# IIASA-Toyota Research Agreement
# April 2010 – March 2011
# Phase III

## FINAL REPORT

*Authors:*
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*Submitted to:*
Toyota Motor Corporation

IIASA Contract N$^o$ 10-129

1 March 2011

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# Contents

## Acknowledgements

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# 1. Introduction

This Final Report documents work at IIASA in the third period of the Toyota Ozone Project (TOP), i.e., April 2010 to March 2011. Main activities in this period included five tasks. In brief, the tasks were (the numbers refer to the task numbers as stated in the work plan for the whole third period):

1 Enable access to the scenarios in the GAINS model developed during the first two periods of the TOP project;
2 Develop projections of reduction potential of ozone precursor emissions for the Asian countries;
3 Host and support the work of the student from Tsinghua University (China) on development of new energy scenario for China until 2030;
4 Provided timely availability of new energy scenarios for China and India, perform ozone optimization for these countries;
5 Development of the shape files for the GAINS domain, including regional population data.

The following milestones were envisaged for the period April 2010 to September 2010:

- Access to the scenarios in the GAINS model,
- Development of the shape files for the modeling domain (consistent with GAINS regions),
- Support of the Tsinghua University student stay at IIASA, and
- Interim Report (September 2010),
- Development and implementation in GAINS of the maximum feasible reduction strategies,
- Implementation of the new energy projections for China and India (provided they are timely developed and provided by the national teams),
- Ozone calculations for China and India, and
- Final report (March 2011).

The envisaged milestones have been achieved to the extent it was possible considering the availability of data on new energy scenarios which have been developed in collaboration with Tsinghua. A comparable dataset for India has not been developed yet. The following sections summarize the achievements within the envisaged tasks.

Additionally, a meeting between Toyota Research and project partners in China, India, and IIASA has been held at IIASA on January 19th 2011 (http://gains.iiasa.ac.at/index.php/other/past-meetings/353-top4-documents). The meeting was co-organized by Toyota Research and IIASA. To enable a wider participation of the Toyota Research leadership and further team members, a parallel video conference and simultaneous English-Japanese translation was supported during the meeting.

## 2. On-line GAINS access

Prior to the TOP project, the GAINS model development for Asia was centred around the module for China and India where we had worked on dedicated projects with local partners under EU and IIASA funding. Consequently the on-line access was restricted to these countries and respective baseline scenarios developed within those activities. The data for other countries were scattered in other GAINS modules not easily accessible. In the last months, we have reorganized the database and moved all the respective data for the remaining Asian countries, included in the TOP study, into the GAINS-*China* and GAINS-*South Asia* modules. The modules can be accessed via the following links (registration required):

GAINS-*China* – http://gains.iiasa.ac.at/gains/EAS/index.login

GAINS-*South Asia* – http://gains.iiasa.ac.at/gains/IND/index.login

The GAINS-*China* module includes China, Japan, South Korea, Democratic People's Republic of Korea, ROC Taiwan, and Mongolia. The GAINS-*South Asia* module includes India and all other Asian countries not included in the GAINS-*China*.

The scenarios devised for use in this project are grouped in the 'TOP' scenario group that can be accessed in each of the modules by selecting it in the respective 'Scenario' GAINS menu. This group contains three scenarios in the *South Asia* module and four in the *China* module. The scenarios have been developed for a number of pollutants including required ozone precursors ($NO_x$, NMVOC) but are also additionally available for methane ($CH_4$) and carbon monoxide (CO).

There are two common scenarios, available in both the GAINS *China* and *South Asia* models, that were specifically developed within the TOP project:

**TOP_0909**

This scenario was developed in September 2009 after the conference call where modification of emission factors for residential combustion sector was agreed. For that purpose, a new 'Asia09' emission set (emission vector) has been developed and used in this calculation. The energy activity data is based on the GAINS implementation of the International Energy Agency World Energy Outlook 2009 projections [*IEA*, 2009]. The agriculture data is based on the IIASA internal projection for China [*Ermolieva T et al.*, 2009] and FAO work for other countries [*Bruinsma*, 2003]. Control strategies rely on the results of the GAINS-*China* project, work within the Annex I activities for Annex I countries and GAINS-Asia work plus recent updates for the remaining countries. For NMVOC only a selection of countries has estimates of emissions from solvent use operations; as reported in the interim report of April 2010.

**TOP_0710**

This is an update of the TOP_0909 scenario introducing changes in the emission vector and activity data sets during the work on the UNEP and WMO *Integrated Assessment of Black Carbon and Troposheric Ozone* (http://www.unep.org/dewa/Portals/67/pdf/Black_Carbon.pdf). The emission factor set is based on the V0_UNEP set 'July2010' which includes previously developed 'Asia09' as well as further modifications introduced in 2010. Control strategies make use of the latest information on penetration of measures as done for the IEA project [*IEA*, 2009] as well as development of strategies for the RCP (Regional Concentration Pathways) process [*Lamarque et al.*, 2010], i.e., development of scenarios for use in the IPCC AR5 (IPCC Fifth Assessment Report). For NMVOC only a selection of countries has estimates of emissions from solvent use operations; as done previously and reported in the interim report of April 2010.

Beyond the above scenarios, each module contains in the TOP group also the GAINS-*Asia* project baseline which is using the national data from the period 2008 and 2009 and was developed for China and then India and Pakistan and not for other countries. In case of GAINS-*China* module the baseline has been updated in May 2009 and is called '**Baseline09**'(see more detailed description of the changes compared to the 'Baseline08' in the model), while for *South Asia* it is called '**Baseline08**'. Assumptions and results for both baselines have been documented in the journal article [*Klimont et al.*, 2009]. Finally, the initial assessment of the further mitigation potential for 2020 and 2030 is presented in the maximum feasible reduction scenario that is currently based on the 0710 baseline, i.e., **TOP_0710_MFR** (see next section for brief discussion of this scenario).

The TOP group in the GAINS-*China* module contains also results of the work on the development of new energy and control scenarios for China done in collaboration with Tsinghua University. Currently it comprises four scenarios; see section 4 of this document for more details.

# 3. Assessment of the further reduction potential in the baseline scenarios

It was envisaged for this phase of the project that IIASA develops an initial assessment of the further reduction potential beyond the current legislation. IIASA has developed region-specific potentials and implemented them in the dedicated scenario (TOP_0710_MFR) that can be already viewed in the on-line application of the model. Since the new baseline and policy scenarios for China have been completed only recently (see section 4 for a detailed discussion) we have not evaluated these draft maxium reduction potentials against the new strategies for China. Consequently, the current implementation includes only the previous baseline (0710).

Figure 3.1 provides an illustration of resulting reduction potential for NOx emissions in China by 2020, i.e, more than 50% cut in comparison to the TOP_0710 baseline which is significantly stronger cut than that achieved in the 'Policy11_TS_ls' case (see Figure 4.3). The largest reductions are expected in power plants and industrial boilers where current legislation does not foresee yet SCR installation. Also transportation has some remaining potential via accelerated introduction of more stringent policies. In the next step such MFR scenario will be tested for the new scenarios for China and also other countries.

