Executive summary and recommendations

1. Background

This assignment is part of the GEF-funded project "Industrial Energy Efficiency in Key Sectors" led by the United Nations Industrial Development Organization (UNIDO). The objective of the project includes the identification and implementation of a demonstration energy efficiency project in the Iranian iron and steel sector and promotion of sector-wide uptake of the selected energy saving technology.

This report assesses the feasibility of retrofitting a hot charging system to transport semi-finished steel products between a new continuous casting machine (currently under construction) and a medium section hot rolling mill at Esfahan Steel Company (ESCo). Recommendations for project implementation are presented. Assistance and training needed by ESCo to ensure successful implementation and operation are identified.

2. Esfahan Steel Company

ESCo is the largest manufacturer of constructional steel products in Iran with a production capacity of 2.5 million tonnes steel per year. Production started in 1971 at its fully integrated steel works located outside Isfahan. Demand for steel in Iran is increasing and ESCo plans to increase production to 4 million tonnes by 2015.

2.1 Energy consumption

ESCo is a significant consumer of energy and natural resources. In 2011, ESCo consumed around 36 million GJ of natural gas and over 600,000 tonnes of coking coal. In terms of efficiency, ESCo consumed 2.1 GJ of fuel (including 1.7 GJ of imported natural gas) for each tonne of steel rolled at Rolling Mill 500 (RM500) in 2012. Comparing the efficiency of ESCo to examples of international best practice, which range from 0.87 to 1.35 GJ/t with hot charging, indicates that significant improvements and energy savings are possible.

2.2 Energy saving opportunities

An energy audit and survey was undertaking at ESCo in 2012 which identified several possible candidate projects to improve energy efficiency at the steelworks. As well as energy saving potential and cost effectiveness, the ability to replicate the technologies across the iron and steel sector in Iran was a critical factor when selecting the demonstration project.

3. Proposed hot charging solution between CCM No.5 and RM500

ESCo proposes to implement a hot charging system to transport hot billets and blooms between the new continuous casting machine No.5 (CCM No.5) and the RM500 heating furnace as the demonstration project in partnership with UNIDO. Hot charging is widely adopted in other countries and can achieve significant cost-effective energy savings. There is also broad scope for replication across the Iranian steel sector. ESCo proposes to consecutively charge the heating furnace with hot billets directly from continuous casting at temperatures up to 700°C followed by cold billets from the stock yard at a ratio of 60% hot 40% cold.

3.1 Benefits of hot charging

The expected benefits compared to the current practice of 100% cold charging include the following.

- Significant energy and production cost savings.
- Higher production and throughput. ESCo is confident that it is possible to increase RM500 and furnace throughput from 140 to 170 t/h (without modification to the rolling mill).
- Shorter production times compared.
- Improved yields and product quality due to reduced scaling, oxidation and decarburisation.
- Waste reduction in following processes (e.g. from descaling).
- Reduced billet and bloom surface and dimension defects caused by crane transfer.
- Reduced use of crane for billet transfer (reduce operation and maintenance costs).

3.2 Applicability and technical feasibility

Applicability and technical feasibility of hot charging could be limited at ESCo by the following technical parameters.

- Billet and bloom quality and control inspection requirements.
- Layout and configuration of the casting plant and ability to modify for hot charging.
- Rolling mill furnace type, existing control system and the ability to increase furnace throughput whilst achieving temperature normalisation within the billet.
- Transfer distance between caster discharge table to furnace roller table
- Steel specifications.
- Billet temperature, heat transfer and conveying time (and time required for the transfer of the cold stock to the heating furnace).
- Sampling and chemical analysis requirements.
- Potential to align the production schedule of the steel casting plant and the production schedule of the rolling mill.

Based on the available information, the hot charging proposal is considered to be technically feasible. However, there remain a number of key technical questions (described below) which should be resolved before going ahead with implementation.

3.2.1 Billet and bloom quality

Normally, hot charging can only be applied if the billet/bloom surface quality is good enough so that cooling and scarfing is not required and billets can be charged directly to the furnace. CCM No.5 includes mould electromagnetic stirrers (M-EMS) which significantly improve billet quality and productivity. Therefore, hot charging should be possible.

3.2.2 Layout and configuration of CCM No.5

CCM No.5 was under construction at the time of the site visit and is due to be completed at the end of 2013. The design and configuration of CCM No.5 could limit the feasibility of hot charging. Hot charging is essentially an extra function to be added to the continuous casting machine.

