Ultrathin, Flexible Supercapacitors and their use in a Flexible Integrated "GreenPatch" Device for use in Green Buildings and Smart Infrastructure

presented by

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ENERGY HARVESTING & STORAGE EUROPE
CO-LOCATED
WIRELESS SENSOR NETWORKS & RTLS EUROPE
ACTIVE RFID APPLIED
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Acknowledgements

- *Thanks to Dr. Mehdi Kalantari Khandani, President and CTO, Resensys Inc.*

- *GreenPatch created by Resensys*

- *Supercapacitors made by OptiXtal and integrated into GreenPatch by Resensys*

- *Field tests and Measurements- Resensys*

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Outline of Presentation

- What are GreenPatch sensors and why do they make business sense?
- Can OptiXtal's supercaps when combined with ambient energy harvesting replace batteries?
- How long Can GreenPatch function with no ambient light?
- Can the Technology be extended to Smart Infrastructure and to Wireless Sensor Networks?
- Conclusions

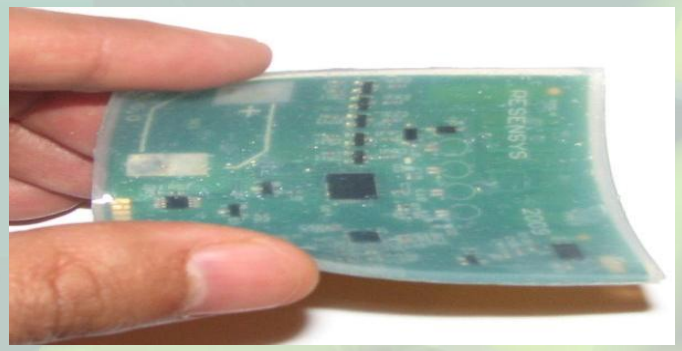
Business Opportunity

- Buildings consume 40% of the US' energy and 70% of its electricity
- Environmental and sustainability concerns → Energy Efficiency is crucial to achieve sustainability and improved carbon footprint in buildings
- We estimate that significant energy savings (up to 40%) can be generated by using GreenPatch
- GreenPatch Pays for itself
- GreenPatch can also be used to implement "Smart Infrastructure"
- Demonstrates adaptability to use in Wireless Sensor Networks

What is GreenPatch?

Devices used for monitoring and optimization of among other things, building energy usage .

- ✓ Measuring energy usage per zone (lighting, HVAC, temperature)
- ✓ Providing energy saving recommendations
- ✓ Micro-actuating: sending automated commands to turn on/off say lighting, HVAC



GreenPatch for building energy efficiency

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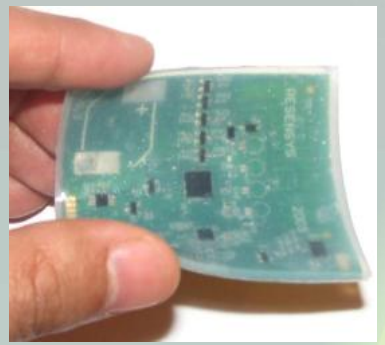
Technical Specifications

Mechanical

- Thin film sensors, mechanically flexible
- Thickness: 1.2-2mm
- Weight: 9.1g
- Minimal installation effort



Measurements

- Temperature
- Light intensity
- Air flow
- Strain (force)
- Vibration

Energy

- Harvest ambient light
- Store in OptiXtal's Supercapacitors
  - Supercapacitor life – 500,000 cycles (battery is 500)
  - No need to change batteries
  - Can be deployed in remote/harsh locale
  - High pulse current capability of supercap (> 2A) – signal transmission range can exceed 0.5 -1 mile
- Guaranteed energy availability in sensors, over 45 hours dark time
- Need 1 GreenPatch per 100-200 Sq. Ft.

