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ARVEDI ESP – FIRST RESULTS AND BUSINESS CASES[1]

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Abstract
In June 2009 industrial production in the endless mode commenced at the new Arvedi ESP (Endless Strip Production) line in Cremona, Italy. For the first time ever, hot-rolled coils can now be commercially produced in a thin-slab casting/rolling plant directly from liquid steel in a continuous and uninterrupted manufacturing process. The thin slab caster converts liquid melt into a solid strand, which is directly fed to the subsequent high-reduction stands followed by an induction furnace and the 5-stand finishing mill, including cooling and coiling facilities. Several technological milestones were achieved, including the casting of 80 mm thin strands at speeds in excess of six meters per minute and hot-strip rolling down to a thickness of 0.8 mm. Strip dimensions meet the geometrical requirements for cold rolling, allowing the conventional cold-rolling process step to be dispensed with for many industrial applications. Newest results on quality, environmental and economical benefits will be highlighted.
Key words: Cast and roll; Real endless rolling; Ultra thin gauges.

ARVEDI ESP – PRIMEIROS RESULTADOS E CASOS DE APLICAÇOES

Resumo
Em Junho 2009 a produção industrial em modo *endless* começou na planta ESP (*Endless Strip Production*) da Arvedi em Cremona, Itália. Pela primeira vez, BQ podia ser produzida comercialmente uma planta de lingotamento e laminação diretamente e sem interrupção. A máquina de lingotamento de placa fina converte aço liquido em uma placa solida, qual diretamente entra num desbastador (de alta redução) seguindo por um forno por indução e um laminador acabador de cinco cadeiras, com refrigeração e bobinamento subsequente. Varias metas tecnológicas foram atingidas incluindo a produção de placa solida de 80 mm de espessura numa velocidade de 6 m/min até conseguir uma espessura final de 0,8 mm. O produto final atinge até o padrão de laminação a frio, substituindo estes produtos em diversas áreas e aplicações. Novos resultados em qualidade, aspectos ambientais e benefícios econômicos serão tratados neste trabalho.
Palavras chave: Lingotamento e laminação; Laminação sem interrupção; Espessuras ultra finas.

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1 INTRODUCTION

Acciaieria Arvedi SpA has been operating a minimill in Cremona, Italy, since 1992 with an annual output of 1.2 million tons of flat products. Production is based on the Inline Strip Production (ISP) process. The quality of the products, especially that of thin gauges and high-strength steel grades, and the dynamics of the European market have made Arvedi consider substantial expansion of production capacity and the possibility of investing in a completely new production route, including an EAF melt shop, thin slab casting and direct rolling followed by a combined pickling and tandem cold rolling mill and strip processing lines. In the areas of casting and rolling, Arvedi conducted in-depth analyses leading to a decision to develop a new plant design by connecting casting and rolling in a true endless process, resulting in final development of the Endless Strip Production (ESP) line. The plant has a minimum nominal capacity of 2.0 million tons and is capable of producing a wide range of premium steels.
Invented by Giovanni Arvedi and implemented together with Siemens VAI, the vision of producing hot-rolled coils directly from liquid steel in an uninterrupted production process has become reality at the Arvedi ESP (endless strip production) plant in Cremona. Already during the first year of industrial operation, a number of milestones were achieved that included casting speeds of 6 m/min; the continuous production of strip coils at widths of up to 1,580 mm and at thicknesses down to 0.8 mm; products characterized by excellent dimensional, metallurgical and mechanical properties; high yield figures; and particularly reliable and stable operating conditions.
Today, production sequences comprising ten ladles with a total of 2,500 tons of liquid steel are routinely processed in a single line to approximately 100 hot-rolled coils. Continuous casting operations are especially dependable with only five breakouts registered during all of 2010. In fact, no breakout incidence occurred whatsoever for half a year during continuous production beginning September 2010. More than 30% of the coils ready for dispatch have a strip gauge of less than 1.5 mm, thus commanding premium sales prices. Once the desired minimum gauge is reached, usually in the early stage of a production sequence, rolling at this thin gauge is typically carried out for the rest of the production campaign. Strip lengths of 150 km and more are normally generated. A cobble rate of less than 0.06% was demonstrated as a monthly average during rolling operations – underlining the stability and reliability of the process.

2 ALTERNATIVE PRODUCTION ROUTES

One of the most important issues steel producers interested in ESP technology deal with is the configuration of overall plant integration, including the type of melt shop, the ESP line (direct sales of high-quality coils) and further processing.

