# Towards BioPort Ireland for Sustainable Aviation Biofuels

## 14 September 2017

**Executive Summary**

BioPort Ireland proposes a bioeconomy plan to the greenification of Irish aviation based on the BioPort model, a regional hub that converts, transports and commercialises regional feedstocks into sustainable and high-quality biofuels-for-aviation. This enables Ireland to achieve several key objectives, namely:

- To reach the CORSIA commitment of 50% reduction of aviation CO2-emissions by 2050 relative to the base year of 2005;
- To creat a significant number of jobs;
- To promote rural development and a significant economic impact through new Irish biorefineries in the aviation-for-biofuels sector; and
- To enable a range of high-added value industries.

The proposal links closely to various existing initiatives supported by the Irish government with respect to Bioeconomy Development, innovation via the SFI Bioeconomy Research Centre, Rural economic development, and the Irish Action Plan for Sustainable Aviation.

The recent initiative for BioPort Ireland is led by the core group of aviation industries and academia and plans to extend its remit to a wider group of national and international stakeholders to ensure the development of a profitable and sustainable market for biofuels-for-aviation in Ireland.

**Cover picture obtained from iStock (# 71331613)**

**The BioPort Ireland Proposal for Sustainable Aviation in Ireland 2017-2050.**

**The aviation challenge.**

Worldwide, flights produced 781 million tonnes of CO2 from approximately 250 million tonnes of kerosene in 2015. This is approximately 2% of human produced CO2 and 12% of global transport emissions. Global passenger-kilometres increase by 4-5% annually, and historic improvements in aircraft fuel efficiency, operations and infrastructure contributed to a combined 1.5% emission reduction per year[1].

As an island, Ireland depends strongly on clean and affordable air transportation. Given the importance of engaging with (US-headquartered) (bio)pharma and ICT companies, long-haul, transatlantic travel dominates much of the business-related transportation to/from Ireland, in addition to travel across the European Union. Therefore, heavy-road, diesel-based transport is important for exports as well as for domestic supply given the relative distributed lifestyle of the Irish population (half in Dublin, the other half spread-out over the whole country). Both sectors face limited alternatives than biofuels and consume a combined 2-3 Mtoe (million tonnes of oil equivalents) per year. The diagram in Figure 1 (SEAI, 2013[2]) summarises Irish primary energy consumption, including that which is used in aviation and other transportation fuels, which increases by 2-3% every year.

