Title: Cather Simpson: University of Auckland

Speakers:

Collection: Perimeter Public Lectures

Date: March 06, 2019 - 7:00 PM

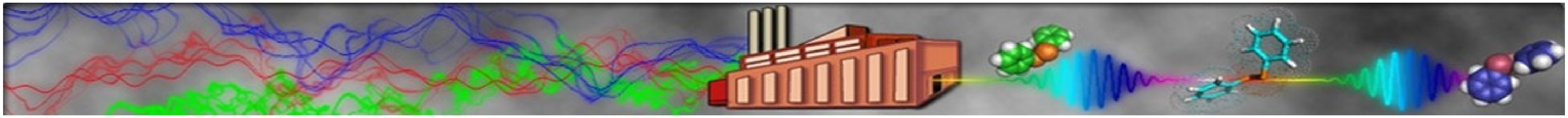
URL: http://pirsa.org/19030103

Abstract: The 21st century may come to be known as the Age of Photonics, as we exploit our ability to make and manipulate light as an amazing carrier of energy and information. From quantum computing and entanglement to eye surgery and solar energy, humans are already reaping the benefits of our own endeavours to understand and control light.

In her public lecture webcast at Perimeter on March 6, Cather Simpson from the University of Auckland will highlight her research in exploring how recent advances in the physics of light are transforming our ability to feed the planet safely and sustainably.

Simpson moved from Case Western Reserve University in the USA to the University of Aucklandâ€™s Physics and Chemistry Departments in 2007. There, she started the Photon Factory, a laser centre whose mission is to exploit exotic, ultrashort pulsed lasers to enable cross-disciplinary research from the very fundamental to the applied and entrepreneurial.

Simpsonâ€™s research explores the interaction of light with matter, particularly how materials can convert light into more useful forms of energy. A relatively recent area of focus is in agriculture, where her work has led to two international award-winning spinout companies. Her many recent accolades include a National Tertiary Teaching Excellence Award, the 2016 Silicon Valley Forum 1st-place AgTech medal, and election as a Fellow of the Royal Society of New Zealand Te ApÄ•rangi.



Farms, Food and Photonics!

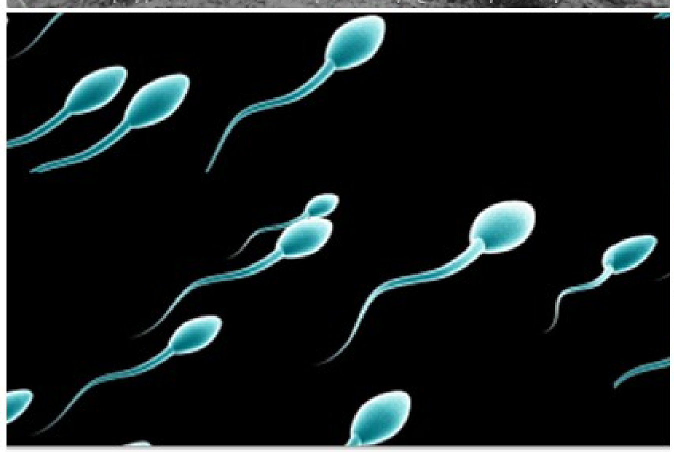
Professor Cather Simpson
Department of Physics
School of Chemical Sciences
Photon Factory
@ptolemytortoise

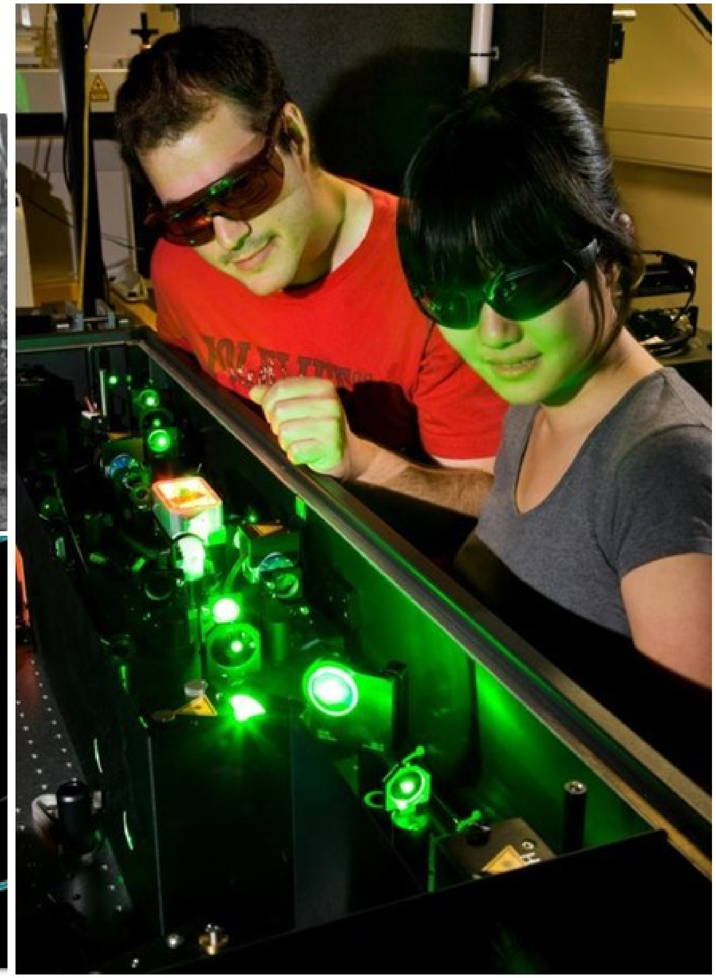
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

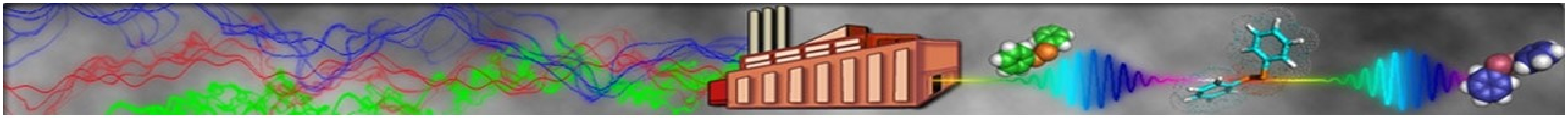
Photon Factory

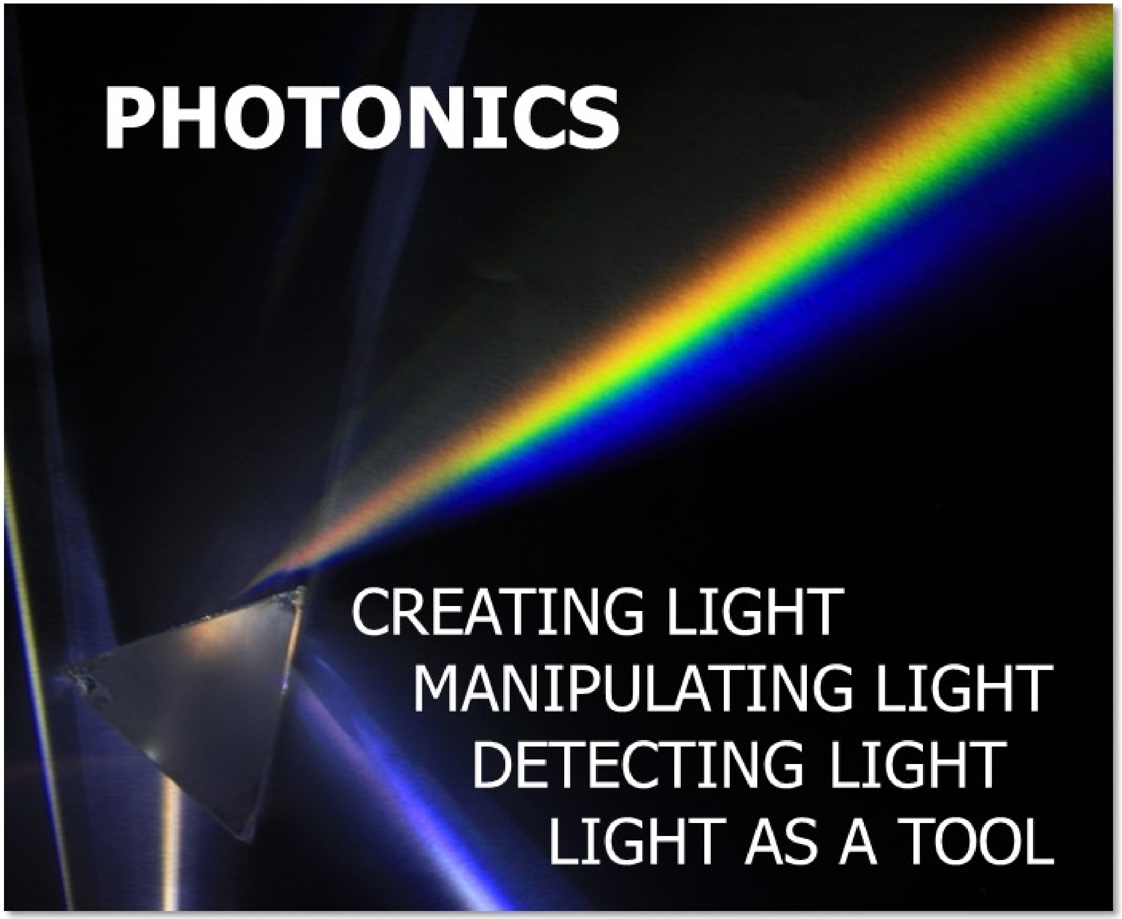
DODD-WALLS CENTRE
FOR PHOTONIC & QUANTUM TECHNOLOGIES

The MacDiarmid Institute
for Advanced Materials and Nanotechnology







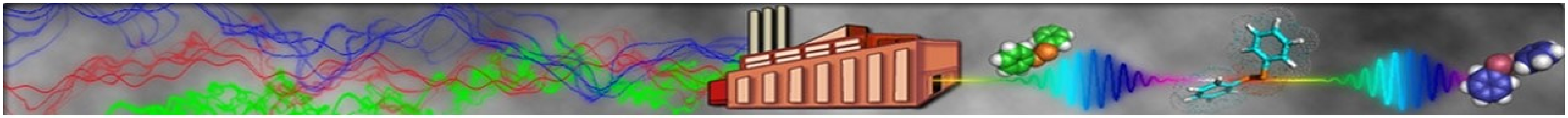


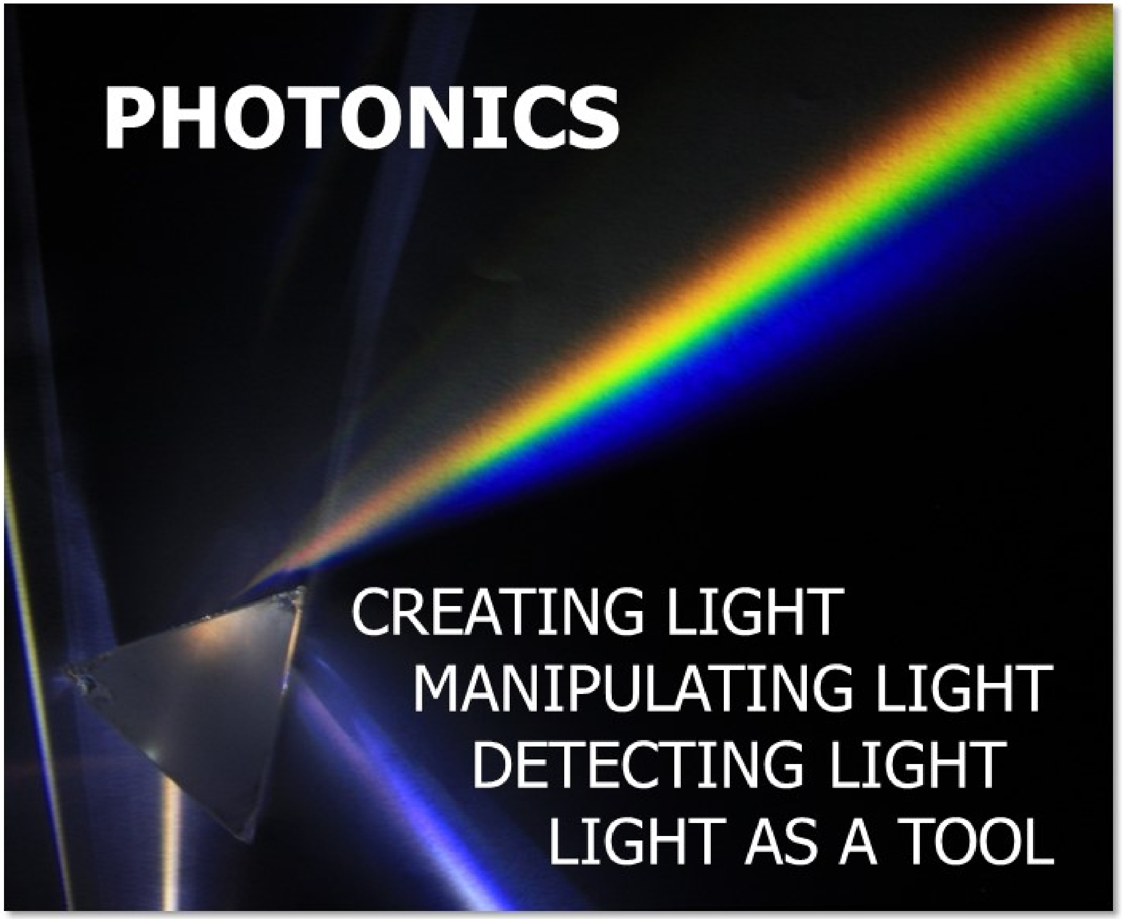
United Nations Educational, Scientific and Cultural Organization

International Year of Light 2015

International Year of Light New Zealand 2015

Te Tau ā-Taiao mō te Māramatanga Aotearoa 2015



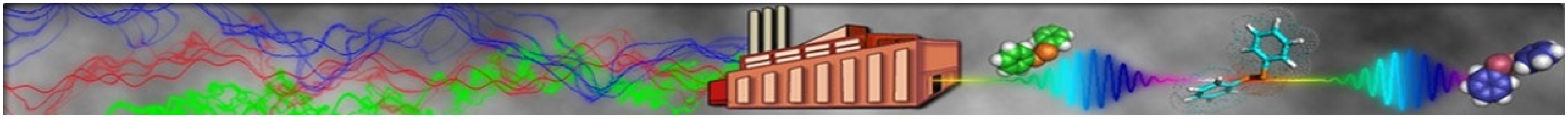


UNESCO
United Nations Educational, Scientific and Cultural Organization

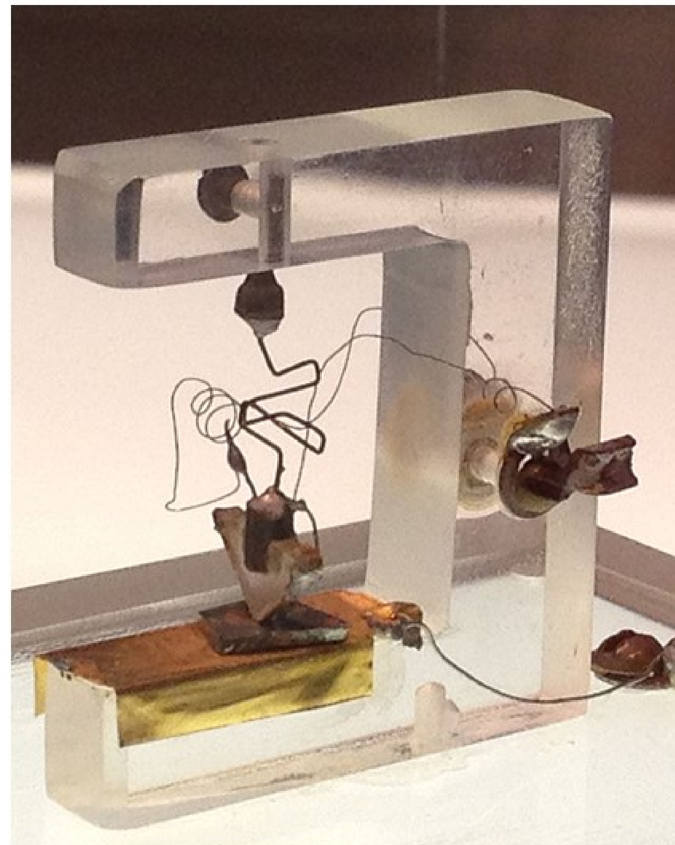
International Year of Light 2015

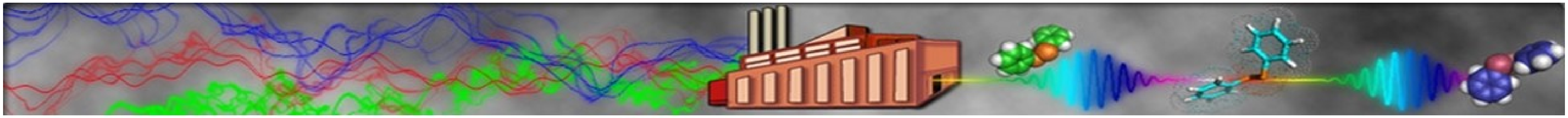
UNESCO
United Nations Educational, Scientific and Cultural Organization

