Lifecycle Energy System Scan (LESS): More about LESS in Long Term Agreements

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ABSTRACT

This paper describes the principal ideas of the computer program LESS (Lifecycle Energy System Scan) which is used within the framework of the second generation of Long Term Agreements (LTA2) on energy efficiency improvement in the Netherlands. The aim of LESS is to calculate the net (fossil) energy savings and thereby the corresponding CO_2-emission reduction related to two new LTA2 themes: application of renewable energy and product chain improvements. From 2001 onwards this calculation tool is necessary, as LTA2 has widened the scope for energy efficiency improvement from process towards product and chain including renewable energy. These new options for fossil energy savings are introduced under the name of "expansion themes".

The LESS calculation procedures for renewable energy are relatively simple. For energy efficient product development the calculation of net energy savings is more complex as a consequence of the introduction of the product lifecycle concept. In spite of the need for more product chain data, the LESS program can still be used in a pragmatic way by the industrial participants of LTA2. Following the calculation by the LTA2 company, the resulting net energy saving needs to be verified on an annual basis. This independent control is carried out by Novem, a government agency commissioned to facilitate LTA2 in general and to monitor its progress.

New Avenues for Energy-Efficiency Improvement

In the Netherlands, Long Term Agreements (LTAs) on improving energy efficiency have been contracted with a large number of sectors from 1992 onwards, as part of energy conservation policy. These LTAs are voluntary and involve a commitment by a sector to make efforts to improve energy efficiency by a set percentage within a pre-arranged term. The industrial approach of first generation LTAs was very successful. It resulted in an energy efficiency improvement of 22.3% on average in the 1989-2000 period.

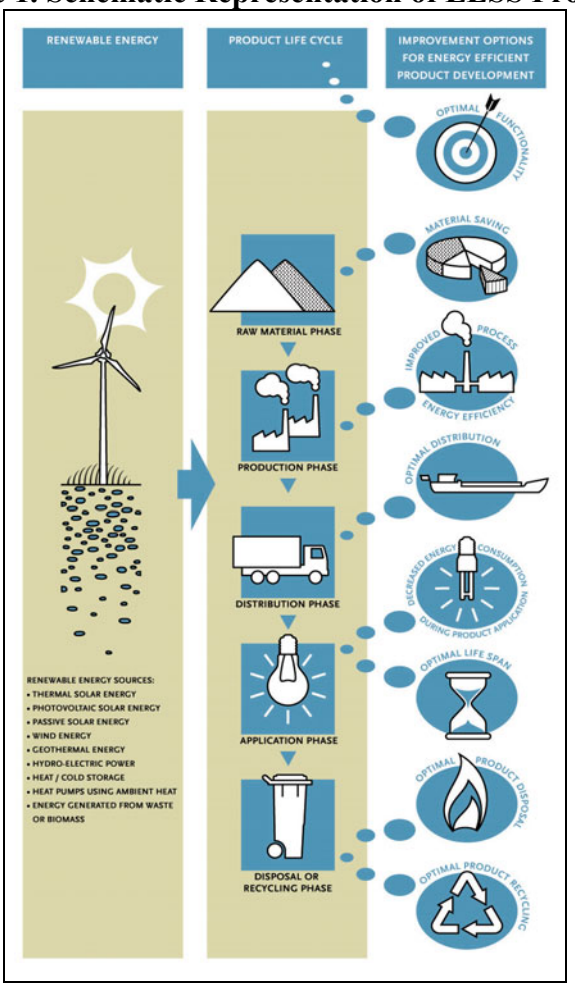
In December 2001 a second generation of Long Term Agreements (LTA2) was signed for the medium energy users in industry for the period 2001-2012. Due to a broader view on energy efficiency two new type of expansion themes are part of LTA2: energy efficient product development (including transportation, application and disposal of product) and renewable energy. Energy efficient product development (EEPD) comprises the improvement of energy efficiency throughout the complete lifecycle of a product, product and services or function (need). Switching from fossil to renewable energy (RE) sources like solar or wind energy is also included in the new measures to reduce CO_2-emission of the LTA2 companies. Novem, a government agency in the field of sustainable development, is commissioned to facilitate the LTAs. More information on Novem, the background and

results of Dutch LTAs can be found in ACEEE paper number 72 (Gerrits & Oudshoff 2003) and LTA2 report on 2001 results (Novem et al. February 2003).

LESS Program for Calculation of Energy Savings of Expansion Themes

The computer program LESS (Lifecycle Energy System Scan) is used within the framework of LTA2 to calculate the net energy savings related to renewable energy and product chain improvements (see figure 1).