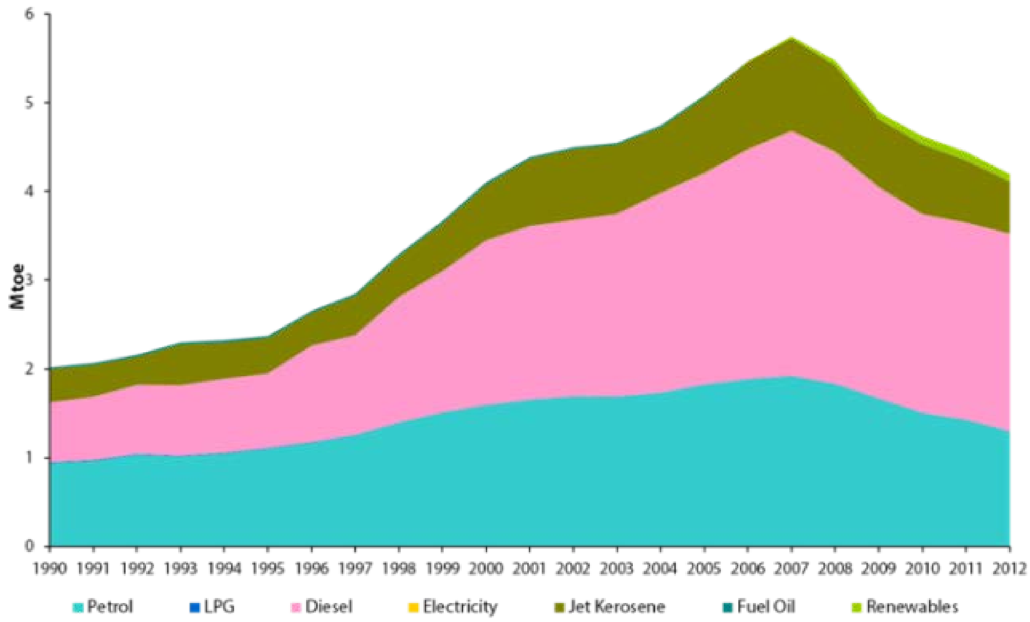


Figure 1. Consumption of transportation fuels for all categories of transport, including aviation in Ireland is essentially of fossil nature and increases 2-3% per year [2].

[1] IATA et al., "Reducing emissions from aviation through carbon-neutral growth from 2020", 2013. https://www.iata.org/policy/environment/Documents/atag-paper-on-cng2020-july2013.pdf

[2] Sustainable Energy Authority Ireland SEAI - Energy in Ireland 2013 Report.

**Ireland agreed to the CORSIA-agreement for reduction of aviation emissions**

On the 6th of October 2016, the International Air Transport Association (IATA) congratulated states which, under the leadership of the International Civil Aviation Organization (ICAO), have achieved an historic agreement to implement a market-based measure that will support airlines' efforts to stabilize emissions with carbon neutral growth. The agreement was reached by states attending the 39th ICAO Assembly which convened in Montreal, Canada. ICAO's 191 member states, which includes Ireland, agreed to implement a Carbon Offset and Reduction Scheme for International Aviation (CORSIA). This translates into carbon neutral growth of aviation from 2020 onwards and will result in halving GHG emissions in 2050 relative to the base year of 2005 (SEAI, 2015[3]). The GHG emission of Irish aviation sector was 2527 kton/yr in 2005, and, therefore, targets 1263 kton/yr in 2050. The current carbon output is approximately 2400 kton/yr and is related to a (fossil) kerosene consumption of approximately 780 kton/yr. The historic growth rate of this metric is approximately 3-3.5 % per year. The current Action Plan for Aviation Emission Reduction of Ireland[4] is mostly based on improvements in Technology (purchase of new, fuel efficient airplanes), Operations (tuning of flight schedules and slots, networks and alliances) and Infrastructure (airport architecture, electric taxiing etc.) – in short :TOI-measures.

The assessment of the Irish situation follows those made previously for The Netherlands[5] and Brazil.[6] The corresponding reports have been used for policy making in the respective countries, which is in the public domain as well.

Investing in newer, more fuel-efficient airplanes has enhanced fuel (cost) efficiency and, consequently, has contributed substantially to the commercial success of the Irish airlines Ryan Air and Aer Lingus. These investments are ongoing but contributions to technological advances seems to have reached a plateau, such as indicated in the Figure 2 below..

[3] SEAI, 2015. Energy in Ireland Key Statistics 2015, SEAI. Available at: https://www.seai.ie/Publications/Statistics_Publications/Energy_in_Ireland/Energy_in_Ireland_Key_Statistics/Energy-in-Ireland-Key-Statistics-2015.pdf [Accessed May 23, 2017].

[4] Ireland's Action Plan for Aviation Emissions Reduction 2015-2019. Department of Transport, Tourism and Sport, June 2016.