2.1 Typical Melt Shop Combinations

The compactness and flexibility of Arvedi ESP offers owners of conventional minimills and operators intending to manufacture flat steel products the perfect opportunity of entering the high-quality steel segment and producing ultra-thin hot-rolled strip with the advantage of the high contribution margins discussed below.

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Figure 1 shows a typical arrangement of an Arvedi ESP line integrated into an EAF-based mini mill, including a compact pickling line and a three-stand tandem cold-rolling mill with minimized space requirements.

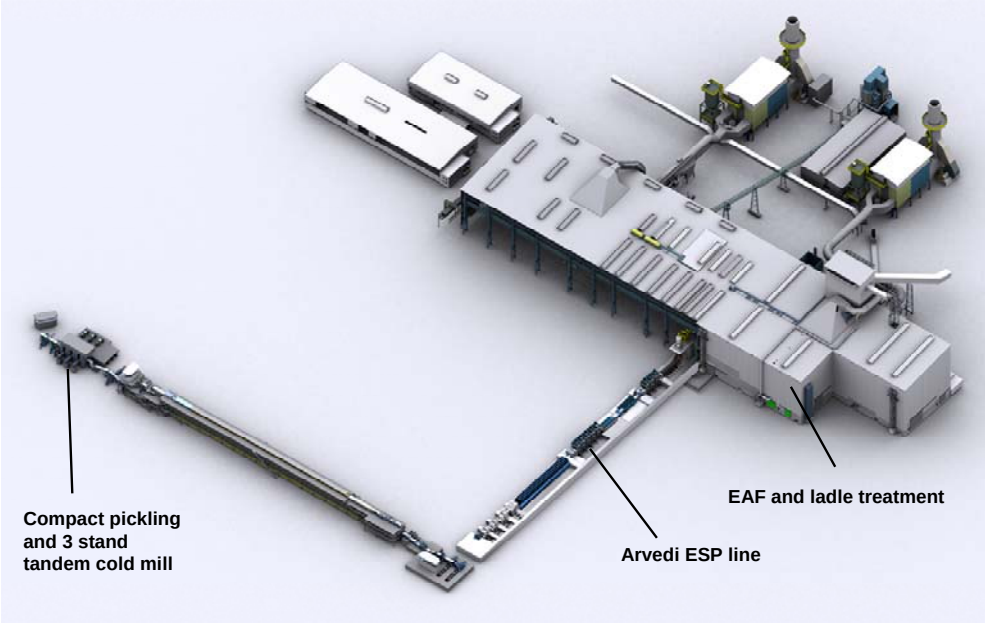

Figure 1. Arvedi ESP integration in EAF based minimill.

Figure 2 shows a typical arrangement of an Arvedi ESP line integrated into a BOF-based minimill. Because of the very short line length, integration is possible in parallel with continuous casting lines without interfering or compromising the typical melt shop logistics in green field projects or even brown field projects with space restrictions.

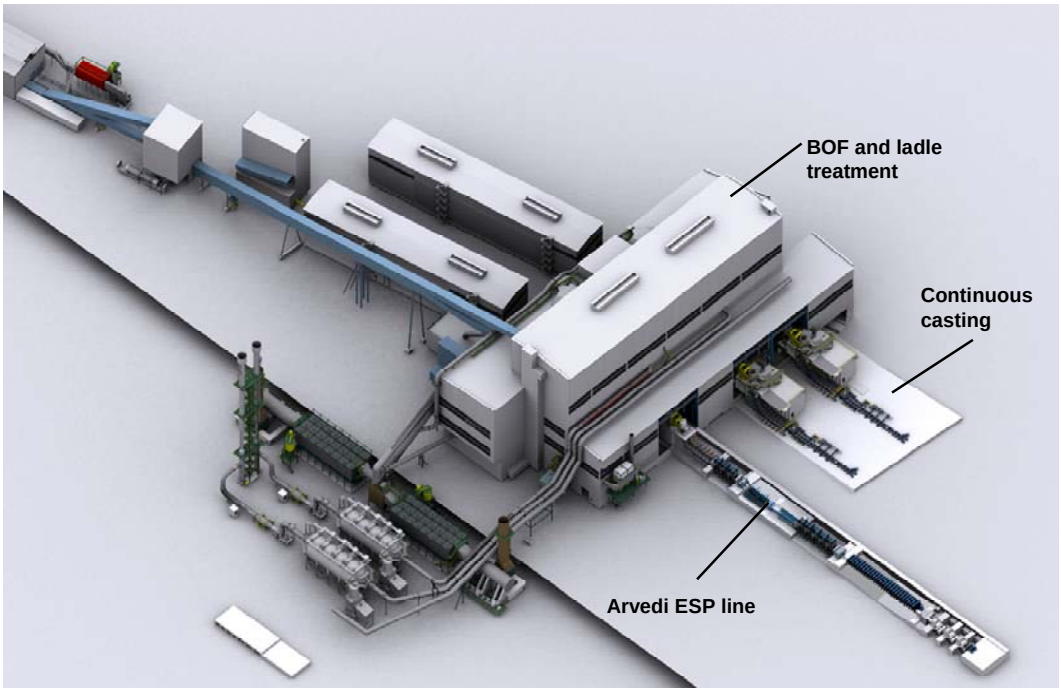

Figure 2. Arvedi ESP integration in BOF shop.

