Systematic Analysis of Rebound Effects for "Greening by ICT" Initiatives

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Abstract: The application of ICT can lead to considerable reductions in the energy consumption of society. Although ICT itself consumes energy, there are many good reasons to explore the possibilities of 'green ICT'. After decades of experiments and research, ICTs designed to be 'green' still holds the promise of leading to substantial ecological benefits by means of dematerialisation, more efficient production processes and changed (more sustainable) human behaviour.
Up till now, the effects of ICT on energy consumption are much less straightforward due to rebound effects: effects that have a negative influence on the intended positive effect. In parallel, rebound effects themselves have in turn other side effects as well, so there are many interacting effects to account for, greatly adding to complexity of the discussion. Despite evidence that suggests otherwise, initiatives that focus on 'greening by ICT' do not account for a consistent analysis of these rebound effects. This paper proposes an approach that enables to map and analyze these rebound effects systematically. This approach is applied in two related cases, teleworking and the use of Smart Working Centres. The Rapid Assessment Program (RAP) is used as a simulation model to identify which chains of effects are most interesting to consider for intervention. The application in the two cases demonstrates that rebound effects can by structured and that the RAP is a very suitable way to do so and provides a good assessment of net sustainability effects.
Key words: rebound effects, Rapid Assesment Program, greening by ICT, teleworking.

ICT applications were originally developed because of a need to work more efficiently. Whether you look at calculators of Hollerith or the analytical Engine of Babbage, the most important driver of computerization is working more efficiently.

When more and more people started using computers, the need for user friendly systems increased. It is for a good reason that they call it a 'personal computer' and with the introduction of graphical user interfaces and more focus on the usability of applications, ICT became more user-friendly.

So Profit was definitely a reason for lots of ICT developments, and ICT has learned that People are its most important stakeholders, but what about Planet? The 2007 analysis of the Gartner Group, in their presentation "Green IT, a new industry shockwave", has received worldwide attention. Especially the claim that the direct energy consumption of ICT is responsible for about 2% of the worldwide energy consumption (comparable to air traffic) convinced the public that the relation between ICT and energy consumption was a very real one. Until then, ICT had the image of a 'clean industry' in the eyes of many.

The Climate Group (2008) expects that usage of ICT will increase substantially in the coming years, therefore paying attention to the direct energy consumption of ICT itself is certainly very important. However, besides the "greening of ICT" activities, it is recognized that the smart application of ICT can have a substantial impact on the 'remaining 98%' as well. This is called 'greening by ICT' and includes for instance a shift from delivering physical products to delivering services: the 'dematerialisation' effect of ICT (ROMM *et al*., 1999). An example is less need for printing because more information will be available electronically (Boston Consulting Group, 1999), although many predictions concerning paperless offices have not yet come true (KOHL, 2004).

However, knowing this raises new questions: how can we estimate, or even calculate the effects of ICT? How can we be sure that ICT indeed has this greening effect? And if we knew that, how could we design ICT applications that enhance sustainability?

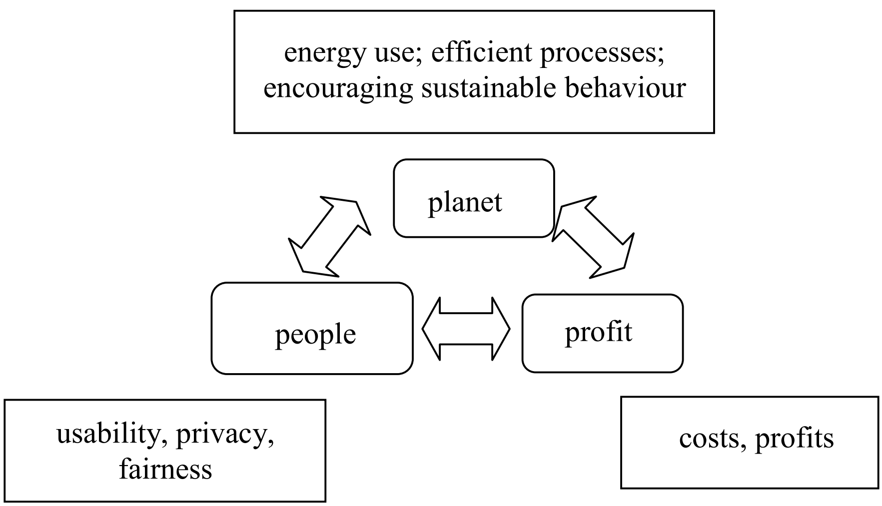
Additionally, the effects of ICT that seem to have good advantages in the short term could be undone in the long run. That can happen due to so called rebound effects. If, for example, ICT enables cheaper production, the demand for products will raise thus increasing pollution. These rebound effects make it difficult to evaluate the effects of ICT on sustainability. What is needed is a method to look at direct, second order and third order effects in a uniform and structured way. The 'Rapid Assessment Program' (RAP) originally meant to study the effects of interventions in public spaces, for instance large infrastructural projects seems to be very well applicable to assess the rebound effects of ICT. RAP was developed by Arcadis, a Dutch engineering consultancy firm.