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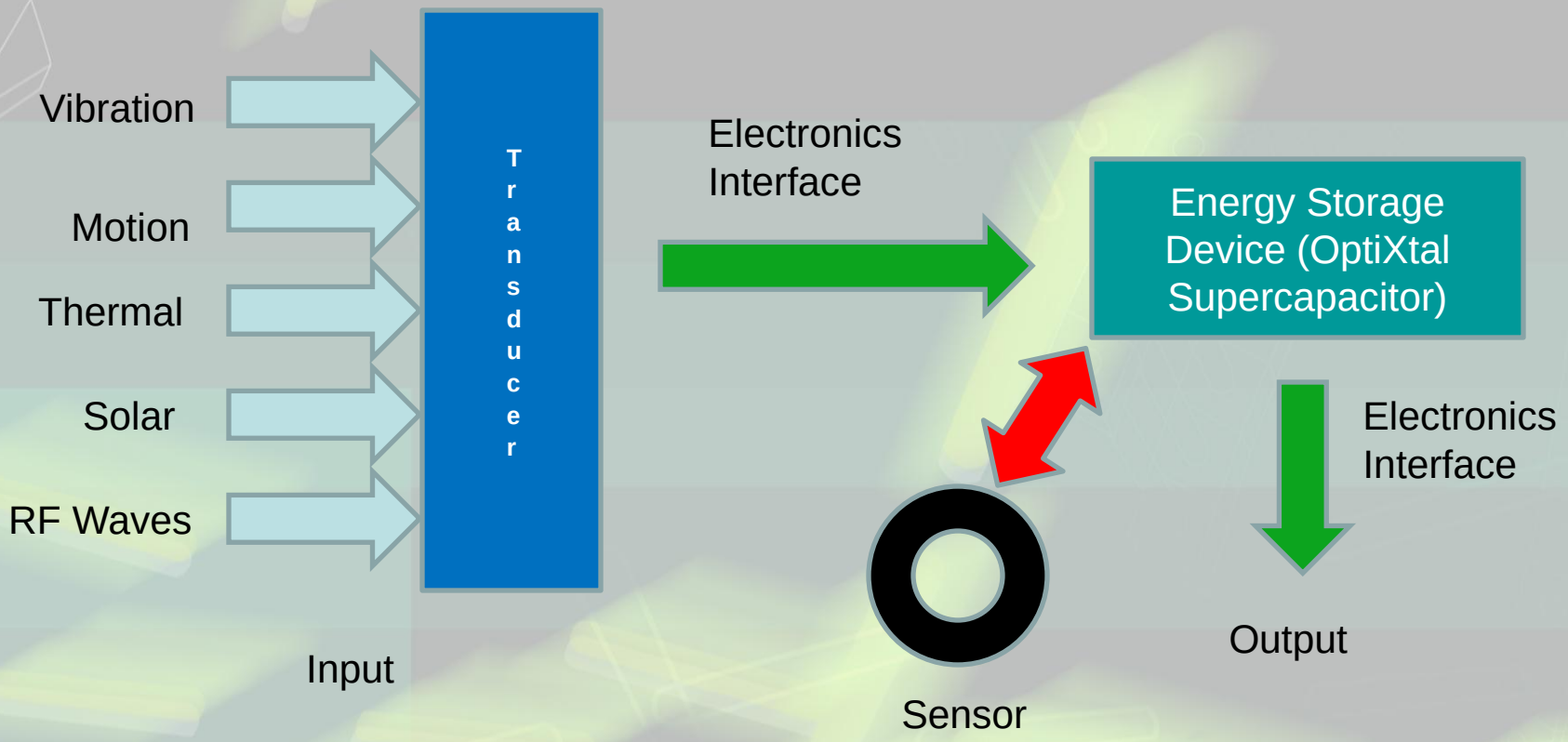
Energy Harvesting Block Diagram



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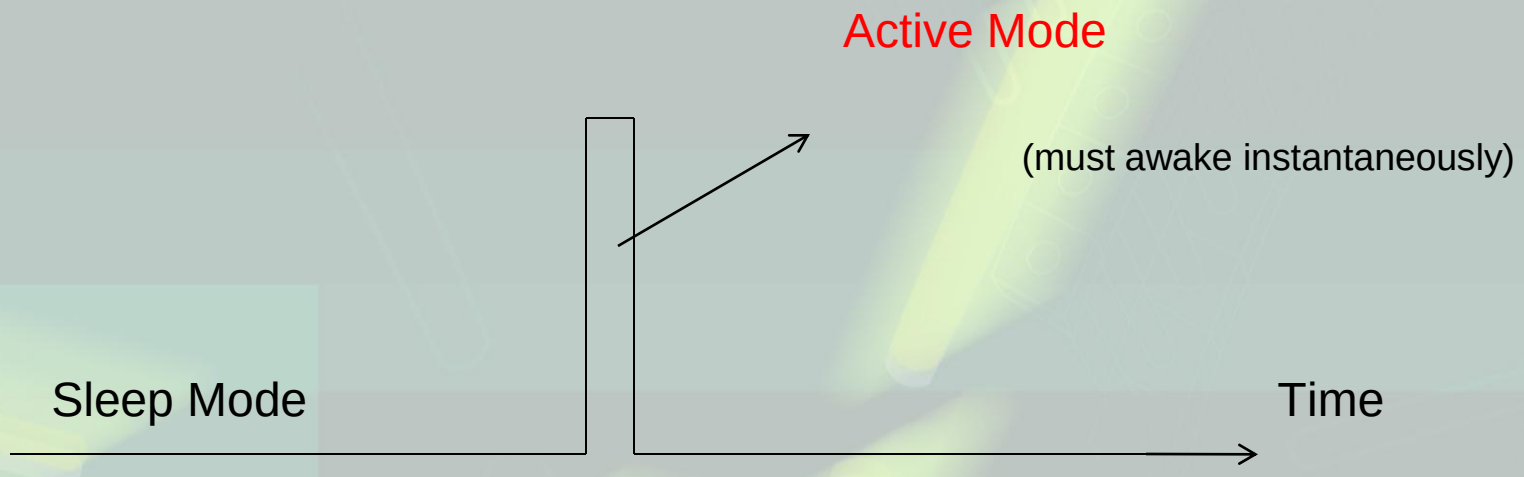
Requirement for a Battery-Free Application

