Executive Summary:
EMInInn aims at assessing the environmental impacts associated with innovation. In a first step EMInInn has assembled and set out coherently, on the one hand, macro-indicators and data of environmental impacts and, on the other hand, indicators and data to measure innovations. The definitions and delineations have been the basis for selecting appropriate analytical frameworks to operationalize assessments of environmental impacts associated with innovation on a macro scale. EMInInn has incorporated and integrated a number of advanced analytical approaches for the ex post assessment of the macro-environmental impacts of innovation. These methodologies have been applied in different areas of technological innovation:
EMInInn has developed an analytical framework for assessing environmental impacts of established as well as emerging technologies. In selected cases options for scenarios to model burden-shifting and rebound effects have been explored. EMInInn has strengthened the science-policy link. In that context EMInInn has addressed EU policies, which affect three major fields of environmental impact:
- resources and waste,
- energy and climate, as well as
- land-use and biodiversity.
By improving environmental assessments of innovation as well as policy-oriented interactions and outputs, EMInInn has generated contributions for improving EU-policies for a transition towards a more sustainable Europe.

Project Context and Objectives:
The Europe 2020 strategy is supposed to pave the way for the EU to become a smart, sustainable and inclusive economy. Its “Flagship Initiative for a Resource-Efficient Europe” aims at promoting sustainable growth and supports a shift towards a resource-efficient, low-carbon economy.

Do we actually know what a “sustainable growth” means? How could we assess implications of major transitions promoted by the European Commission and other governmental actors such as development of a bio-based economy, a green economy, or a low-carbon society? What kind of innovation would be required for that? What does this mean for our energy systems, for transport, for Information and Communication Technology (ICT), for construction or waste management?

A sustainable growth, a green or a circular economy require social and technological innovations. In contrast to plain growth strategies or economic stimulus programs they do not intend to encourage any innovations, but innovations which would support the transition towards sustainability. Thus, innovation intended by Europe 2020 strategy would have a direction. Yet, it is difficult to assess whether specific innovations support a transition in a desired direction or not. Positive or negative macro-environmental impacts of innovations are often unknown. Environmental impacts cannot simply be attributed to specific properties of technologies (e.g. the fuel efficiency of cars). Their contribution to changes of the environment (e.g. by greenhouse effect) are a product of physical, behavioural, social and economic factors. The can amplify or decrease the pressure on the environment or they simply do not play a role at all. A “green” car may be an additional car instead of a substitute. Money saved through fuel-saving might result in shifted expenditures with low or high negative environmental impacts. Positive micro or meso impacts of eco-innovation may be outweighed at the macro level by larger-scale processes which they may have catalysed, or which they are subject to.

The European research project EMInInn tracks the past development and diffusion through the economy of pervasive innovations that can be expected to have had an appreciable positive or negative environmental impact. EMInInn aims at generating deeper insights into the role of innovation in decoupling environmental impacts from economic growth, helping policy makers to both assess the benefits from past innovations as well as maximize benefits from present and emerging innovations.

The general objectives of EMInInn are:
• The delivery of accurate and comprehensive information on the environmental impacts of innovation to strengthen the science-policy link in order to enable policy makers to stimulate eco-innovation and to both assess and maximise its benefits.
• Development of methodologies and quantification of macro-level indicators to monitor the ex-post impacts of innovation processes, including diffusion of innovations into society, their economic impacts, and their impacts on key environmental categories (namely resource flows, waste and recycling, energy, emissions, and land use and biodiversity).
• Contribution to the identification of drivers and barriers relating to eco-innovation, thereby facilitating the full recognition of eco-innovation potential.
• Support for the decision-making process on policy targets and methods for evaluating the environmental impacts of innovation and other relevant policies on the basis of physical indicators.

The EMInInn partner’s research and development objectives:
• Combine the insights and outcomes of recent advanced initiatives and research projects on the measurement of innovation.
• Compile and systematize from different sources the available data to measure the environmental impacts of innovation.
• Provide a common understanding on eco-innovation by creating common definitions and analytical boundaries that will enable the development of ex-post assessments and modeling of the environmental effects of innovation.
• Apply, combine and, where appropriate, integrate methods, tools and approaches to show the macro-environmental results of past innovations in a range of different fields, thereby to create or enhance the ability to make ex-post assessments and modeling of innovation and its related (environmental) impacts in the areas of resource flows, waste and recycling, energy, emissions, and land use and biodiversity.
• Improve the ability to monitor and assess secondary environmental and economic impacts of innovation (e.g. rebound effects).
• On the basis of the assessment of the results, make recommendations that will support policy makers in the design of innovation policies and framework conditions.
• Identify innovations and novel system configurations that may be able to contribute to absolute decoupling of economic growth and environmental pressure as well as to the conditions for this to occur.

Results
EMInInn has established a joint understanding and methodological approaches on macro environmental impacts (WP1) and innovation measurements (WP2) and has combined this in a general analytical framework (WP3). Harmonised approaches were documented in methodological background papers, which describe the essentials needed to carry out the ex-post assessment of the innovations addressed in the case studies:
1. EMInInn framework for ex-post analysis of innovation at macro-level
2. EMInInn glossary of terms
3. Environmental indicators for the EMInInn project
4. Innovation indicators
5. Methods and models for the EMInInn project
6. Case study on the proposed framework for the ex-post analysis of innovation

The interactions of experts, researchers and stakeholders contributed to set out coherently, on the one hand, macro-indicators and data of environmental pressures and, on the other hand, indicators and data to measure innovations. The commonly agreed definitions and delineations are the basis for selecting
appropriate analytical frameworks to operationalize assessments of environmental pressures associated with innovation on a macro scale. Phase 2 of the project has analysed on the macro level the ex-post effects of innovations in five sectors:

1. energy
2. transport
3. construction
4. ICT and
5. waste.

Modelling
Even though EMInInn is primarily about ex-post assessment of environmental impacts, WP9 will additionally perform macro-modelling and ex-ante assessments. WP9 builds upon the ex-post analysis in WP4-8. These WPs after all give historical insight in a variety of very important mechanisms that are of relevance to predict the future impacts of new eco-innovations, as well as potential diffusion speed, etc. Using such insights in an ex-ante analysis will help to develop insight into if and if yes how policy targets can be designed.

Policy implications and dissemination
In phase 3 EMInInn has continued to improve evidence-based policy making through the interaction with experts, stakeholders and policy-makers. In that context EMInInn has addressed EU policies, which affect three main areas that are related to major environmental pressures:

1. resources and waste,
2. energy and climate, as well as
3. land-use and biodiversity.

EMInInn partners

1. Wuppertal Institute for Climate, Environment and Energy
2. UCL Sustainable Resources Institute, University College London
3. Institute of Environmental Sciences, Leiden University
4. Netherlands Organization for Applied Scientific Research
5. Institute for Economic Research on Firms and Growth
6. Swedish Environmental Research Institute
7. Maastricht Economic and Social Research and Training Centre on Innovation and Technology, Maastricht University

Project Results:
WP1
The aim of the Work Package “Macro-environmental impacts: indicators and data” (WP 1 of EMInInn) has been to compile, review and refine indicators for measuring macro-environmental impacts of innovation, and the data sources on which they are based.
The Work Package has consisted of three tasks:
• Task 1: Inventory of existing and proposed macro-environmental indicators
• Task 2: Analysis of information and data generation needs for selected indicators
• Task 3: Further development of indicators
The work has covered indicators and data to be used in EMInInn case studies as well as elsewhere. Further, the work has been carried out both by interaction with project-internal indicator users (i.e. in direct relation to case studies, WP4-8) and with potential project-external indicator users, as well as through literature-based research.

Indicator frameworks – DPSIR and LCIA

Macro-environmental impacts are traditionally connected to the National or EU-level monitoring of environmental indicators. The DPSIR framework (Drivers, Pressures, States, Impacts, Responses) has been adopted by EEA, the European Environmental Agency, to sort different types of indicators in relation to their position in the environmental cause-effect-chain. Pressure indicators, i.e. direct exchanges between the technical system/object of study and the surrounding system, were identified in the EMInInn context, as the most relevant type of environmental indicators. On the level of pressure indicators it is possible to make a link to both: 1) economic (sub) systems and 2) (potential) environmental effects. When studying innovation, it is relevant to look at large number of indicators, as the ambition is to understand whether the choice of one technology or product over another leads to overall reduction of impacts, or maybe burden shifting, i.e. that one impact is reduced, but another increases. As in LCA, it can then be useful to aggregate the pressure indicators into a more limited number of environmental impact categories.

Therefore the indicator work has looked both at the relation between the DPSIR and the LCA indicator frameworks, and then dug deeper into the LCA framework. In WP1, we thus have investigated the usefulness of some selected indicators and methods for aggregation of pressure indicators. The approach to summarize the pressure of several individual substances into aggregated pressures within impact categories is currently common in LCA. This has encompassed resource consumption indicators, water resource indicators (e.g. water footprint), chemical footprint, nitrogen footprint, and monetarized environmental damage indicators, as well as analysis of the data supply options and gaps for these.

The indicators types selected for our work are a) considered relevant, and b) not fully mature within the LCA community, and some exploratory activities could therefore provide added value to EMInInn, as to improve understanding of the properties of these diverse approaches. For some other indicators the methods are more and relatively stable, specifically for Global warming, Ozone depletion, Acidification and Photo-oxidant formation, and these could be used with confidence in the underlying models. For still other themes, e.g. biodiversity, the basic fundamentals are still to be outlined in order for any model to be operational, and this more basic research was considered outside the scope of the EMInInn project.

In the case studies, the five listed indicators have been applied to the extent that data could be found in existing databases, or as a result of limited (due to time constraint) data collection within each case study.

Data

Various databases were reviewed in order to understand to what extent they would be useful in assessing environmental macro-indicators of innovation. The databases can be distinguished in two different types of system boundaries that are applied: Geographically defined, such as national or EU environmental accounts, or functionally defined, such as footprint (or LCA) databases. Both types have their pro’s and con’s, for both types the challenge is to have enough resolution/details to suit the purpose to analyse the macro-environmental impacts of innovation.

Environmentally extended Input-Output tables and General LCA databases were both made use of in the case studies of EMInInn. To a certain extent, WP1 assisted in data gathering in support of other WPs,
notably for the Building sector WP and for the Waste Management WP.

