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# Hallandsås Ridge Tunnel, Sweden

Further information
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## Case Study 118

The Hallandsås Ridge Tunnel project consists of two rail tunnels that run under the Hallandsås Ridge in southern Sweden. The project was one of the most challenging tunneling projects to be undertaken in Sweden and was completed to very high environmental standards.

## Aspects of Sustainability

This project highlights the following:

**Green Aspects**

Energy
Carbon
Materials
Water
Local Impacts

**Social Aspects**

Human Resources
Corporate Community Involvement
Business Ethics
Health and Safety

**Skanska Color Palette™**

Energy
n/a

Carbon
✓

Materials
✓

Water
✓

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## Project Sustainability Highlights

### Economic

- Reduced project time and costs through environmental-related techniques

### Green

- 6% embodied **Carbon** savings
- Zero **Waste** sent to landfill
- Comprehensive tunnel water management & less than 3 % use of potable water

### Social

- Comprehensive stakeholder communication

## Project Background

The Hallandsås Ridge railway tunnel runs between Förslöv and Båstad, near the towns of Ängelholm and Laholm, in southwest Sweden and is part of the country's West Coast Line. The tunnel was constructed to replace a single railway track over the ridge dating from 1885 that was responsible for creating one of the bottlenecks on the West Coast Line. In the 1980s, the European Round Table of Industrialists and the Swedish Rail Administration concluded that a tunnel through the Hallandsås Ridge was the only viable solution.

During the 1990s, plans were drawn up for the 8.7 km long tunnel under the ridge and there were two attempts to construct the tunnel that were aborted. The first attempt suffered major difficulties due to the ridge's variable geology, which includes fractured bedrock with very high water content. The second construction attempt used

**The beginning of Skanska's proactive environmental management**

Skanska was involved in the second failed tunneling attempt in the 1990s, which served as a wake-up call to the company and began its proactive approach to environmental management. Skanska became the first international construction company to certify all its Business Units to ISO 14001 by 2000, which formed the foundation of Skanska's Journey to Deep Green™.

**TBM Key facts**

- TBM length: 12 m
- TBM + service part length: 250 m
- TBM weight: 3,200 tons
- TBM maximum speed: 12 m per day
- Total compressive force: 20,000 tons
- TBM diameter: 10.6 m
- Drilling accuracy: +/- 10 cm over 5.5 km

**Project material facts**

- 40,000 prefabricated tunnel segments
- 85,000 $m^3$ of mortar-and-gravel slurry
- 156,800 $m^3$ of concrete in total
- 20,050 tons of steel

a hazardous sealing compound, which affected local cattle and fish. The project was put on hold following the second attempt while thorough analyses were conducted.

## The Skanska-Vinci consortium

In 2004, a consortium 60 percent owned by Skanska, was commissioned by the Swedish Transport Administration to complete the tunneling project, which has cost US$ 1.3 billion in total. The two main tunnels are linked by 19 emergency and railway installation cross-passages equipped with fire doors. Tunneling was completed in the autumn 2013, and other contractors will install rail infrastructure throughout 2014/15. The tunnels will be fully operational in 2015.

The tunneling project utilized an advanced Tunnel Boring Machine (TBM) known as "Åsa", which was specially built for the difficult rock and water conditions within the Hallandsås Ridge. The TBM was used to bore into the rock with its powerful rotating cutter head whilst simultaneously transporting rock and water out of the tunnel. It also constructed sections of the tunnel as it progressed by installing eight precast concrete tunnel lining segments, each weighing 12 tons, to form a watertight ring around the tunnel. The machine then injected mortar-and-gravel slurry into the void between the rock and the lining to stabilize the tunnel. The TBM was also equipped with three conventional rock drills that were used to probe and pre-treat the rock ahead of the machine to best prepare for the varying rock conditions and water pressure. The TBM was in operation around the clock 360 days per year from 2009 with crews working 12-hour shifts. Some sections of the ridge are highly unstable, such as the "Mölleback zone", which is a 300 m long stretch that consists of highly fractured and weathered rock and high groundwater pressure and flow. The Mölleback zone was stabilized through a combination of freezing and grouting when boring the East tunnel through the zone, whereas the West tunnel was frozen with boreholes filled with brine chilled to -35 °C.

