FN-NANO s.r.o.
273 01 Kamenné Žehrovice 23
IČ:05079233 DIČ: CZ05079233

Company translation

Note: FN-NANO s.r.o. has re-branded the registered FN® brand for commercial reasons in 2021. Currently, two registered brands are used, the international FN NANO® and the Czech FN®. The product here mentioned as FN2 is the same product as FN NANO® 2, which is being sold nowdays.

CZECH TECHNICAL UNIVERSITY IN Prague

Faculty of Mechanical Engineering

Department of Business Management and Economics

COMPARATIVE LCA STUDY OF FN2 AND AIR PURIFIERS

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The comparative life cycle study of the photocatalytic coating FN 2 and the air purifier was prepared within the framework of the research cooperation agreement concluded between Advanced Materials-JTJ s.r.o. and the Czech Technical University in Prague, Faculty of Mechanical Engineering, Department of Business Management and Economics in April 2014.

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I - METHODOLOGY OF THE STUDY

LCA - Life Cycle Assessment is a comprehensive method that enables the assessment of environmental aspects of the product life cycle in a holistic view of the entire production, user and waste system. Its most common applications can be summarized in two basic points:

- a recommendation of a product or process compared with another alternative
- a proposal to improve an existing product or process in relation to the overall environmental performance over the lifetime of the product or process

It follows that LCA is primarily a comparative method, whereby comparing two or more options the evaluator decides which to use in terms of his own and societal interest. Similarly, by comparing one or more variants of one type of product or activity, the evaluator can propose a new, more efficient product design, more perfect in terms of environmental performance. The potential of the LCA method can also be used to find the optimal way to manage waste. However, in no case does this method replace the decision-making process.

Structure of the methodology

The LCA methodology includes 4 phases

1. **Determining the objectives and scope of** the study is the first step of the LCA. This step consists of defining the purpose of the study, its scope, and the expected use of the results; determining the functional unit; and determining the quality assurance procedure for the study.

2. **Life Cycle Inventory Analysis**, which is the process of collecting and processing data designed to quantify the consumption of energy and materials, production of pollutants, solid waste and other outputs over the life cycle of products or processes.

3. **Environmental impact assessment** is a phase of LCA that is based on inventory data and provides both a quantitative and qualitative assessment of the effects of products or activities on human and ecosystem health.

4. **Life Cycle Interpretation**, the last phase of LCA, which builds on the results of the two previous phases. It is based on the needs and given opportunities to innovate a product or activity. The aim is to propose such changes in each phase of the life cycle

Increased awareness of the importance of environmental protection and the potential impacts associated with the products produced and consumed have increased interest in the Life Cycle Assessment (LCA) method. This method has become part of the international standards ISO 14000, which the Czech Republic has adopted as standards:

ČSN EN ISO 14040 Environmental management - Life cycle assessment - Principles and the base

EN ISO 14044 Environmental management - Life cycle assessment - Requirements and guidelines

The life cycle assessment according to these standards shall include the definition of the objective and scope, the inventory analysis and the interpretation of the results as described in Figure 1.

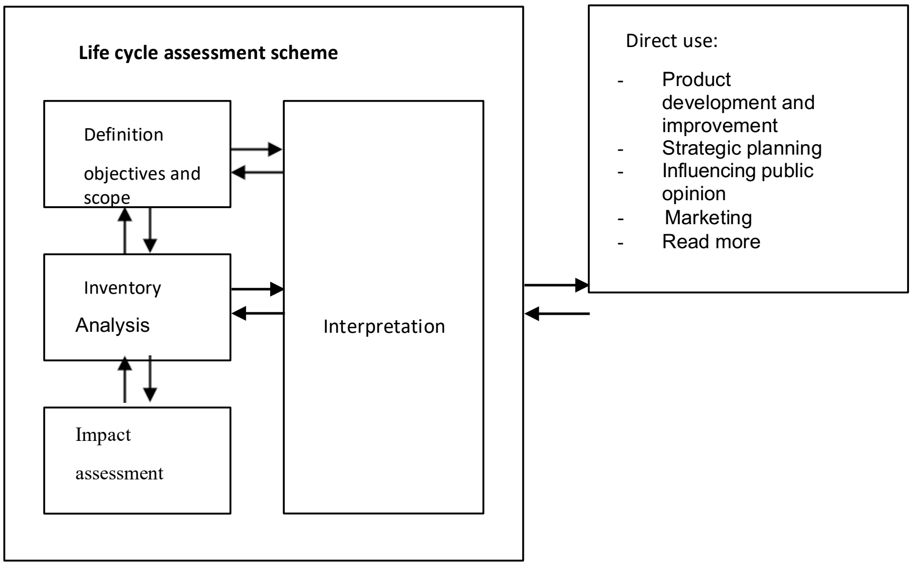


FIGURE 1 LIFE CYCLE ASSESSMENT SCHEME ACCORDING TO ISO 14040 [1]

According to ISO 14040, LCA studies must include:

- a description of the function of the product system or product systems in the case of comparative studies;
- determination of the functional unit;
- a description of the product system under assessment;
- determination of the boundaries of the product system;
- allocation procedures, if used;
- types of impact, impact assessment methodology and subsequent interpretation for use;
- data requirements;
- Prerequisites;
- limitations;
- initial data quality requirements;
- type of critical review, if;
- the type and format of the report required for the study;

The scope should be sufficiently well defined to ensure that the breadth, depth and detail of the study are consistent with each other and sufficiently relevant to the stated objective.

Functions and functional unit

The scope of the LCA study must clearly define the functions of the system under consideration. A functional unit is a measure of the performance of a functional output from a product system. The primary purpose of a functional unit is to provide a basis to which inputs and outputs relate. This basis is necessary to ensure the comparability of LCA results. Comparability of LCA results is particularly important when different systems are being evaluated to ensure that such comparisons are made on a common basis.

A system can have a number of possible functions and the one chosen for the study depends on the objectives and scope of the study. The corresponding functional unit must be defined and measurable.

System boundaries

The system boundaries determine which unit processes must be included in the LCA.

The determination of the boundaries of the system, including the intended use of the study, is determined by several factors, which are the stated assumptions, the limiting criteria, the availability of data, the cost and the intended audience.

The choice of inputs and outputs, the level of aggregation within data categories, and the modelling of the system must be appropriate to the objectives of the study. The system should be modelled in such a way that the inputs and outputs at its boundaries are elementary flows. The criteria used to define the boundaries of the system must be identified and assessed within the scope of the study.

Data quality requirements

Data quality requirements generally specify the characteristics of the data needed for the study. In order to meet the objectives and scope of the study, data quality requirements must be defined. The data quality requirements should cover:

- of the time range;
- geographical scope;
- of technological scope;
- accuracy, completeness and representativeness of the data;
- the adequacy and reproducibility of the methods used during the LCA;
- data sources and their representativeness;
- -uncertainty of information.

Inventory analysis

Inventory analysis involves data collection and computational procedures to quantify the corresponding inputs and outputs of a product system. These inputs and outputs are to include resource use and releases to air, water and land associated with the system. Interpretations may be based on these data depending on the objectives and scope of the LCA. These data are also inputs to the life cycle impact assessment.

The process of performing the inventory analysis is iterative. As data collection is completed and the system is better understood, new data requirements or constraints may arise that require changes in data collection procedures to still meet the study objectives. Sometimes outcomes may be identified that require revision of the objectives and/or scope of the study.

Impact assessment

The LCA phase of the impact assessment translates the results of the inventory analysis through category indicators and characterization facts into the results of the impact category indicators.

Life Cycle Interpretation

Interpretation is a phase of the LCA in which the findings of the inventory analysis and impact assessment are linked together to reach conclusions and recommendations, or in the case of life cycle inventory studies, only the findings of the inventory analysis that are consistent with the defined objective and scope.

In accordance with the objective and scope of the study, the findings of this interpretation may take the form of conclusions and recommendations for the decision maker.

Reporting

The results of the LCA must be fully, completely and accurately described to the intended audience. The type and format of the report must be defined at the scoping stage of the study.

The results, data, methods, assumptions and limitations presented must be transparent and sufficiently detailed to allow the reader to understand the complexities and issues considered in the LCA study. The report must also allow the results and interpretation to be applied in a manner consistent with the objectives of the study.

II - AIM OF THE STUDY

The aim of the LCA study is to provide:

- overview of the environmental impacts of the FN2 product system life cycle
- Comparison of the life cycle environmental impacts of FN2 photocatalytic coating with the environmental impacts of the air purifier life cycle
- assess the importance of nanoparticles for reducing environmental impacts of the life cycle FN2

A PHOTOCATALYTIC COATING FN2

A1 SCOPE OF THE STUDY

A1.1 DESCRIPTION OF THE PRODUCT SYSTEM

The product, registered under the company name FN2, is a suspension used to form a solvent-free mineral topcoat active photocatalytic layer. An important component of the product is nano TiO_2, whose photocatalytic effects serve to remove unwanted microorganisms and airborne pollutants from both indoor and outdoor environments.
These are mainly:

- viruses and bacteria
- air pollutants, e.g. NOx, SO2, CO, VOC act.
- mould
- unpleasant odours,
- dirt on the walls

Use

The product is optimized as a sanitary photoactive coating suitable for all common types of plaster, brick or plasterboard substrates, interior and exterior coatings. The coating is white in colour. Its cleaning effect is immediately visible after exposure to daylight or artificial light with a UV spectrum.

The principle of photocatalysis

Photocatalysis is the process of chemical decomposition of substances in the presence of a photocatalyst and light radiation. It is principally based on photolysis, the natural decomposition of certain substances by the action of light, accelerated by the presence of a photocatalyst. When a material with photocatalytic properties is exposed to light of a suitable wavelength, its surface is activated and a characteristic reaction is triggered. The free electron-hole pair formed primarily and the hydroxyl radicals formed secondarily by contact between the excited photocatalyst molecule and water vapour decompose the organic and inorganic substances present. The final product is then common and stable compounds. [10]

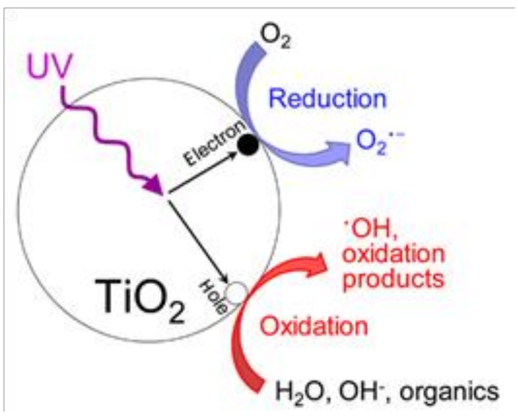


FIGURE 2 MECHANISM OF PHOTOCATALYSIS
Author. Akira Fujishima (President of Tokyo University of Science)

A1.2 SYSTEM FUNCTIONS

Removal of unwanted microorganisms, air pollutants and odours from the indoor environment.

