THE ROLE OF INTELLECTUAL PROPERTY RIGHTS IN ADDRESSING CLIMATE CHAGE: THE CASE OF AGRICULTURE

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1. Introduction

Debate regarding the contribution of intellectual property (IP) rights to lessening climate change is intensifying. On one side, IP optimists emphasize their function in encouraging investment in research and development (R&D) and commercialization. Accordingly, in 2009, the USPTO began a program of fast tracking examination of green technology patents as a means to 'accelerate the development and deployment of green technology' (USPTO 2009). The alternative view, principally associated with developing countries, sees the monopoly rights embodied in IP as a barrier to technology adoption and international transfer. Proponents of the latter view have suggested modifying IP policy, for example, through compulsory license provisions (UNFCCC 2010; IPI 2009). In this article, we consider the role that IP rights can play in delivering technological change to abate greenhouse gas emissions in the agricultural sector.[1] We ask: are formal IP rights an effective means to promote the development and diffusion of abatement technologies or do they simply act as a barrier to the uptake of new technologies?

We begin by outlining an economic framework with which to examine these perspectives. We argue that, first and foremost, the long-term solution must include a policy that ameliorates (the negative) third-party effects of carbon emissions. This means some form of carbon price – either a tax on carbon generating activities (and subsidy for carbon-mitigating activities) scheme, or an emission trading scheme.[2] Once an appropriate carbon price has been established, there is no IP policy difference between technologies which abate greenhouse gas emissions and technologies which meet other needs.

It has, however, long been recognised that the potential role of IP rights varies between technological fields and between industries. In this article, we take a detailed look at abatement technologies in the agricultural sector. Agriculture is an important case study. It contributes between 11 and 12 percent of total anthropogenic carbon dioxide equivalent (CO_2e) and since agricultural abatement strategies are cost competitive, they are expected to play a notable role in the global response (Smith *et al.* 2007). Furthermore, since the agricultural sector makes up a larger share of economic output and emissions in developing countries–it represents an important fault line between the two sides of this debate. Based, inter alia, on 15 semi-structured interviews with agricultural industry groups, private firms and scientists in the public and university sectors, we identify and describe current and prospective abatement technologies. We then discuss the role that IP might play in shaping the incentives to research, develop and use these, in the originating country and around the world.

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[1] We do not consider technologies that enable adaptation to changed climatic conditions, such as drought management technologies. In general, adaptation behaviours do not impose costs or benefits on third parties (economists call these externalities).

[2] Regulation can also reduce emissions but government capacity to design regulations which will equate marginal abatement costs across all areas of the economy is limited. Regulations tend to be more ad hoc with respect to both industry coverage and the implied carbon price.

2. Policy framework

Excessive carbon dioxide and equivalent gasses (CO_2e) have accumulated in the atmosphere because decision makers do not bear the full consequences of their actions. That is, people other than those who directly benefit from carbon emissions (the buyer and seller of products associated with emission) incur costs, in the form of adverse climatic conditions and rising sea levels. The efficient policy response is to ensure that the cost of each additional unit of CO_2e abated is equal across all sectors, and is also equal to the marginal damage cost of emissions prevented. That is, we should pursue the lowest cost abatement options first and we should abate to the point that environmental benefit equals the cost to the market economy. The standard market based solution in these cases is to increase the relative cost of emissions via a carbon tax or cap and trade system. A direct carbon price provides an incentive for abatement, including the adoption of abatement technology and changing output mix.[3]

Once a global carbon price or cap on emissions has been imposed there is nothing special about the provision of climate-change related technology.[4] However, as we know, investment in the creation and diffusion of new technology suffers from another, long recognised, form of market failure. Unfettered markets can often undersupply new technology relative to the social optimum because the originators of new ideas do not take benefits received by third parties into account when making their decisions. Two main policy solutions to this appropriability problem exist: public funding for R&D and legally enforceable IP rights. Each of these policy options has costs and benefits which depend on specific characteristics of the technological field. In the remainder of this section we discuss these costs and benefits and outline those characteristics which determine their relative magnitude and therefore the overall effectiveness of IP rights. Subsequently, in section 3 we consider agricultural abatement technologies in some detail.

