Guidance document on non-technical measures

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1. Introduction

The WGSR at its 59th session recommended developing a guidance document on what is often referred to as 'non-technical measures', that cover structural and behavioral measures as well as policy action aimed at furthering such change. The development of the document is included in the workplan 2024-2025 of the Air Convention. The guidance document should be based on best practices at the national level (focused on meeting national emission reduction obligations) and at the local or regional level focused on reducing health and ecosystem damage).

Abatement of emissions under the Air Convention is mainly the result of regulation. There is a legal obligation to apply specific add-on technologies or meeting emission limit values e.g. for new installations and vehicles. It is relatively easy for air quality policy makers to assess the additional costs of potential technical abatement measures for certain sectors, and they can be compared with the expected benefits for health and ecosystems.

Contrary to technical measures for specific installations or vehicles, the implementation of structural innovations of industrial production processes, changes in final use of products or transitions towards more sustainable transport- or food systems often require a mix of technical and behavioral changes as well as a mix of policy instruments. Apart from regulation, the policy mix could include pricing, research investments, infrastructural planning and awareness raising. In this guidance document, they are grouped together as 'non-technical measures'.

The political assessment of costs and benefits of non-technical measures will often require broader involvement of stakeholders, other ministries than the one in charge of the environment, cities, and the public at large. Benefits could entail more than better air quality. Climate benefits, safety improvements, additional health benefits due to physical activity, less noise, and less nitrate leaching are all potential co-benefits of non-technical measures. Conversely, costs of such measures could entail more than out-of-pocket expenses. The loss of services, time, comfort, or freedom (e.g. to choose what to eat, how to heat your house, or how to move from A to B) are all potential societal costs. Successful implementation of non-technical measures will - at least - require more involvement of the public and of industries in the decision-making process. Their acceptance will also depend on equity issues: who pays, who will benefit? Will small enterprises disappear? Do farmers have to stop their activity? Will prices increase and can low-income groups still pay their energy bill, still access the city or afford healthy meals?

Decisions on non-technical measures will in many cases raise more political debate than strengthening technical emission limit values. Implementation will probably require more time. And the acceptability of such measures as well as the acceptable mix of policy instruments may vary across countries, depending on cultural and political preferences.

This guidance document discusses several options for non-technical measures and their potential contribution to environmental quality improvements. It defines the basic requirements for successful implementation, gives a few examples with proven success, and addresses the challenges

of assessing its costs and benefits. The focus of the measures in this document is on residential heating, mobility, and food consumption. Further, focus is on changes available to citizens rather than to companies, although companies can facilitate changes by citizens. The document builds on an earlier informal document prepared under the Gothenburg Protocol review Group (Informal doc on non-technical measures.pdf (unece.org), 2021).

2. Why do we need non-technical measures?

Implementation of technical emission limit values (ELVs) for installations, vehicles and products is not always sufficient to meet the national emission reduction obligations or the long-term air quality targets to protect human health and ecosystems. In such cases, additional actions in the form of behavioral change measures or changes in the structure of the economy could be considered: e.g., non-technical measures that lead to lower use of fossil fuels, less car traffic, or fewer cattle. Such measures can be initiated at the local or national level but can also be backed by international coordination.

Non-technical measures could include a faster substitution of old and polluting technologies by new and cleaner technologies, the use of cleaner fuels or feedstocks, or greener behavior of consumers. The latter could include a modal shift from private motorized to public or private non-motorized transport, dietary changes or cleaner residential energy use. Sometimes such measures prove to be more efficient and less costly than implementing stricter ELVs, but there can also be hidden non-monetary costs, such as longer travelling time, less comfort, loss of freedom to eat what you want.

Definitions

In this guidance document, non-regulatory consumption changes, production changes and product innovations, that are not included in the technical annexes of the Gothenburg protocol are referred to as 'non-technical measures'. Implementation of such measures involves various policy instruments, such as information campaigns, pricing, as well as regulatory measures, such as vehicle speed limits, which are equally grouped under the term 'non-technical measures. This terminology commonly found in the context of air pollution policy. In other fora, it is more common to use the terms 'behavioral change measure', 'structural change measure', or 'demand-side measures', which represent roughly the same phenomena.

Despite the literal meaning of the term, these 'non-technical' measures can still have technical components. For example, insulation of buildings, the use of solar energy, the redesign of products and processes or advanced public transport systems are all technical examples. Examples of purely non-technical measures are reducing indoor temperature, lower vehicle speed or a shift towards public transport, cycling and walking. There are also technical measures with a high behavioral component, such as improved maintenance routines (e.g. regular checking of pumps, valves and pipelines for leakages, checkup for cars, heating systems, etc.). Other examples of hybrid measures (technical "non-technical" measures) are motion-activated light switches, cruise control functionalities in vehicles, or certified product information so people can be sure they select environmental-friendly dish washers, refrigerators, wood stoves, etc.

