Power Circle

The World's Electric Power Centre Is in Sweden

Sweden
a pioneering country
World-Class research

The Volvo Group hybrid vehicle is equipped with an efficient hybrid solution for heavy vehicles, as trucks and buses, which offers fuel savings of up to 35 percent.

Foto: Bombardier Transportation, Fredrik Carlsson, Åke E:son Lindman, Janne Eriksson, Håkan Flank, Pawel Flato, Nina Holmqvist, Hans Westerlund och Volvo.

Sweden, a driving force in international cooperation in energy

Sweden is one of the world's leading countries in electric power development. We deregulated electricity markets early, which contributed to a well-functioning trade in electricity, low electricity prices, a robust electrical system, and sound knowledge of the entire electric power field.

We have a long tradition in Sweden of cooperation among a range of interest groups, industry, and research. This cooperation has realized the development of large, successful, international industrial and energy business groups in clusters with a large number of subcontractors that are small and middle-sized companies with regional distribution throughout the entire country. Surrounding these companies, leading research centres and advanced industry have grown, and jointly these form an electric power cluster of world class. This creates jobs and growth for the country. It is gratifying that the cooperation in the electrical power industry has made the Power Circle a reality, and that the government has been able to contribute financially to support it. The Power Circle gathers expertise that impels the development of environmentally protective technical solutions that can meet the great future demand for more efficient and diversified electric power supply and use. I welcome this farsighted venture.

In our globalised world, we face enormous global challenges. Two billion people in the world are without access to electricity. The need for electric power will be increasing dramatically in the near future throughout the world, as will demands for modernization, environmental protection, security, and coordinated power transmission. The International Energy Agency (IEA) estimates that investment needs in the global energy sector will be USD 16,000 billion in the next 30 years. How well we manage to meet these challenges will determine our future economic development. By committing to the Power Circle, the government has contributed to Sweden's capability to meet these challenges.

Energy politics are no longer a national matter. The European Union is forging a common approach to energy issues with the goal of a safe, secure, and efficient energy supply through conservation, the development of alternative energy sources, and increased international cooperation. International challenges include finding solutions that both satisfy growing needs for energy while reducing the effects on climate and the environment. The need for knowledge and new technology is great. The EU's Green Book on energy, published in March 2006, will be a critical point of departure for continued dialogue among EU member countries. The importance of new technology in energy politics was appreciated at an early stage in Sweden, so it is in an excellent position to contribute knowledge and technical solutions.

Sweden should continue to be a driving force in international energy and environmental progress. We can and will constitute the hub in electric power research in Europe and the world. In that way we will also reinforce economic growth and employment in Sweden.

Thomas Östros
Swedish Minister for Industry and Trade

Power Circle, the world's grea

Electric power is a requirement for today's development. The modern industrial revolution began a little more than a hundred years ago when electricity altered access to energy. Swedes were pioneers. Because of cheap electrical power and the enormous challenge of transporting power from the rivers of the north to the growing industry in the south, we developed an integrated and well-operating electric power grid early on. Abundant hydro resources drove the development of power plants and created an industry for the production of turbines, generators, and electrical equipment including transmission systems.

Power Circle on the Map

Power Circle is one of the largest industrial clusters in the world. The area hosts participants from all stages of the value chain and competes on the world market in all the electric-power engineering fields. Expertise from world-leading companies and resources for the development of innovative solutions for the electric power industry are gathered in Power Circle. It is at the forefront of research and development, production, transmission, distribution, and consumption of electricity.

The Power Circle encompasses internationally advanced education at well-known universities and at educational centres with developmental opportunities at state-of-the-art laboratories. We have one of the world's most developed markets for electric power engineering with knowledgeable and demanding users. We have the leading industrial participants active on Swedish and international markets.

New technology and solutions followed. ASEA, the Swedish company now called ABB, was one of the industrial innovators in the field and contributed necessary knowledge, which led to great international advances. In 1952 ASEA introduced the first transformer system for 400,000 volts. Since then, the company has developed systems for twice the voltage and invented generators that are fit to produce energy from water, uranium, wind, gas, coal, and other sources of energy. Another technological leap forward took place in Sweden in 1998, when the world's first generator that fed directly into the electric power grid, Powerformer, was built.

