Decreasing the Carbon Intensity of Fuels

Annex A of the Handbook 'Navigating Transport NAMAs'

TRANSfer Project – Towards climate-friendly transport technologies and measures

The concept

The life cycle of carbon emissions of fuels varies considerably and depends not only on the type of fuel (*e.g.* petrol, diesel, natural gas or electricity) but also on the production pathway (*e.g.* petrol from crude oil or from tar sands). Reducing the carbon intensity of fuels is an important measure to cut the overall GHG emission from transport. Due to the variety of fuels and production processes, the emissions have to be evaluated considering the whole life cycle. The resulting overall carbon intensity of a fuel has to be evaluated as emissions of carbon dioxide equivalent (CO_2e) per unit of energy (*e.g.* in MJ), since the energy content per volume of fuel varies depending on the fuel characteristics.

Elements to decrease the carbon intensity of fuels:

- Implement a low-carbon fuel standard
- Set mandatory renewable fuel quotas
- Price carbon emissions of transport fuels (carbon tax or cap-and-trade scheme)

For more details on the elements' characteristics see Box 1.

By cutting the emission per energy unit, vehicle emissions per kilometre are reduced.

Table 1: GHG reduction matrix of decreasing the carbon intensity of fuels

	Avoid	Shift	Improve
Direct effects			☑ Induces a shift towards low-carbon fuels ☑ Reduces the carbon emissions per litre of fuel consumed ☑ Fosters technological advance in fuel feedstock and production processes
Indirect effects	☑ Can increase the costs of car use and thus reduces car dependent urban sprawl	☑ Can increase the cost of car use and thus encourages a shift to alternative modes	☑ Fosters technological advance of vehicles that run on alternative fuels ☑ Fosters the development of infrastructure for low-carbon fuels (*e.g.* hydrogen, natural gas)
Rebound effect	☒ Low-carbon fuel standards (LCFS) can lead to an increase in fuel production, that induces higher transport activity caused by low fuel prices[a]	☒ Can lead to decreasing costs for alternative fuelled car use	☒ Can increase GHG emissions if indirect life cycle emissions are not covered in carbon intensity assessment of transport fuels ☒ Can increase emissions of non-climate relevant air pollutants (*e.g.* particulate matter from biofuels) ☒ Under LCFS high-carbon fuels can be exported to countries without a LCFS in exchange of low- carbon fuels, leading to a global rebound effect (Sperling and Yeh, 2009)
Complementary measures *(to achieve full mitigation potential)*		☑ Rational fuel pricing (see Factsheet '*Sustainable Fuel Pricing*')	☑ Vehicle fuel economy standards that are energy-based (MJ/km), so that they include alternative fuelled vehicles (see Factsheet '*Promotion of Energy Efficient Vehicles*')

[a] Low-carbon fuel standards can lead to higher fuel production and increased GHG emissions, if fuel producers comply with the standard by increasing the production of low carbon fuels without a corresponding reduction in high-carbon fuels (see Box 1) (Holland *et al.,* 2009).

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Box 1: Possible instruments to decrease the carbon intensity of fuels

Implement a low-carbon fuel standard (LCFS)

Low-carbon fuel standards (LCFS) require fuel producers and distributors to ensure that their fuel mix meet a specific carbon intensity target (*e.g.* CO_2e/MJ) set by the national (or regional) government.

Often an emission crediting system is implemented together with a LCFS. Emission credits are provided for fuels with lower carbon intensity than required by the target. Thus, fuel producers that do not meet the required carbon intensity can buy credit from other producers (*e.g.* biofuel producers) to meet the LCFS target.

Overall, fuel suppliers can reduce their emissions by improving the processing process, switching feedstock, blending low-carbon biofuels or by purchasing certificates from deliverers of low-carbon fuels, whose fuel mix has an average carbon content below the target (Creutzig *et al.,* 2011; Yeh and Sperling, 2010).