WP2 Innovation measurement: indicators and data
WP2 has collected data on innovation activities and created indicators for technical change in the areas of energy, transport and waste. The indicators aim at studying the link between technical change and macro-environmental performance in different EU countries.
The main outputs of WP2 are:
1. A report on green growth and eco-innovation, discussing drivers and barriers to eco-innovation, eco-innovation in old and new Member States, diffusion of eco-innovation and green growth, green jobs and cases of green growth.

2. The identification of eco-innovation measures, and discussion of their usefulness for estimating the macro-environmental assessment of innovation, where the following four groups of eco-innovation indicators are being identified:
   o Input measures: Research and development (R&D) expenditures, R&D personnel, and innovation expenditures (including investment in intangibles such as design expenditures and software and marketing costs);
   o Intermediate output measures: the number of patents; numbers and types of scientific publications, etc;
   o Direct output measures: the number of innovations, descriptions of individual innovations, data on sales of new products, technology-specific investments, etc;
   o Innovation measures derived from aggregate data: changes in pollution intensity (P/Y) and resource productivity (Y/R) using decomposition analysis.

3. Calculation of time patterns for pollution intensity and eco-efficiency for three industries (energy industries, road transport and waste) plus an investigation of the correlation of such patterns with the time pattern of innovation indicators such as patents and the diffusion of green technologies (as direct indicators of innovation). What we found is that:
   o The results show a very strong correlation between eco-efficiency (EE) and the capacity shares of CCGT and wind power: for CO2 eq., SOx, NOx, NMVOC and NH3. When calculating correlation coefficients for annual absolute changes in eco-efficiency (EE) and capacity measures for innovation for the EU27 and individual countries we found no statistically significant correlations between ∆EEi and ∆capacity shares for CCGT and wind power for CO2 eq., SOx, NOx and NMVOC, which leads us to conclude that changes in EEi are not caused by changes in capacity of technologies. The low shares of the energy technologies investigated in total energy capacity are one reason why changes in the eco-efficiency of the energy industries are not entirely caused by changes in CCGT and wind power. It was found that they are caused by changes in the shares of all power generation technologies: coal, CCGT, nuclear, co-generation, biomass, solar and hydro in combination with changes in the emission profiles of the technologies.
   o In the case of road transport we obtain significant positive correlation results between vkm/EMi (the measure of eco-efficiency used for road transport) and the share of diesel cars in new passenger car registration, the same holds true for the share of diesel cars in the total fleet and the share of petrol cars with catalytic converters, which is not surprising as all the variables show a rising trend.
   o When comparing the absolute changes in eco-efficiency with changes in technology diffusion, we no longer obtain significant correlations for road transport. There is no significant correlation between absolute changes in vkm/Em and changes in the share of diesel cars in new passenger car registrations,
in total fleet, and changes in the share of petrol cars with catalytic converters. The only cases for which we find positive correlations are for eco-efficiency with respect to NOx and NMVOC and share of diesel cars in new car registrations in Denmark and between eco-efficiency with respect to NMVOC emissions and share of diesel cars in new car registrations in Sweden. The result for catalytic converters is opposite to our expectations. Especially for eco-efficiency with respect to NOx, we expected a strong positive correlation between changes in eco-efficiency and changes in the share of catalytic converters. According to the results of life cycle assessment (LCA), the life cycle emissions per mile for cars with catalytic converters are 76.5% lower for NOx. A possible explanation is that the rise of diesel cars and increased vehicle size annulled improvements in eco-efficiency from the use of catalytic converters. Another, more speculative explanation is that the catalytic converters do not perform well.

Overall, the results show that eco-efficiency changes of sectors depend on more than the diffusion of a single innovation. Eco-efficiency changes are indicative of innovation, but a deeper analysis is required to determine the contribution from specific innovations and other factors.

For road transport, we also examined the correlation between patents and the eco-efficiency measures. Patents are an often used measure for innovation and it will be interesting to see if they are positively correlated with eco-efficiency for different pollutants. The results of the correlation analysis show a strong correlation between patents and eco-efficiency. To test whether this relationship is causal we undertook a panel regression for eco-efficiency for CO2 eq. and NOx. The positive partial correlation found between patents and eco-efficiency is found to be not causal but merely statistical.

4. Creation of a format for innovation fiche, which is illustrated for the case of diesel engine cars.

5. Recommendations for the use of data sources for the macro-environmental assessment of innovation, where we propose the use of the following sources:
- Product catalogues and special studies into product characteristics (for measuring changing product characteristics)
- Product sales and technology-specific investments (for measuring diffusion)
- Data on product stocks and capital stocks for technologies
- Studies on product use and behaviour (ECHP)
- Patent data for technologies and for nations
- National scoreboards for innovation and R&D (CIS, EIO, GCS, ANBERD, GBAORD, ..)

WP3 Analytical frameworks: methods and data
In WP3, a review and comparison has been made of the various analytical methods and tools that are used in the eco-innovation impact analysis, and an indication is provided on how these different methods and tools can be aligned so as to empirically link innovations to their intended results. This activity, described under Task 3.1 has been uploaded on the EmInInn website as Deliverable 3.1.

The main activity of WP 3 was the development of an analytical framework, to be used by the case studies of WPs 4 – 8. The set-up of the framework is targeted at ex post analysis, but a link is made with the ex-ante analysis framework of WP9, to enable a symmetrical set-up of the two types of analysis. The framework is methodological in nature, and describes a series of steps to take in an EmInInn ex-post analysis of environmental impacts of innovations. The framework consists of a brief Guide and five Background papers, each providing more details, methods, models and data to use for each of the steps in the Guide. It is available on the EmInInn website and provides an additional deliverable of the project. The case studies have indeed used the framework, which has provided a common language and a
common approach for the EmInInn case studies. A common language is one of the most important issues in cooperation projects like EmInInn, and one of the most difficult things to achieve. In EmInInn, we have made a large step in that direction.

In addition to the general methodological framework, a more specific method has been developed to identify potential innovations in a top-down analysis, using time series on environmental data and input-output tables. A decomposition analysis can identify whether changes in environmental performance of sectors are due to changes in demand or changes in the environmental profile – and of the latter, whether emission factors have changed or rather the structure of the economy. An interesting finding is that some innovations can be clearly pinpointed, and that these are invariably end-of-the-pipe measures, such as the de-NOx-installations and the covering of landfills. Other innovations are less easy to find. Most likely their effects are dampened by rebound-effects. This sheds a different light on the value of such straightforward rather blunt “innovations” of the end-of-the-pipe kind. They can really be effective, and hardly lead to side-effects as the structure of the economy is unchanged, and equally they do not lead to rebound effects since there are no cost savings. Nevertheless, for some air pollutants we see a reduction over time. A decomposition analysis shows that in most cases, this can be related to a gradual decline in emission factors rather than to structural changes or reduced demand. This points at a gradual introduction of technological innovations in industries: an eco-efficiency improvement. This activity, Task 3.2 has resulted in a Deliverable 3.2 report uploaded on the EmInInn website.

Task 3.3 the bottom-up ex-post analysis, is developed in conjunction with WP6. A paper on how to combine detailed LCA information with information on diffusion and societal developments (IPAT-LCA) has been published in the Journal of Industrial Ecology and is uploaded as Deliverable 3.3. The method is illustrated with a case study on the diffusion of diesel engines in the European passenger car fleet. One of the conclusions is that the environmental gains of using diesel instead of petrol engines are more than compensated by the rebound effect.

The rebound effect is a topic for further investigation, as this seems to be very important and possibly fatal for the effectiveness of many innovations, especially for those of the efficiency type. This sheds a new light on eco-innovation strategies. An overview and classification of activities around incorporating rebound effects, in a broader sense than the original rebound effect which is related to energy efficiency improvements, is published in the Journal of LCA.

A further methodological approach has been developed to assess rebound effects at the micro-level, including the life cycle, published in Environmental Science and Technology. The approach builds on the “classic” approach from neoclassical economics, but broadens it both in concept and in scope. A case study on electric cars has been elaborated in this paper, in cooperation with Work Package 6. A wider array of transport options as selected in WP6 has been analysed with this method and has been published in the Journal of Cleaner Production. From these applications, the rebound effect appears to be very important and possibly fatal for the effectiveness of many innovations, especially for those of the efficiency type. Another finding is that innovations that are expensive are also effective, sometimes more because they prevent other expenditures than because of the innovation itself. This suggests that financial measures such as a carbon tax or a resource tax may be effective. Eco-innovation strategies should consider these issues.

The theoretical basis for task 3.4 on incorporating bottom-up ex-post analysis in input-output models has been completed and implemented in the case study on transport of WP6 (electric cars), in conjunction with WP9. Results are available in a report of WP9. A paper for a scientific journal is being prepared. This will
be the last part of the methodological incorporation of the rebound effect in the EmInInn analytic framework: the macro-level rebound effect. As it looks now, the rebound effect at the macro-level is less marked than that at the micro-level. This result is in line with expectations, as electric cars and their supply chains constitute but a small share of the production inputs of the European economy. Therefore, market price effects are expected to be moderate at best.

The debate on the rebound effect is a profound and interesting one. Present applications are much broader than the original rebound effect, which was contained to re-spending effects related to energy efficiency improvements in industry. In various fields, inside and outside economics, the concept has been broadened to include direct and indirect effects, micro-level and macro-level effects, CO2 emissions and other environmental impacts, consumption-based impacts, and temporal and spatial impacts. This leads to the concern that the concept “rebound effect” will be less meaningful, and will in the end encompass all types of side-effects. As a spin-off of EmInInn, presently there are three additional papers being written. The first contains a treatment of all the different concepts and applications that are styled as “rebound effect” by their authors, and the development of a general framework to position all the existing disciplinary understandings, including the original energy rebound effect. The second paper focuses on the state-of-play of the rebound effect issue in the policy arena, and on ways to mitigate rebound effects through policy pathways. The third paper deals with the study of the technology effect as a source of bias in rebound analysis, that is, how methodological choices in the calculation of the environmental burdens per economic unit propagate uncertainties in final rebound estimates. These aspects have emerged from the EmInInn project as very important, and therefore will prove a good addition to the scientific literature on that topic.

