Rising to the CO_2 challenge

| Part 1 |

In the first of a three part series, Joris Mertens, KBC Process Technology Ltd, the Netherlands, discusses present and future greenhouse gas legislation and its impact on the refining industry.

Although still contested by some, scientific evidence that greenhouse gas (GHG) emissions by man are the cause of a global temperature rise seems to have gained general support by policy makers and there is a willingness to take action. According to the most recent UN assessment report, GHG emissions from industrialised countries must be reduced by 25 - 40% by 2020, compared to 1990 levels, in order to avoid CO_2 levels exceeding 450 ppm.[1] A consensus on what efforts need to be made and the extent of effort sharing is still far away.

This article summarises the GHG legislation in place and the legislation that is currently being processed by lawmakers globally. In addition, the impact on the refining industry in general is discussed and quantified, as well as the relationship between carbon cost and refinery complexity. The next article in this three part series will explain in more detail the importance of carbon efficiency and outline a GHG reduction strategy for refineries.

Europe

The Kyoto Protocol, the main outcome of the third UNFCCC COP (Conference Of Parties) in 1997, was a significant breakthrough. Industrialised countries would reduce their GHG emissions in 2012 by 5.2% compared to 1990. However, it is unlikely that this goal will be achieved. Firstly, the US and Australia did not ratify the protocol (Australia ultimately did in 2007). In addition, some important countries that did ratify (notably Canada and Japan) clearly failed to meet the Kyoto obligations.

It is unsure whether the European Union will be able to meet its emission reduction pledge of 8%, but the EU did take up climate leadership by setting up the EU Emission Trading System (EU ETS). In this system, inspired by the Acid Rain Programme in the US, all installations consuming over 20MW (approximately 12 000 in total) must report their CO_2 emissions and submit permits covering these emissions. Towards the end of the first phase of the EU ETS, which ran from 2005 to 2007, the EU carbon market crashed because nations had given away too many emission rights for free, thus removing the price floor of the system. The green line in Figure 1 shows how the price of the EU Emission Allowances (EUAs) had dropped to nearly zero by early 2007.[2] Consequently, the EU commission forced the nations to reduce the amount of free emissions in their National Allocation Plans.

So far, the current second ETS phase (2008 - 2012) appears to have been reasonably successful. The European carbon market has become more mature, as indicated by the increasing volumes shown by the blue line in Figure 1. Recently, the system has been criticised for its price instability (brown line in Figure 1), caused by the slowdown of the industrial output. Also, there is a sense that additional regulation is required to avoid a financial carbon market bubble, which may cause the system to go off the rails like the financial system.

With the approval of the Climate and Energy package by the EU Council in April 2009,[3] the EU has set the path forward up to 2020. Most relevant of the six sections of the package to the refining and petrochemical sector are the revision of the ETS for the third phase (2013 - 2020), the quality standards for fuels and a CCS (carbon capture and sequestration) regulatory framework. The quality standards ruling obliges fuel suppliers to reduce the life cycle carbon intensity of the fuels supplied by 6% by 2020.[4] This has to be achieved by blending biofuels and by a reduction of flaring. The difference in carbon intensity of various refinery fuels (e.g. hydrocracked diesel versus straight run diesel) is not considered.

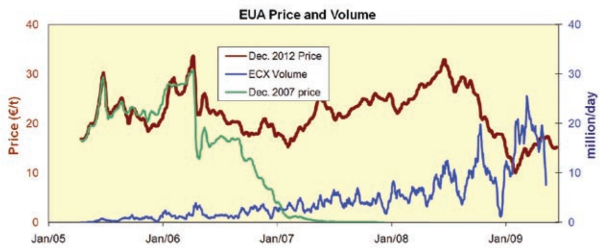

Figure 1. Carbon permit price and market volume.

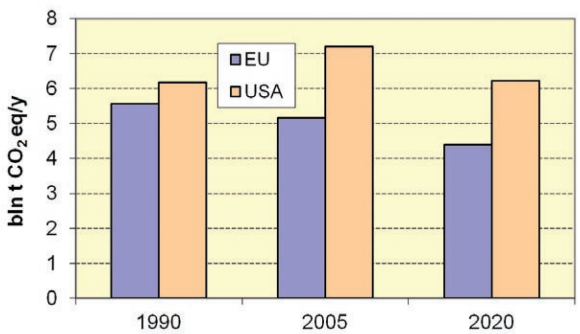

Figure 2. Historical and projected GHG emissions.

