

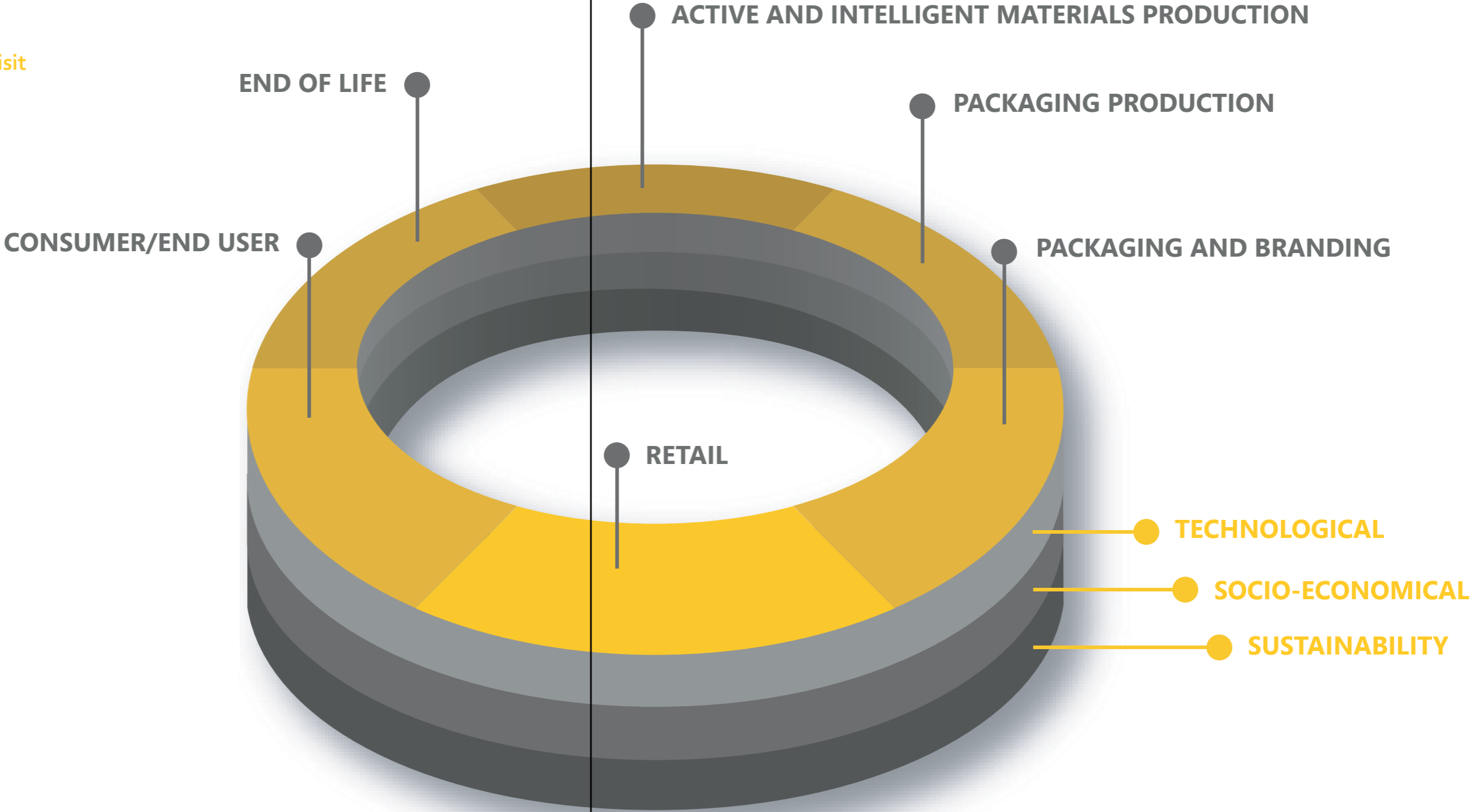
ROADMAPS TECHNOLOGICAL



Groups of researchers concentrated on developing roadmaps for three different levels of active and intelligent packaging development: Socio-economical, Technological and Sustainability.

