indoor food production

Professor Cather Simpson
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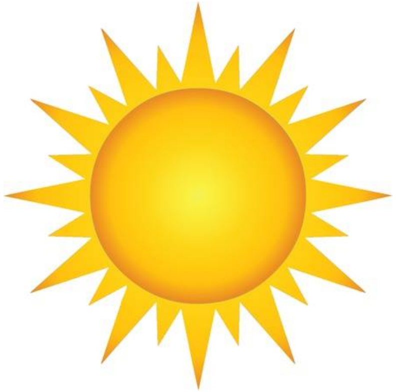
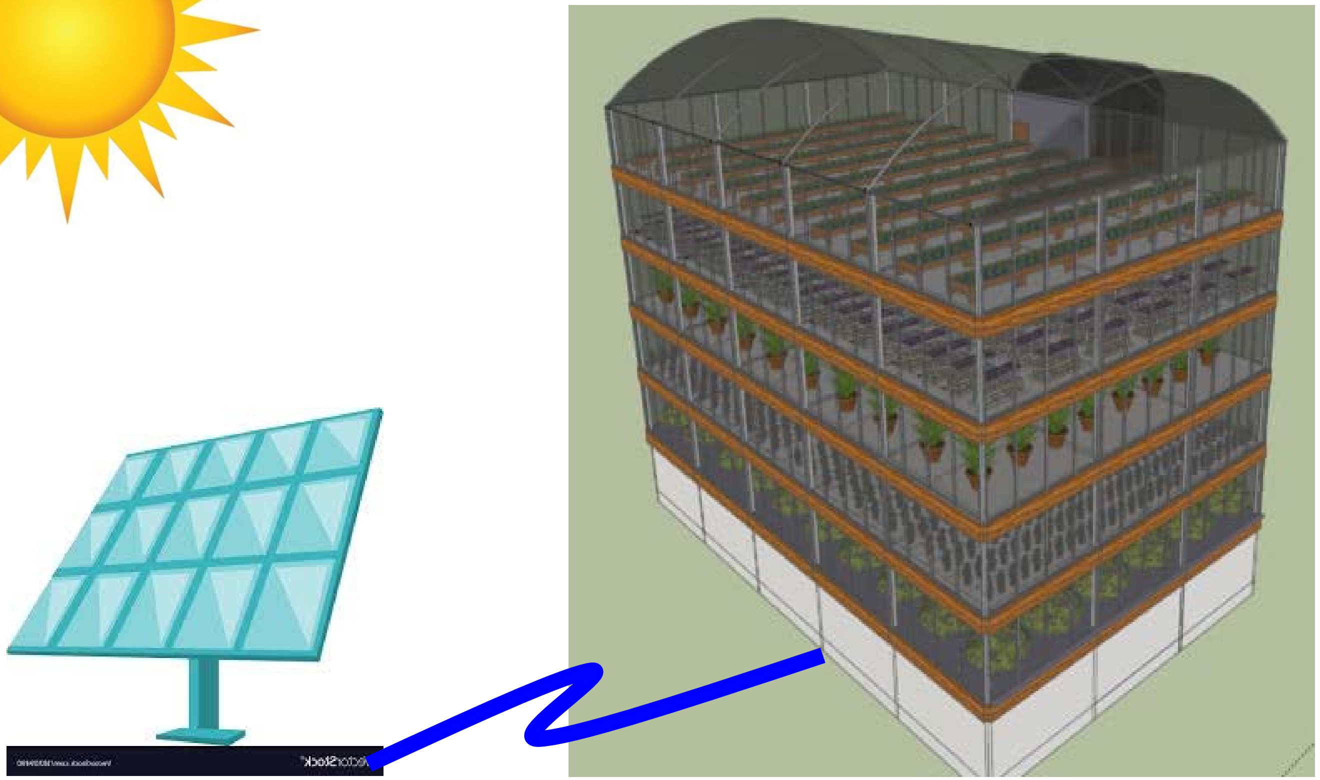
School of Chemical Sciences
Photon Factory
c.simpson@auckland.ac.nz
@ptolemytortoise

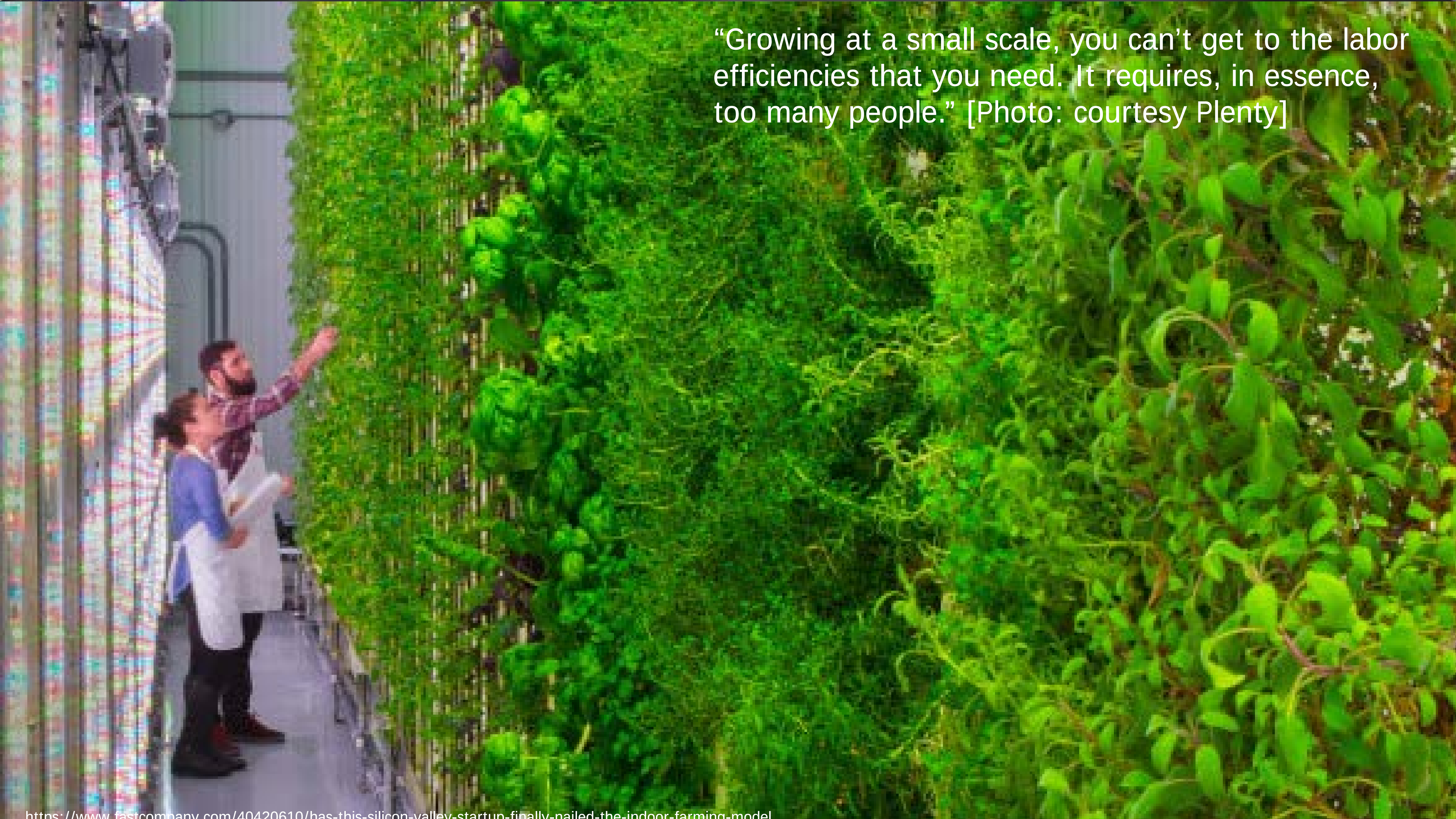




“A London warehouse will be converted into a salad, herb and fish farm, and will produce 200,000 bags of salad a year”

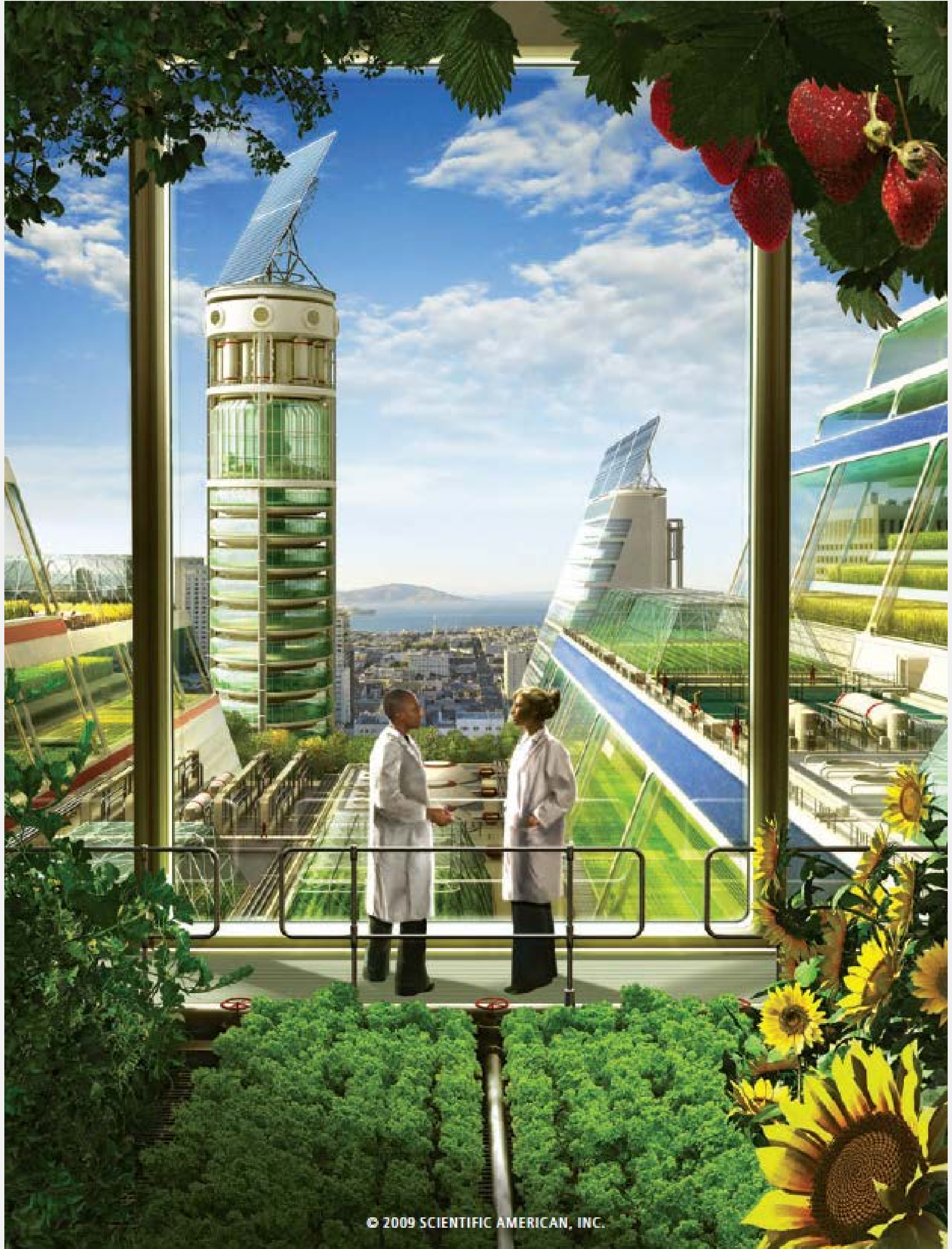
2015, Fresh Produce Journal

http://www.fruitnet.com/fpj/article/164914/uks-first-aquaponic-farm-gets-green-light