[5] https://www.rijkswaterstaat.nl/zakelijk/innovatie-en-duurzame-leefomgeving/lef-future-center/succes-met-lef/duurzame-brandstofvisie.aspx (2014, in Dutch with English summary)

[6] Franco, T.F., and L.A.M. van der Wielen Report of the 3rd AgroPolo Campinas Workshop Bioeconomy "Advanced biofuels for aviation and other heavy transport". School of Chemical Engineering (FEQ), State University of Campinas (UNICAMP) Campinas, October 17-18, 2016. Available for download via www.agropolocampinasbrasil.org

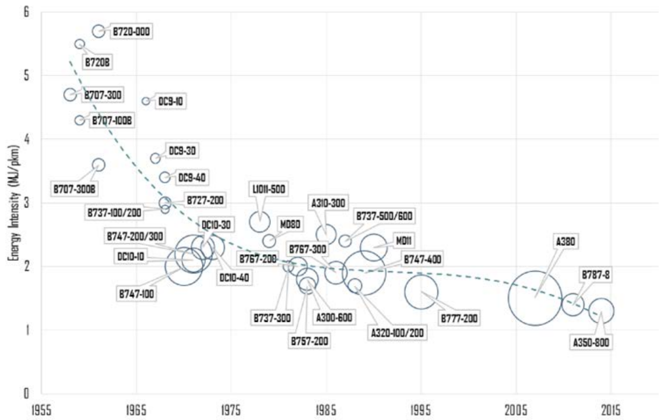


Figure 2. Energy-efficiency in the aviation industry (IEA/OECD, 2009)[7].
The numbers indicate types of airplanes and the circles their scale in numbers of passengers.

Globally, the TOI-contribution is estimated to be approximately 1 - 1.5% GHG emission reduction per year. The remaining consumption increase of around 2% needs to be addressed by alternatives for fossil fuels such as biokerosene, solar fuels etc.

**Maturity and Readiness of Biofuels**

A central topic is the maturity of the biofuels development, as is expressed by the so-called **Biofuels (or Fuel) Readiness Level** (BRL or FRL). This BRL-approach was developed in a European program[8] (RENJET) and aimed to facilitate the decarbonisation of the aviation industry by accelerating the development of renewable jet fuel supply chains in the EU, while simultaneously increasing availability and stimulating demand. One of RENJET's Work Packages (# 1) examined how and under what preconditions substantial volumes of sustainable, next generation biofuels can be made available in the short and medium term (respectively to 2020 and 2035), as well as identified key opportunities to establish sustainable supply chains in the shorter term.

The results are summarised in various reports[9], [10],[11] that review the commercial and technological maturity of various technologies for converting biomass to aviation biofuel, drawing on an extensive review of academic and grey literature published in the field. In particular, it evaluates technologies with regards to their '***fuel readiness level***', progress towards international certification, compatibility with existing infrastructure, economic viability and the opportunity costs of producing biofuels for

[7] IEA/OECD (2009) *Transport, Energy and CO2: Moving toward sustainability*. Paris: International Energy Agency.
[8] RENJET - the EIT Climate KIC project 'Fuel Supply Chain Development and Flight Operations'
[9] R. Mawhood, A. Rodriguez Cobas, R. Slade, Imperial College, "Establishing a European renewable jet fuel supply chain: the technoeconomic potential of biomass conversion technologies", 2014. http://www.climate-kic.org/projects/renewable-jet-fuel-supply-chain-development-and-flight-operations/
[10] Luís A. B. Cortez, Francisco E. B. Nigro, Luiz A. H. Nogueira, André M. Nassar, Heitor Cantarella, Márcia A. F. D. Moraes,Rodrigo L. V. Leal, Telma T. Franco, Ulf F. Schuchardt and Ricardo Baldassin Junior, "Perspectives for Sustainable Aviation Biofuels in Brazil", International Journal of Aerospace Engineering, Volume 2015.
[11] S. de Jong, R. Hoefnagels, A. Faaij, R. Slade, R. Mawhood, M. Junginger, "The feasibility of short-term production strategies for renewable jet fuels – a comprehensive techno-economic comparison", Biofuels, Bioprod. Bioref. 9:778– 800 (2015).

aviation[12]. Clearly this approach can be applied to other long-haul and heavy transport areas, such as the road and marine sectors.

