2-356-19 Heike Brugger

# Energy Efficiency Vision 2050: How do societal changes shape energy efficiency and energy demand?

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## Abstract

New societal trends are currently unfolding, such as digitalization, the sharing economy and changing consumer awareness. All of which might highly influence future energy demand and depending on their realization might enhance or counterbalance projected energy efficiency gains.

This work is a first attempt to analyse quantitatively how these societal trends might interact with energy efficiency gains. An extensive consultation with European experts identified 14 societal trends that are likely to shape future energy demand. Based on these trends three energy demand scenarios were developed for 2050. The EU Reference Scenario (2016) serves as the baseline (BAU). A 'Removing Barriers Scenario' (S1) identifies the prospective decreases in energy demand based on (nearly) cost-effective potentials but excluding major impacts of such new societal trends. Through extensive review of existing studies as well as expert consultations the impacts of new societal trends on all sectors were evaluated in two additional scenarios taking explicitly these trends into account: In scenario 2 the techno-economic potentials are realized, but are counterbalanced by societal trends (e.g. cars might become more energy efficient, but the increased comfort of automation leads to an increase in the kilometres travelled and / or to larger vehicles). Scenario 3 assumes that the Energy Efficiency First Principle is widely established and guides individual and policy decision-making, thus shaping societal trends in a way that facilitates decreasing energy demand. A current study by IEA (2017), based on Wadud et al (2016), shows that by 2050, digitalization might double or decrease transport energy demand by roughly 40%. This gives a rough idea of the spectrum of possible developments.

This paper aims to open up the discussion of how societal trends will shape future energy demand. It explicates that solely relying on unregulated energy efficiency gains to reduce energy demand underestimates the complexity of the interplay of energy demand with changing behaviour through societal trends, while they may also bring about large reduction potentials.

## Introduction

The central aim of the 2015 Paris Agreement is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. To reach this ambitious goal, concerning the energy system two central strategies are principally pursued by the European Union and its Member States: (1) enhancing energy efficiency (EE) and (2) decarbonising energy supply, in particular by large penetration of renewable energy sources (RES).

The order, in which the two main strategies are cited, reflect the "Energy Efficiency First" (EE1) Principle, which was proposed by the European Union as a fundamental principle applied to policymaking, planning and investment in the energy sector. The principal is gaining increasing visibility in European energy and climate policy. Briefly described, the concept of EE1 prioritizes investments in customer-side efficiency resources (including end-use and supply side energy efficiency and demand response) whenever they would cost less, or deliver more value, than investing in energy infrastructure, fuels, and supply alone. Although in the Energy Union Strategy energy efficiency has been recognised as a resource in its own right at the same level as generation capacity and the EE1 as a guiding principle has been brought forward, previous studies suggest that still numerous barriers impede this principle to be streamlined and the benefits of energy efficiency to be adequately taken into account in financial and political planning and decision making (BMU and Fraunhofer ISI 2012; Fraunhofer ISI 2009; Schleich 2009; Schleich and Gruber 2008).

Further, New Societal Trends are arising, linked to general megatrends, which can have potentially large (increasing or decreasing) impacts on energy consumption (see for example Grubler et al. 2018). Such trends include among others: (1) the digitalisation of the economy and of private life, (2) autonomous driving, (3) the trend towards a Shared Economy, (4) the move towards low carbon industrial processes, and (5) the circular economy and material efficiency.

# Methodological Approach

## *Trend Selection, Clustering and Scenario Development*

Under expert consultation three scenarios – beside the baseline - and one variant up to 2050 were developed:

- **Baseline** based on the most recent PRIMES projections from 2016 (European Commission 2016). This scenario provides the reference for the development of drivers of energy consumption. New Societal Trends happen in this scenario but rather as a smooth continuation of previous trends (linear societal trends).
- **Removing Market Barriers:** this scenario focusses on the realization of economic/ near economic potentials for EE, mainly based on technical solutions to EE. New Societal Trends happen in this scenario but rather as a smooth continuation of previous trends (linear societal trends).

The following two scenarios are based on the Removing Market Barriers scenario. In these scenarios, the economic/near economic potentials for energy efficiency are realised, and the potentials are either reduced or enhanced due to new trends. A variant – worst case – has been developed where new Societal Trends operate directly on the Baseline,

- **New Trends Inefficient** Scenario, which is characterised by strong non-linear societal trends due to penetration of shared/digital economy and strong rebound effects, i.e. energy-increasing impacts of the New Societal Trends.
  - **Variant - Worst Case:** For comparison purposes, in this variant New Societal Trends operate directly on the Baseline.
- **New Trends Efficient** Scenario, which is also characterised by strong non-linear societal trends but the realisation of the EE1 Principle strongly contributes to bring forward the energy reducing impacts of the New Societal Trends.

The four scenarios are developed through the following working steps: Trend Identification (Step 1), Deep dive analysis (Step 2), Expert discussion (Step 3) and Scenario development (Step 4). Steps 1 to 3 have focused on the identification of the most relevant societal trends for the energy systems in general, particularly for the increase or decrease of energy efficiency and energy demand. Step 4 focused on the analysis of the impact of societal trends on the modelling parameters and the scenario development (see Figure 1). The trend selection process from 84 trends (60 societal trends and 24 megatrends) to 12 trends identified to be particularly relevant for the energy demand and the implementation of the Efficiency First Principle was based on expert discussions including clustering of similar themes, so that the trends had similar levels of aggregation. Three scenario workshops with on average about 20-30 energy experts were carried out in the period between January and September 2018, to explore the 2050 energy perspective, supported by analytical work. Experts came from across the EU with different professional backgrounds, ranging from industrial branch to environmental NGO representatives. The aim and results of these workshops are described below.