Sweden remains a pioneer in electric power expertise. It has meant considerable positive economic and social effects for society for a long period of time. The profound knowledge that has accumulated over the years has led to a current situation of one of the world's most efficient power systems, global prominence in research and development at universities and in companies. An extensive manufacturing industry produces generators, transformers, power-transmission equipment, monitoring systems, and electric motors. Sweden has the skills and the capability to pursue research in a number of different areas. These include the technology for the production, transmission, distribution, and use of electricity in a range of industrial processes, but also for using electrotechnology in other applications and for powering trains and other vehicles. The result is that we maintain world-leading research and development.

UNIQUE RESEARCH ENVIRONMENT

Sweden is at the forefront of electric power research and is a powerhouse of further development. Research takes place both at the universities and in conjunction with industry. Applied research is carried out at the Royal Institute of Technology in Stockholm, the Ångström Laboratory in Uppsala, High Voltage Valley in Ludvika, and developmental laboratories in Västerås, Stockholm, and Älvkarleby. This unique and advanced research environment attracts researchers and students from all over the world.

test electrical power cluster

Sweden fosters research and development in all areas of electric power. We are forerunners in selected research areas in obtaining electricity from nuclear, hydro, solar, wind, and wave energy. Sweden has also gained international recognition for its transmission systems in distribution technology, production optimization, and materials development. Top-priority research areas include transmission techniques using more than 300 kilovolts (kV) so-called high-voltage direct current (HVDC) using underground cables, electrical motors for hybrid vehicles, and production technology for thin-film solar cells. Vattenfall has initiated a major European project to develop a coal-fired plant without emissions. One of the largest developmental needs in the future electric-power area will involve the use of modern information technology in intelligent systems for better control of the production, transmission, monitoring, and operation of electrical systems. Intelligent electrotechnology is also relevant in fuelling vehicles and a range of manufacturing processes. Advanced research takes place at the Royal Institute in Stockholm, which can boast the only professorship in Europe in the subject.

WORLD-CLASS COMPANIES ARE LOCATED WHERE DEVELOPMENT IS HAPPENING

Sweden leads development in long-distance electrical transmission, selected areas of power engineering, electrical trains, and the management of power grids and stations. This has not only provided the country with the world's best supply of electricity but also a series of prominent power companies, competitive electricity-intensive industry, and world-leading companies in electric power generation, electricity transmission, and electricity usage, including such companies as Bombardier Transportation, Alstom, ABB, and Areva. There is good reason why some of the biggest and best power suppliers in Europe compete in Sweden, companies such as Vattenfall, Fortum, and E.ON. We also see active and prominent international consulting companies, such as Sweco, ÅF, Carl Bro, and Vattenfall Consulting. Many other internationally known companies, including Siemens and Westinghouse maintain research, development, and/or production in Sweden.

> "Sweden has historically been a pioneer in many areas of electric power engineering. Electricity is a necessity for many of the traded goods on world markets and is in itself increasingly traded. It is a condition for industrial development and societal growth. In Power Circle you have a concentration of knowledge of electric power engineering that is unique in the world."
>
> Mats Leijon

> "Collaboration between industry, universities, and research projects is essential to boost research and development. In Power Circle, actors continuously reinforce the networking groundwork of the platform, thereby creating new opportunities for world-class research."
>
> Stanislaw Gubanski

Stanislaw Gubanski, professor at High Voltage Valley and Chalmers.

Mats Leijon, professor in the Theory of Electromagnetic Fields and Electrical Circuits, Uppsala University.

FUTURE

Electric power engineering is the world's biggest market

In the next few years, global demand for electric power engineering products and services will be gigantic. Investments in the energy area are estimated to reach USD 16,000 billion by 2030. In Europe, use of electricity will increase by about 40 per cent during the same period of time while many old stations will need reburbishment.

Needs will vary throughout the world. In some areas the goal will be to obtain access to electricity for more people. In other areas investment will be in modernizing power grids and systems. Together, these needs make electric power engineering a promising industry.

Demands will increase for environmental protection, sustainable electrical use, higher security, stability in production, and the reliable distribution of electricity, as will demands on efficiency and optimization. New areas will develop for electrotechnology, such as electrical and hybrid trains, automobiles, and other transportation alternatives. System management of energy systems based on information technology will be increasing formidably and already make up a considerable part of power company investment. Intelligent electrical systems will be incorporated into most electric power areas such as distribution, operation of vehicles, and a number of production processes. It is in these fields that the greatest technological development is taking place today, and here Sweden holds a leading research position.