A1.3 FUNCTIONAL UNIT

Functional unit: **air purification in a room with a volume of 300 m^3 (room area 100 m^2, height 3 m) for a period of 1 year.**

A1.4 SYSTEM BOUNDARIES

The system boundaries were chosen to cover all phases of the FN2 photocatalytic coating life cycle from raw material extraction, through the production of FN2, its user phase including maintenance and repair, and end-of-life waste management. The system boundaries are shown in Figure 2.

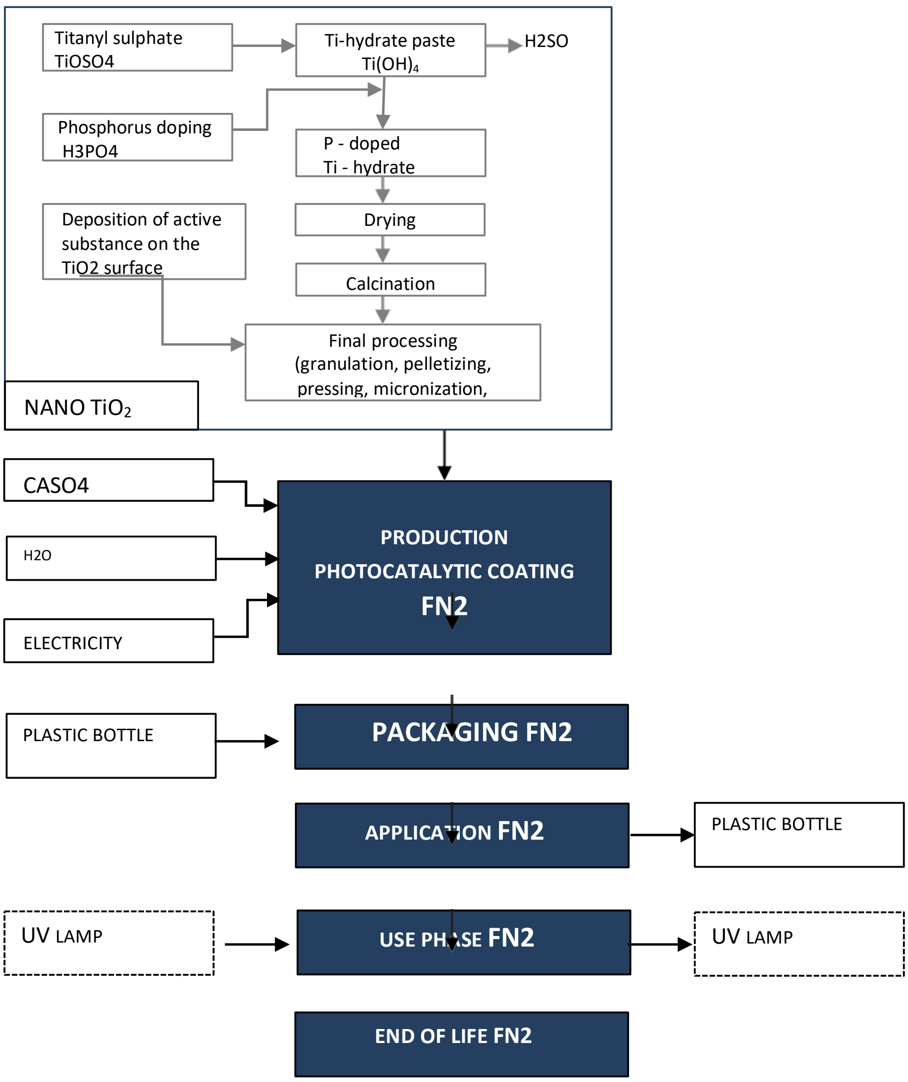


FIGURE 3 LIFE CYCLE BOUNDARIES OF FN2

Note: Inputs in dashed lines were not included in the LCI calculation.

The inputs in the production phase of the photocatalytic FN2 coating are TiO_2 nanoparticles produced by the sulfate method, a binder whose chemical composition is subject to confidentiality and is replaced by gypsum for the purpose of this study, electricity and water. The finished product is packaged in plastic (PE) bottles. The application is done manually, with a paintbrush. After the application of the paint, the water that is part of the FN2 coating evaporates. In order to increase the photocatalytic effects of FN2, the room is equipped with fluorescent lamps in shaded patios in case of lack of natural light.
According to the manufacturer's information, the service life of the coating is 5 years or more. The study assumes a 5-year service life. At the end of the service life, the coating can be repainted. In case of room renovation, the paint is removed with a scraper together with the plaster and placed in a landfill.

A1.5 ALLOCATION PROCEDURES

Weight allocation procedures were chosen for the LCA FN2 study.

A1.6 SELECTED IMPACT CATEGORIES

For the purpose of this study, the midpoint level impact categories corresponding to the EPD requirements would be selected as a basis for possible product certification according to ISO 14025.

Impact category	Category equivalent
Drawing on resources	kg Sb eq.
Global warming (GWP 100)	kg CO_2 eq.
Depletion of the ozone layer (ODP)	kg CFC11 eq.
Acidification (AP)	kg SO_2 eq.
Photooxidant formation (POCP)	kg C_2H_4 eq.
Eutrophication (EP)	kg PO_4^{3-}

The CML 2000 (baseline) method was used to calculate the results of the impact category indicators [8].

In addition to these impact categories, the noise performance of the product in the user phase was also assessed.

A1.6 DATA REQUIREMENTS

Data on the production of the photocatalytic coating FN2, including the production of nano TiO_2, were provided by Advanced Materials, JTJ, s.r.o. Other data, mainly related to the extraction and processing of raw materials and waste management, were obtained from databases:
Ecoinvent 3 - allocation, default - system
Ecoinvent 3 - allocation, default – unit
Ecoinvent system processes
Ecoinvent unit processes
Industry data 2.0
USLCI

A1.7 ASSUMPTIONS

The expected lifetime of the photocatalytic coating is 5 years.

For the purpose of LCA calculations, the user phase was considered in three variations, representing different lengths and intensity of illumination.
The study assumes the manual removal of the FN2 coating from the walls and ceiling at the end of its durability.
The waste will be deposited in a landfill.

A1.8 LIMITATIONS

Not included in the LCA calculation:

- the life cycle of a fluorescent lamp, excluding energy consumption in the user phase
- transport of the product to the consumer
- brush wear
- scraper wear

A1.9 TYPE OF CRITICAL REVIEW

An internal critical assessment will be carried out.

A1.10 TYPE AND FORMAT OF REPORT REQUIRED FOR THE STUDY

The report will be submitted electronically.

A2 INVENTORY ANALYSIS - LCI

A2.1 DATA COLLECTION AND PROCESSING

Primary data were obtained mainly from Advanced Materials.
Other sources were the databases listed in A1.6.

The user phase was calculated in three variations, which differed in the length and intensity of the lighting of the space. Variant I refers to a room largely illuminated by natural light. Option III corresponds to a situation where the need for artificial lighting is increased.

Option I	**Energy consumption**	**Unit**
Lighting time - 12 h per day		
Power consumption 16 W (two 8 W fluorescent lamps)		
Calculation of energy consumption ($LCA_{var\ldots I}$= (16*12*365)/1000)	70,08	kWh
Option II	**Energy consumption**	**Unit**
Illumination time 24 h per day		
Power consumption 16 W (two 8 W fluorescent lamps)		
Calculation of energy consumption ($LCA_{var\ldots II}$= (16*24*365)/1000)	140,16	kWh
Option III	**Energy consumption**	**Unit**
Illumination time - 24 hours a day		
Power consumption 36 W (two 18 W fluorescent lamps)		
Calculation of energy consumption ($LCA_{var\ldots III}$= (36*24*365)/1000)	315,36	kWh

A2.2 PRIMARY DATA

TABLE A1 PRODUCTION OF 1 KG NANO TIO2

INPUTS / OUTPUTS	MULTIPLE	UNIT
ENTRIES		
Water, cooling, unspecified natural origin, RER	0,246	m3
Lime, hydrated, packed {GLO}| market for | Attribute, U	0,363	kg
Iron scrap, sorted, pressed {GLO}| market for | Attribute, U	0,15	kg
Wastewater, average {GLO}| market for | Attribute, U	-0,06545	m3
Waste gypsum {GLO}| market for | Attribute, U	-3,849	kg
Lime, packed {GLO}| market for | Attribute, U	1,38	kg
Hazardous waste, for incineration {GLO}| market for | Attribute, U	-0,007	kg
Residue from TiO2 production, sulfate process {GLO}| market for | Attribute, U	-0,424	kg
Chemical factory, organics {GLO}| market for | Attribute, U	4,00E-10	p
Ilmenite, 54% titanium dioxide {GLO}| market for | Attribute, U	2,094444444	kg
Tap water, at user {Europe without Switzerland}| market for | Attribute, U	77	kg
Energy		
Heat, natural gas, at boiler modulating >100 kW/RER U	12,5	MJ
Heat, natural gas, at boiler modulating >100 kW/RER U	15,76	MJ
Electricity, medium voltage {EU}| market for | Attribute, U	3,0898125	kWh
Electricity - final treatment (milling)	2	kWh
EXITS		
Air emissions		
Carbon dioxide, fossil	0,6072	kg
Hydrogen sulphide	0,000003	kg
Sulphur dioxide	0,00397	kg
Particulates, > 2.5 um, and < 10um	0,000446	kg
Nitrogen oxides	0,00063	kg
Water/m3	0,08015625	m3
Hydrogen	0,001	kg
Water emissions		
Nickel	0,0003	kg
Suspended solids, unspecified	0,012	kg
Sulfate	0,274	kg
Mercury	3,10E-07	kg
Iron	0,018	kg
Chromium	0,0003	kg
Water, RER	0,150675	kg
Zinc	0,0003	kg
Titanium	0,0015	kg
Lead	0,0003	kg
Copper	0,0003	kg
Cadmium	7,99E-07	kg

