

EXAM

SUSTAINABLE BUILDING

Example
8.45h – 11.45h
Location: Your room

Course code 195810400

Attention:

Please, write your concise (beknopt) answers on the attached exam paper. You may answer in Dutch and/or English and you are allowed to use a calculator and ruler.

Start answering of each of the three sections on top of a new page. Fill out your student number on every page of the exam paper, as well as your name, initials, address, study (CEM, CME, SET, etc), course name, course code and exam date. Write in black or blue using a pen or marker. Describe clearly how certain calculations are made using correct formulas and units.

The assigned score to each question is indicated between brackets (in total 100 points). Upon completion of the exam, hand in **all documents (including this exam)** and show your student ID card. This exam has fourteen questions on six pages.

Please fill out your name here:

Exam is composed by:
A.G. Entrop en G.H. Snellink

Section 1: Sustainable Building Project Management (30 points)

Question 1: Governmental regulations (9 points)

Governments all over the world try to stimulate sustainable building. In some countries measures or techniques are in a certain way compulsory and need to be adopted in buildings. Describe three different ways the Dutch government tries to reduce the environmental impact of new or existing houses by means of policies and regulations.

Question 2: Social housing sector (5 points)

Financial costs and financial benefits are weighed when energy techniques are the subject of an adoption process. Especially in the Dutch social housing sector the financial issue forms a problem. Explain exactly what financial barrier exists in the social housing sector and how it prevents a successful introduction of additional energy techniques and measures in social housing.

Question 3: Adoption of a heat pump (10 points)

A heat pump seems a promising technique to heat houses and to reduce the energy use of houses compared to conventional natural gas systems. However, the adoption rate of heat pumps still seems relatively low. How can this low adoption rate be explained from the point of view of the five attributes of Rogers? Please give your considerations per attribute.

Question 4: Life cycle analysis (6 points)

During the lectures it was told that timber is being used and being reused in multiple ways and old metal is being used in the production of new steel. We would like to conduct a life cycle analysis (LCA) research, in which we compare the environmental impact of a plate made out of ply wood and a plate made out of steel of the same size. Please describe what difficulties you can expect in assessing the environmental impact of the two materials in this comparative study.

Section 2: Sustainable Building Technology (24 points)

(In current versions of the exam this section is 30 points)

Question 5: Going beyond the triad approach (6 points)

Five different triads exist to cover different aspects of sustainable building. There are however more aspects involved in sustainable building, than the triads are able to cover. Mention and describe three aspects of sustainable building that are not covered by the triad approach.

Question 6: Analyse a building (10 points)

Please read the following text about the Bank of America Tower in New York City. You are asked to analyse this text regarding the sustainable measures. Please classify all measures and techniques, suggested or mentioned in the text, in a matrix addressing the five triads and three steps.

	Step 1	Step 2	Step 3
Trias ...			
Trias ...			
Trias ...			
Trias ...			
Trias ...			

The design of the building makes it environmentally friendly, using technologies such as floor-to-ceiling insulating glass to contain heat and maximize natural light, and an automatic daylight dimming system. The tower also features a greywater system, which captures rainwater and reuses it. Bank of America states that the building is made largely of recycled and recyclable materials. Air entering the building is filtered, as is common, but the air exhausted is cleaned as well. Bank of America Tower is the first skyscraper designed to attain a Platinum LEED Certification.

The Bank of America tower is constructed using a concrete manufactured with slag, a byproduct of blast furnaces. The mixture used in the tower concrete is 55% cement and 45% slag. The use of slag cement reduces damage to the environment by decreasing the amount of cement needed for the building, which in turn lowers the amount of carbon dioxide greenhouse gas produced through normal cement manufacturing. One ton of cement produced emits about one ton of carbon dioxide into the atmosphere.



Control of the temperature of Bank of America's tower and the production of some of its energy are executed in an environmentally friendly manner. Insulating glass reduces thermal loss somewhat, which lowers energy consumption and increases transparency. Carbon dioxide sensors signal increased fresh air ventilation when elevated levels of carbon dioxide are detected in the building.

Conditioned air for the occupants is provided by multiple air column units located in the tenant space that deliver 17 °C air into a raised access floor plenum. This underfloor air system provides users with the ability to control their own space temperature as well as improving the ventilation effectiveness. When internal refurbishments need to take place, workstation moves can be performed easier with lower cost and less product waste.

