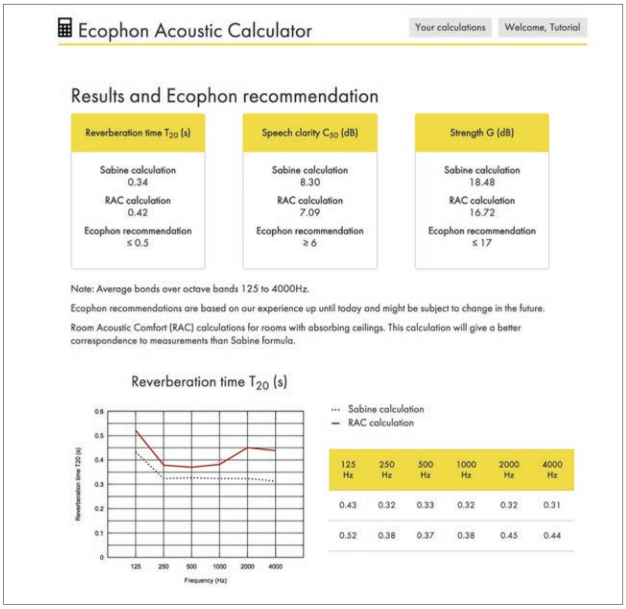
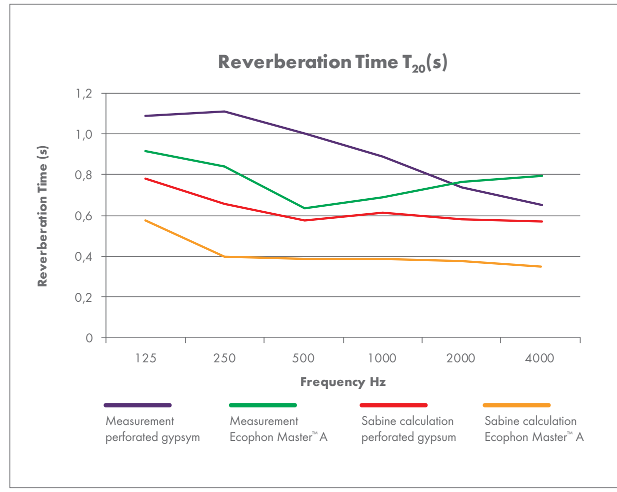
Ecophon Acoustic Calculator

Accurate values in advance

A SOUND EFFECT ON PEOPLE

Idea and layout: Navigator. Printer: Skånetryck AB. Cover: Getty Images/Jacob Ammentorp Lund





All materials, for instance glass wool, stone wool and gypsum, get different values from Sabine calculations and actual measurements. In this graph you can see calculated and measured results for Ecophon Master™ A, and perforated gypsum.

Find out what a room
will actually sound like

Today almost all room acoustic calculations are based on the Sabine formula. Even though it is known that you often get different values when you compare calculations with actual measurements in a room. Therefore, Ecophon has developed a calculator in which you get accurate acoustic values before measurements. The Ecophon Acoustic Calculator is as easy to use for existing rooms as for rooms that have not been built yet.

The fact that you need to consider more parameters than reverberation time is more and more becoming common knowledge in the field of room acoustics. Several standards have already been revised to also include parameters such as speech clarity and sound strength.

At the same time there is a growing understanding that the same acoustic solution can’t be applied everywhere. You need to consider the activity that is to take place, the people performing the activity and the space itself. For instance, if you have a traditional classroom where teaching and learning are the activities, the proper acoustic environment needs to be quite different from the ones being placed in an open-plan office or the entrance hall of a hospital.

All this, along with the knowledge that you don’t get the same results from laboratory measurements according to the Sabine formula, and actual measurements on-site, has led Ecophon to develop a new model for calculating room acoustics. The model is energy-based and the input data for the absorbers is air flow resistance. The results are compatible with the values you get from real-life measurements.

The Ecophon Acoustic Calculator is an easy-to-use e-tool based on the new model. With it you can realize what the acoustic environment will be in a specific space – and if it fulfils the requirements for the designated activity. And of course, most important, if it truly has a sound effect on people.

Activity Based Acoustic Design
an introduction

Many studies have placed attention to the poor conditions in schools and preschools. The stressful situations in open-plan offices are well documented. As are the negative effect of high noise levels in hospitals. Many people carry out their daily activities in such premises and it is of great importance that the acoustic conditions and other indoor environmental factors such as light, air quality and thermal regulation are designed to support the activities. Creating a calm and less stressful atmosphere enhance people´s wellbeing and performance.

Activity Based Acoustic Design
In order to create a space where people can perform a certain activity to the best of their ability, and be comfortable doing so, Ecophon has developed Activity Based Acoustic Design. This is a method for acoustically designing indoor environments. In practice, it means defining the needs from three perspectives – activity, people and space – and finding the common ground where all perspectives benefit.

Activity Based Acoustic Design implies that several room acoustics parameters are needed for a proper characterisation of the sound environment.

1 Activity

What will people do in the space? Be on the phone? Teach? Learn? Rest and recover? Will it be noisy? How much time is spent communicating?

2 People

Who are the people performing the activities? How many are they? Are they young or old? Do they have any special needs?

3 Space

Is it big or small? Where is it situated in the building? Does it have bare concrete walls, ceilings and floors? Are there fans, alarms or other frequent sounds?

Room types

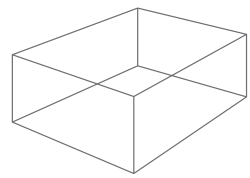
Three room types with different acoustical behaviour can be identified. We have the Sabine room, the room with a suspended sound-absorbing ceiling and the open-plan space.

The Sabine room assumes a diffuse sound field which in turn requires that the sound absorption is quite low and well distributed over all the surfaces. This type of room is well characterised with the use of reverberation time. Further, in the Sabine room speech clarity and sound level are related to the reverberation time.

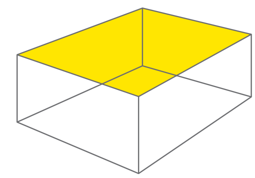
The situation is different for the room with a sound-absorbing suspended ceiling. In this type of room, the sound field is not diffuse and reverberation time, speech clarity and sound level are not simply related to each other. Consequently, these parameters have to be evaluated individually.

Concerning the open-plan space, the reverberation time and speech clarity will depend on the distance from the sound source. In open-plan spaces it is therefore more relevant to introduce measures related to reducing sound propagation.

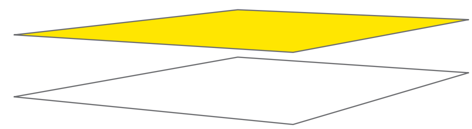
Reverberant room (Sabine room, diffuse sound field)



Room with absorbent ceiling (non-diffuse sound field)



Open plan-spaces (non-diffuse sound field)



Room acoustic parameters

For schools, offices and healthcare premises we use the parameters reverberation time, speech clarity and sound strength to evaluate the acoustic conditions. These measures are defined in the standards ISO 3382-part 1 and 2. For open-plan offices measures related to sound propagation are used and defined in IS0 3382-part 3.

Parameter	Measure	Explanation
Reverberation Time	T_{20} (s)	Measures how fast the sound energy disappears in the space. A shorter reverberation time means the space has less disturbing echoes and feels more calm.
Speech Clarity	C_{50} (dB)	Measures how well speech is perceived in the space. If the value increases, speech clarity is improved.
Sound Strength	G (dB)	Measures how sound reflections from all surfaces contribute to the sound level in a space. A lower value means the sound level in the space is lower.

