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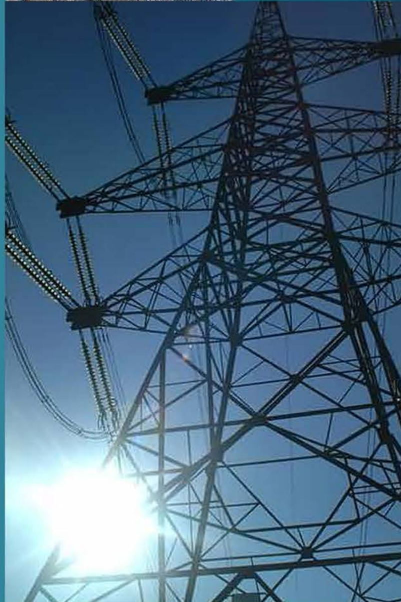

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Dear Reader,

The *"Euro-Asian Journal of Sustainable Energy Development Policy"* is the outcome of the established cooperation among scientists from Europe, Black Sea, Caspian Sea and Central Asia.

It is part of a growing cooperation in the frame of PROMITHEASnet activities. A network that includes members from sixteen countries and remains open to new participants, while its range of activities includes an Annual Scientific Conference, scientific awards, workshops, seminars and joint participation in EU financing research activities.

In addition the PROMITHEAS network disseminates relevant information through its newsletter, to more than 23,000 registered recipients from 170 countries all over the world.

In this context we do encourage scientific synergies and we invite colleagues to join us as authors, article-reviewers or even as partners in research projects.

Our continuous effort is the quality upgrade of the journal's content and to this aim we welcome your contribution.

The translations of abstracts to Russian language were carried out due to the kind contribution of Prof. Olga Efimova and Prof. Haji Melikov.

The editor

Prof. Dimitrios Mavrakis

Дорогой читатель,

“Евро-Азиатский журнал по политике развития устойчивой энергетики” является результатом состоявшего сотрудничества между учеными из Европы, регионов Черного моря, Каспийского моря и Центральной Азии.

Он является частью растущего сотрудничества в рамках деятельности сети PROMITHEAS; сеть, которая включает в себя членов из шестнадцати стран и остаётся доступной для новых участников, а также спектр её деятельности включает Ежегодную Научную Конференцию, научные награды, совещания по обмену опытом, семинары и совместное участие в научных исследованиях, финансируемых ЕС.

Кроме того, сеть PROMITHEAS распространяет существенную информацию через её информационного бюллетеня, более чем 23 000 зарегистрированным получателям из 170 стран по всему миру.

В связи с этим, мы также поддерживаем научное сотрудничество и приглашаем коллег присоединиться к нам в качестве авторов, обозревателей или даже в качестве партнёров в научно-исследовательских проектах.

Наши беспрерывные усилия направлены на повышение качества содержания журнала, и мы приветствуем Ваш вклад для обеспечения этой цели.

Переводы рефератов на русский язык были выполнены при любезной помощи профессора Ольги Ефимовой и профессора Хаджи Меликова.

Редактор

Проф. Димитриос Мавракис

Aim and scope

The PROMITHEAS scientific journal titled "***Euro-Asian Journal of Sustainable Energy Development Policy***" is a semi-annual bilingual (English, Russian) publication addressing policy issues on energy and climate change, mainly from the Black Sea, Caspian, Central Asia and S.E. Europe regions. The aim of the publication is to motivate and encourage the scientific and research human potential of these regions to present their research work in the aforementioned areas. Thus, it is expected that the regional scientific potential will be more easily identified and able to be contacted by regional and EU energy policy and environmental stakeholders. Efforts will be made so as the journal contains articles produced through joint efforts among researchers from the regions and the PROMITHEAS network participants.

The scientific journal will also host articles and executive summaries of scientific reports and studies presented during workshops, organized by the PROMITHEAS Network, regarding energy and climate policy issues. The contents of each issue will be determined by the editorial board.

Major articles will cover a comprehensive range of topics such as:

Energy supply and geopolitics;

Strategic energy planning;

Socio-economics of hydrocarbon reserves exploitation;

Energy interconnections;

Regional Energy Market development;

Emerging hydrogen technologies;

Socio-economics of transcontinental energy corridors;

Implementation of Kyoto Protocol mechanisms;

Analysis and implementation of climate policy instruments;

RTD policies and socio-economics for new forms of energy.

Цели и задания

Научный журнал сети PROMITHEAS под названием ***«Евро-Азиатский журнал по политике развития устойчивой энергетики»*** является полугодовой и двуязычной (английский, русский) публикацией, которая уделяет основное внимание вопросам политики в области энергетики и изменения климата, в основном для регионов Черного и Каспийского морей, Центральной Азии и Юго-Восточной Европы. Целью публикации является стимулирование и поддержка научно-исследовательского человеческого потенциала этих регионов чтобы представить свою исследовательскую работу в вышеперечисленных областях. Соответственно, ожидается, что региональный научный потенциал будет лучше идентифицироваться и связываться с региональными и ЕС участниками по энергетической политики и окружающей среды. Будут предприниматься усилия, чтобы в журнале включались научные статьи, написанные в результате совместного сотрудничества ученых из вышеперечисленных регионов и участников сети PROMITHEAS.

Научный журнал также будет размещать статьи и краткие содержания научных отчетов и исследований, представленных во время совещаний по обмену опытом, организуемых сетью PROMITHEAS, касающиеся энергетической и климатической политики. Содержание каждого выпуска будет определяться Редакционной коллегии.

Основные статьи будут покрывать следующие темы, охватывающие широкий круг вопросов:

- энергоснабжение и геополитика;
- стратегическое энергетическое планирование;
- социально-экономические аспекты использования углеводородных запасов;
- энергетические взаимосвязи;
- развитие регионального энергетического рынка;
- новосоздающиеся водородные технологии;
- социально-экономические аспекты трансконтинентальных энергетических коридоров;
- механизмы осуществления Киотского Протокола;
- анализ и внедрение инструментов климатической политики;
- политики научных технических исследований и социальноэкономические аспекты новых форм энергии.

Contents

Volume 5, Number 1

Germany's path towards a nearly climate-neutral residential building stock: A techno-economic comparison of greenhouse gas mitigation strategies

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Abstract

14% of the total national CO_2 emissions are caused by heating systems in the residential sector. To meet the overall CO_2 reduction target (-40% in 2020, -80% in 2050), the German Federal Government has set a target in its "Energiewende" concept for Germany's building stock to be nearly climate-neutral by 2050 focusing mainly on thermal insulation measures. It is unclear, however, whether this preferred option is the cost-effective strategy.

Different strategies for reducing energy demand and CO_2 emissions from residential building stock up to the year 2050 were investigated. These strategies comprise the Federal Government's energy concept measures, on the one hand, and alternative paths and options using more renewable gases and innovative heating systems, on the other.

The calculations are based on a dynamic simulation model that simulates the residential building stock in detail. The model simulates the effects of various energy-efficiency measures, such as thermal insulation and improvements to heating systems.

The results show that there are alternative strategies which can lead to a climate-neutral building stock. Alternative strategies focusing on an early replacement of heating systems, an increased use of renewable energy, and a forced use of innovative heating systems are cost-effective than strategies which mainly focus on thermal insulation measures. The sensitivity analyses show the robustness of our results.

Keywords

Building stock, thermal insulation, dynamic simulation model, CO_2 reduction, heating system, energy efficiency, renewable energy

1. Introduction

In order to limit global warming to less than 2°C, the EU has committed itself to reducing greenhouse gas emissions by 2020 by 20% compared to 1990 levels and as part of the plans for reducing emissions in industrialized countries to cutting them by 2050 by 80–95% compared to 1990 levels [EU-Rat, 2009]. Buildings are responsible for 40% of total energy consumption and 36% of CO_2 emissions in Europe [EU-COM, 2008]. Improving energy efficiency and an increased use of renewables are therefore decisive measures to ensure a decrease in the EU's dependence on energy imports, the use of fossil energy, and CO_2 emissions. Key parts of the European regulatory framework in this context are the Energy Performance of Buildings Directive (EPBD) [EPBD, 2002], and its recast [EPBD, 2010]. The recast EPBD established the obligation that all new buildings should be nearly zero-energy by the end of 2020.

These targets were confirmed in Germany by the German Federal Government's Energy Concept [Bundesregierung, 2010]. The German Federal Government aims to reduce emissions by 2020 by 40% and by 2050 by 80% compared to 1990 levels. The decision in favour of an accelerated nuclear power phase-out means that climate protection and energy efficiency in the buildings sector are becoming increasingly important [BMWi, 2011]. The private building stock is extremely important here, as it currently accounts for approx. 14% (124 million tonnes) of national CO_2 emissions and 23% (space heating and hot water) of final energy consumption in Germany [AGEB, 2013]. For the buildings sector, the aim is to achieve a climate-neutral building stock by 2050 by reducing the primary energy consumption of existing buildings by 80%. A key aspect here involves enhancing the energy efficiency of buildings by implementing additional thermal insulation measures. Such implementation will be promoted by regulatory measures (e.g. Energy Saving Ordinance) and diverse incentive programmes (e.g. KfW programme for energy-efficient construction and refurbishment). The new German Energy Saving Ordinance (EnEV 2014) came into force in 2014. Therefore, the standard for the construction of new buildings is being raised. From 2016, the maximum primary energy demand of a new building will be 25% lower than the level currently required under EnEV 2009. The amended EnEV 2014 provides for the introduction of a climate-neutral standard for new buildings by 2020 based on primary energy consumption rates [EnEV, 2013].

To achieve a climate-neutral standard for new buildings, different regulatory approaches have been adopted in the EU members states [Annunziata et al., 2013]. A comparison of the definition and introduction of this standard in EU member states can be found in [D'Agostino, 2015]. The cost-optimal design of nearly zero-energy buildings is investigated using simulation-based approaches in [Ferrara et al., 2014a, Ferrara et al., 2014b] for a single-family house in France and in [Pikas et al., 2014] for office buildings in Estonia. Starting with new buildings, this climate-neutral building standard will be implemented in Germany using individual renovation road maps that will begin in 2020 and be expanded to cover existing residential and non-residential buildings by 2050.

Many studies [EWI et al., 2014, EWI/gws/Prognos, 2010, Hoier & H., 2013, Kirchner et al., 2009, Matthes et al., 2013] that deal with reducing CO_2 in the buildings sector in Germany focus solely on the efficiency strategy favoured by the Federal Government. In [McKenna et al., 2013], a bottom-up model is used to analyse the importance of improving the energy efficiency of buildings to achieve the ambitious targets in Germany. Only through intensified policy measures that include the renovation of single-family houses will it be possible to meet the Federal Government's targets. A cost analysis is performed only in a few cases here [Pikas et al., 2015].

This paper investigates alternative strategies and scenarios that could help Germany to achieve its goal of climate-neutral residential building stock. The effects of forced thermal insulation versus the increased use of innovative heating systems and renewables are examined. The impacts are analysed using the dynamic bottom-up model JEMS-BTS[1], which details the German residential building stock

[1] JEMS-BTS = Jülich Energy Modeling Suite - Building Stock and Technology Simulation Model for Space Heating and Hot Water Supply

and installed heating systems using a regionalized approach. It also allows an extrapolation by incorporating re-investment cycles. Scenarios are compared based on primary energy consumption and CO_2 emissions. Costs are compared using the actual cash value of each strategy.

The first section describes the modelling approach used. This is followed by a description of the scenarios with the most important assumptions. Finally, the model-based results are compared by outlining and discussing the potential for increasing efficiency and for decreasing CO_2 emissions as well as costs.

2. Methodology

In order to quantify the potential of efficiency to produce space heat and hot water with higher efficiency, building stock models are used in most cases. For the scenario analysis, the model JEMS-BTS has a particularly high importance. It is a physical bottom-up approach to simulating energy consumption in residential buildings [Foucquier et al., 2013, Kavgic et al., 2010, Rysanek & Choudhary, 2013]. Building stock characteristics must be known in order to estimate the impact of energy-efficiency measures on the stock. To efficiently model the energy consumption of building stock, in a methodological approach similar to that in [Mata et al., 2014], a building stock simulation model was developed for Germany [Hansen, 2011, Hansen et al., 2014, Markewitz et al., 2012]. Using the bottom-up modelling approach in [Asadi et al., 2012], the dynamic simulation model JEMS-BTS extrapolates energy consumption based on the type of building, construction year, climate region, and energy carriers used to the regional and national levels and combines statistical calculation methods with technical and physical calculation methods. For the simulations, an extensive, regionalized building stock database was integrated into the model. It models the residential building stock in Germany based on typologized residential building types, sizes, and age classes including heating and hot water systems as well as corresponding energy conditions. Analyses in [Engvall et al., 2014, Gonçalves et al., 2013] show that energy consumption for heating depends significantly on the age of the building, type of building, and ventilation as well as on the age of the installed heating system. JEMS-BTS can be used to aggregate measures for single buildings in chronological sequence on the stock`s level. The modelling approach described in [Asadi et al., 2012, Ma et al., 2012] enables the simulation of all potential combinations of technical measures concerning the thermal insulation of the building envelope and improvements to heating systems. The development of buildings’ energy requirements over time and the projection of technical options are simulated in the form of scenarios.

The potential for energy efficiency improvement is modelled for each building type using a probabilistic approach for the renovation timing (Weibull-distribution). This methodological approach allows the simulated ageing processes to be used to determine the renovation frequency for each building component. By setting a rate of energy efficiency improvement, the potential for saving energy and reducing CO_2 can be determined for each building type and projected onto the building stock. This approach is expanded to include the calculation of cost-related impacts and the determination of strategy costs [Krause et al., 2011, Markewitz et al., 2012].

In determining the potential for energy savings, the impacts of rebound and prebound effects, which cannot be neglected in an assessment of efficiency potential [Bourrelle, 2014, Hens et al., 2010, Madlener & Alcott, 2009, Sunikka-Blank & Galvin, 2012], must also be considered. The reasons listed by the authors are that efficiency improvement may eventually stimulate energy consumption [Achtnicht & Koesler, 2014] (rebound) and the fact that [Galvin & Sunikka-Blank, 2013] non-insulated houses have a lower and insulated houses a higher energy consumption than the theoretical calculations suggested (prebound). In order to take these effects into account, JEMS-BTS uses consumption values for space heating and hot water supply, e.g. those in [Diefenbach et al., 2010, Walberg et al., 2011], to determine the building's initial energy baseline and it exploits the potential for improvement using the rate of energy efficiency improvement similar to [BMVBS, 2013], for example. Based on these findings, the research in this paper analyses the energy consumption for space heating and hot water supply in residential buildings, taking particular account of the dynamic developments of demographic change and socio-economic factors.

2.1 Definition of the scenarios

For the scenario analyses up to 2050, three scenarios were defined (see Table 1). In the "business as usual" (BaU) scenario, the impacts of measures and efficiency standards already in place are extrapolated. This applies to national regulatory instruments such as EnEV 2014 and the Renewable Energies Heat Act (EEWärmeG), as well as the provisions of the EU Energy Performance of Buildings Directive. Additionally in the BaU scenario, in accordance with the EU Buildings Directive, all new buildings must be nearly zero-energy buildings from 2021 onwards. The current renovation rate of the building envelope remains over the last few years at around 1%/a [BMVBS, 2013] until 2020 before gradually increasing moderately to 1.5 %/a in the subsequent period up to 2050. Old heating systems are replaced predominantly with conventional systems. In contrast to the BaU scenario, the "enhanced thermal insulation" (TI) scenario assumes that the measures for the buildings sector as defined in the Federal Government's Energy Concept are implemented in full. The focus here is on pushing building renovation. A renovation road map is introduced to progressively transfer the nearly zero-energy building standard for new buildings to existing buildings. Key elements are the doubling of the rate of energy efficiency improvement to 2%/a from 2020 onwards and a tightening of the EnEV efficiency standards for existing buildings. Furthermore, higher incentives are offered within the CO_2 Building Renovation Programme and energy contracting is expanded to enhance savings potentials in the rental accommodation sector. Old heating systems are replaced at the same rate as in the BaU scenario, namely 4%/a.

In addition to these scenarios, an alternative scenario was also defined. In the "modern heating systems" (MHS) scenario, the BaU scenario is taken one step further by assuming that measures and instruments applicable to buildings are supplemented by expanding the Renewable Energies Heat Act (EEWärmeG) to include existing building stock. This alternative MHS scenario assumes a renovation rate in line with the BaU scenario and also concentrates on the intensified use of modern and innovative heating systems as well as an increased use of renewables. In addition, the use of local and district heat is taken into account mainly by stepping up network densification. In contrast to the BaU and TI scenarios, the MHS scenario assumes a shorter average renewal cycle of 20 years (technical renovation cycle) instead of 25 years (market renovation cycle) for heating systems. Another important feature is that natural gas is more heavily substituted with admixtures of CO_2-free gases, such as biogas and hydrogen produced from wind. We assume that biomethane feed in and hydrogen production will play a more important role in the MHS scenario (Figure 1). To achieve the goal of 80% CO_2 emission reduction an enforced use of renewables in all sectors is necessary. According to the study of VDE [VDE, 2012] 30 TWh surplus electricity are expected until 2050, which can be converted to hydrogen. In 2050 the share of renewable gas (biogas and hydrogen) amounts 26%

2.2 Underlying data

The scenario calculations are based on the initial thermal state of buildings in 2012 and demographic development up to 2050 according to variant V1 of the Federal Statistical Office's 12th coordinated population projection for Germany [Destatis, 2010]. On this basis, the German Sample Survey of Income and Expenditure (EVS) [Destatis, 2008] and household projections in Germany [DESTATIS, 2007] are used to derive the dynamics of household structure and the demand for living space. Accordingly, the demand for living space increases continuously despite a declining population. It is expected that living space as of 2012 totalling 3.62 billion m^2 will increase to a total of 3.87 billion m^2 (inhabited living space with vacancies) by 2050 despite the decline in the residential population to 69.4 million in the same period (see Table 2). This is explained by the increasing number of single-person and two-person households as well as the higher amount of living space per person. This increasing consumption of living space appeared in the past across all age groups [IDW, 2009]. If we include living space in new buildings constructed in the period 2012–2050 amounting to 0.87 billion m^2, the inhabited living space increases by 7% to 3.67 billion m^2 in 2050. With respect to the development of the vacancy rate, it is assumed that it will rise slightly by 2050 from the current figure of 5.1% to 6.1%. The calculations also assume a constant annual demolition rate of 0.2% accross the entire period.

In addition to these input parameters, the energy prices assumed in the scenarios are an important factor (see Table 3). Energy prices are assumed to develop in line with the same trend in the scenarios in [EWI/gws/Prognos, 2010], which are also used as the basis for the Federal Government's Energy Concept. Accordingly, a continuous increase is assumed in energy prices. For example, the annual rate of increase for light heating oil for private households is approx. 1.8%. With the exception of the price for gas mixtures, identical energy carrier prices are assumed for all scenarios. As the share of renewable gas varies in the scenarios, the prices of the gas mixtures also differ.

In order to extrapolate the heating system structure up to 2050, replacement rates for heating systems are defined. The replacement rate describes the technology-specific substitution rate for heating systems that must be replaced due to age. The combination of replacement rates and the age structure of relevant inventories is used to calculate the current stock of heating systems.

In the BaU and TI scenarios, it is assumed that most of the oil heating systems are replaced but that at least 20% of these oil systems will remain in 2050. Furthermore, it is assumed that these oil heating systems are increasingly replaced by a mixture of gas systems, biomass boilers, and electric heat pumps. In addition, it is assumed that micro-CHP units will begin to penetrate the market. It is assumed that heating systems run on natural gas are replaced from 2020 onwards by gas heating systems only. The highest replacement rates of 52.5% in 2050 apply to gas-fired condensing boilers with solar technology.

In the alternative MHS scenario, it is assumed that old oil and gas heating systems are replaced by a mix of gas heating systems, electric heat pumps, biomass boilers, and local and district heating systems. It is also assumed that more heat pumps and micro-CHP units are installed as replacements for oil and gas heating systems. The substitution rate for gas heating systems in 2050 is based on the assumption that every third heating system is replaced with a micro-CHP unit.

3. German Residential Building Stock

The residential building stock in 2012 is based by the results of the 2011 census [Zensus, 2013] and is made up of around 39.7 million dwellings, which are distributed across 18.5 million residential buildings. Almost 83% of residential buildings (15.3 million) are single-family and multifamily houses. Residential buildings with more than two dwelling units account for 17% and comprise 21.2 million dwellings [Destatis, 2013]. The total living space in residential buildings is currently 3.62 billion m^2.

Figure 2 shows the existing stock broken down into building types and age classes which are divided into architectural building periods. It can be seen that more than two-thirds of today's stock was built before the first German Thermal Insulation Ordinance (WärmeschutzV) came into force in 1978. The greatest share of existing living space is made up of the building age classes 1958–1968 and 1969–1978 which account for 636 million m^2 and 579 million m^2, respectively. Since the introduction of EnEV in 2002, only 7% of living space had been newly built by 2012.

Table 1. Definition of scenarios.

	BaU	TI	MHS
Policy instruments for building renovations	Updating of existing policy instruments	Implementing of energy concept	Measures (like BaU) and extension to the mandatory use of renewable energy in refurbished buildings
Energy efficiency standards	EnEV 2014 for existing buildings; EPBD 2010 requires all new buildings to be nearly zero-energy by the end of 2020	Tighter requirements for existing buildings (2020 and 2030: + 30%); EPBD 2010	EnEV 2014; EPBD 2010
Refurbishment rate of building envelope	1.0%/a and from 2020 moderate increase to 1.5%/a in 2050	Doubling the current rate up to 2%/a by 2020	1.0%/a and from 2020 moderate increase to 1.5%/a in 2050 (like BaU)
Renewal rate of heating systems	4%/a	4%/a	5%/a, increased use of innovative heating systems

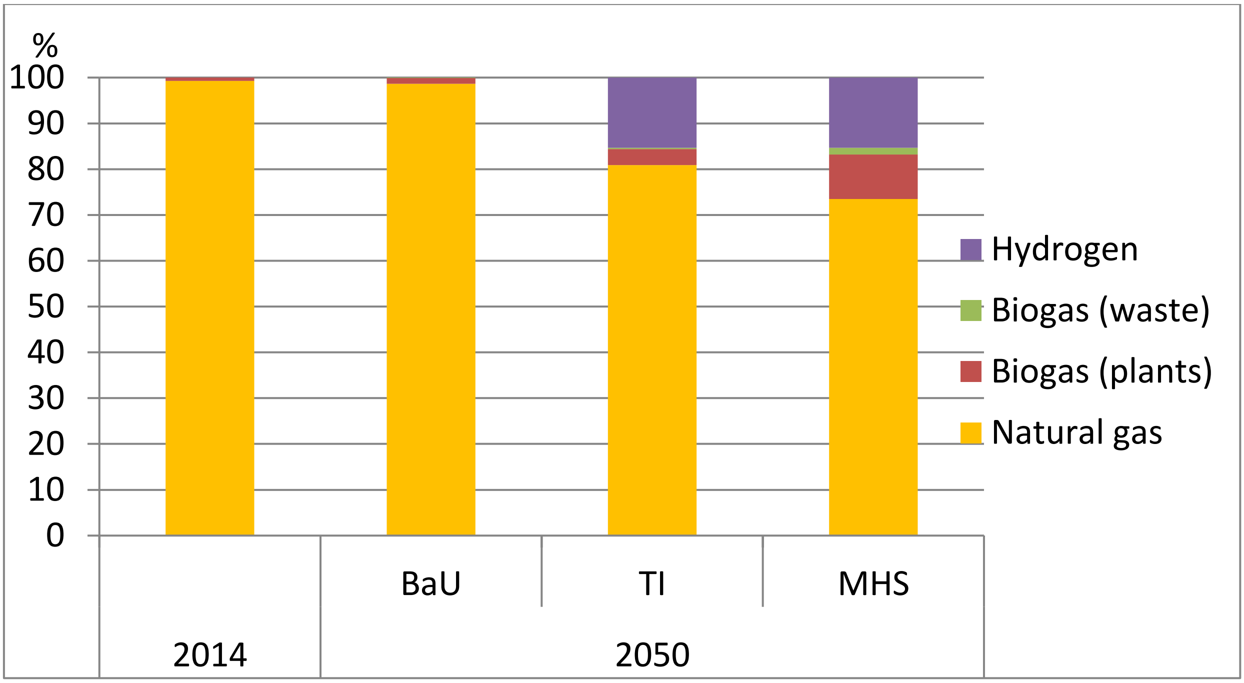

Fig. 1. Gas composition in 2050 in Germany.