For Certain Applications: (Industrial, Civil, Military)



During Sleep Mode: Trickle charge Supercapacitor by harvesting ambient energy

During Active Mode: Discharge the supercapacitor to output information

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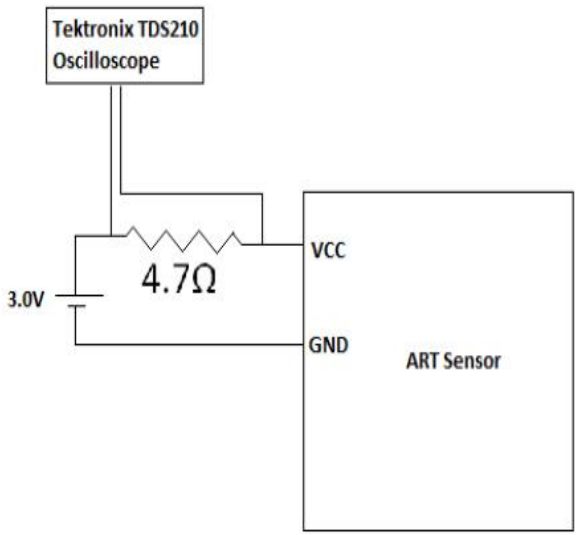
GreenPatch is Battery-Free

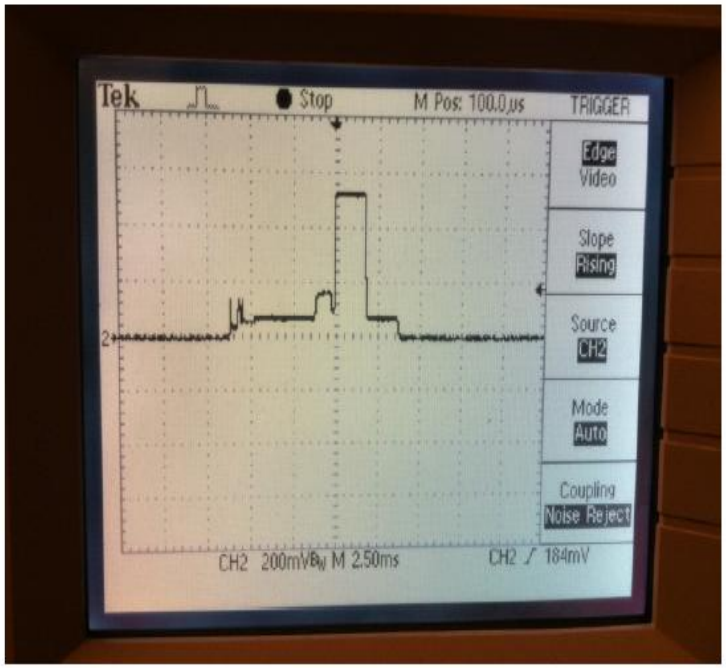
- The sensors stay in sleep mode most of the time - make one transmission of a 58 byte packet every 6 minutes to synchronize with a data collector
- The communication takes approximately 3-4 milliseconds and the transmit power is 100mW – active time = 4 ms/240 s x 100 = 0.002% (Sleep time = 99.998%)
- The sensors (and supercapacitor) evaluated in a room with a window to outside -receive energy during the day and use the energy collected in the daytime during the dark hours- Dark time is about 14 hours

GreenPatch
Energy Analysis–Sensors

- In sleep mode – GreenPatch Sensors consume 0.7µA
- What is the energy consumption during measurement?
- And during transmission?
- How much does the voltage of the supercap drop in the dark?
- And how long can the supercap power the sensor before it runs out?

Data Analysis





Current consumption of a GreenPatch sensor while transmitting. The left circuit shows the used test circuit.

Energy Audit – Sensor

Total energy consumed = 1123 µJ

Total Power Consumed = 1123 µJ/6 x 60 Sec = 3.12 µW

(during each 6 minute interval)

Power Consumed during sleep = 3 V x 0.7 µA = 2.1 µW

Total Power Consumption = 3.12 µW+ 2.1 µW = 5.22µW

Total Current consumption by the sensor = 5.22 µW/3 V = 1.74 µA

Now we will analyze the OptiXtal Supercapacitor

Who is OptiXtal?

