

Leaving Certificate Curriculum Redevelopment - Economics
Consultation Submission

Embedding Bioeconomy Education: A Case for an Interconnected Curriculum

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Prepared by



Ár mbuíochoas le:

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Executive Summary

This submission, prepared by the BioBeo - BiOrbic - BEST Network - CBEC Curriculum Working Group, recommends that the National Council for Curriculum and Assessment (NCCA) adopt bioeconomy as an explicit, cross-curricular organising concept within the redevelopment of Senior Cycle. This submission is provided in response to the NCCA's call for redeveloping the Leaving Certificate Economics specification, treating Economics as the anchor subject for integrating the bioeconomy across the curriculum. Integrating a coherent bioeconomy framework would support the progression of key competencies identified by the NCCA - critical thinking, systems literacy, ethical decision-making, and active citizenship - while strengthening alignment with existing Senior Cycle reform priorities, including wellbeing, inclusion, interdisciplinarity and the provision of flexible learning pathways. A bioeconomy approach, grounded in circularity, regeneration, and responsible resource use, would enable students to understand and navigate the interconnections among climate action, economy, society and culture, and to situate their learning within Ireland's evolving policy landscape.

A bioeconomy framework also provides a culturally relevant basis for curriculum design, integrating the historical and contemporary role of the Irish language (Little & Kirwan, 2021) and drawing on Traditional Ecological Knowledge embedded in rural and coastal communities (Berkes, 2018). This framing enhances thematic consistency across Economics, Climate Action and Sustainable Development, Science subjects, Business, Geography, Engineering, and the Arts, enabling learners to engage with sustainability challenges through inquiry, place-based learning, and disciplinary integration. Embedding the bioeconomy as a unifying construct would support the NCCA's aim to provide a future-focused, coherent, and responsive Senior Cycle curriculum - one that equips students to contribute meaningfully to Ireland's transition to a regenerative, resilient, and socially just society.

This consortium leverages institutional and network expertise from centres such as BiOrbic, the Research Ireland Centre for Bioeconomy and the Bioeconomy Education and Sustainability Teachers (BEST) network. The submission notes the role of the Circular Bioeconomy Education Centre (CBEC) project, which is funded by the Department of Agriculture, Food and the Marine (DAFM) to provide a coordinated

approach to integrating the bioeconomy into the Leaving Certificate and other curricula, aligning with the National Bioeconomy Action Plan.

Embedding the Bioeconomy in Senior Cycle

A policy-aligned proposal to the National Council for
Curriculum and Assessment (NCCA)

Why Integrate the Bioeconomy?

Position the bioeconomy as a cross-curricular organising concept for Senior Cycle reform.
 Use Economics as the anchor subject to link sustainability, systems thinking, and resource use
 across disciplines.

Five Principles Involved

1. Curriculum Reform Principles

Embed cultural relevance, coherence, and modernisation across subjects.
 Integrate the historical and ecological significance of the Irish language.
 Include Traditional Ecological Knowledge in learning pathways.

Extend Key Competencies into Senior Cycle to build systems thinking and sustainability mindsets.

2. Review of Subject Specifications

Climate Action and Sustainable Development specifications align with bioeconomy themes.
 Explicitly naming the bioeconomy strengthens links to systems thinking and evidence-based decisions.
 Bioeconomy concepts naturally connect to Drama, Film, Theatre Studies, Irish, and more.

3. Defining the Bioeconomy

A holistic, systems-based approach replacing fossil resources with renewable biological ones.
 Focus on circular and cascading use of biological materials.
 Highlights interconnections between land, sea, production, innovation, and sustainability.

4. Pedagogy & Content Integration

Teach beyond GDP using frameworks like Doughnut Economics for ecological awareness.
 Prioritise systems thinking and regenerative innovation across subjects.
 Shift assessment toward projects, case studies, and real-world sustainability challenges.

5. Recommendation to NCCA

Embed the bioeconomy across the Leaving Certificate to prepare students for future green careers.
 Use existing national & EU resources (AgroCycle, BioBeo, BiOrbic) being streamlined for schools by CBEC.

Cultural & Place-Based Relevance

Incorporates the heritage and contemporary value of
 the Irish language in ecological thinking.
 Draws on Traditional Ecological Knowledge from rural
 and coastal communities.
 Enhances thematic coherence across subjects, from
 Sciences and Business to Geography, Engineering,
 Arts and Languages.

Curriculum Impact

Aligns with Senior Cycle priorities: interdisciplinarity,
 coherence, future-focused learning.
 Encourages inquiry-based and place-based
 approaches grounded in circularity and
 regeneration.
 Prepares students for Ireland's transition to a
 resilient, regenerative, and socially just society.

Benefits for Learners:

Strengthens key NCCA competencies: critical thinking,
 systems literacy, decision-making, and active citizenship.
 Enhances understanding of the interconnections between
 climate, economy, society, and culture.
 Supports flexible, inclusive, well-being-focused learning.
 Aligns with the National Bioeconomy Action Plan and
 national policy priorities.

Institutional Support

Draws on expertise from BiOrbic, Ireland's
 national Bioeconomy Research Centre.
 Supported by CBEC (funded by DAFM) to
 integrate bioeconomy learning across the
 Leaving Certificate.
 Aligns with the National Bioeconomy Action Plan
 and national policy priorities.

Fig 1: Bioeconomy in Senior cycle

1. Introduction

Overview of this paper

This document is presented as a response to the National Council for Curriculum and Assessment (NCCA) consultation on the redevelopment of the Leaving Certificate curriculum, specifically addressing the review of the Leaving Certificate Economics specification.

At this point of consultation the collective presents the following discussion to outline the concept of a bioeconomy and to articulate the rationale for its integration into education at all levels but most critically within secondary school education where learners cultivate the interdisciplinary understanding and sustainability competencies essential for responding to the challenges of our time.

The submission is structured into five principal sections, following the Introduction:

1. **Foreground Considerations:** This section outlines the guiding principles for curriculum reform, emphasising the need for cultural relevance, coherence, alignment, and currency. Key discussions include integrating the historical and ongoing role of the Irish language (Little & Kirwan, 2021) and incorporating Traditional Ecological Knowledge (TEK) (Berkes, 2018). It also supports the continuation of Key Competencies through the Senior Cycle (Bruner, 1960), ensuring that students develop systems awareness and a sustainability outlook.

2. **Addressing Current Draft Leaving Certificate Specifications:** This section reviews draft subject specifications, including Climate Action and Sustainable Development, and argues that explicitly naming the bioeconomy as a key theme would enhance alignment with aims such as systems thinking and evidence-based decision-making. It also illustrates how bioeconomy principles integrate with subjects like Drama, Film and Theatre Studies and Irish.

3. **Bioeconomy in Practice:** This section defines the bioeconomy as a systems-based, holistic, and circular approach that aims to replace fossil resources with renewable biological resources from terrestrial and marine ecosystems. It provides context for

teaching resource utilisation, innovation, and circular production by describing circular and cascading resource use and emphasising the interconnectedness of sectors.

4. Bioeconomy & Education: Here, the pedagogical and content requirements for integrating the bioeconomy are outlined. It emphasises the need to go beyond GDP in Economics education, incorporating frameworks such as Doughnut Economics (Raworth, 2017) to address ecological overshoot (Ripple et al., 2024). It supports adopting systems thinking (Meadows, 2008), teaching regenerative innovation (Kalro, 2023), and shifting assessment methods towards project-based and case-focused evaluation.

5. Conclusion: The document concludes by urging the NCCA to incorporate the bioeconomy as a unifying, transformative framework throughout the broader curriculum to future-proof the Leaving Certificate. The submission also notes that educational material rich in circular bioeconomy thinking is already accessible through existing initiatives such as the Horizon 2020 project AgroCycle¹, the Horizon Europe project BioBeo, BiOrbic, and the BEST Network and is being streamlined by CBEC for practical transdisciplinary use.

1.1 Why is it needed?

This submission directly addresses the open consultation initiated by the NCCA, reaffirming the NCCA's guidance that curriculum development must be based on research and extensive stakeholder consultation. The main motivation for this intervention is the urgent need to confront environmental breakdown and other interconnected, complex global challenges that go beyond traditional disciplinary boundaries, requiring curriculum structures that promote interdisciplinary skills. This approach aligns with the NCCA objectives for Economics - namely to make Economics relevant to students' lives and to develop their economic literacy.