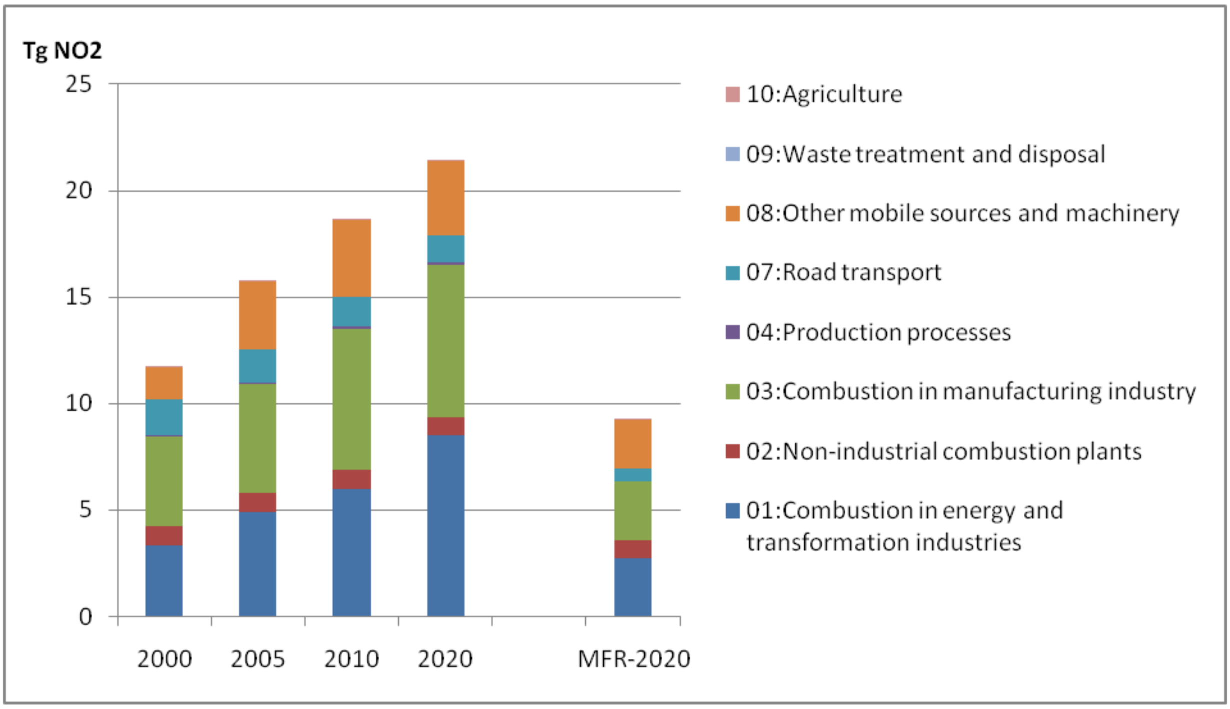


Figure 3.1. Emissions of NOx in China in the baseline scenario (TOP_0710) and in the MFR case for 2020 (TOP_0710_MFR).

# 4. Development of new scenarios for China

IIASA has hosted and supported the work of students from Tsinghua University (China) on the development of a new energy scenarios for China until 2030. The first visit took place in the summer 2010 and was concluded with a workshop held at IIASA on 6–7 September 2010 where Bin Zhao from Tsinghua presented the progress in development of the scenario. The extensive discussion took place among the participants from Tsinghua University (Jiming. Hao, Shuxiao Wang, Bin Zhao) and IIASA (Markus Amann, Janusz Cofala, Zbigniew Klimont) deciding on further steps in order to complete the required modelling work and final implementation in the GAINS model. Bin Zhao returned to IIASA in January 2011 to complete the implementation of the baseline and policy scenario. He achieved that by mid February 2011. Slightly later than originally envisaged, implementation of scenarios left little time (within this phase of the TOP project) to verify some of the assumptions and implementation (see also further discussion in this section) as well as to implement the ozone optimization. The work on the development of the scenarios have proven to be more challenging but resulted in two very interesting scenarios that have been already made available to the TOP project participants via the on-line GAINS model application; see the 'TOP' scenario group, i.e., **Baseline11_TS_ls, Policy11_TS_ls** as well as **Baseline11_TS_st, Policy11_TS_st**. The latter two scenarios are the most recent addition and include the same energy development and emission factors as the '_ls' set but assume more stringent implementation '_st' of emission regulation. Further discussion and analysis in this report considers only the '_ls' scenarios as there was no time yet to make evaluation of the '_st' dataset; an activity we pursue now.

The following key elements have been reviewed and updated in the new scenarios:

- activity data and projection (energy and industrial production)
- control strategies
- structure of the energy use and technology split in the domestic and transport sector
- emission vector.

## 4.1. Energy demand for the new scenarios and comparison with previous assumptions

Tables 4.1 and 4.2 present energy demand by fuel and sector for the newly developed energy scenarios (Baseline and Policy). In the Baseline scenario (Baseline11_TS_ls) the total fuel demand increases between 2005 and 2020 by more than 90 percent. Demand for coal increases by 76 percent. Nuclear and renewables (except traditional biomass) belong to the fastest growing energy sources. Their use increases by about a factor of five. Demand for oil, gas and hydropower increases by about 150 %. The share of coal in total fuel demand decreases from 62 percent in 2005 to 57 percent in

2020. Demand for traditional biomass decreases, which causes that its share in total fuel supply decreases from about 10 percents in 2005 to only five percent in 2020.

Table 4.1. Energy demand by fuel type and sector, Baseline11_TS_ls scenario, PJ

Year: 2005

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 22587 | 650 | 610 | 587 | 90 | 1548 | 9 | 26082 |
| Industry | 18974 | 4842 | 4533 | 0 | 0 | 0 | 0 | 28350 |
| Road transport | 0 | 4017 | 20 | 0 | 0 | 0 | 0 | 4037 |
| Other transport | 0 | 2609 | 0 | 0 | 0 | 0 | 0 | 2609 |
| Residential and other | 5896 | 930 | 840 | 0 | 7482 | 0 | 263 | 15411 |
| Total | 47457 | 13048 | 6004 | 587 | 7572 | 1548 | 273 | 76489 |

Year: 2010

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 30659 | 314 | 983 | 763 | 192 | 2568 | 146 | 35625 |
| Industry | 27824 | 6045 | 8354 | 0 | 0 | 0 | 0 | 42223 |
| Road transport | 0 | 6933 | 55 | 0 | 0 | 0 | 0 | 6988 |
| Other transport | 0 | 3355 | 0 | 0 | 0 | 0 | 0 | 3355 |
| Residential and other | 6903 | 1067 | 1454 | 0 | 7724 | 0 | 511 | 17660 |
| Total | 65387 | 17714 | 10846 | 763 | 7917 | 2568 | 657 | 105851 |

Year: 2015

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 35938 | 265 | 1268 | 1908 | 498 | 3119 | 190 | 43187 |
| Industry | 30056 | 7288 | 9377 | 0 | 0 | 0 | 0 | 46721 |
| Road transport | 0 | 11513 | 125 | 0 | 0 | 0 | 0 | 11638 |
| Other transport | 0 | 3705 | 0 | 0 | 0 | 0 | 0 | 3705 |
| Residential and other | 7403 | 1079 | 2139 | 0 | 7184 | 0 | 778 | 18583 |
| Total | 73397 | 23850 | 12909 | 1908 | 7682 | 3119 | 968 | 123834 |

Year: 2020

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 43984 | 183 | 1655 | 3053 | 773 | 3669 | 237 | 53554 |
| Industry | 31546 | 8448 | 10242 | 0 | 0 | 0 | 0 | 50236 |
| Road transport | 0 | 18268 | 274 | 0 | 0 | 0 | 0 | 18541 |
| Other transport | 0 | 3986 | 0 | 0 | 0 | 0 | 0 | 3986 |
| Residential and other | 7990 | 1088 | 3053 | 0 | 6550 | 0 | 1044 | 19726 |
| Total | 83520 | 31973 | 15224 | 3053 | 7323 | 3669 | 1281 | 146043 |

The policy scenario brings an important decrease in total energy demand. In 2020 the difference compared with the Baseline is 23 EJ, which corresponds to more that 550 million TOE. Demand for coal decreases by 18 EJ. Also demand for oil, gas and traditional biomass is lower. In turn, the policy scenario assumes faster growth of nuclear and hydro power, as well as higher contribution of modern renewable energy sources (solar, wind).

