



# CircEl-Paper: Circular Economy Applied To Electronic Printed Circuit Boards Based On Paper

Gerhard Domann<sup>1</sup>, Daniela Collin<sup>1</sup>, Gael Depres<sup>2</sup>,  
Remy Vié<sup>3</sup>, Oliver Werzer<sup>4</sup>, Valerio Beni<sup>5</sup>, Bernhard  
Brunner<sup>1</sup>, Sara Carniello<sup>4</sup>, Nadège Reverdy-  
Bruas<sup>6</sup>, Jelmer Holman<sup>7</sup>, Anita Sosnowska<sup>8</sup>



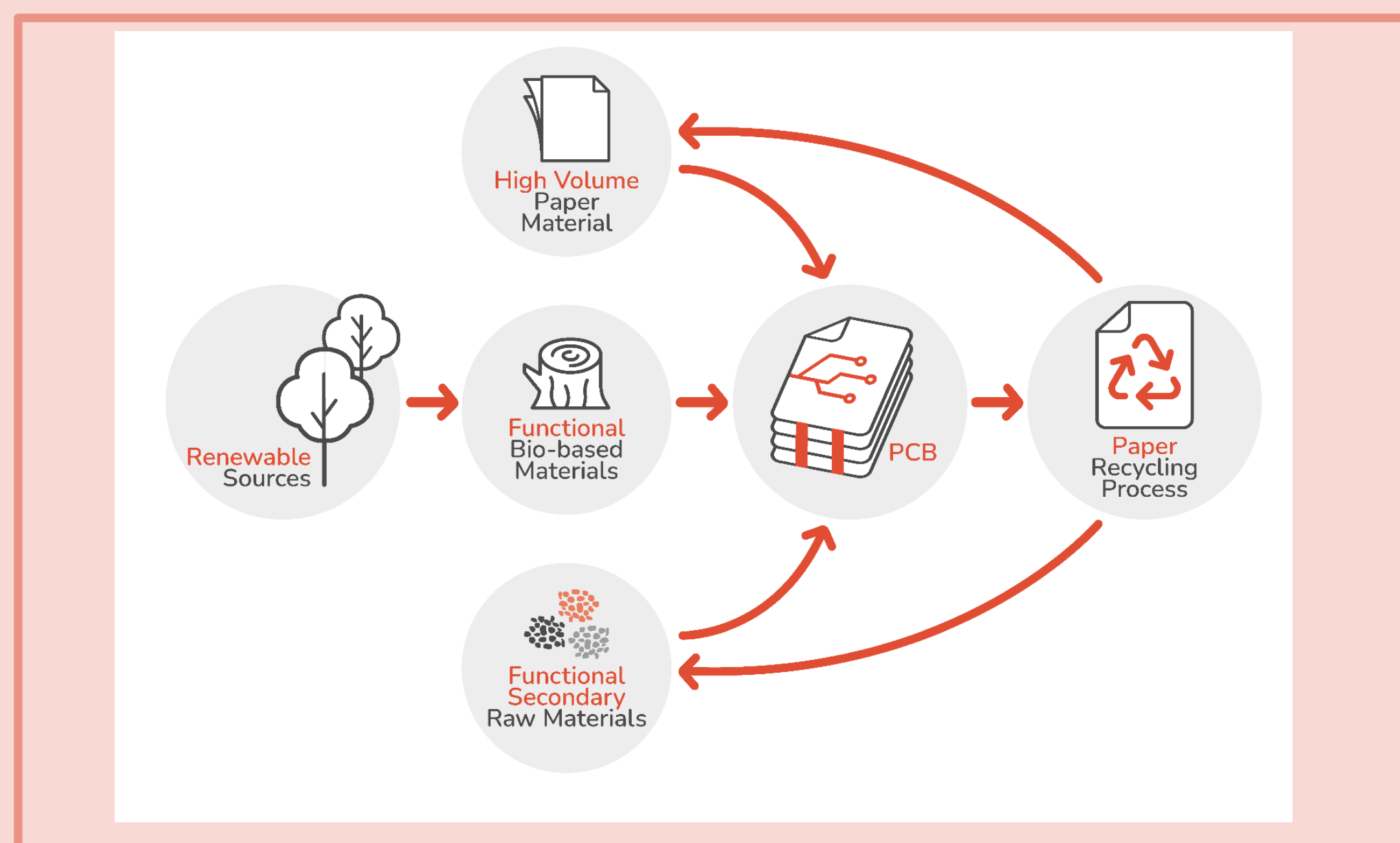
## CircEl-Paper

### Introduction

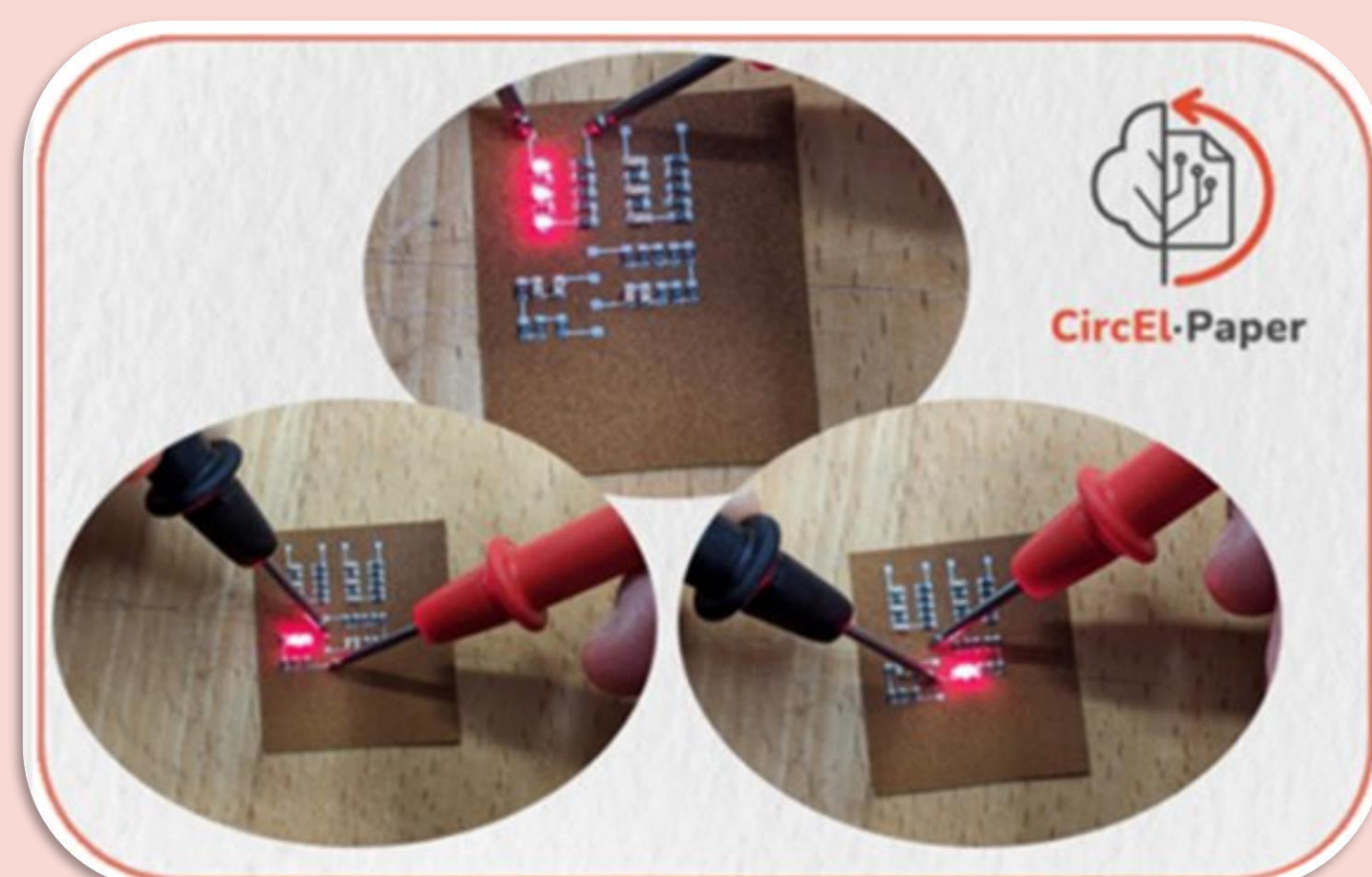
Electronic waste recovery and recycling rate does not meet neither ecological demands nor the targets set by political regulations. When electrical components are recycled, at most precious metals, only are recovered. Printed Circuit Boards (PCB) are used as board technology for electronic circuits.

