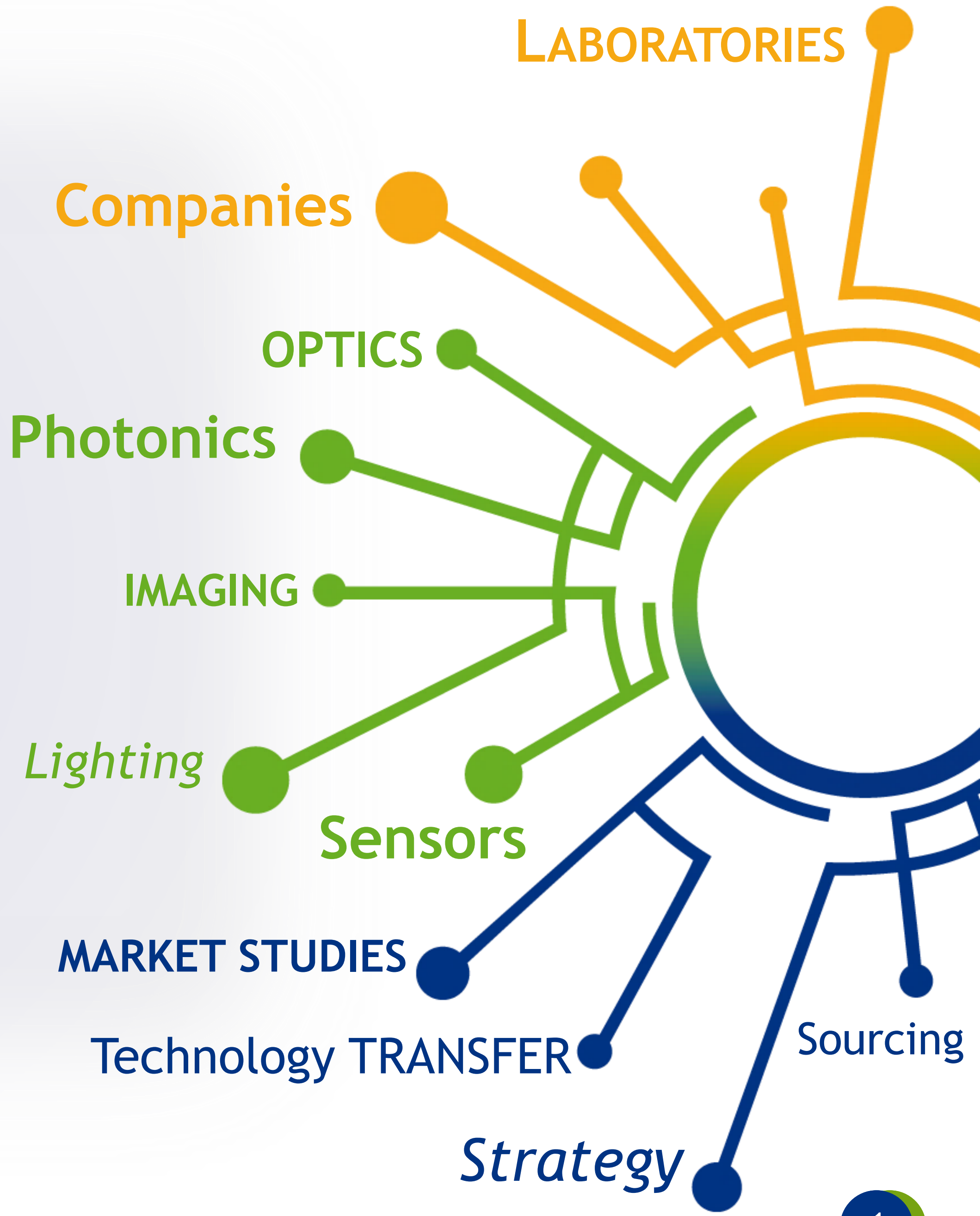
Tematys

Exploration of photonics markets

EPIC workshop

Oslo, 24th April 2024

How to manage innovation in a global but frugal and highly segmented market ?



www.tematys.com – info@tematys.com

About Speaker

- TEMATYS
  - 14 years old company in technology transfer and strategic marketing for Photonic players
  - 220 customers, 22 countries
  - Equally large companies, SMEs, academic lab, governmental entities.
- Our activities : Exploration and Monitoring of Photonics markets
  - More than 200 market studies, licensing deals and due diligence in Photonic Business
  - 3-years periodic report of Worldwide Photonics market (2021/2024)
  - 3-months Quarterly report about laser market (Q3 23 released in Q1 24, next one in July 24)
- Agro-Photonic
  - JC : Chairman of Agrophotonic department in Photonic France Association
  - Several technical contribution released by Spectaris, Arvalis in the last years
  - Partner in EU-projects in machine vision and infrared spectroscopy

Photonics technologies already established in

- Light and Analytics for Plant physiology research
  - Plants produce diverse responses to the quantity, quality, direction, and duration of light cues in their environment, like hormones and other secondary metabolites that affect production yield, food quality, and taste.
- Analytics for Milk, Grain, Floor milling, Oilseed products and raw products
  - Refractometer (BRIC)
  - NIR spectroscopy (protein, fat)
  - NIR reflectance
  - FT-NIR and FTIR
  - Flow cytometry (microbiology)

- Image analysis and spatialisation of data
  - RGB and RGB NIR sensors
  - Automated image analysis
  - X-Ray imaging
  - Spectroscopic sensor

