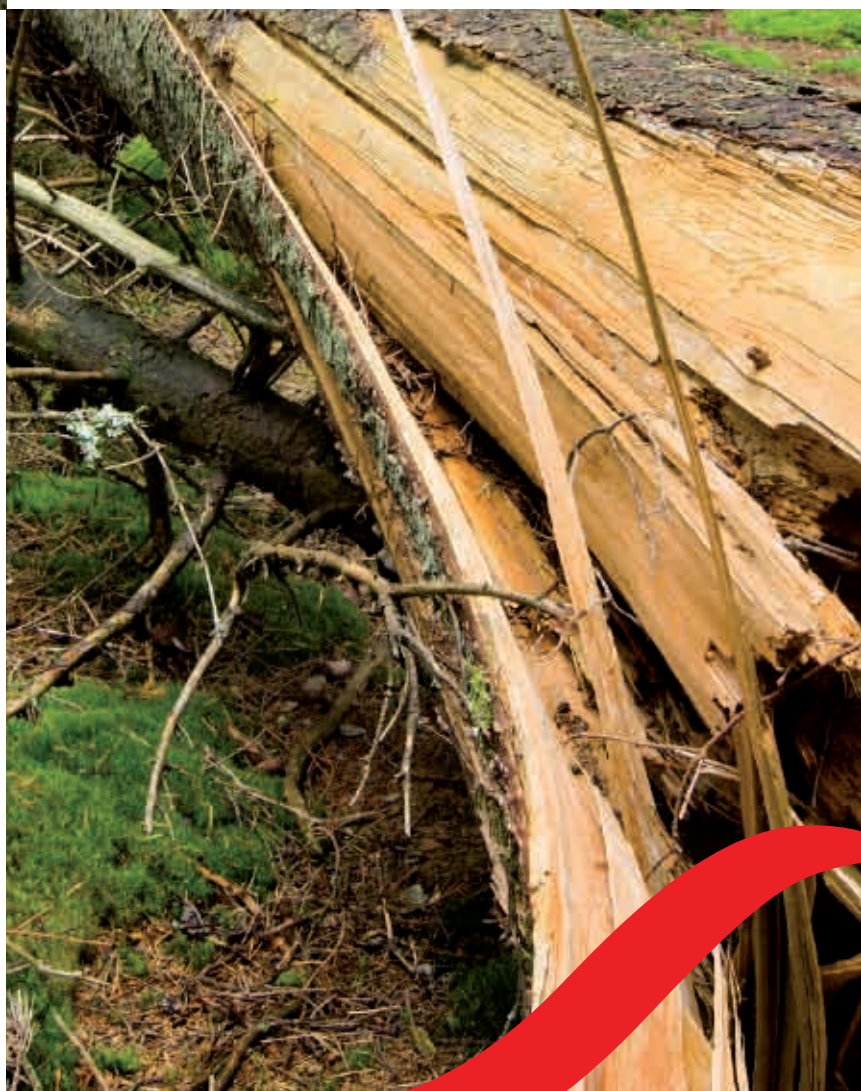
Publication Year 2007

Storm Gudrun

What can be learnt from the natural disaster of 2005?



“Closed because of Storm Gudrun”

Introduction

Storm Gudrun had devastating consequences for the southern parts of Sweden: no other natural disaster in modern times has affected the country so severely.

The general impression of Sweden as a well organised country, with good resources to clear up difficult situations, suffered a severe blow. The storm revealed several weak points. In the most severely hit counties, normal society effectively ceased to operate for some days. The storm damaged the electricity supply and telecommunications infrastructures to an extent that simply had not previously occurred in Sweden. The failure of the telecommunications systems clearly reveals the mutual dependency of the electricity and telecommunications sectors. Mobile telecommunications cannot work without electricity, but without mobile telephones it becomes more difficult to restore the electricity system.

Although Gudrun resulted directly in deaths and injuries, and had major effects on everyday life in the areas hit by the storm, the consequences could have been even worse. The storm struck on a Saturday after an extended public holiday, and during a period of unusually mild winter weather, which eased the situation for those without power and without availability of their normal heating systems. The gradual return of life to normal was assisted to a considerable extent by voluntary efforts from local groups and individuals, as well as by assistance from other countries.

The network operators and telephone companies were severely criticised for their lack of information and slow response. However, it can be noted that the joint assistance organisation of the electricity sector operated well, and that all available resources were deployed.

A NEW LANDSCAPE

The trees blown down by the storm damaged the electricity distribution system to an extent that no one had foreseen. In addition, the storm struck areas with a particularly high proportion of rural homes and industries.

When the storm had died down, there were many in southern Sweden who woke up to new and unrecognisable surroundings. It was not just the forested

landscape that had suffered: hundreds of thousands of customers had lost both electricity and telephone services. Many of them were to face weeks of uncertainty, cut off to a greater or lesser extent from the rest of the country.

The extensive electricity failures brutally demonstrated the dependence of our society on electricity. On the other hand, the response after the storm showed a real solidarity of the population and willingness to work together.

HOW WILL WE DEAL WITH THE NEXT DISASTER?

A year after the storm, work on repairing power lines is still in progress. Wherever possible, a greater proportion of the network will be buried.

The storm showed that there is considerable room for improvement in terms of the preparedness of society, companies and individuals to deal with a crisis in energy supply. Lessons must be learnt from Gudrun in order to improve our ability to prevent and/or tackle the effects of a major disturbance on energy supply.

The storm had very severe consequences, and so it is important to document what we have learnt from it, for future assistance to individuals, companies and the various functions of society in the event of something similar occurring.

A number of consultants' reports have been produced on behalf of the Swedish Energy Agency during the year that has passed since the storm. The purpose of this publication is to present a summary of the experience and conclusions drawn by the Agency on the effects of the storm on energy supply.

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This publication presents a summary of the facts and conclusions concerning the effects of storm Gudrun on energy supply, as presented in reports from the Swedish Energy Agency, the Swedish Emergency Management Agency and Svenska Kraftnät.

It has been prepared by Lars Westling, on behalf of the Swedish Energy Agency, and is published in the context of the Agency's work of publishing information on the security of energy supply.

This English-language edition is introduced with a section describing the various organisations and authorities that are responsible for dealing with a crisis situation.

Contents

Responsibility in a crisis situation

THE SWEDISH CRISIS MANAGEMENT SYSTEM

Sweden's crisis management system is based on three basic principles: the principle of responsibility, the principle of parity and the principle of proximity.

The principle of responsibility, means that whoever is responsible for an activity in normal conditions should assume corresponding responsibility in crisis or war situations.

The principle of parity means that during a crisis or war organisations should as far as possible be organized and located as in peacetime.

The principle of proximity means that crises should be dealt with at the lowest possible level.

This system is based partly on sector responsibility and partly on geographical area responsibility. All public authorities and organisations are responsible for their own working areas, known as *sector responsibility*, which applies at all times and in all situations. *Geographical area responsibility* complements this in the event of a crisis that affects several sectors at the same time. It operates at three levels in society: national (the government), regional (the county administrative boards) and local (local authorities).

THE SWEDISH ELECTRICITY MARKET

Sweden has several thousand physical production units for electricity. Most of them are owned by the three major network operators of Vattenfall, E.on and Fortum, which produce about 90 % of the electricity used in the country. Delivering electricity from its point of production to customers requires an extensive distribution system, which is divided up into the national grid, regional networks and local networks, operating at various voltage levels. The national grid transports electricity from major electricity sources to the regional networks. The state owned Svenska Kraftnät operating agency is responsible for the transmission of electricity over the national grid, as well

as for system operation of Swedish electricity supply. The regional lines carry electricity to the local distribution networks.

Although the electricity market is deregulated, network activity consists of area monopolies, which may be operated by private network operators. The Swedish grid has cross border links with neighbouring countries, and electricity is traded on a competitive market via a common Nordic electricity exchange.

HOW SWEDEN IS GOVERNED

Sweden is governed and administered at three different levels: centrally, regionally and locally. The central level consists of Parliament, the Government and the various national public authorities. Parliament and the Government determine the overall direction of energy policy and the operating conditions for companies in the sector. The ministries operating under the Government are relatively small.

The Government is assisted by a number of public authorities that implement its policies. Each of these public authorities is under the leadership of a director general, who is appointed by the Government. In comparison with corresponding authorities in other countries, these Swedish public authorities have a substantial degree of independence and perform a considerable proportion of the state's duties.

AT THE CENTRAL LEVEL – THE SWEDISH ENERGY AGENCY, THE SWEDISH EMERGENCY MANAGEMENT AGENCY AND THE SWEDISH RESCUE SERVICES AGENCY

The Swedish Energy Agency is a central, national agency with considerable responsibilities in the energy field. Its work is directed towards creating the right conditions for efficient and sustainable use of energy, coupled with a cost efficient supply of energy to the country. This includes ensuring a reliable supply of energy in both the short and the long terms, and also responsibility for the country's contingency planning in the energy sector.

The Swedish Emergency Management Agency is responsible for coordinating the work of developing contingency planning for crisis situations in Swedish society.

The Swedish Rescue Services Agency is a public authority with responsibility for improving the safety of society. It publishes information and prepares regulations, advice and support intended to reduce the number of accidents and their effects.

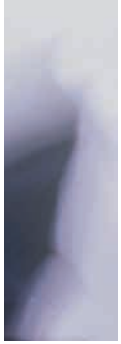
AT THE REGIONAL LEVEL – COUNTIES AND COUNTY COUNCILS

Sweden is divided into 21 geographical counties. Each has its own county administrative board, which represents the state at regional level. Each county administrative board is a public coordinating authority – a service authority – whose duty is to coordinate various interests in the county and to ensure that the national objectives set by the Government are achieved within the board's areas of responsibility. The boards play a key part in the work of developing public contingency planning. Although this work is performed at regional level, it considers both the national perspective and support for local development.

Sweden is also divided into 21 county councils or corresponding bodies, which are responsible for services covering wide geographical areas, and which often require substantial resources. The most important of these is the provision of health care. County councils are very important players in terms of crisis management. In the event of a crisis, health care will either be very vulnerable (e.g. in the event of major power failures), or be very important from an operative perspective.

AT LOCAL LEVEL – LOCAL AUTHORITIES

At the local authority/municipality level, Sweden consists of 290 geographical communities responsible for the provision of local level services such as schools, care of the elderly, refuse disposal and treatment, rescue services and public transport. They therefore have a key role to play in society's level of crisis preparedness. In the event of extraordinary or emergency circumstances, it is the responsibility of local authorities to ensure that services that cannot withstand stoppages continue to operate. If possible, other activities must continue to operate to their normal extent and in their normal forms.