OptiXtal is a Delaware corporation founded by Dr. Sagar Venkateswaran in 2003

Maker of Ultrathin, flexible, low ESR, low self discharge supercapacitors

Properties of OptiXtal's Supercapacitors

Available in various Form Factors:

- sizes
- thicknesses, and
- degrees of flexibility

First to commercialize SuperXcaps
with these special properties

Can make:
Lateral dimensions
as small as 0.2 mm (microelectronics)
as large as 10,000 mm
thickness ≈ 1 mm

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Our Product Line

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Table 1

Type of SuperXcap	Dimensions	Shape
Mini (#9)	8 mm x 11 mm x 0.5 mm	Rectangle
Circle (#8)	25 mm x 25 mm x 0.8 mm	Circle
Oval (#3)	35 mm x 135 mm x 0.8 mm	Oval
M (#2)	60 mm x 65 mm x 0.8 mm	Rectangle
L (#1)	110 mm x 165 mm x 0.8 mm	Rectangle

Comparison: Smallest Cell 15 mm x 20 mm x 1.1 mm (Cap XX)

Have the lowest ESR in their class

For Example, #2 is 2.7V, 5F, 70 mΩ (1/3 ESR of comparables!)

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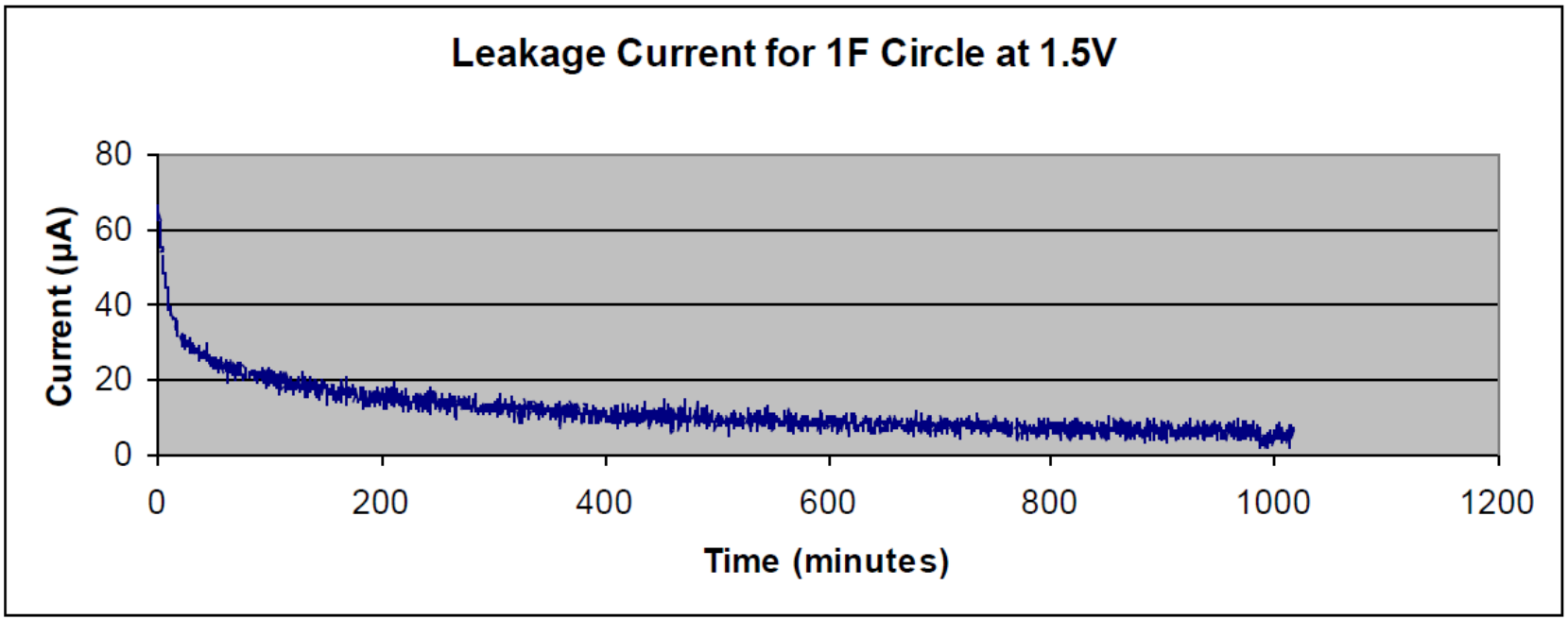
GreenPatch Analysis–OptiXtal Supercapacitor

During winter in North America, up to 14 hours of darkness
Supercapacitor must not run out of power