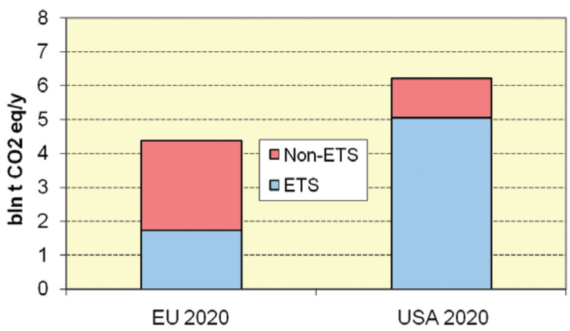

Figure 3. Projected GHG emissions.

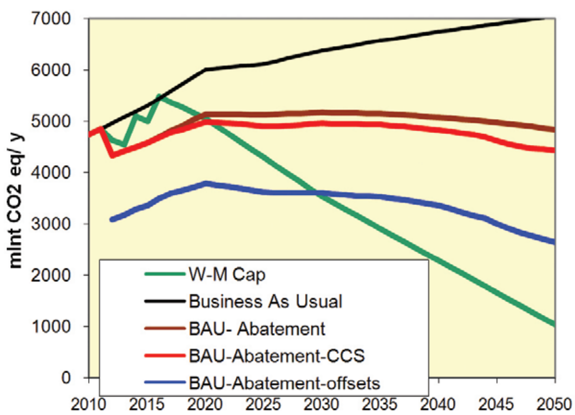

Figure 4. Emission reduction, W-M target and EPA scenario.

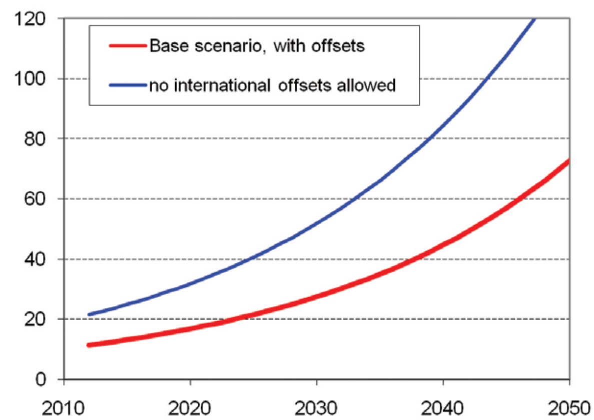

Figure 5. EPA CO_2 price scenario.

The Climate and Energy package aims at reducing the EU27 GHG emissions by 20% versus the 1990 baseline, which corresponds to a reduction of 14% compared to 2005, 3% of which will be covered by 'offsets.' Note that the emitters included in the EU ETS only account for 43% of 5.16 billion t of total GHG emissions in 2005, and the capped emissions will be forced to decrease by 21% compared to 2005.[5]

Offsets are emission reductions that are achieved in an area outside the ETS and largely consist of certified emission rights (CER) generated through UN monitored clean development mechanism (CDM) projects.

Originally, the European commission had proposed to no longer supply the emitters in the ETS with free emission rights. The emission rights would be auctioned instead and consequently, emitters would have to carry the full carbon cost instead of the marginal cost. Only industries that suffer from external competition would further apply for free emissions rights up to 2020.

Although this principle has not been abandoned, it has clearly been relaxed during the negotiation process between the European Parliament and the states, represented by the EU Council. Some auctioning is already taking place in a selection of countries.[6] Full auctioning of all emission rights, however, will not happen until 2027. Even the very carbon intensive coal based power sector, which is not subject to competition from outside the EU cap and trade system, will continue to receive free emission rights after 2012. Emissions allocation after 2012 will still be based on carbon intensity and international competition[7] but the extent to which the industries will further receive free carbon emission permits will also be a negotiation stick during the upcoming UN climate summit in Copenhagen and will therefore only be set after December 2009.

USA: Waxman-Markey

In February 2009, the Obama administration drafted a budget that includes substantial revenues from a cap and trade system. Meanwhile, the US House of Representatives voted the 'American Clean Energy and Security' or W-M Act, H.R.-2454[8] ('W-M'). The act consists of four 'titles,' the third of which concerns the introduction of a cap and trade (ETS) scheme that would start in 2012 and target an emissions reduction of 17% by 2020 compared to 2005 and a further reduction to 17% of the 2005 baseline by 2050. The main difference between the W-M act and the EU ETS is that the American cap would include almost 85% of all USA emissions, while the EU ETS holds less than 45% of EU emissions under its cap.