**Step 1: Trend Identification**

The Trend Identification departed from a study from VDI-Technologiezentrum and Fraunhofer ISI (2017) for the German Federal Ministry of Education and Research (BMBF) , in which a set of megatrends and detailed trend profiles was developed. The search criteria for the identification of societal trends in the BMBF Foresight Process were:

- Social relevance: The importance of a trend is determined by significant social and/or economic and in some cases also disruptive impacts.
- Time dimension: Impacts of the trend are relevant in a period of time extending from now until 2030.
- Relationship to research and innovation (R&I): The trend as a whole or in some aspects should clearly relate to research and innovation.
- Degree of 'newness' of a social trend: The social trend is wholly or partly new for the research and innovation system, or, in the opinion of the authors and experts involved, has received too little attention to date.

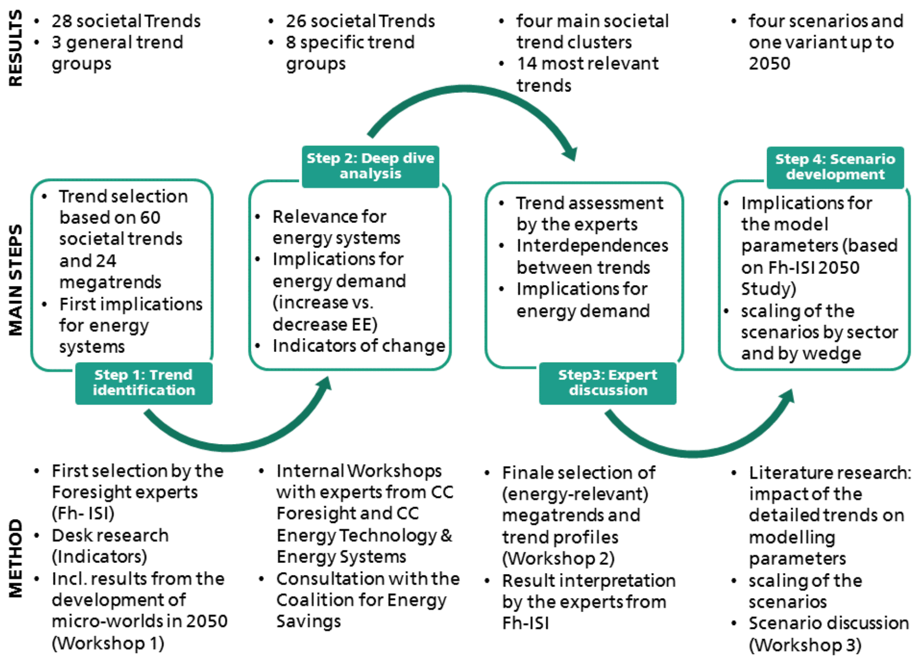


*Figure 1: Scenario development process*

The result of the process were 60 trend profiles in three categories (1) Society / Culture / Quality of Life, (2) Business and (3) Politics and Governance (see VDI-Technologiezentrum and Fraunhofer ISI 2017). Since the database for the development of these 60 trend profiles trends comes from the years 2013-2014, current data and facts have been researched to validate timeliness of the trends. The trends profiles were developed in the context of major changes, so-called megatrends, such as increased urbanisation, increased 65-plus age and increase in life expectancy or digitalisation, which has an influence on employment structure. These megatrends were considered in Step 2 and 3.

### Step 2: Deep dive analysis

A deep dive analysis was carried out in order to assess the relevance of the societal trends for the energy system. The implications for the increase or the decrease of energy efficiency and energy demand were discussed and the specific indicators of change (key parameters) were identified (see example in Table 1).

**Table 1: Template for the Reflexion on the Trends**

| Trend | Describe relevance for the energy system | Describe how this can | | Key parameter(s) |
|---|---|---|---|---|
| | | increase EE | decrease EE | |
| M5 Declining household size [StS] | • quicker uptake of new services<br>• lower rate of ownership<br>• impact on available income and consumption pattern | • If it leads to rapid uptake of EE services and solutions.<br>• If it leads to urbanisation and less commuting. | • If it leads to more appliances and living surface per capita.<br>• If it leads to poverty (capital availability). | • number and age/lifetime of appliances<br>• m2<br>• person km |

### Step 3: Expert discussion

The (energy-relevant) megatrends and trend profiles were selected in an expert workshop, which focused on:

- The selection of trends, creation of clusters or limitation of the selection;
- Identification the potential impact of the trends on the energy system
- Linking the selected trends with the scenario description; and
- Pre-identification of parameters for the modelling of the scenarios.

12 trends were identified to be particularly relevant for the energy demand and the implementation of the Efficiency First Principle. These 12 trends were further clustered into four main Societal Trend Clusters (see Table 2), which formed the basis for the scenario work. The four identified clusters are: 'Digitalisation of Life', 'New Social and Economic Models', 'Industrial Transformation' and 'Quality of Life'. Though the development of the clusters was an iterative process with significant stakeholder and expert involvement, the definition of these clusters is not carved in stone and might be evolving in future work.