International **Day of Light**
16 May

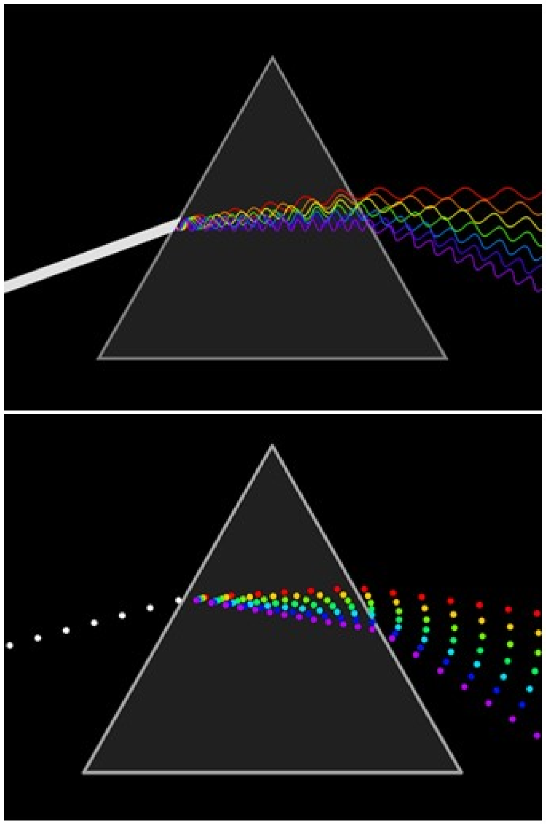


ELECTRONS ⟶ ELECTRONICS



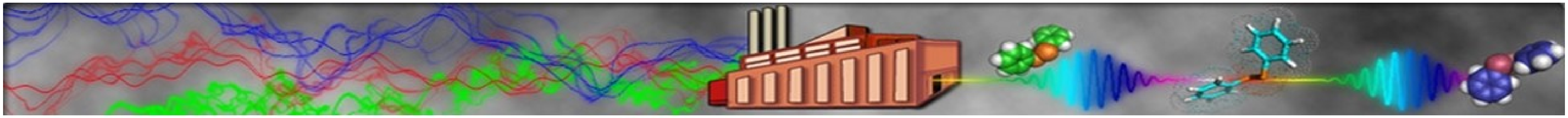


PHOTONS ⟶ PHOTONICS



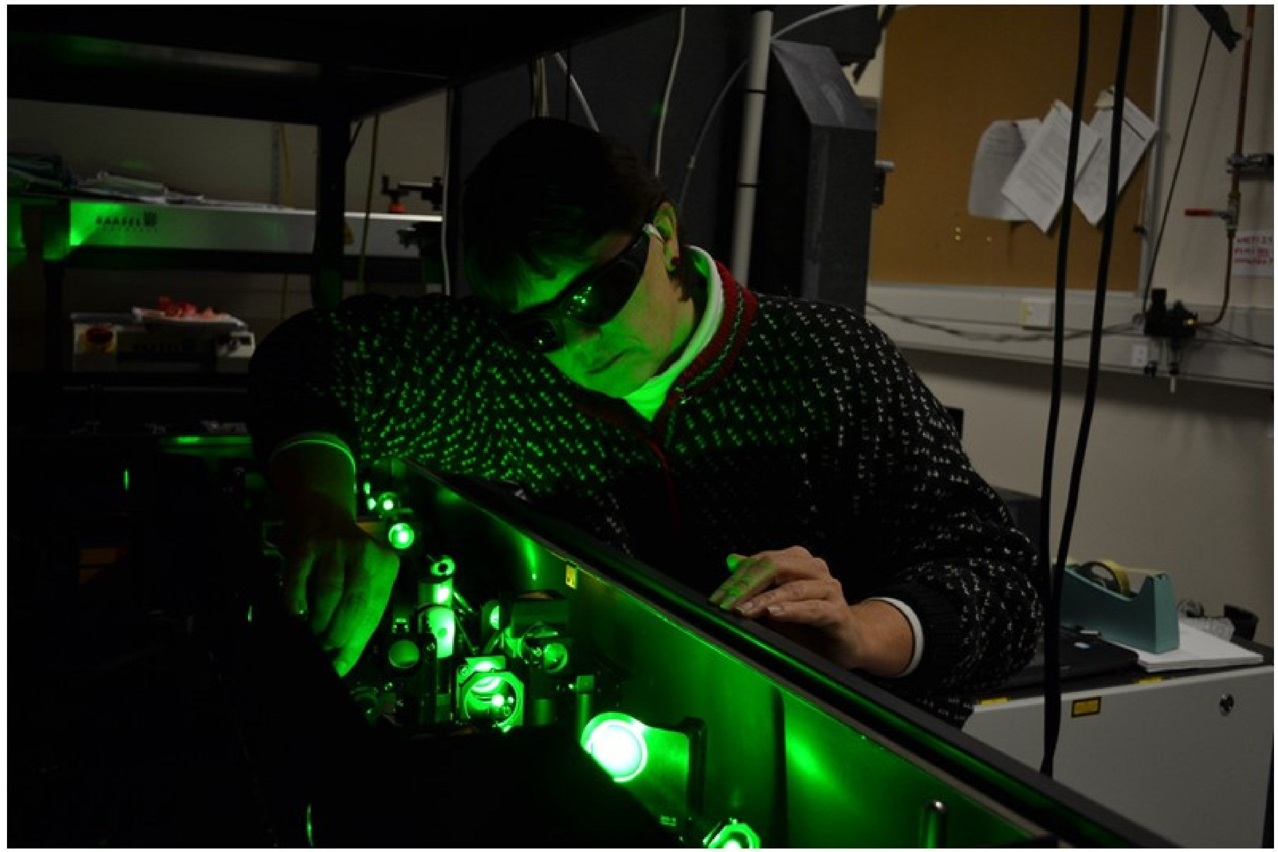
By LucasVB Wikimedia commons

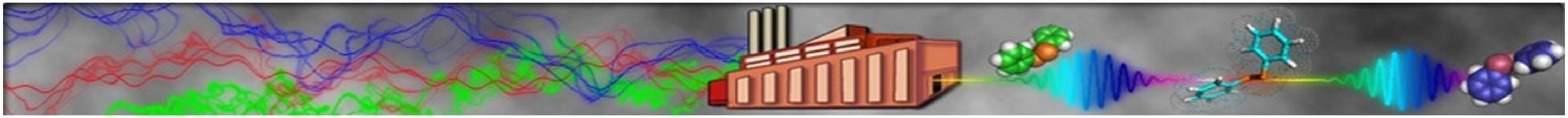
Douglas Hofstadter



PHOTONICS – making light work in the 21st century

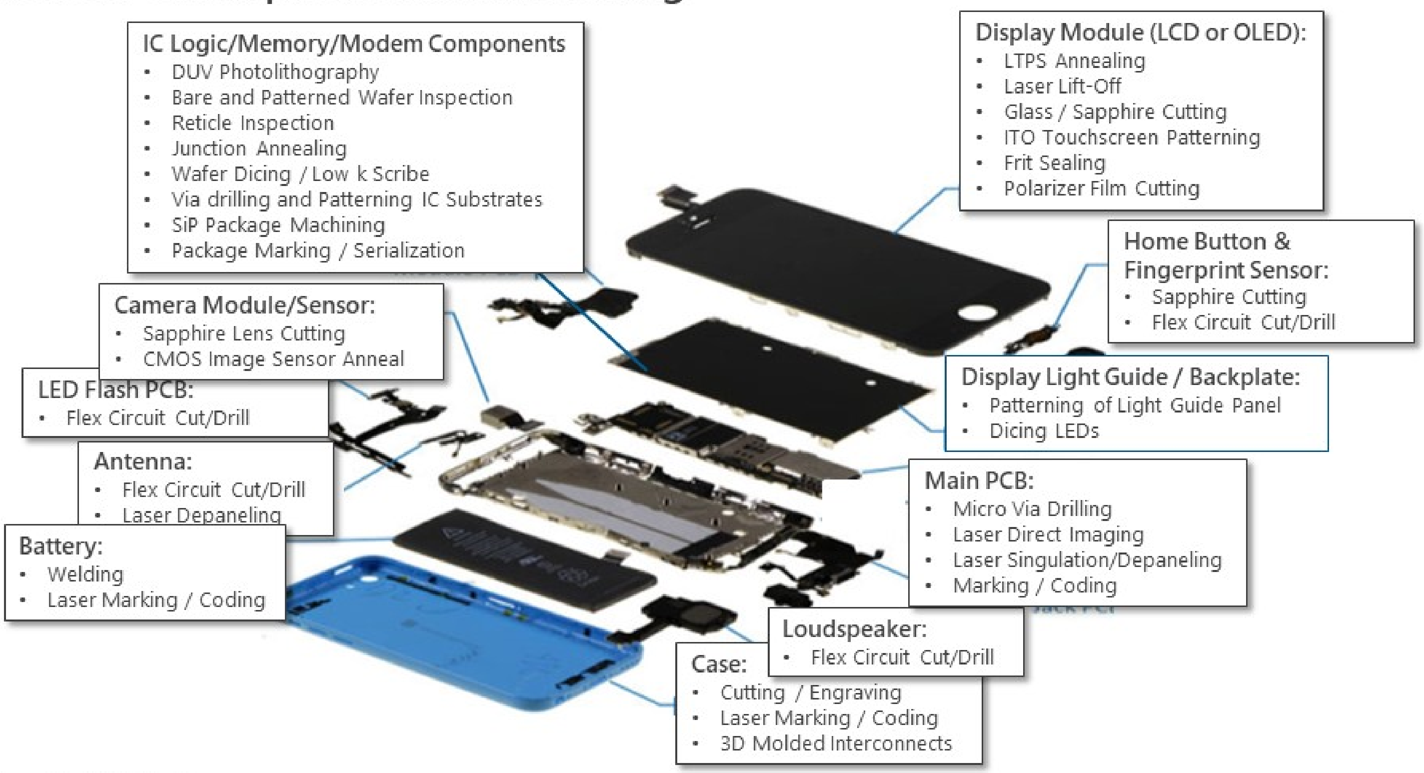

Photo Credit: HRL Laboratories, LLC



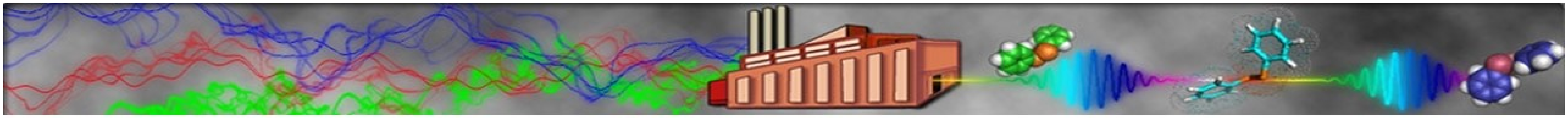


PHOTONICS – making light work in the 21st century

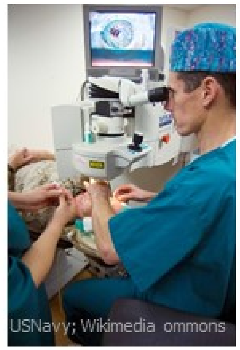
Laser Applications in Smartphone Manufacturing

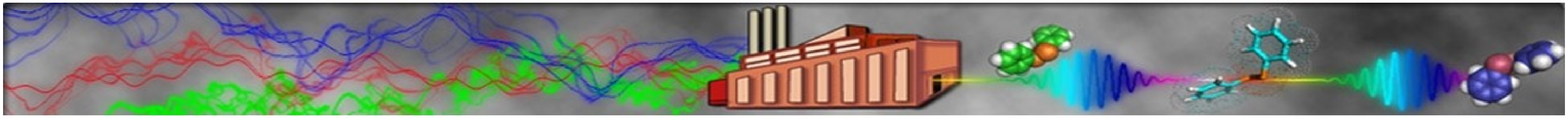


Burkhard Feckner: Coherent LaserSystems GmbH & Co. K

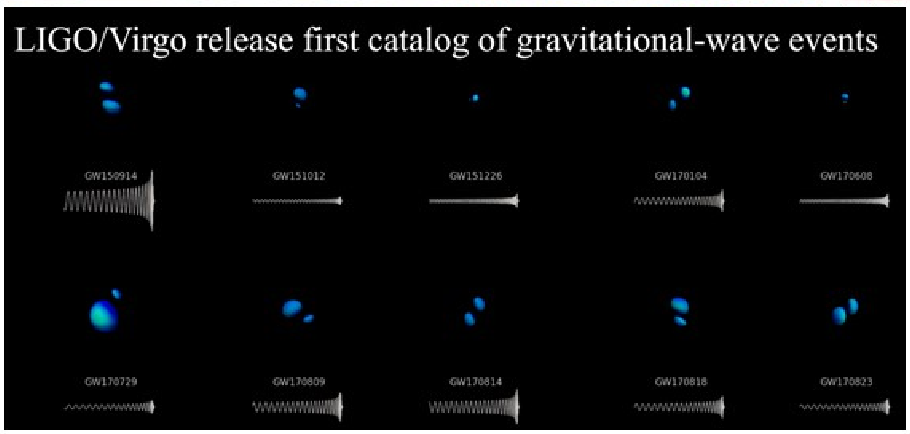


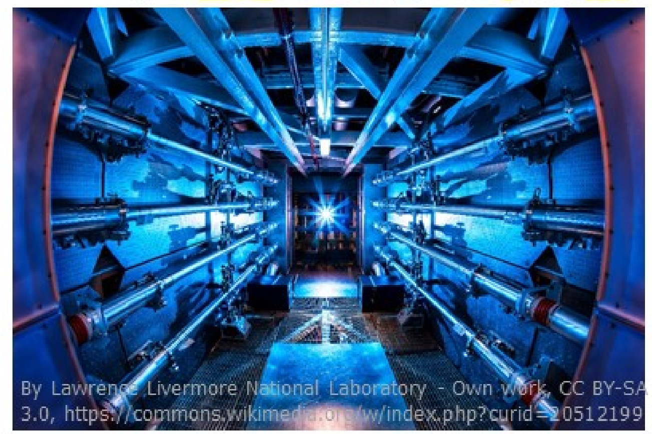
PHOTONICS – making light work in the 21st century

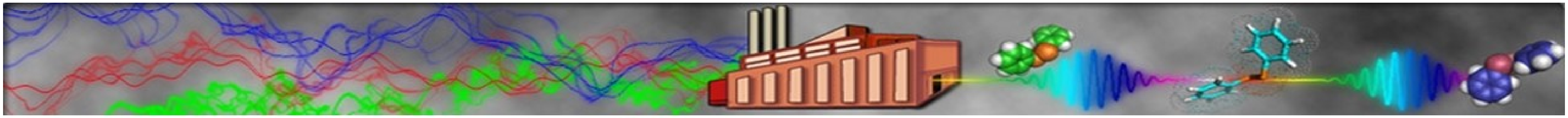




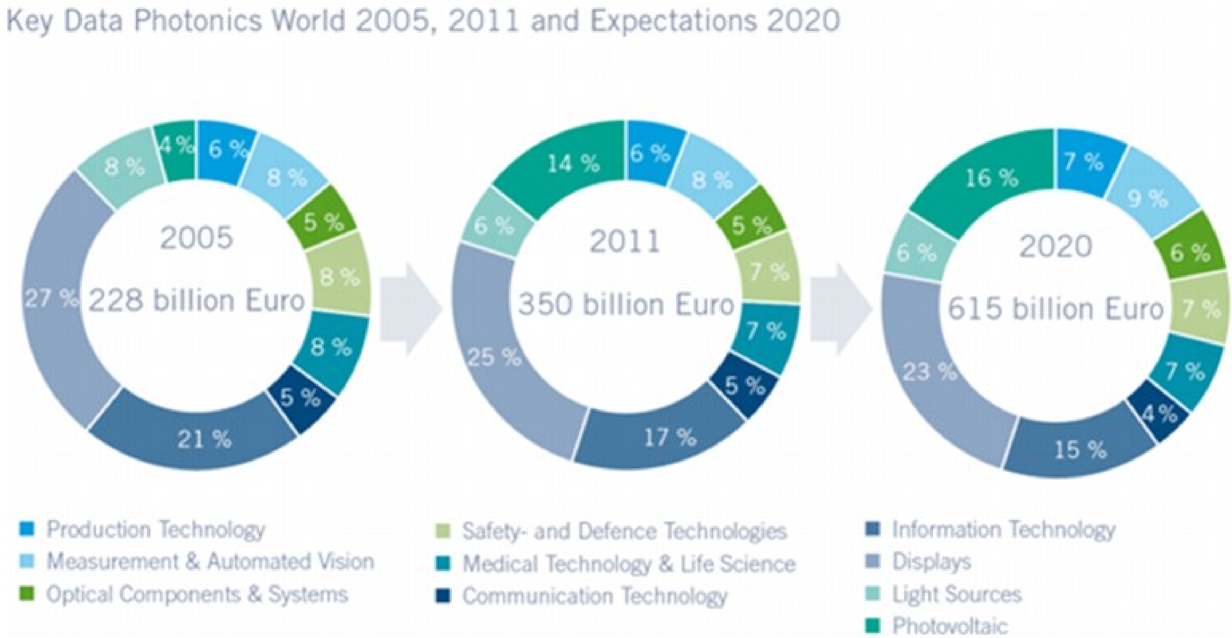
PHOTONICS – making light work in the 21st century







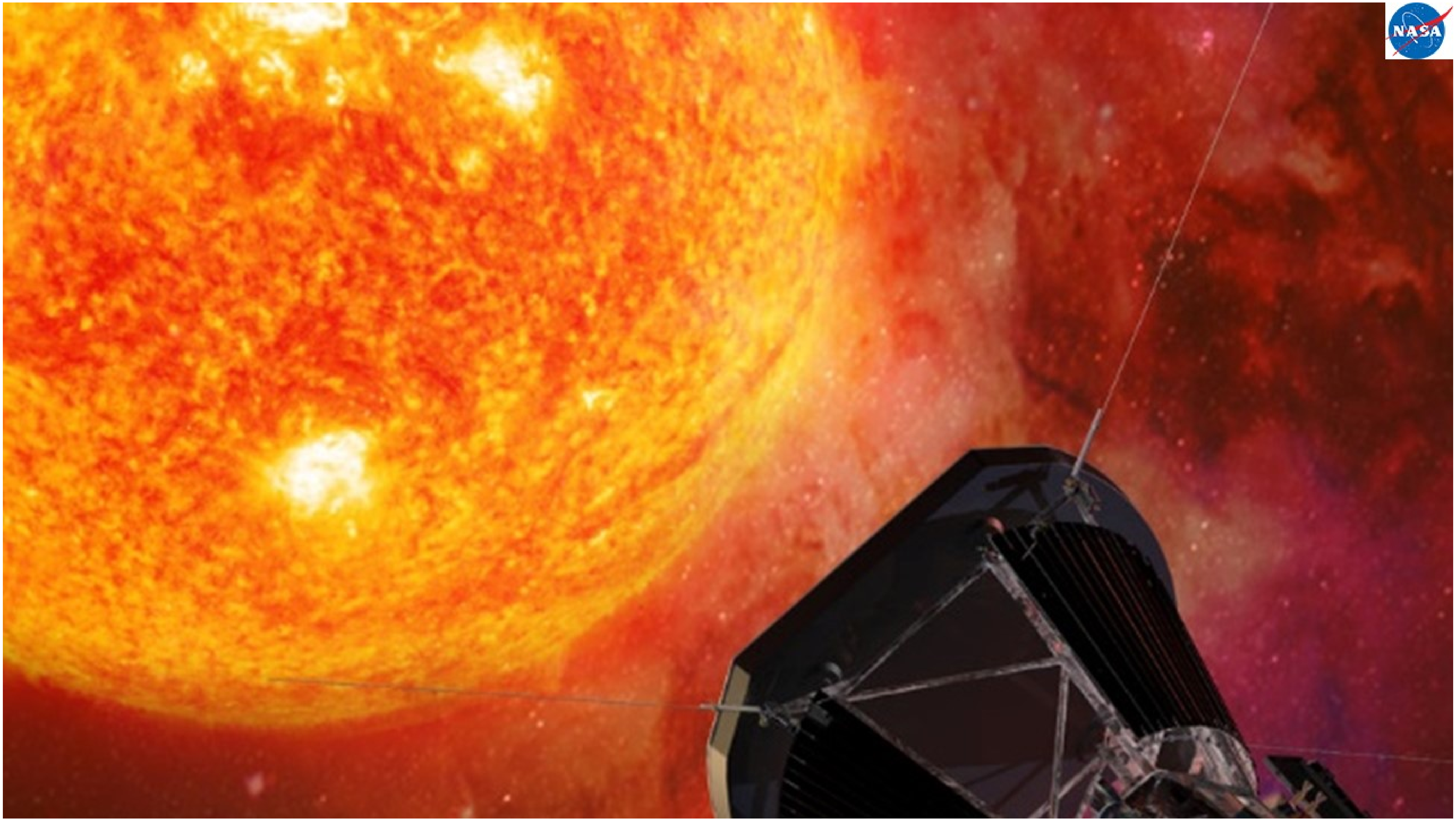
PHOTONICS – making light work in the 21st century

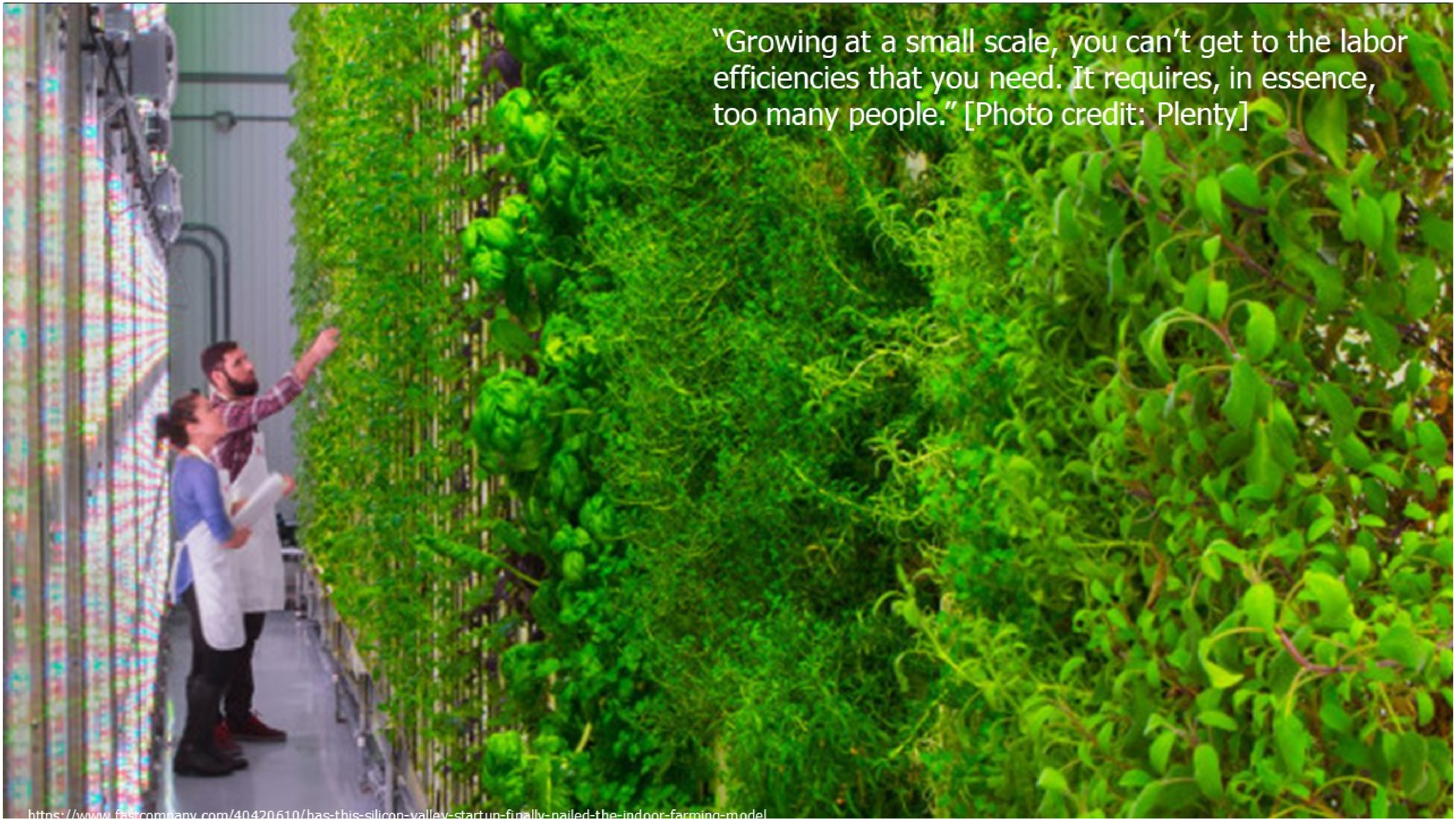


	2005	2011	2020
NZ$:	$379 billion	$582 billion	$1.02 trillion
Can$:	$344 billion	$528 billion	$929 billion

www.light.org

www.photonics21.org

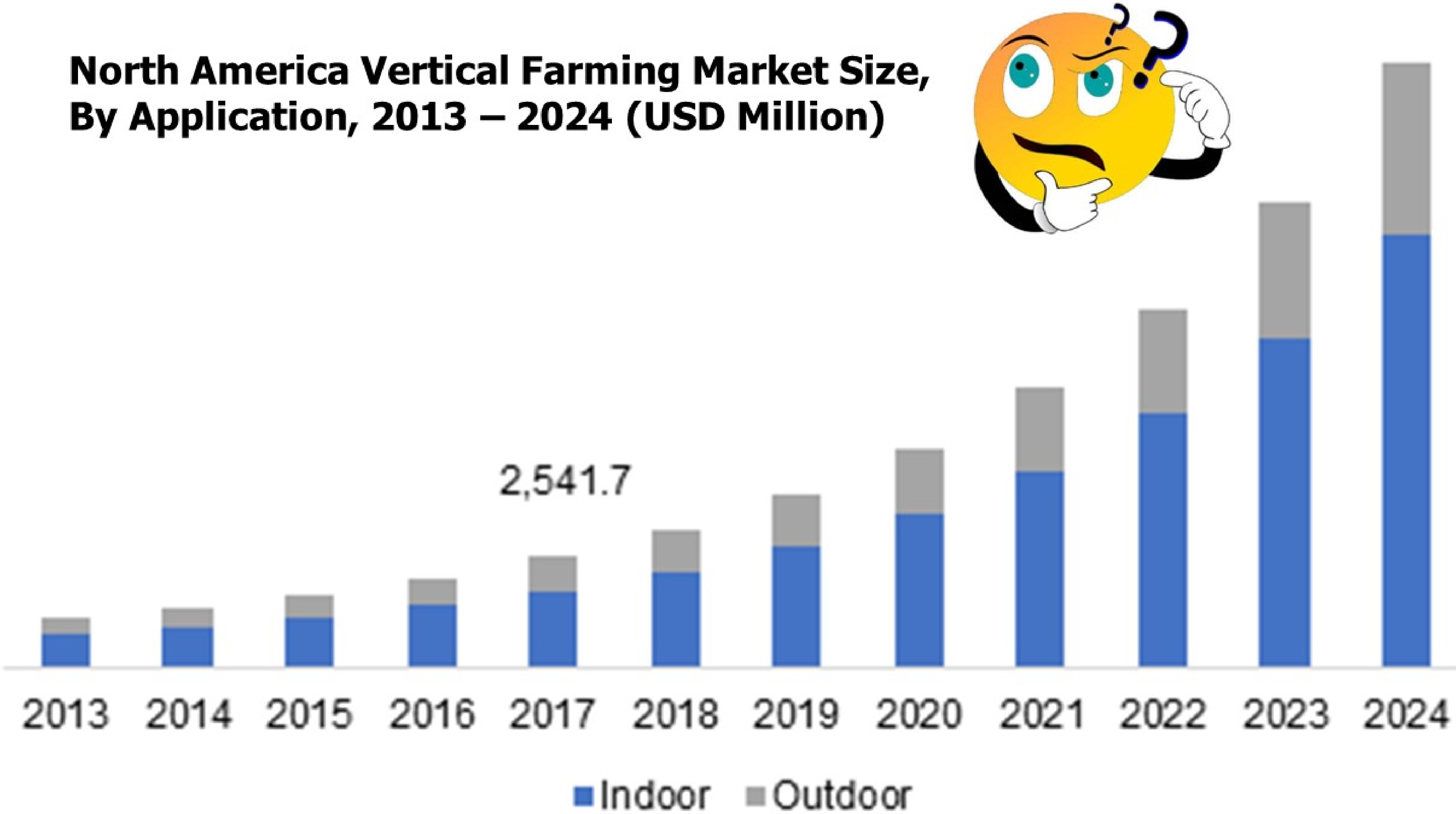



"Growing at a small scale, you can't get to the labor efficiencies that you need. It requires, in essence, too many people." [Photo credit: Plenty]
https://www.fastcompany.com/40420610/has-this-silicon-valley-startup-finally-nailed-the-indoor-farming-model

