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Policies for biofuels in Brazil and the US

An analysis of innovation framework, actors and governance

This report focuses on biofuel policies in Brazil and the US over the period 1970-2012, and in particular on ethanol production. The analysis has been guided by three questions: What are the principal policies in the Brazilian and North American biofuel sectors respectively?; what were the principal factors driving policy formation processes?; and what are the opportunities and challenges going forward?

growth analysis

Forum för innovation
inom transportsektorn

The Swedish Agency for Growth Policy Analysis has been commissioned by the Forum for Innovation in the Transport Sector (Forum) to conduct three studies of policies in other countries to find pathways to these solutions. Forum is a network of public and private players in the transport sector in Sweden and its most important objective is to develop common national strategies for research and innovation – strategies that will increase the competitiveness of Swedish enterprise, make transportation more efficient and reduce the sector's environmental impact, for example from carbon dioxide emissions. Read more at https://transportinnovation.se/

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Förord

Transporter av personer och gods utgör blodomloppen i den globala ekonomin och har de senaste årtiondena blivit allt viktigare, smartare och mer effektiva. Baksidan med denna utveckling är den huvudsakligen fossila energianvändningen och de växthusgasutsläpp som transporterna ger upphov till. Farliga partiklar, trängsel och buller är andra problem som dagens transportsystem förknippas med. Hållbara transportlösningar är således en prioriterad fråga, i Sverige liksom runt om i världen.

Tillväxtanalys har fått i uppdrag av Forum för innovation inom transportsektorn (Forum) att genomföra tre studier av vilka politiska strategier och insatser som görs i andra länder för att hitta nya vägar för hållbara transportlösningar. De områden som studierna fokuserar på är: Elektrifiering av fordonsflottan (Indien, Japan, Kina och Sydkorea), Snabba och attraktiva tågtransporter (Indien, Japan och Kina) samt Biobränslen (Brasilien och USA). Utgångspunkten för urvalet har varit de länder som Tillväxtanalys bevakar samt områden där det bedömts finnas intressanta exempel, inspiration och lärdomar att dra för Forum och andra aktörer i Sverige i arbetet med att utveckla den svenska tranportpolitiken.

Denna rapport diskuterar politik för biobränslen, med fokus på etanol, i Brasilien och USA.

Några av de observationer som görs i rapporten är:

- Oljeprisvariationer över tiden har varit en avgörande faktor för utvecklingen av alternativa bränslen i de två länderna, minst lika viktig som de olika politiska insatser som lanserats för att driva på efterfrågan. Båda dessa drivkrafter har dock varit nödvändiga för att sätta fart på utvecklingen.
- Miljöhänsyn har också varit en pådrivande kraft, men först när dessa blivit akuta. Problemen med smog i olika amerikanska städer var exempelvis en central faktor för hur landets transportpolitik på området utformades. Klimatfrågan har varken i USA eller i Brasilien haft något betydande inflytande, eftersom den inte bedömts av ledande aktörer inom sektorn vara ett överhängande hot och att biltillverkare och politiker har agerat därefter.
- Rapporten visa att politiken fungerat innovationshämmande genom att subventionera gammal teknik. I båda Brasilien och USA har politiken ofta varit kortsiktig, vilket har fått till följd att investerare och andra industriaktörer inte vågat satsa på ny teknik utan istället valt billigare, beprövade alternativ – även om detta på sikt skadat konkurrenskraften i industrin.

Rapporten har författats av Mikael Román (Brasilien, koordinator) och Henrik Mattsson (konsult, Sweco). Martin Flack vid Tillväxtanalys kontor i Stockholm har varit projektledare.

Enrico Deiaco, avdelningschef Innovation och globala mötesplatser

Stockholm, mars 2013

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Sammanfattning

Bakgrund och politiskt sammanhang

Den här rapporten – ”Policies for biofuels in Brazil and the US - An analysis of innovation framework, actors and governance” – behandlar biobränslepolitiken i Brasilien och USA under perioden 1970–2012, och i synnerhet etanolproduktionen eftersom etanolet är det mest använda biobränslet i världen. Etanol används som tillsats i bensin och har som sådan flera positiva effekter: etanol (i) bidrar till att förhindra luftföroreningar från koloxid och ozon; (ii) höjer oktantalet och (iii) ersätter bensin – i sin renaste form till 100 procent. En annan fördel är att etanol när det blandas med bensin i olika proportioner faktiskt sänker bränslets totala kolinnehåll, vilket leder till en minskning av koldioxidutsläppen vid transporter.

Etanol framställs för närvarande av framför allt två grödor – majs (USA) och sockerrör (Brasilien). Det innebär att det finns en viktig länk mellan å ena sidan etanolframställning och å andra sidan markutnyttjande och livsmedelsmarknaden. Traditionellt har etanolpolitiken påverkats av flera olika faktorer som hänger samman med landsbygdsutveckling, miljö och energiförsörjning. Enligt Internationella energirådet beräknas biobränslen, och i huvudsak etanol, stå för upp till 27 procent av världens transportbränsleanvändning vid 2050. Detta grundar sig dock på att man framställer etanol ur någon annan gröda – i första hand cellulosa, vilket i sin tur skulle kräva omfattande teknikutveckling.

Även om etanolproduktionen är en gammal och etablerad teknik finns det fortfarande utrymme för innovation. Det handlar delvis om att förändra energimarknaden och öka användningen av förnybara bränslen, delvis om teknikutveckling för att säkerställa en hållbar och långsiktig bränsleframställning.

Frågeställningar

Den här rapporten tittar närmare på tre dominerande teman. Ett handlar om villkoren som påverkar utformningen av innovationspolitik inom våra respektive områden. Vilka är de utmaningar som styr riktlinjer och politiken inom just denna sektor? Vilka är de aktuella förslagen för att lösa identifierade problem? Vilka är de nuvarande politiska målsättningarna? Ett annat tema handlar om politikens implementerande. Hur förverkligas politik? Vem gör vad och när? Slutligen diskuterar vi även den aktuella situationen i ljuset av tidigare och nuvarande politik. Vilken innovationsnivå har vi just nu? I vilken utsträckning är den ett resultat av direkta politiska ingripanden? Vilka möjligheter och utmaningar finns framför oss?

Huvudfokus i såväl projektet som den här studien ligger alltså på politiken som stöttepelare för innovation snarare än själva innovationerna. I det här sammanhanget utgör vår diskussion om biobränslen en viktig del. Förutom att fördjupa kunskapen om själva etanolindustrin illustrerar den också de särskilda förhållandena för innovationsstimulering i ett befintligt produktionssystem som bygger på en relativt mogen teknik. Termen innovation förutsätter därmed av nödvändighet en ganska bred definition, men ändå baserad på en politisk målsättning, och innebär förändring som inte nödvändigtvis är ny, men som leder till en generell förbättring av hur saker och ting utförs, i förhållande till ett antal – inte alltid ekonomiska – mål.

För att sammanfatta: studien syftar till att besvara tre frågor: (i) vilken är den huvudsakliga politiken inom de brasilianska respektive nordamerikanska biobränslesektorerna, (ii) vilka var de viktigaste faktorerna som formade politiken, och (iii) vilka är möjligheterna och utmaningarna i framtiden?

Både politik och marknadskrafter driver innovation

Den offentliga politiken har tveklöst varit en nyckelfaktor i utvecklingen av Brasiliens och USA:s etanolindustrier. Ländernas regeringar drev först etanolfrågan som ett svar på 1970-talets oljekris. Snabb ekonomisk tillväxt under 1950- och 1960-talen pressade upp efterfrågan på olja tills efterfrågan under tidigt 1970-tal blev högre än tillgången. Mellan 1970 och 1973 fördubblades marknadspriset på olja, och mellan oktober 1973 och mars 1974 orsakade arabländernas oljeembargo mot USA stor bensinbrist. Världskartan för oljemarknaden ritades om genom den mäktiga OPEC-kartellens ökande inflytande. Än viktigare ur ett etanolpolitiskt perspektiv är att det blev tydligt för de amerikanska och brasilianska regeringarna att man inte längre hade tillräcklig kontroll över oljetillgången på hemmamarknaden. Detta faktum blev ännu tydligare 1978 när Iran – världens andra största oljeexportör vid den tiden – drabbades av allvarliga produktions- och exportstörningar som en följd av den iranska revolutionen.

I ett tidigt skede fanns även möjligheten att samtidigt stötta den ekonomiska utvecklingen på landsbygden i USA och den nationellt viktiga sockerindustrin i Brasilien. Vår studie visar att denna politiska drivfaktor, som till en början var mer eller mindre en biprodukt till energiförsörjningspolitiken, i slutänden blev en viktig pådrivande faktor och även drev politiken framåt under perioder när stabilare oljetillgång ledde till färre stimulansåtgärder för alternativ energi. I det perspektivet kom socker- och majsindustrin att bli viktiga intressenter.

Miljöproblem också viktig drivkraft – när de blir akuta

Miljöproblem som smog och andra lokala luftföroreningar ledde också till förändrade fordonskrav, och fordonsindustrin blev därmed en viktig aktör. Fordonsindustrin har dock inte blivit lika viktig som jordbruksindustrin, men fordonslagstiftningen visade sig få stor effekt på etanolmarknaden – framför allt genom att göra etanol till en praktiskt taget obligatorisk tillsats i bensin. Några slumpartade händelser spelade också roll – framför allt det faktum att det ursprungliga antiknackningsmedlet visade sig förta effekten hos katalysatormetallerna, och att det syresättande ämnet MTBE som först användes visade sig vara hälsovådligt och måste ersättas. Etanol gynnades i det här sammanhanget av politiska åtgärder som till en början inte fokuserade på etanol utan på andra substanser som senare måste bytas mot etanol.

Under det senaste årtiondet har etanolproduktionen växt exponentiellt på grund av att energitillgången åter blivit en aktuell fråga, i kombination med en växande uppmärksamhet på koldioxidutsläpp. I det senare fallet har biltillverkarna sett en möjlighet och man har introducerat mer bränsleflexibla fordon, något som ytterligare stimulerat marknaden.

Etanol ses nu som en viktig del av framtidens hållbara energiförsörjning. Men med nuvarande grödor kommer konkurrensen om odlingsmark att öka med stigande matpriser och hunger som följd, och dessutom kritiseras etanolpolitiken för att vara innovationshämmade inom jordbrukssektorn genom att ge långtgående subventioner till gammal teknik.

För att etanolet ska kunna utgöra en betydande del av framtidens bränslemarknad måste etanolproducenterna växla över från första generationens etanolproduktion till andra gene-

rationens cellulosabaserade produktion. Detta är en stor teknisk utmaning och det är tveksamt om rätt stimulansåtgärder finns på plats för att nödvändiga investeringar ska kunna göras. Som tidigare nämnts har etanolpolitiken skapat inflytelserika lobbyorganisationer, och det blir sannolikt politiskt svårt att ändra befintlig lagstiftning. Samtidigt menar många observatörer att en sådan förändring är nödvändig, inte bara för att uppnå en mer hållbar produktionsmetod, utan för att rädda hela industrin för bränsleflexibla fordon, särskilt i ljuset av att nya alternativ som el och gas håller på att introduceras.

Huvudsakliga observationer och lärdomar för Sverige

För Sveriges del finns en viktig läxa att lära av utvecklingen av etanolindustrier i Brasilien och USA, nämligen att den svenska modellen för innovation baserad på ekonomisk tillväxtpolitik fungerar. I fallet med etanol kan man se att förändringar nästan uteslutande beror på innovationskrav. Ett sådant tryck skapas i det här fallet av tre faktorer.

För det första; variationer i oljetillgången kan antingen öka eller minska innovationstrycket helt enkelt genom att sänka eller öka tiden för ROI för investeringar i alternativa bränslen. När oljetillgången minskar och bensinpriserna drar iväg verkar det förnuftigt att investera i etanol, och omvänt. Den här effekten är mycket starkare än skattelagstiftning och liknande.

För det andra; miljöproblem har betydelse när de blir allvarliga. Problemen med smog i amerikanska städer var en pådrivande faktor, precis som hälsoriskerna förknippade med andra bränsleadditiv. Den globala uppvärmningen tycks vara betydligt mindre viktig, kanske för att de allra flesta inte uppfattar den som ett överhängande hot, och biltillverkarna anpassar sin marknadsstrategi efter detta.

För det tredje; ekonomisk utvecklingspolitik kan fungera innovationshämmande genom att gammal teknik subventioneras. Detsamma gäller energipolitiken. Den svenska modellen har byggt sin framgång på att undvika priskonkurrens till fördel för first-mover-konkurrens och andra former av innovationsbaserad konkurrens. I USA och Brasilien är det tydligt att politiken lätt blir kortsiktig på ett sätt som uppenbart urholkar den framtida konkurrenskraften. Mest tydligt är detta när det gäller olja i Brasilien och skiffergas och jordbrukssektorn i USA. Det vore mycket olyckligt om Sverige skulle göra liknande misstag.

Summary

Background and policy context

This report – "Policies for biofuels in Brazil and the US - An analysis of innovation framework, actors and governance" – focuses on biofuel policies in Brazil and the US over the period 1970-2012, and in particular on ethanol production – ethanol being the most widely used biofuel in the world. Ethanol is used as an additive in gasoline and has several positive effects as such: it serves (i) to prevent air pollution from carbon monoxide and ozone; (ii) as an octane booster and (iii) as a replacement of gasoline – in its purer forms to 100 percent. Another pro is that when ethanol is mixed with gasoline to various proportions in effect lowers the total carbon content of the fuel and subsequently leads to a reduction of transportation-related CO2-emissions.

Ethanol is currently produced from mainly two types of feedstock – corn (US) and sugar cane (Brazil). This means that there is an important connection between ethanol production on the one hand, and farmland use and food markets on the other. Traditionally, ethanol policy has been driven by several different factors relating to rural development, environment and energy supply. According to the International Energy Agency biofuels – and mainly ethanol – are projected to constitute up to 27 percent of the world's transportation fuel by 2050. This, is however, based on the development of other feedstock – primarily cellulose which would, in turn, require substantial technological development.

Although ethanol production is an old and established technology, there is nevertheless a lot of room for innovation. In part in terms of change in energy markets towards a larger use of renewable fuels, in part in terms of technological development in order to make the production of such fuel sustainable in the long term.

Main topics

This report elaborates on three broader themes. One concerns the conditions that ultimately influence the formulation of an innovation policy in our respective areas. What are the challenges guiding policies and politics in this particular sector? What are the current proposals to solve identified problems? What are the current policy objectives? A second theme concerns the subsequent administration of policies. How are policies implemented? Who does what and when? Finally, we were also asked to discuss the current situation in the light of past and present policies. What is the current level of innovation? To what extent is it a function of explicit policy interventions? What are the opportunities and challenges going forward?

The principal focus of the project, as well as this particular study, is thereby the policies supporting innovation, rather than the innovations themselves. In this context, our discussion on biofuels provides an important piece of the puzzle. Apart from providing increased knowledge about the ethanol industry itself, it also illustrates the particular conditions of stimulating innovation in an already existent production system based on a relatively mature technology. The term innovation, therefore, by necessity assumes a rather broad, yet policy target based definition, meaning change that is not necessarily new everywhere, but that lead to an overall improvement of the "way of doing things" related to a number of goals, not always economic.

To sum up, the present study sets out to answer three questions: (i) what are the principal policies in the Brazilian and North American biofuel sectors respectively?; (ii) what were the principal factors driving policy formation processes?; and (iii) what are the opportunities and challenges going forward?

