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A Response to the Nuffield Council on Bioethics Consultation Paper

New Approaches to Biofuels

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Introduction

The 21st century's economic well-being will be closely connected to the use of natural resources, but the nature of that connection is changing. All nations are now part of a global economy driven by scientific research and development (R&D) which brings both iterative changes and much bigger, transformative changes which can revolutionize a natural resourced-based industry over a generation or less. Our combined research team is investigating how Canada can benefit from both kinds of change in the context of agricultural genomics, the scientific investigation of the entire set of genes making up a particular organism such as our familiar crops of wheat, flax, canola and corn. We are working to gain greater knowledge and insight regarding the three crucial aspects that scientific discoveries take on the way from the lab bench to the marketplace: intellectual property protection; regulatory; and consumer acceptance. The final aspect of importance is the sustainability of an industry once it has successfully placed products on the market.

When a lab discovery looks like it might be developed into product or process, it is important to ensure that the discovery's value is protected. In genomics research, those that contribution to funding that research need to have a stake in the protection of those discoveries using intellectual property rights including patents and copyright.

The second aspect of scientific discovery is closely connected with the first. While Canada enjoys a mostly reliable regulatory system for introduction of new agricultural practices and bioproducts, that system is seriously challenged by genuinely transformative practices and products. When a new agricultural bioproduct is judged by our regulatory system to be a novel food, feed or crop, an environmental threat or a drug, that product often stalls in the regulatory process, stuck in systems developed for the problems of yesterday, not today. Nobody benefits from stalled inventions: for Canadians to get their money's worth from investment in science R&D, our scientists' and developers' new products need to be evaluated and accepted or rejected as quickly and efficiently as possible. Our response identifies new models for governance of transformative agricultural technologies and bioproducts, helping to ensure that publicly supported research is used efficiently.

In the third aspect of our response we are suggesting new ways to engage the public in contributing to the choices made about new agricultural crops and bioproducts. Transformative changes in agriculture and bioproducts can have large effects on societies, so there needs to be meaningful ways to participate in choices about the way we use new agricultural technologies and products.

The sustainability of biofuels is one of the most crucial aspects of this innovation, but is also an issue that infrequently merits a rigorous discussion. Life-cycle analysis is one option for assessing the impacts of both fossil fuel and biofuel alternatives and while this area of research is increasing, there is a dearth of knowledge at the present.

The following sections of the response examines each of the above four aspects in greater detail. Each of the aspects, while important is their own right, will be collectively required to further the uptake of biofuel technological products and process.

Intellectual Property Management and Technology Transfer

While patents have been used for centuries in some industries as a tool to stimulate research and innovation, these laws are still very new to many forms of crop research. Over the past three decades, several countries have allowed the patenting of biotechnological processes and products, which coincided with technology advancement and the rapid development of private industry. Part of the industry development that has ensued was a consolidation of small firms and the creation of a few large life science companies, each owning the requisite intellectual property (IP) and having freedom-to-operate. Despite the ability and potential gains from doing so, for many years there was very little apparent flow of IP between these firms, which separated some potentially complementary IP.

Recently, there has been a new movement in the agricultural biotechnology industry, one that has seen an increase in gene trait cross-licensing agreements. While these agreements facilitate the much needed sharing of IP across research platforms, they raise additional concerns with respect to market concentration. One aspect of this is cross-licenses between small biotechnology firms and large multi-national biotechnology firms, the other is cross-licenses between the large multi-national firms.

The ‘tragedy of the commons’ is well known in the economics literature. The problem arises from many individual agents having the right to use a resource without the ability to exclude others from using the resource. This asymmetry in the right to use and exclude the results in the overuse of the resource, as each agent does not consider the impact of their actions on the availability the resource to the other agents. The result is an overused resource that often is exploited to the point that there is little economic value. One has only to look at many international fisheries to see the tragedy of the commons.