Table 4.2. Energy demand by fuel type and sector, Policy11_TS_ls scenario, PJ

Year: 2005

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 22587 | 650 | 610 | 587 | 90 | 1548 | 9 | 26082 |
| Industry | 18970 | 4842 | 4533 | 0 | 0 | 0 | 0 | 28346 |
| Road transport | 0 | 4017 | 20 | 0 | 0 | 0 | 0 | 4037 |
| Other transport | 0 | 2609 | 0 | 0 | 0 | 0 | 0 | 2609 |
| Residential and other | 5896 | 930 | 840 | 0 | 7482 | 0 | 263 | 15411 |
| Total | 47453 | 13048 | 6004 | 587 | 7572 | 1548 | 273 | 76485 |

Year: 2010

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 30388 | 311 | 977 | 763 | 152 | 2568 | 146 | 35305 |
| Industry | 27260 | 5970 | 8271 | 0 | 0 | 0 | 0 | 41500 |
| Road transport | 0 | 6835 | 56 | 0 | 0 | 0 | 0 | 6890 |
| Other transport | 0 | 3355 | 0 | 0 | 0 | 0 | 0 | 3355 |
| Residential and other | 6831 | 1008 | 1365 | 0 | 7657 | 0 | 511 | 17372 |
| Total | 64478 | 17479 | 10668 | 763 | 7810 | 2568 | 657 | 104423 |

Year: 2015

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 31809 | 184 | 1453 | 2671 | 702 | 3241 | 319 | 40378 |
| Industry | 26592 | 6691 | 8780 | 0 | 0 | 0 | 0 | 42063 |
| Road transport | 0 | 10956 | 134 | 0 | 0 | 0 | 0 | 11090 |
| Other transport | 0 | 3264 | 0 | 0 | 0 | 0 | 0 | 3264 |
| Residential and other | 6365 | 1011 | 2215 | 0 | 6021 | 0 | 866 | 16479 |
| Total | 64767 | 22105 | 12582 | 2671 | 6723 | 3241 | 1185 | 113274 |

Year: 2020

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 34882 | 1 | 1673 | 4579 | 1159 | 3914 | 499 | 46708 |
| Industry | 24786 | 7253 | 9142 | 0 | 0 | 0 | 0 | 41181 |
| Road transport | 0 | 15532 | 293 | 0 | 0 | 0 | 0 | 15825 |
| Other transport | 0 | 3512 | 0 | 0 | 0 | 0 | 0 | 3512 |
| Residential and other | 5653 | 971 | 3160 | 0 | 4600 | 0 | 1221 | 15605 |
| Total | 65321 | 27269 | 14268 | 4579 | 5759 | 3914 | 1720 | 122830 |

For comparison, Table 4.3 demonstrates energy demand in the same format for the scenario TOP_0710, which was used for China in the last year's report. The TOP_0710 scenario was based on data prepared in 2007 by the Chinese Energy Research Institute. Growth of energy consumption up to 2020 in the "old" scenario is lower than in the recent Baseline scenario. There are also important differences in the assessment for 2005 and 2010. For 2005 the current estimate of total demand is seven percent higher than the previous one. Demand for coal differs by four percent. A high difference in the demand for gaseous fuels is probably due to different treatment of derived gases (coke oven and blast furnace gas) in the two scenarios. More in-depth analysis is needed to explain these differences. The Baseline increase in energy demand in the period 2005–2010 is consistent with the data from the IEA World Energy Outlook 2010. It was much faster than forecasted in the TOP_0710 scenario used in the last year's report. Changes in fuel demand over time are illustrated in Figure 4.1. Main reasons for differences were:

- higher economic growth than anticipated in the 2007 projection,
- lower effects of energy efficiency improvement in industry.
- faster growth of energy demand in transport and in the residential and commercial sectors due to increasing car ownership and rising incomes of Chinese population.

Table 4.3. Energy demand by fuel type and sector, TOP_0710 scenario, PJ

Year: 2005

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 25066 | 752 | 540 | 579 | 54 | 1046 | 390 | 28428 |
| Industry | 17751 | 5620 | 604 | 0 | 0 | 0 | 0 | 23975 |
| Road transport | 0 | 3255 | 51 | 0 | 0 | 0 | 0 | 3306 |
| Other transport | 0 | 3547 | 0 | 0 | 0 | 0 | 0 | 3547 |
| Residential and other | 2821 | 792 | 529 | 0 | 8126 | 0 | 115 | 12384 |
| Total | 45638 | 13966 | 1723 | 579 | 8180 | 1046 | 506 | 71639 |

Year: 2010

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 34820 | 582 | 813 | 710 | 81 | 1543 | 825 | 39375 |
| Industry | 20744 | 6829 | 1036 | 0 | 32 | 0 | 0 | 28642 |
| Road transport | 0 | 4325 | 61 | 0 | 0 | 0 | 0 | 4387 |
| Other transport | 0 | 4409 | 0 | 0 | 0 | 0 | 0 | 4409 |
| Residential and other | 2740 | 825 | 906 | 0 | 7982 | 0 | 224 | 12677 |
| Total | 58304 | 16971 | 2817 | 710 | 8095 | 1543 | 1049 | 89489 |

Year: 2015

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 46668 | 564 | 1495 | 2473 | 144 | 1895 | 1121 | 54360 |
| Industry | 25835 | 8951 | 1447 | 0 | 65 | 0 | 0 | 36299 |
| Road transport | 0 | 7121 | 88 | 0 | 0 | 0 | 0 | 7209 |
| Other transport | 0 | 5727 | 0 | 0 | 0 | 0 | 0 | 5727 |
| Residential and other | 3001 | 1255 | 1350 | 0 | 7602 | 0 | 307 | 13514 |
| Total | 75504 | 23617 | 4380 | 2473 | 7811 | 1895 | 1427 | 117108 |

Year: 2020

| Sector/fuel | Coal | Oil | Gas | Nuclear | Biomass | Hydro | Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| Power plants | 53193 | 522 | 1888 | 3515 | 270 | 2187 | 1532 | 63106 |
| Industry | 27172 | 9611 | 1712 | 0 | 188 | 0 | 0 | 38683 |
| Road transport | 0 | 8921 | 113 | 0 | 0 | 0 | 0 | 9034 |
| Other transport | 0 | 6473 | 0 | 0 | 0 | 0 | 0 | 6473 |
| Residential and other | 2985 | 1611 | 1775 | 0 | 7087 | 0 | 410 | 13868 |
| Total | 83350 | 27138 | 5488 | 3515 | 7545 | 2187 | 1942 | 131164 |