Both public policy and market forces has driven innovation

Public policy has without a doubt been the key actor in the development of the Brazil and US ethanol industries. The push for ethanol was initially made by the governments of these countries as a response to the oil crises of the 1970-s. Rapid economic growth during the 1950-s and 1960-s drove petroleum demand growth until, finally, in the early 1970-s, the demand level began to surpass supply levels. Between 1970 and 1973 the market price for oil doubled, and between October 1973 and March 1974 the Arab oil embargo against the US caused severe gasoline shortages and reshaped the world oil market with the rise of the powerful OPEC-cartel. Most importantly from an ethanol-policy perspective, it became clear to the US and Brazilian governments that they would no longer sufficiently control domestic oil supply. This assessment was further fortified in 1978 when Iran – the world's second largest oil exporter at the time – experienced serious disruption in production and exports following the Iranian revolution.

An opportunity was also present early on to simultaneously support rural economic development in the US and the nationally important sugar industry in Brazil. As our study shows, this policy-driver, which was initially more or less a byproduct of energy security policy, eventually became a key driver in its own right and actually carried policy for extended periods of time in which oil supply stability led to lower energy security incentives. In this sense, the sugar and corn industries became important actors.

Environmental concerns also important – when they are urgent

Environmental issues such as smog and other local air pollution led to changes in vehicle requirements that added the automaker industry as an important player. The industry itself has not been as important actor as the farming industry however, but vehicle regulation legislation turned out to have critical impact on the ethanol market – mainly through regulation making ethanol a more or less compulsory additive to gasoline. Some serendipitous events also played a key role – most notably the fact that the original anti-knocking agent lead turned out to counteract catalytic converter metals and that the originally used oxygenating agent MTBE turned out to be a health hazard and had to be replaced. Ethanol in this sense benefited to a high extent from policies that initially were not targeting ethanol but rather other substances that later had to be replaced by ethanol.

In the last decade, ethanol production grew exponentially due to a resurgence of the energy security issue, coupled with rising awareness about CO2-emissions. In the latter case automakers have recognized an opportunity and have introduced more flexible fuel vehicles, and this has further boosted the market.

Ethanol is now seen as a major contributor to sustainable energy security of the future. However, in relation to its present feedstock it is being challenged by a lack of farmland, its tendency to augment food prices – causing hunger, and ethanol policy is also being criticized for lowering innovation in the farming sector by providing extensive subsidies to old technologies.

In order to deliver on its promise to make up a significant share of future fuel markets ethanol producers need to move from sugar-based first generation ethanol production to cel-

lulosic based second generation production. This poses a serious technological challenge and it is questionable if the right incentives are in place for the necessary investment to take place. As mention, ethanol policy has created strong feed stock lobbies and it will likely be politically difficult to make changes to established legislation. At the same time many observers note that such change is necessary not only to achieve a more sustainable production method but indeed to save the entire flexible fuel vehicle industry – since it is not yet ready to live on its own, especially in light of new alternatives like electric and gas being introduced.

Main observations and lessons for Sweden

For Swedish concerns there is an important general lesson to be learned from the development of ethanol industries in Brazil and the US – namely that the Swedish model of innovation based economic growth policy works. The ethanol case shows that change is almost exclusively related to innovation pressure. Such pressure is in this case created by three factors.

First, oil supply fluctuations may either increase or lower the pressure by simply lowering or increasing the return on investment time for investments in alternative fuel capacity. When oil supply drops and gasoline prices soar, it makes sense to invest in ethanol and vice versa. And this effect is much stronger than that of tax credit legislation and the like.

Second, environmental issues matter, when they are urgent. The smog problem in US cities was a key driver, as well as health hazards related to other fuel additives. Global warming seems to be of much less importance, perhaps for the very fact that it does not seem urgent to most people and the automaker industry formulate market strategy thereafter.

Third, economic development policy may lower innovation pressure by subsidizing old technologies. This is also true for energy policy. The Swedish model has always built its success on avoiding price competition for the benefit of first-mover competition and other forms of innovation-based competition. In the US and Brazil case, it is clear that policy easily falls into shortsighted behavior that clearly undermines future competitiveness. Most evidently so in relation to oil in Brazil and in relation to shale gas and the farming sector in the US. It would be very unfortunate for Sweden to make similar mistakes.

1 Introduction

The present study is part of a larger project, 'Policies for sustainable innovations within the transportation sector', that was assigned to the *Swedish Agency for Growth Policy Analysis (Growth Analysis)*, with the ambition to learn from experiences in other countries and regions.

This report focuses on the particular conditions related to the biofuels sector in Brazil and the US. At a common share of almost 90 percent, Brazil and the US completely dominate global biofuel production. Three broad themes are explored throughout the report. One concerns the conditions that ultimately influence the formulation of an innovation policy in our respective areas. What are the challenges guiding policies and politics in this particular sector? What are the current proposals to solve identified problems? What are the current policy objectives? A second theme concerns the subsequent administration of policies. How are policies implemented? Who does what and when? Finally, we were also asked to discuss the current situation in the light of past and present policies. What is the current level of innovation? To what extent is it a function of explicit policy interventions? What are the opportunities and challenges going forward?

The principal focus of the project, as well as this particular study, is thereby the *policies supporting innovation*, rather than the innovations themselves. In this context, our discussion on biofuels provides an important piece of the puzzle. Apart from providing increased knowledge about the ethanol industry itself, it also illustrates the particular conditions of stimulating innovation in an already existent production system based on a relatively mature technology. The term innovation, therefore, by necessity assumes a rather broad, yet policy target based definition, meaning change that is not necessarily new everywhere, but that lead to an overall improvement of the "way of doing things" related to a number of goals, not always economic. The luxury of dealing with innovation in a political context, as opposed to a private sector context, is that it is a quite straightforward process to distinguish desired change from undesired change. Since biofuel policy has a set of identifiable targets, such as lowering CO2 emissions, increasing energy security, and so on, innovation should arguably be defined as change leading towards set targets.

To sum up, the present study sets out to analyze innovation policies aiming at a sustainable transportation sector by comparing on the parallel development of ethanol industries in Brazil and the United States over the last four decades. The analysis will be guided by three questions: (i) what are the principal policies in the Brazilian and North American biofuel sectors respectively?; (ii) what were the principal factors driving policy formation processes?; and (iii) what are the opportunities and challenges going forward?

1.1 Historical and technical background

There are three major types of biofuel: (i) sugar-based ethanol (1st generation); (ii) cellulosic ethanol (2nd generation), and; (iii) biodiesel (which will not be covered in this report). Each comes with a specific set of possibilities, challenges and particular policy needs – and all are related in terms of innovation policy, since they are more or less interchangeable in the consumer end of the value chain. There are also intricate relationships between the biofuel sector on the one hand, and other sectors, predominantly agriculture and automotive, on the other.

Some basic insight into biofuel production processes and technical characteristics is therefore necessary for anyone wishing to understand the potential and limits of biofuel-promoting policy. The section at hand provides such background information.

Firstly, it should be noted that this report focuses on ethanol since it by a large margin is the most widely used biofuel in the world[1]. Ethanol is used as an additive in gasoline and has several positive effects as such: it serves (i) to prevent air pollution from carbon monoxide and ozone; (ii) as an octane booster and (iii) as a replacement of gasoline – in its purer forms to 100 percent.[2] Another pro is that when ethanol is mixed with gasoline to various proportions – most commonly 10 percent ethanol (E10) and, currently to a lesser extent, 85 percent ethanol (E85) – this in effect lowers the total carbon content of the fuel and subsequently leads to a reduction of transportation-related CO2-emissions.

Ethanol is currently produced from mainly two types of feedstock – corn (US) and sugar cane (Brazil). The production from sugar cane is a straightforward process. First, the cane is cut and relieved from its leaves and other residues, which are normally burnt already in the field. The remaining stalk is thereafter brought to a factory, where a large press squeezes out the juice, leaving the residual stalk, or bagasse, as a byproduct. Subsequently, the sugar juice is then either processed into refined sugar, or turned into ethanol. On a worldwide basis, less than half of the sugarcane (ranging for 35 to 47%) goes to sugar production, while the remainder enters the ethanol market. Traditionally, the bagasse and the other residues have been seen as waste, but technological advancements have recently made it possible – but not yet fully commercial – to utilize them as a source of energy (so called cellulosic ethanol).

Ethanol production from corn is slightly more complicated since the fermentable sugars have to be extracted from other corn-components such as protein and fiber (which, like in the sugar cane case, become animal feed and similar by products). About 80% of the corn used for ethanol is processed by "dry" milling plants (which use a grinding process) and the other 20% is processed by "wet" milling plants (which use a chemical extraction process).[3] The extracted sugar is then fermented into fuel-grade alcohol (ethanol at about 90 percent). Finally, excess water is removed and the fuel is denatured with gasoline to prevent human consumption.[4] Note well that, whether corn or sugar cane is used, this process uses energy and farmland. Critics of ethanol claim that energy and chemical inputs offsets gains in CO2-emissions from using ethanol as fuel but there are not studies to support this, on the contrary, existing studies seem to suggest that energy use and emissions related to ethanol production are marginal.

According to the International Energy Agency biofuels – and mainly ethanol – are projected to constitute up to 27 percent of the world's transportation fuel by 2050:

"While vehicle efficiency will be the most important and most cost-efficient way to reduce transport-emissions, biofuels will still be needed to provide low-carbon fuel alternatives for planes, marine vessels and other heavy transport modes, and will eventually provide one fifth (2.1 gigatonnes of CO2) of emission reductions in the transport sector"[5]

[1] *http://www.eia.gov/oiaf/analysispaper/biomass.html*
[2] *Fuel Ethanol: Background and Public Policy Issues. Updated April 24, 2008. Brent D. Yacobucci. Specialist in Energy and Environmental Policy Resources, Science, and Industry Division (Report for US Congress)*
[3] *Brent 2008*
[4] *Brent 2008*
[5] *Bo Diczfalusy, the IEA's Director of Sustainable Energy Policy and Technology, in relation to the release of the following report: http://www.iea.org/publications/freepublications/publication/biofuels_roadmap.pdf*

Ethanol would also, following the same logic, reduce oil dependence and increase all associated benefits of such reduction. There are, however, also some considerable challenges associated with the production of bioethanol. The above assessment that ethanol could make up 27 percent of all transportation fuel by 2050 is based on the development of other feedstock – primarily cellulose. This would, in turn, require substantial technological development.

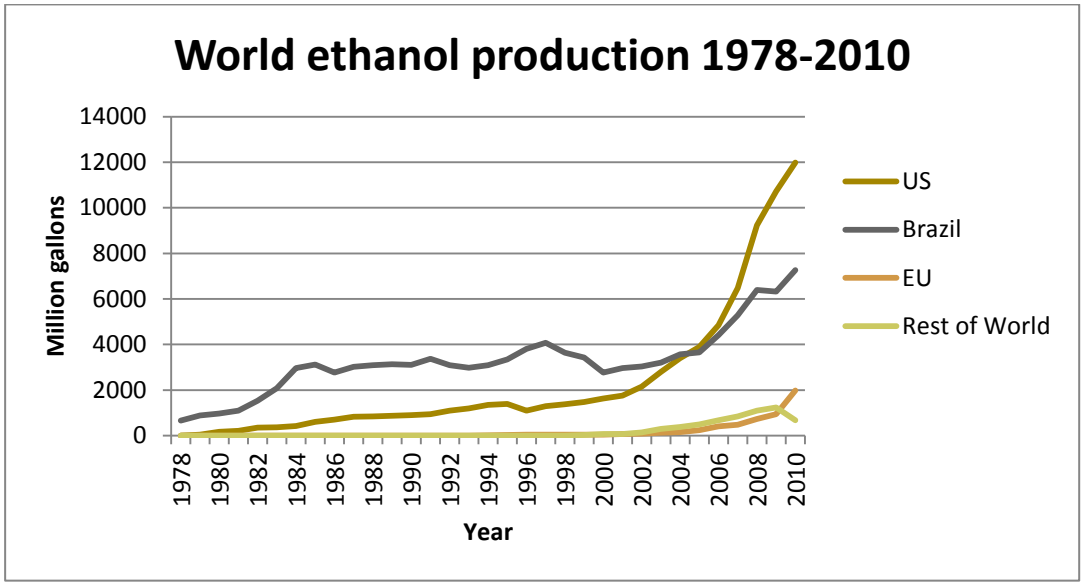

Figure 1-1 World ethanol production 1978-2010

Source: Earth Policy Institute[6]

[6] *With data for 1975-1998 from F.O. Licht, World Ethanol and Biofuels Report , vol. 6, no. 4 (23 October 2007), p. 63; 1999-2005 from F.O. Licht, World Ethanol and Biofuels Report , vol. 7, no. 18 (26 May 2009), p. 3; 2006-2010 from F.O. Licht, World Ethanol and Biofuels Report , vol. 8, no. 16 (28 April 2010), p. 328.*

2 Analytical framework

As stated initially, the present study constitutes an effort to identify the different factors and policies that influence the level of innovation in the biofuels sector, in Brazil and the United States respectively.

Accordingly, the upcoming discussion will evolve around set of theoretical tools that specify its generic components. First, we need a conceptual framework that describes the dynamics the policy process. How do policies come about? What decides whether they are executed or not? Second, we need a similar conceptual tool that describes the production system that policies in this case intend to target. Our ambition here is to introduce a process perspective on the production of ethanol that allows us to distinguish between different types of innovation – for which also different types of policies will be needed. Third, we also need a theory that establishes why innovations come about. What causes some individual actors within the system to innovate and others not? Fourth, in order to say something about the relative success or failure of present policies we shall also introduce some evaluation criteria for technological innovation systems. Finally, we shall also say something about the comparative approach used in this report.

2.1 Intervention Theory and the Policy Process

The present report is first and foremost a study on the evolution and implementation of public policy. For this reason, we shall use the notion of the public intervention logic model as a theoretical entry point.[7] The intervention logic idea, which takes its departure in systems thinking, refers to a conceptual scheme for the study of the ways in which an intervention is formed, adopted, implemented and brings about effects. To that extent it is not a description of the reality but, rather, a heuristic tool to raise critical questions regarding real life events. As such, the public intervention logic model conceives of policy processes as holding four different components.

The first, *intervention formation*, refers essentially to the process in which a specific problem first enters the political agenda until it finally generates a formal action plan, or intervention. It consists thereby of three sub-processes (initiation, preparation and adoption) that hold their respective instances of conflicts and negotiations between different interests. The latter may concern: 1) the nature of the problem, alternative courses of action, consequences, costs, and the definition of goals; 2) considerations regarding implementability, mainly in terms of legality and capability (organizational, managerial, and manpower); and 3) contemplations concerning how a future intervention should be evaluated. As we shall see, each of these instances may also influence how, in our case, innovation policies are finally effectuated.

A second component is the *administration* phase in which the goals and objectives of the adopted intervention are delivered to its targets. This is a far more diversified and complex part of the process than regularly assumed and, just like intervention formation, it involves a substantive amount of negotiations and politicking that similarly may influence the ways in which innovation policies actually plays out. A critical point is, for instance, the varying

[7] *Vedung, E. (1997) Public Policy and Program Evaluation. Transaction Publishers, London & New Brunswick, NJ.*

degree of discretion given to bureaucrats as they translate broad policy goals to concrete action plans through administrative decisions.[8]

Thirdly, one can also distinguish between three classes of *results* coming out of an intervention: a) *outputs* includes everything that actually pour out of the administrative system and in the final analysis influences intervention targets; 2) *outcomes* are what may happen on the addressee (target group, recipient, participant) side, mainly in the form of changed behavior and other actions, as they confront different outputs; and 3) *impacts* that refer to consequences beyond the addressees in a perceived effect chain.