A symmetric problem that has only recently been identified in the economics literature and results in the under use of resource has been aptly named as tragedy of the anti-commons. The anti-commons arise whenever individuals have the ability to exclude others from using a resource but cannot use the resource themselves. Heller (1998) first identified this problem in the former Soviet Union, where many parties could block the use of storefronts, to the point that existing storefronts were going unused.

There are numerous indicators that existing IP strategies utilized by public institutions have fallen short of early expectations. It is an open question whether universities obtaining patents increases or limits knowledge mobilization and product development. Alternative perspectives on IP policy have been proposed and examined in the last decade (Herder and Gold, 2007; Joly, 2007) but they have not specifically addressed the needs of the public, nor have they look at whether the agriculture sector has different needs to other areas of biotechnology research.

Regulatory and Governance

The advent of knowledge-based economies has raised new concerns about who is in charge of governing the economy. In the knowledge economy, the key asset is the ability to innovate – i.e. the facility to develop, adopt and adapt new ideas, products, and organizational structures by combining existing ideas, products and structures in new ways. Ultimately, this process involves the identification, assembly and use of disparate types of information and knowledge through a wide range of social governing systems. Salamon (2002) suggests that finding the right tools to effectively govern in this environment is difficult because these knowledge networks are plurifom (diverse), self-referential, asymmetrically interdependent and dynamic and consequently do not share the same goals, operating styles, skills, worldviews, incentives and priorities.

The complex nature of transformative change leads to much more extensive innovation processes, which involve a much wider array of actors. Translating an invention into a socially embedded innovation involves a complex web of principals, agents, promoters and regulators on the supply side and middlemen, marketers and consumers on the demand side. Constructing new markets for new products or services is seldom straightforward or simple. Transformative changes thus mobilize a much wider range of actors, many who have never before expressed concerns or interest in change. Modeling this environment is difficult.

Ultimately, the transcendent, expansive nature of transformative technological innovation poses some real challenges for governors (Phillips, 2007). This is one of the more significant, identifiable underlying concerns about globalization. Increasing interconnectivity caused by transformative technologies is undercutting both perceptions of and capacity to isolate and specifically control new developments. Information technologies, combined with the many and varied advances in biological and materials processes, have linked previously disconnected parts of our world.

Given the array of crop-based innovations that have been and are planned to flow from research, there are going to be challenges in regulating these new technologies and applications. Traditionally, theories have focused on explaining the causes and consequences of choosing particular policy tools to tackle relatively simple policy problems (e.g. Trebilcock and Hartle, 1982; Linder and Peters, 1998; Eliadis, *et al*., 2005). In response to the increasing complexity of a number of policy fields, more recent theoretical developments have tried to characterize entire policy regimes comprising multiple policy goals and a mix of policy tools designed to achieve these goals (e.g. Bressers and O’Toole, 1998; Howlett and Rayner, 2006). Within a policy sector, policy regimes may have different goals with respect to different issues: Paarlberg (2000) classified policy regimes as promotional, permissive, precautionary or preventive; and Montpetit, *et al*., (2005) distinguished between restrictive and permissive policy designs. Moreover, while transformative change will mobilize a wider range of actors in a more complex set of relationships, the fundamental distinction between the policy network engaged in policy design and the larger policy community impacted by the choice of goals and tools is likely to remain valid in spite of the different terms used to capture the distinction (Atkinson and Coleman, 1992; Borzel, 1998). If so, the theoretical distinction between the appropriate tools needed to coordinate the activities of the policy network (Franciscus, *et al*., 2006) and those needed to communicate between the network and the larger policy community and attentive publics will continue to apply (Schmidt, 2002; Schmidt and Radaelli, 2004).

Democratic Engagement

Concerns about governance in the knowledge economy – especially concerns about who is really responsible for assessing and managing the impacts of transformative technologies – are rapidly reflected in public mistrust and allegations that innovation in applied genomics has escaped the conventional mechanisms of accountability in a democratic society. For all their other advantages in terms of improving the efficiency of outputs, networks based on the exchange of information, the value of which is determined by network members themselves, raise serious problems of input legitimacy (Scharpf, 1999; Hajer and Kesselring, 1999). In particular, the hard currency of scientific knowledge in innovation networks tends to exclude participation by non-scientific actors.