A storm warning in southern Sweden

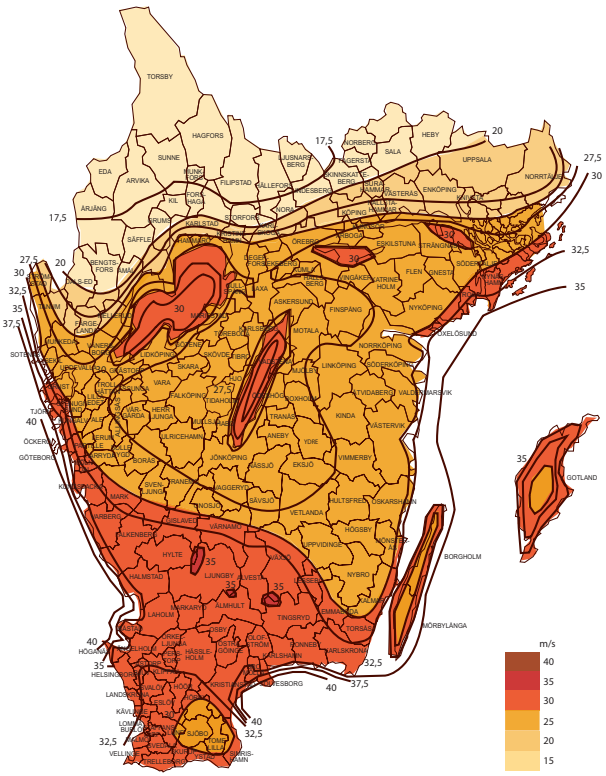
The Swedish Meteorological and Hydrological Institute (SMHI) issued a warning on Friday 7th January 2005 for a deep depression that was forming north west of Ireland. The resulting severe weather hit Sweden during the next day, with the storm winds that preceded the hurricane causing a number of minor power failures during the afternoon. The hurricane reached the west coast at 17.00. Gusts at Hallands Väderö reached a maximum of 43 m/s before the wind speed gauge broke off and disappeared.

Maximum wind speeds were recorded at several places during the evening of 8th January. The winds were strongest in the Bay of Hanö, where the average wind speed reached hurricane level (33 m/s), with gusts of 42 m/s. Wind speeds reached 30 m/s or more in almost all areas of Skåne, Blekinge, Halland, Kronoberg and Gotland, as well as in parts of Jönköping county, Kalmar county and Västra Götaland. In addition, strong gusts were recorded along the Södermanland coast, on Lake Mälaren, around Lake Hjälmaren and in southern parts of Stockholm county. Municipalities, companies and residents in a total of eleven counties suffered from the storm.

The storm cut a swathe across southern Sweden, striking the southern and western parts of Jönköping county, the whole of Kronoberg county, the western parts of Blekinge and the southern and western parts of Kalmar county particularly hard. The worst hit area was around Ljungby in the region of Småland.

The destruction was unexpectedly extensive. Millions of trees were uprooted, while others were broken off part way up the trunk. Fallen trees blocked roads and stopped rail traffic. Power lines were brought down on a scale that Sweden had not previously experienced.

Maximum wind speeds (gusts) at 10 m height



Source: SMHI

730 000 WITHOUT ELECTRICITY

The first power failures were reported at 15.00 in the afternoon. The storm brought down the electricity networks in the western parts of Jönköping and Kronoberg counties first, and then quickly cut off power supplies to much of rural areas in particular. It was estimated that, by midnight on 8th January, about 730 000 end-users were without power. Most of them were in Sydkraft's (now E.on Sverige's) distribution area in southern Sweden. The storm also caused considerable damage to the distribution networks of Vattenfall, KREAB Öst and several smaller distribution companies.

The storm hit that part of the country having the highest proportion of rural population and rural companies. There are major areas of forest, and also many farms, of which several are dairy farms.

The widespread power failures also resulted in failures of telephone and computer networks.

MILD WEATHER HELPED – AND HINDERED

The fact that the storm struck an area with such a high rural population and so many rural companies had severe consequences. However, the situation could have been considerably worse.

Despite occurring at the beginning of January, the weather was unusually mild, with less need of heating than would normally be expected at this time of year. No district heating systems in urban areas suffered from sufficiently long power failures to cause any greater problems with heating. However, in some cases, problems with heating did occur in smaller areas having district heating systems, or in houses in rural areas with individual heating. Fortunately, houses in rural areas often have alternative heating systems that can operate without electricity. They include older log fired boilers with natural circulation radiator systems, classic tiled stoves, log fired cooking or other stoves, and LPG or methylated spirit stoves for cooking. Some properties supplied from small group heating systems maintained operation with the help of mobile power units, although others had to wait while indoor temperatures dropped steadily, until the electricity supply could be temporarily restored.

The mild weather, in other words, reduced the severity of the situation after the storm. However, on the other hand, it was the lack of frost in the ground that meant that so many spruce trees, with their shallow roots, were unable to withstand the pressure of the wind. 75 million m³ of forest were felled, equivalent to several years' normal felling in the area affected by the storm.

MAJOR DAMAGE TO INFRASTRUCTURE

Strong winds, falling trees and flying branches damaged electricity and telecommunications cables and other technical infrastructure. Even power lines in overhead line rides that were thought to be wide enough to avoid damage from falling trees were brought down by trees that were snapped off by the

storm and blown onto the lines. The relatively new insulated overhead lines, too, were hard hit.

Antenna masts on the roofs of buildings, together with other masts for radio links and mobile communications, were blown down and destroyed. In addition to the physical damage to the telecommunications infrastructure, the power failures caused by the storm resulted in major interruptions to electronic communications.

Failure of telephone systems was a major problem, complicating and delaying the work of clearing roads and repairing overhead lines. It also caused considerable problems for social services such as care of the elderly and in home nursing services. As individual personal safety alarms did not work, social services and nursing personnel had to attempt to reach all their clients by physical visits in order to check how they were. Local authority personnel had to drive round to the various parts of their areas as a means of communication and for passing on information and instructions. Attempting to maintain an overview of the situation, and to delegate decisions and instructions, was extremely difficult and troublesome during the first few days after the storm.

IN THE SHADOW OF THE TSUNAMI

Gudrun occurred a little over a fortnight after the major tsunami catastrophe in south east Asia. The widespread concern with the victims of the tsunami probably resulted in many of those suffering from the storm accepting it and its effects in a very different way than might otherwise have been the case. Media concentration on the tsunami also certainly contributed to a relatively restrained treatment of Gudrun and its effects, and to the fact that information to the public was initially relatively sparse.

Becoming involuntarily isolated can have significant psychological effects. Many of those who were cut off regarded the loss of their telephones as being worse than the loss of electricity.

DEATHS AND INJURIES

Many individuals were left sitting in their cars, trapped on blocked roads. Some managed to find their way to gravel pits or other open areas, where the risk of being injured by falling trees was less.

Seven persons were killed in accidents during the night of the storm, and a number were injured. One car driver was killed when a tree fell on his car, while another car accident was put down to the storm. One victim died after having several bales of straw blown over him. Another died from the injuries he received after having fallen from a roof that he was attempting to repair.

Several more deaths occurred in connection with the subsequent clearing up and restoration work after the storm. Two of these were in connection with electrical work: a 17 year old died after having touched a live cable, while the other death occurred as the result of a fall from a pole.

Many injuries occurred in connection with timber clearing in the forests and restoration of electricity supplies.

The difficult situation that many experienced after the storm has also caused psychological reactions and depression. According to the county councils, this can have resulted in misuse of alcohol or drugs, assaults or even suicide.

DAMAGE TO PROPERTY

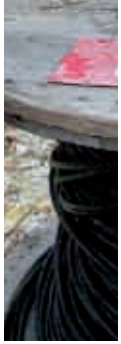
Fires or potential fires occurred when many old fireplaces were pressed into use, or used for bigger fires than intended, in order to keep warm in houses without electricity supplies. Properties that depended on electric pumps for continuous drainage of ground water etc. were damaged by flooding as the water rose. However, as a result of the mild weather, most properties avoided problems caused by freezing of heating pipes or water or drainage pipes.

LIMITED EFFECTS ON THE BIOFUELS MARKET

The storm created chaos in one of Sweden's major forestry production areas. According to some sources, fears that much of the fallen timber would be unusable for sawmill purposes or as pulpwood would result in a substantial surplus on the biofuels market, thus bringing down district heating prices. However, there are factors that are likely to oppose this. One is that the sector is characterised by long term contracts, which means that delivery volumes and prices were already settled for the whole of 2005 and, in many cases, also for 2006. The logging residues that had been harvested before the storm met most of the contracted chip deliveries for the 2005/06 season.

In order to reduce losses as much as possible, felling in the forest areas hit by the storm has been concentrated on sawmill timber and pulpwood, with supplies for biofuel raw materials taking second place. It has been calculated that at least a year's production of logging residues will be lost, which means that the availability of this material will be very limited for the 2006/07 season. To some extent, this can be compensated for by an increasing volume of sawdust and chips from sawmills in southern Sweden. Sawmill chips are normally sold to the pulp industry, but falling prices for chips as a result of the storm mean that some are being sold for fuel. Another contribution is expected from unsold stocks of pulpwood. Some pulp industries expect to be able to use storm felled timber for the next few years. In many cases, companies that are not connected to pulp mills – mainly sawmills – are holding stocks of pulpwood that have not yet been sold. It is mainly this wood that can replace the shortfall of logging residues for the biofuels market.

The conclusion is that there will be some distortion of the market over the next few years. As far as logging residues for biofuels are concerned, it is likely that handling costs in the storm area will be higher over the next few years. Nevertheless, the storm is expected to have only a modest effect on the prices of biofuels. As full use of forest fuels in Sweden is not yet being made, it is unlikely that the storm will result in any shortfall of forest fuels in the area in the somewhat longer term.



Restoration of electricity supply

Electricity in the seven hardest hit counties was supplied by a total of over a hundred network operators of varying sizes. The two largest network operators, E.on and Vattenfall, lost a total of almost 30 000 km of lines during the storm. Of E.on's 21 500 km of damaged lines, over 2000 km had to be completely rebuilt. This can be compared with E.on's activities during the whole of 2004, during which it modernised 1200 km of lines. KREAB Öst, another very hard hit network operator, lost much of its 840 km of lines. After the storm, several network operators ran cables on the ground along roads and through the forests as a temporary measure. One year on, these temporary arrangements are still in use in some places.

MODEST DAMAGE TO REGIONAL NETWORKS

Despite the fact that the regional networks consisted mainly of uninsulated lines, they escaped the storm with relatively little damage. This is explained by the fact that they mainly run through wide rides, clear of trees. The fact that some regional networks were nevertheless damaged by the storm, either directly by the wind or indirectly by fallen trees, is due partly to poor clearance and widening of the rides. The regional networks were given priority attention in connection with restoration of supplies, and were generally back in service relatively quickly, usually within 24 hours. However, it took the hardest hit operator, E.on, seven days to restore its entire regional network in the area.