Product		
Nano TiO2	1	kg

TABLE A2 PRODUCTION OF 1 KG OF PHOTOCATALYTIC COATING FN2

INPUTS / OUTPUTS	MULTIPLE	UNIT
ENTRIES		
TiO2	0,1	kg
CaSO4 (substitute for the actual input, which is subject to classification)	0,02	kg
H2O deionisied	0,7	kg
Electricity	0,5	kWh
Plastic bottle - PE	0,05	kg
EXITS		
FN2 (in plastic packaging)	**1,05**	**kg**

TABLE A3 NANO TIO2 APPLICATIONS

INPUTS / OUTPUTS	MULTIPLE	UNIT
ENTRIES		
Product FN2 in plastic packaging (packaging weight 0,01 kg)	**4,4**	**kg**
Energy - painted by hand	0	kWh
EXITS		
Waste - PE packaging	0,01	kg

TABLE A4 USER PHASE FN2

INPUTS / OUTPUTS	MULTIPLE	UNIT
ENTRIES		
UV lamp	1,752	ks
Electricity - Lighting - **Var. I**	70,08	kWh
Electricity - Lighting - **Var. II**	140,16	kWh
Electricity - Lighting - **Var. III**	315,36	kWh
EXITS		
UV lamp	1,752	ks
Coated walls of a 10 x 10 x 3 m room		
Air emissions		
Water	3,52	kg

TABLE A5 END OF LIFE OF FN2

INPUTS / OUTPUTS	MULTIPLE	UNIT
ENTRIES		
Energy (manual removal)	0	kWh
EXITS		
FN2 (including packaging and after evaporation of water)	0,88	kg
Transport to the landfill	0,00088	tkm

A2.3 CALCULATION OF INVENTORY ANALYSIS RESULTS

The results of the inventory analysis were calculated using the specialized software SimaPro 8.0.2.

A3 IMPACT ASSESSMENT - LCIA

The life cycle impact assessment phase is methodologically the third phase of LCA. This phase follows the inventory analysis phase and aims to understand and evaluate the magnitude and significance of the potential environmental impacts of a product system during the product life cycle.

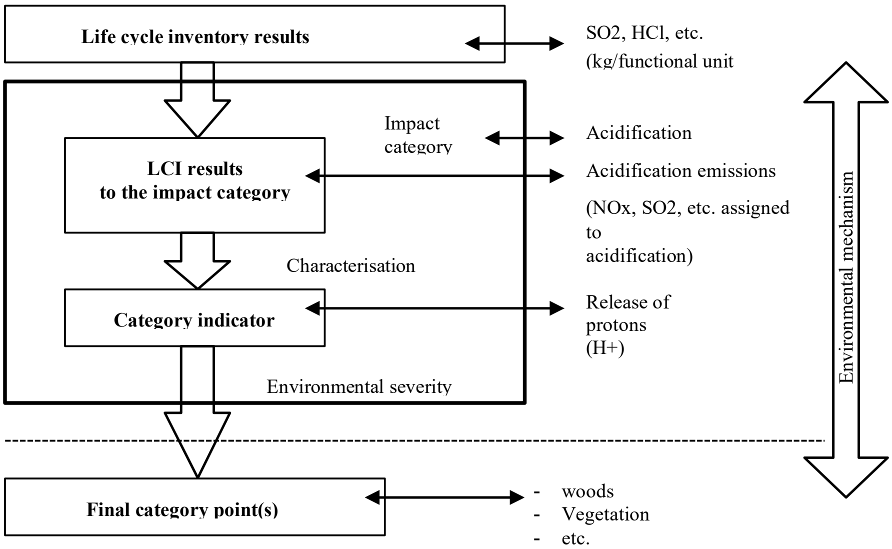


FIGURE 4 CONCEPT OF CATEGORY INDICATORS (ACCORDING TO EN ISO 14044) [2]

The group of outcome indicator categories, sometimes called the LCIA profile, provides information on the environmental impacts that are related to the inputs and outputs of a product system.

A3.1 LIFE CYCLE IMPACT CATEGORY OF PHOTOCATALYTIC COATING FN2

The results of the inventory analysis were assigned to impact categories based on the category indicators and converted to category equivalents (Table A7 - A9) in the range of options I - III using the CML 2 baseline 2000 method [8].

TABLE A6 LIFE CYCLE IMPACT CATEGORY OF PHOTOCATALYTIC COATING FN2 VAR. I

Impact category	Category equivalent	Photocatalytic coating FN2		
		Production	Usage	Waste
Global warming (GWP 100)	kg CO2 eq.	5,219907	42,34008	1,841222
Depletion of the ozone layer (ODP)	kg CFC11 eq.	2,89E-07	1,06E-06	1,14E-08
Acidification (AP)	kg SO2 eq.	0,003516	0,008916	0,000578
Photooxidant formation (POCP)	kg C2H4 eq.	0,034877	0,126422	0,000415
Eutrophication (EP)	kg PO_4^{3-} eq.	0,016366	0,048465	0,010367
Drawing on resources	kg Sb eq.	81,1517	746,0015	1,530315

TABLE A7 LIFE CYCLE IMPACT CATEGORY OF PHOTOCATALYTIC COATING FN2 VAR. II

Impact category	Category equivalent	Photocatalytic coating FN2		
		Production	Usage	Waste
Global warming (GWP 100)	kg CO2 eq.	5,219907	114,666	1,841222
Depletion of the ozone layer (ODP)	kg CFC11 eq.	2,89E-07	2,43E-06	1,14E-08
Acidification (AP)	kg SO2 eq.	0,003516	0,01816	0,000578
Photooxidant formation (POCP)	kg C2H4 eq.	0,034877	0,329962	0,000415
Eutrophication (EP)	kg $PO4^{3-}$ eq.	0,016366	0,559177	0,010367
Drawing on resources	kg Sb eq.	81,1517	1624,777	1,530315

TABLE A8 LIFE CYCLE IMPACT CATEGORY OF PHOTOCATALYTIC COATING FN2 VAR. III

Impact category	Category equivalent	Photocatalytic coating FN2		
		Production	Usage	Waste
Global warming (GWP 100)	kg CO2 eq.	5,219907	257,9985466	1,841222
Depletion of the ozone layer (ODP)	kg CFC11 eq.	2,89E-07	5,46429E-06	1,14E-08
Acidification (AP)	kg SO2 eq.	0,003516	0,040860998	0,000578
Photooxidant formation (POCP)	kg C2H4 eq.	0,034877	0,742413414	0,000415
Eutrophication (EP)	kg $PO4^{3-}$ eq.	0,016366	1,258149368	0,010367
Drawing on resources	kg Sb eq.	81,1517	3655,74875	1,530315

The results of the category indicators show a significant influence of the user phase on all selected impact categories.

The potential impacts of each phase differ only in the user phase, depending on the length and intensity of the illumination of the space.

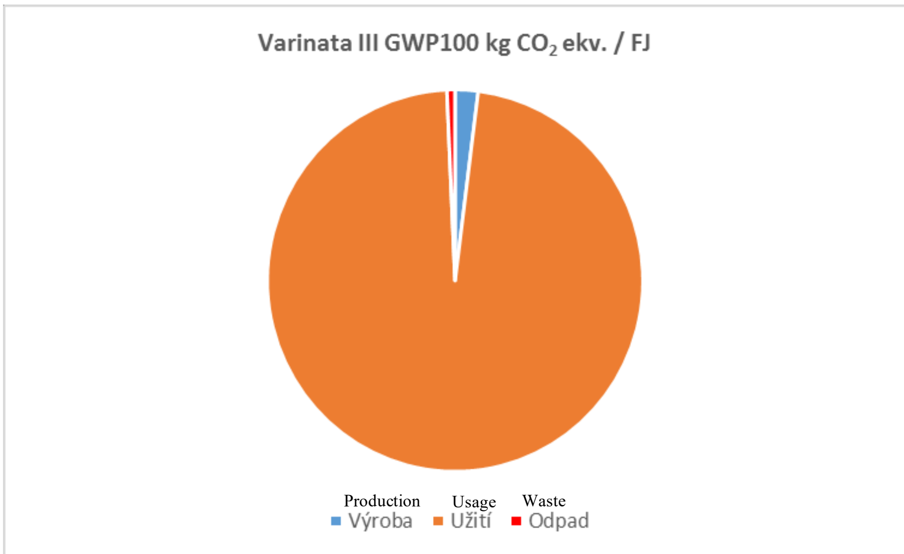


CHART A1 GLOBAL WARMING IMPACT CATEGORY - GWP 100 PHOTOCATALYTIC COATING FN2 VAR. III

The graph shows that the largest contribution to global warming comes from the user phase, which is the use of electricity to light the photocatalytic coating.

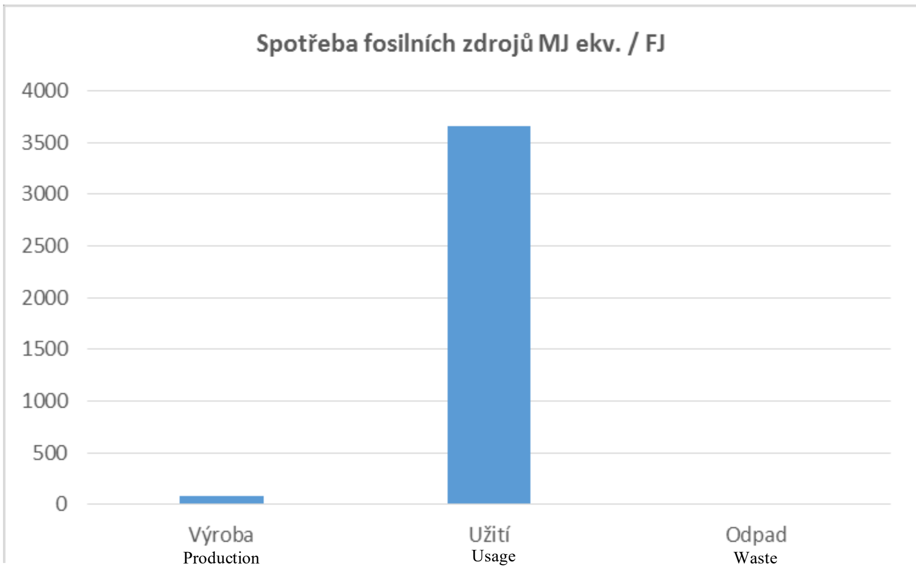


CHART A2 IMPACT CATEGORY FOSSIL RESOURCE CONSUMPTION OF PHOTOCATALYTIC COATING FN2 VAR. III

Fossil fuel consumption also shows similar results to the previous graph. The largest consumption is related to the user phase, i.e. the production of electricity for lighting the space.