Network actors have responded in a variety of ways, many of which focus on efforts to improve the flow of accessible information from the network to potential audiences such as policy-makers, regulatory decision-makers, citizens and consumers. These efforts suffer from the drawback that the audience is constructed as the passive recipients of messages designed to address 'misunderstandings' about genomics research. The traditional methods of survey research and intensive small group studies are well developed and used to understand the characteristics of the audiences in order to craft the message. The primary research problem, which remains important, is to understand how an information source becomes known and trusted and its audience is transformed from a passive recipient to active seekers and users of the information on offer.

This conceptualization of the problem, however, contains two seriously under-theorized elements which currently constrain efforts to translate applied genomics research into innovate technologies. First, 'the public' is presented as an undifferentiated and passive mass, eager to 're-engage' with scientists and regulatory institutions. Five minutes at an open house should be sufficient to convince anyone that 'the public' is highly differentiated, consisting of a variety of publics each with their own motivations for engagement, most of which have very little to do with the project of restoring public confidence in applied genomics. A promising line of research here links this theme with regulation and governance by presenting both information and process as tools of government in their own right (Howlett, 2000). By doing so, a differentiated public comes into view because policy tools are aimed at target populations with a view to changing behaviour in predictable ways. This element of the research links with current work on the social construction of target populations but also on the importance of central or prominent positions in networks (sometimes called 'nodality') as the first resource to which active seekers of information will turn (Hood and Margetts, 2006). It is argued that nodality is especially important on the web and the study of virtual policy networks has resulted in the development of metrics for this phenomenon with implications for comparative research (McNutt, 2006).

However, the second under-theorized element is the framing of the problem as one of reversing a decline in public confidence through better communication. As Wynne notes, citing a United Kingdom inquiry, while misunderstandings about genomics research of the kind that could be cleared up by better communication may be a cause for concern, the underlying issue may be "resentment at having its other legitimate concerns and definitions of what the issue means to them dismissed by the scientific and policy institutions in charge" (2006: 215). Addressing the issue means taking seriously the possibility of alternative ways of framing policy-relevant questions other than how to provide reassurance. It will be tackled by a program of theoretical development and empirical case studies of democratic re-engagement in the era of network governance.

The common thread in the theoretical literature is a desire to find new modes of representation that will open network governance to democratic decision-making, both aggregative and deliberative (Warren, 2008). The vehicles include deliberative democracy, e-democracy, public conversations, participatory budgeting, citizen juries, study circles, collaborative policy making and other forms of deliberation and dialogue among groups of stakeholders or citizens (Bingham, *et al*., 2005). Once again, a significant amount of empirical research has already been done on the advantages and disadvantages of particular methods of engagement. This research theme aims to connect the two, isolating the specific vehicles for engagement that deliver improved legitimacy for network governance involving transformative technologies, together with a better understanding of the 'elective affinities' that engagement vehicles have with particular issue areas, regulatory styles, institutional structures and cultural contexts. The kinds of engagement that work in a context of adversarial legalism – participatory rule-making, for example – are unlikely to be the same as those that have proved effective in more collaborative environments, such as consensus conferences (Susskind, 2006; Einsiedel, *et al*., 2001; Andersen and Jaeger, 1999).

Assessing the Long-term Sustainability of Biofuels

During all of 2007 and the first half of 2008, the world witnessed a dramatic rise in the price of oil as the price of light crude oil rose from US$60 per barrel at the start of 2007 to just over US$140 per barrel in July 2008. In the 18 month run-up in the price of oil, increasing attention was given to the development and role of alternate fuels. The global food crisis of 2007-2008 and the land use issue of food versus fuel production made headlines the world over. The increased demand for biofuel feedstocks, was met by producers transferring land from food crop production to biofuel crop production. Numerous commentators on this crisis speculated and even identified the increase in the demand for biofuels, as the leading cause of the rise in food prices. The increased use of biofuel feedstocks has been examined for its contribution to the increase in food prices and, based upon this, it is not possible to isolate this effect (Gilbert, 2009). Factors with a higher degree of significance have been identified as currency depreciation, rising oil prices and futures trading activity.