MAJOR DAMAGE TO OVERHEAD LINES IN LOCAL DISTRIBUTION NETWORKS

Just where damage occurred to local distribution networks, and how serious it was, seemed to be due largely down to chance. In some places, strong gusts felled swathes of trees, while nearby areas escaped almost entirely. Paradoxically, in some cases, this meant that network operators having a high proportion of buried cables suffered from a relatively higher proportion of customers without power than did companies having a higher proportion of overhead lines.

Nevertheless, in total, network operators with a greater proportion of buried cables suffered a lower proportion of customers without power. They were also able to restore their networks more quickly. For example, more than 90 % of customers of Habo Kraft and Ale Elförening had their power restored within 24 hours. KREAB Öst, on the other hand, has a very high proportion of overhead lines, and all of its 7 200 customers lost their power supplies. Three days after the storm, no less than 57 % of them were still without power.

Distribution networks in the storm hit area (16 out of a total of 100 affected)

Network operator	Local distribution network in affected areas	Cabled routes (%)	Insulated overhead line (%)	Uninsulated overhead line (%)
Vattenfall Eldistribution Mellan	2 200 km	10 %	15 %	75 %
Vattenfall Eldistribution Öst	14 900 km	54 %	22 %	24 %
Vattenfall Eldistribution Väst	9 700 km	31 %	6 %	63 %
Eon	88 650 km	48 %	19 %	33 %
Fortum Distribution	13 700 km	38 %	4 %	58 %
GENAB (Göteborg)	6 422 km	90 %	7 %	3 %
KREAB Öst	840 km	11 %	14 %	75 %
KREAB Skåne	644 km	47 %	4 %	49 %
Härryda Energi	1 030 km	65 %	22 %	13 %
Ale Elförening	920 km	72 %	17 %	11 %
Jönköping Energi Nät	815 km	54 %	3 %	43 %
Vaggeryd Elverk	650 km	55 %	18 %	27 %
Rödeby Elverk	590 km	30 %	50 %	20 %
Habo Kraft	425 km	74 %		26 %
Värnamo Elnät	545 km	58 %	20 %	22 %
Alvesta Energi	600 km	75 %	15 %	10 %
Total	14 631 km			

Source: EuroFutures

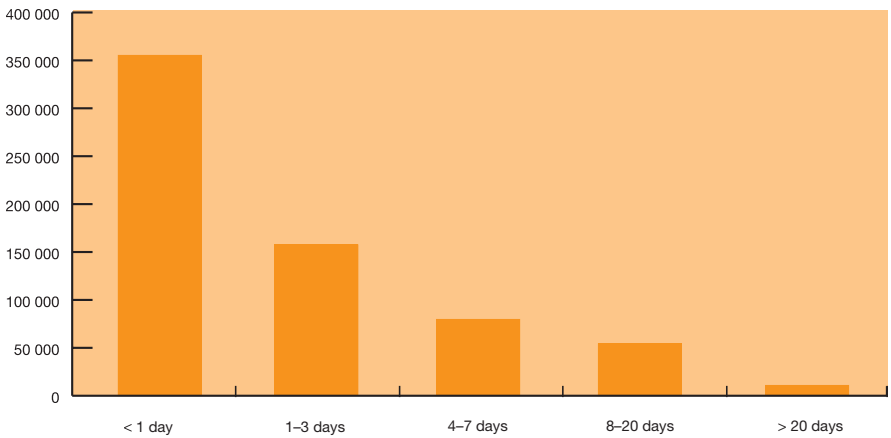
Both insulated and uninsulated overhead lines were brought down by the storm. In some areas, so many trees fell on the lines that they either damaged the insulation, broke the line poles or broke the lines themselves. The only way to avoid such damage to overhead lines is to run the lines along broad rides, and to keep them clear of growing vegetation. However, to ensure that

rides were completely safe from falling trees or broken branches would require a severe incursion into the landscape, and would also make forestry more difficult.

HUNDREDS OF THOUSANDS WITHOUT POWER

Figures issued by the network operators show that about 730 000 customers were without power. Supplies were restored to about half of them within 24 hours. A subsequent survey of 663 000 customers who suffered from the storm found that about 354 000 of them had supplies restored within 24 hours. 159 000 customers were without power for between one and three days, 82 000 without power for between four and seven days, 56 000 without power for between eight and twenty days, and 12 000 without power for more than 20 days.

Number of customers for whom power was restored within various time intervals



There is a clear relationship between the length of supply interruptions and population sparseness. The longer the average length of line per end-user, the longer the interruption.

Power outages in urban areas affected by the storm were generally limited to only a few hours. Most of those suffering power supply failures for more than 24 hours were in rural areas.

Due to its large number of customers who lost their power supplies, E.on was the network operator that experienced the most difficulty in restoring supplies. In the hardest hit area, 4 % of its customers were still without power after 20 days.

In general, smaller network operators came off somewhat better than larger companies. The main explanation for this is that they had a greater proportion of their networks in cable form.

It was 16 days before supplies were restored to all permanent homes in Kalmar county. In Blekinge, the corresponding time was 20 days, while supplies were not restored to all permanent homes in Kronoberg and Jönköping counties until 39 days after the storm. Even so, there were still some holiday homes without supplies after this time. It has been calculated that the power failure resulting from the storm caused about 2.3 million failure days.

MOBILISATION BY THE NETWORK OPERATORS

All the electricity suppliers in the area raised their preparedness immediately after the storm warning from SMHI. Vattenfall and E.on, for example, called in their permanent major incident groups, which include personnel resources for operation, information, repairs and liaison with third parties, on 8th January.

The joint incident groups of the network operators in the southern and western areas had initial contacts as early as the morning of 8th January, and started work during the afternoon. As a result, working with Svenska Kraftnät, they were able to start sending resources to the affected areas as early as the morning of 9th January. Two groups of repair personnel, for example, were flown by a Swedish Air Force Hercules aircraft from Sundsvall to Växjö. A further four transports happened during the Sunday.

In practice, the network operators cooperate with each other in terms of supplying personnel and materials for the repair and maintenance of networks in the event of major external incidents. However, each network operator is first and foremost responsible for its own activities. E.on's substantial personnel requirements were partly met in this way.

Restoration of supplies after the storm created a major need for experienced forestry workers and linesmen. The operators' own resources were clearly insufficient. Using their own and borrowed personnel, the companies were able to mobilise a maximum of 5 000 persons for clearing rides and repairing lines.

A further contribution to making up the shortfall of linesmen saw the borrowing of 300 linesmen from Norway, Finland, Denmark, Germany, the UK and Poland. Together with the Swedish defence forces, Svenska Kraftnät organised about a score of flights of repair groups from northern Sweden and Finland. For the first time, personnel trained by civil defence organisations were used to help repair the networks.

In addition to the network operators' own personnel, additional personnel for the clearance work were provided by the Swedish Armed Forces, the Federation of Swedish Farmers (LRF) and several local contractors. E.on states that about 3 000 LRF workers were contracted for clearance work after the storm. From the military, about 300 officers and other personnel, 1 400 conscripts and at least 1 100 personnel from the National Home Guard were active in the most severely affected areas.

BLOCKED ROADS COMPLICATED RESTORATION WORK

Before the damaged lines could be repaired, it was necessary to clear fallen trees from roads. This was done by personnel from the network operators, local authorities and the National Road Administration, as well as by local landowners and volunteers.

Clearing the roads was dangerous and time consuming. In some areas, many trees had fallen upon each other, making it impossible to clear them through the use of motor saws alone. The work of restoring power supplies was held up by the fact that many roads were impassable in Halland, Kronoberg and southern parts of Jönköping county during the first few days.

Although the National Road Administration is responsible for clearance on public roads, it has no personnel of its own for this work, and generally has no local contingency services available for events of this type.

Many of the smaller roads leading to the lines are owned by local authorities or private landowners. As a result, a large number of persons were

working for the local authorities during the first few days after the storm. In Ljungby, for example, over 800 persons were employed in clearing the smaller roads. At first, priority was given to general access, after which personnel were used for clearing rides for E.on.

VEHICLES AND SUPPLIES

Transporting personnel in the storm hit area required a large number of all terrain vehicles. The defence forces made about 200 vehicles available to the Kronoberg County Administrative Board, to a number of local authorities and to E.on. Svenska Kraftnät provided all terrain vehicles and tracked vehicles. In addition, aircraft and helicopters from the defence forces were used to carry personnel and supplies, as well as for reconnaissance and inspection of lines.

Spare parts stores all over the country were emptied. The lack of materials necessitated improvisations: parts from broken poles were re used and, in some cases, fallen trees or trees that were still standing were brought into service as temporary poles. Insulated cable and pole mounted transformers were imported from all over Europe.

Manufacture of new cable was started in Holland, for delivery directly to the affected area. After the storm, cables were run along roads and through forests in order to provide temporary supplies.

STANDBY POWER UNITS

There is no central register of the availability of standby power units in Sweden. This meant that all those needing standby power supplies had to locate suitable units on their own. As a result, personal initiatives, local knowledge and contact networks played important parts.

After the storm, E.on and the Swedish defence forces, supplemented by the National Road Administration, SOS Alarm and Svenska Kraftnät, provided about 2 000 standby power units for use by local authorities. To these must be added the standby power units already held by the local authorities themselves for use by their social services and water and sewage systems. In several cases, it was difficult to get the units to work satisfactorily.

In addition, the Swedish Rescue Services Agency had 115 standby power

units that were made available to the county administrative boards. Further, at the beginning of February, the Rescue Services Agency received 50 standby power units from Germany and 20 from the Czech Republic through the EU Joint Facilities Mechanism. However, only about 20 of them were actually used, as by that time the majority of electricity supplies had been restored in most of the counties.

A particular problem that was encountered was that the available standby power units were not always suitable for their needs. According to the Rescue Services Agency, more three phase units should have been available. Another problem was that many of the units broke down, not being intended for continuous operation.

In some areas, where the local distribution network was intact, standby power units provided power to 'islands' of subscribers, consisting of several properties or parts of a district. In Lessebo, heating was maintained by sectioning the power supply in buildings so that a limited supply of electricity was available for the most important loads.

COMMUNICATION PROBLEMS

It was difficult, in the immediate aftermath of the storm, to obtain a full picture of the consequences. This was due not only to the sheer extent of the damage, but also to communication difficulties.

The loss of telephone communication systems made the work of restoring power supplies more difficult. Linesmen had to travel miles in order to be able to order what they needed. Couriers were sent out with work orders, and meetings had to be arranged in advance.

In some cases, standby power supplies to the base stations in the GSM network were not arranged until almost a week had passed. As time went on, mobile standby power units were delivered to masts and telephone sub exchanges. However, this did not at first result in the hoped for improvements, as there was also the physical damage to the networks to contend with. In addition, many standby power units suffered from problems due to overloading. Some were stolen.