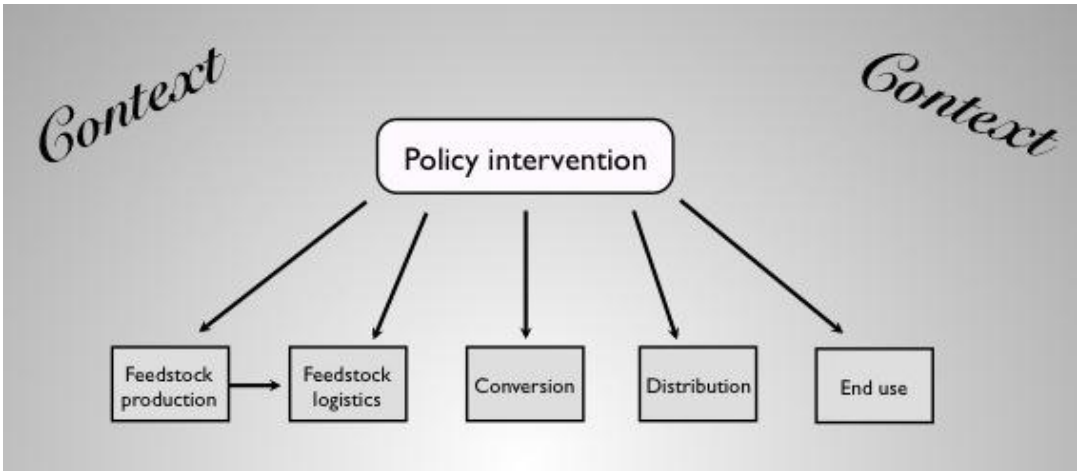

Figure 2-1: Public policy intervention in context

Finally, the public intervention logic model also emphasizes the existence of different *feedback loops*, mainly in the form of different assessment procedures, as a yet a third component in the system. This has, as we shall see, also been a critical component for innovation in the biofuels sector.

In addition to this, we shall for the present analysis add *context* as yet another critical component in the analysis. Although not directly part of the intervention logic model itself, it is very much part of the policy process and, as we shall see in the upcoming analysis, contextual factors have over the years had a strong impact on both Brazilian and US innovation policies in the biofuels sector. What makes these factors particularly important from an analytical point of view is that they in most cases are very difficult to control.

2.2 Value Chains

A second item concerns our understanding of the ethanol industry as our principal object of study. More specifically, we need an additional conceptual tool that describes the production system that policies in this case intend to target. One useful concept is the notion of value chains that in its broadest sense refers to "the full range of activities that are required to bring a product or service from conception, through the different phases of pro-

[8] *Pressman, J.J., Wildavsky, A. (1984) Implementation: How Great Expectations in Washington are Dashed in Oakland, 3rd ed. University of California Press, Berkeley, Los Angeles et al.*

duction (involving a combination of physical transformation and the input of various producer services), delivery to final consumers and final disposal after use".[9]

This theoretical framing, which not only introduces a process perspective but also distinguishes between different activities, is particularly powerful when linked to the public intervention logic model. Through a similar effort, it becomes clear that the production of ethanol not only involve different types of innovation, for which distinct policies will be needed, but that the latter also are contingent on several separate implementation processes. However, this interactive use of the two conceptual models allows us to identify what particular policies are aiming in the overall production system and, consequently, also draw some conclusions on what is missing, or faltering in terms of implementation. It is an implicit assumption that 'no chain is stronger than its weakest link'.[10]

2.3 Innovation and Competition

A third component in our discussion on innovation and biofuels concerns the actors participating in the production of ethanol. What drives their behavior? What are the factors that make them innovate or not?

The issue, it seems, is highly linked to market competition and the pursuit of strategic choices. In short, individual actors are constantly positioning themselves among their competitors on a continuously changing market place. Key to this dynamic is a set of external factors that, depending on their configuration, create different opportunities for individual actors. In order to gain competitive advantage in this shifting landscape, actors may apply various strategies. One of them is to invest in innovation.[11] As we shall see, the latter will then be a function of a particular configuration of forces at a specific point in time. This only underscores the importance of both contextual factors as well as the competitive concerns of actors within the targeted production system.

[9] *Kaplinsky, R., Morris, M. (2001) A handbook for value chain research. Institute of Development Studies, Brighton, UK.*

[10] *Linnér, B.-O., Mickwitz, P., Román, M. (2012) Reducing GHG emissions through development policies: an interventions-based approach to analyze the dynamics. Climate and Development 4, 175-186.*

[11] *Others strategies are: 1) to achieve lower costs; 2) to differentiate products and create niche markets; 3) to increase operational efficiency; and 4) to focus on technology exploitation.*

3 The emergence of a bioenergy industry: 1970-2010

Brazil and the United States have, as already indicated, largely parallel and long-standing experiences with ethanol as a fuel for transportation. This is true also for the more recent efforts to create a domestic biofuels industry, which were initiated largely at the same time, and since then followed similar yet different trajectories. Building on the previous observation, our upcoming analysis will unfold in four different sections, that each represents particular phases in both the Brazilian and US cases.

3.1 The introductory phase: 1970-1989

This section captures the years in which both countries initiated their respective national ethanol programs. The critical questions here are what caused these investments and why Brazil succeeded while the US only had a limited success.

3.1.1 The start of the Brazilian PROÁLCOOL program

Sugar production is intimately linked with Brazilian history and development. The country has since the 16th century been one of the world's leading exporters of sugar and also in the forefront of advancing its energetic use. In fact, ethanol derived from sugarcane was first used as an engine fuel in Brazil already in 1903 and thereafter heavily promoted by the government during the 1930's and 1940's. By 1941, ethanol production had reached 650 million liters and the fuel was mandatory in several states.[12]

Yet, the first truly large-scale effort to introduce ethanol as a transportation fuel emerged in the mid-1970s and is, as such, often interpreted as direct response to the global oil crisis of 1973. Confronted with soaring oil prices, the military government concluded that Brazil, which at the time was heavily dependent on foreign oil supply, had to diversify its energy matrix and become self-sufficient on fuels. Another, less recognized, contextual consideration that also had a decisive impact on the military's decision to scale up the production biofuels, was the declining world market on sugar. The latter had a considerable effect on Brazilian export revenues and hurt thereby the military's most important support constituency, i.e. the large landowning elite.[13] Under those circumstances, the investment in sugar-based ethanol provided not only a means to guarantee energy security but it constituted also a *de facto* opportunity to solve a series of both practical and political problems.

This resulted in the creation of the National Alcohol Fuel Program (PROÁLCOOL), which was formally established on 14 November 1975 (Decree no. 76.593) with the overall ambition to stimulate the production and use of ethanol as part of a larger automotive fuels policy. In effect, the program had four explicit objectives: 1) to increase the net supply of foreign exchange by reducing the demand for imported fuel; 2) to reduce income disparities among regions and individuals; 3) to increase national income through the deployment of underutilized resources; and 4) to increase the growth of the domestic capital goods sector. Implicit in these ambitions were also further aspirations that the new ethanol industry would reduce pollution, create thousands of new jobs, reduce rural poverty, and create a

[12] *Moreira, J.R., Goldemberg, J. (1999) The alcohol program. Energy Policy 27, 229-245. p. 231*
[13] *Hira, A., de Oliveira, L.G. (2009) No substitute for oil? How Brazil developed its ethanol industry. Ibid. 37, 2450-2456.*

new foundation for industrial growth. To the Brazilian militaries, it was also a political project intended to install national self-confidence and gain international recognition.[14]

In order to encourage the implementation of PROÁLCOOL, the government undertook a series of economical and regulatory measures that targeted various parts of the product value chain. First, it stimulated production by providing generous tax exemptions and low-interest loans to agricultural enterprises for the construction of ethanol distilleries. Second, it also secured a market by stipulating that the state-owned oil company, Petrobras, would purchase a certain amount of ethanol at a price that provided a given profit to ethanol producers. Similarly, the government also indexed consumer prices of alcohol at 59 percent to that of gasoline (later this was increased to 80 percent), something that was made possible through a cross-subsidy system, where taxes from gasoline and diesel oil, in effect, partly financed ethanol production. Finally, the government also created production quotas for sugar and established export controls that further regulated the market and, consequently, profit margins.[15]

The policies had an immediate effect and ethanol production increased from 580.000 m^3 in 1975 to 3.676 million m^3 in 1979, thereby surpassing the goal established for that year by 15 percent.[16] Yet, the program was far from consolidated. Instead, funding remained unclear and its implementation was obstructed by a fragmentation of interest both within and outside government that occasionally, and by various means, prevented action. Hence, as late as in 1978 it was still not clear whether PROÁLCOOL was a short-term measure to support sugar producers or a long-term energy solution.[17]

This, however, all changed with the second oil crisis of 1979, when OPEC, following the Iranian revolution, overnight announced a 37 percent price hike on oil. These events hit Brazil even harder than the crisis of 1973. The country's dependence on oil was at the time nearly 85 percent and it accounted, as such, for 32 percent of total import.[18] In this context, there was immediate agreement that PROÁLCOOL should be immediately strengthened and given top priority.[19]

In addition to previous policies, as well as the obvious increase in financial resources, a number of particular measures were now suggested that deserves particular attention. One critical point was, in theoretical language, the decision to support downstream industries directly linked to the production value-chain. In order to guarantee an increase the use of ethanol, the government provided automakers with incentives to produce an engine that could run on straight ethanol (*hydrous*), as opposed the already established engines running on ethanol-blended gasoline (*anhydrous*). This expanded not only the market for ethanol but, more importantly, it brought at an early stage the fuel into the larger transportation socio-technical complex, by effectively creating real and solid links with the car industry. This distinguishes, as we shall see, Brazil from the US ethanol experience. Second, this

[14] *Ibid.*
[15] *Moreira, J.R., Goldemberg, J. (1999) The alcohol program. Ibid. 27, 229-245. pp. 234f.*
[16] *BNDES and CGEE (2008) Sugarcane-based ethanol: energy for sustainable development. BNDES, Rio de Janeiro.*
[17] *Hira, A., de Oliveira, L.G. (2009) No substitute for oil? How Brazil developed its ethanol industry. Energy Policy 37, 2450-2456.*
[18] *BNDES and CGEE (2008) Sugarcane-based ethanol: energy for sustainable development. BNDES, Rio de Janeiro. p. 149.*
[19] *Koizumi, T. (2003) The Brazilian ethanol programme: impacts on world ethanol and sugar markets. FAO. June. FAO Commidity and Trade Policy Research Working Paper No. 1. ftp://ftp.fao.org/docrep/fao/006/ad430e/ad430e00.pdf, (accessed 15 December, 2006). p. 1.*

coincided in turn with the establishment of the Copersucar Center of Technology (CIT), which signaled an additional emphasis on research and development, mainly in the resources input area. Third, on the production side the government also established higher minimum ethanol fuels blend for gasoline (*anhydrous*), which progressively increased to 25 percent. Fourth, to guarantee distribution the government also mandated the availability of ethanol at all gas stations. Finally, it also decided to maintain a strategic reserve to guarantee supply.[20]

In this setting, the administration of the program started run much smoother. Not only did the context itself provide increased legitimacy to PROÁLCOOL, but, more importantly, by targeting the entire value-chain all main actors were effectively involved, thereby diminishing political opposition to the program.[21] Clearly, the authoritarian character of the Brazilian military government at the time also facilitated the implementation of this large-scale program.[22]

The results were in many respects astonishing and can be found at several levels.

In terms of direct output, the large subsides and credit lines were obviously critical the expansion of PROÁLCOOL. During this first phase of the program (1975-1989), an estimated US$ 12,3 billion (US$ of 1995) was invested.[23] Another critical component and, indeed, important institutional innovation was the mandated minimum ethanol fuels blend for gasoline, which later would constitute the basis for the ethanol industry's survival.

The outcomes were many and diversified. At the more immediate level, PROÁLCOOL was instrumental in: 1) creating a guaranteed market for ethanol; 2) supporting a modernization of existing ethanol distilleries; and 3) generating scientific advancements critical to both the cultivation of sugar (for example biological controls, integral use of stillage, and co-generation of energy) as well as the production of ethanol (for example open fermentation, storage, and transportation).[24] This had, in turn, an enormous impact on the production of ethanol and cars. Between 1979 to 1980, only two years after the first cars fueled by ethanol alone came out on the market, the proportion of ethanol powered cars in the total of Otto cycle cars, both passenger and mixed use, manufactured in Brazil increased from 0,46 to 26,8 percent. By 1986 and 1987, the production of ethanol peaked at a level of 12,3 billion liters, thereby exceeding the government's initial goal of 10,7 billion liters by 15 percent. In these years, sales of ethanol-fueled cars also reached its highest point, with nearly 95 percent of total sales of Otto cycle vehicles for the domestic market.[25]

However, the results of PROÁLCOOL also extended beyond it explicit objectives, and the program had considerable positive impact also in other areas. Briefly, it has been estimated that PROÁLCOOL, in the period between 1978 and 1990, created 720.000 direct jobs and more than 200.000 indirect jobs in rural areas. Moreover, in the same period the program generated foreign exchange savings of US$ 18 billion (US$ of 1990). Also, it had, as al-

[20] BNDES and CGEE (2008) Sugarcane-based ethanol: energy for sustainable development. BNDES, Rio de Janeiro.
[21] Maroun, C., Schaeffer, R. (2012) Emulating new policy goals into past successes: greenhouse gas emissions mitigation as a side-effect of biofuels programs in Brazil. Climate and Development 4, 187-198.
[22] Encarnação Jr., G. (2002) Alcohol Revisited. Economy & Energy. VI, 34 October - November. http://www.ecen.com/eee34/alcohol_rev_e.htm.
[23] Moreira, J.R., Goldemberg, J. (1999) The alcohol program. Energy Policy 27, 229-245. p. 229
[24] Macedo, I.C. (2007) The current situation and prospects for ethanol. Estudos Avançados 21, 157-165.
[25] Brazil. Ministry of Science and Technology. General Coordination on Climate Change (2004) Brazil's Initial National Communication to the United Nations Framework Convention on Climate Change. Ministério de Ciência e Tecnologia, Brasília. p. 174

ready indicated, considerable environmental benefits, particular in reducing the emission of local air pollutants in big cities.[26]

3.1.2 The US experience

As in the Brazilian case, ethanol has been used as fuel in the US for a long time. In fact, Henry Ford's Model T car is considered by many as the first flexible fuel vehicle (FFV) and ran on either gasoline or pure alcohol. During the 1920-s and 1930-s a fuel that today would go under the name E25 – that is a gasoline/ethanol-blend with 25 percent ethanol – was commonly used and some US plants would produce almost 20 million gallons of ethanol per year.[27] Still, increasing competition from cheap petroleum and natural gas strictly limited the ethanol market and despite resurging as a result of World War II it would take several decennia until ethanol production got back to the levels of the early 1930-s.

In the government policy context, ethanol-relevant legislation was first seen around World War II, when policies were adopted to encourage ethanol production in order to replace interrupted petrol imports. [28] In the post war era, however, gasoline, which is cheaper to produce and more abundant than ethanol, dominated up until the oil crises. The oil crisis, which as mentioned above was a key driver in the Brazilian context, was perhaps even more significant in the US case since its geopolitical consequences were more directly relevant in this care.

Rapid economic growth during the 1950-s and 1960-s drove petroleum demand growth until, finally, in the early 1970-s, the demand level began to surpass supply levels. Between 1970 and 1973 the market price for oil doubled, and between October 1973 and March 1974 the Arab oil embargo against the US caused severe gasoline shortages in the US, and reshaped the world oil market with the rise of the powerful OPEC-cartel. Most importantly from an ethanol-policy perspective, it became clear to the US government that it could no longer sufficiently control domestic oil supply. [29] This assessment was further fortified in 1978 when Iran – the world's second largest oil exporter at the time – experienced serious disruption in production and exports following the Iranian revolution.

Parallel to these developments, and in line with the Brazilian case, change in ethanol related policy was also driven by the need to replace lead as an octane booster in gasoline. Following increased awareness of health risks associated to smog, California passed several pieces legislation pertain to vehicle emissions in the 1950-s and 1960-s. This marked the start of a process that would result in federal requirements for US vehicles to have catalytic converters.[30] Since lead destroys the catalytic function of the metals in catalytic converters it had to be taken out of gasoline, and ethanol turned out to be a very good octane booster alternative.

