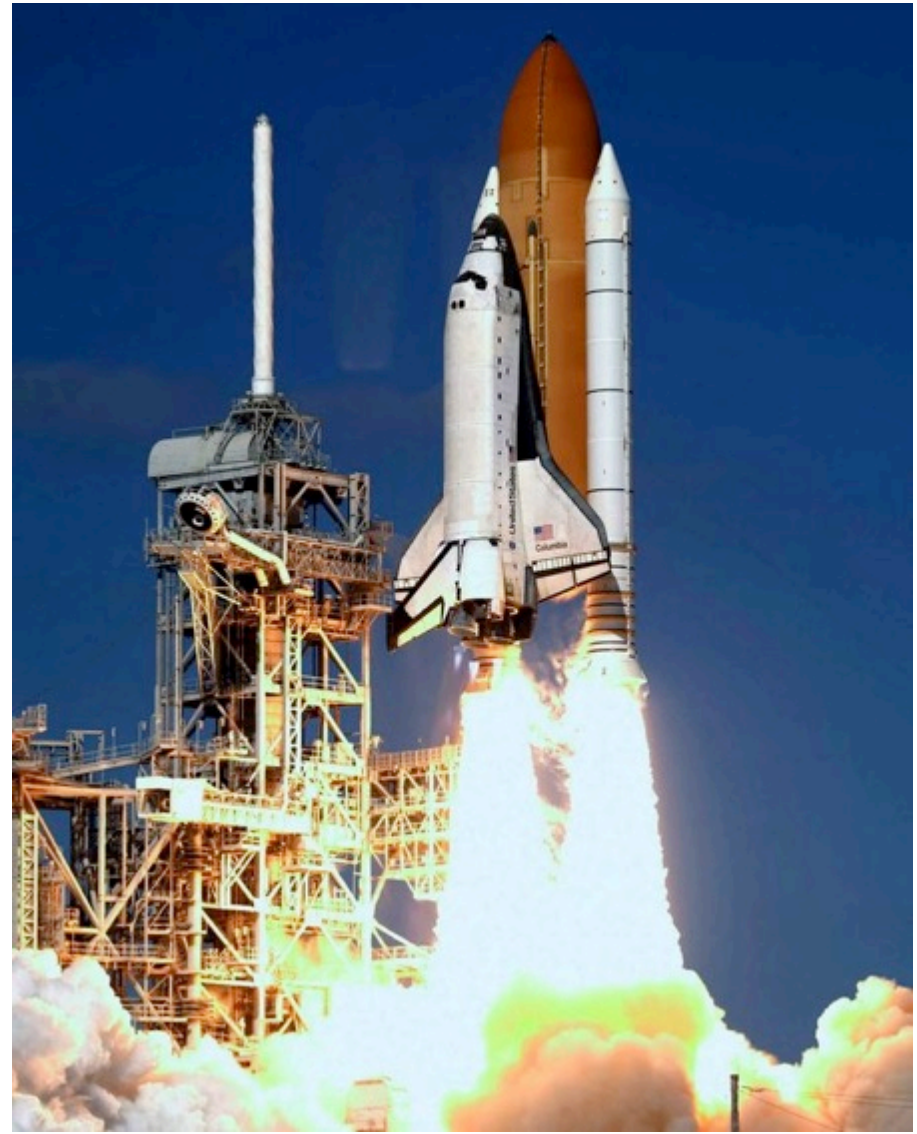