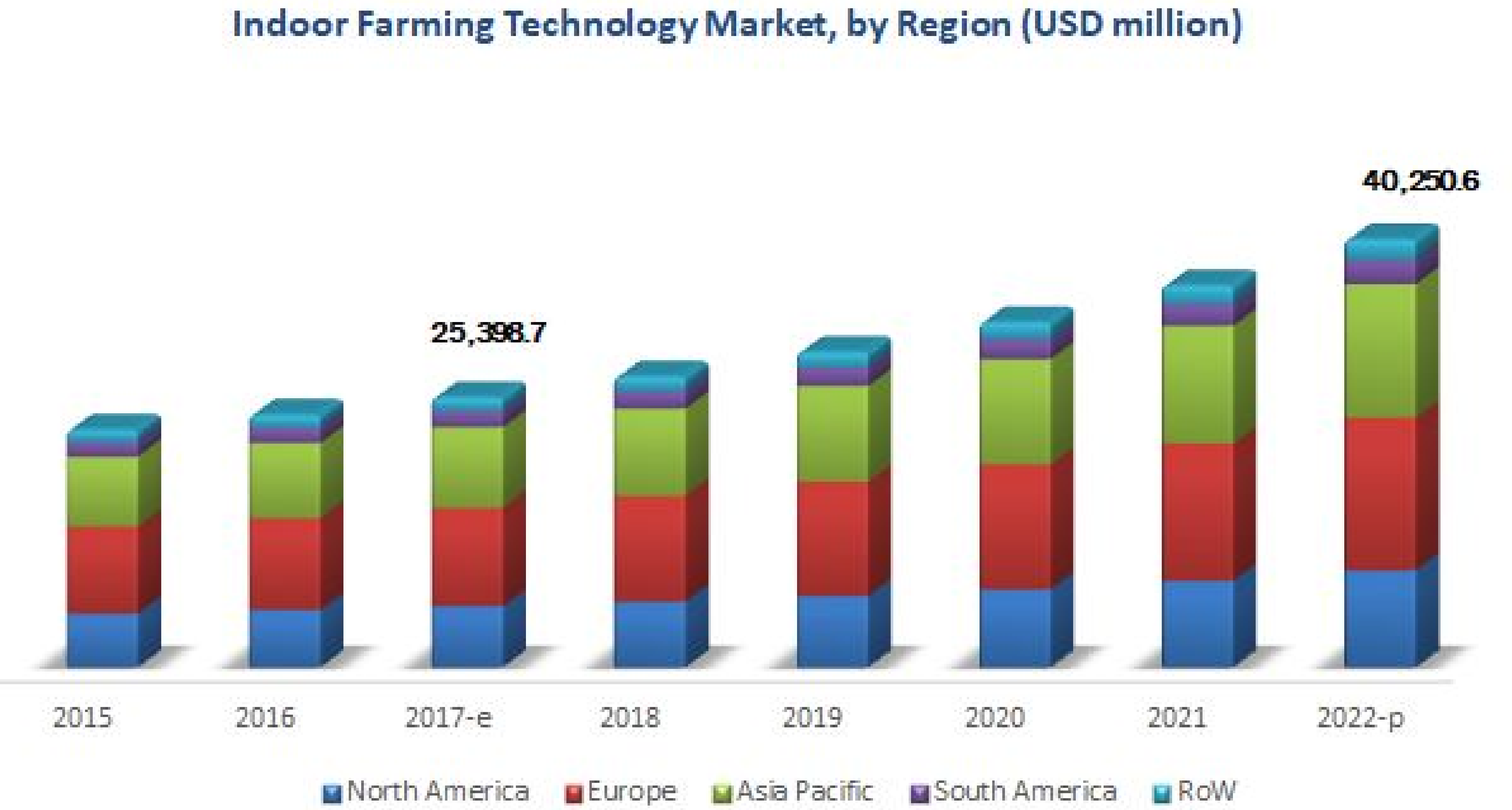
“Growing at a small scale, you can’t get to the labor efficiencies that you need. It requires, in essence, too many people.” [Photo: courtesy Plenty]

https://www.fastcompany.com/40420610/has-this-silicon-valley-startup-finally-nailed-the-indoor-farming-model



The RISE of VERTICAL FARMS

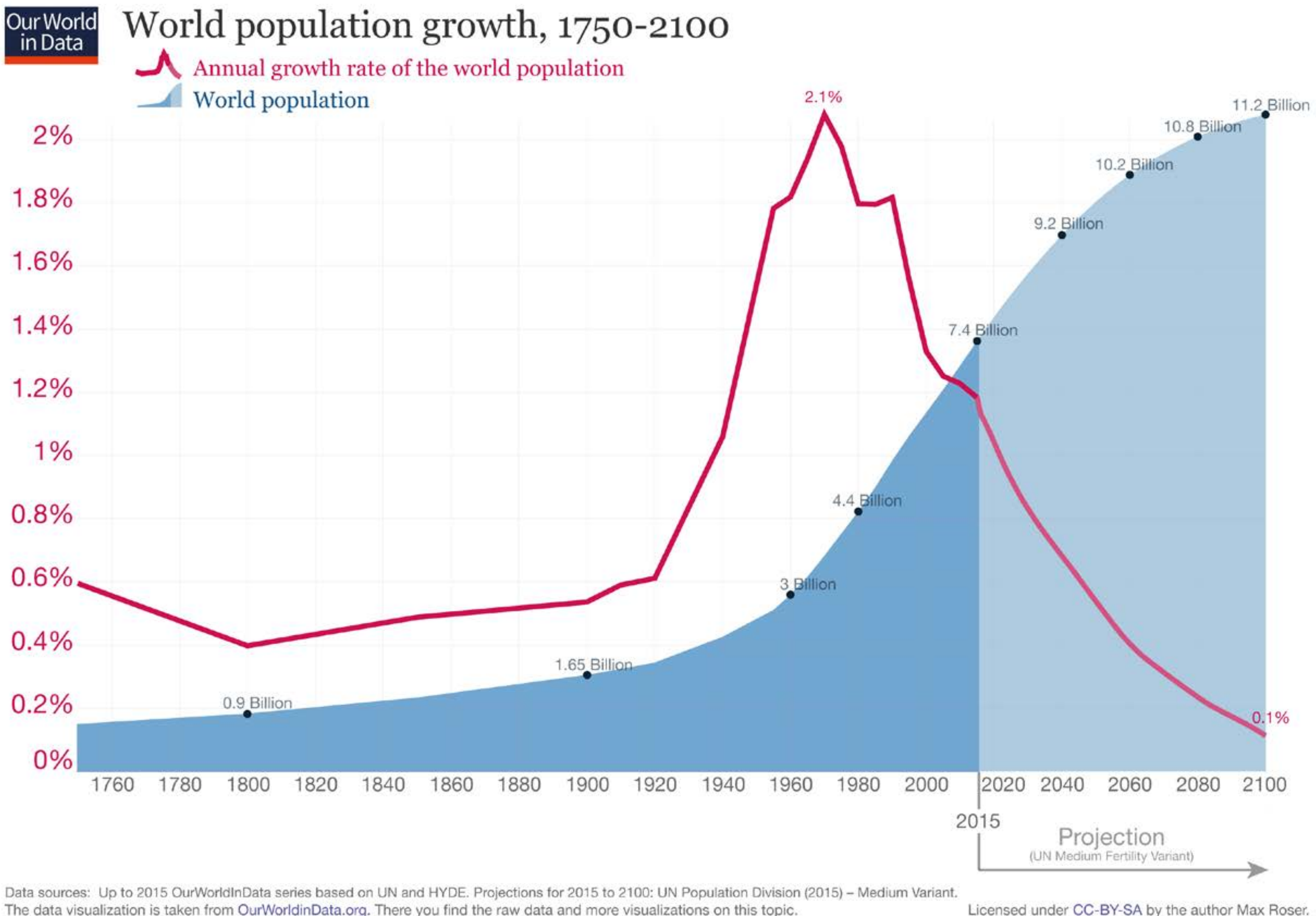
SCIENTIFIC AMERICAN November 2009

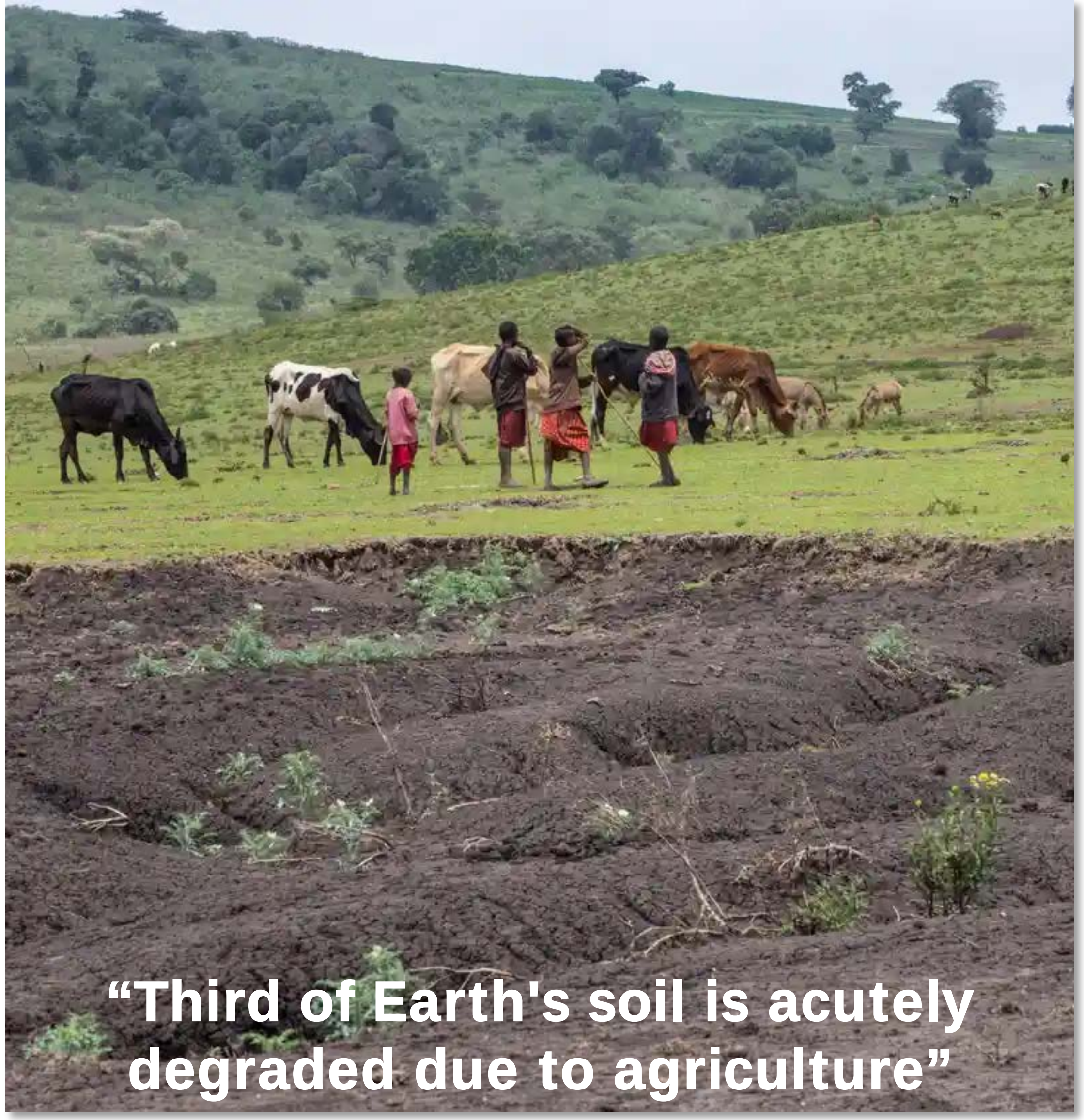


https://www.marketsandmarkets.com/Market-Reports/indoor-farming-technology-market-40175861.html