In some cases, problems were solved in unconventional ways. Network operators signed up to Danish mobile telephone systems, as it is not at present

possible to access several telephone system operators' networks from one and the same SIM card in Sweden, known as roaming. However, after a while, the network operators and local authorities obtained access to temporary roaming cards through the efforts of the county administrative boards.

E.on's and Vattenfall's mobile radio systems did work. However, repair work was complicated by the fact that the subcontractors engaged in the work did not have access to the system.

There is still no common mobile radio system for the electrical sector in Sweden. It has long been desirable that the electricity distributors should be included in Rakel – the new communications system being set up for the 'blue light' services. Access to a system of this type would have considerably simplified and speeded up both the clearance and the restoration work.

INFORMATION WITH DIFFICULTY

Breakdown of the telephone systems and internet made it difficult for the network operators' customers to obtain the information that they needed immediately after the storm. The network operators and public authorities also suffered from a lack of information in the general chaos of the situation. The most reliable information was to be found out in the field, from those directly involved in the work of restoring supplies.

E.on's contingency relief cooperation with the Federation of Swedish Farmers simplified the spread of information in rural areas, and allowed the work of clearing up to be quickly started.

The network operators' forecasts of when power would be restored often turned out to be excessively optimistic. Some households purchased small emergency power units, in the belief that they would not be very long without their normal mains supply. As the time without power became longer and longer, these power units had to be replaced by others with higher capacity.

In some cases, the larger companies' call centres have been outsourced to companies elsewhere in the country. Call centre staffs' lack of local knowledge sometimes resulted in misunderstandings and incorrect information.

Local radio stations had an important part to play in providing information, and were used particularly by local authorities and country administrative boards. The Kronoberg County Administrative Board arranged for some of its

own personnel to be stationed in the Radio Kronoberg studio. However, one problem here was that radio coverage did not reach to all parts of the county. As local radio is based on geographical areas, it was not possible to obtain information from Radio Halland or Radio Skåne for those who could receive them.

The best information in a chaotic situation is often that which is locally available. Centralised information services can therefore become a problem and, in the worst cases, do more harm than good. During the first few days after the storm, it was difficult for agencies such as the Swedish Rescue Services Agency, the Swedish Emergency Management Agency, the county administrative boards or parties such as E.on and Svenska Kraftnät to keep up to date with the latest information.

SHORTAGE OF SPECIALISTS

A serious problem in any major crisis is the shortage of trained personnel that quickly arises when a considerable amount of work of the same type has to be performed in many places simultaneously. In the case of the network operators, problems arose due to the shortage of forestry workers and linesmen. Other professional groups that could not meet the demand for their services included chimney sweeps, electricians and property caretakers.

ORGANISED ELECTRICITY SUPPLY COOPERATION

At the end of the 1990s, the electricity industry set up a national electricity supply cooperation organisation. There are seven such cooperation areas, with Svenska Kraftnät being represented in all of them. Each local organisation works closely with the county administrative boards in its area.

The purpose of the organisations is that, in the event of problems, the network operators will assist each other with resources that are not needed for their own purposes at the time. This has been assisted by the setting up, in October 2004, of the computerised support system, SUSIE, by Svenska Kraftnät, in conjunction with Swedenergy and the network operators. The system allows the network operators to notify their needs of assistance and report the resources that they have available. At the time of the Gudrun storm, not all personnel with the network operators were sufficiently trained to make full use of the system.

In general, the network operators are very pleased with the way that the cooperation organisation worked after the storm. Network operators in the north of the country immediately dispatched personnel, who received their orders on the way to the areas where their help was needed.

Vattenfall and Fortum managed most of their work using their own personnel resources, while E.on needed (and received) significant external assistance. Initially, companies used their resources to deal with faults on their own networks, after which they provided help to more severely hit companies, particularly E.on. The cooperation organisation has also played an important part in assisting deliveries of materials for repairs and restoration.

IMPORTANT CONTRIBUTIONS FROM SVENSKA KRAFTNÄT AND VOLUNTEERS

Svenska Kraftnät (SvK) has an agreement with the defence forces concerning assistance in the event of major supply interruptions. In addition, it has agreements with voluntary civil defence organisations such as the Swedish Federation of Women's Motor Transport Corps and the Swedish Voluntary Radio Organisation. The defence forces estimate that the voluntary defence organisations contributed about 700 person days of work during the storm.

In addition, Svenska Kraftnät has a number of mobile repair groups, supported by contingency stores in Örebro county of such materials as poles, standby power units, cross country vehicles and mobile communication systems. Through its agreement with the defence forces and the voluntary organisations, SvK was able quickly to mobilise and provide crews for vehicles and other resources that considerably assisted the work of restoring power supplies.

The distribution companies drew considerable help from their agreements with individual contractors and the Federation of Swedish Farmers. Most of them have their own machines, making the work of organisation easier. In addition, they are usually well aware of where and how the overhead lines run.

Many individuals, including landowners in the areas concerned, assisted the work. One company received valuable help from an orienteering club through its knowledge of the lines and conditions in the area. Good local

knowledge was very important in all cases, as centralised control of the restoration work was hampered by the lack of working communication systems.

INPUT FROM THE SWEDISH ARMED FORCES

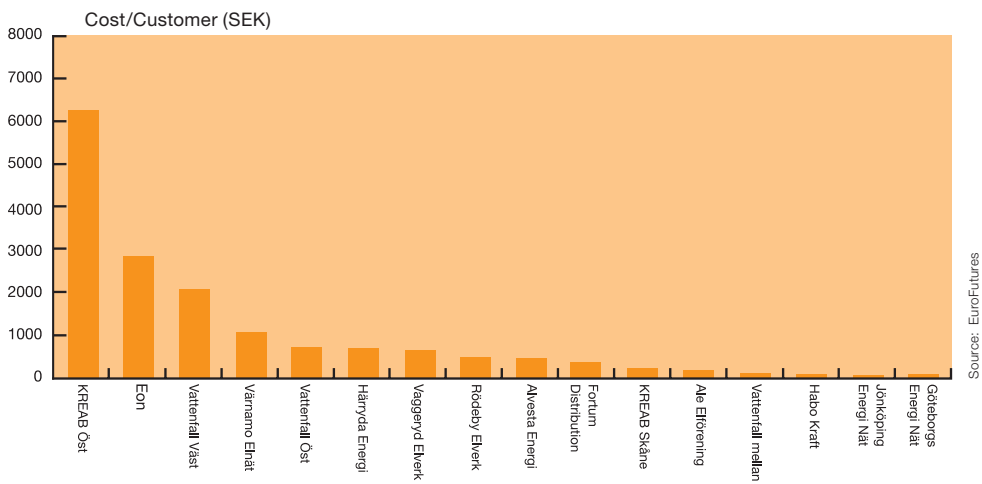
The input from the Swedish Armed Forces after the storm was the greatest that has been performed in peacetime. A total of almost 3 000 officers, conscripts and civil defence personnel were actively involved in the work of restoring a normality of services after the storm.

Conscripts helped with everything from clearance to visits to isolated residents in order to help in such ways as refuelling diesel engines and chopping logs. Fuel supplies to all standby power plants used for local electricity supplies for such as emergency lodges and telephone equipment were also partly looked after by the Swedish Armed Forces.

In addition, the military provided aircraft, helicopters and about 200 vehicles. The aircraft and helicopters were used for transporting personnel and supplies, as well as for inspecting the overhead lines.

NETWORK OPERATORS' COSTS

The extent of the damage is reflected in the diagram below, showing how costs have been spread among all customers.



Source: EuroFutures

Although it appears only in fourth position in the diagram on the former page, Värnamo Elnät had the highest specific cost per customer suffering from the power failure. This is explained by the fact that it was the sparse rural network that was hit the hardest, and that Värnamo Elnät has a high proportion of its customers in such areas. Other companies that expect high restoration costs per customer without power are KREAB Öst, E.on and Vattenfall Väst.

It can be seen from the table below that almost 80 % of the estimated costs arise from clearance, repair and restoration.

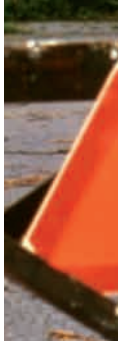
Direct costs resulting from the storm, as estimated by the companies (SEK)

Network operator	Loss of supply	Clearance, repair and restoration	Compensation for loss of supply	Other costs	Total (SEK)
Vattenfall Eldistribution Mellan	2 660 000	20 500 000	25 000 000	5 050 000	53 210 000
Vattenfall Eldistribution Öst	1 100 000	57 200 000	25 000 000	1 000 000	84 300 000
Vattenfall Eldistribution Väst	7 400 000	78 000 000	250 000 000	11 000 000	346 400 00
Eon	40 000 000	1 300 000 000	250 000 000	100 000 000	1 690 000 000
Fortum Distribution	1 800 000	30 000 000	43 000 000	10 000 000	84 800 000
GENAB (Göteborg)	–	–	5 500 000	–	11 600 000
KREAB Öst	500 000	30 000 000	9 500 000	5 000 000	45 000 000
KREAB Skåne	50 000	2 500 000	1 000 000	–	3 550 000
Härryda Energi	70 000	4 850 000	3 300 000	–	8 220 000
Ale Elförening	25 000	1 900 000	75 000	–	2 000 000
Jönköping Energi Nät	–	1 500 000	1 200 000	–	2 700 000
Vaggeryd Elverk	–	1 700 000	670 000	–	2 370 000
Rödeby Elverk	–	–	–	–	2 000 000
Habo Kraft	–	365 000	25 000	–	390 000
Värnamo Elnät	13 000	10 000 000	1 100 000	–	11 113 000
Alvesta Energi	–	2 000 000	200 000	_	2 200 000

Source: EuroFutures

Other costs, not specified

The total estimated cost for all the network operators is estimated as amounting to about something over SEK 2 600 million. Of this, about 25 % is estimated as being for compensation for loss of supply to customers. It should be noted that these figures are preliminary estimates, and that the final total can differ, as the work of restoration is still in progress at the time of writing this report.



The effects of the power failure

When a major natural disaster damages the infrastructure of society to such an extent as was the case after Gudrun, both the wider functions of society and the details of life for individuals are affected.

On behalf of the Swedish Energy Agency, EuroFutures investigated the consequential effects of the storm in Alvesta, Ljungby and Värnamo – three of the most severely hit areas.

HIGH PROPORTION OF RESIDENTS IN SPARSELY POPULATED AREAS

56 % of the 18 900 inhabitants of Alvesta live in rural areas, as defined by the Swedish Rural Development Agency. Much of the rural distribution network was brought down by the storm. It took up to a week until all roads were passable again. Electricity distribution in Alvesta is provided by two network operators; the local authority owned Alvesta Energi and E.on.