Noticeable differences according to ISO 3382-1

Subjective listener aspect	Room acoustic quantity	Noticeable difference
Perceived reverberance	Reverberation Time T_{20} in seconds	5%
Perceived clarity of sound	Speech Clarity C_{50} in dB	1 dB
Percieved level of sound	Sound Strength G in dB	1 dB

Room acoustic design

The aim of room acoustic design is to find an optimized acoustic solution for the activity going on in the room and for the actual type of room. In practice this means to find a balance between our three room acoustic parameters that supports the activity as good as possible. Neither of the extremes in the form of an anechoic chamber or a reverberation room is suitable for ordinary work places. The solution is to find in between.

Based on field investigations and listening tests, Ecophon recommends the following T_{20}, C_{50} and G for a traditional classroom:

Criteria	Quantity	Target values
Speech Clarity	C_{50} (dB)	6-8 dB[1]
Sound Strength	G (dB)	15-17 dB[2]
Reverberation Time	T_{20} (s)	0.40-0.50 s

[1] The early reflections, up to 50 milliseconds, should be 6–8 dB higher than the late reflections.

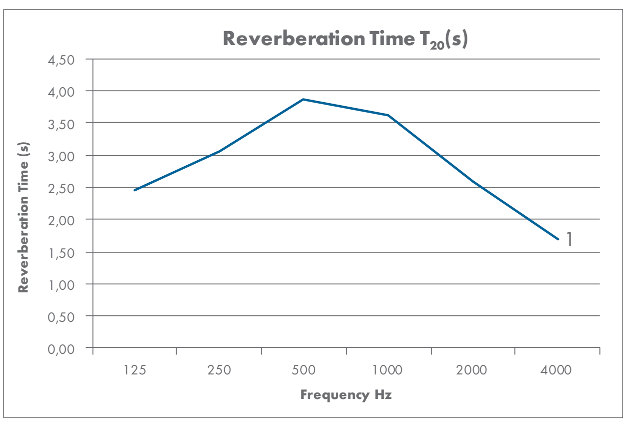
[2] The sound strength should be 15–17 dB louder than the measurement in an anechoic chamber.

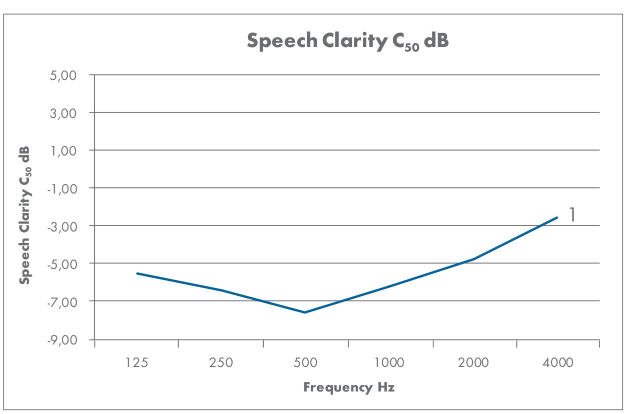
The effect of acoustic treatment on room acoustic parameters

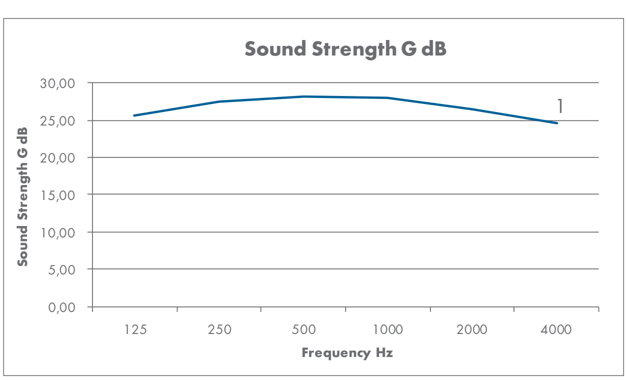
The effect of different acoustic treatment on the room acoustic parameters reverberation time, speech clarity and sound strength is illustrated by measurements in a classroom configuration. The first case shows the results for the empty room without a suspended sound-absorbing ceiling. Comparing with the target values in table 1 we can conclude that we are far away from fulfilment.

1. Room without a suspended sound-absorbing ceiling and no furniture

The reverberation time is long at mid frequencies but decline somewhat towards low and high frequencies. Based on the definition of C_{50} it can give negative values. This means that all the late reflections contain more energy than the early reflections. Early reflections are important for the perceived speech clarity.

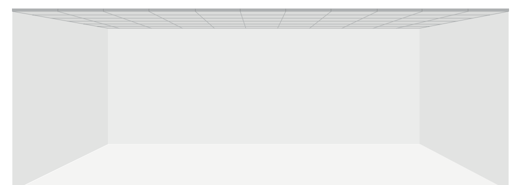


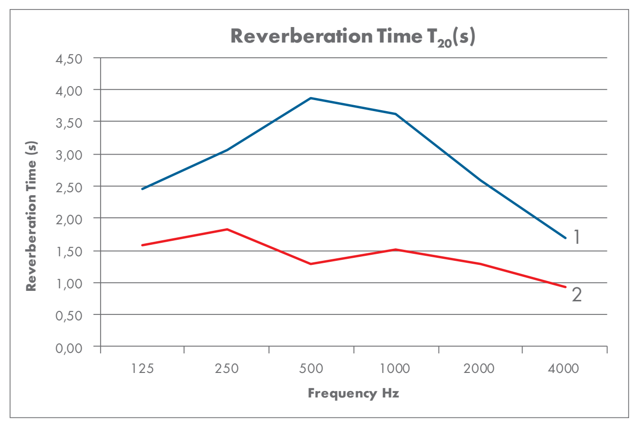


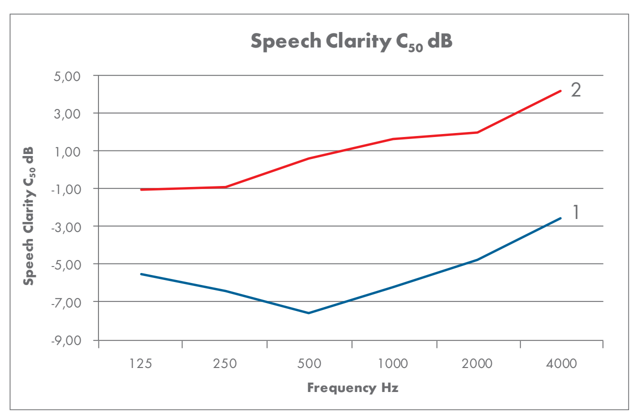


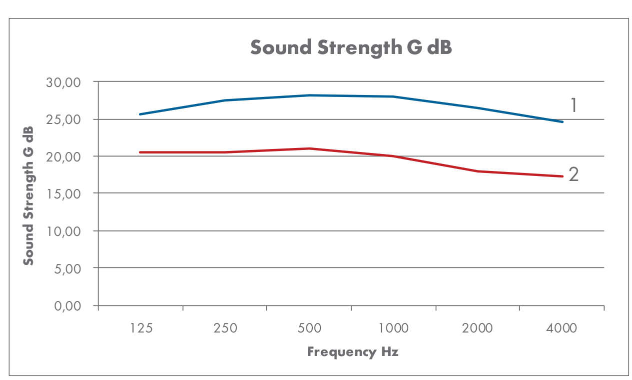
2. Room with a suspended sound-absorbing ceiling but no furniture

All parameters are affected. Still the reverberation time and speech clarity are far from the target values. However, concerning sound strength the target values are more or less fulfilled.