In general, rigid PCBs consist of FR4, which is difficult to recycle. In the project CircEl-Paper the replacement of FR4 by the usage of paper is evaluated as well as screening for much more sustainable materials and technologies. The goal is to match the specification for current state-of-the-art PCBs starting with considerations about paper engineering and functional (conductive and insulative) ink formulation as first steps towards recyclable multi-layer PCBs.

### Overall Concept of the technological CircEl-Paper approach



### One-sided Paper PCB

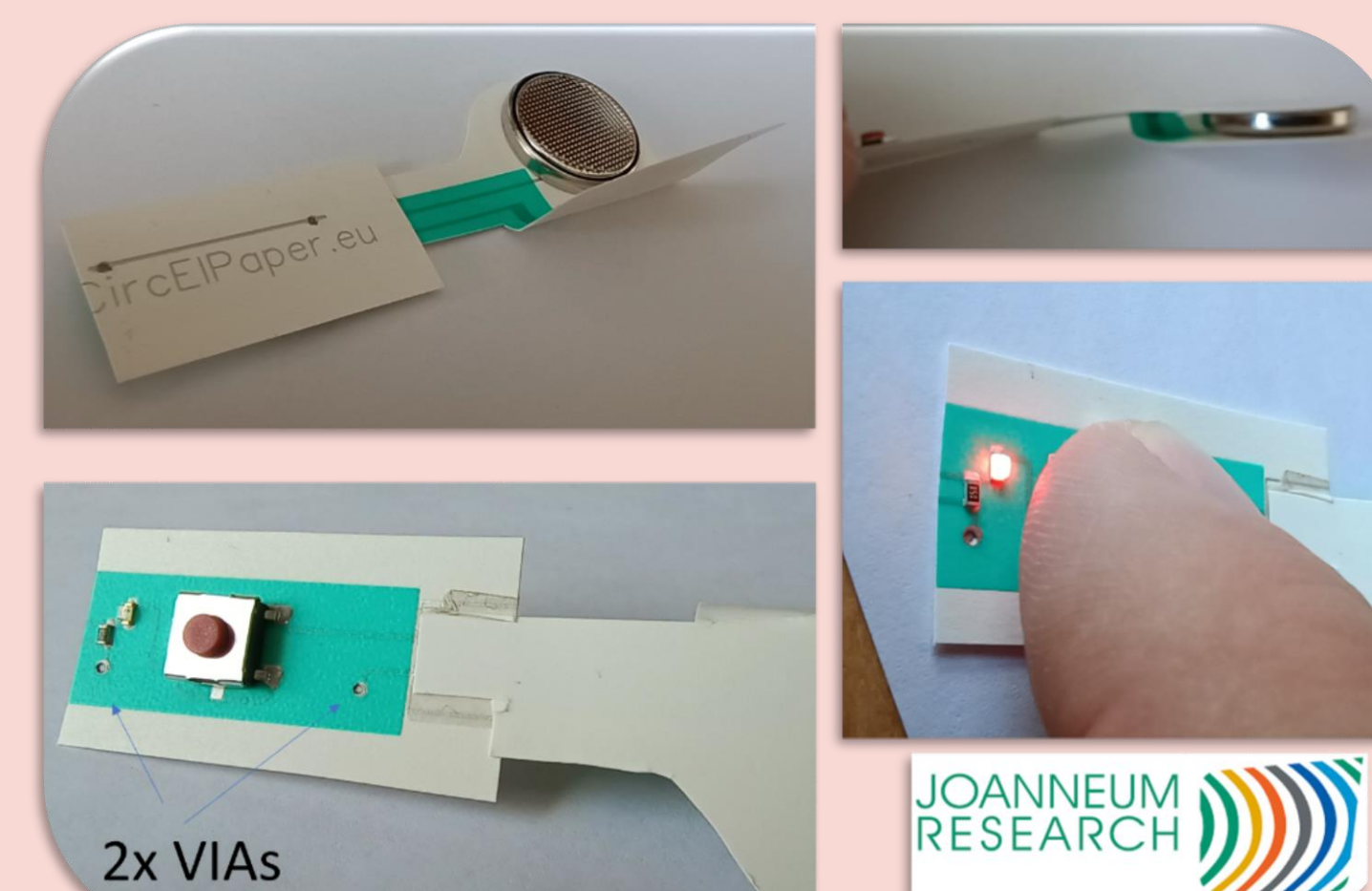
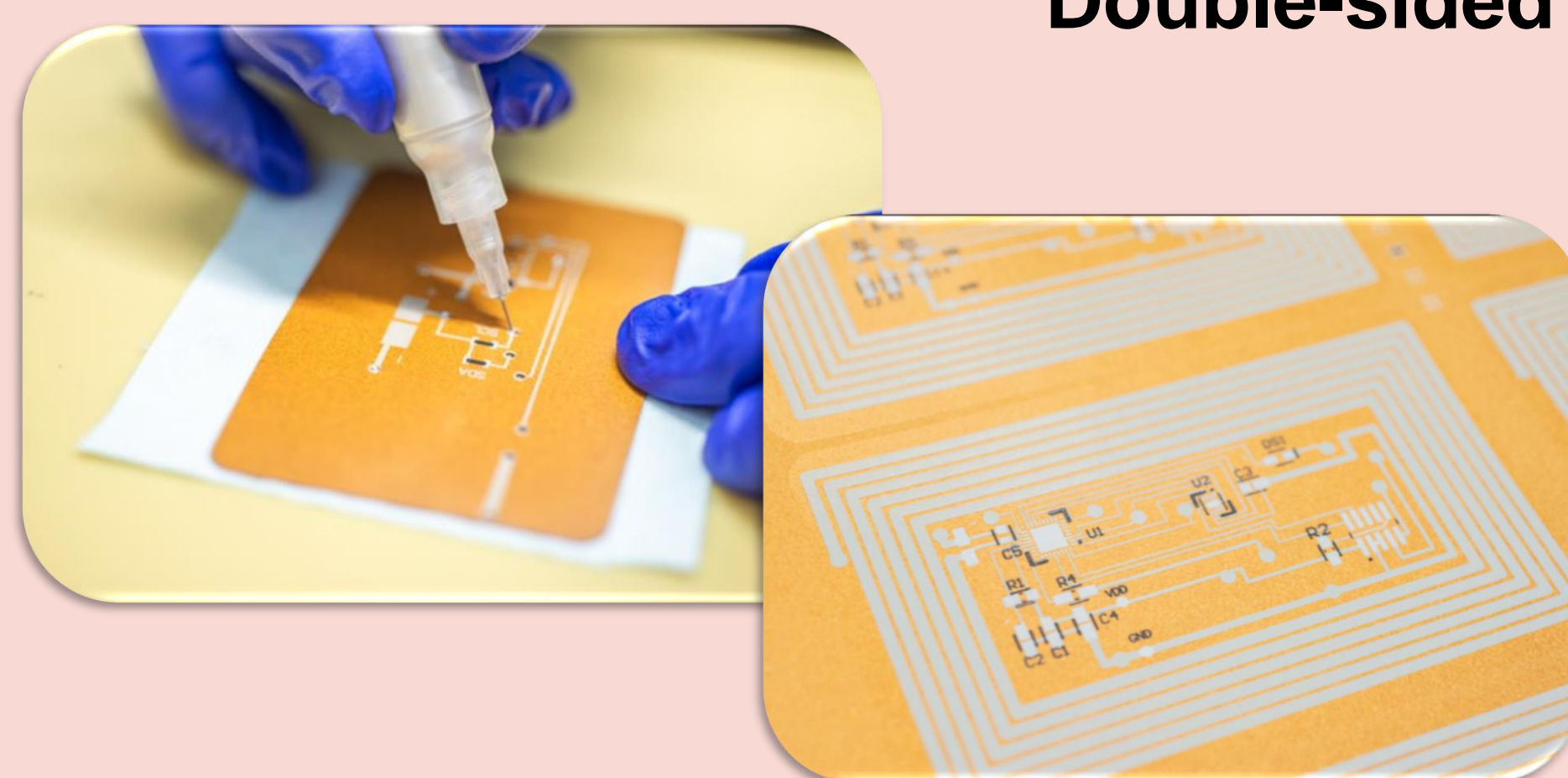