This submission argues for systemic educational transformation due to global complexity and urgency. The need for immediate educational transformation is internationally validated, as the PISA 2018 assessment focused on measuring the

¹ AgroCycle, *Sustainable techno-economic solutions for the agricultural value chain*, Horizon 2020 project focused on reducing waste and improving circularity across European agriculture, coordinated by University College Dublin, <https://agrocycle.eu>.

global competences students require to "thrive in an interconnected world" (OECD, 2018, OECD, 2020, p.1). The fundamental goal of this global competence, as defined by the OECD framework, is to prepare youth for an "inclusive and sustainable world" (OECD, 2018), directly reinforcing the collective call for education aligned with international obligations such as the Sustainable Development Goals. The paper emphasises that education must explicitly incorporate concepts such as bioeconomy to help shape socially and environmentally responsible futures, offering practical guidance for implementing international agreements on Climate Action and Sustainable Development. Including this rationale is essential in secondary education, as learners must develop interdisciplinary understanding and sustainability competencies to navigate the complexity of "wicked problems" (Rittel & Webber, 1973) such as climate change, biodiversity loss, and social inequality. Omitting the bioeconomy risks leaving educational content outdated and disconnected from Ireland's evolving economic realities and sustainability goals, which the collective strives to address by establishing a holistic framework that balances economic wellbeing with environmental regeneration.

1.2 Who we are: BioBeo-BiOrbic-BEST Network-CBEC Curriculum Working Group

The consultation response was developed by a diverse collective of experts, including academics, researchers, and former teachers, alongside concerned citizens. This collective formally operates under the names BioBeo - BiOrbic - BEST Network - CBEC, drawing together key figures involved in Irish bioeconomy research and education. The submission is grounded in the bioeconomy educational materials and pioneering programmes developed through projects such as AgroCycle and BioBeo.

1.3 Why Education Must Respond: International and Irish Policy Drivers

The policy context underpinning this submission is defined by urgent global commitments that demand systemic educational transformation. In particular, the escalating climate crisis and the imperatives of sustainable development require education to adopt a curriculum architecture that builds cross-cutting competencies, recognising that complex issues transcend traditional disciplinary boundaries.

1.4 International Agreements: The "What We Have To Do"

The mandate for transformative action is rooted in several international frameworks, chief among them the United Nations Sustainable Development Goals (SDGs) (UN,

2015) and the Paris Agreement (United Nations Framework Convention on Climate Change, 2015). These agreements establish clear obligations for all nations to pursue sustainable development and aggressive climate action. At the European level, the policy agenda is guided by the European Green Deal (McLoughlin & Deane, 2020), which sets a course for climate neutrality by 2050 and has been operationalised through measures like the “Fit for 55” package that mandates at least a 55% reduction in greenhouse gas emissions by 2030. Crucially, the EU Bioeconomy Strategy (European Commission, 2018), due to be updated in 2025, explicitly calls for harnessing renewable biological resources and circular-economy principles to achieve these climate and sustainability targets. As Ireland is hosting the Global Bioeconomy Summit in 2026, this is another opportunity to show the country’s leadership in curriculum reform with bioeconomy embedded across subjects. This international context defines what must be achieved globally, highlighting that education systems must evolve to equip learners with the cross-cutting skills needed to implement these broad commitments. Education is thus recognised as a key enabler in meeting international targets, consistent with SDG 4.7’s call for Education for Sustainable Development and the Paris Agreement’s emphasis on climate change education and public awareness. In summary, urgent global challenges demand systemic educational transformation, as complex issues like climate change cut across traditional disciplinary boundaries and require a curriculum that fosters interdisciplinary problem-solving and sustainability competence.

1.5 National Policy Developments: The "How We Address It"

Ireland has translated these international commitments into an ambitious national policy framework guiding how the country will fulfill its climate and sustainability obligations. The Climate Action and Low Carbon Development (Amendment) Act 2021 establishes a legally binding framework for Ireland to pursue a 51% reduction in greenhouse gas emissions by 2030 (relative to 2018 levels) and transition to a climate-neutral economy by no later than 2050, mirroring the EU’s climate neutrality objective (Department of the Environment, Climate and Communications, 2021). To fulfill these obligations, the government’s iterative Climate Action Plans (most recently 2023) set out concrete measures across all sectors and emphasise the critical role of education and public engagement in driving the transition. In the realm of sustainable development, the Department of Education’s National Strategy on Education for

Sustainable Development to 2030 reinforces the integration of sustainability competencies in teaching and learning, reflecting Ireland's commitment to SDG 4.7 at the national level. Crucially, the policy landscape also identifies the bioeconomy as a key avenue for climate mitigation, innovation, and green growth.

The first National Policy Statement on the Bioeconomy (Government of Ireland, 2018) and the recent National Bioeconomy Action Plan 2023-2025 (Department of the Environment, Climate and Communications and the Department of Agriculture, Food and the Marine, 2023) articulate a vision for a circular, low-carbon economy, and include dedicated "Knowledge and Skills" pillars aimed at embedding bioeconomy and sustainability concepts into education and training. In practice, the education system has begun to respond. For example, the NCCA has developed a new Leaving Certificate subject, Climate Action and Sustainable Development (draft specification published 2024), to directly advance climate literacy and sustainable thinking in secondary schools. However, fully realising Ireland's policy commitments will require going further, ensuring that transformative concepts like the bioeconomy are woven throughout the curriculum. By aligning the Leaving Certificate reform with Ireland's climate action plan, circular economy strategy, and bioeconomy roadmap, the education system can produce learners who are prepared to advance national commitments.

In sum, Ireland's policy context, from global agreements to EU directives and national strategies, creates both an imperative and an opportunity for curriculum transformation: it demands that education foster the cross-disciplinary understanding, systems thinking, and innovation mindset required to achieve a just and regenerative future.

1.6 Intent of this submission

This submission calls for greater inclusion in economics and across subject areas to illustrate the interconnected nature of bioeconomy. While multiple definitions and perspectives on a bioeconomy exist across policy, industry, and academia, this submission adopts a vision advanced by BioBeo and the EU Bioeconomy Youth Vision (2024). Bioeconomy can be defined as a holistic, circular, systems-based approach that uses renewable biological resources (agriculture, forestry, marine) to generate food, materials, and energy, replacing fossil resources within a framework designed

to reconcile the economy within ecological limits and regenerate ecosystems (Bioeconomy Youth Vision, 2024; BioBeo Project, 2024).

Education initiatives such as the AgroCycle and BioBeo projects, and BioBEC have created pioneering, award-winning programmes which are lesson plan rich and ready to embed circular bioeconomy thinking within school curricula. In addition, the IKC3 initiative provides a range of lifelong learning programmes, including a Certificate in Circular Economy and a Graduate Diploma in Carbon Accounting and Life Cycle Assessment, aimed at preparing individuals and organisations for a sustainable, low-carbon economy. CBEC at Munster Technological University acts as a national hub for education and outreach, connecting higher education, industry, and community partners to promote the circular bioeconomy. BiOrbic, the national bioeconomy research centre, also plays a key role by offering freely available educational resources such as lesson plans, interactive exhibits, and STEM workshops that help build awareness and understanding of the bioeconomy from an early age.

By integrating bioeconomy concepts, learners can engage in meaningful, contextually rich, action-oriented learning about sustainability transitions, thus, the consultation for a new curriculum should purposefully consider how such future-oriented themes are threaded across subjects, learning outcomes and assessment strategies. This would reflect the Knowledge & Skills Pillar of the National Bioeconomy Action Plan 2023-2025 led by the Departments of Agriculture, Food and the Marine and the Climate, Energy and the Environment.

2. Foreground Considerations

When embarking on the consultation phase for a new secondary-school curriculum, it is imperative to foreground several key considerations drawn from international and Irish curricular-studies literature. The NCCA emphasises that curriculum development is guided by research, best practice and wide stakeholder consultation. This document is a response to this open consultation.

It is also essential to consider the cultural context of Ireland, recognising the historical and ongoing role of the Irish language (Gaeilge) in shaping identity, cognition and pedagogical approaches in schools (Little & Kirwan, 2021). Embedding Irish cultural reasoning ensures that curriculum development does not merely replicate international models but responds to the specific heritage and community knowledge systems of this island, with context-dependency a vital element of a bioeconomy. Attention to Traditional Ecological Knowledge (TEK) is critical, particularly in rural and coastal communities where intergenerational knowledge of land, forests, and marine resources remains vibrant (Berkes, 2018). Integrating TEK alongside Irish-language cultural knowledge reinforces local relevance and sustainability literacy.

The new curriculum should be inclusive and participatory, engaging teachers, students, parents and the wider community in its design so that ownership and relevance are enhanced. This is evident in the Irish context where the NCCA process for primary curriculum redevelopment explicitly describes listening to children's voices, collaborating with school communities and leveraging stakeholder networks.