Image from FOSS, Eagle PI, Avantes / YARA, Wageningen University

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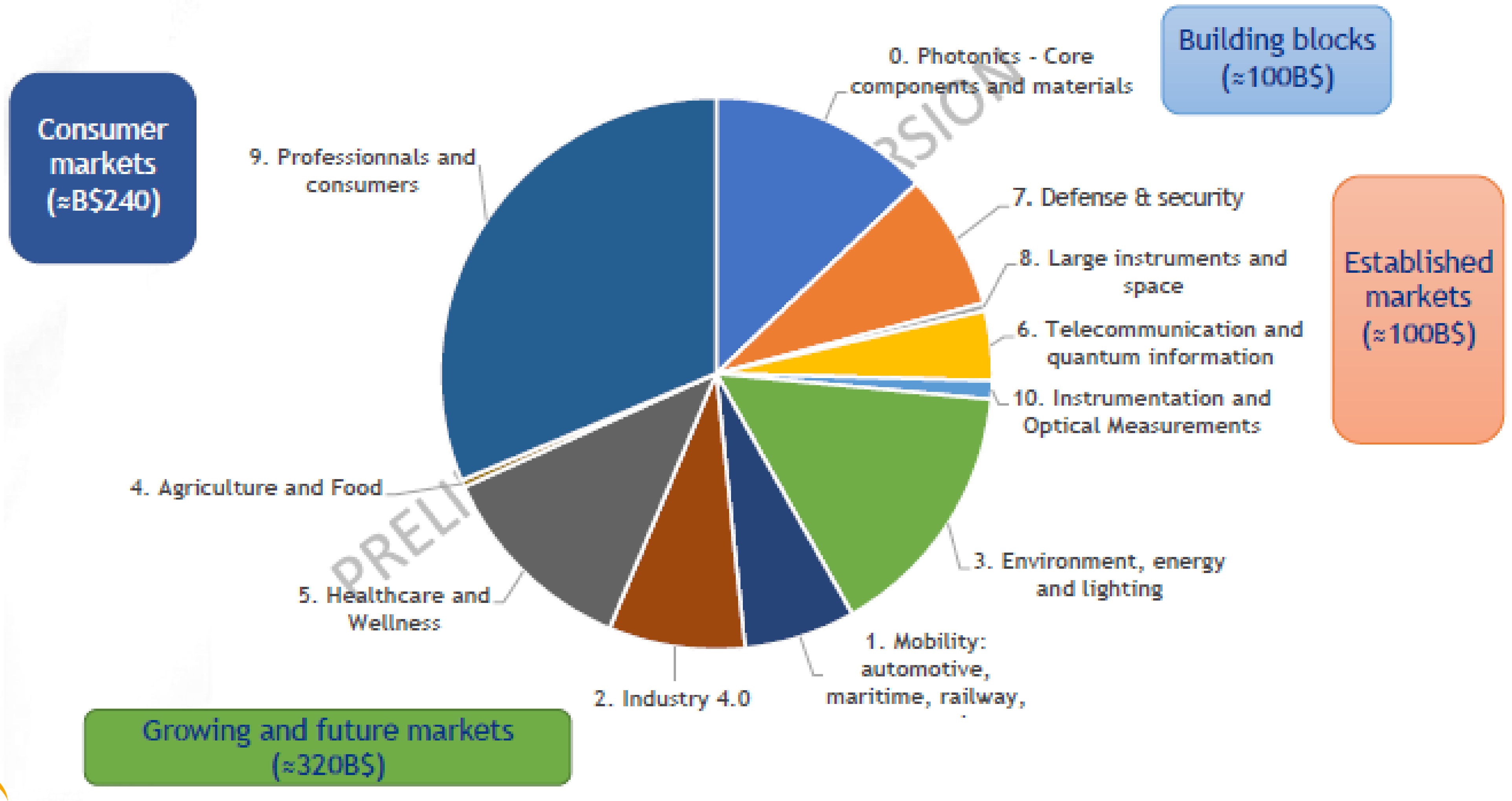
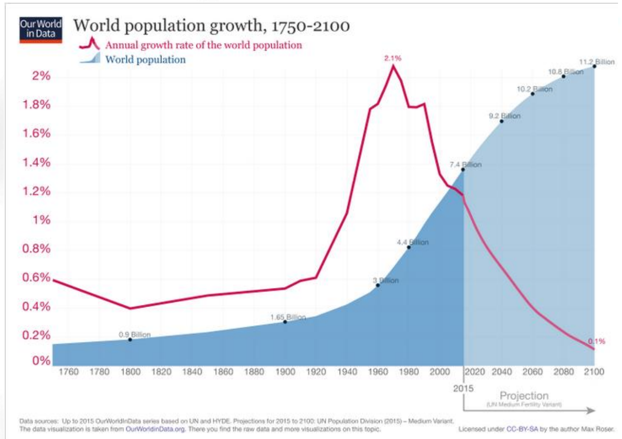
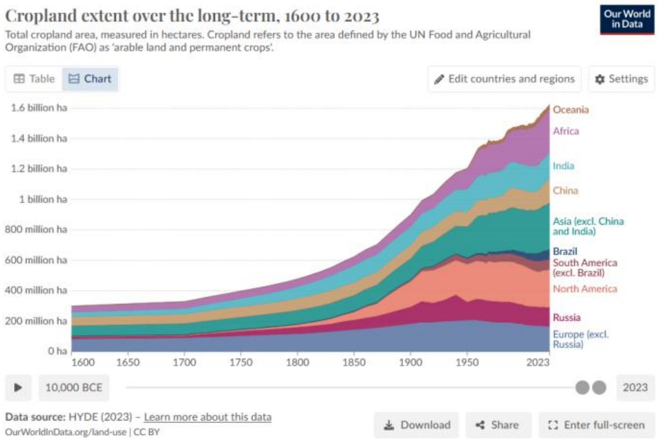
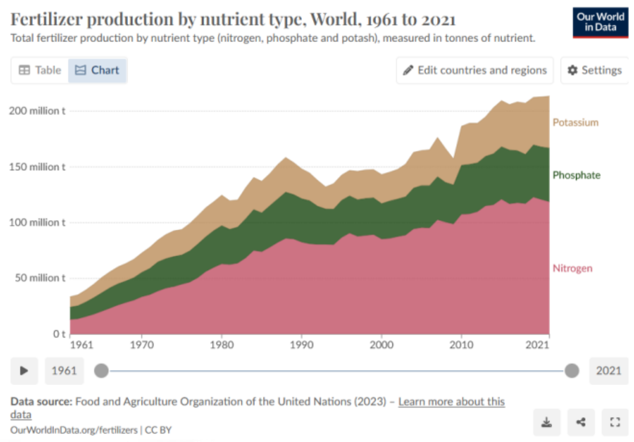
Still a small piece of a 780B$ photonics market

