Industrial regions and climate change policies

Reference document for the Province of Norrbotten

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Methodology

This study has been carried out based on the analysis, compilation and comparison of essentially public data. It is supplemented by interviews conducted with local and national industrial relations and economic actors. We wish to thank the representatives of the following organisations for their support:

LO Sweden,
Sveriges Ingenjörer
The Confederation of Swedish Enterprise (Svenskt Näringsliv)
The Swedish Gasification Centre (Prof. Joachim Lundgren)
The Lulea University of Technology (Prof. Karl-Eric Grip)
The Swedish Energy Agency

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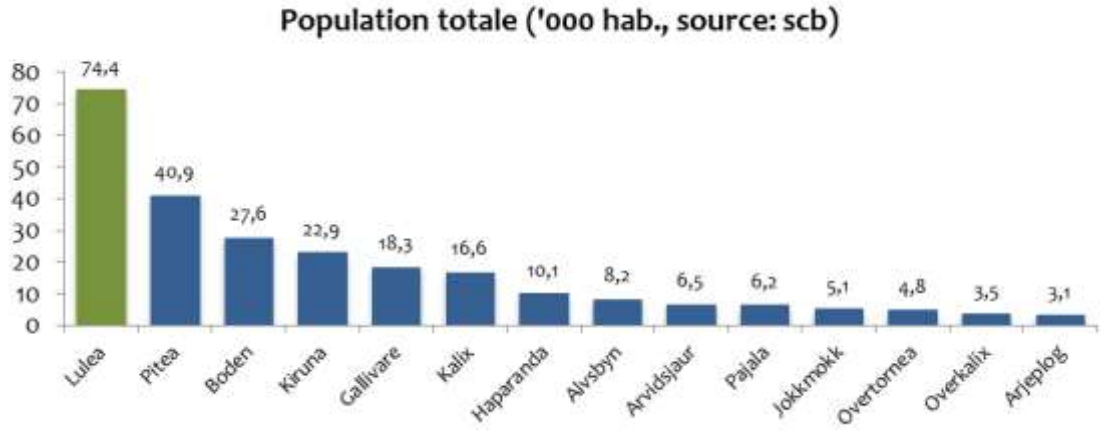
1. The Province of Norrbotten

1.1. Geography

The Province of Norrbotten, situated in the north of Sweden, is the largest province in the country, covering ¼ of its total surface area. Blessed with a strategic geographic location, bordering Norway and Finland, close to both the Arctic Circle and the Barents Sea, it is characterised by its particularly low population density (2.6 inhab. / km^2 compared to a national average of 22.8). In 2013, it had a population of 249,000 inhabitants (2.6% of the Swedish population), mainly divided between 14 municipalities, the most important of which are Lulea and Piteå.



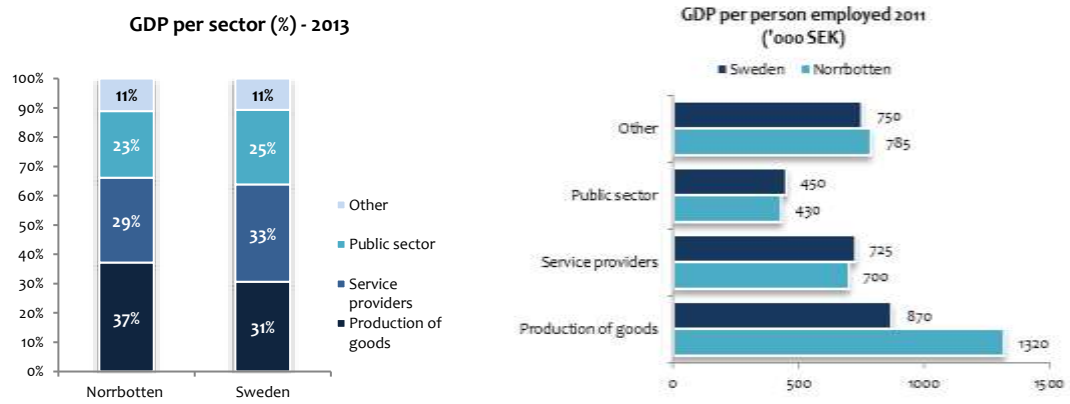
Source: Regional fakta

A forested, partly mountainous region, the Province of Norrbotten is blessed with bountiful natural resources (iron ore, timber, water resources) on which its industrial development has been based.

1.2. Economy

In 2013, the region had a GDP of €10.7 billion, which was 2.6% of Sweden's total GDP (€401 billion). However, relative to the number of inhabitants, this figure places Norrbotten in second place nationally, with a GDP per capita of €43.3 K/year, a figure that is lower than that of Stockholm (€58.7 K) but above the national average (€41.8 K).

The economy of the province is diversified but dominated by the exploitation of raw materials (iron ore, copper, forestry), industry and the manufacturing sector. The contribution of the services sector (ICT, trade, transport, financial services, tourism) to GDP is 29%, compared to 33% nationally. Containing a significant number of SMEs, the Province of Norrbotten is also host to a sizeable number of research & development centres.



Source: Regional fakta

Due to this preponderance of raw materials and industry, the economy of the province is strongly export-orientated (780 export companies). In 2013, the value of exports reached €3.5 billion, mostly to EU countries. As a result, the county benefits from significant transport infrastructure, including 5 airports, highly developed road (9% of the national network) and rail networks as well as port facilities (Pitea, Kalix). The Port of Lulea is one of the 5 largest ports in the country. The mining company LKAB has a limestone works and oil depot, among other facilities, located there.

1.3. Main sectors of activity and industrial actors in the province

In Norrbotten, copper and iron ore are the main resources exploited.

- The ore producer **Boliden Mineral** (4,900 employees, turnover of €3.9 billion in 2015, production sites based in Sweden, Norway, Finland and Ireland), operates the Aitik copper mine, which has estimated reserves of 1,421 Mt. In 2015, the site, located close to Galiivare and which employs around 679 people, produced 39 kt of concentrate, processed at the Ronnskar smelting plant. Investments totalling €64 million were made in 2015 to bring the production capacity of the site to 45 kt.

- **LKAB**, a producer of iron ore (turnover of €1.7 billion, present in 15 countries, 4,000 employees), owns the 2 largest underground mines in the world, located in Kiruna and Malmberget. The group is also involved in activities relating to drilling systems, rail transport and property management. It has 2 R&D laboratories in the province specialising in rock mechanics (Kiruna) and ore processing (Malmberget, opened in 2011).