Figure 1. Schematic Representation of LESS Program



Source: LESS manual (Avest & Vuyk 2003)

Figure 1 consists of three columns. In the middle the life cycle of a product is schematically represented by five phases: 1. raw material phase; 2. production phase; 3. distribution phase; 4. application phase and 5. disposal or recycling phase.

In the near future the product life cycle can be replaced by a product service or function life cycle if the need or function of an old or reference product can be satisfied by a new service or function. For this reason optimal functionality has been included as an improvement option. For instance, this will allow the comparison of videoconferencing with transatlantic flying to bring over a message. For the sake of simplicity the lifecycle is

depicted in LESS as a vertical column[1]. In each phase renewable energy or product development options can be applied. LTA2 companies normally start from the perspective of phase 2. Transport or waste processing companies using LESS would start respectively at phase 3 and 5 to go upwards or downwards deeper into the chain.

In the columns on the left and right side of figure 1 the two categories of fossil energy saving by means of expansion themes are shown: RE and EEPD. In the LESS program the net (fossil) energy saving resulting from application of both themes is calculated step by step for each phase in conformity with the schematic structure as presented in figure 1.

Principal Ideas and Starting Points for the Development of LESS

The principal ideas for the calculation procedures and formulas of the LESS program are outlined in appendix 4 of the LTA2 covenant (Novem et al. 3MJAF02.07 2001). This appendix consists of 12 articles and is named protocol expansion themes. It defines both the expansion themes and the calculation procedures how to monitor the energy effects of the measures on RE and EEPD.

The content of this protocol was forged together on the basis of input from several LTA2 consultation rounds. At these meetings representatives of all participating LTA2 parties were present. They concluded to the following starting points of the LESS-program:

- The LESS program for expansion themes should use and/or link up as much as possible to existing systems and tools (e.g. LTA1, Life Cycle Management and LCA-databases).
- For the completeness of the chain data, the calculation of the net energy effect has to be based on the entire product lifecycle. At the same time, the LESS program should be pragmatic[2] in such a way that employees of the LTA2 company can carry out the calculations without necessary assistance of specialists or consultants.
- The monitoring process of the energy savings as a result of measures on expansion themes should be transparent, uniform and verifiable.
- Comments on the development of LESS have to be gathered via new and existing platforms of various LTA2 consultative groups[3].

On the basis of these starting points it was relatively easy to make appropriate choices with respect to the fundamentals of the protocol expansion themes and the LESS program. These LTA2 guidelines aim at obtaining LESS calculation fit-for-purpose results according to the 20/80 rule of thumb. With 20% of the effort the LTA2 company should obtain reliable results with 80% accuracy on the net energy effect throughout the product lifecycle. This negotiated LTA2 approach can be illustrated by the following pragmatic LESS solutions:

[1] The product lifecycle might also be presented as a circle, as the recycling phase is connected to the raw material phase.

[2] This also means that the effort to calculate the energy effects should be well proportioned to the net energy saving (e.g. less than 1 day for calculation of 1 TJ/a energy saving in the product chain).

[3] These LTA2 groups consist of representatives from three ministries, local permit authorities, industrial branches, individual companies and Novem, the independent LTA2 facilitator.

- A lot of calculations are avoided by defining the expansion theme measure of the new product relative to the reference situation of the old product in the reference year 1998[4].
- In the first years of LTA2 the net energy saving will be calculated by LESS on a voluntary basis for a limited selection of improved products[5].
- If the energy consumption in a certain phase does not change as a result of the improved product, no calculations have to be carried out for this phase.
- If it is known or can be demonstrated, that a net energy saving takes place in a certain phase of unknown magnitude, it is allowed to neglect this energy saving or carry out calculations with the minimum actual energy saving in that phase[6].

This pragmatic LESS approach aims more at proving overall energy saving in the product chain than providing large amounts of data in order to determine whether the saving is 80 or 100 TJ/a. Refinement on the accuracy of input data and calculation results will be worked out in subsequent years of monitoring the energy saving with respect to the reference situation in 1998[7].