Based on its broad, advanced expertise and its diversity, the companies, researchers, and universities in Power Circle lead development in some of the most important future electrotechnical issues. New technology is needed to interconnect and control power grids between countries and regions in a secure and efficient way. Environmental and climate issues are growing evermore important, as is the increased use of new power resources such as wind, wave, and photovoltaic, which put new demands on knowledge, control, and measurement. These resources demand new regulation features to stabilise weather-dependent fluctuations in the output of these plants.

Research and development are ongoing in all these fields, adding to the strengths of the Power Circle.

Morgan Andersson, PhD, President of Elforsk.

> "Elforsk is an R&D broker owned by industry. The idea is probably unique in the world and has contributed to many years of successful cooperation between academia and industry. In Sweden we are the best in the world at carrying out research in the electric power field. Elforsk ensures that our results add powerful knowledge to the field"
>
> Morgan Andersson

Power Circle
clustering many participants

200	consultancies
70	power and grid companies
100	producers and suppliers
400	subcontractors
50	service and installation companies
8	governmental authorities
20	electricity-intensive industries
10	associations and organizations

Some of the largest companies in Power Circle are

ABB, Alstom, Bombardier, E.ON, Fortum, Siemens, SWECO, Svenska Kraftnät, Vattenfall and Westinghouse.

Facts

- Scandinavia has the most secure supply of electricity and the leading electricity market in the world, Nord Pool ASA.
- There are about 2500 companies in the Swedish electricity industry.
- 100,000 Swedes work with electrical power, including 45,000 in Power Circle.
- Over 1,000 researchers are at work in Sweden on the electrical power systems and products of the future.
- SEK 30 billion (USD 3.9 billion) have been invested in Sweden on the development of alternative energy sources and more efficient energy usage since the 1970s
- Some of the world's best and most modern high-voltage and high-power laboratories are located in Sweden.
- Investments of over USD 16,000 billion are expected to be made in the energy field over the next 30 years, which is the equivalent of 1% of total world GNP.
- USD 9,600–11,200 billion is the size of the world market for electric power products
- Exponential development is expected in new products such as electrical hybrids for trains, automobiles, boats, etc.

Borderless cooperation and global networks

Sweden has a long tradition of cooperation among companies, universities, and governmental authorities, both domestically and abroad. Swedes have engaged in international trade since the time of the Vikings. We have developed a unique climate of cooperation. Producers, consultants, subcontractors, and researchers in the electric power industry cooperate in a joint effort to find a win-win partnership, and there are strong connections with other industries, such as telecoms, information technology, and engineering infrastructures, such as water, sewage, and waste management. They are united in Power Circle. The cluster formation creates fertile ground for spin-offs and start-ups in the electricity area.

Power Circle is an international operation. Many of the companies act on a global level and have affiliates and business in other countries around the world. Their development can be activated by researchers from many different countries. Extensive international cooperation unleashes an open, mutually profitable developmental climate that attracts foreign experts and students.

Power Circle is an active force in the European Power Research Network (EPRN) a joint European platform for electrical power expertise.

Elforsk is another example of well-managed cooperation. Elforsk is owned by Svensk Energi and Svenska Kraftnät. Their goal is to improve the effectiveness of shared research and development.

INTELLIGENT ELECTRICAL SYSTEMS

Electrical power systems are currently connected over large areas, nations and continents. To control and monitor power systems, operational management centres were created in the infancy of electrification. Sweden was exemplary then because of our pivotal need to remotely control distant hydroelectric power stations in the far north. We remain prominent in the operational management of power systems today. Vattenfall and ASEA/ABB were early to train engineers to handle these problems and have maintained their leading position internationally.

Modern industry needs effective tools to achieve efficient operations. Power companies are expected to provide electricity of the desired quality dependably at the lowest cost. Intelligent systems have been introduced into most processes and are used in the entire chain of an electric power system. Information technology is a key element in most production areas today and is increasingly interlinked. Computers are usual-

Installation of ABB products, which strengthen power grids and ensure reliable electricity supply.

