EPSRC CENTRE FOR INNOVATIVE MANUFACTURING IN Large-Area Electronics

www.largeareaelectronics.org

Outputs from the workshop on High-Volume Manufacturing of Energy Harvesting Systems

4 June 2014

Introduction to the workshop

The EPSRC Centre for Innovative Manufacturing in Large Area Electronics organised a roadmapping workshop on High-Volume Manufacturing of Energy Harvesting Systems on 4th June 2014 with 23 participants from industry and academia in the UK.

The objectives were to:

- identify technical barriers holding back the development of printed energy harvesters
- define the objectives for a programme to address the most important technical barriers

An initial **roadmap** was generated by collating both the industry needs that will affect the commercial landscape for energy harvesting products and the most promising application domains to meet these needs.

The potential applications were ranked according to **feasibility** of manufacturing a printed system and the value of the **opportunity**. The 21 shortlisted applications were grouped into five **priority applications** for detailed consideration of long-term goals, milestones to achieve the vision and desired future performance characteristics.

Finally the most important **R&D priorities** to deliver these applications were identified.

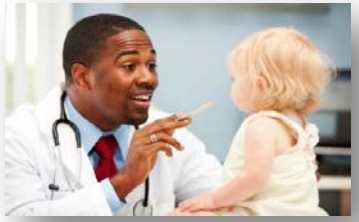
Top 5 industry drivers

3) Energy generation

2) Supporting aging population

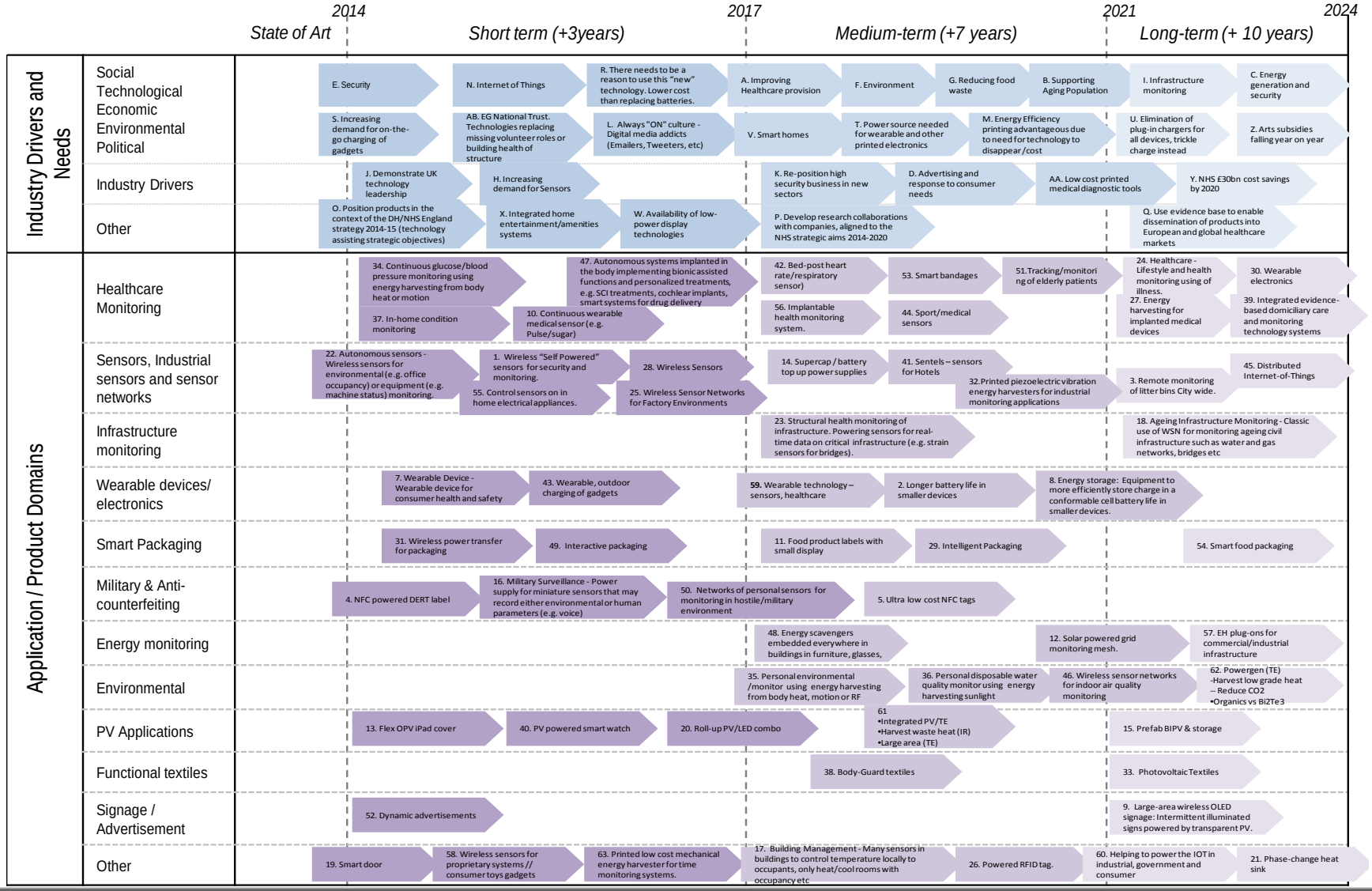
4) Advertising and response to consumer needs