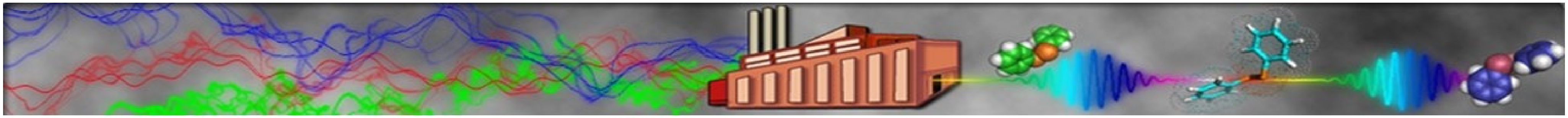
The RISE of VERTICAL FARMS

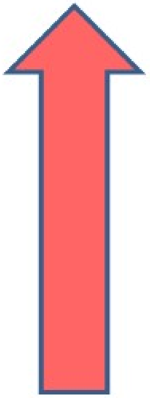
SCIENTIFIC AMERICAN November 2009

North America Vertical Farming Market Size, By Application, 2013 – 2024 (USD Million)

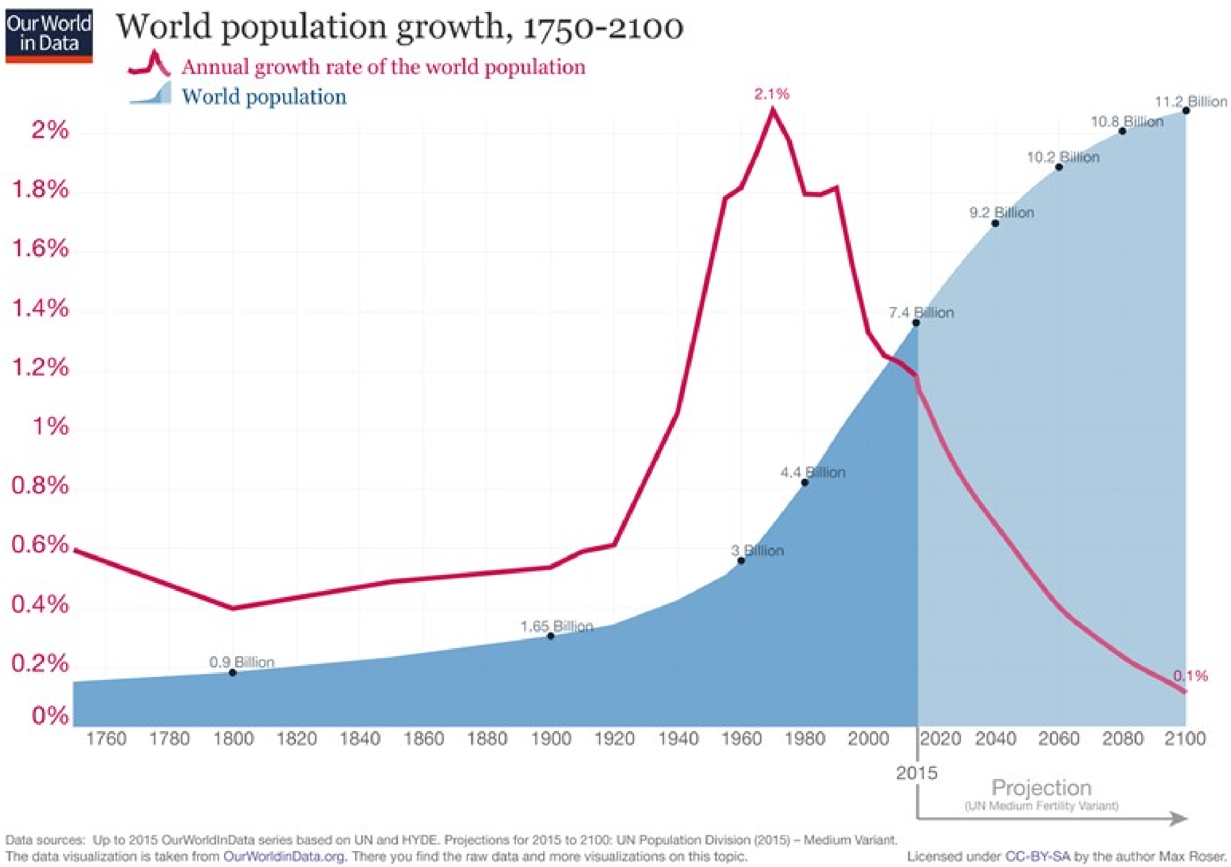


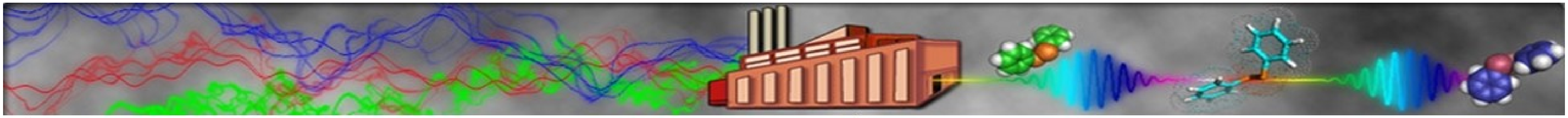
www.fractovia.org/news/industry-research-report/vertical-farming-market

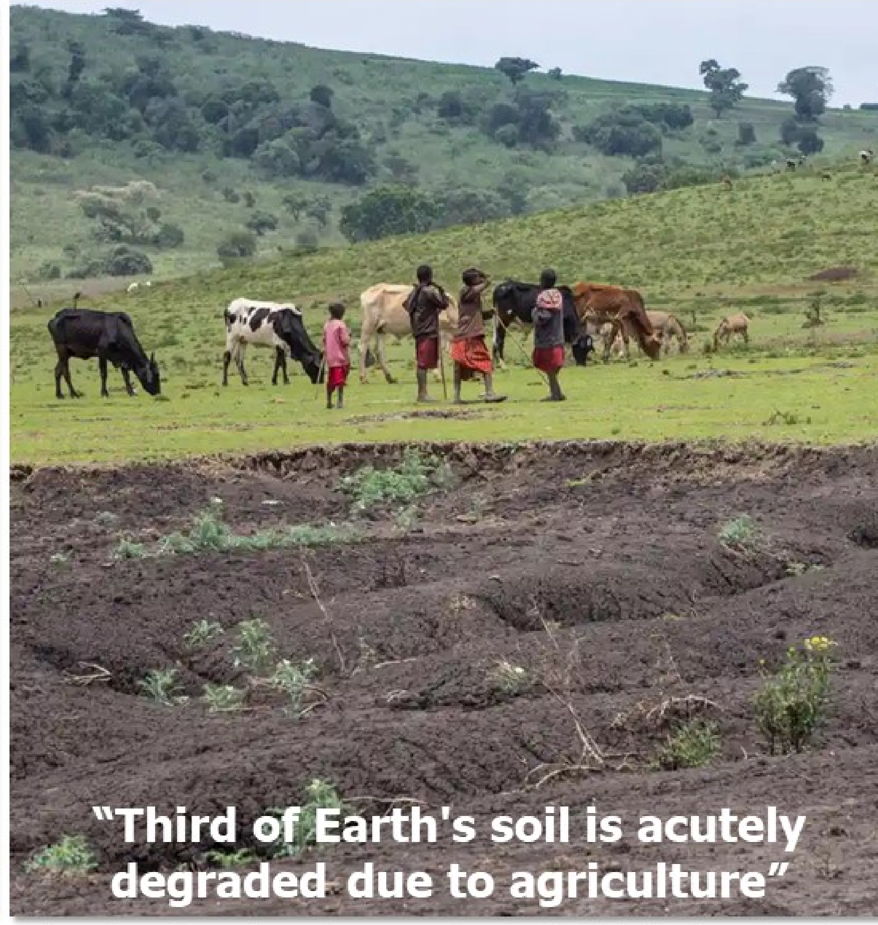




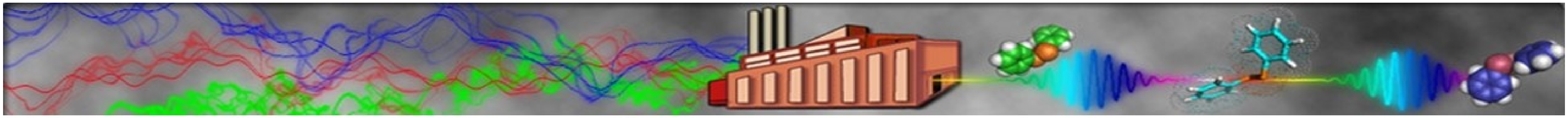
Population= people who eat!







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

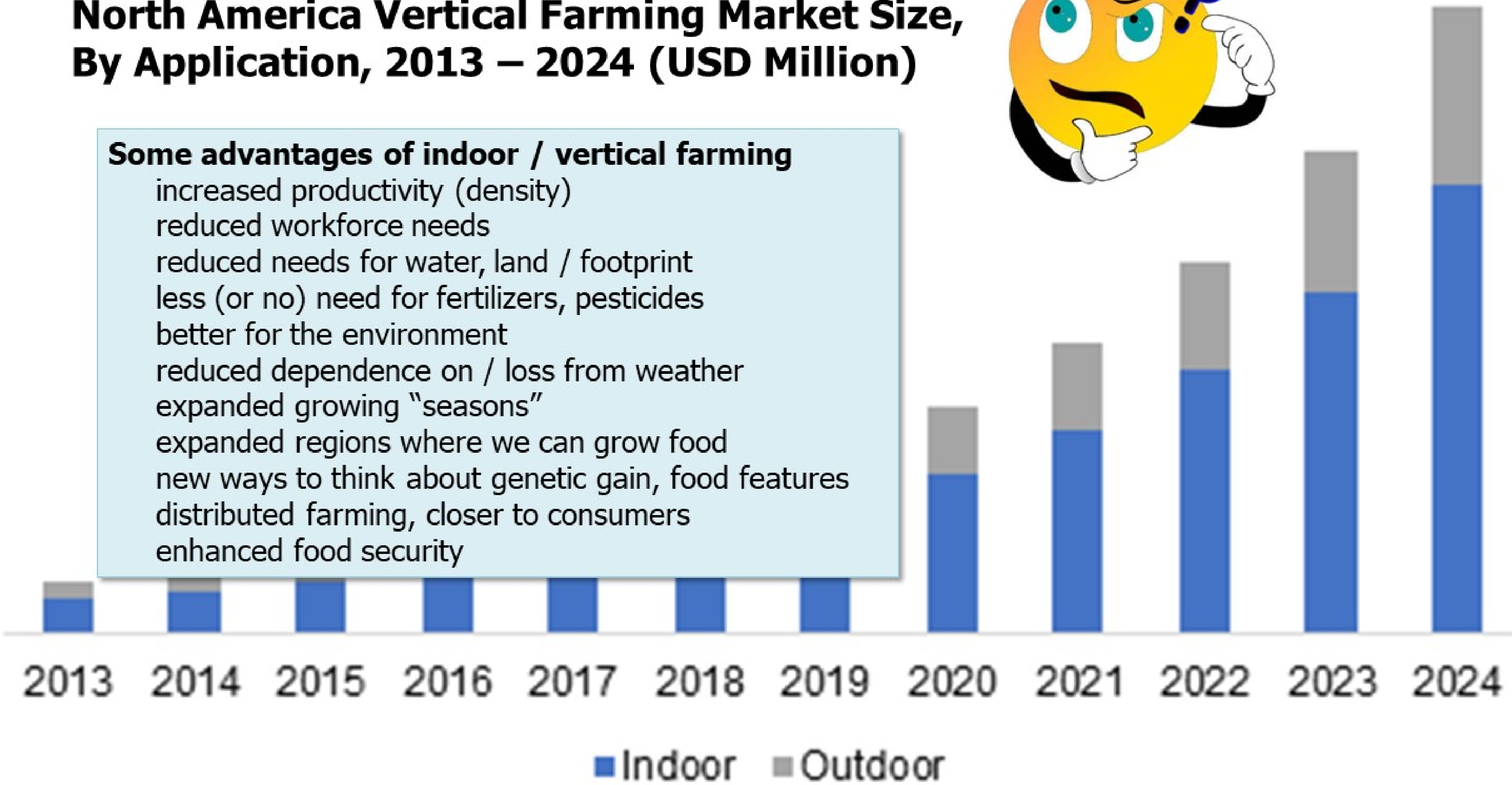



1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE 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

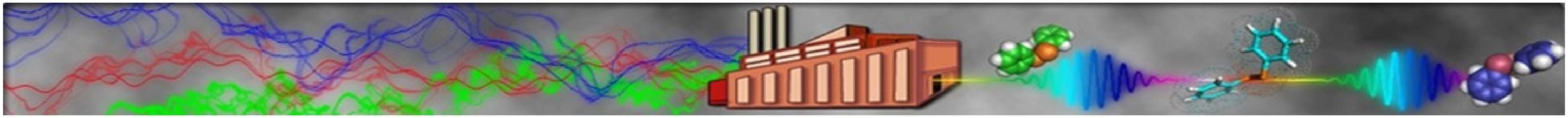
North America Vertical Farming Market Size, By Application, 2013 – 2024 (USD Million)

Some advantages of indoor / vertical farming

- increased productivity (density)
- reduced workforce needs
- reduced needs for water, land / footprint
- less (or no) need for fertilizers, pesticides
- better for the environment
- reduced dependence on / loss from weather
- expanded growing "seasons"
- expanded regions where we can grow food
- new ways to think about genetic gain, food features
- distributed farming, closer to consumers
- enhanced food security

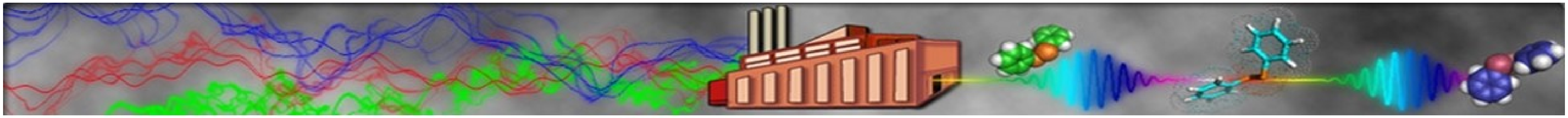


www.fractovia.org/news/industry-research-report/vertical-farming-market



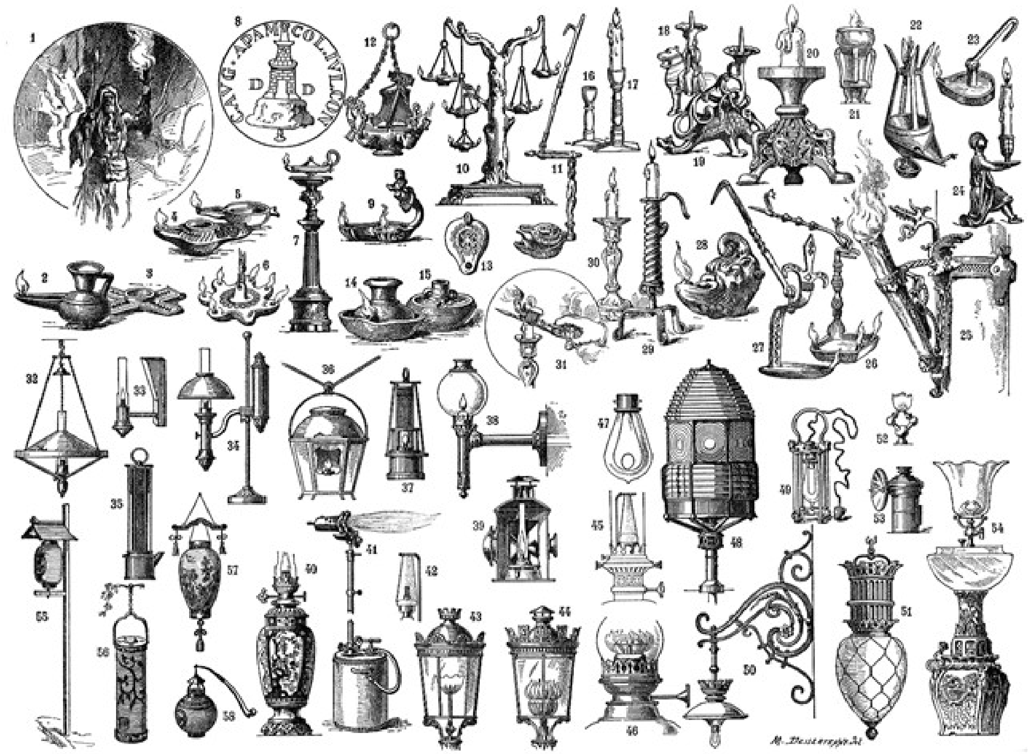
Advances in photonic technologies

Cost of photonic technologies

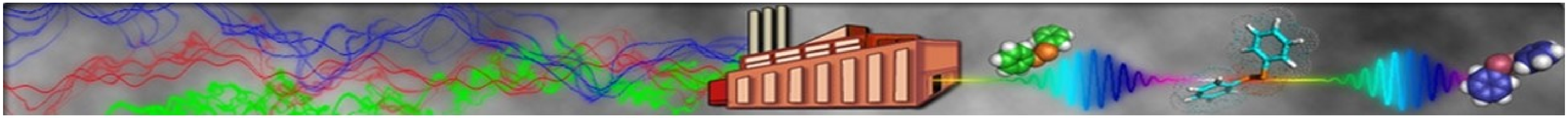


Advances in artificial lighting technology

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/

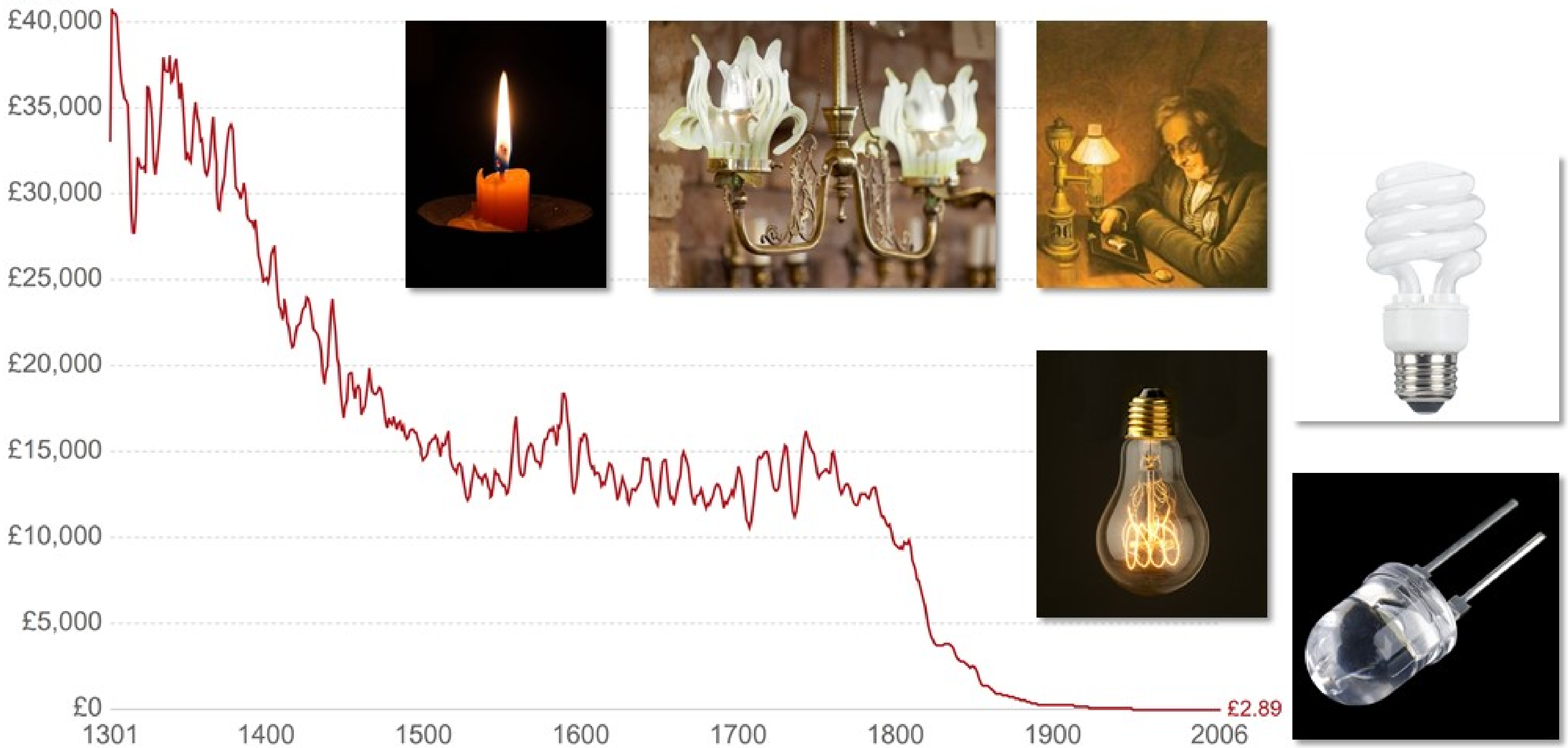


The Price for Lighting (per million lumen-hours) in the UK in British Pound

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

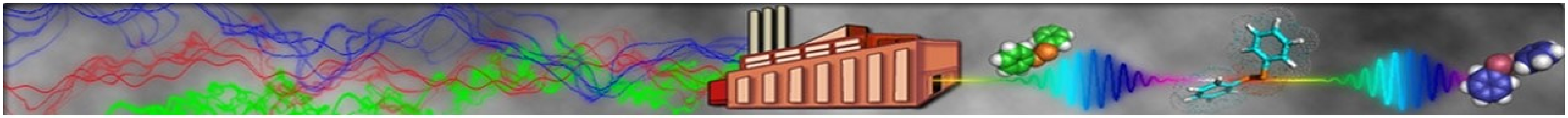
1 lumen hour is equal to the luminous energy emitted in 1 hour by a light source emitting a luminous flux of 1 lumen. For comparison: a standard 100W incandescent light bulb emits ±1700 lumen.

