

Energy-Smart Nidaros Cathedral

Site Information and Energy Data (v. 2018-04-18)

Official project website: <http://climate-kic.org/nidaros>

Organizing partners:



TRONDHEIM
MUNICIPALITY



Climate-KIC



NIDAROS
DOMKIRKES
RESTAURERINGSARBEIDER

Associated partners:



DEN NORSKE KIRKE
Kirkelig fellesråd i Trondheim



TECHNOPORT



Climate-KIC is supported by the
EIT, a body of the European Union

TABLE OF CONTENT

General information about Nidaros Cathedral	1
Cultural heritage conservation and energy consumption	5
Energy consumption of Nidaros Cathedral	6
The surroundings in a historic neighborhood	9
A unique and important urban challenge for the City of Trondheim	14

List of attachments (to be downloaded separately)

- 01 Architecture and technical drawings
- 02 Energy consumption 2014 – 2017
- 03 Outdoor temperature Trondheim Voll station 2014-2017
- 04 Indoor temperature 03.2016-04.2018
- 05 Maps of district heating systems

Organizing partners

Trondheim Municipality
Nidaros Cathedral Restoration Workshop (NDR)
EIT Climate-KIC

Associated partners

The Common Church Council in Trondheim
Technoport

General information about Nidaros Cathedral

History and architecture

Nidaros Cathedral is the world's northernmost medieval cathedral and Norway's national sanctuary. It is the grave church of St. Olav, the patron Saint of Norway and has now become one of Europe's major historical pilgrim destinations. Nidaros Cathedral is also where coronations and royal blessings take place.



The cathedral is mainly built in soapstone. It is located on the foundations of former churches, and the oldest standing parts of the church, the transepts, are from about 1160-70. The church is rebuilt with brick vaults over the choir and western nave, and across the archways under the triforium. The copper-covered roof is carried by steel structures with the exception of the transepts, the chapter house and the extended chapels in the transepts which all have pure wood structures in the roof.

The cathedral is in both Romanesque-Norman style (transepts and tower) and Gothic style. The building seems to have captured examples and inspiration from English architecture

from the same period and was the largest cathedral in Northern Europe in the Middle Ages. Besides the Church of Our Lady, this is the only church from the medieval Trondheim that has survived until today.

Nidaros Cathedral lies alongside with the Archbishop's Palace (Archbishop's and later the lords' residence) in the south end of Midtbyen, Trondheim's city center today. These properties, together with the cemetery, are located with River Nid as a natural boundary to the east and south and the old Waisen House (house of the congregation) as the boundary to the west. The church has been extinguished by fire several times. After the Reformation and until the restoration work started, only the transepts and the church building to the east of them were held and used as a common parish church.



The restoration of the Nidaros Cathedral started in 1869. Since 1930, the western nave was reused after almost sixty years of restoration and reconstruction. In the lower parts of the

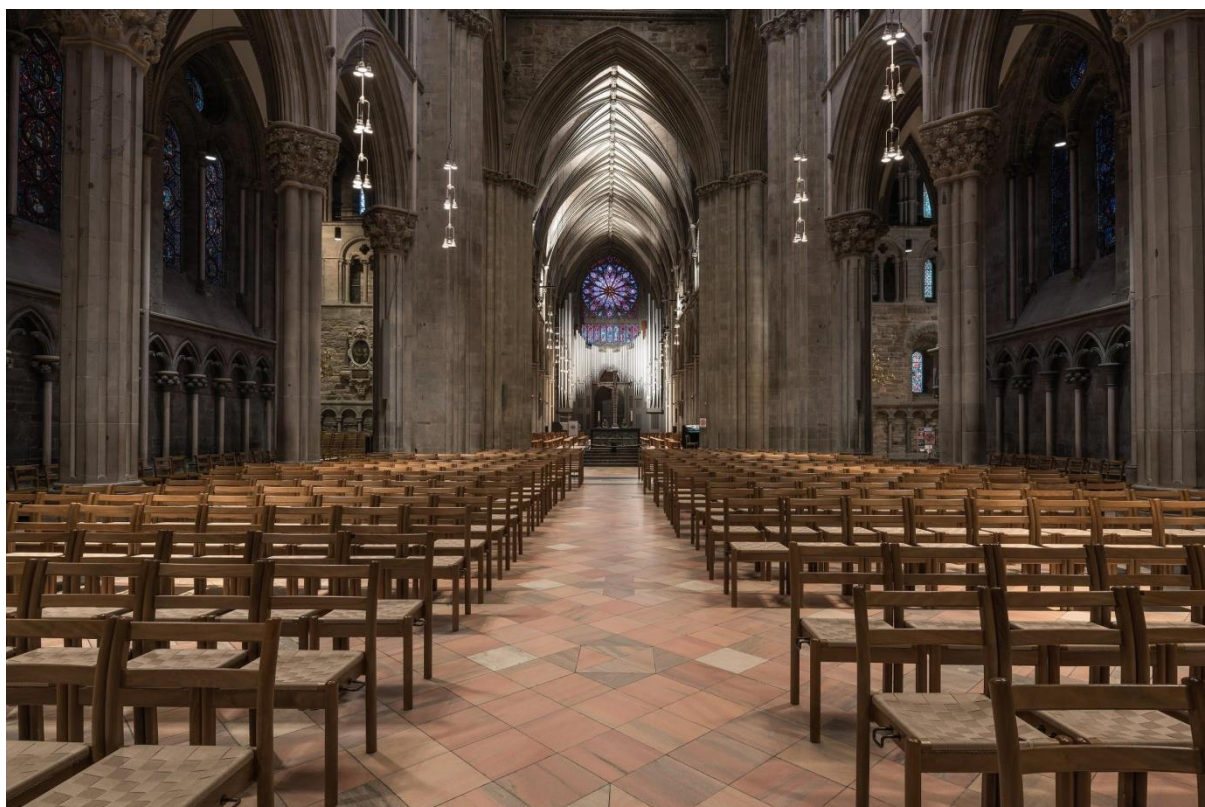
west, the original masonry is still very well preserved. The reconstruction of the cathedral was considered finally finished in 2001 with the completion of the millennium chapel in the northwest tower.