3.2.3 Billet charging temperature

The greatest possible energy saving could be achieved by charging the furnace at the maximum possible temperature. However, transferring billets at high temperatures requires a more robust and expensive handling system. The charging temperature is dependent on distance and conveying time. The horizontal distance between CCM No.5 billet stopper and the furnace roller table is 20.3m, vertical distance is 1.5m and lateral distance from the CCM axis to the furnace roller table axis is approximately 3m.

The charging temperature proposed by ESCo's engineering department of around 700°C should be achievable provided the billets can be charged directly to the furnace over the minimum possible distance (without delay or diversion to undergo quality inspection).

3.2.4 Rolling mill 500 heating furnace

Technically, it is possible to charge the furnace with cold and hot billets without modification and achieve fuel savings by reducing fuel use due to the higher charging temperature and by increasing the charging rate. However, the scope for maximising the percentage of hot charging, increasing productivity and saving energy will be limited by the existing control system and billet resident time.

- Furnace temperature is controlled manually based upon measurements of temperature in the six heating zones and analysis of flue gas at the main exhaust. Increased monitoring and automated control (to regulate temperature inside the furnace more accurately) will increase the ability of operators to save fuel when switching between hot and cold charging.
- Billets are currently resident in the furnace for 120 minutes to allow billet temperature to normalise. Normally, hot charging reduces the resident time due to the reduced heating requirement and so increases productively and reduces specific fuel consumption. The RM500 walking beam furnace can operate at either 80 or 120 minutes. However, according to ESCo, it is not possible to operate at 80 minutes resident time as this is not sufficient time for temperature normalisation. Normally, edge heaters are installed in the furnace to enable temperature normalisation and higher furnace throughput. Burners are already installed in the ceiling and walls of the furnace so normalisation should be possible even at 80 minutes.
- Furnace throughput and rolling capacity is 140 t/hr. According to ESCo, hot charging could increase the capacity from 140 to 170 t/h by increasing throughput and reducing the distance between billets. This would not require modification to the rolling mill. The maximum capacity of 200 t/h is only achievable by increasing walking speed and reducing resident time to 80 minutes (as detailed above). However, this would require additional modifications to the rolling mill to handle billets at this speed. If throughput is not increased, then the percentage of hot charging is limited.

3.3 Equipment and cost

The hot charging system will consist of mechanical, hydraulic, electrical (including motors and drives), and control and automation equipment. The final equipment will depend on the engineering design. For the purposes of estimating the project cost, a preliminary list of main equipment has been drafted with ESCo's Engineering department. Some equipment can be procured locally whilst more advanced plant will have to be imported.

The total cost of the project is estimated at USD 2 million (including quality inspection billet handling system and quality inspection automation and control equipment). If the quality inspection equipment is not necessary, then the overall cost estimate drops to USD 1.1 million.

3.4 Energy saving potential

Assuming the furnace is charged continuously with hot billets at a nominal temperature of 450°C for 60% of production time and charged from cold stock at 40%, the reduction in natural gas use is estimated at 0.4 GJ/tonne or 18% of 2012 consumption. This corresponds to a cash saving of 8,329

Rials/tonne or 8 billion Rials/year (based on 2012 production and assuming a raised gas price of 1,000 Rials/m^3).

Raising the charging temperature to 700°C significantly increases the estimated natural gas saving to 0.55 GJ/tonne or 32% giving a cost reduction of 15,360 Rials/tonne or 14.8 billion Rials/year.

3.5 Economic feasibility

The economic feasibility of the hot charging project is judged upon the financial payback period. This is calculated by dividing the capital investment cost by the annual net cash flow attributed to the project. The annual net cash flow is calculated in two ways:

1. Firstly, including energy cost savings and operational cost savings, and
2. Secondly, including increased revenue as a result of improved yield (as well as energy and operational cost savings).

3.5.1 Including energy and operational costs savings

In the case where the hot charging system directly charges billets from the caster to the furnace, the payback period is estimated at 1.9 years, assuming 60% hot charging at 700°C and a natural gas price of 1,000 Rials/m^3. This is considered to be economically acceptable, solely on the annual energy and operational cost savings alone.

