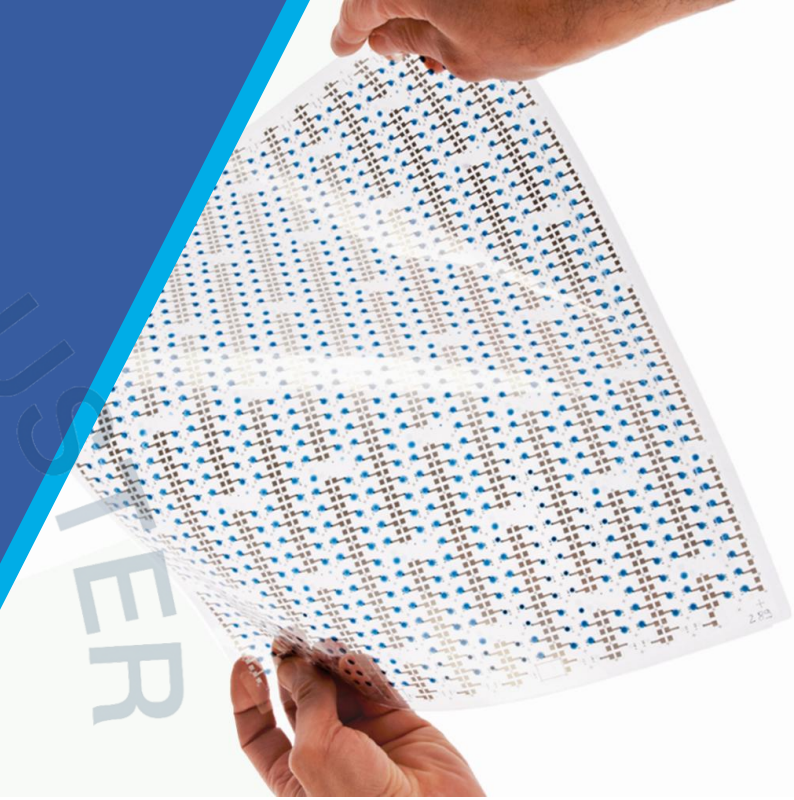


How Global Sensing Mega-Trends are Shaping the Printed and Flexible Sensors Market

6th November 2024

www.IDTechEx.com



IDTechEx



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IDTechEx Printed Electronics and Sensors Portfolio

[IDTechEx.com/Research](https://www.IDTechEx.com/Research)

Printed and Flexible Sensors
2024-2034: Technologies,
Players, Markets



Printed and Flexible Sensors 2024-2034

Sensor Market 2025-2035:
Technologies, Trends,
Players, Forecasts



Sensors 2025-2035

Conductive Inks

Conductive Inks Market 2024-2034:
Technologies, Applications, Players



3D & Additive electronics

3D Electronics/Additive Electronics
2024-2034: Technologies, Players,
and Markets



Lidar

Lidar 2024-2034: Technologies,
Players, Markets & Forecasts



Wearable Sensors

Wearable Sensors 2023-2033



Flexible and Printed Electronics

Flexible & Printed Electronics
2023-2033: Forecasts,
Technologies, Markets



Manufacturing Printed Electronics

Manufacturing Printed Electronics
2023-2033



Environmental Gas Sensors

Environmental Gas Sensor Market
2024-2034: Technology, Trends,
Forecasts, Players



Emerging Image Sensors

Emerging Image Sensor Technologies
2024-2034: Applications and Markets



Slide 2

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IDTechEx

Overview

1. Global sensor markets and technology mega-trends
2. Value proposition of printed and flexible electronics in key sensor markets
3. Case studies of printed sensor commercialization
4. Market outlook and key growth opportunities



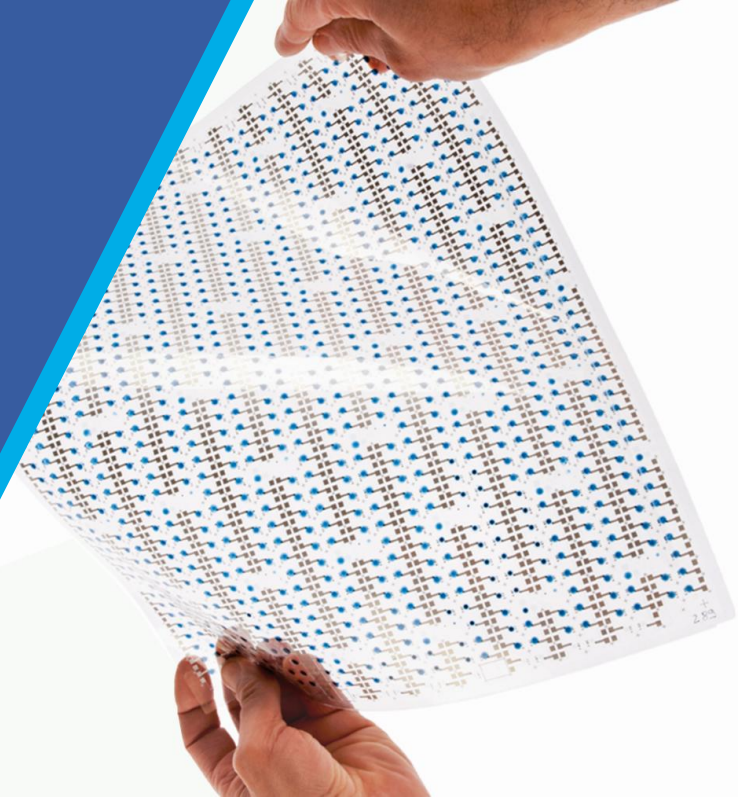
Printed and Flexible Sensors 2024-2034

www.IDTechEx.com/FlexSensors

Sample pages are available for all IDTechEx reports

✉ research@IDTechEx.com

The impact of global technology trends on sensors



Overview of major sensor technology markets

Automotive



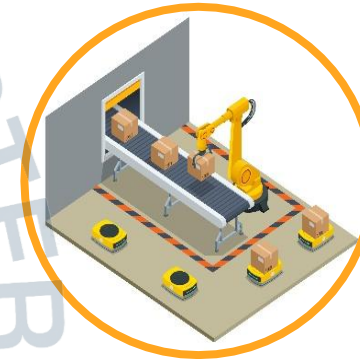
- Fuel-air levels
- Engine oil levels
- Pressure
- Temperature
- Speed
- Parking
- Autonomy (ADAS)
- 'Mobility electronics'

Aerospace



- Navigational
- Speed
- Pressure
- Altitude
- Angle of attack
- Fuel temperature
- 'Avionics'

Industrial



- Fire Safety
- Temperature
- Humidity
- Gas safety
- Automation
- Inventory Management
- 'Industrial IoT'

IDTechEx Research

Consumer



- Motion (IMUs)
- Touch control
- Microphones
- Cameras
- Eye/Hand tracking
- Fitness/Heart rate

Healthcare



- Heart-rate
- Blood oxygen
- Blood pressure
- Glucose
- Hydration

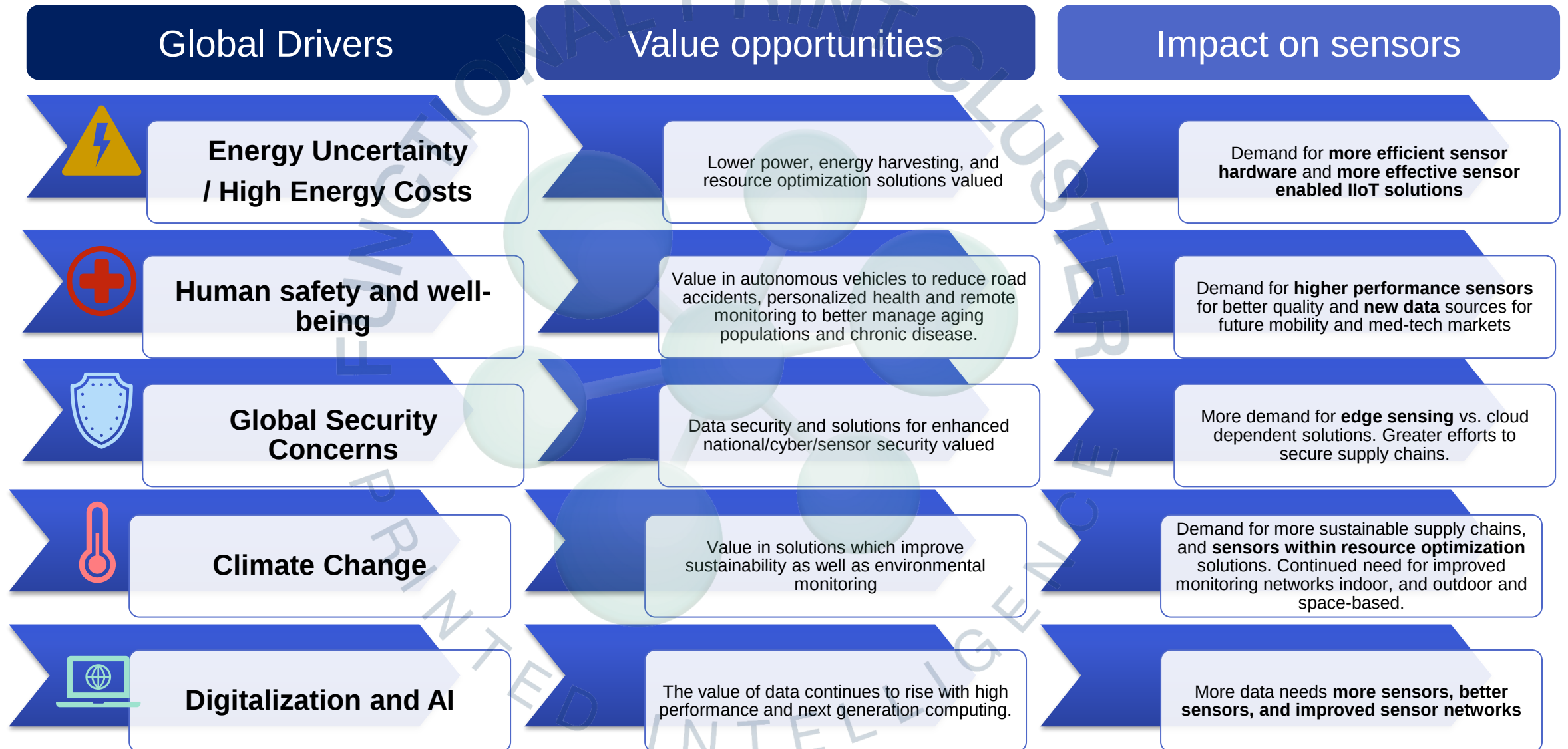
Environmental



- Indoor air quality
- Carbon dioxide
- Particulate matter
- VOCs
- Pollution
- Water monitoring
- Soil Monitoring