In principle, if the benefits from all potential R&D projects were known, and technology consumers could easily be taxed in a non-distortionary manner, then the best solution would be to publicly fund all research, development and commercialization and eschew IP rights. Indeed, in some instances, government-funded R&D has been very successful, such as the green revolution in the mid 20th century. In this vein, some commentators have advocated a "climate change Manhattan project", i.e., a government-sponsored, mission-oriented technology programme. Although others, such as Mowery et al (2010)

[3] It is sometimes erroneously argued that the incentive to increase productivity provides a de facto incentive to abate emissions. Increases in productivity may or may not reduce emissions. Clearly, many (e.g., labour saving) productivity-enhancing innovations of the 20th century led to an increase in emissions per unit of output. Further, even new technology which increases output per unit of (e.g., fuel) input will not necessarily ensure lower total emissions, since this ultimately depends on how output adjusts (which depends, inter alia, on the price elasticity of demand).

[4] Note that undertaking any costly abatement represents foregone consumption, whether through reduced output of high emission products or investing in abating R&D. That is, the price of abatement is equal to the value of goods foregone. Welfare is diminished if any R&D project with a net positive social value is not undertaken, whether the technology is directed at carbon abatement, health care or consumer goods is immaterial.

warn that dependence on centrally planned R&D may not generate sufficient diversity for optimal outcomes, and in any case will not induce adoption of technologies.

In practice of course, R&D is subject to considerable risk and uncertainty relating to technical feasibility and market acceptance. In the light of this, businesses are often better positioned to identify and exploit R&D investment opportunities. Businesses often have access to more information, particularly relating to market demand and production on which to base R&D investment decisions. IP rights, such as patents, plant breeders' rights and copyright[5] decentralize decision making by using market forces to allocate investment in R&D. They achieve this by enabling innovators to charge royalties (i.e. higher prices) on goods and services embodying their technology. Note that IP rights only generate an incentive to invest in R&D where there is a positive willingness to pay for technology; their effectiveness therefore rests crucially on the existence of a carbon price or equivalent. Where there is demand for new technologies, IP rights enhance private investment in research as well as downstream development and commercialization activities. Wherever unfettered imitation is a possibility, IP rights may also encourage research to adapt technology to different environments[6] and the transfer of early stage research to subsequent development and commercialisation.

However, while the patent system creates an incentive to create and adapt technology, the higher price charged under the temporary monopoly of IP protection also prevents people from enjoying the benefits from something that has no cost to society (i.e., after technology is created). This means that in static terms, IP rights result in a loss of social welfare. Because new technology commonly builds on (or extends) what has gone before, inhibiting 'use' through higher prices can potentially reduce the rate of technological progress.[7] By providing legally sanctioned market power associated with IP rights, government effectively replaces one form of market failure with another. It is incumbent therefore upon the architects of the IP system is to ensure it does more good than harm.

Neither direct government funding of R&D nor IP rights offer a perfect solution to the problem of generating and diffusing new technology. On one hand, government provision is limited in its ability to identify valuable projects. On the other hand, encouraging investment from private innovators through the IP system results in deadweight loss. In

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[5] Throughout this paper, we focus primarily on patents and to lesser degree plant breeders' rights and copyright. The reason is that these three legal rights facilitate excludability of technology assets. Trade marks have a subtly different economic function, first and foremost to carry information about 'product' quality and reduce consumer confusion (see Ramello 2006 for a discussion of the economics of trademarks).

[6] This article does not aim to provide a comprehensive survey of the effect of IP in all mechanisms of international technology transfer, rather we aim to discuss their potential role in the entire innovation pathway including R&D, commercialization as well as international transfer, focusing on the specific case of agricultural climate change technologies. For a more in depth discussion of IP and international transfer specifically, see Maskus (2009) and Hall & Helmers (2010).

[7] Several features of the patent system aim to minimise potential negative side effects. Patents require innovators to publicly disclose technical details of their inventions in exchange for a finite period. In principle, the disclosure requirement ensures that new knowledge is made available to other inventors, however, in contrast to this theory, recent evidence indicates that patent disclosures are less important sources of learning for firms than other mechanisms such as interaction with customers and suppliers (Cohen *et al.* 2000; Jensen & Webster 2009).

the light of this, it is generally considered that optimal innovation policy should incorporate a mix of direct financing and IP rights.