**Substrate:** Impregnated Paper

**Circuitry:** Sustainable Ag ink

**Assembly:** Passive components and LED assembled by means of commercial ICA

### Double-sided Paper PCB



**Realization of VIAs:** Laser drilling; Filling by dispensing/stencil printing

**ORIGAMI Folding**

### Substrate



(Impregnated) **Electronic paper** equipped with properties such as:

- Fireproof
- Dimensional stability
- recyclability

### Materials



**Silver ink** based on secondary raw materials (Ag, binder, solvent; > 90 %)



**Sustainable Encapsulants and Dielectrics** based on biobased precursors (e.g. plant oils) and developed for recyclability.

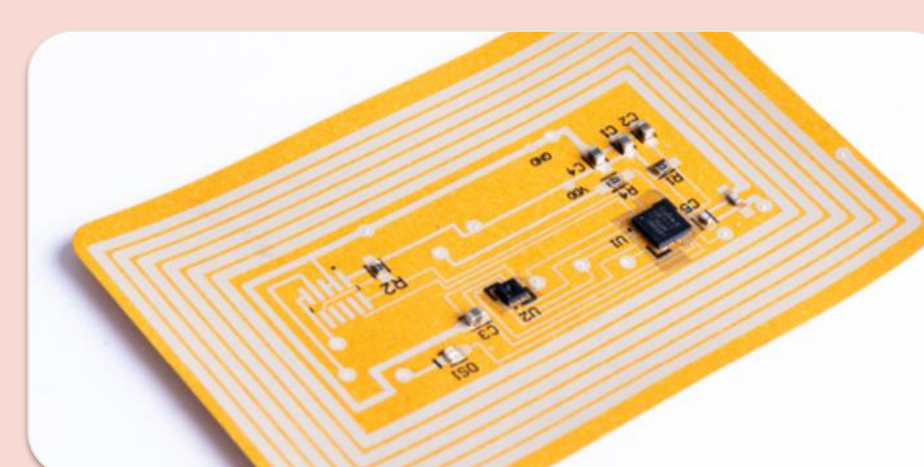


**Zn or Sn based inks** as alternatives for silver-based conductive materials

### Demonstration of feasibility: USE CASES

#### LOGISTICS

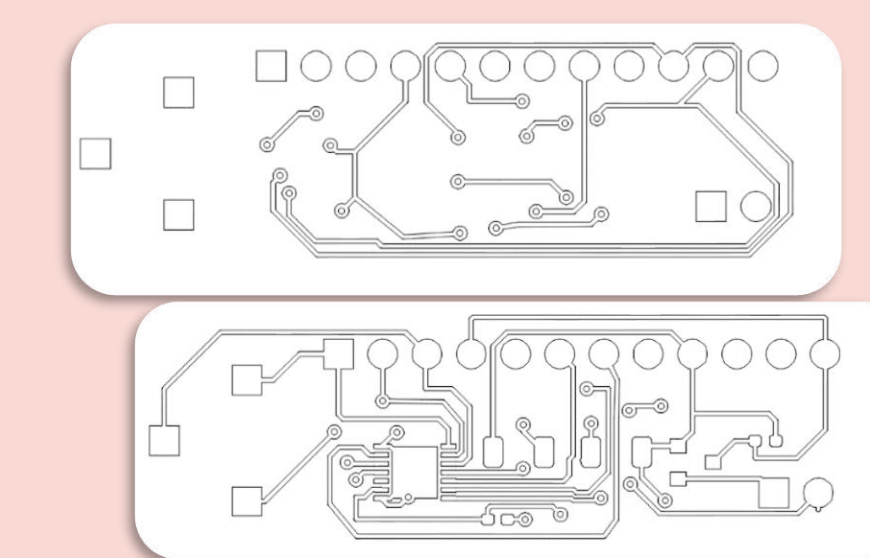
Cold-Chain Monitoring (Time-Temperatur- Logger, TTI)