A3.2 COMPARISON OF THE IMPACT CATEGORIES OF THE DIFFERENT VARIANTS OF THE PHOTOCATALYTIC COATING FN2

If we compare the impact categories of each option, we get the results expressed in Figure A3 - A8.

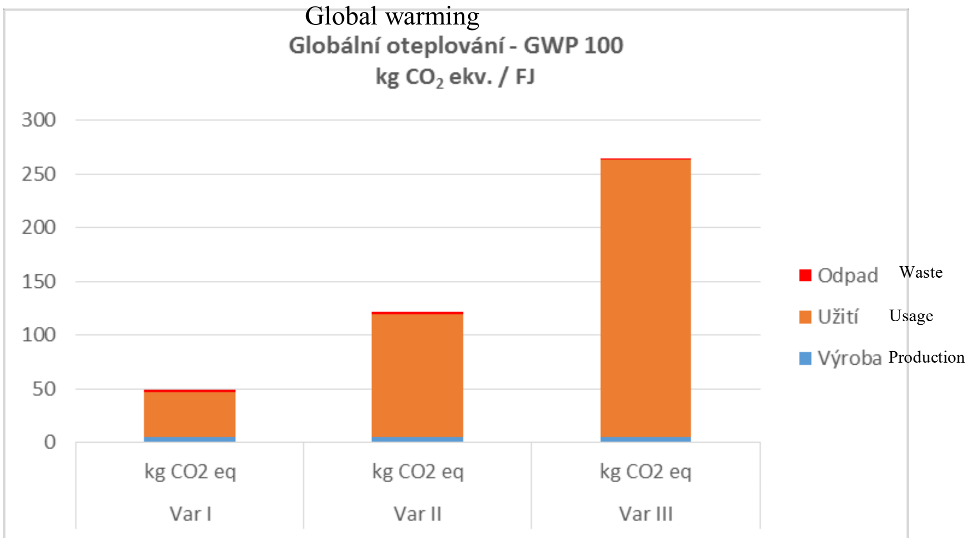


CHART A3 GLOBAL WARMING IMPACT CATEGORY - GWP 100 PHOTOCATALYTIC COATING FN2 VAR. I, II A III

Figure A3 not only presents the significant difference in global warming potential between the options, but also shows the increasing contribution of the user phase with increasing length and intensity of illumination. In rooms sufficiently illuminated by natural light, the electricity consumption for the ceiling lighting corresponds to Option I. In dark rooms without direct daylighting, Option III comes into consideration.

The other impact categories considered, fossil fuel extraction, ozone depletion, acidification, photochemical ozone formation and eutrophication, show similar results to the global warming impact category.

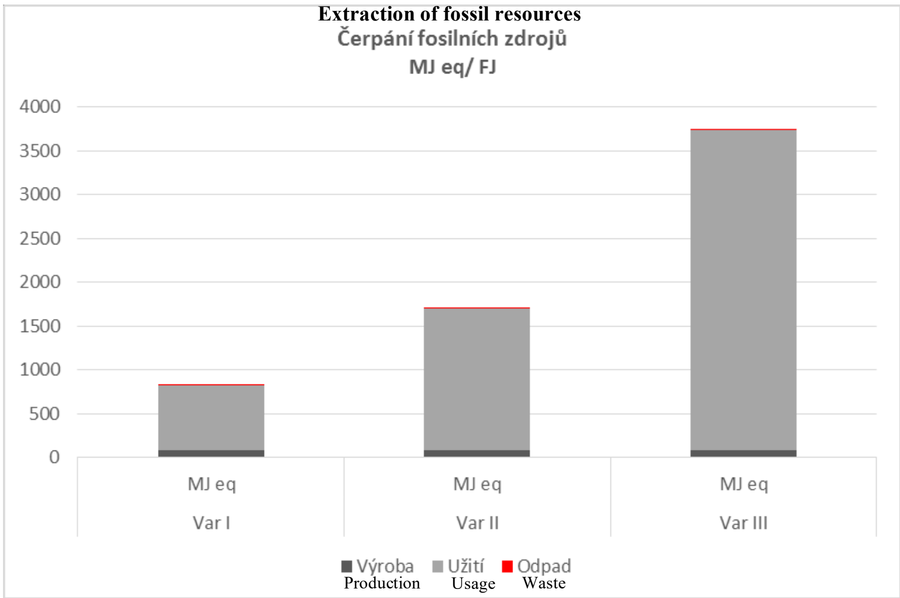


FIGURE A4 IMPACT CATEGORY OF FOSSIL SOURCE EXTRACTION OF PHOTOCATALYTIC COATING FN2 VAR. I, II A III

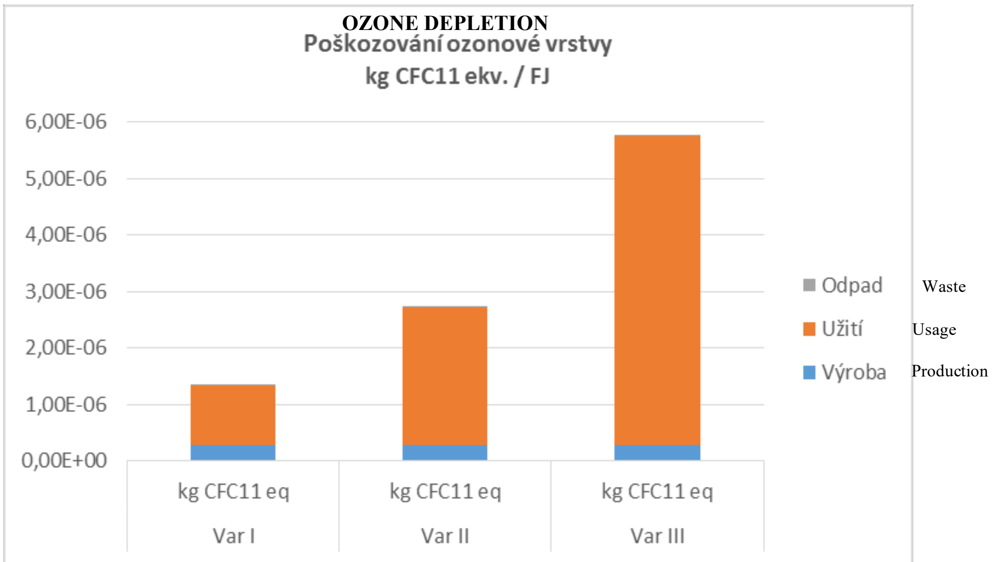
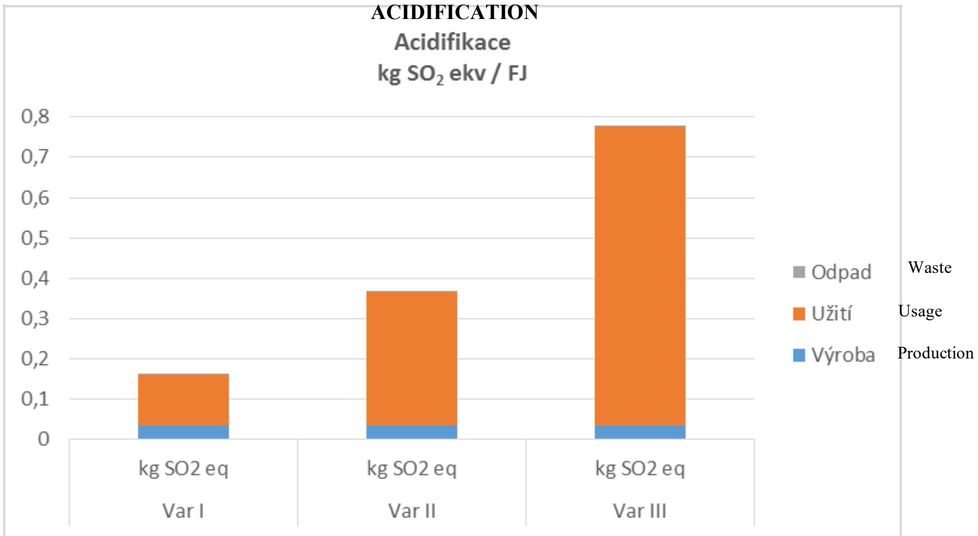
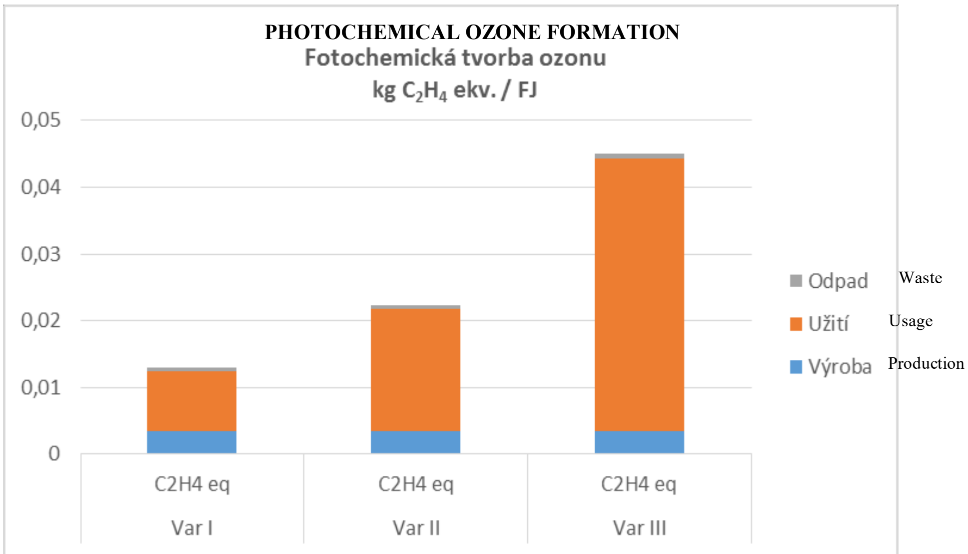