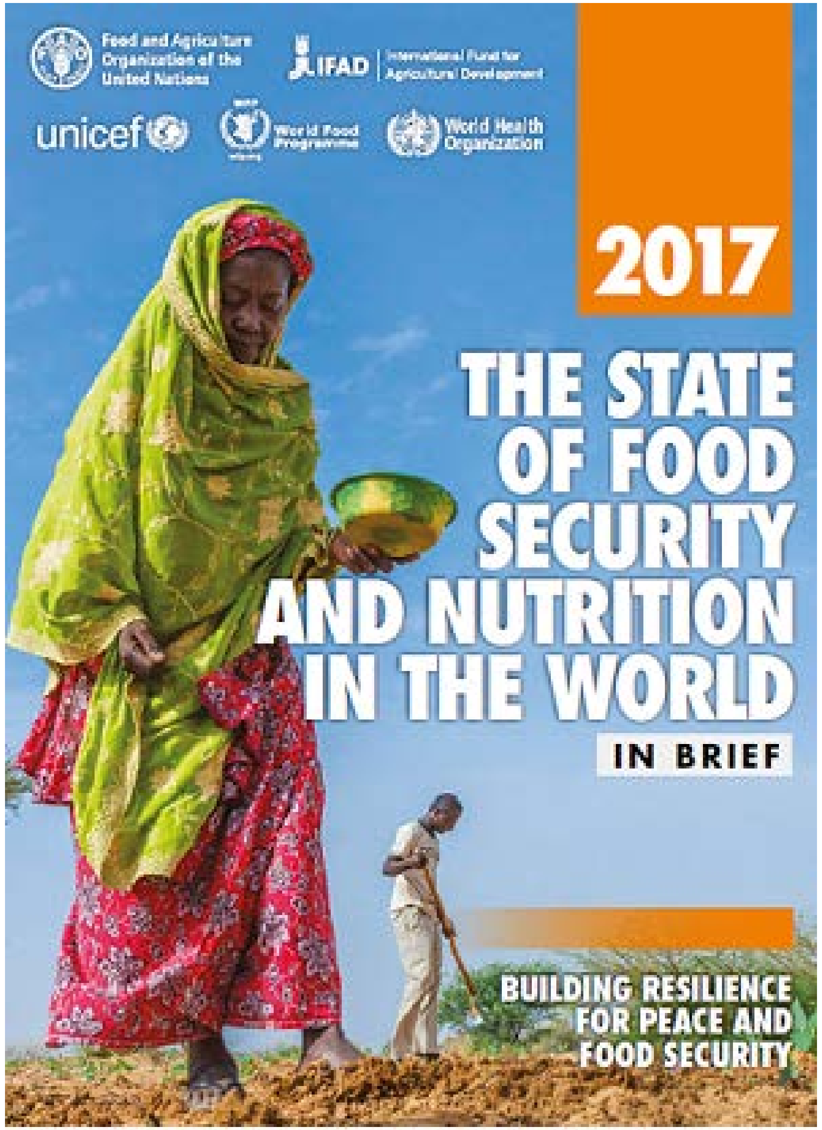
Population= people who eat!

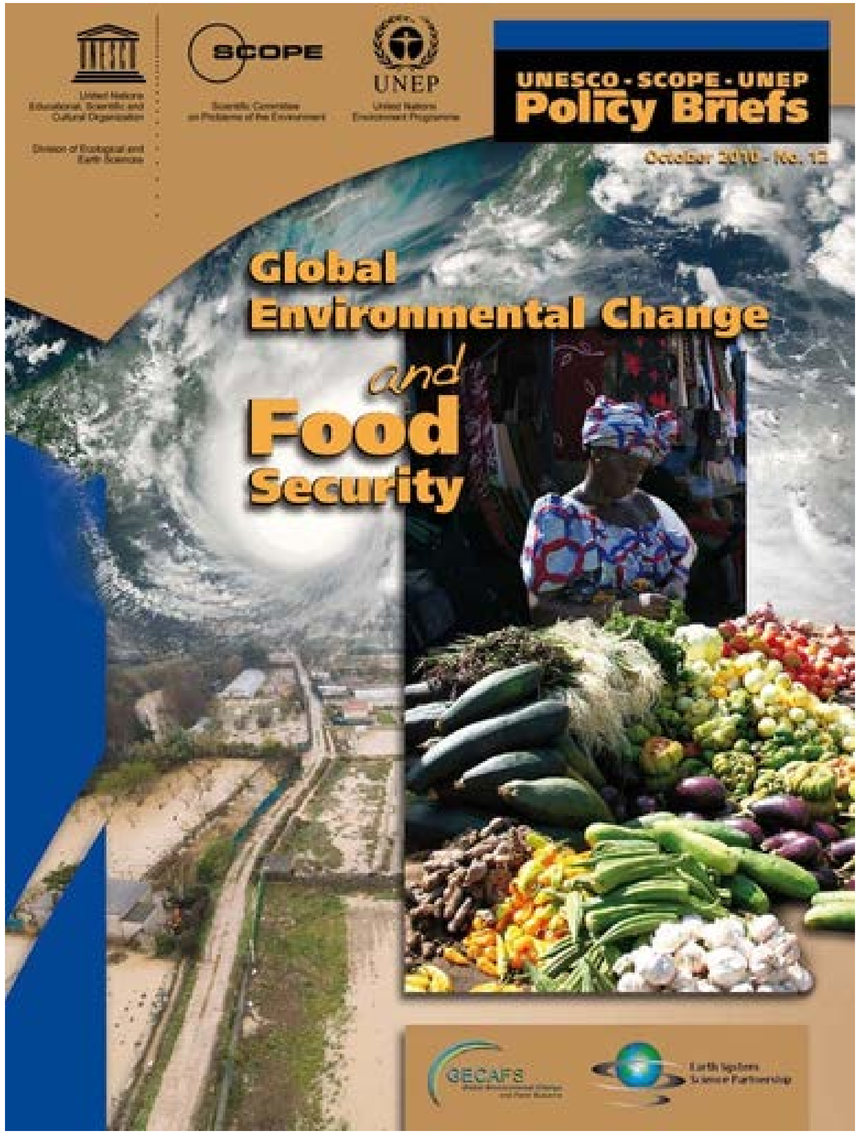
Population= people who eat!





https://www.theguardian.com/environment/2017/sep/12/third-of-earths-soil-acutely-degraded-due-to-agriculture-study





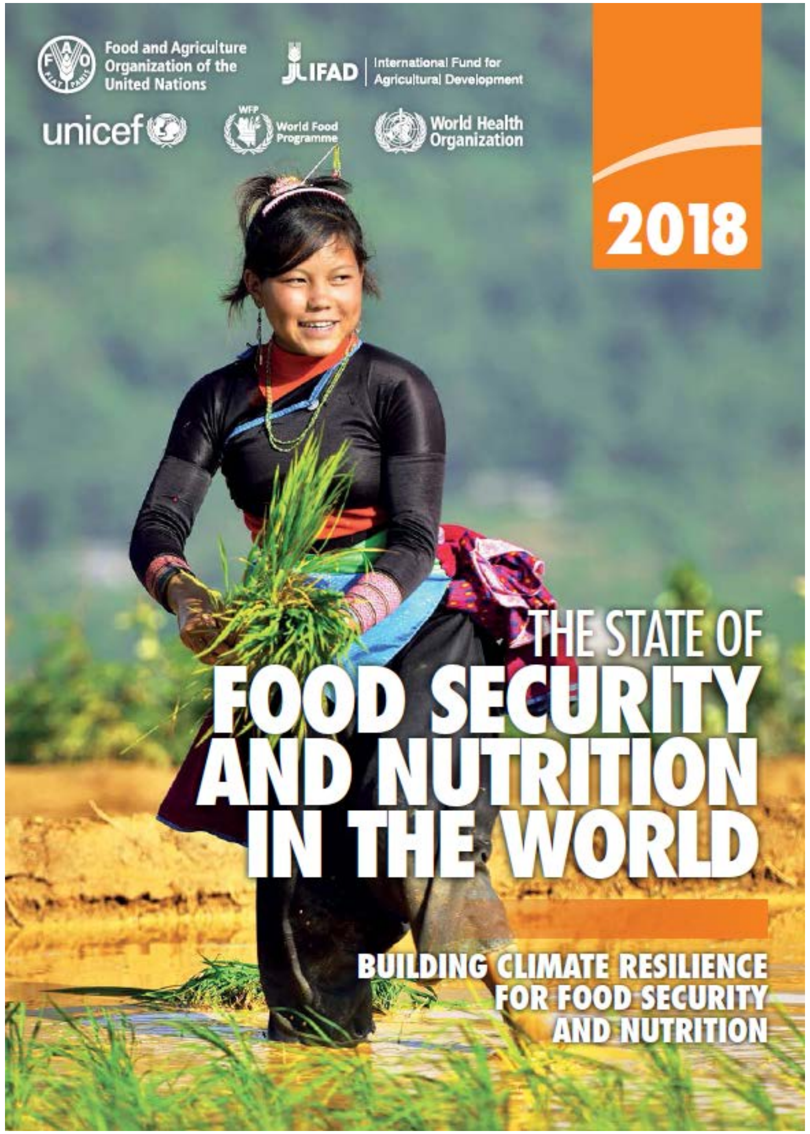


image credits: FAO,IFAD,WFP,UNESCO & WHO

1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS

Advances in photonic technologies

Advances in photonic technologies

Cost of photonic technology

15 TW (terawatt) challenge

Powering the planet: Chemical challenges in solar energy utilization

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*Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA 91125; and
‡Department of Chemistry, Massachusetts Institute of Technology, Cambridge, MA 02139-4307

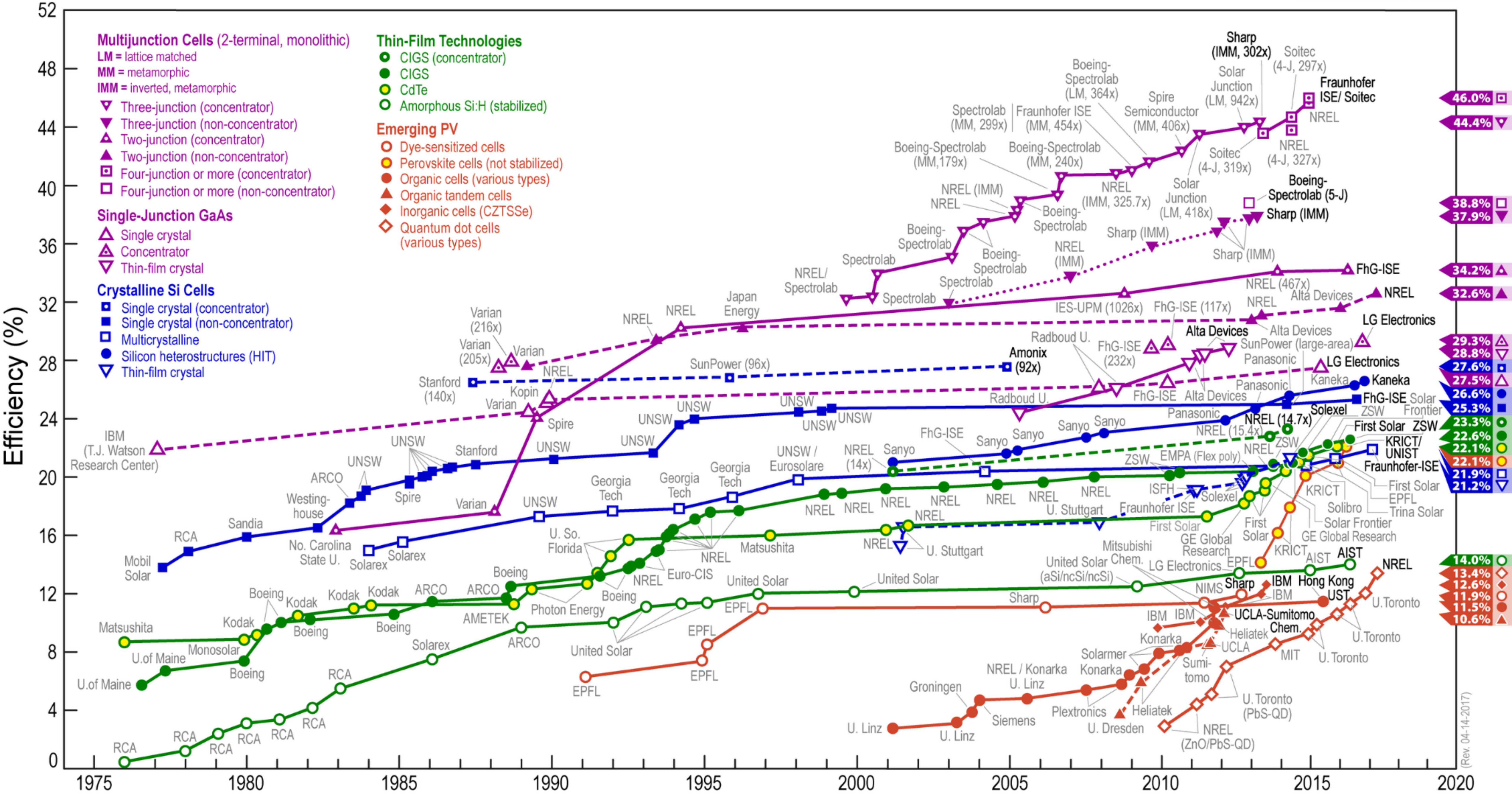
Table 1. World energy statistics and projections

