ROADMAPS

ACTIVE AND INTELLIGENT PACKAGING IMPLEMENTATION

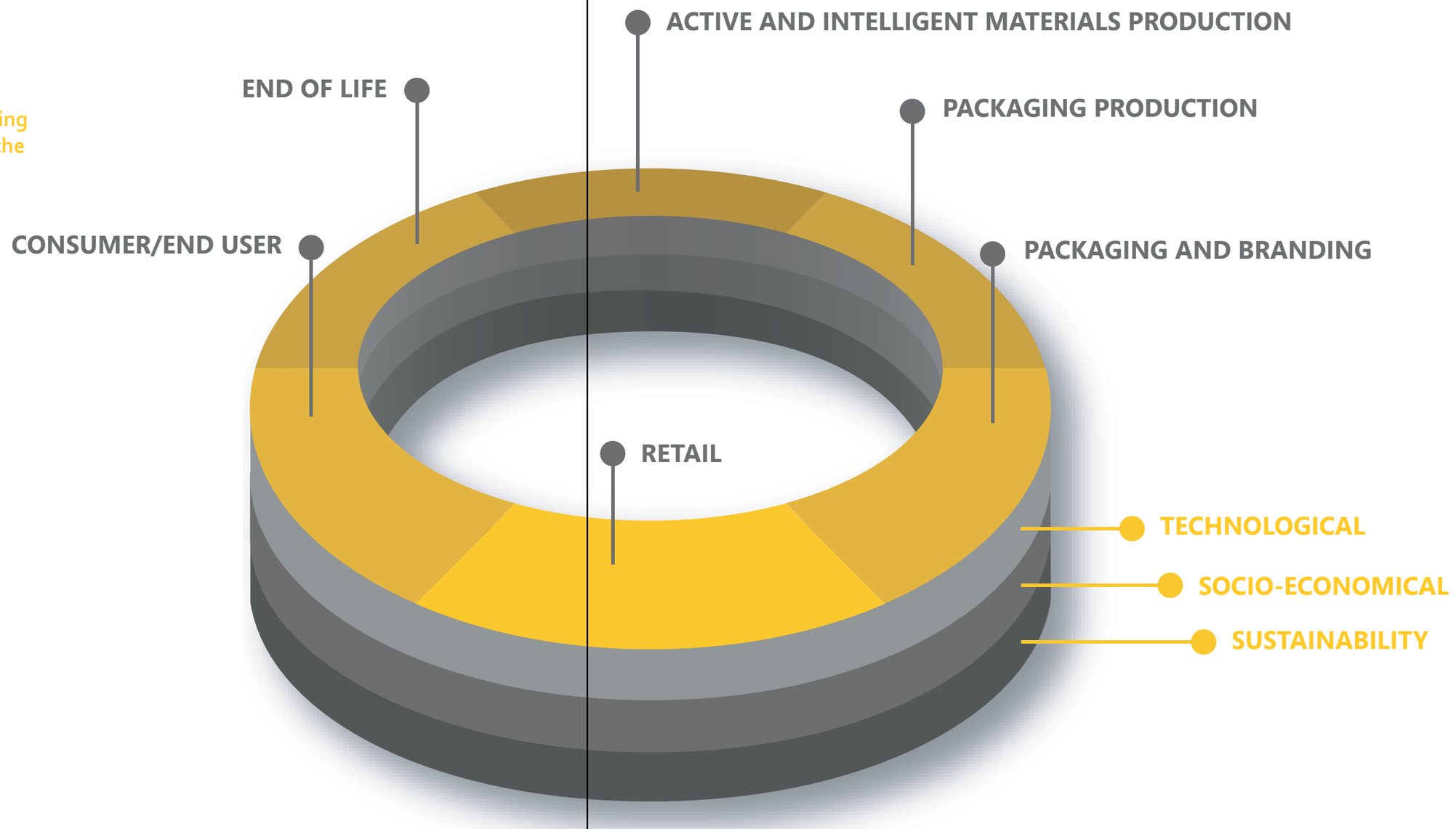
facing the challenges

TABLE OF CONTENT

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.

Explore the roadmaps with clicking on the yellow pointers and find the solution to your problem!



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

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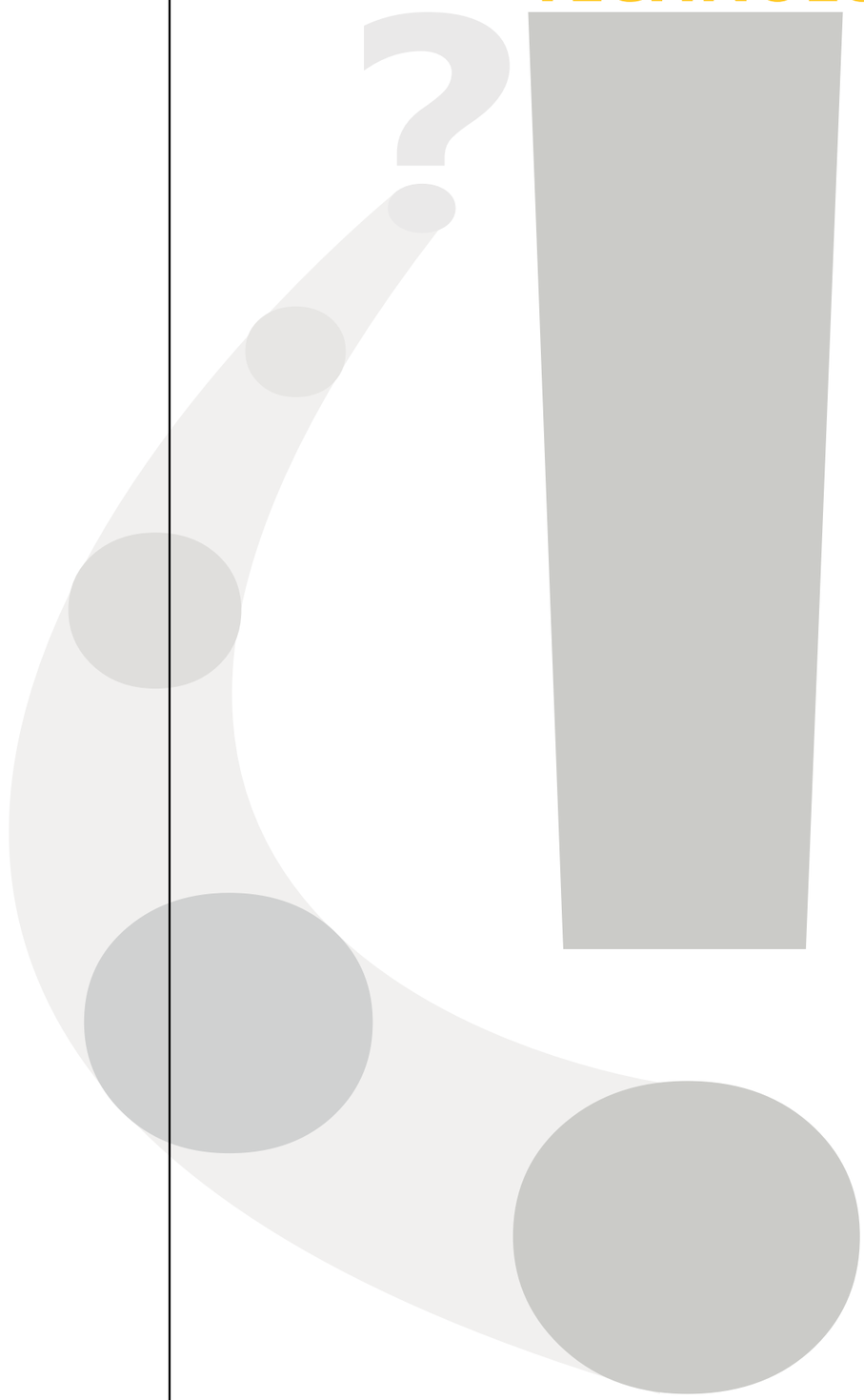
ROADMAPS
TECHNOLOGICAL