**Table 2: Definition of Societal Trend Clusters & Detailed Trends**

| Cluster | Trend |
|---|---|
| Digitalisation of Life | Human Machine / Shift towards smart products and services |
| New Social and Economic Models | Sharing Economy |
| | Prosumer |
| | Awareness (of personal footprint) |
| | Social Disparities / Energy Poverty |
| | New forms of funding - Public spending towards greener and more efficient options |
| Industrial Transformation | Reindustrialisation |
| | Circular Economy - new requirements for material flows for consumer goods |
| | Decarbonization of the Industry |
| Quality of Life | Increasing importance of health (e.g. air quality, noise, heat) |
| | Regionalisation - Urban governance solving global challenges locally in cities |
| | Urbanisation - Global trend towards larger shares of the population living in cities |

**Step 4: Scenario development**

Through a thorough literature research on pre-existing studies in step four, the impact of societal trends on energy consumption was identified. The further process included three main steps (quantifying the results):

- Assessing the magnitudes of the numbers given in the various studies and thereby evaluating the impact of the detailed trends on important modelling parameters of the various wedges set up in the techno-economic scenario. Both, energy-increasing and energy-decreasing impacts were considered. Care was taken, when analysing the studies to understand, which part of the trend was already included in the Baseline development and the Removing Market Barriers Scenario. It will be shown shortly, that both scenarios already include a part of the New Societal Trends, which can be considered the continuation of developments of the past.
- Translating the impacts into modelling parameters while estimating open model parameters. Care was taken to use conservative estimates as to the impacts of such trends (exemplified Table 4) for the household sector).
- Finally scaling of the scenarios by sector and by wedge occurred with the estimated parameters.

## *The Electricity Mix*

Although we focus on the demand side of energy use, the potentials have a major effect on primary energy demand. Primary energy saving potentials are the result of conversion efficiency as well as final energy related efficiency measures. The savings in primary energy demand are thus highly influenced by the shift towards a highly efficient electricity generation mix. For the Baseline Scenario the electricity mix of the EC (2016) is implemented. In the other scenarios an electricity mix is applied which follows the EUCO 3030 Scenario (E3MLab & IIASA, 2016) up to 2030 and then a low carbon mix up to 2050 based on an update of BMU and Fraunhofer ISI (2012), which reaches over 92% of RES in 2050 (Table 3).

**Table 3: Low-carbon electricity generation mix**

| EU long-term | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| RES (without Biomass) | 17% | 30% | 45% | 56% | 66% |

| | | | | | |
|---|---|---|---|---|---|
| Biomass | 4% | 6% | 9% | 18% | 26% |
| Heating Oil | 3% | 1% | 0% | 0% | 0% |
| Natural Gas | 24% | 17% | 11% | 9% | 8% |
| Solids | 25% | 23% | 13% | 7% | 0% |
| Nuclear | 28% | 23% | 22% | 11% | 0% |

# A Techno-Economic Scenario of Energy Efficiency Potentials for the EU until 2050 ("Removing Market Barriers")

The main purpose of this section is to give an overview of the (techno-economic) potentials and possible contributions of energy efficiency and energy saving options to meeting the EU's 2030 and 2050 targets for Energy Efficiency and GHG emissions in a techno-economic scenario ("Removing Market Barriers"). The following issues are addressed in detail:

1. Analysis of the (techno-economic) energy efficiency potentials in the various sectors, considering up to date projections of energy demand and central drivers for energy demand (such as sectoral GDP, population growth and kilometres travelled).
2. Contribution of enhanced energy efficiency in energy conversion and in energy end-use to primary energy savings by 2050.
3. Analysis of the contribution, final energy savings can make to reducing GHG emissions by 2050 through increased energy efficiency and energy savings.

## *Methodology for the techno-economic scenario*

Within the project, ten packages (so-called wedges) were put together for an in-depth analysis. They include specific energy efficiency options and the underlying technologies, which can be addressed by individual policy measures. All saving potentials not covered through these ten wedges are represented in the “estimated wedges”. The model parameters for the wedges need to account for double-counting of certain mechanisms across wedges. Care was taken here to eliminate such double-counting among the different societal trends but more in-depth analysis could better separate such overlapping impacts.

Determining the energy saving potentials is mainly based on the work completed for the policy report "Contribution of Energy Efficiency Measures to Climate Protection within the European Union until 2050" [BMU, Fraunhofer ISI, 2012]. In turn, this study draws from the work of the “Study on the Energy Saving Potentials in EU Member States, Candidate Countries and EEA Countries” [Fraunhofer ISI, 2009a], which includes the quantification of energy saving potentials up to 2030 based on a technology specific, bottom up simulation and the ADAM project [Fraunhofer ISI, 2009b] which served as a basis for extrapolating the potentials as well as the baseline development up to 2050.

The original data were determined in comparison to the baseline energy demand projection of the European Commission from the year 2008 (European Commission 2008). In order to take into account the current projections of energy demand drivers up to 2050 and the fact that time has moved on (with part of the energy efficiency potentials being realised by policy measures or part being "lost" for energy efficiency, as investments have been taken in less efficient technologies) two adjustments were made:

- The potentials were scaled to the projections of the European Commission (2016 - Primes reference scenario). The saving potentials were adjusted considering the updated final energy demand as well as the changed activities and altered energy intensities per sector.
- Furthermore, potentials that were already realized between 2009 and 2016 are deducted from the previously identified potentials.

Thus, a decrease in potentials in some of the sectors is the result of a combination of decreasing activities and/or already realized potentials, while increasing potentials can be traced back to higher activity projections.

The saving potentials identified should be understood as cost-effective and nearly cost-effective technical potentials, rather than theoretical potentials (see Fraunhofer ISI 2009a for more details). Cost-effective technical energy-saving potentials depend on the future development of drivers such as the economic or social development (e.g. the future GDP, population growth, stock of existing buildings etc.). The drivers underlying the present scenario are the ones underlying the reference scenario of EC (2016).

With regard to the cost-effectiveness of efficiency technologies, only economic technologies are selected (i.e. the financial savings that an investor / end-user can expect through the avoided fuel procurement exceed his or her additional investments required to implement the efficiency technology) or at least near-economic ones, in order to include only technologies that are likely to reach market maturity. The latter ones are chosen in such a manner that the energy system costs are not exceeding the present energy system costs.