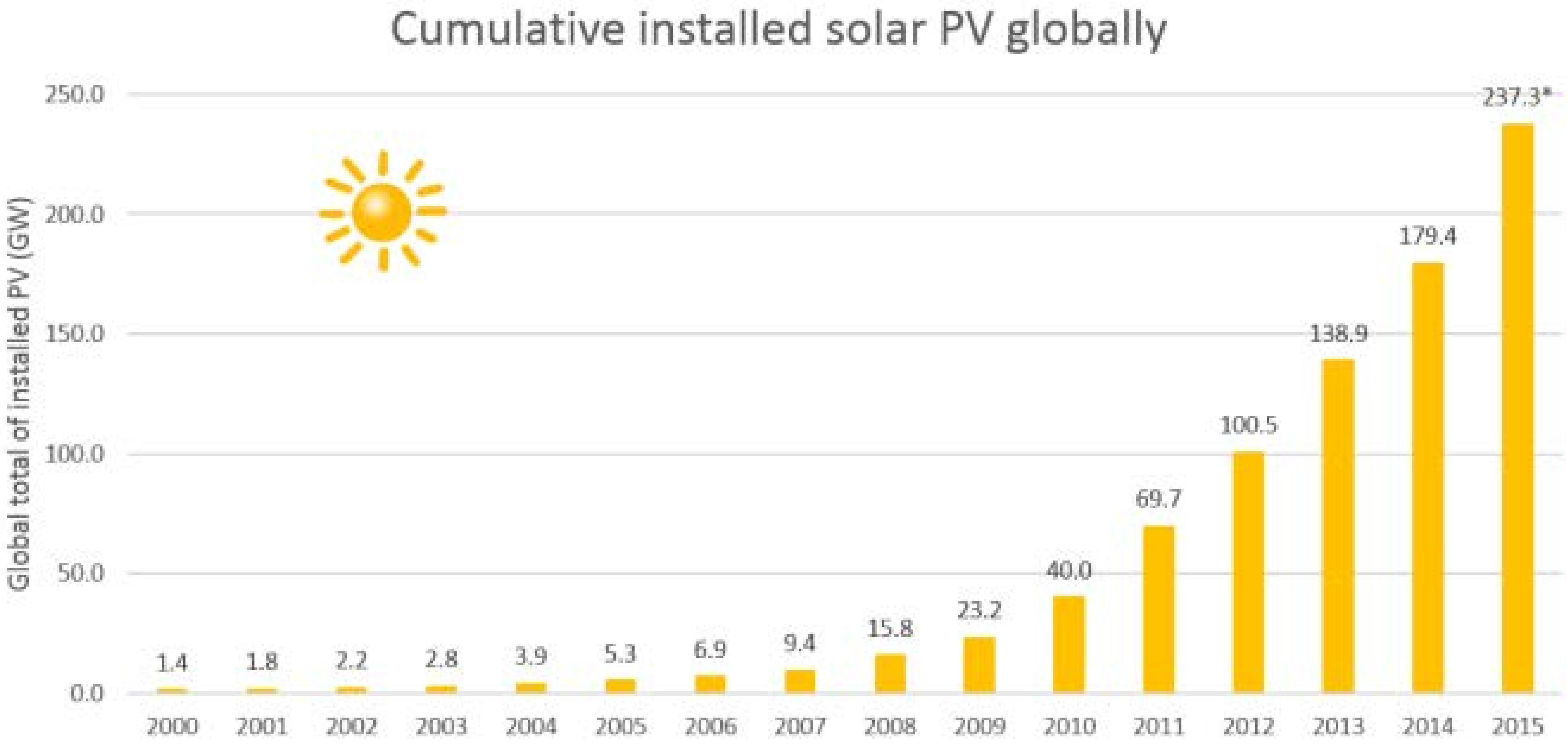
Quantity	Definition	Units	2001*	2050†	2100‡
N	Population	B persons	6.145	9.4	10.4
GDP	GDP§	T $/yr	46	140¶	284‖
GDP/N	Per capita GDP	$/(person-yr)	7,470	14,850	27,320
$\dot{E}$/GDP	Energy intensity	W/($/yr)	0.294	0.20	0.15
$\dot{E}$	Energy consumption rate	TW	13.5	27.6	43.0
C/E	Carbon intensity	KgC/(W yr)	0.49	0.40	0.31
$\dot{C}$	Carbon emission rate	GtC/yr	6.57	11.0	13.3
$\dot{C}$	Equivalent CO_2 emission rate	$GtCO_2$/yr	24.07	40.3	48.8

*$\dot{E}$ = (403.9 Quads/yr)·(33.4 GWyr/Quad)·(10^{-3} TW/GW) = 13.5 TW; and $\dot{C}$ = (24.072 $GtCO_2$/yr)·(12/44 GtC/$GtCO_2$) = 6.565 GtC (adapted from ref. 1).
†$\dot{E}$ = (869 EJ/yr)·(10^6 TJ/EJ)/(60·60·24·365 s/yr) = 27.5 TW [adapted from ref. 2 (Scenario B2), pp. 48–55].
‡$\dot{E}$ = (1,357 EJ/yr)·(10^6 TJ/EJ)/(60·60·24·365 s/yr) = 43.0 TW [adapted from ref. 2 (Scenario B2), pp. 48–55].
§All in year 2000 U.S. dollars, using the inflation-adjusted conversions: $\$_{2000}$ = 1/0.81590 $\$_{1990}$ (adapted from ref. 1), and 'purchasing power parity' exchange rates.
¶In year 2000 U.S. dollars: (113.9 $T\$_{1990}$)·(1/0.81590 $\$_{2000}/\$_{1990}$) = 139.6 $T\$_{2000}$.
‖In year 2000 U.S. dollars: (231.8 $T\$_{1990}$)·(1/0.81590 $\$_{2000}/\$_{1990}$) = 284.1 $T\$_{2000}$.

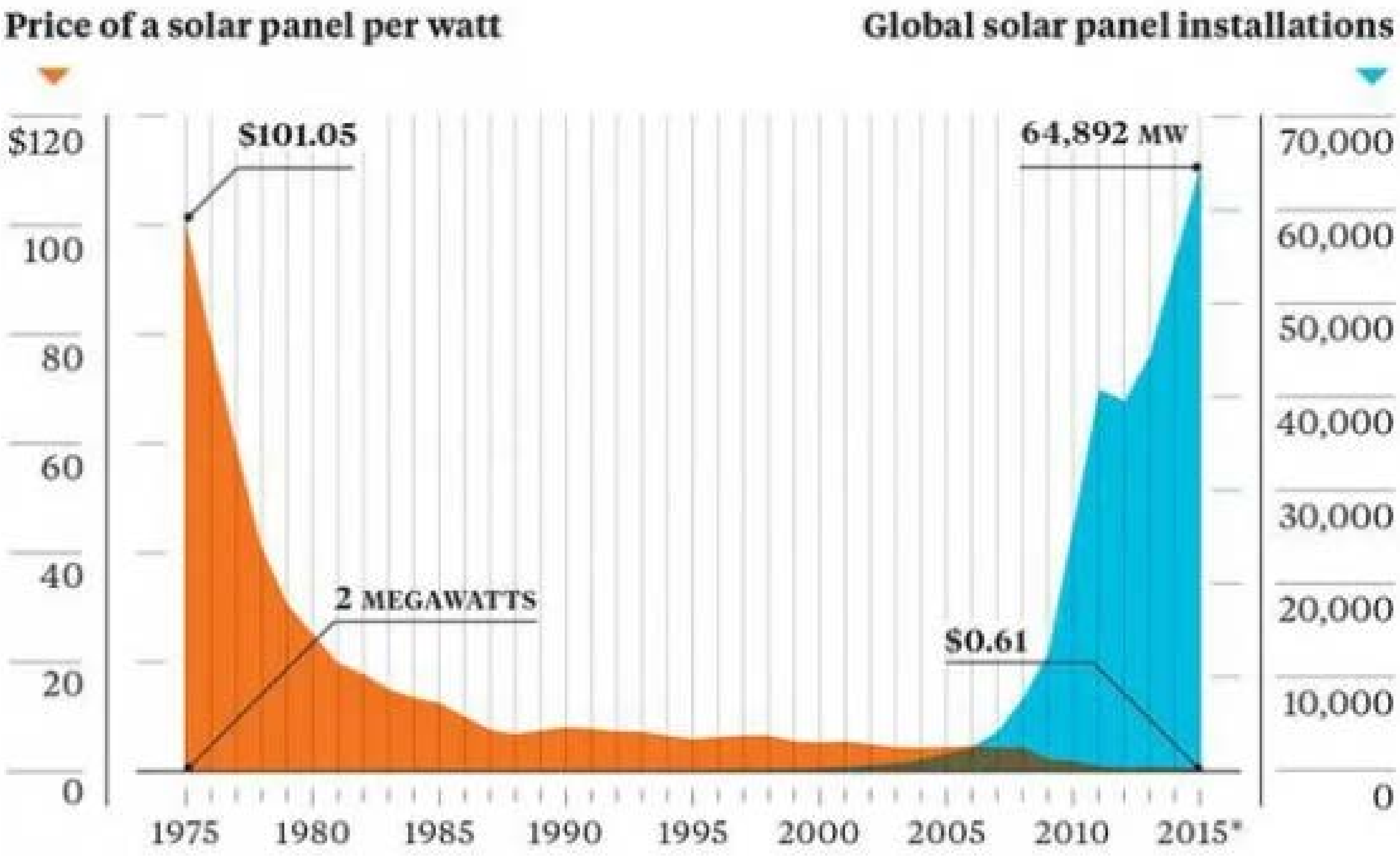
PNAS | **October 24, 2006** | vol. 103 | no. 43 | **15729–15735**