3.5.2 Including increased revenue as a result of improved yield

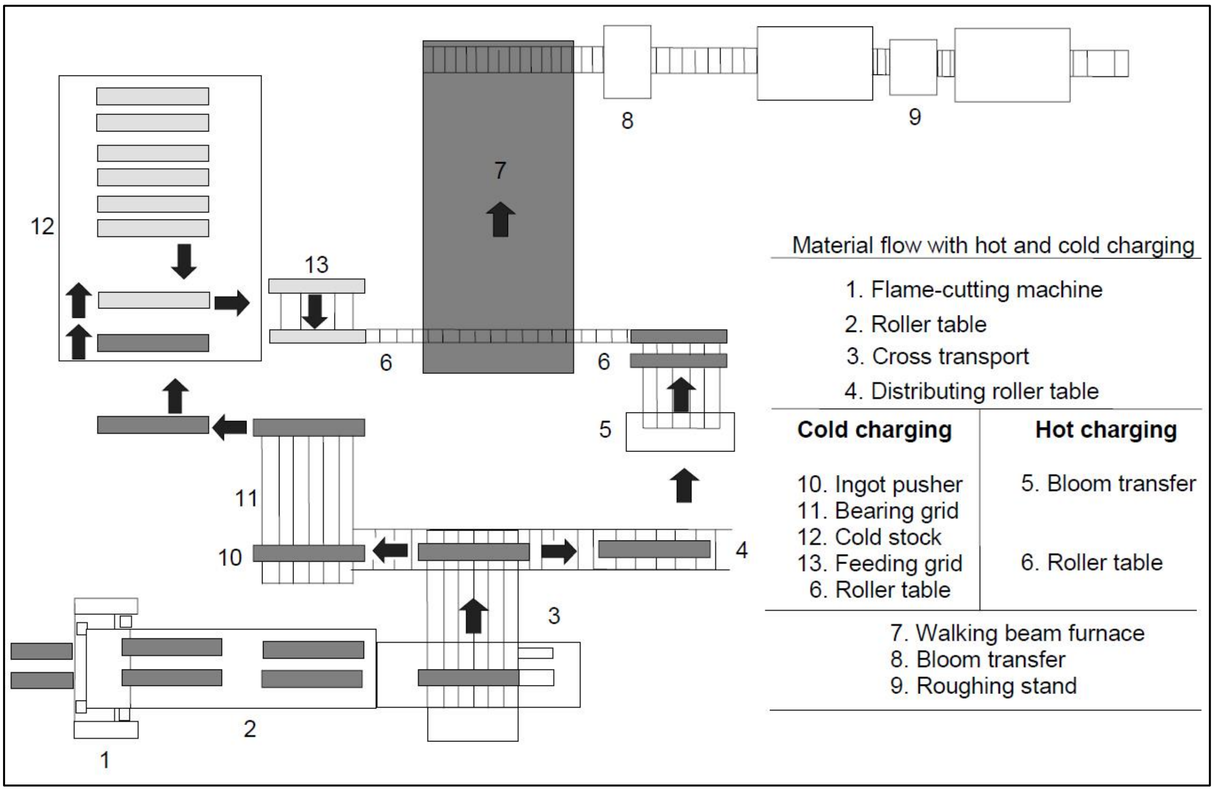
Implementing hot charging should reduce waste resulting in improved yield and increased revenue (e.g. a yield improvement of 0.5% is considered to be achievable when hot charging at 60%). Assuming a price of 18,000 Rials/kg of steel beam product, would give additional revenue of 86 billion Rials/year (equivalent to 3.5 million USD/year at the official UN exchange rate). The payback period is estimated at less than or equal to 0.3 years, when including this additional revenue stream (on top of the operational costs saving). Implementing hot charging is clearly economically feasible when taking the potential benefit of increased yield into account.

Hot Charging Background

Hot charging normally involves charging temperatures of between 300 to 800°C directly from the continuous casting machine to the reheat furnace. Hot charging is normal practice in the steel industry and has several benefits including significant energy cost savings when compared to cold charging. The best available billet transfer technique is direct rolling of billets of around 900 to 1000°C directly to the rolling mill. This state-of-the-art technique removes the need for an expensive reheat furnace entirely being replaced by a smaller induction furnace (if necessary). Direct charging can be expensive to retrofit and is normally limited to new plants.

Figure 1 presents a possible material flow in a plant allowing both cold charging and hot charging. An optimised production planning and control system to synchronise the production schedules of a steelworks and a rolling mill can achieve a hot charging share of over 60 % at about 800°C.

Figure 1 Example plant layout of a cold and hot billet handling system.