LINEAR



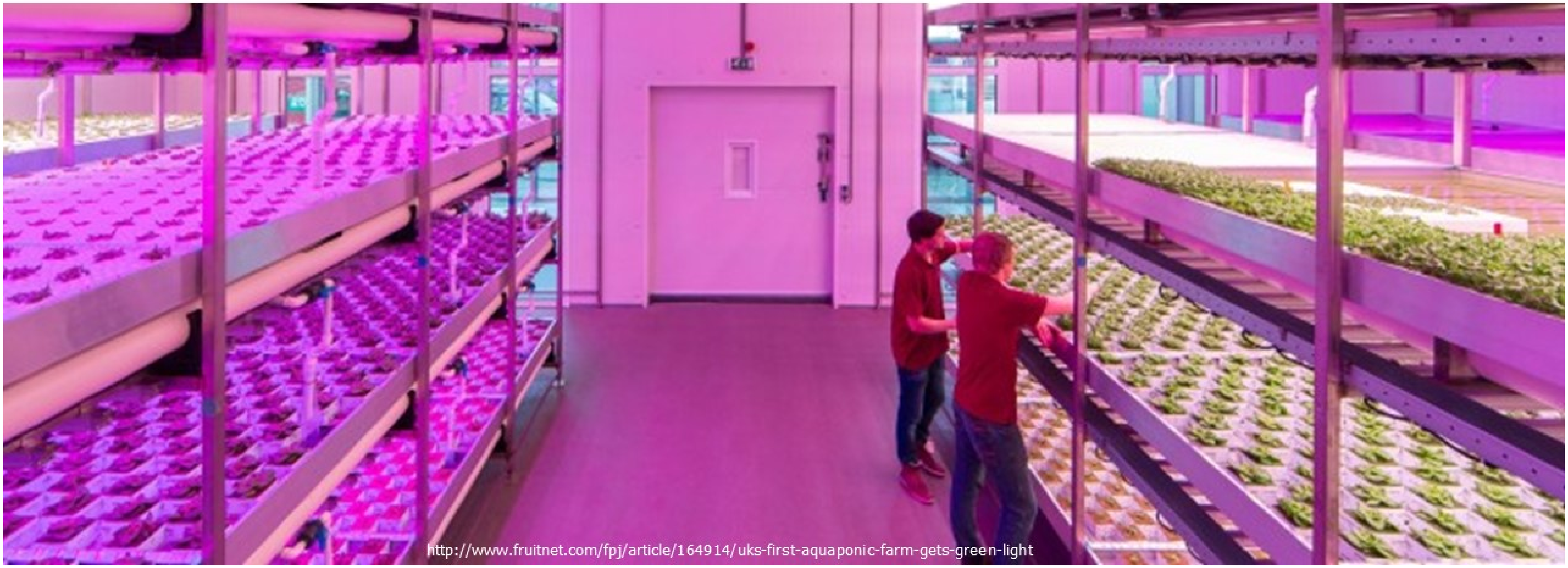
Source: Fouquet and Pearson (2012)

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

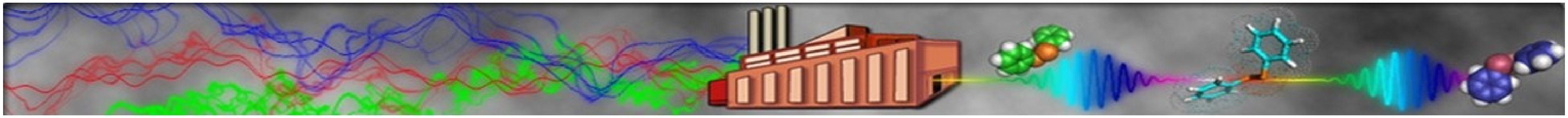


"A London warehouse will be converted into a salad, herb and fish farm, and will produce 200,000 bags of salad a year"

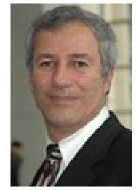
2015, Fresh Produce Journal



https://spectrum.ieee.org/energy/environment/the-green-promise-of-vertical-farms Photo: Harry Goldstein



Powering the planet: Chemical challenges in solar energy utilization



Nathan S. Lewis*† and Daniel G. Nocera†‡

*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
$\dot{C}/\dot{E}$	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].

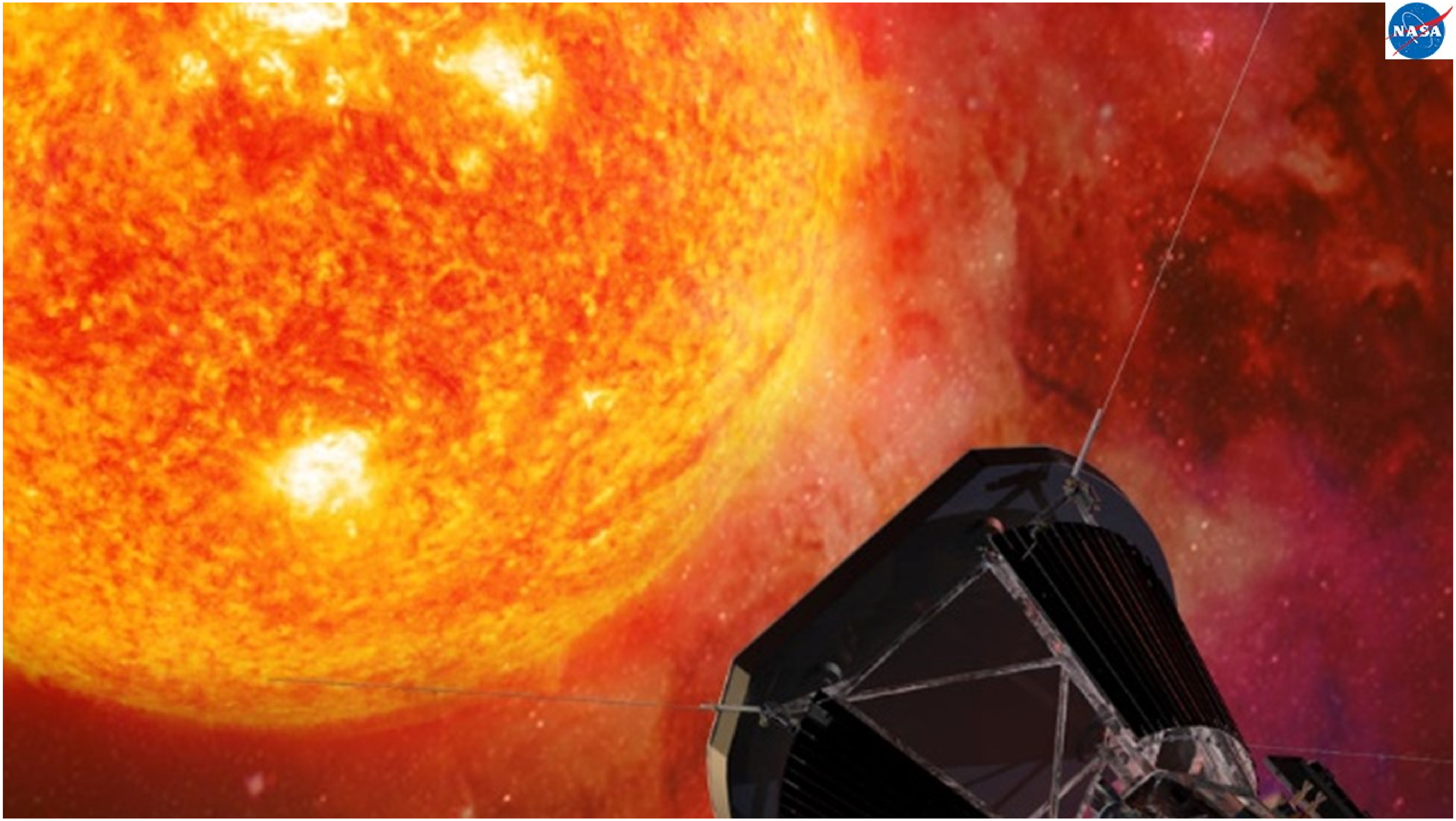
‡$\dot{E}$ = (1,357 EJ/yr)·(10^6 TJ/EJ)/(60·60·24·365 s/yr) = 43.0 TW [adapted from ref. 2 (Scenario B2), pp. 48–55].

§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.

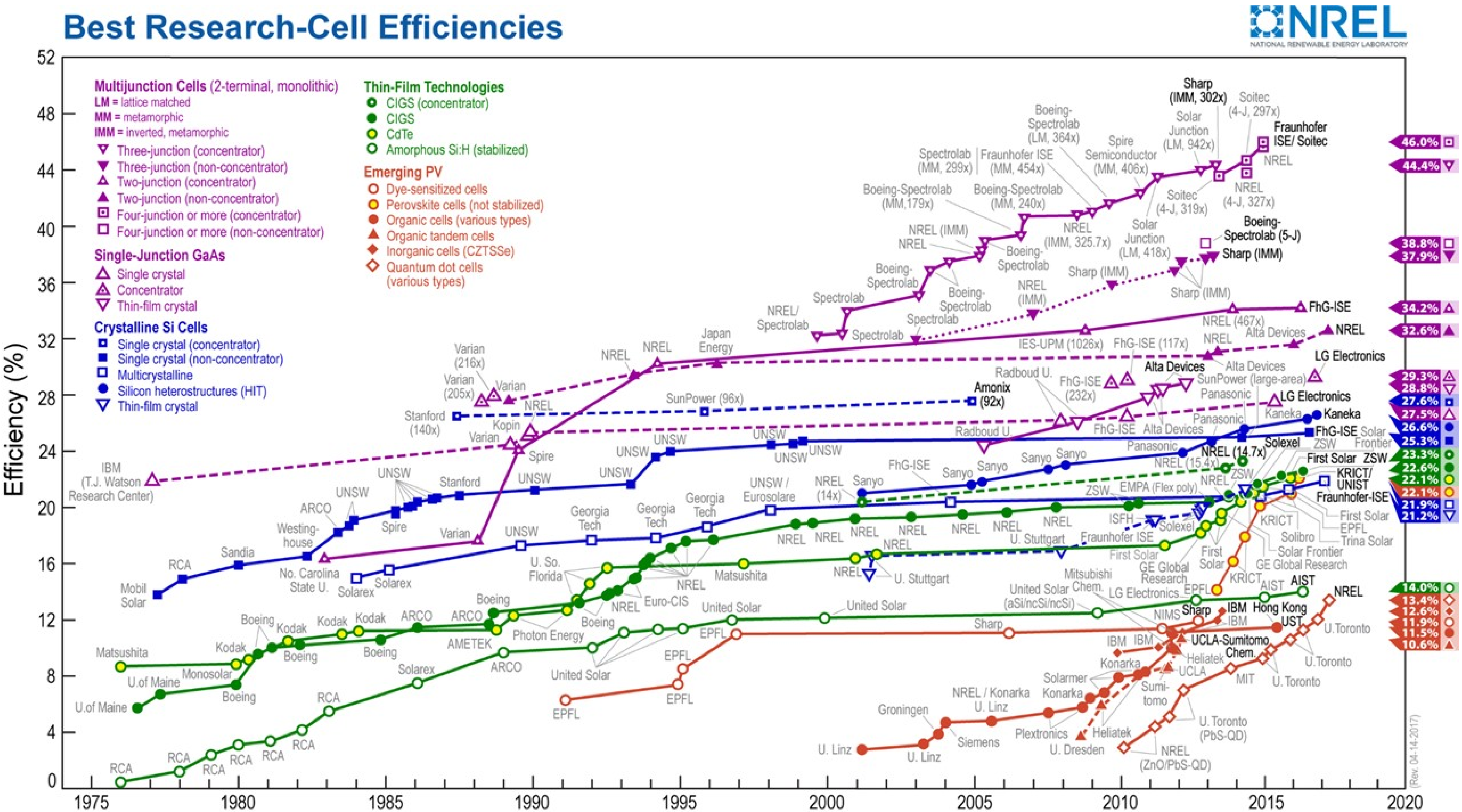
¶In year 2000 U.S. dollars: (113.9 $T\$_{1990}$)·(1/0.81590 $\$_{2000}/\$_{1990}$) = 139.6 $T\$_{2000}$.

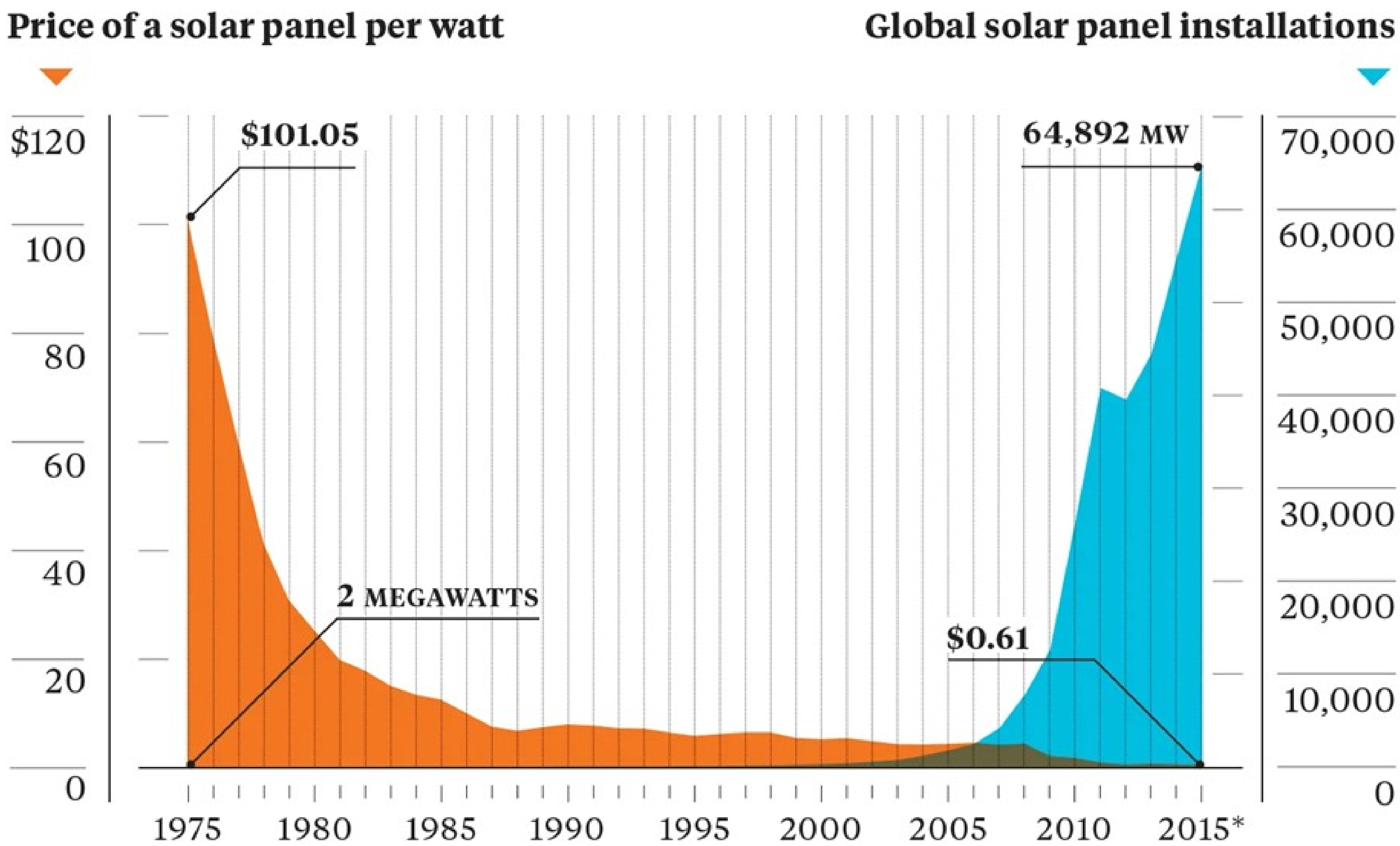
‖In year 2000 U.S. dollars: (231.8 $T\$_{1990}$)·(1/0.81590 $\$_{2000}/\$_{1990}$) = 284.1 $T\$_{2000}$.

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



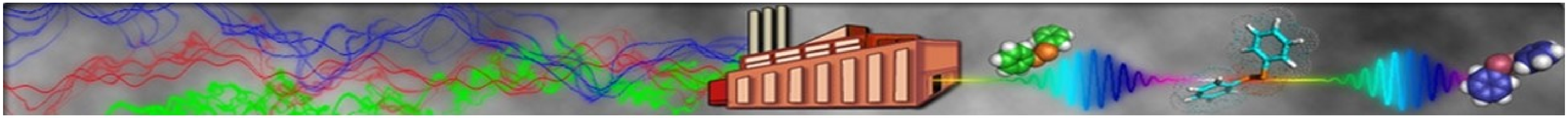
Best Research-Cell Efficiencies





*Estimate. Sources: Bloomberg, Earth Policy Institute, www.earth-policy.org

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



Energy Policy 123 (2018) 700–710

Contents lists available at ScienceDirect

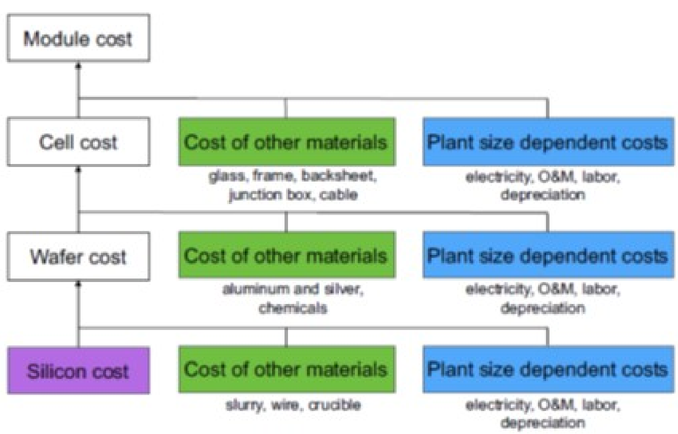
Energy Policy

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

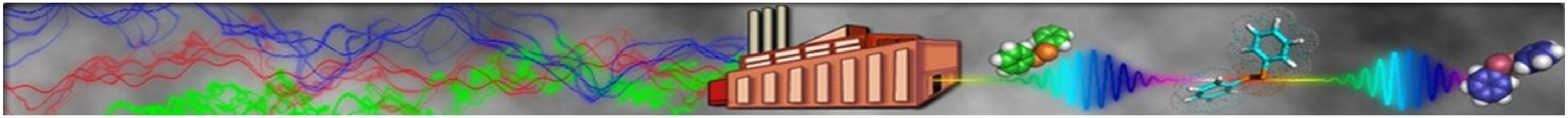
Evaluating the causes of cost reduction in photovoltaic modules

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

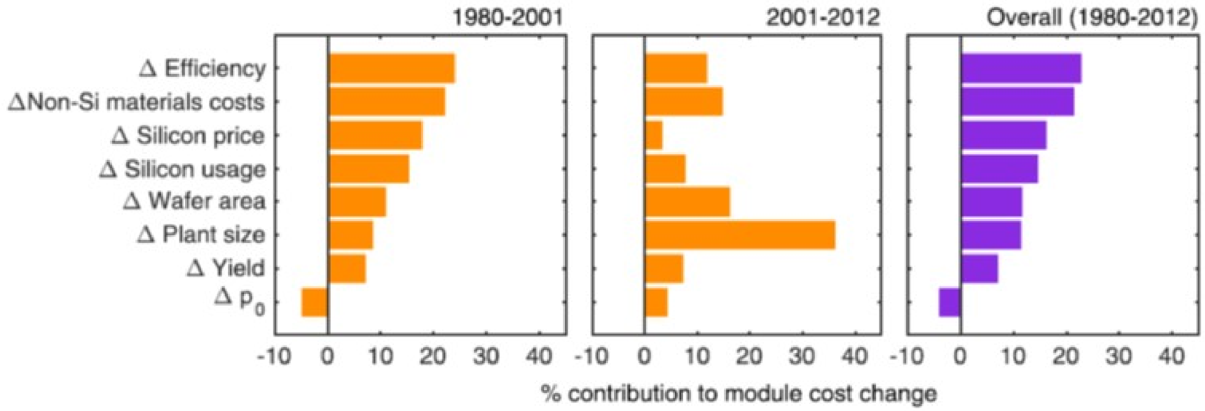


$$C_m\left(\frac{\$}{module}\right) = \underbrace{\frac{1}{y_m}\sum_{i\neq c,w}\phi_{mi}p_i}_{\text{non-cell module costs}} + \underbrace{\frac{n_{mc}}{y_m y_c}\sum_{i\neq w}\phi_{ci}p_i}_{\text{non-wafer cell costs}} + \underbrace{\frac{n_{mc}n_{cw}}{y_m y_c y_w}\sum_{i}\phi_{wi}p_i}_{\text{wafer costs}},$$

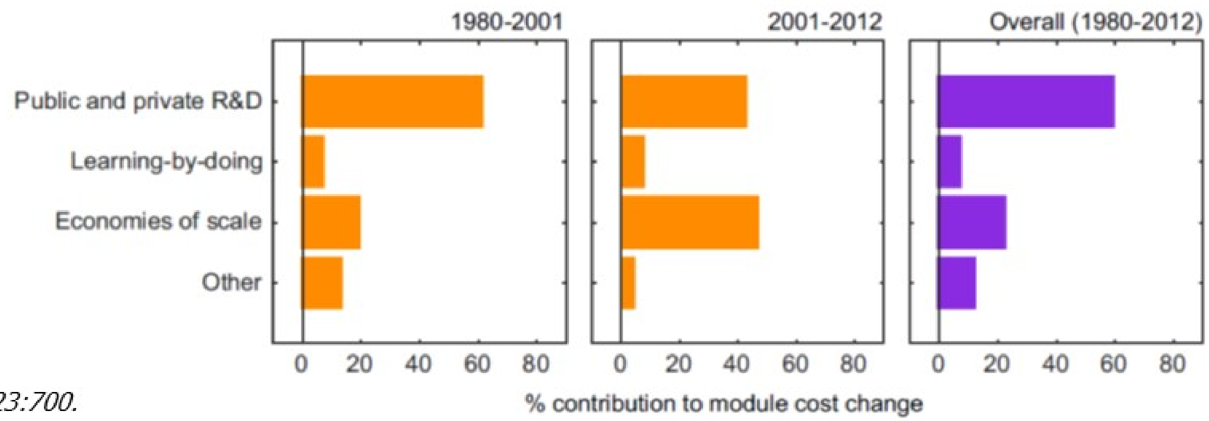


Why are solar panels (modules) dropping in price??

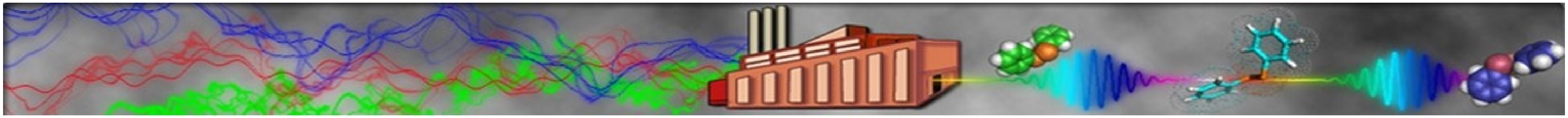
"low level"



"high level"

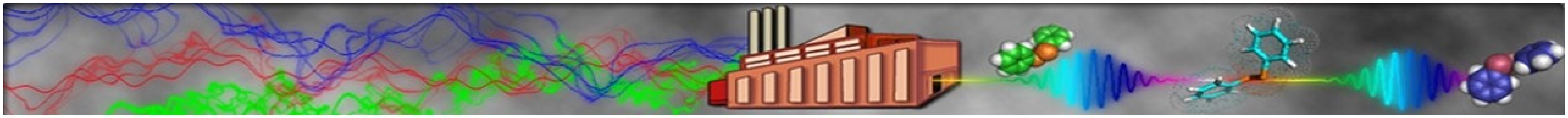


Kavlak et al. Energy Policy (2018) 123:700.