Two-sided paper PCB for TTI

#### MEDICAL

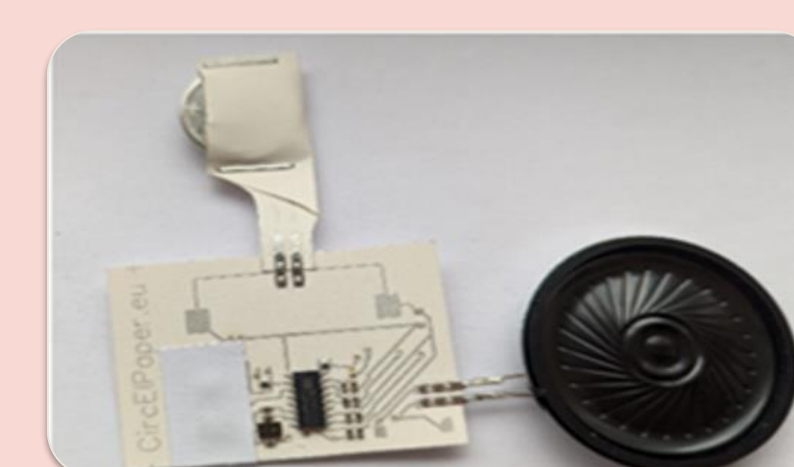
Medical Sensor (Glucose Sensor)



