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OUTOKUMPU'S DUPLEX GUIDE

Why is duplex the right material choice for your storage tank?

In this guide, we will walk you through all the key information on duplex stainless steel as a storage tank material.

Should I choose duplex as the material for my storage tank project?

- If you need a weldable and formable material that has high mechanical strength and excellent corrosion resistance, yes.
- If you are looking for a solution that is both environmentally and economically sustainable, and with which you can achieve substantial weight and cost savings, yes.
- If your tank has a diameter of up to 50m, yes.
- If you wish to store different contents flexibly without the need for protective internal coatings, yes.

After reading this guide, you will understand the difference between duplex and carbon steel as well as the difference between duplex and other stainless steel grades. We will go deeper into the properties and most important benefits of duplex stainless steel for storage tanks and take a look at three different storage tank projects in which duplex proved to be the best choice. Finally, we will assess Outokumpu's stainless steel from a sustainability point of view.

Join us in working towards a world that lasts forever.

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What is duplex stainless steel?

Duplex stainless steel offers a convenient combination of strength and corrosion resistance, making it possible to significantly reduce material thickness and costs in a wide range of applications.

Outokumpu's duplex stainless steel grades have a ferritic-austenitic microstructure, with a phase balance of approximately 50% ferrite and 50% austenite. This microstructure combines many of the beneficial properties of both ferritic and austenitic stainless steels, resulting in high mechanical strength and high resistance to stress corrosion cracking.

Other characteristic properties of duplex grades include good weldability, good abrasion and erosion resistance, good fatigue resistance, high energy absorption, and low thermal expansion.

Compared to other grades with corresponding corrosion resistance, the nickel content of Outokumpu's Forta range duplex is very low. This means greater price stability and easier budgeting.

The most commonly used duplex grades for storage tank applications are Forta LDX 2101, Forta DX 2205, Forta DX 2304, and Forta EDX 2304.

Read more about Outokumpu's duplex stainless steel grades:

outokumpu.com

Benefits of duplex stainless steel for storage tanks

The high strength, excellent corrosion resistance, and cost-saving aspects of duplex stainless steel make it an ideal material for many storage tank applications within industries such as chemical process, food and drink, tank terminals, pulp and paper, water, hydrometallurgy, hydrogen and CCUS.

1. Stronger storage tanks with less manufacturing material

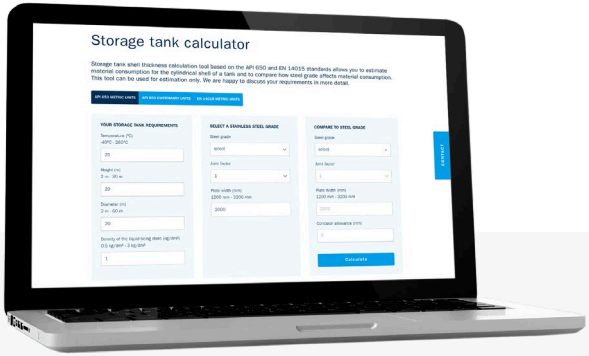
The high mechanical strength of duplex can be utilised in designing tank shells by reducing the thickness of the material needed in construction. This means less material to be purchased, less material to transport and handle, less material to weld, fewer working hours, and less welding consumables. Less material also enables more lightweight constructions.

This simple fact represents not only a significant economic advantage, but also a host of relevant sustainability aspects, as less manufacturing material also produces less burden on the environment throughout the lifecycle of the material. At the end of their service life, all stainless steel grades, including duplex, can be fully recycled without any dilution of their properties.

The bigger the storage tank, the greater the impact of these benefits. In other words, Duplex can help to achieve substantial cost savings especially in large storage tanks – see case 1 in the chapter 3 examples of success with duplex.

Estimate your material consumption with Outokumpu's storage tank calculator

Estimate and compare material consumption with different steel grades with the help of Outokumpu's storage tank calculator. The Outokumpu online storage tank calculator is a handy tool, perfect for estimating the weight gain potential duplex can offer your storage tank project.