How it works and intended effects:

- An LCFS impose an implicit tax on fuels that have a carbon intensity above the standards, whilst it functions as a subsidy for low-carbon fuels below the standard (Holland *et al.,* 2009).
- A LCFS promotes low-carbon fuels and encourages consumers to purchase vehicles that can be powered by these fuels.
- It encourages fuel producers to reduce emissions in upstream processes;
  ➔ The average GHG content of transport fuels is reduced.

Pros and Cons [b]

Pros:

- Low carbon fuel standards are technology and fuel neutral, which means that they do not favour one particular fuel as renewable fuel quotas do. Thus, LCFS offer more flexibility and spur research across all alternative fuels.
- Offers a large flexibility to comply with the standard (emissions can be reduced at different points of the fuel chain).
- Stimulates innovations in fuel processing, transport and distribution as well as in cultivation or extraction of feedstock, since fuel manufacturers that are able to produce cost efficient low-carbon fuels benefit most (Yeh and Sperling, 2010).

Cons:

- High abatement costs[c] (Holland *et al.,* 2009).
- Fuel producer can comply with the standard by increasing the production of low-carbon fuels without corresponding reduction in high-carbon fuels.
- LCFS can actually increase carbon emissions if the standard is not stringent enough or if the demand for high-carbon fuels is relative inelastic. In the latter case, low-carbon fuels may complement rather than supplement high-carbon fuels (Holland *et al.,* 2009).

[b] The suitability of each instrument depends on the individual circumstances in a country. This list of general advantages and disadvantages of each instrument provides a fist step towards such assessment.

[c] Holland *et al.,* (2009) find that average abatement costs of an energy-based LCFS, such as the Californian LCFS, which reduces the carbon intensity by 10 %, range between USD 307 and USD 2 272 per tonne of CO_2e.

Set mandatory renewable fuel quotas

Renewable fuel quotas do not set particular GHG reduction targets, but aim at increasing the share of low-carbon fuels. The mandates require fuel suppliers to blend conventional fuel with a defined share of biofuels to increase the overall share of renewables in transport. Renewable fuel mandates have been implemented in many countries worldwide. However, as outlined earlier (see Factsheet 'Alternative Fuels'), the life cycle emissions of biofuels are difficult to assess and large-scale production of biofuels can lead to environmental degradation and conflicts with food and feed production.

How it works and intended effects:

- Increase the share of low-carbon renewable fuels;
  - ➔ Reduced GHG content of the fuels;
  - ➔ Less dependency on fossil fuels.

Pros and Cons

Pros:

- Biofuels can easily penetrate the market;
- Implementation is less complex than LCFS or carbon taxes as these instruments require life cycle emission assessments across all fuels.

Cons:

- Focus only on renewables;
- Does not stimulate innovation;
- Problematic to assess all direct and indirect life cycle emissions from biofuels; high uncertainties associated with life cycle emission assessments of biofuels;
- Incentivise the production of the most economic (and often less sustainable) biofuels if sustainability criteria so allow.

Price carbon emissions of transport fuels (carbon tax or cap-and-trade scheme)

Additional cost can be imposed on transport fuels according to their carbon content. Carbon taxes and cap-and-trade schemes are instruments to introduce GHG pricing on fuels.

Carbon-based fuel taxation is a special form of fuel taxation. Usually, the taxes are based on fossil carbon content of the fuels and are designed to internalise the external costs of the transport sector's GHG emissions. The design of a carbon tax scheme needs to consider that the price elasticities for petrol and diesel are usually low (see Factsheet '*Sustainable Fuel Pricing*'). Thus, the effect of the carbon tax on the petrol or diesel price has to be sufficiently high. Especially in countries with already high fuel prices, such as Europe with fuel prices equivalent to USD 400 per tonne CO_2, carbon taxes at current levels (far below USD 50 per tonne CO_2) will not make much difference (Litman, 2009; Yeh and Sperling, 2010).

Cap-and-trade schemes can be introduced economy-wide or limited to the transport sector. The national authority limits the amount of CO_2 emissions and sells emission permits. The scheme can be introduced at different levels: upstream (feedstock or fuel production) or midstream (fuel distribution) (Flachsland *et al.,* 2011). The associated emission price will be devolved to the final consumer, thus influencing individual fuel purchase behaviour.