This case study has provided a basis for policy advice and market estimates in The Netherlands and Brazil. In an Irish context, this results in Figures 3 and 4 –based on a simple mass balance model- indicating a possible scenario for CO2 and other GHG emission profiles (top) and development of fossil and renewable aviation fuels (bottom) that meet the CORSIA requirements based on the assumed 3% growth of passenger kilometres, and the average 1%[13] fuel efficiency increases by combined TOI-measures. This scenario underlines the need for a significant contribution of aviation biofuels from biomass and/or solar fuels after 2022 (5 years from now), growing towards approximately 350 kton/year in 2030 and more than 1500 kton/year in 2050. The immediate target of the BioPort Ireland consortium is to verify and challenge these numbers, and explore conditions for the anticipated success.

**Renewable fuel scenario's**. Various studies and national roadmaps are available for the development of sustainable aviation fuels (Brazil, NL, USA)[14]. In general terms, they anticipate 3 subsequent and partially overlapping phases in the development of advanced biofuels:

**1G or today's technology** is based on hydrogenation and/or decarboxylation of vegetable and residual oils and fats, such as used cooking oil. Here, technology is reasonably mature and has been demonstrated on larger scale (such as the Neste plants in Finland, Singapore and The Netherlands) where the fuels already have been (ASTM) certified for use in blends, or which are well advanced in their certification. A significant limitation is the availability of feedstock.

**2G or Tomorrows technology** is relevant for the (2) midterm 5-10 years on various platforms[15] from lignocellulosic and other biorefineries, and (3) longer term (more than 10 years) based on using residual carbon (CO, CO2, CH4 from steel, concrete and other base industries, as well as domestic and industrial waste effluents) and renewable energy from wind and solar sources. For the cases of (2) and (3), feedstocks are substantially more abundant.

In an Irish context, phase 1 will include the processing of tallow and other animal fats as well as used cooking oil related to current food and feed processing residues (estimated to be around 50 kton/yr in Ireland) in dedicated plants or via co-processing in the Whitegate refinery in Cork. Phase 2 relates to agro-forestry residue streams. Phase 3 relates to the relatively limited availability of the C1-streams of the Irish concrete, metal (aluminium), food/feed and power industries and potentially biogas from domestic and industrial effluent streams.

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[12] S. de Jong, "The viability of renewable jet fuel – a general overview", 2016. http://www.ieatask33.org/app/webroot/files/file/2016/WS-May/Viability_deJong.pdf

[13] Given the relatively modern fleet of Irish airlines, much of the Technology-based efficiency gain is already implemented, and we assume a relative conservative TOI-effect of 1% instead of 1.5%

[14] Alves C.M., M. Valk, S. de Jong, A. Bonomi, L. A.M. van der Wielen, S. I. Mussatto, Techno-economic assessment of biorefinery technologies for aviation biofuels supply chains in Brazil. *BioPFR* 11(1), 67-91, 2016

[15] Heeres AS, CSF Picone, LAM van der Wielen, RL Cunha, MC Cuellar. Microbial advanced biofuels production: overcoming emulsification challenges for large-scale operation. *Trends in biotechnology* 32 (4), 221-229, 2014.