This is the context in which the first major ethanol-related legislation was passed in the US. In short, policy change is driven by three strategies: (i) energy security (oil crisis, the rise of OPEC and middle east instability); (ii) environment (starting in the smog problem); and, (iii) rural economic development (see below). Table 1 gives an overview of key pieces of legislation and the following text provides additional information.

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[26] *La Rovere, E.L. (2002) Climate Change and Sustainable Development Strategies: A Brazilian Perspective. OECD, Paris. p. 8.*
[27] *Berger 2010 p. 78ff*
[28] *53 S.D. L. Rev. 425 2008*
[29] *Yergin, Daniel. (1991) The prize: the epic quest for oil, money and power.*
[30] *http://www.arb.ca.gov/html/brochure/history.htm*

The *National Energy Act* of 1978[31] (expired 1984) provided federal tax exemptions of $0.40 per gallon for gasoline/ethanol blends containing at least 10 percent ethanol. The *Crude Oil Windfall Profit Tax Act* [32] of 1980 extended theses tax exemptions until 1992 and also included an income tax credit option. In addition to providing tax exemptions, the *Energy Security Act* of 1980 also provided insured loans for small scale ethanol plants, which is the first US policy measure pointing to an ethanol-based rural development strategy. This dimension is not a primary cause of a change in ethanol policy, but rather a policy opportunity identified by the US government much similar to what happened in the Brazilian case when the government saw a potential for boosting the sugar industry. Indeed, the key target for US ethanol policy during the late 1970-s and the 1980-s was to increase national *production* rather than *consumption* – both: (i) in order to increase domestic energy independence following changes in the global political landscape and (ii) in order to support rural economic development. Environmental targets, though present in federal policy at this time, and urgent in specific states, were in this sense less prioritized – as evident in, among other things, the relative lack of interest in ethanol consumption.

Table 3-1 US Ethanol relevant federal legislation 1970-1989

Legislation	**Main driver (strategy)**	**Main vehicle**	**Enacted**
NATIONAL ENERGY ACT	Energy security	Fuel tax	1978
CRUDE OIL WINDFALL PROFIT TAX ACT	Energy security	Fuel tax	1980
ENERGY SECURITY ACT	Energy security	Loans	1980
DEFICIT REDUCTION ACT	Rural economic development Energy Security	Fuel tax	1984
STEEL TRADE LIBERALIZATION PROGRAM IMPLEMETATION ACT	Rural economic development	Trade barrier	1989
ALTERNATIVE MOTOR FUELS ACT	Rural economic development Energy security Environment	Regulation credit	1988

Despite these policy changes, however, the 1980-s saw only a moderate increase in US ethanol production. Most likely, this can be explained by the fact that oil prices stabilized during this time period, thereby offsetting some of the ethanol production driving incentives created by the abovementioned pieces of legislation. This was also recognized by the US government, who in the *Deficit Reduction Act*[33] of 1984 increased the tax credit to a historically high $0.60 per gallon (current level (2010) is $0.51 per gallon).

Another possible explanation behind the moderate levels of growth in domestic production is that many Caribbean countries, under the 1984 *Caribbean Basin Initiative*[34] (which was more or less set up to counteract communist influence in the Caribbean), did not have to pay special duties on ethanol imports.[35] These special duties were enacted on ethanol imports in order to not allow foreign producers to benefit from the tax exemptions introduced in 1978. Despite being marginal in relation to the US market, imports under the *Caribbean Basin Initiative* were nevertheless capped at 7 percent of US domestic consumption in the

[31] *Energy Tax Act of 1978, Pub. L. No. 95-618, 92 Stat. 3174 (1978).*
[32] *Pub. L. No. 96-223, 94 Stat. 229 (1980).*
[33] *Pub. L. No. 98-369, 98 Stat. 494 (1984).*
[34] *http://www.ustr.gov/trade-topics/trade-development/preference-programs/caribbean-basin-initiative-cbi*
[35] *Pub. L. No. 98-67, 97 Stat. 369 (1983)*

Steel Trade Liberalization Program Implementation Act of 1989. There is a potentially relevant Brazil-US connection through this legislation since it opens for larger amounts of duty-free imports from the involved countries provided that the ethanol is not made from indigenous feed stock – so, in theory, US firms could establish ethanol plants in the Caribbean Basin, import Brazilian feed stock for these plants and then sell the end product duty free to the US market. Such a scenario would counteract the US government rural development strategy but not the environmental strategy or, in any real sense, the energy security strategy.

In the *Alternative Motor Fuels Act*[36] of 1988, regulation credits were introduced specifically aimed at US automakers. Credits effectively lowered the automakers average CAFE-requirement (corporate average fuel economy) which was introduced in 1975 and will stay in effect until 2016[37]. In practice this means that automakers may produce fuel inefficient cars as long as they also produce alternative fuel cars, which, it could easily be argued is somewhat contradictory in the context of ethanol policy. The purpose of this piece of legislation, of course, was to encourage the production of alternative-fuel and dual-fuel vehicles and the main result was that automakers started building so called flexible fuel vehicles (FFVs) that can run on both gasoline and ethanol. This clearly increased the market for ethanol, but also lowered incentives for automakers to innovate broadly in fuel efficiency, since it allows them to offset cost relating to regulation of fuel-inefficient cars by making sure a limited portion of their entire production fleet are FFVs. In addition to this, due to limitation in ethanol-blended gasoline provision infrastructure, many owners of FFVs mostly run their cars on gasoline only – which renders the credit system ineffective.

In summary, the first period analyzed in this paper, 1970-1989, saw the introduction of the first major pieces of US ethanol legislation. The main drivers behind policy at this time were (i) a changing geopolitical landscape, which led to a prioritization of energy security based on domestic production, and (ii) a subsequent identification of the opportunity to benefit rural economic development though increased domestic ethanol production. Seen to the entire period 1975-2013, in which US ethanol production has grown exponentially, there was rather moderate growth in US ethanol production over the period.

3.2 Entering a stalemate: 1990

In this section the focus turns to the challenges of maintaining a system once it reaches a certain maturity. As we shall see, both Brazil and the US had at some point to confront this situation. The reasons, though, were different, as were the solutions.

3.2.1 The implosion of PROÁLCOOL

The first signs that Brazilian ethanol policies were heading towards harsher times appeared already in the mid-1980s. After 1987, a series of factors brought PROÁLCOOL into a stagnation phase that led to a virtual implosion of the program.

Several contextual factors contributed to this development.

[36] *Pub. L. No. 100-494, 102 Stat. 2441 (1988).*
[37] *http://www.nhtsa.gov/fuel-economy*

One was the Brazilian debt crisis of 1982 that effectively dried up the sources of finance. As inflation hit the government coffers, there was simply not enough money to keep subsidizing the program.[38]

A second critical development were the rising prices on the global sugar market, partly caused by a series of droughts, which encouraged sugar producers to leave ethanol production and, instead, switch other markets.[39] This caused severe disruptions in the supply of ethanol, which ultimately hit end-consumers and caused serious credibility problems for the ethanol industry.[40]

These alterations in the sugar market coincided, thirdly, with a drastic fall in global oil prices that after 1986 made gasoline highly competitive again. This renewed interest in oil got an additional boost by the discovery of large offshore oil fields outside the Brazilian coast. The new assets were considerable, covering 80 percent of total Brazilian demand, and all of a sudden energy security was no longer an issue, at least not with regards to oil.[41] More importantly, though, oil and petrol had now remerged as viable transportation fuel competing directly with ethanol.

This had direct repercussion also on the implementation of PROÁLCOOL. One of the more awkward institutional arrangements of the program was the early decision to make the national state oil company, Petrobras, solely responsible for the distribution of ethanol. The construction was an odd one, since Petrobras had no ethanol production of its own but, instead, regarded the ethanol market as a competitor.[42] During the first years of PROÁLCOOL, Petrobras had little choice but to cooperate. However, as the oil market recovered so did the company's political clout, and it progressively became less collaborative. With the distribution lines gradually breaking down, ethanol sales were effectively stalled, and consumers found themselves spending hours waiting at the gas stations. Needless to say, this had devastating effects on the program's legitimacy in the public eye.

Finally, it should be remembered that Brazil under the years 1985-1990 also underwent the first steps of a democratic transition, in which the military regime gradually gave up its powers to a civilian government. This affected not only the ways in which government controlled development policies in general but, more important, it ultimately altered the economic rationale on which PROÁLCOOL had been based. One of the reasons that the Brazilian militaries had to cede was, in effect, that the economic import-substitution policies, on which they built their power, had reached a dead end. Hence, one of the first measures undertaken by the first democratically elected President, Fernando Collor de Mello, as he took office in 1990, was to initiate a massive privatization program and open up markets. Under those circumstances, PROÁLCOOL made even less sense. Consequently, in the years that followed the program was slowly dismantled and all its subsidies and others support functions, such as quotas and taxes, gradually phased out. To many

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[38] Koizumi, T. (2003) The Brazilian ethanol programme: impacts on world ethanol and sugar markets. FAO. June. FAO Commidity and Trade Policy Research Working Paper No. 1. ftp://ftp.fao.org/docrep/fao/006/ad430e/ad430e00.pdf, (accessed 15 December, 2006). p. 2.

[39] Moreira, J.R., Goldemberg, J. (1999) The alcohol program. Energy Policy 27, 229-245. p. 230.

[40] Renata Veríssimo. "Proálcool é alternativa para fim da era do petróleo, diz ministro" O Estado de São Paulo. 08 de novembro de 2005.

[41] Adams, D. (2005) Ethanol: Is it the answer? St. Petersburg Times. 17 October. http://www.sptimes.com/2005/10/17/Worldandnation/Ethanol__Is_it_the_an.shtml, (accessed 22 January, 2006).

[42] Porto, G. (2005) Proálcool: coincidências ajudaram o programa. O Estado de São Paulo 8 November, p. H6. http://www.estadao.com.br/agronegocios/.

observers, PROÁLCOOL had never been economically viable and for the time being it served no competitive or strategic purpose. [43]

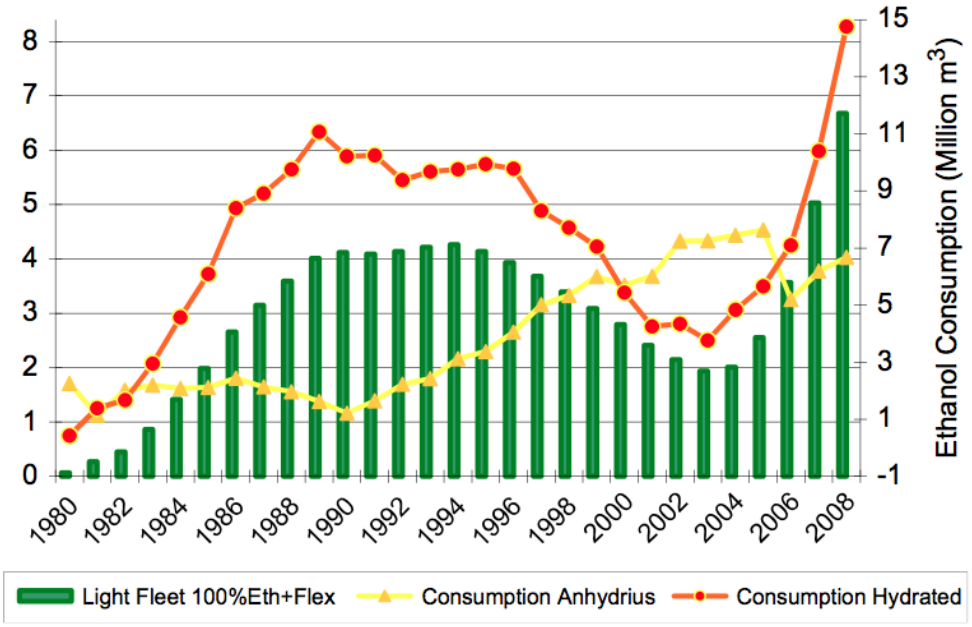

Figure 3-1: Evolution of ethanol light fleet cars and ethanol consumption in Brazil (1980–2008).

Source: Furtado et al, 2011.[44]

The results were quite remarkable. In just a few years, PROÁLCOOL went from being a booming industry to literally nothing. In only ten years, from 1987 to 1997, the sales of ethanol-fueled cars dropped from nearly 95 percent of the market to less than 0,5 percent of new automobile sales.[45] Similarly, several research institutions were closed as the ethanol market seemingly evaporated.

Yet, during these years several measures were also taken, unintentionally as well as intentionally, that would contribute to the ethanol industry's later resurgence. One was the scientific advancement within sugar production more generally. This was a direct consequence of the investments that followed from the collapse of the ethanol industry. As sugar producers no longer could rely on ethanol, they were, instead, forced to put all their effort in to producing sugar for export. The result was astonishing. In only seven years (1992 to 1997), Brazil multiplied its sugar exports fivefold to become the leading world exporter.[46] This was largely a result of major technical and scientific advancements in the area of crop management and production.[47] Thus, the fact that ethanol and sugar industries share the

[43] *Adams, D. (2005) Ethanol: Is it the answer? St. Petersburg Times. 17 October. http://www.sptimes.com/2005/10/17/Worldandnation/Ethanol__Is_it_the_an.shtml, (accessed 22 January, 2006).*

[44] *Furtado, A.T., Scandiffio, M.I.G., Cortez, L.A.B. (2011) The Brazilian sugarcane innovation system. Energy Policy 39, 156-166.*

[45] *Szklo, A.S., Schaeffer, R., Schuller, M.E., Chandler, W. (2005) Brazilian energy policies side-effects on CO_2 emissions reduction. Energy Policy 33, 349-364. p. 351.*

[46] *Furtado, A.T., Scandiffio, M.I.G., Cortez, L.A.B. (2011) The Brazilian sugarcane innovation system. Ibid. 39, 156-166.*

[47] *Macedo, I.C. (2007) The current situation and prospects for ethanol. Estudos Avançados 21, 157-165.*

upstream part of the production value chain, allowed in this case the latter to survive, and even progress, despite the fact that the industry itself had imploded. At the same time, the Brazilian government also tried to maintain a market for ethanol, if only in a more limited scale and presumably for strategic measures, by turning the previous fuels blending policies into a law that stipulated a 20-25 percent mixture of ethanol into gasoline.[48]

3.2.2 US stagnation – a time for groundbreaking policy work

The 1990-s marked an important legislative period in US ethanol history but also had the slowest relative growth for US domestic production ever. This was mainly due to a stabilization of oil supply. With the exception of some turbulence related to the first Gulf War of 1991, oil prices did not fluctuate significantly until towards the end of the millennium.[49] This generally lowered innovation incentives related to the energy security strategy and the environment and rural development strategies became more dominant. Table 2 gives an overview of relevant legislation during the period and these are explained in more detail in the following.

Table 3-2: US Ethanol relevant legislation 1990-1999.

Legislation	**Main driver (strategy)**	**Main vehicle**	**Enacted**
OMNIBUS BUDGET RECONCILIATION ACT	Rural economic development	Fuel tax	1990
TRANSPORTATION EQUITY ACT FOR THE 21ST CENTURY	Rural economic development	Fuel tax	1998
CLEAN AIR ACT	Environment	Programs	1990
ENERGY POLICY ACT	Rural economic development	Fuel tax	1992

The *Omnibus Budget Reconciliation Act* of 1990 effectively lowered the fuel tax credit for ethanol blends to $0.54 per gallon until 2002 but also introduced a $0.10 per gallon payment to small ethanol producers. This would later raise criticism for basically constituting "welfare" for ethanol farmers, and clearly marks a shift in policy strategy from energy security to rural economic development.

The *Transportation Equity Act* for the 21ST century of 1998 extended ethanol tax credits well into the 2000-s but also introduced marginal and subsequent reductions that would land at $ 0.51.