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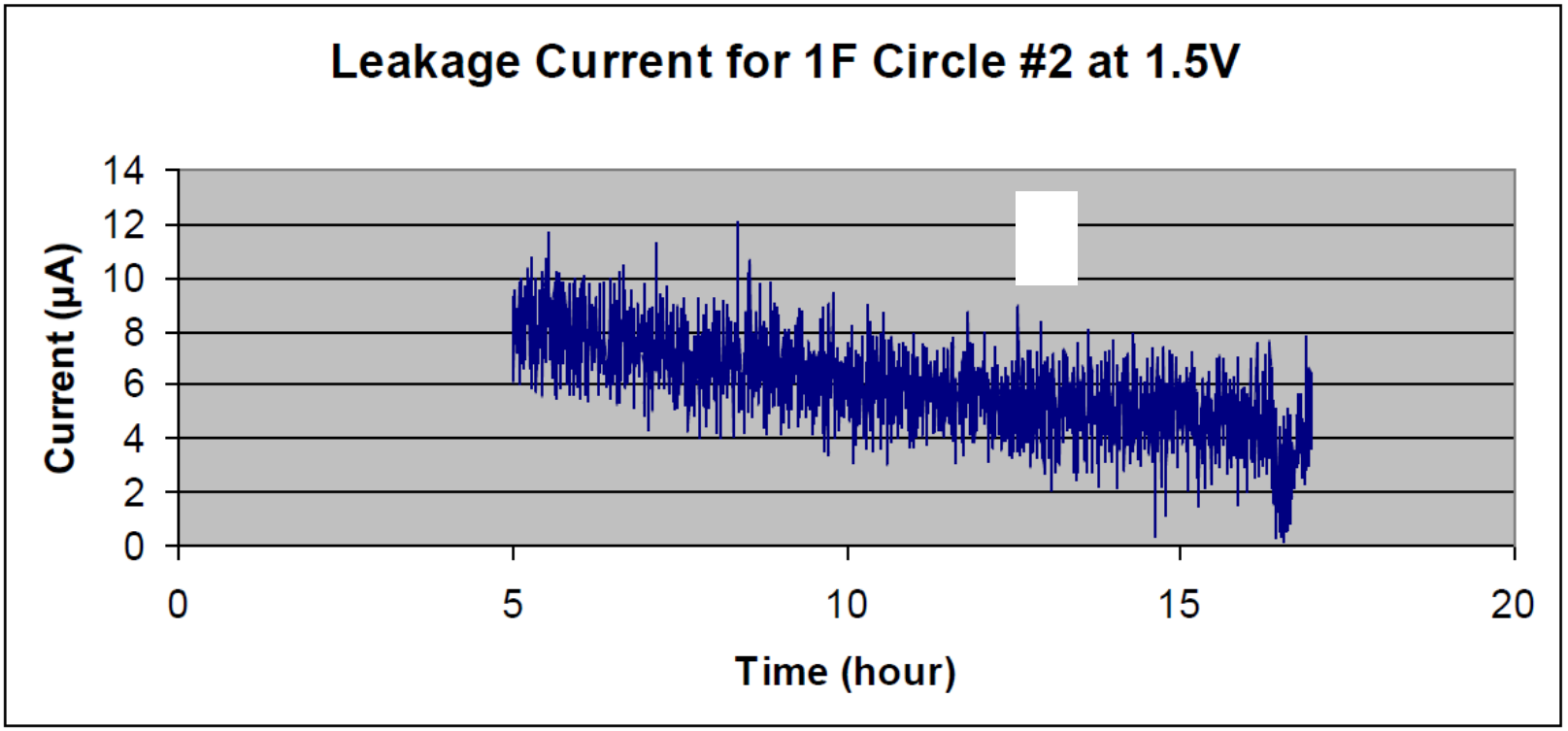
A Closer Look at Leakage Current



Data is noisy due to temp fluctuations; leakage current < 5 µA
Next Step →Field Test : Room with window – No indoor lights

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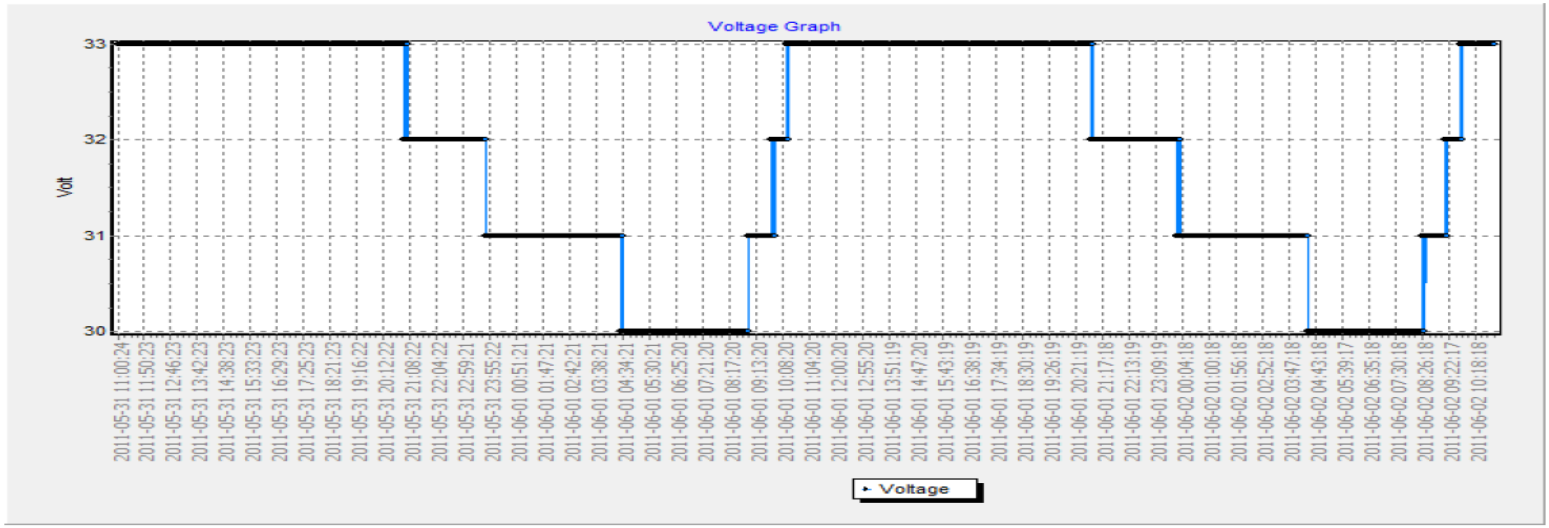
Field Test – Supercapacitor