Preliminary list of equipment, supplies and services

No.	Description of work	Quantity	Comments
1	Engineering and design services		including basic and advanced engineering, and documentation and manuals
2	Procurement		
2.1	Equipment		Assumes use of CCM No.5 control room, process electrical system, process safety/environmental systems, work shop and utility systems (Fire-fighting, water etc)
2.1.1	Mechanical and Hydraulic equipment		
2.1.1.1	Billet cross transport table	1 set	
2.1.1.2	Lifting gear (hydraulic)	2 sets	
2.1.1.3	Rollers	24 sets	
2.1.1.4	Billet cross transport table	1 set	
2.1.1.5	Modifications to CCM No. 5 cross transfer system		
2.1.1.6	Quality inspection billet handling system		Includes rejection and additional cross transport tables
2.1.2	Process electrical systems		
	Electric motors & drives	24 gear motor sets	
2.1.3	Automation and control		
2.1.3.1	Process control automation system	1 set	
2.1.3.2	Quality inspection automation and control equipment	1 set	
2.1.4	Other (e.g. Billet insulation)		
2.2	Bulk materials		Includes civil bulk materials including reinforcement, steel structures - construction and technological, piping, fittings valves and pipe supports, cabling, coatings & insulation, fire protection etc
2.3	Supply of first fills		includes one year of operating consumables
2.4	Supply of spare parts		includes commissioning, fast wearing and operational spares for mechanical, electrical, instrumental, automation & control equipment, communication systems spares etc
3	Transportation & related costs		DDP (Delivered duty paid) & delivery unloaded at ESCo plant site. Includes cost of imported equipment delivery to Bandar Abbas (or other port) and then to site), local equipment to site, insurance, customs clearance, taxes and duties etc)
4	Construction		
4.1	Site establishment		
4.2	Pilling, Foundation, Civil works Execution		
4.3	Plant erection (Building steel structure etc)		
4.4	Equipment installation (plant and utility equipment)		
4.5	Commissioning & startup		
4.6	Performance test		
5	Management & Supervision services		E.g. project management, site management, technical assistance & engineering, construction engineering, Commissioning & performance test supervision
6	Training Services (onsite training)		
7	Production assistance		

Energy consumption

ESCo is a significant consumer of energy and natural resources and emitter of subsequent greenhouse gases (GHG) and air pollutants. In 2011, ESCo consumed around 36 million GJ of natural gas and over 600,000 tonnes of coking coal. The total net energy consumed per tonne of product for ESCo, or specific energy consumption (SEC), is shown in Table 1. SEC indicates the overall energy efficiency of production. SEC of pig iron, crude steel and rolled steel (2009, 2010 and 2011) has been provided by IFCO. (1) The SEC of Rolling Mill 500 is based on data provided directly by ESCo. This shows that overall energy consumption in 2009 was more efficient than compared to 2011. However, the efficiency of Rolling Mill 500 in 2012 has improved by almost 25% compared to 2011. ESCo consumed 2.1 GJ/t of fuel (including 1.7 GJ/t of imported natural gas) for each tonne of steel rolled at Rolling Mill 500 in 2012. Comparing the efficiency of ESCo to examples of international best practice (which range from 0.87 to 1.35 GJ/t with hot charging) indicates that significant improvements and energy savings are possible.

Table 1 Specific energy consumption for pig iron, crude steel and rolled steel in 2009, 2010 and 2011.

Parameter	Unit	2009	2010	2011	2012
Pig Iron:					
Specific Fuel Consumption	GJ/tonne	14.2	15.51	14.76	
Specific Electricity Consumption	GJ/tonne	0.36	0.43	0.49	
Specific Energy Consumption	GJ/tonne	14.55	15.9	15.26	
Crude Steel SEC:					
Specific Fuel Consumption	GJ/tonne	0.11	0.1	-0.14	
Specific Electricity Consumption	GJ/tonne	0.57	0.57	0.54	
Specific Energy Consumption	GJ/tonne	0.68	0.57	0.39	
Rolled Steel SEC:					
Specific Fuel Consumption	GJ/tonne	2.88	3.13	3.11	
Specific Electricity Consumption	GJ/tonne	0.38	0.39	0.37	
Specific Energy Consumption	GJ/tonne	3.26	3.53	3.48	
Rolling Mill 500 SEC:					
Specific Fuel Consumption	GJ/tonne			2.86	2.14
Specific Electricity Consumption	GJ/tonne				
Specific Energy Consumption	GJ/tonne			2.86	2.14
Specific Gas Consumption	GJ/tonne			2.28	1.69

Energy and cost saving potential

The potential energy and cost that could be saved following successful implementation of hot charging has been estimated using a 4-step method and the specific heat capacity of carbon steel.

1. Heat requirement – Calculate heat required to raise temperature of billets from cold to hot charge temperature.
2. Energy requirement – Calculate energy required by the RM500 furnace to meet the heat requirements of billets from cold to hot charge temperature (including total fuel and natural gas).