WP4 Energy sources and conversion technology
The major piece of ex post analysis arising from WP4 was the EEIO-based hybrid LCA, and the application of this tool to European power sector technologies. This analysis represents a more detailed disaggregation of a wide range of power sector technologies than has previously been conducted, and thus represents a novel contribution to the field. The analysis was applied to a set of historical counterfactual scenarios, enabling analysis of the net environmental impacts of each innovation when compared to relevant alternatives. The counterfactual scenarios included representation of some rebound effects (particularly indirect or ‘respending’ rebounds). This work is being presented at a conference in summer 2015, and a journal paper is being prepared. Structural decomposition analysis of the resulting, highly disaggregated environmentally extended input-output (EEIO) table provided further insight into the contributions of different factors, including overall consumption, technology and sectoral shifts, and efficiency improvements. A key finding from this analysis is that solar PV technologies are currently in what might be described as ‘ecological debt’; that is, the net environmental pressures associated with PV in Europe currently exceeds the environmental pressures that have, so far, been offset through PV generation. This is because the emissions associated with PV are generated largely during the production phase, whereas the emissions that are displaced by PV are offset throughout the 20 year lifetime of the panels. This analysis highlights that timescales can make a substantial difference in the comparison of technology options.

A second piece of analysis developed a database of European power plants, by linking a number of existing data sources. This was used to develop an index decomposition analysis of European sulphur dioxide emissions, showing the relative importance of flue-gas desulphurisation (FGD) alongside other methods of sulphur emissions abatement. A key finding is that, while FGD has indeed been important,
other abatement approaches represent a significant portion of abatement in European power plants, suggesting that low-sulphur coals, coal preparation and other technologies have been cost-effective compliance mechanisms. This may reinforce the view that policy structures that allow flexible compliance strategies are desirable.

The work on the sulphur dioxide has not yet been submitted for publication, and this is largely because it is now being extended and taken forward by a Master’s degree student during the summer of 2015. The dataset is being updated with more recent data from the European Environment Agency, which became available in February 2015. It is expected that this will result in a journal article, but this will depend on the outcome of the student’s work, and will not be submitted until Autumn 2015.

Integration of ex post analytic insights with ex ante modelling tools

A major contribution of WP4 was the integration of emissions factors, derived from the IO-based hybrid life-cycle assessment described above, into the European TIMES model, an energy-economy model of Europe’s energy system. This approach is novel, and though one team has previously done something similar, the approach applied in EMInInn made several key methodological advances. In terms of methodological results, therefore, this has clearly advanced the state-of-the-art.

A major class of tool used by policymakers to assess the desirability of energy options is bottom-up energy-economy models, such as MARKAL/TIMES and PRIMES. These models simulate or optimise the energy system, in order to identify technologically-explicit pathways to a lower-carbon future for Europe. As a result, they are used as key analytic inputs into technology prioritisation and assessment processes, such as those undertaken for the SET-Plan.

However, until now these models have assumed that the emissions associated with the construction of energy technologies are irrelevant for determining the best low-carbon technology pathway. The approach developed within EMInInn includes these ‘indirect emissions’ within the model’s decision-making. The result of this methodological development shows that certain technologies become less desirable once their full indirect emissions are taken into account. Initial modelling suggests that the indirect emissions associated with the manufacture of PV might reduce the desirability of this technology by 20%, though this number should be regarded as illustrative rather than definitive. The work demonstrates that indirect emissions can be relevant for informing technology choice. Two journal papers are being prepared to report this work, and both will be submitted to the Journal of Industrial Ecology.

WP5 Information and Communication Technology

Following EMInInn’s framework, the overarching research question for this work package was “Is the Internet an eco-innovation?”. It turned out that this question could not be answered with yes or no and required an extended definition of eco-innovation to be meaningful. The work package did, however, provide insights on aspects of the Internet system of innovation that point either way. It thus gave ideas on which aspects are more likely to enhance the eco-innovation side of the Internet.

The work package included a case study on the drivers and barriers of eco-innovation in the Internet system of innovation. While it is generally agreed that the environment has not been one of the principal drivers for Internet innovation, there are a number of pressures that may result in either relative or absolute ‘greening’ of the Internet system of innovation. This includes a variety of policy initiatives (particularly regulatory approaches to electronic waste and to eco-design) and market-based pressures. In particular, relative increases in energy and resource prices, as well as the market imperative for hand-held devices to improve functionality given weight, size and battery restrictions, can be expected to drive significant
relative environmental improvements. Key barriers to eco-innovation are the rapidity of innovation in the sector, which creates challenges for governance and regulation while also fostering rapid product obsolescence; the global nature of the innovation system, with implications for pollution and emissions leakage to locations with weaker environmental standards; and the market failures associated with most environmental pressures (i.e. damages are externalities not reflected in market prices in the absence of policy).

Patents are often used as indicators of eco-innovation. In the case of internet-related innovation, patent data suggest a relative greening of invention: internet-related invention is increasingly eco-invention (and vice versa). However, it is not clear that this apparent trend is likely to have any relationship with the macro-level environmental outcomes associated with the diffusion of the internet and related innovations. Determining whether a given internet-related innovation is an ‘eco-innovation’ at the macro-level is rarely straightforward: greener ICT products may not have a relevant alternative against which to compare, since they may offer entirely new functionality; ICT systems that facilitate greening of other socio-technical systems (such as transport) require comparison of entire systems, in which case the wider socio-technical landscape in which these systems are embedded are important determinants of the environmental performance and role of the ICT system in question.

Although we find through econometric analysis of survey data at the firm’s level that ICT adoption is robustly and positively correlated to environmental innovation in the EU, we also find that complementarity (i.e. characterizing the relationship between ICT and other innovation processes as a force behind environmental innovation) is not to be taken for granted. In fact, it appears a robust empirical fact with regard to general innovation capacity (R&D and ICT), though when we narrow down the focus to specific techno-organizational innovations, complementarity with ICT is rare as a pillar of green firms’ strategies. There are clear limitations to that kind of study: environmental performance data at firm level are not readily available; the quality of ICT data at the sectoral level (CIS survey) is rather poor. Hence the use of the dataset from Emilia-Romagna region that gives more details but also limited in coverage (one year, 2009).

The work package included several case studies of innovations belonging to the broader Internet system of innovation. Whether looking at the physical Internet (frontend, backend, networks) or Internet-based applications, scaling up environmental assessments from the micro to the macro level faces data availability issues, and above all modelling issues when considering secondary and tertiary effects. Those effects are so far reaching in the case of the ICT/Internet system that any clear-cut assessment on whether or not a particular innovation is an eco-innovation seems difficult. Similar issues arise with top-down approaches.

In the bottom-up environmental analysis micro level environmental questions are scaled-up to the macro level for the ex post evaluation of the environmental pressures associated with the physical Internet (frontend, backend, networks) and the direct Internet economy (two business cases as Internet applications), while accounting for part of the rebound effects. We find that micro-level environmental assessment studies (e.g. life cycle assessments) of ICT-Internet-based products are more useful today without trying to compare with seemingly equivalent analogous products. There is often no meaningful functional unit that can cater to both online and offline worlds. On the other hand analyses of ICT-Internet technologies (e.g. data centres, wireless access networks) are needed (and beyond the diptych energy-emissions) to provide benchmarks for future developments (is the ICT-Internet decoupling environmental pressures from services provided?). We also find that micro-level empirical studies looking at questions such as “Do Internet applications boost sustainable or non-sustainable consumption patterns?” are
needed because they touch upon the indirect and rebound effects of the system. For the top-down environmental analysis of the direct Internet economy we looked into options for modelling (part of) the ICT-Internet system using a hybrid input-output framework. Since all sectors are potentially affected, it is can be a complicated task to split the input-output table. We showed how the main environmental effects of e-commerce could be modelled using an environmentally extended hybrid input-output framework. We focused on the environmental effects resulting from the impact of e-commerce on the demand for transport services. We saw that generating sectorally disaggregated e-commerce penetration rates is possible but requires extensive data preparation and has to rely on a number of assumption due to the lack of diffusion data at the European level. A limitation could not be overcome, however. The effects of e-commerce on demand for transport services are disputed in the literature and have not been quantified.

Per definition, an eco-innovation is an improvement over a relevant alternative. Counterfactual scenarios are therefore needed for the assessment. We discussed the usefulness of this approach in the case of the Internet-ICT system and shows results from two different methodological options. The first option—from the bottom up—would upscale micro-level “counterfactual” life cycle studies. We argue that this approach does not bring any meaningful result in out case. The second option—from the top down—is based on scenario simulations using different elasticities linking GDP growth and Internet penetration rates. We show results from eight counterfactual scenarios of GDP growth without the Internet in the US and the EU-15. The approach is interesting but shows only a “net effect” and does only offer a high level of aggregation, without much detail.

Elements of an ex-ante eco-innovation appraisal could be proposed. The input-output based approach followed for assessing the impact of e-commerce was extended to the period 2010-2050. Time series of future penetration rates of e-commerce at the sectoral level were constructed using logistic functions. The data prepared was then used to run the EXIOMOD model. However, the same limitations regarding the yet unknown quantitative impact of e-commerce on transport indicate that this exercise is a proof-of-concept whose quantitative results are too uncertain to be used directly.

Considering all the above we, therefore, had to conclude that determining whether the Internet or any given Internet-related innovation is an ‘eco-innovation’ at the macro-level is not straightforward. Answering the overall research question about whether or not the ICT-Internet system is an eco-innovation is therefore not possible as such. Greener ICT-Internet products and services often do not have a relevant alternative against which to compare, since they may offer entirely new functionality. ICT-Internet systems that facilitate greening of other socio-technical systems (such as transport) require comparison of entire systems, in which case the wider socio-technical landscape in which these systems are embedded are important determinants of the environmental performance and role of the ICT-Internet.

WP6 Transport
The main objective of WP6 had been to evaluate the macro-environmental impacts of past innovations in European transport systems, in order to understand the extent to which they have contributed to reducing or increasing targeted environmental pressures. A subsidiary objective is to apply the ex post methodology thereby developed to a range of technologies that may be expected to be required to achieve the stringent targets for the mitigation of climate change, in order to identify whether they will actually do so when overall impacts are taken into account, and whether they will also cause unexpected secondary environmental impacts.
For the ex post assessment, the Dynamic IPAT-LCA with environmental rebound effect (DILER) model has been developed. In short, the DILER model upscales life cycle assessment (LCA) results using regional absolute demand and population data and incorporates the environmental rebound effect (ERE) from changes in transport costs induced by innovations.

