CSI CONSULTING
INFORMATION AND COMMUNICATION

Power shortage study

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1 MANAGEMENT SUMMARY

Starting point and objectives

A prolonged power shortage is, according to the Federal Office for Civil Protection, the greatest risk to which Switzerland is exposed [1]. It is assumed that such an event could occur with a frequency of once in 30 to 100 years and could cause damage to the economy and to society of the order of CHF 100 billion. The scenario is based on a 30% power shortage during the winter months, lasting for several months. Envisaged measures in terms of economic national supply are management of supply and demand, such as the imposition of quotas or rolling blackouts (rotational load shedding).

This study sets out to concretise possible measures to ensure the continued provision of essential telecommunications services during a power shortage and to indicate the costs and impact of such measures.

Procedure

As a first step, the existing situation and the target situation were defined: who is to be supplied with what and where? - both in the normal situation and during the power shortage.

- Users and geographical coverage
- Networks, services and content
- How prepared are the telecommunications service providers for a power shortage?

To establish the existing situation in relation to the telecommunications service providers and to clarify the feasibility of measures and their costs, a questionnaire was sent to five telecommunications service providers [5].

Consequences

The most important consequences from the survey are summarised here:

- The telecommunications service providers are only marginally prepared for rolling blackouts in a power shortage situation. It is assumed that fairly significant failures will occur because of consequential damage to hardware. Not only telecommunications service providers, but also IT operators and other organisations in all sectors will be affected by this effect.
- Technical measures to protect telecommunications service providers against rolling blackouts are feasible - diesel generator sets and modern battery systems. Cost estimates do exist.
- The weakest link in the supply chain remains the last mile in fixed networks. Measures which impact mobile radio should therefore be examined as a priority.

Measures and recommendations

In order to indicate the effects during the rolling blackouts and the effectiveness of measures, different scenarios were examined: a power outage in the service and network infrastructure, at the point of presence (POP) and on the last mile.

On the basis of these scenarios and the above-mentioned consequences, the following measures are proposed and recommended for closer study:

Measure		Quantity	Costs	
			Investment	Annually
M1	Installation of diesel generator sets at the service infrastructure locations	70 locations	23 MCHF	4.5 MCHF
M2	Installation of diesel generator sets at the network infrastructure locations	580 locations	50 MCHF	10 MCHF
M3	Installation of batteries in the points of presence	2100 locations	46 MCHF	14 MCHF
M4:	Installation of batteries at the LTE transmission installations	21,000 installations	165 MCHF	50 MCHF

The LTE transmission equipment of different telecommunications service providers may be installed at the same locations (antenna masts). The batteries, however, are installed by the organisation responsible for each item of equipment.

Table 1: Proposed measures to improve the resilience of telecommunications services and networks

Other recommendations concern the legislators, as well as users and critical infrastructure organisations as users of telecommunications services. They are summarised briefly here:

- The concept of a power shortage (imposition of quotas and rolling blackouts) should be reviewed on the basis of the findings of this study, with particular regard to the wide-ranging impact of hardware failures.
- The scope, functionality and quality of the universal service for telecommunications services should be examined and, if necessary, adapted to society's changing communication behaviour.
- Users and critical infrastructure organisations should be informed about the concept of a power shortage and of possible repercussions and precautions.

2 INTRODUCTION

2.1 Initial position and objectives

Initial position

A prolonged power shortage is, according to the Federal Office for Civil Protection, the greatest risk to which Switzerland is exposed [1]. It is assumed that such an event could occur with a frequency of once in 30 to 100 years and could cause damage to the economy and to society of the order of CHF 100 billion. The scenario is based on a 30% power shortage during the winter months, lasting for several months. Envisaged measures in terms of national economic supply are management of supply and demand, such as the imposition of quotas or rolling blackouts.

These measures concern Switzerland as a whole - society, the economy and the critical infrastructures. In particular, telecommunications services and networks are also affected. However, these are of key importance in the event of such extraordinary situations, for informing the population and for critical processes in many different sectors or at important locations.

The Federal Office for National Economic Supply (FONES) and the Federal Office of Communications (OFCOM) have therefore already analysed the situation in various studies and qualitatively identified initial measures for telecommunications service providers [2], [3], and [4].

These include:

- Improvements in relation to emergency power supplies to telecommunications service providers
- Reduction of the scope of services supplied
- Restrictions on telecommunications service providers' secondary processes
- Imposition of quotas

Quantitative statements regarding the feasibility, costs and impact of such measures or other measures have not been evaluated to date.

Objectives

This study sets out to concretise possible measures to ensure the continued provision of essential telecommunications services during a power shortage and to indicate the costs and impact of such measures.

It is intended to constitute the basis for decisions at Confederation level in the area of critical infrastructures.

2.2 Procedure - content

The following procedure was followed:

Definition and evaluation of the current situation

Who is supplied with what and where?

- Consumers and geographical coverage
- Networks, services and content
- How prepared are the telecommunications service providers for a power shortage?

Definition of the target situation

Who should continue to be supplied with which services/content - and where?

With regard to the manifestation of the power shortage, the focus was on rolling blackouts in the worst case - alternating 4-hour outage and 4-hour supply for each geographical sub-area.

Definition of measures

Specification of measures and their impact, plus estimates of the costs.

2.3 Procedure - sequence

The study was elaborated in close co-operation with the client, OFCOM, and the ICT division of FONES within the framework of workshops and/or work meetings.

A questionnaire was sent to the telecommunications service providers to establish the existing situation and to clarify the feasibility of measures and their costs. It was sent to the following companies:

- Quickline
- Salt
- Swisscom
- Sunrise
- UPC

There follows a brief synopsis of the questions (for details see [5]):

General questions

- What is the power consumption of the telecommunications service providers?
- What measures are being taken to deal with a 4-hour power outage?
- Can these measures also cope with rolling blackouts?

Questions concerning the power supply

- What costs can be expected in order to equip power supplies such that the rolling blackouts can be mitigated?

Questions concerning prioritisation of telecommunications services, networks and content

- Is deactivation of telecommunications services or blocking of content feasible and would this save power?
- Can the transmitting power of specific mobile radio antennas be increased?
- What are the costs for connecting specific consumer locations directly using optical fibre?

3 CURRENT SITUATION

3.1 Provision of telecommunications services

3.1.1 Telecommunications services and networks

In the normal situation, in principle the whole of Switzerland - all users across the country - is provided with communications services. The relevant telecommunications services and networks for this basic coverage are listed below:

Telecommunications services
Data communications - via managed network or as "over-the-top" content on the internet
Telephony
Radio and television transmission
Emergency calls (central service and routing)

Table 2: Telecommunications services

Users are connected via the following infrastructures:

Network infrastructures
Fixed, wired networks using copper or fibre optic cable; cable television networks
Terrestrial and satellite-based radio and television systems
Mobile radio networks

Table 3: Telecommunications networks

3.1.2 Content

In the traditional telecommunications world - pre-internet and pre-mobile - the content, or at least the type of content, was essentially defined by the choice of telecommunications service: the telephone was used for individual voice communication, and radio or television was used to obtain information from the big wide world - or Switzerland's capital Berne in the event of a crisis. This clear correlation no longer exists today or is in the process of disappearing. Today, the internet and mobile services allow almost any access to information and enable individual communication away from any fixed device.