**Sensors described are examples of product lines within each industry, and not an exhaustive list;*

Key drivers and associated value opportunities influencing the sensor market



Sensor trends and drivers for adoption of new technology

Overview of Key Global Sensing Technology Trends



Digital twinning

- Virtual environments
- Simulating change



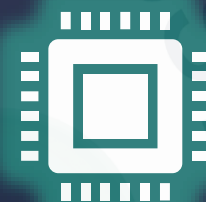
Automation

- Device decision making
- Autonomous operations



Cybersecurity

- Growing data collection
- Privacy concerns



Edge computing

- Smart devices
- Off-grid functionality



AI

- Machine learning
- Predictive functionality

Drivers for Adoption of New Sensor Technology

Cost

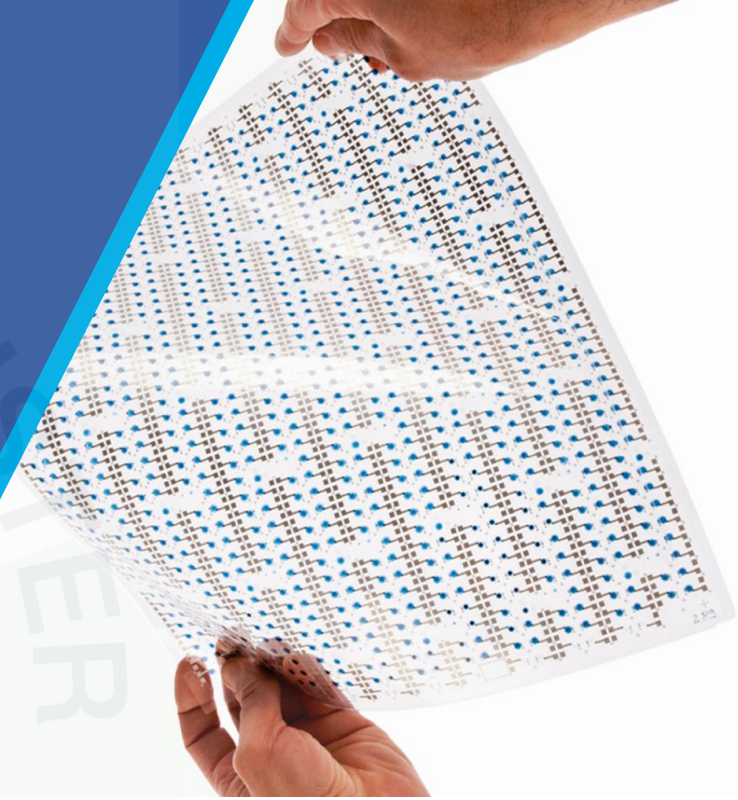
Size

Performance

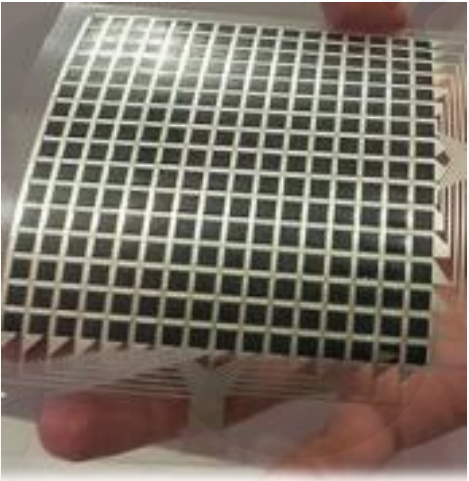
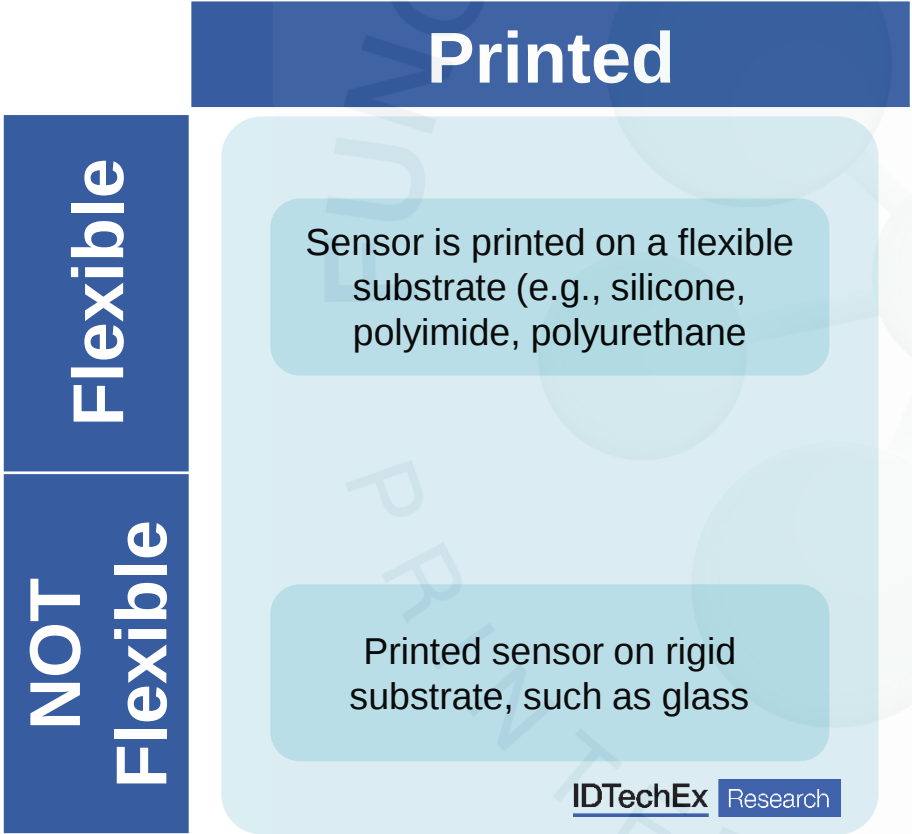
Power
consumption