Will ICT have effects on sustainability?

The question whether ICT contributes to a sustainable society is answered differently by different people. On the one hand we have the optimists that see ICT as a replacement of harmful products and energy. Matter, so they state, will be replaced by bits and ideas (BERKHOUT, 2004). The productivity will rise, but production will not. On the other hand we have the pessimists that stress that ICT in itself is very polluting. Product life cycles will shorten and production will rise. Furthermore ICT consumes energy.

In this paper, we focus on the consumption of energy. Not only the consumption of energy of ICT and ICT applications, but also on the resulting consumption of energy of processes and people. Besides energy, which relates to the 'planet' aspect, the other sustainability aspects 'people' and 'profit' should be taken into account. As these aspects are already well-studied, we will not focus on them in this paper. We confine ourselves to stating that sustainability can only be attained if people, planet and profit are in balance.

Figure 1 – balanced sustainability for ICT



It is important to note that the effects of ICT that seem to have good advantages in the short term could be undone in the long run. That can happen due to so called rebound effects. If, for example, ICT enables cheaper production, the demand for product will raise thus increasing pollution. These rebounds effects make it difficult to evaluate the effects of ICT for sustainability.

Rebound effects

As stated above, rebound effects are important. A rebound effect concerns behavioural changes or other system changes as effects of the introduction of a technological innovation, or other measures that are taken to diminish the use of natural resources. These changes reduce the positive effects of the measures.

An ICT application in one area often has implications in another practice or area, for example by a price effect. The effects are frequently classified into levels. For example, HILTY (2006) defines three types of environmental effects:

- 'First-order' or 'primary' effects: effects of the physical existence of ICT (environmental impacts of the production, use, recycling and disposal of ICT hardware).
- 'Second order' or 'secondary' effects: indirect environmental effects of ICT due to its power to change processes (such as production or transport processes), resulting in a modification (decrease or increase) of their environmental impacts.
- 'Third order' or 'tertiary' effects: environmental effects of the medium- or long-term adaptation of behaviour (e.g. consumption patterns) or economic structures due to the stable availability of ICT and the services it provides.

PLEYPYS (2002) defines rebound effects as an actual growth of the consumption of an energy service, as the price decreases. The chain of effects is as follows: by technological improvement less energy is needed to produce a product. Therefore the costs of that product will decrease thereby increasing the demand for that product. PLEYPYS (2002) defines four types of rebound effects:

- The direct rebound effects are the effects on price on micro level. These are the price effects due to better energy efficiency. This decreases the price per product and that will increase the demand for a good.

- The second order effect arises by an increase in income of consumers. If prices of one good decrease due to more efficient production then there can be more consumption of other products.
- The third order effects concern the effects to the economy as a whole. It focuses on developments on a macro economic level, where all goods and services are well balanced.
- The fourth order effects do not focus on prices but describe the effects of changing consumer preferences and changing production organisations

Developments in ICT: environmental effects and rebound effects

Looking at the environmental impact of ICT, effects and rebound effects can be seen. In this chapter we describe first order, second order and third order effects of ICT on the environment.

First order effects: production and use of ICT consumes energy

The direct environmental effects of ICT use are negative. The production of ICT equipment has multiple harmful effects: energy use, use of water, emission of acids, metals, organic particles, chlorides and other substances. MATTHEWS (2001) showed that pollution by ICT spans from waste and energy to greenhouse gases. Of all production materials, 98% is turned into waste and only 2% turns into the actual product. Additionally, the raw materials are scarce and a lot of toxic substances are used.

