# RENEWABLE ENERGY AND THE ROAD TOWARDS "GREEN" PORTABLE AUDIO PRODUCTS


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## 1 Introduction

At the department of Engineering Design of the Faculty of Industrial Design Engineering, research within the TPA group concentrates on the technical analysis of products, particularly addressing the environmental aspects of product design. Recently, a co-operation has been started with Philips Sound & Vision. Within the framework of this co-operation, one of the topics researched is the environmental benchmarking of audio products using renewable energy. In this study the objectives are: to test the recently developed technical product analysis (TPA) method, to improve insight into the environmental load of audio products with renewable energy sources and to improve existing environmental data on batteries and printed circuit boards (pcb's) to make possible a reliable and valid comparison. In this paper the results are reported for an environmental comparison between 2 radios using renewable energy and 2 radios using batteries.

## 2 Description of the analysed radios

The **BayGen Freeplay** is produced in South Africa. The radio is designed to be used in remote areas where batteries are hard to get or very expensive. The BayGen received world wide attention because of its alternative energy system, invented by Trevor Baylis. Although the radio was not primarily designed as such, it is seen as a "green" alternative by West-European consumers and specific environmental organisations [Benjamin 96], [Belgiovane 95]. In the analysis we focused on the "green" perception of this radio.
The **Dynamo & Solar** radio is produced in China. It can be powered in various ways; batteries, solar panels, net-current or by a hand powered dynamo.
Both the **Grundig Boy 55** and the **Philips AE 1595** are produced in China and are powered by batteries only (2 Penlights, AA/R6).


Figure 1 The analysed radios

# 3 Methods

## EcoIndicator 95

The radios were “environmentally benchmarked” by determining the EcoIndicator 95 value [Goedkoop 95], using EcoIndicator 95 classification factors [Goedkoop 95]. The SIMAPRO software version 3.1 [Pré consultants 95] was used for calculating the Life Cycle Analyses (LCA).

## The Technical Product Analysis (TPA) method

The TPA method is set-up at the Faculty of Industrial Design Engineering in order to obtain a combination of LCA and various other product analysis tools. It focuses on a practical approach in gathering and analysing data of products with a similar or comparable functionality. The TPA method consists of 6 steps:

1. definition of starting points and goals, product acquirement
2. functional description and analysis (product system boundaries, basic input-output diagram, description and analysis of functionality, Life Cycle Inventory)
3. energy analysis (used energy sources, efficiency)
4. mechanical description and analysis (product structure chart, Design for Assembly-analysis, determination of used materials, cost analysis)
5. environmental description and analysis (LCA and analysis of different End-of-Life (EOL) scenarios)
6. analysis assessment (sensitivity analysis of results, assessment of methods and benchmarks used)

In this paper we focus on the results of the steps number 2, 3 and 5.

# 4 Results of the TPA analysis

## 4.1 Description of the energy systems

The **BayGen Freeplay** is charged manually by winding a constant-torque spring. The spring can be wound up to a maximum of 60 revolutions, average charging/winding time is 40 seconds. The required input torque is 1.66 Nm, total required input labour is 628 Joule. The output drum of the spring delivers a constant torque to a gearwheel transmission, which is coupled by a small driving belt to a dynamo (Mabuchi RF 500TB). Total gearing ratio *i* is 1:904 (dynamo speed is approx. 1800 rev/min). A fully wound-up spring allows the radio to play for 30 minutes. By dividing the output at the dynamo of 162 Joule (90 mW x 1800 sec) with the input of 628 Joule, an efficiency of 26% for the total energy system is found.