- Two OptiXtal 1F, 2.7 V, ultrathin, flexible, supercaps in series
- Three 1.8V IXYS small solar cells used to charge the supercaps
- Protection circuit disconnects the solar cells from the system when the voltage across the supercaps reaches 3.3V

Room has window but no indoor light
Voltage measured over 2 days

Drops show energy depletion as a result of consumption and self discharge at night and increases show charging (in excess of consumption) by ambient light during day



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Analysis of the Performance of Supercap

- Charge/self discharge graph repeats over 48 hours
- Voltage drops from 3.3 V to 3 V at night (in decrements of 0.1V)
- At no time does the voltage drop below 3 V
- During the day, rapidly charges up to 3.3 V
- We calculate – can continue to operate for up to 45 hours with no sunlight (voltage will go down to 2V – sensors cannot operate below 2V)

- Competitor's Supercapacitor dropped to 2.8V
  - Higher Leakage Current
  - Fewer hours of operation with no sunlight

Estimates of Energy Savings based on typical energy used
Level 1: sensing and advisory

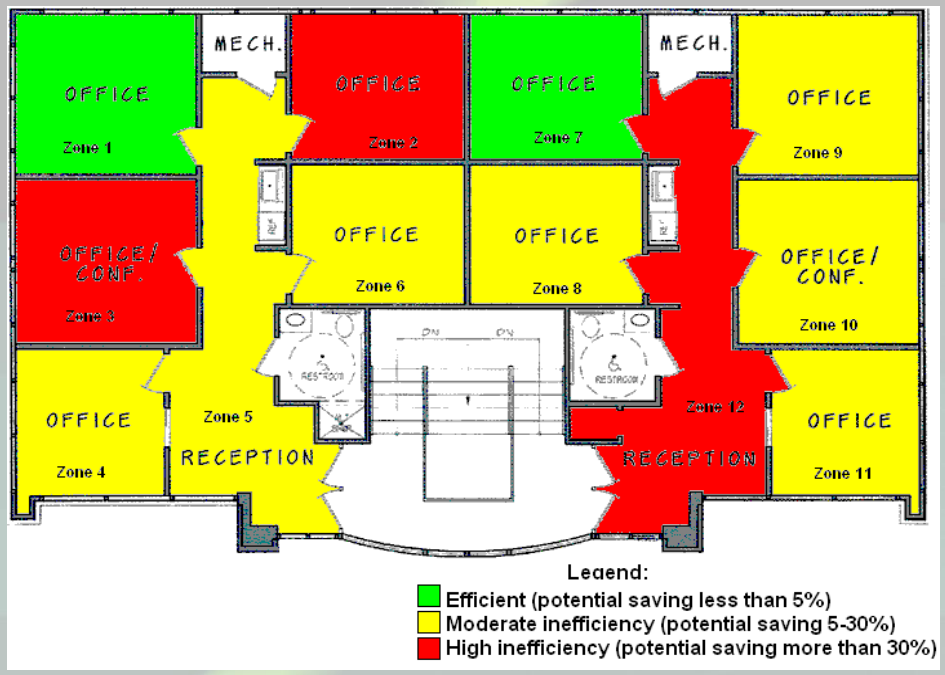
Example GreenPatch monthly reports:

Zone 8 Report (office):
- Average lighting usage: 36KWh
- Average HVAC usage: 83KWh
- Total energy use: 119 KWh
- Average temperature: 74 ˚F
- Potential lighting saving: 11 KWh
- Recommended temperature: 72 ˚F
- Potential HVAC saving: 16 KWh
- **Total potential savings: 27KWh (22.7%)**