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2.2 ESP/ISP Combi Plant

SP enables production of a wide range of steel grades, from carbon grades to special-steel grades in thicknesses ranging from 0.8 mm to 12.7 mm and from minimum to maximum width at full productivity. The main reason for investment in ESP is the capability of producing high volumes of ultra-thin and wide strips. These products render the highest revenues in the strip market. The very unique advantage of ESP is that the production of these ultra-thin and wide strips is entirely independent of the final gauge thickness (as thin as 0.8 mm). Other process routes are significantly restricted.
Arvedi Steel has been operating and further developing the ISP plant since the early nineties. It is a highly valuable plant producing a wide range of products and steel chemistries at speeds between 4.5 m/min and 7 m/min. The ISP design with a Cremona furnace is most appropriate for steel producers wishing to produce a wide spread of very special steel grades, particularly difficult-to-cast grades with final gauge thicknesses down to 1 mm.
SVAI offers a best-of-both solution for the production of a full range of steel grades, even in thin gauges. The ESP/ISP Combi Plant solution is shown in Table 1.

Table 1. ESP/ISP Combi Plant

	ESP	**ISP**
Thickness	0,8 – 12,7 mm	1,0 - 12,7 mm
Steel grades	▪Carbon Steel (Medium Carbon, ULC, HSLA) ▪IF Steel ▪Pipe Grades (up to API X 80) ▪DP & Multi-Phase Steel Grades ▪Silicon Steel	▪Carbon Steel (Medium Carbon, ULC, HSLA) ▪IF Steel ▪Pipe Grades (up to API X 80) ▪DP & Multi-Phase Steel Grades ▪Silicon Steel ▪Stainless Steels* ▪Si- Grades (Go, NGO)*
Productivity	Highest Productivity	reduced productivity for difficult to cast grades *)
	ESP / ISP – Combi Plant	

The ESP/ISP Combi Plant makes it possible to produce high volumes of ultra-thin and wide hot-rolled coils and to switch between standard and difficult-to-cast steel grades. A second-generation Cremona furnace makes it possible to operate the plant in ISP mode. This furnace is easily bypassed in order to operate the ISP/ESP Combi Plant in the ESP mode.

2.3 Combination with Existing Hot Strip Mill

The addition of an Arvedi ESP line to an existing hot-strip mill affords special synergies not achieved in any other plant type. The Arvedi ESP line is capable of producing a high portion of thin products that normally prevent a hot-strip mill from producing at maximum capacity. The existing hot-strip mill is free to optimize the production scheme, resulting in higher overall productivity with either no investment or only minor costs. The overall product portfolio can be broadened and diversified because the products manufactured in an Arvedi ESP line are different from hot-rolled coils produced in other plant types.

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2.4 Pickling, Galvanizing, Cold-Rolling, Slitting

ESP offers the unique option of expanding the product portfolio to a larger number of value-added products. The ESP line can also be a means to produce hot-dip galvanized strip based directly on HRC feedstock, because the required strips have a typical thickness of roughly ranging between 0.8 mm and 1.0 mm. All these products and grades are produced in the ESP line at a typically lowered conversion energy level. Further advantages such as alloy savings and excellent geometrical quality parameters generate additional revenues.
The combination of a compact pickling tandem line with three mill stands facilitates the production of thin-gauge cold-rolled strip in a second production step, e.g. 0.2 mm.
The unique product dimensions and quality of ESP strips most economically serve the market for thin and wide strips and are the reason that the endless ESP process was designed. Full width, ultra-low exit thicknesses, excellent quality, no strip heads and outstanding performance in geometrical dimensions (crown, wedge, flatness) are other advantages of this innovative process. The ESP line is capable of producing narrow strips (slit strips), making production doubly efficient.