Circuitry for glucose sensor

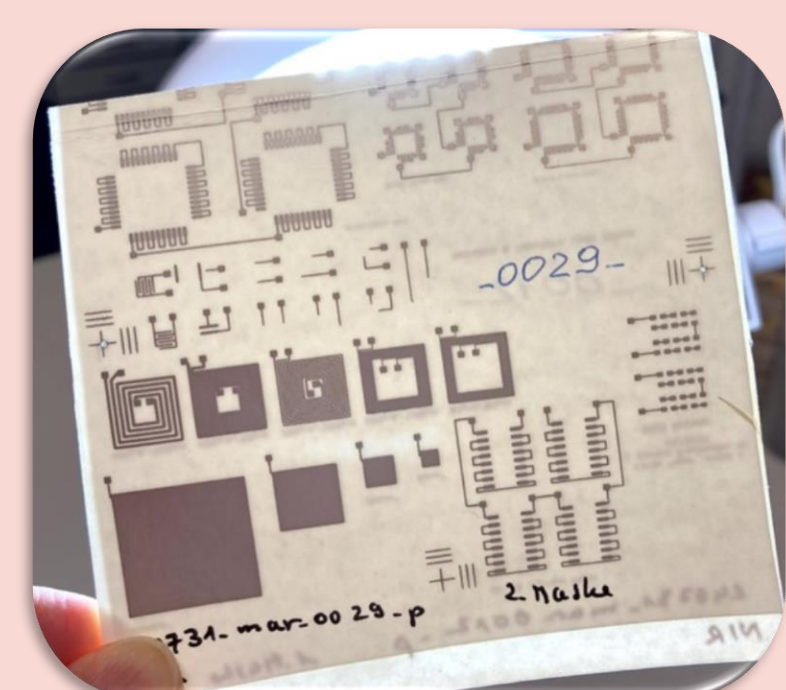
#### CONSUMER ELECTRONICS

Sound Player Paper PCB

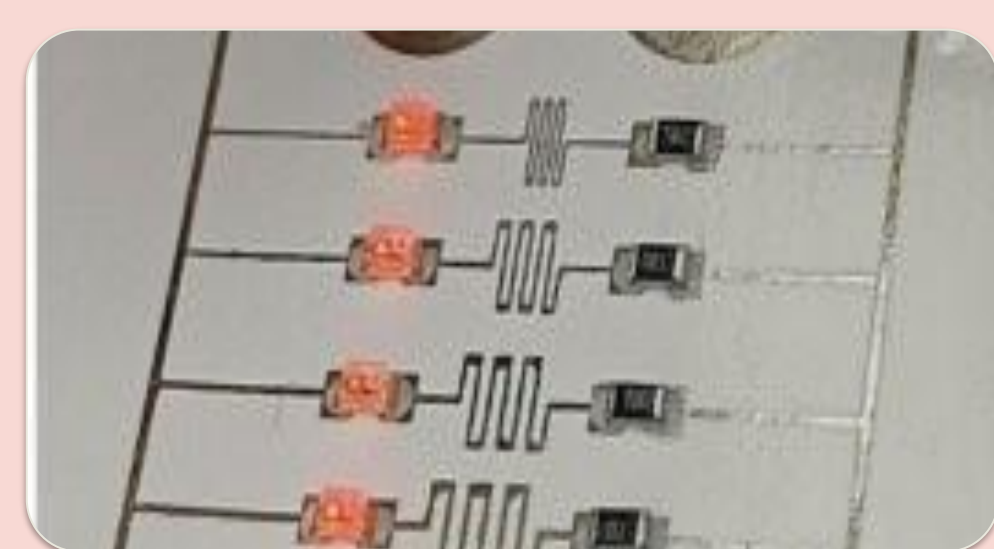


Two-sided paper PCB for sound card

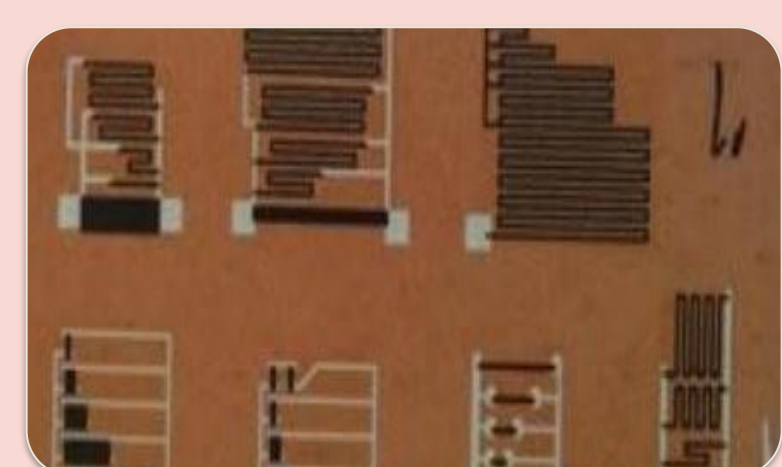
### Processes and Integration



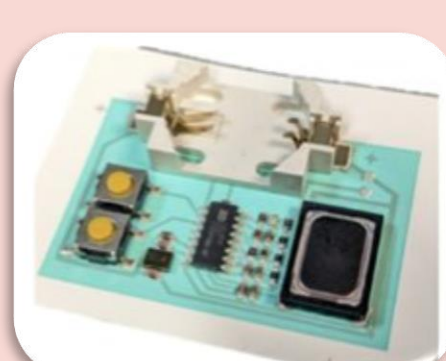
**Lamination** with sustainable glues



**High resolution and high conductivity** printing via different printing techniques



**Printing passive elements** of high reproducibility



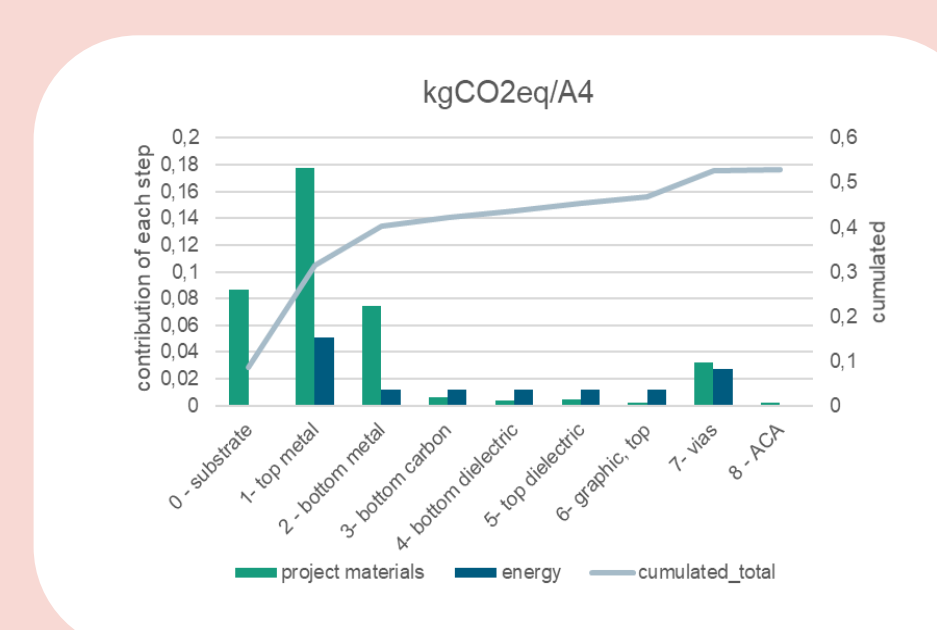
**Assembly** of components using isotropic/anisotropic adhesives

### Recycling, LCA and Toxicity

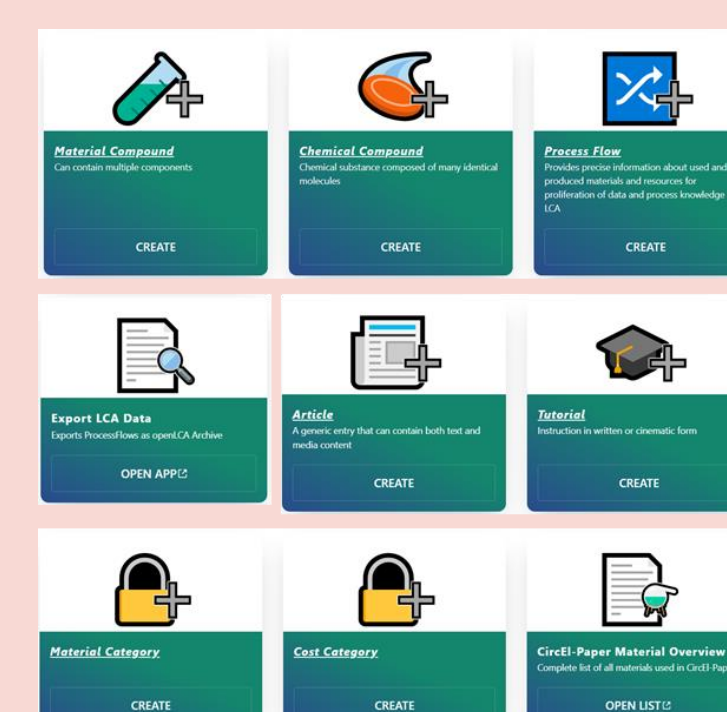
Adaption of **Paper Recycling Processes** for electronic paper waste



