*This project is co-financed by the European Union and the Republic of Turkey*

# Technical Assistance for Improving Emissions Control

Service Contract No: TR0802.03-02/001
Identification No: EuropeAid/128897/D/SER/TR

# Final Report – Part 2: Main Technical Results

**21 October 2012**

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# Final Report – Part 2: Main Technical Results

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| | | | | | | | |

# CONTENTS

## ANNEXES



## TABLES

## FIGURES

# PROJECT SUMMARY DATA

| | |
|---|---|
| Project Title:<br>TA for Improving Emissions Control | Contract Identification Number:<br>EuropeAid/128897/D/SER/TR |
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# GLOSSARY OF ACRONYMS

| | |
|---|---|
| AMR | Aviation, marine (domestic) and rail transport |
| BAT | Best Available Techniques |
| BREF | BAT Reference Document |
| CAFE | Clean Air for Europe |
| CAPEX | Capital cost |
| CBA | Cost-Benefit Analysis |
| CLRTAP | Convention on Long-Range Transboundary Air Pollution |
| CoBoard | Inter-Ministry Coordination Board |
| CoCom | Inter-Ministry Coordination Committee |
| CNG | Compressed natural gas |
| CV | Calorific value |
| DB | Data-base |
| EC | European Commission |
| EF | Emission factor |
| EMS | Emissions management strategy/strategies |
| EU | European Union |
| EU-27 | The 27 Member States of the EU |
| Fert | Fertiliser application to land |
| FGD | Flue gas desulphurisation |
| GAINS | Greenhouse Gas and Air Pollution Interactions and Synergies Model developed by IISA |
| GB | EMEP/EEA Emissions Inventory Guidebook |
| GDP | Gross Domestic Product |
| GHG | Greenhouse gas |
| GWh | Giga Watt-hour |
| HGV | Heavy goods vehicle |
| IA | Impact Assessment |
| IC | Industrial combustion (emissions) |
| IED | Industrial Emissions Directive |
| IIASA | International Institute for Applied Systems Analysis |
| IP | Industrial process (emissions) |
| IPCC | Intergovernmental Panel on Climate Change |
| IPPC | Integrated Pollution Prevention and Control |
| ISO | International Standards Organization |
| LCP | Large Combustion Plant |
| LCPD | Large Combustion Plant Directive |
| Live | Livestock rearing |
| LTO | Landing and Take-off cycle |
| M&T | Monitoring and Targeting |
| MoA | Ministry of Agriculture |
| MoD | Ministry of Development |
| MoENR | Ministry of Energy and Natural Resources |

| | |
|---|---|
| MoEU | Ministry of Environment and Urbanisation |
| MWe | Mega Watt electrical |
| MWth | Mega Watt thermal |
| NA | Not applicable |
| NE | Not estimated |
| NCCAP | National Climate Change Action Plan 2011 - 2023 |
| NEC | National Emission Ceilings |
| NECD | National Emission Ceilings Directive |
| NFR | Nomenclature for Reporting |
| NH3 | Ammonia |
| NMVOC | Non-methane Volatile Organic Compound |
| NOx | Nitrogen oxides |
| NPV | Net Present Value |
| NVZ | Nitrate Vulnerable Zone |
| $O_3$ | Ozone |
| O&M | Operating and maintenance |
| OPEX | Annual operating and maintenance costs |
| PM2.5 | Particulate material having an aerodynamic diameter of 2.5 μm or less |
| PV | Present Value |
| PVR | Petrol Vapour Recovery |
| RC | Residential combustion (emissions) |
| RIA | Regulatory Impact Assessment |
| S | Sulphur |
| SA | Staged Air |
| SCLF | Sulphur Content of Certain Liquid Fuels Directive (99/32/EEC) |
| SCR | Selective Catalytic Reduction – a technique for NOx emissions abatement |
| SNCR | Selective Non-Catalytic Reduction – a technique for NOx abatement |
| SO2 | Sulphur Dioxide |
| TA | Technical Assistance |
| TEİAŞ | Turkish Electricity Transmission Corporation |
| ToR | Terms of Reference |
| TurkStat | Turkish Statistical Institute |
| UK | United Kingdom |
| USD | US Dollars |
| UV | Ultra-Violet radiation |
| WaM | With Additional Measures scenario for emissions projection |
| WHO | World Health Organization |
| WM | With Measures scenario for emissions projection |
| WoM | Without Measures scenario for emissions projection |

# EXECUTIVE SUMMARY

The TA Project 'Improving Emissions Control' was undertaken with the objectives of (i) helping to determine national emission ceilings for Turkey of the pollutants $SO_2$, NOx, NMVOC and $NH_3$ referred to in the NEC Directive (ii) prepare a regulatory impact analysis of NECD implementation and (ii) prepare guidelines for updating the NECD emissions inventory and emissions projections. It was implemented over the period 15 March 2011 to 14 November 2012.

A national inventory for the emissions in Turkey of the NCED pollutants was prepared for the period 1990 – 2010. It indicates that $SO_2$, NOx, NMVOC and $NH_3$ emissions have risen by 55%, 63%, 17%, and -2%, respectively, since 1990. An inventory guideline for the use of MoEU staff has been prepared and passed over to MoEU. The guideline should enable MoEU to update the inventory annually in future and make improvements to it.

As the first systematic inventory in Turkey to cover NECD pollutants only, there are aspects where significant improvements may be made in future. To a substantial extent, improving the inventory will require that institutional mechanisms are put in place, and implemented, to better enable the flow of relevant information to MoEU from other Ministries. Of the areas identified for potential improvement, the priorities are:

- Having quality assured, measured values for the Sulphur content of lignite and coal fuels that are consumed in Turkey.
- Accurate information on the type of emissions abatement equipment installed and operated at large combustion plants (LCPs) in the electricity generation, cement and iron & steel sectors; and information on its emissions control performance ($SO_2$, NOx).
- Comprehensive and systematic measurements of emissions from LCPs in the above sectors, to feed into a comprehensive point-source emissions database.
- Road transport vehicle-km data for a number of years and vehicle types.
- Differentiation of the consumption data for 'petroleum' liquid fuel given in the national energy balance tables into 'petrol' (gasoline), 'diesel' (gas oil), 'aviation fuel' and 'heating' or 'burning oil' – in particular for road transport.
- A country-specific estimation of relevant activity data for VOC solvent use in Turkey and checking whether the emission factors used for residential wood combustion are appropriate.
- Institutional mechanism/s to ensure consistency between the NECD emissions inventory (MoEU) and the GHG emissions inventory (TurkStat).

Subject to the uncertainties indicated above, the electricity generating sector is identified as the principal source of $SO_2$ emissions in 2010, contributing 60% of the 3,260 ktonne national emission; and a major source of NOx emissions, contributing about 34% of the 930 ktonne national emission. Again for 2010, combustion in other industry contributed about 23% of the national $SO_2$ emission, 11% of NOx and 44% of the NMVOC national emission of 700 ktonne. Road transport contributed about 40% of the national NOx emission and 13% of NMVOC emissions; whilst residential and commercial combustion contributed about 17% of national $SO_2$ emissions and 38% of national NMVOC emissions. Agriculture accounted for 98% of the national $NH_3$ emissions load of 515 ktonne in 2010, split between livestock rearing and fertiliser use in the ratio of about 2:1.

NECD pollutant emissions to air cause problems for human health (morbidity and premature death), and adversely affect agricultural productivity, the natural and the built environments. Other EC funded studies (outside of the present project) suggest that the marginal damage costs of NECD pollutant emissions from Turkey are about €3,640/ tonne $SO_2$, €2,280/ tonne NOx, €5,450/ tonne $NH_3$ and €10/tonne NMVOC. Emissions reduction therefore results in significant gross economic benefits – benefits that are usually not recognised by industry etc when subjecting investments to financial appraisal.

Emission management strategies targeted at the NECD pollutants were prepared for each of these sectors (and others) adopting measures based on national policies and internationally proven techniques. Each sectoral EMS comprised one or more of four complementary elements:

(i) Primary policy measures whose implementation has a direct and purposeful impact on one or more NECD pollutant emissions, e.g. flue-gas desulphurisation at LCPs

(ii) Secondary policy measures whose primary goal is not to reduce NECD pollutant emissions *per se*, but whose implementation have significant impacts, e.g. Turkey's adoption of National Climate Change Action Plan 2011-2023 and its goals for expanding electricity generation from renewable, zero-emission sources

(iii) Efficiency measures adopted by private sector firms especially, driven by competitive pressures regarding costs, prices and market positioning; and

(iv) Other policy measures such as funded Outreach Programmes and economic instruments that are designed to influence the behaviour of producers and consumers.

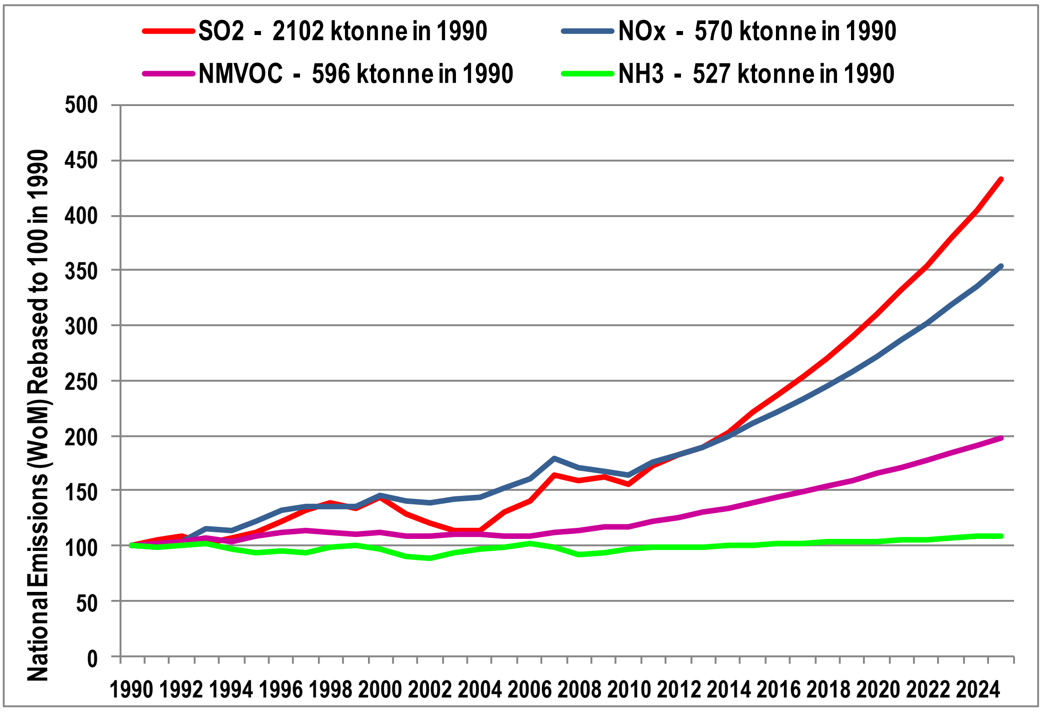
Where appropriate and where indicative costs data were available, the specific emissions control measures identified in the sectoral EMS were subjected to a cost-benefit analysis (CBA) utilising the above marginal costs data to quantify benefits. The estimated benefits of all emissions control techniques subjected to CBA substantially exceeded estimated costs with the exception of the following:

- SCR for downstream NOx control at LCPs: under the By-Law that transposed the LCPD the technique may still be required to meet future NOx emission limits for solid-fuel fired plants having an input thermal capacity of 500 MWth or more.
- Control of solvent use and limiting the solvent content of specific paint and other products (NMVOC control). However, a primary reason for controlling NMVOC emissions is to protect the stratospheric ozone layer, the economic benefits of which are not included in the €10/tonne NMVOC marginal damage cost.
- PVR techniques, especially Stage II PVR, though they may be required to help protect the stratospheric ozone layer.

Three scenarios for emissions growth from 2011 to 2025 were formed and evaluated: the *Without Measures (WoM) scenario*, which allows for population and economic growth but doesn't propose any emissions management measures other than those that are already the norm; the *With Measures (WM) scenario* that accommodates some national policies for emissions management and control – a partial EMS; and the *With Additional Measures (WaM) scenario*, which assumes the application of all EMS in full. An emissions projections guideline was prepared and has been handed over to MoEU staff for their use.

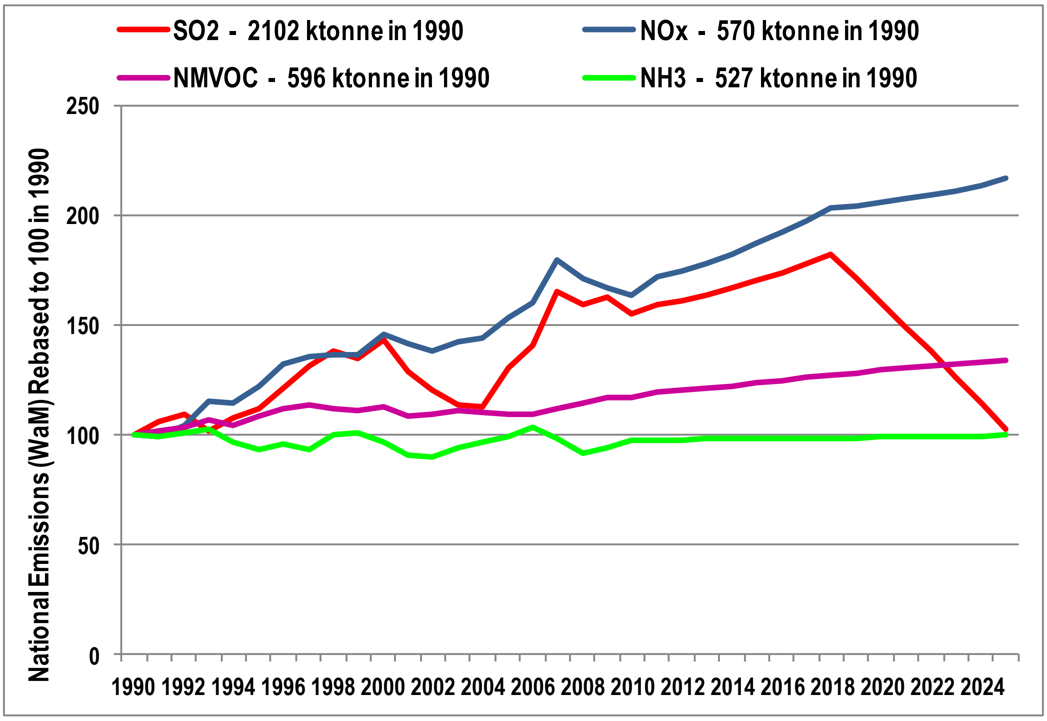
The projections for the WoM Scenario show significant emissions growth from 2010 to 2025: see the chart below, in which all national emissions are rebased to 100 in 1990. Projected national emissions in 2025 in the WoM scenario are estimated as follows: $SO_2$ 9,090 ktonne, NOx 2,020 ktonne, NMVOC 1,180 ktonne, and $NH_3$ 575 ktonne.

**Historic and projected (WoM) national emissions growth (rebased to 100 in 1990)**




However, the WM and especially the WaM scenarios significantly moderate emissions growth: see chart below.

**Historic and projected (WaM) national emissions growth (rebased to 100 in 1990)**



Under the WaM scenario – see the chart above, in which all national emissions are again rebased to 100 in 1990 - the $SO_2$ growth trend is reversed from 2019 as a result of retrofitting FGD at large combustion plants. For the WaM scenario, total national emissions in 2025 are estimated as follows: $SO_2$ 2,160 ktonne, NOx 1,240 ktonne, NMVOC 800 ktonne, and $NH_3$ 530 ktonne.

Possible national emission ceilings for Turkey for 2025 have been based on the WaM emission projection results, moderated to take account of the CBA findings, the possibility of faster GDP growth and an unchanged fuel-mix for residential and commercial combustion. However, the projections are subject to a number of significant planning and other uncertainties regarding EMS implementation – additional to the inventory uncertainties. The possible national emission ceilings identified below, therefore, must be regarded as interim values pending a thorough review by the Government of the Republic of Turkey.

| Basis for National Emission Ceilings | Possible National Emission Ceilings (ktonne) | | | |
|---|---|---|---|---|
| | NOx | $SO_2$ | NMVOCs | $NH_3$ |
| 1 WaM : full EMS | 1240 | 2160 | 800 | 530 |
| 2 WaM: high GDP variant | 1310 | 2340 | 850 | 530 |
| 3 WaM: minus SCR/SNCR | 1360 | 2160 | 800 | 530 |
| 4: WaM: constant fuel-mix for residential heating | 1240 | 2240 | 890 | 530 |

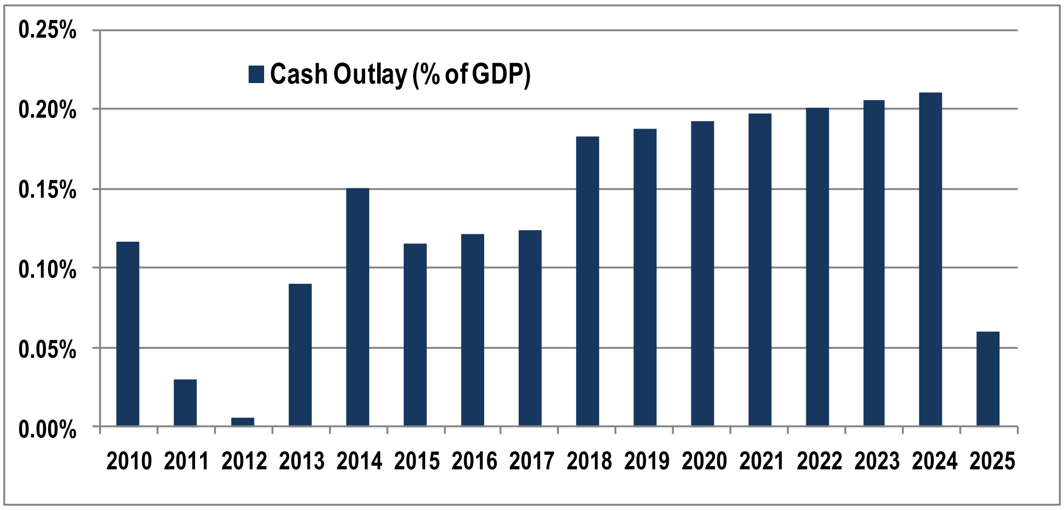
The Regulatory Impact Assessment (RIA) has estimated the total gross benefits and costs of applying the full EMS to meet the first of the above NEC. Comparing the emissions projections under the WaM scenario with those under the WoM scenario, annual gross benefits (at 2010 price levels) increase progressively to reach over €25 billion/y in 2025. *Cumulative gross benefits* from 2011 to 2025 (excluding those resulting from emissions control in the cement and iron & steel sectors) *are estimated to be more than €146 billion*. Most of the benefit results from $SO_2$ emissions control; and most from FGD applied in the electricity generating sector.

The cumulative costs to 2025 (at 2010 price levels) of emissions control to meet the identified possible ceilings are estimated at over €20 billion with the full EMS in place: they exclude the costs to be incurred for $SO_2$ and NOx emissions control in the cement and iron & steel sectors, which may be significant but were indeterminate given the data available to the Project.

The overall estimated cost includes €5.4 billion for NOx control using SCR at lignite and coal-fired electricity generation stations. However, the results of economic appraisal (CBA) suggest strongly that SCR fails the cost-benefit test and may be regarded as beyond BAT in Turkey. The national emission ceiling value for NOx of 1,360 ktonne, therefore, may be the more appropriate value to adopt for Turkey. *Total implementation costs* therefore may be *in excess of €15 billion* instead of €20 billion.

Most EMS implementation costs lie in the electricity generating sector; hence affordability analyses have been undertaken. Comparing the estimated annual cash expenditure (capital investment and O&M) in the electricity generating sector with projected real national GDP suggests that the EMS for the electricity generating sector is affordable at a national level: annual cash outlays are unlikely to exceed 0.21% in any year of the projection period: see chart below.

**Yearly cash outlays on the electricity generating sector EMS as a percentage of national GDP**




At the consumer level, assuming the costs of emissions control are spread evenly across all electricity users, it is likely that households and industrial consumers would see price increases of about 3% and 4.5% respectively over the projection period. This level of price rise is judged to be affordable.

Based on the analyses undertaken in this Project, NECD implementation should be advantageous to Turkey and its people. However, there are a number of significant aspects regarding the preparation of the emissions inventory and EMS-based emission projections where clarifications and improvements are needed prior to the development of Government-led proposals for National emission ceilings.

Making the necessary clarifications and improvements will to a large extent depend on the extent to which institutional barriers to the effective flow of relevant information may be overcome. This is a complex issue whose resolution will depend on the involvement of the highest levels of Government: the proposed inter-Ministerial Coordination Board, to be established under a Prime-Ministerial Decree, is a potentially ideal mechanism for overcoming the institutional barriers.

## Recommendations

The proposed Coordination Board (CoBoard) should be established as soon as possible under the effective leadership of an Under-Secretary from the MoEU. The appointed Under-Secretary should become the ‘Champion’ for implementing the NECD in Turkey, the formulation of credible, binding national emission ceilings and the establishment of practicable programmes of measures to enable Turkey to comply with those ceilings. CoBoard should play a vital role in:

- Coordinating the transposition process;
- Enabling the flow of relevant data and information between Ministries;
- Resolving significant uncertainties regarding the emissions inventory compilation, emission management strategies and emission projections in particular; and
- Overseeing a review of the possible NEC and the formulation of an official draft proposal of the Government of Turkey for National Emission Ceilings ($SO_2$, NOx, NMVOC and $NH_3$).

Once established, CoBoard and its working groups should be the principal mechanism whereby MoEU can resolve the identified uncertainties. Priority issues recommended for CoBoard attention are identified in the Table below.

| Sector | Priority Issue for CoBoard Attention | Report Sections |
|---|---|---|
| Electricity Generation, Cement and Iron & Steel Production | Sulphur content of solid fuels – lignite and coal | 6.5.5/5.10 |
| | Measured, source-specific emissions data | 6.5.6/5.10 |
| Electricity Generation | Reliability of the forecast national electricity demand | 6.5.2 |
| | Growth in electricity generation from zero-emission sources (hydro, wind, geothermal, nuclear, solar) | 6.5.3 |
| | Fuel-mix employed – domestic lignite, imported coal, imported natural gas – and any constraints that may apply | 6.5.4 |
| | SCR for NOx emissions control at lignite and coal-fired stations | 6.5.7 |
| | FGD performance at lignite-fired stations | 6.5.8 |
| | NOx emissions from lignite-fired stations | 6.5.8 |
| | Potential opt-out of lignite-fired stations from transposed LCPD | 6.5.9 |
| Industrial Combustion | Industrial classification and characterisation to provide a basis for the preparation of an EMS of appropriate detail for each sector | 6.5.11 |
| Residential Combustion | National strategy for heating energy supply regarding (i) fuel mix (ii) promoting the use of energy efficient appliances and (iii) improved building insulation | 6.5.13 |
| Road Transport | More comprehensive data regarding (i) the numbers of heavy goods vehicles (ii) vehicle-kilometre data for different vehicle types and (iii) diesel/petrol fuel split | 6.5.14 |
| | Options for a more aggressive approach to limiting NOx and NMVOC emissions | 6.5.14 |
| All | Consistency between the NECD and GHG emission inventories | 2.1.2 |

At an appropriate time, when sufficient information has been received from other Ministries and major uncertainties have been resolved, it is recommended that the MoEU should:

1. Update the NECD emissions inventory, to include 2011 as the latest year (1990-2011), following the guidance contained in the '*Emissions Inventory Guideline' prepared by the TA Project*; and
2. Develop a set of 'activity' data and 'emission factors' for the period 2012 to 2025 and prepare emission projections (2012-2025) following the guidance contained in the 'Projections *Guideline' prepared by the TA Project*. *All stakeholders must participate fully* in this process.
3. Once the emission projections for 2012-2025 have been prepared, MoEU, through CoBoard, should initiate a review of the suggested possible national emission ceilings for Turkey of the NECD pollutants $SO_2$, NOx, NMVOC and $NH_3$.

CoBoard should then establish a consensus amongst stakeholders as to the draft NEC values that the Government may propose to its international partners. When negotiating with its international partners it is strongly recommended that the Government raise the issue of Turkey's potential emissions growth beyond 2025 (as a fast-developing, middle-income country) as a factor when setting binding national emission ceilings for Turkey.

# 1 INTRODUCTION: BACKGROUND, OBJECTIVES AND SCOPE

## 1.1 Project Background

Air pollutants such as sulphur dioxide ($SO_2$), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOC) and ammonia ($NH_3$) adversely affect human health[1]. Increasingly aware of the problems caused by these pollutants, whose impacts are not confined to but cross national boundaries, competent authorities in many countries around the world have made improvements in human health central to their air quality management policies, strategies and plans. The Convention on Long-Range Transboundary Air Pollution (CLRTAP), which Turkey has ratified and the Gothenburg Protocol (which Turkey has not signed) are important manifestations of this shared, international concern.

In the EU the concerns for the impacts of air pollutants on human health are further embodied in the Clean Air for Europe (CAFE) Directive (2008/50/EC) concerning ambient air quality, and a number of Directives regarding emissions control (see Annex 4). Furthermore, the EU's National Emissions Ceilings Directive (NECD, 2001/81/EC) has set national ceilings for $SO_2$, NOx, NMVOC and $NH_3$ (the NECD pollutants) for each EU Member State[2].

The Republic of Turkey has taken many parallel steps in recent years regarding air quality management, at an increasing pace since its formal acceptance as a candidate country to join the EU. It has embarked on a process of screening and approximating its environmental legislation in readiness for EU membership, one aspect of which is the transposition of the NECD.  Co-financed by the European Union and the Republic of Turkey, the 'Improvement of Emissions Control' Project was designed to assist Turkey's Government to transpose the NECD. It has comprised two components: (i) Twinning, with a focus on the transposition process and capacity building within the Ministry of Environment and Urbanisation (MoEU, formerly MoEF) and (ii) Technical Assistance (TA) with a focus on providing technical support in a number of important areas. The MoEU was the main beneficiary and executing agency for both components, providing also the coordination with the many involved stakeholders – see Annex 1.

## 1.2 Project Objectives and TA Purpose

The overall objective of the 'Improving Emissions Control' Project was, '*to improve the environmental conditions in Turkey by implementation and enforcement of the EU environmental acquis in the frame of ambient air quality*'.

The specific purpose of the TA Component, as defined in the ToR, was, '*To help the determining National Emission Ceilings of Turkey for pollutants which referred in the NEC Directive by preparing emissions inventory, dispersions of pollutants, cost-benefit analysis, regulatory impact analysis and guidelines for the effective usage of methodologies and models for the inventory and projections*'.

## 1.3 Duration of TA Project Component

The Technical Assistance Component was undertaken over the period 15 March 2011 to 14 November 2012.

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[1] Even more serious health problems may arise from the emissions to air of fine particulate material ($PM_{2.5}$). Also: $SO_2$, NOx and $NH_3$ may contribute to acidic precipitation; NOx and $NH_3$ may contribute to surface water eutrophication; and NMVOC emissions contribute to tropospheric ozone depletion.

[2] It is likely that this Directive will be amended in future to include emission ceilings for $PM_{2.5}$

## 1.4 Objective Results of the TA Project Component

The TA Project Component aimed to achieve, and did achieve the following major results:

1. National emission inventory for $SO_2$, NOx, NMVOC and $NH_3$ – this was prepared for the period 1990-2010, together with recommended priorities for future improvement in methodology and data.
2. National emission projections for $SO_2$, NOx, NMVOC and $NH_3$ for various scenarios. These were prepared for the period 2011-2025 assuming three scenarios based on (i) projected population and economic growth/development and (ii) various emissions management strategies. The three scenarios examined were: Without Measures (WoM), With Measures (WM) and With Additional Measures (WaM).
3. Emissions management strategies (EMS) for those sectors mainly responsible for NECD pollutant emissions in Turkey. These have been reported in full for the WaM scenario.
4. Cost-benefit analysis (CBA) of emission reduction and control methods potentially required to implement the NECD in Turkey. Whilst a focus of CBA was on emissions control at large combustion plants (>50MWth, LCPs) in the electricity generating sector, it addressed all other relevant and appropriate sectors subject to the availability of costs data.
5. Identified possible national emission ceilings for $SO_2$, NOx, NMVOC and $NH_3$. Possible ceilings for each pollutant were prepared for the years 2020 and 2025, based on the emission projections for the WaM scenario and a consideration of CBA and other factors.
6. Regulatory impact assessment (RIA) of NECD implementation. Focusing on the overall costs and benefits, this was prepared assuming 2025 as the possible date for Turkey to comply with the NECD (see Annex 5).
7. Guidelines for the effective use of methodologies and models for the emissions inventory and emission projections. These were prepared to assist MoEU to update and revise in future the national emissions inventory and emission projections for $SO_2$, NOx, NMVOC and $NH_3$.

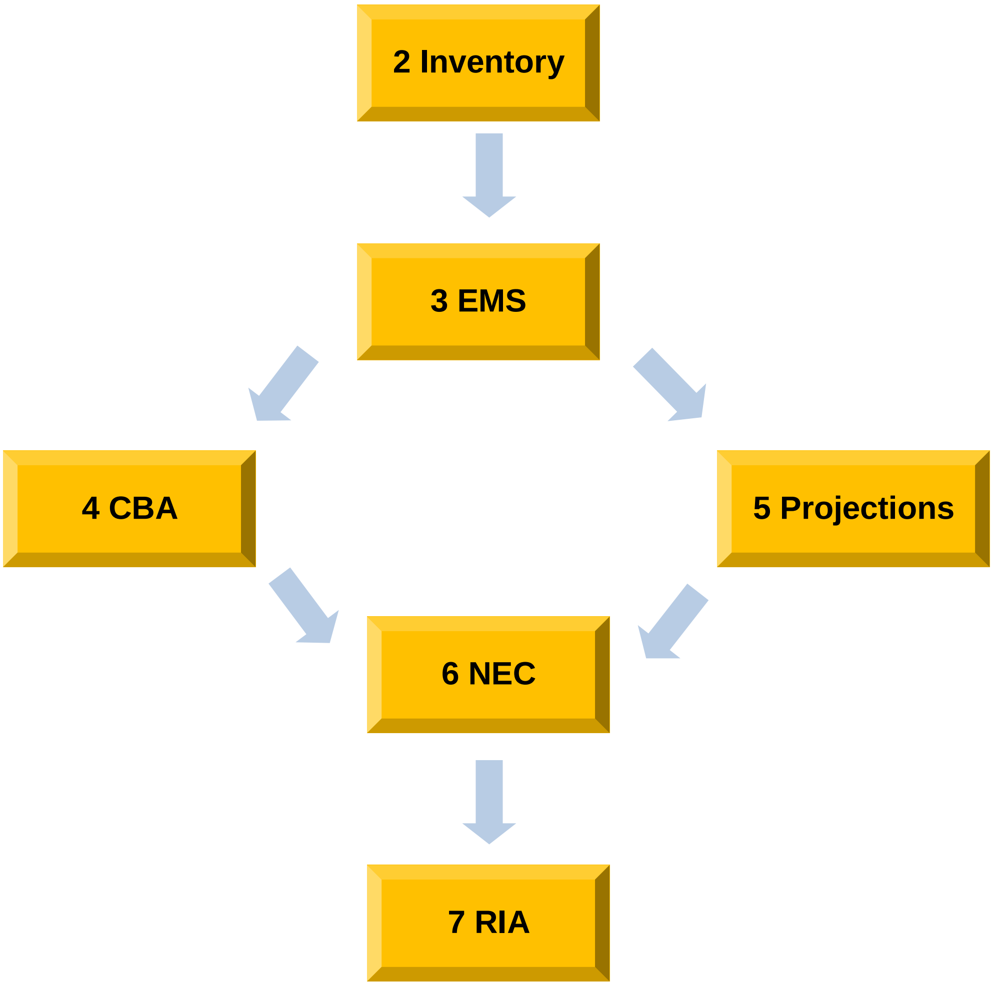
Comprehensive Technical Reports were prepared to present the above results and findings of other activities and the present Final Report is derived from them: the other Reports should be consulted if further details are required. A full listing is provided in Annex 2. If required, electronic copies of these other Reports may be obtained on application to the Air Management Department of the Directorate General Environmental Management, within MoEU.

## 1.5 Final Report Structure

Following this introductory Section the Report comprises six technical Sections – and a concluding Section that makes a number of strategically important recommendations. Figure 1-1 provides Section numbers and a simplified illustration of the inter-relationship between the six technical Sections.

Section 2 provides an overview of the NECD emissions inventory preparation, the results and priority areas for future improvement. The inventory results provide a good indication as to which sectors are mainly responsible for NECD pollutant emissions.

**Figure 1-1 Simplified relationship between the major activities / sections**




Section 3 summarises the EMS identified for each of the significant sectors. The EMS draw on national policy goals and commitments and international experience of effective measures for NECD pollutant emission reduction and control. Section 4 presents the results of CBA applied to the emission reduction and control techniques included in the EMS. It must be noted, however, that there are significant interactions between CBA and the process of EMS development – the latter is essentially an iterative process.

Section 5 presents three scenarios for future emissions and presents the results of estimated emission projections for each scenario. The results of a sensitivity study are also summarised. Stemming from a number of sources, the emission projections contain a number of significant uncertainties. The section concludes by noting the major sources of uncertainty, which are elaborated in Section 6 for future consideration by the inter-Ministerial Coordination Board (CoBoard).

Section 6 provides possible bases for national emission ceilings (NEC), identifies several NEC for each NECD pollutant and gives recommendations for the next steps of the Government, to be facilitated by CoBoard. Section 7 summarises the estimated overall costs of an EMS to meet the possible NEC and the estimated benefits of EMS implementation.

# 2 NECD EMISSIONS INVENTORY 1990-2010

## 2.1 Methodology, Data Collection and Inventory Compilation

### *2.1.1 Obtaining Input Data*

From the outset, the TA Project tried to obtain key input datasets from those Government Ministries most directly responsible for their collection. Official requests were prepared and submitted by MoEU officials to other Ministries. However, whilst many individuals have been supportive, there have been significant institutional barriers to the supply of data from other Ministries. Consequently, a number of important datasets have not been made available to MoEU or the TA Project. As a result, the emission estimates are based on data that are mostly in the public domain. It is expected that the inter-Ministerial Coordination Board will be established soon by Prime Ministerial Decree: once established under MoEU chairmanship, it may better enable the exchange of relevant information.

Emissions are estimated as: ‘Emission’ = ‘Activity’ x ‘Emission Factor (EF)’. The EMEP/EEA Guidebook (GB) provides detailed guidance on the methodologies available for making emission estimates; it also provides a comprehensive set of default values for emissions factors (for use where locally determined EFs are not available. The GB approach was adopted throughout the compilation of the NECD emissions inventory. For major emission sources it is best practice to use at least a Tier 2 methodology. However, by necessity, a simpler methodology (Tier 1) had to be used to estimate emissions from a number of sources.

Most emissions were estimated using a Tier 1 approach for emission factors. The GB values for EF were used extensively, and few source emissions have been estimated using emission factors obtained from other sources. Examples include:

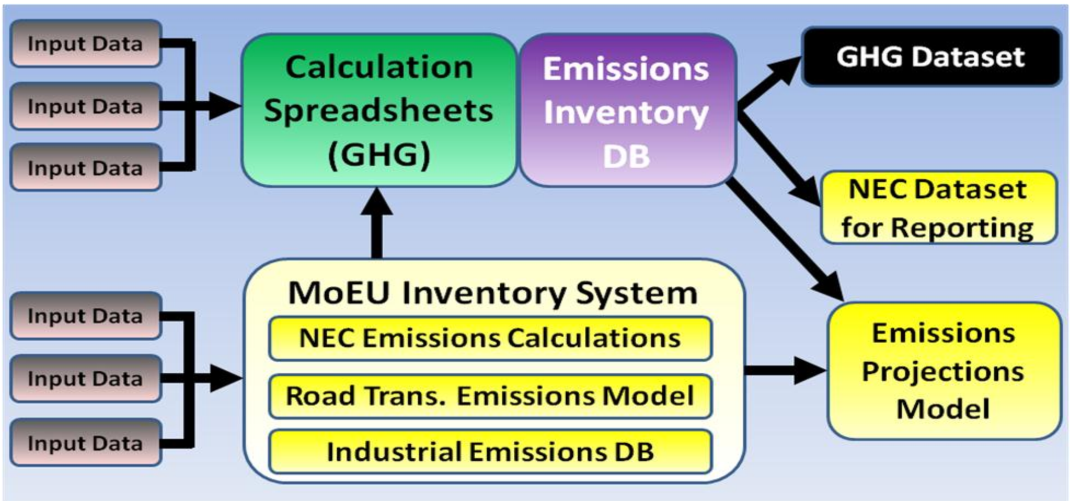
- Road transport – a detailed model has been constructed for estimating emissions from road transport. Emission factors are taken from a United Kingdom (UK) based model, although these are expected to agree well with internationally sourced emission factors.
- Other sources – there are some examples where it is easier to use detailed information from well-respected emissions inventories from other countries that may represent circumstances in Turkey. For example, in the solvent use sector, consumption data for Turkey was not readily available. So emissions per capita were derived from the UK and Irish emissions inventories, and used with Turkish population data to estimate total emissions in Turkey.

The national energy balance tables published by the Ministry of Energy and Natural Resources (MoENR) have provided a key source of information, particularly fuel use in different sectors. In general, the energy balance table provides a good insight into fuel use and combustion sources at a national level. However, there are significant limitations with some data: for example, the fuel used in the road transport sector is simply reported as “petroleum”, with no petrol/diesel split; some of the industrial sectors are also not well resolved.

### *2.1.2 Consistency between the NECD and GHG emissions inventories*

Turkey’s national Greenhouse Gas (GHG) emissions inventory is prepared by the Turkish Statistical Institute (TurkStat). Substantial discussion took place with TurkStat and MoEU on how data handling and emission calculation in the NECD and GHG emission inventories could be aligned so as to ensure consistency. The data flow model shown in Figure 2-1 was proposed as a mechanism for ensuring consistency between the two emission inventories. However, the above-mentioned institutional barriers could not be overcome within the Project's implementation period. Hence the proposed data flow model was not implemented.

**Figure 2-1 Potential relation between the NECD and GHG emissions inventories**




Consequently, no specific measures could be put in place to ensure consistency between the two inventories. However, resolving this consistency issue is recognised to be one of the most important areas for inventory development and improvement in future. In addition to ensuring consistency, the sharing of data and methodologies contributes to making inventory compilation a more efficient and cost-effective process.

## 2.2 NECD Inventory Database

A data base was prepared to hold the NECD emission inventory data and, after Quality Assurance checks were completed, was handed over to the Air Management Department of MoEU. Introductory training was provided to enable relevant MoEU staff to use the data base.

## 2.3 Inventory Results: Sulphur Dioxide - $SO_2$

Figure 4-1 provides an overview of the $SO_2$ emission estimates for Turkey. For comparative purposes, emission estimates from the GHG emissions inventory (for 2009) and GAINS 2010 are included at the right-hand side of the chart. The emissions and trends in emissions with time are dominated by lignite combustion.

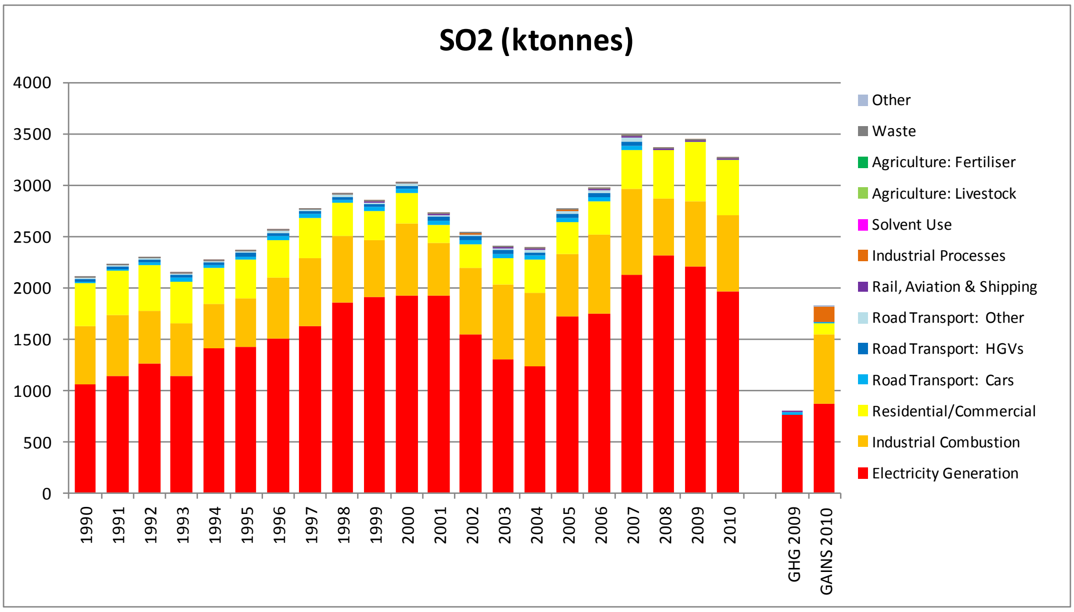
*Comparison with Other European Countries*: There is considerable variability across Europe in terms of national $SO_2$ emissions. Countries that primarily use natural gas (low sulphur content) for electricity generation and residential heating have considerably lower emissions than those based on solid fuels such as coal or lignite. Where countries use solid fuel extensively for electricity generation, the extent to which abatement equipment is used is also very important. For reasons that are outlined below, $SO_2$ emissions in Turkey are considerably higher than many other European countries.