## *The Baseline*

The Baseline is based on the most recent projections of the European Commission with the PRIMES model, for the sectors as well as for the overall final energy demand. Details of these projections can be found in EC (2016). The main features of this scenario are that (1) final energy demand stays relatively stable and even slightly increases after 2040, (2) primary energy demand decreases somewhat, essentially due to the penetration of renewable energy sources and (3) (energy-related) GHG emissions decrease by about 42% compared to 2010, also mainly due to the fuel switch towards renewable energy sources. Though the reduction in GHG emissions is considerable already in the Baseline, overall, these projections are far away from reaching the requirements of the Paris Agreement. Including all GHG emissions and comparing with 1990, in 2050 a reduction of 48% is achieved in GHG emissions (EC, 2016).

## *Identifying techno-economic saving potentials - Example of the Household Sector*

Within the Removing Barriers Scenario it is modelled which demand side potential (nearly) cost-effective energy efficiency measures have in reducing final energy demand. The techno-economic potentials were modelled with a bottom-up approach (Fraunhofer ISI 2009; BMU and Fraunhofer ISI 2012) and have been updated in order to account for realized and lost potentials since the initial study. Within the scope of this paper, no detailed description of the bottom-up modelling of the techno-economic potentials, which are (nearly) cost-effective potentials - and later of the effect of the new societal trends - can be given. However, in order to provide some insight into the approach, the proceeding is explained exemplary for the household sector.

According to Primes 2016, the baseline final energy demand in the household sector is projected to have peaked in 2010 and to decline from 2010 until 2030, with a small increase afterwards. Final energy demand is projected to again reach the level of 2025 in the year 2050 (~290 Mtoe). However, major final energy saving potentials exist, which can lead to a reduction in final energy demand of 63 percent in 2050 compared to the baseline development (Figure 2).

More than half of these savings are related to the building shell refurbishment of existing buildings, with the refurbishment of old buildings (25%) and the restoration of heating system in existing buildings (13%). Furthermore, 12 percent of savings can be realized in the construction of new buildings. The savings in sanitary hot water (4%), efficient lighting (3%) and electric appliances (4%) contribute to a significant lesser extent to the overall savings.

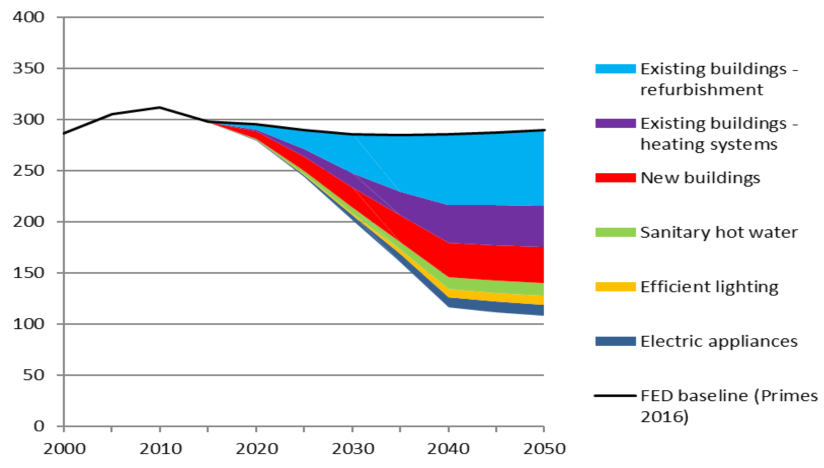


*Figure 2: Final energy demand and energy saving potentials by wedge in the household sector (in Mtoe)*

## *Overall saving potentials*

In the following it will be shown how final and primary energy demand as well as in energy-related $CO_2$-emissions can be reduced when techno-economic potentials in all sectors are realized.

### Overall final energy demand saving potential

The Primes 2016 baseline of total final energy demand has its peak in 2005 and decreases until 2030. Afterwards it is expected to increase slightly. Overall, a change of minus four percent between 2000 and 2050 is projected.

Compared to this baseline development, final energy demand could potentially be reduced through techno-economic potentials by 51 percent in the year 2050. Figure 3 shows that households and the tertiary sector could deliver 22% (wedges 1-5) the industry sector contributes 7% (wedges 6-8) and the technical improvements in the transport sector together with a notable shift towards electric vehicles (wedge 9 & 10) about 14%. Furthermore, the "estimated wedge" contributes about 7% to the savings and subsumes- among others - low impact industry savings, and certain appliances in the tertiary sector. Overall 14% of final energy demand reduction (about 1/3 of the total savings) can be realized solely through building enveloped measures. The agriculture sector is hereby included in the remaining final energy demand in the tertiary sector.