The prospective role of IP depends on a number of industry- and technology-specific factors. IP rights are particularly important where technology is easily copied and where it is difficult or impossible to maintain trade secrets. For example, survey evidence suggests that patents are most important in industrial sectors, such as pharmaceuticals and chemicals, where the technology is highly codified ((Levin *et al.* 1987; Cohen *et al*. 2000; Harabi 1995). In contrast, IP rights are not important in inducing investment in technologies that are inherently excludable, because the technology can be exploited while maintaining trade secrecy or because they are difficult or costly to imitate. Excludable complementary assets can facilitate appropriation of returns from otherwise non-excludable technology assets (as highlighted by Teece 1986). IP rights are also not important where they cannot effectively be used to protect technology from imitation, such as where monitoring is not feasible. Examples may include information about the prevention of disease or production know-how. It is simply not possible to stop word spreading and people taking advantage of it. In this situation, IP titles are unenforceable (if even possible to obtain).

3. Agricultural abatement technology

This section presents a more detailed discussion of current and prospective strategies for abating carbon dioxide equivalent (CO_2e) emissions in the agricultural sector. Agricultural innovation – the development and dissemination of new technologies and farming practices – is currently a cost competitive carbon-mitigation strategy and is therefore expected to play a notable role in the world's response to climate change (Smith *et al.* 2007; Vattenfall & McKinsey 2007). While the emphasis in this section is on the potential role of IP rights, some technical details are given in order to assess their potential contribution to abatement.

Globally, the main components of agricultural emissions are nitrous oxide from soils, predominantly from fertilizer use (38 per cent), and methane from enteric fermentation (32 per cent) and wet rice cultivation (11 per cent) (Smith *et al.* 2007).[8] Nitrous oxide (N_2O) is a greenhouse gas nearly 300 times more potent than CO_2. Urea-based fertilizers and animal urine are important sources of nitrogen that are ultimately the source for N_2O. Methane is produced as a by-product of enteric fermentation, the process whereby microorganisms living in the rumen (a special stomach) of cattle and sheep break down coarse plant material. Methane emissions effectively represent a loss of energy, meaning there is some overlap between technologies and farm practices that reduce methane emissions with those that increase efficiency of feed use. The main factor determining emissions from enteric fermentation is the number of animals. However, strategies to reduce methane from enteric fermentation per animal have the potential for abatement of between 14 and 25 per cent (Eckard 2006). Abatement strategies include feed (diet) management and supplements as well as technologies that act to alter the rumen

[8] The remainder includes biomass burning and manure management

microbial population and its activity. The microorganisms responsible for methane production in the rumen are called methanogens. Methanogens are also active in flooded rice paddies.

As discussed above, IP rights will only be useful when they relate to an idea which can be easily copied and of which the use or embodiment can be monitored. Current agricultural abatement research falls into both the ‘IP-relevant’ and ‘IP-irrelevant’ camps and we discuss each of these in turn. Before we turn to this discussion, we re-emphasis our earlier point: without some form of carbon price, pecuniary incentives for farmers to adopt and abate will be largely absent. Without a carbon price, there will be only nominal private incentives to invest in these technologies and role of IP policy will therefore be largely academic.

3.1 Agricultural abatement technologies: IP-relevant

Most of the IP-friendly technologies are based on pharma-chemical or IT technologies. Formal IP rights can be regarded as enabling carbon emission technologies as they give the original inventing business the confidence to invest in research, development and commercialisation. In this way, IP rights are dynamically efficient since they encourage the production of technologies that would otherwise not exist. However, they still involve a static inefficiency, since once created, the new technologies are sold at prices above cost.

In most cases, the technologies described below need adaptation and calibration to local conditions and therefore cannot be transferred costlessly between regions. IP rights are important to support transfer activities of private firms. In these cases, the existence of IP rights encourages international transfer since possessing a monopoly right increases the returns to product development and adaptive investments. Alternatively, governments can fund adaptive investments directly.

Land management and soil emissions

Computer software decision support tools, based on biophysical models of the agronomic system, offer considerable scope to reduce N_2O emissions from broad acre agriculture and emissions from wet rice cultivation. They can achieve this by optimizing management of agricultural inputs such as fertilizers. For example, the International Rice Research Institute has developed an interactive computer-based decision support tool called *Nutrient Manager* which calculates the optimal amounts of fertilizer to be applied using answers to about 10 simple questions.