3 PLANT ECONOMICS

3.1 Investment Costs

Arvedi ESP is the shortest process route for the production of prime hot-rolled coils directly from liquid steel and in thicknesses ranging between 0.8 and 12 mm. The most important advantage of an ESP plant is its investment costs, which is strongly related to its compact plant design. Both a minimum of processing equipment and significantly less space requirements result in minimized civil works and less steel structure in the bays. Significantly less effort and volume for interconnecting piping and cabling are required.
Figure 3 shows the layout of an ESP line fully integrated into an EAF melt shop. The enclosed space for the ESP line is only approximately 18,500 m², as indicated for the green area. The length from the center line of the ladle turret to the center line of the second down coiler is only approximately 180 m.

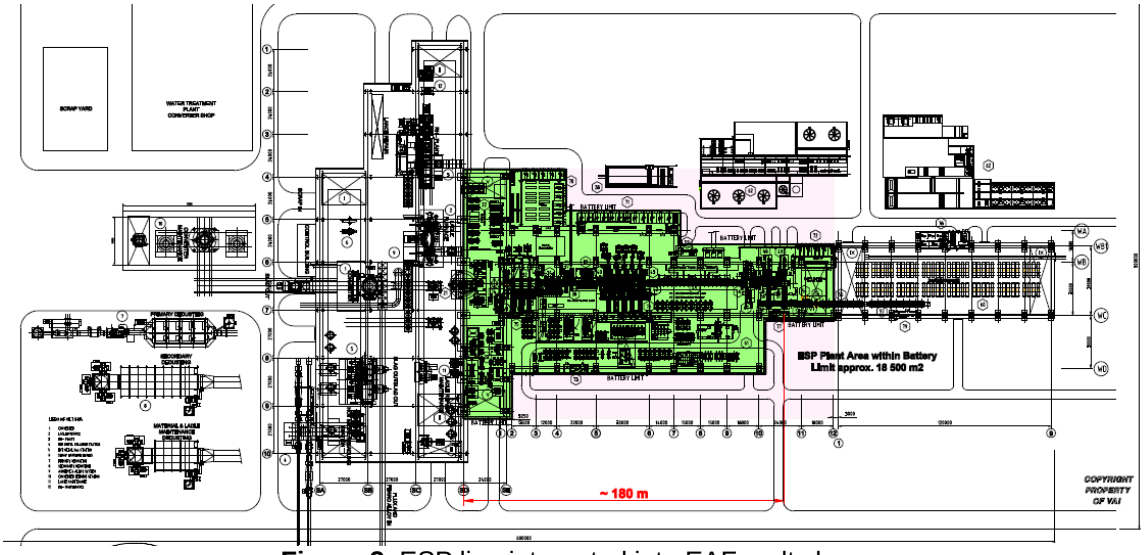

Figure 3. ESP line integrated into EAF melt shop.

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Figure 4 below shows an ESP line fully integrated into a BOF melt shop. The enclosed space for the ESP line again is only roughly 18,500 m².

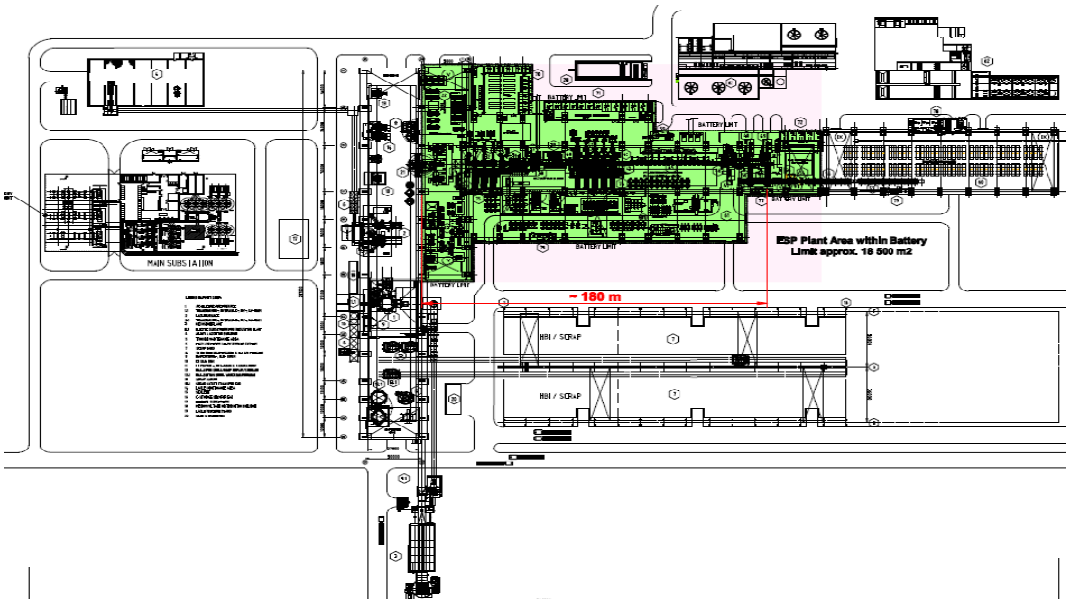

Figure 4. ESP line integrated into BOF melt shop.