*Electricity Generation*: In most countries this source usually makes the largest contribution to the national total: fuel sulphur content and the extent of abatement equipment use are key factors that influence national $SO_2$ emissions: flue gas desulphurisation (FGD) can reduce $SO_2$ emissions by more than 90%. In Turkey, lignite has been the main fuel for electricity generation and limited abatement equipment is in place: it is understood there may be limitations on technology performance due to the nature of this fuel in Turkey. Less coal is used in electricity generation: where it is used, the use of abatement technology substantially reduces the emissions of $SO_2$. A dataset of point-source emissions data for electricity generating stations was compiled, but it was not sufficiently complete or reliable enough for use in inventory preparation.

The sulphur content of lignite was taken from publicly available data on the current fuel reserves. The sulphur content of coal was assumed to be an international default value as is it assumed that hard coal for power stations is mostly imported. Abatement was assumed to be in place for some stations burning lignite. More comprehensive abatement was assumed for coal-fired plant.

The results presented here do not agree well with the estimates from either the GHG emissions inventory or the GAINS dataset. This is an important issue that should be checked in future when updating the emissions inventory.

**Figure 2-2 Emissions of $SO_2$ – 1990 to 2010**



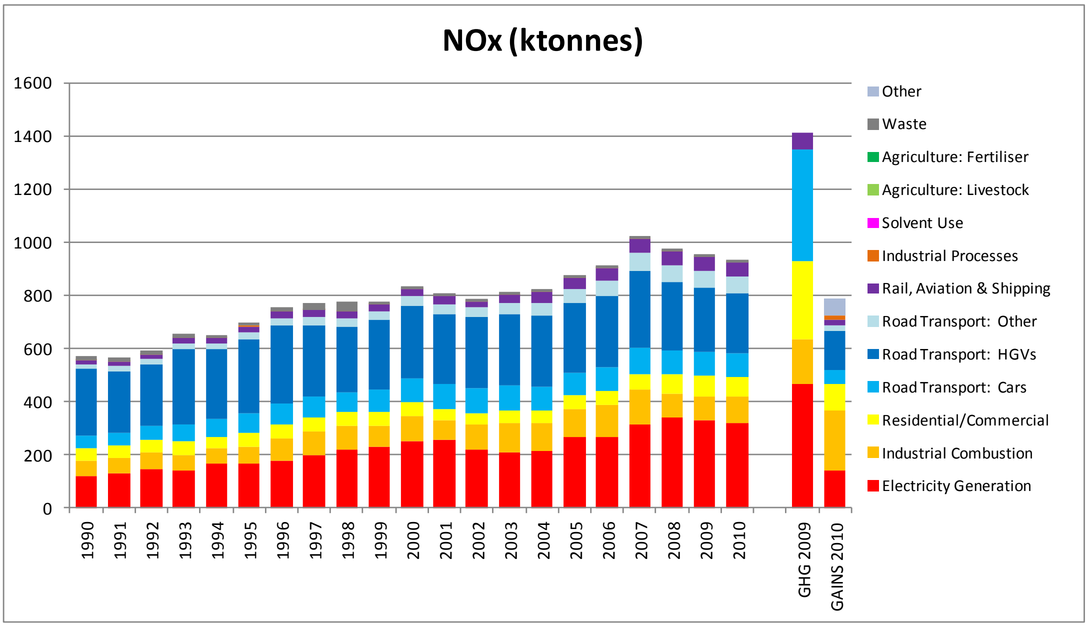

*Industrial Combustion*: Most of the comment made under electricity generation is relevant for industrial combustion also. It was assumed that abatement equipment was used for large industrial sources using coal and lignite, such as the cement and iron & steel sectors, but not in smaller scale installations. Emission estimates could be significantly improved if comprehensive and reliable point source emissions data from the larger installations were made available for use in the inventory.

*Residential Combustion*: Historically, emissions from residential combustion have been dominated by lignite use. However in 2008 there was a very large increase in hard coal consumption. Emissions from the use of natural gas are very small.

## 2.4 Inventory Results: Nitrogen Oxides - NOx

Figure 2-3 provides an overview of the national $NO_X$ emission estimates. The chart also allows the time series to be compared with the NOx emission estimates of the GHG emissions inventory (for 2009) and the IIASA estimates (for 2010) made using the GAINS model. The NOx emissions trend is dominated by the rising level of emissions from electricity generation. There was a slight increase in NOx emissions with time from the road transport sector: emissions from Heavy Goods Vehicles (HGV) decreased with time, as more modern vehicles were introduced into the vehicle fleet, but this effect was more than offset by the growth in emissions from other road transport vehicles.

**Figure 2-3 Emissions of NOx - 1990 to 2010**




*Comparison with Other European Countries*: The percentage contribution to the total from each of the main source sectors is broadly in line with emission estimates for other European countries, though emissions from electricity generation are relatively higher whilst those from road transport are lower. Also, emissions per capita are broadly in line with those of other European countries. For example the UK, with a population of approximately 60 million, reported $NO_X$ emissions of 1086 ktonnes in 2009.

*Electricity Generation*: It is reassuring to note that there is good agreement with the emissions estimates from the GHG emissions inventory. The lower estimate in the GAINS dataset is likely to be due to the selection of emission factor, but may also be due to some fuel being misallocated to the industrial combustion sector.

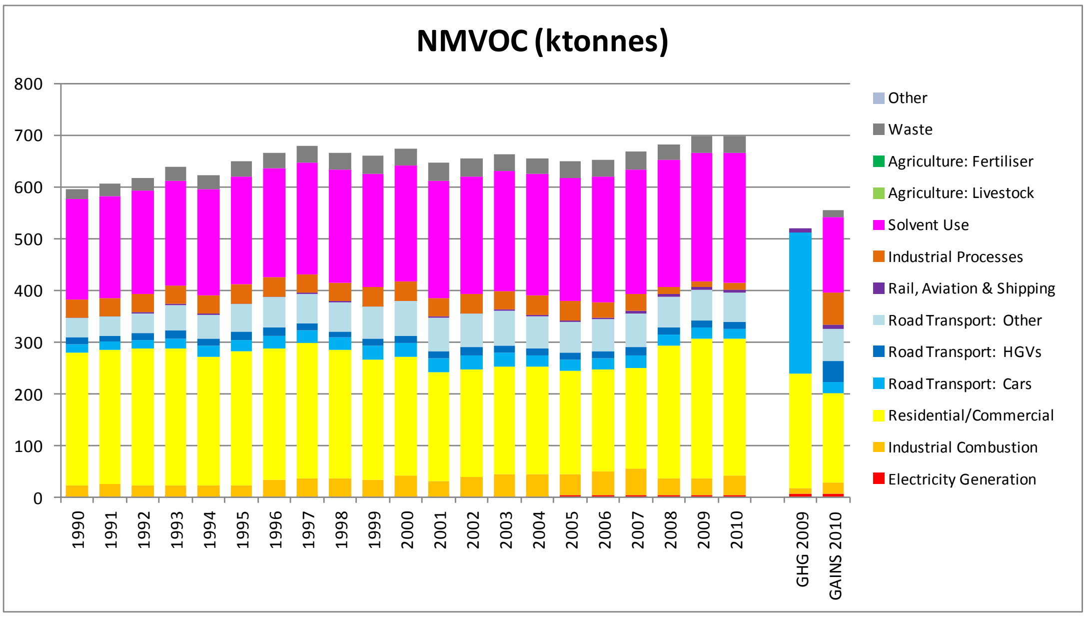
*Residential/Commercial Combustion*: Emission estimates from the GHG emissions inventory are considerably higher. It is likely to be due to the choice of different emissions factors.

*Road Transport*: The methodology used for the NECD emissions inventory was sophisticated, though the accuracy of the estimated NOx emissions will have been limited by the reliability and detail of input data. Nevertheless, it is expected that the adopted approach provides a more accurate estimate of NOx emissions than is provided by the GHG emissions inventory ($NO_X$ emissions are not of high importance to the GHG inventory; hence it is appropriate to use a simpler methodology).

## 2.5 Inventory Results: Non-Methane Volatile Organic Compounds - NMVOC

Figure 2-4 provides an overview of the NMVOC emission estimates for Turkey. The chart also allows the time series to be compared with the NMVOC emission estimates of the GHG emissions inventory (for 2009) and the IIASA estimates (for 2010) made using the GAINS model. Emissions were relatively constant over the time period.

**Figure 2-4 Emissions of NMVOC – 1990 to 2010**




_Comparison with Other European Countries_: Whilst there are usually numerous significant sources for NMVOC emissions, there are some substantial differences between Turkey and other European countries. NMVOC emissions from the electricity generating sector are smaller, a result of the fuel mix having been dominated by coal and lignite though natural gas use has been significant in recent years. Even more noticeable is the significant contribution of NMVOC emissions made by the residential sector, due to wood burning.

_Residential/Commercial Combustion_: Both the GHG and GAINS datasets show broadly comparable results.

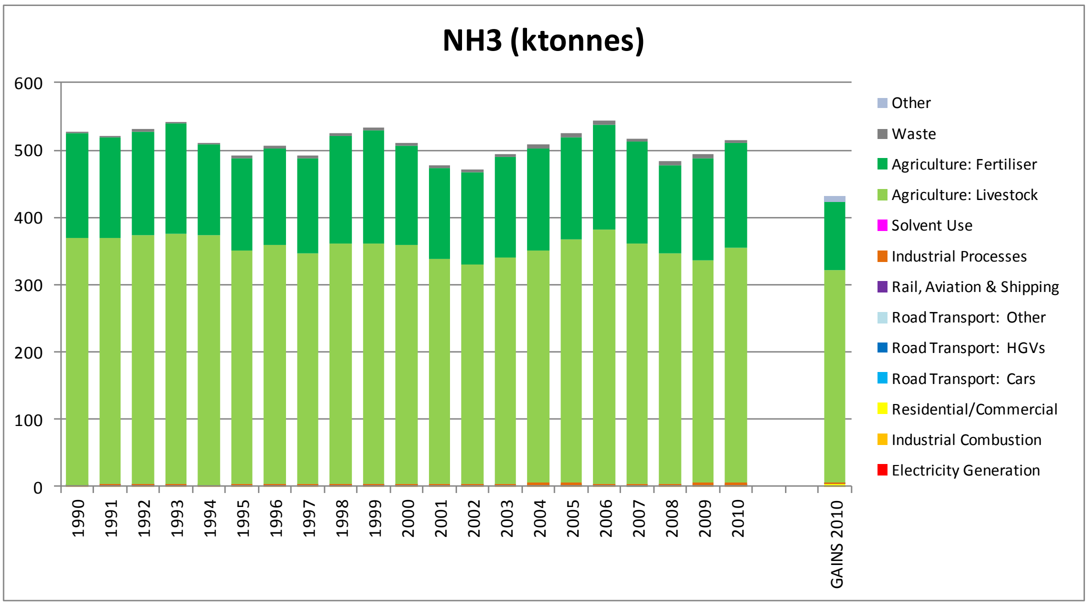
_Road Transport_: As noted in the context of NOx emissions, the NECD has adopted a relatively sophisticated approach to estimate NMVOC emissions from this source: this probably explains the discrepancy between the NECD emission estimates and those of the GHG inventory. There is good agreement between the NECD emissions inventory and the data from GAINS.

_Solvent Use_: Since few data were available, it was difficult to estimate NMVOC emissions from solvent use with any certainty. This difficulty is common across Europe. The methodology used for the NECD emissions inventory draws on product usage from other European countries and by definition, therefore, gives good agreement with other European countries. Solvent NMVOC emissions are in broad agreement with those from the GAINS dataset. No NMVOC emissions from solvent use were included in the GHG emissions inventory for 2009.

## 2.6 Inventory Results: Ammonia – $NH_3$

Figure 5-1 provides an overview of the $NH_3$ emission estimates for Turkey. The time series from 1990-2010 can be compared with the emission estimates provided by the GAINS model. Though varying from year to year, $NH_3$ emissions from livestock management and fertiliser use, the two predominant national sources were relatively constant over the period.

**Figure 2-5 Emissions of $NH_3$ – 1990 to 2010**




*Comparison with Other European Countries*: $NH_3$ emission estimates from livestock are broadly in line with other countries. This was to be expected as a similarly detailed methodology was used. Emissions from fertiliser use make a larger contribution to the total emission than in many other countries. There is good agreement with IIASA's emission estimates using the GAINS model.

*Emissions from Livestock*: Emissions are determined primarily by the livestock numbers. Cattle are the predominant source of $NH_3$ emissions with poultry a significant but secondary source.

*Emissions from Fertiliser Use*: The $NH_3$ emission from this source may simply reflect the fact that Turkey is a relatively large country with a large farming sector.

## 2.7 Major Sectoral Sources of Estimated Emissions in 2010

Table 2-1 summarises the major sectoral contributions to the national emission inventory for each NECD pollutant. The identified sectors account for between 90% and close to 100% of all estimated NECD emissions in 2010. Table fields are left blank where the contributions are less than 5%. Measures to reduce the emissions intensity of sectoral activity and reduce future emissions growth, therefore, need to focus on the sectors identified in Table 2-1. Section 3 presents an emissions management strategy for each of the sectors identified here.

**Table 2-1 Principal sources of emissions in 2010 – priorities for EMS**

| Sector | National emissions in 2010 (ktonne) and sectoral contributions (%) | | | |
|---|---|---|---|---|
| | $SO_2$ 3260 ktonne | NOx 930 ktonne | NMVOC 700 ktonne | $NH_3$ 515 ktonne |
| Electricity generation | 60 % | 34 % | | |
| Industry | 23 % | 11 % | 44 % | |
| Road transport | | 40 % | 13 % | |
| Residential combustion | 17% | | 38 % | |
| Agriculture – livestock | | | | 68 % |
| Agriculture - fertilisers | | | | 30 % |
| Other transport [1] | | 5 % | | |

NOTE 1: NOx emissions of other transport – national shipping, aviation (domestic and international landing and take-off) and rail – are dominated by the national shipping sector.

## 2.8 Areas for Inventory Improvement in Future

The suggested areas for improvement are summarised below, regarding: (i) data provision and consistency (ii) NECD pollutant and (iii) source category. Whilst the primary responsibility for introducing the improvements lies with the Ministry of Environment and Urbanisation, the inter-Ministerial CoBoard is also likely to play an important role through facilitating relevant information exchange between stakeholder ministries and MoEU. The factors identified in the sub-Sections that follow should be explored in the next inventory cycle.

### *2.8.1 Improving data provision and consistency*

The presence of institutional barriers to the exchange of information between Ministries significantly hampered the process of inventory compilation and is likely to have detracted from the inventory's accuracy and completeness. There are many instances where relevant information was not provided to MoEU. These are detailed in Parts 1 and 2 of the TA Report 'NECD Emissions Inventory Report 1990-2010' and summarised below. The following are of greatest significance:

- Sulphur content of lignite and coal fuels used in Turkey;
- Extent of emissions abatement equipment installed and operated at large combustion plants (LCPs) in the electricity generation, cement and iron and steel sectors;
- Comprehensive and systematic measurements of emissions from LCPs in the above sectors. MoEU's point-source data were investigated but were not comprehensive or consistent enough for use;
- Road transport vehicle-km data and petrol/diesel fuel split.

The institutional measures in place to ensure consistency between the NECD and GHG emission inventories are currently lacking. This is an important area for future improvement which the CoBoard may facilitate.

### *2.8.2 Specific pollutants*

*$SO_2$ emissions*: The highest priority for improving $SO_2$ emission estimates is the systematic provision to MoEU of authoritative, quality assured data sets for (i) the sulphur content of lignite and coal (ii) the extent to which FGD is installed at large combustion plants (LCPs) (iii) the operational performance of FGD and (iv) measured point-source emissions from LCPs, especially in the electricity

generating sector. The systematic provision of such data would significantly reduce the uncertainty of $SO_2$ emission estimates.

*NOx emissions*: Similarly to the above, for $SO_2$, the highest priority for improving NOx emission estimates is the systematic provision to MoEU of authoritative, quality assured data sets for (i) the extent of NOx emissions prevention and abatement equipment installed at LCPs (ii) the operational performance of such equipment and (iii) measured point-source emissions from LCPs, especially in the electricity generating sector. The systematic provision of such data would significantly reduce the uncertainty of NOx emission estimates: this is a priority area for improvement.

*NMVOC emissions*: Improvements need to focus on developing a more country-specific method for estimating relevant activity data for solvent use and checking that the emission factors used for residential wood combustion are appropriate.

*$NH_3$ emissions*: The methodology used a combination of country specific data, default data from the literature and expert judgement. There are some important parameters in the methodology, such as N excretion from livestock, where the use of country-specific data would bring a significant improvement.

### *2.8.3 Improvements suggested for specific NFR sectors*

*Stationary Combustions Sources*:

- These sources cover a range of sectors and contribute substantially to the emission of several pollutants. It is therefore important to use an accurate calculation methodology. A simple, Tier 1 method was used, primarily with default emission factors from the GB. This is not sufficiently reliable: improvements are a high priority and the most important improvement to make in the entire inventory.
- It is recommended that the current estimates for LCPs are replaced by point source emissions data. It is believed that the MoENR hold these emissions data.
- The fuel data from the national energy balance tables prepared by MoENR only specifies “petroleum” for liquid fuels. The properties of different liquid fuels are distinct and this should be taken into account in future. A considerable improvement could be made if ‘petroleum’ could be split into the following: ‘petrol’ (gasoline), ‘diesel’ (gas oil), ‘aviation fuel’ and ‘heating’ or ‘burning oil’
- The national energy balance tables identify data for relatively few specific industrial categories. As a result, the fuel use of many sectors – such as pulp, paper & print, food & drink, etc – are reported under ‘other industry’. Consequently, the emissions associated with fuel consumption in a number of significant sectors cannot be differentiated.

*Mobile Machinery*: There are several NFR categories where emissions from mobile machinery are reported. The EFs for mobile machinery can be significantly different to those for stationary combustion. However, the national energy balance tables do not resolve sectoral fuel use into stationary and mobile. Hence all emissions from mobile machinery are included in the corresponding stationary source sector. Improving the resolution of the fuel data in the national energy balance tables (if possible) would allow the use of GB emission factors for mobile sources and would improve the accuracy of the emissions estimates.

*Road Transport*: Areas where improvements should be considered include:

- The national energy balance tables do not split road fuel use into petrol and diesel. Real data on the use of petrol and diesel individually should be obtained.
- Emissions from compressed natural gas (CNG) use were not included in the inventory though it is known that taxis and other vehicles use this fuel. Data for the use of CNG should be obtained.
- Assumptions were made based on limited annual vehicle-km data. Further data by vehicle type are needed to reduce uncertainties.

*Aviation*: Shortcomings in the emissions methodology whose resolution would improve the accuracy of the estimates are: (i) domestic landing and take-off (LTO) data by aircraft type are only available for 2009 and are not available for international flights and (ii) it is assumed that the ratio of fuel use on LTO to Cruise for international is the same as for domestic flights - domestic data are needed.

*Solvent and Other Product Use*: For many of the sources it was not possible to obtain country-specific data. Sourcing national data on solvent use would be an important improvement in future versions of the inventory.

*Agriculture – Livestock*: Whilst official annual livestock data held by the Ministry of Agriculture (MoA) were used, some assumptions had to be made in converting the livestock numbers into the required categories:

- Dairy and non-dairy cattle were assumed to each account for 50% of the total cattle numbers. It is very important that real data be used in future.
- Layers (for eggs) and broilers (for chicken meat) were assumed to be equal in number, and hence each account for 50% of the total number of chickens. An informed estimate should be made in the future.

Nitrogen excretion rates were taken from the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidance, assuming that animals in Turkey are the average of “Western Europe” and “Asian” animals. It would be desirable if country-specific N-excretion rates could be used.

Data on manure management practices were based on default values reported in the GB and the 2006 IPCC Guidelines. Some country-specific data have been provided by the MoA but some parameters are not well characterised e.g. the extent to which manure is handled as solid or slurry. Enhancing the clarity and definition of such data should be given a high priority in making improvements to the calculation methodology.

*Agriculture – Synthetic and Organic Fertilisers*: $NH_3$ emissions from fertiliser application to land were made using a simple Tier 1 approach. The determination and use of country-specific emission factors would be an improvement but would be a large undertaking.

*Waste – Solid Waste Disposal on Land*: The method used estimates the volume of landfill gas from the methane emission listed in the GHG emissions inventory output tables. It would be better to obtain the underlying data from the GHG emissions inventory, which includes the volume of landfill gas.

*Waste – Incineration*: Improvements should focus on obtaining complete activity data across the time series, and providing a clearer definition of green waste so as to ensure the resulting emissions are allocated to the most appropriate NFR category.

# 3 EMISSIONS MANAGEMENT STRATEGIES

## 3.1 Introduction and Scope

The previous Section (Table 2-1) identified the sectors mainly responsible for Turkey's NECD pollutant emissions in 2010: it is most likely to be in those sectors where efforts to reduce or control emissions in future will be most beneficial. Since emissions depend on both activity levels and emission factors, in the absence of measures to reduce emission factors the tendency is for economic growth to result in increased emissions. Unless measures are adopted to reduce emission factors by more proportionately than the growth in activity[3], therefore, emissions are still likely to increase over time as a result of economic growth. Hence even a lessening in the rate of emissions growth might be considered a positive outcome. In general, therefore, it is appropriate to use the term 'emission management strategy' (EMS) rather than 'emission reduction' or 'control strategy'.

Consistent with the summary Table 2-1, sectors for which an EMS has been identified are noted in Table 3-1. For completion, an outline EMS was also prepared for industrial process emissions, though the estimated emission levels are relatively minor when viewed nationally.

**Table 3-1 Sectors for which an EMS is identified**

| Sector | Main Emissions Affected by the EMS | | | |
|---|---|---|---|---|
| | $SO_2$ | NOx | NMVOC | $NH_3$ |
| Electricity generation | ✓ | ✓ | | |
| Industrial production (combustion emissions) | ✓ | ✓ | | |
| Solvents: industrial use; product use (all sectors) | | | ✓ | |
| Industrial production (process emissions) | | | ✓ | |
| Residential / domestic combustion (heating etc) | ✓ | ✓ | ✓ | |
| Road transport | ✓ | ✓ | ✓ | |
| Aviation, marine and rail transport | ✓ | ✓ | | |
| Agriculture | | | | ✓ |

In general terms an EMS may comprise a number of components, for example:

- Primary policy measures whose implementation has a direct and purposeful impact on one or more NECD pollutant emissions. Examples include the adoption of best available techniques (BAT) under the Integrated Pollution Prevention and Control (IPPC) regime and the Large Combustion Plant Directive (LCPD), resulting in the widespread adoption of flue gas desulphurisation (FGD) at LCPs.
- Secondary policy measures whose primary goal is not to reduce NECD pollutant emissions *per se*, but whose implementation have significant impacts, e.g. Turkey's adoption of National Climate Change Action Plan 2011-2023, which *inter alia* sets goals for an expansion of electricity generation from renewable, zero-emission sources. Another example is the implementation of policy to expand the use and electrification of the

[3] Or that less-emission intensive activities substitute for emission-intensive ones.

railway system, with direct effects on rail sector emissions and knock-on effects on activity levels and emissions from the power generation and other transport sectors (road use).

- Efficiency measures adopted by private sector firms, driven by competitive pressures regarding costs, prices and market positioning. The measures might result, for example, in reduced energy consumption through improvements in energy efficiency and reduced use/loss of solvents and other materials (such as ammonia in chemical fertiliser production) from production operations. Such voluntary (self-interest) measures may need to be reinforced by regulation, a prime example being IPPC which, *inter alia*, requires firms to make efficient use of energy and material resources.
- Other policy measures, such as economic instruments and funded Outreach Programmes, designed to influence the behaviour of economic agents (producers and consumers), so as to encourage growth of less-emission intensive activity, its substitution for high-emission intensive activity and the wider adoption of good practice. An example of the former might include tax on the sulphur emissions from fuel use, which could encourage switching from high-sulphur to low-sulphur fuels. An example of the latter might include programmes aimed at encouraging farmers to adopt good practice (voluntarily) in animal manure management and nitrogenous fertiliser application to land.

Hence a range of measures are included in the EMS identified in the following sub-Sections. For emission projection purposes, measures have been incorporated across three Scenarios (Section 5). However, the recommended EMS identified for each sector is the sum of the individual measures and, in each case, is fully expressed in the With Additional Measures (WaM) Scenario.

## 3.2 Good Practice – All Sectors

It should be noted that the adoption of 'good practice' is relevant to all sectors. Even where financial resources constrain significant investment, there are usually improvements to be made that cost little or nothing and may often result in money savings. The concept of 'good practice' has been employed extensively in environmental management. However, it is often beyond the strict regulation of the installation and its introduction relies more on educational material for the operatives. Such material may be provided by the Government, educational services and by the trade associations for the particular type of installation. This latter route is very useful since the guidance on good practice for any given installation will be based on an in-depth knowledge of the sector.

Many of the more significant emission sources are installations which will be regulated under the transposed IPPC/IED Directive and therefore will need to meet BAT regarding NECD pollutant emissions. It should be noted that the BAT Reference Documents (BREFs) include the adoption of good practice measures such as demand management and waste minimisation techniques, including environmental management systems (such as ISO 14001) as BAT.

Good practice should be applied in all sectors in Turkey. At many industrial sites this will be required as installations become regulated under the By Law which transposes the IPPC Directive into Turkish Law. Application of good practice can reduce the emissions of NECD pollutants by up to 10% per unit production and at little or no cost.

## 3.3 Electricity Generation

The EMS for the electricity generation sector focuses on $SO_2$ and NOx since this sector contributed 60% and 34% respectively to total national emissions in 2010. TA Report, 'Cost-Benefit Analysis for NECD Implementation' (May, 2012) gives a description of the control techniques. In practice, the removal of particulate material from the combustion gases is required prior to $SO_2$ emissions control at lignite and coal-fired power plants (to prevent blockages); and it is likely that a future revision of the NECD will establish NECs for fine particulate material ($PM_{2.5}$). Key points of the suggested EMS follow.

### *3.3.1 Expanded use of zero-emission sources*

An important measure is the implementation of relevant aspects of the National Climate Change Action Plan 2011-2023 (NCCAP) regarding the expanded use of hydro, wind, and geothermal for power generation and potential use of solar (all renewable sources). NCCAP includes a collective target of 30% of national electricity generation from these sources though a lower, less ambitious figure might be assumed when estimating future NECD pollutant emissions.

Along with the introduction of nuclear power generation - with a goal of supplying 5% of national demand by the early 2020s - implementation of the NCCAP will boost the generation of electricity from zero-emission sources. Power plants that burn fossil-fuels will provide the balance of Turkey's electricity demand.

### *3.3.2 Emissions control at fuel-fired electricity generation stations*

A basic premise of the EMS is that all power plants which burn one or more of the major fuel types – natural gas, hard coal, lignite and fuel oil – are and will be regulated under the Turkish legislation that has transposed the EU's Large Combustion Plant Directive (LCPD). Another is that these plants will be subject, in future, to Turkish legislation that will transpose the EU's Integrated Pollution Prevention and Control (IPPC) Directive[4], which requires the application of BAT.

***Natural-gas*** fired power plants: as a result of the low sulphur content of this fuel, flue gas desulphurisation (FGD) is not required. New plants shall be equipped with low-NOx, pre-mix burners (or their equivalent) to limit NOx emissions, and existing plants should be retrofitted with them if they are not already in place and it is practicable to do so.

***Hard-coal*** fired power plants: all new plants shall instal and maintain in effective operation the following techniques[5]: (i) FGD to remove 90% of $SO_2$ combustion emissions (ii) low-NOx burners, staged-air supply and (iii) subject to review, selective catalytic reduction[6] (SCR) for NOx control. The control of particulate emissions will also be required. Figure 3-1 illustrates major plant for NECD pollutant emissions control: low NOx burners and staged-air are not shown.

If not already provided and if it is practicable to do so[7], FGD, low-NOx burners and staged-air supply shall be retrofitted to existing plants and operated.

[4] IPPC and a number of other relevant Directives will be superseded by the Industrial Emissions Directive (IED).

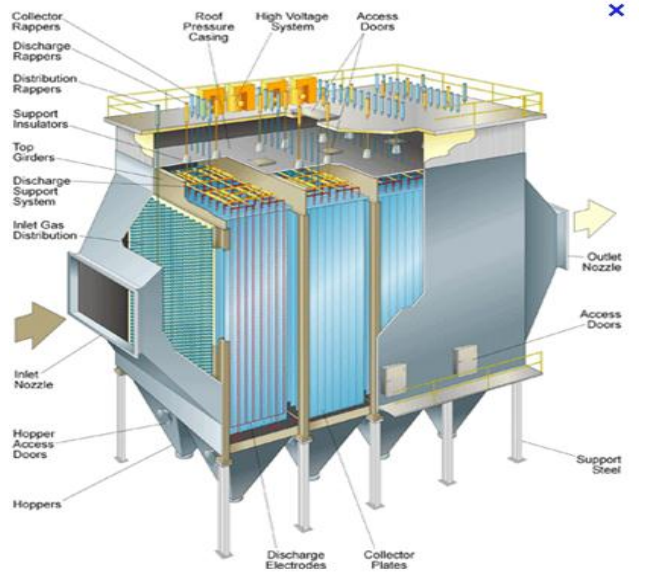
[5] Or other techniques that provide at least an equivalent degree of emissions control, e.g. SNCR.

[6] Or a technique of equivalent effect as SCR. A combination of low-NOx burners and staged air supply may be able to reduce NOx emissions by about 50% relative to uncontrolled levels. The addition of SCR increases the reduction to 75% relative to uncontrolled levels. CBA suggests that SCR may be beyond BAT: see Section 3.4.

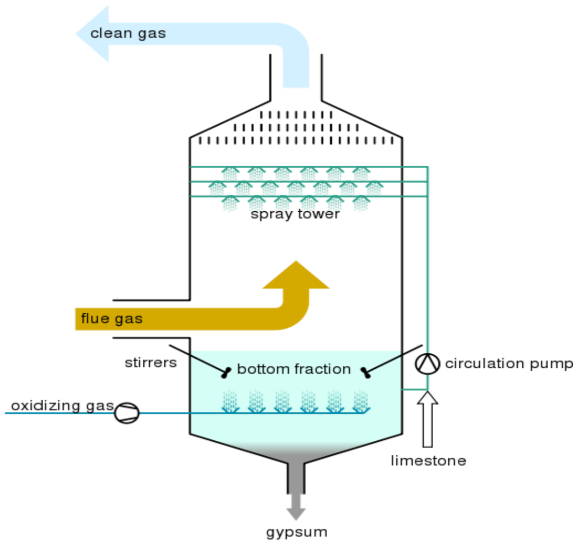
[7] Emission Projection estimates assumes they are in place at existing plants. Owing to practicality and cost considerations, especially if the plant is near end-of life, retrofitting is not universally possible or appropriate.

**Figure 3-1 Illustration of some emissions control options for LCPs**

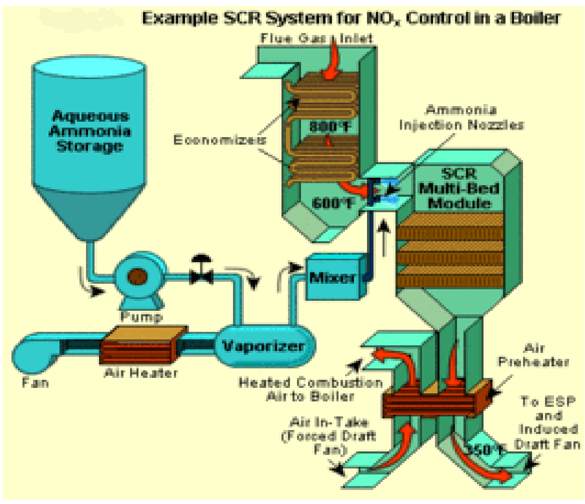
**Electrostatic precipitator – particulate emissions control**




**Wet limestone scrubber – $SO_2$ emissions control**




**Selective catalytic reduction – NOx emissions control**



***Lignite*** fired power plants: techniques for $SO_2$ and NOx control shall be installed and operated at new plants as stated above for coal-fired power plants.

Though some existing lignite-fired plants may have effective $SO_2$ and NOx control systems in place – consistent with those expected at new plants – most do not. In such cases, where control doesn't exist or is ineffective / inoperable, the following shall apply to operators:

*either*

- Retrofit (i) FGD to remove 90% of $SO_2$ and (ii) low-NOx burners and staged-air supply (e.g. over-fire air) – the investments to be phased in and completed by 2019. Operate the retrofit plant from the time of its installation. *NB: The emission projections associated with the WaM Scenario (Section 5) assume that retrofitting is practicable but, due to financial and other constraints*[8]*, adopt an implementation period of 2019 - 2025.*

*or*

- Formally opt-out of the transposed LCPD, subject to accepting a limit of 20,000 operating hours between 31 July 2011 and 31 December 2019: opt-out plant must close after 20,000 hrs operation. It is understood that operators have adopted a policy of not pursuing LCPD opt-out.

***Fuel-oil*** fired power plants: fuel-oil may be used to generate electricity in two ways. One involves burning fuel-oil only; the second involves burning fuel oil at start-up/shut-down and for control purposes at solid-fuel fired plant (lignite and coal). It is assumed that the primary or only method of use now in Turkey is for control and start-up/shut-down: the $SO_2$ and NOx emission control options noted above for hard coal and lignite fuel should be used. In addition:

- Only fuel oil having a sulphur content of less than 1.0% by mass should be used (from 1 January 2012) – to ensure compliance with By-Law No. 27368, (Decision No. 2009/15478) published in the Official Gazette of 6 October 2009.

### *3.3.3 Energy efficiency and good practice measures*

A starting point for estimating NECD emission projections from the electricity generating sector was a forecast of total national electricity demand prepared by the Turkish Electricity Transmission Corporation (TEİAŞ). Efficient electricity generation, transmission and use are vital considerations and it has been assumed that TEİAŞ's plan made allowances for these. Hence they were not been taken specifically into account when preparing the emission projections. Considering each in turn; the efficiency components of the EMS identified for electricity may be summarised as follows.

The wider adoption of energy efficient, good practice measures at fuel-fired *electricity generating stations* – stimulated by environmental regulators and the IPPC system of permits, BAT and inspections – should lead to improvements at-source. For a given quantity of electricity put onto the transmission grid, this should result in reduced $SO_2$ and NOx emissions.

[8] Retrofitting emissions control plant to existing power stations will take time (undertaking the necessary planning, design engineering and obtaining permits) and involve considerable capital investment. Uncertainties as to whether such investments will be made in state-owned plants and uncertainties as to when such plants will be privatised also complicates matters and may cause delays in the programme to install $SO_2$ and NOX emissions control equipment at existing plants.

There may also be scope for improvements in the efficiency of the electricity *transmission grid*. If so, and if they can be implemented, then for a given end-user electricity demand, the amount of electricity generated, the quantity of fuels burned and the emissions of $SO_2$ and NOx will all be reduced. Privatisation of the grid is an option the government may be considering. Were the grid to be privatised, a side-effect could be to stimulate such efficiency improvements.

A wide range of measures might be adopted to *manage consumer demand* for electricity – whether residential, institutional, commercial or industrial. If implemented then, all other things being equal, the quantities of fuels burned in the power plants, and their resulting $SO_2$ and NOx emission loads, should reduce to less than would otherwise be the case. Examples of relevant measures include:

- Better *insulation of homes, institutional and commercial buildings* through improvements in construction standards (building regulations for new construction). Though more difficult to do, fitting insulation materials into existing buildings (where this is feasible and sensible to do) may also be encouraged and promoted. The incentive to improve building insulation may largely lie in reducing the heating requirements (fuel burning in small-scale plant). However, it should reduce the heat gain at hotter periods of the year and, where air-conditioning is installed, should reduce the electricity needed to power it. Demand management systems in institutional and commercial units may also reduce electricity consumption substantially: see energy efficiency in industry (below).

- *Consumer appliances*: lighting, televisions, computers, vacuum cleaners, refrigerators and freezers, dish-washers, washing machines, cookers, etc – the range and number of appliances powered by electricity grows each year and with increasing per capita GDP. Eco- and energy labelling of such compliances accompanied by information programmes to encourage users not to waste electricity – even simple things like not leaving a TV on stand-by mode – may all help to reduce electricity consumption and emissions from its generation to a lower degree than would otherwise be the case. Government-funded programmes that set minimum environmental performance standards for energy-related products may have a role to play here. An example from the UK is the ‘Market Transformation Programme’ which covers all products included in the EU’s Ecodesign Directive.

- *Energy efficiency in industry*: improvements in energy efficiency usually accompany developments in process technologies, which may be implemented when new plant are installed or by replacing old plant units. Electric arc furnaces, chlor-alkali plant and numerous other electricity-intensive technologies have seen substantial improvements in efficiency over the years. Their adoption by enterprises when market and financial circumstances are favourable should be encouraged (the IPPC regime will underpin this).

- In addition, a whole range of *demand management techniques* may be employed to make better use of electricity in industry. They include ‘monitoring and targeting’ (M&T), which examines the relationship between production levels and metered electricity consumption. It can be highly effective in stimulating the search for efficiency improvements – and for quantifying the resultant benefits. Efficiency improvements can be found in generic services such as compressed air distribution systems, lighting systems and in numerous process or technology specific applications. State funded programmes elsewhere have successfully promoted energy efficiency good practice in industry (and in industrial / commercial / institutional buildings). Past examples include the UK's Energy Efficiency Best Practice and Envirowise Programmes.

### *3.3.4 Fuel switching*

Fuel switching from high-S solid and liquid fuels to low-S fuels such as natural gas is an effective method for reducing $SO_2$ emissions. Though there may be practical retrofit difficulties at some sites, it is relatively easy to implement. However, it is understood that higher levels of Government have voiced concerns on the potential impacts of imported natural gas on fuel-supply security and macro-economic stability (balance of payments)[9].

For that reason, fuel-switching at existing power plants from lignite and coal to natural gas was not included in any of the NECD emission projections, and is not included specifically in the EMS. However, it should be noted that the WaM Scenario (and others) allowed for significant gas use at new generating stations.

## 3.4 Industrial Production - Fuel Combustion in all Sectors

The scope of the emissions management strategy (fuels combustion) for the industrial production sector is analogous in a number of respects to that of the electricity generating sector. One difference, however, is that many furnaces, boilers and heaters operated by enterprises in the undifferentiated 'other industries' category may be too small (in terms of thermal capacity) to be regulated under LCPD, IPPC or both. Possible components of an EMS for the industrial production sector are outlined below, with some additional notes for major sub-sectors.

### *3.4.1 Energy efficiency and good practice measures*

The wider adoption of energy efficient, good practice measures should lead to fuel economies and to reductions, relative to what they would otherwise be, in $SO_2$, NOx and NMVOC emissions. These measures apply to:

- Fuel-fired process plant e.g. cement production, iron & steel production;
- Combustion units e.g. steam boilers, reheat furnaces, hot air generators etc operated within any industrial sector;
- Industrial operations that use steam either directly or indirectly via heat exchange systems; and
- Other industrial operations that are heated / cooled using heat exchange systems.