The curriculum at consultation must consider coherence and alignment (between curriculum aims, subject specifications, pedagogies, scientific consensus, and assessment). Without this alignment, reform initiatives risk a disconnection between policy and classroom practice. Hyland & Kennedy's (2023) review of secondary syllabi design in Ireland highlights the importance of template redesign to ensure transparent links between curriculum design and enactment. Building on this, two important developments in the new Primary Curriculum are the introduction of the seven "Key Competencies" and the closer alignment of content with the Junior Cycle. The continuation of this alignment up to Senior Cycle is welcome in order to support a

coherent and connected learning experience. Drawing on Bruner's (1960) idea of the "Spiral Curriculum", the steady reinforcement of these competencies across all stages of schooling would allow students to strengthen their understanding and apply their skills in different contexts. In particular, the competencies of Being an Active Citizen, Being Creative, and Being a Communicator should be seen not only as educational goals but as vital abilities for participation, innovation, and engagement throughout life.

To remain relevant in an era defined by Volatility, Uncertainty, Complexity, and Ambiguity (VUCA), education must go beyond the transmission and accumulation of information. It must cultivate learners' capacity for critical thinking, relational understanding, and adaptive judgement (OECD, 2019a). As familiar social, economic, and ecological systems undergo rapid change due to pressures including climate change and technological advancement, the role of education is not to prepare students to replicate past models, but to equip them to engage with emerging, unpredictable challenges. This calls for a curriculum that prioritises systems thinking, sustainability literacy, and the ability to work constructively with complexity. For secondary-level learners, this means developing the skills and dispositions needed to make sense of interdependent problems, respond with flexibility, and act with responsibility.

Lastly, the consultation should explicitly consider scope for interdisciplinarity and future-facing themes, recognising that global challenges (such as climate change) cut across traditional disciplinary boundaries and thus demand curriculum architecture that supports cross-cutting capacities. With these guiding principles established, one salient reason why the curriculum must explicitly incorporate concepts like the bioeconomy relates to the growing urgency of the climate change challenge and the opportunities for education to contribute to socially and environmentally responsible futures.

3. Addressing Current Draft Leaving Certificate Specifications

The underlying case for transforming the Senior Cycle must recognise the globally validated mandate for educational reform that addresses interconnected issues. This approach is captured by the OECD PISA definition of global competence, which requires preparing young people for an "inclusive and sustainable world" (OECD, 2018) and assesses their ability to "thrive in an interconnected world" (OECD, 2020, Title page). To navigate the inherent complexity of challenges like climate change and economic development, the PISA framework explicitly identifies global competence as a "multifaceted cognitive, socio-emotional and civic learning goal" (OECD, 2020, p. 60), demanding curriculum structures that promote interdisciplinary skills. Students must develop the ability to draw on various knowledge and ways of thinking gained in school to "examine issues of local, global and cultural significance" (OECD, 2020, p. 60).

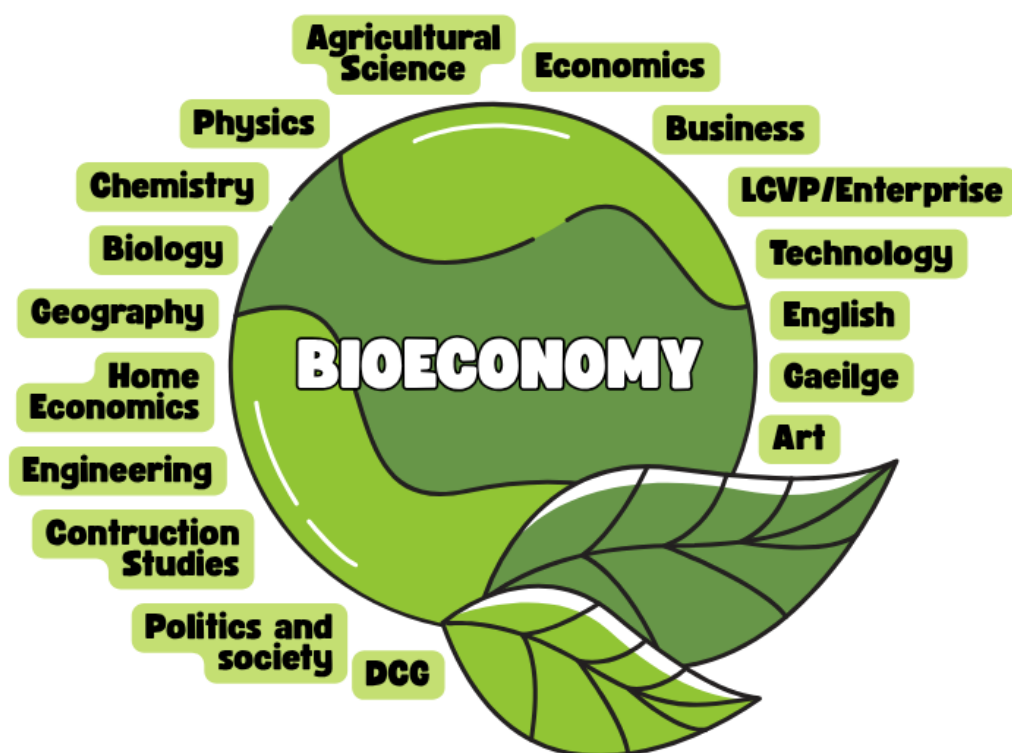


Fig 2: Bioeconomy Links Across Leaving Certificate Subjects

3.1 Addressing Current Draft Leaving Certificate Specifications

The Senior Cycle key-competencies framework states: “Students develop key competencies within and across the curriculum ... [they] learn to make meaningful connections across their different subjects” (NCCA, 2024). By embedding the bioeconomy as a cross-cutting theme, the curriculum supports this integrated vision: biology, economics, geography, business, technology, Gaelige and others become sites where systems understanding, sustainability literacy and inter-disciplinary thinking can flourish. In doing so, we move beyond isolated subject content, and equip learners with the competencies to respond adaptively to complex global challenges, just as the NCCA framework envisages. The following sections outline how the bioeconomy aligns with, and enhances, the learning intentions of each draft Leaving Certificate specification currently under consultation with particular focus on economics

Area	Subject	Strands	Bioeconomy Connections
S C I E N C E S	Biology	Unifying Strand: The Nature of Science Strand 1: Organisation of Life Strand 2: Structures and Processes of Life Strand 3: Interactions of Life	• Ecosystems and biodiversity • Carbon and nutrient cycles • Microorganisms in bioprocessing • Biofuels, bioplastics, biomaterials • Plant breeding and sustainable agriculture
	Chemistry	Unifying Strand: The Nature of Science Strand 1: Nature of Matter Strand 2: Behaviour of Matter Strand 3: Interactions of Matter Strand 4: Matter in Our World	• Biomass conversion • Biorefineries • Green chemistry • Bio-based polymers • Enzyme-based processes
	Physics	Unifying Strand: The Nature of Science Strand 1: Forces and Motion: Kinematics and Dynamics Strand 2: Wave Motion and Energy Transfer Strand 3: Electric and Magnetic Fields and their Interactions Strand 4: Modern Physics Atomic and Nuclear	• Renewable energy systems • Energy efficiency • Properties of bio-based materials • Modelling energy flows • Physical principles in sustainable technology

A P P L I E D S C I E N C E	Engineering	Strand 1: Engineering Processes Strand 2: Automation and Control Systems Strand 3: Design Capability Strand 4: Engineering Principles and Energy	• Bio-based systems and technologies • Energy systems • Materials substitution • Low-waste production • Resource-efficient design
	Construction Studies	Strand 1: Built Environment Strand 2: Design, Materials and Crafts Skills Strand 3: Building Fabric Strand 4: Services and Control Technology	• Bio-based building materials • Low-carbon design • Waste reduction in construction • Life-cycle assessment • Renewable energy in buildings
	Design and Communication Graphics	[MB1]	• Sustainable design principles • Visualising bio-based structures • Technical drawing for low-impact production • Design thinking applications
S O C I A L S T U D I E S	Geography	Unifying Strand: Applying geographical thinking and skills Strand 1: The physical environment Strand 2: The human environment Strand 3: The global environment	• Land use and resource management • Climate resilience • Rural development and bio-based economies • Environmental planning • Mapping biomass and carbon
	Politics and Societies	Strand 1: Power and decision-making Strand 2: Active citizenship Strand 3: Human rights and responsibilities Strand 4: Globalisation and localisation	• Climate justice and just transition • Environmental governance • Land, food, and resource policy • EU and national strategies • Social acceptance of innovation
B U S I N E S S	Economics	Strand 1: What is economics about? Strand 2: How are economic decisions made? Strand 3: What can markets do? Strand 4: What is the relationship between policy and economic performance? Strand 5: How is the economy influenced by international economics?	• Externalities and market failures • Circular economic models • Sustainable growth • Bio-based enterprise • Carbon pricing and policy

