Fuel ethanol at a key economic and technological junction in the USA

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Increased domestic crude production in the USA during the last five years, and the delayed success of second generation biofuels within the renewables sector has changed the relative significance of ethanol as a domestic source of transportation fuel.

Subsequent to the enactment of the Energy Policy Act of 2005 (EPACT 2005), and the Energy Independence and Security Act of 2007 (EISA 2007), the USA experienced a surge in the domestic production of corn-based ethanol. The principal rationale offered by the US government for the promotion of domestic ethanol production was two-fold: decreased dependence on foreign oil, and the reduction of greenhouse gas (GHG) emissions.[1] An additional benefit was government support for the agricultural sector. The 2005 Energy Policy act established a renewable fuel program that required 4 billion gallons of ethanol in 2006 (268,000 bpd), with a step-wise increase to 7.5 billion gallons by 2012 (700,000 bpd). The Renewable Fuel Standard (RFS, sometimes abbreviated in the literature as "RFS2") set in EISA 2007 revised the previous numbers towards an ambitious 36 billion gallons by 2022 (3.4 million bpd).

As shown in Fig. 1, the evolution of ethanol production numbers in the last decade has been truly impressive. Nonetheless, based on present-day ethanol production of around 900,000 bpd, production would have to be almost quadrupled (x3.8) in the next 7 years in order to achieve the ambitious RFS goals. Due to several issues that we discuss here, we argue that there are several key factors that make it a challenge to achieve the RFS goals in the coming years. Two principal factors we consider are:

1. The changing strategic importance of biofuel production *vis a vis* increased domestic crude production due to tight oil.

2. The limited deployment of second generation biofuels.

1. Consequences of increased domestic crude production

When President Jimmy Carter announced the National Energy Plan in April 1977, US crude imports were at historical highs (Fig. 2), and the world was still reeling from the energy crises kicked-off in 1973 by OPEC´s oil embargo.[2] During Carter´s presidency, not only were there concerns over the high US oil consumption rates, but also that inflation rates were rising. Hence there were domestic and foreign concerns that a sustained increase in US demand for oil could derail the global economy and energy markets.[3]

A clear commonality between the 1977 and the 2005/2007 energy plans are concerns over national energy security and dependence on foreign oil. In fact, by 2005 US oil imports had resurged to reach their highest levels in history at almost 10 million bpd (Fig. 2). At the same time, a major difference between the two decades was the relevance of GHG emissions and climate change within the global policy agenda. In 1977, GHG emissions were not a policy driver. In fact, the 1977 plan even promoted increased coal production in lieu of crude imports. Within the context of the 21st century on the other hand, by promoting biofuels the 2005/2007 plans benefited from the additional dimension of potentially reducing GHG emissions.

The seminal Energy Policy Act of 2005 is a broad 550 page piece of legislature with 18 titles including Energy Efficiency (I), Renewable Energy (II), Oil & Gas (III), Vehicles & Fuels (VII), R&D (IX), and Ethanol and Motor Fuels (XV).[4] The sections within these titles are an "oracle´s wish-list" of the technological and policy trends that would sweep the world in the subsequent decade. Two influential sections that helped shape subsequent events in the US and the world are Sec. 322 on "Hydraulic fracturing" and Sec. 1501 on the "Renewable content of gasoline." Sec. 322 was an amendment to the Safe Drinking Water Act from 1974, which among other things had assigned the Environmental Protection Agency (EPA) to regulate the underground injection of fluids.[5] Based on deliberations by the EPA in 2004, the 2005 Sec. 322 amendment allowed for the underground injection of fluids (with the exception of diesel fuel) and propping agents used for hydraulic fracturing. This set the legal ground for the shale gas and tight oil revolution that was to come in the subsequent decade. Meanwhile Sec. 1502 established the renewable fuel program from 2006 to 2012, and also established the assignment and trading of renewable fuel credits between entities that sell gasoline. These policy initiatives were the bedrock on which the surge in US ethanol production was based in the subsequent years.