Outokumpu storage tank calculator:

OPEN

2. Excellent corrosion resistance ensures a long service life

Most other storage tank materials require coating to withstand the outside environment and adequately protect the contents of the tank. Duplex stainless steel is inherently corrosion resistant and, what's more, maintains its high level of corrosion resistance for the entire enduring lifetime of the material.

The alloying content in the steel creates a thin but sturdy chromium oxide layer, which prevents the core material from getting into contact with oxides. When scratched or otherwise damaged, this protective layer reforms instantaneously under the influence of oxygen. Minor surface damage in stainless steel self-heals, whereas a scratched epoxy or paint coating must be hurriedly repainted before the tank suffers any further damage.

Read our expert article to go deeper into what can be stored in a duplex tank and what kind of exterior environments duplex excels in.

3. Low maintenance and extreme durability reduce lifecycle costs

Stainless steel requires less maintenance, inspection, and repair than other storage tank materials. Maintenance is a tedious, time-consuming, and costly process: the less you need to do of it, the better.

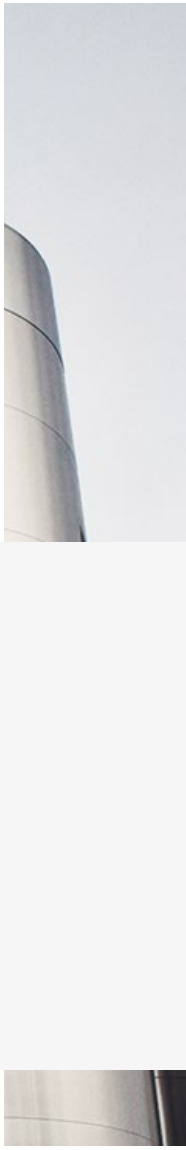
Design codes state how often inspection is needed for different materials, and maintenance often follows after an inspection. There is no stipulation for maintenance of stainless steel storage tanks in the standards. In most cases, just a routine cleaning is enough to keep the tank surface in shape.

The regular interval for internal inspection is 10 years. According to API 653, an inspection standard for steel aboveground storage tanks used in the petroleum and chemical industries, choosing stainless steel allows you to expand the inspection interval to 20 years – double the regular interval for storage tanks made of other materials. This makes an enormous difference, as each inspection means heavy logistics and costs of emptying a tank, costs of the inspection engineers, and of course a lengthy disruption in service.

All these factors help to significantly reduce the lifecycle costs of a stainless steel storage tank. These also depend on the initial investment, the size of the tank, and how much weight can be saved.

The initial cost of a storage tank constructed from duplex stainless steel can be cheaper than a counterpart made from competing materials by up to 5%. In some cases, the initial cost for stainless steel can be more expensive by up to 20%. Even in these cases, the stainless steel solution is generally more affordable already after the first maintenance cycle.

After 15–20 years, the costs of the stainless steel tank are clearly smaller. After 40–50 years, the lifecycle costs of the stainless steel storage tank can be down to half of the total costs of competing solutions.



KEY BENEFITS OF DUPLEX STAINLESS STEEL

1. Stronger storage tanks with less manufacturing material
2. Excellent corrosion resistance ensures a long service life
3. Low maintenance and extreme durability reduce lifecycle costs

> “When choosing storage tank material, consider the difference between a material that will be there for decades and a material that will need to be maintained for decades.”
>
> **– Peder Claesson**
> Head of Project Sales at Outokumpu

Duplex vs carbon steel

The key advantage of duplex stainless steel compared to carbon steel in storage tank application is that duplex does not require a separate coating. Eliminating the need for coating your storage tank on the inside and outside saves costs, maintenance, and repair, and ultimately reduces the tank’s carbon footprint.