Furthermore, the use of ICT consumes a lot of energy. Making a personal computer costs 1800 kWh of energy (MACKAY, 2008). And studies on the usage of ICT in the US suggest that 2 to 3% of the total energy consumption in the US is used by ICT in offices and that percentage is expected to rise to 5% in the coming 20 years (KAWAMOTO et al, 2001; ROTH, 2002). Additionally ICT usage at home is rising.

Second order effects: ICT creates more (energy) efficient production processes and business models

The effects that ICT achieves by creating more efficient production processes are secondary effects. More and more, services are created without any material. Think for example of changed business models where suppliers keep the production facilities and deliver the service instead of the product. Another example is the savings in production chains where products flow more easily through the chain and less space is needed for storage (BCG, 1999). Many researchers state that the growth of the past years is due to ICT. An interesting result in this case is the report by the American Council for Energy-Efficient Economy that says:

> "For every extra kilowatt-hour of electricity that has been demanded by ICT, the U.S. economy increased its overall energy savings by a factor of about 10" (ACEEE 2008).

Third order effects: ICT teaches us about environmental effects and enables us to act

An example of a tertiary effect is the fact that most of our knowledge on the environment is realized by the use of ICT and sensor applications: ICT applications enlarge our knowledge on the environment. On many locations worldwide, the environment is observed via ICT programs, such as the global forest watch. Based on this knowledge, we are able to act.

To conclude, we see different authors and different models define primary, secondary and third order effects in different ways. One can distinguish direct, indirect and systemic effects (Hilty); or focus on the economic impact (Plepys), or introduce a classification that describes the impact of ICT.

The RAP simulation model (introduced in chapter 3) does not distinguish between these effects; it just numbers them, so even sixth order effects are possible. We suggest a more practical way of describing effects and rebound effects:

- direct effects: effect of the production and use of ICT, for example the energy use of a PC or data centre;
- indirect effects: the effects of the use of ICT on the use of energy, for example less work-home traffic kilometres when working at home is possible;
- system effects: by behavioural changes or completely different industrial processes and usage patterns will develop to a new level. For example the development of a whole new way of working such as "The New World of Work" (RSM and Microsoft 2007) or different forms of generating and distributing energy (Smart Grids).

■ Two cases: teleworking and Smart Working Centres

Teleworking is often mentioned as a prime example of system effects: how ICT can change patterns of working and travelling (see for instance WWF, 2008). However, these measures should be taken cautiously because many rebound effects are present. Some examples:

- teleworking leads to a reduction of travelling during peak hours, which reduces the amount of energy needed for this transport; (this is the primary intended effect);
- teleworkers tend to spend more leisure / private travelling during the day, compared to the situation where they were working at the office (HJORTOL, 2002);
- teleworkers need to illuminate and heat their homes during the heating season or to cool their homes during the hot season, where this would not be needed when working at the office; (besides, heating houses is usually less efficient than heating offices because in houses only one person occupies the whole building);
- reduced presence of personnel at offices does not always proportionally reduce an office's energy need; (only in offices with flexible space, where people do not have their 'own' desks or rooms, it is possible to accommodate illumination and heating to the actual presence of personnel);
- teleworking may stimulate workers to live farther away from their offices, increasing the travel distance on office days;
- teleworkers have a higher need for ICT and office equipment and materials at their homes (at the office, the reduction is not proportionally lower);
- less traffic during peak hours may attract travellers that would otherwise travel at other times or would refrain from travelling at all, thus leading to an increase in traffic during peak hours;
- increased demand for equipment and materials in turn, increases the amount of 'embodied carbon' for production, the amount of transport, and ultimately also the amount of waste (both municipal waste and e-waste).

When studying literature or interviewing teleworkers or experts, it is easy to expand this list. The resulting discussion can easily become very complicated, because there are 'loops' in the model. As a consequence, it is not possible to distinguish between the direct effects, the indirect effects and the system effects. Another complicating factor is the confusion between 'automatic' effects (less transport causes less energy used), and the effects that can be influenced by companies or governments by policy decisions.