The DILER model offers the following advantages:

• It keeps the high technology detail and life cycle approach of LCA.
• It offers behavioral realism by incorporating overall changes in demand due to changes in prices.
• It describes environmental pressures from single innovations at the macro-economic level.
• It allows to incorporate technological change and offer temporally dynamic results.
• By linking technology and demand via the ERE, it permits to calculate the aggregate contribution of an specific innovation to changes in environmental pressures in terms of technology and demand.

The DILER model has been applied to seven relevant past transport innovations: catalytic converters, diesel engines, direct fuel injection (DFI) systems, high speed rail (HSR) systems, park-and-ride (P+R) facilities, car sharing schemes (CSS) and bicycle sharing systems (BSS). The results describe overall large discrepancies between the results from product-level results (that is, comparative LCA estimates in terms of environmental pressures per demand unit) and the results from the DILER model, both in terms of environmental pressures per demand unit and total environmental pressures. The differences in environmental pressures per demand unit from the two approaches (LCA and DILER) stem from the inclusion of the ERE in the latter, whereas differences in total macro environmental pressures derive from the ERE as well as considering market diffusion of competing technologies and/or technological changes over time. In general, the results from the DILER model describe worse scores than those initially estimated using LCA, because of a positive environmental rebound effect.

In absolute terms, the studied innovations caused an overall increase in greenhouse gas (GHG) emissions. Such increase, however, did not have a notable impact in terms of GHG emissions from total transport final demand, representing only a 0.02% increase for the year 2007. Diesel engines and DFI systems contributed the most to the increase of GHG emissions, whereas P+R schemes and HSR systems decreased emissions but did not have a notable impact because of their still low diffusion. The innovation that curbed emissions the most was P+R facilities with a marginal decrease of 0.001%. In summary, studied innovations did not have a relevant impact on transport GHG emissions and, in any case, they induced an overall increase in emissions.

The results of the ex post assessment provide a number of insights to be considered in the design of eco-innovation policies:

• Considering the increasing momentum that LCA is gaining as a policy support tool (Pothen 2010), it is important to take LCA estimates with caution, as our results highlight the notable impact that costs differences can induce on absolute environmental results.
• Costs differences do not entirely stem from the technical characteristics of new technologies, but also from systemic aspects, such as fuel prices or the relative impact with respect to other products from the consumption basket. These aspects have thus a notable influence in the overall environmental
performance of transport innovations and should be seen as active elements of policy rather than a fixed background. This gives a wider range of possible policy actions to improve the environmental performance of current transport systems, such as green taxes or sustainable consumption policies aimed at key consumption sectors (e.g. food production).

- Even under current conditions, policies can allocate resources to foster those innovations that offer a better environmental performance once considering the ERE. This is the case, for instance, of P+R and CSS.
- While more active elements come into play to curve environmental pressures from transport, a number of trade-offs take place. For instance, minimizing cost differences induced by innovations can hinder their diffusion due to the market-driven nature of society. Also, because of the structural role of transport in the economy, changes in transport systems can cause undesired spillover effects on other economic sectors. Our conclusions lead thus to a double-edged picture when it comes to improve the environmental performance of transport systems, which calls for careful attention when designing new policies.

WP7 Built environment

EMInInn project is all about the assessment of environmental impact of innovations. In WP 7 the authors have focussed on the case of housing, providing for a context of innovations intended and designed to reduce the pressure of the environment. Within this case study we have considered both history and the future; trying to understand the past to shed some light in the future on sustainable housing.

The first deliverable report describes the diffusion of a selection of innovations in the past (20 to 40 years); analysing the main drivers and barriers influencing the patterns of diffusion. Ultimately the diffusion of innovations has been put in numbers corresponding with a percentage of dwellings (of full housing stock), having a certain innovation applied.

Innovations have their specific functional life cycle, and for reasons of sound measurement, the environmental costs and benefits over this cycle should be taken into account. EcoInvent data provided us with detailed data on the embodied energy corresponding with the production stage of technologies, the innovations. For representation of the benefits of these innovations, an energy simulation model (VIP) was used to calculate the consequences of the innovations implemented. A standard house was designed for this task, which functioned like an actual residence for a family of four, in different climate zones. This enabled us to calculate the annual investments and benefits in terms of energy consumption for heating, warm water and lighting.

For assessing the macro environmental impact of the selected innovations, two perspectives have been explored. The first perspective departed from the bottom up, and was applied to indicate the individual environmental impact of an innovation multiplied with the diffusion rate, the number of dwellings having this innovation applied, and measured over time.

Second perspective travels the reverse road, this top down perspective is explored by means of a Structural Decomposition Analysis (SDA). Herewith the macro data from WIOT, environmental extended input output has been analysed, and decomposed over different factors influencing the ultimate energy consumption domestically.

Conclusions based on the analysis in this report might feed the interpretation that notwithstanding the energy efficiency benefits enabled by the technical innovation in operation, factors like rebound effects, income effects and spill-over effects carry the potential to take back nearly all positive effects. Suggestions for further focus on the generation of sustainable and renewal energy for ensuring the positive environmental impact in the housing sector has been taken into consideration in the subsequent
Most significant results - Deliverable 7.1;
We have been able to quantify the diffusion trajectory of several eco-innovations in the housing sector. The influence of drivers and barriers of both market and policy side have been analysed in explaining the diffusion trajectory.
Innovations have been quantified both in terms of environmental costs (materials and energy for production), substitution (alternative technologies) and their benefits (reduction of energy use in their application, over the time in use). At the household level we have been able to model the actual energy consumption reduction, for different climate zones. With the ultimate net environmental effect we have been able to apply to the diffusion curves of innovations, which led to a picture of the overall energy reduction due to these innovations, over time, in a small set of countries.

Focus on the Future
Within the second deliverable report on the case of built environment and buildings, the focus went to the potential impact in reducing environmental pressures from a set of promising technologies in the built environment.
First sections contain a detailed description of promising technologies, bearing potential to contribute to the efforts to reduce environmental pressures of buildings in the near future. Technologies that, in some cases already exist but, have not find their way into high market shares yet. Afterwards, a set of possible future scenarios (based EU2050 scenario studies) has been developed, in which the diffusion of technologies are projected (modelled), and a reduction of energy use or carbon emissions is been determined (quantified). Within this realm, the diffusion of innovations is defined as the speed in which technologies are taken up by the market. In other words, how fast and how many products are being adopted by consumers over a period of time. Each of the future scenarios contains a certain mix of technologies, next to a standard set of basic characteristics to add to variety (like demography, average energy consumption, RES production etc etc.). Ultimately, the variety determines a penetration rate over technologies in the projected future.
Moreover, the deliverable report contains the preliminary assessment of the eventual environmental effects of the technologies and their diffusion in the scenarios. The complete assessment is been discussed in more detail in WP 9 where all the sector-studies from WP’s 4 till 8 have been assessed and discussed. Point of departure of assessing the environmental effects is ultimately the level of the (single) household, representing the micro level. What is the result of applying a future house (new built or retrofitting) with certain new types of insulation, heat recovering systems in the mechanical ventilation and or PV panels? A life cycle inventory on a short list of innovations, provided the analysts with the efficiency data on the micro level (both in terms of inputs and results, outputs).
To bridge the gap to the macro level, one needs a more comprehensive analysis of the innovations. We have mapped for this reason the innovations, the technologies, to see what intermediate products, materials and services are needed to produce the innovation. This step basically expands the sector boundaries of built environment and buildings. From here, the building sector is linked to sectors with different industrial and non-industrial products and services, which in the end allowed us to assess the macro economic effects (over all sectors).
Adding this information to the diffusion scenarios, provided us with results, on how the diffusion of certain technologies would be influencing the overall energy use of households, the material consumption, relative share of energy expenditure etc. In the chapters 6 and 7 (Del 7.2) we have extensively elaborated on the interpretation of the outcomes.

Main significant results – Deliverable 7.2;
The first round of modelling results proofs the relevance of running environmental innovation diffusion patterns in different future scenarios, providing a low, middle and a high diffusion pattern towards 2050 and corresponding results in terms of energy efficiency and further economic and environmental effects. Methodologically, a novel approach to link the theory of innovation diffusion with the mechanisms of economic and environmental impact assessment is developed and presented.

WP8
The waste innovation system (framework): WP8 elaborated an original analytical scheme for waste innovation analysis based on the strong interrelatedness of the waste system and the many technological options available - or possibly being invented - to manage the same waste type. Eco-innovation for waste - i.e. innovation reducing environmental pressures - can be found at different levels: (i) prevention innovation, or ‘waste efficiency’ innovations in consumption and production processes; (ii) micro-invention, that is inventions that can change ex ante the expected environmental pressure of waste within a specific management option, e.g. landfill; (iii) micro-innovation, i.e. adoption of specific existing innovations within a specific management option; (iv) management-option innovation, that is the shift of management of a waste type (e.g. municipal solid waste) from a technology option (e.g. landfill) to another (e.g. recycling, which implies the diffusion of a set of technologies at the expenses of others); (v) organisational innovation, that is the invention and adoption of solutions that change the process of collecting, handling, preparing, transferring waste, which should often seen as pre-conditional or complementary for the deployment (on a significant scale) of technological innovations under (i) to (iv). Discrimination between eco- and non-eco innovations at all these levels must be done in term of the associated change in environmental pressures. The scale of diffusion of innovations at levels (i) to (v), especially when interrelated in a coherent change of waste production and management regime, can deliver eco-innovation for waste at the macro-level. Drivers of eco-innovation for waste can be found mainly in markets and prices, e.g. for primary materials and energy, and especially in waste policies, which has been in place since the 1970s at the EU level. Given their pervasiveness, we assigned to policies the role of a key engine of the ‘waste innovation system’ in which all levels of innovation are influenced by policies themselves. The main focus of WP8 has been on ‘management-option innovation’ at level (iv), that is waste management technology diffusion, which is also the main focus of most EU waste policies because it can deliver major reductions of pressures at the European scale.