Table 2. Input data.

	2012	2020	2030	2040	2050
Population (million)	80.5	79.9	77.4	73.8	69.4
Private households (million)	40.7	40.9	40.6	39.3	37.7
1	16.5	16.8	17.0	17.1	17.1
2	14.0	14.6	14.9	15.0	15.2
3	5.1	4.8	4.4	3.6	2.7
4	3.7	3.5	3.2	2.8	2.2
5 and more	1.3	1.2	1.1	0.8	0.5
Persons per household	1.99	1.95	1.91	1.90	1.84
Living space (billion m^2)	3.62	3.68	3.83	3.88	3.87
New construction (billion m^2)	0.00	0.16	0.40	0.65	0.87
Inhabited living space (billion m^2)	3.43	3.34	3.24	3.01	2.80
Vacancies (%)	5.1	5.2	5.5	5.8	6.1
Living space per person (m^2)	44.7	46.1	49.5	52.6	55.8
Living space per household (m^2)	88.9	90.0	94.3	98.7	102.7

Table 3. End-user prices for private households (including VAT).

	2012	2020	2030	2040	2050	Δ 2012–2050
	ct/kWh					%/a
Gas (BaU)	6.6	7.0	7.6	8.1	8.7	0.7
Gas (TI)	6.6	7.0	7.6	8.3	9.5	1.0
Gas (MHS)	6.6	7.0	7.7	8.6	9.9	1.1
Oil	6.9	8.5	10.1	11.9	13.4	1.8
Briquettes	4.6	4.2	3.9	3.7	3.4	-0.8
District and local heat	7.7	8.4	9.0	9.6	10.2	0.7
Pellets	4.2	4.6	5.2	5.8	6.4	1.1
Electricity	25.1	26.9	28.8	30.8	32.5	0.7
Electric heat pumps	19.4	20.7	22.2	23.7	25.0	0.7

Almost 84% of the final energy demand of private households in 2012 is due to the production of space heating (69%) and hot water (15%). The temperature-adjusted final energy consumption of private households for space heating and hot water in the period from 1990 to 2013 decreased by approx. 14% compared to 1990 levels to 2,097 PJ. The initial thermal state of residential building stock can be characterized according to building age classes and installed heating systems based on the final energy consumption determined from the thermal insulation of residential buildings. In accordance with the analyses of the data basis in [Diefenbach et al., 2010] and the level of modernization in [Walberg et al., 2011], the level of thermal insulation in residential buildings can be determined for 2012 according to building type and age class. Consequently, in 2012, more than 50% of the 18.5 million residential buildings had no or insufficient thermal insulation. A further 30% had at least a partially insulated building envelope and less than 20% of residential buildings were fully insulated. According to the distribution of existing living space, the age classes 1958–1968 and 1969–1978 have the largest quotas of residential buildings which simultaneously have the worst insulation.

In addition to the quality of measures to insulate the building envelope, the installed heating systems are also essential in characterizing final energy consumption for space heating and hot water. According to statistical analyses and surveys, existing residential buildings were equipped with more than 23.2 million heat generators in 2012. At the end of 2012, installed heating systems in private households were dominated by 13.1 million gas heating systems. In 2012, some 4.0 million gas condensing boilers were installed in residential buildings. At the same time, more than two-thirds of existing boilers in 2012 were technically inefficient and allowing for a mean replacement cycle of 25 years they can also be classified as antiquated and in need of renewal [BDH, 2013, DEPV, 2013, Shell & BDH, 2013, ZIV, 2013]. Therefore, replacing heating systems has huge potential for energy efficiency.

4. Results

4.1 Final energy consumption

Final energy demand for space heating and hot water decreases considerably in the three scenarios for the period from 2013 to 2050 (see Fig. 3). The energy demand for heat and hot water supply in residential buildings drops by 35% by 2050 in the BaU scenario compared to the energy demand of 2012. This drop is due to the demolition of older buildings and the construction of new energy-efficient housing as well as the energy-efficient renovation of old housing stock. Overall, the energy demand in the BaU scenario is reduced by 730 PJ by 2050. Accounting for almost 600 PJ, natural gas is the dominant energy carrier.

The calculations for the TI scenario show that doubling the rate of energy efficiency improvement to 2% per annum combined with a tightening of energy efficiency standards compared to the situation in the BaU scenario are the main factors that lead to a saving of more than 560 PJ by 2050. Overall, the heat demand up to 2050 in the TI scenario decreases by a further 27% compared to levels in 2012. The energy demand therefore drops to approx. 800 PJ by 2050.

The largest decrease among the energy carriers by 2050 was ascertained for the use of natural gas, which drops by almost 710 PJ. Heating oil consumption drops by 450 PJ and in 2050 only a residual demand of 16 PJ for heat and hot water supply in private households needs to be covered by heating oil. Power consumption is reduced by almost 115 PJ and the use of district heating by a total of some 80 PJ by 2050. By adding biogas to conventional natural gas, this renewable gas mixture covers around 3% of the final energy demand in 2050 with 22 PJ. The share of renewables excluding renewable gases is successfully increased by more than 400 PJ by 2050.

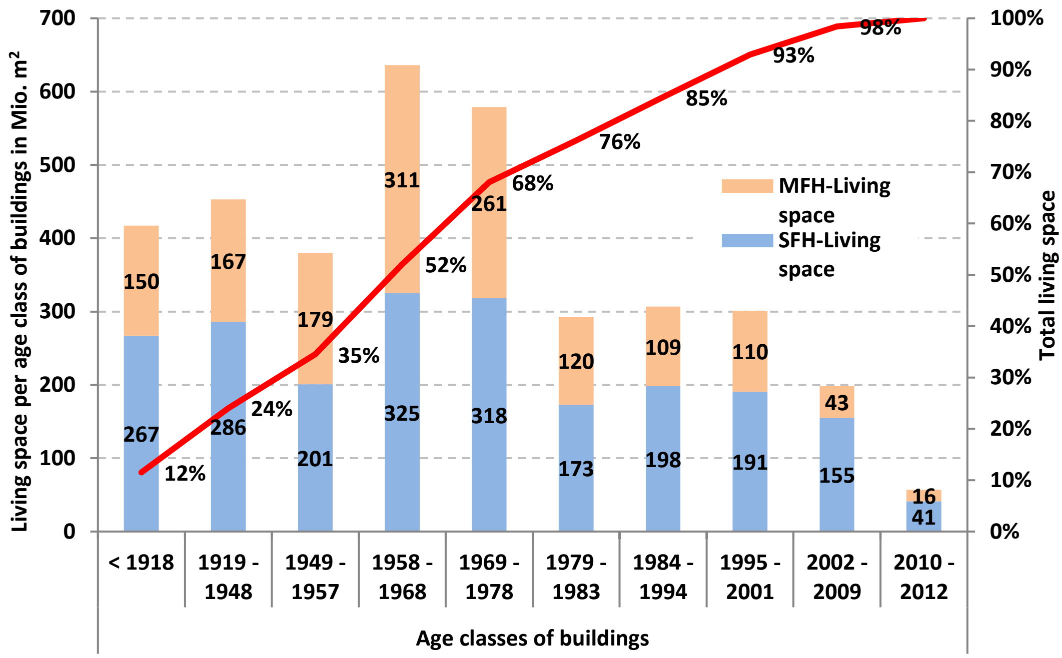

Fig. 2. Residential building stock 2012.

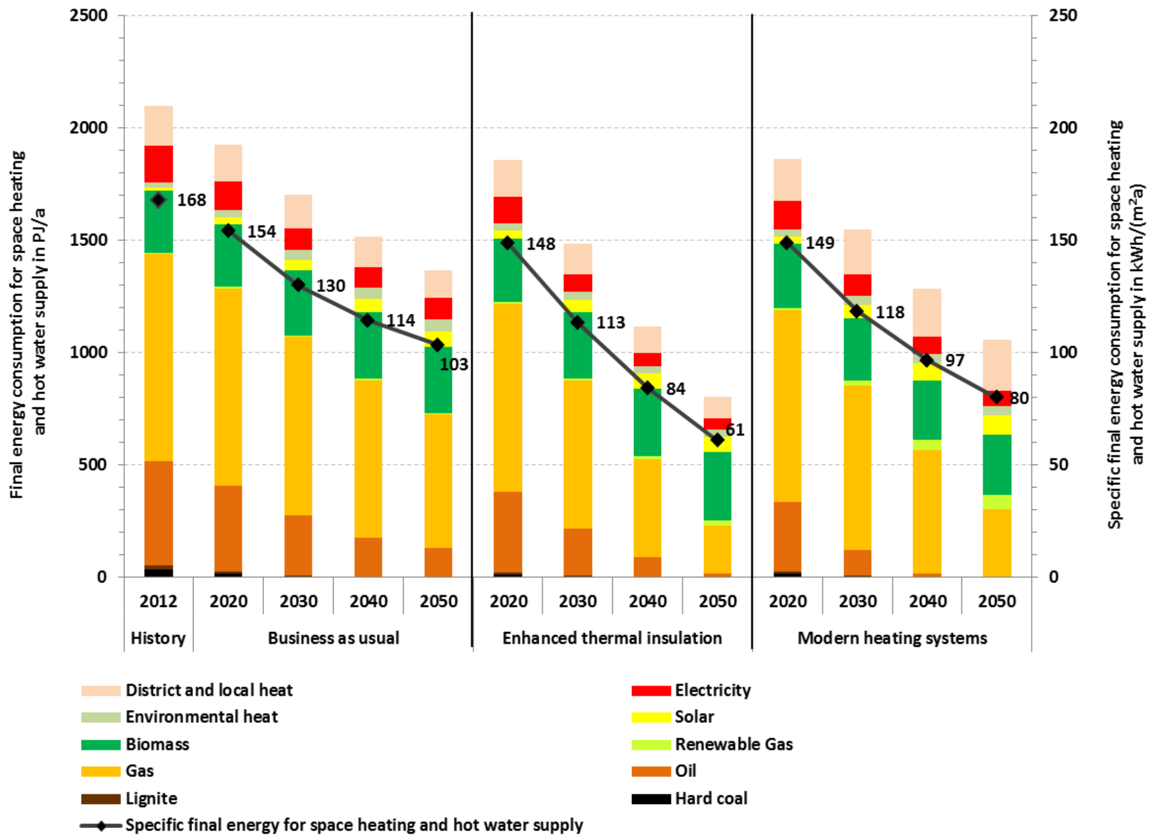

Fig. 3. Final energy consumption for space heating and hot water supply.

Heating oil consumption drops by 450 PJ and in 2050 only a residual demand of 16 PJ for heat and hot water supply in private households needs to be covered by heating oil. Power consumption is reduced by almost 115 PJ and the use of district heating by a total of some 80 PJ by 2050. By adding biogas to conventional natural gas, this renewable gas mixture covers around 3% of the final energy demand in 2050 with 22 PJ. The share of renewables excluding renewable gases is successfully increased by more than 400 PJ by 2050.

The building renovation measures and measures for increasing the efficiency of heating systems in the MHS scenario enable the 2012 final energy demand of households for space heating and hot water to be reduced by almost 50% (1,040 PJ) by 2050. The demand for heat up to 2050 therefore decreases by almost 310 PJ more than in the BaU scenario. However, the savings are lower in the BaU scenario than in the TI scenario. The additional savings in the TI scenario compared to the BaU scenario can be explained by shorter replacement cycles for heating systems and predominantly by the growing use of innovative heating systems such as micro-CHP units. Heating oil is completely replaced by other energy carriers by 2050. The use of conventional natural gas is decreased by 620 PJ by 2050. In contrast, the use of renewable gases is increased to 64 PJ by 2050 through the admixtures of H_2 and biogas. The renewable gas mixture has a share of 6% in the total energy demand in 2050. The power demand decreases by more than 90 PJ in total by 2050 and the energy demand for local and district heat increases by 17 PJ. The share of renewables from biomass, solar energy, and environmental heat increases by 27%.

An indicator for energy savings is the area-specific energy consumption for the production of space heating and hot water. The values shown in Fig. 3 apply to the entire residential building stock. The area-specific consumption decreases for inhabited living space from 168 kWh/(m^2a) in 2012 to 103 kWh/(m^2a) in the BaU scenario by 2050. Due to the measures in the TI and MHS scenarios, an area-specific demand of 61 kWh/(m^2a) and 80 kWh/(m^2a), respectively, emerges.

4.2 *Primary energy consumption and CO_2 emissions*

If the energy demand for space heating and hot water in the TI and MHS scenarios is calculated using the primary energy factors defined in EnEV [EnEV, 2013], then the primary energy consumption (PEC) can be determined. Fig. 4 shows that both scenarios achieve the 80% reduction envisaged in the Energy Concept by 2050 compared to levels in the base year 2008. Primary energy demand, therefore, drops by 80% in the MHS scenario (PEC-MHS) by 2050. In the TI scenario, primary energy demand is reduced by almost 84% in 2050. In addition, the emissions savings verify that CO_2 emissions produced by space heating and hot water supply of 28% in 2012 are decreased by 2050 in both scenarios by more than 80% compared to 1990 levels. The climate target of -80% compared to 1990 levels has therefore been exceeded in the MHS scenario (MHS-CO_2) where emissions are reduced by 88% and in the TI scenario (TI-CO_2) with a reduction of 91%. (Figure 4).

In the BaU scenario, over the course of the scenario up until 2050, emissions are successively reduced. In 2050, the emissions reduction totals a good 120 million tCO_2 and emissions are thus 71% lower than levels in 1990. The measures for increasing efficiency and reducing CO_2 emissions that are already in place today and are extrapolated up to 2050 are responsible for this reduction. Climate protection targets set by the government, however, are not achieved in this scenario.

The measures in the TI scenario and the MHS scenario lead to greater CO_2 reductions than in the BaU scenario with figures of 35 million tCO_2 and 29 million tCO_2, respectively, by 2050. These figures also show that the Energy Concept measures have a greater impact on emissions than the measures in the MHS scenario. The main reason for this is higher building renovation rates compared to the MHS scenario.

Up to 2020, the reduction in emissions in the TI and MHS scenarios is of a similar magnitude to that in the BaU scenario because the measures in the TI scenario only begin to take effect after the rate of energy efficiency improvement is doubled in 2020.

4.3 Costs

The simulation model calculates the total investment costs and annual operating costs for the measures and on this basis assesses the annual costs of the scenarios from an end user's perspective. In order to calculate the net present value (NPV) the annual costs of the scenarios were discounted with an interest rate of 4% . The total costs (NPV) of the TI scenario are higher than those of the BaU scenario and at approx. € 75 billion are also higher than the equivalent figures in the MHS scenario at approx. € 26 billion (see Table 4). The main reason for this are the high investment costs for renovation measures, which due to the higher rate of energy efficiency improvement and the tightened energy efficiency standards are much higher than the investment costs in the MHS scenario. Doubling the rate of energy efficiency improvement, in particular, necessitates the implementation of measures beyond the usual renovation cycles, which in turn explains a considerable proportion of the higher additional investments. However, the energy savings in the TI scenario are considerably higher, which means that expenditure for energy is lower than in the MHS scenario. Overall, the reduced energy costs in the TI scenario cannot compensate the increased investments. The specific CO_2 avoidance costs in the TI scenario are approx. € 158/tCO_2 for cumulative CO_2 savings of 475 million tCO_2. In the MHS scenario, the specific avoidance costs in contrast are approx. € 58/tCO_2 for cumulative CO_2 savings of approximately the same magnitude at 445 million tCO_2.

4.4 Sensitivity analysis

A lot of assumptions are necessary to describe and calculate the scenarios described in the previous chapters. However, there are some key parameters characterising the scenarios. Key parameters are lifetime of heating systems, refurbishment outside the renovation cycle and fuel price assumptions, which might have a significant impact on the results. Taking this into account, we did a sensitivity analysis (Table 5) to get an advice about the robustness of the results.

S1: Impact of renewal rate of heating systems. If in S1 in the TI scenario, the replacement cycle for heating systems is reduced from 25 years on average to 20 years from 2020 onwards while the substitution rate is retained, then the energy costs in the period up to 2050 are € 47 billion lower. New heating systems with improved efficiencies replace old systems faster. However, this increase in the renewal rate from 4% to 5% per annum leads to additional investments of € 67 billion while simultaneously saving an additional 155 million tCO_2 bringing the total emissions saved to 630 million tCO_2. The additional costs in the TI scenario increase in S1 from € 75 billion to € 96 billion and the specific avoidance costs decrease to € 152/tCO_2.

S2: Impact of energy renovations within the technical renovation cycle. In S2, it is assumed for the TI scenario that energy efficiency improvements only occur within the technical renovation cycle. This assumption leads to a decrease in additional investments in thermal insulation of around € 70 billion and simultaneously the cumulative emissions savings drop to 266 million tCO_2. Reduced energy-efficient renovation activities increase the energy costs by € 20 billion by 2050, which causes the strategy costs to decrease by a total of € 50 billion. Overall, in S2 the specific avoidance costs drop to € 94/tCO_2. If sensitivity analyses S1 and S2 are combined, (which comes closer to the MHS scenario) then compared to the TI scenario the increased replacement of heating systems and thermal renovation of homes in the technical renovation cycle lead to emissions savings of 421 million tCO_2 and specific avoidance costs of € 107/tCO_2. In conclusion, S1 and S2 as well as the combination of S1+S2 show that the specific avoidance costs are consistently higher than in the MHS scenario.

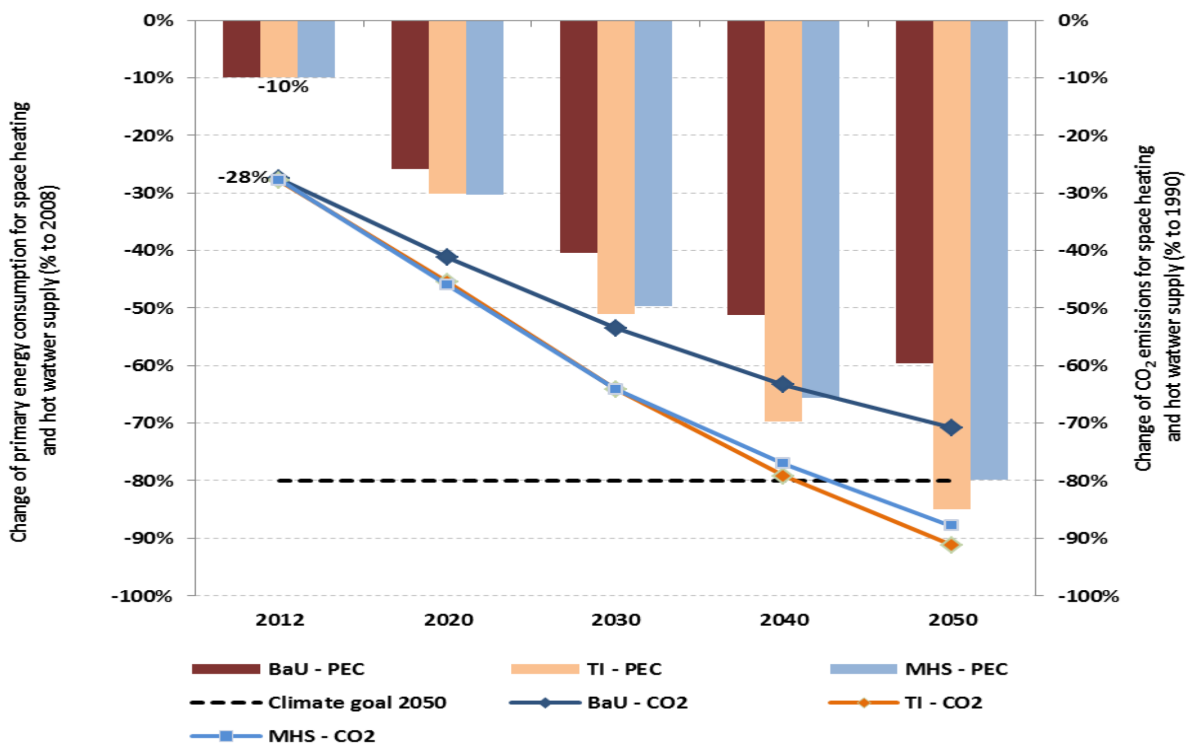

Fig. 4. Primary energy demand and CO_2 emissions.

Table 4. Costs over strategy (present value 2013–2050).

		BaU	TI	Δ to BaU	MHS	Δ to BaU
Investment costs	billion €					
heating systems in existing buildings		443	617	174	515	72
heating systems in new buildings		270	270	0	343	73
thermal insulation of existing buildings		40	39	-1	39	-1
thermal insulation of new buildings		87	262	175	87	0
		46	46	0	46	0
Fuel costs	billion €	802	703	-99	755	-47
Net costs	billion €	1245	1320	75	1270	26
CO_2 emissions	million tCO_2	2364	1889	-475	1919	-445
Specific reduction costs	€/tCO_2			158		58

Table 5. Overview of sensitivity analysis.