The EU limits the accountability of the emitters to their own site emissions. The Waxman-Markey (W-M) act, however, extends the accountability to the emissions 'from combustion of any fuel produced or imported.'[9]

Refineries in particular are affected by this, since they not only have to submit allowances for their own emissions, but also for the emissions of the consumers of the fuels they produce. Depending on the source quoted,[10, 11, 12] US refinery emissions from hydrocarbons combustion vary from 205 million - 280 million tpy. The total emissions from refinery products, however, are 10 times higher.[13] This approach has the benefit of capturing transportation emissions inside the ETS but it puts the carbon burden caused by the end consumers on the back of the refineries. Refineries have limited control over the tailpipe emissions and could only potentially reduce these considerably by reducing output dramatically, which is probably not why the system is set up accordingly. In reality, the ruling will come down to the refineries acting as collectors of the carbon cost/tax related to tailpipe emissions.

It should be noted that the 2020 target set forward by the US House Committee looks all but ambitious when set to a 1990 instead of a 2005 baseline. Indeed, while EU 27 GHG emissions decreased by 7% from 1990 to 2005,[14] US emissions increased by 16% in the same period.[15] This moves the projected emissions by 2020 back to the 1990 level, as can be seen in Figure 2. Figure 3[16, 5] shows that the split between the emissions that are part of the ETS and the emissions that are kept outside the ETS in the EU is significantly different from the split in the W-M proposal.

The cost debate

Like in any market, the cost of carbon allowances will be set by supply and demand. In principle, the amount of emission permits in a cap and trade system is fixed, which sets the supply. Demand then has to match this supply and the cost of carbon will equal the cost to reduce GHG emissions down to that level. As the cap is further reduced with time, more costly investments have to be made to achieve the required GHG emission reduction or 'abatement.'

However, in addition to 'real' carbon emission reductions materialised in the capped system, the W-M draft allows the use of up to 2 billion tpy of offsets, 1.5 billion of which could be international (similar to CDM), the remainder national. The EU also allows the use of CDM emission offsets. As mentioned earlier, these offsets are GHG emissions reductions that are achieved outside the ETS. Most domestic offsets in the USA will be carbon emission reductions achieved through forestry. The influx of additional cheaper offsets puts a downward pressure on the carbon price; which is the reason why the EU has limited the use of offsets in the European cap and trade system.

'Banking' of emission permits is another important flexibility mechanism in the W-M act: in case there is an excess of permits, then it will be possible to put these aside, to 'bank' them, and use them later when there is a shortage.

On 23rd June, 2009, the Environmental Protection Agency (EPA) issued an assessment of the impact of the W-M climate bill.[16] Figure 4 shows the results of this assessment with the IGEM model. The black curve ('business as usual') gives the emissions of the system under the cap if there would be no cap. Initially, the emissions increase steeply since some sectors are scheduled to enter only after 2012. However, after 2020, when all emitters have been incorporated, the emissions are expected to continue to rise from 6 billion to 7 billion tpy in 2050 if no further action is taken. The brown curve shows the emission in the investigated W-M scenario, i.e. with the cap in place and active. Most of the emissions reduction will materialise in the power generation sector. It is clear that the physical GHG emissions reduction under the cap is much less than 83%. So how is the 83% emission reduction achieved?

The first element to bridge the gap is CCS, which the model expects to further reduce CO_2 emissions from 2020 onwards, down to the level shown by the red curve.

The second, and more significant, contributor however, is the offsets, most of which are emission reductions achieved abroad. By accounting for these, the emission curve drops to the level of the blue line in Figure 4.

Note that in 2012, at the start of the programme, the blue curve is well below the target, while by the end of the programme, reported emissions, including CCS and offsets are much higher than what is allowed. The gap is closed by banking the excess emissions the first years and 'unbanking' them after 2030.

According to the EPA, the carbon cost is expected to be moderate at the start of the programme and to gradually increase as shown in Figure 5.[16] The blue line in Figure 5 shows that without international offsets, the carbon price would almost double.