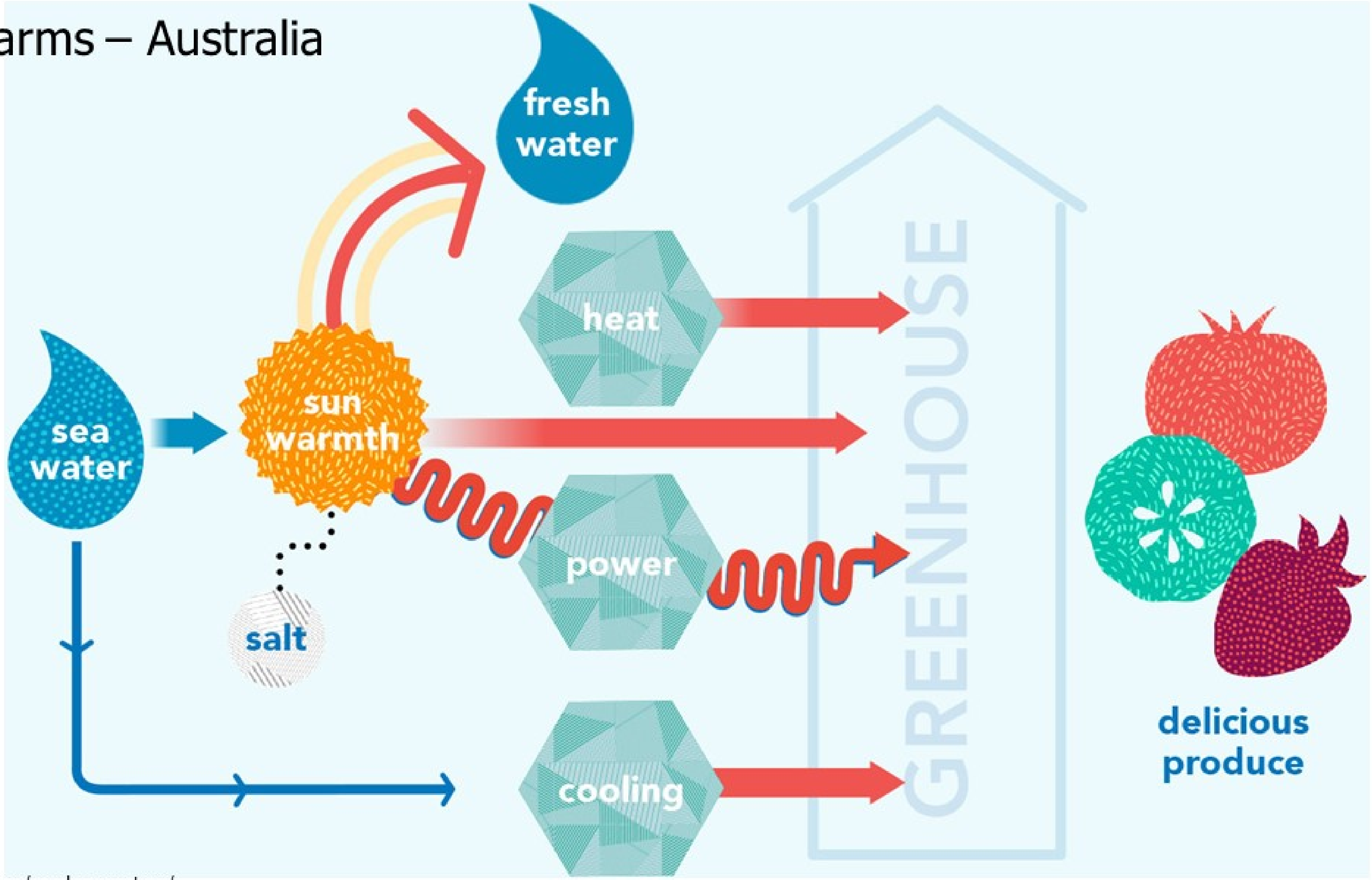


Sundrop Farms
"Australian desert farm grows 17,000 metric tons of vegetables with just seawater and sun "

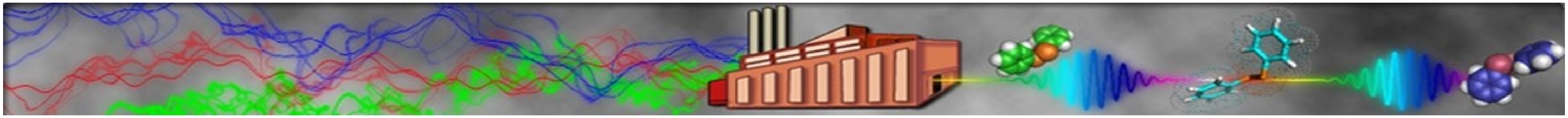
https://inhabitat.com/australian-desert-farm-grows-17000-metric-tons-of-vegetables-with-just-seawater-and-sun/?variation=c



Sundrop Farms – Australia



http://www.sundropfarms.com/sundrop-system/



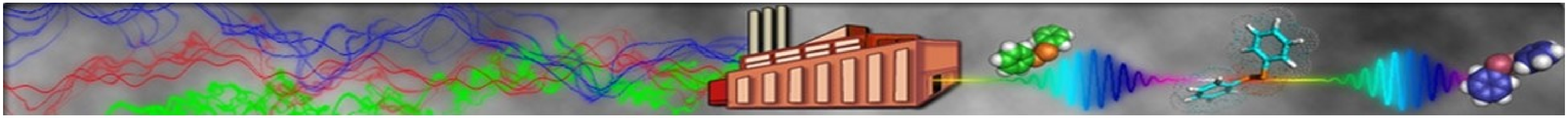
Advances in solar energy technology

Cost of solar energy

Advances in artificial lighting technology

Cost of artificial lighting


PHOTONICS
CREATING LIGHT
MANIPULATING LIGHT
DETECTING LIGHT
LIGHT AS A TOOL
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

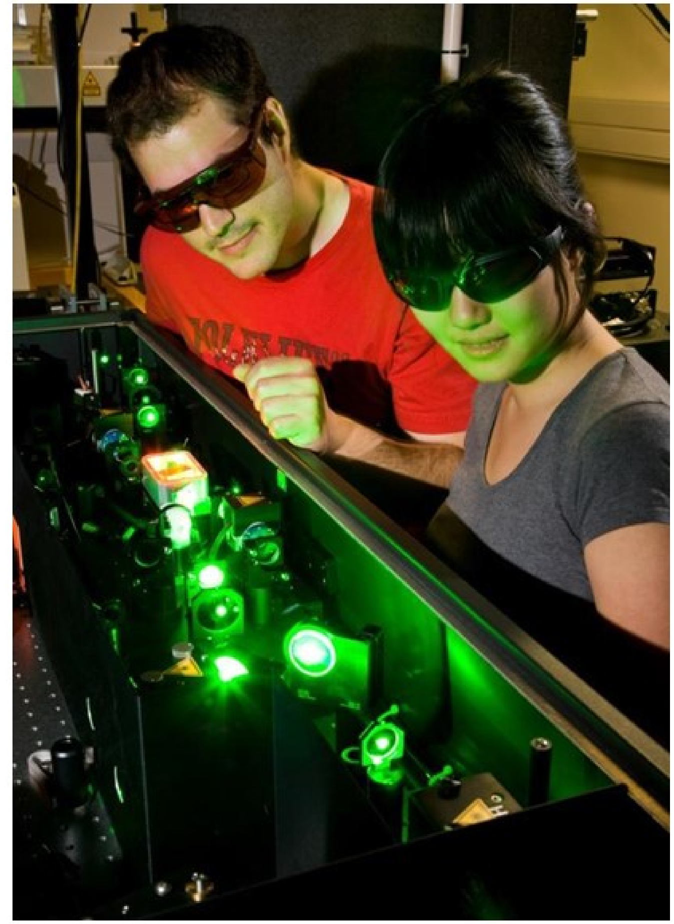


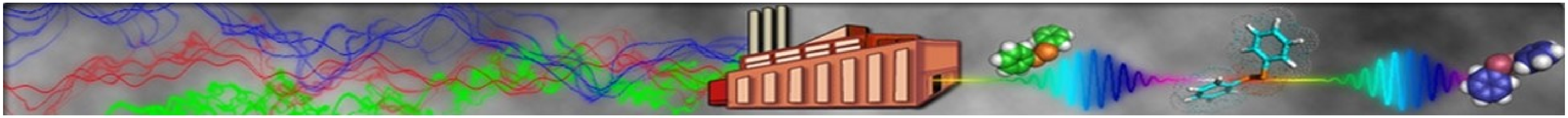
Photon Factory: Exotic laser pulses for science & high-tech industry

THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

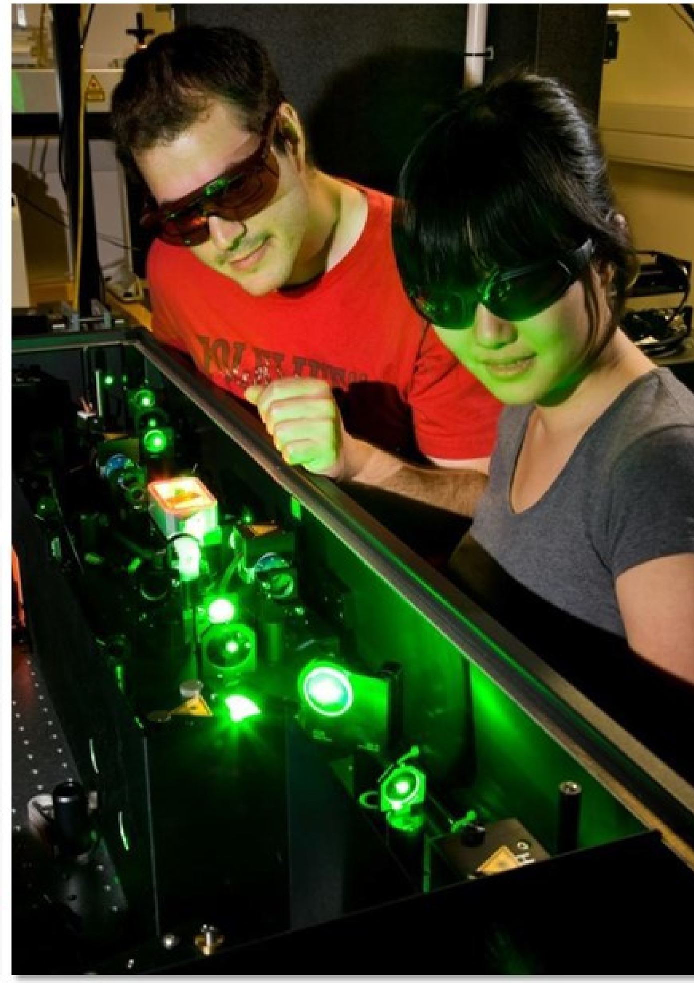
The MacDiarmid Institute
for Advanced Materials and Nanotechnology

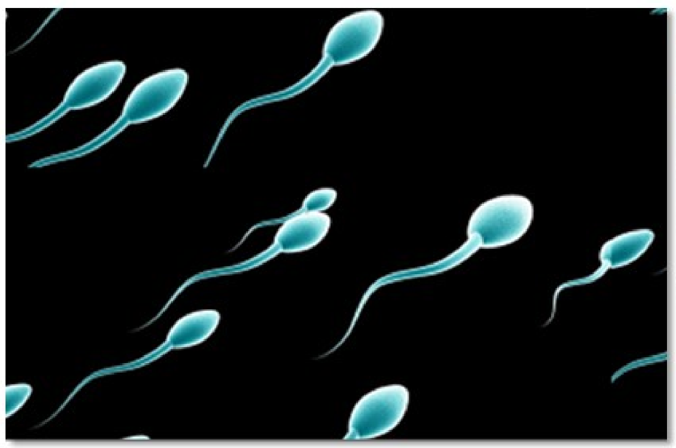
DODD-WALLS CENTRE
FOR PHOTONIC & QUANTUM TECHNOLOGIES

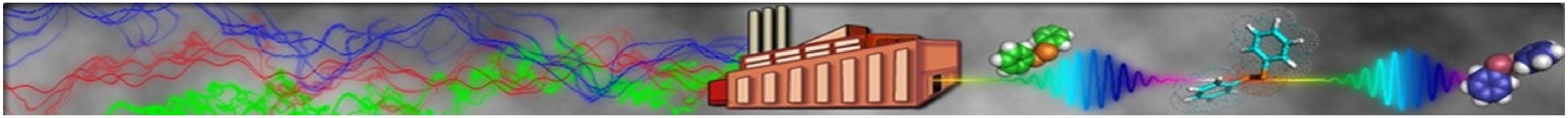




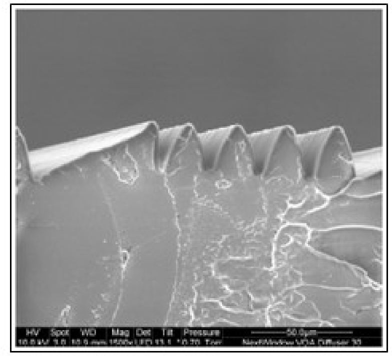
Lasers, Milk and Sperm!

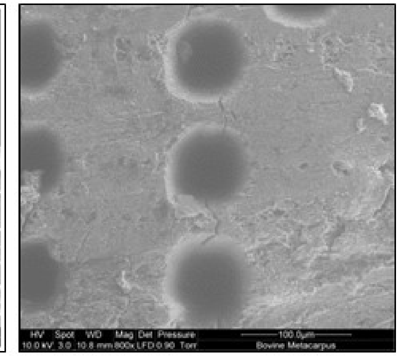


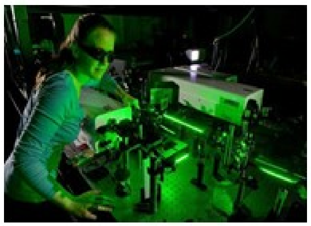


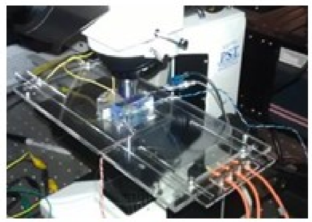


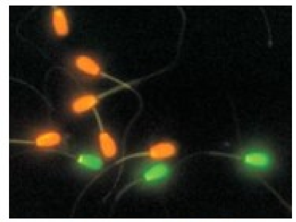
Photon Factory: Basic & applied research & entrepreneurship











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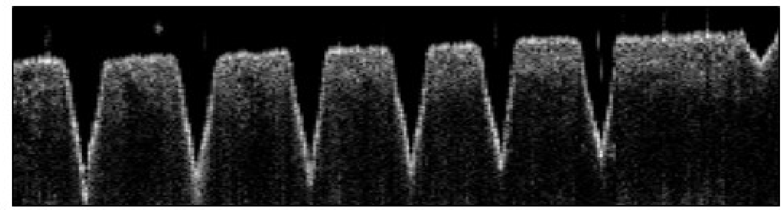
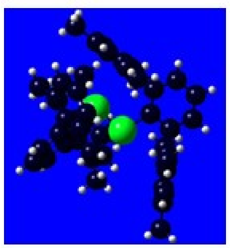
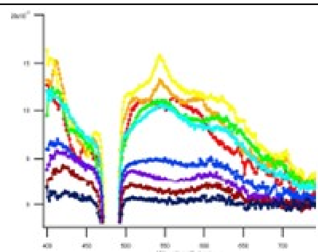
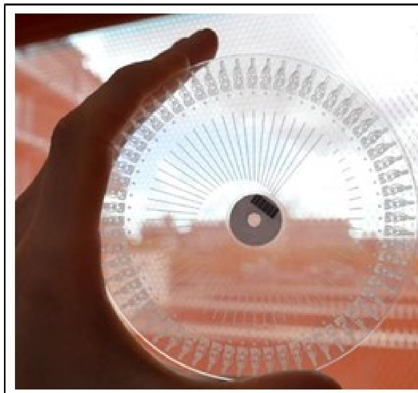








ORBIS
MILK ON A DISK

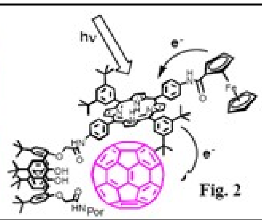
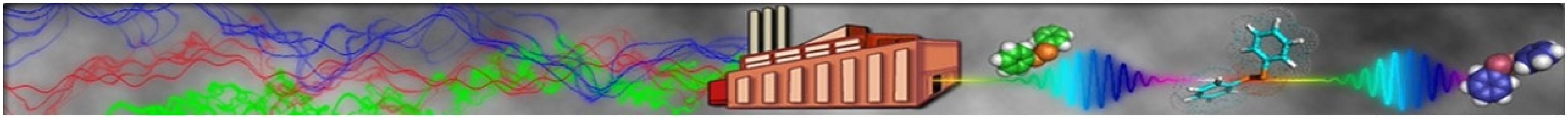
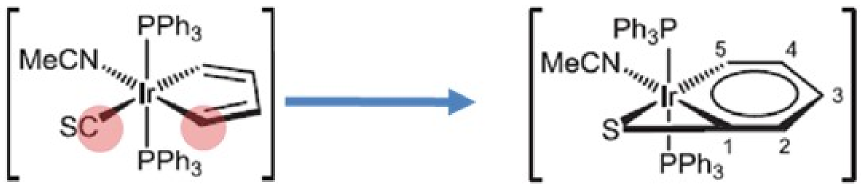
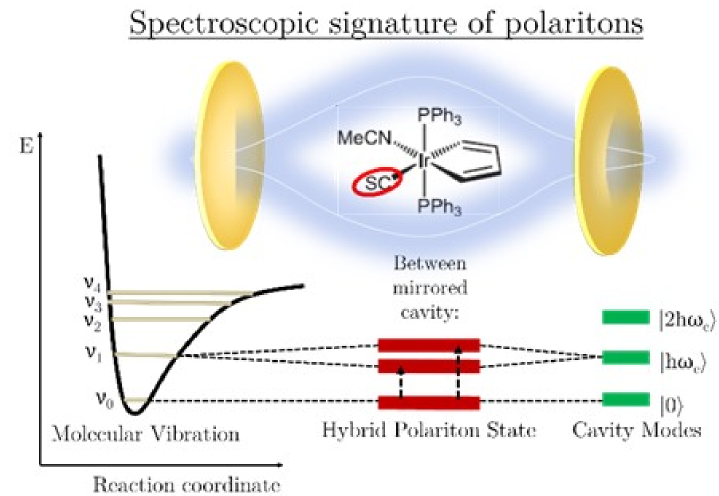


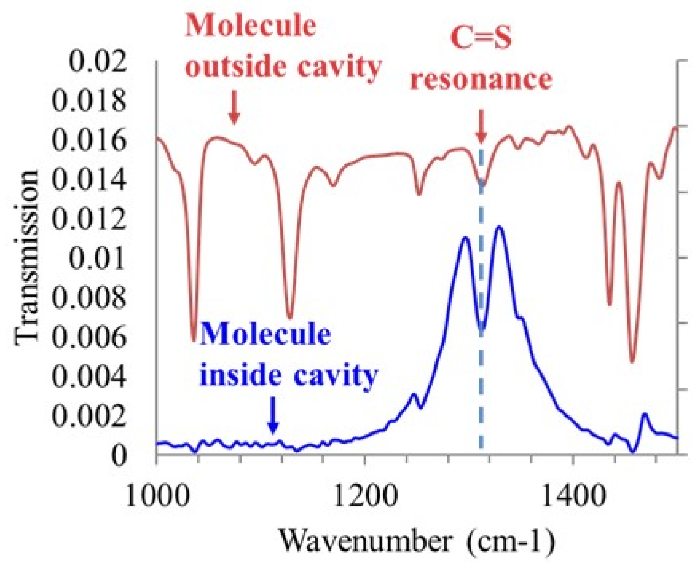
Fig. 2

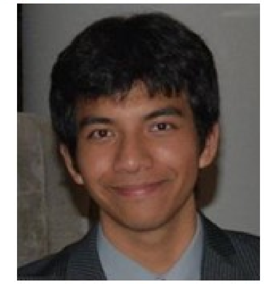


Quantum optics tuning reaction rates





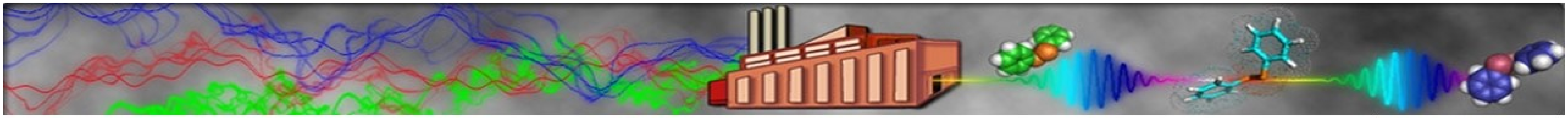




Rakesh Arul

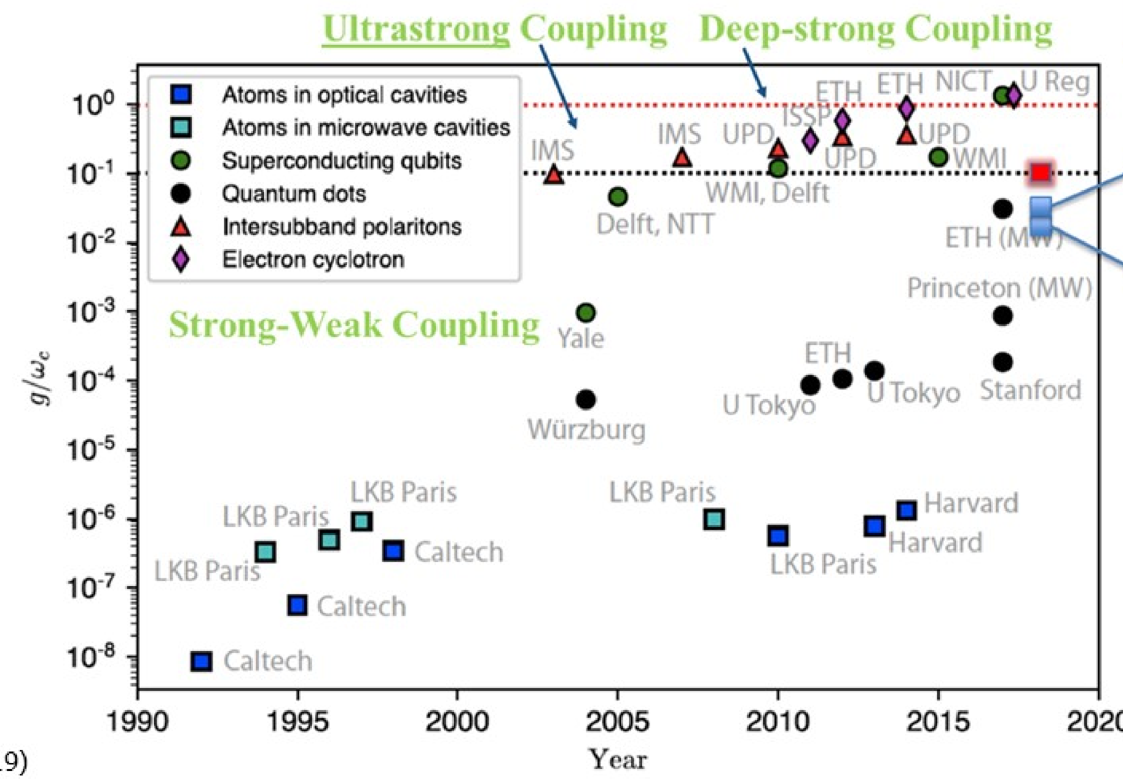
Prof James Wright

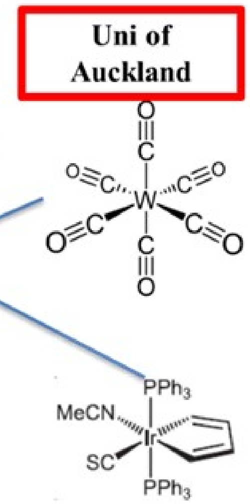
Arul et al. (in prep 2019)