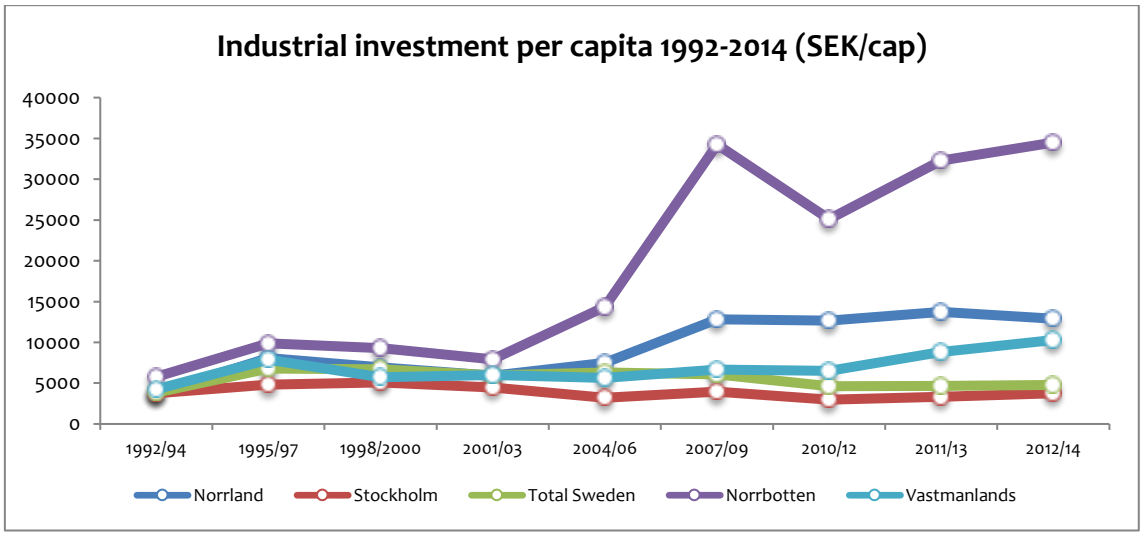
The ore mined by LKAB is processed by, among others, **SSAB**, a producer specialising in high-strength steel, tempered steel, tubular products and construction solutions. The Lulea plant, which is part of the group's European division specialising in strips, flat and tubular products intended mainly for the automotive industry, employs almost 1,200 people.

The Province of Norrbotten also possesses significant forestry reserves: productive resources make up around 34% of its territory. The timber industry, concentrated in the area

between Pitea and Kalix, employs close to 4,000 people and had an estimated turnover of €1.7 billion in 2009. The sector is organised around several activities, such as logging, sawmills, production of wood pulp, paper and packaging, as well as construction. Major companies are present in the province, such as **Sveaskog (forestry), Alvsbyhus, Lindback Bygg (construction), Smurfit Kappa and SCA** (Paper and Packaging)[1]**. Billerud Skog** has a production site (pulp and paper) in Kalsborgs with a capacity of 300 kt. /year, and which employs 430 people[2].

Other industries present in the region are connected with eyewear manufacturing (Polaris eyewear), the health sector (Liko AB) as well as the automotive sector. Gestamp has an equipment production site in the province while Ferruform produces chassis for trucks and buses.

1.4. Industrial investment



Source: Regional fakta

Industrial investment in the province amounted to an average of €915 million per year over the 2012-2014 period, which was 16% of national industrial investment (€5.5 billion/year). In 2013, the level of investment per capita was €3,600, a figure well above the average for the country (€585). Growth in investment has been especially marked since the early 2000s, particularly in respect of buildings and industrial machines.

This growth can be explained by investments in the mining and metallurgical sector as well as by the opening, in 2011, of social network Facebook's 3rd datacentre. The investment, encouraged by the natural characteristics of the province (cool climate, renewable energy)

[1] http://www.sca.com/en/timber/about-us/our-units/munksunds-sawmill/
[2] http://www.billerudkorsnas.se/en/About-Us/Our-Production-Units/Karlsborg/

and the existence of qualified labour (Lulea University of Technology) should eventually enable the creation of 2,200 direct jobs (2/3 of them in Lulea) and contribute up to 1.5% to local gross domestic product[3].

1.5. Research centres

Norrbotten County has a number of research centres and institutes, foremost of which is the aforementioned Lulea University of Technology (LTU), the Energy Technology Centre in Pitea (ETC) as well as SWEREA MEFOS and SWEREA SICOMP:

- The activity of the **Lulea University of Technology (LTU)**[4] covers 72 areas of research, including construction, mining, renewable energy, engineering, industrial processes, sustainable transport and information technology. With a budget of €170 million (59% of which is devoted to research), it has 16,000 students, 1,700 employees (including 216 professors) and 319 Ph.D. students.

- The **Energy Technology Centre** in Pitea **(ETC)** is a research organisation that specialises in thermochemical conversion of biomass (particularly in the area of combustion, gasification and bio-refining). It collaborates with the academic world, public agencies and industry.

- **Swerea** is a research group for industrial renewal and sustainable development. Partially owned by the state (42%) and by industry (450 companies via 5 associations)[5], its objective is to disseminate advances in scientific research in the area of development of products, materials and production processes. Swerea is composed of 5 institutes, 2 of which have a presence in Lulea: Swerea MEFOS[6] (specialising in the area of metallurgy and energy technologies) and Swerea SICOMP[7] (research in the area of polymer fibre composites).

1.6. Employment

The main employers in the province are the health and social services sector (18% of employment), manufacturing industry and the mining sector (14%), corporate services, education and research (10%) and trade and construction (9%).

Gainfully employed by sector & gender, 2012
Percentage of total

[3] https://www.facebook.com/notes/lule%C3%A5-data-center/connecting-creating-contributing/640487766019915
[4] http://www.ltu.se/ltu/Organisation/LTU-i-siffror/Fakta-pa-fickan-2015-1.95875?l=en
[5] http://www.swerea.se/en/about-swerea
[6] http://www.swerea.se/en/mefos
[7] http://www.swerea.se/en/sicomp

Sector	women	men	Total	Norrbotten	Sweden
Agriculture /forestry/fishing	998	3 423	4 421	4%	2%
Manufacturing/mining	**2 932**	**13 748**	**16 680**	**14%**	**14%**
Energy, water, waste	312	1 301	1 613	1%	1%
Construction	**1 039**	**10 013**	**11 052**	**9%**	**7%**
Trade	**5 280**	**5 810**	**11 090**	**9%**	**12%**
Transport & storage	1 026	5 076	6 102	5%	5%
Hotels & restaurants	2 276	1 412	3 688	3%	3%
Information & communication	1 036	1 840	2 876	2%	4%
Finance	924	580	1 504	1%	2%
Property management	565	1 092	1 657	1%	2%
Business services	**5 090**	**6 460**	**11 550**	**10%**	**11%**
Civil authorities	4 110	4 768	8 878	7%	6%
Education & research	**9 269**	**3 014**	**12 283**	**10%**	**11%**
Health care & social services	**17 908**	**3 557**	**21 465**	**18%**	**16%**
Others	3 599	2 617	6 216	5%	6%
Total	**56 364**	**64 711**	**121 075**		