TECHNOLOGICAL ACTIVE PACKAGING

CURRENT SITUATION

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

TECHNOLOGICAL ACTIVE PACKAGING

VISIONARY SITUATION

A&I COMPONENT PRODUCER

Availability
- Standard production technologies are established
- Active componeInnts 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 controll 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 effectst

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 alue of the active packaging

Technology
- Active packaging can be produces 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
- Released of active agents can be contolled according to the applications
- No undesired effect on the optical, physical, or mechanical properties of materials
- Quick and easy quality controll tests is available

PACKAGING PRODUCER

Availability
- No activation step is necessary or the activation is done without an additional step which requires significant investements 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 controll 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 controll 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
- Organoloeptics / 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

TECHNOLOGICAL CHALLENGES INTELLIGENT PACKAGING

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

COMPONENT PRODUCER

General
- Reliability - hudge 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.

COMPONENT PRODUCER INTELLIGENT PACKAGING

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

COMPONENT PRODUCER INTELLIGENT PACKAGING

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

Socio-economic roadmap was done with contribution of the WG2 members of the Cost Action "ActInpak" and with major contributions from the following members:

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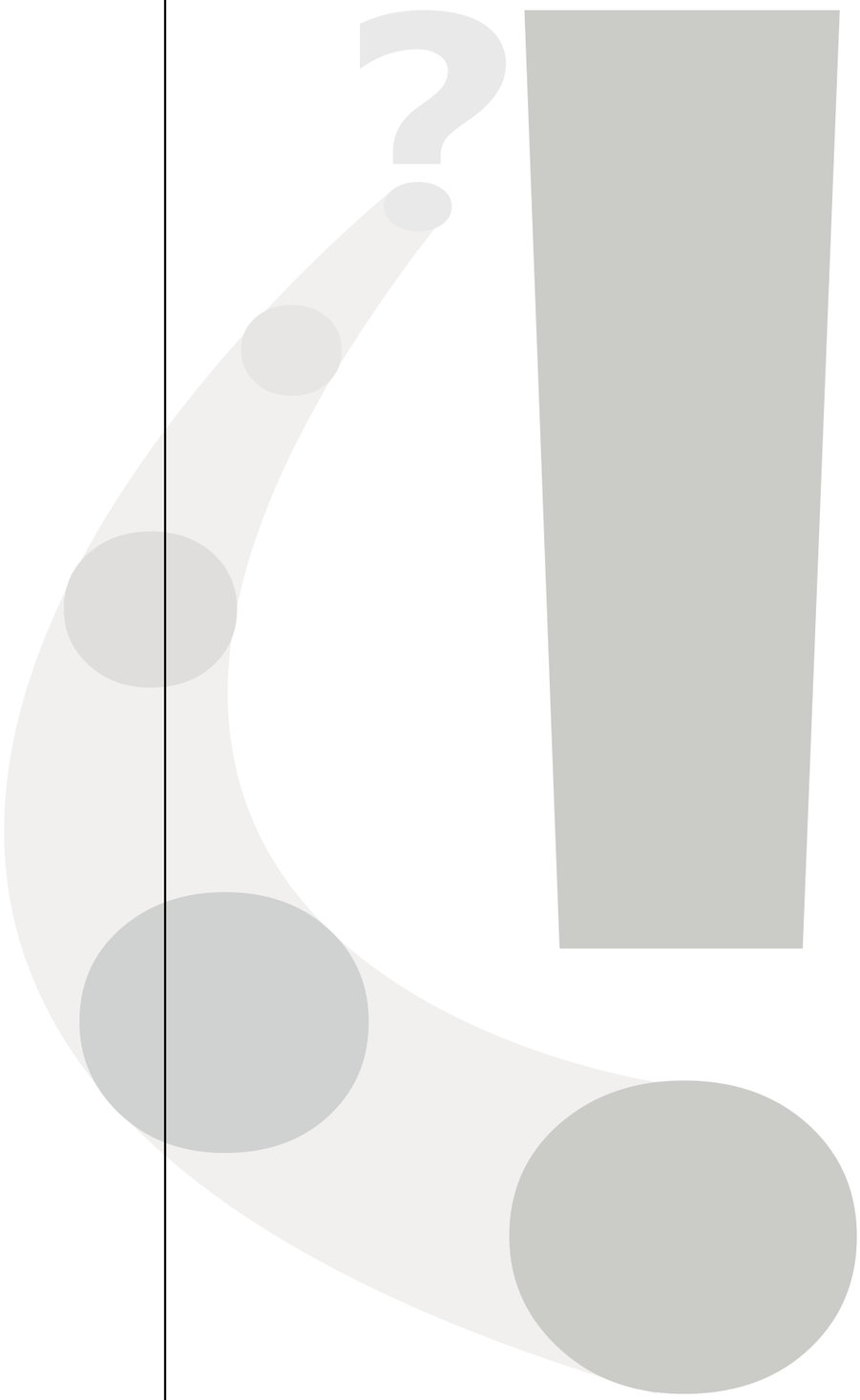
Johanna Lahti
Mieke Buntinx

ROADMAPS
SOCIO-ECONOMIC



SOCIO-ECONOMIC

CURRENT SITUATION

A&I COMPONENT PRODUCER

Dependency
- Packaging machines dictate properties
- Behaviour of components in combination with up scaled production not yet known

Costs versus revenues
- Customer willingness to pay unknown
- ROI unclear

Availability
- Willingness and flexibility to produce not yet established
- Batch / production size not matching demand
- Market readiness not sufficient

Legislation
- Complex and unclear matter
- Potential migration issues

PACKER/BRAND OWNER

Awareness
- Possibilities unknown/unclear
- Potential benefits unknown/unclear

Costs versus revenues
- Willingness to pay for A&I packaging and to what extent uncertain
- ROI unclear
- Less food loss/waste = lower production/sales = lower profits

Availability
- Willingness and flexibility to produce not yet established
- Batch / production size not matching demand
- Market readiness not sufficient
- Existing infrastructure not flexible enough

Trust in technology
- Fear of consumer rejection
- Fear of failures affecting reputation

Legislation
- Complex and unclear matter
- Potential migration issues

PACKAGING PRODUCER

Awareness
- Possibilities unknown/unclear
- Potential benefits unknown/unclear

Costs versus revenues
- Willingness to pay for A&I components uncertain
- Customer willingness to pay uncertain
- ROI unclear
- Lower food loss & waste = lower production = lower profits

Availability
- Willingness and flexibility to produce not yet established
- Batch / production size not matching demand
- Market readiness not sufficient
- Production machines dictate which AIP technologies are possible to use

Legislation
- Complex and unclear matter
- Potential migration issues

RETAILER

- Awareness

Possibilities unknown/unclear
- Potential benefits unknown/unclear

Costs versus revenues
- Willingness to pay for A&I packaging and to what extent uncertain
- ROI unclear
- Indicators might cause product losses

Transparency
- Desire to control freshness without showing the consumer

Trust in technology
- Fear of consumer rejection
- Fear of failures affecting reputation
- Reliability
- Unknown who is liable?