Best Research-Cell Efficiencies





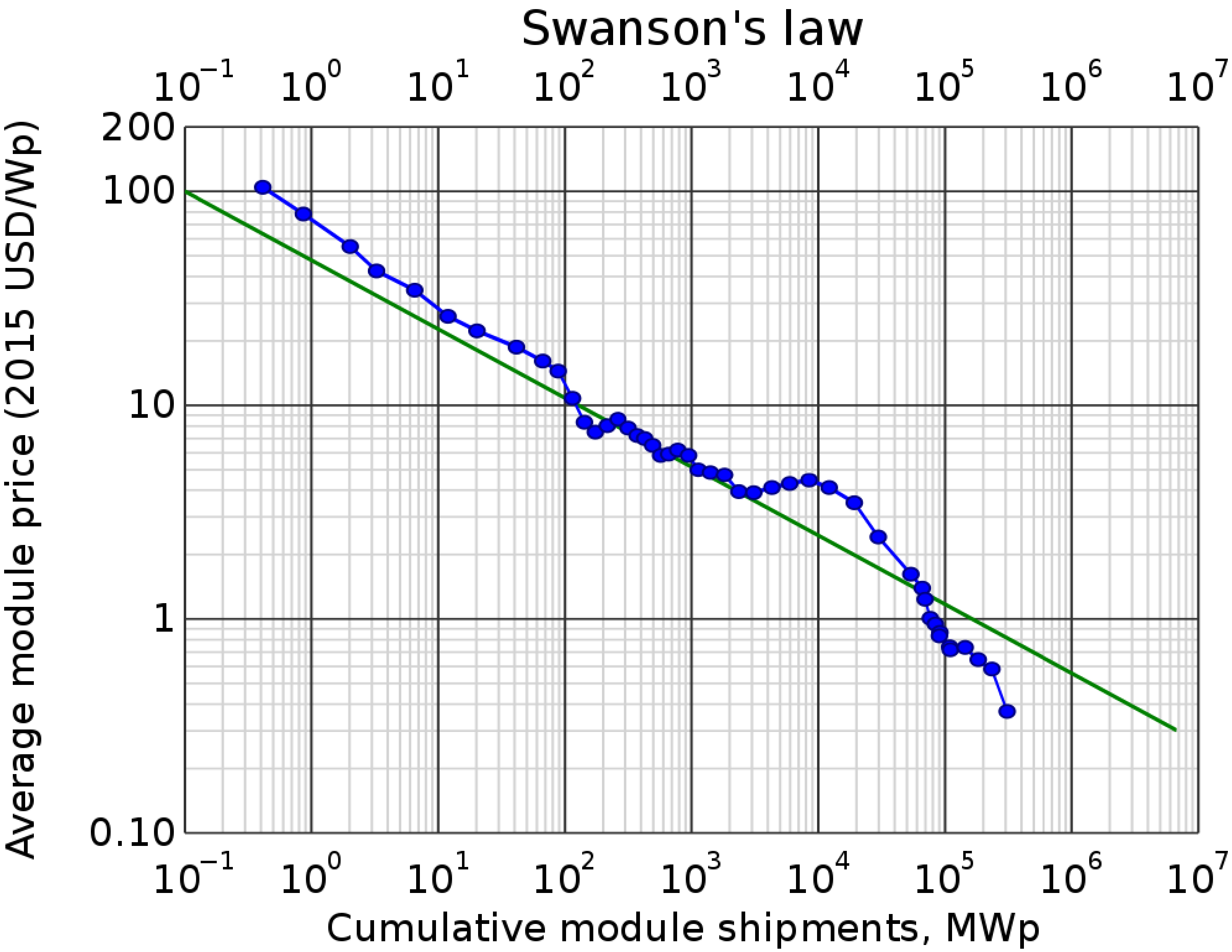
https://cleantechnica.com/2014/09/04/solar-panel-cost-trends-10-charts/



https://cleantechnica.com/2014/09/04/solar-panel-cost-trends-10-charts/

Solar module cost drops by ~half every ~10 years

SUNPOWER®



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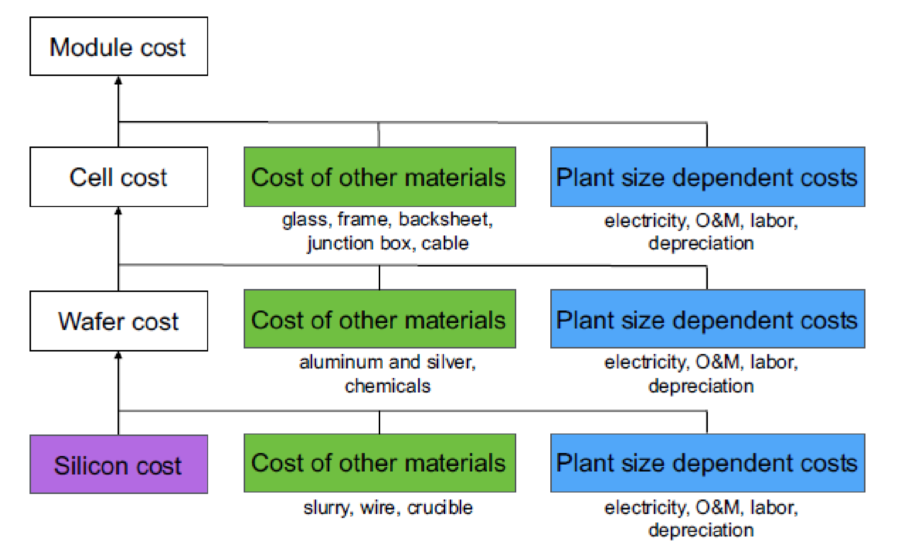
journal homepage: www.elsevier.com/locate/enpol

Evaluating the causes of cost reduction in photovoltaic modules

Goksin Kavlak[a], James McNerney[a], Jessika E. Trancik[a,b,*]

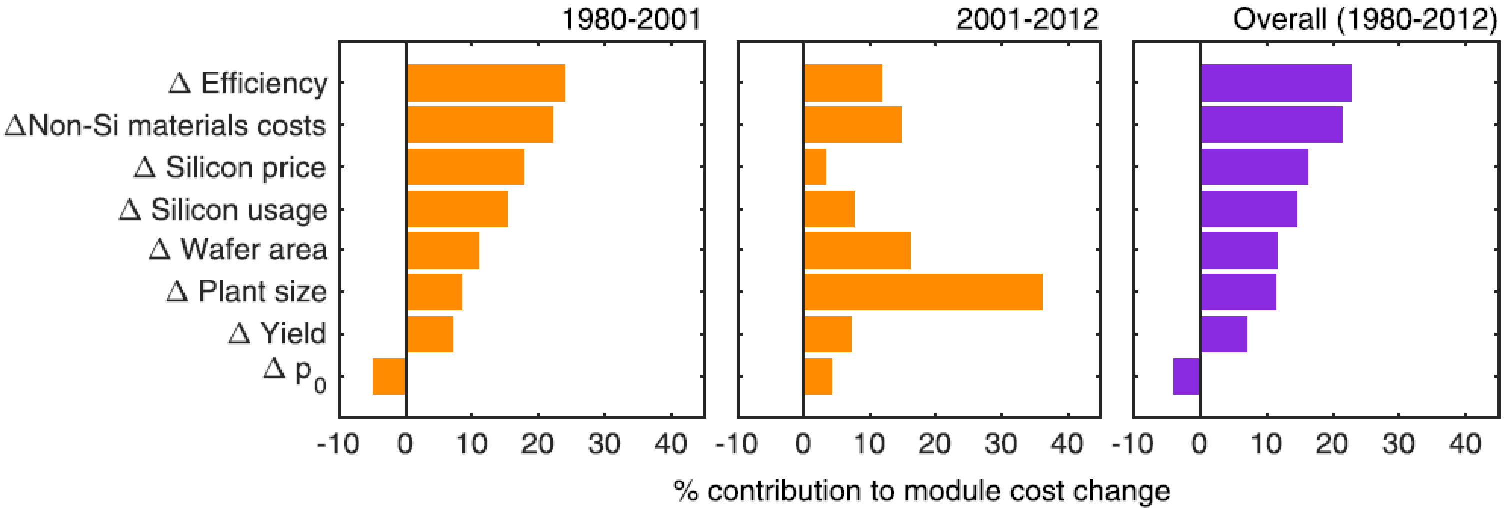
[a] Institute for Data, Systems and Society, Massachusetts Institute of Technology, Cambridge, MA, USA
[b] Santa Fe Institute, Santa Fe, NM, USA



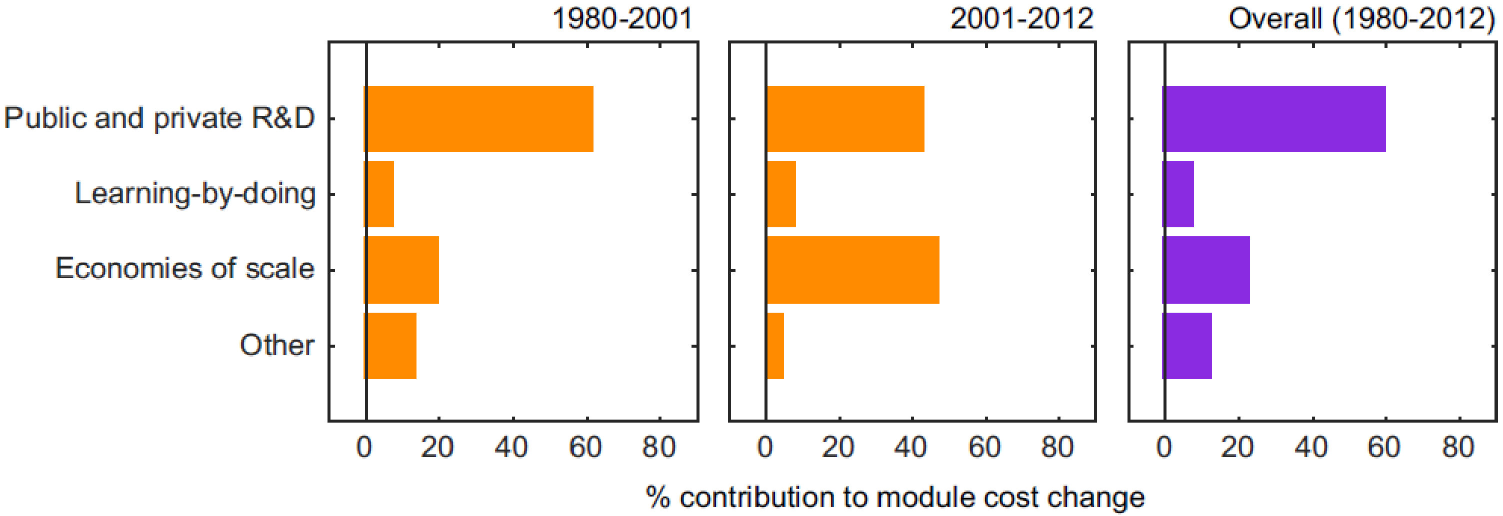
$$C_m\left(\frac{\$}{module}\right) = \underbrace{\frac{1}{y_m}\sum_{i\neq c,w}\phi_{mi}p_i}_{\text{non-cell module costs}} + \underbrace{\frac{n_{mc}}{y_m y_c}\sum_{i\neq w}\phi_{ci}p_i}_{\text{non-wafer cell costs}} + \underbrace{\frac{n_{mc}n_{cw}}{y_m y_c y_w}\sum_{i}\phi_{wi}p_i}_{\text{wafer costs}},$$

Why are solar panels (modules) dropping in price??