The cathedral has no permanent seating or fixed church benches. It is possible to put out approx. 1200 chairs during masses and arrangements.

There are three large organs in the cathedral: a Steinmeyer organ from 1930 (rest 2014), being the largest in the Nordics with about 10,000 pipes mainly located in the western nave, a Wagner organ from 1739 (rest 1997) and a new organ placed in the southern choir triforium (2016). In the high altar (Octagon) there are twelve old chairs in oak wood with golden leather from the 18th century, and in the chapterhouse there is a parament chest in oak wood from the 13th century. These are recognized as vulnerable furnishings beside the organs and a few paintings in the transepts and the west nave.

The floor plans and the schema heating system can be found in the attachment:

- 01 Architecture and technical drawings



Interior inside Nidaros Cathedral (from east towards west)

Management and operation

The congregation of "Nidaros Cathedral and Our Lady's Church" (Church of Norway) is the user of the church building, which is run jointly with the national agency Nidaros Cathedral Restoration Workshop (NDR). Nidaros Cathedral is managed, maintained and restored as a cultural heritage by NDR.

Nidaros Cathedral and Our Lady's Church are important arenas for art and culture in Trondheim. Other than religious gathering and messes, they also organize public events in Nidaros Cathedral such as concerts, literary and stage productions, art exhibitions, seminars and more, both self-initiated and in collaboration with other cultural institutions in the city.

Nidaros Cathedral is open all the days of the year. NDR and the Church dispose the cathedral at different times of the day and during the year. In the opening hours of the NDR, visitors may enter for a fee. Nidaros Cathedral is one of the most popular tourist attractions in Trondheim and Norway.

TABLE: Number of visitors in Nidaros Cathedral

	2013	2014	2015	2016	2017
January	8 918	3 787	9 044	11 661	14 329
February	13 173	4 944	15 350	16 000	23 675
March	18 873	10 397	13 916	17 531	20 213
April	20 048	12 334	18 377	13 409	22 364
May	35 198	22 428	29 160	25 281	28 995
June	51 468	48 986	49 118	61 101	62 647
July	66 364	62 778	73 497	87 600	93 396
August	44 696	44 598	49 529	63 810	62 995
September	24 094	19 276	21 404	29 890	28 646
October	18 442	14 070	18 470	23 825	23 715
November	8 918	17 747	17 121	19 472	20 851
December	19 228	24 458	31 281	28 564	26 570
Jan-Apr	61 012	31 462	56 687	58 601	80 581
May-Aug	197 726	178 790	201 304	237 792	248 033
Whole Year	329 420	285 803	346 267	398 144	428 396

Remark: It is possible to get more detailed statistics at hourly and daily level if needed. It is also possible to gather information about various types of user groups from the booking calendar, but this is a time-consuming task and will only be done upon further inquiry.)

St. Olav Festival (Olavsfestdagene) is held every year around St. Olav Day (Olsok, July 29) with an extensive program of cultural and church events, putting Nidaros Cathedral and its surroundings in focus. The festival is organized by its own foundation.