For instance, less demand for 'traditional' office space, caused by an increased uptake of teleworking, can be answered by a) more flexible office space and (much) less traditional office space or b) doing nothing.

It is interesting to note that some rebound effects may be countered by introducing a slightly adapted concept, the 'smart work center' or SWC (CISCO, 2009). This concept, in earlier versions known as satellite office initiatives or traditional multi-tenant business centers, was introduced in Amsterdam late 2008 and has the following characteristics:

- SWCs are located close to residential quarters and main traffic arteries. SWCs are being scaled as a fine-mazed network of many small centers as opposed to a small number of large outfits;
- SWCs carry a business model that is based on work stations rather than square meters or square feet. This allows for a far more effective and efficient use of space and energy per worker as the space taken up by e-work stations is not designated to one single tenant but is taken up on a day by day heterogeneous basis;
- New SWCs sites and interior outfits can and must be constructed and procured based on high standards regarding energy efficiency and sustainability;
- SWCs require communication technology that enables the knowledge worker to orchestrate his or her work in a truly distributed fashion and to collaborate and have virtual meetings that equal the physical meeting experience using for instance telepresence facilities;
- SWCs, require affordable high-end symmetric bandwidth in order to host telepresence type of facilities and allow for high end connectivity to multiple tenants;
- SWCs need to be recognized and utilized as an instrument in policies, incentive packages and 'cocktail solutions' defined by employers, governments and municipalities in addressing congestion and mobility agendas;
- SWCs – and SWC networks in particular – require advanced reservation systems for the use of employers and individual users. Eventually, reservations are to be allowed over multiple platforms to include PC, mobile phone, phone and car navigation services;
- SWC use requires cultural and psychological changes for many. Under the SWC pilot, programs have been initiated by participating employers, encouraging the use of SWCs by their workers.

Some rebound effects are mitigated in the SWC concept:

- the tendency for workers to make more 'leisure travels' during the day;

- inefficiencies in private homes, where the whole building is heated for only one occupant;
- the need for additional office and ICT equipment and materials is reduced because there are more economies of scale and reuse at SWCs.

Although no evaluations have been carried out yet to confirm these hypotheses, the preliminary analysis that is introduced in the next chapter indicates that introduction of SWCs could have a net positive effect when compared to teleworking.

■ Systematic analysis with Rapid Assessment Program

Modelling of effects

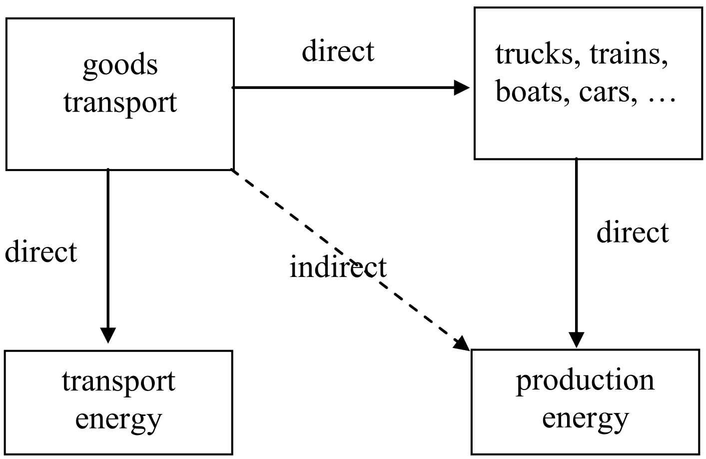
As illustrated in the example in the previous chapter, rebound effects tend to complicate discussions. Consequently, it is easy to overlook effects. For office and transport related ICT sustainability initiatives, we have identified some main categories of rebound effects. This list may act as a check list when listing rebound effects.

Table 1 - Rebound effects categories

Category	*Examples*
Work space and buildings	Office space m^2; Building extra offices
User	Attitude towards sustainability; Products and services demand; Style of living and working
Industrial production	Production of computers
Transport	Transporting goods Travel (during peak / off peak; work related or private)
Waste	Production waste e-Waste Discarded packages
Energy	Energy for heating, cooling and illumination of buildings Energy for goods transport Energy for handling waste (-/- energy produced from waste)

It is important to try to identify only the direct relations between effects and to not immediately make a projection on the ultimate output variable (in our case: energy use), because the 'intermediairy' effect may be influenced by another factor that would otherwise be overlooked. For instance, more goods transport leads to more energy needed for transportation, but it also increases the production of means of transportation which by itself costs energy as well. So there is an indirect relation between goods transport and the production energy, through the 'intermediairy' effect (increased number of vehicles). This intermediairy effect could be influenced by, say, a development that increases the number of vehicles needed for transportation like a tendency for smaller vehicles. Or otherwise, the number of vehicles has an effect on another effect like traffic jams during peak hours. So it is important not to leave out these intermediariy effects when making a model.