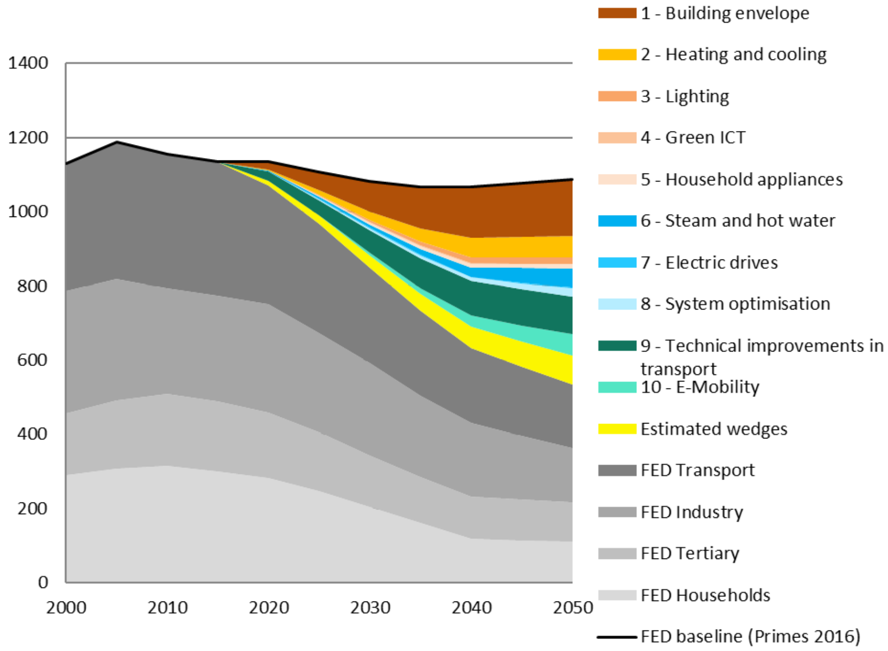


*Figure 3: Overall final energy demand and final energy savings (Mtoe)*

### Overall primary energy saving potentials

Based on a decrease of final energy demand in the Primes 2016 baseline, the primary energy demand will also decrease slowly but steadily. The primary energy demand hereby includes non-energy uses. In the baseline scenario, it is expected to be 15% lower in 2050 as compared to 2010.

The primary energy saving potentials, as shown in Figure 4 are divided into “conversion savings” triggered by the shift towards a highly-efficient, mainly renewable energy-based electricity supply system (Table 3) and “final energy savings” due to exploiting the final energy saving potentials described above.

Primary energy demand can be reduced by up to 20% by 2050 due to conversion savings. The transport sector’s contribution here is negligible since it does not benefit from an increase in conversion efficiency (e.g. for oil products). Final energy related savings imply an additional 40% reduction in primary energy demand making a total of 60% avoidable.

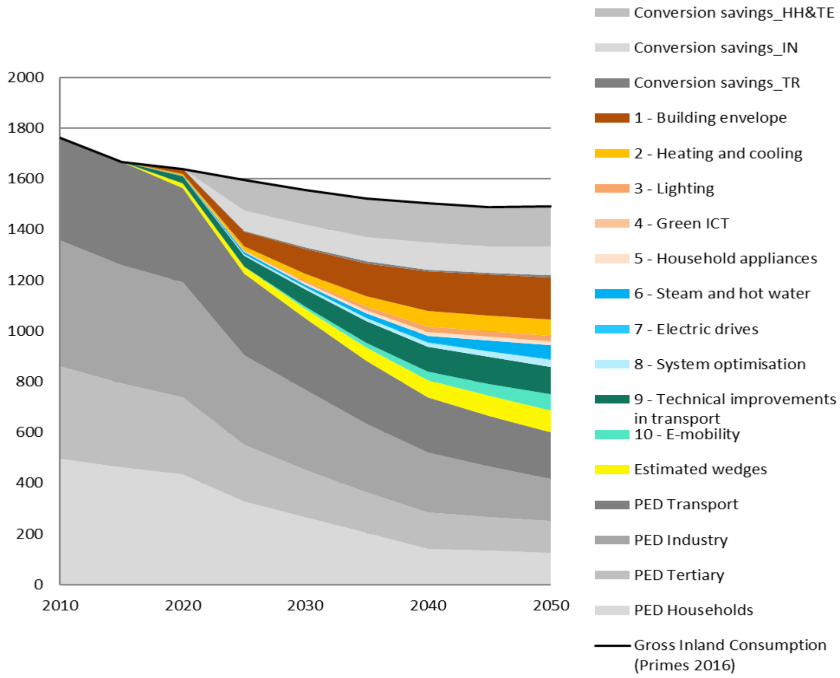


*Figure 4: Gross Inland Consumption for all Sectors - Baseline and 'Removing Market Barriers' Scenario (including non-energy use) (Mtoe)*

### Energy efficiency contribution in GHG emission reductions

In the Primes 2016 baseline, GHG emissions are projected to decrease drastically by 43 percent between 2010 and 2050 (Figure 5). This is based on the fact that electricity is increasingly generated using low-carbon generation technologies. The additional emission reduction potential due to "conversion savings" lies at 21% in 2050 compared to the baseline, 13.5% of which are due to the increase of electric vehicles in passenger transport.