Renewable Energy Options

In striving for the CO_2-emission reduction target set in the Kyoto protocol, the Dutch government has chosen to include renewable energy (RE) as one of the two new options in LTA2. For the medium-energy-intense industrial as well as non-industrial sectors this widens the scope for achieving fossil fuel savings and curtailing climate change. Switching from fossil to RE sources counts as a saving option within LTA2, even if the actual energy efficiency of the processes in the plant is not changed. There are three ways to contribute to the fossil energy saving target of LTA2 through stimulation of application of RE sources: buying, generating and facilitating. A RE scan is available for LTA2 companies to outline the potential implementation routes. Depending on, for instance, the size of the company, buying "clean" electricity may be a more appropriate option than installing a private wind turbine. On sustainable industrial estates, on the other hand, the latter is a very popular option. The definition of what exactly is a sustainable and/or RE source could be a topic of social debate. Therefore, a well-defined list of permitted RE sources is presented in the LTA2 protocol expansion themes. The non-fossil energy sources included in the expansion themes are: a. thermal, photovoltaic and passive solar energy; b. wind energy; c. geothermal energy; d. hydro-electric power; e. heat/cold storage; f. heat pumps using ambient heat; g. energy generated from waste or biomass.

The energy yield of renewable sources can vary each year and may depend on geographical location. In the Netherlands, a photovoltaic solar panel of one square meter will

[4] Only changes in product composition, life span, transport or recycling routes, and others as a consequence of improvement or adaptation of the product compared to the old product have to be taken into account.
[5] LTA2 companies are expected to carry out calculations for rather simple measures with only minor changes in most phases of the product chain and a relatively large energy saving in one phase outside the production phase.
[6] On the other hand, if energy consumption increases in a certain phase, it is not allowed to neglect this energy increase. If insufficient or partly unreliable data are available for that phase, it is allowed to carry out calculations with the maximum negative energy effect of that phase.
[7] At the introduction of this LTA2 approach it is important to encourage the companies to start thinking about and working on the prospects of expansion themes and not to discourage them by tedious calculation details.

generate typically some 100 kWh per year. A typical wind turbine can generate up to 1.5 GWh per year. Each year the LTA2 companies have to provide data on actual fossil energy saving as a consequence of application of RE. Externally bought electricity is also only marked as ("green") RE when it derives from one of the above-mentioned non-fossil sources.

RE can also be used in the product life cycle. Indirect use of RE, outside the boundaries of the production plant, can therefore also be included in LTA2 fossil energy saving. For example, switching to raw materials that were manufactured using renewable energy sources leads to a decrease in fossil fuel consumption. This indirect renewable energy effect will be taken into account by adjusting the Gross Energy Requirement (GER)-value[8] of that specific material. Another option is the development of products that run on RE during application, such as battery chargers that use solar cells as an energy source.

Energy Efficient Product Development Options

Energy efficient product development (EEPD) comprises the creative process of adapting an old product or designing a new product with the aim to reduce energy consumption throughout the product life cycle. This implies a wider scope for achieving energy savings in the product life cycle, via sustainable products, optimisation of transport and logistics in the chain and sustainable industrial estates. These extra options for energy saving and CO_2-emission reduction are included in the expansion themes, i.e. areas expanding from direct process towards indirect product chain energy efficiency effects. EEPD is closely related to Life Cycle Management (LCM) and other product lifecycle tools. In LTA2 this innovation is defined in a pragmatic way. The improved product is designed and manufactured by a company in such a way that energy consumption will be minimised over the entire product life cycle. This product life cycle is divided in five phases (see figure 1). EEPD contributes to an improved indirect energy efficiency in eight different ways:

- **Optimal functionality**: Map out the functional consumer demand (need) that a product provides for and design a new and more energy efficient implementation that satisfies the same function, need, product service or product demand.
- **Material saving**: Lower indirect energy use per unit product by decreasing the consumption of raw materials or switching to less energy-intensive materials.
- **Improved process energy efficiency** (process installations outside boundaries of own plant): Lower direct energy use per unit product by lowering energy use in heating or cooling processes and/or driving of pumps, compressors or other process units.
- **Optimal distribution**: Lower energy use per unit product in transport and storage.
- **Decreased energy consumption during product application**: Lower direct and indirect energy use per unit product, during the actual life span of the product, due to innovative design or implementation changes.

[8] GER-values represent the energy content of a material per kg: all energy used in extraction, production, processing etc.

- **Optimal life span**: Lower direct and indirect energy use per unit product due to optimal choice of product life span. One can choose to design the product so that the actual life span will be close to the technical life span ("fashion-proof" design) or to discontinue the life of an old product prematurely when launching an innovative and less energy-consuming product.
- **Optimal product disposal**: Measures taken to minimise energy consumption, per unit product, for the subcycle of treatment of the discarded product: collection, transport, incineration, gasification or land fill.
- **Optimal product recycling**: Measures that involve recycling and thus allow reusing the energy content of materials in the discarded product with relatively little extra energy use.