	Business	Unifying strand: Investigating Business Strand 1: Exploring the Business Environment Strand 2: Understanding enterprise Strand 3: Leading in Business Strand 4: Being Informed and Making Informed Decisions	• Bio-based entrepreneurship • Sustainable supply chains • Innovation and product development • Corporate social responsibility • Circular business models
A R T S	Art	Strand 1: Research strand Strand 2: Create strand Strand 3: Respond strand	• Sustainable materials in artistic practice • Eco-design and creative reuse • Visual storytelling on environmental themes • Artistic responses to climate and biodiversity • Natural pigments and biomaterials
L A N G U A G E S	English	Strand 1: Exploring Strand 2: Creating Strand 3: Comparing Strand 4: Analysing	• Environmental themes in literature • Writing and communication for sustainability • Argumentation on climate issues • Media literacy • Nature-based creative writing
	Gaeilge	Strand 1: Tuiscint Strand 2: Labhairt Strand 3: Scríobh Strand 4: Prós Strand 5: Filíocht	• Environmental themes in Irish-language texts • Sustainability-related vocabulary • Creative work based on landscape and heritage • Oral communication on climate topics • Place-based cultural perspectives
	Music	Strand 1: Performing Strand 2: Composing Strand 3: Listening	• Natural soundscapes • Musical responses to environmental change • Sustainable materials in instrument craft • Cultural traditions linked to land • Composition inspired by natural systems
	LCVP / Enterprise		• Bio-based student enterprise • Circular design challenges • Sustainability audits • Green entrepreneurship

	Home Economics		• Sustainable food systems • Food waste reduction • Nutrition and environmental impact • Bio-based textiles • Consumer choices and sustainability
	Technology		• Bio-based product design • Sustainability criteria • Circular product lifecycles • Prototype solutions
	Applied Mathematics	Strand 1: Mathematical Modelling Strand 2: Mathematical modelling with networks and graphs Strand 3: Mathematically modelling the physical world; kinematics and dynamics Strand 4: Mathematically modelling a changing world.	• Modelling resource flows • Optimisation in circular systems • Statistical analysis of environmental data • Predictive modelling • Systems-based problem solving
	Agricultural Science	Strand 1: Scientific Practices Strand 2: Soils Strand 3: Crops Strand 4: Animals	• Circular and regenerative farming • Bioenergy crops and anaerobic digestion • Soil health and carbon sequestration • Sustainable livestock systems • Agri-innovation and value chains

Fig 3: Interdisciplinary Connections Between Bioeconomy and the Curriculum

3.2 Economics

The current Leaving Certificate Economics specification, introduced in 2019, already recognises the subject as a social science that “questions and inquires about economic patterns, relationships and principles” and situates students in the study of resource allocation, market mechanisms and government intervention (NCCA, 2019). The background paper for the forthcoming review notes, however, that since the specification’s introduction, the global economic landscape has shifted markedly, shaped by geopolitical fragmentation, rising inequality, climate change and the transition to a low-carbon, circular economy (NCCA, 2025c). It explicitly states “evolving consideration must be given to the sustainability and relevance of the subject

in a rapidly changing world” (NCCA, 2025c). The scientific literature reinforces this urgency: the State of the Climate report calls for bold, systemic economic transformation toward post-growth and regenerative models to stay within planetary boundaries (Ripple et al., 2024). An updated Economics specification must therefore reflect this scientific consensus.

This provides a clear mandate to position the bioeconomy and wider sustainability transition at the heart of a revised Economics course. The background paper highlights policy developments such as the Circular Economy and Miscellaneous Provisions Act 2022, the Deposit Return Scheme, climate-related taxes, and EU initiatives including the Farm to Fork Strategy and the European Green Deal, all of which link directly to bioeconomy themes (NCCA, 2025c). Building on this, a redeveloped specification could make explicit how Ireland’s shift from a “take-make-waste” model to a circular, low-carbon, bio-based economy transforms notions of value, production, employment and wellbeing. Students would examine how measures beyond GDP (e.g. Doughnut Economics, Genuine Progress Indicators, and wellbeing frameworks) reframe economic success in terms of staying within planetary boundaries while meeting social needs, and how Irish policy instruments operationalise these goals.

The 2025 background paper also identifies the need to strengthen research and data analysis skills, especially in the Additional Assessment Component (AAC), and to respond to emerging challenges such as generative AI and the growth of digital data (NCCA, 2025c). The bioeconomy offers a powerful applied context for this. The AAC could invite students to investigate, for example, the local impacts of carbon pricing, the economics of peatland restoration or forestry, biobased innovation in agriculture, or circular business models using organic waste streams. Such projects would develop the incremental research and data-handling capacities the background paper calls for, refining a line of inquiry, analysing quantitative and qualitative evidence, and communicating findings clearly, while grounding learning in Ireland’s real-time transition to a sustainable, bio-based economy.

Finally, the brief for the review emphasises that a new specification should help students understand “the relevance and importance of economics in the 21st century” and foster deep analysis and debate on economic, social and financial issues (NCCA, 2025c). Explicitly integrating the bioeconomy, climate action and circular-economy

policy into core strands of the Economics course would deliver on this ambition. It would allow students to connect micro-level decisions (households, firms, behavioural nudges) with macro-level challenges (ecological overshoot, just transition, demographic shifts, AI-driven labour market change), and to see Economics as a toolkit for navigating, and helping to shape, a turbulent future rather than merely interpreting the past.

3.3 Climate Action and Sustainable Development

The emerging Leaving Certificate Climate Action and Sustainable Development specification explicitly names the bioeconomy as a key economic approach to sustainability. In outlining core concepts, this draft requires students to “outline the following economic approaches to sustainable development,” including Bioeconomy, Circular Economy, Degrowth, and Doughnut Economics (NCCA, 2024c). This recognition provides a clear entry point, as supported by the aforementioned vision of Bioeconomy advanced by the Bioeconomy Youth Vision and BioBeo; “a holistic, circular, systems-based approach that uses renewable biological resources to generate food, materials, and energy, replacing fossil resources within a framework designed to reconcile the economy within ecological limits and regenerate ecosystems (Bioeconomy Youth Vision, 2024; BioBeo Project, 2024).

Teaching units on the bioeconomy could be incorporated into Climate Action & SD modules (e.g. as case studies on renewable resource management or biobased innovation). It also supports the subject’s goals of systems-thinking and sustainable futures - for example, by linking bioeconomy strategies (like replacing fossil fuels with biowaste products) to the broader theme of climate mitigation. Embedding the bioeconomy here would align with Ireland’s national and EU climate commitments (Green Deal, Climate Action Plan) and model systems thinking (showing how energy, food and manufacturing interconnect). The proposed emphasis on the bioeconomy as a pathway to sustainable development aligns directly with PISA’s focus on cultivating student agency and action. The fourth dimension of global competence is specifically defined as the ability to “take action for collective well-being and sustainable development” (OECD, 2020, p. 60).

While this provides a clear disciplinary home, the bioeconomy is inherently cross-cutting and its principles can and should be meaningfully woven into other Senior Cycle subjects. Embedding these concepts across Economics, Science, Geography, Business, Technology, and Gaeilge ensures a coherent whole-curriculum approach aligned with Ireland's sustainability commitments and the overarching goals of Senior Cycle reform.

3.4 Science (Biology, Chemistry, Environmental Science)

The new Science specifications explicitly frame learning in terms of sustainability and stewardship. For example, the draft Biology curriculum describes participating in society by “critique[ing] and challenge[ing] systems that damage the natural world” and using biological knowledge “for sustainable futures”, with “wellbeing and relationships” named as a Guiding Principle for the Biology Senior Cycle. As the draft specification notes, “by studying biology, students appreciate the role of community and society in the complex ecology of the planet and of its sustainable development” (NCCA, 2023a). The bioeconomy offers a natural extension of this perspective, bridging the micro insights of biological processes with the macro considerations of ecological systems, circularity, and sustainable resource management.

Likewise, the Chemistry specification encourages students to develop “knowledge of sustainable futures” as they analyse harmful systems and make choices that contribute to a “more sustainable world” (NCCA, 2023b). These science subjects offer natural avenues for bioeconomy content: teachers can introduce biochemistry and ecology units on biodegradable materials, renewable biofuels, or conservation of genetic resources. In practice, this might look like lab or field projects on composting organic waste, the carbon cycle in agriculture, or marine bioproducts, all linking chemical and biological principles to circular-resource thinking. Embedding such examples will deepen students' understanding of global challenges and support the curriculum's emphasis on systems-thinking and sustainability literacy (aligned with Education for Sustainable Development goals).