3. Heat requirement and fuel saving – Calculate heat and energy required to raise the temperature of billets to 1250°C inside the furnace.
4. Energy and cost saving – calculate natural gas saving and cost saving.

Additional heat requirement between cold and hot charge

Firstly, the amount of heat required to raise the temperature of billets from the ambient cold charge temperature to various hot charge temperatures ranging from 400 to 700°C was calculated, as shown in Table 2.[1]

Table 2 Heat required to raise the temperature of billets from the cold charge temperature to various hot charge temperatures.

Temperature difference	From cold charge temperature	To hot charge temperature	Furnace heat requirement		Furnace fuel consumption	
ΔT	°C	°C	GJ/tonne	GJ/year	GJ/tonne	GJ/year
ΔT1	25	400	0.21	201,628	0.54	523,549
ΔT2	25	450	0.24	232,601	0.63	603,973
ΔT3	25	500	0.27	265,254	0.71	688,760
ΔT4	25	600	0.35	339,994	0.91	882,832
ΔT5	25	700	0.44	428,963	1.15	1,113,849

Additional energy requirement between cold and hot charge

Secondly, the equivalent energy required by RM500 furnace, including total fuel and the natural gas, is calculated as shown in Table 3.

Table 3 Equivalent energy required by the Rolling Mill 500 reheat furnace, including total fuel and the natural gas.

Temperature difference	From cold charge temperature	To hot charge temperature	Furnace natural gas use		
ΔT	°C	°C	Ratio % (in 2012)	GJ/tonne	GJ/year
ΔT1	25	400	79%	0.43	415,185
ΔT2	25	450	79%	0.50	478,964
ΔT3	25	500	79%	0.57	546,202
ΔT4	25	600	79%	0.72	700,105
ΔT5	25	700	79%	0.91	883,307

[1] This applies Specific Heat Capacities (C_p) for carbon steel (composition Manganese (Mn) 1%, 0.1% < Silicon (Si) ≤ 0.6%) of 446, 501, 545, 582, 699 and 971 J/kg·K at 300, 400, 500, 600, 800 and 1000 K, respectively, assuming that the majority of rolled products at RM500 are Steel Grade St 37-3 and St 44-2.

Heat and fuel requirement to raise to rolling temperature

Thirdly, the heat required to raise the temperature of one tonne of billet inside the furnace to the desired discharge rolling temperature of 1250°C and equivalent fuel and natural gas required by the furnace (in GJ/Tonne) is shown in Table 4. This assumes the furnace is cold charged and hot charged at 450°C, at various selected overall ratios of cold and hot billets.[2]

Table 4 Specific heat required to raise the temperature per tonne of billet inside the furnace to 1250°C and the fuel and natural gas requirement of the furnace (in GJ/Tonne).

Cold charge	Hot charge	Resident time	Specific heat required (G/tonne)			Furnace fuel required	Natural gas required
%	%	Minutes	Cold charging	Hot charging	Total	GJ/tonne	GJ/tonne
100%	0%	120	0.82	-	0.82	2.14	1.69
50%	50%	120	0.41	0.29	0.70	1.82	1.45
40%	60%	120	0.33	0.35	0.68	1.76	1.40
25%	75%	120	0.21	0.44	0.64	1.67	1.32
0%	100%	120	-	0.58	0.58	1.51	1.20

The annualised heat and energy requirements are then calculated following (in GJ/tonne) as shown in Table 5. This assumes the furnace is cold charged and hot charged (at a conservative temperature 450 °C) at various selected overall ratios of cold and hot billets.[3]

Table 5 Annual heat required to raise the temperature of billets inside the furnace to 1250°C and the potential energy (in GJ/Year).

Cold charge	Hot charge	Resident time	Annual heat required (GJ/Year)			Furnace fuel required	Natural gas required
%	%	Minutes	Cold charging	hot charging	Total	GJ/year	GJ/year
100%	0%	120	794,276	-	794,276	2,062,424	1,635,548
50%	50%	120	397,138	280,838	677,976	1,760,437	1,396,066
40%	60%	120	317,710	337,005	654,715	1,700,040	1,348,169
25%	75%	120	198,569	421,256	619,825	1,609,444	1,276,325
0%	100%	120	-	561,675	561,675	1,458,451	1,156,584

1.1.1 Estimated energy cost saving

Finally, the equivalent energy and cost savings from reduced natural gas consumption were then estimated, as shown in Table 6. This assumed that the furnace is cold charge at 25°C and hot charged at

[2] Heat is given in GJ/Tonne based upon annual production of 965,685 tonnes of finished steel in 2012. Fuel to be supplied to by the furnace to provide the heat required is calculated assuming a thermal efficiency of 39% (based on 2012 performance). Natural gas constitutes 79% of the fuel (again based on 2012 data).