Figure 2 - Direct and indirect relations



Rapid Assessment Program

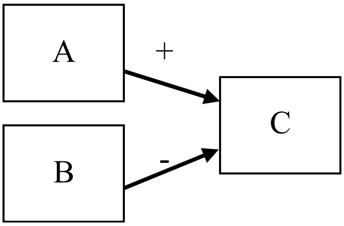
To assess the direct, indirect and system effects, we have used the 'Rapid Assessment Program' (RAP). Originally, RAP is a simulation model that was meant to study the effects of interventions in public spaces, for instance large infrastructural projects. The approach resembles the System Dynamics approach followed by HILTY *et al.* (2006), but is especially well-suited for modelling relationships that have unknown quantitative values. First, this chapter describes the program and then the two cases, teleworking and Smart Work Centres are analysed using the RAP simulation model.

The RAP computer program is used to analyze which paths through an intervention / effect model, have a positive, reinforcing effect, or have a negative, dampening effect. The relations between effects are qualitative. Therefore, it is suitable to use in situations where most experts agree that an effect exists, but when how big that effect is is unknown or disputed.

Every relation is qualified as strong, medium, or light, and can be positive or negative. For instance, a strong positive relation would be: more traditional office space leads to more energy consumption. A negative relation would be: more teleworking leads to somewhat less travel during peak hours.

Because the relations are not quantified, no calculations can be done. The only 'values' are +++, ++, +, 0, -, --, ---. Therefore, competing effects cannot be solved:

Figure 3 - Competing effects



In this case, it cannot be judged whether A or B are stronger. Consequently, in the analysis a bandwidth will be assigned for C: the net effect could have any value between -- and ++. This would however lead to unstable results, so the simulation software propagates the increase/decrease in C in weakened form: C will be between – and +.

Other special situations are:

- Positive feedback: an example would be litter in public places, it is known that the presence of litter attracts more litter. Although these effects may occur in practice, usually a modelling error has been made when this occurs.

- Mutually strengthening and weakening effects: this can lead to the well-known hog cycle, especially when an increase in A leads to a decrease in B, which in turn (but with a time delay) leads to a decrease in A.

- Mutually reinforcing effects: A increases B, and B increases A. Here it may also be the case that this is the real situation, but usually this condition indicates that there is confusion as to what is the actual causal relationship.

It is important to note that RAP does not account for the time dimension: only the probable existence of an effect can be demonstrated, but not its timing. A similar remark can be made for the space dimension: in our analyses, we have chosen the Netherlands as the spatial system boundary. When spatial effects are important, it is possible to make specific sub-models for different parts of the country or continent.