3.5 Business

The updated Business curriculum explicitly builds in ethical and sustainable practice. One aim is for students to develop “an informed and critical understanding of ethical

and sustainable business practice” (NCCA, 2024a). In this subject, the bioeconomy can be introduced through topics like green entrepreneurship, circular supply chains, and social enterprise models. For instance, case studies could examine how local companies use forestry, algae or biowaste to create biobased products, or how agricultural cooperatives diversify into eco-friendly offerings. These examples would link directly to the specification’s learning outcomes on innovation and critical thinking in real-world business contexts (NCCA, 2024a). Embedding bioeconomy themes in Business also cultivates key competencies: students practice initiative and creativity (as required) by designing sustainable business plans, and they engage with citizenship by considering environmental ethics in commerce.

3.6 Geography

The draft Geography specification situates students in the study of human-environment systems “to contribute to shaping a more sustainable future from a critically informed perspective” (NCCA, 2025a). Sustainability is explicitly identified as a central concept: for example, students will “assess the impact and sustainability of ... [agricultural and engineering] strategies on the human environment” (NCCA, 2025a). Specific learning outcomes already include evaluating sustainability in Irish agriculture (contrasting intensification, organic methods, urban food production) (NCCA, 2025a). These topics dovetail with bioeconomy principles such as sustainable land use, bioresource management, circularity and regional resilience. Geography classes can therefore incorporate bioeconomy by exploring how landscapes supply food, timber and biomass; by comparing renewable versus extractive practices; or by mapping natural cycles or local bio-based industries and their carbon footprints. This cross-cutting content reinforces geographic skills in systems analysis and data interpretation while addressing the curriculum’s global citizenship goals.

3.7 Engineering

New technology subjects explicitly embrace sustainable engineering and design. The draft Leaving Cert Engineering specification, for instance, “plays a pivotal role ... in promoting sustainable living within a circular economy”(NCCA, 2025b). Its aims include fostering “an awareness of the environmental, social, and economic impacts of engineering decisions” and promoting “sustainable practices and ethical

responsibility”(NCCA, 2025b). In practice, this means classrooms will teach regenerative design, repair-over-replacement values, cascading uses of biomass, and life-cycle thinking. Engineers-in-training might study how materials science and engineering can produce bioplastics, bio-composites or energy from waste and support learners to make informed material-selection decisions based on ecological impact.

Embedding bioeconomy concepts could involve design projects (e.g. creating a biodegradable product prototype) or calculations of resource use in civil projects. Similarly, Design and Communication Graphics or Technology subjects can integrate sustainable design briefs. All these align with the stated aim that students make “informed decisions about the impact of engineering and technology on society” (NCCA, 2025b). Embedding the bioeconomy in Technology subjects thus directly serves the cross-cutting key skill of systems-thinking, as students evaluate how technological solutions fit within environmental constraints.

3.8 Gaeilge

Integrating the bioeconomy into Irish-language teaching can reinforce both language learning and cultural relevance. The Department of Education’s new Action Plan for Irish in English-Medium Schools (2025-2027) emphasises “provid[ing] better learning experiences of Irish” and “increasing the use of Irish” (Government of Ireland, 2025). Linking Gaeilge curricula to sustainability topics - for example, having students research and discuss environmental issues in Irish, or read Gaeilge-language literature about nature and community - will enrich learners’ vocabulary and engagement. For senior students, essays or oral presentations on Ireland’s natural heritage and economic practices can develop communication skills while reflecting curriculum values (literature and personal reflection components often highlight connection to land and identity). In junior and senior cycle Irish specifications, key skills like critical literacy and cultural appreciation can be developed through texts on ecology or rural life. Thus, cross-curricular projects (perhaps integrated into TY or DCG modules) that require Gaeilge use, such as bilingual reports on a local forest project, would align with the Action Plan’s goal of fostering positive attitudes and support for Irish.

3.9 Transition Year and Cross-Curricular Projects

The new Transition Year Programme Statement explicitly highlights sustainability and citizenship. It notes that TY students “actively participate in creating a more sustainable world” and build key competencies as national and global citizens (NCCA, 2024b). Developmental indicators for TY even include “Education on sustainable development, including a meaningful action for a more sustainable world” (NCCA, 2024b). Therefore, Transition Year provides an ideal forum for interdisciplinary bioeconomy education. Schools might implement TY modules or community projects on topics like organic farming, renewable energy in the locality, or marine bio-resources. Such projects would give practical context to Leaving Cert concepts, reinforce systems thinking and teamwork, and contribute to the school’s green initiatives.

3.10 Conclusion

By weaving bioeconomy themes through these subjects and stages, the Leaving Certificate reform will fully realise Ireland’s education-for-sustainability commitments. Each subject’s existing emphasis on sustainability, citizenship and key skills (critical thinking, problem-solving, systems-awareness) can be extended with bioeconomy case-studies, problem-based learning and project work. This approach supports the Knowledge and Skills pillar of the National Bioeconomy Action Plan (2023-2025) by enhancing students’ awareness and understanding of the bioeconomy. It also aligns with the NCCA Senior Cycle framework which envisions students grappling with “social, environmental, economic, and technological challenges and to deepen their understanding of human rights, social justice, equity, diversity and sustainability” (NCCA, 2024b). In sum, embedding the bioeconomy across Leaving Certificate subjects - from Economics and Sciences to Gaeilge and Technology - leverages existing cross-cutting priorities (sustainability, systems thinking, ethical reasoning) and ensures that Irish students are prepared to contribute to a regenerative, circular economy.

4. Bioeconomy in Practice

What is the bioeconomy, and how could it be used as a framework for teaching sustainable resource use, innovation, and circular production in Ireland to LC students?

Although there is no overall agreed international definition²³, as all bioeconomy developments have very specific local characteristics, many organisations (EU, UN FAO), research projects and activities have broadly framed it as a holistic, circular approach to resource use. As defined by European youth advocates, “bioeconomy is a holistic approach to achieving a resilient, circular, bio-based economy through a just-transition that consciously aims to reduce economic throughput within our planet’s regenerative capacity” ([Bioeconomy Youth Vision](#), 2024).

Similarly, the Horizon funded BioBeo Project (2024) states:

“A bioeconomy is a systems-based approach that seeks to replace fossil resources in a sustainable manner with renewable biological resources from terrestrial and marine ecosystems - such as forests, crops, animals, fish, microorganisms, organic waste, and agricultural side streams, to produce food, feed, fibres, energy, bio-based products, and services within a circular economy framework designed to optimise resource use based on a cascading hierarchy of utilisation options. A sustainable and circular bioeconomy requires the application of education and training programmes, scientific research, technology, and innovation with the aim of not only creating economic value, but also regenerating and expanding ecosystems and biodiversity as well as improving the health and the well-being of society. By addressing these systemic changes in the economy, environment, and society, the bioeconomy contributes to achieving a better and more sustainable future where no one is left behind.”

Students must have the opportunity to explore how biological cycles (carbon, nitrogen, food webs) underpin all economies, and how overshoot disrupts them. In Ireland’s context, content might show how renewable biological resources (grass, crops, forest

² [Bioeconomy Strategy - Environment - European Commission \(europa.eu\)](#)

³ [Sustainable bioeconomy for agrifood systems transformation | Food and Agriculture Organization of the United Nations \(fao.org\)](#)

timber, seaweed, agri-food residues) can be turned into food, materials or energy in ways that recycle nutrients, upcycle by-products and reduce waste.

- Circular & cascading resource use: Use case studies (e.g., biogas from farm waste, sustainable forestry for bio-products) to illustrate circular production and cascading use. Emphasise regeneration, reuse, upcycling per the vision's call to "minimise consumption within ecological limits and embrace a circular approach to feedstocks".
- Interconnected sectors: Highlight how agriculture, forestry, and fisheries interlink (e.g., biorefineries that turn forestry residues to biobased plastics or biomaterials), reinforcing that bioeconomy solutions require interconnection and knowledge across disciplines and systems. This supports a truly transdisciplinary curriculum.

The CBEC project, funded by the Department of Agriculture, Food and the Marine in support of the delivery of the Knowledge & Skills Pillar of the National Bioeconomy Action Plan 2023-2025, is working to provide a coordinated approach to the integration of the bioeconomy into Leaving Certificate and other curricula. This will be achieved through the co-creation of a transformational programme to be piloted in selected secondary schools, building on the educational material developed in the AgroCycle, BioBeo and BioBEC projects. Much of the content described is already available through education programmes such as AgroCycle, BioBeo, BioScaleUP, Teagasc and BiOrbic.