Often 'non-technical measures' are associated solely with behavioral change. However, as illustrated above, they encompass much more. The most important aspect of the types of measures discussed in this document is that they are NOT regulated in the technical annexes of the Air Convention. Given the possibility of narrow or potentially misleading interpretation of the terminology 'non-technical measures', the broader term 'structural measures' or 'structural changes' may be more appropriate when referring to measures that are additional to the end-of-pipe techniques prescribed in the technical annexes to the protocol. The common feature of structural changes is that they cannot easily be implemented via permitting of specific activities. They often require a combination of actions by various players in the production chain, as well as by consumers. As the term 'structural changes' suggests, it could even include a transition towards a new economic structure that relies less on the use of fossil fuels or animal-based food.

3. Policy instruments to implement non-technical measures

Very simplified, we can distinguish four types of policy instruments: regulatory, economic, social (information and communication) and public investments (including Research and Development)[1]: These instruments can be combined in various ways. Below are some examples focusing on these four types of policy instruments in the transport system.

1. Regulatory instruments: some cities have closed parts of the city centers to cars or have withheld permits (e.g. for parking or for new roads). The 2020 lockdown due to the COVID-pandemic has demonstrated that regulation of vehicle activity in the event of a societal emergency can be acceptable.
2. Economic instruments: These could include a tax based on the pollution emitted by cars; subsidies for clean alternatives; innovation support for scaling up new technologies, compensation for the early scrapping of old cars; and increased parking fees in city centers[2].
3. Social instruments: These could include raising awareness, and public involvement in monitoring and city planning, or incorporate communication strategies that suggest or promote a (modal) shift toward less polluting options. Such instruments may not always be sufficient to effectively change individual behavior of a sufficient part of the population but can also improve societal support for the use of one of the other policy instruments mentioned above and contribute to adapting social norms that in turn influence individual behavior.
4. Public investments: These could include physical planning and targeted investment in infrastructure that could provide an important opportunity for the public sector to bring about structural change. For example, investment in public transport, the removal of parking spaces and the replacement of car lanes by bus or bicycle lanes have a proven effect on traffic intensity and on modal change, and thus on polluting emissions. Additionally, country governments could adopt policies to expand electric vehicle (EV) infrastructure, and to replace government motor vehicle fleets with EVs.

Extensive research has been done into the optimal mix of policy instruments, including research made by political scientists, economists and other social scientists, such as psychologists and even neurological researchers.[3] Efforts to find a theoretical optimal policy mix do not lead to a single answer. Much depends on the actual preferences and power of stakeholders. In practice, pragmatic policy choices are sometimes made that acknowledge limited public acceptance of certain policy instruments, the fact that long-term goals cannot be realized at once, and that policy makers sometimes have to start with small steps in the right direction.

[1] Awareness raising and Research & Development are necessary instruments, but insufficient when applied stand-alone. Their impacts are indirect and there difficult to quantify.

[2] See Guidance document on economic instruments to reduce emissions of regional air pollutants, 2013: https://www.unece.org/fileadmin/DAM/env/documents/2013/air/eb/ECE_EB.AIR_118_ENG_01.pdf.

[3] See https://implementconsultinggroup.com/article/harness-the-potential-of-habits-at-work; https://www.visualcapitalist.com/wp-content/uploads/2017/09/cognitive-bias-infographic.html).

4. Inventory of effective non-technical measures

Energy

Explorations of the potential emission reductions from structural changes in the energy sector are well covered by energy models such as PRIMES. The results of energy scenarios show that a shift from fossil fuels to renewables such as wind and solar energy could significantly reduce fuel related emissions like SO_2, NO_x, $PM_{2.5}$ and BC. Such co-benefits from climate and energy policies are included in the GAINS-scenarios developed by CIAM. However, the side effects of climate measures will not always be positive. The use of carbon-capture and storage would require substantially more energy, and this could increase NO_x-emissions if no additional add-on technology is used. Also, the use of hydrogen or ammonia as energy carriers would require additional (technical) measures to minimize an increase in emissions of air pollutants. And biomass burning in the residential sector can increase $PM_{2.5}$ emissions depending on the fuels it replaces. These side effects are covered in the GAINS-scenarios, which is not always the case for calculations of non-technical measures to reduce emissions from residential heating, transport and food.

Residential heating

Emissions from wood stoves are the combined result of technical standards and wood burning behavior. For the reduction of emissions from domestic wood burning (a coherent package of) 'non-technical' measures are likely to be more effective and suitable than technical measures. Examples of such measures, together with the policy instruments thought to induce them, are:

(i) Public investment programs providing grants, incentives or rebates to accelerate the removal or replacement of old and polluting wood burning appliances,
(ii) Regulatory policies for prohibiting use of all, or less efficient, devices during high pollution events,
(iii) Social instrument training programs for proper installation and regular maintenance schemes,
(iv) Social instruments encouraging good burning practices and use of dry wood,
(v) Economic instruments incentivizing energy renovation (reducing heat demand), etc.

