TEAGASC TECHNOLOGY FORESIGHT
Workshop No. 5: Vision and Next Steps

The Castleknock Hotel and Country Club, Dublin, December 17th 2015

The Purpose of this Workshop

We are now in the final phase of the TTF2030 initiative. The goal of this workshop is to:

- Agree a vision for how technology will have transformed the Irish agri-food and bio-economy sector by 2030 and
- Describe the research, innovation, training and development actions that Teagasc and its partners must immediately implement so as to drive the realisation of this vision.

So far in TTF2030, we have completed the following activities:

- Nine TCWG papers, providing an **inventory of new and emerging technologies** of relevance for the Irish agri-food and bio-economy sectors and the challenges they will help to address,
- A workshop to identify **breakthrough technologies** that will play a key role in lifting the sector to a new level of performance; FW1 held in Dublin on June 29th 2015,
- A **sense-making** workshop, FW2 held in Dublin on the July 31st 2015, to understand the relationship between these breakthrough technologies and the systems in which they must be embedded if they are to succeed in bringing about this transformation,
- The development of **preliminary scenarios** to explore in detail what this technology-driven transformation will mean, at FW3 held in Dublin on September 17th 2015,
- A **deep-dive** workshop, FW4 held in Dublin on October 16th 2015, to understand the complexity hiding in these scenarios and the full story of how these new breakthrough technologies need to work together in systems to support new research programs and the provision of new services.

In today's workshop we need to synthesize the insights gained over the last year, in terms of a series of **visions for technology driven transformation**, along with the **next steps needed** to make them happen.

The focus will be on actions that can be immediately embedded in ongoing programs, including the development of roadmaps, to guide the work of Teagasc and its partners for the coming 10 to 15 years.

The Need for Transformation and Systemic Change

The "Food Wise 2025" report published in July 2015 sets out the ambitions for growth of the Irish agri-food industry for the coming decade. Although many of the actions needed to help industry achieve these goals are already in place and are being implemented by Teagasc and its partners, the scale of ambition in Food Wise 2025 creates a number of significant challenges for the entire agri-food sector and the wider rural economy, in particular for the production of milk and beef.

There is little doubt that industry will succeed in opening up and expanding markets to the extent envisioned by Food Wise 2025. The real challenge will be to do this in a manner that meets our obligations in terms of compliance with environmental and climate change legislation, while satisfying the increasing demands of global consumers. The intensification of Irish agri-food to which Food Wise 2025 aspires can only be achieved if accompanied by intensification in the provision of public goods and services needed to comply with environmental and climate policies and other criteria dictated by global consumers.

Just as importantly, the ambitions of the agri-food sector must be achieved in ways that improve the prosperity of Irish farms and rural economies, notably by placing agriculture at the centre of an expanding and increasingly circular[1] bio-economy that includes not only farming and tourism, but forestry and fisheries, horticulture, aquaculture, , energy and fuel, chemicals, textiles and construction, as well as the provision of ecological and environmental goods and services. This, in turn, will rely on the further development of rural regions in ways that encourage private investment in an expanding and increasingly circular bio-economy that embeds farming and food production as key components of bio-economic value chains.

In responding to these growing market opportunities, Ireland can benefit from the technology revolution currently underway. Breakthroughs in nutrition, genetics, informatics, remote sensing, precision farming and low impact agriculture, among others, can further improve livestock and crop yields while reducing their environmental impact.

Policy makers and scientists agree that the world cannot adopt a "business-as-usual" approach in producing the additional food needed by a growing and increasingly wealthy world population. Producers will need to modify their methods in a way that will not further degrade the environment nor compromise the world's capacity to produce food in the future. It will also be critical to tackle waste and consumption distribution. These challenges are as relevant to Ireland as elsewhere-and possibly even more so, given the country's positioning in the marketplace as a producer of premium quality, "clean, green" food.

This means that Ireland will have to focus on options for increasing farm-level productivity and efficiency and ensuring environmental sustainability through greater resource efficiency. Increasing the emphasis on resource efficiency so that more can be produced over time with fewer inputs will contribute to both productivity and sustainability, help increase the viability of agriculture and reduce Ireland's global environmental footprint.