This has also caused a change in people's behaviour. The younger generations in particular communicate using new devices and channels (social networks and smartphones). Information about personal experiences, activities or intentions is acquired from "friends". Information about events, disruptions and dangers is therefore also obtained via these channels; in the past such information was communicated in a targeted and orchestrated manner by the authorities using dedicated services.

Content and its prioritisation in the event of a power shortage have therefore been defined as follows to provide a differentiated approach:

Content	Criticality	Explanation
Emergency calls	High	The authorities and rescue and safety organisations must continue to be accessible even during the power shortage.
Signals (data) for critical processes	High	Signals for certain organisations' critical processes must continue to be transmitted even during the power shortage. For example: • Data transmission to hospitals • Data transmission to logistics centres • Data transmission for payment transactions
Individual communication	Moderate	Objective: to ensure normal behaviour as far as possible. The quality and scope of communication services for the individual may, however, be reduced (in favour of geographical, functional or organisational units).
Information (for the population)	Low	The population must be informed about the power shortage at the start of the shortage and then periodically (e.g. daily). The reception of such information is therefore always possible within 12/24 hours during the power shortage.
Signals (data) for non-critical processes	Low	The transmission of signals for non-critical processes should be guaranteed, within the bounds of possibility.

Table 4: Content and criticality

Note:

- Critical or non-critical signals/processes. Organisations must decide whether the signals are critical. The telecommunications service provider cannot differentiate on its own. Examples of such organisations include hospitals, banks and remote heating facilities.
- “Critical” means: critical for Switzerland, i.e. for services which the organisation provides for the population and the economy (not for the organisation as such).

3.1.3 Users and coverage

Users

Users are, in principle, the population of Switzerland. To define a differentiated approach, a distinction is made between the following types:

- the population - all natural persons
- businesses - legal entities
- critical infrastructures - processes, systems and equipment which are essential for the functioning of the economy and the well-being of the population.[1]

Coverage

[1] National strategy to protect critical infrastructures 2018-2022; The Swiss Federal Council. 8 December 2017

For coverage in the normal situation the term "nation-wide" is used. This means the greatest possible coverage by the fixed and mobile networks. The telecommunications service providers addressed for the purposes of the survey cover

- approximately 87% of fixed-network telephony,
- approximately 87% of internet access and
- approximately 95% of mobile radio services.

Restrictions are described qualitatively - districts, towns and cities, municipalities and regions - since a quantitative measurement based on different technologies or network topologies is not practicable.

3.2 Results from the survey of telecommunications service providers

The survey of telecommunications service providers produced the following results:

3.2.1 Return of the questionnaires

- Five of the six companies approached responded.
- The deadline for answering the questions was tight (approximately 4 weeks), so not all questions could be answered.
- The answers were compared and consolidated.

3.2.2 General questions

The telecommunications industry's power consumption

The power consumption of the companies surveyed amounts to approximately 1.5% of Switzerland's total power consumption and is equivalent to approximately 720 GWh per year, 94% of which, 680 GWh per year, is used for operating services and networks and 6% for the telecommunications service providers' secondary processes.

The telecommunications service providers have back-up power for up to 72 hours at key locations, in order to be able to bridge any imposition of quotas.

Consequence 1:

- The telecommunications service providers' power consumption is low, considering Switzerland as a whole. Imposing quotas on these companies is therefore not very effective or rather may result in more damage than benefit. Parts or areas of the company are not affected at all by the imposition of quotas, as usage locally is too small.
- A restriction on telecommunications service providers' secondary processes brings only marginal power savings and is hardly appropriate in terms of its consequences (the temporary shutdown of substantial parts of the organisation).

Measures against 4-hour power outages

The central service sites, the network infrastructure and the points-of-presence are equipped with diesel generator sets, uninterruptible power supplies and batteries. Autonomy is between 2 hours and 72 hours. In the case of one company, the network infrastructure and the points-of-presence are only 50% protected.

There are assertions that the autonomy at certain locations is planned to be reduced to 30 minutes.

However, the last mile has practically no protection from power outages for either fixed or mobile networks (autonomy of 1 hour in rare cases). Protection in this segment would be useful only if users' systems are likewise protected from power failures (inside the buildings or the campus).

Consequence 2:

- In general, in the ordinary situation, telecommunications service providers are well equipped against power outages as far as the point-of-presence. The bridgeable time period has quite a wide variation – from 2 to 72 hours, depending on the site's importance.
- The weak point is the last mile, where there is *de facto* no "support". However, it can be assumed that in the event of a power failure on the last mile of fixed networks, local users would also be affected, and any measures are useless without measures on the part of users.
- In the case of mobile radio, terminals are powered by batteries; measures in the last mile could therefore be effective in relation to mobile radio networks.

Resilience against rolling blackouts

The telecommunications service providers are not specifically prepared for rolling blackouts. At those locations which in any event have 72-hour or more autonomy thanks to emergency power generators, bridging rolling blackouts is guaranteed, at least for the back-up duration. However, logistical measures are essential for the supply of fuel in order to bridge a power shortage.

At locations where batteries are installed to bridge power outages for up to 4 hours, they were not designed to accommodate rolling blackouts. At battery-assisted locations with 4-hour autonomy, resilience against rolling blackouts is the exception, both in terms of accumulator technology and the design of charging installations (including the supply of power to the location). Back-up times of 4 hours with battery support are the exception; usually only short power outages (typically up to 1 hour) are bridged in this way.

Furthermore, the telecommunications service providers assume that rolling blackouts will lead to hardware failures within a short time and therefore greater and more persistent disruption can be expected.

Consequence 3:

- Telecommunications service providers are only marginally prepared for rolling blackouts.
- It is assumed that the hardware cannot withstand rolling blackouts and that large failures will occur.
- Not only telecommunication service providers, but also IT operators and other organisations in all sectors will be affected by this problem.

An attempt to model the effect of hardware failures is made below, in order to be able to estimate their extent over time.

Rolling blackouts during a power shortage represent a particular and little studied problem for the networks and their unprotected equipment. A cumulation of the following effects occurs:

- Architecture:
  - Although in principle the overall architecture of the networks should withstand a restart of all components or parts thereof, no guarantee can be given for any network if this operating condition is not regularly induced ("exercising"). It is precisely larger and uncontrolled power supply outages which bring about exceptional situations (dual-path/back-up systems, isolated operation, split operations) which are not active in normal operation and which accordingly have not been effectively tested in operational circumstances. In addition, cyclical load peaks occur on loss and restarts (e.g. error messages and initialisations), which have not previously arisen in this form. Owing to the multiplicity of untested and unknown conditions, it must be assumed that hidden defects in the architecture will become apparent in many locations when the rolling blackouts begin, leading to failures.