Legislation
- Complex and unclear matter
- Potential migration issues

CONSUMER/END USER

Awareness
- Unknown makes suspicious
- Possibilities unknown/unclear
- Benefits unknown/unclear
- Costs versus revenues
- Willingness to pay and to what extent uncertain

Trust in technology
- Safety and healthiness doubted
- Visible versus invisible technology/info
- Blind faith in technology versus use of senses

Perception
- Freshness-perception vs extended shelf-life
- Active parts considered ‘additives’ =undesired
- Way of communication
- Negative communication affects acceptance
- Different consumer groups (geography, age, education) have different concerns = different way of addressing them

SOCIO-ECONOMIC

VISIONARY SITUATION

A&I COMPONENT PRODUCER

Dependency
- Industry is closely cooperating and the interdependency between components and packaging machines is rather an opportunity than a challenge
- Packaging machines are more flexible
- Components are flexible and adaptable to different packaging production systems

Costs versus revenues
- Optimal relation cost vs benefit: minimal cost, maximal benefit while being sustainable

Availability
- 50% of packaging is active and/or intelligent

Legislation
- Clear legislation is in place

PACKER/BRAND OWNER

Awareness
- Social impact is regained
- Companies are well-informed about the possibilities, potential benefits and challenges
- Companies actively search cooperation with other stakeholders

Costs versus revenues
- Optimal relation cost vs benefit: minimal cost, maximal benefit while being sustainable
- AIP costs the same as conventional packages
- Benefits outweigh costs, proven by successful business cases
- Reduction of food loss & waste outweigh lower production/profits and companies have embraced this different business approach
- Companies gain alternative benefits from lower food waste/loss through government funding

Availability
- 50% of packaging is active and/or intelligent
- AIP is produced at industrial level

Legislation
- Clear legislation is in place
- Legislation makes AIP the standard: all products should be packed in AIP

PACKAGING PRODUCER

Awareness
- AIP widespread for packaged goods and benefits are well-known
- Large companies have invested in communication to and education of the consumer to raise the awareness and acceptance

Costs versus revenues
- AIP costs the same as conventional packages
- Benefits outweigh costs, proven by successful business cases
- Benefits in other areas (such as food loss reduction or consumer loyalty) outweigh production costs and companies have embraced this different business approach
- Companies gain alternative benefits from lower food waste/loss through government funding

Availability
- AIP is produced at industrial level
- Small companies started and proved the potential, but large companies have followed and made it the standard

Acceptance
- Brands see AIP as a useful tool in their kit to make their business profitable and enhance their reputation
- Large companies have invested in communication to and education of the consumer to raise the awareness and acceptance
- Trust in technology
- AIP enables new food supply chain and business models

Legislation
- Legislation makes AIP the standard: all products should be packed in AIP

RETAILER

Awareness
- AIP widespread for packaged goods and benefits are well-known
- Consumers are used to buy discounted (closer to expiry date) products and trust its quality through AIP
- Only AIP products are available in supermarkets

Costs versus revenues
- AIP costs the same as conventional packages
- Benefits outweigh costs, proven by successful business cases
- Benefits in other areas (such as food loss reduction or consumer loyalty) outweigh production costs and companies have embraced this different business approach

Transparency
- AIP is widely used to transparently inform stakeholders about the product
- It is common and without consequence to transparently communicate to the consumer

Trust in technology
- Retailers completely accept AIP in their stores and know that a failure will not affect their reputation if they are transparent.

Reliability
- The value chain as a whole is liable and made agreements about this.

Legislation
- Legislation makes AIP the standard: all products should be packed in AIP

CONSUMER/END USER

Awareness
- Consumers are aware of the benefits and demand AIP from companies (they don't buy conventional packaging anymore)

Costs versus revenues
- Benefits are well-known to consumers on different levels (shelf-life extension, second shelf life, reduction of food losses, more natural food)
- Consumers are willing to pay 10% more for AIP, but in practice the products costs the same as conventional packaging due to availability

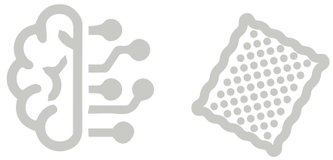
Trust in technology
- Consumers only trust and buy sensitive food equipped with AIP
- Consumers are well-educated in this field but also educated to trust their own senses
- AIP is transparent towards consumer

Perception
- No wasted food is the most important to the consumer, therefore second shelf life is guaranteed by AIP
- Education of consumers has proven that extended shelf life does not equal lower freshness but equals more natural food

Way of communication
- Honest and positive communication, also information about benefits and why food waste is a problem
- Government supports it with official statements and advertising

SOCIO-ECONOMIC CHALLENGES

A&I COMPONENT PRODUCER



- Dependency
- Costs versus revenues
- Availability
- Legislation

PACKAGING PRODUCER

- Awareness
- Costs versus revenues
- Availability
- Legislation

PACKER/BRAND OWNER

- Awareness
- Costs versus revenues
- Availability
- Trust in technology
- Legislation

RETAILER

- Awareness
- Costs versus revenues
- Transparency
- Trust in technology
- Reliability
- Legislation

CONSUMER/END USER

- Awareness
- Costs versus revenues
- Trust in technology
- Perception
- Way of communication

A&I COMPONENT PRODUCER

MARKET DRIVERS

Sustainable goes mainstream
- Transition towards bio-based and 100% recyclable
- Extending shelf life = less food loss/ waste
- Lightweight: optimisation of material

E-commerce
- Enable the merge offline with online

Technological development
- Lower costs due to technological development
- Public investment and technology transfer

Legislation
- Legislation under development

SOLUTIONS

SHORT-TERM
- Increase shelf-life to reduce food waste
- Packaging improvement
- Raise awareness of packaging producers
- Educational strategies for packaging producers

MID-TERM
- Lower costs due to increased production and technological development
- List of approved active compounds in packaging
- Collect more data to get compounds to be approved

LONG-TERM
- Continuous development of new and safe A&I components for specific purposes
- High throughput testing technologies
- Shorter time from application to approval of safety of compounds

ENABLING TECHNOLOGIES

SHORT-TERM
- Market-ready technologies as currently developed
- New, green processes to obtain A&I components

MID-TERM
- New (green) materials
- New (green) processes

LONG-TERM
- Move industry production from SMEs (low batch sizes) to large companies (large production runs) increasing availability

RESOURCES

SHORT-TERM
- Production facility
- Process knowledge
- Green chemistry knowledge
- Legislation

MID-TERM
- Knowledge and Technology transfer from science to industry

LONG-TERM
- Knowledge and Technology transfer from small industry to large industry

PACKAGING PRODUCER

SOLUTIONS

SHORT-TERM

- Increase shelf life to reduce food waste
- Packaging improvement
- Packaging interaction with the consumers
- Raise awareness of packers/ brand owners
- Educational strategies for packers/brand owners

MID-TERM

- Tax food waste
- Simplify legislation

LONG-TERM

- More strict legislation about food and packaging safety

MARKET DRIVERS

Sustainable goes mainstream
- Replacement of aluminium
- Transition towards bio-based and 100% recyclable
- Bio-degradability
- Natural (health, responsible living)
- Extending shelf life = less food loss/waste
- Lightweight: optimisation of material

E-commerce
- Online food suppliers
- Technological development
- Integration of A&I components in roll-to-roll processes, e.g. embedding electronics, sensors, actuators and software during or after the production process.