New and
relevant
metrics

Contextualizing the value proposition of printed sensors



Advantages of Printed and Flexible Sensors

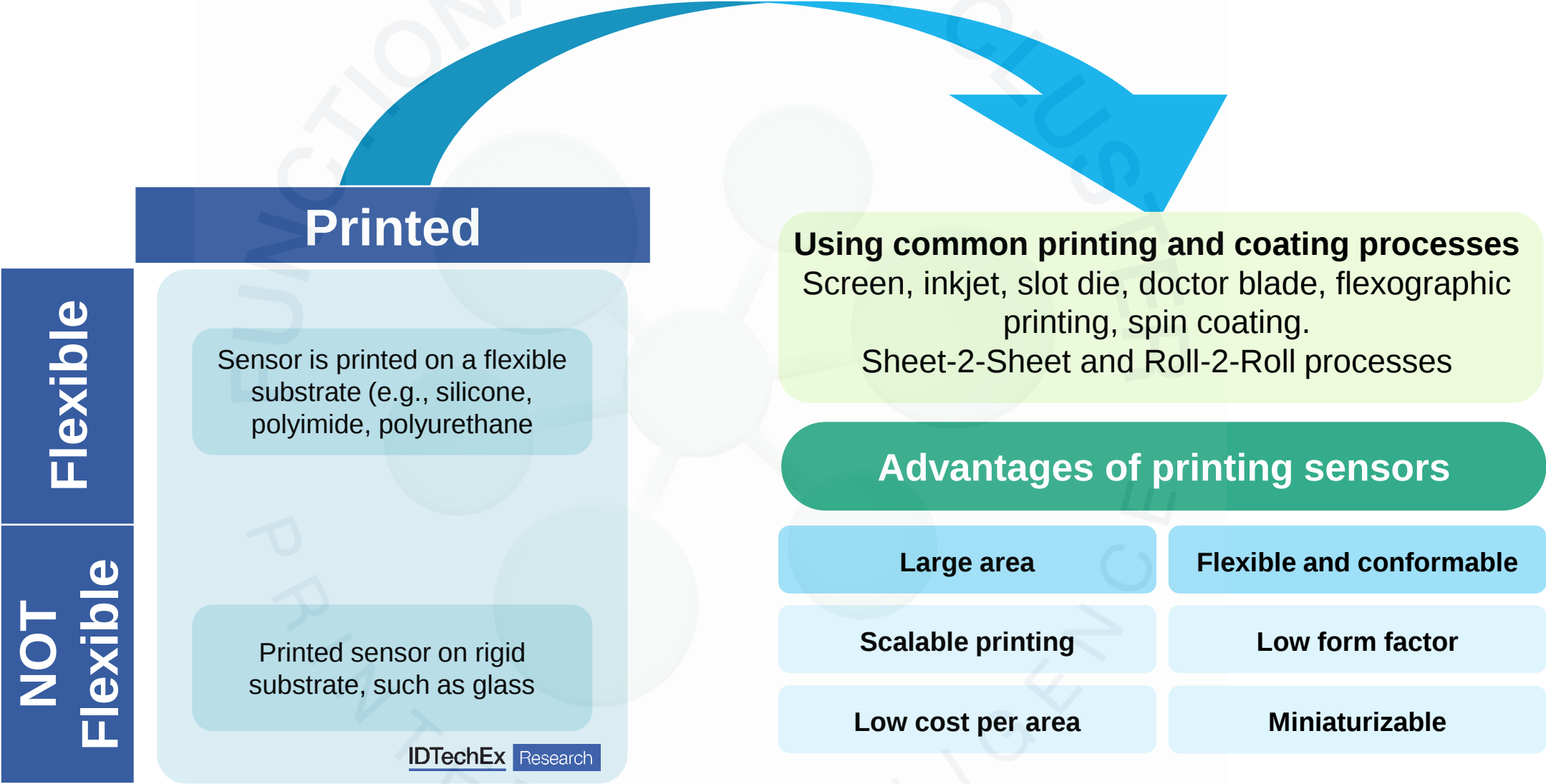


PST Sensors



Isorg

Advantages of Printed and Flexible Sensors



Printed and Flexible Sensor Technologies and Current Market Size

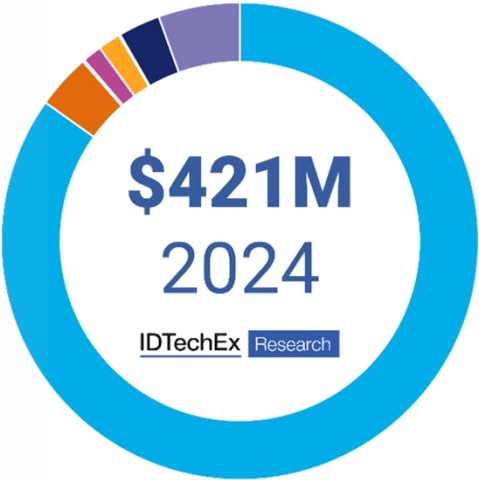
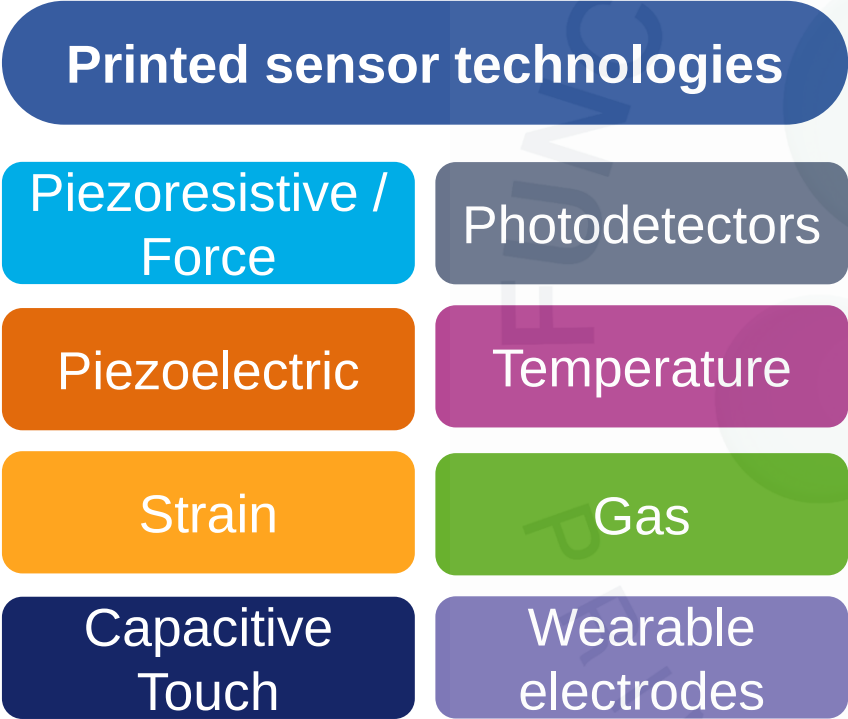
Printed sensor technologies

- | | |
|------------------------|---------------------|
| Piezoresistive / Force | Photodetectors |
| Piezoelectric | Temperature |
| Strain | Gas |
| Capacitive Touch | Wearable electrodes |

Printed Sensor Annual Revenue (USD, millions)



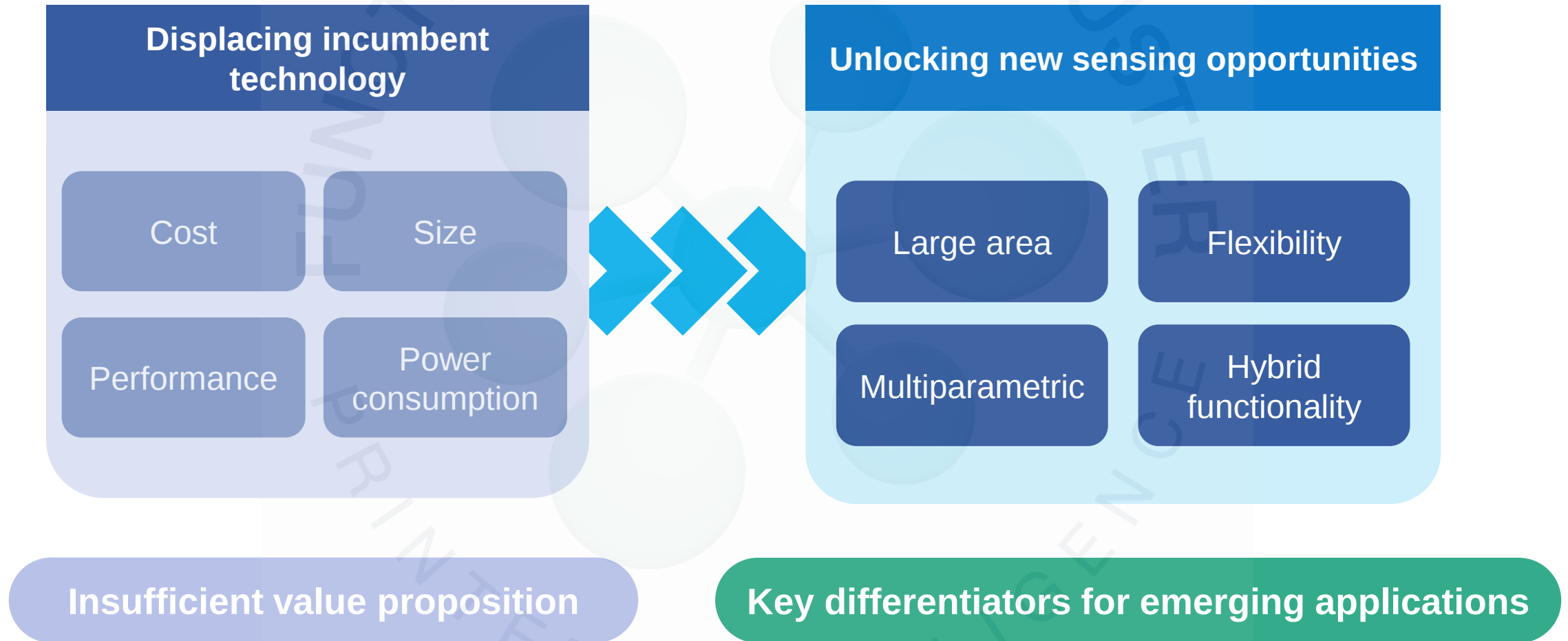
Printed Sensors Struggle to Capture Revenue Share of Large Sensor Market



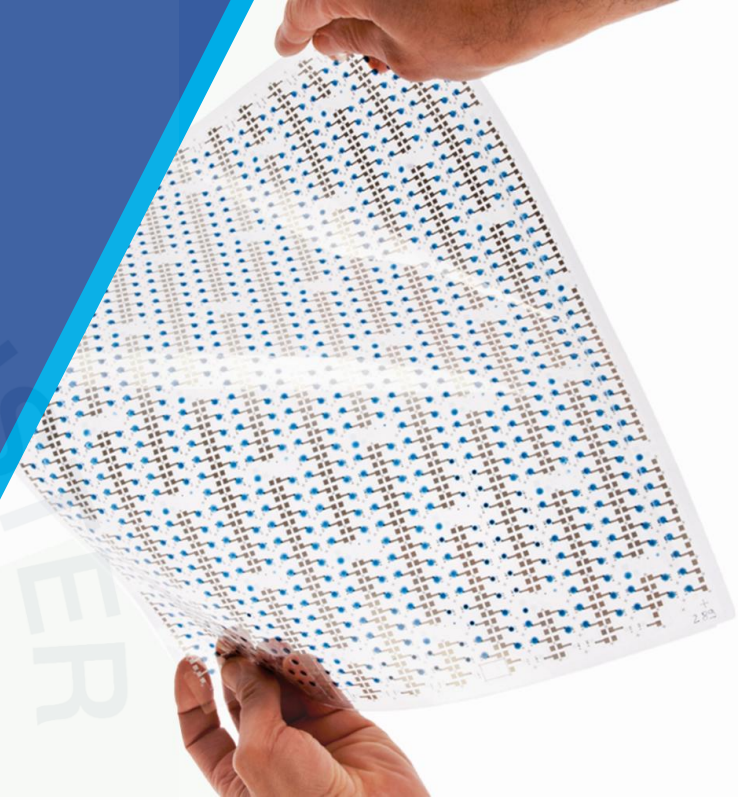
Printed and flexible sensors

All sensor technology

Evolving Value Proposition for Next Generation Printed Sensor Technologies



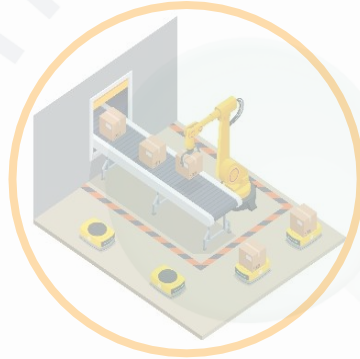
Key emerging printed sensor markets and case studies



Growth markets for printed and flexible sensor technology



Automotive



Industrial



Consumer



Healthcare

Variety of reasons
for encouraging
growth prospects

- ✓ Capitalizing on broader market trends
- ✓ Measuring new and relevant metrics
- ✓ Technology performance advancements compete with incumbent solutions
- ✓ Emerging applications with strong product-market fit
- ✓ Levering differentials of printed and flexible technology platforms
- ✓ Technology is co-developed with products and solutions
- ✓ Unlocking low-cost high-volume manufacture threshold

Automotive mega-trends and printed sensor opportunities



IDTechEx Research

Printed sensor technologies

- Battery health monitoring
Seat occupancy detection
- Battery health monitoring
Fuel storage integrity monitoring
Haptic feedback
- Infotainment systems
Human machine interfaces

- Piezoresistive / Force
- Photodetectors
- Piezoelectric
- Temperature
- Capacitive Touch
- Strain

- Spatial mapping
Biometric authentication
- Thermal management
Battery health monitoring
Low-power heating
- Battery health monitoring
Human machine interfaces

Materials, performance, and benchmarking of printed sensor technologies can be found at www.idtechex.com/FlexSensors

Battery health monitoring and optimization opportunities

Extending electric vehicle lifetime is a valuable problem to solve.