- Server operating system/software:
  - Even in the case of individual systems it is not entirely certain that they would survive an initial uncontrolled cycle. Restarting systems which have hitherto been running for many years in a stable environment without restart may cause a multiplicity of software problems (including the operating system). For example, certain storage areas of the hard disk or certain operating system files have to be read only during a restart, and possible damage would not have been identified in stable operation. Also, incompatibilities in the configuration or in the patch status often become apparent only on restarting.

- Server hardware:
  - The hardware of systems which have been running for many years under stable environmental conditions is susceptible to restart problems. Apart from the mechanical hard disk, it is above all the power supply with its soldered connections and components (capacitors and power transistors) which is vulnerable to the high starting current and thermal/mechanical load. Since the server infrastructure of the networks is bridged in high-quality locations, the thermal cycle is small (ambient temperature does not fall below 20°C) and the power supply is protected from extremes (excessively low voltage, e.g. in the event of a "brown-out" and voltage peaks). The hardware is therefore at less risk.

- Network architecture:
  - Although network architecture is in principle prepared for power outages, here too there is a risk of hidden vulnerabilities in the context of large-scale outages/restarts. In particular, the first-time discovery of incompatibilities and inconsistencies in configuration or firmware/patch status cannot be excluded.

- Network equipment hardware:
  - A full thermal cycle down to below freezing point, as would occur in winter in the event of a power shortage, is also for the hardened last-mile products a major stress. In addition, electrical stress due to under- and overvoltages can be assumed during switching processes; this often affects equipment directly. Both material fatigue (soldered joints as well as moving and non-moving mechanical devices) and first-time/premature component failures after many years of continuous operation will cause failure of the hardware. None of the customary industry standards covers thermal cycling and electrical stress over hundreds of cycles. Operation which involves rolling blackouts does not correspond to any tested operating state.

To illustrate the problem, modelling of the last-mile network elements has been undertaken, including both first-time/premature component failures and failures due to fatigue. The model is based on the following two empirical assumptions:

1. Early failures after years of thermally and electrically stable (“steady state”) operation involve the failure of one device in every 1000 in the first cycle; in the second cycle one device in every 2000 and in the third cycle one device in every 4000. With each cycle the probability of a failure falls by a factor of 2. After a few days these early failures are negligible.

2. Fatigue failures occur primarily due to the periodic thermal and mechanical stress. The model initially assumes one failure per 10,000 devices. With each cycle the probability increases by 1%. After approximately one month therefore, one failure per 5000 devices can be expected.

The cumulative effect of the two models is shown in Figure 1. It shows that a peak of network element failures occurs during the first cycles at the beginning of the rolling blackouts and from the 10th cycle it decreases sharply. Considering the 10,000 or more last-mile elements, however, this means that failures in single figures can be expected during each cycle.

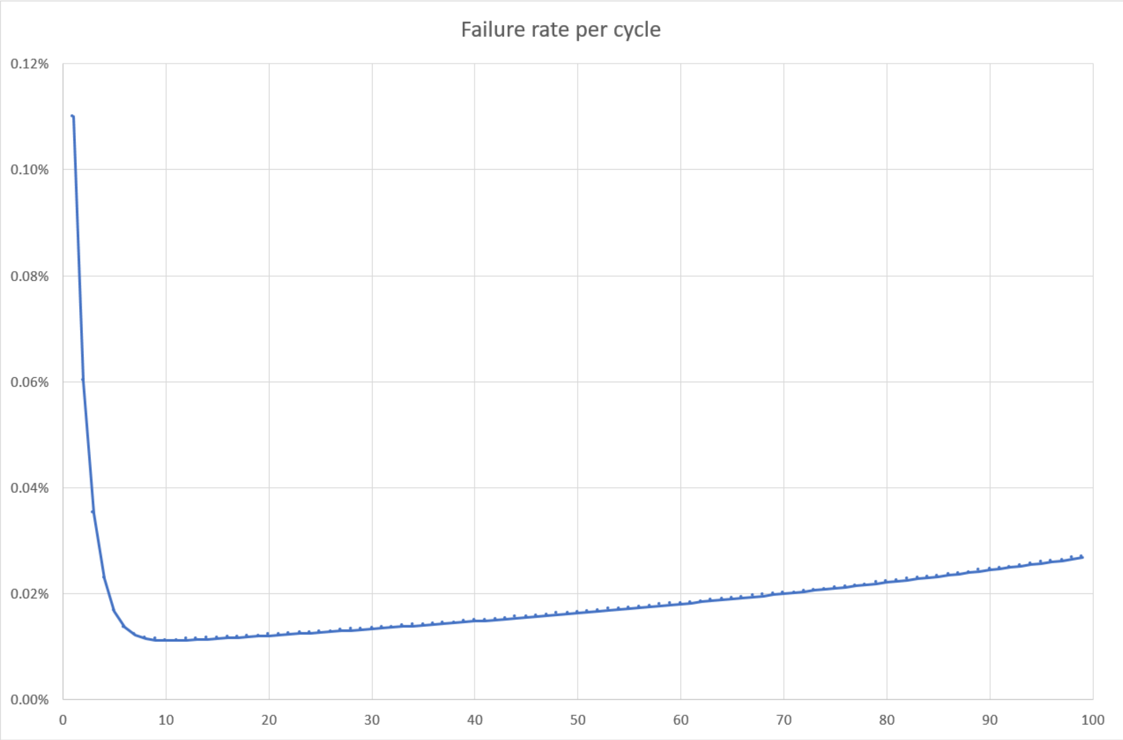


Figure 1: Failure rate as a function of the number of blackout cycles

The remaining serviceable devices are critical for security of supply; these are shown in graphical form in figure 2.

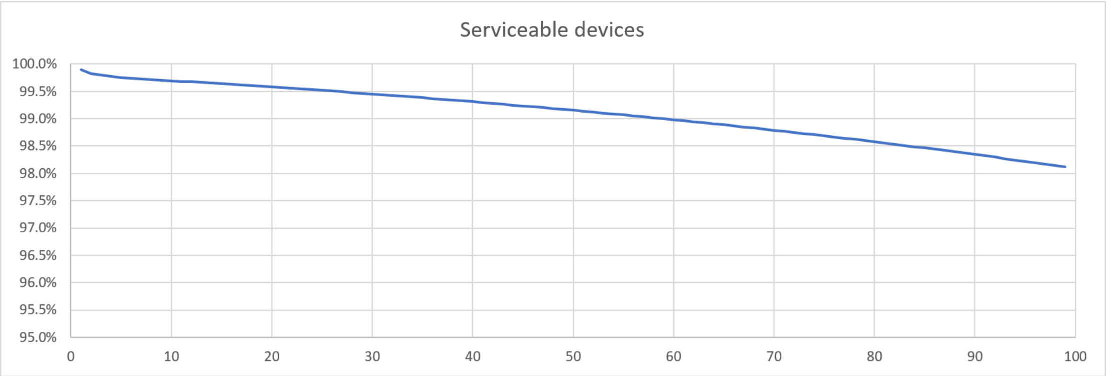


Figure 2: Serviceable devices as a function of the number of blackout cycles

In relation to supply, a distinction must be made as to whether users have access to multiple terminals, as is the case with mobile radio access, and therefore failures in the low-percentage range can generally be bridged without problems. In the case of the topology of the fixed network, however, the user is connected to only one point-of-presence. Its loss leads directly to a loss of service coverage.