Each of the three levels has multiple stages and concerns, tips and solutions are presented for everyone of the following: Active and Intelligent Materials, Packaging, Packaging and Branding, Retail, Consumer Behaviour, End of life.

You are currently in the Technological roadmap. Please visit www.actinpak.eu/roadmaps for more info.



A&I COMPONENT PRODUCER

Availability

- Production of active components not yet established
- Batch / production size not matching demand
- Not sufficient suppliers

Stability

- Storage conditions of active agent before processing not defined yet
- Behaviour of active components in up scaled production not yet known
- Activity consistence not evaluated yet
- Thermal & chemical stability not evaluated yet
- Quality control tests are not available or too complicated

Safety

- Migration/toxicity not evaluated yet
- Safety of production of active compounds are not studied
- Safety of nano-size particles unknown/ unclear

PACKER/BRAND OWNER

Availability

- Additional process is necessary
- Investment required

Technology

- Scale-up not implemented yet
- Optimal storage conditions for active packaging materials is not established
- Most suitable production/integration method not clear yet (e.g. coating, extrusion)
- Activity decreases during the integration process
- Release of active agents is not controlled
- Homogenous dispersion not guaranteed
- Active agents or incorporation process affect the optical, physical, mechanical properties (transparency, barrier, etc.)
- Quality control tests are not available or too complicated

RETAILER

Stability

- No optimal storage conditions for active packaging films is established
- Influence of the storage conditions (temperature, humidity) on the activity is not known
- Activity of the active films can not be monitored during the logistic chain
- Quality control tests are not available to food producer or too complicated

PACKAGING PRODUCER

Availability

- Activation steps on production line (UV, moisture, etc.) may be needed
- Additional processing step may be needed
- Investment required
- Product specific applications may require change in materials for the production

Technology

- Suitable format/volume of active packaging and amount of food not defined yet
- Deactivation or interaction of active packaging with food is not yet known
- Active packaging may influence organoleptic properties of food
- Storage conditions for food is different than that of active packaging
- Quality control tests are not available to food producer or too complicated
- Safety

Migration to food not evaluated yet

- Active function not guaranteed yet

CONSUMER/END USER

Awareness

- Active packaging hinders the recyclability of the material
- Recovery processes of the active components is not available
- No data available of long-term impact of active packagings on the environment
- Antimicrobials: increase of bacteria resistance unknown
- Environmental impact of nanomaterials unknown
- Active compounds may hinder the biodegradability of the packaging

A&I COMPONENT PRODUCER

Availability

- Standard production technologies are established
- Active components are available in the amounts demanded
- Several suppliers available

Stability

- Storage conditions of active agent before processing is defined
- Behaviour of active components in up scaled production is known
- Activity is consistent
- Active agents are thermally and chemically stable
- Quick and easy quality control tests is available

Safety

- Migration/toxicity of active components are known
- Active components in the potential applications are safe to consumers
- Production is safe to the workers
- Effect of nano-size is known
- Size of the materials are optimized not having any health effects

PACKER/BRAND OWNER

Availability

- No additional process or investment is required
- Alternatively the additional cost due to the implementation of the new process is less than the added value of the active packaging

Technology

- Active packaging can be produced on a fully industrial scale
- Optimal storage conditions for active packaging is established
- Stable and enough activity after the integration process
- Most suitable integration methods for each active compounds are established
- Homogenous dispersion is achieved
- Release of active agents can be controlled according to the applications
- No undesired effect on the optical, physical, or mechanical properties of materials
- Quick and easy quality control tests is available

PACKAGING PRODUCER

Availability

- No activation step is necessary or the activation is done without an additional step which requires significant investments or may increase the cost of production
- Packaging process is versatile to pack different products

Technology

- Best form and format of active packaging for each application is defined
- No deactivation of the active packaging happens
- No undesired interaction between food and packaging is occurring
- Quick and easy quality control tests is available
- Activity of the active packaging is adapted to the storage conditions of food

Safety

- No migration from packaging to food
- Activity is stable

CONSUMER/END USER

Awareness

- Active packaging has no influence on recyclability of the whole packaging
- Active components can be recovered for a separate end of life
- Active packaging has no impact on the environment
- Antimicrobials are not released to the environment
- Active components added to biodegradable materials do not influence the biodegradability