5. Bioeconomy & Education

Building on this call for coherence across the Senior Cycle, Economics offers a particularly effective entry point for integrating the bioeconomy into post-primary education. Embedding the bioeconomy within Leaving Certificate Economics aligns the curriculum with Ireland's climate and sustainability commitments, including the Bioeconomy Action Plan, the Circular Economy and Miscellaneous Provisions Act 2022 and the Climate Action Plan. It bridges theory and practice by contextualising economic concepts such as externalities, market failure and sustainable growth through tangible Irish examples like biogas from farm waste and biomaterials from forestry residues. This integration supports the reimagined the Senior Cycle's vision of equity, excellence and learner-centred, future-focused education. It complements the new Climate Action and Sustainable Development subject, fostering interdisciplinary coherence and equipping students with essential skills for a green economy and sustainable enterprise. In this section we focus on Economics as the key entry point for bioeconomy education.

Systemic thinking

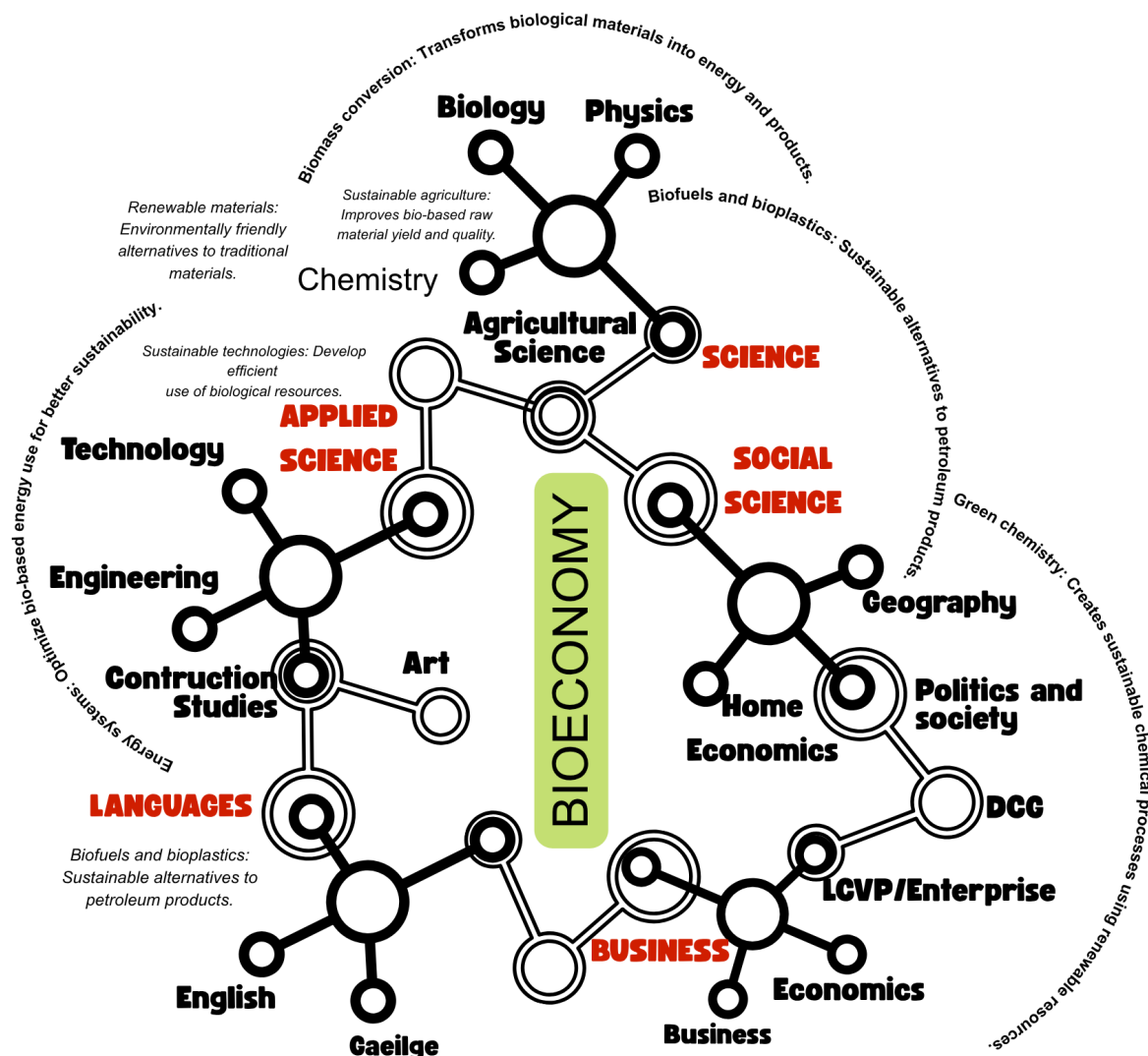


Fig 4: Systems thinking across multiple discipline connecting bioeconomy

5.1 Policy Imperative

Failing to include the bioeconomy risks rendering Economics education outdated and disconnected from Ireland's evolving economic realities and sustainability targets. This concern is widely documented: students report that economics teaching often lacks real-world orientation (Pühringer & Bäuerle, 2019), and programme audits show an over-weighting of technical methods over contemporary challenges such as climate and inequality (Rethinking Economics, 2024). Scholarly reviews further note that the dominant neoclassical core is ill-suited to 21st-century problems because of unrealistic assumptions (BU-IED, 2020). In Ireland, the NCCA has already acknowledged the legacy outdatedness of LC Economics prior to redevelopment (NCCA, 2015). The

bioeconomy provides a vital framework for understanding how innovation, circularity and policy can reconcile economic prosperity with environmental regeneration. To prepare students to actively shape Ireland's just, circular, and bio-based economy, Leaving Certificate Economics must explicitly incorporate bioeconomy concepts. Doing so will enhance economic literacy, support critical engagement with national and global policy, and strengthen the curriculum's relevance in the 21st century.

5.2 Redefining Value

How should the economics curriculum move beyond GDP and profit maximisation to include measures of natural capital, ecosystem services and wellbeing?

Economics must shift from narrow GDP growth to meeting human needs within ecological limits. Kate Raworth's *Doughnut Economics* (2017) encapsulates this: instead of maximising GDP, societies should aim to bring all people into a "safe and just space" where social foundations are met without overshooting planetary boundaries (Rockstrom, 2009).

The Collective very much welcomes the proposed inclusion of Bioeconomy and Doughnut Economics under Strand 3: Global Connections in the Draft Leaving Certificate Climate Action and Sustainable Development specification.

Recent climate science echoes this: the 2024 State of Climate report identifies ecological overshoot - driven by the "perilous illusion" of unlimited growth on a finite planet - as the root cause of climate breakdown (Ripple et al., 2024). Students should be exposed to a variety of alternative frameworks in economic thinking, such as post-growth and steady state economics (Kallis et al., 2025).

Students should learn that the economy is *embedded* in society and the biosphere (Raworth, 2017), so that growth is understood as bounded, and that limitless economic growth eats away at the economy's own foundations. They should learn how to evaluate commonly repeated misleading statements used to justify extractive economic models, e.g., that corporations have an obligation to maximise shareholder gains (Stout, 2012)

Given the challenge of this transition, and other challenges including the predicted developments in technology and employment over the next decade, education

systems must adapt to prepare learners for a future where AI-driven disruption and rapid skill change are the new norm (WEF, 2025). Given these interconnected shifts, students should also learn about resilience and regeneration, and how societies can scale, be supported and adapt to changing conditions with dignity as part of a just-transition. In an era where it is predicted artificial intelligence will perform most analytical and administrative functions, economic value must be redefined around what remains uniquely human: care, creativity, contextual judgment, and the stewardship of living systems. The post-growth curriculum must therefore prioritise wellbeing, resilience, and ecological integrity over productivity or scale.

- Planetary and social benchmarks: Use Doughnut indicators (social floors, planetary boundaries as learning goals, rather than GDP. Emphasise that long-term prosperity requires staying within Earth's regenerative capacity.
- Embedded economy: Teach the economy-as-system concept. OECD researchers stress that the economy is *bounded by nature*, and nested within and therefore dependent on other systems, social and environmental (OECD, 2019b). Lessons can compare traditional growth models with ecological economic models that prioritise long-term system health (as per Donella Meadows' warnings about overshoot ((Meadows, Meadows, & Randers, 2004)).

5.3 Policy and Behaviour

How could economic models include the incentives and policy tools that support a transition to a net zero emissions, biobased economy 2050?