Convergence in MSW management technologies across EU countries (diffusion). It is the relevant whether EU countries are dynamically converging towards the benchmark countries in terms of waste management. We applied convergence analysis, an approach extensively used in the economics of growth (Beta convergence and Sigma convergence. The results of the econometric analysis indicate a decline in heterogeneity in waste management practices across countries (Sigma-convergence) and a Beta-convergence of laggard countries towards ‘better’ (waste hierarchy) management options. Incineration is not an option in some countries. Country-specific factors (e.g. national policies) play little role in driving the convergence. To achieve the benchmark country (for recycling and/or incineration) some
A laggard country is predicted to need up to 30 years. The implication is the need to accelerate the transition in shifting waste from landfills in all the EU laggard countries.

From landfills to a circular economy: LCA-based pressure analysis. A macro-scale Life Cycle Assessment (LCA) has been carried out to assess the environmental pressures of the total mix of waste management technologies for MSW from 1996 to 2030. The scope was EU27 and Sweden. The technologies considered in the model are Landfill; Incineration (including energy recovery); Material recycling; Composting and digestion. The impact categories cover Global Warming (GWP); Acidification (AP); Eutrophication (EP); Photochemical Ozone Creation (POCP). For recycling, paper&cardboard, plastic, metal, glass are considered. Results show that the substitution of recycling/composting and incineration for landfill in MSW management, even with non-decreasing amounts of MSW produced, can save significant amounts of pressures of the categories we have considered. In the case of EU27, the shift from landfill to other technologies brought, for example, to a reduction of 67 Mt CO2 eq, or -53%, in 2011 compared to 1996, while it is expected to further bring to a negative total CO2 emissions of -68 Mt in 2030. For acidification potential, net emissions are estimated at -110 Kt in 2011, with a reduction of 55% compared to 1996; the already negative acidification potential will further improve (more negative) by 48% in 2030. In the case of Sweden, in spite of the diversity of scenarios considered, GWP from MWS management passed from 400 Kt SO2 eq in 1996 to -1.3 Kt in 2011, and it is further expected to reach 1.6-2.0 million tons of CO2 eq in 2030. Positive trends are also recorded and projected for acidification, eutrophication and POCP.

From landfills to a circular economy: LCA-based pressure analysis for Italy. The objective was to identify environmental advantages of shifting from landfill to incineration of MSW in Italy at the regional level (ex post). Another objective was to analyse environmental impacts of incineration and landfill for three potential future scenarios of different penetration rates of incineration, landfill and recycling at the macro-regional level (ex ante). By using a LCA, a LCA of incineration plants in Italy (2000-2012) (ex post) is produced together with a LCA of three scenarios for the diffusion of incineration in Italy (2013-2050) (ex ante). Pressures considered are: Global Warming Potential (GWP), measured in kg CO2-eq; Acidification Potential (AP), measured in kg SO2-eq; Eutrophication Potential (EP), measured in kg Phosphate-eq; Photochemical Ozone Creation Potential (POCP), measured in kg Ethene-eq. Results indicate that shifting MSW treatment from landfill to incineration reduces environmental burdens. Environmental impacts depend on the type of incineration technology. Amounts of MSW and RDF flows vary between regions and, therefore, affect the results for the total and per capita environmental impacts. North macro-region produces the highest environmental burdens/savings due to the largest amount of the total waste treated. Results for GWP indicate that waste treated in incineration plants has increased from 2.5 million tonnes in 2000 to almost 6 million tonnes in 2011. Three scenarios for the diffusion of Incineration in Italy (2013-2050) are elaborated (ex ante). The overall conclusion is that incineration of waste results in lower environmental burdens than landfill. Ex ante analysis – Lombardia rates model results in the lowest environmental burdens per 1 tonne. Further data on waste flows between the regions is necessary to allocate burdens accordingly. Further analysis is necessary which includes recycling, technological changes of waste treatment technologies, energy conversion factors.

Innovation in waste management: EU policy drivers: We econometrically tested whether environmental policies can have two different types of effects on environmental performances, one direct effect and one indirect effect mediated by its effect on technological change. Patent stock is used as a proxy of innovation. A specific policy indicator has been elaborated for the analysis. Results of econometric testing indicate that environmental policies are always significant drivers of environmental innovation.
Environmental policies are a significant driver of landfill diversion and recycling and incineration promotion, but are not able to incentive waste prevention. Environmental innovation is a significant driver of the transition from the old landfill dependent waste management paradigm to a new system which rely more on recycling, material recovery and incineration. The effect of environmental policies on waste performances is not only direct, but it is partially mediated by the effect that the policies exert on innovation.

Innovation in waste management: Drivers with decentralised governance. We exploited the last wave of the EU CIS (Community Innovation Survey) 2006-2008, which covers environmental innovations (EI) adoption, to produce econometric analyses on waste, water related innovation adoption as well as material reduction by firms. The analysis at EU level shows that despite some differences across countries, this type of eco-innovation is correlated to R&D, ICT adoption and cooperation actions by firms. Resource efficiency oriented eco-innovation strongly correlate in their adoption to other eco- and non-eco-innovation strategies, such as CO2 abatement, process and product innovations, organizational innovations. This configures a web of related innovation strategies. The analysis on Italy illustrates that firms adopt eco-innovation on the basis of some relational factors, while key factors such as R&D does not have a significant impact. Evidence show that firms located in regions where the waste system shows better performances concerning separated collection of waste and waste tariff diffusion are more likely to adopt eco-innovation for waste and material efficiency. Results highlight that the adoption of eco-innovation is highly influenced by the (regulatory) features of the region: the firm and its innovation choices must be addressed in the relevant policy context.

‘Producer responsibility’ and innovation in WEEE management. The aim is to evaluate the status of implementation of the WEEE Directive (Directive 2002/96/EC) with a specific focus on the provisions on producer responsibility (PR), which is a case of organisation innovation driven by policy. Both WEEE as a waste stream and its management across Europe are very complex. There are more than 160 (B2C and B2B e-waste) collective schemes in the EU-27. We produced a comparison between the e-waste systems of 5 best performing MS (Denmark, Finland, Sweden, Ireland, and Germany), selected based on their results in terms of WEEE separate collection and reuse/recycling/recovery. The comparison shows that these e-waste systems are different under many respects, so that there is no one single best solution suitable for all the MS. At the financial level, based on the available information, all the existing collective schemes apply the market share approach (i.e. collective financial responsibility) to cover the costs associated with the management of both new and historical e-waste. This “locked-in effect”, which is in breach of the WEEE Directive, is also the result of the uncertainties surrounding the concept of PR and its practical application. The recast Directive (2012/19/EU) invites the European Commission to report by August 2015 to the European Parliament on the possibility of developing criteria to incorporate the real end of life costs into the financing of WEEE by producers.

Role of non-waste ‘product innovation’ and ‘scraping schemes’ for waste production through reduced lifetime of goods. We addressed the possible role of non-waste policies and non-waste innovation for the production of waste. Industrial strategies of continuous product innovation can drive to shorten the life of goods with relevant implications for resource use and waste production. The same effect may arise from policies that induce an accelerated substitution of products under mixed environmental efficiency and economic recovery aims. The car market in Italy is adopted as the case study. The analysis is based on detailed information on the car fleet and the deregistration of cars in the Italian market (scraping policies) and information on newly released models of car by category (innovation). The results of empirical (econometric) analysis suggests that a substantial amount of the rate of deregistration in the last decade
has been driven by accelerated innovation coupled with car scrapping schemes. This accelerated rate of scrapping is accompanied by two main effects. First, new cars are on average more fuel efficient and less polluting than average existing cars. Second, the accelerated rate of scrapping has strong implications in terms of useful life and thus on the generation of waste from end-of-life vehicles. Further analysis will be required to quantify exactly the amount of net additional waste produced by both innovation and scrapping schemes, which together reduce the average life of cars, including their environmental pressures.

WP9

In order to ensure that a minimum set of homogenous and uniformed results would be produced out from all case studies, which will in turn be fed into WP9, TNO proposed an approach to be used by a selection of case studies. This is a relevant input to be used for the development of diffusion scenarios in the ex-ante modelling for a selected number of innovations. Put simply, it is a necessary input for the development of the model to include the representation of technology diffusion based on the homogenous outcomes of the Phase 2 and the evidence available from historical data collected in WP4-8 (e.g. past penetration rates, technological characteristics, energy saving and environmental effects of a certain innovation). Therefore, this model is the operational part of the analytical framework which will be used to establish a link between Phase 2 and Phase 3 of the project.

Based on the feedbacks of partners and the detailed discussion on the conceptual model in the EMInInn economic workshop, TNO has developed a modified version of Structural Decomposition (SDA) and a MATLAB tool (SDAMAT). The tool functions as a top-down ex-post method in EMInInn to analyse the effects of the historical changes in environmental and energy indicators for sectors within an economy and assess the determinants of these changes and driving forces that influence the trend of energy consumption and environmental pressures. A practical use of the SDA model in the ex-post analysis of the EMInInn case studies (WP4-8) is that the results can be easily incorporated to the ex-ante analysis in WP9.

Using information on past penetration rates and technology characteristics, an initial estimate is made of a possible diffusion scenario of the technology(s). Performance of this task is reported in D9.1 Report on diffusion scenarios. The diffusion scenarios for the ex-ante analysis of WP9 are collected and presented in D9.1. This includes information on GDP (and other economic and budgetary) projections for the 28 EU countries, demographic and productivity improvements and the development of the fuel mix. Moreover, we collected additional data needed to upscale the micro-level Life Cycle Inventory (LCI) data used for the ex-ante analysis of WP 4 (Energy), WP 6 (Transport) and WP7 (Built Environment and Buildings). During the modelling exercise for D9.2 (the scenario runs) some data needed to be adjusted to have more consistency with the macro economic model.

D9.2 presents ex-ante assessment of the identified technical improvement options in the areas of Built Environment, Energy, Transport, ICT and Waste with the economic-environmental model EXIOMOD. EXIOMOD is a large scale and highly detailed world model built on the detailed environmentally-extended database EXIOBASE. It is a macro-economic ‘computable general equilibrium’ (CGE) model that divides the global economy in 44 countries and a Rest of World, and 164 industry sectors per country. The model includes 5 types of households, a representation of 29 types greenhouse gases (GHG’s) and non-greenhouse gases (non-GHG’s) emissions, different types of waste, land use and use of material resources (80 types).