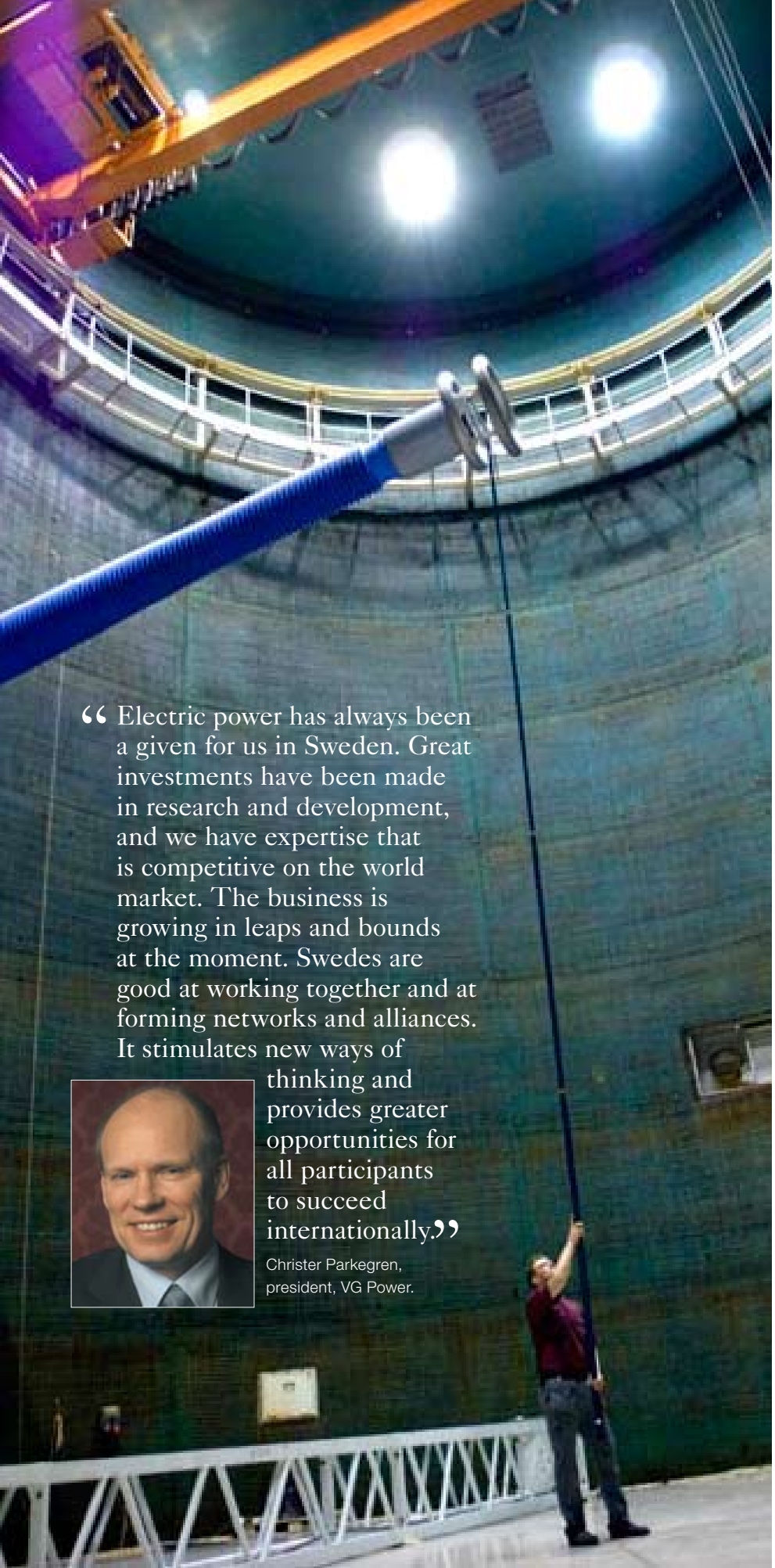
Grid control centre at Svenska Kraftnät, Stockholm.

The Regina train is developed and manufactured by Bombardier Transportation, Sweden. Bombardier has sold 70 Regina trains in Sweden and another 40 Regina trains have been sold to China.

ly connected and communicate with management centres in which managers can monitor production and control and direct flow and events. In the power industry, advanced network monitoring and simulation tools have been introduced to prevent operational disruptions. There are often optimization programs for production control included in these systems. Advancement is rapid, and the electric power industry must keep apace to remain a qualified supplier of expertise and electric power. The power companies of Western Europe have therefore invested extensively in computerized management systems. Another strong, driving factor is the deregulation of the industry, all over the world. With this rapid pace of development, systems are becoming increasingly complex, which powers research and greater demands for knowledge. In Sweden we have Europe's sole professorship in this area at the Royal Institute of Technology. The professorship in Industrial Information and Control Systems is a source of advanced research.