Legislation
- Legislation under development

The internet-of-things
- On request of the packer to follow up the condition of his products;
- On request of the brand owner who wants to interact with the consumer via the packaging, etc.

RESOURCES

SHORT-TERM

- Multidisciplinary approach
- LCA
- Specific treatment after-life packaging
- Legislation

MID-TERM

- Knowledge and Technology transfer from science to industry

LONG-TERM

- Knowledge and Technology transfer from small industry to large industry

ENABLING TECHNOLOGIES

SHORT-TERM

- Market-ready technologies as currently developed
- New, green processes to integrate A&I

MID-TERM

- New (green) materials
- Flexible processes

LONG-TERM

- Optimised and flexible production processes capable to match all ranges of needs (also lower batch sizes)

PACKER / BRAND OWNER

SOLUTIONS

SHORT-TERM

- Create awareness
- Identification of market-ready technologies
- Build business cases to identify market opportunities
- Flexible risk assessment methods for compliance

MID-TERM

- Cooperation with academic society
- Government funding
- Database of market ready technologies
- media promotion of AIP

LONG-TERM

- Cooperation with academic society
- Government funding
- Database of market ready technologies
- Media promotion of AIP
- More strict legislation about food and packaging safety

MARKET DRIVERS

Sustainable goes mainstream
- Enter the circular economy
- Extending shelf life = less food loss/waste
- Lightweight: optimisation of material
- Reuse of packaging or recycling possibilities
- Food without artificial preservatives (cosmetics, pharma)

Competitive value
- Emerging of new products
- Higher value products
- Trademark
- Customer demands certain packaging solutions (regarding safety) which gives additional value to the product, decreasing cost and food waste

Production
- Lower costs = higher volume
- Profit
- Increasing demand on AIP decreases costs

E-commerce / the internet-of-things
- Online food suppliers
- Sustained growth upcoming years gives opportunities

Personalisation
- Personal connections
- Use of big data for connection with customer

RESOURCES

SHORT-TERM

- Investments to modify the existing production process
- Raise awareness to resolve investment decisions
- Raise awareness of the technologies in the whole value chain
- Raise awareness of the food waste issue and find strategic partners

MID-TERM

- Social media promotions

LONG-TERM

- Integration with other industries and services to create Smart Homes

ENABLING TECHNOLOGIES

SHORT-TERM

- Market-ready technologies as currently developed
- New, green processes to integrate A&I

MID-TERM

- Upgraded sensors
- Smart shops
- Smart household equipment

LONG-TERM

- Smart houses and household devices
- Digitalisation
- Technologies for IoT and resources

RETAILER

MARKET DRIVERS

Benefits
- Awareness of increased profit
- Motivate retailers (big players) to adapt AIP to their own advantage, not focusing on consumers
- Reduce AIP costs
- Reduce waste of food/perishable items

Retail spaces become brand experience spaces
- Online and real-world shopping ecosystems are merging

Consumer behaviour
- Assumption: no change in consumer behaviour or regulation in next 5-10 years

E-commerce / the internet-of-things
- Online food suppliers
- Sustained growth upcoming years gives opportunities

SOLUTIONS

SHORT-TERM
- Communication to customers in-store
- Get feedback from consumers
- Train employees
- Prove practical application through usefulness
- Make strategies specific for target groups
- Create trends in AIP
- Lobby for support from related industry groups

MID-TERM
- Willingness to pay for AIP by the consumer
- Easy and clear communication
- Consumer perception
- Consumer interaction
- Keep up with consumer trends

LONG-TERM
- Reduce food waste and food spoilage
- ensure storage conditions cold chain
- ensure quality and safety of food product and package

ENABLING TECHNOLOGIES

SHORT-TERM
- Integration with new non-packaging technologies (AR, smart fridges, shopping via Alexa, ...)
- Determine the need for staff >> training plan

MID-TERM
- Specific packaging for different consumers i.e. disabled people
- Communication / dissemination activities

LONG-TERM
- Integration of smart houses and smart packaging: the house works for you; food scanned, app telling when your food is spoiled (continuous tracking) or when perfect to eat

RESOURCES

SHORT-TERM
- Trained staff
- Prepared stores (shelfing, special space and place)
- Communication measures
- ROI matrix to explain the change in sales

MID-TERM
- New electronics to support AIP retail

LONG-TERM
- Integration with other industries and services to create Smart Homes

CONSUMER / END USER

MARKET DRIVERS

Sustainable goes mainstream
- Consumers become more aware of the environmental cost of modern conveniences like one-time use packaging
- Driven by convenience, cost, availability (most consumers)

Gen-Z
- This generation (1995-2018) are considered digital natives and are now getting jobs and income creating a new market and generation of consumer

Changing consumer needs
- Different consumer needs of gen-X and gen-Z
- Early adopters of AIP technologies
- Ageing population needs

Engagement
- Micro-influencers
- Videos
- Social media = transparency, always connected
- Activism: food waste prevention, health and nutrition sustainability

Hi-tech
- Consumers embrace virtual entertainment industry, now trend moves on to other areas

Adversity
- There will always be consumers against technology

SOLUTIONS

SHORT-TERM
- Educate customers about AIP
- Latest concern or food scare does not stay in consciousness for long
- Inform via advertising / social media
- Start using AIP in common products and with big brands

MID-TERM
- Engage early adopters in educational campaigns
- Tailoring AIP for packaging and consumer needs

LONG-TERM
- Discounts for pre/early shopping online (better planning >> better prices)
- Rewards for sustainable buyer behaviour (food and material waste reduction)

ENABLING TECHNOLOGIES

SHORT-TERM
- Social media advertising
- Mobile phone interaction with labelling

MID-TERM
- New communication channels

LONG-TERM
- Target next generation (instead of traditional) in shops and innovation
- Price of AIP comparable to conventional products
- Good recyclability of AIP
- Afraid of being manipulated by producers or retailers

RESOURCES

SHORT-TERM
- Home deliveries with amazon
- Kids are nowadays decision makers regarding what to buy
- Information campaign about products, food waste, new technologies
- Social media, videos to spread information