[3] Heat is given in GJ/Year based upon annual production of 965,685 tonnes of finished steel, total fuel consumption of 2,062,424 GJ/year and natural gas use of 1,635,548 GJ/year in 2012. Again equivalent furnace fuel consumption is calculated applying a thermal efficiency of 39%. Natural gas constitutes 79% of the fuel (again based on 2012 data).

450°C at the selected overall ratios of cold and hot billets charge to the furnace. The natural gas cost saving is based upon 2012 gas consumption at a purchase price of 778 Rials/m^3.

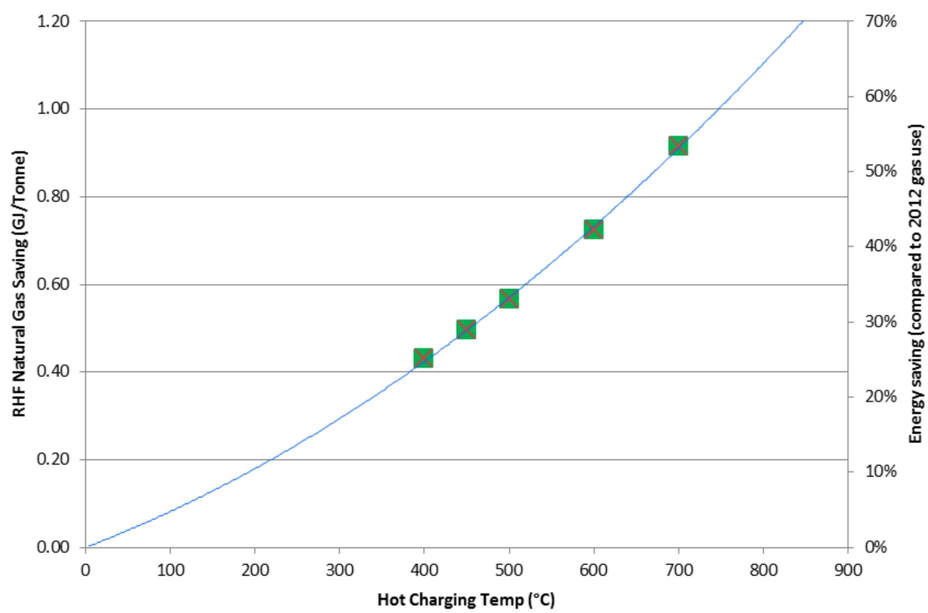
The analysis shows that charging the furnace with 100% of billets at a conservative temperature of 450°C will achieve an estimated natural gas savings of 18% or 0.5 GJ/Tonne, as shown by Figure 2. If the charging temperature is raised to 700°C, then the equivalent natural gas savings could be over 50% or 0.9 GJ/tonne.

Table 6 Equivalent energy and cost savings from reduced natural gas consumption, assuming the furnace is cold charge at 25°C and hot charged at 450°C, and at the selected ratios of cold and hot billets.

Cold charge	Hot charge	Natural gas saving				
%	%	GJ/tonne	GJ/year	%	Rials/tonne	Billion Rials/year
100%	0%	-	-	0%	-	-
50%	50%	0.25	239,482	15%	5,400	5.2
40%	60%	0.30	287,378	18%	6,480	6.3
25%	75%	0.37	359,223	22%	8,100	7.8
0%	100%	0.50	478,964	29%	10,800	10.4

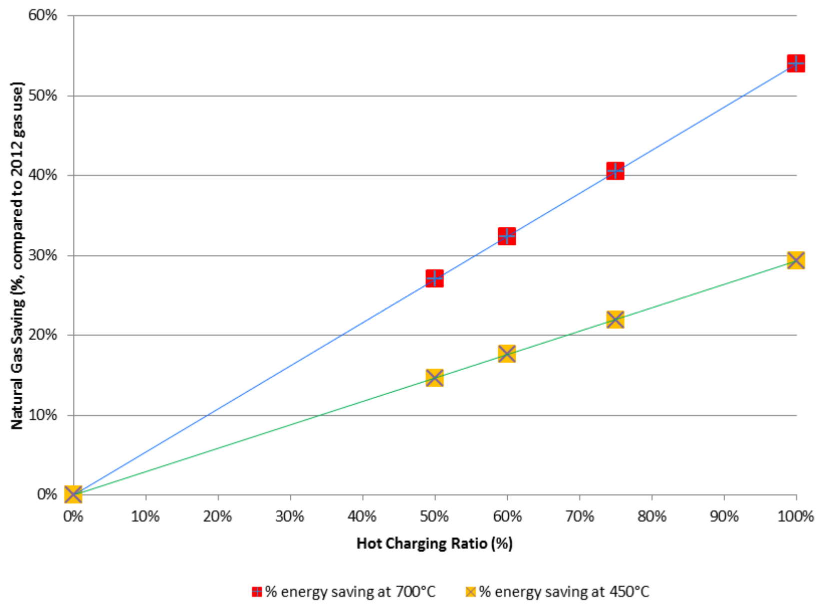
The energy costs saving is dependent on the gas price paid by ESCo. Applying the price of natural gas 778 Rials/m^3 set by Government in 2012, gives an energy cash saving of 6,480 Rials/tonne and 6.3 billion Rials/year when hot charging at 450°C for 60%. Raising the charging temperature to 700°C gives a cost reduction of 11,950 Rials/tonne and 11.5 billion Rials/year.