How it works and intended effects:

- The carbon content of fuels is reflected in the fuel price, leading to higher costs for carbon intensive fuels like diesel and petrol;
  - ➔ Induces a shift from petrol and diesel to low-carbon fuels;
  - ➔ Long term effect on the vehicle purchase.

Pros and Cons

Pros:

- Technology and fuel neutral;
- More cost effective than LCFS[d] (Holland *et al.,* 2009);
- Provide abatement incentives;
- Does not induce an increase in travel activity;
- Certainty about the impact on GHG emissions (cap-and-trade).

Cons:

- Political unpopular;
- Vehicle efficiency improvements can reduce the consumer response to fuel price changes;
- Neglect upstream emissions;
- Cap-and-trade schemes are difficult to implement;
- Uncertainty about the impact on GHG emissions (carbon price).

[d] Holland *et al.,* (2009) estimated that the abatement cost for a 10 % reduction in carbon intensity are USD 60 to USD 868 for a carbon tax scheme, whereas the for LCFS abatement cost for similar emission reductions range between USD 307 and USD 2 272.

GHG mitigation effect and co-benefits

The GHG mitigation effect of the instruments to reduce the carbon intensity of transport fuels varies depending on the design of the scheme (*e.g.* stringency of low-carbon fuel standards, level of carbon taxes or required renewable fuel shares). Additionally, framework conditions such as demand elasticity of different transport fuels largely influence the emission mitigation effect of carbon taxes and LCFS.

Yeh and Sperling (2010) investigate the effect of a LCFS on the US transport system. In their scenario, a LCFS that reduces the carbon intensity of transport fuels by 10 % from 2010 to 2030 is implemented. Their analysis assumes that the fuel use will remain the same as in the business-as-usual scenario (BAU). The authors find that, compared to the BAU, the total transport fuel life cycle GHG emissions in the US are reduced by 306 million tonne of CO_2e. However, further reductions can be achieved as a LCFS can also reduce the energy consumption of transport. This is for two reasons: firstly, the promotion of electricity or hydrogen can lead to energy saving as the propulsion technology of electric engines is much more efficient than conventional internal combustion engines (see Factsheet '*Electric Vehicles*'). Secondly, LCFS can reduce fuel consumption if fuel costs are increased by the scheme. For instance, Holland *et al.,* (2009) assume that a LCFS could achieve a GHG reduction of 20 to 25 % in the US.

The co-benefits of implementing instruments to reduce the carbon intensity of fuels are:

- Reduce the country's dependency on oil imports due to diversification of the fuel mix;
- Economic benefits since it stimulates local fuel development;
- Reduce the environmental damage of unconventional oil extraction[1].

Towards implementation

Low-carbon fuel standards and renewable fuel quotas (see Box 1) address the national fuel producers, refiners, importers and suppliers, who have to comply with the regulations and have to bear the costs of non-compliance (Creutzig *et al.,* 2011).

Carbon pricing of transport fuels targets all fuel consumers (*e.g.* private vehicle owners, logistic companies, public transport operators) and is intended to influence the individual fuel consumption behaviour.

Key stakeholders

- National ministries of environmental affairs:
  Responsible for the evaluation of different fuels (life cycle assessments); implements environmental guidelines and emission limits;
- National ministries of finance/taxation:
  Responsible for the realisation and enforcement of carbon based taxation.

[1] At the stage of feedstock recovery, unconventional fuels (*e.g.* tar sands) can have 4.5 times larger GHG emissions than conventional oil (Creutzig *et al.,* 2011).