Solution - Battery health monitoring to optimize battery charging and deployment.

Solution requirements:

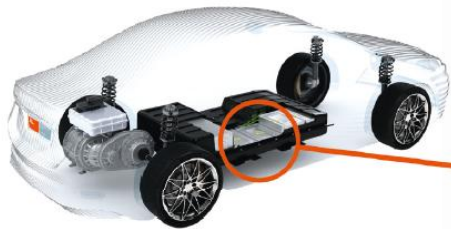
- Lightweight
- Low power
- Low cost
- Relevant metrics
- Active monitoring solution

Key metrics:

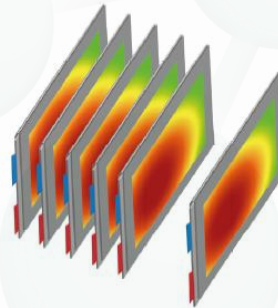
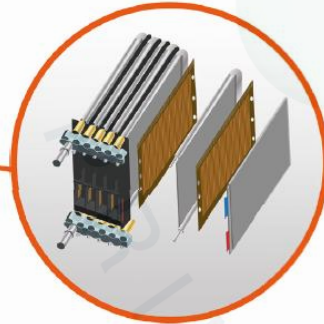
State of charge

Swelling

Temperature

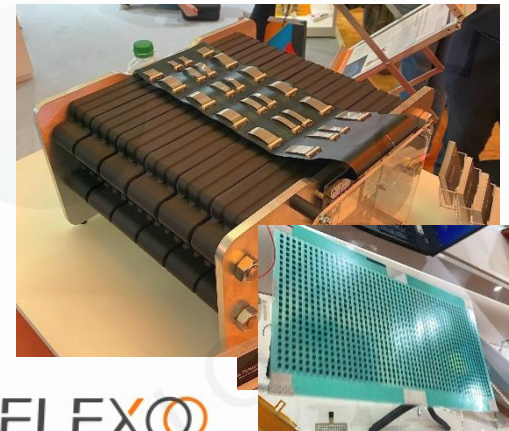
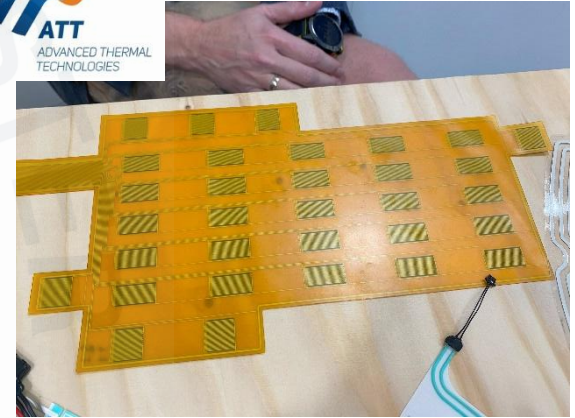


Source: Flexoo.



Value of solution = up to \$3000 in savings per vehicle

Battery health monitoring with printed electronics



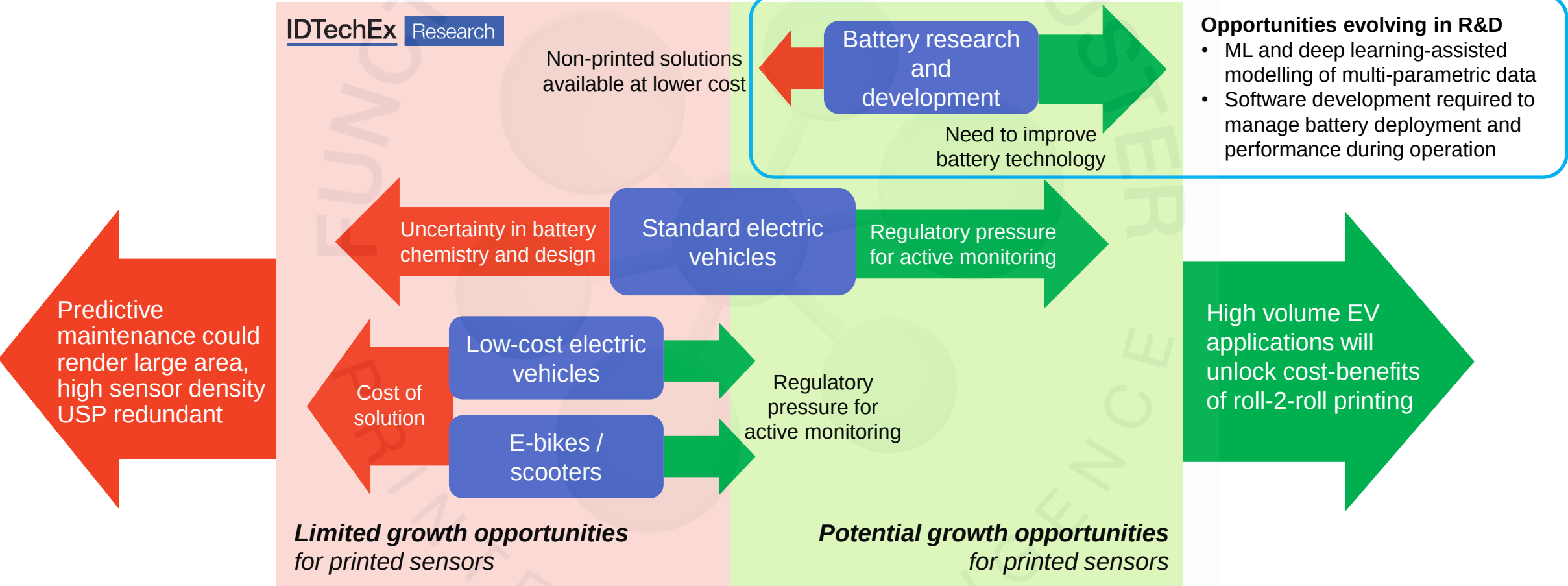
FLEXOO



a sense for **IEE**
innovation

Factors dictating when and if printed sensors for battery health monitoring will be required

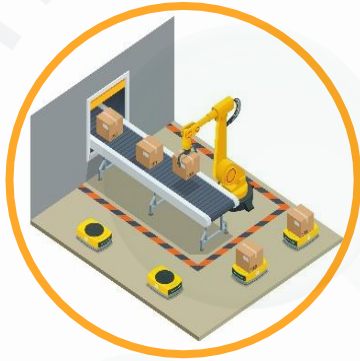
Value proposition of printed sensors for battery health monitoring



Growth markets for printed and flexible sensor technology



Automotive



Industrial



Consumer



Healthcare

Drivers for
Technology Adoption

Productivity

Reducing OpEX



Opportunities for
printed sensors

Improving
safety

Optimized
maintenance

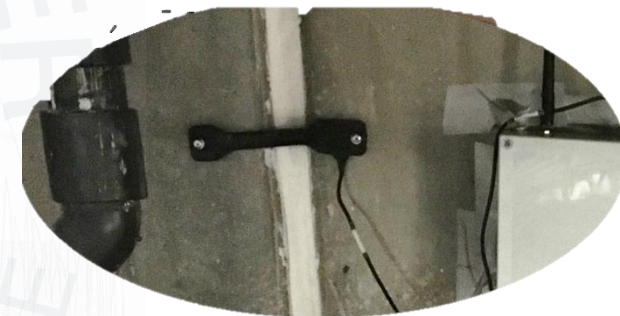
Piezoelectric and strain sensors for structural health monitoring

IDTechEx Research	Operation	Materials	Strengths	Weaknesses
Piezoelectric sensor	Force-induced electric field generation	• PZT (lead zirconium titanate) • PVDF	• High sensitivity • Self-powered	• High cost
Strain sensor	Deformation induces change in capacitance	• Silicone • Conductive carbon	• Cheap • Durable	• Low sensitivity

Current market

Displacement sensing, structural and machine health monitoring for equipment and infrastructure

Key players



Piezoelectric and strain sensors for structural health monitoring

IDTechEx Research	Operation	Materials	Strength	Weakness
Piezoelectric sensor	Force-induced electric field generation	- PZT (lead zirconium titanate) - PVDF	- High sensitivity - Self-powered	High cost

Future market

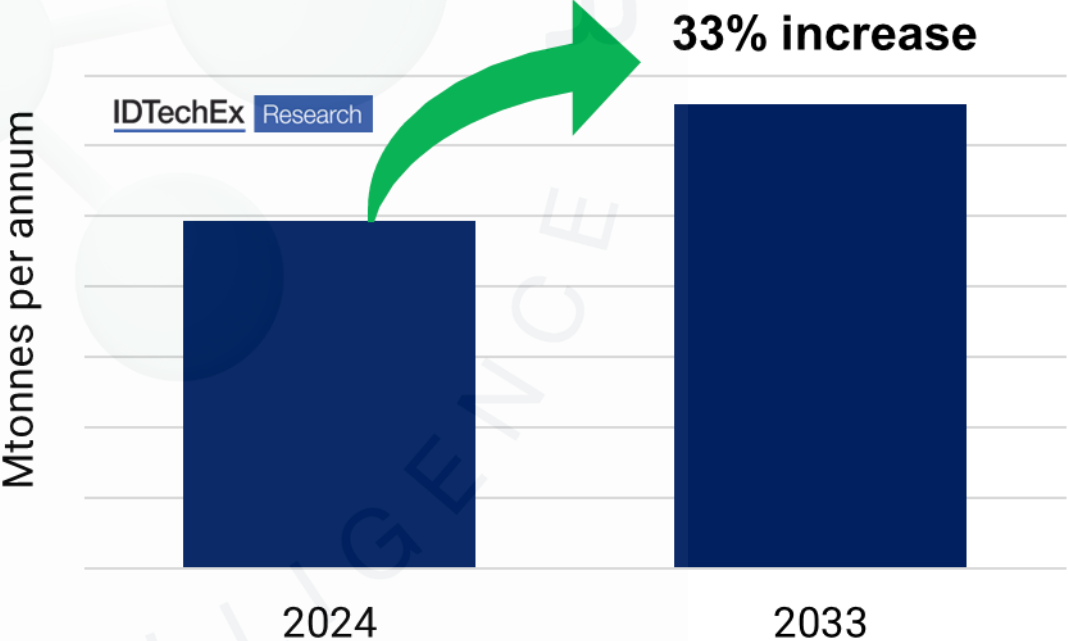
Structural health monitoring for **hydrogen storage**