The lighting system is being upgraded

The current lighting system is from the 1960s and was designed for the church audience to read the hymn books. NDR, the Church and St. Olav Festival have long seen the need for a total upgrade. The new system aims to shed much better light on the architectural treasures in this iconic building. The upgrade of the entire lighting system also gives a good opportunity to examine the overall energy consumption of the cathedral.

The total cost for the new system is estimated to be between 20 to 22 million NOK (Norwegian kroner). It is scheduled to be completed in 2019, when NDR celebrates its 150 years' anniversary.

In 2030, the millennial celebration of St. Olav's heritage will take place. This will also be a celebration of Norway as a nation. The ultimate intension of this Urban Challenge is to evaluate the feasibility of transforming Nidaros Cathedral and its surrounding to an energy-positive complex by then, making a historic and religious monument power-generating in more ways than one.

Cultural heritage conservation and energy consumption

Buildings are responsible for 40 per cent of energy consumption and 36 per cent of CO₂ emissions in the EU. The EU has therefore set the target for all new buildings to be nearly zero-energy buildings within 2020. How do we apply the necessary knowledge and innovation to existing building stock? Old buildings and new technologies should have room for each other. This is about both reducing energy consumption and increasing the use of renewable energy sources. With this said, protected buildings are estimated to account for less than 1 per cent of the already built environment.

As the climate impact from building phase (production of materials, transport, construction) has already been taken into account, old buildings represent an important resource that we must continue to use. It is fully possible to increase energy efficiency of buildings without destroying their characters and historic values. Often it can be done at low cost, while

reducing the energy bills and improving the comfort of the users. For protected buildings, it is not often possible to reduce energy consumption to the level which corresponds to new buildings. The use of renewable energy can thus compensate for this in order to reduce the climate impact.

For the conservation of protected buildings and cultural heritage, it is important to implement energy efficiency measures on the building's premises. Major changes to facades and interiors should be avoided. One should also prevent measures that lead to moisture and rot damage, weakened fire safety or poor indoor climate. It is therefore important to understand how the building works and be aware of the consequences of the various measures. There is no single solution that works best. Each property has its own character both technically, architecturally and operationally and must therefore be assessed individually.

There are strict protective regulations on every step that can make changes to constructions and appearance (interior and exterior) of Nidraos Cathedral and its immediate surroundings. Approvals are required before any digging activities because of the status as a protected archaeological area. However, it is also known that there have been changes over time to make the cathedral more suitable for modern use. The rule of thumb is to make as little change as possible and not more than necessary. One should try to build solutions on earlier ditches for infrastructure.

In Norway, the Directorate for Cultural Heritage is responsible for the management of all archaeological and architectural monuments and sites and cultural environments in accordance with relevant legislation. (Website: <https://www.riksantikvaren.no/en/>)

Useful report (in Norwegian):

[Råd om energisparing i gamle hus](#) (Advice on energy saving in old buildings)

Energy consumption of Nidaros Cathedral

In the year of 2017, Nidaros Cathedral consumed 1.5 GWh of energy, 79 per cent from district heating and 21 per cent from electricity. It is spent 1.04 million NOK on energy bills (without VAT), 73 per cent for district heating, 11 per cent for the amount of electricity and 16 per cent for electricity grid. In the table on the next page, a monthly overview is presented.

TABLE: Monthly energy consumption and cost in 2017

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
District heating (kWh)	149180	149470	156940	130840	72940	30770	18050	16510	34340	100120	157550	174380	1191090
Cost (NOK)	87159	89259	93151	78298	50023	27008	21565	21127	30965	62163	95949	103481	760148
Electricity (kWh)	28082	22426	28438	17382	17393	17704	18528	20743	19003	23288	29690	70222	312899
Cost for electricity (NOK)	9787	8269	10214	6227	6350	5735	5876	7067	7480	8238	11881	26251	113375
Cost for grid (NOK)	14820	12759	14896	12254	12541	11895	12341	12814	12172	13356	15732	24687	170268
Total energy consumption (kWh)	177262	171896	185378	148222	90333	48474	36578	37253	53343	123408	187240	244602	1503989
Total energy cost (NOK)	111766	110287	118260	96779	68914	44638	39782	41008	50617	83757	123562	154419	1043790

Other energy data can be found in the attachments:

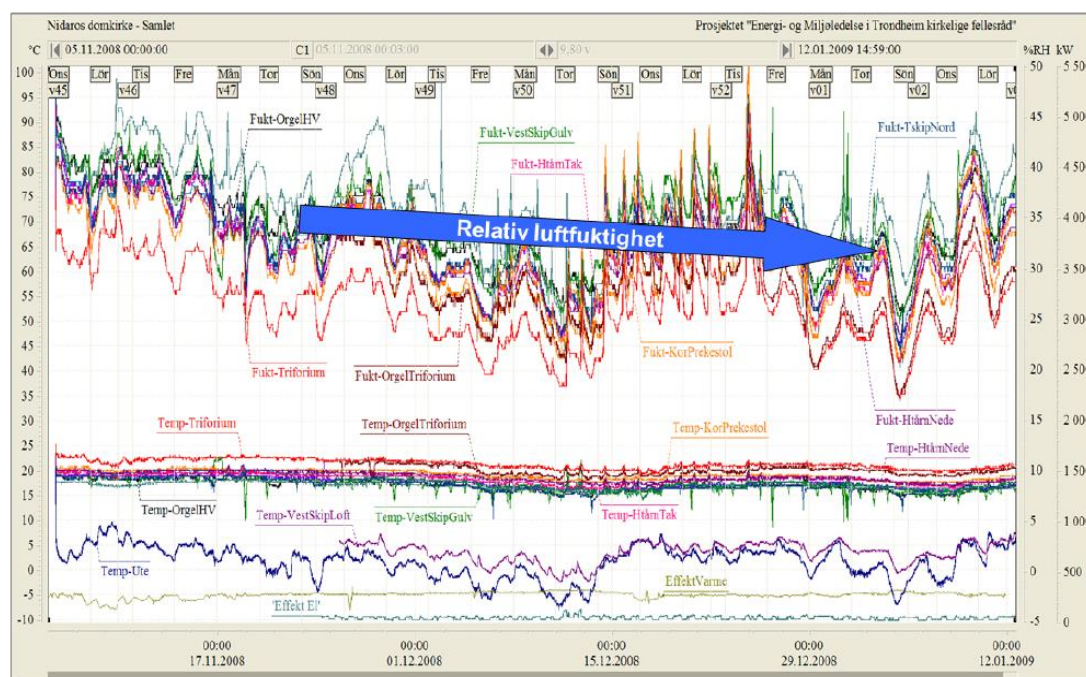
- *02 Energy consumption 2014-2017*: the monthly energy consumption of Nidaros Cathedral during 2014-2017
- *03 Outdoor temperature Trondheim Voll station 2014-2017*: daily measurement in Trondheim over the period of these four years
- *04 Indoor temperature 03.2016-04.2018*: temperature measurement over two years at five points: vestskip (west nave), tverrskip sør (transept south), tverrskip nord (transept north), oktagon/kor (high altar/choir), triforiet/klerestoriet (triforium/clerestory).

The Common Church Council in Trondheim and Nidaros Cathedral Restoration Workshop (NDR) are jointly responsible for the operation and maintenance of Nidaros Cathedral. In 2009, a report was compiled with results from the assignment of *active follow-up and measurement of temperature, moisture and energy use* in order to strengthen the energy and environmental management of the cathedral.

The diagram below shows that temperature inside the cathedral stayed relatively constant whether the cathedral is in use or not. Constant heating close up to use temperature gives

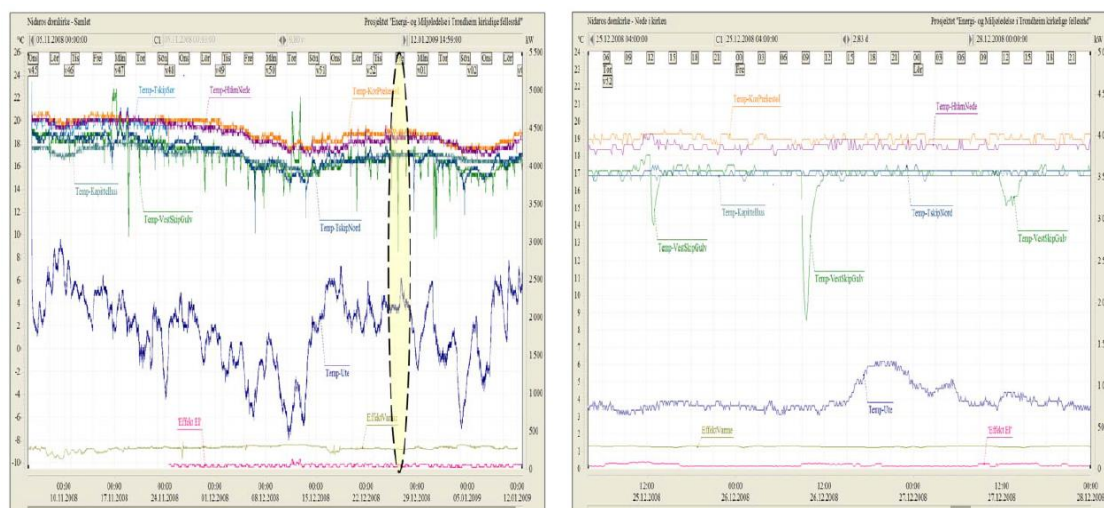
low moisture, and this is unfavorable for conservation of the organs and other valuable interior.