1) Improving healthcare provisions



5) Security

Summary roadmap



Selection Criteria

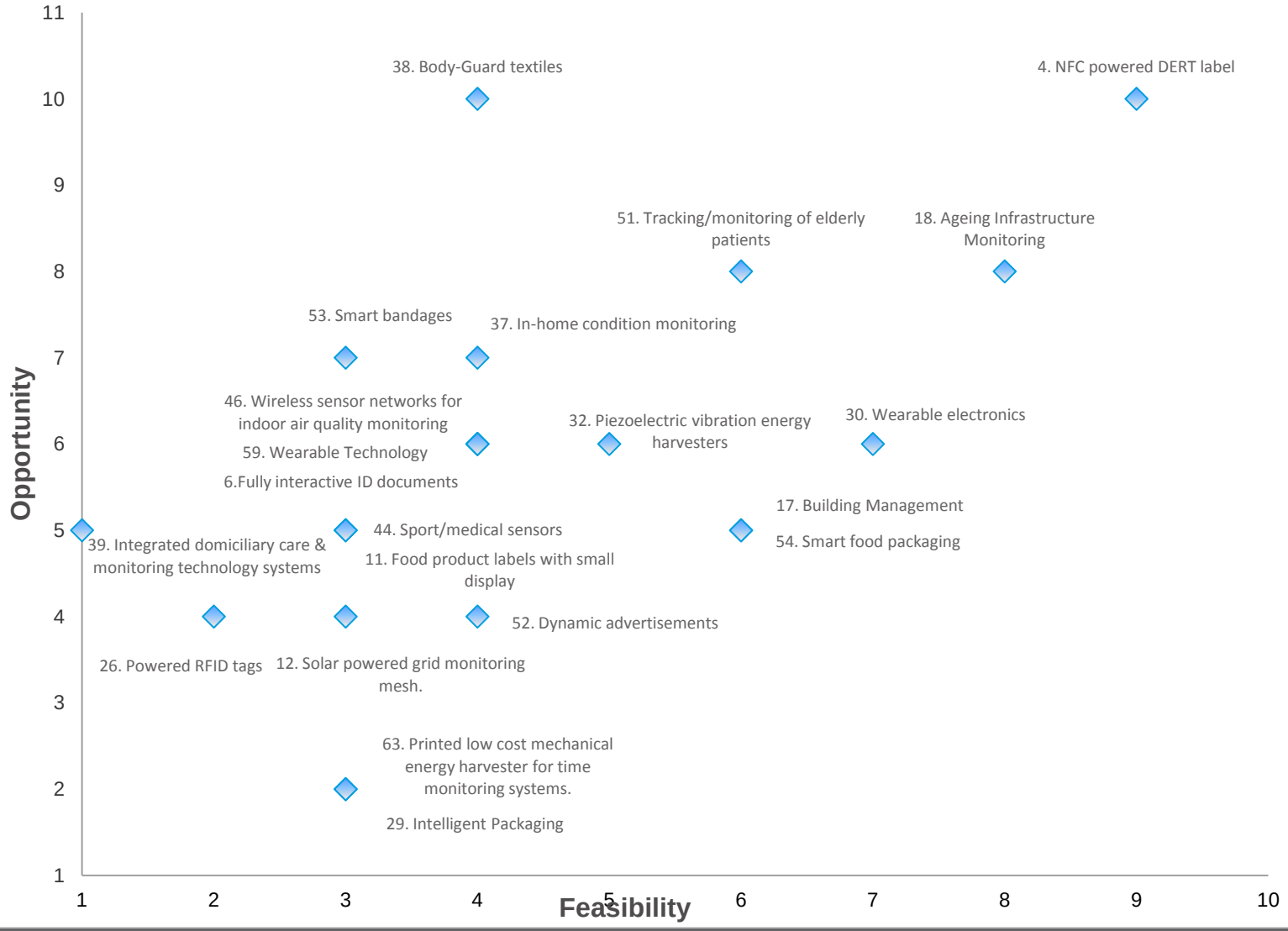
Value of Opportunity

Does Energy Harvesting make sense versus (“NO” = fail)	• Use of batteries alone • Use of mains power
Size of market when mature	• big is good
Size of margin	• big is good
Amount of competition	• few companies / technologies is good
Is it a platform for other products	•“ YES” is good

Feasibility of a (part-) printed system

Does printing some / all of EH system offer: 1. Form factor/physical benefits to end-user/integrator 2. Cost reduction 3. Ease-of-integration	•“YES” is good
How appropriate is the degree of technology difficulty	Research & Development (i.e. academia + industry R&D) lasts: <2 years Low 3 - 4 years Medium 5 - 7 years High 8 - 12 years Medium 12+ years Low
Fit to UK manufacturing capability	•“YES” is good

Prioritising applications by value and feasibility



Top 5 application priorities

3) Wearables

2) Healthcare

4) Smart packaging

1) Antennas and circuits

5) Sensor networks

Roadmap for antennas and circuits

Antennas and Circuits

Including: Everything
Excluding: Nothing
System Components:

Cell phone near field coupled → Antenna Design (coupled) → Supercapacitor → OLED Display

RESEARCH PRIORITIES
- Diode development RF – UHF etc
- Antenna design (materials etc)
- Logic circuit – development (load for system)

MILESTONE 1
Phase I
Evaluate antenna, power output

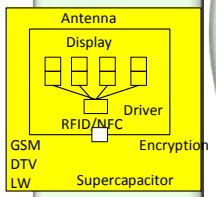
TECHNICAL REQ
- Antenna
- Material Design
- Impedance
- Diode - 2 GHz?