Detect cracks and breaks with ultrasonic sensors



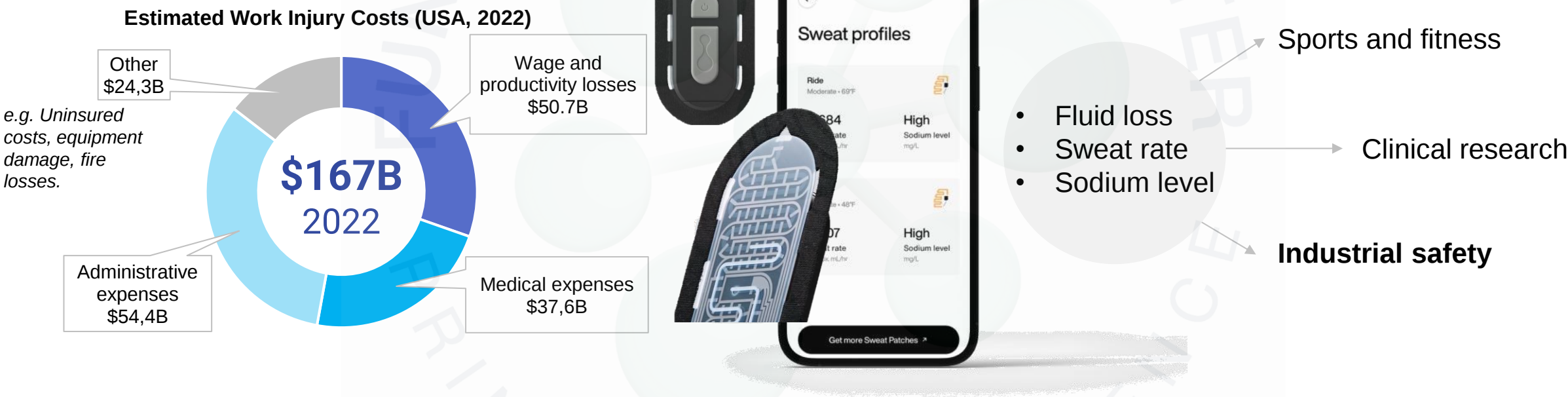
ARKEMA

Cumulative Global Hydrogen Demand (Mtpa)
2024-2033



Commercialization of printed microfluidic hydration sensors in industrial safety and fitness markets

Skin-like microfluidic wearable sensor for hydration and electrolyte analysis



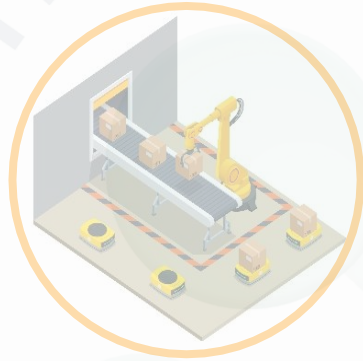
Data source: National Safety Council.



Growth markets for printed and flexible sensor technology



Automotive



Industrial



Consumer



Healthcare

Drivers for Technology Adoption

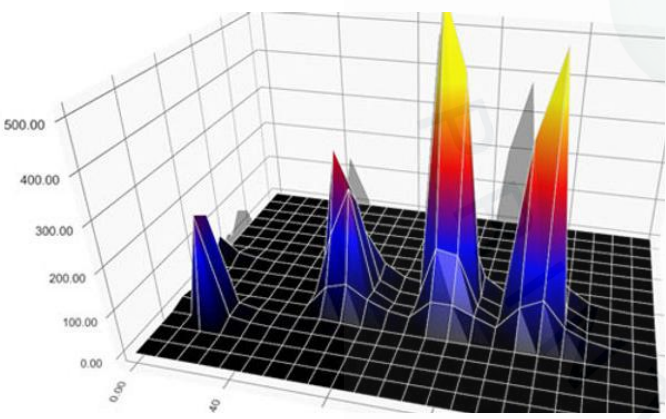
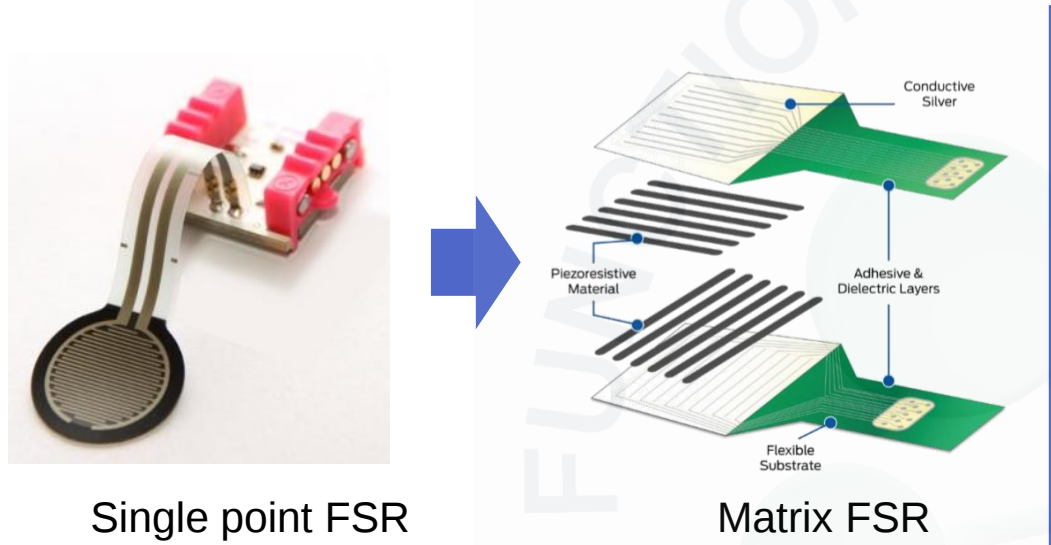
Product
differentiation

New
functionality

Improved
aesthetics

Smaller, faster,
cheaper...

Force sensing resistors land in consumer laptops for 3D touch, but impact will be short lived

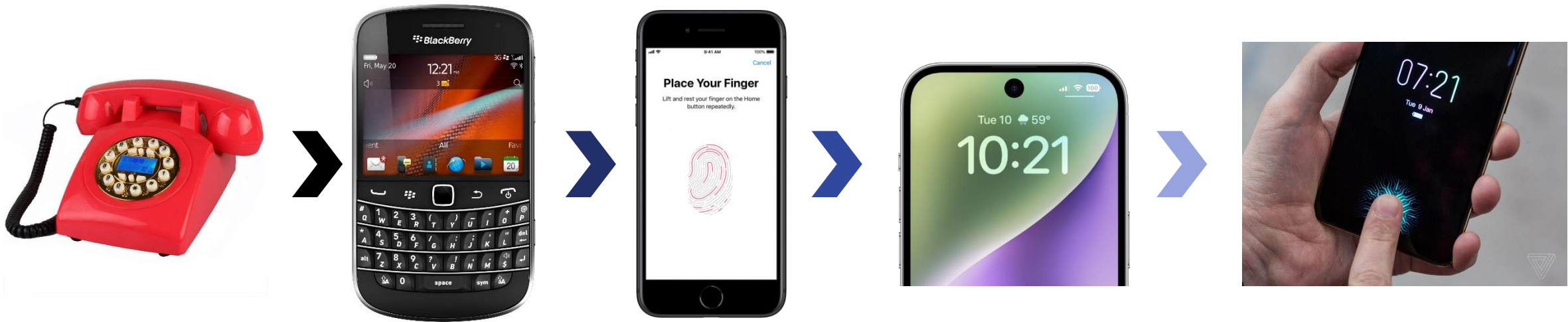


Source: Sensel.

- ✓ Large area sensing
- ✓ Multiparametric
- ✓ Low-cost solution
- ✗ Not flexible
- ✗ Weak performance with glass



Evolution of security and biometric user authentication technology



No security -
access restricted
to home/office

Pin/password

Fingerprint
(off-screen)

Facial
recognition

Under-display authentication
(fingerprint/face)



Printed photodetectors are emerging machine for biometric authentication with improved display quality



Under-display authentication
(touch/face)

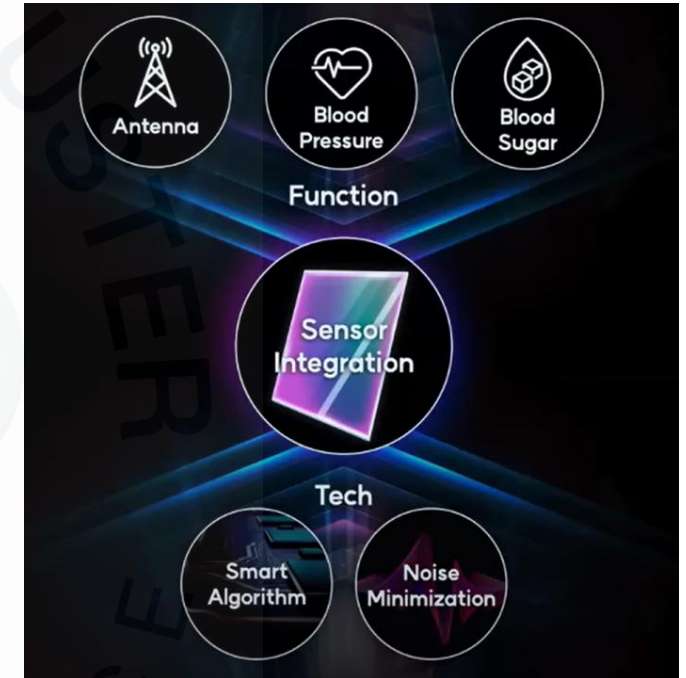
Current and emerging sensing solutions

- **Optical (visible light)**
- **Optical (short wave infrared)**
- Ultrasonic

In-cell organic photodetectors (OPDs)