Economic, social and environmental impacts of packages of technical improvement options are calculated relative to the baseline scenario that is consistent with the EU baseline scenario and includes assumptions
from latest Europe Aging Report 2012 and PRIMES runs for Energy roadmap. The impacts of six packages of technical improvement measures have been assessed: (1) Built Environment area, (2) Transport area, (3) Energy area, (4) Waste area, (5) ICT area and (6) all improvement areas combined. All considered technical improvement options in the areas of Built Environment, Transport, Energy, Waste and ICT are aimed at decreasing the total GHG and non-GHG emissions during the use stage. It can be the case that an increase in emissions related to the construction stage may outweigh the benefits from the use stage. This is the case for Transport and Waste improvement areas that leads to overall increase in GHG emissions. Transport improvement area also leads to an increase in non-GHG emissions. This is due to increase in emissions during the construction stage and the rebound effects due to implementation of electric cars that makes driving cheaper.

The rest of improvement areas and especially Built Environment and Energy improvement areas result in the overall reduction of GHG and non-GHG emissions despite the rebound effect and the effects in the construction stage. The largest positive effects in terms of reduced emissions are associated with the implementation of Energy improvement area.

Technical improvement areas have different effects on EU28 GDP. Implementation of Transport and Built Environment improvement areas leads to negative effects on EU28 GDP. Built Environment improvements are related to less use of electricity services and own production of electricity by households. This leads to lower demand for electricity and hence lower production level. As a result the overall effect on GDP becomes negative. Implementation of Transport improvement area leads to more demand for electricity and less demand for gasoline. Given the production structure of the electricity and petroleum manufacturing sectors these shift leads to overall reduction in value added and hence GDP.

In D9.3 a comparison is made between different types of modelling approaches which include innovation when being applied to environmental economic problems. The model as described in the Emininn deliverable D9.2 EXIOMOD, is compared to the GDynE model, the ETM-UCL model and a simplified general equilibrium model. This comparison is aimed at the identification of insights that can be obtained by these models. So what are the insights that each of the modelling frameworks has provided, and what can we learn from this given the uncertainties and inherent strengths/limitations of each approach. Furthermore we address the added value of having results from a set of models and which additional insights are obtained in comparison of having only individual model results.

The comparisons have been done in parallel processes with methods most suitable for the models in consideration. For each of the comparisons interesting specific insights have been obtained from which also conclusions are drawn in the more general context. These conclusions can be further condensed as follows:

• There is a clear added value of an assessment using results of more than one model (with soft or hard linkages) even if they have differences in model structure and inputs. A combination of different models, which incorporate therefore also different assumptions, can broaden the insights and improve the interpretation potential of results. Comparison of models can provide insights in the relative influence of the assumptions on the results, which can support further model development/improvement.

• Although it will entail complexities which could potentially make interpretation of results more difficult, a hybrid model for Europe which combine both top-down (Macro economy perspective) and bottom-up approaches (sectoral perspective), provides an added value for a more complete understanding of the real impact of policies taking into account the rebounds in other sectors.

• It should always be kept in mind that each aggregation level has its own advantages and disadvantages which should be taken into account when selecting a model for a specific purpose and when assessing the
Rebound effects

The modelling in WP9 identified potential rebound effects arising from the diffusion of the resource-saving innovations examined. The rebound effect is defined here as the environmental savings that are thwarted or enhanced as a consequence of behavioural and systemic responses to technical changes. Because technology-based or engineering estimates of environmental savings generally fail to capture such responses, the actual savings might differ once these are incorporated. The rebound effect is thus commonly understood as the difference between the engineering and the actual savings. For this we compare two approaches; firstly, a partial equilibrium (PE) approach that provides us with both direct rebounds, and secondly the Computable General Equilibrium (CGE) approach used in Deliverable 9.2 that includes both direct and indirect rebound effects. The exogenous shock we introduce is based on the direct effects of the technical improvements/eco-innovations used in the computable general equilibrium model EXIOMOD used in Deliverable 9.2.

We see a clear consumption shift compared to the baseline in the partial equilibrium approach, for both the eco-innovations introduced in the Transport WP and the Built Environment WP. This consumption shift, i.e. a redistribution of consumer expenses, can also be seen as a rebound effect (indirect). So, the eco-innovations have opposite effects on different product groups.

Moreover, in case of the eco-innovation introduced in the Built Environment WP, we see that the change in fuels (all energy sources, except electricity) and metals (and minerals, however effect is smaller) use for the CGE is larger than resulting from the PE simulations. Since a CGE model captures wider economic effects, i.e. both direct and indirect effect of the eco-innovations and the PE model only measures the direct effect. For the eco-innovations analyzed in the Transport WP we see that the change in fuels, biomass, metals, and minerals use for the CGE is larger than resulting from the PE simulations. The relative PE results are very small (around zero, i.e. almost equal to the baseline). However, we must state that the CGE includes the changes in production (in each sector) and the PE only includes changes in production plus the changes in intermediate consumption between sectors caused by the input output linkages.

Comparing the emissions output of the PE results with the CGE results, we see that some of the environmental gains (less emissions) resulting from the eco-innovations is lost, i.e. the PE show lower emissions relative to the baseline, than the CGE results. This can also be identified as a clear rebound effects. This also holds for the both the eco-innovations analyzed in the Transport WP and the Built Environment WP.

The impacts on considered improvement areas on the exports and imports of EU28 countries are small. The total impacts on exports are almost equal to the total impacts on imports, which is due to the trade balance constraint.

Finally, the sensitivity analysis shows small variations in the results. This indicates that the model results are robust. The changes in production emissions are more affected than the changes in GDP. The sensitivity analysis was done by varying the elasticity of substitution between capital and labour by multiplying and dividing it by two.

Recommendations for impacts assessment studies

• Impacts of individual eco-innovations on GDP and other macro-economic indicators are quite small which means that it makes sense to assess packages of improvement options with macro-economic
models

• It is important to take a systemic view on the impacts of eco-innovations. For example our analysis has shown that environmental impacts of electric vehicles strongly depend upon the electricity mix of EU countries. The combination of renewable electricity with introduction of electric vehicles has the highest environmental benefits.

• Results of ex-ante analysis have the highest sensitivity towards the assumptions about the penetration rates of eco-innovations. This means that sound scientific research is needed to be able to provide such forecasts.

• Impact of rebound effects on the environmental effects of eco-innovations strongly depends upon the type of innovation. The highest rebound effects are associated with overall improvement in energy efficiency.

• Proper sensitivity analysis is an important part of ex-ante impact assessment of eco-innovations.

WP10

The EMInInn project has explored the challenges of identifying whether specific innovations actually generate environmental savings, and it has developed a variety of tools for improving assessments of the environmental consequences of specific innovations. An important conclusion is that it is not always straightforward to identify the environmental consequences that arise from specific innovations, either ex ante or ex post. Unintended consequences are a real risk for technology-specific policies. Detailed assessments of the indirect effects of specific innovations, across the life-cycle and incorporating various economic feedback effects, can help avoid such unintended consequences.

WP10 reviewed current policy practice in impact assessment documents, to assess the methods and tools with which policymakers currently represent the relationship between innovation, environmental outcomes and policy. The impact assessment documents of environmental policies (covering waste, energy and climate change, and biodiversity and land-use; across the European Commission, UK, Sweden, Italy and Germany) were assessed for their representation of innovation; while impact assessments of innovation policies (from the European Commission, UK and Italy) were assessed for their representation of induced environmental effects. The reviews indicated that the tools, methods and indicators used often overlook potentially important induced effects. A particular area of apparent confusion in impact assessments concerns the potential for rebound effects, which were understood, reported and framed in different and at times conflicting ways in different impact assessment documents.

EMInInn studied rebound effects in a number of ways, and some further analysis in WP10 examined the implications of emissions policies on the environmental consequences of indirect (or re-spending) rebounds. More-efficient cars, for example, free-up money that consumers might then spend on other energy-using goods and services. The emissions consequences of that induced energy consumption might undermine (partially or even completely) the emissions savings associated with the energy-efficient product. The environmental consequences of that additional demand depends, in part, on price signals. In the presence of a carbon price, each unit of additional consumer spending can be expected to be directed towards lower-carbon activities than would otherwise have been the case.

This can be demonstrated with the outputs of the economic model EXIOMOD. Here, the marginal carbon intensity of economic activity is shown declining as a function of carbon price. While much of the analytic and policy work on the rebound effect has focused on whether and how large a rebound might be, this analysis illustrates that the environmental consequences of rebound effects are a policy choice: strong carbon prices will direct induced consumption towards low-carbon goods and services.
Improving environmental assessments in policy design and ex post policy evaluation

The major challenge of effective technology-specific innovation policy (such as support for the deployment of specific technologies) is often thought to be uncertainty about whether a particular technology will become cost effective and profitable without the need for subsidy. However, determining the environmental pressures that might arise from diffusion of a technology has also been revealed to be very challenging. Too often, the environmental desirability of a particular technology is asserted rather than assessed. Of particular relevance is that the ultimate environmental effects of many technologies depend on the policy and market environment in which they are diffused. The environmental consequences of a technology are not solely an attribute of the technology itself, and a broader assessment is required that highlights how policymakers can ensure that environmental policy goals are met.

Inter-sectoral influences are often forgotten or ignored in impact assessments. Consequently it is unclear whether the time and budgets are used in the most effective way and policy makers are regularly negatively surprised by unwanted and unexpected side effects. A policy might also be negatively assessed when no effect is visible within the sector but it turns out to generate the right outcome in another sector (for instance taxation on a price-inelastic activity which reduces the available household budget for other expenditures).

To include the expected innovation effects of a policy and then the expected environmental implications of innovation can be important for good policy design—reducing the prevalence of unintended effects. Impact assessments associated with EU policy proposals are generally focused on the issue at stake and the expected economic consequences of the proposed policy, with limited consideration of indirect effects on the environment as mediated by innovation (be it at work outside the policy scope or induced by the policy itself, intentionally or not). Even where policies focus on inducing innovation (or even deploying specific technologies) the treatment of environmental consequences of that policy often neglects key processes, particularly rebound effects. The analysis within EMInInn suggests that improvements to such processes are possible, and offers a range of analytic tools for assessing policies. EMInInn has also produced a conceptual framework that helps policy makers to think about how innovation affects the environment, and this can help to identify the processes that may need to be included within assessment processes.