Alvesta Energi distributes electricity in the Alvesta and Moheda urban areas, as well as in a smaller part of the rural area. E.on's network is primarily in the northern and southern parts of the area, and is primarily a rural network.

Alvesta Energi's distribution system in Moheda failed for almost 24 hours, with the interruptions in the company's rural network lasting from two to 18 days.

E.on's network was hit considerably harder, with supply interruptions lasting up to 45 days. Of the company's about 5 300 customers, three quarters suffered loss of power. The average time without power was 16 days. Several businesses were without power for periods ranging from a few days up to a few weeks.

PREPARATIONS BY THE LOCAL AUTHORITY

After the storm warnings issued by SMHI, the Alvesta local authority started to take preparatory steps. Early on Sunday morning, a meeting was arranged between officials from the rescue services, the county administrative board, SOS Alarm, the Swedish Armed Forces, Växjö local authority and other parties.

After the storm had passed, much of the area was without power and many roads were impassable. Telephone connections had been knocked out over much of the area.

Three priority areas were a) the provision of services and resources for older persons, residents in care homes, and visiting social workers; b) decisions on which schools that could be opened after the Christmas holiday, and c) the provision of shelters and premises for evacuated persons. Information to the public, and the provision of standby power supplies, were also high on the action list.

E.on provided a large number of standby power units, and asked the local authority for help in determining which customers were the most important. The local authority contributed a number of standby power units of its own, while others were provided by the county administrative board, other local authority councils or through purchases.

HEATING AND PROVISIONS TO INHABITANTS

Older persons, the ill and disabled persons had to be evacuated from their homes or be provided with alarms, mobility equipment, oxygen and medicines.

Standby power units were not available in all old people's homes, and had to be borrowed where necessary. In one area, for example, arrangements were made for emergency accommodation of sixty older persons. Most of those who could not remain in their own homes were accommodated by relatives and friends. The Red Cross, civil defence organisations and individuals assisted with the home visiting service.

Four schools and four child day care centres had to be closed. After two days, provision was made for their pupils elsewhere in the area.

Initially, the local authority gave priority to the provision of standby power supplies to the district heating plant and to the council's nine waterworks. Standpipes were arranged in a number of places, and a couple of smaller effluent treatment plants were out of operation for some days.

As far as clearing up fallen trees was concerned, priority was given to public roads and parks, after which the work was concentrated on clearing private roads to all inhabitants and to restarting the school transport service.

The local authority housing company set up a number of relief centres to which people could turn for information, food, showers and other services.

Information to the public was provided via Radio Kronoberg, the local press and the council's noticeboards at the fire stations. Information on the council's website often managed to reach out via workplaces, relatives and friends.

DIFFICULTIES FOR COMPANIES AND INDIVIDUALS

Alvesta has about 400 farms and forestry companies, of which about 350 have livestock. Almost all of them suffered from the power failure, varying from about an hour to a maximum of 45 days. For most of them, the power failure lasted about 10 days.

Farmers with their own standby power units could largely maintain their production. However, it became clear that many did not have the standby power resource that was required. In some cases, the lack of electricity meant that milk had to be poured away.

For companies in Alvesta, the often long lasting power failures resulted in increased costs for the provision of standby power and loss of income due to loss of production. Many employees turned their hand to clearance of fallen trees on their own or others' land and, in some cases, were unable to get to work due to impassable roads.

Retailers noted a marked reduction in interest in items such as jewellery, clothes and books. On the other hand, sales of batteries, torches, maps and tinned foods increased. Sales of petrol and oil for all the standby power units and forest machinery increased markedly.

Shops in rural areas suffered from reduced sales and increased costs for spoiled goods, standby power, security and additional work.

One household was without power for no less than seven weeks. Telephone services were not completely restored until over two months had passed. The greatest problem for the family was the provision of water, which had to be fetched from a neighbour who had a hand pump. One of the adults in the family was able to take showers at work, while the other could shower at her parents in an urban area. Heating was less of a problem, as the house had several stoves and cookers. The outdoor playhouse served as a refrigerator,

while lighting was provided by paraffin lamps, candles, torches and strap on headlamps. On two occasions, the household borrowed a standby power unit, partly so that the children could watch television.

SIMILAR EXPERIENCES IN LJUNGBY AND VÄRNAMO

3 250 electricity customers in Ljungby were still without power 21 days after the storm. The local authority opened 18 relief centres. The rescue services and the military visited all the community's inhabitants older than 70, and 110 persons were evacuated to the council's old people's homes. 25 persons were still unable to return to their homes a month after the storm.

30 000 m³ of untreated sewage effluent ran out into rivers and lakes during January and February as a result of the power failures.

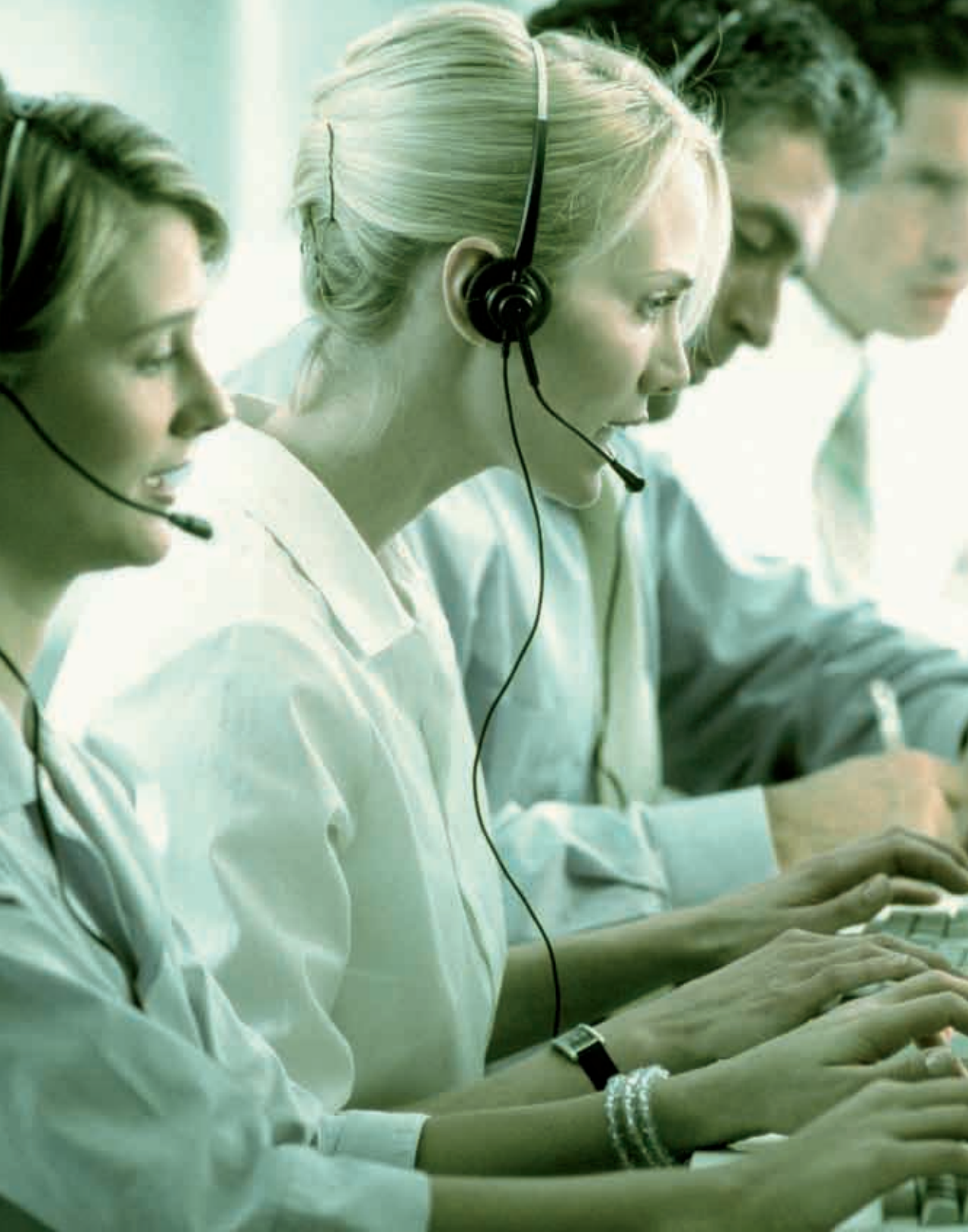
Postmen helped by delivering fliers from the council with information on conditions. In addition, local information was published each week in the form of a full page announcement in the Smålänningen newspaper.

The local authority borrowed 30 standby power units from E.on and distributed them to livestock farmers. In a number of cases, the farmers shared the power units, moving them around from one farm to another.

In Värnamo, the power failure resulted in the local authority old people's homes being without hot water, with lifting equipment that did not work, with dementia patients being without working alarms or entry/exit control, without on site cooking facilities and various other problems.

GOOD BUSINESS FOR SOME

At the other end of the spectrum there were, of course, some businesses that increased their sales as a result of the storm. Hotels, hostels and restaurants experienced a growth in demand as the towns filled with contractors clearing the forests and mending overhead lines. Contractors and suppliers of machinery did good business. Transport companies benefited from the storm as well. In addition, there was a lot of new investment in machinery, purchase of spare parts, motor saws, forestry equipment and more transport.

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Cost to society

A natural disaster such as Gudrun unerringly results in major costs for society, companies and individuals. Many of these costs are difficult to evaluate in strict monetary terms. One of the reasons for this is that the damage can be long term: for forest owners, for example, the consequences will last for generations.

Other costs relate to losses of security and human tragedies. Seven persons died during the storm. In addition, up to January 2006, a further eleven persons had died during clearance work. During 2005, the Work Environment Authority registered 141 accidents at work, caused by Gudrun. Half of them occurred in connection with the use of motor saws.

Livestock has suffered on farms without sufficient standby power supplies. The storm has probably also caused environmental damage that is difficult to pin down.

The map and diagram on the next page show an estimate of those costs that can be calculated and which affected society, business and households as a result of the interruptions to energy supply.