Something that was not looked at was the impact of banking. Towards 2050, the scenarios investigated rely heavily on the use of offsets that were purchased 30 years earlier. If banking would be limited in time, then emission reductions by the sectors under the cap would have to be substantially higher, and carbon price would consequently end up much higher as well.

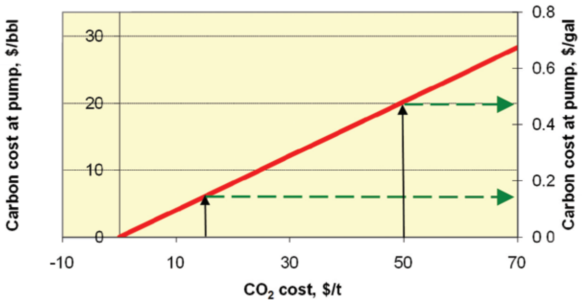

Figure 6. Impact of CO_2 cost on product prices.

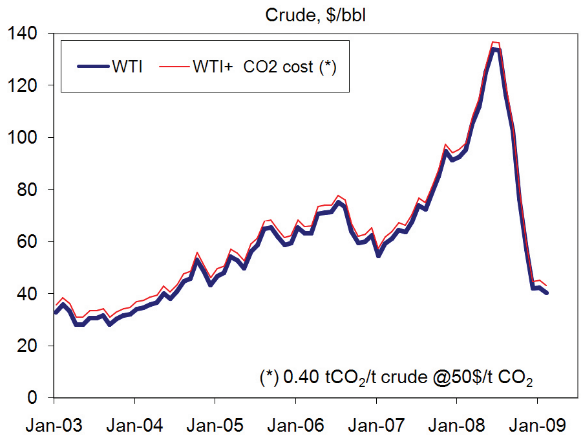

Figure 7. Cost of crude, without and with carbon burden for refinery emissions.

Table 1. Refinery CO_2 emissions	
	t CO_2/ t crude
Location	
EU 27 average	0.22
Refinery configuration (1)	
Hydroskimming	0.08 - 0.15
FCC + VB	~0.2
HCU + coker	0.2 - 0.35
RDS + RFCC	0.3 - 0.4

Although criticised for its lack of ambition by some, while blamed for causing an 'overwhelming burden' on American refiners by others,[13] the fact that the cap and trade system is on the table alone is a huge step.

Free permits

The US House Committee has proposed to freely distribute most of the emission permits from 2014 until 2026. In order to get support from the states with significant coal mining and coal based power generation, some 35% of the emissions will be allocated to the power sector. The 2.25% permits for refineries cover approximately 40% of refinery emissions but less than 5% of the emissions from refinery products, which has been heavily criticised by the petroleum industry.[17] So far, the coal industry clearly came out as the winner of the negotiations.

However, discussions are not over yet and the W-M act is not a done deal, as the voting process in the senate turns out to be difficult.

Other countries

The industrialised countries that ratified the Kyoto Protocol, other than the former Soviet Union and its satellites, which benefitted from a 'carbon crunch' after the collapse of the Soviet Union, failed to tackle GHG emissions reduction seriously.

Canada introduced a complex system of benchmarks that did not have much impact. However, most of the Canadian provinces have announced the intention to pass cap and trade bills and recently, Environment Minister Jim Prentice announced that Canada would probably follow US legislation.[18]

Japan also failed to achieve any significant emission reductions from a voluntary scheme. In 2008 Japan was emitting 16% more than its Kyoto protocol pledge. Yukio Hatoyama, the new Prime Minister in office, pledged to cut Japan's greenhouse gas emissions by 25% by 2020 from 1990 levels, a more ambitious target than the 8% reduction of outgoing premier Taro Aso's administration.[25]

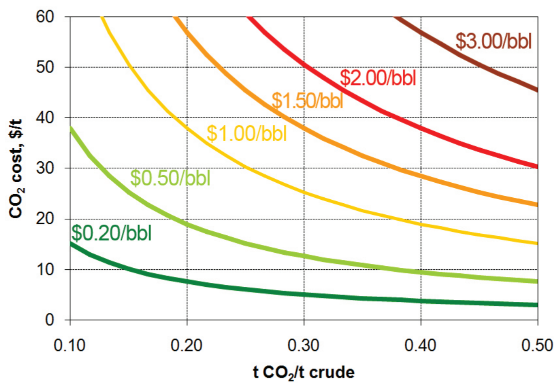

Figure 8. Carbon cost from refinery emissions (US$/bbl).