Convenient construction without a complex coating process

Constructing and assembling a storage tank is easier and more affordable without the extra phase of building a scaffolding to blast and paint the coating on the tank shell. Stainless steel tanks also do not need separate inner roofs to protect the top beams of the tank from humidity, as properly selected duplex stainless steel answers to the demands of both the outside environment and the content without external protection.

Furthermore, the coating process is dependent on favourable weather conditions. This makes it difficult to ensure that the project will be finished, and the tank delivered on time. Stainless steel tanks come with a more predictable timetable as they do not require complex, costly, and seasonally dependant additional processes.

Which material can contain and protect the content in the best possible way?

When building a storage tank, one of the first questions should be: what kind of material can contain and protect the content that we want to store in the best possible way? Some contents require a high level of hygiene for health and safety reasons. With duplex stainless steel, you can prevent contamination without worry about epoxy dust or other traces of the coating of a carbon steel tank dissolving into the content.

Storage tanks are often used to store a variety of contents during their service life. Carbon steel tanks often need to be recoated when the content is exchanged, as different liquids require different properties in the internal coating. In most cases, stainless steel tanks can simply be cleaned in between different contents, instead of taking the tank out for costly maintenance and recoating. Stainless steel tanks are also quicker and easier to clean than coated carbon steel tanks.

Long-lasting service without maintenance issues

Coated carbon steel solutions can offer a good level of corrosion resistance in the beginning of their lifecycle. However, coatings wear down over time and their corrosion resistance diminishes if they are not refurbished or repainted after 10–15 years. Duplex stainless steel maintains its high corrosion resistance without an external coating and with minimal maintenance.

Long-lasting stainless steel solutions produce a significantly more modest carbon footprint than coated carbon steel tanks in the long run. Manufacturing and maintaining the coating, replacing the entire tank after 50 years and recycling old coatings all create environmental impact that can be avoided in a stainless steel tank.

Maintenance and recoating also create safety risks for employees. The safest way to do extensive maintenance is not to do extensive maintenance – in this case, the simpler solution also brings more safety and control.

Lightweight, strong, and smooth material for flexible application

The high strength of duplex grades makes it possible to work with thinner-gage material that can be manufactured into cold rolled steel coils, strips, and sheets for flexible use in a range of applications.

Cold rolled stainless steel has a smoother surface, which means you can avoid a lot of extra grinding and polishing that would be required with carbon steel. Hot rolled stainless steel, on the other hand, serves well when a carbon-steel-like surface roughness is desired.

Fig. 1. Strength and corrosion resistance: Forta Duplex vs Austenitics.

Duplex vs other stainless steel grades

Duplex is distinguished from other stainless steel grades most importantly by its high strength, which helps to save weight, costs, and environmental impact in storage tank construction.

Some duplex grades also offer higher corrosion resistance than their standard austenitic steel counterparts. The microscopic structure of duplex provides exceptional resistance to stress corrosion cracking – this alone can be the deciding factor for choosing duplex in some cases, for example when building a tank to store ethanol or similar corrosive contents.

Unlike austenitic steel grades, duplex grades are magnetic due to their ferrite content. This can be useful during the manufacturing process and transportation, where magnetic tools can be used to lift the steel and hold it in place while drilling, for instance.

Thermal expansion factors:
Duplex vs Austenitic steel vs Carbon steel.

Table 1

Steel	Thermal expansion factor
Duplex stainless steel	13
Austenitic stainless steel	16
Carbon steel	11–12

Finally, duplex has a lower thermal expansion factor than austenitic steels, which means storage tank structures built with duplex expand and contract less in changing temperatures. In this regard, duplex is similar to carbon steel, which also has low thermal expansion.

Three examples of success with duplex

1. Tank terminal | Substantial weight and cost savings in a large storage tank

A massive storage tank requires an enormous amount of surface protection. This can add up to huge costs if the tank is manufactured with coated carbon steel.

The surface area of this tank is roughly 7500 m², the size of a regular soccer pitch. With Duplex Forta LDX 2101 stainless steel, the manufacturer was able to use less material – saving weight and costs.