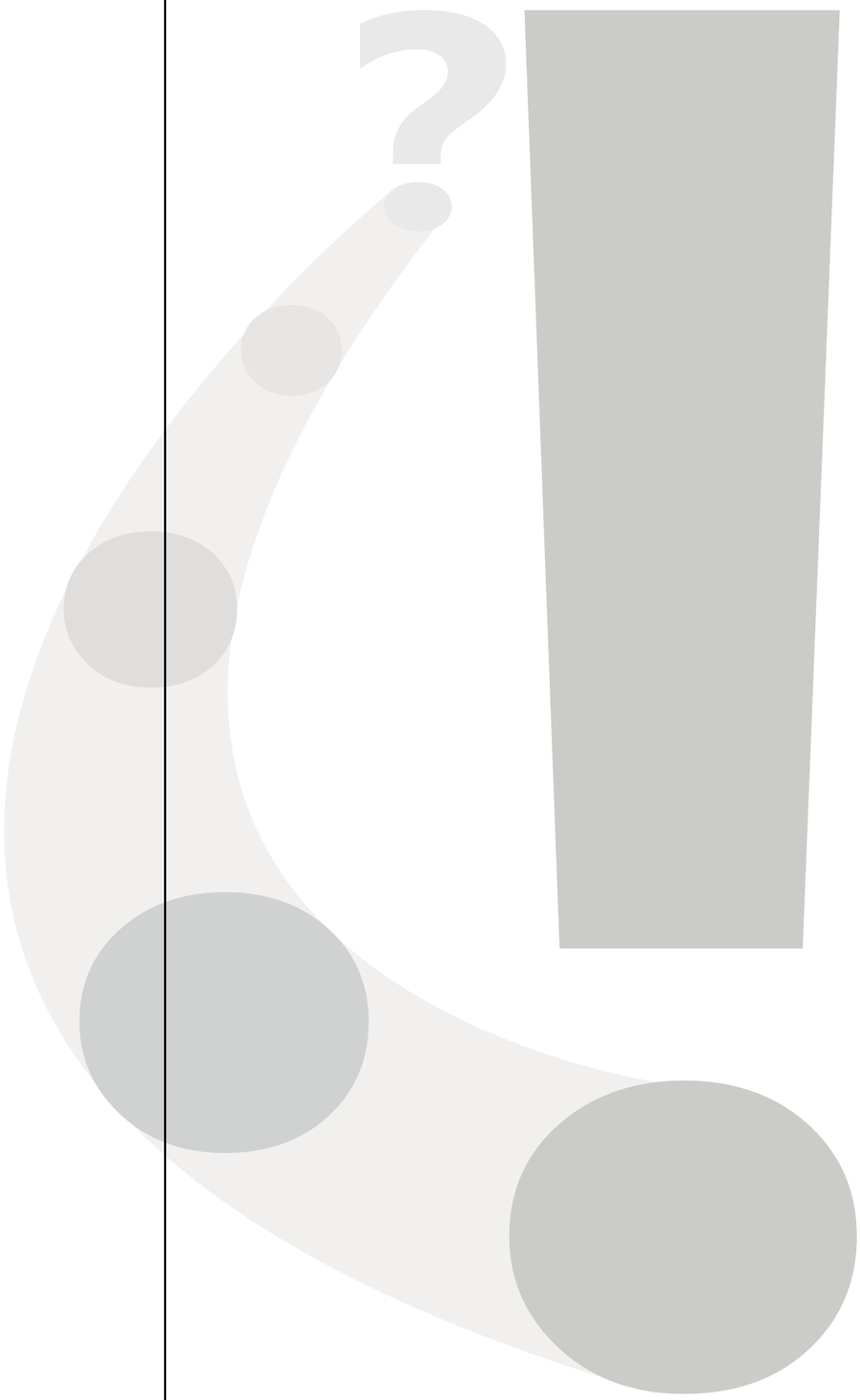
MID-TERM
- Influencers, e.g. bloggers

LONG-TERM
- Strategic partnerships

Sustainability roadmap was done with contribution of the WG2 members of the Cost Action "ActInpak" and with major contributions from

Greg Ganczewski

ROADMAPS
SUSTAINABILITY



SUSTAINABILITY CHALLENGES

A&I COMPONENT PRODUCER

- Health and safety issues of A&I components
- Reliability from sustainability perspective
- Impact assessment data availability for components

PACKAGING PRODUCER

- How additional processes required to integrate A&I components into packaging impact sustainability (higher temperatures, Surface treatment)
- Processing impact assessment data availability

PACKER/BRAND OWNER

- Interaction with food – health and safety
- Extra processing steps – environmental impacts

RETAILER

- Stability of active packaging from sustainability perspective
- Different processes in logistics
- Impact of additional investements in infrastructure from sustainability perspective

CONSUMER/END USER

- End of life
- Recyclability
- Energy recovery
- Compostability/Bioegradability
- Recovery of the active component
- Long term impact
- Environmental impact
- Impact assessment data availability

A&I COMPONENT PRODUCER

MARKET DRIVERS

- Sustainability as a market trend
- Legislation is reflecting sustainability
- Production costs of A&I are high
- Trends in increasing safety and quality of products

ENABLING TECHNOLOGIES

- LCA in its current state of methodology
- SLCA in its current state of methodology
- Lab scale research on A&I components and its interactions
- Green chemistry solutions – biobased plastics (Green-PE, Green-PET etc)

RESOURCES

- Materials producers and suppliers cooperation
- EU research grants for development of new materials
- Lobbying for clear A&I legislation
- Research into materials and processes inputs, outputs and emissions for LCA and SLCA data
- Development of new data collection standard for LCA
- Current LCA software

SOLUTIONS

SHORT-TERM

- Development of clear legislation relevant to A&I packaging and food waste
- Development of LCA methodology
- Development of impact assessment databases for more packaging materials and food products
- Development of new A&I solutions

MID-TERM

- New renewable resources development
- Optimisation of production of A&I components
- Development of Social LCA methodology
- Shift from plastic-based to bio-based solutions
- Clear EU strategy on packaging sustainability issues

LONG-TERM

- New renewable resources development
- Development of unified LCA methodology (environmental, social and economic LCA)

PACKAGING PRODUCER

MARKET DRIVERS

- Sustainability as a market trend
- Legislation is reflecting sustainability
- Packaging industry is slow in change

ENABLING TECHNOLOGIES

- LCA in its current state of methodology
- SLCA in its current state of methodology
- Lab scale research on A&I integration in packaging and its interactions
- Implementing optimisation schemes

RESOURCES

- Materials producers and suppliers processing instructions
- Machinery for applying A&I solutions in packaging
- Research of processes inputs, outputs and emissions for LCA and SLCA data of processing step
- Development of new data collection standard for LCA
- Packaging testing – food contact approval – migration, organoleptic testing
- Current LCA software

SOLUTIONS

SHORT-TERM

- Development of clear legislation relevant to A&I packaging and food waste
- Development of LCA methodology
- Use of natural based food additives – EFSA approved
- Good practice guides

MID-TERM

- Optimisation of A&I processing
- Bridge research with industry and distributors
- Development of Social LCA methodology
- Clear EU strategy on packaging sustainability issues