All these measures will likely be more cost-effective than retrofitting the existing domestic wood burning equipment stock with a catalyst or an electro-static precipitator and other technical abatement measures. See the code of good practice for solid fuel burning developed by TFTEI for more information.[4]

In many countries, there are efforts to raise awareness of the indoors and outdoors health risks of wood burning to stimulate voluntary action. Awareness raising is often a first necessary step to change behavior and this can help the acceptance of regulation on how and when to burn wood, in case awareness raising alone proves to be insufficiently effective. Several countries or cities go further than awareness raising, e.g.:

- The U.S. EPA certifies residential wood stoves for meeting emission limits and efficiency requirements. In this case the government has a unique role as a trusted third party.
- German chimney sweepers check that households engage in correct wood burning behavior.
- Some states in the U.S. have legal obligations not to burn wood in case of unfavorable

[4] see Code of good practice for solid fuel burning and small combustion installations, 2019: https://www.unece.org/fileadmin/DAM/env/documents/2019/AIR/EB/ECE_EB.AIR_2019_5-1916518E.pdf

weather forecast (such as low wind speed or inversion).

- Several countries give financial compensation for scrapping old wood stoves, such as Belgium and Denmark.
- Some cities in the Netherlands have introduced wood-burning-free neighborhoods.

These are all examples of policies to further reduce emissions from wood stoves in addition to technical standard setting.

Transport

Measures at the national level to implement non-technical measures include e.g. programs to expand the EV infrastructure and provide incentives for increasing EV sales; logistical programs to reduce emissions from goods transport; national speed limits, increase of fuel duties, national road pricing, investments in public transport, agreements with cities on low-emission zones, scrapping schemes and public awareness raising on the health benefits of active mobility (walking and cycling).[5]

There are several inventories of promising local traffic measures, for instance Haneen Khreis et al. (2023)[5] and review reports published in 2019 by Public Health England (2020), UBA and others.[6]

Kreis et al. identified 58 unique local measures (or interventions), of which 20-25% are mainly technical (vehicle emission regulation, retrofitting, inspection and maintenance). Of the non-technical measures that were identified 14% were related to the use of pricing instruments (parking charges, road pricing, fuel taxation), 8% to awareness raising (promotion of public transport, active mobility, car sharing), 14% to infrastructural investments (public transport, bicycle lanes, speed bumps, roadside vegetation) and 5% to city planning (transit-oriented development)[7]. The remaining 60% of the non-technical measures were related to regulatory instruments (low-emission zones, speed limits[8], traffic circulation, imposed local fleet management).

Evaluation of the potential outcomes of such interventions is often based on qualitative judgement of the feasibility and effectiveness or on (ex-ante) modelling results. Ex-post measurement of the outcomes in terms of reduced pollutant emissions and exposure or health improvements is very

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[5] https://www.sciencedirect.com/science/article/pii/S0160412023000788?via%3Dihub#s0195 Urban policy interventions to reduce traffic-related emissions and air pollution: A systematic evidence map - ScienceDirect, https://doi.org/10.1016/j.envint.2023.107805

Kuss and Nicholas (2022): A dozen effective interventions to reduce car use in European cities: Lessons learned from a meta-analysis and transition management - ScienceDirect

[6] https://assets.publishing.service.gov.uk/media/5fbf93258fa8f559dbb1add9/Review_of_interventions_to_improve_air_quality_March-2019-2018572.pdf ; REA (2018): Rapid Evidence Assessment of Interventions to Improve Ambient Air Quality, Supplementary material to PHE (2019): Reports REA1 (Industry), REA2 (Structural/Planning Interventions), REA3 (Transport), REA4 (Agriculture), REA5 (Social Science/Behavioural Interventions), https://app.box.com/s/kt5m8gugipky7lif3xyskjjwf3o5s1m6

UBA 2016: Guideline on Air Quality Plans, German Environment Agency, ISSN 2363-832X, August 2016. https://www.umweltbundesamt.de/publikationen/guideline-on-air-quality-plans.