RETAILER

Dependency

- Logistic conditions are established
- No influence of logistic conditions on the activity
- Technologies are available to monitor the activity of the active films during the whole supply chain
- Activity of the active films can be monitored during the logistic chain and any change is traceable
- Quick and easy quality control tests is available

TECHNOLOGICAL CHALLENGES ACTIVE PACKAGING

COMPONENT PRODUCER

- Most challenging: antimicrobial packaging systems
- Activity consistence & maintenance
- Thermal & chemical stability
- Controlled release
- Organoleptic properties
- Product availability
- Storage of active agent before processing
- Metals in scavengers, metallic (nano) particles in film
- Nano-size
- Migration/toxicity

PACKAGING PRODUCER

- Biggest challenge: scale-up!
- Activity: integration in polymer films vs. Sachet application
- Active agent has to survive processing (e.G. Extrusion): pressure, temperature, pH, loss of volatile agents, interaction with other materials - What is the suitable production/integration method?
- Homogenous dispersion
- Maintenance of optical/physical/mechanical properties (transparency, barrier, etc.)
- Storstorage of active packaging material before usage might be different
- Activation step necessary? (Uv, moisture, etc.)
- Production line: separate processing step or line needed
- Coating/printing: separate process necessary

PACKER/BRAND OWNER

- Selection of suitable format/volume of active packaging and amount of food
- Deactivation or interaction with food
- Limited use for specific products
- Organoleptics / color
- How to control the activity /release duration?
- Can we guarantee the function / food safety?
- Ethylene absorber/releaser: ripeness differs (nature)
- Co₂-releaser: not applicable for low moisture food
- Uv-activated materials can be challenging to food
- Considering extra processing step/ devices or activation
- Food contact / migration

RETAILER

- Storability*
- Influence of storage conditions on activity (temp sensitivity, humidity, different climates)
 - Shelf life of active packaging material? (Time stability)
 - Standardization

CONSUMER/END USER

- How do we deal with that?
- Recyclability? Recovery of the product?
- What do we know about long-term impact of the ap?
- Antimicrobials: increase of bacteria resistance?
- Recyclability of metal-based scavengers?
- Particularly nano - what is the environmental impact?

COMPONENT PRODUCER ACTIVE PACKAGING

MARKET DRIVERS

Enablers

- Transition towards bio-based and biodegradable active components

Risks/Barriers/Knowledge gaps

- Trust in functionality of active components

SOLUTIONS

Availability

- Establish standard production technologies for active components
- Increase supplier availability of active components by increasing awareness and necessity of active packaging
- Identification of new potential sources for gaining biobased active components

Stability

- Performance of storage tests of active agents to define optimal storage conditions before processing
- Performance of activity tests
- Performance of thermal & chemical stability tests
- Establishment of quick and easy quality control test

Safety

- Performance of migration/toxicity tests
- Evaluation of consumer safety
- Establish workplace safety concept for the production of active components
- Evaluate health effect of nano-sized materials
- If necessary: Optimize nano-sized materials to not having any health effect

ENABLING TECHNOLOGIES

- Extraction methods at industrial scale
- Social Media/digitalisation: increase of awareness

RESOURCES

- Biobased active components
 - Suppliers of active components
- For the performance of all the tests and studies required:*
- Funding
 - Staff and knowhow
 - Infrastructure and lab equipment

PACKAGING PRODUCER ACTIVE PACKAGING

MARKET DRIVERS

Enablers

- Transition from passive to active packaging
- Reuse of packaging materials or recycling possibilities

Decision points

- Lightweight: optimization of material

Risks/Barriers/Knowledge gaps

- Flexible production processes

SOLUTIONS

Technology

- Implement industrial scale up
- Adapt current production processes with the integration of active components
- Establishment of most suitable integration processes
- Optimisation of integration process to avoid activity loss
- Optimisation of homogenous dispersion
- Optimisation of optical, physical, and mechanical properties of active packaging materials

Stability

- Performance of controlled release tests of active agents
- Performance of storage tests of active materials to define optimal storage conditions before packaging
- Evaluation of activity over time
- Evaluation of thermal & chemical stability
- Establishment of quick and easy quality control tests

Cost

- Evaluate new process implementation cost in contrast to the added value of the active packaging

ENABLING TECHNOLOGIES

- Integration processes at industrial scale (e.g. extrusion, lamination, etc.)