	Scenario	Sensitivity
S1	TI	Replacement cycle of heating systems:20 years
S2	TI	Heat insulation measures not outside the technical renovation cycle
S3	TI, MHS	Fuel prices

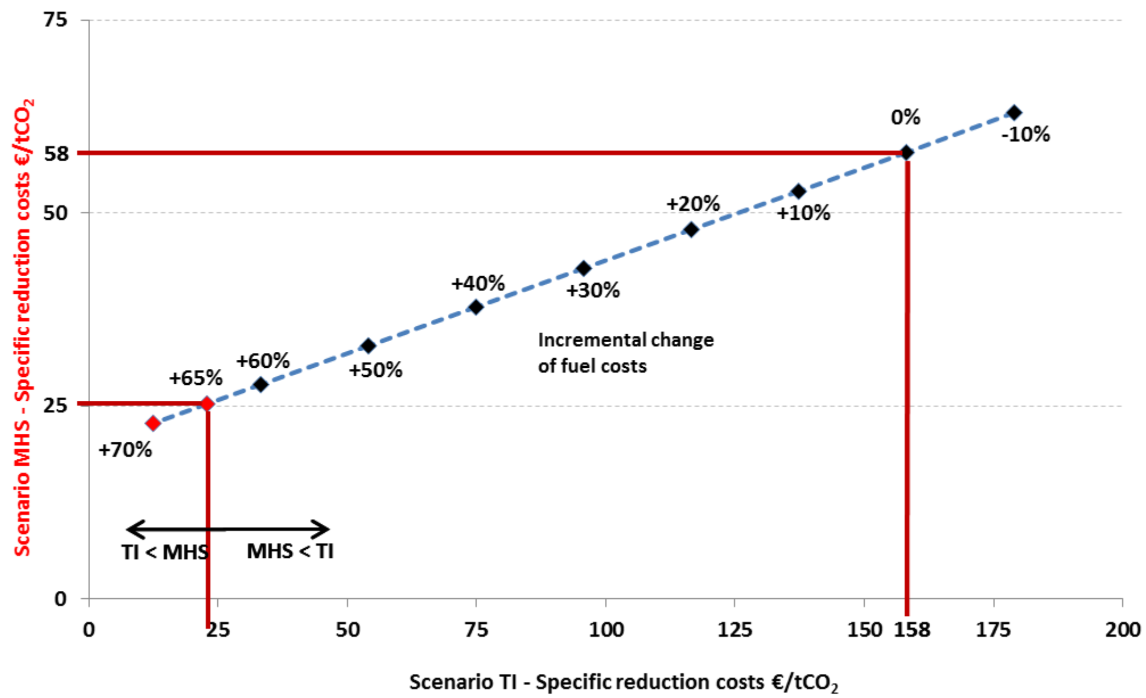

Fig. 5. Incremental change of fuel costs (S3).

S3: Impact of fuel costs. If the end-user prices listed in Table 3 are varied, then also the specific avoidance costs differ. How sensitively the specific avoidance costs react to changes in end-user prices can be seen in Figure 5. If the end-user price of energy carriers is decreased by 10%, then the specific avoidance costs increase in the MHS scenario from € 58/tCO_2 to € 63/tCO_2 and in the TI scenario from € 175/tCO_2 to € 179/tCO_2. Conversely, a 10% increase in energy costs gives rise to a decrease in the specific avoidance costs to € 53/tCO_2 in the MHS scenario and to € 137/tCO_2 in the TI scenario. Only when the end-user price is increased by 65% do the strategy costs in the TI scenario lead to specific avoidance costs of € 23/tCO_2 to € 25/tCO_2, which are lower than in the MHS scenario. For S3, it can therefore be concluded that only if the energy price is increased annually by 3% is the TI scenario more cost-efficient than the MHS scenario.

5. Conclusions

The results clearly show that simply continuing the current measures put in place by the German Federal Government is not enough to achieve a climate-neutral building stock by 2050. Further measures will be necessary, similar to those proposed in the TI and MHS scenarios. The results also show that the currently favoured strategies in the residential building sector, which focus predominantly on energy-efficient measures for the building envelope, are not the only option for achieving climate-neutral residential building stock by 2050 and that interesting alternatives exist which are simultaneously more cost-efficient. Implementing the package of measures in the two scenarios is ambitious. This applies in particular to the demanding renovation road map in the TI scenario but also to the measures in the MHS scenario, which envisage the early replacement of heating systems and a heightened use of innovative heating systems. Both scenarios involve several technical identical measures, but they differ in the capacities of installed heating systems. In all scenarios analysed, improving efficiency through thermal insulation measures represents a central and indispensable field of action. However, the analyses also indicate that by altering the priorities and focusing more on support measures, a climate-neutral building stock can be achieved at much lower costs. Today, incentives in the form of subsidies are already in place to encourage the implementation of existing political measures in the buildings sector (e.g. the KfW programmes). The sensitivity analyses clearly show that the results of the scenarios are robust. Higher energy prices become relevant when they increase by 65% compared to the baseline energy prices.

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Путь Германии к климатической нейтральности зданий жилого фонда: технико-экономическое сравнение стратегий уменьшения выбросов парниковых газов

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Краткое изложение:: 14% от общего объема выбросов CO_2 в стране приходится на отопительную систему жилых помещений. Для сокращения выбросов CO_2 (-40% в 2020 г., -80% в 2050 г.) Федеральное правительство Германии поставило целью в своей концепции «Energiewende» для жилого фонда Германии быть климатически нейтральным к 2050 году через оптимизацию средств теплоизоляции. Тем не менее, остается неопределенным, является ли данная мера экономически эффективной.

Проведено исследование различных стратегий сокращения спроса на энергию и выбросов CO_2 от жилого фонда до 2050 года. Эти стратегии включают в себя меры Федерального правительства в части энергетической концепции, с одной стороны, и альтернативные варианты с использованием возобновляемых газов и инновационных систем отопления, с другой.

Расчеты основаны на динамической имитационной модели, которая детально имитирует деятельность жилого фонда. Модель воссоздает эффекты от различных мер по повышению энергоэффективности, таких как теплоизоляция и улучшение систем отопления.

Результаты показывают, что существуют альтернативные стратегии, которые могут привести к климатической нейтральности жилого фонда. Такие стратегии, основанные на ранней замене отопительных систем, расширении использования возобновляемых источников энергии, а также на обязательном использовании инновационных систем отопления, являются экономически эффективными, в отличие от тех, которые в основном сосредоточены на мерах тепловой изоляции. Анализ чувствительности доказывает обоснованность полученных результатов.

Ключевые слова: жилой фонд, теплоизоляция, динамическая имитационная модель, сокращение выбросов CO_2, система отопления, энергоэффективность, возобновляемые источники энергии.

Energy civilization through industrial modernity and beyond

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Abstract

Three of the authors (Jensen Shearing, Skauge) are in the core group of the SANCOOP project: Transition to Sustainable Energy Systems in Emerging Economies. It is a South African Focused Comparative Project, financed by the Norwegian and South African Research councils 2014-2016. The included countries are Brazil, China, India and South Africa. This paper is based on theoretical discussions early in the project and some preliminary impressions from our interviews.

Energy systems have gained new relevance. Dominated by their electricity component, energy systems were the main ingredient in forming advanced industrial-based civilizations. These energy systems are now a main actor that threatens to destroy them. The IPCC (2014) declared electrical energy production (especially coal) as the main driver of climate change. Through energy production patterns, humans are now able to destroy nature's foundations of their civilizations; we are in the age of the Anthropocene. The paper will discuss the relation between humans and nature, as seen through energy. At the start, energy was mainly a local, even family matter, requiring skill and care. Since energy in itself is not a scarce resource, the problem of energy sources, organization and institutions comes into focus. We will discuss the perspectives and practices towards nature that came with industrialism, the new forces of governance and the resulting institutions of huge electricity grids and big power plants that resulted. The climate change challenge is one driver of change. Other drivers are cultural in nature: The century-old institutions of power production are developing problems of change and learning, but they remain powerful. Consumers start to be actors in new ways, in ordinary markets, but also as energy citizens and co-producers of energy. Technology development and structural changes point to smaller scale, flexibility and decentralization of energy production. These factors work together and create rapid development of new niches of energy production and many of them are approaching their tipping points to become major production regimes. The paper concludes with a discussion of actors forming the new system, including consumers as energy citizens and the crucial new regulatory challenges that emerge.

Keywords
energy civilization, energy systems

1. Introduction –The Challenge of the Anthropocene

Energy systems have gained new relevance. Dominated by their electricity component, they were the main ingredients in forming advanced, industrial-based civilizations. These energy systems are now a main actor that threatens to destroy them. IPCC (2014) declared electrical energy production (especially coal) as the main driver of climate change. Through energy production patterns, humans are now able to destroy nature's foundations of their civilization; we are in the age of the Anthropocene.

What is a good theory that can capture relations between humans and nature, as seen through energy? What theories capture changes, change agents and forces that hinder and promote change for climate-friendly energy systems?

At the start energy was mainly a local, even a family matter, requiring skill and care. Since energy in itself is not a scarce resource, the problem of energy sources, organization and institutions come into focus.

The paper discusses several perspectives and practices towards nature that came with industrialisation, the new forces of governance and the resulting institutions of huge centralized grids and big power plants that resulted. The climate change challenge is one force of change. Other forces are institutional and social: The century-old institutions of power production developing problems of change and learning, but they are large and powerful. Consumers start to be actors in new ways, even energy citizens and co-producers. One path of technology development and structural changes points to smaller scale, flexibility and decentralization of energy production. These factors work together and create rapid development of new markets, new manufacturing and new niches of energy production and many of them are approaching their tipping points to become major production regimes.

An alternative path is created by the forces of expertise, big organisations and ideas for economic efficiency. This path is heading towards standardization and even more centralized systems. Changes can be hindered by path-dependency forces (Berkhout, 2002).

Our paper concludes with a discussion of actors forming the new system, including consumers as energy citizens and the crucial new regulatory challenges that emerge.

Our research has its origin in the questions that the Anthropocene era has raised, and is raising, as humans recognize that they are collectively now geological agents[2] capable of eroding the eco-system services upon which they depend both for their biophysical survival and for the survival of their social world (civilizations). Today, we humans have in a double sense become children of the Anthropocene. We are both living through the consequences of impacts of our actions on earth systems and are becoming increasingly aware of our new and emerging status as geological agents. We know who we are, who we have become and who we are capable of becoming.

The combination of impacts (damage) to ecological systems that we humans have already realized, the knowledge we now have of what we have and are capable of doing to both destroy and rehabilitate ecological systems is a frightening prospect. The concept of the Anthropocene era (Schwägerl, 2014) is a parallel to the concept of Risk Society (Beck, 1992). The central idea was that the new technology of nuclear power and the nuclear bomb, for the first time in history, gave man the capacity to destroy human life and civilizations more so than natural disasters. The first uses of the concept were mainly negative, like the example of nuclear weapons, but in principle it is more about a new

[2] The distinction between ecological and geological refers to the fact that human influence now reaches further than the living ecosystem; it includes the climate, oceans and land structures as well.

human position as conscious actors, shaping, maintaining, destroying or enhancing our own conditions, and fate.

2. Our Research

In our research program we have sought to locate specific topics and geographical areas that can be studied for a fruitful analysis of the above themes.

To realize this we have singled out the production and distribution of electrical energy as our core focus. The production of electricity has both played, and will continue to play, a crucial role in shaping the trajectory of human civilizations and human impacts on earth systems such as climate systems.

A foundational assumption that grounds, and shapes, our research is that human civilizations (and the economies that sustain them) will continue to require (demand) a constant and expanding supply of electricity. Today electricity is a *sin qua non* of human civilization. While it might be possible for humans to survive as biophysical beings without abundant electricity, their contemporary ”worlds” will collapse (Diamond, 2005) without this.

As awareness of the Anthropocene and its implications has emerged so has the search for alternative ways of engaging in the extractive and production processes that contemporary human civilizations require.

Crucial within energy production and distribution has been the search for alternative methods of generating sustainable (that is eco-system friendly) electrical energy. There are major initiatives underway globally to produce energy in more sustainable ways. Indeed these developments are at the very forefront of efforts to respond to the challenges of the Anthropocene such as climate change.

Our research is focused on understanding conditions shaping developments with respect to the production and distribution of electricity. We are in particular looking for game changing forces and/or premises.

Our research strategy is to explore countries that have rising energy needs that vary significantly with respect to energy generation history and associated regulatory regimes. Specifically we have focused our attention on the four BASIC countries; Brazil, South Africa, India and China.

3. What is energy?

First, energy is <u>not a limited resource</u>. For example, the sun alone is capable of delivering all the energy that humans are ever likely to require (McKevitt and Ryan, 2013). In addition there is the indirect old energy from the sun (coal, oil and gas), the gravitational force of the moon (tidal power), there are also wind, waves, geothermal energy, hydrogen energy (Rifkin, 2002) and many others. Finally the conversion of matter into energy (nuclear - both fission and fusion) has a potential that again in theory can deliver as much energy that may ever be needed without depleting nuclear fuel resources in any significant way.

Second, <u>energy is never lost</u>; it is transformed and moved along long and complicated chains. In the very long run the energies of the earth and sun will probably gradually dissipate into cold space according to the second law of thermodynamics. At present and at the global and human scale of time and space scale it seems that humans forced the earth system into the state of dissipating too little energy back to the universe (this results in global warming, or more precisely, too much energy left in the climate systems). This is a process that paradoxically may postpone the possibility of the cold death of all life from the second law of thermodynamics with a very tiny fraction.

The technology of concentrating some energy resources, such as fossil fuels, and the conversion of their intrinsic energy into heat so they can provide electricity has been of great importance for development of human civilizations. Given this, a crisis in this area quickly becomes a social crisis that can lead to the destruction of civilizations - mundicide. These technologies were of course not seen as problematic when they were institutionalized and may, as we shall see later, be seen as unfortunate choices among other possibilities. Today they may seem so dominating in the socio-technical energy regime that the historically new insight of its damaging capabilities may look overwhelming. On the other hand, the long history of the less problematic technologies of hydro-electrical energy is one indication that reminds us of earlier and more fortunate choices and of new opportunities.

The impression that energy constitutes a "limited resource", and a resource that damages earth systems while used, is a construct of special historical and techno-social factors. The close links that developed historically, given the preferred energy technologies, between fossil fuels (stored solar energy) and electrical energy generation technology creates the impression of a limited and dangerous energy system. Behind this appearance are strong social and technological investments and institutions. They could have been changed earlier, but it did not seem necessary. Now it is necessary.

It is the institutionalized reliance on technologies that have used non-renewable resources to produce energy - a reliance that has a very long history - that is at the root of many of the features of the Anthropocene such as the destruction of ecological systems that are crucial for human survival as biophysical entities. Provision of energy for maintaining welfare and society is a social and political problem, not resource- or technology-based.

Our focus is on electricity, its production and distribution. Electricity in itself is relatively harmless with today's technology and administration; the problems are mostly linked to how other energy sources are used for the generation of electricity.

4. Humans, energy, society and the crisis

What is special about humans is the level of energy that they have been able to produce (=concentrate) through processes of enrolment of other parts of earth systems - these include the early enslavement of biophysical forms (humans and animals) plus the use of physical features of different earth systems. This has enabled humans to sustain massive levels of social organization (civilizations). Today energy in its electrical form is the crucial energy required for social organization (this is especially true of low-power cyberspace even if this is an extremely energy-efficient mode of communication).

A crucial driver of human engagements with earth systems has been the ongoing supply of the high levels of energy required to sustain their civilizations. This is unlikely to change without a major shift in power balance between central actors. We expect such shifts to occur through social acceptance and definition of crisis-situations, like pollution (China), supply system breakdown (South Africa) and of course the gradually developing concern for the climate and the evolving crisis of more extreme and more frequent weather events.

5. The Crisis

The crucial challenge of the Anthropocene is the challenge of preserving earth systems that are vital to human flourishing while continuing to produce the levels of energy needed to sustain the forms of social existence that have come to define humans. Established (industrial) ways of delivering electrical energy have promoted earth systems changes that are likely to push many societies over a tipping point of unsustainability in the foreseeable future (IPCC, 2014).

Our empirical examples come from the BASIC countries that are facing this challenge in extreme forms - needing huge energy inputs to "catch up" in development and suffering from the negative side effects of existing means of generating electrical energy.

The normative goal of this research is to be able to identify conditions that will favor pathways that will <u>enable a global transition to high-energy ecological civilization.</u>

As noted the crisis of the Anthropocene is a crisis of loss of civilizations; "loss of worlds". The crucial question for humans is not simply how can humans sustain the conditions necessary for their biophysical survival - although this is of course necessary. The crucial question is how can humans sustain their social worlds. The crucial question is how can we humans continue to produce the high levels of energy our civilizations require while sustaining the eco-systems that these civilizations need to sustain humans as biophysical beings.

6. Consumption and production are not the primary problems

The level of human activity (called production or consumption) in a society is not the fundamental problem, since the level of energy flowing through is not a constraint. The real problems arise through the damaging side effects that vary with the organization and technology used. Societies have fallen apart even on low levels of consumption, if the way they use energy is damaging (Diamond, 2005) and vice versa. Given a particular form of harmful energy production, the level of usage (consumption) is of course important, like in a coal-based industrial system, but it is not the key to understanding the challenge.

Stopping or reversing the general level of activity (called welfare, consumption or production) is therefore not necessary in a strictly logical way; this depends on the way energy is "produced". The key is the way it is done, not the volume.

This fact is often hidden behind ways of doing statistics (like Gross National Product (GNP)) that mix all kinds of activity together; both activities that damage and activities that heal or are neutral to nature, both living with nature and against it.

The gradually more precise focus on carbon energy extraction as a main factor in damaging climate (IPPC, 2014) also implies an understanding of this premise.

7. Knowledge and values

When it comes to knowledge and motivation regarding the climate challenge and its links to some forms of energy concentration and production, it becomes slightly more complicated.

The well-documented and simple fact is, however, that the problem of the climate challenge is accepted and the basic mechanisms of climate change are well known. Humankind is rightly concerned. There might be disputes or distrust with regards to the details (how much warming is happening, are the storms this year really due to climate change) but the robust answer is that people all over the world are worried and share a basic understanding of the climate change issue. As nature is never fully deterministic and always more complex than the models, science will seldom be spot on. It may seem like it has been very difficult to see how the effects of "warming" (=more energy stored) are divided between different practical effects such as higher temperatures, more extreme and more frequent weather events and ocean current changes. But the generally accepted attitude is more and more that we have a responsibility and should act and that the effects are already accumulating around the world. Surveys tend to show that individual people are willing to act and make priorities even if they are not fully convinced by the researchers, and this can be interpreted as a quite reasonable principle of being cautious and respectful. Governments and business, the institutional level, however, are not always prepared to accept that climate change requires action from them.

8. Our basic assumptions

The main problem to be addressed here is at the organizational/institutional level. The problem is that institutional patterns of action have a long half-life; motivation and required action at the institutional level always lag behind shifts in the contexts within which they operate. Institutions develop lock-ins that are very resistant to change. This is essentially Geels' point about regimes. Regimes get stuck in past contexts - they are very conservative. But they do change. And when they change they can change very suddenly, very rapidly and very radically, given that the new technological regime existed in a niche. One can move very quickly from one regime to another. Again this is based on Geels' multi-level analysis (Geels, 2004; Elzen, Geels and Green, 2004). In our context: the institutional setting from early 1900's (large, top-down structure based on energy sources that do not take sustainability or climate into consideration), but the same mechanism is also an advantage: when political processes and drivers for change reach their tipping point, the new pattern will be more or less self-propelled and hard to change.

The idea that "systems move" and "institutions resist" are mystifying generalizations that need to be filled with people that act. Change is linked to the will and action of people, often organized in nodal networks (Burris et al., 2005), that cross boundaries of institutions, or by people in institutions that do more, or different things, compared to their role-manuscript prescribed by the formal institutional setup and tradition. Transitions away from an old institutionalized setup are our focus and in these periods, networks, individuals, bottom-up politics and markets will usually be crucial, much more than in a steady-state period.

In the next part we will analyze the two important concepts of "institutions" and "values" and bring them together. And after that we will be more specific on electrical energy systems and case studies on the lock-ins and possibilities.

9. Actors and Values

a. *The respect for fire*

The practical skill of making a fire was not far from the commodified product "energy". It was an important personal skill learned in the family setting, it was life saving and comfort-providing and necessary. It is also linked to religious beliefs. This is not a tale from hundreds or thousands of years ago, it is still a necessity for many, and we all have some part of it. For many, the positive symbolism (and taste) of "real wood fire"-such as bread/pizza baked in wood-fired ovens and the Argentinian, South African (SA) and US grill tradition (braai in SA) and the symbolic coziness and religious symbolism in lighting a candle. The skills and proudness of making a camp fire or the importance of being able and trusted by the family to handle and have your own "primus" for camping kerosene cooking. This is only to remind us that energy is originally a tale of skill, personality, family, food, survival, religion, honor, socializing, tradition and good taste, more fundamental and established long before the construction of an energy market. Fire encompasses a range of values and is tightly linked to personal and family values. As does classical fire, energy itself supports values in different forms and is integrated into personal and family life.

b. *Governance and nature: Nature as value and the danger of commodification*

Even if there is a long and important line of religious and cultural (and even scientific) expressions for the positive value of "nature", we must discuss a few very important different perspectives.

The classic ideals of governance come with several different views on “nature”. The influential classic Greek elitism of Plato had a quite special construction where the ruling elite itself should be free from important aspects of their human character. Love, sexuality, emotions or children should be banned from the elite so they could have the virtue of pure reason. The whole Plato governance construct centered around a form of pure calculating reason that should be placed to rule from a point above “nature”. After the classic period, the centuries of Christian/Catholic influence had their own twist where the “rational men” were to be trusted as rulers and not women because they had more nature in them (and less “God”). Nature was created by God and should be respected, but also ruled by humans (men) by applying rules and reason. In the Renaissance, governance took a turn away from religion and became more of a way of acting and thinking in its own right. Hobbes’ construction of a mighty Leviathan (1651) that the weak and chaotic humans have in their interest to be ruled by is a little similar to Plato. Machiavelli advises on politics as a culture/art/craft that can be mastered and all are part of a movement away from both religion and the personalized king towards nation states ruled from a central point, applying reason and social power. In the debates on governance, morals and citizenship and their relationship to nature was also discussed. Some of the central actors, such as John Stuart Mill and John Dewey, (Selznik, 1992) pointed out that humans were in, not above, nature, and that the “untouched” nature was (therefore) not an ideal, nature should be seen in the perspective of value and relevance to humans. In the discussion Selznik (1992: 58) points out the damage that is done when rationality is used without the braking force of reason and plural values. This is an important point that the new "modern" rationality attempts to use the emerging sciences as a model for politics. Hobbes used physics and mathematics as the model for his political visions, mathematicians/philosophers like Laplace (1749-1817) and Quetelet (1796-1874) argued for a ruling system based on top-down mathematical/statistical methods (Hayek, 1955). The Hobbesian vision of a one-point ruling system above humans and nature merged with new sciences that had the promise of making this possible in a precise way that included ever more aspects of nature and society taken in under the governing system (Foucault 1978, published 1991). And then we arrive at governance in the age in modernity. Governance and regulation will be further discussed in the next part. First we will use a few pages on the relevant forms of thinking and the culture and actor-forming that is relevant.