LONG-TERM

- New renewable resources development
- Development of unified LCA methodology (environmental, social and economic LCA)

PACKER / BRAND OWNER

MARKET DRIVERS

- Sustainability as a market trend
- Legislation is reflecting sustainability
- Trends in increasing safety and quality of products
- Personalization

ENABLING TECHNOLOGIES

- LCA in its current state of methodology
- SLCA in its current state of methodology
- Lab scale research on A&I influence on packed products
- Implementing optimisation schemes in packaging processes

RESOURCES

- Packaging machines producers and suppliers
- EU research grants for optimisation
- Research into materials and processes inputs, outputs and emissions for LCA and SLCA data for packaging step
- Development of new data collection standard for LCA
- Implementing Big Data methods and tools – analysing production
- Current LCA software

SOLUTIONS

SHORT-TERM

- Development of clear legislation relevant to A&I packaging and food safety
- Development of LCA methodology
- Development of impact assessment databases for packaging processes
- Use of biodegradable/compostable/edible materials in packaging
- Use of natural based food additives – EFSA approved

MID-TERM

- Optimisation of packaging processes
- Development of Social LCA methodology
- Shift from plastic-based to bio-based solutions
- Marketing orientation in A&I adoption

LONG-TERM

- Efficient packaging processes developed
- Development of unified LCA methodology (environmental, social and economic LCA)

RETAILER

MARKET DRIVERS

- Product losses
- Legislation is reflecting sustainability
- Packaging industry is slow in change

ENABLING TECHNOLOGIES

- LCA in its current state of methodology
- SLCA in its current state of methodology
- RFID monitoring

RESOURCES

- Lobbying for clear A&I legislation on logistics
- Research into materials and processes inputs, outputs and emissions for LCA and SLCA data for transport and logistics
- Complex combined primary/ secondary/tertiary (transport) packaging testing
- Development of new data collection standard for LCA
- Implementing Big Data methods and tools – analysing logistics
- Current LCA software

SOLUTIONS

SHORT-TERM

- Development of clear legislation relevant to A&I packaging and food waste including logistics
- Development of LCA methodology
- Development of impact assessment databases for logistic processes
- Universal benchmark of logistic options according to LCA

MID-TERM

- Development of Social LCA methodology
- Logistics monitoring technologies
- Quick quality tests

LONG-TERM

- New logistics methods
- Development of unified LCA methodology (environmental, social and economic LCA)

CONSUMER / END USER

MARKET DRIVERS

- Sustainability as a market trend
- Legislation is reflecting sustainability
- Circular economy (A-Z economies)
- Green economy (A-Z economies)
- Policy instruments

ENABLING TECHNOLOGIES

- Lab scale research on recyclability or A&I packaging and components – mechanical separation, chemical separation, physical-chemical separation)
- Compostability tests of A&I packaging (where relevant -> paper and bioplastics)
- Industry scale research on recyclability
- Reuse technologies for A&I components (especially sensors)
- LCA in its current state of methodology to compare end-of-life options
- SLCA in its current state of methodology

RESOURCES

- Lobbying for clear A&I legislation on end-of-life
- EU grants into A&I packaging end-of-life tests
- Recyclability testing
- Social media and education infrastructure (schools, universities etc.)
- Implementing Big Data methods and tools – analysing waste streams
- Biodegradability/compostability testing (where relevant)
- Current LCA software

SOLUTIONS

SHORT-TERM

- Development of clear legislation relevant to A&I packaging and food waste
- Development of LCA methodology
- Development of impact assessment databases for end-of-life processes
- Eco-design guidelines (design for recyclability and end-of-life)
- Education and information to consumers – how to use and how to dispose

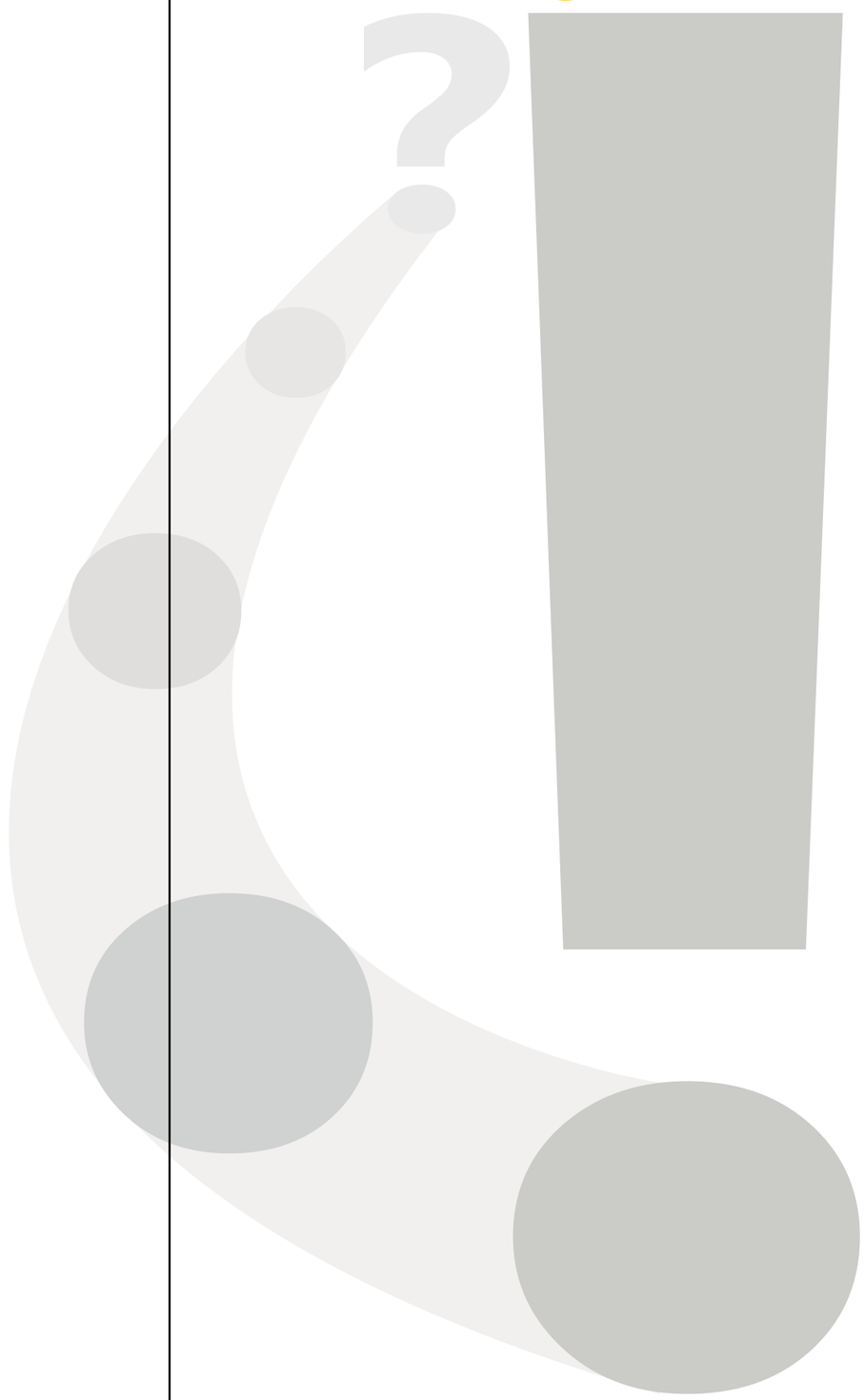
MID-TERM

- New renewable resources development
- Investment in new recycling plants – EU grants
- Development of Social LCA methodology