The environment of a LTA2 company is important for achieving results on product development. In co-operation with customers, suppliers, transport companies and other companies on industrial estates significant energy gains can be realised during the lifecycle of a product. Collaboration in the product chain, however, calls for new forms of regional and/or (inter)national partnerships and sharing of relevant product information, also to be used in the LESS calculations.

There are many possibilities for energy efficient innovations. However it is emphasised that the effects of taken measures have to be quantified over the entire product lifecycle. For instance, an increase in life span might be achieved by using more raw materials. This will therefore result in a higher energy content of the more durable product as well as an increased energy consumption for transport. There might also be beneficial or negative effects at the stage of product recycling or disposal. All these energy effects have to be included and subsequently compared to the effect of the prolonged life span. This EEPD measure will only contribute to LTA2 energy efficiency target, if the net effect is a lower energy use per unit product per unit time.

Redesigning products for optimal functionality often requires an entirely new way of thinking. One option is to lease products, instead of selling them. This results in a longer life span, as proper maintenance is assured, and also facilitates collection of discards for energy efficient recycling or disposal. Another option is illustrated by the example of "video conferencing". By an entirely different implementation of a concept, energy savings are achieved by cutting back travel. Clearly, optimisation on the level of functionality causes changes all along the product or function lifecycle that have to be assessed carefully.

Two actual examples of industrial companies searching for product development options are:

- **Chicken manure instead of phosphorus ore**: ThermPhos uses ore for the production of phosphorus products. They are trying to find alternative sources of phosphorus. Potentially, phosphate sludge from water treatment plants and manure from livestock industries will be options in the near future. This will result in an entirely different product chain, with entirely different suppliers.
- **Asphalt collector**: The asphalt collector of Ooms Avenhorn is a heating and cooling system that can be installed in asphalt. It ensures lasting quality of the road surfaces and prolongs the life of the asphalt considerably. The system consists of closed water circuits. Water absorbs summer heat and winter cold from the road surface, through a

system of hoses that is installed just below the top layer. The asphalt is thus protected against temperature extremes.

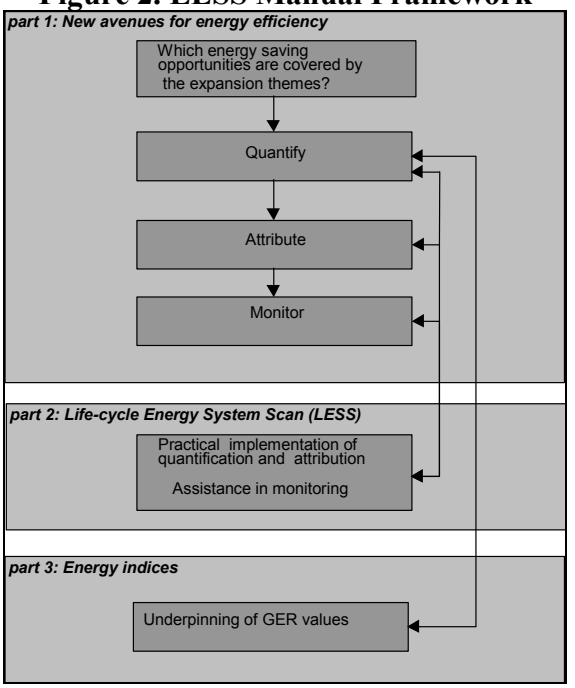
There are long lists of various examples of energy efficient product innovations[9]. However, it is up to the LTA2 companies to find and implement those improved product options that fit within their strategy, provide interesting chances to reduce overall energy consumption and (energy) costs and often bring about other advantages (increased market share, public relation, etc.).

In conclusion, chain-based collaboration and partnerships via EEPD provide new prospects and can lead to direct gains: lower production costs and higher margins. Also it contributes to corporate social responsibility of the LTA2 companies on all three dimensions of people, planet and sustainable profit.

Structure of LESS Manual

The framework of the LESS manual for quantification, attribution and annual monitoring of product chain measures is outlined in figure 2.

Figure 2. LESS Manual Framework



Source: LESS manual (Avest & Vuyk 2003)

The LESS manual (Avest & Vuyk 2003) consists of three parts, covering LTA2 appendix 4 on expansion themes, the software tool itself and the scientific underpinning of the GER-values used in the LESS program. The LESS manual and computer program provide the employees of LTA2 enterprises with a practical elaboration on the calculation procedures of the energy savings resulting from measures in the field of expansion themes.

[9] see e.g. www.ezp.novem.nl/english

The LESS program facilitates the step-by-step assessment of the net energy efficiency improvement. The LESS calculations have to be carried out by the LTA2 companies themselves including the collection of required data on changes in product lifecycle.