Economic models must internalise environmental costs and actively reward sustainable behaviour. Instead of treating pollution, biodiversity loss, or resource depletion as “externalities,” these impacts should be recognised as intrinsic system costs. As Meadows argues, “there is no such thing as an externality - all impacts return to the system” (Meadows, 2008, p. 139). In line with ecological economics, the concept of externalities ought to be “composted”: reframed so that consequences of economic activity are treated as endogenous feedbacks within the socio-ecological system (Daly, 2014; Costanza, 2020). Instruments such as carbon pricing, budgeting, pollution

taxes, and tradable permits can help align market signals with ecological reality, ensuring that prices reflect environmental harm and climate targets. These tools are essential for achieving Ireland's legally binding climate commitments: a 55% reduction in net greenhouse gas emissions by 2030 (relative to 1990 levels) and a climate-neutral economy by 2050 (Government of Ireland, 2021).

In Ireland, the transition away from peat extraction, led by Bord na Móna's rewetting and rehabilitation of degraded bogs, demonstrates how policy, economics, and ecosystems can converge. Payments for ecosystem services, such as carbon farming or peatland restoration, offer economic incentives to landowners and farmers who sequester carbon and enhance biodiversity (European Commission, 2023). These regenerative activities not only mitigate climate change but also support rural livelihoods and cultural landscapes, making them a powerful tool for aligning the economy with planetary boundaries.

In addition, economics education should explore why markets failed to prevent ecological overshoot and discuss "post-market mechanisms" such as commons governance, value webs, regenerative business models, and mechanisms to efficiently allocate resources for higher value products for a more circular, resource-efficient, biobased economy. A multiplicity of economics (ecological, doughnut, degrowth, post-Keynesian, bioeconomy, regenerative etc) must be available for exploration for students rather than just neoclassical, and supported in a realisation that all policies are moral choices, not neutral equations, and understand who benefits, who bears the cost. Students should be exposed to the insights of behavioural economics, which highlights the role that bias plays in economic decision-making (Kahneman, 2011)

Encourage deliberation on redistribution, care, and ecological debt.

- Internalise costs: Teach the "polluter pays" and "beneficiary pays" principles. For instance, a tax on chemical fertilisers or logging fees makes the price of food or timber reflect ecological impact. Similarly, subsidies or tax breaks can be used for innovations with positive ecological effects (renewables, regenerative farming).

- **Economic Diversity:** Instead of just learning about taxes or subsidies, students should understand how power and ideology shape incentives, and the different ways to manage the ‘economies’ to fulfil obligations of the Paris Agreement.

5.4 Local and Global Contexts

Ireland’s agriculture, forestry, and marine sectors are key bioeconomy areas. How can economics teaching connect local and regional resource management to global trade, sustainability, and climate goals?

Economics teaching must tie Ireland’s economy, as well as our land and sea resources to global systems. Ireland’s bioeconomy (encompassing land and sea; agriculture, forestry, fisheries; biobased industries etc - see EU definition for full details) not only sustains local jobs and communities but also links to worldwide science, technology and innovation, markets, and climate change. Ireland’s bioeconomy uses plants, animals and organic waste to make food, energy and materials while aiming to cut fossil use and create local green jobs. However, significant gaps remain in achieving circularity. According to *The Circularity Gap Report*, authored by Circle Economy and the Department of the Environment, Climate and Communications (2023), 97% of the materials used in Ireland’s economy originate from virgin sources, with only 2.7% coming from recycled or secondary materials - well below the 2023 global average of 7.2%. This highlights both the urgency and the opportunity to embed circular economy principles more deeply within Ireland’s economic strategy and education system.

Ireland’s total consumption-based carbon footprint is about 74% higher than its domestic emissions, mainly due to imported goods. This provides a good opportunity to teach ecological dependency: Ireland’s imported food, energy, and data infrastructure link it to planetary extraction. The essential bioeconomy content for Leaving Certificate is already well-developed through funded projects like AgroCycle, BioBeo, BioBEC, BiOrbic, BioScaleUP, Teagasc and through the CAP Network, now being streamlined by CBEC for an effective transdisciplinary approach.

5.5 Case Study

BioBeo’s “Interconnectedness” education materials show how local Irish fisheries link to global ecosystems, while “Outdoor Learning” uses local forests to explore carbon storage and trade. Students can analyse forestry’s carbon balance and study

overfishing in “Life Below Water” or local food waste in “Food Loop,” using real Irish case studies such as wool processing and food waste valorisation. These resources provide rich, practical content to connect economics, environment, and society seamlessly.

- **Interconnectedness:** Use BioBeo themes, for example, “Interconnectedness” lessons (available through BioBeo co-created by teachers and academics) can show how a fish caught in Irish waters enters global supply chains, affecting distant ecosystems. “Outdoor Learning” can involve visiting a local forest to discuss carbon storage and trade (timber exports impact forests abroad).
- **Forestry and carbon:** Students can calculate how much CO₂ an Irish forest absorbs versus how much is emitted when wood is burned or shipped overseas. This ties local forestry management to climate goals.
- **Life Below Water / The Food Loop:** In “Life Below Water” topics, study fisheries in the context of global overfishing (stocks and flows, law of replenishment). In “Food Loop”, examine local food waste (composting) vs food imports/exports. Use the Bioeconomy projects from CAP Network (e.g. wool, food waste valorisation) (CAP Network Ireland, 2023) to provide concrete examples.

5.6 Interdisciplinary and Transdisciplinary Thinking

Should economics education include insights from biology, environmental science, and social justice? What benefits or challenges might arise from a more integrated approach?

Economics education must integrate biology, ecology (systems thinking), anthropology and social justice. The root words remind us: *oikonomia* (household management) and *oikologia* (household of nature) share the same “oikos” (home). Ecological economists argue the economy is a *subsystem of the planet*, not separate from it. Thus, they note that efficient allocation must respect ecological limits and social equity (Costanza, 2012). Including insights from environmental science (e.g. carrying capacities, ecosystem interdependence) and social justice (e.g. fair distribution of resources) enriches economic understanding.

Integration now also means bridging digital and ecological literacy. Understanding how AI systems consume energy, data, and attention connects technology education to

environmental limits. Students should be able to trace both metabolic and informational flows through society, recognising that the future economy will be simultaneously biophysical and algorithmic.

- Historical roots: Introduce the origin of economics as household management, linked to ecology. This helps students see why purely abstract models (assuming endless growth) fail on a finite planet.
- Ecological economics: Draw on Robert Costanza's view (Costanza, 2012) that economic thinking needs to bridge ecology and anthropology, studying humans embedded in life-support systems. Teach that scale matters: infinite growth on a finite earth is impossible and leading to collapse.

5.7 Ethics and Equity

How can a new curriculum ensure that the transition to a bioeconomy is just and is addressing rural livelihoods, gender equity, and developing countries' access to green technology?

A new curriculum must foreground justice and inclusivity at every step. All students should learn that the climate transition is first and foremost a social transformation rather than a technical fix. For example, gender equity is explicitly linked to sustainability: young advocates note that women and girls often bear the worst climate burdens, so empowering them (through education, rights) is essential, as mentioned in the conclusion of the State of the Climate Report (Ripple et al., 2024).

Recent research from Oxfam finds that the richest 0.1% of the global population emit more in a single day than the poorest 50% emit in a year, and that super-wealthy investment-portfolios rival entire countries' emissions. This level of carbon inequality means that any serious curriculum on economics, sustainability and the bioeconomy must empower students to understand not just markets and resources, but the power hierarchies and wealth-driven dynamics that shape our planetary systems.

Lessons can discuss how economics models have historically marginalised rural communities and the Global South; the new approach emphasises cooperation, technology sharing, and local participation. As the Youth Bioeconomy Vision (2024) stresses, solutions must be *inclusive* globally, embracing diverse cultures, past & future generations, and knowledge systems.

- Rural and livelihoods: Include case studies of how a just green transition can support farmers (e.g. co-ops for organic farming, training in regenerative techniques). Show that rural jobs and traditions can be enhanced, not abandoned.
- Gender and social equity: Cover ecofeminist or development economist perspectives. For instance, cite that closing gender gaps in decision-making leads to more sustainable policies. Discuss how subsidies or tech grants should explicitly help poorer countries adopt renewables, not just rich nations.
- Social justice lens: Integrating gender and development studies shows how economic policies affect different groups. Studies show that high inequality undermines cooperation and productivity; more equal societies are more stable and have less excess. Economics curricula should therefore include content regarding marginalised groups for a just-transition in Ireland.

5.8 Innovation and Entrepreneurship

How can students learn to identify and evaluate business opportunities within the circular and bioeconomy sectors?