DIAGRAM 1: Temperature and relative moisture indoor



(05.11.2008-12.01.2009)

DIAGRAM 2: Temperature measure at various points indoor and outdoor



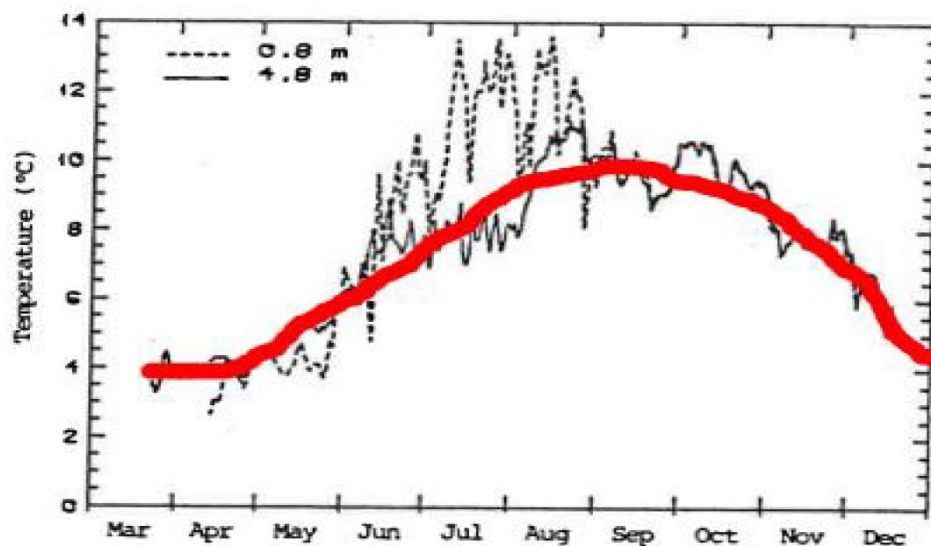
(Left: 05.11.2008-12.01.2009, right: 25-28.12.2008)

The surroundings in a historic neighborhood

In Norway, Enova is the funding agency owned by the Norwegian Ministry of Climate and Environment with the mandate to work on reduced greenhouse gas emissions, development of energy and climate technology and a strengthened security of supply. Since the beginning of 2016, Enova launched a new concept study program ([Enovas konseptutredning](#)) calling for innovative energy- and climate-related solutions in buildings, neighborhoods and energy systems. Can a historic neighborhood be transformed into a "smart sustainable district" (Climate-KIC's [Smart Sustainable Districts](#) initiative) with the help of state-of-the-art concept and technology? This open innovation competition would like to draw attention to this issue.

What about locally-produced renewable energy? While the possibility of making visible changes to the facades and interiors to the Nidaros Cathedral can be rather limited, one may to a greater extent examine the potentials in the surrounding neighborhood. One should exercise similar concerns for conservation in a historic neighborhood, but there are sites and spaces that give opportunities in between the protected buildings. Attached are the maps of district heating systems to Nidaros Cathedral and its surrounding. This is existing infrastructure which one may consider to build solutions upon.

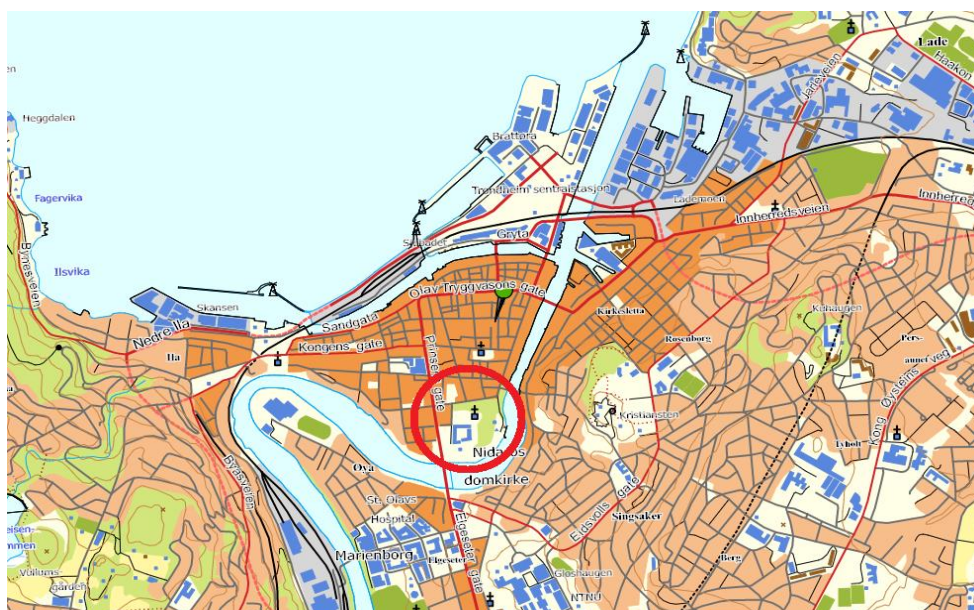
The figure below shows temperature measurements (daily mean value) in the River Nid in 1981 (source: SINTEF). More updated data is not available.