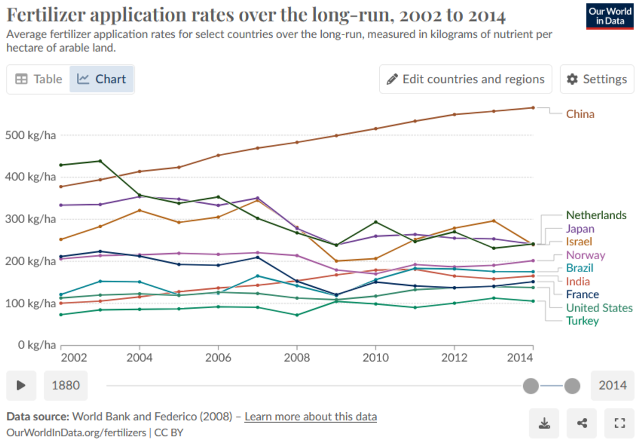


Agriculture and agroindustry faces great challenges





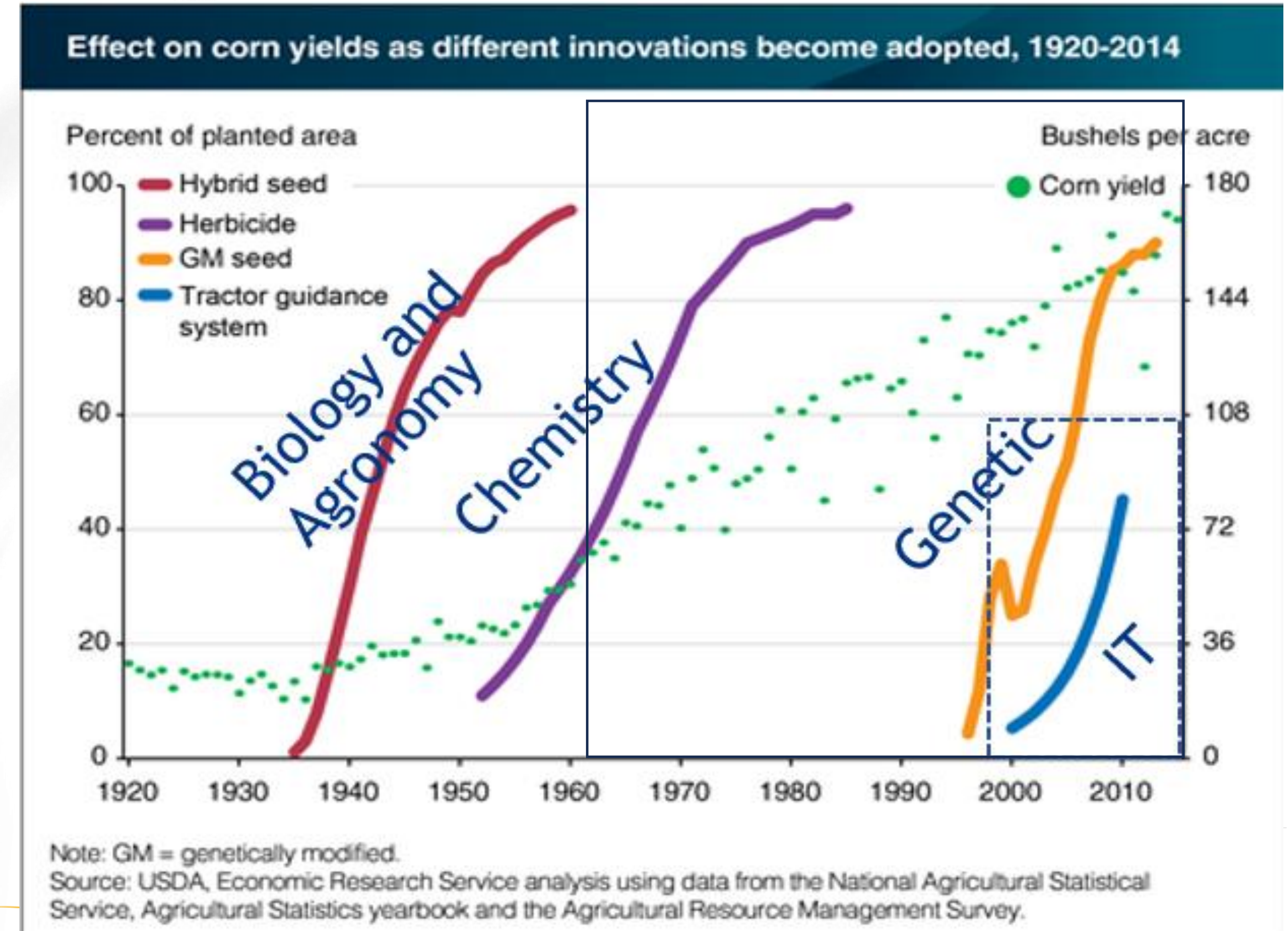




The challenges ahead

- Demography / feeding the world
- End undernourishment and improve access to high quality food
- Stop land degradation
- Reduce pesticide
- Reduce but also adapt to global warming impact
- Reduce GHG emissions

And former solutions reached their plateau



- For long, agriculture could feed the world by cultivating more land and increasing inputs, fertilizers and pesticides.
- But since the 80's, a limit has been reached. To add more and more inputs is becoming less efficient and the consequent pollution of excess inputs in soil becomes concerning and less acceptable.
- GMOs took over in the 1990s
- Since the 2000's, the only way to increase agriculture's productivity is to improve the "total factor productivity", in other words, produce more and better per hectare:
  - improve farming practices
  - take in account the local soil and climate when choosing crop varieties
  - monitor crop growth
  - detect diseases and pest early
  - optimize the use of inputs
  - invest in adapted machinery
  - etc.