From a long term perspective, the most important pieces of legislation during the period were related to environmental concerns, not the least smog reduction and other air quality measures. Most important of all, the *Clean Air Act* of 1990, established the *Oxygenated Fuels Program* and the *Reformulated Gasoline Programs*. These programs aimed at reducing air pollutants in some of the US most heavily traffic polluted cities. The main solution was to require a certain amount of oxygen in gasoline, and adding ethanol turned out to be one good way of achieving this. The main method at the time, however, was based on a petroleum product called methyl tertiary butyl ether (MTBE). The *Clean Air Act* also requires public or private fleet operators with more than 10 or more centrally fueled vehicles to purchase increasing volumes of clean fuel vehicles. This includes gasoline powered

[48] *Hira, A., de Oliveira, L.G. (2009) No substitute for oil? How Brazil developed its ethanol industry. Energy Policy 37, 2450-2456.*
[49] *http://tonto.eia.doe.gov/dnav/pet/hist/rwtcA.htm*

vehicles meeting clean fuel vehicle standards. This requirement has not had much impact on ethanol consumption however – mostly because a vast majority of metropolitan areas addressed by the legislation opted out. Another explanation is that owners of FFVs still to a large extent run them on gasoline only. As the National Energy Policy Development Group created by George W. Bush notes in a 2001 report:

"The success of the federal alternative fuels program has been limited, however. The program focuses on mandating that certain fleet operators purchase alternative fueled vehicles. The hope was that this vehicle purchase mandate would lead to expanded use of alternative fuels. That expectation has not been realized, since most fleet operators purchase dual-fueled vehicles that operate on petroleum motor fuels. Reforms to the federal alternative fuels program could promote alternative fuels use, such as expanding the development of an alternative fuels infrastructure."[50]

The Energy Policy Act[51] of 1992 extended abovementioned fuel tax credits and lowered the qualifying ethanol content to around 6 percent. The latter was done to encourage ethanol as an oxygenate for gasoline and increase ethanol competitiveness vis-à-vis MTBE.

During the 1990-s US ethanol policy was largely carried by what had initially been seen a as policy opportunity, namely the rural ethanol producing industry. Overall, ethanol demand was growing slower than ever but as subsequent sections show, the 1990-s saw some new legislation that would prove crucial in the years to come.

3.1 The resurgence (and demise) of ethanol: 2000

This chapter illustrates how both countries managed to revitalize their respective ethanol industries, largely due to different innovations. Yet, again, the conditions and policies differ considerably.

3.1.1 The Brazilian experience revisited

The first steps towards a revitalization of the Brazilian ethanol industry came, as already indicated, already in the late 1990s. Once again, the process was initially driven by developments on the global oil and sugar markets. But, this time it occurred in a context characterized by economic deregulation and a general ambition to achieve efficiency and innovation through private initiatives.

A decisive moment for this development was the Brazilian government's decision in 1997 to intervene downstream in the value-chain and deregulate fuel markets all across the board. One of the first steps in this process was to liberalize the price of hydrated ethanol. From this followed the year after a new legislation (Provisional Measure no. 1662) that established a minimum of 22% anhydrous ethanol in the gasoline mix.[52] The rationale in the latter case was rather to create an internal demand for sugar, when prices on the global sugar market were plunging.[53] Also, it was very much a reflection of the organizational

[50] *"Reliable, Affordable, and Environmentally Sound Energy for America's Future" Report of the National Energy Policy Development Group (2001)*
[51] *Pub. L. No. 102-486, 106 Stat. 2776 (1992)*
[52] *Brazil. Ministry of Science and Technology. General Coordination on Climate Change (2004) Brazil's Initial National Communication to the United Nations Framework Convention on Climate Change. Ministério de Ciência e Tecnologia, Brasília. p. 175*
[53] *US Department of Agriculture (2002) Sugar: World Markets and Trade. USDA. November. http://www.fas.usda.gov/htp/sugar/2002/November/complete%20circular.pdf, (accessed 16 December, 2006). p. 1.*

fact that the Ministry of Agriculture at the time was responsible for ethanol policies and, accordingly, determined the blend ratio between gasoline and ethanol. In this context, the Ministry's primary objective was, obviously, to protect the domestic sugar industry from outside competition. Although fundamentally a protectionist measure it strengthened, as we shall see, private innovation in the ethanol market. Finally, in 1999 the prices on anhydrous ethanol were also deregulated and all subsidies to ethanol blend gasoline producers phased out, or radically reduced. Also, the distribution monopoly given to Petrobras was finally abolished.[54]

These measures, based on a general strive towards deregulation and open markets, gave ethanol production a boost and made way for new actors to take action. With global oil prices rising at the end of the decade, and the production apparatus for ethanol already in place, there was a strategic competitive opportunity for carmakers to gain a new market. This led in March 2003 to the introduction of a new car model, the *Volkswagen Gol 1.6 TotalFlex*, which had an engine that adjusted to any combination of gasoline and ethanol. This meant, in effect, that neither the car companies nor the individual drivers were no longer locked into a particular fuel. The *flex-fuel* concept was an instant success and immediately picked up by other car producers. With that the market exploded and the sales of flex-fuel cars went from 39.095 sold entities in 2003 to 2,5 million in 2009, when they made up for nearly 95,4 percent of the fleet.[55] This generated, in turn, an almost exponential growth in the production of hydrous ethanol that went from 5.608 thousand m^3 in 2002/2003 to 18.177 thousand m^3 in 2008/2009.[56] Once again, the ethanol industry had been stimulated by innovations in the downstream ancillary car industry.

This reemergence of the ethanol industry was further strengthened by the advent of climate change as central topic on the international political agenda at the turn of century. In the debate that followed, biofuels, and in particular Brazilian ethanol, was by many seen as one of the principal mitigation strategies in preventing global warming. This presented new opportunities for both ethanol producers, that saw new market opportunities emerging also outside Brazil, as well as the Brazilian government itself, that gained considerable political prestige from once having incentivized PROÁLCOOL. Consequently, in the years that followed major investments were made by both public and private actors to increase production. Also, both parties made coordinated efforts to have ethanol turned into a global commodity. The latter involved everything from lobbying activities to hand-on investments as well as technology and knowledge transfer to other tropical countries with similar conditions, mainly in Africa and the Caribbean.[57]

These combined efforts were initially successful but around the middle of the decade a number of contextual factors, once again, changed the premises for the ethanol industry.

A first decisive event in this development was the global food crisis in 2007 – 2008 that raised a heated debate over biofuels' impact on food prices. Some studies seemed to indi-

[54] *Koizumi, T. (2003) The Brazilian ethanol programme: impacts on world ethanol and sugar markets. FAO. June. FAO Commidity and Trade Policy Research Working Paper No. 1. ftp://ftp.fao.org/docrep/fao/006/ad430e/ad430e00.pdf, (accessed 15 December, 2006). p. 2.*

[55] *ANFAVEA (2012) Anuário da Indústria Automobilística Brasileira. ANFAVEA, São Paulo, SP.*

[56] *UNICA (2013) Produção de Etanol Hidratado, 2002/2003 - 2008/2009. UNICA., (accessed 20 February, 2013).*

[57] *Brianezi, T. (2009) Brasil exporta modelo de produção de etanol a países da África e do Caribe. Reporter Brasil 9 December. http://reporterbrasil.org.br/agrocombustiveis/exibe.php?id=111, (accessed 20 February, 2013), Pamplona, N. (2005) A conquista do mercado mundial. O Estado de São Paulo 8 November, p. H2. http://www.estadao.com.br/agronegocios/.*

cate that there was, indeed, a link between the two and the UN special rapporteur on the right to food, Jean Ziegler, went as far as to call the production of biofuels "a crime against humanity", calling for a five-year ban on the practice.[58] The discussion eventually became more nuanced but ethanol had already lost some of its earlier credibility and was now under scrutiny.

This led to further investigation of both the social and environmental practices related to its production. Again, the initial critique had strong emotional overtones and occasionally not fully supported by empirical facts. It was, for example, argued that the production of ethanol would speed up the deforestation of the Amazon rainforest, although this is not only practically impossible, since sugar cane does not grow in similar ecosystem, but also explicitly prohibited in Brazilian Law.[59] Moreover, there were serious concerns regarding the treatment of the labor in the ethanol. The latter were in many instances legitimate claims but failed at the same time to consider improvements already underway.[60] This created at some point not only severe diplomatic tensions but, more important, it further deteriorated the credibility of the sector.

At another level, the interest in biofuels more generally also diminished considerably as the breakdown of the global climate change negotiations in Copenhagen in December 2009. In Brazil, this was further evidenced by the combined fact of, on the one hand, the discovery of major oil resources outside the Brazilian coast, the so-called Présal, and, on the other hand, the global crisis of 2008 that soon became the principal policy priority. This led to a series of efforts that would further undermine the ethanol sector. One was the decision in 2011 to move the responsibility of ethanol policies from the Ministry of Agriculture to the Ministry of Mining and Energy. This meant, in practice, that the ethanol industry became subject to the regulatory competence of the National Agency for Petroleum, Natural Gas and Biofuels (ANP) and that ethanol policies, in effect, fell into the shadow of the expanding oil and gas sector.[61] A second critical development was the informal decision in that same year to use the regulated gasoline price as a means to combat inflation. The latter had serious repercussions on ethanol sales that continued to follow market prices. In order to compete, ethanol prices have also been held at a level that keeps the revenue close to zero.

This led to a slow but continued downturn of the sector, where the general sentiment was one of neglect and lack policies on part of the government. In this process, the sector also lost a substantial part of its innovative capacity, with a resulting loss in productive capacity and increasing domestic prices.[62] This latter trend became almost painfully clear in 2011

[58] *Ferret, G. (2007) Biofuels 'crime against humanity'. BBC News 27 October. http://news.bbc.co.uk/2/hi/americas/7065061.stm, (accessed 22 February, 2013).*
[59] *(2009) Lula lança plano que proíbe cultivo da cana na Amazônia e Pantanal. Folha de São Paulo 17 September. http://www1.folha.uol.com.br/folha/ambiente/ult10007u625438.shtml, (accessed 8 March, 2013).*
[60] *Rumsey, J., Wheatley, J. (2008) Poor practices taint Brazil's ethanol industry. Financial Times 21 May. http://www.ft.com/intl/cms/s/0/f7b164b2-26d0-11dd-9c95-000077b07658.html#axzz2LgneYofm, (accessed 22 February).*
[61] *(2011) ANP assume o setor de etanol. Globo Rural 20 September. http://revistagloborural.globo.com/Revista/Common/0,,EMI266480-18077,00-ANP%20ASSUME%20O%20SETOR%20DE%20ETANOL.html, (accessed 8 March, 2013).*
[62] *Pereira, R. (2011) Falta de investimento ameaça etanol. O Estado de São Paulo 22 May. http://economia.estadao.com.br/noticias/economia%20brasil,falta-de-investimento-ameaca-etanol,68072,0.htm, (accessed 3 June, 2012).*

when ethanol production declined by 17 percent[63] and Brazil, the second largest producer of ethanol in the world, had to import ethanol from the United States, whom it so desperately had tried to convince about the virtue of a global ethanol market.[64]

3.1.2 US ethanol enters the 21st century – resurgence of security and unforeseen consequences of 1990-s policy making

In the year 2000, US ethanol production was the 2nd largest in the world (producing 35 percent of the world's ethanol, corresponding to 60 percent of Brazil's production). Over the next 10 years, the US ethanol industry would see a sevenfold production growth, passing Brazil in 2005 and producing more than half of the world's ethanol in 2010. This extreme growth was triggered by what could be described as a "perfect storm" of world events, and further increased by US policy responses to these events – both at the federal and state levels.

The main policy-external factor during this period is a strong resurgence of energy security and a destabilization of oil prices following the September 11 terrorist attacks and the 2nd Iraq War. In addition to this, strong economic growth further press oil prices upwards. Secondly, large crops hit markets for corn and other farming products, driving prices downwards, which create economic hardship in the US farming sector – this lead to an intensification of policy efforts to uphold prices on farming products by encouraging corn use for ethanol production. Finally, the main oxygenate alternative to ethanol – MTBE – which was banned in California in 1999, is phased out worldwide, leaving ethanol as more or less the sole alternative for fulfilling requirements set by legislation in the previous decade. Table 3 summarizes policy change in the 2000-s and the following describes its components and its impact.

Table 3-3 US Ethanol relevant legislation 2000-2010

Legislation	Main driver (strategy)	Main vehicle	Enacted
COMMODITY CREDIT CORPORATION BIOENERGY PROGRAM	Rural economic development	Tax credit	2000
National Energy Policy Development Group (not legislation)	Energy security	Land access and fuel tax	2001 (pub)
FARM SECURITY AND RURAL INVESTEMENT ACT	Rural economic development	Tax credit and production incentives	2002
AMERICAN JOBS CREATION ACT	Rural economic development	Fuel tax	2004
ENERGY POLICY ACT	Energy security	Production levels and programs, loans	2005
ENERGY BILL	Rural economic development Energy security	Tax credits	2005
AGRICULTURAL RISK PROTECTION	Rural economic development	Tax credit and	2005

[63] *Leahy, J., Pearson, S. (2012) Brazil gives big sweetener for sugar biofuel. Financial Times 11 January. http://www.ft.com/intl/cms/s/0/f16f5546-3c7f-11e1-8d38-00144feabdc0.html#axzz2KPm1UQpl, (accessed 7 February, 2013).*

[64] *Magossi, E. (2012) Brasil importa recorde de 1,1 bi de litros de etanol dos EUA em 2011. O Estado de São Paulo 10 January. http://economia.estadao.com.br/noticias/economia,brasil-importa-recorde-de-11-bi-de-litros-de-etanol-dos-eua-em-2011,98950,0.htm, (accessed 3 June, 2012).*

Legislation	Main driver (strategy)	Main vehicle	Enacted
ACT		production incentives	
ENERGY INDEPENDENCE AND SECURITY ACT	Energy security	Production levels, feedstock proportions and R&D funding	2007

At the federal level, in 2001 the National Energy Policy Development Groups submitted a comprehensive strategy proposal to the President which recognized a "tremendous potential" for ethanol as an oil-replacement, "if ethanol production could be expanded".[65] All recommendations of the NEPD Group did not convert into actual legislation but the report gives important insight into how high-level US administration (the group was headed by Dick Cheney) thought about ethanol at the time. The NEPD made the following recommendations pertaining to ethanol and other biofuels:

1. That the President direct the Secretaries of the Interior and Energy to reevaluate access limitations to federal lands in order to increase renewable energy production, such as biomass (particularly ethanol page 6-4), wind, geothermal, and solar. (page 6-3)
2. The NEPD Group supports the increase of $39.2 million in the FY 2002 budget amendment for the Department of Energy's Energy Supply account that would provide increased support for research and development of renewable energy resources. (page 6-4)
3. That the President direct the Secretary of Energy to conduct a review of current funding and historic performance of renewable energy and alternative energy research and development programs in light of the recommendations of this report. *Based on this review, the Secretary of Energy is then directed to propose appropriate funding of those research and development programs that are performance-based and are modeled as public-private partnerships.*(Page 6-4, Swecos italics)
4. That the President direct the Secretary of Treasury to work with Congress to continue the ethanol excise tax exemption (page 6-9)

Furthermore the NEPD Group made several recommendations for stimulating hydrogen use, which has indirect positive effects on ethanol due to its being an excellent energy source for hydrogen extraction.

In line with NEPD Group recommendations the ethanol tax credit was extended until 2010 by the *American Jobs Creation Act*[66] of 2004, but also simultaneously abolished the designated blend levels – leaving it to fuel producers to set blend levels.