Compared to a conventional hot strip mill with an annual capacity of roughly 4 m t/a., the space requirements for an ESP line of an annual capacity of 2.3 – 2.7 m t/a are less than 50% (Figure 5).

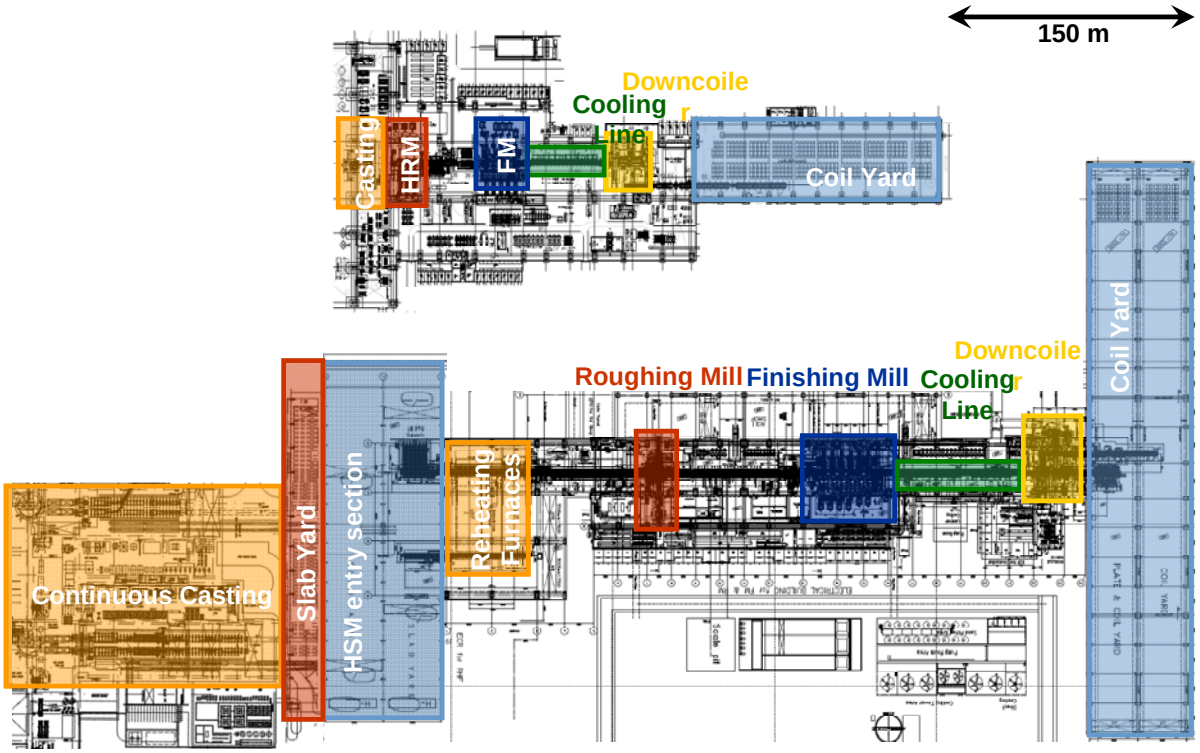

Figure 5. Comparison conventional hot strip mill with ESP line.

Casting bays and surrounding areas of an existing steel shop are often restricted, making ESP more sensible. The minimum space requirements make it possible for

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an ESP plant to easily fit into the majority of existing plant configurations, minimizing the influence of existing steel melt shop logistics.

3.2 Conversion Costs

The following unit rates were chosen as the basis for calculating the specific conversion costs for an Arvedi ESP plant.