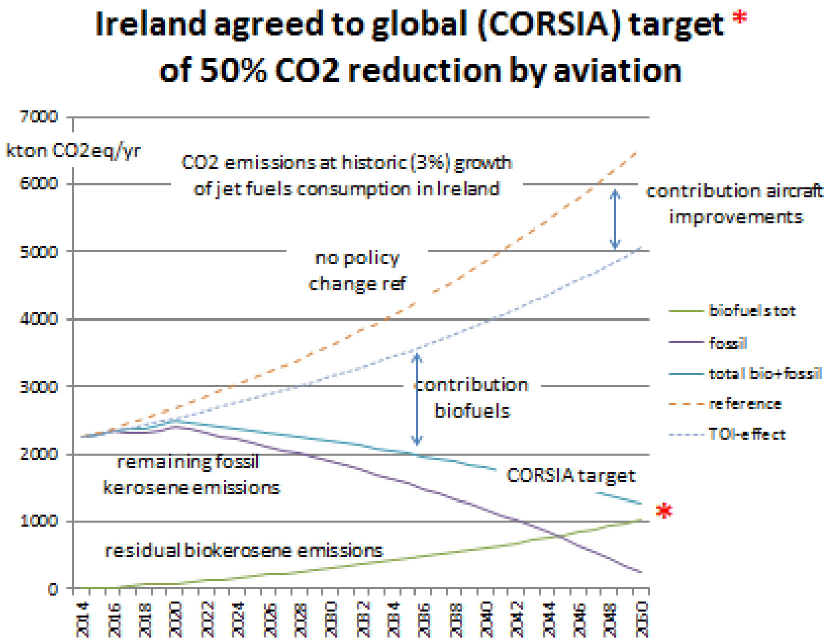


Figure 3. Reference and proposed emissions profiles in ktons/yr of

CO2-equivalents to meet the target (*) of the CORSIA-commitment.

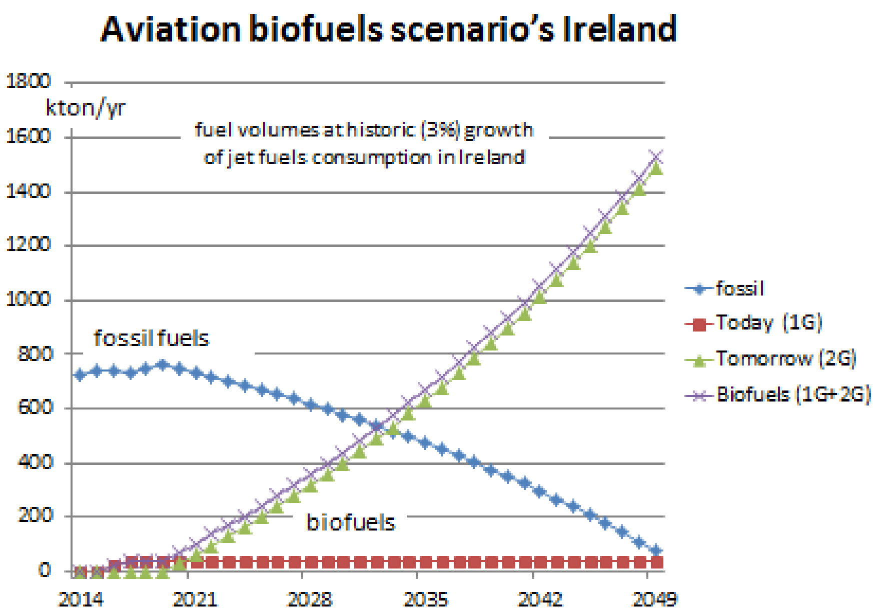


Figure 4. Fossil and renewable fuels in ktons per year to meet the CORSIA-commitment[16].

[16] The initial 'wiggle' in fossil consumption is due to the assumed introduction scenario of biofuels over the various categories. Slightly different assumptions give slight variations but don't influence the essential trends.

Our initial estimates, show that Phase 1 can start reasonably quickly once the feedstock is secured and will help to develop the biofuels-for-aviation market, which is currently non-existent in Ireland. These estimates, based on Irish feedstock availability, also indicate that the impact is limited towards maximum blending volumes of 5-10% in 2022). The large growth in aviation biofuels should be seen by the lignocellulosic feedstocks (Phase 2), whereas only the first commercial biorefinery plants are emerging now[17]. This gives a 5-year lead time to develop and to test aviation biofuels in Ireland to serious scale, and have the associated commercial, incentive and other frameworks in place.