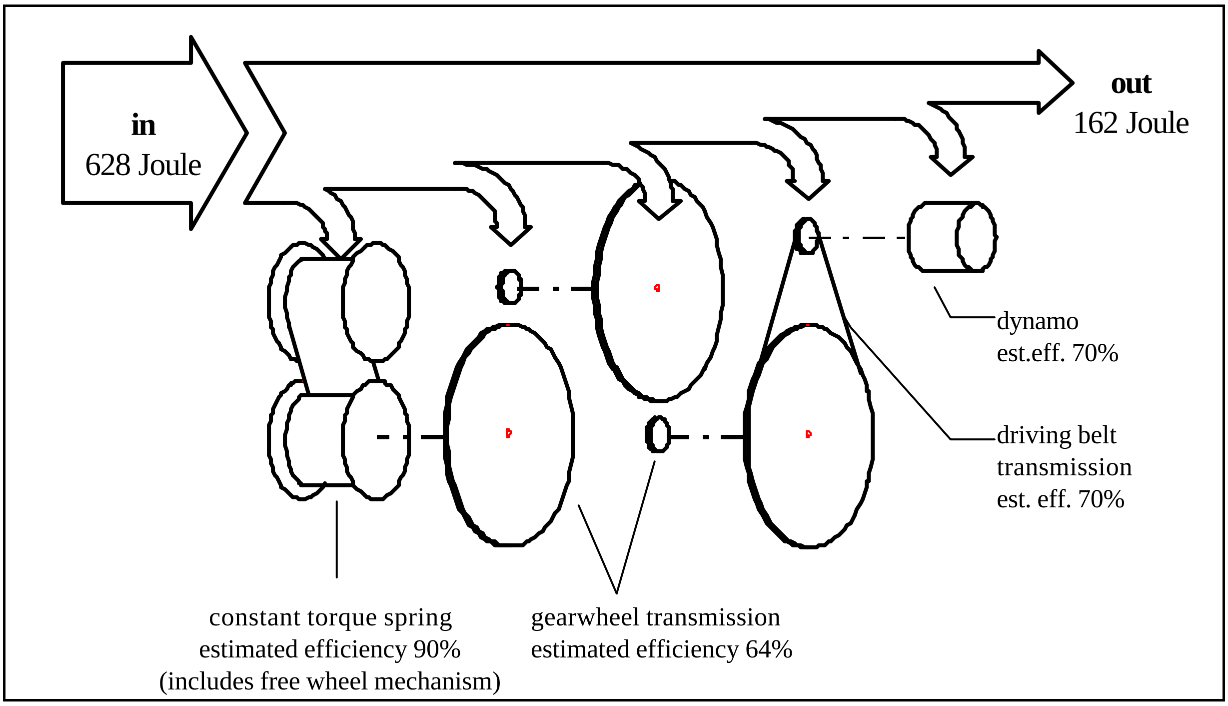


Figure 2 BayGen Freeplay energy system

The **Dynamo & Solar radio** (D&S) has a versatile energy system, it can be powered by batteries (2 penlights) or by a build in NiCd battery (2 Varta V280R cells, capacity 280 mAh). The build-in NiCd battery can be charged by a solar panel (amorphous Si, 25 cm$^2$), by net-current or by a hand-powered dynamo. When winding the handle at maximum speed, the NiCd batteries are charged with 100 mA. Winding the handle at a sustainable speed, it takes about 11 hours (at 25 mA) to charge the build-in battery. The solar panel is able to charge the batteries with 0-5 mA (cloudy day) to a maximum of 48 mA (bright sunshine).

| | power consumption at 70 dB(A) [mW] | weight of the energy system [gram] | stored amount of electrical energy [Joule] | energy/weight factor [Joule/gram] |
|---|---|---|---|---|
| BayGen Freeplay | 90 | 1670 | 162 | **0,09** |
| Dynamo & Solar | 32 | 68,8 | 2670 | **38** |
| Grundig | 58 | 37,0 (= 2 ZnCl batteries size AA) | 10500 | **284** |
| Philips | 33 | | | |

Table 1 Power consumption, weight and stored energy

## 4.2 LCA results

The LCA is fully based on use of the radios in the Netherlands. The radios are transported by containership to Rotterdam harbour (at 0,44 mPt/tonkm). Transport of radios in country of origin and in-land transport from Rotterdam is not included. End-Of-Life (EOL) data are based on the scenario that the radios will be treated as household waste. These EOL data however do **not** include the electronics in the radios.

Data for the environmental assessment of electronics is limited available. The data in this paper for pcb's including components, are based on data of the Philips CFT EcoDesign group, a value of 1350 $mPt/m^2$ is used.

In figure 3, the results of the SIMAPRO analysis on production are presented. The high BayGen score is due to its large and heavy energy system (3,7 mPt due to steel spring) and resulting large and heavy housing, compared to the other radios (also see fig. 1). The difference between D&S, Grundig and Philips are mainly due to a larger pcb and the energy system of the Dynamo & Solar radio (2 mPt estimated for the production of the solar panel, 1 mPt estimated for the production of the NiCd battery).