FAO. 2021. The State of the World's Land and Water Resources for Food and Agriculture - Systems at breaking point. Synthesis report 2021. Rome. https://doi.org/10.4060/cb7654en

Photonics potential at each step of value chain

Phenotyping
Seed development
Seed quality

Yield forecast & Maturity control
Disease & pathogen detection
Urban Farming

Fruit calibration
Sorting

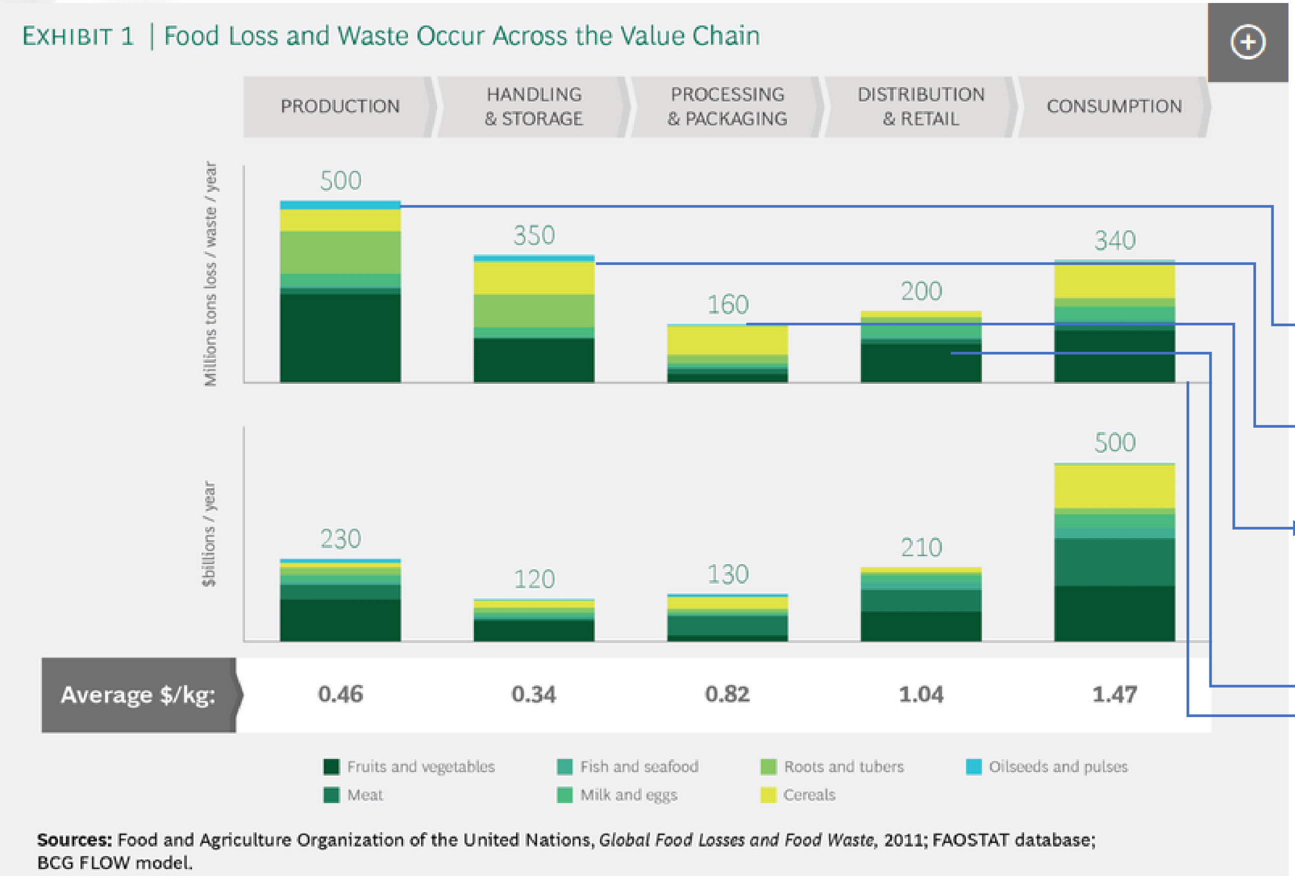
Process control
UV Treatment
Process cleaning and disinfection

Quality Control
Rapid microbiology Methods
Foreign bodies detection

Packaging Control
Warehouse control
Retail control
,Consumers Quality Control

Source: Tematys, Feuille de route Photonique, 2018, France Photonique

And all along the chain, as in food waste management



Data :
25 to 30% of food is lost and wasted.
Between 1,3 and 1,6Bt/year
Around 1.180 B$/year