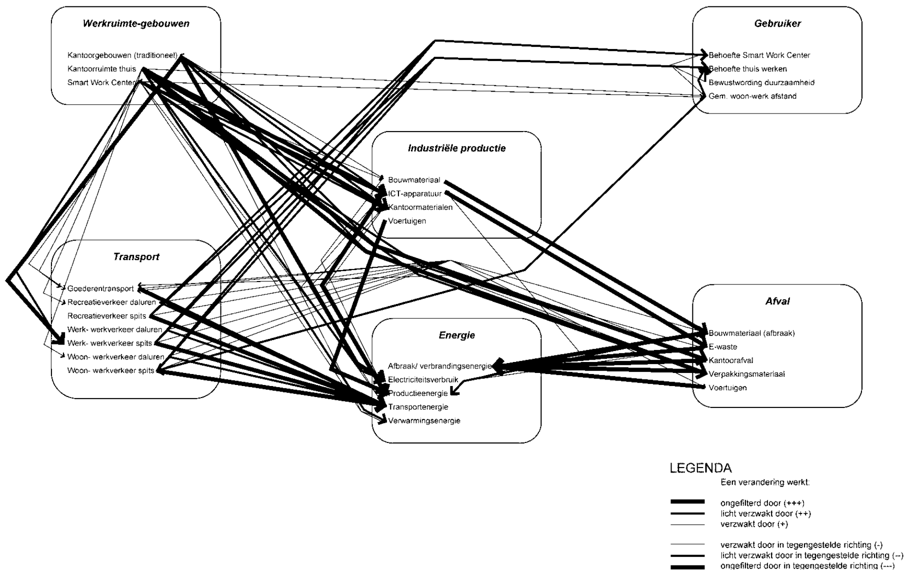
Analysis of the cases using RAP

Our two cases (teleworking and SWCs) are analysed using the RAP. Our analysis was based on a number of assumptions:

- the energy mix remains the same, so CO_2 emissions are directly related to energy consumption;
- the modal split (division between travel by car or public transport) remains the same;
- the system boundary is the geographical system (for instance a municipality, a region, a country), so this is not about one company;
- human factors like image, labour efficiency, satisfaction etc., are not accounted for;
- the measures and characteristics are focused on office related professions;
- timing issues, leading to temporarily unexpected effects, are not modelled. For instance, a reduced demand in office space will not be effectuated immediately due to longer term tenant contracts.

It is important to identify those relations that are 'external': relations that are mainly existent because of measures or policies. These relations are kept out of the model, instead they are used to compare scenarios. In our cases, we did this for the aspect 'use of office space': more demand for teleworking will lead to a decrease of traditional office space (when more offices are equipped with flexible work spaces) or will remain the same (the traditional office, but with more rooms unoccupied than usual).

Figure 4 – Model



Scenarios analysed with RAP

Two ICT applications that should have a positive systemic effect, namely teleworking and Smart Work Centers, are analysed.

Smart Work Center

To assess the impact of the introduction of Smart Work Centers, we created three scenarios. The first, reuse, comprises of converting traditional office space to space in Smart Work Centers (SWC). The total office space remains the same. The second scenario is growth exclusively by traditional office space. In the third scenario, growth of SWCs is directly translated to more office space without reduction of regular offices.

Scenario 1, no net growth, reuse of buildings

When traditional office space is converted to space in a SWC, the RAP method shows a decrease in kilometres driven during peak hours from home to work. This results in an energy reduction for transport. It also lowers the production of vehicles and therefore reduces the energy necessary for production.

This scenario, the conversion of traditional office space to space in a SWC, shows no effect in electricity use, heating use or energy use handling of waste. SWCs contribute as much to these criteria as traditional office spaces do.

Scenario 2, growth with traditional office space

This could be called the 'business as usual' scenario: no special measures are taken. The increase in commuting traffic is largest in this scenario. An 'automatic' side effect will however be the increased demand for teleworking and/or SWCs.

Scenario 3, growth with SWCs

When office space grows, transport energy needed also grows, but less than in the previous scenario: SWCs are located more closely to homes than offices. A rebound effect could be that people can afford to live farther away from their regular office.

A comparison of scenarios 2 and 3 leads to the conclusion that the net effect of SWCs is positive: less traffic during peak hours. Although there is still the effect that people can afford to live farther away from their work in the SWC scenario, this does not balance the net effect of less travel. It can be seen that the resulting bandwidth that the tool produces is in the range 0..++ for scenario 3, and 0..+++ for scenario 2. This means that the probability of more energy use in scenario 2 is higher. However, when the model produces a range of outcomes, this is an indication that a more quantitative model is needed to produce a definite answer. The model furthermore indicates that this bandwidth of outcomes for this type of energy is present as a third order effect: the effect has propagated through three other effects after showing up.

Teleworking

We have identified two scenarios: teleworking with flexible office space, and teleworking without. In the first scenario, there is a net reduction in office space needed, because the office is dimensioned on the expected employees' population, not the maximum. In the second scenario, nothing is really changed, except that employees are given the option to work from home.