Energy efficiency improvements are usually adopted by enterprises because it is financially advantageous for them to do so. But, where the industrial activity is regulated under the IPPC regime, their efforts may also be stimulated by environmental regulators through the system of permits (outlining BAT) and inspections. Experience elsewhere, suggests that a 10% improvement in energy efficiency ought to be achievable, without having to make major financial investments: capital investment may yield greater efficiency improvements.

[9] Budget speech made by the Minister of Energy and Natural Resources in the summer of 2011.

State funded programmes also have a positive role to play. Elsewhere they have successfully promoted energy efficiency good practice in industry and in industrial buildings. Past examples include the UK's Energy Efficiency Best Practice and Envirowise Programmes.

*3.4.2 Fuel switching*

Fuel switching from high-S solid and liquid fuels to low-S fuels such as natural gas is a successful method for reducing $SO_2$ emissions. It may be appropriate especially for smaller combustion applications where flue gas desulphurisation would be prohibitively disproportionate and costly. However, as noted above, there may be concerns regarding the effects of increased natural gas imports on national fuel-supply security and macroeconomic stability (balance of payments).

*3.4.3 Combustion emissions control*

Process plants in the iron & steel and cement sub-sectors should comply with the requirements of BAT under IPPC. Sites that operate or plan to construct such plants should expect to apply techniques to abate $SO_2$ and NOx emissions to meet the standards appropriate to BAT – see Sections 3.5 and 3.6.

*3.4.4 Other sectors and processes regulated under IPPC*

Many industrial sites falling into the 'other industry' category may in future be regulated under legislation which transposes the IPPC Directive. Energy production units of integrated plants such as integrated sugar production and textile plants may or may not be of sufficient capacity to be regulated under LCPD. For those that do come under LCPD also, emissions control will need to be applied.

However, most 'other industry' IPPC sites probably do not fall under LCPD. The IPPC permits for such sites are unlikely to impose further emission standards on the combustion units but will likely require that an energy efficiency programme be developed and implemented. In practice, it may be expected that some reduction in emission factors for specific installations should in fact result from modernisation of combustion units. Such sites should also consider fuel-switching, from high-sulphur fuels to low-sulphur natural gas.

Programmes that promote energy efficiency would need to include such sites in their target audience.

*3.4.5 Sectors and processes that are not regulated under IPPC*

The costs of applying emissions control techniques at the numerous 'other' industrial sites that do not fall under IPPC are likely to be disproportionately expensive and inappropriate. Such sites are unlikely to be regulated with any great rigour.

The operators of such sites should be made aware of the benefits of energy efficiency measures and of fuel-switching, from high-sulphur fuels to low-sulphur natural gas: operators should be encouraged to implement appropriate good practice measures.

## 3.5 Iron & Steel Production – Fuel Combustion

Combustion operations in this sector are numerous, ranging from the reduction of iron ore in blast furnaces fired with (coal-based) coke, to reheat furnaces possibly fired by coal or natural gas. Electric-arc and other furnaces for producing steels and alloys (of many compositions) may also involve limited carbonaceous combustion and generate $SO_2$ and NOx, but such may be regarded as process emissions.

All production sites in this sector may be regulated in future under the Turkish legislation that transposes the EU's IPPC Directive. It is probable that all energy stations in the integrated plants will meet the limiting thermal capacity criterion (≥50 MWth) for regulation under the transposed LCPD. All such sites, therefore, will be required to apply BAT in controlling *inter alia* their $SO_2$ and NOx emissions. The operators of existing sites should expect to establish an improvement programme and to justify, to the environmental regulator (MoEU), their site-specific interpretation of BAT. Operators of any new sites, or at existing sites planning significant expansion of production, should expect to apply more extensive measures in pursuit of BAT.

The following range of measures may be appropriate BAT for the control of $SO_2$ and NOx emissions from the iron and steel production sector:

- Apply good practice measures as identified in, for example the Iron & Steel sector BREF and national/international sector guides;
- Use low sulphur coke as fuel for blast furnaces;
- Consider fuel switching to low-sulphur natural gas where it is feasible and economic to do so;
- Collect all significant point source emissions of $SO_2$ and NOx for emissions abatement and emissions monitoring prior to venting via a single stack to atmosphere;
  - Abate $SO_2$ emissions using FGD process employing limestone or, for some larger plant, wet scrubbing;
  - Abate NOx emissions at larger iron and steel installations only using SNCR (or possibly SCR).

It may be expected that improvements at existing plants to comply with IPPC requirements will not be required prior to 2018, and would be phased in over a number of years thereafter.

## 3.6 Cement Production – Fuel Combustion

Cement production involves the production of clinker in a kiln. Clinker is formed from the high-temperature reaction of a mixture of limestone and clay, the high temperatures formed by the combustion of one or more of many fuels. The combustion gases are in intimate contact with the limestone/clay mixture. Coal and petroleum coke were the main fuels used in Turkey in 2010. However, cement producers also use a range of combustible wastes as fuels (as) do other countries.

Installations for the production of cement clinker in rotary kilns with a production capacity exceeding 500 tonne per day will be regulated in future under the Turkish legislation that transposes the EU's IPPC Directive. In particular, this will require those installations to meet the requirements of BAT for cement production as set out in the respective BREF (Cement, Lime and Magnesium Oxide Industries, May 2010).

Such sites, therefore, will be required to apply BAT in controlling *inter alia* their $SO_2$ and NOx emissions. The operators of existing sites should expect to establish an improvement programme and to justify, to the environmental regulator (MoEU), their site-specific interpretation of BAT. Operators of any new sites, or at existing sites planning significant expansion of production, should expect to apply more extensive measures in pursuit of BAT.

In complying with BAT emission limits for $SO_2$ and NOx, the following range of measures may be appropriate BAT for the cement production sector:

*$SO_2$ control*

- Apply good practice measures as identified in, for example the BREF for the Cement sector and national/international sector guides;
- Optimise operating conditions in the rotary kiln so as to absorb as much as possible of the $SO_2$. Cement is an alkaline substance and, depending on kiln conditions, will tend to absorb $SO_2$. Conditions have to be optimised so that product quality is consistent with market requirements and is not jeopardised;
- Consider fuel switching to lower-sulphur content fuels;
- Consider dry reagent addition (lime) in a scrubbing system downstream of the kiln, prior to emissions monitoring and the release of gases to air;
- For larger plants having a production capacity above about 1000 tonne per day, the installation of a particulate removal system and wet-limestone scrubbing system (FGD) downstream of the kiln should also be considered. Emissions should be monitored before release.

*NOx control*

- Apply good practice measures as identified in, for example, the BREF for the Cement sector and national/international sector guides;
- Optimise operating conditions in the rotary kiln so as to minimise NOx formation;
- Fit low-NOx burners and air-staging if possible to do so;
- Consider fuel switching from solid fuels to natural gas or spent solvents;
- For larger plants having a production capacity above about 1000 tonne per day, the installation of SNCR technology (or one having an equivalent effectiveness) should be considered. Emissions should be monitored before release to air.

It may be expected that improvements at existing plants to comply with IPPC requirements will not be required prior to 2018 and would be phased in over a number of years thereafter.

## 3.7 Industrial Use of VOC Solvents and Inclusion in Products

Solvent use tends to increase with increasing economic activity as measured by GDP. The four sub-Sections that follow outline a four-component EMS for NMVOCs, one that seeks to at least reduce the rate of growth of such emissions in an expanding economy.

### *3.7.1 Industrial solvents management – implementing 1999/13/EC as amended*

Legislation that transposes the Solvents Directive is likely to be the main policy instrument for reducing industrial emissions of NMVOCs in Turkey. It should cover a wide range of solvent-use activities including – subject in most cases to production or solvent use thresholds - printing, surface cleaning and degreasing, vehicle and other coating applications, dry cleaning, extraction and refining of vegetable oils, impregnation of wood with preservatives and the manufacture of footwear, coatings, printing inks and pharmaceutical products.

This policy instrument is designed to reduce solvent losses to air from installations engaged in such sectors. Implementation may require that the following measures are taken:

- Identification of the extent and scale of the industrial and commercial activities that will be subject to regulation under this legislation;
- National decision to be taken whether or not to develop and implement a 'National Plan for Solvents Reduction', within which it may be possible to exempt certain existing installations from emission limit requirements;
- Establishment of prioritised registration and authorisation procedures for new and existing installations (subject to thresholds), and for substantial changes (increases) in existing installations. Where installations are regulated under IPPC also, the IPPC authorisation procedure and permit must take proper account of the solvent management and minimisation requirements of Directive 1999/13/EC. It is assumed that the requirements of Directive 1999/13/EC are subsumed into IPPC.
- Issue, monitor and enforce authorisation permits that should *inter alia* set out the requirements of installation operators regarding their need to :
  - Control solvent NMVOC emissions to air in waste gases and fugitive losses;
  - Adopt appropriate measures so as to comply with waste gas, fugitive or total emission limit values, as required;
  - Prepare and implement solvent management plans as a means of demonstrating compliance with the legislation. (Through the mass balance mechanism, they also help operators to identify their solvent savings, which can be cost-beneficial.)

Appropriate actions that operators should take as a first step include the adoption of good practice measures that may help to minimise solvent use and wastage at low or zero cost to themselves (see Section 5.2.3 also). Based on experience elsewhere, such low cost measures might achieve solvent savings of about 10% or so. Greater levels of solvent use reduction will likely require closed-loop system allowing for the containment of solvent emissions, their reuse and solvent recycling. Adoption of such measures may result in incurring significant costs.

Implementation of the transposed "Deco-Paints" Directive (2004/42/CE) should primarily influence the quantity of solvent evaporation in product use in future (see below). However, it will also tend to reduce solvent emissions from manufacturing sites.

Based on trends observed in other countries it is possible that, by 2025, the effect of implementing the transposed VOC Solvents Directive (supported also by IPPC and Deco-Paints implementation) could be to reduce NMVOC emissions by 20% from what they would otherwise be.

### *3.7.2 Integrated Pollution Prevention and Control - 2008/01/EC*

Legislation that transposes the IPPC Directive may be regarded as a supportive policy instrument for reducing industrial emissions of NMVOCs in Turkey. The IPPC Directive requires all installations engaged in prescribed activities, or above a minimum capacity within certain sectors, to be permitted and to meet the requirements of Best Available Techniques (BAT).

Where the environmental regulator considers that NMVOC emissions loads are significant, operators should be required to apply BAT to control solvent NMVOC emissions at IPPC installations.

### *3.7.3 Outreach programme – good practice for solvent management*

Operators of installations that use significant quantities of solvents may need information and other practical assistance to help them reduce their solvent use and solvent losses. Provision of support to operators through an Outreach programme – funded by trade associations and or by Government – complements the regulatory approach. Also, it may stimulate those enterprises that are not subject to regulation under the Solvents or IPPC legislation to take effective action to reduce their solvent losses to air.

A range of information products and services might be provided, potentially including any or all of the following:

- Benchmark guides to solvent use in significant sectors and sub-sectors. For those operators who record the solvent quantities they use in their production activities – likely to be majority as the material has to be paid for – such guides enable them to compare their use with sector averages, good performance and bad performance - such benchmark guides should be anonymous. They may stimulate operators to try to do better, for competitive reasons.
- Sector–specific case studies demonstrating what can and has been achieved regarding solvents management in an actual enterprise/s – ideally from within Turkey, but from elsewhere if that helps.
- Generic or sector-specific guide/s to the preparation and effective use of site solvent management plans.
- Sector-specific guides regarding the approach/s to adopt in preparing a submission for authorisation under the Turkish legislative equivalent of the Solvents Directive.
- Telephone and internet help-lines.
- Organised events with industry and other expert speakers to disseminate information, including the guides and case studies noted above;
- Limited on-site expert advice to operators, helping them to initiate and prioritise their action/s.

### *3.7.4 Reducing the solvent content of products – implement 2004/42/EC*

The Deco-Paints Directive came into full effect in EU in 2010, so any products subject to this Directive, and imported to Turkey from the EU after that date should meet its requirement – increasingly beyond 2011. However, it is likely that most of such products sold in Turkey are produced domestically.

Hence legislation that transposes Directive 2004/42/EC might be the second main policy instrument for reducing solvent NMVOC emissions in Turkey. Its scope should cover the following products that contain solvents – paints (a wide range of applications, from primer to top coat), varnishes and (road) vehicle refinishing products. The legislation should establish maximum VOC contents for paints, varnishes and vehicle refinishing products.

By limiting the total content of solvents in certain paints and varnishes and vehicle refinishing products, the quantity of NMVOC emissions generated when these products are used will thereby by reduced.

Implementation arrangements may require that an appropriate system for ensuring that the maximum VOC contents of the regulated products should be set up: the system could be a new one but would most likely be an adaptation of an existing product testing scheme.

As the solvent contents of products subject to the transposed Deco-Paints Directive are reduced, so NMVOC emissions from domestic product use should decline. The rate of decline will be moderated by people using up their existing stock of older paints, etc.

Based on trends observed in other countries it is possible that, by 2025, the effect of implementing both the transposed Deco-Paints Directive and the VOC Solvents Directive will be to reduce by 50% the solvent contents of many solvent-based products in domestic use. Hence by 2025 this may lead to NMVOC emissions from products that are 50% of what they would otherwise be.

## 3.8 Industry – Other Process Emissions

Two components of an overall EMS appropriate to the process industry sectors are suggested. However, a greater in-depth knowledge of the relevant process sectors would be needed to propose quantitative emission reductions.

### *3.8.1 IPPC*

The more significant industrial sources are likely to be installations which will be regulated in future under the requirements of the transposed IPPC/IED Directive and therefore will need to meet Best Available Techniques (BAT) regarding NECD pollutant emissions. The process emissions from such sources will be subject to review when permit conditions are set. Some reductions in emissions factors ought to be possible, though detailed sector and site-specific information would be needed to estimate this.

### *3.8.2 Good practice*

Regardless of whether or not an industrial site is regulated under IPPC, much can also be achieved by operating installations in an efficient manner according to the principle of ‘Good Practice’, which can be considered to be part of BAT.

The concept of Good Practice has been employed extensively in environmental management. However it is often beyond the strict regulation of the installation and its introduction relies more on educational material for the operatives of the installations provided by the Government, educational services and perhaps more importantly by the trade associations for the particular type of installation. This later route is very useful since the guidance on good practice will be based on an in-depth knowledge of the operation of installations in the specific sector.

## 3.9 Domestic & Commercial Heating

Post-combustion emissions control are or are likely to be inappropriate for residential and commercial heating systems, whether homes are heated individually, centrally as apartment blocks or by district heating systems. Three components of an emissions management strategy appropriate for this sector are outlined below:

- Fuel mix at a national level;
- Technology of combustion units;

- Building standards – insulation.

### *3.9.1 Fuel mix*

The fuel-mix at a national level is probably the most important component. Many changes have occurred in the recent past. Since 2000 there has been substantial change: (i) wood and waste (animal and vegetation origin) contribution declined by more than half from above 40% to about 20% of total primary energy; wood and waste are used as fuel primarily in the more rural districts (ii) oil contribution declined steadily but dramatically from about 23% to a little under 6% of the national total (iii) natural gas contribution rose from 20% to a peak of 42% in 2007 before falling back to about 30% in 2010; the natural gas distribution system in Turkey expanded over this period and further expansion is planned (iv) hard coal's contribution to the heating needs of this sector jumped from about 4% to 20% in 2008 and was 24% in 2010; this is a result of Government policy to grant fuels to poorer people in Turkey (v) lignite contribution tended to increase gradually from a range of 5% - 10% in the early years to about 13% by 2010; there was no increase in 2008, but both 2009 and 2010 saw year-on-year increases and (vi) geothermal and solar contribution collectively was stable at about 6% of the total; solar's contribution increasing from 11% initially to 22% of the collective supply by 2010. Taking account the recent trends, therefore, an appropriate EMS for this sector may comprise the following:

1. Geothermal and solar continue to expand at similar rate as before, and continue to provide just over 6% of the sector's energy needs. Support measures to stimulate continued growth might be considered;
2. Contribution of oil is allowed to decline to 3% of energy needs;
3. Households in rural districts are encouraged to adopt fuels other than wood and waste. Economic development in the rural districts and migration of people from rural to urban areas may be the prime motivating factors. It is conceivable that the historic trend may continue, though slow down somewhat, such that the contribution of wood and waste to the sector's energy needs declines to about 10% by 2025;
4. No extension of the Government's policy regarding fuel grants. As the economy develops further, then the needs for such support to poorer sections of society might fade. Adopting a cautious stance, the EMS assumes that the absolute quantities of granted fuel – coal and or lignite – remain unaltered at 2010 levels; and that, whilst the sector's overall heating need increases over time, the proportion of the sector's energy needs provided by hard coal and lignite will decline consequently;
5. Extension of the natural gas distribution system into parts of Turkey not hitherto reached, accompanied by its increased use in urban areas where there is inward migration from small towns and rural communities.

A further aspect, whose effects on projected emissions have not been evaluated, is the future use of smokeless fuels. Were the NECD to be amended to include $PM_{2.5}$ also, an appropriate policy response could be to demand their use, at least in certain areas, instead of hard coal, lignite, wood and waste. The use of smokeless fuels would also reduce NMVOC emissions substantially, though it would probably increase NOx emissions. However, infrastructure might be needed to produce these fuels; also, time would be required for the conversion of existing combustion units or the installation of new ones compatible with the fuel.

### *3.9.2 Technology and fuel-efficiency of combustion units*

The maintenance of existing heating units, and their adaptation or replacement by more fuel-efficient units could also be potentially significant. For example, central heating systems using condensing boilers would be significantly more fuel efficient than older non-condensing boilers. Households, apartment blocks and district heating systems should be encouraged to adopt energy efficient technologies when appropriate for them to do.

### *3.9.3 Insulation of buildings*

This component was introduced above - regarding electricity consumption (air conditioning). Better insulation of homes, institutional and commercial buildings through improvements in construction standards (building regulations for new construction) should reduce heating requirements and emissions. The fitting of insulation materials into existing buildings (where this is feasible and sensible to do) may also be encouraged and promoted.

## 3.10 Road Transport

Looking to the future, as opposed to the past (leaded petrol, sulphur content of petrol) an NECD-specific EMS for the road transport sector needs to address NOx and NMVOC emissions. Particulate emissions ($PM_{2.5}$) ought to be included also, as a priority, but is excluded here as $PM_{2.5}$ does not lie within the scope of the present NECD or Project ToR. The EMS has three components: (i) Euro standards regarding the exhaust emissions from different vehicle classes (ii) vehicle testing system and (iii) petrol vapour recovery (PVR Stages I and II).

### *3.10.1 EURO standards*

A first component is the application of EURO standards regarding exhaust emissions for a range of vehicle types. Considerable progress has been made in Turkey already in ensuring that all new vehicles meet the appropriate standards. Currently, they are the EURO 5 standards for Passenger cars and Light Commercial Vehicles and the EURO V standards for Heavy Duty Goods vehicles. The respective EURO 6 and VI standards to be applied in the EU to new vehicles from 2013-2015 should be adopted by manufacturers in Turkey also. If adhered to, these standards should help bring about substantial further reductions relative to EURO 5 and V in NOx emissions, up to 25% to 80% depending on vehicle type. It would also permit exports of vehicles to the EU of vehicles manufactured in Turkey.

Typically, vehicles produced before a EURO standard has been adopted by manufacturers are not retrofitted (unless a specific national policy is put in place), so it takes time – a number of years – for the effects of a given standard to take full effect. Hence the technological composition of the vehicle fleet (for a given type) evolves with time. In addition to new vehicles added to the fleet, each year some vehicles are scrapped due to old age (end-of-life); or are written-off after accidents; whilst other used cars, of various ages and technology, are imported or exported. Figure 3-2 illustrates the actual and projected compositions for passenger cars in Turkey.

The effects of introducing EURO standards on vehicle fleet composition and emission factors has been taken into account in estimating the emission projections of Turkey's road transport sector to 2025 (see Section 5).

### *3.10.2 Vehicle testing*

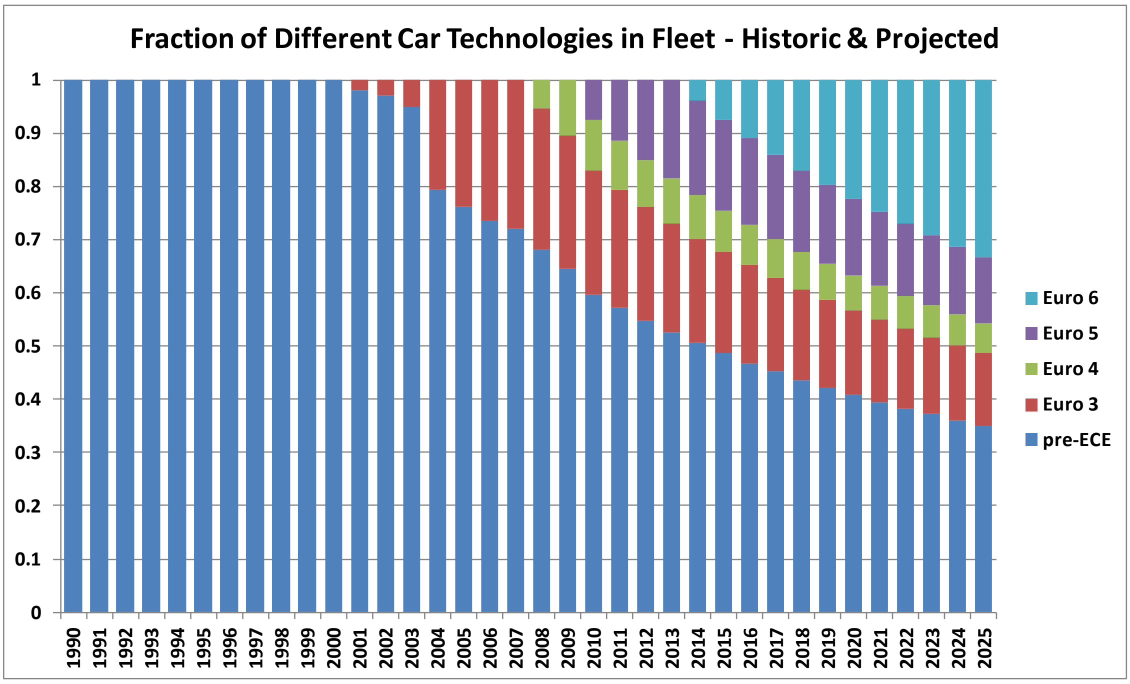
Good maintenance of existing vehicles – whatever their technology and performance when new – can be important for maintaining vehicular emissions at as low a level as is technically achievable. Hence a second component of the EMS for road transport is the implementation and enforcement of a strict regime for the enforcement of vehicle roadworthiness and emission regulations.

Turkey introduced a national vehicle testing scheme (TÜV TURK) in August 2005 as part of the transposition process for the Vehicle Testing Directive. Progress since then has been somewhat limited: a transition period of up to 2013 has been allowed, during which the established TÜV regulations have not been followed strictly. For the national vehicle testing scheme to contribute meaningfully to vehicular emissions management it will be necessary to:

- Enforce the TÜV Regulations fully after 2013; and
- Ensure that vehicles which fail the Testing Scheme are not permitted to be driven on the road until they have been repaired, retested and passed the Test.

No account has been taken of the potential effects of this component on estimating the emissions of Turkey's road transport sector to 2025.

**Figure 3-2 Illustration of the changing composition of the vehicle fleet**




### *3.10.3 Petrol vapour recovery (PVR)*

Two EU Directives – 94/63/EC and 2009/126/EC - deal with petrol vapour recovery (PVR) i.e. with NMVOC emissions. The first concerns the control of NMVOC emissions resulting from the storage of petrol and its distribution, from terminals to service stations. It is known as the *Stage I Petrol Vapour Recovery* Directive and aims to reduce emissions from the evaporation of petrol at all stages of the fuel storage and distribution chain. In particular it lays down harmonised technical specifications for the design and use of:

- Storage installations at terminals;
- Equipment for loading and unloading mobile containers at terminals;

- Mobile containers;
- Equipment for loading into storage installations at service stations.

The second, known as the *Stage II Petrol Vapour Recovery* Directive concerns NMVOC emissions from vehicle refuelling at service stations. It aims to ensure that petrol vapour displaced from the fuel tank of a motor vehicle during refuelling at a service station is recovered. In EU-27 Member States the Directive applies to: (i) by 1 January 2012 at new installations or those having undergone major refurbishment and with an annual throughput in excess of 500m$^3$ and (ii) by 31 December 2018 at all other existing service stations with a throughput of 3000m$^3$. In Turkey:

- Most fuel storage depots already have Stage I PVR techniques fitted.
- Stage II PVR techniques are being introduced in the larger petrol filling stations.

Note that the effects of further applications of Stage I and Stage II techniques have not been taken into account in estimating Turkey's NMVOC emissions from the road transport sector in the period 2011 to 2025 (Section 5).

## 3.11 Other Transport

The national NECD emission projections assume relatively passive approaches to emissions management in these other transport sectors:

- *Aviation (LTO)*: reliance is placed on improvements to engine efficiency and fuel economy being made by manufacturers and airlines (to the extent that the latter are able to do so). It is assumed that a 5% improvement may be possible by 2025, which would result in a 5% less fuel being burnt on landings and take-offs than would otherwise be the case – it is assumed this applies to both domestic and international flights. The net effect is to moderate emissions growth from growing air traffic.
- *National shipping*: the only measure assumed in estimating the emissions from this sector is implementation of the Turkish legislation that transposes the Sulphur Content of Certain Liquid Fuels (99/32/EEC). This limits the sulphur content to 1% S by weight and takes effect at the beginning of the projection period, 2011-2012.
- *Railways*: significant expansion of the Turkish railway system and of rail traffic is planned. Electrification of much of the system is also planned. Whilst this may limit the increase in diesel fuel consumption and emissions associated with an increase in traffic, or even reduce them, the direct impact on emissions at a national level will be minimal. Its indirect effects on electricity generation and the potential diversion of traffic from the roads have not been considered.

## 3.12 Agriculture

### *3.12.1 Livestock rearing*

For obvious reasons, only $NH_3$ emissions from the rearing of housed animals may be managed: emissions arising from animals grazing in-the-field are excluded from the EMS.

- Poultry are mostly housed, assuming intensive production.
- Both the emissions inventory and the projections assume that cattle are housed for 50% of the time.

*Intensive poultry – laying hens and broilers*: it can be expected that poultry units having at least 40,000 places will, in future, be subject to control under Turkish legislation that transposes the Integrated Pollution Prevention and Control Directive (IPPC)[10]. Permits for such units may require the operator to adopt feeding, ventilation and manure management systems that reduce $NH_3$ emissions.

Prepared by the IPPC Bureau for the EC and published in 2003, the relevant BREF document ('Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs') introduces a range of such techniques. Much experience been gained since that time. Good practices such as those described in the BREF and elsewhere may reduce $NH_3$ emissions to less than they would otherwise be. The TA Report, 'NECD Emission Projections 2011 to 2025', intimated that a 15% reduction might be reasonable.

Supporting the regulatory approach, an Outreach programme to raise the awareness of operators regarding good practice, and to provide them with information/guidance, would be helpful. Rather than a programme that focuses exclusively on emissions management in farming, it may be more appropriate to provide such materials and guidance as part of a broader programme to promote agricultural productivity and good practice.

For poultry rearing that is not subject to IPPC or other strict environmental regulatory regime, emissions management would require that operators/farmers take voluntary action. An Outreach programme to promote the adoption of good practices could also be targeted at the smaller poultry units, in addition to those units regulated under IPPC. Care would need to be paid to identifying the benefits to operators of adopting good practice, and ensuring that these are clearly presented to operators/farmers.

*Cattle*: the rearing of dairy and other cattle is not subject to environmental regulation under IPPC hence emissions management will require that operators/farmers take voluntary action. An Outreach programme to promote the adoption of good practices could be helpful. As for the non-regulated small poultry-rearing units, attention would need to be paid to identifying the benefits to operators/farmers of adopting good practice and presenting these clearly. The reductions in $NH_3$ emissions resulting from such an outreach programme would help to offset the emission increases resulting from larger-sized dairy cattle.

### *3.12.2 Fertiliser application to land*

As noted earlier, both synthetic and organic fertilisers are used, the latter comprising mostly cattle manure. A strategy for managing $NH_3$ emissions from fertiliser use needs to take into account factors that are likely to influence farming practice over the period 2011 to 2025. There are two components to the EMS identified here: one *regulatory* and one based on *voluntary*, self-interested action supported by the promotion of good practice through a government of otherwise funded agricultural *programme*.

*Regulatory component*: The EU's Nitrates Directive requires that areas of land which drain into waters polluted by nitrates are designated as Nitrate Vulnerable Zones (NVZs). Farmers with land in NVZs have to follow mandatory rules to tackle nitrate loss from agriculture. These rules impose constraints on farmers' use of nitrogenous fertilisers, affecting the amounts they can use and the timing

[10] Intensive pig-rearing is also subject to IPPC control but is not relevant in Turkey.

of application. Though the NVZ rules are directed primarily at preventing water pollution, by reducing the quantities of fertiliser applied to land, they also have the effect of tending to reduce $NH_3$ emissions[11]. It may be expected that Turkey's land mass contains areas which might be classified as NVZs as defined in the Nitrates Directive[12]. Transposition in future of the EU's Nitrates Directive into Turkish legislation, therefore, is likely to result in regulatory restrictions placed on nitrogenous fertiliser application in such areas. The implementation and enforcement of such a regulatory approach might take some time to become effective, as experience of it is gained.

An Outreach programme funded by the government, by farmers' organisations or by both, might stimulate awareness, provide technical information and guidance to farmers and promote good practice on environmental management aspects of fertiliser use. Targeting such a programme at commercial as opposed to subsistence farmers might provide greater returns on the effort invested. Such an initiative would complement regulation.

*Voluntary component*: It may be expected that farming will increasingly develop to become more of a commercial than subsistence activity. Associated with this trend, farms are likely to consolidate into larger units and become less labour-intensive. Farmers of such commercially oriented farms should have a greater capacity (greater than that of subsistence farmers) to adopt good practice techniques. Regardless of NVZs, good practice is to control the amount and timing of fertiliser application so as to optimise its use – minimising waste and associated $NH_3$ emissions to air.

The *Outreach programme* noted above could disseminate good practice experience (case studies) and guidance on fertiliser use, promoting the voluntary approach also.

[11] The $NH_3$ emission factor per tonne of fertiliser use is assumed to be unaffected.

[12] Turkey is currently not included under EEA Reporting Obligations Directive for Annex V Nitrate Report.

# 4 COST-BENEFIT ANALYSIS OF EMISSIONS CONTROL TECHNIQUES

## 4.1 Introduction to Cost-Benefit Analysis (CBA)

CBA is a widely used technique to decide whether it is justified to undertake a change to a process or to a procedure. As its name suggests, the technique compares the value of the benefits of a particular course of action with the costs associated with it. If the outcome is positive, then there is possible justification in undertaking that course of action. In the case of NECD implementation, CBA takes the:

- *Costs* associated with the introduction of a specific emission reduction technique (or an EMS) to control/reduce NECD pollutant emissions

  and compares them against the

- *Benefits* in economic terms of the avoided harm to man and the environment resulting from the expected reduction in pollutant emissions.

There may be more than one technique (or EMS) available to control/reduce the emission of a given NECD pollutant, and the one chosen should seek to minimise the costs involved and maximise the reduction in emissions i.e. maximising the benefits. Costs may be one-off e.g. the capital costs of fitting an abatement unit to an installation, on-going e.g. the operating costs of running that abatement unit over the period of operation, or both.

Benefits are most often received over a period of time. In its simplest form, for relatively simple and low cost measures, financial appraisal of an investment uses only financial costs and financial benefits and might involve the calculation of a payback period, i.e. the time it takes for the net financial benefits of implementing a measure to repay its investment costs. When appraising efficiency measures, many industrial companies look for a payback over a specified maximum period of time e.g. three years. However, the simple pay-back technique is of limited value for strategic decision making, for a number of reasons e.g.

- Investments may take place over a period of time, not just the first year.
- The benefits achieved (net cost savings, reduced emissions and improved health etc) may vary from year to year.
- Significant benefits such as reduced pollution and improved health - known as “externalities” – are not taken into account in financial appraisal. For example, a company having to decide whether to spend on pollution control would not include such considerations in their financial appraisal.
- Pay-back doesn’t account satisfactorily for time-preference, whereby a given cost or benefit is valued more highly at the present time than in future. Time preference is distinct from considerations of price inflation. To illustrate, even if price inflation is zero, society will still prefer to incur costs in the future rather than now, whilst preferring to receive benefits earlier rather than later.

For the above reasons a financial pay-back approach is not appropriate to the CBA of NECD implementation. A better approach is to employ economic appraisal based on discounted cash flow (DCF) analysis: externality costs and benefits are specifically included in such analysis. Externality damage costs (the benefits of pollution control are avoided damage costs) taken into account in the CBA presented here are:

- *Human health* - the economic value expressed in monetary terms of a period of illness or in the extreme case, of a premature death brought about by the emission of a NECD pollutant.
- *Agriculture* - the economic value (again, expressed in money terms) of reduced crop yield and or quality caused by the emission of a NECD pollutant.

From an economic perspective the dominant adverse impact of air pollution is on human health. However, other externality costs may also be significant locally, e.g. the impacts on *heritage and tourism* of air pollution resulting from NECD pollutant emissions. Buildings and other physical structures may be vulnerable to erosion, whilst a reputation for poor air quality may deter tourists. Such impacts are not taken into consideration in the reported analysis (marginal damage costs data for this impact are not available) but might be borne in mind for future consideration.

CBAs for a number of techniques for controlling pollutant emissions are given in sub-Sections 4.4 to 4.9. They draw on published EU costs data and studies in which the marginal health and agricultural damage costs of emissions (including NECD pollutants) have been identified over an extensive region, a region that covers the EU-27 and many neighbouring states including Turkey.

A simplified appraisal approach is adopted in the present Section in which (i) the year of implementation of a specific technique is not considered (ii) investment costs are assumed to arise only at the initial implementation stage and (iii) that the subsequent operating costs and benefits are constant with time. The Regulatory Impact Assessment (RIA) provided in Section 7 also presents the results of an economic appraisal of the full EMS (2011-2025) for the electricity generating sector – where it may be expected that the greatest costs (and benefits) will lie.

## 4.2 Benefits of Emissions Reduction or Minimisation

The emission of NECD pollutants can cause considerable damage to human health and to the environment. For that reason, the marginal damage costs (€ per incremental tonne emitted) of NECD pollutant emissions have been estimated in a series of Clean Air for Europe (CAFE) studies undertaken by AEA Technology and published by the European Environment Agency (EEA). Modelling studies published in November 2011[13] updated earlier estimates of the marginal damage costs (€ per tonne of emission) to health and the environment resulting from NECD (and other) pollutants emitted from industrial facilities. The EEA results published in 2011 were used in the TA Project.

The overall approach used was based on existing policy tools and methods such as those developed under the CAFE Programme[14]. They have been regularly used for CBA and have underpinned both EU and wider international policy making on air pollution. Turkey was included in these studies for the first time. Table 4-1 shows the estimated marginal damage cost arising from Turkey's emissions (€ per tonne per year at year 2010 prices), adopting the lower-bound, lowest damage costs.

[13] Revealing the costs of air pollution from industrial facilities in Europe. EEA Technical Report No.15/2011

[14] http;//europa.eu.int/comm./environment/air/cafe/index.htm

**Table 4-1 Indicative marginal damage costs of Turkey's emissions**

| Marginal Damage Costs (€ per tonne) | $SO_2$ | NOx | NMVOCs | $NH_3$ |
|---|---|---|---|---|
| For Turkey @ 2005 prices (EEA, 2011) | 3,064 | 1,918 | 8 | 4,583 |
| For Turkey @ 2010 prices assuming annual inflation of 3.5% | 3,640 | 2,278 | 9.5 | 5,445 |
| Average EU-25 at @ 2010 prices (CBA Report [15]) | 5,600 | 4,400 | 950 | 11,000 |

A number of key points have to be borne in mind when interpreting these reported externality costs:

- Effects likely to be of greatest significance were quantified but others were excluded. Quantified effects were:
  - Chronic effects on human mortality (premature death) and morbidity (illness), and acute morbidity effects of human exposure to $PM_{2.5}$ and secondary particulates (sulphate aerosols, damage assigned to $SO_2$; nitrate aerosol, damage assigned to NOx; and ammonium aerosol, damage assigned to $NH_3$);
  - Acute morbidity and mortality effects of human exposure to ozone;
  - Crop yield loss as a result of crop exposure to ozone.
- A number of other impacts were not assessed. They include the impacts on ecosystems and cultural heritage; the role of NMVOCs in forming organic aerosols, the carcinogenic effects of the NMVOCs benzene and butadiene, and the impact of NMVOCs on stratospheric ozone depletion – the principal underlying reason for their control in the VOC Solvents and Deco-Paint Directives. The inclusion of such impacts would increase marginal damage costs to higher figures than shown.
- Mortality was valued adopting the value of life-year (VOLY) approach, assuming median values; core morbidity functions were adopted (sensitivity functions that give higher damage costs were not assumed); and an ozone cut-off concentration of 35 ppb was adopted: effects are taken to be zero at concentrations below this cut-off value.
- Damage costs were estimated by modelling[16] the impacts across a wide region (EU-27 plus Neighbouring States) of an additional one tonne of pollutant emission. The analysis was performed assuming emissions from each State, independently. Emission dispersion, exposure and impacts depend on location and population distribution. However, impacts external to i.e. to the east of the region were excluded from the analysis. Hence estimated marginal damage costs vary with the assumed source of the incremental emission, tending to be highest in areas of high population density and lowest in peripheral States - see Annex 3.
- The study assumed major industrial facilities (E-PRTR) were the locations of emissions, ignoring the locations of other emission sources such as

[15] TA Report, 'CBA for NECD Implementation'; data for Cyprus were excluded for technical reasons.

[16] Dispersion modelling was based on the EMEP model, with a 50 x 50 km resolution and updated chemistry and meteorology functionality. Impact modelling is defined in AEA Technology's report (March, 2005).

households, road transport and agriculture (though it may be expected though that the locations of major industries, urban road transport and households correlate to some extent. An earlier report[17] published by the EEA allowed for these other source locations, but it considered the EU-25 Member States only, i.e. it excluded Turkey and other Neighbouring States. Despite the more restricted geographical extent of these data they are of interest: they also are summarised in Table A4-1.

The apparently low damage costs for NMVOC emissions in Turkey are notable. The modelling results might be spurious, reflecting the modelling complexities for this group of pollutants and a lack of comprehensive data. Annex 3 suggests certainly that the marginal damage cost of NMVOC emissions in the EU-27 is significant, though at a lower level than that of other NECD pollutants.

However, even if the actual marginal damage costs of Turkey's NMVOC emissions were some 100 times greater than shown in Table 4-1, i.e. approximately equal to the EU-25 average in the Table, the indicative damage caused would still be only a quarter to a third that of $NH_3$ and NOx, respectively, the second and third ranking causes of damage.

## 4.3 Scope of Analysis

Not all of the measures identified in the EMS given above have been subject to cost-benefit analysis. Many are secondary measures – for example, electricity generation from zero-emission sources – which are implemented to achieve objectives other than reducing NECD pollutant emissions. Others are efficiency measures which may be expected to yield positive net financial benefits to the economic actor that implements the measures: by definition, such measures should be cost beneficial. Also, Outreach programmes, whether financed by the Government or other sources, ought to be designed and managed so as to be economically efficient. Fuel-switching from high to low-sulphur content natural gas has been excluded from CBA since energy security and balance of payment considerations may act against it. And there are other measures, such as the adoption of EURO standards for the emissions from newly manufactured road vehicles, which have been or should have been already factored in by the affected industrialists and exporters.

CBA has been applied to a limited range of specific emission control measures, therefore. Sections 4.4 to 4.9 summarise the CBA of the following measures:

- Flue gas desulphurisation (FGD) at large combustion plants (LCP)
- Limiting the sulphur content of liquid fuels
- NOx emissions prevention and control at LCPs
  - Low-NOx burners – NOx prevention
  - Staged air supply e.g. over-fired air – NOx prevention
  - Selective catalytic reduction (SCR) – NOx abatement control
- NMVOC emissions control – industrial solvent use and product content
- NMVOC emissions control - petrol vapour recovery, Stages I and II
- $NH_3$ emissions control – livestock rearing.