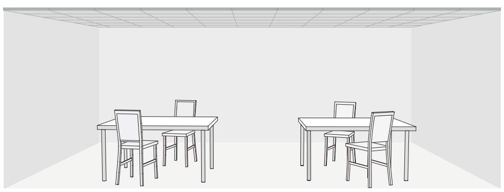


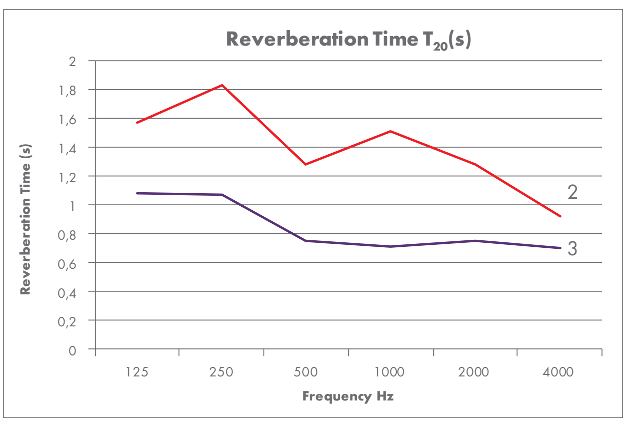


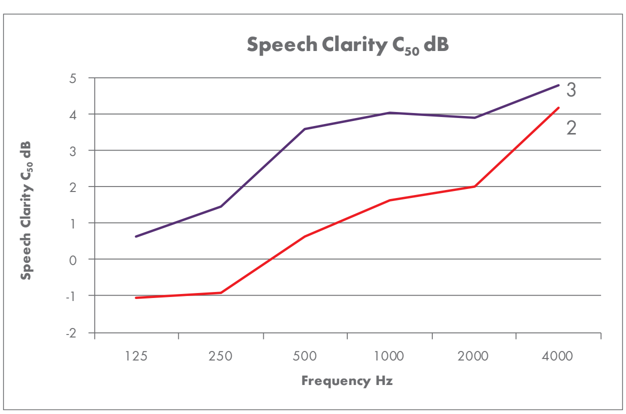


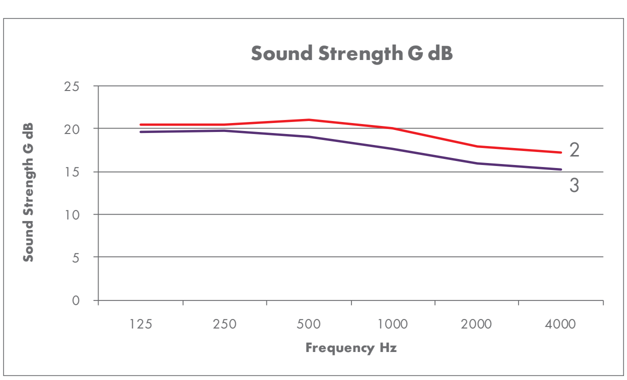
3. Room with a suspended sound-absorbing ceiling and furniture

Furniture contributes to absorption and sound scattering. In combination with a sound-absorbing ceiling the effect of scattering on reverberation time and speech clarity is significant. But we still do not reach the target values.



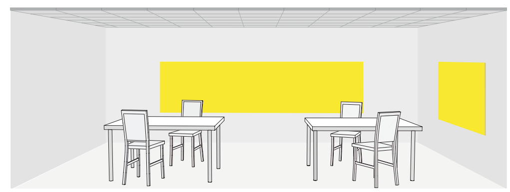


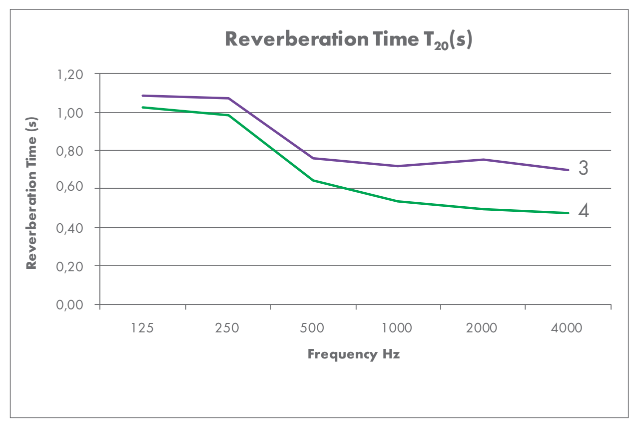


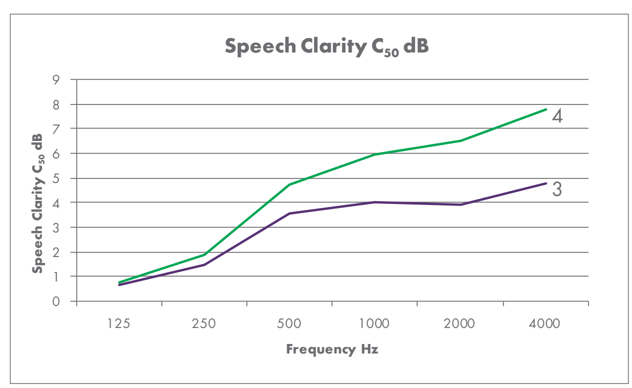


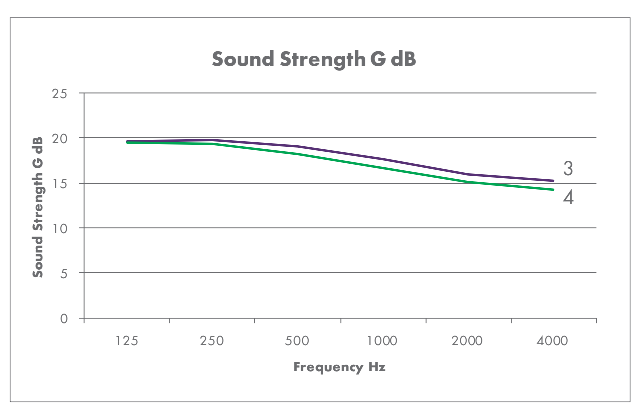
4. Room with a suspended sound-absorbing ceiling, furniture and wall absorbers

Adding wall absorbers will have a significant effect on reverberation time and speech clarity but less effect on sound strength. Now we reach the target values for the reverberation time and sound strength at high frequencies. However, the values at low frequencies are still not good.