In this case, duplex was 3% cheaper than the corresponding carbon steel solution already in the investment phase and will be up to 30% cheaper in the long run, when comparing the total life cycle costs of both materials.

Tank design:

Application:	Storage of mild chemical
Location:	The Netherlands. by the sea
Tank height:	25 m
Tank diameter:	30 m
Volume:	17,700 m^3
Density of content:	1.3 g/ml
Design temperature:	20 °C
Tank manufacturer:	Ellimetal N.V.
Design code:	EN 14015

Competing materials:

Stainless Steel:	Forta LDX 2101
	Type 304
Carbon steel:	S355 (~A572)

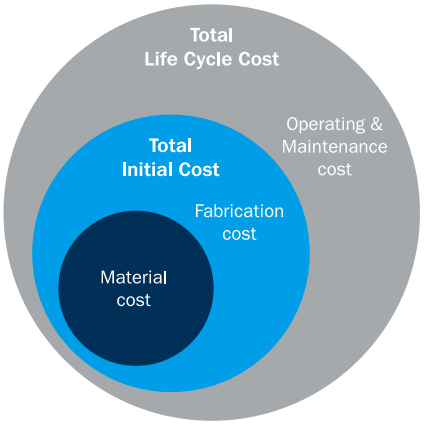


Fig. 2. Total Life Cycle Cost.

LCC parameters

Real discount rate: 4%

Life cycle duration: 30 yrs.

Complete recoating of carbon steel after 10 and 20 yrs.

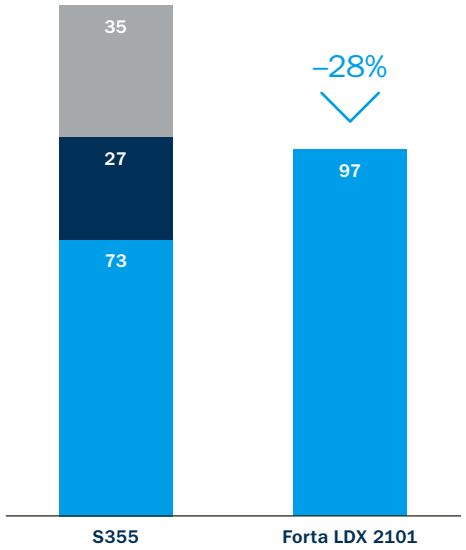


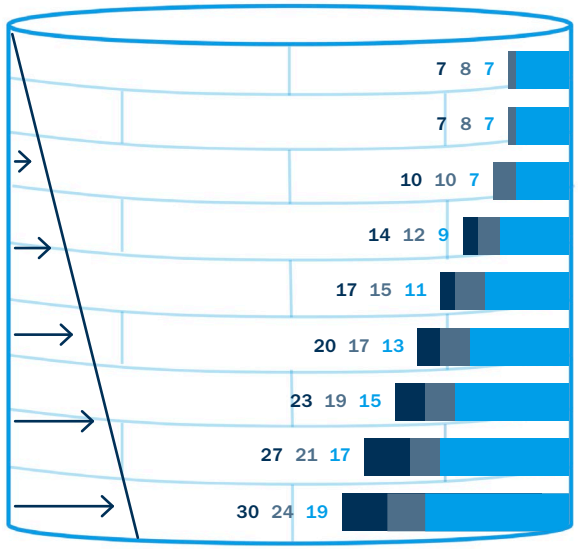
Fig. 3. Cost savings in a large storage tank.

Life cycle maintenance cost

Protective coating cost

Tank material and fabrication cost

The total life cycle cost of the duplex tank is ~30% less than carbon steel tank



S355 (incl. corrosion allowance)
Design stress = 238 MPa
Min. thickness = 8 mm

Type 304
Design stress = 160 MPa
Min. thickness = 6 mm

Forta LDX 2101
Design stress = 260 MPa
Min. thickness = 6 mm

Thinner gauges – Less material:
~25% (35%) weight saving of cylindrical shell using Forta LDX 2101 compared to S355 (304L).