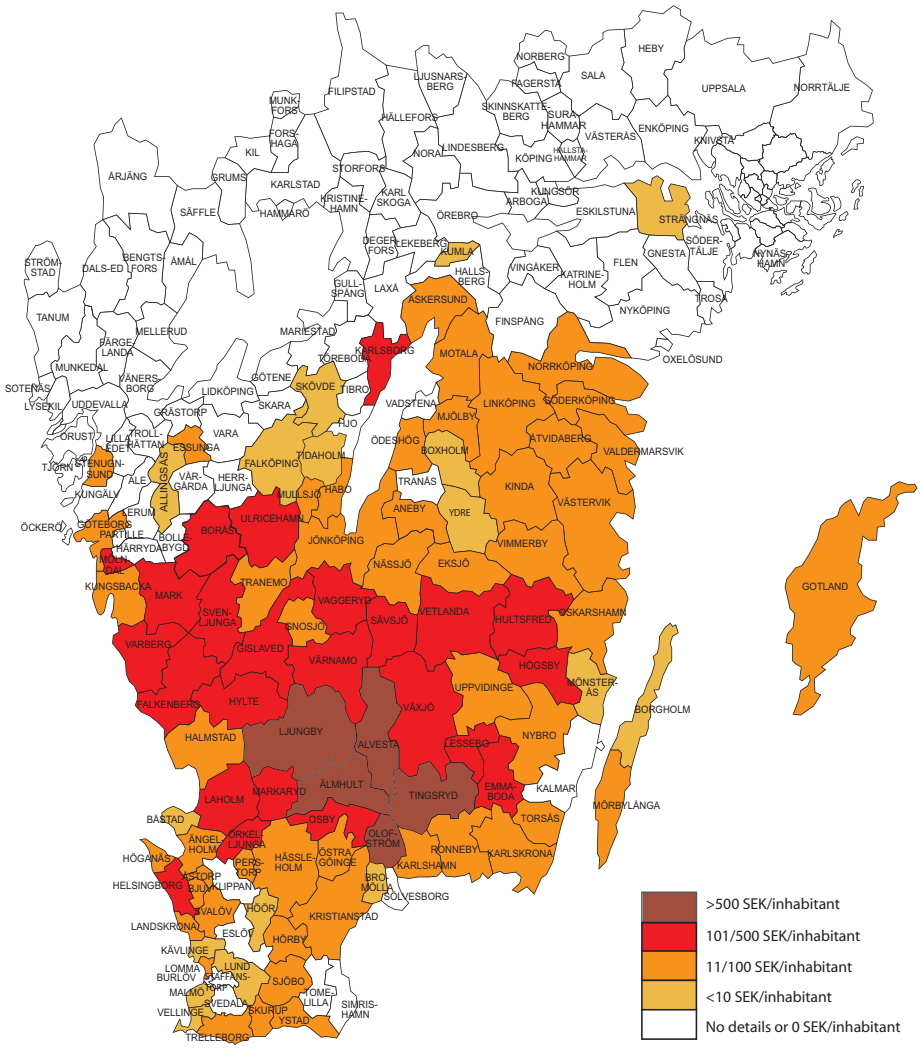
PUBLIC SECTOR COSTS

For county councils, the effect of the storm has been to increase their costs for various forms of personal care. Many hospitals had to rely on their standby power supplies during the power failure.

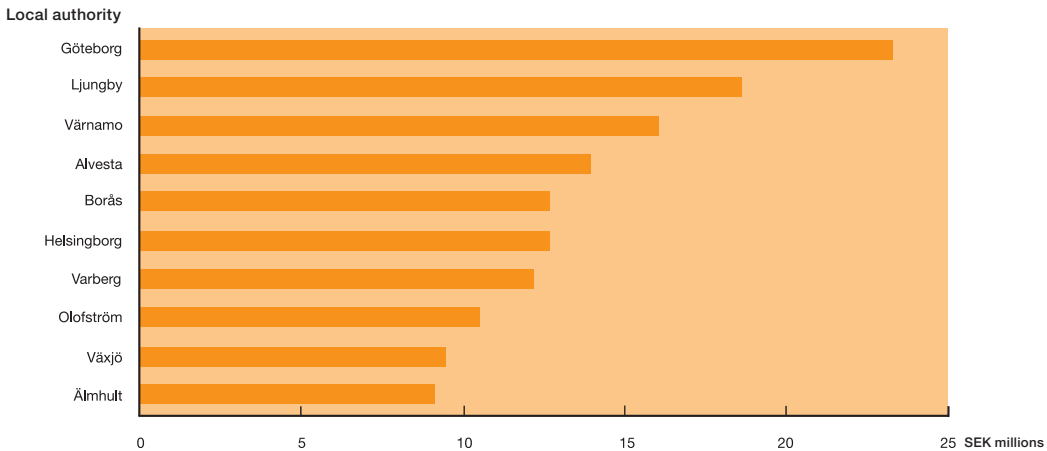
For the state, costs arose in the form of work carried out by county administrative boards, the armed forces, Svenska Kraftnät, the Rescue Services Agency, the National Road Administration and others.

Over 80 local authorities have reported their storm costs to the Ministry of Industry and Commerce, amounting to a total of SEK 273 million. Of them, 47 local authorities had direct costs exceeding SEK 1 million.

The cost impact of storm damage in the public sector (SEK per inhabitant)



Local authorities suffering direct costs exceeding SEK 9 million



In total, the costs of the storm to the public sector are estimated as amounting to SEK 400–500 million, to which must be added the loss of value of the State's forest holdings.

THE COSTS TO AGRICULTURE

The economic consequences to business and industry were both positive and negative. The hardest hit was the farming sector, with its high proportion of dairy farms. Additional costs were incurred for standby power, loss of production and the farmers' own additional work input.

Average figures indicate a loss of about 14 days' production, at a cost of about SEK 5 000 per day. The total costs of losses in the hardest hit area are calculated as about SEK 60 000–80 000 per dairy farm.

The total additional costs for agriculture (excluding forestry) have been estimated as amounting to about SEK 200–250 million.

COSTS TO MANUFACTURING INDUSTRY

Businesses in Kronoberg county estimate the cost of the storm to business and industry in the county (excluding the agricultural sector) as amounting

to at least SEK 35 million per interrupted day. Businesses in other counties suffered less severely.

The total cost to business and industry in Kronoberg, Jönköping, Kalmar and Blekinge counties is estimated as SEK 700–1 000 million. Most of these costs arise directly from the loss of power supply, although some can also be ascribed to breakdown of the telecommunications system and the fact that, for various reasons, employees were not able to work after the storm.

COST TO THE RETAIL AND SERVICES SECTOR

The ravages of the storm resulted in both increased cost and – for some companies – increased revenue. Grocery shops in rural areas and IT companies were among the losers, while those benefiting from the storm were the hotel and restaurant trade, transport companies and forest machinery contractors.

Treated as a single group, the retail and service sector has not suffered any costs as a result of the failure of the power supply. However, revenues and costs have been redistributed between sectors and companies. In addition, there will have been a change in terms of time: forest machinery contractors' good business immediately after the storm will probably be followed by a downturn over the next few years, as previously planned felling operations are no longer needed.

DOMESTIC COSTS

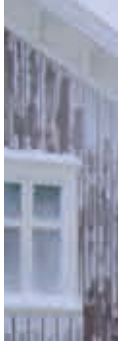
It is difficult to calculate domestic costs, which can also vary widely.

Direct additional cost to households consisted of the purchase of batteries, candles, paraffin and heating oil, as well as for the loss of foodstuffs. Households suffering a long power outage rented or purchased standby power units. In addition, they have also incurred additional work such as maintaining fires, fetching water and additional transport. The total additional costs for 600 000 households affected by the storm, with an average of four days without electricity, has been calculated as amounting to about SEK 360 million.

AN OVERALL ESTIMATE OF THE COST TO SOCIETY

The total cost to society for the electricity failure has been estimated as about SEK 1 600–2 100 million. To arrive at an overall total cost, we need to add the network operators' costs to this figure, estimated as amounting to about SEK 2 600 million for all the network operators in the area hit by the storm. The conclusion is that the loss of power supply after storm Gudrun resulted in an additional cost to society of about SEK 4 000–5 000 million.

In November 2005, the European Parliament decided to grant SEK 768 million from the EU Solidarity Fund towards the extra cost incurred by Sweden after the storm.



If it had been colder…

The fact that storm Gudrun occurred during a period of mild winter weather in southern Sweden meant that the problems caused by it were considerably less than might have been the case. The mild weather meant that there was no need for rapid evacuation of a large number of people. Nor was there any snow on the ground, which assisted the work of clearing felled timber.

But what might have happened if the winds had been even stronger, if there had been snow, if the temperature had fallen below –10 °C immediately after the storm, or if an even greater area of the country had been affected? The following description is a possible scenario.

NATIONAL GRIDLINES DAMAGED AND IMPASSABLE ROADS

If the wind and precipitation conditions had been so severe that the national gridlines had been put out of operation, there would have been a total loss of electricity in southern and south western Sweden for at least a week.

Large quantities of snow on the roads, in combination with fallen trees, would have made the work of clearing up extremely difficult. Resources for sanding roads are not of sufficient capacity for dealing with other than the main roads, and salt is ineffective at low temperatures. All clearance work would initially be concentrated on opening roads sufficiently to enable ambulances and other rescue service vehicles to get through.

Loss of the national electricity grid affects all urban areas. All forms of work direction would be very much more difficult. A considerably greater number of people would be affected, introducing a completely different dimension to needs for help. Without thoroughly prepared and rehearsed contingency plans, local authorities would be facing very severe problems in terms of providing a large number of people with, for example, food and heating.

THE EFFECTS OF COLD ON PERSONS, LIVESTOCK AND PROPERTY

In the event of severe cold, very little time is available for planning and carrying out rescue operations. With the telephone system overloaded or out of

order, it is also difficult to contact the rescue services. Gudrun showed that the 112 service was unable to cope with the flood of calls received during Saturday night. In the event of a more severe crisis, the 112 service would be able to deal with only a few of all those wanting help. There is a risk that many life threatening situations could not be dealt with.

A widespread loss of electricity, in combination with cold weather, quickly directs attention to the importance of maintaining heat supplies. A temperature of 10 °C is regarded as being the lowest acceptable indoor temperature. If the temperature drops below this, people start to feel considerable discomfort from being in the building.

At a temperature of 0 °C, there is a risk of permanent frost damage to buildings. In the case of detached houses not having a traditional tiled stove or some form of log burning stove, the situation can become critical after about only one day. Properties heated by district heating also require electricity for operating pumps and controls. In the major power outage in Canada in 1998, there were many deaths due to fires or toxic smoke as a result of unsuitable forms of fires for heating. Attempting to provide heating by lighting barbecue stoves, lighting a fire in a garage or similar attempts can have disastrous results.

From experience, we know that it can be expected that those living in urban and rural areas cope with long power failures in different ways. Households in rural areas often have alternative forms of heating, and have experience of earlier, similar events. Awareness of how to deal with such problems is less in urban areas, and more persons will be affected. It may be necessary quickly to arrange emergency accommodation for a large number of people.

A LONGER WAIT FOR HELP

Storm Gudrun had effects over much of southern Sweden. If the affected area had been larger, resources in more or less all the important areas would quickly have been used up. Many persons would have been forced to manage unassisted while waiting for help from central bodies at public authority level.

PSYCHOLOGICAL PRESSURES AND CONFLICTS OF LOYALTY

In this scenario, we can expect considerably more severe problems of psychological health than occurred as a result of Gudrun.