LONG-TERM

- Development of unified LCA methodology Development and innovation in end-of-life technologies (composting, gasification, Anaerobic digestion)

ROADMAPS
OVERVIEW



TECHNOLOGICAL ACTIVE PACKAGING

	A&I COMPONENT PRODUCER	PACKAGING PRODUCER	PACKER / BRAND OWNER	RETAILER	CONSUMER / END USER
MARKET DRIVERS	Transition towards bio-based and biodegradable active components Trust in functionality of active components	Transition from passive to active packaging Reuse of packaging materials or recycling possibilities Lightweight: optimization of material Flexible production processes	Shelf life extension - less food loss/waste Clean label products Less processed food Application of recycled packaging materials Increasing demand on AP decreases costs Trust in functionality of active packaging	Reduce waste of food/perishable items Increased flexibility in logistics due to longer shelf life	Transition towards bio-based and biodegradable Enter the circular economy Reuse of active packaging materials or recycling possibilities
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	***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	***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	***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	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	Extraction methods at industrial scale Social Media/digitalisation: increase of awareness	Integration processes at industrial scale (e.g. extrusion, lamination, etc.)	Packaging technologies	Monitoring systems Intelligent packaging	LCA tools Social Media/digitalisation: increase of awareness
RESOURCES	Biobased active components Suppliers of active components	Recycled, biobased and biodegradable packaging materials	Packaging machinery	Measurement devices	LCA databases
	For the performance of all the tests and studies required: Funding Staff and knowhow Infrastructure and lab equipment				

TECHNOLOGICAL INTELLIGENT PACKAGING

	MARKET DRIVERS	SOLUTIONS	ENABLING TECHNOLOGIES	PROCESSES	NEEDS AND GAPS	PRODUCTS (VISION)
INTELLIGENT FIBRE-BASED PACKAGING	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	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	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	***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	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	***General*** Packaging becomes an interactive engagement platform with added low-cost/ low-power electronics. ***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 Moving to high performance, low cost, application driven packaging techniques Moving to collective wafer-level-packaging technique standards

SOCIO-ECONOMIC

	A&I COMPONENT PRODUCER	PACKAGING PRODUCER	PACKER / BRAND OWNER	RETAILER	CONSUMER / END USER
CHALLENGES	Dependency Costs versus revenues Availability Legislation	Awareness Costs versus revenues Availability Legislation	Awareness Costs versus revenues Availability Trust in technology Legislation	Awareness Costs versus revenues Transparency Trust in technology Reliability Legislation	Awareness Costs versus revenues Trust in technology Perception Way of communication
MARKET DRIVERS	Sustainable goes mainstream E-commerce Technological development Legislation	Sustainable goes mainstream E-commerce Technological development Legislation The internet-of-things	Sustainable goes mainstream Competitive value Production E-commerce / the internet-of-things Personalisation	Benefits Retail spaces become brand experience spaces Consumer behaviour E-commerce / the internet-of-things	Sustainable goes mainstream Gen-Z Changing consumer needs Engagement Hi-tech Adversity
SHORT TERM (NOW - 2020)	***SOLUTIONS*** Increase shelf-life to reduce food waste Packaging improvement Raise awareness of packaging producers Educational strategies for packaging producers ***ENABLING TECHNOLOGIES*** Market-ready technologies as currently developed New, green processes to obtain A&I components ***RESOURCES*** Production facility Process knowledge Green chemistry knowledge Legislation	***SOLUTIONS*** Increase shelf life to reduce food waste Packaging improvement Packaging interaction with the consumers Raise awareness of packers/brand owners Educational strategies for packers/brand owners ***ENABLING TECHNOLOGIES*** Market-ready technologies as currently developed New, green processes to integrate A&I ***RESOURCES*** Multidisciplinary approach LCA Specific treatment after-life packaging Legislation	***SOLUTIONS*** Create awareness Identification of market-ready technologies Build business cases to identify market opportunities Flexible risk assessment methods for compliance ***ENABLING TECHNOLOGIES*** Market-ready technologies as currently developed New, green processes to integrate A&I ***RESOURCES*** Investments to modify the existing production process Raise awareness to resolve investment decisions Raise awareness of the technologies in the whole value chain Raise awareness of the food waste issue and find strategic partners	***SOLUTIONS*** Communication to customers in-store Get feedback from consumers Train employees Prove practical application through usefulness Make strategies specific for target groups Create trends in AIP Lobby for support from related industry groups ***ENABLING TECHNOLOGIES*** Integration with new non-packaging technologies (AR, smart fridges, shopping via Alexa, ...) Determine the need for staff >> training plan ***RESOURCES*** Trained staff Prepared stores (shelfing, special space and place) Communication measures ROI matrix to explain the change in sales	***SOLUTIONS*** Educate customers about AIP Latest concern or food scare does not stay in consciousness for long Inform via advertising / social media Start using AIP in common products and with big brands ***ENABLING TECHNOLOGIES*** Social media advertising Mobile phone interaction with labelling ***RESOURCES*** Home deliveries with amazon Kids are nowadays decision makers regarding what to buy Information campaign about products, food waste, new technologies Social media, videos to spread information
MID TERM (2020 - 2025)	***SOLUTIONS*** Lower costs due to increased production and technological development List of approved active compounds in packaging Collect more data to get compounds to be approved ***ENABLING TECHNOLOGIES*** New (green) materials New (green) processes ***RESOURCES*** Knowledge and Technology transfer from science to industry	***SOLUTIONS*** Tax food waste Simplify legislation ***ENABLING TECHNOLOGIES*** New (green) materials Flexible processes ***RESOURCES*** Knowledge and Technology transfer from science to industry	***SOLUTIONS*** Cooperation with academic society Government funding Database of market ready technologies media promotion of AIP ***ENABLING TECHNOLOGIES*** Upgraded sensors Smart shops Smart household equipment ***RESOURCES*** Social media promotions	***SOLUTIONS*** Willingness to pay for AIP by the consumer Easy and clear communication Consumer perception Consumer interaction Keep up with consumer trends ***ENABLING TECHNOLOGIES*** Specific packaging for different consumers i.e. disabled people Communication / dissemination activities ***RESOURCES*** New electronics to support AIP retail	***SOLUTIONS*** Engage early adopters in educational campaigns Tailoring AIP for packaging and consumer needs ***ENABLING TECHNOLOGIES*** New communication channels ***RESOURCES*** Influencers, e.g. bloggers
LONG TERM (2025 - 2030)	***SOLUTIONS*** Continuous development of new and safe A&I components for specific purposes High throughput testing technologies Shorter time from application to approval of safety of compounds ***ENABLING TECHNOLOGIES*** Move industry production from SMEs (low batch sizes) to large companies (large production runs) increasing availability ***RESOURCES*** Knowledge and Technology transfer from small industry to large industry	***SOLUTIONS*** More strict legislation about food and packaging safety ***ENABLING TECHNOLOGIES*** Optimised and flexible production processes capable to match all ranges of needs (also lower batch sizes) ***RESOURCES*** Knowledge and Technology transfer from small industry to large industry	***SOLUTIONS*** Cooperation with academic society Government funding Database of market ready technologies Media promotion of AIP More strict legislation about food and packaging safety ***ENABLING TECHNOLOGIES*** Smart houses and household devices Digitalisation Technologies for IoT and resources ***RESOURCES*** Integration with other industries and services to create Smart Homes	***SOLUTIONS*** Reduce food waste and food spoilage ensure storage conditions cold chain ensure quality and safety of food product and package ***ENABLING TECHNOLOGIES*** Integration of smart houses and smart packaging: the house works for you; food scanned, app telling when your food is spoiled (continuous tracking) or when perfect to eat ***RESOURCES*** Integration with other industries and services to create Smart Homes	***SOLUTIONS*** Discounts for pre/early shopping online (better planning >> better prices) Rewards for sustainable buyer behaviour (food and material waste reduction) ***ENABLING TECHNOLOGIES*** Target next generation (instead of traditional) in shops and innovation Price of AIP comparable to conventional products Good recyclability of AIP Afraid of being manipulated by producers or retailers ***RESOURCES*** Strategic partnerships