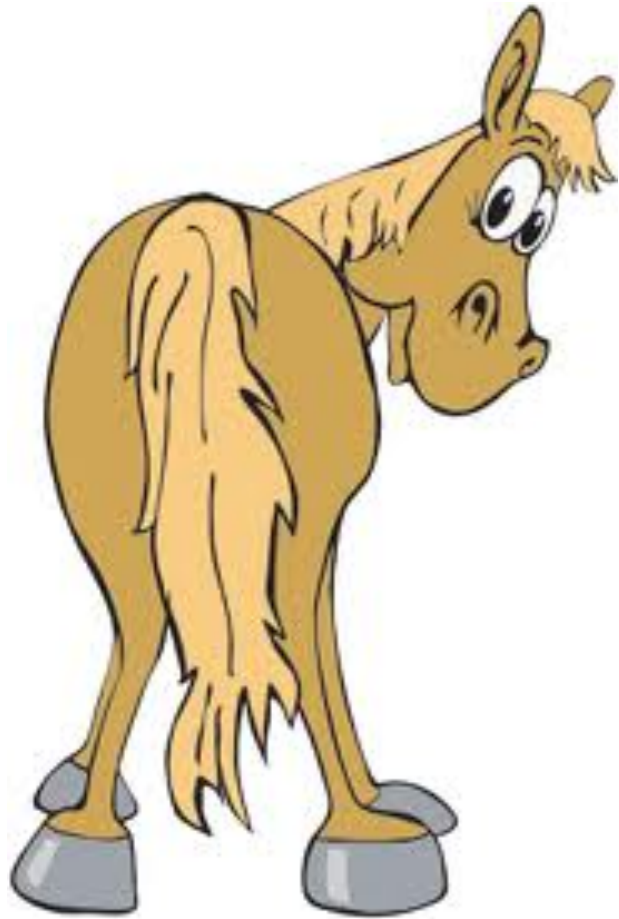