“low level”

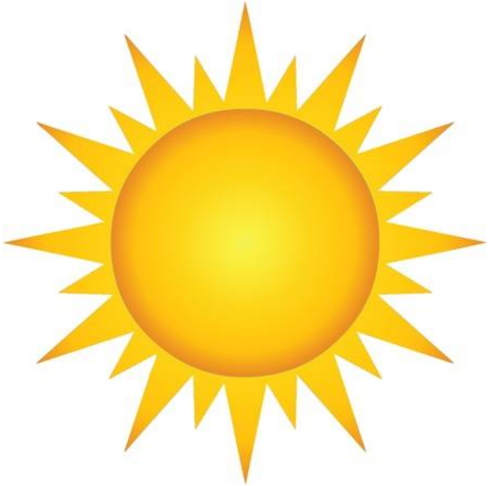


“high level”



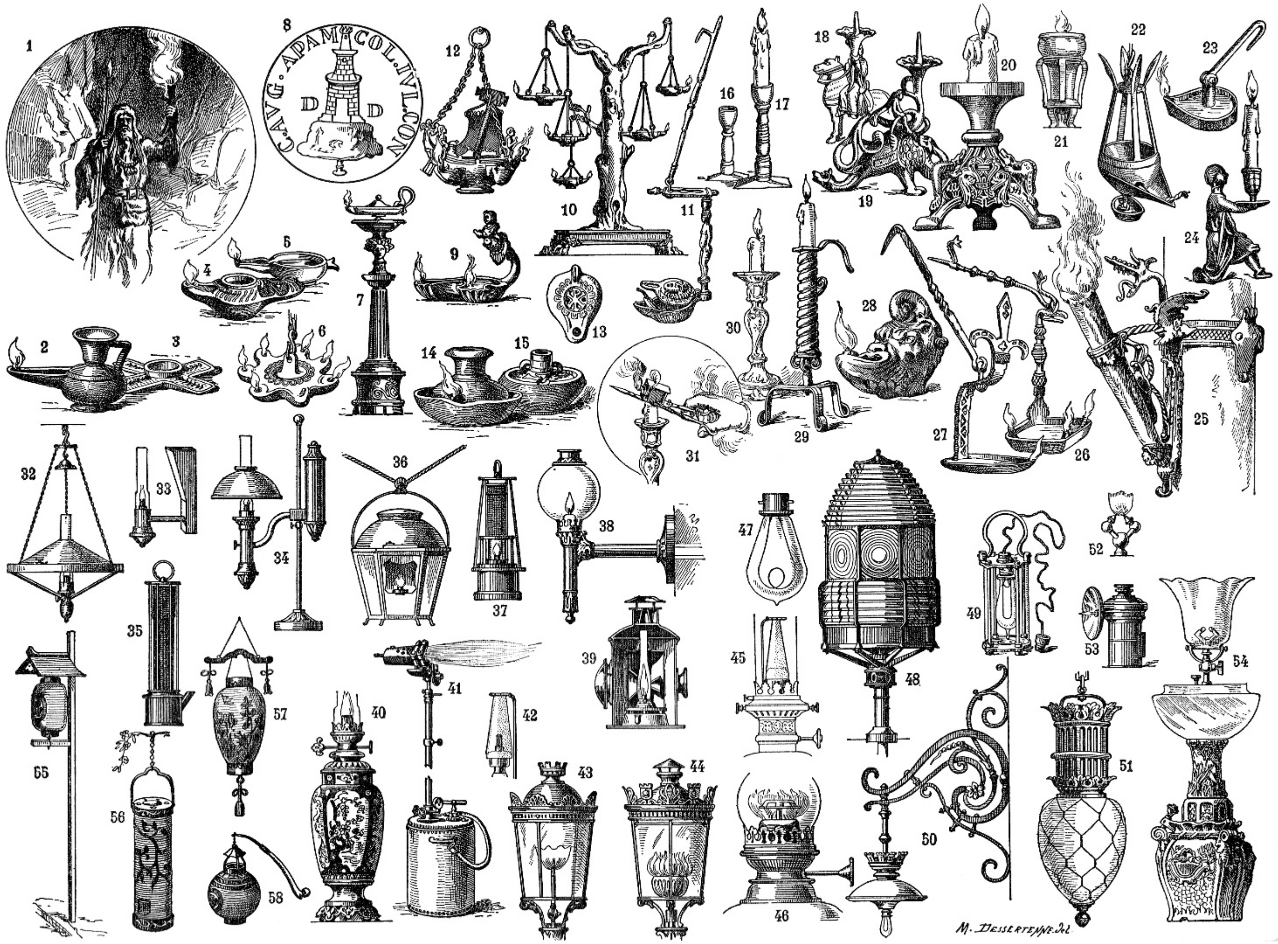
Advances in solar energy technology

Cost of solar energy



Advances in artificial lighting technology

Cost of artificial lighting

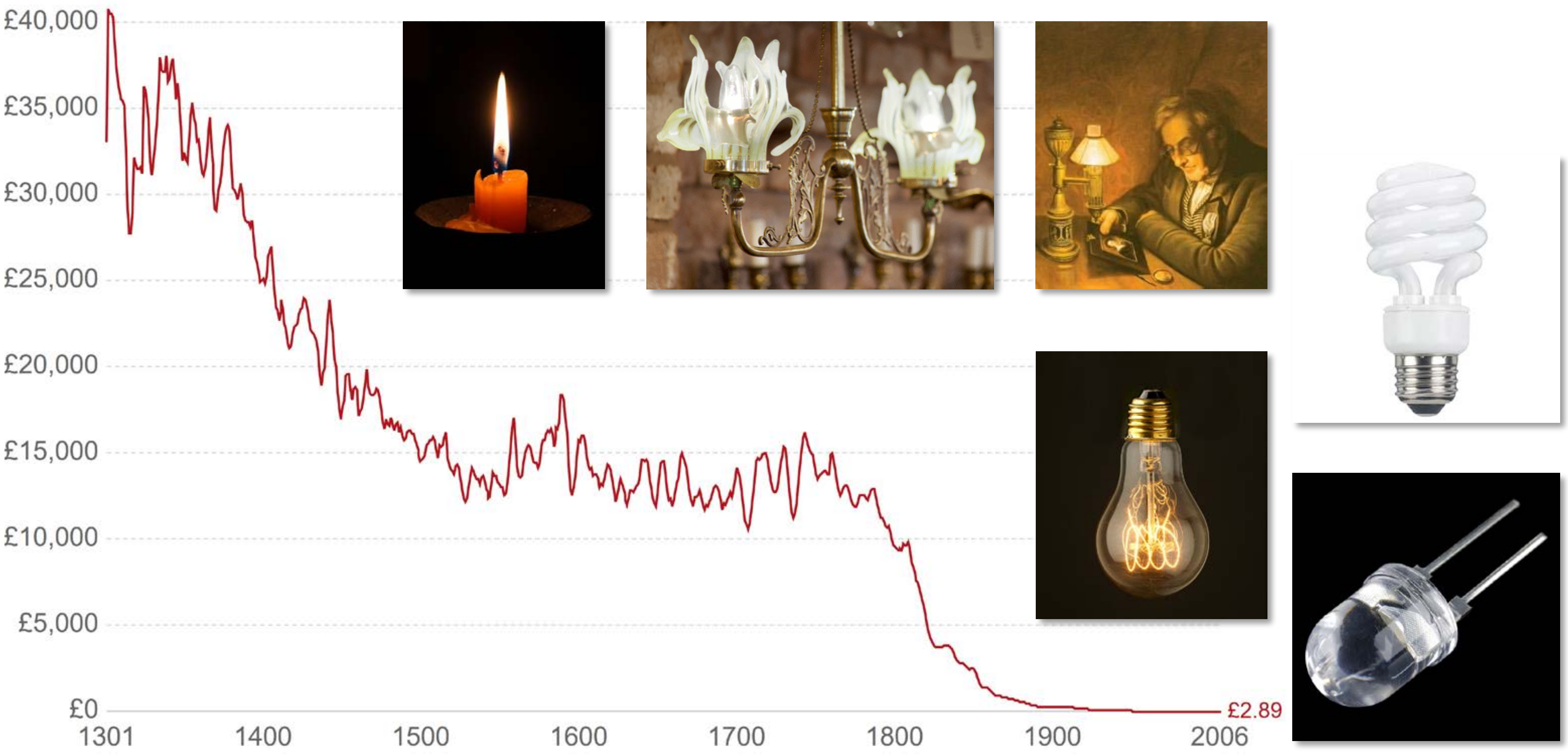


By Maurice Dessertenne - "Eclairage", in Nouveau Larousse Illustré, tôme quatrième E-G, Public Domain, https://commons.wikimedia.org/w/index.php?curid=6405106
https://www.superbrightleds.com/moreinfo/through-hole/rgb-fast-color-changing-led-2/1041/2504/

The Price for Lighting (per million lumen-hours) in the UK in British Pound

1 lumen hour is equal to the luminous energy emitted in 1 hour by a light source emitting a luminous flux of 1 lumen. For comparison: a standard 100W incandescent light bulb emits ±1700 lumen.

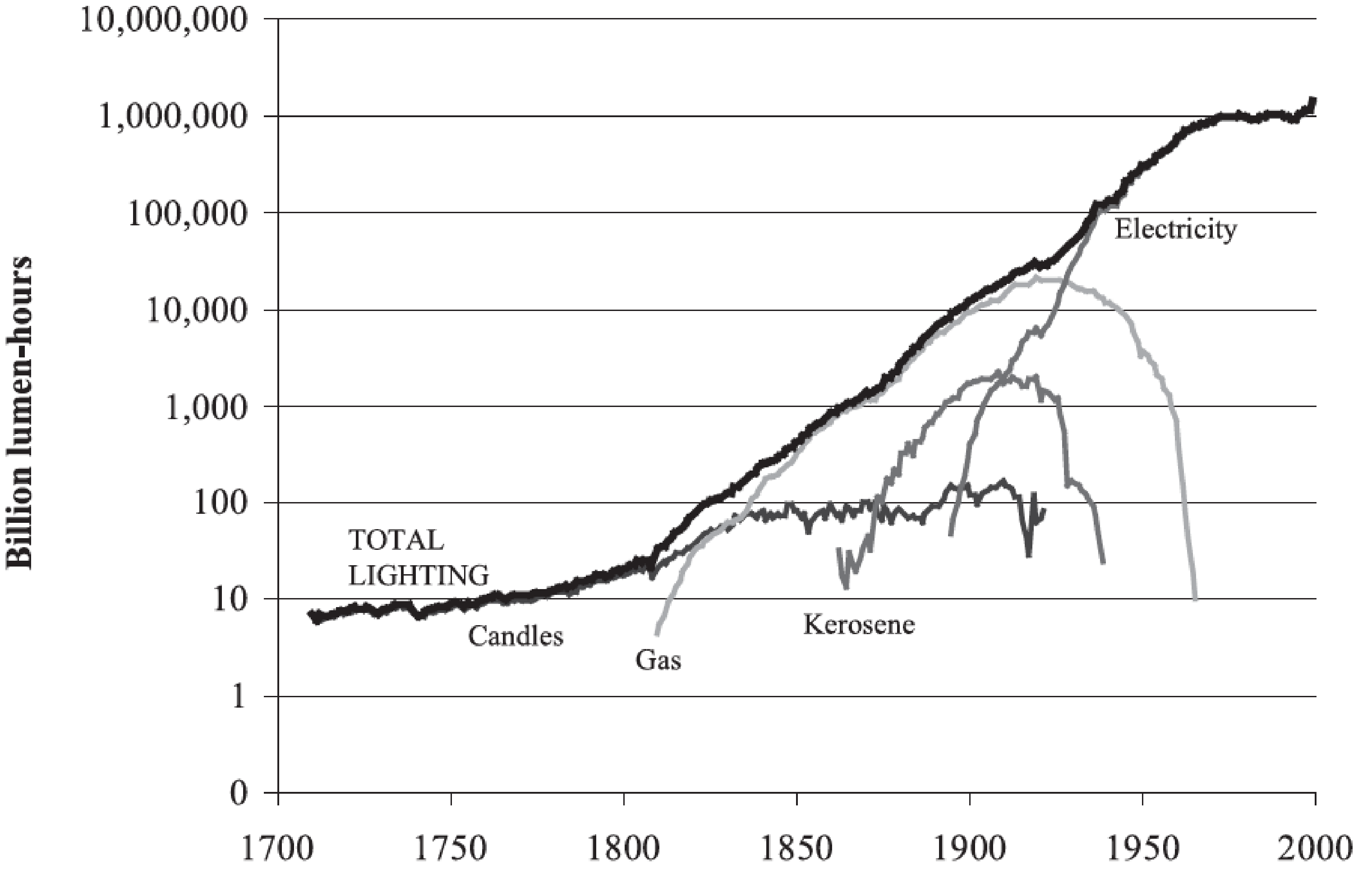
Our World in Data https://ourworldindata.org/light



Source: Fouquet and Pearson (2012)

Note: The price is adjusted for inflation and expressed in prices for the year 2000. Shown is a 5-year moving average.