Table 2. Material unit rates and hot rolled coils sales price

Cost type	Unit	Cost/Unit
		€
Liquid steel	t	350.00
Scrap	t	250.00
Return scrap credit	t	250.00
Natural gas	MWhth	21.20
Electric energy	MWhel	48.90
Personnel	Man years	30,000
Refractories CC	kg	4.50
Copper mold	Kg	1.34
Rolls	Kg	5.00
Depreciation (noncash)	%	6.7%
Base sales HRC price	t	450.00

A calculation of the specific cost types (yield losses, energies, other supplies and personnel) for an Arvedi ESP plant indicates overall conversion costs of € 28.4 per ton of hot-rolled coils.
Figure 6 shows a comparison of conversion costs of Arvedi ESP with two other production routes (conventional hot-rolled coil production/other thin slab casting and rolling):

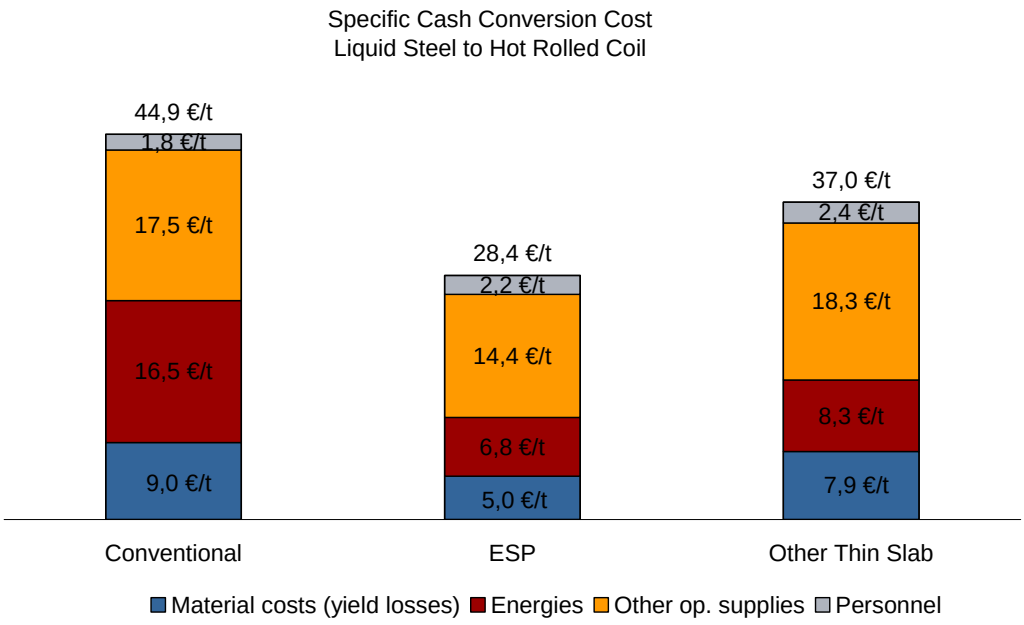

Figure 6. Specific cash conversion costs.

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Below is a detailed evaluation of the advantages of Arvedi ESP in relation to the individual cost types as used in the above calculation.

3.3 Yield

Operational results of the new Arvedi ESP plant during the past months confirm an average yield (liquid steel to prime hot-rolled coils) ranging between 97% and 98% with the following advantages:

- minimum accumulation of scale during reheating due to the very short inductive heating track of roughly 10 m only;
- no head and tail losses in the finishing mill.

3.4 Energy Costs

The new ESP line design achieves the world's best energy balance for producing hot-rolled coils from liquid steel and in thicknesses ranging from 0.8 mm to 12 mm. The heat after casting is optimally utilized for rolling operations, thus reducing the demand for deformation energy to a minimum since the strip is still soft in the center during initial reduction steps. A very unique effect is that Arvedi ESP, unlike other thin slab processes, requires less energy when increasing line capacity and productivity. With ISP, at highest casting speeds, the consumption of electrical energy in the induction heater even drops to zero in specific cases.
Full integration of the casting and rolling processes results in significantly reduced energy consumption, by more than 50% as compared to conventional processes, even when taking hot charging into consideration. Conventional gas-fired heating or reheating furnaces require permanent heating during planned or non-planned interruptions, while the Arvedi ESP induction heater transfers the electrical power directly into the transfer bar, only as required.
The lower volumes of greenhouse and noxious gases (NOx and CO) directly and indirectly emitted from the Arvedi ESP plant are clearly linked to lower energy consumption, which is reduced by 45% as compared to conventional production methods.

3.5 Other Operating Supplies

Expenses for Arvedi ESP spare and wear parts, external maintenance, refractory, lubrication, rolls, casting powder, etc., are considerably reduced by the compact design of the process units.
The most important savings are as follows:

- roll consumption in all parts of the line due to continuous processing of material in 2-step rolling;
- less maintenance in reheating section due to compact design of Arvedi ESP inductive heater;
- negligible refractory consumption in the 10 m Arvedi ESP inductive heating section versus refractory and roll consumption in a roller heath furnace of some 200 m in length.