Figure 2 Potential energy savings from reduced natural gas consumption for various hot charge temperatures, assuming the furnace is hot charged at 100%.



Accounting for the real situation where the furnace is charged continuously with hot billets for 60% of production time and charged from cold stock for 40%, the reduction in natural gas consumption is estimated at 0.4 GJ/tonne or 18% at a charging temperate of 450°C, as shown in . Raising the charging temperature to 700°C increases the estimated natural gas saving to 0.55 GJ/tonne or 32%.

Figure 3 Potential energy savings from reduced natural gas consumption when charging the furnace at 450°C and 700°C, and at various selected overall ratios of cold and hot billets over time.



Gas price sensitivity analysis

IFCO has indicated that the gas price could be raised by the Government during 2013. To account for this possible increase, the potential cost saving over a range of gas prices is estimated for hot charging at 450°C and 700°C in Table 7.[4]

Table 7 Impact of an increasing natural gas price on the potential energy cost saving.

Parameter	Unit	Low	Medium	High
Gas Price	Rials/m³	778	1000	1500
Cost saving at 450°C hot charge	Billion Rials/year	6.3	8.0	12.1
	Rials/tonnes	6,480	8,329	12,494
	USD/year	252,629	324,716	487,074
Cost saving at 700°C	Billion Rials/year	11.5	14.8	22.3

[4] Savings in USD are calculated by applying the official UN exchange rate of 24,770 Rials to the dollar.

hot charge	Rials/tonnes	11,950	15,360	23,041
	USD/year	465,900	598,843	898,264

Assessment of economic feasibility

The economic feasibility of the hot charging project is judged by calculating the financial payback period (i.e. the period of time required for the return on an investment to "repay" the sum of the original investment). This is calculated by dividing the capital investment cost by the annual net cash flow attributed to the project. The annual net cash flow is the sum of all annual operational savings and revenue attributed to the hot charging project minus the annual operational costs. The annual net cash flow is calculated in two ways:

1. Firstly, including energy cost savings and operational cost savings, and
2. Secondly, including increased revenue from reduced waste (on top of the energy and operational cost savings).

The annual operating and maintenance staff costs for hot charging equipment is estimated at 2.5% of the capital cost. The cost of spare and replacement parts is included in the capital cost. The cost parameters are listed in Table 8.

Table 8 Parameters used in the calculations of payback period.

Parameter	Unit	Costing 1*	Costing 2	Note
Capital cost	USD	-1,074,255	-1,969,695	Costing 2 includes quality inspection and additional billet handling equipment
Annual operational costs				
Operation & maintenance (O&M) staff costs	USD/year	-26,856	-49,242	2.5% of capital cost
Replacement of parts and fillers	USD/year	-	-	Included in Capex
Annual operational savings				
Energy cost saving	Million Rials/year	6,258 - 22,250		Range values depending on gas price
Energy cost saving	USD/year	252,629 - 898,264		
Crane O&M savings	USD/year	6,000		Crane transport reduced by 60%. Assuming O&M costs USD $10,000/year for maintenance and power costs.
Increased revenue				
Improved yield from waste reduction	%	0.5%		Assuming minimum improvement of 0.5%
Mass (billets)	kg/year	965,685,000		2012 RM500 production
Price	Rials/kg	18,000		
Increased revenue	Million Rials/year	86,912		Assuming price of IPE steel beam is IRR 18,000/kg
Increased revenue	USD/year	3,508,746		Official UN exchange rate USD 1 = IRR 24,770

*Costs are highlighted in red and are deemed to be of negative value.

Including energy and operational costs savings

The first assessment incorporates the following cost savings.