# Safety matters

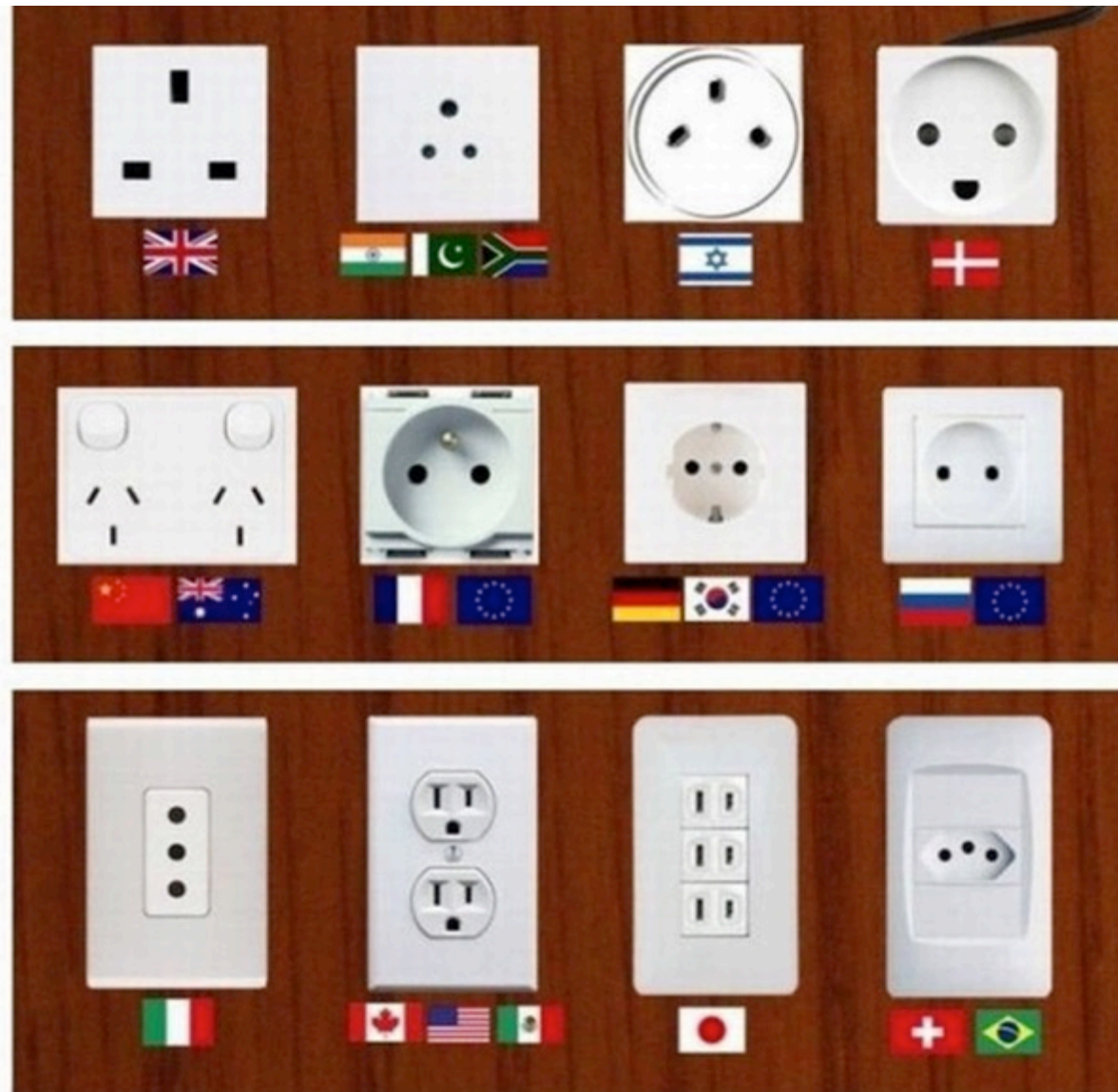




# Understand logistics



# Regional standards



# Risk assessment



# Product design considerations

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- Capital cost
- Adaptability to new technology
- Multi-market viability
- Multi-application viability
- User needs and wants
- Branding
- Durability
- Mechanical Safety
- Chemical safety
- Good to touch / feel factor
- Visual aesthetics
- Cleanliness
- Environmental supply chain
- Ethical supply chain
- Embodied energy
- Disposal at end of life
- Speed of production
- Ease of use
- Physical size & Weight
- Logistics & packaging