EISA in 2007 doubled-down on some of the objectives in EPACT 2005, especially in the realm of energy efficiency and sustainability. EISA´s Title II on "Energy Security Through Increased Production of Biofuels" is key in furthering the vision of increasing biofuel production, in addition to promoting biofuel R&D and infrastructure.[6] Sec 202 establishes the RFS, and starting from 2008 onwards, increases the requirements set in EPACT 2005. It also establishes targets and policy distinctions between different types of renewable fuels, with specific standards for "renewable fuels" and the subdivision defined as "advanced biofuel." The latter subdivision in turn includes "cellulosic biofuel" and "biomass-based diesel."

EPACT 2005 catalyzed two important industrial developments that had tremendous influence on the global politics and economics of energy. During the 2005-2007 period, crude imports in the USA were at record highs (Fig. 2), and it made economic and political sense to promote both biofuels and hydraulic fracturing for the purposes of energy security. With the potential exception of a select group of visionary experts, the subsequent successes of both hydraulic fracturing and ethanol production in the USA were beyond the expectations of most observers. Between 2007 and 2015, the USA almost doubled its domestic production of crude, while decreasing its imports by about 27% (Fig. 2). Meanwhile, between 2005 and 2015, ethanol production almost tripled, to the point at which ethanol now constitutes 10% of the volume of gasoline sold in the USA (Fig. 3).

On face value, both EPACT 2005 and EISA 2007 have been highly successful in terms of promoting energy security. Interestingly, this success has changed the strategic energy landscape in the USA. Up to 2011, the volume of ethanol produced in comparison to crude production was always increasing (Fig. 1). However, since the surge in crude production after 2011, ethanol volumes are becoming less significant as a proportion of the available crude. Given the present scenario, further increasing ethanol production for the purposes of energy security may not be seen as critical as it was in 2005. This is of course dependent on how long current production levels due to tight oil can be maintained. At the same time, subsequent to COP21 in Paris, the reduction of GHG emissions is taking a more central role. Hence, sustainability and life-cycle GHG emissions would be the primary long term incentive to further increase the production and use of ethanol as a renewable fuel.

2. The 10% blend wall and the slow arrival of second generation biofuels

Since the development of the internal combustion engine in the 19th century, alcohol has vied with petrol as a source of fuel[7]. In the 1975-1985 period, Ethanol showed its great potential in Brazil, where the government was able to boost production significantly.[8] The decades after this initial period in Brazil where rather choppy, though fuel alcohol consumption got a second boost with the promotion of flex fuel vehicles (FFVs) in 2003. FFVs benefited from tax benefits and allowed for a higher range of gasoline and alcohol mixtures. FFVs are important because they allow the ethanol blend to go above the 10-15% "blend wall" in terms of ethanol content. Depending on the make and year, most newer gasoline engines, including in the USA, are certified for normal operation in the 10-15% range. With an FFV, one could go up to an 85% ethanol blend. The "blend wall" refers to the lack of a sufficient number of vehicles in circulation and fuel pumps that can go beyond the 10% blend usage.

As illustrated by Fig. 3, US ethanol sales have been near the 10% gasoline blend wall for the last five years. From here, an upward trend can go through two main potential avenues. On the short term, one could increase the number of E15 gasoline stations. This would require infrastructure installations for E15 pumps, but no significant changes in the US auto fleet. However, to go towards and past the 15% blend, several things would have to happen. First, EISA 2007 envisions that the production of ethanol beyond the 10% blend would be supported by advanced biofuels. The simplest candidate for advanced biofuels would be ethanol produced from agricultural residue such as cellulose, a natural polymer which is structural component of corn stover or sugar cane bagasse. Part of the biological function of cellulose in plants is structural integrity and protection from the environment. Hence it is no surprise that the chemical breakdown and use of cellulose is technically more complex (and more expensive) than the use of the simpler C6 and C5 sugar monomers on which cellulosic material is based. Furthermore, in addition to the advanced biofuel production hurdle, if growth beyond 15% of renewable fuels is to be supported by ethanol of any origin, then the proportion of FFVs in the US auto fleet would have to increase. Alternatively, if there is no momentum towards the deployment of FFVs, then the advanced biofuels that go beyond the 10-15% blend need to be "drop-in" substitutes for gasoline. Although this is a real technical possibility, there is no indication that drop-in fuels produced by biotechnology are entering the market in significant amounts within at least the next five years.[9]