Urban Agenda for the EU (2018): Code of Good Practices for Cities' Air Quality Plans, Part IV Inspiring Examples, produced within the Partnership on Air Quality - Urban Agenda for the EU. ISBN 9788894413540, https://ec.europa.eu/futurium/en/system/files/ged/cgp_for_cities_aqps_part_iv.pdf

J. Burns, H. Boogaard, S. Polus, L.M. Pfadenhauer, A.C. Rohwer, A.M. van Erp, R. Turley, E.A. Rehfuess (2020): Interventions to reduce ambient air pollution and their effects on health: An abridged Cochrane systematic review, Environment International, Volume 135, 2020, 105400, ISSN 0160-4120, https://doi.org/10.1016/j.envint.2019.105400

[7] In general, speed bumps are not (only) meant to reduce pollution, but to increase safety. Infrastructural measures are mainly to improve traffic flows, but could also reduce traffic in living areas (see: Changing the urban design of cities for health: The superblock model - ScienceDirect), although they could also increase emissions. Roadside vegetation will not reduce emissions, but could marginally reduce exposure to pedestrians and cyclists (see Life-Respira project – footnote 10)

[8] 30 km speed limits in Berlin proved to reduce exposure to NO_2 by PM10 2-4 µg/m^3 locally: Traffic management in Berlin, Germany — European Environment Agency (europa.eu); see for the effect of 100 km speed limit on highways: D'Elia et al., 2018, https://www.sciencedirect.com/science/article/abs/pii/S1309104217306529

limited, and such outcomes also depend on local circumstances. This complicates the inclusion of impacts of such local interventions in a coherent quantitative and multi-country modelling framework such as GAINS.

An exception is the measurement of the impact of low-emission zones on exposure and health impacts.[9] However, here (at least part of) the impacts are decreasing over time, since older vehicles will have to be replaced anyhow at the end of their lifetime. Also, for the impact of interventions such as planting trees and scrubs and the use of catalytic paint measurements studies are available, which show that their impact is not significant[10].

In general, promotion of cleaner vehicles and limitation of car traffic will be the most effective measures in reducing exposure to NO_2 and primary $PM_{2.5}$ in a city. Limitation of car traffic would also reduce non-tailpipe emissions, such as tyre-, break- and road-wear. Limited low emission zones and traffic circulation plans to reduce exposure at so-called hotspots could increase the exposure in other parts of the city. Emissions and average exposure (and total health damage) could even increase, if the circulation plan increases total mileage in a city. For $PM_{2.5}$, the average exposure in many cities depends largely on emission sources outside the city, such as industry, highways, shipping and agriculture (through secondary particles formed by ammonia emissions). The impact of traffic measures within a city will therefore only have a modest effect on the average exposure to $PM_{2.5}$ in a city.

City-level decision makers could still learn from sharing of experiences from other cities and from national and international experts and policy makers.[11] Effective interventions to reduce car use in cities differ among cities and countries. In some countries road pricing proved to be very effective, e.g. in London and Stockholm[12], while in other countries this measure was judged as politically unacceptable because it could increase social inequalities. In other countries infrastructural changes, such as providing more public transport, removing parking places and downgrading main roads prove to be more acceptable from a social policy point of view. Clearly, there is not one silver bullet solution for all countries.

Food

For transforming the food system, the most effective non-technical measure is to support a transition towards healthy plant-based diets and reduce dairy and meat consumption and production. This can be achieved by collaborative efforts to improve *food environments*[13] to make healthy and sustainable food options affordable, accessible, and acceptable. This could form a powerful way to reduce emissions of ammonia and methane. It would offer the opportunity for a structural shift towards less intensive farming, that would also contribute to biodiversity restoration, and improved water quality. Other relevant and effective measures related to emissions from food production are continued bans on agricultural waste burning, improved routines for mineral fertilizer application, and improved

[9] London ULEZ: expanded_ultra_low_emission_zone_six_month_report.pdf (london.gov.uk); Italy; D'Elia et al., 2009, https://www.sciencedirect.com/science/article/pii/S1352231009007675; Low-emission zones in Germany | Umweltbundesamt; Overview Transport and Environment: 2019_09_Briefing_LEZ-ZEZ_final.pdf (ams3.cdn.digitaloceanspaces.com);

[10] Fernando Martin, Pamplona study, Life-Respira project, LIFE 3.0 - LIFE13 ENV/ES/000417 (europa.eu)

[11] Position paper on Clean Air in Cities, draft document from the Expert Panel on Clean Air in Cities (EPCAC) under the Task Force on Integrated Assessment Modelling (TFIAM), to be published end 2024

[12] Has the London Congestion Charge Zone Improved Air Quality? (selectcarleasing.co.uk)

[13] This means the availability and visibility of (un)healthy food products in streets and shops

manure management practices. For more information on these three measures, see the 2017 report from IIASA on measures to address air pollution from agricultural sources.[14]

The recent TFRN-report Appetite for Change[15] shows how an effective mix of policy instruments could look like when changing the food system, including diets. Changing diets, if followed by reduced dairy and meat production, would reduce nitrogen losses and have co-benefits for nutrition quality and public health. The main message is to engage all stakeholders in the decision-making process and in policy evaluations in order to address unintended effects of policies. Recent farmer protests in Europe show how important this is. Farmers and rural communities require new economic incentives if industrial farming becomes restricted. An agreement with large feed and seed producers, food traders, supermarkets, and banks would also be needed.