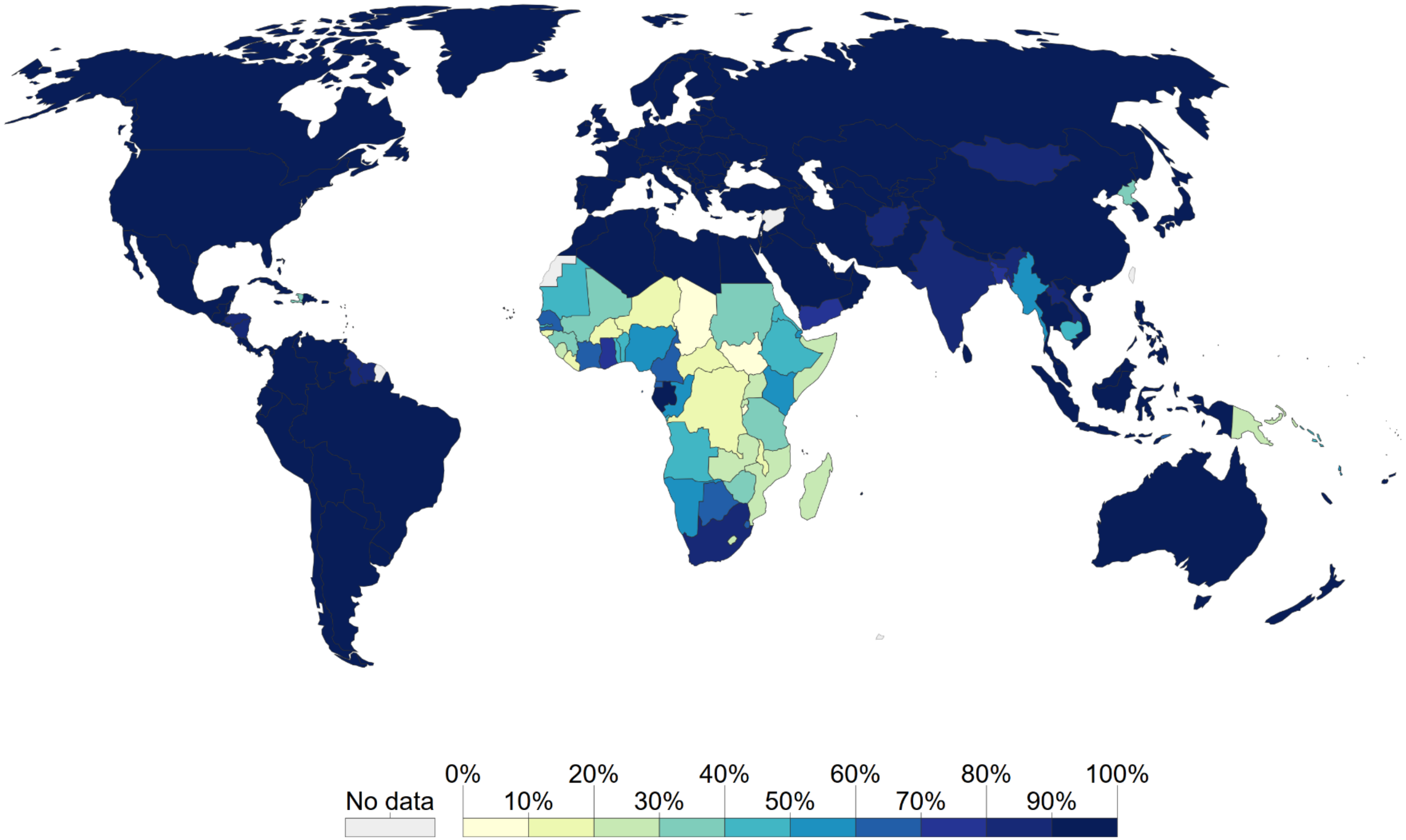
Consumption of lighting from candles, gas, kerosene and electricity in the United Kingdom (in billion lumen-hours), 1700-2000 – Fouquet and Pearson (2007)



https://ourworldindata.org/light

Share of the population with access to electricity, 2016

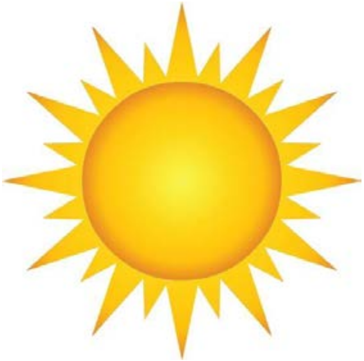
Data represents electricity access at the household level, that is, the number of people who have electricity in their home. It comprises electricity sold commercially, both on-grid and off-grid.



Source: The World Bank

Advances in solar energy technology

Cost of solar energy



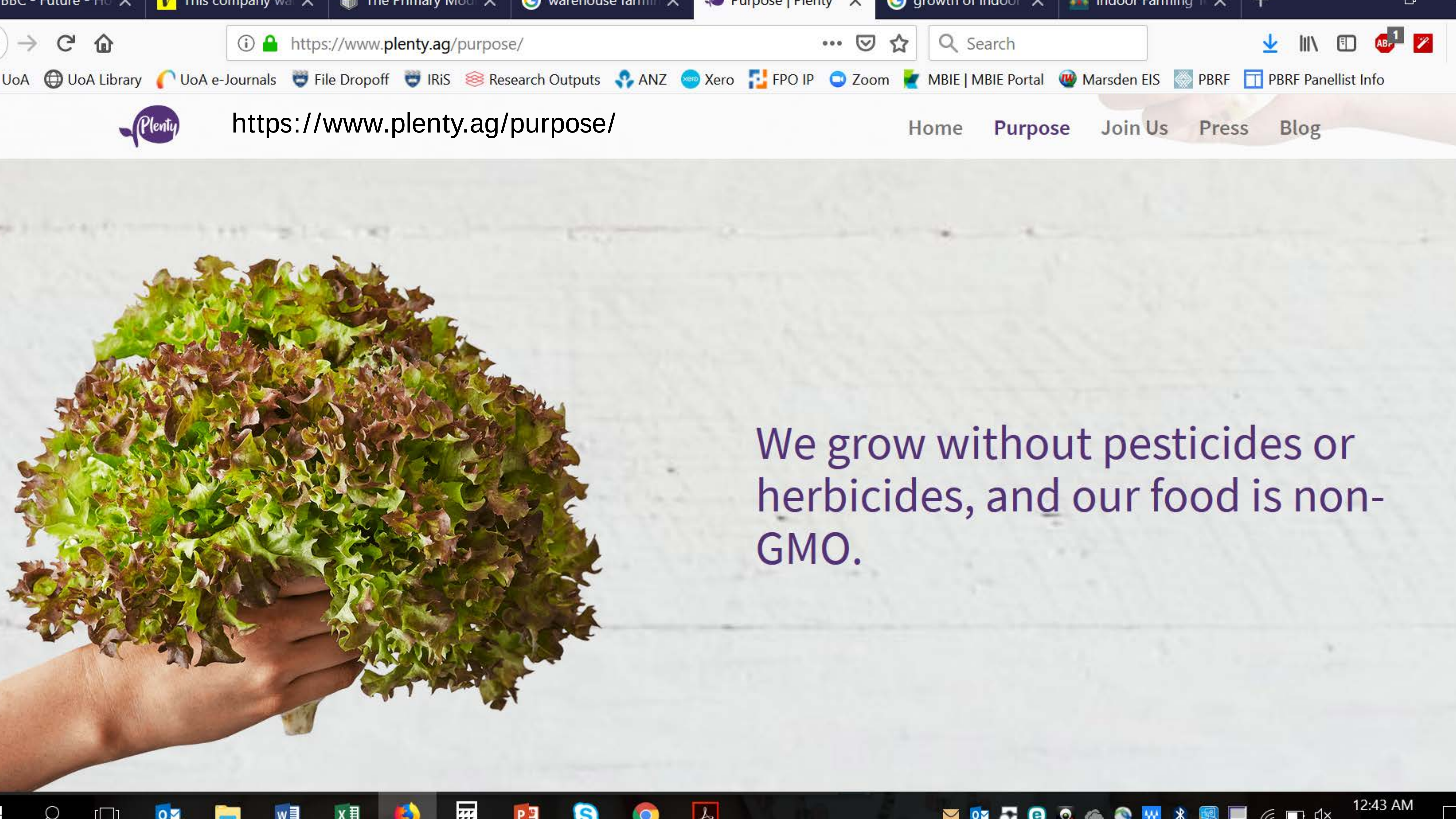
Advances in artificial lighting technology