In the age of industrialism, attitudes towards nature became more aggressive and one-sided; it was all about exploitation of resources and central planning. The (short-term) progress made was easy to see (Soviet Union, Nazi Germany). This is an age that still forms parts of our thinking and values, and also was the formation period of the dominant energy regimes of today: the technology, the structure, the popular raw materials to use, the computational skills, the mentalities as well as the distribution system and all its social fabric (Hughes, 1988). With electricity as an energy carrier; electrical grid-based energy systems became crucial to industrial growth; they became centralized and one of the main public utilities.

An old power station is a symbol of pride. Often it will have polished brass, copper and marble integrated in the technical layout and the building itself is designed as a temple of progress and prosperity. In paintings and pictures (good examples are China, Soviet-Union, US, Norway) the buildings and the high-voltage gridlines through woods and over mountains were presented in a glorious symbolic manner. It was man's victory over nature. This romantic and progress-oriented perspective is also today important (and reasonable) as symbol and value in poor countries. To be connected to electricity is the sign of progress in welfare, hygiene, education and family safety.

This modernity-type symbolism includes much more than electrical energy, even if electricity is an important and good example. The basic topic is the relation to nature in the industrial era. An important (1930's) critique came from the German philosopher Martin Heidegger (1977). He argued that modern industrialism created a way of thinking, a perspective that formed our value system with few possibilities of escape. This way of thinking makes nature appear very special: as a "standing reserve" for production. Trees are for paper, waterfalls for energy, soil for large-scale food production or metals, air is a source for fertilizer and so on. How to get the other values and the holistic soul of nature back into the human picture of nature? Heidegger thought it was almost impossible from within industrialism and searched for a solution inspired by the Nazi movement.

One specific aspect of "value" is the tendency to see it as money. With the modernity perspective of which Heidegger accuses industrialism, nature has no value *per se*, the only value is the one linked to its usage for production purposes. Even if early works of Karl Marx had a (for the time) good understanding of the metabolism of nature (Foster, Clark and York, 2010), his theory of value is linked only to the work that goes into the extraction and production. His analytical system (and his legacy) still remains a production-side value-system, where human work is the only significant value. This is also emphasized by Schumacher in his classical "Small is Beautiful" from 1973. There is a complicated addition that allows for a contribution to the owner of the land/resource, but our main argument remains.

This tendency for industrialized countries to see nature as a kind of free (and sometimes endless) stockpile of resources and recipient for waste is of great importance. We are not using the term capitalistic; the East European socialist countries had the same attitude to nature. The examples are many; one is that until the 1970's researchers and policy bodies in Norway believed that there was no connection between fishing and the actual amount of fish in the sea (Vartdal, 1975; Kolle, 2010)

But Heidegger is not only concerned about value as "price of extraction". It goes deeper, to genuine values, to the mystery, soul or spirit of nature and our lost ability to see it. Rachel Carson, by many called the mother of the modern environmental movement, was a biologist and her book (The Silent Spring, 1962) was mainly about facts. But in another work (The Sense of Wonder, 1965) she says:

> *To counter the "sterile preoccupation with things that are artificial, the alienation from the sources of our strength" it is necessary to cultivate a renewed "sense of wonder" toward the world and living beings. It is not enough to contemplate life. It is necessary to sustain it, which means actively opposing the "gods of profit and production".*

This is connected to the notion that the era of mass production also is the era of a special form of detachment, called commodification or alienation. It means that the background information and emotional links to products and its sources are gradually disappearing, replaced by calculation. We lose the attachment and the information and the emotional links to the production disappear: the place, the materials, the worker, the country and tradition. Finally, the goods become only commodities, with no known relevant qualities besides price and technical properties. And this way of seeing the world also gradually becomes the way we see each other, the society, and finally, ourselves. Naturally this is not only discussed as negative by philosophers (from James Mill in late 1700, with Marx and Freud as the best known) it has also been counteracted by many forces; from branding and history telling and personalization of products via authenticity (Taylor, 1911/1998) as a strong force in markets. The pressure from consumers for products with authenticity is easy to see in many areas. Organizations such as Slow-Food try to decommodify food from its industrial settings, using words like sensuality, authenticity, tradition and social quality (Petrini, 2007).

Again, electrical energy seems to be a very good example of a commodity resource. Electrical energy flows invisibly through cables and into our appliances at the flick of a switch and we have few ideas to its production, its toll on nature, and the people who do the work of generation and distribution. Electricity seems to be a fully interchangeable form of energy, being able to provide heat, light, cooling, movement; drawn from the electrical socket and manifested in the electrical device; as long as voltage and other technicalities are suitable for the device. Electrical energy is one of the most important and most commodified resources in modern life. Electrical energy as part of nature, as extracted and concentrated in ways that may harm the environment is not easily visible. Energy entangled in nature's processes is not easy to see. There are however a few authors (Paulus and Pierce, 2010; Murphy, 2007) that attack this perspective and argue for the possibility and necessity of linking nature and authenticity back into energy. One of the simplest arguments for this is that it will create possibilities for <u>responsible energy citizens</u> who treat electricity with the respect nature deserves.

There are already two practical tendencies in the energy markets that now can be seen as a small reversing of commodification. The <u>first</u> is the attempt by some producers to "label" and "brand" their energy in different ways. The simplest way is to guarantee that they only deliver sustainably produced energy and that their chain of production is environmentally friendly as it goes into the net. They can also, like other producers, make claims regarding their organizational behavior (Corporate Social Responsibility or CSR) and take values and nature into their electricity in indirect ways (one example is that the producer will guarantee contribution to rainforest support, according to energy purchased). So electrical energy is not only energy, it is infused by values and branded as such. The <u>other</u> process is connected more directly to the generation of electricity. More sustainable and decentralized technologies are being developed into deliverable products and also distributional markets are more decentralized and diversified around many technologies. Off- grid technologies (solar, mini-hydro, mini-wind, heat-pumps) make it possible for individuals, families, neighborhoods, islands, boats, lighthouses, villages, individual farms and cottages as well as companies to be self-powered with their own energy. This can also be blended into their grid connection in several ways, the simplest being that grid usage is only happening when there is need above the locally produced energy or (more complicated) if there is an excess of local energy production which can be exported into the grid. (To use external energy only when needed is quite simple and included in modern solar water heaters, to deliver excess to a grid is a bit more complicated, but is implemented in large scale networks in several countries, like Germany).

c. *Electrical power and decent behavior*

Like all other social phenomena, energy is linked to norms that fundamentally express values. In some cultures you don't leave the lights on, in rooms you are not using. This is deeper than the electricity bill; it is about the values we share and the codes for decent behavior.

Generally, the idea of the rational market actor has hampered our ability to see such value-driven fundamentals (Etzoini, 1988). Consumers cannot be understood from a generic private rationality-perspective alone (“Price matters, values decide"). Use of energy to make a “warm” welcoming home for guests in cold countries is as important as the habits of turning off as you leave the house. The values linked to sustainability gradually become built-in manners of decent behavior, both for individuals and companies. Recycling and waste sorting are going through such a process. Often such changes are too slow to be noticed or the analysts themselves share the values in a way that blocks this insight into them as something other/more than "the only way”. Foucault (1991) and Rose (1989) have highlighted the processes that build values into individual behavior. Daily-life values, habits, technologies and practices often show huge changes in a more sustainable direction, contrasting with more macro-oriented measures. Daily handling of waste, shopping selection of declared environmental-friendly goods and services and a respectful attitude to nature are easily detectable and often in contrast to large-scale factors like oil export and GDP growth.

In Burckhardt's (1860) analysis of the civilization process of the Renaissance in Italy, he is clear that the (self-) construction of a socially responsible individual was an important part of a process that made the whole society more decent and concerned, creating power structures that had to take a web of factors into consideration, and where even the Doge of Venice and other noble rulers had to rule according to the norms of decent behavior. This was replacing an earlier system where "The King is the Law" (*L’etat c’est moi*) in which the level of brutality was significantly higher. Norbert Elias (1994) makes the point from another angle about how rules of behavior gradually change into a more "civilized" pattern, where "civilized" means rituals and habits that may be seen as treating the world and each other more gently and respectfully. A relatively new contribution is from Rifkin (2009) that uses the concept of "empathy" and includes the biosphere. An interesting contribution is from Bruno Latour that invites us to see the bonds (network elements) between nature, things and humans as the basic relations of a governing network (Actor-Network Theory (ANT)).

For us the point is that habits and internalized values change and reflect underlying beliefs and considerations, and considerations of energy usage and its link to nature may be one of them. There are many organizations and public initiatives today that actually work in this area, classifying both levels and type of energy usage into areas of "decent behavior". In the corporate world the popular concept of CSR (Corporate Social Responsibility) is gradually replaced by CSV (Creating Shared Values) that remind us to see also the corporate world as actors with values, and values that can be shared and, as often is the case, represent popular and non-contested values of nature.

d. On the planet Dune

One of the most famous science fiction novels ever written is DUNE by Frank Herbert (1965). The DUNE series consists of several volumes adding up to around 4 000 pages from 1965 and was dedicated to dry land ecologists, who at that at that time formed a very small part of the science community.[3]

On the planet Dune, water is the really scarce resource that has to be concentrated, organized, saved, stored and circulated. The villain of the story is a high-technology culture protected in large spheres, using imported energy. They have all the traditional aspects of an industrial-modernist perspective on nature: They use technology to be protected from nature, living inside their high-technology bubble. The heroes, on their side, well aware that they are part of nature, have a set of values and traditions, as well as some selected, advanced technologies. All dedicated to respecting and handling water. The metaphor of dying is "to give your water back to the tribe". Water handling and respect for the planets' very limited water resources is the foundation of the civilization and is within all sub-parts of its social systems: Religion, hierarchy, family values, trade, and technology regimes. The ability of the heroes to respectfully be a part of nature is, in the end, the secret of their victory. This kind of story is of course repeated in later popular culture and the recent Avatar-movie (2012) is an example, where the heroes literally melt into nature and the villains are high tech-protected exploiters. For our purpose it reminds us that governance and its roles and actions are rooted in ways of thinking and in organized daily-life value systems.

e. Energy citizenship

The classic notion of "citizenship" is changing. It used to be linked to nation-state duties and rights, especially in the formal political system. But individual freedom and resources, as well as the changing character of nation-states, have created different citizens' identities and initiatives in many sub-areas (Isin and Wood, 1999). Citizenships, responsibilities and actions are formulated and socially created around platforms of race, sex, gender, consumerism, environmentalism, food, and (of course) energy. They are platforms for formulations of values, rights and interests, making organizations and actions emerge and forming individuals' minds. The struggles of indigenous people are examples, as is the gay movement. Food as a platform for citizens' responsibilities and actions were clear already in the early years of the role of housewife (also linked to the science and education in "home economics"). Linkages to traditional politics were made through campaigns for saving resources, reducing imports and more generally, educating new responsible citizens in food-related areas. After the era of the housewife, this citizenship was no longer connected to a personalized role; it became more generalized and was gradually linked to broader social values. The big range of food-related organizations (farmers, processors, distributers, sellers) are increasingly taking up topics such as fighting industrialization (=commodification), health considerations, environmental and climate responsibility, diversity and culture as well as minority interests and fairness for developing countries.

Energy citizenship is only in its beginning. The concept has also (in the US) been used by big oil companies pushing the interpretation as "the right to energy". But mostly the idea has been linked to the responsible energy behavior that takes the environment into consideration and there are some examples in the literature on the conditions for developing such a citizenship role. Responsible energy behaviour can be seen as an arm or a further development of "Consumer Citizenship" and its conceptual cousin "Political Consumerism". Consumer Citizenship is a common concept that covers school education, international Non-

[3] The movie (1984, by David Lynch) is not recommended in our setting, as it concentrates on the "war- and action" aspects of the story.

Governmental Organizations (NGO’s), governmental initiatives and a substantial stack of literature. Our general argument of taking responsibility and linking to values of sustainability and nature is very clear. Citizenship development depends on the ability to have a choice, make a difference, to take responsibility and that again requires market possibilities and information on consumption and the consequences of the consumption. Technologically this also points to energy monitoring devices such as "smart" meters and the organization and information capacity of organizations (often NGO's, but paradoxically often also the sellers/producers of electricity).

The biggest users of energy are companies (50-70% of total). They are also actors (organization-level citizens) and including energy in their CSR/CSV work (even sometimes the using energy citizenship concept) is becoming more common. The fact that companies are the main consumers of electricity must be taken into account when actions and changes are discussed.

Also parallel to the food citizenship is the (anti-commodifying) process of shortening the social and geographical distance between production and consumption. The popular example is the growing “farmers’ markets” and the Slow Food movements. This puts producers more directly in contact with consumers. The result is information and knowledge on food as nature, discussions on how to prepare food, the values included and how to grow etc. Consumers will become more proficient at producing and more selective about consumption, and this will impact their own activities, leading to the phenomenon of the prosumer (Toffler, 1980). The concept is a combination of “consumer” and “producer” and is used for describing consumers that are engaging seamlessly into the producer role. This can be seen in the rapidly growing popularity of many kinds of urban food production, examples are the renaissance of school gardens and allotments, as well as farm holidays. For the energy sector this will emerge as the gradual mobilization of consumers from active consumers to co-producers (prosumers) of energy, both for their own consumption and for delivering to the grid (limited by their private usage, their company needs or and access to a smart grid). Parallel to the food sector, there is a gradual development from increasing responsibility and economy in the home, to more neighborhood and political-type action and even involvement in (alternative) production. Energy is becoming linked to nature and establishes a platform for consumer actions and even a role as an energy citizen. This role is one of the most important drivers of change, given institutional and regulatory opportunities.

f. The weak consensus values

What kind of political value is in the link between nature and energy? We stated earlier that the value was more or less consensual: It is not seriously contested. We will probably have no political parties that state clearly that they oppose taking nature into consideration regarding electricity generation. Quite the opposite, at symbolic levels most companies and actors pay tribute to these values. Even British Petroleum (BP) tried to explain their name as meaning "Beyond Petroleum" and both Shell and Norwegian Statoil are advertising in newspapers about their commitment to clean sustainable energy. In our daily shopping life, there are tens of thousands of declarations, markings and claims on all kinds of products and services regarding sustainability. Also popular culture has changed, categories like Eco- thrillers and Climate-thrillers are now quite common. Even the famous Matrix (1999) movie-trilogy started with energy for computers being unavailable due to human-made climate change and the need for new sustainable energy sources. Surveys also underline this culture of being concerned and taking nature seriously.

So why do we use "weak consensus values" in this section heading? In this discussion, we focus on the institutional level. The basic and traditional party structure of most industrialized countries was made around the material interests of production (workers, owners, farming, fishing). There are exceptions and they are growing in number (green parties), but the primary political structure is still evolving around production-side interests. Around this political structure there usually is a system of strong organizations that are represented in committees and formal negotiations. They are even more marked by the production- side bias. And more and more there is a system of paid lobbyists strongly representing the owner side of production systems. Many lobbyists are people with green values like others, but in their work they are bound to their institutional roles of promoting their organization's particular viewpoint or product.

It is a relevant observation that this logic not only applies to values of nature and climate; it also applies to development, nutrition, health and peace. They are all rooted in social consensus, but may be at odds with the structure and values of the formal political power system and its implementation bodies. Again, this could be seen as more or less reasonable when knowledge of damage to nature was missing and benefits of economic growth was easy to see in health and living standards. But now these common consensual values seem to become a dramatic problem when they are rejected by institutionalized power systems. There is, however, one positive side of the consensus-logic: it seems to be like a "ratchet", that is moving forward in small and largely irreversible steps. Values like nature and climate, have a good media potential, and they will gradually change practices; again the example is the myriad of small, daily life habitual changes, in new regulatory rules, labelling, the application of criminal law to environmental damage and in the emerging international negotiations (e.g. COP21 and the Paris Climate Accord).

Our task is to look for openings and configurations that link individuals to institutions in ways that makes change possible.

10. Governance, Regimes, Regulations and Institutions

a. Governance

The discussion of governance in the previous section ended with a pessimistic discussion of the problematic merger between Hobbesian centralism and industrial modernity hubris that lead to commodification of nature among other problems. This has been analyzed critically and it was found that attitudes have started changing, practically and also at the theoretical level. The popularity of the term "governance" that replaces "government" is a good indication, "governance" pointing to the loosely composed set of actors and systems that govern. The classical government is one of the important parts in such a system, but it is open and empirically defined, and then also open to multitudes of values and actors.

b. Governance of nature

This is not the place for a lengthy discussion on the character of governance activities towards nature and the trends in change, but two different and classic studies of forest governance will be discussed before we continue to more energy-specific topics.

All trees present and accounted for… (James C Scott: *Seeing like a State: How Certain Schemes to Improve the Human Condition Have Failed* 1998).

Scott's book has a strong theoretical argument in the Hayek tradition of explaining how a central authority (state) must simplify and standardize in its governance; they have to "see" the world in a special way characterized by standardization, simplification, accounting procedures and statistical techniques of averaging. And because of this tendency mistakes are made, especially when dynamic processes and pluralism are involved (like nature). Scott has his background in political science, anthropology and agrarian studies and his examples and case studies in the book are mostly from large-scale attempts to govern nature. One example is from Germany in the 19th century and is also a good illustration of Heidegger's point. It is the attempt to centrally and rationally govern the forest as a production system for wood. The best way from the state perspective is to line up the trees in rows (to allow easy counting and control procedures), to ensure they are as similar as possible and to minimize all other life forms that might disturb the process. Then it is possible to calculate production, plan the tree felling and have a rational plan for the usage of the wood, with very precise information on volume and quality. This was (and is) not so special; it is used by most industrial farm-/plantage- like enterprises. It is the long-time frame for Scott's study and the forest as a complex natural system that clearly shows that probably this strategy was not optimal. It was a kind of success in the short run, for the first few (2) generations of trees. But for all other usages of the forest and in the longer run it was a disaster that exemplifies very well how the industrial/centralized way of seeing like a state is ruining nature.

The forest becomes complicated… (Kaufmann, 1960; Tipple and Wellman, 1991).

Herbert Kaufmann's *The Forest Ranger* (1960) is a classic study in political science, about the role of the governing agent of the forest. For us, one of the main point points is that the stability, unity and success of the forest rangers are being made possible through two factors. One is the relatively limited scope for the "governing" forests, maybe "protecting" or "inspecting" are better words for the set of relevant goals with efficiency and economy as keywords for the internal life of the system. The other is a structure of freedom and fragmentation at the bottom level, leaving the individual forest ranger with broad possibilities for adaption to local conditions. Thirty years later, his study is re-analyzed by Tipple and Wellman (1991) in *Herbert Kaufman's Forest Ranger Thirty years later: From simplicity and Homogeneity to Complexity and Diversity*. One of their main observations is that Kaufmann could see the policy goals for natural resource management as stable and simple, in accordance with the limited scope of governance and the lack of conflicts in this area of politics. Thirty years later the environmental movement is an independent political force, the indigenous groups are organized and have relevant interests, the tourist industry is reaching into the forests and generally the list of values and interest to be taken into account is not only significantly longer, it has become unpredictable and unstable. Not only has the forestry system grown more complex, containing ever more shifting values and interests, but in addition the evolving scientific premises are being led by new sciences of ecology and climate. The structure of policy implementation has changed from a simple hierarchical system to a complex system of representation, negotiation and responsiveness. From a hierarchical government implementation system of limited scope to a system of governance to be interpreted, created and handled at the local level.

Together these two contributions to understanding "governance of nature" highlight both the problems of the centralized simple implementation of a production-side perspective on nature and the challenges of the more complicated modern shifting multi-stakeholder governing systems, highlighting the many different human roles and interests that relate to nature. Just a few decades ago, energy production was almost only engineering and economic matters. Now major energy projects face a long series of possible considerations relating to an ever more complicated knowledge of nature, indigenous groups, agriculture, fishing and forests, tourist interests, aesthetical considerations, evaluation of electromagnetic fields and their possible harm, district interest and (if nuclear) a time-frame of thousands of years. Most people today will accept that this is about values and politics linked to a wide range of different skills and knowledge, while the common attitude in 1960s and 1970s was that energy projects were simple engineering/economic matters.

c. To govern and regulate public utilities

Energy systems are both very relevant for nature and a central public welfare utility. At least from the Roman era, public utilities have been at the core of state responsibilities, or we could go further back to Egyptian irrigation systems. They have been owned, maintained, organized, used and paid for in many ways, but the responsibility and initiative have always been at some governmental level. The governmental responsibility is normally built into laws that give public bodies special monopoly or regulatory powers and duties. The areas have been infrastructural services like water supply, sewage, waste handling roads and canals. Urban development brought these infrastructural elements more into relevance and modernity and technical progress added new elements like railways, gas distribution and several forms of electricity as well as more sophisticated services linked to planning and administration. The special aspect of electricity usage, both as energy (our interests) and communication (from telegraph to internet), is that it starts when modern industrialism and modernity starts their rapid growth and is built and institutionalized in the era of high modernity and industrialism, infused with these values. There is one important difference between electricity as energy and electricity as communication. Electricity as communication went through a dramatic period of reorganization, decentralization and technological change from the 1980's with personal computers, mobile phones and the Internet. The traditional physical copper-wire grid is no longer necessary for telecommunications; national monopolies are difficult to defend and many countries in the developing world can leap-frog the level of a physical grid and go directly to internet/mobile structures. The idea that electricity energy systems stand before a parallel revolution is important to consider. Decentralization, standard-setting to replace direct central command and a series of new technologies with the capability of downscaled energy production, from solar cells on mobile phones and lamps to wind and solar systems on houses to local area-based hydro-electrical, wind, wave, solar or biogas generation technologies. This is the direction of the technological possibilities that opens up. Utility-scale, grid-delivered electricity costs are not decreasing, while most of the small-scale electricity generation systems are becoming more economical and these technologies may profit from the advantages of electronic mass-production that drove the computer and mobile phone revolutions.

Electricity systems emerged in most countries as small-scale private and local public initiatives, but were soon to be transformed into huge centralized, state-regulated systems, driven both by economies of scale and by general trends in governance and state development. The steep rise in electricity production in the first half of the 100s facilitated and was caused by the growth of heavy and concentrated industry, further emphasizing large plants and grids. Municipal ownership of electrical plants is as old as the industry, both the first municipal and the first private plant in the U.S.A was built in 1882, thereafter there was a steeper growth than for any other utility area for around four decades (Thompson and Smith, 1941).

It is important to note that even if public utilities can be built, owned and run by private enterprises, the basic responsibility for their existence, functions and price lies with the state (Thompson and Smith, 1941). In some countries the main part of important public utilities has been privatized (like electricity in the US in the 1930's), but they are heavily regulated due to their role as public utilities *".... by legal definition, they are vested with public interest and perform a public function even though privately owned"* (Thompson and Smith, 1941: 600). As explained in traditional (=not neoliberal) economics, this is due to at least three arguments: 1) the service's nature is critical to society (=the "public utility argument"); 2) the service being a "natural monopoly" in its nature and 3) the combination of huge up-front investment and low unit costs in production, making both investment and production vulnerable and in need of regulation for protection. It is important to note that the final responsibility is political: this necessitates a very special regulatory regime for electrical energy supply as a public utility, even more so when we take into consideration that public ownership and/or special granted money are involved in most of the large electrical energy system projects (and 100% if they are nuclear).

d. Regulation

Regulation, in our context, can be seen as the use of power systems (classical: state power) that ensure that (market) actors are acting in a way that is socially wanted.