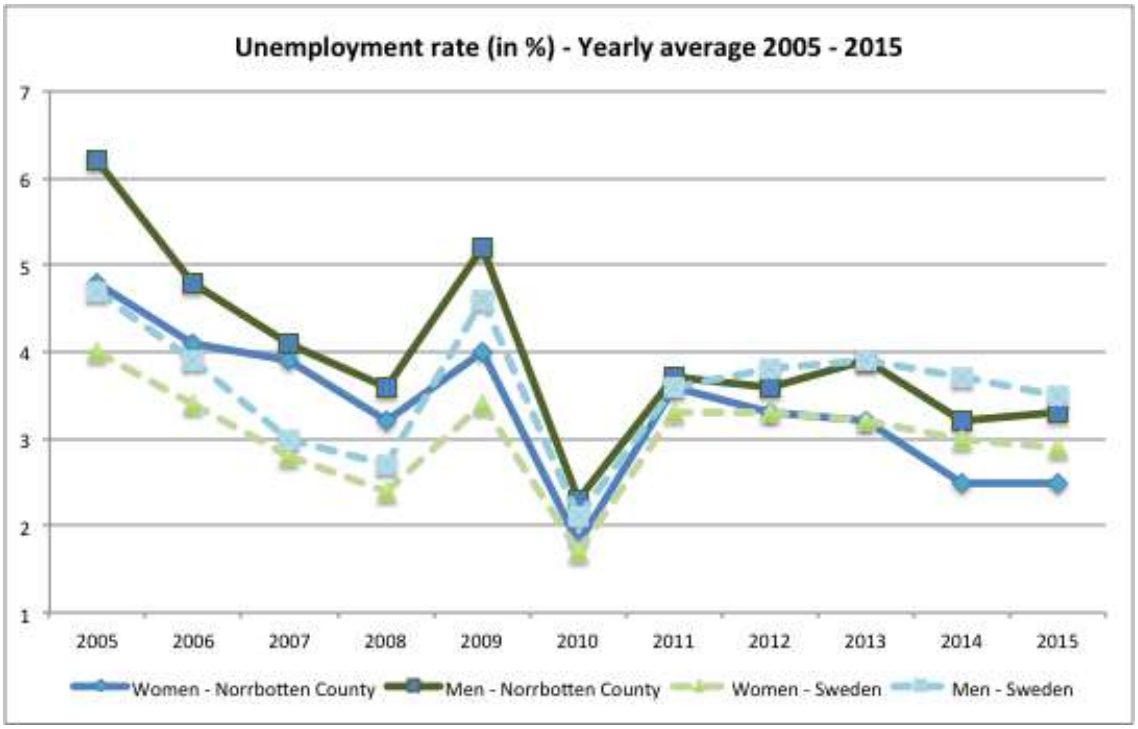
Source: Province of Norrbotten

The main private employers are LKAB (3,725 employees) and the metallurgist SSAB (1,375). They are followed by COOP (shops and supermarkets) and the mining company Boliden Mineral.

Main employers in Norrbotten County

Private sector	2013	2009	Public sector	2013
LKAB mining	3725	2675	Norrbotten County Council	7425
SSAB EMEA AB	1375	1675	Lulea Municipality	7025
Samhall AB	1075	1125	Pitea Municipality	4275
COOP Norrbotten	825	975	Boden Municipality	2875
Boliden Mineral AB	725	525	Swedish Armed forces	2675
TeliaSonera Sverige AB	625	425	Kiruna Municipality	2125
Gestamp Hardtech AB	575	525	Gallivare Municipality	1875
Smurfit Kappa Kraftliner Pitea AB	575	625	Kalix Municipality	1575
Ferruform AB	550	625	Lulea University of Technology	1525
Billerud Karlsborg AB	425	425	Alvsbyn Municipality	1275
Inre Kraft i Norr AB	425		Haparanda Municipality	1125
SCA Munksund AB	325	325	Arvidsjaur Municipality	925
IKEA Forsaljnings	225		Swedish police	725
Last & terrang Haggroths traktor AB	225		Pajala Municipality	575

In the province, the average annual unemployment rate in 2015 was 2.5% among women and 3.3% among men, figures that are lower than the national averages (2.9% and 3.5% respectively). However, these figures do not include people participating in employment policy programmes.



Source: Regional fakta

2. CO2 emissions

Although in 5th place in terms of GDP per capita among member countries of the OECD, Sweden is 2nd in the ranking of least carbon-intensive economies. In 2012, the level of its emissions reached 44.3 million tonnes, which was 1/19th of total EU emissions.

2.1. Sweden's CO2 emissions

Since 1990, the country has reduced its CO2 emissions by 20%, thereby noticeably exceeding Kyoto Protocol targets and its national targets. This period has been marked by an especially pronounced decoupling of emissions from GDP growth[8], which is all the more remarkable given the relatively energy-intensive character of the Swedish economy, linked to its cool climate, responsible for the high energy consumption of households, and the power of Sweden's industrial base. This industrial base, which is strongly export-orientated, is dominated by the engineering sector, telecoms, steel production and the manufacturing sector (pharmaceuticals, automotive industry). Industry accounts for 26.5% of GDP, which is higher than the average for OECD countries (24%), compared to 72% for services and 2% for agriculture.

In Sweden, the main source of carbon emissions is the transport sector which accounts for 48% of the total[9]. Other sectors with high emissions are the manufacturing sector (34%)[10] and the residential sector. Electricity generation has been significantly decarbonised, due to the development of nuclear and hydroelectric power. Since 1990, the main reductions in emissions have been in the manufacturing sector, electricity and gas production (-27%) and household transport (-18%). The most spectacular reduction has been in residential heating (-93%), whose share of total emissions has fallen from 12% to 1%.

Impact of climate policies

The low carbon intensity of the economy is partly the result of structural factors (nuclear power, abundance of renewable resources, historically low share of fossil fuels in industrial energy consumption) and economic factors (economic crisis). Nevertheless, it is also related to the implementation of an integrated environmental policy, centred on the taxation of fossil energy (energy tax, excise duties), CO2 emissions (carbon tax on the generation of residential and industrial heat and in the transport sector) and polluting emissions (SO2, NOx).

This taxation, combined with numerous other instruments of environmental policy (energy efficiency programmes, innovation and investment grants, certificates of origin, renewable energy, etc.) has resulted in profound changes in the Swedish energy balance:

[8] Since 2000, the economy has grown by 30% while CO2 emissions have declined by almost 16%. This relative decline is one of the highest among OECD member countries.
[9] With 20% for private transport, 14% for maritime transport and 8% for road transport;
10 Here, the manufacturing sector also includes industry, in accordance with the nomenclature adopted by Eurostats.

- A shift in the demand for fossil fuels (particularly oil) towards renewable sources which, today, account for 35.7% of primary energy consumption[11]. Their development has been especially marked in industry, transport and district heating.
- An improvement in energy efficiency, mainly as a result of increases in energy prices. This improvement is partially linked to households and the energy efficiency of buildings, and partially to industry. The manufacturing sector, the chemical industry and metallurgy have, in this way, seen an annual average improvement +3% in energy efficiency over the past 30 years.

Taxes générales sur l'énergie et l'environnement au 1er janvier 2015	Unité	Taxe énergie	Taxe CO_2	Taxe SO2	Total des taxes (€)	Total taxes € cents/kWh
Carburants - production de chaleur						
Fioul chauffage (<0,05 % souffre)	€/m³	92	348		440	0,04
Fioul lourd, (0,4 % souffre)	€/m³	92	348	12	451	0,04
Charbon (0,5 % sulphur)	€/ton	70	303	16	389	0,05
LPG	€/ton	118	366		484	0,04
Gaz naturel	€/1000 m³	101	260		362	0,03
Crude tall oil	€/m³	440			440	0,04
Tourbe, teneur en humidité 45 % (0,3 % souffre)	€/ton			5	5	
Carburants - transports						
Pétrole, sans plomb, classe environmentale 1	€/l	0,35	0,28	-	0,63	0,07
Ethanol	€/l	0,04			0,04	0,01
Diesel, classe environmentale 1	€/l	0,20	0,35	-	0,55	0,06
EMAG, faible teneur	€/l	0,18			0,18	0,02
EMAG, Haute teneur	€/l	0,11			0,11	0,01
Gaz naturel/méthane	€/m³		0,26	-	0,26	0,02
LPG	€/kg		0,37		0,37	0,03
Utilisation d'électricité						
Electricité, Reste du pays	€/kWh	2,1	-	-	2,1	0,02
Electricité, Suède du Nord	€/kWh	3,2	-	-	3,2	0,03
Electricité, processus industriel	€/kWh	0,1	-	-	0,1	

Source: Swedish Energy Agency

In Sweden, while the carbon tax and the energy tax on production of heat are generally applicable, there are, nevertheless, specific measures for industry, to avoid impacting competitiveness, and for cogeneration:

- The industrial sectors not covered by the ETS and agriculture benefit from a 70% exemption from the energy tax and a 40% exemption from the CO2 tax.
- The industrial sectors covered by the ETS (excluding district heating) do not pay the carbon tax and can also take advantage of a 70% exemption from the energy tax.
- The heat used by industry, for the purpose of heating buildings, has, since 2015, been subject to an energy tax equivalent to SEK 0.024 /kWh.