Following this calculation step carried out by the LTA2 company, the resulting net energy saving needs to be verified on an annual basis by the Novem "LTA2 Monitoring and Verification Office". This independent control is carried out for reasons of uniformity and transparency. In this monitoring process the quality of provided data is checked. Also this verification step guarantees that all significant energy effects in the product lifecycle have been included in the LESS calculations as agreed upon in LTA2 covenant. The LESS guidelines enable the employees of LTA2 companies to quantify, attribute and monitor the energy savings of the measures in the field of expansion themes, according to a set of accepted criteria. The independent verification process is also based on these guidelines.

The two main questions addressed in LESS manual part 1 "New avenues for energy efficiency" are:

- Which types of energy-saving measures are covered by the expansion themes?
- How should these measures be quantified, attributed and monitored?

Quantifying the energy savings that result from product lifecycle measures is in most cases not very easy. Energy saving measures taken in one stage of the product chain, may in practice bring about increased energy use at another stage. Some effects may occur abroad. Finally, energy use during the application of a product, the consumption phase, depends among other things on the life span and number of users.

In case energy saving measures are implemented in co-operation with neighbouring companies (industrial ecology) or other actors in the product chain, the resulting energy savings are attributed to the involved companies via a pre-defined LTA2 allocation formula.

The total energy saving has to be split up among the involved LTA2 companies. These companies are allowed to divide this saving in any ratio they have agreed upon as long as the sum of allocated energy savings is less or equal to the net energy saving. If the LTA2 companies can not agree on how to allocate the saving, they have to use the following LTA2 allocation formula:

- 50% of saving is allocated proportional to the distribution of project efforts among the involved LTA2 companies;
- 30% of saving is allocated to LTA2 company or companies who invented the new product chain, started the industrial collaboration or designed the new product;
- 20% of saving is allocated proportional to the distribution of direct energy consumption of the involved LTA2 companies.

The second part of the LESS manual provides the numerical methodology for quantifying and attributing energy savings. A quick scan can be used to assess whether a potential energy saving measure is covered by the expansion themes. The aim is to calculate the reduction of fossil energy consumption and corresponding CO_2-emission reduction related to measures in the field of RE and EEPD.

The third part of the LESS manual provides background information on data to be used such as GER-values. The database consists of separate tables for e.g. basic materials,

renewable energy, transport, utilities, waste and recycling. It is coupled to the software program LESS. Crucial is that all GER-values comply with a uniform set of characteristics.

Indices for LTA2 Energy Saving

The total energy saving results as calculated by the LESS program are presented by means of a dimensionless index. This index is named the Total Energy Efficiency Index (TEEI). This TEEI is calculated in a similar way as the improvements of the traditional LTA1 process energy efficiency are expressed as Energy Efficiency Index (EEI). The energy savings (both actual ΔPE in identical way as in LTA1 and the calculated ΔEP and ΔRE by LESS) are related to a reference energy consumption (Eref) in the reference year 1998 according to the formulas:

$$EEI = 100 \times \frac{(Eref - \Delta PE)}{Eref} \qquad EPI = 100 \times \frac{(Eref - \Delta EP)}{Eref} \qquad REI = 100 \times \frac{(Eref - \Delta RE)}{Eref}$$

EEI: Energy Efficiency Index of LTA2 process installations in year "x";
EPI: Energy-efficient Product development Index in year "x";
REI: Renewable Energy Index in year "x";
Eref: Reference energy consumption of plant in year "x";
Eref is defined by the virtual energy consumption of a plant in year "x" that would be needed if the product volume in year "x" would have been produced with the specific energy consumption of the reference year 1998.
ΔPE: Process Energy saving within the boundaries of LTA2 company in year "x" relative to 1998;
ΔEP: Energy-efficient Product development saving in year "x" relative to 1998;
ΔRE: The saving of fossil energy as a result of the amount of Renewable Energy that has been produced or purchased by LTA2 company in year "x" relative to 1998.