SUSTAINABILITY

	A&I COMPONENT PRODUCER	PACKAGING PRODUCER	PACKER / BRAND OWNER	RETAILER	CONSUMER / END USER
CHALLENGES	Health and Safety Reliability Impact assessment data availability	Impact of additional processes Processing impact assessment data availability	Food contact – Health and Safety Environmental impacts of processing	Stability New processes in Logistics Impact of additional investment in infrastructure	Recyclability Energy recovery Biodegradability/Compostability Recovery of A&I components Short term and long term impacts Impact assessment data availability
MARKET DRIVERS	Sustainability as a market trend Legislation is reflecting sustainability Production costs of A&I are high Trends in increasing safety and quality of products	Sustainability as a market trend Legislation is reflecting sustainability Packaging industry is slow in change	Sustainability as a market trend Legislation is reflecting sustainability Trends in increasing safety and quality of products Personalization	Product losses Legislation is reflecting sustainability Packaging industry is slow in change	Sustainability as a market trend Legislation is reflecting sustainability Circular economy (A-Z economies) Green economy (A-Z economies) Policy instruments
SOLUTIONS	***SHORT TERM*** Development of clear legislation relevant to A&I packaging and food waste Development of LCA methodology Development of impact assessment databases for more packaging materials and food products Development of new A&I solutions ***MEDIUM TERM*** New renewable resources development Optimisation of production of A&I components Development of Social LCA methodology Shift from plastic-based to bio-based solutions Clear EU strategy on packaging sustainability issues ***LONG TERM*** New renewable resources development Development of unified LCA methodology (environmental, social and economic LCA)	***SHORT TERM*** Development of clear legislation relevant to A&I packaging and food waste Development of LCA methodology Use of natural based food additives – EFSA approved Good practice guides ***MEDIUM TERM*** Optimisation of A&I processing Bridge research with industry and distributors Development of Social LCA methodology Clear EU strategy on packaging sustainability issues ***LONG TERM*** New renewable resOurces development Development of unified LCA methodology (environmental, social and economic LCA)	***SHORT TERM*** Development of clear legislation relevant to A&I packaging and food safety Development of LCA methodology Development of impact assessment databases for packaging processes Use of biodegradable/compostable/edible materials in packaging Use of natural based food additives – EFSA approved ***MEDIUM TERM*** Optimisation of packaging processes Development of Social LCA methodology Shift from plastic-based to bio-based solutions Marketing orientation in A&I adoption ***LONG TERM*** Efficient packaging processes developed Development of unified LCA methodology (environmental, social and economic LCA)	***SHORT TERM*** Development of clear legislation relevant to A&I packaging and food waste including logistics Development of LCA methodology Development of impact assessment databases for logistic processes Universal benchmark of logistic options according to LCA ***MEDIUM TERM*** Development of Social LCA methodology Logistics monitoring technologies Quick quality tests ***LONG TERM*** New logistics methods Development of unified LCA methodology (environmental, social and economic LCA)	***SHORT TERM*** Development of clear legislation relevant to A&I packaging and food waste Development of LCA methodology Development of impact assessment databases for end-of-life processes Eco-design guidelines (design for recyclability and end-of-life) Education and information to consumers – how to use and how to dispose ***MEDIUM TERM*** New renewable resources development Investment in new recycling plants – EU grants Development of Social LCA methodology ***LONG TERM*** Development of unified LCA methodology Development and innovation in end-of-life technologies (composting, gasification, Anaerobic digestion)
ENABLING TECHNOLOGIES	LCA in its current state of methodology SLCA in its current state of methodology Lab scale research on A&I components and its interactions Green chemistry solutions – biobased plastics (Green-PE, Green-PET etc)	LCA in its current state of methodology SLCA in its current state of methodology Lab scale research on A&I integration in packaging and its interactions Implementing optimisation schemes	LCA in its current state of methodology SLCA in its current state of methodology Lab scale research on A&I influence on packed products Implementing optimisation schemes in packaging processes	LCA in its current state of methodology SLCA in its current state of methodology RFID monitoring	Lab scale research on recyclability or A&I packaging and components – mechanical separation, chemical separation, physical-chemical separation) Compostability tests of A&I packaging (where relevant -> paper and bioplastics) Industry scale research on recyclability Reuse technologies for A&I components (especially sensors) LCA in its current state of methodology to compare end-of-life options SLCA in its current state of methodology
RESOURCES	Materials producers and suppliers cooperation EU research grants for development of new materials Lobbying for clear A&I legislation Research into materials and processes inputs, outputs and emissions for LCA and SLCA data Development of new data collection standard for LCA Current LCA software	Materials producers and suppliers processing instructions Machinery for applying A&I solutions in packaging Research of processes inputs, outputs and emissions for LCA and SLCA data of processing step Development of new data collection standard for LCA Packaging testing – food contact approval – migration, organoleptic testing Current LCA software	Packaging machines producers and suppliers EU research grants for optimisation Research into materials and processes inputs, outputs and emissions for LCA and SLCA data for packaging step Development of new data collection standard for LCA Implementing Big Data methods and tools – analysing production Current LCA software	Lobbying for clear A&I legislation on logistics Research into materials and processes inputs, outputs and emissions for LCA and SLCA data for transport and logistics Complex combined primary/secondary/tertiary (transport) packaging testing Development of new data collection standard for LCA Implementing Big Data methods and tools – analysing logistics Current LCA software	Lobbying for clear A&I legislation on end-of-life EU grants into A&I packaging end-of-life tests Recyclability testing Social media and education infrastructure (schools, universities etc.) Implementing Big Data methods and tools – analysing waste streams Biodegradability/compostability testing (where relevant) Current LCA software

March 2019

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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EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

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