Several (voluntary) bottom-up approaches to sustainable food systems are emerging at the local and regional level. However, large scale reductions in meat and dairy consumption are not yet visible in agricultural statistics. Nonetheless, there are significant differences in meat consumption across the UNECE region. These can partly be explained by differences in income, but also by cultural differences in diets. The latter suggests that promotion of recipes from countries with low meat diets (such as some Mediterranean and Nordic countries) could raise an appetite for change in broader parts of the UNECE.

The TFRN report shows that a policy target aimed at prescribing vegan or vegetarian menus would lead to relatively high societal costs due to a perceived loss of freedom to choose what to eat. Instead, stimulating partial vegetarian (demitarian) menus would be optimal from a societal costs point of view. They would achieve substantial reductions of nitrogen wastes, thereby reducing the need for costly farm level (technical) measures. The overall societal benefit of such mixed policy measures is higher than for measures excluding such diet changes. Nevertheless, the scientific consensus of the health impacts of too much meat consumption and of its impact on animal welfare, the nitrogen losses to the environment and its contribution to climate change is in several countries driving the need to develop national food strategies that affect dietary change. Awareness raising is a necessary first step for the acceptance of policies that affect dietary choices, but such a policy strategy will need to include regulatory or financial measures and be supported by research and innovation in sustainable food. For the moment, dietary change via labelling of food and via dietary guidelines seems to be relatively acceptable but has shown little effect so far. Some countries have gone further. Austria subsidized organic food and Denmark proposed in 2024 to introduce a carbon tax on livestock.[16] There are also emerging collaborative efforts between associations of diet advisors, universities, and food retailers to commercialize sustainable food and many retailers are setting plant/animal targets for their protein sales[17].

Conclusions

There is no silver bullet solution when it comes to the most effective non-technical measures and their

[14] IIASA report on measures to address air pollution from agricultural sources, 2017: https://iiasa.ac.at/web/home/research/researchPrograms/air/policy/SR11-AGRICULTURE-FINAL.pdf

[15] https://www.clrtap-tfrn.org/sites/clrtap-tfrn.org/files/Appetite%20for%20Change%20full%20report.pdf

[16] See e.g. https://edition.cnn.com/2024/06/26/business/denmark-cows-carbon-tax/index.html and for an earlier proposals: The effects of the Danish saturated fat tax on food and nutrient intake and modelled health outcomes: an econometric and comparative risk assessment evaluation | European Journal of Clinical Nutrition (nature.com)

[17] Kugelberg, S., Bartolini, F., Kanter, D.R., et al., 2021. Implications of a food system approach for policy agenda-setting design. Glob. Food Sec. 28, 100451. https://doi.org/10.1016/j.gfs.2020.100451

implementation. What is acceptable in one country or city will not always work in other countries or cities. E.g., road pricing seems to be more acceptable in Anglo-Saxon countries, but encounters protest elsewhere. Effective instruments aimed at individual behavioral change seem to encounter most societal and political resistance. Policies that involve a change in transport behavior seem to be less acceptable than measures to stimulate the use of cleaner vehicles. Wood burning and meat consumption seem to be regarded as human rights by many people, and non-technical measures in these fields often raise fierce political debate.

5. Modelling potentials, costs, and benefits of structural and non-technical measures

Discussions on structural changes have taken place over many years. The 2007 report of the TFIAM on the review of the original Gothenburg protocol already concluded: "*In addition to available end-of-pipe emission control measures, non-technical and local measures will be of increasing relevance, especially if multiple policy objectives are pursued.*"

This conclusion is still relevant and has become even more pertinent to be able to meet the long-term targets of the Air Convention. But how much could such measures contribute to a low pollution environment? How much would they cost compared to technical measures? What are their benefits?

Recent scenario modelling by CIAM with the GAINS model sheds some light on the first question. CIAM developed a 'LOW' scenario (i.e., application of Maximum Technically Feasible air pollution Reduction (MTFR) controls plus consistency with a Paris Agreement greenhouse gas emission pathway plus inclusion of structural changes as well as dietary shifts). They compared this with a MTFR scenario in which mainly end-of-pipe measures are used to reduce emissions. The LOW scenario shows further reduction of agricultural emissions of methane and ammonia compared to the MTFR scenario. Compared to the baseline, by 2030, almost 160 million more persons in the UNECE region could be living in areas where concentrations of fine particulate matter are below 5 $\mu g/m^3$, if emissions followed the LOW scenario. In the MTFR scenario this would be 110 million more).[18]