RESOURCES

- Recycled, biobased and biodegradable packaging materials

For the performance of all the tests and studies required:

- Funding
- Staff and knowhow
- Infrastructure and lab equipment

PACKER / BRAND OWNER ACTIVE PACKAGING

MARKET DRIVERS

Enablers

- Increasing demand on AP decreases costs
- Less food loss/waste

Decision points

- Shelf life extension (leads to less food loss/waste)
- Clean label products
- Less processed food
- Application of recycled packaging materials

Risks/Barriers/Knowledge gaps

- Trust in functionality of active packaging

SOLUTIONS

Technology

- Establishment of packaging processes to be versatile to pack different products
- Optimisation of activation (step) of active packaging
- Definition of best form and format of active packaging for each application

Stability

- Evaluation of interaction between food and packaging (e.g. organoleptics, deactivation, etc.)
- Adaption of activity of the active to the storage conditions of the food
- Establishment of quick and easy quality control tests

Safety

- Performance of food migration tests
- Performance of food quality tests

ENABLING TECHNOLOGIES

- Packaging technologies

RESOURCES

- Packaging machinery

For the performance of all the tests and studies required:

- Funding
- Staff and knowhow
- Infrastructure and lab equipment

RETAILER ACTIVE PACKAGING

MARKET DRIVERS

Enablers

- Reduce waste of food/perishable items
- Increased flexibility in logistics due to longer shelf life

SOLUTIONS

Stability

- Activity evaluation of active materials over storage time and under different conditions (temp, humidity)
- Establishment of optimal storage conditions for active packaging films
- Development of an activity monitoring system for the active films during the whole supply chain
- Implementation of the monitoring system for tracability of the activity of the active films over the whole logistic chain
- Establishment of quick and easy quality control tests

ENABLING TECHNOLOGIES

- Monitoring systems
- Intelligent packaging

RESOURCES

- Measurement devices
- For the performance of all the tests and studies required:*
- Funding
 - Staff and knowhow
 - Infrastructure and lab equipment

CONSUMER / END USER ACTIVE PACKAGING

MARKET DRIVERS

Enablers

- Transition towards bio-based and biodegradable

Decision points

- Enter the circular economy

Risks/Barriers/Knowledge gaps

- Reuse of active packaging materials or recycling possibilities

SOLUTIONS

- Evaluation of recyclability of the whole active packages
- Establishment of recycling strategies and implementation thereof
- Evaluation of biodegradability of active packages
- Establishment of active component recovery for a separate end of life
- Establishment of antimicrobial component inactivation from active packaging materials
- Performance of LCA studies of active packaging materials
- Consumer education

ENABLING TECHNOLOGIES

- LCA tools
- Social Media/digitalisation: increase of awareness

RESOURCES

- LCA databases
- For the performance of all the tests and studies required:*
- Funding
 - Staff and knowhow
 - Infrastructure and lab equipment

PACKAGING PRODUCER

General

- Extra processing step required - costly
- Optimisation of process - still expensive
- Well fixed to packaging - printing label vs. Embedded
- Size?

RFID (+ sensor enabled)

- Printing development, challenges in printing
- Coupling

Sensor-based systems

- Inside vs. External
- Gas-based indicators/sensors: use of correct barrier structure
- Activation during processing?

PACKER/BRAND OWNER

General

- Printed on a separate tag, extra step required

RFID

- Anti-counterfeiting
- Sensitivity to water/humidity, interaction with food components

Sensor-based systems

- Tti: high variety: choose the right technology
- Considering extra processing step/ devices or activation
- Food contact / migration
- Need transparent packaging to see

CONSUMER/END USER

- Recyclability: huge problem for ip systems
- Environmental impact could be a problem
- Separation?
- Food waste: increase or decrease??
- Freshness indicators: do they maybe even create food waste? Customer always buy the freshest one!

COMPONENT PRODUCER

General

- Reliability - huge problem
- Functionality?
- Big variety of products: what to choose?