The *Energy Policy Act* of 2005 was a very important piece of legislation since it in effect guaranteed a 7.5 billion gallon ethanol market by 2012. It did this by mandating a RFS – renewable fuel standard – that effectively connects gasoline production to ethanol production by requiring a certain amount of all fuel production to be biofuel (predominantly ethanol). At the producer level a credit system was introduced, allowing producers to trade in

[65] *"Reliable, Affordable, and Environmentally Sound Energy for America's Future" Report of the National Energy Policy Development Group (2001) 6-8*
[66] *Pub. L. No. 108-357, 118 Stat. 1418(2004).*

under- or overuse of ethanol additives – so the legislation addresses national production levels rather than individual actors. The most important impact of the guaranteed levels was that it mitigated investor risk by guaranteeing a minimum market size.

The *Energy Policy Act* also started to address sustainability issues by providing incentives for cellulosic ethanol production by introducing the *Cellulosic Biomass Program*. Under this program every gallon of cellulosic ethanol counted as 2.5 gallons towards satisfying RFS-requirements. Additionally, the program provides loans of up to $250 million per production facility, which roughly covers establishment cost for an average size plant. Funding is also provided for technology development programs with the purpose of further refining cellulosic capabilities.

The *Energy Bill* of 2005 provides tax credits for small producer capacity ethanol plants and for fueling infrastructure for alternative-fuel vehicles.

Several pieces of legislation and federal programs during the period focused on supporting the US farming sector following large crop surpluses that pushed prices downwards and created economic problems for US framers. *The Commodity Credit Corporation Bioenergy Program* of 2000 provided cash payments for producers buying farmed biofuel feedstock – by the logic that this would increase farm product demand and help stabilize prices across the board. The *Farm Security and Rural Investment Act* of 2002, as well as the Agricultural *Risk Protection Act* of 2005 included several program that in similar ways rewarded investments in biofuel capacity in the farming sector.

Finally, the *Energy Independence and Security Act* of 2007 expanded the RFS to 36 billion gallons by 2022 (current production is about 12 billion gallon) and set feedstock proportions at 58 percent cellulosic and 42 percent corn for the same year. Recognizing the contemporary technological, market and infrastructural restrictions, the act also expands next generation biofuel research programs, ethanol fueling infrastructure investment incentives and FFV market growth analyses.

At the state level, several pieces of environmental regulation have been the real vehicle for phasing out MTBE and have also mirrored federal legislation regarding RFS. California, in particular, has been **the** early mover and an important player not only in implementing federal policy but indeed for driving US policy in some areas. The full scope of state legislation and regulation, however, is impossible to include in this report.

4 Current situation and future directions: 2010-

The discussion up to this point illustrates how Brazil and the US in an almost parallel fashion, yet for different reasons and by different means, both developed extensive industries around the production of ethanol. The question now is what will happen over the next couple years that seem to be characterized by continued economic hardships along with major alterations on the global energy market. What are the factors in play? What are the strategic choices? Where is the biofuels industry heading and what is the role of innovation in this context.[67]

4.1 Brazil

If the last decade started with the Brazilian ethanol industry booming, its latter half provided instead a number of challenges that put most of the initial euphoria on hold. More than anything else, these events proved that the Brazilian ethanol production is highly interlinked with, and therefore contingent of, a series of other industries as well as larger macro-economic considerations. As we have seen, with the global economic crisis and other contextual events the situation for the ethanol industry also became increasingly precarious.

Yet, in a crisis resides also an opportunity and there are currently indications that the Brazilian ethanol production is slowly recovering. The question is what will happen next. Is the current development merely a reflection of market fluctuations, or does it follow from deliberate activities within the sector? What are the strategic choices laying ahead?

4.1.1 The competitive context

Strategic decisions are always made in a larger context. The backdrop for the recent demise of Brazilian ethanol industry is, like in most other instances, the global economic crisis. Initially it seemed as if Brazil was doing better than most other countries. In fact, the country actually came out of the first crisis in 2007-2008 relatively intact. Then, after a temporary retraction in the second crisis of 2009, the Brazilian economy had a 7,5 percent GDP growth in 2010.[68] However, since then many of the country's inherent structural problems, such as administrative red tape, precarious infrastructure, and lack of skilled labor, have become painfully visible. The result has been a considerable slowdown in the economy that still prevails. Preliminary data indicate that the Brazilian economy grew by a mere 0,8 to 1,6 percent in 2012.[69] This decline was mainly explained by a significant retraction in industrial production.[70] In this process, ethanol policies turned into an instrument to compensate for some of these problems.

[67] *Built on Berger, E.M. (2010) Dynamics of innovation of biofuel ethanol: Three decades of experience in the U.S. and Brazil. Doctoral thesis. School of Public Policy. Georgia Institute of Technology.*
[68] *Resende, T., Campos, E., Peres, L. (2013) 2012 foi ano de crise, parecido com 2009, diz Mantega. Valor Econômico 1 March. http://www.valor.com.br/brasil/3028258/2012-foi-ano-de-crise-parecido-com-2009-diz-mantega, (accessed 6 March, 2013).*
[69] *Martello, A. (2013) 'Prévia do PIB' tem crescimento de 1,6% em 2012, revela Banco Central. G1 Globo.com 20 February. http://g1.globo.com/economia/noticia/2013/02/previa-do-pib-tem-crescimento-de-16-em-2012-revela-banco-central.html, (accessed 23 February, 2013).*
[70] *Resende, T., Campos, E., Peres, L. (2013) 2012 foi ano de crise, parecido com 2009, diz Mantega. Valor Econômico 1 March. http://www.valor.com.br/brasil/3028258/2012-foi-ano-de-crise-parecido-com-2009-diz-mantega, (accessed 6 March, 2013).*

The structural factors mentioned above should not be neglected since they are, in effect, fundamental to Brazil's competitiveness and innovative capacity. As such, they also establish some of the internal challenges that the country's ethanol industry now has to confront. Brazil ranks today as 48 (out of 144 countries) in terms of competiveness[71] and only a mere 58 (out of 141 countries) with respect to its innovative capacity.[72] Shortly, we shall discuss more in detail what this means for the ethanol industry.

4.1.2 The influence of competing industries

Yet, there are additional factors in the surrounding environment, or context, that more directly influence strategic decisions of any industry. One is the *influence of competing industries* that offer substituting products or services.

In the case of Brazil, the oil and gas industry has over the years been closely linked to ethanol policies. As noted, the government has in recent years effectively subsidized the oil industry through ethanol sales and different pricing mechanisms, something that has had a considerable negative impact on ethanol sales. This is now changing. In late January 2013, the Minister of Energy, Edison Lobão, announced a 6,6 percent price increase on gasoline at the refineries. Only a few days later, he also declared that the amount of anhydrous ethanol in gasoline would increase from 20 to 25 percent by 1 May, 2013.[73] The two policies were, ironically, a blessing for both oil and ethanol industries. To the latter, it meant that: 1) ethanol again was competitive with oil; and 2) there was a de facto increase in the ethanol market. To the former, or more specifically Petrobras, it meant that: 1) there was less demand for imported gasoline; and 2) as oil prices become more on par with the global market the company was no longer subsidizing the price of gasoline at the pumps.[74]

In this context, it should be noted that light-duty vehicles and private cars are not permitted to run on diesel fuels in Brazil. This follows from a law that was imposed during the oil crises of the 1970's largely as a complement to PROÁLCOOL. In order to protect commercial road transportation, the Brazilian government decided to restrict the use diesel for commercial use and trucks only. Interestingly, it simultaneously lowered taxes on diesel something only further cemented the use of trucks as the principal means of commercial transportation. Consequently, diesel has now become the single-largest fluid fuel in the Brazilian energy mix. This makes the competitive context for ethanol in Brazil considerably different than in, for example, Europe.

Another question is what will happen to the investments in natural gas. One of the critical mandatory components of the Brazilian *Petroleum Law* from 1997 was the increased use of natural gas, both for energy purposes as well as transportation. Since there has been mixed progress. After a somewhat bumpy start there was a rapid expansion between 2004 and 2007, particularly in the Southern and Southeastern parts of the country, but it has since then slowed down. In 2011, natural gas constituted 2,6 percent of the total road transportation fuels mix.[75] This may seem irrelevant at first. Yet, there may be reasons to

[71] *Schwab, K. (2012) The Global Competitiveness Report 2012–2013. World Economic Forum, Geneva.*
[72] *Dutta, S. (2012) The Global Innovation Index 2012: Stonger Innovation Linkages for Global Growth. INSEAD, Paris.*
[73] *Bitencourt, R., Campos, E., Veloso, T. (2013) Gasolina terá 25% de etanol a partir de 1º de maio. Valor Econômico 31 January. http://www.valor.com.br/brasil/2990648/gasolina-tera-25-de-etanol-partir-de-1, (accessed 23 February, 2013).*
[74] *Ibid.*
[75] *Empresa de Pesquisa Energética (2012) Balanço Energético Nacional 2012: Ano base 2011. EPE, Rio de Janeiro, RJ.*

follow the development of natural gas. First, while the use is concentrated to the South and Southeast there are in fact strong regional markets. Interestingly, they largely coincide with major industrial areas, such as São Paulo and Rio de Janeiro. Second, there are major domestic gas findings, principally through Presál, that will be commercialized in the upcoming years. This creates in turn a new supply that potentially could go into the transportation sector. Third, there are also regional aspects to the issue. Several South American countries, such as Bolivia and Argentina, are strongly gasified both in terms of production and use. This means that there is considerable potential for trade and further investments in infrastructure and research. Finally, there are preliminary indications that Brazil is sitting on considerable sources of shale gas. The numbers range between 5 700 and 15 700 billion m^3 of gas and would, if verified, be the fourth largest reserves in the world (the current reserves of conventional gas amounts to 450 billion m^3). If these pieces all fall in place, Brazil could be self-sufficient on gas in five years.[76]

4.1.3 The influence of other market actors

A second factor affecting strategic behavior is the *influence of competing actors on the same market*. The case in point here would be the United States, which whom Brazil has a complicated relationship. The US is, already noted, the largest ethanol producer in the world but has notoriously kept its market closed to other countries, mainly through a 54-cents-per-gallon tariff levied against imported ethanol. Similarly, American firms have rarely acted outside the US. This was for a long time a source of major frustration to the Brazilian government that, along with the ethanol industry, wanted to turn ethanol into a global commodity. The issue has been a matter of diplomatic dispute and Brazil has on several occasions threatened to bring it to the World Trade Organization (WTO).[77] Also, in order to exert even more pressure the country took in 2010 a unilateral decision about an elimination of tariffs between the two countries.

The actions seemed to have paid off. To the surprise of many, the US Congress decided in 2011 not to extend the previous import tariffs as of 1 January, 2012. In a stroke of a pen, the US market was thereby suddenly open to imports. At the same time, Congress also cut some of the production tax credits that had been provided to US producers for almost three decades. These changes complemented the measures already taken by Brazil and created, in effect, a hemispheric free market in ethanol.[78]

From this things evolved quickly. Of critical importance were a series of US regulatory arrangements that further sped up the process. One was the US Environmental Protection Agency's standard for advanced biofuel, which establishes the volumes of corn-based and advanced biofuels that refiners must blend into the fuel that they sell. This created a *de facto* need for Brazilian ethanol, since the American corn-based ethanol does not meet the

[76] *Ordoñez, R. (2012) Brasil tem reservas de R$ 340 bilhões de gás 'não-convencional'. O Globo 12 October. http://oglobo.globo.com/economia/brasil-tem-reservas-de-340-bilhoes-de-gas-nao-convencional-6388673, (accessed 12 October, 2012), Rosa, B. Ibid.Autossuficiência em gás natural pode vir em em até cinco anos. 4 November. http://oglobo.globo.com/economia/autossuficiencia-em-gas-natural-pode-vir-em-em-ate-cinco-anos-6633708?topico=desafios-brasileiros, (accessed 4 November, 2012).*

[77] *(2008) Brazil is poised to begin WTO protest over ethanol tariffs. New York Times 30 July. http://www.nytimes.com/2008/07/30/business/worldbusiness/30iht-30ethan.14880834.html?_r=0, (accessed 25 February, 2013). Colitt, R. (2011) Exclusive: Brazil steps up WTO measures in currency war. Reuters 21 January. http://www.reuters.com/article/2011/01/21/us-brazil-trade-wto-idUSTRE70K5OI20110121, (accessed 25 February, 2013).*

[78] *Mathews, J. (2012) The end of the U.S. ethanol tariff. Energy Bulletin 9 January. http://www.energybulletin.net/stories/2012-01-09/end-us-ethanol-tariff, (accessed 7 February, 2013).*

stipulated criteria.[79] A second regulatory instrument that had a similar effect was the California Low Carbon Fuel Standard. The latter, that took effect in 2011, constitutes in effect the world's first greenhouse gas standard for transportation fuels and establishes a 10 percent reduction in carbon intensity to 2020. Also these requirements turned out to be impossible for the American corn-based ethanol to meet, wherefore Brazilian ethanol, again, become an option.[80]

The changes have been profound. Major Brazilian ethanol companies, such as Copersucar, are now investing inside the US itself.[81] Similarly, regulations have also created incentives for American firms, such as Dow, to invest in Brazil.[82] In 2012, US imports of ethanol from Brazil were the highest since 2008 and the trend is going towards a further increase.[83] At the same time, Brazil similarly imports ethanol from the US, mainly between harvests when local supply occasionally may be short. This has created the somewhat bizarre situation that an almost identical product, although made from different feedstocks, is travelling thousands of kilometers in both directions.

4.1.4 The potential of an expanding market

This new dynamic between Brazil and the United States has implications also beyond bilateral trade. Perhaps more importantly, it opens up real possibilities for the two countries to co-develop their ethanol policies and argue for free markets for ethanol around the world. In effect, Europe is already isolated insofar that it imposes a still-heavy tariff on ethanol imports along with subsidies to its sugar beet producers.[84] The demand for a global ethanol market seems to be there. A recent report, "Global Biofuels Outlook, 2010-2020: Projecting Market Demand by Country, Region and Globally", estimates that the demand for global biofuels will grow by 133 percent by 2020, regardless of the economic crisis and disputes over environmental practices and global warming.[85] This opens up various opportunities for Brazil that could establish itself as the principal actor in this process. If, for example, Brazil were to substitute ethanol for 5 percent of world demand for gasoline within the next 20 years, the country would have to quadruple its sugarcane production.[86] Building on similar observation, another study from the São Paulo State Industry Federation (FIESP) envisions, for example, a scenario where Brazilian export of ethanol could

[79] *Crooks, E. (2012) US rules boost imports of Brazilian ethanol. Financial Times 9 April. http://www.ft.com/intl/cms/s/0/5564f822-8252-11e1-9242-00144feab49a.html#axzz2KPm1UQpl, (accessed 7 February, 2013).*

[80] *McNulty, S. (2010) Brazil's ethanol producers take a big bet on biofuels. Ibid.27 September. http://blogs.ft.com/energy-source/2010/09/27/brazils-ethanol-producers-look-past-the-us-downbeat-mood-on-renewables-amid-economic-difficulties-to-its-future-as-a-big-market/#axzz2KPuPdwkh, (accessed 15 February, 2013).*

[81] *Pearson, S. (2012) Deal to produce biggest ethanol trader. Ibid.6 November. http://www.ft.com/intl/cms/s/0/ce1c4440-279e-11e2-8c4f-00144feabdc0.html#axzz2KPm1UQpl, (accessed 7 February, 2013).*

[82] *Ewing, R. (2013) Analysis: Big crop, policy revive Brazil's sugar-ethanol mills. Reuters 11 February. http://www.reuters.com/article/2013/02/11/us-brazil-ethanol-investments-idUSBRE91A14A20130211, (accessed 8 March, 2013).*

[83] *Crooks, E. (2012) US rules boost imports of Brazilian ethanol. Financial Times 9 April. http://www.ft.com/intl/cms/s/0/5564f822-8252-11e1-9242-00144feab49a.html#axzz2KPm1UQpl, (accessed 7 February, 2013).*

[84] *Mathews, J. (2012) The end of the U.S. ethanol tariff. Energy Bulletin 9 January. http://www.energybulletin.net/stories/2012-01-09/end-us-ethanol-tariff, (accessed 7 February, 2013).*

[85] *(2010) Global Biofuels Outlook, 2010-2020: Projecting Market Demand by Country, Region and Globally. Hart Energy Publishing.*

[86] *Furtado, A.T., Scandiffio, M.I.G., Cortez, L.A.B. (2011) The Brazilian sugarcane innovation system. Energy Policy 39, 156-166.*

increase by 457 percent until 2020, i.e. from 1,8 billion liters in 2010/2011 to 10,27 billion liters in 2021/2022.[87]

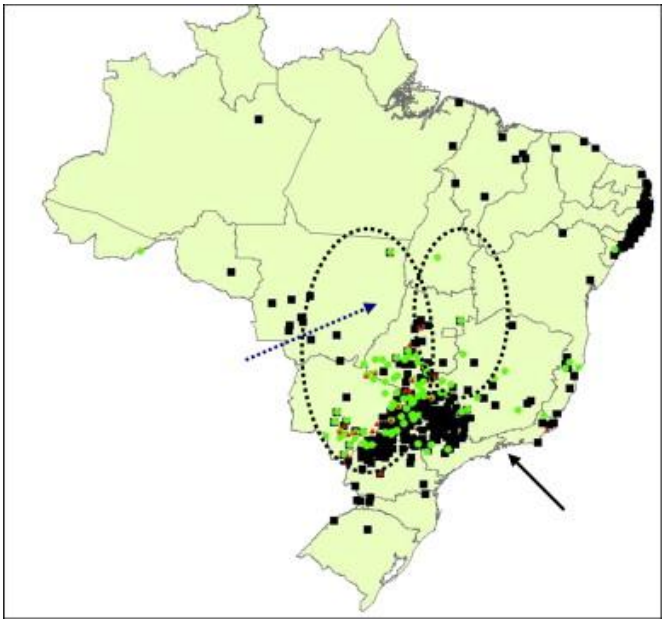

Figure 4-1: Location of sugarcane mills in Brazil by the end of 2008.