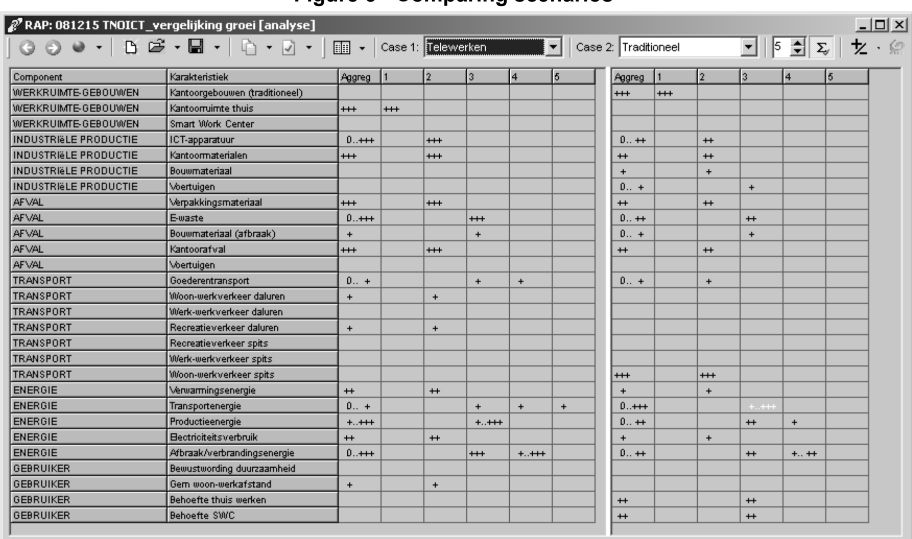
Scenario 1, introduction of teleworking combined with flexible offices

In this scenario teleworking is combined with flexible office space: only those parts of the office that are really needed will be used, therefore causing less heating/cooling/illumination energy demand when less employees are present. On the other hand, at homes more energy is needed in this scenario because people work at home. Increased demand for ICT equipment and office equipment and materials, including more (e-) waste. The effects on transport energy needed are ambiguous. Because of more industrial production (ICT equipment) and more (e-) waste, there will be more goods and waste transport. However, commuting traffic decreases. Only quantitative analysis can indicate whether there will be a net effect or not.

Scenario 2, introduction of teleworking without flexible office space

The effects on office-related types of energy needed (production, heating/cooling, illumination) is larger than in the previous scenario, because the energy needed by offices will be roughly the same. For the other types of energy (transport), there is no difference.

Figure 5 - Comparing scenarios



RAP: 081215 TNOICT_vergelijking groei [analyse]

Case 1: Telewerken | Case 2: Traditioneel | 5

Component	Karakteristiek	Aggreg	1	2	3	4	5	Aggreg	1	2	3	4	5
WERKRUIMTE-GEBOUWEN	Kantoorgebouwen (traditioneel)							+++	+++				
WERKRUIMTE-GEBOUWEN	Kantoorruimte thuis	+++	+++										
WERKRUIMTE-GEBOUWEN	Smart Work Center												
INDUSTRIëLE PRODUCTIE	ICT-apparatuur	0..+++		+++				0.. ++		++			
INDUSTRIëLE PRODUCTIE	Kantoormaterialen	+++		+++				++		++			
INDUSTRIëLE PRODUCTIE	Bouwmateriaal							+		+			
INDUSTRIëLE PRODUCTIE	Voertuigen							0.. +			+		
AFVAL	Verpakkingsmateriaal	+++		+++				++		++			
AFVAL	E-waste	0..+++			+++			0.. ++			++		
AFVAL	Bouwmateriaal (afbraak)	+			+			0.. +			+		
AFVAL	Kantoorafval	+++		+++				++		++			
AFVAL	Voertuigen												
TRANSPORT	Goederentransport	0.. +			+	+		0.. +		+			
TRANSPORT	Woon-werkverkeer daluren	+		+									
TRANSPORT	Werk-werkverkeer daluren												
TRANSPORT	Recreatieverkeer daluren	+		+									
TRANSPORT	Recreatieverkeer spits												
TRANSPORT	Werk-werkverkeer spits												
TRANSPORT	Woon-werkverkeer spits							+++		+++			
ENERGIE	Verwarmingsenergie	++		++				+		+			
ENERGIE	Transportenergie	0.. +			+	+	+	0..+++			+..+++		
ENERGIE	Productieenergie	+..+++			+..+++			0.. ++			++	+	
ENERGIE	Electriciteitsverbruik	++		++				+		+			
ENERGIE	Afbraak/verbrandingsenergie	0..+++			+++	+..+++		0.. ++			++	+.. ++	
GEBRUIKER	Bewustwording duurzaamheid												
GEBRUIKER	Gem woon-werkafstand	+		+									
GEBRUIKER	Behoefte thuis werken							++			++		
GEBRUIKER	Behoefte SWC							++			++		