The conventional understanding in business circles is that in order for fuel ethanol sales to increase in a sustained fashion, the price needs to be competitive when compared to gasoline. As shown in Fig. 4, in the two decades before EPACT 2005, there was usually an 0.5-0.7 USD/gallon differential in the cost of production between ethanol and gasoline. In practice this differential was reduced in large part by excise tax reductions that ranged between 40-51 cents per gallon in the period 1978-2012.[10] The latest iteration, the Volumetric Ethanol Excise Tax Credit (VEETC) was a 0.45 USD/gallon excise tax subsidy for ethanol, which ended on Dec. 2011. EIA estimates indicate that termination of the VEETC signified a decrease in government tax expenditure on the order of USD 6 billion per year.[11] In the absence of the VEETC, there are no direct subsidies on ethanol as a final product. However, the Renewable Volume Obligation (RVO) imposed on refineries and blenders by EISA 2007 is likely to exert an effect on ethanol trading prices.[12] The RVO is implemented by the issuing of Renewable Identification Number (RIN) credits which are attached to each gallon of biofuel produced or imported into the US.[13] Obligated parties obtain their RIN quota by either buying the biofuel and getting the associated RIN, or by buying RINs from obligated parties that have a surplus.

As illustrated by Fig. 4, since 2005 the market price of first generation ethanol has been in a comparable range to gasoline. As long as ethanol prices remain within a similar range as gasoline, current levels of ethanol use at the 10% blend level would be sustainable for the foreseeable future. To go beyond this 10% level, it is important that the price of 2nd generation biofuels is also competitive, especially since the planned RVOs pertaining to 1st generation biofuels plateau after 2015. Public estimates of second generation ethanol production costs are not easy to come by. Reference data points in Fig. 4 show estimates based on a study by Lux Research.[14] Based on these estimates, none of the US-based operations are below the 3 USD/gallon mark. The lowest production cost estimates are those of Raizen and Gran Bio, both of which operate in Brazil based on sugarcane. In addition to the high price for 2nd generation ethanol, the associated production levels are still quite low. Since 2012 at the latest, it had become clear that cellulosic ethanol expectations in the near term were not to be met by the corresponding production numbers. In 2013, the RFS requirements for cellulosic ethanol were originally 1 billion gallons for the year. Based on the lack of production, the EPA initially reduced this to 6 million gallons, and subsequently further reduced the requirement to 810,185 gallons by the end of 2013.[15] As cellulosic plants subsequently came online, by the end of 2015 the EPA´s finalized cellulosic fuel standards for 2014, 2015 and 2016 were set at 33, 123 and 230 million gallons, respectively.[16] The proposed standard for 2017 is 312 million gallons of cellulosic biofuel.[17]

Discussion and Conclusion

The RFS set forth in EISA 2007 envisioned that "conventional" biofuel production would reach 15 billion gallons per year by 2015, and that it would subsequently stay at that level till 2022. The Sep. 2014-Aug. 2015 production numbers for fuel ethanol in the USA was 14.66 billion gallons (USDA), which is very close to the EISA 2007 objectives. Meanwhile cellulosic ethanol was expected in

2007 to go from 1 billion gallons in 2013 to 3 billion in 2015, and 16 billion by 2022. However, the present reality is that the USDA´s 2015 projections for the combined production of major US operations involved in 2nd generation biofuels is less than 100 million gallons (three main actors being DuPont, Poet-DSM and Abengoa).

It is now evident that the expectations placed on second generation biofuel technologies were overly optimistic during the first decade of this century. Nine years after EISA 2007, there are still price competitiveness and scaling problems associated with 2nd generation biofuels. The optimistic assessment would be that 2nd generation biofuels still hold the promise of delivering a substantial portion of what was envisioned in EISA 2007, however this delivery will follow a more delayed schedule. In the specific case of 2nd generation cellulosic ethanol, the industry needs to demonstrate the capacity to produce significant amounts (say at least 1 billion gallons) at competitive prices. Once that is achieved, scaling to higher volumes is a matter of time and investment. Whether they subsequently reach 16 billion gallons by 2022 is not as important as demonstrating economic and scaling viability in the next 5-10 years. In our opinion, even producing 5 billion gallons per year by 2022 would be an indication that 2nd generation production with lower GHG emissions can complement 1st generation production.