# Language and Expectations

# Mixed messages



# Vested interest groups



# Society...

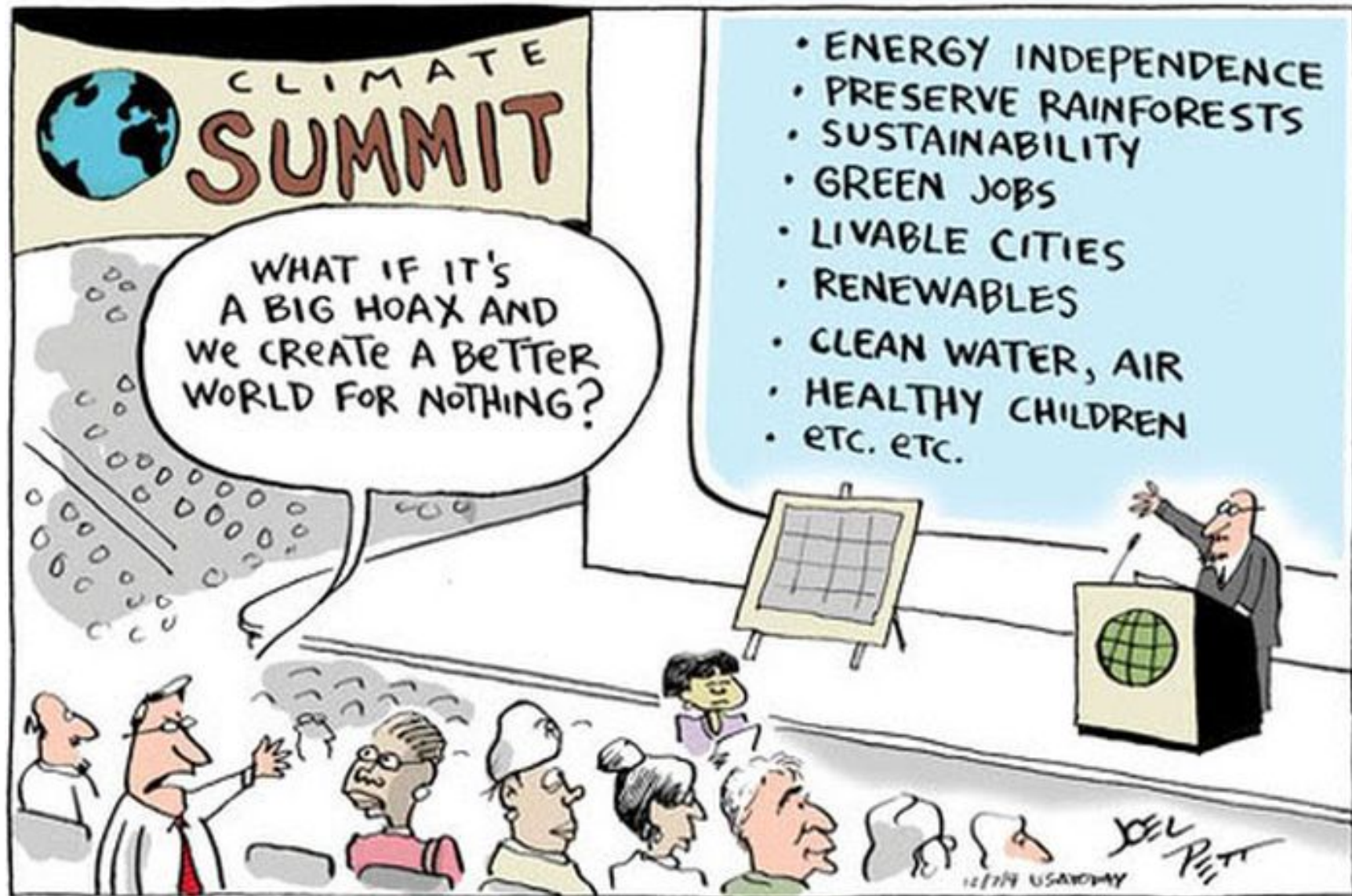