The term "sustainable intensification" is often used in referring to the production of more food from a fixed or slightly declining land area, while reducing environmental impacts and respecting social and economic priorities. A core principle of sustainable intensification is that it is dependent on the ***greater application of knowledge per hectare***. Accordingly, the intensification of Irish agriculture will not be mainly concerned with the use of more fertilizers, pesticides or machinery applied per hectare, but with the practice of much more knowledge intensive management of scarce resources to produce food and environmental outputs with minimal disturbance to the natural environment.

Multiple approaches will be required in implementing sustainable intensification, including the adaptation of existing farming techniques, the development of completely new production systems

[1] The "circular economy" is one of the most important current models for development of sustainable economies based on local clusters of industries where waste from one becomes the raw material for another.

and the creation of novel approaches to crop and livestock genetic improvement. Underlying all of these new approaches will be a requirement for greater effectiveness in anticipating new challenges and in modeling potential solutions based on a greatly enhanced data analytical capacity.

There are two fundamental pathways by which sustainable productivity growth in farming can be achieved:

- Developing, adapting and applying new technologies and practices for agricultural production and farm management, and by
- Increasing and accelerating the more widespread adoption and application of existing technologies and practices.

The first pathway enhances the potential for more productive use of resources by expanding the frontier of production possibilities. The second enables farmers to gain more of this potential growth by advancing towards the existing production possibilities frontier, i.e. closing the yield gap.

The principal focus of Teagasc Technology Foresight 2030 and of today's workshop is on the first of these two pathways, namely on how new technologies and practices can support Irish agriculture to achieve greater productivity while meeting the many current and future environmental and other challenges.

These are the challenges to which Teagasc must respond. Meeting these challenges will require the mobilisation of resources for research, innovation and economic development, involving many partners across the spectrum of actors, not only in agri-food , but also in areas where cooperation has only recently started to intensify, such as ICT and sensor technologies.

The motivation for this Teagasc Technology Foresight initiative has been to take stock of the new and emerging technologies that will leverage and amplify our on-going efforts in the core disciplines of breeding, animal husbandry and veterinary science, pasture and crop science, soil science, economics and the study of local eco-systems, needed not only to address the significant challenges implied by Food Wise 2025 , but the concurrent challenge of developing new bioeconomy sectors that ensure favourable framework conditions for the development of a vibrant agri-food sector, by embedding it in the value chains of a new, emerging and circular bio-economy.

The world is experiencing a spate of disruptive innovation from rapidly accelerating scientific discoveries and new technologies. These are causing fundamental shifts in our economic landscape and introducing new risks and opportunities for the economy, the environment and society. Advances in big data, 3D printing, artificial intelligence, robotics, nanotechnology and biotechnology are already altering existing economic systems and business models. Each of these core technologies is also reinforcing and expediting the development of the others, leading to an even faster pace of change.

These technologies will ultimately impact almost every sector of the economy, including agri-food and the bioeconomy sector. Ireland cannot disregard nor minimize the potential rate and extent of change resulting from these technologies, including in agri-food. To do so, could very well threaten our future competitiveness, preparedness and resilience. Instead, in agri-food, we must be clear as a nation as to what our vision is for the sector; how some or all of the many new technologies discussed in the foresight process could help achieve that vision and what policies and strategies will support the use of those technologies.

Developing more sustainable and resilient food production systems will require the inputs of many of the generic technologies discussed above. It will also need the identification and active dissemination of current best practice and accumulated knowledge, as well as the further refinement of those practices.

The importance of bringing together the new technologies with longer-established agricultural technologies and practices can be illustrated in many areas. The concept of Precision Agriculture, for example, involves the application of many rapidly developing technologies; however, unless these are linked with the complex biological processes involved in the production of crops and animals, the gain achieved will be limited.

Similarly, to ensure sustainable productive capacity, a key resource which must be protected and requires specific consideration in agricultural production, is the soil. A greater understanding of the functioning of the soil and the impacts of management such as soil cultivation, intensive annual cropping and compaction from animals and machines, illustrates the need to mobilise and focus the technologies discussed in this document onto a complex but key resource on which agriculture's production depends.