When it comes to energy security, both EPACT 2005 and EISA 2007 were largely successful in increasing the amount and stability of energy supply in the USA. Both hydraulic fracturing and 1st generation ethanol production have added energy production channels that were negligible at the beginning of the century. Furthermore, the US has started to make inroads into renewable production of electricity using wind and solar.[18] However, it should be noted that in terms of energy security, the broad-based success of these policies has changed the strategic importance of ethanol in comparison to other energy sources. For policy makers, the considerable national investment into infrastructure and know-how, and the success of having 10% ethanol in the transportation fuel mix are likely to be strong arguments for keeping 1st generation ethanol production at its present levels. However, future support for advanced biofuels, and particularly cellulosic ethanol, may be highly dependent on the near term success of these technologies.

Ironically, the delay in the arrival of 2nd generation cellulosic biofuels to market can have a very significant cost for both the fossil fuel and biofuel industry. Despite the fact that some in the oil and gas industry see biofuels as a competing and potentially ambitious "new kid on the block", it is possible that the delay in achieving significant production numbers in 2nd generation biofuels can present unforeseen dangers for oil and gas companies as well. The blending of 2nd generation cellulosic biofuels in the transportation fuel supply is a means by which life-cycle GHG emissions can be reduced for combustion engines. However, if 2nd generation biofuels are too late to arrive to market in significant volumes, the technological future of low emission road transportation may be one in which combustion engines and biofuels are bypassed all-together. In that eventuality, the likelihood of a disruptive transition towards electrical vehicles becomes higher.

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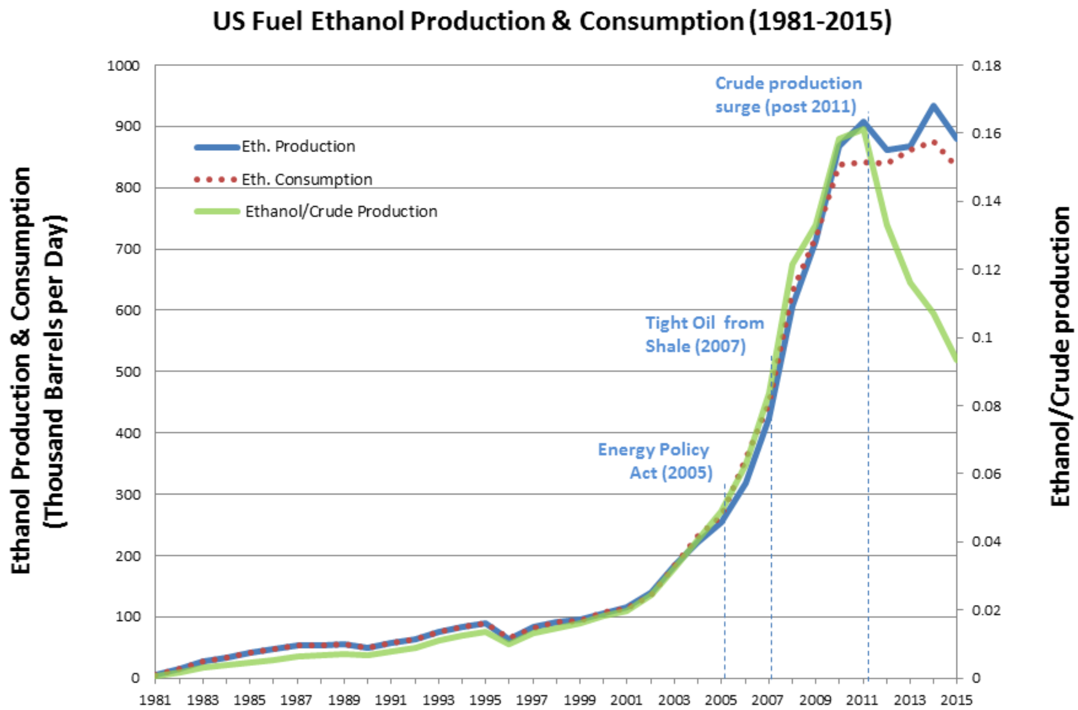

Fig. 1. Yearly ethanol production and consumption were in lockstep till 2010. Meanwhile the volumetric proportion of ethanol with respect to US crude field production was increasing till the shale induced upsurge in crude production (data source EIA)