[17] Damages per tonne emission of $PM_{2.5}$, $NH_3$, $SO_2$ , NOx and VOCs from each EU-25 Member State (excluding Cyprus) and surrounding seas; AEAT for CAFE Programme March 2005

## 4.4 Flue Gas Desulphurisation (FGD) at LCPs

### *4.4.1 FGD techniques*

FGD is a collective term for technologies used to abate emissions of $SO_2$ from the flue gases of fossil fuel combustion plants and chemical producers of sulphur oxides. For a typical coal or lignite-fired power station, for example, FGD may remove up to 95% of the $SO_2$ present in the flue gases. For costing purposes, an abatement efficiency of 90% was assumed.

The LCPD (2001/80/EC) was transposed into Turkish law by the By-Law No. 27605 of 8 June 2010. It sets limits for $SO_2$ emissions from LCPs, i.e. combustion plants having a capacity equal to or greater than 50 MWth. The By-Law applies to:

- New plant using ‘other' fuels from 8 June 2010;
- New plant using ‘liquid' fuels from 1 January 2012; and
- Existing plant from 8 June 2019.

If they are not already so equipped, existing lignite and coal-fuelled LCPs (whether existing or new) will need to install some form of FGD[18] to enable them to comply with the limits for $SO_2$ emissions set by the By-Law. Most FGD systems installed employ two stages: a first stage for ash removal – usually an electrostatic precipitator; and a second stage for $SO_2$ removal. Possible methods of FGD are outlined in the TA Report, ‘Cost-Benefit Analysis of NECD Implementation'. Here, the most commonly used method is assumed, scrubbing of the gases in an alkaline slurry, usually of limestone or lime (see Figure 3.1).

The removal of particulates from the flue gases in the FGD process (needed for the LCPs to meet the limit set by the LCPD for dust[19]) is a valuable bonus, but is often ignored in the overall costing of FGD. It is ignored in the analysis presented here though indicative costs are provided elsewhere, in TA Report ‘Emissions Management Strategies, Possible Emission Ceilings and RIA'.

Wet scrubbing using limestone has been used in Turkey and is considered a suitable option. Currently, a significant fraction of the LCPs at coal and lignite fuelled power plants in Turkey are already fitted with FGD using this option. One potentially significant barrier to achieving 90% $SO_2$ emissions reduction at lignite-fuelled LCPs in Turkey is that the properties (water content, ash content, and net calorific value) of domestically produced lignite are reportedly very variable. It is understood that this causes process instability, resulting in difficulties of process control and an overall reduction in process performance.

### *4.4.2 Capital costs of FGD*

A representative power plant capacity in Turkey of 150 MWe has been assumed, and FGD using limestone wet-scrubbing of the combustion gases. It is possible that fitting FGD to a new plant will incur lower costs than retrofitting FGD to an existing plant of the same capacity. However, for the purposes of CBA it has been assumed that they are the same. The source and basis of the capital and operating costs data that underpin the CBA for this option are given in Annex 3.

[18] It has been demonstrated that FGD is usually beyond BAT under IPPC for some LCPs above the threshold of 50 MWth and below 100 MWth. However, it is assumed that all LCPs having a rated thermal input ≥ 50 MWth will be covered under both IPPC and LCPD. Even where the combustion plant is below 50 MWth and outside LCPD, it could still be covered under IPPC if it forms an integral part of an IPPC regulated installation.

[19] Note: it is possible that the NECD may be extended to cover particulate emissions also.

The capital costs of FGD plant tend to increase with increasing plant capacity but to a decreasing extent. At plant capacities above 100 MWe, FGD capital costs are largely independent of the size of the plant. The capital costs of installing FGD at a lignite or coal-fired power plant of 150 MWe capacity – regarded as typical in Turkey - is estimated to be about €45.9 million at year 2010 price levels. Assuming a plant life of 15 years and an annual discount rate of 3.5% this is equivalent to an amortised annual sum of €3.99 million.

### *4.4.3 Operating costs of FGD*

The operation of FGD plants involves regular expenditure on a number of items, of major importance being (i) raw materials, especially lime or limestone (ii) energy, electricity especially (iii) transport of by-product gypsum ($CaSO_4.2H_2O$) and its use as raw material in plaster-board manufacture or disposal to landfill, (iv) materials for routine maintenance and repair (v) labour for routine operation and maintenance (vi) intermittent contract maintenance and (vii) water.

The annual rate of consumption of many of these items will depend on the plant capacity, actual operational throughput and operating time (hours per year). Theoretically, a plant operating at full capacity for all of the time over a period of 1 year may be said to have a load factor equal to 1.0. In practice, though, a power plant operating under reasonably good conditions is more likely to have a load factor of about 0.75. However, the difficulties of process control at lignite-fired LCPs in Turkey, aggravated perhaps by a low degree of plant reliability resulting from low levels of investment, results in load factors of about 0.50.

For present purposes it is assumed that annual operating and maintenance costs (OPEX) are directly proportional to [plant capacity x load factor][20] and that the annual costs of operating a coal or lignite-fired plant are the same[21]. Adopting these assumptions, the annual operating and maintenance costs given in Annex 1 for a base case have been adjusted to estimate the annual costs for a 150 MWe plant (capacity) run at different load factors. Table 4-2 gives the estimated cost figures (OPEX) for a coal or lignite-fuelled plant.

**Table 4-2 Annual operating expenditure for FGD at a 150 MWe LCP**

| Load Factor | OPEX at 2010 prices (€ million) |
|---|---|
| 0.75 | 3.88 |
| 0.50 | 2.59 |

### *4.4.4 Marginal costs of FGD for $SO_2$ emissions control*

Table 7-2 gives the estimated marginal costs for FGD at lignite and coal-fuelled power plants for two values of load factor. They have been calculated from the above costs data for a 150 MWe capacity plant, assuming 90% $SO_2$ removal from the combustion gases and the fuel property data given in Annex 3. The calculations were made using a relatively simple spreadsheet, provided separately to MoEU.

[20] It is recognised though that labour and maintenance costs are likely to be fixed, invariable costs. The effect of this will tend to increase the costs at low load factors to above the figures shown in Table 4-2.

[21] In practice, whilst many components of operating expenditure will not depend on fuel type, the higher sulphur content of lignite is likely to result in higher rates of lime or limestone consumption and higher costs for gypsum transport and disposal. Reported total operating costs do not give a breakdown, which otherwise would have allowed a more refined analysis.

Marginal costs are presented in terms of both € per tonne of fuel and € per tonne of $SO_2$ emission reduction. The respective values for lignite and coal-fuelled plants differ as a result of their differing properties (heating value and sulphur content). If due allowance was made for the higher sulphur content of lignite relative to coal, and the consequently greater chemical consumption and gypsum transport/ disposal costs associated with the higher S-content fuel then it is possible the differences would be less marked.

**Table 4-3 Marginal costs of FGD for $SO_2$ emissions control**

| | Parameter – for a plant of 150 MWe capacity | Lignite (load factor) | | Coal (load factor) [1] | |
|---|---|---|---|---|---|
| | | 0.50 | 0.75 | 0.50 | 0.75 |
| A | Fuel input (TJ/y) | 6.76 | 10.14 | 6.76 | 10.14 |
| B | Fuel input (million tonne/y) | 0.768 | 1.15 | 0.504 | 0.757 |
| C | Fuel input sulphur (tonne/y) | 15,358 | 23,028 | 6,056 | 9,084 |
| D | $SO_2$ emissions removed (tonne/y) | 27,645 | 41,468 | 10,901 | 16,352 |
| E | $SO_2$ emissions to air (tonne/y) | 3,072 | 4,608 | 1,211 | 1,817 |
| F | Amortised annual capital cost (€ million per year) | 3.99 | 3.99 | 3.99 | 3.99 |
| G | OPEX (€ million per year) | 2.59 | 3.88 | 2.59 | 3.88 |
| H | Total annual cost (€ million per year) (F + G) | 6.57 | 7.87 | 6.57 | 7.87 |
| | **Marginal Costs** | | | | |
| I | Fuel based (€ per tonne fuel) (H/B) | 8.6 | 6.8 | 13 | 10 |
| J | $SO_2$ control (€ per tonne $SO_2$ removed) (H/F) | 240 | 190 | 600 | 480 |

[1] Note: it is thought that Turkey's coal-fired plants (newer and fed with fuel having relatively constant characteristics) do not experience the same process control and other problems that the lignite plants do. Hence it is likely that coal-fired plants operate at a load factor close to 0.75.

### *4.4.5 Cost-benefit analysis of FGD for $SO_2$ emissions control*

The marginal cost of FGD for $SO_2$ emissions control at a coal-fired plant with a load factor of 0.75 appears to be about €480/tonne $SO_2$ removed, i.e. double the marginal cost of a lignite-fired plant operating at a load factor of 0.50. However, Table 3-1 indicates that the marginal damage costs of $SO_2$ emissions from Turkey are about €3,640 per tonne $SO_2$ at 2010 prices, substantially in excess of the marginal costs of FGD implementation (investment and operation) at either lignite or coal-fired plants.

**Cost Benefit Analysis for $SO_2$ using FGD**

The total marginal cost of $SO_2$ emissions control using FGD for lignite and coal-fired plants are likely to be substantially less than the marginal damage costs of $SO_2$ emissions (€3,640). This conclusion holds over the whole range of potential load factors.

This provides a clear justification for FGD to be fitted to all existing LCPs (where FGD has not already been fitted) and to all new LCPs when first permitted.

It is recommended, therefore, that MoEU should ensure that the requirements of the By-Law which transposed the LCPD into Turkish legislation are strictly enforced from the due dates. This should provide for the required abatement of $SO_2$ emissions from these plants to be achieved, and will make a large contribution towards achieving the future National Emission Ceiling for $SO_2$.

## 4.5 Limiting the Sulphur Content of Liquid Fuels

### *4.5.1 Background*

Council Directive 93/12/EEC of 22 March 1993 relating to the sulphur content of certain liquid fuels (SCLF) as subsequently amended[22] sets limits and requires Member States to stop using:

- Gas oil where the sulphur content is more than 0.10% by mass: from 1 January 2008; and
- Heavy fuel oil where the sulphur content is more than 1.00% by mass: from 1 January 2003.

The Directive was transposed into Turkish law by the By-Law No. 27368 published in the Official Gazette of 6 September 2009. This established that fuel oil types whose sulphur content exceeds 1% cannot be used in the borders of the Country from 1 January 2012[23].

### *4.5.2 Costs of using compliant fuels*

No capital costs are involved with the use of compliant fuels, though capital costs may be incurred in their production at oil refineries. The additional refining costs will be included in the price charged to users of these oils.

The oil refining industry in Europe constantly claims that the compliant fuels are difficult to produce. This may be true but it also enables them to justify charging a premium for these compliant fuels. In general, the prices paid by the user for compliant fuels are between 10% and 20% in excess of non-compliant fuels[24].

In March 2012 the price of non-compliant heavy fuel oil was about €500/tonne. Assuming an average premium of 15% over non-compliant heavy fuel oil, this equates to an additional cost to users of €75/tonne fuel oil.

### *4.5.3 Marginal cost and CBA of reducing $SO_2$ emissions*

Compliance with the requirements of the By-Law may reduce the sulphur content of heavy fuel oil from about 2.5% to 1.0% at least. Hence for each tonne of heavy fuel oil burned, the emitted sulphur load will be reduced by 0.015 tonne (equal to 0.025 minus 0.010), which is equivalent to a reduction in $SO_2$ emission of 0.03 tonne[25].

Since the marginal cost to the user of burning one tonne of compliant fuel oil (relative to non-compliant oil) is about €75/tonne fuel oil, the marginal cost of reducing $SO_2$ emissions by this route may be estimated as about 75 / 0.03 i.e. €2,500 per tonne of $SO_2$ emission avoided.

Table 4-1 indicates the marginal benefit of $SO_2$ emissions reduction is about €3,640 per tonne at 2010 prices, which is about 30% more than the marginal costs to users.

[22] Amended by Directives 98/70/EC, 1999/32/EC and 2005/33/EC.

[23] Note: the EC estimates that by 2020 the respective amount of $SO_2$ emitted from the marine sector could be greater than that from land-based sources. This is one of the main drivers for the EC's intention to extend the scope of the NECD to include all marine sources. The current NECD (Article 2) specifically excludes emissions from international marine traffic.

[24] This is the principal reason why non-compliant fuels (for land-based uses) are used for international marine purposes – international marine uses are excluded from the scope of the NECD.

[25] One tonne of sulphur is equivalent to 2.0 tonne of $SO_2$

It is recommended therefore that MoEU should ensure that the By-Law which transposed the SCLF Directive is fully enforced so that only compliant fuel is used in Turkey from 1 January 2013. This recommendation applies to all industrial facilities, regardless of age and technological status. There should be no exceptions.

## 4.6 NOx Emissions Prevention and Control at LCPs

### *4.6.1 Principles of NOx formation and control*

NOx is produced in combustion processes by the reaction of oxygen and nitrogen present in the combustion air. Both the chemical composition and the amount of NOx produced depend on a number of factors, not least the:

- Temperature of combustion[26];
- Amount of air present and the temperature at which it is fed into the combustion zone;
- Physical layout of the burners and combustion zone;
- Overall operation of the combustion process and whether it operates under 'steady state' or variable conditions.

A number of techniques are available to minimise the formation of NOx in LCPs: they are termed 'primary measures'. Once NOx have been formed and are in the hot gases leaving the combustion chamber, their emission may be abated to a certain extent by so-called 'secondary measures – see Section 4.6.3.

### *4.6.2 Primary measures to prevent NOx formation*

Table 4-4 summarises a number of the many approaches introduced to minimise the formation of NOx in combustion processes – see Table 4-4. Commonly they, they consist of combining 'low NOx' burners (LNB) with 'air staging' (AS) often using 'over-fire air' (OFA).

**Table 4-4 Primary measures for reducing NOX emissions**

| Primary measure | | NOx reduction rate | General applicability | Limitations |
|---|---|---|---|---|
| Low NOx burners | | 10-44% | All fuels | Incomplete combustion |
| Air staging in the furnace | Burner out of surface (BOOS) | 10-70% | Generally restricted to gas and oil fired plants for retrofit only | Incomplete burn-out (and therefore higher CO and unburned carbon levels) – applies to BOOS, BBF and OFA |
| | Biased burner firing (BBF) | | All fuels for retrofit only | |
| | Over-fire Air (OFA) | | All fuels | |
| Flue-gas recirculation | | 20-50% | All fuels | Flame instability |
| Reduce preheat | | 20-30% | Not suitable for coal-fired wet bottom boilers | |

Low NOx burners are designed to control fuel and air mixing at the burner in order to create larger and more branched flames. Peak flame temperature is thereby reduced, and this results in less NOx formation. The improved flame

[26] This could be significant for the lignite burned in Turkey. Because of its high water and ash contents, it may burn at a lower temperature than 'usually' observed for coal or lignite combustion.

structure also reduces the amount of oxygen available in the hottest part of the flame thereby improving burner efficiency.

Combustion, reduction and burnout are achieved in three stages in a conventional low NOx burner. In the initial stage, combustion occurs in a fuel-rich, oxygen deficient zone where the NOx are formed. In the second stage a reducing atmosphere is maintained: hydrocarbons are formed here and react with the NOx formed previously. In the third stage, internal air-staging completes the combustion but may result in additional NOx formation though this can be minimised by maintaining a relatively air-lean environment.

Low NOx burners can be combined with other primary measures such as air staging, re-burning or flue gas recirculation. Experience shows that a combination of low-NOx burners with other primary measures can reduce NOx formation by up to 70%. However, it is clear from Table 4-4 that NOx reduction rates for the different primary measures – alone or in combination - cover a wide range of values. In addition, the reduction rates are often affected by the specific physical characteristics of the individual burner. For the purposes of CBA it was assumed that the use of:

- Low NOx burners reduces NOx formation by 30%; and
- Low NOx burners combined with air-staging (usually over-fire air) reduces NOx formation by a total of 50%.

### *4.6.3 Secondary measures for NOx control – selective catalytic reduction (SCR)*

In addition to LNB and air-staging, many large combustion plants also instal NOx abatement technologies downstream of the combustion unit so as to further reduce NOx emissions. These technologies are chemical processes which convert NOx to elemental nitrogen and water. They can be selective or non-selective catalytic reduction, SCR and SNCR respectively, the main difference being that SNCR does not involve the use of a catalyst. In both processes a gaseous reactant - typically anhydrous ammonia, aqueous ammonia or urea - is added to the flue or exhaust gas. Figure 3.1 illustrates SCR.

Commercial SCR systems are typically fitted to large utility boilers, industrial boilers and municipal solid waste boilers. Based on reported performance it was taken that the combined effect of equipping a large combustion plant with LNB, AS and SCR would reduce NOx emissions by 75% from what they otherwise would be, i.e. the marginal effect of SCR would be the removal of 25% of uncontrolled NOx emissions[27].

### *4.6.4 Capital costs*

Similarly to $SO_2$ emissions control using FGD, a representative power plant capacity of 150 MWe was assumed for the installation (retrofitting to existing or installing at new plant) of NOx emissions prevention, abatement or both to a lignite or coal-fired plant. Similar assumptions and caveats stated with regard to FGD apply here also. Table 4-5 gives the estimated capital costs for the three levels of emissions control assessed. It also gives the amortised annual costs, assuming a discount rate of 3.5% and a plant lifetime of 15 years.

[27] In theory, SNCR can achieve the same efficiency as SCR and without the additional costs of the catalyst used in SCR. However, constraints of temperature, time, and mixing often lead to worse results in practice.

**Table 4-5 Capital costs: NOx emissions control options (at 2010 prices)**

| Emissions control technique | Low NOx burners | Low NOx burners + Air Staging | Low NOx burners + Air Staging + SCR [1] |
|---|---|---|---|
| NOx emissions reduction (%) | 30 | 50 | 75 |
| Capital cost (million €) | 4.15 | 6.03 | 41.5 |
| Amortised capital cost (€/y) | 360,000 | 523,000 | 3,600,000 |

[1] The capital costs of a standalone SCR is taken to be €34.5 million. For the highest degree of emissions control, this has been added to the capital cost of low NOx burner plus Air Staging.

Annex 3 gives the sources and basis of the capital and operating costs data that underpin the CBA of NOx emission control options and the basic economic appraisal parameters.

*4.6.5 Operating costs*

The additional costs (over and above those of conventional combustion plant) of operating and maintaining the preventive measures for NOx emissions control – LNB and air staging – are essentially trivial. For present purposes they are taken as zero. However, in addition to being capital intensive, selective catalytic reduction (SCR) incurs significant operating costs. Again, as for FGD, operating costs were assumed to be directly proportional to operational duty as given by [plant capacity x load factor], and that the operating costs (€ per year) of SCR are independent of fuel type – lignite or coal. Table 4-6 summarises the estimated cost figures (OPEX) for a 150 MWe (capacity) coal or lignite-fuelled plant.

**Table 4-6 Annual operating expenditure for NOx emissions control**

| Load Factor | OPEX at 2010 prices (€ million) | | |
|---|---|---|---|
| | Low NOx burners | Low NOx burners + Air Staging | Low NOx burners + Air Staging + SCR |
| 0.75 | 0.00 | 0.00 | 1.178 |
| 0.50 | 0.00 | 0.00 | 0.786 |

*4.6.6 Marginal costs of NOx emissions control at LCPs*

Tables 4-7 and 4-8 give the estimated marginal costs for NOx emissions control at lignite and coal-fired power plants, respectively, each for two values of load factor. Marginal costs have been calculated from the above costs data for a 150 MWe capacity plant, assuming the NOx removal efficiencies stated in Sections 4.62 and 4.6.3. All calculations and other data employed were made using a simple spreadsheet that was provided separately to MoEU.

Marginal costs are presented in terms of both € per tonne of fuel and € per tonne of NOx emission reduction. The respective values for lignite and coal-fuelled plants are not the same since their heating values and emissions factors differ. Owing to the high water content of the domestically-mined lignite used in Turkey's power stations, it is possible that the combustion temperatures in Turkeys lignite-fired LCPs are lower than those of plants that have provided the basis for the GB's NOx emission factors. If so then the GB NOx emissions factor for lignite used in this CBA might be higher than it is in practice: no emissions data were made available to check this supposition. However, if NOx emissions from lignite combustion are in fact lower than those presented, then the marginal costs per tonne of fuel would be unaltered but the marginal costs per tonne of NOx removed would actually be higher. (The simple costs model used assumes that removal efficiency and costs are independent of NOx emission rates.)

**Table 4-7 Marginal costs of NOx emissions control at LCPs – lignite**

| Parameter – for a plant of 150 MWe capacity [1] | | Load factor = 0.50 | | | Load factor = 0.75 | | |
|---|---|---|---|---|---|---|---|
| | | LNB | LNB + AS | LNB + AS + SCR | LNB | LNB + AS | LNB + AS + SCR |
| A | Fuel input (TJ/y) | 6.76 | 6.76 | 6.76 | 10.14 | 10.14 | 10.14 |
| B | Fuel input (million tonne/y) | 0.768 | 0.768 | 0.768 | 1.15 | 1.15 | 1.15 |
| C | NOx emissions factor if no control (g/GJ) | 360 | 360 | 360 | 360 | 360 | 360 |
| D | NOx emissions if no control (tonne/y) | 2,433 | 2,433 | 2,433 | 3,649 | 3,649 | 3,649 |
| E | NOx emissions removed (tonne/y) | 730 | 1,216 | 1,825 | 1,095 | 1,825 | 2,737 |
| F | NOx emissions to air (tonne/y) | 1,703 | 1,216 | 608 | 2,554 | 1,825 | 912 |
| G | Amortised annual capital cost (€ million/year) | 0.360 | 0.523 | 3.60 | 0.360 | 0.523 | 3.60 |
| H | OPEX (€ million per year) | 0.00 | 0.00 | 0.786 | 0.00 | 0.00 | 1.178 |
| I | Total annual cost (€ million per year) (G + H) | 0.360 | 0.523 | 4.39 | 0.360 | 0.523 | 4.78 |
| **Marginal Costs at 2010 prices** | | | | | | | |
| J | Fuel based (€ per tonne fuel) (I/B) | 0.47 | 0.43 | 5.7 | 0.31 | 0.45 | 4.2 |
| K | NOx (€ per tonne NOx removed) (I/E) | 490 | 430 | 2,400 | 330 | 290 | 1,750 |

[1] Note: if in future, new lignite-fired LCPs in Turkey can overcome the process control and other operational difficulties that affect the existing (old) plants, then the higher load factor (0.75) might apply.

**Table 4-8 Marginal costs of NOx emissions control at LCPs – coal**

| Parameter – for a plant of 150 MWe capacity [1] | | Load factor = 0.50 | | | Load factor = 0.75 | | |
|---|---|---|---|---|---|---|---|
| | | LNB | LNB + AS | LNB + AS + SCR | LNB | LNB + AS | LNB + AS + SCR |
| A | Fuel input (TJ/y) | 6.76 | 6.76 | 6.76 | 10.14 | 10.14 | 10.14 |
| B | Fuel input (million tonne/y) | 0.504 | 0.504 | 0.504 | 0.757 | 0.757 | 0.757 |
| C | NOx emissions factor if no control (g/GJ) | 310 | 310 | 310 | 310 | 310 | 310 |
| D | NOx emissions if no control (tonne/y) | 2,095 | 2,095 | 2,095 | 3,142 | 3,142 | 3,142 |
| E | NOx emissions removed (tonne/y) | 628 | 1,047 | 1571 | 943 | 1,571 | 2,357 |
| F | NOx emissions to air (tonne/y) | 1,466 | 1,047 | 524 | 2,200 | 1,571 | 786 |
| G | Amortised annual capital cost (€ million/year) | 0.360 | 0.523 | 3.60 | 0.360 | 0.523 | 3.60 |
| H | OPEX (€ million per year) | 0.00 | 0.00 | 0.786 | 0.00 | 0.00 | 1.178 |
| I | Total annual cost (€ million per year) (G + H) | 0.360 | 0.523 | 4.39 | 0.360 | 0.523 | 4.78 |
| **Marginal Costs at 2010 prices** | | | | | | | |
| J | Fuel based (€ per tonne fuel) (I/B) | 0.71 | 1.0 | 8.7 | 0.48 | 0.69 | 6.3 |
| K | NOx (€ per tonne NOx removed) (I/E) | 570 | 500 | 2,790 | 380 | 330 | 2,030 |

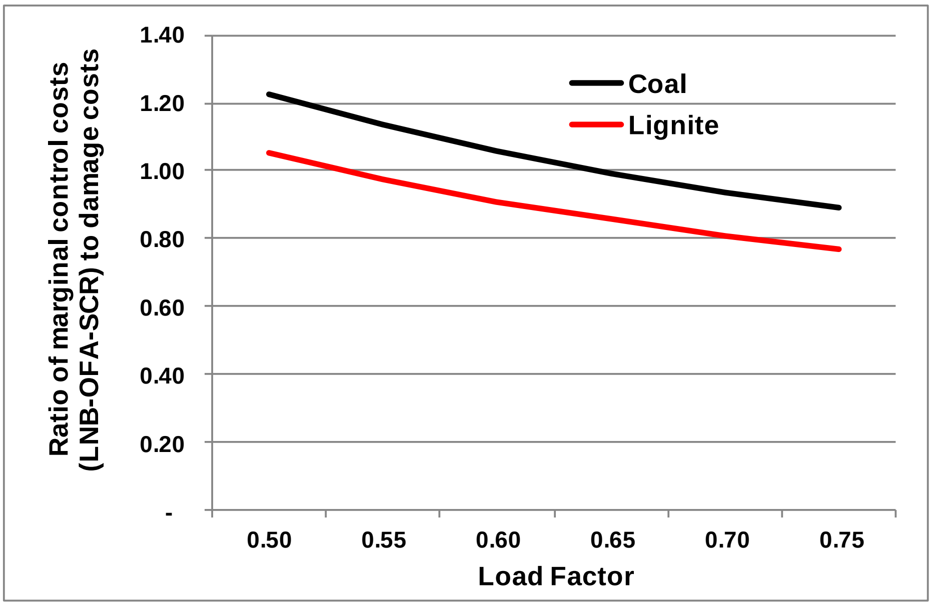
[1] Note: it is expected that the higher of the two load factors apply to LCPs using imported hard coal.

### *4.6.7 Marginal emission control and damage costs compared*

Table 4-1 gives the marginal damage costs of NOx emissions from Turkey as about €2,280 per tonne NOx at 2010 prices. Comparison of the marginal emission control costs (€ per tonne NOx removed) for the LNB, and LNB plus air-staging options in Tables 4-7 and 4-8 are substantially lower than this marginal damage cost, suggesting clearly that the application of these two options is justified on CBA grounds. This conclusion is valid regardless of fuel type – lignite or coal – or load factor within the analysed range. Also, in addition to controlling NOx emissions to a greater extent, the marginal cost of the combined LNB plus AS emissions control option may be slightly below that of LNB alone. Based on cost-benefit considerations alone, therefore, LNB and OFA should be fitted to all new LCPs and, if technically possible, retrofitted to those existing LCPs not already fitted with these technologies.

For the higher degree of NOx emissions control offered by the combined LNB-OFA-SCR option, however, the same conclusion cannot be drawn. As can be seen in the above Tables and in Figure 4-1, the emission control costs of the three options combined appear to be similar to the reported damage cost and, over much of relevant range of load factors, exceed it.

**Figure 4-1 Ratio of marginal emission control to damage costs with SCR**




It seems clear then that the additional NOx removal provided by the inclusion of SCR in the emissions control approach is achieved at a high cost. Indeed, as shown in Table 4-9 for lignite-fired plant (the same will apply to coal plant), for Turkey's LCPs the marginal emission control cost of SCR alone exceeds substantially the marginal avoided damage costs of €2,280 at 2010 prices.

**Table 4-9 Marginal costs of SCR for NOx emissions control – lignite LCP**

| Parameter – for a plant of 150 MWe capacity | | Load factor = 0.50 | Load factor = 0.75 |
|---|---|---|---|
| A | NOx emissions with LNB-OFA (tonne/y) | 1,216 | 1,825 |
| B | NOx emissions removed by SCR (tonne/y) | 608 | 912 |
| C | Amortised annual capital cost (€ million/year) | 3.08 | 3.08 |
| D | OPEX (€ million per year) | 0.79 | 1.18 |
| E | Total annual cost (€ million per year) (D + E) | 3.87 | 4.26 |
| K | Marginal cost of SCR(€ per tonne NOx removed) (B/E) | 6,360 | 4,670 |

Based on this analysis, therefore, and with the information available, the adoption of SCR in Turkey is not justified on CBA grounds, though it may be required in order to comply with mandatory NOx emission concentration limits set under the

LCPD. In a number of other European countries the marginal damage costs of NOx emissions are considerably higher than for Turkey – see Annex 3 - and the above observations do not apply. Clearly, however, common rules have to apply to Member States of the European Union, and the requirement to meet standard NOx emission limits for LCPs is one manifestation of that principle.

**CBA of the NOx emission control techniques considered**

CBA fully justifies the requirement that:

- All existing LCPs in coal and lignite-fired power stations should be retrofitted (if technically possible) with both Low NOx burners and Air Staging (AS, such as OFA) from 8 June 2019;
- All new LCPs using coal or lignite should be fitted with both Low NOx burners and Air Staging from the time of first permitting.

However, SCR is not justified in Turkey on cost-benefit grounds for

- Existing or new LCPs whether fuelled by coal or lignite.

Despite the above conclusion, future investment in and operation of SCR may be required at new LCPs in Turkey in order to meet limiting emission concentration standards. This particularly applies to LCPs larger than 500 MWth, for which tighter standards for NOx apply from 2018.

It is recommended therefore that MoEU should fully enforce (from the due dates) the requirements of the By-Law which transposed the LCPD into Turkish law.

## 4.7 NMVOC Emissions Control – Industry and Industrial Products

### *4.7.1 Relevant EU Directives*

NMVOCs are widely used in industry as cleaning agents and as solvents in manufacturing process. They are also present as ingredients in a wide range of finished products, such as paints and pharmaceuticals used in the residential, commercial and other sectors. Being relatively cheap to produce this meant that in the past they were not used very responsibly. That is, until the potential harm that they could cause to the protective ozone layer in the stratosphere was understood, and their role as precursors in the formation of tropospheric ozone – where it is harmful – was fully recognised. Three main EU Directives which limit the use of NMVOCs in the manufacturing process and in the finished product:

- *IPPC (2008/1/EC)* which requires that the operation of processes using NMVOCs should be permitted in such a way that operation meets the requirement of BAT. In particular, this means minimising NMVOC emissions to air and minimising waste (containing NMVOCs). In particular the Directive refers to '*Installations for the surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with a consumption capacity of more than 150 kg per hour or more than 200 tonnes per year.'*
- *Solvents/VOC Directive (1999/13/EC)* which seeks *' to prevent or reduce the direct and indirect effects of emissions of volatile organic compounds into the environment, mainly into air, and the potential risks to human health, by providing measures and procedures to be implemented for certain activities where the respective solvent consumption thresholds is above defined thresholds'.*

- Deco-Paints Directive (2004/42/EC) which has the purpose *'to limit the total content of VOCs in certain paints and varnishes and vehicle refinishing products in order to prevent or reduce air pollution resulting from the contribution of VOCs to the formation of tropospheric ozone..'*

### *4.7.2 Marginal costs associated with the implementation of IPPC*

As with the NECD, IPPC does not establish any particular standards to be met by regulated installations. Instead it requires installations to be permitted so that their operation meets the requirements of BAT: in most cases these are established by other related EU Directives. For CBA it was assumed that the implementation of IPPC would not involve any costs additional to those associated with the implementation of related EU Directives.

### *4.7.3 Marginal costs and CBA associated with the Solvents Directive*

Relevant marginal costs data associated with the Solvents/VOCs Directive have been abstracted from GAINS – see Annex 3. The marginal costs (€ per tonne NMVOC abated) for NMVOC emission prevention and control cover a very wide range. For existing plant involving 'surface cleaning/degreasing', marginal costs range from €1,420 to nearly €54,000; marginal costs for new plant range from about €1,550 to over €71,000.

They are all substantially higher than the estimated marginal damage cost (€9.5 per tonne NMVOC) of NMVOC emissions from Turkey noted in Table 4-1. However, inspection of Annex 3 shows a similarly wide range of marginal damage costs resulting from national emissions, though there is some, limited overlap between the two sets of costs. It does appear therefore that adopting some of the techniques, in some of the EU-27 Member States, might be justified on cost-benefit considerations alone. Noting that not all impacts of NMVOC emissions were taken into account in the reported evaluation of NMVOC marginal damage costs, actual benefits should be somewhat higher than indicated.

**Cost Benefit Analysis**

In Turkey, none of the NMVOC abatement techniques considered for meeting the Solvents/VOCs Directive is justified on the basis of cost-benefit alone.

### *4.7.4 Marginal costs associated with the Deco-Paints Directive*

Relevant marginal costs data associated with the Deco-Paints Directive have been abstracted from GAINS - see Annex 3. Marginal emission reduction costs appear to lie in the range €600 to €870 per tonne NMVOC avoided emission. Whilst substantially higher than the marginal damage cost of €9.5 for NMVOC emissions from Turkey, the costs lie below the marginal damage costs of emissions of many EU-27 Member and Neighbouring States (Table 4-1 and Annex 3).

**Cost Benefit Analysis**

CBA for Turkey does not justify NMVOC control associated with the Deco-Paints Directive. However, it can be justified on cost-benefit grounds for many EU-27 Member States. Actual benefits may he higher than presented.

## 4.8 NMVOC Emissions Control – Petrol Vapour Recovery

### *4.8.1 Relevant EU Directives*

Two EU Directives deal with petrol vapour recovery (PVR).

*Directive 94/63/EC* of 20 December 1994 concerns the control of VOC emissions resulting from the storage of petrol and its distribution from terminals to service stations. It is known as the *Stage I Petrol Vapour Recovery* Directive and aims to reduce emissions from the evaporation of petrol at all stages of the fuel storage and distribution chain. In particular it lays down harmonised technical specifications for the design and use of (i) storage installations at terminals (ii) equipment for loading and unloading mobile containers at terminals (iii) mobile containers and (iv) equipment for loading into storage installations at service stations.

*Directive 2009/126/EC* on *Stage II Petrol Vapour Recovery* during refuelling at service stations aims to ensure that petrol vapour displaced from the fuel tank of a motor vehicle during refuelling at a service station is recovered.

It is noted that most Fuel Storage Depots in Turkey have Stage I PVR techniques already fitted, and that Stage II PVR techniques are being introduced in the larger petrol filling stations.

#### *4.8.2 Marginal costs of NMVOCs reduction*

Marginal NMVOC reduction costs from GAINS data for Stage I and Stage II PVR are set out in Annex 3. Marginal costs vary from about €670 per tonne for Stage I techniques to about €6,400 per tonne for Stage II techniques.

Whilst substantially higher than the marginal damage cost of €9.5 for NMVOC emissions from Turkey, PVR Stage I marginal costs lie below both the average marginal damage costs applying to emissions from a number of Member and Neighbouring States (Table 4-1 and Annex 3).

PVR Stage II marginal reduction costs appear to be higher than the marginal damage costs of emissions emanating from Turkey or any of the EU-27 Member and Neighbouring States.

**Cost Benefit Analysis**

Based on marginal damage costs associated with NMVOC emissions from Turkey, none of the NMVOC abatement techniques considered for the Stage I and Stage II PVR Directives are justified on cost-benefit considerations alone.

However using the marginal damage costs associated with EU-27 emissions then probably the NMVOC abatement techniques considered for the Stage I Directive can be justified, but not those for the Stage II PVR Directive.

## 4.9 Agriculture

#### *4.9.1 Livestock rearing - techniques for reducing $NH_3$ emissions*

A number of options exist for reducing gaseous emissions to air, some of which primarily concern greenhouse gases (especially methane) while some contribute to $SO_2$ and NOx emissions reduction indirectly[28]. Regarding $NH_3$ emissions control, options in the livestock rearing sector involve better farm management and range from:

- Reducing emissions at source by controlling animal feed composition so that less nitrogenous material is excreted;

[28] Biogas plants that produce renewable energy for heating and electricity from manure – a renewable energy source.

- Adaptation of ventilation in livestock accommodation. However the cost may be prohibitive at individual farm level;
- Improving manure management and application techniques e.g. covered slurry storage facilities, techniques for spreading manure so as to minimise air-manure contact (thus minimising $NH_3$ emissions) and the appropriate timing of applications so as to maximise the incorporation of nitrogenous materials into the soil. All such techniques reduce $NH_3$ emissions and make best use of a valuable resource for the soil.

### *4.9.2 Marginal costs for reducing $NH_3$ emissions*

Marginal $NH_3$ abatement cost data from GAINS relevant to manure management are set out in Annex 3. For all techniques considered, the marginal cost of $NH_3$ abatement is considerably less than the marginal damage costs for Turkey of €5,445/tonne (Table 4-1).

**Cost Benefit Analysis**

All animal manure techniques identified in Annex 3 are justified in Turkey on the grounds of cost-benefit.

### *4.9.3 Fertiliser application to land*

Farmers in EU-27 Member States are required to (i) use the minimum amounts of nitrogenous fertiliser (ii) apply the fertiliser at the most effective time of the growing season, when it will provide maximum nutrient for the plants grown and (iii) prevent it being washed in the rainwater run-off into nearby streams and rivers or groundwater resources. This is especially the case for any area designated a Nitrate Vulnerable Zone under EU Directive 91/676/EEC (as amended) on protection of waters against pollution caused by nitrates from agricultural sources: the so-called Nitrates Directive.

Over the period 2011 – 2025 it is expected that farms in Turkey may consolidate, individual farms becoming bigger as farming develops increasingly to become more a commercial than subsistence activity.

Within Turkey's land mass it is quite possible that there are areas which might be classified as nitrate vulnerable zones as defined in the Nitrates Directive (see Section 3.12.2). In future, such areas may have restrictions placed on the application of synthetic nitrogenous fertilisers to land.

As a result of these factors it is considered that the amount of synthetic (nitrogenous) fertilizers applied to land in Turkey may fall from what might otherwise be the case. Since fertiliser use should become more efficient, it is assumed that the net costs to farmers will be zero.

# 5 NECD EMISSION PROJECTIONS 2011-2025

## 5.1 Staged Process: October 2011 to July 2012

The NECD pollutant emission projections for 2011-2025 presented here resulted from an extended consultation with stakeholders. Table 5-1 summarises the stages in its preparation since October 2011. A number of documents issued by Government and other official sources within Turkey were consulted together with international sources – see Table 5-2. Nevertheless, significant uncertainties in the emission projections need to be resolved in the near future – see Section 5.9.