Maps of the surrounding neighborhood

For the purpose of this open innovation competition, the boundary of the neighborhood is drawn with Erling Skakkes gate to the north, Prinsens gate to the west and the surrounding River Nid to the east and south. One may also feel free to use the [open map system](#) via the website of Trondheim Municipality if more information is needed.

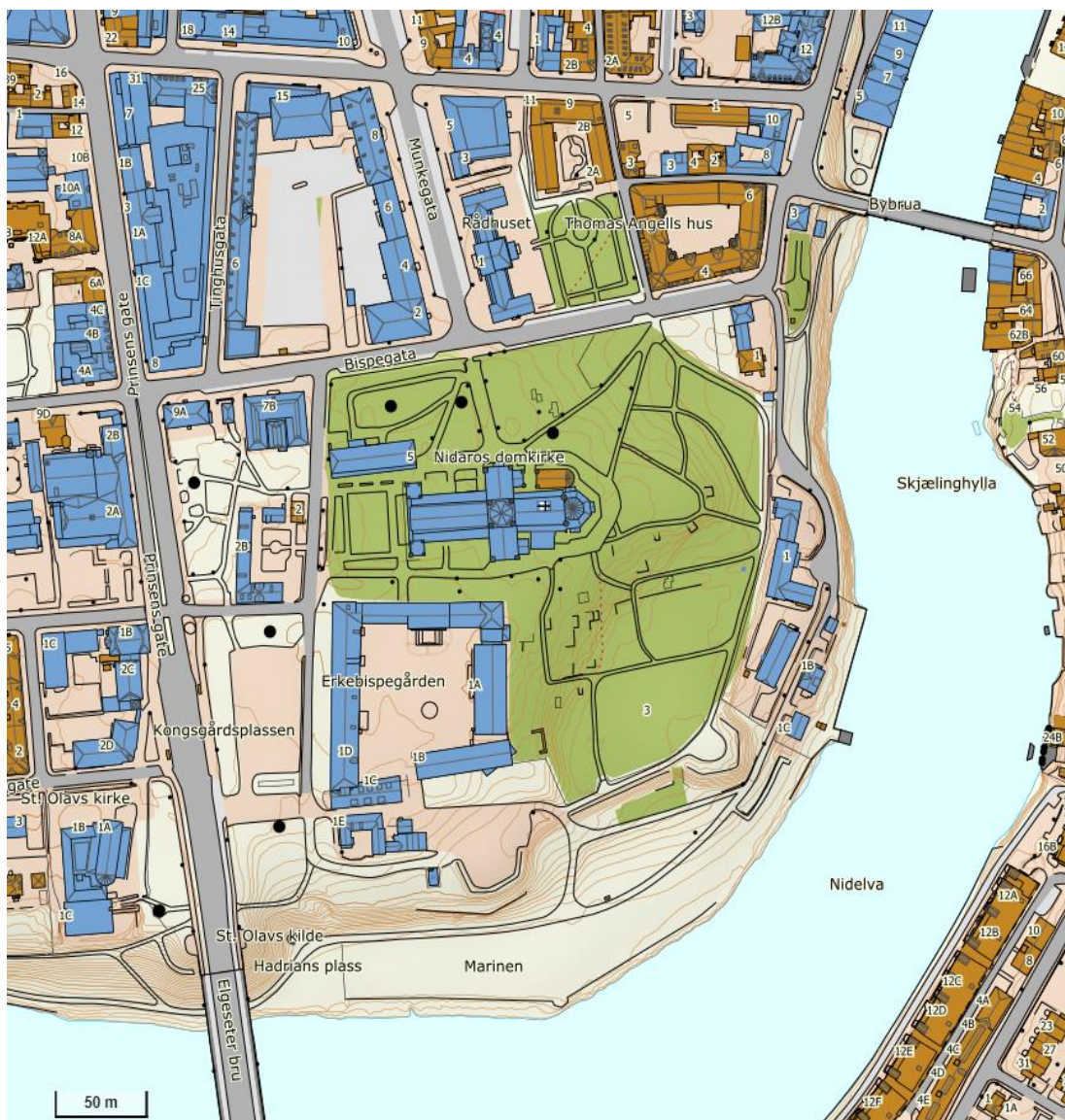
MAP: Trondheim city center (with Nidaros Cathedral and its surrounding marked in red circle)