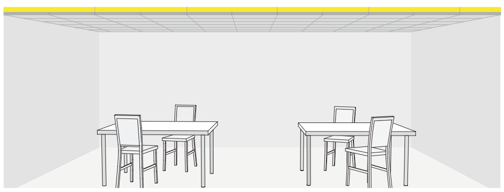


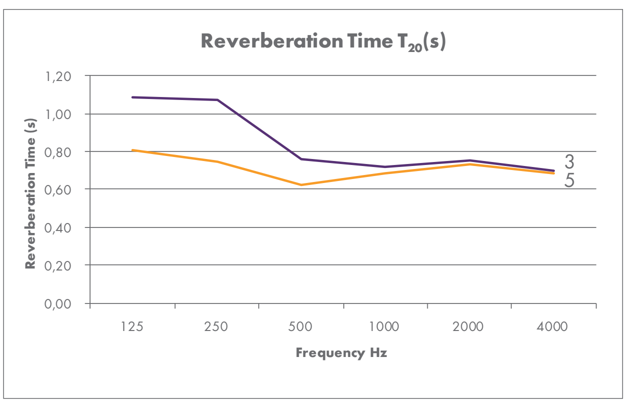


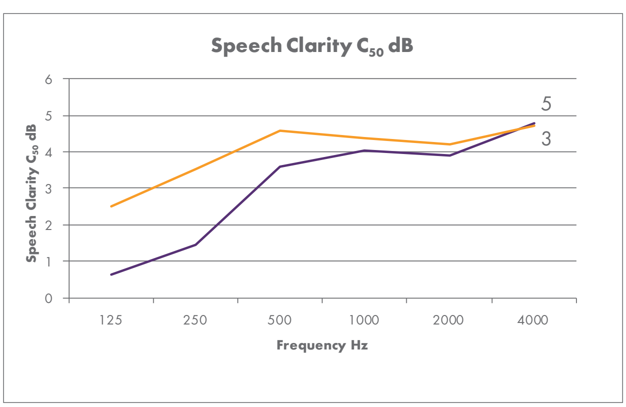


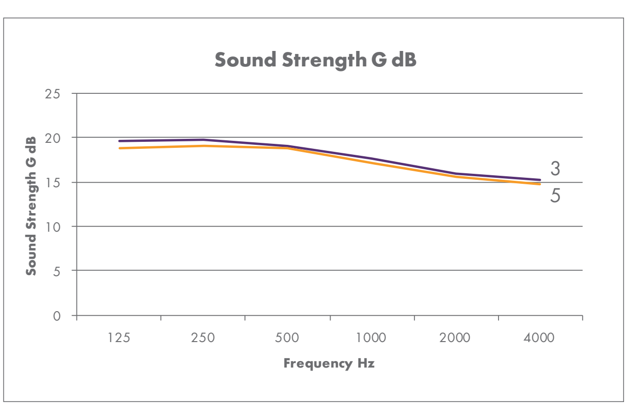
5. Room with a suspended sound-absorbing ceiling, furniture and low-frequency absorbers

An efficient way to improve the absorption in the low frequencies is to add specific low-frequency absorbers above the suspended ceiling. The low-frequency absorbers will especially improve the reverberation time and speech clarity at 125 and 250 Hz.



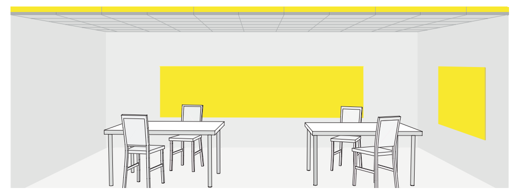


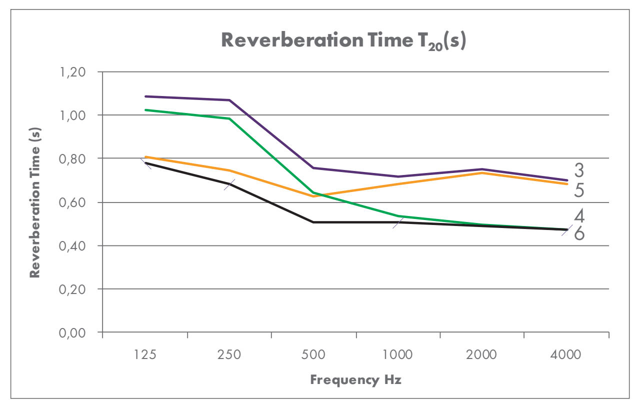


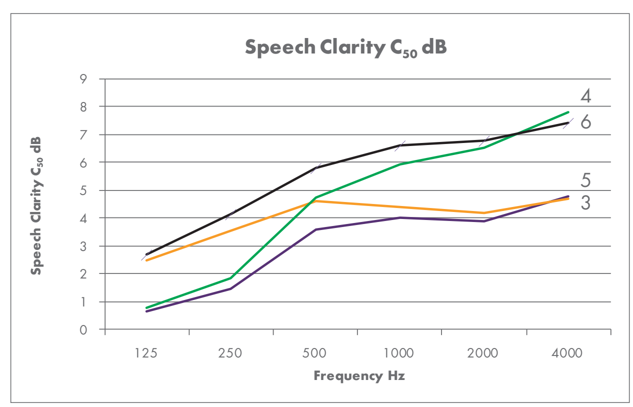


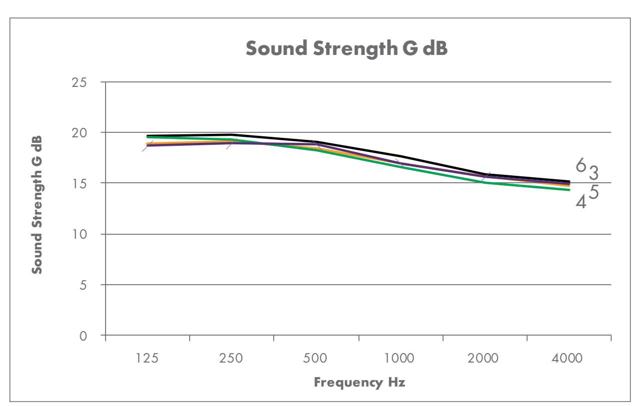
6. Room with a suspended sound-absorbing ceiling, furniture, wall absorbers and low-frequency absorbers

For the sparsely furnished classroom in the example, we can conclude that the combination of a suspended sound-absorbing ceiling, wall absorbers on two adjacent walls and the low-frequency absorbers on top of the suspended ceiling will reach all the recommendations.









Comparison with Sabine

If we go back to the classroom with a suspended sound-absorbing ceiling but without furniture and do a calculation of the reverberation time according to the Sabine formula, the results indicate that the target values are already fulfilled. This emphasize that if there is a lack of sound diffusion in a rectangular type of room and the absorption is mainly focused on one surface, the results given by the Sabine formula can be very misleading. Even in sparsely furnished rooms measured reverberation times normally differ from the ones calculated by the Sabine formula. Another circumstance is that the Sabine calculation does not reveal the great effect of wall absorbers on reverberation time and speech clarity in a room with a suspended sound-absorbing ceiling.

In conclusion all these examples motivate the need of a calculation model especially adopted for rooms with a sound-absorbing suspended ceiling.

New model for calculating
room acoustics

Calculations and measurements of reverberation time alone are most often used to evaluate rooms. Even though a long tradition of research shows that multiple acoustic descriptors are necessary to secure good room acoustics in for instance educational, office and healthcare facilities. Acoustic descriptors such as reverberation time, speech clarity and sound strength support low noise levels and good speech intelligibility. Therefore, Ecophon has promoted these acoustic descriptors since 2007.

Background – Sabine and ISO 3382-1/2

Reverberation time was developed by Wallace Sabine in the 1890s and requires a diffuse sound field (reflexes from all surfaces/angles). It still remains the preferred acoustic descriptor, even though most facilities where speech and communication take place cannot be described as having a diffused sound field. The reason for this is that most of the absorption material often is on one surface; the ceiling. Despite this, reverberation time calculation tools based on the Sabine equation are available online on a lot of platforms.