CHALLENGES

One great challenge will be to provide the electric power industry with a totally integrated informational support system for cost-effective operations. Another challenge is to provide the processing industry with intelligent electrical systems. A third challenge is the development of intelligent control systems for electrically powered or hybrid vehicles. A hybrid vehicle is an electrical power system in miniature that can make use of a primary energy source such as hydrogen or a diesel motor to load its batteries and thus combines high efficiency with low environmental impact.



“Electric power has always been a given for us in Sweden. Great investments have been made in research and development, and we have expertise that is competitive on the world market. The business is growing in leaps and bounds at the moment. Swedes are good at working together and at forming networks and alliances. It stimulates new ways of thinking and provides greater opportunities for all participants to succeed internationally.”

Christer Parkegren, president, VG Power.

Sweden –

a country w research an

With its unique location, advanced technology, advanced workforce, and high influx of foreign direct investment, there are few countries that can match Sweden's potential to position itself globally.

Sweden's strategic location is in the heart of northern Europe and the Baltic Sea region. For emerging markets such as Russia and other countries around the Baltic Sea, Sweden is a natural gateway to eastward expansion. As part of the European Union, Sweden has access to enormous consumer areas. Besides benefiting from an attractive location, Sweden offers access to excellent R&D facilities, new products, and technologies. Combined with a qualified workforce, outstanding telecommunications networks, low corporate taxes, an excellent infrastructure, and a stable political environment, Sweden has become a highly attractive country for foreign companies establishing a presence in Scandinavia.

Sweden already hosts a large number of multinational companies, and the number of multinational companies per capita is among the highest in the world. Consequently, Sweden has a high influx of foreign investment. Between 1998 and 2002, UNCTAD listed Sweden

Climate test hall at STRI in Ludvika for full scale pollution and ice testing of equipment for system voltage up to 800 kV. STRI is an accredited and independent company för consulting and testing services.

ell suited to developing d business

as the world's eleventh receiver of foreign direct investments. In 2004 the World Economic Forum ranked Sweden as third in the world, both on international competitiveness and prospects for future growth. Foreign investment activity in Sweden takes a variety of different forms, including greenfield expansion investment, joint ventures, strategic alliances, and mergers and acquisitions.

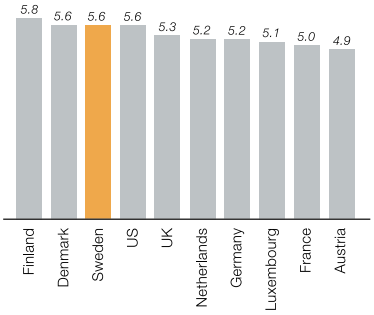
STABLE GROWTH AND A HEALTHY INVESTMENT CLIMATE

Sweden holds a strong international position in industries such as information and communication technologies, biotechnology, and electric power engineering. Sweden has maintained a stable macroeconomic environment. Large public investments have been made in education, research, development, and infrastructure. The Central Bank's independence has been strengthened. Strict government spending limits under parliamentary control have been imposed. As a testimony to success, productivity increases in Swedish industry and overall economic growth have exceeded the OECD average for the past ten-year period. Sweden consistently receives high marks in infrastructure and public-sector efficiency in internationally recognized surveys.

Anders Aabakken, director of engineering, Bombardier.

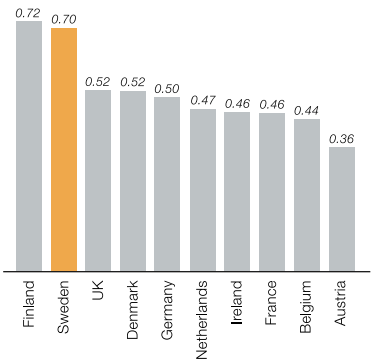
"Sweden is one of the world's most experienced markets for electrically powered trains. Customers on the Swedish market have long been and still are both knowledgeable and very demanding. This, combined with the fact that Swedish industries and traffic companies, public and private, put high demands on efficiency in their train systems, makes them open to new technology that makes train traffic more attractive and economically viable. In this environment we have developed highly competitive products and systems. Today we are world leaders in operating systems for electric trains and hold about 30 per cent of the global market."