Photonics TECHNOLOGY PORTFOLIO

Sorting devices on Production areas

Gas sensing in Handling and storage

Imaging and Process control devices in Processing and packaging

Spectroscopic and imaging device in retail

Spectroscopic device for consumer

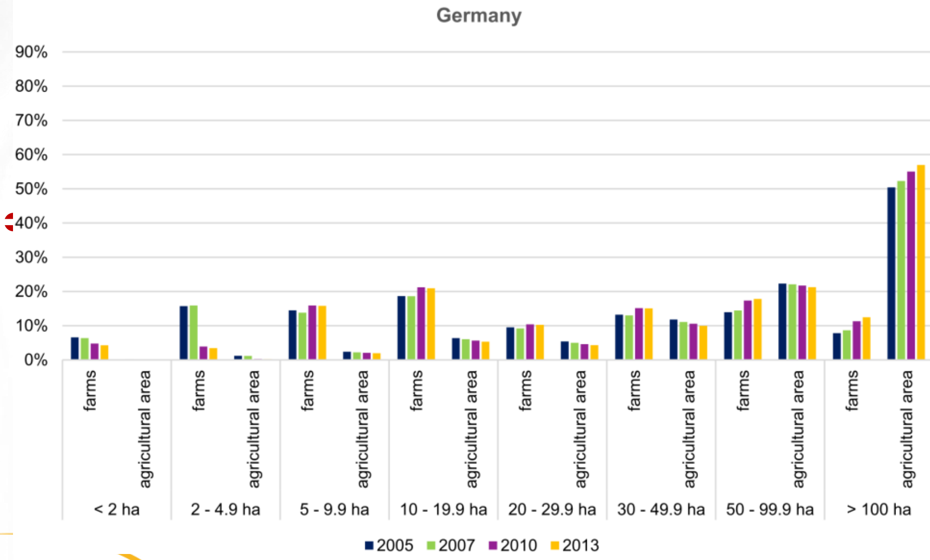
A wide portfolio of products

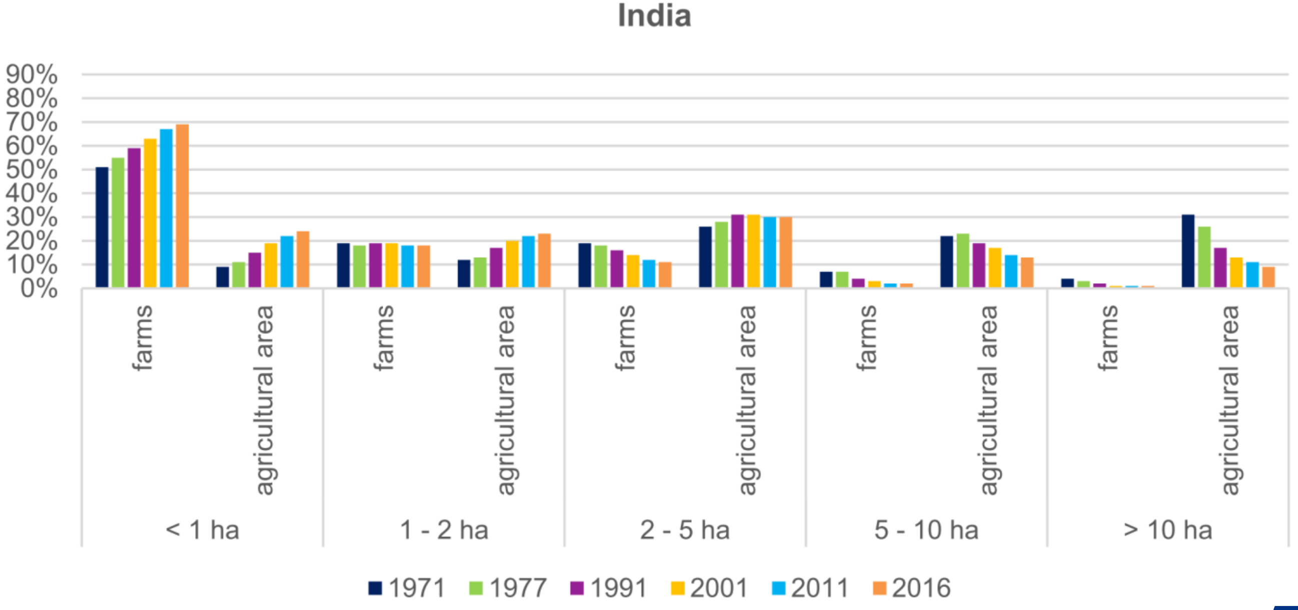
Markets	Functions	Technologies
Agriculture & agro-equipement	• Varietal innovation, adaptation of plants to climates and soils (phenotyping), plant protection, biocontrol • Systems and management of field crops, vines, including agricultural machinery / robotics • Remote sensing and spatial information systems	• 3D Laser Scan, active and passive Hyperspectral active et passive imaging, Terahertz imaging and spectroscopy (hydration sensing), Thermal imaging (evapotranspiration), NIR-MIR & Raman Spectroscopy, High resolution machine vision • CMOS and CCD cameras, NIR and UV handheld spectroscopy, Multispectral and Hyperspectral Cameras, UV lighting, Biosensors, • VIS-NIR-SWIR-MIR imaging, SWIR sensors, High resolution satellite imaging, anemometer,
Agriculture in synthetic environment	• Greenhouses, Vertical farm, Urban farms • At home greenhouse	• LED lighting (UV-B and Vis), Fibre optics Solar lighting, Fibre optic sensing, Various Spectroscopic devices, holographic and interferometric measurement (fish farms)
Breeding and aquaculture	• Feed, additive, nutrition • Precision breeding • Diagnostic, veterinary drugs • slaughterhouse • Fish farms	• Spectroscopy (handheld, on-line) • CMOS cameras, High speed cameras (biomechanics, Vision, Stereovision) • Biosensors (SPR, PIC, fiber-based) • 3D imaging, UV lighting, , Spectroscopy • Holographic and other interferometric devices
Food industry	• At-line & On-line control • Rapid Microbiology methods (detection, identification, characterization of particles below 10µm) • Foreign bodies detection	• Infrared spectroscopy (SWIR & MWIR), Hyperspectral Terahertz and Raman imaging, Cytometry, PIC, laser scanning, Plenoptic imaging • Cytometry, Plasmonic devices, Spectroscopy (Raman, SPR), Non conventional imaging (Holographic, speckle), PIC • Machine vision, X-rays, Terahertz imaging,
Retail	• Presentation of food products at the point of sale (freshness, ripeness)	• LED lighting, RGB imaging, Hyperspectral and SWIR imaging • Embedded Micro spectrometers