While the recent spike in food prices has largely been alleviated, food prices have not returned to the pre-spike levels (Zilberman, 2009). Given that the food crisis was not based upon biotechnology and biofuels, it raises the question of whether agricultural biotechnology can contribute to minimizing the impacts of future crises. While much of the developing world maintains an aversion to agricultural biotechnology research and the resulting crop varieties, genetically modified (GM) food grains have been commercialized in South Africa and the Philippines. The adoption of GM crops increases year-over-year and the benefits of this adoption will be able to contribute to off-setting a portion of the next food crisis.

While it is not possible to ascertain to directly attribute the increased growth of land used for biofuel feedstock production and the rise in food prices, the reality is, there will be an increase in biofuel feedstock production. While it is possible that some of this increased production could come from marginal agricultural land that is presently grassland, some will have to come from food producing land. Additionally, the potential exists that some of the strain to use food producing land could be alleviated through the use of agro-forestry or food crop residues.

Modeling the use of and role for biofuels reveals they can be an alternative to fossil fuels and additionally, that their production can reduce fuel prices, reduce the incentives for the supply of fuel sources such as coal and tar sands and reduce greenhouse gas emissions (Vulsteke, 2009). However, these benefits are not costless, there is substantial subsidization of biofuels which puts pressure on domestic budgets in a period of global economic downturn. Research on the production of ethanol in the US indicates that without government subsidies, the ethanol industry is unsustainable (Crawford, 2009).

If ethanol production is not sustainable in the long-term, what other options exist? It is anticipated that the second generation of biofuels will contribute at a substantially higher level than the first generation of biofuels. Cellulosic biofuels would appear to have a more favourable economic perspective, yet they have been slow to develop due to the limited success of scale-up plants and limited investment funding. Algae has the potential to produce 10,000 gallons of biofuel per acre, per year, whereas corn-based ethanol production ranges from 400-600 gallons per acre, per year (Kovacevic, 2009). However, using current algae production technologies, it is unable to economically compete with existing technologies, such as soybean oil. Research is underway regarding switchgrass and willow as biofuel feedstock (Richardson, 2009). One of the challenges faced by biofuel production is to identify land that is not presently engaged in the production of food crops.

One of the leading constraints in the further development of second and third generation biofuels is the dramatic lack of scale-up capacity. In part, this might be due to a lack of public funding, however it could also be partially due to the market power exerted by existing fuel companies. The inability to financially compare the economic costs of biofuel scale-up and the market price of second generation biofuels create a defined knowledge gap regarding the development of the biofuel industry.

The first of the emerging bioeconomy issues is the speculation that a combination of weather problems in key exporting countries, high oil prices that pushed up the price of agricultural inputs and transportation, policies to encourage the growth of biofuels and other policies of key exporter nations that reduced food exports, led to the 2007-2008 spike in world food prices. The rise in commodity prices increased the income of some developing world farmers but reduced the incomes and raised the price of staple food products for millions of poor people. The annual reports of the International Service for the Acquisition of Agricultural Applications[1] (ISAAA) identify that agricultural biotechnology has spread rapidly from developed to developing countries, however transition from commodity crops to staple crops such as rice, wheat, cassava, beans and bananas, has been considerably slower.

A second issue is the sustainability of the biofuels industry. As a means of encouraging investment into this area of the bioeconomy, many governments around the world have provided subsidies to biofuel production. In addition to subsidization, there are a host of logistical issues from railcar shortages to outdated docking facilities in dense population centers. Issues of importance are the long-term sustainability of biofuel growth and to better ascertain how biotechnology can contribute to the growth of biofuels.

While some arguments have been advanced that the need for this research is less important now that the price of oil has retreated, the reality is that this research is more important than ever. Biofuel research investments need to continue to ensure that the next time there is a run-up in the price of oil, there are viable alternatives to assist in off-setting the cost of oil.