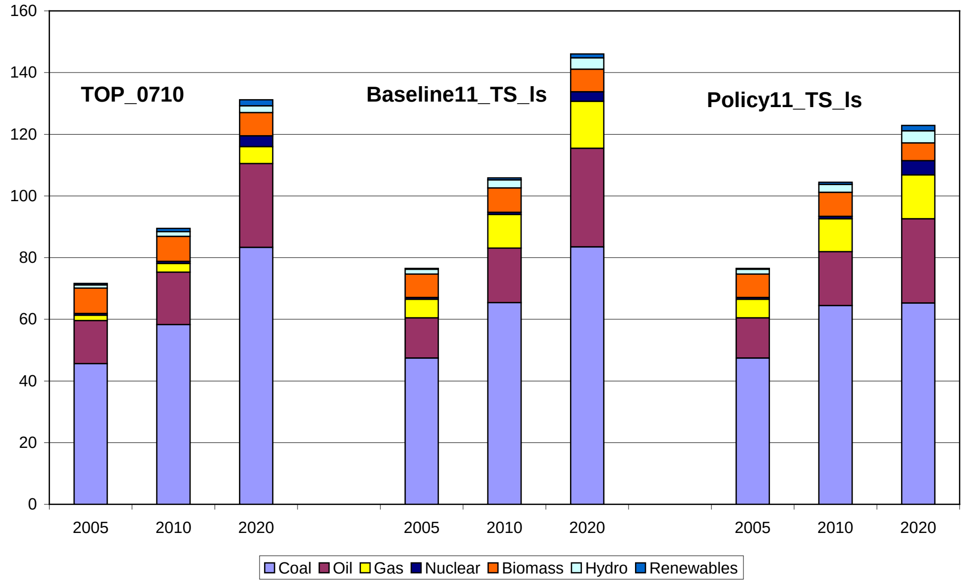


Figure 4.1. Energy demand by fuel type and scenario, 2005 – 2020, PJ

Figure 4.2 demonstrates changes in gross electricity generation between 2005 and 2020 in the three scenarios. Between 2005 and 2020 the electricity generation increases in the Baseline scenario from 2.6 TWh to 6.6 TWh. Policy scenario results in lowering the demand by 630 GWh.

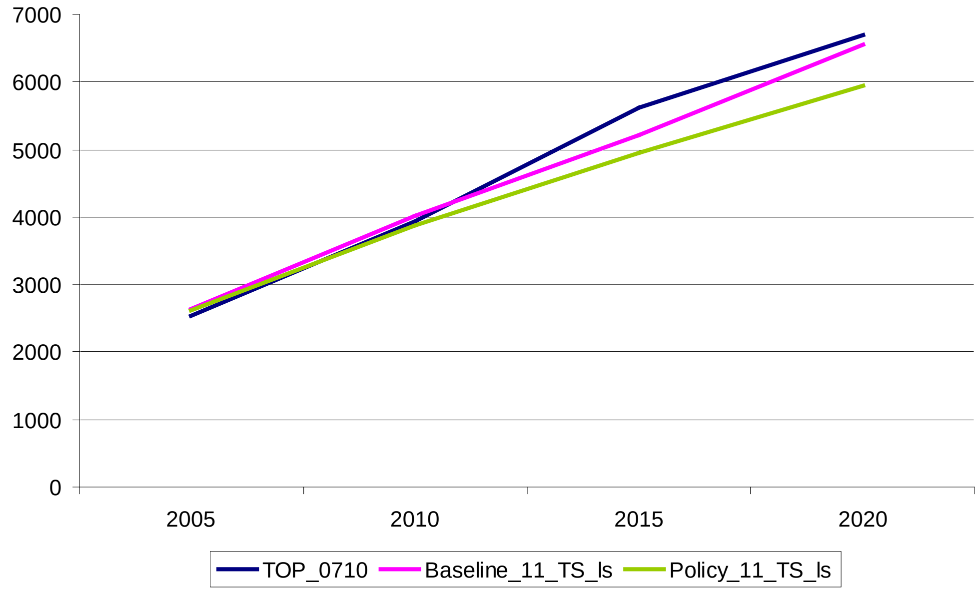


Figure 4.2. Gross electricity generation 2005 – 2020 by scenario, GWh

It needs to be stressed, that in the 2011 scenarios electricity production and demand are for some years inconsistent, which would imply relatively high net exports of electricity from China. In order to avoid this (rather unlikely) situation, generation numbers have been corrected. After this correction electricity production figures for historic years become comparable with values reported in the IEA statistics. This first order correction needs to be cross-checked in the course of further work.

## 4.2. Emissions of nitrogen oxides

Table 4.4 demonstrates development of emissions of nitrogen oxides for the 2011 scenarios by CORINAIR SNAP sectors and compares them with the emissions from the last year's assessment. Compared with 2005, the emissions increase from about 16 to 24 million tons, i.e., by 50 percent. The highest increase occurs in the industrial combustion sector, where the emissions rise by 80 percent. Further increase of $NO_x$ emissions in the baseline scenario clearly demonstrates the need for more stringent emission standards, in particular for power plant and industrial sources. Also legislation on mobile sources (both: road and non-road) needs to be strengthened.

Implementation of policies aiming at decreasing energy consumption and changing its structure bring substantial benefits in terms of lower emissions of $NO_x$. In 2020 the emissions become 4 million tons, or 16 percent lower compared with the Baseline. Figure 4.3 illustrates changes in $NO_x$ emissions by major sector and compares the current scenarios with the last year's assessment.

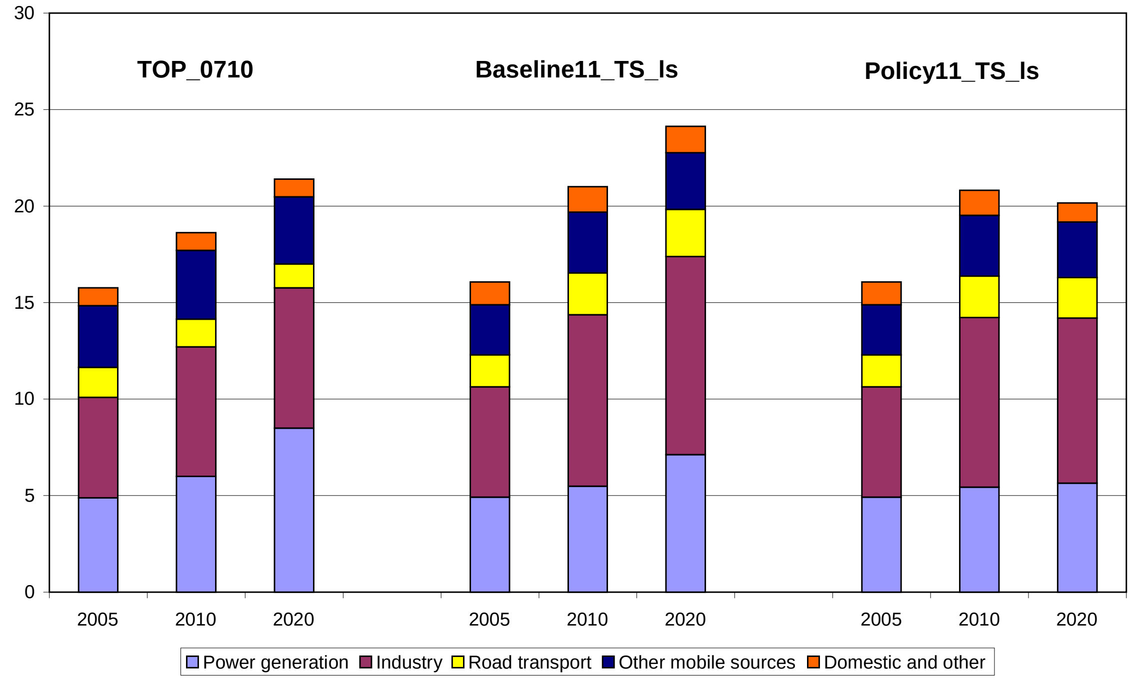


Figure 4.3. Emissions of $NO_x$ by major sector 2005 – 2020 by scenario, Gg $NO_2$