Farmers must rise to this challenge by adapting their farming systems to meet changing circumstances, taking up established and new technologies and practices as necessary to provide the best mix of outputs with minimum use of non-renewable inputs. Adapting their farming systems may also include the enhanced use of local and natural resources, promoting ecological resilience and identifying and enhancing the provision of ecosystem products and services.

Another critical issue, particularly in the context of Irish agriculture, is the need to ensure the more universal uptake of existing technologies and practices. In a farming context in which many farmers, particularly in the beef and sheep sectors, do not employ existing best practices on their farms, the question could reasonably be posed as to the relevance of futuristic technologies in general in an Irish farming context.

While this is a reasonable question to raise on the basis of the evidence to date, many new challenges are now coming into play which suggest that technology will have to be more widely adopted in future across all types of Irish farms. We are facing into a new era of global competition and new demands, both market and regulatory, which will create a new context for Irish farmers.

Accordingly, Irish policy makers, scientists, farmers, food processors and consumers need to prepare for future technology. To do this well, they will need a clear understanding of how technology might shape the global economy and society, as well as their own sector, over the coming decades. They will need to decide how to invest in new forms of education and infrastructure, and figure out how disruptive economic change will affect comparative advantages.

The scale of transformation required for ensuring delivery on the ambitions of Food Wise 2025 and the longer term development of the agri-food sector and bioeconomy can't be achieved on an incremental basis, using simple drop-in technology components. It requires the phased introduction of a whole new set of knowledge and data intensive systems for research and service provision. To ensure the completion of this transformation by 2030, Teagasc will start today by laying out its vision for the transformation that is needed by then, the technology that will underpin this transformation and the immediate steps that it will take to make it happen based on its existing programs.

The Morning Session: Validation of the Vision

A “vision” is a generic management tool that drives the important and often exceptional undertakings of an organisation. It is a guide for planners and program managers that need to break away from established routines to embark upon new trajectories. It enables the coordination of actions that span the boundaries of organisations and disciplines. It helps higher level managers identify gaps in the strategy portfolio.

A vision that is “fit for purpose” must have several important qualities:

- It must be **CREDIBLE**. In our case, for example, it must inspire hope that the goals laid out in documents such as Food Wise are achievable.
- It must be **AMBITIOUS** and **EXCITING,** because it has to mobilize a large number of creative people from a wide range of disciplines who will focus their energies and resources on the problems that need to be solved to realise the vision. It must also motivate the partnerships needed to achieve its ambitious goals.

We already have key elements of the vision for TTF2030. We can assume that by 2030 Ireland will have achieved and surpassed the growth ambitions set out in Food Wise 2025. This growth will have been enabled by ensuring that the sector as a whole complies with climate change and environmental legislation and adopts auditable practises that respond to the expectations of increasingly demanding global consumers.

This (or some variation on this) is the “what” part of the overall vision. It is in effect the preamble to the “how” part of the TTF vision, the part that interests us, because it explains the role that technology will play It will help guide and structure the research and innovation strategies of Teagasc and its partners in the coming years.

Based on the progress made in the four workshops held so far, it appears most likely that breakthroughs in a small number of general areas of technology will drive major changes in the agri-food and bioeconomy sectors over the next two decades. These are summarised in the five “proto-visions” below.

They are provided as inputs to four breakout working group sessions to be held in the course of the morning. The animators of these sessions are asked to develop and improve these visions. Ideally, they will have worked on this before the workshop and will have an improved text from which to work.

Proto-Vision 1: ***The prosperity of farm business is transformed for the better. This transformation is driven in part by increasing levels of adoption of modern agri-food production models and management practices, in all sectors but especially in the beef and dairy. It is also driven by the realization of other income streams from the participation of farms in the supply chains of an increasingly competitive circular bio-economy that produces both public and private goods and services.***

Wide-scale adoption of existing technologies (which themselves will be improving) and new sensor and cloud-based technologies will enable next-generation farm management systems that support QA programs such as Origin Green and the payment of fees rather than subsidies for the provision of public goods and services.