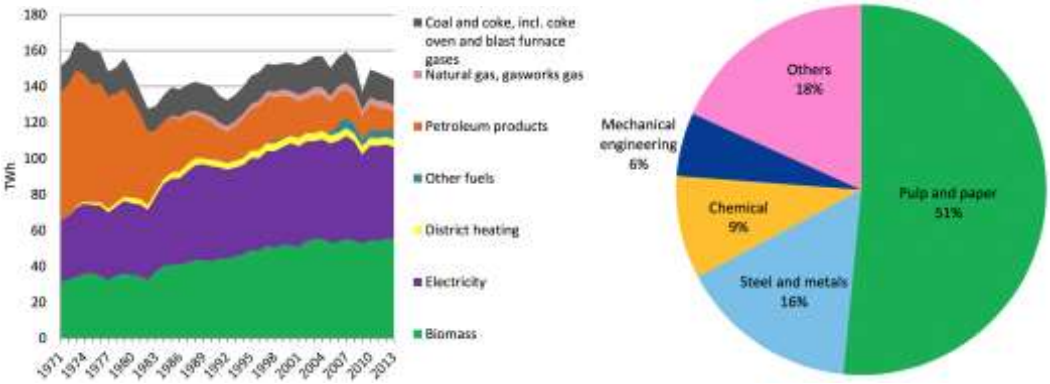
[11] 23% for biomass and waste, 10.5% for hydroelectricity and 2.2% for geothermal, wind and photovoltaic – 2013 data – source OECD/IEA 2015.

The energy tax and the carbon tax are not applied to the generation of electricity. Nevertheless, use of electricity is subject to the energy tax. Special rates are applied to the northern regions and to use of electricity in industrial processes.

2.2. Energy consumption and carbon emissions of Swedish industry

Swedish industrial energy consumption represents 38% of final energy consumption. Biomass and electricity are the two preferred sources and account, respectively, for 38% and 35% of the total, compared to 23% for fossil fuels (petroleum products, coal, coke and natural gas). Oil accounts for 7%, compared to 48% in 1970.

Final energy demand by fuel and by sector (2013)



Source: Swedish Energy Agency

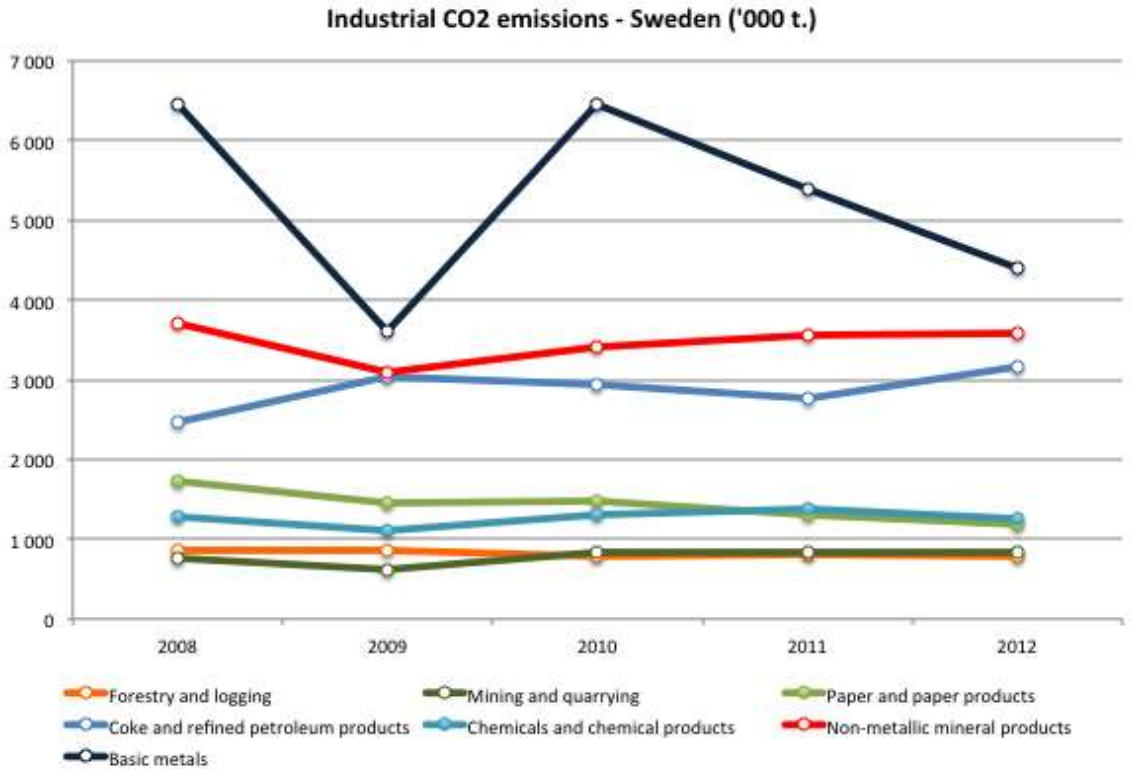
3/4 of industrial energy consumption is attributable to 3 sectors:

- The paper industry accounts for 51% of industrial energy consumption. This consumption is mainly linked to electricity and biomass, via use of black liquor, a by-product of the paper pulp industry. Formed from wood pulp, during the chemical separation of cellulose fibres, it is used locally as a liquid fuel[12].
- Production of steel and non-ferrous metals represents 16% of the total (mainly coal, coke and electricity), compared to 9% for the chemical industry.
- Finally, 6% of consumption is attributable to the mechanical engineering sector, 5% to the timber products sector (mainly biomass) and 13% to the other sectors, including agri-food, textiles and non-metallic mineral products (glass, cement).

[12] Black liquor is composed of lignin, hemicellulose and chemical product residue. It can be converted into syngas, dimethyl ether or even methanol and can therefore serve as a source of biogas or as second-generation biofuel for use in vehicles.

As regards emissions for the industrial sector, they have a somewhat different structure. They are dominated by the metal production sector (9.9% of total Swedish emissions in 2012), non-metallic mineral products (8.1%) and refining and coke production (7.2%). The paper industry and the chemical industry account for 2.7% and 2.9%, respectively, of the country's total emissions.

This difference between the structure of energy consumption and that of emissions can be largely explained by the different energy mix used by these industries. Since 2008, the sectors that have experienced the greatest fall in CO2 emissions are metallurgy (-32%) and paper production (-31%).