A further point concerns the operation of emergency power (diesel) generators. These are not designed for cyclical operation with hundreds of start-up cycles every 8 hours. As an alternative, it would be possible to allow the generators to run continuously during the power shortage, thereby possibly contributing to mitigating the power shortage. However, this comes up against logistical limits.

3.2.3 Questions in relation to the telecommunications service providers' power supply

These questions were intended to determine the feasibility, costs and quantitative framework for providing protection from rolling blackouts. Not all telecommunications service providers were able to provide details for all questions, but figures are available which are adequate for the following considerations of measures. An overview of quantities and typical cost data is given below.

Infrastructure	Quantity
Network infrastructure locations	
Service infrastructure	approx. 70 locations
Network infrastructure	approx. 580 locations
Point-of-presence	approx. 2100 locations
Last mile, fixed networks	> 4500 locations
Total locations	***> 7500 locations***
Mobile radio transmission equipment (mobile radio last mile)	
GSM technologies	approx. 26,000 transmission installations
UMTS technologies	approx. 26,000 transmission installations
LTE technologies	approx. 21,000 transmission installations
Total transmission installations	***approx. 73,000 transmission installations***

Locations are defined as telecommunications service providers' buildings with the corresponding infrastructures.
Transmission installations are defined as technology-specific equipment (GSM-R, LTE, and UMTS). Several such transmission installations can be installed on one antenna mast.

Table 5: Quantitative frameworks (sum of the telecommunications service providers surveyed)

Infrastructure	Measure	Cost data
Service infrastructure locations	Diesel generators	up to 3000 kCHF
Network infrastructure locations	Diesel generators	up to 150 kCHF
Point-of-presence locations	Batteries	up to 100 kCHF
Last-mile locations (fixed)	Batteries	up to 15 kCHF
Last-mile transmission equipment (mobile)	Batteries	up to 8 kCHF

The cost data are per location and are the maximum values of the survey results.
Locations with diesel generators also include in each case battery-assisted power supplies, to enable bridged start-up of the set.
Locations with batteries are equipped in such a way that the 4-hour outages can be bridged.

Table 6: Cost data for providing protection from rolling blackouts (investments)

Consequence 4:

- Technical measures for power supplies for the service and network infrastructures in order to provide protection from rolling blackouts are feasible; cost estimates are available. The measures are predominantly based on battery-assisted solutions but also on diesel generators.
- If diesel generators are used, it must be ensured that local stocks of diesel and replenishment during the power shortage are regulated accordingly.[2]
- These statements also apply to the last mile in the mobile radio networks (antenna sites) – battery support is in principle possible. The smallest installations (so-called pico-cells) are exceptions.
- Over the last mile of the fixed networks, such measures are in most cases not feasible for reasons of space.

3.2.4 Questions in relation to the prioritisation of telecommunications services, networks and content

These questions involved determining the feasibility and possible costs of prioritising of telecommunications services or the blocking of specific content. In addition, it was clarified whether an increase in the transmitting power of transmission equipment is possible and what costs are typically incurred for a direct fibre connection to prioritised user locations.

Consequence 5:

- Dedicated deactivation of services or blocking of content is hardly possible and has no effect on the power consumption of the equipment.
- Energy savings of between 30 and 50% could be made by switching off technologies in the mobile radio sector.
- More detailed clarification and measures in relation to the ordinance on non-ionising radiation and radio network planning are needed in the context of an increase in transmitting power.
- A direct fibre connection of up to 40 km is possible using new technologies.

3.3 Other findings

As part of the work on the study, the following points were also raised which are not directly related to the power shortage but could have an effect on both the telecommunications service providers and regulation.

- The "All-IP" technology trend - which is actually already state-of-the-art - and the developments in society mentioned above under 3.1.2 are resulting in a distinct shift of content from the classic services to the internet as so-called over-the-top (OTT) services. There is additionally a shift of "service intelligence" away from the classic network infrastructures to the service providers or user terminals (e.g. Skype).

[2] The FONES has stocks at its disposal which guarantee supply for three months (throughout Switzerland and all consumers).

- The dissemination of radio and television content must also be placed in this context. This too will be increasingly distributed and consumed as OTT on the internet. Consequently, no further measures for radio and television transmission via the traditional terrestrial and satellite-based infrastructures are assessed in this study. In any event, if a rolling blackout occurs, radio and television sets themselves will be without power.

Consequence 6:

- The changed communication behaviour in society, as well as the technological trends, involves a shift of content away from traditional telecommunications services to OTT services on the internet. There is likewise a shift of “service intelligence” away from the traditional network infrastructures to service providers or users' terminals and equipment.
- In the light of these developments, the scope, functionality and quality of the universal service in the Telecommunications Act would have to be examined and amended.

4 SITUATION IN THE POWER SHORTAGE

4.1 General

The power shortage scenario is based on a 30% power shortage during the winter months, lasting for several months. Envisaged measures in terms of national economic supply are management of supply and demand, such as the imposition of quotas or rolling blackouts.

For the study, the focus was on rolling blackouts - an alternating 4-hour outage and 4-hour supply for each geographical sub-area. Specific geographical sub-areas are cut off by the energy companies every 4 hours and then switched back on again after 4 hours - the blackouts lie within the competence of the energy suppliers. Who, when and where is affected is not published but will be published by OSTRAL, the emergency organisation for power supplies, according to the respective scenario.

Consequence 7:

- Users are not aware of the concept of a power shortage, the possible measures in the event of an incident and the consequences.

A rolling blackout occurs indiscriminately at the (power) network level 5. These blackouts then directly affect the subordinate segments of network level 7. Here the bulk of end consumers is typically connected at 230/400 V (households, businesses, small enterprises and telecommunications service providers' points-of-presence of mobile radio equipment).

Switching power off in such a geographical sub-area therefore interrupts the communications link from the point-of-presence to the user terminal. Systems over the last mile of the fixed networks or equipment in users' buildings fail.

Only equipment supplied with back-up power is functional for a period of time which cannot be planned for. This includes primarily mobile devices.

Consequence 8:

- Primarily, measures affecting mobile radio are to be examined, because at present only for this technology are terminals with an autonomous power supply widespread.
- During the rolling blackout, fixed service coverage will have no power - neither over the last mile and nor on users' premises.

4.2 Effects on the telecommunications service providers – scenarios

4.2.1 Overview

In order to indicate the effects during rolling blackouts and the effectiveness of measures, different scenarios were examined:

- Power failure affecting the service infrastructure
- Power failure affecting the network infrastructure
- Power failure at the point-of-presence
- Power failure over the last mile

For all scenarios "a damage value" (D) is determined, consisting of three components:

- Where does the failure have effects - geographical coverage?
- Who is affected by the failure - users?
- What is affected - services and content?