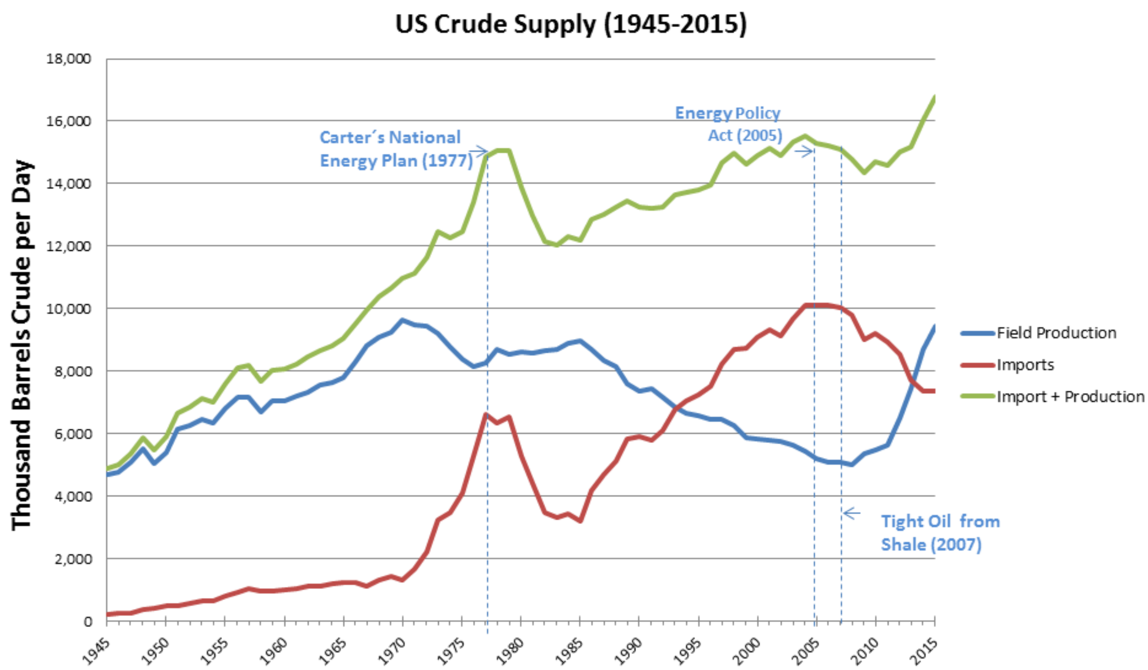

Fig. 2. US crude imports reached local maxima in 1977 and 2005. Meanwhile declining US production reversed after the widespread development of tight oil from shale (data source EIA)