Fig. 4. Cost savings in a large storage tank.

2. Biogas industry | High corrosion resistance, excellent mechanical properties and added flexibility with a bolted solution

Duplex Forta LDX 2404 was selected for this fermentation residue tank in biogas production for two main reasons. First, high corrosion resistance is extremely important when storing fermentation residues that typically have a corrosive effect on standard stainless steel. Secondly, the excellent mechanical properties of this duplex grade resulted in significant weight and cost savings.

Bolted tank solutions are designed for flexibility and re-use. They can be taken apart and rebuilt in another location, which is a big advantage for example if a tank terminal is moved 5 km along the coastline after 15 years or if a fermentation residue tank is built in a temporary place and relocated later.

The surface of a bolted tank has angles, unlike the flat surface of a welded tank. This allows the manufacturer to work with thinner material, further highlighting the weight saving aspect of this material choice.

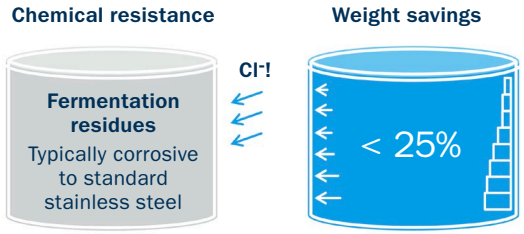


Fig. 5. Material performance.

Tank design:

Application:	Pure Bolted fermentation residue tank for biogas production acid tank
Location:	Germany
Tank height:	7.5 m
Tank diameter:	30 m
Engineering:	Börger
Stainless Steel:	Forta LDX 2404

Forta LDX 2404 substituting 1.4571 (316Ti):

- High corrosion resistance
- Excellent mechanical properties
- Weight and cost savings!

3. Biofuel industry | Superior resistance to stress corrosion cracking

Duplex Forta LDX 2101 was chosen for these ethanol storage and fermentation tanks in Ohio, USA, because of its superior resistance to pitting and stress corrosion cracking. These qualities are especially important in an outside environment that is high in chlorides.

Together with the distinguished mechanical properties of this duplex grade, this resulted in lower maintenance costs, weight savings and overall cost savings.

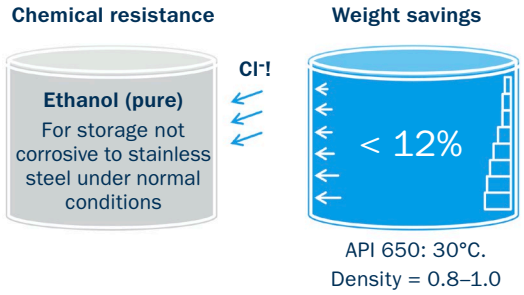


Fig. 6. Material performance.

Tank design:

Application:	Ethanol storage and fermentation tanks
Location:	Lima, Ohio, USA
Tank height:	15 m
Tank diameter:	18 m
Owner:	Greater Ohio Ethanol Facility
Stainless Steel:	Forta LDX 2404

Forta LDX 2101 substituting type 304:

- Superior pitting and SCC resistance (outside environment high in chlorides) – Lower maintenance cost!
- Superior mechanical properties – Weight and cost savings!

Build sustainable storage tanks with duplex stainless steel

Stainless steel is a superb material for sustainable solutions as it is 100% recyclable and long-lasting. The sustainability advantages of Outokumpu's high performance duplex stainless steel in storage tank applications include:

- in principle, there is no limit to the service life of storage tanks made of duplex stainless steel
- weight saving significantly reduces environmental impact
- little or no maintenance at all when properly specified
- over 90% recycled content
- duplex is 100% recyclable without any dilution of its properties
- high recapture rate, reusable as a valuable raw material without any downcycling
- the lowest carbon footprint in the stainless steel industry

Outokumpu's environmental product declarations (EPDs) conform to international standards and help to provide a reliable overview of the climate burden of a storage tank project. This streamlines calculating your overall sustainability performance and makes it easier to report transparently to your customers.