D value	Where - geography	Who - users	What - content
0	Nowhere affected	No-one affected	Nothing affected
1	Individual locations	Individual users	Little (Content of low criticality)
2	Towns and conurbations	Specific groups	Moderate (Content of moderate criticality)
3	Whole regions	Everyone	High (Content of high criticality)
4	Everywhere		Everything

Prioritisation of content: See 3.1.2
D value: Damage value

Table 7: Damage assessment

The total damage value for a scenario is calculated as the product of the individual damage values.

S = 0: no damage (normal situation)

S = 48: maximum damage (everything has failed everywhere, everyone is affected)

The damage value makes a purely qualitative statement.

For the effectiveness (E) of a measure, the remaining damage value D_M is determined (after implementation of the measure). The effectiveness is the difference between the two values:

$$W = D - D_M$$

4.2.2 Scenario 1: Failure of an item of service infrastructure

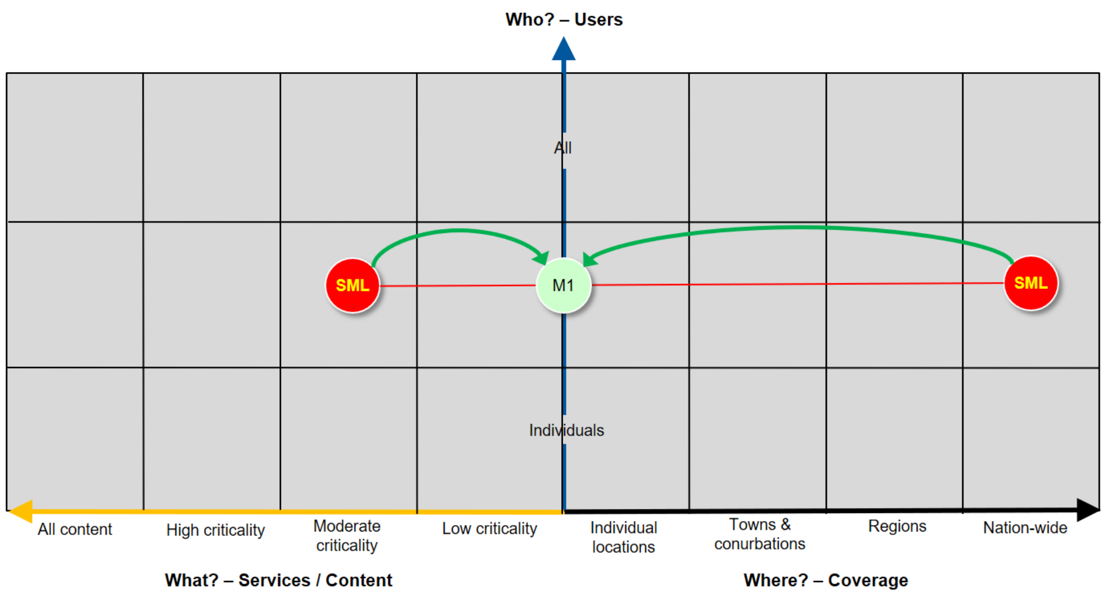
Description:

- The service infrastructure (e.g. data centre) for a specific service is affected by the rolling blackout.
- All users of these services and content are affected throughout Switzerland.
- As a measure, the network infrastructure is equipped with a diesel generator set with a sufficiently large fuel tank or possibly battery back-up and is therefore protected from a rolling blackout.

Damage assessment:

Damage value DML without the measure			Damage value with the measure		
D_{where}	4	Nationwide failure	D_{where}	0	In principle the service is again available everywhere to users
D_{who}	2	The users of this service	D_{who}	0	
D_{what}	2	Content of this service	D_{what}	0	
D	**16**		**D_M**	**0**	
Effectiveness: 16 or 100% improvement					

Table 8: Damage assessment scenario 1



SML: Extent of damage in the power shortage
M1: Extent of damage with measure 1

Figure 3: Service infrastructure failure

Comments on the figure:

The figure should be interpreted as follows:

- The three components which may be affected (where, who and what?), are shown on the three axes (right, top and left) with the possible damage values.

- "SML" denotes the extent of damage when the power shortage kicks in (here; nationwide, specific groups, moderate criticality).
- "M1" denotes the extent of damage after implementation of measure 1.
- The effect of a measure is shown graphically by the green arrows.

4.2.3 Scenario 2: Failure of network infrastructure (backbone, gateways)

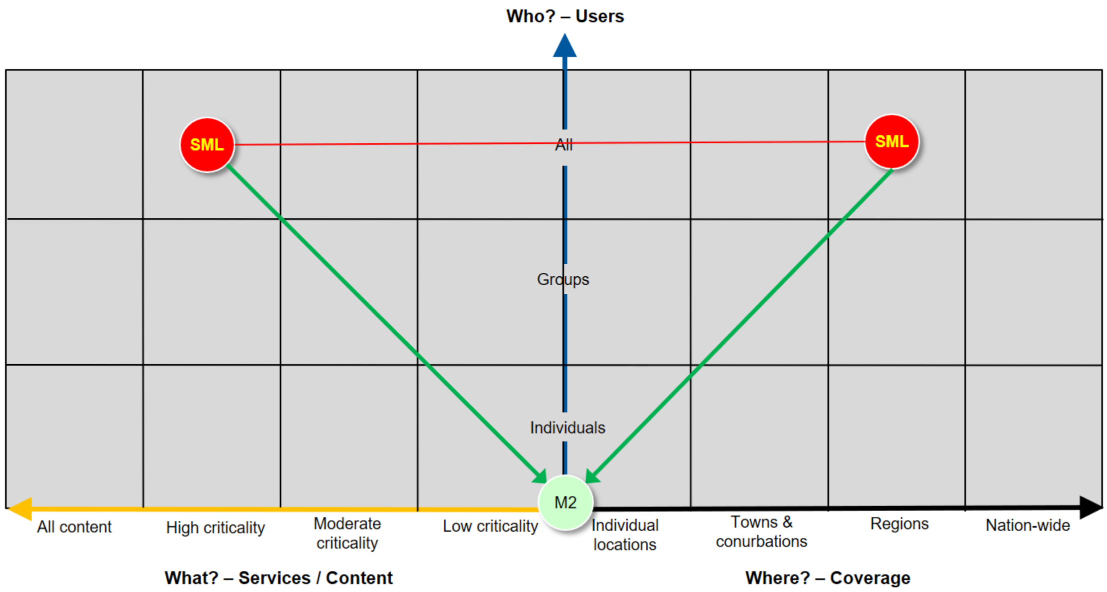
Description:

- The network infrastructure (e.g. important locations of the backbone networks) is affected by the rolling blackout.
- This affects all users of the telecommunications service provider in the region concerned.
- It affects all services and content operated on this infrastructure.
- As a measure, the network infrastructure is equipped with a diesel generator set with a sufficiently large fuel tank or possibly battery back-up and is therefore protected from a rolling blackout.