The Hallandsås Ridge Tunnel project will increase capacity from 3-4 trains per hour to 24 trains per hour along the West Coast Line, which is a vital connection between Sweden, Denmark (Copenhagen) and Norway (Oslo). The tunnel will also allow freight trains that are twice as heavy to use the route and will allow speeds of over 200 km/h, compared with 80 km/h prior to the project.

## Contributing Toward Sustainable Development

Following the previous failed attempts to construct the Hallansås Tunnel, the Skanska-led project was characterized by comprehensive environmental planning, monitoring and improvement in order to minimize environmental risks and meet high environmental requirements. The project's environmental requirements involved thorough chemical selection and reporting processes to ensure that only environmentally responsible substances were used. The team reduced the project's carbon footprint by 6 percent and zero waste was sent to landfill through efficient waste management procedures. In addition, potable water was only used for concrete to ensure concrete standards were met during the construction of the tunnel and effective tunnel water management and treatment processes were implemented. During construction, the team worked to minimize environmental impacts and communicate with project stakeholders. Project time and cost savings were achieved through techniques related to the project's comprehensive environmental management approach. The project benefitted the regional economy during construction by using construction workers and materials from the surrounding area. The tunnel will benefit the regional economy when completed by enhancing the regional rail capacity. The Hallandsås tunnel was constructed to ensure a design lifespan of 120 years.

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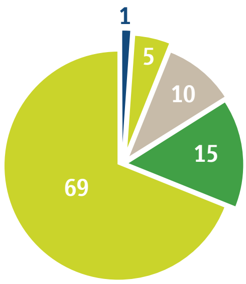
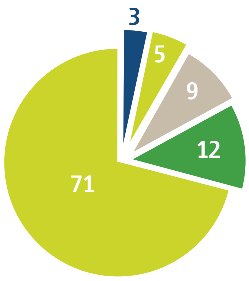



**Carbon footprint for the Hallandsås Project**

Materials and consumables – 69%
Equipment – 15%
Energy – 10%
Transport – 5%
Labor – 1%
Waste – 0%




**Materials and Consumerables**

Concrete – 71%
Steel reinforcement – 12%
Supply / Miscellaneous – 9%
Backfill – 5%
Steelworks – 3%

# Green Aspects

## Carbon

### Carbon footprinting

The carbon footprint of the Hallandsås tunneling project has been calculated to amount to 187,000 ton $CO_2e$. Materials and consumerables accounted for the greatest share of the footprint, amounting to 128,560 tons $CO_2e$. In particular, concrete was the most significant source of carbon emissions, due to the large quantity of concrete used on the project.

### Reducing embodied carbon

The team worked to reduce the project's carbon footprint and realized savings of 11,070 ton $CO_2e$, or 6 percent of the preliminary project footprint. 5,000 ton $CO_2e$ was saved by locating the concrete tunnel lining segment factory close to the site and by transporting the segments to the site by rail. The sourcing of electricity from renewable sources saved 3,600 ton $CO_2e$ and the use of low emission vehicle fuel reduced emissions by 1,500 ton $CO_2e$. The team also reduced emissions by sourcing local well water instead of municipal water. Part of the rock filling sub ballast in the tunnels under the railway was sourced from tunnel excavated rock masses.

The team reduced the amount of energy used to construct the tunnel as the project progressed by more effectively using the TBM. For example, the TBM used 27,000 MWh less energy to bore the second tunnel, compared with the first. Freezing 200 m of the Möllebackzonen tunnel saved 3,286 MWh by allowing the TBM to advance quicker and saving 6 months of machine operation.

## Materials

### Environmentally responsible materials

During the tunneling project, several European chemical companies altered the chemical formula of their products to meet the Hallandsås project's environmental requirements. This involved hazardous substances being removed from chemical products.

Only approved chemicals were utilized on the project following thorough risk analyses overseen by the various project partners. The local and regional authorities had access to the project's approved chemical list and were informed when new chemicals were to be used. Environmentally responsible substances used on the project included oil and machine grease derived from vegetable oil. All large vehicles complied with Euro III emission standards as a minimum and vehicles up to 3.5 ton were not allowed to be more than 12 years in age.