Source : TEMATYS, Fench AgriPhotonics Roadmpa, www.hdigitag.fr

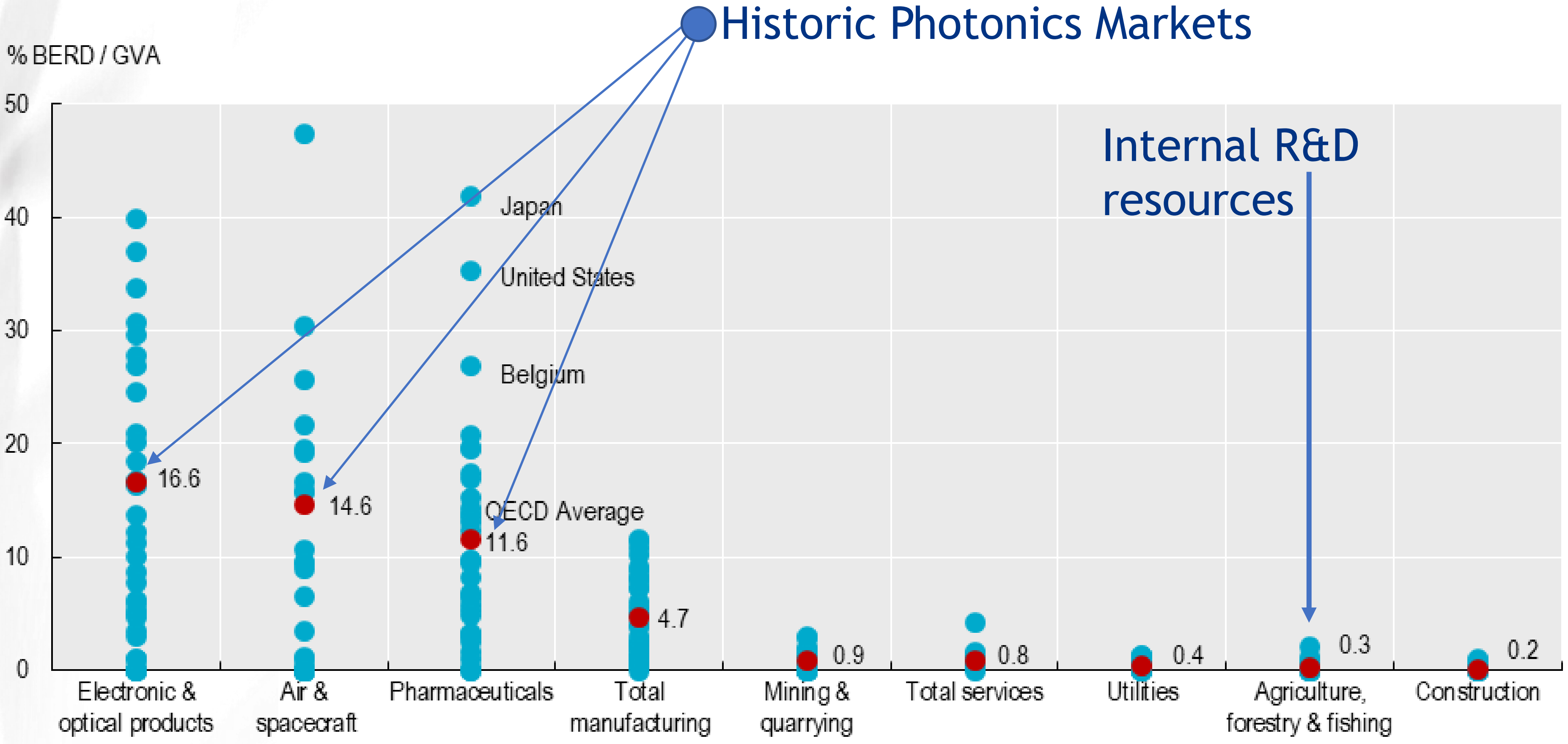
Reason 1 : Technology has to fit with Highly segmented market

- But before being widely adopted in agriculture, photonics faces four great challenges that must be addressed with a realistic and humble approach:
  1. **Crops and livestock are incredibly diverse**. There are more than 10000 varieties of apples! More than 8000 varieties of tomatoes! More than 800 exploited races of cows! Each variety of crop or animal race has its specific shape, size, colour, physiology, disease and pest. Each variety of crop or animal race is adapted to a specific climate and land. Each of them will produce or be suitable for a specific food. In other words, The challenge is not only to develop a photonic sensors or equipment. The challenge is to make it sufficiently versatile to be useful and efficient whatever the varieties and by adjusting the operating parameters by software. This way, the same hardware can be used in sufficiently big series and be produced at acceptable cost.
  2. **Many farmers have a limited investment capacity**. It has been seen previously that there are huge farms which can afford to invest in innovating tools but also a great number of small farms with much less revenue. Bigger farmers are and will be the early adopters, not only because of their investment capacity but also because they usually have a higher technical background. But in long term, all farmers, even the small ones, should have access to more advanced technologies that will provide them a better revenue while respecting their tradition. Feeding the global population and addressing the sustainability challenges are at stake.





Reason 2 : R&D & deployment hast to fit with scarce resources



Source: OECD Analytical Business Enterprise R&D (ANBERD), Structural Analysis (STAN) and System of National Accounts (SNA) databases.