Farm revenues are diversified by the development of a circular economy that integrate agri-food production with a more diverse agri-food, feed and forestry sector, and supply chain networks that include actors involved in aquaculture, energy, recycling and biomass conversion.

This is supported by the completion of smart grid and micro-grid systems for the distribution of electricity and natural gas, as well as systems to simplify the logistics involved in the recycling of organic waste from farming and forestry, the processing of food and wood, from other industries as well as from restaurants, hotels, food service companies and domestic households.

It is supported by pro-active public procurement policies the emergence of increasingly sophisticated systems for the trading of carbon and green house gas emissions at regional, national and European levels

New actors will enter the sector: for example, people in their fifties who grew up on farms but have only now have an opportunity to engage in the profession, as well as young people with backgrounds in IT and engineering as well as the natural sciences, but with no real relationship to the land, but an interest in food, nature and the environment, and who see in agri-food and bioeconomy, an opportunity for entrepreneurial endeavor.

Proto-Vision 2: ***The productivity and competitiveness of Irish agri-food production is transformed by the application of automation, robotics and precision agriculture driven by 20 years of rapid progress in the development of sensors, big data, data-analytics and the Internet of Farm Things.***

The sector is enabled by rapidly maturing and increasingly affordable technologies for precision agriculture and the application of automation in the farming and food processing sectors. These low cost technologies enable the data intensification and automation of tasks such as milking, herd management, feeding, and identification of heat, surveying crops and yield management, weed and plant disease management, as well as the simplification and automation of administration and reporting. High resolution weather forecasting will be an integral part of decision making, and decision support systems will incorporate multiple layers of information on individual fields and animals, some of which will br dynamic and captured in real time. Data analytics will be widely used to provide sensible decision support from this information or to make decisions for automated processes.

We will see the large-scale adoption of automation based on sensor-rich, data intensive systems using nanotechnologies, IoT and IoFT systems, as well as drones, autonomous vehicles, tractor-based sensing and micro-satellite deployments. These must be highly usable and affordable as a prerequisite for large scale adoption, even by small farmers.

The previously low rates of first generation precision farming techniques, the use of milking robots and the adoption of B2B, B2C and B2G applications of e-commerce have been largely overcome. Ireland now has one of the highest rates of adoption of these technologies in the world, which will give a competitive advantage to the Irish agri-food industry.

This has been driven as much by innovation in terms of creative new business and service models making adoption of these technologies, simple, easy and affordable, as much as by advances in technology itself.

Progress has been accelerated by the participation of large numbers of end-users in test-beds or innovation platforms using a citizen-science or citizen-innovation approach to product and service development.

Proto-Vision 3: ***A high degree of sustainable intensification has been achieved, especially in the beef and dairy sector, based on the introduction of a new breeding system enabled by the large scale application of high-speed low-cost next generation sequencing technologies along with advanced breeding techniques, and systems for the continuous monitoring of performance.***

The system is best described as a "system of systems". It generates actionable insights to drive the decision-making of farmers and food producers concerning breeding, nutrition and whole system optimization by combining systemic, genetic and performance data of consumers and the products they consume, the animals and plants from which they are derived, as well as the production systems in which they are produced. (This is linked to Proto-Vision 2).

These systems enable the development of breeds of cattle for beef and dairy, simultaneously optimized for performance measured in terms of environmental, commercial, and market based criteria. This allows farmers to simultaneously reduce the emissions of their herds, while improving feed conversion and pricing of the animal based on the quality of its milk or meat. These systems rely on the automatic sequencing of animals at birth, as well as on the continuous or quasi real-time capture of performance data from animals in terms of their diet, their yield, their susceptibility to disease and tolerance of adverse weather conditions, and their compatibility with on-farm automation. These new breeding systems will employ a variety of techniques including traditional breeding, sexed semen, cisgenics and gene-editing, and they will apply not only to dairy and beef, but also to the pigs, sheep and poultry.