- Printed super-capacitor
- Material, area, connection

MILESTONE 2
- Hybrid circuit
- Power – Load

- Phase II
Circuit logic

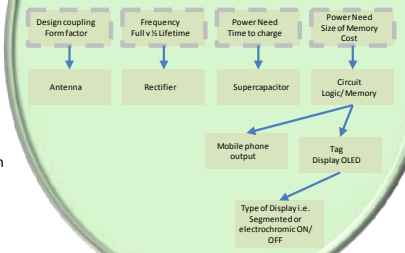
TECHNICAL REQ
- Energy from GSM, TV etc
- Logic
- Display
- Electronics
- Interaction with Phone - App

MILESTONE 3



TECHNICAL REQ
- Printed super-capacitor with variable tolerance
- Display
- OLED

VISION
A circuit applicable to many different products.



State of Art (2014) — *Short term* (2017) — *Medium-term* (2021) — *Long-term* (2024) — *Vision*

Roadmap for patient monitoring

Healthcare

Including: ID of patient, motion sensor, tracking using multiple base station(s) in the building, sensors for blood pressure, body temperature, blood oxygen and possibly also include blood sugar and / or heart rate.

Excluding: Outdoor tracking, Energy harvesting for installed base stations and any treatment (to lower regulatory burden)

System Components:

RESEARCH PRIORITIES
- Development of printed sensor elements
- Printed rechargeable battery
- Printed power conditioning circuit
- Integrating sensors and electronics with pre-printed PV

MILESTONE 1
PV and one motion sensor plus wireless reporting (proof of concept)

TECHNICAL REQ
- BP
- Printed temperature sensor
- Print antenna
- PV on separate substrate

MILESTONE 2
PV plus multiple sensors (not necessarily printed)

TECHNICAL REQ
- High efficiency PV materials + module design
- Develop new sensor types specific to conditions or patient type
- Flex/printed analog or logic if/or where appropriate
- Low power transceiver (silicon)