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3.6 Personnel Costs

Specific personnel cost savings in the operation of an ESP line as compared to other production lines are due to the following factors:

- one caster operation group only;
- avoidance of slab storage staff;
- one fully automated process line requires fewer supervisors;
- reduced overall plant dimensions and compactness of the plant requires a payroll staff, including maintenance, of roughly 180 members.

4 VALUE ADDED

4.1 High Proportion of High-Quality Thin Gauges

Market prices for thin gauge flat products show increasing premiums. Hot-rolled flat products below 1.5 mm are already sold in the market segments of cold-rolled coils. As the productivity of most hot rolling processes decreases significantly below 2.5 mm, the ESP process shows practically no decrease in the thin gauge rolling segment and can even go down to 0.8 mm. Every percent of annual production of 0.8 mm to 1.2 mm low-gauge products results in about 1.3 million Euros of additional yearly revenues. The endless process can deliver up to 60% of less than 1.2 mm thickness in the low-carbon steel segment. An assumed wide-spread Arvedi ESP product mix chosen for a realistic calculation consists of more than 30% thin gauge products (< 1.5 mm). These cost advantages plus price benefits lead to extensive profitability of the ESP process route.
To produce high quality steels at extremely thin gauges is one of the most important benefits to the steel industry and provided by the ESP design. The main benefit, however, of Arvedi ESP is its capacity to produce a large volume of ultra-thin and wide strips. These products render the highest sales prices on the strip market. Unique to Arvedi ESP is that production of these ultra-thin and wide strips is independent of the final gauge thickness while other process routes are significantly restricted. The only restriction in producing ultra-thin gauges with ESP technology would be in steel grades that are known as difficult-to-cast grades, e.g. peritectic steels.
The diagram in Figure 7 summarizes the unique potential of Arvedi ESP in comparison with other production routes.

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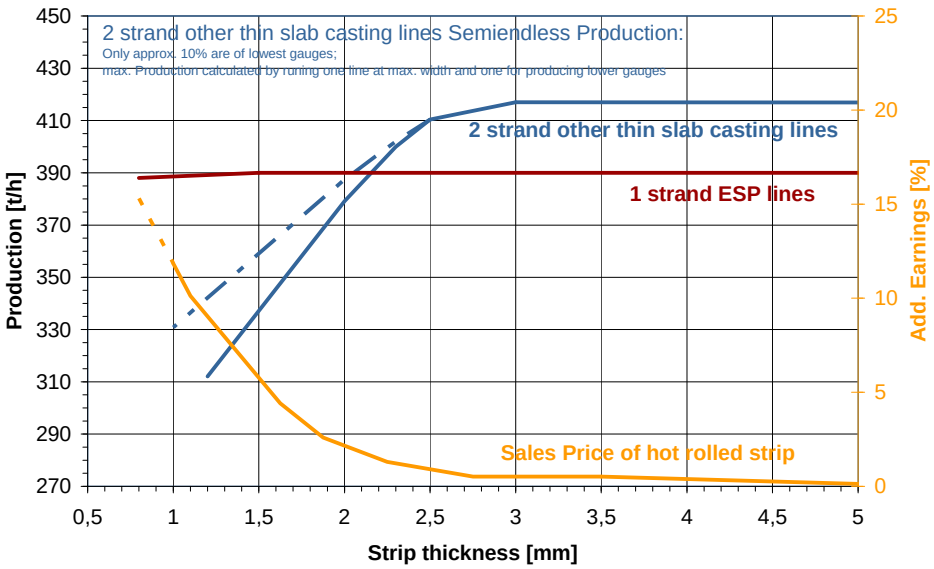

Figure 7. Arvedi ESP value added.

4.2 Cold-Rolled Strip Substitute

The use of thin-gauge hot-rolled strip instead of cold-rolled strip is even more promising because this saves the energy required for cold rolling, annealing and skin passing. The high-quality thin gauges provided by the endless process route contribute to the steadily growing acceptance of thin-gauge hot-rolled coil.
Starting from a thin hot rolled product with excellent precision, dimensional and flatness characteristics, Arvedi ESP offers the advantage of obtaining gauges as thin as 0.3 mm and 0.2 mm with a limited number of cold-rolling steps with lower investment and lower processing costs.

4.3 Contribution Margin and Return on Investment

A comparison of the contribution margin of Arvedi ESP with other production routes for hot-rolled coils, based on the figures above, is shown in the Figure 8.