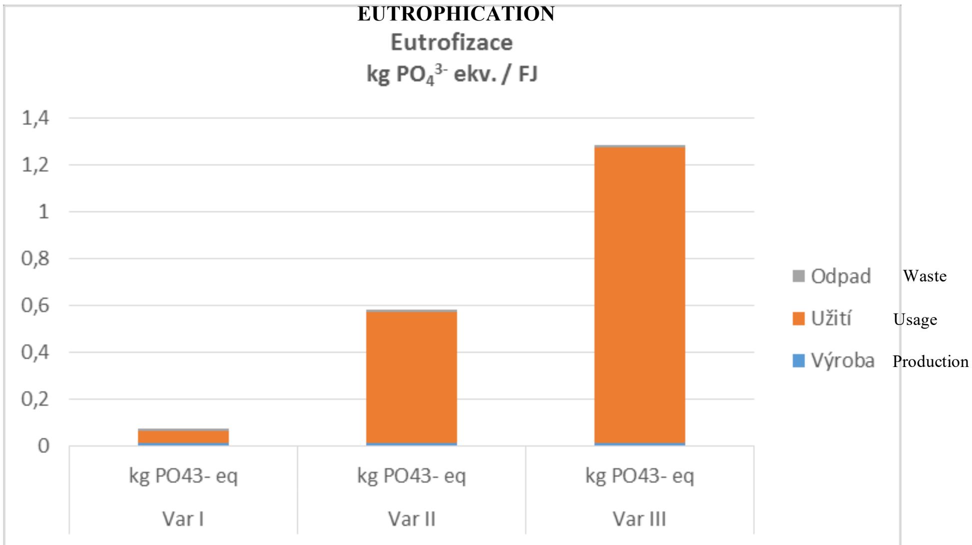
CHART A5 OZONE DEPLETION IMPACT CATEGORY OF PHOTOCATALYTIC COATING FN2 VAR. I, II A III



GRAPH A6 ACIDIFICATION IMPACT CATEGORY OF PHOTOCATALYTIC COATING FN2 VAR. I, II A III



GRAPH A7 IMPACT CATEGORY PHOTOCHEMICAL OZONE FORMATION OF PHOTOCATALYTIC COATING FN2 VAR. I, II A III



GRAPH A8 EUTROPHICATION IMPACT CATEGORY OF PHOTOCATALYTIC COATING FN2 VAR. I, II A III

In all categories considered, the user phase is the main contributor to the impacts of the different options, which is related to the required UV intensity. Rooms using natural light have significantly lower impacts in all categories assessed than rooms requiring artificial lighting.

A4 INTERPRETATION

The result of the LCA of the photocatalytic coating FN2 shows that the highest environmental impact in all impact categories assessed is the user phase, which represents the use of electricity to illuminate the coating to increase its photocatalytic effects. Reducing the intensity of artificial lighting in favour of natural light reduces the negative environmental impacts of FN2.

B AIR PURIFIER

B1 SCOPE OF THE STUDY

B1.1 DESCRIPTION OF THE PRODUCT SYSTEM

Air purifier

For the purpose of the study, one of the best air purifiers on the market was selected to represent air purification technologies including photocatalysis.

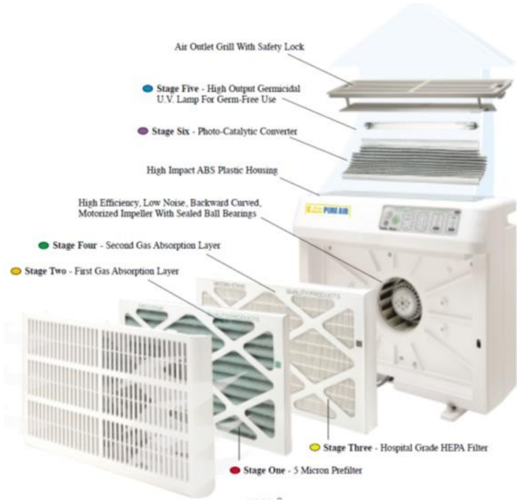


FIGURE 5 PHOTO CATALYTIC PURE AIR PURIFIER [9]

All data about the cleaner were taken from the manufacturer's technical specification [9].

	PARTS	SERVICE LIFE
Dimensions	21.5" width x 18.0" height x 8.0" depth	
Dimensions	0,5461 m width x 0,4572 m height x 0,2032 m depth	
Weight	10.45 kg	
Composition	Air Outlet Grill With Safety Lock	10years
	High Impact ABS Plastic Housing	10years
	Motorized Impeller With Sealed Ball Bearings	10years
	Filter One - 5 Micron Prefilter	2years
	Filter Two - First Gas Absorption Layer	2years
	Filter Three - Hospital Grade HEPA Filter	2years
	Filter Four - Second Gas Absorption Layer	2years
	Filter Five - High Output Germicidal	2years
	Filter Six - Photo-Catalytic Converter	2years
	U.V. Lamp For Germ-Free Use	1years

Operate the air purifier according to the manufacturer's instructions:

"Heavy duty" - intensive air purification for severe allergie

"Light duty"- lower air cleaning intensity for milder allergic reactions

70% effectivity - designed for sleeping periods

The different variants differ in power consumption and noise intensity.

B1.2 SYSTEM FUNCTIONS

The air purifier is designed for air purification in closed rooms such as homes, offices, hospitals. It removes dust, viruses, bacteria, air pollutants and odours.

B1.3 FUNCTIONAL UNIT

Functional unit: **air purification in a room with a volume of 300 m^3 (room area 100 m^2, height 3 m) for a period of 1 year.**

B1.4 SYSTEM BOUNDARIES

The system boundaries were chosen to cover all phases of the air purifier life cycle from raw material extraction, through the production of the purifier, its user phase, including maintenance and end-of-life waste management. The system boundaries are shown in Figure 6.

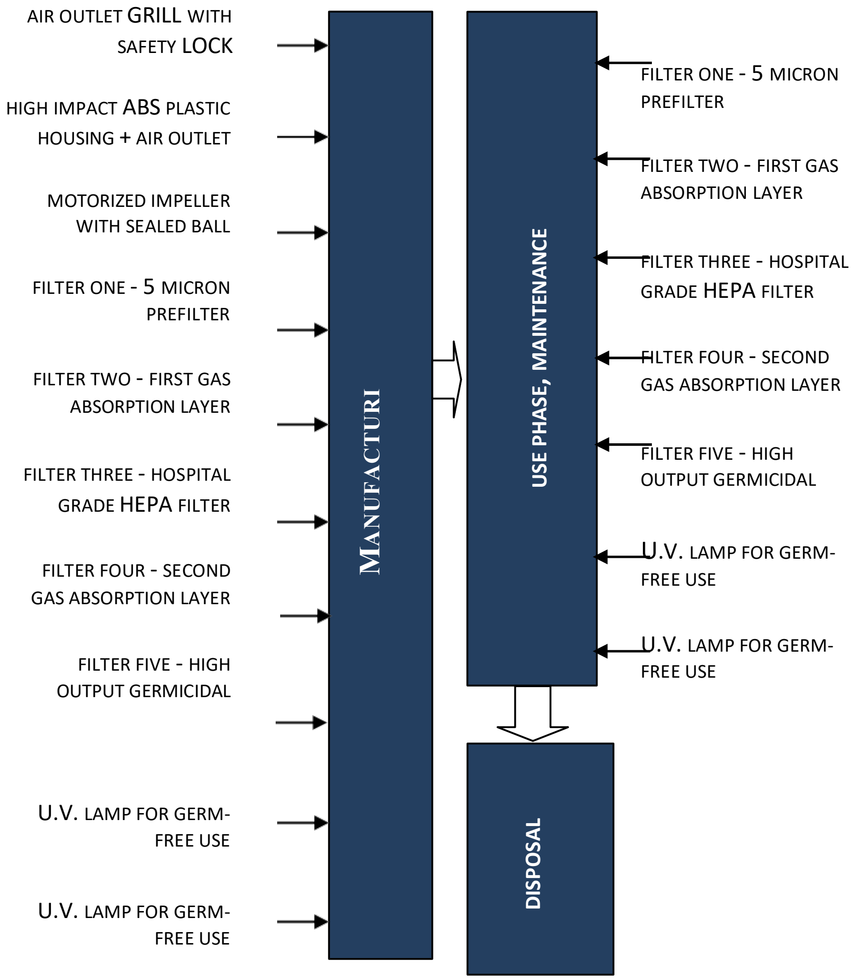


FIGURE 6 AIR PURIFIER LIFE CYCLE DIAGRAM - SYSTEM BOUNDARIES

The air purifier is portable, housed in a plastic box that contains a mechanism for air intake and exhaust, 6 filters and a fluorescent lamp to enhance the photocatalytic effects. The lifetime of the purifier itself is 10 years. The lifetime of the filters is 2 years, the lifetime of the fluorescent lamp 1 year. Replacement of filters and fluorescent lamp is necessary for the desired performance of the purifier. At the end of its service life, the purifier can be landfilled or recycled as an electronic device.

B1.5 ALLOCATION PROCEDURES

Weight allocation procedures were chosen for the LCA FN2 study.

B1.6 SELECTED IMPACT CATEGORIES

For the purposes of this study, the impact categories chosen would be the same as for the photocatalytic coating
(chapter A1.6)

B1.6 DATA REQUIREMENTS

The data on the composition of the air purifier and its operation were taken from the manufacturer's technical specification. Other data, mainly data related to raw material extraction, material production and precipitation loading, were obtained from the specialised databases listed in A1.6.

B1.7 ASSUMPTIONS

The expected lifetime of the air purifier is 10 years.

For the purpose of LCA calculations, the user phase was considered in three variations representing the length and intensity of air purifier use.

The air purifier will be landfilled at the end of its useful life.