## ARGUMENTS AGAINST-



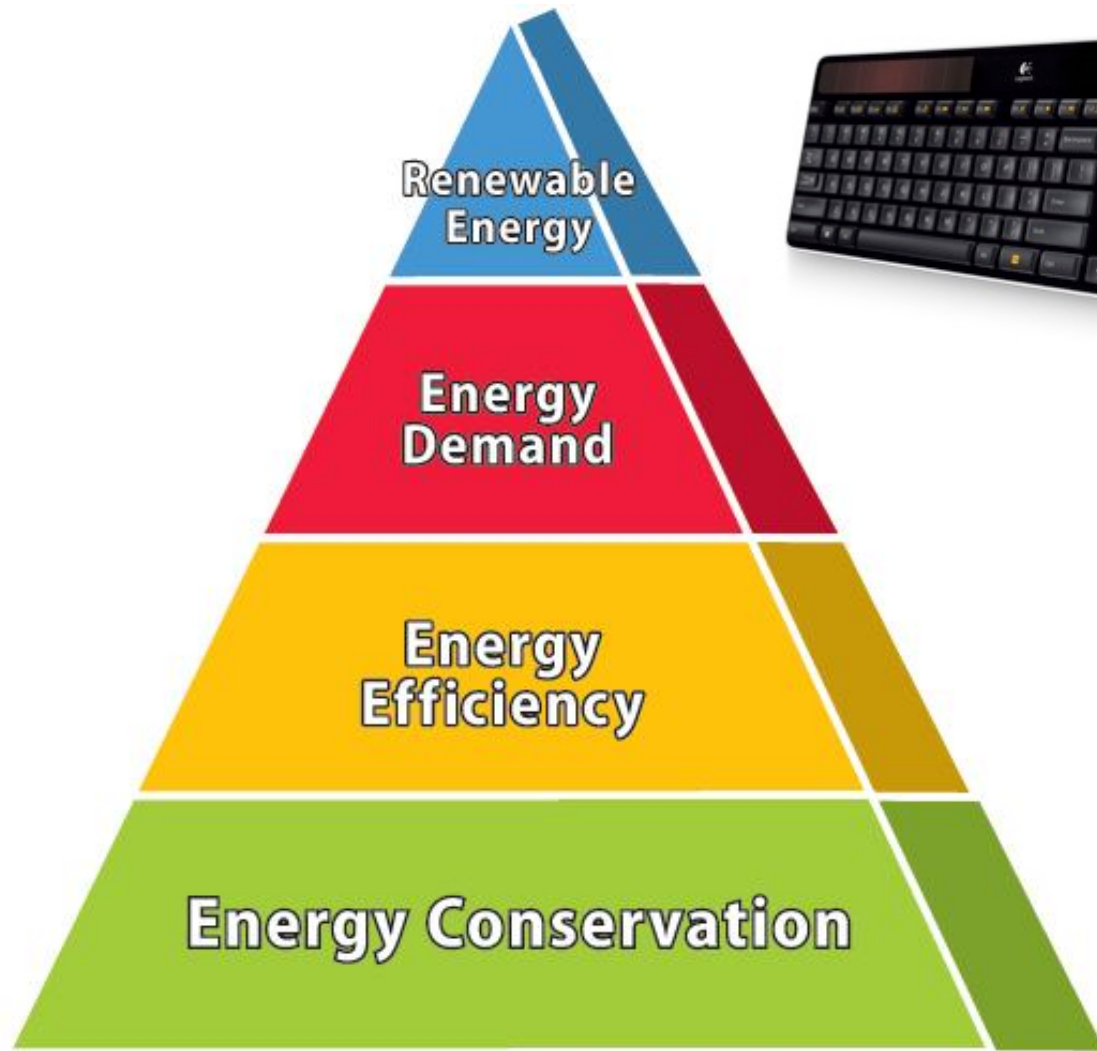
JOE HALLER ©2011 GREENBANK PRESS GAZETTE