Source: Swedish Energy Agency

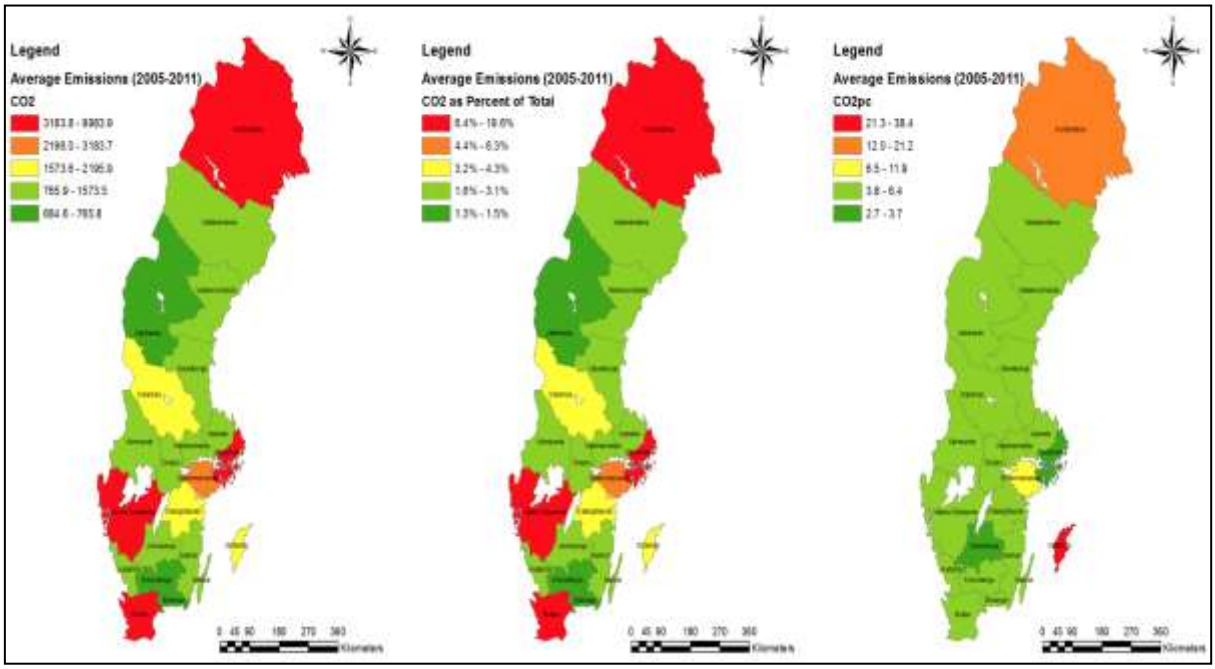
2.3. Carbon intensity of the Province of Norrbotten

Due to the presence of highly carbon intensive industry (mainly metallurgy), the Province of Norrbotten is one of the country's most intensive areas of emissions. Primary industry is responsible for 75% of final energy consumption in the province.

In 2011, Norrbotten energy consumption accounted for 30.8 TWh, of which 54% was from fossil fuels, 19% from renewable sources, 21% for electricity and 6% for district heating. The consumption of fossil fuels is, to a large extent, linked to the reducing agents used in metallurgy.

Apart from industry, the main consumers of energy are the transport and residential sectors. Some 91.5% of electricity in the province is from hydroelectric power and accounts for 10% of national production.

CO2 emissions in Sweden - Annual averages and per capita



Source: SLU

3. Decarbonisation strategies in the Province of Norrbotten

Swedish climate strategy contains ambitious targets that go further than the unilateral commitments to which the country has signed up at European and international level. Between now and 2020, Sweden has set the following target:

- A 40% reduction in greenhouse gas emissions for sectors not covered by the ETS over 1990 levels.
- A 50% share by renewable energy in the country's energy balance and 10% in the transport sector.
- A 20% increase in energy efficiency (compared to 2008 levels).
- The elimination of any use of fossil fuel in the heating sector[13].

In the longer term, the country plans to become carbon neutral. Last February, 7 of the 8 groups present in the parliament adopted the proposal of the Environmental Affairs Committee aimed at reducing greenhouse gas emissions by 85% in 2045, with the remaining 15% to be achieved via projects carried out abroad (CDM)[14]. A legislative proposal should follow shortly. While the strategy has not yet been defined, it is likely to focus, to a large extent, on the transport sector, since production of electricity and heat is already extensively based on renewable sources.

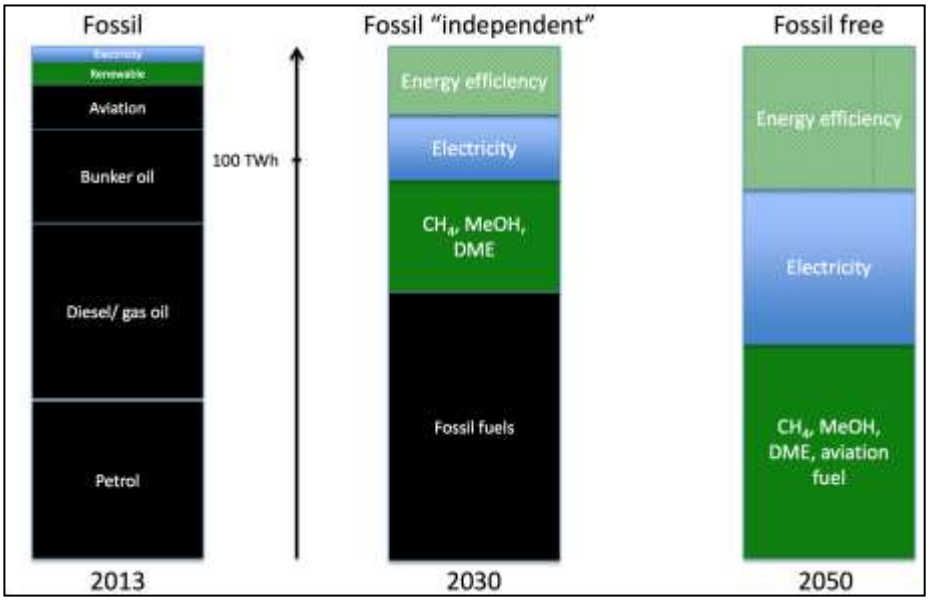
Achieving these objectives will involve the development and marketing of new technologies. In the Province of Norrbotten, numerous research and development works and initiatives, mainly being carried out under the auspices of the Lulea University of Technology, have seen the light of day. The examples presented here concern work relating to use of biomass in the transport sector and the reduction of emissions in the metal production sector.

3.1. Use of biofuels in the transport sector

Swedish climate policy is aimed at decarbonising the transport sector, which makes it necessary to develop electrification and biofuels as well as intensifying efforts in the area of energy efficiency. In Lulea, work has been carried out, among others, on gasification of biomass and the production of biofuels.

Decarbonisation scenarios for the transport sector

[13]http://www.government.se/government-policy/environment/objectives-for-swedens-climate-and-air-quality-policy/
[14] http://www.climatechangenews.com/2016/02/11/sweden-to-go-carbon-neutral-by-2045/



Source: SGC

The work of the Swedish Centre for Biomass Gasification (SGC)

Lulea University of Technology (LTU) is responsible for the Swedish Centre for Gasification (SGC), founded in 2011, whose objective is to conduct R&D in the area of biomass gasification.

This enables a fuel gas mixture (syngas or synthesis gas) to be produced, by means of thermochemistry, from wood or residue from the timber and paper industry (black liquor) which, after cooling and treatment (cleaning, removal of CO2 via amine scrubbing), can be converted, depending on the process used, into different biofuels (DME, ethanol), into fuels to generate energy and/or heat (methane, SNG) and into renewable chemical products (hydrogen).