RFID

- Printing technology - extra process - more cost
- Resources

Sensor-based systems

- Reliability of sensors/ coupling / connection difficulties (e.g. Sensor& rfid combination)
- Only 1 fake information will lead to neglectance of the consumer for the future
- Humidity stability, chemical/ activity stability
- Biosensors / freshness indicators: readiness of technology
- Biosensors: matching to different pathogens, reliability!

RETAILER

RFID (+ sensor enabled)

- Reading system and network required
- Deactivation? (Magnetic, electronic)
- Big advantage, but have to invest in infrastructure
- Competition with small spaces

Sensor-based systems

- Storability - have to deliver the packaging material in controlled environment until it is used
- Sensitivity of the products.

MARKET DRIVERS

- The need for IP: safety, security, origin, counterfeit, uniqueness/ product differentiation, quality of products, convenience, brand enhancement, entertainment, merchandising and increasing sales, error prevention
- Consumer driven: consumers are more demanding, wealthier, more aware of sustainability issues
- Unbalanced supply chain
- Little market pull
- Inadequate cost reduction
- Failure to solve technical problems
- Legal constraints/legislation
- Internet shopping
- Increased demand for up-to-date information

SOLUTIONS

- Internet
- Communication technologies
- Technology push
- New IP components and creative design
- Electronic graphic design
- Emerging technologies
- Basic hardware platforms
- Smart substrates/advanced substrate technology
- Packaging as media channel
- More functionality, more convenience
- Development: more sensors, more memory, low power
- System integration
- Smart products platform – NFC enabling product integrity and consumer engagement

ENABLING TECHNOLOGIES

- Digital technologies and wireless communications
- IoT connecting consumer products to the Web and managing real-time data to drive applications and analytics throughout the product lifecycle
- IoT in supply chain – full control of the logistics and distribution chain
- Augmented reality – interactivity, image recognition
- Printed electronics – high-volume low-cost manufacturing
- Functional inks/advanced materials
- Nanotechnology
- Biotechnology
- Block Chain Technology
- Industry 4.0
- 3D printing

PROCESSES

Production

- minimizing machine downtime
- flexible capacities
- easy changeovers
- consistent quality

Machines

- easy to operate and maintain
- increased automation and integration

Printing

- highly integrated hybrid system

NEEDS AND GAPS

- Integration in packaging (scale up, cost, stability, effectivity, maintenance)
- In-line inspection and testing equipment
- Higher performance functional inks/advance materials
- Simulation and design tools
- Robust manufacturing platforms
- From mass production to individual solution – personalizing manufacturing technologies
- reading system and network required
- Reliability of sensors/ coupling / connection difficulties (e.g. sensor& RFID combination)
- Humidity stability, chemical/activity stability
- sensitivity to water/humidity, interaction with food components
- Biosensors: matching to different pathogens, reliability!
- gas-based indicators/sensors: use of correct barrier structure
- recyclability: huge problem for IP systems