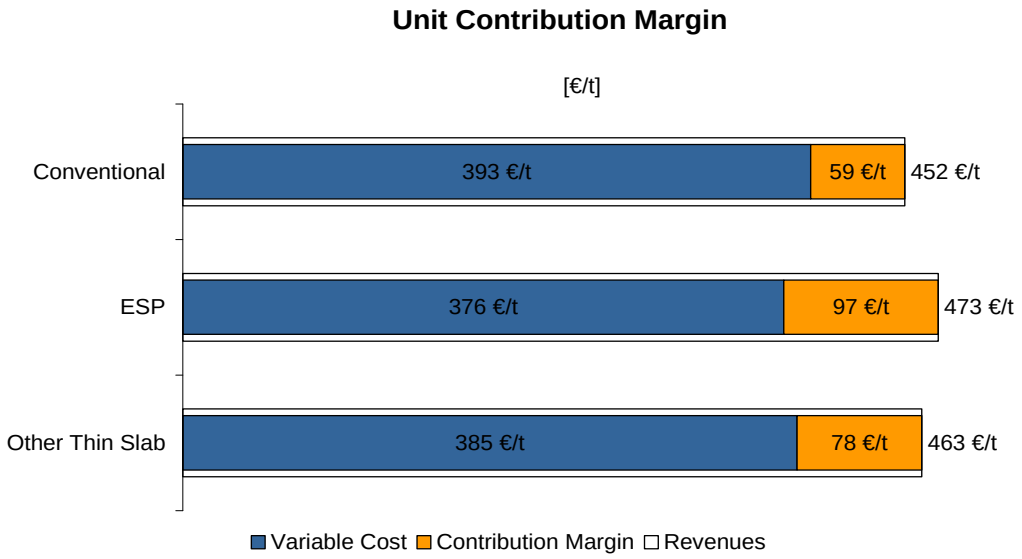

Figure 8. Contribution margin.

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Based on achievable contribution margins, Figure 8 shows the advantage of Arvedi ESP thin-gauge production. Such positive results are also reflected by the IRR (internal rate of return) calculation comparing ESP technology to other thin slab casting and rolling technologies, based on the sensitivity of variation in annual production (Figure 9).

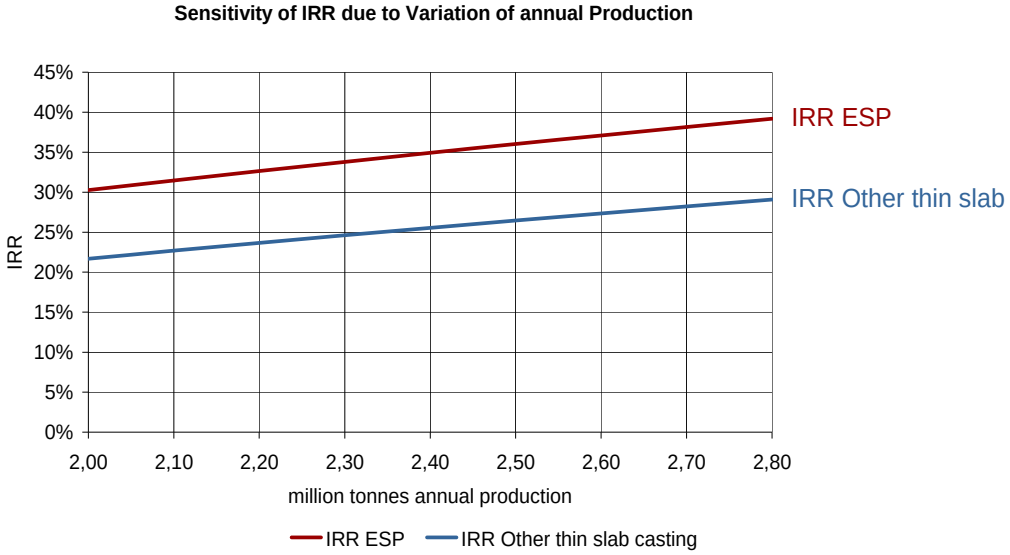

Figure 9. Internal rate of return.

Arvedi ESP leads to >30% IRR, which is more than a quarter higher than in other thin slab technologies.

5 SUMMARY

The arguments in favor of ESP technology are summarized in four main aspects that are advantageous to both the contribution margin and rate of return:

- Sales revenue premium of up to 30% for 0.8-1.5 mm hot-rolled coils
- Lowest conversion costs per ton (€ 28.4)
- Highest flexibility and productivity
- Low investment and maintenance costs due to compact plant layout

Arvedi ESP technology is the No. 1 technology for add-on investments of integrated plants in the thin-gauge market. Other important advantages are backward integration, the creation of one's own hot-rolled feedstock and entrepreneurial diversification in the area of flat steel products.