The climate community also delved into the issue of non-technical measures. The Sixth IPCC Assessment Report – Working Group III, 2022, p47 - gives an indication of the potential contribution of structural and behavioral "demand-side" changes to emission reductions of greenhouse gases. It shows that the potential contribution of dietary change (i.e. implementation of the healthy Willett diet)[19] could be as large as all measures to reduce residential fossil fuel use together. A reduction in fossil fuel use is linked to emission reduction of both greenhouse gases (CO_2) and air pollutants (particulate matter, SO_2 and NOx…). The same holds for dietary change towards less meat and more plant-based production that will reduce emissions of methane and N_2O, as well as of ammonia (an important precursor of the formation of secondary particulate matter). More specifically, the analysis shows that (non-technical) 'demand side' measures aimed at a shift from animal to plant based proteins could have the largest effects on greenhouse gas emissions, followed by demand side measures aimed at buildings and transport (such as less heating and less driving). In relative terms, by 2050, non-technical measures could potentially reduce greenhouse gas emissions from food production by around 40% (including methane and ammonia emissions) and energy use in buildings and transport by 25% (including the associated NOx-emissions).

All in all, both GAINS modelling and climate scenarios show a large emission reduction potential by non-technical measures in 2050. This explains the interest in the feasibility of including these types of measures into air quality policies as well as in the cost optimized scenarios developed with the GAINS model. To sum up, the expected benefits of including non-technical measures are:

[18] https://unece.org/sites/default/files/2024-05/Agenda%20item%20%282%29%20Draft%20policy%20brief%20health%20ecosystems.pdf

[19] Willett, W · Rockstrom, J · Loken, B · et al. *Lancet.* 2019; **393**:447-492; Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems (thelancet.com)

1. Non-technical measures will lead to lower air pollution, or to lower air pollution control costs to reach certain objectives than if estimated based on end-of-pipe measures alone.

2. Structural change could play a key role in further reducing emissions in sectors such as domestic wood combustion, transport and agriculture.

3. By reducing emissions of air pollutants and greenhouse gases simultaneously, non-technical measures will have larger (synergetic) reduction potentials than simple add-on controls that address mainly one pollutant.

4. Given policy developments in other areas (climate, energy, nutrient management, transport, agriculture, biodiversity, …) it is more prudent to consider other measures than only technical end-of-pipe techniques (Emission limit values or ELVs in the technical annexes). A switch to cleaner fuels and cleaner technologies, energy saving and energy efficiency action, structural changes in transport or agriculture, behavioral changes in diets, modal shift to public transport, etc. could prove to be more cost-effective than applying end-of-pipe technologies. This may reduce the relevance of setting stricter ELVs to further reduce emissions in the longer term.

In general, GAINS cost optimizations do not (yet) consider the potential of non-technical and local measures. GAINS has a focus on add-on technical solutions (measures with direct impact on the emission factors). Structural changes can be simulated by introducing changes in the baseline activity level projections (i.e., for energy, agriculture, etc.), as shown above in the comparison of the impacts of the LOW and MTFR scenario for human health. Such simulations require analyses using a set of linked European wide models, e.g. for energy use (PRIMES), agriculture (CAPRI) or transport (COPERT). Additionally, input from national and local experts on envisaged or potential structural changes in their country or city would be valuable.

There are still challenges to be faced when we want to include structural and behavioral changes in decision support models such as GAINS and in the cost optimization. Some of these challenges relates to modelling of emission reduction potentials:

- How to translate local experiences into reliable estimates of the measure implementation rates and potential emission reductions applicable for the whole UNECE domain?
- It should also be taken into account that while the implementation rates of end-of-pipe measures are predictable in modelling and verifiable (ex-post), the degree of application of measures aimed at behavioral change is less predictable or verifiable with reasonable certainty (i.e., measures aimed at a modal shift from private cars to public transport or the promotion of best practices in residential wood burning). This also hampers the estimation of the related costs.

Other modelling challenges relates more to the modelling of costs of the measures:

- The costs of integrated city-transport planning (e.g., a metro-connection to a new neighborhood) are difficult to attribute to air pollution, climate and urban accessibility, respectively. The same holds for the related benefits. Here, assumptions made for the attribution of costs to the various goals, could have a large impact on the relative cost effectiveness of such structural measures for reducing air pollution.
- Further, what are the undesired welfare effects of behavioral changes? To be consistent, such welfare effects should be included as ‘costs’ in a GAINS model optimization. Examples of relevant negative welfare effects that are yet to be estimated are effects on leisure time,

comfort, level of services, or degree of self-determination (i.e., freedom of choice). Off course, some NTMs might imply desired welfare effects (in addition to the desired effects on air quality and deposition) that can balance out the undesired. Examples are effects on health from active travel modes, and reduced travel time in congested cities. Several studies have made theoretical assumptions on how to monetize non-monetary costs, but more development would be beneficial.[20]