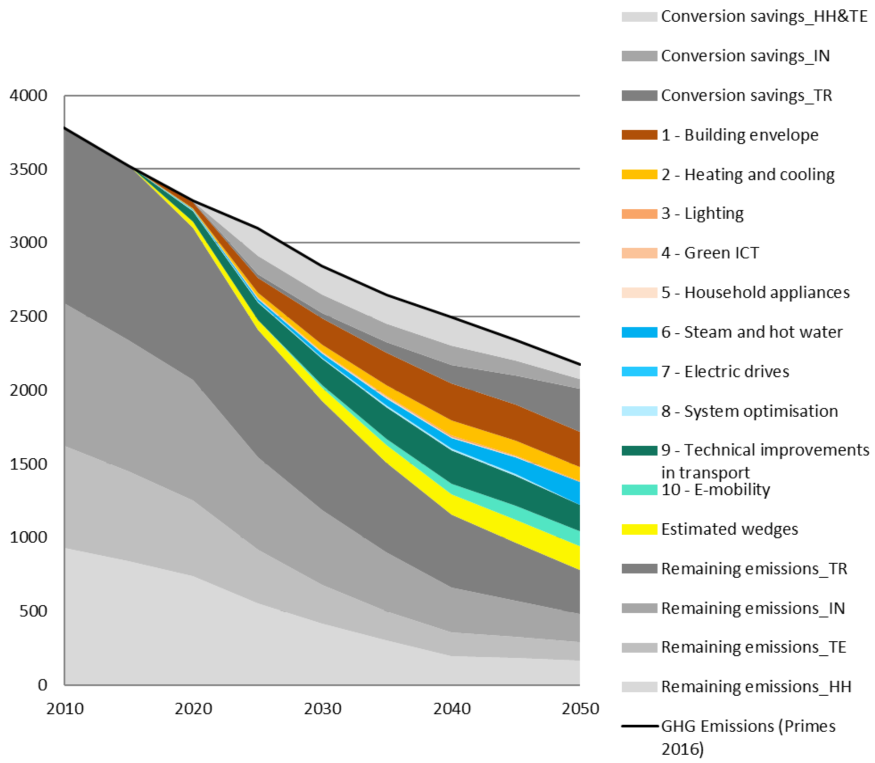


*Figure 5: Energy related GHG emissions resulting from final energy savings (in Mt CO2-equivalent)*

The overall contribution from energy efficiency measures related to final energy lowers GHG emissions by an additional 43% compared to the baseline emissions. This can be translated into a 79% emission reduction compared to the 2010 level and 81% emission reduction compared to the 1990 level (of 4.139 Mt $CO_2$-equivalent). It has to be noted, that these figures represent only energy related GHG emissions reduction potentials and do not reflect measures in other areas with further GHG emission reduction potentials.

As already mentioned, it is worth pointing out once again that the higher the initial share of electricity as a final energy carrier in a sector, the lower the contribution of this sector to additional GHG emission reduction (compared to the baseline) as a result of the autonomous decarbonisation of the power sector under the baseline.

## Efficient and Inefficient New Trends Scenarios

Two scenarios complement the baseline and techno-economic scenarios, which take structural and societal changes and their (increasing or decreasing) impacts on energy consumption more explicitly into account, contrasting the techno-economic scenario. The two scenarios developed here are contrasting scenarios: in particular the "New Trends Inefficient" Scenario is gathering the increasing impacts of these trends while the "New Trends Efficient" Scenario supposes that realisation of the EE1 Principle leads to the enhancement of the decreasing impacts of the trends on energy consumption. De facto, increasing and decreasing impacts may be observed at the same time. This could be established by evaluating the likelihood of one or the other trend, e.g. in further expert workshops, but is not yet covered within the present work.  In this section, first the method for evaluating the effect of new societal trends on final energy demand is laid out. This procedure is then exemplified for the household sector. Afterward it is laid out how total final energy demand will develop in the various scenarios as well as the contribution of enhanced energy efficiency in energy conversion and in energy end-use to primary energy savings by 2050. Finally it is analysed, which contribution final energy savings can make to reducing GHG emissions by 2050 through increased energy efficiency and energy savings.

### *Methodology for the Efficient and Inefficient New Trends Scenarios*

The Efficient and Inefficient New Trends Scenarios rely on the following working steps:

- Thorough literature research on pre-existing studies – impact of societal trends on energy consumption.
- Assessing the numbers given in the various studies and thereby evaluating the impact of the detailed trends on important modelling parameters of the various wedges set up in the techno-economic scenario. Both, energy-increasing and energy-decreasing impacts were considered (Table 4 provides an example). Care was taken, when analysing the studies to understand, which part of the trend was already included in the Baseline development and the techno-economic scenarios. It should be recalled that both already include a part of the New Societal Trends, which can be considered the continuation of developments of the past.
- Translating the impacts into modelling parameters.
- Estimating open model parameters. Care was taken to use conservative estimates as to the impacts of such trends
- Scaling of the scenarios by sector and by wedge with the estimated parameters.

### *Evaluating the Impact of New Societal Trends Exemplary for the Household sector*

For the household and tertiary sectors the following main impacts of the New Societal Trends on energy consumption and scenario parameters are relevant:

In the New Trends Inefficient Scenario (increasing impacts on energy consumption):

- Building automation and interconnection of appliances increases the energy demand of the buildings
- Despite of a widespread awareness consumers have increasing energy demands (e.g. due to changes in comfort levels)

In the New Trends Efficient Scenario (decreasing impacts on energy consumption):

- Building automation raises consumer awareness
- Decentral generation of electricity raises the awareness of the value of energy
- Urbanization contributes to reducing living areas and adapting them to the living context.
- Consciousness about the personal (carbon) footprint impacts consumer choices on buildings and appliances.

Behavioural choices such as the adaptation of space to the living context, consciousness about the personal footprints and decentral generation of electricity, supported by policy settings, contribute to New Trends Efficient Scenario. The major impacts by New Societal Trends in the Efficient and Inefficient New Trends

Scenarios for the different wedges in the household sector are given below (Table 4). Both, energy-increasing and energy-decreasing impacts were considered. The speech bubbles show exemplary how the parameters were derived. Results for final energy demand (EU28) in the three scenarios and the variant is provided in Figure 6.