Regulation is one of the oldest and most efficient ways of changing behavior. In its classic form it emanates from single-point holder of power that makes rules in order to regulate (market) transaction, procedures and individual conduct. Most classic textbooks put the logic of regulation into a market society. Regulation is about making rules to ensure that the output of the market is within socially acceptable limits. In recent years this one-way, state-centered perspective has changed (Braithwaite, 2008) into a more dynamic and multi-centered perspective that provides a wider map of regulative relations that has many actors of many kinds (state, regions, companies, independent classification and certification organizations, NGOs, etc.) on several levels (regions, nations, international, global, sectors, value-centered) with a large toolbox of regulatory techniques. At the heart of regulation is the shaping of motivation-incentives so as to reshape patterns of action at both individual and organizational levels. Since state regulation in the electricity sector is usually old and institutionalized, the modern marketization reforms usually building upon older systems of knowledge and regulation, often even more so than in the case of the producers, it is important for us to identify the web of different regulatory forces and even nodal networks. Regulatory incentives are often seen as the best way of changing a market, creating the necessary opportunities for the changing (even game-changing) actors. One example is the tariff systems that make production of wind energy profitable for investors. The regulatory web is bridging between actors in the market, both producers and consumers on the one hand and the institutionalized systems on the other. The fact that these divisions are not clear-cut adds to their importance as dynamic possibilities of change. The situation for the regulation of electrical energy production is unique in many ways: More often than not energy sources and production facilities are publicly owned, and even more often the sources are seen as national natural resources that need special protection and rules. Technically, energy production needs a standardized distribution system that reaches the final users, creating a chain of interdependent systems that form the whole electricity sector. Again this can be organized in many ways; traditionally many countries used the basic division between levels of public administration, that is, from state via regional to local authorities. Since the strong belief in the central state has changed to a strong belief in markets, the organizational setup has changed so that some element of competition is possible at some points in the system. These systems have all the hallmarks of public utilities, and natural monopolies and present many structural challenges to multi-supplier systems. As a result the regulatory regimes are rather complicated and often involve the state, state-owned enterprises and state initiated regulatory bodies. Only small sections of the system resemble the traditional setup of a “free” market overseen by a state-initiated regulatory body. In this complicated landscape there will be regulatory and institutional lock-ins that block change as well as islands of opportunity that could be used by new actors and new technologies. One example of such a lock-in is the South African system where the monopoly of the regional and local authorities are combined with the consumers dependence on electricity into a convenient way of generating revenue for the public sector[4]. An opposing example would be the free market for solar water heaters and solar photovoltaic (PV) panels on private homes that are not accessible by regulators, but that can be subsidized and (for the solar PV panels), connected to smart meters systems and included in the grid structure (as in Germany and many other countries).

e. Regimes

From system dynamics (Geels, 2004), the concepts of a socio-technical landscape is of great importance, especially because it reminds us of the inter-linkedness of technology, organizations and people. Within a technological landscape there are a few (dominating) regimes that represent a technology and its embeddedness in the society. Other technologies may be possible and exist in niches. The challenge of working with change is to understand the conditions for turning a niche into a regime and dismantling an old regime, hopefully not as a result of a destructive/disruptive crisis. These concepts are important, but as we see it, they will not by themselves explain changes. That needs the inclusion of actors, through democracy and citizenship on

[4] In Norway the Court system ruled that it was not legal to use electricity prices as a kind of tax income for municipalities. But it was allowed to sell an electricity company (for profit). After this decision local government bodies sold off their electrical utility companies. One effects is that at least this kind of lock-in is avoided.

many levels, through consumer action and market dynamics, and helped by regulatory means. As such change needs actors that connect and act outside the paths laid out by institutions, often nodal networks can bring niches over the tipping point and into new (more sustainable energy) regimes.

f. Energy regimes, in the eyes of a modern state

The way a society is organized structures the way a problem or aspect is seen from the point of view of decision-making actors.

For a long, and important period of time (the first and second industrial revolutions) energy has been produced through a few technologies that have produced power centrally and then distributed it through a centralized grid. This arrangement made rapid and significant "progress" possible. However, gradually the cost of this "progress" was that it restricted the ability of humans and institutions to imagine and realize other more sustainable possibilities.

Indeed these alternatives became viewed as either problems or as irrelevant. An example is the energy crisis in South Africa – where the problem-solving energy alternatives that are structured by the existing grid and the pressure to provide "energy security" took precedence over other solutions. The consequence is that other possibilities are either overlooked or rejected if they do not support the existing coalition of interests of producers, government systems and consumers. The old institutional setup in production, distribution and consumption has created systems of learning and handling that support these systems and have created series of organizational and mental lock-ins that make new directions and solutions seem "impossible" or "too expensive".

Through the lens of state institutions, the energy landscape may seem simple to describe due to its relatively centralized and standardized character, however this view fails to see the underlying opportunities for considering alternatives. For us, the most interesting parts are in the niches, where possibilities for change exist.

g. New energy regimes: Multi-sourced, decentralized

The problem with the structure we have now is not only that most of the existing energy production systems use technologies with high levels of carbon (CO_2) emissions. They also have problems that derive from the huge size of their production facilities, expensive grids and very complicated storage and reserve facilities.

The new technologies that are already functioning in niches have become innovative in two related areas. Firstly, new possibilities for new sustainable sources have been revealed. Many of them can be up scaled and downscaled in size and will therefore give possibilities of decentralization and flexibility, across the whole system. Secondly, there are new niches in grid development that are facilitating prosumer (se section 6.5) developments. Regional organization and multi-center systems are emerging. As mentioned above, the computer network revolution might be a good parallel for what is happening in energy systems - that is the death of the system with few mainframes, passive terminals and huge central grids evolving into a system of almost endless and flexible number of units linked into self-structuring nets ruled by standards more than by command-and-control regulation.

h. Institutions

Institutions may be seen as sets of rules and values that are guiding actions, putting values into actions through routines, Power, values, interests are attended to without the day-to-day struggle or discussions. Most of our political institutions were cast (infused with their values) in a time where growth, industrialization, mass production and general measures of "welfare" were on the agenda and before the costs to nature and hence the cost to our own fundamentals became known and created an opposing political force. And these political systems did well. Linked to the construction of national states we got the centralized way of seeing problems of society. This is an era of huge and important discussions and conflicts, but for our purposes two main hypotheses are used:

In a way, we can say that institutions are taking on a life of their own, leaving the actors and conditions of their formation period behind. Most of the time this is good, since we can grapple with a problem, develop a solution, create an institution, go to the next challenge, and the running of the system only needs actors that perform according to their traditional roles. But when the task or the knowledge or the technology changes, this fundamental ability becomes the problem. The basic institutions of energy supply belong to the era before the environmental, sustainability and climate challenges and before the series of technological niches of solar, wind, waves and heat pump energy became usable technologies.

As these institutional assemblages emerged they were tightly coupled to the construction of nation states. As this happened, a centralized way of seeing problems of society – (like in Scott's (1998) *Seeing like a State)* - emerged.

The classic mental picture of a modern institution is as often as a "governmental body", where values and practices and power is linked to tradition, law and democracy in a package of governance.

But values can be infused and changed into habit and routine in other ways. One of the classic ways is through the agency of religion or basic beliefs and values. The Jewish tribe of the Old Testament was a classic, nomadic society. Most of their rules and administration needs were done with a minimum of institutional bodies, most were handled through religious beliefs: sexuality, family matters, food practices, and hygiene. These values were built into the backbones of the citizens and socially enforced on all levels.

The successful handling of climate challenge in Dune (see above) is also an example. Some high technology solutions, some tribal rules, some religious influences, coupled with some charismatic leadership; all built into a fundamental respect for the planet and its water. The point for us is that values can work in many ways, and that our form of modernity with heavy reliance on formal administration is not the only way to go, or more precisely: not the only way that is in action.

Most modern societies have strong channels between individual values and policy. We will be interested in the importance of democracy and its citizenships and markets as such possible means, and the markets contain both companies/entrepreneurs and consumers and some important mixes between them.

In a more general way we can say that organizations and (socially fabricated) systems must be seen as actors (or actants) in themselves (Latour, 2005). For us this is easy to see: A huge power plant will require a grid, many competent people, an administrative body for distribution to many customers and linkages to many sets of actors who must have certain skills. More than that, it will invite and maintain a set of experts and knowledge systems. These will be good at running a centralized energy system, and equally suspicious of and uncomfortable towards other solutions. In many societies (China, SA) this way of delivering electrical energy became tightly connected (both as symbols and at the practical level) to the project of national production growth, and welfare and consumption. Historically this was especially evident in the Soviet Union where engineering, huge power plants and (metal) industry were seen as the main driving forces of progress and became the symbol of the victorious revolution and the new society.

11. Path-dependency and government regulations

One theoretical tradition that is useful for our discussion on institutions, power and actors is the theory on path dependencies.

> *"The message of path dependency appears to be simple: once you´re on you probably can´t get off." (Meyer and Schubert, 2007: 24)*

Within the theory of path-dependency there are different theories and suggestions as to how the path actually occurs and evolves through time. Time and "history matters" will be central, but also the ability of different actors to shape and create the path. These actors could be powerful actors like government, industry or public groups.

"Path-dependency" is described through theory in many different ways. Some researchers say "path-dependence" refers to the case where history matters (Mahoney, 2000: 507), others claim an adequate definition is rare or hard to find (Pierson, 2000: 252). Path-depending process is used increasingly to explain the emergence of novelty (Garud and Karnøe, 2001). Social scientists do distinguish between the two important terms "path-dependence" and "path-creation".

In a path-dependence process, it is claimed that early stages of the path will be most critical for the development of the path.

The figure presented above shows three phases.
(1) from the start of a path-dependence process;
(2) emergent of the path and,
(3) the lock-in phase.

The process starts with many different possibilities. By making some choices in Phase 1 the range of available options is narrowed. In the beginning of Phase 2 the emerging of the path could be seen, and at the end of this phase the path becomes clearer and clearer. When Phase 3 is reached, the availability to select other options is lost. As Jörg Sydow and Schreyögg (Sydow et al., 2009: 692) explain, the flexibility is gone and businesses or regions are restricted to certain choices or action patterns. At this point the "lock-in" occurs.

It is anticipated that path-creation is not that unlike a path-dependence process. Both are based on the same assumptions that the technological development is embedded historically, the path might stabilize and if it does it is difficult to reverse it (Meyer and Schubert, 2007: 26). Uli Meyer and Cornelius Schubert (2007: 27) argue that there is a problematic simplification with the classical path-dependency concepts. The simplification could be addressed by highlighting the deliberated aspects in path creation:

1. *Powerful actors can strategically influence the development of a path. They can shape the path, while over time they are themselves shaped by the path.*
2. *Increasing returns and lock-in are subject to deliberate actions and tied in with broader social dynamics.*
3. *The creation, but also the ending of a path may be caused by deliberated actions which do not necessarily have to be external.*

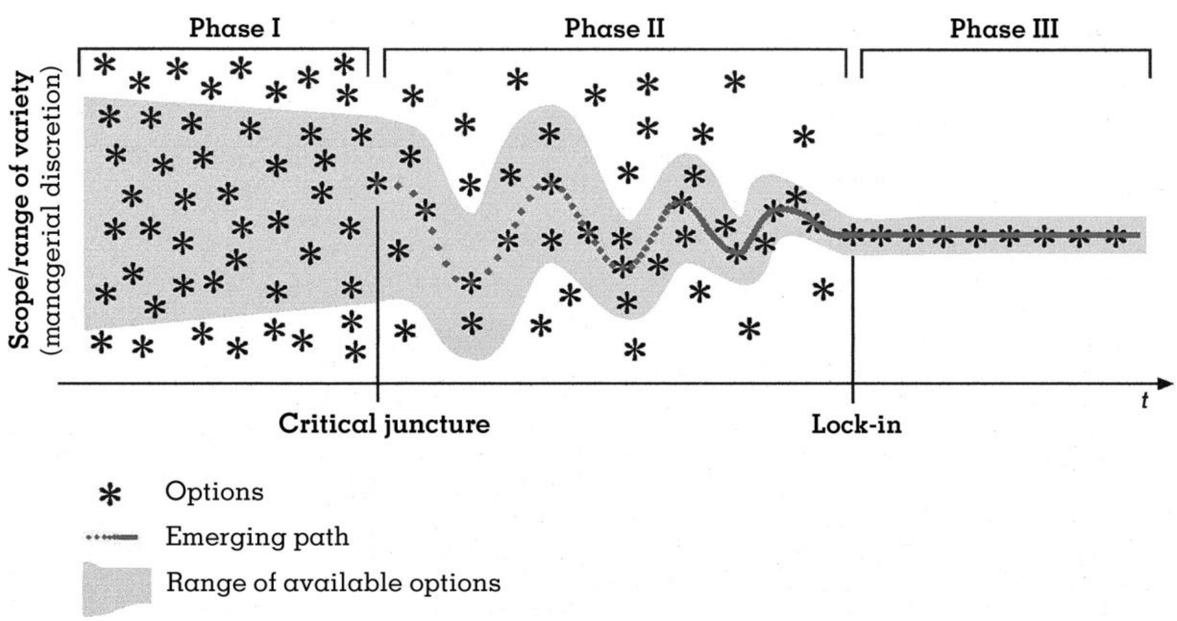

Fig. 1: A path develops and locks in.

Path-creation on its own is insufficient to describe how a path evolves after it is created (Meyer and Schubert, 2007: 27). The path-creation processes is set in motion by entrepreneur in real time. The aim is to shape institutional, social and technical facets of an emerging technical field (Garud and Karnøe, 2001). By understanding path creation, it could be possible to understand how entrepreneurs escape from technological lock-in (Garud and Karnøe, 2001).

The Master's thesis "Wind power success in Brazil" (Persson, 2015) has used the path-dependence theory to explain how and why wind power technology and production during the PROINFA-programme (Program of Incentives for Renewable Energy) (Persson 2015:9) was lifted out of it niche-character. In November 2014, Brazilian companies managed, through energy auctions, to provide wind-generated electricity at prices competitive to those from hydropower and non-renewable sources. Persson (2015) concludes that the government policy to create a new energy path for renewable energy – path creation - was a necessary institutional action to reduce risk for investors. He discusses three possible explanations for the Brazilian wind-power success. New technology and entrepreneurs looking for profit were not sufficient factors for explanations. Lock-ins of energy production paths had to be opened up by a governmental actor as well, pointing to the general important role of governmental regulation in the energy sector (Persson, 2015: 85).

12. Summing up, focusing on factors that press for change

Our research topic is to understand the dynamics that will change the electricity energy system towards sustainability, narrowing sustainability into harmful climate impacts. In this section we will list the factors we have discussed, classify them and group them together into clusters, underlining the fact that most changes have more than one driver.

The first of the group of factors is general in its character, explaining possible reasons for change. The first and most fundamental is **the Anthropocene**, the fact that we as humans are influencing/making/destroying our habitat and are aware that this is the situation and that this should fundamentally change our ideas of and our abilities to effect change. We are reconstructing ourselves as Anthropocene actors. For energy this is narrowed down to the harm that is done by the burning of fossil fuels and hydrocarbons to extract energy and emitting huge amounts of CO_2 and other greenhouse gases into the atmosphere. Energy production is the most significant single factor that harms the climate through CO_2 emissions

The second factor is closer to our own health and short-term damage; it is about more **local pollution factors**. This is most visible in China and in some local areas around production plants, but is certainly visible and creating attention and direction.

The third factor is linked to a general consequence of modernity; **commodification,** that means that goods and services production become disconnected from the producing forces of nature and humans become anonymous and generalized, like electricity in the grid. Since the start of modern industrialism commodification has created several kinds of discomfort at the human and cultural level resulting in a longing for the personal and authentic and the responsible role of the actor-citizen.

The fourth factor is **technology development** that continuously widens the menu of possible solutions. In the energy sector these are many and will continue to be developed, due to the nature of energy as: 1) not a finite resource, 2) embedded in the fabric of the universe in so many ways. The developments may be theoretical/experimental (like nuclear fusion), developed as working prototypes (like Nuclear Generation IV), developed into real-life technologies (like wave energy and Concentrated Solar Power) or on its way out of the niche into a sociotechnical landscape of its own with mass-production and predictable pricing (like conversion to hydrogen using renewable energy from solar panels and wind). To these production technologies we must add developments in grid technology in the direction of grid intelligence and decentralization. In all cases these are possibilities that create awareness and direction for change. But which technologies become dominant, alone or in combination, will depend on many factors that create new paths. Too much literature in this field is a bit limited by technological determinism, that something must happen because it is possible (one important example is "J. Rifkin (2002), The Hydrogen Society").

The fifth and last factor we will discuss is linked to **grid-based electricity production/delivery problems**. Dependence on electricity becomes more significant, especially in urban areas. Electrical security is part of civilization. This security may be threatened by production and grid reliability crises (as in in South Africa), by more complicated and vulnerable communication and grid-loading infrastructure services and new developments in power usage (like electrical cars and induction stoves).

Pressure for change is created through actors and combinations of alternatives. Three examples are easy to observe:

1. The very visible and dangerous air pollution in China goes together with Anthropocentric consciousness (Circular Economy, Ecological Civilization (Xi Jinping 2014, Geall/Hilton 2013)) and manufacturing profitable possibilities (wind, sun) (Mathews 2015)
2. The electrical supply-crisis in South Africa goes together with commercially available new technology (solar, wind, batteries) and Anthropocentric considerations have resulted in pressure to change;
3. The anti-commodification cultural trends among consumers fits well with new developments in decentralized electricity production and smart grids, in some countries also linked to Anthropocentric values.

So far we have described awareness and possibilities for change. But will change happen? And which possible (combination of) developments will make new paths and change institutions to a new change-resistant pattern? This is of course a complicated guesswork of motivations and possible paths, but some elements seem to be crucial. Involvement at the political/regulation level seem to be of special importance for electricity for several reasons. Energy supply is linked to welfare and civilization in a way that makes it a core public utility. For whoever is responsible for the production of electrical energy it becomes a political task to ensure that adequate energy security exists. Energy production and distribution also have some special properties that call for regulation and protection. The classic form of centralized production is extremely loaded with big up-front investments, long implementation times and low running costs. This is a classic recipe for market failure if there is no protective regulation. The new decentralized and sustainable sources may benefit from market-based mass-manufacturing and consumer demand, but they also need external support to reach a tipping point of cost, volume and standardization. Herein the case of many renewable energy technologies the running costs are so low that the risk of race-to-the-bottom price wars is high, which might make these ventures financially risky. As it is for telecommunications, connectivity and standardization depends on regulation. There are also safety issues with distributed and autonomous sources of energy. The role of regulation can also be seen the other way around: How existing regulation is protecting old patterns and blocking changes. This happens by having been created to serve the old structure/ so rules, routines and culture are not adapted to the new energy sources. And also by regulation actively blocking alternatives because of vested interests that make new technology appear as a threat to the old systems and the sources of revenue they depend on. Regulation can thus both create lock-in loops and doors that can be closed or opened to change.

To end up with an optimistic and possible pattern of possible change, the following chain of events may happen so that a new sustainable energy socio-technical landscape will be the normal path:

Anthropocene responsibility will be a factor on many actor levels (politics, companies, citizens) that fit with new and more decentralized and sustainable ways of energy production, storage, distribution and consumption. This also fits well with the tendency for modern consumers to want a clearer actor status with less commodification. These forces are helped and formed by regulative skills and structures so that the new systems pass the tipping points and become the new mainstream. The material and immaterial structures of the old industrial modernity will be left to creative destruction, propelled by its destructive effects of pollution, climate damage and lack of adaptability to energy demands in developing countries. The old will give way to new forces and on the way create opportunities for energy citizenship and production that are sustainable and non-destructive.

What will be the energy scenario of this development? The possibilities are many, but there are some clear directions that point to a more decentralized multi-source production and co-production, supported by a more bidirectional and communicative grid management as well as better off-grid possibilities. The sustainable sources of wind and sun are already as cheap as the old technologies, and faster in implementation. Their limitations of intermittency are linked to the rapid development of storage technologies (batteries and hydrogen) and some prevailing large-scale plants of old technologies. Many factors press in this direction. This scenario is one of many, its only purpose is to be part of argumentation discussion that, in short, is saying that the special energy regime of industrial modernity can be changed for an energy regime that is fitted for a post-modern and Anthropocene-conscious era.

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Энергетическая цивилизация через промышленную современность и вовне

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Краткое изложение: Трое из авторов (Дженсен, Ширинг, Скауг) находятся в основной группе проекта SANCOOP: Переход к устойчивым энергетическим системам в странах с формирующейся экономикой. Это Сравнительный Проект, сфокусированный на Южной Африке, финансируемый советами по научно-исследовательским работам Норвегии и Южной Африки 2014-2016 гг. Вовлеченными странами являются Бразилия, Китай, Индия и Южная Африка. Данный доклад основан на теоретических дискуссиях в начале проекта и некоторых предварительных впечатлениях от наших интервью. Энергетические системы приобрели новую актуальность. Энергетические системы, в которых преобладает электричество как компонент, являются основным "ингредиентом" в формировании передовых цивилизаций на основе промышленности.

Эти энергетические системы являются теперь главным участником, который угрожает разрушить их. МГЭИК (2014) объявил, что производство электрической энергии (особенно уголь) являются основным фактором изменения климата. Посредством производства энергии люди теперь способны разрушить основы природы их цивилизаций; мы живем в эпоху антропоцентризма. Доклад рассмотрит отношения между человеком и природой через энергопотребление. В начале, энергопотребление было, главным образом, местным, даже семейным, требующим мастерства и усердия.

Поскольку энергия сама по себе не является дефицитным ресурсом, проблема источников энергии, организация и учреждения оказываются в центре внимания. Мы будем обсуждать перспективы и практики по отношению к природе, что пришли с индустриализмом, новыми силами управления и как результат огромными электросетями и большими электростанциями.

Изменение климата является фактором к изменению. Другие факторы являются культурными по своей природе: вековые учреждения, специализирующиеся на производстве энергии являются развивающимися проблемами изменения и обучения, но они по-прежнему остаются влиятельными. Потребители начинают участвовать на обычных рынках по-новому, а также граждане, потребляющие энергию, и со-производители энергии. Развитие технологии и структурные изменения указывают на меньшие масштабы, гибкость и децентрализацию производства энергии. Эти факторы работают вместе и развивают новые ниши производства энергии, и многие из них приближаются к переломным моментам становления основными производственными режимами. Доклад завершается обсуждением участников, формирующих новую систему, включая потребителей, таких как граждане, потребляющие энергию, и возникающих важнейших новых нормативных задач.