Responses to Specific Questions

Question 1: What is your view on society moving towards greater use of Biofuels?

The current debate about biofuel sustainability echoes issues raised over a decade ago by policy analysts. Among all viable renewable energy technologies, the range of possible outcomes with respect to fundamental ethical, social and environmental issues is by far the greatest with biofuels. Significant benefits or disbenefits will arise from society's greater use of biofuels depending heavily on implementation details. Sophisticated policy and programming are essential to ensure that benefits are maximized. Our view is that society can derive generally positive outcomes if biofuel production is implemented within a strong policy framework, thus our most important concern is that these benefits will not be realized because of inadequate attention to policy development and implementation detail.

Question 2: What are the most important ethical challenges raised by the prospect of future generation biofuels?

The most important ethical challenge from future generation biofuels is the development of comprehensive biofuels policy that guards against the following risks:

1. Food insecurity – increased biofuels production could displace food production in already food-insecure countries or displace food production necessary to maintain adequate international reserves to meet demand in crisis circumstances.
2. Biodiversity Loss – either directly by increased biofuels production resulting in increased deforestation in biodiverse regions, or indirectly by displacing traditional agriculture to regions of higher environmental and biodiversity value.
3. Energy inefficiency – inappropriate value-chain choice undermines the fundamental rationale for biofuels – lower greenhouse gas emissions. The choice of feedstocks, logistics, processing technologies and end-use services will depend fundamentally on local circumstances. For example, in developing country situations the highest benefit biofuel value chain may be for electricity production rather than transportation fuels as it requires significantly simpler processing technologies.

[1] For the most recent report of the ISAAA go to their website at: http://www.isaaa.org/.

Question 3: Do you regard yourself as well-informed about biofuels? Where do you get your information from?

It is important to be informed on all aspects of biofuels, and this can be challenging as biofuels cross many sectors. It is especially important to be aware of new technological developments, government policy, and the business of biofuels as these areas are not always in step. Information on new biofuels developments can be obtained from academic literature, particularly if the technology is researched at institutes and universities. Tradeshows and trade publications can also be important sources of information on technological developments when the technology was developed for commercialization by the private sector. Besides being sources of information on new technology, tradeshows and trade publications are also important sources of information on biofuels business as they can provide information on the types of undertakings being developed and financed. Information on policy is primarily drawn from government publications, websites and workshops.

Question 4: Which factors are going to be the most important in driving the development of biofuels in the future? To what policy concerns should priority be given? What advantages not mentioned here could and should future biofuel production aim to deliver?

Well-designed and implemented biofuels strategies can provide multiple ecological goods and services (EGS) beyond climate mitigation – they include watershed services, degraded land reclamation and nutrient management.

Question 5: Which of the new approaches to biofuels will be most successful in generating GHG emission savings? How should these be encouraged? Are there any reasons why these new approaches should NOT be encouraged?

The biofuels with input requirements (fertilizer, pesticide) similar to conventional cropping systems should not be encouraged given their higher life cycle GHG emissions and their vulnerability to input price volatility.

Question 6: Which of the new approaches to biofuels will be most successful in improving energy security? How should these be encouraged? Are there any reasons why these new approaches should NOT be encouraged?

The biofuels with the greatest prospect to improve energy security will be those that are both economically attractive to producers, sustainable and demonstrably energy efficient. The failure of conventional ethanol to provide economic returns to producers without an elaborate subsidy support structure, and the vulnerability of conventional ethanol to fundamental criticisms around energy and GHG efficiency provide a stark counterpoint. Essentially, the greatest contribution to energy security is a biofuels strategy that flourishes through broad support among producers, processors, and consumers.

Question 7: Which of the new approaches to biofuels will be most successful in supporting economic development? How should these be encouraged? Are there any reasons why these new approaches should NOT be encouraged?