Table 2. Refinery CO_2 emissions			
	Hydroskimming	RDS/RFCC	Delta
Light products, m^3/t crude	0.6	1.1	0.5
CO_2 cost, t/t light products	0.23	0.44	0.68
CO_2 cost, US$/bbl light products (US$ 50/t CO_2)	1.5	2.7	4.1

The Australian government was planning to introduce a carbon cap in July 2011,[18] which would cut emissions to 5 - 25% below the 2000 level by 2020; but on 13th August the senate rejected the proposed cap and trade legislation.

Refinery impact

When considering the carbon burden for refineries, a distinction should be made between emissions from the products and the refinery emissions.

The former is applicable according to the W–M act but not in the European ETS, in which the refiners are only accountable for their own emissions.

Calculations by KBC in Figure 6 show that even if the CO_2 price is only US$ 15/bbl, the carbon burden from the refinery products would be approximately US$ 5/bbl of gasoline sold. At US$ 50/t of CO_2 the cost would rise to US$ 20/bbl. It is obvious that the refineries will have to recover this cost from the consumer.

In principle, this will be the case, provided that the resulting price hike does not seriously affect demand, since imports from geographical areas outside of the US will also have to buy carbon emission allowances according to the W-M act.[9]

Figure 6 also shows that prices at the pump would increase by US$ 0.13/gal., at US$ 15/t of CO_2 and US$ 0.45/gal. at US$ 50/t of CO_2. This is only a fraction of the price hikes seen in recent years, but it is considerable enough that it could have some impact on fuel consumption, which will indirectly reduce refinery profit margins.

The EU ETS experience has proven that carbon prices can be as volatile as crude prices. Hence, under the proposed US cap and trade act, refiners will also have to live with an additional volatile cost component.

CO_2 emissions by the refineries themselves have to be accounted for in all cap and trade scenarios. Table 1 shows average refinery emissions for the European refining sector, expressed as tonnes of CO_2 /t of crude, as calculated from crude processing and refinery emissions data,[19,20] and the refinery CO_2 emissions that can be expected for different types of refineries. The estimates were calculated using KBC Petro-SIM software to estimate unit rates, hydrogen consumption and FCC coke production, and the KBC best technology energy benchmarking methodology to calculate the carbon footprint of different refinery configurations. It is assumed that hydrogen, steam and power are produced on site. The CO_2 emissions for a certain refinery configuration are crude and fuel specific but also depend on energy efficiency.

The hydrocracker (HCU) plus coker combination is more carbon intensive due to the high hydrogen consumption. The resid desulfurisation (RDS)/resid cracking option (RFCC), a viable option for the production of 0.5% fuel oil, will emit even more CO_2 due to high hydrogen usage and RFCC coke yield.

The blue curve in Figure 7 plots the cost of West Texas Intermediate benchmark crude, assuming the refinery has to pay for all its emissions. In the red curve, the carbon cost has been added to the crude cost, assuming a relatively high carbon cost (US$ 50/t) and a refinery with a high carbon footprint (0.40 t of CO_2/t of crude processed).

In relative terms, the difference is small and negligible compared to the fluctuations of the crude price. Consequently, hardly any impact can be expected on consumption if the cost is transferred to the consumer. However, if the additional cost cannot be passed on to the refined products, then refinery profitability might be seriously affected. This is illustrated by Figure 8, which shows the carbon cost /bbl of crude as a function of the refinery carbon intensity (t of CO_2/t of crude processed) and the carbon cost (US$/t of CO_2), again assuming no free allocation of carbon emission rights.

For a high conversion refinery, the carbon cost by the refinery emissions may exceed US$ 2/bbl, which is a significant fraction of the typical refinery margin. US Gulf Coast margins were well above US$ 5/bbl between 2004 and 2008 but dropped recently. Late 1990s margins were approximately US$ 3/bbl.[21] Moreover, these margins do not include depreciations and operating costs, which account for more than half of the gross margin.[22]

Complex high conversion refineries are penalised more than low conversion complexes. Table 2 compares the carbon cost /bbl of light liquid products (from LPG to distillates) of a hydroskimming and RDS/RFCC refinery. Liquid product in the conversion refinery entails a carbon cost of US$ 2.7/t of product versus US$ 1.50/t for hydroskimming refineries. This means that the carbon cost for an additional tonne of high value products generated in the conversion refinery will be US$ 4.1. This is almost three times more than the carbon cost of the hydroskimming refinery.