International Competitiveness
2004, Scoore



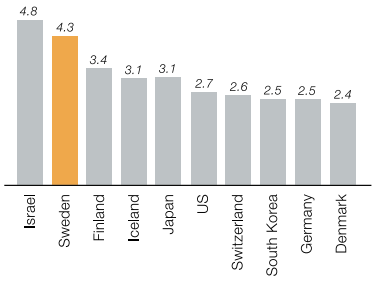
Note: The ranking includes European Union countries and the United States.
Source: The Lisbon review 2004, World Economic Forum.

Innovation Performance in the European Union
2003, Scoore



Source: European Innovation Scoreboard, European Commission, 2004.

Total Expenditure on Research and Development
2002, percent of GPD



Source: IMD, World Competitiveness Yearbook, 2004.

Laying underground high voltage cable from ABB, for reliable and invisible power transmission.

Sweden for the electric power professional

Career move

The Swedish electric power engineering industry is highly internationalized. A relatively small domestic market has meant that companies have had to make international ties early on. That is why employment in Sweden can be a smart career move for the person who wants to work internationally. Besides, Sweden is a good place to reinforce skills in the electric power area.

English on the job

Swedes speak the English language well. The vast majority of young people speak English fluently. Anyone who speaks English can easily live and work in Sweden.

Tax incentives

Key persons, such as researchers and other experts, are eligible for a special tax rate lowering their income tax by 25 per cent.

Open environment

Swedish workplaces are known for their open and non-hierarchical atmosphere with an emphasis on cooperation and sharing knowledge.

Reasons to invest in Sweden

- Sweden is strategically located in the Baltic Sea region for access to Scandinavian and northern European markets.
- Sweden is a valuable base for global R&D and an ideal market for early commercialization in terms of testing and launching new technology, product applications, and services.
- As the world's top knowledge-based economy, Sweden offers access to unique expertise.
- Sweden is expected to lead the convergence of mobile and internet technologies.
- For three consecutive years, the IDC has listed Sweden as the world's leading information society.
- Public ventures and investments promote the use of new technology.
- Sweden spearheads innovation in the European Union. Three Swedish regions appear on the list of Europe's ten most innovative regions.
- The combination of university-based innovation and commercialization systems and a sophisticated venture capital industry has created an integrated chain from academic discovery to global launch. This ensures a supply of high technology start-ups and opportunities for partnership and investments.
- Sweden offers good living conditions.

Sweden for the electric power student and researcher

Standards are high

Sweden has a long and proud history of academic excellence, with outstanding universities dating back to the fifteenth century.

Today Sweden's reputation for innovation is built on close cooperation between industry and academia. Swedish universities are renowned for their investigative research and independent thinking. That reputation is cemented with rigorous quality control and nationally certified degrees. Sweden has one of the most ambitious educational evaluation programs in Europe, aimed at maintaining this competitive edge.

Choice

Swedish universities offer over 200 master's programs in English, ranging from human rights to mechanical engineering. Programs are structured in response to student demand. The result is a student-centric educational system with open, informal relations between students and teachers where personal initiative and critical thought are prized.

Foreign students are welcome

Sweden's educational policy is based on the recognition that a multicultural student body is a resource, and its foreign student population continues to be one of the world's fastest growing, according to the OECD. Many students studying in Sweden come from abroad. There are PhD candidates from some 80 countries working on their degrees in Sweden.

Sweden's investment in its educational resources also remains among the world's highest.

English Is spoken by all

Almost all Swedes speak fluent English, and many Swedish companies use English as their official working language. This makes adapting to new surroundings much easier.

Chandur Sadarangani, professor atat the Royal Institute of Technology (KTH) in Stockholm:

– The research environment in Sweden in the field of electric power engineering is quite unique. There is close cooperation between research institutes, universities, industry, and public institutes. These combined resources make it possible to achieve high quality research where new ideas and concepts are encouraged and there is a strong incentive for creativity.

Juliette Soulard, senior researcher at the Competence Centre in Electrical Engineering at KTH:

– I moved to Sweden as a post-doctoral student in 1998. Soon after, I became senior researcher at KTH in Stockholm. And I do not regret my choices. Leading a research group in Sweden is an exciting and rich experience full of challenges, all the more so as most of our research activities are carried out in close collaboration with Swedish companies. People from all over the world come to study and do research at KTH. So it went really smoothly for me to adapt to the multicultural, English-speaking working environment.