SAMSUNG DISPLAY



On-cell printed photodetectors



OPD



OPD

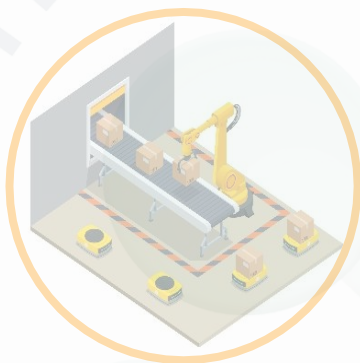


Quantum Dot (PbS)

Growth markets for printed and flexible sensor technology



Automotive



Industrial



Consumer



Healthcare

Preventative
healthcare

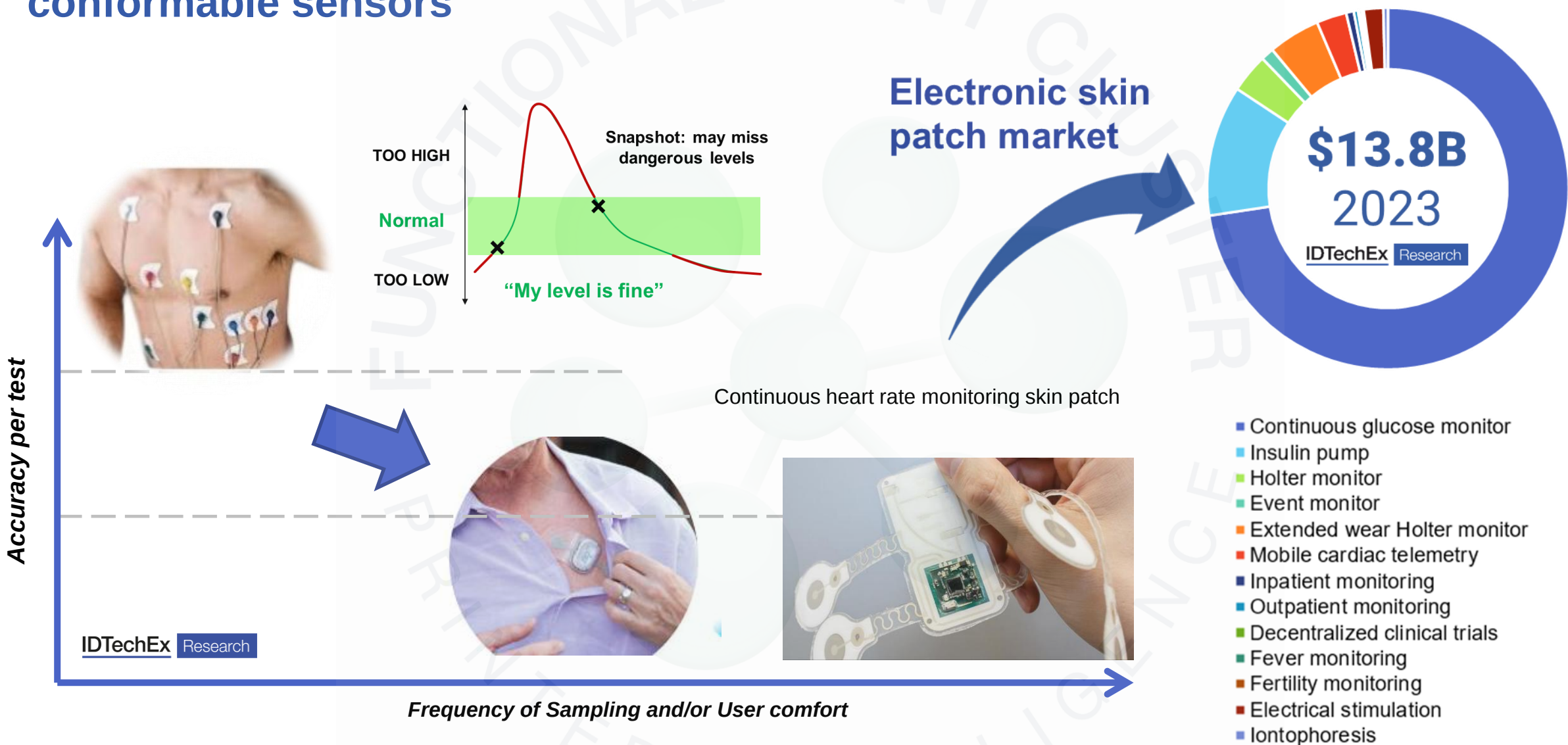
Remote
healthcare

Digital
healthcare

Continuous
monitoring

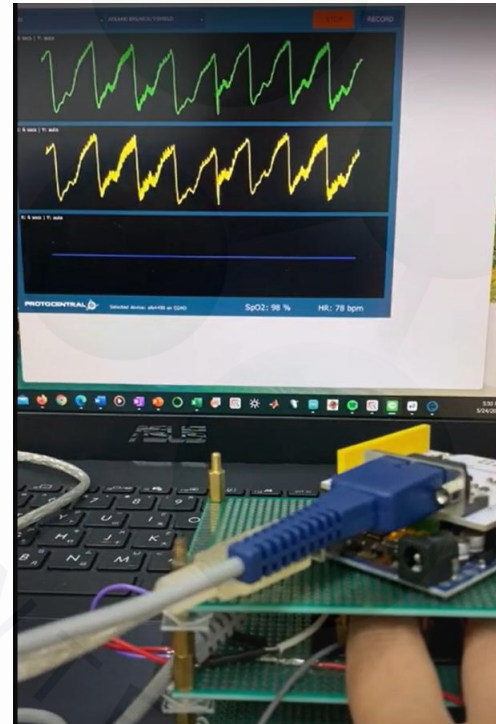
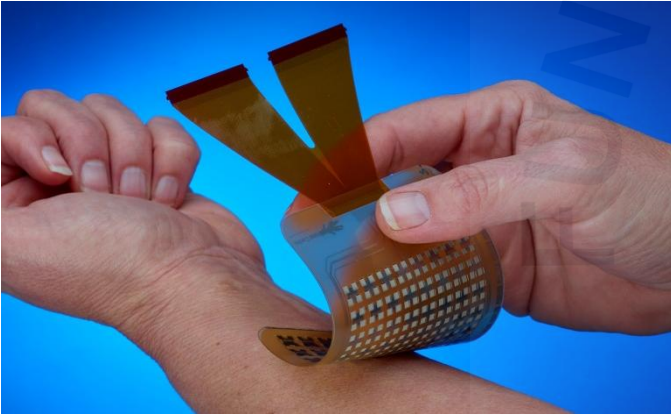
Patient-Centric Medicine

Shift to continuous healthcare monitoring presents opportunity for conformable sensors



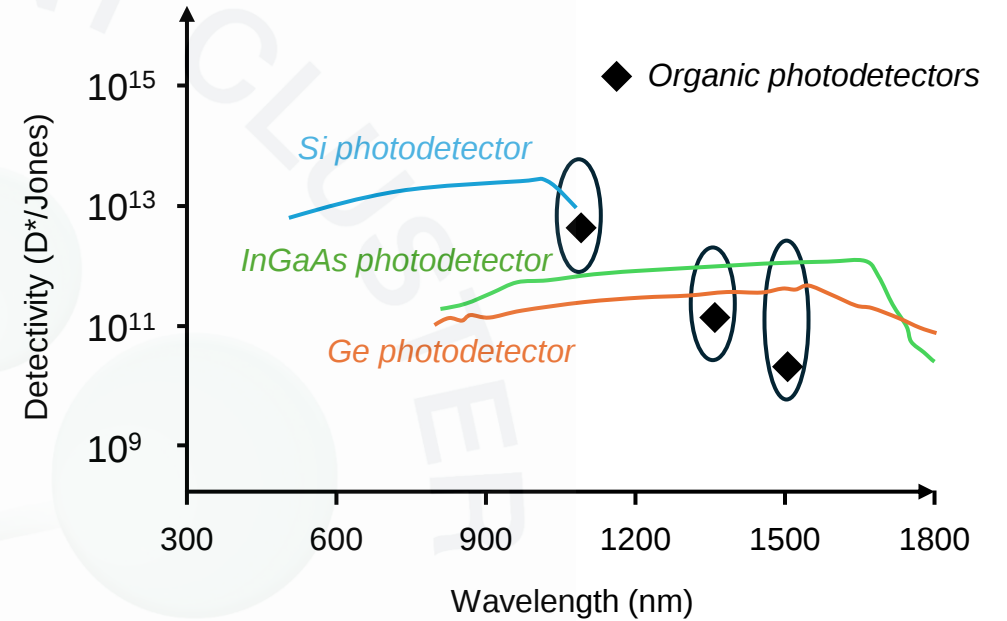
Printed photodetectors offer cardiovascular monitoring in flexible form-factors

Printed and flexible **near-infrared** sensors based on organic photodetectors



Key measurables:

- Optical heart rate
- Blood-oxygen saturation
- Pulse wave velocity



Performance parity with silicon / InGaAs

=

Unlock low-cost continuous cardiovascular vital sign monitoring

Key players

isorg

SAMSUNG
SAMSUNG DISPLAY

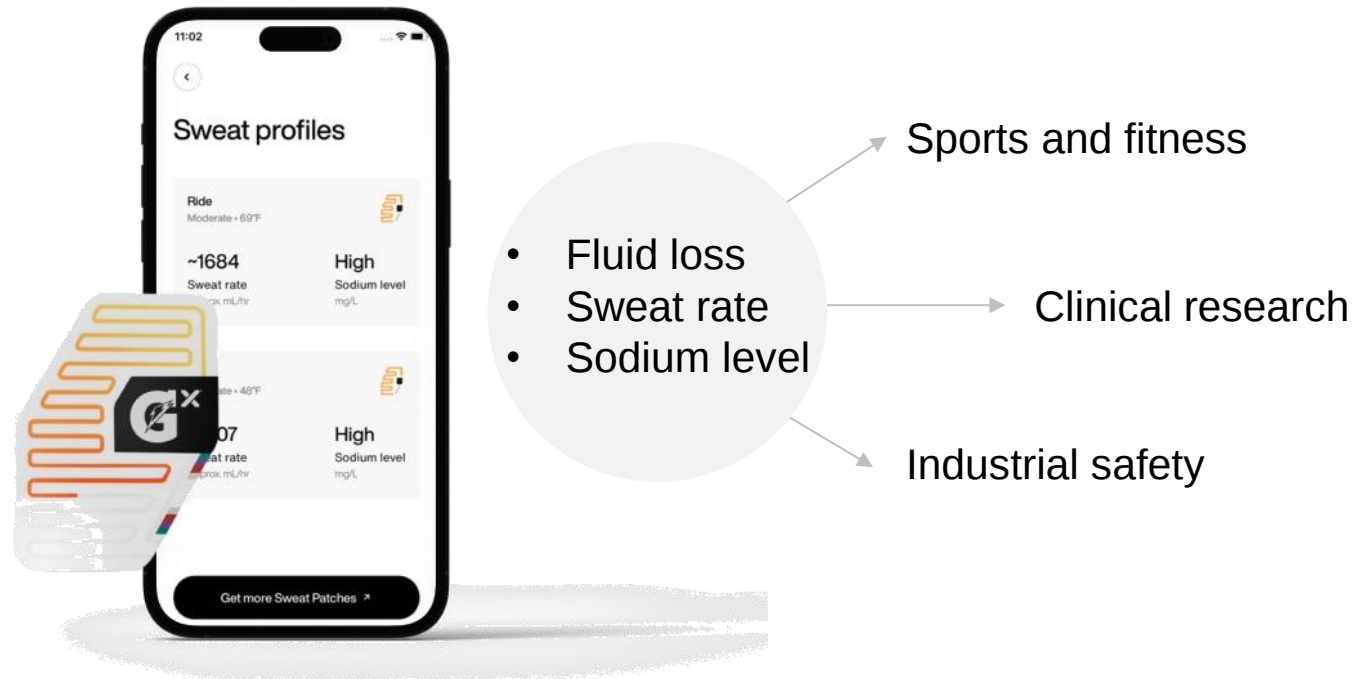
RAYENERGY TEK
the inventive solution

Holst Centre
Powered by imec & TNO

QDI
systems

Commercialization of printed microfluidic hydration sensors in medical and fitness markets, with R2R manufacturing demonstrated

Skin-like microfluidic wearable sensor
for hydration and electrolyte analysis



EPICORE
BIOSYSTEMS

innovize
let's make it better

3M



PEPSICO

Medical wearables applications

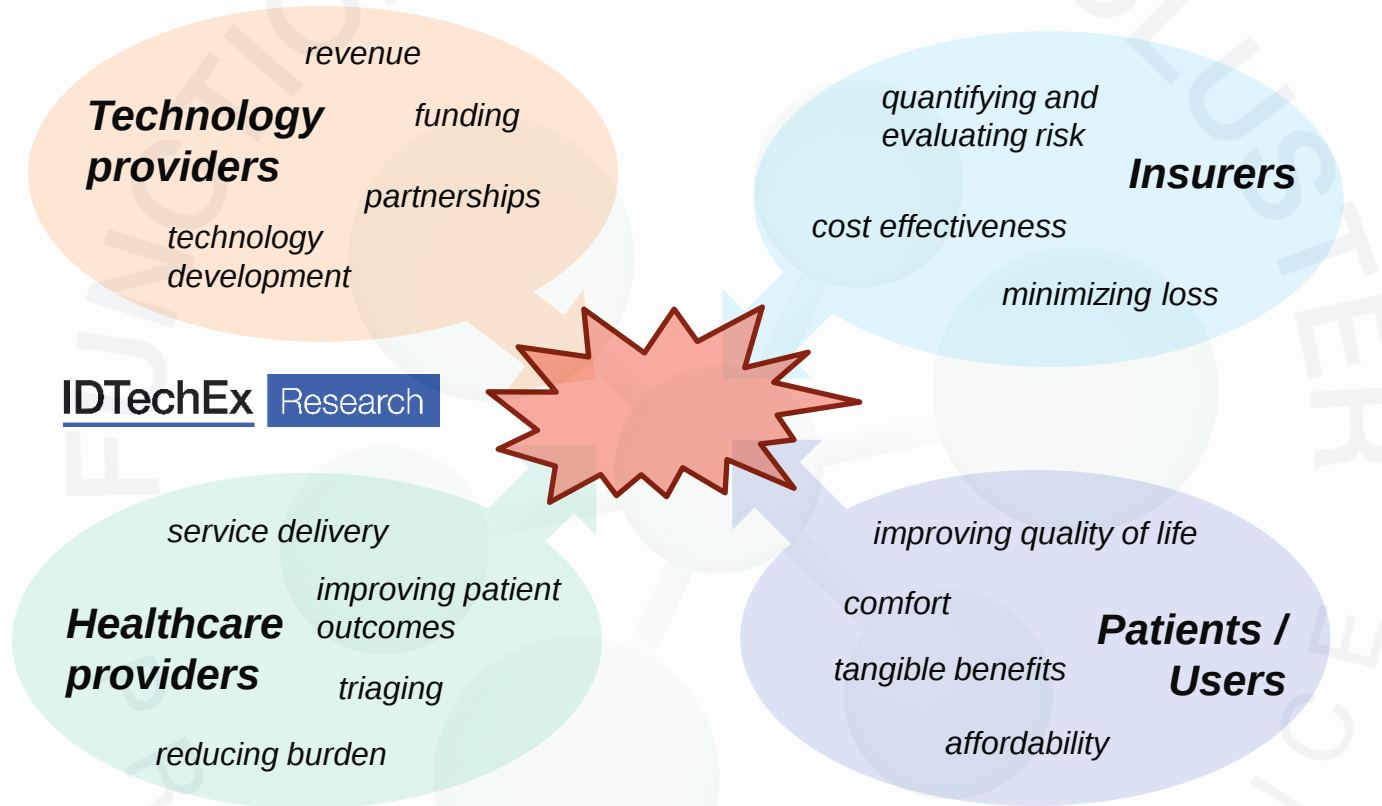
- Hydration
- Nutrition
- Stress
- Women's health



Advantages of printed sensors

- Roll-2-roll enables high throughput manufacturing
- Low cost enables single use devices
- Flexible and conformable for comfort
- Clinically relevant biomarkers

Technology co-development represents a persistent barrier to commercialization of printed sensors in medical wearables



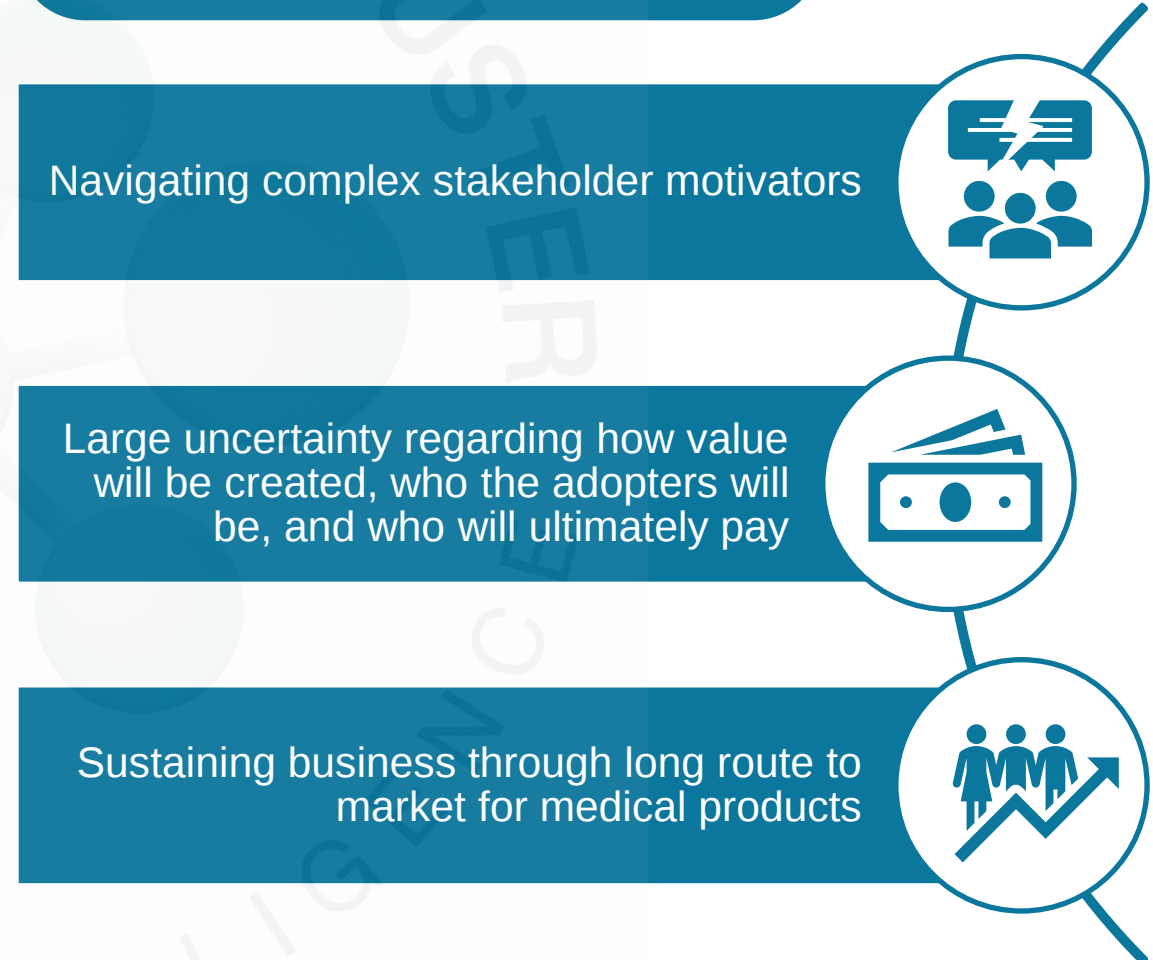
- ✗ Numerous stakeholders with conflicting motivators
- ✗ Payment mechanisms are major barrier
- ✗ Challenges compounded by regulatory approval process