If both the telephone and the radio stop working, many persons will be left completely without information, which makes their situations very difficult. Without food, most of us suffer a reduction in stress tolerance. Many would be very worried about relatives who might be affected, and yet who cannot be contacted.

There can also be conflict of interest, when it is necessary to decide between staying at home and looking after family, or going to work and helping to play a part for society. Many would probably stay at home, which would mean that fewer were available for the work of clearing trees and restoring supplies.

INFORMATION PROBLEMS

There is a great need for information in a crisis situation. In the event of a total loss of power, solutions can be provided by distributing leaflets, arranging meetings, sending out loudspeaker vehicles or opening temporary information centres.

Local radio is an important means of providing information. However, if they are to be able to receive it, listeners must have access either to a vehicle radio or a battery radio at home.

PRIORITY OF FUEL SUPPLIES

Service stations need electricity to be able to run their pumps. A power failure quickly creates major problems in supplying fuel in an area.

There are service stations that have the means of connecting standby power supplies but, in most cases, there is no designated power unit that has been reserved so that it can be quickly connected.

If standby power supplies are arranged, it is necessary to give priority to important customer groups, as the amount of fuel available is not likely to be sufficient for all. There will also be problems for customers in paying for their fuel, as only limited amounts of cash are available and card terminals will not be able to communicate with the banks.

THE TRANSPORT INFRASTRUCTURE STOPS

In the event of a longer power failure, the entire transport sector will be reduced to operating at very low capacity. Computerised ticketing systems will not work, and problems with fuel supply will very quickly surface. Roads may also be impassable, and this will be a further limiting factor. Some vehicles with large engines can be very difficult to start during the winter, and need engine heaters in order to get them going, but such heaters would not be working during a power failure.

Much of manufacturing industry is based on just in time deliveries, and would have to stop or reduce production if the transport sector was not working.

There would have to be major restrictions on passenger traffic, with priorities given to certain groups.

Trains would have to be replaced by other traffic for the duration of the power outage. This would introduce capacity limitations, caused by the availability of fuel supplies, personnel and vehicles.

WATER AND SEWAGE SYSTEMS AT RISK

Most water and sewage systems have standby power units. However, if these should fail, there will quickly be problems with drinking water supplies, particularly in urban areas.

There is an interdependent relationship between water and sewage. If standby power supplies are available for drinking water supply, but not for effluent treatment plants, it will not be possible to treat the effluent, which may make it necessary to cut off fresh water supplies. Discharges of untreated effluent would cause environmental problems, although these would not be so severe at low temperatures, which would hamper the growth of bacteria.

EVACUATION / HOMES

A few people were evacuated from their homes after Gudrun. However, in this cold weather scenario, there will be much greater need of evacuation.

In some areas, it will be necessary to assign priorities to those needing to be evacuated. Any larger evacuation operation would require quick planning of matters such as priorities, rescue and transport, heat supplies, water,

food and other necessities, beds, hygiene items, clothes, washing facilities etc. Some potential evacuees would not want to leave their homes due to fear of looting or because of frost damage.

HEALTH CARE

Health care would suffer from reduced capacity, as standby power facilities are not sufficient to maintain all aspects of the service in operation.

Ambulances and rescue services would have difficulty in reaching those in need, with resulting delays in providing them with the necessary care. Social services would have problems in reaching all their clients, as roads would be impassable for a while.

After Gudrun

CLEARER RULES FOR ELECTRICITY DISTRIBUTION COMPANIES

After the storm, the Energy Market Inspectorate was instructed to draft function requirements intended to ensure operationally reliable networks. The Government presented its Reliable Electricity Networks bill in October, which was passed by Parliament in December 2005.

The new legislation includes requirements for electricity distributors to pay compensation to consumers in the event of interruptions lasting longer than twelve hours. In addition, the companies must provide an improved level of information to their customers. The legislation also sets out clear requirements on network operation: one such requirement is that, except under exceptional conditions, no interruption of power supply may exceed 24 hours. These function requirements must be met by not later than 2011.

The legislation includes several new requirements. Companies must, for example, regularly notify their customers of their rights in relation to the supplier. In addition, power supply interruptions lasting more than three minutes must be reported to the Energy Markets Inspectorate. Companies must also prepare annual risk and vulnerability analyses for the power carried by their networks. Another new element is that the network operators may, when necessary, produce their own electricity from permanently installed standby power units.

PLANNING OF PRIORITY ELECTRICITY USERS

Even before the storm, the Agency had started an investigation into the feasibility of finding technical, legal and organisational ways of giving priority to various categories of electricity users during times of limited availability of electricity. The resulting feasibility study was circulated for comments in the spring of 2005. There is broad agreement among recipients that work on this planning should continue.

The Agency has also started work on enabling Sweden to establish a national strategy for the provision of standby power supplies.

NETWORK OPERATORS' PLANS

The network operators have changed their investment strategies after Gudrun, and increased the rate of converting their networks. Where previously the aim had been to use plastic coated BLX or BLL cable in overhead lines run on poles, the new emphasis is to bury the cable where possible. Another change has resulted from the new legislation concerning compensation for interruption of power supplies. Investments are now being concentrated in areas where there is the greatest risk of having to pay compensation. This means that, at least initially, it is the high voltage network that will be given priority over lines in sparsely populated areas.

Experience from Gudrun has resulted in a greater concentration on dialogue with agencies and authorities concerning the relationship between public interests and electricity supply. E.on, for example, appointed special contact personnel who were outplaced with various local authorities and other bodies. This arrangement has now been made permanent in order to ensure ongoing dialogue and readiness for future crisis management work. The contact personnel's main duties are primarily to serve as links between local authority crisis management organisations and E.on.

The company has also reviewed its investment plans in the light of its experience from Gudrun. SEK 1 200 million will be invested in a programme that includes widening overhead line rides. About 90 % of the 17 000 km of overhead lines in E.on's area will be buried. Where rock or other ground conditions prevent this, overhead cable run on poles will be used. For further safety, there are plans to secure the cable with shear pins so that, if necessary, it can fall to the ground without being damaged if trees fall on it. During 2005, E.on has been burying about 20 km of cable per week.

Vattenfall intends to complete its work of protecting its regional network against falling trees. For its local networks, it is carrying out a programme of continued insulation of the remaining 250 km of uninsulated bare wire overhead lines. The company is investigating to what extent it will use buried cables, and expects to have converted its uninsulated lines in forest areas within five years.

Fortum is planning to convert the most exposed parts of 2 500 km of uninsulated overhead lines in forest areas within five years, and in other ex-

posed areas within ten years. Converting all overhead lines to cables is limited by the availability of field personnel and other resources at a time when the industry is increasing its investments.

Other electricity distribution companies affected by the storm, such as Härryda Energi, Rödeby Elverk, KREAB, Ale Elförening, Habo Kraft, Göteborg Energi, Värnamo Elnät and Alvesta Energi, are continuing and intensifying their investments in more reliable networks.

The Electricity Supply Cooperation Organisation will be developed and refined, working closely with Svenska Kraftnät. The storm provided an opportunity for the companies to test their SUSIE support system under real conditions, and the system will now undergo a further three years of development. Public authorities and agencies such as the police, the armed forces, the Swedish Emergency Management Agency, the Rescue Services Agency, the Swedish Energy Agency, the National Electrical Safety Board, the National Telecommunications Coordination Group, county administrative boards and government ministries will be able to connect to SUSIE in order more quickly to receive reports of crisis situation information.

Cooperation between the electricity industry and the telecommunications sector will be increased, in order to improve the security of mobile communications. Telecom operators, for example, will be able to provide information on how long base stations are expected to be without power.

The gaps in information provision that were revealed by Gudrun have resulted in improvements on the part of the network operators in providing their customers with better information. An example of such an improvement is that E.on has complemented its website with maps, from which its customers can see which individual substations or distribution stations that have been affected by an interruption. The public will also be given access to the Electricity Supply Cooperation Organisation's website, from where there will be links to all the network operators' fault information.

Swedish Radio's Ojje computer system continues to be developed. Electricity network operators will be able to connect to it to supply information that will then be broadcast to the public in radio transmissions.

LOCAL AUTHORITIES INCREASE THEIR CONTINGENCY AWARENESS

The public authorities affected by the storm have since taken a number of steps to increase their preparedness for major future electricity failures. Examples include:

- Planning of stationary standby power for care homes etc. in progress.
- Contingency planning for evacuation.
- Improved overhaul, maintenance and readiness of standby units.
- Investigation and clarification of safety aspects for the connection of standby power sources.
- Preparation of advice to the public on what to do in the event of power failures.

Lessons learnt from work after the storm will provide a basis for future risk and vulnerability analysis and preparation, as well as for rehearsals and exercises of crisis management organisations.

Several local authorities are paying greater attention in their future contingency planning work to the problem of fuel supplies. If service stations are to be of any use, they must have power supplies for their pumps. Some of the local authorities intend to involve the oil companies in their risk and vulnerability analyses.

Links and cooperation with the network operators will be developed and improved. Many local authorities are discussing future investments and priorities with the network operators.

Emmaboda council is taking steps to ensure that livestock farmers in its area have the necessary standby power facilities.

Experience and conclusions

The severe effects of storm Gudrun served as an alarm call for many parties in today's increasingly electricity dependent Sweden. Experience from the work of restoring supplies has resulted in closer cooperation between parties in order to be able better to deal with future crises. The following are some of the lessons, conclusions and proposals that have emerged in the wake of the storm.

SOCIETY IS BECOMING INCREASINGLY DEPENDENT ON ELECTRICITY

When Sweden's present electricity network was being planned and constructed, there was probably no-one who could foresee just how dependent on electricity society would become within a few decades. The storm's rampages have mercilessly revealed just how vulnerable companies and households are in the event of a longer power failure. The younger generations, in particular, seem to find more difficulty in dealing with such situations. The interdependence of electricity and telecommunications was also clearly demonstrated. The apparently fundamental ability to use the telephone disappeared, resulting in delays to rescue efforts and a lack of information.

THOUSANDS OF KILOMETRES OF OVERHEAD LINES DAMAGED

About 9 % of the damaged distribution network requires complete rebuilding. Work on restoring supplies and burying temporarily run cables is still in progress, more than a year after the storm. Those parts of networks that were already buried suffered no damage. Damage to overhead lines did not provide any unambiguous indication of what overhead line technology is preferable, as both new and old poles were brought down, and even insulated overhead cables were broken by falling trees.

Rides for local distribution networks are not generally wide enough to make them safe against falling trees, but widening them would visually affect the landscape and would also be very expensive.

Electricity distribution networks in urban areas are generally underground, with redundancy provided by alternative supply paths, while supplies

in rural areas are generally provided over insulated or uninsulated overhead lines. Network operators have been burying their cables since the 1970s, with the result that more than half of all local networks are now buried.