Computer programs are inherently non-excludable in the absence of legally enforceable IP (copyright or software patents). However, there are also a range of technological options for preventing unauthorized use of such models. For example, the most widely employed decision support tool for broad acre agriculture in Australia is run from remote servers, which prevents unauthorized use without the need for legally enforced IP rights.

Transfer between different agronomic environments, including international transfer of these technologies faces a number of obstacles, most importantly the need for complementary investment. While the fundamental science behind computer-based biophysical models is internationally transferrable, the models require local data input which is expensive and time consuming to collect. In these cases IP protection can allow firms undertaking this additional work to charge a price sufficient to cover the costs.

Enhanced efficiency fertilizers and soil emissions

Enhanced efficiency fertilizers are chemical additives which improve the longevity of fertilizer nitrogen in the soil and thereby reduce N_2O emissions. These compounds can also be employed in the management of animal manure (urine patches and feedlot effluent). As chemical entities, enhanced efficiency fertilizers are protectable by patents.

However, as in the case of computer based biophysical models, adaptive research represents an important barrier to the utilization and uptake of fertilizer technologies to reduce N_2O emissions – particularly between different environments, required for international transfer. The issue is that achieving maximum effectiveness of enhanced efficiency fertilizers requires an understanding of the interaction of these chemicals with soil and environmental variables (Chen *et al*., 2008). Therefore an important complementary area of research is focused on understanding how these compounds behave in different bio-physical contexts. Excludability of the primary technology (enhanced efficiency fertilizers) can, in principle, generate an incentive for private firms to invest in this complementary research to the extent that demonstrating effectiveness is important for encouraging sales.

Pharmaceuticals and livestock emissions

Abatement of methane emissions from livestock can potentially be achieved by manipulating the rumenal microbial population and its function. One approach is to develop pharmacological agents, like antibiotics and defaunation agents.[9] As was noted above, it is generally considered that patents are an important factor in encouraging private firms' investment in new chemical entities. It is hoped that ongoing research will produce new pharmacological agents, though at this stage, research is generally considered to be at a pre-commercial stage and there appear to be few patented pharmaceuticals with a proven ability to reduce methane emissions.

It has been claimed that antibiotics already in use in the feedlot industry to control disease and increase feed-use efficiency, including as Monensin and Rumencin, may contribute to abatement. However, more research is needed to better understand the function of these chemicals, the contexts in which they are effective, sustainability of effect, and trade-offs with other aspects of animal husbandry (such as feed use efficiency) (Eckard 2006).

Another prospective technology is a methanogenic vaccine. Research into a methanogenic vaccine which promises very low (marginal) cost abatement strategy is ongoing. However at the time of this study this technological option is very much blue-sky (e.g., no proof of concept or commercialisation stages have yet been reached). Like pharmaceutical products, a methanogenic vaccine would have limited natural excludability so IP rights, such as patents would be important to stimulate private funding.

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[9] Defaunation agents affect protozoa (another type of micro-organism) which support methanogens.

Forage crops and livestock emissions

Beneficial forage crops can reduce livestock methane emissions in an extensive context. Research aims to identify and develop plants which contain natural chemicals, such as tannins or alkaloids, that can be sown into pastures for grazing livestock. At this stage, there are no such crops in use at a commercial level. Beneficial forage crops (e.g., tanniniferous crops) would theoretically be protectable by plant breeders' rights or potentially patents, particularly if GM varieties are developed in the future. Our consultations suggested that currently research to this end, in Australia at least, is dominated by the public research sector, though with the introduction of a carbon price this could change.

Emissions measurement technology

As discussed, a carbon price is necessary to underpin an incentive for farmers to adopt new abating technologies (as highlighted for example by Mowery *et al.* 2010). To achieve this requires not only a price for carbon, but also, CO_2e accounting that records the actions of individual farmers. While farm-level monitoring is not commercially viable, experimental systems have been used to measure NH_3 and CH_4 from intensive animal production systems. Monitoring technology for livestock emissions includes two component technologies: physical instrumentation and bio-physical models. The latter use actual emissions to calibrate simulations of emissions from animals. Commercially viable physical instrumentation at the farm-level, needs more portable and affordable (battery operated) open path lasers for CH_4 and NH_3, in combination with newly developed micro-metrological techniques. Emissions measurement technologies are likely to be easily copied and suitable for patent or copyright protection and it is therefore unlikely that these technologies will flourish without proper IP protection.