This important development is completely aligned to the recent SFI investments in Beacon, the lignocellulosic biorefinery Research Centre, that was launched at September 7 2017 in Dublin by An Taoiseach, Leo Varadkar TD, by An Tánaiste and Minister for Business, Enterprise and Innovation, Frances Fitzgerald, T.D., and by Minister of State for Training, Skills, Innovation, Research and Development, John Halligan, T.D. The Centre is led by prof. Kevin O'Connor of UCD. The BioPort Ireland consortium aims to develop this biofuels-for-aviation plan in close development with the Beacon Biorefinery Research Centre.

The Beacon Bioeconomy Research Centre, as well as other bioeconomy initiative funded by private sector as well as EU's H2020 program will have an excellent opportunity to align high-added value developments[18] to a biofuels-for-aviation driven development. On the industry side, we plan to present this plan for higher TRL-level funding with the Biobased Industries Joint Undertaking[19], the €3.7 billion partnership between the EU and the Bio-based Industries Consortium.

Fig. 5 The DSM-POET lignocellulosic biorefinery in commercial operation in Emmetsburg, USA (feb 2017) [20]

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[17] Liberty by DSM-POET joint venture in Emmetsburg, USA and GranBio in Lagoas, Brazil. Both lignocellulosic ethanol plants started operations in 2015, and after initial technological and logistic problems are operating at commercial scale. This also provides some initial job creation and techno-economic data, which we use in this work.

[18] For instance the LIBRE program for sustainable composite materials on the basis of lignocellulosic residue, or FIBRESHIP linking to opportunities for advanced materials development for mobility (aircraft, car and ship manufacturing). Both programs are led by scientists from the Bernal Institute of the University of Limerick in the framework of the Irish Composites Research Center of Enterprise Ireland and IDA.

[19] https://www.bbi-europe.eu/

[20] https://www.dsm.com/corporate/media/informationcenter-news/2017/02/2017-02-16-poet-dsm-plans-on-site-enzyme-manufacturing-facility-at-project-liberty.html

**Job generation and required investments.**

The above production scenarios for advanced biobased and other renewable fuels can be translated into required capital investments and job generation using the initial estimates that are benchmarked against those of the emerging lignocellulosic biorefineries such as the DSM-POET ethanol plant in Emmetsburg, USA.

Basic assumptions:

- **Investments**: a typical number for the fuels and large scale chemicals industry is approximately € 100 million investment per 100 kton/year of production capacity. This number is double for industry with solids handling such as lignocellulosic and other agro-forestry residues.
- **Added value**: McKinsey indicates approximately € 100-250 added value per ton or raw biomass. For lignocellulosic biomass this implies €300 - € 400 per ton biojet fuel. In our initial analysis, we use a more conservative numbers, in terms of margins of 10% on sales of € 1000 per ton BJ-fuel.
- **Job generation**: approximately 100 direct FTE's per 100 kton/jr production capacity[21] and double that number in indirect jobs. The direct jobs are related to fuels production in a modern lignocellulosic biorefinery, of which there are only very few examples still, so the numbers should only be used as a first indication. But related industry such as pulp & paper, starch industry, vegetable oils use comparable numbers. The indirect jobs are related to flanking activities throughout the supply chains. Depending on, for instance, scale of biomass production (self employed small holders versus industrial forestry plantations), these numbers can vary significantly and also these should be used as a first indication.

Projected Impacts:

| | **Direct jobs** | **Indirect jobs** | **Total jobs** | **CAPEX / M€** |
|---|---|---|---|---|
| 2020 | 40 | 80 | 120 | 40-80 |
| 2030 | 398 | 797 | 1195 | 400-800 |
| 2050 | 1527 | 3055 | 4582 | 1500-3000 |

This type of investment is expected to result in an aviation biofuels market of € 1.5 bn / year and GDP impact of hundreds of millions of euros, in addition to a complete greenification of one of the key transport sectors of the country.

[21] For comparable numbers see those of organisations like VNCI (Chemical Industry Association), USA/BIO, Europa Bio and other branch organisations.