Diagram of production of syngas from biomass (source: SGC)

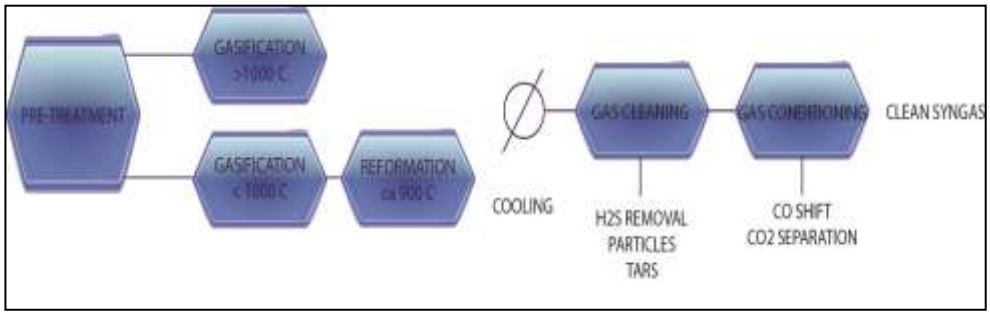
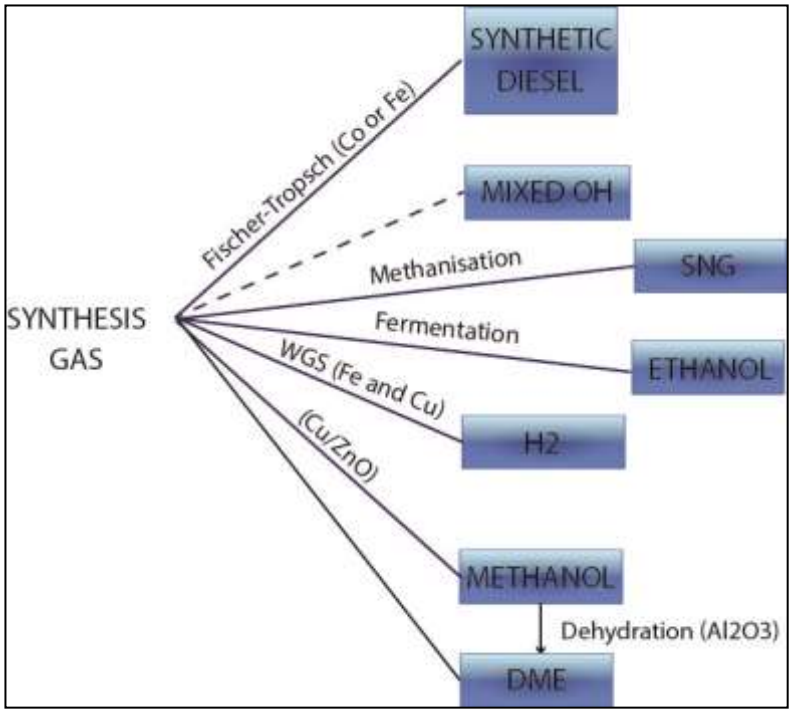


Diagram of production of biofuels from syngas



Source: SGC

The SFC, which has an annual budget of around €6.2 million, encompasses 20 companies, 8 universities and 2 institutes, with a total of some 30 to 35 researchers and around forty Ph.D. students. It is divided into 3 distinct centres, each working on a specific gasification technology[15]:

- The centre for direct fluidised bed gasification (CDBG), under the responsibility of the KTH Royal Institute of Technology[16].
- The centre for indirect gasification of biomass (CIBG), run by Chalmers University of Technology, whose technology enables production of a dry, clean nitrogen-free gas which can be used, directly or after processing, as a substitute for fossil oil or natural gas.
- Bio4G (Universities of Lulea and Umea, the Energy Technology Centre in Pitea), whose activity is focused on suspension flow gasification which enables the production of methanol[17] and BioDME[18].

[15] http://www.ltu.se/centres/Svenskt-forgasningscentrum-SFC?l=en
[16] https://www.kth.se/en/che/divisions/chemical-technology/research-1.294587
[17] http://biofuelstp.eu/factsheets/methanol-fact-sheet.html
[18]http://www.ltu.se/research/subjects/Energiteknik/Forskningsprojekt/Forskningsomrade-2/Bio4Gasification

The research being conducted in Lulea is focused on the production of second-generation biofuels (methanol[19] and BioDME[20]) for the transport sector. The research is mainly carried out at the LTU Green fuels pilot facility, located in Pitea which is supplied with black liquor by the SmurfitKappa paper production site. This facility, owned by the University since 2013 and with a capacity of 4 t/day, was built in 2010 within the context of the BioDME project[21]. The purpose of this pilot project, initiated by the company Chemrec, in cooperation with the ETC in Pitea, Volvo, Total, Haldor Topsoe and Delphi, among others (14 million total investment), was to develop biofuels for road transport. During the project, refuelling stations were set up and the fuels tested on a dozen pilot trucks (around 800,000 km travelled).

Sunpine project

In 2010, the Sunpine project[22] enabled the construction of a production facility for biodiesel derived from tall oil. Tall oil, which is also a by-product of the paper industry, is obtained via the separation of calcium soaps contained in the black liquor, which are then treated and acidified to form the oil in question. The technology used here consists of mixing the oil obtained with biomethanol and sulphuric acid. Once this mixture has been esterified and distilled, it is incorporated into the end fuel. The facility, situated in the Port of Pitea, is owned by a consortium made up of the refiner Preem, the logging companies Sveaskog and Sodra, and Kiram AB. With a production capacity of 100,000 m^3, it required an investment of €23 million.

Bewhere

Production of biofuels on a large scale entails the wide-scale exploitation of biomass resources, which raises questions about, among other things, availability, renewal and price fluctuations, against a backdrop of considerably heightened demand and competition with other economic sectors (industry, generation of heat and electricity). The complexity of developing the logistics chain and the high cost of production make advance infrastructure planning a necessity.

Bewhere [23] is a techno-economic engineering model developed to optimise renewable energy-based power systems. It identifies the optimal location, size and appropriate technology for the generation of renewable energy in a given region, based on forecasts of supply and demand for raw materials (in this case biomass), finished products (biofuels) and existing or planned production capacities. Developed in 2006 by the IIASA and Lulea University, it is optimised on a continuous basis. Gradually extended Europe-wide since 2010, it now covers not only biomass but also other areas such as solar, wind and hydroelectricity.

In 2013, a study conducted by F3 (in cooperation with Lulea University, among others) using Bewhere[24] analysed the development scenarios for biofuels in Sweden up to 2030 (4 to 9 TWh/year, respectively, depending on the high or low option). The study concluded that each

[19] http://biofuelstp.eu/factsheets/methanol-fact-sheet.html
[20]http://www.ltu.se/research/subjects/Energiteknik/Forskningsprojekt/Forskningsomrade-2/Bio4Gasification
[21] http://biofuelstp.eu/bio-dme.html
[22] http://www.chemrec.se/SunPine_producing_tall_oil_diesel.aspx
[23]http://www.iiasa.ac.at/web/home/research/modelsData/Bewhere/BEWHERE1.en.html
[24] http://www.f3centre.se/projects/RD-BeWhere-2

of the scenarios was feasible. Nevertheless, it estimated that total demand for biomass (biofuels and industry) would increase from 14 TWh to 35-50 TWh/year between now and 2030, which represents up to 97% of the total techno-ecological potential. Realising these scenarios is likely to require the construction of 6 to 9 plants with a capacity ranging from 0.2 to 2.2 TWh/year, in locations enabling integration with other industries (synergies, pooling of transport costs). The total investment required for the biofuel sector has been estimated at €+1.3 billion compared to an investment scenario without any large-scale development of biofuels (€2.4 billion in case of non-integration with other industries).