Challenges facing printed sensor and medical wearable markets

Printed sensors



Medical wearables

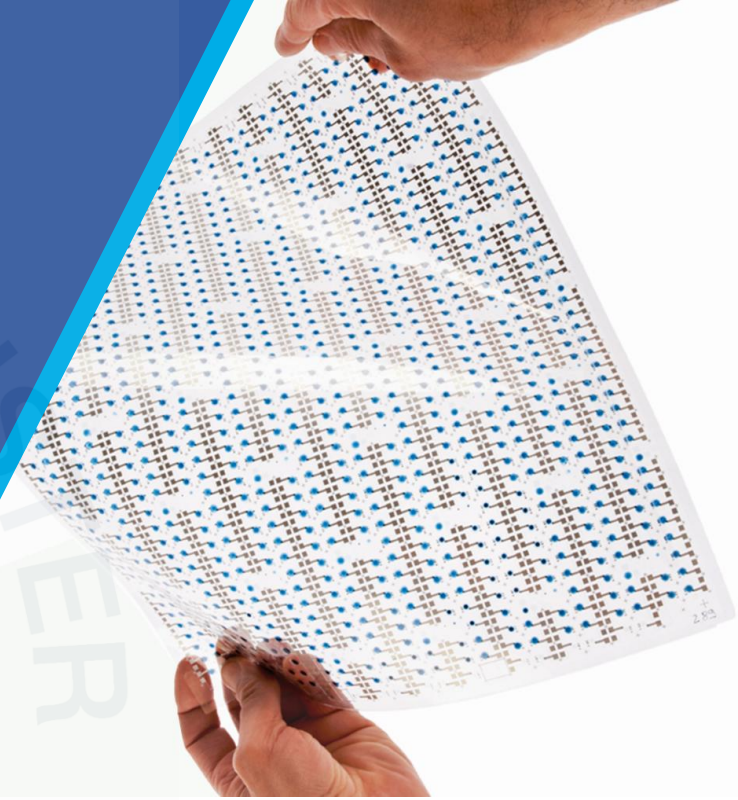


Key player target markets highlight the spectrum of commercialization strategies available

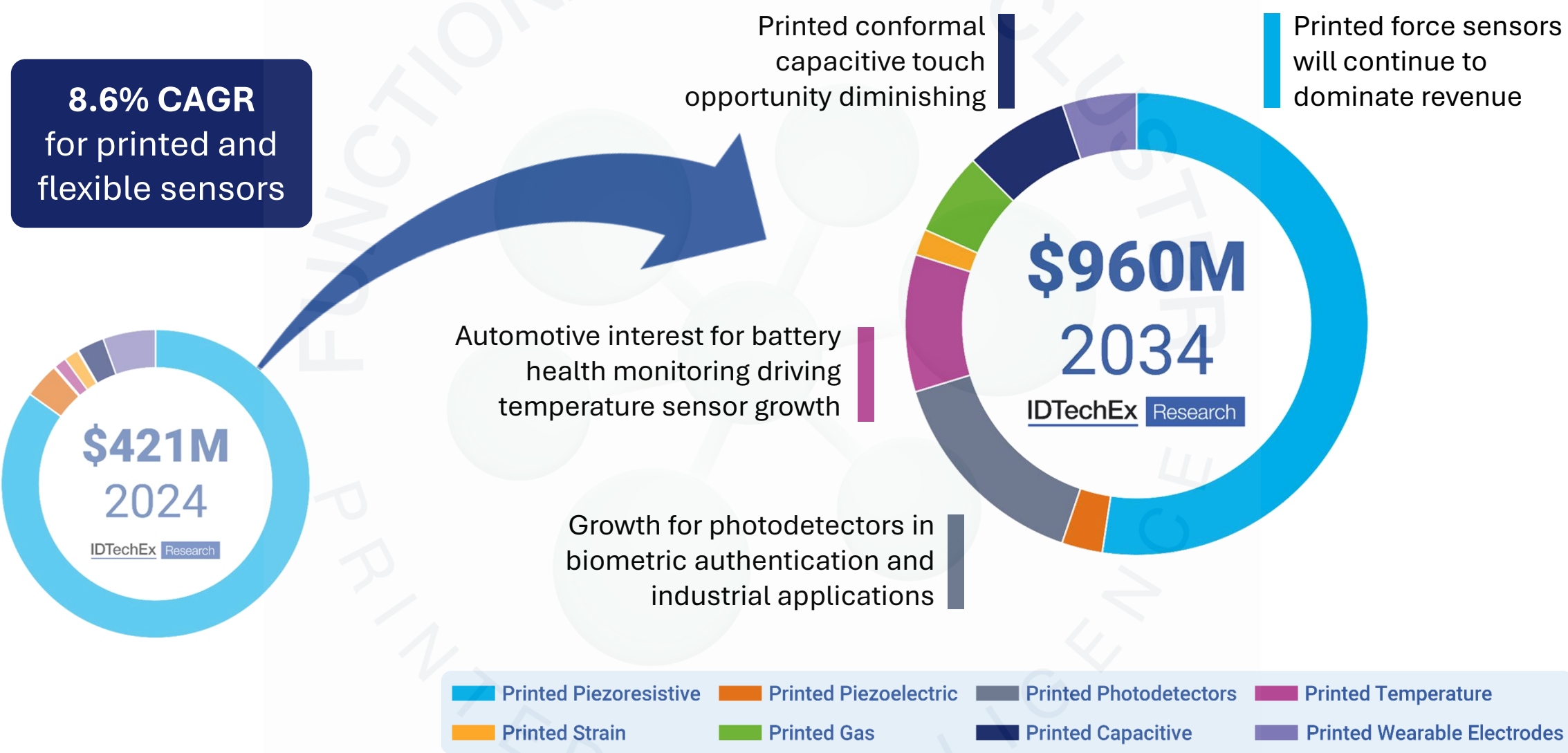


Company profiles and full market forecasts available at:
www.IDTechEx.com/FlexSensors

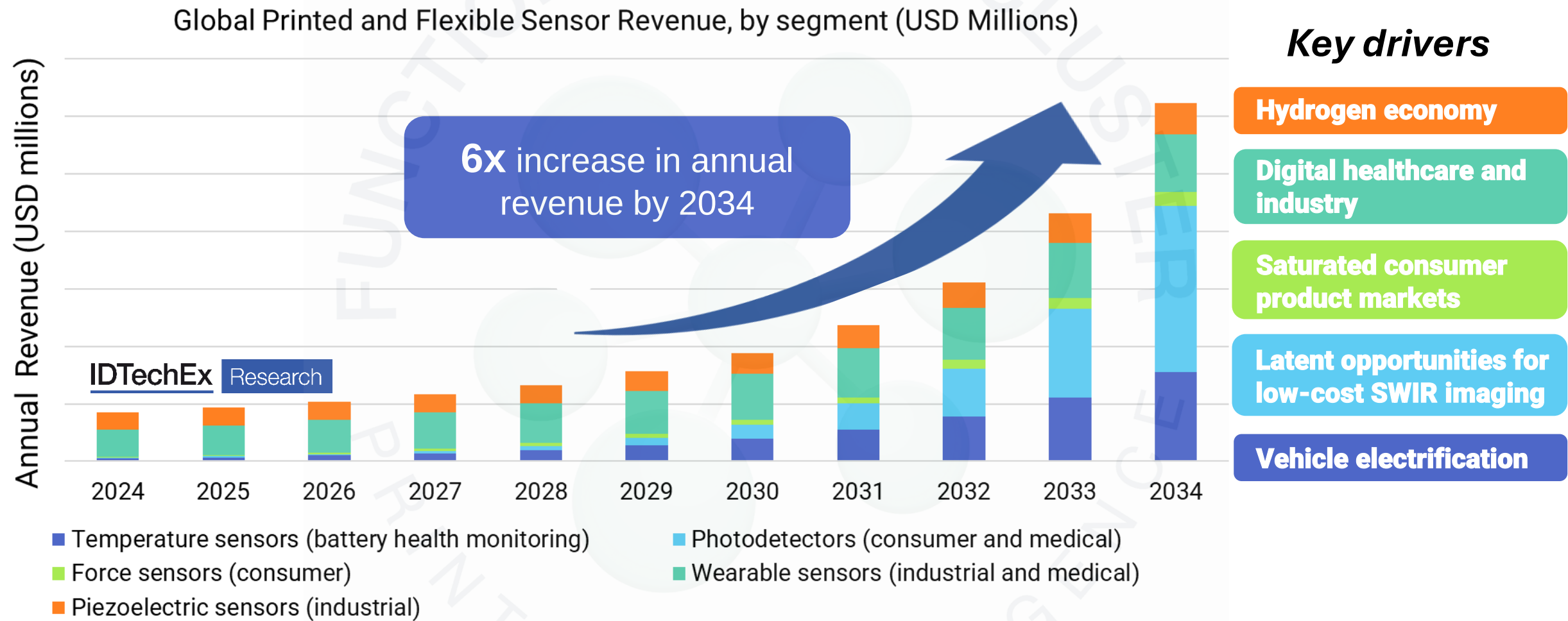
Printed sensor market outlook



Printed and Flexible Sensors Forecast and Key Growth Opportunities



High growth forecast for printed sensor technologies capitalizing on global technology trends



Summary - Printed sensor market to reach US\$960 million by 2034, with CAGR 8.6%

Key Conclusions

- Key global mega-trends including **future mobility, AI and automation, edge computing, IoT, and digital healthcare** are reshaping sensor requirements.
- Printed and flexible sensors **must leverage flexibility, multiparametric and large area sensing differentials** to compete within established sensor hardware markets.
- **The decarbonization transformation of industrial and automotive markets** present a clear opportunity for printed electronics technology penetration. **Medical applications have been more challenging to mature** due to **complex stakeholder dynamics and steeper regulatory requirements and approval processes**.
- Printed sensor technology offered as a **complete product that is easily integrated and deployed into an application bear greater commercialization prospects**.



Printed and Flexible Sensors 2024-2034

[IDTechEx.com/FlexSensors](https://www.IDTechEx.com/FlexSensors)

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