Switching from fossil to renewable energy is thus expressed in LESS as REI. REI is 100 by definition if no renewable energy is involved and this index will equal 50 if half of the (virtual reference) energy consumed in the various processes in the plant originates from renewable sources. The energy savings in the product lifecycle as a result of EEPD are also relatively expressed as EPI. For LTA2 the Total Energy Efficiency Index (TEEI) score is defined as follows:

$$TEEI = EEI + EPI + REI - 200$$

Via this formula three completely different approaches for reduction of CO_2-emission are combined in one overall index on total energy efficiency improvement. This calculated TEEI score has to be provided each year by the companies to the Novem "LTA2 Monitoring and Verification Office". Via the TEEI score the annual progress can be reported on the total energy efficiency improvement of each individual LTA2 company, each industrial LTA2 sector or all LTA2 companies. Furthermore, this TEEI index can be used for target setting in the near future. All four indices are percentages of Eref, which relates to the total process energy consumption of the plant. Positive values of ΔPE, ΔEP and ΔRE indicate net (fossil) energy savings. The energy savings ΔEP and ΔRE as a result of expansion theme measures

have to be calculated on the basis of a strict set of rules as defined in the LTA2 covenant. The LESS program is developed to facilitate and standardise these calculation procedures. It is noted that in some cases the values of ΔEP and/or ΔRE might be greater than Eref. This means that more energy has been saved in the entire product lifecycle since 1998 or more RE has been produced (and exported!) since 1998 than the amount of energy used in the processes of the plant. A resulting negative value of TEEI of e.g. –50 equals a 150% improvement of total energy efficiency. However, up to now this type of giant steps in efficiency improvement has not been experienced for any LTA2 company. The LTA2 approach would already be quite successful if the TEEI-scores starting from 100 in year 1998 would reach 65-75 within 12 years (2-3% annual energy efficiency improvement).

Illustration of LESS by Examples of an Improved TV-Set

The LESS methodology is illustrated below by several potential improvements to the production of a TV-set. A modern wide-screen television is taken as a reference, the newest model of company X. This TV-set weighs 40 kg and consists of several materials that are listed in table 1 with their GER-values. The resulting energy content per TV-set of each material, as well as the total energy content of the TV-set, are given in the last column.

Table 1. Composition and Energy Content of the Reference Wide-Screen TV-Set

Material	Mass (kg)	GER value (MJ/kg)	Energy content (MJ)
Glass	20	11	220
Synthetics	10	80	800
Aluminium	2	150	300
Copper	2	100	200
Electronics	6	500	3000
Total	**40**		**4520**

Within the context of the LTA2 expansion themes several energy saving options can be identified in the production process and the lifecycle of this TV-set. Five examples are listed in table 2 and the corresponding energy savings are quantified in the text below.

Table 2. Options for Energy Saving in the Lifecycle of the TV-Set

Lifecycle phase	EEPD implementation option	Example
Raw material phase	Use less energy-intensive raw material(s)	1. Replace synthetic by wooden casing
	Decrease amount of raw material(s)	2. Develop thinner television tube
Distribution phase	Optimal distribution	3. Transport partly by train instead of lorry
Application phase	Decreased energy use during application	4. Automatic switch-off in standby mode
	Optimal life span	5. Increase quality and thus durability

- **Example 1 -** Company X wants to assess the energy saving potential of using wooden casings. Wood has a much lower GER-value (30 MJ/kg) than synthetic materials (80 MJ/kg). Replacing the casing may have consequences at other stages in the life cycle, such as disposal or recycling. We assume that both wood and the synthetic material are incinerated completely and that heat recovery is the same

(10kg x 80MJ/kg) –
(10kg x 30MJ/kg)
= 500 MJ

for both casings or can be neglected. Using the EEPD-rule for "material saving", we calculate an energy saving of 500 MJ per TV-set of 40 kg.

- **Example 2** - The R&D-department of Company X developed a thinner tube, involving 5 kg less glass during production and hence a reduction of the total weight of the TV-set. This results in energy saving in three ways: reduced raw material use, decreased energy for transport and glass recycling or disposal. This last aspect will yield a small net energy saving (and can therefore be neglected) knowing that glass is almost fully recycled in the Netherlands. The other two effects have to be calculated with the corresponding EEPD-rules. Due to material saving, an energy saving of 55 MJ is realised. Due to decreased total weight, one-eighth of the energy for transport is saved. For a distance of 100 km and a transport index value of 1.7 MJ/tonkm and reference weight of 40 kg, the energy saving will be 0.85 MJ per TV-set. Compared to the total energy content of the reference TV-set (4.52 GJ), this transport saving is very small. In total, this example 2 yields a saving of 56 MJ per TV-set.

  20kg x 11MJ/kg - 15kg x 11MJ/kg = 55 MJ

  0.04ton x 100km x 1.7MJ/tonkm – 0.035ton x 100km x 1.7MJ/tonkm = 0.85 MJ

- **Example 3** - For half of the distance of 100 km the TV-set is transported by train (0.6 MJ/tonkm) instead of lorry (1.7 MJ/tonkm). This may bring about energy saving relative to the reference situation, in which transport is carried out only by lorry with semitrailer. Assuming partly transport by rail in the new situation, the resulting energy saving per TV-set equals 2.2 MJ.