### Waste management during construction

The project created 699 tons of waste on average per year between 2009 ad 2012 and zero waste was sent to landfill. 67 percent of the material was reused or recycled, 27 percent was combusted to generate energy and 6 percent was treated off-site as hazardous waste. Waste was carefully sorted on site into clearly labeled containers, and potentially hazardous waste was separated into oil, used grease, used spill kits, batteries and contaminated soil. 40,000 tons of excavation material was collected on site before being reincorporated back into the project as tunnel sub ballast, or reused in other construction projects in the region, such as in highway construction.

## Water

### Water efficiency

Water for construction processes was primarily sourced from treated tunnel water that was treated in an on site water treatment plant. The only potable water used in construction was for batching concrete and to produce concrete segments in order to fulfil material quality requirements, which amounted to less than 3 percent of the total water used during construction.

### Tunnel water management

The Hallandsås Ridge consists of heterogeneous rock mass, varying from fractured bedrock to hard rock, with very high water content and pressure. Tunnel water management has been a major issue for all the tunnelling works (including the Skanska-Vinci project). The team consequently worked to minimize the amount of discharge from the tunnel and ensure potential contaminates did not infiltrate groundwater systems in accordance with environmental legislation. During tunnel activities from 2006, approximately 16 million $m^3$ of water was treated by on site facilities before being safely discharged into the sea. The team reduced the amount of groundwater discharge from the west tunnel by about half to approximately 4.6 million $m^3$ compared to the east tunnel that was constructed first. These savings were achieved following the approval of amended legislation, which allowed the quicker advance of the TBM and a significantly reduced overall discharge, the optimization of the TBM and the freezing of the Mölleback zone.

Legislation also specified that suspended solids in the discharged water must be less than 65 mg/l. The team consequently installed an on site purpose-built water treatment plant to treat discharge water from the tunnel. The plant used coagulant and flocculent techniques to separate water and solid

particles, and acid to adjust the pH. A technique to run “clean treatment” was also developed which helped to reduce the amount of water treatment chemicals by 90 percent when the TBM was not operating. Between 2009 and 2013, the plant used clean treatment for a period of 20 months in total. The treated tunnel water was either used on site or safely discharged into the sea.

Potential impacts on local flora and fauna were regularly monitored at over 800 locations. Ground water level was monitored in 440 wells above the tunnel. A temporary reduction in groundwater levels was observed when the TBM passed through the ridge, although the groundwater generally returned to its original level within a year.

### Other Green Aspects

#### Minimizing environmental impacts

The construction site was certified according to Skanska's internal Green Worksite (Grön Arbetsplats) environmental management system, which is aligned with Skanska Sweden's ISO 14001 certification. The system surpasses Swedish environmental regulations in terms of emission standards for site machinery, the use of energy-efficient construction lighting, requirements for chemicals and waste management. Certified renewable electricity was used to power the TBM and the prefabricated segments were transported to the site by rail.

#### Enhancing biodiversity

The previous projects had created a central temporary access tunnel at the midway point from the surface of the ridge. The project team filled this tunnel in again once the central tunnels were in place and efforts were taken to enhance biodiversity on the ridge. A wild seed mix was planted on disturbed soil instead of typical grass seed. Bird and bat nesting boxes were installed in trees, a dead wood habitat was retained and enhanced, and a small wetland habitat was restored.

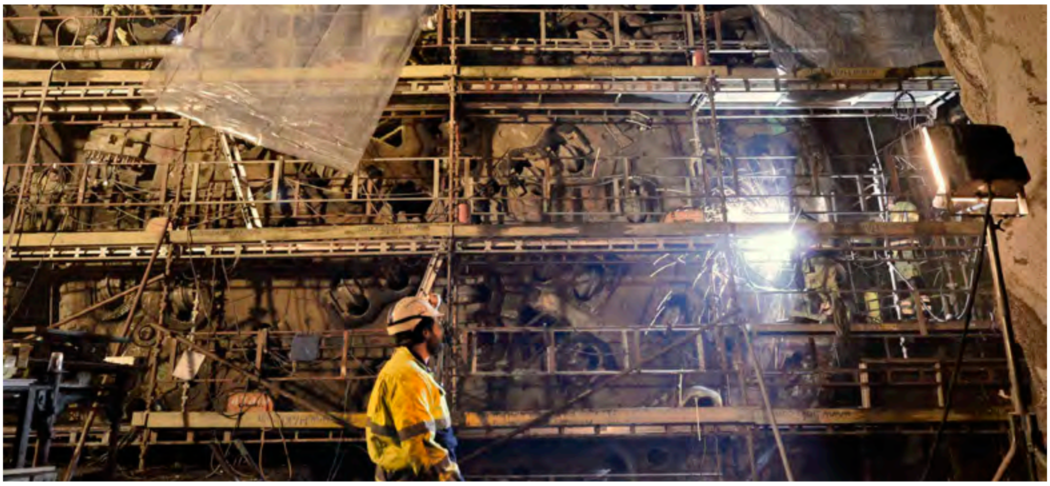
#### Raising sustainability knowledge and awareness