The Sabine formula is based on the diffuse sound field theory but this is difficult to obtain in reality. When you have absorption on only one surface the decay will not follow a straight line according to the theory. Instead we will get an early part correlating more or less to the theory and a later part with a longer reverberation time (fig. 1).

In rooms with sound-absorbing material on more than one surface (ceiling + adjacent walls) and dense/heavy furnishings, the sound field can be classified as diffused. In this case the Sabine formula seems to work quite well.

In many building regulations and local guidelines reverberation time is the only descriptor to be evaluated. Reverberation time is defined in ISO 3382-2 as the time it takes for the sound to decrease by 60 dB after the source emission has stopped. Reverberation time is more commonly measured in a 20 or 30 dB range (T_{20} and T_{30}) and extrapolated to the full 60 dB range.

However, the measurement starts at 5 dB below the initial level (fig. 2). This is problematic since this part of the decay contains a lot of information – both direct sound and early reflections – important for the perception of sound and speech clarity. The human ear analyses so much more than the defined reverberation time and we need better tools to predict the actual room acoustics – tools that are based on reality and not laboratories.

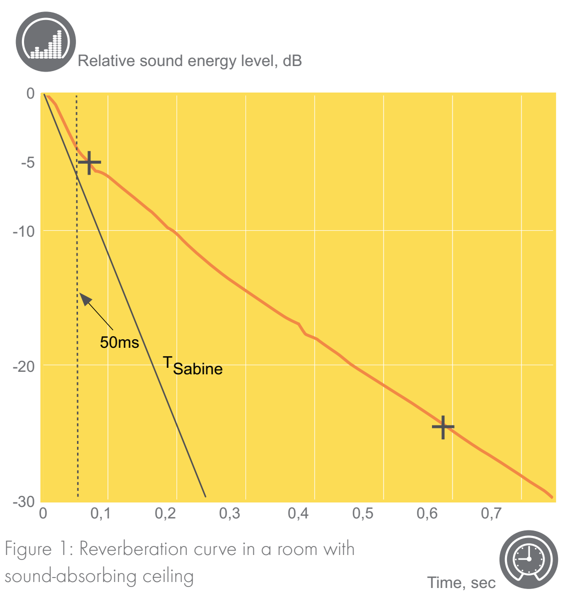


Figure 1: Reverberation curve in a room with sound-absorbing ceiling

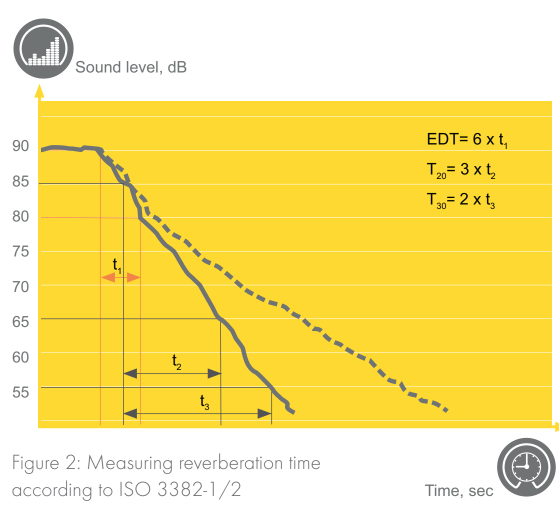


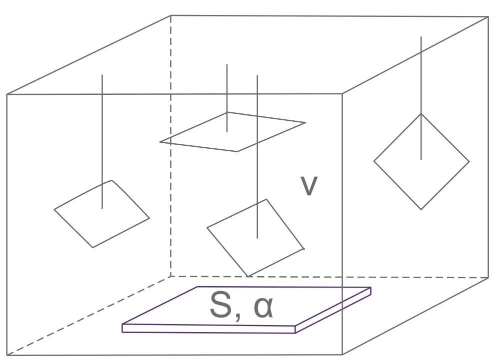
Figure 2: Measuring reverberation time according to ISO 3382-1/2

ISO 354 and the practical absorption coefficient α_p

In order to determine the sound absorbing properties of building material (or products), such as for example suspended ceilings and wall panels, the Sabine formula is utilized according to ISO 354. In a reverberation chamber a diffuse sound field is created with the help of sound reflecting objects (such as boards in various positions and angles). The reverberation time is measured with and without the material to be characterized.

The product to be tested is installed on the floor of the chamber. For suspended products there should be an air gap between the product and the floor. The height of the air gap has a significant influence on the absorbing properties of the product. For practical reasons the measurements are only done with a few different air gap heights.

Knowing the reverberation times with and without the product (T_{with} and $T_{without}$), the volume of the test chamber (V) and the area of the material tested (S), the following calculation is carried out and the absorption factor α is established.



$$\alpha = \frac{0,16V}{S}\left(\frac{1}{T_{with}} - \frac{1}{T_{without}}\right)$$

According to the definition the absorption factor has a value between 0 and 1.0. However, due to the diffraction effect results above 1.0 can occur (fig. 3). The reason for this is the limited test sample area. The size of the area will influence the absorption coefficients (diffraction phenomenon) – especially at the low and mid frequencies.

Based on the measured α, a simplified absorption coefficient called the practical absorption coefficient α_p,

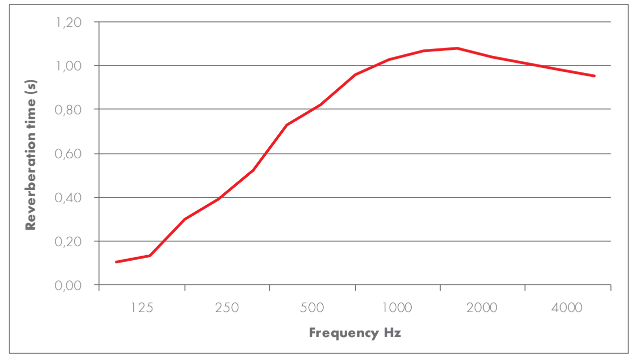


Figure 3: Measurement of sound absorption in a reverberation room. ISO 354

is calculated. It is always between 0 and 1 and is given in octave bands, according to ISO 11654.

Since the sound field in the reverberation chamber is diffuse, i.e. the sound waves/energy will hit the material from 'all' directions, the absorption coefficient is in a strict sense only valid for diffuse sound fields.

To summarize, there are three important limiting factors incorporated in the absorption coefficient:

- The measurements are only done with a few air gaps (different air gaps give different results)
- It is only valid for diffuse sound fields
- The absorption properties in some frequencies are over-estimated due to the diffraction phenomenon

When we test acoustic absorbers according to ISO 354 the labs also play an important role. Due to allowed tolerances in the standard, for instance regarding geometry of the room and measurement procedures, there are differences in measurement results between labs. Therefore, the results should only be used to compare products' performance if they are measured in the same lab at the same occasion. The α_p is to be seen as a specific lab product property only – not as a product property in regards to acoustic design in reality.

ISO 11654 and the classification of products

When we compare acoustic absorbers we often do it according to ISO 11654 that in a simple way classifies products from A to E (+ unclassified). This standard gives us a weighted sound absorption index and is a further simplification based on the α_p. The α_p values are compared to fixed reference curves and based on these the product is classified and we get the α_w for the product (fig. 4).

It is easy to communicate this weighted index and α_w to all target groups and it is maybe the easiest way to communicate acoustic performance to laymen, but we need to remember that this index is a simplified ‘version’ of α_p. Since it can change the classification of a product, you also have to specify an overall depth of a system in connection to your absorption class. Further, the index does not contemplate if the space above the absorber is only air or for instance filled with insulation. All this considered, the index does not give us the answer to how a product will perform in reality. Instead it gives us a comparable number based on lab results.