Investigating urban sustainable energy policies in Europe: Experiences from the Covenant of Mayors

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Abstract

Local governments play a crucial role in reducing GHG emissions. In order to endorse and support the efforts of local authorities, in 2008 the European Commission launched the Covenant of Mayors (CoM). Covenant signatories commit to reduce CO_2 by at least 20% in 2020, to prepare a Baseline Emission Inventory (BEI) and to submit a Sustainable Energy Action Plan (SEAP). The BEI is a quantification of the amount of CO_2 emitted due to energy consumption in the territory of a Covenant signatory within a given period of time. It allows identifying the principal sources of CO_2 emissions and their respective reduction potentials. The SEAP is the key document in which the Covenant signatory outlines how it intends to reach its CO_2 reduction target. It defines the activities and measures set up to achieve the target, together with time frames and assigned responsibilities. Each SEAP include a list of actions for reducing emissions and the quantification of their intended emission reductions.

The paper is structured as follows: i) analysis of baseline emissions and intended emission reductions distribution for emissive sectorial sources; ii) assessment of the most relevant categories of actions to reduce emissions and policy instruments in the achievement of reduction targets; iii) analysis of the drivers influencing emissions and intended emission reductions strategies in cities.

The analysis is based on data provided by a subset of cities participating at the Covenant of Mayors initiative. The cities included in the sample have been selected based on their size and on the SEAP acceptance status: all European cities with more than 100.000 inhabitants and with an accepted SEAP by February 2014 are included in the study.

More than 5.400 actions planned by cities are analysed. They have been classified based on their official description into a “category of action” (area of intervention targeted by an action) and into a “policy lever” (instrument used by the local authority to implement the action).

Most relevant actions in terms of recurrence and mitigation impact are individuated. Cities are then categorized according to a set of features (Population size, Heating Degree Days (HDD), GDP per capita, Population density, Geographical area and Electricity Emission Factor (EEF)), to verify if these features influence cities' emissions and cities' reduction strategies. Cities in the sample account for a total of 370 Mton of CO_2 emissions for selected baseline years and 94 Mton of intended reductions of yearly emissions, to be reached by 2020. The total level of emission reduction planned by cities corresponds to 25% of baseline emissions in the sample. The results of the analysis show that the distribution of intended emission reductions is coherent with the weight of emissions for different sectors. *Building* and *Transport* stand out as the most relevant sectors for emission reductions in SEAPs. Local electricity production is a very promising sector while the industrial sector (non-ETS) is expected to yield a minor contribution to the overall target, despite its relevance in the BEI.

Keywords

Covenant of Mayors, SEAPs, CO_2 emission reductions strategies, policy and measures evaluation.

1. Introduction

1.1 Role of cities in climate change mitigation

Cities are responsible for 67% (IEA, 2012) of the total global energy consumption and more than 70% of greenhouse gas emissions. Data from world cities suggest that climate, technology, density and wealth are important drivers of energy use and CO_2 emissions (Kennedy et al., 2009). However, the empirical relation between urbanization and GHG emission per capita is not conclusive (Lankao et al. 2008). Inventories show that levels of urban emissions per capita can differ considerably in the world, from 2 to 30 tCO_2eq (Dodman, 2009; Kennedy et al., 2009; Sovacool and Brown, 2009). Differences in emissions levels depend on specific local features: climate conditions, urban form, demographic features, economic activities in place, state of technology, mobility and housing infrastructures and prices, income and life style of city residents and users (UN-Habitat, 2011; Croci et al., 2011).

Municipalities have the administrative power to decrease their energy dependence. They are increasingly recognised to have a high potential to drive sustainable energy and climate change mitigation thanks to their competences in several climate-related sectors. Thus, sub-national and local actors need to be involved by central governments to properly address energy and climate change issues (Bulkeley et al., 2013).

1.2 The Covenant of Mayors initiative

The CoM was launched in 2008 by the European Commission (EC) to endorse and support the efforts of local authorities in GHG reduction and energy efficiency. The CoM fosters cities to commit to climate mitigation targets and elaborate corresponding strategies. Signatories vary in size from small villages to major metropolitan areas: by end of November 2015 6.629 local authorities signed the CoM, for a total of ca. 160 million inhabitants in the EU-28, and ca. 186 million inhabitants in the whole initiative (JRC, 2015). Cities signing the Covenant: i) commit to a CO_2 reduction target (20% minimum) for year 2020, ii) compute a Baseline Emission Inventory (BEI) and iii) submit a Sustainable Energy Action Plan (SEAP). The BEI is a quantification of the amount of CO_2 emitted due to energy consumption in the territory of a Covenant signatory within a given period of time. It allows identifying the principal sources of CO_2 emissions and their respective reduction potentials (EC, 2010). The SEAP is the key document in which the Covenant signatory outlines how it intends to reach its CO_2 reduction target. It defines the activities and measures set up to achieve the target, together with time frames and assigned responsibilities.

Cities signing the CoM commit to follow given rules in the implementation of the agreement: i) signature of the Covenant of Mayors and creation of adequate administrative structures; ii) Baseline Emission Inventory and SEAP development; iii) regular submission of implementation reports. The main responsible for the CoM initiative is the European Commission - DG Energy that endorses and supports the efforts deployed by local authorities in the implementation of sustainable energy policies. The EC established the Covenant of Mayors Office (CoMO) that is responsible for the coordination and daily management of the initiative. It provides signatories with administrative support and technical guidance, facilitates networking between Covenant stakeholders and ensures the promotion of their activities. The scientific and technical part of the initiative is managed by the Joint Research Centre (JRC) that is responsible for providing the technical and scientific support to the initiative. It works in close co-operation with the CoMO to provide signatories with clear technical guidelines and templates in order to assist delivery of their commitments as well as to monitor implementation and results. The EC also recognizes CoM Coordinators (supporting signatories in conducting CO_2 emission inventories as well as in preparing and implementing their SEAPs) and CoM Supporters (providing tailored advice to signatories and identifying synergies with existing initiatives).

1.3 Objectives of the paper

The aims of the paper are i) to analyse the strategies adopted by cities to achieve their CO_2 reduction targets, ii) to assess the correspondence between the baseline emissions and the intended emission reductions planned by cities and iii) to verify which are the drivers influencing emissions and intended emission reduction strategies in cities. To achieve these goals the paper is structured as follows: i) analysis of baseline emissions and intended emission reductions distribution for emissive sectorial sources; ii) assessment of the most relevant categories of actions to reduce emissions and policy instruments in the achievement of reduction targets; iii) analysis of the drivers influencing emissions and intended emission reductions strategies in cities.

2. Methodology

Covenant signatories elaborate the BEI and the SEAP and periodically report emissions. The set of data of emissions and intended emission reductions reported directly by cities are used in the paper to analyse cities' strategies to reduce CO_2 emissions and to assess drivers that influence their choices. The outcomes of cities' strategies are SEAPs which aggregate sectorial mitigation actions. A potential CO_2 yearly reduction (up to 2020) is assigned to each specific action in a SEAP. Actions have been classified according to a hierarchical scheme (see par. 2.2) in order to analyse i) the overall strategies adopted by cities, ii) the sectors and the actions with the highest potential of emission reduction, iii) the drivers affecting the choices made by signatories.

This chapter describes the methodology used to analyse the sample. The first paragraph describes the city sample composition and the variables used for the classification of the sample. The second describes the approach used to classify the actions and analyse the strategies and the third paragraph addresses data quality issues related to the disaggregation level of emissions and intended emission reductions data.

2.1 Definition of the sample

The analysis is based on data provided by a subset of cities participating in the EU CoM initiative. The cities included in the sample have been selected based on their size and on the SEAP acceptance status[5]: all European cities with more

[5] The acceptance of the SEAP assures that a quality check of the baseline emission inventory and the intended emission reduction, as performed by the Joint Research Centre of the European Commission, has been successfully passed.

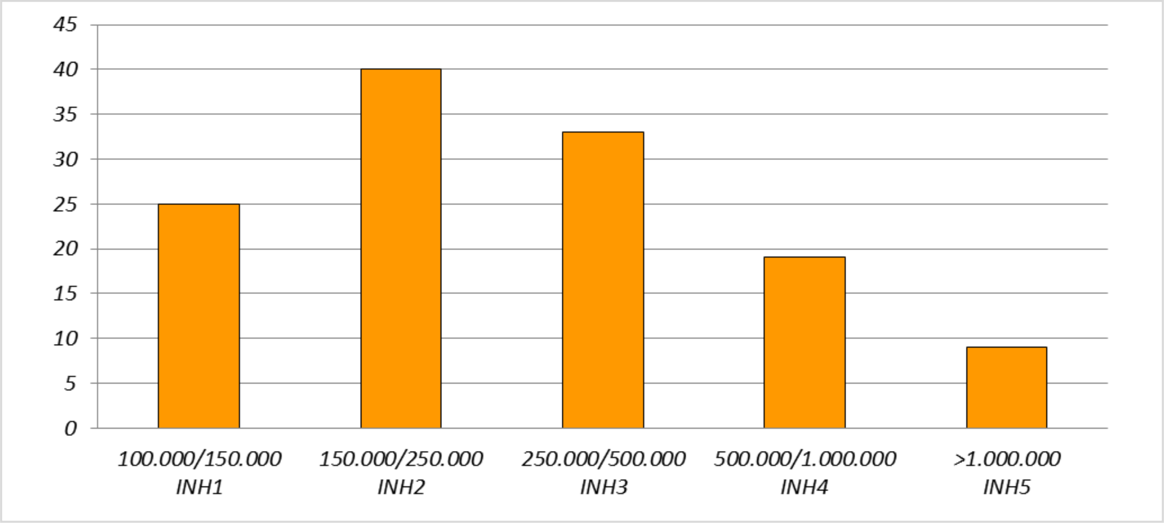

Fig. 1. Population.

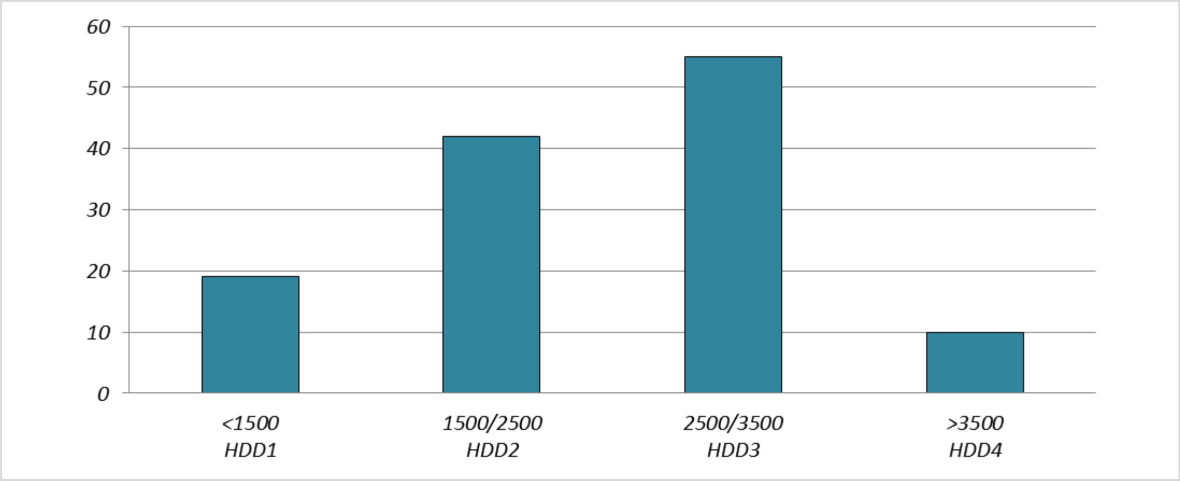

Fig. 2. Heating degree days.

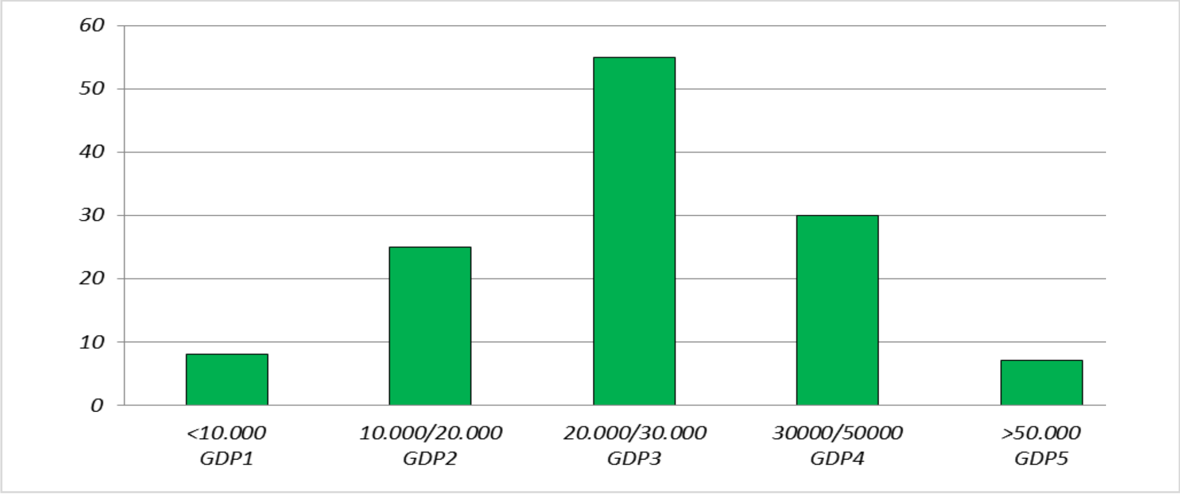

Fig. 3. Gross domestic product.

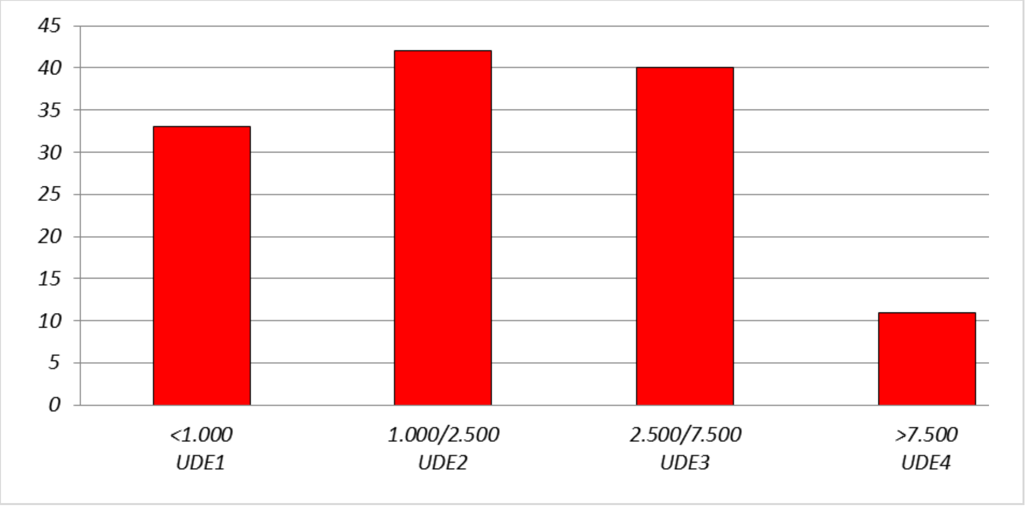

Fig. 4. Urban density.

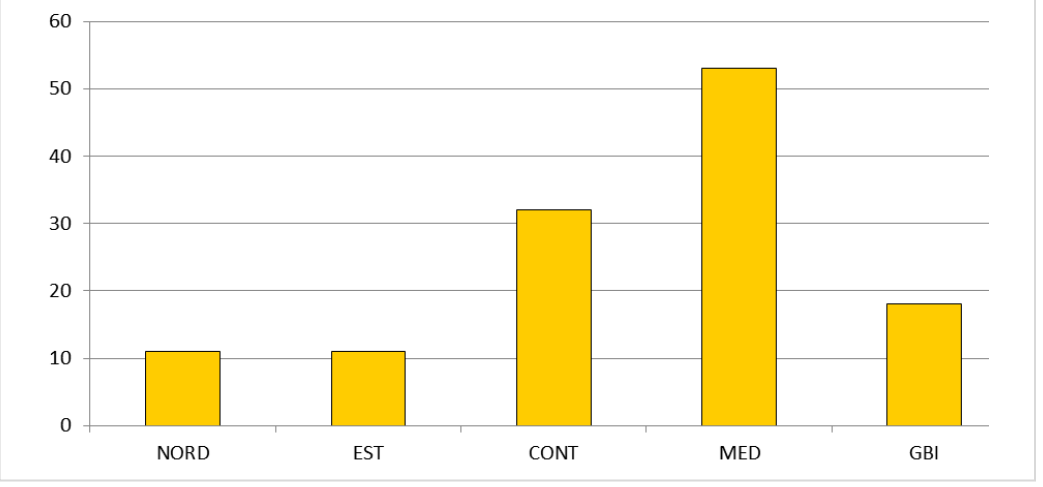

Fig. 5. Geographical area.

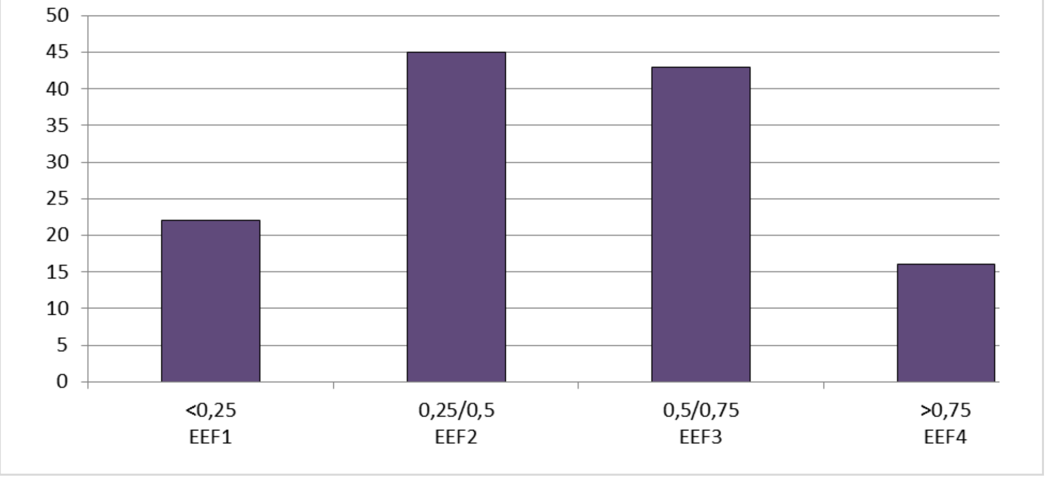

Fig. 6. Electricity emission factor.

than 100.000 inhabitants and with an accepted SEAP by February 2014 are included in the study. The sample is composed by 124 cities, with population ranging from about 108.000 to 7.67 million. Cities are well spread across Europe: 42% are in Mediterranean Europe, 26% in Continental Europe, 14% in the UK and Ireland, 9% in Northern Europe and 9% in Eastern Europe.

Cities have been grouped according to 6 variables: *Population size*[6] (Fig.1), *Heating Degree Days (HDD)* (Fig. 2)[7], *GDP per capita*[8] (Fig. 3), *Population density*[9] (Fig. 4), *Geographical area*[10] (Fig. 5) and *Electricity Emission Factor (EEF)*[11] (Fig. 6). These variables can affect both the distribution of emissions in the BEIs and SEAPs and the choice of policies to achieve the CO_2 emission reductions target. The variables have been selected on the basis of previous literature (Peterson et al., 2009; UNFPA, 2009; Glaeser and Kahn, 2010; Minx et al., 2013; Makido et al., 2012; Wiedenhofer et al., 2013, Kennedy, 2009; Croci et al., 2011; Seto, 2014; Grubler and Schulz, 2013).

Looking at GDP, cities are mainly concentrated in the range 20.000-30.000€ (55 cities). Considering population and urban density, cities are equally distributed among the different ranges. Considering the geographical area, cities are concentrated in the Mediterranean area (53 cities), because the majority of cities that joined the CoM are from Italy and Spain. Finally, considering HDD and EEF, cities are concentrated in the average values of the ranges.

2.2 Definition of the classification approach: sectors, sub-sectors, category of actions and policy levers

The CoM set up the first harmonized framework for data compilation and city emissions reporting at the European level (European Commission, 2014). The reporting framework for baseline emissions and intended emission reductions is therefore common to all cities participating in the CoM. All BEI sectors and subsectors have a correspondent one in the SEAP, however, additional sectors are included in the SEAP to support cities in the classification of planned actions. In order to ensure consistency and homogeneity in the analysis of baseline emission sources in the BEIs and in the analysis of intended emission reductions in the SEAPs, a re-classification of sectors and subsectors respect to the BEI template[12] has been performed, based on their

[6] Population size on the BEI year and on the signing year, as self-declared by cities, has been used to assess scale effects on baseline emission and intended emissions reduction.

[7] Climatic conditions for the cities in the sample are proxied by Heating Degree Days at NUTS 2 level, as provided by EUROSTAT. The closest available year to in the dataset has been associated to the relevant city according to the chosen BEI year.

[8] Average GDP per capita for the BEI year and for the year of adhesion to the CoM have been computed based on the Urban Audit data (EUROSTAT). This allowed distinguishing between the level of GDP for the relevant year of baseline emissions and GDP in the year of emission reductions estimation, respectively. GDP at current market prices by NUTS 3 region has been associated to cities for available years. When the BEI (or signing year) was not available in the Urban Audit dataset, the closest available year in the Urban Audit has been adjusted multiplying it by the appropriate national GDP growth at market prices (for the period between the closest available year and the year of interest). GDP growth was extracted from the World Development Indicators.

[9] Average population density has been computed as the ratio between population and city surface. Self-declared surface has been checked and corrected with data available on the official website of cities, when appropriate.

[10] Cities from Hungary, Poland and Romania have been included the Eastern European group; cities from Greece, Italy, Portugal and Spain are included in the Mediterranean Europe; Denmark, Finland, Lithuania and Sweden have been included the Northern Europe; Belgium, France and Germany to Central Europe. The last group includes cities from the United Kingdom and Ireland.

[11] The local electricity emission factor is the self-declared amount of CO_2 emissions associated to a unit of electricity consumed in the city. This is a combination between national average emission factors for electricity consumed in the country and the emission factor associated to the share of electricity produced and consumed locally.

[12] The BEI template constitutes the reporting framework of the Covenant of Mayors initiative. The template has

description. The table shows how the sectors has been re-classified and underlines which sectors and subsectors correspond between BEI and SEAP.

The *Building* sector is divided into 4 subsectors: *residential buildings and facilities*, *tertiary building and facilities*, *municipal buildings and facilities and mixed actions* (additional subsector for holistic actions). The *Transport* sector includes: *private and commercial transport*, *public transport*, *municipal fleet and mixed actions* (additional subsector for holistic actions). Compared to the CoM, we consider the *Public lighting* subsector and the *Industrial* subsectors as independent sectors. As in the SEAP, additional sectors for the classification of intended emission reductions are *Local electricity production*, *Local heat/cold production*, *Land use planning*, *Working with citizens and stakeholders*. The reclassification of the sectors also involved the inclusion of a further sector: *Waste and water*. Any other sector is classified as *Other*.