Assessment of damage:

Damage value SML without the measure			Damage value with the measure		
D_{where}	3	Failure in one region	D_{where}	0	In principle the service is again available everywhere in full.
D_{who}	3	All users	D_{who}	0	
D_{what}	3	Contents of the affected service	D_{what}	0	
D	**27**		**D_M**	**0**	
Effectiveness: 27 or 100% improvement					

Table 9: Damage assessment scenario 2



SML: Extent of damage in the power shortage
M2: Extent of damage with measure 2

Figure 4: Network infrastructure failure

4.2.4 Scenario 3: Point-of-presence failure

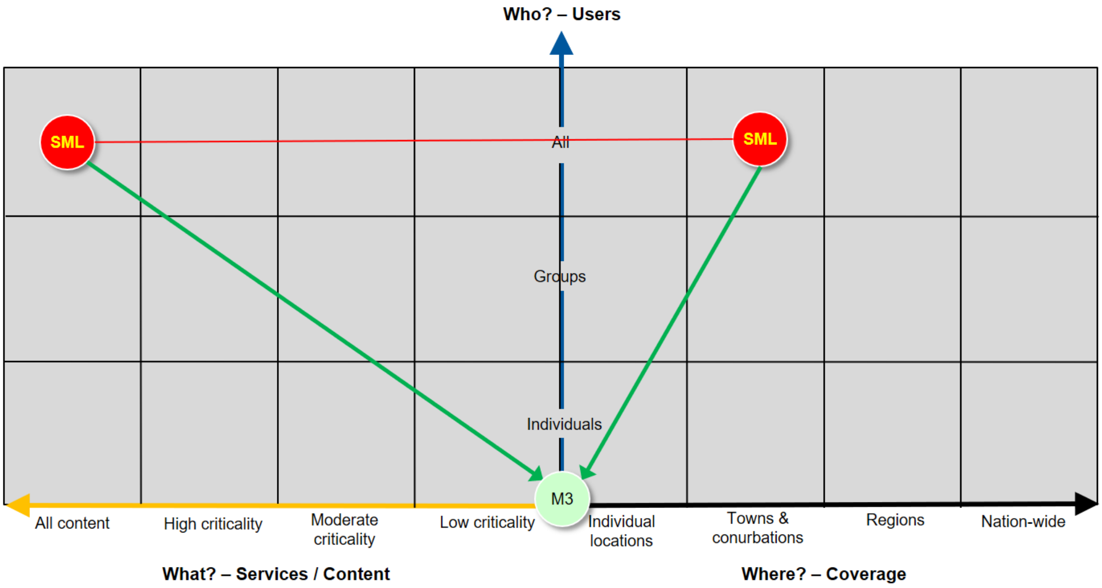
Description:

- A point-of-presence is affected by the rolling blackout.
- This affects all users within the perimeter of the point-of-presence, typically districts or smaller cities.
- It affects all services and content operated on this point-of-presence.
- As a measure, the point-of-presence is equipped with batteries which can bridge the rolling blackouts (diesel generators would be also conceivable, but the high number of locations should be taken into consideration).

Damage assessment:

Damage value SML without the measure			Damage value with the measure		
D_{where}	2	City/conurbation failure	D_{where}	0	In principle everything is again available everywhere.
D_{who}	3	All users	D_{who}	0	
D_{what}	4	All services and content	D_{what}	0	
D	**24**		**D_M**	**0**	
Effectiveness: 24 or 100% improvement					

Table 10: Damage assessment scenario 3



SML: Extent of damage in the power shortage
M3: Extent of damage with measure 3

Figure 5: Point-of-presence failure

4.2.5 Scenario 4: a last mile failure (mobile radio and fixed networks)

Description:

- The last mile is without power - fixed as well as mobile networks (failure of transmission equipment and systems in the distribution networks).
- This affects all users within this perimeter, typically districts or smaller cities. Partial coverage is still possible via the adjoining cells of the mobile radio networks.
- This then affects all services and content.
- As measure, the transmission equipment is equipped with batteries which bridge the rolling blackout. As a result, at least some users (those with charged smartphones) will be able to access a majority of content via mobile radio services.

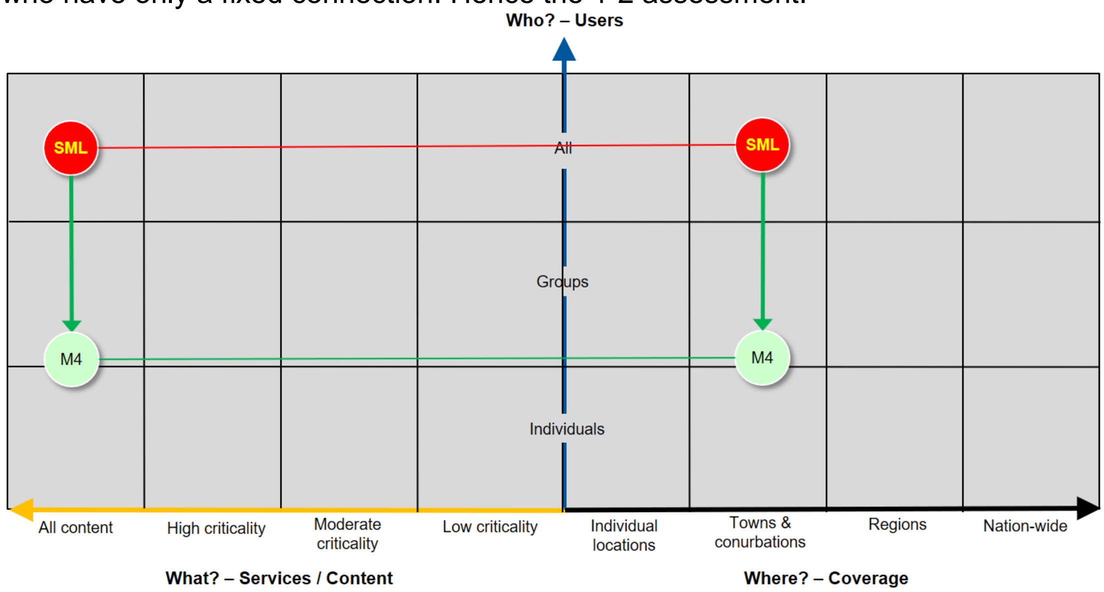
Damage assessment:

Damage value SML without the measure			Damage value with the measure		
D_{where}	2	Failure in one region	D_{where}	2	District/city failure
D_{who}	3	All users	D_{who}	1-2	Users in the fixed network
D_{what}	4	Content of the affected service	D_{what}	4	All services and content
D	**24**		**D_M**	**8-16**	
Effectiveness: 8-16 or 33 to 66% improvement					

Table 11: Damage assessment scenario 4

Note:

It can be assumed that the proportion of mobile users is very high compared to users who have only a fixed connection. Hence the 1-2 assessment.