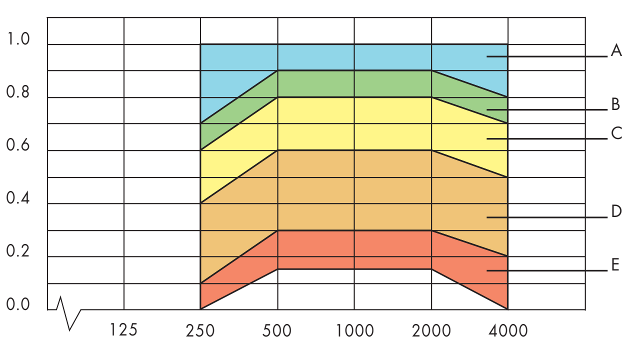


Figure 4: Absorption classes

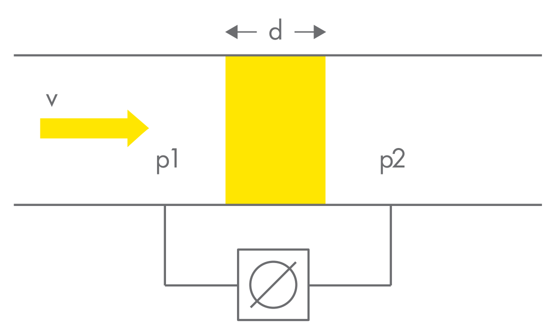
Introducing air flow resistance (AFR)

A more product specific property for characterizing porous absorbers is air flow resistance. By using air flow resistance, it is possible to calculate absorption coefficients that are more applicable to Activity Based Acoustic Design. And therefore more suitable to be used as input data in acoustic calculation models.

Air flow resistance is a pure product specific property and the testing method does not have the same problems as mentioned above, describing ISO 354 and ISO 11654. Air flow resistivity is tested according to ISO 9053 and it simply evaluates sound waves’ propagation through the absorber by measuring the difference between p1 and p2 (p=pressure) and divide it by the speed (v) times the thickness of the absorber (d). Air flow resistance is only divided by the speed (v).

It is important to state that there is no such thing as one ‘perfect’ air flow resistance value for a porous absorber. Instead there is an optimum air flow resistance value for each absorber at a certain o.d.s. (overall depth of system).

When you measure air flow resistance, the deviations in regard to reproducibility are very low and their effect on absorption coefficient calculations is minuscule (fig. 5).



$$\text{Flow resistivity } r = \frac{\Delta p}{v \cdot d} \quad \left(\frac{\text{Pa s}}{\text{m}^2}\right)$$

Figure 5: Testing method for AFR – ISO 9053

Calculations of absorption coefficients utilizing air flow resistance

As mentioned it is possible to calculate absorption coefficients on porous products when air flow resistance is known. Delany and Bazley's model from 1970 is empirical and the basis for other models today. Ecophon has chosen to use Miki's model from 1990. It was developed from Delany and Bazley's model – and is a bit more accurate at the lower frequencies. Using this model, we get an absorption coefficient that reflects reality and not a testing method in a lab. It is worth mentioning that large differences in air flow resistance (by number) don't always result in large differences in the end.

$$Z_c = \rho_0 c_0 \left[1 + 0.070 \left(\frac{f}{\sigma}\right)^{-0.632} - j0.107 \left(\frac{f}{\sigma}\right)^{-0.632} \right]$$

$$k_t = \frac{\omega}{c_0} \left[1 + 0.109 \left(\frac{f}{\sigma}\right)^{-0.618} - j0.160 \left(\frac{f}{\sigma}\right)^{-0.618} \right]$$

In short – when we know the air flow resistance of a porous absorber we will have the possibility to calculate more accurate absorption coefficients – and then we can calculate not only reverberation time but also other acoustic descriptors like speech clarity and sound strength.

Calculations based on air flow resistance will often show other results than what we can calculate using the Sabine equation and α_p – but the results will be more accurate when we compare it to what actually happens in reality – as shown in many measurements. We must never forget that the Sabine equation in itself is based on a condition that is difficult to obtain in reality. On top of this α_p according to ISO 354 is to be seen as a product parameter which is influenced by the measurement procedure – and not directly an applicable design parameter.

Air flow resistance should never be an argument in itself in regards to what products perform 'best'. Air flow resistance is a product property that helps us to calculate more accurate acoustic descriptors.

New model for calculating sound decay in rooms

A new model for calculating the sound decay in rooms with absorbing ceilings has been developed by Ecophon. The model is especially adapted for the acoustical conditions that appear in rooms with sound-absorbing ceilings. The main idea behind the model is that the sound field in this type of room can be subdivided into two components referred to as the grazing and non-grazing sound fields. The grazing sound field comprises sound waves travelling more or less parallel to the ceiling and the non-grazing field comprises 'diffuse waves' with a steeper angle towards the ceiling. Addition of the grazing and the non-grazing decay curves gives the total reverberation decay curve (fig. 6).

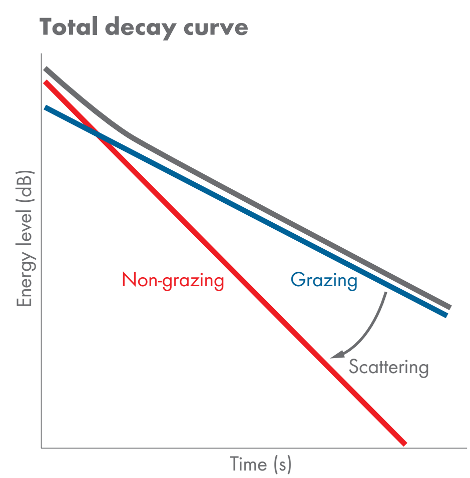


Figure 6: Total decay curve

Based on the total decay curve speech clarity, reverberation time and sound strength can be calculated. An important property of the model is that sound scattering due to furniture or other interior objects can be quantified as the transferring of sound energy from the grazing to the non-grazing sound field. Another feature in the model is that air flow resistance is used as input data for porous ceiling absorbers. Starting with air flow resistance, calculations considering the effect of the actual mounting height and other circumstances that is not inherent in the practical absorption coefficient can be taken into account, such as the fact that the sound absorption depends on the angle of incidence.