The level of disaggregation in SEAPs is the same of the BEIs (sectors and sub-sectors), but SEAPs provide specific information and description of planned actions for intended emissions reduction. Thus the actions have been classified based on their official description into a "*category of action*" describing the area of intervention targeted by an action, and into a "*policy lever*" describing the instrument used by the local authority to implement the action. In total 117 categories of actions and 28 policy levers were defined. Categories of action are associated to a specific *sector* and *subsector*. Policy levers can be common to different sectors (e.g. awareness raising) or specific to a sector (e.g. building standards). For example, if the action is "Thermal insulation of residential buildings", the category of action is the "Building envelope" and the policy instrument could be setting new "Building standards". Finally the sub-sector is "Residential" and the sector is "Buildings". The following graph synthesizes the analysis classification used in the paper and gives an example of classification for the building sector:

In the intended emission reductions classification made by cities a certain amount of CO_2 emissions has not been disaggregated into actions (see par. 2.3). Residual sectors for non-disaggregated emissions and intended emission reductions were created.

These sectors are: i) "*Emissions not disaggregated into specific actions",* collecting emissions and intended reductions that have not been disaggregated among subsectors by municipalities; ii) "*Not possible to assign",* reporting the level of emissions associated to actions with unclear descriptions (e.g. alphanumeric codes attributed to an action instead of a description of it) and thus impossible to classify in a category. Based on the share of emissions by sector and subsector in the sample obtained using the described classification approach, an analysis of the baseline emission and intended emission reductions sectorial distribution was developed. Finally, the categories of actions and the policy levers have been analysed in terms of recurrence in the SEAPs and in terms of intended emission reductions attributed to them by cities.

2.3 Breakdown of emissions and intended emissions reduction

The analysis of self-reported data in BEIs and SEAPs confirms that cities face increasing difficulties in computing emissions and emission reductions at the increase of the degree of detail (disaggregation) to be provided (sector; subsector; energy source; SEAP actions; etc.). In order to encourage cities to join the CoM, only reporting at sector level is mandatory, thus the detail of analysis is sometimes limited by data availability.

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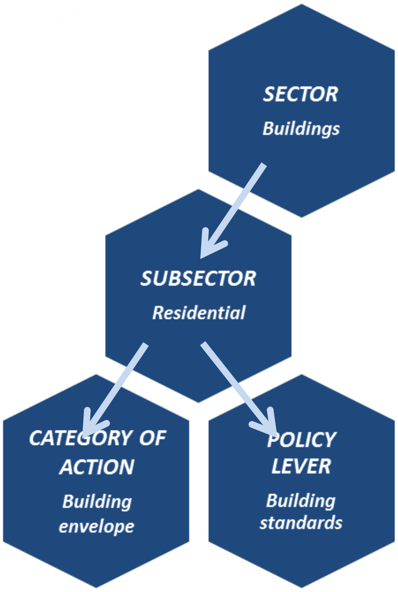
been developed by the Covenant of Mayors Office and the Joint Research Centre of the European Commission with the collaboration of a group of practitioners from local and regional authorities. It has been designed to assist signatories in summarising the quantification of the amount of CO_2 emitted due to energy consumption in their territory allowing to identify the principal sources of CO_2emissions and their respective reduction potentials.

Table 2. Re-classification of sector and sub-sectors performed by IEFE-JRC.

SECTOR and subsectors	BEI	SEAP	ADDITIONAL sectors and subsectors
BUILDINGS	**x**	**x**	
Residential	*x*	*x*	
Tertiary	*x*	*x*	
Municipal	*x*	*x*	
Mixed actions		*x*	*x*
TRANSPORT	**x**	**x**	
Private and commercial	*x*	*x*	
Public	*x*	*x*	
Municipal fleet	*x*	*x*	
Mixed actions		*x*	*x*
INDUSTRY	**x**	**x**	
PUBLIC LIGHTING	**x**	**x**	
LOCAL ELECTRICITY PRODUCTION	*	**x**	
LOCAL HEAT/COLD PRODUCTION	*	**x**	
LAND USE PLANNING		**x**	
WASTE AND WATER	**x**	**x**	
WORKING WITH THE CITIZENS AND STAKEHOLDERS		**x**	
OTHER	**x**	**x**	

* Emissions from electricity and heat/cold production are implicitly allocated to the sector of final consumption (Buildings; Transport; Other) in the BEI. The local authority can decide whether to compute a local emission factor based on the energy sources used to produce electricity and heat/cold within the city boundaries and following CoM guidelines.



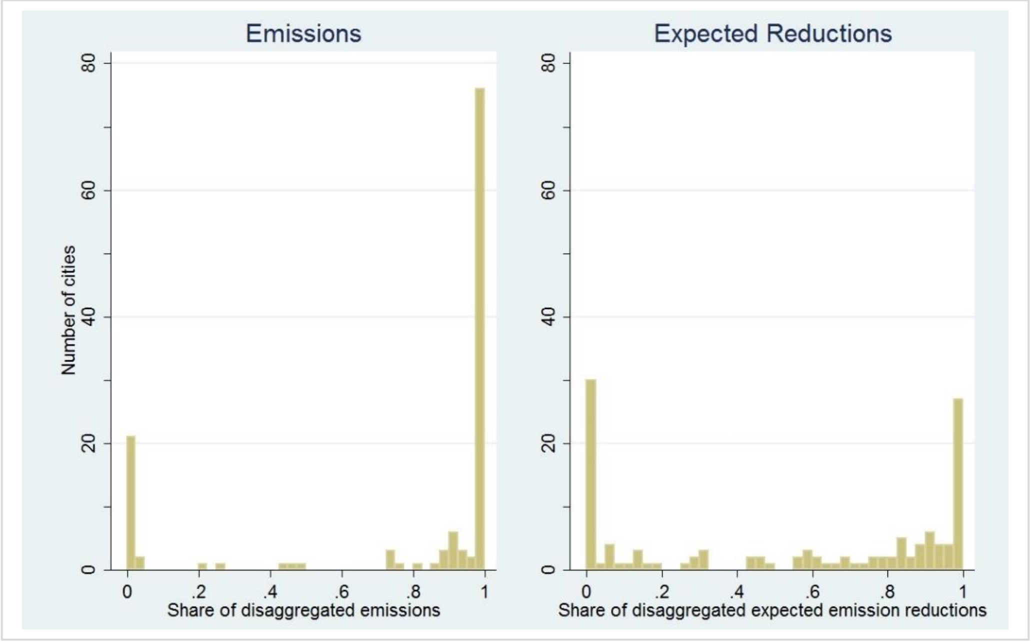


Fig. 7. Disaggregation of emissions between sectors.

More than 75% of total emissions reported in baseline inventories can be disaggregated between the main sectors of analysis (*Buildings; Transport; Public Lighting; Industry; Other*). Non-disaggregated emissions derive mainly by a limited number of cities that do not perform any disaggregation between sectors (Fig. 7, left side). Very few cities provide a partial disaggregation.

Cities face even higher difficulties in estimating emission reductions from planned actions. In particular, emission reductions to be associated with soft measures, such as awareness raising campaigns, are difficult to forecast and thus no figure is generally provided. Moreover, some cities decided to focus on planning actions to be implemented in the short term, while remaining actions to reach the committed level of emission reduction, by 2020, are left to be designed subsequently. Indeed, Fig. 7 (right) shows that cities most frequently perform either a complete disaggregation or no disaggregation. However, differently from the case of emissions, there is a relevant share of cities providing only a partial disaggregation of total intended emission reductions.

The share of disaggregated baseline emissions and intended reductions varies a lot between cities, so a sub-sample of cities has been built in order to compare the patterns of emissions and reductions across classes of selected variables. The sub-sample has been selected based on: (i) disaggregation of at least 80% of emissions or at least 80% of reductions (reducing the sample to 102 cities) and (ii) sectors that are present both in the BEI and in the SEAP (building; transport; other). Intended emission reductions from additional sectors in the SEAP and non-disaggregated emissions and reductions are distributed among the above-mentioned sectors with a common rule. For each city, all (i) non-disaggregated baseline emissions, (ii) non-disaggregated emissions reductions and (iii) emission reductions from additional sectors are allocated to selected sectors in the corresponding inventory (building; transport; other) according to their weight in the inventory. For example, if city A disaggregated 85% of emissions and 50% of intended reductions, both non-disaggregated emissions and non-disaggregated reductions are allocated among the selected sectors (buildings; transport; other) according to their relative weight in the inventory of baseline emissions. The sub-sample analysis is reported in par. 3.3.

3. Results

Cities in the sample account for a total of 370 Mton of CO_2 emissions for selected baseline years and 94 Mton of planned reductions of yearly emissions, to be reached by 2020. This mainly corresponds to direct CO_2 emissions in sectors covered by the Covenant of Mayors[13].

Total emissions in the sample correspond to 10% of total CO_2 emissions from the European Union in 2013, in all sectors (Jos et al., 2014). The total level of emission reduction planned by cities corresponds to 25% of baseline emissions in the sample, beyond the minimum target of 20% required by the CoM.

This chapter presents the results obtained for each part of the analysis. The first paragraph describes baseline emissions and intended emissions reductions by sector and subsector, comparing their relative importance. The second one describes the intended emission reductions by category of action and policy lever. The third one performs a comparison between the relative importance of sectors and subsectors across selected variables.

3.1 Baseline emissions and intended emission reductions by sector and subsector

In order to analyse and compare the relative importance of baseline emissions and expected emission reductions in the most relevant CoM sectors, we re-compute the share of emissions by sector and subsector with respect to the total of *disaggregated* emissions only. Fig. 8 and Fig. 9 summarize the comparison between sectors and subsectors in the BEI and SEAP, excluding baseline emissions and expected emission reductions that were not possible to disaggregate.

The *Building* sector is the most relevant source of emissions. It accounts for 49% of total disaggregated emissions in the sample, with residential emissions being the most relevant component with almost 2/3

[13] Indeed, most cities in the sample computed direct emissions based on IPCC emission factors, while only 12% followed a LCA approach. On the contrary, almost half of the cities (45%) included emissions of other greenhouse gases in the inventory, converted into CO_2 equivalents according to their global warming potential, but their importance in CoM sectors is minor.

of emissions from the building sector (emissions per subsector: residential 30,6%; tertiary 16,2%; municipal 2,2%). The transport sector accounts for 26,3% of emissions, with private and commercial transport being essentially the only responsible of it, with over 90% of emissions in the sector (emissions per subsector: private and commercial 20,6%; public 1,6%; municipal fleet 0,6%). Almost all the rest of emissions (22,1%) comes from the Industrial (non-ETS) sector. Public lighting accounts for 0,3% of emissions only. Finally, the residual category "Other" (2,2% of total emissions) is optional for cities and may include additional areas of intervention that the city wants to tackle, such as waste and wastewater treatment. The most emitting sector (*Buildings*) is also the main focus of city action for emission reduction (30,7% of total expected CO_2 emission reductions). The distribution of intended emission reductions broadly replicates the relative importance of subsectors in terms of baseline emissions: actions in the residential building sector are expected to yield 15,8% of reductions, while tertiary buildings should account for 8% and municipal buildings for 2,8%.

The *Transport* sector follows in importance the building sector, both for baseline emissions and intended emission reductions (20,6%). The ranking of subsectors within the transport sector is the same as for baseline emissions; however, their relative weight is different. Cities expect to be able to reduce emissions from public transport proportionally more than from private and commercial transports. Indeed, private and commercial transport accounts for 24,6% of baseline emissions, while it is expected to contribute to only 10,6% of reductions. Conversely, emissions from public transports represent 1,6% of transport emissions, but it is expected to contribute to 5,6% of CO_2 reductions. Additional areas of interventions are municipal fleet (0,3%) and mixed actions (4,1%).

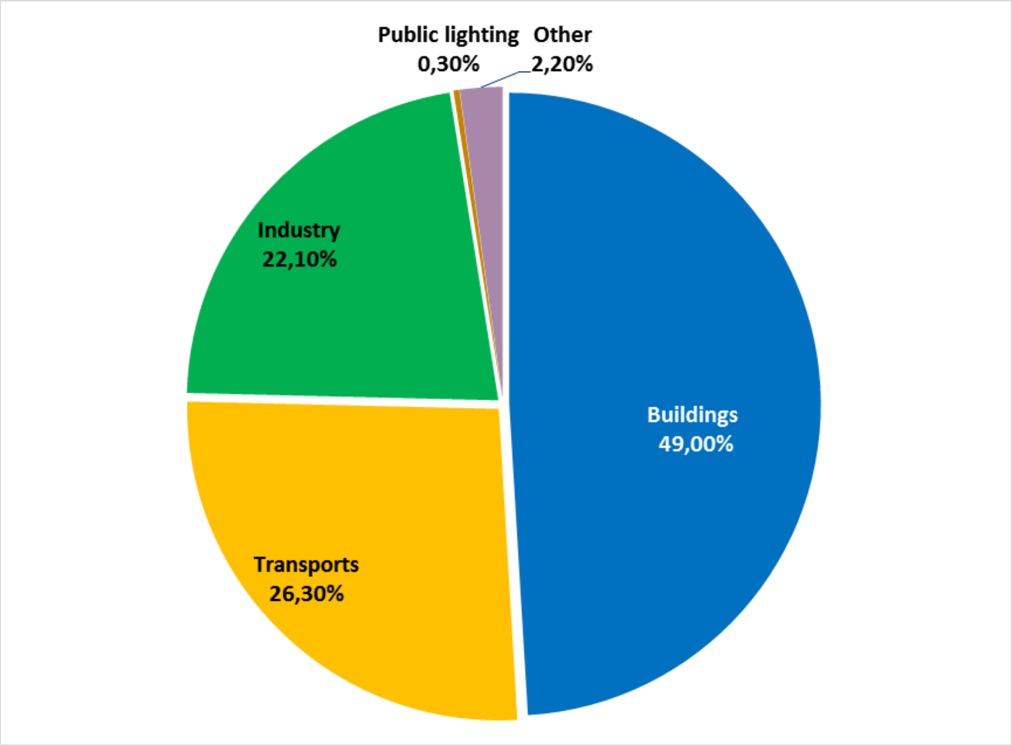
Local electricity production is also a very promising sector, contributing to 21,3%. This cannot be compared to a BEI sector because baseline emissions are associated to the sector of final consumption. Intended emission reductions in this sector benefit all BEI sectors according to their share of electricity consumption, as it will decrease the level of emissions embedded in the electricity used within the city.

Similarly, *Local heat/cold production (6,5%)*, *Land use planning (3,4%)* and *Working with citizens and stakeholders (0,4%)* are sectors that do not have a correspondence in the BEI. The introduction of these sectors has generated a higher level of detail in the emission reductions distribution, because the number of the sectors in the SEAPs is higher than the baseline. Thus this different level of disaggregation increased the differences in the allocation of emissions among sectors compared to baseline emissions. Nonetheless, these sectors are minor contributors to total expected reductions[14].

Finally, most cities decided to tackle the *Industrial* sector (optional in the CoM). Despite its relevance in the BEI (22,1% of disaggregated emissions are from local non-ETS industries), planned actions for emission reduction are expected to yield a minor contribution to the overall target (2,5% of intended emission reductions in the SEAP).

Overall, cities prove to be better able to plan actions, and compute related emission reductions, in the public sector. The analysis of the share of intended emission reductions by sector and subsector points out that baseline emissions from public transports, municipal fleet, municipal buildings and public lighting show the strongest expected decreases: 54%, 33% and 20%, respectively. Planned reductions in all other BEI subsectors correspond to less than 10% of their baseline emissions. In total, baseline emissions are expected to decrease by 15% only, based on planned actions and disaggregated data.

[14] 6,5%, 3,4% and 0,4%, respectively



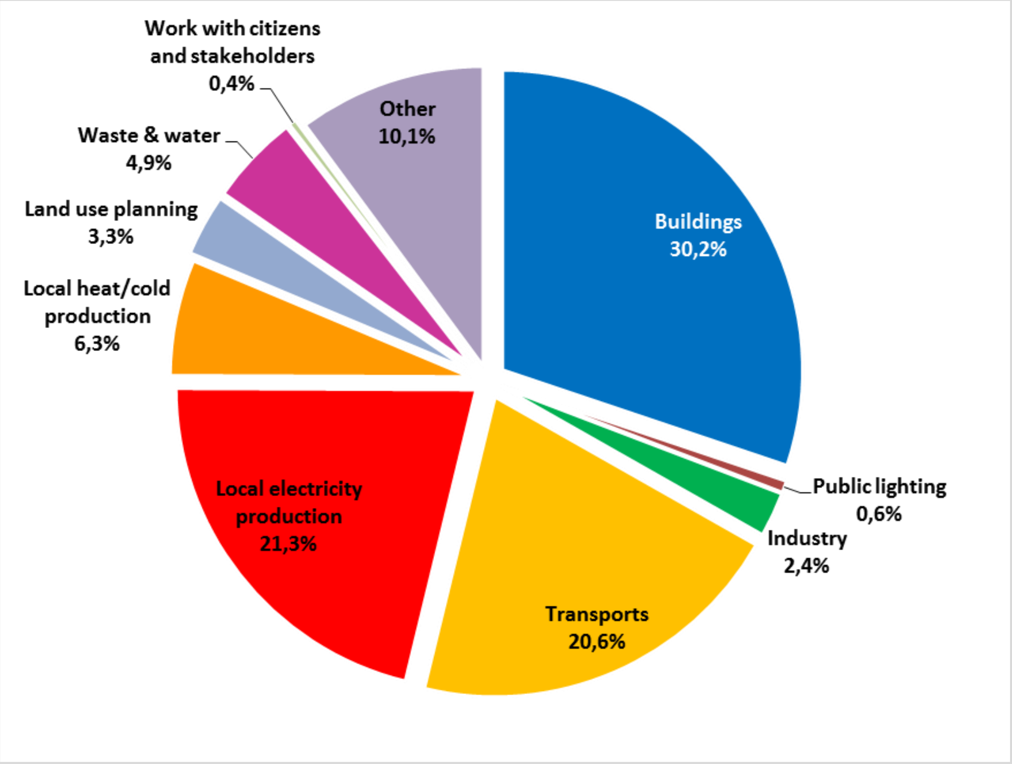


Fig. 8 and Fig. 9 Distribution of emissions and intended emission reductions between sectors.

Table 3. Comparison between the relative importance of sectors and subsectors in the BEI and SEAP (excluding non-disaggregated emissions) and corresponding expected reduction of baseline emissions.

SECTOR and subsectors	**BEI**	**SEAP**	**% reduction of BEI**
BUILDINGS	49,0%	30,2%	8%
Residential	*30,6%*	*15,8%*	*8%*
Tertiary	*16,2%*	*8%*	*8%*
Municipal	*2,2%*	*2,8%*	*20%*
Mixed actions	-	*3,6%*	-
TRANSPORT	26,3%	20,6%	12%
Private and commercial	*24,6%*	*10,6%*	*7%*
Public	*1,6%*	*5,6%*	*54%*
Municipal fleet	*0,1%*	*0,3%*	*33%*
Mixed actions	-	*4,1%*	-
INDUSTRY	22,1%	2,5%	2%
PUBLIC LIGHTING	0,3%	0,7%	29%
LOCAL ELECTRICITY PRODUCTION	*	21,3%	-
LOCAL HEAT/COLD PRODUCTION	*	6,5%	-
LAND USE PLANNING	not present	3,4%	-
WASTE AND WATER	-	4,9%	-
WORKING WITH THE CITIZENS AND STAKEHOLDERS	not present	0,4%	-
OTHER	2,2%	15,5%	
TOTAL	100%	100%	15% **

* Emissions from electricity and heat/cold production are allocated to the sector of final consumption in the BEI. The local authority can decide whether to compute a local emission factor based on the energy sources used to produce electricity and heat/cold within the city boundaries and following CoM guidelines (EU, 2010).

** The aggregated reduction of BEI, is 25%. This is the emission reductions target computed as the ratio between planned actions disaggregated by subsector and baseline emissions disaggregated by subsector.

The following table summarises all the results from the comparison between BEIs and SEAPs data. The last column of Table 3 reports the share of intended emission reductions by sector and subsector, considering disaggregated emissions only.

3.2 Intended emission reductions by category of action and policy lever results

Most cities in the sample tackled all of the three most relevant sectors: 68% of cities planned actions in the *Building* sector, 66% in the *Transport* sector and 49% in the *Local electricity production* sector. For this reason, we choose to report only the full results of the classification concerning these sectors that have the greatest weight in the strategies adopted by cities.

In the *Building* sector, most frequently used categories of actions are: "*integrated actions"* and the "*energy efficiency in space heating and hot water"* (they appear respectively 435 and 171 times). These categories of action represent respectively 4,5% and 1,1% of the total intended CO_2 reductions. The "*purchase of green energy production*" category of action has a very low frequency (5) but has a relatively high potential of CO_2 emission reduction (2,3%). The "*purchase of green energy production*" category of action is not so used but it has a high amount of CO_2 emission reduction. For this reason the average intended reduction per category of action has been calculated, dividing the amount of intended emission reductions by the number of recurrences.. In this way the intended potential of each category has been verified. The average CO_2 reduction for the two categories are: *Integrated action* 9.799 tCO_2/year; *Purchase of green energy without production* 40.939 tCO_2/year. The most used policy levers include the "*energy management",* "*awareness raising"* and "*construction of infrastructure"* (respectively 555, 310 and 276 times). In this case there is full correspondence between the lever frequency and the intended CO_2 reduction that has been attributed to them (energy management 4,4%, infrastructure and construction 2,8% and awareness raising 1,9%).

The *Transport* categories of actions most frequently used are related to the "*road network optimization*" (cycle paths, restricted traffic zones, etc.) and the "*modal shift to walking & cycling*" (they appear respectively 265 and 184 times). In this case their frequency does not always coincide with a high reduction of CO_2 (respectively 0,51% and 1%). Instead the categories that foster the "*use of cleaner vehicles"* (2,84%) and "*electric vehicles"* (1,58%) are the ones that have the greatest amount of intended emissions reduction. The average intended emission reductions underline that potentially the most efficient category of action is "*modal shift to public transport"* (49.9817 tCO_2 per year) followed by "*electric vehicles"* (34.177 tCO_2 per year) and *"cleaner/efficient vehicles"* (19.237 tCO_2 per year). The most used policy levers in the transport sector are related with "*management and organization*", *"transport and mobility planning*" and "*awareness raising*" (respectively 391, 204 and 137 times). In this case the intended CO_2 emission reduction from each lever is coherent with the frequency: "*management and organization*" 3,56%, "*transport and mobility planning*" 2,34%, "*Awareness raising*" 1,17% (graph 3.12). This is demonstrated also by the average intended reduction value: 8.583 tCO_2 per year, 10.838 tCO_2 per year, 5.147 tCO_2 per year respectively.