MILESTONE 3
PV plus printed sensors

TECHNICAL REQ
- Printed power conditioning
- Rechargeable or disposable flexible
- Printed sensors
- All flexible components integrated

VISION
Patient tracking in home or care environment
intermittent monitoring each 15 minutes for 24 hours/day
Format:
Wrist band with PV on outside and sensors on inside surface
Need:
Require monitoring for 1 year after intervention – lower cost by removing patient from hospital

State of Art (2014) *Short term* (2017) *Medium-term* (2021) *Long-term* (2024) *Vision*

Roadmap for RF powered light emitting label

Smart Packaging- RF Powered light emitting label

Including: Food product labels with small display, dynamic advertisements
Excluding: Smart food packaging, intelligent packaging
System Components:

RESEARCH PRIORITIES
- Supercapacitors
- Printed Capacitors
- High-Q printed coils
- Printed microprocessor (or comparator + ADC)

STATE OF ART
Hybrid integrated Si + printed EL

Si-based data - loggers

MILESTONE 1
Hybrid printed flashing label – step up

LC EL

TECHNICAL REQ
- Thin capacitor 10μf/mm²
- Integrated diode (printed) ≥ 13.56 MHz
- Antenna Printed (cc £ costs) 30<Q
- Thin, flexible super caps - Pick/place capable or lamination, Low cost 10c/F
- Silicon microprocessor + ancillaries

MILESTONE 2
All printed flashing label + thin flex on board store logistics
- Charge once
- Sample once/hour

TECHNICAL REQ
Capacitors: Multi layer 100μf/mm²
Antenna: Q=50
Microprocessor: Silicon microprocessor
Printed ADC

MILESTONE 3
All printed tracking label with hourly sensing and printed piezo speaker driver

TECHNICAL REQ
Antenna: Q=100
Microprocessor: externally printed?

VISION
On-pack advertising

Toys and games

Super cheap authentication e.g. ticketing

State of Art (2014) *Short term (2017)* *Medium-term (2021)* *Long-term (2024)* *Vision*

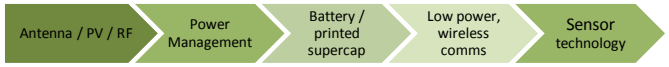
Roadmap for air quality sensor network

Sensor networks

Including: Indoor air quality monitoring

Excluding: Grid monitoring mesh, building Management, ageing Infrastructure Monitoring and printed piezoelectric vibration energy harvesters for industrial monitoring applications

System Components:



RESEARCH PRIORITIES
- Printed diodes
- System integration
- Full printed devices

STATE OF ART
Hand held damp monitors
CO_2 monitor

TECHNICAL REQ
- Antenna: Printable, low Q factor
- PV: Printable, cost, form factor
- RF Harvester: Not printable
- Conventional IC for power management
- Energy storage: Printable rechargeable batteries "feasible"

MILESTONE 1
Blue tooth
fungi
damp

TECHNICAL REQ
- Antenna: Improve reproducibility,
- PV: reduce cost, improve performance
- Power mngt: Printed 100 kHz circuits
- Commercial printed energy storage, printed supercaps
- Printed sensors

MILESTONE 2
Weekly:
Fungi, damp
Hourly: CO_2, CO, VOC

TECHNICAL REQ
- Antenna: reduce cost, resistivity
- PV: improve lifetime (barrier propserties)
- RF: printed diodes
- Single IC for Comms, Power mgt, RF harvest, Sensor front end
- improved energy storage, printed supercaps
- Sensors: improve number/sensitivity

MILESTONE 3
Multi sensors
- customer specific

TECHNICAL REQ
- System integration
- PV: Full integration
- Single IC for Comms, Power mgt, RF harvest, Sensor front end
- Sensors: Graphene enabled sensor

VISION
Home patch - domestic air quality sensor using hybrid PV-RF energy harvesting

State of Art (2014) *Short term* (2017) *Medium-term* (2021) *Long-term* (2024) *Vision*

R&D priorities

The most important **R&D priorities** to deliver these applications were:

- Printed diode development (RF – UHF)
- High Q printed antennae (design, materials etc)
- Printed logic circuits (e.g. power management, comparator/ADC, microprocessor etc)
- Development of printed sensors
- Printed rechargeable battery
- Integration (e.g. sensors and electronics with pre-printed PV and other EH systems)
- Supercapacitors
- Printed capacitors
- Fully printed devices