**Table 5-1 Stages in the evolution of Version 2 NECD Emission Projections**

| Period | Stage in Preparation |
|---|---|
| October 2011 | MoEU issued an official request to the Ministries of Energy and Natural Resources (MoENR), Transport (MoT) and Agriculture (MoA) for activity data relevant to historic NECD Emissions Inventory and Projections. |
| November 2011 | Ministries advised MoEU that planning data – a basis for the emission projections – could not be released to MoEU and the TA Project team in the absence of a high level protocol. |
| December 2011 | A first inter-Ministry Coordination Committee (CoCom) meeting was held under the chairmanship of MoEU to begin a process that would help facilitate the transposition of the EU National Emission Ceilings Directive (NECD) into Turkish legislation and *inter alia* facilitate the provision of planning data for use in making NECD emission projections. |
| December 2011 - January 2012 | TA Project team prepared three draft Scenarios (WoM, WM and WaM) as a basis for Emission Projections and presented them to a Seminar on 30 January. The Scenarios were subsequently revised and reduced to two in response to comments from stakeholder representatives at the Seminar. |
| December 2011 - March 2012 | TA Project team prepared a technical basis for the estimation of NECD emission projections and presented this (in Turkish language) to a second, inter-Ministry Co-Com meeting (15 March) organised by MoEU to establish a Coordination Board and its working procedures. This document was based on the TA Team's interpretation of Turkey's national energy and other policies, including the National Climate Change Action Plan 2011-2023 (NCCAP), and expert professional judgement / analysis. Official planning data were not made available during document preparation. Participating Ministries were requested to comment by 31 May. |
| March – April 2012 | Version 1 of the NECD Emission Projections was prepared and reported on (the draft was submitted to MoEU on 1 May for review and comment). |
| May 2012 | A third CoCom meeting was held 8 May. An internal meeting was held 25 May in MoEU, chaired by the Director General, to review the Version 1 Scenarios and resulting Emission Projections. In response to the detailed comments received at this meeting, the TA team restructured the Scenario contents significantly and restored the number to three (WoM, WM and WaM), in part so as to achieve greater consistency with the approach adopted for Turkey's GHG projections.<br>MoEU organised a stakeholder meeting on 30 May to obtain (i) official comments on the Version 1 Emission Projections basis and (ii) new, official documentation for use in the preparation of Version 2. |
| June 2012 | Newly available official documentation and comments on Version 1 were reviewed by the TA team in consultation with MoEU. Available information (Table 5-2) was used to develop further the three scenarios and the bases for estimating Version 2 NECD emission projections. The three scenarios and bases for projections were agreed by MoEU and the TA team. |
| July 2012 | Version 2 NECD emission projections were made and reported. |

**Table 5-2 Key sources of information**

| Reference<br>Source of Information |
|---|
| Ministry of Energy and Natural Resources, Turkish National Energy Balance Tables (1990-2010) |
| TEİAŞ (November 2011), Turkish Electrical Energy 10-Year Generation Capacity Projection (2011 – 2020) |
| Ministry of Environment and Urbanisation (July 2011), Republic of Turkey National Climate Change Action Plan, 2011-2023 |
| Ministry of Development (May 2009), Acceptance of Electricity Energy Market and Security of Supply Strategy Certificate. Attachment:1 |
| Ministry of Development, 'Medium Term Development Programme (2012-2014) |
| Ministry of Economy (June 2012), Turkish National GDP Analysis 1998-2010 by Sector at 1998 Prices (spreadsheet file) |
| Taner Yildiz (2011), Minister of the Ministry of Energy and Natural Resources, Budget Speech 2011 |
| OECD (2010), 'Total Population' in Population and Migration, OECD Factbook 2010, pp. 12-15. |
| European Environmental Agency (June 2009), 'EMEP/EEA Air Pollution Emissions Inventory Guidebook' |

## 5.2 Scenarios

It is good practice to follow internationally accepted definitions when creating emission projection scenarios. Conforming to good practice and consistent with the approach adopted for GHG projections, three NECD emission scenarios were adopted – see Table 5.3 and below. The scenarios agreed with MoEU were:

- *Without Measures Scenario (WoM)*. The WoM Scenario establishes a baseline for the projected growth in emissions from 2010 (the last year of the historic inventory). Projected activities that influence NECD pollutant emissions were assumed to grow in response to population and economic growth. But policy and other measures that affect emissions growth were assumed to be 'frozen' to reflect the situation in year 2010. For this reason, this scenario used often to be known as "business as usual" though this terminology is now out of favour as its definition is insufficiently precise.
- *With Measures Scenario (WM)*. WM assumes the same rates of population and economic growth as in the WoM Scenario but activity levels are assumed to change also in response to national policies such as the National Climate Change Action Plan and legislation. Also, the effects on emission factors of EU standards (up to and inclusive of EURO 6 and VI) regarding road transport vehicles, the EU Directive regarding Sulphur Content of Certain Liquid Fuels and the By-Law regarding waste landfills (which transposes the EU Landfill Directive) were taken into account. New power plants were assumed to operate with emissions control consistent with LCPD compliance.
- *With Additional Measures Scenario (WaM)*. This built on the WM Scenario by taking into account the effects on emission factors of the transposition of a number of relevant 'other' EU Directives into Turkish legislation and the implementation of that legislation. Implementation of the transposed 'other' Directives will establish the mechanisms for additionally controlling the emissions from relevant activities. *NB: the scenario projections assume that $SO_2$ and NOx emissions control will be retrofitted to existing lignite-fired power plants over the period 2019-2025 not 2011-2019.*

**Table 5-3 Scenarios – major policy and legislative drivers**

| Core Drivers for Change (activity / emission factor) | Without Measures (WoM Scenario) | With Measures (WM Scenario) | With Additional Measures (WaM Scenario) |
|---|---|---|---|
| **Population** | Population grows from 76.51 million in 2010 to 87.76 million in 2025. | Same as for WoM Scenario | Same as for WM Scenario |
| **GDP (real, i.e. adjusted for price inflation)** | Real GDP grows according to MoD forecasts to 2014 and at 5% per year thereafter. | Same as for WoM Scenario | Same as for WM Scenario |
| **National energy policies and National Climate Change Action Plan 2011-2023 (NCCAP)** | Increase in national electricity demand based on TEİAŞ's "high demand" projection to 2020, extrapolated beyond 2020 to 2025.<br>No implementation of NCCAP, i.e. no solar, no expansion of hydro, wind or geothermal electricity generation capacity beyond 2010.<br>Fuel mix for combustion in power generation, industry, residential and commercial sectors remains as at 2010.<br>No electricity generation by nuclear or solar. | Increase in demand as for WoM, but national policy is implemented regarding:<br>- NCCAP: expansion of hydro, wind and geothermal for electricity generation.<br>- Introduction of nuclear for electricity generation.<br>- Collection and utilisation of biogas from landfill sites.<br>- Reducing by 2025 the quantity of biodegradable municipal waste (BMW) disposed of to landfills / dumpsites to 35% of the 2005 value. | Same as for WM Scenario |
| **EURO standards - road transport vehicles** | The effects of manufacturers' earlier adoption of EURO Standards (3, 4, 5; III, IV and V) are included. Later ones are not. | As for WoM, but the effects of adopting EURO 6 and VI standards are assessed also. | Same as for WM Scenario |
| **Rail transport policy** | Growth in traffic is related to but is slower than the rate of GDP growth.<br>The fuel mix of year 2010 is maintained to 2025. | Significant expansion of railway traffic (freight 3 x and passengers 5 x year 2009 levels). | Significant increase in system electrification. |
| **EU Directives** | Implementation of EU Directives is not taken into account. | Same as for WoM Scenario except for the implementation of (i) Sulphur Content of Certain Liquid Fuels Directive (SCLF) (ii) BMW diversion targets, consistent with EU Landfill Directive 1999/31 (iii) and emissions control at new coal or lignite fired plants that would comply with LCPD. | As for WM Scenario but the transposition and implementation of the following EU Directives also are taken into specific account: (iii) Large combustion plant (LCPD) at existing plants; (iv) Integrated pollution prevention and control (IPPC); (v) VOCs - Solvents, Storage & Deco-Paints; (vi) Wastes incineration; and (vii) Nitrates. |
| **Agriculture** | Historic trends in livestock numbers and synthetic fertiliser use are assumed to continue into future years. The average size of dairy cattle increases to that of Western European cattle. Fertiliser use increases with population. | Same as for WoM Scenario | As for WM Scenario but taking into account the direct / indirect effects of certain EU Directives on the management of manures & fertiliser application. |

Table 5-3 identifies the key drivers for change and summarises qualitatively how they were taken into account in the three scenarios. Growth in both population and overall economic activity expressed as GDP are the principal drivers for activity levels – affecting the vast majority of sources that emit NECD pollutants.

- Turkey's population was taken to increase from 76.5 million in 2010 to 87.8 million in 2025.
- Turkey's real, national GDP was taken to increase by 7.5 % in 2011, 4.0% in 2012 and 5.0% a year thereafter to 2025.

The implementation of national policies is likely to have a major influence on both activity levels and emission factors in future, whilst the transposition, implementation and enforcement of relevant EC Directives – see Annex 4 - may be expected to have a major impact on emission factors in specific sectors: electricity generation and manufacturing industry in particular.

Annex 6 notes the major sectoral considerations and provides selected emission factors over the projections period to 2025. For further details, the TA Report "NECD Emission Projections 2011-2025" (July 2012) should be consulted. It should be noted that, unless specifically noted to the contrary, the suggested EMS for each sector (Section 3) is fully embodied in the WaM Scenario.

## 5.3 $SO_2$ Emission Projections

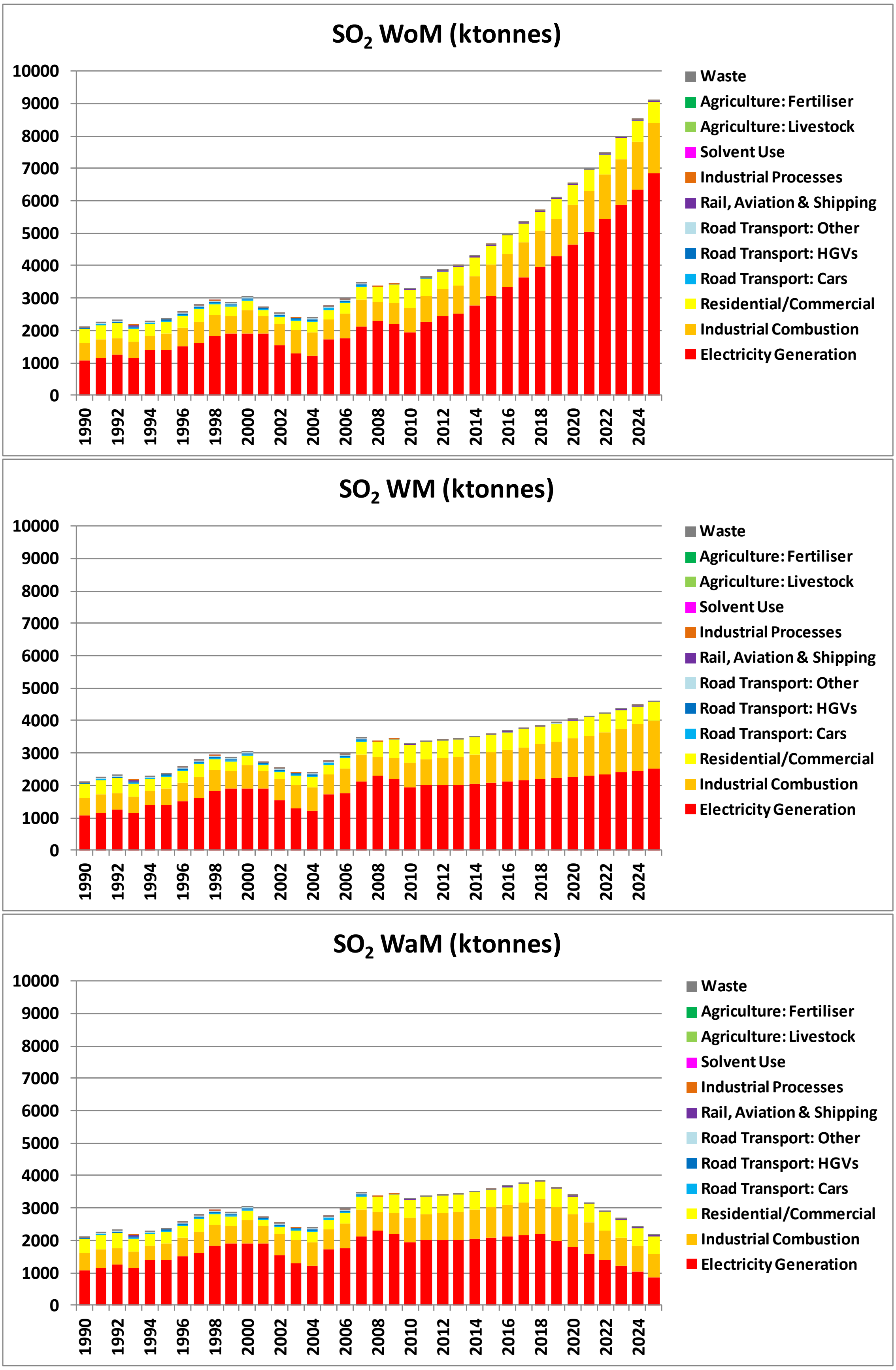
The results of the $SO_2$ emission projections for the WoM, WM and WaM Scenarios to 2025 are summarised below and plotted in Figure 5-1.

*WoM Scenario*: All of the major $SO_2$ sources increase with time, but the most pronounced is the substantial growth in the emissions from electricity generation. This is based on forecasts of electricity demand, which indicate a substantial growth with time. Furthermore, it is assumed here that the fuel mix remains constant, and that there are no measures implemented to control emissions. As a result, the use of lignite for electricity generation (which dominates the historic emissions) continues to dominate the emissions across 2011 – 2025. Emissions from industrial combustion also increase significantly with time, reflecting the expected growth of the economy in Turkey.

*WM Scenario*: Compared to the emissions in the WoM scenario, $SO_2$ emissions in the WM scenario are considerably smaller – nearly a half (a total for year 2025 of 4,592 compared to 9,094 ktonnes). This reduction is almost entirely due to controls implemented in the electricity generating sector, with all other sources contributing only 200 ktonnes to the difference. The large reduction in the emissions from electricity generation is driven by the introduction of effective FGD to all new lignite electricity generating stations. Other measures are also taken into account, such as the introduction of the SCLF Directive. But the impacts of these are small compared to the reductions that are predicted for new lignite-fired electricity generating stations.

*WaM Scenario*: The WaM scenario is similar to WM, but additional legislation is assumed to be introduced that controls emissions from stationary combustion sources (LCPD, IPPC). This more thorough implementation of emissions control has a marked impact on $SO_2$ emissions from existing lignite-fired stations. Emissions from industry are also reduced. The combined impact gives rise to an overall decrease of the total emissions. The effective control of emissions from electricity generation – existing lignite-fired stations in particular - is the most important difference between the scenarios.

**Figure 5-1 $SO_2$ emissions and projections for three scenarios**



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## 5.4 NOx Emission Projections

The results of the NOx emission projections for the WoM, WM and WaM Scenarios to 2025 are summarised below and plotted in Figure 5-2.

*WoM Scenario*: The source which has the largest contribution to the trend in total NOx emissions is electricity generation. This is because there is a large growth in electricity demand, and under the WoM scenario, no increased use of abatement technology is assumed.

There is also a substantial increase in the use of road vehicles. However, the turnover of the fleet means that newer and considerably less polluting vehicles are introduced into the national fleet in place of older, more polluting vehicles. Even under this WoM scenario (where the technology of new vehicles is assumed to be frozen at Euro 5 and V), the impact of the vehicle fleet turnover is comparable to and almost offsets the impact of increased traffic growth (vehicle-kms). Consequently only a small growth in NOx emissions from road transport is projected from 2010 to 2025.

*WM Scenario*: The most significant difference between the emissions presented here, and those presented for the WoM scenario are that NOx emissions from electricity generation are substantially reduced. Under the WM scenario, considerably less fossil fuel – lignite particularly - is used in electricity generation, which is responsible for the majority of the NOx emissions from this source. In addition, new plants that are constructed to meet the rapidly increasing energy demand are assumed to incorporate emissions abatement. So the emissions intensity is also reduced.

The WM scenario also includes measures introduced to control emissions from other sectors, such as industry and road transport. However the impacts are relatively small when compared to those in the electricity generation sector.

*WaM Scenario*: The WaM scenario is similar to WM but additional legislation is factored in that controls emissions from existing stationary combustion sources (LCPD, IPPC). This more thorough implementation of emissions control means that emissions from electricity generation (and industrial combustion) are lower in the WaM scenario than the WM scenario. The overall impact on emissions is considerable, with the 2025 WaM total NOx emissions being some 40% and 15% lower than the WoM and WM scenarios respectively.

## 5.5 NMVOC Emission Projections

The results of the NMVOC emission projections for the WoM, WM and WaM Scenarios to 2025 are summarised below and plotted in Figure 5-3.

*WoM Scenario*: Whilst there are a number of significant sources of NMVOC at the national level, the projections indicate that the largest contribution to the time series trend comes from solvent use. This is because substantial growth is expected in the industrial sectors and in the consumption of domestic products that contain solvent. In the WoM scenario, no emission controls are included. Consequently, the increases in the consumption of solvents and solvent containing products translate directly to increased emissions.

The projected increase in NMVOC emissions from road transport is caused by the increased use of motorcycles. More modern motorcycles emit less NMVOC per km compared to older motorcycles, but the reduction is not as pronounced as other vehicle classes. As a result, the projected impact of the growth in use of motorcycles more than offsets the impact of introducing newer motorcycles into the fleet. Hence emissions from that source increase with time.

**Figure 5-2 NOx emissions and projections for three scenarios**

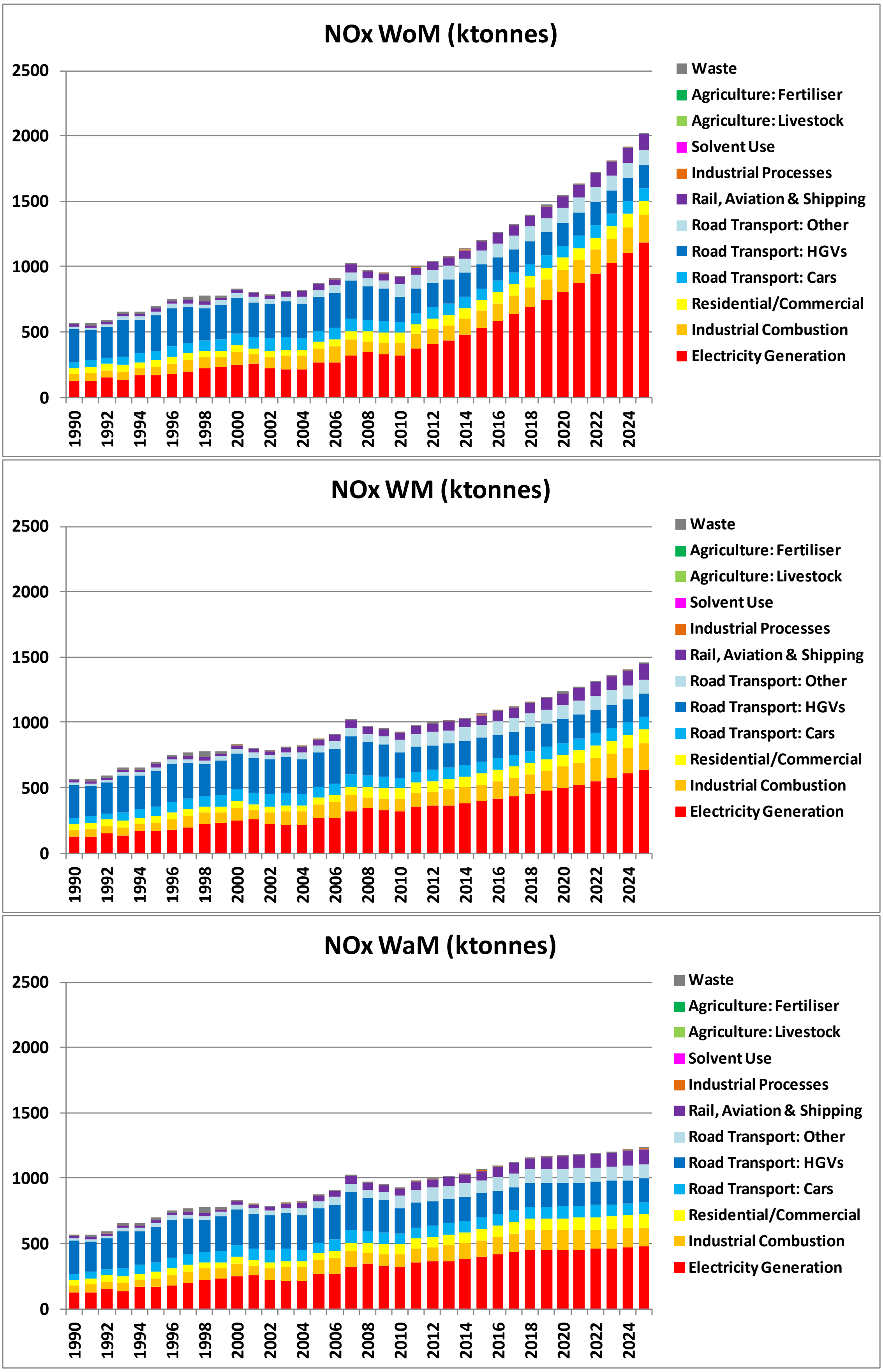
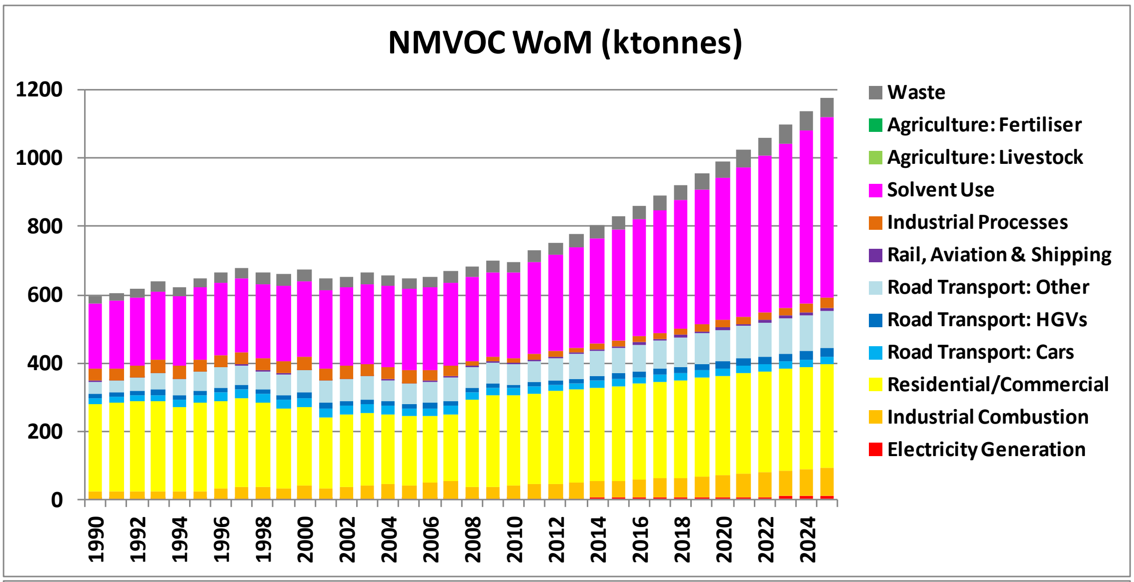
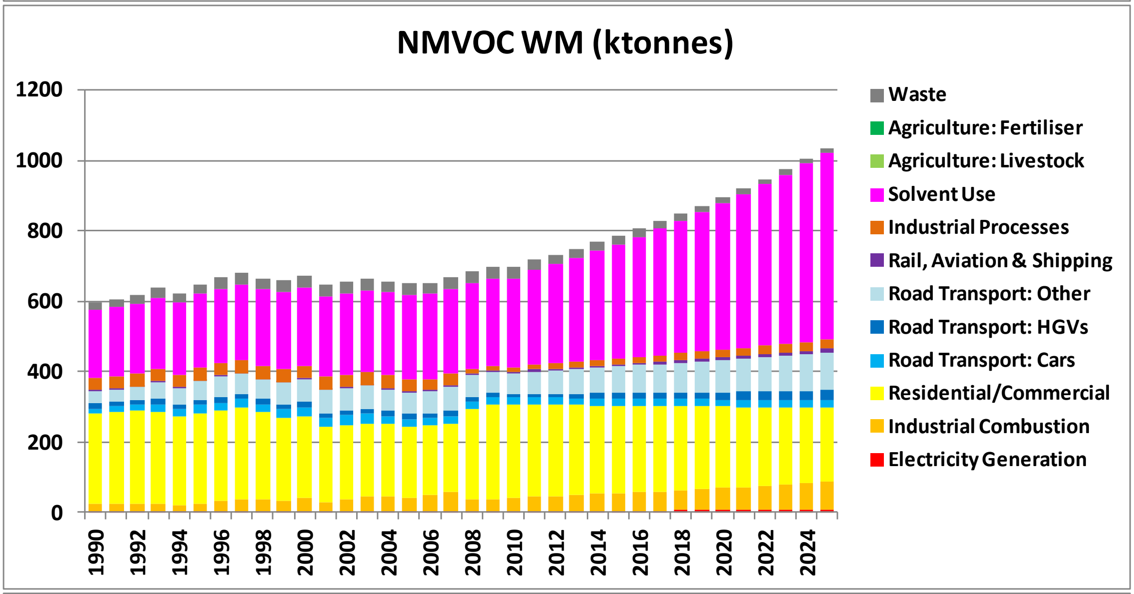
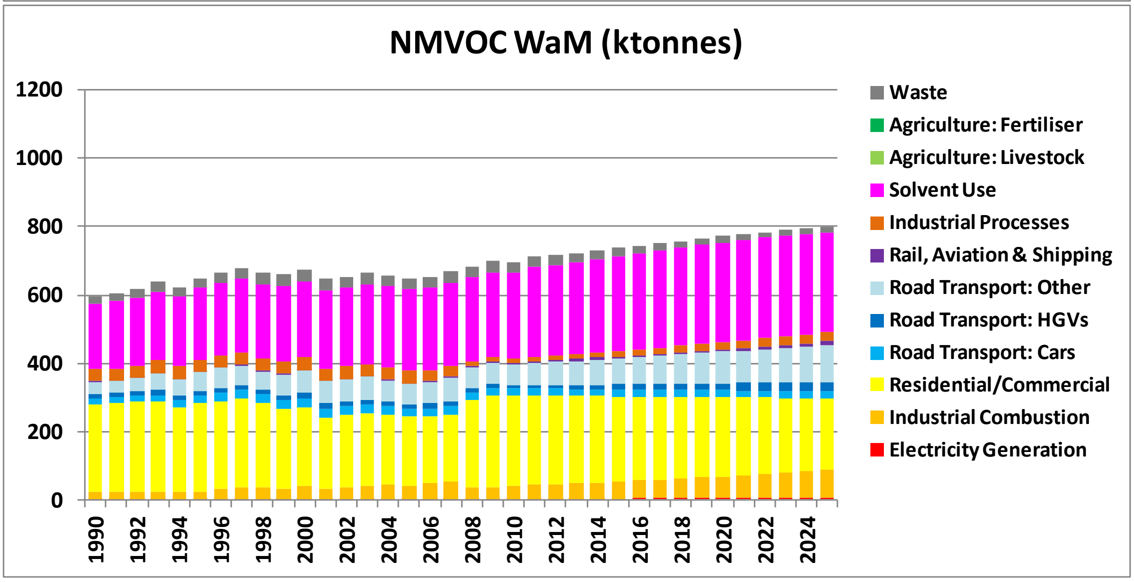


**Figure 5-3 NMVOC emissions and projections for three scenarios**



*WM Scenario - NMVOC*: When comparing the NMVOC emissions for the WoM and WM scenarios, the largest differences are in the emissions from the residential combustion and waste sectors. For the residential combustion sector, the WM scenario assumes a substantial decrease in the use of wood for residential heating, and wood combustion is one of the larger sources of NMVOC emission from that sector. For waste, the WM scenario assumes less waste going to landfill, and more recovery/flaring of landfill gas.

Emissions from the use of solvents and solvent containing products in the WoM and WM scenarios are the same.

*WaM Scenario - NMVOC*: All NMVOC sources are similar across the WM and WaM scenarios, with the exception of solvent use. The implementation of both the Solvents Directive and Deco-paints Directive in the WaM scenario significantly impacts the emissions from industrial solvent use and the residential use of solvent containing products. As a result, the total 2025 emission of NMVOC in the WaM scenario is projected to be ~20% lower than that in the WM scenario.

## 5.6 $NH_3$ Emission Projections

The results of the $NH_3$ emission projections for the WoM, WM and WaM Scenarios to 2025 are summarised below and plotted in Figure 5-4.

*WoM Scenario*: Emissions of $NH_3$ are dominated by emissions associated with farming livestock (dairy cattle in particular) and the use of synthetic fertiliser. The number of cattle is predicted to remain fairly constant across 2011 – 2025. However, it is assumed that the average weight of dairy cattle increases, to bring farming practices in line with the more intense systems observed in Western Europe. As a result, $NH_3$ emissions from dairy cattle would increase: this factor accounts for most of the overall increase in $NH_3$ emissions. Changing animal numbers result in relatively smaller other changes in $NH_3$ emissions: those from sheep decrease; those from poultry increase.

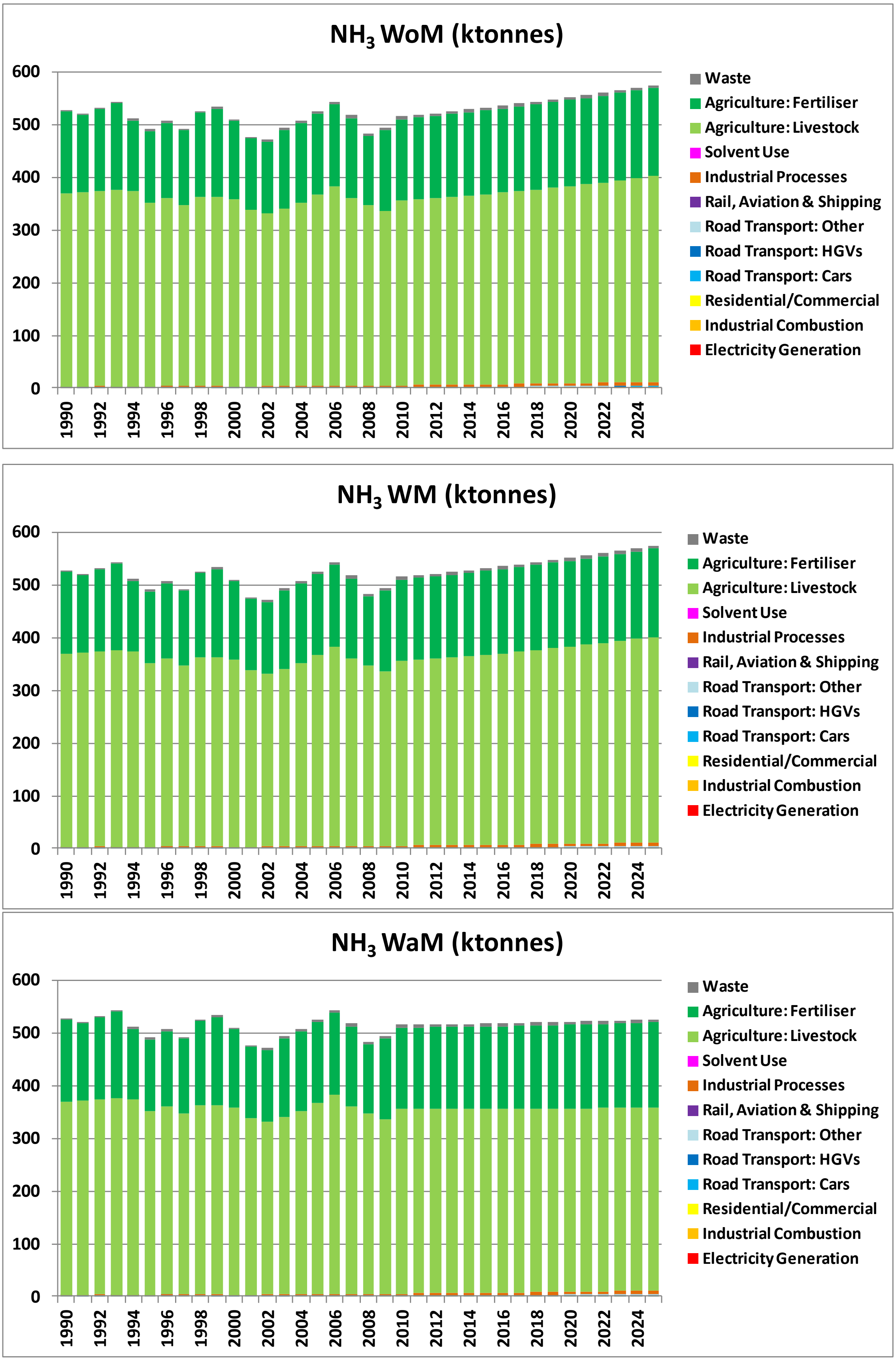
Emissions from the use of synthetic fertiliser show a small increase, representing the slight increase in projected fertiliser consumption.

*WM Scenario*: Emissions from the WoM and WM scenarios are almost identical. This is because the assumptions used to calculate emissions from the agriculture sector are the same in the two scenarios. Slight differences between the WoM and WM scenario projections result from changes in other source sectors, but they make very small contributions to the national $NH_3$ emissions total.

*WaM Scenario*: Under the WaM scenario, emission controls are introduced in the agriculture sector through the transposed EU Nitrates Directive; it is also assumed that national level activities are also undertaken to introduce farm practice improvements.

The impact of introducing these changes is not large (the total $NH_3$ emission in year 2025 of the WaM scenario is lower than that of the WM scenario by ~8%). The net effect is to hold $NH_3$ emissions at a broadly constant level.

**Figure 5-4 $NH_3$ emissions and projections for three scenarios**



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## 5.7 Sensitivity Analysis for With Additional Measures (WaM) Scenario

### *5.7.1 Purpose and scope*

Whilst the projection results for all Scenarios are helpful in gauging the extent to which the potential NECD emissions of Turkey might be managed, it should be expected that the WaM Scenario projections will form the main basis for identifying possible National Emissions Ceilings. To assist that process, a limited sensitivity study was undertaken.

The analysis considered the effects of modifying a number of assumptions on the emissions projected for the years 2020 and 2025. The sensitivity analysis was limited in that it did not consider interactions between various factors but considered their effects in isolation. Nevertheless, the results provide an insight into the significance of a number of parameters used in the emission projections. The potential effects of the following were considered:

- Population growth – an increase in population varying in the range 85% to 115% of the increase projected from 2010 to 2025.
- GDP growth within the range of 4% to 6% annually beyond 2014.
- Variation in the proportion of Turkey's total electricity generation derived by 2025 from zero-emission sources (hydro, wind, geothermal, solar and nuclear), ranging from 20% to 35%.
- A less than 90% $SO_2$ removal rate at FGD plants installed at lignite/coal fuelled electricity generating stations: $SO_2$ removal rates of 70%, 80% and 90% were considered.
- No change in values from 2010 for the fuel mix of residential (stationary) combustion.

Highlights of the sensitivity analysis results are presented below.

### *5.7.2 Population growth*

All three Scenarios included a base assumption that the population of Turkey increases from 76.51 million in 2010 to 87.76 million in 2025. Table 5-4 presents the estimated total national emissions in 2020 and 2025 for alternative population increases. The variants considered (85% and 115% of the WaM increase) give year 2025 populations of 86.07 million and 89.44 million respectively.

**Table 5-4 Influence of population growth**

| NECD Pollutant | Year | Projected Total National Emissions (ktonne) for WaM and Variant Population Increases | | |
|---|---|---|---|---|
| | | 85% increase | WaM | 115% Increase |
| NOx | 2020 | 1167 | 1174 | 1182 |
| | 2025 | 1225 | 1236 | 1246 |
| $SO_2$ | 2020 | 3340 | 3372 | 3404 |
| | 2025 | 2130 | 2156 | 2182 |
| NMVOC | 2020 | 768 | 771 | 775 |
| | 2025 | 794 | 798 | 803 |
| $NH_3$ | 2020 | 521 | 521 | 521 |
| | 2025 | 525 | 526 | 526 |

As expected, higher population growth results in higher emissions in all cases. However the differences are small. For example, $SO_2$ emissions for the 85% and 115% population calculations are respectively lower and higher than the WaM scenario by less than 2%: considerably less than the impact of other underlying assumptions.

### *5.7.3 GDP Growth*

The Ministry of Development has forecast GDP growth in the first four years of the Projection period (2011-2014) as 7.5%, 4.0%, 5.0% and 5.0% respectively: the WaM scenario assumed a uniform annual growth rate of 5.0% for the period 2015-2025. Table 5-5 presents the estimated national emissions of NECD pollutants in 2020 and 2025 for variant annual GDP growth rates (2015 to 2025) of 4% and 6%.

**Table 5-5 Influence of GDP growth**

| NECD Pollutant | Year | Projected Total National Emissions (ktonne) for WaM and Variant GDP Growth Rates | | |
|---|---|---|---|---|
| | | 4% Growth in 2015 and beyond4 | WaM – 5% Growth in 2015 and beyond | 6% Growth in 2015 and beyond |
| NOx | 2020 | 1139 | 1174 | 1211 |
| | 2025 | 1170 | 1236 | 1308 |
| $SO_2$ | 2020 | 3213 | 3372 | 3538 |
| | 2025 | 1994 | 2156 | 2334 |
| NMVOC | 2020 | 750 | 771 | 794 |
| | 2025 | 757 | 798 | 843 |
| $NH_3$ | 2020 | 520 | 521 | 521 |
| | 2025 | 525 | 526 | 526 |

Unsurprisingly, higher GDP growth would result in higher emissions: a significant number of sources are assumed to grow in proportion to GDP. National emissions appear to be more sensitive to changes in GDP than population. For NOx, the lower and higher GDP growth values give rise to emissions that differ from the WaM scenario by approximately 5%.

### *5.7.4 Electricity Generation from Zero-Emission Sources*

Based on TEİAŞ’s 2011-2020 electricity plan (Table 5-2), the WaM Scenario assumes that the contribution made by zero-emission sources to electricity generation from 2015 will remain at 27.1% of the total through to 2025. Two factors suggest that the influence of alternative proportional contributions by 2025 should be considered:

- Policy statements that (i) renewable energy sources (hydro wind and geothermal) should provide 30% of electricity generation by 2023 and (ii) nuclear should provide 5% of electricity generation. Hence the effects of a higher (35%) contribution from zero-emission sources by 2025 should be assessed.
- The number and size of the WaM projected investments in zero-emission sources of electricity generation beyond 2015 would be substantial. There are grounds, therefore, for adopting a more cautious view as to whether the projected investments would be achieved in the timescale. Hence assessing the impacts of a lower contribution from zero-emission sources, say 20% by 2025, was also considered to be of interest.

These variants are phased in over the 10-year period 2016-2025 in this sensitivity analysis. Table 5-6 presents the estimated total national emissions of $SO_2$ and NOx and in 2020 and 2025 in response to the above factors.

**Table 5-6 Influence of electricity generation from zero-emission sources**

| NECD Pollutant | Year | Projected Total National Emissions (ktonne) for WaM and Variant Contributions of Zero-Emission Sources to Electricity Generation | | |
|---|---|---|---|---|
| | | 20% by 2025 | WaM 27.1% by 2025 | 35% by 2025 |
| NOx | 2020 | 1197 | 1174 | 1150 |
| | 2025 | 1283 | 1236 | 1184 |
| $SO_2$ | 2020 | 3460 | 3372 | 3276 |
| | 2025 | 2239 | 2156 | 2064 |

Though only one sector is affected in this variant the impact is substantial. There is a noticeable difference at the total emission level. The variants investigated result in a 4% difference relative to the WaM scenario in 2025.

### *5.7.5 Performance of FGD at Lignite-fuelled Power Plants*

The WaM Scenario assumes a 90% $SO_2$ removal rate at FGD technology installed on LCPs. However, the lignite mined in Turkey and used in the power stations has a low heating value and high water and ash contents. Its quality is therefore poor and is, moreover, quite variable. It was understood that the variable quality of Turkish lignite causes considerable difficulties for process control and sustained operation; and that these difficulties impair the performance of FGD units installed on such plants.

Hence a range of $SO_2$ removal rates at lignite-fuelled plants, from 70% to 90% (the latter as in WaM), was adopted to consider the potential influence of this issue. It must be noted that $SO_2$ removal rates below 90% are inconsistent with LCPD compliance. Hence, whilst the influence of low-performing FGD plants could be a factor to take into account when identifying a possible NECD emission ceiling for $SO_2$, it would raise a significant other issue; namely, the sustainability of using Turkish-mined lignite for generating electricity. Table 5-7 presents the estimated impacts on national $SO_2$ emissions.

**Table 5-7 Influence of FGD performance at lignite-fuelled power plants**

| NECD Pollutant | Year | Projected Total National Emissions (ktonne) for WaM and Variants on FGD $SO_2$ Removal Efficiency (Lignite Power Plants) | | |
|---|---|---|---|---|
| | | 70% $SO_2$ Removal | 80% $SO_2$ Removal | WaM 90% $SO_2$ Removal |
| $SO_2$ | 2020 | 3995 | 3683 | 3372 |
| | 2025 | 3581 | 2869 | 2156 |

An $SO_2$ removal efficiency of 80% would increase total year 2025 emissions (over WaM) by 33%: an efficiency of 70% would increase emissions by 66%.

These results illustrate the importance of providing reliable data to the historic emissions inventory and projections on the sulphur content of fuels used in electricity generating stations, the extent to which FDG is used and the performance efficiency of FGD.

### *5.7.6 Fuel Mix for Stationary Combustion – Residential and Services*

The WaM Scenario assumed that for the residential sector there would be further expansion of natural gas use, reductions in absolute and proportional uses of oil, wood and waste and no change from 2010 in the absolute quantities of coal and lignite burned. One variant on WaM has been considered, that in which the fuel mix for the residential sector would be maintained at the 2010 mix throughout the projection period to 2025. In fact, this variant is identical to the residential sector in the WoM Scenario. Table 5-8 compares the projected emissions.