SML: Extent of damage in the power shortage
M4: Extent of damage with measure 4

Figure 6: Last mile failure

5 MEASURES

5.1 Overview

On the basis of the scenarios investigated above and the above-mentioned consequences, the measures listed below are to be examined.

All the indicated measures are of a preventive character. The horizon for implementation differs, but is expected to last for a few years in the case of the technical measures. The implementation of the measures must first be decided and then an implementation plan and concept should be drawn up which takes into account the long term, also in the context of technology life cycles.

Measures during the power shortage, e.g. information and instructions concerning users' behaviour, were not addressed within the framework of the study.

5.2 Measures from the scenarios

These measures involve costs for the telecommunications service providers and must be either mandated or recommended by the regulator. Funding would have to be regulated.

The measures are described qualitatively above, in Chapter 4. The variants and their cost consequences are specified here. The quantities and costs relate to the information from the telecommunications service providers; the quantity designates the quantity across all providers and therefore across Switzerland as a whole.

The cost data for the telecommunications service providers includes capital outlays. The annual costs were computed from these as follows:

For measures with diesel generator sets:

- Annual costs of maintenance, spare parts, operating materials, etc.: 15% of the investments
- Lifetime: 20 years
- Annual costs: (investments + 20 x 15% of the investments) / 20

For measures with batteries:

- Annual costs of maintenance, spare parts, operating materials, etc.: 20% of the investments
- Lifetime: 10 years
- Annual costs: (investments + 10 x 20% of the investments) / 10

Measure		Quantity	Investment costs	Annual costs
M1	Installation of diesel generator sets at the service infrastructure locations	70 locations	23 MCHF	4.5 MCHF
M2	Installation of diesel generator sets at the network infrastructure locations	580 locations	50 MCHF	10 MCHF
M3	Installation of batteries in the points of presence	2100 locations	46 MCHF	14 MCHF
M4	Installation of batteries at the transmission installations of the mobile radio networks	73,000 installations	579 MCHF	173 MCHF
M4a:	As M4 but LTE transmission installations only	21,000 installations	165 MCHF	50 MCHF
M4b:	As M4 but GSM transmission installations only	26,000 installations	207 MCHF	62 MCHF
M4c:	As M4 but UMTS transmission installations only	26,000 installations	207 MCHF	62 MCHF

The quantities and costs are based on the survey of telecommunications service providers. The quantity is the total of locations across the surveyed telecommunications service providers, the costs are an averaged value of the information from the telecommunications service providers. Annual costs, as described above.

Table 12: Measures from the scenarios - figures apply to implementation throughout Switzerland

The effectiveness of an individual measure (at one location/installation) is compared to the costs in the following graph:

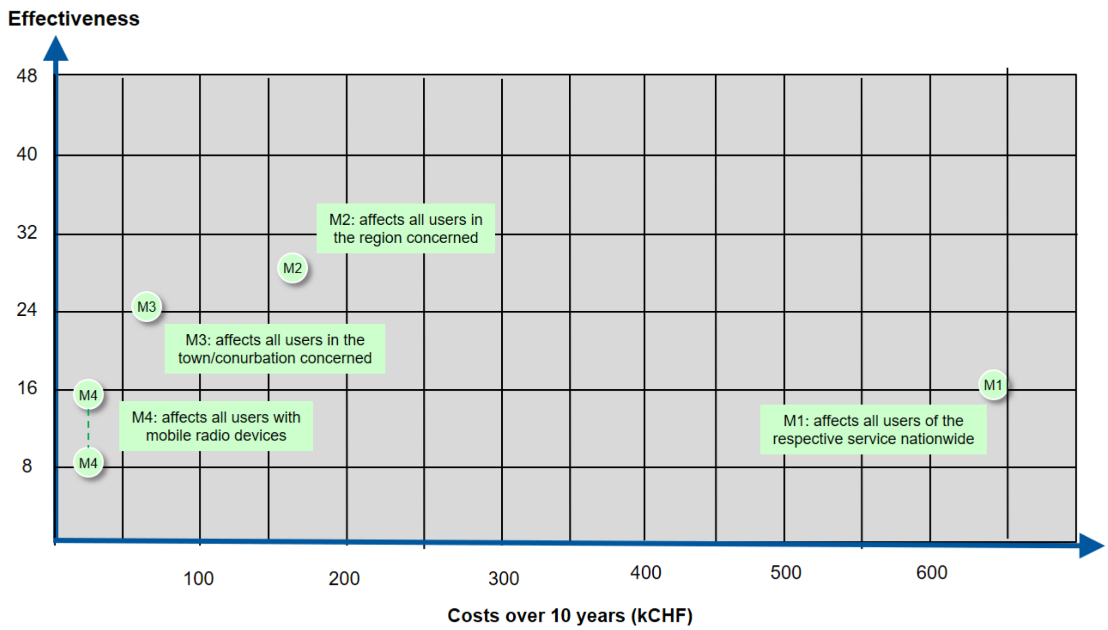


Figure 7: Costs and effectiveness (benefit) of the measures

Effectiveness according to the scenarios in Chapter 4.

5.3 Measures from the consequences

Measures from the consequences in Chapter 3 are:

	Measure	Source	Addressee
M5	Exempt telecommunications service providers from the imposition of quotas during a power shortage, as the sector's consumption is comparatively low (currently not technically possible because of connection at network level 7)	Conseq. 1	FONES
M6	The concept of rolling blackouts - in the worst case with alternating 4-hour outage and 4-hour supply for each geographical sub-area - should be reviewed, as the consequences of hardware failures have a wide-ranging impact beyond telecommunications services on all users and critical infrastructures. As an alternative, a comprehensive "smart metering solution" should be considered which can implement targeted power disconnections.	Conseq. 3	FONES, OSTRAL, ELCOM
M7	For telecommunications service providers' locations with diesel generator sets (continuous operation during the power shortage), an overarching supply concept should be drawn up which ensures the timely provision of fuel during the power shortage.	Conseq. 4	FONES, OSTRAL
M8	The question of increasing the transmitting power of mobile radio antennas should be examined - cost and benefit to be clarified.	Conseq. 4	OFCOM
M9	Critical infrastructure organisations or others should be advised to connect their important locations directly to a point of presence using optical fibre and also where appropriate to take measures to cope with rolling blackouts.	Conseq. 5	FONES
M10	The scope, functionality and quality of the universal service for telecommunications services should be examined and, if necessary, adapted to society's changing communication behaviour.	Conseq. 6	OFCOM
M11	Companies and organisations as well as the economy and the population should be informed about the concept of the power shortage. In particular, businesses and organisations should be able to prepare for the schedule of the power outages in order to power down their IT infrastructure.	Conseq. 7	Users via FONES
M12	Businesses and the population should be informed that in the event of a power shortage the supply to mobile radio will be prioritised (in so far as the above measures are implemented).	Conseq. 8	Users via OFCOM, FONES

Table 13: Measures from the consequences

6 RECOMMENDATIONS

The following is recommended for further action:

6.1 Legislature

For measures M5, M6 and M10 (for details see 5.3), the following next steps should be taken:

- Competencies should be verified.
- The content of the measures should be specified in detail with the competent authorities and placed in the respective legal context.
- Feasibility should be clarified generally and within the framework of any revisions to legislation in progress and the consequences should be indicated.
- Any implementation should be planned.