3.2. Reduction of emissions in the metallurgical sector

In the metallurgical sector, significant efforts have been underway for a number of years already to reduce the levels of CO_2 emissions. The main initiatives include, among others, the installation, within the context of ULCOS, of the LKAB experimental blast furnace, the various work carried out on carbon capture and storage (Swerea MEFOS, BASTOR), the use of biomass in the process of direct reduction and use of the waste heat by the district heating system.

LKAB's experimental blast furnace

ULCOS (Ultra-Low Carbon dioxide Steelmaking) is a cooperative R&D initiative, conducted between 2004 and 2010, aimed at achieving a minimum 50% reduction in CO_2 emissions compared to current steel production methods. With a budget of €75 million, 40% financed by the European Commission via the 6th Framework Programme and the Research Fund for Coal and Steel (RFCS), it brought together the main European steel companies as well as partners from the energy and engineering sector, research institutes and universities. Within the framework of ULCOS, 4 promising innovative technologies were identified as being likely to achieve the objectives: ULCORED (direct reduction using natural gas and melting in electric arc furnaces), ULCOWIN (electrolysis), HIsarna (bath smelting) and top gas recycling.

The concept of a top gas recycling blast furnace relies on separation of the off gases so that the useful components can be recycled back into the blast furnace and used as a reducing agent (CO, H_2). This reduces the amount of coke needed in the furnace. In addition, oxygen replaces preheated air in the furnace, preventing the formation of nitrogen and thereby facilitating CO_2 capture and storage (CCS). In order to test this concept, a gas separation plant was constructed next to LKAB's experimental blast furnace in Luleå, Sweden. This blast furnace is fitted with equipment that enables it to produce cast iron using pure oxygen (O_2) via reinjection of carbon monoxide (CO)[25]. The work carried out has helped to identify a

[25] Source: ULCOS

potential reduction of 24% in emissions associated with the process. Carbon capture, via a VPASA pilot unit, and storage could enable a further reduction of 52%[26].

Stepwise project

The objective of the Stepwise project, started in May 2015, is to conduct R&D into converting off gas from blast furnaces into hydrogen and nitrogen-rich fuel, with applications in metallurgy and electricity and heat generation. The process includes the separation and capture of CO2. With a budget of €13 million for a 4-year period, financed by the European Horizon 2020 research programme, the project provides for the construction of a pilot plant on the Swerea MEFOS site (1 of the project's 9 partners) in Lulea. The plant will be supplied with gas via a pipeline from the SSAB site. According to the partners involved, the project has the potential to reduce emissions by 2.1 Gt/year.

Bastor project

The BASTOR project is a consultancy project aimed at identifying the possibilities for creating shared regional infrastructure for the transport and storage of CO2 in the Baltic Sea region. The rationale behind the project is to identify a significant number of sources of CO2 emissions (217 industrial and electricity generation sites in Scandinavia alone) within a small radius (Scandinavia, Poland, Northern Germany, the Baltic States), which account for estimated emissions of 100 Mt/year. In case of development of CCS, storage in the Baltic Sea would present definite economic benefits, due to its proximity to the sources of emissions and, therefore, the reduction in transport-related costs (in comparison with storage in the North Sea, for example).

The Bastor project comprised 2 phases. The first (2011/2012), financed by the Swedish Energy Agency and industrial partners, was aimed at defining an action plan for evaluating the possibilities for storage, securing funding and establishing a networking platform. The second, conducted by Finnish industrialists and TEKES, consisted of evaluating the geological potential as well as the social and environmental impacts, the legal and tax conditions as well as the economic conditions for transport[27].

BioDRI project

This project, conducted by Lulea University, in cooperation with numerous industrial partners (Swerea MEFOS, LKAB, AGA, Sveaskog, Billerud, Hoganas) and the ETC in Pitea examined the

[26] https://www.lkab.com/en/Future/RD/Smart-Steel-Production/EBF/EBF-publications/
[27] http://www.sciencedirect.com/science/article/pii/S1876610214017664

possibility of replacing (completely or partially) the reduction process in blast furnaces[28] with a direct reduction process using gasified biomass (and not coal or gas, which is usually the case for DRI). According to the project creators, this technique could enable a reduction in emissions of 0.45 tonnes of CO_2 per tonne of steel produced.

Budget of the BioDRI project (in €)			
Partner	**Category / sector**	**Financial investment**	**Co-financing**
LTU	University	114 624	26 882
Swerea MEFOS	Research institute	109 677	26 882
ETC	Research institute	134 409	26 882
LKAB	Metal industry	40 215	40 215
AGA	Gas producer	10 753	10 753
Sveaskog	Forestry	26 882	26 882
Billerud	Paper industry	10 753	10 753
Hoganas	Iron ore	32 258	32 258
Total		**479 571**	**201 505**

Source: LTU

The project was structured around 4 thematic blocks: logistics, gasification (on the pilot plant at the ETC in Pitea), DRI reduction process and use (tests conducted in the laboratories of LKAB and Hoganas) and economic aspects. The study concluded that the process was technically feasible. From an economic perspective, the simulations highlighted difficulties that were likely to be encountered, particularly in terms of demand and pricing, in the event of development of industrial use of biomass.

Use of waste heat for district heating purposes

In Sweden, industrial waste and heat are increasingly used for heating purposes[29]. In this way, in Lulea, SSAB, via the Lulekraft cogeneration plant, jointly owned with Lulea Energi, supplies 97% of the heat produced for the district heating system and also generates electricity. The fuel used is composed of leftover gas from the manufacture of metal sheets[30]. In Kiruna[31], the municipality has partnered with LKAB, Tekniska Verken and Kiruna AB to construct a new energy system. Eventually, 90% of district heating will be supplied by the LKAB iron pellets production site. The remaining 10% will come from the burning of biomass, during shutdowns (e.g. for maintenance) of the ore producer's facilities. Today, only 5% of the heat used is waste heat from industry, with other sources being the burning of domestic and industrial waste (75%), biomass, electricity and fuel oil (15%).

[28] The unit considered here has a capacity of 2 Mt/year.
[29] http://www.theguardian.com/sustainable-business/2015/may/01/leftover-industrial-heat-to-warm-swedens-chilly-northern-city
[30] http://www.northsweden.eu/english/news/ssab.aspx
[31] http://www.lkab.com/en/media/news1/?ni=7140&c=&m

4. Employment, economic and social impacts and trade union perspectives

Decarbonising the Swedish economy entails putting in place an industrial strategy that takes account of the economic and social aspects of the transition.

4.1. Employment impacts

As things stand, in the absence of any detailed roadmap, it is difficult to get an idea of the precise social affects and impacts on the labour market of the environmental and climate policies that will be implemented. These should, however, be focused on transport, where there is the greatest potential for reducing emissions, and the development of alternative sources of energy (biomass, biofuels, etc.) In terms of employment, the transition is likely to have the following positive impacts:

- Directly on certain sectors such as forestry, refining, machinery and equipment production as well as research and development.
- Indirectly, particularly on services, in high growth areas, as well as on development of infrastructure. Developing large-scale use of biomass is likely to necessitate, for example, adaptation of transport infrastructure (construction, renovation), particularly in Northern and Central Sweden, where the main forest reserves are situated.