**Table 4: Major parameter settings derived from studies and estimates for the main trend clusters and main wedges in the household and tertiary sectors**

| | Energy demand | |
|---|---|---|
| | Heating and Cooling | Appliances and Lighting |
| **New Trends Efficient Scenario** | | |
| Digitalisation of Life | 0.95 | 0.79 |
| New Social and Economic Models | | |
| *Consumer / Citizens* | 0.8 | 0.9 |
| *Sustainable Finance* | 0.95 | 1 |
| Industrial Transformation | 1 | 1 |
| Quality of Life | | |
| *Health & Comfort* | 1 | 1 |
| *Regionalization / Urbanization* | 0.9 | 1 |
| Total Scenario Changes | 0.65 | 0.71 |
| **New Trends Inefficient Scenario** | | |
| Digitalisation of Life | 1.1 | 1.5 |
| New Social and Economic Models | | |
| *Consumer / Citizens* | 1.1 | 1.1 |
| *Sustainable Finance* | 1 | 1 |
| Industrial Transformation | 1 | 1 |
| Quality of Life | | |
| *Health & Comfort* | 1.1 | 1.1 |
| *Regionalization / Urbanization* | 1 | 1 |
| Total Scenario Changes | 1.33 | 1.82 |

Own estimate based on projections by *IEA 2017 - Digitalization & Energy*

Gains through increased public spending in renovation

Increasing demand based on longer heating and cooling hours due to remote control

Own estimate based on *UKERC - Energy 2050 - Energy Demand Lifestyle and Energy Consumption*

Changes in comfort levels, e.g. room temperatures

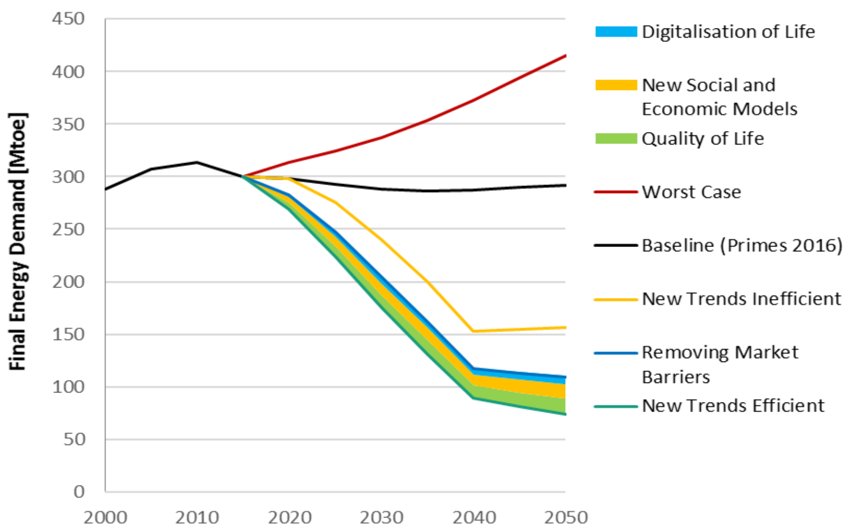


*Figure 6: Final energy demand household sector (EU28) in the three scenarios and the variant Worst Case. The graph shows the contribution of the four large Trend Clusters in the case of the New Trends Efficient Scenario*

## *Overall results for the Efficient and Inefficient New Trends Scenarios*

Similarly to the household sector the impact of the new societal trends on final energy demand was determined for the other sectors. The sectoral energy demand within the various scenarios can thus be added up in order to determine the paths for the total final energy demand (Figure 7).

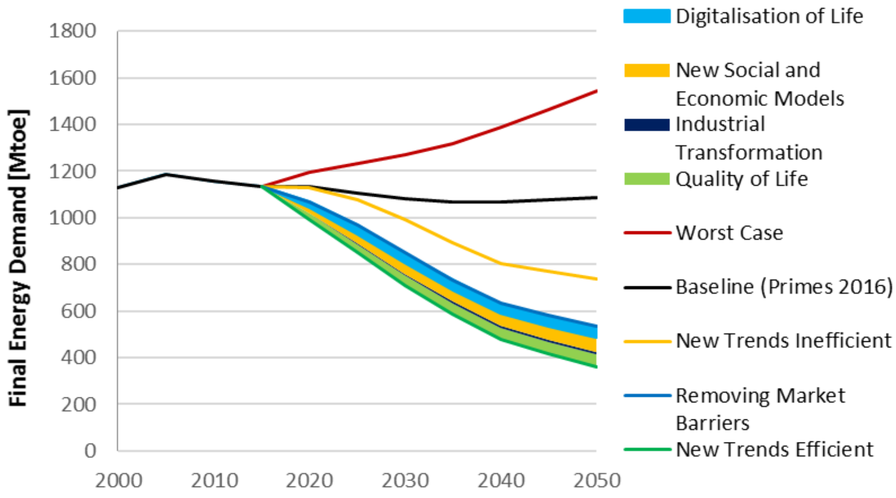


*Figure 7: Final energy demand (EU28) in the three scenarios and the variant Worst Case. The graph also shows the contribution of the four large Trend Clusters in the case of the New Trends Efficient Scenario*

Figure 7 also indicates to which extent the four societal trend clusters contribute to the decreasing final energy demand from the Removing Barriers Scenario (mere techno-economic potentials) to the New Societal Trend Scenario. The main findings from the analysis of the total final energy demand are the following:

- New Societal Trends without EE1 (New Trend Inefficient Scenario) could diminish the effect of the realized techno-economic potentials for FED to a 32% reduction.
- If the New Societal Trends would unfold the energy increasing trends, without the realisation of the techno-economic potentials (Worst Case variant to the New Trends Inefficient Scenario), the FED could be strongly increased by up to 42% above the Baseline
- New Societal Trends supported by a strong EE1 Principle (New Trends Efficient Scenario) could decrease FED further (-67% compared to the Baseline in 2050)

The Gross Inland Consumption and the (energy-related) $CO_2$-emissions are based on the final energy demand and the low carbon electricity mix shown in Table 3. The resulting Gross Inland Consumption and CO2-emissiions within the various scenarios and the variant are visualized in Figure 8 and Figure 9.