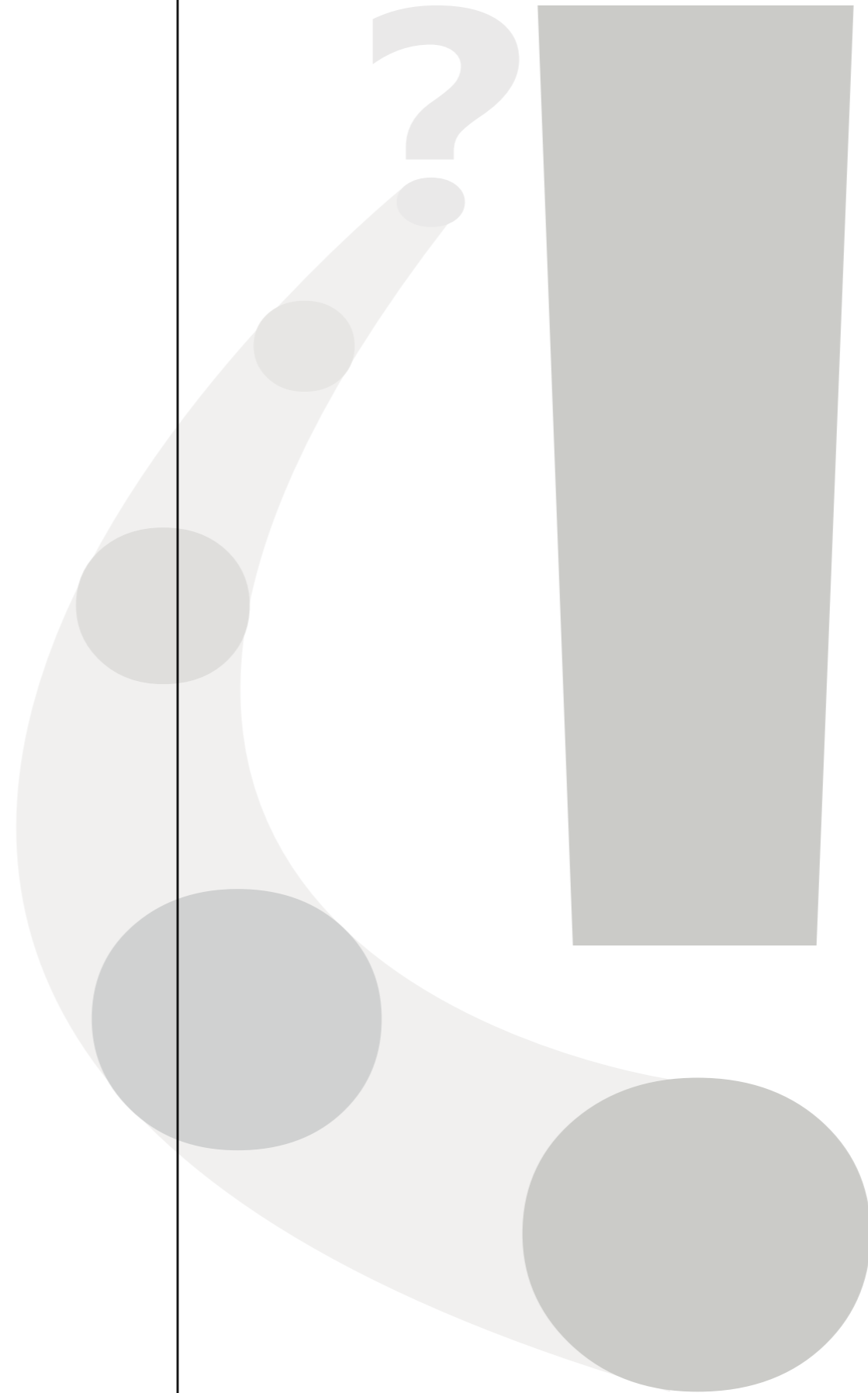
PRODUCTS (VISION)

- Packaging becomes an interactive engagement platform with added low-cost/low-power electronics.
- Moving to high performance, low cost, application driven packaging techniques
- Moving to collective wafer-level-packaging technique standards

Some of IP mechanisms:

- Transparent and invisible electronics
- Tightly rollable electronics
- Fault tolerant electronics
- Stretchable and morphing electronics
- Edible electronics
- The package becomes the delivery mechanism
- Electronic release, dispensing and consumer information
- Winking image label, talking label, recording talking label, scrolling text label, moving color picture label
- Timer, self adjusting use by date, drug and cosmetic delivery system
- Other sensing electronics