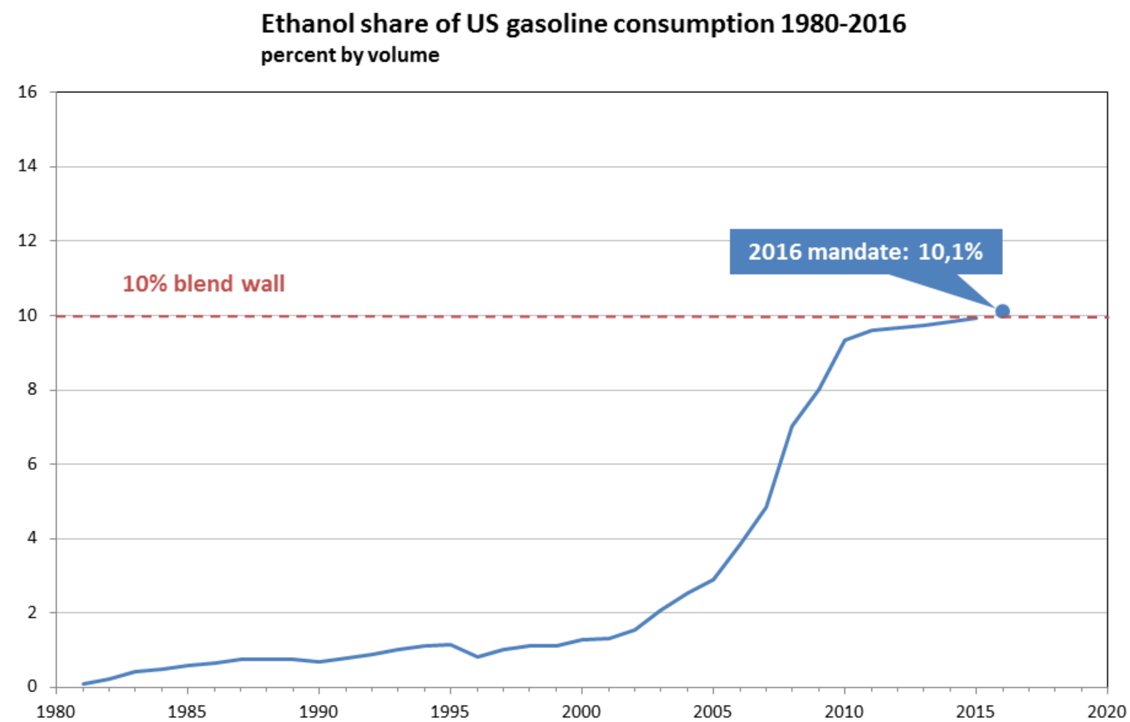

Fig. 3. Ethanol production levels have been near the 10% blend wall for the last 5 years (data source EIA).

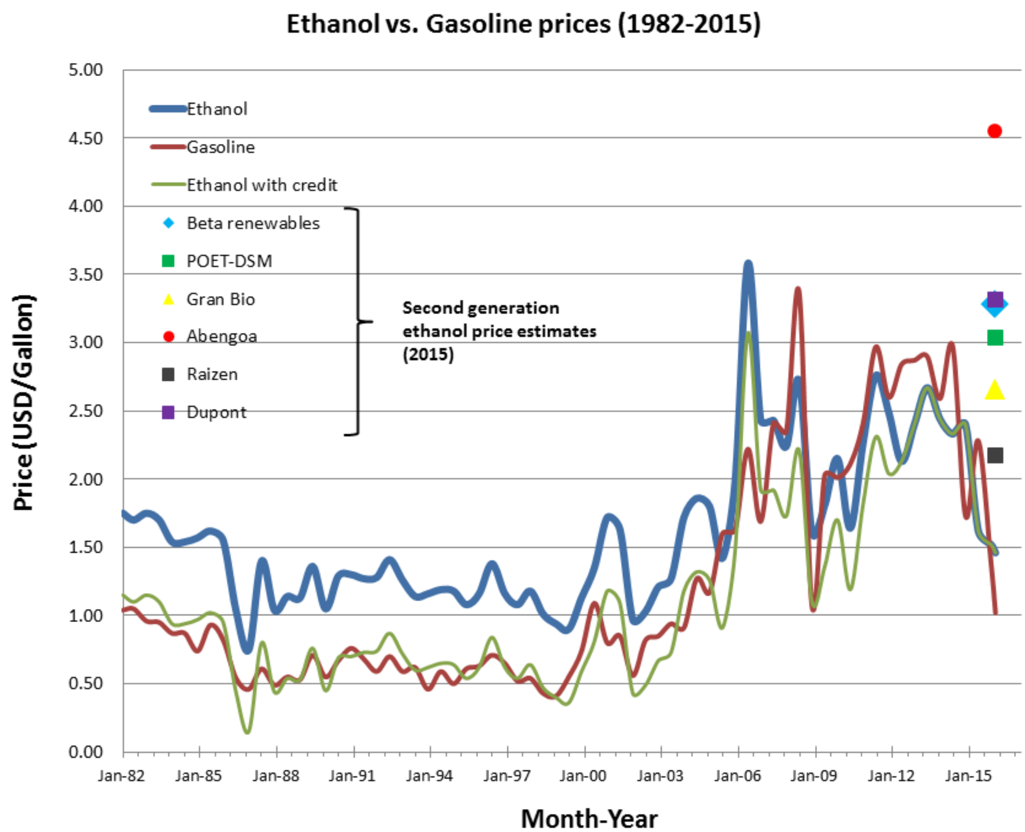

Fig.4. Market price of 1st generation ethanol has been comparable to gasoline since 2005. 2nd generation ethanol in the US is likely to be at least 1.5 USD/gallon more expensive than the 1st generation variant (data sources USDA [1st gen.] and Lux Research [2nd gen.])

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