3.2 Agricultural abatement technologies: IP-irrelevant

In this section we discuss a few abatement technologies and management practices for which IP is inappropriate, mainly because the knowledge relates to an idea which can be easily copied and of which the use or embodiment cannot be monitored. In the case, of animal breeds, IP is not relevant as the new 'technology' is completely embodied in tangible material. Consultations suggest IP-averse technologies have considerable potential to contribute to abatement, though again, without a carbon price, the lack of pecuniary incentive to adopt and abate means there is little private incentive to invest in these. What research is being undertaken appears to be generally publicly financed.

Land management practices

Improved land management practices have considerable scope to contribute to abatement. Such agronomic practices are essentially know-how embodied in agronomists, farmers and other land custodians. They cannot be protected by formal IP. The main barrier to adoption is the cost of transferring tacit knowledge and demonstrating advantages in specific agricultural contexts. In the absence of private incentive to invest in demonstration and adoption, these appear to be a strong candidate for government funding.

Safe alternate wetting and drying is one management strategy which reduces methane emissions from wet rice cultivation. Safe alternate wetting and drying relates to the optimal timing of drying out and flooding of paddies including crop rotation – the word 'safe' implies that it is undertaken with no loss of productivity. Flooded rice paddies emit methane while, on the other hand, dry paddies emit nitrous oxide. Research into optimizing the trade-off in different environments is ongoing. The International Rice Research Institute is a key proponent of this research which is funded by contributor governments and from corporate donations and therefore not reliant on IP rights to attract funding. Tangible or embodied technology requirements for safe alternate wetting and drying are virtually negligible. It therefore appears to be a cost effective means of achieving abatement. However, there are other important barriers to adoption. First, the lack of incentive for farmers to implement these management practices (due to the absence of a carbon price). Second, reliable water supplies are a prerequisite to the application of safe alternate wetting and drying methods, and these are not always present in developing countries with limited infrastructure.

Conservation tillage is another practice with potential to contribute to abatement and sequestration. Conservation tillage is the practice whereby crops are grown with minimal disturbance to the soil and with more crop residual maintained. Additionally, conservation tillage generally relies on the application of herbicides such as glyphosate (Roundup) for weed control. Reduced tillage practices are highly effective in soil water conservation, and show the potential to increase soil carbon (i.e. sequestration). However, research suggests that the effect is dependent on other environmental considerations, most importantly sufficient rainfall. More research is needed to establish how and in what circumstances tillage practices can contribute to sequestration. According to industry groups, barriers to the adoption of conservation tillage include the need for investment in adapted tilling equipment on behalf of the farmer. A recent report found that barriers to the adoption of conservation tillage in China included the perceived potential for yield reductions and herbicide (glyphosate) requirements (Vere 2005). Glyphosate was protected by patents owned by US multinational enterprise, Monsanto, but the protection expired at the beginning of last decade. Since that time the price of glyphosate has decreased, and it is widely believed that availability of generic glyphosate produced in China has played a role in this.

Other options for abatement in livestock industries

As mentioned above, methane emissions from livestock can be influenced through managing cattle diet and feed supplements. However, much of this knowledge is relatively 'low-tech', well-known and therefore unpatentable. For example, optimizing carbohydrate to protein ratios and providing high quality pastures can increase efficiency and reduce emissions. In intensive contexts (feedlots), coconut oil and cottonseed oil are routinely added to feed to increase the productivity of feed use and therefore reduce emissions per quantity of ouput. Other feed additives that can potentially reduce the methane production in the enteric fermentation process include organic acids, tannins, saponins and yeasts. Some manipulation of animal feed base is possible in an extensive context through the control of forage crops. Further research in this area will continue to improve strategies for abatement. However, since discoveries in this area would emerge as unexcludable know-how and use commonly available materials, they are unlikely to be protectable by IP rights. This makes research in this area a good candidate for public funding.