Source: Walter et al, 2011[88]

Against this background, several of the principal corporate actors are already making their moves. Petrobras, for example, has declared that it plans to triple its share of the Brazilian ethanol production by 2015.[89] Their example is followed also by other foreign oil companies, such as Shell and BP, that have made considerable investments in the Brazilian ethanol market, mainly with the ambition to exploit rising demand for biofuels in Europe and the US.[90] Similarly, one of the dominating Brazilian ethanol producers, Copersucar, has, as already indicated, bought the dominating share of US-based Eco-Energy, so that the two companies now hold nearly 12 percent of the global ethanol market.[91] Also other international actors from, for example, India and Japan are making similar moves.[92] Finally, new actors, like the Brazilian construction company Odebrecht, are now investing in other markets, such as Cuba.[93]

[87] *(2012) Etanol desperta interesse global. Valor Econômico 20 November. http://www.valor.com.br/brasil/2908878/etanol-desperta-interesse-global, (accessed 22 February, 2013).*
[88] *Walter, A., Dolzan, P., Quilodrán, O., de Oliveira, J.G., da Silva, C., Piacente, F., Segerstedt, A. (2011) Sustainability assessment of bio-ethanol production in Brazil considering land use change, GHG emissions and socio-economic aspects. Energy Policy 39, 5703-5716.*
[89] *Pearson, S. (2011) Petrobras to boost ethanol production. Financial Times 31 July. http://www.ft.com/intl/cms/s/0/a561fa96-bb65-11e0-a7c8-00144feabdc0.html#axzz2LgneYofm, (accessed 22 February, 2013).*
[90] *Ibid.*
[91] *Pearson, S. (2012) Deal to produce biggest ethanol trader. Financial Times 6 November. http://www.ft.com/intl/cms/s/0/ce1c4440-279e-11e2-8c4f-00144feabdc0.html#axzz2KPm1UQpl, (accessed 7 February, 2013).*
[92] *Faust, A. (2010) Os novos usineiros. Exame.com 24 March. http://exame.abril.com.br/meio-ambiente-e-energia/noticias/novos-usineiros-547695, (accessed 8 March, 2013).*
[93] *Buchanan, R. (2012) Brazil to invest in Cuban sugar, Energing markets/beyondbrics, Financial Times.*

4.1.5 Environmental and social considerations

A final set of contextual factors that will influence the strategic choices of the sector is the environmental and social impacts of ethanol production. The issue has, as noted, been one of both opportunities and contention. This contrarian situation is likely to prevail. What seems clear, though, is that Brazilian ethanol policies have had a positive impact in reducing greenhouse gas (GHG) emissions.[94] Similarly, it has also allowed for the phasing-out of different toxic substances, such as lead additives, MTBE, and sulfur.[95] This proves that the industry under certain circumstances may benefit from increasing environmental and social awareness.

Instead, there are two main environmental problems, for which the Brazilian ethanol industry does not yet have a clear solution, that are more likely to cause controversy in the future. One concerns the mandatory requirement, established in the new Brazilian Forest Code, that every farming establishment must preserve a forested area. A second issue refers to the future expansion of sugar production and the general misconception that the Amazon is at risk, while, in fact, it is the savannah region (*cerrado*) that is under pressure.[96]

In either case, environmental and social regulations are increasingly part of the corporate landscape and could, as such, serve both as barriers of entry or an opportunity for niche marketing.[97] Consequently, environmental and social considerations are also an increasingly integrated part of corporate strategy for Brazilian ethanol producers, particularly in combination with technology development. Building on the discussion so far, finding the exact configuration on these issues might, in fact, be the principal strategic source of competitive advantage.

4.1.6 The strategic choices

From the discussion above it is clear that the Brazilian ethanol industry is currently facing a series of strategic decisions to retain its competitive position. Essentially, such decisions could follow two paths, either one chooses to: 1) improve the performance of existing production system so as to perform similar activities better than one's rivals (*operational efficiency*); or 2) do something different from one's rivals or performing similar activities in a different way (*strategic positioning*). Although more explicit in the latter, both approaches may involve aspects of innovation (Porter, 1998).

4.1.7 Operational efficiency

The Brazilian success in the ethanol sector is, as indicated, based on two factors: 1) the country's climatic conditions and abundance of arable land; and 2) considerable technological advancements in the management of sugar cane and production of ethanol. So far, the results have been astonishing. Between 1975 and 2008, productivity rates grew by 125

[94] *Maroun, C., Schaeffer, R. (2012) Emulating new policy goals into past successes: greenhouse gas emissions mitigation as a side-effect of biofuels programs in Brazil. Climate and Development 4, 187-198.*
[95] *Hira, A., de Oliveira, L.G. (2009) No substitute for oil? How Brazil developed its ethanol industry. Energy Policy 37, 2450-2456.*
[96] *Abramovay, R. (2008) A political-cultural approach to the biofuels market in Brazil. University of São Paulo (USP).*
[97] *Reinhardt, F.L. (2000) Down to Earth: Applying Business Principles to Environmental Management. Harvard Business School Press, Boston, MA, Vogel, D. (1995) Trading Up: Consumer and Environmental Regulation in a Global Economy. Harvard University Press, Cambridge, MA.*

percent per cultivated area while, at the same time, costs decreased by almost 70 percent.[98] As a result, Brazil produces today around 23 billion liters of ethanol per year on total area of around 4,5 million hectares. Given the access to land, recent studies indicate that is an additional 64 million hectares previously degraded land that could be used to expand production.[99]

Obviously, this provides Brazil with an enormous opportunity just expanding and improving current ethanol production. The Brazilian Sugar Cane Industry Association (UNICA) has estimated that, in order to meet domestic demand and a 15 billion liters target of exports to the United States by 2020, Brazil will have to increase the area of sugar cane plantations to over 15 million hectares. In the last year, the Brazilian government has also stepped up its investments, which are mainly administered by the Brazilian Development Bank (BNDES), to facilitate this process. Through different loans and credit lines, primarily directed towards ethanol production, the government seeks to renovate and enlarge millions of hectares of plantations. [100] In terms of innovation, this implies mostly technological development, mainly related to the production phase of the value-chain.

4.1.8 Competitive strategy

Yet, there are many who argue that a single-minded focus on productivity improvements may be counter-productive in the long run. Instead, the main gains would be to consider also additional opportunities coming out of the production of ethanol. This would, in practice, require innovation and creative thinking throughout the entire value-chain and involve everything from new resource input to new products.

The interest in so-called second-generation ethanol has up to this point been relatively limited, with little resources directed towards research and innovation. This is not surprising given, on the one hand, the enormously advantageous conditions for sugar cane ethanol, that under all conditions will be more economically competitive than second-generation ethanol, and, on the other, the policy priorities described earlier that left the ethanol issue somewhat on the side for a number of years.

It seems, though, as the trend might be turning.

One important factor is, clearly, the opening up of the US market. This creates several incentives for an increased emphasis on second-generation ethanol also in Brazil. The first resides in the very configuration of the US policy framework that, because of its differentiated and sequential phasing in of second-generation ethanol, is currently supporting the import of Brazilian ethanol. At some point, however, the same policies will in fact have the opposite effect. Once the US has the technology for second-generation ethanol, and the quota for first-generation ethanol diminishes, Brazilian ethanol producers will lose its recently gained share of the US market. Under those circumstances, it won't matter if sugarcane ethanol still continues to be more economically advantageous. Instead, in order to participate on the market Brazil will also have to adapt.

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[98] da Cunha, M., Lima, M.A. (2010) Um salto para o futuro. Valor Econômico 29 April. http://www.valor.com.br/arquivo/821385/um-salto-para-o-futuro, (accessed 25 February, 2013).

[99] Ulhoa, M. (2013) Terra ruim para plantar alimentos pode ser boa para gerar etanol. Correio Braziliense 23 January. http://www.correiobraziliense.com.br/app/noticia/ciencia-e-saude/2013/01/23/interna_ciencia_saude,345518/terra-ruim-para-plantar-alimentos-mas-boa-para-gerar-etanol.shtml, (accessed 8 March, 2013).

[100] Leahy, J., Pearson, S. (2012) Brazil gives big sweetener for sugar biofuel. Financial Times 11 January. http://www.ft.com/intl/cms/s/0/f16f5546-3c7f-11e1-8d38-00144feabdc0.html#axzz2KPm1UQpl, (accessed 7 February, 2013).

A second factor is the potential that Brazil holds also with respect to second-generation ethanol. The key here is the recent decades' tremendous progress in the agricultural sector, stemming from longstanding investments in research and innovation. This is clearly something to build from, particularly since many of the practices related to second-generation ethanol are directly related to a more efficient agriculture.

Several efforts are also underway. The more visible ones build on the already established market volume of ethanol and focus, more specifically, on finding new down-stream applications to broaden the use of ethanol as transportation fuel. Some of the initiatives have a direct Swedish involvement, such as Scania's introduction in 2011 of a truck with an ethanol engine, thereby building on previous experiences in buses. On another front, Honda and Yamaha have since 2009 developed a flex-fuel engine for motorbikes specifically for the Brazilian market. Finally, Brazilian airplane manufacturer Embraer licensed already in 2005 the world's first airplane, Ipanema, running entirely on hydrated ethanol. The next step, in the views of many, is the use of ethanol also for hybrid cars.[101]

Other efforts build on the addition use of feedstock and residues directly linked to the production of ethanol. One example is the investments in co-generation of energy that started at the end of the 1990 as a direct result of the privatization of the national grid.[102] This process has been quite successful and co-generation currently makes up for 31 percent of thermo-electricity in Brazil.[103] Yet, there is a lot more potential. Recent estimates indicate that only one-third of the energy in sugar cane is taken care of in the production of first-generation ethanol. Another two-thirds are still in the bagasse and the straw. These residues could technically be used for the production of energy or be purified as some sort of liquefied fuel.[104]

The critical point, though, is that the techniques of producing liquefied fuel apply also to other cellulose crops. Herein lies also one of the principal observations regarding second-generation ethanol in the Brazilian context. Given the high energy content of sugar cane itself, it actually makes little sense to produce considerably more expensive ethanol from its residues, particularly since one thereby will compete with oneself on the same market. Instead, these residues are more likely to go into other areas, such generation of electricity. The greater benefits apply, instead, for other crops, where the additional production of biofuel constitutes a side benefit and does not interfere with the main activity. This is now increasingly recognized and becomes as such a means to meet some of the new environmental standards that de facto require more efficient resource use.

A second strand of research that is getting increasing attention, and that complements this previous focus on resources input, is the potential for new products from agricultural crops and the discussion regarding green chemistry. This discussion is currently gaining terrain in Brazil and opens such up for interesting opportunities in an agricultural power of the present size. One piece of the puzzle, of direct relevance to the present study, is the possibility to generate diesel fuels and other oils through various forms of pyrolysis. Another is

[101] *Batista, F., Barros, B. (2013) Uso de etanol se amplia e desafia indústria. Valor Econômico 7 March. http://www.valor.com.br/empresas/3034822/uso-de-etanol-se-amplia-e-desafia-industria, (accessed 7 March, 2013).*
[102] *Román, M. (2007) What Order in Progress? Brazilian Energy Policies and Climate Change in the Beginning of the 21st Century. Centre for Climate Science and Policy Research, Norrköping.*
[103] *Geração Energisa (2013) Sobre a Bioeletricidade. http://www.grupoenergisa.com.br/Geracao/biomassa/sobrebioeletricidade.aspx, (accessed 8 March, 2013).*
[104] *Virmond, E. (2011) Potencial de cogeração de energia elétrica a partir de resíduos do processamento de sorgo sacarino. Agroenergia em Revista 3, 37-38.*

the potential for bio-plastics that similarly could substitute petroleum and fossil oil. Although still very incipient, these technologies are of major strategic importance for a country like Brazil.[105]

The question now is what development paths and innovations we will see in the area of second-generation ethanol, or biofuels more broadly. There are a couple of options. One is more relates to broader changes in industry structure, including alterations in production systems and business models. Another possibility takes a clearer agricultural path and focuses more on, for example, the improvement of seeds and equipment. The choice, if any, is still to be made.

4.1.9 The Brazilian innovation system for ethanol

The question at this point is to what extent Brazil is prepared to take on the innovation challenges that inevitably follow from these strategic choices. What are the institutional premises? What does the innovation system for ethanol look like?

The uncertainty on this issue is rendered by the simple fact that Brazil, as stated initially, ranks comparatively low in terms of innovation climate. More broadly, the country suffers from: 1) comparatively low investments in research, development and innovation; 2) a high regional concentration of research and development more generally; 3) a strong of concentration of research to public federal universities; 3) virtually no investments in research and innovation among private firms; 4) very little collaboration between academia and the private sector. Similarly, there is a widespread understanding of innovation as technology development (*invention*) plain and simple. This pattern is repeated in all economic sectors, apart from: oil and gas, agriculture, aviation, as well as the mining sector.[106]

Several of these traits can be found also in the ethanol sector. Yet, the perhaps striking feature is how much the conditions for its innovation system have changed over the years. If, at some point, the federal government was nearly omnipresent, deciding everything from its basic rules to the premises for commercialization and levels of subsidies, its role has more recently been restricted to limited financing of research and deployment of new technology, mainly through BNDES. For almost two decades production in the sector has been entirely financed by private means. This applies also to the most of the research.