Table 2: Potential barriers to implementation and countermeasures

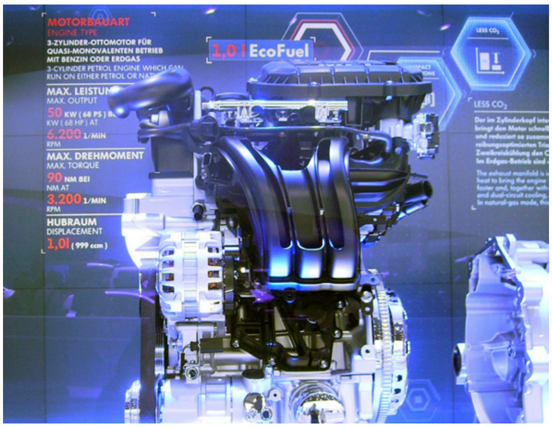
Barriers	Options to overcome
Political opposition from consumers	■ Provide fuel tax reduction for alternative fuels; ■ LCFS increase the price for high-carbon fuel but reduce the price for low carbon fuels, thus only consumers of high-carbon fuels have to bear additional costs under a LCFS scheme (Holland *et al.,* 2009); ■ Public awareness campaigns that inform about the possibility to reduce individual fuel costs if low-carbon fuels are purchased.
Political opposition from fuel producers	■ Strong political leadership; ■ Complementary policies might be necessary to facilitate a market penetration of low-carbon fuels to ensure that fuel producers can sell these fuels (Yeh and Sperling, 2010).
Consumers reject the purchase of alternative or blended fuels	■ It has to be ensured that the infrastructure for alternative fuels is provided; ■ Accelerate the development of alternative fuel vehicles; ■ Consumers need proper information about the ability of their vehicle to run on blended or alternative fuels; ■ Fuel tax reduction for alternative fuels.
Technical barriers for the use of low-carbon fuels: fuel production, supply infrastructure and vehicles	■ Sound planning of supply infrastructure, and policies to stimulate market diffusion of alternative fuel vehicles.
Difficult assessment of the life cycle emissions of different fuels	■ Close cooperation with research institutions.

Success factors

- Careful design and implementation of the instruments to reduce the carbon intensity of fuels to ensure that actual GHG emission reductions are realised.
- Life cycle emissions of the various fuels have to be evaluated. Considering tailpipe emissions only can lead to adverse effects.
- Include additional sustainability criteria (*e.g.* air pollution, environmental damage) in the fuel assessment. For instance, diesel emits less CO_2e/MJ but emits more particulate matter, which endangers human health (Katsouyanni *et al.,* 1997).
- Assess the framework conditions for a fuel standard carefully and carry out an ex-ante evaluation to quantify its net effect. If the standard is relatively loose or if the demand for high-carbon fuel is very inelastic (*i.e.* increasing prices have only little effect on the demand) producers will tend to increase the production of low-carbon fuels without reducing high-carbon fuels (Holland *et al.,* 2009).
- Combine the measure with activities to increase the energy efficiency of vehicles and with disincentives for car use so that adverse effects can be limited.
- Enable a large scale use of alternative fuels (*e.g.* provide infrastructure, support research in vehicle technology).
- Plan and evaluate the transition to large scale use of alternative fuels carefully.

Practical example: California's Low-Carbon Fuel Standard

In 2007, California enacted the California Low-Carbon Fuel Standard (LCFS) that mandates a 10 % emission reduction in the transport fuel mix. By 2010, fuel providers, including refiners, blenders, producers and importers have to reduce the average fuel carbon intensity of their fuel by 10 % below the average value in 2010. Yeh and Sperling (2010) analysed the potential effects of the LCFS in California. They estimate that the standard would lead to an increase in the use of alternative fuels, which would have a share of 16 % of the transport fuel supply in 2020. Ethanol, followed by biodiesel, is expected to experience the largest increase, whereas CNG, LPG and electricity have only small shares. The abatement costs are estimated to range between –USD 125 and +USD 24 per tonne of CO_2. Infrastructure costs and vehicle costs are not included in the abatement cost.



IAA Frankfurt – Photo by Jonathan Gómez, 2011

Further reading

- **Creutzig, F., McGlynn, Minx, J. and Edenhofer, O. (2011)** '*Climate policies for road transport revisited (I): Evaluation of the current framework*', Energy Policy, vol. 39, pp. 2396–2406.
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- **Sperling, D., and Yeh, S. (2009)** '*Low carbon fuel standards*', Issues in Science and Technology, pp. 57–66.
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