**Recovery** of cellulose fibers (top) and silver (down)



**LCA – Process flow** for two-sided electronic paper



**Proliferation of data and process knowledge** from materials research. **EcoSafety Database** for Toxicity Assessment of CircEl-Paper materials



Funded by the European Union under Grant No 101070114



<sup>1</sup> Fraunhofer-Institut für Silicatforschung, Würzburg, Germany

<sup>2</sup> Fedrigoni, 10 rue Jean Arnaud, 38500 Voiron, France

<sup>3</sup> VFP Ink Technologies, 4 av. J. Moulin, 30380 Saint-Christol-lès-Alès, France

<sup>4</sup> Joanneum Research - MATERIALS, Leonhardstr. 59, 8010 Graz, Austria

<sup>5</sup> RISE Research Institutes of Sweden Department Smart Hardware Södra Grytgatan 4, 602 33 Norrköping, Sweden

<sup>6</sup> Univ. Grenoble Alpes, CNRS, Grenoble INP, LGP2, 38000 Grenoble, France

<sup>7</sup> ICAPE Malmö Monstertorget AB, Flygplansgatan 5, 21239 Malmö, Sweden

<sup>8</sup> QSAR Lab Sp. Z o.o., Trzy Lipy 3, 80-172 Gdansk, Poland