The economic potential for biofuels will likely be maximized the closer value-addition is realized at the farm-gate, which implies a highly decentralized production and processing system. From a rural development perspective, a decentralized production and processing system will create more rural jobs; from a thermodynamic perspective the life-cycle energy efficiency of biofuels is highly dependent on the spatial logistics – for example, the shorter biofuel transportation distances, the more efficient is the overall system. Biofuel systems that rely on highly centralized processing systems will contribute less to rural development and should be discouraged.

Question 8: Of all the new approaches to biofuel feedstock development, pretreatment and processing (including any additional to those mentioned here), which is looking most promising for eventual commercial and sustainable use? Over what timescales such developments might be commercialized? Are there any risks associated with these developments?

The biofuels development will likely be completely different in five to ten years due to the development and commercialization of new conversion technologies. If public support to the industry is provided to anywhere near the levels provided to the first generation ethanol industry, biofuels will be produced using feedstocks that do not compete with food crops. This would include vegetation and woody biomass produced from marginal lands such as riparian zones and wetlands, as well as perennial cropping systems from degraded land. This trend will be driven in part by a desire by biofuels producers to decouple from the unpredictable price fluctuations of global commodities markets.

Using managed wetlands for biofuels feedstock production can address multiple policy objectives. Harvesting biofuel feedstocks from wetlands can remove phosphorous and nitrogen from watersheds, improving water quality downstream.

Question 9: Is the use of the following technologies to develop new approaches to biofuel production appropriate? Why?

Advanced plant breeding strategies? Yes, particularly if focused on perennial biofuels cropping systems that can provide be used on degraded lands that simultaneously improves economic and environmental performance and is consistent with the principle that well-designed biofuel policy can increase the overall flow of ecological goods and services (EGS) to society – this notion of EGS is not limited to simply low GHG energy supply.

Genetic engineering? Yes, if focused on processing technologies, for example genetically engineered (GE) enzymes for processing woody, perennial biofuels. One of the sources of public skepticism regarding biofuels is that it is driven by commercial interests wanting another outlet for proprietary GE cropping systems rather than by the core environmental sustainability objectives used by policy-makers to justify biofuel investments.

Synthetic biology? The potential application of synthetic biology to biofuels is great, but requires significant analysis. The potential could range from designing optimum feedstocks or organisms to perform conversions, to the design of entire biosystems that can both synthesize feedstocks and produce fuel in a single process.

Question 13: Are new approaches to biofuels likely to raise problems related to land use? If yes, how? If not, how do new approaches avoid these issues?

Inevitably yes, though these will be minimized with ecologically sound and rural development-friendly biofuel strategies. Land use conflict will be minimized through an integrated package of rural extension that advises on the use of low-value agricultural land for biofuels production, policy incentives for production of high appropriate feedstocks and R&D on feedstocks with high EGS and high local value addition.

Question 14: What differences are there between the developed world and developing countries with regards to the potentially problematic effects of future generation biofuel production on land use?

A key ethical consideration is potentially disenfranchising the rural landless and rural poor with weak land tenure for whom the marginal lands targeted for biofuels production may be the only land to which they have usufruct. The challenge for biofuels policy is therefore to develop sufficiently flexible implementation protocols compatible with participatory rural development.

Further ethical concerns include issues of equity, for example, should biofuel feedstocks intended for transportation fuel be grown in regions where the foremost energy priority is household energy or power generation. Another land-based ethical issue concerns water resources allocations. Water scarcity is projected to be one of the most ubiquitous impacts of climate change and in the absence of a strong policy framework we foresee a potential conflict between water allocations for commercial biofuels and for food production.

Question 15: Should iLUC be considered when evaluating the GHG emissions savings of new approaches to biofuels, and if so, how?

In principle yes, as ignoring iLUC issues will provide inadequate policy guidance even if the cause and effect chain can only be described approximately. A comprehensive life cycle analysis should provide tight uncertainty estimates around the elements of the life cycle for which emissions are known with relative certainty. Elements of the life cycle with relatively higher uncertainty should be acknowledged or even excluded from the quantitative component of the analysis. If iLUC issues are not included quantitatively, at a minimum the direction of bias that results from their exclusion should be acknowledged.

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