Emerging challenges related to modelling of emission reduction potentials and costs are to find answers to questions like:

- How much additional effect of non-technical measures is needed to meet WHO-guideline values or critical loads after all technical measures have been implemented? How much traffic reduction or reduction of livestock would be required and where?
- What will be required in terms of public expenses for enforcement and how much public money will be needed to convince citizens and industries to adapt their consumption choices and behavior? Whilst this is not an important cost item for technical measures, it may well represent a considerable share of overall costs to reach specific structural and behavioral changes.
- What is more cost-effective: additional local measures or additional national and international measures?
- How high should financial incentives be to reach sufficient behavioral change? To define the optimal level for a levy that covers the external costs created by pollution linked to a given choice or behavior, also the (policy) costs of implementing the measure in question needs to be known, as well as the behavioral resistance by those who needs to change their behavior.

In addition, more efforts are needed to understand the perceived welfare effects of structural changes and individual behavioral change. Both diets and domestic wood combustion are household decisions and incentives from the public sector to change these behaviors are often met with strong opposition from citizens, despite their cost-effectiveness.[21]

[20] C. Carnevale, et al. Evaluating economic and health impacts of active mobility through an integrated assessment model - ScienceDirect, 2018; and: S. Åström. How to express socio-economic costs of pro-environmental behavioural change? - a suggestion for Cost-Benefit Analysis purposes (2024) IVL report

[21] E.g. the potential emission reductions and associated health benefits of changes in wood burning behavior can be very significant. For example, the U.S. Environmental Protection Agency in a study estimating the benefit per ton of reducing PM2.5 precursors from seventeen sectors has estimated that health benefits of reducing PM2.5 emissions from the residential wood combustion sector are on the order of $400,000 per ton. https://www.epa.gov/sites/default/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf

6. Political and social challenges of non-technical measures

As for all emission control options there are certain challenges and limitations affecting successful and effective implementation of non-technical measures. In this chapter we have grouped these challenges and limitations into challenges and limitations in the political and social spheres.. Financial challenges are off-course also relevant but require little clarification. Some of the challenges are like those of the modelling challenges mentioned above. But it is important to stress that non-technical measures are not only a challenge for modellers, but special attention is also needed by decision makers when contemplating implementing them.

Political challenges and limitations

The political challenges and limitations are different between different 'types' of non-technical measures. For the non-technical measures that are technical or hybrid in their nature but not based on ELVs (such as building insulation, installing solar panels, redesign of products, behavior-inducing technologies), much of the political challenges and limitations relate to coordination barriers between policy spheres (to borrow language from innovation system sciences)[23]. For these types of non-technical measures, coordination between climate, energy, and air pollution policy makers, departments, and agencies are important for successful implementation. The importance of coordination between these policy spheres has long been stressed but can be considered as especially important for these technical and hybrid non-technical measures. Here we assume that the policy makers from different spheres are aware of the co-benefits of these technical and hybrid control measures. If this assumption is erroneous, it will also be important that the coordination is complemented by efforts to increase co-benefit awareness between spheres.

Furthermore, a challenge for all types of non-technical measures is that the effective policy instrument will vary and most often it is likely that policy instruments must be combined for effective implementation. As an example, road charging (an economic instrument) benefits from being combined with awareness raising (social instrument). These instruments will also have to be aimed at various types of actors in the value chain of a product or service (energy & raw material providers, industrial manufacturing, transport providers, industry networks, final consumers). In general, for regulatory instruments the effectiveness is below but rather close to 100%, although often assumed to be 100%. For pricing the effectiveness depends on income- and price sensitivities, and will thus differ among countries and targeted behavior. Voluntary tools (information and infrastructural investments) will not have a significant effect if not combined with regulation or pricing. However they are a necessary precondition for the acceptance regulation and pricing,

In addition, it is not as straightforward to predict implementation, compliance and effectiveness of several non-technical measures. Effectiveness of road charging schemes for example, must be evaluated through counterfactual analysis of how traffic intensity could have evolved if the road charge had not been introduced, or via comparison with past traffic intensities. But traffic intensities are a function of several parameters that might change during the time of implementation. Another impediment for the prediction is the challenge related to the large number of emitting units affected by the measure. Changes in driving patterns will be the product of several millions of car drivers changing ever so slightly, and incentives for clean burning will also in some countries affect millions of stove users. A final challenge for predictability to overcome is the human response. Humans are after all famous for not behaving like 'The economic man' (*Homo Economicus*). Many other psychological factors, such as preferences affect the outcome, as well as the level of knowledge of all impacts of a given behavior. For non-technical measures aimed at companies, stakeholder market power can for

[23] Åsa Löfgren and Johan Rootzén, "Brick by Brick: Governing Industry Decarbonization in the Face of Uncertainty and Risk," Environmental Innovation and Societal Transitions 40 (2021): 189–202, https://doi.org/10.1016/j.eist.2021.07.002.

example affect the response to changes in incentives.