The Ecophon Acoustic Calculator

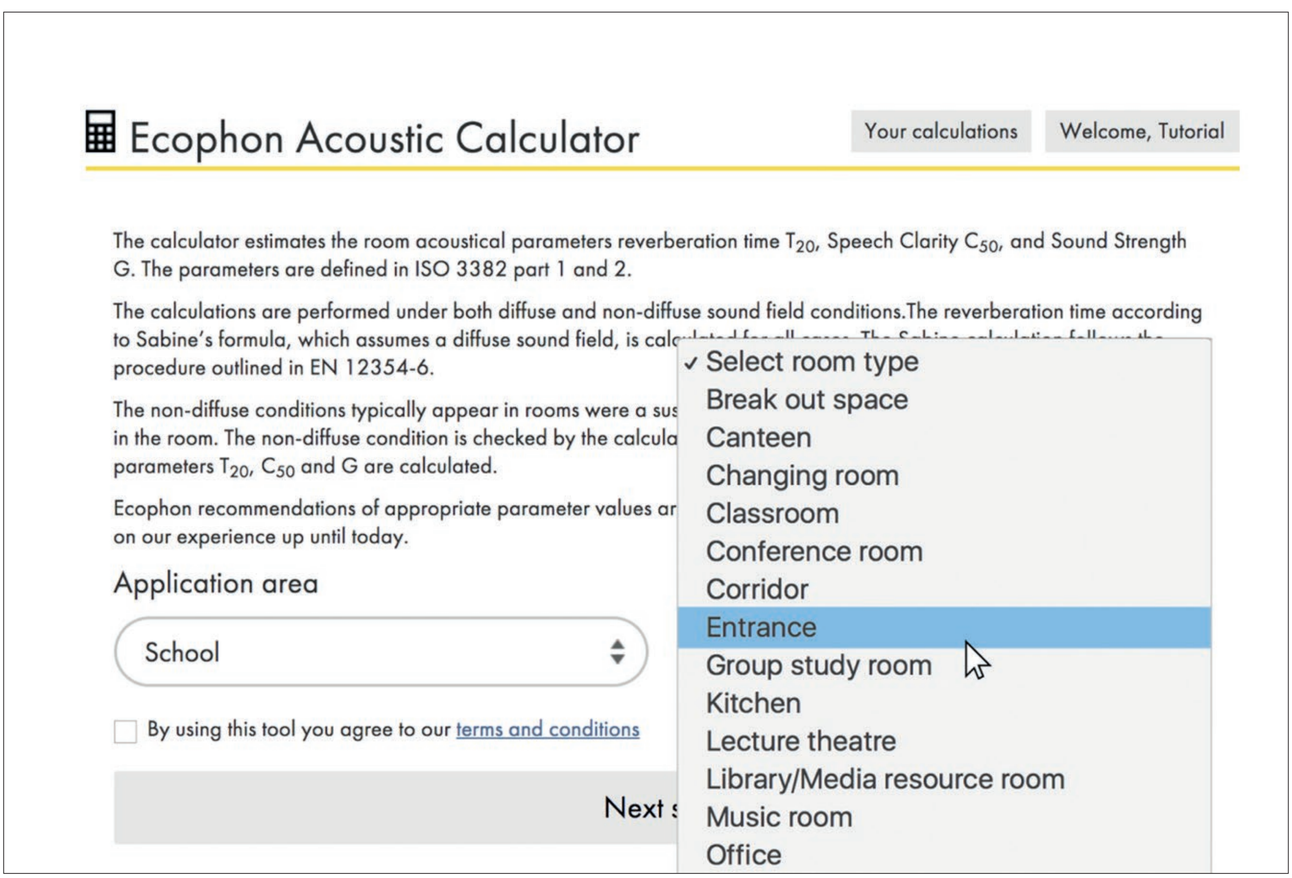
Free to use

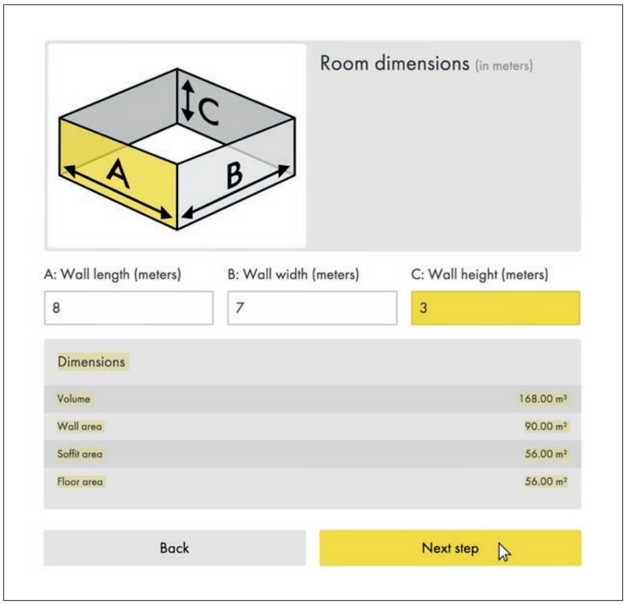
The Ecophon Acoustic Calculator is an easy-to-use e-tool that is free to use. By using it you will be able to get correct acoustic values without the need of actual measurements. This means you can now design spaces and really know that they will enhance people´s wellbeing and performance. Already at the drawing table.

You find the calculator at ecophon.com/e-tools.

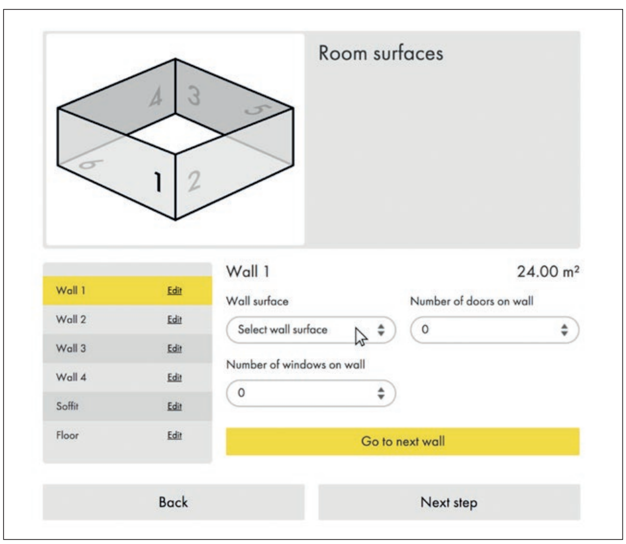
The calculator will guide you step-by-step through the information you need to provide. Most of the information is given by choosing between options in drop-down menus.

1. The type of space you want to calculate.
If it for instance is a cellular office, a sports hall in a school or a canteen in a hospital.