A similar strategy will apply to the development of new plant varieties that will be simultaneously optimized for high growth, high nutrient value, nitrogen capture and abiotic stress tolerance. These strategies will apply also to pastures, with a view optimizing varieties of pasture grasses and sward mix.. This will build upon a global search for new crop and pasture grass varieties, the routine sampling of indigenous varieties, and the comparison of genetic make-up with performance tracked in terms of growth and nutrient needs in the field (or in the greenhouse), as well as their nutrient value to humans and animals. They will employ a variety of new techniques including cisgenics and gene editing as well as small chromosome technologies, chromosome stacking and RNAi spraying for the just-in-time local-adaption of varieties to changing climate conditions.

Advisory and other knowledge based services provided to farmers will support the gathering of farm, animal and plant specific genetic data as well as the deployment of on-farm performance monitoring technologies. It will provide actionable support to farmers in terms of options for the breed + plant variety + feed choices, as well as the soil + climate + crop + nutrient combinations, required for obtaining excellent results from a next generation data-driven farm-based business.

Proto-Vision ***4: In 2030, the application of science and technology to the understanding and management of micro-biota and the environments they inhabit will enable us to better address a number of challenges of great importance for the agri-food and greater bioeconomy sectors.***

These challenges include:

- The development of new food concepts that will have a positive impact on human nutrition, health and well-being, in particular, new food concepts adapted to the biology of individuals, their age and genetic make-up as well as their life-style requirements. This includes new nutrition concepts and food products that address issues related to allergies, food intolerances, the challenge of healthy ageing and the increase of diet and life-style related non-transmissible diseases. This will rely on improvements in understanding the human digestive system, flora of the human gut and their role in digestion, general health, the feeling of satisfaction and satiety as well as mood. New and emerging technologies that will accelerate and amplify the progress already being made in areas such as proteomics and metabolomics, include whole biome sequencing, 3D printed organs and organelles, lab-on-a-chip and organ-on-chip technologies, the use of wearable sensors and life-logging technologies by consumers, and their use of social media to participate in consumer-driven science and innovation initiatives.
- The development of new feed and animal nutrition models as well as related services, based on a deeper understanding of the role of micro-biota that inhabit the digestive systems of farm animals. This will help to improve the efficiency of feed conversion and the reduction of GHG emissions, not to mention the general health and well-being of the animal. As above, progress will be driven by new and emerging technologies that include biome-sequencing, 3D printed organs and organelles, lab-on-a-chip and organ-on-chip technologies as well as the use of implantable and wearable sensors in animals. It will leverage performance data made available by on-farm IoFT deployments as well as data from the systematic sequencing of farm animals.
- The development of new pasture- and crop-management models and services based on a deeper understanding of soil biota and their role in production, water quality and emissions management, nitrogen and carbon capture, plant nutrition and disease management. This means understanding interactions between insects, fungi, bacteria and other micro-organisms with moisture, soil structure and chemistry, and their role in plant and field performance. As above, these will be enabled by rapid advances in biome sequencing. Challenges exist in terms of obtaining performance data, in terms of comprehensive soil sampling and the collection of location specific performance data.
- The development of new bio-reactor technologies and concepts to improve the performance and yield of bio-reactors and, the ability to integrate higher value-added parts of chemical and fuel supply chains. This will benefit from the application of technologies for whole biome sequencing, improvements in sensing technologies to provide more dynamic performance data, lab-on-a chip technologies and synthetic biology.

Proto Vision 5: In 2030, the agri-food value chain, innovation system and policy environment will be characterized by agility, integration and the capacity to respond rapidly to consumer and citizen needs.

The impact of technology and practice innovation depends upon the people who develop, implement and use the technologies; the system within which the technology applies. The human dimension of research, development and implementation is critical, therefore, in terms of achieving a positive impact in the different areas identified in the previous visions in three domains,

- The value chain, which encompasses the private realm of product (multi-functional) production

- The innovation system, which encompasses the researcher-innovator-user realm
- The policy environment, which encompasses the public realm

These areas build upon scientific developments in behavioural, organizational and information sciences.