The cooling system produces and stores ice during off-peak hours, and allows the ice to melt to help cool the building during peak load, similar to the ice batteries in the 1995 Hotel New Otani in Tokyo, Japan. Ice batteries have been used since absorption chillers first made ice commercially 150 years ago, before the electric light bulb was invented.

Water conservation features in the tower include waterless urinals, which are estimated to save 8 million gallons of water per year and reduce CO₂ emissions by 144,000 pounds per year (as calculated with the Pacific Institute water-to-air model). The tower has a 4.6-megawatt cogeneration plant, which provides part of the base-load energy requirements. Onsite power generation reduces the significant electrical transmission losses that are typical of central power production plants.

Question 7: Connections between multiple triads (8 points)

When some measures or techniques are being analysed, it can often be noticed that they fit in the scope of two or more triads. In other words two or more aspects relate with each other. An A-label dish washer for example needs less water and energy than a B-label dish washer.

A. Please explain the relation between the aspects of transport and space use in the case of spatial planning.

B. Please draw out in a figure and explain the relation between the aspects of water and energy in the case of a household water system, that contains a water saving shower head, drain water heat exchanger and an ecoplay¹ in line.

¹ A system, containing a reservoir and pumps, that enables the use of shower and bathing water to flush toilets.

Section 3: Sustainable Building Physics (46 points)

(In current versions of the exam this section is 40 points)

Question 8: Energy balance (8 points)

There are three different Energy Performance Indicators (EPI's) in use in the Netherlands which all reflect on the construction related energy use (gebouwgebonden energiegebruik) of a house or in other words on a house its architectural design and the installed systems. The actual energy use of houses for a whole year is (most likely) not the same as this so called construction related energy use per year, because some categories of energy use are not addressed in the calculation methodologies underlying the EPI's.

A. Give an overview of the different categories of energy use that are addressed in calculating EPI's. Give for each category a short description.

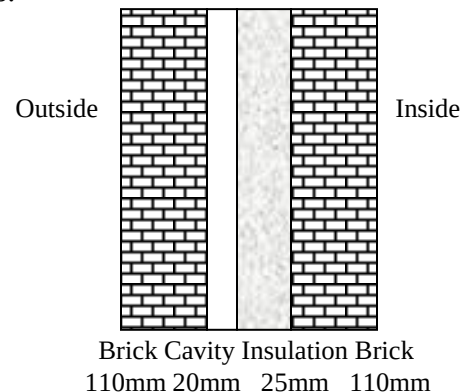
B. Give an overview of different categories of energy use that are **not** addressed in calculating EPI's, but which do contribute to the total actual energy use of houses. Give again for each category a short description.

C. Formulate an energy balance for a house, using your categories from A and B, addressing its actual energy use.

Question 9: Condensation risk in an insulated wall (10 points)

See the wall construction in the Figure and Table below. Calculate the **temperature drop** across each layer and the temperature at each boundary by using the given values. Calculate in the same scheme the **vapour pressure drops** across each of the layers by using the psychrometric chart, find the dew-point temperature at each boundary. The inside temperature is 22 °C with a relative humidity of 50%. The outside temperature is 2 °C with 4.0 gram moist per kilogram air. Plot the **dew-point temperatures and the boundary temperatures** in one figure and show if a **condensation risk** exists. Describe clearly how the calculations are made using correct formulas and units.

	Heat transmittance / resistivity	Vapour resistivity
Internal surface R_{si}	0.13 m ² ·K/W	n/a
External surface R_{se}	0.04 m ² ·K/W	n/a
Brick (inside)	0.56 W/m·K	60 MN s/ g·m
Brick (outside)	0.77 W/m·K	50 MN s/ g·m
Cavity	0.18 m ² ·K/W	n/a
Insulation	0.03 W/m·K	300 MN s/ g·m



Question 10: Designing a ventilation system (8 points)

An electrician needs to know the capacity (in m³/h) of a fan for the central ventilation system of a standard row house originating from 1985. This house has a natural inflow and mechanical outflow. The outlets for the outflow are located in the kitchen, toilet and bathroom. The specifications of the house are given in the Table at the next page.