Insulated overhead lines in the form of cables or insulated BLX cables withstand falling trees better than uninsulated bare wire cables. That not all overhead lines are yet insulated is due to the fact that the physical life of a power line is about 30–40 years. However, the storm showed that there is reason to question whether their economic lives are as long as this. A severe storm in 1999, together with a number of frequently recurring snowstorms, has caused discussion of accelerated conversion of uninsulated lines in forest areas. The severe damage that was caused by Gudrun has accelerated discussion between the network operators concerning suitable technology for overhead lines in future.

Swedenergy, the industry association, estimates that it would cost SEK 60 000–80 000 million to bury all overhead lines in Sweden, which would amount to about SEK 11 500–15 500 per customer. The National Electrical Safety Board puts the total cost at SEK 40 000–50 000 million.

An alternative to burying the lines is to widen the rides. However, widening them sufficiently to eliminate the risk from falling trees would cost thousands of millions of crowns, and involve major changes to the landscape. If just E.on alone were to widen its rides for its regional networks, it would have to negotiate with some thousands of landowners.

Another way of reducing the risks of falling trees is to clear the rides more frequently. Many network operators have started to do so in recent years: in 2002, E.on reduced its clearance interval from eight years to six years.

NETWORK OPERATORS HAD GOOD PREPAREDNESS BUT INSUFFICIENT RESOURCES

The Electricity Supply Cooperation Organisation worked well, as did cooperation with Svenska Kraftnät, with resources being assigned as well as possible. However, the combined total of resources in the country was insufficient, both in terms of personnel and of materials.

The insufficiency of resources for clearing fallen trees was made very clear, as was the need for local liaison in order to start clearance as effectively

as possible. Several network operators, and particularly the smaller companies, see a need for signing contingency contracts with various contractors in order to be able better to meet future needs in the event of a major crisis. This probably also applies to the telecom operators.

The very long power interruptions after the storm affected only rural areas, yet it is these networks that would be most expensive to strengthen. Ultimately, these investments would result in higher network charges.

VOLUNTARY ASSISTANCE VERY IMPORTANT

The shortage of clearance resources delayed restoration of the electricity networks. A large number of volunteers helped to clear the felled trees after Gudrun: some were organised, while others were individual volunteers.

Despite the fact that Sweden has a relatively high degree of organisation in its society, voluntary organisations played an important part in the work of restoring supplies and saving lives. Assistance from local networks within LRF, the Red Cross, church organisations, sports associations and individuals was very important in clearing roads, reaching the elderly and ill, providing water and food transport and so on. Work on restoring supplies and providing assistance in other ways showed the importance of existing networks at personal level in resolving crises.

In some cases, the opportunities for making use of voluntary assistance were limited by insurance aspects. In some cases, the work was so dangerous that only those with specific insurance protection could be used. There are therefore many who would like to see improved organisation and custom insurance policies that would enable better use to be made of volunteer labour in the event of a similar crisis.

THE IMPORTANCE OF MILITARY RESOURCES

Military personnel and equipment provided an important resource in the work of clearing up after Gudrun. If there had been half a metre of snow in the area – which is not at all unusual at that time of year – it would have been necessary to use military all terrain vehicles. We can ask ourselves what the additional delays to rescue work would have been if the storm had occurred after the current armed forces reductions had been completed. In future, it

will be necessary to replace these additional military resources with purely civilian resources. It is therefore important to investigate how such resources should be structured and/or provided.

OVERVIEW OF RESERVE POWER RESOURCE AVAILABILITY

Gudrun revealed shortcomings in access to, and distribution of, standby power units. There is today no central register providing information on the availability of standby power units in the event of a serious electricity crisis.

A total of more than 3 000 standby power units were used during the power outage, provided by county administration boards, municipalities, the military and network operators. Smaller units were already owned by, or were borrowed by, individual farmers or householders. Many standby power units were already installed at various sites around local authority areas as a general emergency situation readiness. However, their actual utility was limited by the fact that many of them were not suitable for their duty, or had been poorly maintained and therefore simply did not work. Some units were supplied too late to be of any value, while others were unfortunately stolen.

In some cases, local authorities arranged allocation and distribution of the units, while in other cases this was done by the county administrative boards. The question of who is responsible for determining priorities, distributing and (if necessary) relocating available standby power units should be properly investigated in order to prevent similar problems from arising again. Contracts and terms and conditions for lending/renting standby power units should be designed so that they can be quickly brought into use when and where needed. In addition, better knowledge is needed of where heating requirements are likely to be acute in the event of a crisis.

Substantial resources were required in order to resolve the logistic problems of fuel supplies to all standby power units. There is a need for improved planning of such fuel supply, based on maps, local knowledge and suitable means of transport, together with information on tank sizes, fuel consumption and transfers of power units.

In some places, standby power was used to provide power to ‘islands’ of customers, consisting of limited parts of a network. This is an arrangement that should be further developed. However, it also requires appropriate train-

ing and instructions for how and where the standby power units are to be connected. If this is not done correctly, there is an increased risk of electrical accidents.

Small motors that are important to operation of heating systems should be of single phase type, in order to simplify connection of a standby power source.

DEPENDENCE OF THE TELEPHONE NETWORK ON ELECTRICITY IS A PROBLEM AREA

Lack of power, and physical damage to the telephone/telecoms infrastructure, quickly put telephones out of use in much of the area affected by the storm. The resulting communication problems made it difficult to direct the work of supply restoration, and caused delays which made a major contribution to the high costs of the effects of the storm.

WIDER ACCESS TO RAKEL WOULD BE DESIRABLE

The Rakel radio system is a robust radio network for the 'blue light services', which is being rolled out across Sweden. The system should be fully in place and available for at least some of the agencies by 2009. The first stage was commissioned in southern Sweden in 2006. The system's redundancy and robustness are intended to provide reliable communications for those entitled to use it.

The network operators are not included among the user groups which, as originally planned, will have access to the system. However, this view has changed since Gudrun: it is now proposed that more parties, including the network operators, municipality services and social services should be included in the system.

EXTENSIVE DISTRIBUTION OF FUEL REQUIRES PLANNING

Despite the extensive electricity failures, there was never a shortage of fuel for the thousands of standby power units that were used in order to provide some degree of electricity supply for certain users. However, supplying these power units and forest machinery with fuel over a long period of time was found to be a difficult logistics and information problem, particularly as both power units and machinery were being moved around, requiring constant changes to the distribution tanker routes.

LOCAL AUTHORITIES, COMPANIES AND HOUSEHOLDS NEED TO BE BETTER PREPARED

Gudrun showed that most local authorities have a good level of preparedness for crisis management arising from power failures. However, it is uncertain as to how a situation with a longer duration loss of district heating could have been dealt with. If the power failure had stopped the pumps in district heating systems for several days at normal winter temperatures, it would have been necessary to take emergency measures within 24 hours in order to avoid catastrophic consequences. Gudrun showed that improvements are needed to planning and resources for crisis management and supply restoration work than is the case today. The supply of fuel to standby power units alone requires resources in the form of organisation, personnel, vehicles and physical equipment.

Individuals, too, need to take more responsibility for how they will deal with a longer power failure. In general, older persons in rural areas managed better than younger persons. The former group often live in houses still having tiled stoves, other stoves and even wood fired cookers. Younger persons tend to live in houses in which old heating systems have been replaced by newer systems, but which require electricity in order to be able to work.

Dairy farms are particularly vulnerable to longer electricity failures. Standby power units are not always of sufficient capacity, while stocks of fuel are sometimes insufficient.

On the whole, manufacturing industry managed well, although many companies suffered major costs. In today's competitive markets, companies often have to work within very narrow time margins, which means that even slight delays in production can result in considerable costs.

Information to companies and households needs to be improved. Space heating systems that do not require electricity should be investigated and developed. Supported by greater availability of standby power, this would improve the ability of individuals and businesses to withstand more extensive and longer duration power failures.

PROPOSALS FOR REGULATORY CHANGES

The Swedish Emergency Management Agency notes that society's ability to deal with the problems arising during and after the storm was only just capable of doing so.

If a greater area, including more towns, had been affected, resources in more or less all important capacities would have run out very quickly. Many persons would have had to manage without any help for several days.

The very vital priorities that are needed in such conditions mean that there must be some form of crisis management organisation at national level. Several county administrative boards have, after Gudrun, stated that both sector responsibility and geographical area responsibility must be clarified. Methods of interworking in a crisis must be developed, and all involved must be aware of their roles, duties and responsibilities.

Another problem is that of unclearness between what is to be regarded as the normal duties and responses of the rescue services and when these duties change to responding to an abnormal event. Many public functions want to be able to call upon state resources, such as from the military, and also to have their costs met by the state when they have to deal with abnormal events.

Greater clarity is needed in respect of what can be required of companies and utilities providing important services in connection with response to, and coordination with others when dealing with, a crisis situation, and also in respect of their participation in contingency planning.

The military will continue to be an important source of support to society in peacetime crisis situations. However, there are several legal aspects to be considered in connection with its involvement in peacetime crisis management that need to be resolved.

The work of restoring supplies after Gudrun has revealed the need for rules governing priorities of scarce resources for electricity users, telecommunications and the clearing of roads and railways. Investigations being carried out at present by the Swedish Energy Agency and by the Swedish Emergency Management Agency may result in proposals for new legislation that allows giving priority to certain end-users in peacetime crises.

Rules are needed to assist the participation of volunteers. They constitute a valuable resource in times of serious peacetime crises, and local authorities and county councils ought to have plans for their use. Aspects that need to be considered include third party liability, payment, insurance, employer liability and application of the Work Environment Act.

More information and detailed reports in Swedish can be found on the website www.energimyndigheten.se.

PHOTOS: Ina Agency Press, p 43, 60, Johnér Bildbyrå, p 5, Matton, p 50, Naturfotograferna, p 12, Norrlandia Bildbyrå, cover, p 6, 56, 62, Scandinavian Pictures, p 2, Scanpix, p 8, 15, 18, 21, 22, 26, 31, 34, 38, 44, 66

How can we become better at dealing with natural catastrophes?

When storm Gudrun struck a large area of southern Sweden on 8th January 2005, it put the functions of society and the Swedish electricity distribution system to a severe test.

The work of restoring electricity supplies started immediately. Nevertheless, some electricity customers in sparsely populated areas were without power for up to six weeks.

The storm blew down large parts of the overhead line distribution system, leaving 730 000 customers without power. The long periods without power showed just how vulnerable society is to more serious disturbances. A particular problem, which exacerbated others, was that telecommunications stopped working.

Much has been learnt by the providers of various services in society, by companies and by individuals. This publication describes what happened, what the effects were and what those working in the energy sector have learnt from the most serious natural disaster to strike Sweden in recent times.

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