Researchers in Australia have also undertaken research into animal's genetic predisposition to emit methane, suggesting a possibility to develop low-emission livestock breeds. At this time this approach is considered blue-sky. Genetic improvement can potentially be achieved via traditional breeding programmes, though in the future this may be achieved through transgenic technologies (i.e. genetically modified). Our consultations suggested that patents do not play an important role in new breeds, because intangible assets associated with naturally bred animals are always embodied in tangible products (animals and semen) and are therefore excludable. IP rights many become more important if molecular genetic technologies are developed in this field.

3.3 Overview of technologies identified and the role of IP rights

In the preceding section we have identified a range of innovations which can contribute to abatement in the agricultural sector that are not protectable by IP rights. These include know-how embodied in agricultural advisors and farmers, for example, relating to animal husbandry and land management practices like safe alternative wetting and drying. In some senses these reflect 'low tech' options. However, our consultations suggested that a consensus that more scientific research is required to better understand how these can best be applied to abate CO_2e emissions. Further investment is also required to support demonstration and diffusion. Developing and transferring these technologies will largely need to be financed through public funds.

We have also identified a number of agricultural abatement technologies which IP rights can play an important role in preventing imitation which might otherwise undermine the commercial return to innovators. These include computer software decision support tools and chemicals used in enhanced efficiency fertilizers and to abate methane emissions from ruminant livestock. Most of these technologies appear to require investment in complementary research to facilitate optimal deployment and technology transfer across regions. In the case of enhanced efficiency fertilizers, a critical complementary area of research focuses on understanding how these fertilizers behave in specific local environments. Private investment in such research might be forthcoming but it will depend on their ability to charge royalties on fertilizer sales. Similarly while the basic science behind biophysical models is internationally applicable, it requires costly collection of data and calibration to local conditions. IP rights can enable organisations which collect and calibrate local data to re-coup their costs through higher prices or license fees. Given the large contribution to emissions made by livestock, blue-sky research into pharmaceutical and biologically active agents that can mitigate associated emissions may be the most important technology identified.

Irrespective of whether the technology is IP-friendly or –averse, without a carbon price, or the clear prospect of a carbon price, there is little incentive for private firms to invest in the research stage as there is little incentive that farmers will take up the new technology.

4. Conclusion

Superficially, the broad and sizable third-party benefits associated with carbon-mitigating agricultural technologies might be thought to contraindicate the use of IP which tends to raise the price of technology and therefore inhibit adoption. However, this erroneous view mixes up two different and entirely independent externalities. Once an appropriate price on carbon has been established, the policy problem of ensuring optimal investment in abatement technology is essentially the same as any other technology. Governments currently employ an array of policies to address the market failure inherent in the process of innovating. The questions we then ask is: what is the best mix of policies for agricultural abatement innovation?

First, a price on carbon, administrated in such a way as to account for individual farmer actions is necessary to create pecuniary incentives to adopt carbon abating technologies. A corollary is that the potential positive contribution of IP rights largely depends on an appropriate price on emissions (or a credible commitment to introduce one). If an appropriate carbon mitigating regime is not forthcoming, the attractiveness of IP as a policy option is greatly diminished. In this case, IP rights are unlikely to induce private abatement R&D and the negative consequences associated with monopoly provision of technology and potential freedom-to-operate restrictions are likely to outweigh the benefits.

Second, we highlight the considerable potential of innovation in areas in which IP rights are unsuitable or are not needed. These include abatement achievable through new and improved agronomic practices relating to land management and animal husbandry. Developing best practice demands ongoing research to understand both the basic science and location specific aspects of agronomic systems. The global IP system is unlikely to affect investment in, or international transfer of, these innovations. Alternatively, there appears to be a strong case for public funding of research and extension services to facilitate deployment in cases where IP rights are unsuitable.

Finally, we have identified a number of promising fields of technology in which IP rights are important in facilitating appropriation by innovators. However, we suggest caution in not overstating the relative magnitude of the barrier IP rights represent in terms of international technology transfer. In most cases, it appears that the need for adaptive research, demonstration or complementary assets represent a more immediate barrier. In the absence of alternative mechanisms for funding these adaptive activities, there is no strong rationale for weakening IP over these technologies.

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