Table 4.4. $NO_x$ emissions aggregated by CORINAIR SNAP1 sector, Gg

**Scenario: TOP_0710**

| SNAP code | 2005 | 2010 | 2020 |
|---|---|---|---|
| 1: Power generation | 4,884 | 5,999 | 8,494 |
| 2: Domestic | 897 | 888 | 885 |
| 3: Industrial combust. | 5,137 | 6,622 | 7,151 |
| 4: Industrial processes | 71 | 89 | 120 |
| 7: Road transport | 1,549 | 1,439 | 1,230 |
| 8: Other mobile sources | 3,197 | 3,553 | 3,482 |
| 9: Waste management | 10 | 9 | 8 |
| 10: Agriculture | 26 | 25 | 25 |
| Sum | 15,770 | 18,624 | 21,396 |

**Scenario: Baseline11_TS_ls**

| SNAP code | 2005 | 2010 | 2020 |
|---|---|---|---|
| 1: Power generation | 4,921 | 5,486 | 7,118 |
| 2: Domestic | 1,149 | 1,280 | 1,332 |
| 3: Industrial combust. | 5,641 | 8,797 | 10,153 |
| 4: Industrial processes | 71 | 89 | 120 |
| 7: Road transport | 1,653 | 2,162 | 2,443 |
| 8: Other mobile sources | 2,597 | 3,151 | 2,925 |
| 9: Waste management | 10 | 9 | 8 |
| 10: Agriculture | 26 | 25 | 25 |
| Sum | 16,069 | 20,999 | 24,125 |

**Scenario: Policy11_TS_ls**

| SNAP code | 2005 | 2010 | 2020 |
|---|---|---|---|
| 1: Power generation | 4,921 | 5,443 | 5,649 |
| 2: Domestic | 1,149 | 1,265 | 950 |
| 3: Industrial combust. | 5,641 | 8,692 | 8,426 |
| 4: Industrial processes | 71 | 89 | 120 |
| 7: Road transport | 1,653 | 2,144 | 2,104 |
| 8: Other mobile sources | 2,597 | 3,151 | 2,877 |
| 9: Waste management | 10 | 9 | 8 |
| 10: Agriculture | 26 | 25 | 25 |
| Sum | 16,069 | 20,818 | 20,159 |

# 5. Preliminary assessment of ozone concentration and impacts in China and India

Making use of the previously developed baseline scenario (TOP_0710) and new projections for China (Baseline11_TS_ls and Policy11_TS_ls), we have calculated the ozone concentrations and two impact indicators: SOMO35 and premature deaths from ozone. The presented calculations consider emissions of $NO_x$ and NMVOC as estimated in the GAINS model for the currently implemented scenarios while not accounting for changes in methane and CO emissions, i.e., they are kept at the levels assumed in baseline in the TM5 model. Finally, the optimization runs for ozone have not been performed yet owing to the late completion of the new scenarios for China, i.e., the scenarios were eventually implemented in the GAINS model by mid-February 2011 and the verification has been continuing until now (see discussion in the previous section).

The Figure 5.1 shows ozone concentrations calculated in the GAINS model for the base year (2005; upper left corner) and projections for 2020 in three different scenarios. The baseline from mid 2010, based on the GAINS-*Asia* project work with modifications of emission factors performed under TOP project (TOP_0710) and the recently revised baseline developed in collaboration with Tsinghua (Baseline11_TS_ls) are comparable although show in some regions different distribution. This is even more evident in the SOMO35 maps (Figure 5.2) and finally in the scenario comparison chart (Figure 5.3) where the change in total (whole China) SOMO35 and premature death number is comparable while the changes at a level of single provinces are much more pronounced. In general , the SOMO35 and number of premature deaths, compared to 2005, grows from few to nearly 50% for Guizhou province in the 'Baseline11_TS_ls' scenario (the maximum change in the 'TOP_0710' was estimated also for Guizhou, as well as for Shanghai, Heilongjiang province, however at the level of 25-30% increase compared to the year 2005 (Figure 5.3). At the level of China the change for both baseline scenarios was estimated at about +20% (Figure 5.3).

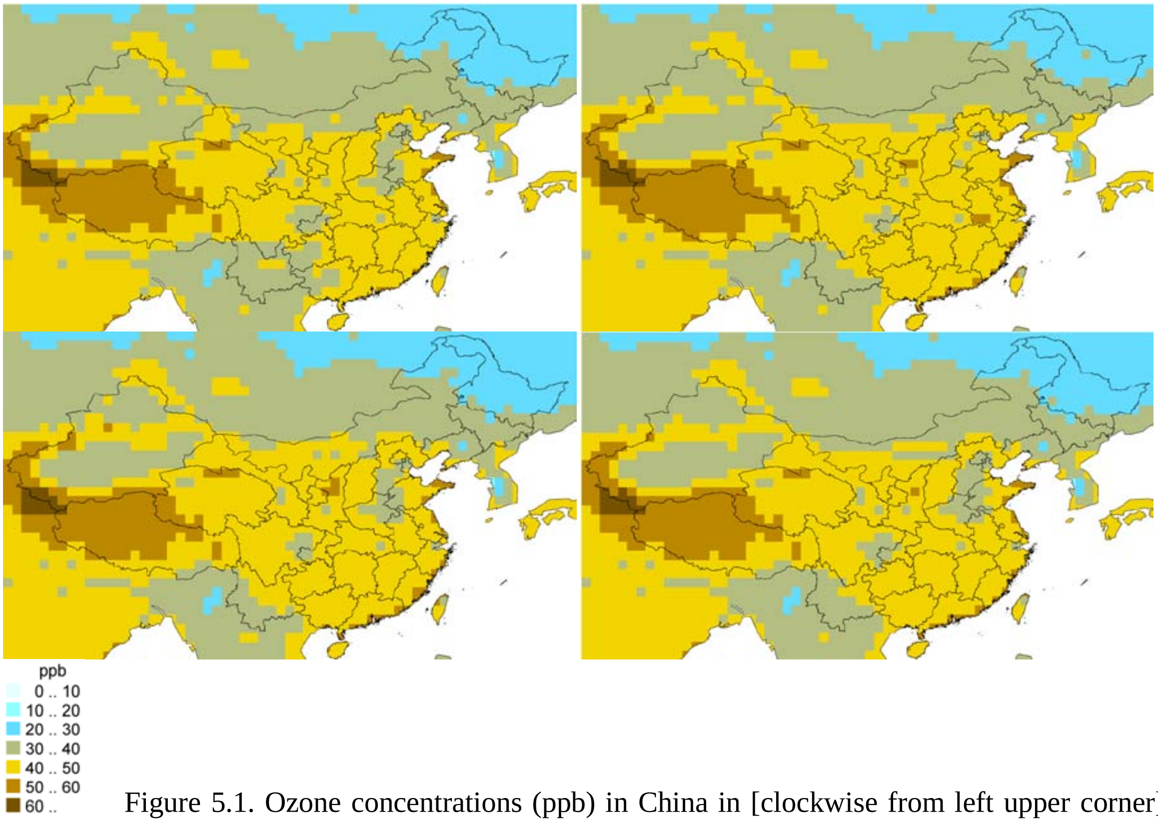


Figure 5.1. Ozone concentrations (ppb) in China in [clockwise from left upper corner] 2005, 2020 (TOP_0710), 2020 (Baseline11_TS_ls), and 2020 (Policy11_TS_ls).