Consequently, if product prices do not increase accordingly, there will be less incentive to invest in conversion capacity and an incentive to export fuel instead or buy lighter crudes. This should not be overstated though, it is more likely that the market price be set by the cost of the most expensive products, which will include carbon cost of conversion; provided carbon leakage is not an issue!

Carbon leakage

A cap and trade system will result in a substantial increase of the refinery operating cost if emission rights are not distributed free of charge. In that case, it is necessary that a significant fraction of the carbon cost can be passed on to the end consumers. The resulting increase at the pump will be small (<US$ 0.05/gal.) if the refinery only has to account for its own emissions but will be much more substantial (US$ 0.15 – 0.50/gal.) if the tailpipe emissions are also carbon taxed (Figure 6).

Refineries will be able to reduce the carbon cost to some extent but not completely. Part of the carbon emissions from additional VGO and resid conversion, in particular, is chemical and can therefore not be avoided by improving energy efficiency but only by reducing conversion itself.

Allowing imports from areas where CO_2 can be emitted at no additional cost could have a dramatic impact on the local refining industry since it will limit the ability of the carbon constrained sites to transfer the cost to the consumer.

It will lead to a collapse of the local industry if importers would not have to pay for tailpipe emissions and local refiners would. Local refineries would shut down and product imports from non-capped areas would increase. This would be a dramatic form of 'carbon leakage,' which is the shift of carbon emissions to a geographical area outside the cap. However, this carbon cost is not applied in the European ETS and the proposed Energy and Security

Act in the USA will also charge importers for the tailpipe emissions, thus eliminating carbon leakage from tailpipe emission carbon taxation.[9]

However, since carbon cost of refinery emissions alone may also equal a substantial part of net refinery margin (Figure 8), these too should be largely passed on to the consumer if the refinery has to buy all of its emission rights. Otherwise, the additional operating cost will increase local prices, thus opening the window for additional imports, which will put pressure on the product prices and consequently reduce the profitability of the refineries under the carbon cap.

It is difficult to quantify how the carbon cost will affect imports to the US and product prices. At the moment there is not really a trade of gasoline or diesel to the US East Coast, the major import hub from areas with no carbon cap. Firstly, because the US has fenced itself off from imports of finished products by its requirements for certification on reformulation and CARB standards. Secondly, because most of the imports of gasoline intermediates to the East Coast market originate from Europe, rather than the Middle East.

The price of these imports in the high season, when the local US gasoline production cannot fulfil market demand, is largely set by the European markets plus the transportation cost. The current construction of refineries in India and the Middle East will change this balance and the carbon cost related with gasoline production in Europe and the US may result in the Europe-US trade being replaced by trade in which, in addition to crude, the Middle East would also export refinery intermediates to the US.

Avoiding carbon leakage can be achieved by charging imports for their refinery carbon emissions or by giving free emission allowances to the industry. The EU is currently investigating to what extent the different industries will be affected,[7] and the American Climate and Security schedules to give 2.25% (or approximately 100 million t in 2014) of all allowances to the refining industry,[23] covering approximately 40% of refinery emissions. Both the US and the EU plan to phase out free allocation before 2030.

Conclusion

There is a legitimate concern from the refining industry that profitability is under threat in a carbon capped environment. A cap and trade system or carbon tax increases refinery operating costs substantially, even if only refinery emissions have to be accounted for. Emission for conversion of heavy feeds are high and not all due to energy inefficiency. Hence, refineries should either receive part of their allowances for free or else have the possibility to transfer a substantial fraction of the carbon cost to the consumer. This can be achieved by imposing a carbon tax on imports from countries with no carbon cap.

It seems like the authorities both in the EU and the USA are willing to supply the refining industry with free emission allocations covering part of their baseline emissions. Whether this will be sufficient is still subject to study (in the EU) and debate (in the US). Further, the WTO recently indicated that it does not necessarily oppose carbon taxes on imports.[24]

However, all this should not conceal the fact that it is possible to reduce the carbon footprint of a refinery to some extent and often even considerably. Blaming competition from abroad will not always be justified. Being blind to its own inefficiency may cause a refinery to sink under its heavy carbon load, even if competition only comes from other refineries under a carbon cap.

The next article of this series will explain in more detail the importance of carbon efficiency and outline a GHG reduction strategy for refineries.

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