Comparing the teleworking scenarios with the traditional 'business as usual' scenario yields the conclusion that the energy needed for transportation in the teleworking scenarios is significantly reduced, but that there is also a noticeable rise in other types of energy. However, specifically the bandwidth of outcomes for production energy (caused by higher demands for ICT and office equipment and materials) indicates that quantitative models are needed to give a final answer.

In figure 5 the detailed outcome of the analysis for the two scenarios is presented. The pluses and minuses, including a possible bandwidth in some cases, are shown on both an aggregated level (first column of each scenario), and for the first, second, third, and higher orders. This enables a deeper analysis of the 'strength' of an effect: is it caused by only one straightforward relation, or is it influenced by other indirect relations as well? It may also give an indication of the timing of an effect, although time is not handled in the RAP model.

Conclusions from the analysis

The net effect of all scenarios can be summarized as follows.

Teleworking and Smart Work Centres are initiatives aimed at reducing carbon emissions. Both aim to reduce energy by reducing travel. However, implementation of teleworking leads to various rebound effects. It is shown that the impact of these rebound effects can be reduced somewhat when offices are simultaneously changed into flexible concepts.

We also concluded that introducing Smart Work Centers leads to positive effects (less travel). The net effect is positive only when a new SWC replaces a traditional office. The rebound effects of teleworking (more energy needed for heating, illumination of homes, increased demand for ICT equipment) are also present in the SWC scenarios; however their impacts are not so strong in this case because in SWCs economies of scale play a role.

We have tried to include longer term effects like changed attitudes as well in the models, but this yielded no conclusive result because it is very tempting to model psychological factors influencing attitude and behaviour in the same way. However, a side effect of teleworking and the introduction of SWCs may cause increased awareness with respect to more environmentally responsible behaviour.

■ Conclusions

Study the effects of ICT with a structured approach

Deciding what measures should be taken to create more environmental friendliness in the industry is not easy. The effects of ICT that seem to have good advantages in the short term could be undone in the long run. This is due to so called rebound effects, which may play a role on various levels. Direct effects are the effects of the production and use of ICT; indirect effects are the effects of the use of ICT on the use of energy; and system effects are the effect of behavioural changes or completely different industrial processes and usage patterns by ICT.

As rebound effects tend to complicate discussions, it is advisable to use standard categories of effects and to focus only on direct relationships between effects. Using standard categories helps the analysis by ensuring that no effects are overlooked; modelling direct relations only breaks the model down in smaller components.

Use of simulation models

Working with simulation models like RAP has the advantage that it helps to arrange effects and measures in an orderly manner. As such, it helps structure the objective assessment of measures. In particular, the confusion arising from higher order effects is taken out of the discussion. Additionally, having a structured method to assess effects enables a more objective comparison of different measures and different projects.

A possible disadvantage is that too many different paths are identified, leading to a 'bandwidth' of effects. This can be solved only by assessing the actual quantification of the effects. When data is not available, (costly) research can then be confined to those quantifications that have the largest net effect. By doing so, the simulation model reveals which parts of the problem need most attention.

Another disadvantage of the presented method is that it is easy to keep on adding more effects: the method does not impose guidelines on the choice of the system boundary. And, in the process of adding additional effects, the bandwidth of the possible outcomes tends to increase as well. A way to cope with this is to only add effects that are relevant to the goals, in our case energy consumption. However, there is a clear need to establish some kind of standard on how to define system boundaries for evaluating sustainability measures, so that the outcomes of different studies can be compared more easily.

Green initiatives should be assessed more systematically

Although there are many scientifically sound experiments, pilots, projects and measures that are initiated by governments or companies are usually based on very sketchy assessments of the net sustainability effects. By systematically analyzing possible rebound effects, their relations, and the way these relations interact, better decisions can be made on which pilots, projects or measures are worth up scaling.

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