The policy case ('Policy11_TS_ls') brings quite significant reductions in ozone indicators cutting them at the level of China by about half compared to the baseline scenarios for 2020 (Figure 5.3). Similar improvements are estimated also for single provinces although there is some variation in the extent of the reduction. This seems a bit surprising at first, bearing in mind the discussion in previous chapter which shown that the overall fuel consumption and NOx emissions are reduced in the policy case by not more than 20 percent. Obviously, location of the reductions matter and the policy efforts, as implemented in the current 'policy' scenario and associated control strategy in GAINS, concentrate on the areas with higher population density.

While there are some grids where ozone concentration drops in the policy case below the values calculated for 2005 (Figure 5.1) in none of the provinces the impact indicators in 2020 are below the levels in 2005 (Figure 5.3). In several provinces they are still 15–20% higher than in 2005.

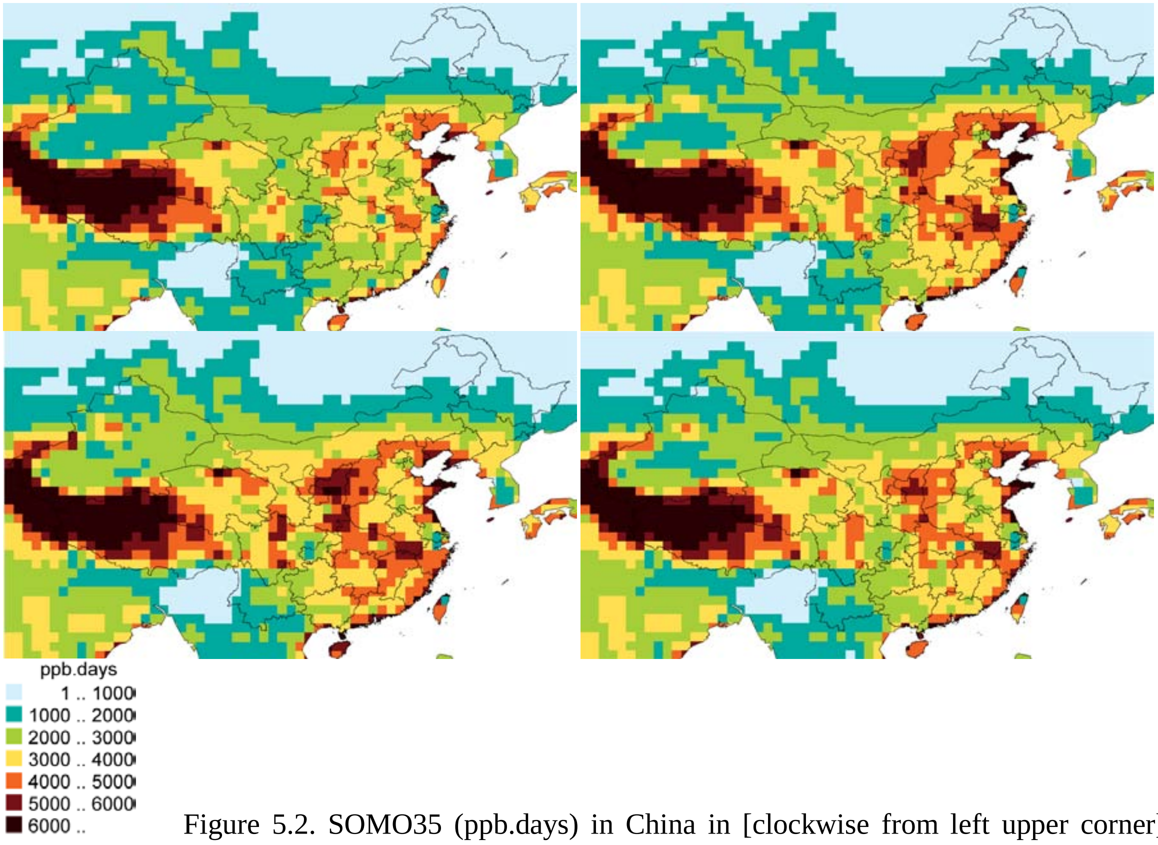


Figure 5.2. SOMO35 (ppb.days) in China in [clockwise from left upper corner] 2005, 2020 (TOP_0710), 2020 (Baseline11_TS_ls), and 2020 (Policy11_TS_ls).

As indicated in the earlier text (section 4), two additional variants of the new scenarios for China have been developed where more stringent implementation of emission regulation was included for both, the baseline (Baseline11_TS_st) and policy (Policy11_TS_st) energy scenarios. The scenarios are already available from the on-line application of the model but owing to only limited time from their implementation and lack of wider verification we refrain at this stage from analysis and comparison. It is envisaged to continue the analysis and dialog with Tsinghua to clarify some of the issues and further also compare all of the scenarios with the most recent World Energy Outlook scenarios.