In particular, the EMInInn analysis leads to the following recommendations for Impact Assessments, monitoring and ex-post evaluation. However, it is clear that such detailed and therefore costly assessments should only be carried out in proportion to the expected outcome of the policy:

• Authors of IAs and ex-post evaluations should be clear about limitations in their approach. Where uncertainties exist, information should be provided on how they might affect the outcome of the assessment, for example by conducting sensitivity analysis. A positive example where this has been done is the ex-post evaluation of the CIP Eco-Innovation market replication programme.

• Triangulation can be a useful tool to confirm the reliability of information. With triangulation a range of different methods, such as modelling, expert assessments, public consultation, surveys or case studies, are used in parallel. While modelling is used widely in many studies these days, it can provide a false sense of security. It is therefore advisable to counter-check model assumptions and results against other sources, such as expert opinions or public consultation. The case of the EU’s biofuels policy shows that failing to interrogate model assumptions can contribute to a failure to anticipate unintended consequences.

• When assessing the impact of innovation and technologies effects across the entire life-cycle of products should be considered.
• Also potential trade-offs between environmental pressures should be considered, as positive effects in one environmental area might lead to negative effects in another area. Mostly policy makers focus on
reducing environmental pressures in a given priority area that the policy proposal aims to address and therefore tend to oversee potential negative environmental effects in other areas. This was for example the case with the EU’s biofuels policy.

- EMInInn has shown that while rebound effects can significantly offset environmental benefits on the marco-level, they are generally not considered in IAs and ex-post evaluations. Policy makers should therefore make use of the tools developed by EMInInn to take account of rebound effects in their assessment of policy options.

- If EU policy is being implemented at Member State level it is important to streamline monitoring activities in countries to ensure data comparability and therewith provide the basis for sound ex-post evaluation. The recent history of plant-by-plant data collection under the Large Combustion Plant Directive emphasizes this point: data submissions in early years used different plant naming conventions to later years, creating significant obstacles for attempts to use the data for monitoring the contribution of specific technologies to emissions abatement.

- When reporting environmental savings associated with specific technologies (or technology-specific policies), a screening of potential rebound effects should be undertaken in order to avoid over-stating the expected contribution of the technologies. Where this takes place, it would be desirable to report savings under a range of future environmental pricing scenarios. For example, expected emissions savings associated with measures to promote energy efficiency might be reported under a range of carbon price scenarios, taking into account the way in which environmental consequences of rebound effects differ under different pricing regimes.

- Providing guidance for policy makers and external consultants that are responsible for assessing eco-innovation is key to improve current policy practice. The Commission should therefore actively compile, communicate and promote available guidance material. For example the “Guidebook to assessing environmental impacts of research and innovation policy” could be uploaded on the Commission’s website and promoted more actively in the policy evaluation community.

WP11

WP11 has used several communication channels such as workshops, conferences, reports, journal articles as well as IT-supported tools. The target groups of the Dissemination WP has been mainly in policy-making and research. The general public has also been informed about the output of the project (e.g. by making the reports publicly available).

Capacity-building has included workshops with the following functions:

- Feed-back on preliminary thinking and results of EMInInn which were part of the interactive research design of the WPs
- Connecting EMInInn to on-going research on environmental indicators and macro assessments (such as DESIRE, FLAGSHIP, RECREATE)
- Connecting EMInInn to related activities of the EEA, Eurostat, etc.
- Dissemination

Clearly significant results

WP11 could meet all of the above functions by means of several significant outputs:

1. Expert and stakeholder workshops
2. a website
3. Flyer and brochure
4. Presentations
5. Peer-reviewed journal articles
Expert and stakeholder Workshop
As follow-up of the kick-off meeting the consortium had defined experts and stakeholders to be addressed. A meeting with a selected group of experts took place in Brussels on June 13th 2012 in order to develop first ideas for the conceptual framework of EMInInn. The results were used to lay the methodological foundations of EMInInn with a number of background papers (see project summary). This process culminated in the “Essential of EMInInn” workshop. This workshop was scheduled for September 27th 2012 in Brussels, directly feeding into the stakeholder workshop, which took place on September 28th 2012, at the Permanent Representation of Sweden in the centre of Brussels. It was attended by about 30 persons, including governmental stakeholders e.g. from the OECD, the European Commission as well as non-governmental stakeholders from the European Trade Union Confederation, Greenovate, Eurochambres or the German Association of Engineers (VDI).

In phase 3 (Policy implications and dissemination) five thematic workshops (one for each theme in WP4-8) have taken place (see further details in relevant WP description and chapter “Use and dissemination of foreground” section A2, list of dissemination activities).

Eventually, EMInInn has explored the policy implications of the previous analysis in policy-papers, both in relation to innovation policy and in relation to policies on resources and wastes, energy and climate as well as land-use and biodiversity, all of which aimed at stimulating innovation where this is perceived to solve environmental problems.

Website
On the EMInInn web page the public information about the project is shared. The website has been updated regularly. For reaching a large interested audience the EMInInn also used the electronic newsletter of the Wuppertal Institute, which is generated in English and German. The newsletter has been actively subscribed by approximately 10.000 users. A special electronic dissemination database has been created in order to reach specific groups beyond the project.

Flyer and brochure
The consortium has also produced a flyer, an identity brochure and policy papers. For the creation of websites, flyers, brochures and the broshures EMInInn has cooperated with the Visualization Laboratory (VisLab) at the Wuppertal Institute, which consists of a team of professional designers and communication officers with specialization in sustainability-related public relations.

Presentations
The output of the project has been distributed among relevant stakeholders and at European and international conferences related to (eco-)innovation in which partners will be encouraged to take actively part with presentations and papers. Among others the project has presented at the following events:

- Panel Discussion “Green Economy” at the conference of the Bayer Young Environmental Envoy:s A Green Economy. Fact and challenges, Leverkusen, 05.11.2012
One of most visible output of WP11 have been two joint sessions organised in cooperation with the FP7 projects DESIRE (Development of a System of Indicators for a Resource Efficient Europe), POLFREE (Policy Options for a Resource Efficient Europe) and BRAINPOoL (Bringing alternative Indicators into Policy) at the World Resources Forum (WRF), which took place on 07-09 October 2013 in Davos, Switzerland.

Final Conference
The final conference of the EMInInn project took place in Brussels on 18th March 2015. The event was organised as part of a wider forum for discussing how research on resource efficiency and eco-innovation can contribute to evidence-based policy-making. Thus, the EMInInn final conference served as anchor for two related events of the FP7-projects “Developing a System of Indicators for Resource Efficiency” (DESIRE) and “Forward Looking Analysis of Grand Societal Challenges and Innovative” (FLAGSHIP), which also hosted dissemination workshops on 17th and 19th March respectively.

A wide variety of stakeholders attended the event to learn and discuss about the topics above. Policy makers from DG ENV, DG RTD and DG Connect, as well as from national ministries; members from the OECD, EEA, or WHO; business representatives from Euromines, Plastics Europe, etc.; and academics and researchers with very different backgrounds were part of an audience of altogether 77 people who took part in a lively discussion during the final conference.

Journal Articles
The success of the project is conditioned to the delivery of objective and reliable information on innovation and its implications. In this context, the output has also been spread through traditional scientific channels such as scientific journals, books, etc. In total EMInInn researchers have produced 20 journal articles including award-winning publications (see chapter “Use and dissemination of foreground” list of scientific publications template A1).

Potential Impact:
WP1
A major impact in the longer term could be that publically available databases are more directly useful in the context of assessment of innovation and their macro-environmental impacts. The findings of EMInInn will contribute here, but it is also true that other initiatives, such as the Product and organisational environmental footprint initiative run by The European Commission will also be important in promoting the availability of such databases.

WP2
We expect the recommendations for eco-innovation measurement to be used by other researchers. We hope to encourage that more attention is given to especially direct innovation indicators. The WP on innovation measurement is a cross-cutting contribution during phase II and III in order to improve and adapt innovation measurements according to the requirement of the different environmental and economic analytical frameworks. We did not engage in external dissemination activities other than
through the reports we produced.

WP3
In EmInInn, a systems approach has been taken to specify the environmental impacts of innovations. The use of tools such as LCA, widely applied by the EmInInn case studies, shows that it is important not to just focus on the (implementation of the) innovation itself, but to include the whole life cycle. A saving in one life cycle stage may be offset by extra emissions in other life cycle stages. It has also been clearly established that including the life cycle is not sufficient. By performing an LCA, alternatives can be compared at the micro-level. How that actually works out at the macro-level is then a next step. For that, additional information is required on the uptake rate of the innovation, on whether it replaces existing products or processes or is additional to them, on whether this innovation triggers other changes in society, and last but not least on the rebound effect.

The value of EmInInn lies in some realisations that have been underpinned by the application of the theoretical framework as developed in WP3 to the EmInInn case studies:

1. There is generally no such thing as a straightforward win-win improvement. Innovations that reduce emissions and also reduce costs, invariably have rebound effects that counteract the effectiveness of the innovations, sometimes even completely reverse them.

2. It appears that financial incentives, such as a resource tax or a carbon tax, could be very effective. This conclusion can be drawn from the fact that innovations that are more expensive than their alternatives have a “negative rebound effect”: they bind money instead of liberating it, thus preventing other expenditures. A tax system that thus internalises external (environmental) costs would help shift society in a more sustainable direction, although the consideration of welfare levels, especially for low income groups, is key.

These are powerful messages for a resource efficiency policy. These messages have been disseminated via the scientific literature and via presentations for relevant audiences. An overview of the publications and presentations is given below. It shows that the work for WP3 / WP6 resulted in the publication of 4 peer-reviewed articles in well-established scientific journals. The article in the Journal of Industrial Ecology won the Graedel Prize for the best paper by a young researcher. The article in The International Journal of Life Cycle Assessment was awarded with the CML-Publicatieprijs for the best scientific publication of 2014 of CML employees.