Facts about Sweden

Sweden is located in northern Europe and is the largest of the Scandinavian countries. The country is a democratically governed, constitutional monarchy with a parliament and strong municipal government. The climate is temperate with obvious seasons. Sweden is one of the world's most modern countries, with a widespread use of technology, well-educated population, high standard of living, and well-developed level of equality in international comparison.

Sweden is one of the world's most research-and-development intensive countries. Its research maintains a high scientific quality. Sweden sets aside almost four per cent of its gross national product (GNP) for research and development.

Sweden is one of the world biggest users of electricity per capita and has doubled its electricity use since 1970. Sweden has advanced most in Europe in terms of reducing dependence on oil. The 34 per cent oil energy consumption is used mainly to fuel vehicles. The Swedish electric power grid is about 620,000 kilometres, which is the equivalent of encircling the world 15.5 times, and is owned by 117 companies.

Area: 450,000 sq km
Population: 9 million
Capital: Stockholm
Currency: Swedish kronor, abbreviated SEK
Academic education: 61 colleges, graduate schools, universities, and private institutions that provide academic education in Sweden. Approximately 20 per cent of the population has post-secondary school education.
Number of companies and organizations: 900,000

ABB AB Teknoplan AcobiaFLUX Ahlsell AB Allelektro Team Automation Sverige AB Alstom Alteco Elkonsult Areva T&D ARHO Mekan AB Aros Circle AB Aros Quality Group AB Awetek Konsult AB Balfour Beatty Rail AB Banverket BEAB Elkonsulter Bjerking AB Björklinge Energi AB Bombardier Transportation Boxco Bristol Babcock Sweden AB BRONCO Transmission BWB Elkonsult Caldaro Canpro Carl Bro AB Certus Elkonsulter Cintec Condesign Contac Teknik Crouzet AB DATEK Industrielektronik Deltagruppen Industrikonsult DJ Stork Automation Drivkraft Norden E.ON EKAB Energikontroll El Concept Sweden Electro Trading ETC Elektro Aros Montage Elektrosandberg Elforsk Elinstallation i Eskilstuna Elkonstruktioner i Västerås Elproman AB Elrond Komponent Eltel Networks Energimyndigheten Energisystem Stockholm Energo AB ENT Energiteknik Epsilon Hightech Innovation AB Etteplan Technical Systems Forsmarks Kraftgrupp AB Fortum FVB Sverige Hagerud Elteknik Heenius Ingenjörsbyrå Hexaformer High Voltage High Voltage Valley Holmen AB Honeywell AB IKG Mälardalen IMEK VVS Rådgivande Ingenjörer Indutrade Injab Kraftteknik Instra Installationskonsult Sta Kablageproduktion i Västerås AB Kanalsjös Ingenjörsbyrå KAESER Kompressorer AB Korsnäs Packaging Koteko KTH L.E.B Consult Maskin och teknik konsulterna Megacon AB Mekanex Maskinaktiebolag Midroc Motion Control i Västerås Mälardalens Högskola MälarenergiAB Neweng Consulting Nexans IKO Sweden AB Novotek ORAB Orbit One Ovako Steel Paratel PowerboxA PQR Prevas Programma Electric AB ProswecoTechnical Consultants Radscan AB Rahlmark Kosult Rejlers Ingenjörer Retea Råbe Tooling Sandvik Sauter Automation SCA Schneider Electric Sweden Seabased Semcon Sollentuna Energi SSAB Stora Enso Studsvik Svea Teknik STRI SWECO Swedmeter AB SwedPower Svenska Energihuset Svensk El Entreprenad ochKonsult Svensk Energi Svensk Rökgasenergi AB Svenska Kraftnät Svenskt Näringsliv Sveriges Tekniska Industrikonsulter Tekla Software AB Teknoplan Teleca Telge Energi AB TestElek Svenska Thurne Teknik Tibco Software TietoEnator Trinergi AB Wahlings Installationsservice Vattenfall Weishaupt Svenska AB Wesmar AB Westinghouse Electric Sweden AB VG Power Viessman Värmeteknik Wijk Installation VM-data WSP Sverige Vägverket Västmanlands Elektriska

power circle

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