Make a **ventilation scheme** that shows how the system is composed. There is a loss of ventilation capacity in the ducts of 10 % for the ground floor and 5 % for the 1st floor, which needs to be regarded for calculating the fan's capacity. What should be the **minimum**

capacity of the fan (in m^3/h)? Describe clearly how the calculations are made using correct formulas and units.

Table

	Area	Surface	Ventilation rate
ground floor	Living room	35 m^2	$0.7 \text{ dm}^3/\text{s} \cdot \text{m}^2$
	Open kitchen	-	$21 \text{ dm}^3/\text{s}$
	Toilet	-	$7 \text{ dm}^3/\text{s}$
1 st floor	Bedroom 1	16 m^2	$0.7 \text{ dm}^3/\text{s} \cdot \text{m}^2$
	Bedroom 2	13 m^2	$0.7 \text{ dm}^3/\text{s} \cdot \text{m}^2$
	Bedroom 3	12 m^2	$0.7 \text{ dm}^3/\text{s} \cdot \text{m}^2$
	Bathroom	-	$14 \text{ dm}^3/\text{s}$
2 nd floor	Attic	40 m^2	$0.7 \text{ dm}^3/\text{s} \cdot \text{m}^2$

Question 11: Illuminance (8 points)

A lamp acts as a point source with a mean spherical intensity of 1500 cd. It is fixed 1 m below the ceiling, and 2 m above the centre of a circular table which has a radius of 1.5 m. The ceiling has a reflectance of 0.75. Calculate the total illuminance at the edge of the table.

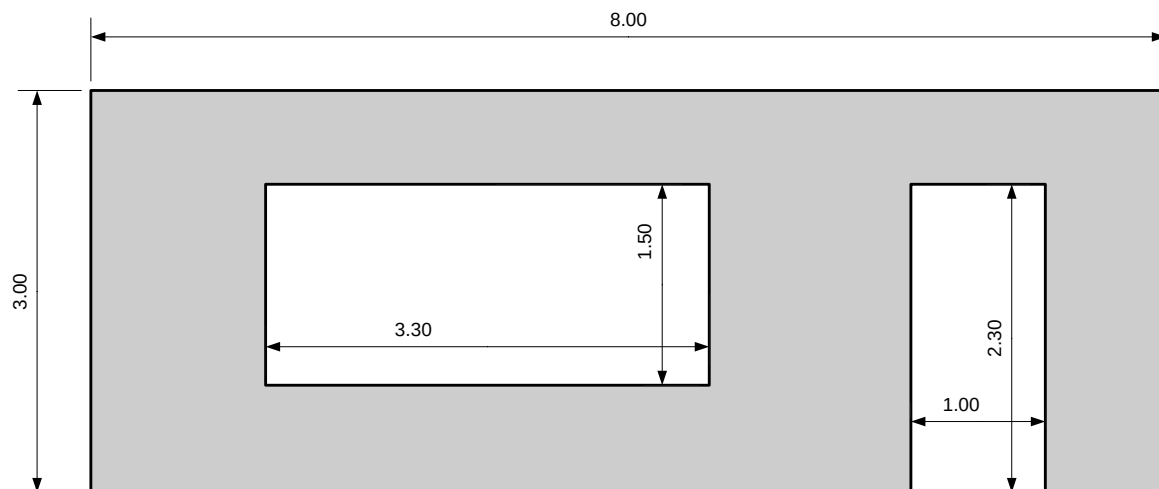
Question 12: Phon-scale (2 points)

The Loudness level has the unit "phon". What is the difference between the decibel-scale and the phon-scale?

Question 13: Sound reduction (8 points)

A thick wall contains a window and a wooden door, see the figure and values below (shown distances are expressed in meters). Calculate the Sound Reduction Index.

Figure



$$\begin{aligned} \gamma_{\text{wall}} &= 2000 \text{ kg/m}^3 & t_{\text{wall}} &= 210 \text{ mm} \\ \gamma_{\text{glas}} &= 2600 \text{ kg/m}^3 & t_{\text{glas}} &= 14 \text{ mm} \\ \gamma_{\text{wood}} &= 800 \text{ kg/m}^3 & t_{\text{door}} &= 60 \text{ mm} \end{aligned}$$

Question 14: Reverberation time (2 points)

What is the reverberation time?