Zone 3 Report (conference room):
- Average lighting usage: 45 KWh
- Average HVAC usage: 112 KWh
- Total energy use: 157 KWh
- Average temperature: 74 ˚F
- Potential lighting saving: 36 KWh
- Recommended temperature: 70˚F (winter)
- Potential HVAC saving: 31 KWh
- **Total potential savings: 67KWh (42.7%)**

Overall report (building):
- Average lighting usage: 2250 KWh
- Average HVAC usage: 5346 KWh
- Total energy use: 7596 KWh
- Potential lighting saving: 840 KWh
- Average potential HVAC saving: 830 KWh
- **Total potential savings: 1670 KWh (31.2%)**
- **Monthly Saving : $501.00 per month**

GreenPatch Energy Efficiency Map



Highlights:

✓**Per zone:** GreenPatch per zone: 1-2 (depending on zone size)

✓**Easy:** Installation time of all wireless patches: **less than an hour**

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Estimates of Energy Savings based on typical energy used
Level 2: sensing, advisory and micro-actuation

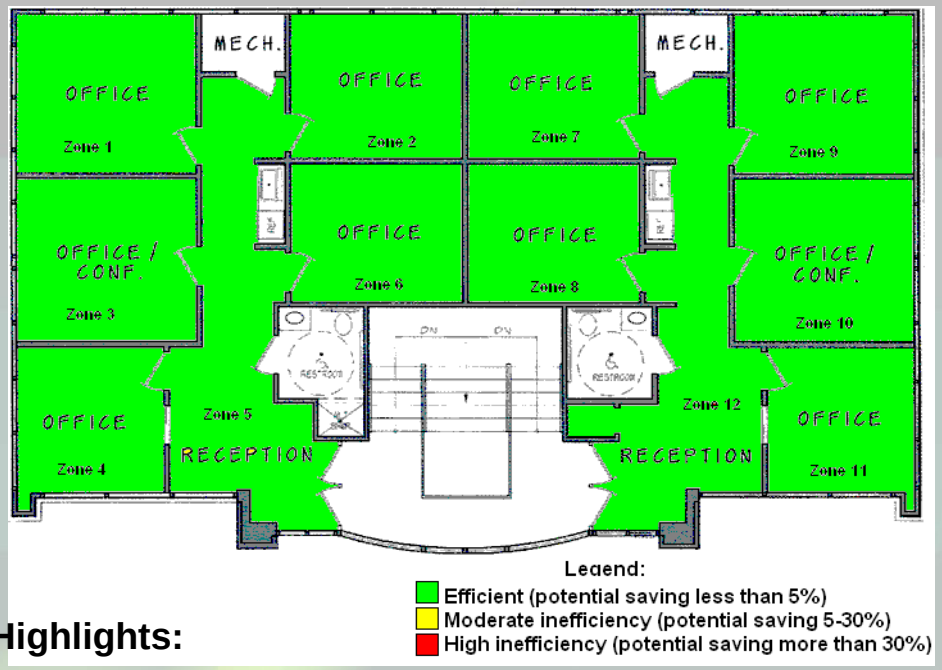
Example GreenPatch monthly reports:

Zone 8 Report (office):
- Average lighting usage: 25 KWh
- Average HVAC usage: 67 KWh
- Total energy use: 92 KWh
- Average temperature: 72 ˚F
- **Energy savings: 27KWh**

Zone 3 Report (conference room):
- Average lighting usage: 9 KWh
- Average HVAC usage: 76 KWh
- Total energy use: 85 KWh
- Average temperature: 70 ˚F
- **Total potential savings: 67KWh**

Overall report (building):
- Average lighting usage: 1410 KWh
- Average HVAC usage: 4516 KWh
- Total energy use: 5926 KWh
- **Total potential savings: 1670 KWh**

GreenPatch Energy Efficiency Map



Highlights:

✓**GreenPatch devices use micro-actuators to send commands to lighting & HVAC**

✓**Easy retrofit to existing wiring systems is possible**

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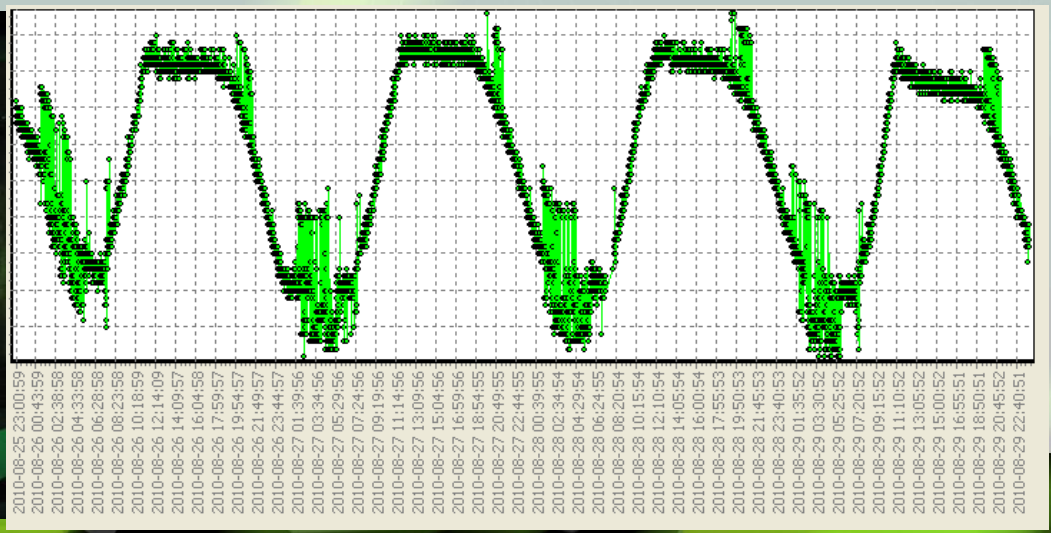
GreenPatch for Infrastructure



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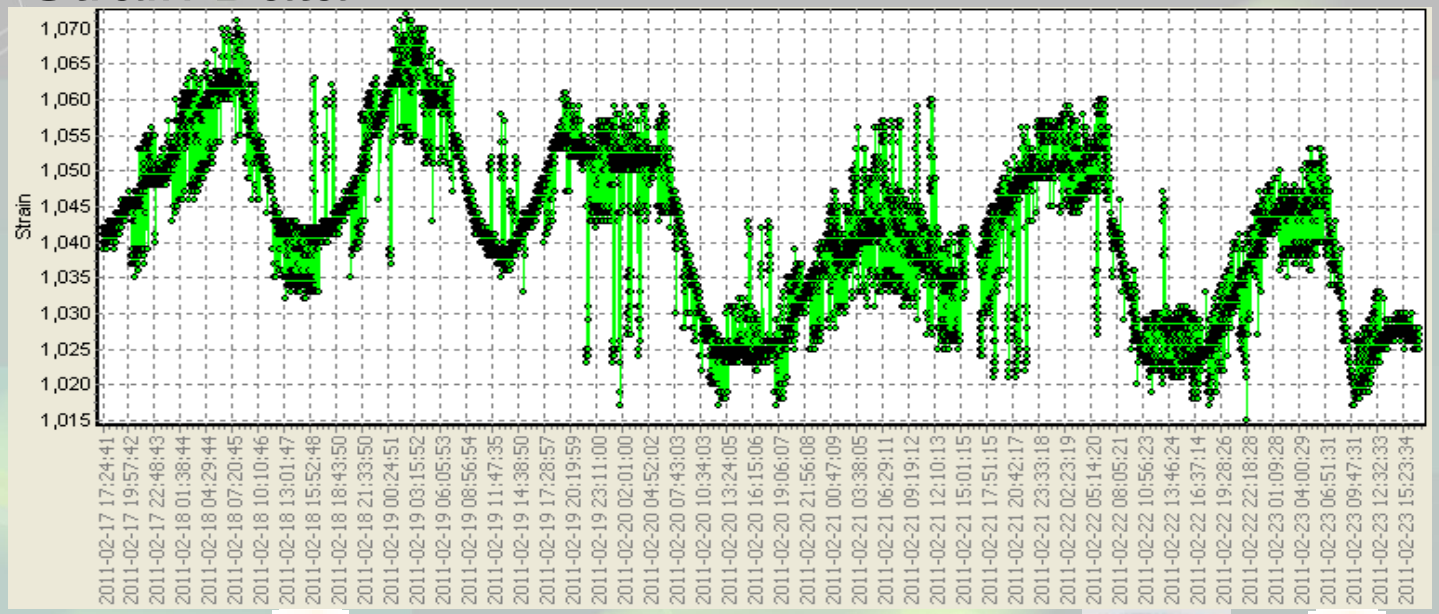
GreenPatch Data Visualization Tool

Robust Weather-Proof Operation

A seven-day strain graph of a GreenPatch installed on Northwest Branch bridge on **Capital Beltway (I-495).** Data collected from 2/17/11 to 2/23/11.

Strain Data



2/17 2/18 2/19 2/20 2/21 2/22 2/23

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Conclusions

- Low leakage current OptiXtal Supercaps have been integrated into Resensys' GreenPatch: a battery-less wireless sensing, advisory and actuating system
- Easy to install, flexible patch can generate energy savings of up to 40% - pays for itself
- Sensors are asleep more than 99% of the time
- Solar cells harvest energy from ambient light and store them in supercaps
- Supercaps can provide power to the sensor for up to 45 hours in the absence of ambient light (voltage will go down to 2V)
- Similar smart monitoring can also be implemented in other infrastructure such as bridges and roads
- Technology can be used to create wireless sensor networks

Thank you

A Copy of this presentation is available online at
http://www.optixtal.com/technical-papers.htm

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