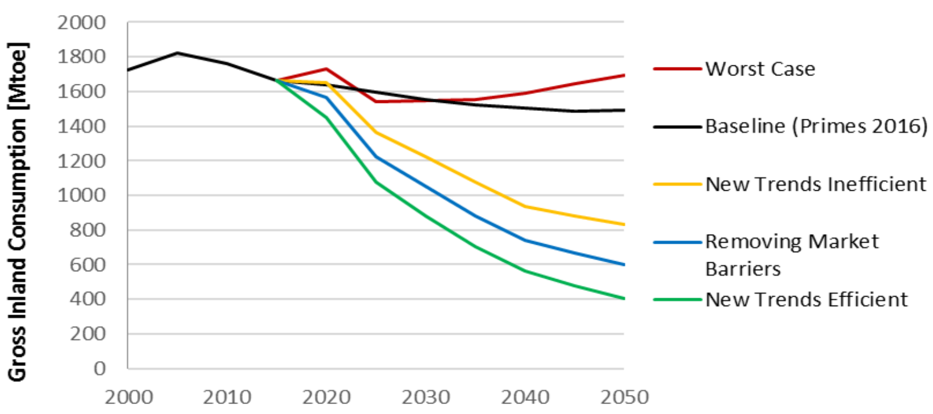


*Figure 8: Gross Inland Consumption in the three scenarios (EU 28) and the Variant Worst Case*

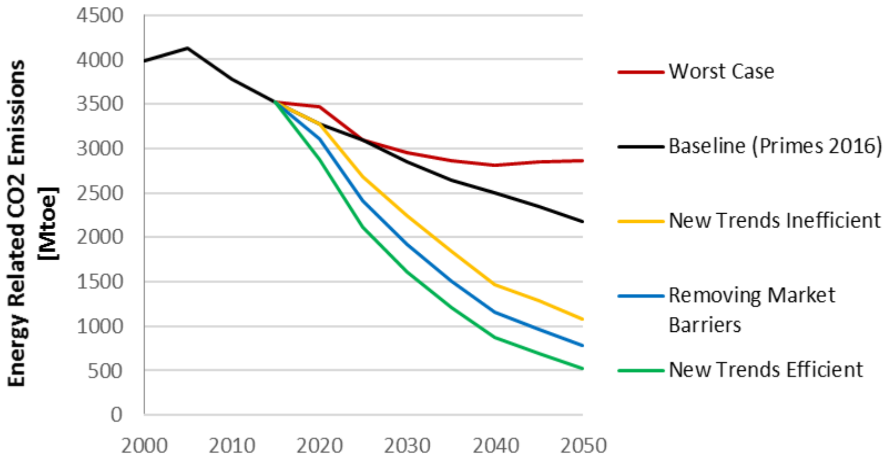


*Figure 9: Energy-related GHG emissions in the three scenarios (EU28) and the Variant Worst Case*

## Limitations of the work

This exploratory work comes with some limitations of this work have to be kept in mind. First, since European ambitions develop rather rapidly, the latest updates of the primary energy efficiency mix (notably the reviewed Renewables Directive) could not be taken into account. Second, this analysis is based on cost-effective potentials previously identified (BMU & Fraunhofer ISI 2012; Fraunhofer ISI 2009a). Although all potentials were updated considering structural changes, altered activities and updated energy intensities, some haziness cannot fully be excluded. Third, the potentials were updated based on Primes 2016. Thereby, assumptions on structural and lifestyle changes (or the lack of the same), changing activity sizes and energy intensities are adopted from Primes 2016 as well. We consider the work performed here in many regards a pioneering work. It has gathered information on the relation of New Societal Trends to the best of present knowledge and closed gaps with estimates. However, limitations arise due to the current data and study availability. For many trends no previous studies exist, which determine the even the qualitative effects of the trend on the energy consumption (e.g. consumer; financing; urbanization) and had to be completed by own expert estimates on impacts. Specifically, there is quite often yet no quantification of these trends. Furthermore, existing studies are often not transparent in their baseline assumptions. Some trends were assessed on other regional scales. Therefore, parameters needed to be adopted to the EU context. Specific EU studies may enhance the validity for the European context. As mentioned previously, the assessment of the effects on energy demand of the various mechanisms has to account for double-counting. A multiplication of the effects (rather than an addition) was chosen as a more conservative calculation method in order to minimize remaining double-counting effects. More studies on individual trends, and especially on their interplay, are required in the future to gain more certainty on the quantitative impacts. In the current work estimates were carried out in a conservative way, in order to not to overestimate the impacts of the New Societal Trends for which data availability is still challenging.

## Conclusion

Efficiency gains play a crucial role in realizing the European's climate goals. However, these efficiency gains do not by themselves lead to a reduction of energy demand. As the transport sector has exemplified over the last years, the potential reduction of energy demand by increasing efficiency is counterbalanced by an ever growing demand of private car transport and larger vehicles. This paper aims in opening up the discussion of how energy demand might change through new societal trends. As the various scenarios depict in a stylized way, new societal trends could unfold in a way that further decreases energy demand beyond merely realizing the techno-economic potentials, if the energy efficiency first principle guides individual and policy decision making in a beneficial way. However, the effects of the new societal trends could also counterbalance efficiency gains in a way that leads further away from the realization of the EUs goals.

The results of this analysis show, that the path that final energy demand will take in the years to come is less than certain and will depend not only on the realization of techno-economic potentials but to a vital part on how societal trends will unfold. It will thus be crucial to further intensify the work on studying not only the cost-effective potentials but also to further quantify the effects that societal trends will have on future energy demand. This might ultimately inform policy makers on how policies have to be designed in order to shape political, commercial and individual decision-making in a way that further decreases energy-demand rather than counterbalances efficiency gains.

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