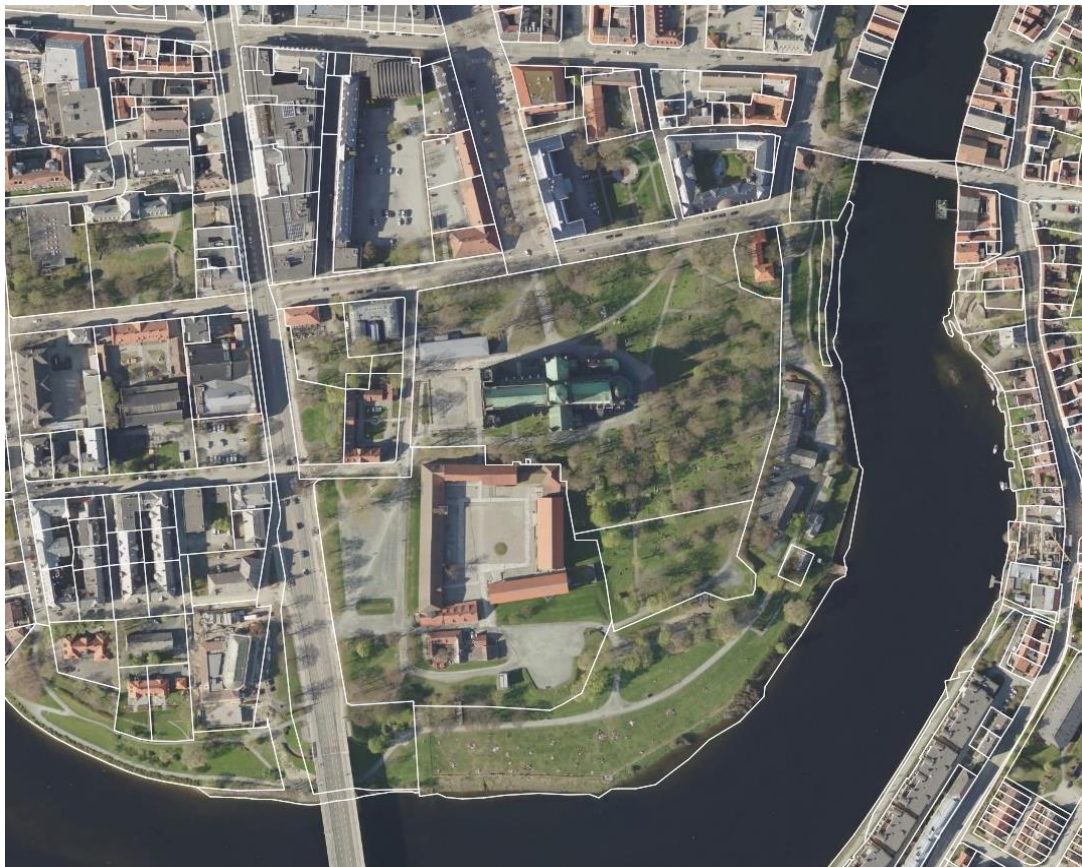
MAP: Neighborhood boundary (North: Erling Skakkes gate. West: Prinsens gate)