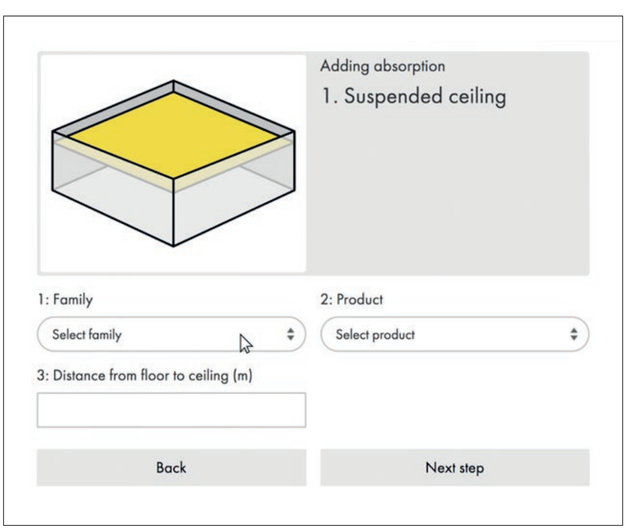


2. Room dimensions

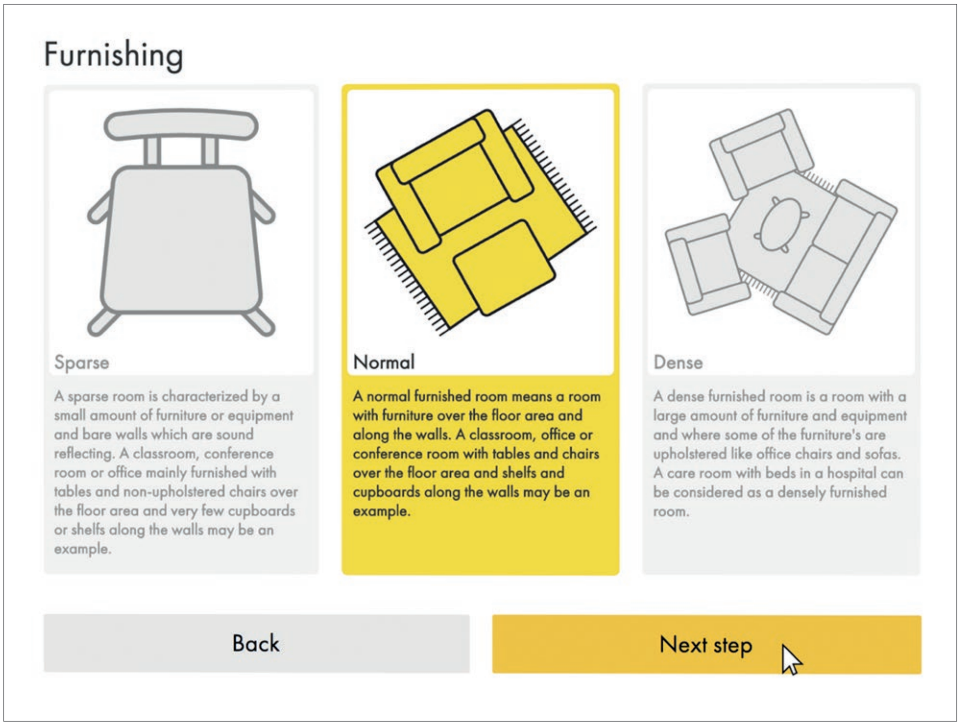


3. Walls, floor and soffit material

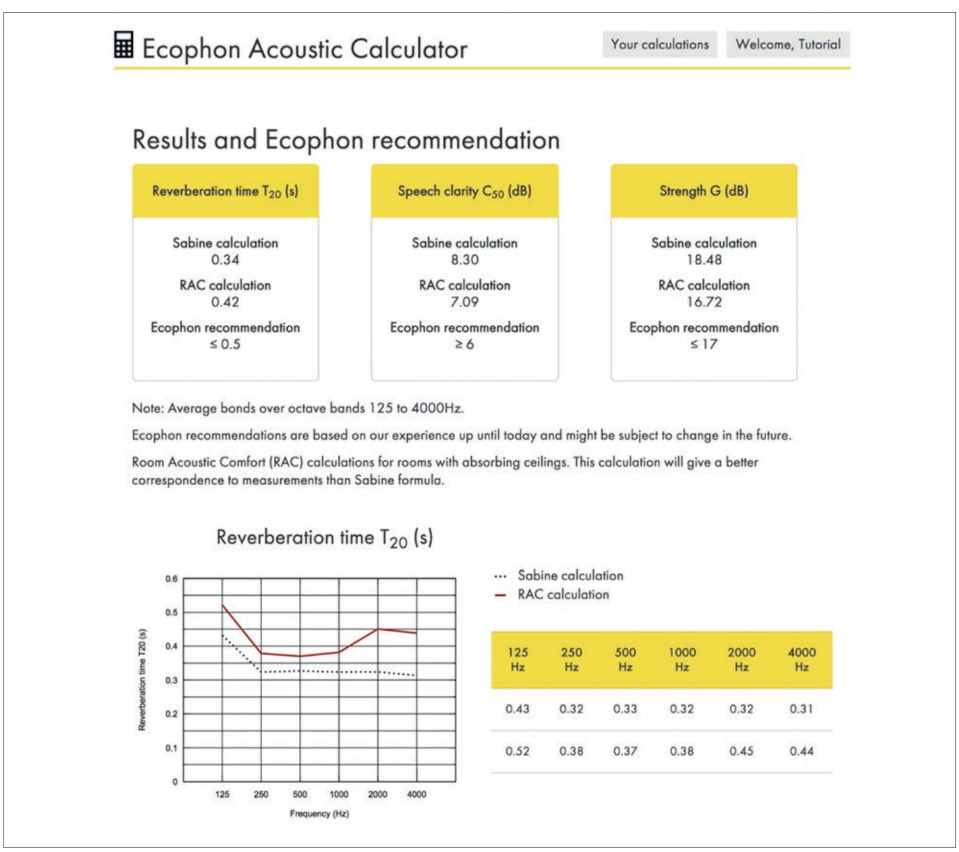
4. The number and sizes of doors and windows



5. Your choice of sound absorbers for the ceiling and walls



6. The amount of furniture likely to be in the room



7. Instant results

When this is done, the calculator will in just a few seconds give you the results and recommendations. For you to be able to compare the figures to the traditional Sabine formula, this is also included in the results.

Ecophon Acoustic Calculator

Your calculations | Welcome, Tutorial

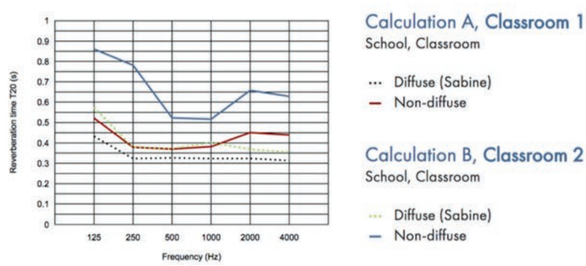
Comparing calculations

Calculation A, Classroom 1
School, Classroom

Calculation B, Classroom 2
School, Classroom

	Reverberation time T_{20} (s)		Speech clarity C_{50} (dB)		Strength G (dB)	
	A	B	A	B	A	B
Diffuse (Sabine)	0.34	0.41	8.30	6.67	18.48	19.23
Non-diffuse	0.42	0.66	7.09	4.49	16.72	17.70
Ecophon recommendation	≤ 0.50	≤ 0.50	≥ 6.00	≥ 6.00	≤ 17.00	≤ 17.00

Reverberation time T_{20} (s)



	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
	A	B	A	B	A	B	A	B	A	B	A	B
Diffuse (Sabine)	0.43	0.57	0.32	0.38	0.33	0.37	0.32	0.40	0.32	0.37	0.31	0.35
Non-diffuse	0.52	0.86	0.38	0.78	0.37	0.52	0.38	0.52	0.45	0.66	0.44	0.63

8. Save your calculations

Using the calculator is completely free. If you are a registered user you can also:

- save all your calculations
- send them via e-mail
- compare calculations
- download pdf reports

Non-registered users can:

- download pdf reports

Welcome to the Ecophon Acoustic Calculator!

Ecophon®
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A SOUND EFFECT ON PEOPLE

Ecophon is the leading supplier of acoustic solutions. We contribute to healthier indoor environments, improving quality of life, wellbeing and working performance. As evolution has adapted the human senses to a life outdoors, our focus is to bring the ideal acoustic environments of nature into our modern indoor spaces. We know they will have a sound effect on people.

The principles guiding our work are grounded in our Swedish heritage, where a human approach and a common responsibility for people's lives and future challenges come naturally.

Ecophon is part of the Saint-Gobain Group, a world leader in sustainable habitat solutions. This is also one of the top 100 industrial groups in the world, constantly innovating to make living spaces more comfortable and cost-efficient. Saint-Gobain offer solutions to the major challenges of energy efficiency and environmental protection. No matter what new needs emerge in the habitat and construction markets, the future is made of Saint-Gobain.

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www.ecophon.com

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