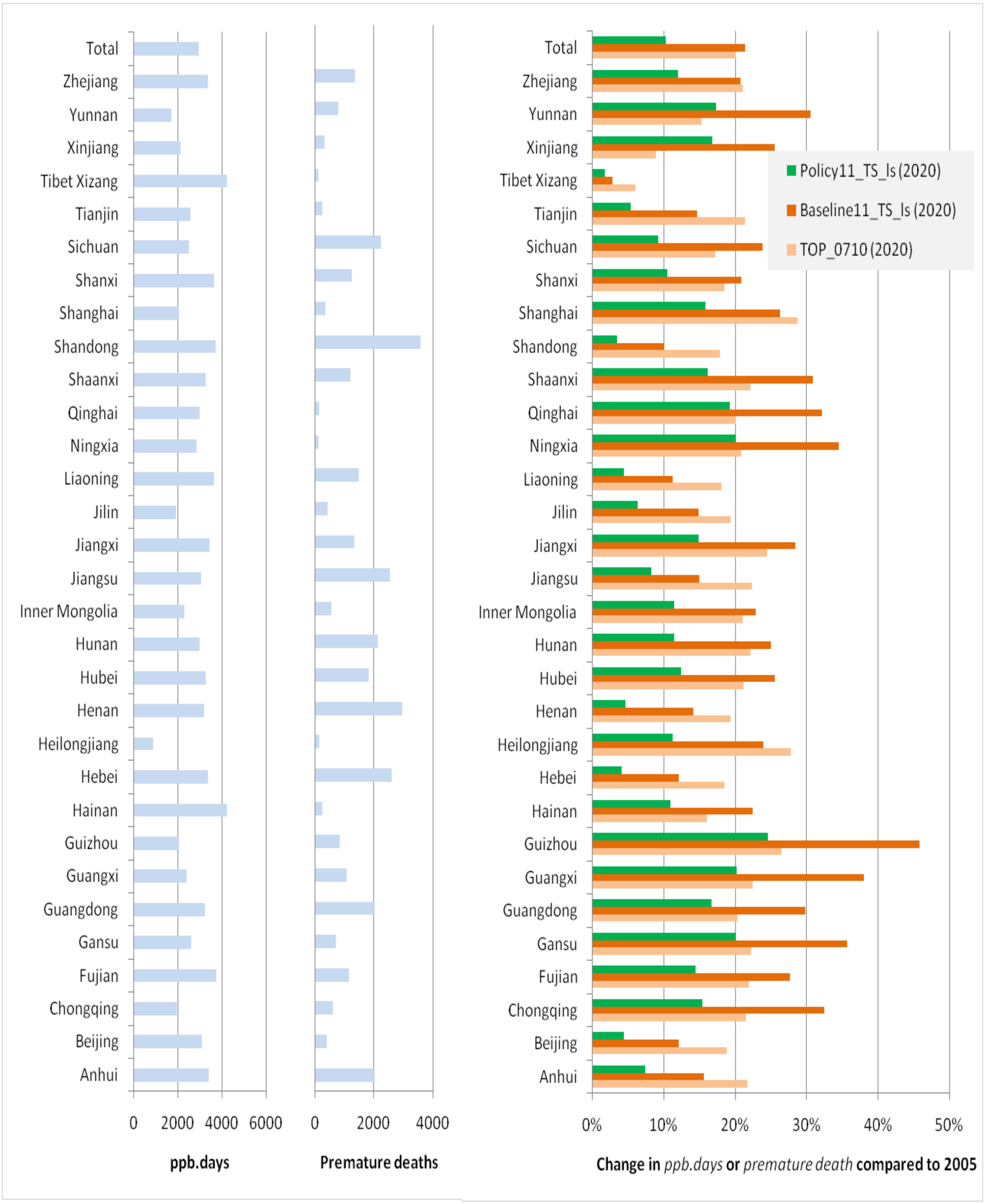


Figure 5.3. Assessment of SOMO35 and premature death from ozone for China in 2005 (two charts from the left) and the change in indicators in the projections for 2020 in the TOP scenarios (right).

The following figures show calculation for India. At this stage we had at our disposal only the TOP baseline scenario (TOP_0710) as the new national projections have not been developed yet. This baseline, drawing largely on the GAINS – *Asia* project energy projection shows significant increases in ozone concentrations across India (Figure 5.4), SOMO35 (Figure 5.5), and consequently the impact indicators for the whole country change (increase) by about 50 percent by 2020 compared to 2005, with some states exceeding 60 percent (Figure 5.6).

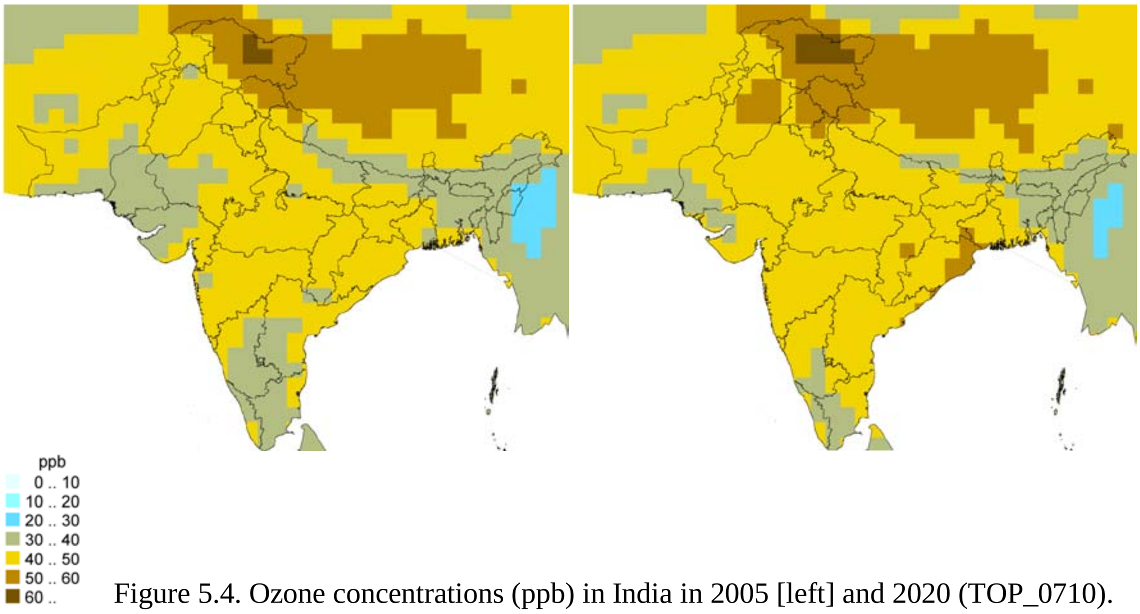


Figure 5.4. Ozone concentrations (ppb) in India in 2005 [left] and 2020 (TOP_0710).

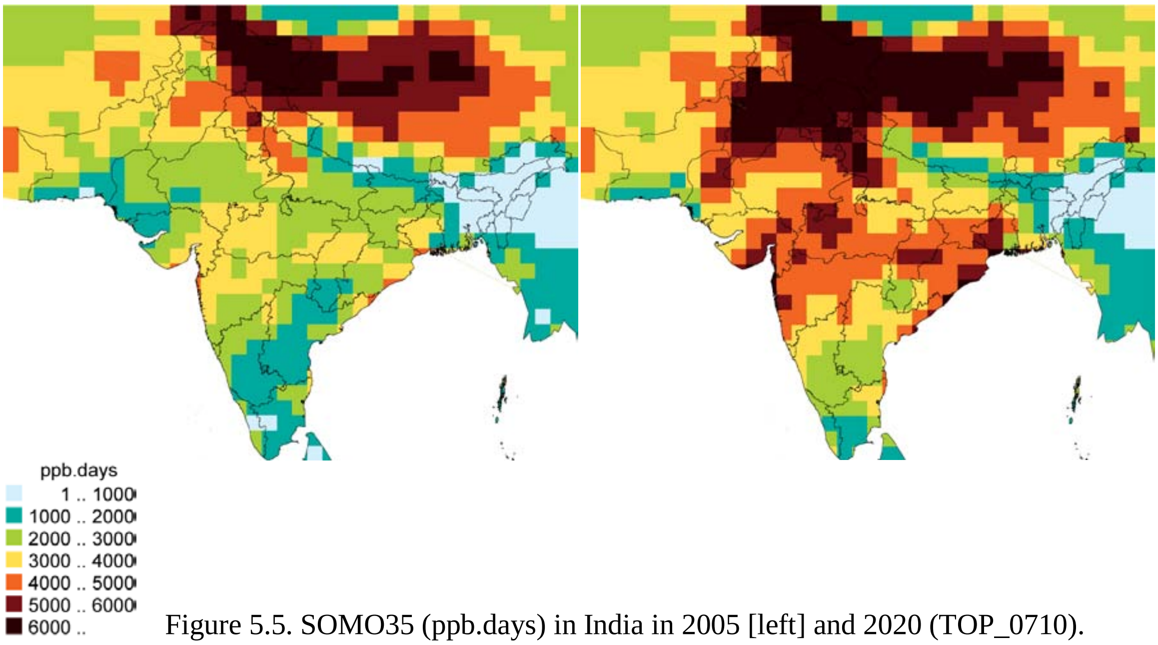


Figure 5.5. SOMO35 (ppb.days) in India in 2005 [left] and 2020 (TOP_0710).