ROADMAPS OVERVIEW



TECHNOLOGICAL ACTIVE PACKAGING

	A&I COMPONENT PRODUCER	PACKAGING PRODUCER	PACKER / BRAND OWNER	RETAILER	CONSUMER / END USER
MARKET DRIVERS	<p>Transition towards bio-based and biodegradable active components</p> <p>Trust in functionality of active components</p>	<p>Transition from passive to active packaging</p> <p>Reuse of packaging materials or recycling possibilities</p> <p>Lightweight: optimization of material</p> <p>Flexible production processes</p>	<p>Shelf life extension - less food loss/waste</p> <p>Clean label products</p> <p>Less processed food</p> <p>Application of recycled packaging materials</p> <p>Increasing demand on AP decreases costs</p> <p>Trust in functionality of active packaging</p>	<p>Reduce waste of food/perishable items</p> <p>Increased flexibility in logistics due to longer shelf life</p>	<p>Transition towards bio-based and biodegradable</p> <p>Enter the circular economy</p> <p>Reuse of active packaging materials or recycling possibilities</p>
SOLUTIONS	<p>Availability</p> <p>Establish standard production technologies for active components</p> <p>Increase supplier availability of active components by increasing awareness and necessity of active packaging</p> <p>Identification of new potential sources for gaining biobased active components</p> <p>Stability</p> <p>Performance of storage tests of active agents to define optimal storage conditions before processing</p> <p>Performance of activity tests</p> <p>Performance of thermal & chemical stability tests</p> <p>Establishment of quick and easy quality control test</p> <p>Safety</p> <p>Performance of migration/toxicity tests</p> <p>Evaluation of consumer safety</p> <p>Establish workplace safety concept for the production of active components</p> <p>Evaluate health effect of nano-sized materials</p> <p>If necessary: Optimize nano-sized materials to not having any health effect</p>	<p>Technology</p> <p>Implement industrial scale up</p> <p>Adapt current production processes with the integration of active components</p> <p>Establishment of most suitable integration processes</p> <p>Optimisation of integration process to avoid activity loss</p> <p>Optimisation of homogenous dispersion</p> <p>Optimisation of optical, physical, and mechanical properties of active packaging materials</p> <p>Stability</p> <p>Performance of controlled release tests of active agents</p> <p>Performance of storage tests of active materials to define optimal storage conditions before packaging</p> <p>Evaluation of activity over time</p> <p>Evaluation of thermal & chemical stability</p> <p>Establishment of quick and easy quality control tests</p> <p>Cost</p> <p>Evaluate new process implementation cost in contrast to the added value of the active packaging</p>	<p>Technology</p> <p>Establishment of packaging processes to be versatile to pack different products</p> <p>Optimisation of activation (step) of active packaging</p> <p>Definition of best form and format of active packaging for each application</p> <p>Stability</p> <p>Evaluation of interaction between food and packaging (e.g. organoleptics, deactivation, etc.)</p> <p>Adaption of activity of the active to the storage conditions of the food</p> <p>Establishment of quick and easy quality control tests</p> <p>Safety</p> <p>Performance of food migration tests</p> <p>Performance of food quality tests</p>	<p>Stability</p> <p>Activity evaluation of active materials over storage time and under different conditions (temp, humidity)</p> <p>Establishment of optimal storage conditions for active packaging films</p> <p>Development of an activity monitoring system for the active films during the whole supply chain</p> <p>Implementation of the monitoring system for tracability of the activity of the active films over the whole logistic chain</p> <p>Establishment of quick and easy quality control tests</p>	<p>Evaluation of recyclability of the whole active packages</p> <p>Establishment of recycling strategies and implementation thereof</p> <p>Evaluation of biodegradability of active packages</p> <p>Establishment of active component recovery for a separate end of life</p> <p>Establishment of antimicrobial component inactivation from active packaging materials</p> <p>Performance of LCA studies of active packaging materials</p> <p>Consumer education</p>
ENABLING TECHNOLOGIES	<p>Extraction methods at industrial scale</p> <p>Social Media/digitalisation: increase of awareness</p>	<p>Integration processes at industrial scale (e.g. extrusion, lamination, etc.)</p>	<p>Packaging technologies</p>	<p>Monitoring systems</p> <p>Intelligent packaging</p>	<p>LCA tools</p> <p>Social Media/digitalisation: increase of awareness</p>
RESOURCES	<p>Biobased active components</p> <p>Suppliers of active components</p>	<p>Recycled, biobased and biodegradable packaging materials</p>	<p>Packaging machinery</p>	<p>Measurement devices</p>	<p>LCA databases</p>
	<p>For the performance of all the tests and studies required:</p> <p>Funding</p> <p>Staff and knowhow</p> <p>Infrastructure and lab equipment</p>				