Using RETEX and price decrease from other industries

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Defense & PNT markets

Smart building

HEALTH technologies, Pharmaceuticals, Sports management

Process control, Process Analytical Technologies, Microbiology
Pharmaceuticals, O&G

Machine Vision

Source : TEMATYS, Fench AgriPhotonics Roadmpa, www.hdigitag.fr

Some examples to illustrate

- X-rays in airports (1970) ➔ Detection of foreign bodies by X-ray sorter in agroproduction (1990)
- Landsat (1972) ➔ Farmstar (2001)
- Flow cytometers in Pharma-Biotech (1980’s) ➔ First use of Flow Cytometers in agroindustry (2000)
- LED lighting (2002) ➔ Greenhouse LED lighting (2007) (Signify - *why so fast ??)*
- Detection of suspect behaviors (Defense industry) (2005) ➔ Tools for livestock farming 2015 (Faromatics…)
- Raman PAT in Process Industry 2015 ➔ Raman as on-line analyzers (2025) (MarqMetrix ?)
- Next-one ? reproduction of highway tolls into high-end spraying devices (GreenEyes ?)

https://www.greenhousegrower.com/technology/lights-camera-celebration-horticulture-lighting-company-marks-15-years-of-innovation/

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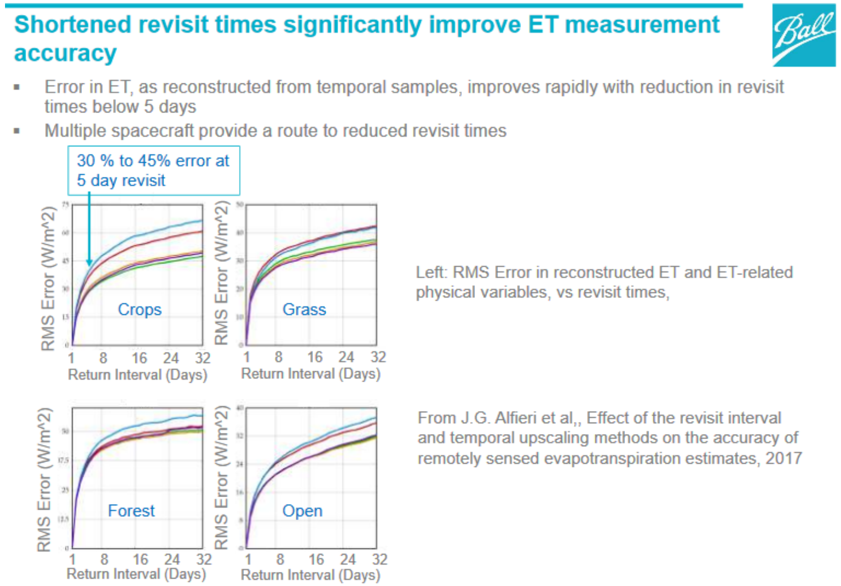
Cost decrease in UV & infrared lighting

Food Sorting

Fill Level Detection

- Evapotranspiration (ET), a key Earth Science variable, combines
  - Evaporation from the earth's surface
  - Transpiration, the release of water vapor from plant cell surfaces
- ET returns the majority of precipitation falling on land to the atmosphere
- ET varies substantially spatially AND temporally
- ET contributes significantly to a variety of local and global phenomena including local climate, weather, carbon cycle, earth's energy balance, biodiversity



https://esto.nasa.gov/forum/estf2019/presentations/Osterman_%20S1P1_ESTF2019.pdf, Ball Aerospace

Exploration of photonics markets

Evolution of Trade-off in CAPEX / OPEX

Principal bottlenecks of photonics deployment (high cost, size, not power efficient, requirements of skilled people to operate) are to be solved within the next years. Current developments in photonics (LIDAR for automotive, fiber optic sensors) lead to compact, frugal, resilient devices and allow the development of Building blocks in :

- ➔ High volume manufacturing
  - ➔ integrated circuits (from Telecom/Datacom to MedTech and process monitoring)
  - ➔ Wafer-level packaging and coupling (from Datacom to Sensing)
  - ➔ Opto-mechanical assembly with high accuracy
- ➔ Less parts per device
  - ➔ freeform optic (from Space to lighting and micro-optics devices)
  - ➔ 3D engraving (for multiple function on the same component)
- ➔ And befits from IoT developments
  - ➔ Frugal data acquisition and transfer (LTE, passive time-lapse monitoring)
  - ➔ 5G and 6G based devices
  - ➔ Standardization in components

AI as photonics' enabler

While yield sensors provide very accurate maps, their interpretation remains difficult, in the absence of techniques to map with the same precision the potential root causes of yield variations (variations in the physical or chemical composition of the soil).