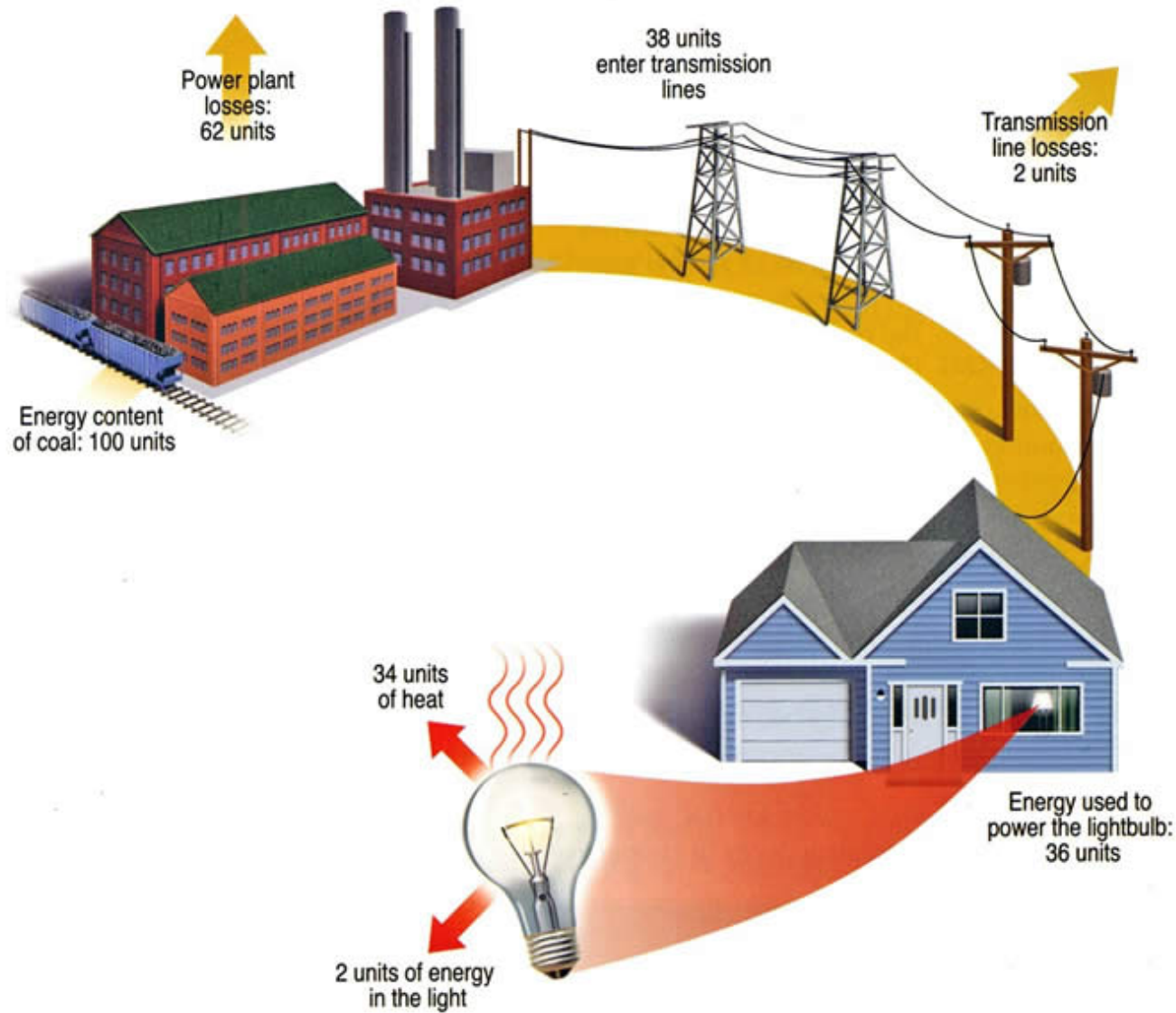
# We fear change










# Greater understanding



# Small changes, large savings

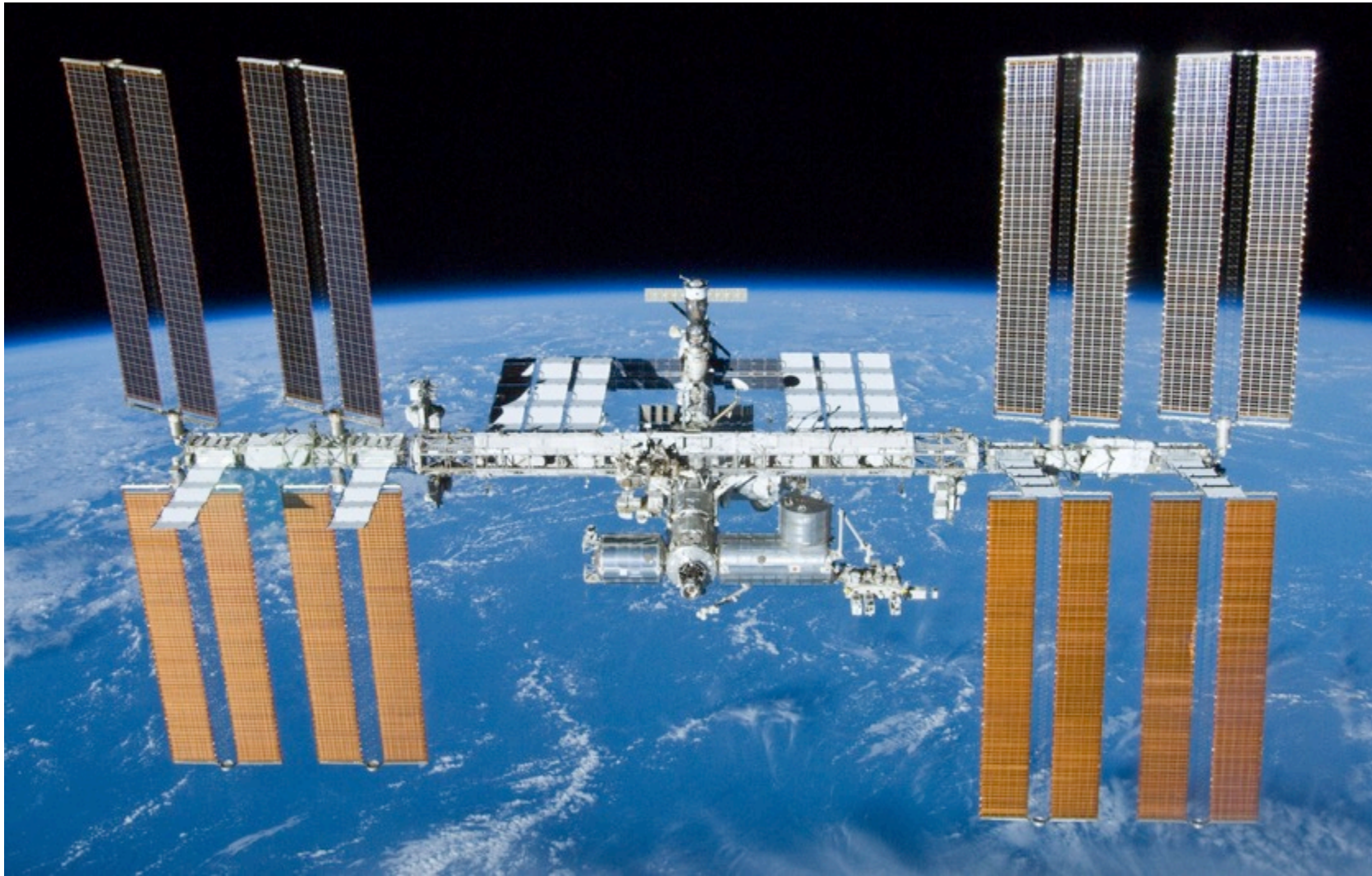


# Change the language

Commercial Module Efficiency							
Technology	Thin Film					Crystalline Silicon	
	(a-Si)	(CdTe)	Cl(G)S	a-Si/ $\mu$ c-Si	Dye s. cells	Mono	Multi
							
Cell efficiency							
Module efficiency	4-8%	10-11%	7-11%	7-9%	2-4% (LAB)	13-19%	11-15%
Area Needed per KW (for modules)	~ 15 m <sup>2</sup>	~ 9m <sup>2</sup>	~ 10m <sup>2</sup>	~12m <sup>2</sup>		~7m <sup>2</sup>	~8m <sup>2</sup>

Source: EPIA 2010. Photon international, March 2010. EPIA analysis  
Efficiency based on Standard Test conditions.