For the *Local electricity production,* no subsectors were identified. The results show that there is no match between the intended emission reductions and the recurrences for the categories of action. In fact the category of action that has the greatest frequency is *Photovoltaics* (134) with a total intended reduction of 0,53%. The category of action *"combined heat and power"* recurs 88 times and has an intended CO_2 emission reduction of 3,32%. The same happens for the *"wind power"* and *"biomass power plant"* categories of action (recurrences: 55 and 21; intended CO_2 emission reduction: 2,95% and 1,17%). The aggregation of the data shows that the categories with the highest intended CO_2 emission reductions are: *"combined heat and power"* (3,32%), *"wind power"* (2,95%), *"biomass power plant"*

(1,17%). This is confirmed by the average intended emission reduction: *"combined heat and power"* with 35.546 tCO_2 per year; *"other"* 66.318 tCO_2 per year and *"wind power"* with 23.055 tCO_2 per year.

The frequency and the intended CO_2 emission reductions for the policy levers are coherent except in two cases: "*access to credit*" and "*management and organization*". In the first case there is a low frequency (2) which corresponds to a relatively high intended emission reduction value (0,3%; average intended reduction: 27.1553 tCO_2 per year). There is no correspondence between CO_2 reduction emission and frequency for the "*management and organization*" lever (recurrences: 387; intended emission reduction: 0,1%; average intended reduction: 22 tCO_2 per year). The policy levers that have the highest amount of CO_2 expected emission reductions are: "*infrastructures and construction*" (1,68 %; average intended reduction: 1.579.950 tCO_2 per year), "*access to credit*" (0,29%) and "*study and research*" (0,2%; average intended reduction: 27.1553 tCO_2 per year).

In general, the most efficient category of actions is related with the *Transport* and *Local electricity production* sector (*modal shift to public transport; purchase of green energy without production; combined heat and power; electric vehicles*). The same happens for the policy levers: cities expect more efficiency from the *Local electricity production* sector policy levers (*Access to credit, Other, Transport/mobility planning regulation*).

3.3 Comparison between the relative importance of sectors and subsectors across selected variables

In order to study the possible drivers of influence of the CO_2 emission sources and of the choices of the SEAP strategies, cities have been grouped into one-dimensional classes according to 6 drivers. The analysis points out that population density and GDP variables influence both emissions and intended emission reductions. No other variable is significant for the intended emissions reductions. Instead, for baseline emissions both EEF and geographical area result to be significant. Graphs 10 and 11 show the relative weight of sectors (in terms of emissions and intended reductions respectively) across classes of selected variables.

As anticipated in par. 2.3, the quota of emissions that are not disaggregated between subsectors varies a lot between classes, possibly biasing the results. So a sub-sample of cities has been built to study the possible influence of the considered variables on the emissions and intended emission reduction distribution (see par. 2.3). The re-allocation of intended reductions from additional SEAP sectors to relevant sectors (buildings, transport, other), as well as the allocation of non-disaggregated reductions, changes the distribution emissions between sectors increasing the weight of the building and transport sectors respect to the other sector (see graphs 12 and 13). Nonetheless, the relative weight of the building and transport sectors follow a similar distribution across the classes of the selected variables.

Overall, the results show that in the sub-sample of cites different variables (population, population density, HDD and EEF) seem not to influence the distribution of emissions among sectors both for the baseline emissions and for the intended emission reductions. In fact, the distribution of intended emission reductions in the sectors broadly replicate the importance of baseline emissions in the same sectors for the classes of analysis of the variables mentioned above. This means that cities do not plan to reduce proportionally more (or less) emissions in some sectors, compared to distribution of baseline emission in the same sectors.

Conversely, different emissions distribution peculiarities can be detected for city GDP and geographical area variables. In particular, higher levels of GDP are associated to proportionally lower emissions from the Building sectors, in favour of other sectors.

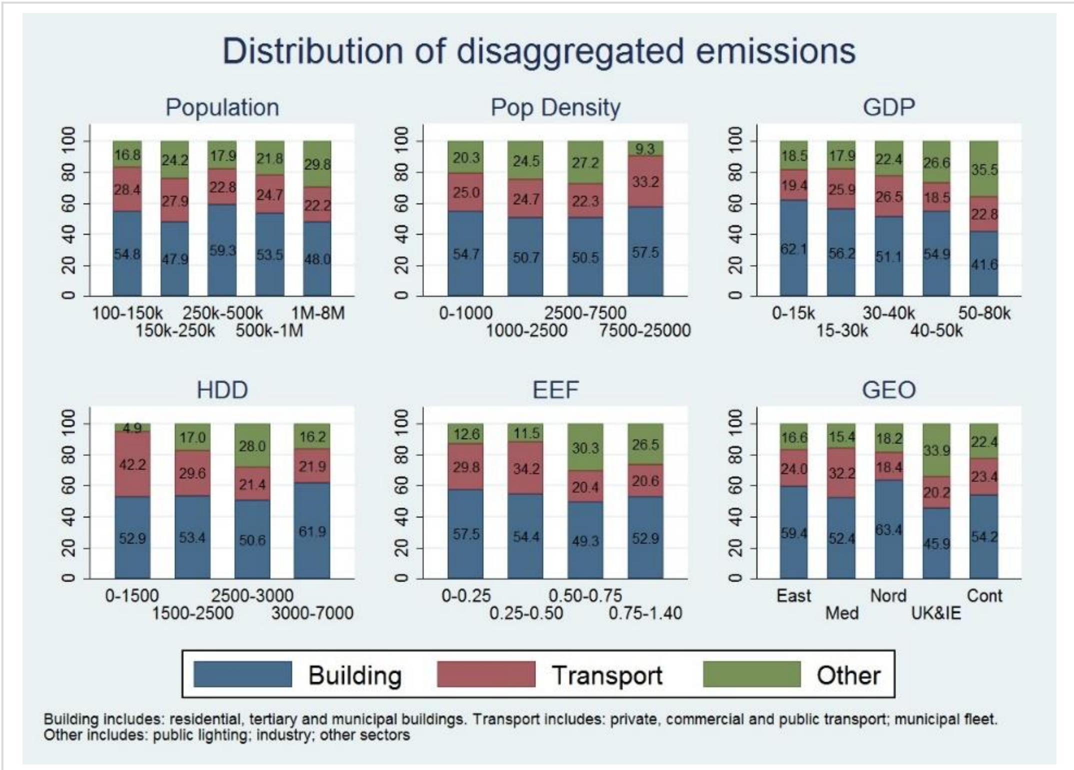


Fig. 10 Distribution of disaggregated emissions between main sectors for different classes of selected variables.

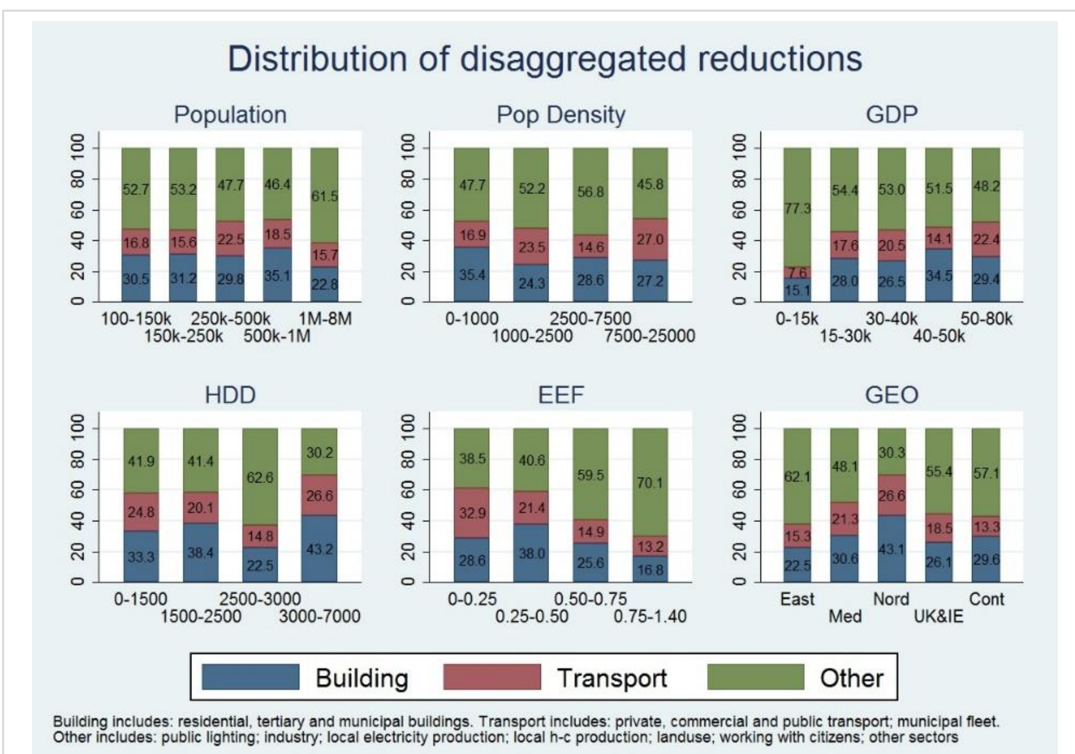


Fig. 11 Distribution of disaggregated intended emission reductions between main sectors for different classes of selected variables.

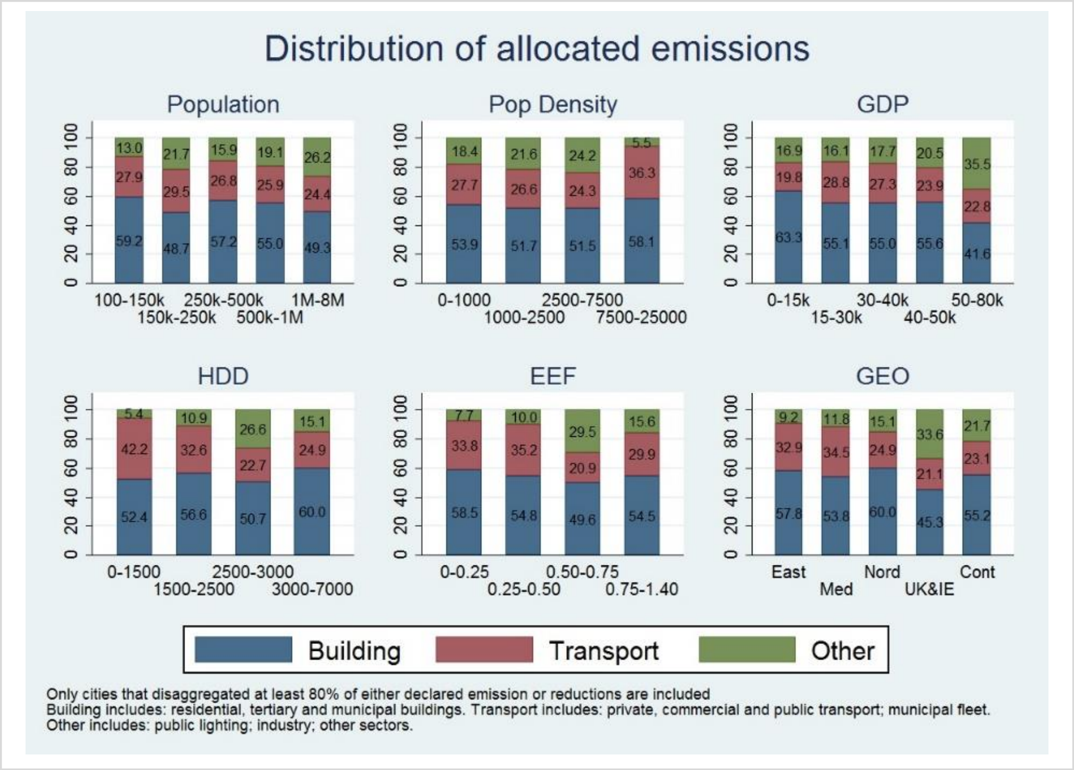


Fig. 12 Distribution of allocated emissions between main sectors for different classes of selected variables.

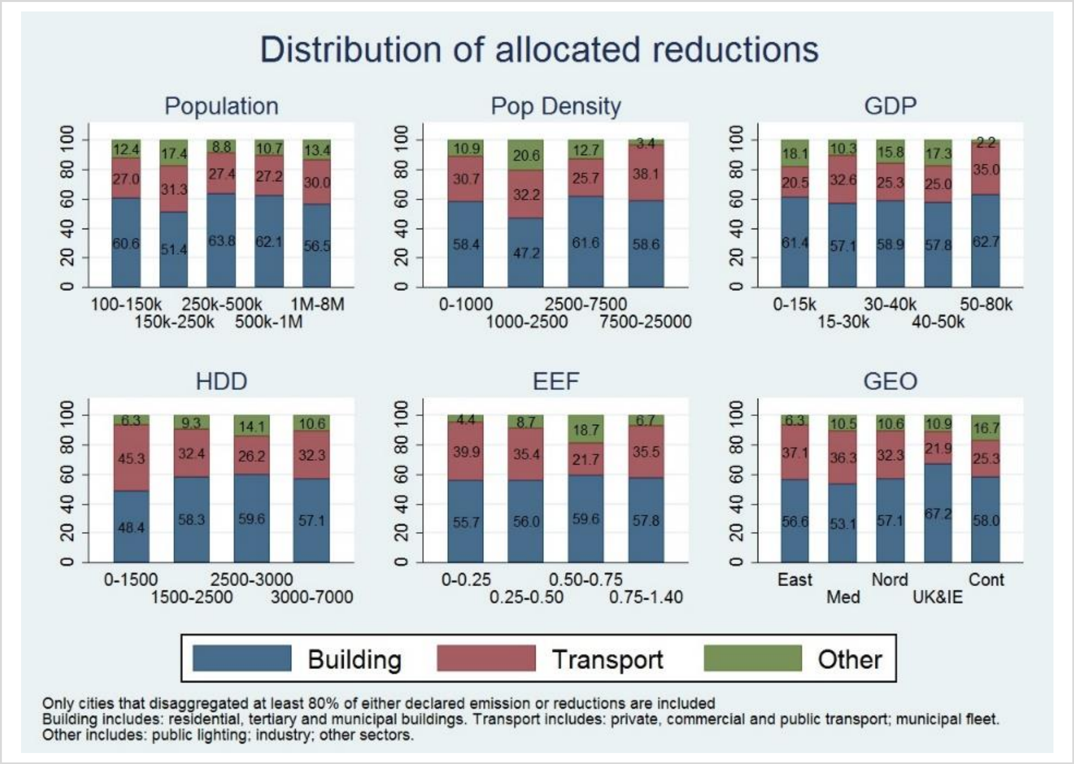


Fig. 13 Distribution of allocated intended emission reductions between main sectors for different classes of selected variables.

On the contrary, the share of planned reductions does not decrease for higher levels of GDP. Richer cities seem to face higher opportunities of investment for the enhancement of energy efficiency in buildings, leading both to lower baseline emissions and higher additional reductions, compared to the baseline. Richer cities seem also to plan proportionally higher reductions from the transport sector, strongly reducing the contribution of other (residual) sectors to the total level of committed reductions.

The geographical locations also influence the weight of emissions from the *Building* sector that results to be higher for northern European cities, even if they do not plan proportionally more reductions from the sector. Moreover, cities from the UK and Ireland are associated to proportionally lower levels of emissions from buildings, but strongly higher planned reductions, compared to cities in other parts of Europe. Finally, the *Transport* sector is more important in Mediterranean cities both for baseline emissions and intended reductions.

4. Conclusion

The paper outlines: i) the analysis of baseline emissions and intended emission reductions distribution for emissive sectorial sources; ii) an assessment of the most relevant categories of actions to reduce emissions and policy instruments in the achievement of reduction targets; iii) an analysis of the drivers influencing emissions and intended emission reductions strategies in cities.

Cities in the sample are committed to achieve a reduction of 25% of baseline emissions by 2020. The distribution of intended emission reductions is coherent with the weight of emissions for different sectors and subsectors. *Building* and *Transport* sectors stand out as the most relevant for emission reductions in SEAPs. *Local electricity production* is a very promising sector while the *Industrial* sector (non-ETS) is intended to yield a minor contribution to the overall target, despite its relevance in the BEI. In general intended emission reductions are higher in public activities in relation to emissions in base year, even if the weight of public activities is relatively low compared to private activities.

Given their relevance for emission reductions, the *Building* and *Transport* sectors should be prioritized in mitigation strategies. In particular, the most promising and efficient category of action in the building sector are integrated actions, which combine several types of interventions to maximise energy efficiency of buildings. For the transport sector, the most promising and efficient category of action appears to be the modal shift, which implies a transition from the use of private transport to public and cleaner transport modes. Looking at policy levers, the most promising ones in terms of emission reductions in the building transport are "*energy management", "awareness raising"* and "*infrastructure and construction".* Energy management can provide a boost to energy saving in buildings by tackling the often overlooked savings potential that they offer. Awareness raising contributes by sensitizing all types of stakeholders in optimizing energy uses and investing in energy efficiency. Infrastructure and construction implies the concrete implementation of the different types of planned measures. These types of policy levers can be combined to maximise the measures emission reduction potential. For the transport sector, the most promising policy levers in terms of emission reductions are "*management and organization*", *"transport and mobility planning*" and "*awareness raising*". Similarly, to the building sector, also for transport the management and organization lever can contribute to tackle the existing overlooked savings potential by increasing the efficiency of the system.

Finally, cities have been grouped into classes of analysis according to 6 variables to verify if these could have any influence in the cities emissions and in the emissions reductions strategies choices. The results show that for the entire sample population density and GDP variables influence both emissions and intended emission reductions. No other variable is significant for the intended emissions reductions. Instead, for baseline emissions both EEF and geographical area result to be significant. Since the quota of emissions that are not disaggregated between subsectors varies a lot between classes, possibly biasing the results a sub-sample of cities has been built to study the possible influence of the considered variables on the emissions and intended emission reduction distribution. In this case different variables (population, population density, HDD and EEF) seem not to influence the distribution of emissions among sectors both for the baseline emissions and for the intended emission reductions. Conversely, different emissions distribution peculiarities can be detected for city GDP and geographical area variables.

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Изучение устойчивой энергетической политики в европейских городах: опыт соглашения мэров

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Краткое изложение:: Местные органы исполнительной власти играют важную роль в сокращении выбросов парниковых газов. Для поддержки и поощрения местных органов власти в 2008 году Европейская комиссия инициировала Соглашение Мэров (СМ). Сторонники Соглашения берут на себя обязательство по сокращению выбросов CO_2, не менее, чем на 20% в 2020 году, по подготовке Базового кадастра выбросов (БКВ), а также по представлению Плана действий по устойчивому энергетическому развитию (ПДУЭР). В БКВ приводятся количественные показания выбросов CO_2 в результате энергопотребления на территории городов-подписантов Соглашения Мэров в течение определенного периода времени. БКВ позволяет определить основные источники выбросов CO_2 и соответствующий потенциал их сокращения. ПДУЭР является ключевым документом, в котором подписанты Соглашения описывают каким образом они намерены достичь своей цели по сокращению выбросов CO_2. В нем определены деятельности и мероприятия, направленные на достижение цели, а также временные рамки и то, как распределены обязанности. Каждый ПДУЭР включает в себя перечень мер по сокращению выбросов и количественные показатели таких предполагаемых сокращений.

Данная документация состоит из следующего: i) анализ базовых выбросов и предполагаемое сокращение выбросов по отраслевым источникам; ii) оценка наиболее значимых категорий мер по сокращению выбросов и мер реализации политики, направленной на достижение цели по сокращению; iii) анализ влияющих на выбросы факторов, а также стратегий городов по предполагаемому сокращению выбросов.

Анализ основан на данных, предоставленных подмножеством городов, участвующих в инициативе Соглашения Мэров. Включенные в выборочное обследование города были отобраны на основании их размера и факта утверждения их ПДУЭР: в исследование включены все европейские города с населением более чем 100 000 жителей и с утвержденным по состоянию на февраль 2014 года ПДУЭР.

Было проанализировано более 5 400 запланированных данными городами мероприятий. Они были классифицированы на основе их официального описания в "категории мероприятий" (целевая область вмешательства мероприятия), а также в "рычаги политики" (инструмент, используемый местными органами власти для осуществления мероприятия).

Большинство соответствующих мероприятий были выделены из ряда подобных по признаку их повторяемости и степени их воздействия. Города затем классифицируются в соответствии с рядом особенностей (численность населения, градусосутки отопительного сезона (ГОС), ВВП на душу населения, плотность населения, географическая зона и коэффициент выбросов от производства электроэнергии (КВЭ)), чтобы проверить, если эти особенности влияют на уровень выбросов в данных городах и на стратегии по их сокращению. Выборочно включенные в исследование города в общей сложности ответственны за 370 Мт выбросов CO_2 за выбранные базовые года и предположительно в них к 2020 году будет достигнуто сокращение выборов в размере 94 Мт. Общий уровень запланированного городами сокращения выбросов соответствует 25% от базового уровня выбросов по исследованию.

Результаты анализа показывают, что уровень предполагаемых сокращений выбросов по различным отраслевым секторам взаимосвязан с характерным для них уровнем выбросов. Строительство и Транспорт выделяются как наиболее важные секторы для сокращения выбросов в ПДУЭР. Местное производство электроэнергии является очень перспективным сектором, в то время как промышленный сектор (не входящих в Систему торговли квотами на выбросы ETS), как ожидается принисет незначительный вклад в общую цель, несмотря на его актуальность в БКВ.

Категория мероприятий, которые имеют больший потенциал для сокращения выбросов CO_2 относятся к секторам строительства и местного производства электроэнергии (комплексное мероприятие на зданиях, комбинированная выработка тепла и электроэнергии и ветроэнергетика). Рычаги политики с большим потенциалом сокращения выбросов CO_2 состоятся от строительных и транспортных секторов (энергетический менеджмент и организация, управление и организация, инфраструктура и строительство, транспорт / градостроительное регулирование мобильности).

Переменные, влияющие на базовый уровень выбросов, а такжена предполагаемые сокращения выбросов, это плотность населения и ВВП. Ни одна другая переменная не является существенной для предполагаемых сокращений выбросов. На самом деле, коэффициент выбросов электроэнергии (КВЭ) и географическая зона являются значительными для базового уровня выбросов.

В некоторых случаях, сила результатов ограничивается количеством выборочно включенных в исследование городов и ограниченной степенью детализации, предоставляемых некоторыми из них. Тем не менее, единый подход к учету выбросов обеспечивает сопоставимость городов и согласованность результатов в отношении доступных данных.

PROMITHEAS Network, the origin of which is the Project Development Fund of BSEC, aims to promote scientific cooperation on the energy and climate policy issues between the countries of BSEC and EU and thus to contribute in knowledge transfer to that region, as a basic precondition for the development of human potential that will materialize policies of cooperation.

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NOA	National Observatory of Athens, Greece
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UA	University of Aegean – Department of Environment, Energy Management Laboratory, Greece
INEXCB-Kz	Independent Expert Consulting Board to Promote Scientific Research Activity in Kazakhstan, Kazakhstan
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