WP4
A key impact of the work has been methodological – the results will inform the community of energy systems modellers about an important set of assumptions and methodological options. Interest has already been expressed by analytic teams working within other European-funded projects (in particular the ADVANCE project, which is pushing forward the state-of-the-art in integrated assessment modelling). As a direct result of the EMININN project, the UCL team has been approached by other European modelling teams to pursue potential collaborative opportunities building on the work.

Key UK policymakers have also been engaged in the analysis and work. Key modelling and science analysis teams, both from the Department of Energy and Climate Change and the independent statutory body the Committee on Climate Change, have attended and spoken at workshops. The TIMES modelling team at UCL works collaboratively with the modelling teams at the Department of Energy and Climate Change, and our main model (the UK TIMES model) is open-source. The team is also closely involved in the IEA Energy Technology and Systems Analysis Programme, which is a major global hub organisation
for energy system modellers. As a result of these existing networks, the methodological developments within EMININN have clear informal routes to utilisation and impact, in addition to the formal published outputs (two journal articles are being submitted reporting on the TIMES modelling work). The specific findings (i.e. in addition to methodological advancements) are important in the sense that they make clear that upstream emissions are a non-negligible factor in determining optimal energy decarbonisation pathways, but also that the effect is not large: in other words, existing analytic tools such as PRIMES and TIMES models do a reasonable job at determining the relative attractiveness of technologies, but are biased slightly towards technologies that have zero use-phase emissions. This is useful knowledge, particularly where such tools use optimisation and first-best approaches, since it may be relatively small differences in technological characteristics that drive large differences in selected technology portfolios. A journal article is being submitted to report this work.

The work on decomposition of flue gas desulphurisation has been shared with the European Environment Agency. A master’s degree student is extending and completing the EMININN work this summer, and once complete the database will be provided to the EEA, who have expressed interest in making use of the work for ongoing analysis of sulphur emissions. It is anticipated that this work will also generate a journal article.

WP5

The main dissemination activity used Web technology, quite fittingly for an Internet case study. We broadcasted and recorded an open webinar. The recording of the webinar remains available on the EMInInn website. We could win a high profile speaker for the webinar. Arjen Kamphuis is co-founder and Chief Technology Officer of Gendo, a management consultancy specialising in technological innovation, and a much sought-after international speaker on technology policy issues he gives over 100 keynote talks every year.

The study could contribute with others to impact data policy. It showed that data is needed for bottom-up analysis (systematic environmental footprint of ICT/Internet technologies and services, timely diffusion data for macro-level assessments), econometric and input-output analyses (company and sectoral). All data should ideally be collected and made available more often and more rapidly (to keep up with ICT innovation and adoption pace), and cover a larger scale (at least EU-wide).

ICT/Internet innovations can be linked to policy in at least three different ways: (1) policy encourages a new industry and/or consumer behaviour deemed beneficial (e.g. E-Commerce Directive), (2) policy indirectly (and inadvertently) created the conditions for a new service or product to emerge (e.g. copyright laws and streaming), (3) policy reacts to developments it did not foresee nor encouraged and that are not covered in the current body of laws and regulations (e.g. crowdfunding platforms, cryptocurrencies etc.). These three types of policy interventions are most of the time devoid of environmental considerations. They may even indirectly have negative environmental consequences and thus go against other policy goals.

We argue that both ex-post and ex-ante environmental assessments of ICT/Internet innovations are necessary but not sufficient for keeping macro environmental effects in check. It is due to secondary and tertiary effects and unpredictable future ICT/Internet innovations or other innovations building upon those. A way towards a solution would need to: (1) internalise all environmental costs (beyond energy price signals; considering the entire life cycle of products and services), and (2) set limits to physical growth (beyond energy efficiency and emission cap goals, e.g. with material resource consumption caps etc.) while still allowing economic growth based on a dematerialised, service-based e-economy within the set physical boundaries.
It is of course extremely delicate to set prices and limits at that level but it is necessary to avoid the drawbacks (burden shifting, rebound effects) of more narrowly defined product- and substance-based regulations (that have their own advantages and are still needed). Regulatory instruments providing the two characteristics above would also give policy a heads up (at least for environmental effects) and limit the necessity to react to technological and societal changes occurring at an increasingly rapid pace. This is the new deal imposed to policy makers by the ICT/Internet as a general purpose technology.

WP6

The project resulted in the creation of two macro-environmental assessment models: the IPAT-LCA and the Environmental Rebound Effect model. The combined application of the two models provide a number of insights to be considered in the design of eco-innovation policies:

• Considering the increasing momentum that LCA is gaining as a policy support tool (Pothen 2010), it is important to take LCA estimates with caution, as our results highlight the notable impact that costs differences can induce on absolute environmental results.
• Rebound effects should be anticipated for cost-saving innovations. The rebound effects will curb the environmental gains and may even lead to an overall increase in environmental pressures for certain emissions.
• Costs differences do not entirely stem from the technical characteristics of new technologies, but also from external factors, such as fuel prices or the relative impact with respect to other products from the consumption basket. These aspects have thus a notable influence in the overall environmental performance of transport innovations and should be seen as active elements of policy rather than a fixed background. This gives a wider range of possible policy actions to improve the environmental performance of current transport systems, such as green taxes or sustainable consumption policies aimed at key consumption sectors (e.g. food production).
• Even under current conditions, policies can allocate resources to foster those innovations that offer a better environmental performance once considering income effects. This is the case, for instance, of P+R and car-sharing schemes.
• While more active elements come into play to curve environmental pressures from transport, a number of trade-offs take place. For instance, minimizing cost differences induced by innovations can hinder their diffusion due to the market-driven nature of society. Also, because of the structural role of transport in the economy, changes in transport systems can cause undesired spillover effects on other economic sectors. Our conclusions lead thus to a double-edged picture when it comes to improve the environmental performance of transport systems, which calls for careful attention when designing new policies.

Results have been disseminated via academic publications, conferences, the media and a workshop. An overview of the publications and conference presentations is given below. It shows that the Work for WP6 resulted in the publication of 4 peer-reviewed articles in top-tier journals. The article in the Journal of Industrial Ecology won the Graedel Price for the best paper by a young researcher. The article in The International Journal of Life Cycle Assessment was awarded with the CML-Leiden University price for the most relevant scientific publication by Leiden University in 2014.

WP7

The potential impact of the results of EMInInn and more specific of WP 7 focussing on the built
environment and buildings, is in fact an improved methodology and set of instruments to reflect upon the environmental pressures, when influencing particular variables and or indicators. Enabling policy makers, industry, contractors and research agencies to have a more comprehensive picture of effects (including rebounds, behavioural and indirect economic effects) of installing energy efficient measures, that seem promising the world on the first sight.

By enabling the assessment of the whole life cycle of an eco-innovation, makes it possible to look for a balanced intervention strategy.

Dissemination activities so far have been focusing on the scientific community mainly, by means of workshops, publications and opinion papers. For the near future, the researchers involved in the execution of WP 7 EMInInn research work on making results and methodologies more dedicated in order to meet the market stakeholders’ needs in the end. For example, the tool that allowed us to calculate the direct and indirect rebound effects, touches upon a certain need from suppliers and manufacturers in the construction sector, to know what are potential rebounds to take into account when installing PV panels, or getting high performing insulation materials installed.

With the latter adjustments, this tools will open the door for further exploitation (potentially commercial beneficial) of the results of EMInInn in general and WP 7 in particular. When results, products and tools meet the type of strategic market questions, where commercial companies can benefit from, the commercial potential for exploitation goes up.

WP8

The main potential impact of WP8 results is to contribute to the scientific evidence basis for the development of the Circular Economy in Europe. The results of WP8 confirm on environmental and (partially) economic grounds the validity of the European Waste Hierarchy, which is one of the main drivers of change towards a circular economy. The whole results of WP8 on waste and recycling have been communicated and transferred to DG Environment with the aim of providing the above-mentioned support. These same results have been communicated and transferred to the EEA – European Environment Agency through the activities of the ETC/WMGE – European Topic Center on Waste and Materials in a Green Economy (2014-2018), the international consortium to which two partners of EMInInn (IRCRES and Wuppertal Institute) do belong. Within the multi-annual program of activity of the ETC/SCP for the EEA, a specific work package is on waste management and prevention and it involves researchers form IRCRES and WI who can transfer the knowledge and main results achieved through EMInInn. The same researchers contribute to the development of the European Reference Model on Waste, which is being managed by EEA and ETC/WMGE on behalf of DG Environment. The European Reference Model on Waste has benne used for the production of the Impact Assessment of the Circular Economy package proposal of 2014 and is being used for the new Circular Economy proposal expected by Autumn 2015. Many quantitative results of EMInInn WP8 may be integrated into the future developments of the Waste Model. We foresee also a potential impact for policy making in some specific areas of waste and the circular economy, for example, policies on WEEE, on which WP8 produced evidence on implementation issues not available before, on the role of durability of goods for the production of waste and other environmental pressures, on the role of policy approaches for the convergence towards the waste hierarchy and benchmark European standards of regions/countries that are lagging behind in waste management.

WP9

The modelling in WP9 identified potential rebound effects arising from the diffusion of the resource-saving
innovations examined. The rebound effects are in most observed cases significant and can even be larger than the positive direct effect. One important conclusion that was brought forward by the results, is that it is important to take a systemic view on the impacts of eco-innovations.

Results have been presented and were welcomed by the participants at the final conference of Emininn. Also at other occasions and within other ongoing projects these insights have been communicated and used.

Dissemination in the final reporting period:
- EAERE paper on EmInInn project modeling results submitted (waiting for approval)
- Presentation at the Dutch Ministry of Transport on a new DG MOVE modeling system in which economic modelling is included.

WP10
The final deliverable from the work package, deliverable 10.4 represents a major report setting out the key findings and conclusions from the EMININN project as a whole. The report, and its findings, were presented at the EMININN final conference, alongside the policy briefs that were developed directly drawing on material developed in work package 10. As a result, the work package provided the key synthesis and policy review function that enabled the results to be tailored for, and targeted at, relevant audiences—including both policymakers and analysis able to make use of the methods developed within the project.

In addition to its synthesis and policy review function, the work package also contributed to more purely academic work. Assessment of the treatment of rebound effects in policy impact assessments, and the treatment of indirect innovation and environmental effects generally, is now being written up in two journal papers.

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