The transition is also likely to have positive effects on the environmental sector. This sector is not very labour intensive and only accounts for 2.1% of total added value produced by the Swedish economy (16,000 companies, 72,000 jobs). Nevertheless, decarbonisation policies implemented in the past have contributed to its development. Turnover for the sector grew by 49% between 2003 and 2013 while employment increased by 14%, mainly in the waste treatment sector (23% of jobs in the sector), renewable energy (17%), energy consultancy (10%), energy efficiency (9%), and education & research (8%).

Key figures relating to the environmental sector in Sweden				
Environmental sector	**Number of companies**	**Turnover**	**Export**	**Total employment**
Air pollution	128	3 029	1 276	1 449
Wastewater treatment	946	14 240	2 430	6 467

Waste treatment	2 757	35 168	4 478	16 801
Soil and groundwater	435	2 402	392	1 402
Noise and vibrations	39	281	--	157
Environmental consultancy	1 555	7 691	649	7 015
Education, research and inspection	261	1 307	98	5 993
Material recycling	1 933	38 910	11 856	7 259
Renewable energy	2 687	90 107	9 142	12 224
Energy and heat savings	901	13 692	6 187	6 189
Sustainable agriculture and fishing	4 513	7 954	292	5 024
Forest conservation	102	6 403	29	786
Others (including eco-tourism)	177	1 210	--	1 214
TOTAL	***16 434***	***222 393***	***37 061***	***71 980***

4.2. Economic and social impacts

The development of decarbonisation policies also requires reflecting on their cost and the sharing of the burden between the different economic actors. The measures put in place may impact industry, encouraging carbon leakage, as well as households, particularly those on low incomes, via an increase in the price of goods and a rise in energy prices. Policies to reduce emissions and improve energy efficiency impact sectors such as agri-food, energy, transport and construction, which have significant emissions and whose activity/products serve to satisfy the "basic" needs of the population (food, heating, mobility, housing).

In Sweden, the first decarbonisation policies were implemented within the framework of wide-ranging tax reforms, aimed at reducing labour costs ("green tax shift" or double dividend policy). In 1991, introduction of the carbon tax was, in this way, combined with a simplification and €6 billion lessening of the tax burden. Revenue from the new tax enabled a portion of the lost tax income to be offset, along with the exemptions granted to industry. Once again, in 2001, the government adopted the principle of a gradual increase in environmental taxes of €3.25 billion over a period of 10 years in order to further lower taxes on labour and capital[32].

Today, environmental taxation is at a lower level than the European average. In 2013, it accounted for 2.36% of GDP (compared to 2.44% for the EU-28). As regards policies to reduce emissions, the burden was mainly transferred to households (application of full rate of the CO2 tax and the energy tax, taxation of transport fuel). The price of district heating experienced a marked increase, just like electricity for the residential sector, which, today, is

[32] Firstly (2001 – 2006), environmental taxes were increased by €1.6 billion with a corresponding reduction in the amount of taxation targeted at lower income households. While the programme was subsequently abandoned, further easing of the tax burden on labour occurred between 2003 and 2013, at the same time as a further increase in taxes on polluting activities. In the end, according to the OECD, environmental and energy taxes increased by around 15% between 2000 and 2012. At the same time, the tax to GDP ratio fell, even though the tax burden on labour was reduced by around 20% between 1995 and 2011.

5% higher than the European average[33], even though it was markedly lower at the end of the 20th century. However, this rise has been offset by an increase in energy efficiency. In this way, the final energy demand of households has remained stable over the past 30 years.

As for industry, the tax exemption and reductions, as well as increasing use of biomass and the implementation of energy efficiency improvement programmes (such as the PFE, for example), have, up to now, limited the increase in energy costs. However, the rates of carbon tax and energy tax have recently been revised upwards and the objectives of decarbonisation have become challenging. The issue is an important one: energy-intensive industries are strongly export-orientated and account for around 5% of total employment and 19% of added value.

4.3. Trade union positions

In Sweden, the union membership rate is particularly high at 71%. The main trade unions are LO (1.5 million members), which represents manual workers, TCO (1.2 million members, representing non-manual workers) and SACO, the trade union for graduate employees (0.6 million members).

Trade union organisations are participating in the dialogue about low carbon strategies both at local and national level. At local level, they are participating by exercising their power of negotiation and rights connected with the information and consultation procedures arising under the Law on Co-determination (MBL, 1976) and the agreement on efficiency and participation (Utvecklingsavtalet, UVA, 1982). This agreement lists, among other things, the areas in which the trade unions and employers are encouraged to negotiate: the development of work organisation, with the aim of improving "the skills and experience" of each worker; technical developments and issues associated with the company's economic situation, such as purchasing policy, investments, marketing and research[34]. Trade unions also have representatives on works councils, in most structures with more than 25 employees[35]. At national level, trade unions are stakeholders in the dialogue via, among other things, the consultations and the "green transition and competitiveness" analysis group, organised under the auspices of the Ministry for Strategic Development and Nordic Cooperation[36].

The two trade union organisations that we interviewed as part of this study, LO and Sveriges Ingenjörer, a member of SACO, are in favour of reducing emissions and support the positions of the International Trade Union Confederation (fair transition, decent, quality jobs, target of limiting global warming to 1.5°C)[37].

[33] However, it was 20% higher than the EU average in 2007 and 33% higher in 2011 (source: Eurostat).
[34] Source: workers-participation.eu
[35] http://www.worker-participation.eu/Systemes-nationaux/Pays/Suede/Representation-aux-conseils-des-entreprises
[36] http://www.government.se/government-policy/mission-the-futre/analysis-groups/
[37] http://www.ituc-csi.org/ituc-response-to-paris-climate

In a position recently published[38] jointly with the Swedish Farmers' Union (LRF) and the Confederation of Swedish Enterprise, the LO trade union calls for the implementation of an ambitious decarbonisation policy, seen as a driver of growth. According to the LO, the country possesses a significant number of assets, most notably the expertise and know-how of Swedish businesses and workers, as well as the country's natural resources. However, this transition must fulfil certain conditions:

- Encourage the export of low carbon goods and work towards an international climate agreement.
- Create a flexible framework, allowing for adjustments in line with changes in reduction efforts undertaken by other countries, to avoid endangering national output and the country's economic growth.
- Be primarily focused on low cost emission-reducing measures and not impose overly burdensome taxation or overly high targets on sectors that do not have access to technical solutions enabling levels of CO_2 to be reduced.
- Avoid imposing additional requirements on sectors covered by the ETS.

The other element arising from the discussions is that the implementation of a low carbon policy requires, above all else, real political will[39], both in terms of industrial strategy and financing (sharing of efforts). In this respect, investment in research and development is of fundamental importance and should favour the circular economy (for example, using industrial waste), the transport sector, via electrification and carbon capture and storage technologies, the development of which is essential for a 90% reduction in emissions. Within this context, combatting carbon leakage is a major issue, particularly for the metallurgical sector, cement production and the chemical industry. Nevertheless, border adjustments do not appear to be a viable solution but rather an obstacle to trade, which may be detrimental to the Swedish economy and that of the Province of Norrbotten, both of which are strongly export-orientated.

[38] http://www.dn.se/debatt/sex-punkter-for-framtidens-svenska-klimatpolitik/
[39] In this respect, see, *inter alia*: http://www.ltu.se/ltu/media/news/Tvingas-varsla-samtliga-vid-LTU-Green-Fuels-1.146781?l=en