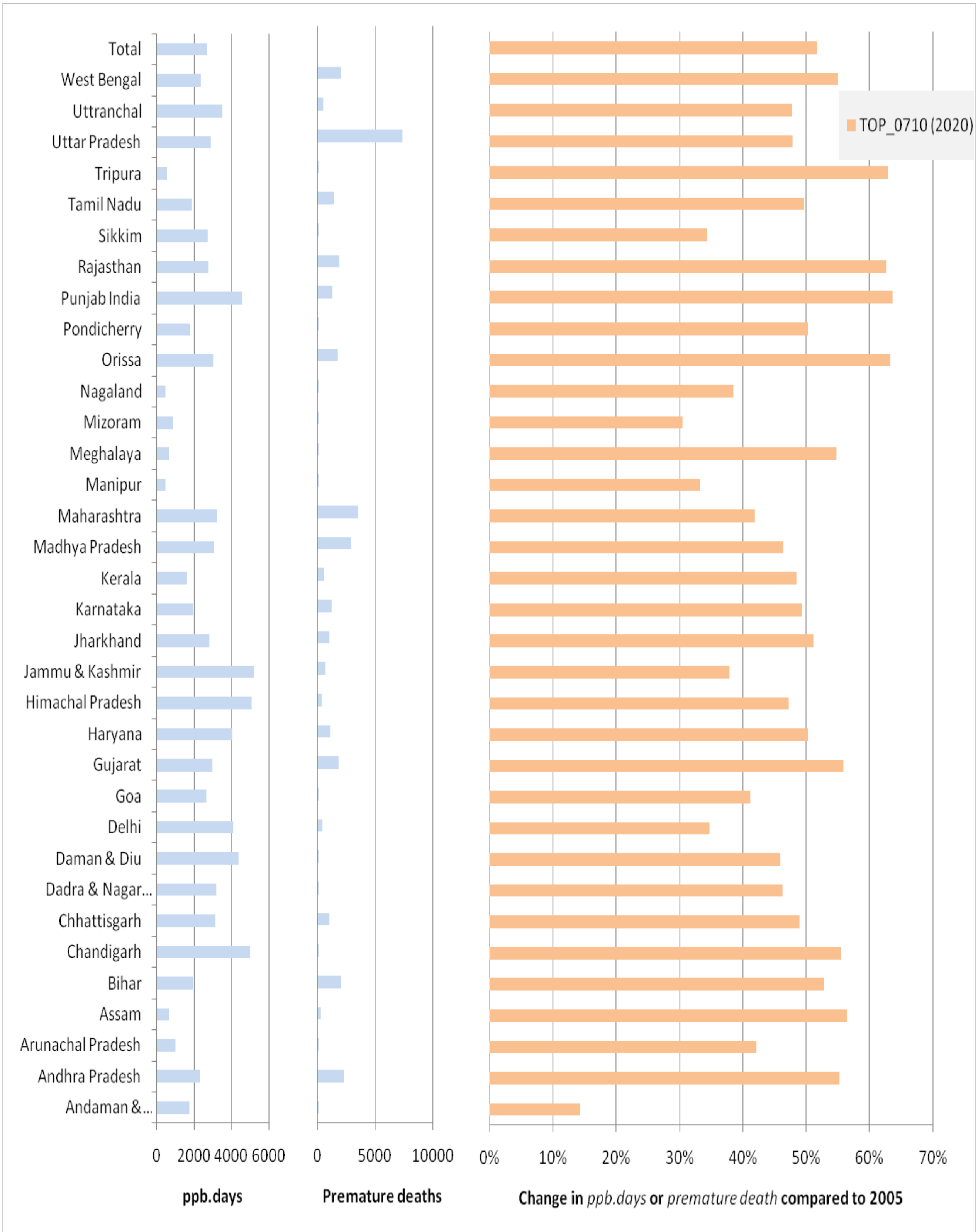


Figure 5.6. Assessment of SOMO35 and premature death from ozone for India in 2005 (two charts from the left) and a change in indicators in the projections for 2020 in the TOP (0710) scenario.

# 6. Supporting gridding activities

IIASA has prepared 'shape' files for the whole Asian domain, distinguishing specifically regions included in the GAINS model (Figure 6.1). Furthermore, associated population data was also submitted. The respective files have been made available from the IIASA ftp server and consequently acquired/downloaded by the Toyota partner.

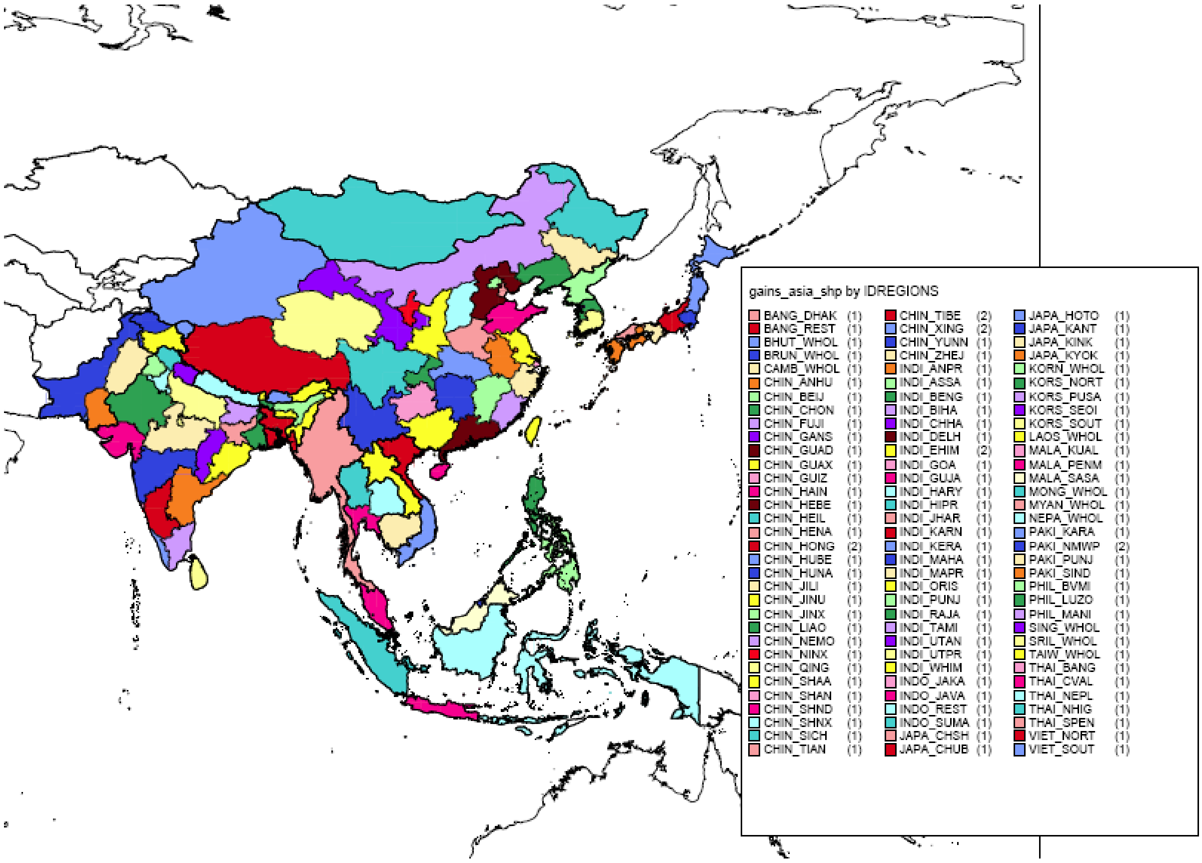


Figure 6.1. Regions included in the GAINS modelling domain in the GAINS-*China* and GAINS-*South Asia* modules.

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