Moreover, for non-technical measures it is less easy to prove their cost-effectiveness if applying a 'welfare economic' lens. This is because there are *non-monetary costs* involved. Examples of such welfare aspects include longer traveling time, less comfortable indoor temperatures, loss 'choice autonomy', etc. There are of course non-monetary benefits involved, but these are largely already incorporated in the decision support modelling delivered to the Air Convention through the monetization of positive effects on human health.

All in all, regarding political challenges and limitations, it can be recommended that for non-technical measures pragmatic policy choices must be made. These choices must acknowledge that *public acceptance* of such measures has limitations, that long-term goals cannot be realized at once, and that one should be satisfied with gradual change in the right direction.

Social challenges and limitations

Implementation of non-technical measures has challenges and limitations that vary in nature compared to challenges and limitations of implementing technical measures. Some challenges are rather similar, like investments and maintenance costs needed to align social drivers facilitating the desired measure, such as costs for construction of bicycle paths to facilitate a modal shift from cars to bicycles. Other challenges are rather different, such as establishing knowledge on where there are populations with demographic and cultural prerequisites for pro-environmental behavioral interventions.

Further, it is important to recognize that non-technical measures that imply a challenge towards current norms in society will be difficult to enforce. One of the reasons for this can be the fact that pro-environmental information campaigns often send a message that runs counter to social norms (such as consumerism and individualism) and price signals.[24] Further, the policies will have to consider characteristics such as cost-effectiveness, total costs, cost distribution, moral implications, and diversity of possible consequences.

For climate policies (at least), Zvěřinová, Ščasný and Kyselá (2013)[25] suggest that the amount individuals would be willing to pay increases if the policy is effective and has a high probability of success. Also important is that ancillary benefits (such as air pollution reduction) are well identified. Potential revenues from the project should be reinvested in environmental protection and the polluters pay principle should be followed. Further, policy instruments such as subsidizing pro-environmental products and services are preferred to taxing out polluting products and services.

The available evidence and theories, briefly described above, but described in more detail in Åström (2024)[26], suggests that policies aimed at individual behavioral change are likely acceptable if the individual is:

- aware and concerned about the problem to be solved by the policy,

[24] Susan Owens and Louise Driffill, "How to Change Attitudes and Behaviours in the Context of Energy," *Energy Policy* 36 (2008): 4412–18, https://doi.org/10.1016/j.enpol.2008.09.031.

[25] Iva Zvěřinová, Milan Ščasný, and Eva Kyselá, "What Influences Public Acceptance of the Current Policies to Reduce GHG Emissions?," 2013., 10.13140/RG.2.1.1080.0161/1

[26] S. Åström. How to express socio-economic costs of pro-environmental behavioural change? - a suggestion for Cost-Benefit Analysis purposes (2024) IVL report

- aware of the most tangible consequences of the problem if not solved,
- feel a moral obligation to contribute to the solution,
- perceive the proposed policy as fair and environmentally effective,
- trust the institution from which the policy proposal origins.

In general, policy proposals seem to be discouraged if they imply considerable influence on the individuals' own behavior and if the policy would restrict personal freedom.

7. Conclusion

This document gives a concise overview of the potential emission reductions from structural changes and non-technical measures that can be considered during the Gothenburg protocol revision. Further contributions are foreseen from TFRN, TFTEI and the Parties.

There is still much to learn from each other. Effective interventions to induce behavioral change differ among countries. This was shown at the example of road pricing to reduce car use in cities, which proved to be very effective in some countries, while in other countries this measure was not acceptable due to its expected social consequences. In some countries, infrastructural changes, such as more public transport, removing parking places and narrowing main roads proved to be more acceptable than road pricing policies. This shows that there is no one silver bullet.

Measures with the largest potential impact in terms of emission reductions, such as dietary change, also seem to encounter most resistance among the public and farmers. Restriction of wood burning receives much opposition in all countries, although the health benefits are clear.

There are also challenges to quantify *ex ante* the potential benefits and costs of various non-technical measures, both in terms of impacts on emissions, health and the environment, and in terms of costs of implementing and enforcing such measures. Country culture and history are likely to play a role in the uptake and acceptability of a given non-technical measure. This difficulty, as well as the fact that costs and benefits are likely to differ between countries and locations, presents a challenge also for including non-technical measures into optimized policy scenarios, as modelled for example in GAINS.

For the Gothenburg Protocol revision, it could be discussed whether a less optimized intermediate approach could consist in estimating how much livestock and traffic densities would be permissible and how much wood could be burned in the residential area after all technical GAINS measures have been implemented so that WHO air quality guidelines can be met.