**Table 5-8 Influence of residential combustion energy mix**

| NECD Pollutant | Year | Projected Total National Emissions (ktonne) for WaM and Variant Fuel Mix for Residential Combustion | |
|---|---|---|---|
| | | Energy Mix as at 2010 | WaM Energy Mix |
| NOx | 2020 | 1176 | 1174 |
| | 2025 | 1238 | 1236 |
| $SO_2$ | 2020 | 3432 | 3372 |
| | 2025 | 2240 | 2156 |
| NMVOC | 2020 | 832 | 771 |
| | 2025 | 892 | 798 |
| $NH_3$ | 2020 | 521 | 521 |
| | 2025 | 526 | 526 |

Compared to the WaM scenario, the impact of maintaining the 2010 fuel mix for the domestic sector varies considerably across the pollutants:

- There is little impact on NOx and $NH_3$ emissions;
- There is only a 4% increase in emissions of $SO_2$. This is caused by the larger amounts of lignite and coal that are used. The effect is comparable to varying the projected population.
- However emissions of NMVOC in 2025 are 12% higher than the WaM scenario. This is because NMVOC emissions from wood use in the residential sector is a particularly important source, and the emissions in the WaM scenario are half that of the above variant.

## 5.8 Summary of Emission Projections

Figures 5-5 to 5-8 summarise and compare the emission projections, for $SO_2$, NOx, NMVOC and $NH_3$ respectively, for the three scenarios.

In interpreting these results it is important to note that the $SO_2$ and NOx emissions projections for the WaM scenario assume that emissions controls at existing (2010) lignite-fired electricity generation stations are phased in over the period 2019 to 2025, not 2011-2019 as specified in Turkish legislation. This assumption reflects a more cautious approach to implementation in recognition of the financial and other constraints that are likely to apply in practice (see Section 3.3.2 also). A number of semi-quantitative points may be made:

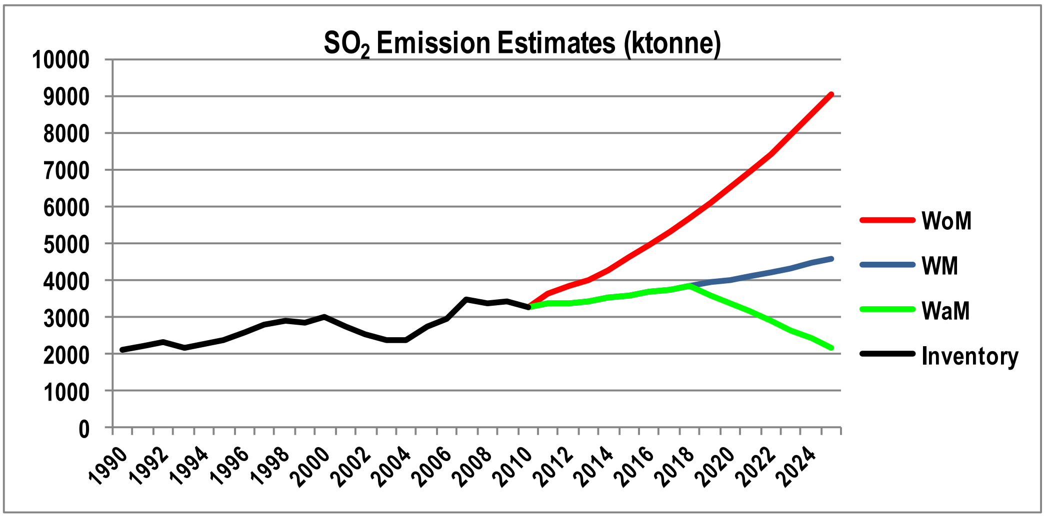
- WaM scenario emissions in 2025 are identical as, under both approaches, all existing plants will be retrofitted by 2025. This is significant as the WaM projected emissions for 2025 form a basis for identifying possible national emissions ceilings. But;
- Delaying to 2019-2025 the retrofitting of emissions control equipment to existing lignite-fired power stations will cause the cumulative economic

benefits of emissions reduction over the period 2011-2025 to be less than if retrofitting was carried out 2011-2019.

- Assuming no changes in technology and relative prices, the cumulative costs of emissions control will be the same under the two approaches. However;
- Delaying the retrofit programme to 2019-2025 should increase its affordability as the investments in emissions control will occur at a time when Turkey's overall economy is expected to be substantially larger.

$SO_2$ emissions: The projection results show that $SO_2$ emissions are substantially influenced by the introduction of FGD abatement equipment in the electricity generating sector (WM and WaM) to comply with the LCPD. Adopting the full EMS of Section 3, estimated emissions year 2025 in the WaM scenario are 2,156 ktonne compared with the inventory value for 2010 of 3,261 ktonne.

**Figure 5-5 Comparison of $SO_2$ emission projections for three scenarios**




NOx emissions: The emission projections under the WaM scenario suggest an emission of 1,236 ktonne in 2025, compared to 932 ktonne in 2010. The projected growth in emissions after 2010 in the WoM scenario is moderated in the WaM scenario (full EMS) by the substantial control of emissions from lignite combustion in LCPs, especially for electricity generation.

NMVOC emissions: The EMS for the WaM emissions scenario moderates the growth of NMVOC emissions under the WoM and WM scenarios. The principal agents for NMVOC reduction in the WaM scenario were the controls on solvent use and a decline in the combustion of wood in the residential sector. Emissions in 2010 were estimated to be 698 ktonnes and were projected to rise to 798 ktonne by 2025 in the WaM scenario.

$NH_3$ emissions: Emissions of $NH_3$ in the WaM scenario are managed by the introduction of controls and good practice to reduce the emissions from both livestock and manure management and fertiliser application. WM emissions are not shown in the plot below as they are indistinguishable from those for WoM. Emissions for the WaM scenario were projected to grow by a small amount from 515 ktonnes in 2010 to 526 ktonnes by 2025.

**Figure 5-6 Comparison of NOx emission projections for three scenarios**

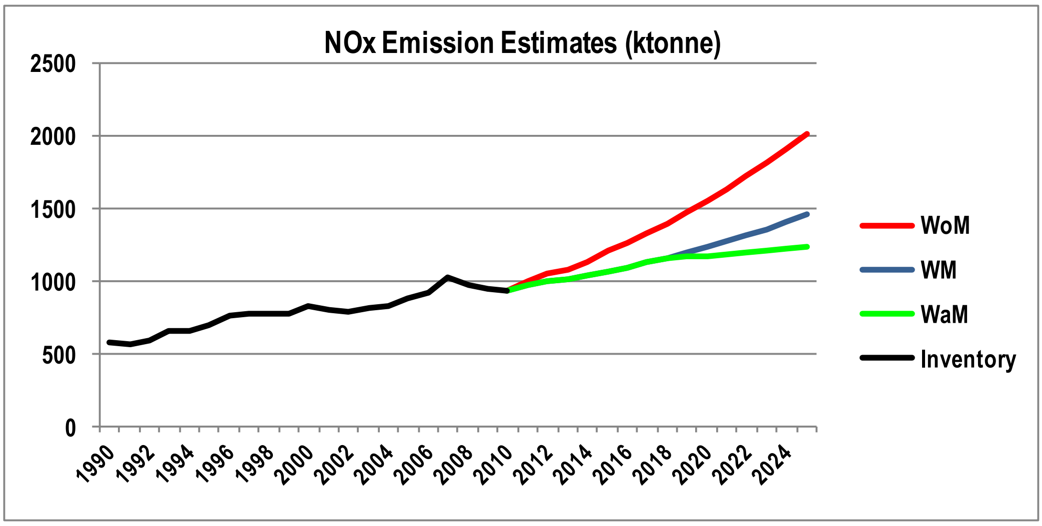



**Figure 5-7 Comparison of NOx emission projections for three scenarios**

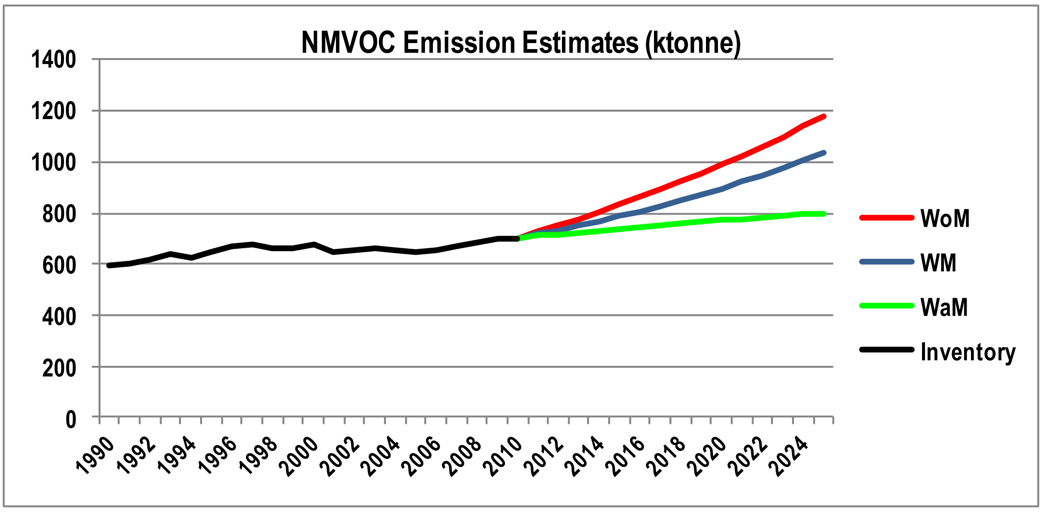
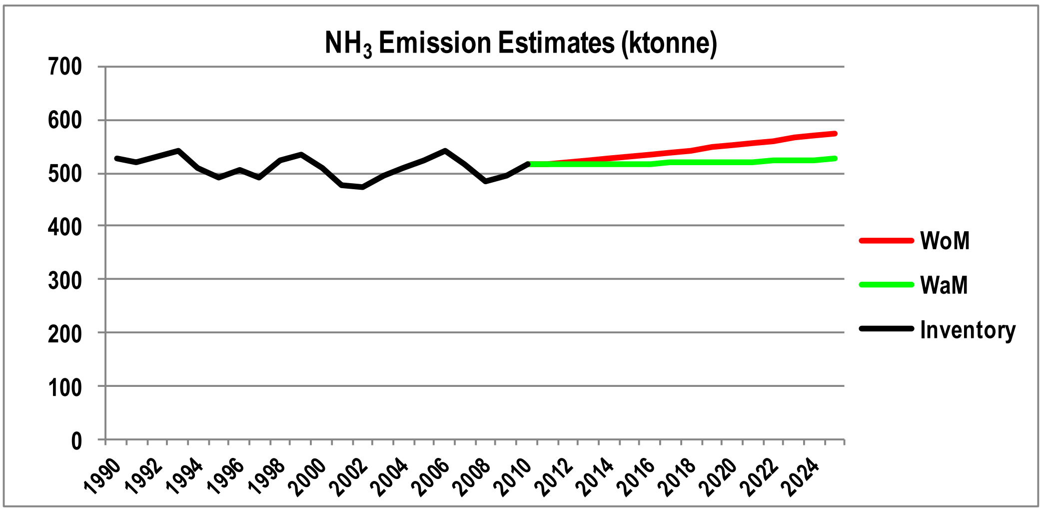



**Figure 5-8 Comparison of NH3 emission projections for two scenarios**



## 5.9 Areas of Significant Uncertainty – Improvement Needed in Future

The NECD emission projections are important since they form a basis for identifying possible national emission ceilings for Turkey – Section 6. However, whilst considerable efforts were taken to gain a consensus view on appropriate scenarios and the basis for making the projections, some care should be taken with the projection results given here and the conclusions reached. Several factors contribute to issuing this cautionary note. They include the following:

- Uncertainty is inherent in projecting economic activity levels and emission outcomes to a time 15 years in the future;
- The emission projections use the final year of the historic NECD emissions inventory 1990 to 2010. As a result, acknowledged uncertainties in the inventory and in the sectoral EMS (electricity generation especially) have been carried through into the emission projection calculations. The more significant uncertainties are introduced at the conclusion of Section 6: they should be resolved prior to Turkey entering international negotiations on national emission ceilings.

# 6 POTENTIAL NATIONAL EMISSIONS CEILINGS

## 6.1 International Agreements

### *6.1.1 Convention on Long-Range Transport of Air Pollutants (CLRTAP) and the Gothenburg Protocol*

The UN/ECE CLRTAP is overarching legislation that applies across the UN/ECE. Parties to the Convention (the individual Countries) elect to sign up to specific Protocols. One of the Protocols (the Gothenburg Protocol)[29] specifies 2010 emission ceilings for NOx, $SO_2$, NMVOC and $NH_3$. As such it is a very similar piece of legislation to the NECD, and most countries have the same 2010 respective emission ceilings under the Gothenburg Protocol as for the NECD. Turkey has ratified the CLRTAP but has not signed up to the Gothenburg Protocol, though it might do so in future.

However there are some substantial differences between the Gothenburg Protocol and the NECD. There are no punitive measures for non-compliance with the Protocol. When a country exceeds the ceilings specified in the Gothenburg Protocol, this is announced by the organising body of the UN/ECE and Parties are strongly encouraged to take steps to comply with their commitments. But unlike the NECD, it is not possible to impose financial penalties on Parties that exceed their ceilings.

The Gothenburg Protocol is in the process of being revised and will almost certainly include emission ceilings for 2020. Details are to be confirmed, but the most significant changes to the Gothenburg Protocol might be that:

1. Commitments to reduce emissions will be determined by percentage reductions (probably from a 2005 base year) rather than absolute ceilings.
2. Mechanisms will be put in place to allow “adjustments” to be made to emission inventories. This is where unforeseen changes are made to the emission estimates which are beyond the control of the country but impact on compliance with the emission targets.

### *6.1.2 National Emissions Ceilings Directive (NECD)*

The NECD specifies respective 2010 emission ceilings for EU Member States for $SO_2$, NOx, NMVOC and $NH_3$ emissions. Once a Member State has met these respective emission ceilings, it is required to maintain its national emission levels below its agreed ceilings (for 2010) in future years.

Much attention internationally is paid to the NECD, primarily because the EC has the ability to impose large financial penalties on EU Member States that do not meet their respective national emission ceilings.

The EC has announced that the NECD also will be revised. The terms of revision of the NECD are less clear (than that of the Gothenburg Protocol) but proposals may be published within the next year, which should clarify the situation. It is expected that the revisions to the NECD will generally follow the revisions to the Gothenburg Protocol, but it is possible that emission ceilings may be chosen for 2025. There are a number of reasons for updating the legislation. These include:

- The emission ceilings were for the year 2010, which has now passed. So it is sensible to develop new and probably tighter ceilings for future years.

[29] It should be noted that currently Turkey is not a signatory to the Gothenburg Protocol

- The science has developed, hence emission inventories have been updated and revised.
- The legislation needs to be more sophisticated, so that it may accommodate revisions to emission inventories driven by an improved understanding of the science.

## 6.2 Basis of Identified Potential National Emissions Ceilings

In principle, three approaches exist for setting national emissions ceilings for pollutants. One is an '*objective-led*' approach in which health impact and environmental quality assessments are used to help identify (overall) national emission levels, whose achievement should ensure that pre-determined, acceptable levels of human health and environmental quality are attained. The task then is to develop or identify the mix of policy instruments and measures whose implementation will deliver the desired outcome at least overall cost to society. Adoption of this approach to setting NEC requires a prior agreement on objective levels of health and environmental protection and extensive information on *inter alia*

(i) Ambient air quality and its geographical distribution

(ii) Emission sources and emission levels, and

(iii) Quantified relationships between (a) ambient air quality and health impacts and (b) ambient air quality and environmental impacts.

The ability to model the impacts of changes in emission levels is also essential, as is the ability to develop and evaluate policy instruments and measures to affect those changes in emission levels.

A second may be termed the '*pragmatic*' approach. This approach acknowledges that the emission to air of pollutants such as $SO_2$, NOx, NMVOC and $NH_3$ causes damage to human health and the environment, and that reduced emission rates are desirable to reduce potential harm. However, this approach also recognises that the quantity, quality and overall availability of the information needed to apply the objective approach are limited. The approach also recognises that, where known policy instruments and measures (such as the use of zero-emission sources of electricity generation and the application of the 'other' EU Directives identified in Annex 4) have not been fully applied, it is sensible to implement these. This allows the impacts to be considered before other policy measures are evaluated for implementation. In this approach, the likely effects on future national emission levels (allowing for economic development) of applying known, practicable policy measures are estimated, and the results are used to establish national emission ceilings.

A third might be called the '*negotiated*' approach. This lies somewhere in-between the first and second approaches. Specifically, the EC might adopt the first, to suggest NEC values based on large-scale modelling studies (but with limited country-specific information), whilst Turkey might suggest NEC values based on the second approach. Negotiations may then ensue between the two parties and a compromise solution may be identified and agreed.

The present NECD Project does not have a sufficiently extensive evidence base to draw on to apply the 'objective-led' approach. Hence possible national emission ceilings for Turkey were identified using the 'pragmatic' approach, i.e. the possible emissions ceilings identified here were based on what was considered to be practically achievable in Turkey by the stated dates.

Table 6-1 provides a rationale for four sets of possible emission ceilings. One set reflects the WaM Scenario emission projections, rounded off to the nearest 10 ktonne. The three other sets are variants on the WaM Scenario. For each there is a plausible explanation as to why a higher ceiling value than that estimated for the WaM Scenario may be appropriate.

**Table 6-1 Summary rationale for determining possible NECs for Turkey**

| Basis for Possible NEC | Rationale and Description |
|---|---|
| 1 WaM : full EMS | The WaM Scenario involves the implementation of all relevant national measures and EU Directives which impose controls on the emission of NECD pollutants.<br>This Scenario would be expected by the EC. |
| 2 WaM: high GDP variant | Higher GDP growth results in higher emissions of NECD pollutants. This variant on WaM takes into account the possibility that the rate of increase in GDP is greater than the 5% per annum assumed from 2014.<br>This variant was chosen from those examined in the projections sensitivity analysis as this had a larger impact than other changes to the underlying data.[30] |
| 3 WaM: minus SCR/SNCR | This variant takes into account the findings of the CBA study, which suggested that SCR/SNCR for the reduction of NOx emissions at LCPs is not justified on CBA grounds.<br>It must be noted however that SNCR/SCR may still be needed in future for LCPs ≥ 500 MWth to meet the tighter NOx emission limits set by the LCPD. |
| 4: WaM: constant fuel-mix for residential heating | This variant supposes that the forecast decline in wood and oil consumptions for domestic heating, and other changes, does not occur. This would result in the fuel mix remaining the same as in 2010. |

## 6.3 Potential National Emission Ceilings for 2025

Table 6-2 suggests possible emission ceilings for NECD compliance by 2025. All NEC values are rounded off to the nearest 10 ktonne. These ceilings could be appropriate to Turkey for NECD implementation assuming that year 2025 will be the target year for compliance.

**Table 6-2 Possible national emission ceilings for 2025**

| Basis for National Emission Ceilings | Possible National Emission Ceilings (ktonne) | | | |
|---|---|---|---|---|
| | NOx | $SO_2$ | NMVOCs | $NH_3$ |
| 1 WaM : full EMS | 1240 | 2160 | 800 | 530 |
| 2 WaM: high GDP variant | 1310 | 2340 | 850 | 530 |
| 3 WaM: minus SCR/SNCR [1] | 1360 | 2160 | 800 | 530 |
| 4: WaM: constant fuel-mix for residential heating | 1240 | 2240 | 890 | 530 |

[1] An approximate value estimated from the influence of SCR/SNCR on NOx emissions from LCP.

However, an important *caveat* to the NEC given above must be recorded. None take into account the potential growth in emissions beyond the first compliance year i.e. 2025. The period 2011-2025 should see a significant reduction in

[30] $SO_2$ emissions are higher where a lower FGD efficiency was assumed. However, these are not considered suitable for use in determining emission ceilings, because such plant would not be compliant with the LCPD.

emissions intensity of many economic activities but significant economic growth may be expected to continue beyond 2025. In the absence of further policy measures, it follows that further economic growth may see further emissions growth for NOx, NMVOC and $NH_3$ whilst the expected reductions in national $SO_2$ emissions to 2025 may be reversed to some extent if the consumption of lignite and coal were to increase further. However, as stated in Section 6.1.2 regarding NECD compliance, '*Once a Member State has met these respective emission ceilings, it is required to maintain its national emission levels below its agreed ceilings in future years.*'

Clearly, therefore, the national emission ceilings given above should be regarded as interim. It may be that an appropriate allowance for Turkey's emissions growth in response to further economic development (beyond 2025) is an issue that would best be resolved through negotiation with Turkey's international partners.

But as noted above in connexion with the emission projections, a number of uncertainties exist in the emissions inventory to 2010 and in the sectoral EMS: they are carried through into both the emission projections to 2025 and the possible national emission ceilings. The highest priority therefore should be placed on resolving those uncertainties. Only then should serious effort be devoted to identify the additional emissions "head-space" above the identified national emissions ceilings.

The TA Project's recommendations on the next steps for the Government are provided below. It covers in outline the possible negotiation process whereby NEC values may be agreed for Turkey but introduces in some detail the issues of uncertainty that should be resolved as a high priority.

## 6.4 Recommended Next Steps for Government of Republic of Turkey

### *6.4.1 Coordination Board (CoBoard) and priority issues for review*

It must be stressed again that the possible emission ceilings presented in Table 6-2 above are an initial proposal for discussion within the MoEU, and then more broadly across Government via the Coordination Board (CoBoard), which is being established under Prime Ministerial decree and which it is expected will be chaired by MoEU. There are a wide range of stakeholders who will want to be involved in the process of agreeing the proposed national position with regard to the ceilings and the necessary investment programmes. The proposed CoBoard would appear to be the most appropriate institutional mechanism for facilitating this process of dialogue and decision making.

Before the Government enters any negotiations with its international partners it is strongly recommended that the significant uncertainties that bedevil the emissions inventory, the emissions management strategies and the emission projections are addressed and resolved within Turkey. CoBoard provides an appropriate institutional mechanism for resolving these issues. Each of the major uncertainties and issues are introduced below: see Sections 6.4.2 to 6.4.16.

Once the Government has resolved the identified issues to its own satisfaction it may wish to negotiate with the EC on finally agreeing the respective national ceilings under the NECD. The EC has undertaken studies at the European level, and even has their own estimates of the emissions in Turkey. Consequently, the EC will have a broader scientific evidence base that can be used to propose emission ceilings that they consider to deliver emissions reductions which would give rise to positive impacts regarding human health and the environment. These emission reductions would, of course, also need to be achievable.

It is possible that the EC proposes lower emission ceilings than those first suggested by Turkey; hence some negotiation may be required. However, it may be expected that the EC will respect the fact that Turkey now has an emissions inventory that draws on country specific information and which should be more reliable than the results from Europe-wide studies. If the differences between the ceilings proposed by the EU and those proposed by Turkey are large, then the two emission inventories (the inventory from Turkey and data in the GAINS model for the EC) will probably be compared, and the reasons for differences identified and resolved. Some consensus should then be possible in determining respective national NECD emission ceilings for Turkey.

It is perhaps at this stage, in negotiation with the EC, that the issue of allowing "head space" in the national ceilings to allow for Turkey's expected economic growth may be discussed and agreement reached.

### *6.4.2 Review reliability of the forecast national electricity demand*

As the identified NEC for $SO_2$ and NOx have been based on emission projections that have adopted TEİAŞ's forecast of electricity demand for 2011 to 2023, the reliability or robustness of the forecast demand should be explored.

This observation is not intended to cast any criticism on the forecast, or the forecasters, but the demand increase is so substantial, and the consequent effects are potentially so significant, that the forecast ought to be reviewed by CoBoard or a CoBoard working group (once established). Aspects that might be considered include:

- Any in-built bias in the forecast that might lead it to err significantly on the side of caution, i.e. to overestimate demand. It may be useful to compare past forecasts of demand with out-turn figures to gauge whether past forecasts have been consistently more (or less) than the out-turns;
- Extent to which the forecast's assumptions for GDP growth match the Ministry of Development's latest, near-term forecasts;
- Extent to which potential energy efficiency improvements (generation, transmission and use) have been taken into account.

### *6.4.3 Planned electricity generation from zero-emission sources*

Zero-emission sources for electricity generation comprise renewable energy sources (hydro, wind, geothermal and solar) and nuclear. Table 6-3 notes the collective percentage contributions of zero-emission sources to electricity generation at 5-year intervals, and electricity generation, adopted in the WaM Scenario.

**Table 6-3 Projected contribution of zero-emission sources to electricity output**

| Electricity Output of Zero-Emission Sources | WaM Scenario | | | |
|---|---|---|---|---|
| | 2010 Actual | 2015 | 2020 | 2025 |
| % of total national output | 22.2% | 27.1% | 27.1% | 27.1% |
| GWh | 55.4 | 82.1 | 117.7 | 166.9 |
| **Electricity Output of Zero-Emission Sources** | **NCCAP and Nuclear Targets Are Met** | | | |
| | **2010 Actual** | **2015** | **2020** | **2025** |
| % of total national output | 26.2% | 27.1% | 31.0% | 35.0% |
| GWh | 55.4 | 82.1 | 134.7 | 215.3 |

Table 6-3 also provides equivalent figures assuming that the following targets are met in full by 2025 (i) NCCAP's target of 30% of electricity supply from renewables by 2023 and (ii) nuclear energy to provide 5% of national electricity demand.

The WaM Scenario foresees the electricity output from zero emission sources increasing by a factor of 3 to 2025 whilst meeting all the targets will see it increasing by 4 times. Mindful of the potential adverse consequences for fuel consumption, $SO_2$ and NOx emissions and the NEC values, Co Board may wish to review the following:

- The feasibility of such an increase in electrical output from zero-emission sources over the time period, bearing in mind (i) the likelihood that the most cost-effective and attractive hydro-power locations may have been exploited already (ii) that the projected increase in wind power (NCCAP) involves an even more substantial proportional increase from a low base and (iii) that the time period remaining for nuclear power to come on stream, to the envisaged extent, is quite limited for such complex projects.
- Were actual electricity outputs from zero emission sources to fall substantially below the figures given above, then this would result in more fuel having to be burned at thermal power plants so as to meet demand. This would result in more $SO_2$ and NOx emissions. The former could be especially significant if there were also shortcomings in FGD plant performance – a particular concern for lignite-fired stations, see below.

### *6.4.4 Planned fuel-mix for electricity generation*

Emissions for the fuel-based power stations will depend substantially on fuel type and the national mix of fuels used. Hence the fuel mix which is adopted in practice may influence NECD emissions significantly. The emission projections on which the suggested NEC values are based have assumed the fuel mix is as given for 'firm' capacity in TEİAŞ's electricity plan for 2011-20. Since the plan makes no judgement as to what fuels will be used by the additional generating capacity needed to meet demand growth, the fuel-mix is a major assumption.

**Table 6-4 Projected fuel consumptions to 2025**

| Fuel and Units | WaM Scenario | | | |
|---|---|---|---|---|
| | 2010 Actual | 2015 | 2020 | 2025 |
| Natural gas (million $m^3$) | 21,471 | 27,515 | 39,332 | 55,760 |
| Hard coal (ktonne) | 7,582 | 13,644 | 19,614 | 27,807 |
| Lignite (ktonne) | 55,436 | 74,585 | 106,569 | 151,081 |
| Fuel Oil (ktonne) Note | 925 | 3,203 | 4,271 | 6,055 |

Note: The apparent jump in oil consumption from 2010 to 2015 may be an artefact, resulting from using two sources of data (one source for 2010, another for the later period).

Moreover, the projected fuel consumptions for electricity generation, Table 6-4, raise a number of significant strategic issues which CoBoard may wish to reflect upon. They include:

- Whether or not the substantial increase of lignite consumption to 151 million ktonne by 2025 is credible, bearing in mind that total Turkish lignite production peaked at just over 76 million tonne in 2008 (MoENR National Energy Balance Tables);

- Whether the substantial increase (2 to 3 times) in the consumption of imported natural gas and hard coal is (i) technically feasible i.e. not constrained by supply or distribution capacity factors and (ii) supportable on the grounds of energy security and the balance of payments.

Clearly, however, if the projected electricity demand is to be met then the energy will need to be obtained from somewhere. The Government ought to express a considered view on the fuel mix to be employed in future, so that investors can respond in the light of that strategic guidance. This issue is critical and involves many considerations other than emissions and emission ceilings. However, it would seem to lie within CoBoard's remit to raise this issue for discussion and resolution.

*6.4.5 Sulphur contents of coal and lignite – electricity generation*

The electricity generating sector is the largest source of estimated $SO_2$ emissions in Turkey, yet universally agreed values for simple but fundamental property data are not available to the MoEU: the average sulphur content of each fuel burned, lignite and coal in particular. Apart from providing a basis for estimating $SO_2$ emissions (Tier 1 approach) it also provides the basis for checking the performance of FGD plant in terms of $SO_2$ removal efficiency.

It is believed that the sulphur contents of solid fuels burned in the power stations are monitored as a matter of routine by their operators. Such site-specific data ought to be made available in summary form to MoEU and other interested ministries. CoBoard needs to make this happen.

*6.4.6 Availability of source-specific emissions data – electricity generation*

The electricity generating sector is the largest estimated source of $SO_2$ emissions and the second largest estimated source of NOx emissions in Turkey. A Tier 1 approach had to be adopted in estimating the emissions from plants in this sector (and of large combustion plants in the industrial sector, Section 6.4.10). It would be much better if measured, source-specific emissions data were made available for use in the inventory, which provides the basis for emission projections.

MoEU have regulatory inspection, monitoring and enforcement roles through the permitting system, which may be strengthened following IPPC transposition. Through this mechanism, MoEU ought to be able to collect these data independently of CoBoard. However, CoBoard may wish to ensure that, for an interim period at least, operators provide summarised, site-specific emissions monitoring data to MoEU. This would enable MoEU to improve the emissions inventory and projections in the near-medium future.

*6.4.7 SCR for NOx emissions control at coal or lignite-fired LCPs*

Retrofitting SCR at existing plants is excluded, but its implementation at new electricity generating stations is included in the EMS for the electricity generating sector. Though in most of the populous EU Member States it is observed that SCR's benefits outweigh its costs, CBA work undertaken in this Project indicates that the marginal benefits of applying this technology in Turkey are likely to be exceeded by the costs of installation and operation. Hence it might be argued that SCR is beyond BAT under IPPC.

If that argument was made and accepted, and SCR not installed at new coal and lignite fuelled electricity generating stations in Turkey, then NOx emissions might be higher than in the WaM Scenario. For new plants, estimated NOx emissions without SCR might be double those observed if SCR was installed[31] in addition to low-NOx burners and staged-air supply. Since new-plant capacity is projected to increase substantially by 2025, the implications for NOx emissions from this sector of not installing SCR could therefore be significant.

### *6.4.8 Emissions control at lignite-fired electricity generating stations*

Two other issues of potential significance should be considered by MoEU, plant operators, and other stakeholders under the auspices of CoBoard. Both relate to the quality of indigenous lignite, in particular its high ash content and water content and their variability.

*FGD performance and $SO_2$ emissions*

It is understood that the water and ash contents of Turkish lignite are high, possibly about 40% and 25%, respectively. In addition, the water and ash contents of Turkish lignite are very variable and it is understood that this causes big problems for the process control of FGD units; problems that may lead to variable and substantially sub-optimal performance in terms of $SO_2$ removal efficiency. The potential implications are serious. If, for example, $SO_2$ removal efficiencies were as low as 75% then such plants would not comply with the transposed LCPD and, in theory at least, should not be allowed to operate or they should be forced to opt out. Again, however, emissions data that quantify the effects in terms of $SO_2$ removal efficiency have not been made available.

Nor is it clear whether process control problems have been experienced at the older lignite-fired plants only or also at newer plants. If problems have been found at older plants only, and if the problems cannot be overcome, then it seems reasonable to conclude that the plants should be phased out. They should be phased-out over a period established by the Government, and their capacity replaced by investing in new power plants.

However, if FGD units have been observed to perform poorly at new lignite-fired plant also, then the implications would be much more significant. Indeed it would raise the question as to whether the use of Turkish lignite in LCPs is compatible with compliance with the transposed LCPD. Clearly, given the strategic value Turkey places on lignite as its only major, fossil fuel energy resource, this issue would be of huge importance, one that ought to demand attention at the highest levels of Government.

*NOx emissions*

High water and ash contents such as 40% and 25%, respectively, result in a fuel of low calorific value (CV), one that will tend to generate a lower combustion temperature than that of a fuel having a greater CV. Since NOx formation (oxidation of nitrogen in the air, as opposed to oxidation of fuel-based nitrogen) increases with combustion temperature, there is a *prima facie* case that the NOx emissions of a plant fired with Turkish lignite might be lower than those of a plant fired with more conventional lignite (of a higher CV). Operator representatives have indicated as such to MoEU and the TA team. But no emissions data have been provided to substantiate either this claim or the implicit suggestion that a plant fired with Turkish lignite might comply with LCPD without NOx prevention and control techniques being installed.

[31] For a station equipped with low-NOx burners, staged-air supply and SCR, NOx emissions might be about 25% of uncontrolled levels. IF SCR was omitted, NOx emissions might be about 50% of uncontrolled levels.

### 6.4.9 LCPD opt-out of existing lignite-fired electricity generating stations

Two other potential issues or risks may be identified for CoBoard consideration.

First, operators of existing lignite power plants could decide to opt out of LCPD, and limit their operational hours to 20,000 over the period 2019 to 2025 - as they ought to under the opt-out provision. The operators would then not invest in FGD and NOx control. Hence their collective emission levels from 2019 to 2025 might be significantly higher than in the WaM projections (despite their reduced operating time.).

Second, if operators of existing lignite power plants decide to opt out of LCPD but, in practice, do not limit their operational hours. Were this to be allowed, or if enforcement efforts were ignored or overruled for the sake of the 'greater good' of electricity supply, then $SO_2$ and NOx emissions from the existing lignite plants would continue as now. Since the national total emissions for $SO_2$ are dominated by those of the electricity sector, a likely result would be that national emissions would exceed the identified NEC value by a substantial amount. A similar observation applies to NOx emissions.

### 6.4.10 Sulphur contents of solid fuels and source-specific emissions data – industrial combustion

Industrial combustion is second to electricity generation as a contributor to national $SO_2$ emissions; it contributes significant NOx emissions also. However, this assessment is based on estimates derived from assumptions regarding fuel-sulphur content and emissions performance. The comments made above with regard to the electricity generating sector apply here also:

- The average sulphur content of each fuel burned, and solid fuels in particular[32] provide a basis for (i) estimating $SO_2$ emissions (Tier 1 approach) and (ii) checking the performance of emissions control in terms of $SO_2$ removal efficiency.
- Authoritative, site-specific data on the sulphur contents of solid fuels burned in large industrial plant ought to be made available in summary form to MoEU and other interested ministries. CoBoard needs to make this happen.
- A Tier 1 approach has had to be adopted in estimating the emissions from industrial combustion plants. It would be much better if measured, source-specific emissions data were made available for use in the inventory, which provides the basis for emission projections. Such data ought to be made available for plants in the iron & steel and cement sectors at least.
- MoEU have regulatory inspection, monitoring and enforcement roles – through the permitting system, which may be strengthened following IPPC transposition. Through this mechanism, MoEU ought to be able to collect these data independently of CoBoard. However, CoBoard may wish to ensure that, for an interim period at least, operators provide summarised, site-specific emissions monitoring data to MoEU. This would enable MoEU to improve the emissions inventory and projections in the near-medium future.

[32] Coal, coke, petroleum coke, lignite and wood.

*6.4.11 Industrial classification and characterisation – industrial combustion*

Industrial production is diverse. Even within a sector such as the iron & steel sector or the cement sector, there may be significant variations in terms of age of plant, technology employed, production capacity and emissions performance. For NECD inventory purposes and for preparing comprehensive, credible emissions management strategies, these differences may be crucial. It is suggested therefore that CoBoard may wish to authorise a working group to review and analyse the composition of the overall industrial production sector, analysing it in sufficient detail to enable credible sub-sector emission estimates and emissions management strategies to be prepared in future.

*6.4.12 Industrial solvent use*

Limited in-country data were available on which to base the emissions inventory and emission projections for solvents use: population, car manufacture, textiles and tyre manufacture. Other input data had to be estimated using other sources. It was not possible to derive any estimates for the printing sector.

A concerted initiative to survey the extent and scale of the industrial and commercial activities subject to regulation under the identified legislation ought to be pursued. CoBoard might oversee such an initiative, ensuring that different sectors of industry and Ministries cooperate in undertaking the survey. A number of case studies – with anonymity ensured – might then be undertaken to study the actual situation in sectors giving rise to significant NMVOC solvent emissions.

*6.4.13 Residential and commercial combustion*

CoBoard may wish to consider further the national strategy and plan for energy supply (heating) to the residential sector. Particular attention might be paid to (i) fuel-mix issues, bearing in mind that the $SO_2$ emissions with the EMS in place could represent 26% of the national total by 2025 – up from 17% in 2010, and identifying mechanisms for promoting (ii) the use of fuel-efficient combustion units and (iii) better insulation in the stock of existing buildings.

*6.4.14 Road transport*

A sophisticated model was applied to estimate emissions from the road transport sector in the historic emissions inventory and subsequent projections. However, considerable scope has been identified for improving the quality and reliability of the transport data used in the model. These are described elsewhere (TA Report, “NECD Emissions Inventory 1990 to 2010: Parts 1 and 2”) and concern, in particular the:

- Numbers of heavy goods vehicles;
- Vehicle-kilometre data for different vehicle types.

Given the significance of the road transport sector for Turkey’s total NOx emissions, there should be scope for improving transport data provision under CoBoard’s strategic guidance.

The projected NOx emissions for this sector indicate the benefits of the above EMS, to the extent that projected sectoral NOx emissions change little (an increase of 2%) from 2010 to 2025. However, it may be complacent to imagine that nothing else would need to be done regarding NOx emissions control. By 2025 this sector’s NOx emissions contribution reduces to 31% of the national total – down from 40% in 2010. However, this is solely due to substantially higher rates of emissions growth in other sectors. Hence CoBoard might wish to explore options for a more aggressive management of NOx emissions from this sector in future.

NMVOC emissions from the road transport sector are unaffected by the EMS and have been estimated to increase by 73% from 2010 to 2025. Managing NMVOC emissions from this sector may, therefore, require the identification and implementation of more aggressive policy measures. CoBoard may wish to investigate options with the Ministry of Transport.

*6.4.15 Aviation – LTO data*

Aviation was a sector where improvements in input data were identified as necessary. A CoBoard working group may wish to consider facilitating the collection of the following data for future inventory development: (i) domestic landing and take-off (LTO) data and fuel use by aircraft type for a number of years (ii) similar data for international LTO.

*6.4.16 Agriculture*

Key data quality issues have been identified for the livestock sector. Through one of its working groups, CoBoard might facilitate the collection of the following data for future inventory development: (i) real data regarding the distribution of total cattle numbers between dairy and non-dairy (ii) real data regarding the percentage of time cattle are housed and (iii) real data regarding the distribution of total chicken numbers between layers (egg production) and broilers (meat production).

*6.4.17 Lower priority other issues*

Additional issues for CoBoard consideration are of lesser priority but should be addressed in order to improve the inventory, emission projections and proposals for national emission ceilings. They are noted below:

*Solvents use*: owing to limited available, in-country data it is recommended that a concerted effort be made to survey the extent and scale of the industrial and commercial activities subject to (future) regulation under the identified legislation ought to be pursued. CoBoard should ensure that different sectors of industry and Ministries cooperate in undertaking the survey. A number of case studies – with anonymity ensured – might then be undertaken to study the actual situation in sectors giving rise to significant NMVOC solvent emissions.

*Aviation*: A CoBoard working group may facilitate the collection of the following data for future inventory and projections development: (i) domestic landing and take-off (LTO) data and fuel use by aircraft type – they are needed for a number of years (ii) such data are also needed for international LTO.

*Agriculture*: CoBoard might facilitate the collection of real data for future inventory and projections development regarding the: (i) distribution of total cattle numbers between dairy and non-dairy (ii) percentage of time cattle are housed and (iii) distribution of total chicken numbers between layers (egg production) and broilers (meat production).