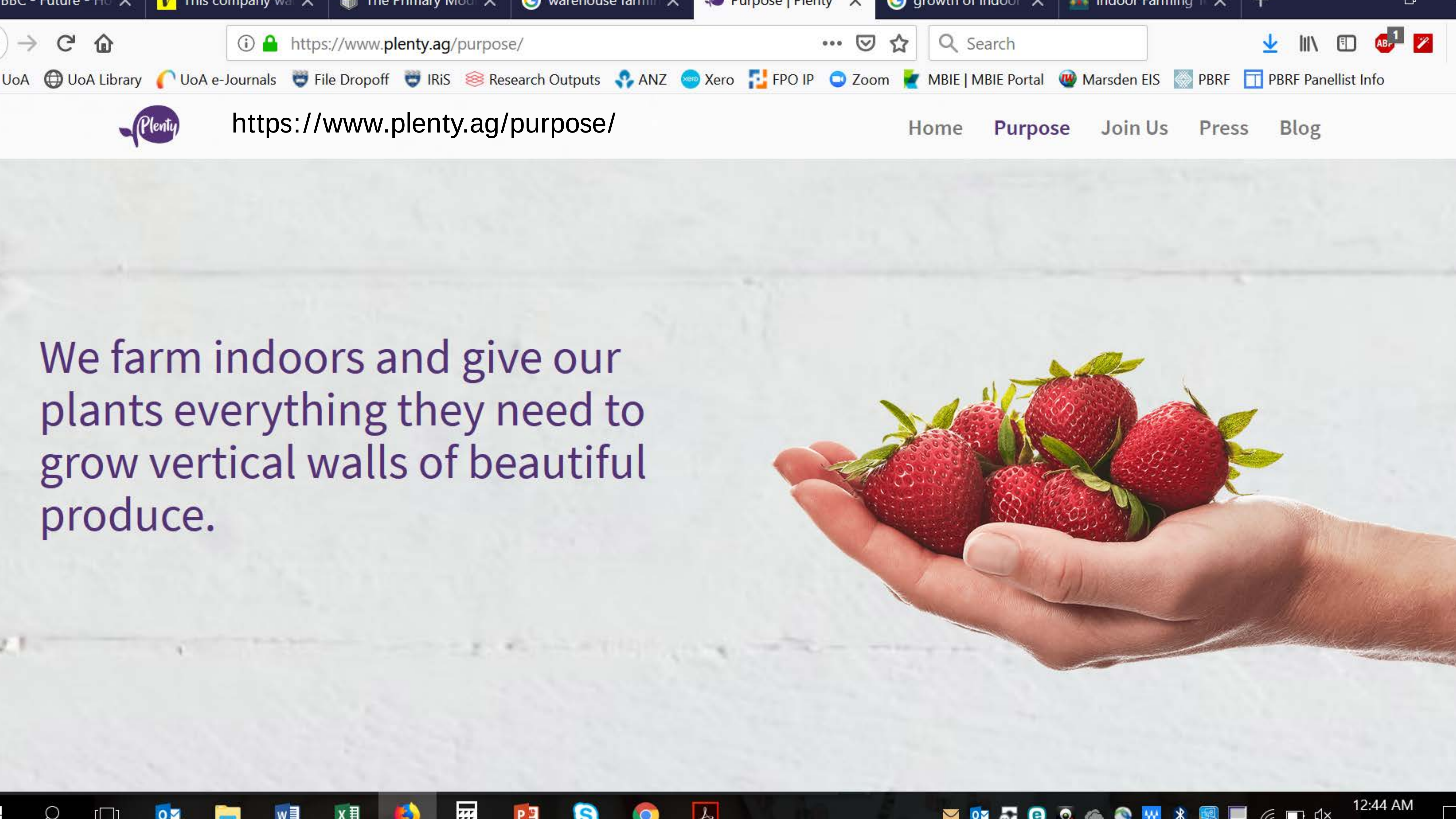
Cost of artificial lighting

https://www.plenty.ag/purpose/

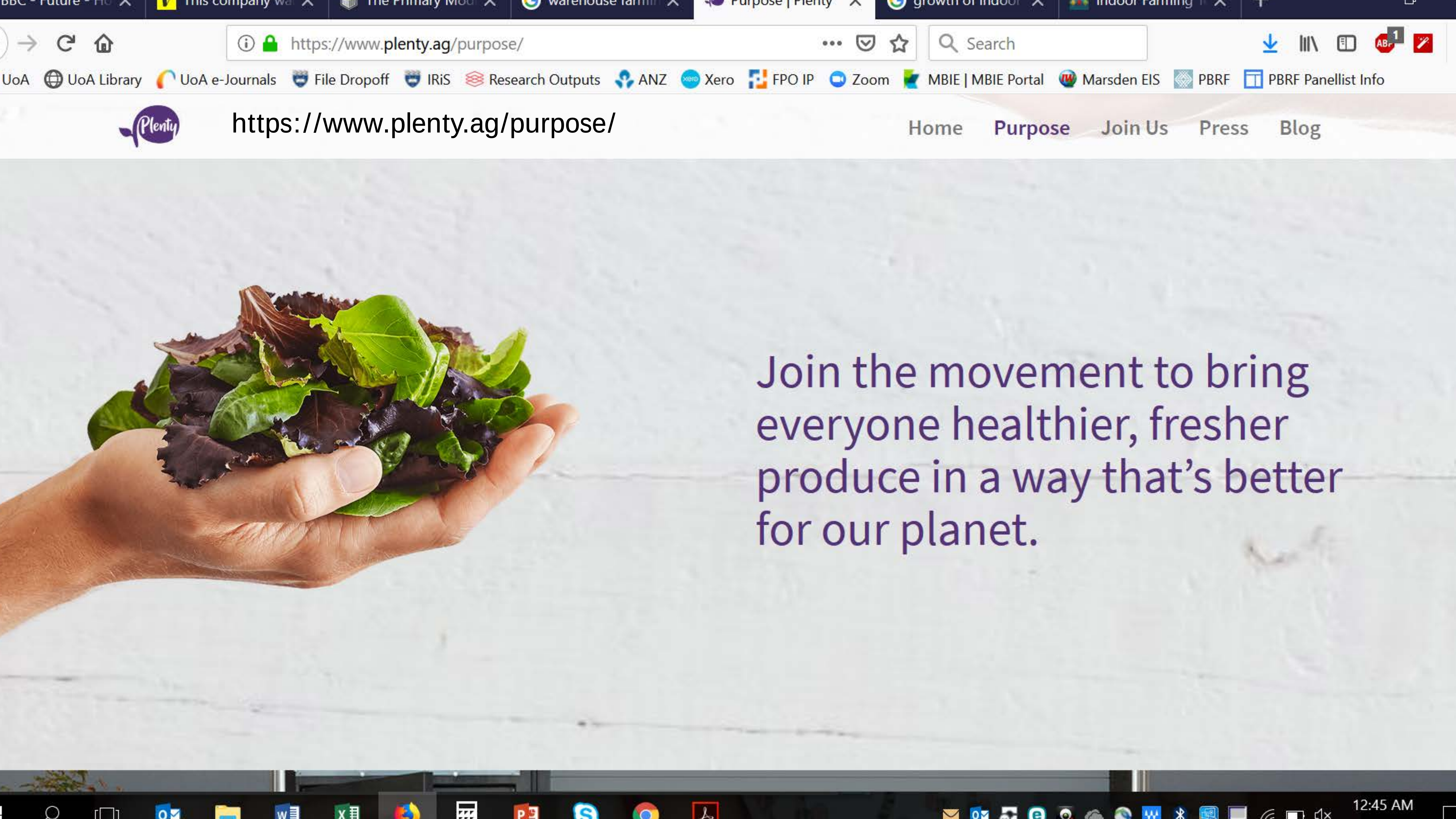
Home Purpose Join Us Press Blog

We build our farms next to where people live, so our produce is grown a short drive from your local store.


https://www.plenty.ag/purpose/
Home
Purpose
Join Us
Press
Blog
We grow without pesticides or herbicides, and our food is non-GMO.


https://www.plenty.ag/purpose/
Home
Purpose
Join Us
Press
Blog
We farm indoors and give our plants everything they need to grow vertical walls of beautiful produce.

https://www.plenty.ag/purpose/



Sundrop Farms

“Australian desert farm grows 17,000 metric tons of vegetables with just seawater and sun “

https://inhabitat.com/australian-desert-farm-grows-17000-metric-tons-of-vegetables-with-just-seawater-and-sun/?variation=c

Sundrop Farms

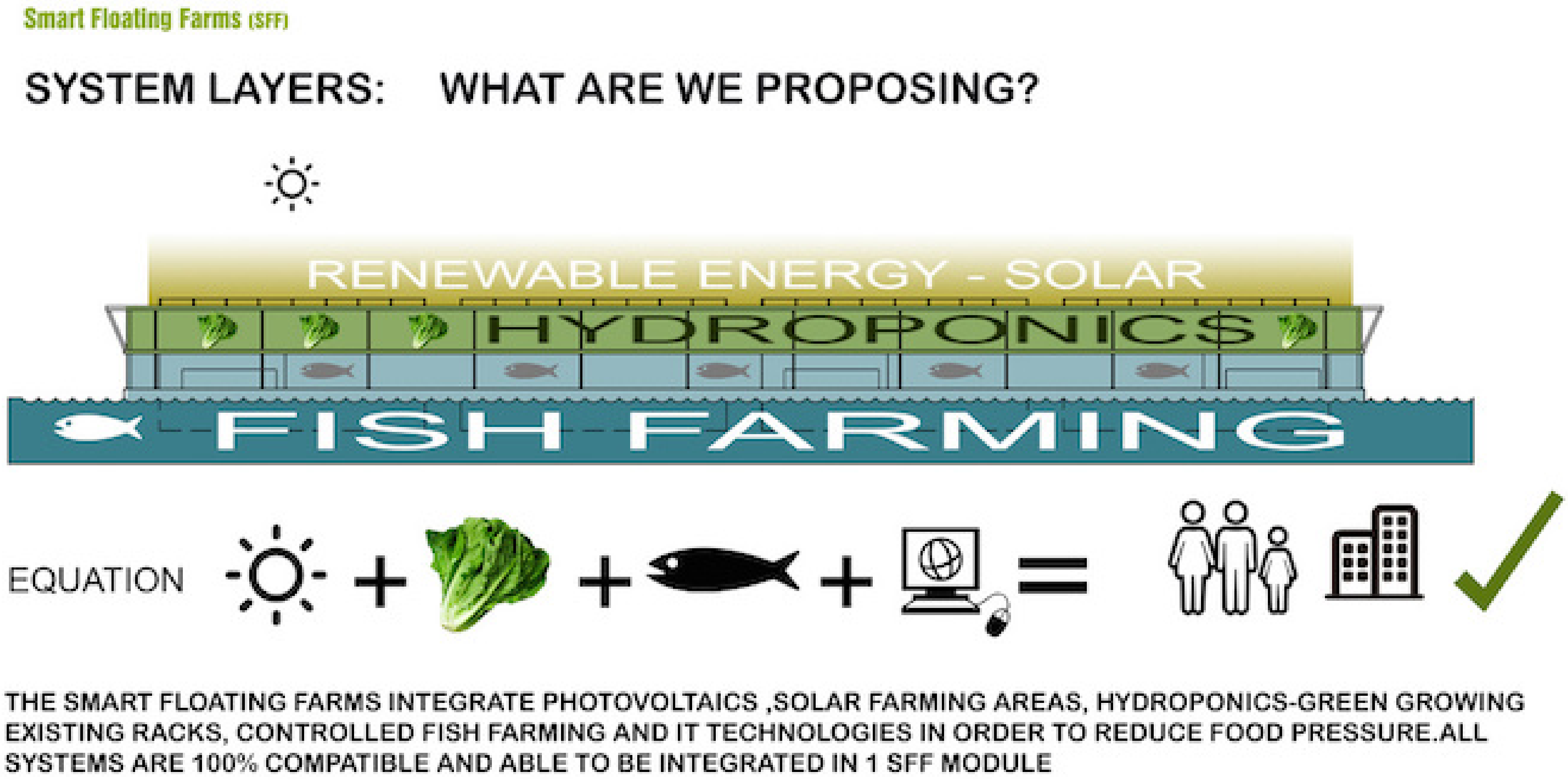
Concentrated solar power → heating, desalination (fresh water), electricity
Seawater → desalinated (solar) → plants + brine
39 MW peak power

https://inhabitat.com/australian-desert-farm-grows-17000-metric-tons-of-vegetables-with-just-seawater-and-sun/?variation=c

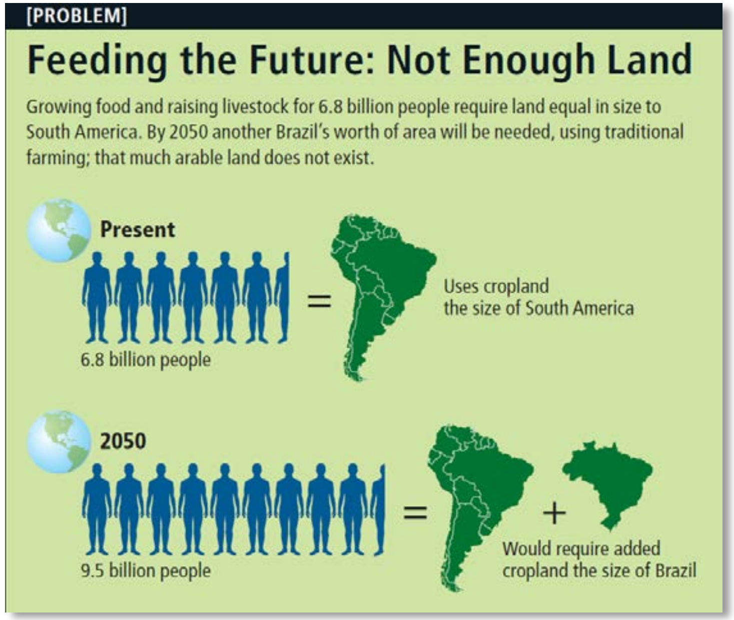
Sundrop Farms – Australia

Smart Floating Farms by Forward Thinking Architecture

Smart Floating Farms by Forward Thinking Architecture



The Need



The Photonics

The Cost