The expected noise level of the air purifier during operation is 55 - 75 dB

End-of-life of the air purifier: as the "raw material extraction" phase of the life cycle of the air purifier has a minimal contribution to the overall environmental impact, this study does not address the issue of recycling of the air purifier, but assumes that it will be landfilled at the end of its life.

B1.8 LIMITATIONS

The following items were not included in the calculation of the LCA of the air purifier due to the limitations of obtaining data from the manufacturer:

- the life cycle of a fluorescent lamp, excluding energy consumption in the user phase
- data relating to the actual manufacture/moulding of the individual parts and assembly of the purifier
  air
- transport of the product to the consumer
- recycling of the purifier at the end of its service life

B1.9 TYPE OF CRITICAL REVIEW

An internal critical assessment will be carried out.

B1.10 TYPE AND FORMAT OF REPORT REQUIRED FOR THE STUDY

The report will be submitted electronically.

B1 INVENTORY ANALYSIS

B2.1 DATA COLLECTION AND PROCESSING

Information on the material requirements for the production of the air purifier was obtained from the manufacturer's technical specification. Other sources were the databases listed in A1.6.

The user phase was calculated in three variants, which differed in the operating mode and the duration of the air purifier use.

Option I	**Energy consumption**	**unit**
8 h "light duty" mode	90	Wh
8 h 70% efficiency	77	Wh
Calculation of energy consumption ($LCA_{var... I}$= [(90*8)+(77*8)*(365*1)]/1000)	487,64	kWh
Option II	**Energy consumption**	**unit**
8 h "heavy duty" mode	110	Wh
8 h "light duty" mode	90	Wh
Calculation of energy consumption ($LCA_{var... I}$. = [(110*8)+(90*8)*(365*1)]/1000)	584,00	kWh
Option III	**Energy consumption**	**unit**
8 h "heavy duty" mode	110	Wh
8 h "light duty" mode	90	Wh
8 h 70% efficiency	77	kWh
Calculation of energy consumption ($LCA_{var... III}$= [110*8)+(90*8)+(77*8)*(365*1)]/1000)	808,84	kWh

B2.2 PRIMARY DATA

TABLE **B1** AIR PURIFIER PRODUCTION **(Catalytic Pure Air - small)**

INPUTS / OUTPUTS	**MULTIPLE**	**UNIT**
ENTRIES		
High Impact ABS Plastic Housing + air outlet	7,05	kg
Motorized Impeller With Sealed Ball Bearings	2,5	kg
Filter One - 5 Micron Prefilter	1	ks
Polyamide	100	g
Cardboard	100	g
Filter Two - First Gas Absorption Layer	1	ks
Polyamide	100	g
Cardboard	100	g
Activated carbon	50	g

Filter Three - Hospital Grade HEPA Filter	1	ks
Fiberglass	50	g
Al construction	50	g
Cardboard	100	g
Filter Four - Second Gas Absorption Layer	1	ks
Polyamide	100	g
Cardboard	100	g
Activated carbon	50	g
Filter Five - High Output Germicidal U.V. Lamp For Germ-Free Use	1	ks
Filter Six - Photo-Catalytic Converter	1	ks
Al grill	50	cm2
NanoTiO2	2	g

TABLE B2 AIR PURIFIER USER PHASE

INPUTS / OUTPUTS	MULTIPLE	UNIT
ENTRIES		
Electricity - consumption for 1 year **var. I**	487,64	kWh
Electricity - consumption for 1 year **var. II**	584,00	kWh
Electricity - consumption for 1 year **var. III**	808,84	kWh
Replacing fluorescent lamps	0,9	ks
PM filter	0,4	ks
The first gas filter	0,4	ks
HEPA Filter	0,4	ks
Second gas filter	0,4	ks
Photo-Catalytic Converter	0,4	ks
EXITS		
Waste fluorescent lamps	0,9	ks
PM waste filter	0,4	ks
Waste first gas filter	0,4	ks
Waste HEPA Filter	0,4	ks
Waste second gas filter	0,4	ks
Photo-Catalytic Converter	0,4	ks

TABLE B3 END OF LIFE OF AIR CLEANER

INPUTS / OUTPUTS	MULTIPLE	UNIT
ENTRIES		
Catalytic Pure Air - small	0,1	ks
Transportation for removal	0,01045	tkm

B2.3 CALCULATION OF INVENTORY ANALYSIS RESULTS

The calculation of the results of the inventory analysis was performed using the specialized software SimaPro 8.0.2.

B3 AIR PURIFIER LIFE CYCLE IMPACT ASSESSMENT

B3.1 AIR PURIFIER LIFE CYCLE IMPACT CATEGORY

The results of the inventory analysis were assigned to impact categories based on the category indicators and converted to category equivalents (Table B7 - B9) using the CML 2001 method for the range of options I - III.

TABLE B4 LIFE CYCLE IMPACT CATEGORY OF AIR PURIFIER VAR. I

Impact category	Category equivalent	Air purifier		
		Production	Usage	Waste
Global warming (GWP 100)	kg CO_2 eq.	6,031438	400,8018	0,835058
Depletion of the ozone layer (ODP)	kg CFC11 eq.	3,86E-07	8,56E-06	4,26E-09
Acidification (AP)	kg SO_2 eq.	0,007704	0,0644	0,000142
Photooxidant formation (POCP)	kg C_2H_4 eq.	0,035944	1,154038	0,000126
Eutrophication (EP)	kg PO_4^{3-} eq.	0,019891	1,946733	0,002321
Drawing on resources	kg Sb eq.	110,3007	5685,684	0,217994

TABLE B5 LIFE CYCLE IMPACT CATEGORY OF AIR PURIFIER VAR. II

Impact category	Category equivalent	Air purifier		
		Production	Usage	Waste
Global warming (GWP 100)	kg CO_2 eq.	6,031438	479,6347	0,835058
Depletion of the ozone layer (ODP)	kg CFC11 eq.	3,86E-07	1,02E-05	4,26E-09
Acidification (AP)	kg SO_2 eq.	0,007704	0,076885	0,000142
Photooxidant formation (POCP)	kg C_2H_4 eq.	0,035944	1,380887	0,000126
Eutrophication (EP)	kg PO_4^{3-} eq.	0,019891	2,331167	0,002321
Drawing on resources	kg Sb eq.	110,3007	6802,718	0,217994

TABLE B6 LIFE CYCLE IMPACT CATEGORY OF AIR PURIFIER VAR. III

Impact category	Category equivalent	Air purifier		
		Production	Usage	Waste
Global warming (GWP 100)	kg CO_2 eq.	6,031438	663,5781	0,835058
Depletion of the ozone layer (ODP)	kg CFC11 eq.	3,86E-07	1,41E-05	4,26E-09
Acidification (AP)	kg SO_2 eq.	0,007704	0,106018	0,000142
Photooxidant formation (POCP)	kg C_2H_4 eq.	0,035944	1,9102	0,000126
Eutrophication (EP)	kg PO_4^{3-} eq.	0,019891	3,228181	0,002321
Drawing on resources	kg Sb eq.	110,3007	9409,132	0,217994

The results of the category indicators show a significant influence of the user phase on all selected impact categories.

The potential impacts of each phase differ only in the user phase, depending on the length of and the intensity of air purifier use.

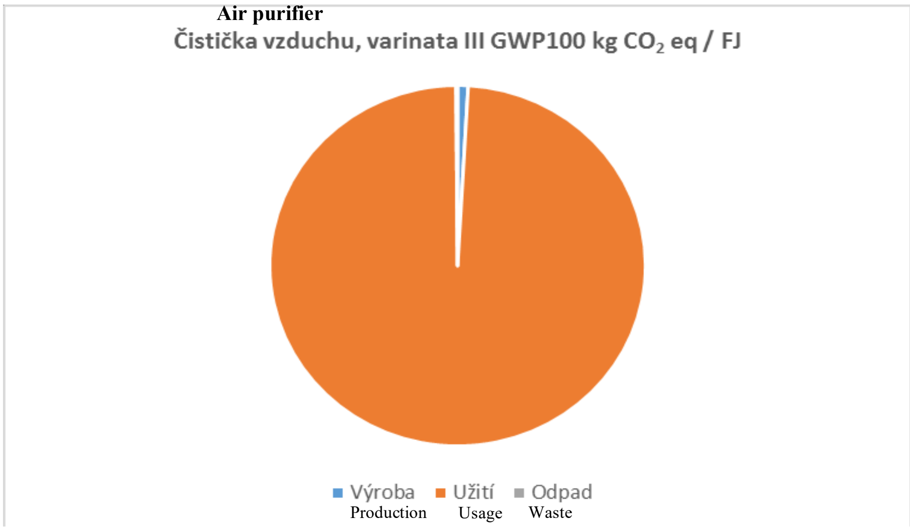


CHART B1 GLOBAL WARMING IMPACT CATEGORY - GWP 100 AIR CLEANERS VAR. III

The graph shows that the largest contribution to global warming comes from the user phase, which represents the electricity consumption during the operation of the air purifier. The environmental impacts of the other phases of the purifier life cycle are negligible compared to the user phase.

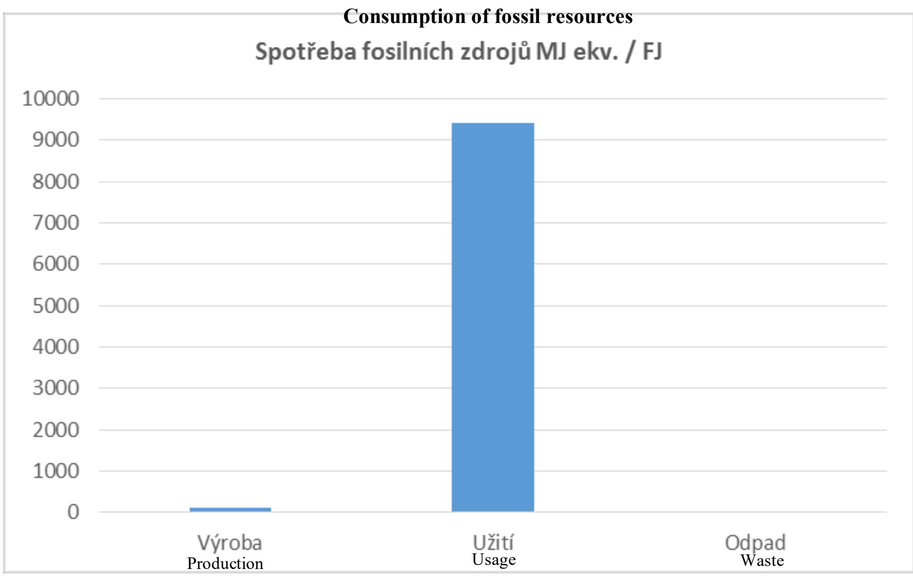


CHART B2 IMPACT CATEGORY FOSSIL RESOURCE CONSUMPTION AIR PURIFIERS VAR. III

Consistent with the previous chart, fossil fuel consumption is also related to the electricity used to light the room.