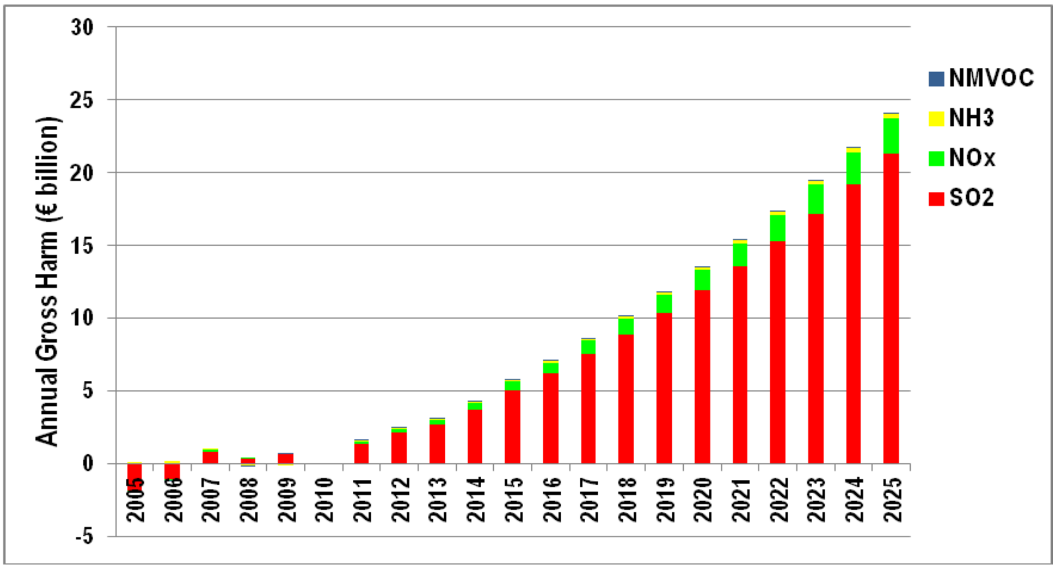
# 7 REGULATORY IMPACT ASSESSMENT (RIA)

## 7.1 Introduction

Regulatory Impact Assessment (RIA) establishes a set of logical steps to be followed when preparing policy proposals (for example the introduction of new Regulations). It is a process that prepares evidence for political decision-makers on the advantages and disadvantages of possible policy options by assessing their potential impacts. An RIA was undertaken for the implementation of NECD in Turkey. In particular it dealt with the overall costs and benefits of the EMS presented in Sections 3. Strategy implementation is consistent with the possible emission ceilings for Turkey presented in Section 6 and would enable them to be met.

Limiting or controlling $SO_2$, NOx, NMVOC and $NH_3$ emissions is very important for Turkey, especially $SO_2$ and NOx emissions, as the damage they can cause to human health and to other receptors can be very substantial. Figure 7-1, for example, shows that uncontrolled or weakly controlled emissions growth (WoM Scenario) above year 2010 levels would lead to damage to human health and agriculture valued at about €24 billion in 2025 at year 2010 price levels.

**Figure 7-1 Growth in annual marginal damage costs estimated to result from emissions growth in Turkey from 2010 (WoM Scenario)**




Cumulative damage costs over the period 2011-2025 would be higher still, of course. They have been estimated at about €165 billion at year 2010 price levels. These figures were derived from project emissions growth and the values for the marginal damage cost of emissions from Turkey (Table 4-1).

It follows that the implementation of the NECD and a number of 'other' EC Directives (see Annex 4) should be a vital objective for Turkey. Implementation of these Directives should be viewed on their merits, the benefits they may deliver, not merely as necessary requirements of the Accession process for Turkey to join the EU. It underpins the management of air quality leading to improved health, and reductions in harm to agriculture, buildings and cultural heritage.

## 7.2 EMS Costs

Most sectors will incur some costs for capital investment and for operating and maintenance (O & M) in implementing the emissions management strategies described in Section 3. Estimated cumulative costs at constant year 2010 prices for the period up to 2025 are presented in Table 7-1, broken down sector-by-sector. The TA Report, 'NECD Emissions Management Strategies, Possible Emission Ceilings and RIA' should be consulted if further details are required.

**Table 7-1 Cumulative costs of EMS implementation to 2025**

| Sector | Cumulative Costs (€ billion) NOTE 5 | | |
|---|---|---|---|
| | Capital | O & M | Total |
| Electricity generation | 14.4 | 3.9 | 18.3 |
| Industry – combustion: emissions control cement, iron & steel (IC) NOTE 1 | NE | NE | NE |
| Industry – combustion: energy efficiency in all sectors NOTE 2 | 0 | 0 | 0 |
| Solvents use NOTE 3 | NA | NA | 1.8 |
| Industry – process (IP) | NE | NE | NE |
| Residential – combustion (RC) | NE | NE | NE |
| Road transport | NE | NE | NE |
| Aviation, Marine, Rail transport (AMR) | 0 | 0 | 0 |
| Agriculture – livestock rearing (Live) NOTE 4 | NA | NA | 0.13 |
| Agriculture – fertiliser application (Fert) | 0 | 0 | 0 |
| **Total** | **≥14.4** | **≥3.9** | **20.2** |

NOTE 1: Emissions control will be needed at most installations in the cement and Iron & steel sectors but separate, dedicated studies would be needed for the costs to be estimated.

NOTE 2: The net costs of energy efficiency measures implemented by industry are taken to be zero.

NOTE 3: The costs assume mid-range unit costs of good practice techniques: some measures may have unit costs substantially less, others substantially more than the mid-range values.

NOTE 4: Costs given here are in the middle of a range from €8 million to €250 million.

NOTE 5: NE, not estimated. NA, not available, only marginal costs (CAPEX, O&M combined) were given.

It is evident that significant costs will be incurred in the electricity generating sector, totalling about €18 billion over the entire period (at constant year 2010 prices). In view of these costs an economic appraisal (complementing the CBA of Section 4) of the full EMS for this sector was undertaken, taking into account the phasing over time of the investment and O&M costs. The appraisal showed a substantial positive net present value (NPV) for FGD technology (€89 billion), positive NPV for LNB & AS for NOx control, but a negative NPV for SCR.

**Table 7-2 Results of economic appraisal of emissions control in the electricity generating sector**

| Emission Control Technology | Total Capital | Residual Value in 2025 | Cumulative Operating Costs | Operating Costs in 2025 | Total Benefits | Benefits in 2025 | NPV |
|---|---|---|---|---|---|---|---|
| All units are € billion at 2010 prices | | | | | | | |
| FGD | 8.67 | 5.36 | 3.12 | 0.54 | 138 | 24.4 | 88.6 |
| LNB & AS | 1.14 | 0.70 | 0.00 | 0.00 | 3.9 | 0.7 | 2.3 |
| SCR | 4.64 | 2.66 | 0.78 | 0.12 | 1.6 | 0.2 | -1.4 |
| **Total** | **14.5** | **8.7** | **3.9** | **0.66** | **144** | **25.4** | **89.5** |

Substantial costs may also be incurred in controlling solvent use and emissions, amounting to nearly €2 billion over the period. Costs in other sectors are relatively modest, as in the agricultural livestock sector, and zero in those sectors where efficiency measures are introduced at an (assumed) zero net cost to the operator.

However, it is likely that the enterprises in the cement and iron & steel sectors will have to invest significant sums in emissions control systems. In the absence of sufficiently detailed information for these sectors, though, those costs have not been estimated here. Nor, in Tables 7-3 and 7-4, has account been taken of the impacts of emissions control in these two sectors on emissions and benefits.

## 7.3 EMS: Influence on Emissions and Benefits Relative to WoM

The effects of the suggested EMS may be viewed from two perspectives. In one, emission levels are compared with those in year 2010: a reduction implies that the EMS produces absolute improvements in air quality – improved health outcomes etc. In a second, emission levels are compared with those estimated for the WoM Scenario, i.e. weakly controlled emissions growth: a reduction here implies relative improvements in air quality. Ideally, with an EMS in place, emissions should be lower than both WoM projected and year 2010 levels: if lower than WoM but higher than at 2010 levels, emissions remain on a growth path (though moderated) and air quality may deteriorate further beyond 2010.

**Table 7-3 Cumulative decrease in emissions to 2025 and gross benefits with the EMS in place - relative to WoM Scenario emission levels**

| Sector | Cumulative Decrease in Emissions with EMS in Place Relative to WoM Projection Levels (ktonne) | | | | Cumulative Benefits with EMS in Place: Relative to WoM Projections (€ billion) | | | |
|---|---|---|---|---|---|---|---|---|
| | $SO_2$ | NOx | NMVOC | $NH_3$ | $SO_2$ | NOx | NMVOC | $NH_3$ |
| Electricity | 36,100 | 4,400 | Minor | Minor | 130 | 10 | Minor | Minor |
| Industry (IC) NOTE 1 | 1,100 | 150 | Minor | Minor | 4.1 | 0.35 | Minor | Minor |
| Solvents use | NA | NA | 1,540 | NA | NA | NA | 0.015 | NA |
| Industry (IP) NOTE 2 | NE | NE | NE | NE | NE | NE | NE | NE |
| Residential (RC) | 731 | 15 | 730 | Minor | 2.7 | 0.035 | 0.007 | Minor |
| Road transport | Minor | 37 | 0 | Minor | Minor | 0.084 | 0 | Minor |
| AMR transport | 62 | 1 | 1 | Minor | 0.23 | 0.002 | Minor | Minor |
| Agriculture (Live) | NA | NA | NA | 318 | NA | NA | NA | 1.7 |
| Agriculture (Fert) | NA | NA | NA | 51 | NA | NA | NA | 0.28 |
| **Totals** | **37,993** | **4,603** | **809** | **369** | **134** | **10** | **0.02** | **2.0** |

NOTE 1: Only the influence of energy efficiency improvements are given here.

NOTE 2: The cumulative emissions increase for industrial processes applies to the WoM Scenario projection. Detailed studies would be needed to estimate the effects of the proposed EMS on emissions.

Table 7-3 summarises the estimated effects of the EMS on cumulative emissions growth and gross benefits relative to the WoM Scenario projections.

- $SO_2$ and NOx emissions and the associated benefits are predominant, the electricity generating sector in particular. Useful but minor contributions are provided by the industrial and residential combustion sectors.
- NMVOC emission reductions are most evident in the solvent use and residential combustion sectors: the associated benefits are trivial, though

they may be underestimated to a significant extent[33]. The agricultural sector is the only significant source of $NH_3$ emissions: the estimated reductions and benefits are largest for livestock rearing.

The effects of emissions control at large industrial sites in the cement, iron & steel sectors are not taken into account in Table 7-3: only energy efficiency improvements have been assumed at such sites. However, it should be noted that the reported NECD emission projections do assume the full EMS for the cement and iron & steel sectors are in place. Taking the estimated impacts of emissions control in these sectors also into account, the decreases in $SO_2$ and NOx emissions would be higher at 3,300 and 250 ktonne, respectively. Gross benefits are proportionately higher also.

## 7.4 EMS: Influence on Emissions and Benefits Relative to 2010

Emissions with the EMS in place are bound to be lower than if emissions are uncontrolled or only weakly controlled. The harder test to be applied is to consider emissions relative to the base year, 2010. Table 7-3 does this, prepared on exactly the same basis as Table 7-2. It may be seen that, with the exception of $SO_2$ emissions from electricity generation, NMVOC emissions from residential combustion and $NH_3$ emissions from livestock rearing, cumulative emissions of all sectors and pollutants are higher than year 2010 levels. Consequently, cumulative benefits are negative with the above exceptions, i.e. emission growth tends to continue though heavily moderated by the effects of the sectoral EMS.

**Table 7-4 Cumulative decrease in emissions to 2025 and gross benefits with the EMS in place – relative to year 2010 emission levels**

| Sector | Cumulative Decrease in Emissions with EMS in Place Relative to Year 2010 Levels (ktonne) NOTE 1 | | | | Cumulative Benefits with EMS in Place Relative to Year 2010 Emission Levels (€ billion) NOTE 1 | | | |
|---|---|---|---|---|---|---|---|---|
| | $SO_2$ | NOx | NMVOC | $NH_3$ | $SO_2$ | NOx | NMVOC | $NH_3$ |
| Electricity | 2,930 | -1,620 | Minor | Minor | 10.7 | -3.7 | Minor | Minor |
| Industry (IC) NOTE 2 | -4,790 | -650 | Minor | Minor | -17.5 | -1.5 | Minor | Minor |
| Solvents use | NA | NA | -470 | NA | NA | NA | -0.005 | NA |
| Industry (IP) NOTE 3 | -17 | -8 | -295 | -77 | -0.007 | -0.019 | -0.001 | -0.17 |
| Residential (RC) | -95 | -194 | 399 | Minor | -0.35 | -0.44 | 0.004 | Minor |
| Road transport | Minor | -52 | -522 | Minor | Minor | -0.12 | -0.005 | Minor |
| Transport - AMR | -34 | -36 | -468 | Minor | -0.13 | -1.1 | Minor | Minor |
| Agriculture (Live) | NA | NA | NA | 32 | NA | NA | NA | 0.17 |
| Agriculture (Fert) | NA | NA | NA | -44 | NA | NA | NA | -0.24 |
| **Totals** | **2,006** | **2,560** | **1,356** | **89** | **-7.2** | **-6.9** | **-0.015** | **-0.24** |

NOTE 1: The comparison is with emission levels if they were to persist unaltered from 2010 through to 2025.

NOTE 2: Only the influence of energy efficiency improvements are given here

NOTE 3: The cumulative emissions increase for industrial processes applies to the WoM Scenario projection. Detailed studies would be needed to estimate the effects of the proposed EMS on emissions.

[33] The influence of solvent emissions on stratospheric ozone is not accounted for. Nor are the carcinogenic properties of certain NMVOC species. Using an identical methodology, the marginal damage costs of NMVOC in many European countries has been reported as greater than Turkey's by two orders of magnitude.

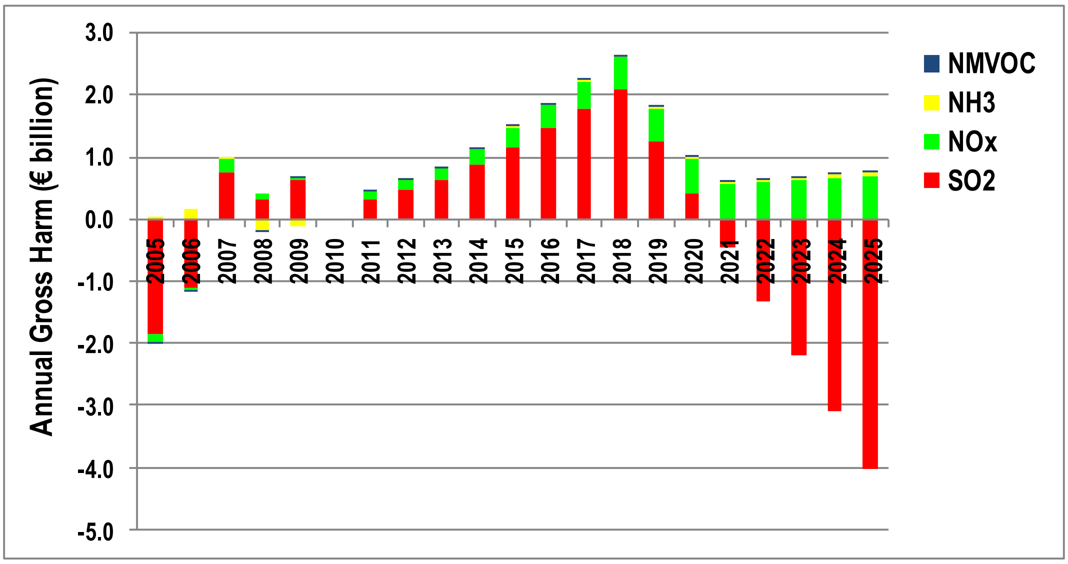
Nevertheless, the estimated decrease in $SO_2$ emissions from the electricity generating sector is highly significant, given the dominance of this sector and the significance of $SO_2$ emissions regarding damage costs. However, without the emissions control envisaged in the industrial EMS, the estimated growth in $SO_2$ emissions from industrial combustion outweighs the potential emission reductions of the electricity sector.

This observation reinforces the need to implement the full EMS for industrial combustion, especially in the cement and iron & steel sectors. Taking the estimated impacts of $SO_2$ emissions control also into account, the cumulative (2011-25) increase in $SO_2$ emissions may fall from 4,790 ktonne to 2,600 ktonne whilst the gross marginal damage may fall from €17.5 billion to €9.5 billion. Indeed, the projection results suggest that, with the full EMS in place, $SO_2$ emissions from industrial combustion could be lower by year 2025 than in year 2010 (715 ktonne as opposed to 741 ktonne). With the full EMS in place the cumulative increase in NOx emissions from industrial combustion is also estimated to fall, from 650 ktonne to 550 ktonne, whilst the gross marginal damage from NOx emissions may fall from about €1.5 billion to €1.2 billion.

Taking the above factors into consideration, it is possible that with all proposed EMS in place, overall reductions in harm to human health and agricultural productivity from NECD pollutant emissions could be achieved – at least over the projection period. Looking further into the future, beyond 2025, the catch-up effect of retrofitting emissions control to LCPs will fall out. In the absence of other measures, growth in industrial output and national electricity demand beyond 2025 will tend to push $SO_2$ (and NOx) emission levels upwards again.

Figure 7-2 illustrates the possible dynamic changes to 2025 assuming the full EMS is in place in all sectors. A highlight is the beneficial effects of retrofitting emissions control technologies to existing, large combustion plants. Growth in emissions would result in increasing harm up to 2018, after which time annual damage costs may begin to decline: from 2022 or so the collective EMS may deliver net benefits in terms of air quality and health outcomes.

**Figure 7-2 Projected annual gross harm (€ billion) relative to year 2010 emissions: assuming the full EMS is in place**

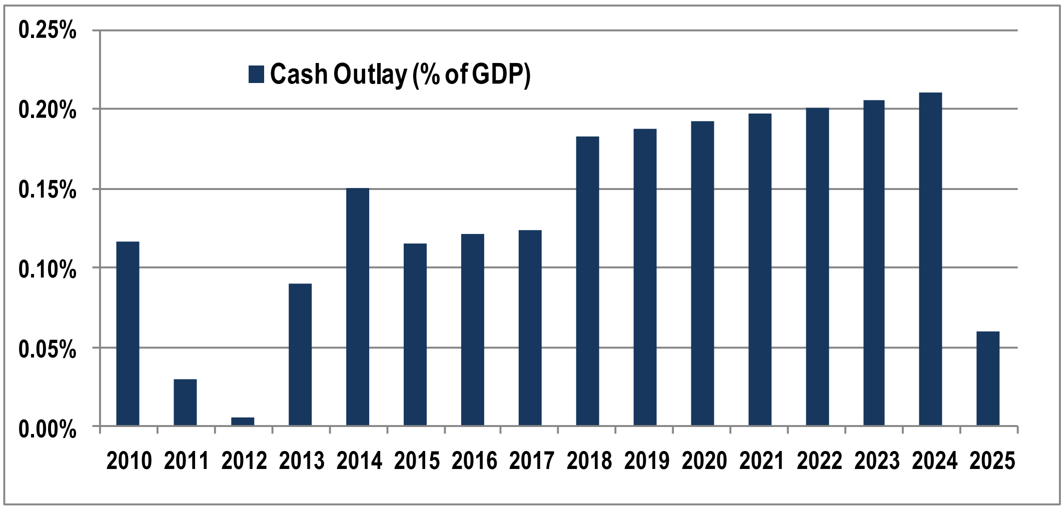



**NOTE**: Negative harm is a benefit.

## 7.5 Affordability of the Electricity Sector EMS

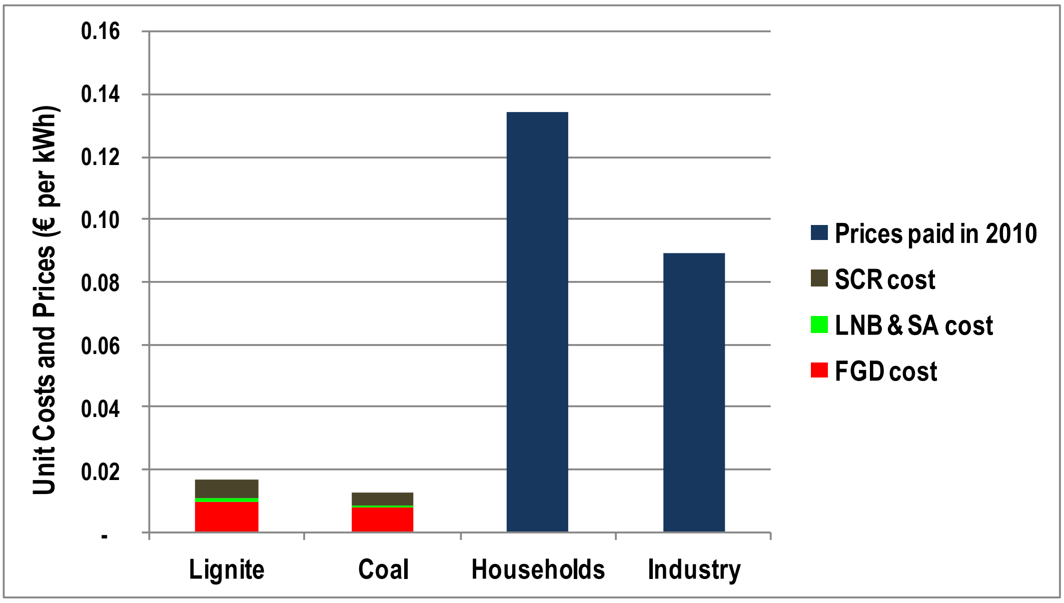
Whilst the suggested EMS for the electricity generating sector should provide substantial reductions in estimated emissions and substantial economic benefits, the costs of implementation would also be significant. Annual cash expenditure (cash outlay on capital investment and O&M) was compared with projected real national GDP, therefore, as a measure of affordability at the national level. Estimated expenditure peaks at a little over 0.2% of GDP in the period 2020-2024; see Figure 7.3.

**Figure 7-3 Yearly cash outlays on the EMS as a percentage of national GDP**




However, at the consumer level, it is the additional price paid for electricity that is an appropriate indicator of affordability. The cost of EMS implementation at lignite and coal-fired electricity generating stations was estimated at €0.013 - 0.018 per kWh at year 2010 prices: see Figure 7.4.

**Figure 7-4 Comparison of estimated unit costs of emissions control with electricity prices in Turkey**




Allowing for energy-mix factors (most electricity is generated from natural gas-fired stations and zero-emission sources, and this is expected to continue into the future), it was estimated that the net effect of $SO_2$ and NOx emissions control at lignite and coal-fired stations could be to increase the average prices that household and industrial consumers pay for electricity by about 3% and 4.5% respectively.

## 7.6 Summary of Costs to Reach the Possible Emission Ceilings

The cumulative estimated costs to 2025 of meeting the identified possible ceilings are summarised in Table 7-5.

**Table 7-5 Cumulative costs to 2025 to achieve possible national emission ceilings**

| Basis for National Emission Ceilings | Possible National Emission Ceilings (ktonne) | | | | Cumulative Costs [1] |
|---|---|---|---|---|---|
| | NOx | $SO_2$ | NMVOCs | $NH_3$ | € billion |
| 1 WaM : full EMS | 1,240 | 2,160 | 800 | 530 | 20.2 |
| 2 WaM: high GDP variant [2] | 1,310 | 2,340 | 850 | 530 | > 20.2 |
| 3 WaM: minus SCR/SNCR | 1,360 | 2,160 | 800 | 530 | 14.8 |
| 4: WaM: constant fuel-mix - residential heating [3] | 1,240 | 2,240 | 890 | 530 | 20.2 |

NOTE 1: The estimated costs do not include those which may be incurred in providing emissions control ($SO_2$ and NOx) in the cement and iron & steel sectors. They should be estimated and added to the total once the structure of these sectors and their emissions control needs have been better established – see Sections 3.5, 3.6 and 6.4.11.

NOTE 2: Costs will be higher than for WaM as a result of, for example, higher electricity demand and a further increase in electricity generation capacity and emissions control investment etc.

NOTE 3: Estimating the costs for the EMS for the residential combustion sector was not appropriate or possible hence the gross costs of meeting possible ceilings do not reflect measures in this sector.

## 7.7 Impacts of NECD Implementation on MoEU

### *7.7.1 Ministries and other national bodies involved*

The possible NECs are based on the implementation of practicable emission management strategies which, in addition to highly significant national policies, will require the transposition and implementation of a number of 'other' EU Directives (Annex 4) that help to control or limit the emission of NECD substances. Annex 4 also notes the wide range of Ministries[34] and State Bodies in Turkey that need to be involved in NECD implementation.

For this reason and to ensure that all parties were fully involved in the transposition process, the MoEU has proposed the establishment, via a Prime-Ministerial Circular, of an inter-Ministerial 'National Emission Ceilings Coordination Board' (CoBoard). It is envisaged that the CoBoard will be chaired by the MoEU and comprise representatives from all major Stakeholder Ministries at Under-Secretary level. Table 7-6 provides an indicative composition. It is expected that the President of the Turkish Union of Chambers and Exchange Commodities (TOBB) and a representative from TÜBITAK (Marmara Research Centre) may also be invited to participate.

[34] It has been assumed that the Ministry of Energy and Urbanisation (MoEU) and the Ministry of Health (MoH) are affected by the implementation of each of these 'other' Directives.

**Table 7-6 Indicative ministerial composition of the proposed CoBoard**

| | |
|---|---|
| Foreign Affairs<br>Finance<br>EU Affairs<br>Health<br>Transport<br>Maritime Affairs and Communications | Food, Agriculture and Livestock<br>Science, Industry and Technology<br>Energy and Natural Resources<br>Environment and Urbanisation<br>Development<br>Treasury<br>Economy |

### *7.7.2 CoBoard unit within MoEU*

Once formed and fully established, CoBoard will have a vital role to play in:

1. Aiding the transposition process; and especially
2. Enabling the exchange of relevant data and information between Ministries;
3. Resolving significant uncertainties regarding the emission management strategies and other issues, such as those identified in Section 6; and
4. Overseeing a review of the possible national emission ceilings and the formulation of an official draft proposal of the Government of Turkey for national emission ceilings ($SO_2$, NOx, NMVOC and $NH_3$).

The draft Prime-Ministerial Circular proposes placing CoBoard under the Chairmanship of the MoEU. This may be seen as a coordinating role: it is unlikely to provide MoEU with the power to make decisions when, for example, two or more Ministries do not agree on the best course of action to take.

Care will need to be taken so that the MoEU does not find itself in the classic dilemma of being ‘responsible’ for the implementation of NECD but without the ‘power’ to undertake the duties required.

Firstly the CoBoard must be fully established so that MoEU and the other Ministries and National Bodies are made aware of MoEU’s responsibilities and overall powers as regards the implementation of the NECD. MoEU may then seek more powers as required. It is recommended that a CoBoard Unit should be established within the MoEU and that the Unit should be headed by an Under Secretary (as in the terms of the draft Prime-Ministerial Circular). It might consist initially of four (4) permanent staff, as follows:

- Two (2) lawyers to deal with issues of legislation concerning ‘other’ EU Directives; and
- Two (2) technically qualified staff to advise on the proposed methods to meet the requirements of the ‘other’ Directives.

Other staff could be seconded to the Unit as needed to deal with particular issues. The Head of the CoBoard Unit within the MoEU would be a critical appointment as he / she will need to act as the ‘Champion’ for Turkey to propose and meet its national NECs.

# 8 CONCLUSIONS AND RECOMMENDATIONS

## 8.1 Overall Conclusions

A national inventory for the emissions in Turkey of the NCED pollutants $SO_2$, NOx, NMVOC and $NH_3$ has been prepared, covering the period 1990 – 2010. It indicates that $SO_2$, NOx, NMVOC and $NH_3$ emissions have risen by 55%, 63%, 17%, and -2%, respectively, from 1990 to 2010.

An inventory guideline for the use of MoEU staff has been prepared and passed over to MoEU. The guideline should enable MoEU to update the inventory annually in future and make improvements to it.

As the first systematic inventory in Turkey to cover NECD pollutants only, there are aspects where significant improvements may be made in future. To a substantial extent, improving the inventory will require that institutional mechanisms are put in place, and implemented, to better enable the flow of relevant information to MoEU from other Ministries. Of the areas identified for potential improvement, it was concluded that the priorities are:

- Having quality assured, measured values for the Sulphur content of lignite and coal fuels that are consumed in Turkey.
- Accurate information on the type of emissions abatement equipment installed and operated at large combustion plants (LCPs) in the electricity generation sector and at integrated plants that produce their own energy; and information on its emissions control performance ($SO_2$, NOx).
- Comprehensive and systematic measurements of emissions from LCPs in the above sectors, to feed into a comprehensive point-source emissions database.
- Road transport vehicle-km data for a number of years and vehicle types.
- Differentiation of the consumption data for ‘petroleum’ liquid fuel given in the national energy balance tables into ‘petrol’ (gasoline), ‘diesel’ (gas oil), ‘aviation fuel’ and ‘heating’ or ‘burning oil’ – in particular for road transport.
- A country-specific estimation of relevant activity data for VOC solvent use in Turkey and checking whether the emission factors used for residential wood combustion are appropriate.
- Institutional mechanism/s to ensure consistency between the NECD emissions inventory (MoEU) and the GHG emissions inventory (TurkStat).

Subject to the uncertainties indicated above, the electricity generating sector was the principal source of $SO_2$ emissions in 2010, contributing 60% of the 3,260 ktonne total national emission. It was also a major source of NOx emissions, contributing about 34% of the 930 ktonne total national emission.

Again for 2010, combustion in other industry contributed about 23% of the national $SO_2$ emission, 11% of NOx and 44% of the NMVOC national emission of 700 ktonne.

Road transport contributed about 40% of the national NOx emission and 13% of NMVOC emissions in 2010.

Residential and commercial combustion contributed about 17% of national $SO_2$ emissions and 38% of national NMVOC emissions in 2010.

Agriculture accounted for 98% of the national $NH_3$ emissions load of 515 ktonne in 2010, split between livestock rearing and fertiliser use in the ratio of about 2:1.

NECD pollutant emissions to air cause problems for human health (morbidity and premature death), and adversely affect agricultural productivity and both the natural and built environment. EC funded studies (outside of the present project) have assessed human health and agricultural impacts assessed in and quantified in economic (monetary) terms: they suggest that the marginal damage costs of NECD pollutant emissions from Turkey are about €3,640/ tonne $SO_2$, €2,280/ tonne NOx, €5,450/ tonne $NH_3$ and €10/tonne NMVOC[35]. Emissions reduction therefore results in significant gross economic benefits – benefits that are not usually recognised by industry etc when it makes a financial analysis of a project.

The emission management strategies prepared in the Project have targeted NECD pollutant emissions from each of these sectors, adopting national policy measures and internationally proven techniques. Where appropriate and where indicative costs data were available, the specific emissions control measures identified in the sectoral EMS were subjected to a cost-benefit analysis (CBA) utilising the above marginal costs data to quantify benefits. The estimated benefits of all emissions control techniques subjected to CBA substantially exceeded estimated costs with the exception of the following:

- SCR for downstream NOx control at LCPs: under the By-Law that transposed the LCPD the technique may still be required to meet future NOx emission limits for solid-fuel fired plants having an input thermal capacity of 500 MWth or more.
- Control of solvent use and limiting the solvent content of specific paint and other products (NMVOC control). However, a primary reason for controlling NMVOC emissions is to protect the stratospheric ozone layer, the economic benefits of which are not included in the €10/tonne NMVOC marginal damage cost.
- PVR techniques for NMVOC emission control, especially Stage II PVR.

The emission projections for the WoM Scenario showed significant emissions growth from 2010 to 2025. National emissions in 2025 are estimated as follows: $SO_2$ 9,090 ktonne, NOx 2,020 ktonne, NMVOC 1,180 ktonne, and $NH_3$ 575 ktonne.

Under the WM and especially the WaM scenarios, emissions growth would be moderated to a significant extent. Under the WaM scenario, national emissions in 2025 are estimated as follows: $SO_2$ 2,160 ktonne, NOx 1,240 ktonne, NMVOC 800 ktonne, and $NH_3$ 530 ktonne. A highlight of the projections is the reversal of the $SO_2$ emission growth trend after 2018, the result of retrofitting FGD at large combustion plants in the electricity sector.

Possible national emission ceilings for Turkey for 2025 have been based on the WaM emission projection results, moderated to take account of the CBA findings, the possibility of faster GDP growth and an unchanged fuel-mix for residential and commercial combustion. However, the projections are subject to a number of significant planning and other uncertainties regarding EMS implementation – additional to the inventory shortcomings. The possible national emission ceilings below, therefore, need to be regarded as interim values pending a thorough review by the Government of the Republic of Turkey.

[35] This figure is two orders of magnitude less than that applying to many EU-27 Member States: see Section 4 and Annex 3.

| Basis for National Emission Ceilings | Possible National Emission Ceilings (ktonne) | | | |
|---|---|---|---|---|
| | NOx | $SO_2$ | NMVOCs | $NH_3$ |
| 1 WaM : full EMS | 1240 | 2160 | 800 | 530 |
| 2 WaM: high GDP variant | 1310 | 2340 | 850 | 530 |
| 3 WaM: minus SCR/SNCR | 1360 | 2160 | 800 | 530 |
| 4: WaM: constant fuel-mix for residential heating | 1240 | 2240 | 890 | 530 |

The Regulatory Impact Assessment (RIA) has estimated the total gross benefits and costs of applying the full EMS to meet the first of the above NEC. Comparing the emissions projections under the WaM scenario with those under the WoM scenario, annual gross benefits (at 2010 price levels) increase progressively to reach over €25 billion in 2025. Whilst the cumulative gross benefits from 2011 to 2025 (excluding emissions control in the iron & steel and cement sectors) are estimated to be more than €146 billion. Most of the benefit results from $SO_2$ emissions control; and from emissions control in the electricity generating sector.

The cumulative costs to 2025 (at 2010 price levels) of emissions control to meet the identified possible ceilings are estimated at over €20 billion with the full EMS in place: they exclude the costs to be incurred for $SO_2$ and NOx emissions control in the cement and iron & steel sectors, which may be significant but were indeterminate given the data available to the Project. The overall estimated cost includes €5.4 billion for NOx control using SCR at lignite and coal-fired electricity generation stations. However, the results of economic appraisal suggest strongly that SCR fails the cost-benefit test and may be regarded as beyond BAT in Turkey. The national emission ceiling value of 1360 ktonne, therefore, may be the more appropriate value to adopt for NOx in Turkey. Total implementation costs therefore may be in excess of €15 billion instead of €20 billion.

Most EMS implementation costs lie in the electricity generating sector. Comparing the estimated annual cash expenditure (capital investment and O&M) in the electricity generating sector with projected real national GDP suggests that the EMS for the electricity generating sector is affordable at a national level: annual cash outlays are unlikely to exceed 0.21% in any year of the projection period. At the consumer level, assuming the costs of emissions control are spread evenly across all electricity users, it is likely that households and industrial consumers would see price increases of about 3% and 4.5% respectively over the projection period. This level of price rise is judged to be affordable.

Based on the analyses undertaken in this Project, NECD implementation should be advantageous to Turkey and its people. However, there are a number of significant aspects regarding the preparation of the emissions inventory and EMS-based emission projections where clarifications and improvements are needed prior to the development of Government-led proposals for National Emission Ceilings. Making the necessary clarifications and improvements will to a large extent depend on the extent to which institutional barriers to the effective flow of relevant information may be overcome. This is a complex issue whose resolution will depend on the involvement of the highest levels of Government: the proposed inter-Ministerial Coordination Board, to be established under a Prime-Ministerial Decree, is a potentially ideal mechanism for overcoming these institutional barriers.

## 8.2 Recommendations

The proposed Coordination Board (CoBoard) should be established as soon as possible under the effective leadership of an Under-Secretary from the MoEU. The appointed Under-Secretary should become the 'Champion' for implementing the NECD in Turkey, the formulation of credible, binding national emission ceilings and the establishment of practicable programmes of measures to enable Turkey to comply with those ceilings. CoBoard should play a vital role in:

- Coordinating the transposition process;
- Enabling the flow of relevant data and information between Ministries;
- Resolving significant uncertainties regarding the emissions inventory compilation, emission management strategies and emission projections in particular; and
- Overseeing a review of the possible NEC and the formulation of an official draft proposal of the Government of Turkey for national emission ceilings ($SO_2$, NOx, NMVOC and $NH_3$).

Once established, CoBoard and its working groups should be the principal mechanism whereby MoEU can resolve the identified uncertainties. Issues recommended as priorities for CoBoard attention are identified in Table 8-1.

**Table 8-1 Priority issues for CoBoard attention**

| Sector | Issue | Report Sections |
|---|---|---|
| Electricity Generation, Cement and Iron & Steel Production | Sulphur content of solid fuels – lignite and coal | 6.5.5<br>6.5.10 |
| Electricity Generation, Cement and Iron & Steel Production | Measured, source-specific emissions data | 6.5.6<br>6.5.10 |
| Electricity Generation | Reliability of the forecast national electricity demand | 6.5.2 |
| Electricity Generation | Growth in electricity generation from zero-emission sources (hydro, wind, geothermal, nuclear, solar) | 6.5.3 |
| Electricity Generation | Fuel mix employed – domestic lignite, imported coal, imported natural gas – and any constraints that may apply | 6.5.4 |
| Electricity Generation | SCR for NOx emissions control at lignite-fired and coal-fired stations | 6.5.7 |
| Electricity Generation | FGD performance at lignite-fired stations | 6.5.8 |
| Electricity Generation | NOx emissions from lignite-fired stations | 6.5.8 |
| Electricity Generation | Potential opt-out of lignite-fired stations from transposed LCPD | 6.5.9 |
| Industrial Combustion | Industrial classification and characterisation to provide a basis for the preparation of an EMS of appropriate detail for each sector | 6.5.11 |
| Residential Combustion | National strategy for heating energy supply regarding (i) fuel mix (ii) promoting the use of energy efficient appliances and (iii) improved building insulation | 6.5.13 |
| Road Transport | More comprehensive data regarding (i) the numbers of heavy goods vehicles (ii) vehicle-kilometre data for different vehicle types and (iii) diesel/petrol fuel split | 6.5.14 |
| Road Transport | Options for a more aggressive approach to limiting NOx and NMVOC emissions | 6.5.14 |
| All | Consistency between the NECD and GHG emission inventories | 2.1.2 |

At an appropriate time, when sufficient information has been received from other Ministries and major uncertainties have been resolved, it is recommended that the MoEU should:

1. Update the NECD emissions inventory, to include 2011 as the latest year (1990-2011), following the guidance contained in the 'Emissions Inventory Guideline' prepared by the TA Project; and
2. Develop a set of 'activity' data and 'emission factors' for the period 2012 to 2025 and prepare emission projections (2012-2025) following the guidance contained in the 'Projections Guideline' prepared by the TA Project. <u>All stakeholders must participate fully</u> in this process.
3. Once the emission projections for 2012-2025 have been prepared it is recommended that MoEU, through CoBoard, should initiate a review of the suggested possible national emission ceilings for Turkey of the pollutants $SO_2$, NOx, NMVOC and $NH_3$.

CoBoard should then establish a consensus amongst key stakeholders as to the draft NEC values that the Government may propose to its international partners. When negotiating with its international partners it is strongly recommended that the Government raise the issue of Turkey's potential emissions growth beyond 2025 (as a fast-developing, middle-income country) as a factor in the setting of binding national emission ceilings for Turkey.