M5	Exempt telecommunications service providers from the imposition of quotas during a power shortage.
M6	The concept of rolling blackouts - in the worst case with alternating 4-hour outage and 4-hour supply for each geographical sub-area - should be reviewed, as the consequences of hardware failures have a wide-ranging impact beyond telecommunications services on all users and critical infrastructures. As an alternative, a comprehensive "smart metering solution" should be considered which can implement targeted disconnections.
M10	The scope, functionality and quality of the universal service for telecommunications services should be examined and, if necessary, adapted to society’s changing communication behaviour.

6.2 Telecommunications service providers

To improve the resilience of telecommunications services and networks, the following steps should be taken for measures M1, M2, M3 and M4a (for details see 5.2):

- Telecommunications service providers should be informed about the findings of the study and made aware of the potential effects of rolling blackouts.
- It should be clarified with the telecommunications service providers whether the measures, or some of them, can be introduced as part of the regular infrastructure lifecycle processes.
- OFCOM and FONES should check whether, with a view to security of supply, conditions should be imposed on telecommunications service providers for implementation.
- Measure M7 should be introduced as an accompanying measure to M1 and M2.

M1	Installation of diesel generator sets at the service infrastructure locations
M2	Installation of diesel generator sets at the network infrastructure locations
M3	Installation of batteries in the point of presence
M4	Installation of batteries at the transmission installations of the mobile radio networks
M4a	Installation of batteries at the LTE transmission installations
M7	Overarching diesel supply concept for the locations of the telecommunications service providers.

6.3 Users and critical infrastructures

For measures M9, M11 and M10 (for details see 5.3) the following next steps should be taken:

- General information for Switzerland concerning the concept of the power shortage, in particular concerning possible consequences and individual precautions (failure risks of equipment, provision of batteries).
- Specific information to the critical infrastructure organisations and companies concerning possible consequences of rolling blackouts (failure risks) and possible precautions to ensure the provision of telecommunications services (direct fibre connections and batteries on site).
- The responsibility for these "information campaigns" must be checked - FONES and/or OFCOM.

M9	Direct fibre connection to point of presence and preventive measures locally for critical infrastructure organisations as well as other organisations.
M11	Information for companies and organisations as well as the economy and the population about the concept of the power shortage.
M12	Information for businesses and the population to the effect that in the event of a power shortage, the supply to mobile radio will be prioritised.

7 REFERENCES

Number	Document
[1]	Katastrophen und Notlagen Schweiz: Technischer Risikobericht 2015 [Switzerland, Catastrophes and Emergencies: Technical Risk Report 2015, relevant fact sheet]
[2]	Bericht über die Sicherstellung der Telekommunikation bei Strommangellagen [Report on securing telecommunications in the event of power shortages: OFCOM, FONES, 2016]
[3]	Massnahmen zur Stärkung der IKT-Resilienz der Telekommunikation [Measures to reinforce the ICT resilience of telecommunications; 2017]
[4]	Risiko- und Verwundbarkeitsanalyse des Teilsektors Telekommunikation; BWL, 2018 [Risk and vulnerability analysis of the telecommunications sub-sector; FONES, 2018]
[5]	Fragebogen für die Fernmeldedienst- und Netzanbieter betreffend die Studie Strommangellage – SML; BAKOM 26. April 2018 [Questionnaire for telecommunications service providers and network providers concerning the power shortage - PS - study: OFCOM 26 April 2018]

Table 14: References

8 TERMS – DEFINITIONS AND ABBREVIATIONS

The following terms and definitions are used in this document.

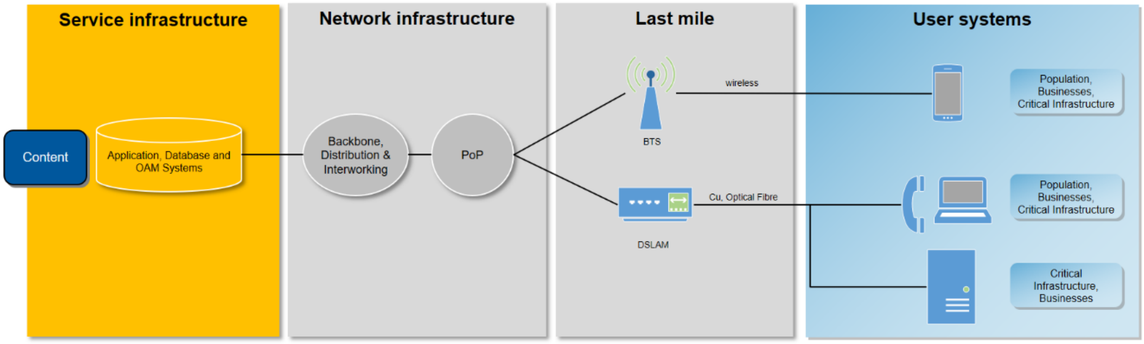


Figure 7: Terms - Definitions

Term/abbreviation	Definition
Service infrastructure	Central applications, databases and operating systems well as the underlying technical platforms and systems for the provision of telecommunications services. These are typically found in a (service) computer centre or a computer centre-like environment.
Network infrastructure - backbone, distribution & interworking	Central network elements to ensure connectivity (Layers 1 to 3) between the service infrastructure, distribution centres and gateways. Terms and the demarcation between backbone and distribution may differ depending on the network provider and the technology and are used here as generic "placeholders". Assumptions concerning the power supply are the same as those relating to the service infrastructure.
Network infrastructure - PoP (point-of-presence)	Local/regional network elements in distribution centres to ensure connectivity (Layers 1 to 3) between the central network elements and the systems in the last mile.
Last mile	Network elements which ensure connectivity (Layers 1 to 3) with equipment on users' premises and therefore with users.
User systems	Systems or customers' terminals for the use of telecommunication services.
Users	Users of telecommunications services. • Population • Businesses • Critical infrastructures
Content	Content means the information which is distributed or transferred via telecommunications services and networks.
Imposition of quotas	In this context the term means the imposition of power quotas which the national economic supply can implement during a power shortage. These affect large consumers; possible quota rates are 90%, 80%, 66% and 50%. Large consumers are those businesses which consume more than 100 MWh per annum. The restriction of telecommunication services or content is dealt with by the term "deactivate" or "block".

Term/abbreviation	Definition
Rolling blackouts	The switching-off at intervals of parts of the power supply net-works in accordance with prepared plans for power outages. These are implemented by means of different outage cycles (4h/8h or 4h/4h).
OFCOM	Federal Office of Communications
FONES	Federal Office for National Economic Supply
ICT	Information and communications technologies
OPNIR	Ordinance on Protection from Non-Ionising Radiation
OSTRAL	Organization for power supplies in extraordinary situations. It becomes active in the event of a power shortage on instruction from the National Economic Supply.

Table 15: Terms - Definitions and abbreviations