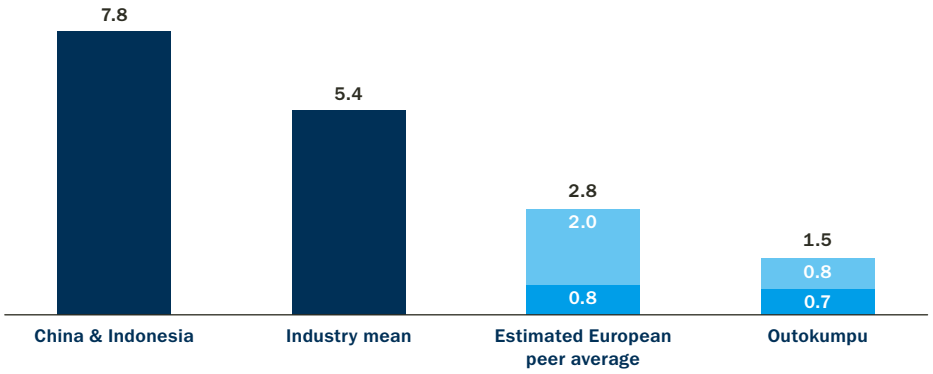
Outokumpu: the global leader in sustainable stainless steel

At Outokumpu, we are at the heart of moving society towards more ecologically, socially, and economically sustainable solutions. Our aim is to become the industry benchmark for sustainability.

We are committed to the Science Based Targets initiative's 1.5-degree target to mitigate climate change. Our emissions reduction ambition covers all direct and indirect emissions, as well as those of our supply chain.

Read more about how we contribute to a more sustainable world:

outokumpu.com



Outokumpu scope 1 & 2 also includes FeCr, unlike peers.

Source: ISSF for stainless industry mean emissions, companies' annual reports, 3rd party esitmate of European peer average emissions in Scope 3.

Fig. 7. Value chain emissions, tCO_2-eq/t of stainless steel.

High recycled content lays the foundation for a circular economy

Stainless steel is not only fully recyclable, but also made from recycled material to begin with. Outokumpu's mill in Tornio in northern Finland is the largest material recycling center in Europe. The mill annually recycles over one million tons of metal – the equivalent of the weight of 100 Eiffel towers.

Outokumpu's stainless steel has an exceptionally high recycled content at 90%. This figure stands out globally, as the recycled content of stainless steel ranges between 20–90% worldwide.

High recycled content saves considerable amounts of resources and energy, and significantly reduces waste, making it one of the most effective ways to reduce the environmental impact of production processes.

The lowest carbon footprint in the stainless steel industry

Outokumpu's carbon footprint is less than 30% of the global industry average. Key reasons for our low carbon footprint are our own ferrochrome, high recycled content, and the use of low carbon electricity.

We help our customers develop solutions that reduce climate burden by means of the right material choices. On an annual level, our clients are able to reduce their carbon footprint by 8 million tons.

Conclusion

A brief review of the key benefits of duplex stainless steel as a storage tank material:

- Duplex is a weldable and formable material that has high mechanical strength and excellent corrosion resistance.
- Outokumpu's duplex stainless steel is both environmentally and economically sustainable, and it can help to achieve substantial weight and cost savings in your storage tank design.
- Duplex is best suited to tanks that have a diameter of up to 50 m.
- With duplex, you can store different contents flexibly without the need for protective internal coatings.

Our experts are happy to help with any further questions.

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If you have any questions or would like to discuss with Outokumpu expert, don't hesitate to contact us:

Contact request

Working towards a world that lasts forever

We work with our customers and partners to create long lasting solutions for the tools of modern life and the world's most critical problems: clean energy, clean water, and efficient infrastructure. Because we believe in a world that lasts forever.

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