# This is off-grid PV



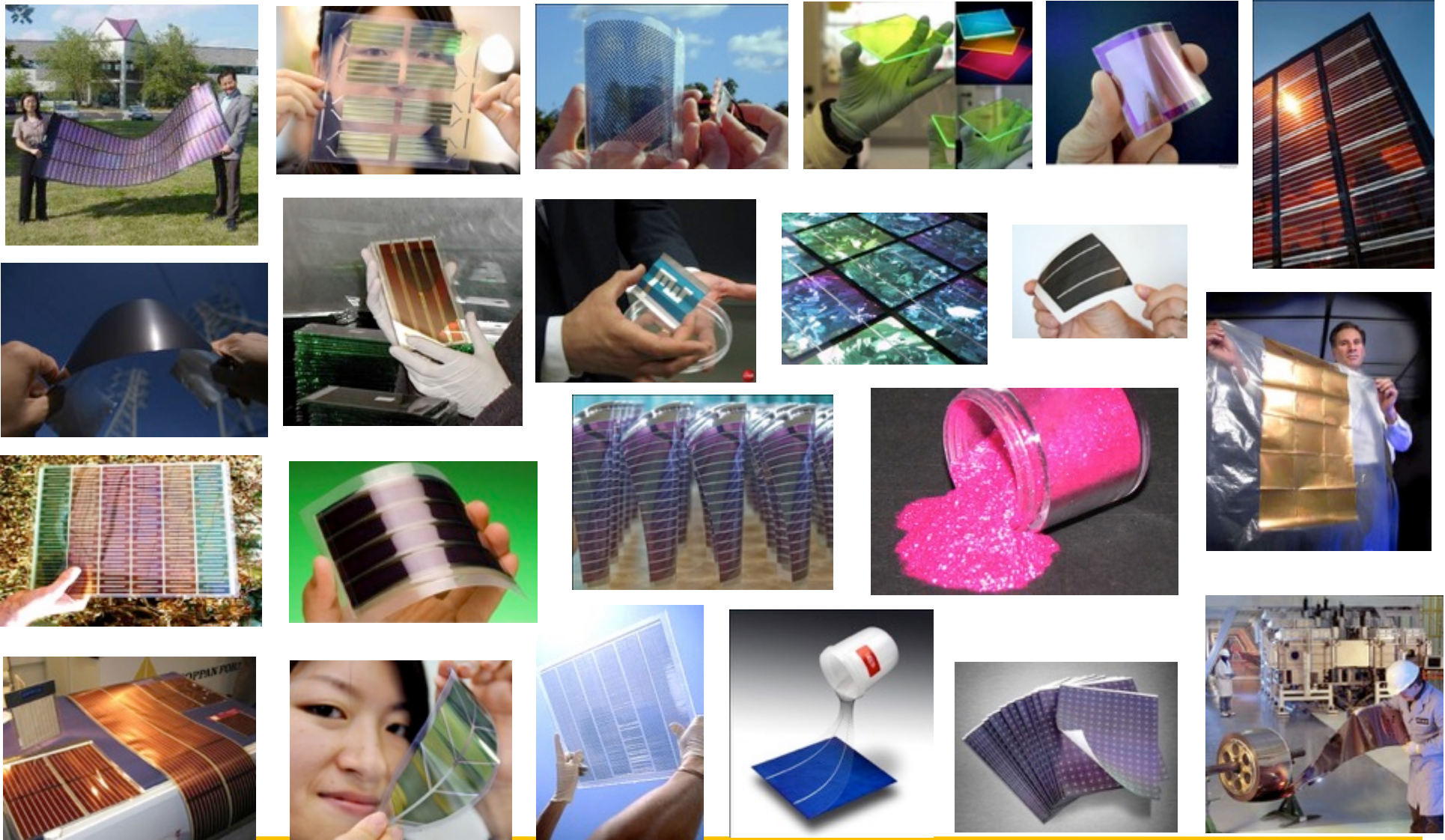
# But so is this...



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**One Day, Everyone Will Use Solar**

# The future of solar

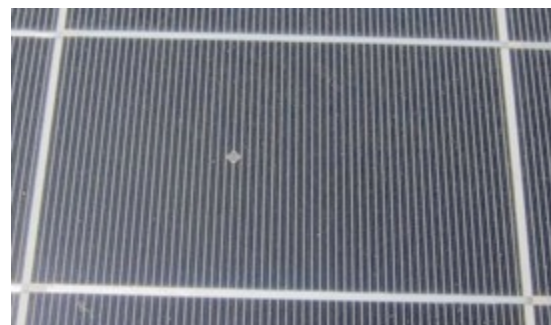




# PV in our lives



# PV brand emergence



# Don't wait for technology



# Apply what we have

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# Learn to improvise



## Be humble



# Thank you