# ANNEXES

# Annex 1 Major Stakeholders & Stakeholder Events

**Table A1-1 Major stakeholders and their significance for NECD implementation**

| Stakeholder | Significance to NECD Implementation |
|---|---|
| Ministry of Environment and Urbanisation | Overall responsibility for implementation of NECD |
| Central Ministries of<br>• Development<br>• Foreign Affairs<br>• EU Affairs<br>• Economy<br>• Finance<br>• Treasury | Consistency with national policies and plans of central Government |
| Ministry of Health | Health effects due to emissions of NECD pollutants |
| Ministry of Energy and Natural Resources | Energy supplies |
| Ministry of Industry, Science and Technology | Industrial production |
| Ministry of Transport and Communication/<br>Ministry of Maritime Affairs and Communication | Transport (Road, Rail, Air and Shipping) |
| Ministry of Agriculture and Village Affairs | Agriculture – livestock and fertiliser; Waste disposal to land; Sewage sludge application to land |
| Ministry of Forestry and Water Management | Forestry; Water Management |
| Electricity Generating Companies and TEİAŞ | Electricity generation and transmission |

**Table A1-2 Stakeholder events held during project implementation**

| Event Type | Activity | Date | Title and Purpose |
|---|---|---|---|
| Seminar | 1.1 | 06/04/11 | *'Improving Emissions Control - NEC Directive'*<br>To introduce the Project's scope and the NEC Directive |
| Workshop | 1.2 | 12/05/11 | *'Emissions Inventory Methodology and Data Requirements/Sources'*<br>To introduce the inventory methodology and to identify data availability |
| Workshop | 1.6 | 30/09/11 | *'Emissions Inventory Preparation – Progress Review'*<br>To inform stakeholders about progress in inventory preparation and to identify the potential availability of additional data |
| Seminar | 1.12 | 31/01/12 | *'NECD Emissions Inventory and Emissions Management'*<br>To provide the emissions inventory results and to introduce potential scenarios for emissions management and emission projections |
| Workshop | 3.1 | 15/03/12 | *'Regulatory Impact Assessment (RIA) – an Introduction'*<br>To introduce the RIA procedure and RIA scope and to present some preliminary CBA results to MoEU staff and major affected stakeholders |
| Workshop | 3.3 | 15/05/12 | *'Regulatory Impact Assessment – Progress'*<br>To inform stakeholders on ongoing RIA studies and to gain their insights |
| Seminar | 3.5 | 12/09/12 | *'Regulatory Impact Assessment of NECD Implementation in Turkey'*<br>To inform stakeholders on the costs and strategic importance of NEC Directive implementation in Turkey |
| Conference | 4.3 | 16/10/12 | *'Improving Emissions Control - Dissemination Conference'*<br>To disseminate major project outputs and recommendations and to outline the expected future role of the inter-Ministerial Coordination Board. |

# Annex 2 Technical Report Outputs of TA Component

All the Reports and Guidelines listed below are collated as electronic files (in both English and Turkish languages). Further soft copies may be accessed on application to the Air Management Department of the General Environment Directorate of the MoEU.

| Contractor Report Ref. No | Report Title | Report Date |
|---|---|---|
| 201 | Emissions Inventory Status and Gap Analysis | 21/07/11 |
| 202 | Emissions Inventory 1990 – 2010 Part 1: Summary of Results | 14/03/12 |
| 203 | Emissions Inventory 1990 – 2010 Part 2: Informative Inventory Report (IIR) | 14/03/12 |
| 204 | Emissions Inventory Guideline | 24/05/12 |
| 205 | The Role of Emissions Dispersion Modelling in Cost-Benefit Analysis Applied to Urban Air Quality Management: Part 1 – the Approach | 18/05/12 |
| 206 | The Role of Emissions Dispersion Modelling in Cost-Benefit Analysis Applied to Urban Air Quality Management: Part 2 – Supporting Details | 18/05/12 |
| 207 | Cost-Benefit Analysis of NECD Implementation | 24/05/12 |
| 208 | NECD Emission Projections for 2011-2025 | 19/07/12 |
| 209 | Emissions Management Strategies, Possible Emission Ceilings and RIA | 21/10/12 |
| 210 | Projections Guideline | 10/08/12 |

An Inception Report and seven Progress Reports were produced in addition to the above Technical Reports and Guidelines.

# Annex 3 Costs and Benefits Data

## A3-1 Costs of FGD and NOx Emissions Control at LCPs

Cost data were obtained from a number of sources but principally the following:

- **AMEC (ENTEC)**: Assessment of the Possible Development of an EU-wide NOx and $SO_2$ Trading Scheme for IPPC Installations Final Report June 2010 Entec UK Limited. Available at: CIRCA:

  http://circa.europa.eu/Public/irc/env/ippc_rev/library?l=/emissions_trading/final_report_first/report_10235i2pdf/_EN_1.0_&a=d

- **BREF**: European Commission IPPC Reference Document on Best Available Techniques for large combustion plant, July 2006.

  Available at http://eippcb.jrc.es/reference/

- **IEA Clean Coal Centre**: http://www.iea-coal.org.uk/site/2010/database-section/clean-coal-technologies

- **GAINS**: Greenhouse Gas and Air pollution Interactions and Synergies model produced by IIASA (International Institute for Applied Systems Analysis). Abatement cost data produced to assess impacts of revision of Gothenburg Protocol on Turkey.

  Available at: http://www.iiasa.ac.at/rains/gains.html

### Base-plant characteristics and economic appraisal assumptions

Regardless of fuel type – lignite or coal – the characteristics of base-plant and emissions control techniques adopted for analysis are given below.

| Parameter | | Units | Value |
|---|---|---|---|
| Electricity generation capacity | | MWe | 250 |
| Thermal efficiency | | % | 35 |
| Load factor | | % | 75 |
| Capital cost | FGD | Million € | 45.9 |
| | Low NOx Burner | Million € | 4.15 |
| | Over-Fire Air | Million € | 1.875 |
| | SCR | Million € | 35.475 |
| Total annual operating cost | FGD | Million €/year | 6.467 |
| | Low NOx Burner (LNB) | Million €/year | 0.0 |
| | Over-Fire Air (OFA) | Million €/year | 0.0 |
| | Selective catalytic reduction (SCR) | Million €/year | 1.964 |
| Plant life | | years | 15 |
| Discount factor | | % | 3.5 |

Capital and total annual operating costs for the base-plant were adopted or adjusted for a smaller plant capacity (150 MWe) and a range of load factors as described in Sections 7 and 8 of the CBA Report. FGD was assumed to remove 90% of $SO_2$ emissions. Relative to the NOx emission rate without controls, LNB was assumed to remove 30%; LNB plus OFA 50%; and LNB plus OFA plus SCR 75% of NOx emissions.

**Fuel Properties and NOx Emission Factors (in the absence of control)**

A number of properties - for lignite and coal fuels - were adopted for the purpose of CBA: lower heating value (net calorific value and sulphur content (mass %). NOx emission factors in the absence of emission control had also to be adopted. The values adopted are given below.

| Property | Units | Lignite | Coal |
|---|---|---|---|
| Lower heating value | GJ / tonne | 8.8 | 13.4 |
| Sulphur content | Mass % | 2.0 | 1.2 |
| NOx emission factor | g / GJ fuel energy | 360 | 310 |

All other parameters used in the CBA were derived from the above data and the marginal damage cost values of Table 4-1. All cost calculations were made using a simple spreadsheet model, made available separately to MoEU.

## A3-2 Costs for NMVOC Emissions Control in Industry

The Tables below contain marginal cost data for NMVOCs abatement taken from GAINS (see A3-1) regarding the following EU Directives: (i) Solvents/VOCs (ii) Deco-Paints and (iii) Stage I and Stage II Petrol Vapour Recovery.

| NMVOC Abatement – Solvents/VOCs Directive | Marginal Abatement cost €/tonne @ 2010 prices |
|---|---|
| **Surface cleaning – Degreasing - Existing Plant** | |
| Water based cleaning process | 1,420 |
| Basic emissions management techniques | 1,470 |
| Closed (sealed) degreaser: use of chlorinated solvents | 1,530 |
| Activated carbon adsorption | 4,896 |
| Basic emissions management techniques and carbon adsorption | 4,991 |
| Cold cleaner | 5,409 |
| Closed (sealed) degreaser | 6,292 |
| Combination of the above options | 10,192 |
| Closed (sealed) degreaser: use of fluorinated solvents (HFC, HFE) | 50,048 |
| Combination of the above options | 53,631 |
| **Surface cleaning – Degreasing – New Plant** | |
| Closed (sealed) degreaser: use of chlorinated solvents | 1,551 |
| Water based cleaning process | 1,893 |
| Cold cleaner | 7,530 |
| Closed (sealed) degreaser | 7,978 |
| Combination of the above options | 126,42 |
| Activated carbon adsorption | 44,833 |
| Closed (sealed) degreaser: use of fluorinated solvents (HFC, HFE) | 67,038 |
| Combination of the above options | 71,125 |

| NMVOC Abatement – Deco-Paints Directive | Marginal Abatement cost €/tonne @ 2010 prices |
|---|---|
| Re-labelling costs | - |
| Take-back and destruction of non-compliant paint | - |
| Abatement costs for the Paints Directive | 601 |
| Weighted average of a range of techniques | 869 |

| NMVOC Abatement – Stage I and Stage II Petrol Vapour Recovery | Marginal Abatement cost €/tonne @ 2010 prices |
|---|---|
| Transport & depots (for mobile sources)-IFC and Stage IA (single stage) controls | 673 |
| Transport & depots (for mobile sources)-IFC and Stage IA (double stage) controls | 849 |
| Transport & depots (for mobile sources)-Stage IA (single stage) -t gasoline depots | 1,187 |
| Transport & depots (for mobile sources)-Stage IA (double stage) -gasoline depots | 1,436 |
| Service stations-Stage II and IB at service station | 2,386 |
| Service stations-Stage IB controls at service stations | 3,639 |
| Service stations-Stage II controls at service stations | 6,388 |

## A3-3 Costs for $NH_3$ Emissions Control in Agriculture

The Tables below contain unit cost data for ammonia ($NH_3$) abatement in agriculture taken from GAINS (see A3-1). They have been calculated on the basis of the following average $NH_3$ emission factors:

Cows: 40kg $NH_3$/year (40,000 tonne $NH_3$ per year per million cows)

Chickens: 0.25 kg $NH_3$/year (250 tonne $NH_3$ per year per million chickens).

| Sector and Technology | Abatement cost @2010 prices | |
|---|---|---|
| Cattle & Dairy Cows Sector: Liquid (slurry) systems | €M / M animals | €/tonne $NH_3$ |
| Combination of Low nitrogen feed_Animal house adaption | 105 | 26.3 |
| Low nitrogen feed | 2 | 50 |
| Low ammonia application; high efficiency | 4 | 50 |
| Covered outdoor storage of manure; low efficiency | 5 | 125 |
| Low ammonia application; low efficiency | 6 | 150 |
| Combination of Low nitrogen feed_Low ammonia application | 7 | 175 |
| Animal house adaption | 103 | 258 |
| Combination of Animal house adaption_Low ammonia application | 112 | 280 |
| Combination of Low nitrogen feed_Animal house adaption_Low ammonia application | 115 | 288 |
| Covered outdoor storage of manure; high efficiency | 20 | 500 |
| Combination of Low nitrogen feed_Covered outdoor storage of manure | 23 | 575 |
| Combination of Covered outdoor storage of manure / low ammonia application | 30 | 750 |
| Combination of Low nitrogen feed_Covered outdoor storage of manure_Low ammonia application | 32 | 800 |
| Cattle & Dairy Cows Sector: Solid systems | | |
| Low nitrogen feed | 2 | 50 |
| Low ammonia application; high efficiency | 4 | 100 |
| Low ammonia application; low efficiency | 6 | 150 |
| Combination of Low nitrogen feed_Low ammonia application_high | 7 | 175 |
| Combination of Low nitrogen feed_Low ammonia application_low | 8 | 200 |
| Other Cattle:Solid Systems | | |
| Low ammonia application; high efficiency | 1 | 25 |
| Low ammonia application; low efficiency | 1 | 25 |

| | | |
|---|---|---|
| Covered outdoor storage of manure; low efficiency | 3 | 75 |
| Covered outdoor storage of manure; high efficiency | 9 | 225 |
| Animal house adaption | 101 | 253 |
| Combination of Animal house adaption_Low ammonia application; mean efficiency | 104 | 260 |
| Combination of Covered outdoor storage of manure; mean efficiency_Low ammonia application; mean efficiency | 12 | 300 |

| Sector and Technology | Abatement cost @2010 prices | |
|---|---|---|
| **Laying Hens Sector** | €k/M animals | **€/tonne $NH_3$** |
| Covered outdoor storage of manure; low efficiency | 0 | 0 |
| Low ammonia application; high efficiency | 0 | 0 |
| Low ammonia application; low efficiency | 0 | 0 |
| Low nitrogen feed | 0 | 0 |
| Covered outdoor storage of manure; high efficiency | 100 | 40 |
| Combination of Low nitrogen feed_Covered outdoor storage of manure; mean efficiency | 100 | 40 |
| Combination of Low nitrogen feed_Covered outdoor storage of manure; mean efficiency_Low ammonia application; mean efficiency | 100 | 40 |
| Combination of Low nitrogen feed_Low ammonia application; mean efficiency | 100 | 40 |
| Combination of Animal house adaption-Low ammonia application; mean efficiency | 100 | 40 |
| Combination of Low nitrogen feed_Animal house adaption | 300 | 120 |
| Combination of Low nitrogen feed_Animal house adaption_Low ammonia application; mean efficiency | 300 | 120 |
| Animal house adaption | 300 | 120 |
| Biofiltration | 1,100 | 440 |
| Combination of Biofiltration_Low ammonia application; mean efficiency | 1,100 | 440 |
| Combination of Biofiltration_Covered outdoor storage of manure; mean efficiency | 1,200 | 480 |
| Combination of Biofiltration_Covered outdoor storage of manure; mean efficiency_Low ammonia application; mean efficiency | 1,200 | 480 |
| Combination of Low nitrogen feed_Biofiltration | 1,200 | 480 |
| Combination of Low nitrogen feed_Biofiltration_Covered outdoor storage of manure; mean efficiency | 1,200 | 480 |
| Combination of Low nitrogen feed_Biofiltration_Covered outdoor storage of manure; mean efficiency_Low ammonia application; mean efficiency | 1,200 | 480 |
| Combination of Low nitrogen feed_Biofiltration_Low ammonia application; mean efficiency | 1,200 | 480 |

## A3-4 Estimated Marginal Damage Costs of NECD Pollutant Emissions from Different States

**Table A3-2 Marginal damage costs (Low VOLY) at 2010 prices of NECD pollutant emissions from EU-27 Member and Neighbouring States: NOx and NMVOC**

| State | NOx |
|---|---|
| Switzerland | 22,323 |
| Germany | 16,537 |
| Luxembourg | 14,493 |
| Austria | 14,307 |
| Hungary | 13,635 |
| France | 12,284 |
| Slovakia | 12,111 |
| Slovenia | 11,910 |
| Romania | 10,694 |
| Croatia | 10,412 |
| Czech Republic | 10,268 |
| Italy | 9,969 |
| Belgium | 9,896 |
| Netherlands | 9,207 |
| Moldova | 8,605 |
| Poland | 7,860 |
| Bosnia & Herzegovina | 7,668 |
| Bulgaria | 6,851 |
| Ukraine | 6,676 |
| Belarus | 6,314 |
| United Kingdom | 6,153 |
| Lithuania | 5,432 |
| Ireland | 4,747 |
| Denmark | 4,527 |
| FYRoM | 4,225 |
| Albania | 4,212 |
| Spain | 3,974 |
| Latvia | 3,589 |
| Sweden | 2,739 |
| Norway | 2,363 |
| **Turkey** | **2,278** |
| Estonia | 2,258 |
| Greece | 1,957 |
| Finland | 1,698 |
| Portugal | 1,606 |
| Cyprus | 768 |
| Malta | 679 |

| State | NMVOC |
|---|---|
| Belgium | 2,287 |
| Luxembourg | 2,115 |
| Netherlands | 1,654 |
| Germany | 1,482 |
| France | 1,182 |
| United Kingdom | 1,163 |
| Switzerland | 967 |
| Austria | 938 |
| Denmark | 849 |
| Ireland | 742 |
| Italy | 742 |
| Poland | 671 |
| Ukraine | 624 |
| Slovenia | 597 |
| Czech Republic | 576 |
| Lithuania | 523 |
| Moldova | 514 |
| Belarus | 445 |
| Sweden | 441 |
| Latvia | 439 |
| Croatia | 437 |
| Portugal | 382 |
| Spain | 349 |
| Slovakia | 340 |
| Norway | 330 |
| Malta | 325 |
| Hungary | 311 |
| Finland | 292 |
| Estonia | 247 |
| FYRoM | 224 |
| Romania | 186 |
| Albania | 157 |
| Bosnia & Herzegovina | 143 |
| Greece | 71 |
| **Turkey** | **10** |
| Cyprus | - 56 |
| Bulgaria | - 152 |

**Table A3-3 Marginal damage costs (Low VOLY) at 2010 prices of NECD pollutant emissions from EU-27 Member and Neighbouring States: $SO_2$ and $NH_3$**

| State | $SO_2$ |
|---|---|
| Switzerland | 16,074 |
| Netherlands | 15,227 |
| Germany | 14,616 |
| Belgium | 13,162 |
| Luxembourg | 11,832 |
| Austria | 11,662 |
| France | 11,430 |
| Czech Republic | 10,043 |
| Hungary | 9,693 |
| Slovenia | 9,658 |
| Italy | 9,494 |
| Slovakia | 9,455 |
| Poland | 8,706 |
| Croatia | 8,537 |
| Ukraine | 8,028 |
| Moldova | 7,384 |
| Romania | 7,305 |
| Belarus | 7,163 |
| Ireland | 6,885 |
| Spain | 6,311 |
| Bosnia & Herzegovina | 6,066 |
| Lithuania | 5,913 |
| Denmark | 5,586 |
| Latvia | 5,279 |
| Albania | 5,050 |
| United Kingdom | 5,050 |
| Estonia | 5,030 |
| Bulgaria | 4,968 |
| Portugal | 4,254 |
| FYRoM | 3,860 |
| Greece | 3,740 |
| Sweden | 3,702 |
| **Turkey** | **3,639** |
| Finland | 3,494 |
| Malta | 3,380 |
| Norway | 2,839 |
| Cyprus | 1,665 |

| State | $NH_3$ |
|---|---|
| Belgium | 32,326 |
| Luxembourg | 27,610 |
| Germany | 24,396 |
| Czech Republic | 23,500 |
| Netherlands | 23,475 |
| Slovakia | 21,815 |
| Slovenia | 20,691 |
| Croatia | 20,299 |
| Hungary | 19,866 |
| Austria | 18,135 |
| United Kingdom | 18,004 |
| Bosnia & Herzegovina | 17,802 |
| Italy | 15,593 |
| Poland | 15,375 |
| France | 12,567 |
| Switzerland | 12,066 |
| Ukraine | 11,211 |
| Belarus | 10,911 |
| Malta | 9,332 |
| Denmark | 9,256 |
| Romania | 8,922 |
| Moldova | 8,362 |
| FYRoM | 8,341 |
| Estonia | 8,066 |
| Bulgaria | 7,580 |
| Sweden | 7,528 |
| Lithuania | 6,842 |
| Latvia | 6,795 |
| Spain | 6,291 |
| Greece | 6,024 |
| Portugal | 5,552 |
| **Turkey** | **5,443** |
| Finland | 5,360 |
| Albania | 4,152 |
| Ireland | 2,796 |
| Norway | 2,263 |
| Cyprus | 1,586 |

# Annex 4 EU Directives Most Relevant to the Management of NECD Pollutant Emissions

**Table A4-1 EC Directives most relevant to the management of NECD pollutants**

| EC Directive | Official Gazette No. | Major Sectors and NECD Pollutants Affected |
|---|---|---|
| National Emission Ceiling Directive: (2001/81/EC) | NA | All sectors<br>$SO_2$, NOx, NMVOC and $NH_3$ |
| Sulphur Content of Certain Liquid Fuels Directive: (93/12/EEC) | 2009/15478<br>No.27368<br>06/10/2009 | Electricity Generation; Combustion in Industry; Transport (mainly shipping); Domestic Heating<br>$SO_2$ |
| Large Combustion Plants Directive: (2001/80/EC) | No.27605<br>08/06/2010 | Electricity Generation; Combustion in Industry<br>$SO_2$ and NOx |
| Industrial Emissions Directive: 2010/75/EC will replace Integrated Pollution Prevention and Control 96/61/EC (replaced by 08/01/EC)<br>*and* | NA | All but mainly Electricity Generation, Industry and Agriculture<br>$SO_2$, NOx, NMVOC and $NH_3$ |
| VOC Directives:<br>(Solvents -1999/13/EC)<br>(Storage – 94/63/AT)<br>(Deco-paint – 2004/42/EC) | NA | Industry; Transport; Domestic Use<br>NMVOC |
| Petrol Vapour Recovery Directives:<br>Stage I (*1994/63/EC*)<br>and<br>*Stage II (2009/126/EC)* | | Industry and Transport<br>NMVOCs |
| Testing of Vehicles Directive<br>(96/96/EC) | | Transport<br>NOx |
| EURO Standards for new vehicles<br>EURO 6 (Directive 715/2007/EC)<br>EURO VI (Reg. 595/2009) | | Transport<br>NOx |
| Nitrates Directive<br>(91/676/EEC) | | Agriculture and Water sector<br>$NH_3$ |
| Sewage Sludge to Agricultural Land Directive (86/278/EEC) | No. 27661<br>03/08/2010 | Agriculture and Water sector<br>NOx, NMVOCs and $NH_3$ |
| Waste Incineration Directive<br>(2000/76/EC) | No. 27721<br>06/09/2010 | Municipalities<br>NOx and, depending on the nature of the waste, $SO_2$ and NMVOCs. |
| Landfill Directive<br>(99/31/EC) | No. 27533 | Waste disposal and water sector<br>NMVOC, NOx and $NH_3$ |

# Annex 5 Basis for Identifying 2025 as a Possible Date for Turkey's Compliance with NECD

The date by which Turkey will be expected to comply with the requirements of the NECD has not yet been finalised. This ultimately will be a matter for negotiation between the Government of Turkey and the European Commission.

Nevertheless, it is possible to arrive at a possible date based on a number of observations and by making a number of assumptions. In particular:

- MoEU received August 2012 the TA Project's suggestions for possible NECs for Turkey for NECD pollutants;
- These will need to be discussed with the other Ministries involved. It may then take a further year for the Turkish Government to review the proposed NECs, to revise them using updated information, and to agree its final proposed NECs;
- It make then take a further year for the Turkish Government to negotiate final NECs for Turkey with the EC;
- In which case the earliest that the NECs for Turkey could be published would be mid 2014;
- As such, the beginning of the compliance period for the NECD could not be earlier than late 2014 or most probably early 2015;
- The existing Member States were given a period of just over 8 years to meet the respective NECs – that is, from 23 October 2001 when the NECD was published in the Official Journal to the year 2010;
- Since Turkey must be granted at least a similar period of time for compliance with the NECs, then implementation of the requirements of the NECD should be completed by the year 2023 or 2024;
- Because of possible over-runs in this proposed schedule of events, it seems likely that the compliance date could be set as the year 2025.

For the purpose of appraising emissions management strategies (EMS), Turkey's compliance date with the NECD was assumed to be the year 2025.

The proposed date for compliance will also depend heavily on the dates that Turkey intends to implement the number of 'other' EU Directives that will control/reduce the emission of NECD pollutants – see Annex 4.

Possible implementation dates for these 'other' Directives in Turkey are set out in Table A5-1. It will be seen that most should be implemented fully or at least in part in Turkey by the suggested date for Turkey's compliance with the NECD i.e. the year 2025.

**Table A5-1 Potential compliance schedule - 'other' EU Environment Directives**

| Directive | Scheduled Compliance Date - Turkey |
|---|---|
| National Emission Ceiling Directive<br>(2001/81/EC) | Start 2014<br>Compliance 2025 |
| Sulphur Content of Certain Liquid Fuels<br>(93/12/EEC) | 1/1/2012 Fuel oils >1% S |
| Large Combustion Plants Directive<br>(2001/80/EC) | 8/6/2010 applies for New plant – other fuels<br>1/1/2012 applies for New plant – liquid fuels<br>8/6/2019 applies for existing plant |
| Industrial Emissions Directive<br>2010/75/EC will replace<br>Integrated Pollution Prevention and Control | Start 2012<br>New plant 2013<br>Existing plant 2016 - 2030 |

| Directive | Scheduled Compliance Date - Turkey |
|---|---|
| 96/61/EC replaced by 08/01/EC and | |
| Volatile Organic Compounds<br>(Solvents -1999/13/EC)<br>(Storage – 94/63/AT)<br>(Deco-paint – 2004/42/EC) | Gradual transposition after 2011 |
| Nitrates Directive<br>(91/676/EEC) | In force from 18/2/2004<br>Gradual transposition |
| Sewage Sludge | Completion 2011/12 |
| Waste Incineration Directive<br>(2000/76/EC) | Completion end 2023 |
| Landfill Directive<br>(99/31/EC) | |
| Testing of vehicles<br>(96/96/EC) | Implemented 2013 |
| EURO Standards for new vehicles | EURO 6 and VI standards 2013-2015 |

# Annex 6 Emission Projections – Sectoral Considerations and Selected Emission Factors

The sub-sections below note how changes across the Scenarios are projected in the sectors principally responsible for NECD pollutant emissions.

### A6-1 Electricity generation - combustion

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| National electricity demand grows as described in TEİAŞ's projections for 2011-2020, high demand Scenario 1. The trend is assumed to continue to 2025.<br>No increase in energy efficiency of the transmission grid.<br>No increase in electricity generated from zero-emission sources (hydro, wind, geothermal) from year 2010 levels.<br>No electricity generation from solar or nuclear sources.<br>The consumption of fuels increases to meet the increase in demand. Fuel ratios (GWh electricity output) are calculated from the projections of TEİAŞ (high demand, scenario 1) and are maintained at the projected 2020 levels up to 2025.<br>No changes in emission factors for fuels combustion. | Growth in national demand is the same as for WoM. No change in transmission losses relative to WoM.<br>The proportional contributions of different energy sources in meeting this demand are as projected by TEİAŞ (high demand, scenario 1) for the period 2011-2020. Year 2020 values are extrapolated to 2025.<br>Growth in output from all sources over and above TEİAŞ's planned output figures will occur so as to match supply to projected national demand.<br>Electricity generation from nuclear sources will be initiated to provide 5% of national demand.<br>By 2025 the contributions (% of national GWh demand) of the different energy sources will be as follows:<br>Lignite: 15.8%; Hard coal: 10.6%; Natural gas: 42.6%; Oil: 3.2%; Other fuels: 0.7%; Zero-emission sources (Hydro, geothermal, wind, solar and nuclear): 27.1%.<br>SCLF implementation is assumed. New coal and lignite fired plants are equipped with emissions control to comply with LCPD. | Growth in national demand is the same as for WoM. No change in transmission losses relative to WM.<br>Activity levels (energy source mix and fuel consumptions) are the same as for WM.<br>Emission factors for the combustion of lignite and hard coal in new plants assume compliance with LCPD.<br>Emission factors for the combustion of lignite in existing plants are reduced over the period 2019 to 2025 to reflect the retrofitting of NOx and $SO_2$ emission control measures so as to comply with LCPD. |

Given projections for (i) national electricity demand (GWh) to be satisfied by the electricity generating sector and (ii) the percentage contributions provided by different energy sources, average specific fuel consumption (SFC) values (e.g. ktonne fuel/GWh electrical) may be used to estimate future fuel consumptions.

TEİAŞ's 2011-2020 electricity plan projects the national electricity demand to 2020 and states the 'firm' supply capacity, i.e. that of existing plants and those under construction with a licence. An important consideration is that TEİAŞ's 'firm' supply capacity (GWh electrical generation) falls below the projected national demand by year 2018; the gap increasing substantially in later years. This gap provides an advance signal to investors of a market demand for additional generating capacity. It was assumed that, on average and over the time period considered, the need for additional electricity generation would be met as follows:

- WoM Scenario: utilising fuels only (lignite, coal, natural gas, oil and other) in the same proportions as reported for 'firm' capacity in TEİAŞ's plan for 2011-2020, continuing unaltered to 2025.
- WM and WaM Scenarios: utilising all the various energy sources (fuels as above plus zero-emission sources) in the same proportions as reported for 'firm' capacity in TEİAŞ's plan for 2011-2020, continuing unaltered to 2025.

### A6-2 Iron & steel, non-ferrous metals and cement - combustion

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Growth of activity is directly proportional to national GDP growth.<br>No change in fuel mix or emission factor. | Same fuel mix as WoM but activity grows to 90% of WoM value by year 2025 resulting from the implementation of fuel efficiency measures.<br>Emission factors same as for WoM except that those for oil combustion are reduced to reflect implementation of SCLF | Fuel mix and activity as for WM.<br>Emission factors for lignite and coal combustion reduced to reflect the implementation of emission control measures required for compliance with IPPC. |

The fuel mixes for all scenarios was assumed to be the same as in the final year (2010) of the historic inventory - fuel consumptions were taken from the MoENR Energy Balance tables.

However, it should be expected that energy efficiency improvements, introduced by industrial firms so as to comply with IPPC permits and to cut costs will reduce fuel consumption by 2025 to below the values estimated in the WoM Scenario. Available evidence suggests that an improvement of about 10 % ought to be possible in these sectors by 2025.

Emission factors (EFs) for fuel combustion in the WoM and WM Scenarios were assumed to be the same as in the final year (2010) of the historic inventory, except for the consequences of SCLF implementation in the WM Scenario. In the WaM Scenario, EFs of power units of the integrated plants were reduced to those for LCPD compliance (as for electricity generation). WaM projections assumed that all plants in this sector grouping met the thermal capacity criteria for coverage under LCPD.

### A6-3 Other industrial sectors – combustion

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Growth of activity is directly proportional to national GDP growth.<br>No changes in fuel mix or emission factor from 2010 values. | Same fuel mix as for WoM but activity grows to 90% of WoM value by year 2025 resulting from the implementation of fuel efficiency measures.<br>Emission factors are the same as for WoM. | Fuel mix and activity are the same as for WM.<br>Emission factors are the same as for WoM. |

The fuel mixes for all scenarios were assumed to be the same as in the final year (2010) of the historic inventory. As above, the assumption in the WoM Scenario that activity (fuels consumption) in the general industrial sector would increase from 2010 at a rate proportional to the growth in national GDP was considered reasonable. This view was based on the stable contribution of industrial activity to GDP growth in recent years.

Similarly to above, it was assumed that energy efficiency improvements would result in fuel consumption values in the WM and WaM Scenarios reducing to 90% of WoM values by 2025. However, it was assumed that there would be no changes in EF values from those of the emissions inventory for 2010.

### A6-4 Residential & commercial – stationary combustion

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Total fuel consumption increases in direct proportion to the increase in population.<br>Fuel mix of 2010 is assumed to be maintained without change to 2025. | Total fuel consumption increases to the same extent as in WoM.<br>The fuel mix changes in response to a range of factors including the planned extension of the natural gas distribution system. | Same as for WM. |

Excluding electricity consumption, the energy mix of the residential and service sectors proposed in the three Scenarios are presented below. Significant changes occurred in the final decade of the historic inventory (1990 – 2010) and it may be considered likely that there will be further changes in future.

**Energy / Fuel mixes in 2025 for the WoM and WM/WaM Scenarios**

| Energy Source | Percentage Contribution to Supply in 2025 | |
|---|---|---|
| | WoM Scenario<br>No Change in Energy Mix from 2010 | WM and WaM Scenarios<br>Change in Energy Mix after 2010 |
| Geothermal and Solar | 6.3 % | 6.3% |
| Wood and Waste | 20.6 % | 10.0 % |
| Oil | 5.8 % | 3.0 % |
| Hard Coal | 24.2 % | 20.4 % |
| Lignite | 13.2 % | 11.5 % |
| Natural Gas | 29.7 % | 48.8 % |
| **Total** | **100.0 %** | **100.0 %** |

### A6-5 Agriculture – stationary combustion

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Growth of activity is proportional to national GDP growth.<br>No change in emission factor from 2010. | Same as for WoM. | Same as for WM. |

### A6-6 Aviation – domestic LTO

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Growth of activity in line with GDP.<br>No change in emission factor from 2010. | Activity grows to 95% of WoM value by year 2025 reflecting improvements in engine energy efficiency (gradual renewal of fleets and engines with more fuel-efficient models).<br>No change in emission factor. | Same as for WM. |

### A6-7 Aviation – international LTO

| WoM Scenario | WM Scenario | WaM Scenario |
| --- | --- | --- |
| Growth of activity in line with GDP plus 0.5% per year growth.<br>No change in emission factor. | Activity grows to 95% of WoM value by year 2025 reflecting improvements in engine energy efficiency (gradual renewal of fleets and engines with more fuel-efficient models).<br>No change in emission factor. | Same as for WM. |

### A6-8 Road transport

| WoM Scenario | WM Scenario | WaM Scenario |
| --- | --- | --- |
| Relevant activity levels increase in line with historic.<br>Composition of the fleet evolves so that the effect on emission factors of Euro Standards (3, 4 and 5; III, IV and V) are taken into account. | As for WoM but allowing the fleet composition and, hence, emission factors, to evolve further as newer higher performance vehicles (Euro 6 and VI engine emission standards) gradually replace the older vehicles. | Same as for WM. |

### A6-9 Railways

| WoM Scenario | WM Scenario | WaM Scenario |
| --- | --- | --- |
| Growth of activity equal to GDP growth minus 2.5% per year.<br>No change in emission factor from 2010 level. | Up to 2025, total railway traffic and activity level increases by a factor of about 4 from 2010 levels.<br>No change in emission factor from WoM. | Total activity is assumed to be as for as for WM but its composition is modified significantly by the electrification of routes and traffic. Electrification is assumed to expand from 11% of total activity in 2010 to 50% by 2025.<br>No change in emission factor from WM. |

### A6-10 National shipping

| WoM Scenario | WM Scenario | WaM Scenario |
| --- | --- | --- |
| Growth of activity is proportional to GDP growth plus 0.5% per year.<br>No change in emission factor. | Same as for WoM. | Same as for WM. |

### A6-11 Industrial processes

| WoM Scenario | WM Scenario | WaM Scenario |
| --- | --- | --- |
| Growth of activity proportional to national GDP growth.<br>No change in emission factor. | Same as for WoM. | Same as for WM. |

Many industrial installations might be regulated under IPPC in future: their process emissions will be subject to review when permit conditions are set. Some reductions in emissions factors ought to be possible but site and sector specific information would be needed to propose a specific figure for emissions reduction.

### A6-12 Solvent use – industrial and commercial

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Growth of activity proportional to national GDP growth.<br>No change in emission factor. | Same as for WoM. | Activity is the same as in WM.<br>Emission factors for solvent use in industrial sectors are reduced following the transposition of the VOC Solvents Directive. |

The WaM Scenario assumed the same activity levels as in the WoM and WM Scenarios but considered the effects of implementing future By-law/s to transpose EU Directives regarding solvent use and their inclusion in certain products.

It was assumed that the combined effect of implementing the transposed VOC Solvents Directive and the Deco-Paints Directive (2004/42/CE) would reduce the NMVOC emissions factor for the industrial sector to 80% of its year 2010 value by the year 2025. This was based on trends observed in other countries.

### A6-13 Solvent use – residential (domestic)

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Growth of activity is proportional to growth in GDP.<br>No change in emission factor. | Same as for WoM. | Activity is the same as in WM.<br>Emissions of solvent NMVOCs from residential sector reduced to below WoM and WM levels to reflect the implementation of Deco-Paints Directive. |

Since the "Deco-Paints" Directive came into full effect in EU Member States in 2010 it may be assumed that any products subject to this Directive, and imported into Turkey from an EU Member State producer beyond 2010, will meet its requirements. However, the effects of this Directive will depend mainly upon the timing of its transposition into Turkish legislation, its implementation and its enforcement.

Based on trends observed in other countries it was assumed that the overall impact on the NMVOC emissions factor for this sector would result in a reduction of 50% of its year 2010 value by the year 2025.

### A6-14 Agriculture: livestock

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Relevant activity levels increase in line with historic trends.<br>Size of dairy cattle increase to West European levels by 2025, causing a rise in the emission factor for $NH_3$ (kg/y per animal). | Same as for WoM | Activity levels as for WM.<br>$NH_3$ emission factors fall, reflecting better practices in livestock feeding and housing and improved management of manures generated by housed livestock. These result from a combination of implementing IPPC (intensive poultry), good practices (all livestock) and the Nitrates Directive (reducing $NH_3$ emissions from fertiliser use). |

### A6-15 Agriculture: synthetic N-fertiliser

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Relevant activity levels increase in line with historic trends.<br>$NH_3$ emission factor unchanged from year 2010 level. | Activity levels are the same as for WoM.<br>$NH_3$ emission factor unchanged from year 2010 level. | Activity levels are lower, reflecting the adoption of better, more efficient practices for applying fertilisers to land. The drivers are the transposed EU Nitrate Directive and improved awareness of good practice.<br>$NH_3$ emission factor unchanged from year 2010 level (as in WoM and WM Scenarios). |

### A6-16 Waste

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Growth of activity (waste to landfill) is proportional to national GDP growth.<br>No change in emission factor. | Activity is reduced to 35% of the year 2005 level by 2025.<br>NMVOC emission factor for the remaining BMW disposed of to landfill (the 35% noted above) is reduced to reflect the combustion of landfill gas (beneficial use or flared using BAT). | Activity and emission factors as for WM. |

### A6-17 Wastewater and small-scale waste burning

| WoM Scenario | WM Scenario | WaM Scenario |
|---|---|---|
| Growth of activity is proportional to national population growth.<br>No change in emission factor. | Same as for WoM. | Same as for WM. |

### A6-18 Emission Factors

Table A6-1 provides selected examples of the emission factors that have been used to compile the emission estimates. Emission factors are taken from the last year of the historic emissions inventory, and then scaled for future years according to information on how they might change with time. Many emission factors are kept constant across the time series: for such activities the intensity of the emission is expected to remain constant and the only variable that is expected to change is the extent of the activity, i.e. the activity data. However, where technology change is planned, or the introduction of new abatement equipment, then changes to the emission factors need to be incorporated into the emission projection calculations.

The majority of emission factors that are used in the historic emissions inventory are obtained from the EMEP/EEA Emissions Inventory Guidebook (GB), hence most of the emission factors used to estimate emission projections were based on GB values but incorporated a degree of rescaling.

**Table A6-1 Selected emission factors for projected years under the WaM Scenario**

| NECD Pollutant | Fuel | Units | Emission Factors | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOx | | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
| Electricity Generation | lignite | tonne/ktonne | 3.2 | 2.9 | 2.8 | 2.8 | 2.7 | 2.6 | 2.4 | 2.3 | 2.2 | 1.9 | 1.7 | 1.5 | 1.3 | 1.1 | 0.9 | 0.8 |
| Electricity Generation | coal | tonne/ktonne | 7.3 | 6.8 | 6.5 | 6.6 | 6.2 | 5.8 | 5.7 | 5.5 | 5.4 | 5.1 | 4.8 | 4.5 | 4.2 | 4.0 | 3.8 | 3.7 |
| Electricity Generation | gas | tonne/million $m^3$ | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| Iron & Steel (combustion) | lignite | tonne/ktonne | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.2 | 1.0 | 0.9 | 0.7 | 0.5 | 0.4 |
| Iron & Steel (combustion) | coal | tonne/ktonne | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.2 | 3.9 | 3.6 | 3.3 | 2.9 | 2.6 | 2.3 |
| Iron & Steel (combustion) | gas | tonne/million $m^3$ | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| $SO_2$ | | | | | | | | | | | | | | | | | | |
| Electricity Generation | lignite | tonne/ktonne | 35 | 32 | 31 | 31 | 30 | 28 | 27 | 25 | 24 | 21 | 18 | 16 | 14 | 12 | 10 | 9 |
| Electricity Generation | coal | tonne/ktonne | 0.8 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 |
| Electricity Generation | gas | tonne/million $m^3$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Iron & Steel (combustion) | lignite | tonne/ktonne | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 40 | 34 | 28 | 22 | 16 | 11 | 5 |
| Iron & Steel (combustion) | coal | tonne/ktonne | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 26 | 22 | 18 | 15 | 11 | 7 | 3 |
| Iron & Steel (combustion) | gas | tonne/million $m^3$ | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| NMVOC | | | | | | | | | | | | | | | | | | |
| Residential Combustion | wood | tonne/ktonne | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| Residential Solvent Use | solvent use | kg/person | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 |
| Solvent Based Paint | paint | kg/person | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| $NH_3$ | | | | | | | | | | | | | | | | | | |
| Dairy Cattle | | kg/head | 28 | 29 | 29 | 30 | 30 | 31 | 31 | 32 | 32 | 32 | 33 | 33 | 34 | 34 | 35 | 36 |
| Chickens (Layers) | | kg/head | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Chickens (Broilers) | | kg/head | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Synthetic Fertiliser Use | | kg/kg N applied | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

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