B3.2 COMPARISON OF THE IMPACT CATEGORIES OF THE DIFFERENT AIR PURIFIER OPTIONS

If we compare the impact categories of the different air purifier intensity options, we get the results expressed in Figure B3 - B8.

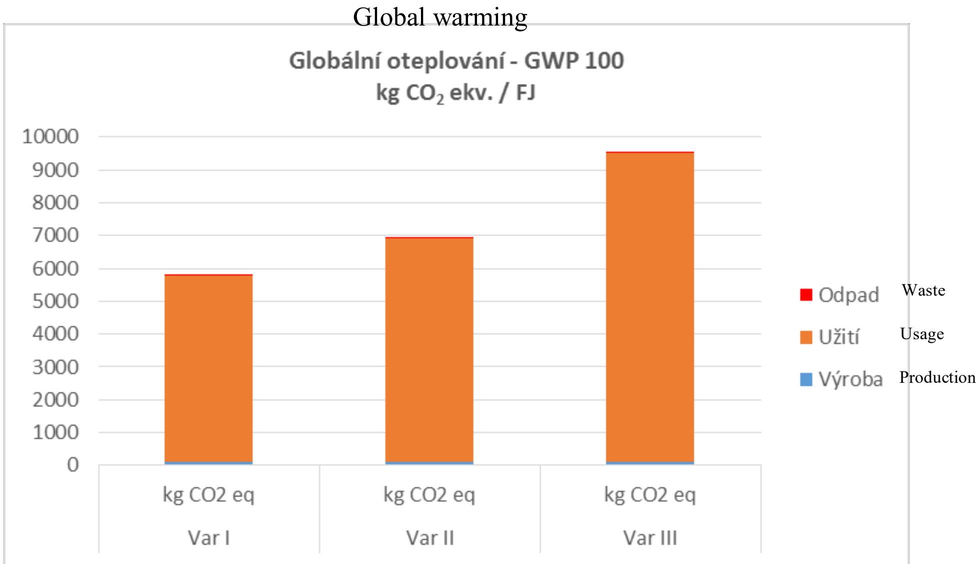


CHART B3 GLOBAL WARMING IMPACT CATEGORY - GWP 100 AIR CLEANERS VAR. I, II A III

Figure B3 presents not only the significant difference in global warming potential between the different options, but also within each option, with the user phase contributing more than 98% of the global warming contribution. The production and end-of-life phases contribute minimally to the overall impacts of the air purifier. They do not exceed 2% of the total environmental impact.

The other impact categories considered, fossil fuel extraction, ozone depletion, acidification, photochemical ozone formation and eutrophication, show similar results to the global warming impact category.