**Irish feedstock: the forestry opportunity.**

One specific opportunity to explore in this context is the active forestry policy of the Irish government that has increased the area of national forest estate in Ireland to approximately 700,000 hectares (10% of land area) from roughly 1 % in at the end of the 19th century. In 1996, the Irish government initiated a plan to increase the forest estate to 1.2 million hectares (17% of total land area) by 2030. Currently, the fraction of Irish-grown trees converted into usable timber is small due to the combination of temperature and rain, so alternatives such as feedstock for aviation (kerosene) and heavy duty fuels are widely used by transportation sectors.  Conversely, well and sustainably-managed forests produce around 10-15 ton / ha per year of lignocellulosic biomass in this climate range, corresponding to 10-15 mio tonnes of wood per year. If 80% of Irish forests are sourced for fuel consumption, and a modest conversion yield of 25% of biomass-to-advanced biofuel converts to approximately 3 million tons of biofuels including biokerosene, then this would position Ireland to be a self-sustaining supplier of aviation biofuels as well as  a key driver in the long haul road and marine transport sector.

**Fig.6** The forestry opportunity for greening Irish aviation

**Sustainable development of biofuels-for-aviation.**

The true sustainability of the development of aviation biofuels is key. The BioPort Ireland Consortium is firmly rooted in a group of global scientific experts with links to reputed organisations such as Worldbank Group, SCOPE (UNESCO/UNEP's Scientific Committee of Problems of the Environment) and others. A number of recent studies[22],[23], [24]  have provided guidelines for the actual sustainable development and those will be taken as the basis for the proposed development.

[22] Souza G.M. et al. The role of bioenergy in a climate-changing world. *Environment Develop*.  23, p57-63, 2017.

**BioPort Ireland (in close collaboration with SkyNRG)**[25]

There is currently very little dedicated sustainable jet fuel production capacity in the world. It's a specialty product with a relatively high price. To bring down the cost price of sustainable jet fuel, we need scale. Therefore, our main long term effort lies in increasing production capacity. This requires partnering with airlines and airports to create the structure and the market influence to enable regional, sustainable jet fuel supply chains, particularly with regard to financial stability and growth.. We call these regional supply chains "BioPorts". The Bioport model is based on a regional approach. This way the benefits can reach well beyond carbon reduction. We see energy security, reduced price volatility, (potential) development of local communities and rural areas, adding value to (marginal) lands and economic growth as main drivers for engagement with a broader group of stakeholders (e.g. governments, farmers, investors, NGOs).

For a Bioport , we will use the feedstock that makes most sense for the region and we will engage with the right conversion technology and partners. As long as the end product meets the technical specifications and our sustainability criteria, are met we are willing to consider any feedstock/technology combination. In this new initiative around BioPort Ireland, the Shannon Group (Shannon Airport and partners), the Bernal Institute of University of Limerick and a number of international biofuels players such as KLM/AirFrance spin-out SkyNRG explore the opportunity to develop a market for sustainable biofuels in Ireland.

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Limerick, Ireland, 2017 09 12

[23] LR Lynd, et al. A global conversation about energy from biomass: the continental conventions of the global sustainable bioenergy project. *Interface focus*, 2011 Apr 6; 1(2): 271–279

[24] Souza, G.M., et al. (Eds.), Bioenergy & Sustainability: Bridging the Gaps, 72. SCOPE, Paris. France (2014), pp. 258–301. (ISBN 978-2-9545557-0-6) http://bioenfapesp.org/scopebioenergy/images/chapters/bioen-scope_chapter09.pdf).

[25] SkyNRG is a spinout of KLM-AirFrance leading the development of a sustainable biofuels-for-aviation market worldwide (Scandinavia, The Netherlands, USA and elsewhere) . The BioPort model, such as tested via BioPort Holland, BioPort LA, BioPort Scandinavia is essentially a partnership between governments-academia and private sector. http://skynrg.com/our-services/bioport-development/