  0.04ton x 100km x 1.7MJ/tonkm – (0.04ton x 50km x 1.7MJ/tonkm + 0.04ton x 50km x 0.6MJ/tonkm) = 2.2 MJ

- **Example 4** - In standby mode, television sets still use energy: assume 10 W. The management of company X wants to assess the energy saving potential of an added functionality that causes the TV-set to be switched off completely after one hour in standby mode. Assuming that on average, a TV-set is in standby mode for 8 hours per day or 2920 hours per year, the annual energy consumption is 29.2 kWh in standby mode. This is equivalent to 263 MJ of primary fossil fuel (1 kWh = 9 MJ at 40% electricity conversion efficiency). In the new situation, the TV-set would be in standby mode only for 1 hour per day. The resulting annual energy saving equals 7/8 x 263 = 230 MJ per TV-set. In the entire lifecycle of ten years this leads to a saving of 10 yr x 230 MJ/yr = 2.3 GJ per TV-set.
- **Example 5 -** Company X wants to assess the energy effects related to increasing the life span of their reference TV-set from 10 to 15 years. Energy savings would take place at several stages in the lifecycle. However, for increasing durability the amount of copper in the TV-set has to be increased by 0.2 kg (+10%). Therefore, the net saving of this option has to be calculated using at least two EEPD-rules: material saving and optimal life span. The effects of optimal product recycling and transport are very small (as shown in examples 2 and 3) and are for the sake of simplicity neglected in this example[10]. The GER-value of copper is 100 MJ/kg, so the additional amount of copper increases energy content by 20 MJ per TV-set. The total energy content is now 4540 MJ, plus 2000 MJ for energy consumption during production, which should be spread

[10] According to the protocol expansion themes this simplification is only allowed if the change in energy consumption in a phase is less than 10 % of the total net energy effect throughout the product lifecycle.

out over 15 years for the new TV-set. For the reference TV-set this was 6520 MJ over 10 years. On annual basis a saving of 216 MJ will be realised per TV-set. In the lifecycle of 15 years this leads to a total saving of 15 yr x 216 MJ/yr = 3.24 GJ per TV-set. In this example it is assumed that the annual energy consumption during application is the same for both the reference and new TV-set.

6520MJ / 10yr – 6540MJ / 15yr = 216 MJ/yr

Based on the summary of energy savings in table 3, this fictitious LTA2 company X might conclude to start working out the options 4 and 5, as these improvements would lead to highest net energy savings in the entire lifecycle.

Table 3. Summary of Energy Savings in the Lifecycle of the TV-Set (Examples 1-5)

EEPD implementation option	Energy saving relative to reference per TV-set (MJ)
1. Replace synthetic by wooden casing	500
2. Develop thinner television tube	56
3. Transport partly by train instead of lorry	2.2
4. Automatic switch-off in standby mode	2,300
5. Increase quality and thus durability	3,240

The reference energy consumption of company X in 2002 (Eref) is 500 TJ for manufacturing all their electronic products. In 2002 company X has produced for the first time 10.000 improved TV-sets with automatic switch-off in standby mode. The following LESS calculations can be carried out:

- The saving in year 2002 relative to 1998 (ΔEP) equals then 10.000 x 2300 MJ = 23 TJ.
- This energy saving can be allocated for 100% to company X (only LTA2 company in this product lifecycle, also originator of idea and 100% owner of project).
- The energy efficient product development index (EPI) is therefore 100 x (500-23) / 500 = 95,4 for year 2002.
- Assuming no process energy saving (EEI = 100) and no application of renewable energy sources (REI = 100) this leads to a total energy efficiency improvement of 4,6% in 2002 relative to 1998 (TEEI = 100 + 95,4 + 100 – 200 = 95,4).

Need for International Co-Operation on Life Cycle Management like LESS

LTA2 aims to improve the energy efficiency and thereby to reduce the CO_2-emission of the participating companies in the Netherlands. As Dutch products are exported to a large extent and therefor some raw materials even have to be imported, it is clear that a significant part of the energy saving effects of product innovations takes place outside the Netherlands. In LTA2 it is therefore agreed upon that the net energy saving of measures on EEPD have to be calculated for the complete lifecycle of an improved product regardless whether the savings are realised in the Netherlands or abroad. As the Dutch government still likes to know the impact of expansion themes on energy savings and CO_2-emissions realised in the Netherlands, the companies have to quantify the energy saving abroad separately.