- Energy cost savings from reduced natural gas consumption as presented in Table 7 (over a range of gas prices at different charging temperatures).
- Operation and maintenance cost savings achieved by a 60% reduction in the transfer of billets by crane.

The overall investment cost is estimated at USD 1.1 million in the case where the hot charging system directly charges billets from the caster to the furnace (see “Costing 1” in in Table 8). The range of payback periods for hot charging at 450 and 700°C are shown in Table 10. The payback period is estimated at 1.9 years, assuming 60% hot charging at 700°C and a natural gas price of 1,000 Rials/m^3. This is considered to be economically acceptable, solely on the annual operational savings alone.

Table 9 Payback periods for hot charging system which directly charges furnace, assuming charging at 450°C and 700°C over a range of natural gas prices.

Parameter	Unit	Low	Medium	High
Gas price	Rials/m^3	778	1000	1500
Payback period at 450°C hot charge	Years	4.7	3.6	2.3
Payback period at 700°C hot charge	Years	2.5	1.9	1.2

The overall investment cost is estimated at USD 1.5 million where additional quality inspection and billet handling equipment is included (see “Costing 2” in in Table 8). The range of payback periods for hot charging at 450 and 700°C are shown in Table 10. The payback period is estimated at 7 years, assuming 60% hot charging at 450°C and a natural gas price of 1,000 Rials/m^3.

Table 10 Payback periods for hot charging system including quality inspection and additional billet handling equipment, assuming charging at 450°C and 700°C over a range of natural gas prices.

Parameter	Unit	Low	Medium	High
Gas price	Rials/m^3	778	1000	1500
Payback period at 450°C hot charge	Years	9.4	7.0	4.4
Payback period at 700°C hot charge	Years	4.7	3.6	2.3

Including reduced waste, increased yield and increased revenue

Implementing hot charging will reduce the need for descaling and reduce waste resulting in improved yield and increased revenue. This potentially significant economic benefit should be included in the assessment of economic feasibility.

A conservative improvement of 0.5% is considered to be achievable when hot charging at 60%, based upon examples of best practice. (4) Assuming a price of 18,000 Rials/kg of steel beam product, would give additional revenue of 86 billion Rials/year (equivalent to 3.5 million USD/year at the official UN exchange rate). The payback period for the hot charging project is estimated at less than or equal to 0.3 years, when including this additional revenue stream (on top of the operational costs saving).

Implementing hot charging is clearly economically feasible when taking the potential benefit of increased yield into account.

Summary of Financial Assessment from ESCo view

Overall investment cost estimation proposed by ESCo is USD1.5 million as ESCo believes that many of the work could be performed locally and as a result the total investment cost will not be more than mentioned amount. USD 500,000 is financed by GEF/UNIDO and therefore, the total amount financed by ESCo in the project will be USD 1 million.

Table 16 represents the financial assessment from ESCo view with investing of USD 1 million.

Table 16: Financial benefit of Energy Saving

Investment Cost = 1,000,000 (USD)		Gas Price (Rials/NM3)		
		778	**1000**	**1500**
450 C hot charging	Amount of Saving at (GJ/year)	287,378		
	Cost Saving (USD/year)	252,629	324,716	487,074
	Simple Pay back (year)	**4**	**3.1**	**2.1**
700 C hot charging	Amount of Saving (GJ/year)	529,964		
	Cost Saving (USD/year)	465,900	598,843	898,264
	Simple Pay back (year)	**2.1**	**1.7**	**1.1**

The above calculations are only for energy saving without considering revenue due to "Improved yield from waste reduction" as can be seen in table 13.

The project has more benefit when the revenue of 0.5% waste reduction will be taken into account. The result has been shown in table 17.

Table 17: Total Financial benefit (Energy Saving and Cost Saving due to 0.5% of waste reduction)

Investment Cost = 1,000,000 (USD)		Gas Price (Rials/NM3)		
		778	**1000**	**1500**
450 C hot charging	Cost Saving (USD/year) [1]	252,629 +3,508,746	324,716 +3,508,746	487,074 +3,508,746
	Simple Pay back (year)	**0.27**	**0.26**	**0.25**
700 C hot charging	Cost Saving (USD/year) [2]	465,900 +3,508,746	598,843 +3,508,746	898,264 +3,508,746
	Simple Pay back (year)	**0.25**	**0.24**	**0.23**

Conclusion

The calculation represented in table 17, obviously shows that the project is entirely feasible from ESCo view as an economical enterprise. Partnership with UNIDO will facilitate the provision of international equipment and services which require for the implementation of the project.