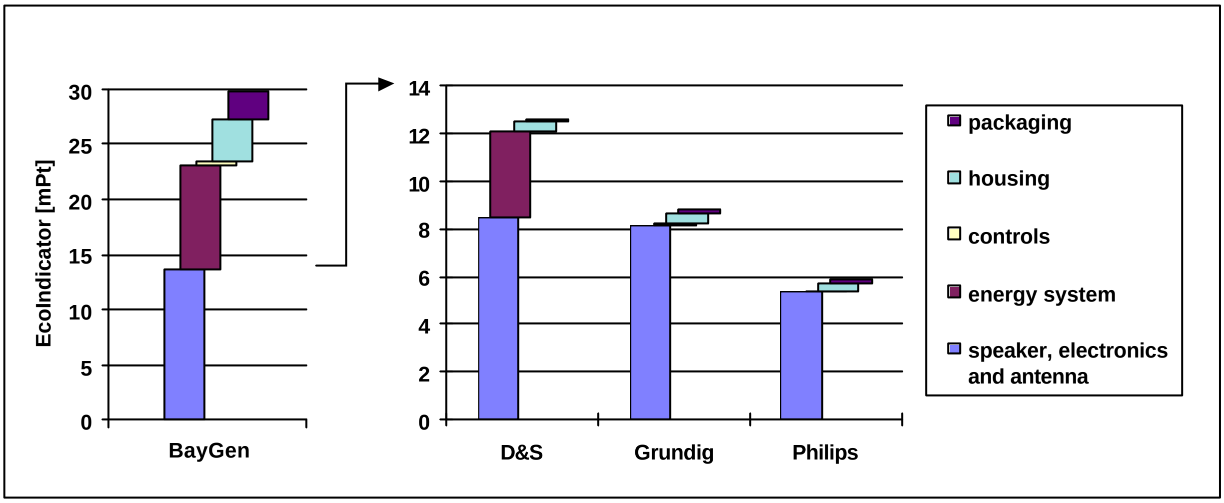


Figure 3 Ecoindicator 95 values for production (mind different scales!)

The environmental impact of the use of the radios is compared by defining the following "functional unit": ***1 hour radio at 70 dB(A) a day during a five year period***. (5 x 365 = 1825 hours). This five year period is based upon estimated life time for the radios.

The battery consumption of the radios was measured by playing the radios until the batteries were exhausted. In the case of the Dynamo & Solar radio, the alternative energy system has not been used. Power consumption (see Table 1) was measured in order to compare the measured and calculated life time of the batteries. Only small differences (<10%) were found between the life time test and the calculated values. The amount of batteries used in the five year life cycle is an extrapolation of the average of tested and calculated battery lifetime; the Grundig radio uses 62 batteries in 5 year, both Philips and D&S use 32 batteries in 5 year.

Studies show that the environmental impact of batteries mainly depends on EOL scenarios. In this report, the Ecoindicator 95 value for the production of batteries (0,44 mPt/battery, ZnCl, AAtype) is generated by the Philips CFT EcoDesign group. Full-recycling has been chosen as EOL scenario, assuming 1,6 mPt as EcoIndicator value for EOL (source: Philips CFT).

The EcoIndicator values for the total life cycle of the four radios have been calculated using SIMAPRO. Transport value for BayGen is high due to its size and weight. EOL values for Grundig and Philips are to low to be visible in the graph. EOL value for D&S is assumed 1 mPt for solar panel and 2 mPt for NiCd battery.