Value Chain

Moving up the value chain will require greater integration across the agri-food supply chain. A more integrated value chain requires

- Proper consumer-based price and market information to flow in an interpretable form to all components (farmer, producer, logistics, marketing, retailing etc) in the value chain.
- Behavioural Science to understand the motivations and drivers of the different components.
- Organisational developments so that the value chain can work seamlessly as a single unit responding to consumer need, rather than as a series of competing autonomous entities.
- Information technologies to facilitate information flows.

Innovation Eco-System

Supporting a more effective value chain, building upon the technologies and practices that are developed in the design of the system in which the technology is developed and applied. Technology cannot be developed in isolation. Technology development without adoption has no impact.

More effective innovation systems will move from concepts such as uptake and adoption to concepts like co-design, where technologies are developed not only to improve for example profit, but also incorporate usability and ease of use; effectively a circular innovation system, rather than a linear top-down innovation system.

Smart Policy

The advent of new technologies also allows for smarter policy Design, facilitating a variety of multi-functional objectives. The advent of sensors and localised information envisaged in the other visions, allows for more targeted policy. As sensors become cheaper, and become embedded in the landscape, there will be opportunities for policy and regulation to be have a finer resolution, targeting measures in space and in time to maximize impact at minimum cost.

Methodology

The five workshops will use these texts as starting points for the development of a vision. The goal is simply starting with these to create better texts. The new versions should not exceed one page each. They may require further consultation and discussion, but the main elements should by now be clear.

In terms of methodology, we suggest that the session leaders arrive with their own improved or edited version. They might like to appoint an “editor” to take charge of the writing whilst the group debates. The final text should pass the test of being credible, ambitious and exciting.

These new texts will be printed out, as they will be needed as inputs for use in the afternoon session.

The Afternoon Session: Validation of the Next Steps

A vision is also a “call for action.” Its mere existence begs the question “what next?” It must be accompanied by a plan of action that immediately mobilizes resources needed to get started on implementation. Defining this plan of action is our task for the afternoon session of this workshop.

From a Teagasc point of view, the main tools available for the implementation of the vision are its on-going programs. The same will hold for Teagasc partners that have a stake in the realisation of the vision.

Teagasc’s four Heads of Programme have therefore been asked to lead one of the breakout sessions planned for this afternoon. We won’t have enough time in one afternoon to develop entire vision implementation plans for the coming years. The Heads of Programme are therefore, asked to prepare for this in advance. The workshop will mainly serve to validate in a broad sense the proposals that they bring to the workshop.

Each Head of Programme should, therefore, prepare in advance a document indicating how their programs will respond to the challenge of working towards the realisation of the vision over the next couple of years. The good news is that all programs already contain elements that are working towards these goals. It is enough for now to identify these relevant elements and see what else is required to ensure progress.

Each Head of Programme is therefore asked to provide in advance a SHORT document that identifies:

- The elements of their own programme that already contributes to the realisation of the vision
- Further actions that will need to be developed following the completion of the Foresight project
- The kind of partnership-cooperation that will need to be cultivated and maintained

In addition, the workshop will provide an opportunity to discuss the setting up of a light structure, such as task force, to ensure “delivery” of the vision. The goal of the task force would be to:

- Continuously develop and flesh out details of the vision
- Ensure the development and periodic update of a roadmap for implementation
- Monitor and communicate progress in implementation
- Identify and recruit key partners to the cause.

A complete roadmap, which will be completed in the aftermath of the Foresight, should

- Span the fifteen years from now until 2030
- Include tasks to be launched immediately
- Include all other tasks that must be carried out up until the end
- Include research, extension, education and training.

The implementation of such a roadmap should have implications not only for the design of future Teagasc research programs, but also:

- The partnerships it will need to systematically identify, create and develop
- The system for knowledge transfer (education, training, and extension)
- Future skill needs in the agri-food and bio-economy sector

- The sources of funding it will need to mobilize.
- New skill profiles it will need to hire.

It will not be possible to cover so much ground in the course of our workshop. We need to cover at least the tasks to be launched immediately. The development of the full roadmap and other issues could be incorporated as part of the list of tasks to be launched now.