TECHNOLOGICAL INTELLIGENT PACKAGING

	MARKET DRIVERS	SOLUTIONS	ENABLING TECHNOLOGIES	PROCESSES	NEEDS AND GAPS	PRODUCTS (VISION)
INTELLIGENT FIBRE-BASED PACKAGING	<p>The need for IP: safety, security, origin, counterfeit, uniqueness/product differentiation, quality of products, convenience, brand enhancement, entertainment, merchandising and increasing sales, error prevention</p> <p>Consumer driven: consumers are more demanding, wealthier, more aware of sustainability issues</p> <p>Unbalanced supply chain</p> <p>Little market pull</p> <p>Inadequate cost reduction</p> <p>Failure to solve technical problems</p> <p>Legal constraints/legislation</p> <p>Internet shopping</p> <p>increased demand for up-to-date information</p>	<p>Internet, Communication technologies</p> <p>Technology push</p> <p>New IP components and creative design</p> <p>Electronic graphic design</p> <p>Emerging technologies</p> <p>Basic hardware platforms</p> <p>Smart substrates/advanced substrate technology</p> <p>Packaging as media channel</p> <p>More functionality, more convenience</p> <p>Development: more sensors, more memory, low power</p> <p>System integration</p> <p>Smart products platform – NFC enabling product integrity and consumer engagement</p>	<p>Digital technologies and wireless communications</p> <p>IoT connecting consumer products to the Web and managing real-time data to drive applications and analytics throughout the product lifecycle</p> <p>IoT in supply chain – full control of the logistics and distribution chain</p> <p>Augmented reality – interactivity, image recognition</p> <p>Printed electronics – high-volume low-cost manufacturing</p> <p>Functional inks/advanced materials</p> <p>Nanotechnology</p> <p>Biotechnology</p> <p>Block Chain Technology</p> <p>Industry 4.0</p> <p>3D printing</p>	<p>Production</p> <p>minimizing machine downtime, flexible capacities, easy changeovers, consistent quality</p> <p>Machines</p> <p>easy to operate and maintain, increased automation and integration</p> <p>Printing</p> <p>Highly integrated hybrid system</p>	<p>Integration in packaging (scale up, cost, stability, effectivity, maintenance)</p> <p>In-line inspection and testing equipment</p> <p>Higher performance functional inks/advance materials</p> <p>Simulation and design tools</p> <p>Robust manufacturing platforms</p> <p>From mass production to individual solution – personalizing manufacturing technologies</p> <p>reading system and network required</p> <p>Reliability of sensors/ coupling / connection difficulties (e.g. sensor& RFID combination)</p> <p>Humidity stability, chemical/activity stability</p> <p>sensitivity to water/humidity, interaction with food components</p> <p>Biosensors: matching to different pathogens, reliability!</p> <p>gas-based indicators/sensors: use of correct barrier structure</p> <p>recyclability: huge problem for IP systems</p>	<p>General</p> <p>Packaging becomes an interactive engagement platform with added low-cost/ low-power electronics.</p> <p>Some of IP mechanisms</p> <p>Transparent and invisible electronics</p> <p>Tightly rollable electronics</p> <p>Fault tolerant electronics</p> <p>Stretchable and morphing electronics</p> <p>Edible electronics</p> <p>The package becomes the delivery mechanism</p> <p>Electronic release, dispensing and consumer information</p> <p>Winking image label, talking label, recording talking label, scrolling text label, moving color picture label</p> <p>Timer, self adjusting use by date, drug and cosmetic delivery system</p> <p>Other sensing electronics</p> <p>Moving to high performance, low cost, application driven packaging techniques</p> <p>Moving to collective wafer-level-packaging technique standards</p>

Technological roadmap was done with contribution of the WG1 members of the Cost Action "ActInpak" and with major contributions from the following members:

Selcuk Yildirim

Bettina Röcker

Diana Gregor-Svetec

Joana Mendes

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COST FP1405 ActInPak aims to identify and overcome the key technical, social, economic and legislative barriers to a successful deployment of renewable fibre-based functional packaging solutions such as active and intelligent packaging. Currently, 43 countries are involved in the network, with participants representing 209 academic institutions, 35 technical centers, and 83 industrial partners.

For more information, please visit the ActInPak website: www.actinpak.eu

COST (European Cooperation in Science and Technology) is a funding agency for research and innovation networks. Our Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation.

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