A project exhibition is situated by the entrance to the southern tunnel, which tells the story of the project and the work to minimize environmental impacts. The exhibition includes photos, film, illustrations and models. Guided tours are offered to schools, students, companies and associations. The exhibition is open to the public and has attracted annually around 15,000 visitors to the site in recent years, and around 100,000 visitors in total. The visitor center also has a lecture hall for 70 people where lectures and meetings about the project are held.

## Social Aspects

### Stakeholder communication

Following the previous failed tunneling attempts, stakeholder communication was a vital part of the Skanska-led consortium. Stakeholder communication was led by the Swedish Transport Administration. Biannual information meetings were held where the project directors and other experts from the Skanska-led consortium and Trafikverket met local people to present and discuss the project's progress and future plans. Between three and four newsletters were also distributed to local stakeholders each year, weekly updates were posted on the project's website and an open house was arranged each year when members of the public were able to visit the project site. In addition, stakeholders were issued with specific information about potential disturbances, such as a temporary lowering of the groundwater.



### Reducing noise disturbance

Potentially noisy activities were monitored to ensure they did not exceed predetermined limits. Vibrations were also monitored during underground blasting activities. Low-noise tunnel fans were also installed to reduce disturbance.

### Occupational health and safety

The rolling 12 month Lost Time Accident Rate was 4.6 per million hours worked as of August 2013 with over 870,000 hours worked in the past 12 months. Safety was given maximum priority during the project. The project was typified by behaviour related health and safety training and the extensive on site health and safety support, which went beyond the legal requirements for the project. A comprehensive risk inventory was conducted prior to the start of activities, which was incorporated into project procedures. Regular health and safety inspections and safety drills were carried out throughout the project.

## Economic Aspects

### Regional construction workforce and materials

Between 250 and 550 people worked on the tunneling project between 2007 and 2013. Several regional suppliers were used in the project, which benefitted the regional economy, and often saved time and reduced the environmental impacts associated with transportation. Regionally sourced materials included beams and arches, timber, steel, pipes, lifting equipment and the water treatment plant construction materials.

### Project financial savings

During construction, the project team realized significant financial savings by constructing the west tunnel in half the time it took to construct the east tunnel. This reduced time was achieved by optimizing the TBM, the implementation of new court legislation, pretreatment of cross tunnel 5 and 6, and the freezing of the Mölleback zone. Energy savings from the quicker development of the second tunnel (even when considering the energy used to freeze the Mölleback zone) resulted in reduced costs of around US$ 437,000. The clean treatment used by the water treatment plant also made financial savings of around US$ 200,000 between 2009 and 2013 compared with conventional water treatment methods by reducing the amount chemicals required to treat the tunnel water. Incorporating 40,000 tons of excavated material back into the project saved approximately US$ 620,000 in reduced material costs alone. The reuse of excavated materials additionally led to time and transport cost savings.

### Improved regional rail network

The Hallandsås Ridge Tunnel will help to promote regional economic development by allowing a more frequent and reliable rail service with greater capacity along Sweden's West Coast Line. The tunnel will also provide better opportunities for people to commute and travel by rail between Norway, Sweden and Denmark.

## Learning From Good Practice

The Hallandsås Tunnel Ridge project was characterized by thorough planning, preparation, and continual improvements, which helped to minimize environmental impacts on a technologically complex project. Communication and transparency were also vital components of the project following the two previous failed construction attempts, particularly in assuring local stakeholders that the project would have minimal environmental impact.