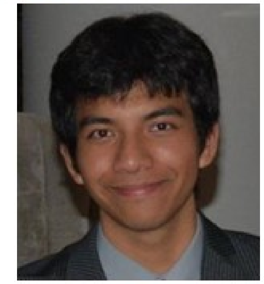


Quantum optics tuning reaction rates

Light-Matter Coupling Strength







Rakesh Arul

Prof James Wright

Arul et al. (in prep 2019)

Photon Factory: since 2010

aeroQUAL
Fisher&Paykel HEALTHCARE
Footfalls & Heartbeats
nextwindow
A SMART Technologies company

$3.5+m

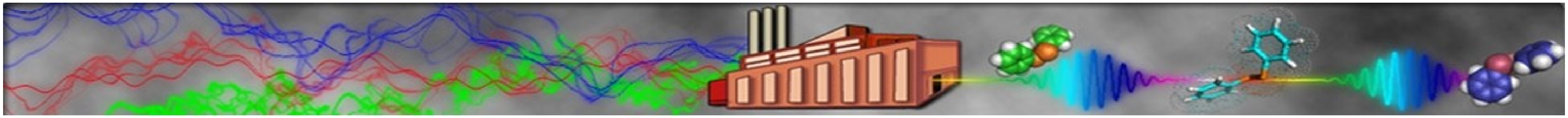
Fletcher Building
puredepth®
MULTI LAYER DISPLAY™
Finisar

PacificChannel
Life Sciences and Clean-Tech Ventures
INTUITIVE SURGICAL®
MORNINGSIDE
Fonterra™
Dairy for life
e4
PPG
SPRINGFIELD
Springfield Financial Advisory Ltd.

rakon
Fisher&Paykel

$26m

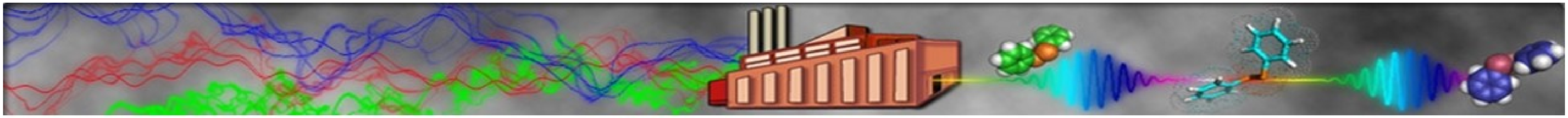
iZON
ZENITH TECNICA
MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI
ENGENDER
CORBIS
MilkTestnz™
LEADING IN MILK TESTING
Ministry for Primary Industries
Manatū Ahu Matua
NEW ZEALAND



Photon Factory: impact

Right Hon. Bill English, 39th Prime Minister of NZ (and Henry)

Hon. Paul Goldsmith, then Minister of Science & Innovation, Tertiary Education (and Henry)



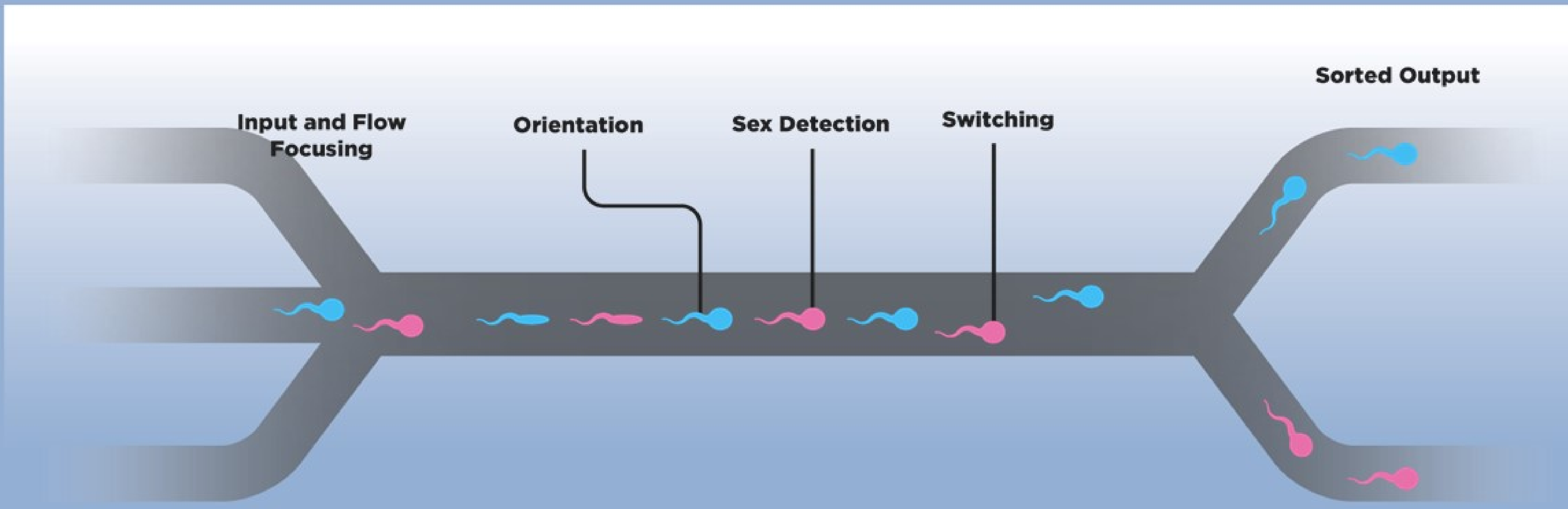
Photon Factory: Primary Industries (Food, Farms)

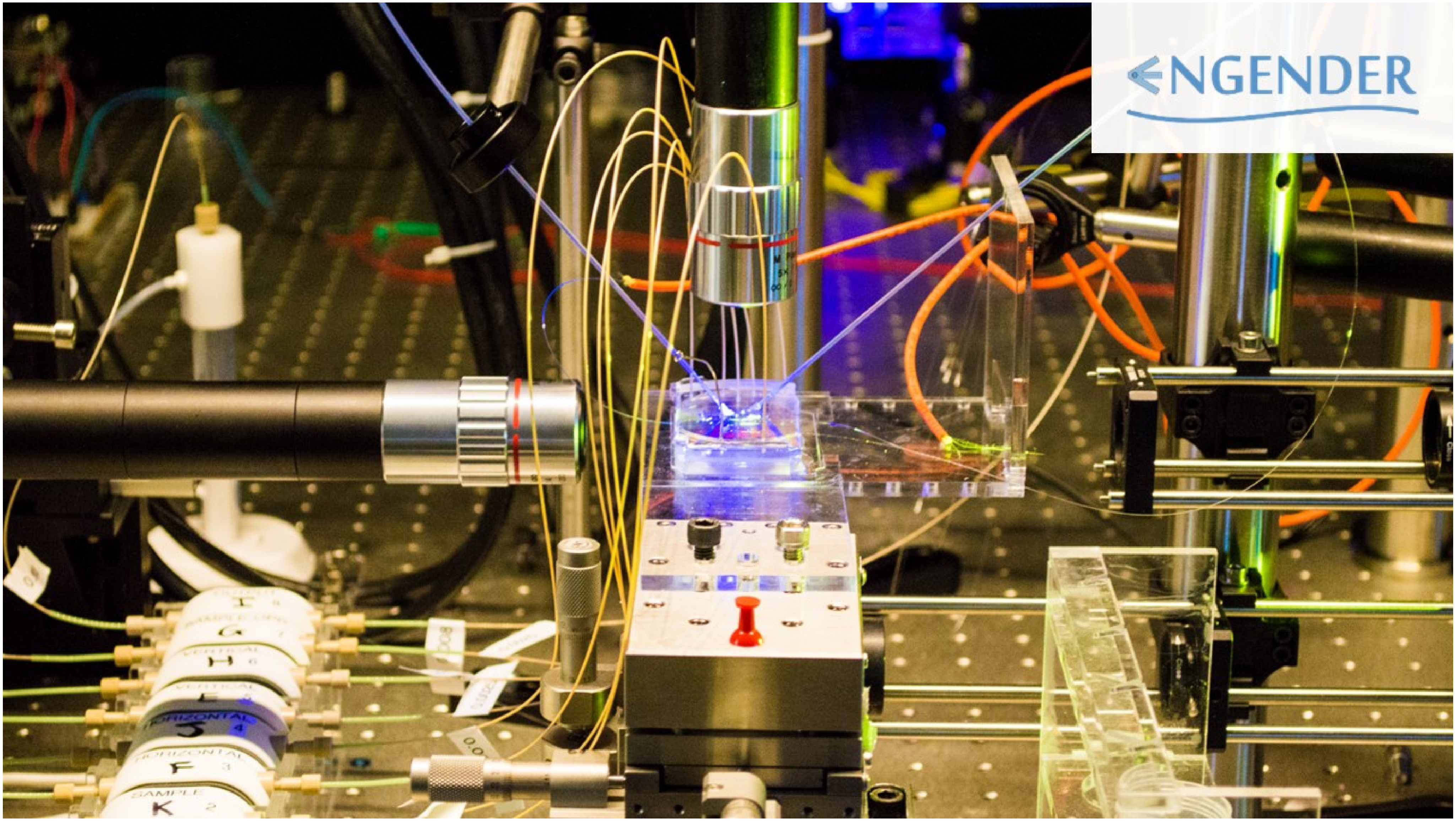
Ministry for Primary Industries
Manatū Ahu Matua
NEW ZEALAND


ENGENDER


ENGENDER

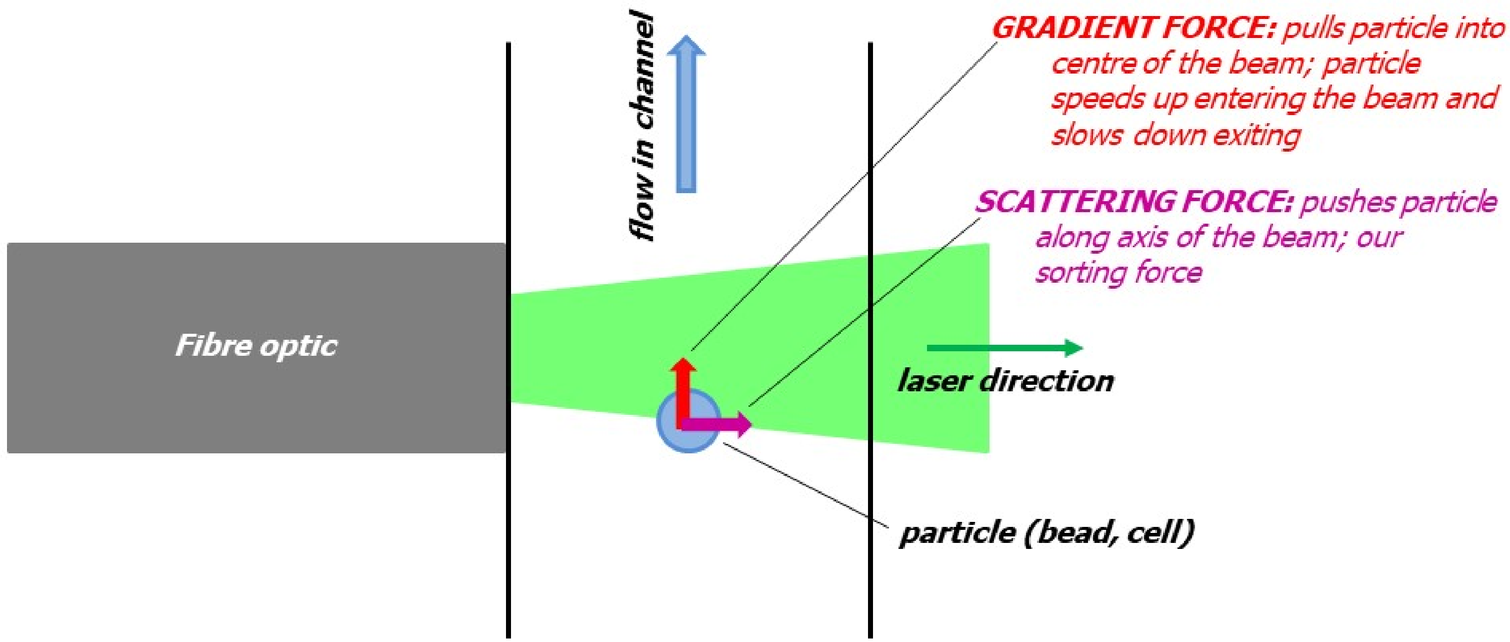
How does it work?



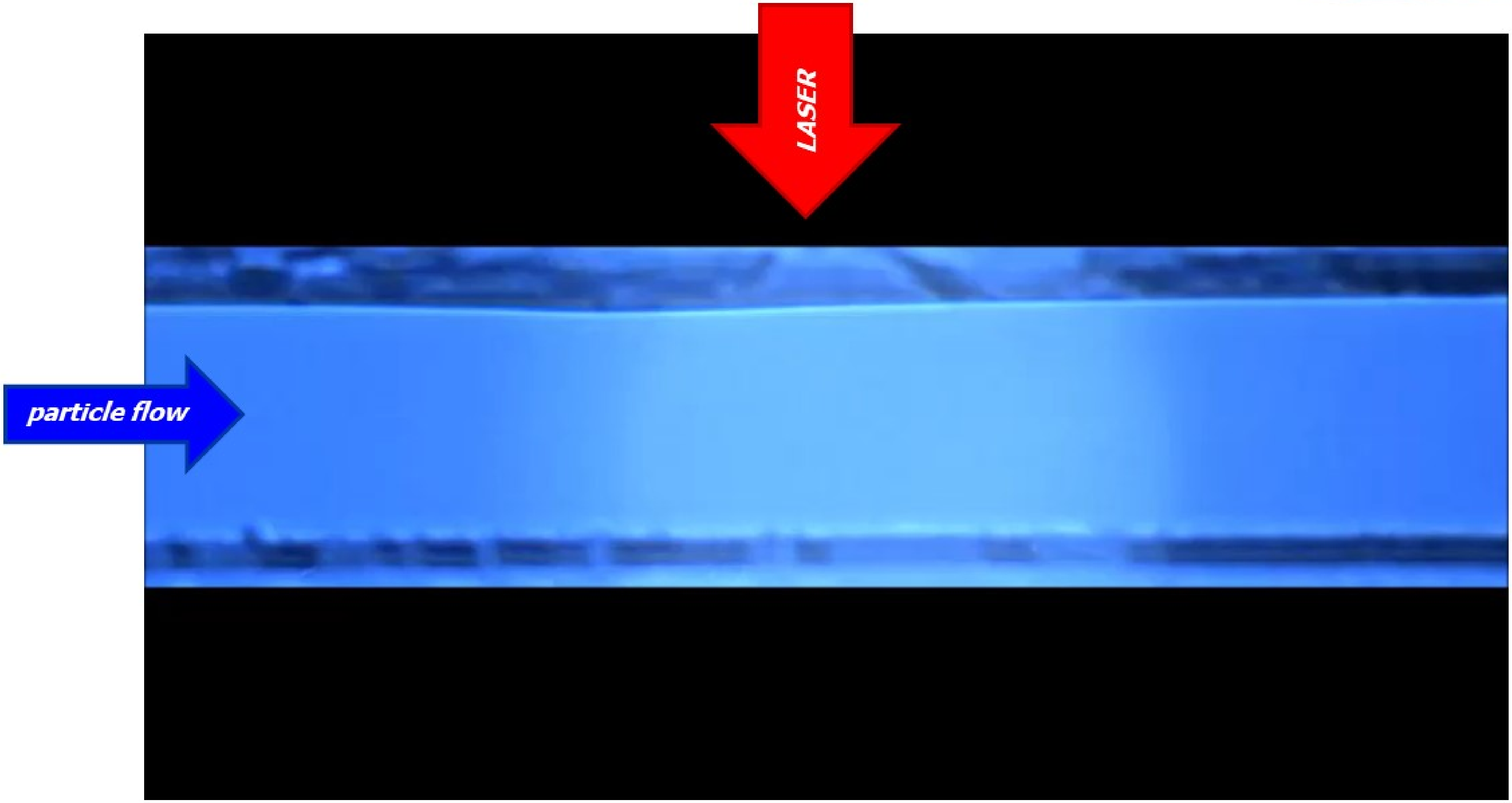

ENGENDER
HORIZONTAL
F
HORIZONTAL
J
SAMPLE
K

The basic physics

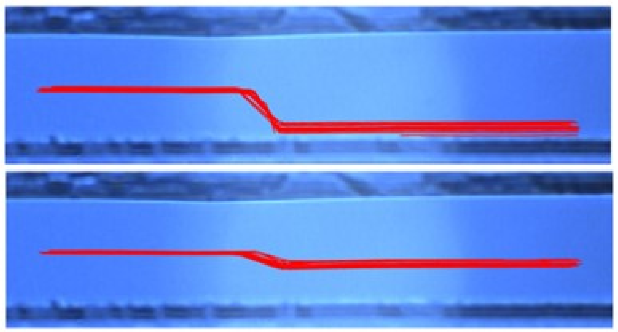
- *the interaction of light with matter generates a force (nudging)*
- *the interaction of light with an asymmetric particle generates a torque (orientation)*

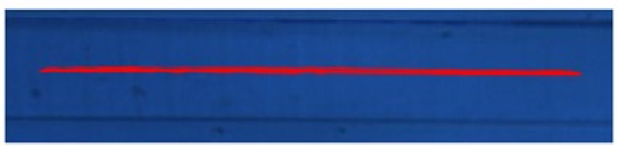


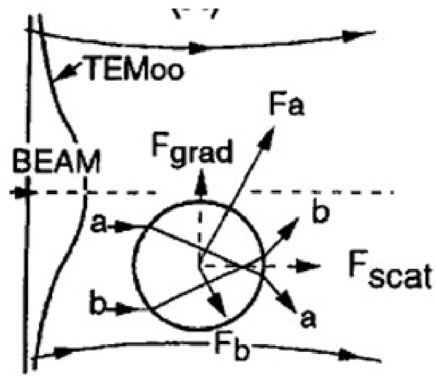
2018 Nobel Prize in Physics

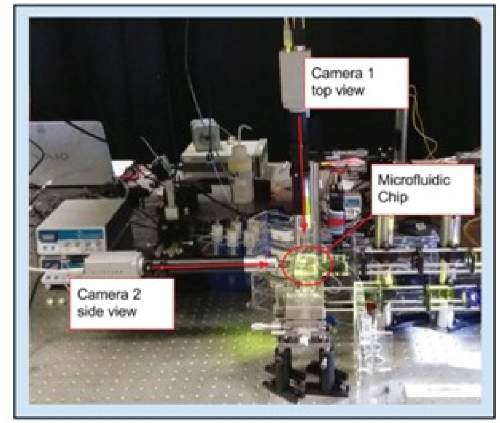

LASER
particle flow

The basic physics







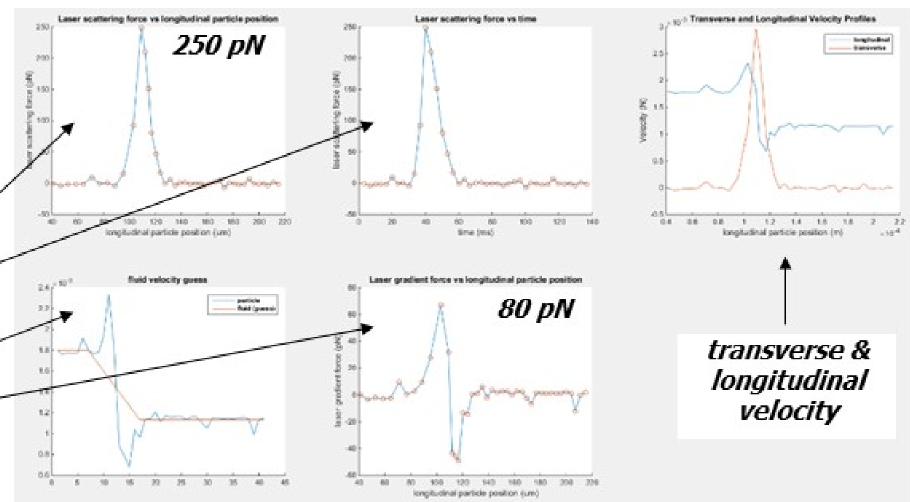


scattering force vs longitudinal position

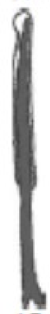
scattering force vs time

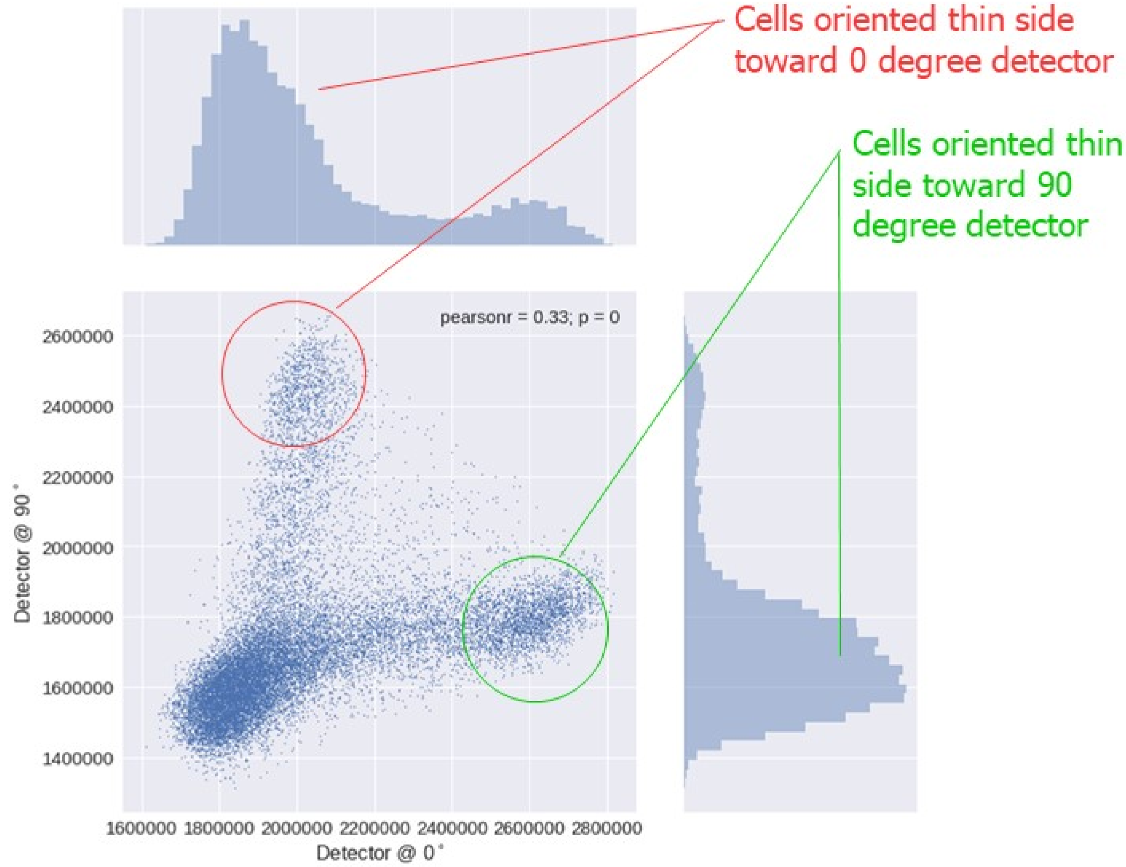
fluid velocity

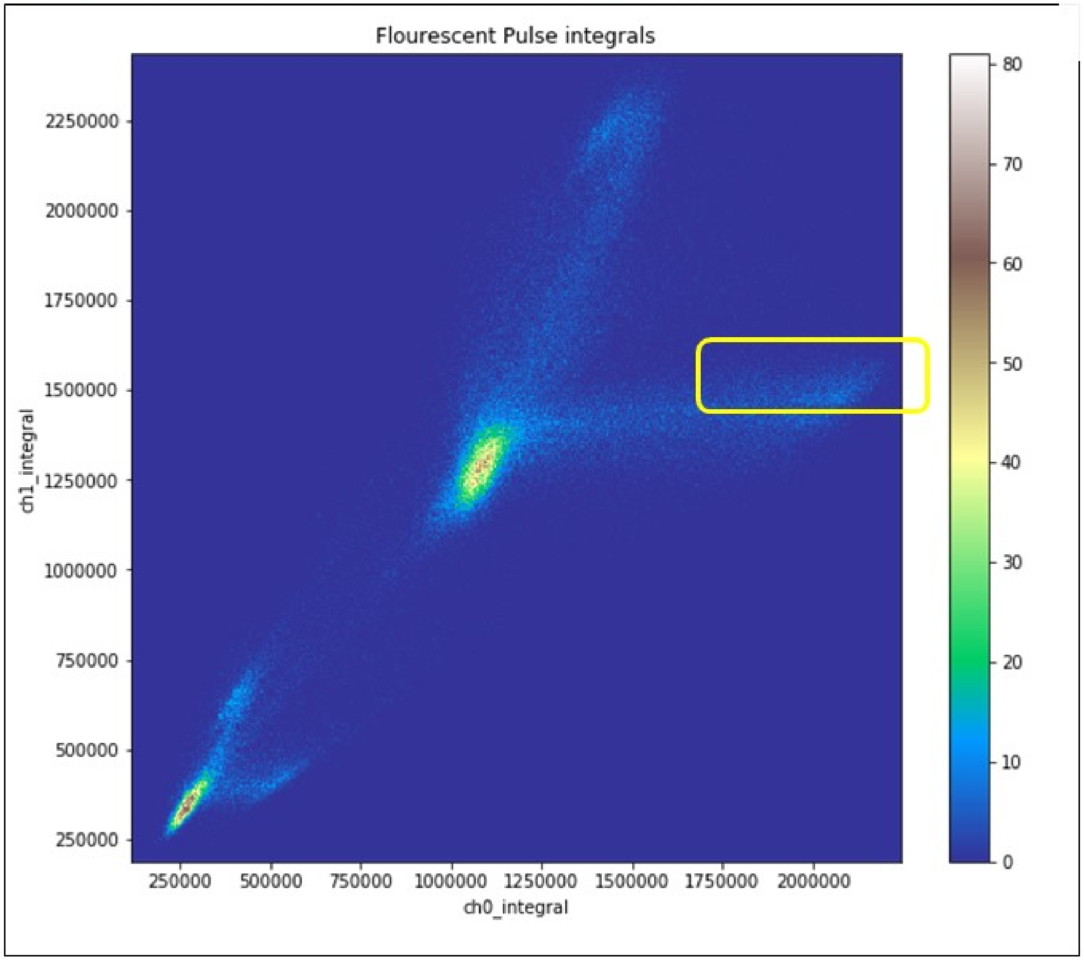
Gradient force vs longitudinal position



Sperm are not simple!