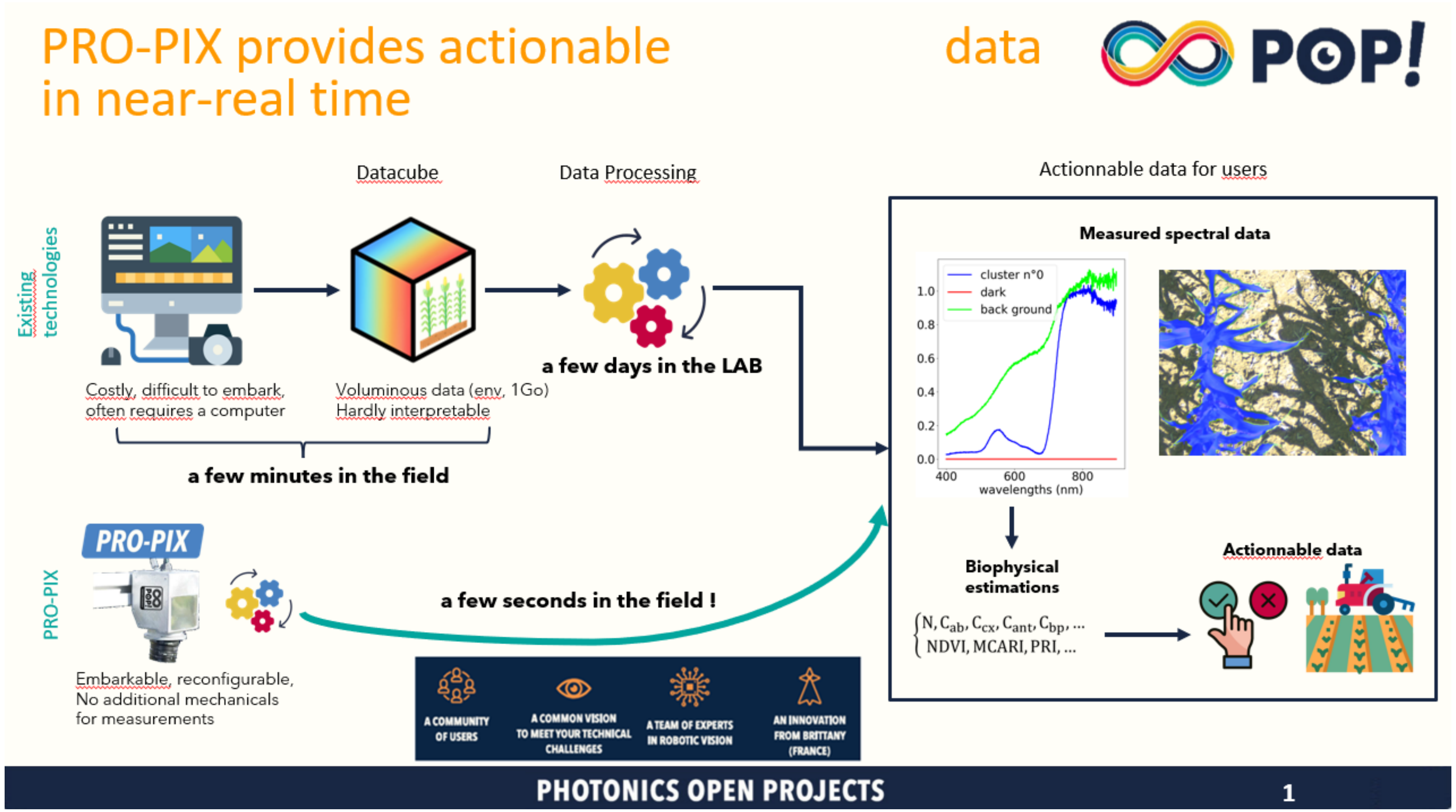
There is therefore a strong imbalance between the amount of descriptive information of crops (huge number of data), and the density of information on the factors that explain their yield potential (soil and climate information with lower spatial and temporal resolution).

As a result, it is difficult to quickly deduce fertilizer or pesticide application maps from the yield cartography, which could then be implemented by precision sprayers. **This imbalance between descriptive information and explanatory information is still a major limitation to transform data in diagnostics.**

Photonics is an enabler to develop High spatio-temporal data acquisition of various parameters but requires parallel development in artificial intelligence and further Modeling to extract the highest value from Photonic sensing.

➔ Example of predictive analysis to introduce beyond real-time sensing

- ➔ Short term weather forecast to define irrigation tasks
- ➔ Yield forecast to define fertilizer inputs
- ➔ Pest infection timeline and trajectory


PRO-PIX provides actionable data
in near-real time
POP!
Datacube
Data Processing
Actionnable data for users
Existing technologies
Costly, difficult to embark,
often requires a computer
Voluminous data (env. 1Go)
Hardly interpretable
a few days in the LAB
a few minutes in the field
Measured spectral data
cluster n°0
dark
back ground
wavelengths (nm)
Biophysical estimations
N, Cab, Ccx, Cant, Cbp, ...
NDVI, MCARI, PRI, ...
Actionnable data
PRO-PIX
PRO-PIX
a few seconds in the field !
Embarkable, reconfigurable,
No additional mechanicals
for measurements
A COMMUNITY OF USERS
A COMMON VISION TO MEET YOUR TECHNICAL CHALLENGES
A TEAM OF EXPERTS IN ROBOTIC VISION
AN INNOVATION FROM BRITTANY (FRANCE)
PHOTONICS OPEN PROJECTS
1

Takeaways

- **Cost is key**. As for cytometers, LEDs, Raman, initial price point is often too high for agroproduction, hampering market deployment till price erosion put the component at the required level.
- **Reliability is just behind.** 24/7 analysis is the standard in Agroindustry production. As margins are low, ROI takes time. Loss of production is immediately at cost for supplier. Full availability of photonic system should have been demonstrated in a relevant industrial environment.
- **Moving from non-miscible communities to emulsion**. The photonics community demonstrated boundless creativity to develop smart solutions, but photonics engineers are not farmers, and farmers and agronomists are not physicists. Stronger porosity in last decades allowed joint discussions to understand the complexity of growing crops or livestock and translate it into appropriate photonics parameters.
- **Time to transfer is lowering**. From 30 years for X-ray imaging or NIR spectroscopy, the transfer time is now about 10 years or less (LEDs), allowed by cost decrease and stronger reliability in mainstream photonics (micro-optics, integrated optics). 30 years on R&D investigation on plants and living organisms with photonics tools carry a strong knowledge database for future agrophotonic product development.
- **AI maturity**. Expected Versatility of sensors will be increased by conjunction of smart sensors, spectral databases, and Artificial intelligence to transform a generic sensor into a customised one.

Questions