As it is in general more difficult to obtain reliable data on products and material flows from abroad, the Dutch LTA2 participants from both government and companies are eager to

broaden their scope for information exchange. Participation in international networks such as ACEEE is therefore highly desirable to address issues on LCM like LESS. Co-operation in the product chain requires new forms of international partnerships and sharing of relevant product information. The following lessons using LESS have been learned from Dutch LTA2 experience up to now which might be of potential interest to other countries that have ambitions in this field:

- The LTA2 expansion themes are of major importance for the realisation of ambitious goals on fossil energy saving and reduction of CO_2-emission in the Netherlands.
- Within the context of LTA2 the participating companies have widened their scope on energy efficiency from the orientation on only process towards product and chain including application of renewable energy.
- The LESS manual and computer program appear to be crucial tools for assisting the companies on their calculations of the energy saving related to EEPD and RE.
- As to be expected at this early stage of development, a number of issues still needs to be resolved before LESS can be successfully applied for more complex product innovations.
- LTA2 companies are increasingly aware of the interesting opportunities for energy savings by expansion themes and are willing to work out measures in this field. However they often encounter difficulties in collecting crucial data outside their company to assess the energy saving of measures in the field of EEPD.
- For simple product innovations the net energy savings can be quantified, attributed to and monitored on the basis of the present version of LESS. For further improvement and refinement of the LESS program and databases the LTA2 participants appreciate to receive comments from various sources inside and outside the Netherlands.

In conclusion, there is an urgent need for more international co-operation because information exchange on energy saving measures is required in the combined field of RE and EEPD. Furthermore, there is a need to share product chain information including comments on LCM and associated data. Based on the benchmarking information each country can determine its present position and ambition for the future. By setting up appropriate networks this knowledge dissemination can effectively take place while accelerating the rate of CO_2-emission reduction world-wide.

Conclusions and Recommendations

The following conclusions can be drawn on the basis of the application of the LESS program in the second generation of long term agreements in the Netherlands.

- The LESS program is an important tool for the calculation of the (fossil) energy savings and reduction of CO_2-emission as a result of measures in the field of expansion themes covering both renewable energy and energy efficient product development.
- The LESS program is the first application of a Life Cycle Management tool that has been developed under the umbrella of and agreed upon by participants of a voluntary agreement between public authorities and industrial parties.

- The LESS program follows the pragmatic 20/80 rule of thumb. With 20% of the effort the LTA2 company should obtain reliable results with 80% accuracy on the net energy effect throughout the product lifecycle.
- The LESS program is designed and developed to encourage employees of LTA2 companies to start thinking about and working out saving options for product innovation and not to discourage them by tedious calculation details.
- The guidelines in the LESS manual enable the LTA2 companies to quantify, attribute and monitor the energy savings of expansion themes, according to a set of accepted criteria.
- Via the formula of the Total Energy Efficiency Index (TEEI) three completely different approaches for reduction of CO_2-emission can be combined in one overall index on energy efficiency improvement. This TEEI score has to be calculated each year by the LTA2 companies and subsequently verified by Novem.
- Via the TEEI score the annual progress can be reported on the total energy efficiency improvement of both individual LTA2 companies and industrial LTA2 sectors.
- The concept of the TEEI index might also be used for LTA2 target setting on expansion themes in the near future.

There is an urgent need for more international co-operation and information exchange on sustainable development topics like voluntary agreements, energy efficiency improvement and Life Cycle Management. The following recommendation is based on lessons learned using the LESS program in the context of LTA2.

- More active participation in international networks such as ACEEE is highly desirable to address issues on Life Cycle Management like LESS and to exchange information on product data and material flows. This will strengthen the fundamentals of the LESS program and alleviate the difficulties of the LTA2 companies to gather reliable product information from sources outside the Netherlands. Furthermore, this knowledge dissemination will accelerate the rate of CO_2-emission reduction world-wide.

References

Gerrits, R., and B. Oudshoff. 2003. "Energy efficiency through Long Term Agreements; broadening the horizon in the new LTA approach" In *Proceedings of the ACEEE 2003 Summer Study on Energy Efficiency in Industry.* New York, July 29 – August 1, 2003.

Novem et al. February 2003. "Long-Term Agreements on energy efficiency in the Netherlands; Results 2001". (www.lta.novem.org).

Novem et al. 2001. "Meerjarenafspraak Energie-efficiency 2001-2012. Den Haag, December 6th, 2001". LTA2 covenant text nr. 3MJAF02.07 (www.lta.novem.org).

Avest, G.H. ter, and E. Vuyk, 2003. LESS manual "Handreiking verbredingsthema's" (in progress, see www.verbredingsthemas.novem.nl).