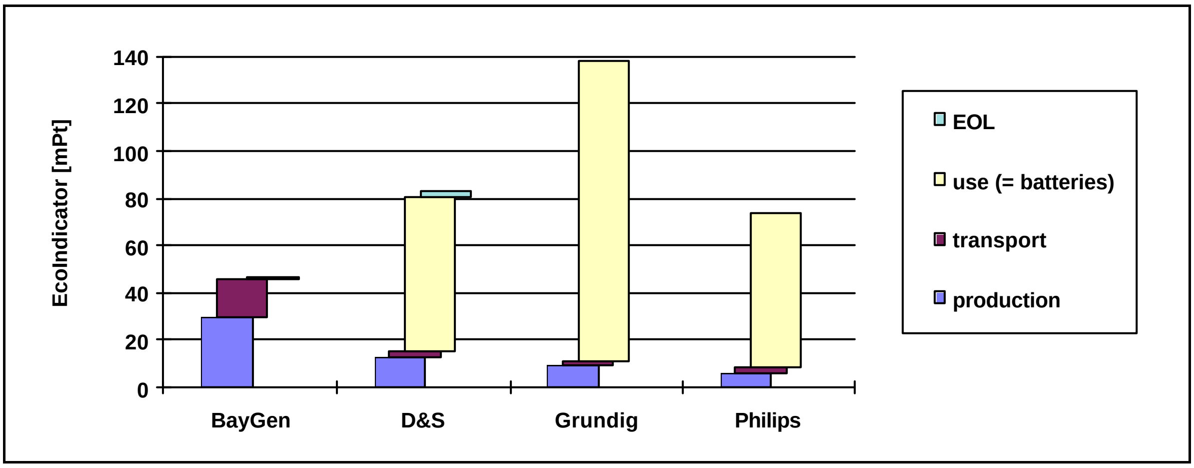


Figure 4 Ecoindicator 95 value for total life cycle of radios

Starting off with the sum of the EcoIndicator values for production, transport and EOL and adding the EcoIndicator values for the use of batteries, gives a graph as shown in figure 5. Break-even points (environmental load BayGen equals radio x) can mathematically be determined. See table 2.

| | amount of batteries used in 5 year lifetime | Break-even with BayGen [year] |
|---|---|---|
| Grundig | 62 | 1,4 |
| Dynamo & Solar | 32 | 2,2 |
| Philips | 32 | 2,9 |

Table 2 Amount of batteries used and break-even point with BayGen

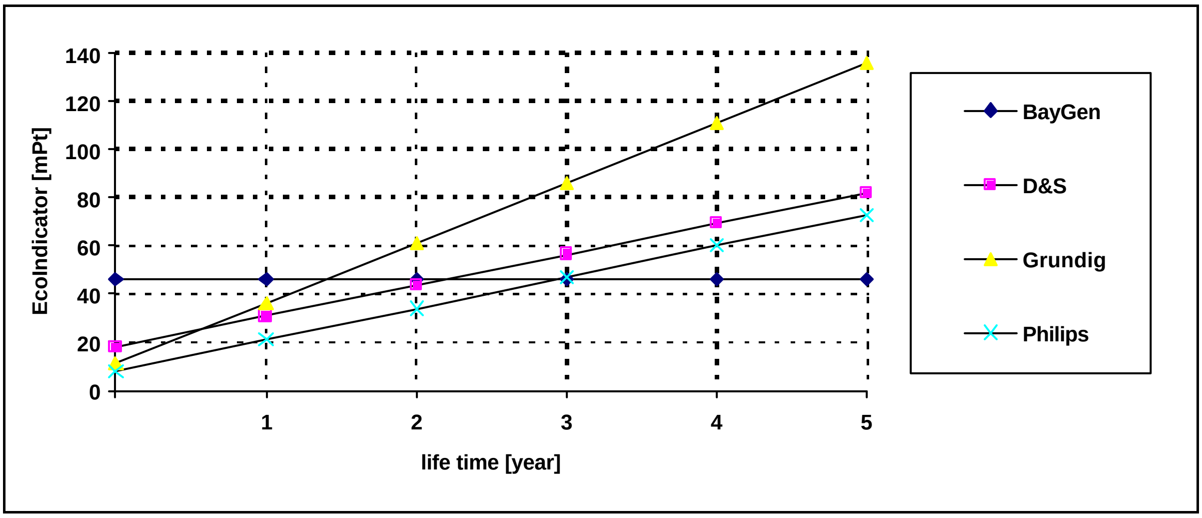


Figure 5 Ecoindicator 95 value during life time (starting point is sum of production, transport and EOL values)

# 5 Conclusions

The TPA method is a useful tool in analysing products and giving a clear overview. This overview can be used in tracing “green” options and to set priorities in product improvement. The technical product analysis shows there is considerable room for the improvement of the design of radios with alternative energy sources;

- The NiCd battery inside the Dynamo & Solar radio can not be taken (unless soldered) out before discarding the radio. This means that the battery will end up at a landfill or will be incinerated. Recently, products containing non-removable batteries have been prohibited in the Netherlands [Dutch Government 95].
- Improvement potential for the BayGen Freeplay consists of reduction of the size and weight of the housing, upgrade of the electronics and better packaging (no PS foam). In this way reducing the EcoIndicator value for production with approx. 8 to 10 mPt. Reduction of the weight of the radio will also affect the EcoIndicator value for transport.
- In case the environmental load of products is dominated by the use of batteries, reduction of the power consumption has to be the first green option (also see table 1 and 2).

Perception (of consumers) of products with alternative energy systems, only reflecting on the absence of batteries, should not lead to the conclusion that “no batteries” equals a “green” product. (Human powered) renewable energy may be an alternative for batteries in some product but the environmental trade-off has to be watched carefully.

The conclusions of this benchmarking study mainly depend on the chosen EOL scenario for batteries (in this case full-recycling). Further studies should chart the effects of different EOL scenarios.

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