Dimension	Bull
Length (μm)	9.1
Head sagittal section	
Width (μm)	4.7
Head profile	
Area (μm^2)	34.5
X–Y difference (%)	3.8
Sorting index[b]	131

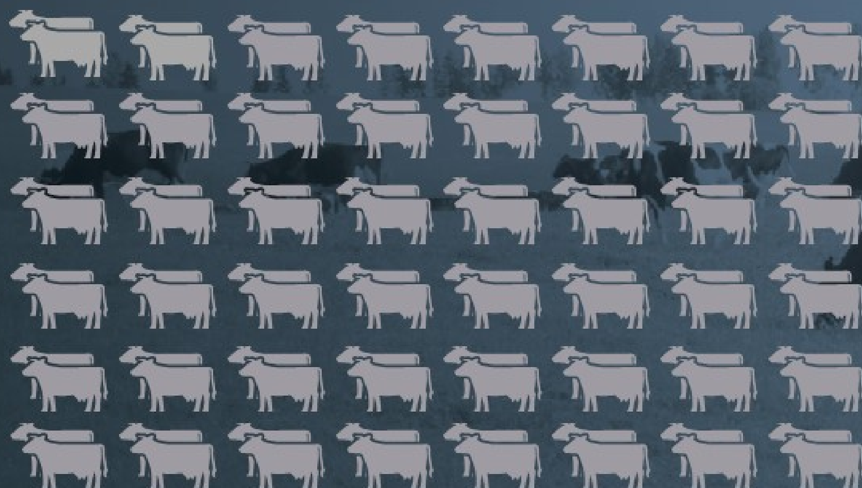




Flourescent Pulse integrals
ch1_integral
ch0_integral
2250000
2000000
1750000
1500000
1250000
1000000
750000
500000
250000
250000
500000
750000
1000000
1250000
1500000
1750000
2000000
80
70
60
50
40
30
20
10
0

ENGENDER

Economic impact of artificial insemination (dairy)



Unsorted semen

$4-10 per straw

>175 million straws pa

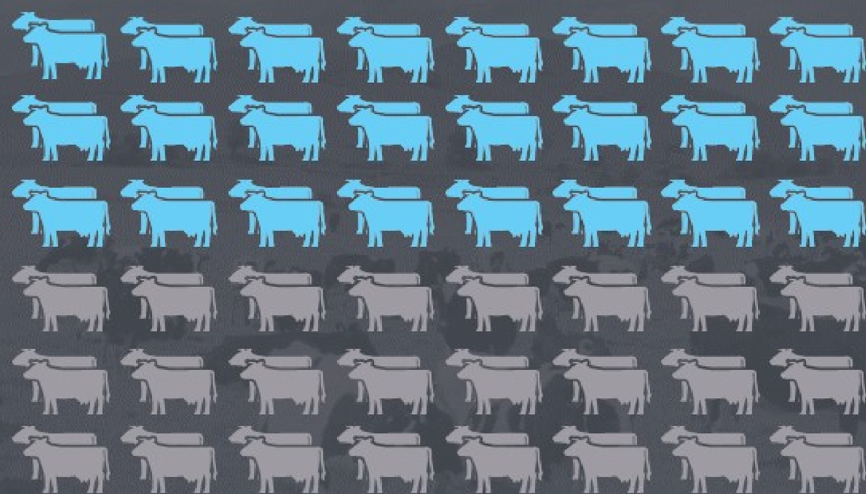
US$2+ billion pa market

ENGENDER

Economic impact of sex-sorted semen today

ENGENDER

Economic impact of sex-sorted semen tomorrow



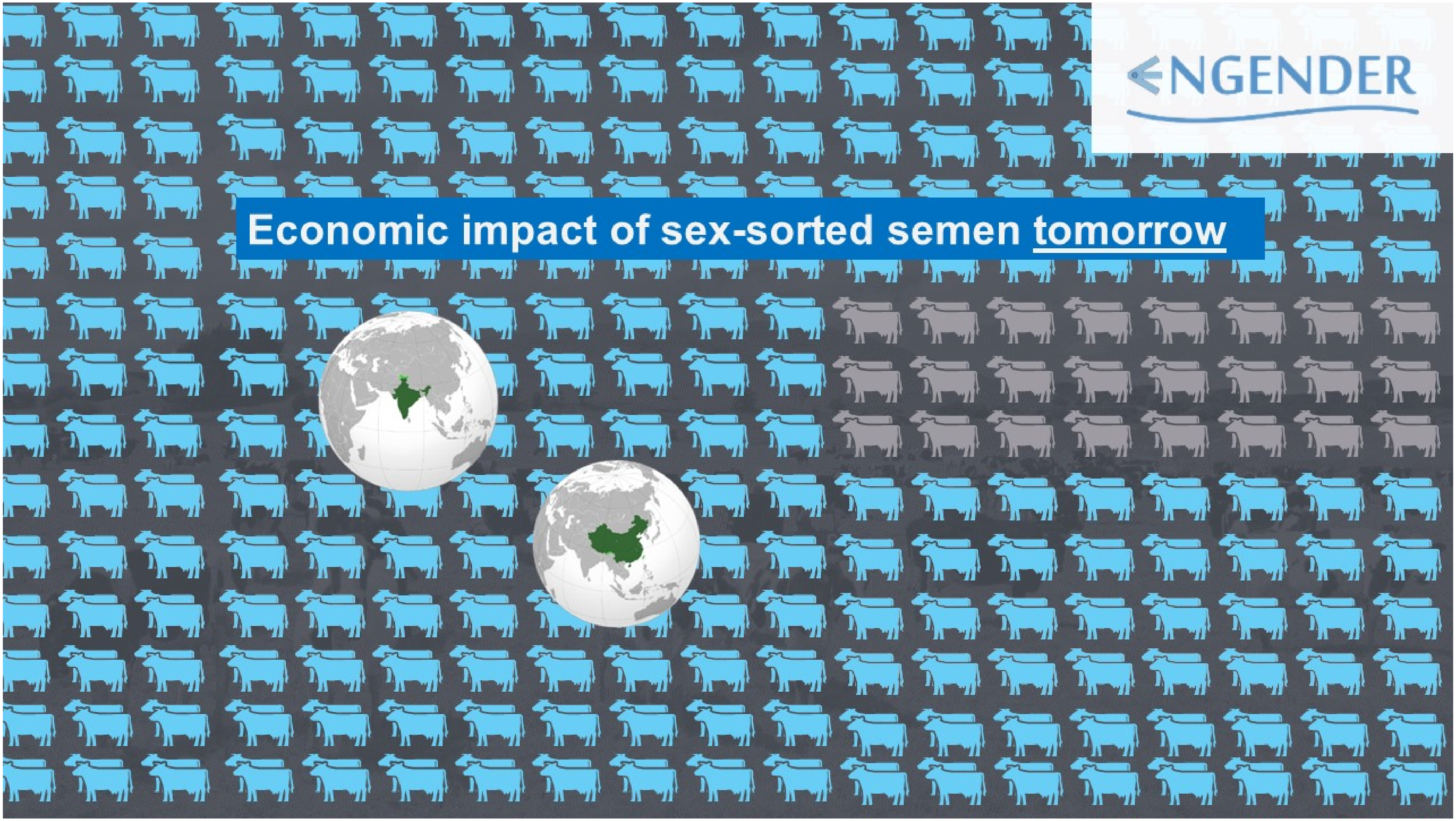
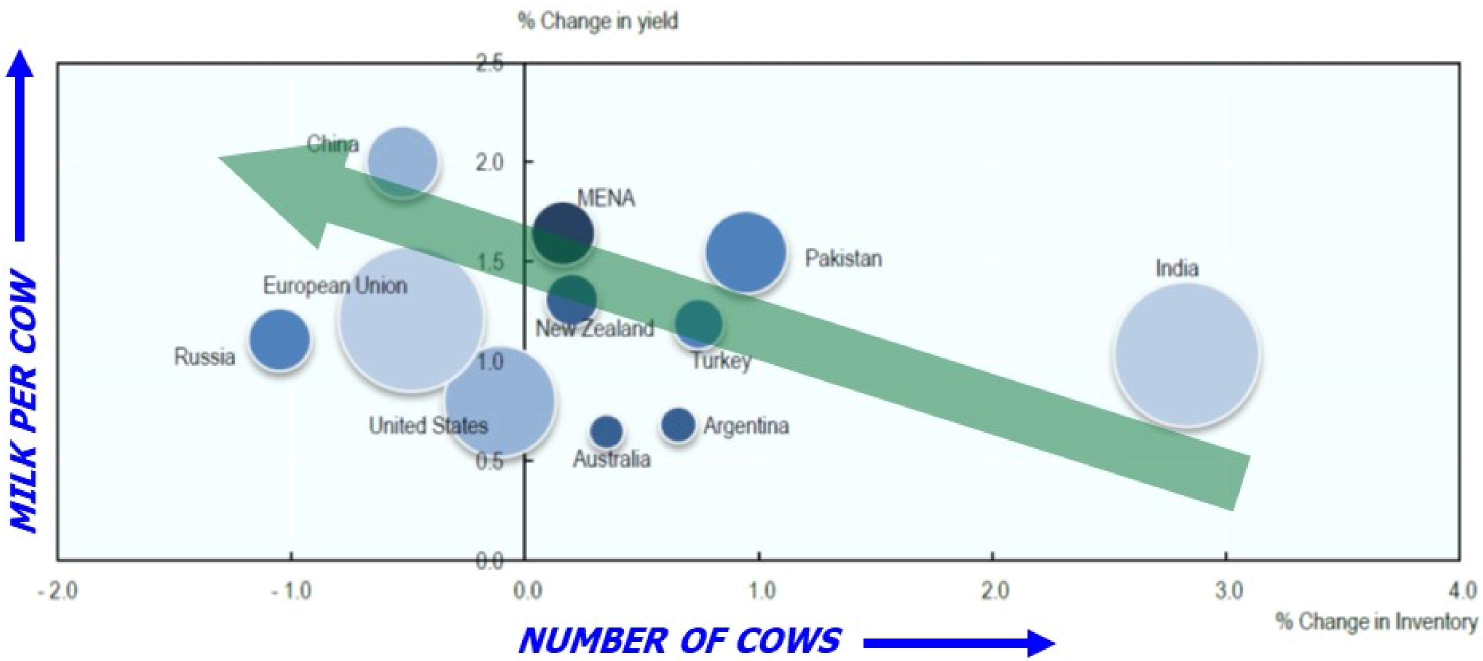
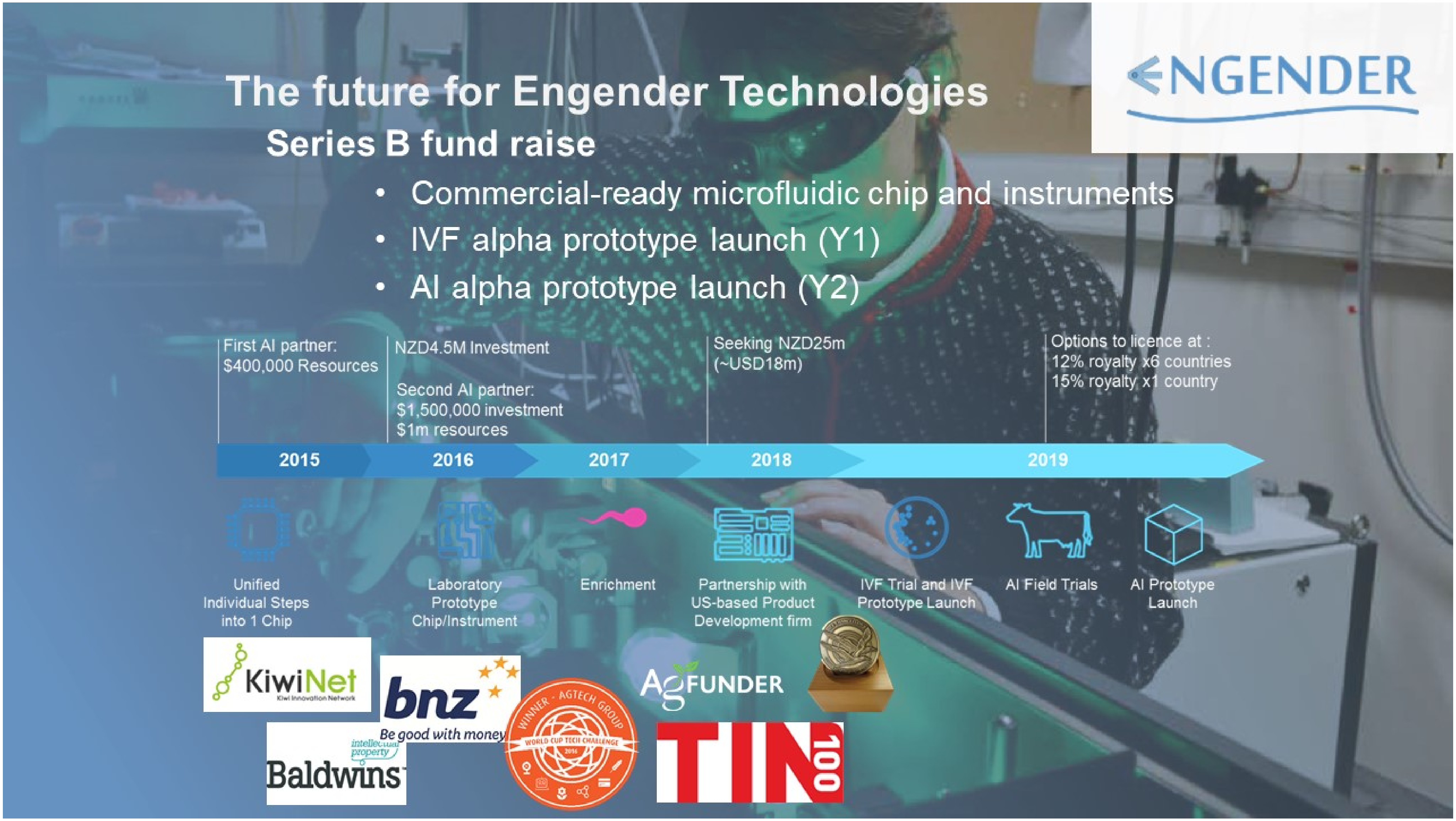

ENGENDER
Economic impact of sex-sorted semen tomorrow

Figure 7.3. Annual changes in inventories of dairy herd and yields between 2017 and 2027



Note: The size of the bubbles refer to the total milk production in the base period 2015-17.
Source: OECD/FAO (2018), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

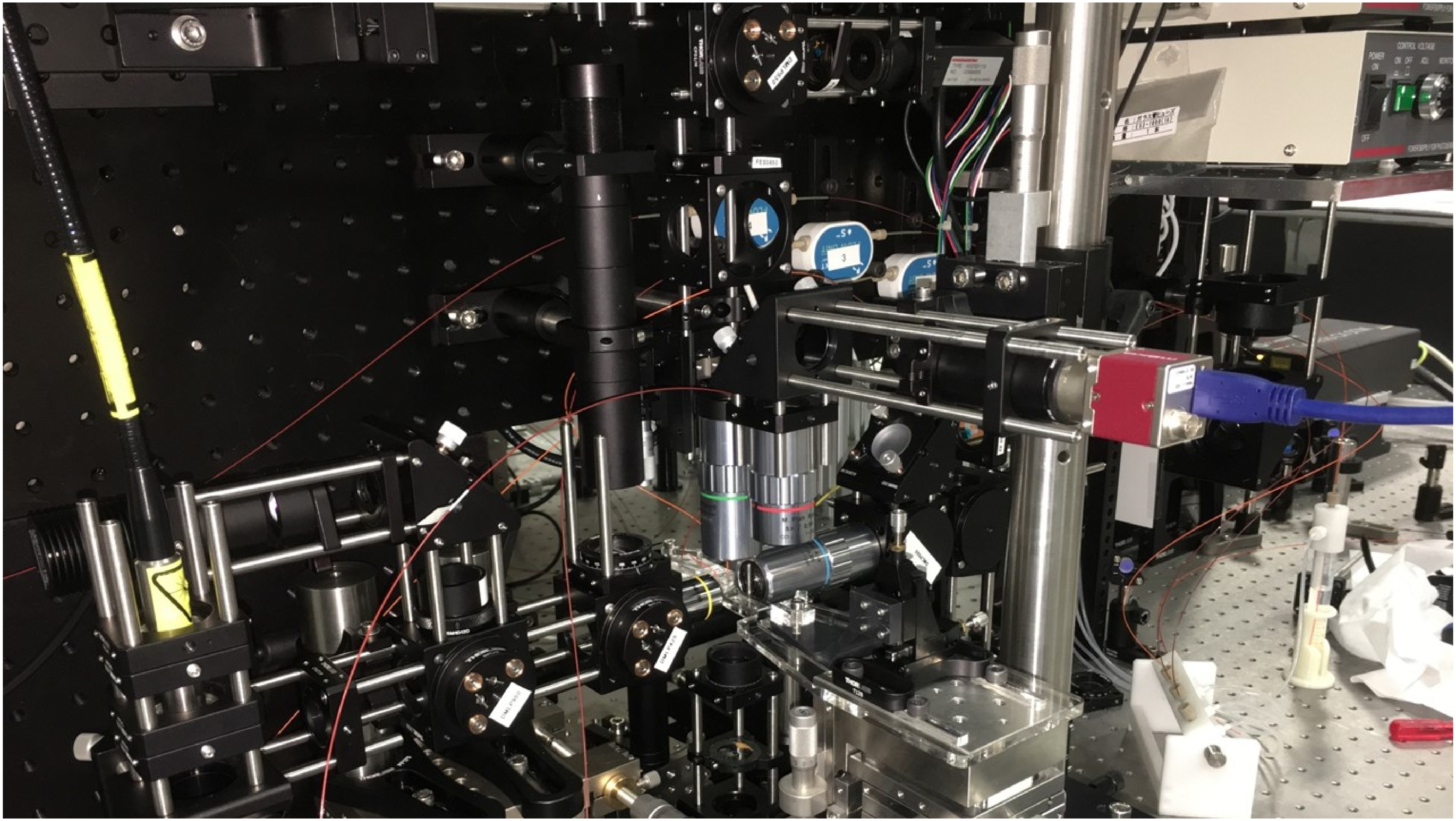
StatLink http://dx.doi.org/10.1787/888933743480


The future for Engender Technologies
Series B fund raise
• Commercial-ready microfluidic chip and instruments
• IVF alpha prototype launch (Y1)
• AI alpha prototype launch (Y2)
ENGENDER
First AI partner:
$400,000 Resources
NZD4.5M Investment
Second AI partner:
$1,500,000 investment
$1m resources
Seeking NZD25m
(~USD18m)
Options to licence at :
12% royalty x6 countries
15% royalty x1 country
2015
2016
2017
2018
2019
Unified Individual Steps into 1 Chip
Laboratory Prototype Chip/Instrument
Enrichment
Partnership with US-based Product Development firm
IVF Trial and IVF Prototype Launch
AI Field Trials
AI Prototype Launch
KiwiNet
Kiwi Innovation Network
bnz
Be good with money
Baldwins
intellectual property
WINNER - AGTECH GROUP
WORLD CUP TECH CHALLENGE
2016
AGFUNDER
TIN 100


The future for Engender Technologies
Series B fund raise
• Commercial-ready microfluidic chip and instru
• IVF alpha prototype launch (Y1)
• AI alpha prototype launch (Y2)
ACQUIRED
First AI partner: $400,000 Resources
NZD4.5M Investment
Second AI partner: $1,500,000 investm $1m resources
2015
2017
2018
2019
Unified Individual Steps into 1 Chip
Partnership with US-based Product Development firm
IVF Trial and IVF Prototype Launch
AI Field Trials
AI Prototype Launch
KiwiNet
bnz
Be good with money
Baldwins
AgFUNDER
TIN 100
ENGENDER
CRV