Rather than hunting for “opportunities” that simply expand the bioeconomy market, students can learn to co-create and co-design solutions that deal with social and environmental problems in a holistic sense and at the same time develop critical thinking. As Alice Kalro argues, many so-called business opportunities are built into the same destructive logic that caused overshoot and environmental breakdown. True sustainable enterprises must be *regenerative* and *inclusive*. In practice, this means projects and startups that aim for environmental restoration and social benefit first, rather than short-term financial profit (Kalro, 2023).

- Root-cause focus: Teach that a viable business model must not depend on degrading nature or impoverishing workers. Alice Kalro observes that if a company’s profits rely on ecological overshoot or social destitution, it is inherently unsustainable. Use her “Unsustainable Core Business” concept to evaluate ventures.

- Examples of regenerative models: Highlight cooperatives based on principles of collaboration and focused on meeting human/ecological needs, this could also extend to social enterprises. For instance, a student project might design a community solar energy co-op, a platform for sharing surplus food, or a startup making biodegradable packaging from waste fibres. These models should have democratic governance and reinvest profits in community or ecological health.

5.9 Systems and Complexity

Traditional economics often simplifies markets and actors. Teaching systems thinking can help students grasp the complex and interconnected nature of the economy, society, and environment. Unlike traditional models that assume simple cause-effect, systems thinking highlights relationships, feedback loops, delays, and unintended effects. This should better equip students to think non-linearly, and understand the economy as evolutionary and nested within other systems.

As Meadows shows in her work on systems dynamics, system structures produce persistent problems until restructured at a deep level (2008). For example, a subsidy designed to help farmers might trigger a reinforcing loop of monoculture and degradation unless holistically managed (like in the EU). In class, students could learn systems thinking concepts, identify stocks and flows (e.g. carbon in atmosphere vs ocean uptake), and consider how one policy cascades through the system. Meadows notes, systems thinking “gives us the freedom to identify root causes of problems” and shows that problems only yield when one sees “the system as the source of its own problems” (Meadows, 2008).

The economic system that today’s students will inherit is likely to be environmentally post-tipping and technologically transformed by AI, requiring fewer workers. This introduces new challenges, and requires education around policies that can provide safety nets for these seismic shifts. Some of these policies include: Public job guarantees for work with social or environmental benefits, UBI, Modern Monetary Theory (Kelton 2020), Debt Jubilees (Keen, 2021) and more.

- Feedback and dynamics: Students could be introduced to simple stock, flow models (for example, forest biomass versus logging rate, or carbon emissions versus sequestration) to show how lag times complicate policy responses.

Emphasise that many effects are non-linear, such as climate tipping points, and that feedback loops can amplify or dampen system behaviour.

- **Holistic solutions and the bioeconomy:** Students should learn that incremental fixes often fail, and that using systems language, such as leverage points, nested systems, and resilience, enables them to think in terms of whole-system transformation. Systems thinking provides a conceptual foundation for understanding the bioeconomy, helping learners to see how biological, social, and economic systems interdependent on each other, and to design interventions that will sustain rather than deplete natural capital.
- **Pedagogy and Assessment:** To embed these ideas meaningfully, inquiry-based and experiential pedagogies should be encouraged. Activities such as participatory mapping, simulation games (e.g. the supply chain game) (Senge, 1990), or community-based projects tracing the life cycle of common goods (Rivoli, 2014) can make complexity visible. Assessment could move beyond individual recall towards project-based tasks that evaluate student's ability to map feedback loops, anticipate unintended consequences, and propose adaptive policy responses. This aligns with NCCA's emphasis on key skills such as critical and creative thinking, being an active learner, and working with others (Clerkin and Perkins, 2017).
- **Develop an understanding of the complexity of modern supply chains** with games and simulations (e.g., the supply chain game discussed in Senge, 1990) and mapping exercises where students attempt to map where something that they consume is produced (a great starting point could be the book by Rivoli, 2005)
- **Values and Citizenship:** Ultimately, systems thinking encourages ecological literacy, ethical awareness, and civic responsibility, preparing learners to participate thoughtfully in shaping equitable and sustainable economic futures. It complements the Irish curriculum's broader aims of developing reflective, adaptable citizens capable of engaging with complexity and uncertainty in the twenty-first century.

5.10 Economic Citizenship

What knowledge, skills, and values should a Leaving Cert student have to be an informed citizen and decision-maker in a sustainable, biobased economy?

To co-create a biobased economy, students need a systems outlook, critical skills, and values. Key knowledge includes understanding ecological limits (the idea of a “safe operating space”) and three goals of sustainability economics (sustainable scale, fair distribution, and efficient allocation) (Costanza, 2020). They should be able to understand the concept of life-cycle assessments or impact on biodiversity.

Skills should include critical thinking, systems mapping, collaboration, and empirical analysis of local supply chains. Above all, values like interdependence, equity, and stewardship are central. For example, Costanza emphasises that solving tomorrow’s problems requires bridging disciplines and engaging stakeholders - a citizenry that sees itself embedded in ecosystems.

Students should be familiar with basic concepts in data literacy. It is impossible to make informed decisions in a complex world without a basic understanding of how to interpret data and critically evaluate information.

Systems literacy: Students should grasp basic ecology and social science principles: e.g. how a budget surplus (economic) might translate into land-use change (environmental).

Some potential skills to prioritise:

- Systems literacy
- Relational intelligence
- Collapse literacy
- Cooperative governance
- Emotional maturity
- Digital-ecological ethics

5.11 Assessment and Engagement

How could assessment methods better capture students' understanding of the bioeconomy compared to traditional written exams?

Assessment should move beyond one-off written exams to project-based and case-oriented evaluation that expand students' adaptive capacity through skills like collaboration, ethical reasoning, regenerative design etc). Real-world tasks (group projects, case studies, enterprise simulations, field studies) better capture understanding of complex bioeconomic concepts and allow for greater depth inquiry and 'metabolization' of knowledge as opposed to surface level study and knowledge accumulation (Machado de Oliveira, 2025). Research on bioeconomy education recommends problem-based, interdisciplinary, experiential learning. For example, students might collaborate on a local case study of a bio-based enterprise (like a sustainable farm or recycling/upcycling venture) and present how it meets "Doughnut" criteria. Portfolios or project reports can include systems diagrams, policy proposals, or social impact analyses.

The recommendation for active learning approaches, such as problem-based and interdisciplinary learning, is validated by PISA research indicating that pedagogic approaches involving "teamwork, peer-to-peer learning, simulations, [and] problem-based learning" are effective for developing global competence (OECD, 2020, p. 179). To accurately measure the application of bioeconomy principles, assessment methods must evaluate complex skills, notably the capacity to "evaluate actions and consequences" (OECD, 2020, p. 60, 281) in scenarios such as those concerning "Rising sea levels" (OECD, 2020, p. 86).

In an age of AI, these human relational skills will become increasingly important. Embedding relational pedagogical approaches in this work will be of significant benefit to students who are moving through a very disconnected world in terms of relationality and nature with the constraints of climate change and AI.

- Community-linked projects: Use local enterprises (e.g. a cooperative dairy or biogas plant) for case studies. Have students interview entrepreneurs or farmers, linking curriculum to lived experience.
- Interdisciplinary teams: Organise cross-subject projects (economics + biology + civics) so that solutions must draw on multiple fields and the boundaries

contributing to the idea of separability are dissolved. This aligns with calls for “transformative and interdisciplinary” education - as Mary Robinson argues, “Education for climate justice must integrate knowledge from science, economics, law, and social justice”.

- Continuous assessment: Include short presentations, journals, or reflective essays on sustainability topics throughout the year. This avoids high-stakes single exams and rewards understanding of change processes.

6. Conclusion

In conclusion, the collective warmly commend the NCCA for its openness, responsiveness, and genuine willingness to engage with a wide range of voices during this important phase of curriculum redevelopment.

This inclusive, consultative approach reflects international best practice and Ireland's long-standing educational values of dialogue and collaboration. In light of the robust, research-based evidence presented throughout this document, the collective respectfully recommend the NCCA to extend the conceptual reach of the bioeconomy beyond the confines of the Climate Action and Sustainable Development subject and weave it as a unifying, interdisciplinary, transdisciplinary thread across the broader curriculum.

The bioeconomy represents not merely a scientific or environmental theme, but a transformative framework for reimagining how knowledge, creativity, and civic responsibility intersect across disciplines, in particular, the redeveloped Economics specification itself should explicitly embed bioeconomy concepts, serving as the core link between these disciplines.

Embedding this concept not only within economics but across multiple subjects would not only future proof the Leaving Certificate but would also affirm Ireland's commitment to cultivating reflective, innovative, and ethically grounded learners prepared to lead within a regenerative, sustainable society in line with our culture and heritage.

Ní neart go cur le chéile.

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