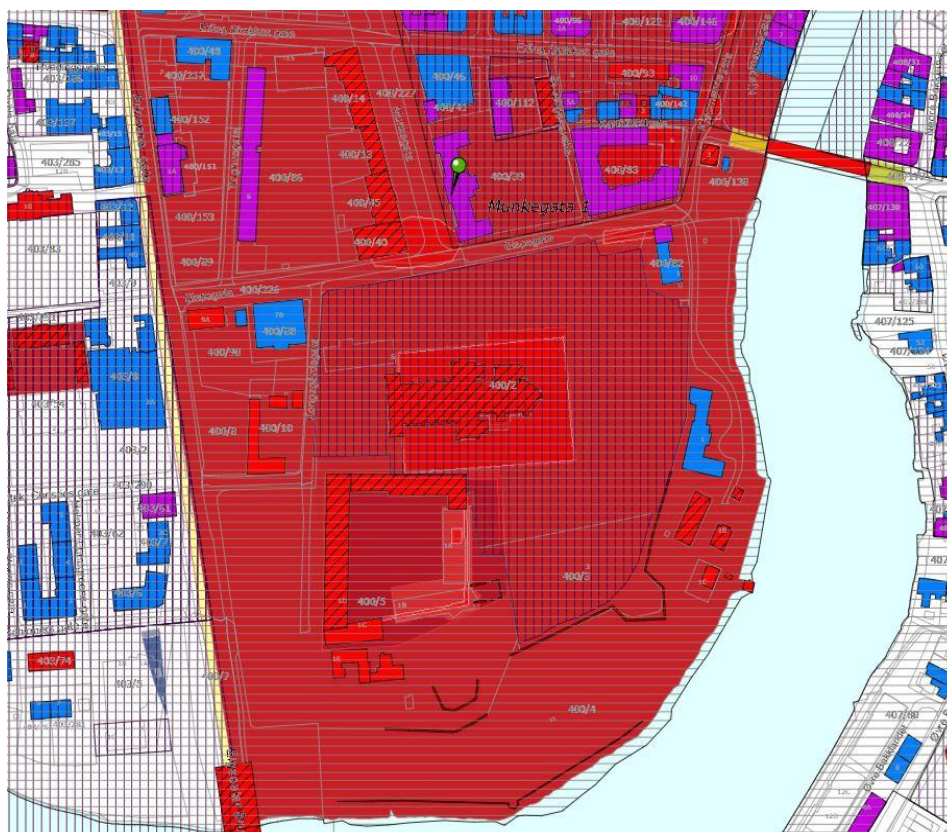
MAP: Detailed street map



MAP: Satellite map with property boundary



MAP: Color codes of cultural heritage conservation



In the advanced map database, caution map (aktsomhetskart) for cultural heritage provides information about different protection levels of buildings and urban spaces. The information is categorized and visualized in the following color codes for buildings:

- **Red** - Very high antiquarian value
- **Purple** - High antiquarian value
- **Blue** - Some antiquarian value

The red background color for the area means that it is “protected area and archaeological cultural heritage”, and this applies for the entire neighborhood for this competition.

In Trondheim, the Municipal Conservation Office is responsible for the evaluation of building status together with the equivalent authorities at national and regional level. Buildings and facilities that are protected according to the Cultural Heritage Act have the highest status of protection by law. This can also include the interior.

For more information: see [Aktsomhetskart kulturminne](#)

A unique and important urban challenge for the City of Trondheim

The City of Trondheim aims to be a frontrunner for development of climate-friendly technologies. The Municipal Plan for Energy and Climate 2017-2030 set the ambition to reduce greenhouse gas emissions by 80 per cent by 2030 (1991 baseline).

Can a large cultural heritage monument contribute to set a good example? Trondheim is known as the technological capital of Norway and at the same time a thousand-year-old city with a large number of protected buildings and cultural heritage monuments. This makes a unique playground for innovation.

Trondheim aims to become a smart and sustainable city. The *Knowledge Axis*, stretching from Sluppen in the south to Brattøra/Nyhavna in the north, is the focal urban area for development and display of smart sustainable solutions. Norway's first new-built Powerhouse will soon be realized at Brattørkaia on the northern edge of the Knowledge Axis by the Trondheim Fjord. The building produces more clean and environmentally-friendly energy than it consumes. This world-class pilot project can be an inspiration to a national symbol like Nidaros Cathedral, which in many ways can be considered the heart of the Knowledge Axis. The cathedral played a vital role for knowledge since the medieval age.

In November 2017, energy dialogs between Powerhouse Brattørkaia and Nidaros Cathedral were organized. Five key words were pointed out: totality, complexity, process, costs and reputation. These can be important factors for the contestants to take into consideration.

The competition questions are the following:

- **Deep energy retrofit and smart energy management of a large historic monument, taking into account the cultural-historic features and user experience.** Nidaros Cathedral and its surroundings is an important arena for cultural and religious events and one of the most famous tourist attractions in Norway. Is it possible to make it more energy-efficient without reducing its activity frequency and user comfort?
- **Transforming a historic urban district into a smart energy system with decentralized production of renewable energy.** Can Nidaros Cathedral and its surroundings become a "prosumer" of renewable energy?

With all the existing limitations, this is reckoned as a very challenging but exciting task. There is need to establish dialogues through multidisciplinary partnership across areas such as cultural heritage conservation, architecture and design, and energy technology for smart buildings and districts. This Open Innovation Competition is planned in connection to Technoport events in order to maximize the ripple effects for green innovation. Through established platforms which promote technological development and entrepreneurship, the concepts and solutions developed have higher chances to be scaled up and reach out to Europe and beyond.

In Norway, Enova focuses increasingly on the development of urban energy systems and the understanding of the interplay within such systems. An energy concept with Nidaros Cathedral as the focal point can be groundbreaking.