ENGENDER

CRV




ENGENDER


ORBiS
MILK ON A DISK

"point of cow" diagnostics – making complex solutions simple for farmers

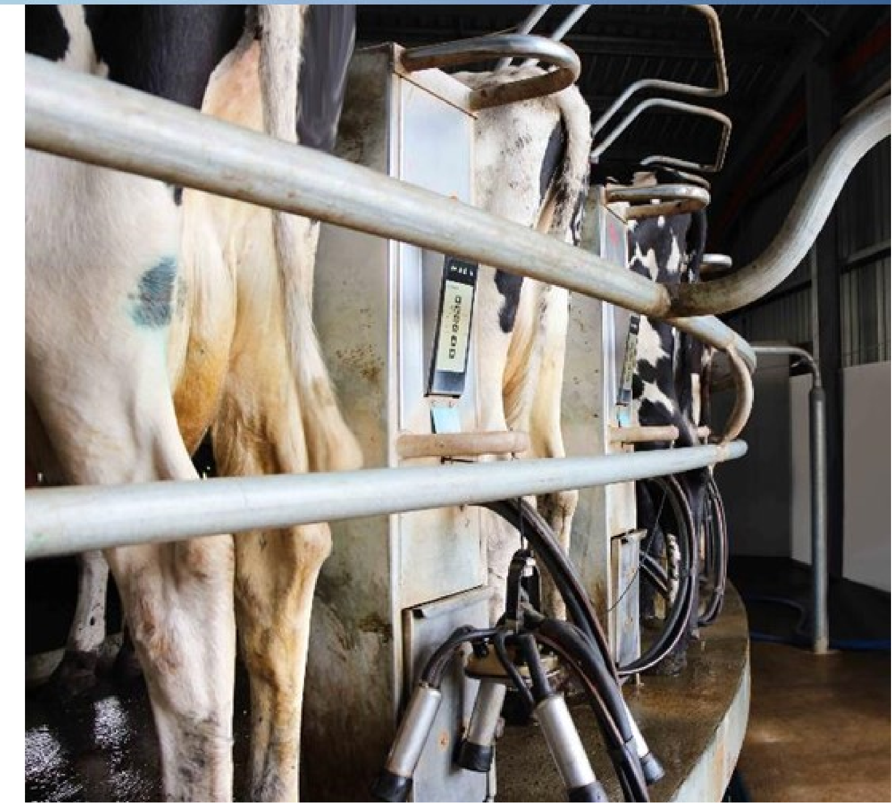
automated milk composition "lab" in the shed

The pain

Global cost of mastitis = $35B pa

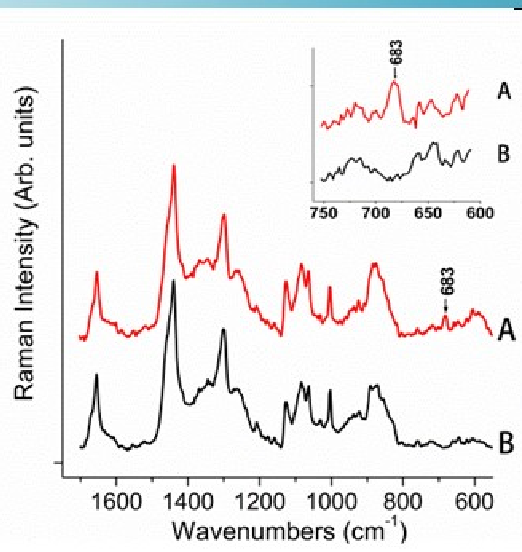
Cost of missed impregnation
= $150k per 1000 head herd pa

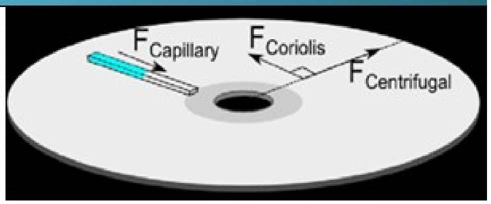
Value of increased genetic gain
= $90k per 1000 head herd pa

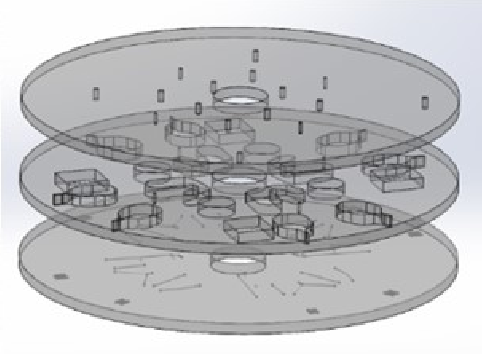


How does it work?

CENTRIFUGAL MICROFLUIDICS + PHOTONICS
=
ROBUST SENSOR PLATFORM

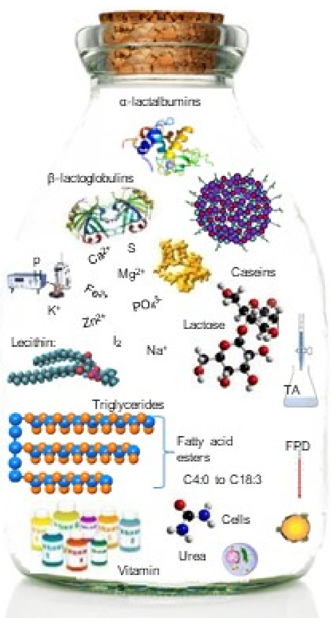


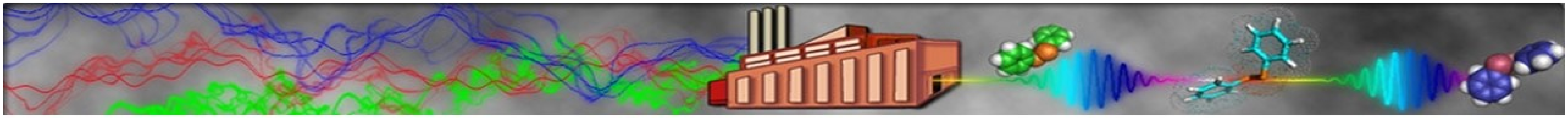




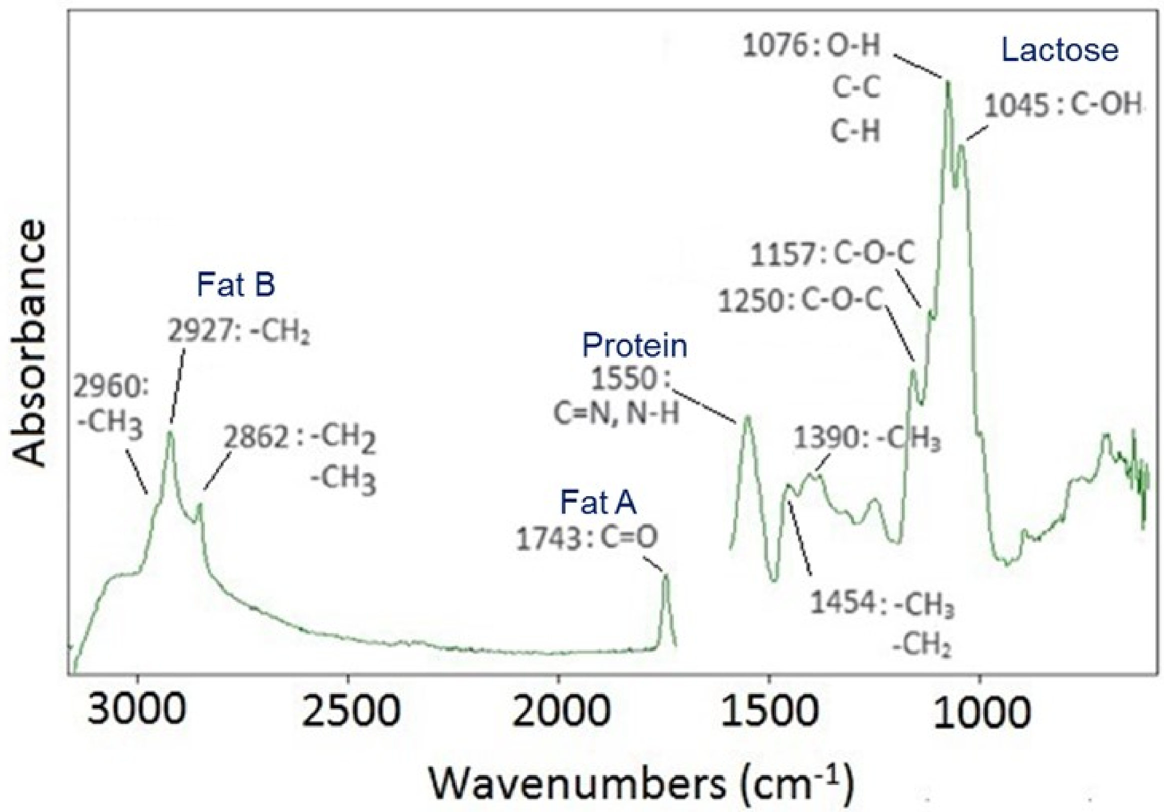
Milk has >10, 000 different molecules!

Major Components	Mass/ 100g	Minerals	Mass/ 100g	Vitamins	Mass / 100g	Amino acids	Mass/ 100g	Fatty acids	Mass / 100g
Water	87.7 g	Calcium	114 mg	Vitamin A:		Isoleucine	0.15 g	**Saturated FAs:**	
Protein	3.28 g	Phosphorus	87 mg	Retinol	80 μg	Leucine	0.30 g	4:0 Butyric	0.1 g
Total fat	4.0 g	Sodium	39 mg	B-carotene	23 μg	Lysine	0.26 g	6:0 Caproic	0.084 g
Lactose	4.7 g	Potassium	150 mg	Total activity	84 μg	Methionine	0.07 g	8:0 Caprylic	0.049 g
Ash	0.71 g	Magnesium	9.3 mg	Vitamin E	0.11 mg	Cysteine	0.027 g	10:0 Capric	0.11 g
Cholesterol	11.37 mg	Sulphur	28 mg	Vitamin C	1.4 mg	Phenylalanine	0.16 g	12:0 Lauric	0.12 g
		Iron	0.027 mg	Thiamin (B_1)	0.1 mg	Tyrosine	0.15 g	14:0 Myristic	0.40 g
		Zinc	0.37 mg	Riboflavin (B_2)	0.2 mg	Threonine	0.14 g	15:0 Pentadecylic	0.054 g
		Copper	3 μg	Niacin	0.11 mg	Valine	0.20 g	16:0 Palmitic	1.05 g
		Manganese	5 μg	Vitamin B_6	0.034 mg	Arginine	0.12 g	17:0 Margaric	0.03 g
		Iodine	7 μg	Pantothenate	0.3 mg	Histidine	0.09 g	18:0 Stearic	0.41 g
				Biotin	2.8 μg	Alanine	0.11 g	**Monounsaturated FAs:**	
				Folate	5.3 μg	Aspartic acid	0.25 g	10:1 Caproleic	0.012 g
				Vitamin B_{12}	0.35 μg	Glutamic acid	0.62 g	14:1 Myristoleic	0.047 g
						Glycine	0.063 g	16:1 Palmitoleic	0.1 g
						Serine	0.18 g	17:1 Margaroleic	0.02 g
								18:1 Oleic	0.893 g
								Polyunsaturated FAs:	
								18:2 Linoleic	0.073 g
								18:3 Linolenic	0.060 g





laser vibrational spectroscopy – rich info!



Dr. MICHEL NIEUWOUDT
Senior Research Fellow

MilkTestnz
LEADING IN MILK TESTING

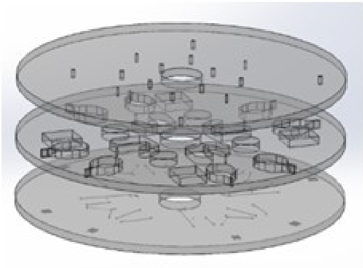
Fonterra
Dairy for life

Winning awards

ORBIS
MILK ON A DISK

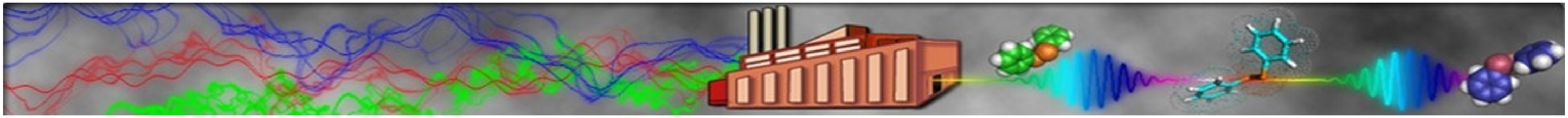
SPIE. The international society for optics and photonics

where are we headed?

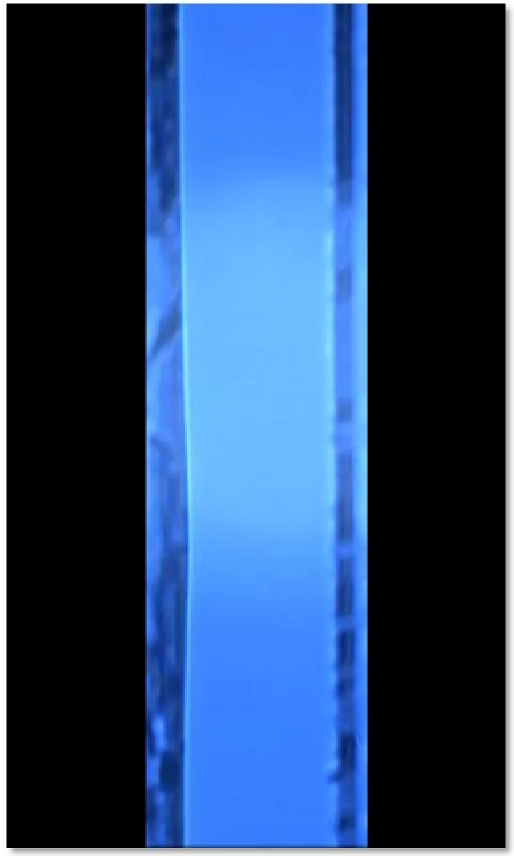


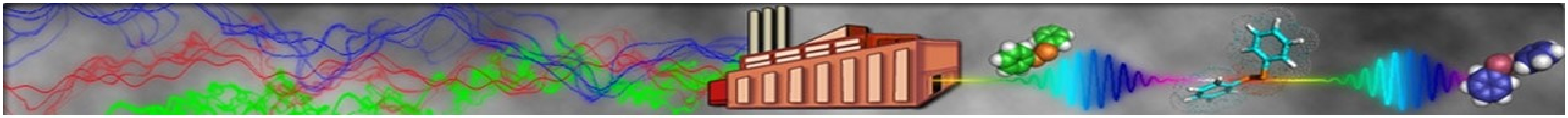
- Fat (total and components)
- Protein (total and components)
- Somatic cell count
- Progesterone, luteinising hormone etc.
- Ketosis (beta hydroxybutyrate)
- Bacterial identification (i.e. Gram-ve/+ve)
- Lactose
- BVD
- Tuberculosis
- Johnes Disease
- Mycoplasma bovis


ORBiS
MILK ON A DISK

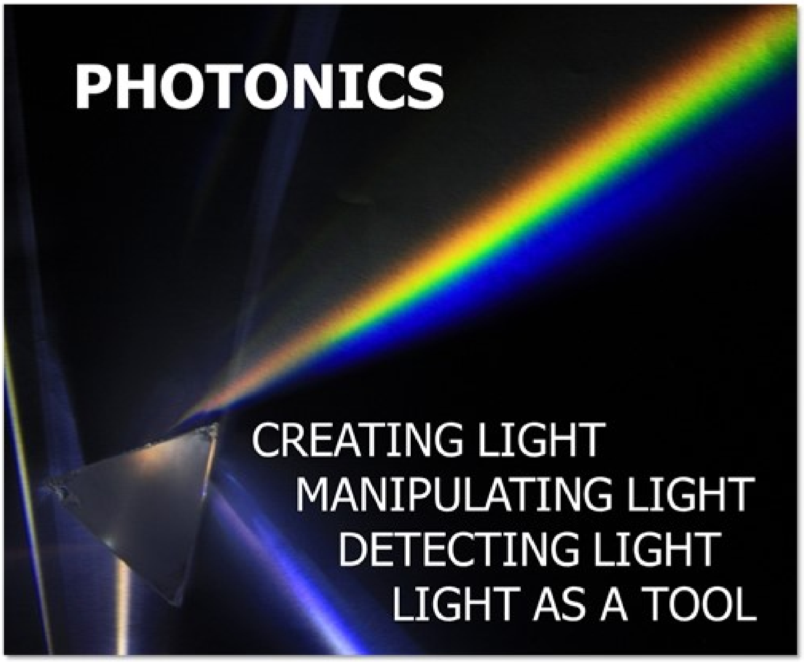


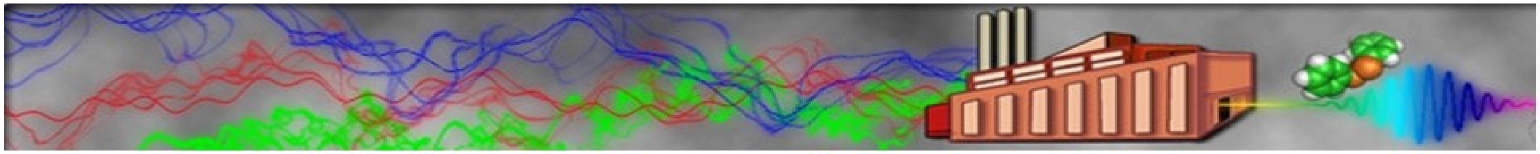
Farms, Food and Photonics





Farms, Food and Photonics - People, Planet!





ENGENDER

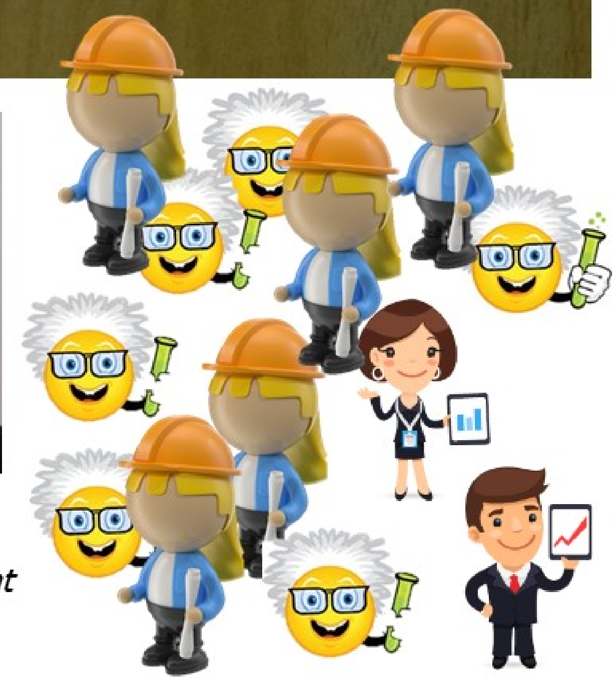
People!

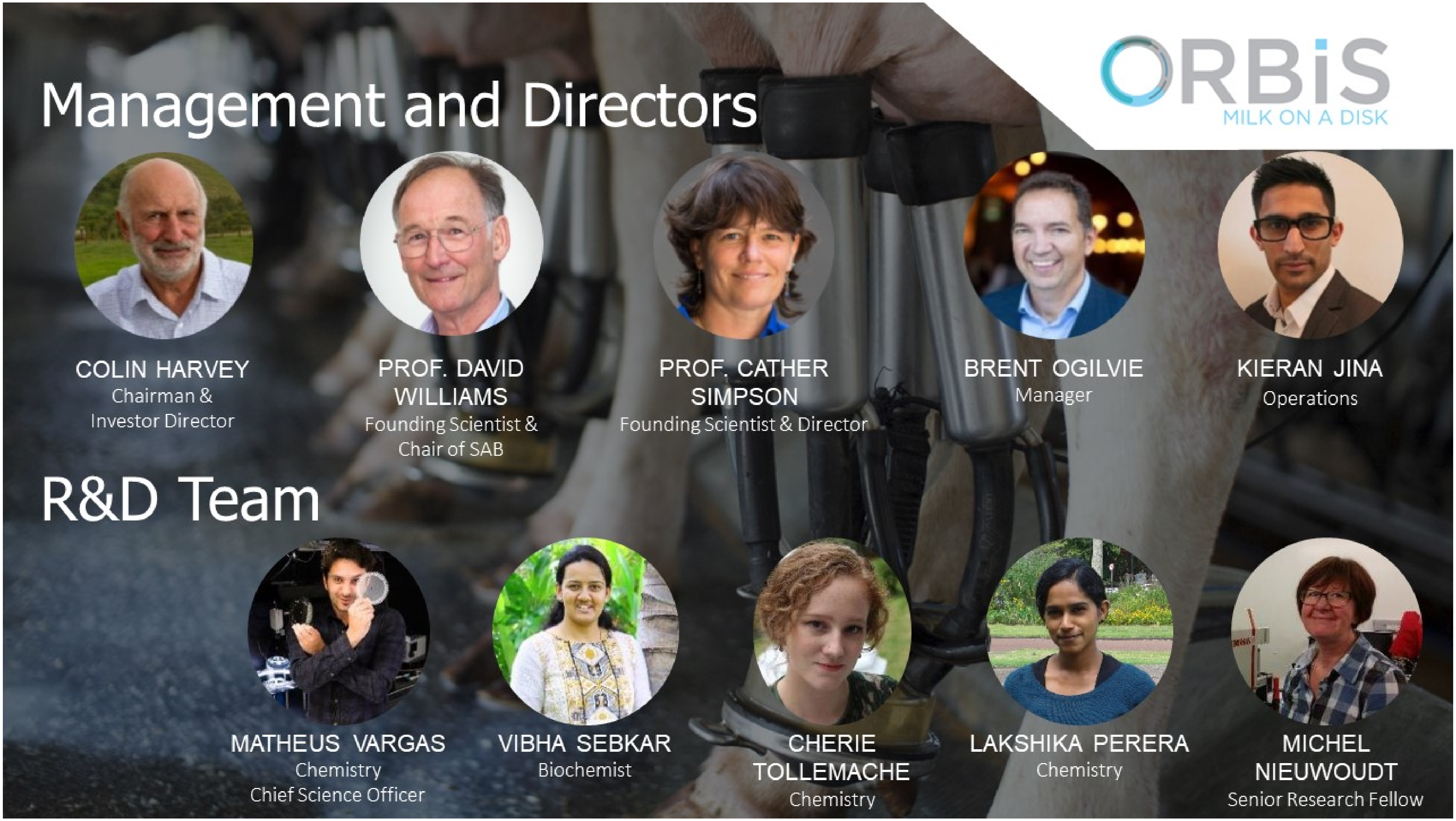
Peter Hosking
BEng(H) Mechatronics
PhD student, Physics

Dr. Maggie Au
Biology

Simon Ashforth
PhD student, Physics

Michael Keough
MSc Industrial
Manufacturing Mgmt

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Investor Director
PROF. DAVID
WILLIAMS
Founding Scientist &
Chair of SAB
PROF. CATHER
SIMPSON
Founding Scientist & Director
BRENT OGILVIE
Manager
KIERAN JINA
Operations
R&D Team
MATHEUS VARGAS
Chemistry
Chief Science Officer
VIBHA SEBKAR
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