What came out of this process was a highly concentrated sectorial innovation system, which was almost entirely financed by and located in the State of São Paulo, where also more than 55% of the ethanol production takes place.[107] This would have consequences also for its characteristics. The São Paulo region differs from the rest of Brazil insofar that it brings together producers, capital goods manufacturers, research institutes and universities. Perhaps more important, though, it has a tradition of promoting private over public research.[108]

This combination of private research institutions, largely supported by public money, generated initially important research advancements in both the agricultural and industrial aspects of ethanol production. Yet, it was always incremental innovation, mainly perfecting the productive system already established by the large sugar mills since the mid-1900s,

[105] *CGEE (2010) Química verde no Brasil: 2010-2030. Centro de Gestão e Estudos Estratégicos, Brasília, DF.*
[106] *Cruz, C.H.d.B., Chaimovich, H. (2010) Brazil, UNESCO Science Report 2010: The Current Status of Science around the World. UNESCO, Paris, pp. 103-121.*
[107] *UNICA (2013) Área colhida com cana-de-açúcar, 2011 - 2011. UNICA. (accessed 8 March, 2013).*
[108] *Furtado, A.T., Scandiffio, M.I.G., Cortez, L.A.B. (2011) The Brazilian sugarcane innovation system. Energy Policy 39, 156-166.*

with sole ambition to increase productivity. As such, it has been most successful over the years.[109]

The question is whether this innovation system will be able to cope with the present challenges that arguably require more radical innovations. Issues such as climate change and green chemistry are each calling for entirely new technologies. Similarly, there are no ways to meet the productive leap implied in a global expansion of ethanol without a new technological path. Hence, many argue that in order not to lose its competitive advantage Brazil need to fundamentally reorient its research priorities. This, however, will most likely require more profound changes of the innovation system itself, not the least in the sense that it will have to recognize the need for radical innovation. However, it will also require a re-orientation and approximation between distinct, and occasionally competing, innovation systems. This is nothing new to the sector. Quite the contrary, the Brazilian ethanol industry grew out of an interplay between different innovation systems, such as those related to the oil, car and agriculture industries. The point, though, is that also these sectors are also changing with current technological developments. The most poignant example is probably the agricultural sector that is rapidly becoming a nexus for such diverse areas as energy, food, fuels, and materials. From this follows that also its innovation systems are changing, so as to both overlap and compete with the ethanol sector. The same thing can be said for the oil and gas sector that is currently seeing an increasing stake in the biofuels sector. These are changes to which the innovation system in the ethanol sector will have to adapt.

4.1.10 Current and emerging government policies

Clearly, there are changes underway. Only a few days after the US scrapped its import tariffs on foreign biofuels, the Brazilian development government (BNDES) announced new credit lines of R$ 4 billion (US$ 2.2 billion) to the ethanol industry in an effort that was expected to increase Brazilian ethanol production by 17.5 per cent in two years.[110] Since then the federal government has put even more money on the table in what appears to be a general effort to increase the participation of biofuels (including also charcoal, lye and bagasse) in the energy mix from 29.3 to 33.3 percent until year 2021. Of the R$ 1 trillion (US$ 510 billion) going into the energy sector in the next decade, nearly 7 percent will be designated the biofuels segment. Over this period, nearly R$ 71 billion will be invested in the construction and modernization of new and existent ethanol plants. In addition, nearly R$ 7 billion is being allocated for a similar upgrade and construction of ancillary infrastructure, such as pipelines and ports.[111]

Perhaps more important, an increasing amount of money is also put into research. One example is the Bioen program, financed by the State of São Paulo through its principal research fund FAPESP, which is explicitly intended to target innovation in the bioethanol sector. Similarly, the federal government has also provided new funding streams, mainly administered by BNDES and the Brazilian Innovation Agency (FINEP), that are specifically intended to spur research and innovation. This has, among other things, generated the

[109] *Ibid.*
[110] *Leahy, J., Pearson, S. (2012) Brazil gives big sweetener for sugar biofuel. Financial Times 11 January. http://www.ft.com/intl/cms/s/0/f16f5546-3c7f-11e1-8d38-00144feabdc0.html#axzz2KPm1UQpl, (accessed 7 February, 2013).*
[111] *(2012) Etanol desperta interesse global. Valor Econômico 20 November. http://www.valor.com.br/brasil/2908878/etanol-desperta-interesse-global, (accessed 22 February, 2013).*

creation of the National Biofuels Science and Technology Laboratory (CTBE) that is rapidly becoming scientific point of reference. [112]

Yet, although these initiatives are both substantive and well-intended, they are still criticized for not having been able to solve the principal problem in the Brazilian innovation system for biofuels, which is to narrow the bridge between research and business. The latter is reflected at many levels. As already noted, there is comparatively little research in Brazilian firms and what there is often has a strong technological character. In order to overcome these problems, BNDES and FINEP opened in 2011 a specific program, PAISS, which, apart from technology development, puts additional emphasis on business development and innovation in its proper sense. Another critical point is the lack of venture capital in almost all economic sectors. This is arguably a major impediment for both technical breakthrough and business development in general.

Other important signs of the government's renewed and growing interest in the ethanol sector are some recent regulatory changes that may fundamentally alter the conditions for the sector. One such regulatory change is the decision to increase the volume of anhydrous ethanol in gasoline from 20 to 25 percent as of 1 May 2013. This, it has been estimated, will increase the internal market for ethanol by 15 to 20 percent.[113] A second measure of potentially even greater impact is the recent announcement of a new regulatory regime for the ethanol market. The exact design of this new regulatory framework is, at the time of writing, still unclear. Yet, preliminary reports indicate that it will allow for series of tax exemptions to which ethanol producers can qualify if they, in return, comply with a series of demands and requirements linked to increased efficiency and investments in technology. In the case of ethanol, this would entail, among other things, an increase in planted area, level of production as well as the stock.[114]

Finally, it is a significant sign that the Ministry of Mines and Energy, and most critically the National Agency for Petroleum, Natural Gas and Biofuels (ANP), has taken a stronger stance on these issues. As noted, the ethanol issue was, after it was no longer the responsibility of the Ministry of Environment (MMA), for some time without clear policies. Instead, it was due to its cross-sectorial characteristics at some point a central issue in eleven (!) different federal ministries. To this one can also add various initiatives at the state level. Needless to say, under similar circumstances it is virtually impossible to get an overview of different research initiatives, advances, areas of investigation, or databases among research centers.

4.2 US challenges and issues for the future

All in all, public policy intervention has been a key driver in pushing the domestic ethanol production industry past Brazil's, into a world leading position. The industry faces significant challenges, however. Although it has not yet reached maximum production capacity, it is clear that further growth within current technologies and methods is very limited. Pol-

[112] *Furtado, A.T., Scandiffio, M.I.G., Cortez, L.A.B. (2011) The Brazilian sugarcane innovation system. Energy Policy 39, 156-166.*
[113] *Batista, F. (2013) Raízen estima aumento de suas exportações de etanol. Valor Econômico 28 February. http://www.valor.com.br/empresas/3026042/raizen-estima-aumento-de-suas-exportacoes-de-etanol, (accessed 6 March, 2013).*
[114] *Bitencourt, R., Borges, A. Ibid.Governo traça novo 'regime' para o etanol. 7 February. http://www.valor.com.br/empresas/2998710/governo-traca-novo-regime-para-o-etanol, (accessed 17 February, 2013).*

icy has efficiently addressed some challenges, but not others, and has also created new challenges.

As previous sections show, the US ethanol industry is heavily dependent on what is going on in alternative fuel markets – in fact, the oil price is traditionally the key determining factor for ethanol growth. Recent policy has addressed this issue by linking ethanol production to petroleum production – but a new "oil" – shale gas – has emerged of late, which may replace both oil and ethanol, or in any case move significant investments from the biofuel sector to the shale gas sector. Nor does setting ethanol production levels help if the industry lack technological means to move beyond current feedstock limits posed by the heavy dependence on corn.

Making the move to cellulosic ethanol will be vital for the future development of ethanol. If this move is not made, production levels will be capped by feedstock availability limitations, greenhouse gas emissions reductions will be limited, and upwards pressure on commodity prices will likely increase to unsustainable levels, eventually driving food prices to unprecedented levels and potentially causing large scale starvation.

US biofuel policy was initially driven by energy security and environmental strategies, and these are the strategies that will be important for the future. During the 1990-s and 2000-s, however, rural economic development strategies gained an important place in ethanol policy and this is likely to hinder necessary development. First, there are still many incentives in place that reward investment in 1st generation ethanol technology. Second, decades of corn-ethanol encouragement have created a strong corn-lobby that likely will make it hard for US policy makers to move away from this limiting production technology, even once it is made technologically obsolete. In addition to this, heavy subventions and regulation have probably rendered the FFV and fueling infrastructure markets less competitive than they should be, and it is unclear to what extent they are viable on their own.

Ethanol policy history clearly shows that tangible challenges and benefits, such as local environment hazards and job creation, dominate over more abstract issues, such as global warming in a distant futures and energy security in times of geopolitical stability in terms of constituting drivers for political change. It is in this sense, worrying that the challenges faced by the biofuel industry are about long-term investment in new technology and prioritization of structural change over short term economic growth. There is hope, however, since growth within the current state of affairs already is starting to create tangible problems for other sectors, most notably in terms of driving of prices of animal feed and other farm commodities, which means that there is growing political force for change within the non-corn part of the US framing community.[115] In the end, lobby groups may neutralize each other and open up for political change in the necessary direction.

[115] *Fuel Ethanol: Background and Public Policy Issues. Updated April 24, 2008. Brent D. Yacobucci. Specialist in Energy and Environmental Policy Resources, Science, and Industry Division (Report for US Congress)*

5 Concluding discussion

This final chapter focuses on the most important lessons of the Brazil and US cases for the Swedish policy context. As evident from previous chapters, Brazil and the US constitute two rather different experiences. The stories are best told in their own right and basing an analysis on their juxtaposition would easily lead to a comparison of stories, rather than a comparison of events and processes that are actually related – which is why there has been limited comparison throughout the report. There are some common issues, however, that hold lesson for Swedish policy.

5.1 Systemic innovation is fundamental notion for innovation policy

The first lesson could be summarized as a paraphrase of the management expression "culture eats strategy for lunch", meaning that management intervention cannot be efficient if it is not sensitive to the fundamental forces of the system in which it is intervening. The ethanol case in both the US and in Brazil demonstrates that "innovation systems eat innovation policy for lunch". Policy may enhance fluctuations in innovation pressure created by related industries but can hardly be efficient when "working against the tide". For ethanol, oil supply fluctuations either increase or lower the pressure by simply lowering or increasing the return on investment time for investments in alternative fuel capacity. When oil supply drops and gasoline prices soar, it makes sense to invest in ethanol and vice versa. And this effect is much stronger than that of tax credit legislation and the like. The most efficient ethanol policies in the present cases were designed to connect ethanol production to gasoline rather than make ethanol production compete head on with gasoline.

Innovation policy could however work efficiently within established systems – both in terms of system protection and in terms of long term investments in innovation based competitiveness. These points are illustrated in the present case by how established and emerging system components could be handled. While oil is an established and entrenched component that more or less must be accepted by and integrated into energy policy, new components like shale gas could be handled in the larger policy framework. The single biggest threat to the further development necessary to grow ethanol production and consumption is arguably the recent rise of shale gas. Shale gas could quickly replace biofuels as a transportation fuel since most FFVs and gasoline vehicles are already compatible with, or could easily be converted to be compatible with gas. In addition to this, it is cheap to extract and readily available in the US. The problem, of course, is that shale gas is a fossil fuel and that its extraction through hydraulic fracking is associated with significant environmental damage, not the least through the huge water consumption involved. The scientific evidence regarding shale gas and its impact on the environment is not clear but tends to point to shale gas may be at least as bad as other fossil fuels both in terms of greenhouse gas emissions and extraction damage. The big threat, however, is to innovation. There is a tangible risk that shale gas exploitation leads to an end, or at least a significant decrease in investment in cellulosic fuel technology, which would mean that the structural change in

energy markets that most observers agree are vital would be put on hold indefinitely and replaced by what must fundamentally be considered a new type of oil.[116]

From a Swedish point of view, economic development policy may lower innovation pressure by subsidizing old technologies. This is also true for energy policy. The Swedish model has always built its success on avoiding price competition for the benefit of first-mover competition and other forms of innovation-based competition. In the US and Brazil case, it is clear that policy easily falls into shortsighted behavior that clearly undermines future competitiveness. Most evidently so in relation to oil in Brazil and in relation to shale gas and the farming sector in the US. It would be very unfortunate for Sweden to make similar mistakes.

5.2 Serendipity and emulating previous experiences

Another important lesson, albeit perhaps a harder one to integrate into specific policy formulation processes, is that unexpected events are significant deciders of success. In the case of ethanol, two such events were present. First, the octane booster lead turned out to counteract the chemical function of metals used in catalyst converter technology, which opened up for ethanol as an octane booster when smog-problems in US cities forced the introduction of catalytic converters. Second, the oxygenate MTBE turned out to be a significant health hazard and had to be phased out as well, leaving the second place alternative ethanol as the sole inheritor of the oxygenate market. Without these events taking place, ethanol pushing policy would likely have had much less effect and the ethanol market would likely have been significantly smaller today.

Several lessons can be learned from this. In the present context the most notable ones are: (i) that these events, although unanticipated, became important because they pertained to "nonnegotiable" factors and; (ii) that there is an inherent risk in picking innovation vehicles. Nonnegotiable factors in this case include health (MTBE) and (which is of course related) local environment (lead/smog). Such factors seems to be subject to a distance decay effect in the sense that more abstract or geographically distant health and environment factors, for example those related to global warming, tend to be more negotiable in the eyes of the electorate. In terms of innovation vehicle risk, these serendipitous events teach us that it could of course have been ethanol, and not MTBE, that turned out to be a health hazard. One such problem has already partly played out in the form of first generation ethanol feedstock's effect on food prices. This effect is, in line with the above argument, however, too "distant" to at the moment seriously pose a political problem to ethanol policy.

5.3 The importance of pressure for change and ROI

To summarize, one could argue that all of the above boils down to one single consideration for biofuel policy formation. It is all about managing pressure for socio-technological change in general and return on investment (ROI) time-frames in particular. Ethanol production has flourished in times of high oil prices and with the help of legislation that shortens the time in which investors in production and fueling infrastructure get returns on their investment. The introduction and scaling up of biofuels require substantial investment in such infrastructure and also in technological development. It would be naïve to think that these investments would take place if policy did not point out a clear direction (like the *US*

[116] *One could also argue, however, that since many severe conflicts in the world are about oil security, there are security benefits to shale gas that should be considered.*

Energy Policy Act of 2005 did for production levels) or provided economic incentives for infrastructural and technological investment. Along with the same lines of thought, anything that lowers pressure for change and increases ROI-timeframes constitute a threat to the biofuel sector – whether it is the rise of new fuel like shale gas or investment incentives for obsolete feedstock like sugar and corn. Figure 5 illustrates this policy context.

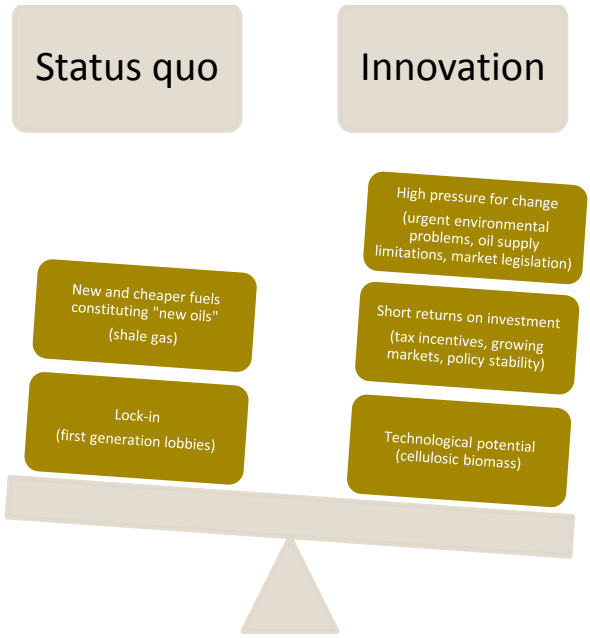

Figure 5-1: An illustration of the forces involved in innovation policy and the threats to change.

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