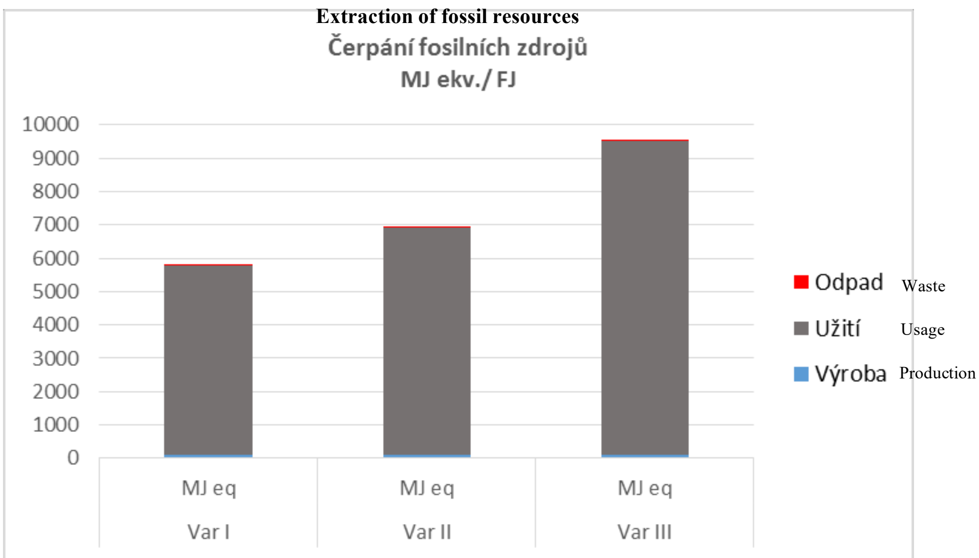


CHART B4 IMPACT CATEGORY OF FOSSIL SOURCE PUMPING AIR PURIFIERS VAR. I, II A III

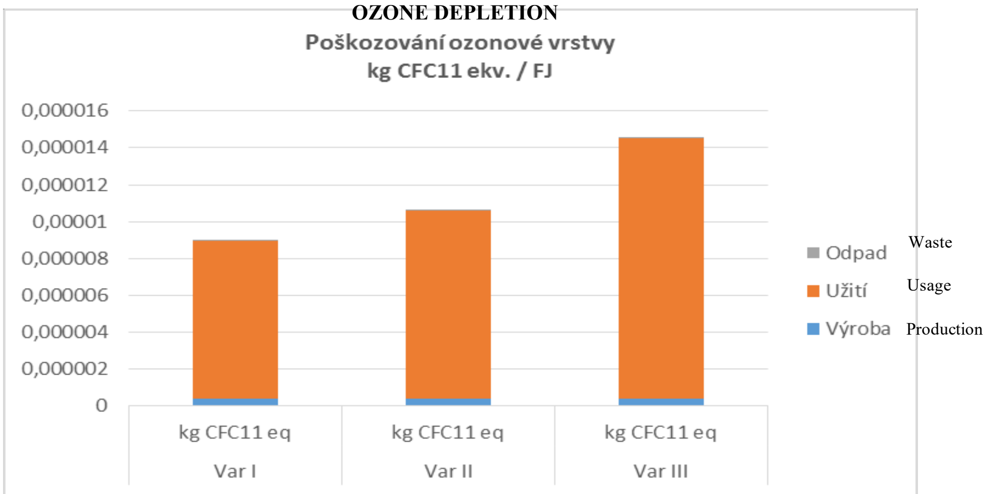


CHART B5 OZONE DEPLETION IMPACT CATEGORY OF AIR PURIFIER SOURCES VAR. I, II A III

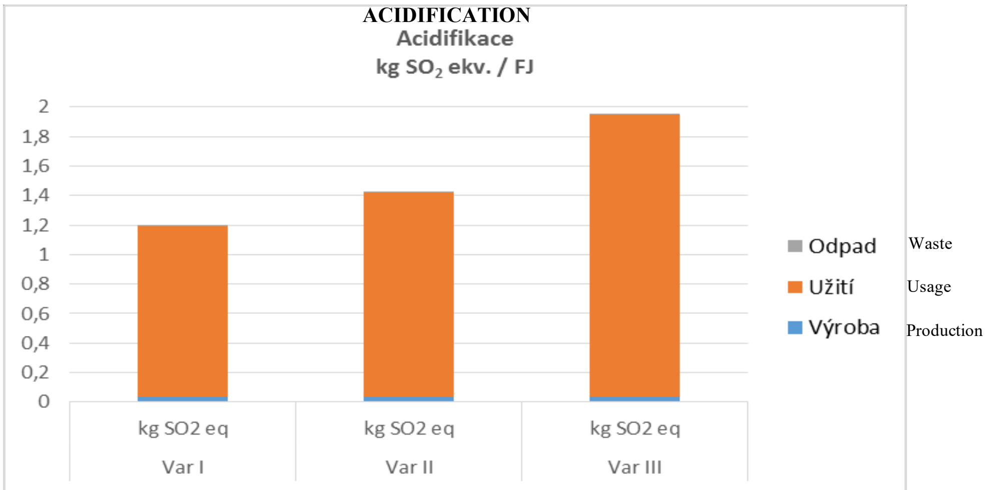


CHART B6 IMPACT CATEGORY OF AIR PURIFIER ACIDIFICATION VAR. I, II A III

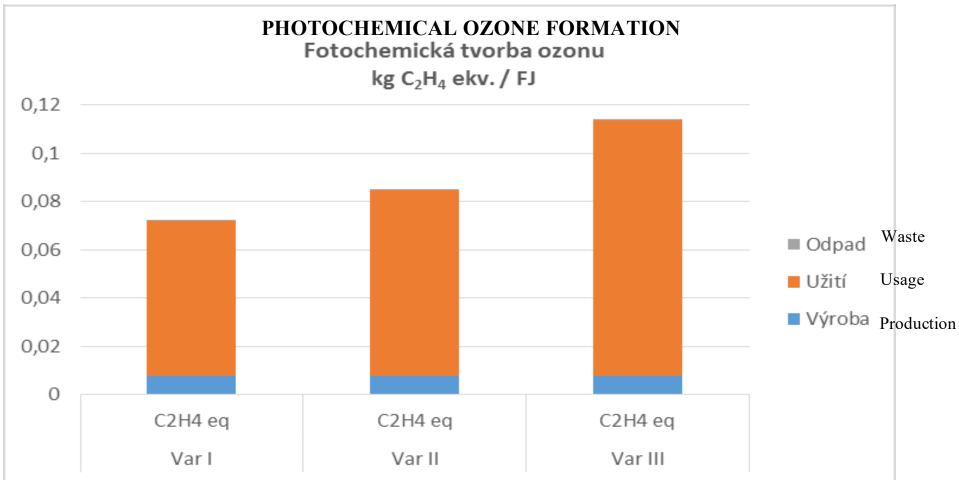


CHART B7 IMPACT CATEGORY PHOTOCHEMICAL OZONE FORMATION AIR PURIFIERS VAR. I, II A III

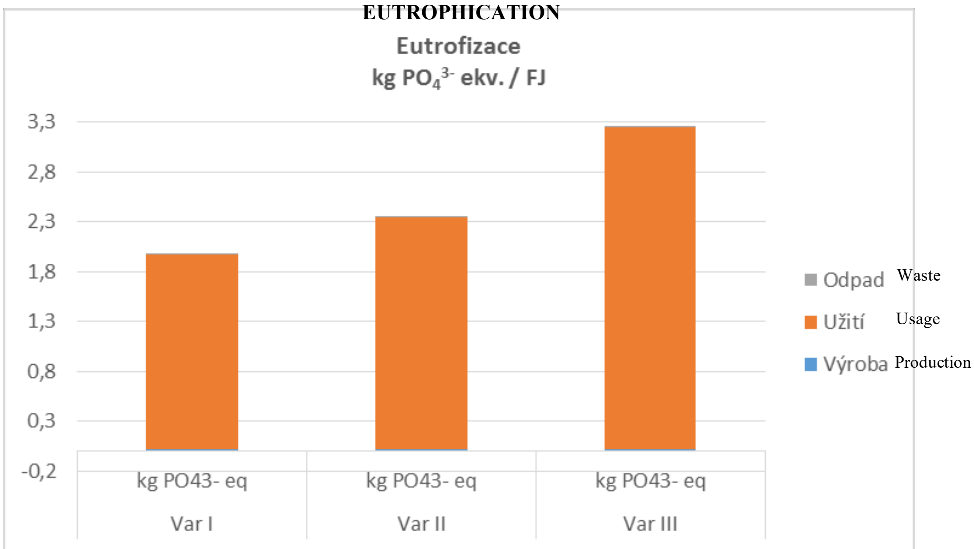


CHART B8 EUTROPHICATION IMPACT CATEGORY OF AIR PURIFIER VAR. I, II A III

The results of the calculation of the category indicators for the individual variants of air purifier use are mainly influenced by the user phase in all categories considered, which is related to the considered operating mode of the purifier and the associated electricity consumption. Option III, which represents intensive use of the air purifier with 24-hour operation and a combination of 'heavy duty' (8 hours), 'light duty' (8 hours) and 'night mode' (8 hours), has the highest electricity consumption and therefore the highest impact in the user phase. The other two variants of air purifier use have operation limited to 16 hours only. Of these, Variant II operates 8 hours in 'heavy duty' mode and 8 hours in 'night mode' operation. Variant I operates 8 hours in 'light duty' mode and 8 hours in 'night mode' operation.

The production and waste phases contribute minimally to the overall environmental impact of the air purifier.

B4 INTERPRETATION

The result of the LCA of the air purifier shows that the highest environmental impact in all assessed variants is in the user phase, where the main contribution to global warming is made by the use of electricity during the operation of the purifier.
Both the length of operation and the higher intensity of use of the air purifier increase the environmental impact of the overall life cycle of the purifier.

C COMPARISON OF PHOTOCATALYTIC COATING FN2 AND AIR PURIFIER

The following chapter deals with the comparison of the environmental impacts of the life cycle of the air purifier (AP) and the photocatalytic coating FN2.

The basic assumption for comparing the life cycles of both product systems is that they have the same function. Both systems are used to remove unwanted microorganisms and airborne pollutants from the indoor environment of hospitals, school facilities and other enclosed spaces with a higher concentration of people, but also for households. The following are removed from the air:

- viruses and bacteria
- air pollutants, e.g. NOx, SO2, CO, VOC act.
- mould
- unpleasant odours

In addition, the air purifier removes solid dust particles, while the photocatalytic coating removes dirt on the walls and can be used to provide the same function in the outdoor environment.

Accurately comparing the performance of the two product systems is difficult due to the lack of standardised procedures to assess their performance levels on a comparable basis.

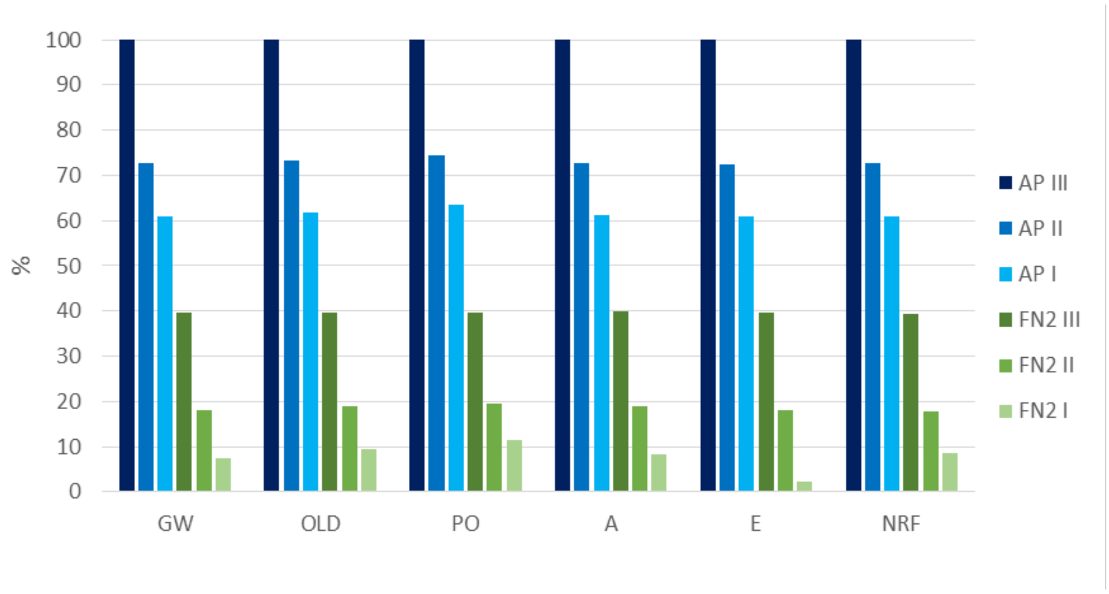


CHART C1 COMPARISON OF THE RESULTS OF THE IMPACT CATEGORIES OF THE AIR CLEANER AND THE PHOTOCATALYTIC COATING FN2

AP - Air Purifier var. I, II and III, FN2 - Photocatalytic Coating FN2 var. I, II and III

GW - Global warming (GWP100), OLD - Ozone layer depletion, PO - Photochemical oxidation A - Acidification, E - Eutrophication, NRF - Non renewable, fossil

Figure C1 shows a significant difference in the environmental impacts of the air purifier and the photocatalytic coating FN2. Even the relatively intensively illuminated photocatalytic coating, Option III, has approximately 20% lower impacts in the categories considered than the lowest intensity and duration of operation, Option I of the air purifier.

The intensively used air purifier - Variant III and the photocatalytic coating that uses natural light - Variant I, are very different. In most categories the impact is approximately 90%.

However, there is a considerable difference between the most environmentally friendly variant of the air purifier - variant I and the most intensively illuminated photocatalytic coating FN2 - variant III.

The LCA of both products also shows that both have relatively high environmental impacts in the user phase compared to other phases of their life cycle. In the case of the photocatalytic coating, these impacts are related to the room illumination to increase the photocatalytic effects of the nano TiO_2 and in the case of the air purifier to the intensity of use of the purifier, the operating mode used and the maintenance of the purifier (filter and lamp replacement). In both cases, this is a phase in which the user intervenes significantly. However, the human contribution to the performance of each system varies. While the photocatalytic coating only requires the replacement of the fluorescent lamp at the end of its lifetime, the air purifier requires not only the replacement of the fluorescent lamp but also the replacement of the 6 filters. The human factor can therefore significantly affect both the performance and the impact of the user phase.

Another difference is the noise level of operation. The photocatalytic coating has zero noise in the user phase, yet the noise level of the air purifier is 55 - 75 dB during operation.

III. CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

1. CONCLUSIONS

Based on this study, it can be concluded that the use of the photocatalytic coating FN2 is significantly more environmentally friendly to the environment than using an air purifier.

Using daylight to illuminate the FN2 photocatalytic coating can significantly reduce the environmental impact of the user phase.

The way both products are used, especially the air purifier, can greatly affect the performance of the system and with it the environmental impacts of the user phase.

2. RESTRICTIONS

Data relating to the actual manufacture/moulding of the individual parts and assembly of the air cleaner has not been used to calculate the life cycle results of the air cleaner.

The impacts of photocatalytic coating on human health and ecosystems have not been assessed. The study was based on the assumption that nano TiO_2 has no toxic or otherwise harmful effects in this regard.

3. RECOMMENDATIONS

Produce an LCA study to address the constraints outlined in section 3.2.

Recommendations for research: Assess the effects of nano TiO_2 on human health and ecosystems.

IV. INFORMATION RESOURCES

1. ISO 14040:2006 Environmental management - Life cycle assessment - Principles and Framework
2. ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines
3. Project information from University of Nottingham partners within FP7 SHYMAN
4. Procházka, J., Advanced Materials, personal communication, [2014]
5. SimaPro. Ecoinvent inventory database. Simapro software. Pré Consultants, 2013
6. Zilka, M; Freiberg, F, Ticha, M, Stieberova B. Project meeting presentation, Valladolid, Spain, 2014
7. Guinée, J.B.; Gorrée, M.; Heijungs, R.; Huppes, G.; Kleijn, R.; Koning, A. de; Oers, L. van; Wegener Sleeswijk, A.; Suh, S.; Udo de Haes, H.A.; Bruijn, H. de; Duin, R. van; Huijbregts, M.A.J. Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background. Kluwer Academic Publishers, ISBN 1-4020-0228-9, Dordrecht, 2002, 692 pp.
8. CML-IA - LCA methodology, Center of Environmental Sciences (CLM)), Leiden University, The Netderlands, http//cml.leiden.edu/software/data-cmlia.html
9. Air Purifier, technical specification, http://www.catalyticpureair.com/wp-content/uploads/2012/02/cpa_user_manual.pdf
10. Journal of Photochemistry and Photobiology C: Photochemistry Reviews, 2012, in press, DOI: 10.1016/j.jphotochemrev.2012.1007.1001)